2012

Beaver-Dredged Canals and their Spacial Relationship to Beaver-Cut Stumps

Matthew J. Abbott

Brandon Fultz

Jon Wilson

Jody Nicholson
Marian University - Indianapolis, jnicholson@marian.edu

Matt Black

See next page for additional authors

Authors
Matthew J. Abbott, Brandon Fultz, Jon Wilson, Jody Nicholson, Matt Black, Adam Thomas, Amanda Kot, Mallory Burrows, Benton Schaffer, and David P. Benson Ph.D.

2013. Proceedings of the Indiana Academy of Science 121(2):91–96

BEAVER-DREDGED CANALS AND THEIR SPATIAL RELATIONSIHP TO BEAVER-CUT STUMPS

Matthew J. Abbott, Brandon Fultz, Jon Wilson, Jody Nicholson, Matt Black, Adam Thomas, Amanda Kot, Mallory Burrows, Benton Schafer and **David P. Benson***: School of Mathematics and Sciences, Marian University, Indianapolis, IN 46222

ABSTRACT. *Castor canadensis* Kuhl (North American beavers) are central place foragers who collect woody plants and building materials from their surroundings and return to a main body of water containing a lodge or food cache. It has been suggested that beavers dredge water-filled canals to extend access to foraging areas; however, the possibility that these engineered transportation routes function as extensions to the beavers' "central place" has yet to be considered. Our objective in this study was to gain a better understanding of the formation and utilization of canals by beavers and thus further elucidate the complex foraging behavior of these ecosystem engineers. During 2004–2011, we mapped beaver ponds, canals, and cut stumps in eight groundwater-fed wetlands, from at least four separate colonies, in Indianapolis, IN. We found that the mean length, depth, and width of the beaver-dredged canals were 604.3 ± 493.1 m, 28.0 ± 22.2 cm, and 107.7 ± 107.1 cm respectively. Two of the canal systems were mapped for multiple years and their length, depth, and width increased over time and supported the prediction that beavers continuously "engineer" these canal systems to extend their foraging area into new locations. In addition, and in contrast to previous studies, we found that the number of beaver-cut stumps was negatively related to distance from canals, but not from the body of water containing their lodges. We recommend that studies of optimal foraging in beavers take canals into account, where applicable, when relating foraging to distance from the "central place."

Keywords: North American beaver, canal, *Castor canadensis*, foraging

INTRODUCTION

As central place foragers, *Castor canadensis* Kuhl (North American beavers) gather food and return to a central location, usually a water body with a lodge, dam, and/or food cache (Aldous 1938, Brenner 1962, Jenkins 1980, Belovsky 1984, Raffel et al. 2009). They feed on herbaceous vegetation as well as the bark and cambium of woody plants including Aspen (*Populus tremuloides*), Willows (*Salix* spp.), Cottonwood (*Populus deltoides*), Ashes (*Fraxinus* spp.), and Maples (*Acer* spp.) (Denney 1952, Hall 1960, Brenner 1962, Belovsky 1984, Roberts and Arner 1984, Baker and Hill 2003). Woody vegetation is either eaten where it is cut, or the stems are transported to a food cache near the lodge or to the lodge itself for construction (Busher 1996).

Beavers usually forage within 100 m of the main water body containing the lodge (Hall 1960, Jenkins 1980, Howard and Larson 1985). Hall (1960) for example, found that 90% of cut stumps were within 35 m of the water body with the lodge. Optimal foraging studies of beavers have found that beavers forage less, and more selectively, the farther they are from the main water body containing the lodge (Jenkins 1980, Belovsky 1984, McGinley and Whitham 1985, Fryxell and Doucet 1991, Raffel et al. 2009). However in some locations, beavers dredge canals apparently to increase accessibility to foraging areas (Berry 1923, Warren 1927, Townsend 1953, Naiman et al. 1986, Rebertus 1986, Johnson and Naiman 1987, Mitchell and Nierring 1993, Butler and Malanson 1994, Gurnell 1998, Rosell et al. 2005). Canals are often flooded by groundwater seeps and can be up to 1 m wide and 100 m long (Berry 1923, Rebertus 1986, Butler and Malanson 1994, Gurnell 1998). How these canals affect their central place foraging behavior has not been studied.

In this study we examine the geomorphology of beaver-dredged canals by measuring and mapping eight canal systems in the Indianapolis,

* *Corresponding author*: School of Mathematics and Sciences, Marian University, 3200 Cold Spring Road, Indianapolis, IN 46222; email dbenson@marian.edu; phone 317-955-6028

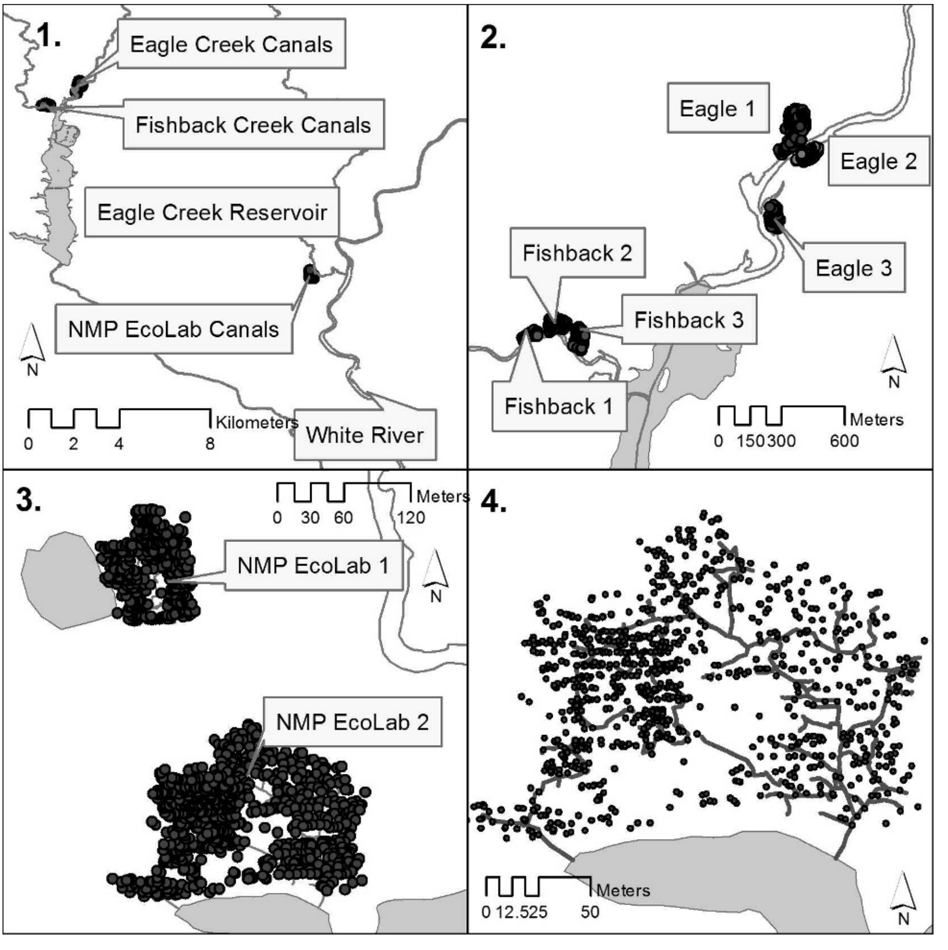

Figure 1.—Beaver-dredged canals and cut stumps in Indianapolis, IN.; (1.) Shows location of Eagle Creek, Fishback Creek, and Nina Mason Pulliam EcoLab beaver-dredged canals in the northwest quarter of Marion County; (2.) Shows the distribution of the Eagle and Fishback Creeks canal systems; (3.) Shows the relationship between the canal systems in the NMP EcoLab; and (4.) The 2009 map of canal system NMP EcoLab 2 showing the relationship between beaver-cut stumps, beaver-dredged canals, and water nbody containing beaver lodges.

IN area. Two of these canal systems were mapped over two consecutive years to examine changes over time. In addition, to assess how canals affect central place foraging behavior, we mapped the distribution of beaver-cut stumps in each of these canal systems.

METHODS

During autumn seasons in 2004–2011 we mapped beaver canals in eight canal systems in Indianapolis, Marion County, IN. Two canal systems were associated with at least one beaver colony on Fishback Creek (FB) (39.884779N, 86.308443W; WGS84), two with at least one colony on Eagle Creek (EC) (39.893472N, 86.297650W; WGS84), and one canal system for each of two colonies at the Nina Mason Pulliam (NMP) EcoLab at Marian University on Crooked Creek (39.818161N, 86.205897W; WGS84; Figure 1). In both the Fishback Creek and Eagle Creek areas, only one lodge was found nearby each, so we assume one colony created the canals in each of the two areas respectively. These canal systems contained primarily groundwater-fed wetlands that were dominated by Willows, Green Ash (*F. pennsylvanica*), Dogwoods (*Cornus racemosa* and *C. amomum*) and American Elm (*Ulmus americana*).

The Fishback Creek canal systems were 1.5km from the Eagle Creek canal systems and both were 11km from the NMP EcoLab canals along Crooked Creek (Figure 1). Canal systems often contain dry segments, segments containing water, and check dams. The Fishback Creek and the Eagle Creek canal systems were connected to their respective creeks by dry segments – essentially a deep-cut trail. The canal systems at the NMP EcoLab each had a check dam separating the canals from the water bodies upon which the lodges were sited. Although the canal systems at the NMP EcoLab were only separated by 120m, we considered them to be created by two different colonies of beaver for the following reasons: 1. there were no signs of movement (trails, tracks, or sightings) between the two areas. 2. there were no cut stumps in the 120m gap between the two areas; and 3. there were two lodges in each of the two areas.

Beaver canals were mapped by walking their length and all tributaries with a hand held Global Positioning System (GPS) unit (accurate to within ± 1 m). The canals were defined as gutter-like trails or paths that were dredged lower than the adjacent ground and that were connected to the larger water body containing the lodge. Canals often contained beaver-cut roots, obvious signs of dredging (e.g. pushed/packed mud and debris on the edges of the canal ways), beaver-chewed sticks, and/or beaver-cut stumps. In contrast to a stream or creek, most active canals also contained non-moving water (Berry 1923). Using measuring tape, we measured canal depth at its center, canal width, and water level at the center of each canal at approximately every 10 m along its length. We repeated this mapping procedure for two of the canal systems in 2008 and 2009 to detect changes in canals over time.

To map beaver-cut stumps we walked transects that paralleled the water bodies containing the lodges and were at approximately 10 m intervals and extended to 10 m beyond the farthest canal. We recorded all beaver-cut stumps within 1 m of the transect using GPS. Cut stumps of all sizes were mapped and shrubs with multiple cut stems were considered a single stump. Trees that were girdled without felling were not included. The age of the cut was categorized as "fresh" (i.e. youngest) if the surface of the cut was whitish and unblemished, "old" if mottled with various shades of gray, and "rotten and old" (i.e. oldest) if the cut stump was losing its form. Cut stumps were not mapped in 2008 for the two canal systems that were re-mapped in 2009. In these systems, stumps recorded as "fresh" were assumed to be cut in 2009, because they tend to become gray, and thus would be recorded as "old," in less than a year. Minimum distances of cut stumps from canals and water bodies with lodges were calculated using ArcView GIS 9.2 (Environmental Systems Research Institute, Inc., Redlands, CA) and Kendall's rank correlation coefficient ((T) (Kendall 1938)) was used to determine statistical dependence between cut stumps and distance to main water body with lodge or canals. Means are given $\pm$ standard deviation.

RESULTS

Geomorphology of beaver-dredged canals.—We mapped a total of 4834 m of beaver-dredged canals in the Indianapolis area (Fig. 1). Collectively, these canals had a mean depth of 28.0 ± 22.2 cm, a mean width of 107.7 $\pm$ 107.1 cm., and they contained an average of 13.2 ± 16.2 cm standing water. We found 2662 beaver-cut stumps along the transects with 16% of them being freshly cut, 60% old, and 24% rotten and old.

Between 2008 and 2009 there was a 10% increase in canal length in canal system NMP EcoLab 2 (Figure 1; Table 1). In addition, the average width of the canals increased 21% and the average depth of the canals increased 27% within that same year. In canal system NMP Ecolab 1, there was a 2.5% total increase in canal length, a 6.7% increase in canal width, and an 8.3% increase in canal depth between 2008 and 2009 (Table 1). Evidence of deliberate modification or dredging in both of the canal systems was present in the form of pushed/packed mud and debris on the edges of the canal ways. Of the 932 stumps found in NMP Ecolab 2 in 2009, 26% were freshly cut; while in NMP Ecolab 1, only 2% of the reported 421 stumps were considered fresh (Table 1)

Spatial relationship of beaver-cut stumps to beaver-dredged canals.—In all eight canal systems the number of beaver-cut stumps had a strong inverse relationship with distance from canals ($T = -0.9818$; 2-tailed $p < 0.001$), but not distance from the water bodies containing the lodge ($T = 0.036$; 2-tailed $p = 0.737$) (Table 2 and Fig. 2). Furthermore, 90% of the

Table 1.—Characteristics of eight beaver-dredged canal systems in Indianapolis, IN, 2004–2011. "Main Water 90%" and "canal 90%" are the distances (m) from the main water body containing the lodge or a canal to 90% of the beaver-cut stumps. Means are ± standard deviation.

Canal system	Total length (m)	Mean width (cm)	Mean canal depth (cm)	Mean water depth (cm)	% Flooded	# Stumps mapped	% Fresh-cut stumps	Main Water Pond 90% (m)	Canal 90% (m)
FB1	215	200.4 ± 88.8	50.0 ± 20.9	0	0.00%	83	6.02%	30	12
FB2	253	75.6 ± 28.4	28.9 ± 20.5	0	0.00%	261	11.49%	58	18
FB3	1152	63.1 ± 27.9	17.0 ± 7.8	3.0 ± 4.1	41.67%	206	23.41%	96	20
EC1	1115	170.6 ± 170.2	34.8 ± 24.4	24.5 ± 17.7	100.00%	451	17.29%	154	20
EC2	254	59.0 ± 20.4	29.2 ± 23.2	1.8 ± 4.5	20.00%	130	1.54%	50	16
EC3	201	88.3 ± 84.6	28.9 ± 25.5	3.0 ± 8.3	33.33%	178	3.37%	90	28
NMP1 (2008)	321	120.7 ± 55.6	25.4 ± 9.2	9.1 ± 7.1	100.00%	N/A	N/A		
NMP1 (2009)	329	128.8 ± 52.5	27.5 ± 10.4	16.3 ± 9.9	100.00%	421	2.14%	54	20
NMP2 (2008)	1193	79.2 ± 48.9	23.3 ± 17.4	11.0 ± 12.8	61.04%	N/A	N/A		
NMP2 (2009)	1315	95.8 ± 52.2	29.6 ± 21.0	14.2 ± 19.1	80.33%	932	26.29%	116	16

Table 2.—Spearman rank correlation coefficients showing a strong negative relationship between (a) canals and beaver-cut stumps, but not between (b) main water bodies containing the lodge and cut stumps for eight canal systems in Indianapolis, IN, 2004–2011.

Canal System	(a) Canal (T)	(b) Main Water (T)
FB1	−0.718	−0.005
FB2	−0.771	0.321
FB3	−0.771	0.341
EC1	−0.863	0.303
EC2	−0.716	0.368
EC3	−0.605	0.382
NMP1	−0.920	−0.096
NMP2	−0.926	−0.151

cut stumps in all canal systems were within a range of 30–154 m from the water body with lodge, while 90% of the stumps had a distal range of only 12–28 m from the canals (Table 1). There were no discernible patterns associated with stump age: 90% of fresh stumps were within 8 m of the canals and within 116 m of the main water; 90% of old stumps were within 16 m of the canals and withion 124 m of main water; and 90% of rotten stumps were within 16 m of canals and within 100 m of the main water.

DISCUSSION

Geomorphology of beaver-dredged canals.— The canals described in this study were dredged by beavers and filled with water primarily from groundwater seeps. Our observations were similar to those in other studies that have described canals or "moats" in areas such as peatlands without a constant surface water inflow (Rebertus 1986, Gurnell 1998). However, the canals described in this study were slightly wider and deeper than those that have been found in other areas (Gurnell 1998).

It is apparent that beavers are continuously modifying and lengthening their canal systems over time. In canal systems NMP EcoLab 1 and 2, changes made to the canals (i.e. lengthening, widening, and deepening) between 2008 and 2009 were associated with increased feeding (i.e. more freshly-cut stumps) in the area where those changes took place. This association suggests that the beavers focus their energy on modifying the canals where current food sources are located.

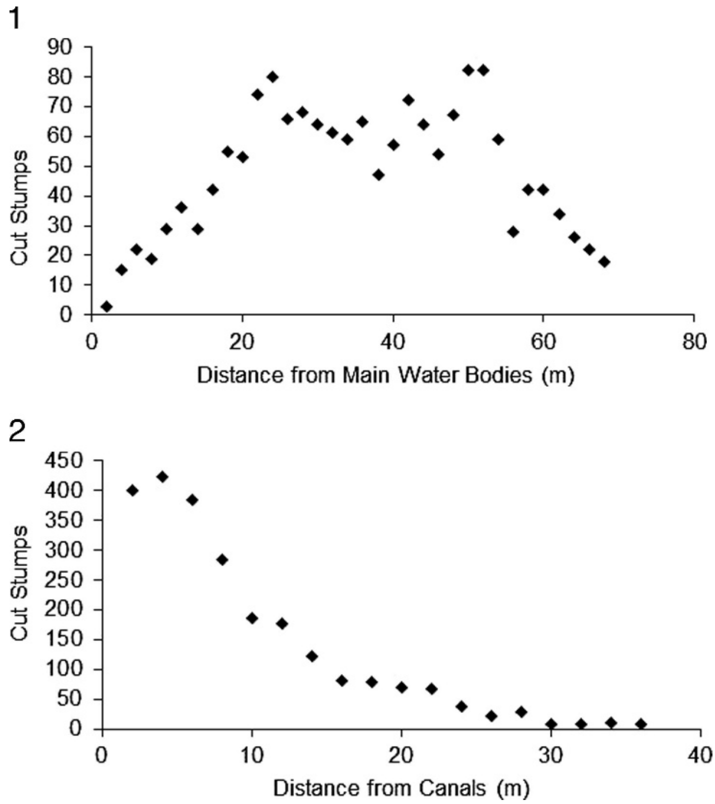

Figure 2.—Distance from main water bodies containing lodges to cut stumps (1.), and from beaver-dredged canals to cut stumps (2.) for beaver-dredged canal systems in Indianapolis, IN, 2004–2011.

In canal system NMP EcoLab 1, the original colony of beavers abandoned the lodge in 2008. The lodge was re-colonized (or at least "visited"), however, by a different colony of beavers just before the canals were re-mapped in 2009 (Pers. Obs.). Consequently, no beaver foraging activity took place for the majority of the time between 2008 and 2009 (Pers. Obs.), this is likely the reason why this canal system did not change as dramatically as the other system and why there was a smaller percentage of fresh (less than one year-old) stumps. When comparing canal systems NMP EcoLab 1 and 2, then, it was evident that the rate of change in canal characteristics was associated with the amount of foraging activity (i.e. fresh stumps) that took place. Canals are likely used as safer and/or easier routes for transporting food back to the lodge or cache (Berry 1923).

Spatial relationship of beaver-cut stumps to beaver-dredged canals.—Most studies of optimal foraging in beavers have found that the distance from a water body with lodge or the "water's edge" is inversely related to the number of woody stems cut (Hall 1960, Jenkins 1980, Belovsky 1984, McGinley and Whitham 1985). We found that the number of beaver-cut stumps was negatively associated with distance from beaver canals, but not from the main water bodies containing the lodges. Therefore, our results suggest that the water body with lidge should not be assumed to be the "water's edge." The beavers in our study utilized their engineered canal systems to forage for 90% of their food sources far beyond the "limited" radius described by Hall (1960) for colonies without canals. Because water filled canals are easier and perhaps safer travel-ways for beavers to use to reach their "central place," when assessing optimal foraging, straight-line distance from a water body with lodge to the lodge or cache may be inadequate to describe the complexity of habitat traversed.

ACKNOWLEDGEMENTS

Overall support of this project was provided by D. Elsener, T. Enneking, and L. Bertocci. C.

Nielsen, S. O'Brien, R. Patrick, D. Bauman, J. Woodward, J. Stumpf, and M. Wilson gave helpful suggestions and comments on the manuscript. M. Van Bruaene gave field assistance. The Marian University School of Mathematics and Sciences funded this project.

LITERATURE CITED

Aldous, S.E. 1938. Beaver food utilization studies. Journal of Wildlife Management 2:215–222.

Baker, B.W. & E.P. Hill. 2003. Beaver (Castor canadensis). Pp. 288–310. In Wild Mammals of North America: Biology, Management and Conservation. G.A. Feldhamer, B.C. Thompson & J.A. Chapman, (eds.). Johns Hopkins University Press, Baltimore, MD. 1216 pp.

Belovsky, G.E. 1984. Summer diet optimization by beaver. The American Midland Naturalist 111:209–222.

Berry, S.S. 1923. Observations on a Montana beaver canal. Journal of Mammalogy 4:92–103.

Brenner, F.J. 1962. Foods consumed by beavers in Crawford County, Pennsylvania. Journal of Wildlife Management 26:104–107.

Busher, P.E. 1996. Food caching behavior of beavers (*Castor canadensis*) – selection and use of woody species. American Midland Naturalist 135:343–348.

Butler, D.R. & G.P. Malanson. 1994. Beaver landforms. The Canadian Geographer 38:76–79.

Denney, R.N. 1952. A summary of North American beaver management 1946–1948. Colorado Fish and Game Department Report 28:1–14.

Fryxell, J.M. & C.M. Doucet. 1991. Provisioning time and central-place foraging in beavers. Canadian Journal of Zoology 69:1308–1313.

Gurnell, A.M. 1998. The hydrogeomorphological effects of beaver dam-building activity. Progress in Physical Geography 22:167–189.

Hall, J.G. 1960. Willow and Aspen in the ecology of beaver on Sagehen Creek, California. Ecology 41:484–494.

Howard, R.J. & J.S. Larson. 1985. A stream habitat classification system for beaver. Journal of Wildlife Management 49:19–25.

Jenkins, S.H. 1980. A size-distance relation in food selection by beavers. Ecology 61:740–746.

Johnston, C.A. & R.J. Naiman. 1987. Boundary dynamics at the aquatic-terrestrial interface: the interface of beaver and geomorphology. Landscape Ecology 1:47–57.

Kendall, M. 1938. A New Measure of Rank Correlation. Biometrika 30(1–2):81–89.

McGinley, M.A. & T.G. Whitham. 1985. Central place foraging by beavers (*Castor canadensis*): a test of foraging predictions and the impact of selective feeding on the growth form of cottonwoods (*Populus femontii*). Oecologica 66:558–562.

Mitchell, C.C. & W.A. Nierring. 1993. Vegetation change in a topogenic bog following beaver flooding. Bulletin of the Torrey Botanical Club 120:136–147.

Naiman, R.J., J.M. Melillo & J.E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (Castor canadensis). Ecology 67:1254–1269.

Raffel, T.R., N. Smith, C. Cortright & A.J. Gatz. 2009. Central place foraging by beavers (*Castor canadensis*) in a complex lake habitat. American Midland Naturalist 162:62–73.

Rebertus, A.J. 1986. Bogs as beaver habitat in north-central Minnesota. American Midland Naturalist 116:240–245.

Roberts, T.H. & D.H. Arner. 1984. Food habits of beaver in east-central Mississippi. Journal of Wildlife Management 48:1414–1419.

Rosell, F., O. Bozser, P. Collen & H. Parker. 2005. Ecological impact of beavers *Castor fiber* and *Castor canadensis* and their ability to modify ecosystems. Mammal Review 35:248–276.

Townsend, J.E. 1953. Beaver ecology in western Montana with special reference to movements. Journal of Mammalogy 34:459–479.

Warren, E.R. 1927. The Beaver – its work and its ways. 1st Edition. Williams and Wilkins Co., Baltimore, MD. 177 pp.

Manuscript received 16 March 2012, revised 30 January 2013.