ESTIMATING BLACK BEAR POPULATION SIZE IN GUSTAVUS, ALASKA: IMPLICATIONS FOR DETERMINING THE EFFECT OF HUMAN CAUSED MORTALITY ON POPULATION SIZE

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ABSTRACT

Estimating Black Bear Minimum Population Size in
Gustavus, Alaska: Implications for Determining
the Effect of Human Caused Mortality on Population Size

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Wildlife managers rely on accurate population estimations to contribute to the working knowledge of game and non-game animals. Until recently, there have been no regional population studies on black bears (*Ursus americanus)* in southeast Alaska, yet harvest rates are set at 10% of the total population. This research is based on an in-depth literature review of the history of bear harvest and the use of noninvasive genetic sampling and mark-recapture methodology. Noninvasive genetic sampling techniques using rub trees and hair traps were used during the spring, summer, and fall months of 2011 and 2012 to estimate the minimum number of black bears within the Gustavus, Alaska forelands. I collected harvest records from the Alaska Department of Fish & Game and compared the population estimate with the average number of harvested bears from 1990 – 2011 to determine if harvest rates were either set at unsustainable or overly conservative levels. I collected 196 bear hair samples and marked 33 black bears and 14 brown bears over two field seasons with hair collected off of 25 rub trees and 8 scented hair traps. Using the Huggins linear logistical model in program DENSITY, I estimated the population of black bears to be 54.5 ± 10.3 (95% CI=41.6 – 84.8). The average number of black bears killed by humans annually from 1990 – 2011 was 3.68 indicating that the current harvest level meets the 10% harvest objective but future research is encouraged to obtain more precise population estimates allowing wildlife managers to monitor black bear population trends and continue to make responsible management decisions.

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I: LITERATURE REVIEW

Introduction

For over a century, wildlife managers have increasingly sought to understand population dynamics of game and nongame animals in order to sustainably manage these populations faced with ever-growing threats. Human caused mortality and multiuse demands of these natural resources has created a need to obtain more rigorous data on population size, rate of population growth, and age and sex distributions. Obtaining quantitative data to inform the impacts of humans on game and nongame animals, as well as practicing adaptive management as a systematic approach to sustainably managing populations is vital for the conservation of wildlife species. The emerging need for quantitative data to inform wildlife managers on population trends has led to the development of management actions such as bag limits and seasonal hunting restrictions on game animals. More recently, wildlife viewing and other non-consumptive use of natural resources has added to the value of game and nongame wildlife found throughout the North American continent, especially as many of these species become increasingly rare.

In Southeast Alaska, bears are widely valued for their general biological, cultural and economic importance to the region. But until recently, the specific population trends of these animals have been unknown throughout most of the region. One early estimate found 4,155 brown bear populations on Chichagof, Baranof, and Admiralty islands, an area comprising of 6,115 km^2. This estimate comprised approximately 70% of the total population of brown bears in Southeast Alaska (Titus and Beier 1993). Research shows brown bear density on Admiralty and Kodiak islands to be some of the highest in the world, at 2.6 bears per km^2 (Schoen and Beier 1990). In contrast, studies on brown bears on the North Slope, located in northern Alaska, show densities as low as 1 bear per 300 square miles (ADF&G 2013).

Compared to the growing number of studies on brown bear populations, black bear populations have not been widely studied in Alaska. Peacock (2011) was the first to estimate black bear populations on Kuiu Island in Southeast Alaska concluding that populations are probably larger than originally thought. The population of black and brown bears in Glacier Bay National Park (GLBA) and the surrounding areas has never been determined (National Parks Conservation Association 2008). The Alaska Department of Fish & Game (ADF&G) set black and brown bear harvest rates at a certain percentage of the total population in designated management areas, but without current population research it is possible to set the harvest rate at either unsustainable or overly conservative levels. Information collected from harvested bears could offer valuable insight about population trends and harvest sustainability if used in conjunction with empirical population estimates (Barten 2004). Black bear estimates for the region are based on research conducted in the 1960's and 1970's in Washington State (Poelker and Hartwell 1973). ADF&G also uses anecdotal information from hunters and harvest data to assess black bear populations (ADF&G 2011a). While both of these sources provide valuable insight into bear population trends, quantitative data about bear populations in Southeast Alaska would prove invaluable in the bear management decision making process. Kendall (2008) discusses the value of estimating population trends as they correlate to landscape changes, and how understanding these changes will allow managers to “reverse negative, or enhance positive changes in the population.”

Glacier Bay National Park lies within one of the largest protected wilderness areas in the world (National Park Service 2010). Wildlife within GLBA is managed by the National Park Service (NPS) in accordance to the Organic Act of 1916 (National Park Service n.d.). Both black and brown bears frequently move beyond the boundaries of the National Park or protected area and the State lands, where most hunting occurs, requiring interagency cooperative bear management. Wildlife on the adjacent private and state land to the south of GLBA is under the management of ADF&G. Bears are important for wildlife viewing opportunities within GLBA as well as provide sport hunting opportunities in areas surrounding the park, such as adjacent to the town of Gustavus. This small town, located approximately 40 miles west of Juneau, Alaska, has a year-round population of approximately 450 people (U.S. Census Bureau 2010), which increases dramatically during the summer due to the high rate of seasonal employment. Tourism, including wildlife viewing, is a large industry for Gustavus because it is the gateway to Glacier Bay National Park and also offers hunting and wildlife viewing opportunities in the area.

In order to maintain sustainable populations of bears for both wildlife viewing and hunting, both State and Federal bear managers are concerned about potential increases in bear harvest in Gustavus due to increased access to the community via the Alaska ferry system, as well as the recent transfer of land ownership at Falls Creek from federal National Park land to State land. The previously protected Falls Creek area is a high quality spring habitat for bears that is now open for hunting. Additional human caused

Defense of Life and Property (DLP) bear mortalities add to the number of animals removed from the environment. Understanding bear populations and trends allows wildlife managers to understand how these mortalities impact trends within the local bear populations.

Within the past 15 years, many studies on black and brown bears have been conducted throughout the North American continent. This research has provided information on previously unknown populations and guided management (Bittner et al. 2002, Boersen et al. 2003, Boulanger et al. 2002, Kendall et al. 2008, Poole et al. 2001); for Alaska, however, significant information gaps remain, and establishing precise regional population estimates of black bears is a central objective for sustainable management.

Recent advances in genetic tagging have allowed wildlife managers to gain insight into bear populations using noninvasive methodology. Using a combination of rub trees and baited hair traps, hair samples can be collected providing information on species distribution, sex (Taberlet 1993), genetic population structure, and individual genealogies (Woods et al. 1999). From these techniques, scientists can extrapolate population densities, abundance, and trends using mark-recapture statistics. This is a noninvasive, relatively inexpensive, and accurate method for determining minimum population counts in comparison to live capture and collaring techniques (Stetz et al. 2010, Kendall et al. 2008). With the advancement of these new methodologies, research on bear and other elusive species has increased dramatically. These methods can be applied in Southeast Alaska allowing further insight into bear population trends within important management units and inform management protocols.

The main objectives of this research were to explore the history of bear harvest management in Southeast Alaska, with particular emphasis on documenting harvest trends of 1990-2011 in Gustavus, Alaska. Following this a review of the development of the noninvasive genetic sampling and mark-recapture analysis of bear species and its' implications on bear management, potential management implications. Secondarily, to determine a minimum population count and density estimate of black bears within the Gustavus forelands using noninvasive genetic sampling, and, finally recommendations for wildlife managers for sustainable harvest rates of black and brown bears in the Gustavus forelands management zone.

Bear Harvest History

Throughout the United States and Canada bear hunting has been a common practice in many communities. With westward European expansion, grizzly bear populations in the lower 48 States were hunted almost to the point of extinction leaving only small island populations in the states of Washington, Montana, Wyoming, and Idaho (Knibb 2008). The benefit of grizzly bear recovery has been widely debated over the past few decades and continues to be a contentious topic. The listing of grizzly bears as an endangered species in 1975 ceased the hunting of the species in the lower 48 states, but grizzly bear hunting in Alaska remains a large industry throughout the state. Black bears continue to be hunted throughout the United States and Canada and continue to have robust populations throughout a wider area of the continent. Although most black bear ranges are limited to forested areas with low human density (Pelton 1982), they have also adapted to living among humans when their presence is tolerated (Powell et al. 1997). Most large carnivores are susceptible to anthropogenic influences due to their large home ranges, smaller population sizes, long generation times, and increased interactions (often with negative outcomes for the bears) with humans (Noss et al. 1996). There is a direct correlation between surviving populations of grizzly bears and human scarcity (Mattson and Merril 2002). Because of limited urban areas, high quality and plentiful habitat, and miles of inaccessible terrain Alaska is home to some of the densest populations of both black and brown bears on the planet (Peacock 2011, Scott 2009). The unlikely event of full urban development in these remote Alaskan locations makes hunting pressure one of the top anthropogenic forces affecting bear populations (Milner et al. 2007, Harris et al. 2002).

Bear harvest levels vary across game management units (GMU) throughout Alaska due to available habitat, human access, jurisdictional regulations, geography, and species distribution. Southeast Alaska, primarily the Alexander Archipelago and the adjacent mainland, contains some of the densest populations of bears allowing for a larger historical harvest rate. For example, in GMU 1C, a unit comprised of 1,700 square miles in Southeast Alaska (Figure 1.1), and an area of abundant high quality bear habitat, approximately 68 black bears and seven brown bears were harvested in 2011. In comparison, GMU 20A, located in the interior of Alaska near Fairbanks and spanning down to Denali National Park, an area with abundant habitat but a lesser abundance of high quality available food such as salmon, approximately 28 black bears and zero brown bears were harvested the same year (www.secure.wildlife.alaska.gov). The large variation between populations throughout Alaska creates a need for area-specific population research to determine the sustainability of ADF&G's harvest rate region to region.

Bears have been regularly hunted for sport and subsistence in Southeast Alaska for many generations (Barten 2004). Within the past century, attitudes towards bears throughout the United States and Canada have shifted where the conservation of bear populations outweighs the ideology that bears are a nuisance animal that must be eradicated to promote development and human safety (Miller 1989). While brown bear conservation continues to be an issue of debate in the lower 48 because of the greater likelihood of negative bear-human interactions due simply to larger human populations, brown bears populations in Alaska are considered healthy and, in most areas, not considered to be in danger of critical population depletion. As a result, harvest regulations have evolved in an attempt to allow for subsistence and sport hunting at sustainable levels.

Up until the early part of the 20th century, bears were hunted in Alaska without regulation. The first bag limit set on coastal brown bears occurred in 1902 (Miller 1989) offering them a small amount of protection. Hunting brown bears continued at unsustainable levels until 1925, when a new game law was passed that eliminated market hunting of big game (Thornton 1992). The historical viewpoint towards brown bear harvest management well into the early 20th century was that bears were a "nuisance" or hindrance to development in Alaska. Thomas Riggs, Alaska Governor from 1915-1921, spoke freely about the impediment of the brown bear on development and actively sought to extirpate the species from the state (Sherwood 1979).

Throughout the decades to follow, with the development of the Alaska Department of Fish & Game, as well as the Alaska Board of Game, bag limits were reduced and hunting seasons were introduced. The development of quantitative science and rigorous wildlife ecology research enabled wildlife managers and citizens alike to demand more responsible game management and wildlife conservation from public and state land managers. Beginning in 1973, it was required that harvested black bears be sealed, a process in which a sealing officer places a locking seal on the skull and hide until the skull is measured, a tooth is extracted, and date, location and cause of mortality is recorded. This enables game managers to record trends on harvested animals in designated game management units (GMU). Sealing continues to occur with harvested animals to this day and is the primary contributor to the working knowledge of harvested bears and their population trends (Barten 2004). Game management in Alaska continues to develop in an attempt to maintain sustainable harvest levels. In the case of bear management in Southeast Alaska, more precise population estimates would allow for a more accurate prediction of population trends and allow wildlife managers to implement regulation accordingly.

Bear Harvest Trends in GMU 01C

Since 1973, when sealing became a requirement for harvested bears, trends have shown a steady increase in harvested black bears with a mean of 47 in the 1970’s, 73 in the 80’s, and 96 in the 90’s (Barten 2004). Brown bears are hunted less often in GMU 01C with averages nearing 10-20 bears annually. This is in part due to lower densities of brown bears and the availability of nearby hunting opportunities in GMU 04 which contains some of the largest populations of brown bears in Southeast Alaska (Scott 2009). Black bear harvest has continued to increase through the 2000’s but the upward trend has slowed since the beginning of the decade (Figure 1.2).

Brown bears have just recently begun showing up in small numbers within the Gustavus forelands since their extirpation in the early 1900's. 2010 was the first year in decades where multiple brown bear sightings occurred within the town and sightings continued to increase annually (Lewis 2012). It is possible that brown bear populations will continue to rise as they inhabit areas of the Gustavus forelands. There is high quality brown bear habitat with abundant food resources available, such as miles of shoreline containing grasses and sedges, an essential spring and early summer food, as well as multiple salmon bearing streams and rivers. These resources may allow brown bear populations to increase during the next few years.

Within the town of Gustavus and bordering state lands, human caused mortality of bears can be divided into three categories: harvest, defense of life and property (DLP), and road kill. The majority of human caused bear mortality in the Gustavus area is classified as DLP. In the case of a DLP kill, nuisance bears are shot and the hides of the animals are forfeited to ADF&G. As a result, licensed hunters frequently use their tags on DLP kills in order to keep the hides (Lewis 2009). These occurrences must be considered when determining the primary cause of bear mortality within the Gustavus area. DLP kills are common in the area but records show that they only account for a small percentage of the total annual mortality (Figure 1.3). Unfortunately, it is impossible to determine the number of instances this occurs annually because there is no method of reporting in place that can adequately represent these occurrences. 80% of hunting in GMU 01C for both black occurs in the spring months when food availability consists of vegetation growing near the intertidal zone allowing easier access by boat and visual identification by hunters (Barten 2008).

The availability of hunting opportunities in the Gustavus forelands has expanded, coinciding with the establishment of ferry access beginning in 2011, the recent transfer of ownership of Falls Creek, and the increases in the local brown bear population. It is now more important than ever to keep detailed records of harvest trends and begin more in-depth research on bear populations. With rising annual harvest rates and lack of empirical population data, it is unknown whether current human-caused mortality of bears in Gustavus is at a sustainable level. Brown bears encroaching on previously black bear dominated areas could also have a dramatic impact on species distribution and total black bear numbers. The current density of black bears in Southeast Alaska is estimated by extrapolating from a bear population study conducted by Poelker and Hartwell (1973) from western Washington State. In addition, skull seals and anecdotal information from local residents and hunters contribute to the total working knowledge of bear populations in the area. Noninvasive genetic sampling of bears in the area will increase this knowledge allowing for a more precise population estimate that will enable wildlife managers to predict current and future impacts of human-caused mortality.

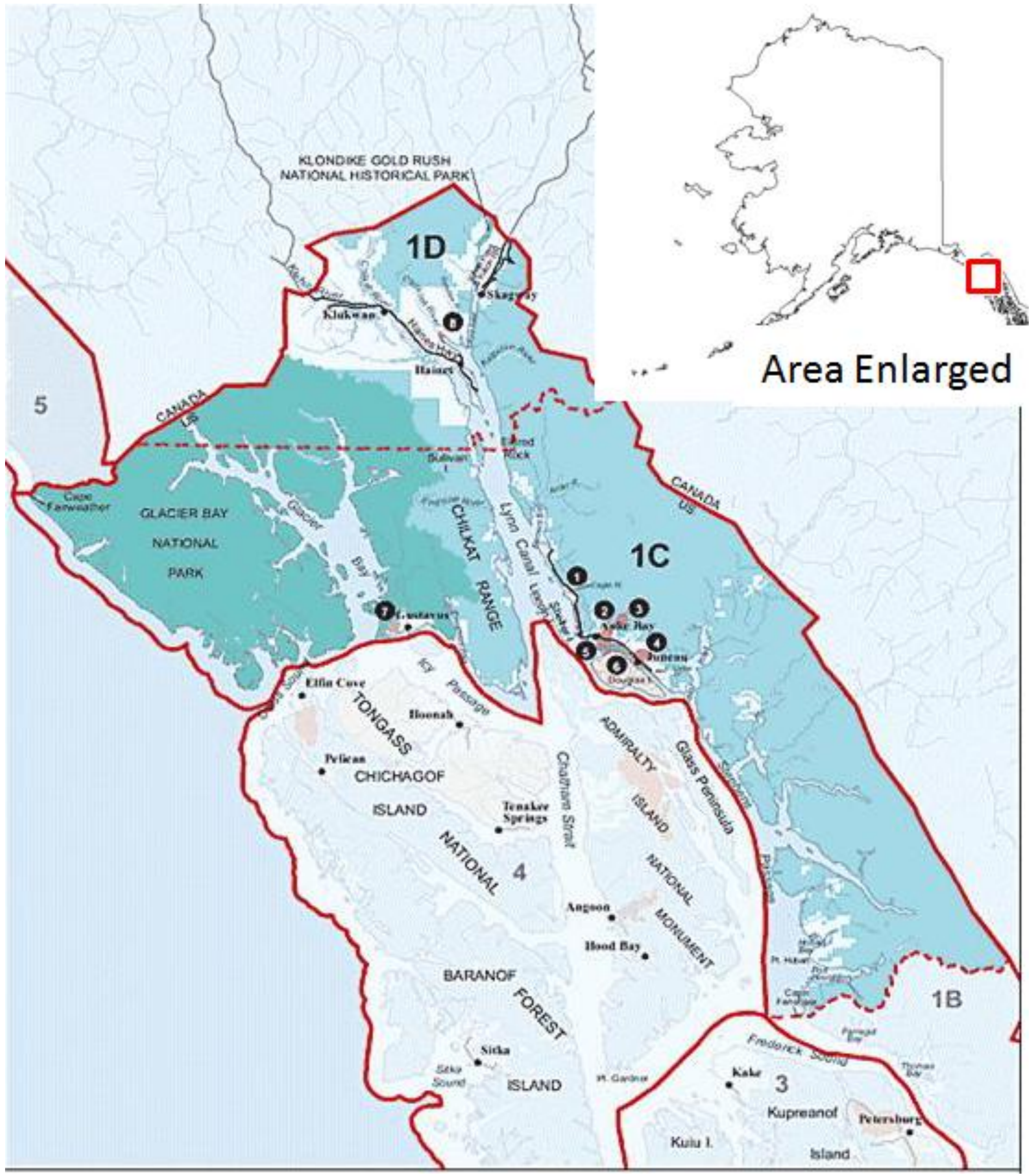

Figure 1.1. GMU 01C-01D.

Game management unit 01C - an area comprising over 1,700 square miles of high quality bear habitat and containing Federal (Glacier Bay National Park), State, and private lands (ADF&G n.a.).

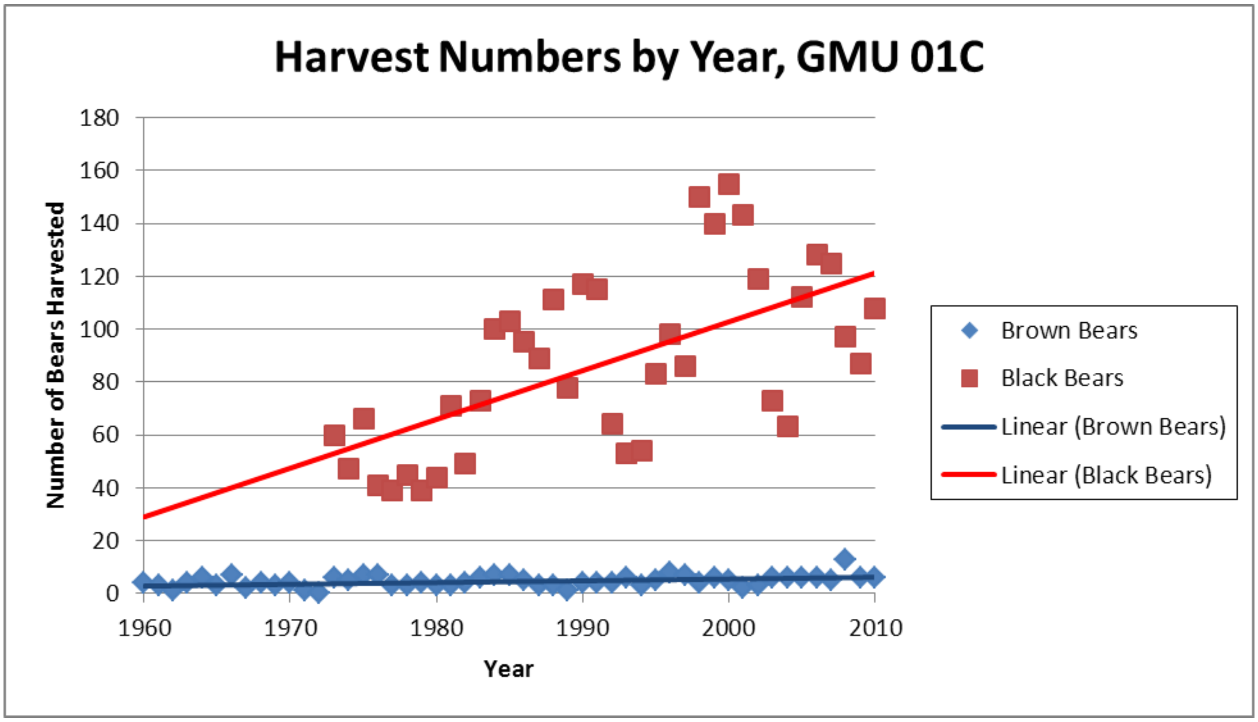

Figure 1.2. *Numbers of black and brown bears harvested by year in GMU 01C, 1996-2011 (Neil Barten, Ryan Scott ADF&G).*

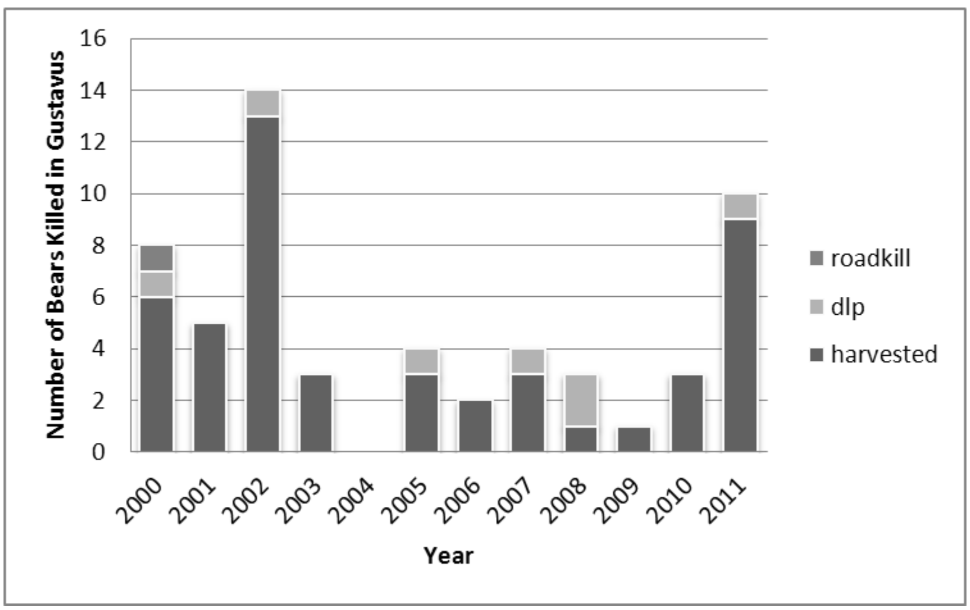

Figure 1.3. *Number of bears killed by year in Gustavus by category: road kill, defense of life or property (DLP), or harvested/hunted, 1996-2011 (Neil Barten, Ryan Scott ADF&G).*

History of Noninvasive Genetic Methodology of Bear Species

Recent advances in noninvasive genetic tagging have enabled wildlife managers around the world to obtain more precise estimates of bear populations (Kendall et al. 1999, Paetkau 2004, Boulanger 2002, Boulanger et al. 2004, Wegan et al. 2012, Waits and Leberg 2000, Taberlet et al. 2009, Stetz et al. 2010, Sawaya et al. 2012, Pool et al. 2001). DNA analyses of animal hair dates back to the early 1990's (Morin and Woodruff 1992), but these techniques were not used for bear population estimates until the late 1990's (Woods et al. 1999, Poole et al. 2001, Boulanger et al. 2002, Paetkau 2003, Boersen et al. 2003). Prior to the use of noninvasive genetic tagging, wildlife managers frequently used methods involving live capture and collaring techniques. While effective in determining movement and population size, these techniques proved to be costly, and time consuming. Moreover, in regions characterized by dense forests, other techniques used to estimate populations, such as aerial surveys, are not feasible and pose the risk of identification error. The challenges of estimating wildlife populations with large home ranges in remote locations continue to impede wildlife managers' ability to obtain accurate abundance and density estimations and thus the search for more robust techniques has continued to develop.

Noninvasive sampling methods

One common form of sampling hair from bears for genetic analysis comes from the use of bear rub trees. Bear rubs are naturally occurring and can be easily identified by claw and bite marks found on the bark of trees along bear and human use trails. Both black and brown bears rub on trees throughout the summer season but studies have shown bear rubs peak during the months of May and June (Green and Madson 2003).

This behavior is thought to occur at higher rates during the molting and breeding season though rubbing can continue through the summer and fall until hibernation. To increase sample quality, two foot-long strands of barbed wire can be installed on a rub tree. Bear rubs are a repeatable data source frequented by ursine over an extended time frame and a single tree is commonly used by more than one bear (Green and Mattson 2003). The sole use of bear rubs for mark-recapture analysis is not recommended due to the bias caused by unequal frequency of use between differing sexes and species (Sawaya 2012).

Another method developed for sampling bear hair deploying hair traps. This method was developed within the past 15 years and greatly increases sample size and reduces capture heterogeneity. Hair traps are barbed wire corrals surrounding scent lure, usually a mixture of rotten cow's blood, emulsified fish oil, and glycerin. The hair traps are set up by encircling a group of trees using 30 meters of barbed wire at approximately 50 cm above the ground. When bears investigate the scent lure in the center of the trap, their hair is snagged on the barbed wire. These samples are then analyzed by a genetics lab where specific loci extracted from the roots of the hair are then amplified using polymerase chain reaction (PCR). By using multiple methods of obtaining black and brown bear hair samples, there is a reduction in the heterogeneity of capture probability (Boulanger et al. 2008). This implies that using data sources such as rub trees and hair traps limits bias based on variables such as species, sex, or age by allowing the probability of capture to be equal.

Study Design Techniques

Woods et al. (1999) was the first study to use noninvasive genetic sampling on a large scale for estimating black and grizzly bear genetic variability in the Columbia River basin of British Columbia, Canada. In this study they researched new methodology for obtaining genetic samples from free ranging bears using three separate field trials. These trials show baited barbed wire enclosures (i.e. hair traps) are the most successful in obtaining high numbers of samples from a diverse population of bears in the study area. Following this study the methodology behind the genetic tagging of black and grizzly bears has undergone many alterations in an attempt to alleviate biases associated with capture probability. For example, Sawaya et al. (2012) showed high detection of female grizzlies and male and female black bears, but a low detection of male grizzlies using only hair traps. Conversely, bear rub trees had a higher detection of both male and female grizzlies as opposed to black bears. Therefore, a combination of both barbed wire enclosures and barbed wire installations has proven to reduce capture heterogeneity and limit gender bias (Boulanger et al. 2008, Sawaya et al. 2012). This is a single example of the evolution of genetic tagging and in the past decade there have been a growing number of articles published addressing similar issues related to the refining of field and DNA extraction techniques (Paetkau 2003, Boulanger et al. 2002, Boulanger et al. 2008, Sawaya et al. 2012).

Research design for optimal capture probability has also recently undergone much scrutiny with researchers attempting to balance cost with sampling distribution and intensity (Stetz 2008). Most studies involving the noninvasive genetic sampling of bears use a grid overlay system where each grid across the study area represents the minimum home range of a female black bear (Otis et al. 1978). Within each cell a single hair trap is deployed and checked at a frequency designated by the study design. Wegan et al. (2012) found that to avoid biased population estimates, and to increase the cost effectiveness of a project, the sampling of bear hair should occur between late spring and early summer while the hair samples are of higher quality, coinciding with annual molt. To increase capture probability and avoid closure violations, simple random sampling is not required for collecting mark-recapture data (Williams et al. 2002). More commonly a stratified random approach is used by installing traps in high quality bear habitat within one of the randomly selected cells. The frequency of the sampling sessions as determined by Woods et al. (1999) is typically 10-14 days.

Using baited hair traps in combination with barbed wire installations and naturally occurring rub trees, biologists can collect fur samples from individual barbs. DNA extracted from the roots of 3-5 guard hairs per sample are analyzed by identifying a suite of a minimum of six microsatellite markers. This number was determined by Paetkau (2003) when analyzing proper methods to reduce genotyping errors in mammalian hair analysis. The individual markers given to individual animals through this process can then be used in mark-recapture analysis to determine abundance, density, and total population size respectively. This method was developed within the past two decades in previous studies of brown and black bear populations in Canada, Alaska, and the North Continental Divide (Kendall et al. 2009, Wilder 2003, Woods et al. 1999, Boulanger 2002). There are many factors that must be considered when conducting this research in order to provide accurate results. For example, rain and sun can degrade the hair sample rendering it useless for DNA extraction. Another consideration is to avoid cross contamination between samples. If two animals are detected within a single sample, it will be unusable (Long and Zielinski 2008). These factors have been studied throughout the past 20 years making this methodology one of the most widely used in field research surrounding the population estimates of rare and elusive species (Woods et al. 1999, Boulanger 2002, Boulanger et al. 2004, Kendall et al. 2009).

Open and Closed Population Modeling for Mark-Recapture Analysis

Understanding animal population size and trends has been important to biologists for centuries in order to understand trends and make informed management decisions. One way researchers have obtained these population estimates is through mark-recapture methods. This process involves the capture, marking, and releasing of a portion of a population. Later another portion of the population is captured and the previously marked animals are counted. In theory, the number of marked animals captured during the second capturing occasion should be proportional to the number of marked animals in the whole population (Amstrup et al. 2005). Methodology surrounding mark-recapture analysis has continued to develop and our understanding of wildlife populations now includes detailed analysis of population structure of many species in a wide variety of environmental conditions. Until recently, the use of mark-recapture methods on rare and elusive species has been limited due to the inability of gathering information from those species, or our inability to reliably "mark" them. Modern field methods described above allow researchers to successfully mark and recapture animals efficiently and reliably. Mark-recapture methods have been used to estimate population sizes by taking the total number of animals captured during two or more sampling sessions. Mark-recapture using noninvasive methods uses this same technique but also includes the associated probability of detecting the individual animals (Long and Zielinski 2008). In these studies, the animal is not physically marked but rather has a specific genetic mark, or id, associated with each individual. Boulanger et al. (2002) conducted one of the first studies investigating the efficacy of noninvasive genetic sampling using bear rub trees and baited hair traps to determine a population estimate of grizzly bears in British Colombia and the United States. In his analysis, he describes three principle concerns when applying mark-recapture methods to black and grizzly bears:

1. Widespread movement of bears can violate the assumption of population closure therefore positively biasing the given population estimate.
2. Capture probability can be biased based on sex and age classes of bears.
3. Obtaining adequate sample sizes can be challenging given typical bear densities.

A closed population is one where it is assumed that the total number of individuals within a study area is unchanging. This means there is no emigration, immigration, deaths, or births (Amstrup et al. 2005). Recent models demonstrating mark-recapture analysis rely heavily on this assumption as well as the assumptions that the animals will not lose their tags, that all tags are recorded correctly, and that the animals act independently. Any violation of these assumptions can lead to biased results, typically a positive bias creating a population estimate that is larger than the 'true' population. Poole et al. (2001) accounted for this inflated population estimate of grizzly bears in northeastern British Columbia, Canada. Male grizzly bears have a larger home range than females (Boulanger and McLellan 2001) and therefore, by reducing the total estimated population by a percent proportional to the estimated number of male grizzly bears, Poole and colleagues were able to reduce the bias created from closure violation. Closure violation usually results in an inflated estimate because animals move in and out of the mark-recapture grid and are therefore counted as part of the total population (Boulanger and Mclellan 2001). Because the natural world does not function by standards such as these, and having a truly closed population is uncommon, it is difficult to find a species or study area that does not violate closure on some level. By limiting the duration of the study scales (both temporally and spatially), researchers can limit the effects of emigration, immigration, births, and death on population estimation (Boursen et al. 2003, Bittner et al. 2002).

In recent decades open population models have become more accurate and have been used more frequently by researchers in the field. Open population models allow for birth, death, emigration, and immigration but require that the subjects have equal probability of capture. The Jolly-Seber (Jolly 1965, Seber 1965), and other additions to this model, are the most commonly used models when investigating open populations. There are few time restrictions with this model as long as intervals between trapping sessions remain constant. For example, each session must occur once every day, week, month, or year, without adding or subtracting sessions during the study. After occasion 1, unmarked and marked animals that are caught are recorded and the unmarked animals are then marked and released back into the population (White 1998). This process continues for the entire sampling period. Once completed, analyses using the Jolly-Seber model can help determine minimum population, apparent survival, and capture probability. It is important to account for capture heterogeneity, or probability of capture between sex, age, and other demographic classifications, in order to avoid inflated population results as discussed above with closure violations.

Concerns with Genetic Sampling

DNA sampling techniques are based on Paetkau's (2003) research regarding the use of microsatellite molecular markers to obtain multilocus genotypes of individual animals. These individual markers are then used in mark-recapture analysis to determine abundance, density, distribution, genetic relatedness, and overall population. The noninvasive nature of this type of study offers many advantages to conventional population analysis involving "hands on" techniques but care must be taken during DNA extraction and analysis because of genotyping errors. These errors commonly occur when there is low DNA quantity or quality, or poor extract quality within a single sample (Taberlet et al. 2009). These errors are known as allelic dropout, or a misidentification of alleles because only one allele of a heterozygous individual is detected or because of extreme DNA degradation of the single sample (Taberlet and Luikart 1999). Allelic dropout is one of the more common types of genotyping error associated with noninvasive genetic sampling but other considerations must also be made when analyzing genetic material.

During the process of DNA extraction, a number of individual loci are extracted and analyzed giving a unique "mark" to each sample. It is possible for individuals to have identical genotypes at a limited number of loci examined (Mills et al. 2000). This error is known as a "shadow effect" and is most commonly seen within closely related populations and populations with little genetic variation (Mills et al. 2000). The problem most commonly associated with the shadow effect is the failure to identify certain individuals in a population, resulting in a negatively biased population estimate and a positively biased survival rate. The single solution to this problem is to simply analyze a greater number of loci per sample. Waits and Leberg (2000) discuss the potential drawbacks of adding loci stating the genotyping error rate increases with increased loci per sample which has the opposite effect as the shadow effect, creating an inflated population estimate. The balance between number of loci analyzed and the probability of increased genotyping error has been well researched during the past decade and improved methodology continues to decrease errors associated with genetic tagging.

Conclusion

Black and brown bears in Southeast Alaska have a large cultural, economic, and biological impact on the areas where they reside. Throughout the 20th century, and progressing into the 21st century, research on bear biology and behavior in Southeast Alaska has been slowly increasing. Brown bears have been widely studied in specific regions mainly due to extremely high densities and opportunities for sport hunting. There has been very little research conducted on black bear populations throughout the region and until recently all population estimates were based on studies done in Washington State in the 1960’s and 1970’s. Alaska Department of Fish and Game collect data from harvested bears as well as anecdotal information from recreationists and hunters to inform them of current population trends of both black and brown bears. Recent harvest records have shown a gradual increase in harvest of both black and brown bears throughout the Southeast region of Alaska. In order to assure sustainable harvest rates, accurate population counts would prove invaluable for wildlife managers. Recent advances in noninvasive genetic tagging have allowed biologists to acquire accurate population counts of ursine species throughout the North American continent using mark-recapture modeling. Research methodology has evolved to account for errors associated with field techniques, genetic extraction, mark-recapture statistical modeling, and capture heterogeneity based on species, gender, and age of the bears.

Bears located in Gustavus, Alaska, bordering Glacier Bay National Park, frequently cross between state, federal, and privately owned land. There has never been a population study done on either black or brown bears in Gustavus and its' surrounding areas. Bears are important for wildlife viewing and sport hunting opportunities that draw people from all over the world. Federal and state wildlife managers are concerned about the impacts of potential annual bear harvest increases on bear populations in Gustavus; and without a baseline population estimate it is impossible to know at what level to set the maximum sustainable harvest rate. It is possible that harvest rates are either set too high, where the harvest is greater than the reproduction rate; or too low, where there is the potential for increased harvest without danger of depleting the current population. Peacock's (2011) research on black bear populations on Kuiu Island, Alaska, shows that current population estimates based off of harvest information and anecdotal reports from recreationalists can be misleading by having an inaccurate population estimate. This misinformation could have a large impact on bear populations. With the recent advancement in population monitoring technology, researchers and wildlife managers should continue to pursue information on bear populations throughout Southeast Alaska to reduce the negative impacts of human-caused mortality. The development of more robust population estimates will contribute and inform multiple agencies and organizations decisions about how to implement sustainable bear harvest and management. The continued refinement of these methods encourages adaptive management practices within the agencies that will promote healthy populations of bears and responsible use of one of southeast Alaska’s most valuable natural icons.

II: BLACK BEARS IN GUSTAVUS, ALASKA: POPULATION AND HARVEST MANAGEMENT.

Estimating wildlife population size and understanding population trends are central concerns for species management. Noninvasive sampling techniques have been developed over the past two decades allowing wildlife managers the ability to obtain data on elusive wildlife species' population size, distribution, and genetic variance, within and among populations (Woods et al. 1999, Boulanger et al. 2008, Boulanger et al. 2002, Mowat and Strobeck 2002, Kendal et al. 2009). These noninvasive methods have been increasingly used by researchers to study the population trends and assess the effects of human-caused mortality on certain animal species. Obtaining quantitative data to inform the impacts of humans on game and nongame animals, as well as practicing adaptive management as a systematic approach to sustainably managing populations is vital for the conservation of wildlife species. Even in large, remote areas of North America, excessive animal harvest can have large impacts on the game animals' population, and, as a result, impact the larger ecosystem as a whole (Levi et al. 2012).

Within the past 15 years, a large amount of research has been conducted on black (*Ursus americanus*) and brown (*Ursus arctos*) bears throughout North America providing information on previously unknown populations and their management implication (Bittner et al. 2002, Boersen et al. 2003, Boulanger et al. 2002, Kendall et al. 2008, Poole et al. 2001). These studies have shown the need for more precise regional population estimates of black bears in Alaska. Black and brown bears in Southeast Alaska are commonly hunted for subsistence and sport purposes and are also valued for viewing opportunities. While brown bear populations in the region have been widely studied, until recently (Peacock 2011), no population studies existed for black bears in Southeast Alaska. Current population estimates of black bears are extrapolated based on results from research completed in Washington State in the 1960’s and 1970’s (Poelker and Hartwell 1973). Studying population dynamics of black bears in designated game management units, where harvest levels varies, can increase the understanding of impacts of human-caused mortality on bear species by providing insight on population trends. This knowledge will contribute to adaptive management and conservation strategies and actions proposed by resource agencies, conservation organizations, and other stakeholders.

The Gustavus forelands, a 200 km^2 area of land comprising federal, state, and private lands, are an example where bear populations move between National Park Service land where they are protected and state and privately owned land where an annual harvest limit of 10% the total population is in place (Figure 2.1) (ADF&G 2011a). During a 2010 Region I board meeting, members of ADF&G discussed regional estimates of black bear populations and the potential for maximum black bear harvest. Using the mean number of bears harvested per year and per area from 2007 – 2009 to assess the harvestable surplus, the board members decided on 10%. Because the black bear population of the Gustavus forelands is currently unknown, it is impossible for managers to know for certain whether the harvest objective of 10% has been met. For bear management decisions to be effective, it is essential that a cooperative process exists between both the National Park Service (NPS) and Alaska Department of Fish and Game. Both agencies value the animals and strive to promote a healthy and sustainable bear population, even if each agency has different management objectives. Both State and

Federal game managers are concerned about the potential increase in bear harvest due to increased access to the community via the Alaska Ferry, which began service to Gustavus in 2010, and the recent transfer of land ownership from federal National Park land to State land for the Falls Creek hydroelectric project. With this potential increase in access to bear harvest, it is essential that wildlife managers begin monitoring black bear populations within the area.

Non-invasive mark-recapture methods using barbed wire installations on rub trees and scented hair traps are relatively inexpensive and accurate ways to determine population estimates and densities of bears in comparison to live capture and collaring techniques (Stetz et al. 2010, Kendall et al. 2008). Rub trees are a repeatable data source frequented by black and brown bears over an extended time frame (Green and Mattson 2003). Hair traps add rigor to the study by increasing sample size and reducing bias based on gender and species (Sawaya 2012). Hair collected from sample trees and hair traps can be analyzed to determine individual identification, sex (Taberlet, 1993), species, genetic population structure, and individual genealogies (Woods et al. 1999). The genetic data collected from the rub trees and hair traps can be used to assess population trends and the impacts of certain management decisions such as allowable annual harvest. Kendall (2008) discusses the value of estimating population trends as they correlate to landscape changes, and how understanding these changes will allow managers to "reverse negative, or enhance positive changes in the population." Providing a baseline population structure of black bears will allow future researchers comparable data that could inform shifts in species distribution, population shifts, and human caused impacts on both species. The objectives of this research are to 1) determine a population estimate of black bears within the Gustavus forelands, 2) establish a monitoring protocol for evaluating population trends and future research, 3) explore sources of human-caused bear mortality and harvest trends, and 4) explore possible interagency bear management actions to ensure sustainable bear harvest levels.

Study Area

Glacier Bay National Park is comprised of 3.3 million acres of protected federal land and is adjacent to four other protected lands making it one of the largest protected areas in the world at over 25 million acres (NPS 2013). The 200 km^2 study area of this project includes most of the Gustavus forelands located in Southeast Alaska at the southern border of Glacier Bay National Park approximately 40 miles west of Juneau, Alaska (Figure 2.1). This small triangle of land is surrounded by the waters of Icy Straight to the south, the Sitakaday Narrows to the north and west, and the alpine and sub-alpine peaks of Excursion Ridge to the east. The forelands are jurisdictionally divided east to west by state and private land, and National Park Service land. The town of Gustavus, located in the southern section of the study area has approximately 450 year-round residents, but this population increases dramatically during the summer season due to the high amount of seasonal employment (U.S. Census Bureau 2010). Gustavus is the gateway to Glacier Bay National Park and is the only developed area adjacent to the park and the surrounding lands and therefore is the main jumping off point for hunting and wildlife viewing opportunities. All access to Gustavus is by boat or airplane, as there are no roads that connect to other towns, only 10 miles of paved road connecting the town to the National Park. Tourism is a large industry due to the proximity of Gustavus to Glacier Bay National Park. Most tourism to the area is by cruise ship or tour boat where the visitors do not set foot in Gustavus, but still thousands of people visit the town itself for recreation, hunting, and sightseeing (NPS 2012).

The Gustavus forelands are the largest flat plain in all of Southeast Alaska (ADF&G 2013) with a primarily sandy substrate and a spruce dominated forest. The vast forested area includes multiple salmon-bearing streams and rivers providing excellent habitat for robust bear populations and other species such as moose (*Alces alces)* and wolf (*Canis lupus)* (White et al. 2006).

METHODS

During the months of July – October of 2011 and May – September 2012, I collected hair from 25 opportunistically found rub trees within the study area. Scented hair traps were deployed from May - September 2012 only (Table 2.1). Scented hair trap stations were designed using protocols from Woods et al. (1999). Sawaya et al. (2012) found high detection of female grizzlies and male and female black bears, but a low detection of male grizzlies using only barbed wire corrals. Conversely, bear rub trees had a higher detection of both male and female grizzlies as opposed to black bears. I used a combination of both barbed wire enclosures (scented hair traps) and barbed wire installations (rub trees) in an attempt to reduce capture heterogeneity and limit gender bias.

DNA-based marking for capture-mark-recapture (CMR) studies are beneficial because marks given to an animal from a DNA sample cannot be lost like physical markers such as ear tags or collars. Sampling design to ensure limited bias and maximum capture probability was modeled after Boulanger et al. (2004) and Woods et al. (1999). The DNA sampling technique uses microsatellite molecular markers that provide genetic structure and unique marks for individual animals. The results of the genetic analysis were organized and analyzed using program DENSITY to estimate a minimum population of black bears within the study area.

Field Techniques

Bear Rub Trees

Rubbing is a naturally occurring behavior among both male and female bears (Sawaya et al. 2012). Both black and brown bears rub on trees throughout the summer season but studies have shown bear rubs peak during the months of May and June (Green and Madson 2003). This behavior is thought to occur at higher rates during the molting and breeding season though rubbing can continue through the summer and fall until hibernation. Bear rub trees are found at different densities and can be located by following game or human use trails. They are identifiable by the scratch and bite marks in the bark inflicted by the bear. It is common for a rub tree to be used by multiple bears throughout the season and some trees may be used for many generations (Green and Madson 2003).

I located 25 rub trees within the study area. Multiple rub trees were commonly found within one square mile of one another and therefore, to maximize the likelihood of capture and reduce the chance of sampling redundancy, I chose only 3-4 trees in a given area. I installed two, 1.5 ft. strands of barbed wire at approximately three feet and five feet on the tree at a diagonal angle. This method helps ensure capture of younger and smaller bears by putting the strands of barbed wire lower on the tree where they are more likely to come in contact with it.

Each tree was checked on a 12-14 day interval from July - October 2011 and May - September 2012 (Table 2.1). Each 12-14 day interval is considered a single sampling session. There were a total of 7 sampling session in 2011 and 10 in 2012. This frequency of return decreases errors associated with genotyping by ensuring hairs in a single sample are from one individual (Taberlet 2009). Each clump of hair was treated as an individual sample. Hair samples were collected using tweezers and were placed in a small paper coin envelope and given a unique identifier including location of the tree, hair sample number, and the date. If the hair samples were wet or moist they were dried at low heat using a food dehydrator and then placed directly into a small paper envelope and plastic bag containing silica desiccant. A cigarette lighter was used to burn off any remaining hair on the barbs after the samples had been collected to avoid sample contamination from future rubs.

Scented Hair Traps

I deployed 8 hair traps at one time within the study area. The locations of the traps were determined using a grid system overlay of the study area where each cell within the grid represented the minimum home range of a female black bear (Otis et al. 1978). This grid design balances effort across the area and reduces capture variation (White et al. 1982). All bears must have an equal opportunity of capture in order to reduce the occasion of underestimating the population size (Pollock et al. 1990). I subjectively chose sites within the cells for trap placement to maximize capture probability (Woods et al. 1999). Traps were deployed in areas with bear sign and high quality bear habitat. Because there is no information on minimum home ranges of female black bears within the study area, I used the ranges of black bears documented by the Juneau region Alaska

Department of Fish and Game (ADF&G). Minimum female black bear home ranges in the region span from 10-25km and therefore each cell within the study area is approximately 4km x 4km. There were eight cells within the study area. It is suggested by White et al. (1982) and Woods et al. (1999) that there be a trap set in each cell per sampling session.

Hair trap design and location was modeled after Woods et al. (1999). Samples were collected from May - mid-September (Table 2.1). Hair traps were approximately 30 meters in circumference with a single strand of barbed wired around several trees 50-75cm above the ground running the circumference of the unit. The center of the trap was baited with a liquid scent deposited on a pile of wood. This scent was a two to one ratio of rotted cow's blood and fish oil mixed with 150ml of glycerin. This method ensured there is no food reward for the bear that enters the trap and also bait will not have to be replaced between sampling occasions. I changed the scent throughout the season by subtracting the fish oil and applying skunk essence oil to nearby trees to reduce the chance of trap response by the bears. All depressions in the earth below the barbed wire corral were filled with debris to ensure the bears could not get to the bait without contact with the barbed wire. Any individual hair clump found was given an identifier associated with the trap number and considered a single and unique sample. All traps were set at a minimum of 500 meters from human development including trails, home sites and campgrounds. There was signage near any hair trap alerting any passerby of its presence.

Because of restrictions of personnel and time restraints traps remained in the same spot throughout the study. As with the rub trees, the hair traps were checked every 10-14 days. These intervals represent a single trapping session. Throughout the study there were 7 trapping sessions in 2011 and 10 sessions in 2012.

Table 2.1 Number and dates of sampling sessions for rub trees and scented hair traps for 2011 and 2012. Each sampling session was 10-14 days in length where all rub trees and hair traps were checked one time per session. Session 1 and 8 were also representative of installation dates of rub trees and hair traps.

2011(Rub trees only)		2012	
Sampling Session #	Dates within Sampling Session	Sampling Session #	Dates Within Sampling Session
1	6/28/2011 - 7/15/2011	8	5/1/2012 - 5/15/2012
2	7/16/2011 - 7/30/2011	9	5/16/2012 -5/30/2012
3	8/1/2011 - 8/15/2011	10	6/1/2012 - 6/15/2012
4	8/16/2011 - 8/30/2011	11	6/16/2012 -6/30/2012
5	9/1/2011 - 9/15/2011	12	7/1/2012 - 7/15/2012
6	9/15/2011 - 9/30/2011	13	7/16/2012 - 7/30/2012
7	10/1/2011 - 10/15/2011	14	8/1/2012 - 8/15/2012
		15	8/16/2012 - 8/30/2012
		16	9/1/2012 - 9/15/2012
		17	9/15/2012 - 9/30/2012

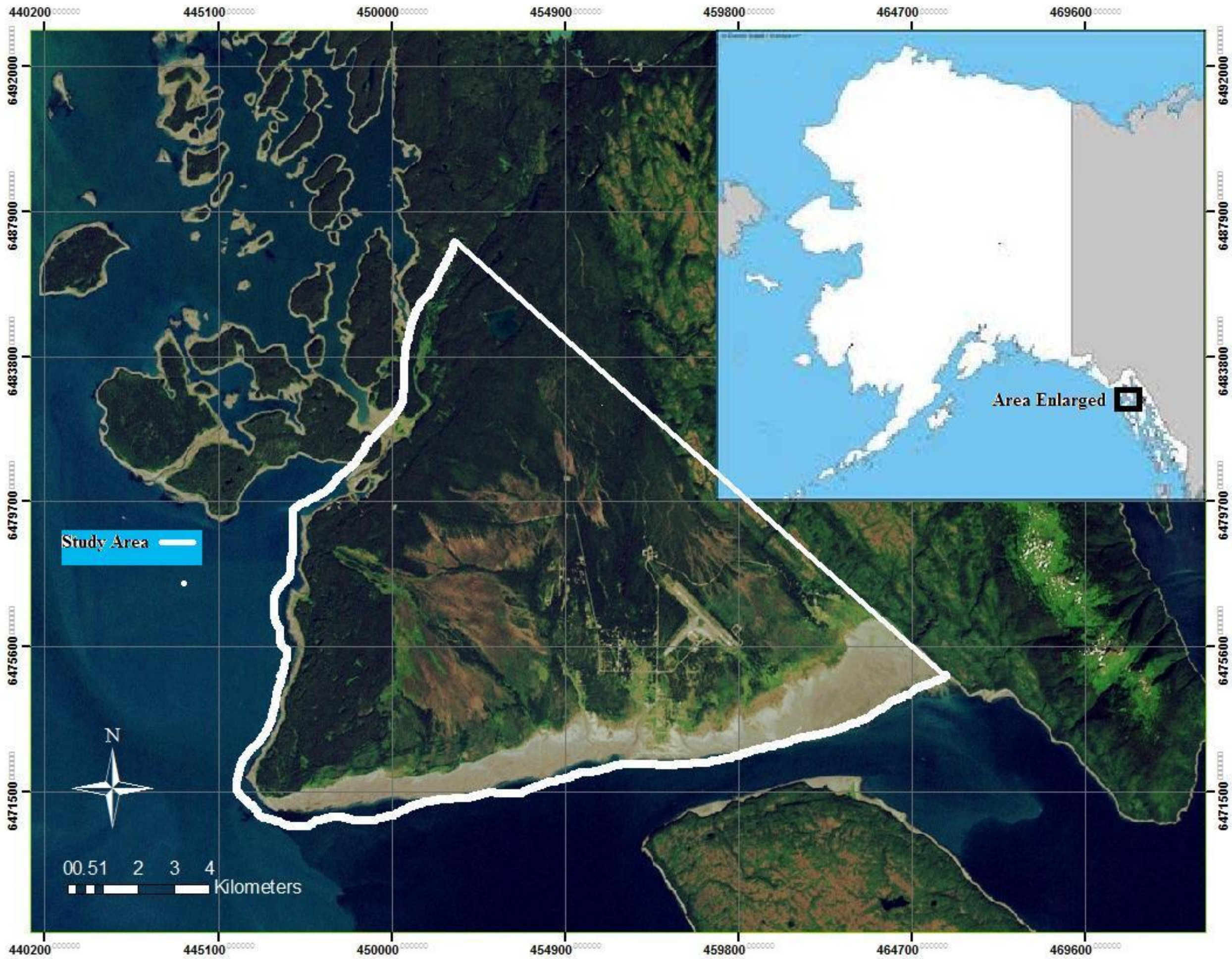

Figure 2.1. *Study Area - Gustavus forelands with 4 km² grid overlay. Total area within the study area is 200 km². Source: ESRI software, ArcGIS.*

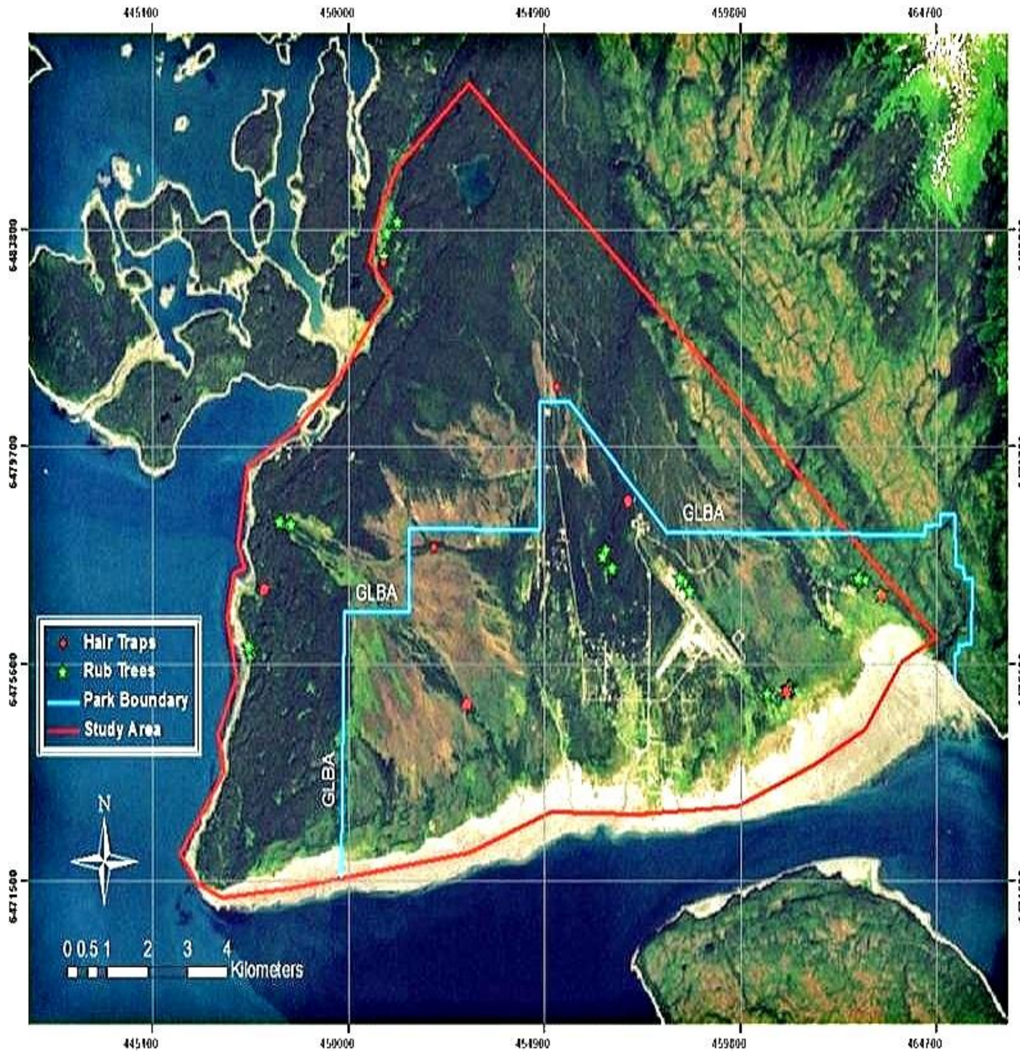

Figure 2.2. *Rub Tree and Trap Locations - 8 Scented hair traps were deployed May, 2012. One hair trap was deployed within each 4 km² cell. 25 rub trees were equipped with barbed wire throughout the study area during June and July of 2011.*

Methods of Analysis

Genetic Analysis

Analysis of hair was conducted at Wildlife Genetics International, British Columbia, Canada. DNA was extracted using QUIAGEN's DNeasy Blood and Tissue kits, following manufacturer's instructions for use (Paetkau 2012). The roots of 10 guard hairs per sample were analyzed by identifying the suite of seven microsatellite markers

G10B, G1D, G10J, G10M, MU50, MU59, and G10U. Typically, a suite of six microsatellite markers are used, but the seventh, G10U, is to compensate for the relatively low variability in marker MU50 in black bears within the study area. This number was determined by Paetkau (2003) when analyzing proper methods to reduce genotyping errors in mammalian hair analysis. This method has been used in previous studies of brown and black bear populations in Canada, Alaska, and the North Continental Divide (Kendall et al. 2009, Wilder 2003, Woods et al. 1999, Boulanger 2002). Once individuals were identified, any samples containing more than two alleles at a locus were assumed to contain DNA from one or more individuals and were thus discarded from the data to avoid population calculation errors.

Statistical Analysis

Capture histories for each unique individual genotype produced from the genetic analysis were created for closed population mark-recapture analysis in program DENSITY (Efford 2012). This model assumes there is geographic closure, where there is no emigration or immigration on or off the study area, demographic closure, where there are no births or deaths within the time frame of the study, no marks lost, and that every animal has equal capture probability. Analysis of 2011 and 2012 capture histories were run both separately and together. A population estimate of black bears within the study was produced using the more conservative of the two analyses. This is to account for possible overestimation in population due to violations in geographic closure, where bears entering from outside the study area could have inflated the estimate. Human-caused deaths were accounted for by removing the individual from the statistical analysis but including that individual in the final count (Otis et al. 1978).

I ran two analyses using the data collected from the field seasons. For the first analysis, I divided the two sampling occasions between 2011 and 2012, to reduce the chance of possible closure violation as a result of births and deaths within the population between sessions 7 and 8 (Oct. 15, 2011 – May 1, 2012). I ran analyses on the 2012 only because it contained data from both rub trees and hair traps. I used the closed population Huggins (1989) linear logistical model with no time covariate because the sampling sessions were constant. This model assumes there was little to no migration to and from the study site. Geographic closure can be assumed on two of the three sides of the study area because two sides of the triangular study site are large bodies of water. Natural mortality of black bears should be negligible within a single sampling year due to their relatively high survival rate, and births are unlikely to occur multiple times throughout the season. One black bear captured during this study in was killed by a hunter in 2012. As advised by Otis et al. (1978), I omitted the capture history from analysis, but added the number of lost animals (one) to the final estimate.

For the second analysis, I used the data set including both 2011 and 2012 and used the Huggins Linear Logistic model with time covariate to account for time in between sampling seasons to estimate population size. Both models assumed no behavioral effect on capture, meaning once an animal was captured once, the probability of being captured again would not change.

Harvest Records

I compared the results of the genetic and statistical analyses to ADF&G's bear harvest records, looking at trends in human-caused black bear mortality over a 21-year period from 1990-2011 to determine if the community of Gustavus is a population sink for black bears. A population sink as defined by Pulliam (1988) is where within-habitat reproduction is insufficient to balance local mortality. I used the population estimate obtained through the statistical analysis and compared it with the harvest trends from the past 21 years to determine if harvest rates are currently set at either overly conservative levels or unsustainable levels. By assessing the average number of black bears harvested per year I was able to produce a percentage of the total estimated population of bears taken annually.

Because of the low sample size of bear hair collected from brown bears from the two field seasons, as well as the historically low rate of brown bear hunting that occurs within the study area, I limited my analysis to understanding the effects of human-caused mortality on black bear rather than including both bear species.

RESULTS

Sampling Effort

A total of 196 bear hair samples were collected from rub trees, hair traps, and opportunistically during the two field seasons. During the months of June - November of 2011, 58 hair samples were collected from rub trees and two samples were collected opportunistically within one of the study area's 4km x 4km cells. From May – September of 2012, 134 total samples were collected. 82 samples were collected from rub trees, 49 from hair traps, and three opportunistically found samples in areas located within the study area.

Genotyping Success

Of the 196 total samples, 57 (29%) did not contain sufficient DNA material to assign an individual id. The first batch of samples collected in 2011 were sent in June of

2012 and had a lower success rate (36%) than that of the second and third batch (93%), sent within a month after collection in the field. The low success rate in 2011 is largely attributed to the rainy conditions when samples were being collected in the fall as well as the delayed analysis of 7 months which likely contributed to the degradation of the samples. Of the 139 successful samples, 51 were assigned to 14 individual brown bears, and 88 were assigned to 33 individual black bears. Four samples lacked suitable material for DNA extraction, one (0.5%) sample was excluded based on appearance (thought to be ungulate), 51 (26%) samples failed to provide sufficient DNA for analysis, and one (0.5%) sample showed evidence of multiple species' hair. Mean observed heterozygosity among the seven locus used in individual identification was 0.62 (Table 2.2). The expected heterozygosity was 0.65 with an average difference of 0.03. DNA analysis of foot pad samples collected from harvested bears in Gustavus showed that only one bear was shot and sealed in 2012 that was also marked in this study.

Mark-Recapture Analysis

The Huggins Linear Logistical model for the pooled data set of 2011 and 2012 resulted in a population estimate of 54.5 ± 10.3 (95% CI=41.6 – 84.8) black bears within the study area (Population size N-hat ± SE (95% CI). The capture probability (P – hat) was equal to 0.0508. A total of 17 trapping sessions, 47 captures, and 32 individual bears were documented in this analysis (Table 2.3). This indicates approximately 58% of the total population of black bears were captured within the two year study.

The analysis using the Huggins Linear Logistical model for the 2012 only data set resulted in a population estimate of 72.7 ± 27.8 (95% CI=41.5 – 162.7) black bears within the study area. The capture probability for this analysis was P – Hat=0.0413. A total of 10 trapping sessions, 30 captures, and 25 individual bears were marked in this analysis (Table 2.3).

Table 2.2. Variability of microsatellite markers used to determine individual identity of black bears in the Gustavus, Alaska forelands.

Locus	K	N	H_E	H_O	H_E-H_O
G10B	4	75	0.617	0.573	0.044
G1D	4	75	0.719	0.707	0.012
G10J	9	75	0.649	0.64	0.009
G10M	5	75	0.722	0.693	0.029
Mu50	4	75	0.411	0.32	0.091
Mu59	7	75	0.667	0.653	0.014
G10U	9	75	0.764	0.733	0.031
Average			0.650	0.617	0.033

K=number of alleles observed per marker

N=number of individual genotypes used in the calculation

H_E= Expected Heterozysosity

H_O=Observed Heterozygosity

Table 2.3. Capture results for trapping sessions 1 – 17 from the data set including 2011 and 2012 and capture results for trapping sessions 1 – 10 from the data set including only 2012. 32 total black bears were captured between the two sampling years of 2011 and 2012 and 25 total bears were captured during the single sampling year of 2012. There was only one marked bear harvested and sealed by ADF&G throughout the sampling seasons in 2012.

Mark Recapture Results 2011 & 2012

Session i[a]	n(i)[b]	u(i)[c]	f(i)[d]	M(i + 1)[e]	losses[f]
1	2	2	22	2	0
2	0	0	7	2	0
3	3	2	2	4	0
4	4	4	0	8	0
5	4	2	1	10	0
6	2	1	0	11	0
7	0	0	0	11	0
8	0	0	0	11	0
9	3	2	0	13	0
10	9	5	0	18	1
11	6	4	0	22	0
12	3	2	0	24	0
13	2	1	0	25	0
14	1	1	0	26	0
15	1	1	0	27	0
16	3	2	0	29	0
17	4	3	0	32	0

Mark Recapture Results 2012

Session i[a]	n(i)[b]	u(i)[c]	f(i)[d]	M(i + 1)[e]	losses[f]
1	0	0	20	0	0
2	3	3	5	3	0
3	8	6	0	9	1
4	6	5	0	14	0
5	3	2	0	16	0
6	1	1	0	17	0
7	1	1	0	18	0
8	1	1	0	19	0
9	3	3	0	22	0
10	4	3	0	25	0

[a] Number of trapping session
[b] number of animals caught at time i
[c] number of animals first caught at time i
[d] number of animals caught exactly i times
[e] number of marked animals after time i
[f] number of animals lost after time i

Harvest Data

Between the years of 1990 and 2011 a total of 82 black bears were killed by humans as documented by ADF&G. The mean annual harvest rate for these years was 3.68. The annual harvest rate and mean harvest rate showed a slight upwards trend

(Figure 2.3). There is some uncertainty with regard to the true level of harvest due to underreporting by local hunters. Of the 81 total harvested bears from these two decades, 11 were DLP, 2 were road kill, and the remaining 68 were legally harvested (Table 2.4).

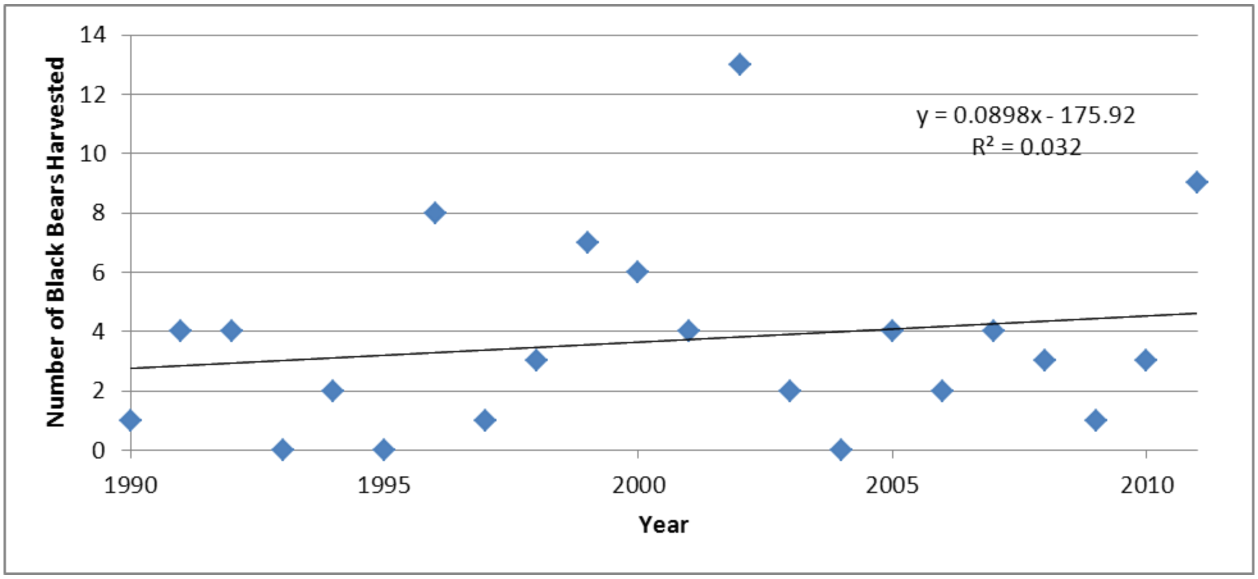

Figure 2.3. *Number of black bears harvested in Gustavus, Alaska by year. The trend line showed a slight increase in harvest over the course of 21 years with an R^2 value of 0.032 (ADF&G 2011b).*

Year	DLP	Roadkill	Legal Harvest	Total
1990	0	0	1	1
1991	0	0	4	4
1992	0	0	4	4
1993	0	0	0	0
1994	0	1	1	2
1995	0	0	0	0
1996	4	0	4	8
1997	0	0	1	1
1998	0	0	3	3
1999	1	0	6	7
2000	1	1	4	6
2001	0	0	4	4
2002	1	0	12	13
2003	0	0	2	2
2004	0	0	0	0
2005	1	0	3	4
2006	0	0	2	2
2007	1	0	3	4
2008	2	0	1	3
2009	0	0	1	1
2010	0	0	3	3
2011	0	0	9	9
total	11	2	68	**81**
average	0.52	0.09	2.8	**3.68**

Table 2.4. *Bear harvest rates by category in Gustavus, Alaska 1990-2011. The total number of bears killed in the last 21 years was 81 with the average of 3.68 bears killed annually (ADF&G 2011b).*

DISCUSSION

This study produced the first estimation of black bear populations in Gustavus, Alaska. The ability to compare data sets using rub trees only in 2011 and to compare rub trees and hair traps from 2011 and 2012, enabled the calculation of a reliable baseline population estimate of 54.4 ± 10.3 (95% CI = 41.6 – 84.8). This baseline population estimate can be used by wildlife managers to assess black bear populations and harvest management and as a comparison with future data. Using bear hair traps and rub trees throughout the course of two sampling seasons, I was able to provide an estimate of black bear populations within the Gustavus forelands using two separate statistical analyses in program DENSITY. The most conservative statistical models were chosen by systematically analyzing the closed population models found in program DENSITY. For the purposes of this research, the objective was to determine if Gustavus is a population sink for black bears, therefore the most conservative estimates of black bear populations will likely inform us if further research and more precise estimates are required. As described by Sawaya et al. (2012), the combination of rub trees and hair traps reduces capture heterogeneity, increases sample size, and reduces gender bias. Kendall et al. (2009) found that pooling data sources such as rub trees and hair traps in mark recapture analysis greatly increases the precision of the estimate as opposed to running multiple analyses for single sources of hair collection (Boulanger et al. 2008, Kendall et al. 2008). For this reason I did not test models using rub tree or only hair trap data only.

Statistical Analysis and Study Design

The first analysis of data from both 2011 and 2012 using the Huggins Linear Logistical model with time covariance resulted in a smaller population estimate (54.45 ± 10.3 (95% CI=41.6 – 84.8)) as compared to the second analysis of the 2012 only data (72.7 ± 27.8 (95% CI=41.5 – 162.7). There were also 60 additional samples from 2011 used in the first analysis

It is important to acknowledge that because of the low capture probability (P-Hat=0.0508), estimates may be less precise than those with values greater than 0.1-0.25 as reported by Kendall et al. (2009) and 0.19 as reported by Poole et al. (2001). Although it was assumed there was no behavioral change from the traps, the low capture probability may be due to a trap response, where the animal either returns to the trap frequently or avoids it all together. To account for this possibility and avoid further trap response, I used different scent lures throughout the season. Due to logistical and time constraints, however, hair traps were not moved between sessions as recommended by Boulanger et al. (2006). Moving traps between sampling sessions can reduce the trap response of individual bears, either enticing them to return (trap happy) causing negatively biased population estimations, or trap avoidance (trap shy), causing a positively biased population estimation (Nichols et al. 1982). If future mark-recapture studies are done within this study area, moving trap locations between sessions would be advised to increase capture probability and sample size. The large variation in the confidence interval also indicates the need for conservative harvest rates, at least until further, more precise estimates are made. There is still a lot unknown about the black bear population within this study area, but this study enables future researchers a conservative baseline population for comparative use.

This study was designed after Woods' and colleagues' (1999) and Kendall's (2009) research conducted in British Colombia, Canada and northwestern Montana on black and brown bear populations and their distribution. Most studies using hair snaring techniques for bears cover a vastly larger area (33,480 km^2; Kendall et al. 2009) and obtain a much larger sample size (33,741 hair samples; Kendall et al. 2009), but this project was designed to cover a much smaller area with the expectation of acquiring far fewer samples.

It was assumed throughout this study that the population was closed. As seen by the results of the closed population modeling containing relatively low capture probability and high confidence intervals, it is possible there were closure violations. The models used for analysis account for certain violations such as permanent loss, but open population models could provide more precise estimations on this population. One assumption that may be violated with my approach is that the marked individuals must be as likely to be re-marked as un-marked individuals. To account for this possible violation, the use of rub trees in addition to the hair traps reduces the amount of capture heterogeneity in the study. This study was designed to provide a baseline population estimate of black bears located in the Gustavus forelands, an area of only 200 km^2. Historically, evaluating population trends that will contribute to harvest management has been a difficult task due to imprecise estimates and large coefficient of variation (CV>20; Boulanger 2002). As mark-recapture analysis gains popularity with wildlife managers, the inefficiencies within the study designs should decrease allowing for more precise and more effective use of population estimates.

Harvest Rates

The current harvest objective for black bears in the Gustavus forelands is 10% of the total population annually. Using the mark-recapture results obtained from this study (total black bear population = 54 ± 10 (95% CI = 41.6 – 84.8) and the average annual harvest (3.68), the current harvest rate falls within the 10% allowance. Although, it is important to recognize that throughout the 21 year data set, five of those years had black bear harvest that exceeded the 10% limit. Years with harvest rates that greatly exceed the 10% limit such as 2002 (13 harvested black bears) are a rare occurrence but can have a large impact on a small population of bears. If considering the lower confidence interval of 41.6 bears, the 10% management objective was exceeded 10 of the 21 years. With harvest trends increasing due to increased access to hunting opportunities by the transfer of Falls Creek from Federal to State land and the recently added ferry access it is possible for the harvest rate to quickly exceed the allotted sustainable harvest rate. In 2011, nine black bears were legally harvested. If the modeling is correct, even at the upper end of the population estimate, around 85 bears, nine bears harvested annually still exceeds the 10% management objective. In addition to population estimates, more information on birth and survival rates would greatly improve wildlife managers' ability to predict outcomes on bear populations of annual harvest rates that occasionally exceed the allotted 10%.

MANAGEMENT IMPLICATIONS

Noninvasive mark-recapture methods can be used within game management units in southeast Alaska to assess population trends as they relate to human-caused mortality.

This is the first study to use noninvasive techniques to assess black bear population status in Gustavus, Alaska. Current harvest rates are set at 10% the total population but until now, the total population was unknown. My results indicate that harvest rates could be currently set at unsustainable levels where more than 10%, or 4.2 – 8.5 bears, are killed annually. Although the method used in this study proved to be immediately useful to wildlife managers, further research is recommended to produce results with higher capture probabilities and, thus, more precise population estimates. In addition, information on survival and birth rate will add to the precision of future studies concerning negative harvest impacts on black bear populations. The statistical modeling for the data can be examined further for more precise estimates by running open population models and exploring the possible closure violations further, but due to logistical and time constraints my examination of the data is limited to the two models described above. If funding and logistics allows, an extension of the study area as well as a devoted field crew could potentially increase sample size, decrease capture heterogeneity, decrease possible violations in closure by extending the study area and moving traps between sessions, and thus provide increasingly more precise population estimates. Black bears are a slow to reproduce, reaching sexual maturity at the average age of three and only reproducing every two to four years. Because of this low reproductive rate there could be concern surrounding the depletion of the population over extended time frames. In addition, human-bear interactions could increase as access and visitation to Gustavus increases. Increased interactions between humans and bears could result in higher annual defense of life and property (DLP) counts unless management both on a Federal and State level are diligent about their outreach to visitors as well as the community about bear safety and awareness. These are some of the factors surrounding human-caused black bear mortality.

Brown bears were also present throughout the study area and may have a large impact on black bear populations and distribution over the coming years as their population increases. During my two year study I captured and identified 14 individual brown bears. Mark-recapture analysis was not run on the brown bear population because of small sample size and time constraints. Although, capturing 14 brown bears within the study area is significant in and of itself. Anecdotally, brown bear presence within the Gustavus forelands has been limited with a few sightings reported annually. Brown bears were extirpated from the area during early settlement times but since 2010, more sightings have been reported, increasing in 2011 and 2012 (NPS unpublished data). This naturally occurring colonization of brown bears into the Gustavus forelands is an event that should be looked at and studied closely by wildlife managers for a number of reasons. Brown and black bears have substantial habitat and diet overlap (Herrero 1972, Mattson 1988). There is continuing research on the effects of cohabitation by both black and brown bears within a certain area (Mattson et al. 2005). The Gustavus forelands has abundant food sources for both black and brown bears but it is unknown whether a larger brown bear presence will cause diminished black bear presence, or whether brown bear encroachment will be impeded by the high population of black bears. Continued research studying populations of both species could be achieved by repeating this study in three to five years. Natural causes of mortality and displacement of black bears such as disease, habitat changes, and brown bear encroachment, compiled with human-caused mortality only increases the need for further research to ensure the black bear populations are sustainably managed.

III. CONLUSIONS AND RECOMMENDATIONS

Black bears are an important natural resource throughout southeast Alaska. Their cultural and economic contributions to the area have great value both for the people that reside in the area as well as their biological contributions to the natural lands they inhabit. Quantitative data on black bear populations in southeast Alaska has been limited to a single study published as recently as 2012 (Peacock 2011). While it is generally agreed upon that black bear populations in southeast Alaska are at healthy levels and not in immediate danger of decline, without empirical baseline population data this is a dangerous assumption that could lead to poor management decisions concerning allowable harvest. With harvest rates at 10% allowable take of the total population in much of southeast Alaska, it is important for wildlife managers to have a firm understanding of the total estimated population, trends, and distribution of bear species throughout these game management units (GMU) in order to avoid local depletion of black bears. Recent advances in noninvasive genetic tagging and the use of mark-recapture techniques have allowed managers to acquire more precise estimates of bears across the North American continent (Boulanger et al. 2002, Kendall et al. 2009, Mowat and Strobeck 2002, Boersen et al. 2003). Wildlife managers must use an adaptive management and interdisciplinary approach to successfully manage the population of a game species. The multivariable environment for which these animals reside shows the importance of focusing not only on the biological variables but also the cultural and economic values as well.

This research is the first to obtain a population estimate of black bears within the Gustavus, Alaska forelands using noninvasive genetic tagging and mark-recapture analysis. By comparing the results with the harvest data given by the Alaska Department of Fish & Game (ADF&G), I was able to infer that there is the potential for harvest levels to be set at an unsustainable rate over the course of many years. In addition to the field research, my investigation into the history of bear harvest both in Alaska and the lower 48 states, where bears have seen dramatic population and habitat declines, only strengthens the argument that continued research of bear populations in Gustavus, Alaska is imperative for informing continued bear management. A slow decline of the total population of black bears by human-caused mortality can be avoided if managers continue to monitor populations and to collect harvest data from legal, illegal, defense of life and property (DLP), and road kills. As human encroachment continues and the interface between bears and humans increases the need for adaptive management and multiple agency cooperation also increases.

Recommendations

As this is only the first population estimate in this area, and because of logistical and time constraints in the field, it is highly recommended that the study be repeated in three to five years to compare data and assess possible trends. While the estimate produced from my analysis may provide immediate management implications, the value of this research is more a call for further study using similar techniques. More precise mark-recapture statistics could be used if the multiple year data sets contained both rub trees and hair traps. As mentioned above, moving traps in between each sampling session would also increase the precision of the mark-recapture output as well. Analyzing sex distribution and capture probabilities could add to our knowledge of capture heterogeneity based on sex. Running mark-recapture analysis separating male and female, then running analysis with both would give insight into the relatively low capture probabilities produced from my research.

This study was developed between the needs of multiple agencies including Alaska Department of Fish & Game and the National Park Service. The results indicate the need for further management actions which include:

- Continued monitoring of harvested black and brown bears.
- Consider management action if the average annual harvest of black bears exceeds 4 bears.
- Analyze results using open population models.
- Repeat study using similar but refined methodology every 5-10 years.

    -Move hair traps between sessions.

    -Increase study area to include excursion ridge and bear track cove.

    -Locate more trees to increase sample size and capture probability.

    -If sample size allows, run population estimate on brown bears.

- Continue to monitor brown bear activity in the Gustavus forelands.

Interdisciplinary Effort

The interdisciplinary nature of wildlife management involves the application of scientific, social, technical, mathematic, and economic knowledge. Understanding how these all work together is imperative when compiling research that may impact future management decisions. The social and economic side of research concerning game species matters greatly because many times the effort behind the scientific research may have social and economic implications. Bear harvest regulation, for example, may be informed by this study resulting in impacts on allowable harvest. These scientific findings will contribute to the working knowledge of bear species, their distribution, and their populations.

Black and brown bear populations and harvest management issues will continue to be an issue of concern in the Gustavus, Alaska forelands. Research on bear species and game management that reaches across institutional barriers and promotes active contribution from wildlife managers and biologists of multiple agencies is sure to improve future management decisions. Understanding the history of harvest and accounting for the economic and social dimensions of game management allowed me to gain further insight into the importance of an interdisciplinary approach to conservation biology and wildlife management.

For many years wildlife managers have sought to understand population dynamics in order to make informed management decisions that will ensure the health of game and nongame wildlife species. The continued use of bear species both for consumptive and non-consumptive purposes add value to the animals and increase the need for rigorous management. This management must begin with the understanding of the animals' population trends, sex, and species distribution. Multiple agency cooperation, as well as shared information between agencies, will allow managers to make informed decisions about sustainable harvest and maintaining healthy populations. My research has contributed to the working knowledge of black and brown bears in the Gustavus, Alaska forelands but it is imperative that there be continued work analyzing population trends as they relate to allowable harvest. Bears can continue to enrich their environment as well as provide sport and subsistence hunting, and wildlife viewing opportunities for years to come as long as care is taken by wildlife managers to ensure that reality.

LITERATURE CITED

Alaska Department of Fish and Game. 2011a. Board of Game Direction on Black Bear Guide Allocations and Harvest in Southeast Alaska. Alaska Department of Fish and Game Division of Wildlife Conservation. Juneau, Alaska.

Alaska Department of Fish and Game. 2011b. ADF&G Bear Harvest Database 1960-2011.

Alaska Department of Fish and Game. www.secure.wildlife.alaska.gov. Date retrieved: Sept. 2012.

Amstrup, Steven C., McDonald, Trent L. Manly, Bryan F. J. 2005. Handbook of Capture-Recapture Analysis. Princeton, New Jersey: Princeton University Press.

Barten N. 2008. Unit 1C Black Bear Management Report. Pages 30-47. Black Bear Management Report of Survey and Inventory Activities 1 July 2004 – 30 June 2007. Alaska Department of Fish & Game. 17.0. Juneau, Alaska.

Barten N. 2004. Unit 1C Black Bear Management Report. Black Bear Management Report of Survey and Inventory Activities 1 July 2001-30 June 2004. Alaska Department of Fish and Game. 17.0. Juneau Alaska.

Bittner, S. L., T. L. King and W. F. Harvey. 2002. Estimating population size of Maryland’s black bears using hair snaring and DNA analysis. Proceedings Annual Conference of Southeastern Association of Fish and Wildlife Agencies 56: 312-21.

Boersen, M.R., Clark, J.D., King, T.L. 2003. Estimating Black Bear Population Density and Genetic Diversity at Tensas River, Louisiana, Using Microsatellite DNA Markers. Wildlife Society Bulletin 31:197-207.

Boulanger, John, Katherine C. Kendall, Jeffrey B. Stetz, David A. Roon, Lisette P. Waits, and David Paetkau. 2008. Multiple Data Sources Improve DNA-Based Mark–Recapture Population Estimates of Grizzly Bears. Ecological Applications 18:577–589.

Boulanger J, Proctor M, Himmer S, Stenhouse G, Paetkau D, et al. 2006. An empirical test of DNA mark-recapture sampling strategies for grizzly bears. Ursus 17: 149–158.

Boulanger, John, White, Gary C., McLellan, Bruce N., Woods, John, Proctor, Mike, Himmer, Sefan. 2002. A Meta-Analysis of Grizzly Bear DNA Mark-Recapture Projects in British Columbia, Canada: Invited Paper. Ursus, 13:137-152. 2002.

Boulanger, John and McLellan, Bruce. 2001. Closure Violation in DNA-Based Mark-Recapture Estimation of Grizzly Bear Populations. Can. J. Zool 79:642-651.

Efford, M.G. 2012. DENSITY 5.0: software for spatially explicit capture–recapture. Department of Mathematics and Statistics, University of Otago, Dunedin, New Zealand.

Harris, R. B., Wall, W.A., Allendorf, F.W. 2002. Genetic Consequences of Hunting: What Do We Know and What Should We Do? Wildlife Society Bulletin. 30:634-643.

Herrero, S. 1972. Aspects of evolution and adaptation in American black bear (Ursus americanus Pallas) and brown and grizzly bears (U. arctos Linne´.) of North America. International conference of Bear Research and Management 2:221–231.

Huggins RM 1989. On the statistical analysis of capture experiments. Biometrika 76: 133–140.

Jolly, G. M. 1965. Explicit Estimates From Capture-Recapture Data With Both Death and Immigration: Stochastic Model. Biometrika 52:225-247.

Karanth, K. U. and Nichols, J.D. 2002. Monitoring Tigers and Their Prey. Centre for Wildlife Studies, Bangalore, India.

Kendall, Katherine C., Stetz, Jeffery B., Roon, David A., Waits, Lissette P., Boulanger, John B., Paetkau, David. 2008. Grizzly Bear Density in Glacier National Park, Montana. Journal of Wildlife Management, 72(8):1693-1705.

Kendall, Katherine C., Stetz, Jeffrey B., Boulanger, John, Macleod, Amy C., Paetkau, David, White, Gary C. 2009. Demography and Genetic Structure of a Recovering Grizzly Bear Population. Journal of Wildlife Management, 73(1):3-17.

Knibb, David. 2008. Grizzly Wars: The Public Fight Over the Great Bear. Eastern Washington University, Washington.

Levi T, Darimont CT, MacDuffee M, Mangel M, Paquet P, et al. 2012. Using Grizzly Bears to Assess Harvest-Ecosystem Tradeoffs in Salmon Fisheries. PLoS Biol 10(4): e1001303. doi:10.1371/journal.pbio.1001303

Lewis, Tania. 2009. Glacier Bay National Park Bear Management Plan.

Lewis, Tania. 2012. Shoreline Distribution and Landscape Genetics of Bears in a Recently Deglaciated Fjord: Glacier Bay, Alaska. University of Alaska, Fairbanks. M.S. Thesis. 103 pp.

Long, Robert A. and Zielinski, William J. 2008. “Designing Effective Noninvasive Carnivore Studies.” Noninvasive Methods for Carnivores. Washington D.C.: Island Press.

Mattson, D.J., Herrero, S., Merrill, T. 2005. Are Black Bears a Factor in the Restoration of North American Grizzly Bear Populations? Ursus 16(1):11-30.

Mattson, D.J., Merrill, T. 2002. Extirpations of grizzly bears in the contiguous United States, 1850–2000. Conservation Biology 16: 1123-1136.

Mattson, D.J. 1998. Diet and morphology of extant and recently extinct northern bears. Ursus 10:479–496.

Miller, Sterling D., 1989. Population Management of Bears in North America. International Conference of Bear Restoration and Management. 8:357-373.

Mills, Scott L., Citta, John C., Lair, Kevin P., Schwartz, Michael K., Tallmon, David A. 2000. Estimating Animal Abundance Using Noninvasive DNA Sampling: Promises and Pitfalls. Ecological Applications 10(1):283-294.

Milner J., Nilsen E. B., Andreassen, H.P. 2007. Demographic Side Effects of Selective Hunting in Ungulates and Carnivores. Conservation Biology. 21:36-47.

Morin, P.A., and D.S. Woodruff. 1992. Paternity exclusion using multiple hypervariable microsatellite loci amplified from nuclear DNA of hair cells. *Paternity in Primates: Genetic Tests and Theories.* Karger, Basel, Switzerland.

Mowat, G., and Strobeck, C. 2002. Estimating Populations Size of Grizzly Bears Using Hair Capture, DNA Profiling, and Mark-Recapture Analysis. Journal of Wildlife Management 64:183-193.

National Parks Conservation Association. 2008. Minding the Gap: Is Wildlife Research Sufficiently Funded in Alaska’s National Parks. National Parks Conservation Association, Alaska Regional Office.

National Parks Conservation Association. 2006. Who’s Counting? How Insufficient Support for Science is Hindering National Park Wildlife Management in Alaska. National Parks Conservation Association, Alaska Regional Office.

National Park Service. “Glacier Bay 2010 Fact Sheet.” [Brochure] 2010.

National Park Service. “Glacier Bay 2012 Fact Sheet.” [Brochure] 2012.

National Park Service. Date Unknown. *Nps.gov.* Retrieved Nov. 3, 2013, from http://www.nps.gov/glba/naturescience/research.htm.

Nichols, James D., Hines, James E., Pollock, Kenneth H. 1982. Effects of Permanent Trap Response in Capture Probability on Jolly-Seber Capture-Recapture Model Estimates. North Carolina State University Press.

Noss, R.F., Quigley, HB, Hornocker, MG et al. 1996. Conservation Biology and Carnivore Conservation in the Rocky Mountains. Conservation Biology 10:949-963.

Otis, D. L., Burnham, K. P, White, G. C. Anderson, D.R. 1978. Statistical Inference from Capture Data on Closed Animal Populations. Wildlife Monographs, 62:1-135.

Paetkau, D. 2012. Project g1207 Glacier Bay 2012. Wildlife Genetics International Project Report.

Paetkau, D. 2003. An Empirical Exploration of Data Quality in DNA Based Population Inventories. Molecular Ecology, 12:1375-1387.

Peacock, Elizabeth, Titus, Kimberly, Garshelis, David L., Peacock, Mary M., Mirowlaw Kuc. 2011. Mark-Recapture using Tetracycline and Genetics Reveal Record-High Bear Density. The Journal of Wildlife Management, 75:1513-1520.

Pelton, M.R. 1982. Black Bear. Wild Animals of North America: Biology, Management, and Economics. Johns Hopkins University Press, Baltimore and London.

Poole, K.G., Mowat, G. Fear, D.A. 2001. DNA-Based Population Estimate for Grizzly Bears *Ursus Arctos* in Northeast British Columbia, Canada. Wildlife Biology, 7:105-115.

Powel, Roger A., Zimmerman, John Wayne, Seaman, David Erran. 1997. Ecology and Behavior of North American Black Bears. T.J. Press, Padstow, Cornwall, England.

Sawaya, Michael A., Stetz, Jeffery B., Clevenger, Anthony P., Gibeau, Michael L., Kalinowski, Steven T. 2012. Estimating Grizzly and Black Bear Population Abundance and Trend in Banff National Park Using Noninvasive Genetic Sampling. Plos One, Vol. 7, Issue 5.

Scott, Ryan. 2009. Unit 1 Brown Bear Management Report. Brown Bear Management Report of Survey and Inventory Activities 1 July 2006-30 June 2008. Alaska Department of Fish and Game. Juneau, Alaska.

Seber, G. A. 1965. A Note on the Multiple Recapture Census. Biometrica 52:249-259.

Sherwood, Morgan. 1979. Specious Speciation in the Political History of the Alaskan Brown Bear. The Western Historical Quarterly, 10(1):49-60.

Shoen, J.W. and Beier, L.R. 1990. Brown Bear Habitat Preferences and Brown Bear Logging and Mining Relationships in Southeast Alaska. Final Report. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration Project W-22-1, Study 4.22. Juneau, Alaska.

Stetz, Jeffrey Brain. 2008. Using Noninvasive Genetic Sampling to Assess and Monitor Grizzly Bear Population Status in the Northern Continental Divide Ecosystem, Montana. Graduate Thesis. The University of Montana, Missoula: USA.

Stetz, Jeffrey B., Kendall, Katherine C., Servheen, Christopher. 2010. Evaluation of Bear Rub Surveys to Monitor Grizzly Bear Population Trends. The Journal of Wildlife Management, 74(4):860-870.

Taberlet, P., Mattock, H., Dubois-Paganon, C., Bouvet, J. 1993. Sexing Free-Ranging Brown Bears *Ursus Arctos* Using Hairs Found in the Field. Molecular Ecology 2:399-403.

Taberlet, P. and Luikart, G. 1999. Noninvasive Genetic Sampling and Individual Identification. Biological Journal of the Linnean Society 68:41-55.

Taberlet, P., Waits, Lisette P., Leukart, Gordon. 2009. Noninvasive Genetic Sampling: Look Before You Leap. TREE 14(8):323-327.

Titus, K., Beier, L. 1993. Population and Habitat Quality of Brown Bears on Admiralty and Chichagof Islands. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Progress Report. Project W-24-1. 40pp.

Thornton, Thomas F. 1992. Subsistence Use of Brown Bear in Southeast Alaska. Technical Paper No 214. Alaska Department of Fish and Game Division of Subsistence. Juneau, Alaska.

U.S. Census Bureau. 2010. Gustavus, Alaska. Censusviewer.com. Retrieved 13 April, 2013.

Waits, Juliann L. and Leberg, Paul L. 2000. Biases Associated with Population Estimation Using Molecular Tagging. Animal Conservation 3(3):191-199.

White, G. 1998. Lecture on Open Population Capture-Recapture Models. Colorado State University.

White, K.S., Barten, N.L., Crouse, J.A. 2006. Ecology of Moose on the Gustavus Forelands: Population Eruption, Nutritional Limitation, and Conservation Implications. Proceedings of the fourth Glacier Bay Science Symposium, Oct. 26 – 28, 2004. U.S. Geological Survey Scientific Investigations Report 2007 – 5047. P. 25 – 28.

Wegan, Michael T., Curtis, Paul D., Rainbolt, Raymond E., Gardner, Beth. 2012. Temporal Sampling Frame Selection in DNA-Based Capture-Mark-Recapture Investigations. Ursus 23(1):42-51.

Wilder, James M. 2003. Quantifying Bear Populations and Bear-Human Conflicts using Non-Invasive Genetic Sampling in the Kennicott Valley of Wrangel-St. Alias National Park and Preserve, Alaska. Graduate Thesis. University of Idaho: USA.

Williams, B. K., Nichols, J. D., and Conroy, M.J. 2002. Analysis and Management of Animal Populations. Academic Press, New York.

Woods, John G., Paetkau, David, Lewis, Lewis, Dave, McLellan, Bruce N., Proctor, Michael, Strobeck, Curtis. 1999. Genetic Tagging of Free-Ranging Black and Brown Bears. Wildlife Society Bulletin, 27(3):616-627.