RIO GRANDE BEAVER *(CASTOR CANADENSIS MEXICANUS)* SURVEY IN BIG BEND NATIONAL PARK

by

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ABSTRACT

The Rio Grande River forms the 176 km boundary of Big Bend National Park with Mexico and is home to the southwestern subspecies of North American beaver, *Castor canadensis mexicanus*. The last survey for the Rio Grande beaver, sometimes known as the Mexican beaver, in Big Bend National Park was conducted in 1981 by P. Strong and J. Bissonette. Our objectives were to document centers of beaver activity and estimate the population of beaver in Big Bend National Park. We surveyed the Rio Grande River on float trips with kayaks and canoes from the mouth of Terlingua Creek to the mouth of Boquillas Canyon. We recorded water depth, type of vegetation, sign of active beaver colonies (presence of dens, beaver tracks, scat, and cuttings), and ranked the amount of beaver activity within each colony as high, medium or low. From these data, we created a map using ArcGIS showing bathymetry of the river, vegetation profiles, and active beaver sign. We delineated a total of 98 active beaver colonies in the study area occupying deeper pools along the Rio Grande. We conducted camera surveys on 11 of the colonies to estimate the number of beaver in each colony. With camera survey data and activity ranking of each colony, we estimated a population of 185 beavers occupying the 98 colonies. This represents a 38% increase in the beaver population along the Rio Grande since 1981.

I. INTRODUCTION

The North American beaver (Castor canadensis) is a large semi-aquatic rodent of the family Castoridae. The family is represented by one genus with two species, C. canadensis in North America, and C. fiber in Eurasia. Twenty-four subspecies were originally described in North America for C. canadensis, but their current status and distribution are confused in many parts of the United States by reintroductions of beavers from source populations different from the original subspecies (Wilson and Ruff, 1999). Subspecies were presumably originally segregated by major watersheds (Boyle and Owens, 2007).

Although the species currently is considered secure across its range, unregulated fur harvest and habitat destruction caused severe declines or extirpation of beavers in many parts of the United States by 1900. Conservation efforts, including harvest monitoring, enforced trapping regulations, protection of wetland habitats, and reintroduction efforts were initiated by the early 1900s. These efforts to restore beaver populations have led to recovery and maintenance of stable populations where suitable habitat remains in much of its original range (Novak, 1987; Boyle and Owens, 2007). The current beaver population in North America has rebounded to an estimated 6-12 million; however this is still a fraction of the originally estimated historical population of 60-400 million (Ringelman, 1991).

The North American beaver inhabits rivers, streams, lakes, reservoirs, and wetlands across North America. Beavers occur throughout most of Alaska, Canada, the continental United States, and in portions of northern Mexico (Boyle and Owens, 2007). According to Boyle and Owens (2007) beaver do not inhabit the tundra of northern

Alaska and Canada, parts of the Midwestern United States, much of South Carolina, or peninsular Florida. Beaver create and modify their habitat by building dams. These dams exert such a strong influence on aquatic and riparian communities that the beaver is considered a keystone species (Boyle and Owens, 2007). Beaver activities can increase biodiversity through creation of beaver ponds and wetlands. As wetlands and riparian habitat are formed and enlarged by beaver activities, aquatic plants colonize newly available watery habitat. Insect, invertebrate, fish, mammal, and bird diversity are also expanded by creation of beaver ponds and wetlands (Boyle and Owens, 2007).

Research on beaver in North America has been extensive, covering beaver biology and ecology. Beavers live in colonies, which can be defined as a group of beavers occupying a pond, ponds, or a stretch of stream, utilizing the same food cache, and maintaining communal dams where habitat allows (Hay, 1955). A colony usually consists of an adult breeding pair, their young of the year (kits), and the previous year's offspring (yearlings), and may occasionally include one or two non-breeding subadults (Rutherford, 1964; Novak, 1987). Colony size typically ranges from three to eight beavers, with larger colonies occurring in the central parts of the beaver's geographic range such as Colorado, Nebraska, and South Dakota (Novak 1987). In Colorado, Rutherford (1964) estimated an average of 5.1 beaver per colony in aspen habitat and 4.5 beaver per colony in willow habitat. Peterson and Payne (1986) estimated an average of 5.6 beaver per colony in Wisconsin, while Bhat et al. (1993) estimated an average of 4.8 beaver per colony in New York. When calculating population parameters from colony sampling data, an average of five beavers per colony is often assumed (Hay, 1955; Henderson, 1960; Fitzgerald et al., 1994). Factors that contribute to variation in density

of beaver populations include water quality, habitat suitability, human exploitation (trapping), area available for new colonization, length of habitation time relative to available resources, diseases, local predation events, and territoriality (Baker and Hill, 2003). There is a wide range in the density of colonies, from near zero to 4.6/km^2 according to Novak (1987).

Territory size and home range are key factors when estimating beaver populations. Although territorial behavior and boundaries are not precisely defined, colony boundaries can be determined by various elements such as colony size, topography, valley width, stream gradient, food availability, or territorial defense by adjacent colonies (Rutherford, 1964; Brenner, 1967; Allen, 1983). Scent mounts are the primary expression of territoriality and may define the location and limits of the territory which minimizes aggressive encounters with neighbors and discourages colonization by dispersing beaver (Novak, 1987; Baker and Hill, 2003). Scent mounds, which advertise the sex and age status of beavers in a colony, are constructed of mud and vegetation scented with deposits of castoreum (Novak, 1987; Baker and Hill, 2003; Boyle and Owen, 2007). These scent mounts are also used by dispersing beaver to detect the absence of scent from an adult of the opposite sex, who may join the colony and become part of a new breeding pair (Butler and Butler, 1979; Novak, 1987; Boyle and Owen, 2007). Home range size depends on sex, age, social organization of the family unit, type of occupied habitat, and seasonal constraints (Baker and Hill, 2003). Home range and territory sizes range from 0.4-8.0 ha (Lovejoy and Black, 1979; Fitzgerald et al., 1994). Aleksiuk (1968) suggests that the average beaver territory along a river is 0.8 km in length, with the central 0.4 km being the main activity area.

Beavers are herbivores, feeding year round primarily on the inner bark, twigs, leaves, and buds of deciduous woody plants (Wilson and Ruff, 1999; Baker and Hill, 2003). Beavers will also eat many herbaceous and aquatic plant species (Allen, 1983; Davis et al. 1994). Although beavers utilize a wide range of woody and herbaceous plant species, most of their food is taken from a small number of selected species (Jenkins and Busher, 1979). Throughout their range, beavers select species from the willow family (Salicaceae). Nolet et al. (1994) found that beavers in willow-dominated habitat in the Netherlands fed mostly on willow but selected uncommon non-willow species in greater proportion than their availability, suggesting that willows alone may not provide enough nutrition for the beaver. Food preferences may vary with seasons due to changes in the availability and nutritional value of food species (Jenkins, 1979; Davis et al., 1994).

Beavers shelter in constructed lodges and bank dens for resting, breeding, escape from predators, and thermoregulation (Jenkins and Busher, 1979). In ponds and shallow lakes, they may construct a lodge, which is a dome-shaped structure made of woody stems held together by mud (Allen, 1983). An underwater entrance leads to a feeding chamber, and a higher and drier chamber is used for sleeping and rearing kits (Baker and Hill, 2003). Beavers also dig bank dens on the shore of rivers, streams, ponds, and lakes. They may use both bank dens and lodges, or only bank dens (Boyle and Owens, 2007). Bank dens have an underwater entrance and one or more narrow openings to the surface for ventilation (Baker and Hill, 2003). Lodges and dens provide a year-round thermoneutral zone for beavers (Buech et al., 1989 in McKinstry et al., 1997), important for winter survival in colder regions. In summer, other dens may be used as kits are being born, yearlings expand their range, or the colony extends its territory (Boyle and Owens,

2007). By fall, additional dwellings are abandoned and the entire colony returns to the main lodge or bank den (Hay, 1955), where huddling behavior helps to conserve body heat.

However, gaps in knowledge of beaver population dynamics still exist. Beaver management could be enhanced by more information on the factors influencing population dynamics such as colony site longevity and factors affecting habitat quality (water sources and levels, food availability), mortality, fecundity, and dispersal patterns (Boyle and Owens 2007).

The southwestern subspecies of beaver, C. canadensis mexicanus, also known as the Rio Grande beaver inhabits the Rio Grande River and the Pecos River (Bailey, 1913, 1927). Historically, beaver were reported in the Rio Grande and Pecos River drainages from Brownsville, Texas extending into New Mexico (Bailey, 1905, 1913; Schmidly, 2001). Findley and Caire (1977) reported this subspecies to occur sporadically on the Rio Conchos as well. Big Bend National Park is located in Brewster County where Swepston (1976) estimated 300-500 beavers inhabited the Rio Grande River. The last survey on the Rio Grande beaver in Big Bend NP was conducted in 1981 by Strong and Bissonette (1981). Beyond the two surveys conducted in 1976, and 1981 (Connor and Feeley, 1976; Strong and Bissonette, 1981), there has been no extensive research done on the Rio Grande beaver. This subspecies of beaver is well adapted to the river systems crossing the Chihuahuan desert (Conner and Feeley, 1976). These beaver dig burrows rather than building lodges, in response to continually changing water levels and periodic flooding of the river. The main food source of the Rio Grande beaver on the Rio Grande River is two types of willow; seepwillow (Baccharis spp.), and Salix spp. Giant reed

(Arundo donax), common reed (Phragmites spp.), Cottonwood (Populus spp.), and tamarisk (Tamarix pentandra) also make up part of the beaver's diet (Conner and Feeley, 1976).

Objectives of my research were to: a) document and record the location of beaver dens and colonies along the Rio Grande within Big Bend NP, b) provide a current estimate of the beaver population along the Rio Grande River, c) describe riverine habitat within existing beaver colonies, and d) compare current beaver population estimate to estimates from previous surveys. This information will provide a better understanding of the native Rio Grande beaver populations in Big Bend NP and assist the National Park Service and Mexican Protected Area managers in their efforts to conserve beaver along the river drainages of the Southwest.

II. STUDY SITE

Big Bend NP is the largest protected area of Chihuahuan Desert in the United States, covering 324,219 ha. When combined with Big Bend Ranch State Park, Texas, the U.S. protected area is over 400,000 hectares (National Parks Conservation Association, 2015). It contains more than 1,200 species of plants, more than 450 species of birds, 56 species of reptiles, and 75 species of mammals (National Parks Service, 2015). The Rio Grande River forms the southern boundary of the park as well as the international boundary between Mexico and the United States. Big Bend NP preserves one of the largest Chihuahuan Desert ecosystems remaining in the United States. The park's topographic extremes and diversity of habitat support a multitude of diverse flora and fauna including more than 40 species of plants and animals listed as "rare", "threatened", or "endangered"(National Park Service, 1996). The 172 km stretch of the Rio Grande River, which forms the southern boundary of the park, meanders through a portion of the Chihuahuan Desert and cuts through three mountain ranges (Mesa De Anguila, Mariscal, Sierra Del Carmen) in deep canyons (Santa Elena, Mariscal, and Boquillas) with nearly vertical walls. The Rio Grande supports a ribbon of riverine and riparian habitats that provide habitat for diverse populations of flora and fauna not commonly found in the desert environment. Between the river and the mountains, the open desert slopes and plains support a vast array of typical Chihuahuan Desert species (National Park Service, 1996).

The wettest months are May-October (Waver, 1973; in Strong, 1982) with an average annual rainfall of 25 cm (Strong, 1982). The average width of the Rio Grande River in the park is 30 m, with an average water depth of less than one meter during the

month of January (Connor and Feeley, 1976). For this reason, I conducted my study between the months of January-May. My study area was the Rio Grande River from the mouth of Terlingua Creek to the mouth of Boquillas Canyon, approximately 130 river kilometers. Along its course are found sufficient wetland and riverine habitat to support beaver populations. Approximately 10,000 ha of wetlands and 315 water sources exist within Big Bend NP, many found near or along the Rio Grande (Shaw and Finch, 1996).

The riparian areas of Big Bend NP are comprised of dense stands of common reed (Phragmites australis), the introduced giant reed (Arundo donax), willow (Salix sp.), willow baccharis (Baccharis glutinosa), salt cedar (Tamarix sp.), bermudagrass (Cynodon dactylon), along with the occasional cottonwood (Populus fremontii) (Feeley and Connor, 1977).

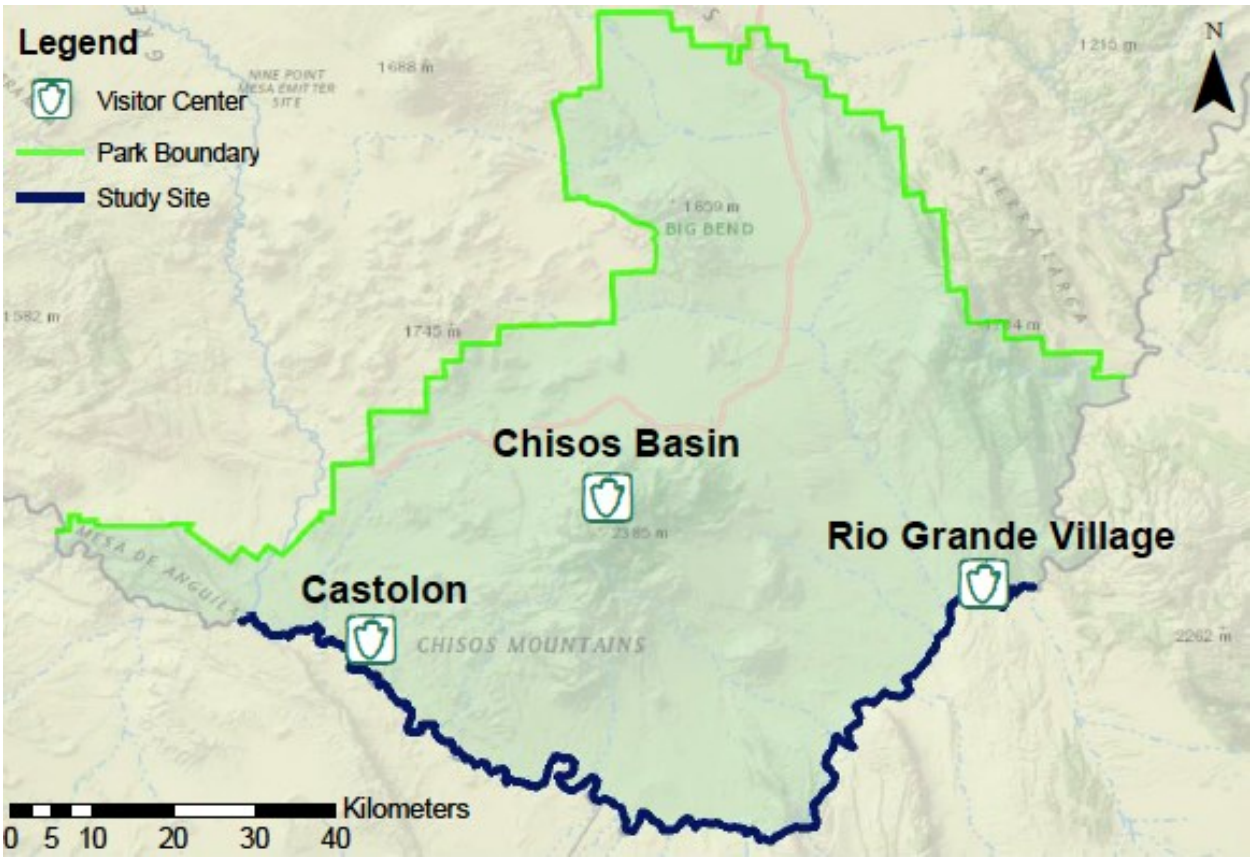

Figure 1. GIS map of the study site in Big Bend National Park.

III. MATERIALS AND METHODS

I surveyed 130 km of the Rio Grande River, from the mouth of Terlingua Creek to the mouth of Boquillas Canyon (Fig. 1), during the course of several float trips (28 February-3 March 2013, 11-12 April 2013, 9-16 May 2013, and 14-21 May 2014) using kayaks and canoes. During these trips, I outlined the river by setting waypoints on a handheld GPS every 5 m along the water's edge on both sides of the river. This was recorded to see the current path of the river. I also recorded water depth, stream discharge, gage height, vegetation, location of beaver dens, and areas of beaver activity. Water depth was measured every 5 m in 1 m increments using a 5 m telescoping pole in order to create a detailed bathymetry map of the river in Big Bend NP. I recorded GPS waypoints only at locations where water depth changed. Stream discharge and gate height was recorded by monitoring the gaging station (Table 2). Activity areas were locations where vegetation cutting (foraging activity), tracks, slides and other beaver sign were found. I used data collected from the float trips combined with camera trapping to delineate beaver colonies and estimate the beaver population in Big Bend NP.

GIS Mapping

Using satellite images from basemaps in ArcGIS and ground observations during floating trips allowed me to delineate rapids in the river, steep vs gradual sloping banks, and types of vegetation. I drew polygons around different vegetative types, rapids, and different water depths. Using this data, I constructed a map defining beaver habitat parameters along the Rio Grande and predicting areas of actual and potential beaver activity. Furthermore, this map will assist in estimating the population of beaver in Big Bend NP.

I delineated beaver colonies by assessing den positions, gaps in beaver activity, and by natural barriers to beaver movements (e.g., rapids and shallow water areas). Based on these delineations, I marked centers of beaver activity and measured the territory used by each beaver colony from the first sign of beaver to the last sign of beaver for each colony.

To determine if locations of beaver dens were related to water depth, I placed a 5 m radius buffer around each den and recorded the maximum water depth inside the buffer. I used the 5 m buffer to eliminate overlap between different dens. I randomly selected points along the river equal to the number of beaver dens along the 130 km of river. I also placed a 5 m radius buffer around each of the randomly selected points and recorded the maximum depth inside the buffer. I continued to randomly select points until none of the buffers overlapped other random points or a beaver dens. No locations were sampled more than once. Using R version 3.0.2 (R Core Team 2013), I conducted a chi-squared analysis on the maximum water depths at each den and each randomly selected point to determine if beaver dens were randomly distributed with regard to water depth. A 95% confidence interval was used to determine the water depth beaver are selecting.

Camera Trapping

I used a camera trapping technique to assess the number of beavers per colony and the total population along the Rio Grande. From March 2013-May 2014, I used Bushnell Trophy Cam HD 8MP motion activated infra-red cameras (Bushnell Outdoor Products, Overland Park, Kansas) to take photos and videos of beavers near dens, active feeding areas, and areas where beaver had been reported in the past. I secured cameras to

2.5 x 5.1 x 122 cm wooden stakes using cable ties. I placed the stakes within 5 m of active beaver areas. Two cameras were often used in one location, positioned at a 45° angle to the water line pointing to the same location at water's edge on each side of the active beaver area. With this configuration, I was able to see both sides of beaver as they emerged from water. I placed Murray's Quill Beaver castor (Murray's Lure & Trapping, Walker, WV) in front of cameras to lure beavers into photo range. Because of the remoteness of much of the Rio Grande River in Big Bend National Park, I limited camera trapping operations to stretches of river between Santa Elena Canyon and Cottonwood Campground, and from Daniels Ranch to the Rio Grande Village River Access Boat Ramp. Based on kayak surveys along these two sections of river, I randomly selected five active colonies in each of the two sections of river. I also surveyed the beaver pond at Rio Grande Village and included it as the eleventh survey site. Photos and videos from the motion activated cameras allowed me to note distinguishing characteristics of individuals, such as body scars, cuts on the tail, size of individual, or presence of enlarged teats on females. Based on these data, I estimated the number of beaver using each location.

For each of the ten colonies, I ranked the amount of beaver activity as high, medium, or low based upon the amount of cuttings, tracks, and beaver sightings. For den sites that had less than five beaver trails coming out of the water and going into feeding areas, I ranked as low beaver activity. Den sites with 5-10 beaver trails, were ranked as medium beaver activity, and those sites with more than 10 trails were ranked as high beaver activity.

Camera trapping was also used to determine natural barriers to beavers as well as territory size. Camera traps were placed in areas that were possible barriers to beaver, areas of river rock and shallow water rapids, and baited with castor lure.

Live Trapping

Live traps were used in an effort to estimate beavers present in colonies through Peterson mark and recapture estimates. Live trapping took place from February-May 2014. I placed Tomahawk live traps and a custom built double door trap at each of the 10 randomly selected beaver dens for marking and data collection. Extra-large Tomahawk live traps (Model 609 with easy release door, 91.44 x 30.48 x 35.56 cm) were used in attempts to trap live beaver entering a feeding area. Large Tomahawk live traps (Model 608 with easy release door, 81.28 x 25.4 x 30.48 cm) were used at entrances of beaver dens in attempt to trap live beaver exiting a den. I also built a custom double guillotine door live trap to trap beaver walking or swimming through a narrow passage way. I also placed motion sensitive cameras near the traps to monitor beaver behavior in the presence of a live trap.

At feeding areas, I placed beaver castor lure in the back of the trap behind the trigger pan along with fresh cut willow sticks. Once baited, I placed mud and debris on the bottom of the trap to cover the wire, taking care that no mud or debris collected under the trigger pan. The traps were then covered with surrounding vegetation to make the trap look more natural.

At colonies with multiple den entrances, I placed a large tomahawk at or inside all entrances of that colony. I also baited these traps with castor lure and fresh cut willow

sticks, as well as covering the bottom of the trap with mud and covering them with surrounding vegetation.

I constructed the body of my double door custom built beaver trap (101.6 x 30.48 x 40.64cm, Fig. 2) from a welded galvanized wire panel with 10.16 x 10.16 cm square spacing. Frames for the trap doors were constructed from the 1.905 cm angle iron and welded to the wire panel body. Guillotine doors, trigger and trigger mechanism were constructed from 0.635 cm steel rods. The trigger mechanism at the top of the trap could be activated from both directions. The trigger mechanism was placed 20.32 cm from the top of the trap, allowing for smaller animals to pass through the trap without triggering the trap doors and reducing the chance of a beaver missing a conventional trigger pan. Also, hanging the trigger from the top of the trap allowed me to place this trap in the water or mud while not having to worry about debris collecting under a trigger pan. The trigger mechanism was designed to drop both guillotine style doors simultaneously when an animal reached the middle of the trap as seen in Figure 2.

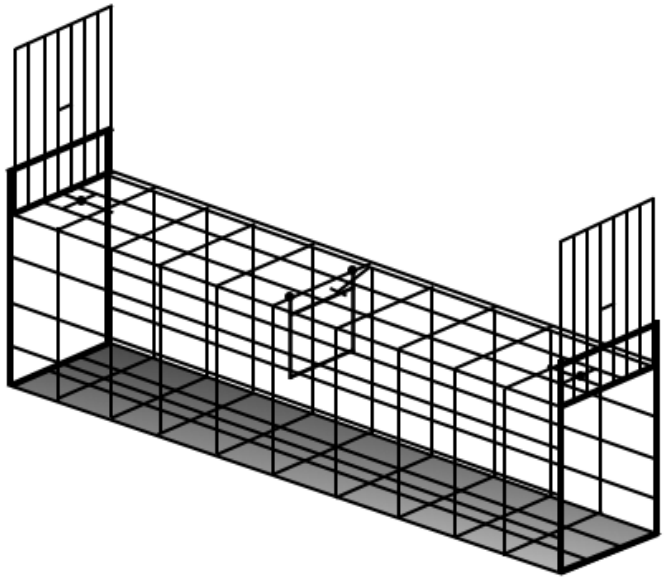

Figure 2. Custom build live trap was used to trap beaver in Big Bend National Park. This trap is 30.48cm wide, 40.64cm tall and 101.6cm long. It features two guillotine trap doors that drop simultaneously when a beaver passes through the trap.

After capturing a beaver, I recorded the sex, live weight, tail length and width, as well as any distinguishing markings. I marked beaver by using hair dye (Revlon Colorsilk Beauty Color Permanent hair color in black and ultra-light ash blonde) to be able to identify the particular individual on camera in the future. I dyed the front half of the beaver with the black hair dye and the back half of the beaver with the blonde hair dye to see which color would last longer and show up better on camera.

IV. RESULTS

River Survey and Habitat Mapping of the Rio Grande River in Big Bend National Park

I and student assistants surveyed 130 km of the Rio Grande over the course of 12 days (Table 1). I recorded a total of 854 GPS locations of beaver activity, cuttings, and tracks and 1704 water depth measurements from Terlingua Creek to Boquillas Canyon. The average river depth was less than 1m throughout the study site. River conditions such as water depth and discharge were approximately the same for each of the survey trips (Table 2). While floating from Solis to La Clocha, we were not able to survey approximately five kilometers of river between San Vicente and La Clocha due to flash flooding in 2013.

Table 1. River survey of the Rio Grande River in Big Bend National Park with the dates of survey, location of survey, length of river surveyed, number of active dens, and the number of colonies found.

Date	Starting Location	Ending Location	Length of River Surveyed	Number of active dens	Number of Colonies
2-28-2013	Terlingua Creek	Cottonwood Campground	12.8 km	28	16
4-11-2013	Cottonwood Campground	Buenos Aires	8 km	15	6
4-12-2013	Buenos Aires	Black Dike	9.7 km	10	7
5-14-2014	Black Dike	Loop Camp	12.9 km	27	21
5-15-2014	Loop Camp	Talley	27.4 km	13	11
5-9- 2013	Talley	Solis	16.1 km	18	11
5-10-2013	Solis	San Vicente	17.5 km	9	11
5-15-2013	La Clocha	Daniels Ranch	6.4 km	8	6
5-16-2013	Daniels Ranch	Rio Grande Village	1.6 km	7	3
5-16-2013	Rio Grande Village	Boquillas Canyon	8km	7	6

Table 2. Gage height and discharge recordings from the USGS gage on the Rio Grande River near Castolon, Tx for the dates of river survey (U.S. Geological Survey, 2012).

Start Date	End Date	Gage Height, ft	Discharge, ft^3/s
2-28-2013	3-3-2013	2.46-2.50	24-28
4-11-2013	4-12-2013	2.24-2.29	10-12
5-9-2013	5-16-2013	2.03-5.23	3.5-612
5-14-2014	5-21-2014	2.46-2.54	17-25

I also surveyed Terlingua Creek, from the mouth of Terlingua Creek to approximately 1 km upstream of the gauging station. Gillette (1933) described Terlingua Creek in 1885 as a bold, running stream with many cottonwoods. During my survey water level was extremely low, with only pools of water holding in Terlingua Creek. All pools of water were < 1 m in depth. There were approximately 3 km of dry river bed between the Rio Grande River and the first pool of water in Terlingua Creek. There was no sign of beaver in Terlingua Creek.

I located 142 den sites representing 98 different beaver colonies (Figs 3 - 9) while surveying the river. I did not locate dens at 23 colony sites due to dense vegetation concealing den entrances or no above water den entrance. Most den entrances were underwater and difficult to find in active feeding areas with steep banks and deeper water (>1 m). I located underwater dens by probing the river bank with the telescoping pole or by following drag marks. The number of dens per colony ranged from 0 to 6 dens with a mean of 1.4. The majority of dens were located in water ≥ 1 m. (Table 3). The river length used by each colony ranged from 218 m to 991 m, with a mean of 550 m.

Table 3. Water depth found at the entrance of beaver dens and the number of dens associated with each water depth.

Water Depth (m)	Number of Dens
<1	27
1	102
2	9
3	2
4	1
5	1

Natural barriers to beaver were dry stretches of river or shallow water rapids. Camera trapping was used to determine if beavers were traveling through areas of shallow water rapids. No sign of beavers traveling through or around these areas of shallow water rapids was found, these areas were typically stretches of river rock. To confirm the absence of beaver in these areas, camera trapping was also used in areas of river rock and baited with castor lure; I detected zero beavers in 47 camera trapping nights.

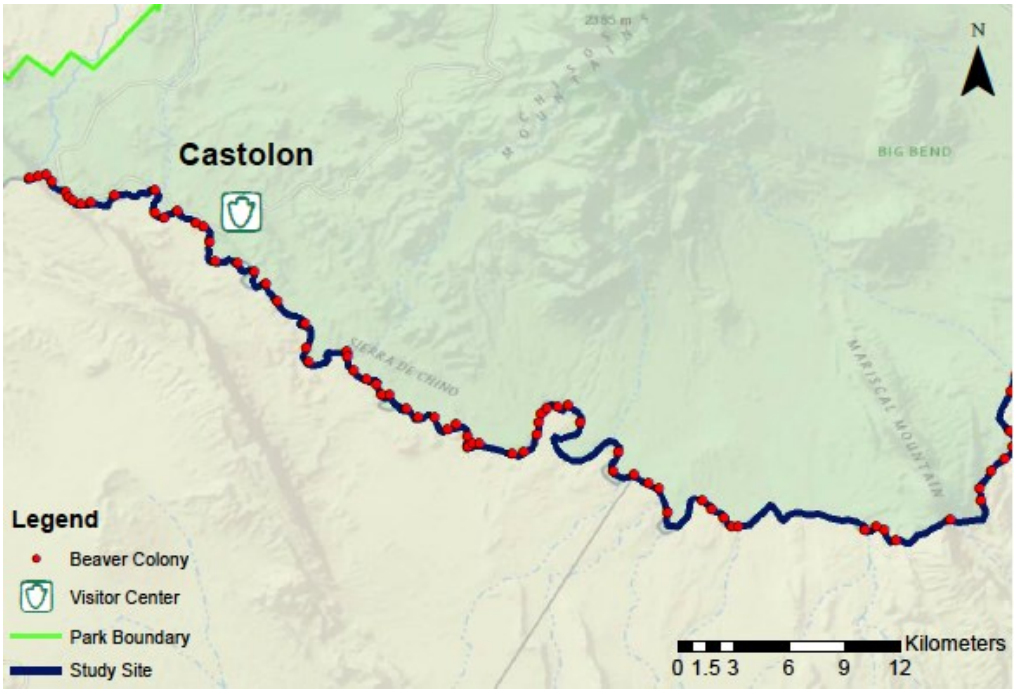

Figure 3. GIS map of the western half of the study site, Terlingua Creek to Mariscal Canyon, in Big Bend National Park with beaver colonies.

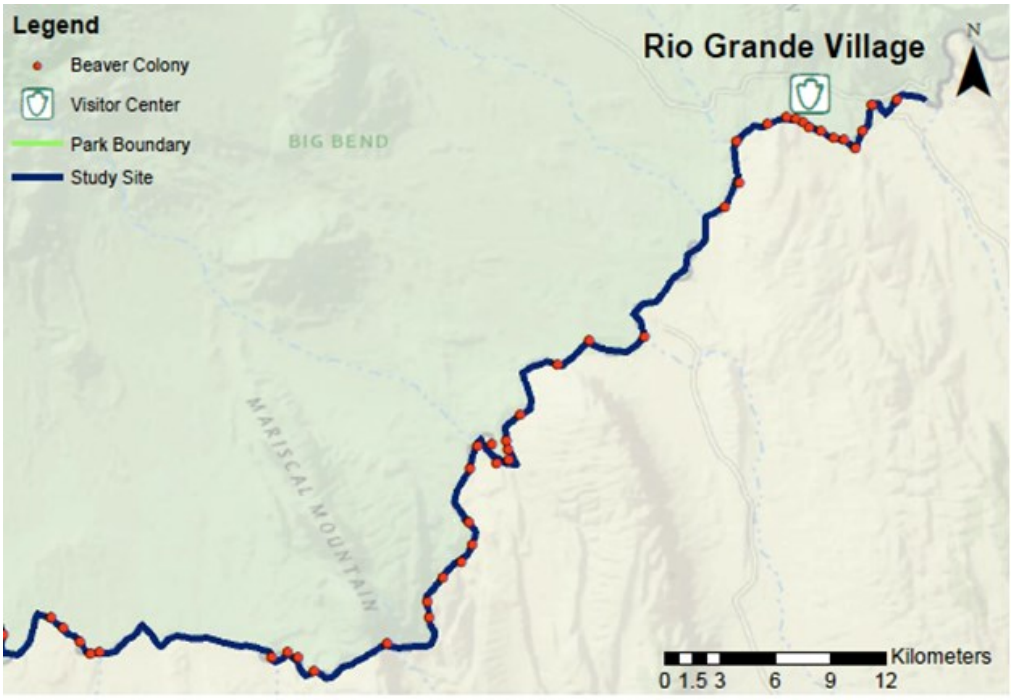

Figure 4. GIS map of the eastern half of the study site, Mariscal Canyon to Boquillas Canyon, in Big Bend National Park, Texas with beaver colonies, 2013.

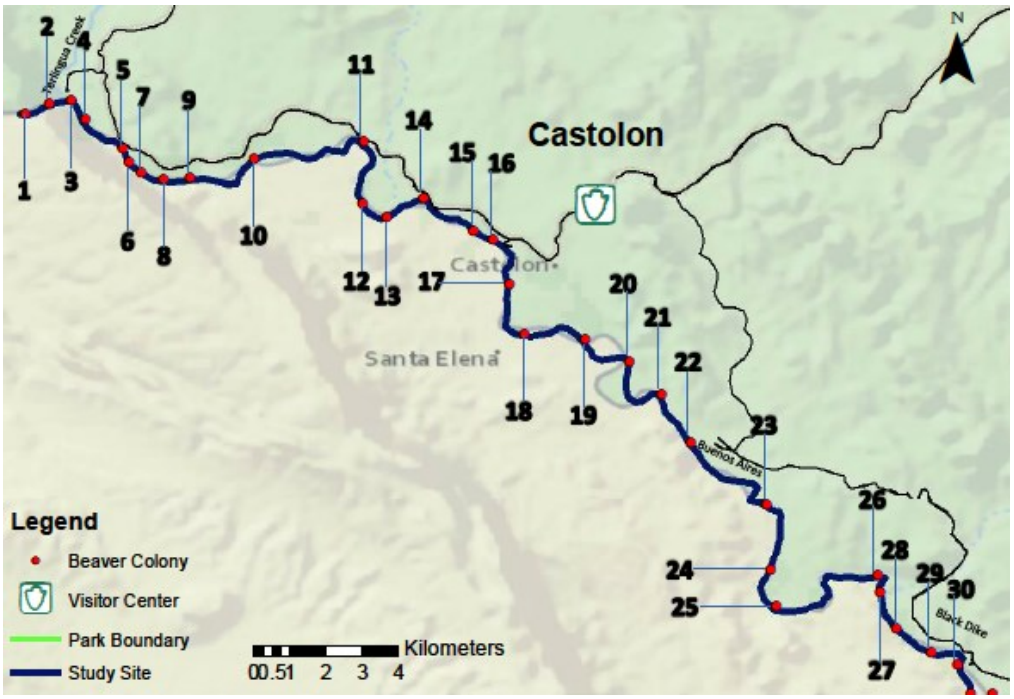

Figure 5. GIS map of beaver colonies from the mouth of Terlingua Creek to Black Dike.

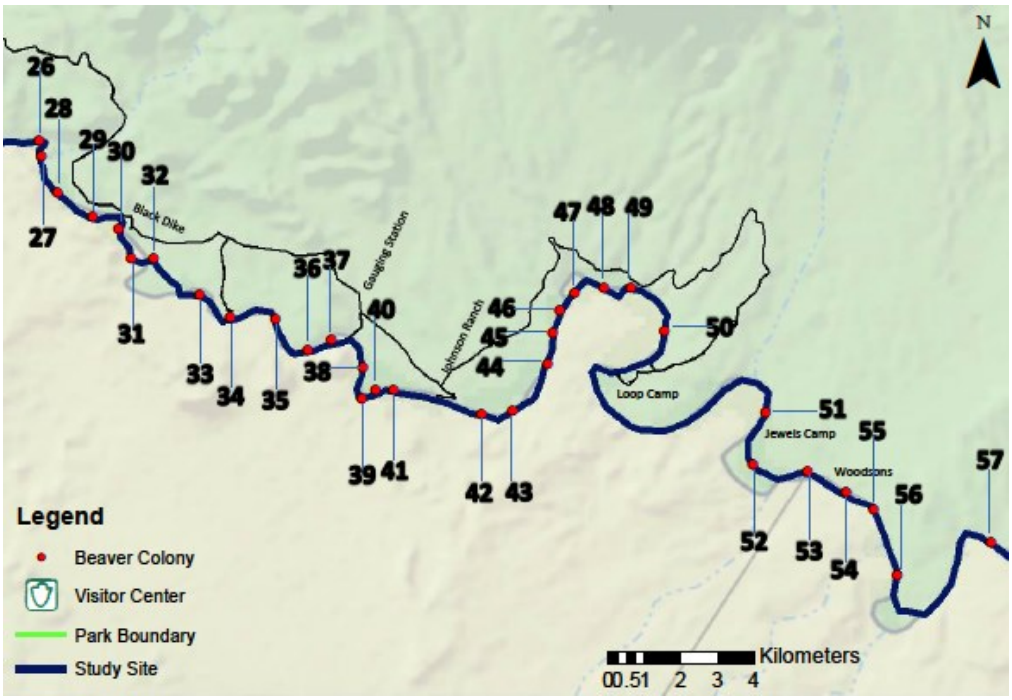

Figure 6. GIS map of beaver Colonies from Black Dike to Woodsons.

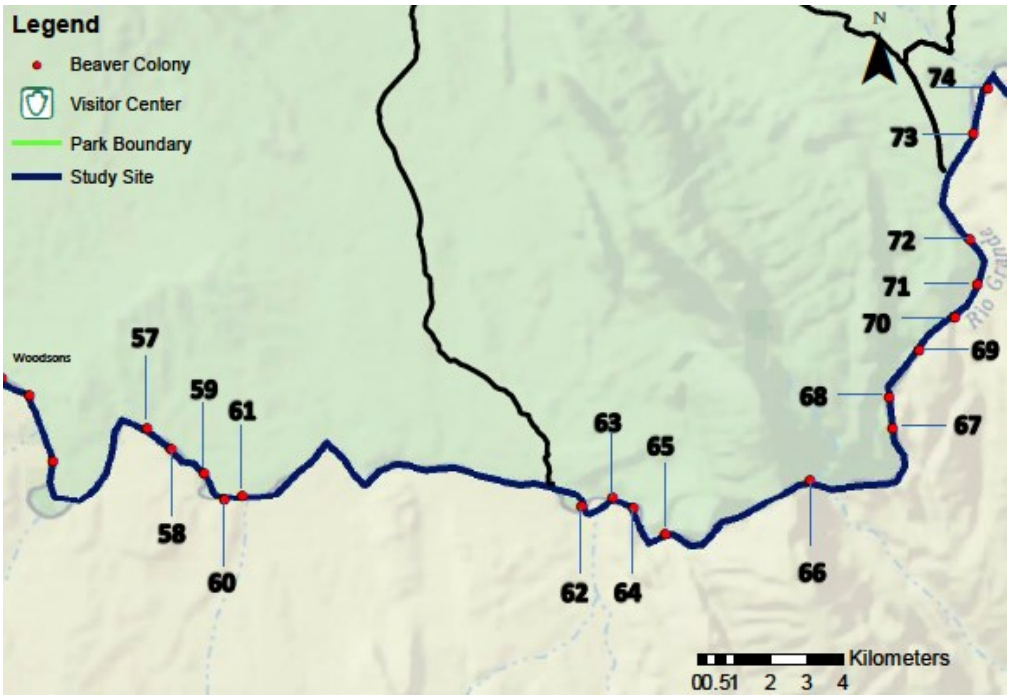

Figure 7. GIS map of beaver colonies from Woodsons to Solis.

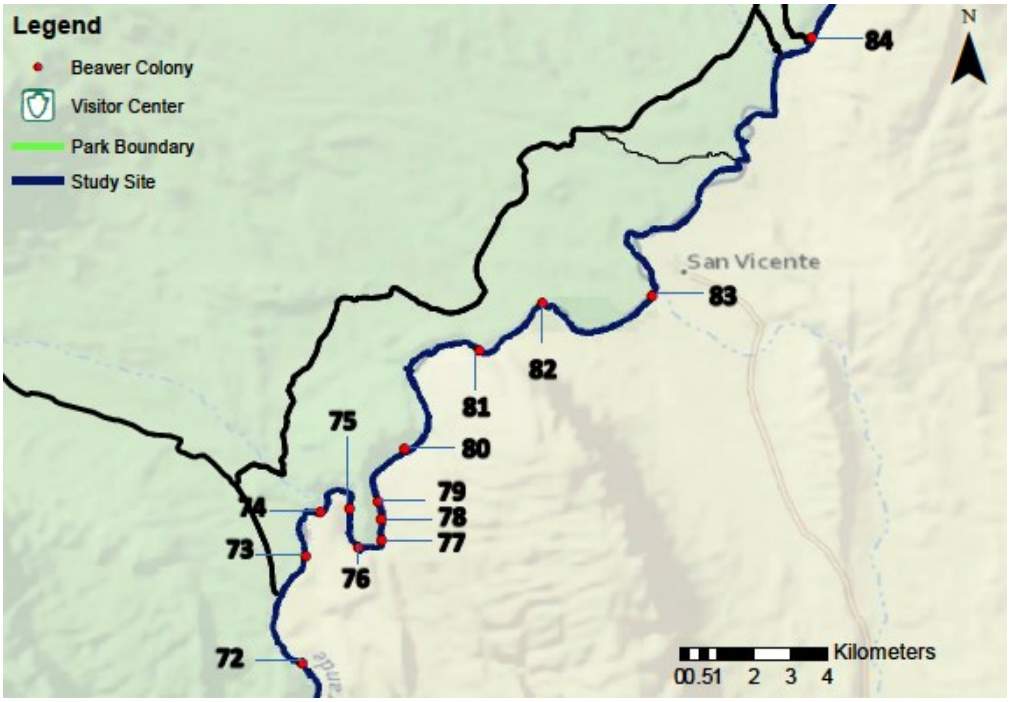

Figure 8. GIS map of beaver colonies from solis to Gravel Pit.

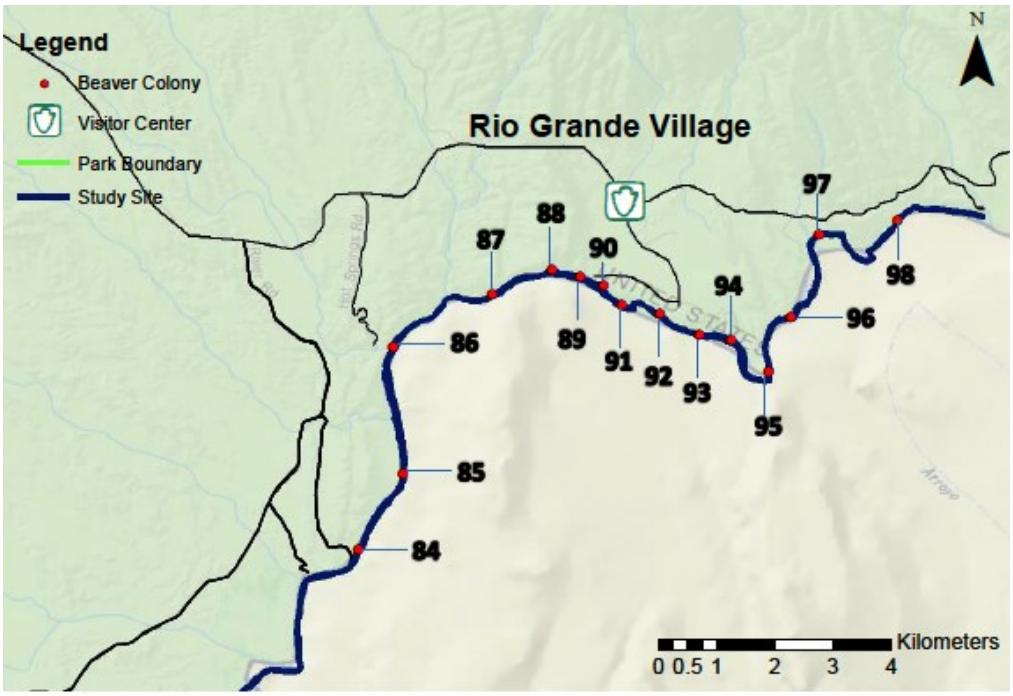

Figure 9. GIS map of beaver colonies from Gravel Pit to Boquillas Canyon.

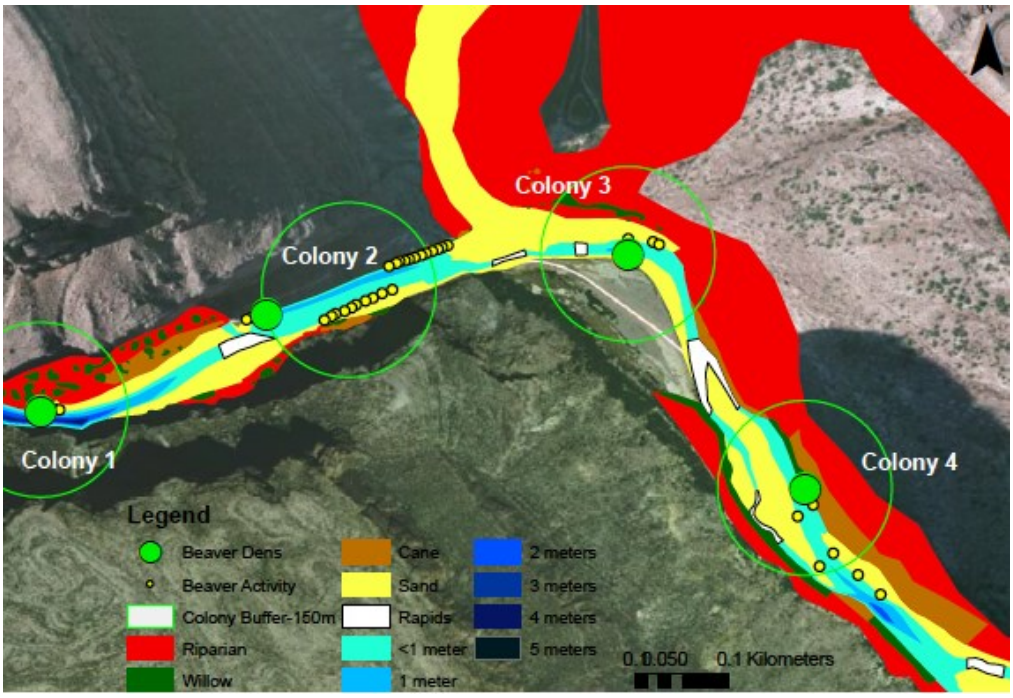

Figure 10. Example section of the completed GIS map, (mouth of Terlingua Creek), with all layers (list the layers) for Big Bend National Park, Texas, 2013.

I have a completed GIS map with all the layers seen in Figure 10 for the entire study site. The entire GIS map would be too long to include in the thesis. However, I will submit the entire GIS map to the park officials in Big Bend NP.

There were 115 active beaver dens located in water ≥1 m and 27 dens in water <1 m in depth. Beavers dens were located in significantly deeper water in comparison with randomly selected sites (X^2 = 133.0556, df = 1, P < 0.001, 95% CI = -0.7676 to -0.5984) along the Rio Grande; suggesting selection by beavers for deeper sections of the river.

Vegetation and Foraging Activity

I recorded the presence of giant cane, common reed, and willow along the full extent of surveyed river. I also noted that most beaver dens were found at the base of cane, indicating beaver might rely upon the cane roots to maintain the structure of their dens. Cane was the dominant vegetative species at most of the beaver colonies found in this survey.

Willow (*Salix* sp.) was the dominant food source used by beaver in the Rio Grande River of Big Bend NP (Table 4). Seepwillow (*Baccharis* sp.) was the second most utilized food source for beaver in Big Bend NP. I found only one beaver colony without willow or baccharis, in Marascal Canyon. At this colony, I observed foraging (cutting) on prickly pear and cocklebur.

Table 4. Food Species of *C. Canadensis Mexicanus* based on cuttings in Big Bend National Park, Texas

Common Name	Scientific Name
Willow	*Salix* sp.
Sedges	*Cyperaceae*
Tamarisk	*Tamarix pentandra*
Fremont Cottonwood	*Populus fremonti*

Table 4. Continued

Prickly Pear	*Opuntia* sp.
Seep-Willow Baccharis	*Baccharis salicifolia*
Wild Tobacco Tree	*Nicotina glauca*
Common Reed	*Phragmites communis*
Sunflower	*Helianthus* sp.
Giant Cane	*Arundo donax*
Cocklebur	*Xanthium strumarium*

Beaver Population Estimates

I completed a total of 276 camera trapping nights at the 10 selected colonies and Beaver Pond at Rio Grande Village, producing >2,100 pictures of beavers and other wildlife in Big Bend NP. Colony #, colony location, number of camera trapping nights, and estimates of minimum and maximum number of beaver at each colony can be seen in Table 7.

Camera trapping was also conducted in the Beaver Pond at Rio Grande Village to determine if beaver or nutria (*Myocastor coypus*) were still using this area. After 10 camera trap nights in the Beaver Pond, there was no sign of beaver or nutria occupying the area. Cattail and cane appear to be too dense for beaver or nutria to access the Beaver Pond. There is also a 5 to 10 m vertical bluff on the river side of the Beaver Pond. This bluff may make it impossible for beaver and nutria to access the Beaver Pond.

The estimated number of beavers per colony is based on photos and videos collected at each of the surveyed dens. The range of beavers at each colony is due to the possibility of counting the same individual more than once. I was able to identify 60% of beavers (n = 21) based on individual characteristics; however, some individuals had no distinguishing characteristics. By comparing estimated numbers of beaver at these

colonies to sign of activity, I developed an activity ranking which I assigned to the remaining colonies in the survey area. At colony sites with a low ranking of beaver activity, I gave that colony a minimum estimate of 1 beaver. At colony sites with a medium ranking of beaver activity, I gave that colony an estimate of 2 beavers. And at colony sites with a high ranking of beaver activity, I gave that colony an estimate of 3 beavers. After floating the entire section of river in the study area and ranking the amount of beaver activity at each den site, I estimated the number of beaver at each colony throughout the study area (Appendix 2). In summary, I estimated the number of beaver in the study area of Big Bend National Park to be 185 beavers with an average of 1.89 beaver per colony and 1.41 beaver/km of river.

Live Trapping

One beaver was captured from 80 trap nights over a 7 day period. On 19 May 2014, using the custom-made trap placed in the middle of a small stream of water flowing into the river from an adjacent pool of water, I captured an adult female in the custom trap (mass = 23.5 kg, tail length= 27 cm, tail width = 13 cm). This female has a large section of the end of her tail missing. Her pelage was dyed and released at the capture site. The difficulty in trapping and marking beaver resulted in no population estimates based on Peterson mark and recapture models.

V. DISCUSSION

Water levels in the Rio Grande in Big Bend NP were generally low in the spring before the summer rains. Once summer rains started in May, water levels in the river remained high throughout the winter. Survey trips in canoes and kayaks were most successful when water levels were low, January-May. The low water levels exposed muddy banks and allowed easier identification of beaver sign in the soft mud. However, river travel was more difficult when water levels were low because we had to drag canoes and kayaks through many shallow areas. Other difficulties resulting in cancelation or delay of river surveys included river flooding with very high water levels and flow (16 May 2013) and a rare law enforcement incident (May 2013, Woodsons). I skipped this section of river in 2013, but was able to survey this section of river in 2014. Approximately 5 km of river were not surveyed between San Vicente and La Clocha due to continued flooding in 2013.

Connor and Feeley (1976) suggested that Rio Grande beaver have slightly larger territories to accommodate the harsh conditions of the Chihuahuan desert. However, I found that the mean river length used by each colony was 549.5 m, which lies within Aleksuik's (1968) estimate of 400m and 800m. Strong (1982) reported colony boundaries being difficult to determine, especially where activity was continuous over long stretches of river. Strong (1982) found one 8 km stretch of river with continuous use and considered this as one colony because colony boundaries could not be determined. In these long stretches of continuous use, Strong (1982) estimated the number of colonies based upon the mean size of recognizable beaver colonies. This method could lead to an over or under estimated number of beaver colonies. Camera

trapping allowed me to overcome this problem by understanding natural barriers to beaver in the Rio Grande of Big Bend NP

According to Bailey (1927), the "average" beaver colony consists of two adults, two-yearlings, and three to six kits. In Connor and Feeley's (1976) study of the Mexican Beaver in Big Bend National Park, they estimated two beavers per colony with a maximum of four per colony. Their estimate was derived by counting the number of willow trees cut between Daniel's Ranch and Rio Grande Village and comparing this number to a study in Northern Michigan (Bailey, 1927) that stated how many trees were cut by a family of six for a winter supply (Connor and Feeley, 1976). Connor and Feeley (1976) also conducted an intensive study of a beaver colony between Hot Springs and Boquillas Canyon. They surveyed the area by floating the river and on foot to get maximum activity data. Burrows, scent mounds, tracks, and cuttings were recorded to map out precise colony sizes (Connor and Feeley, 1976). However, the method used to determine size of the colonies found between Hot Springs and Boquillas Canyon was not explained. Connor and Feeley (1976) estimated 94 beavers with a max of 125-165 in 41 colonies between Cottonwood campground and Boquillas Canyon.

Strong (1982) determined beaver densities by surveying five colonies at night. Strong (1982) found 17 beavers in the five colonies, yielding a mean of 3.4 beaver per colony. Strong (1982) assumed high habitat quality was correlated with high beaver density. Strong (1982) then compared habitat quality with the number of beaver at each of the 5 surveyed colonies. Strong (1982) used the relationship between number of beaver per colony to habitat quality to produce an estimate of 134 beavers between Santa

Elena Canyon and Boquillas Canyon, an overall density of 1.02 beaver/km. Strong's (1982) mean number of beaver per colony throughout the study site was 2.48.

I estimated 21 beavers occupying the 10 beaver colonies surveyed, a mean of 2.1 beavers per colony. I assumed high beaver use was correlated with high beaver densities because I found high habitat quality did not always represent high beaver densities. Extrapolating this relationship to the entire study site, I estimated 185 beavers between the mouth of Terlingua Creek and the west end of Boquillas Canyon. This represents an overall density of 1.41beaver/km and a colony density of 1.89 beaver per colony.

Although my estimate is higher than estimates by Connor and Feeley (1976) and Strong (1982), it is surprisingly similar in size. All surveys relied on similar techniques of evaluating presence and comparing to habitat parameters. By using GIS technology and remote sensing cameras, I was able to identify colony parameters that were not mentioned in previous studies and collect more accurate estimates for the number of beaver in each colony.

Foraging Activity

Food preferences may vary with seasons due to changes in the availability and nutritional value of food species (Jenkins, 1979; Davis et al., 1994). Bailey (1927) suggested that beaver are very adaptable to new situations if food and water are limited. During this study, willow appeared to be a staple food for beaver in the study area. Throughout their range in North America, willow is recognized as a major food source for beaver (Bradt, 1938; Shadle et al., 1943; Hall, 1960; Northcott, 1971; Strong, 1982). Nolet et al. (1994) found that beavers in willow-dominated habitat in the Netherlands fed mostly on willow but selected uncommon non-willow species in greater proportion than

their availability, suggesting that willows alone may not provide enough nutrition for the beaver. *Baccharis salicifolia* was another heavily used food source for beaver during this study, which was also noted by Connor and Feeley (1976) and Strong (1982).

Connor and Feeley (1976) found eight of 51 beaver feeding sites in tamarisk dominated areas. With the introduction of the tamarisk beetle in 2004, vast stretches of Tamarisk along the Rio Grande River have been defoliated. I found no areas dominated by tamarisk, although it was still present in many areas. I recorded only small areas along the Rio Grande where beavers were foraging on tamarisk.

Connor and Feeley (1976) reported high used of sedges by beaver, while Strong (1982) reported beaver grazing on sedge only in Hot Springs Canyon in June and July of 1980. During this study, I observed only one site where beaver were foraging on sedges between Gravel Pit and Hot Springs in May 2013. I also found sunflower cut by beavers in the same colony that was feeding on sedge. I found no other sign of use of sedge or sunflower along the river even though these plants were fairly common throughout the study area. Like Connor and Feeley (1977), I found one beaver colony in Marascal Canyon without willow. Connor and Feeley (1977) stated that the beaver colony in Marascal Canyon were adapting to a lack of other food species by feeding on white-thorned acacia. Although, I did not observe any foraging activity by beaver on white-thorned acacia, I recorded this colony feeding on prickly pear and cocklebur. No mention of prickly pear, sunflower or cocklebur as part of a beaver's diet has been made in recent literature.

Once common, few cottonwood trees are to be found along the Rio Grande in Big Bend National Park today (Strong, 1982). Denyes (1956) once stated that cottonwoods

overhung the water along much of the Rio Grande. The reason for the decrease in native cottonwoods in Big Bend NP is not fully known (Strong, 1982). However, human impact and the invasion of tamarisk are often cited factors responsible for the decrease (Schmidly and Ditton, 1976). Although cottonwoods have been protected in the park since 1944, farmers continue to use cottonwoods for building purposes, and livestock continue to browse cottonwood shoots along the Mexican floodplain (Strong, 1982). Destruction of riparian vegetation along the Rio Grande by trespass livestock is still a problem in Big Bend NP. No accounts of beaver damage to cottonwoods were recorded in this survey. This could be due to the small number of native cottonwoods and their distance from the river (Strong, 1982).

Live Trapping

Live capture success was extremely low, 1 capture in 80 trap nights. I think this is likely due to trap shy behavior, resulting in beavers avoiding the areas where traps were placed. Another factor that could have affected my trapping success might have been people traffic on the river. Live trapping took place during the peak visitation period for Big Bend NP.

One example of avoidance behavior occurred while trapping with the large Tomahawk live traps at den entrances. At two different den locations, I placed the large Tomahawk live trap inside the den entrance in order to capture beaver exiting their den. The next morning I found both traps had been pushed out of the den entrance by beaver, and the den entrance had been blocked with sticks and debris.

The night of 23 May 2014 I returned to the site where I had captured and marked the adult female beaver from “the beaver pool.” This was my last night of camera

trapping in the park. I placed 18 cameras along the river in attempt to capture the marked female on camera. That night there was a large storm in the mountains of Mexico which flooded the Rio Grande River. The river rose nearly 1.5 m overnight which flooded my cameras. I lost 2 cameras to the river and 4 more cameras were destroyed by being underwater. Therefore, I was not able to recapture the marked beaver on camera.

VI. FUTURE MONITORING

Future monitoring on beaver in Big Bend NP can be conducted by following the index I developed. Beaver colonies can be counted by observing dens, beaver sign, and natural barriers. Breaks in beaver sign and natural barriers will indicate colony boundaries. In areas where there are no breaks in beaver sign or no natural barriers occur, one can use 550 m as the average length of river used by each colony to estimate the number of colonies in that area. By counting beaver sign within a beaver colony, one can rank the activity level and estimate the number of beaver in each colony.

I found a total of 98 active beaver colonies, indicating a healthy population of beaver in the park. Information generated from this project will be used by the National Park Service in implementing several management practices to restore the river and riparian area to a more natural state. Practices include the removal of the exotic plant and animal species as well as planting and managing for native plant species such as cottonwoods and willows.

APPENDIX SECTION

Table 5. Beaver colonies along the Rio Grande River in Big Bend National Park.

Colony #	Activity Rank	Estimated Population	Number of Burrows found	GPS Location of Burrows latitude	GPS Location of Burrows longitude	Length of River in Colony (meters)	River Depth at Den Entrance (meters)
1	LOW	1	1	-103.6151539	29.16447322	476	4
2	HIGH	3	1	-103.6186654	29.16297159	371	1
3	LOW	1	1	-103.6095319	29.16538437	266	1
4	MEDIUM	2	1	-103.6067856	29.16175861	570	<1
5	LOW	1	2	-103.59953	29.15650919	282	1
				-103.5990107	29.15589916		1
6	MEDIUM	2	1	-103.5981552	29.15332725	291	<1
7	MEDIUM	2	2	-103.5962087	29.15158935	305	3
				-103.5953963	29.1513187		5
8	LOW	1	0			469	
9	LOW	1	5	-103.5867254	29.15055231	280	1
				-103.5865555	29.15057159		1
				-103.5865258	29.1505601		1
				-103.5864787	29.1505432		1
				-103.5855296	29.1504883		1
10	LOW	1	0			429	
11	LOW	1	1	-103.5521249	29.15729815	980	>1
12	LOW	1	2	-103.5522846	29.14552209	978	1
				-103.5520078	29.14565694		1
13	HIGH	3	3	-103.5490651	29.14329182	421	1
				-103.5489026	29.1432163		1
				-103.5465511	29.14403504		<1
14	LOW	1	1	-103.5404766	29.14634627	973	1
15	MEDIUM	2	4	-103.5309836	29.14093905	382	1
				-103.5303688	29.14030823		1
				-103.5305322	29.14011017		1
				-103.5302787	29.13992593		1
16	LOW	1	3	-103.5274216	29.13889613	482	1
				-103.5263619	29.13794898		1
				-103.5258486	29.1377748		1
17	MEDIUM	2	6	-103.5237762	29.13153338	869	1
				-103.5234568	29.13011676		1
				-103.5234208	29.12991366		1
				-103.5233983	29.12986035		1
				-103.5234638	29.12882502		1
				-103.52327	29.12788281		1
18	MEDIUM	2	5	-103.5223599	29.12055921	991	1
				-103.5221817	29.12045728		1
				-103.5188479	29.12004967		2
				-103.5178923	29.12022494		1
				-103.5174179	29.12023097		1
19	MEDIUM	2	1	-103.5084653	29.11879867	568	1
20	LOW	1	1	-103.4998583	29.11439826	306	1
21	LOW	1	1	-103.4935321	29.10803178	618	2
22	LOW	1	1	-103.4878195	29.09870365	361	1
23	LOW	1	1	-103.4729328	29.08662306	701	1
24	MEDIUM	2	1	-103.4720271	29.07385851	629	1
25	MEDIUM	2	1	-103.4711496	29.06661813	611	<1
26	MEDIUM	2	1	-103.4511185	29.07273595	464	1
27	LOW	1	1	-103.4507472	29.06960939	256	<1
28	HIGH	3	4	-103.4491614	29.0647939	890	1

Table 5. Continued

				-103.448162	29.0637413		<1
				-103.446666	29.06168145		1
				-103.4454118	29.06087184		1
29	LOW	1	1	-103.4406435	29.05782125	287	1
30	HIGH	3	3	-103.4349371	29.05609883	519	1
				-103.4353572	29.05525796		1
				-103.4353367	29.05456008		1
31	HIGH	3	1	-103.4327833	29.04965198	412	1
32	HIGH	3	0			402	
33	HIGH	3	3	-103.4197589	29.0426836	634	1
				-103.4194142	29.04260397		1
				-103.4193275	29.04259626		1
34	HIGH	3	4	-103.4138964	29.03805293	642	<1
				-103.4138033	29.03805604		<1
				-103.4131372	29.03810029		1
				-103.4106306	29.03911685		1
35	HIGH	3	0			412	
36	MEDIUM	2	2	-103.3985458	29.03140407	664	1
				-103.3970022	29.03213657		1
37	HIGH	3	1	-103.3937921	29.03348027	859	1
38	MEDIUM	2	2	-103.387283	29.02918572	561	<1
				-103.3872852	29.02790312		<1
39	MEDIUM	2	1	-103.3873259	29.02232438	506	<1
40	MEDIUM	2	3	-103.3851766	29.02303366	360	<1
				-103.3848783	29.02378233		2
				-103.3846358	29.02381175		2
41	MEDIUM	2	3	-103.3815805	29.02450728	600	<1
				-103.3806895	29.0242233		1
				-103.3800594	29.02386095		<1
42	LOW	1	1	-103.3637242	29.01939549	648	<1
43	LOW	1	1	-103.3576248	29.01984132	560	<1
44	MEDIUM	2	0			456	
45	MEDIUM	2	2	-103.3498875	29.03467695	500	1
				-103.3495623	29.03584958		1
46	LOW	1	0				
47	LOW	1	0			538	
48	HIGH	3	0			722	
49	LOW	1	0			372	
50	LOW	1	0			453	
51	LOW	1	0			501	
52	LOW	1	0			307	
53	HIGH	3	0			793	
54	MEDIUM	2	2	-103.2916641	29.00380884	555	<1
				-103.2917868	29.00390238		<1
55	HIGH	3	3	-103.2868816	29.00145235	878	1
				-103.2866437	29.00125747		1
				-103.2862043	29.00086486		1
56	HIGH	3	1	-103.2817093	28.98780485	918	<1
57	MEDIUM	2	1	-103.2631842	28.99421625	452	1
58	MEDIUM	2	1	-103.2583337	28.99011893	600	1
59	MEDIUM	2	0			532	
60	MEDIUM	2	3	-103.247922	28.98049072	468	1
				-103.2474894	28.98051402		1
				-103.247181	28.9805566		1
61	MEDIUM	2	2	-103.244383	28.9811627	721	1
				-103.2442767	28.98116563		1
62	HIGH	3	3	-103.1775908	28.98012612	819	<1
				-103.1775004	28.97894603		1

Table 5. Continued

				-103.1757266	28.97760568		<1
63	MEDIUM	2	3	-103.1713331	28.98051739	307	2
				-103.1710916	28.98042242		1
				-103.1709494	28.98042494		1
64	MEDIUM	2	3	-103.1679638	28.97888283	218	1
				-103.167767	28.97881779		1
				-103.1673819	28.9786276		1
65	LOW	1	2	-103.1613297	28.97346033	350	1
				-103.1610594	28.97364741		2
66	MEDIUM	2	0			449	
67	HIGH	3	2	-103.1159782	28.99395626	622	<1
				-103.1161966	28.99405902		<1
68	HIGH	3	1	-103.1167991	29.00046046	801	1
69	HIGH	3	1	-103.1109996	29.00969605	887	1
70	HIGH	3	0			681	
71	MEDIUM	2	2	-103.0996407	29.02169692	463	1
				-103.0991289	29.02298262		1
72	LOW	1	1	-103.1011024	29.03144265	828	1
73	LOW	1	0			290	
74	LOW	1	1	-103.0976181	29.06046993	412	1
75	HIGH	3	4	-103.0918467	29.06239199	899	1
				-103.0919305	29.06224815		1
				-103.0919737	29.06129597		1
				-103.0918411	29.06075693		1
76	MEDIUM	2	0			270	
77	MEDIUM	2	2	-103.0854879	29.05487744	512	1
				-103.0854899	29.05498968		1
78	MEDIUM	2	1	-103.0856078	29.05905448	405	1
79	MEDIUM	2	1	-103.0862426	29.06228093	981	1
80	MEDIUM	2	0			784	
81	MEDIUM	2	0			712	
82	LOW	1	0			527	
83	LOW	1	0			441	
84	HIGH	3	1	-103.001441	29.15226686	871	1
85	HIGH	3	3	-102.9958048	29.16097373	987	2
				-102.9957294	29.16137924		2
				-102.9959822	29.16245582		<1
86	LOW	1	1	-102.9967756	29.17730419	533	<1
87	MEDIUM	2	1	-102.9845662	29.18367025	341	1
88	HIGH	3	1	-102.9774738	29.18674809	318	1
89	MEDIUM	2	1	-102.9739163	29.18609052	339	1
90	MEDIUM	2	1	-102.9710334	29.18483778	320	1
91	HIGH	3	1	-102.9688062	29.18247735	322	1
92	LOW	1	5	-102.9649949	29.18207534	418	1
				-102.9649185	29.18195137		1
				-102.9637423	29.18115308		1
				-102.963442	29.18090858		1
				-102.9633621	29.18085979		1
93	LOW	1	1	-102.9592203	29.17883942	382	1
94	LOW	1	1	-102.9552762	29.17834246	501	1
95	LOW	1	2	-102.950655	29.17357433	725	1
				-102.9504177	29.17512381		<1
96	HIGH	3	2	-102.9491795	29.18089567	774	3
				-102.9471403	29.18217969		2
97	MEDIUM	2	1	-102.944425	29.19124271	388	1
98	LOW	1	0			378	

Table 6. Random sample locations with maximum depth found in buffer.

Sample Number	Sample GPS Location Latitude	Sample GPS Location Longitude	Maximum Depth in Buffer (meters)
1	-103.159099	28.973447	<1
2	-103.166089	28.975081	<1
3	-103.134827	28.983569	<1
4	-103.157737	28.973092	<1
5	-103.155708	28.972358	<1
6	-103.135903	28.983201	<1
7	-103.146235	28.976815	<1
8	-103.153247	28.972086	<1
9	-103.165845	28.977821	2
10	-103.152157	28.974201	<1
11	-103.129742	28.982775	<1
12	-103.129305	28.982474	<1
13	-103.148211	28.976186	<1
14	-103.169643	28.980049	<1
15	-103.130909	28.98331	<1
16	-103.29616	29.006543	<1
17	-103.187384	28.983867	<1
18	-103.251676	28.984988	<1
19	-103.178897	28.981963	<1
20	-103.232348	28.986716	<1
21	-103.281904	28.990786	1
22	-103.309862	29.009285	1
23	-103.281916	28.987094	<1
24	-103.281721	28.98799	<1
25	-103.234907	28.985705	<1
26	-103.234618	28.986174	<1
27	-103.250995	28.983918	<1
28	-103.216309	28.986895	<1
29	-103.194687	28.984716	<1
30	-103.200383	28.986633	<1
31	-103.127495	28.98212	<1
32	-103.108741	29.013198	<1
33	-103.116199	29.001808	<1
34	-103.098148	29.025252	<1
35	-103.115993	28.993429	1
36	-103.115991	28.984604	<1
37	-103.113476	29.005816	<1
38	-103.098329	29.027792	<1
39	-103.114072	29.00515	<1

Table 6. Continued

40	-103.121858	28.9841	<1
41	-103.115685	28.984689	<1
42	-103.116015	28.992945	<1
43	-103.105895	29.036458	<1
44	-103.116388	28.98423	<1
45	-103.115059	28.985861	<1
46	-103.341712	29.028458	<1
47	-103.338379	29.019651	<1
48	-103.344875	29.043535	<1
49	-103.351155	29.028868	<1
50	-103.373175	29.022379	<1
51	-103.326333	29.016299	<1
52	-103.360746	29.018286	<1
53	-103.309864	29.025762	<1
54	-103.350132	29.030176	1
55	-103.327516	29.039975	<1
56	-103.351477	29.028217	<1
57	-103.327245	29.039042	<1
58	-103.30685	29.0235	<1
59	-103.348853	29.037506	1
60	-103.308121	29.018925	<1
61	-103.085315	29.060599	<1
62	-103.079016	29.073418	1
63	-103.066952	29.092349	1
64	-103.054845	29.100729	<1
65	-103.037713	29.097701	<1
66	-103.064699	29.09158	<1
67	-103.069214	29.093497	<1
68	-103.080391	29.072768	<1
69	-103.076614	29.091426	<1
70	-103.034487	29.10035	<1
71	-103.032557	29.102925	<1
72	-103.091974	29.058537	<1
73	-103.104441	29.045892	<1
74	-103.100728	29.050137	<1
75	-103.080045	29.087274	<1
76	-103.010167	29.137364	<1
77	-103.015425	29.132678	<1
78	-103.018814	29.126787	<1
79	-103.006093	29.149186	<1
80	-103.027664	29.115907	<1
81	-103.014405	29.135866	<1
82	-103.032977	29.114979	<1

Table 6. Continued

83	-102.998144	29.157791	<1
84	-103.015522	29.134934	<1
85	-103.008745	29.139663	<1
86	-103.030143	29.115355	<1
87	-103.023006	29.1232	<1
88	-103.009122	29.137453	<1
89	-103.037609	29.112432	<1
90	-103.02493	29.118333	<1
91	-103.444015	29.06025	<1
92	-103.547543	29.142773	<1
93	-103.612567	29.164931	<1
94	-103.489009	29.100888	<1
95	-103.404694	29.0392	<1
96	-103.404688	29.037542	<1
97	-103.604345	29.158993	<1
98	-103.391371	29.03495	2
99	-103.435852	29.058177	1
100	-103.472606	29.0678	2
101	-103.549967	29.143372	1
102	-103.472917	29.086642	<1
103	-103.452275	29.072441	<1
104	-103.523825	29.130362	<1
105	-103.396123	29.032288	<1
106	-102.965493	29.182284	<1
107	-102.965036	29.181979	1
108	-102.965787	29.182486	<1
109	-102.9659	29.182554	<1
110	-102.975231	29.186428	<1
111	-102.996242	29.166898	<1
112	-102.983067	29.184861	<1
113	-102.974994	29.186341	<1
114	-102.995944	29.163473	<1
115	-102.980788	29.185925	<1
116	-102.98787	29.183106	<1
117	-102.986628	29.183134	<1
118	-102.996753	29.168274	<1
119	-102.982643	29.185003	<1
120	-102.997783	29.173596	<1
121	-102.987267	29.183248	<1
122	-102.966191	29.182737	<1
123	-102.99687	29.169142	<1
124	-102.97227	29.185183	<1
125	-102.952973	29.173771	<1

Table 6. Continued

126	-102.948272	29.180985	1
127	-102.935918	29.191112	<1
128	-102.934995	29.192114	<1
129	-102.945793	29.182848	<1
130	-102.938005	29.188941	<1
131	-102.950777	29.17834	<1
132	-102.961584	29.179768	1
133	-102.953734	29.176561	1
134	-102.935271	29.191696	<1
135	-102.948525	29.180797	<1
136	-102.954465	29.17782	1
137	-102.93789	29.18901	<1
138	-102.944864	29.188171	<1
139	-102.937129	29.190002	<1
140	-103.575719	29.152466	<1
141	-103.564578	29.1545	<1
142	-103.552635	29.150581	1

Table 7. Minimum and Maximum number of beaver estimated at each of the surveyed colonies with the number of camera trapping nights.

Colony #	Location	# of Camera Trapping Nights	Min. # of beaver	Max. # of beaver
1	Inside mouth of Santa Elena Canyon	84	3	6
2	Mouth of Terlingua Creek	56	1	2
3	Santa Elena Canyon river access	8	1	1
4	11.2 km downstream of Terlingua Creek	30	1	3
5	0.8 km upstream of Cottonwood Campground	24	2	2
6	1.0 km upstream of Daniels Ranch	4	2	2

Table 7. Continued

7	0.6 km upstream of Daniels Ranch	3	3	3
8	1.0 km downstream of Daniels Ranch	11	2	2
9	2.0 km downstream of Daniels Ranch	7	2	3
10	4.0 km downstream of Daniels Ranch	39	4	11

Table 8. GPS location of nutria activity in Big Bend National Park, Texas

Latitude	**Longitude**
-102.941438	29.191433
-102.936698	29.190633
-102.935785	29.191718

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