Title: Post-release Survival of Bitumen-Contaminated North American Beaver (*Castor canadensis*) Following Rehabilitation.

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INTRODUCTION

Current and Future Oil Use Trajectories

Exploration and extraction of hydrocarbons is intensifying (Yang et al. 2011) to meet the rising global demand for oil. Non-conventional methods of extraction are becoming more common as conventional crude oil reserves are depleted, leading to increased interest and investment in the oil sands of Alberta (Giesy et al. 2010). As the Alberta oil sands house the world's largest reserves of bitumen, it is inevitable that ecosystems will continue to become contaminated with bitumen oil (Yang et al. 2011). Bitumen is the heaviest form of petroleum, which, in near-solid state at room temperature and highly resistant to biodegradation, is completely different in chemical composition than conventional crude oil (Yang et al. 2011). Understanding its chemical composition and its effects on ecosystems and wildlife will assist in preparing for potential oil spills and responding appropriately to associated environmental problems (Yang et al. 2011, Tamis et al. 2012).

Rehabilitation and Release

In regards to oiled and rehabilitated wildlife, few scientific studies report concrete evidence of long-term post-release survival and benefit to individual animals or their populations (Estes 1991, Estes 1998, Ben-David et al. 2002). It was common among studies that the survival rates of oiled and rehabilitated wildlife were lower than non-oiled wildlife (Ben-David et al. 2002, De La Cruz et al. 2013), but there are no documented studies on bitumen-contaminated wildlife, nor are there existing studies on the post-release survival of North American beavers (*Castor canadensis*), specifically, following rehabilitation. Rehabilitation of oiled wildlife is a complex practice because its success is dependent on identifying and responding to several factors, including type of oil contamination, severity of external and internal contamination, resulting physiological responses (De La Cruz et al. 2013), and effects of captivity, among others. Post-release survival is highly variable among different species and depends on several factors, such as severity of oil contamination, rehabilitation success, length of captivity, suitability of the release site (De La Cruz et al. 2013), predation, poaching, traffic, and intraspecific and interspecific competition (Guy et al 2013). Controversy surrounding wildlife rehabilitation, and specifically the rehabilitation of oiled wildlife, arises from the extensive economic resources invested in the practice when its efficacy is highly debated (De La Cruz et al. 2013). Assuming that people will continue the rehabilitation process with oil-contaminated wildlife, whether or not there is evidence supporting their motives, maximizing post-release success is necessary (Briggs et al. 1997).

2013 CNRL Bitumen Spill

A bitumen oil spill at Canadian Natural Resources Ltd.'s (CNRL) Primrose oil sands project located within the Cold Lake Air Weapons Range in Alberta was first reported at the end of June 2013 (Timoney and Lee 2014). It is not known exactly when bitumen started leaking through fissures in the underlying rock, but total volumes of bitumen have been estimated by the Alberta Energy Regulator at 1.5 million liters (Linnitt 2013). As of September 5, 2013, CNRL reported 43 birds, 104 amphibians, and 40 small mammals had been killed due to bitumen exposure (Timoney and Lee 2014). Two adult beavers, likely the parents of the three beavers under study, were euthanized because of severe bitumen contamination (Rodrigues 2013). Staff from the Wildlife Rehabilitation Society of Edmonton (WRSE), Oiled Wildlife of British Columbia, and International Bird Rescue were called to site by CNRL to mitigate impacts on local and transient wildlife from the spilled bitumen (Rodrigues 2013). Three beavers and two muskrats were captured, washed, and rehabilitated at the WRSE and released on September 11, 2013 in a naturalized agricultural dugout near Bowden, Alberta.

Research Objectives and Hypothesis

The purpose of this study is to assess, through two research phases, the post-release survival of three North American beavers exposed to bitumen oil. The main research objectives of this study are to:

1) use telemetry to document the survival of the beavers at the release site over time.
2) monitor and assess the three beavers' behavior patterns and activities to observe whether they are showing signs of illness or impairment, and whether they are exhibiting behavior and carrying out activities congruent with those of wild, non-contaminated, non-rehabilitated beavers.
3) determine if the beavers are progressing in lodge and food cache development quickly enough to be prepared for freeze-up.

To investigate the first objective, the null hypothesis that exposure to bitumen oil does not influence the post-release survival of the three beavers will be tested. The second objective will be met by testing the null hypothesis that the behavior of the beavers will not be influenced by bitumen contamination, rehabilitation, and release. The three beavers will resume normal post-release behavior, carry out normal activities, and will not show signs of illness or impairment. Finally, the third objective will be met by testing the null hypothesis that bitumen contamination and rehabilitation will not compromise the beavers' abilities to build a sufficient lodge and food cache in time for winter.

METHODS

Rehabilitation

Three oiled beavers and two muskrats were taken to the WRSE following capture at the spill site and cleaned with Dawn dishwashing detergent. Fish Body Implant Series F1100 radio transmitters were implanted into each beaver. The transmitter types were crystal-controlled 2-stage with a calibration tolerance of +/- 2.5 kHz, frequency stability of +/- 2.5 kHz, and had operating temperatures between -20°C and +40°C. They operated on a silver oxide battery and their lifespan was approximately 400 days. Each radio transmitter had a different frequency that corresponded with a specific channel on the accompanying Advanced Telemetry Systems model R410 Scanning Receiver. The receiver covered a frequency range of 4 MHz with 1 kHz channel spacing. The beavers were named by the staff at WRSE, and these names were retained throughout the study to preserve consistency in communicating between the various organizations involved. The female adult beaver was named Mary, the male juvenile was named Brownie and the female juvenile, Blondie. Additional veterinary and rehabilitation protocols can be obtained by contacting the Wildlife Rehabilitation Society of Edmonton.

Release

On September 11, 2013, the WRSE transported the beavers and muskrats in cloth-covered crates to a waterbody near Bowden, Alberta, where they were released. Supplemental support was provided for the beavers to increase their probability of survival. These support measures included supplemental feed, a fence surrounding the pond and foraging area, and a wooden shelter to serve as a temporary lodge. A CNRL representative delivered aspen cuttings biweekly. Two liters of monkey or rodent chow and a variety of vegetables were provided each time a researcher or rehabilitation staff member visited the site until the end of October, 2013.

Animal Care Considerations

Part I - Institutional Animal User Training Program was completed before research proceeded. Minimal time was spent inside the fenced enclosure to discourage influencing the beavers' behavior. Time spent within the enclosure was for data collecting purposes.

Study Area

The translocation site is a 1,150 m^2 an older agricultural dugout 24 km northwest of Bowden, Alberta (Figure 1). Vegetation surrounding the pond is predominantly willow (*Salix* spp.) and poplar (*Populus tremuloides and Populus balsamifera)*. Extending in all directions around the treed area is agricultural land. A 4-foot fence with a perimeter of 299 m was installed around the pond and a portion of the treed area to reduce predation threats. The foraging area enclosed within the fence had an area of 4399 m^2.

This site was selected for various reasons. Staff from the Medicine River Wildlife Center contacted the landowners of this site who were willing to accept the rehabilitated beavers on short notice. As it was late in the season, the site needed to be prepared for when rehabilitation was complete. Beavers had previously occupied this site, but for an unknown amount of time. The site was appropriate for short-term residency of the beavers, but dispersal will be necessary when foraging availability is depleted. Removal of the fence later in the study can prolong residency by giving access to a larger foraging area.

Figure 1. Release site on agricultural land west of Bowden, Alberta of three beavers previously contaminated by bitumen near Cold Lake, Alberta.

Data Collection

Frequency

Two evenings and at least one afternoon every week was reserved from September 11, 2013 to November 8, 2013 to collect data at the beaver release site. Slight deviations from the schedule occurred, but observation periods were relatively consistent throughout this study.

Survival

I measured survival of each beaver through the use of telemetry and direct observation. Each visiting day at the site, the audio signal from the receiver confirmed the presence of the beavers and gave reference to their relative location. Due to the small site size, identification using telemetry was difficult because overlapping signals occurred. The beavers did not have distinct physical markers, such as ear tags or paint markers to assist in identification, but colour patterns and size helped with individual identification.

Behavior

Behavior of the beavers was observed two evenings per week. Observation took place atop an adjacent hill on the east side of the pond, outside the fenced enclosure. I began observations when the first beaver emerged from the lodge and concluded when dim light conditions did not permit accurate observations. Night vision technology was utilized but was found to be ineffective from outside the fenced enclosure. I recorded behavior sequences and categorized into one of the behavior categories in Table 1. Categories are similar, but with a few minor changes, to those used in the remote videography study conducted by Bloomquist and Nielsen, (2009).

Table 1. Behavioral categories used to quantify activities of the beavers released following bitumen contamination.

Category	Description
Food cache construction	Cutting trees down and bringing branches/trees to food cache, diving under cache with branches/trees
Lodge construction	Bringing branches/trees/mud to lodge, placing branches/trees/mud on lodge
Ingestion	Eating/chewing on leaves, bark, twigs, or provided food
Channel construction	Swimming in and out of channels, diving in or in front of channels
Locomotion	Quadrupedal walking, bipedal walking, running, swimming
Grooming	Individual grooming, allogrooming
Play	Non-aggressive climbing, wrestling, tumbling on and over each other
Exploration	Walking or swimming for no other obvious reason; curiously looking, smelling, or touching objects
Reactionary	Behavior in response to being disturbed by people, such as slapping the tail, moving away from person
Cutting	Chewing down trees, not obviously using cut stem for food cache or lodge development
Unknown	An unidentifiable behavior
Other	A behavior not listed

I categorized behavioral sequences based on the final behavior of the sequence. If a beaver cut down a tree, then swam with the cut stem to the food cache and deposited it under the water, this behavior sequence would be categorized as food cache construction. Other information collected included the time of day of the behavior, the identification of the beaver exhibiting the behavior, if possible, and the quadrant of the pond or shore in which the behavior took place. The pond was divided into the northeast, northwest, southeast, and southwest quadrants to provide locations for the beavers' activities.

Foraging Patterns

On three occasions throughout the study period, I recorded GPS locations using a handheld Garmin 60CX GPS at each location where stems had been cut by the beaver. The quantity, diameter, and species of stems cut were recorded at each site. Diameter was measured with a calliper and recorded in millimeters. To avoid documenting a cut stem twice, each cut stem was marked with a black X.

Lodge Dimensions

To measure the width of the lodge over time, two 3-m staff gauges were placed near the shoreline 5 meters to the east and west of the center of the lodge. From a static photo reference point on the south shore, I took photographs of the lodge each day research was conducted.

Microsoft PowerPoint was used to upload the pictures and the line feature in drawing tools was placed overtop the photo to represent 1 meter sections, to scale. I then used duplications of that line to discern the distances from the edges of the lodge to each staff. Those distances were subtracted from 10 meters to reveal the width of the lodge as it changed over time. Using a staff placed directly beside the lodge and taking pictures from the same location, I was also able to determine lodge height. At the time of positioning the rear staff, the bank height was 0.45 m above water level, and so 0.45 m was added to each measurement to attain the lodge height from the water level. All lodge height measurements were calculated from the baseline water level despite fluctuating water levels. Drawing tools were again used to determine height over time.

Food Cache Dimensions

Each day research was conducted, a photo was taken perpendicular to the food cache facing east, using the west staff as the photo reference point. A smaller wooden stake was placed directly on top and near the front of the lodge. The initial distance between the wooden stake and the tip of the lodge in the water was 1.14 m. Photos were uploaded to Microsoft PowerPoint, and the line feature in drawing tools was used to represent 1.14 m segments, and then duplicated to determine growth in food cache over time.

Data Analysis

Survival was analyzed as a categorical variable, based on whether or not the beavers' frequencies registered on the telemetry receiver, and whether they were seen during observation periods. Behavioral data were analyzed primarily as counts of occurrence once the beavers emerged from the lodge during each observational period. Although multiple behavior categories were documented, analyses predominantly focused on channel construction, food cache construction, lodge construction, and ingestion because these behaviors were critical for the beavers' over-winter survival. A chi-square test of homogeneity and chi-square goodness-of-fit test were applied to discern distribution patterns among behavior counts. I also used Tukey's HSD multiple comparison test to analyze changing channel lengths and widths over time. Many data, including growth in the lodge and food cache, were visualized with descriptive statistics to determine changes over time. Time-dependent data (e.g., lodge size) were analyzed using 'days since release' and 11 September 2013 was considered Day 1. Foraging sites, pond modification, and site metrics were visualized and analyzed using ESRI ArcMap^{TM}.

RESULTS

Survival

Of the three beavers released, the adult, Mary, and the juvenile, Brownie, survived. The other juvenile, Blondie, was alive for 12 days post-release. Due to her sudden mortality post-release, data collected on Blondie is excluded from analysis. Although two muskrats were released along with the three beavers, analyses in this research paper are limited to the remaining two beavers. A second phase of the project will provide more insight into over-winter survival rates for the remaining two beavers.

Behavior

Behavior was monitored to assess whether the released beavers were exhibiting behavior congruent with wild, non-contaminated, non-rehabilitated beavers, and whether the beavers were showing signs of illness or impairment. Behavior was monitored a total of 32 hours and 32 minutes. Behavioral data are excluded from October 27 and November 8 because weather conditions did not permit data collection.

There was an uneven distribution of counts of behavior combined between Mary and Brownie (Figure 2, $X^2 = 10.87$, $df = 3$, $P < 0.025$). Individual Chi-Square Goodness of Fit tests revealed that the differences in distribution of ingestion ($p < 0.05$), food cache construction ($p < 0.05$), and channel construction ($p < 0.05$) counts between Brownie and May were driving the significance of this result.

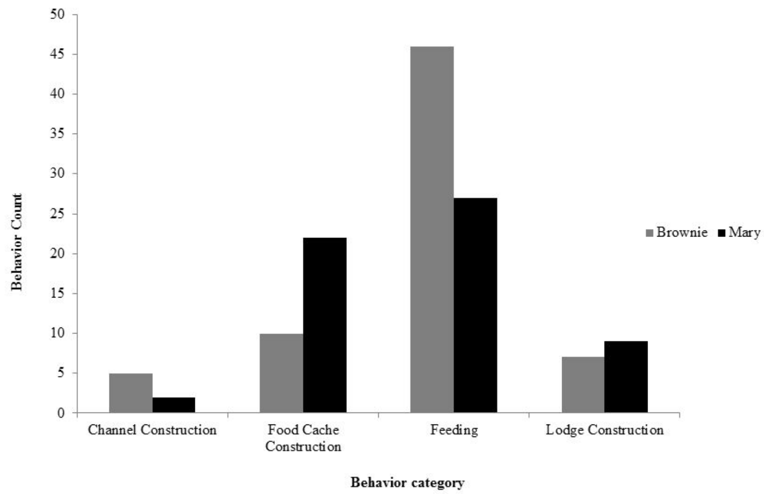

Figure 2. Activity counts for channel construction, food cache construction, feeding, and lodge construction for Brownie (grey bars) and Mary (black bars) observed from 14 September 2013 to 26 October 2013 at the release site near Bowden, Alberta.

Foraging Patterns

The beavers cut a total of 340 stems during my 59-day research period. For most of the analyses on foraging behavior, only 323 of the 340 stems were used because the initial documentation of stems cut did not include necessary information such as the site number. Willow species composed 65% of all stems cut. Trembling aspen was the next highest at 30.6%, while buffaloberry (*Shepherdia canadensis*), red-osier dogwood (*Cornus stolonifera*), and alder (*Alnus* sp.) composed the remaining 4.4%. The beavers utilized all aspen stems delivered by CNRL, which are estimated to be between 135 – 180 stems.

I created three categories to represent sites where differing number of stems were cut. The largest foraging sites contained between 11 and 22 cut stems (n = 4 sites). Three of these sites were located on the same shore side as the lodge, the north shore.

Lodge and Food Cache Construction

Lodge construction began immediately by Mary (the adult female) on 11 September 2013. There was a small lodge established by day 4, however measurements of lodge dimensions were not recorded until the following week. Lodge width and height gradually increased over time. Measurements were not taken for lodge height and width on days 47 and 59 because snow cover did not permit accurate readings. A food cache was first observed 6 days following release, but measurements were not taken until day 13 due to logistics. The majority of food cache growth occurred after day 26 (6 October 2013; Figure 3). Consistent overnight lows at or below zero occurred after 30 September 2013 (20 days following release; Figure 3). The pond was initially frozen over completely by day 48 and permanently covered in winter ice by day 59.

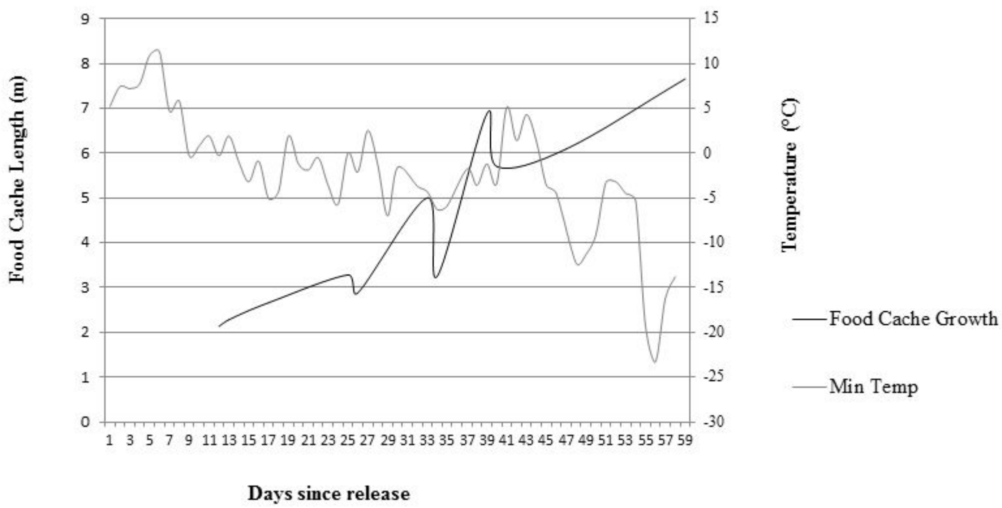

Figure 3. Length of food cache (m) and minimum temperature (°C) at the beaver release site near Bowden, Alberta from 11 September 11 to 8 November 2013.

Pond Modification

Pond modification includes changes to the perimeter through beaver channel construction and foraging runs. Site metrics analysis using ArcMap 10.1 revealed the beavers increased the pond area by 99 m^2 (8.6%), and increased the perimeter of the pond by 123 m (83.7%). There were also differences in the lengths of four major channels (A, B, C and D) relative to days since release (Table 2). There was an increase in channel construction after day 26 (6 October 2013).

Table 1. Tukey's HSD multiple comparison test comparing differences in mean channel lengths measured on five separate occasions, day 12 ($\bar{x}_{channels}$ = 2.06 m), 17 ($\bar{x}_{channels}$ = 2.238 m), 26 ($\bar{x}_{channels}$ = 2.39 m), 33 $\bar{x}_{channels}$ = 2.89 m), and 40 ($\bar{x}_{channels}$ = 2.96 m) since release on 11 September 2013 at the beaver release site near Bowden, Alberta. Significant *p*-values are in **bold**.

Day	D12	D17	D26	D33	D40

D12	-	0.943	0.655	**0.031**	**0.018**
D17	0.943	-	0.967	0.108	0.063
D26	0.655	0.967	-	0.284	0.176
D33	**0.031**	0.108	0.284	-	0.997
D40	**0.018**	0.063	0.176	0.997	-

DISCUSSION

SURVIVAL

The cause of death of Blondie could not be verified because no body was recovered on which to conduct a necropsy. There may have been a variety of contributing factors causing her death, including both antecedent and post-release events, such as incomplete rehabilitation, compromised thermoregulation due to loss of insulation (Troisi and Borjesson 2005), damaging physiological effects from oil ingestion (Briggs et al. 1997, Troisi and Borjesson 2005, Troisi 2013), and physical injury, among others. Predation seems unlikely, as there was no visible evidence of her tunnelling outside the enclosure or another animal gaining access under or over the fence. The confusion lies around not being able to hear her audio signal with the telemetry receiver, because the radio transmitter should have been transmitting a readable frequency, regardless if the animal was dead or alive. The transmitter could have failed, or if she was at the bottom of the pond or buried within the lodge, the signal might have been compromised. Despite Blondie's death, the remaining two beavers signify that post-release survival from bitumen-contamination and rehabilitation is possible for North-American beavers. The null hypothesis that beaver survival is not influenced by exposure to bitumen oil and rehabilitation practices is supported by my study. Following my study, over-winter survival will be monitored using telemetry and checking the vent-hole for frost.

BEHAVIOR

The purpose of observing behavioral trends among the three beavers was to assess whether they were exhibiting normal behavior and conducting activities congruent with those of non-contaminated, non-rehabilitated beaver. Close monitoring of behavior patterns helped determine whether the beavers showed signs of illness and impairment in their ability to function normally post-release. I observed a variety of behavior categories, but my analysis focused primarily on ingestion, food cache and lodge construction because these activities were imperative for their survival during the winter months. Foraging patterns and pond modification (including channel construction) were also analyzed to gauge whether the beavers were behaving as expected. There was no control group of non-contaminated, non-rehabilitated beavers, but known beaver natural history in literature and Dr. Hood's expertise in beaver ecology provided a knowledge base for comparison.

Behavior counts for Brownie, in categories such as channel construction (Figure 2), were higher than behavior counts for Mary. It is possible Mary actually did conduct certain behaviors more frequently than Brownie, but did so after nightfall when the observation period had terminated.

Brownie and Mary mirrored the expected behavior patterns for lodge emergence, feeding, and constructing. After emerging from the lodge, Brownie immediately began feeding on the supplemental feed or adjacent vegetation. Once Mary emerged, she followed suit. After eating, they would assume lodge and food cache construction. Other studies determined that the first portion of a beaver's active period each evening is spent feeding, and the second portion is allocated to construction and repair (Müller-Schwarze and Sun 2003). The beavers in my study followed that same pattern.

My ability to monitor behaviour from the day of release until freeze-up allowed me to assess age-specific differences in behavior. Immediately following release there was a disparity between age and critical activity engagement, as shown by Mary who began scouting a site for lodge location while Brownie and Blondie wrestled and ate. There was also an uneven distribution of activity between Mary and Brownie (Figure 2). Despite shorter observation periods, Mary was seen conducting lodge and food cache construction activities more frequently than Brownie (Figure 2). A release date so close to freeze-up made it necessary for the beavers to quickly establish a lodge and food cache. Tasks associated with food acquisition and lodge construction or maintenance are primarily accomplished by adult beavers (Novak et al. 1987) but older offspring often help (Müller-Schwarze and Sun 2003). Young beaver learn survival skills by mimicking their older siblings and parents' behavior, though in a less complete and effective manner (Müller-Schwarze and Sun 2003). As before, the beavers in my study demonstrated similar behaviors.

Foraging Behavior

The feeding preference of beaver for aspen and willow is well known (Slough 1978), which supports my finding that *poplar* and *willow* species composed the vast majority of all stems cut. This result is consistent with species preference, but also due to the majority of species present at the site being either willow or aspen. Three of the four largest sites for number of stems cut were located on the same side of the pond as the lodge. This result demonstrates foraging behavior consistent with energy-maximizing objectives of central foraging organisms (Fryxell and Doucet 1993), meaning less energy is expended in cutting and transporting stems near the lodge than stems farther away.

Lodge and Food Cache Construction Behavior

Lodge and food cache construction takes place mostly at night (Müller-Schwarze and Sun 2003), a fact that resulted in my ability to only observe a small fraction of these activities that actually occurred. To test whether the beavers would be prepared for winter, I was able to use data relative to lodge and food cache growth over time. If the lodge and/or food cache appeared to be insufficient before freeze-up, the beavers would have been recaptured to overwinter at the Wildlife Rehabilitation Society of Edmonton. Mary assumed lodge building immediately upon release. Increases in lodge width and height were gradual over time but showed a marked increase throughout the duration of this study. A lodge capable of housing the beavers overnight was established by 14 September 2013, just four days following release.

In northern latitudes, beavers are known to start constructing their food caches in late August and early September (Müller-Schwarze and Sun 2003). At the time of release, other beaver ponds in the area had substantial food caches already established. I observed a food cache 6 days following release. Northern latitude food caches store mostly willow (Müller-Schwarze and Sun 2003), which is congruent with willow species being the most numerable of all harvested species at the release site. Other studies show beaver to use larger, waterlogged stems to sink and act as a raft or cap to hold the food pile below water (Slough 1978), which explains the size fluctuations seen in food cache length (Figure 3). The beavers likely built up the food cache below the surface of the water and then placed larger, heavier cuttings on top to sink the pile. Food cache construction activity also appeared to respond to temperature fluctuations (Figure 3). Consistent overnight lows at or below zero occurred after 30 September 2013 (20 days following release), and food cache activity was observed to notably increase 25 days following release (Figure 3), which confirms the documented patterns that the onset of food caching commences in relation to the first frost (Novak et al. 1987). Both the lodge and food cache appeared to be sufficient prior to freeze-up, which allowed the beavers to overwinter at the release site.

Pond Modification Behavior

Beavers are classified as ecosystem engineers; they modify their environment to suit their needs. The two beavers under study, Brownie and Mary, were no exception. They excavated four major channels around the release site, three of which were on the same shore as their lodge, which implies proximity to the lodge is a factor in determining where channels are built. A break was evident in the channel length data when looking at change over time; channel length and channel mouth width increased sharply after 6 October 2013, (day 26). On day 33, combined channel lengths and mouth widths were significantly higher than on day 26 (Table 1). Food cache (Figure 3) and lodge growth increased around the same time, thus suggesting that an increase in channel lengths is useful in transporting cut stems to the food cache, as well as using the excavated material to aid in lodge development. Beavers construct channels for ease of transporting cut stems, and to connect separate water bodies for safer mobilization due to decreased chances of predation (Morgan 1986). Mary and Brownie demonstrated normal pond modification behavior relative to these factors.

Behavioral Findings

Overall, the analysis of what constitutes normal behavior and activities of North American beaver in comparison with Mary and Brownie's observed behaviors supports the null hypothesis that the bitumen-contaminated beavers will resume normal behaviors and activities post-release following rehabilitation, but perhaps only on the premise that younger beavers are accompanied by adult beavers. However, the amount of contamination must also be considered given the deaths of two beavers at the spill site. Both the lodge and food cache appeared to be sufficient for the beaver to successfully overwinter, which suggests that bitumen contamination and rehabilitation, followed by a late season release, did not compromise the beavers' ability to build a lodge and food cache before freeze-up.

CONCLUSION

Rehabilitation centers all over the world invest substantial resources into rehabilitating and releasing animals, with very little information on the efficacy of post-release survival following rehabilitation. Oil exploration is forecasted to continue increasing in intensity, and wildlife encounters with oil are inevitable, though deterrence methods are improving. My research can help inform oiled wildlife management and rehabilitation practices, and aid in the pursuit of standardized practices within rehabilitation work. Further studies can help develop post-release protocols, suitable release sites, and standardized ages at which animals can appropriately be released.

Studies conducted on the rehabilitation and release of common species can provide useful insights for the rehabilitation and release of rare species, which are unsuitable for experimental manipulation (Molony et al. 2006). Potential for full recovery in rehabilitated animals favors continuing practices of rehabilitation, but because survival rates are widely unknown for the majority of oiled wildlife, euthanasia on-site might provide a more humane alternative (Anderson et al. 1996) and in turn, direct economic resources towards larger conservation-practices (Jessup 1998).

My study found that the survival of yearling beavers likely depends on accompaniment with adult beavers, although the cause of Blondie's death remains unknown. Standards need to be further developed for appropriate habitat selection to avoid release into habitats that increase likelihood of maladaptation or death of rehabilitated animals. Young beavers depend on adult beavers for food acquisition, lodge development, and food cache construction. Phase 2 of this research project will address the necessity to conduct long-term post-release research that includes over-winter survival rates. Documenting over-winter survival rates will inform decisions of appropriate times of year to release rehabilitated beaver. Further post-release research must be conducted to further our understanding of whether rehabilitation is a viable option for bitumen-contaminated wildlife. In general, more research is necessary to make informed decisions to enhance survivability of all rehabilitated wildlife, and make the most efficient use of resources invested in the rehabilitation process.

ACKNOWLEDGEMENTS

Funding for this study was provided by Canadian Natural Resources Limited. I want to express my gratitude to Dr. Glynnis Hood, for supervising this project. I would also like to thank Coleen Doucette and the staff at Wildlife Rehabilitation Society of Edmonton, and Judy Boyd at the Medicine River Wildlife Centre for involving me in this project, and for assistance and collaboration, as well as staff from International Bird Rescue for involving me in the release of the beavers and muskrats. I would like to especially send thanks to the landowners, Gary and Silvia Bracken, for graciously providing habitat for the rehabilitated beavers.

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