

**WILDLIFE MANAGEMENT: BASELINE DATA; BEAVER REINTRODUCTION
SURVEY AND MANAGEMENT RECOMMENDATIONS**

Final Report

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Prince William Forest Park

and Manassas National Battlefield Park

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ABSTRACT

Population size and density estimates were made from data gathered on beavers at Manassas National Battlefield Park and Prince William Forest Park; both located in Prince William County, Virginia.

Teams consisting of two researchers searched along the major streams and tributaries of each park for the following beaver signs: live or dead beavers, tracks, drag trails, dams, lodges, bank burrows, limb (sapling) caches, and tree cuttings. Manassas National Battlefield Park was surveyed in January, March and October 1997. Prince William Forest Park was surveyed during January-August 1997 and again in May 1998. Estimates of beaver population size were based upon the number of active lodges or bank burrows found in each park using the figures taken from the literature of 4.0 beavers per active lodge and 2.4 beavers per active bank burrow.

The population size at Manassas National Battlefield Park was based on data gathered in October 1997 (12 active lodges, five active bank burrows), giving an estimate of 70 beavers. The highest concentrations were in Bull Run Creek north of Farm Road, Young's Branch between Bull Run Creek and U.S. Rt. 29, Young's Branch at Prince William County Rt. 622, and a tributary of Young's Branch at the two ponds which feed it. The greatest concentration of beaver signs was along Young's Branch at Rt. 622. Since Manassas National Battlefield Park consists mostly of open fields and beaver habitat is restricted to gallery forest

along the main waterways, beaver are more crowded and their density much higher in suitable areas than at the the larger Prince William Forest Park. Estimated density of beavers at Manassas National Battlefield Park was 0.14 beavers per acre (0.034 per hectare) for the entire park, but as high as 0.62 per acre (1.54 per hectare) of gallery forest.

The 1997-1998 population size estimate for Prince William Forest Park based on 15 active lodges and nine active bank burrows was 81.6 beavers, an overall density for the park of 0.011 beavers per acre (0.0272 per hectare). The highest concentration areas of beaver sign were North Fork of Quantico Creek (NFQC) near the Pyrite Mine Reclamation Site; NFQC northwest of the Farms to Forest (extension) Trail; South Fork of Quantico Creek (SFQC) east of High Meadows Trail; Mary Bird Branch at Scenic Drive; and the western tributary to SFQC at the confluence of the two intermittent streams which form it. The greatest of these was along the western tributary of SFQC where three large dams (which formed a large three-tiered pond), four active lodges, three drag trails, three fresh limb/sapling caches, and many new tree cuttings were present. Three of the five high concentration areas appeared essentially unchanged in May 1998, but beaver activity had decreased since 1997 where Mary Bird Branch crosses Scenic Drive and at the three dam site on the western tributary of SFQC. At the last site, the largest of the three dams had been broken, apparently by humans, and the three-tiered pond had drained.

Reproductive status of female beavers at Prince William Forest Park was assessed in 1998. Seven females were trapped, sacrificed, and dissected between January and May. Those reproductively active weighed over 39 pounds (17.7 kg), and were trapped before 1 March. Mean litter size based on counts of corpora lutea was 4.80 young (3-7); however, litter size based on the number of embryos present was only 2.75 (1-3), comparable to most others reported in the literature. Using a mature female to male ratio of 1:1 and an estimated 2:1 ratio of immature females to mature females, the 1998 total population reproductive rate based on embryo counts was 37.4 young.

The seven dissected females were also examined for health status and parasite loads. Five of the seven females had prime pelts, one an average pelt, and one a low average pelt. Subcutaneous fat deposits and those at the base of the tail were moderate to high in all females. Four contained moderate mesenteric deposits, while three had low to no mesenteric fat present. No abnormalities were found in the lungs, heart, liver or kidneys. Six females had suffered wounds to either the tail or body (one), possibly from male courtship. The females harbored two of the most common beaver helminths: the stomach nematode, *Travassosius americanus* (100% incidence) and the cecal trematode, *Stichorchis subtriquetrus* (85.7% incidence). Compared to other reported studies, these worm burdens were moderate to average. Health of the Prince William Forest Park beaver population in 1998 was average to above average.

INTRODUCTION

In the precolumbian period, the American beaver (*Castor canadensis*) inhabited most of North America, except the areas of tundra and those desert regions of extreme dryness and heat (Hill, 1982). Several subspecies were found within this range (Jenkins and Busher, 1979; Hall, 1981), of which *Castor canadensis canadensis* Kuhl, 1820 occurred over most of Virginia. With the development of the fur trade in the eighteenth and nineteenth centuries, beavers became the most widely and intensively sought natural resource in North America. So much so that eastern populations were severely decimated, and almost extinct in the mid-Atlantic region by 1900. The beaver was extirpated in Virginia by 1911 (Hill, 1976), and those in northern Virginia disappeared during this period (Handley, 1991). In the early 1950s Virginia's Department of Game and Inland Fisheries reintroduced *Castor canadensis canadensis* into northern Virginia, and that subspecies exists here today. Since its reintroduction it has invaded new waterways and increased in numbers to the point of often being a destructive nuisance (Davis, 1992).

On 16 September 1950 two beaver were brought to Prince William Forest Park by Philip R. Collins of the Virginia Commission of Game and Inland Fisheries (VCGIF) and released into the South Branch of Quantico Creek in an attempt to reintroduce the rodent to the park. A second pair of beaver was released into Mary Bird Branch on 8 February 1952 by Robert E. Merritt and

L. G. Kesterloo of the VCGIF. From these humble beginnings the population has grown considerably.

Until 1959 no population surveys were conducted to determine the size of the resident beaver population. Between 1959 and 1968 no population estimates were made, but active dams were counted on the North and South forks of Quantico Creek. Population estimates were made for the years 1968 (39 beavers) to 1974 (approximately 58 beavers), but once again no population estimates were made for the years 1975-1977. From 1978 to 1985 the estimation of beaver populations within the park was again resumed, with surveys conducted by teams of biology students from Montgomery College, Rockville, Maryland under the direction of Associate Professor Betty B. Myers. The population of beavers was estimated to be only 42 in 1978, but by 1984 the estimated population size had increased to 146. In 1985, the maximum carrying capacity of beavers in the park was estimated to be 275 beavers (Mike Drummond, Resource Management Technician, 1985 unpublished memo to Resource Management File N1427). It was also predicted that the carrying capacity would be reached and the first population density problems would occur in 10 years (1995), and by 1996 the park would possibly support as many as 300 beavers.

By 1996, it was obvious that such an increase in beaver numbers had not taken place, and that former calculations of beaver numbers had been inaccurate. It was decided that new population size and density estimates should be made of the

beaver population at Prince William Forest Park during the years 1997 and 1998. At the same time assessments of the relative health and reproductive rate of the beavers in the park were also to be made. Since there had never been an estimate of the beaver population at the nearby Manassas National Battlefield Park, this site was also included in the study.

A contract to conduct this research was awarded to George Mason University in 1997; the results of which are presented below.

METHODS AND MATERIALS

Population Surveys: Field surveys were conducted at Prince William Forest Park and Manassas National Battlefield Park during 1997 and 1998. Teams consisting of two researchers searched for the following beaver signs along the major streams and tributaries in each park: live or dead beavers, tracks, dams, bank burrows, lodges, new or old tree cuttings, drag trails, and limb (sapling) caches. When found, each type of sign was plotted on a USGS 1:24,000 topographic map using a predesignated coding system (Table 1).

The following waterways were surveyed within the Manassas National Battlefield Park in January and March 1997 and again in October 1997: Bull Run Creek, Young's Branch, Holcum's Branch, Dogan Branch, and an unnamed tributary of Young's Branch. The unnamed tributary of Young's Branch was fed by two small ponds which were located near Prince William County Rt. 705 just east of Stuart's Hill.

Streams and tributaries surveyed within Prince William Forest Park during the period January-August 1997 were: the North Fork of Quantico Creek (NFQC), the South Fork of Quantico Creek (SFQC), and the three major tributaries to the South Fork which are encircled by Scenic Drive. The eastern most of these is Mary Bird Branch (site of one of the reintroductions by the VCGIF, see above). The western most begins at the confluence of two intermittent streams, flows southeast crossing High Meadows Trail, and empties into SFQC between parking lots H and I; this

TABLE 1. Codes Used for Marking Topographic Maps during 1997-1998 Beaver Surveys.

1. Live or dead beaver
2. Beaver tracks
3. Beaver dam
4. Beaver bank burrow
5. Beaver lodge
6. Old beaver tree cuttings
7. New beaver tree cuttings
8. Beaver drag trail
9. Beaver limb cache

unnamed tributary will be referred to as the western tributary of SFQC. The major tributary to SFQC, which is located between the other two, begins just north of Old Black Top Road and flows southeast crossing Old Blacktop and Farm roads, and High Meadows Trail and empties into SFQC just northeast of parking lot I. This unnamed tributary will be referred to as the middle tributary of SFQC.

In May 1998, several of the areas with high concentrations of beaver sign were resurveyed in Prince William Forest Park. These included NFQC near the Pyrite Mine Reclamation Site, NFQC northeast of Farms to Forest (extension) Trail, SFQC east of where it meets High Meadows Trail, Mary Bird Branch where it intersects Scenic Drive, and the western tributary of SFQC at the confluence of the two intermittent streams which form it.

Estimates of beaver population size were based upon the number of active lodges and bank burrows found in each park. In the most extensive population study of beavers, Bradt (1938) found an average of four beavers per lodge and 2.4 beavers per bank burrow in Michigan, and his calculations have become almost universally used in population studies of this mammal in North America. The number of active lodges and bank burrows within each park were therefore multiplied by 4 and 2.4, respectively, to obtain the appropriate population estimates. Field data collected from January-August 1997 were used to calculate the population size at Prince William Forest Park; whereas data collected during October 1997 were used for the population size

estimate at Manassas National Battlefield Park.

Trapping Protocol: Beaver collection was subcontracted to a professional trapper, Andrew A. Angelacci, Burke, Virginia.

Most trapping was done in waterways adjacent to Prince William Forest Park on the Quantico Marine Base, so as to not interfere with the beaver population surveys being conducted in the park. Since the beavers of the two national facilities share common waterways, they can be considered a continuous population.

The traps used were 330 Conibears. When set, the trap opens into a 10 inch (25.4 cm) square with trigger wires extending from a notched latch or "dog" fastened to keep the trap jaws open and its springs compressed. With the trigger wires positioned in the center of the square, the beaver must touch them with its face as it attempts to swim through the trap. When the trigger wires are displaced, their base is pulled out of the notch and the latch is released allowing the springs to rapidly expand closing the jaws with great force. The closing jaws usually strike the beaver dorsally directly behind the ears at the base of the skull and ventrally at the base of the throat, killing it instantly.

Traps were set in natural or fabricated channels leading to a scent mound. Such channels were of sufficient depth to completely submerge the entire trap. Once the trap was set and in place, a small 3-4 foot (90-120 cm) and 3-4 inch (7-10 cm) diameter pole of dead wood was positioned over it, perpendicular to the channel so that any beaver swimming at the surface would

be forced to dive below the surface and into the trap. This "dive" pole also helped to reduce the chances of human and/or animal interference with the trap.

The "bait" was a visually attractive scent mound, generally composed of a pile of mud and leaves 6-12 inches (15-30 cm) high and wide with the olfactory allure of beaver produced castorium mixed with beaver oil. Approximately a teaspoonful of this mixture was placed on top of the mound. Usually a 12 inch (30 cm) twig of sweetgum (*Liquidamber styraciflua*) with the bark removed was also put on the scent mound for further attraction.

Reproductive Assessment: Seven female beavers were captured, weighed in the field and then brought to the laboratory at George Mason University between 25 January and 26 April, 1998 for dissection to determine their reproductive status (see Appendix 1). Dates of individual dissections were recorded to correlate embryonic development through the season.

The abdominal cavity was incised longitudinally along the midline of the body, and secondary lateral incisions were made off the midline incision on both the right and left sides at the level of the forelegs and pelvic girdle. This allowed the body wall to be pulled back to expose the viscera. The female reproductive tract was removed above mid-vagina, and the uterus was incised to allow examination for embryos. The number of corpora lutea on each ovary and number of embryos in each uterine horn were recorded from the fresh reproductive tracts. Embryos

present were counted and then measured with a metric ruler, after which both embryos and the reproductive tract were fixed in 40% neutral formalin. After 24-48 hours the formalin was replaced with 70% ethyl alcohol for preservation.

Health Assessment: The same dissected female beavers were examined to determine health status (Appendix 1). The amount of subcutaneous fat deposition (high, medium, low) was noted, as was the amount of deposited tail fat. Condition of the pelt (prime, average, poor) was also recorded, and any wounds on the body or tail noted.

The digestive tract was excised from the lower esophagus to the rectum. A lengthwise incision was made along the entire tract, and the stomach, intestines and cecum were examined macroscopically for parasitic helminths. The heart, lungs, liver, kidneys and bladder were also dissected and examined for parasitic worms. The site and numbers of any worms present were noted. Worms were collected and fixed in 40% neutral formalin, and transferred to 70% ethyl alcohol after 24-48 hours for preservation and future identification.

RESULTS AND DISCUSSION

Manassas National Battlefield Park:

Population Status: Results of the 1997 field surveys at the Manassas National Battlefield Park are summarized in Tables 2-3 and on the maps in Appendix 2. Old and new tree cuttings were found along all of the park's waterways, and other beaver signs, while not as prevalent, were found in fair numbers. A total of 31 dams, five bank burrows, 14 lodges (12 active, two old), 12 drag trails, and eight limb or sapling caches were found during the October 1997 survey.

The following areas of Manassas National Battlefield Park possessed the highest concentrations of beaver sign during the October 1997 surveys: Bull Run Creek north of Farm Ford, Young's Branch between Bull Run Creek and U.S. Rt. 29, Young's Branch at Prince William County Rt. 622, and the unnamed tributary of Young's Branch at the two ponds which feed it (Table 4, Appendix 2). The largest of these areas was Young's Branch at Rt. 622, with numerous new tree cuttings present on both sides of the road. Immediately west of Rt. 622, a large flooded area was found with four dams, two drag trails, and one limb cache. Immediately east of Rt. 622, another large flooded area had three dams and three lodges. Each of the other high concentration areas also possessed at least one lodge and dam, new tree cuttings, drag trails, and limb caches (Table 4, Appendix 2).

Based on the number of active lodges and bank burrows in

TABLE 2. Manassas National Battlefield Park Beaver Surveys: Winter 1997.

Location	Date	Beaver	Tracks	Dam	Burrow	Lodge	New Tree Cutting	Old Tree Cutting	Drag Trail	Limb Cache
Bull Run	1/7/97	0	1	0	4	0	present	present	8	0
Wetland at Stone Bridge Parking Area	1/7/97	0	0	1	0	1	present	present	0	0
Holkum's Branch	1/8/97	0	0	1	0	0	absent	present	1	0
Young's Branch between Bull Run and Rt. 29	1/8/97	0	0	1	0	0	present	present	0	0
Young's Branch between Rts. 29 and 234	1/7/97	0	1	1	0	1	present	present	0	0
Young's Branch between Rts. 234 and 622	1/21/97	0	1	5	1	0	present	present	2	1
Young's Branch between Rts. 622 and 705	1/30/97	0	0	1	0	1	present	present	1	0
Dogan Branch behind Groveton Cemetery	1/28/97	0	0	2	0	1	absent	present	0	0

TABLE 3. Manassas National Battlefield Park Beaver Surveys: Fall 1997.

Location	Date	Beaver	Tracks	Dam	Bank Burrow	Lodge	New Tree Cutting	Old Tree Cutting	Drag Trail	Limb Cache
Bull Run	10/31/97	0	0	2	2	2	present	present	1	2
Wetland at Stone Bridge Parking Area	10/31/97	0	0	0	0	0	present	present	0	0
Holkum's Branch	10/31/97	0	0	0	0	0	absent	present	0	0
Young's Branch between Bull Run and Rt. 29	10/21/97	0	0	2	2	1	present	present	3	2
Young's Branch between Rts. 29 and 234	10/21/97	0	0	2	0	1	present	present	1	1
Young's Branch between Rts. 234 and 622	10/21/97	0	0	9	1	5	present	present	2	2
Young's Branch between Rts. 622 and 705	10/24/97	0	0	7	0	1	present	present	3	1
Dogan Branch behind Groveton Cemetery	10/24/97	0	0	2	0	1	absent	present	0	0
Two ponds which feed unnamed tributary of Young's Branch	10/24/97	0	0	1	0	3	present	present	1	0
Unnamed tributary of Young's Branch immediately below two ponds (approx. 100m)	10/24/97	0	0	5	0	0	present	present	1	0

TABLE 4. Areas in Manassas National Battlefield Park with the Highest Concentrations of Beaver Sign.

Area	Evidences of Beaver	
Bull Run immediately north of Farm Ford	10/31/97	2 lodges 1 bank burrow 1 dam 1 drag trail new tree cuttings present
Young's Branch between Bull Run and Rt. 29	10/21/97	1 lodge 2 bank burrows 2 dams 3 drag trails 2 limb caches new tree cuttings present
Young's Branch within 100 m of each side of Rt. 622	10/21/97 and 10/24/97	Large amounts of new cuttings present on both sides of 622 Immediately west of 622 a large ponded area existed with: 4 dams 2 drag trails 1 limb cache Immediately east of 622 another large ponded area existed with: 3 lodges 3 dams
Two ponds which feed into unnamed tributary of Young's Branch and the unnamed tributary just below the ponds	10/24/97	3 lodges 7 dams 2 drag trails new tree cuttings present

October 1997, the population estimate for Manassas National Battlefield Park was 70 beavers (Table 5). The total acreage of Manassas National Battlefield Park is 5,079 acres (2,055 hectares) (Bryan Gorsira, pers. comm.). If a simple density is calculated based on this area, there are 0.014 beavers per acre (0.034 per hectare) in the park. However, since the majority of beaver habitat within the park consists of gallery forest along the major waterways, this is not an accurate density estimate. There are approximately 48,900 linear feet of major streams (Bull Run and Young's Branch) which flow through Manassas National Battlefield Park. If it is assumed that 50 feet (15 meters) on either side of these streams is available beaver habitat, approximately 112.2 acres (45.44 hectares) of beaver habitat are present within the park. If this is true, the actual density of beavers at Manassas National Battlefield Park is 0.62 beavers per acre (1.54 per hectare) rather than the 0.014 beavers per acre calculated above.

A greater crowding problem exists for beavers at Manassas National Battlefield Park than at the larger Prince William Forest Park which has a much greater area of suitable forest habitat (see below).

Prince William Forest Park:

Population Status: Results of the 1997 population surveys at Prince William Forest Park are summarized in Tables 6-8 and on the maps in Appendix 3. Old and new tree cuttings were found

TABLE 5. Calculations for Beaver Population Size Estimate at Manassas National Battlefield Park, Virginia.

Fall 1997: 12 active lodges x 4 beavers/lodge = 48 beavers
 + 5 bank burrows x 2.4 beavers/burrow = 12 beavers

Fall 1997 Total = 70 beavers

PARK TOTAL: 70 beavers

TABLE 6. Prince William Forest Park Beaver Surveys: North Fork Quantico Creek (NFQC).

Location	Date	Beaver	Tracks	Dam	Bank Burrow	Lodge	New Tree Cutting	Old Tree Cutting	Drag Trail	Limb Cache
NFQC between confluence with SFQC and Lake One Road	3/31/97	0	0	2	3	2	present	present	3	3
NFQC between Lake One Road and Burma Road	5/4/97	0	0	0	0	0	present	present	0	1
NFQC between Burma Road and eastern most portion of Farms to Forest (extension) Trail	5/18/97	0	0	17	2	1	present	present	4	3
NFQC between eastern most portion of Farms to Forest (extension) Trail and NW border of park	8/9/97	0	0	18	2	3	present	present	7	3
Major tributary to NFQC along Farms to Forest (extension) Trail	5/7/97	0	0	14	0	1	present	present	5	6

TABLE 7. Prince William Forest Park Beaver Surveys: South Fork Quantico Creek (SFQC).

Location	Date	Beaver	Tracks	Dam	Bank Burrow	Lodge	New Tree Cutting	Old Tree Cutting	Drag Trail	Limb Cache
SFQC between confluence with NFQC and Scenic Drive (near parking lot A)	1/14/97 and 2/6/97	0	0	0	0	1	present	present	0	0
SFQC between Scenic Drive (near parking lot A) and Liming Lane	3/6/97	0	0	0	1	0	present	present	3	0
SFQC between Liming Lane and Mawavi Road	3/13/97	0	0	0	0	2	present	present	2	2
SFQC between Mawavi Road and Rt. 619	5/18/97	0	0	2	0	0	present	present	0	0

TABLE 8. Prince William Forest Park Beaver Surveys: Major Tributaries to South Fork.

Location	Date	Beaver	Tracks	Dam	Bank Burrow	Lodge	New Tree Cutting	Old Tree Cutting	Drag Trail	Limb Cache
Mary Bird Branch	4/8/97	0	0	4	0	2	present	present	0	0
Middle tributary to SFQC	4/13/97	0	0	0	0	1	present	present	0	0
Western tributary to SFQC	4/27/97	0	0	13	3	5	present	present	4	3

along virtually all waterways in the park. Other beaver signs were not as prevalent, but were still found in fair numbers. A total of 70 dams, 11 bank burrows (nine active, two old), 18 lodges (15 active, three old), 28 drag trails, and 21 limb/sapling caches were found.

Several live or dead beavers were also observed during the period of the study by individuals other than the primary researchers. Five live beavers were seen at the Pyrite Mine Reclamation Site on the morning of 2 October 1997 (Ann S. Brazinski, pers. comm.). During the spring of 1998, one male beaver and one beaver kit were trapped at the Pyrite Mine. The remains of a dead adult beaver were also found in spring 1998, near the large pond on SFQC at Lake One Road (Andrew A. Angelacci, pers. comm.).

The following areas of the park possessed the highest concentrations of beaver sign in 1997: NFQC near the Pyrite Mine Reclamation Site; NFQC northwest of the Farms to Forest (extension) Trail; SFQC east of High Meadows Trail; Mary Bird Branch at Scenic Drive; and the western tributary to SFQC at the confluence of the two intermittent streams which form it (Table 9; Appendix 3). The largest of these areas was along the western tributary to SFQC, where three large dams (which formed a large three-tiered pond), four active lodges, four drag trails, three fresh limb/sapling caches, and many new tree cuttings were present. While not as large as that site, each of the other high concentration areas typically possessed new tree cuttings, drag

TABLE 9. Areas in Prince William Forest Park with the Highest Concentrations of Beaver Sign.

Area	Evidences of Beaver	
NFQC near Pyrite Mine Reclamation Site	3/31/97	2 lodges 2 bank burrows 2 dams 3 drag trails new tree cuttings present
NFQC north of Farms to Forest (extension) Trail and south of housing development on Rt. 234 which borders park	8/9/97	1 lodge 1 bank burrow 1 large dam which forms a large pond 2 drag trails new tree cuttings present
SFQC east of where it meets High Meadows Trail	3/13/97	1 lodge 1 drag trail 2 limb caches large amounts of new tree cuttings present
Mary Bird Branch where it crosses Scenic Drive	4/8/97	1 lodge 2 dams 1 limb cache new tree cuttings present
Western tributary to SFQC at confluence of two intermittent streams which form it	4/27/97	2 large lodges 2 small lodges 3 large dams which form a large, three-tiered pond 4 drag trails 3 fresh limb caches large amounts of new tree cuttings present

trails, limb/sapling caches, and at least one dam and lodge (Table 9; Appendix 3).

Three of the five high concentration areas appeared essentially unchanged when resurveyed in May 1998. SFQC east of High Meadows Trail and near the Pyrite Mine Reclamation Site, and NFQC northwest of the Farms to Forest (extension) Trail all had recent signs of beaver activity in May 1998, including at least one active lodge and dam.

At two of the high concentration sites, however, beaver activity appeared to have decreased since 1997. Where Mary Bird Branch crosses Scenic Drive, no new tree cuttings were found in May 1998, the lodge which was present in 1997 was missing, and the previously active dam was in disrepair. The site at the western tributary of SFQC, which had the greatest beaver activity in 1997, also appeared abandoned as no active beaver signs were found in May 1998. The largest of the three dams was visibly broken, and all three of the beaver ponds were drained. In addition, all of the lodges were missing and no new tree cuttings were present.

The 1997-1998 population size estimate for Prince William Forest Park was 81.6 beavers (NFQC, 44.8 beavers; SFQC, 14.4; major tributaries of SFQC, 22.4 beavers) (Table 10). Based on a total area of 12,573.6 acres (5,092.3 hectares), the total beaver density in the park in 1997-1998 was 0.006 beavers per acre (0.016 per hectare). The NFQC watershed with 4,073.6 acres (1649.8 hectares) within the park, had a 1997-1998 beaver density

TABLE 10. Calculations for Beaver Population Estimate at Prince William Forest Park, Virginia.

NFQC: 7 active lodges x 4 beavers/lodge = 28 beavers
 + 7 bank burrows x 2.4 beavers/burrow = 16.8 beavers

NFQC Total = 44.8 beavers

SFQC: 3 active lodges x 4 beavers/lodge = 12 beavers
 + 1 bank burrow x 2.4 beavers/burrow = 2.4 beavers

SFQC Total = 14.4 beavers

TRIBS: 5 active lodges x 4 beavers/lodge = 20 beavers
 + 1 bank burrow x 2.4 beavers/burrow = 2.4 beavers

TRIBS Total = 22.4 beavers

PARK TOTAL: 81.6 beavers

of 0.011 beavers per acre (0.0272 per hectare). Similarly, the total SFQC watershed within the park, including the three major tributaries, contained 8,500 acres (3442.5 hectares) and had a 1997-1998 beaver density of 0.005 per acre (0.011 per hectare). Area figures were taken from Drummond (1985, Unpublished memo to Resources Management File N1427).

Several problems exist with the population estimates made by Montgomery College. The most important of these is the method used to estimate population size. At first glance, it is unclear on what they based their estimates. In a 7 March 1985 letter from Betty Myers to Diane Probus, it is stated that the estimates the estimates were based on four beavers per lodge (A number used by VCGIF to estimate beaver colony size). In another 17 January 1983 letter from Betty Myers to Robert Haney, however, it was stated that the estimates were based on four beavers per active dam site. From an examination of the sheets containing the raw data submitted by Montgomery College, it appears that the population estimates were in fact based on four beavers per dam site. Since several dams are usually associated with one lodge or bank burrow, the numbers of beavers proposed by Montgomery College were probably too high.

The problems associated with basing the population estimate of four beavers per dam site are best illustrated by the estimate made by the college group in 1984. The 1984 estimate (146 beavers) included 72 beavers (18 dams) reported by team VIII. According to Montgomery College's survey protocol, team VIII

surveyed Mary Bird Branch from the Nature Center upstream to its source. Anyone who has walked this stretch of stream will realize that 72 beavers is a gross overestimation. Estimates from the present study indicate no beavers from this area. The colleges's own surveys of this area indicate only eight beavers in 1982 and none in 1985. The problem of overestimation in 1984 was compounded because future population predictions and recommendations were partially based upon it (see next paragraph).

In a 29 August 1985 memo (Resource Management File N1427), Mike Drummond made beaver population predictions based on surveys conducted up to that point (Table 11). Drummond estimated the maximum carrying capacity of Prince William Forest Park to be approximately 275 beavers, and stated that the beavers could potentially exceed this carrying capacity by 1996. One problem with this prediction is that the rate of increase upon which it is based used the 1984 estimate made by Montgomery College as its endpoint. Because the 1984 estimate was too high, the resulting increasing population trend used by Drummond was skewed. If the 1984 population estimate is adjusted to correct for this by eliminating all but four (the average number of beavers found by team VIII during other surveys by Montgomery College) of the 72 beavers reported by team VIII, then the beaver population at the park would actually have decreased between 1983 (115 beavers) and 1984 (78, see also Table 11). If we also consider the Montgomery College estimate for 1985 (118 beavers), it seems as though the

beaver population was stabilizing at this point instead of rapidly increasing. Taking these factors into consideration, it can be understood why the beavers have not overpopulated the park by 1996, and in fact will probably never do so with their freedom to emigrate from the park to adjacent waterways (especially Quantico Marine Base).

In spite of the problems discussed above, general comparisons can be made between the present survey and those previously conducted at Prince William Forest Park. Areas of high beaver concentration noted in previous surveys correspond surprisingly well with high concentration areas in the present survey (see Table 9 for 1997-1998 areas of high beaver concentration). In a 1968 survey, the following areas of high beaver concentration were noted: a tributary of SFQC which crosses trail 10 (High Meadows Trail); SFQC near Lakes 2 and 5; a tributary to NFQC along Farms to Forest Trail; NFQC west of Burma Road; and NFQC at Lakes 1 and 4. In general, all of these areas still support active beaver colonies. Three of the five high concentration areas from 1968 correspond almost exactly with 1997-1998 high concentration areas. The 1968 area found on a tributary to SFQC (which crosses trail 10) probably corresponds to the high concentration area on the western tributary to SFQC found in the present survey. The 1968 area near Lakes 2 and 5 is just upstream from the present high concentration area found on SFQC east of where it meets High Meadows Trail. In 1968, four specific sites of beaver activity were found on NFQC west of

Burma Road. In the present survey, 36.3 percent of the beavers in Prince William Forest Park were estimated to have come from NFQC west of Burma Road. The most striking similarity between the 1997-1998 study and the Montgomery College studies is the presence of high concentrations of beaver sign along the western tributary of SFQC in both. Once the 1984 population estimate is adjusted as discussed above, 22.4 percent of all beavers found by Montgomery college groups (all available raw data were lumped over all years) were said to have come from the western tributary to SFQC. This corresponds well with findings of the present survey, as the high concentration site on the western tributary of SFQC was by far the single greatest site of beaver activity in Prince William Forest Park during the 1997-1998 surveys.

Reproductive Status: In North America, *Castor canadensis* experiences one reproductive cycle per year. Mating usually takes place in the winter, normally in January or February, but sometimes as early as December (Bergerud and Miller, 1977; Hodgdon and Hunt, 1953). Copulating beavers were observed in Quantico Creek at Prince William Forest Park on 22 January 1998 by the trapper employed in the study, Andrew Angelacci (pers. comm.).

The gestation period is about 100-128 days, with parturition usually taking place in May or June (Bergerud and Miller, 1977; Bradt, 1939; Hodgdon and Hunt, 1953; Osborn, 1953), but may occur from as early as February (Miller, 1948) to as late as November

(Cook and Maunton, 1954; Thomas, 1943). Apparently, the reproductive season may vary with either latitude or habitat (Thomason and Jacobson, 1978).

The earliest collection date of a pregnant Prince William Forest Park female during the current study was 23 January 1998 (Table 12), indicating a December or early January mating. The last pregnant female was trapped on 1 March 1998. No lactating females were captured. The seven females dissected averaged 40.1 pounds (18.2 kg) and ranged from 18-57 pounds (8.2-25.9 kg). Those over 39 pounds (17.7 kg) were reproductively active (Table 12). Yearling females trapped on 1 March (18 pounds, 8.2 kg) and 26 April (21 pounds, 9.5 kg) showed no signs of reproductive activity (Table 12); both sexes become sexually mature at about 1.5-2.0 years of age (Brenner, 1964; Henry and Bookhout, 1969; Larson, 1967).

Although large males were trapped or seen after 1 March, no large females were in evidence. Pregnant females are apparently more solitary than adult males (Bergerud and Miller, 1977), and probably retire to lodges with the yearlings during the late stages of gestation to await the birth of the kits, while males move to bank burrows (Bradt, 1939).

Table 13 presents comparative reproductive parameters of *Castor canadensis* taken from selected North American studies. Based on numbers of corpora lutea or placental scars, most populations have mean litter sizes of 3-4 and a range of 1-9 young; however, litter size may vary with both latitude and

TABLE 12. Reproductive Data for Female Beavers Collected at Prince William Forest Park, Virginia.

Collection Date	Weight (lbs.)	Corpora Lutea	Embryos	Embryo Length
1/23/98	53	1L:4R	0	N/A
1/25/98	57	2L:3R	2L:1R	1-2 mm
2/10/98	51	1L:3R	1L:0R	1-2 mm
2/15/98	42	1L:2R	1L:2R	3.5-4 mm
3/1/98	39	3L:4R	3L:1R	6-7 mm
3/1/98	18	0	0	N/A
4/26/98	21	0	0	N/A

TABLE 13. Selected Reproductive Data Reported for North American Beavers, *Castor canadensis*.

Corpora Lutea	Placental Scars	Embryos	Litter Size	Gestation Period (days)	Source
-	-	-	3.72	90-120	Bradt, 1938, 1939, 1947
-	3.1	3.4	-	-	Leege & Williams, 1967
4.4	3.9	-	-	-	Henry & Bookhout, 1969
-	2.8	2.6	2.2-5.5	-	Wigley et al., 1983
2.8	2.9	2.9	-	-	Payne, 1984
-	1.33-3.75	2.25-3.05	3.12	-	Osborn, 1953
-	3.95	3.72	3.55	-	Hodgdon, 1949
-	-	-	4.0	-	Henderson, 1960
-	-	3.8	1.0-6.0	-	Grasse & Putnam, 1950
-	-	-	4.0-5.0	-	Paradiso, 1969
-	-	1-2	-	-	Miller, 1948
-	-	-	1-2	-	Guenther, 1948
9	-	-	8	-	Hay, 1957
5.04	-	5.5	-	-	Brenner, 1964

habitat (Pearson, 1960; Rutherford, 1964; Yeager and Rutherford, 1957). Litter size is positively correlated with the weight of the mother (Pearson, 1960), but does not necessarily increase with age. It is probably more correlated with the quality and quantity of winter food supplies and severity of the winter weather (Jenkins and Busher, 1979).

At Prince William Forest Park, mean litter size, based on the number of corpora lutea present on the ovaries of five adult females, was 4.80 (3-7) (Table 12). The right ovary was more active in these females, ovulating 16 eggs compared to only eight by the left ovary. However, mean litter size, based on embryos present in four of the adult females, was only 2.75 (1-3). An adult female collected 23 January 1998 had five corpora lutea but no embryos. It is possible that she had not yet mated, or that the eggs had only just been fertilized and were not detected during macroscopic examination of her oviducts.

Mean fertility rate for beavers with embryos was 57.89 percent (25-100). Mean fertility rate for all beavers with corpora lutea was 45.83 percent (0-100). Although 16 corpora lutea were present on the right ovaries of the five females examined, their right uterine horns only contained four embryos, or a 25 percent fertility rate. Their left ovaries had eight corpora lutea, and the left uterine horns seven embryos, a 87.50 percent fertility rate.

The rate of embryonic growth from 1-2 mm in late January to 6-7 mm in early March (Table 12), assuming fertilization occurred

no later than 15 January, seems to indicate a gestation period of about 120 days at Prince William Forest Park, with parturition in mid- to late May. This agrees closely with data published from other populations (Table 13).

A determination of the sex ratio of the beaver population at Prince William Forest Park is also a useful datum from which other inferences can be drawn (such as reproductive capacity, see below). *Castor canadensis* is probably monogamous, or only slightly polygamous, with an adult male and female usually remaining together until the death of one partner (Bradt, 1939; Novak, 1977; Jenkins and Busher, 1979; Svendsen, 1989). An individual beaver colony occupies a pond or a section of a stream, and is composed of 4-8 individuals (Bergerud and Miller, 1977; Bradt, 1938), with an average colony size of 5.1 (Bradt, 1938). Within the colony, the sex ratio of adult males to adult females is usually 1:1 (Bradt, 1938), as is also the sex ratio of litters (Bradt, 1938, 1939).

Since the male to female sex ratio is essentially 1:1 (see above), an estimation can be made of the annual reproductive capacity for the park's beaver population. If the 1997-1998 estimated population size of 81.6 is used, then half, 40.8, are females, but some of these females were immature. The sex ratio in litters is also about 1:1 (see above), so in every litter of 4.8 young, 2.4 should be females. Using an estimate of two immature females to each adult female, the Prince William Forest Park population contained 13.6 mature females in 1997-1998, which

each could produce an average of 4.8 young in a single litter. This results in an overall reproductive capacity of 65.3 young in 1997-1998 (NFQC, 36.0 young; SFQC, 11.5; tributaries of SFQC, 17.9). However, if the number of average uterine embryos found in the dissected females, 2.75, is used as the litter size, the reproductive capacity is greatly reduced. Approximately 7.8 mature females would be present which could produce 37.4 young (NFQC, 20.6; SFQC, 6.4; tributaries of SFQC, 10.2). Postpartum mortality would eliminate still more of the young.

Health Status: Five of the seven dissected females had prime pelts, one an average pelt, and the last collected, a low average pelt with several wounds. Quantity of subcutaneous fat was moderate to high in all specimens. Four females contained moderate mesenteric fat deposits, while three had low to no mesenteric fat. Fat deposits at the base of the tail were moderate to high in all seven females. Overall, fat reserves were judged to be moderate to high. Six females had suffered wounds on either the body (one) or tail, possibly from amorous males (Table 14).

The beavers harbored two species of helminths (Table 14), the stomach nematode, *Travassosius americanus* (Chapin, 1925), and the cecal trematode, *Stichorchis subtriquetrus* (Chapin, 1925), which apparently are common, widespread parasites of beavers (Babero, 1953; Bennett and Humes, 1939a; Brenner, 1970; Erickson, 1944). No helminths were found in the heart, lungs, kidneys,

TABLE 14. Health Data for Female Beavers collected at Prince William Forest Park, Virginia.

Collection Date	Weight (lbs.)	Pelt Condition	Tail Damage	Fat Reserves	Nematodes	Trematodes
1/23/98	53	Average	Yes	Moderate-High	19	24
1/25/98	57	Prime	No	Moderate-High	27	0
2/10/98	51	Prime	Yes	Low-Moderate	1	46
2/15/98	42	Prime	No	Moderate-High	112	26
3/1/98	39	Prime	Yes	Moderate-High	31	16
3/1/98	18	Prime	No	Moderate-High	76	36
4/26/98	21	Low Average	Yes	Moderate	354	19

urinary bladder or body cavity.

Travassosius americanus was found in 100% of the females examined from Prince William Forest Park. Host incidence of the stomach nematode is often high; Erickson (1944) reported that 124 (88.6%) of 140 Minnesota beavers examined harbored this worm, and Babero (1953) found it in 34 (60.7%) of 56 Alaskan beavers.

The Prince William beavers averaged 88.5 (1-354; S.D. 122.9) *T. americanus*, but contrary to the findings of Brenner (1970) in Pennsylvania, the numbers of *T. americanus* were greatest in the two smallest (youngest) individuals and lowest in the larger (older?) beavers (Table 14). Beavers over 50 pounds (22.7 kg) averaged only 15.7 stomach nematodes, but those weighing 42 pounds (19.1 kg) or less averaged 143.2, with the two smallest individuals having 76 and 354 worms, respectively. Only one of 620 *T. americanus* was found in the duodenum, just outside the stomach. There was also a trend toward a greater stomach nematode load with advance of season, as the earlier dissected beavers had less worms than those dissected later in the season, but, again, this may be a function of size or age as the largest beavers were trapped earlier than the smaller individuals. Erickson (1944) reported an average of 142 *T. americanus* per beaver in Minnesota with a maximum of 1,197, and Babero (1953) also found infestations of over 1,000 worms in Alaskan beavers. The maximum number of stomach nematodes in Pennsylvania beavers was 225 (Brenner, 1970).

Even in heavy infestations there is no evidence of *T.*

americanus causing injury to the stomach lining, although they are probably ingesting blood from the lining (Erickson, 1944); all Prince William *T. americanus* were deep red in color, probably indicating that they had been feeding on blood. However, it is possible that they may injure the beaver through the production of toxins, as is known from some other nematodes that feed on blood.

The life cycle of *T. americanus* is unknown, but Erickson (1944) speculated that it is probably direct with the eggs of the nematode passing out in beaver feces to be later ingested by other beavers.

Only two of three Prince William Forest Park beavers over 50 pounds (22.7 kg) contained the cecal trematode, *Stichorchis subtriquetrus*; mean 23.3 (0-46) (Table 14). The trematode is easily found, and we do not believe it was overlooked in the female trapped on 25 January. Trematodes were present in all beavers collected on or after 10 February. Brenner (1970) also found fewer *S. subtriquetrus* in larger (older?) Pennsylvania beavers. Prince William beavers averaged 23.8 (0-46, S.D. 14.7) trematodes per individual; those with *S. subtriquetrus* averaged 27.8 (16-46). Erickson (1944) recovered cecal trematodes from 110 (78.6%) of 140 Minnesota beavers examined, but Babero (1953) found the worm in only eight (14.0%) of 56 Alaskan beavers. Brenner (1970) reported a maximum of 65 cecal trematodes from Pennsylvania beavers.

According to Bennett and Humes (1939a, 1939b) and Schell

(1970), eggs of *Stichorchis subtriquetrus* are passed in beaver feces and hatch in about three weeks into a miracidium larval stage which penetrates the freshwater snail *Fossaria parva*. Within the snail the parasite undergoes two successive rediae larval stages, the first in 48 hours and the second in 21 days, and amphistome cercariae develop at about day 35 from the second (daughter) rediae. The cercariae leave the snail and encyst within 24 hours on aquatic vegetation, and probably also the various cut saplings in beaver caches; beaver eventually ingest the cercariae from these sources.

Two other helminths have been reported from wild North American beavers. The large strongyle nematode, *Castorstrongylus castoris* (Chapin, 1925), has also been found in the cecum and large intestine of North American beavers by Babero (1953), Brenner (1970) and Erickson (1944), but was not discovered during this study. It is more prevalent in beavers under two years of age, and since only two young individuals were dissected, its presence at Prince William Forest Park can not be ruled out. The small y-shaped trematode, *Stephanoproraoides lawi* Price, 1934, has been reported from the small intestine of beavers in Minnesota and Ontario by Erickson (1944) and Price (1934), and is apparently restricted to higher latitudes than Virginia.

The helminth loads of beavers from Prince William Forest Park are generally higher than those reported for Pennsylvania beavers by Brenner (1970) but lower than those from Alaskan and Minnesota beavers examined by Babero (1953) and Erickson (1944),

with the greatest loads occurring in medium to small individuals. Brenner (1970) also found young beavers to be more heavily parasitized than older individuals. Perhaps an inquired immunity factor is involved, or possibly feeding habits change with size/age bringing large adults into less contact with the infective stages of the parasites.

In spite of the worm burdens, beavers at Prince William Forest Park appear to be of average to above average health.

RECOMMENDATIONS

1. Since the sampling method used in this study is prone to variance, and thus gives only a rough estimate of population size, it is recommended that a 2-3 year mark-recapture study be carried out at both Manassas National Battlefield Park and Prince William Forest Park to determine more accurately the sizes of the beaver populations at each. Such studies should also include determination of the sex and juvenile/adult ratios to better characterize the populations and estimate turnover rates.

2. Home ranges and migration movements of individual beavers of each sex should be determined at both parks with radio-telemetry.

3. Cut trees, lodges, dams and food/sapling caches should be examined to identify the tree species used by beavers at each park.

4. After the mark/recapture studies have been completed, an estimation of the carrying capacity for beavers should be calculated for both parks. Unfortunately, estimating the carrying capacity will not be an easy task. Such estimates must consider the following factors: species of trees present and their proportions, proportion of large trees to saplings, distance of trees to water, slope of the land, and availability of other plant foods (Bradt, 1938). Given the restrictions of the present study, precise calculations are not possible, but a crude estimation of carrying capacity at each park is presented below.

Mike Drummond (1985, Unpublished Memo to Resource Management File N1427) estimated that suitable areas of Prince William Forest Park could support 0.0625 beavers per acre. He further estimated that only 35 percent of the 12,573.6 acres (including portions of the NFQC and SFQC watersheds found within Prince William Forest Park) were suitable beaver habitat. According to these estimates, the 4400.76 acres of suitable habitat within Prince William Forest Park have a carrying capacity of 275 beavers. Using Drummond's calculations, we can obtain a similar estimate of carrying capacity at Manassas National Battlefield Park. Accordingly, the 1,777.65 acres (35 percent of 5,079 acres) of suitable habitat at Manassas National Battlefield Park have a carrying capacity of 111 beavers (using 0.0625 beavers/acre).

Currently, neither Manassas National Battlefield Park nor Prince William Forest Park is at its estimated carrying capacity. Should the beaver population at either park continue to grow, however, measures to reduce their numbers will be necessary. It is recommended that ten adult female beavers be trapped and sacrificed between January and May for two years. In addition, those sacrificed at the Manassas National Battlefield Park should be dissected to determine the reproductive characters and parasite load of the population there. Since beavers seem to be causing proportionally more damage at that park than at Prince William Forest Park, removal of twenty females will help keep the population at a manageable level.

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