BEAVER POPULATION SIZE ESTIMATION IN MISSISSIPPI

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Abstract: Methods to better quantify beaver (*Castor canadensis*) population size need to be developed to assist in the direct control methods being implemented by Wildlife Services. Many state game and fish departments rely on lodge counts, cache counts, or fur harvest reports to estimate a statewide or regional population of beaver. However, Wildlife Services is concerned with estimating population size on a per site basis to assist in estimating project costs and to minimize the number of non-target captures. Six sites in Mississippi were selected to test various methods of population estimation. Various methods included indexing population size based on the amount of sign and physical site characteristics, and spotlighting beaver to derive estimates based on actual counts, extrapolations, and the Lincoln-Petersen model. All derived estimates were compared to number of beaver captured during total harvest. Number of lodges, bank dens, and beaver dams were not significantly related to total harvest. Number of scent mounds was positively correlated with total harvest; however, number of scent mounds was not significant. Area and perimeter distance of each site was positively correlated with total harvest of beaver. Spotlight counts were conducted from the bank of each site and from a boat and only combined for data analysis. Research indicated that managers and wildlife biologists should use caution and expect differences when spotlighting beaver. A combination of actual numbers of beaver viewed during bank counts and boat counts was significantly correlated to total harvest. Overall, spotlighting beaver for population estimates was determined to be an ineffective technique.

Key Words: beaver, *Castor canadensis*, index, Mississippi, population size, spotlight, wildlife management

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INTRODUCTION

Beaver are considered important animals in the Southeastern United States due to their production of fur and possible economic gains (Moore and Martin 1949; Arner et al. 1966; Anonymous 1967; Hill 1974; Woodward et al. 1976; Arner and DuBose 1978a, 1978b), ecological influence on wetland habitats (Arner et al. 1967a, 1967b; Reese and Hair 1976; Wesley 1978), and potential economic impacts to agriculture, timber, and roadways (Arner 1964, Hill 1976, Hill et al. 1977, Wesley 1978). Detrimental effects of beaver to these systems include: flooding and herbivory of desirable plant species, flooding and inundation of right-of-ways and roads, and burrowing and digging under roadways. Federal and state trapping programs have been implemented to control populations of these animals where damage to property and economic losses occur (Miller 1987). Wildlife Services, a program administered under the U. S. Department of Agriculture/Animal Plant Health Inspection Service, offers beaver control assistance in all 82 counties of Mississippi. This assistance provides direct control to solve beaver problems associated mainly with roadways, but also protects agricultural and timber resources on private property, and reduces human health and safety concerns.

Determination of population size and assessment of property damage is usually required to evaluate needs for beaver population management. Beaver population size is generally estimated from indices that assume a specific number of animals present for each detected sign (e.g., lodge, castor mound, food cache) (Bradt 1938). Aerial surveys of caches and lodges are often used to estimate population size of beaver colonies (Hay 1958, Dickinson 1971, Payne 1981). Bergerud and Miller (1977) and Peterson and Payne (1986) converted cache counts to population estimates by multiplying mean estimated colony size by number of caches detected. This method also could be applied to lodge counts; however, problems exist with an actual quantifiable number that can be assigned to colony size. Significant correlations were found between cache size and number of beaver per colony in Michigan (Kafcus 1987) and in Montana (Easter-Pilcher 1990).

Other indices have been used to derive beaver population estimates. Significant differences in scent mounding activity were found in Ohio with differences occurring among sites and over years (Svendsen 1980). Wagner and Nolte (in press) suggest no relationship is present between colony size and dam densities in Washington. Due to beaver living in bank dens and not building caches, Broschart et al. (1989) was not able to relate beaver created impoundments to colony density in Minnesota. Use of bank dens appears to decrease the need for lodges in many habitats (D. Arner, Mississippi State University, personal communication). Hill (1982) stated that to predict an accurate population size of beaver based on an index, techniques should be effective and rapid. To date, methods for developing indices related to population levels of beaver in the southern United States have not been investigated adequately.

Spotlight surveys of beaver have been used, but no information on animal detectability or survey accuracy exists. Hodgdon and Larson (1973) conducted spotlight counts of beaver to document social behavior, but did not attempt to estimate population size. Marking beaver for resighting purposes can increase data sets that were not possible with traditional tagging methods. Marked beaver populations can be estimated using the Lincoln-Petersen model (Seber 1982). Total trapline captures can be used to index abundance of furbearers (Wood and Odum 1964) and as a population estimation method (Smith et al. 1984). Hay (1958) cautioned that live-trapping is slow and unreliable for a practical census method. However, kill-trapping was found to be more accurate and expedient than live-trapping and essential for determining average number of animals/colony during winter (Hay 1958).

Accurate estimation of the number of beaver present would be an asset to natural resource managers to assess potential damages and problems associated with high beaver populations. Wildlife agencies performing beaver removal could improve cost-estimating procedures and shorten trapping periods. Shortened trapping periods could in-turn reduce potential non-target captures. Therefore, population estimations based on indices or spotlight surveys should be investigated in beaver populations of the southeastern United States.

STUDY AREAS AND METHODS

Research was conducted on 6 study sites adjacent to the Tennessee-Tombigbee Waterway located in Lowndes County, Mississippi in 2000 and 2001. Sites were initially selected based on overall age, vegetative characteristics, size, and most importantly presence of an established beaver colony. All sites were classified as oxbows formed by the changing course of the Tombigbee River. Names for each study site were assigned based on location; and starting with the northern most, were: Dwayne Hayes, Lock and Dam, Owens 82, White Lake, Second Lake, and Far South.

Indices and Site Characteristics

Ground counts of lodges, caches, bank dens, scent mounds, and beaver dams at each study site were conducted using complete coverage surveys. Complete coverage surveys were assumed to detect all beaver sign present and were conducted in late January and early February, 2001. All beaver sign was categorized according to activity status. Lodges were assumed to be active if fresh mud and/or fresh vegetation were present. Bank dens were assessed for activity based on bottom firmness, presence of muddy water in runs and entrances, and/or presence of fresh vegetation around the entrance. Banks dens which had collapsed or that were not maintained were considered inactive and were not included in analyses. Bank dens covered with wooden debris were considered bank dens, not lodges. Scent mounds and beaver dams were tallied by walking and visually inspecting the entire perimeter of the impoundment. Scent mounds were considered active if fresh mud or debris was recently added to the mound. The smell of castor also was used as an indicator of beaver activity. Beaver dam activity was assessed based on fresh sign and maintenance.

Study site area and perimeter distance were measured on each site to aid in planning of spotlight surveys and for use in correlating indices to predict total number of beaver harvested. Area and perimeter distance were measured in late November and December, 2000. Due to low water levels, study site area included the current water level and riparian shoreline to adjust for water fluctuations. Data points referencing each study site were collected in an area function using a Geographic Positioning System. Each study site was mapped using Trimble Pathfinder® Office (Trimble Pathfinder Office Version 2.11. 1998. Trimble Navigation Limited. Sunnyvale, CA) and converted for use in Arc View 3.2 (Arc View GIS Version 3.2. 2000. Environment Systems Research Institute, Inc. Redlands, CA).

Spotlight Surveys

Two different spotlight surveys were used to test 3 methods of estimating beaver populations. Spotlight surveys included bank counts and boat counts. Bank counts were conducted on foot around the perimeter of each study site, and boat counts included use of a boat to spotlight beaver approximately from the middle of each study site. Spotlight surveys were conducted similar to variable circular plot methods described by Reynolds et al. (1980). Bank counts and boat counts were conducted on separate nights due to differences in methodology, and only combined during analyses to increase chances of developing a technique that accurately estimated population size. Spotlight surveys were grouped into 4 series (5 bank and 3 boat in each series) separated by trapping periods as follows: the first series before the trapping and marking period, the second series after trapping and marking but before the recapture period, the third series after the recapture period but before the total harvest period, and the fourth series following the total harvest period (Table 1).

Table 1. Research activities conducted on six study sites during 2000 and 2001.

Activity	Months, Year
Mapping of Study Sites	November – December, 2000
1st Series of Spotlight Surveys	December, 2000 – January, 2001
Complete Coverage Surveys for Indexing	January – February, 2001
1st Trapping and Tagging Period	January – March, 2001
2nd Series of Spotlight Surveys	February – March, 2001
2nd Trapping and Tagging Period (Recapture)	March – April, 2001
3rd Series of Spotlight Surveys	March- April, 2001
Total Harvest Period	April – July, 2001
4th Series of Spotlight Surveys	June – July, 2001

Surface water of study sites was illuminated with a spotlight to detect presence of beaver. We assumed probability of seeing a beaver was equal to 1.0. When a beaver was detected, a rangefinder was used to calculate distance of the observed beaver from the observer. Additionally, viewing distance for each stop was calculated by estimating the greatest distance a beaver could be seen with a rangefinder. Total area viewed per bank count was determined by finding the area of a semicircle using the viewing distance as the radius for each stop (Reynolds et al. 1980). Total area viewed per boat count was calculated similarly. However, the area of a circle was used as the sampling area, because beaver could be detected in a circular pattern (Reynolds et al. 1980). Sampled area form bank counts and boat counts were calculated as follows, respectively:

a = (©)(r^2)/2,

a = (©)(r^2),

where a is the area sampled, and r is the viewing distance.

Three methods of analyzing the spotlighting data were: actual counts, extrapolations of number of beaver sighted, and the Lincoln-Petersen model. The simplest method was spotlighting beaver and using the exact number seen as the population size estimate. This estimate involves no extrapolation based on area sampled or computation based on marked and unmarked animals. Total number of beaver spotlighted was summed each night per study site. The mean of 5 bank counts per study site (1 series) and the mean of 3 boat counts per study site (1 series) were compared to total number of beaver harvested per study site. Additionally, the mean number of beaver observed during bank counts and boat counts were pooled and compared to total number of beaver harvested.

Extrapolations of spotlight data were computed to determine 100% coverage of each study site. Extrapolation estimates were calculated by converting number of beaver seen per area viewed to number of beaver per study site. This computation was performed to adjust for the amount of area viewed. If less than the total area was viewed, the estimate was increased to equal 100% coverage. If spotlight counts overlapped and overestimated the population, the extrapolation would decrease the number of beaver seen to equal 100% coverage. The following equation was used to calculate number of beaver observed within a 100% coverage survey (Seber 1982):

$$\hat{N} = \frac{1}{(\sum a/A)}(x_i),$$

where $\hat{N}$ is the estimated population size, a is the area sampled, A is total area of the study site, and x_i is number of beaver counted per study site i. Extrapolations were computed for bank counts, boat counts, and pooled data from the 2 techniques and compared to total harvest.

The Lincoln-Petersen model required capture of beaver for marking so resighting data could be collected. Beaver were live-captured in snares according to McKinstry and Anderson (1998). Each beaver was marked subcutaneously in the dorsal neck region with a PIT tag (Supplier: AVID Microchip Identification Systems. Folsom, LA). Individually numbered, modified ear tags were then placed in each ear (Miller 1964). Modified ear tags were numbered, 2.2 cm, vinyl laminated discs (Supplier: Floy Tag Company. Seattle, WA) attached with 1005-4 monel small animal ear tags (Supplier: National Band and Tag Company. Newport, KY) (Swafford 2002). Beaver were released at the site of capture after full recovery from immobilization (Swafford 2002).

A resighting period was conducted for 5 additional bank counts and 3 additional boat counts after marking to establish a ratio of marked and unmarked beaver. A recapture period was then conducted until 50% of the marked animals were recaptured or 5 days of trapping had expired to increase number of marked animals in the population. An additional series of spotlight surveys were performed after the recapture period. Ratios of marked and unmarked beaver from the second and third series of spotlight counts were placed in the Lincoln-Petersen model to estimate population size based on the following formula (Lancia et al. 1996):

$$\hat{N} = n_1 n_2 / m_2,$$

where $\hat{N}$ is the estimated population size, n_1 is total number of beaver marked and released, n_2 is total number of beaver sighted during a spotlight count, and m_2 is number of marked beaver that were resighted during a spotlight count. The second and third series of bank counts and the second and third series of boat counts were combined to form a combined bank count and combined boat count, respectively. These series were combined to increase the sample size used to compute the mean of the Lincoln-Petersen estimator.

Total harvest of beaver was conducted after the third series of spotlight counts to determine number of beaver present in each study site. Lethal trapping was conducted using body-gripping traps (jaw spread 25.4 X 25.4 cm), double long-spring foothold traps (jaw spread 18.4 cm), and cable snares to remove beaver. Night shooting was performed from banks and/or a boat when beaver had become trap shy and trapping success declined. Newby (1955) recommended trapping until no animals were caught for at least 3 days or evidence of beaver activity was not apparent. Total number of beaver harvested served as actual beaver population or colony size. Spotlight counts were conducted following the total harvest period to confirm extirpation of beaver from each study site.

Statistical Analysis

All samples collected regarding indices and spotlighting were assumed to be random. Data not meeting the normality assumption were transformed. Actual estimates derived from the first series of boat counts were squared to achieve normality, and the reciprocal was used to achieve normality for all estimates derived using the Lincoln-Petersen model (Dowdy and Weardon 1991). Correlation analyses between population estimates and number of beaver harvested were performed using PROC CORR and Pearson Correlation Coefficients (SAS Institute 2000). All hypotheses were tested at $\alpha = 0.05$.

RESULTS

Indices and Site Characteristics

Total number of beaver harvested quantified colony size and was compared to the indexing and spotlight survey data (Table 2). Four of the 6 study sites contained at least one beaver lodge which was completely surrounded by water (Table 2). White Lake and Far South did not contain an active beaver lodge. Food caches were not observed on any study sites (Table 2). Bank dens, scent mounds, and beaver dams were present on all study sites (Table 2). Lodges ($P = 0.95$), bank dens ($P = 0.17$), and beaver dams ($P = 0.66$) did not relate significantly to total number of beaver harvested. Number of scent mounds ($r = 0.80$, $P = 0.056$) was correlated positively with total number of beaver harvested; however, number of scent mounds was not significant at $\alpha < 0.05$. Arc View 3.2 yielded an area measurement (ha) and perimeter distance (m) which were used as additional indices (Table 2). Study site area and perimeter distance were correlated positively with total harvest of beaver ($r = 0.89$, $P = 0.02$) and ($r = 0.82$, $P = 0.04$), respectively.

Table 2. Beaver sign, area (ha), perimeter distance (m), and # beaver harvested on 6 study sites located in Lowndes County, Mississippi, 2000 - 2001.*

Study Site	Lodges	Bank Dens	Scent Mounds	Beaver Dams	Area (ha)	Perimeter Distance (m)	# Beaver Harvested
Dwayne Hayes	1	17	14	3	8.90	3,211	17
Lock & Dam	2	5	9	5	5.30	1,936	4
Owens 82	1	2	8	3	5.14	1,581	9
White Lake	0	7	7	3	4.53	1,212	9
Second Lake	1	2	9	1	4.01	1,437	5
Far South	0	9	6	1	1.21	647	2

*Note: Caches were not present on any study sites.

Spotlight Surveys

The first 3 series of actual spotlight count numbers were compared to total number of beaver harvested. First series of bank counts ($P = 0.51$), first series of boat counts ($P = 0.47$), second series of bank counts ($P = 0.13$), second series of boat counts (P = 0.80), third series of bank counts (P = 0.10), and third series of boat counts (P = 0.11) were not significantly correlated to total number of beaver harvested. After pooling the actual number of beaver spotlighted from the third series of bank counts with the third series of boat counts, a positive correlation was detected between the combination and total number of beaver harvested (r = 0.84, P = 0.04).

Extrapolations of population size for 100% coverage from the third series of bank counts and boat counts were compared with total number of beaver harvested. Third series of bank counts was not significantly correlated to total number of beaver harvested (P = 0.15), and third series of boat counts was not significantly correlated to total number of beaver harvested (P = 0.55). Combining the third series of banks counts with the third series of boat counts was attempted to develop an alternative technique to estimate beaver population size. However, a significant correlation was not detected (P = 0.09).

Lincoln-Petersen estimates were determined from second and third series of bank counts and boat counts. Second series of bank counts (P = 0.41), second series of boat counts (P = 0.55), third series of bank counts (P = 0.32), and third series of boat counts (P = 0.39) were not correlated significantly to total number of beaver harvested. Combinations of bank count estimates from the Lincoln-Petersen model (P = 0.36) and boat counts estimates from the Lincoln-Petersen model (P = 0.46) also were not correlated significantly to total number of beaver harvested.

DISCUSSION

Indices and Site Characteristics

Four of the tested indices were ineffective in predicting total number of beaver harvested from study sites. Lodges and beaver dams, often the most visible beaver signs, were not useful for population estimation. Hay (1958) had similar findings and reported that even though beaver lodges were the most universally used index for beaver population estimation, it is not synonymous with colony size. Hay (1958) also found presence of dams to be unreliable because of their dependence on topography. Wagner and Nolte (in print) also found beaver dam densities were not good indicators of population size in Washington.

Research in Michigan (Kafcus 1987) and Montana (Easter-Pilcher 1990) found significant correlations between cache size and colony size. This contradicts our findings in Mississippi, because we did not observe any caches regardless of beaver colony density or study site size. We believe that presence of caches is related to weather conditions and food supplies, and that beaver in the southeastern United States generally do not cache food supplies. Therefore, cache surveys cannot be used to index beaver population size in Mississippi.

Bank dens also proved unusable to estimate population size. Broschart et al. (1989) developed a technique to estimate beaver populations based on beaver created impoundments and reported difficulty in estimating beaver population size if bank denning was common. Broschart et al. (1989) stated his technique will not work where beaver live in bank dens or do not develop food caches. Obtaining an accurate count of banks dens was possible; however, there was no significant correlation to total number of beaver harvested.

Positive correlations were found between 3 indices and total number of beaver harvested. Even though not significant at P = 0.056, a relationship was present between scent mounds and total number of beaver harvested at each study site. Number of scent mounds/colony varied greatly in Colorado (Hay 1958), but this parameter might be useful to estimate population size of beaver in Mississippi. Positive relationships between study site area and perimeter distance to total number of beaver harvested proved to be statistically and logically important. These relationships yielded strong positive correlations and might aid in quantifying beaver numbers before harvest. As area or perimeter increases, unexploited beaver population estimations should increase. Findings of area and perimeter distance were similar to methods used by damage management specialists to predict an expected number of beaver before harvest. Logically, the speculation of the greater the area, the larger the beaver population was proven to be true.

It is important to note that the above indices were related to unexploited beaver populations. Trapping efforts had not been used on the 6 study sites in the previous 2 years to allow beaver populations to become established.

Spotlight Surveys

Data indicated that pooling actual bank count and actual boat count estimates proved useful when correlating numbers of beaver viewed with total number of beaver harvested. However, pooling extrapolation estimates from bank counts and boat counts was more closely significantly related to number of beaver harvested than when extrapolation estimates were analyzed separately. Increase in significance is likely due to lessened variation, because the 2 techniques increased sample size and better measured the population. However, Lincoln-Petersen model estimates were not enhanced by pooling the 2 spotlighting techniques. Further investigation into merging the 2 techniques (bank counts and boat counts) might improve the accuracy and lower the variance when estimating beaver population size through spotlighting.

Spotlighting beaver after the total harvest period helped quantify the accuracy of estimates derived from intensive harvest to an actual population. Findings of the total harvest period yielding more accurate and expedient estimates than live-trapping are similar to Hay (1958). Hay (1958) used trapping data to determine average-winter colony densities. However, techniques proved useful in determining spring-summer colony densities in Mississippi. The range of 2 to 17 beaver per colony is similar to densities reported by Jones and Leopold (2001).

MANAGEMENT IMPLICATIONS

Even though lodges, bank dens, caches, and beaver dams proved to be statistically insignificant in predicting total number of beaver harvested, usefulness for indicating beaver activity is apparent. Managers and wildlife biologists may not be able to predict population size or total number of beaver harvested from these indices, but they can still assess potential problems and benefits associated with beaver activities. Accurately estimating beaver populations based on area or perimeter distance can improve population reduction projects by assisting with more accurate cost-estimating and a reduction in non-target captures, and thus improve wildlife management. This technique for estimating beaver populations is used by many damage management specialists and is now proven to be effective for population estimation of beaver in riverine habitats.

Research also indicated spotlight surveys of beaver may be ineffective for population estimation in Mississippi. Increased replication per study site and further research in different habitat types might improve accuracy of spotlight surveys. Managers and wildlife biologists should use spotlight counts for monitoring beaver activity, but should expect differences when spotlighting beaver for population estimation. Overall, spotlighting beaver for population estimates was determined to be an ineffective technique.

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