Moose Management of Insular Newfoundland

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Moose were introduced to Newfoundland in 1904 and since then the population has increased drastically, reaching an estimated 150 000 at its peak in the late 1990s. In some locations the population density can reach up to 7 moose per square kilometer, the highest anywhere in the world. Due to the high density of moose, the forest ecosystem has suffered by not allowing the regeneration of young trees, causing detrimental impacts to the environment. Through the study of moose hunting, fencing, wildlife crossings and movement corridors as mitigation techniques to the high densities of moose in Newfoundland, the goal is to create a sustainable and healthy population.

Introduction

The Island of Newfoundland is one of the few remaining places that still has a true sense of nature running from coast to coast, often a short commute can place you into desolate back country where nature roams wild all the way from the insects in the ground to the larger game animals that reside here, but as we continue to exploit the resource rich land such as the forestry sector removing 8400 hectares of mature forests annually (Department of Fisheries, Forestry and Agrifoods, NL) this means pressure is being put on certain species such as the moose. causing them to become more concentrated in specific areas. Therefore, we are seeing areas throughout the province being over-browsed in regions with dense populations of moose and it is leading to a biodiversity loss. I am interested in the influence of hunting species here on the island including Moose and their impact on the environment and what other alternative moose management practices can be considered to foster ecological integrity.

Moose play an important role in the ecosystem because they are a keystone species helping to preform ecological functions such as nutrient cycling and forest succession (Hammersmark, 2002) when found in sustainable populations. Moose are ungulates that browse for their food and given the right conditions can increase the diversity of plant life in that ecosystem. With diversity we have resilience, which ultimately is the goal for sustainable moose population. Resilience is the ability for an ecosystem to adapt to change over time. The more resilient a certain system is the better it will deal with issues such as global climate change. The moose species is responsible for trampling the ground, resulting in the stimulation of more fertile soil. Their grazing leads to biodiversity of plant species from the stimulation of soil on the forest floor, and the transportation of seeds. If moose do not have a healthy population either, if moose do not have a sustainable population, either too high due to lack of predators or dangerously low due to a loss of habitat, then it will have a cascade effect on numerous other animals down the trophic levels.

The scope of this paper is too improve our understanding of moose densities and alternative methods aside from hunting that can be implemented in order to regulate the population. To reach a broader audience some literature will explain the impact moose have on the ecosystem here in Newfoundland and what we can do to foster ecological integrity to maintain sustainable resources

in the province. So why should alternative management practices be considered on the Island of Newfoundland? An overview of the pros and cons of hunting on the Island of Newfoundland will show where hunting has its place in moose management but also some areas where it could be improved. If diversity in management approaches are considered it is more likely that the population will be more sustainable over time. This gives purpose for the research of alternative population management practices such as introduction of new predators, relocation and sterilization to help regulate the population over time.

Methods

Case Study Analysis

Given that the hyper-abundance of large ungulate deer species is a common problem throughout North American there are plenty of examples of wildlife management that have been successful that could be applied here in the province. Along with the successful examples it is beneficial to also learn from the mistakes made and where areas can be improved upon. This is an excellent opportunity to use active management in Gros Morne National park with the help of the park's employees and the cooperation of the public "a robust research method particularly when a holistic, in-depth investigation is required " (Zainal, 2007). Through the case study analysis it is possible to draw upon these examples and apply them to the current moose management system on the Island of Newfoundland, this typically works best when looking at issues with similar environmental constraints.

Case studies can provide useful knowledge that has proven too be useful because they have been applied in the field and reduced the population successfully. The advantage of using this method to help further the knowledge as mentioned by Zainal (2007) is that studies often produce detailed qualitative accounts that help to explore or describe the data in real-life environment, but also help to explain the complexities of real-life situations which may not be captured through experimental or survey research." (Zainal, 2007). Qualitative data can provide groundwork to the research in Gros Morne; this will help to educate the stakeholders and Parks employees about the overabundance issue inside the park and some possible methods that can be applied over time with the right implementation help to bring down the numbers of moose throughout this area and others around the Province.

The three case studies I have choose to examine have experienced forest degradation due to the over grazing deer this causes a series of problems such as loss of habitat, biodiversity and the process of deforestation to grasslands in the park. All three studies have unique constraints such as the interactions with human population due to the advancing suburban and agricultural landscapes. Addressing the overabundant population with the lack of predators and the effects that overabundance has on the environment. How the regional wildlife departments chose to deal with these issues will be addressed throughout the remainder of the paper.

Literature Review

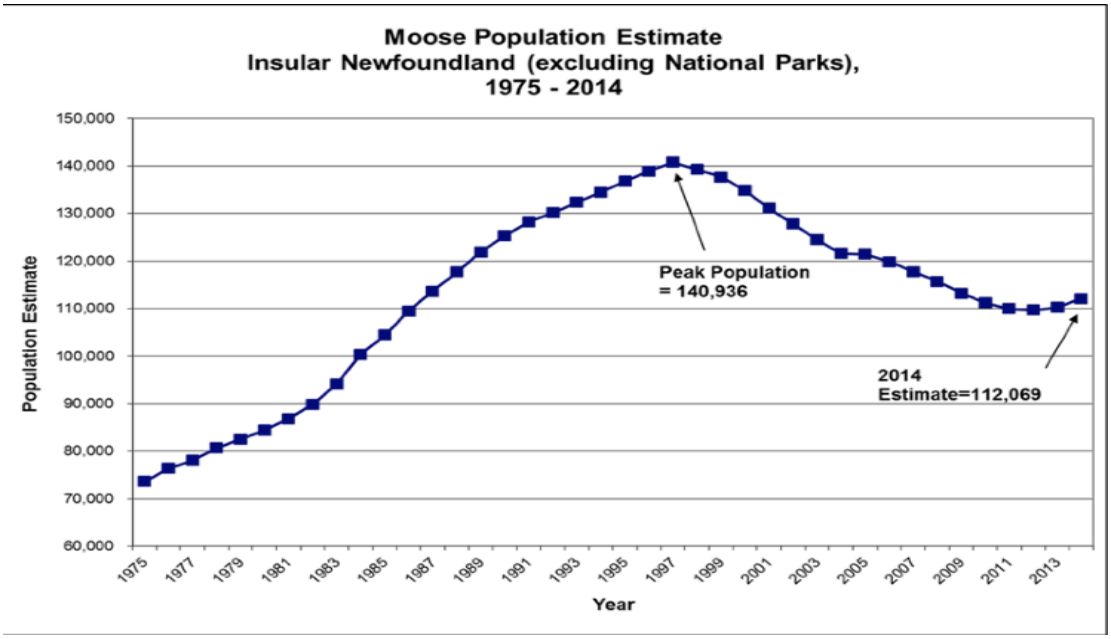
Moose History

Moose (*Alces alces*) is the largest of the North American deer species, they were originally introduced on the Island of Newfoundland in 1878 bringing over just two animals moose from New Brunswick. It is believed that these two did not successfully populate the island but years later when four more were brought over from New Brunswick in 1904. The idea behind bringing moose to Newfoundland was to provide social and economic benefits such as providing an impetus to further develop outfitting opportunities and thus attract many sportspeople from across the world to the island to hunt and fish from across the globe. Soon after the introduction, it was quickly noted that the moose population was beginning to flourish in Newfoundland. As early as 1907 there had been several moose sightings across the island and in 1912 one had been shot in the Gander Bay area (Byrne, 2012). With a push to bring more tourism to the island and create revenue a moose hunt was opened in the year 1945. As the moose spread across the island numbers seemed to be increasing for quite some time during the 1950s and licenses increased accordingly until about the 1960s.

When the moose population suddenly began to decline. Given the declining numbers the provincial department responsible for wildlife conservation decided to make some changes to the management system and this led to the introduction of a license lottery. The island was divided into moose management areas so that license allocation could be better matched to moose population densities (Byrne, 2012). Newfoundland Island was divided into areas so that the greater number of licenses issued to a specific area with the highest population density. This same license lottery is still in place today, given there has been much research on managing large ungulate species that may be more effective here in Newfoundland it may be time to consider some alternative methods to regulate these animals. Alternatives need to be considered because high densities of moose are detrimental to the forest ecology, as we can see from Figure 1 the extreme fluctuations of the moose population on the Island of Newfoundland.

Insular Newfoundland Moose Population

Figure 1



Newfoundland and Labrador, Department of Environment and Conservation. Moose Management Plan 2015-2020 (2015)

Adult moose can weigh in anywhere from 600-1100 pounds depending on gender and health, in order to maintain this size of course they need to feed constantly. During the winter it feeds on twigs and shrubs - about (18 - 22 kg) (40 to 50 pounds) a day. In the summer moose eat many types of leaves of trees and shrubs such as birch and maple. They also feed on water plants consuming a total of (22 - 27 kg) (50 to 60 lbs.) a day (Department of Environment and Conservation, 2015). Given the ideal habitat nearly 4 million m3 of productive forests (Environment and Conservation, 2015) and increasing population moose reaching approximately 140 000 animals the population began to reach numbers above their carrying capacity, reaching nearly seven moose per square kilometer in some areas and just over 1 moose per square kilometer for the entire Island of 112 000 km2 (Mercer, 2002). These densities are among the highest anywhere in the world; densities of 1.2 moose per square mile were considered to be too high to allow forest regeneration in Alaska (Taras, 2011).

It was noticeable that the forests were becoming over browsed due to the high density of moose in certain areas (Bergeron, 2011). Many forested areas throughout the island were not able to regenerate due to the grazing moose and in certain areas, particularly in Gros Morne National Park, these areas were turning into grassland and a change of vegetation was noted (Zhu et al. 2010). Moose are attracted to the young growth Balsam fir and it is also the target species of the pulp and paper industry, therefore when areas are harvested for timber or destroyed due to insect breakout the Moose then move in and prevent the forest to grow at normal rates. Along with the Balsam fir other successional species are also taking a hit from moose over-browsing a forested area. Taking

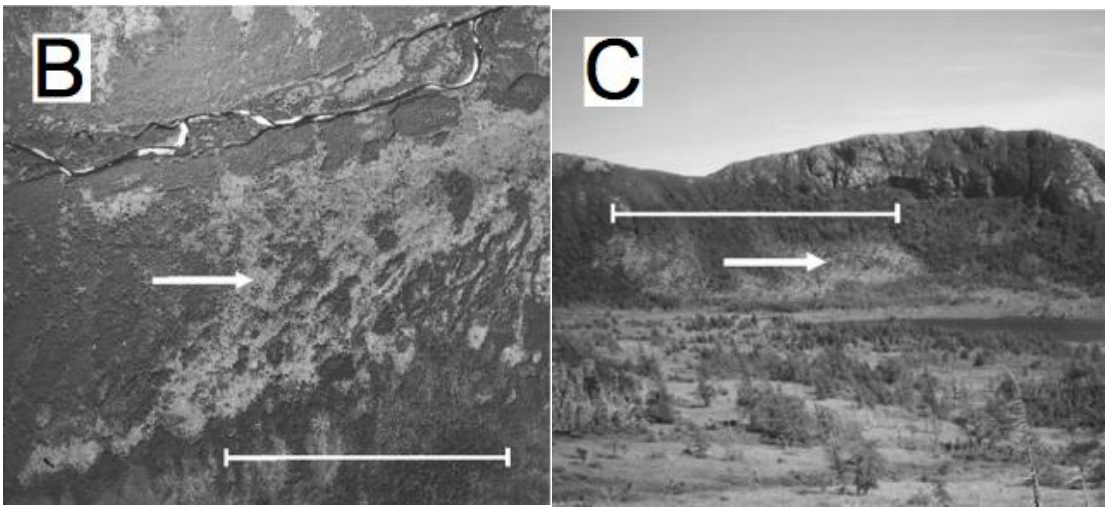
a look at Figure 2 image B this area was forested some 25 years ago but could never regenerate due to moose feeding this cutover successively. As we can see from the example below these, regions in both Terra Nova and Gros Morne National Park suffered from high densities of moose. In example B this was an area harvested for timber over 25 years ago but once the moose moved in to graze over the young balsam fir trees it could not grow at natural rates (Zhu et al. 2011).

A study was conducted to determine the effects of wood harvesting combined with moose browsing in Gros Morne National Park. Several different scenarios were examined including 1. Moose browsing where there is no harvesting or hunting, this is the control group 2. Areas where there has been commercial wood harvesting 3.Areas that have domestic wood harvesting by the local residents near the park, that was allowed when the park was created in 1973 in order to work with the local communities bordering the park. It was found that both domestic and commercial wood harvesting attracted moose to the region in the same manner and the old growth forests in the Park were not ideal locations for the moose of browse so they became over-population in areas where there has been wood harvesting in the recent past (Zhu et al. 2011). In 1971 there was an estimated 271 animals in Gros Morne, and when the park was officially established in 1973 hunting was prohibited inside its borders. This led to an increase in the numbers of moose in the area to an outstanding 7753 moose in 1998 creating one of the highest moose densities anywhere. A short time after numbers began to decline but remained steady around 4.8 animals per km^2 (Zhu et al. 2011). The forage of choice for the moose consists of mostly balsam fir (*Abies balsamea*) and white birch (*Betula papyrifera*). In Newfoundland white birch are in relatively low in numbers and if browsing continues at these levels it is possible it may disappear all together in Gros Morne (Zhu et al. 2011).

Similar to Newfoundland Sweden also has an abundant moose population over a expansive area. Sweden relies heavily on the forest industry to provide revenue for the many communities throughout the country “However, the high number of moose causes grazing damage to forests, particularly young pine forests, which leads to reduced growth and timber quality, which in turn leads to lower economic returns. The Swedish Forestry Research Institute has estimated the losses to about 1.3 billion Swedish crowns or ca. €150 000 per year” (Sandstrom, Wennberg, Ohman. 2013). Using a community based management perspective Sweden is able to reduce the density of moose in the country from the high number of hunters in the area approximately 280, 000 harvesting nearly 100, 000 moose each year (Sandstrom et al. 2013). It was found in Sweden that the top-down management style did not work very well and was a slow process; this is where the stakeholders took action and developed a CBRM style of moose management.

Examples of Moose Browsing in Terra Nova and Gros Morne

Figure 2



(Aerial Photographs of Blue Hill, Terra Nova and Halfway Cliff Gros Morne, 1996 McLaren et al.)

In order to understand the influence of moose on a forest region first one must understand how the region would develop both with and without the moose present. Through the tracking forest succession, a method called linear programming is one way to help a track forest development, forest supply and regeneration characteristics (Johnson and Scheurman 1977). In this case it is looking at if residential woodcutting is viable with such high moose densities for a sustainable and healthy forest. Before the moose were introduced to Newfoundland the forests were regenerated, since the introduction of moose and their impacts were combined with these natural processes, it has prevented the younger growth and canopy to be stunted due to the moose browsing.

Newfoundland Island is not the only place experiencing the over population of a large herbivore species. Over-abundance is a common problem in North America and Europe with deer species and their impact on the environment. Similar to moose, deer also can populate areas very quickly due to high fertility rates and can be found in densities that are not sustainable to the environment (Augustine, DeCalesta, 2003). Through case studies of alternative management practices can be studies and possibly be considered here in Newfoundland.

Case Study 1

Looking at the white-tailed deer population and management practices in southwest Ontario can be used to help understand the fluctuating population of moose and what are some alternative practices to dealing with this issue aside from hunting. This case study applies to small-scale important heritage areas that have been over populated with deer located in Point Pelee Nation Park and Long Point National Wildlife Area are two important regions in Ontario. Deer populations are known to spike quite rapidly so catching these issues before they get out of hand

is very important so eradication of the species can be avoided. Deer herds have been known to double in size in just one year because of the high fertility rates (Ellingwood and Caturano, 1988). Due to increased deer-vehicle collisions and loss of forest undergrowth action was needed to maintain the ecology of the land.

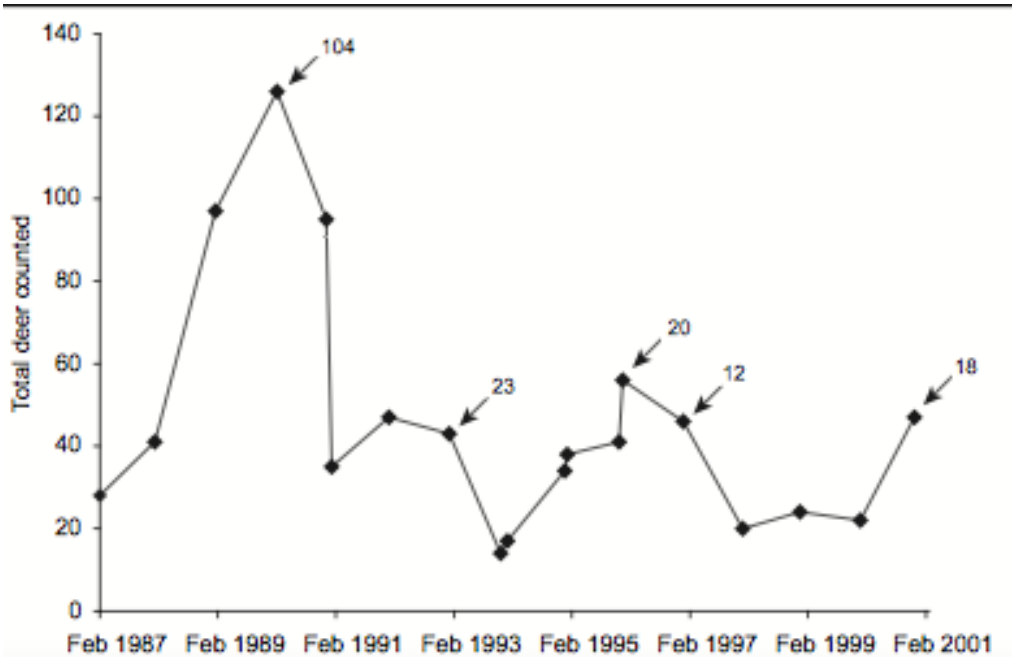
The options that were considered include; 1. Do nothing and simply let nature take its course. Eventually the deer will run out of food and habitat due to high densities of the animals and the population would see an increase in death rates. But this method the land would still be severely impacted by the deer before the population began to come down. Fencing was also implemented at site-specific areas in Point Pelee and it could have been rotated throughout the park to allow small tracks of land to regenerate. It was found that this method required too much maintenance. Other practices that were looked into include fertility control and capture/ relocation but ultimately not applied.

So it was decided that a deer cull was the management of choice in the Park area. Some concerns include the safety of park visitors and hunters alike. The cull would bring a significant amount of hunters to the area. Targeting of young female deer was the scope of the cull because it would still allow the population to rebound after some time (Reive, Stephenson, 2001). Timing would be the most important factor when hunting due to the reproduction cycles of the deer it was much more likely to see male deer in the fall but more likely to see young females for the rest of the year. The first cull was implemented in January 1991 and removed 100 animals (Reive, Stephenson, 2001) there was several other small culls in the park in the years to follow in 1991,1996,1997 and 2001. By only allowing few animals to be taken each cull it would still allow the population of deer to survive while not letting it get out of hand. The ideal population for the deer in this area was about 35 animals annually, so regular monitoring of the herb plays a very important role in knowing when to apply the cull.

Hunters do play an important role in management and tend to be an effective method when looking at areas that can be accessed easily. A suggestion to relate this study to the Island of Newfoundland is too work with the Aboriginal Populations and allow them to participate in the culls to help maintain a sustainable population. Although there are some major differences between the Point Pelee case study and Gros Morne such as; Gros Morne is not a closed system like Point Pelee meaning that the moose can move freely in and out of Gros Morne. The migration can prevent a cull from being successful unlike the much smaller scale and segregated population of animals on Point Pelee.

Point Pelee Deer Population

Figure 3



Dan Reive and Bill Stephenson (2001)

Case Study 2

Isle Royale National Park located near Lake Superior took a different approach to moose management. Instead of hunting it looks at the relationship between wolves and moose and how they are related to one another. With this understanding of how wolves and moose populations interact with one another introducing wolves to Newfoundland Island could be a possible method to regulate moose densities.

The predators on Newfoundland Island include only black bears and the non-native species of coyotes (Department of Environment and Conservation, 2015) and moose are not the target prey for these animals but occasionally they will attack a vulnerable adult or a young calf. Wolves are larger predators and are known to harvest moose for their main source of food on the Isle of Royal wolves accounted for more than "80 percent of moose deaths and the mean annual predation rate among moose (>9 months of age) is 9.9%" (Montgomery et al. 2014). The study of the predator-prey relationship on the Isle of Royale is the longest study of its kind this makes it easy to see the trend of how the moose and wolves interact and balance one another's population over time.

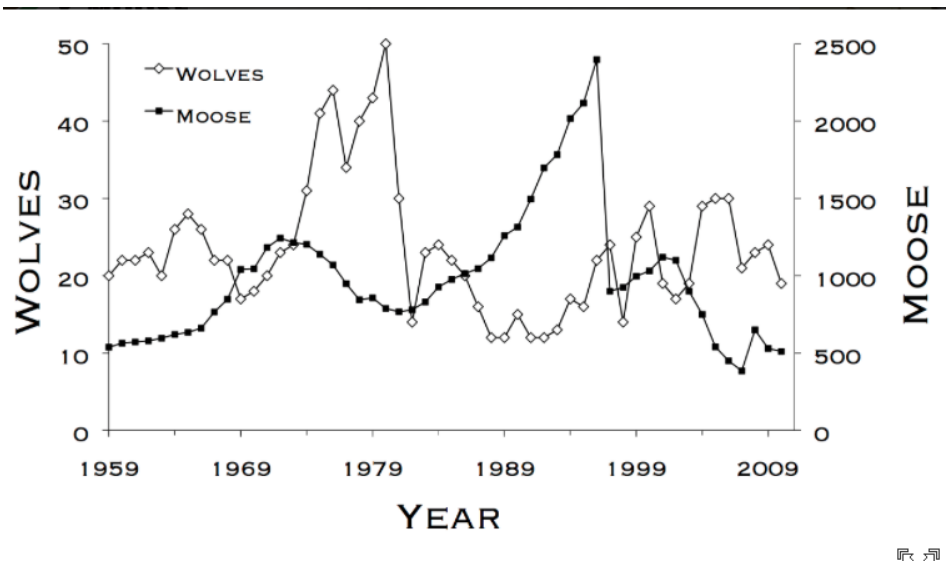
The figure 4 shows that following a peak or trough in the population of one species the other species does the opposite. "By 1980, the study in its 22nd year, the moose population had tripled from its original size and then declined to half its maximum size. During that time, wolves more

than doubled to fifty. By now it was apparent. Rich, dynamic variation, not 'balance of nature' seems to be the force that guides nature." (Vucetich, Peterson. 2012). There will never be a perfect balance in nature all populations experience fluctuations but over time they regulate one another and this leads to a sustainable and healthy population. Similar to the issue of climate change the world has been experiencing shifts in the average global temperatures for thousands of years but it is only since the population of humans the mean global temperatures has shot higher than they have anytime in the past.

By looking at the time period during the late 1980s the wolf population had reached an all-time low giving a chance for the moose to flourish on the island reaching the highest it has seen since this data has been recorded. Higher populations of moose also older population who were able to give birth to an increasing number of young calves provided an easy food source for the wolves and allowing them to bounce back after years of declining numbers. (Vucetich, Peterson. 2012).

Wolf Vs. Moose Populations

Figure 4



(Vucetich, Peterson. 2012)

Case Study 3

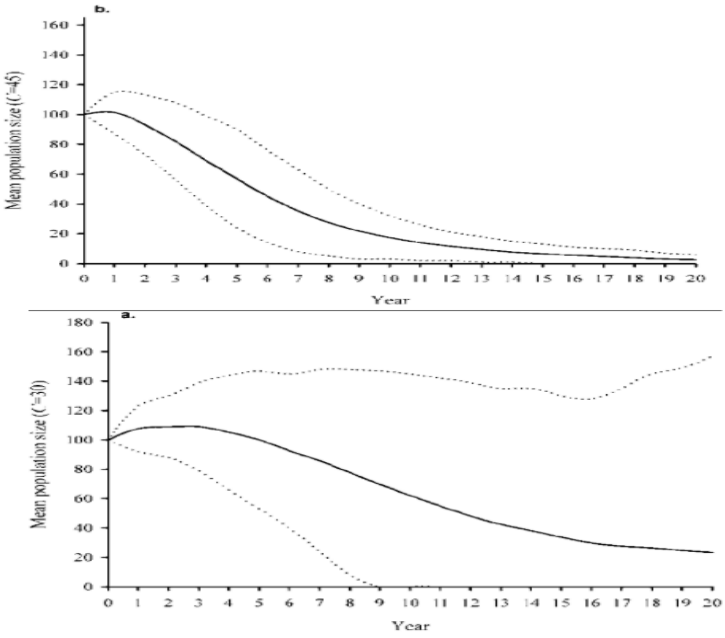
Sterilization is another management practice used to reduce fertility rates this example in Cayuga Heights, New York. They have noticed issues revolving around over abundant white-tailed deer and resulting in negative impacts to the forest ecology. Due to its close proximity to suburban landscape and agricultural lands methods such as hunting or a cull of the deer was not accepted by the stakeholders in the area because of safety issues so alternatives had to be considered. The stakeholders also didn't want to extirpate the deer altogether so they chose to sterilize a portion of the productive females to decrease the population over time. (Merril, Cooch, Curtis. 2006).

These are two models of the population showing the predictions of how sterilization of both a group of 30 and 45 female white tailed deer will influence the population over time, note figure 5 below. It is a delicate balance because with a group of 45 deer the population would lead to collapse overtime given a 95% confidence interval but with a group of 30 the population decrease to desirable numbers (Merril et al. 2006). The first 2-3 years following the capture and sterilization of the deer no change or even a possible increase would be noticed because it would take time for the sterilized population to become prime aged while the fertile females died off due to natural mortality (Merril et al. 2006).

Hunters tend to only target areas that are easily accessed leaving other areas untouched and able to grow to very high densities. This being said hunting does play a role in how moose will be regulated on the Island so below are some brief points on the success and also some downfalls to hunting. Similar to the Point Pelee case study this is also a much smaller population of animals that experience little in migration only during the winter months. Given the outside recruitment of animals in Gros Morne it is unlikely to see much success from sterilization of the moose.

Prediction Models of Deer Population after Sterilization

Figure 5



(Merril, Cooch, Curtis. 2006)

Pros of Hunting

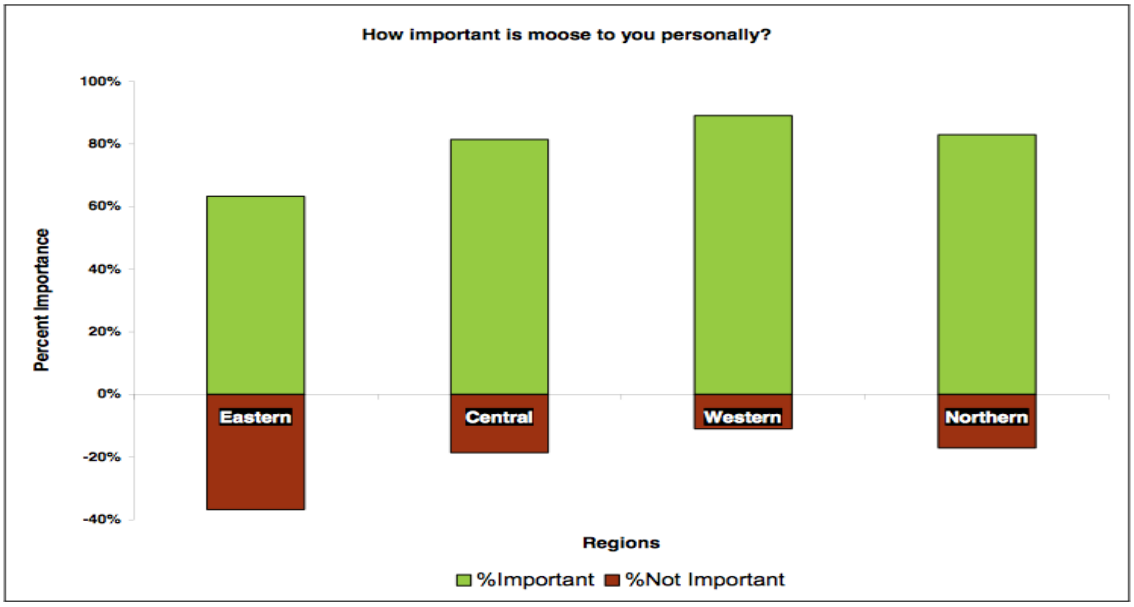
Hunting has long been the method of moose population management here on the Island of Newfoundland, it has been tried and true is proven to work and it benefits both the hunters by supplying them with fresh organic game meat and the economy through tourism, outfitters and travel expenses. Annually resident hunters harvest about 25 000 animals from the island resulting in nearly 8 million pounds of wild game meat. Hunting helps the flow of money in the province.

We have a history of hunting here in Newfoundland and it has become a part of our culture to participate in an annual big game hunt during the fall season, typically there is over 60 000 resident applications to the big game license draw (Environment and Climate Change, 2015). With a human population of under 500 000, 60 000 moose hunting applicants represents significant interest in this activity. In many cases the ones closest to the resource are the ones who should be helping to maintain and monitor its population so there can be a sustainable hunt for future generations. It has been found that relocation of large ungulate species is not a cost effective way to reduce a population size and requires a significant about of time and resources to conduct (Anthony DeNicole, 2013). While sterilization has been successful in smaller capacities where the species has restrictions on migration. Through selective harvesting a method used to target certain areas with higher moose densities than others have allowed to province to lower moose populations in these areas (Newfoundland and Labrador Outfitting Association, 2016). This is where outfitters in the province come into play with 120 active companies in Insular Newfoundland (Newfoundland and Labrador Outfitting Association, 2016) are able to target hard to reach areas that the residential hunters do not access helping to regulate these higher densities of moose.

If the management process is able to adapt and fine-tune its target areas where the density of moose is over the ideal carrying capacity then hunting is a very viable way to manage the moose population. Newfoundland conducted a study of the opinions and values of the resident as we can see from figure 6 below, stakeholders and policy/ decision makers to get an idea of what they would like to be done with the population of moose on the Island. This resulted in a five-year moose management plan from 2015-2020 “This five-year plan will allow managers to work within an adaptive framework, recognizing that moose abundance and management priorities will change over time.” (Crummel, 2015). With the aid of hunters, outfitters and the general public will provide an excellent resource for obtaining data about the moose numbers. It is the hunters and outfitters that are out in the field often and can relate their experience-based knowledge to the moose management plan. Taking a more regional approach meaning that the different regions within the Island of Newfoundland would take on different management styles. For example a cull or sterilization might be accepted on the eastern coast of the Island while it would not work on the west coast because moose are valued differently across Insular Newfoundland. This method of hunting management aims to please the most amounts of residents and stakeholders while still allowing the population of moose to be a productive resource.

Opinions on Moose Insular Newfoundland

Figure 6



Newfoundland and Labrador Department of Environment and Conservation. Moose Management Plan 2015-2020 (2015)

We can see regional differences about hunting on the island, the residents on the eastern part of the province would rather have more licenses at a lower success rate to help reduce moose vehicle collisions while on the other hand members on the western part of the province care more about an abundant moose population with higher hunter success rates (Department of Environment and Conservation, 2015). With the new moose management plan in place it has increased the amount of licenses along the Trans-Canada Highway that cuts across the island, this is to help cut down on moose-vehicle collisions in Newfoundland. On average on the island of Newfoundland there are 600-800 moose vehicle accidents per year in the insular sections (Anthony P, Clevenger, 2011). This results in 3.85 million annual loss of revenue from the moose vehicle collisions on the island (Clevenger, 2011)

While an increase in licenses along roadways is a possible solution to bring down moose population in high traffic areas this is why the Province working together with Terra Nova and Gros Morne National Parks implement 100 licenses for Terra Nova and 950 for Gros Morne (Hunting and Trapping guide, 2016-17). Aiming to reduce the amount of moose vehicle collisions along roadways. What also needs to be addressed is the moose populations that are hard to reach on the interior portions of the island where there is little road access to hunt the animals. This is where hunting outfitters play a role in helping to keep the population more stable and relatively consistent across the Island of Newfoundland. Although outfitting lodges do not span the entirety of the province, there are still areas that are virtually untouched by hunters creating an uneven distribution of moose densities. That being said outfitters do help to reach remote locations on the interior of the island that may not be accessible by the average resident hunter, the densities of

moose in these areas tend to be significantly higher but allow the outfitters to boast a 90 percent success rate when it comes to hunting moose. Nearly 4000 licenses are allotted to the outfitters annually (Department of Environment and Climate Change, 2015) a 6-day hunt in Newfoundland at an with an outfitter lodge can go from 3000-7000 dollars last year there was 3930 moose licenses allotted for outfitters on the Island (Hunting and Trapping Guide, 2016-17), on the conservative side that is a 15 million dollar industry (Condon, 1995) and that does not account for extra time spent on the island and expenses getting here. So to go along with the economic benefit we also see more evenly distributed moose densities in Newfoundland Island.

Cons of Hunting

Although hunting is an important part of moose management in Newfoundland it also has some negative aspects that go along with it. Here are a few reasons that provoked this research for alternative moose management practices on the Island of Newfoundland. A major issue with hunting is that it's very difficult to consistently manage the population over time because hunters cannot take the place of predators in an ecosystem they will not fluctuate with the populations as a wolf would so in times of stress and low fertility rates the hunting will still continue and bring down the population. This could go on for years if there is no annual monitoring of the species.

The satisfaction of the hunters both resident and non-resident is another factors because once you give someone the privilege to hunt it is very difficult to take away and now the issue of economic versus environment comes into play. Due to a fluctuating populations regular research and monitoring has to be conducted annually in order to get accurate densities of moose and the amount of licenses need to be constantly adjusted. The problem with this is that often due to budget constraints in the province at times it is very difficult to invest money into this type of research and development. This prevents the predator and prey relationship to be under constant stress. The province regulates the number of licenses with respect to area and gender with a total of 31 000 licenses in the year 2016, 19 000 were either sex tags while 12 000 were male only or calf tags (Environment and Conservation, 2015). The major issue with this system is that it does not take into consideration the age class of the animals, which is a major factor when it comes to population health and density. Age structure is very important when talking about the health of a population it was found that the prime age for deer fertility range from 2-7 years (Festa-Bianchet, Gaillard, Cote, 2003) so depending on what the target species is it can have serious impacts on the population of the species.

There are several other management styles and mitigation techniques that can help to decrease the impact of moose both on the environment and to the residents. Moose are large ungulates and are normally preyed upon by predators such as grey wolves and in some cases black bears will hunt small calves for food. Since wolves were listed as extinct from the island because there was a cull placed on the species with intent to extirpate them around the same time moose were introduced around 1930 (John E. Maunder, 1991). This was common across North America at the time. The function of wolves was yet to be understood of how they help to regulate populations of large herbivores, as they have been able to roam free with little to no predation to regulate population. With no predators the moose were able to grow until they were limited by a food source, this is referred to as bottom-up regulation "Under bottom-up regulation, predation is absent and the population is free to increase until it reaches carrying capacity, at which point it becomes limited

by its food supply" (Orihuela, Terborgh, Ceballos, Glander, 2014) the animals will continue to grow in population until they are limited by a food source.

Results/Discussion

After examining the three case studies and the relative literature it is clear that hunting plays a significant role in moose management on the island portion of the province, both when looking at it from a resident's perspective and also a conservation perspective. The social and economic advantages of having an annual moose hunt create considerable revenue for the province and allow the reduction of moose densities. With a moose harvest Newfoundland is able to regulate the amount of moose taken out of each moose management area, so with the help of monitoring these areas on a consistent basis it is possible to accurately increase or decrease the licenses accordingly.

Along with the moose hunt in Newfoundland some other management initiatives should be implemented as well if they are feasible, such as moose fences. It has proven to be effective in other regions across North America as a method to reducing moose vehicle collisions "Fencing, alone or with crossing structures, is a proven technique and highly effective at reducing collisions with ungulate species (deer, elk, moose), reducing rates by as much as 95% in some areas" (Clevenger, 2011). This has been implemented on the western part of the island for the last several years therefore it should be easy to introduce in other parts as well where the density of moose is higher to reduce the amount of moose vehicle collisions.

It has been found that relocation of large ungulate species is not a cost effective way to reduce a population size and requires a significant about of time and resources to conduct (Anthony DeNicole, 2013). While sterilization has been successful in smaller capacities where the species does not migrate excessive amounts.

The introduction of new predators may not be the best practices for Insular Newfoundland because of the decreasing woodland caribou populations a keystone species here on the island with cultural significance to the residents, stakeholders and Aboriginal people of Newfoundland. So introducing a predator that could possible cause more stress on the Caribou population may not be accepted.

An ecosystem management style would be the best plan in order to create a healthy and sustainable population, focus not only on the moose but the whole ecosystem down to the vegetation because that is what the goal is to protect when talking about reducing the moose population. Annual monitoring of the ecosystem is necessary to increase understanding of the environment and how it interacts with certain changes, with an adaptive management style it is possible to adjust to these changes and manipulate the management initiatives accordingly. With any management style such as sterilization or predation annual monitoring is the key to achieve the desired goals. As presented with the Isle of Royal case study it was over the time period of 53 years the longest of its kind when looking at predator-prey relationships. From the case study it was determined that no two years in a row were the same (Vucetich, JA and Peterson RO. 2012). This is why continual research of moose management practices is necessary to sustain the population along with monitoring to notice any changes in the population.

References

Anthony J. Gaston, T. E.-L. (2002). *Lessons from the Islands Introduced species and what they tell us about how ecosystems work.* Queen Charlotte, British Columbia: Canadian Wildlife Service.

Anthony P. Clevenger, B. C. (2001). Highway mitigation fencing reduces wildlife-vehicle collisions. *Wildlife Society Bulletin , 29*, 646-653.

Barbara Condon, W. A. (1995). *The economic value of moose hunting in Newfoundland.* St.John's, Newfoundland and Labrador, Canada: Natural Resources Canada.

Beckman, J. A. (2010). *Safe passages: Highways, wildlife and habitat connectivity.* Washington DC: Island Press.

Brage B.Hansen. Snorre Henriksen, R. A.-E. (2006). Ungulate impact on vegetation in a two-level trophic system. *Polar Biology , 30* (5), 549-558.

Brian E. Mclaren, B. A.-C. (2004). Effects of Overabundant Moose on the Newfoundland Landscape. *ACLES , 40*, 45-59.

Byrne, A. (2012). *The Intoduction of Moose to the Island of Newfoundland.* Newfoundland and Labrador Provincial Historic Commemorations Program.

Change, E. a. (2017, March 5). *Big Game Management in Newfoundland and Labrador*. Retrieved March 20, 2017, from Newfoundland Labrador Canada: www.ecc.gov.nl.ca/wildlife/wildlife_research

Charron, L. (2016). *Restoring Forests Degraded by Overabundant Moose on the Island of Newfoundland.* Memorial University of Newfoundland, Department of Biology, St.John's.

Clevenger, A. P. (2011). *Moose-vehicle collisions and their mitigation in Newfoundland.*

Conservation, A. D. (2011, June). *Interior Alaska Moose News*. (L. M. Mike Taras, Editor) Retrieved April 3, 2017, from www.adfg.alaska.gov

Coulson, T. (1999). The Science of Overabundance: Deer Ecology and Population Management. *Biodiversity and Conservation , 8* (12), 1719-1721.

Dale R. McCullough, S. T. (2009). *Biology and Management of Native and Introduce Populations.* Japan: Springer.

Daniel Simberloff, J. A. (1992). Movement Corridors: Conservation Bargains or Poor Investments? *Conservation Biology , 6* (4), 493-504.

David J. Augustine, D. D. (2003). Defining deer overabundance and threats to forest communities: From individual plants to landscape structure. *Ecoscience , 10* (4), 472-486.

DeNicole, A. J. (2013). *White-tailed Deer Population Control Options.* Mt. Lebanon, Pennsylvania: White Buffalo Inc.

Gabriela Orihuela, J. T. (2014, April 17). *When Top-Down Becomes Botto up*. Retrieved March 16, 2017, from PLOS one: journals.plos.org/plosone

Hammersmark, C. T. *Moose (Acles acles) and Their Influence upon Terrestrial Ecology in the Copper River Watershed, Alaska.* Alaska.

Janick Gingras, S. C.-P. (2014). Opposite responses of body condition and fertility in adjacent moose populations. *The Journal of Wildlife Management , 78* (5), 830-839.

Jerome B. Robinson. (2003). 150,000 Moose; Newfoundland. *Field & Stream* (6), 62-65.

John A. Merril, E. G. (2006). Managing an Overabundant Deer Population by Sterilization of Immigration, Stocasity and the Capture Process. *Journal of Wildlife Management , 70* (1), 268-277.

Jonathat B. Losos, R. E. (2010). *The Theory of Island Biogeograpy Revisited.* Princeton: Princeton University Press.

Kohler, N. (2011). Awake the lumbering giants. *Maclean's , 124* (44), 38-39.

Lister, N.-M. (2017). *ARC*. (ARC Solutions) Retrieved March 20, 2017, from arc-solutions.org/what-is-arc/

LM, H. (2014). *Ontario Moose Hunting and Moose Management Survey.* Thunder Bay, Ontario, Canada: Centre for Northern Forest Ecosystem Research.

Ltd, C. R. (1989). *Effects of the Okanagan Connector Freeway on wildlife and effectiveness of mitigation techniques.* Ministry of Highways, Victoria.

Marco Festa-Bianchet, J.-M. G. (2003). Variable age structure and apparent density dependence in survival of adult ungulates. *Journal of Animal Ecology , 72*, 640-649.

Mark R. Christie, L. L. (2015). Habitat corridors facilitate genetic resilience irrespective of species dispersal abilities or population sizes. *Evolutionary Applications , 8* (5), 454-463.

Maunder, J. E. (1982). The Newfoundland Wolf. *The Osprey , 13* (2), 36-49.

McGary, K. (n.d.). Retrieved March 22, 2017, from Ontario: www.ontario.ca/pages/factors-affecting-moose-survival

McLaren B. E, M. W. (2005). How management Unit License Quotas Relate To Population Size, Density, And Hunter Access in Newfoundland. *ACLES , 41*, 75-84.

McShea, W. J. (2012). Ecology and management of white-tailed deer in a changing world. *Annals of the New York Academy of Sciences , 1249*, 45-56.

Mercer, W. (2002). Evidence of carrying capacity effects in Newfoundland moose. *Acles , 38*, 121-141.

(2015). *Newfoundland and Labrador Moose Management Plan.* Newfoundland and Labrador Wildlife Division, Environment and Conservation. St.John's: Environment and Conservation.

Okihiro R. Norman, L. E. (1999). Mounties, moose & moonshine: the patterns & context of outport crime. *Canadian Journal of Sociology , 24* (2), 314-316.

Pelly, C. (2016, November 22). *the overcase*. Retrieved march 17, 2017, from Newfoundlands Alternative Newspaper: theovercast.ca/a-brief-history-of-the-extinct-nl-wolf-and-recent-wolf-capture-in-nl/

Rea, R. (2003). Modifying roadside vegetation management practices to reduce vehicular collisions with moose Alcles acles. *Wildlife Biology , 9* , 81-91.

Robert Montgomery, J. A. (2014). Where Wolves Kill Moose: The Influence of Prey Life History Dynamics on the Lancscape Ecology of Predation. *PLOS ONE , 9* (2), 1-7.

Sandström, C., Wennberg Di Gasper, S. & Öhman, K., (2013). Conflict resolution through ecosystem-based management: the case of Swedish moose management. International Journal of the Commons. 7(2), pp.549–570.

Steeve D. Cote, T. P.-P. (2004). Ecological Impacts of Deer Overabudance. *Ecology, Evolution and Systematics , 35*, 113-147.

Stephenson, R. O. (2013). Wolf Kill Rates Across Winter in a Low-Density Moose System in Alaska. *The Journal of Wildlife Management , 77* (8), 1512-1522.

(2016). *Timber Resource Analysis Insular Newfoundland.* Government of Newfoundland and Labrador, Department of Fisheries, Forestry and Agrifoods.

Waithaka, J. (2008). Policy on Management of Hyperabundant Wildlife Populations in Canada's National Parks. *Parks for Tomorrow Conference.* Gatineau: Parks Canada.

Xinbiao Zhu, C. P. (2010). Predicting the effects of woodcutting and moose browsing on forest development in Gros Morne Nation Park, Newfoundland, Canada. *The Forestry Chronicle , 86* (2), 178-192.

Zainal, Z. (2007). *Case Study as a research method.* University Teknologi Malaysia, Faculty of Management and Resource Development, Teknologi.