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Survey of Habitat and Otter Population Status

Alan Woolf
Southern Illinois University Carbondale

Richard S. Halbrook
Southern Illinois University Carbondale

D. Todd Farrand
Southern Illinois University Carbondale

Chad Schieler
Southern Illinois University Carbondale

Ted Weber
Southern Illinois University Carbondale

W-122-R-3.

SURVEY OF HABITAT AND OTTER POPULATION STATUS

FINAL REPORT

Federal Aid Project W-122-R-3

Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

Presented to:

Division of Wildlife Resources
Illinois Department of Natural Resources

Principal Investigators

Alan Woolf
Richard S. Halbrook

Graduate Research Assistants/Staff

D. Todd Farrand (Graduate Assistant)
Chad Schieler (Graduate Assistant)
Ted Weber (Researcher II)

July 1997

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FINAL REPORT

<u>STATE OF ILLINOIS</u>

<u>W-122-R, Study 1</u>

<u>PROJECT PERIOD</u>: 1 July 1994 through 30 June 1997

<u>STUDY 1</u>: Survey of habitat and otter population status

Prepared by Alan Woolf, D. Todd Farrand,
Theodore C. Weber, and Richard Halbrook

Cooperative Wildlife Research Laboratory
Southern Illinois University at Carbondale

<u>NEED</u>: River otter (*Lutra canadensis*) populations in many parts of North America have gradually declined over the past century as a result of indiscriminate, unregulated trapping and usurping of suitable habitat (Jenkins 1983). Otter populations probably also were adversely affected by environmental contaminants (Duplaix and Simon 1976, Wren 1985). The river otter is an Illinois listed endangered species and efforts are currently underway to recover this species in Illinois. Major components of the recovery effort include releases of wild-caught otters and development of a framework for protecting and enhancing key habitats. Qualitative data provided by field biologists were used to identify potential release sites and, assumedly, habitats capable of supporting river otters. However, more detailed, quantitative data are needed on a landscape scale to compare and rank key habitats, thereby allowing an ordered, cost-effective approach to target habitats for protection and enhancement efforts by management agencies in Illinois. Data on the relative quality of habitats within and between drainages will provide a framework for evaluating the success of releases based on colonization and range extension, and direct efforts to monitor presence/absence and relative abundance of otters in a cost-effective manner.

OBJECTIVES

1. Develop and evaluate criteria to identify suitable habitat and monitoring techniques for river otters in Illinois.

2. Develop a framework to detect otter presence/absence and quantify their relative abundance in Illinois river basins.

3. Identify key river otter habitats in southern Illinois.

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EXECUTIVE SUMMARY

In January 1994, the Illinois Department of Natural Resources (IDNR) released 50 otters in the Wabash Landscape Management Unit (LMU) as the first step toward implementing a recovery goal defined in a River Otter Recovery Plan (Bluett 1995). Prior to the first release, IDNR biologists used qualitative criteria to evaluate potential river otter habitats throughout Illinois.

A River Otter Recovery Team reviewed the evaluations, established landscape management units, and selected and prioritized units for reintroductions (Bluett et al. 1995).

Our project was designed to produce information that would enable IDNR staff to (1) target southern Illinois rivers, basins, watersheds, and local habitats for protection and enhancement efforts, and (2) adopt a cost-effective approach for monitoring otter presence/absence and relative abundance. Strategies identified by Bluett et al. (1995) for achieving objectives 3, 4, and 6 of the River Otter Recovery Plan require reliable information that was expected as a result and benefit of this project.

The first phase of the project involved intensive field studies in the Wabash LMU. We wanted to determine if the criteria used to select and prioritize basins for releasing otters could reliably measure differences in habitat quality within population and landscape management units. We also wanted to determine if these data could be used to predict otter habitat

utilization and design cost-effective, reliable monitoring methods.

We anticipated that otter sign following a release might be uncommon until a population became established, so we used areas inhabited by beaver (*Castor canadensis*) as an indicator of suitable otter habitat. We surveyed and sampled a 122 km portion of the Little Wabash River (LWR) from the confluence of the Fox River south to Carmi, Illinois. Habitat suitability criteria effectively characterized variations in quantity and quality of river otter habitat within the LWR study area (Schieler 1995). However, the survey was so labor intensive and logistically difficult we concluded the approach was not useful to characterize habitats at population or landscape management unit scales. Instead, measurement of habitat characteristics on a population management unit scale was emphasized using remotely sensed and digital data sets.

Job 1.1 also included the objective to "determine appropriate methods to monitor river otter presence/absence and relative abundance in southern Illinois." To accomplish this objective, we reviewed the literature and tested a variety of techniques on portions of the Little Wabash and Skillet Fork rivers within the Little Wabash Population Management Unit (PMU). Information was incorporated into Job 1.2 (Framework for Otter Monitoring) which was designed to develop a framework to detect otter presence/absence and to quantify their relative abundance in Illinois river basins.

We attempted to document presence of otters released in the Little Wabash PMU using reported sightings and a variety of methods to detect otter tracks or other sign. We concluded that given our limited success in detecting otter tracks/sign and logistical difficulties in traveling rivers by watercraft (or even accessing rivers at some locations), ground survey techniques would not be cost effective to employ in Illinois until populations increase considerably. In the interim, sightings/reports should be actively solicited to document otter presence and known limits of distribution. Also, if favorable snow conditions occur, aerial surveys using a helicopter offer an efficient method to detect otter sign along waterways and nearby wetlands.

We agree with other researchers who suggest that a combination of monitoring approaches be used. Further, whether or not a particular technique is appropriate to use will vary temporally and spatially. We examined the strengths and weaknesses of currently available monitoring options (Appendix E) and recommend that a flexible monitoring framework be adapted that will drop or add techniques as changing circumstances alter cost-benefit ratios of a particular method. Furthermore, we emphasize that each PMU may differ in relative suitability for a given technique, and notwithstanding the need for some standardization to allow comparison between PMUs, regional differences should dictate the method (or suite of methods) selected to document otter recovery.

In the short term (<5 yrs post-release), we recommend that sighting data be solicited from hunters, trappers, commercial fishermen, and environmental organizations such as the Illinois Riverwatch Network, or Illinois Resource Watch. Sighting reports will lose efficiency and utility over time and there should be planned supplementation with field techniques that can cost-effectively provide a reliable index. Based on our experiences, access limitations and other constraints (fluctuating water levels, bank substrate and characteristics, and weather) may preclude consideration of scent stations to monitor otters. Road bridge surveys are a cost effective method to search for evidence of otters; however, standardization is necessary before they can provide a useful index of relative abundance. Further testing to standardize or measure the efficacy of monitoring techniques must await increased population abundance and distribution, or research using a cohort of radio-marked otters.

The pattern recognition (PATREC) and habitat suitability index (HSI) models developed in Job 1.1 can serve as a tool to identify, conserve, and monitor habitats which Bluett (1995) identified as a key priority of recovery efforts. Both models assigned relative quality ratings to the available habitats within study areas. The HSI model assessed variations in local habitats, particularly riparian widths, while the PATREC model assessed subunits within PMUs. Importantly, both models produced very similar predictions of basin quality; they differed in prediction of the "best" quality basin, but the remaining 5 of 7 areas studied ranked in the same order. The PATREC model gave greater importance to nearby wetlands than the HSI model which emphasized width of wooded riparian zones.

The PATREC model was used to generate population estimates for each study area basin (see Tables 7 and 8). While speculative, these estimates provide data that the recovery team can use to determine if otter recovery goals and objectives are being met. Both models were used together to rank subunits within each release basin in rank order from high to low quality. This ranking modified by the protected status (public vs private ownership) of available habitats within basins was used to generate priority for protection, or other management strategy (see Table 12). Finally, the PATREC and HSI model outputs can be used by biologists in combination with their knowledge and local expertise to design effective and efficient ground surveys to meet recovery plan monitoring requirements.

In conclusion, we demonstrated the ability to quantify attributes associated with otter habitat at the landscape level using existing digital and remotely sensed data sets. Wildlife managers must have such tools to manage landscapes. The data on the quantity and relative quality of habitats within and between basins provide a means for biologists to: (1) evaluate the success of otter releases; (2) direct efforts to monitor populations cost-effectively; and (3) generate hypotheses about otter-habitat relationships for further research.

Our conclusions (see Job 1.4) recommend a monitoring framework that uses a combination of techniques, and has flexibility to deal with various habitat types and changing circumstances over time. Our findings also suggest that the Recovery Plan objective that calls for conserving enough habitat to support a minimum of 200 otters among at least 4 LMUs can be supported on existing public lands in 2 LMUs (Kaskaskia and the Shawnee), but not in the Wabash LMU where the first releases occurred. However, when considering landscape level management nearly anywhere, it becomes obvious that private lands are of paramount importance.

Many large wetlands remaining in southern Illinois are already in public ownership. However, rivers, streams, and their associated riparian habitats are all "critical" habitats in need of protection and management, and only about 12% of wooded riparian habitat is owned and managed by public agencies. Clearly, public-private partnerships, and support for conservation practices on private lands offer the best hope for successful landscape level management. The National Conservation Buffer Initiative, provisions of the 1996 Farm Bill, and other federal programs offer opportunities to conserve riparian habitats by getting private landowners involved. If wooded riparian zones can be lengthened and widened, broad benefits beyond protecting and enhancing otter habitat can accrue. We urge emphasis in creating innovative public-private partnerships to conserve, enhance, and even restore wetland and riparian habitats. Every opportunity should be identified and aggressively pursued. If such initiatives succeed, otter restoration will be assured; but importantly, water quality will be improved, soil erosion will be minimized, non-point source pollution will be reduced, additional wildlife habitat will be created, and the overall benefits envisioned for ecosystem management can become a reality.

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ACKNOWLEDGMENTS

We thank Robert Bluett (Furbearer Program Manager, Illinois Dep. Nat. Resour.) for his encouragement and administrative support throughout this project. As with most Laboratory projects, this was a team effort with many laboratory staff and students contributing in numerous ways. We especially thank Researchers T. Hollenhorst and T. Evans for their technical support, and Graduate Research Assistants Joel Porath and Blake Smietanski for their help during field surveys of the Little Wabash River. Our office staff, A. Hagen and J. Elders provided essential administrative support. This project final report includes information derived from the Master of Science theses of Chad T. Schieler completed in 1995 and D. Todd Farrand completed in 1997 at Southern Illinois University, Carbondale, Illinois, USA.

JOB 1.1. OTTER HABITAT CRITERIA AND MONITORING

OBJECTIVES: (1) Evaluate and develop criteria to identify suitable habitats for river otters in southern Illinois; and (2) determine appropriate methods to monitor river otter presence/absence and relative abundance in southern Illinois.

INTRODUCTION

Understanding and predicting habitat needs is critical to effective management of wildlife populations (Clark et al. 1993). Edwards (1983) stated that knowledge of habitats occupied by otters can aid in determining habitat preferences and more beneficial management practices to insure the preservation of suitable habitat. However, quantification of habitat characteristics is lacking (Goodman 1981).

A review of the literature revealed that otters are habitat generalists, utilizing a wide variety of aquatic habitats, including, streams, rivers, backwater sloughs, wetlands, ponds, and lakes. Ultimate factors of habitat selection include food availability, stable water supplies (Melquist and Hornocker 1983), and adequate cover (Wayre 1979). Availability of these components plays a key role in determining duration and intensity of habitat use. Melquist (1981) noted habitat utility in Idaho was almost entirely determined by forage and loafing sites.

Proximate factors of habitat selection are not well understood (Toweill and Tabor 1982), however, several studies have shown that otters prefer areas clustered with numerous lowland marshes and swamps interconnected with meandering streams and small lakes (Eveland 1978, Melquist and Hornocker 1983, Anonymous 1986). Eveland (1978) observed that wetland areas were important in providing food, water, and cover, and in impeding development. Degree of stream meander is related to habitat selection as it promotes greater habitat diversity (Melquist and Hornocker 1983, Anonymous 1986). Further, high water quality and a low degree of human impact were considered important in Indiana (Johnson and Madej 1994), and Missouri (Erickson and Hamilton 1988).

METHODS

Habitat Characterization

In the initial project segment, Schieler (1995) characterized the available stream habitat along 122.5 km of the Little Wabash River (LWR, PMU 19, Bluett 1995) from the Fox River south to Carmi, IL, (Fig. 1). This intensive study area encompassed a 1994 release site in Wayne County, near Golden Gate, IL. Physical and biological attributes of the river and its adjacent habitats were recorded or measured from maps (United States Geological Survey 7.5 minute quadrangles), aerial photographs (National Aerial Photography Program 1:40,000 high altitude color infrared) scanned into a geographic information system (GIS) (MIPS, MicroImages, Inc., Lincoln, NE), or by river surveys with watercraft. Habitat attributes measured included: width of riparian corridor (km), bank cover and slope, stream meander, number of associated wetlands, number of adjoining tributaries, instream structure, and fishing pressure. These efforts provided an accurate representation of the stream habitat, but were logistically cumbersome for characterizing habitats at increasing scales.

Later segments of the project emphasized measuring habitat characteristics on a PMU scale using remotely sensed and digital data sets. The study area was expanded to include 7 river basins in southern Illinois, corresponding to PMUs 14 - 20 as defined by the Recovery Plan (Bluett 1995) (Fig. 2). The basins vary in size, from 147,541 ha (Bay Creek), to 1,504,461 ha (Kaskaskia), and are aggregated into 3 LMUs: the Kaskaskia LMU, comprised of the Kaskaskia River (PMU 14) basin; the Shawnee LMU, encompassing the Bay Creek (PMU 17), Big Muddy River (PMU 15), Cache River (PMU 16), and Saline River (PMU 18) basins; and the Wabash LMU, encompassing the Embarras River (PMU 20), Little Wabash River (PMU 19), and Vermilion River (PMU 21) basins. The Vermilion River was excluded from this analysis because it was not considered for releases due to its isolation from other basins in the unit (Bluett 1995:38).

As of April 1996, 179 river otters were released in the expanded study area. Releases occurred in the Little Wabash (at Newton Lake, Golden Gate on the Little Wabash River, and near Helm on the Skillet Fork), Embarras (Embarras River at Fox Ridge State Park and North Fork at Casey), and Kaskaskia (at Lake Shelbyville, Carlyle Lake, and Shoal Creek at Litchfield) basins (Bluett 1996).

A literature review identified relevant GIS procedures and appropriate digital data sources. Two habitat models were built to assess otter habitat, each functioning at different levels of resolution. The PATREC approach investigated the suitability of drainages (landscape level), and the HSI approach investigated the suitability of riparian banks at 30 m (pixel size).

PATREC.--Three factors were considered important in assessing otter habitat at the landscape level: food availability, bank cover type, and potential for negative human impacts. As otters are opportunistic carnivores, we assumed that food availability would be satisfied if stable water supplies were present. The stable water requirement was considered fulfilled if water was present year round (perennial) or exhibited regular periodicity. Optimum bank cover was determined to be woody vegetation as it provides both den sites and instream structure for foraging. Potential for negative human impacts was considered a function of urban development. To capture these components, 5 landcover data layers were created in a GIS for each study area basin.

Available aquatic habitats were delineated into 2 main classes, streams and wetlands. A perennial streams layer was created by extracting those lines from 1994 Topologically Integrated Geographic Encoding and Referencing data files (TIGER, 1:100,000 scale) which represented perennial waterways (streams, ditches, and shorelines of major rivers). Intermittent streams were not included in the analysis because of insufficient data.

Digital National Wetlands Inventory data (NWI, 1:24,000 scale, compiled for Illinois primarily from 1:58,000 color infrared photography spanning spring 1980 to spring 1987) were used to delineate wetland habitats, which were partitioned into separate perennial and intermittent layers. Perennial wetlands were defined as all palustrine and lacustrine wetlands >1 ha with permanently flooded and intermittently exposed water regimes (Suloway and Hubbell 1994). Intermittent wetlands were defined as all semipermanently and seasonally flooded palustrine and lacustrine wetlands >5 ha. Filtering wetland layers by size served 3 functions: 1) it reduced computational complexity by eliminating numerous small wetlands; 2) it served as a qualitative assessment of wetland habitats by eliminating farm ponds and small, short duration intermittents; and 3) it accounted for the age of the data sets, reasoning that small wetlands may no longer be extant.

The extent of wooded riparian habitats within the study area was mapped by extracting woodland areas from 30-m resolution Landsat 5 TM scenes (spanning 26 May 1988 to 13 June 1991) classified into 7 classes for 98 Illinois counties by the Cooperative Wildlife Research Laboratory (CWRL, Southern Illinois University (SIU), Carbondale), and palustrine forested wetlands from NWI data. Woodland areas were combined with forested wetlands, and those areas beyond 0.5 km of perennial water (as defined by NWI and TIGER data) were eliminated. Combining forested wetlands with woodland areas allowed for more accurate representation of woods by filling in holes in the Landsat data left by inaccurate stream locations. Setting riparian width at 0.5 km included areas affected by flooding.

To estimate the extent of negative human impacts, an urban use layer was created by updating urban areas (from Landsat data) with TIGER data. Urban areas were defined in the Landsat data as major roads (state and federal highways), cities and towns, and industrial areas such as oil fields.

A hydrologic data file delineating watershed (catchment and subcatchment) boundaries for Illinois was obtained from the Illinois Natural History Survey (INHS). Catchment boundary data were used to define the extent of each study area basin. Subcatchments were combined into fewer and more evenly sized areas (subunits) on the basis of size, adjacency, hydrologic flow, and INHS classifications; later, subunit boundaries were used to subdivide each basin into component watersheds (Fig. 3).

The 5 landcover data layers (perennial streams, perennial wetlands, riparian woods, intermittent wetlands, and urban use) were combined in raster format to produce a potential habitat map composed of 10 patch types: Riparian Woods, Streams, Wooded Streams, Urban, Perennial Wetlands, Wooded Perennial Wetlands, Intermittent Wetlands, Wooded Intermittent Wetlands, Major Rivers, and Other. Wooded Streams, Wooded Perennial Wetlands, and Wooded Intermittent Wetlands represent areas where woods and water overlapped. The Major Rivers class included areas of the Mississippi, Ohio, and Wabash rivers which fell within the boundaries of Illinois; shorelines of these rivers were left classified in a stream class because otters used shoreline areas of the Mississippi for foraging (Anderson and Woolf 1984), and shorelines were characteristically under Illinois' jurisdiction. The Other class contained all unclassified areas, and primarily consisted of agricultural land uses. The relative area of each patch type was calculated with IDRISI (Clark Univ., Worcester, MA).

The quantity of mapped habitat attributes required to support otter populations is not known. To estimate the critical levels of each habitat attribute, areas of known presence were compared to areas of absence.

An updated list (as of May 1996) of sightings in Illinois was obtained from IDNR. Sightings from study area basins were plotted over TIGER data using MIPS software; only sightings which could be located within a Township, Range, and Section, or to a distinct geographic feature (i.e., Newton Lake, Heron Pond, etc.), were plotted. Sighting plots were then assigned to the subunits into which they fell. Unplotted sightings which fell unambiguously into a subunit also were assigned to it. Eight subunits which contained at least 1 sighting per year in 3 or more years since 1982 were considered currently supporting otters, and were selected for analysis under the present category. To this group were added those subunits which contained the release sites in PMU's 14, 19, and 20 (8 total, 16 overall). For comparison, an equal number of subunits were selected at random from the pool of subunits which lacked sightings (Fig. 4).

Present and random subunits were imported into Habitat Analysis and Modeling System (HAMS, Roseberry and Hao 1996) software to calculate landscape and patch metrics. These metrics were tested under the null hypothesis that means did not differ between groups. Recognizing that randomly selected areas could include favorable habitat, alpha for the t-test was set at 0.10. Uncorrelated metrics with different means were selected as candidates for model building (Table 1). Each candidate was evaluated for its biological meaning and manageability; a limited number were selected for model building (Table 2).

A PATREC model was built to identify watersheds (subunits) capable of supporting otters based on the sightings data. The PATREC approach involves 3 steps: 1) identification of 2 or more habitat suitability classes; 2) identification of required habitat components and their critical levels; and 3) a set of conditional probabilities which reflect the degree of association between the required habitat attributes and each suitability class (Kling 1980). Two suitability classes, High and Low, were identified. Required habitat components used in the model were defined by the subunit comparisons described above. Critical values of each habitat attribute were determined from the frequency distributions of each variable by listing all subunit scores from high to low and looking for breaks which best separated the present and random groups. The conditional probabilities represent the proportion of each group which fell above the threshold. For example, 69% of present areas had >65 km of wooded streams, while only 44% of random areas met this criterion (Table 3). The original model was applied to the present areas to determine both the accuracy of its predictions and the effect of each variable on the model. The model was refined through several reiterations and variables (Table 4).

The model outputs a value between 0 and 1, which represents the probability that an area falls in the High suitability category based on its particular collection of habitat attributes. It is an index of inherent habitat quality that can be used to predict the distribution of otters. The computations to provide an output are detailed in Appendix A.

HSI.--Factors considered important in assessing otter habitat at the riparian bank level were the same as for the landscape level. However, working at a finer resolution allowed us to define the factors in greater detail: only year round foraging habitat was considered, and food availability was based on relative fish abundance; all bank cover types were evaluated, and riparian width was assessed; and potential for negative human impacts was based upon road density.

Data were processed in Unix ARC/INFO (Environmental Systems Research Institute, Inc., Redlands, CA) on a computer workstation at SIU’s Morris Library. All coverages were clipped using the basin boundaries developed for the PATREC model, projected in Universal Transverse Mercator (UTM) Zone 16, and converted to grids with 30-m cell resolution, the same as the CWRL Landsat images.

The layers of perennial streams, lakes, and permanent wetlands developed for the PATREC model were grouped together as potential year-round feeding habitat and important travel routes. Water cells from the CWRL land use grid, if belonging to a contiguous aggregation at least 1 ha in size, also were added to the grouping of perennial streams, lakes, and permanent wetlands because the land use water did not always correspond exactly to the TIGER and NWI water delineations. Because of a lack of detailed hydroperiod data, the water regime was greatly aggregated; perennial water bodies were included in the model, but intermittent water bodies were not included.

Illinois Environmental Protection Agency's (IEPA) Index of Biotic Integrity (IBI) was used to estimate the relative abundance of fish in perennial streams (Ettinger 1989, Kelly et al. 1989, Hite et al. 1990, Hite et al. 1991, Hite et al. 1993, Muir et al. 1995, Muir et al. 1996). This index is a measure of the fish community of a stream, calculated on the basis of 12 fish community metrics (total number of fish species; number and identity of darter species; number and identity of sunfish species; number and identity of sucker species; number and identity of intolerant species; proportion of individuals as green sunfish; proportion of individuals as omnivores; proportion of individuals as insectivorous cyprinids; proportion of individuals as piscivores; number of individuals in sample;

proportion of individuals as hybrids; and proportion of individuals with disease, tumors, fin damage, and skeletal anomalies). These metrics are assigned values of 1, 3, or 5 which are then summed to produce an IBI score between 12 and 60, with 60 being high and 12 low.

For lakes, we used the Degree of Impairment for Aquatic Fish and Wildlife Use, from the 1988-1989 Illinois Water Quality Report (1990). Riparian banks were defined as those cells immediately adjacent to water cells. The following values were computed for each bank cell: 1) IBI of adjacent water body; 2) CWRL land use; 3) Distance to nearest riparian wood edge; and, 4) Distance to nearest road.

Woods were extracted from the land use grid. Distance to nearest riparian wood edge was defined as the distance from the bank cell to the nearest land cover other than woods or water. If the cell was not wooded, this distance equaled zero. Similarly, distance to nearest road was defined as the distance from the bank cell to the nearest road cell.

Roads were obtained from IDNR county street and highway coverages, appended together within each watershed. The IDNR road coverages were derived from the US Geological Survey (USGS) 1:100,000 Digital Line Graph files, transportation layer, 1980-1986. The Interstate, US, and State highways were current as of 1993 and augmented the roads included on the analog 1:100,000 base map series. Publication dates of the USGS maps used as sources ranged from 1980 to 1986. The maximum estimated error in horizontal position based on National Map Accuracy Standards was 50.9 meters.

A program was written in ArcInfo Macro Language (AML) to clip coverages for each subunit (as defined above), and extract statistics for these coverages (Appendix B). The statistics for each subunit were combined and organized in Excel (Microsoft Corporation, Redmond, WA), using a Visual Basic program.

A HSI model was developed to evaluate each bank cell. The model combines suitability index estimates (SI's) of food availability, bank cover, and negative human impact into an overall assessment of habitat quality (HSI) for each riparian bank cell according to the formula:

$$HSI = (SI_{food} * ((SI_{lu} + SI_{fw})/2) * SI_{road})^{1/3};$$

where SI_{food} is the aquatic life support SI of the adjacent water body, SI_{lu} is the land use SI at the cell's position, SI_{fw} is the riparian forest width SI at the cell's position, and SI_{road} is the SI for the distance from the bank cell to the nearest road. Suitability indices were determined from their respective data sets by the tables listed in Appendix C. Cover type and riparian width attributes were averaged into bank cover suitability. Then, the SI variable groups representing food, cover, and human impact were combined by taking their multiplicative mean; if any of these 3 life requisites was entirely missing, the habitat could not support otters, and thus the HSI should equal zero.

Otter Monitoring

Scent Stations.--During the initial project segment, the scent station technique was identified as a feasible method for monitoring river otters in Illinois, and a pilot test was conducted on 11 - 13 March 1995 in concert with the Skillet Fork release. Two scent stations were set at each of 5 locations in the LWR basin: Skillet Fork Bridge crossing 0.25 km north of Wayne City; Skillet Fork Bridge crossing due east of Wayne City; adjoining tributary to the Skillet Fork, 4 km southeast of Wayne City; Village Creek Bridge crossing on Wayne/Edwards County line road, 8 km northeast of Hedge Bridge; and Union Drainage Bridge (BR 394), 6 km southeast of Hedge Bridge.

Scent stations were created in 3 ways depending on bank substrate consistency and prevailing conditions. One type was created by digging a 2-m diameter x 2.54-cm deep depression near the water's edge and sifting it full of moist sand or silt. Another type was created by using a garden rake to prepare a 2 x 2-m impressionable surface near the water's edge. The last type was created at natural water exiting points where bank consistency would allow identifiable tracks. Suitable scent station substrates allowed easy identification of a thumb print. Each station was scented with approximately 15 ml of Hawbaker's Otter Lure (S. Stanley Hawbaker and Sons, Fort Loudon, PA) centrally placed on a tuft of grass, stick or corn cob. Stations were located on both the upstream and downstream sides of bridge crossings within 1.5 m of the water's edge. Each station was visited at least once during the 2 or 3 nights of operation.

Reported Sightings.--The LWR from the Fox River south to Carmi, IL, was searched by watercraft for signs of otters. The 1994 release at Hedge Bridge in Wayne County was publicized and reports of otters solicited by distributing posters and report cards designed by IDNR staff to various business locations in Albion, Fairfield, Golden Gate, and Wayne City, IL. Report cards also were given to landowners adjacent to the river and fisherman encountered throughout the study area.

RESULTS

Habitat Characterization

PATREC.--Obvious differences exist between the basins, primarily in their proportions of riparian woods and wetlands (Table 4). These patch types are more abundant in the southern portion of the study area (PMU's 15 - 18) than in northern areas (PMU's 14, 19, and 20).

Fifty-nine of 180 delineated subunits (Appendix D), contained at least 1 sighting; 32 were selected for analysis (Fig. 4). For each selected subunit, 114 variables were measured, and means were calculated across each group (present and random). Variables that had different means ($P \leq 0.10$) were selected as candidates for model building (Table 1). Subunits in the present category differed from random primarily in relation to intermittent wetlands. Eleven of the 35 candidates addressed the number, size, shape, and adjacencies of intermittent and wooded intermittent wetlands. In addition, diversity index was directly related to the presence of intermittent wetland types, while contagion, dominance, and % other were inversely related.

The original model consisted of 8 habitat attributes derived from candidate metrics (Table 2). Model entrants represented a combination of habitat attributes identified as important to otters in the literature, and those identified by the subunit comparisons. Although neither wooded stream perimeter nor perennial wetland perimeter differed between groups, both were deemed important in light of the literature.

Model refinements reduced the model to 4 variables (Table 3). Not all subunits in the present category were rated high by the model, primarily due to a lack of wetlands in some of the release areas (Table 5). As suspected, the random category included subunits with favorable, but currently unoccupied habitat.

HSI.--Figure 5 depicts example sections from the Cache River basin of data layers used in the HSI analysis. Summary statistics for all study area basins, including mean HSI score for each subunit, are listed in Tables B-2 to B-8 of Appendix B. Table B-1 in Appendix B summarizes riparian land use by watershed; basins with the highest percentages of wooded banks occur in the southern portion of the study area.

Otter Monitoring

Scent Stations.--Raccoons (*Procyon lotor*), muskrats (*Ondatra zibethicus*), beavers, coyotes (*Canis latrans*), and otters visited the 10 scent stations operable between 11 - 15 March 1995. Otters tracks were detected at only the 2 stations located on the Skillet Fork north of Wayne City.

Reported Sightings.--Otter tracks were noted in the vicinity of the release site once, but no other sign of otters was detected during river searches from watercraft. Reports in the first year following release remained centered around release sights (Table 6). Nearly 25% of the reports occurred within 3 months of the January releases.

DISCUSSION

Habitat Characterization

Recognizing the lack of quantitative habitat data for river otters (Goodman 1981), and the need for a cost effective approach to habitat assessment on a scale meaningful to populations, we quantified attributes associated with otter habitat at the landscape level from existing digital and remotely sensed data sets. Habitat assessments at this scale are well-suited to the spatial analysis capabilities of GIS, and GIS-based habitat models are most effective for habitat generalists (Clark et al. 1993).

Both otter habitat models were limited to a few measurable variables because some data sets related to otter habitat suitability were either unavailable, incomplete or could not be remotely sensed (e.g., beaver density, commercial fishing pressure, and intermittent streams). However, the factors captured within each model are solidly supported in the literature, and alternate data would be logistically prohibitive to obtain for the study area.

Food Availability.--The PATREC model assumed that food availability was fulfilled by stable water supplies, which entails the assumptions that food availability is constant across stable water and that water quality is not limiting on food. While these assumptions are generally met across the study area, they may not be met for every stream segment. Thus, IBI was included in the HSI model as it was the best available estimator of relative fish abundance. This metric is not without its own limitations, however, as data had to be extrapolated to some sites and some components may have no relevance to otters (e.g., number and identity of darter species). Additionally, the PATREC model included intermittent wetlands as potential foraging habitats. Although they also may serve as pup rearing areas (Melquist and Hornocker 1983), intermittent wetlands were excluded from the HSI as their banks could not support otters year round.

Bank Cover Type.--The conditions created by adequate riparian habitat probably increase the likelihood that an area will be used by otter (Melquist and Dronkert 1987). Tree root cavities, the presence of fallen or partly submerged trees, and logjams were noted as important cover in several studies including Anderson and Woolf (1984), Zaccagnini (1974), Beck (1993), and Newman and Griffin (1994). The PATREC model restricted adequate cover to woody vegetation, assuming that instream structure, potential den sites, and beaver presence could be confidently predicted by the presence of trees. These data are not available in digital format and cannot be remotely sensed; field surveys to obtain this information would be logistically prohibitive. Although non-wooded streams and non-wooded shorelines of perennial wetlands provide potential foraging habitat, year round cover may be lacking. Inclusion of these variables in the model tended to depress model outputs for areas whose waterways were primarily wooded (providing both forage and cover).

Cover requirements, however, also can be met by dense bankside vegetation such as cattails (*Typha* spp.), sedges (*Carex* spp.) (Beck 1993), and tall grasses (Melquist and Dronkert 1987). The HSI model addressed the issue by incorporating additional cover types, but their relative value had to be estimated. Furthermore, the HSI assessed the width of the wooded riparian zone, which the scale of the PATREC model would not allow. Width of the riparian corridor affects water quality, the availability of stable den sites during flooding, and the length of time an area remains suitable. Distance to cover outside the 5-year floodplain would be a good surrogate variable for availability of secure den sites during floods, but unfortunately these data were not available. Severe flooding, such as 100-year floods, was judged too rare to severely effect an established population of otters.

Potential for Negative Human Impacts.--Urban development was dropped from consideration in the PATREC model because it was a poor estimator of negative human impacts. Thus, the model assumes that the potential for negative human impacts is not a factor determining habitat suitability at the landscape scale. Human impacted areas do not restrict otter movements (Mack 1985), though high human activity has been implicated in seasonal shifts in activity period (Melquist and Hornocker 1983, Mack 1985).

Human activities are a major cause of river otter mortality (Melquist and Dronkert 1987), and may play a role in determining habitat suitability at the local scale. The variable chosen to represent negative human impacts in the HSI model was distance from roads. Although 6 released otters have been killed by vehicles, 9 have either drowned in hoopnets or beaver traps (B. Bluett, IDNR, pers. comm.). No data are available for hoopnet density or trapping pressure for particular stream stretches, nor can these data be remotely sensed. The number of fishing and trapping licenses sold could serve as a surrogate for comparisons between PMUs. However, data are not currently compiled in this manner, and purchase in a basin does not necessarily constitute use there. These factors may be captured in the HSI model under riparian corridor width. Schieler (1995) reported that commercial fishing pressure increased on the LWR as riparian width decreased.

Other factors identified in the literature as being related to otter habitat use include stream gradient (Dubuc et al. 1990) and availability of open water in winter (Anderson and Woolf 1984). Neither of these were considered limiting factors in southern Illinois. Water quality also affects habitat use (Melquist and Dronkert 1987), but water quality assessments in Illinois are at least partially based on indices irrelevant to otters (e.g., turbidity, presence of endangered species, etc.). Otters are considered susceptible to bio-accumulation of pesticides and other contaminants (Johnson and Madej 1994, Bluett 1995), but contaminant concentrations reported by Halbrook et al. (1996) for Illinois otters do not indicate detrimental effects from toxins.

Other sources of possible errors included: changes in water boundaries and other data layers over time, differing ages of data sets, the correlation error between aquatic life use support assessment and actual food availability, land use classification errors, and the positional accuracy of data layers. However, considering the wide-ranging and generalist nature of otters, and that the data layers were compiled in the same manner for each study area basin, relative comparisons between basins is appropriate.

Otter Monitoring

Scent stations attracted a variety of species, including the river otter. The use of naturally occurring bank substrates and raked substrates were the most efficient means of scent station construction. The only stations visited by otters were located on the Skillet Fork <10 km downstream of the March 1995 release site. Stations were set on the day of release and were visited by otters on the 2nd and 3rd nights after construction.

Soliciting sighting reports involved the public in the release effort and met with a favorable response. Two-thirds of the reports in the first year came from the area where posters and report cards were distributed, and half of these were made by landowners adjacent to the river.

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Table 1. Metrics organized by metric type for which means differed ($P < 0.10$) between Present and Random groups.

Metric Type	Metric	Present	Random	*P*
Landscape	Contagion	0.80	0.84	0.0404
	Dominance	0.70	0.76	0.0391
	Diversity Index	0.31	0.25	0.0660
	% Other	81.31	85.63	0.0675
	% Perennial Wetlands	1.80	0.50	0.0796
	% Intermittent Wetlands	1.02	0.22	0.0096
	% Wooded Int. Wetlands	10.63	0.29	0.0062
	Shared Edge: Other - Riparian Woods	21,442.73	14,139.50	0.0754
	Shared Edge: Other - Stream	3,549.47	2,229.69	0.0471
	Shared Edge: Wooded Per. Wetl. - Wooded Int. Wetl.	102.87	3.44	0.0204
	Total Ha Streams and Wooded Streams	335.65	232.02	0.0436
	Total Ha Perennial Water	1,183.97	369.51	0.0067
	Total Perimeter Perennial Water (m)	383,029.53	272,135.00	0.0590
	Stream Shape Index	0.61	0.76	0.0535
Patch Class: Riparian Woods	# Patches	340.87	223.75	0.0293
	Total Ha	3,761.06	2,189.94	0.0465
Patch Class: Streams	Total Perimeter (m)	136,261.33	87,800.00	0.0368
	Total Ha	144.53	96.32	0.0284
Patch Class: Urban	Mean Size (ha)	48.97	126.07	0.0296
Patch Class: Perennial Wetlands	# Patches	34.40	32.69	0.0802
	Mean Size (ha)	17.15	3.93	0.0349
	Total Ha	848.32	137.49	0.0190

Table 1. Continued.

Metric Type	Metric	Present	Random	*P*
Patch Class:				
Wooded	# Patches	66.73	53.13	0.0702
Perennial	Mean Size (ha)	2.03	0.43	0.0165
Wetlands	Total Perimeter (m)	33,388.00	20,500.00	0.0428
	Total Ha	85.11	30.26	0.0084
Patch Class:	# Patches	72.64	14.50	0.0214
Intermittent	Mean Size (ha)	5.81	3.19	0.0382
Wetlands	Total Perimeter (m)	67,471.43	12,656.25	0.0082
	Total Ha	343.02	57.37	0.0112
Patch Class:	# Patches	34.14	9.69	0.0150
Wooded	Mean Size (ha)	22.33	5.71	0.0479
Intermittent	Total Perimeter (m)	95,792.86	21,423.75	0.0358
Wetlands	Total Ha	456.19	76.92	0.0163

Table 2. Habitat attributes, derived from candidate metrics, used to build the PATREC model.

Model Entrant	Candidate Metric
Area Riparian Woods (ha)	Riparian woods: Total Ha
Stream length (km)	Streams: Total Perimeter
Wooded stream length (km)	Landscape: Total Perimeter Perennial Water
Stream Shape Index[a]	Landscape: Stream Shape Index
Length of perennial wetland shoreline (km)	Landscape: Total Perimeter Perennial Water
Length of wooded perennial wetland shoreline (km)[b]	Wooded Perennial Wetland: Total Perimeter
Intermittent wetland perimeter (km)	Intermittent Wetland: Total Perimeter
Wooded intermittent wetland perimeter (km)	Wooded Intermittent Wetland: Total Perimeter

[a] defined as the total perimeter of all streams (km) divided by their total area (ha).

[b] includes edge of wooded perennial wetlands (swamps, etc.)

Table 3. PATREC model habitat attributes and their respective High and Low conditional probabilities used to evaluate the suitability of drainages for river otters.

Habitat Attributes	Conditional Probabilities High	Conditional Probabilities Low
Area contains $\geq$65 km of wooded streams	0.69	0.44
Stream shape index[a] $\geq$0.88	0.75	0.63
An increase in wooded riparian habitats of $\geq$20% offered by wooded shoreline of perennial wetlands	0.63	0.25
Area contains $\geq$20 km of intermittent wetland edge	0.81	0.38

[a] Stream shape index is defined as the total perimeter of all streams (km) divided by their total area (ha).

Table 4. Landscape composition, as a percentage of total area, for study area Population Management Units (PMUs).

Class	PMU 14	15	16	17	18	19	20
Riparian Woods	7.3	14.1	11.5	24.2	12.4	8.2	6.9
Streams	0.5	0.3	0.6	0.4	0.4	0.5	0.5
Wooded Streams	0.5	0.7	0.6	0.9	0.6	0.6	0.5
Urban	4.0	4.2	3.2	1.2	2.4	2.4	3.3
Perennial Wetlands	1.9	2.6	0.5	0.3	1.0	0.5	0.3
Woods - Perennial Wetlands	0.1	0.5	0.4	0.2	0.2	0.1	0.0
Intermittent Wetlands	0.3	0.7	1.4	0.5	0.3	0.1	0.0
Woods - Intermittent Wetlands	0.2	1.5	2.1	0.9	0.7	0.1	0.1
Rivers	0.0	0.8	0.5	0.5	0.1	0.2	0.1
Other	85.3	74.7	79.4	71.0	82.0	87.4	88.4

Table 5. PATREC model attribute values and outputs for subunits in the Present and Random categories.

Category	ID	Location	Wooded Stream (km)	SSI	% Riparian Increase	Int. Edge (km)	Model
Present	14_110	East Lake Shelbyville: Kaskaskia River - Wolf Creek Arm	15.7	0.88	268.4	63.7	0.78
	14_206	Lake Carlyle: Wildcat Ditch - Dam	61.7	0.89	82.3	197.8	0.78
	14_307	West Fork Shoal: Headwaters - Shoal Creek	60.0	0.91	48.9	3.6	0.33
	15_202	Clear Creek: Headwaters - Mississippi River	208.4	0.93	21.7	382.1	0.91
	16_101	Cache River: Post Creek Cutoff - Big Creek	69.3	0.84	6.3	191.1	0.53
	16_104	Cache River: Boar Creek - Cache (city) Cutoff	76.9	0.84	66.1	276.6	0.85
	16_201	Cache River: Headwaters - Belknap Blacktop Road	164.8	0.91	5.1	131.2	0.67
	16_203	Cache River: Belknap Blacktop Road - Post Creek Cutoff	58.8	0.93	32.3	141.0	0.78
	17_105	Bay Creek: Rt. 146 - Sugar Creek	46.6	0.93	21.7	66.7	0.78

Table 5. Continued.

Category	ID	Location	Wooded Stream (km)	SSI	% Riparian Increase	Int. Edge (km)	Model
	17_106	Bay Creek: Headwaters - Rt. 146	137.4	0.92	15.0	69.5	0.67
	18_104	S., Middle, and Main Fork Saline River: Rt. 145/ Rt. 13 - Equality	74.4	0.89	40.9	124.6	0.91
	19_107	Big Muddy Creek: Little Muddy Creek - LWR	161.8	0.89	32.3	26.0	0.91
	19_113	Little Wabash River: W. Side Diversion Ditch - Briar Branch	69.3	0.86	12.0	22.5	0.53
	19_202	Skillet Fork: Marion Co. Rd. 300N - Horse Creek	86.1	0.89	21.7	43.9	0.91
	20_110	Embarras River: Indian Creek - U.S. Hwy 40	123.6	0.87	5.6	1.4	0.14
	20_123	North Fork Embarras River: Headwaters - Clark Co. Rd. 475N	133.3	0.89	4.5	0.0	0.22
Random	14_107	Robinson Creek: Headwaters - Kaskaskia River	73.8	0.89	0.3	0.0	0.22
	14_119	Kaskaskia River: Douglas Co. line - W. Fork Kaskaskia	16.5	0.87	0.0	0.0	0.05

Table 5. Continued.

Category ID	Location	Wooded Stream (km)	SSI	% Riparian Increase	Int. Edge (km)	Model
14_211	Ramsey Creek: Headwaters - Kaskaskia River	62.1	0.90	13.9	0.0	0.09
14_212	Kaskaskia River: Becks Creek - Ramsey Creek	69.9	0.90	2.5	3.8	0.22
14_414	Silver Creek: Mill Creek - Loop Creek	101.0	0.87	8.1	38.5	0.53
15_108	Pond Creek: Headwaters - Herrin/Freeman Spur Rd.	42.6	0.92	171.2	78.3	0.78
15_115	Little Muddy River: Headwaters - Franklin Co. Rd. 1100N	73.9	0.89	13.7	91.1	0.67
15_120	Galum Creek: Headwaters - Beaucoup Creek	85.2	0.87	65.5	98.1	0.85
18_102	South Fork Saline: Strip Mines - U.S. 45	76.9	0.94	41.5	31.8	0.91
19_106	Little Wabash River: Panther Creek - U.S. Hwy 50	53.3	0.87	2.1	2.5	0.05
19_108	Big Muddy Creek: Headwaters - Little Muddy Creek	40.7	0.90	2.7	0.0	0.09

Table 5. Continued.

Category ID	Location	Wooded Stream (km)	SSI	% Riparian Increase	Int. Edge (km)	Model
19_115	Little Wabash River: White Co. Rd. 2575N - Siegler Bridge	36.8	0.54	6.8	14.2	0.05
19_116	Little Wabash River: Siegler Bridge - Possum Rd. Gauge	13.8	0.36	20.9	3.8	0.22
19_201	Skillet Fork: Headwaters - Marion Co. Rd. 300N	73.0	0.88	17.6	7.6	0.22
20_120	Embarras River: Business U.S. Hwy 50 - Wabash River	61.0	0.94	16.7	54.3	0.41
20_301	Little Vermillion River: Elwood/Carrol Twp. line - State Line	42.8	0.89	6.4	0.0	0.09

Table 6. Illinois river otter sightings in southern Illinois reported between January 1994 and April 1997.

Observation	Date	Location	PMU[a]	Observer
Tracks observed	2/94	Thomas Hill, 1.0 km E of Hedge Bridge, Wayne Co.	19	Gregg Burgess
Tracks observed	2/94	Iced over pond, 0.8 km E of Hedge Bridge, Wayne Co.	19	Gregg Burgess
2 otters observed	2/18/94	Bridge over White Oak Slough, 2.75 km NE of Hedge Bridge, Wayne Co.	19	Gregg Burgess
2 otters observed	2/20/94	Rt. 15 Bridge over Little Wabash River, Wayne Co.	19	Ray Fisher
Otter observed	2/28/94	Crossing a field, 1.0 km SE of Golden Gate, Wayne Co.	19	Junior Harris
Otter observed	3/04/94	On bank of Little Wabash, 2.6 km S of Golden Gate Wayne Co.	19	Junior Harris
Otter observed	7/94	Crossing gravel road, NW side Hedge Bridge, Wayne Co.	19	Kerry Michael
4 otters observed	8/1/94	Crossing Rt. 45, SE of Cisne, where road turns 90° and goes south, Wayne Co.	19	Terry Tittman
3 otters observed	8/13/94	1.25 km S of Hedge Bridge, Wayne Co.	19	Ray Fisher

Table 6. Continued.

Observation	Date	Location	PMU[a]	Observer
Carcass	9/25	Drowned in hoopnet, near Hedge Bridge, Wayne Co.	19	Bob Bluett
Otter observed	10/05/94	Mouth of Village Creek on Little Wabash River, Wayne Co.	19	John Keener
Otter observed	10/13/94	Near Newton, Jasper Co.	20	Mike Hooe
Otter observed	11/11/94	Newton Lake, Jasper Co.	19	Bob Carter
Otter observed	12/02/94	Newton Lake, Jasper Co.	19	Chris Bickers
Otter observed	12/04/94	Near Latona, Jasper Co.	19	unknown
Otter observed	12/12/94	Near New West York, Crawford Co.	20	unknown
Otter trapped and released	12/94	Coyote set on dry land 1.25 km E of Hodgson Bridge 0.75 km NE of BR392, Wayne Co.	19	unknown
Otter observed	1/06/95	Pond bank just N of Olney - Noble Airport, Richland Co.	19	James Wilson
2 otters observed	3/12,13/95	Near Sullivan, Moultrie Co.	14	Mike Skinner
Otter observed	3/20/95	Near Texico, Jefferson Co.	15	Jed Lisenby
Carcass	4/10/95	Killed by dogs, W part of Grove Township, Jasper Co.	20	unknown
Otter observed	4/25/95	Near Sullivan, Moultrie Co.	14	John Bzuik

Table 6. Continued.

Observation	Date	Location	PMU[a]	Observer
2 otters observed	unknown	Playing on a log near Wayne City, Wayne Co.	19	Vonal Anderson
Otter observed	unknown	On creek bank in Robinson, Crawford Co.	20	Beth Estep
Otter observed	7/95	In Kickapoo Creek, near Downs, McLean Co.	14	Susan Enerson
Otter observed	9/95	Near Mt. Carmel, Wabash Co.	19	Josh Redman
Otter observed	10/14/95	Near Robinson, Crawford Co.	19	Garry Otey
2 otters observed	10/19/95	Oxbow of the Skillet Fork near Mill Shoals, White Co.	19	Darrel Locke
Carcass	12/31/95	Conibear trapped in Puncheon Creek, Webber Township, Jefferson Co.	19	Dick Porter
Tracks observed	1/8/96	Perks Bridge, Rt 37	16	Dan Woolard
4 otters observed	1/9/96	Dog Island, Pope Co.	17	Mike Murphy
Carcass	1/23/96	Conibear trapped 1.6 km SSW of New Athens, St Clair Co.	14	Glenda Zanders
Carcass	3/7/96	Roadkill, Mile marker 39 on I-64, 1.6 km from Kaskaskia River	14	Terry Esker

Table 6. Continued.

Observation	Date	Location	PMU[a]	Observer
2 Carcasses	4/14/96	Drowned in hoop net, Embarras River, 0.8 km north of bridge on County Road 13, Jasper Co.	20	Jeff Carr
Otter observed	5/4/96	On bank of ditch emptying into Cache River, 1.5 km east of Rt. 37 and County Road 7, Johnson Co.	16	Mike Janssen
Carcass	3/16/96	Found dead, 1.6 km upstream of release site on Shoal Cr., Shoal Creek, Montgomery Co.	14	Paul Oller and Maynard Hampton
3 otters observed (1 Adult, 2 Juvenile)	7/30/96	In N. Fork Embarras River, near Hunt City, Jasper Co.	20	Dennis Clauncey
Otter observed	8/3/96	Jasper Co.	19 or 20	Kate Shipley
Otter observed	7/20/96	Near Du Quoin, Perry Co.	15	unknown
Otter observed	7/22/96	Wolf Creek St. Park, Moultrie Co.	14	unknown
2 otters observed	8/96	In N. Fork Embarras River, Jasper-Crawford Co. line	20	unknown
Otter observed	10/10/96	Near New Memphis, Clinton Co.	14	Casey Hinden
Otter observed	11/10 and 11/30/96	Near Ellery, Wayne Co.	19	Mike Roosevelt

Table 6. Continued.

Observation	Date	Location	PMU[a]	Observer
Otter observed	11/13/96	Shoal Creek, 3.2 km N of Panama, Montgomery Co.	14	Bill Wilson
Carcass	12/9/96	Lake Glendale, Pope Co.	17	Bob Aaron
Otter trapped and released (untagged)	?/96	Little Wabash River, near Centerville, White Co.	19	Phil Bunting
Otter observed	12/16/96	20 m NE of intersection of of Co. Rds. 2330E and 750N, Douglas Co.	20	unnamed hunter
Carcass	12/31/96	0.4 km W of Rt. 14, 1.6 km W of McLeansboro, Hamilton Co.	19	Leon Bishop
4 otters observed	1/17 and 1/19/97	0.7 km up Elm Creek ditch from Little Wabash River, Wayne Co.	19	Les Frankland
Otter observed	2/25/97	Swimming in river, near Charleston, Coles Co.	20	Jon Vanatta
Otter observed	3/12/97	3.2-4.8 km above mouth of Wabash River, Gallatin Co.	19	Scott Bosaw

[a]Population Management Unit.

Fig. 1. Intensive study area (thick black line) on the Little Wabash River, and the location of release sights (circles) within the basin.

insert Fig. 2

insert fig 3a.

insert Figure 3b.

insert Fig. 3c.

insert Fig. 3d.

insert Fig. 3e.

insert Fig. 3f.

insert Fig. 3g.

insert Fig. 3h.

insert fig 4.

Figure 5. Examples of data layers developed as steps in calculating HSI values for riparian grid cells: a) perennial streams from Tiger; b) permanently flooded and intermittently exposed lakes and wetlands >1 ha from NWI; c) landcover classified from 30-m Landsat TM data; d) riparian bank cells from a, b, and c; e) woods extracted from Landsat data; f) distance to edge of wood patches; g) IBI of perennial streams (solid line indicates minor impairment, dashed line indicates moderate impairment); h) distance from roads, with roads shown as solid lines; I) HSI calculated for each riparian bank cell, with higher values shown darker; j) riparian bank cells predicted as best otter habitat (>0.8 only).

Fig. 5

Fig. 5

Appendix A. PATREC model sample calculation for determining the relative ability of a subunit to satisfy the habitat requirements of river otters.

The computations to provide an output are as follows. First, an area of unknown suitability is selected, and the required habitat attributes are inventoried. As an example, Hedge Bridge (19_113), a release site on the Little Wabash River, is inventoried and found to contain:

- 69.3 km of wooded streams
- a stream shape index of 0.86
- a 12% increase in available habitats offered by wooded shorelines of perennial wetlands
- 22.5 km of intermittent wetland edge.

Hedge Bridge meets the 1st and last criterion, but does not meet the 2nd nor the 3rd criterion. Once inventoried, the data are then used as input into Bayes' Theorem:

$P_{suit} = (P(h) \times CP(h)) / ([P(h) \times CP(h)] + [P(l) \times CP(l)])$

This equation utilizes 3 probabilities: the prior, the conditional, and the posterior. The prior probabilities, denoted here as P(h) and P(l), represent the chance that any given area will fall into either suitability class, and is usually determined as the percentage of the study area or surrounding areas which fall into each class. If this value is not known, as it was not in this study, a value of 0.5 can be used which essentially means that any area has a 50/50 chance of being in either suitability class. The conditional probabilities, denoted here as CP(h) and CP(l), are the probabilities that the inventory data we measured have high or low suitability potential, respectively. The posterior probability is the model output, denoted here as P_{suit}, and represents the probability that a given area will support a high density of otters, based on the inventory data.

To arrive at this output, CP(h) and CP(l) must first be calculated, this is done by multiplying the conditional probabilities for each individual habitat attribute in the model.

$$CP(h) = (0.69)(1-0.75)(1-0.63)(0.81)$$

$$= 0.052$$

$$CP(l) = (0.44)(1-0.63)(1-0.25)(0.38)$$

$$= 0.046$$

Notice that when model criterion are not met, as was the case for the 2nd and 3rd attributes for Hedge Bridge, both conditional probabilities are subtracted from 1.

Substituting these values into the model,

$$P_{suit} = (0.5 \times 0.052) / ([0.5 \times 0.052] + [0.5 \times 0.046])$$

$$P_{suit} = 0.53$$

We calculate $P_{suit} = 0.53$, or, given its collection of habitat attributes, there is a 53% chance that this area will support a high density of otters.

Appendix B. Summary statistics generated for each subunit in the development of the HSI model.

Table B-1. Riparian land use by watershed.

Land use	Bay Creek cells	%	Big Muddy cells	%	Cache cells	%	Embarras cells	%	Kaskaskia cells	%	Little Wabash cells	%	Saline cells	%
No data	2135	4	1426	1	105	0	318	0	138	0	270	0	2	0
Crops	3473	7	51265	19	19832	27	86041	39	108187	29	85280	35	37235	40
Woods	28751	59	127010	48	31382	43	69017	31	119135	32	88742	37	36884	40
Grass	13698	28	60718	23	19870	27	55609	25	127035	34	61702	26	16294	17
Water	104	0	17079	6	344	0	4476	2	3134	1	1875	1	1653	2
Urban	316	1	3919	1	1506	2	5369	2	13272	4	3520	1	1117	1
Orchards	0	0	91	0	47	0	0	0	29	0	0	0	20	0
Total	48477	100	261508	100	73086	100	221161	100	370897	100	241389	100	93205	100

Table B-2. Summary statistics for subcatchments of Bay Creek watershed.

Measurement	Subcatchment ID						
	101	102	103	104	105	106	107
Subcatchment size (ha)	52450	10769	12861	16235	11436	30544	13248
Area of woods (ha)	29662	5913	9873	6557	4641	17309	8648
Mean human pop. density (people/km2)	8	10	3	4	5	11	3
Approx. length of rip. banks (km)	576	111	120	164	110	291	179
Percent of riparian banks in IDNR-defined natural areas	5.39	10.81	13.52	0.02	0.00	6.87	1.18
HSI:							
Mean	0.71	0.78	0.89	0.60	0.66	0.74	0.66
Std. dev.	0.24	0.24	0.19	0.24	0.22	0.22	0.23
Distance from bank cells to nearest riparian wood edge (m):							
Mean	83	92	183	68	32	90	60
Std. dev.	112	97	147	146	48	103	77
Distance from bank cells to nearest intermittent wetland (m):							
Mean	5403	3692	13132	1010	1436	5160	1630
Std. dev.	4840	2522	2663	1270	1411	4440	1777
Distance from bank cells to nearest road (m):							
Mean	320	443	666	397	457	519	334
Std. dev.	235	319	388	255	284	330	229
Human population density at bank cells (people/km2):							
Mean	9	12	2	4	6	11	3
Std. dev.	29	52	5	12	11	223	7
COOPUP land use (%):							
Crops	4	2	0	23	12	6	6
Woods	54	67	87	45	44	67	32
Grass	29	22	0	32	44	26	15
Urban	1	2	0	0	0	0	0
Orchards	0	0	0	0	0	0	0

Table B-2. Continued.

Measurement	Subcatchment ID						
	101	102	103	104	105	106	107
IDNR land use (%):							
High density urban	0	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0
Medium density urban	1	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0
Major roadways	0	0	0	0	0	0	0
Active railroads	0	0	0	0	0	0	0
Abandoned railroads	1	0	0	0	0	0	0
Row crops	7	3	1	19	9	6	16
Small grain crops	4	1	3	7	3	2	1
Orchards/Nurseries	0	0	0	0	0	0	0
Urban grassland	0	0	0	0	0	0	0
Rural grassland	20	14	7	13	19	11	9
Deciduous forest, closed canopy	30	40	70	18	25	51	29
Deciduous forest, open canopy	5	3	2	1	1	1	0
Coniferous forest	2	0	4	2	4	3	1
Open water	5	8	0	1	1	1	6
Perennial streams	6	5	8	6	7	7	4
Shallow marsh/wet meadow	1	0	0	3	1	2	2
Deep marsh	0	0	0	0	0	0	2
Forested wetlands	16	23	3	28	22	12	21
Swamp	0	1	0	0	3	1	4
Shallow water wetlands	1	0	0	1	3	1	2
Barren land	0	0	0	0	0	0	0

Table B-3. Summary statistics for subcatchments of Big Muddy watershed.

Measurement	Subcatchment ID											
	101	102	103	104	105	106	107	108	109	110	111	112
Subcatchment size (ha)	39774	16670	11325	22825	26330	25673	23362	24735	58682	20574	38439	31289
Area of woods (ha)	21992	7438	4056	9853	12283	7375	5017	7136	11663	5039	5192	7554
Mean human pop. density (people/km2)	15	5	61	54	45	31	89	35	10	21	8	29
Approx. length of rip. banks (km)	481	157	120	279	358	234	321	229	328	193	287	214
Percent of riparian banks in IDNR-defined natural areas	1.71	1.66	0.00	0.60	1.10	0.00	0.00	0.00	1.14	2.61	0.00	0.38
HSI:												
Mean	0.62	0.69	0.66	0.61	0.73	0.58	0.51	0.49	0.47	0.58	0.44	0.48
Std. dev.	0.36	0.34	0.26	0.32	0.31	0.34	0.35	0.35	0.34	0.33	0.36	0.34
Distance from bank cells to nearest riparian wood edge (m):												
Mean	93	94	54	49	140	49	46	35	40	60	26	40
Std. dev.	124	124	57	61	154	70	62	50	62	73	45	65
Distance from bank cells to nearest intermittent wetland (m):												
Mean	5043	7033	4084	5389	3753	2580	987	1749	4079	713	2040	5116
Std. dev.	4404	1393	2441	3881	2504	2330	976	1299	4589	1055	2194	3802
Distance from bank cells to nearest road (m):												
Mean	320	391	366	334	325	333	340	345	393	381	277	300
Std. dev.	250	265	264	253	265	307	247	265	265	309	218	224
Human population density at bank cells (people/km2):												
Mean	9	5	67	51	50	21	69	34	10	10	8	20
Std. dev.	29	10	270	248	109	25	302	101	57	44	46	49
COOPUP land use (%):												
Crops	16	13	6	7	6	17	23	22	27	15	27	14
Woods	62	68	68	60	68	48	53	38	47	56	34	41
Grass	15	19	23	22	15	21	19	18	21	16	22	26
Urban	0	1	1	8	1	2	2	2	0	3	2	11
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-3. Continued.

Measurement	Subcatchment ID											
	101	102	103	104	105	106	107	108	109	110	111	112
IDNR land use (%):												
High density urban	0	0	0	1	0	0	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	1	1	0	1	0	0	0	0	1	1
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	1	0	0	0	0	0	0	0	0	1	1
Active railroads	0	0	0	1	0	0	0	1	1	1	1	1
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0	0
Row crops	12	4	4	5	6	10	23	25	20	9	21	11
Small grain crops	1	0	0	2	1	2	1	3	2	1	3	2
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	0	0	2	1	0	2	1	1	0	1	0	1
Rural grassland	4	7	10	8	11	19	9	16	15	10	10	14
Deciduous forest, closed canopy	29	52	33	47	32	19	16	8	6	8	13	12
Deciduous forest, open canopy	0	0	0	1	2	3	1	2	3	1	2	2
Coniferous forest	0	1	0	0	6	1	0	2	0	1	0	0
Open water	14	22	14	2	19	3	7	7	5	3	7	3
Perennial streams	4	4	7	8	5	8	6	6	12	9	2	10
Shallow marsh/wet meadow	2	1	0	0	1	0	3	2	1	2	4	1
Deep marsh	0	0	0	0	0	1	1	0	0	1	1	0
Forested wetlands	30	8	23	20	11	17	25	17	31	42	8	32
Swamp	0	0	0	0	1	1	2	0	1	4	3	2
Shallow water wetlands	2	1	5	2	4	12	5	9	3	5	21	7
Barren land	0	0	0	0	0	0	0	0	0	1	1	0

Table B-3. Continued.

Measurement	Subcatchment ID											
	113	114	115	116	117	118	119	120	201	202	203	204
Subcatchment size (ha)	32475	37363	36832	23667	26143	19931	59651	42153	21530	58312	34458	63080
Area of woods (ha)	6493	7510	4822	4850	4780	4912	11574	6977	6236	31642	9145	17763
Mean human pop. density (people/km2)	11	20	14	8	23	8	6	4	3	22	6	21
Approx. length of rip. banks (km)	233	405	173	139	206	379	386	542	580	760	320	589
Percent of riparian banks in IDNR-defined natural areas	0.00	1.52	0.00	0.00	0.00	0.00	0.40	0.00	7.14	6.86	9.64	1.71
HSI:												
Mean	0.56	0.52	0.47	0.54	0.58	0.58	0.54	0.41	0.43	0.46	0.39	0.54
Std. dev.	0.32	0.33	0.32	0.31	0.30	0.30	0.35	0.33	0.33	0.37	0.32	0.31
Distance from bank cells to nearest riparian wood edge (m):												
Mean	50	46	19	42	38	56	42	28	105	69	69	33
Std. dev.	83	65	32	72	45	72	65	56	158	118	119	50
Distance from bank cells to nearest intermittent wetland (m):												
Mean	3169	1667	3526	2303	2093	2452	4452	2440	310	2377	790	8385
Std. dev.	2477	1492	3350	1749	1601	1770	2591	1825	434	2930	1012	3758
Distance from bank cells to nearest road (m):												
Mean	361	283	378	298	358	274	338	286	712	246	456	318
Std. dev.	248	208	249	202	248	231	236	240	610	234	420	249
Human population density at bank cells (people/km2):												
Mean	7	21	11	8	7	5	7	2	2	14	2	11
Std. dev.	10	118	49	40	17	15	21	9	15	65	8	45
COOPUP land use (%):												
Crops	17	18	26	17	15	10	22	29	24	24	29	16
Woods	46	54	37	46	58	60	48	35	35	44	33	47
Grass	30	25	35	36	24	29	28	35	13	14	24	36
Urban	1	2	0	1	0	0	1	0	0	2	1	0
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-3. Continued.

Measurement	Subcatchment ID											
	113	114	115	116	117	118	119	120	201	202	203	204
IDNR land use (%):												
High density urban	0	0	0	0	0	0	0	0	0	0	1	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	0	0	0	0	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	0	0	0	0	0	0	1	0	0
Active railroads	1	0	0	0	0	1	0	0	0	1	1	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	1	0
Row crops	6	14	18	9	15	16	14	30	11	24	20	14
Small grain crops	2	1	4	6	2	2	3	3	1	3	2	5
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	0	1	0	0	0	0	0	0	0	0	0	0
Rural grassland	27	9	21	29	6	19	23	26	1	9	3	27
Deciduous forest, closed canopy	14	23	17	19	26	23	19	12	2	27	7	23
Deciduous forest, open canopy	0	1	0	0	2	6	0	1	0	1	0	0
Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0
Open water	1	8	1	0	9	10	3	5	46	2	29	6
Perennial streams	7	5	8	6	7	2	7	3	1	6	2	7
Shallow marsh/wet meadow	1	1	1	0	1	0	0	1	2	2	1	0
Deep marsh	0	1	0	0	0	0	0	0	0	2	0	0
Forested wetlands	37	25	25	27	23	13	28	12	30	18	26	12
Swamp	0	2	0	0	0	0	0	0	0	1	1	0
Shallow water wetlands	4	7	3	3	8	6	3	4	5	3	4	5
Barren land	0	0	0	0	0	0	0	0	0	0	0	0

Table B-4. Summary statistics for subcatchments of Cache watershed.

Measurement	Subcatchment ID								
	101	102	103	104	201	202	203	204	205
Subcatchment size (ha)	27312	15395	26579	25331	41062	22108	33364	33033	25248
Area of woods (ha)	5837	4255	13790	8688	15024	7171	8483	7470	6545
Mean human pop. density (people/km2)	12	63	11	10	17	9	6	30	46
Approx. length of rip. banks (km)	198	169	264	211	342	172	266	329	267
Percent of riparian banks in IDNR-defined natural areas	31.28	0.00	0.17	1.40	12.90	2.40	1.96	1.13	0.92
HSI:									
Mean	0.59	0.51	0.57	0.54	0.66	0.57	0.48	0.51	0.52
Std. dev.	0.24	0.25	0.26	0.28	0.25	0.20	0.23	0.23	0.26
Distance from bank cells to nearest riparian wood edge (m):									
Mean	34	20	51	48	49	27	23	25	27
Std. dev.	50	33	104	75	69	40	57	52	48
Distance from bank cells to nearest intermittent wetland (m):									
Mean	1718	5489	2491	881	1866	3027	1078	2223	1482
Std. dev.	2234	3301	2116	1081	2922	1940	1136	2476	1307
Distance from bank cells to nearest road (m):									
Mean	422	228	303	289	436	388	357	378	282
Std. dev.	271	177	267	260	308	241	308	306	226
Human population density at bank cells (people/km2):									
Mean	15	60	17	11	9	10	4	23	15
Std. dev.	109	227	81	28	33	71	6	135	56
COOPUP land use (%):									
Crops	31	20	0	26	11	14	42	43	28
Woods	44	38	50	54	55	45	25	33	37
Grass	24	35	1	17	31	40	22	23	28
Urban	0	5	1	3	2	1	1	0	5
Orchards	0	1	0	0	0	0	0	0	0

Table B-4. Continued.

Measurement	Subcatchment ID								
	101	102	103	104	201	202	203	204	205
IDNR land use (%):									
High density urban	0	0	0	0	0	0	0	0	2
Medium-high density urban	0	0	0	0	0	0	0	0	0
Medium density urban	0	1	1	1	0	1	0	1	1
Low density urban	0	0	0	0	0	0	0	0	0
Major roadways	0	1	1	0	0	1	1	0	1
Active railroads	0	2	0	0	0	0	1	0	2
Abandoned railroads	0	0	0	0	0	1	0	0	1
Row crops	20	12	17	25	6	9	38	38	23
Small grain crops	2	6	5	4	3	3	2	2	3
Orchards/Nurseries	0	1	0	0	0	0	0	0	0
Urban grassland	0	1	0	0	0	0	0	0	1
Rural grassland	16	31	17	7	17	23	18	16	12
Deciduous forest, closed canopy	12	17	29	13	26	35	7	5	10
Deciduous forest, open canopy	1	2	1	0	4	2	2	2	0
Coniferous forest	0	0	0	0	1	1	0	0	0
Open water	0	1	0	2	1	3	1	4	6
Perennial streams	11	8	9	9	11	8	11	5	6
Shallow marsh/wet meadow	2	1	0	1	2	1	2	1	2
Deep marsh	0	0	0	0	0	0	0	0	0
Forested wetlands	27	14	18	27	26	11	15	22	26
Swamp	6	0	0	7	1	0	2	2	0
Shallow water wetlands	2	2	1	2	1	1	1	2	4
Barren land	0	0	0	0	0	0	0	0	0

Table B-5. Summary statistics for subcatchments of Embarras watershed.

Measurement	Subcatchment ID											
	101	102	103	104	105	106	107	108	109	110	111	112
Subcatchment size (ha)	48023	28255	19091	15392	22779	39869	14333	20397	26441	29221	15158	39668
Area of woods (ha)	383	74	838	247	20	1253	1630	3909	1443	4800	1560	7719
Mean human pop. density (people/km2)	6	85	5	3	4	7	5	9	21	5	6	7
Approx. length of rip. banks (km)	271	194	146	127	160	248	133	192	207	273	171	373
Percent of riparian banks in IDNR-defined natural areas	0.00	0.00	4.63	0.02	0.00	0.27	4.27	0.91	1.91	1.43	0.00	0.07
HSI:												
Mean	0.16	0.14	0.32	0.19	0.04	0.32	0.38	0.44	0.28	0.49	0.50	0.58
Std. dev.	0.27	0.22	0.35	0.30	0.15	0.36	0.38	0.37	0.34	0.33	0.33	0.33
Distance from bank cells to nearest riparian wood edge (m):												
Mean	4	0	21	6	0	14	25	28	10	30	21	35
Std. dev.	16	3	41	18	3	36	38	50	22	43	31	45
Distance from bank cells to nearest intermittent wetland (m):												
Mean	16973	8679	7525	13337	23821	10151	5460	15830	22067	12558	16819	13820
Std. dev.	7460	4687	2751	2792	3299	5260	2919	3664	4155	5739	4352	4923
Distance from bank cells to nearest road (m):												
Mean	261	234	298	248	310	276	310	259	222	351	258	329
Std. dev.	189	178	201	187	225	185	190	190	183	242	187	210
Human population density at bank cells (people/km2):												
Mean	8	146	6	4	3	6	3	9	35	6	9	8
Std. dev.	20	486	8	29	12	26	5	36	183	7	16	8
COOPUP land use (%):												
Crops	63	62	48	67	90	49	45	32	42	23	22	16
Woods	8	1	29	11	1	23	38	40	22	38	41	48
Grass	21	30	22	20	8	26	14	25	24	27	34	28
Urban	8	7	1	1	2	2	0	2	12	0	0	1
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-5. Continued.

Measurement	Subcatchment ID											
	101	102	103	104	105	106	107	108	109	110	111	112
IDNR land use (%):												
High density urban	0	1	0	0	0	0	0	0	1	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	1	1	0	0	0	0	0	0	3	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	1	0	0	0	0	0	0	0	0	0	0
Active railroads	1	1	0	1	0	0	0	0	0	0	0	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0	0
Row crops	38	44	29	45	59	29	26	19	20	27	27	24
Small grain crops	3	3	1	2	2	4	2	4	4	4	9	6
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	2	1	0	0	1	1	0	0	3	0	0	0
Rural grassland	23	30	19	21	15	21	14	14	22	11	22	15
Deciduous forest, closed canopy	2	0	8	1	0	10	16	27	19	24	23	32
Deciduous forest, open canopy	1	0	1	1	0	3	3	2	3	1	2	1
Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0
Open water	0	0	3	2	0	1	1	2	1	2	0	0
Perennial streams	16	15	18	14	22	17	18	12	17	11	14	15
Shallow marsh/wet meadow	2	0	0	0	0	0	0	0	0	0	0	0
Deep marsh	2	0	0	0	0	0	0	0	0	0	0	0
Forested wetlands	8	0	20	11	0	13	18	17	6	18	2	5
Swamp	0	0	0	0	0	0	0	0	0	0	0	0
Shallow water wetlands	1	1	0	1	0	1	0	1	2	1	0	1
Barren land	0	0	0	1	0	0	0	0	0	0	0	0

Table B-5. Continued.

Measurement	Subcatchment ID											
	113	114	115	116	117	118	119	120	121	122	123	201
Subcatchment size (ha)	18855	28778	20190	25459	20186	25713	22707	27711	29186	54681	38194	23867
Area of woods (ha)	3808	5393	3299	2116	4368	2640	4888	2767	4078	7253	4212	440
Mean human pop. density (people/km2)	5	6	3	4	10	11	10	27	7	5	4	8
Approx. length of rip. banks (km)	156	158	106	166	142	128	121	248	269	395	370	141
Percent of riparian banks in IDNR-defined natural areas	1.52	3.10	0.00	1.45	1.16	0.05	0.00	0.02	0.00	0.00	0.93	0.74
HSI:												
Mean	0.51	0.40	0.58	0.31	0.48	0.42	0.45	0.26	0.44	0.50	0.35	0.41
Std. dev.	0.34	0.36	0.31	0.34	0.35	0.33	0.36	0.32	0.38	0.37	0.35	0.26
Distance from bank cells to nearest riparian wood edge (m):												
Mean	30	27	44	14	30	32	35	15	30	33	12	4
Std. dev.	39	49	53	26	40	57	51	33	41	49	25	13
Distance from bank cells to nearest intermittent wetland (m):												
Mean	9180	6468	9664	6433	4688	2623	6036	2250	6813	7162	21182	43179
Std. dev.	4998	3774	2884	3103	3868	1806	2413	2290	2514	3747	3376	2332
Distance from bank cells to nearest road (m):												
Mean	285	331	269	283	331	307	248	304	239	332	262	286
Std. dev.	197	213	171	193	224	233	170	263	172	204	194	180
Human population density at bank cells (people/km2):												
Mean	5	4	3	3	10	20	12	36	8	6	5	15
Std. dev.	6	7	4	9	18	112	53	99	20	20	11	63
COOPUP land use (%):												
Crops	22	39	16	49	29	23	30	52	34	31	43	20
Woods	38	38	61	28	49	43	49	26	48	48	25	11
Grass	26	20	22	20	21	25	17	20	15	20	27	65
Urban	0	1	1	2	0	8	4	2	2	0	3	3
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-5. Continued.

Measurement	Subcatchment ID											
	113	114	115	116	117	118	119	120	121	122	123	201
IDNR land use (%):												
High density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	0	0	0	0	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	0	0	0	0	0	0	0	0	0
Active railroads	0	0	0	0	0	0	0	1	0	0	0	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0	0
Row crops	31	28	14	31	17	22	19	37	20	22	25	6
Small grain crops	7	2	5	4	3	5	3	3	4	5	4	3
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	0	0	0	0	0	0	0	0	0	0	1	1
Rural grassland	11	5	8	5	5	7	4	7	10	10	13	30
Deciduous forest, closed canopy	21	23	32	15	25	16	12	9	28	30	30	21
Deciduous forest, open canopy	0	1	1	0	1	1	0	0	1	1	1	3
Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0
Open water	2	6	0	8	7	1	3	2	0	1	0	3
Perennial streams	8	12	14	12	13	17	13	10	12	13	11	15
Shallow marsh/wet meadow	0	1	0	1	0	1	0	3	0	0	0	0
Deep marsh	0	0	0	0	0	0	0	1	0	0	0	0
Forested wetlands	18	21	25	24	26	27	42	21	21	17	12	17
Swamp	0	0	0	0	0	2	0	0	0	0	0	0
Shallow water wetlands	1	1	1	1	2	1	2	4	2	0	2	1
Barren land	0	0	0	0	0	0	0	1	0	0	0	0

Table B-5. Continued.

Measurement	Subcatchment ID									
	202	203	205	207	208	209	210	211	301	302
Subcatchment size (ha)	38129	9213	32361	30970	43378	22571	29589	3941	22372	30877
Area of woods (ha)	665	345	5477	6698	9473	3701	3368	472	673	51
Mean human pop. density (people/km2)	4	3	10	9	5	8	14	2	20	3
Approx. length of rip. banks (km)	229	10	165	223	416	157	178	49	130	183
Percent of riparian banks in IDNR-defined natural areas	0.00	0.00	0.00	2.18	1.29	2.16	5.69	11.27	0.00	0.00
HSI:										
Mean	0.25	0.51	0.41	0.48	0.45	0.49	0.34	0.37	0.39	0.16
Std. dev.	0.28	0.28	0.32	0.34	0.36	0.36	0.35	0.37	0.32	0.25
Distance from bank cells to nearest riparian wood edge (m):										
Mean	2	15	15	19	26	35	29	58	8	0
Std. dev.	10	23	28	30	42	44	54	86	20	2
Distance from bank cells to nearest intermittent wetland (m):										
Mean	32296	29404	20610	16628	11588	4742	3626	1402	51904	35092
Std. dev.	5581	4956	7383	7858	7411	2893	2397	853	3464	5930
Distance from bank cells to nearest road (m):										
Mean	327	371	285	305	355	343	349	375	332	286
Std. dev.	205	272	205	211	251	269	277	328	198	210
Human population density at bank cells (people/km2):										
Mean	4	5	10	6	5	7	21	2	12	3
Std. dev.	7	3	29	31	6	28	92	3	23	10
COOPUP land use (%):										
Crops	54	18	25	28	34	29	39	35	31	69
Woods	6	35	32	37	39	51	37	36	16	0
Grass	40	47	37	34	22	14	15	11	49	29
Urban	0	0	5	0	1	1	5	2	3	1
Orchards	0	0	0	0	0	0	0	0	0	0

Table B-5. Continued.

Measurement	Subcatchment ID									
	202	203	205	207	208	209	210	211	301	302
IDNR land use (%):										
High density urban	0	0	0	0	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	1	0	0	0	1	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	0	0	0	0	2	0	0
Active railroads	0	0	0	0	0	0	0	0	0	0
Abandoned railroads	0	0	0	0	0	1	0	0	0	0
Row crops	33	11	18	17	21	14	18	25	15	42
Small grain crops	2	4	4	6	3	3	3	2	3	3
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0
Urban grassland	0	0	2	0	0	0	1	0	0	1
Rural grassland	22	22	10	11	9	8	5	5	24	28
Deciduous forest, closed canopy	10	31	28	32	36	28	15	7	19	3
Deciduous forest, open canopy	1	5	1	1	1	1	1	1	2	1
Coniferous forest	0	0	0	0	0	0	0	0	0	0
Open water	2	4	3	1	4	6	8	19	2	1
Perennial streams	17	14	13	12	10	12	9	2	14	19
Shallow marsh/wet meadow	0	0	0	0	0	0	1	2	0	0
Deep marsh	0	0	0	0	0	0	0	0	0	0
Forested wetlands	13	8	17	18	15	25	34	34	20	2
Swamp	0	0	0	0	0	0	0	0	0	0
Shallow water wetlands	0	1	2	2	1	2	3	2	1	0
Barren land	0	0	0	0	0	0	0	0	0	0

Table B-6. Summary statistics for subcatchments of Kaskaskia watershed.

Measurement	Subcatchment ID											
	101	102	103	104	105	106	107	108	109	110	111	112
Subcatchment size (ha)	10590	23201	19087	8311	22062	16883	32000	18685	15798	15183	13628	24593
Area of woods (ha)	2347	3747	1861	1899	3307	2613	2161	3220	1101	1185	359	761
Mean human pop. density (people/km2)	5	5	4	4	9	6	5	5	4	5	11	4
Approx. length of rip. banks (km)	60	146	145	81	162	168	219	219	143	157	118	190
Percent of riparian banks in IDNR-defined natural areas	0.10	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.36	0.11	0.00	0.00
HSI:												
Mean	0.49	0.51	0.42	0.40	0.50	0.45	0.41	0.61	0.39	0.35	0.22	0.29
Std. dev.	0.35	0.34	0.35	0.34	0.37	0.35	0.33	0.34	0.36	0.37	0.32	0.35
Distance from bank cells to nearest riparian wood edge (m):												
Mean	21	32	14	13	33	18	11	47	18	16	5	10
Std. dev.	37	56	28	30	55	35	25	62	37	31	16	23
Distance from bank cells to nearest intermittent wetland (m):												
Mean	11699	25414	17588	13230	17425	15534	14913	3206	3102	2173	7064	6708
Std. dev.	3903	3080	4593	3575	5632	4079	4103	2247	3433	2229	3906	2905
Distance from bank cells to nearest road (m):												
Mean	351	324	288	373	297	302	275	318	330	268	277	283
Std. dev.	186	217	186	233	207	199	183	247	234	203	179	195
Human population density at bank cells (people/km2):												
Mean	5	6	5	2	10	7	6	6	5	6	11	7
Std. dev.	4	20	7	4	23	8	7	6	13	8	31	12
COOPUP land use (%):												
Crops	30	23	33	36	29	30	30	9	41	44	63	53
Woods	35	43	27	22	42	31	23	53	27	27	13	19
Grass	35	33	39	39	29	36	45	31	32	26	23	26
Urban	2	1	1	0	0	1	2	8	0	3	0	1
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-6. Continued.

Measurement	Subcatchment ID											
	101	102	103	104	105	106	107	108	109	110	111	112
IDNR land use (%):												
High density urban	0	0	0	0	0	0	0	1	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	0	0	0	0	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	0	0	0	0	0	0	0	0	0
Active railroads	0	0	0	0	0	0	0	0	0	0	0	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0	0
Row crops	13	9	22	23	19	19	33	10	18	10	42	23
Small grain crops	1	4	4	1	1	1	3	1	5	2	4	2
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	1	0	0	1	0	0	1	0	0	2	0	1
Rural grassland	22	32	31	23	22	30	25	19	21	18	18	23
Deciduous forest, closed canopy	16	29	17	16	31	20	10	51	16	27	11	9
Deciduous forest, open canopy	0	0	0	0	0	0	0	0	3	3	2	2
Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0
Open water	1	0	0	1	0	0	0	7	6	9	0	5
Perennial streams	17	15	15	16	14	15	17	6	14	11	14	20
Shallow marsh/wet meadow	1	0	0	0	0	0	0	0	0	0	0	0
Deep marsh	0	0	0	0	0	0	0	3	12	16	1	0
Forested wetlands	26	9	10	18	11	14	9	3	4	2	6	14
Swamp	0	0	0	0	0	0	0	0	0	0	0	0
Shallow water wetlands	1	1	0	1	0	0	0	0	2	1	0	0
Barren land	0	0	0	0	0	0	0	0	0	0	0	0

Table B-6. Continued.

Measurement	Subcatchment ID											
	113	114	115	116	117	118	119	120	121	200	201	202
Subcatchment size (ha)	27880	14939	34448	22623	26391	17884	13406	14234	14214	15392	9755	31362
Area of woods (ha)	789	259	236	650	327	64	237	141	31	2425	989	2333
Mean human pop. density (people/km2)	7	5	3	9	17	2	4	7	49	4	6	5
Approx. length of rip. banks (km)	183	127	191	170	203	112	100	86	93	126	99	215
Percent of riparian banks in IDNR-defined natural areas	2.40	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HSI:												
Mean	0.26	0.19	0.16	0.23	0.18	0.11	0.21	0.16	0.10	0.58	0.45	0.37
Std. dev.	0.34	0.30	0.29	0.32	0.29	0.22	0.32	0.26	0.21	0.36	0.33	0.33
Distance from bank cells to nearest riparian wood edge (m):												
Mean	10	5	4	11	5	0	8	1	0	55	19	35
Std. dev.	24	18	16	30	22	2	24	8	3	76	39	71
Distance from bank cells to nearest intermittent wetland (m):												
Mean	6197	6688	18917	3922	16712	29613	10750	25977	41992	1931	939	4593
Std. dev.	3724	3525	5203	3424	7861	5210	5151	4987	5235	1510	819	2473
Distance from bank cells to nearest road (m):												
Mean	269	246	262	261	285	282	279	260	208	259	252	326
Std. dev.	191	187	189	186	198	197	186	190	182	191	181	254
Human population density at bank cells (people/km2):												
Mean	6	6	3	10	27	2	5	4	54	4	3	3
Std. dev.	10	6	9	18	96	11	8	8	190	11	5	4
COOPUP land use (%):												
Crops	57	68	71	59	67	76	60	66	51	14	19	33
Woods	21	11	9	17	6	0	14	3	1	52	27	34
Grass	21	21	19	22	25	22	20	30	19	28	45	26
Urban	2	0	1	2	2	2	6	1	29	5	7	6
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-6. Continued.

Measurement	Subcatchment ID											
	113	114	115	116	117	118	119	120	121	200	201	202
IDNR land use (%):												
High density urban	0	0	0	0	0	0	1	0	2	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	0	0	0	0	1	0	8	1	0	0
Low density urban	0	0	0	0	0	0	0	1	2	0	0	0
Major roadways	0	0	0	0	0	0	0	2	1	0	1	1
Active railroads	0	0	0	1	0	0	0	0	0	0	1	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0	0
Row crops	20	34	34	29	48	58	28	36	40	9	14	15
Small grain crops	5	3	3	3	2	2	2	5	2	2	3	5
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	1	0	1	0	0	1	1	0	10	1	1	1
Rural grassland	26	23	25	21	20	16	21	31	17	16	22	23
Deciduous forest, closed canopy	6	6	2	2	1	0	5	2	0	6	6	7
Deciduous forest, open canopy	3	2	1	1	1	0	1	1	1	0	0	0
Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0
Open water	2	1	0	3	0	0	1	0	1	1	3	0
Perennial streams	24	21	28	23	24	23	28	21	13	9	6	13
Shallow marsh/wet meadow	0	1	0	0	0	0	1	0	0	0	1	0
Deep marsh	2	2	0	0	0	0	1	0	0	2	1	0
Forested wetlands	10	7	4	14	4	0	7	0	0	52	38	33
Swamp	0	0	0	0	0	0	0	0	0	0	0	0
Shallow water wetlands	0	0	0	0	0	0	1	1	3	2	5	2
Barren land	0	0	0	0	0	0	0	0	0	0	0	0

Table B-6. Continued.

Measurement	Subcatchment ID											
	203	204	205	206	207	208	209	210	211	212	213	301
Subcatchment size (ha)	31072	20331	37782	47493	53394	52115	34442	27787	27334	19801	36253	28608
Area of woods (ha)	4046	881	5632	3387	8330	6458	6189	2092	5242	3014	6689	4031
Mean human pop. density (people/km2)	13	9	22	30	5	10	4	7	4	4	10	41
Approx. length of rip. banks (km)	220	98	227	294	406	270	384	230	156	172	315	194
Percent of riparian banks in IDNR-defined natural areas	0.04	5.65	0.00	0.00	0.71	0.00	0.38	0.00	0.00	0.00	1.75	0.00
HSI:												
Mean	0.49	0.43	0.46	0.54	0.50	0.51	0.51	0.40	0.46	0.51	0.51	0.45
Std. dev.	0.32	0.32	0.34	0.27	0.34	0.35	0.35	0.34	0.34	0.33	0.33	0.32
Distance from bank cells to nearest riparian wood edge (m):												
Mean	40	21	37	24	36	22	31	12	26	20	28	18
Std. dev.	59	42	54	51	56	34	50	29	51	42	53	43
Distance from bank cells to nearest intermittent wetland (m):												
Mean	3942	3919	9440	2442	14757	11861	9040	5162	17800	4582	15934	2180
Std. dev.	3043	2726	5858	3821	8229	7022	7125	3573	7338	3296	7074	1652
Distance from bank cells to nearest road (m):												
Mean	323	311	218	386	327	343	296	291	334	350	264	304
Std. dev.	228	207	159	281	237	221	193	210	216	214	197	208
Human population density at bank cells (people/km2):												
Mean	10	5	30	18	5	8	3	6	4	5	8	44
Std. dev.	22	5	67	53	12	38	6	22	4	6	41	143
COOPUP land use (%):												
Crops	21	25	13	12	21	23	24	30	28	23	19	26
Woods	46	28	46	31	43	39	41	22	36	31	39	27
Grass	30	44	26	56	34	36	34	42	35	46	40	44
Urban	3	3	15	1	2	2	0	6	1	0	2	2
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-6. Continued.

Measurement	Subcatchment ID											
	203	204	205	206	207	208	209	210	211	212	213	301
IDNR land use (%):												
High density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	1	0	1	0	0	0	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	1	0	0	0	0	1	0	0	0	1
Active railroads	1	0	1	0	0	0	0	0	0	0	0	0
Abandoned railroads	1	0	0	0	0	0	0	0	0	0	0	0
Row crops	8	13	5	4	11	12	13	20	11	18	14	15
Small grain crops	3	3	1	1	1	2	1	1	4	1	2	3
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	1	2	2	1	1	0	0	0	0	0	0	1
Rural grassland	18	28	19	21	24	27	26	35	30	27	29	19
Deciduous forest, closed canopy	11	7	26	12	18	20	16	14	21	12	27	5
Deciduous forest, open canopy	0	0	1	0	0	0	0	0	0	0	0	0
Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0
Open water	0	0	2	8	0	0	0	1	0	0	0	0
Perennial streams	13	12	11	6	16	15	14	9	13	15	15	12
Shallow marsh/wet meadow	1	0	0	6	2	1	1	1	2	1	0	0
Deep marsh	0	0	0	1	0	1	0	0	0	0	0	0
Forested wetlands	41	32	29	29	25	20	27	14	18	24	11	40
Swamp	0	0	0	0	0	0	0	0	0	0	0	0
Shallow water wetlands	1	1	2	9	2	2	1	2	1	1	1	2
Barren land	0	0	0	0	0	0	0	0	0	0	0	0

Table B-6. Continued.

Measurement	Subcatchment ID											
	302	303	304	305	306	307	401	402	403	404	405	406
Subcatchment size (ha)	37291	21533	26343	36253	45964	41492	22950	18232	24382	23249	17577	35289
Area of woods (ha)	2695	3474	2791	6560	4789	4410	5860	1839	5334	1985	3446	5651
Mean human pop. density (people/km2)	7	7	5	22	10	9	8	10	22	12	12	9
Approx. length of rip. banks (km)	126	125	165	222	277	203	188	303	176	213	318	158
Percent of riparian banks in IDNR-defined natural areas	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	5.45	0.00	3.20	1.94
HSI:												
Mean	0.57	0.50	0.54	0.52	0.47	0.46	0.63	0.39	0.53	0.37	0.42	0.64
Std. dev.	0.31	0.34	0.37	0.34	0.35	0.34	0.31	0.34	0.35	0.32	0.35	0.34
Distance from bank cells to nearest riparian wood edge (m):												
Mean	48	23	38	23	23	34	55	23	28	12	43	73
Std. dev.	65	40	57	39	42	73	66	48	41	30	82	83
Distance from bank cells to nearest intermittent wetland (m):												
Mean	3163	3111	6127	12146	11559	6832	1784	1006	10467	4955	924	5628
Std. dev.	2293	1720	4465	5545	6747	4421	2226	1070	4695	2763	950	2853
Distance from bank cells to nearest road (m):												
Mean	362	377	356	323	323	276	352	279	347	291	217	347
Std. dev.	238	241	232	205	211	190	244	220	229	237	188	234
Human population density at bank cells (people/km2):												
Mean	7	9	5	21	9	12	5	11	13	6	14	8
Std. dev.	16	9	8	68	53	21	10	47	58	31	57	21
COOPUP land use (%):												
Crops	14	21	19	21	23	22	11	33	23	36	20	12
Woods	50	33	41	38	33	28	60	28	45	19	36	63
Grass	33	38	28	37	36	41	27	38	31	44	34	21
Urban	1	3	4	2	5	4	1	1	1	0	9	3
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-6. Continued.

Measurement	Subcatchment ID											
	302	303	304	305	306	307	401	402	403	404	405	406
IDNR land use (%):												
High density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	0	0	0	0	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	1	0	0	0	0	0	0	0	0
Active railroads	0	0	0	0	0	0	1	1	0	0	0	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0	0
Row crops	10	13	13	12	18	23	10	8	18	18	6	6
Small grain crops	2	1	2	2	3	5	4	3	6	5	2	2
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	0	0	1	0	1	0	0	0	0	0	0	0
Rural grassland	18	26	23	25	27	27	14	27	12	22	31	11
Deciduous forest, closed canopy	6	20	31	20	21	21	21	10	26	17	8	12
Deciduous forest, open canopy	0	0	0	0	0	0	0	0	1	0	0	0
Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0
Open water	0	3	1	0	1	3	13	18	0	9	11	3
Perennial streams	13	10	9	12	10	10	7	4	19	8	2	12
Shallow marsh/wet meadow	1	1	2	1	2	2	1	3	1	0	1	0
Deep marsh	0	0	0	0	0	1	1	2	0	1	1	0
Forested wetlands	47	24	16	24	15	6	23	18	11	10	29	49
Swamp	0	0	0	0	0	0	0	0	0	0	1	0
Shallow water wetlands	1	2	2	2	1	2	4	5	5	8	5	3
Barren land	0	0	0	0	0	0	0	0	0	1	0	0

Table B-6. Continued.

Measurement	Subcatchment ID									
	407	408	409	410	411	413	414	415	416	417
Subcatchment size (ha)	22979	25032	28331	21523	14078	15245	31637	32775	41118	42223
Area of woods (ha)	3622	5115	3612	1523	554	2041	3125	2261	3751	1514
Mean human pop. density (people/km2)	6	7	34	17	191	68	53	13	15	19
Approx. length of rip. banks (km)	77	201	285	213	153	200	284	248	233	279
Percent of riparian banks in IDNR-defined natural areas	0.00	2.06	0.09	0.00	0.00	1.52	0.27	0.00	0.00	0.00
HSI:										
Mean	0.64	0.60	0.41	0.30	0.24	0.39	0.36	0.48	0.56	0.39
Std. dev.	0.37	0.31	0.33	0.31	0.27	0.35	0.34	0.30	0.32	0.27
Distance from bank cells to nearest riparian wood edge (m):										
Mean	66	72	25	10	4	51	30	27	32	10
Std. dev.	75	110	59	24	13	99	66	55	51	25
Distance from bank cells to nearest intermittent wetland (m):										
Mean	7478	1473	12894	11948	10470	2494	3628	8765	16701	7525
Std. dev.	5710	1430	6663	5945	2405	2050	2949	5349	9243	4473
Distance from bank cells to nearest road (m):										
Mean	403	355	312	271	217	240	281	291	326	279
Std. dev.	254	296	208	187	172	217	201	193	220	185
Human population density at bank cells (people/km2):										
Mean	5	7	15	14	122	47	51	14	12	20
Std. dev.	12	14	49	53	430	198	170	23	28	82
COOPUP land use (%):										
Crops	17	10	30	42	31	25	31	19	13	19
Woods	61	57	30	18	9	36	32	33	42	17
Grass	20	29	37	35	40	29	26	45	39	56
Urban	1	2	2	3	19	10	11	2	3	6
Orchards	0	0	0	0	0	0	0	0	0	0

Table B-6. Continued.

Measurement	Subcatchment ID									
	407	408	409	410	411	413	414	415	416	417
IDNR land use (%):										
High density urban	0	0	0	0	2	1	1	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	0	1	4	1	1	0	0	1
Low density urban	0	0	0	0	0	0	0	0	0	0
Major roadways	0	1	0	0	1	0	1	1	1	0
Active railroads	0	0	0	0	0	0	0	0	1	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0
Row crops	7	11	20	27	18	19	21	18	11	23
Small grain crops	2	2	10	9	5	4	4	5	4	4
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0
Urban grassland	0	0	0	0	5	3	3	0	0	1
Rural grassland	10	8	12	13	13	18	15	24	17	33
Deciduous forest, closed canopy	12	1	22	22	21	15	10	17	18	7
Deciduous forest, open canopy	0	0	1	2	2	0	0	0	1	0
Coniferous forest	0	0	0	0	0	0	0	0	0	0
Open water	0	2	0	1	3	1	1	1	0	1
Perennial streams	12	8	17	11	7	11	14	12	17	12
Shallow marsh/wet meadow	0	1	0	0	0	1	0	0	0	1
Deep marsh	1	0	0	0	0	0	0	0	0	0
Forested wetlands	54	61	11	6	9	21	27	21	27	16
Swamp	0	0	0	0	0	0	0	0	0	0
Shallow water wetlands	2	2	5	8	9	2	2	1	4	1
Barren land	0	0	0	0	0	1	0	0	0	0

Table B-7. Summary statistics for subcatchments of Little Wabash watershed.

Measurement	Subcatchment ID											
	101	102	103	104	105	106	107	108	109	110	111	112
Subcatchment size (ha)	14534	47589	35827	24684	70434	14845	64361	17741	18198	10994	39762	19714
Area of woods (ha)	564	5630	6348	3789	12954	1724	7082	2637	3179	1296	5115	3341
Mean human pop. density (people/km2)	27	12	12	72	9	5	5	11	4	4	9	3
Approx. length of rip. banks (km)	162	484	319	182	717	107	447	85	156	57	214	163
Percent of riparian banks in IDNR-defined natural areas	0.00	1.29	0.00	0.00	0.00	0.11	0.67	0.00	7.86	0.00	0.00	4.60
HSI:												
Mean	0.29	0.40	0.51	0.50	0.52	0.46	0.49	0.52	0.58	0.46	0.55	0.41
Std. dev.	0.30	0.35	0.34	0.36	0.31	0.34	0.34	0.33	0.34	0.37	0.32	0.38
Distance from bank cells to nearest riparian wood edge (m):												
Mean	10	17	22	27	39	29	31	32	55	32	37	36
Std. dev.	22	42	37	50	59	47	53	46	71	44	55	55
Distance from bank cells to nearest intermittent wetland (m):												
Mean	28414	17496	22411	7818	15409	3913	5384	8250	4641	4528	2755	9442
Std. dev.	4102	7399	4690	5015	4706	1968	3780	3222	3005	3294	2360	2304
Distance from bank cells to nearest road (m):												
Mean	196	273	306	284	335	306	368	318	428	413	321	345
Std. dev.	163	197	196	204	217	218	256	203	280	271	210	276
Human population density at bank cells (people/km2):												
Mean	76	13	13	72	8	4	4	7	2	1	12	2
Std. dev.	415	32	47	192	57	9	7	13	8	2	21	3
COOPUP land use (%):												
Crops	35	34	22	19	19	27	26	21	18	36	18	39
Woods	20	27	38	41	49	40	41	49	57	49	50	42
Grass	37	36	38	31	31	29	32	28	21	14	32	16
Urban	7	3	2	8	1	2	0	2	1	0	0	0
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-7. Continued.

Measurement	Subcatchment ID											
	101	102	103	104	105	106	107	108	109	110	111	112
IDNR land use (%):												
High density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	2	0	0	0	0	0	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	1	0	0	0	0	0	0	0	0
Active railroads	0	0	0	0	0	0	0	0	0	0	0	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0	0
Row crops	33	28	16	13	14	23	21	14	14	31	20	29
Small grain crops	4	7	5	8	5	2	5	6	1	0	5	4
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	1	0	0	0	0	0	0	0	1	0	0	0
Rural grassland	18	14	21	16	16	5	12	17	5	1	11	8
Deciduous forest, closed canopy	13	24	23	27	24	9	18	24	5	2	18	9
Deciduous forest, open canopy	1	1	1	1	2	1	1	0	0	0	1	1
Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0
Open water	6	2	0	0	1	3	3	0	3	1	5	1
Perennial streams	16	18	23	21	23	21	18	22	25	22	15	18
Shallow marsh/wet meadow	0	0	0	0	0	0	1	0	2	1	0	0
Deep marsh	0	0	0	0	0	0	0	0	0	0	0	0
Forested wetlands	4	4	9	12	15	35	19	15	41	40	22	29
Swamp	0	0	0	0	0	0	0	0	0	0	0	0
Shallow water wetlands	0	0	1	0	0	1	1	1	1	1	2	1
Barren land	0	0	0	0	0	0	0	0	0	0	0	0

Table B-7. Continued.

Measurement	Subcatchment ID											
	113	114	115	116	117	118	119	201	202	203	204	205
Subcatchment size (ha)	27256	31745	15292	9111	26337	24399	41238	54123	37078	28764	36801	23768
Area of woods (ha)	4465	4647	1663	847	4797	4267	5820	11973	8962	6455	4194	2122
Mean human pop. density (people/km2)	7	10	6	12	8	7	6	4	4	7	9	7
Approx. length of rip. banks (km)	210	219	105	50	199	100	168	353	188	158	167	135
Percent of riparian banks in IDNR-defined natural areas	4.36	4.84	9.52	20.43	8.19	0.00	0.45	0.72	0.00	0.00	0.00	0.00
HSI:												
Mean	0.36	0.31	0.36	0.45	0.42	0.56	0.57	0.62	0.50	0.47	0.39	0.20
Std. dev.	0.37	0.36	0.31	0.34	0.35	0.33	0.31	0.29	0.38	0.33	0.34	0.31
Distance from bank cells to nearest riparian wood edge (m):												
Mean	27	27	26	31	24	48	48	52	32	23	21	12
Std. dev.	47	55	37	39	34	56	63	72	48	37	38	32
Distance from bank cells to nearest intermittent wetland (m):												
Mean	3825	3941	2172	2403	2006	5773	7133	7449	7356	10977	6288	3423
Std. dev.	2993	2887	1672	1511	1361	3068	4116	3616	5232	5733	3091	2457
Distance from bank cells to nearest road (m):												
Mean	354	294	247	282	376	266	261	337	366	344	386	311
Std. dev.	269	213	156	238	274	196	182	218	247	213	290	228
Human population density at bank cells (people/km2):												
Mean	2	6	3	8	4	5	6	7	4	6	5	2
Std. dev.	3	26	12	20	28	10	8	18	3	11	7	10
COOPUP land use (%):												
Crops	46	51	37	20	34	19	12	9	32	28	38	63
Woods	36	31	43	53	43	63	58	58	48	40	34	17
Grass	16	15	18	19	21	17	27	32	20	32	27	17
Urban	0	1	0	8	2	0	3	1	0	0	0	1
Orchards	0	0	0	0	0	0	0	0	0	0	0	0

Table B-7. Continued.

Measurement	Subcatchment ID											
	113	114	115	116	117	118	119	201	202	203	204	205
IDNR land use (%):												
High density urban	0	0	0	1	0	0	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	1	0	0	0	0	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	0	0	0	0	0	0	0	0	1
Active railroads	0	0	0	0	0	0	0	0	0	0	0	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0	0
Row crops	31	34	44	33	42	13	12	8	20	14	27	53
Small grain crops	6	4	3	7	5	7	6	5	5	6	6	4
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	0	0	0	1	0	0	0	0	0	0	0	0
Rural grassland	7	6	4	7	6	11	12	15	10	20	12	6
Deciduous forest, closed canopy	5	10	8	15	11	12	9	21	15	13	8	2
Deciduous forest, open canopy	0	1	2	1	1	1	0	1	1	2	1	1
Coniferous forest	0	0	1	0	0	0	0	0	0	0	0	0
Open water	0	2	16	26	13	0	0	1	2	0	2	1
Perennial streams	12	14	8	0	7	25	26	21	19	25	23	8
Shallow marsh/wet meadow	2	0	1	0	2	0	0	1	0	0	0	1
Deep marsh	0	0	0	0	0	0	0	0	0	0	0	0
Forested wetlands	36	26	13	5	11	28	30	25	26	18	19	15
Swamp	0	0	0	0	0	0	0	0	0	0	0	0
Shallow water wetlands	1	2	1	3	1	1	2	2	1	2	2	7
Barren land	0	0	0	0	0	0	0	0	0	0	0	0

Table B-7. Continued.

Measurement	Subcatchment ID										
	206	207	208	301	302	303	304	305	306	307	308
Subcatchment size (ha)	46425	28679	19345	59489	12849	15950	13532	27293	23772	4296	11741
Area of woods (ha)	4176	2820	2091	7547	1086	1132	1366	2884	3656	1080	2292
Mean human pop. density (people/km2)	5	5	3	4	12	10	7	6	3	0	0
Approx. length of rip. banks (km)	439	132	51	432	106	230	105	153	223	54	273
Percent of riparian banks in IDNR-defined natural areas	0.00	0.00	0.00	0.00	0.00	3.81	2.88	0.09	2.44	22.08	0.96
HSI:											
Mean	0.20	0.41	0.56	0.32	0.22	0.26	0.22	0.35	0.34	0.51	0.08
Std. dev.	0.28	0.36	0.32	0.35	0.32	0.35	0.30	0.37	0.33	0.34	0.24
Distance from bank cells to nearest riparian wood edge (m):											
Mean	5	31	36	20	10	27	9	30	23	41	13
Std. dev.	16	51	42	42	24	61	23	58	39	49	65
Distance from bank cells to nearest intermittent wetland (m):											
Mean	11984	4612	2879	14912	3288	3532	5635	4729	1284	1157	1005
Std. dev.	4918	2420	1641	3364	2682	2643	3126	3680	986	779	857
Distance from bank cells to nearest road (m):											
Mean	310	309	349	354	252	311	267	294	206	411	357
Std. dev.	249	241	205	263	174	254	269	218	195	326	325
Human population density at bank cells (people/km2):											
Mean	3	2	4	3	4	7	5	6	2	0	0
Std. dev.	7	3	11	4	4	19	9	18	4	0	0
COOPUP land use (%):											
Crops	60	37	17	50	57	47	50	41	33	18	86
Woods	10	38	54	28	18	21	16	33	34	39	9
Grass	30	22	26	21	17	12	19	17	22	14	1
Urban	0	0	1	0	6	4	0	2	1	0	0
Orchards	0	0	0	0	0	0	0	0	0	0	0

Table B-7. Continued.

Measurement	Subcatchment ID										
	206	207	208	301	302	303	304	305	306	307	308
IDNR land use (%):											
High density urban	0	0	0	0	1	0	0	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	0	0	0	0	0	0	0	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	0	0	0	0	0	0	0	0
Active railroads	0	0	0	0	1	1	0	0	0	0	0
Abandoned railroads	0	0	0	0	0	0	0	0	0	0	0
Row crops	62	35	27	29	29	33	38	30	35	23	79
Small grain crops	6	2	5	5	7	4	2	4	4	1	0
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	0	0	0	0	1	1	0	0	0	0	0
Rural grassland	11	5	7	10	8	8	6	4	2	0	0
Deciduous forest, closed canopy	3	5	10	10	13	7	14	13	4	7	1
Deciduous forest, open canopy	1	1	3	0	0	0	0	1	0	0	0
Coniferous forest	0	0	1	0	0	0	0	0	0	0	0
Open water	1	3	13	1	0	4	3	1	12	20	2
Perennial streams	9	16	18	22	21	12	21	19	6	2	0
Shallow marsh/wet meadow	0	0	2	0	1	2	1	1	2	2	2
Deep marsh	0	0	0	0	0	0	0	0	1	1	0
Forested wetlands	5	28	13	20	16	27	12	24	28	38	13
Swamp	0	0	0	0	0	0	0	0	1	0	1
Shallow water wetlands	2	4	1	1	1	1	1	2	3	4	1
Barren land	0	0	0	0	0	0	0	0	0	0	0

Table B-8. Summary statistics for subcatchments of Saline watershed.

Measurement	Subcatchment ID												
	101	102	103	104	105	106	107	108	109	110	111	112	201
Subcatchment size (ha)	23189	14768	26278	22097	14441	14874	21288	20117	38184	44988	24533	40047	13285
Area of woods (ha)	8511	5546	11438	7382	9063	7679	3180	7278	6321	5026	3808	8150	3084
Mean human pop. density (people/km2)	21	8	20	9	2	2	6	9	32	6	4	5	18
Approx. length of rip. banks (km)	253	223	356	250	151	232	132	315	265	164	102	159	201
Percent of riparian banks in IDNR-defined natural areas	0.00	2.04	0.03	0.02	0.28	1.15	0.00	0.16	0.07	0.42	0.00	0.00	0.66
HSI:													
Mean	0.60	0.50	0.49	0.39	0.49	0.46	0.39	0.41	0.33	0.43	0.32	0.35	0.18
Std. dev.	0.32	0.31	0.38	0.35	0.39	0.36	0.34	0.33	0.35	0.37	0.33	0.33	0.29
Distance from bank cells to nearest riparian wood edge (m):													
Mean	56	37	62	41	69	51	27	32	21	27	12	15	21
Std. dev.	68	55	104	75	110	78	41	63	42	42	22	32	48
Distance from bank cells to nearest intermittent wetland (m):													
Mean	5015	4274	6409	1830	1071	2480	857	4373	4660	3482	8191	15319	902
Std. dev.	3288	4522	2425	1847	983	2593	982	2093	3675	3441	5216	5089	734
Distance from bank cells to nearest road (m):													
Mean	266	389	434	396	330	440	467	312	303	351	382	303	342
Std. dev.	208	300	325	266	238	273	312	279	223	231	239	242	285
Human population density at bank cells (people/km2):													
Mean	23	5	9	7	2	1	4	4	30	4	2	3	14
Std. dev.	60	10	26	13	3	3	22	10	147	5	3	5	127
COOPUP land use (%):													
Crops	12	23	34	44	38	50	47	40	50	41	51	41	66
Woods	61	47	51	38	51	39	37	36	31	40	24	26	14
Grass	23	30	14	17	9	10	13	22	14	17	24	32	3
Urban	3	0	0	1	0	0	2	0	5	1	0	0	1
Orchards	0	0	0	0	0	0	0	0	0	0	0	0	0

Table B-8. Continued.

Measurement	Subcatchment ID												
	101	102	103	104	105	106	107	108	109	110	111	112	201
IDNR land use (%):													
High density urban	0	0	0	0	0	0	0	0	1	0	0	0	0
Medium-high density urban	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium density urban	1	0	0	0	0	0	0	0	1	0	0	0	0
Low density urban	0	0	0	0	0	0	0	0	0	0	0	0	0
Major roadways	0	0	0	0	0	0	0	1	1	0	0	0	0
Active railroads	0	1	0	0	0	0	0	0	0	0	0	0	0
Abandoned railroads	0	1	0	0	0	0	0	0	0	0	0	0	0
Row crops	8	8	19	22	20	41	34	17	31	25	36	45	66
Small grain crops	3	2	1	2	3	1	4	3	3	4	4	3	2
Orchards/Nurseries	0	0	0	0	0	0	0	0	0	0	0	0	0
Urban grassland	1	0	0	0	0	0	0	0	3	0	0	0	0
Rural grassland	14	18	12	13	14	6	6	21	13	13	13	13	2
Deciduous forest, closed canopy	26	23	30	15	22	25	9	11	6	7	7	4	4
Deciduous forest, open canopy	1	3	3	2	6	2	1	4	3	2	4	4	0
Coniferous forest	5	2	1	2	2	1	1	4	0	0	0	0	0
Open water	14	7	2	7	3	2	10	12	3	5	2	4	4
Perennial streams	6	7	9	8	9	7	5	5	10	10	10	11	1
Shallow marsh/wet meadow	0	0	0	2	1	2	0	0	1	1	0	0	1
Deep marsh	0	3	0	0	0	0	0	0	0	0	0	0	1
Forested wetlands	16	18	16	20	14	9	26	15	19	30	22	11	13
Swamp	0	1	0	0	0	0	0	0	0	0	0	0	2
Shallow water wetlands	4	6	4	7	5	3	3	7	5	2	1	2	2
Barren land	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C. Suitability index (SI) tables for habitat attributes included in the HSI model.

The IBI values at stream monitoring stations are listed in IEPA intensive surveys of Illinois watersheds (Kelly et al. 1989; Hite et al. 1990; Hite et al. 1991; Hite et al. 1993; Muir et al. 1995; Muir et al. 1996). Another source of data was the 1988-1989 Illinois Water Quality Report (1990). IEPA has categorized the IBI into aquatic life use support assessments:

IBI	Aquatic Life Use
0-20	Non-support
21-30	Moderate impairment
31-40	Minor impairment
41-60	Full support

Food availability was estimated from the aquatic life support of the adjacent water body. The aquatic life use support assessment received SI values as follows:

Aquatic Life Use	SI value
Non-support	1.0
Moderate impairment	0.8
Minor impairment	0.5
Full support	0.1

For lakes, the Degree of Impairment for Aquatic Fish and Wildlife Use, from the 1988-1989 Illinois Water Quality Report, was used, grouped into four categories:

Impairment	SI value
None	1.0
Slight	0.8
Moderate	0.5
High	0.1

An exception to using the 1988-1989 Illinois Water Quality Report was Horseshoe Lake, which was ranked as moderately impaired in the report, but given an IBI of 0.8 based on recent observation. For water bodies unranked in the 1988-1989 Illinois Water Quality Report, the SI was set to the nearest water body for which data was available, unless the nearest water body was an unconnected stream or lake with point source pollution. In such cases, pollution was assumed to travel downstream, and unconnected water bodies were not affected.

The cover requisite averaged the riparian land use SI and the riparian forest width SI at the cell’s position. Riparian land use was ranked as follows:

Riparian land use	SI value
Woods	1.0
Grass	0.5
Crops	0.1
Orchards	0.1
Urban	0.0

Woods were judged to provide twice the cover value as grass, partly because woods have more structure, partly because more den sites may be available in woods, and partly because grass provides poor cover in the winter. Crops and orchards have a low SI because they are frequently disturbed.

Riparian forest width was ranked as follows:

Riparian forest width (m)	SI value
> 100	1.0
30 - 100	0.5
1 - 30	0.2
0	0.0

Negative human impact was estimated as the SI representing the distance from the bank cell to the nearest road. Distance from roads was ranked as follows:

Distance from roads (m)	SI value
>= 200	1.0
0 - 200	road distance * .005

Appendix D. County locations, landmark descriptions, and number of sightings (since 1982/total) for study area subunits. Landmark features in bold type are included within that subunit. The first 2 digits of ID indicate PMU.

ID	County Membership	Location Description	Sighting Reports
14_101	Fayette, Shelby	Becks Creek: Opossum Cr. - Kaskaskia River	
14_102	Shelby, Christian	Becks Creek: Headwaters - **Opossum Cr.**	
14_103	Shelby, Fayette	Mitchell Creek: Headwaters - Becks Cr.	
14_104	Fayette, Shelby, Effingham	Kaskaskia River: Richland Cr. - Becks Cr.	
14_105	Shelby, Effingham	Richland Creek: Headwaters - Kaskaskia River	0/1
14_106	Shelby	Kaskaskia River: Lake Shelbyville Dam - Richland Cr.	
14_107	Shelby	Robinson Creek: Headwaters - Kaskaskia River	
14_108	Shelby, Moultrie	Southern Lake Shelbyville: Wolf Cr. Arm - Dam	
14_109	Shelby, Moultrie	NW Lake Shelbyville: West Okaw River - Wolf Cr. Arm	2/2
14_110	Moultrie, Shelby	East Lake Shelbyville: Kaskaskia River - **Wolf Cr. Arm**	2/2
14_111	Moultrie, Coles	Whitley Creek: Headwaters - Lake Shelbyville	
14_112	Coles, Moultrie	Kaskaskia River: **Flat Branch** - Lake Shelbyville	1/1
14_113	Moultrie, Macon, Shelby	West Okaw River: Stringtown Branch - Lake Shelbyville	2/2
14_114	Moultrie, Coles	Jonathan Branch: Headwaters - Kaskaskia River	1/1
14_115	Moultrie, Piatt	West Okaw River: Headwaters - **Stringtown Branch**	
14_116	Coles, Douglas, Moultrie	Kaskaskia River: **West Fork Kaskaskia** - Flat Branch	
14_117	Douglas, Moultrie, Piatt, Champaign	Lake Fork: Triple Cr. Landing Strip - Kaskaskia River	
14_118	Piatt, Champaign	Lake Fork: Headwaters - Triple Cr. Landing Strip	
14_119	Douglas, Champaign	Kaskaskia River: Douglas Co. Line - W. Fork Kaskaskia	
14_120	Champaign	Kaskaskia River: Champaign Co. Rd. 700N - Douglas Co. Line	
14_121	Champaign	Kaskaskia River: Headwaters - Champaign Co. Rd. 700N	
14_200	Washington, Clinton	Kaskaskia River: Crooked Cr. - Shoal Cr.	0/1
14_201	Clinton	Kaskaskia River: Lake Carlyle Dam - Crooked Cr.	
14_202	Washington, Clinton	Crooked Creek: Rt. 127 - Kaskaskia River	
14_203	Marion, Clinton, Washington	Crooked Creek: Raccoon Cr. Reservoir outlet - Rt. 127	
14_204	Clinton, Marion	Lost Creek: Headwaters - Crooked Cr.	
14_205	Marion Reservoir outlet	Crooked Creek: Headwaters - Raccoon Cr.	
14_206	Clinton, Marion, Fayette	Lake Carlyle: **Wildcat Ditch** - Dam	1/1

Appendix D. Continued.

ID	County Membership	Location Description	Sighting Reports
14_207	Clinton, Marion, Fayette	East and North Forks Kaskaskia: Headwaters - Lake Carlyle	
14_208	Fayette, Bond, Montgomery	Hurricane Creek: Headwaters - Lake Carlyle	
14_209	Fayette, Effingham	Kaskaskia River: U.S. Hwy 40/Rt. 185 - Lake Carlyle	
14_210	Fayette	Kaskaskia River: Ramsey Cr. - U.S. Hwy 40/Rt.185	
14_211	Fayette, Montgomery, Shelby	Ramsey Creek: Headwaters - Kaskaskia River	
14_212	Fayette	Kaskaskia River: Becks Cr. - Ramsey Cr.	
14_213	Fayette, Effingham, Shelby	Big Creek: Headwaters - Kaskaskia River	
14_301	Clinton, Bond	Shoal Creek: E. Fork Shoal - Kaskaskia River	
14_302	Clinton, Bond	Beaver Creek: Headwaters - Shoal Cr.	1/1
14_303	Bond, Montgomery	East Fork Shoal: Coffeen Lake outlet - Shoal Cr.	
14_304	Montgomery	East Fork Shoal: Headwaters - **Coffeen Lake outlet**	
14_305	Bond, Madison, Montgomery	Shoal Creek: **Bearcat Cr.** - E. Fork Shoal	
14_306	Bond, Montgomery, Macoupin	Shoal Creek: **Middle Fork Shoal** - Bearcat Cr.	1/1
14_307	Montgomery	West Fork Shoal: Headwaters - Shoal Cr.	2/2
14_401	Randolph	Kaskaskia River: Plum Cr. - Mississippi River	
14_402	Randolph, Monroe, St. Clair	Kaskaskia River: Richland Cr. - Plum Cr.	
14_403	Randolph, Monroe	Horse Creek: Headwaters - Kaskaskia River	
14_404	Randolph	Plum Creek: Headwaters - Kaskaskia River	
14_405	Monroe, St. Clair	Kaskaskia River: Rt. 4/Rt. 15 - Richland Cr.	2/3
14_406	St. Clair, Randolph, Washington, Perry	Mud Creek: Headwaters - Kaskaskia River	
14_407	Washington	Elkhorn Creek: Headwaters - Kaskaskia River	
14_408	St. Clair, Washington, Clinton	Kaskaskia River: Shoal Cr. - Rt. 4/ Rt. 15	1/1
14_409	Monroe, St. Clair	Richland Creek: **Prairie du Long Cr.** - Kaskaskia River	
14_410	Monroe, St. Clair	Richland Creek: **Douglas Cr.** - Prairie du Long Cr.	
14_411	St. Clair	Richland Creek: Headwaters - Douglas Cr.	
14_413	St. Clair	Silver Creek: **Loop Cr.** - Rt. 15	
14_414	St. Clair, Madison	Silver Creek: Mill Cr. - Loop Cr.	
14_415	Madison, Bond	Silver Creek: **E. Fork Silver Cr.** - **Mill Cr.**	
14_416	Madison, Macoupin, Montgomery	Silver Creek: Headwaters - E. Fork Silver Cr.	
14_417	Clinton, St. Clair, Madison, Bond	Sugar Creek: Headwaters - I-64	
15_101	Jackson, Union	Big Muddy River: Carbon Lake - Mississippi River	2/3

Appendix D. Continued.

ID	County Membership	Location Description	Sighting Reports
15_102	Jackson	Kincaid Creek: Headwaters - Big Muddy River	
15_103	Jackson	Big Muddy River: Crab Orchard Cr. - **Carbon Lake**	
15_104	Jackson, Union	Crab Orchard Creek: Dam - Big Muddy River	
15_105	Williamson, Jackson, Union	Crab Orchard Lake: Crab Orchard Cr. - Dam	
15_106	Williamson	Crab Orchard Creek: Headwaters - Crab Orchard Lake	
15_107	Jackson, Williamson, Franklin	Big Muddy River: Plumfield Gauge - Crab Orchard Cr.	
15_108	Williamson, Franklin	Pond Creek: Headwaters - Herrin/Freeman Spur Rd.	
15_109	Franklin, Hamilton, Jefferson	Middle Fork Big Muddy: Headwaters - I-57	
15_110	Franklin	Big Muddy River: Rend Lake Dam - Plumfield Gauge	
15_111	Franklin, Jefferson	Rend Lake	1/1
15_112	Jefferson	Casey Fork: Headwaters - Rend Lake	2/2
15_113	Jefferson	Big Muddy River: Headwaters - Rend Lake	
15_114	Jackson, Franklin, Perry	Little Muddy River: Franklin Co. Rd. 1100N - Big Muddy River	0/1
15_115	Franklin, Perry, Jefferson, Washington	Little Muddy River: Headwaters - Franklin Co. Rd. 1100N	
15_116	Jefferson, Washington	Rayse Creek: Headwaters - Big Muddy River	
15_117	Jackson	Beaucoup Creek: Galum Cr. - Big Muddy River	
15_118	Jackson, Perry	Beaucoup Creek: Pinckneyville railroad - Galum Cr.	
15_119	Perry, Washington	Beaucoup Creek: Headwaters - Pinckneyville railroad	
15_120	Perry	Galum Creek: Headwaters - Beaucoup Cr.	
15_201	Jackson, Union, Alexander	Mississippi River: Big Muddy River - Ohio River	
15_202	Union, Alexander	Clear Creek: Headwaters - Mississippi River	12/12
15_203	Randolph, Jackson	Mississippi River: Kaskaskia River - Big Muddy River	2/2
15_204	Randolph	Mary's River: Headwaters - Mississippi River	2/2
16_101	Pulaski, Johnson, Union	Cache River: Post Cr. Cutoff - Big Cr.	5/7
16_102	Pulaski, Union	Cache River: **Big Cr.** - U.S. 51	1/1
16_103	Pulaski, Alexander, Union	Cache River: U.S. 51 - Boar Cr.	
16_104	Pulaski, Alexander	Cache River: **Boar Cr.** - Cache (city) Cutoff	4/5
16_201	Union, Johnson, Pulaski	Cache River: Headwaters - Belknap Blacktop Rd.	6/11
16_202	Johnson	Dutchman Creek: Headwaters - Cache River	1/1
16_203	Johnson, Pulaski, Massac	Cache River: Belknap Blacktop Rd. - Post Cr. Cutoff	3/4

Appendix D. Continued.

ID	County Membership	Location Description	Sighting Reports
16_204	Pope, Massac	Ohio River: Hamletsburg - **Massac Cr.**	2/2
16_205	Massac, Pulaski, Alexander	Ohio River: Massac Cr. - Mississippi River	2/3
17_101	Hardin, Pope	Ohio River: Saline River - Golconda	1/3
17_102	Pope	Ohio River: **Golconda** - Bay Cr.	1/1
17_103	Pope	Lusk Creek: Headwaters - Quarrel Cr.	
17_104	Pope, Massac, Johnson	Bay Creek: Sugar Cr. - Ohio River	1/1
17_105	Johnson, Pope	Bay Creek: Rt. 146 - **Sugar Cr.**	3/3
17_106	Johnson, Pope	Bay Creek: Headwaters - Rt. 146	6/6
17_107	Massac, Pope	Ohio River: Bay Cr. - Hamletsburg	1/1
18_101	Johnson, Williamson	South Fork Saline: Headwaters - Strip Mines	
18_102	Johnson, Williamson, Saline	South Fork Saline: **Strip Mines** - U.S. 45	
18_103	Johnson, Williamson, Saline, Pope	South Fork Saline: U.S. 45 - Rt. 145	
18_104	Saline, Pope, Gallatin	S., Middle, and Main Fork Saline River: Rt.145/Rt.13 - Equality	3/4
18_105	Saline, Pope, Gallatin, Hardin	Eagle Creek: Headwaters - Saline River	
18_106	Gallatin, Hardin	Saline River: FR1697 - Ohio River	
18_107	Gallatin	Saline River: Equality - FR1697	
18_108	Williamson, Saline	Bankston Fork: Headwaters - Middle Fork Saline River	
18_109	Williamson, Franklin, Saline, Hamilton	Middle Fork Saline: Headwaters - Rt. 13	
18_110	Gallatin, Saline, White, Hamilton	North Fork Saline: U.S. 45 - **Crawford Cr.**	
18_111	Saline, Hamilton	North Fork Saline: Hamilton Co. Rd. 200N - U.S. 45	
18_112	Hamilton	North Fork Saline: Headwaters - Hamilton Co. Rd. 200N	
18_201	Gallatin	Ohio River: Wabash River - Saline River	0/1
19_101	Coles, Shelby, Cumberland	Little Wabash River: Headwaters - Lake Mattoon Dam	
19_102	Shelby, Cumberland, Effingham	Little Wabash River: Lake Mattoon Dam - U.S. Hwy 40	
19_103	Effingham	Little Wabash River: U.S. Hwy 40 - Salt Cr.	1/1
19_104	Effingham	Salt Creek: Headwaters - LWR	
19_105	Effingham, Clay	Little Wabash River: Salt Cr. - **Panther Cr.**	1/1
19_106	Clay	Little Wabash River: Panther Cr. - U.S. Hwy 50	
19_107	Jasper, Clay, Richland	Big Muddy Creek: **Little Muddy Cr.** - LWR	4.4
19_108	Jasper, Clay, Effingham	Big Muddy Creek: Headwaters - Little Muddy Cr.	
19_109	Clay, Richland, Wayne, Edward	Little Wabash River: U.S. Hwy 50 - Fox River	1/1
19_110	Richland, Wayne, Edward	Fox River: Richland Co. Rd. 500N - LWR	

Appendix D. Continued.

ID	County Membership	Location Description	Sighting Reports
19_111	Jasper, Richland	Fox River: Headwaters - Richland Co. Rd.500N	1/1
19_112	Wayne, Edwards, Richland	Little Wabash River: Fox River - W. Side Diversion Ditch	0/1
19_113	Wayne, Edwards	Little Wabash River: W. Side Diversion Ditch - **Briar Branch**	14/15
19_114	Wayne, Edwards, White	Little Wabash River: Briar Branch - White Co. Rd. 2575N	2/2
19_115	White	Little Wabash River: White Co. Rd. 2575N - Siegler Bridge	
19_116	White	Little Wabash River: Siegler Bridge - Possum Rd. Gauge	
19_117	White, Gallatin	Little Wabash River: Possum Rd. Gauge - Wabash River	0/1
19_118	Clay, Wayne	Elm River: Enterprise, IL - LWR	
19_119	Wayne	Elm River: Headwaters - Enterprise, IL	1/1
19_201	Marion, Clay, Wayne	Skillet Fork: Headwaters - Marion Co. Rd. 300N	
19_202	Marion, Wayne	Skillet Fork: Marion Co. Rd. 300N - Horse Cr.	2/2
19_203	Jefferson, Marion, Wayne	Skillet Fork: **Horse Cr.** - **Shoe Cr.**	
19_204	Jefferson, Wayne	Skillet Fork: Shoe Cr. - I-64	
19_205	Hamilton, Wayne, White	Skillet Fork: I-64 - Big Creek Drain main outlet	
19_206	Jefferson, Hamilton, Wayne	Big Creek Drain: Headwaters - Skillet Fork	1/1
19_207	White, Hamilton	Skillet Fork: Big Creek Drain main outlet - White Co. Rd. 475E	
19_208	White	Skillet Fork: White Co. Rd. 475E - LWR	1/1
19_301	Richland, Lawrence, Wabash, Edwards	Bonpass Creek: Headwaters - Negro Cr.	
19_302	Edwards, White, Wabash	Bonpass Creek: **Negro Cr.** - Wabash River	
19_303	Wabash	Wabash River: White River (IN) - Bonpass Cr.	1/1
19_304	Wabash	Wabash River: **Catfish Bend** - White River (IN)	
19_305	Wabash, Lawrence	Wabash River: Embarras River - Catfish Bend	
19_306	White	Wabash River: Bonpass Cr. - Wabash Levee Ditch	
19_307	White	Wabash River: Wabash Levee Ditch - LWR	
19_308	Gallatin	Wabash River: LWR - Ohio River	
20_101	Champaign, Douglas	Embarras River: Headwaters - U.S. Hwy 36	
20_102	Douglas, Champaign, Coles	Scattering Fork: Headwaters - Embarras River	
20_103	Douglas, Coles	Embarras River: U.S. Hwy 36 - Douglas/ Coles Co. Line	
20_104	Douglas	Brushy Fork: Douglas Co. Rd. 2510E - Embarras River	
20_105	Douglas, Edgar	Brushy Fork: Headwaters - Douglas Co. Rd. 2510E	
20_106	Coles, Douglas, Edgar	Embarras River: Douglas/Coles Co. Line - Rt. 133	

Appendix D. Continued.

ID	County Membership	Location Description	Sighting Reports
20_107	Coles, Douglas	Embarras River: Rt. 133 - Coles Co. Rd. 1000N	
20_108	Coles, Edgar	Embarras River: Coles Co. Rd. 1000N - **Indian Cr.**	
20_109	Coles	Kickapoo Creek: Headwaters - Embarras River	1/1
20_110	Coles, Cumberland	Embarras River: Indian Cr. - U.S. Hwy 40	1/1
20_111	Cumberland, Coles	Muddy Creek: Headwaters - Rt 121	
20_112	Jasper, Effingham, Cumberland	Muddy Creek: Rt 121 - Embarras River	
20_113	Cumberland, Jasper, Clark	Embarras River: U.S. Hwy 40 - **Range Cr.**	2/2
20_114	Jasper	Embarras River: Range Cr. - Crooked Cr.	2/2
20_115	Jasper, Cumberland	Crooked Creek: Headwaters - Embarras River	
20_116	Jasper, Crawford, Richland	Embarras River: Crooked Cr. - Big Cr.	1/1
20_117	Crawford, Lawrence, Richland	Embarras River: Big Cr. - Muddy Cr.	1/1
20_118	Lawrence, Richland	Muddy Creek: Headwaters - Embarras River	
20_119	Lawrence, Crawford	Embarras River: Muddy Cr. - Business U.S. Hwy 50	
20_120	Lawrence, Crawford	Embarras River: Business U.S. Hwy 50 - Wabash River	
20_121	Crawford	Big Creek: Headwaters - Embarras River	
20_122	Clark, Crawford, Jasper	North Fork Embarras River: Clark Co. Rd. 475N - Embarras River	
20_123	Coles, Edgar, Clark	North Fork Embarras River: Headwaters - Clark Co. Rd. 475N	
20_201	Edgar, Vermilion	Brouilletts Creek: Little Brouilletts Cr. - State Line	
20_202	Edgar	Brouilletts Creek: Headwaters - Little Brouilletts Cr.	
20_203	Edgar	Coal Creek and Little Sugar Creek: Headwaters - State Line	
20_205	Edgar, Clark	Sugar Creek: Headwaters - State Line	
20_207	Clark, Edgar	Wabash River: State Line - Big Creek	
20_208	Clark, Edgar	Wabash River: Big Creek - **Mill Cr.**	
20_209	Crawford, Clark	Wabash River: Mill Cr. - Merom, IN	
20_210	Crawford, Lawrence	Wabash River: Merom, IN - Russellville, IL	
20_211	Lawrence	Wabash River: Russellville, IL - Embarras River	
20_301	Vermilion	Little Vermilion River: Elwood/Carrol Twp Line - State Line	
20_302	Vermilion, Edgar	Little Vermilion River: Headwaters - Elwood/Carrol Twp Line	

JOB 1.2. FRAMEWORK FOR OTTER MONITORING

***OBJECTIVE*:** (1) Develop a framework to detect otter presence/absence and to quantify their relative abundance in Illinois river basins.

INTRODUCTION

The otter's secretive nature, flexible social structure, and a lack of den site fidelity have thus far confounded the development of reliable census techniques (Melquist and Dronkert 1987). Although distribution and presence can easily be determined by tracks, scat and other sign, Melquist and Hornocker (1979) concluded there was no simple way to census otters. Various field techniques have been tested and used in an effort to estimate river otter populations including: road-bridge surveys, winter ground and aerial track counts, radioactive isotope marking, radio telemetry, sign surveys, and scent stations. These techniques provide insight into population density, distribution and structure, but their ability to accurately measure population parameters is uncertain (Melquist and Dronkert 1987).

Objective 3 of the Illinois River Otter Recovery Plan calls for monitoring otter distribution and relative abundance to determine when and if changes in their legal status are warranted (Bluett 1995). River otters will be reclassified from endangered to threatened status when stable or increasing populations have been documented in 3 LMUs. Two units presently meet this criterion, the Rock/Mississippi North and the Shawnee (Anderson 1995). River otters will be delisted from threatened status when: 1) stable or increasing populations have been documented in 4 LMU’s, and presence has been documented in at least 60% (13/21) of PMU’s; or 2) stable or increasing populations have been documented in 5 LMU’s.

Reports of otters and their sign have been collected in Illinois since first compiled by Anderson (1982). However, observations reported by the general public may be less reliable (collectively) than observations made by trained personnel. Field surveys are a desirable component of monitoring; changes in the species’ legal status will require reliable information on distribution and relative abundance.

METHODS

During this project we tested the applicability of the scent station technique for southern Illinois. Additionally, various other field surveys were conducted in the LWR basin including: road bridge, watercraft, winter ground track counts, and aerial surveys from helicopters.

Scent Stations.--During the second project segment, we tested the utility of a scent station route in determining presence/absence and in providing an index of relative abundance. This route was surveyed once per month between August 1995 and March 1996, except January, to determine variation in seasonal response. No scent station surveys were conducted during the final project segment due to logistical difficulties.

Scent stations were constructed as described in Job 1.1. Briefly, stations about 1 m in diameter were created in wet substrate by smoothing the surface with the back of a rake to provide an impressionable area free of tracks. Stations created in drier substrate were raked to form a powdered surface where track impressions could be identified. Effectiveness of a musk lure and an anal gland lure were tested in pairs with a nearby control (no lure) if space permitted.

Stations at a site were spaced as close to 100 m apart as water level and bank characteristics permitted; we selected relatively level and accessible areas. All stations were placed on the water's edge whenever possible, but never more than 1 m from the water. One or more identifiable tracks was considered a single visit. Tracks were identified by size and appearance as described in various field guides.

The scent station route was established along about 120 km of the LWR in August 1995 and surveyed in August and September 1995. The route was comprised of 19 potential river access points described by Schieler (1995). Sites were at active or inactive bridges over the river, except 1 site was a boat launch area near Carmi. We did not set stations at access points with evidence of high human disturbance.

The route was revised in October to more efficiently cover the PMU. This route was comprised of 13 access points on the LWR and the Skillet Fork, selecting access points on the basis of stream bank and offsite characteristics. This route was surveyed

October - December 1995, and February - March 1996; the January survey was canceled due to poor weather conditions.

Miscellaneous Surveys.--Several road bridge surveys were conducted between March 1994 and February 1996. Surveys consisted of visiting each bridge or public road offering river access to determine access for monitoring, assess habitat quality, and search for evidence of otter presence. River areas surveyed included: the LWR from Carmi north to Clay City; the Skillet Fork from its confluence with the LWR upstream to Orchardville Blacktop Bridge, about 3.8 km south of Orchardville, IL; and Big Muddy Creek and its tributaries between its confluence with the LWR and Newton Lake.

A river survey was conducted by watercraft on the LWR from the Fox River south to Carmi between March and August 1994. In addition, a 14 km segment of the Skillet Fork upstream from its confluence with the LWR was surveyed in June and July 1995.

Intensive ground searches of stream banks and offsite wetlands were conducted by 1 or 2 observers on the area up to 2.3 km downstream of the Hedge Bridge release site in October, November, and December 1995, and March 1996. The area up to 1 km north of Hedge Bridge was also searched in November 1995.

Aerial surveys were conducted over the LWR from Carmi north to the Fox River on 9 January 1996, and 13 January 1997. One or 2 observers searched for otter sign in the snow along banks and on logjams from a helicopter flying at an altitude of 15 - 30 m.

RESULTS

Scent Stations.--Only 2 otter visits were recorded. Over 176 operable scent station nights between August 1995 - March 1996. On 11 February, an otter visited both stations at Orchardville Blacktop Bridge on the Skillet Fork, showing no preference for either lure.

Miscellaneous Surveys.--Road bridge surveys of the LWR, the Skillet Fork, and Big Muddy Creek revealed no otter sign. Access was limited and even more so in terms of suitable sites to launch watercraft.

During watercraft surveys, a single set of otter tracks was located on the Skillet Fork on 23 June 1995. The track location was about 9.5 km upstream from its confluence with the LWR, adjacent to a forested slough bordering Skillet Fork. Evidence of a substantial fish kill was noted the same day. Otter sign was not detected during watercraft surveys of the LWR intensive study area, a limited canoe search of segments of Skillet Fork north of Wayne City on 30 June 1995, nor a repeat search of lower reaches of Skillet Fork on 26 July 1995.

The October ground survey revealed the locations of 6 distinct latrine sites on the water's edge, but only 3 appeared to have been recently used. These were located at 0.9, 1.0, and 1.3 km downstream of Hedge Bridge. In November, no evidence of recent use was found in the area. The December ground survey revealed the locations of a latrine site and separate set of otter tracks 1 km downstream of the bridge. Otter spraint was collected underneath Hedge Bridge in February. Position of the scat indicated that the otter had used the area during recent flooding. No sign was observed in the March ground survey, but a single otter was observed at 0700 hrs on 5 March, approximately 1.3 km downstream of Hedge Bridge (the same area signs were observed during the December ground survey).

The January 1996 aerial survey revealed possible otter tracks at 3 locations on the LWR: approximately 1 km upstream from its confluence with the Skillet Fork, approximately 1 km downstream from Cherry Shoals Bridge, and approximately 2.5 km downstream of Tait Bridge. All locations were near open water; more than 50% of the river was frozen over. The January 1997 aerial survey revealed 8 possible locations of otter tracks, 6 within 20 km (river distance) of the release site at Hedge Bridge. Only 1 of the locations was considered probable, located near White County Road 2550 N approximately 35 km downstream of the release site.

Reported Sightings.--Fifty-three new reports were received during the project (Table 6). These do not include scent station visits, nor the live otter reported above.

DISCUSSION

Monitoring Techniques

Reported Sightings.--Reported sightings have generally been in the vicinity of release sites in the months following a release, with sightings becoming dispersed over time. Sighting reports of juveniles in the North Fork Embarras and of an untagged otter in the LWR suggest that pregnant females released in these basins were successful at rearing pups and that reproduction may be occurring.

Sighting reports can be a very cost effective monitoring tool, but care must be exercised in their interpretation. Sightings will vary in their reliability and accuracy. Also, the highest quality habitats may turn out to be the least accessible, so lack of sightings from an area will not necessarily imply that it is unoccupied. In Missouri, sightings eventually became a function of observer effort (D. Hamilton, Missouri Dep. Conserv., pers. commun.), and their value as an index was minimized. Despite this, sighting reports have been sufficient to monitor the stability and range expansion of remnant populations (Anderson 1995), and will continue to be a useful tool for monitoring releases.

Scent Stations.--Otters visited scent stations during the pilot study (Job 1.1). Given the proximity (in time and space) of the stations to the Skillet Fork release, this result may be biased; otters would naturally investigate new surroundings. The scent station route detected the presence of an otter at Orchardville Blacktop Bridge. However, the route failed to detect the presence of an otter at Hedge Bridge, though sign was abundant at times and an individual was observed. Clearly, this technique can detect presence, but a lack of visitations does not imply absence, nor do visitations imply occupancy.

Visits to scent stations can be influenced by sex, season, habituation to scent, and natural wariness (Robson 1982). In addition to these limitations, substrate, rain, and subfreezing temperatures restrict the applicability of this technique. The most effective substrate for this technique was clay which was easy to smooth with the back of a rake, and provided a superior impressionable surface for reading tracks.

Rain proved to be a problem, causing waters to rise and inundate stations. Sub-freezing temperatures also created problems. Although stations could be created during the afternoon, bank substrate hardened overnight such that no tracks could be registered. In many places, subsurface water froze creating ice crystals which pushed up through the smoothed surface. These problems may be alleviated by using conventional methods of construction (i.e., sifted sand or dirt), but such methods present undesirable logistical problems, especially when banks are steep or slippery.

Scent stations have been used in several southeastern states to obtain indices of distribution and relative abundance of river otters, but methodological consistency is lacking due to differences in habitats and objectives (Clark 1982). These states differ from Illinois in having established populations of river otters. Under this condition, survey routes like the one attempted here are sufficient to detect presence/absence. The lack of visits recorded at Hedge Bridge indicates that our lack of visitations is an artifact of the diffuse nature of otter presence in the LWR and not an indication of absence.

Although the HSI model may identify (see Job 1.3) better locations for scent stations, potentially increasing the likelihood of encountering an otter, accessibility to these areas may prove logistically impractical. Furthermore, the technique is only useful where the right combination of substrate type, bank slope, and climactic conditions (dry and above freezing temperatures) exist. Humphry and Zinn (1982) reported that scent station construction was time consuming and generated limited data; our experience supports these observations. Assessing every potential station site within the release basins for proper substrate and bank slope and coordinating surveys with weather is logistically prohibitive given the limited population data it could currently generate.

Miscellaneous Surveys.--Road bridge surveys were used as a quick and cost effective method of determining distributions in Europe (Macdonald and Mason 1982). This technique is currently being tested in Missouri (D. Hamilton, Missouri Dep. Conserv., pers. commun.), by searching banks within 600 m of bridge crossings for tracks or other sign. Although the road bridge surveys we tested were only conducted in the immediate vicinity of an access point, no otter sign was found. However, our efforts may have been too restrictive; winter ground surveys of the LWR near Hedge Bridge only located sign after searching nearly 1 km from the bridge. As with scent stations, this technique may be more applicable when populations reach higher levels.

The watercraft surveyed sections of the LWR and the lower portion of the Skillet Fork (below Illinois Route 45) could be traveled with a small outboard motor powered jon boat when water levels were high enough. Water travel on other segments was possible only with a canoe, but numerous logjams made travel difficult and inefficient. Furthermore, summer conditions made sign difficult to spot.

Winter ground and aerial track counts are contingent on snowfall conditions, but have been used successfully in Illinois and Missouri (Anderson and Woolf 1984, D. Hamilton, Missouri Dep. Conserv., pers. commun.). Both techniques detected otter presence within the LWR, but the rarity of proper snow conditions in southern Illinois limits their applicability. As with scent stations and road bridge surveys, winter ground track counts will be time consuming and generate limited data until populations increase. Aerial surveys, however, have the distinctive advantages of time efficiency and allowing surveys of areas that cannot be surveyed with other techniques.

Although these various types of sign surveys can be employed to determine distribution, Melquist and Hornocker (1983) cautioned that density does not correlate with the amount of sign. Seasonal fluctuations in the amount of sign were reported by Humphry and Zinn (1982), Robson (1982), and Foy (1984). Foy

(1984) attributed these fluctuations to variations in habitat and behavior rather than changes in density.

Monitoring Framework

Foy (1984) stated that annual survey routes covering the same area and season could provide an index of relative abundance. Similarly, the recovery plan highly recommends collecting population data annually from standard field survey routes (Bluett 1995). Clark (1982) pointed out that low turnover rates in otter populations made annual monitoring unnecessary, but Clark was considering areas with established populations. Circumstances in Illinois (i.e., investment in releases, low density may increase reproductive rates, etc.) justify the expense of annual monitoring. Given the limited success and logistical difficulties we experienced, scent station surveys, road bridge surveys, or winter ground track counts would not be cost-effective for Illinois until populations increase considerably. Aerial surveys offer an efficient method for monitoring populations in the interim, if conditions are favorable.

Most researchers suggest a combination of field techniques with surveys of trappers, carcasses, and sightings (Melquist and Dronkert 1987). Appendix E summarizes the strengths and weaknesses of currently available monitoring options. Although many of these options would not be cost-effective now, management needs will change as populations increase and any monitoring framework should be flexible enough to include new techniques as changing circumstances alter their cost-benefit ratios. Furthermore, it should be recognized that each PMU may differ in relative suitability for a given technique (e.g., northern Illinois provides better opportunities for winter surveys than southern Illinois). In the short term (i.e., up to 5 years post-release) general data on distribution and reproduction can be gained cost-effectively through diligent attention to the detail of sighting locations and examination of retrieved carcasses. Such information should be solicited from hunters, trappers, commercial fisherman, and environmental organizations such as the Illinois Riverwatch Network. These general data will be sufficient to determine if listing changes are warranted.

As stated before, sighting reports will lose efficacy over time. In the long term, accurate data on relative abundance will be necessary to produce population estimates that can be used to regulate harvest. Generating accurate data will require further research. Field survey techniques (i.e., scent stations, road bridge surveys, aerial track counts, etc.) should be tested concomitantly to determine which may provide more accurate data on relative abundance. Furthermore, collection of carcasses for necropsy will provide detailed data on reproductive parameters for use in population modeling. Such modeling may be the only method by which accurate population estimates can be made, and the efforts of Missouri in this arena should be closely monitored.

Agency staff discounted the use of radio telemetry during releases on the basis of: 1) well-established parameters for survival and movements of translocated otters; and 2) the high cost of telemetry for animals with large home ranges and long-distance dispersals (Bluett 1995). However, telemetry offers benefits that other monitoring techniques cannot. Telemetry could be used to determine habitat use of Illinois otters, thereby testing and refining the models developed in this research. Only telemetry data can locate otters to a sufficient resolution for testing the HSI model. Further, comparing habitat use from areas ranked differently by the PATREC model could test density assumptions (e.g., 1 otter per 16 km in areas rated Low), thereby allowing for more accurate population projections based on habitat composition.

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Appendix E. Summary of available river otter monitoring methods and their advantages and disadvantages for Illinois. Methods are classed into Application Periods Short-term (<5 years post-release), Mid-term (5-10 years post-release), and Long-term (>10 years post-release).

Monitoring Technique	Value	Methods	Application Period	Advantages	Disadvantages
Sighting Reports	Primarily for monitoring distribution. Potential to yield limited information on reproduction, habitat use, and population stability.	Distribute report cards via Digest of Hunting and Trapping Regulations and other IDNR publications;	Short-term	Cost-effective means to determining whether criteria for de-listing have been met; Database for maintaining records already in place; Public participation may increase resistance to harvest type management.	Some reports may not be reliable; Reports are a function of habitat accessibility and observer effort; Public participation may increase resistance to harvest type management.
		Distribute posters and reports cards to state-owned sites, furbuyers, and hunter check stations;	Short-term		
		Solicit reports from trappers, commercial fishermen and Department personnel annually;	All periods		
		Solicit reports from related government agencies and NGOs;	Short-term		
		Record reported sightings and plot locations in a GIS.	Short-term		
Aerial Track Surveys	Primarily for monitoring distribution. Potential to yield habitat use data.	Survey streams and wetlands from a helicopter at a height of 15 - 30 m with 1 or 2 observers.	All periods	All potential habitat can be surveyed; Time efficient.	Proper conditions may may be rare in southern Illinois; High cost of operating a helicopter.
Ground Track Surveys	Primarily for monitoring distribution.	Visit access points at regular intervals (e.g., >8 km apart) along riverine and wetland habitats;	Mid- to Long-term	All access points are potentially suitable;	Density does not seem to correlate with the amount of sign;

Appendix E. Continued.

Monitoring Technique	Value	Methods	Application Period	Advantages	Disadvantages
(incl. bridge and winter ground)	Potential to yield habitat use and reproduction data.	Search a set distance (e.g., 600 m) from access along all banks for otter tracks or other sign by at least observers;	Mid- to Long-term	Annual surveys could provide an index of relative abundance and changes in distribution.	Amount of sign varies seasonally; Winter surveys may lack sufficient snowfall in southern Illinois; Expensive in terms of logistics and manpower.
		Locate sign on maps and record in a database.	Mid- to Long-term		
Scent Stations	Primarily for monitoring distribution. Potential to provide information on reproduction.	Assess access points for suitable substrate and bank characteristics;	Mid- to Long-term	Theoretically brings otter sign to the observer, reducing effort; Can be executed by a single person and is less time consuming than Ground Track Surveys; Annual surveys could provide an index of relative abundance and changes in distribution.	Limited by accessibility of habitats and suitability of access points for stations; Visitation rate influenced by a variety of biological and environmental factors; Fall and spring flooding and subfreezing temperatures limit applicability during best seasons.
		Set stations at access points no closer than 8 km; check and reset for 2 nights;	Mid- to Long-term		
		Record and maintain database of visitation rates per station.	Mid- to Long-term		
Radio Telemetry	Primarily for monitoring habitat use, home range size, survival, and movements.	Capture Illinois otters and implant radios, OR purchase additional otters, implant and release into unoccupied habitat.	All periods	Provides the best opportunity to test model assumptions.	Limited by low capture rate of otters and high cost of equipment and manpower.

Appendix E. Continued.

Monitoring Technique	Value	Methods	Application Period	Advantages	Disadvantages
Population Modeling	Primarily for predicting population size and growth rates.	Examine carcasses collected in Illinois to gather information on natality and mortality rates; Gather natality and mortality rate information from literature; Combine information to predict population size and growth rate.	All periods All periods All periods	Models are easy to construct, and can be used to predict the effects of different management activities; Examination of carcasses can yield information on reproductive parameters, demographics, and individual health.	Unknown correlation between predicted and actual population numbers; Males more likely to be trapped, and carcasses may be rare until population size increases.

JOB 1.3. IDENTIFY SUITABLE HABITATS

OBJECTIVE: (1) Identify suitable river otter habitat in southern Illinois.

INTRODUCTION

Determining the distribution of suitable habitats is key to the effective management of river otters. Thus, both models were used to assess the distribution and relative quality of available habitats within the study area. Additionally, it is necessary to ensure that these areas retain optimal suitability to ensure the long term viability of otters in southern Illinois. Objective 4 of the Recovery Plan calls for conserving enough habitat to support a minimum 200 otters among at least 4 LMUs (Bluett 1995).

METHODS

We conducted a gap analysis to identify the protected status of the potential river otter habitat in southern Illinois by overlaying available habitats with coverages of public land ownership. Most state and federal land ownership coverages were obtained from IDNR (nature preserves, state conservation areas, state fish and wildlife areas, state forests, state parks, and federally-owned lands). Several sites were missing from these data; these boundaries were obtained from the 1983 Inventory of Public Recreation Land Sites (IPRLS, Greene 1990). Furthermore, the Shawnee National Forest boundaries were purchase boundaries only; ownership boundaries as of 1983 were obtained from the IPRLS. The IPRLS had a coarser resolution (map scale 1:500,000) than IDNR data, but was the only available source of some boundaries. The following site boundaries were added from IPRLS: Baldwin Lake, Shawnee National Forest, Crab Orchard National Wildlife Refuge, Little Black Slough, Burnham Island, Lusk Creek Canyon, Pounds Hollow, Fort Chartress, and part of Rend Lake.

All publicly-owned land delineated in the above sources was defined as "protected," and combined into 1 data layer, a grid with 30-m cell resolution, for each basin. All other land (in most cases, privately-owned) was defined as "unprotected."

PATREC.--To determine the distribution and relative quality of suitable habitats at the landscape level, the final PATREC model was applied to all 180 study area subunits, and model outputs were categorized into 3 habitat quality ratings: Low (<0.33), Medium (0.34 - 0.65), and High (>0.66). Rating categories were used to generate potential population estimates for each subunit by assigning each category a density estimate found in the literature, and multiplying the appropriate estimate by the total length of wooded riparian habitat (wooded stream length plus wooded perennial shoreline length) within the subunit. High and Medium ratings were assigned density estimates of 1 otter per 4 km and 1 otter per 8 km, respectively, based on telemetry studies of released otter in Missouri (Erickson et al. 1984). For the Low rating, an estimate of 1 otter per 16 km seemed a reasonable progression, and is in line with other estimates in the literature (Melquist and Dronkert 1987, Bluett

1995). Wooded riparian habitat lengths and population estimates were summed across each basin.

To determine the current management status of available habitats, the public ownership grid was compared to the potential habitats map for each study area basin. Publicly owned areas were extracted with MIPS, and imported into HAMS to calculate total wooded riparian length. Total wooded riparian length for each public area, and the habitat rating for the subunit which encompassed it, were used to determine the potential population the area could support. Public wooded riparian lengths and potential populations were summed across each basin.

Basins were ranked high to low and assigned values 1 to 7, respectively, for each of 3 variables: proportion of riparian habitats classified as wooded, proportion of wooded riparian habitat under public ownership, and overall basin quality (i.e., average model output). Ranks were averaged for each basin to produce an Average Rank Score. Low rank scores represent relatively higher quality basins. Rank scores were used to assess the relative importance of each basin to maintaining a viable population in southern Illinois.

HSI.--To determine the distribution of suitable habitats at the pixel level, the HSI model was applied to all study area basins. Riparian bank cells were divided into 3 quality classifications according to their HSI scores: <0.5 (poor), 0.5 - 0.8 (fair), and >0.8 (good), and the protected status of each class was assessed. Using the ArcView 3.0 (Environmental Systems

Research Institute, Inc., Redlands, CA) Spatial Analyst module, the land ownership layers were used to create histograms that summed the number of cells in each of the 3 HSI categories that intersected 1), protected land; and 2), unprotected land. Basins were ranked as to the proportion of cells scoring >0.8, the overall basin quality (i.e., number of cells >0.8 per unit area), and proportion of cells >0.8 that were protected.

HSI Aggregation.--For each watershed, ArcView Spatial Analyst was used to identify those areas with the highest aggregations of suitable otter habitat. The neighborhood statistics function summed the HSI grid cell values over a circular area with 500-m radius. The HSI values originally varied continuously between 0 and 1, but were converted to integers varying between 0 and 255 in the process of moving from a Unix to PC platform. Non-riparian cells had a value of zero, and did not add to the neighborhood sum. Thus, the neighborhood sum combined 2 factors for each 30-m cell in the watershed: quantity of riparian habitat within 500 m, and relative suitability of this habitat as predicted by the HSI model.

The neighborhood HSI sum grids were then filtered to include only those cells overlaying perennial streams, lakes, and permanent wetlands, and divided by 255 to convert back to multiples of HSI scores. A neighborhood sum of 10 at a given water cell could alternatively represent 10 riparian cells within 500 m with an HSI of 1.0, 20 cells with a mean HSI of 0.5, or any other combination. Since all perennial water bodies were grouped together, the HSI sum at any cell could also result from any combination of nearby streams, lakes, and permanent wetlands.

The HSI sums were then categorized into 3 groups. The best locations were considered to be cells with an HSI sum >80. We reasoned that a stream with both banks having high HSI values (mean HSI >0.8), and meandering with a length increase of at least 50% from straight-line, would provide optimal habitat within the limitations of the model. Within the neighborhood search radius of 500 m, this would correspond to a sum of $0.8 * (1000 / 30) * 2 * 1.5 = 80$.

Poor locations were considered to be cells with an HSI sum <33. We reasoned that a stream with both banks having low HSI values (mean HSI <0.5), and with no meander, would provide poor habitat within the limitations of the model. Within the neighborhood search radius of 500 m, this would correspond to a sum of $0.5 * (1000 / 30) * 2 * 1 = 33$.

Cells falling into the middle range, between 33 and 80, were considered intermediate locations. In the figures, this intermediate range was divided at midpoint, into the ranges 33-56 and 57-80.

Combined Analysis.--Estimates of relative habitat quality within and across basins were compared between the PATREC and HSI models. These comparisons were used to suggest areas important to the maintenance of stable populations.

RESULTS

PATREC.--All 180 subunits contained at least some of the modeled attributes (Appendix F); landscape composition varied within basins as well as between them (Fig. 6). Figure 7 depicts 2 example subunits; one rated High (Fig 7a), and 1 rated Low (Fig. 7b). The subunit rated High contains more wetlands and wooded streams than the subunit rated Low. Basins with higher proportions of subunits classified as high quality habitat correspond to those units which had higher proportions of wetland and riparian patch types in Table 1.

Using habitat quality ratings to assign density estimates for each subunit yields a population estimate for the study area of around 2,400 individuals (Table 7). Public lands comprise approximately 12% of the available wooded riparian habitat within the study area (Table 8). Based on the habitat quality ratings of the subunits in which they fall, these areas could support about 400 otters. The Big Muddy River basin (PMU 15) accounts for 44% of these public lands and half their estimated population.

Study area PMUs vary relative to one another with respect to the quantity, quality, and protected status of their available wooded riparian habitats (Table 9). The Big Muddy consistently ranks high, while the LWR (PMU 19) and the Embarras (PMU 20) consistently rank low.

HSI.--Figure 8 contains 2 sample maps of model results, showing the distribution of riparian cells scored as potentially good otter habitat (HSI >0.8), and state or federally-owned lands. Figure 8a shows a section of the Cache watershed (PMU 16), including the Heron Pond-Little Black Slough area mapped in Figure 5, and part of Cypress Creek NWR. Figure 8b shows a section of the Embarras watershed (PMU 20), including the Walnut Point State Fish and Wildlife Area. The Cache section displayed both more suitable habitat and more protected area than the Embarras section.

As with the PATREC model, the HSI model detected differences in habitat composition within and between basins (Fig. 9). Except for Bay Creek (PMU 17), all watersheds exhibited fewer cells in each successively higher HSI rating class. Bay Creek had more cells scoring Good (HSI >0.8) than Poor (HSI <0.5).

Figure 10 shows the distributions of protected and unprotected riparian bank cells, by HSI category, for each watershed. All watersheds displayed more unprotected area than protected area in all 3 HSI classes. Only 8% of riparian bank cells in all study area watersheds fell within state or federal ownership boundaries; 92% did not.

Study area basins were ranked according to the proportion of riparian cells scored as good habitat (HSI >0.8), the number of these cells per unit area, and their protected status (Table 10). The Bay Creek watershed (PMU 17) consistently ranked highest and the Embarras (PMU 20) ranked lowest.

<u>HSI Aggregation</u>.--Similar to the rankings by PATREC score and density of riparian cells with an HSI >0.8, the release basins had the fewest highly suitable aggregations per unit area;

and the Bay Creek, Big Muddy, and Cache watersheds had the highest (Table 11).

Sample maps of HSI aggregations for sections of the Cache and Embarras watersheds (Fig. 11) clearly show that the Cache section has far more perennial water rated as good potential otter habitat than the Embarras section where most perennial water rated poorly. Most of the predicted locations of best otter habitat (HSI focal sum >80) were on the Cache River which meanders greatly and is bordered by numerous wetlands. Many of these locations fall outside protected areas. In contrast, the best locations within the Embarras section fell exclusively within Walnut Point State Fish and Wildlife Areas (Fig. 11). Although this area of the Embarras basin contained numerous riparian cells with HSI >0.8 along the Embarras River, Little Embarras River, and Brushy Fork (Fig. 8b), these stream sections rated mostly intermediate (HSI focal sum 33-80) in the focal aggregation analysis (Fig. 11).

Combined Analysis.--Each model depicts the relative quality of available habitats within basins differently (Figs. 6 and 9). However, model outputs compare favorably between basins (Tables 9 and 10). According to both models, basins in the Shawnee (LMU) rank above basins in the Kaskaskia and Wabash LMUs.

DISCUSSION

Identifying, conserving, and monitoring habitats key to the long-term viability of river otter populations should be a priority of recovery efforts (Bluett 1995). Both otter habitat models assign relative quality ratings to the available habitats within the study area. Lacking detailed information on otter-habitat relationships, divisions in quality were based on the assumption that more is better (i.e., higher quantities of modeled attributes indicate areas of higher quality and, therefore, key habitats). However, habitat quality is related to the rates of survival and reproductive success of the individuals that live there (Van Horne 1983), to the vitality of their offspring, and to the length of time the site remains suitable for occupancy (Morrison et al. 1992).

In the construction of the PATREC model, we attempted to set qualitative divisions on an empirical basis by comparing used versus unused areas. This approach could not be used for the HSI model as most sighting locations could not be reliably plotted within 30 m. While an empirical approach is best, absence due to extirpation does not constitute selection against an area. This is a flaw in the PATREC approach that could cast doubt on model thresholds, outputs, and population projections. However, lacking telemetry data on released otters, comparing sighting data to random areas was the best available option. Further, it is logical to assume that an area with a model output of 0.91 is higher quality than an area with a score of 0.05. However, whether or not an area with a value of 0.67 (lowest score rated High) offers significantly higher rates of survival and reproductive success than an area with a model output of 0.58 (highest score rated Medium) is not known.

Each otter habitat model seems to say different things about the quality of habitats within the PMUs, primarily due to differences in their scale of investigation. Morrison et al. (1992) stated that habitat features must be investigated on the scale at which an animal perceives differences in quality. Due to the flexible social structure of otters and large variation in home range sizes reported in the literature (Melquist and Dronkert 1987), as well as IDNR's focus on viable populations, the PATREC model was designed to assess areas large enough to support multiple individuals. Due to the limitations of available computer processing tools, the PMUs could not be evaluated without first dividing them into component parts. Subunit boundaries, though natural, have no biological meaning in relation to otter habitat use. However, they were convenient for assessing the variability in spatial composition within basins in that they were large enough to support multiple individuals and capture spatial aspects of habitat, yet small enough to be easily handled with the computer power at our disposal. As subunits are the basis for comparisons, the PATREC model is unable to detect habitat variation within subunits, and therefore cannot identify the relative quality of local habitat features (e.g., stream order, wetland type, etc.).

It is logical to assume that habitat quality will vary within subunits and the distribution of habitat attributes will determine patterns of habitat use. The HSI model was developed to assess variations in local habitats, particularly riparian width. However, whether otters perceive qualitative habitat differences at the 30-m resolution of the HSI model is not known. Certainly, density and other population parameters cannot be assessed at this level; the number of cells rated Good required to support even one otter is not known.

Although the models say different things about local habitats within each PMU, they compare favorably when ranking the units relative to one another (Tables 9 and 10). The models predict different basins as the best in the study area, but 5 of the 7 basins ranked in identical order. According to both models, the release basins rank lowest. In the PATREC model, this is primarily due to their lack of wetlands, while in the HSI model it is primarily due to their lack of wide wooded riparian zones. Both of these trends are due in large part to intense agricultural use in these basins, but neither make the basins uninhabitable. Rather, otters in these basins will exist at lower densities, possibly decreasing the opportunities for successful interactions (i.e., breeding) and increasing their susceptibility to negative stochastic and human influences. Therefore, release basins constitute higher management priority.

Key habitats (i.e., areas key to the long-term viability of populations) within basins are best defined as the wetlands and wooded streams with subunits rated Medium or High by the PATREC model (Fig. 12). These areas are likely to serve as population sources from which otters will disperse into other areas. Although rated Low due to a lack of perennial and intermittent wetlands, subunits containing release sites in the Embarras basin (subunits 20_110 and 20_123, Appendix D) also should be treated as key habitats. Telemetry studies of released otter in Missouri showed that post-release distribution remained centered around release sites (Erickson and McCullough 1987); similar post-release distributions may occur in Illinois.

Key local habitats within Medium and High rated subunits can be identified and targeted from HSI model outputs. Aggregations of bank cells scoring >0.8 represent relatively higher quality local habitats. Although otters do not require contiguity of bank cells rated Good by the HSI model, large aggregations covering both banks of a stream segment would represent target areas for protection and monitoring efforts; theoretically, otters will inhabit these areas first.

Summing HSI scores over an area modeled potential river otter habitat at a scale intermediate between individual 30-m cells and subcatchments. This helped identify sections of perennial water with the best nearby habitat, within the limitations of the model. The aggregation model assumes otters will prefer areas, especially when choosing den sites, with significant nearby high-quality habitat over areas surrounded by lower-quality habitat.

Both quantity of nearby habitat, and their suitability according to the HSI model, contributed to the focal sum. The best otter sites computed by this aggregation contained a large number of neighboring riparian bank cells with high HSI scores.

Among the contributors to highly ranked sites were meandering streams, oxbows, numerous wetlands, convoluted lake or wetland edges, extensive riparian woods, little or no aquatic biotic impairment, and sparse road density (especially lack of roads closely paralleling water shores).

The release basins contained both lower HSI scores on average, and lower densities of riparian cells, than the other basins. By both of these metrics, the Embarras watershed ranked the lowest, followed by the Little Wabash. The aggregation rankings reflected these distributions. If carrying capacity related to habitat availability and quality, then according to the model, the release basins will support lower long-term otter densities than the other basins studied, assuming habitat conditions do not change. Within watersheds, otters should theoretically prefer the sites with highly suitable habitat aggregations (HSI focal sum >80).

As a cautionary note, the relationship between quantity and quality of potential habitat is unclear, other than general observations that home ranges may vary inversely with habitat quality; i.e., the better the habitat meets the animal's life requisites, the less area it needs. Melquist and Hornocker (1983) reported that river otter home range sizes varied with watershed drainage patterns, habitat, prey availability, weather conditions, topography, and reproductive activities. Although population density is not strictly a function of habitat, more favorable habitat often supports denser populations. Erickson et al. (1984) reported greater densities of released otter in Missouri in more suitable habitat.

Lacking data on quantity/quality relationships, we used a simple summation of riparian bank cells within 500 m multiplied by their HSI score. However, it is purely conjecture that an otter would equally prefer a location with 160 riparian cells within 500 m having a mean HSI of 0.5, and a location with 80 riparian cells within 500 m all having an HSI of 1.0.

Further, the 500 m search radius was arbitrary. Since computation time increases with the square of increasing search radius, search radii on the order of otter home ranges (7-16 km diameter, according to Toweill and Tabor (1979) and Erlinge (1967)) would have been impractical without resampling the data to a coarser resolution. Ideally, a larger neighborhood search should not be circular, but elongated along waterways, although otters are highly mobile and travel overland as well as through water.

Another problem with the 500 m circular aggregation was its inapplicability to large lakes. Shores of lakes wider than 500 m scored low, even if the bank cells were rated Good by the HSI model, because only one bank was within the search radius. Portions of lakes more than 500 m from shore had no banks within the search radius, and received an HSI sum of zero. Since such lakes have a large forage area and may provide excellent otter habitat, the HSI focal sum should be used only to compare streams and narrow lakes and wetlands. The HSI cell model may be used to compare banks of water bodies wider than 500 m, or the criterion for highly suitable sites halved (to HSI focal sum >40) to compensate for the exclusion of the opposite bank.

For each release basin, key habitats were ranked first by their PATREC rating then by the proportion of Good bank cells within them (Table 12). Further, these areas were rated as high, medium or low priority for protection efforts, based on their ranking and the presence of protected habitats (i.e., high quality unprotected areas were rated high priority for protection). Subunits containing the release sites in the Embarras (PMU 20) and LWR (PMU 19) basins are rated highest, given the lack of protected habitats and the overall lower quality of these basins, as well as the aforementioned post-release distributions observed in Missouri. Other areas were rated high priority if both models predicted high quality habitats within them. Areas were rated low priority for protection if publicly owned lands containing aggregations of Good bank cells existed within the subunit.

Despite its limitations, the HSI aggregation model can also help monitoring, future release, and protection efforts. Model output (e.g., Fig. 12) can be mapped within subcatchments rated high by the PATREC model, or containing otter release sites, and reference data layers like roads and quad boundaries added. Other subcatchments of interest may also be mapped. The best locations (HSI focal sum >80 for water bodies <500 m wide, focal sum >40 for water bodies >500 m wide) within these subcatchments can be selected for field assessment to monitor releases, or select future release sites. With land ownership or management layers added, the distribution of best locations can supplement the PATREC and cell-based HSI results while developing protection strategies.

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Table 7. Total length of wooded riparian habitat, the proportion of wooded riparian habitat in each habitat rating class, and the subsequent population estimates for each study area basin.

PMU[a]	Total Length (km)	High	Medium	Low	Population Estimate
14	4,192.5	26.3	28.9	44.8	543
15	3,882.4	76.8	23.2	0.0	857
16	906.9	84.5	15.5	0.0	209
17	727.2	45.6	34.2	20.2	122
18	1,181.7	38.0	36.9	25.1	185
19	2,909.7	19.1	8.1	72.8	303
20	2,504.8	0.0	16.9	83.1	183
Total	16,305.4	37.9	22.0	40.0	2,401

[a]Population Management Unit.

Table 8. Total length of wooded riparian habitat owned and managed by public agencies, and the potential populations they can support based on model outputs.

PMU[a]	Total Length (km)	% of PMU	Population Estimate
14	352.8	8.4	71
15	872.0	22.5	200
16	262.6	29.0	60
17	268.8	37.0	46
18	120.2	10.2	20
19	57.5	2.0	8
20	40.9	1.6	3
Total	1,974.9	12.1	408

[a]Population Management Unit.

Table 9. Average rank scores for study area Population Management Units (PMUs) based on rankings of: 1) proportion of riparian habitat classified as wooded; 2) average PATREC model output; and 3) the proportion of wooded riparian habitat under public ownership. Low values represent relatively higher quality habitat and lower management priority, while higher values represent relatively lower quality and higher management priority.

	Rankings			Average
PMU	% Wooded Riparian	Average P_{suit}	% Public Domain	Average Rank Score
14	7	5	5	5.7
15	2	1	3	2.0
16	4	2	2	2.7
17	1	4	1	2.0
18	3	3	4	3.3
19	5	6	6	5.7
20	6	7	7	6.7

Table 10. Average rank scores for study area Population Management Units (PMUs) based on rankings of: 1) proportion of riparian bank cells rated Good (scoring >0.8); 2) number of Good cells per unit area; and 3) the proportion of Good cells under public ownership. Low values represent relatively higher quality habitat and lower management priority, while higher values represent relatively lower quality and higher management priority.

	Rankings			
PMU	% Cells Rated Good	# Good Cells/Ha	% Public Domain	Average Rank Score
14	4	5	5	4.7
15	2	2	3	2.3
16	3	3	2	2.7
17	1	1	1	1.0
18	4	4	4	4.3
19	6	6	6	6.0
20	7	7	7	7.0

Table 11. Distribution of HSI focal sums by watershed. For each perennial water cell, all riparian HSI scores were summed within a circular radius of 500 m. The HSI sum for each water cell is a combination of quantity of riparian habitat within 500 m, and relative suitability of this habitat as predicted by the HSI model.

Watershed	Area	No. Water Cells	No. Cells/km^2		
			HSI Sum <33	HSI Sum 33-80	HSI Sum >80
Big Muddy	7,952.73	341,028	23.84	16.73	2.31
Bay Creek	1,475.41	41,248	8.24	17.42	2.30
Cache	2,494.31	78,528	18.22	12.05	1.21
Saline	3,180.89	80,880	13.60	10.88	0.95
Kaskaskia	15,044.61	444,645	19.22	9.39	0.94
Little Wabash	9,979.66	192,353	10.04	8.69	0.55
Embarras	9,175.56	162,146	11.09	6.46	0.12

Table 12. Key habitats, listed in rank order from high to low, within each of the release basins based on outputs of both models. Key habitats are rated as high (H), medium (M) or low (L) priority for protection based on the quality and protected status of their available habitats.

ID	PATREC Score	% HSI >0.8	Protection Priority
20_208	0.44	0.22	L
20_118	0.41	0.13	M
20_120	0.41	0.08	M
20_119	0.33	0.22	M
20_123[a]	0.22	0.17	H
20_110[a]	0.14	0.20	H
19_202	0.91	0.35	M
19_111	0.91	0.29	M
19_107	0.91	0.25	H
19_114	0.67	0.14	M
19_308	0.67	0.14	M
19_307	0.67	0.05	M
19_306	0.53	0.19	M
19_113	0.53	0.18	H
19_208	0.33	0.32	M
19_101	0.33	0.04	M
14_406	0.91	0.48	H
14_408	0.91	0.37	H
14_108	0.78	0.45	L
14_109	0.78	0.21	L
14_110	0.78	0.21	L
14_206	0.78	0.20	L
14_208	0.67	0.33	M
14_302	0.67	0.23	M
14_405	0.67	0.21	L
14_301	0.67	0.19	M
14_413	0.67	0.18	M
14_402	0.67	0.17	L
14_306	0.58	0.26	M
14_401	0.53	0.41	L
14_209	0.53	0.32	M
14_414	0.53	0.13	M
14_415	0.44	0.16	M
14_201	0.41	0.20	M
14_116	0.41	0.09	M
14_304	0.33	0.39	M
14_102	0.33	0.30	M
14_303	0.33	0.29	M

Table 12. Continued.

ID	PATREC Score	% HSI >0.8	Protection Priority
14_307	0.33	0.23	H
14_210	0.33	0.18	M
14_112	0.33	0.16	M
14_114	0.33	0.08	M

[a] Units containing release sites should be treated as key habitats.

insert Fig. 6

Fig. 7. Examples of subunits rated a) High (14_408) and b) Low (20_105) by the PATREC model.

Fig. 8. Two sample maps of HSI model results, showing the distribution of riparian cells with an HSI >0.8 and state or federally-owned lands: a) section of the Cache watershed; b) section of the Embarras watershed.

insert Fig. 9

Figure 10. Distribution of protected and riparian bank cells by HSI rank in: a), Bay Creek (PMU 17); b), Big Muddy (PMU15); c), Cache (PMU 16); d), Embarras (PMU 20); e), Kaskaskia (PMU 14; f), Little Wabash (PMU 19); and g), Saline (PMU 18) basins.

Insert Fig. 10

Fig. 11. Two sample maps of HSI aggregations, showing perennial water predicted by the model to be good otter locations (HSI sum >80), intermediate locations (HSI sum 33 - 80), and poor locations (HSI sum <33); and state or federally-owned lands: a) section of the Cache watershed; b) section of the Embarras watershed.

Fig. 12.

Appendix F. Final model inputs and outputs for all study area subunits. The first 2 digits of Subunit ID indicate Population Management Units.

ID	Wooded Stream Length	Stream Shape Index	% Riparian Increase	Intermittent Wetland Edge (km)	Model
14_101	32.9	0.91	0.0	0.0	0.09
14_102	52.9	0.94	24.7	0.0	0.33
14_103	52.3	0.90	0.5	0.0	0.09
14_104	36.7	0.91	1.6	0.0	0.09
14_105	73.9	0.92	0.5	0.0	0.22
14_106	76.6	0.88	3.1	0.0	0.22
14_107	73.8	0.89	0.3	0.0	0.22
14_108	28.9	0.88	386.5	26.4	0.78
14_109	20.0	0.89	153.6	47.7	0.78
14_110	15.7	0.88	268.4	63.7	0.78
14_111	22.2	0.90	0.4	10.1	0.09
14_112	46.9	0.91	24.2	0.0	0.33
14_113	50.3	0.91	4.1	19.2	0.09
14_114	16.9	0.89	22.4	8.0	0.33
14_115	20.7	0.89	0.0	0.0	0.09
14_116	37.2	0.89	0.0	23.1	0.41
14_117	13.9	0.95	0.0	0.0	0.09
14_118	0.2	0.89	0.0	0.0	0.09
14_119	16.5	0.87	0.0	0.0	0.05
14_120	4.0	0.87	3.0	0.0	0.05
14_121	0.5	0.84	57.1	0.0	0.22
14_200	44.3	0.90	13.0	16.4	0.09
14_201	25.1	0.89	17.6	35.9	0.41
14_202	85.7	0.90	6.9	1.9	0.22
14_203	107.1	0.92	7.4	14.8	0.22
14_204	40.3	0.97	1.1	18.5	0.09
14_205	92.0	0.87	31.1	9.8	0.44
14_206	61.7	0.89	82.3	197.8	0.78
14_207	181.7	0.90	4.7	15.8	0.22
14_208	115.1	0.89	6.4	33.7	0.67
14_209	146.7	0.83	7.7	27.8	0.53
14_210	48.2	0.89	37.4	7.0	0.33
14_211	62.1	0.90	13.9	0.0	0.09
14_212	69.9	0.90	2.5	3.8	0.22
14_213	130.1	0.90	6.1	0.0	0.22
14_301	92.8	0.93	8.1	30.7	0.67
14_302	66.7	0.93	2.4	28.7	0.67
14_303	47.1	0.93	46.5	8.8	0.33
14_304	51.2	0.91	79.2	1.9	0.33
14_305	110.6	0.95	4.1	0.0	0.22
14_306	88.1	0.91	37.7	5.1	0.58

Appendix F. Continued.

ID	Wooded Stream Length	Stream Shape Index	% Riparian Increase	Intermittent Wetland Edge (km)	Model
14_307	60.0	0.91	48.9	3.6	0.33
14_401	71.0	0.36	18.1	108.6	0.53
14_402	49.1	0.44	52.0	133.3	0.67
14_403	73.1	0.90	11.4	5.8	0.22
14_404	40.1	0.85	14.0	24.0	0.29
14_405	59.3	0.32	76.0	159.7	0.67
14_406	78.4	0.89	23.3	20.5	0.91
14_407	42.7	0.90	11.7	10.1	0.09
14_408	75.7	0.89	25.3	86.9	0.91
14_409	85.5	0.87	10.0	11.2	0.14
14_410	35.6	0.86	32.8	0.0	0.22
14_411	19.8	0.82	23.2	0.0	0.22
14_413	59.7	0.87	30.5	25.1	0.67
14_414	101.0	0.87	8.1	38.5	0.53
14_415	71.7	0.87	26.6	6.4	0.44
14_416	96.0	0.89	8.5	3.7	0.22
14_417	68.9	0.94	3.1	8.5	0.22
15_101	151.6	0.39	75.5	110.6	0.85
15_102	30.8	0.91	371.9	0.0	0.33
15_103	61.3	0.92	35.3	2.8	0.33
15_104	133.3	0.92	21.3	14.4	0.58
15_105	72.6	0.90	350.6	49.3	0.91
15_106	70.6	0.88	89.4	56.1	0.91
15_107	105.0	0.93	42.2	102.6	0.91
15_108	42.6	0.92	171.2	78.3	0.78
15_109	124.0	0.90	31.3	96.9	0.91
15_110	67.7	0.87	41.0	221.0	0.85
15_111	19.2	0.89	712.7	94.0	0.78
15_112	78.8	0.89	49.4	37.7	0.91
15_113	97.5	0.91	28.9	50.0	0.91
15_114	107.8	0.88	130.3	208.7	0.91
15_115	73.9	0.89	13.7	91.1	0.67
15_116	57.5	0.90	6.4	57.1	0.41
15_117	72.9	0.92	83.3	61.0	0.91
15_118	45.7	0.91	364.0	125.5	0.78
15_119	140.7	0.90	43.4	10.4	0.58
15_120	85.2	0.87	65.5	98.1	0.85
15_201	128.9	0.37	28.7	466.2	0.85
15_202	208.4	0.93	21.7	382.1	0.91
15_203	77.7	0.62	21.9	307.7	0.85
15_204	184.5	0.89	33.4	2.3	0.58
16_101	69.3	0.84	6.3	191.1	0.53
16_102	56.0	0.92	19.5	41.5	0.41

Appendix F. Continued.

ID	Wooded Stream Length	Stream Shape Index	% Riparian Increase	Intermittent Wetland Edge (km)	Model
16_103	102.8	0.91	3.0	120.5	0.67
16_104	76.9	0.84	66.1	276.6	0.85
16_201	164.8	0.91	5.1	131.2	0.67
16_202	60.0	0.92	28.2	25.8	0.78
16_203	58.8	0.93	32.3	141.0	0.78
16_204	74.5	0.84	31.4	204.7	0.85
16_205	85.3	0.76	25.5	110.1	0.85
17_101	231.4	0.86	7.7	52.4	0.53
17_102	53.2	0.86	23.9	8.8	0.22
17_103	80.1	0.93	1.1	0.0	0.22
17_104	70.0	0.88	3.0	104.9	0.67
17_105	46.6	0.93	21.7	66.7	0.78
17_106	137.4	0.92	15.0	69.5	0.67
17_107	33.9	0.78	31.2	68.5	0.67
18_101	72.9	0.88	129.8	18.5	0.58
18_102	76.9	0.94	41.5	31.8	0.91
18_103	158.1	0.90	11.8	0.0	0.22
18_104	74.4	0.89	40.9	124.6	0.91
18_105	60.2	0.88	20.7	75.0	0.78
18_106	73.0	0.91	8.9	34.2	0.67
18_107	35.9	0.55	19.9	137.2	0.67
18_108	69.5	0.76	81.4	7.0	0.44
18_109	84.1	0.95	25.0	16.5	0.58
18_110	60.7	0.72	13.4	90.1	0.29
18_111	37.1	0.92	1.5	34.0	0.41
18_112	38.0	0.86	34.3	0.0	0.22
18_201	20.7	0.68	92.8	59.0	0.67
19_101	25.3	0.88	91.0	0.0	0.33
19_102	144.9	0.89	14.6	0.0	0.22
19_103	132.1	0.89	7.5	0.0	0.22
19_104	82.8	0.89	1.6	0.0	0.22
19_105	339.6	0.89	2.2	0.0	0.22
19_106	53.3	0.87	2.1	2.5	0.05
19_107	161.8	0.89	32.3	26.0	0.91
19_108	40.7	0.90	2.7	0.0	0.09
19_109	88.8	0.88	1.3	3.0	0.22
19_110	30.0	0.88	0.3	6.2	0.09
19_111	75.4	0.89	73.0	57.0	0.91
19_112	62.2	0.86	6.9	0.0	0.05
19_113	69.3	0.86	12.0	22.5	0.53
19_114	55.3	0.86	21.2	28.2	0.67
19_115	36.8	0.54	6.8	14.2	0.05
19_116	13.8	0.36	20.9	3.8	0.22

Appendix F. Continued.

ID	Wooded Stream Length	Stream Shape Index	% Riparian Increase	Intermittent Wetland Edge (km)	Model
19_117	61.0	0.37	29.3	18.8	0.22
19_118	57.8	0.91	4.9	2.0	0.09
19_119	92.1	0.88	4.4	3.5	0.22
19_201	173.0	0.88	17.6	7.6	0.22
19_202	86.1	0.89	21.7	43.9	0.91
19_203	69.2	0.91	8.1	13.4	0.22
19_204	56.7	0.92	17.1	4.2	0.09
19_205	15.9	0.83	92.1	10.3	0.22
19_206	47.8	0.79	11.1	0.0	0.05
19_207	41.4	0.86	34.2	11.3	0.22
19_208	15.6	0.92	40.6	1.8	0.33
19_301	134.7	0.86	6.7	0.0	0.14
19_302	30.0	0.89	1.5	9.7	0.09
19_303	57.5	0.69	2.6	20.0	0.29
19_304	24.1	0.72	13.7	3.3	0.05
19_305	55.6	0.78	10.0	4.5	0.05
19_306	73.8	0.70	18.8	105.9	0.53
19_307	14.8	0.51	58.7	38.3	0.67
19_308	5.6	0.26	183.4	124.7	0.67
20_101	32.7	0.88	0.8	0.0	0.09
20_102	2.1	0.87	0.0	0.0	0.05
20_103	45.2	0.89	10.7	4.1	0.09
20_104	19.2	0.89	0.6	0.0	0.09
20_105	1.2	0.89	0.0	0.0	0.09
20_106	74.9	0.89	2.3	0.0	0.22
20_107	48.8	0.91	2.9	3.4	0.09
20_108	80.2	0.77	12.8	0.0	0.14
20_109	60.4	0.88	2.5	0.0	0.09
20_110	123.6	0.87	5.6	1.4	0.14
20_111	72.9	0.90	3.3	0.0	0.22
20_112	171.2	0.90	3.0	0.0	0.22
20_113	63.0	0.91	11.1	0.0	0.09
20_114	60.8	0.76	33.6	2.2	0.22
20_115	52.4	0.78	4.2	0.0	0.05
20_116	56.3	0.84	11.7	1.3	0.05
20_117	57.9	0.90	14.0	12.8	0.09
20_118	56.8	0.88	10.2	46.8	0.41
20_119	51.5	0.92	28.9	3.1	0.33
20_120	61.0	0.94	16.7	54.3	0.41
20_121	124.5	0.89	7.9	1.1	0.22
20_122	190.3	0.91	0.4	2.8	0.22
20_123	133.3	0.89	4.5	0.0	0.22
20_201	46.4	0.89	3.3	0.0	0.09

Appendix F. Continued.

ID	Wooded Stream Length	Stream Shape Index	% Riparian Increase	Intermittent Wetland Edge (km)	Model
20_202	56.8	0.90	0.0	0.0	0.09
20_203	4.3	0.96	0.0	0.0	0.09
20_205	70.2	0.93	15.5	0.0	0.22
20_207	115.4	0.90	2.0	0.0	0.22
20_208	160.1	0.84	38.9	9.4	0.44
20_209	49.7	0.54	11.3	9.2	0.05
20_210	74.1	0.70	5.8	14.2	0.14
20_211	16.4	0.52	13.0	8.2	0.05
20_301	42.8	0.89	6.4	0.0	0.09
20_302	10.9	0.87	0.0	0.0	0.05

JOB 1.4. ANALYSIS AND REPORT

OBJECTIVE: To analyze results from Jobs 1.1, 1.2, and 1.3 and to provide recommendations to enhance efforts to recover the river otter in Illinois so that it can be removed from the state's endangered species listing.

CONCLUSIONS

This study demonstrates the ability to quantify attributes associated with otter habitat at the landscape level using existing digital and remotely sensed data sets. The strengths of this approach are associated with the scale of investigation, the ability to quantify available habitats, and the ability to assess large areas cost-effectively. The dendritic home ranges, generalized food and habitat requirements, and mobility of river otters, plus IDNR's focus on viable populations, necessitate investigations at the landscape level. Further, data on the quantity and relative quality of habitats within and between basins provides a foundation for: (1) evaluating the success of releases; (2) directing efforts to monitor populations cost-effectively; and (3) generating hypotheses about otter-habitat relationships for further research.

This approach could be used to assess areas for additional releases, to identify focus areas for population monitoring, and identify unprotected key habitats. Objective 4 of the Recovery Plan calls for conserving enough habitat to support a minimum 200 otters among at least 4 LMUs (Bluett 1995). Publicly owned lands can meet the goals of Objective 4 in the Kaskaskia LMU (PMU 14), and in the Shawnee LMU (PMU’s 15 - 18), but not in the Wabash LMU (PMU’s 19 and 20). Habitat acquisition and enhancement would be prohibitively expensive in these units, but public-private partnerships and current federal programs (e.g., Conservation Reserve Program, riparian easements, etc.) offer opportunities to conserve otter habitat by getting landowners involved. These avenues could potentially protect and enhance far more habitat than agencies can purchase. Creation of foraging habitats (i.e., wetlands) may not be feasible, but lengthening and widening wooded riparian zones is and offers broad benefits beyond protecting otters (e.g., erosion control, water quality improvements, corridors for other wildlife, etc.).

Population monitoring will be necessary to document population trends to meet recovery objectives. Lacking a single efficient method to census otter populations, the monitoring framework will require a combination of several techniques, and should be flexible enough to deal with various habitat types and changing circumstances over time. The monitoring options listed in Appendix E are labeled as to the time periods post-release in which they may be useful: short-term (<5 years), mid-term (5-10 years), and long-term (>10 years). In addition, the techniques are subjectively ranked within each time frame as to their relative cost-effectiveness and the data they could generate. Although sighting reports will lose utility over time, the technique is listed under all time periods with the understanding that continued contact with trappers and commercial fisherman will be necessary to monitor mortality (i.e., rates of incidental capture). Application periods and rankings are guidelines only; relative utility of a given technique in a given time frame will depend on the biological and political circumstances encountered.

It is logical to assume that otters will expand first into quality habitats proximal to release areas. Thus, field surveys, especially in the first application period, would best be conducted in release areas and in the surrounding subunits where bank cells rated Good are aggregated. In later application periods, field surveys will need to be expanded concentrically from release areas as populations expand.

LITERATURE CITED

BLUETT, R., ed. 1995. Illinois river otter recovery plan. Ill. Dep. Nat. Resour., Springfield. 96pp.