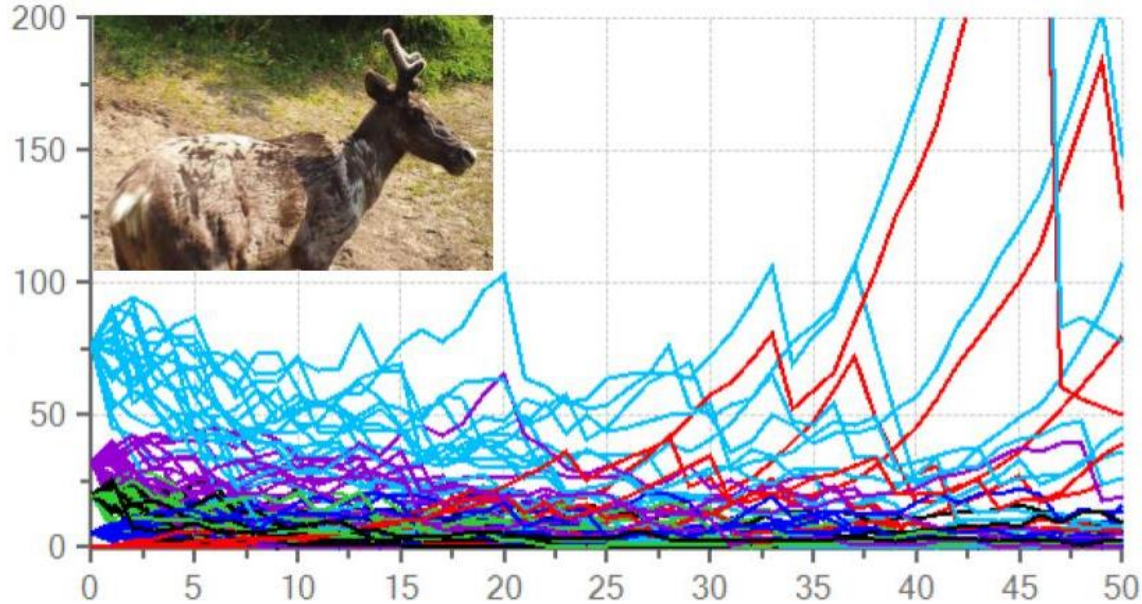
METAPOPULATION VIABILITY ANALYSIS OF WOODLAND CARIBOU IN THE LAKE SUPERIOR RANGE

by

Brian Hardy-Cooper



Faculty of Natural Resources Management

Lakehead University

Thunder Bay, Ontario

April 28, 2022

Metapopulation Viability Analyses of Woodland Caribou in the Lake Superior Range

by

Brian Hardy-Cooper

0877839

An Undergraduate Thesis submitted in partial fulfillment of the requirements for the degree of Honours Bachelor of Environmental Management with a Specialization in Wildlife Conservation and Management

Faculty of Natural Resources Management

Lakehead University

April 28, 2022

Brian McLaren
Supervisor

Serge Couturier
Second Reader

LIBRARY RIGHTS STATEMENT

Signature:

Date: 2022-04-28

A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific environmental management.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty, or Lakehead University.

ABSTRACT

Woodland caribou populations in the Lake Superior range have deteriorated. The caribou's decline follows industry growth since the 1900s. Islands like those in Slate Islands Provincial Park, Michipicoten Island and Caribou Island offer periods of escape from wolves, the main predators of caribou. Minute mainland populations exist because of translocations conducted in the early 1980s and late 2010s with A.T. Bergerud, and later Gord Eason at the head. Together with the island populations, the safest and most common areas of translocations, the mainland connects what can be considered a metapopulation. Population viability analyses (PVAs), run on Vortex10, were conducted to determine ways of creating a stable metapopulation with consideration given to future arrivals of wolves and future translocations to the Lake Superior islands. The probability of icing events for caribou dispersion were factored into the PVAs. Wolf appearance on islands has been the chronic limiting factor of caribou abundance. Allowing no translocations created a high probability of functional extinction. Specific translocation starting in the present and continuing until 10 years created the highest likelihood of persistence of the metapopulation. The Slate, Michipicoten, and Caribou islands are crucial to metapopulation persistence. Further recovery of the woodland caribou populations in the Lake Superior range should view translocations as a beneficial management approach.

Keywords. Conservation, extinction, iterations, *Rangifer tarandus*, refuge islands, translocation

ACKNOWLEDGEMENTS

I would like to thank Dr. Brian McLaren for always making time to provide expertise and encouragement in my work. He reviewed and commented on many rough drafts that I sent his way and connected me with scientists are working on this subject. He also allowed me to make my own timelines and trusted me with the large responsibility of taking on the task he offered.

I would like to thank Serge Couturier for agreeing to be my second reader. The notes and edits were much needed. Serge's comments guided my thesis to a higher level of professionalism.

I would like to thank Brian McLaren, Serge Couturier, Gord Eason, and Christian Schroeder for meeting with me in the middle of the process multiple times. It helped greatly to reaffirm the thesis direction and different ways of showing significance with each figure. I also thank you all for the words of importance and motivation surrounding my work.

I would like to thank Dr. Nancy Langston and Jordan Kelley for providing access to their collection of relevant articles, notes, and other media. These sources were what I considered and used for initial population sizes.

CONTENTS

TABLES

FIGURES

INTRODUCTION

Active management has become important for the survival of charismatic organisms like Woodland Caribou (*Rangifer tarandus caribou* Gmelin) in North America's boreal forest. Woodland caribou populations are sensitive to environmental and anthropogenic disturbance. This sensitivity has led the Slate Islands Provincial Park population in Ontario to decline along with populations in surrounding areas near Lake Superior. Historically, management of small populations has not been effective in this area long-term. The comparison of single population management and metapopulation management models could focus the scope of caribou restoration efforts for the Lake Superior area. It has been 28 years since Gogan and Cochrane (1994), working with the National Park Service in the U.S. regions around Lake Superior, concluded that populations of caribou on the Slate Islands archipelago could not persist without viewing the population differently.

Lake Superior Caribou populations in the past century have included Slate Islands Provincial Park, Pukaskwa National Park, Caribou Island, Michipicoten Island, Pic Island, Leach Island, other areas along Lake Superior's North Shore, Montreal Island and Otter Island. In the United States, Isle Royale National Park's archipelago once supported a population in Michigan, the Apostle Islands National Lakeshore in Wisconsin, and Voyageurs National Park and areas to the east in Minnesota (Gogan and Cochrane 1994). Islands like the Slates and Pic have had depleted food resources in the past from 1976-1978 (Ferguson et al. 1988). Lake Superior's North Shore and Isle Royale are now occupied by wolves (*Canis lupus* L.). Caribou are able to swim great distances in the summer and travel on winter ice bridges to escape wolf predation.

Immigration by the same means of travel between locations should then be key to the survival of the metapopulation. With increasing effects from climate change, ice bridges will be likely less frequent when caribou need to escape from wolves in the winter.

This thesis is not the first viability analysis of a woodland caribou population within the metapopulation that remains today along Lake Superior. Shuter et al. (2009) used population viability analysis (PVA) to predict the population on the Slate Islands to be facing extinction in 2039, lasting from 2009 for an average 30 years. Focusing on the population of the Slate Islands provides an interesting chance to explore management of part of an at-risk metapopulation. Another viability analysis was done for Pukaskwa National Park determining the usefulness of translocations where the finding was that translocations would not have intended effects with wolf densities greater than 5 for every 1000 km^2 (Gonzales et al. 2015). Managing the Slate Islands or the Pukaskwa caribou as part of a metapopulation is expected to be an improved approach over managing singular herds.

The premise for this thesis is that certain populations within the Lake Superior caribou metapopulation will contribute to the successful recovery more than others and these differences should be understood for active management of woodland caribou in the region. Such source populations could act as reservoirs for future translocations to keep the metapopulation stable. Identifying them requires using caribou demographic parameters, predator influences, and carrying capacity ideally estimated from reliable sources. The goal of this thesis is to determine if the Lake Superior caribou metapopulation can be viable. Accounting for dispersal and translocation of individuals to other populations can allow a PVA to better resemble natural interactions between caribou and their landscape, and conservation managers and population recovery. The first objective is to use a historical review with literature updates toward determining a range of possible outputs for a PVA. The second objective is to explore some of these options using Vortex 10, a popular PVA modelling software.

LITERATURE REVIEW

This literature review updates an original review by Gogan and Cochrane (1994), the original discussion paper that sought potential caribou translocation destinations toward a self-sustaining metapopulation in the Lake Superior region north and south of the U.S. border.

DISTRIBUTION OF WOODLAND CARIBOU

The regional woodland caribou's historic range extended south of the Great Lakes Region and spanned into northerly parts of Minnesota, Wisconsin, and Michigan until expansion of U.S. pulp production disturbed much of the range making it unsuitable (Vos 1964). Beginning around 1960, the progression into Canada of forest operations to produce wood products coincides with the caribou's declining northern range (Racey and Armstrong 2000). Modelling shows that the probability of a caribou occupying the southern half of Ontario changed starting in 1941 (Vors et al. 2007). Areas with 51-75% probability declined to 26-50%, and the majority of the land now rests at 0-25% probability of occupancy. Caribou of the Great Lakes Region have dwindled despite recovery attempts. Aerial surveys in 2016 (Shuter et al. 2016), 2019 and 2021 along the northern shore of Lake Superior have found potential caribou tracks, and people in the area have seen and even photographed a few individuals on the mainland north and east of the Slate Islands (Couturier et al. 2021). The Slate Islands population was functionally extirpated by the wolves in 2017 as only two to four males were still alive. In January 2018, the emergency translocation of nine adult caribou (one male, eight females) was carried out by MNRF from Michipicoten Island to the Slate

Islands. These animals joined the adult males that were still on the islands (Couturier et al. 2021). The Slate Islands population is monitored by remote cameras and was estimated to be 30 in 2020 (Couturier et al. 2021). This is now the largest part of the Lake Superior Caribou (LSC) metapopulation. This review includes details on population dynamics for the best studied populations, those on the Slate Islands and the mainland in Pukaskwa National Park.

HABITAT USE

Ground lichen and arboreal lichen, which hang from tree branches are a major part of the woodland caribou's diet. Lichen requires sun the majority of the day. When there is a tree density of 3000 to 5000 per hectare, ground lichen cover reaches 0-30%. About 550 trees per hectare is estimated to allow for almost 100% ground lichen cover (Antoniak and Cumming 1998). Conclusions and recommendations of the associated study also include that forest canopy that promotes caribou use should allow enough sun for lichen to grow and sustain caribou but still have overhead cover to reduce snow depth for movement. The forestry rotation period of Jack Pine (*Pinus banksiana* Lamb.) and Black Spruce (*Picea mariana* [Mill.] Britton) stands should be pushed from 60-80 years back to 100 years to give caribou the most benefit of lichen growth (Antoniak and Cumming 1998).

Caribou may or may not avoid rugged terrain to decrease encounters with Moose (*Alces alces* L.) or wolves and conserve energy (McClinchey 2018). Caribou in Pukaskwa National Park, especially pregnant females, are regularly spotted <2 km from shorelines and on adjacent islands from mating grounds. This is theorized as a strategy for predator avoidance (Bergerud et al. 2014). Caribou benefit from rare ice bridge events that enable travel to islands without predator stresses. One recent such event happened in 2014 (Drake et al. 2018), and ice has extended more than 500 m offshore in 1977, 1980, 1985, potentially connecting the mainland to Otter Island, a common caribou refuge island near Pukaskwa National Park (Bergerud et al. 2014).

Approximately 15% of the Slate Islands and Michipicoten Island has been disturbed (ECCC 2017). Most of the anthropogenic disturbances are found on the mainland and less on the off-shore islands. Disturbances such as mines are generally avoided by caribou as reported by Weir et al. (2007). Their caribou monitoring at the Hope Brook Mine site and in the surrounding area in south-western Newfoundland showed that larger herds avoid disturbance more than smaller ones. Small herds within 6 km of the mine were observed to be made up of males and yearlings that are less fearing. In general, caribou kept a 4-km buffer from the mining operation (Weir et al. 2007).

HOME RANGE AND DENSITY

The Slate Islands are 9 km off-shore near Terrace Bay and their area is 36 km^2 (Couturier et al. 2021). The Slate Islands caribou population is a maintenance phenotype where most traits (body size, antlers, utters) are smaller than other populations' traits (Bergerud et al. 2007). Also, the phenotype's calves reach maturity later than others. Based on the mean lichen litter-fall on the Slate Islands, the winter carrying capacity was estimated by Bergerud et al. (2007) to be 109 caribou. The regular carrying capacity for the Slate Islands was estimated by Bergerud in 2001 as 450 caribou. Before wolves reached the Slate Islands during the historic record, caribou were bottom-up limited by summer foraging, and poor summers led to decreased health in winter and increased mortalities in late winter of that year. Snowshoe Hare (*Lepus americanus*, Erxleben) is a forage competitor that can reduce White Spruce (*Picea glauca* [Moench] Voss) sapling abundance, along with the presence of Butt Rot in White Spruce, suggests a decrease in available food resources for caribou on the Slate Islands (Bergerud et al. 2007).

An instance of anti-predator regulation in wolf and caribou population growth appears for LSC when the caribou population in Pukaskwa National Park (on the mainland) decreased and predation increased (Bergerud et al. 2014). Caribou in Pukaskwa National Park prefer the habitat located near the shore (1 km from the shore). Aerial surveys have shown more calf recruits and adult caribou are easily accounted for in years of no land-fast ice or years of extended periods of land-fast ice. Frequent Gray Wolf visits to the shoreline later created positive density dependence, an Allee effect usually associated with the extinction vortex. Caribou populations in British Columbia are heavily affected by direct wolf predation and the Allee effect at low densities (Wittmer et al. 2005). Positive density dependence in caribou because of wolf effects is likely the most impactful for the persistence of the Lake Superior Caribou.

PREDATORS

Caribou populations are easily stressed when wolf populations are nearby. In Northern Alberta, wolf movement was decreased within caribou habitat when their primary prey was Moose (Latham et al. 2013). Similar observations have been made in southern Quebec (Courbin et al. 2014). A large part of a wolf's summer diet consists of the North American Beaver (*Castor canadensis* Kuhl; Latham et al. 2013). Beaver and caribou occupancies can overlap, attracting wolves to prey on caribou more often than in the winter. Moose and beaver abundance have increased in Ontario over the last century, leading to prey enrichment for wolves. Increasing wolf abundance by means of increased primary prey leads to higher rates of incidental encounters with the secondary prey, caribou. The same patterns are seen when moose and elk (*Cervus elaphus* L.) populations increase (Bergerud et al. 2014). Disturbances such as forest operations have short-term negative effects on caribou populations. Within two decades of a disturbance, moose abundance in the area will increase and caribou abundance will decrease (Vors et al. 2007). Disturbance to the forest leading to earlier successional stages can have benefits for moose, which in turn increases nominal wolf predation on caribou, and a positive feedback cycle is created.

In Pukaskwa National Park, on the Lake Superior mainland, caribou will use land-fast ice to retreat to refuge islands from wolves (Bergerud et al. 2014). This use of ice bridges works both ways, as some years have large enough icing events to allow wolves to travel from the mainland to islands in search of caribou. The first pair of wolves that crossed over to the Slate Islands did so in the winter of 1993-1994 (Carr et al. 2012). A single wolf crossed to the Slate Islands in 2004 and another pair crossed in 2014; each of the pairs stayed one additional year and the third reported crossing led to the functional extirpation of caribou from the Slate Islands (Bergerud et al. 2020). It is noteworthy that the population viability analysis for caribou on the Slate Islands carried out by Shuter et al. (2009) did not account for wolf predation in modelling extinction probabilities.

PARASITES AND DISEASES

There have been no significant updates since the report by Gogan and Cochrane (1994) to the dynamics involved with parasites and diseases and the woodland caribou.

POPULATION DYNAMICS

The population of the Slate Islands was first reported around 1907 during winter, when there were sightings of the woodland caribou tracks traversing the lake ice (Bergerud 2001). It is hypothesized that logging activities and increased pressure from predators on the mainland coerced caribou to seek out refuge. The Slate Islands population fluctuated from 177 to a high of 485 from 1974-2000 (Bergerud et al. 2007; Couturier et al. 2021; Figure 1), although the King census counts likely included double-counts and are overestimates (Bergerud et al. 2020).

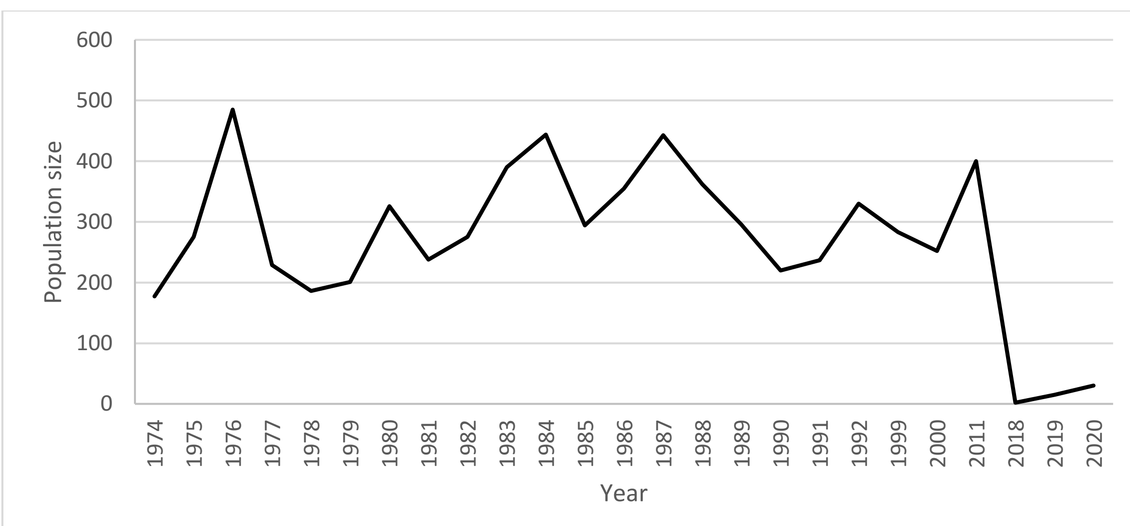


Figure 1. The Slate Islands historic woodland caribou population fluctuations.

It was in the 1980s when caribou were first tagged on the Slate Islands and observed on the mainland around Terrace Bay, 9 km from the islands (Eason 2011). In 1984, three caribou moved from the Slate Islands to Cape Victoria, and mating success occurred between the two populations. In 1985, five caribou traveled from the Slate Islands to Bowman Island and then to St. Ignace Island and neighbouring islands avoiding wolves. Caribou population growth was neutral throughout the first two occupancies of the Slate Islands Provincial Park (hereafter known as SIPP) by wolves (Bergerud et al. 2020). Only with the third occupancy of a pair of wolves did the population plummet (Bergerud et al. 2020). The population decline was also linked to caribou emigrating from SIPP around 2013-2014. In March of 2019, ice bridges existed between the mainland and SIPP (Couturier et al. 2021). It was estimated to be thick enough for ungulate travel although it was not confirmed.

Pukaskwa National Park grew from 15 to 31 caribou from 1972-1979 (Wade 1998). From 1980-1993 the population fluctuated between 14 and 27. From 1995-1997 it increased from six to 11 caribou. In 2003, there were nine caribou and in 2007 there were five caribou remaining (Bergerud et al. 2007). A March 2019 survey estimated that <20 caribou remained in all mainland North Shore populations (Couturier et al. 2021). The same survey estimated that <60 caribou remain in all the Lake Superior Caribou metapopulation.

RESTORATIONS AND TRANSLOCATIONS IN THE LAKE SUPERIOR REGION

The Slate Islands were used as a source to move caribou to other island populations and ranges. In 1982, eight caribou were moved from the Slates to

Michipicoten Island (Eason 2011). In 1984, seven caribou were moved to Montreal Island. One died during transfer, and one escaped to the mainland. One caribou shortly after the translocation traveled to Leach Island. In 1986, two caribou were moved from the Slates to Montreal Island. In 1986, three caribou were translocated to Leach Island. One caribou died in transfer. In 1989, 39 caribou were moved from Slate Islands Provincial Park to the Gargantua Peninsula in Lake Superior Provincial Park. Most remained on the mainland, while some moved to Devil's Warehouse Island. Three of the 39 died during the move and most died in the months following the translocation, likely due to poor body condition at the time (Eason, G., pers. comm.).

No translocations occurred in the period of 1990 to 2017. In January 2018, a translocation to the Slate Islands of nine caribou (eight females) from Michipicoten Island (Couturier et al. 2021). Later in 2018, three adult males and four calves were seen on an extended remote camera array. The 2018 translocation seemed to keep the population alive; all the females were observed alive and about six calves were seen interspersed. Bergerud et al. (2020) estimated the population to be extirpated by 2018 and it was functionally extinct before this time, with only two to four males observed on remote cameras (Couturier et al. 2021). Arthur Bergerud's prediction would have been reality if not for the translocation in 2018 leading to an estimated 15-23 caribou in 2021. Racey and Armstrong (2000) suggested landscape-level management because population management has not resulted in long-term success for woodland caribou.

METAPOPULATIONS

A metapopulation is a number of populations represented by spatial patches and associated with each other by migration (Hanski 1998). Immigration and emigration increase and decrease population size and extinction risk, respectively. Regional stochasticity like extreme weather conditions can decrease connectivity in a metapopulation. Mortality during migration has a higher rate than within the habitat patches of a metapopulation. Individuals can still be observed within habitats that have deteriorated passed the holding threshold; this can give managers a false sense of security and compromise time that would be needed for recovery of a habitat patch. The species could be undetectably declining from a quick glance. The main goal of conservation is to preserve habitat area. The Slate Islands PVA can be used to identify key locations and migration routes to protect, for the success of the metapopulation. There is a general rule for continued survival of an at risk metapopulation that 15-20 habitat patches or fragments should be present for long-term persistence. Populations that are isolated existing in habitat fragments are not predicted to be long-term so to include their long-term existence it must be within a metapopulation.

METHODS

The most recent caribou sightings by people and scientific studies were considered as the initial population abundances (Table 1). These data were collated by Jordan Kelley (Masters Student of Environmental and Energy Policy at Michigan Technological University), and Nancy Langston (Professor of Environmental History at Michigan Technological University). The largest populations today are in the Slate Islands, Pic Island, Caribou Island, and in Pukaskwa National Park (hereafter known as PNP). Inputs such as dispersal followed an assumption that more caribou would leave a larger population than a smaller one and more often. Michipicoten Island was estimated to have less mortality and greater success because of the different vegetative landscape it has compared to Pic Island, PNP, and Caribou Island, which are more similar to SIPP.

Table 1. Initial population estimates and sources.

Population	Initial abundance	Source
Slate Islands	32	Couturier et al. 2021
Pic Island	20	Bergerud et al. 1984
Pukaskwa National Park	5	Bergerud et al. 2007
Michipicoten Island	0	Brent Patterson (Brian McLaren, Gordon Eason, pers. comm.)
Caribou Island	20	2021 camera traps

Vital rates from published works on woodland caribou populations on SIPP and PNP (see Literature Review) were entered into the program Vortex 10 (Appendix 2). Pic Island, Caribou Island and PNP population parameters were assumed to mirror the estimates from SIPP. Genetic input was not used in the modelling process. Wolf occurrence was modeled by random, singular events (a 6% chance annually) that negatively affected reproductive success and survival rate. Separate random, singular events of land-fast ice bridges occurring (a 5% chance annually) increased survival rate as a reflection of overall positive outcomes of dispersal in a metapopulation (although these events were entered in Vortex10 under the heading “Catastrophes”). The number of iterations chosen to allow for a consistent average was 1000, as suggested by Shuter et al. (2009). Over 1000 iterations the population forecasts do not fluctuate and become consistent. For most runs, the metapopulation was projected for 50 years.

RESULTS

The population viability of the Slate Islands caribou follows the same trend described by Shuter et al. (2009) when run with the same parameters and without wolves (Figure 2.1). The highest population average estimate at 50 years is 14. Although, the average extant population by year 50 still had 28 caribou remaining. The probability of caribou surviving for 50 years is 49.3%. On average most runs became extinct at approximately 30 years. With wolves, a faster decline occurs (Figure 2.2). Including wolf catastrophes decreased caribou abundance by 14% of the population and decreased survivability by 7.3%. The final average population structure of extant iterations were 10 males and 14 females totaling 24 caribou.

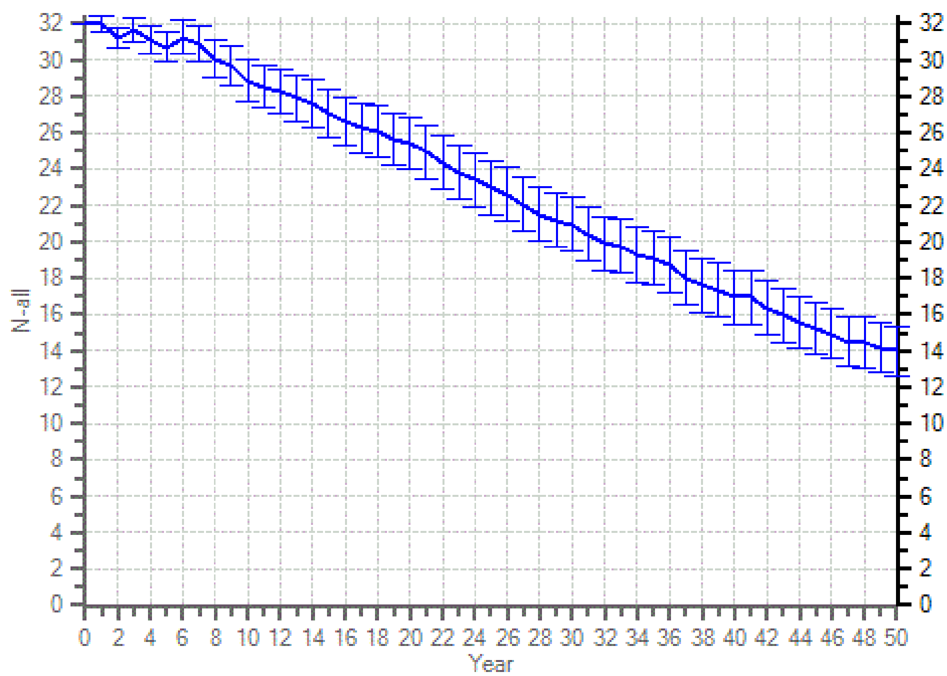


Figure 2.1. The average abundance of the Slate Islands Provincial Park caribou with no wolf occurrences.

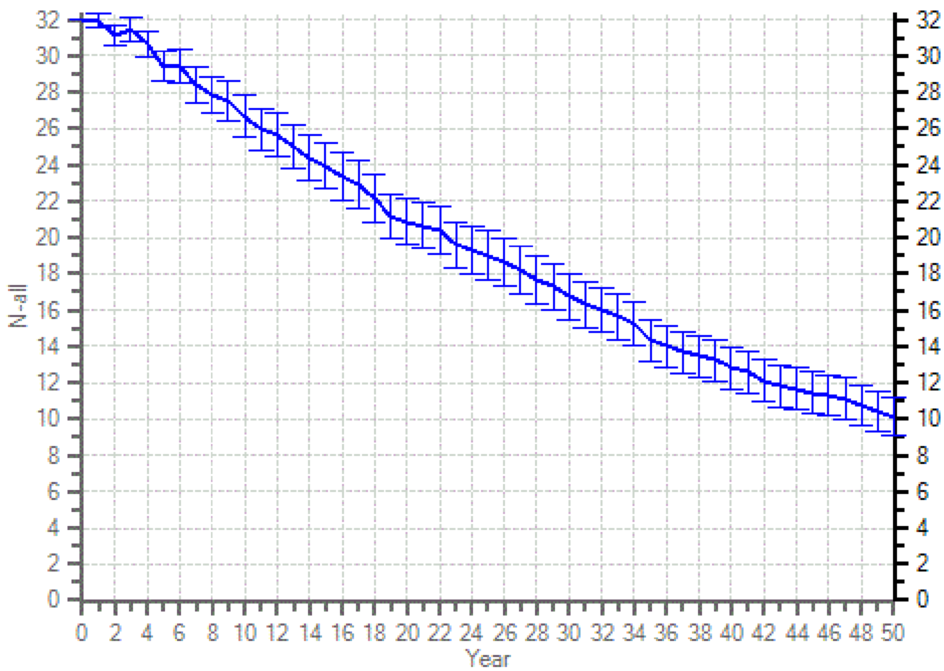


Figure 2.2. The average abundance of the Slate Islands Provincial Park caribou with wolf occurrences.

The addition of other populations creates an interesting metapopulation dynamic that not only allows for more stability but adds a chance of mortality to dispersing individuals. In the metapopulation projection represented by Figures 3.1 and 3.2, the Slate Islands (SIPP) caribou abundance and survival probability is much lower than when modeled by itself. Without active translocations, the SIPP population is near extinction at 40 years averaging just three caribou at 50 years. Populations on Pic Island, PNP, and Caribou Island follow the same declining trend, reaching an average of two caribou each around year 30. Michipicoten Island begins seeing increasing numbers of caribou from dispersal by year 20 with an average of five Caribou immigrating. After year 26, Michipicoten Island becomes the majority of the metapopulation. Many of the other populations become sustained and reliant in many of the projections on

Michipicoten Island's emigrants. Pic Island, PNP, and Caribou Island were on average recolonized after going extinct in six years, three years, and 11 years, respectively. Caribou Island has the lowest survival probability out of all the populations and all populations by year 28 have less than a 50% chance of surviving.

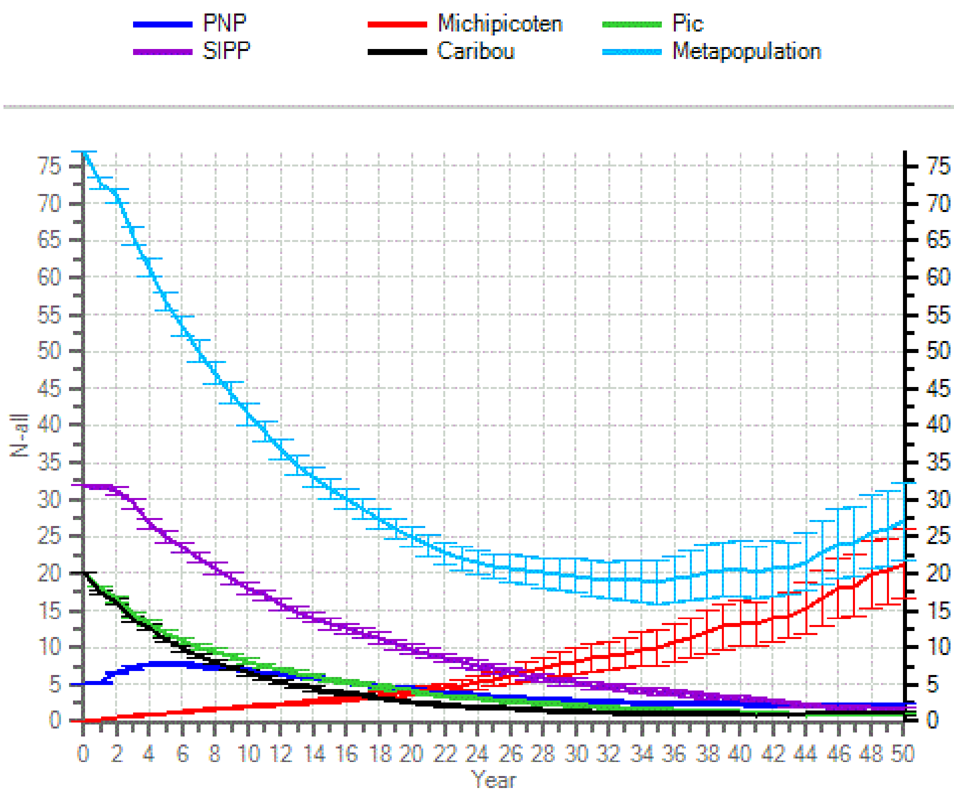


Figure 3.1. Average abundance of the LSC metapopulation. No translocation occurs.

With translocations from Caribou Island, the probability of success for SIPP caribou is 30% out of the 1000 iterations modeled (Figures 4.1, 4.2). On average the SIPP population goes extinct 25 years into the projection. It takes six years to be recolonized, and 25% of the recolonized SIPP iterations survive to year 50. The population structure in only extant populations by year 50 is five male and six female caribou. Caribou Island populations usually survived to year 11, but only 4% were extant at year 50. Populations that did survive had a structure of nine males and five females.

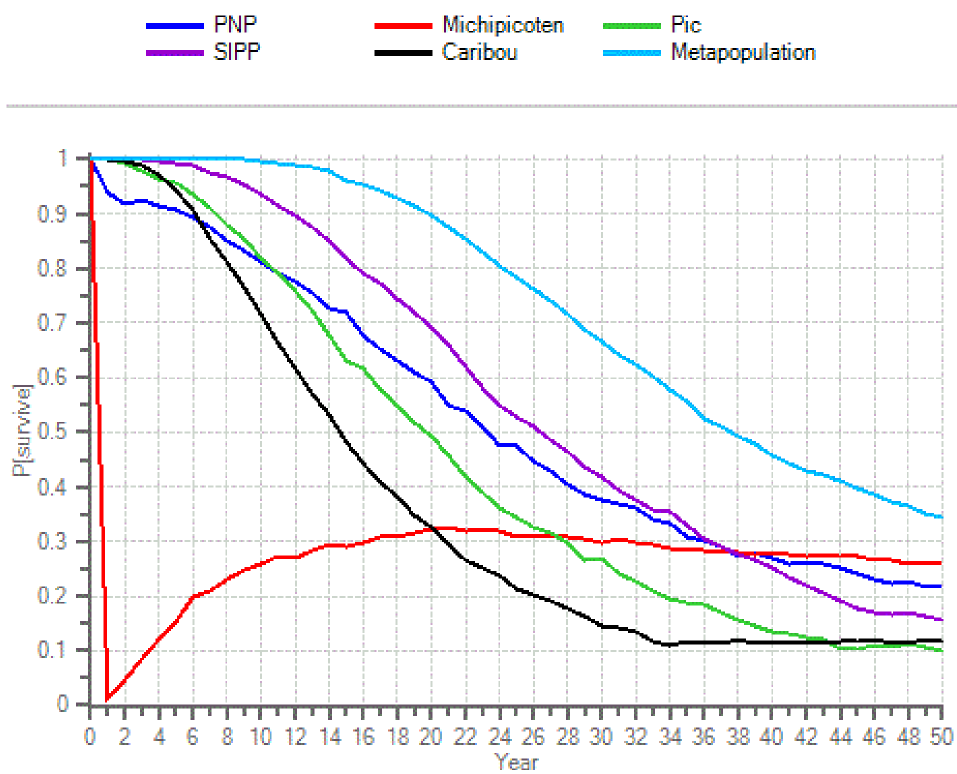


Figure 3.2. Average survival probability of the LSC metapopulation. No translocation occurs.

This metapopulation has a 62% probability of success. Iterations of the metapopulation that went extinct usually did so at year 32. Extant metapopulation structure consisted of 101 male and 94 female caribou. The growth rate of the average metapopulation in years without supplementation was -0.0175 (0.0012 SE, 0.2339 SD). When Caribou Island is the source of translocations, its caribou population had lower than a 50% chance of survival at year nine. Michipicoten Island's caribou survival probability can be described with initial steep declines, but a leveling out with every two-year interval of translocation; this population never has less than 50% survival over 50 years.

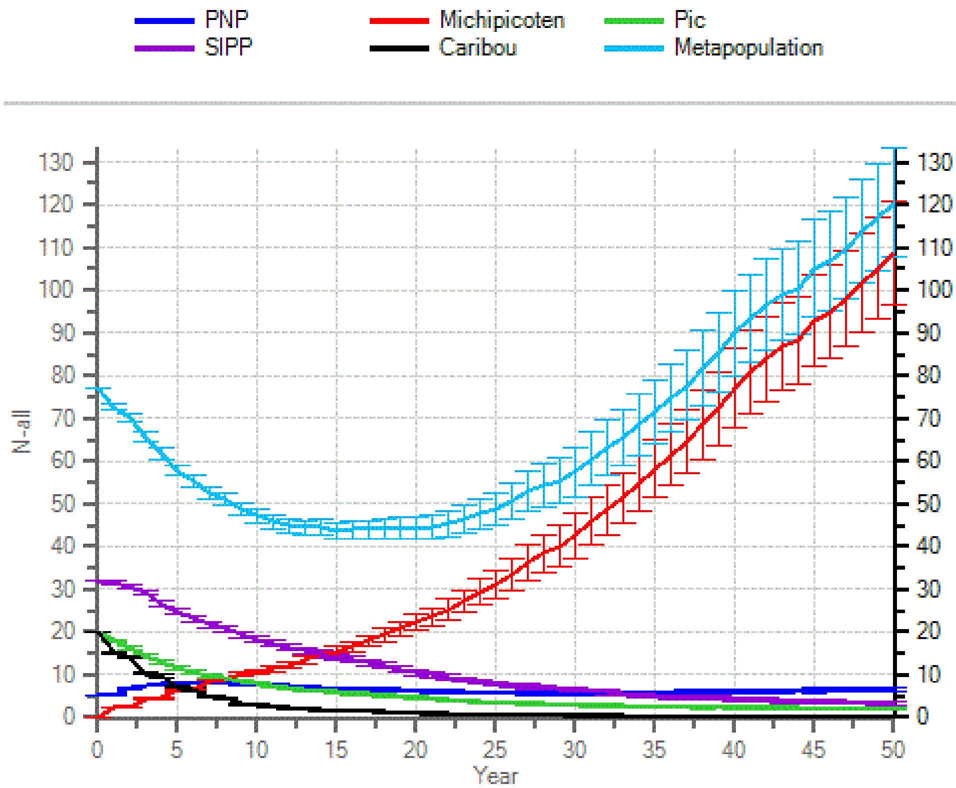


Figure 4.1. The average abundance of the LSC metapopulation. Translocations source population is Caribou Island, and the recipient population is Michipicoten Island.

When the source population for translocations is SIPP, initially to Michipicoten Island, the model predictions become more optimistic (Figures 5.1, 5.2). SIPP in this scenario has a 35% probability of success over the 50 years and the average time to go extinct is 20 years. Recolonization takes eight years after extinction and 17% of recolonizations are extant populations at year 50. The SIPP extant population structure by year 50 is five male and five female caribou. Caribou Island with relief of translocations sees most model runs survive to year 17. Although Caribou Island has a later extinction year, the probability of populations to be extant is lowered at 2% compared to when it is the source for translocations.

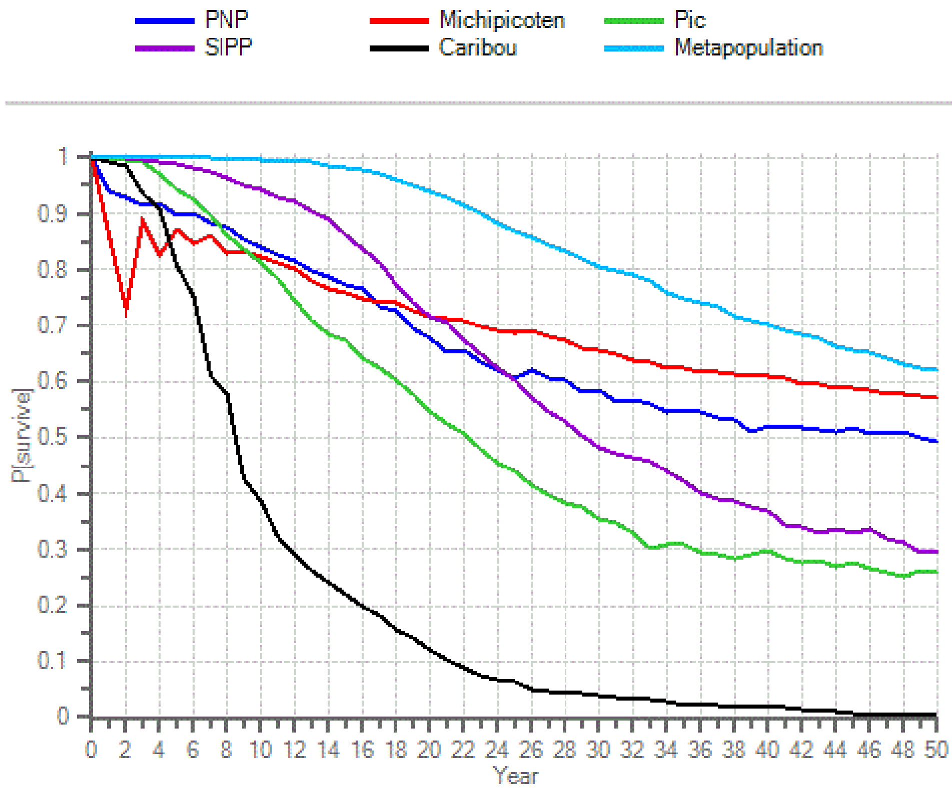


Figure 4.2. Average survival probability of the LSC metapopulation. Translocations source population is Caribou Island, and the recipient population is Michipicoten Island.

The extant population structure of Caribou Island caribou is three male and three female caribou. Pic Island and PNP populations usually survive to year 17 and year 13, respectively. Comparing source populations, the metapopulation is modelled as increasing from initial conditions of 120 (Caribou Island as source, Figure 4.1) to about 180 (SIPP as source, Figure 5.1). In the SIPP source population scenario, the metapopulation has a 71% probability of success to year 50 (Figure 5.2). The metapopulation extant structure is 131 male and 122 female caribou. In years without translocation, the growth rate is -0.0020 (0.0012 SE, 0.2375 SD).

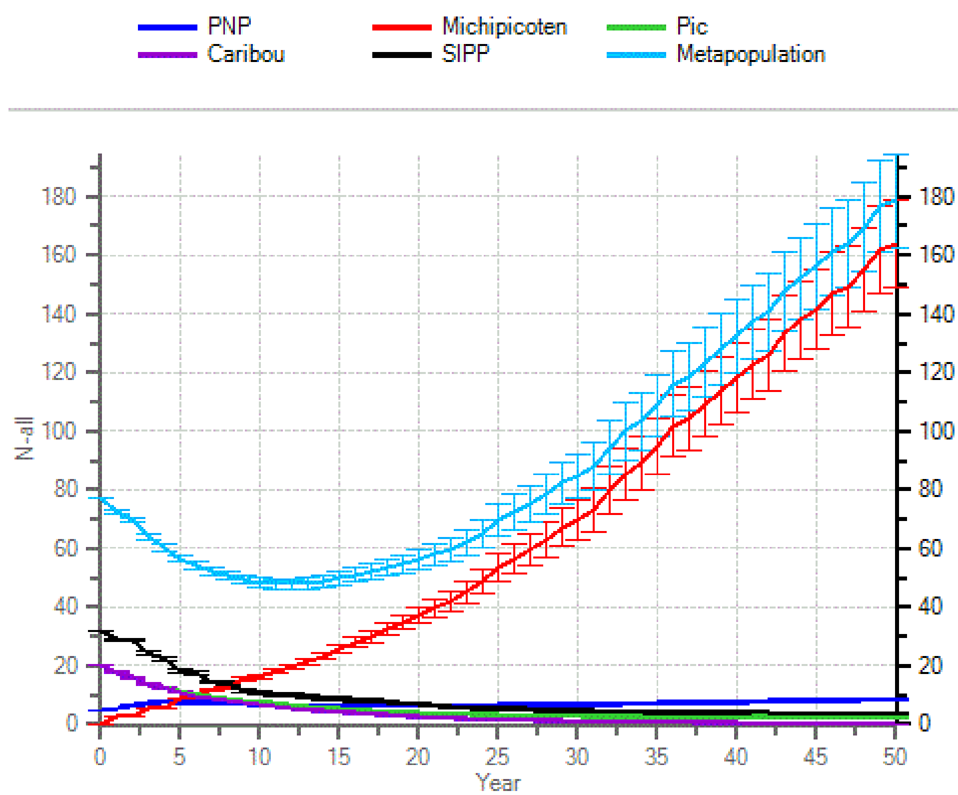


Figure 5.1. The average abundance of the LSC metapopulation. Translocations source population is SIPP, and the recipient population is Michipicoten Island.

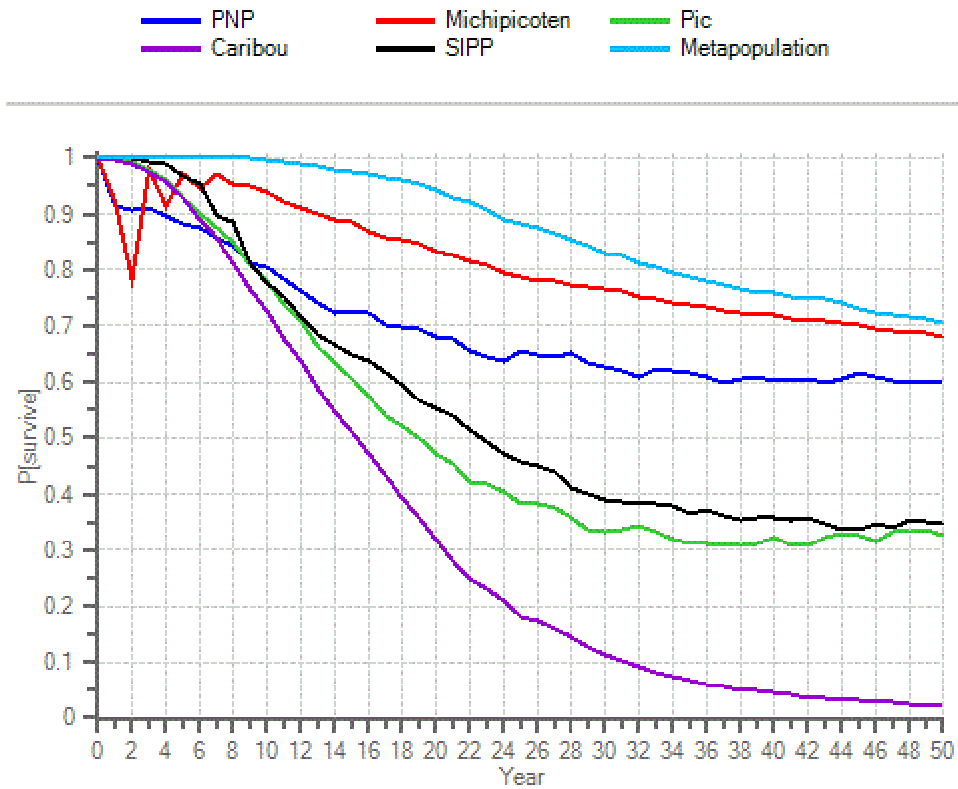


Figure 5.2. Average survival probability of the LSC metapopulation. Translocations source population is Slate Islands Provincial Park (SIPP), and the recipient population is Michipicoten Island.

DISCUSSION

The importance of the SIPP caribou population and translocations to Michipicoten Island for the longevity of woodland caribou in the Lake Superior metapopulation is described in this thesis by use of PVA. The Slate Islands population might be able to survive past 50 years on its own, but many iterations go extinct before 30 years. While the results in this paper parallel Shuter et al.'s (2009) findings, the results of average year of extinction is extended by 10 years. The result is likely due to the larger carrying capacity. Using these carrying capacities was decided on because of the historical population abundances of the Slate Islands and Michipicoten Island. The Slate Islands was predicted to become limited around 109 caribou but this caribou population has been estimated greater than 400, multiple times from 1974 to 1990 (Bergerud et al. 2007). Michipicoten Island caribou abundance was estimated to be at 680 in 2011 without wolf pressure (Patterson 2017). Therefore to better represent natural ranges of carrying capacities the inputs were doubled.

Wolf presence was not accurately represented in the models. The historical impact that two healthy wolves have had within two years of arriving on the Slate Islands was massive (Bergerud et al. 2020). The population exhibited negative growth rates and became functionally extinct (only one gender in the remaining population). Vortex 10 was able to show indirect effects on reproduction and survival rates but not to the level that has occurred on the islands. In future models, more liberty needs to be used when addressing predation with minimal literature resources.

Historically, SIPP and Michipicoten Island's woodland caribou populations have not been able to withstand predation on their refuge islands (Bergerud et al. 2020;

Patterson 2017). Now knowing these are the two populations that have the best probability of creating a stable metapopulation they should be managed and conserved as such. The Slate Islands translocation to Michipicoten Island is the best management option result in this thesis; however, keeping all populations in a metapopulation extant and healthy takes precedence (Hanski 1998). Shown in the different source populations, when the Slate Islands is the source of tranlocations to Michipicoten Island, the Slate Islands and Caribou Island are close to surviving until year 20. Using Caribou Island as the source, its population's survivability decreases heavily while the Slate Islands' population life decreases from the 25th to the 20th year. The management of the Lake Superior caribou metapopulation should reflect the best practices to recover the metapopulation. Hanski's (1998) principles guide metapopulation management towards conserving every population involved at a sustainable level. Caribou Island is the closest to its carrying capacity so the first translocation might prefer to be a one time move with around eight caribou. After the population on Caribou Island receives some relief, my management suggestion is to translocate three tagged caribou using this thesis' translocation details from the Slate Islands to the recipient population of Michipicoten Island. These two management steps should start the process of growing the metapopulation to a self-sustainable level.

Preservation of the dwindling caribou range is very important. Modelling with Vortex10 shows that with careful management, woodland caribou in the Lake Superior metapopulation can be restored. Island woodland caribou of Lake Superior have characteristics with potential to offer mainland populations when necessary. Although genetics was not an input, population literature fears any loss of genes in a declining species and so every individual lost is a big stress to the system; it is the same with each population comprising a metapopulation.

CONCLUSION

The history of wolf arrivals on islands housing caribou populations in the Lake Superior region in the past, when presumably wolf predation had less influence on caribou dynamics, shows the significance of a modelling exercise that identifies when land-fast ice tips the balance between predator and prey. Within a couple of years, a predator can decimate a healthy prey population in an insular ecosystem. Dispersal to refuge islands and migration between populations in a metapopulation can benefit reproductive rates and survival. The threat of exceeding carrying capacity in any one population decreases if prey is able to emigrate to other populations. Recolonization of extinct populations through dispersal is the only hope of the no-management choice for the Lake Superior caribou. The decision to restore caribou by active management, starting with translocations, is likely the right one. The more populations within a metapopulation the lesser its chances of extinction.

What has happened with the Slate Islands caribou population in the recent past, wolf arrival, and functional extirpation (only one sex is extant) should be considered in future management. With small populations and a looming threat of unpredictable wolf arrival, actions and discussions about ‘how and what’ Lake Superior caribou management need to take place. Discussions about ‘why and when’ are now in the past.

LITERATURE CITED

Antoniak, K. and Cumming, H. 1998. Analysis of forest stands used by wintering Woodland Caribou in Ontario. Rangifer, Special Issue, 10:157-168.

Bergerud, A.T. 2001. Herbivores of the Slate Islands, 1974-2001. Unpublished report.

Bergerud, A.T., Dalton, W., Butler, H., Camps, L. and Ferguson, R. 2007. Woodland Caribou persistence and extirpation in relic populations on Lake Superior. Rangifer, Special Issue, 17:57-78.

Bergerud, A.T., McLaren, B., Dalton, W., Camps, L., Butler, H. and Ferguson, R. 2020. Changes among Caribou (*Rangifer tarandus*) in Slate Islands Provincial Park following successive arrivals of Gray Wolves (*Canis lupus*). Canadian Field-Naturalist, 134:4.

Bergerud, A.T., McLaren, B., Krysl, L., Wade, K. and Wyett, W. 2014. Losing the predator-prey space race leads to extirpation of Woodland Caribou from Pukaskwa National Park. EcoScience, 21:3-4.

Carr, N., Rodgers, A., Kingston, S., Hettinga, P., Thompson, L., Renton, J. and Wilson, P. 2012. Comparative Woodland Caribou population surveys in Slate Islands Provincial Park, Ontario. The 13th North American Caribou Workshop. Rangifer, Special Issue, 20:205-217.

Carter, J. 2004. Island of the yellow sands, Caribou Island. Lake Superior Magazine, 59:24-32.

Courbin, N., D. Fortin, C. Dussault, and R. Courtois. 2014. Logging-induced changes in habitat network connectivity shape behavioral interactions in the wolf—Caribou—moose system. Ecological Monographs, 84(2):265-285.

Couturier, S., Eason, G., Pellegrini, M., Schroeder, C., and McLaren, B. 2021. Status of the Lake Superior caribou populations: Results of two aerial surveys of the north shore region, March 2019 and February 2021. Report published by the *Michipicoten First Nation,* Wawa, Ontario. *47 pp.*

Drake, C., Manseau, M., Klutsch, C., Priadka, P., Wilson, P., Kingston, S. and Carr, N. 2018. Does connectivity exist for remnant boreal Caribou (*Rangifer tarandus* caribou) along the Lake Superior Coastal Range? Options for landscape restoration. Rangifer, 38:1.

Eason, G. 2011. Caribou introductions-Wawa District. Implications for Caribou restoration in Lake Superior area. Ontario Ministry of Natural Resources, Wawa. Unpublished report.

Environment and Climate Change Canada (ECCC). 2017. Report on the Progress of Recovery Strategy Implementation for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal population, in Canada for the Period 2012-2017. Ottawa, ON. ix + 94 pp.

Ferguson, S.H., Bergerud, A.T. and Ferguson, R. 1988. Predation risk and habitat selection in the persistence of a remnant caribou population.

Gogan, P.J.P. and Cochrane, J.F. 1994. Restoration of Woodland Caribou to the Lake Superior Region. U.S. National Park Service Publications and Papers. 11.

Gonzales, E., Nantel, P., Rodgers, A., Allen, M. and Drake, C. 2015. Decision-support model to explore the feasibility of using translocation to restore a woodland caribou population in Pukaskwa National Park, Canada. Rangifer, 35. Special Issue, 23: 27-48

Hanski, I. 1998. Metapopulation dynamics. Nature 396, 41–49.

Latham, D., Latham, Cecilia., Knopff, Kyle., Hebblewhite, M. and Boutin, S. 2013. Wolves, white-tailed deer, and beaver: implications of seasonal prey switching for Woodland Caribou. Ecography, 36:1276-1290.

McClinchey, J. 2018. Is ruggedness a key habitat feature for Woodland Caribou along the Lake Superior Coast? Faculty of Natural Resources Management, Lakehead University. Undergraduate Thesis.

Patterson, B. 2017. ADM briefing. Power point presentation.

Racey, G. and Armstrong, T. 2000. Woodland Caribou range occupancy in Northwestern Ontario: past and present. Rangifer, Special Issue, 12:173-184.

Shuter, J., Kingston, S., and Lipsett-Moore, G. 2009. Slate Islands Provincial Park. Ontario Parks. Detailed Life Science Report.

Shuter, J., Asselin, N. C. and Rodgers, A. 2016. Results of the 2016 Lake Superior Coast Range (LSCR) caribou (*Rangifer tarandus caribou*) aerial survey. Ontario Ministry of Natural Resources and Forestry and Parks Canada, Thunder Bay, ON.

Vors, L., Schaefer, J., Pond, B., Rodgers, A. and Patterson, B. 2007. Woodland Caribou extirpation and anthropogenic landscape disturbance in Ontario. Journal of Wildlife Management, 71(4):1249-1256.

Vos, A. 1964. Range changes of mammals in the Great Lakes Region. American Midland Naturalist, 71(1):210-231.

Wade, K. 1998. Historical and present status of Woodland Caribou (*Rangifer tarandus*) in Pukaskwa National Park, Ontario and implications for metapopulation management, a review. Unpublished report. Parks and Protected Areas Research in Ontario. Pukaskwa National Park.

Weir, J., Mahoney, S., McLaren, B. and Ferguson, S. 2007. Effects of mine development on Woodland Caribou *Rangifer tarandus* distribution. Wildlife Biology, 13:66-74.

Wittmer, H., Sinclair, A. and McLellan, B. 2005. The role of predation in the decline and extirpation of Woodland Caribou. Oecologia, 144:257-267.

APPENDICES

Appendix 1

Different iterations

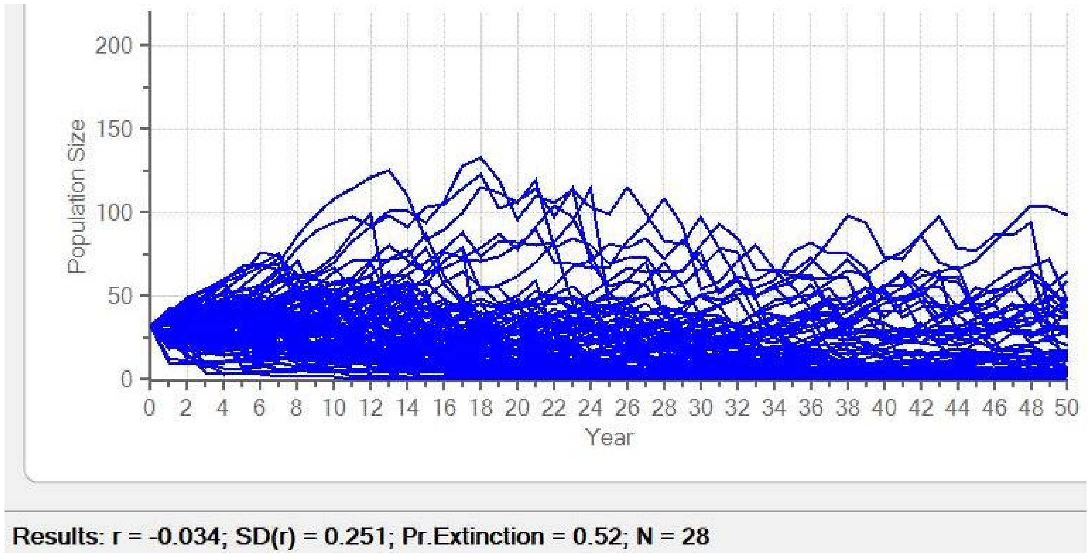


Figure 6.1. 100 iterations of the SIPP caribou population with no wolf occurrences.

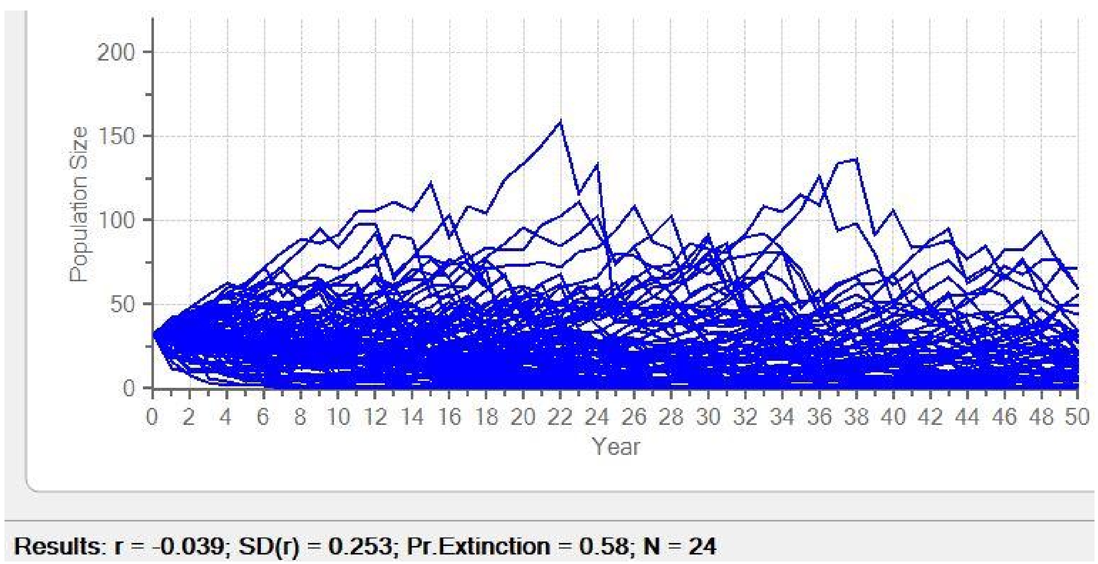


Figure 6.2. 100 iterations of the SIPP caribou population with wolf occurrences.

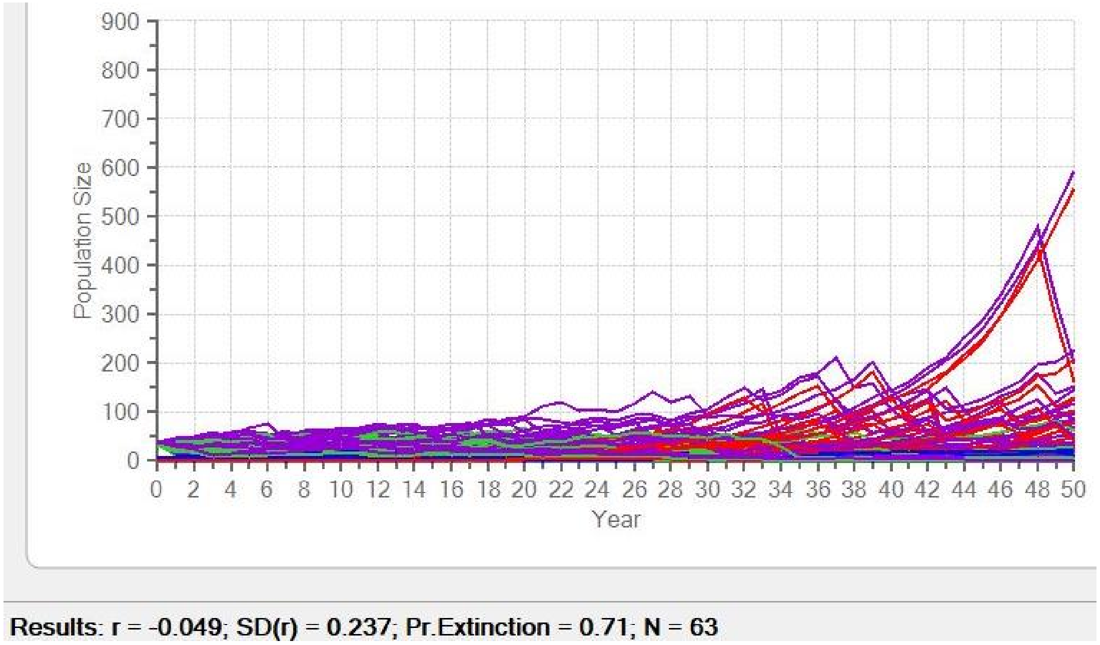


Figure 7. 100 iterations of a caribou metapopulation comprised of SIPP, PNP and Michipicoten Island. Wolves have a chance of occurring.

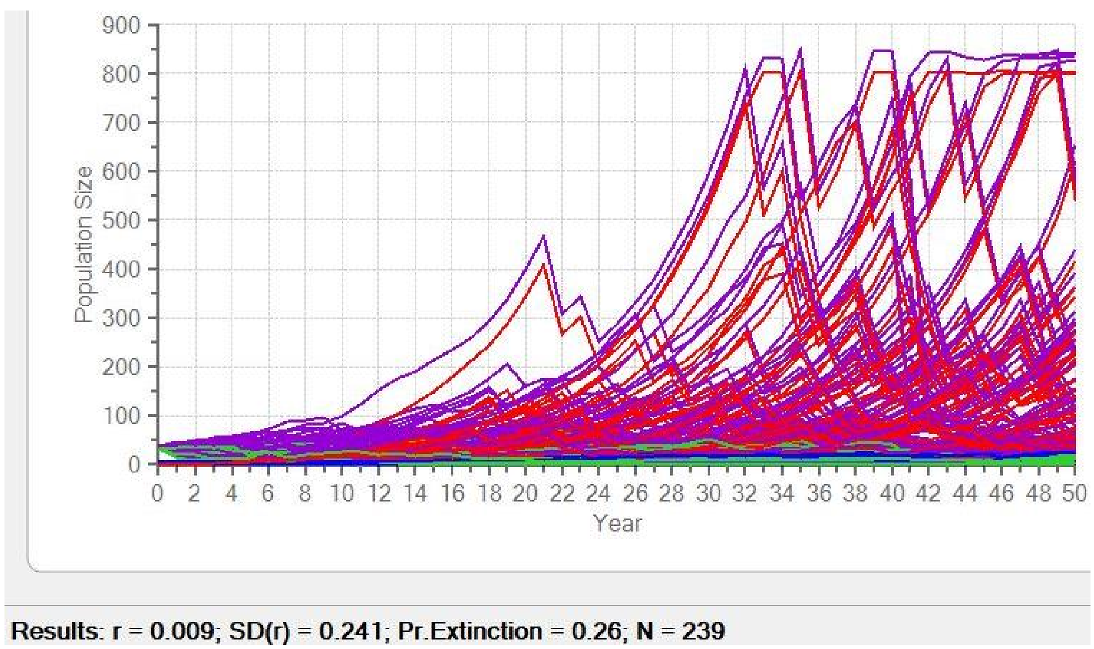


Figure 8. 100 iterations of a caribou metapopulation comprised of SIPP, PNP and Michipicoten Island. Wolves have a chance of occurring. Translocations of two female caribou two to three years old and one male caribou 3+ years old from year five to ten every two years. Source population is the SIPP and recipient population is Michipicoten Island.

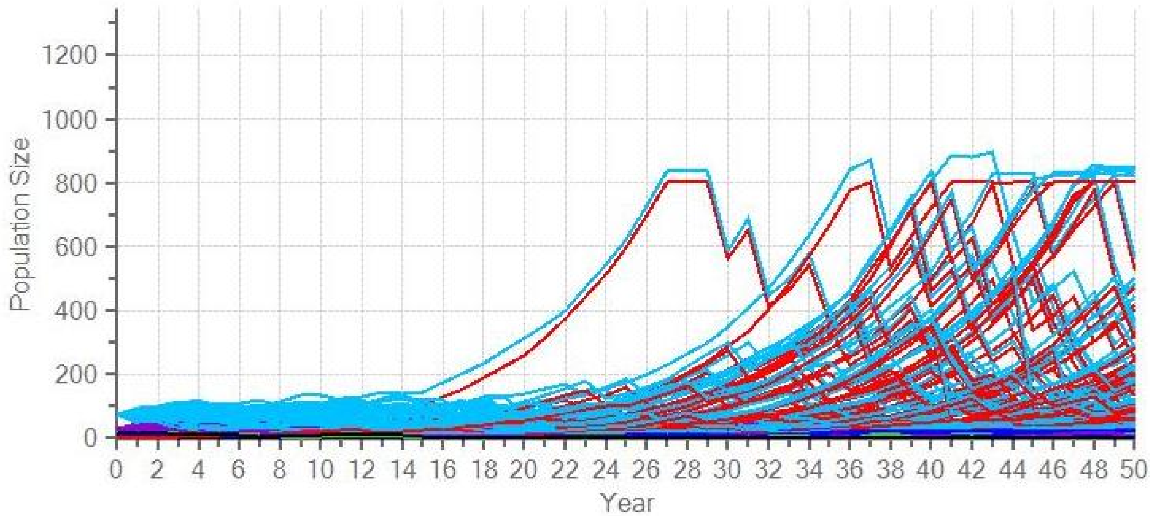


Figure 9. 100 iterations of a caribou metapopulation comprised of SIPP, PNP, Michipicoten Island, Pic Island and Caribou Island. Wolves have a chance of occurring. Translocations of two female caribou two to three years old and one male caribou 3+ years old from year five to ten every two years. Source population is the SIPP and recipient population is Michipicoten Island.

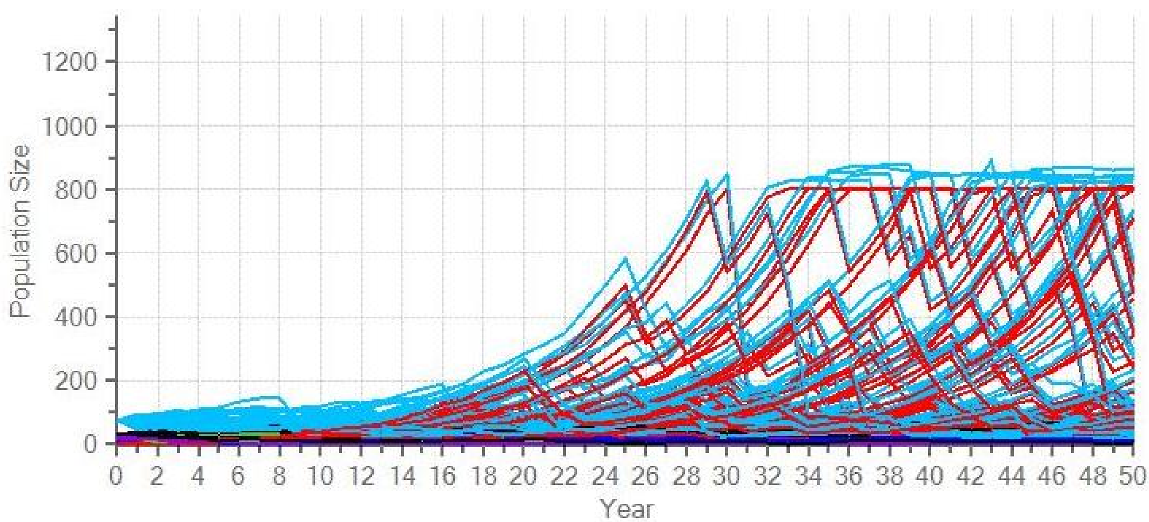


Figure 10. 100 iterations of a caribou metapopulation comprised of SIPP, PNP and Michipicoten Island. Wolves have a chance of occurring. Translocations of 2 female caribou two to three years old and one male caribou 3+ years old from year five to ten every two years. Source population is the Caribou Island and recipient population is Michipicoten Island.

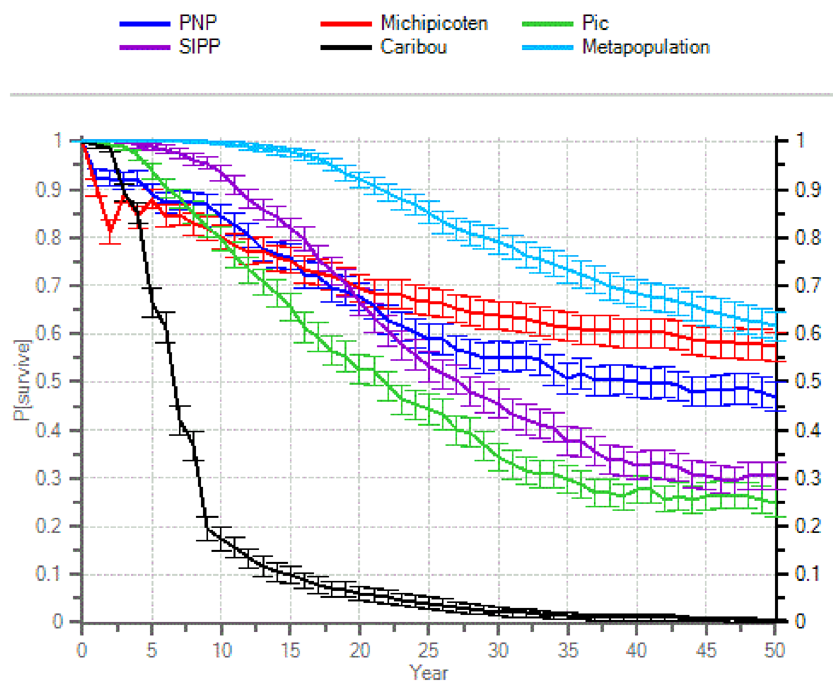


Figure 11. Translocation details include two males and two females every two years for 10 years from Caribou Island.

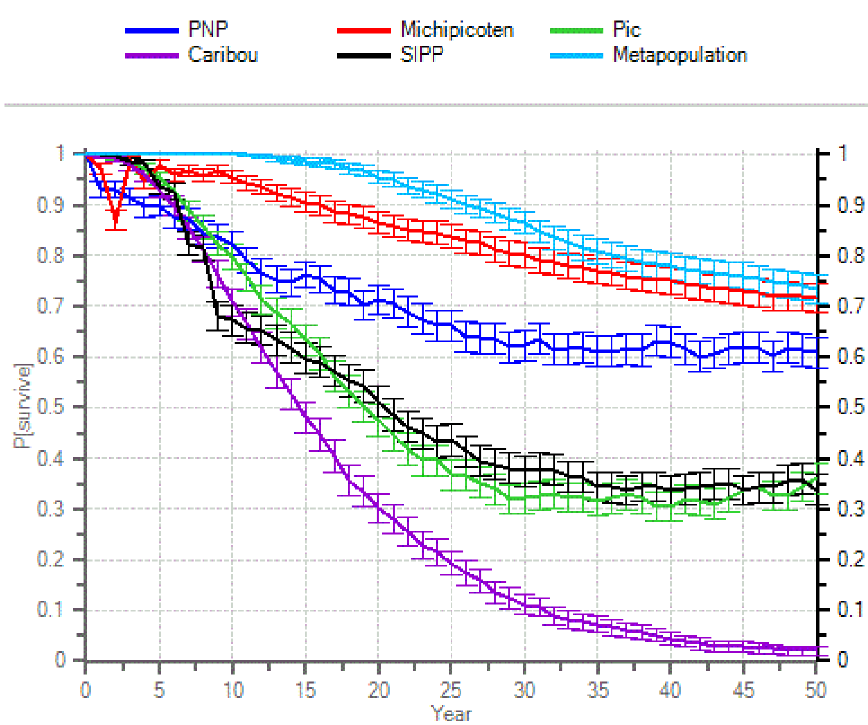


Figure 12. Translocation details include two males and two females every two years for 10 years from SIPP.

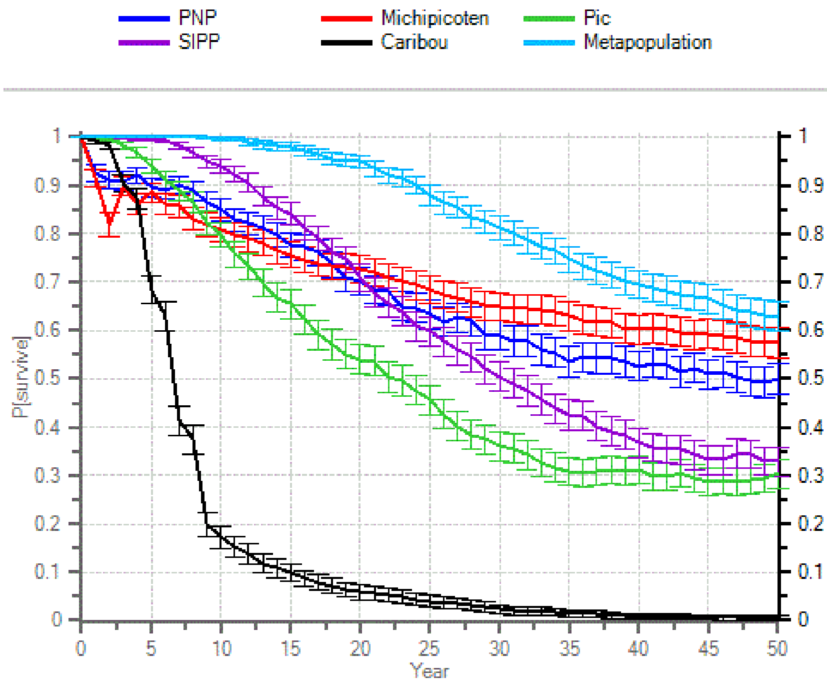


Figure 13. Translocation details include two males and four females every two years for 10 years from Caribou Island.

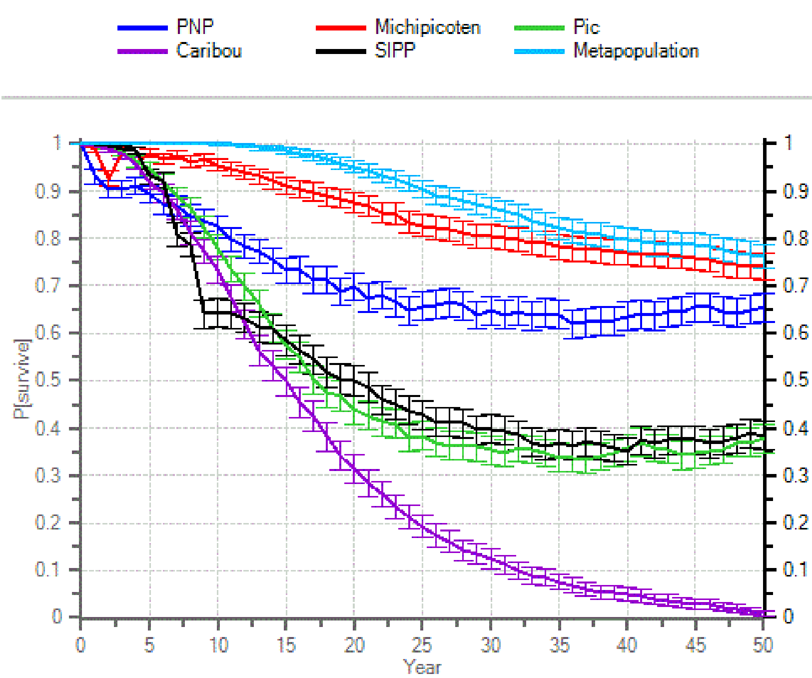


Figure 14. Translocation details include two males and four females every two years for 10 years from SIPP.

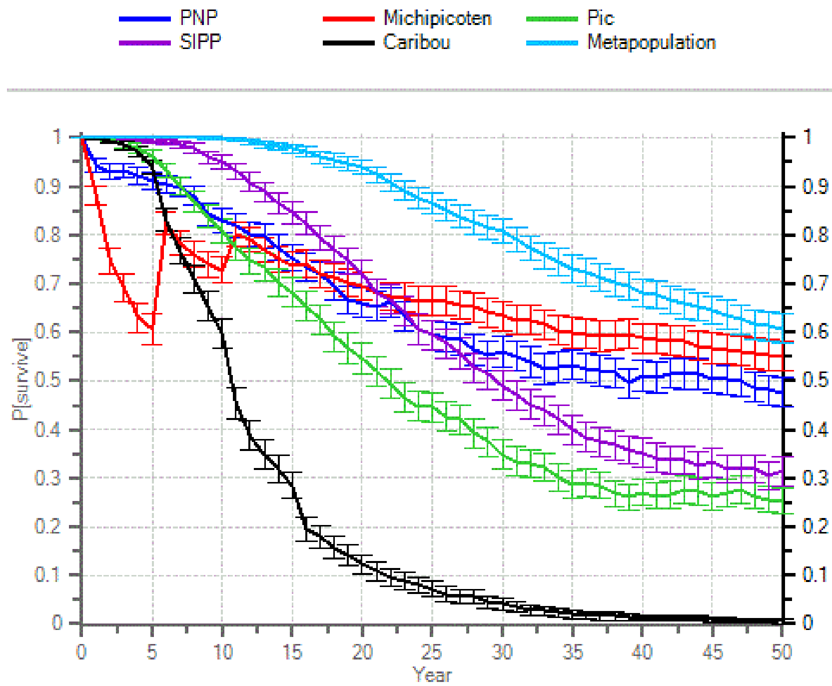


Figure 15. Translocation details include one male and two females every five years for 20 years from Caribou Island

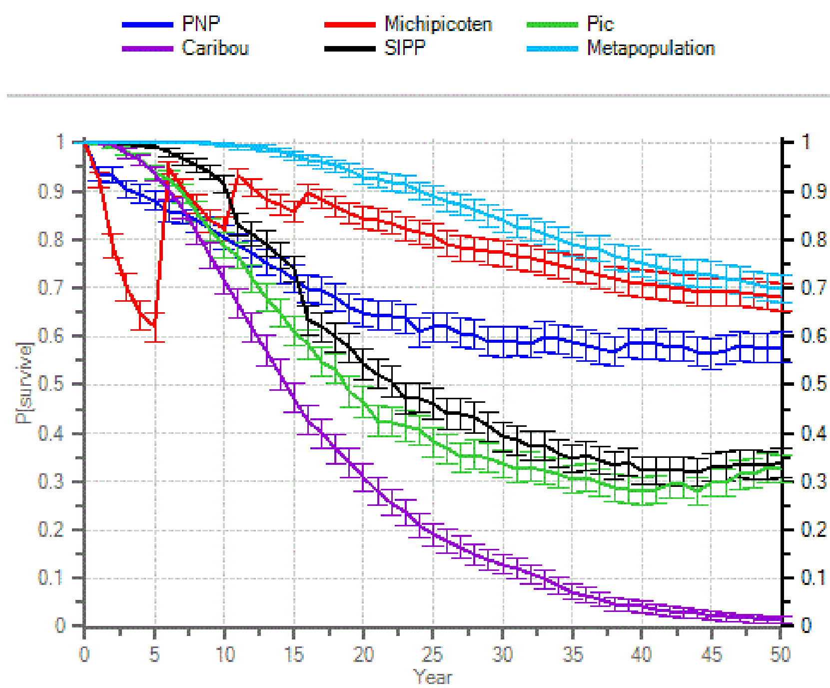


Figure 16. Translocation details include one male and two females every five years for 20 years from SIPP.

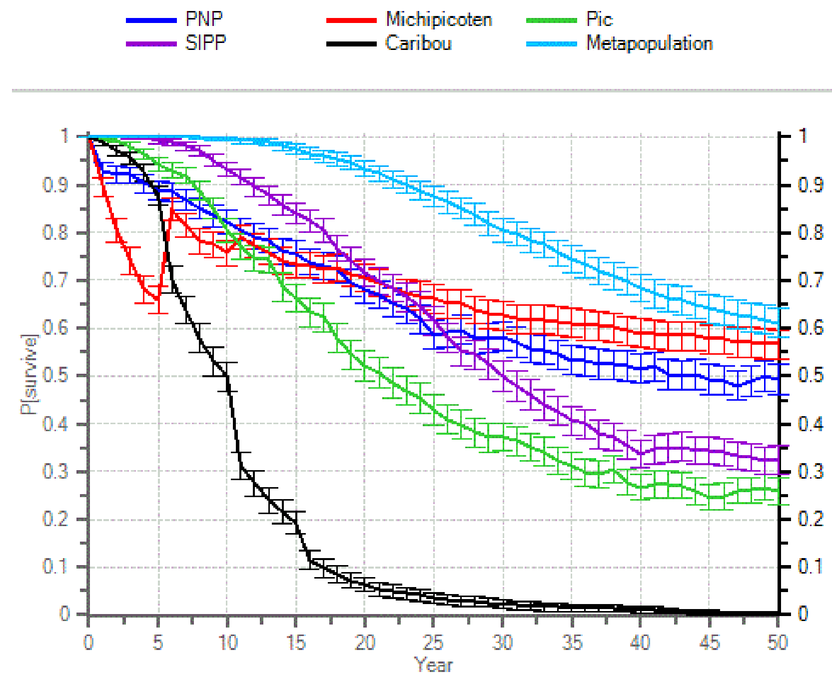


Figure 17. Translocation details include two males and four females every five years for 20 years from Caribou Island.

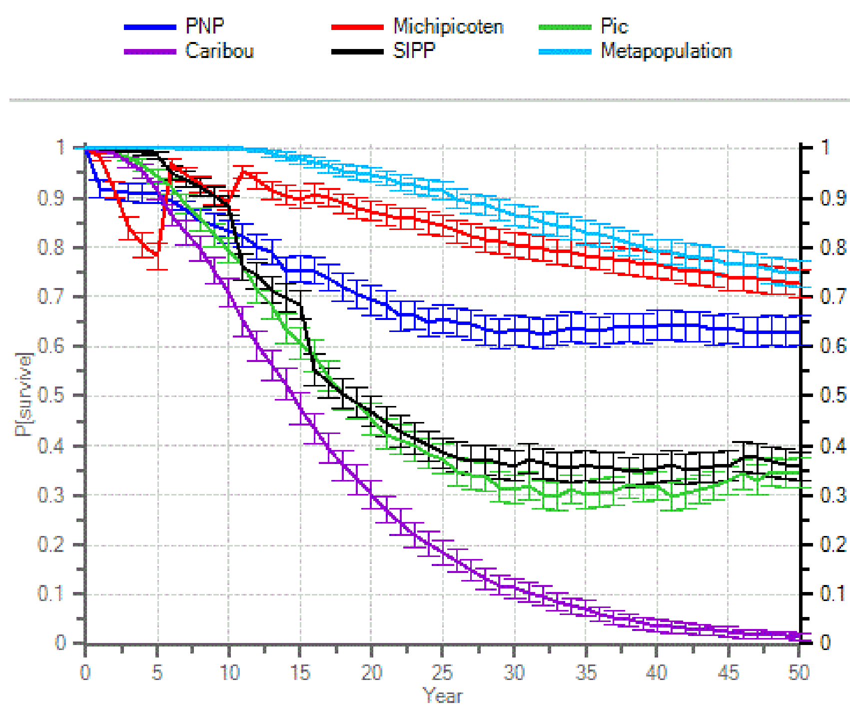


Figure 18. Translocation details include two males and four females every five years for 20 years from SIPP.

Appendix 2

PVA Inputs

Parameters	My Value's	Source
simulated iterations	1000	shuter suggestion
simulated years	50	good time period-Gord Eason
Duration of year	365	-
Define extinction	single sex	don't have critical population size data
Number of populations	5	Metapopulation
inbreeding depression	yes	small populations
# lethal equivalents	3.14	ralls et al 1988
% genetic load to lethals	50	ralls et al 1988/default
EV correlation between reproduction+survival/ amoung populations	0.5	Bergerud 2001
Age of dispersing classes	2-16	assumed only class not dispersing would be yearlings
Dispersing Sexes	both	-
% survival of dispersers	95	default

Dispersal (row=source, column= receiver)	Pukaskwa	Michipicoten	Pic	SIPP	Caribou	
Pukaskwa		3	5	5	0	thinking about it as dispersal would be begin to be likely
Michipicoten	3		0	0	1	once a herd is greater than 10. 5% of 20 is one animal dispersing.
Pic	5	0		1.5	0	pic island starts with 20
SIPP	5	0	1.5		0	
Caribou	0	1	0	0		

# catastrophes	2	-			
% probabiltiy catastrophe (Wolves & Ice no wolves)	6,5	Bergerud 2020 (5%)			
effects on Reproduction and Survival	(0.96,0.9&1,1.2)				
% females breed @ k	-	-			
% males sire offspring over breeding cycle	25				
% males in breeding pool	100	-			
intial pop	ipicoten-0, Pic island-20, SIPP-32, Caribou-14				
stable age distribution?	yes				
K	ibou-30, Michipicoten-800, Pic-3	Bergerud 2014, Couturier 2021, CCP meetings			
Trend Projected in k	-	-			
population harvest	-	-			
population supplementation	1 males, 2 females	-			
% Survival upon release	99	-			
Genetics	-	-			

Reproduction type	polygynous	-	
F age of first offspring	4	accounting for many population should go with averagish	
F Max breeding age	16	Bergerud 2001	
M age of first offspring	3	Same as females	
M Max breeding age	13	Bergerud 2001	
maximum life span	16	Bergerud 2001	
Maximum # of broods per year	1	-	
Max # of young per brood	1	-	
sex ratio @ birth	M 52:48	Bergerud 2001	
Repoduction DD?	yes (SIPP)	bergerud 2006	
P(0)	54.8	Bergerud 2001	
P(K)	11.9	Bergerud 2001	
B	1	Bergerud 2001, needed a whole number	
A	0	Bergerud 2001	
% adult females breeding	((54.8-11.9)*((N/K)^1)))*(N/(0+N)	Bergerud 2001	michipicoten island possibly represents northern populations, 80=maximal
SD % breeding due to EV	7.6-SIPP, 10-rest as default	Bergerud 2001	
Specify exact distribution of 1 offspring per female	100	-	
Calf mortality (0-1)	-	already incorporated into DD equation	
F 1-2	18, Mich-10	Bergerud 2001	
F Adult	18, Mich-10	Bergerud 2020	
M 1-2	18, Mich-10	Bergerud 2001	
M Adult	18, Mich-10	Bergerud 2020	

Table 2. Vortex10 inputs of Woodland caribou traits.