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# RELATIVE ABUNDANCE OF BEAVERS IN ILLINOIS

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# RELATIVE ABUNDANCE OF BEAVERS IN ILLINOIS

**FINAL REPORT**

**Federal Aid Project W-135-R-3**

**Submitted by:**

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**and**
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**Presented to:**

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# FINAL REPORT

**STATE OF ILLINOIS**

**W-135-R (1-3)**

**Project Period:** 1 July 1999 through 30 June 2002

**Project**: Relative Abundance of Beavers in Illinois


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**NEED:** Beavers (*Castor canadensis*) are an important wildlife species because they create and maintain wetland habitats, provide recreational and economic opportunities through a regulated trapping season and, in some cases, cause serious human-wildlife conflicts. The Illinois Department of Natural Resources needs to improve its ability to estimate and detect changes in the relative abundance of this species on statewide and regional levels.

**OBJECTIVES:**

1. To evaluate methods for monitoring the relative abundance of beavers.
2. To recommend methods and sampling strategies adequate for detecting a 20% change in the statewide population.
3. To estimate and compare regional differences in relative abundance.

## EXECUTIVE SUMMARY

### Job 1.1. Techniques to Monitor Beaver Relative Abundance

The objective of this job was to evaluate methods for monitoring the relative abundance of beavers. We needed reliable data on beaver colony composition and demographics to achieve overall project goals and we obtained the information as a task under this job. We evaluated aerial survey techniques, bridge surveys, ground searches of 2.59-$km^2$ sample blocks, and surveys of lacustrine habitats by vehicle and watercraft. We concluded that aerial survey was the most efficient technique.

We developed an aerial survey based on watersheds (Population Management Units) to test survey design and efficiency. We used GIS to classify and quantify aquatic habitats within each watershed and determined that 20 randomly selected 2.59-$km^2$ blocks was an adequate number to sample aquatic habitats in proportion to their composition in the watershed, except that 30 blocks were required in the largest watershed. The complete aerial survey of 8 southern Illinois watersheds that included 170 blocks was conducted between 24 November 2000 and 19 March 2001; 44.5 flight hours were required. We detected evidence of beaver in 43.5% of blocks searched. Ground searches of blocks in 3 watersheds where beaver sign was not detected confirmed that aerial results were correct 80% (range 75-90%) of the time.

**Job 1.2. Statewide Beaver Population Trends**

This job's objective was to recommend methods and sampling strategies adequate for detecting a 20% change in the statewide population. We evaluated ability to detect various types of beaver sign in different habitats to develop a correction factor that could be used to convert aerial counts to estimates of total beaver colonies in the study area. We conducted 3 replicate surveys in the Big Muddy Watershed to measure variance that could be used to estimate confidence limits for the mean number of colonies per watershed. Stream habitat density estimates (sign/km) had low variation ($\bar{x} = 0.456 \pm 0.089$ SD); lacustrine density estimates (sign/ha) were more variable. Using the stream density variation, our best estimate of statistical precision ($P < 0.05 \pm 2$ SE) of the population survey technique approached the desired goal of 20%.

**Job 1.3. Regional Relative Abundance**

The objective of this job was to estimate and compare regional differences in relative abundance. The habitat category of streams which shared the most common attributes among watersheds (and accounted for ~80% of estimated number of colonies) was used to compare regional differences. The Cache Watershed had the highest stream density index (0.601 colonies/km stream) followed by the Vermilion (0.539 colonies/km stream). The estimated number of colonies in all habitats sampled was greatest in the Big Muddy (1,689) followed by the Embarras Watershed (1,376). The overall estimate of beaver colonies located in stream, lacustrine <100 ha, and palustrine-emergent habitats in the 8 watersheds sampled was 6,389 ± 657 (2 SE) colonies. It should be noted that this estimate does not include beaver colonies inhabiting lakes >100 ha, or the Ohio, Mississippi, and Wabash rivers bordering the southern Illinois region.

## STUDY 1. RELATIVE ABUNDANCE OF BEAVERS IN ILLINOIS

### JOB 1.1. TECHNIQUES TO MONITOR BEAVER RELATIVE ABUNDANCE

Objective: To evaluate methods for monitoring the relative abundance of beavers.

### INTRODUCTION

Multiple and varied research tasks were performed under the auspices of this job to evaluate methods and obtain data necessary to fulfill the objectives for Jobs 1.2 and 1.3. Therefore, the methods section for this job also describes those employed to obtain data for all jobs.

Obtaining reliable data on beaver colony composition and demographics was an important need for the overall project. This task was accomplished with a graduate study conducted by Stanley T. McTaggart that led to a thesis in partial fulfillment of the degree of Master of Science awarded by Eastern Illinois University. The thesis (McTaggart 2002) is appended to this report; methods are not described elsewhere in this final project report, but results are used as appropriate to address objectives for all jobs in the study.

### METHODS

#### Aerial Survey

*Sample Plot Selection.*—Maps of 8 southern Illinois watersheds (Bay Creek, Big Muddy, Cache, Embarras, Kaskaskia, Little Wabash, Saline, and Vermilion) were prepared using ArcView (Environmental Systems Research Institute, Redlands, California, USA) Geographical Information System (GIS) software. Wetlands identified in the Illinois land cover database (Luman et al. 1996) were aggregated into the following classes: streams, permanent wetlands (wooded and other), and intermittent wetlands (wooded and other). Streams included perennial waterways, ditches, and the shorelines of large rivers identified from the 1994 Topologically Integrated Geographic Encoding and Referencing data files (TIGER, 1:1,000,000 scale). Streams were further classified as wooded or non-wooded, with wooded streams consisting of forested areas overlapping streams identified in the National Wetlands Inventory (NWI, 1:234,000 scale). Wooded palustrine wetlands included riparian woods and palustrine forested wetlands. The category "other" consisted of ponds and lakes >1 ha in size and all other classes of non-wooded permanent wetlands. Intermittent wetlands consisted of wooded and non-wooded intermittent wetlands >5 ha in size. We then used the GIS software to compute area of each wetland class in the entire watershed.

Townships and township sections were randomly selected from the watershed to sample habitats within the unit. Individual township sections were kept as sampling units as long as areas classified as water were within its boundaries; sections without water were discarded. The boundaries of retained township sections were traced and used to clip the water grid. The number of pixels in each category was recorded for each sampling block. Additional township sections were then chosen until the total percent composition of pixels within the sampling blocks approximated the percent composition of pixels in the entire watershed.

Preliminary trials indicated that 20 blocks per watershed approximated wetland composition of the entire watershed, except that 30 blocks were selected for the Kaskaskia Watershed (the largest). Sampling blocks were identified by the number assigned to the township by the Illinois Department of Natural Resources (IDNR) (1996; column labeled Township_ in the data table, not Township_i), and the number of the township section chosen (1-36).

*Aerial Survey*.—We delineated sample blocks on U.S. Geological Survey (USGS) 7.5 minute topographic maps. Coordinates of 1 corner were determined and entered into a Global Positioning System (GPS) unit to facilitate navigation from block to block. We flew the survey with a Bell Jet Ranger (Model 206-L) helicopter and a crew consisting of the pilot and 2 observers. The observers sat in front and back seats on the left side of the aircraft so both could search the same area and verify sightings. Sample plots were located and boundaries identified using GPS and pilotage. All aquatic habitats within the plot were searched at slow airspeeds

(<50 knots) and low altitudes (<100 m above ground level) selected to optimize observations consistent with safety. Sign of beaver presence was classified as cuttings, food cache/lodge, dams, or other and recorded on the 7.5 minute topographic map. We also recorded crew, weather conditions (ceiling, visibility, and wind direction/velocity), and flight times (block searches and total).

*Mapping Aerial Survey Observations*.—Farrand (1997) created maps and related digital files of river otter (*Lutra canadensis*) habitat for all watersheds, except Vermilion, based on Population Management Units (PMU; Bluett 1995) that are relevant to this project's objectives. Relevant files were converted from TNTMips (Map and Image Processing System, Lincoln, Nebraska, USA) to ArcView and ArcGIS software (Environmental Systems Research Institute, Redlands, California, USA) format. Content of files obtained from Farrand (1997) were watershed boundaries, streams, palustrine-emergent areas, and lacustrine areas. Corresponding files for the Vermilion Watershed were obtained from the Illinois Digital Datasets (Illinois Department of Natural Resources 1996). Files not in Universal Transverse Mercator (UTM) North American Datum (NAD) 1983 projection were converted to UTM NAD 83 using ArcToolbox (Environmental Systems Research Institute, Redlands, California, USA).

We classified associations based on location type; streams, lacustrine, and palustrine-emergent wetlands. Streams were perennial flowing water such as streams, ditches, and the shorelines of large rivers identified from the 1994 TIGER data files (1:100,000 scale). Perennial streams were identified using a query to identify intermittent streams and delete them from the file. The resulting file identifying perennial streams was used in all further analyses. Lacustrine areas were classified as <10 ha, 10-100 ha, and >100 ha. Lacustrine areas were further divided with a category for areas such as old mines that are closer to palustrine emergent than lacustrine.

The unit area sampled was based on the amount of each wetland type within the watershed and sample unit blocks for each watershed. Streams within the sample units were identified by clipping the streams within the sample units file. Lacustrine and palustrine emergent areas associated with sample blocks were identified by intersecting sample units with the corresponding wetland type. The watershed boundary was used to clip the streams, lacustrine, and palustrine emergent file, as well as wetland type within sample units generating files for each watershed. The length (km) of streams and area (ha) of lacustrine and palustrine-emergent areas within the watershed and sample units was estimated using the X-Tools extension (Oregon Department of Forestry, Salem, Oregon, USA) in ArcView to update the appropriate measurement field in the attribute table, and the summary statistics function on the field to estimate the total within sample units and the watershed.

Beaver sign observed and mapped on printed topographic maps during the aerial surveys was digitized from an on-screen display of the topographic map using ArcView and ArcMap (Environmental Systems Research Institute, Redlands, California, USA). Digital versions of the USGS 7.5' topographic maps and digital orthophotographic quarter quadrangles (DOQQ) for each sample unit were downloaded from the Illinois Natural Resources Geospatial Data Clearinghouse (http://www.isgs.uiuc.edu/nsdihome/ISGSindex.html). Sign was classified as dam, cache/lodge, and other. Bank dens were included as cache/lodge, and other included cuttings, peeled sticks, and slides. Additional information added to the attribute table for the locations included sample unit number, topographic map name, type of sign, survey type, and time of survey.

Sign was assigned an association based on the closest proximity to one of the categories (streams, lacustrine <10 ha, lacustrine 10-100 ha, lacustrine >100 ha, and palustrine-emergent). The abundance of beaver sign was calculated on a regional basis by watershed. We calculated the amount of sign associated with each wetland type by summing the amount of each type of sign associated with the wetland type. Cuttings were considered to be separate occurrences when they occurred >750 m apart. Presence of 2 types of sign at the same location (e.g., a food cache and a dam or cuttings) also was considered a single occurrence.

To further refine the estimates, wetland types were classified as forested and non-forested. Forested areas were identified from the Illinois Land Cover Database (Illinois Department of Natural Resources 1996) by selecting all forested areas (deciduous closed canopy, deciduous open canopy, coniferous, and forested wetlands) and converting to a shapefile. Forested streams were those within 100 m of forested areas. The association of beaver sign with each wetland type was re-evaluated to determine if the wetland was forest-associated, and sign density was recalculated.

**Variability and Aerial Detection Indices**

*Large Lakes*.—We searched shorelines of 3 lakes >100 ha in the Big Muddy Watershed from small watercraft to determine number of visible food caches/lodges and variability of number/km shoreline. Aerial counts (some with replication) were conducted on 2 of these lakes, and on a third lake that had not been surveyed by watercraft, to determine detection variability.

*Aerial Detection*.—Thirty-two 2.59-$km^2$ study plots located in eastern-central and southern Illinois were selected by EIU project staff for intensive ground and aerial surveys in fall/winter 1999/2000. Plots selected were representative of the full range of suitable beaver habitats and included 18 riverine, 8 lacustrine, and 6 palustrine/pond plots. In 2001, following aerial surveys in the Big Muddy, Cache, and Saline watersheds we ground-searched blocks where no sign was observed to obtain another indication of aerial detection rate.

**Bridge Survey**

Results from the Illinois Department of Natural Resources 2001 Furbearer Sign Survey were obtained from Robert Bluett (Illinois Department of Natural Resources, Springfield, Illinois, USA). The USGS 7.5' topographic maps for bridge survey locations were downloaded from the Illinois Natural Resources Geospatial Data Clearinghouse and locations of the sites used digitized in ArcMap from an on-screen display of the topographic map based on the verbal description, coordinates, and water body name provided. We classified sites as beaver present or absent based on the results of the 2001 survey. Due to the low number of survey sample locations per watershed (2-9), direct comparisons to aerial survey results were not possible. Therefore, survey locations were compared to the closest aerial survey blocks for comparison of beaver presence.

**Road Survey**

We conducted a pilot study to evaluate whether road surveys can be used to provide an index of beavers using ponds and borrow pits. The survey was conducted by searching these habitats along Interstate 57 between Champaign and Mt. Vernon, Illinois. Surveys were conducted during the first week of March 2000. The perimeter of each pond was searched thoroughly from the roadside using a 20x spotting scope. We recorded presence or absence of beavers based on observed sign (food caches, lodges, or fresh cuttings) in or adjacent to these ponds.

## RESULTS

**Distribution and Characteristics of Aerial Sample Plots**

The randomly selected aerial survey blocks were well distributed throughout the watersheds (Fig. 1). Percent deviation of all classes of wetlands differed little between pooled sampling blocks (20 per watershed except 30 blocks in the Kaskaskia Watershed) and the entire watershed. For example, perennial streams in sample blocks were equal to their proportional occurrence in 5 of 8 watersheds. The greatest deviation was 4% in 1 watershed and that reflected over representation of proportion of streams in the Embarras Watershed sampling blocks. The pooled category "wooded permanent wetlands" was the largest component of wetland classes; average difference between sample blocks and the entire watershed was 5%. Based upon their distribution and wetland class composition, we concluded that the random survey blocks provided a reliable sample of the entire watershed.

INSERT FIGURE 1

**Aerial Survey**

The complete aerial survey included 170 2.59-$km^2$ plots (township sections) randomly selected in 8 southern Illinois watersheds (Bay Creek, Big Muddy, Cache, Embarras, Kaskaskia, Little Wabash, Saline, and Vermilion). The blocks were sampled between 24 November 2000 and 19 March 2001; 44.5 hrs flight time were required. Evidence of beaver occupancy was detected in 43.5% of blocks surveyed (Table 1). Blocks ($n$ = 30) where beaver sign was not detected were ground searched in the Big Muddy, Cache, and Saline watersheds to evaluate reliability of the aerial search. In the Big Muddy, Cache, and Saline watersheds, negative aerial results were correct (absence of beaver sign confirmed by ground search) 80% (range 75-90%) of the time.

The block size selected for aerial surveys (2.59-$km^2$) was efficient to search; average search time per block was 4.6 min. Total block search time was 12.96 hrs with the remaining flight time (~31.5 hrs) being ferry time between blocks within watersheds, and to and from survey areas. It required 11 days to survey the 8 watersheds. We began surveys shortly after leaf off was complete and scheduled flights when weather conditions permitted. We generally scheduled flights when surface winds were <10 knots and visibility provided for safe flight conditions; overcast sky was preferred to clear because of less glare, but was not a flight condition requirement.

Surveys of the Embarras Watershed in blocks east of Olney, Illinois and the upper half of the Wabash Watershed were flown during high water conditions that made sighting food caches difficult and may have covered fresh cuttings at the base of trees. Ice and snow cover precluded surveys in December; these conditions persisted in January and increased the probability that sign was missed during survey flights of Wabash, Saline, and Bay Creek watersheds. By late January, ice/snow cover and high water were no longer a factor and the final 5 surveys were flown under good to excellent conditions except for high water in a few blocks of the Big Muddy Watershed. Overall, ambient weather or flight conditions adversely affected results of surveys of 3

Table 1. Aerial search of sample blocks to detect beaver sign in 8 southern Illinois watersheds, November 2000-March 2001.

| Watershed | Number of blocks | Blocks with sign present | Sign present (%) |
|---|---|---|---|
| Bay Creek | 20 | 10 | 50 |
| Big Muddy | 20 | 14 | 70 |
| Cache | 20 | 11 | 55 |
| Embarras | 20 | 8 | 40 |
| Kaskaskia | 30 | 5 | 17 |
| Little Wabash | 20 | 7 | 35 |
| Saline | 20 | 11 | 55 |
| Vermilion | 20 | 8 | 40 |
| | 170 | 74 | 43.5 |

watersheds and portions of 2 others. Hence, estimates of sign abundance in these watersheds are conservative.

**Variability and Aerial Detection Indices**

*Large Lakes*.—The number of food caches/lodges detected by watercraft search of 3 large (>100 ha) lake shorelines varied from 0.21-0.45/km shoreline (Table 2) suggesting that large lakes offered habitat of varying quality and that an estimate of colony abundance could not be generalized for all large lakes. Water was clear and lake levels relatively low during our watercraft surveys which facilitated detection of the structures. Important sources of error that were not measured were (1) inability to detect bank dens other than those associated with food caches, and (2) the relationship between food caches and colonies. Hence, the range of shoreline structures built by beavers provides only a crude estimate of numbers of colonies inhabiting a given lake.

*Aerial Detection*.—Aerial searches were conducted of shorelines of 2 lakes searched by watercraft (Table 2), but detection indices were equivocal because of the time between watercraft and aerial observations and high water when aerial searches were conducted. A 75-minute flight to search Little Grassy Lake on 2 February 2000 detected 14 active caches. The difference between water and aerial counts was reconciled with a very low altitude, often at a hover, aerial search on 28 February. We confirmed the 14 sites detected previously plus 3 additional (2 were old and very hard to see) for a total of 17 that should have been visible during the 2 February flight yielding a 82.4% aerial detection rate. Five sites mapped during the summer water surveys were no longer detectable because they were either entirely underwater, or broken up. A different observer crew (not familiar with the area) repeated the search on 26 March. They detected 15 sites, but 2 of the 17 confirmed were missed and 1 site was new. The detection rate was 76.4%.

An aerial search of Devil's Kitchen Lake was conducted 16 February 2000 under late afternoon conditions of extreme glare caused by low sun angle on a bright, cloudless day; 19

Table 2. Number of active beaver food caches/lodges detected by watercraft shoreline surveys of 3 southern Illinois lakes, summer 1999.

| Lake | Caches/lodges | Km shoreline | Number/km shoreline |
|---|---|---|---|
| Devil's Kitchen | 14 | 38 | 0.37 |
| Kinkaid | 24 | 116 | 0.21 |
| Little Grassy | 18 | 40 | 0.45 |

caches were detected. An intensive aerial search on 28 February was conducted to reconcile air versus ground counts. The 19 sites detected 16 February were confirmed, 6 sites mapped during the summer water search were located, but 2 were badly broken up and likely would have been missed had their exact location not been known. Thus we assumed 23 sites could have been detected on 16 February for a 82.6% detection rate.

Two aerial searches of another lake (Cedar Lake) with an unknown number of caches were conducted to determine concordance. Nine caches were detected during a flight in late afternoon with bright sun and extreme glare. A repeat flight another day under better conditions detected 14 caches, including the 9 detected during the first flight (concordance between flights 64.3%).

The 32 EIU sample plots were searched 19 and 20 February 2000. Aerial searches averaged 5.5 min/plot across all habitat-types. Lacustrine habitats required more time for surveys (9.4 min/plot) than riverine and palustrine/pond habitats which averaged 4.2 and 4.0 min/plot, respectively.

Water in riverine habitats was high and turbid, obscuring many food caches and dams resulting in low visibility indices (Table 3). Further, food caches were smaller and less visible in February than in the preceding November when ground surveys were conducted, even in lacustrine habitats where other sign was visible. Consequently, visibility indices ranged from 0.0:1 for food caches in riverine habitats to 1:1 for cuttings in lacustrine and palustrine/pond habitats (Table 3).

We ground-searched 8, 12, and 10 blocks, respectively, in the Big Muddy, Cache, and Saline watersheds where no sign was observed during the 2000/01 aerial survey. We found 75% detection rates for the Big Muddy and Cache watersheds and 90% in the Saline. Lack of concordance (2 blocks) in the Big Muddy was attributable to high water obscuring sign during the aerial survey. In the Cache Watershed, the observers simply missed obvious sign by not thoroughly searching 3 blocks. The single block in the Saline where sign was missed only

Table 3. Visibility indices for beaver sign in 3 habitat-types based on the ratio of sign observed during helicopter surveys (Feb 2000) to sign observed during intensive ground surveys (Nov 1999).

| | Type of Sign | | | |
|---|---|---|---|---|
| Habitat-type | Cuttings | Lodges | Food caches | Dams |
| Riverine | 0.8:1 (14/18) | 0.3:1 (3/11) | 0.0:1 (0/11) | 0.1:1 (1/10) |
| Lacustrine | 1:1 ( 8/ 8) | 0.9:1 (7/ 8) | 0.6:1 (5/ 8) | na |
| Palustrine/ Pond | 1:1 ( 6/ 6) | 0.7:1 (7/10) | 0.0:1 (0/ 2) | na |

contained a few cuttings in a creek that would have been difficult to detect from the air; a nearby cache/lodge (outside the sample block) was noted.

**Bridge Survey**

The Furbearer Sign Survey used 33 sample points within the watersheds considered in the aerial survey; 27 (81.8%) had beaver present. In contrast, 45.3 % of aerial survey blocks were occupied. However, 4 bridge survey locations were >16 km (3 >20 km) from any aerial survey block making comparisons meaningless. Nineteen (65.5%) of the remaining 29 bridge survey locations closer to an aerial survey block had the same occupancy status. Four of the 10 locations with different occupancy status were in different local drainages. Aerial surveys of the remaining 6 were at the headwaters, or on a tributary feeding the water body sampled by the bridge survey. In the case of 10 bridge survey points that were <5 km from an aerial survey sample block, 8 had the same occupancy status in both surveys. In the 2 samples lacking concordance, there was less water present in 2 aerial survey blocks lacking sign than in the nearest bridge survey location with beaver present.

**Road Survey**

Beaver sign was present in 6 of 111 (5.4%) ponds surveyed. All of the ponds occupied by beavers had woody or brushy banks which provided winter food supplies. Most unoccupied ponds surveyed were surrounded by grassy shores and lacked woody shoreline vegetation.

**DISCUSSION**

**Bridge and Road Surveys**

The differences we found between results of the bridge surveys and the aerial surveys were not surprising given the purpose and design of the bridge surveys. Bluett (1999) noted that beaver were so common in Illinois that data on presence/absence derived from bridge surveys might not be sensitive to changes in abundance within a desired level of precision. We concur based on our findings. The bridge surveys provide a reliable index of distribution, and perhaps offer more sensitive detection of minimal sign (tracks and small cuttings) than aerial surveys;

however, they offer no means to obtain estimates of density per unit area of different habitat types.

The road survey was only useful to detect beaver occupancy of small bodies of water entirely visible from a road. Low occupancy rate (5.4%) of the ponds/borrow pits in the area searched limit utility of the technique. Aerial search of Interstate highways 57 and 24 south of Benton, Illinois detected 3 of 30 (10%) of ponds/borrow pits occupied. The combined sample (9 of 141) provides a useful estimate (6.4%) of occupancy of a specific habitat-type. However, whether these small bodies of water are inhabited by solitary animals or families is uncertain. Also, they offer limited habitat and thus are not useful for tracking population trends.

**Aerial Surveys**

The utility of aircraft to survey wildlife was noted by resource managers early in the history of our profession and the technique has been applied to surveys of numerous species in varied habitats. For beaver, most aerial surveys are planned after leaf fall and prior to freeze-up (Novak 1987); in Wisconsin, surveys are conducted between 25 October and 15 November (Kohn and Ashbrenner 1995) and surveys for beaver in Ohio occur during a similar period (Dyer 1999). This time period is preferred because visibility is good, fresh cuttings are more evident, and new food caches (under construction or complete) can be more readily distinguished from old caches.

We conducted our surveys over a much wider time frame (late Nov to mid Mar) because of weather constraints (flight conditions, high water, and ice) and helicopter availability. We recognize this led to reduced survey efficiency as described in results, and juvenile dispersal (post Feb) could introduce a bias. Nevertheless, logistic constraints are a reality and we believe aerial surveys for beaver can be effective throughout the leaf-off period so long as they are not flown during periods of ice cover or when rainfall events lead to streams overflowing their banks. Further, flight and environmental conditions should be noted for each survey and limitations in visibility and detection recognized.

The efficiency of aerial surveys is measured by detection which is a product of a number of important variables. Novak (1987) noted this as varying efficiency and summarized published outcomes ranging from poor results (not specified) to detection rates >90%. We achieved comparable high detection rates in some habitats under good survey conditions (see Table 3) with overall detection rates (survey blocks and large lakes) of 82-90% except for 75% sign detection rates in 2 watersheds that were caused by either high water or observer error. We expect that a trained flight crew operating under optimum flight and environmental conditions should be expected to detect ~90% of sign during aerial surveys for beaver in our region.

Greater detection rates of sign suggesting presence of a colony are constrained by the behavioral ecology of beaver inhabiting our region. In our region bank dens are more common than lodges, and food caches are not constructed by many colonies living in riverine habitats where fluctuating water levels and fast currents preclude cache construction (or break up caches by early to mid-winter). Thus our aerial surveys use a zone of fresh cuttings (750 m apart from another zone) as an indicator of colony presence whereas surveys in more northern regions rely on more visible lodges/caches as the measure of colony presence. Nevertheless, we concluded that our aerial surveys for beaver were efficient and more effective than alternative approaches to monitor beaver abundance in Illinois.

## JOB 1.2. STATEWIDE BEAVER POPULATION TRENDS

Objective: To recommend methods and sampling strategies adequate for detecting a 20% change in the statewide population.

## INTRODUCTION

The results of Job 1.1 led to the conclusion that an aerial survey would be the most effective tool to sample the statewide beaver population with adequate precision to detect a 20% population change. We began with the premise that watersheds were a useful population management unit as proposed by Bluett (1995). Thus we placed some emphasis on design of a valid sampling scheme based on watersheds assuming there would be value in ability to compare populations among watersheds, and detect changes within watersheds over years.

Adverse weather conditions and limited helicopter availability precluded obtaining the measures of precision we originally planned, but we evaluated sign detection (see Job 1.1) and obtained useful measures of variance between watersheds and years which enabled us to accomplish the objective of this job.

The discussion and recommendations that follow are based on the findings described previously and a review of pertinent literature. We paid special attention to strategies and sampling designs employed by biologists in other Midwestern states to monitor their beaver populations.

## DISCUSSION AND RECOMMENDATIONS

### Midwestern State Beaver Surveys

Longley and Moyle (1963) described pioneering attempts to census beavers in Minnesota. In 1941, townships ($n$ = 64) were used as the sampling unit to census about 7% of the optimum beaver range in the state; 2 of these townships were censused using aircraft. Although ground checks revealed inaccuracies in the aerial counts, the efficiency of aerial counts was apparent, and after 1946 all beaver censuses were made from aircraft. After 1957, stream and ditch systems became the sampling unit and predetermined routes in certain watersheds were flown to derive a count of active colonies per 160 km (100 mi) of stream. Counts along waterways ranged from 9-155 colonies/100 mi stream; the average of 13 routes was 35.6/100 mi. Excluding outliers, a median of 26 active colonies/100 mi (1/6.2 km or 0.16/km) was considered representative. In this northern portion of the midwest, lodges/food caches were a visible and reliable measure of colony presence. However, this sampling technique did not provide a measure of variance that could predict the standard error of a population estimate.

Wisconsin biologists (Kohn and Ashbrenner 1995) described a helicopter survey conducted between 25 October and 15 November (leaf-off to snow cover) in 1992 that produced a population estimate ±21% (reported as 2 SE). Trial surveys were used to determine the number of blocks necessary to obtain population estimates within ± 20%. Active beaver colonies were located in randomly selected 4-6 $mi^2$ blocks. A survey of 35 blocks (174 $mi^2$) in 1990 produced an estimate of ±32%. The 1992 survey used 88 random blocks (475 $mi^2$) to achieve the desired precision. They used Payne's (1981) estimate of 81% detection and an average colony size of 5.5 to develop population estimates from the number of active colonies counted in the blocks.

A helicopter survey technique for beaver in Ohio detected a ±20% population change (Dyer 1999). Topographic maps of eastern Ohio were stratified by potential to support beaver. Twenty-four quadrangles were randomly drawn; 10 in the high stratum, 10 in the moderate, and 4 in the low. Two in the low stratum were later dropped because of development-associated habitat loss. A 5-minute sample area (26.4 $mi^2$) in each quadrangle was searched for both active and inactive beaver food caches and colonies. Loran C and GPS were used to establish locations of sample areas, transect, and sign; a moving map display with plotter was used to ensure plot coverage and colony locations. In 1999, the survey detected an average of 9.05 active colonies/plot (2-10.2) yielding an average density of 0.34/$mi^2$. They used an expansion factor of 5 beaver/colony to extend statewide colony estimates to a population estimate.

**Illinois Aerial Survey Results**

Using the sampling design, criteria, and survey techniques described in Job 1.1, we surveyed 8 southern Illinois watersheds November 2000-March 2001 (Table 1). We recorded number of sign in the categories of cache/lodge, dam, and "other" in each sample block according to habitat class, and estimated density based on the area of that habitat in the sample unit (Table 4). The density estimated multiplied by the area (km of stream or ha of other habitats) of habitat in the entire watershed yielded a colony estimate for each watershed (Table 5) excluding lakes >100 ha.

Table 4. Number and density of beaver sign (cache/lodge, dam, other) detected during a helicopter aerial survey of 8 watersheds in southern Illinois, November 2000-March 2001. Blank spaces indicate no sign observed.

| Watershed sign | Streams | | Lacustrine <10 ha | | Lacustrine 10-100 ha | | Palustrine | |
|---|---|---|---|---|---|---|---|---|
| | Number | Density[a] | Number | Density | Number | Density | Number | Density |
| Bay Creek | | | | | | | | |
| Cache/lodge | 1 | 0.033 | | | | | | |
| Dam | 2 | 0.066 | | | | | | |
| Other | 12 | 0.396 | | | | | | |
| Total | 15 | 0.495 | | | | | | |
| Big Muddy | | | | | | | | |
| Cache/lodge | 1 | 0.041 | 11 | 0.094 | 9 | 0.077 | | |
| Dam | 3 | 0.124 | 0 | 0.000 | 1 | 0.009 | | |
| Other | 6 | 0.249 | 9 | 0.074 | 7 | 0.060 | | |
| Total | 10 | 0.414 | 20 | 0.168 | 17 | 0.146 | | |
| Cache | | | | | | | | |
| Cache/lodge | 3 | 0.113 | | | | | 0 | 0.000 |
| Dam | 4 | 0.150 | | | | | 0 | 0.000 |
| Other | 9 | 0.338 | | | | | 1 | 0.013 |
| Total | 16 | 0.601 | | | | | 1 | 0.013 |
| Embarras | | | | | | | | |
| Cache/lodge | 2 | 0.060 | 4 | 0.648 | 1 | 0.052 | | |
| Dam | 3 | 0.090 | 0 | 0.000 | 0 | 0.000 | | |
| Other | 7 | 0.210 | 3 | 0.020 | 0 | 0.000 | | |
| Total | 12 | 0.360 | 7 | 0.668 | 1 | 0.052 | | |
| Kaskaskia | | | | | | | | |
| Cache/lodge | 1 | 0.025 | 0 | 0.000 | 1 | 0.024 | | |
| Dam | 0 | 0.000 | 0 | 0.000 | 0 | 0.000 | | |
| Other | 4 | 0.098 | 2 | 0.161 | 0 | 0.000 | | |
| Total | 5 | 0.123 | 2 | 0.161 | 1 | 0.024 | | |

Table 4. Continued.

| Watershed sign | Streams | | Lacustrine <10 ha | | Lacustrine 10-100 ha | | Palustrine | |
|---|---|---|---|---|---|---|---|---|
| | Number | Density[a] | Number | Density | Number | Density | Number | Density |
| Little Wabash | | | | | | | | |
| Cache/lodge | 1 | 0.027 | | | 0 | 0.000 | | |
| Dam | 0 | 0.000 | | | 0 | 0.000 | | |
| Other | 3 | 0.082 | | | 2 | 0.084 | | |
| Total | 4 | 0.109 | | | 2 | 0.084 | | |
| Saline | | | | | | | | |
| Cache/lodge | 3 | 0.084 | | | 0 | 0.000 | | |
| Dam | 1 | 0.028 | | | 0 | 0.000 | | |
| Other | 10 | 0.279 | | | 1 | 0.094 | | |
| Total | 14 | 0.391 | | | 1 | 0.094 | | |
| Vermilion | | | | | | | | |
| Cache/lodge | 6 | 0.154 | 1 | 0.249 | | | | |
| Dam | 9 | 0.231 | 0 | 0.000 | | | | |
| Other | 6 | 0.154 | 0 | 0.000 | | | | |
| Total | 21 | 0.539 | 1 | 0.249 | | | | |

[a] Density of streams is number/km, density of other habitats is number/ha.

Table 5. Beaver colony density estimates for the Big Muddy Watershed derived from observed beaver sign during 3 replicate aerial surveys, March 2000, March 2001, and December 2001.

| Replication | | Streams (Colonies/km) | | Lacustrine (Colonies/ha) | |
|---|---|---|---|---|---|
| | | All Sign | Cuttings | <10 ha | 10-100 ha |
| 1 | | 0.373 | 0.249 | 0.145 | 0.069 |
| 2 | | 0.414 | 0.249 | 0.168 | 0.146 |
| 3 | | 0.580 | 0.290 | 0.101 | 0.120 |
| | Mean = | 0.456 | 0.263 | 0.138 | 0.112 |
| | SD = | 0.089 | 0.019 | 0.034 | 0.039 |

We did 3 survey replicates of the Big Muddy Watershed to estimate sampling error to assess the aerial survey design. Sign observed in streams (colonies/km) was less variable over the 3 replications than was sign in lacustrine habitats (Table 5). Although cuttings was the least variable category of sign, we believe that variability of all sign observed in stream habitats offers the best estimate of survey precision.

We recognize that beaver sign observed in sample blocks are both temporally and spatially autocorrelated. Therefore, a post-hoc time series analysis that accounts for autocorrelation is the most appropriate statistical approach. However, as a preliminary assessment appropriate for adaptive management, we believe it is useful to predict precision of our estimate of number of colonies using the standard error of the replicate mean. Further, because there is no reason to expect that variability would differ among watersheds, we believe data from our replicate surveys of the Big Muddy Watershed can be extended to estimate the standard error of the entire survey. Given these assumptions, the survey was capable of detecting a population change of $\pm$10.3% at the 95% confidence level.

**Recommendations**

- Aerial survey should be adopted as the standard tool to detect change in regional beaver populations. Population Management Units proposed by Bluett (1995) offer a useful and ecologically valid framework for monitoring and change detection.
- The sampling design for an aerial survey of beaver appeared to have excellent precision (2 SE = 0.103) that met the target goal of ability to detect a 20% population change. However, the estimate of precision is based on a single watershed and the assumption that the variance measured from repetitive sampling in that watershed is representative of all should be tested.
- Once validated with additional testing, the entire survey should be conducted once every 3 years. More frequent surveys should be conducted of any PMU where biological reasoning or evidence suggests change $\geq$20% may have occurred or be underway.

- The aerial survey model proposed does not adequately sample lakes >100 ha. Pilot studies suggest it should be possible to improve the estimate of colonies/km shoreline of large lakes by characterizing suitability of shoreline habitat. This should be done so colonies in this habitat can be estimated with precision and included in colony estimates for each PMU. In the interim, data from 3 southern Illinois lakes provide crude estimates of upper (0.45/km) and lower (0.21/km) numbers of colonies. Alternatively, the mean (0.34) ± 0.14 (2 SE) of the number of colonies/km shoreline can be used on an interim basis to estimate colony abundance for all lakes >100 ha.
- The proposed survey is not designed to estimate the number of beaver colonies associated with large river habitats. Independent sampling schemes should be developed to estimate number of colonies associated with the Mississippi, Ohio, and Wabash rivers in southern Illinois, and other large rivers if the survey is extended statewide.

## JOB 1.3. REGIONAL RELATIVE ABUNDANCE

Objective: To estimate and compare regional differences in relative abundance.

### INTRODUCTION

Our goal for this job was to use findings from Jobs 1.1 and 1.2 to estimate the number of colonies inhabiting stream and lacustrine (<100 ha in size) habitats in 8 southern Illinois watersheds that correspond to Bluett's (1995) PMUs. We applied results of surveys of 3 lakes >100 ha in the Big Muddy Watershed to develop more complete population estimates (that included lakes >100 ha) in the Big Muddy, Cache, and Saline watersheds (PMUs 15, 16, and 18, respectively).

We expected density estimates to differ between watersheds based on previously constructed models of these watersheds designed to evaluate potential otter habitat (Farrand 1997, Woolf 1997) and it was not our intent to characterize magnitude or cause of these expected differences. However, we compared density estimates of beaver colonies/km stream derived from our aerial survey to otter model predictions to assess agreement and reliability of our estimates of regional differences in relative abundance.

## RESULTS AND DISCUSSION

### Regional Relative Abundance

The estimated number of beaver colonies in a watershed is a function of quantity and suitability (quality) of available habitat. Greatest variability was in stream habitats and that is reflected in the stream density estimates based on observed sign (Tables 4 and 6). The Cache, Vermilion, and Bay Creek watersheds had the highest estimated stream densities, but 2 other watersheds (Embarras and Big Muddy) had greater numbers of estimated colonies inhabiting streams than either Cache or Bay Creek; and Bay Creek had the lowest estimated number of colonies among the 8 watersheds surveyed (Table 6).

Stream habitats accounted for ~84% of the number of estimated colonies in all watersheds; only the Big Muddy had other habitats accounting for a greater proportion (~35%) of total estimated colonies. Therefore, we recommend that colonies/km stream be adopted as the most reliable measure of regional relative abundance

### Contribution of Lakes >100 ha to Regional Beaver Abundance

Large lakes (which we defined as >100 ha) were excluded from the watershed-based sampling scheme devised to estimate and compare regional abundance. First, the distribution of large lakes was restricted (none present in many watersheds) and not amenable to the aerial sampling scheme. For example, there were 9 such lakes in the Big Muddy Watershed, 2 in the Cache, and 1 in the Saline (Table 7) and our sample blocks only included small portions of 2 lakes in the Big Muddy and 1 in the Cache. Only 1 other large lake (in the Little Wabash) was included in the randomly selected aerial survey blocks. Further, our preliminary watercraft and aerial surveys (see Job 1.1) revealed greater than 2-fold differences in number of food caches/lodges/km shoreline among lakes (Table 2) and our observations revealed clumped

Table 6. Estimated number of beaver colonies in 8 southern Illinois watersheds calculated from density estimates derived from a helicopter aerial survey conducted 24 November 2000-19 March 2001.

| Watershed | Streams | | Lacustrine <10 ha | | Lacustrine 10-100 ha | | Palustrine-emergent | |
|---|---|---|---|---|---|---|---|---|
| | Number/km | Number | Number/ha | Number | Number/ha | Number | Number/ha | Number |
| Bay Creek | 0.495 | 359 | | | | | | |
| Big Muddy | 0.414 | 1,095 | 0.168 | 115 | 0.146 | 479 | | |
| Cache | 0.601 | 652 | | | | | 0.013 | 17 |
| Embarras | 0.360 | 1,223 | 0.668 | 121 | 0.092 | 32 | | |
| Kaskaskia | 0.123 | 616 | 0.161 | 105 | 0.024 | 33 | | |
| Little Wabash | 0.109 | 388 | | | 0.084 | 61 | | |
| Saline | 0.391 | 411 | | | 0.094 | 90 | | |
| Vermilion | 0.539 | 592 | | | | | | |
| Total Colonies | | 5,336 | | 341 | | 695 | | 17 |

Table 7. Lakes >100 ha in 3 southern Illinois watersheds and their estimated number of beaver colonies based on mean (± 2 SE) colonies/km shoreline derived from pilot studies of 3 lakes.

| Watershed | Lake | Area (ha) | Perimeter (km) | | Estimated colonies[a] |
|---|---|---|---|---|---|
| Big Muddy | Campbell | 134 | 10 | | 3.4 |
| | Cedar | 651 | 70 | | 23.8 |
| | Crab Orchard | 2,943 | 160 | | 54.4 |
| | Devil's Kitchen | 283 | 38 | | 12.9 |
| | Kinkaid | 953 | 116 | | 39.4 |
| | Little Grassy | 367 | 40 | | 13.6 |
| | Lyerle | 128 | 7 | | 2.4 |
| | Rend | 8,238 | 271 | | 92.1 |
| | Washington County | 112 | 23 | | 7.8 |
| | | | Watershed total | = | 249.8 ± 34.7 |
| Cache | Horseshoe | 266 | 26 | | 8.8 |
| | Mermet | 167 | 11 | | 3.7 |
| | | | Watershed total | = | 12.5 ± 1.7 |
| Saline | Lake of Egypt | 842 | 99 | = | 33.7 ± 4.7 |

[a] Estimated number of colonies = km shoreline x (0.34); watershed total = mean ± 2 SE (0.139). Both mean and SE derived from Table 2.

distribution of sign based on physical and biotic features of individual lakes. We concluded that each lake would require a complete shoreline search (by air or watercraft) to reliably estimate beaver colonies inhabiting the lake.

Large lakes are important components of the total beaver population in many watersheds. Therefore, we used the mean ±2 SE of the 3 lakes sampled in the Big Muddy Watershed (Table 2) to assess contribution of large lakes to the total estimated number of colonies in 3 watersheds (Table 7). Big Muddy Watershed ranked first overall in estimated number of colonies (1,689; Table 6); the additional 250 ± 35 colonies estimated to be present in large lakes (Table 7) represented 14.8% of that estimate. In contrast, colonies associated with the 2 large lakes in the Cache Watershed represented <2% of the total present in other habitats. The estimated 35 ± 5 colonies in Lake of Egypt represents about 7% of the total beaver population in the Saline Watershed excluding large lakes.

In summary, substantial numbers of beaver colonies are present in large lakes and should be considered in estimating PMU beaver populations. However, in our limited evaluation, they tended to account for <15% of the total number of colonies estimated to be present in other habitats. Also, addition of the estimated number of colonies associated with lakes >100 ha to totals estimated in other habitats would not change the rankings of relative abundance (Table 6). Nevertheless, to obtain the best possible population estimate, we recommend that representative lakes >100 ha be sampled (by watercraft or aerial survey) in each watershed to determine with reliability the number of colonies associated with such lakes in a given watershed. Representative lakes can then be selected for periodic survey to detect any population change.

**Estimate of Population Abundance**

Extending estimates of colony abundance to population estimates requires multiplication by some estimate of average colony size and possibly incorporating a detection factor. In Wisconsin, a population estimate was derived by dividing observed colonies by a 0.81 observation rate and multiplying that number of colonies by 5.5 beaver/colony (Kohn and

Ashbrenner 1995). Ohio did not employ a colony detection correction factor and used 5 beaver/colony to derive a population estimate (Dyer 1999).

We estimate a detection rate for our survey of 0.80. McTaggart (2002) found an average colony size of 5.6 for 28 trapped out colonies in the Embarras and Vermilion watersheds. McTaggart's mean colony size is in the mid- to upper-range of reports from across North America (McTaggart 2002:38). However, complete removal of 8 colonies in the Big Muddy Watershed yielded an average of 3.9 beaver/colony, suggesting differences among Illinois watersheds. Lacking better data, we simply selected 5 beaver/colony to approximate colony size for the 8 watersheds sampled.

The estimated number of colonies inhabiting stream, lacustrine (<100 ha), and palustrine-emergent habitats in the 8 watershed surveyed (Fig. 1) was 6,389 $\pm$ 657 (2 SE) colonies (Table 6). Corrected for a detection factor, the mean colony estimate was 6,389/0.80 = 7,986 $\pm$ 821. This colony estimate multiplied by 5 beaver/colony yielded a conservative mean population estimate of 39,930 (range 35,825-44,035) beaver inhabiting the 8 southern Illinois watersheds surveyed. We consider this estimate conservative because our estimates of colonies inhabiting large lakes in 3 of the 8 watersheds surveyed (Table 7) are not included, nor are estimates of beaver inhabiting the Mississippi, Ohio, and Wabash rivers which border the southern Illinois watersheds we surveyed.

**Comparison of Watershed Rankings Determined by Aerial Survey and Otter Models**

Although not an objective of this project, our findings afforded opportunity to assess validity of previously reported rankings of 7 of the 8 (Vermilion excluded) watersheds based on models to predict habitat suitability for river otter (Woolf 1997). When developing the otter models, we had assumed that similar attributes defined habitat quality for both beavers and otters, and data supported that assumption (Schieler 1995). If this assumption was correct, and our models had validity, we hypothesized that watersheds ranked according to beaver abundance (colonies/km stream) would be similar to rankings from otter models (Woolf 1997). Indeed, this was the case; the top 3 watersheds were similar in all comparisons, albeit rankings did not agree 100%. Further, the Saline Watershed ranked in the middle of all comparisons and the bottom grouping was similar (Table 8). These comparisons support our conclusions concerning both the otter habitat models and the aerial survey for beaver sign; both appear to offer valid tools for science-based management.

**JOB 1.4. ANALYSIS AND REPORT**

Objective: To analyze data from Jobs 1.1-1.3 and prepare reports in a timely manner.

The objective of this job was accomplished by periodic meetings with R. Bluett, IDNR Program Manager, submission of annual performance reports, a thesis by McTaggart (2002) that is appended, and this final report. Data are archived to further support IDNR's goals of science-based management of beaver inhabiting PMUs.

Table 8. Watershed (PMU) rankings (colonies/km stream) derived from the November 2000-March 2001 aerial survey (excluding the Vermilion Watershed) compared to rankings of the watersheds from Woolf (1997).

| Watershed (PMU) | Colonies/km stream | Average Rank Score[a] | HSI >80[b] |
|---|---|---|---|
| Bay Creek (17) | 2 | 1 | 2 |
| Big Muddy (15) | 3 | 2 | 1 |
| Cache (16) | 1 | 3 | 3 |
| Embarras (20) | 5 | 7 | 7 |
| Kaskaskia (14) | 6 | 5 | 5 |
| Little Wabash (19) | 7 | 6 | 6 |
| Saline (18) | 4 | 4 | 4 |

[a] Woolf (1997:144)
[b] Woolf (1997:145)

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ATTACHMENT

McTAGGART 2002