Feasibility of non-lethal approaches to protect riparian plants from foraging beavers in North America

Dale L. Nolte[1,*], *Mark W. Lutman*[2], *David L. Bergman*[2], *Wendy M. Arjo*[1] *and Kelly R. Perry*[1]

[1]United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 9730-B Lathrop Industrial Drive, Olympia, Washington, 98512, USA

[2]United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, 2224 West Desert Cove Avenue, Suite 209, Phoenix, Arizona 85029, USA

*Corresponding author, email: Dale.L.Nolte@usda.gov

Abstract. Beavers in North America will occupy almost any wetland area containing available forage. Wetland restoration projects often provide the resources necessary for dispersing beavers to create desirable habitats. Their wide distribution and ability to disperse considerable distances almost assure that beavers will establish themselves in new wetlands. Although beavers are a natural and desirable component of a wetland ecosystem, their foraging behaviours can be destructive. Fencing may be a feasible approach to reduce damage to small, targeted areas, and textural repellents may provide some utility to protect established trees. However, these non-lethal approaches will be marginally effective when beaver populations become excessive. Beaver populations need to be maintained at levels that permit viable colonies while still permitting plant communities to flourish. This will require a better understanding of beaver movements, site and forage selection, and reproductive characteristics. This is particularly true when management objectives and regulations prohibit beaver removal from project sites.

Introduction

Beavers (*Castor canadensis*) occupy wetlands throughout most of North America (Hill 1982; Miller and Yarrow 1994). Pristine range for these aquatic mammals included almost any site containing a continuous water source and winter forage (Hill 1982). However, trapping pressure during the late 1800s caused a significant decline in beaver numbers. Populations estimated at 60 million before European arrivals were nearly exterminated by 1900 (Seton 1900). Over the past century, beaver populations have rebounded primarily because of trapping regulations and translocation programs conducted by wildlife agencies (Hand 1984). At present, beavers are once again established throughout their original range and some dispersing animals have invaded previously unoccupied sites (Wilson and Ruff 1999).

Beavers often modify environmental attributes (Rutherford 1955). Given a water source, beavers are probably the most capable species, except humans, at creating suitable habitats for themselves (Hand 1984). Beavers dams and resultant ponds have benefited riparian restoration projects (Albert and Trimble 2000). Beaver ponds create standing water, which increases vegetation diversity and edge effects, and reduces erosion (Hill 1982). These attributes generally benefit other wildlife species (Rutherford 1955). Although beavers are a natural and desirable component of a wetland ecosystem, their behaviours can be destructive. Reduced water flow is detrimental to some fauna, and high beaver populations can negatively impact on native plant communities (Hill 1985). Extensive foraging can destroy plant restoration projects (Nolte 1998). Beavers have severely hampered efforts to establish vegetation to improve salmon habitat in the Pacific Northwest (DuBow 2000).

Excessive beaver activity was credited for destroying vegetation established by the Tres Rios Riparian Restoration Project, near Phoenix, Arizona, United States of America (USA). This project converts treated city waste water into wetland areas. Tres Rios has established small wetland habitats occupied by a variety of flora and fauna. Although animal foraging on plant materials is a natural component of a balanced ecosystem, beaver activity at these sites became destructive. Some areas were rendered barren of aquatic plants because of heavy foraging by beavers. Numerous trees, primarily cottonwood (*Populus deltoides*) and willow (*Salix* spp.), were cut or girdled, and extensive burrowing undermined dikes and islands. Visual signs, including burrows, clipped vegetation, and runways, all indicated high beaver numbers. Spotlight-surveys counted 14 animals within a single evening. A prior study indicated that spotlight-surveys reveal approximately 33% of actual beaver densities (unpublished data). Thus, beaver populations on these sites were estimated to be between 34 and 50 individuals on the 4.5 ha site. Further, a nearby river serves as a continuous source for additional animals to invade the site. Beavers may be coming from the river to forage on vegetation surrounding the demonstration sites. Roads surrounding demonstration ponds were marked by beavers dragging cut trees across them, and evidence suggested beavers were using the demonstration ponds as corridors to reach and cut larger trees.

Although the Tres Rios group recognised that beaver activity had to be suppressed, they did not consider lethal removal a viable option. Capture and removal also was not possible because beavers already occupied the desirable habitat in Arizona. Placing additional animals in these areas would have only made new animals vulnerable to starvation, or caused displacement of existing animals. The only alternative options were to exclude beaver from desirable plants, or reduce desirability of plants or the site. Objectives of this study were to assess the: (1) efficacy of fencing and frightening devices to protect aquatic vegetation; (2) efficacy of fencing, frightening devices, and textural repellent to reduce gnawing of cottonwood trees; and (3) impact of these non-lethal approaches on other wildlife species.

Study area

The Tres Rios Project is located in Maricopa County, Arizona. The area is approximately 14.8 km in length and 1.6 km wide and encompasses approximately 2,250 ha. The Salt River flows into the Gila River just upstream of the 115th Avenue crossing. The Aqua Fria River flows into the Gila River near the demonstration end of the study area. Elevations vary from about 285 to 310 m. Irrigation channels crisscross the surrounding area—otherwise, standing water is scarce. Mean annual precipitation is less than 20.5 cm. The potential evapotranspiration is slightly less than precipitation during January, and greater during all other months. Ecological communities within the vicinity of the project area have been broadly assigned to three categories: desert wash or riparian, desert outwash plain, and desert upland.

The study was implemented on the Tres Rios demonstration plots. These plots consist of approximately 4.5 ha emergent marsh and free-water surface wetlands. Cobble and Hayfield sites each contained two ponds similar in size, approximately 0.8 ha on the Cobble and 1.2 ha on the Hayfield. Terrestrial plots (4 × 4 m) were established along the perimeters of these ponds, in areas known to have been frequented by beaver. Plot corners were marked with a metal T-post. A minimum interval of 8 m separated plots.

Materials and methods

The study indirectly measured beaver response to control measures by monitoring amount of damage inflicted to cottonwood stems and aquatic plants. Beaver numbers were unknown, but attempts were made to establish each experimental replicate within separate beaver colony territories. Replicate independence, however, was most likely compromised because of pond size and beaver movements.

Aquatic treatments

An aquatic replicate was established at each end of the two Hayfield ponds. Three treatments and an untreated control were randomly assigned among the four plots established within each of these four replicates. Treatments implemented to protect aquatic vegetation were an electronic frightening device, an electro-shocking device, and fence. The electronic devices were located in the centre of the plot, and the fence encircled the plot perimeter. Electronic frightening devices were created by attaching a CritterGitter (AMTEK, San Diego, California) to each side and 5 cm from the bottom of a 10.2 × 10.2 cm post. A flashing light (Enhancer Model EH/ST-1) was attached immediately above each CritterGitter. A 5 cm hole centered through the post core permitted the frightening device to be installed over a metal T-post. The device was set atop and secured to a flotation platform that maintained the motion detectors a few centimetres above water level. An electro-shocking device, previously developed by the National Wildlife Research Center scientists for beaver dispersal in water, was modified to be triggered by the frightening device. Therefore, this device was the same as the frightening device, except the surrounding water received a low electrical current when activated. This current causes a tingling sensation at the perimeter of the electrical field or a mild shock at the central post. The perimeter radiated approximately 2–3 m around the central post. A switch operated by remote control activated the device. The fence exclosures were constructed with 2 m metal T-posts set at plot corners, and a 0.95 m high, woodland-green vinyl-coated, 5 cm mesh, 0.095 core 9 gauge chain-link fence. Untreated plots were marked by installing T-posts at each corner of the plot. Equipment status was recorded and repaired at 1-week intervals if necessary.

Four 4 m line-transects were used to monitor changes in aquatic vegetation. Transects ran parallel to the bank. A transect was stretched from a randomly selected point to the same point on the opposite plot side within each quarter (1 m) of a plot, to stratify placement. Species composition and cover were determined by recording the intercept distance for each species that crosses a line-transect. Vegetation was monitored when the trials were implemented and then at 2-week intervals for 4 months. A photographic record was kept for each plot at the same 2-week intervals.

A one-factor analysis of variance with repeated measures was used to determine whether aquatic plant cover varied among treated plots over time. Plant cover was the dependent variable. The treatment factor had four levels and bi-weekly monitoring was the repeated measure (eight levels).

Terrestrial treatments

Two terrestrial replicates were established on islands within ponds on the Cobble sites and two replicates were placed along the banks of the Hayfield ponds. Each replicate consisted of four plots containing nine cottonwood stem segments (8–20 cm diameter) at 1 m intervals and 1 m from the plot edges. These stems were collected from a stand near the Tres Rios demonstration plots. Each 2 m stem segment was buried upright to a depth of approximately 1 m, leaving 1 m of the stem exposed above ground. Three treatments and an untreated control were randomly assigned to one of the four plots established along each pond. Treatments in this trial were an electronic frightening device, a textural repellent, and a fence. The electronic frightening device was the same as described above except set at ground level. Textural repellent was a simple mixture of 70 mil sand and alkyd paint (140 g/L). The mixture was kept well mixed until painted evenly on cottonwood stems. A fence was constructed as described for the aquatic treatments. Untreated plots were marked by installing a metal T-post at each corner of the plot.

Damage to the cottonwood stems inflicted by beavers was recorded when the trials were implemented and then at 1-week intervals for 4 months. Damage intensity was scored from 0 to 7 for each stem by visual estimation: 0 = no damage; 1 = tooth marks; 2 = <10% bark removed; 3 = 10–25% bark removed; 4 = 25–75% bark removed or stem gnawed less than 25% through; 5 = 25–75% bark removed or stem gnawed between 25 and 50% through; 6 = >75% bark removed or stem gnawed between 50 and 75% through; 7 = stem gnawed through. Damaged stems were not replaced. Equipment status was recorded and, if necessary, repaired at 1-week intervals.

A one-factor analysis of variance with repeated measures was used to determine whether damage inflicted to cottonwood stems varied among treatments over time. Damage scores were the dependent variable. Treatment was the comparative factor (four levels) and weekly recordings were the repeated measures (16 levels).

Plot observations

An observational point overlooking all four plots within each replicate was identified where activity could be observed with minimal disturbance for most native fauna. Bird and mammal activity was observed from these points on each pond for 30 minutes on a fixed schedule: dawn (–1 to +1 hour of sunrise); mid-morning (+2 to + 4 hours post-sunrise); late afternoon (–4 to –2 hours before sunset); and dusk (–1 to +1 hours post-sunset) once every 2 weeks. Night (+3 to + 8 hours post-sunset) observations were made once every 4 weeks. Observation order was counter-balanced among replicates, and all observations for a specific fortnight were made within a 4-day period. Species present and activity (e.g. swimming, perched) were recorded for each plot at 1 m intervals. Vegetation surrounding terrestrial plots inhibited similar observations. However, species or an indicator observed while conducting other activities were recorded.

Species sighted and individual responses were recorded and summarised. Statistical comparisons among treatments were not conducted.

Results

Aquatic plant cover increased over time ($P < 0.0001$) regardless of treatment ($P > 0.35$; Figure 1). Overall plant cover increased by approximately 60% during the study. Mean cover within a plot at the start of the study was 420 cm, and mean cover by the end of the study was 713 cm. There was no interaction between treatment and time ($P > 0.35$).

Damage to the cottonwood stems also increased over time ($P = 0.0014$), but was not significantly different among treatments ($P > 0.35$; Figure 2). No beaver activity was observed on the Hayfield site. Therefore, the analysis was repeated using only replicates with activity recorded on at least one plot. Results were similar—damage increased over time ($P = 0.0018$) with no differences detected among treatments ($P > 0.35$). There were no interactions ($P > 0.35$). Overall, beavers inflicted minimal damage to cottonwood stems during the study. However, mean damage scores collected during the last survey were probably indicative of the potential efficacy for each treatment. The mean damage score for control plots was 1.95 (se = 1.90). The mean damage score was higher for plots with the electronic frightening device (2.39, se = 1.03) and

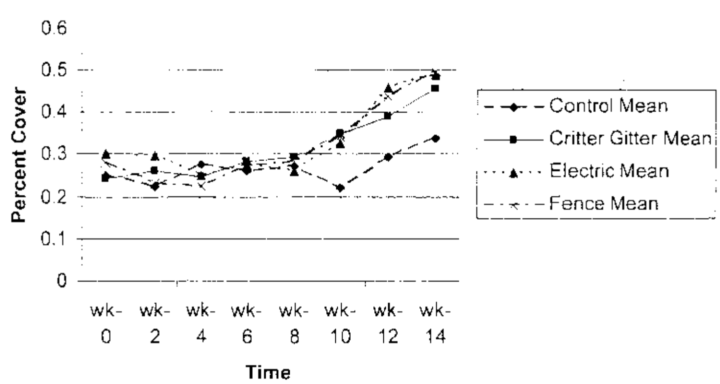

Figure 1. Mean percentage plant cover on plots with fencing, a frightening device, an electro-shocking device, or an untreated control at the start and at 2-week intervals throughout the study.

lower for stems treated with the textural repellent (0.89, se = 0.78). There was no evidence that beaver entered fence plots, which was reflected in the mean damage score (0.0, se = 0.0).

Numerous birds (70 species), mammals (10 species), and reptiles/amphibians (5 species) were observed at the Tres Rios site during the study. Other than during the first few hours, the electronic devices appeared to have minimal impact on target or non-target species. Some waterfowl developed nests within a few metres of the devices. Fences appeared to have impeded mammal movements and restricted swimming birds. Birds were observed perching on the fences and American coots (*Fulica americana*) constructed nests inside the exclosures.

Discussion

Minimal beaver activity was observed during the study. Beavers were frequently observed the year before and their impacts on aquatic vegetation and nearby trees were considerable. Why beaver activity declined is unknown. Increasing human activity may have contributed to the demise of beavers. Although hunting is prohibited, humans may have had a negatively impact on beaver populations on developed property, thus creating a sink for animals to disperse and greatly limiting a source for invading animals. However, if humans contributed or caused a decline in beaver numbers, then a rebound in the beaver populations can be anticipated. Human activity will decline as the project progresses and better protective measures are implemented. It also is possible that manipulating the mineral content of effluent discharged into the wetlands rendered the water less desirable to beavers. Natural predators most likely account for some beaver mortality, but predation pressure has likely not changed over the past year.

Regardless, the Tres Rios wetlands provide optimum beaver habitat and beavers will continue to occupy these sites. Beavers should be considered a desirable component of these wetland habitats. A high beaver population, however, can be a destructive force (Miller and Yarrow 1994). Aquatic vegetation may once again decline and mature trees will likely disappear. Eventually, existing vegetation will be replaced by less palatable and highly competitive species, such as salt-cedar. As a result, beaver populations can be expected to decline once habitat quality declines. Thus, a natural 'balance' between beavers and vegetation components of the system will eventually be achieved. Beavers are the primary, non-human force determining wetland habitat conditions (Hill 1982). Unfortunately, vegetation status in 'balance' with high beaver activity can be anticipated to be well below current or desirable status, such as an extensive wetland and riparian flora supporting a diverse fauna.

Although minimal damage occurred, the study did provide insight into the feasibility of the non-lethal approaches tested. The electronic frightening device was ineffective for any prolonged period. Beavers and muskrats were observed swimming along plots protected by these devices. Activated devices appeared to have minimal impact on their behaviour. Further, cottonwood stems protected by these devices were frequently damaged. These results are similar to reports of attempts to apply frightening devices to deter other species. Frightening devices (e.g. artificial light, automatic exploders, pyrotechnics) rarely work for more than a few days or at most a week (Koehler et al. 1990). Incorporating the shocking device as implemented in this study did not appear to improve efficacy in deterring animals. Efficacy could probably be improved by increasing electrical current. However, associated potential hazards may render this device unacceptable for use in publicly accessible areas. A positive attribute was that non-target species did not appear to be negatively impacted by either device. Species observed and behaviours exhibited did not vary among treatments. Regardless, these devices have minimal long-term utility for deterring beavers. They may work well, however, if installed in stream channels to inhibit beavers from repairing dams for a few days, permitting short-term water drainage.

Effective repellents render a plant less attractive to foraging animals. An animal may select one plant over another because it is attracted to the first or because it is avoiding the alternative (Galef 1985). Thus, the likelihood

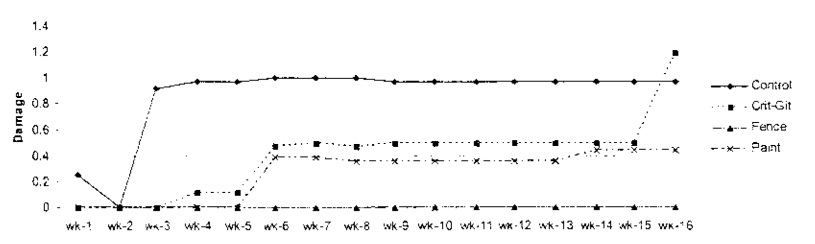

Figure 2. Mean damage scores for plots containing cottonwood stems treated with fencing, a frightening device, a textural repellent, or untreated controls at 1-week intervals throughout the study. A damage score of 0 indicates none of the stems were damaged, while a score of 7 indicates all stems were cut down by beavers.

of a particular plant being eaten depends on its own palatability, and availability and desirability of alternative foods (Nolte and Mason 1998). Chemical repellents have limited utility to reduce gnawing by beavers (unpublished data). However, chemical repellents can reduce damage when applied directly to foliage consumed by beavers (DuBow 2000). Label restrictions may severely restrict applying chemical repellents in riparian zones. Textural repellents may offer an alternative. Cottonwood stems painted with the textural repellent were damaged less than control stems or stems planted near frightening devices. Textural repellent, however, did not totally impede gnawing. A few trees were cut and others were stripped of bark. These results were less supportive than pen trials assessing efficacy of textural repellents to reduce beaver gnawing on cottonwood stems (unpublished data). Untreated stems or stems painted with untreated paint were severely damaged during this 2-week trial, while treated stems received minor damage. Eight of ten beavers completely avoided stems treated with 30 mil sand, and gnawing by the other two beavers was very limited. Painting cottonwood stems in this study did not adversely affect vigour of the stems. Buds sprouted through the paint and new foliage appeared.

Beavers did not penetrate fences installed on aquatic or terrestrial plots. Fencing is a feasible approach to reduce foraging pressure while plants are established. Beavers do not climb, so fences need not be constructed very high. Fences installed for this study were not visually obtrusive because they were relatively short, often protruding above water less than 0.5 m and their green colour-coated vinyl blended with vegetation. Extensive fencing, however, will be expensive and probably require considerable maintenance. The small fenced plots used in this study had minimal impact on non-target species, probably because animals could easily move around the perimeter. However, extensive fencing would impede movements of some species. Aquatic mammals also are less likely to circumvent a large fenced area. Beavers are capable of burrowing beneath a fence, thus regular monitoring for tunnels would be necessary—a rather difficult task for fences installed in murky waters.

References

Albert, S. and Trimble, T. 2000. Beavers are partners in riparian restoration on the Zuni Indian Reservation. Ecological Restoration, 18, 87–92.

DuBow, T.J. 2000. Reducing beaver damage to habitat restoration sites using less palatable tree species and repellents. Thesis. Logan, Utah State University, 76 p.

Galef, B.G. 1985. Direct and indirect behavioral pathways to the social transmission of food avoidance. In: Braveman, N.S. and Bronstein, P., ed., Experimental assessments and clinical applications of conditioned food aversions. New York, New York Academy of Sciences, 203–215.

Hand, D. 1984. The beaver's tale: out of the woods and into hot water. Smithsonian, 15, 162–171.

Hill, E.P. 1982. Beaver. In: Chapman, J.A. and Feldhamer, G.A., ed., Wildlife mammals of North America. Baltimore, Maryland, The Johns Hopkins University Press, 256–281.

Miller, J.E. and Yarrow, G.K. 1994. Beavers. In: Hygnstrom, S.E., Timm, R.M. and Larsen, G.E., ed., Prevention and control of wildlife damage. Lincoln, Nebraska, University of Nebraska Cooperative Extension, B1–B11.

Koehler, A.E., Marsh, R.E. and Salmon, T.P. 1990. Frightening methods and devices/stimuli to prevent mammal damage—a review. Proceedings of the Vertebrate Pest Conference, 14, 168–173.

Nolte, D.L. 1998. Wildlife considerations when planning plant projects. In: Rose, R. and Haase, D.L., ed., Native plant propagating and planting. Corvallis, Oregon State University, 118–123.

Nolte, D.L. and Mason, J.R. 1998. Bioassays for mammals and birds. In: Millar, J. and Haynes, K., ed., Methods in chemical ecology. London, Chapman and Hall Publishers, 326–395.

Rutherford, W.H. 1955. Wildlife and environmental relationships of beavers in Colorado Forests. Journal of Forestry, 53, 803–806.

Seton, E.Y. 1900. Lives of games animals. Revised 1953 by Charles T. Branford Company, Boston Massachusetts, USA, Volume 4, 441–500.

Wilson, D.E. and Ruff, S. 1999. The Smithsonian book of North American mammals. Washington D.C., Smithsonian Institution Press, 750 p.

2003. G. R. Singleton, L. A. Hinds, C. J. Krebs, and D. M. Spratt, editors. Rats, Mice and People: Rodent Biology and Management. Australian Centre for International Agricultural Research, Canberra, Australia.