1. Contestant profile

▪ Contestant name:	**Gordon B. Stenhouse**
▪ Contestant occupation:	Research Scientist and fRI Research Grizzly Bear Program Lead
▪ University / Organization	fRI Research
▪ Number of people in your team:	8 (4 biologists and 4 students)

2. Project overview

Title:	The co-existence of a threatened population of grizzly bears with quarry mining in Alberta, Canada.
Contest: (Research/Community)	Research
Quarry name:	Lehigh Cement Quarry, Cadomin Alberta

Abstract

This project was undertaken within the Quarry Life Award program to investigate and understand how non-invasive genetic sampling could assist in monitoring grizzly bear occupancy, movement, and co-existence in the area in and around the Lehigh Cement Quarry, located near Cadomin, Alberta, also known as the Cadomin limestone quarry. Using established field techniques, we worked with a team of high school students and quarry operational staff to gather grizzly bear hair and scat samples within the mineral surface lease area during the period of April 7 – May 31, 2018. Scat samples were collected throughout this time period as encountered and hair samples were collected in two week sampling intervals at established hair snag sites. Following DNA extraction from the samples submitted to genetic laboratories, six unique grizzly bears (four males and two females) were identified. To show the broader value of these results, we linked our results with our long-term research database (1999-2018) on genetics, movements, age and habitat use which has been gathered within a broader regional study effort. Project objectives were achieved with the training and learning opportunities provided to high school students who worked alongside research biologists, and with the participation of quarry employees. Our results show the value and utility of these applied, non-invasive research techniques for the monitoring of species at risk, and the potential application for other species found on quarry sites around the world. Recommendations for continuing this type of monitoring effort using non-invasive techniques are provided, which would contribute to local, regional and provincial grizzly bear recovery efforts for this threatened species.

Introduction

Grizzly bears (*Ursus arctos*) are a threatened species in Alberta, Canada, and are often considered to be an indicator of ecosystem health (Helfield and Naiman 2006, Miller et al. 2001). Along the eastern slopes of Alberta's Rocky Mountains grizzly bears occupy a landscape highly influenced by recreational and industrial activities including forest harvesting, oil and gas exploration and extraction, and **mining**. Mining is often thought to be a natural resource extraction activity that is not conducive to the long-term survival and conservation of this species, and is an activity that has figured prominently in environmental review processess in Alberta (Gadd v. Director Alberta Environment 2005).

Over the past 18 years (1999-2018), the fRI Research Grizzly Bear Program (fRI GBP) has amassed the most comprehensive data set on grizzly bears anywhere in North America. This data set includes detailed information on individual bears, their movement, health, habitat use and selection, survival and productivity. While these individual bear data sets were being collected, our research group also gathered population level data on the distribution and abundance of grizzly bears in many of the bear management areas (BMA's) in Alberta (Stenhoue et al. 2015, Boulanger, Nielsen and Stenhouse 2018).

Some of the individual level data has been collected using more invasive techniques (GPS collaring requiring capture and handling), but more recently our team has focused on the value, importance and utility of collecting grizzly bear data using non-invasive techniques (without the need to capture and handle bears directly; Taberlet et al. 1999, Mills et al. 2000).

Recent international collaborative work by our research team has developed new noninvasive techniques that can be used to further our understanding of grizzly bears and to assist in monitoring efforts. We feel these techniques have global applicability for monitoring a variety of species where human activites may impact local and regional wildlife populations and thus affect biodiversity.

Our project was intended to demonstrate the application of these new approaches on a species at risk (threatened) where active quarry operations have been underway for many years. We wanted to show how a company could apply these approaches as part of a biodiversity monitoring effort to help inform and educate stakeholders, employees and the public. This project also aimed to provide scientific data to understand how quarry operations can co-exist on a shared landscape with grizzly bears in a boreal forest ecosystem and in turn support education efforts for those concerned with conservation and natural resource management.

Our research project engaged quarry employees and local high school students in non-invasive genetic sampling to identify individual grizzly bears using the Lehigh Cement Quarry property near Cadomin, Alberta, also known as the Cadomin Limestone Quarry. By combining genetic samples retrieved from grizzly bear hair and scat, with camera trap data and existing data from fRI GBP's long-term database, we wanted to demonstrate the value and effectiveness of these monitoring approaches.

Project Objectives

Our project objectives were developed in the context of applied scientific research that can be used for biodiversity monitoring in landscapes where co-existence with wildlife populations is considered a necessary goal of natural resource management:

1. Gather scientific data using non-invasive genetic techniques and camera traps to identify and understand occupancy, survival, and reproductive performance of grizzly bears found within the Lehigh Cement Quarry surface lease area.
2. Hire and train young scientists (students) in field biology techniques and data collection of a species that is found where the students live and recreate.
3. Engage company (Lehigh Cement) employees in science to foster appreciation of local biodiversity of a species that occurs where they work.
4. Raise local awareness of how local residents (students and employees) are involved in monitoring biodiversity around the Lehigh Cement Quarry through media reporting and social networking.
5. Identify the value of non-invasive sampling for wildlife populations and showcase the importance of new scientific techniques for long-term monitoring of ecosystem health where anthropogenic disturbance exists

Methods

Project Staff

The four fRI Research Grizzly Bear Program research biologsts began recruiting grade twelve high school students for this project in January 2018. To select the students, we visited the two local high schools in Hinton, Alberta and spoke to the grade twelve science classes. We discribed the project, explained the Quarry Life Award program and discussed what the work would entail. Interested students were asked to write a short letter to our team explaining why they wanted to participate and what their future career plans were relative to scientific studies. Based on the information in the letters, we hired four students (two from each high school) who worked as field assistants to collect data for this project. The role of the students was to assist in site establishment and data collection that occured on a two week return interval over the period from April 7 until May 31, 2018.

The field assistants worked with experienced field biologist from our research program and were instructed on field procedures, data entry using tablets, correct handling procedures with biological samples, reviewing and storing photographs from field cameras, and safety procedures within quarry operations (Lehigh standards) as well as safety training related to conducting research on grizzly bears.

In addition the students were instructed in the preparation and posting of materials for their Quarry Life Project blog and gained experience working with local media outlets (Hinton newspapers) by participating in interviews related to the project.

Field Methods

The primary data collection methods used in this project involved gathering genetic samples from grizzly bears to allow for DNA analysis. More specifically, we collected hair samples from bears using scent lures and barb wire hair snag stations in four separate sampling sites (full methods described in Stenhouse et al. 2015). All sites were selected in conjunction with the Quarry Manager to ensure that there would be no safety concerns and that sites would not impact daily operations. Each sampling site was marked with caution tape and signs to prevent people from disturbing the sites or putting themselves in close proximity to scent lure stations where bears could be present. The sampling sites also had a motion activated trail camera installed to capture images of any wildlife that visited the sites during the sampling sessions.

Once established, the four sites were visited every two weeks, hair samples were collected and scent lure refreshed, for three sampling sessions. Field crews also downloaded all photographs from the trail cameras at sampling sites and filed the photos for further review following the fieldwork.

Our sampling period was relatively short (eight weeks) in terms of other population inventory work which typically occurs over a 10 week period from mid May until the end of July. Our sampling period was adjusted to allocate enough time for the genetic analysis at two DNA laboratories, as we required genetic results to be recieved by September 1st to allow time for data analysis and report preparation to meet the Quarry Life project submission deadline.

The second source of genetic samples used within this project was scat. Grizzly bear scat samples that were opportunistically found on and adjacent to the quarry property by fRI GBP staff and students, **and importantly quarry employees**, during the months of April and May, formed part of the project dataset. The scat samples were gathered during the same time period as hair sample collection. Quarry staff members were provided with simple sampling kits to collect a small amount of any bear scat encountered during their regular operations.

The methods and techniques used in this project (scat, hair and genetics) have been previously published by our research team and represent the most current state of science for grizzly bear population monitoring (Stenhouse et al. 2015, Solberg et al. 2006).

Laboratory Analysis – DNA

Hair samples were sent to Wildlife Genetics International in Nelson, British Columbia, Canada for genotyping analysis. This laboratory has a long history of genetic analysis of hair samples from grizzly bears in Alberta. DNA was extracted using QiaGEN DNeasy Tissue kits following standard protocols (Paetkau 2003). Samples were examined under a dissecting microscope, and those with the visual characteristics of black bear hair (jet black from root to tip) were removed. Samples that passed the visual examination underwent a prescreen using a species-specific marker (G10J) to distinguish grizzly bear from black bear samples (Paetkau 2003). Individual grizzly bears were first genotyped to seven loci (markers G10J, G1A, G10B, G1D, G10H, G10M, G10P) and sex

was assigned using a ZFX/ZFY gender marker (Paetkau et al. 2003). Then to determine parent-offspring relationships, samples were genotyped to 21 loci (markers G1D, G10H, G10M, G10P, G10C, G10L, G10U, G10X, CXX20, CXX110, MU50, MU59, REN145P07, CPH9, Msut2, Mu51, Mu23). Error checking protocols included selective re-analysis of similar genotypes (those matching at 1, 2 or 3 loci) to confirm the genotype or resolve errors, thus eliminating genotypes created through genotyping error (Paetkau 2003, Waits and Paetkau 2005, Kendall et al. 2009).

Scat samples were sent to the Norwegian Institute of Bioeconomy Research laboratory in Svanhold, Norway for genotyping analysis. This laboratory is recognized as one of the most experienced in the world for DNA extraction from Ursid feces. One measuring spoon (approx. 1/4tsp) of excrement was weighed and transferred to tubes containing 8 ml of Stool Stabilizer. Both the tube and the remainder of the scat sample was then stored at -20 °C. DNA was then extracted from 1.5 ml of excrement. From the eluate of the DNA extraction, polymerase chain reaction (PCR) is carried out with 1 µl DNA template for 14 different PCR primers (G1A , G1D , G10B , G10L , Mu05 , Mu09 , Mu10 , Mu15 , Mu23 , Mu26 , Mu50 , Mu51 , Mu59 and amelogenin XY). The PCR products are mixed with size marker and formamide, denatured at 96 °C and run in capillary electrophoresis (). Results above the threshold value (200 units=3130, 600 units=3730) are analyzed in Gene Mapper, calibrated against eight positive controls (four different controls) on every full plate, replica compared, and DNA profile and gender determined. The main rules for replica are two for heterozygous results and three for homozygous results. Any deviation in replica repeats throughout the DNA is analyzed at least once more. When searching the existing genetic database with DNA profiles a conformity assessment with respect to matches with identical DNA profiles was made (full details are provided in Andreassen et al. 2012).

Trail Camera Data

All images taken from the trail cameras at each of the four sites were downloaded in the field as crews maintained the cameras (changed batteries and installed new memory cards). The photographs were then reviewed in the office and those containing images of grizzly bears and other species were labelled by sample site and session and incorporated into the project database. Images of bears at sites were also used as a source of information to assist species determination of hair to be sent to the lab for analysis.

Historic Genetic Datasets

One of our primary objectives within this project was to clearly show the value and importance of long-term genetic monitoring efforts. With only one short season of sampling this would not have been possible, therefore we utilized our research program's long-term genetic database to compare with samples from the Quarry Life project. The long term data also included information on bear age and home range size as well as previous capture locations.

Results

During the three sampling sessions,seven scat samples were collected by Lehigh Cement operations staff and 19 hair samples were collected by the research team from the four barb wire hair collection sites. DNA extraction rates are known to differ between the biological mediums used (hair and scat). From our samples, 2 of the 7 scat samples amplified successfully and produced complete results, while 9 of the 19 hair samples provided complete results. Samples that produced complete results could identify the sample to an individual bear while samples that did not provide complete results could only indicate the bear species. The 5 scat results that did not produce complete results did show that 4 of the scats came from grizzly bears and one from a black bear.

In total, the genetic sampling identified 6 unique grizzly bears using the Lehigh Cement Quarry site over the 8 week sampling period. Maps and spatial data for each of these individual bears have been prepared and they provide supplementary information on the individual bears (as per report submission guidelines these results have been sent separately to the National Coordinator).

From the existing long-term grizzly bear database, we were able to provide the following information on each of the 6 grizzly bears identified within this project:

Bear 1 = AB_0978 (hair sample): Summary from genetic data sets only

This male grizzly bear (at least 10 years of age in 2018) originally came from southern Alberta near Pincher Creek. He underwent a short distance (about 100 km) translocation to the north in August 2011 as an adult, because his movement into human settlements were considered a public safety risk. One year later he was moved again (July 2012), from the Porcupine Hills area for getting to close to people. This time he underwent a long distance move of about 470 km into the Swan Hills area in central Alberta. Then in October 2013 he was moved again from the Valleyview area in north central Alberta to west central Alberta, a distance of approximately 180 km. He was detected on the Lehigh Cement Quarry during this project, approximately 75 km south of where he was released in the fall of 2013. This finding is very important for management in that a “conflict animal”, where survival was unknown, was found on the quarry site and is still alive. Survival information is very important for ongoing management decisions affecting the recovery efforts for this species.

Bear 2 = 95-1a-2 (hair sample): Summary from genetic data sets only

This male grizzly bear was first detected on the landscape in 2011,15 km northeast of the Lehigh Cement Quarry, during a DNA population census. He was detected again during the 2014 DNA population census at a location about 10 km to the northwest of the Lehigh Cement Quarry. We do not know the exact age of this bear, but we do know from genetic records that he is the father of a male bear born in 2011, which indicates that he was born no later than 2005 (assuming male bears do not successfully breed until 5 years of age). Therefore, this bear is at least 13 years of age in 2018. He also

bred with a collared research bear called G039 to become the father of a female bear (286-3b-2), who was also detected during the 2014 DNA population inventory conducted within the bear management unit where the quarry is located.

Bear 3 = G139 (hair sample): Summary from genetic and GPS movement data

Bear G139 is a 6 year old adult male who was born in 2012. His parents are G035 (mother) and G053 (father). GPS movement data from this bear (collected from satellite radio collars), as well as from his parents, shows that these bears have used the area in and around the Lehigh Cement Quarry for years. From hair snag samples collected during this project, we now know that G139 is alive and continues to use the same landscape where his parents resided and where he grew up. This finding shows co-existence on a generational scale within a shared landscape. Our genetic records also show that G139 has two full siblings (Bear 286-4c-3 and Bear 285-16e-3) that share the same parents, as well as several half siblings as a result of sharing the same father.

Bear 4 = G160 (hair sample): Summary from GPS movement data only

Bear G160 is a 7 year old adult male born in 2011. This bear was identified twice during the hair collection of this project within two separate sampling sessions. Our genetic records to date do not indicate who his parents are. G160 was collared as part of a large predation study in 2016-2017 in which our GBP team visited many of his GPS locations to determine the frequency and types of meat he was consuming. From the many site visits of his locations, we discovered that throughout the year his meat diet consisted largely of elk, moose and sheep.

Bear 5 = G113 (scat sample): Summary from genetic data sets and GPS movement data

Bear G113 is a 13 year old adult female born in 2005. From our long-term genetic records, we know her parents are G100 (mother) and G055 (father). As part of the scat samples collected by the quarry staff (this sample was found adjacent to the shop at the Lehigh site) this bear has been identified, her survival confirmed and the spatial location of the scat sample shows that she is within her previously documented home range and also within the range used by her parents. Genetic records from other grizzly bears in the area indicate that G113 has several half siblings. G259 shares the same father, while Bear 93-1a-2, Bear 93-2b-2, and Bear G119 share the same mother.

Bear 6 = Cuar115 (scat sample)

Bear Cuar115 is a new bear for our database and has not been previously identified within our work. The genetic data from the scat sample shows that this is a female bear and also identifies that she is a cub of Bear G113. G113's denning behavior (data from GPS satellite collars on movement rates and denning period length) this spring in 2018 suggested that she had new cubs with her and we suspect Bear Cuar115 is one of them. The genetic samples in this case show that Bear G113 is moving about the

same landscape used by her parents to find food and shelter and now with her own cub (Cuar115) she is passing on the same lessons and experiences which includes moving in and around the Lehigh quarry property without difficulty or conflict with humans.

Additional Species Presence: Information from Camera Traps

In additional to gathering pictures with dates and times of grizzly bears present at our hair sampling sites, we obtained images of other species including red fox, small mammals (voles or mice), pine marten, red squirrel, snowshoe hare, big horn sheep, elk, gray jays and American robins. These images are a further example of the biodiversity at the Lehigh quarry site and demonstrate the utility of camera trap techniques. A detailed species list with dates and times has been provided to the National Coordinator.

Discusssion

Our Quarry Life Award project has demonstrated the utility and practical application of non-invasive genetic sampling to provide scientific data on the occurence, habitat use, survival and productivity of a species at risk (grizzly bears) within the area of an active quarry site in Alberta, Canada. Data collected during this project have added significantly to provincial and regional grizzly bear recovery efforts by documenting survival and productivy of local bears as well as an individual who was part of previous management actions (translocated bear)[1]. We also demonstrated the utility of combining two methods of gathering genetic materials to support monitoring efforts. During this project, some bears indentified were only found with scat samples and did not deposit any hair at the hair snag stations.

Perhaps the most important part of this project is that the scientific data was easily gathered over a short time period by newly trained high school students and quarry staff working on site. All data were also collected without any disturbance to the bears under study and at relatively low cost. The high school students, who were an integral part of this work, showed dedication to the project and in data collection efforts and they gained significant hands on experience working on an environmental topic in an area where, like some of the bears, they live and have grown up.

This work shows that by collecting biological samples (hair and scat), resource managers and scientists can learn a great deal about grizzly bear populations (or other species) if the data becomes part of a long-term monitoring effort. By incorporating the Quarry Life Project data with our larger dataset we were able to draw conclusions as a result of having strong genetic data in place that had been collected over 18 years within our

[1] *Note with the permission of HeidelbergCement we believe these data should be shared with Alberta Environment and Parks who are responsible for provincial grizzly bear recovery efforts.*

program. The samples gathered allowed us to not only identify individual bears, along with their gender, but also to understand parentage and productivity within this ecosystem of which the Lehigh Cement Quarry is a part. The data from this project clearly shows generational occupancy by grizzly bears within the area in and around the quarry site.

Although we did not have time to pursue other laboratory analysis using the hair samples collected here, our program's new research has shown that we are now able to extract reproductive hormones from hair samples (of adequate volume; Cattet et al. 2017 and Cattet et al. 2018). This additional data can be used to determine pregnancy status in females, lactation status for females, and age class. All these measures contribute further insights into local bear populations and their health profiles in relation to environmental conditions and anthropogenic landscape change.

To our knowledge this is the first monitoring effort by a quarry operator to understand local grizzly bear populations that co-occur on a shared landscape.in North America. We feel the information contained here supports the view that this quarry is, and has been, co-existing with grizzly bears in the area for many years. This information is useful for resource managers in reviewing quarry applications within grizzly bear habitat in North America and for stakeholders and shareholders who are concerned about the environmental impacts of quarry operations.

A key recommendation from our research team is to encourage Heidelberg Cement (Lehigh) to consider continuing the monitoring effort. With our long-term database that has been gathered over the past 20 years in this region and the new data collected during this project in 2018, there is a unique opportunity to continue this monitoring effort to support biodiversity monitoring and regional grizzly bear recovery efforts for this threatened species.

We believe that with two annual sampling periods (5 weeks in May-June) and (5 weeks in September), Lehigh could gather samples using the established non-invasive methods we have shown to monitor grizzly bears in this area. This work could continue with the active involvement of Lehigh staff and, if desired, could be coordinated by our research team at fRI Research. fRI Research could provide sample vials and field materials and could coordinate sample submissions to the appropriate laboratories. Based on expected sample sizes, we forecast this monitoring would cost between $6000-$8000/year, primarily for laboratory costs. We also recommend that the results of this project (along with maps provided to National Coordinator) be shared with the quarry staff to raise their awareness and appreciation of this work and to recognize their contributions to this project. We also feel that this type of program, with staff engagement, will increase the understanding and appreciation for the working environment for employees at the Lehigh Cadomin Quarry.

Final Conclusions

This research effort took place within HeidelbergCement's Quarry Life Award program and our team feels that we achieved our stated project objectives. A group of students and quarry staff members worked with research biologists using non-invasive genetic sampling methods to gather samples from a threatened population of grizzly bears that were using the quarry surface lease area. Although this took place in a relatively short time period, the results are clear and show use of the quarry site by at least six grizzly bears. Our historic database shed additional light on these findings to show long-term use of the quarry area by the same individuals, generational use of the landscape, and the confirmed survival of a bear that had been translocated many years previously from another part of Alberta. These results are important at both the regional and provincial level.

Our team of biologists hired, trained and worked with local students to give them hands on experience with scientific data collection and provided unique field experience using the lastest sampling techniques for grizzly bear monitoring. Quarry staff worked in providing valuable samples as they went about their regular duties and their samples contributed interesting and informative data to the project.

Perhaps the most important message that we can leave the reader with is that we have shown what is possible regarding the value and ease with which non-invasive techniques can form part of monitoring for biological diversity. Grizzly bears were our focal species for this work and they are an umbrella species for biodiversity monitoring, however, non-invasive techniques and approaches could be applied to any species (scat, hair, fur, feathers, etc. can be collected) and any quarry around the world where wildlife monitoring data is needed. With the accumulation of long-term data sets, which could correspond with a quarry's life span, these data would serve important management and communication needs to promote, monitor and conserve biodiversity and to support quarry operation plans and reclamation activities.

Authorship and Acknowledgements

This project was a true team effort among our project members who included: Anja Sorensen, Isobel Phoebus, Karen Graham, Adam Danis, Bryce Hennings, Hunter Sewid, Morgan Bailey and Gordon Stenhouse. Tom Chizmadia graciously provided guidance and suggestions to our team and supported our research efforts.

A special word of thanks goes to the Cadomin Quarry staff who collected grizzly bear scat samples for this project and to Carlos Morales, quarry manager, who assisted in site selection, safety training and access to the quarry site for our work. To the laboratory staff of Wildlife Genetics International (WGI) and Norwegian Institute of Bioeconomy Research (NIBIO), we thank you for rushing our samples through your system to meet our tight deadlines. Finally, we would like to thank the grizzly bears for leaving us their samples so we could further understand their world which they share with us.

To be kept and filled in at the end of your report

Project tags (select all appropriate):

This will be use to classify your project in the project archive (that is also available online)

Project focus:

- ☒Beyond quarry borders
- ☒Biodiversity management
- ☒Cooperation programmes
- ☒Connecting with local communities
- ☒Education and Raising awareness
- ☐Invasive species
- ☒Landscape management
- ☐Pollination
- ☐Rehabilitation & habitat research
- ☒Scientific research
- ☐Soil management
- ☒Species research
- ☐Student class project
- ☐Urban ecology
- ☐Water management

Flora:

- ☐Trees & shrubs
- ☐Ferns
- ☐Flowering plants
- ☐Fungi
- ☐Mosses and liverworts

Fauna:

- ☐Amphibians
- ☐Birds
- ☐Insects
- ☐Fish
- ☒Mammals
- ☐Reptiles
- ☐Other invertebrates
- ☐Other insects
- ☐Other species

Habitat:

- ☐Artificial / cultivated land
- ☐Cave
- ☐Coastal
- ☐Grassland
- ☐Human settlement
- ☒Open areas of rocky grounds
- ☐Recreational areas
- ☒Sandy and rocky habitat
- ☒Screes
- ☒Shrub & groves
- ☐Soil
- ☐Wander biotopes
- ☒Water bodies (flowing, standing)
- ☐Wetland
- ☒Woodland

Stakeholders:

- ☐Authorities
- ☒Local community
- ☒NGOs
- ☒Schools
- ☐Universities