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Article *in* Wetlands · October 2015

DOI: 10.1007/s13157-015-0688-5

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Wetlands (2015) 35:1013–1019
DOI 10.1007/s13157-015-0688-5

SHORT COMMUNICATION

Fate of 150 Year Old Beaver Ponds in the Laurentian Great Lakes Region

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Received: 26 March 2015 / Accepted: 3 August 2015 / Published online: 15 August 2015

Abstract The North American beaver, *Castor canadensis*, has recovered from historic overtrapping, recolonizing much of its former range as its population expanded. Previous studies using historical aerial photos document recent increases in number of beaver ponds, but the long-term sustainability of beaver populations and their ponds over centuries of landscape alteration is unknown. This paper analyzes the fate of beaver ponds mapped in 1868 near Ishpeming, Michigan, USA. Of the 64 beaver dam and pond sites mapped in the 1860s, 72 % were still discernible in 2014. Land use changes that altered the terrain (mining, residential development) or stream paths (channelization) were the main sources of beaver pond loss. This remarkable consistency in beaver pond placement over the last 150 years is evidence of the beaver's resilience.

Keywords *Castor canadensis* · Dam · Stream · Landscape · Land use · Ecological engineer

Introduction

The North American beaver (*Castor canadensis*) is the quintessential ecosystem engineer, causing structural change through its dam building that results in abiotic and biotic environmental changes (Jones et al. 2010; Hood and Larson 2015). The beaver is also a keystone species for riparian obligate animals, providing habitat for many species of waterfowl, wildlife, fish, and invertebrates through its pond building (Grover and Baldassarre 1995; Brown et al. 1996; Ray et al. 2004; Hood and Larson 2014). Beavers were extirpated in many regions by over-trapping during the 1700s and 1800s (Naiman et al. 1988), but beaver populations recovered during the 20th century throughout much of North America and Europe (Ingle-Sidorowicz 1982; Nolet and Rosell 1998).

Given the beaver's relatively recent reappearance, we know little about the long-term sustainability of beaver populations and their ponds. Aerial photos provide evidence of beaver population recovery by documenting the physical evidence of beaver ecosystem engineering, but the earliest aerial photos date back only 75 years to the 1940s. Changes since that time represent a period of beaver expansion as beaver populations increased and dispersed to exploit new habitats (Snodgrass 1997; Syphard and Garcia 2001; Morrison et al. 2015). This paper asks, "Can the artifacts of beaver engineering still be detected after a century or more?"

A unique map, prepared in 1868, exists to address that question. Lewis H. Morgan was a 19th century industrialist, anthropologist, and naturalist who became enamored with the American beaver during his visits to the Upper Peninsula of Michigan, USA. He was on the Board of Directors of the Marquette and Ontonagon Railroad (M&O), which provided access from Lake Superior through a roadless forest to multiple inland iron mines. In his book, "The American Beaver and His Works," Morgan (1868) wrote:

> It so happened that this Railroad passed through a beaver district, more remarkable, perhaps, than any other of equal extent to be found in any part of North America. By opening this wilderness in advance of all settlement, the beavers were surprised, so to speak, in the midst of their works, which, at the same time, were rendered accessible for minute and deliberate investigation, in a

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manner altogether unusual. A rare opportunity was thus offered to examine the works of the beaver, and to see him in his native wilds.

Morgan's 1868 book contains a 19×25 cm fold-out map (1:51, 914) of 64 beaver dams along streams that he fished while visiting the Ishpeming, Michigan area between 1855 and 1867. Beavers were still abundant in the region, although the beaver fur trade in Michigan had begun to decline by the late 1830s (Johnson 1919). In addition to the beaver dams, Morgan's map shows major lakes, rivers, railroads, mines, and settlements as they existed in the 1860s (Fig. 1a). The map was drawn from "materials furnished by the author" by L. K. Dorrance and William H. Steele, civil engineers who worked for the M&O (Morgan 1868). Mapping methods are not described, but Morgan photographed and measured a number of the beaver dams, describing them in the book.

The Ishpeming area has developed since the 1860s, particularly as mines noted on Morgan's map expanded and coalesced. However, beaver ponds still exist there, and can now be mapped with digital aerial imagery and geographic information systems (GIS), tools that were unavailable to Morgan.

The purpose of this research is to evaluate the long-term sustainability of beaver ponds by determining the fate of beaver ponds mapped by Morgan 150 years ago. Specific goals are: (1) to determine if the original map is sufficiently accurate to compare with current data, (2) if so, to compare beaver ponds visible on contemporary imagery with those marked on the 1860s map, and (3) to classify the land use changes that affected those 1860s beaver ponds.

Study Site and Methods

The 124 km^2 study area (46°29′N, 87°42′W) has Precambrian metamorphic bedrock overlain by thin glacial drift and outwash (Simmons 1974; Jerome 2006). Elevation ranges from 403 to 545 m (Fig. 2). The study area straddles the drainage divide between Great Lakes Superior and Michigan: Carp Creek flows east to Lake Superior, whereas Ely Creek flows south into the Escanaba River and Lake Michigan. Average discharge of Carp Creek at Ishpeming is 0.34 cms, and that of Ely Creek at National Mine is 0.15 cms (Wiitala et al. 1967). All lakes mapped within the study area are of natural origin, except Deer Lake was greatly expanded by the 1911 construction of the Carp River hydroelectric dam (compare Fig. 1a and b). Natural land types (forest, shrubland, grassland, wetland, water) cover 77 % of the study area, with the remainder in barren land (i.e., mines) or development (USGS 2015a). Residences are concentrated within Ishpeming (population 6470) and West Ishpeming (population 2662); the population density in rural Ishpeming Township is only 14.9 persons per km^2.

I prepared a map of beaver meadow, pond, and dam locations corresponding to those on Morgan's map using established aerial photo interpretation methods (Johnston and Naiman 1990) and on-screen delineation of 2014 color digital orthoimagery (1-m pixels), supplemented by orthoimagery downloaded for 1993, 1999, 2005, and 2012 (USDA 2015; USGS 2015b), and inspection of other image dates in Google Earth (http://www.google.com/earth/). Features were digitized as lines (dams) or polygons (ponds & meadows), classified according to fate. All site confirmations were done with aerial imagery.

A pivotal feature of the Morgan map is the location of the M&O Railroad and its branches, which paralleled Carp and Ely Creeks. The railroad was abandoned by the time of this study, but its roadbed was clear on the aerial imagery. The 1952 Ishpeming topographic map aided interpretation of abandoned railroad location (USGS 2015c).

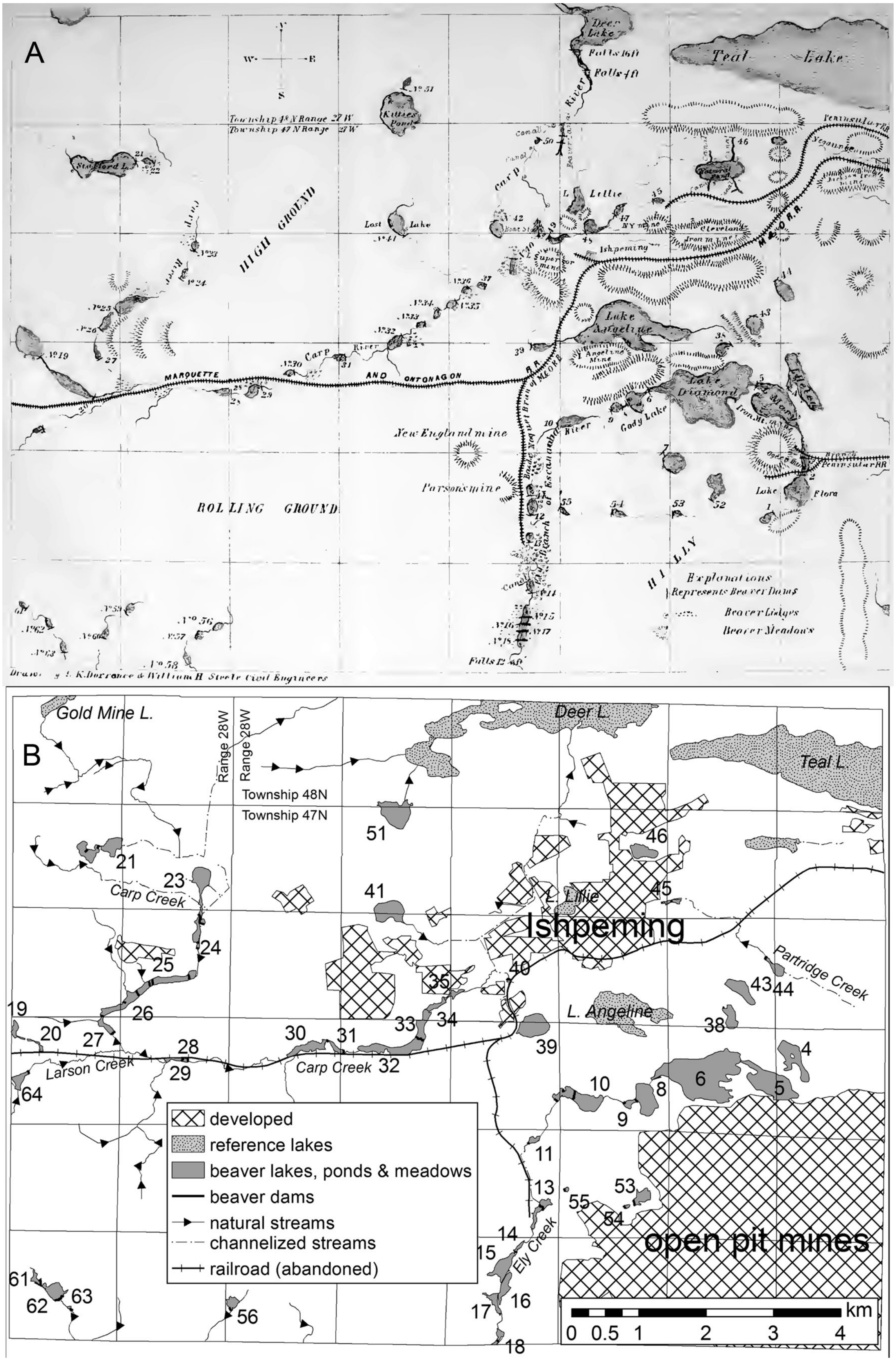
Ancillary data used for map creation included Public Land Survey System (PLSS) boundaries (Michigan Geographic Data Library 2015) and 1/3 arc-second digital elevation data (USGS 2015d). Lake and stream locations were extracted from the National Hydrography Dataset (NHD) (USGS 2015e), and I classified all NHD streams into "channelized" (straightened, presence of spoil banks) and "natural" (meandering) based on aerial photo evidence. I also delineated polygons to show areas of concentrated development and mining based on aerial photo evidence and the 2011 National Land Cover Database (USGS 2015a). All image and GIS data layers were projected as NAD83 UTM Zone 16 N using ArcMap 10.1.

Results

Accuracy of the Morgan Map

Morgan's map was created by civil engineers who were familiar with the location of the railroads, which were probably surveyed using a theodolite and stadia rod. The railroads I drew in Fig. 1b appeared on the 1952 topographic map, and generally followed the route of the old M&O on Morgan's map (Fig. 1a). Railroad beds are relatively immovable features that are persistently visible as linear features on aerial photos, but some may have been eliminated by mining and urban development (e.g., in the vicinity of sites #39 and 40, Fig. 1). Some mismatch in railroad location is probably due to inaccuracies in Morgan's map.

Fig. 1 Map of beaver ponds and other landscape features near ▶ Ishpeming, Michigan. **a** Original map from *The American Beaver and His Works* (Morgan 1868). **b** Map of beaver ponds and dams as of 2014 for the same area


A
Teal Lake
Deer Lake
HIGH GROUND
ROLLING GROUND
HILLY
MARQUETTE AND ONTONAGON
Lost Lake
Lake Angeline
Lake Diamond
Gody Lake
Ishpeming
Cleveland
New England mine
Parsons mine
Explorations
Represents Beaver Dams
Beaver Lodges
Beaver Meadows
B
Gold Mine L.
Deer L.
Teal L.
Range 28W
Range 28W
Township 48N
Township 47N
Carp Creek
L. Lillie
Ishpeming
Partridge Creek
L. Angeline
Larson Creek
Carp Creek
Ely Creek
developed
reference lakes
beaver lakes, ponds & meadows
beaver dams
natural streams
channelized streams
railroad (abandoned)
open pit mines
0 0.5 1 2 3 4 km

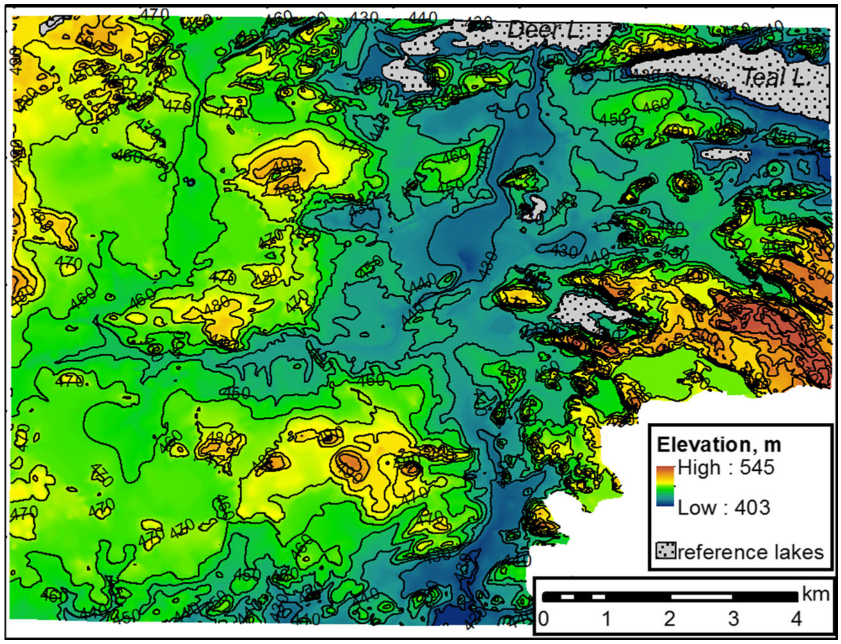


Fig. 2 Elevation of the area mapped, derived from the National Elevation Dataset (USGS 2015d)

The PLSS, which established the boundaries of each square-mile "section" of land in the study site (grid lines on Fig. 1), may have aided the positional accuracy of Morgan's map. However, field evidence of the PLSS was scant (section corner monumentation consisted of posts in rock piles and blazes on nearby "witness trees"; Schulte and Mladenoff 2001), so Morgan may not have benefitted from the PLSS in sketching his field maps.

The location and boundaries of the permanent lakes in the study area were relatively accurate, although many of the lake names changed since the 1860s. Lake Flora no longer exists due to mining activities. Mapping errors by Morgan include the exaggerated size of Teal Lake and the location of "natural pond" (pond #46), which is farther west than mapped by Morgan (Fig. 1).

Stream locations generally matched between Morgan's map and current conditions. Of the 69.7 km of streams in the study area, 22 % were channelized by humans around urban and mining areas prior to 1952, the date of the historical topographic map. The location of Ely Creek was also offset on Morgan's map in comparison to current stream flowpaths, but the 2014 flowpath is more consistent with topographic constraints (Fig. 2). I compensated for this streambed offset by searching for beaver evidence relative to the stream itself rather than using absolute geographic coordinates. With this adjustment, I concluded that Morgan's map was generally accurate.

Extant Beaver Dams, Meadows, Ponds, and Lakes

Artifacts of nearly three-fourths (46 out of 64) of the beaver dam and pond sites mapped by Morgan in the 1860s were still discernible on aerial imagery in 2014 (Fig. 1, Table 1). Sixteen sites were still beaver ponds. Seven natural lakes and ponds that had previously supported beaver were still present. Twenty-three sites were riparian wetlands with vegetation (shrub, meadow) typical of abandoned beaver ponds. Only 18 sites were undetectable; destroyed by human earth-moving activities (mining, residential development), stream channelization, or obscured by forest (Table 1).

Most of the extant beaver dams were located along Carp and Ely Creeks. Although Morgan's map depicts most of these dams as forming discrete ponds, the riparian areas of these creeks are now nearly filled with beaver meadows that are crossed by relict beaver dams. Dams typifying this condition include 13–18 along Ely Creek and 25–31 along Carp Creek (Fig. 1b). The cumulative area of extant beaver ponds and meadows was 128 ha, which constituted 1.0 % of the 124 km^2 study area.

Table 1 Fate in 2014 of beaver ponds mapped by Morgan (1868). Site numbers refer to beaver ponds shown in Fig. 1

Category	Count	Site numbers
Gone – buried	10	1, 2, 3, 7, 36, 37, 47–49, 52
Gone – channelized	4	12, 22, 42, 50
Gone – forested	4	57–60
Extant – beaver pond	16	4, 8, 9, 23, 24, 38, 40, 44, 45, 53–55, 61–64
Extant water body – no beaver dam	7	5, 6, 39, 41, 43, 46, 51
Extant – beaver meadow	16	10, 11, 13–18, 21, 25–31
Extant – shrub wetland	7	19, 20, 32–35, 56

Three beaver dams remained at the outlets of three small lakes as of 2014: Lake Helen (#4, now Lake Miller), Stafford Lake (#21, now North Lake), and Gunpowder Lake (#44). Lake outlet dams raise the water level in a lake but do not create the water body. Lakes having outlet beaver dams in the 1860s but not in 2014 were Lake Mary (#5, now Lake Ogden), Lake Diamond (#6, now Lake Sally), Lost Lake (#41, now Rock Lake), Lake Minnie (#43), and Kittie's Pond (#51, now Cooper Lake) (Fig. 1b).

A beaver dam described in detail by Morgan was and still is located at the outlet of "Grass Lake" (#8). Morgan was impressed by the dam's 80 m length, 1.9 m height, and large volume of material. The site is certainly in the same location because Grass Lake is labeled on the 1952 topographic map, and the present dam is the same distance downstream from Lake Diamond (now Lake Sally) as described in Morgan's text. The 11.2 ha Grass Lake was mostly filled with water in 2014, although beaver canals were visible traversing the marshes along its south end. The dam and western shore of Grass Lake are now an electrical power line right-of-way, which has altered the upland vegetation but not the presence of beaver.

The largest beaver-created feature in 2014 was the 12.3-ha pond #10, located 500-m downstream of Grass Lake. Its 2014 extent was larger than that mapped by Morgan, implying that its dams were raised over time. The 1993 and 1999 orthoimagery showed that the site contained a 150-m dam (Fig. 3). By 2005, the downstream dam had been raised to a level that submerged the 150-m dam, flooding the entire area. The downstream dam was breached before 2012, re-exposing the 150-m long dam, and by 2014 it was a beaver meadow. The path of the stream flowing through this pond remained in the same location despite being submerged between 1993 and 2012 (Fig. 3).

Missing and Abandoned Beaver Dams

Mine tailings in the southeast corner of the study area have greatly altered this landscape, burying beaver ponds and a permanent lake. Dams #1-3 in the headwaters of Ely Creek were completely obliterated by iron mines and their tailings, as were dams #7 and #52. Fortunately, the bedrock terrain that contains most of the iron ore (marked "HILLY" on Fig. 1a) contained only headwater streams with relatively few beaver ponds, so losses were few despite the large extent of the mine tailings. Five beaver dams were destroyed by the development of Ishpeming, and four dams were destroyed by stream channelization. Four sites mapped by Morgan along tributary streams in the southwest corner of the study site (#57–60) were not identifiable at all, and were forested as of 2014 (Table 1).

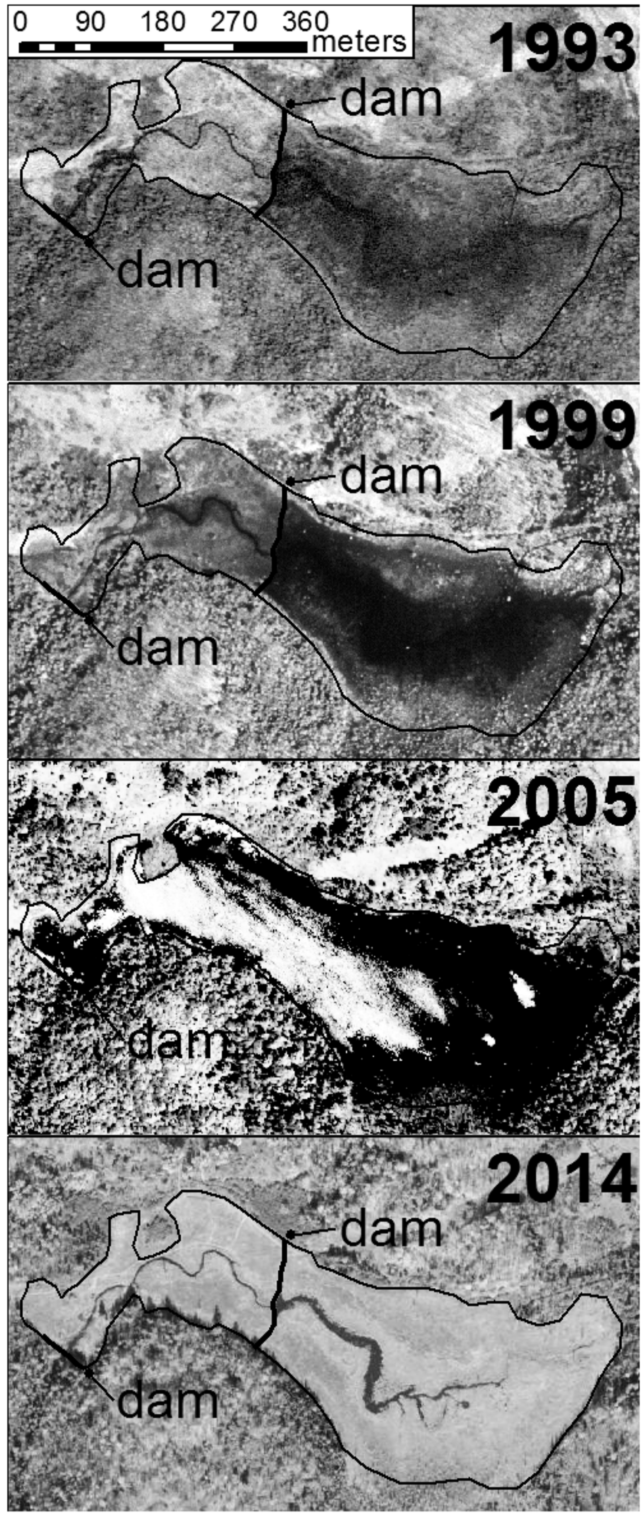


Fig. 3 Aerial imagery of pond #10 showing location of beaver dams, 1993–2014. Bright white streaks on 2005 photo are due to mirror-like (specular) reflection from the pond water surface

Discussion

This analysis demonstrates that beaver dams, ponds, and meadows are durable landscape features. It is unlikely that individual sites were continuously occupied by beavers because ponds are abandoned when forage becomes depleted (Fryxell 2001; Hyvönen and Nummi 2008), but the sites were probably reused over time. Recolonization of abandoned sites repeatedly sets back vegetation succession (Ray et al. 2001; Little et al. 2012; Johnston and Windels 2015); recolonization return intervals of 9 to 30 years after abandonment have been reported (Remillard et al. 1987; Hyvönen and Nummi 2008). Continuous pond occupation can be as long as 31 years (Stevens et al. 2006), and 20 % of beaver ponds were continuously occupied in an 11-year Ontario study (Fryxell 2001).

Older beaver ponds are biologically more diverse. Ponds of intermediate age (11–40 years) had the highest plant diversity (Ray et al. 2001), and older ponds (>25 years) supported breeding and reproduction of the wood frog (*Lithobates sylvaticus*) (Stevens et al. 2006). The earliest-established beaver ponds also tend to be larger and less prone to abandonment than later-established ponds (Johnston and Naiman 1990; Cunningham et al. 2006). Knowing the age of beaver pond establishment can thus aid evaluation of habitat value to other pond denizens.

Land use changes since Morgan's time have affected the presence of beaver in that system. The mining that prompted construction of the M&O railroad has completely re-sculpted 14 km^2 of land in the southeast corner of the study area. Roads and additional railroads have been built in the region since the 1860s. Railroads tend to be located in the lowland areas frequented by beavers because both trains and beaver dams require gentle slopes. The M&O railroad bed not only provided Morgan with access to the beaver ponds, but also provided an elevated platform from which to observe them and a frame of reference for mapping them. Beavers often utilize roadbeds in dam construction, flooding large areas by plugging road culverts (Johnston 2012), a phenomenon that I observed on the aerial imagery at several new ponds (not mapped) within the study area. Outburst floods from beaver dam failure have significantly impacted railway lines (Butler and Malanson 2005).

There was no evidence that the beaver dams affected channel stability. I saw no channel migration when I compared the 1993 versus 2014 orthoimagery at pond #10 (Fig. 3) nor anywhere else in the study area. This observation is consistent with the finding of Curran and Cannatelli (2014) that there was no channel migration when beaver dams were destroyed in a flood in Virginia, USA, but differs from observations in the western U.S. that beaver dams promote vertical aggradation of the floodplain and alter channel form (Pollock et al. 2007; Westbrook et al. 2011).

Lewis Morgan's work continues to inspire contemporary conservationists (Gewertz and Errington 2015). He was not the first naturalist to describe beaver works, but he was the first to provide quantitative data about a large number of beaver ponds, dams, and lodges. His geospatial data were sufficiently well documented to make them scientifically useful. Mapping methods in the 1860s were primitive in comparison to today's methods, lacking the aerial photography, global positioning systems, and ancillary digital data that enable contemporary map-making. Given those restrictions, the features on Morgan's map are surprisingly recognizable in the 21st century.

This study shows remarkable consistency in beaver pond placement over the last 150 years, despite some land use changes that altered beaver habitat. This constancy is evidence of the beaver's resilience, and a reminder that beaver works have been altering the North American landscape for centuries.

Acknowledgments Suggestions from four anonymous reviewers improved the quality of this manuscript. This work was supported by National Science Foundation grant DEB-1349240 and USDA Hatch Project H505-14.

References

Brown D, Hubert W, Anderson S (1996) Beaver ponds create wetland habitat for birds in mountains of southeastern Wyoming. Wetlands 16:127–133

Butler DR, Malanson GP (2005) The geomorphic influences of beaver dams and failures of beaver dams. Geomorphology 71:48–60

Cunningham JM, Calhoun AJK, Glanz WE (2006) Patterns of beaver colonization and wetland change in Acadia National Park. Northeastern Naturalist 13:583–596

Curran JC, Cannatelli KM (2014) The impact of beaver dams on the morphology of a river in the eastern United States with implications for river restoration. Earth Surface Processes and Landforms 39: 1236–1244

Fryxell JM (2001) Habitat suitability and source–sink dynamics of beavers. Journal of Animal Ecology 70:310–316

Gewertz D, Errington F (2015) Doing good and doing well: prairie wetlands, private property, and the public trust. American Anthropologist 117:17–31

Grover AM, Baldassarre GA (1995) Bird species richness within beaver ponds in south-central New York. Wetlands 15:108–118

Hood GA, Larson DG (2014) Beaver-created habitat heterogeneity influences aquatic invertebrate assemblages in boreal Canada. Wetlands 34:19–29

Hood GA, Larson DG (2015) Ecological engineering and aquatic connectivity: a new perspective from beaver-modified wetlands. Freshwater Biology 60:198–208

Hyvönen T, Nummi P (2008) Habitat dynamics of beaver *Castor canadensis* at two spatial scales. Wildlife Biology 14:302–308

Ingle-Sidorowicz HM (1982) Beaver increase in Ontario: result of changing environment. Mammalia 46:167–175

Jerome DS (2006) Landforms of the Upper Peninsula, Michigan. Natural Resource Conservation Service, Marquette

Johnson IA (1919) The Michigan fur trade. Michigan Historical Commission, Lansing

Johnston CA (2012) Beaver wetlands. In: Batzer DP, Baldwin A (eds) Wetland habitats of North America: Ecology and Conservation Concerns. University of California Press, Berkeley, pp 161–171

Johnston CA, Naiman RJ (1990) Aquatic patch creation in relation to beaver population trends. Ecology 71:1617–1621

Johnston CA, Windels SK (2015) Using beaver works to estimate colony activity in boreal landscapes. Journal of Wildlife Management. doi: 10.1002/jwmg.927

Jones CG, Gutiérrez JL, Byers JE, Crooks JA, Lambrinos JG, Talley TS (2010) A framework for understanding physical ecosystem engineering by organisms. Oikos 119:1862–1869

Little AM, Guntenspergen GR, Allen TFH (2012) Wetland vegetation dynamics in response to beaver (*Castor canadensis*) activity at multiple scales. Ecoscience 19:246–257

Michigan Geographic Data Library (2015) Michigan Public Land Survey Sections (online database). http://www.mcgi.state.mi.us/mgdl/?rel=ext&action=sext. Accessed 13 Nov 2014

Morgan LH (1868) The American beaver and his works. J. B. Lippencott & Co., Philadelphia. https://archive.org/details/americanbeaverhi68morg. Accessed 12 Nov 2014

Morrison A, Westbrook CJ, Bedard-Haughn A (2015) Distribution of Canadian Rocky Mountain wetlands impacted by beaver. Wetlands 35:95–104

Naiman RJ, Johnston CA, Kelley JC (1988) Alteration of North American streams by beaver. Bioscience 38:753–762

Nolet BA, Rosell F (1998) Comeback of the beaver *Castor fiber*: an overview of old and new conservation problems. Biological Conservation 83:165–173

Pollock MM, Beechie TJ, Jordan CE (2007) Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforms 32:1174–1185

Ray AM, Rebertus AJ, Ray HL (2001) Macrophyte succession in Minnesota beaver ponds. Canadian Journal of Botany-Revue Canadienne De Botanique 79:487–499

Ray HL, Ray AM, Rebertus AJ (2004) Rapid establishment of fish in isolated peatland beaver ponds. Wetlands 24:399–405

Remillard MM, Gruendling GK, Bogucki DJ (1987) Disturbance by beaver (*Castor canadensis* Kuhl) and increased landscape heterogeneity. In: Turner MG (ed) Landscape heterogeneity and disturbance. Springer, New York, pp 103–122

Schulte LA, Mladenoff DJ (2001) The original US public land survey records: their use and limitations in reconstructing presettlement vegetation. Journal of Forestry 99(10):5–10

Simmons, GC (1974) Bedrock geologic map of the Ishpeming quadrangle, Marquette County, Michigan (1:24,000 Map). Miscellaneous Geologic Investigations Map GQ-1130. U.S. Geological Survey, Reston, VA

Snodgrass JW (1997) Temporal and spatial dynamics of beaver-created patches as influenced by management practices in a south-eastern North American landscape. Journal of Applied Ecology 34:1043–1056

Stevens CE, Paszkowski CA, Scrimgeour GJ (2006) Older is better: beaver ponds on boreal streams as breeding habitat for the wood frog. Journal of Wildlife Management 70:1360–1371

Syphard AD, Garcia MW (2001) Human- and beaver-induced wetland changes in the Chickahominy River watershed from 1953 to 1994. Wetlands 21:342–353

USDA (2015) Geospatial Data Gateway (online spatial dataset). https://gdg.sc.egov.usda.gov/. Accessed 12 Jun 2015

USGS (2015a) National Land Cover Database 2011 (online spatial dataset). U.S. Geological Survey. http://www.mrlc.gov/nlcd11_data.php. Accessed 16 Jun 2015

USGS (2015b) Orthoimagery (online spatial dataset). U.S. Geological Survey. http://nationalmap.gov/ortho.html. Accessed 16 Jun 2015

USGS (2015c) Historical Topographic Map Collection (online spatial dataset). U.S. Geological Survey. http://nationalmap.gov/historical/ Accessed 16 June 2015

USGS (2015d) National Elevation Dataset (online spatial dataset) http://ned.usgs.gov/. Accessed 16 Jun 2015

USGS (2015e) National Hydrography Dataset (online spatial dataset). U.S. Geological Survey. http://nhd.usgs.gov/. Accessed 16 Jun 2015

Westbrook CJ, Cooper DJ, Baker BW (2011) Beaver assisted river valley formation. River Research and Applications 27:247–256

Wiitala, SW, Newport, TG, and Skinner, EL (1967) Water resources of the Marquette Iron Range area, Michigan. U.S. Geological Survey Water-Supply Paper 1842. U.S. Government Printing Office, Washington, DC