BACKGROUND REPORT ON BEAVERS TO SUPPORT PLANNING FOR THE BONANZA BIODIVERSITY CORRIDOR WETLAND RESTORATION PROJECT

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INTRODUCTION

The Bonanza Biodiversity Corridor (BBC) is a large wetland complex located between Summit and Slocan lakes in south-central British Columbia. The Slocan Lake Stewardship Society (SLSS) has received funding for a multi-year wetland restoration project for the BBC. This paper was prepared for the SLSS to provide background research required to:

- Develop a beaver inventory and mapping program to support the wetland restoration project
- Assess options to mitigate beaver obstructions

Information in this report includes an introduction to beavers, beaver habitat requirements, methodologies for determining beaver populations, information on setting up wildlife cameras to gain a deeper understanding of the local beaver population, and how to mitigate beaver obstructions.

NATURAL HISTORY

Castor canadensis, the North American beaver, is the official animal symbol of Canada. These "ecosystem engineers" have the power to drastically alter riparian habitats by building dams, creating open water, cutting down trees and shrubs, digging canals, and building beaver lodges (Haemig 2012). These activities increase stream complexity, improve water storage, moderate stream temperatures, reduce stream velocities, create habitat, and reduce flooding (Kinas et al. 2017). Beaver impoundments play a critical role in maintaining ecological diversity and successional changes within streams (Ministry of Environment, Lands and Parks 2001). Figure 1 beautifully illustrates the beaver's ability to positively impact ecosystems on all trophic levels.

Flooding and coppicing of riparian vegetation followed by collapse of the impoundment and renewal of stream cover result in the deposition of rich organic soils that in turn support a greater diversity of organisms (Ministry of Environment, Lands and Parks 2001)

Around the world, beavers are being recognized for their role in watershed health and ability to act as a tool for climate change adaptation and species-at-risk recovery efforts (Kinas et al. 2017). Beavers are the largest rodent in North America and are considered a keystone species (Wright and Jones 2002, Novak 1987). They can increase the biodiversity of riparian ecosystems through transforming running water into ponds and wetlands (Wright and Jones 2002). Their primary habitat is both terrestrial and aquatic zones in the riparian area (Taylor et al. 2017).

Beavers are crepuscular, which means they are mostly active at twilight (i.e., the period immediately after dawn and before dusk), and nocturnal (Hatler and Beal 2017, Taylor et al. 2017). Beavers are highly adapted to aquatic habitats (Taylor et al. 2017). While under water, a special membrane protects their eyes (Pollock et al. 2017). Their lips can close behind four large incisor teeth which allows them to haul branches underwater without ingesting water (Taylor et al. 2017). Their valvular nose and ears allow them to comfortably remain submerged for long periods of time (Taylor et al. 2017). Their signature large, flat, scaled, nearly hairless tail is used as a prop while sitting upright, a rudder for swimming, an alarm by slapping the water surface, and a fat reserve for lean winter months (Taylor et al. 2017). Beavers will slap their tail on the

water to create a loud sound to warn others of danger or to scare off intruders (Taylor et al. 2017, Pollock et al. 2017).

Figure 1. Beavers' ability to positively influence all trophic levels in an ecosystem (Martinez Beavers 2018).

Figure 2 (on following page) shows the beaver's large incisors with a bright orange outer enamel layer (Pollock et al. 2017). The incisors grow continually throughout the beaver's life and are bevelled so they are continuously sharpened as the beaver chews (Taylor et al. *2017).* The average weight of an adult beaver is 16 to 23 kg (35 to 50 lbs), although individuals can exceed 45 kg (100 lbs) (Taylor et al. *2017).* The average lifespan of beavers is 10 years, although individuals can live up to 21 years (Taylor et al. *2017).*

Diet

Beavers are semi-aquatic herbivores that eat both herbaceous and woody plants, including aspen, poplar, birch, maple, willow, alder, black cherry, red oak, beech, pine, spruce, grasses, forbs, cattails, water lilies, and other aquatic vegetation (Müller-Schwarze & Sun 2003). The main food source of beavers throughout the year is the bark and twigs of deciduous trees and shrubs, especially poplars and willow (Hatler and Beal 2017).

Figure 2. *Castor canadensis* (Martinez Beavers 2018).

The preferred food of beavers includes alder, aspen, birch, cottonwood, maple, poplar, willow, cattail, and water lily tubers. They use their dexterous front paws to roll lily pads like cigars to eat them. Contrary to popular belief, beavers do not eat fish or other animals (Beaver Solutions 2020).

Beavers will collect food and create a larder, or cache, by submerging large amounts of small trees and limbs to serve as a food source after ice forms on the surface of their pond (National Trappers Association 2012). The food cache forms a woven floating mat and can be anchored to the lodge or located on the water surface near where the beaver colony winters (Novak 1987).

Lodges

Beavers are colonial mammals that live in lodges. They can live in either a cone-shaped lodge that is created using sticks, logs, rocks, and mud, or a bank lodge that is dug into the riverbank (Müller-Schwarze 2009). The lodges can be surrounded by water or they can touch land with burrows dug into riverbanks. Bank lodges are typically created where the water is too deep or fast-moving to build a cone-shaped lodge (Mapes 2009). It is common for a beaver to construct a dam and then build the lodge in the pond that formed behind the dam (Mapes 2009). To prepare for winter, beavers will often plaster mud on the surface of their lodge for added protection and insulation. On the top of the lodge, beavers will leave a breathing hole to ensure ventilation. Every lodge has at least two underwater tunnels that lead from the lodge to the pond (Taylor et al. 2017). Inside each lodge is a large chamber where beavers birth and nurse their kits, as well as sleep, eat, and groom each other.

To determine if a beaver lodge is active during spring-fall, one can see if there is a fresh larder of sticks and branches nearby. Beavers do not hibernate; they remain inside their lodges for the winter except when they swim under the ice to retrieve food from their food cache (Beaver Solutions 2020).

Dams

Beavers build dams to create a deep water refugium that allows them to escape from predators as well as provide access to their underwater food cache in winter (Novak 1987). By flooding the surrounding forest, the dam also provides safe access to their favorite foods of leaves, buds, and cambium layer of trees. In areas where deep water is already present, the beaver may decide to dwell in a bank burrow with an underwater entrance. The dam is created using tree branches, rocks, grass, and mud. These extremely industrious creatures will work in groups to create dams. In general, fall is when beavers focus on preparation for the coming winter by building and repairing dams. The sound of running water triggers the beaver to build a dam (Wikipedia contributors 2020). To test the theory that beavers respond to the sound of running water by building a dam, scientists conducted an experiment where a tape player emitting the sound of running water was placed on a dry field near a beaver pond. When they returned, the beaver had covered up the tape player with branches and mud (Richard 1983).

Beavers have been known to excavate canals over one hundred feet long in order to bring water closer to a desirable stand of trees. This allows them to float edible branches back to the pond as well as to swim away quickly if danger is present.

Site selection for dams is primarily based on topography and food supply (Beaver Solutions 2020). Beaver dams are often correlated with low-lying areas with shallow, moving water. They prefer low-gradient streams (<6% slope) and generally populate the lowest gradient sites first (slope <1-2%) (Pollock et al. 2017). Being excellent engineers, beavers will utilize natural features such as a fallen log, a constriction in the streambed, or a tree stump to anchor their dams. They look for sites where a dam will flood a large flat area with plenty of their favorite woody plants growing nearby. In general, if the stream is greater than two feet deep or has a strong current, they will find another spot to dam (Beaver Solutions 2020).

A beaver colony will usually create one large pond where they build their lodge and then create a series of smaller dams up- and downstream to create other ponds for safe passage as they forage for food. On average, a colony will dam just under a kilometer of a small stream (Beaver Solutions 2020).

Behaviour

Beavers are monogamous and mate for life (Beaver Solutions 2020). If a beaver's mate dies, they will partner with another mate. Figure 3 shows a summary of the annual cycle for beavers. Normally, 1-6 kits are born each year. The beaver colony is composed of the adult parents, their kits, and yearlings. In large beaver colonies, which can have as many as 12 members, they will often build more than one lodge (Müller-Schwarze & Sun 2003).

The gestation period for beaver kits is approximately 128 days. The female will give birth to 3-4 kits between March and June and nurse them for 6-12 weeks. The kits are born fully furred with incisors erupted through the gums and their eyes partially open. Kits become sexually mature at 1.5 years (Taylor et al. 2017). In spring, while a new litter is being born, the adult male and kits

will temporarily live in a bank den while the adult female lives in the lodge (National Trappers Association 2012).

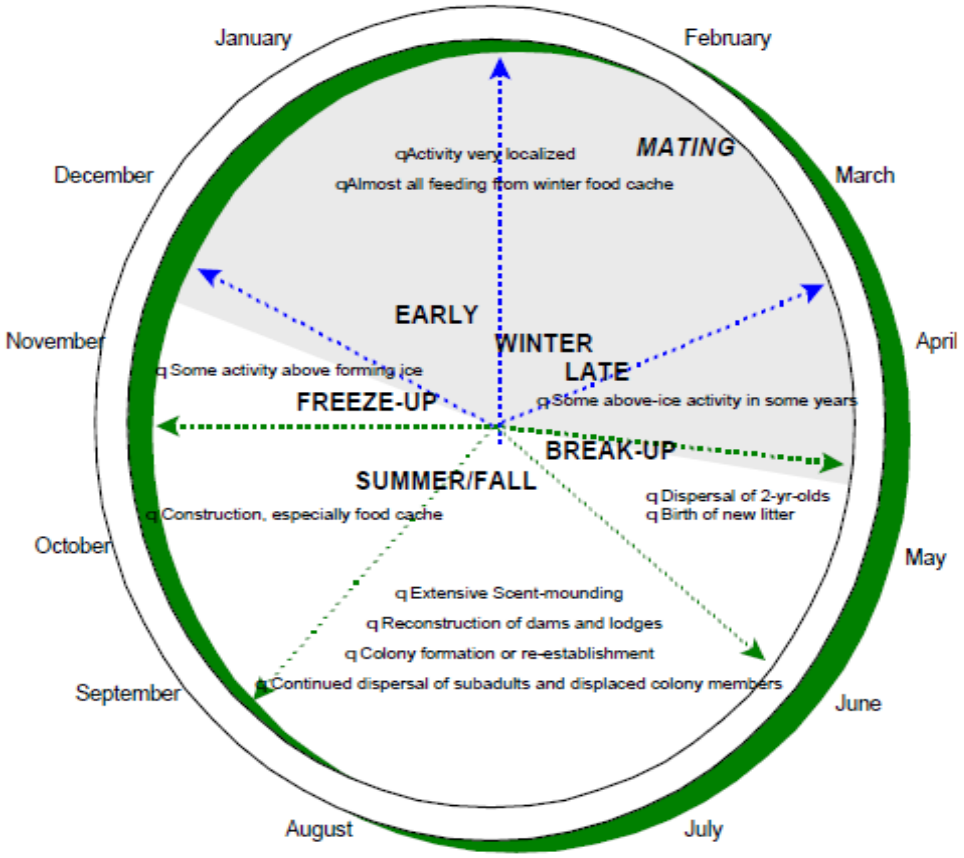

Figure 3. Annual Cycle for Beavers. The shaded area represents the approximate period of time of under-ice existence (Hatler and Beal 2017).

Between the ages of 1-3 years, the young beavers will leave the colony and find new territory so they can establish a colony of their own. This emigration will often occur in spring just prior to the birth of the new litter. In high quality habitat, the young beavers will remain in the colony longer (Slough and Sadleir 1977). Some young beavers will travel 16 or more kilometers to find a suitable home. Distances of emigration up to 238 stream kilometers have been recorded (Hibbard 1958). Both male and female solitary beavers are referred to as "bachelors" (National Trappers Association 2012). These solitary beavers will travel up- or downstream to find new territory where they will find a mate and start a colony of their own. Most new colonies are created within a few miles of the home colony (National Trappers Association 2012).

Beavers are extremely social animals with strong family bonds. They are mostly peaceful animals, although they will defend their territory by violently fighting off any unrelated beaver from its pond (Müller-Schwarze and Heckman1980). Starting in spring, they will mark the boundaries of their territory by creating scent mounds (Figure 4) to coincide with the emigration of the younger beavers (Taylor et al. 2017). These mounds are composed of piles of mud, debris, and castoreum (a strongly scented urine-based substance that is excreted through their castor sacs)

(Müller-Schwarze & Sun 2003). Scent mounds, also known as "castor mounds", can leave a reddish stain on the bank with a powerful odour easily detectable by humans (National Trappers Association 2012).

Figure 4. Castor mound created by a beaver to mark its territory (Pollock et al. 2017).

If a foreign beaver is detected, finding the intruder and fighting it off becomes the top priority (Müller-Schwarze and Heckman 1980). To avoid potential conflict, a beaver will mark its territory with as many scent mounds as possible to demonstrate to a potential intruder that the territory holders have enough energy to maintain their territory, thereby having enough energy to put up a good defense. The result of this behaviour is that territories with more scent mounds are generally avoided by other beavers more frequently than territories with fewer scent mounds (Abbot *et al.* 2012).

Generations of beavers may continuously inhabit a high quality habitat, building dams, lodges, and canals to float food from inland cutting sites (National Trappers Association 2012). Only when food supplies are exhausted do beavers relocate. Even in optimal habitats, beaver colonies will stay well-separated from each other. Average population densities in British Columbia rarely exceed one colony per kilometer of shoreline (Hatler and Beal 2017).

Tracks and Signs

Beaver have front feet that are small in comparison to their back feet (Figure 5). These small dexterous front feet allow them to carry branches and build their dams and lodges effectively. Their hind feet are webbed to aid in swimming and have a slit claw used for grooming.

Figure 6 shows a picture of beaver scat, which is made predominantly of wood chips. The oval pellets are approximately 2.5-3 cm in length and 2 cm wide.

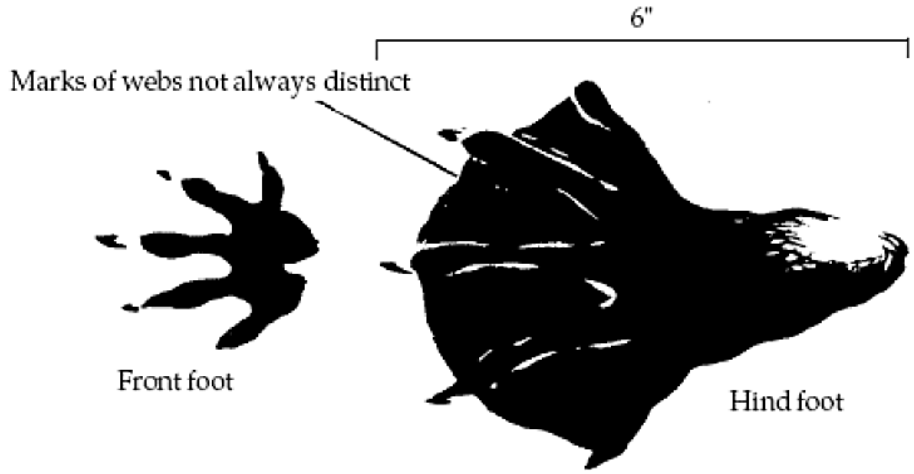

Figure 5. Beaver Tracks (Taylor et al. 2017).

Figure 6. Beaver Scat (Taylor et al. 2017).

BEAVER HABITAT

Beavers are used as a management indicator species due to their status as a keystone species and their close association with riparian and aquatic habitats. Beck *et al.* (2010) used habitat modelling to determine that the most suitable beaver habitat in South Dakota was lower elevation riparian habitat near perennial water and in close proximity to aspen and willow. In a study conducted at Yellowstone National Park, Smith *et al.* (1996) found that most of the 51 beaver colonies detected were associated with willows.

Slough and Sadleir (1977) found that in BC's northern interior, beaver occupancy along lakes and streams was related to the availability of food. Beavers preferred areas along lakes where aspen was present and along streams, they preferred areas with cottonwood present. They

suggested that the most powerful management option for maintaining and enhancing beaver habitat is to conserve existing aspen stands. They also discovered that the dispersal of young beavers is a natural method to repopulate vacated habitats.

Beavers require a stable aquatic habitat, which is why they will select sites with a low gradient or narrow stream where they can create a dam. Site preferences for beaver colonies include areas where there is an adequate supply of food and building materials. These materials must be in close proximity to the colony site (Slough and Sadleir 1977). Hall (1960) determined that 90% of all cutting was done within 30 m of the water (although cutting has been recorded up to 200m away).

Steep landscapes can limit a beaver's ability to find food. Beavers prefer streams flowing in and out of lakes and/or low marshy areas that allow them to build canals and dams to increase the availability of food. In order of preference, the following are the top four species that are favoured by beavers in British Columbia (Slough and Sadleir 1977):

1. aspen (*Populus tremuloides*)
2. willow (*Salix* spp.)
3. cottonwood (*P. balsamifera trichocarpa*)
4. alder (*Alnus* spp.)

Riparian areas with muddy shores and bottom areas are preferred by beavers as it makes burrowing, channelling, and damming easier than in areas with rocky substrate (Hatler and Beal 2017).

When beavers primary food source is willow, their population ecology is more stable than populations that depend on trees for winter food. This is due to the tenacity of willows and their ability to grow back very rapidly after being browsed, whereas trees are subject to depletion (Smith *et al.* 1996). In habitats where there are both willow and aspen, beavers prefer to harvest aspen trees first (Novak 1987).

In areas with prime unexploited optimum habitat, beaver populations can increase rapidly and expand over the landscape (Pollock *et al.* 2017). In areas that are at or near carrying capacity, beaver population density changes slowly over time (Pollock et al. 2017).

WILDLIFE CAMERAS TO ASSESS AND MONITOR BEAVER ACTIVITY

Wildlife cameras have become a popular tool for biologists to monitor aspects of ecology and behaviour of various animals. Bloomquist and Nielsen (2009) developed a remote videography system for monitoring beaver behaviour and demography inside lodges and bank dens. They fitted beavers with tail-mounted identification tags and used a burrow probe system consisting of a fiber optic camera, infrared light, and a video recorder. A PVC pipe housed the burrow probe system and was inserted through the roof of the lodges and bank dens. They collected over 300 hours of footage of beaver activity within four lodges and two bank dens.

They determined that "the remote videography system was generally useful and can provide wildlife biologists with demographic and behavioural information to support population modelling and management programs for beavers."

Advice from local naturalist Joanne Siderius regarding installing and using wildlife cameras is to get Master Craft python locks (the ones for trail cameras) to keep the camera secure if it is attached to a tree. She likes Browning cameras (B&H website; they ship to Canada for free) or Moultrie and Bushnell on Amazon.ca. She recommends getting the cameras that have a screen to help point the camera on your point of interest. In order to allow enough memory to capture videos, use larger SD data cards and rechargeable batteries that can last a couple of weeks.

Beavers are crepuscular and nocturnal (Hatler and Beal 2017, Taylor *et al.* 2017) so having a wildlife camera that can capture video at low or no light is critical. Identifying all active beaver lodges and placing the wildlife cameras focused on the beaver dams, lodges, and ponds may give an idea of how many beavers are living in each lodge and if kits are present. If this method is unsuccessful at capturing footage of the beaver colony, one may unblock one of the culverts they have dammed and focus the camera on the culvert to watch them repair the breach. Beavers have an excellent sense of smell, so insure that you try to minimize any scent you put on the camera when installing it.

METHODOLOGIES FOR ESTIMATING BEAVER POPULATIONS

Several methods have been developed to document the presence and distribution of beavers. Developing a monitoring program to assess changes in beaver populations over time is extremely important in determining the impact of a wetland restoration project in the BBC. If there are any active beaver trappers in the BBC, it would be beneficial to ask them to voluntarily share the total annual number of beavers they have harvested.

BC's Ministry of Environment, Lands and Parks (1998) developed a detailed protocol for monitoring beavers in the province. They recommended the following inventory methods at three levels of intensity:

1. Presence/not detected
    - Ground physical sign survey: Surveyors conduct ground surveys, monitor for signs of beaver activity
    - Create a map showing areas that were searched and the locations of beavers and their sign
2. Relative abundance
    - Food cache (colony count): Surveyors can conduct food cache surveys by ground, air, or boat. If conducting the survey by air, a helicopter can provide greater survey efficiency, than by plane due to its increased maneuverability.
    - Relative abundance can be reported as number of food caches (colonies) per unit area.
    - Create a map showing search areas and/or transects as well as the locations of caches and other beaver sign.
    - Estimate number of individuals by multiplying the number of colonies found with mean colony size (using mean colony size found in literature).

3. Absolute abundance

- Food cache (colony count) (with estimate of colony size): No cost-effective, reliable methods are recommended at this time.

Swenson *et al.* 1983 determined that conducting an aerial survey for beaver food caches was unreliable at indicating population size on two prairie rivers in Montana. They found that there was approximately 90% accuracy in locating caches that were constant over time and area, but colony size varied with time and area. In order to properly assess the aerial cache-survey results, information on age, sex, and reproduction needed to be collected to accurately determine colony size.

In contrast, a study conducted by Hay (1958) found that aerial surveys of caches reflected the findings of the ground survey to determine the number of active beaver colonies in Colorado, where the beavers built dams and lodges. The study determined that aerial cache surveys were both an accurate and practical approach to determine the number of beaver colonies present.

One thing to consider is even if aerial surveys accurately determined the number of active beaver colonies, changes in colony counts may not reflect changes in population size as colony size can change on from year to year (Townsend 1953, Bergerud and Miller 1977).

Consolo Murphy and Smith (2003) wrote an interesting paper where they compared the use of aerial and ground surveys to monitor trends in beaver populations in Yellowstone National Park. The goal was to find the best method to accurately and cost-effectively monitor beaver populations in the park. Their method for ground surveys involved one to two people hiking suitable riparian corridors and recording current signs of beaver activity, including lodges that had been augmented with freshly cut trees and stems with stripped branches, newly placed mud, new food caches, bank dens, fresh beaver runs, or recently enhanced dams. The second method used to monitor trends in beaver population included flying over suitable beaver habitat using a fixed-wing air craft at 100-175 feet at 55-65 mph. Repeat flights were sometimes required to census beaver colonies in high-density habitats. These signs of beaver activity were easiest to spot in fall before the arrival of snow, when beavers are busy preparing for winter and the deciduous plants have shed their leaves. They recommended that aerial surveys be conducted at two- to three-year intervals.

Consolo Murphy and Smith (2003) also determined that aerial surveys are effective at monitoring active beaver colonies. The ground surveys were more costly, not as effective at locating beaver colonies, and difficult to conduct as the terrain was very hard to walk through due to wetland features and large amounts of dense shrubbery. They recommended that periodic ground surveys be conducted to ground-truth the results obtained from the aerial surveys. These ground surveys could provide important additional information on the location of the bank-dwelling beavers that are harder to locate from the air. Furthermore, ground surveys allow for more detailed observation of beaver behaviour, such as tree and shrub cutting, construction, and habitat alteration. Table 1 below shows a summary of the comparison of the two methods.

In non-mountainous terrain, ground surveys can be more accurate than aerial surveys but can be more costly due to the large amount of survey time required. Using aerial surveys to document food caches in fall are both cost-effective and easily conducted, but may miss documenting the presence of bank-denning beavers (Robel and Fox 1992).

Table 1. A comparison of ground and aerial surveys for beavers - costs and results (Consolo Murphy and Smith 2003).

Results Compared	Ground survey	Aerial survey
Number of beaver colonies found	17	23
Number not found by other method	1	7
Detection probability	17 of 24 (69%)	23 of 24 (94%)
Time required (10-hr person-days)	8.0	0.188
Cost of survey	$1,270	$212 w/o ferry time

Slough and Sadleir (1977) found that the intensity of land use by beavers was easily measurable by determining the number of colonies present (so long as the animals per colony does not vary greatly throughout the study area). They also found that the density of colonies is an accurate indictor of habitat quality. The more colonies the higher quality of habitat. If a twin lodge (two lodges of the same size and construction less then 8m apart often with a shared food cache) was found while surveying beaver colonies it should be considered a single colony site. They stated that: *The use of total colony sites may be a better method of determining carrying capacity than beaver population census or active colony site surveys owing to variation in the degree of habitat saturation by beavers in different areas.*

With this in mind, it may be useful for the BBC project to find historic photos of the area and look at the number of lodges to get an estimate on the number of colonies that were historically present.

Hatler and Beal (2017) have a very simple method for censusing beaver populations. They stated that:

> *Local beaver populations are usually censused by counting the number of active lodges (those with food caches in late fall) and multiplying that number by an assumed average number of beavers per colony (usually five in most areas). For example, in a 198.5-km section of the Nechako River in north central BC, intensive surveys over a 13-year period found an average of 119 active lodges which, using the factor of five, translates to a population averaging 595 beavers in the area over that time period.*

Fitch (2016) agreed that *A typical colony contains an average of five individuals; the adult pair, kits of the year, and kits of the previous year*. Novak (1987) stated that the average beaver colony size across North America is six beavers.

The Beaver Management Guidelines of British Columbia (1988) concurred that the best time to inventory beaver colonies is in fall (usually September or October) when beavers are the most active and after the leaves have fallen. During the survey, each area showing beaver activity should be classified as active (with a food cache) or inactive. The size of the food cache can give an indication of the size and vigour of the colony. A large well-supplied food cache can indicate a larger colony, whereas a smaller food cache with exhausted food supplies around the beaver lodge can indicate a colony in decline.

When conducting aerial surveys for food caches, it is important to search for other beaver activity, such as cut trees, beaver lodges, dams, and freshly peeled sticks, which shine brightly white when viewed from above. If any of these beaver signs were spotted, the biologists would circle back to search for a food cache (Smith *et al.* 1996).

Using aerial censusing to determine beaver population size, trend, and distribution is an accepted methodology (Novak 1987). If more in-depth information is required, such as average colony size, reproduction, movements, or effects on riparian areas, more involved studies would be required, such as ground surveys, video surveillance, and/or attaching transmitters to the beavers. Aerial surveys should be conducted every other year (Smith 1998).

Setting up a beaver monitoring program using live traps (*e.g.,* with Hancock traps) and marking a sample of the beaver population could help to determine demographic data on beaver colonies. A typical program could include using such techniques as tagging beavers with Passive Integrated Transponders (PIT tags), collecting hair samples, and sexing beavers (Pollock 2017). Data on beaver reproduction, age structure, sex ratio, and condition would be valuable to better understand the roles of beavers in a given area (Smith 1998).

DESIGN OPTIONS TO MITIGATE BEAVER OBSTRUCTIONS

Beavers are drawn to the sound of running water and will often block or dam culverts. Road culverts are the most common sites for problematic beaver damming. A blocked culvert or a beaver dam can quickly cause dangerous and expensive road safety issues. Fortunately, nearly every road or trail can be protected from beavers in a cost-effective and humane way. The two main flow devices to protect culverts and roads from beavers blocking water flow are to install either a culvert protective fence (also known as a "beaver baffler") or a pond leveling device. These flow devices use a combination of exclusion and deception to maintain positive water flow (Taylor *et al.*, 2017). These devices prevent beavers from getting close enough to the pipe intake by inhibiting their ability to detect water movement. It should be noted that all structures in and about a stream will require some maintenance.

Culvert Protective Fences

Culvert protective fences, or "beaver bafflers" are structures that are fixed to the inlet end of a culvert to prevent beavers from damming the culvert intake. The "Beaver Stop" is one brand of these structures that includes a double-walled wire cage fastened to the upstream end of the culvert.

Culvert screening devices allow water to flow through the culvert without being blocked by the beaver. Culvert screening is most effective when combined with corrugated pipe to create a flow device (Taylor *et al.* 2017). In general, the device works by pushing the beaver access further from the culvert so that they can't block the culvert and so the sound and feeling of running water is decreased, thereby reducing their tendency to dam the culvert.

Figures 7 and 8 show examples of both types of beaver bafflers where water flow is disbursed over a larger area, thereby decreasing the beavers' desire to dam the waterflow.

Design recommendations include (Nolte *et al.* 2005):

- Build the fence using 6-inch reinforced steel mesh held in place with steel posts
- Fence off an area 10 to 20 feet on each side of the culvert
- Ensure the fence blocks access from the shore and across the top of the culvert
- Include a mesh 'floor' so the beavers can't swim underneath and access the culvert
- Extend the fence 2 feet above high water mark

Note that due to the presence of fish in Bonanza Creek, the structure should be designed and installed to promote fish passage where applicable.

Figure 7. – Flow device using an exclusion fence at the culvert intake (lower right) (Taylor et al. 2017)

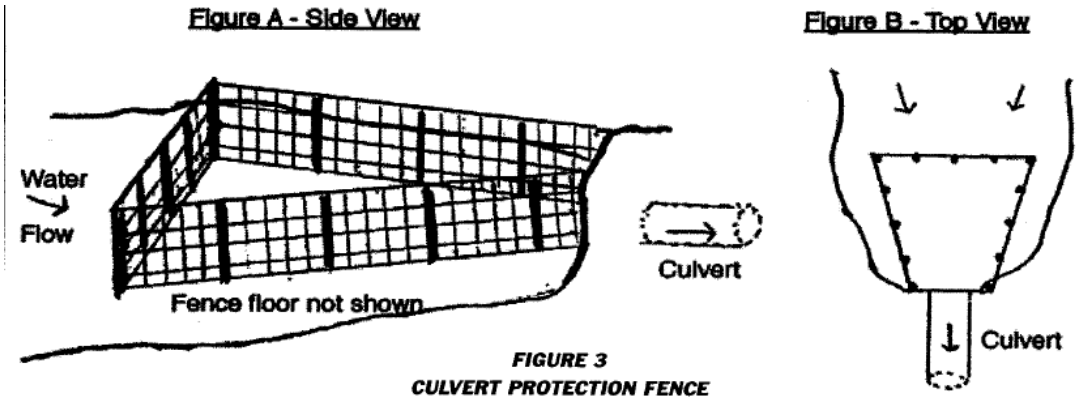

Figure 8. Culvert Protection Fence (*Beaver Solutions 2020).*

Exclusion devices placed directly on or adjacent to the culvert that lack the fencing (i.e., culvert grates or T-culverts) are not recommended. These devices are poorly designed as they catch floating debris and require a lot of maintenance. Furthermore, beavers will dam the device, which has the same impact as directly plugging the culvert (Taylor *et al.* 2017).

To ensure the effectiveness of the beaver-baffler structure, the Ministry of Environment, Lands and Parks (2001) suggests the following design criteria be followed:

- The cage should be sized to fit the appropriate culvert and protrude far enough from the end of the culvert in order to remain submerged and to prevent the beaver from plugging the wire mesh.
- The cage should be constructed of a durable material that will provide service for a period of not less than that expected for the culvert.
- The cage should be suspended at least 0.5 m above the pond floor to deter anchoring of dam materials to the bed of the pond by the beaver.
- The wire mesh should have openings of about 15 cm as this will allow fish passage but hinder attempts by the beaver to plug the gaps, and it should enclose the intake end.
- The culvert and mesh assembly should be designed to withstand a 1:10 year storm event and sized to allow fish passage.

Pond Levelers

Pond levelers also use a combination of corrugated pipe with an exclusion fence to maintain positive water flow. Figures 9 and 10 show pond leveling devices that allow the beaver dam to remain intact but allows the operator to control the level of the pond behind the dam. Breaching beaver dams is a short term solution to reduce the elevation of the water in the reservoir (Taylor *et al.* 2017). Beavers tend to rebuild dams very quickly. As I like to put it, they work nights and we work days.

Figure 9 shows a Clemson Pond Leveler where the intake and reducer sleeve slow water movement through the system. Inside the wire cylinder is a perforated intake pipe. The wire cage around the intake prevents the beavers from getting close enough to block the perforations with debris. Placing a T-joint at the outlet provides control over the water level of the pond. When the bottom of the T-joint is open, the pond will drain; when the bottom of the T-joint is plugged, the water will increase to the height of the riser (Nolte *et al.* 2005).

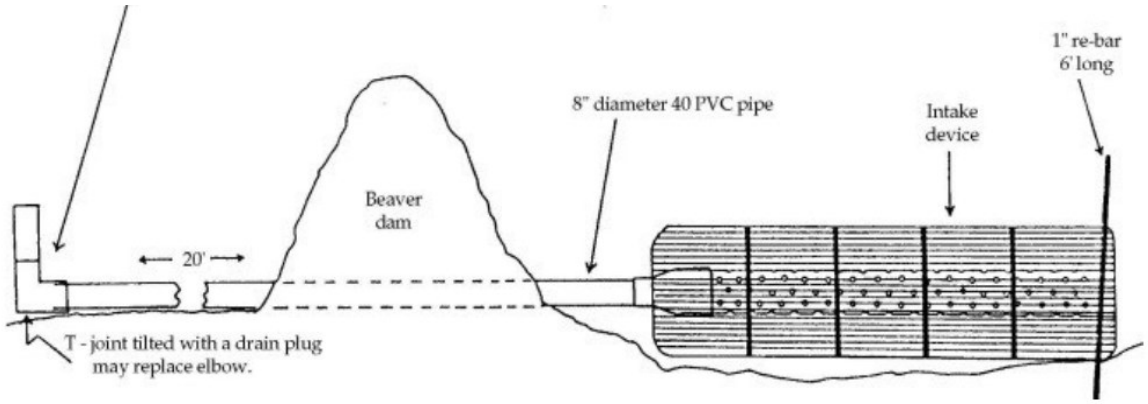

Figure 9. Ridged pond leveler used to control the water level at a dam (Taylor et al. 2017)

The Flexible Pond Leveler in Figure 10 works in a similar way to the Clemson Pond Leveler by creating a permanent leak through the dam that the beavers cannot stop. A pond depth of at least 3 feet is required for pond levelers to function properly. The elevation of the pipe in the dam sets the pond level. Water will continue to flow through the pipe until the water level drops below the peak of the pipe. When installing the pond leveler, the pipe can be installed in the dam at the desired pond level and can be adjusted up or down as desired (Beaver Solutions 2020).

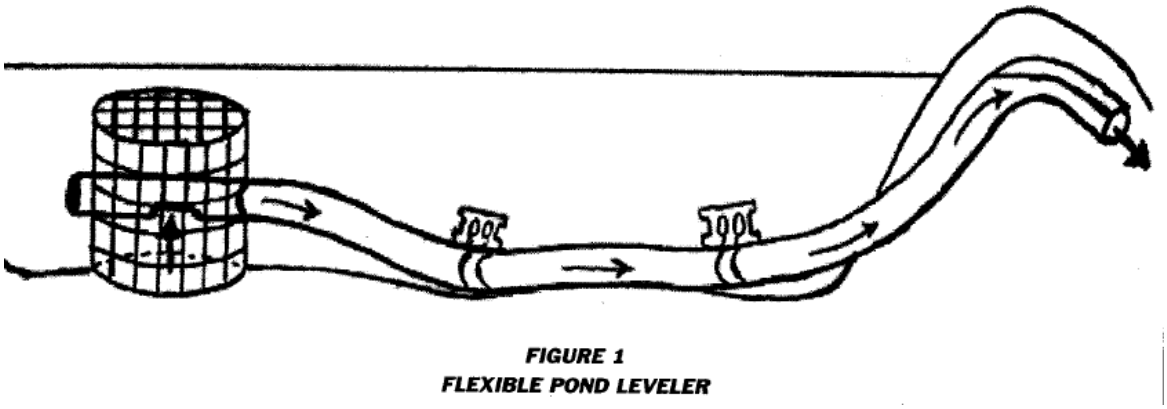

Figure 10. Flexible Pond Leveler (Beaver Solutions 2020).

CLOSING REMARKS

Beavers truly are amazing creatures and are powerful allies in our climate change adaptation and species-at-risk recovery efforts. Beavers can be used as a management indicator species due to their status as a keystone species and their close association with riparian and aquatic habitats. The most powerful management option for maintaining and enhancing beaver habitat is to conserve existing aspen stands.

Changes in beaver populations over time can be helpful in determining the impact of the wetland restoration work in the Bonanza Biodiversity Corridor (BBC). The key recommendations for establishing a monitoring program that will determine trends on the number and distribution of colonies include:

- Asking active beaver trappers in the BBC to voluntarily share the total annual number of beavers they have harvested.
- Finding historic photos of the area and looking at the number of lodges to get an estimate on the number of colonies that were historically present. This can help to determine the potential carrying capacity of the BBC for beavers.
- Conducting an inventory of beaver colonies in fall (usually September or October) when beavers are the most active and after the leaves have fallen.
- Using aerial surveys to document food caches and determine the total number of beaver colonies. Multiply the colony count by a factor of five to get an estimate on the total number of individuals.
    - Repeat every 2 years
- Using ground surveys to ground-truth the findings of the aerial surveys and collect additional information, such as determining the location of the bank-dwelling beavers (they are harder to locate from the air) and gathering more detailed observations of beaver behaviour, such as tree and shrub cutting, construction, and habitat alteration.
    - Repeat every 5 years

To gain a deeper understanding of demographics and behaviour of the beaver population, wildlife cameras could be installed to view beaver activity around beaver dams, lodges, and ponds.

Beaver obstructions can be mitigated by using flow devices such as Culvert Protective Fencing or Pond Levelers. These two devices can provide long-term solutions to control water levels behind a dam or through a culvert. Any device placed in the stream will need periodic monitoring and maintenance.

The BBC is an extraordinary wetland complex with the ability to be a stronghold for beavers in our area. Understanding changes in the BBC beaver population over time can help to illuminate successes and failures of the upcoming wetland restoration project.

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