BEAVER TRAPPING CLOSURES
PUBLISHED STUDIES AND STUDY RESULTS

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EXECUTIVE SUMMARY

Twelve peer-reviewed, published studies were obtained that evaluated how beaver activity, and, in many studies, habitat changed in response to a trapping closure. Eleven studies occurred in the United States and one in England. Two additional studies are included. One was a peer-reviewed published study in an area not closed but that captured the impact of beaver presence and then removal via trapping on a section of stream (Fouty 2018). The second was an unpublished 1942 Oregon State University Bachelor of Science thesis. This study gives insight into the information presented in the Kebbe (1960) publication on Oregon's trapping history from 1899-1952. Study locations are found in Figure 1 and references in Table 1.

A variety of features were examined in these studies and publication dates range from 1942 to 2018. Studies occurred in California, Maine, Massachusetts, Minnesota, Montana, Oregon, New York, Wyoming, and southwest England. The study time periods ranged from 4 to 89 years and covered ecosystems ranging from boreal forests to semi-arid regions. Closure size ranged from 56.8 acres (England exclosure study) to 63 million acres (state of Oregon).

In the closure studies, mortality from human-caused trapping and hunting was eliminated. All other mortality causes remained (e.g., carnivore predation, disease, changing habitat conditions, accidents).

Three closure studies occurred in Oregon. The first closure study was done by Chester Kebbe (chief biologist, fur resources) and published in the Oregon State Game Commission Bulletin (Kebbe 1960). Kebbe examined Oregon's trapping history and responses to trapping closures and reopening from 1899 to 1952. During this time Oregon was entirely closed to beaver trapping/hunting twice: 1899-1917 and 1932-1952 with large partial closures at other times involving entire counties. In general, only agricultural lands were opened in order to confine trapping to areas of damage and prevent over-trapping on mountain streams. National Forest lands were closed from 1899-1952 except for 6-7 years when Benton and Marion Counties were completely open in 1917 and 1918 to 1923. A 1942 unpublished Master's Thesis from Oregon State University explains the reasons for changes in the state's trapping policy. It also explains how the opening of the state from 1923 to 1931 affected national forests (Gilliam 1942). There were no BLM lands until 1946.

The two other Oregon studies examined changes on Bridge Creek in Wheeler County, a spatially complex closure due to multiple land management and ownerships (Demmer and Beschta

2008; Weber et al 2017). The watershed includes BLM managed lands, national forest lands, private lands, a national monument, and state lands. The portions of the watershed that occur on federally-managed public lands are closed under two different closures. The closure of the portion of the watershed on BLM land only closed Bridge Creek and its tributaries. The surrounding BLM land is open which is the foraging area for beaver. The closure of the portion of the watershed that resides on the Ochoco National Forest (headwaters) closed both water and the land foraging base. The remaining areas (national monument, private lands, state lands) are open to beaver trapping and hunting.

Features Measured or Tracked

Features studied fell into four general categories: beaver-related, habitat-related, wildlife (excluding beaver), and social (Table 2). The most common beaver-related feature measured was active colonies and/or beaver dams. Assessment of active colonies was based on one or more of the following: active dams, bank dens, lodges and food caches. Also examined were changes in density of active beaver colonies, beaver age classes, number of live beavers, number reported trapped, and number relocated. Habitat features examined were changes in riparian habitat and water-related habitat types, pond number and dimensions, water quality, stream flows, water levels, and sediment deposited or eroded. Wildlife features examined were changes in density of breed pairs of selected waterfowl species. Social features examined were number of complaints or relocations, trapping history, and land owner interest in beaver presence. Most studies evaluated more than one feature.

Methods

The studies examined how various features changed over time in response to a closure. Methods of determining change included ground-based measurements, aerial photos, aerial (fixed-wing plane) surveys, repeat photos, information from reports or records, live trapping, dead trapping, and mark and release (Table 3). Methods varied as a function of available technology, questions asked, and metrics being measured. A number of studies had a field and office component.

Closure Results

The closure studies found increases in the number of beaver dams, active colonies, and populations. The study that examined population in Sagehen Ck, CA and Prescott Peninsula, MA, over 47 and 42 years respectively, captured fluctuations in populations in response to changes in habitat availability and drought conditions (Busher and Lyons 1999). Studies that evaluated riparian and/or water-related habitat found these expanded in abundance and complexity with increased beaver activity. Changes observed were increased amounts of ponded water, riparian areas, willows, complex and diverse water-habitat types (i.e., bogs, marshes, wetlands) and sediment deposition. Studies that evaluated water quality found decreases in stream temperatures, suspended sediment, nitrogen, and phosphate. The one study that evaluated stream flows in response to rainfall events found lower flood peaks with

longer durations. Regardless of geographic area, all studies showed ecosystem improvements as a result of the increased presence and activities of beaver following closure driven by increased beaver dams.

Two studies tracked complaints. Complaints increased with increased beaver activity. In eastern Warren County, NY, the dominate complaints were related to plugged culverts, flooding land and plugging ponds (Parson 1975). The majority of the county is private land. The causes of the complaints in the 1960 Oregon publication were not specifically listed (Kebbe 1960) but appear to be related to private lands and agriculture (Kebbe 1960). This assumption was confirmed in Gilliam (1942).

Trapping Results

Five studies provide insight into the effect of beaver trapping in 1) an area previously closed and then reopened, 2) two areas both previously trapped and only one closed, and 3) where beaver had existed long enough to build and maintain multiple dams despite the area being opened, then trapped out. The studies occurred in Oregon, Maine, Montana, and New York.

Closed then reopened

Oregon was fully closed to beaver trapping from 1899 to 1917 and from 1932 to 1952. (Kebbe 1960). The decision to reclose most of the state in 1931 after only eight trapping seasons and the entire state in 1932 was due to the rapid reduction in beaver numbers as indicated by number of beaver reported trapped. While the national forests were officially closed during this time it was noted that "opening seasons adjacent to the national forests was equivalent to opening the forests themselves" (Gillman 1942). Kebbe also noted a change in beaver numbers after the 1952 season [first 3-month open season in 30 years]. He noted that while the number of complaints received were comparable to the previous year [1951], most complaints involved only a pair of animals where previously large colonies had to be remove (Kebbe 1960).

In New York, eastern Warren County was closed to beaver trapping from 1965 to 1968 then the area reopened in 1969 (Parson 1975). Active beaver colonies increased from 11 in 1964 (pre closure) to 56 by 1967. No census data was gathered in 1968 because the airplane was required for other uses. In 1969, after a single open season, the number of active colonies had decreased to 41.

Comparison of two areas

The Maine study compared two sites during 1988-1992, one recently closed to trapping and a similar site that remained open to trapping (McCall et al 1996). The study found distinct differences over time between the two areas. The density of beaver colonies increased in the untrapped area but changed little in the trapped area. Number of maintained dams increased in untrapped area but showed little change in the trapped area. Number of wetlands increased in both areas but more in the untrapped area. Beaver created all new wetlands on both sites.

Total surface area of water increased on the untrapped area but remained the same on the trapped area. Flooded vegetation lifeforms increased in untrapped area but showed minimal changed in the trapped area. Changes in the density of waterfowl breeding pairs varied depending on the species. Number of wetlands used by waterfowl breeding pairs increased the most in the untrapped area.

Open area that is trapped

In Montana, beaver moved into a cattle exclosure, built dams, and were then removed via trapping as the area was open. In less than three years post-trapping dams failed, ponds drained and sediment eroded and the stream was again disconnected from its valley floor. A downstream control area saw no changes in water levels, volume of channel filled with water, or channel form despite the erosion of upstream sediment from behind the dams and elimination of beaver ponds (Fouty 2018).

The results from the documents cited are found in Table 4. Also included are study years, closure area if known, closure information, study goal(s), features tracked, and methods used. This additional information provides context to the results. Figure 1 and Tables 1-4 are found below.

All documents cited are available upon request.

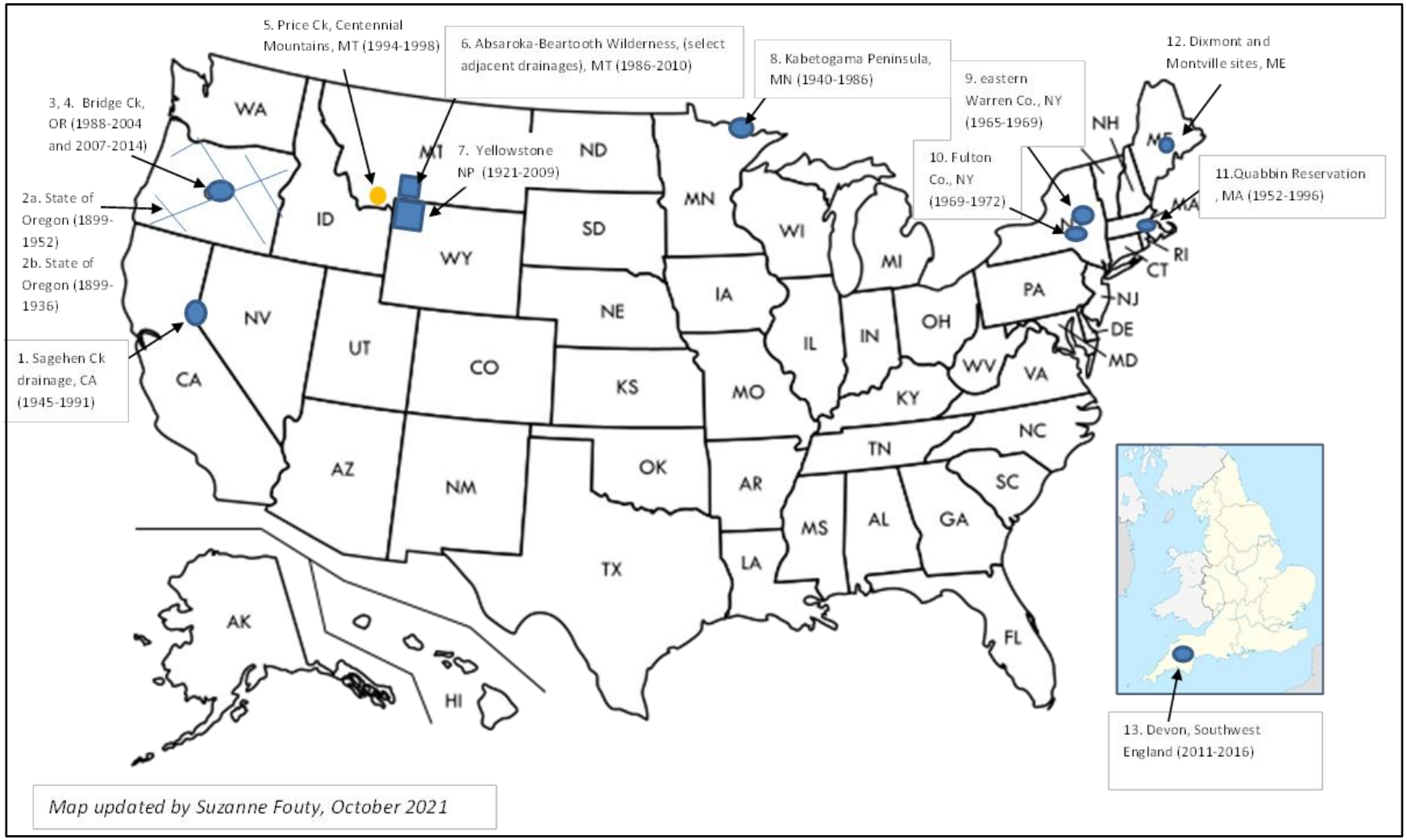

Figure 1. Generalized locations of published studies related to beaver trapping/hunting closures, changes in an open area related to arrival and subsequent trapping (#5, orange dot), and one unpublished Master's thesis (#2b). The years represents the period of study. The numbers correspond to the references found in Table 1.

Table 1. References and map number of beaver trapping closures studies, the unpublished Master's thesis (#2b), and one study of channel changes related to beaver arrival and subsequent removal via trapping in an open area (#5). All closures studies include land and water closures *except* ODFW's Bridge Creek Bureau of Land Management (BLM) closure (#3, 4). Only its creek and its tributaries are closed. The National Monument inside the BLM is open.

Map No.	Location	Reference
1	Sagehen Ck, California	Busher P.E., Lyons P.J. (1999) Long-Term Population Dynamics of The North American Beaver *Castor Canadensis* on Quabbin Reservation, Massachusetts, and Sagehen Creek, California. In: Busher P.E., Dzięciołowski R.M. (eds) Beaver Protection, Management, and Utilization in Europe and North America. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-4781-5_16
2a	State of Oregon	Kebbe, C.E. (1960). Oregon's beaver story. Oregon State Game Commission Bulletin. February 1960. No. 2, Vol. 15: pp. 3-6.
2b	State of Oregon	Gilliam, L. L (1942). History of beaver planting in Oregon with recommendations for planting in the future. Bachelor of Science thesis. School of Forestry, Oregon State University. 31p. (unpublished but available)
3	Bridge Creek, Oregon (study 1/2) ***Land base open***	Demmer, R. and Beschta, R. L. (2008). Recent History (1988 – 2004) of Beaver Dams along Bridge Creek in Central Oregon. Northwest Science, Vol. 82. No. 4, pp. 309 – 318.
4	Bridge Creek, Oregon (Study 2/2) ***Land base open***	Weber, N., Bouwes, N., Pollock, M.M., Volk, C., Wheaton, J.M., and Wathen, G. (2017). Alteration of stream temperature by natural and artificial beaver dams. PLoS ONE 12(5): e0176313. https://doi.org/ 10.1371/journal.pone.0176313
5	Price Creek, Centennial Mountains, Montana	Fouty, S. C. 2018. Euro-American beaver trapping and its long-term impact on drainage network form and function, water abundance, delivery, and system stability [Chapter 7] In: *Johnson, R. Roy; Carothers, Steven W.; Finch, Deborah M.; Kingsley, Kenneth J.; Stanley, John T., tech. eds. 2018. Riparian research and management: Past, present, future: Volume 1. Gen. Tech. Rep. RMRS-GTR-377. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station*. p. 102-133. doi: http://doi.org/10.2737/RMRS-GTR-377-CHAP7.
6	Hellroaring, Buffalo Fork, and Slough drainages in the Absaroka-Beartooth Wilderness, Montana	Scrafford, M. A. and d. B. Tyers, D. T. Patten, and B. F. Sowell. Beaver habitat selection for 24 yr since reintroduction north of Yellowstone National Park. (2018). Rangeland Ecology and Management 73, no. 2: 266-273. doi: 10.1016/j.rama.2017.12.
7	Yellowstone National Park, Wyoming	Smith, D. W. and D. B. Tyers. (2012). The history and current status and distribution of beavers in Yellowstone National Park. Northwest Science 86:276-288.

Map No.	Location	Reference
8	Kabetogama Peninsula, Minnesota	Naiman, R. J., Johnston, C. A. and Johnston. J.C. (1988). Alteration of North American Streams by Beaver. BioSciences, Vol. 38, No. 11, pp. 753- 762. URL: http://www.jstor.org/stable/1310784 and Dr. John Pastor, email correspondence, 2020)
9	eastern Warren County, New York	Parson, G. R. (1975). Effect of a 4-year closure of the trapping season for beaver in eastern Warren County, New York. New York Fish and Game Journal Vol. 22, No. 1
10	Fulton County, New York	Parson, G. and M. Brown (1978). Effect of a Four-year closure of trapping season for beaver in Fulton County. New York Fish and Game Journal, Vol. 25, No. 1.
11	Prescott Peninsula, Quabbin Reservation, Massachusetts	Busher P.E., Lyons P.J. (1999) Long-Term Population Dynamics of The North American Beaver *Castor Canadensis* on Quabbin Reservation, Massachusetts, and Sagehen Creek, California. In: Busher P.E., Dzięciołowski R.M. (eds) Beaver Protection, Management, and Utilization in Europe and North America. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-4781-5_16
12	Dixmont and Mountville sites, Maine	McCall, T.C., Hodgman, T. P., Diefenbach, D. R. and R. B. Owen, Jr (1996). Beaver populations and their relation to wetland habitat and breeding waterfowl in Maine. Wetlands. Vol. 16, No. 2, pp. 163-172.
13	Devon, SouthWest England	Puttock, A., Graham, H. A., Cunliffe, A. M., Elliott, M. and R. E. Brazier (2017). Eurasian beaver activity increases water storage, attenuates flow and mitigates diffuse pollution from intensively-managed grasslands. Science of the Total Environment 576, pp. 440-443.

Table 2. Features examined for change over time in response to beaver activity

Feature examined	Reference Number
Beaver feature	
Beaver dams	3, 4, 5, 6, 8, 12, 13
Active colonies (based on active dams, bank dens, lodges, food caches)	6, 7, 9, 10, 11,12
Density of active beaver colonies	12
Beaver populations	1
Beavers relocated	2a, 2b, 10
Beavers reported trapped	2a, 2b, 9
Beaver age classes	11
Habitat features	
Riparian vegetation and water-related habitat types	3, 6, 7, 8, 12
Water quality	4, 8, 13
Ponds (dimensions, volumes, surface area)	3, 8
Channel water depths	3, 5
Sediment deposited/eroded	5
Stream flows	13
Channel complexity	3
Wetted channel area	4
Surface water stored	13
Wildlife feature	
Density of breeding pairs of select waterfowl	12
Other	
Complaints	2a, 10
Trapping history	2a, 2b, 5, 9, 12
Landowner interest in beaver presence	2a

Table 3. General methods used to assess changes to a feature over time in response to beaver activity.

Methods Used	Reference Number
Field-based	
Ground-based measurements	1, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13
Aerial (fixed-wing plane) surveys	7, 9, 10, 12
Repeat field photos	3, 5
Mark and release	1, 11
Live trapping	1, 11, 12
Office-based	
Aerial photos	4, 8, 9, 10, 11, 12
Unpublished reports and/or records	2a, 2b, 7, 8, 9, 10, 11, 12
Published but not peer-reviewed reports	7
Published, peer-reviewed literature	2b, 7

Table 4. Descriptive information and results of beaver trapping closures studies, one study of channel changes related to beaver arrival and subsequent removal via trapping in an open area (#5), and one unpublished Thesis. The closures include land and water closures *except* ODFW's Bridge Creek Bureau of Land Management (BLM) closure (#3, 4). Only its creek and its tributaries are closed. The National Monument inside the BLM closure streams is open.

1. Sagehen Ck, California (Busher and Lyons 1999)
Study years: 1945 – 1991 (47 years) **Closure area:** Entire drainage closed but no size provided. Portion west of highway 89 presented in paper as the portion intensively studied. Total stream length = 13.5 km (8.4 miles) but only portion west of Hwy 89 presented in this study. **Closure information:** CA Department of Fish and Game introduce four adults into the area in 1945. No trapping/hunting permitted. **Study Goal:** Determine changes in numbers and dynamics of a local unexploited beaver population. **Features measured or tracked:** 1) Number of live beavers, not colonies **Methods used: L**ive trapping, mark and release, observation of colonies primarily during summer and autumn.
RESULTS: 1948 -1956: increase from 2 to 10 animals. (Phase 1 = slow growth) 1956 -1959: increase from 10 to 20 animals. (Phase 2 = more rapid increase) 1959 -1963: relatively stable, ranging between 18 and 22 animals. (Phase 3 = fluctuating populations at relatively high levels) 1963 -1969: decline from a high of 22 to 2 animals. (Phase 4 = steep decline) 1969 -1979: increase from 2 to 23 animals (Phase 5 = rapid increase) 1982 -1991: decline from 20 to 7 animals. (Phase 6 = steep decline) Second decline (Phase 6) due to two drought years and animal movement from west of Hwy 89 to the portion of the stream east of Hwy 89. "The second decline phase of the Sagehen Creek beaver population in the late 1980s supports this view of habitat saturation. It is possible that after two periods of high beaver numbers (early 1960s, 1970s) the vegetation in potentially marginal habitat may have been effectively depleted. (p. 157)"
2a. State of Oregon (Kebbe 1960)
Study years: 1899- 1952 (54 years) **Closure area:** Entire state of Oregon. 63 million acres (98,438 sq. miles). Covers open and closed periods. **Closure information:** State fully closed from 1899 -1917-1918 and 1932 to 1952. Partial closures other times involving entire counties. In general, only agricultural lands were opened in order to confine trapping to areas of damage and prevent over-trapping on mountain streams. National Forest lands closed from 1899-1952 except for 6-7 years when Benton and Marion Counties completely open (1917/1918-1923) **Study Goal:** Provide an overview of the history of beaver trapping and hunting closures in the state from 1899 to 1952 and results of various closures. **Features measured or tracked:** 1) trapping closure history in the state

2) number of beaver relocated to mountain streams
3) Damage complaints
4) Number of landowners interested in perpetuating beaver
5) Take of state trappers and then later private citizen trappers
Methods used: Number of dead beavers, relocation numbers, complaint number

RESULTS:

Closure History: State was completely closed twice to beaver trapping/hunting. The first was from 1899 to1917/1918 after which Benton and Marion Counties were opened. In 1923 entire state was opened except national forests and the five southwest counties. The entire state was again closed by the 1931 legislature from 1932 to 1952. The second statewide closure ended in 1952 when the legislature gave the Game Commission the authority to set trapping seasons and bag limits in 1951. States that "in general, only agricultural lands were opened in order to confine trapping to areas of damage and prevent over-trapping on mountain streams. (p.5)"

1938: Began relocating beavers from agricultural lands where their activities were seen as destructive and moved to places where their actions would bring benefits. Over 3000 beaver were relocated between 1938 and 1945 when dead trapping and pelting began. The change from relocation to dead trapping was due to the scarcity of suitable transplanting sites, increasing damage complaints, and a rapidly increasing beaver population over the entire state.

1942: 656 beaver were removed from complaint areas. By 1944 the number exceeded 2000.

1945: Landowners interested in perpetuating beaver were included in the management program. 590 landowners participated in 1945 and that increased to 1,500 in 1950 the last year the cooperative agreements were in effect.

1945 to 1950: Number of beaver removed by state trappers increased from 3,000 to 6,000/year. When state trappers under this program failed to remove a satisfactory number from complaint areas and had no effect on the large surpluses available elsewhere, legislation followed to set bag limits, open seasons and open streams and areas in 1951. In general, only agricultural lands were open.

[After 1952 season, 3-month open season first in 30 years] Complaints were received in numbers comparable to the previous year. One difference was noted, however, in that most complaints involved only a pair of animals where previously large colonies had to be removed.

"This [efforts post-1932 closure] restoration is a remarkable example of a fur species responding to protection and other management practices."

2b. State of Oregon (Gilliam 1942, unpublished OSU Bachelor of Science thesis)

Study years: 1899-1936 (38 years)
Closure area: Entire state of Oregon. 63 million acres (98,438 sq. miles). Covers open and closed periods.
Closure information: See Kebbe 1960 above**.**
Study Goal: Present a clear view of the beginning, progress, and present status of beaver planting in Oregon and 2) point out the advisability of planting beaver on public or private lands in Oregon.

Features measured or tracked:

1) Oregon's trapping and closure history
2) Numbers of licenses issued and beaver trapped during open trapping years (1923-1931)
3) History of beaver relocations/planting on national forests, numbers and locations and success
4) Relocation methods and factors considered

Methods used:

Review of existing studies and work carried on by the U.S. Forest Service, Oregon State Game Commission, and Pittman-Robertson Federal Aid Program in Oregon.

RESULTS:

Listed reasons for the initial state closure in 1899, the state reopening, and subsequent reclosure:

- Initial interest generated by ranchers who saw benefits of beaver related to stream flows and how that affected irrigation with focus in eastern Oregon. Baker and Malheur Counties are the first to be closed.

- Reopening in 1917 and 1918 in Benton and Marion Counties because beaver creating trouble in agricultural lands.

- Entire state reopened in 1923 in response to numerous complaints brought by ranchers against beaver damaging fruit trees and diverting irrigation water. Legislation ignored fact that the 1893 law allow landowners to control the animals doing damage. Two effects noted of opening: 1) Opening seasons adjacent to the national forests was equivalent to opening the forests themselves [National Forests had remained closed to trapping]. 2) Only part of the anticipated value of the fur crop would be realized due to wasteful methods of trapping and skinning by inexperienced persons.

In the first open season (1923-1924), 12,019 beavers were reported trapped. In the 1924-1925 season 3,669 were reported followed by 2,019 (1925-26), 1,336 (1926-27), 1,267 (1927-28), and 1,549 (1928-29). No beaver were reported for the 1929-1930 and the 1930-1931 seasons. The numbers reported are noted as low because 10 to 40% of the licenses failed to report on their catch.

- 1932 closure in response to rapid decline in number of beaver.

Relocating beaver in Oregon begins in 1932 after the state was closed to beaver trapping.

Between 1932 and 1936 beaver were relocated to eight national forests. Total number of beaver relocated were 637. Number of colonies = 131. Sources of beaver were lowlands were beaver were doing damage. Beaver relocated to the Deschutes, Fremont, Malheur, Ochoco, Rogue River, Umatilla, Wallowa, and Whitman NFs.

Examination of 53 plantings [relocations] on the Ochoco NF indicate that about 50% of the colonies settle in the vicinity of the planting site and the remainder disappear.

In 1936 state removed 264 beaver by dead-trapping, and co-operating agencies removed 370 by live-trapping [animals removed from private lands].

Presents information at the time on how to properly trap, handle, select, and transport live beavers for maximum success and site selection.

3. Bridge Creek, Oregon (study 1/2) (Demmer and Beschta 2008)

Study years: 1988- 2004 (17 years)
Closure area: Spatially complex closure. Bridge Ck and tributaries on BLM-managed lands are closed but waters only. Land base is open while those headwaters located on the Ochoco National Forest are closed (land and water). The National Monument and private land sit in the middle of the BLM area. The private, state, and National Monument are open. Estimated closure size = ¼ of watershed or 43,058 acres (67.3 sq. miles).
Closure information: ODFW closes Bridge Ck and all its tributaries on BLM-managed lands area to beaver trapping after 1991. Waters closed; land open. It remains an ODFW existing closure.
Study Goal: Determine impact of livestock grazing reduction (1988) and beaver trapping closure (post 1991) on the condition and characteristics of Bridge Creek and the riparian zone. Study examined a 31.7 km (19.7 miles) reach of Bridge Ck. Private lands excluded.
Features measured or tracked:

1) Beaver dams
2) riparian, channel complexity, secondary beaver-created channels
3) pond surface area, pond dimensions, pond volumes

Methods used: Ground surveys, photo points, field measurements, beaver dam surveys twice a year (early summer and late fall)

RESULTS:

1988: 36 beaver dams.
1989 – 1992: dams increase from 9 to 103 (low spring flows)
1992 – 1998: dams decrease from 103 to 9 (large spring high flows knock dams out). As water depths remained relatively high, beaver shifted to bank dens.
1998 – 2002: dams increase from 9 to about 60.
2002 – 2004: dams decrease from about 60 to 40.

Stability of dams related to magnitude of spring flows acting on dams in an incised channel. However, while dams failed during high flow years, the amount and complexity of the riparian zone and channel complexity increased. Dams remained in place from < 1 to 7 years. 75% lasting ≤ 2 years.

Vegetated riparian zones increased in width throughout much of the study reach as did the diversity of species (from coyote willow dominant to other species of willow, alder, water birch, red-osier dogwood and black cottonwood).

Channel complexity increased in the form of increased channel sinuosity, roughness via vegetation and woody material, secondary beaver-created channels, and ponds.

Pond dimensions: Max pond width = 8 m (± 5 m), pond lengths = 26 m (± 18 m), max pond depths = 0.8 m (± 0.3 m), pond surface areas = 120 m^2 (± 150 m^2), Pond volumes = 80 m^3 (± 130 m^3)

4. Bridge Creek, Oregon (Study 2/2) (Weber et al 2017)

Study years: 2007-2014 (8 years)
Closure area: Spatially complex closure. Bridge Ck and tributaries on BLM-managed lands are closed but waters only. Land base is open while those headwaters located on the Ochoco National Forest

are closed (land and water). The National Monument and private land sit in the middle of the BLM area. The private, state, and National Monument are open. Estimated closure size = ¼ of watershed or 43,058 acres (67.3 sq. miles).

Closure information: ODFW closes Bridge Ck and all its tributaries on BLM-managed lands area to beaver trapping after 1991. Waters closed; land open. It remains an ODFW existing closure. Study examined a 34 km (21.1 miles) reach of Bridge Ck. Private lands excluded.

Study Goals: Determine if and how natural beaver dams and/or BDA restoration structures

1) influence longitudinal surface water temperature regimes at the scale of stream segments, over seasons and at multiple scales
2) induce channel-scale temperature heterogeneity during periods of extreme surface water temperature during summer

Features measured or tracked:

1) Beaver dam numbers and distributions
2) Water quality (stream temperatures)
3) Changes in wetted channel area (includes ponded areas and flowing water)

Methods used: Aerial photos, ground surveys, 23 stream temperature loggers, BDA installation on 4 km of stream length and monitoring of effects

RESULTS: Beaver dams increased by an order of magnitude from 24 to 120 dams in reaches without beaver dam analogs (BDAs). Beaver also built and maintained dams on many of the BDAs in an additional 46 active beaver dams. The BDAs increased stream roughness and were more resistant to failure due to their design leading to decreased stream power during high flows. Their installation in a portion of the Bridge Creek allowed beaver dams to persist and increase in numbers and distributions beyond the BDA reach as a result of reduced stream power.

Average maximum daily stream temperatures decreased in the area with beaver by 2.6 *C when compared to the upstream control area pre and post BDA and beaver dams being built. Also, an increase in minimum stream temperatures by 1.76 *C compared to control site. The net result was a decrease in daily temperature variations.

In beaver-dominated areas the wetted channel area increased with values varying from 56% to 283% to 334% depending on location. In the control/no dam area, wetted area increased 16%.

5. Price Creek, Centennial Mountains, Montana (Fouty 2018)

Study years: 1995-1998

Closure area: Not a closure. Drainage area from 8.7 to 14.28 sq. km (3.4 to 5.5 sq. miles).

Closure information: While not a closure this publication is included because study captured channel changes related to beaver arrival and subsequent removal by trapping. Beaver moved into a cattle exclosure prior to 1994 and built multiple dams. Beaver trapped out post 1994 field season and prior to 1995 field season. Cross-sections inside the cattle exclosure were measured 1995, 1997, 1998. Cross-sections in the control area were measured 1994, 1995, 1997, 1998 (XS 17) and 1994, 1995, 1998 (XS 18)

Study Goals: Determine changes in channel cross-section areas and available channel capacity as a function of presence/absence of beaver dams, distance upstream of a dam, and dam integrity.

Features measured or tracked:

1) Beaver dam integrity (intact, failing, breached)
2) Changes on 14 channel cross-sections. Twelve were inside a cattle exclosure with multiple beaver dams. Exclosure cross-sections were distributed in several reaches. Two were located downstream of the exclosure and in a reach without dams.
3) Water depths, Available channel capacity, sediment deposited or eroded

4) Distance upstream of a beaver dam

Methods used: Repeat surveys of monumented cross-section sites in reaches with and without beaver dams, photos, field observations.

RESULTS:

In 1995 the available channel capacity (amount of channel not filled with water) at the 12 cross-sections inside the cattle exclosure ranged from 0% (channel full) to 69% (pond water level low) depending on integrity of the downstream dam. Distance from a beaver dam ranged from 3 to 35 m (10 to 115 ft).

Though dams appeared visually intact in 1995, the differences in water levels between sites revealed that some were in the early stages of disrepair. Clear breaching was visible in 5/12 sites by 1997. All 12 had breached by 1998 with 4/12 dams completely removed.

The available channel capacities (ACC) at the 12 sites increased from 0-69% in 1995 to 68 to 95% in 1998 as dams failed and were not repaired and ponds drained and sediment eroded. All 12 cross-sections in the cattle exclosure increased in ACC due to pond drainage but only cross-sections less than 15.2 m (50 ft) upstream of a dam (5/12) saw an increase in channel size as previously deposited sediment trapped behind the dams eroded.

The two cross-sections located downstream of the cattle exclosure and in reaches without beaver dams saw little to no change in their ACCs between 1995 and 1998 (87 to 89% and 94 to 94%). Water levels were similar and minimal to no sediment deposition or erosion occurred.

Area saw a net loss in sediment as the sediment previously trapped behind the beaver dams in the cattle exclosure moved through the system due to a lack of sediment trapping features downstream.

6. Hellroaring, Buffalo Fork, and Slough drainages in the Absaroka-Beartooth Wilderness portion of the Custer-Gallatin National Forest, Montana (Scrafford et al 2018)

Study years: 1986 – 2010 (24 years)

Closure area: 128,263 acres (200.4 sq. miles) (*Source: Scrafford 2011, M.S. Thesis and email comm. July 2020)*

Closure information: 46 beaver were reintroduced into area by US Forest Service between 1986 and 1999 after a 40-year absence. Montana Fish, Wildlife and Parks put a moratorium on trapping in Hellroaring, Buffalo Fork and Slough drainages.

Study Goal: Determine whether the desired outcomes of beaver reintroduction (restoring populations and riparian environments) were met

Features measured or tracked:

1) Active colonies (via beaver dams, food caches, bank dens, and lodges)
2) Density of active-beaver colonies and dams
3) Changes in willow cover
4) Habitats associated with beaver expansion since reintroduction

Methods used: Ground surveys

RESULTS:

Number of active beaver colonies increased with their density appearing to level in 2000. Colonies ranged from 1.23-1.44 active colonies/stream km from 2000-2010.

Number of active beaver dams increased. Range was 2.04-2.71 active dams/stream km from 2000-2010.

Beaver expanded from original meadows to 10 additional meadows within 9 years.

Meadows increased in willow cover from 1981 to 2011 by 16%.

Beaver reintroduction can be successful in riparian areas where willow stand condition is less than optimal.

7. Yellowstone National Park, Wyoming. (Smith and Tyers 2012)

Study years: 1921 to 2009 with focus on 1996 to 2009 (89 years)
Closure area: 2,221,440 acres 3471 sq. miles* *(from web*)
Closure information: Park established in 1872 but area was trapped. Sometime after establishment, beaver trapping and hunting ends.
Study Goals:

1) determine beaver abundance, distribution and population trend in YNP from 1996-2009
2) summarize early beaver censuses and compare to contemporary ones to reconstruct beaver abundance and areas of use over the last 90 years
3) review willow and aspen literature from the Northern Range to aid interpretation of beaver population fluctuations.

Features measured or tracked:

1) Active colonies. Early researchers not consistent on colony definition. Authors used a fresh lodge and/or recent beaver sign with a fall food cache as indication of active colony. Fall food cache was definitive measure as it included both lodge and bank dens.
2) changes in willow and aspen abundance and distribution

Methods used: Methodology changed as technology did. Early surveys were ground surveys. Later surveys (1988-1989 and 1994) augmented ground surveys with one fixed-wing fight to check on what was ground surveyed. Beginning in 1996, used aerial surveys to cover the park every other year.

Reviewed published but not peer-reviewed reports, unpublished reports and/or records, and published literature. Reviewed willow and aspen literature from NR and used to aid interpretation of beaver population fluctuations. Compared early censuses to contemporary ones to reconstruct beaver abundance and areas of use over the last 90 years.

RESULTS:

Changes in Active colonies:
1921 and 1923: 25 colonies found in limited area of NR. Using aspen and willow as building material and food.
1953: 6 colonies found in NR. Earlier sites from 1920s not active and no aspen reported. Some location reported from park interior.
1979-1980: limited ground survey. No results provided.
1988-1989 and 1994: two incomplete, mostly ground surveys. 71 and 44 colonies respectively in YNP.
1996, 1998, 1999, 2001, 2003, 2005, 2007, and 2009: complete, park-wide aerial surveys. Active colonies ranged from 44 (1996) to 127 (2007) with increasing trend.

"….in a period of about 90 years (1920s-2000s) the beaver population in the northern portion of the park appears to have declined in the NR and then increased probably because of a willow recovery. (p. 276)"

Aspen primary woody food and building material in the early 1900s. Willows were the primary woody food and building material in the 1996-2000s.

Limited aspen currently available to beavers in interior region. Willow, aspen, and cottonwood present on the NR.

Willow release has occurred since mid-1990s, coincident with mid-1990 wolf reintroduction. Some evidence that approximately 10 years after willow (mid-late 2000s), aspen also are releasing.

Most colonies from 1996 on associated with willows. A few showed minimal cottonwood use.

Based on 1996 -2009 and changes in beaver activity, beaver appeared to be rotating areas.
Speed of recent beaver expansion due in part to beaver being reintroduced north of YNP by the Gallatin National Forest from 1986-1999 which complimented beaver movement upstream from the Yellowstone River.

Population fluctuations in the interior of YNP less clear because limited work done especially during the early surveys. Appears beaver populations are stable and subsisting on willows.

Excellent discussion of various reasons/hypotheses as to why beaver and willow have increased. Discusses role of elevated water table in helping willow to grow and expand and inverse relationship found between elk numbers and beaver numbers, and evidence for/against a climate influence.

8. Kabetogama Peninsula, Minnesota (Naiman et al 1988)

Study years: 1940 to 1986
Closure area: 11,136 acres (17.4 sq. miles). More than 300 km [186 miles] of stream available for colonization.
Closure information: Timber operations on the Peninsula closed in the 1940s. Remoteness and cessation of logging road maintenance made access difficult creating a de facto closure. In 1975, the Peninsula became part of Voyageurs National Park which made it an official closure.
Study Goal: Quantify response of a boreal forest landscape to beaver activity
Features measured:

1) Beaver dams
2) Changes in hectares of ponds, wet and moist areas
3) % of peninsula impounded by beavers
4) upland changes in the riparian zone
5) Av. Redox potential and acidity in 1986 for soil and sediment in the different vegetative-hydrologic cover types
6) Available forms of soil/sediment nitrogen and total nitrogen for 1940 and 1986 for the different vegetative-hydrologic cover types.

Methods used: Eight sets of aerial photos (1940-1986), unpublished reports and/or records, information on number of active colonies since 1958

RESULTS:

1940: 71 beaver dams and 1% of the peninsula impounded by beavers.
1986: 835 beaver dams and 13% of the peninsula impounded by beavers.

1940-1986: An additional 12-15% of uplands in the riparian zone were altered during the same time due to beaver browsing.

Development of a mosaic of different vegetation types due to dynamic hydrology of beaver ponds, diversity of pre-impoundment vegetation and changes caused by beaver foraging in the riparian zone.

Some impoundment types were resistant to change while others changed rapidly as they were flooded and then abandoned.

Pond surface area increased from 16 ha (39.5 acres) in 1940 to 1371 ha (3388 acres) in 1986. Wet and Moist areas (indicative of near surface water table) increased from 243 ha (600.5 acres) in 1940 to 2396 ha (5921 acres) in 1986.

Shift from scattered individual impoundments to a mosaic of contiguous impoundments along entire valleys.

"In 1940s, beaver were primarily creating new impoundments rather than altering existing ones….During the 1970s, new impoundments constituted only 9% of the changes. (p. 759).

9. Eastern Warren County, New York (Parson, 1975)

Study years: 1965-1969 (5 years)
Closure area: Portion of county east of Hudson River. No size provided
Closure information: Closed from 1965 to 1968. Opened in 1969. No census survey in 1968 because airplane not available.
Study Goal: Effect of trapping closure on beaver abundance
Features measured or tracked:

1) Active colonies (parameters examined to determine activity not described)
2) Potential sites
3) Trapping pressure

Methods used: Aerial surveys to assess active sites during closure, infra-red aerial photographs to assess potential sites, aerial and ground surveys to assess trapping pressure, unpublished reports and/or record, reports of pelt tags trapping pressure surveys.

RESULTS:

Number of active colonies increased during the closure and decreased significantly after only one season. 1964 baseline year: 11 known active colonies. Post trapping closure: 1965 (39), 1966 (47), 1967 (56). No aerial census data in 1968 because airplane required for other uses. Opened for trapping in 1969 from March 1 - April 6 (37 days). 41 active colonies counted based on ground and aerial surveys.

1969: 75% of the colonies were being trapped. 131 beaver pelts were tagged in 1969 from towns studied. No information for years prior to 1965 because not required that pelts be tagged. Large variations between towns in increases and decreases in number of beaver colonies. Believed that these variations may, at least in part, be attributed to pattern of illegal trapping based on evidence found of beaver trapping occurring prior to season.

"….aerial censuses of beaver colonies are subject to some error….instances reported in which colonies had been missed, with bank colonies being missed most frequent. On occasion, colonies were counted as active that, when investigated on the ground, were found to be inactive. (p. 60)."

"….recognized that counts of active colonies do not necessarily provide a true measure of a beaver population. It is possible that, due to behavioral patterns and family structures among beaver, populations could double without any increase in colony count or colony counts could double with only a slight increase in population. (p.60)."

"…the reductions in colony count after 1969 trapping season may have reflected a much larger population reduction, since colonies which had some but not all beaver removed still remained active. (p. 60)."

Concluded "...the reduction in colony count must be interpretated to reflect a substantial decrease in the beaver population, presumably caused by trapping. (p.61).

10. Fulton County, New York (Parson and Brown, 1978)

Study years: 1969 – 1972 (4 years)
Closure area: 318,080 acres (497 sq. miles)
Closure information: County closed to beaver trapping from 1969 to 1972 because populations in northern zone were at very low level and trapping was identified as probably the principal cause.
Study Goal: Effect of trapping closure on beaver abundance.
Features measured or tracked:

1) Active colonies (defined by fresh food caches)
2) Number of complaints
3) Complaint type
4) Number of nuisance beaver relocated

Methods used: Aerial surveys to assess active colonies; aerial photos to assess potential sites in AF section; analysis of watershed, stream gradient and vegetation used to assess potential sites in Mohawk section; complaint reporting

RESULTS:

Active colonies in portion of the county surveyed all three years increased (mostly within the AF section). 1969 = 17 colonies, 1971 = 57 colonies, 1972 = 75 colonies. Full Mohawk and Adirondack Foothills (AF) sections surveyed in 1971 and 1972. AF section active colonies increased. In 1971 = 95 and 1972 = 115. Mohawk section active colonies increased. In 1971 = 55 and 1972 = 69.

Complaints rose. AF section complaints: 1967 (1), 1968-1971 (4 or less), 1972 (18). Mohawk section complaints: 1967 (3), 1968-1970 (5 or less), 1971 (11), 1972 (25). [NOTE: Mohawk section mostly private lands with 50% devoted to farming. AF section 36% state land and forest preserve with < 10% is farmed.]

Majority new complaints were plugging road culverts, flooding land, plugging ponds. Represented 87% of complaints in 1971 and 95% in 1972. Total complaints in 1971 = 15. In 1972 = 43.

AF section: 17 beaver relocated, 4 died. Mohawk section: 38 beaver relocated. 9 died.

With respect the question of % occupancy of potential sites and rising complaints the authors noted that "There is need for more information concerning the value of beaver colonies in relation to the cost of servicing damage complaints."

11. Prescott Peninsula, Quabbin Reservation, Massachusetts (Bushner and Lyons, 1999)

Study years: 1952-1996 (42 years)
Closure area: 5018 ha (12,400 acres, 19.4 sq. miles)
Closure information: The beavers returned to this area after being absent for more than 200 years. No trapping/hunting permitted
Study Goal: Identify changes in numbers and dynamics of a local unexploited beaver population.
Features measured or tracked:

1) Number of active colonies (identified by food cache, recent tree and shrub cuttings, evidence of lodge and dam maintenance)
2) Distribution of active colonies
3) Changes in age-class composition of the population

Methods used: Aerial photos and anecdotal reports from early researchers, watershed managers and game managers (1950s and 1960s), live trapping and mark and release (1960s and 1970s), autumn food cache/activity surveys and boat surveys along shorelines (1969 to 1996)

RESULTS:

1952-1968: Active colonies increase from 2 to 16. (Phase 1 = slow growth)
1968-1975: Active colonies increase from 16 to 46. Increase in number of shore colonies contributed to rapid increase. (Phase 2 = rapid growth)
1975-1983: Active colonies remain high but fluctuate between 42 and 54. (Phase 3 = fluctuating populations at high levels)

- 1969-1983 rapid colonization of new sites on peninsula and shore. By 1983 many marginal sites occupied.

1983-1988: Active colonies decline from 44 to 12 precipitated by a reduction in number of shore colonies. No shoreline colonies by 1988. (Phase 4 = steep decline)
1988 – 1996: Number of active colonies fluctuate between 10 and 15. (Phase 5 = relative stability at low levels).

Population changes from 104 (1969) to 257 (1978) to 40 (1988). Relative percent of the various age-class groups also change over time. In the 1969 and 1978 counts, adults were 35.6 and 37.4%, yearlings were 25 and 28.8%, and kits were 33.7 and 30.4% or roughly a third each. 2-year olds made up only 3.5-5.8% of the population. Between 1974 and 1988, percent of adults and 2-year olds increases (reproductive animals) while yearling and kit percent of the population decreases to less than 20% each (pre-reproductive).

Two factors suggested as influencing population numbers and age classes.

1) Dispersal of 2-year old beavers was high when there was still suitable (if marginal) areas available to disperse to. Decline during 1983-1988 suggests that shore sites are not optimal for beaver occupation because these areas are subject to water fluctuations during drought years when the reservoir is not full (p.156)

2) “A second factor that may have influenced the beaver population is the occurrence of whitetail deer, on the peninsula. The deer population was very dense through the 1980s. Deer reduce the

regeneration of trees by eating the saplings. There is evidence that deer activity on the peninsula was inhibiting forest regeneration. Thus, woody species that beaver would have used for food after they regenerated were being removed by deer. (p. 157)

12. Dixmont and Montville Sites, Maine (McCall et al 1996)

Study years: 1986- 1992 (7 years)
Closure area: Dixmont site (untrapped site) = (111 sq. km, 42.9 sq. miles.) Montville Site (trapped site) = (111 sq. km, 42.9 sq. miles)
Closure information: The two sites were 12 km apart in similar topography. Dixmont site was closed from March 1988-December 1992. At least 70% of new closure area had been open to trapping in the 10 years prior to the study. Pre-closure data available for closure area on beaver, wetlands, and waterfowl for 1986 and 1987. The Montville site (Open) only had beaver colonies density available from fall 1988.
Study Goals:

1) Determine yearly changes in density of beaver colonies
2) Monitor annual numbers and morphology of wetlands
3) Examine the annual change in area of lifeforms of wetland vegetation
4) Compare these data to changes in the density of breeding pairs of selected waterfowl species.

Features measured or tracked:

1) Evidence of beaver colonies in wetlands in the Dixmont Site (1986-1987)
2) Active lodges (1988-1992)
3) Beaver dam condition (3 categories: good, fair, poor with clear definitions)
4) Changes in numbers of wetland, total basin area, total surface water area, perimeter of surface water area.
5) Changes in vegetation lifeforms (6 categories)
6) Changes in number and distribution of breeding pairs of selected species of waterfowl.

Methods used:
Beaver Activity: Annual census of active beaver lodges using fixed-wing aircraft, ground inspections of each lodge to verify activity, live-trapping of beaver.
Wetland changes: Repeat photography using fixed-wing aircraft and ground surveys to verify flight observations.
Waterfowl changes: Two ground census of breeding pairs of selected species of waterfowl each year

RESULTS:

Active beaver colonies: In untrapped site, the density of active beaver colonies began the increasing first year following closure to trapping and continued to increase during the study period (17 to 36). In trapped site the number of colonies site changed slightly (12 to 22).

Beaver harvest in the trapped site (Montville) declined from 39 to 18 (54%) during 1989-1992 as did percent of colonies trapped. Positive correlation found between harvest and pelt price and between the proportion of colonies trapped and pelt price. Though beaver harvest and percent of colonies trapped per year declined, colony density did not change.

Maintained dams: In untrapped site, number increased from 33 to 54. In trapped site, number was stable (24 to 26),

Unmaintained dams but holding water: In untrapped site, number increased from 13 to 26. In trapped site number increased from 11 to 18.

Unmaintained dams and not holding water: In untrapped site, number declined from 27 to 13. In trapped site, number remained unchanged (22 to 32).

Number of wetlands: In untrapped site, number increased from 120 to 134. Trapped site increased from 103-110. Beaver created all new wetlands on both sites. Numerous wetlands were flooded and abandoned by beaver during the study, but all sites impounded in 1989 were still wetlands in 1992.

Wetland Basin area: In untrapped site wetland area increased from 456 to 475 ha (4% or 19 ha). In trapped site it increased from 294 to 298 (2% or 6 ha).

Surface water area: In untrapped site, increased from 115 to 158 ha (36% or 43 ha) with small decline in last year. In trapped site, value remained stable.

Surface water area perimeter: In the untrapped site, perimeter increased from 85,961 to 92,442 m (8% or 6,481 m). In trapped site increased from 65,693 to 67,093 m (2% or 1400 m).

Flooded vegetation lifeforms: In untrapped site, open water (27 to 30 ha), emergent herbaceous (24 to 31 ha), ericaceous (11 to 22 ha), alder and willow (7 to 18 ha) and timber (12 to 23 ha) increased. On trapped site, all flooded lifeforms changed < 1 ha.

Density of waterfowl breed pairs: Density of breeding pairs of black ducks remained relative stable on untrapped site (27 to 32 pairs/100 km^2) and on the trapped site (28 to 21 pairs/100 km^2). Pairs of Canada geese on untrapped site increased from 4 to 9/ 100 km^2 and mallards increased from 7 to 12/100 km^2. Pairs of Canada geese on trapped site increased from 8 to 10/100 km^2 and no change in density of mallard pairs. Densities of hooded mergansers were higher on the untrapped site (23 to 29 pairs/100 km^2) compared to their pre-closure values (14 to 14 pairs/100 km^2) surveyed in 1986-1987 prior to the 1988 closure. Trapped site showed yearly changes similar to that the untrapped site with density increasing from 7 to 11 pairs/100 km^2.

Number of wetland used by waterfowl: Though density of breeding black ducks changed little on untrapped site, number of wetlands used by pairs increased from 31 to 43 (39%) during 1989-1991 with a small decline in 1992. On trapped site, number of wetlands used was stable (22 to 23) from 1989 to 1992.

Number of wetlands used on the untrapped site increased for Canada geese (5 to 14), mallards (7 to 12), and hooded mergansers (16 to 27). On trapped site, less change in number of wetlands used: Canada geese (7 to 10), mallards (10 to 14), and hooded mergansers (5 to 12).

13. Devon, SouthWest England (Puttock et al 2017)

Study years: 2011-2016 (6 years)
Closure area: 3 ha (7.4 acres) with 20 ha (56.8 acres) of contributing area (first order stream). Stream length = 183 m (600 ft)
Closure information: Two Eurasian beaver introduced into an exclosure in wooded site in 2011.
Study Goals: Quantify impacts of reintroducing Eurasian beaver into a first order tributary which drains an intensively managed grassland on water storage, water quality and flow regimes
Features measured or tracked:

1) Beaver dams

2) surface water stored
3) total event discharge per rainfall event above and below exclosure
4) peak event discharge per rainfall event above and below exclosure
5) peak rainfall to peak discharge lag time
6) water quality (suspended sediment, nitrogen, phosphate, dissolved organic carbon)

Methods used: field observations, water quality sampling and testing, stream flow and rainfall monitoring.

RESULTS:

Dams increased from 0 to 13.

Surface water storage increased at the site via the pond storage by about 1000 m3 (264,172 gallons).

Total event average discharge for all events was 34 ± 9% lower when it left the site than when it entered. (59 rainfall events were measured.)

Peak event average discharge for all events was 30 ± 19% lower when it left the site than when it entered.

Peak rainfall to peak discharge lag time increased by 29 ±21% and the average event duration was 32% longer.

22% more water entered the site than left the site.

Water quality: Suspended sediment, total oxidized nitrogen, phosphate loads were lower leaving the exclosure then when they entered. pH of water samples were slightly more acidic above than below the site. Dissolved organic carbon were higher leaving the site than entering it.