THE COMMUNITY ECOLOGICAL MONITORING PROGRAM ANNUAL DATA REPORT 2016

Charles J. Krebs Todd Powell, Mark O'Donoghue, Tom Jung, Val Loewen, Scott Gilbert, Shawn Taylor, Alain Fontaine, Rudy Boonstra, Stan Boutin, and Alice J. Kenney

Executive Summary

This is the tenth annual report to summarize the data on white spruce cone crops, ground berry production, small mammals, snowshoe hares, and carnivore abundance at Kluane Lake, Mayo, Faro, Watson Lake, and Whitehorse. White spruce cone counts were moderate to high in all areas in 2016 except for Kluane with an emerging pattern of 2 years between high cone crops. Ground berries in the forest were moderate to low in 2016 with some variability from site to site. Watson Lake and Faro had very low ground berry counts, and Mayo had low cranberry counts again in 2016. Red-backed voles collapsed to low numbers on all sites in 2015 with only small increases in 2016. Snowshoe hares were at a peak in 2016 in all areas except Watson Lake, recovering from their cyclic low of 2010-12. The hare decline in the southern Yukon is beginning in winter 2016-17. Soapberries were abundant in 2016 at Whitehorse and Mayo, but low at Kluane. Snow track counts in winter for mammalian predators were completed at Kluane and Mayo, but very poor snow conditions prevented predator snow tracking at Faro and Watson Lake. At all CEMP sites lynx numbers appeared to be increasing rapidly with good reproduction during 2016. Marten numbers dropped off dramatically in 2016 at Kluane but remained high at Mayo, while weasel numbers collapsed at both sites. We are investigating whether remote cameras can substitute for snow tracking to census mobile predators and possibly moose and bears in the Kluane region. The climate models we have developed can make predictions of how the monitored populations will perform in 2017, and a table of predictions for 2017 is provided.

Introduction

Since detailed ecological studies of the Kluane boreal forest began in 1973 we have been monitoring the ecological integrity of the Kluane region, and have over the years improved the monitoring methods being used. In 2005 we were able to expand some of the monitoring protocols to Mayo, Watson Lake, and Whitehorse, and in 2007 we began collecting data at Faro. This has permitted us to focus on regional trends in measures of ecosystem health and change. The Community Ecological Monitoring Program (CEMP) is a partnership between biologists at Environment Yukon, Yukon College, and the Arctic Institute Research Station at Kluane Lake. Additional monitoring in the Yukon is being done by Parks Canada and other research groups but we have not tried to summarize all of this monitoring here. We concentrate here on the CEMP monitoring being carried out in the central and southern Yukon.

Why Monitoring is needed and our Goals

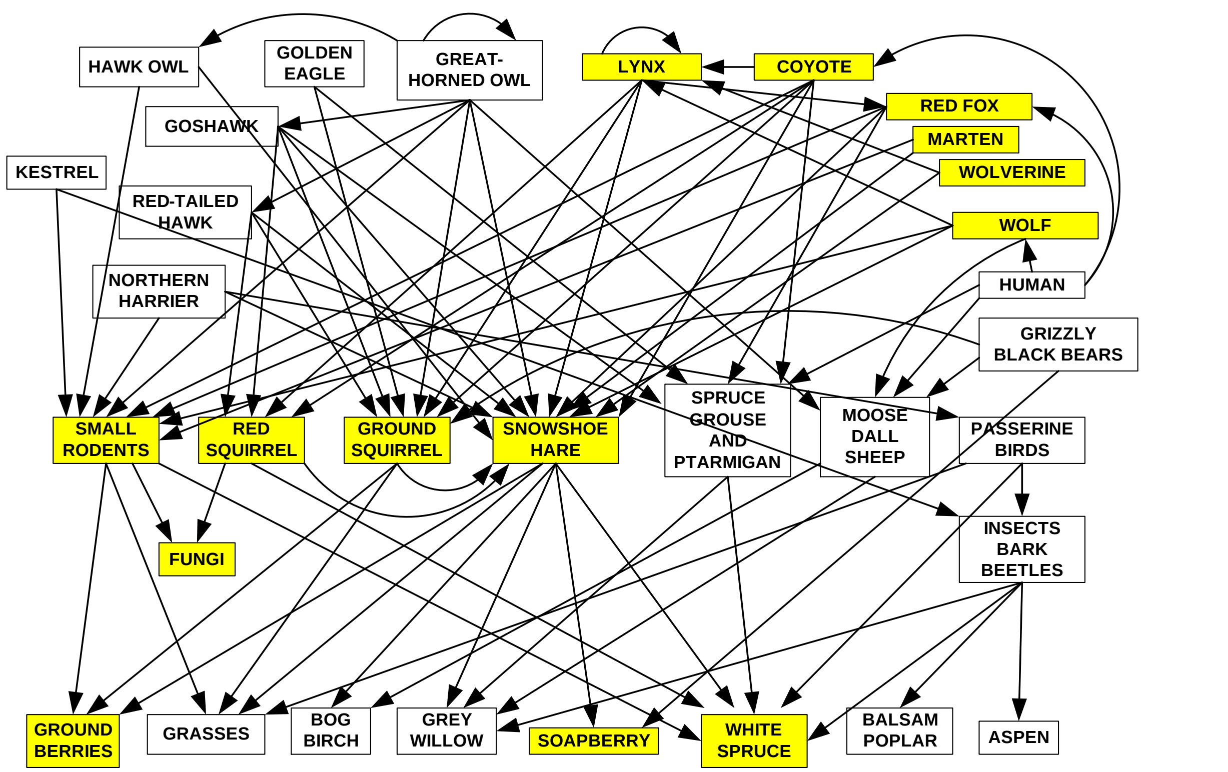
It is important to keep in mind where we are headed in any monitoring design. The key question we need to be able to answer is ***how will the Yukon's ecosystems respond to climate change*?** The answer to this simple question is not simple. Some parts of our Yukon ecosystems like spruce cone crops are directly dependent on climatic variables like temperature and rainfall. Others, for example snowshoe hares, depend immediately on the abundance and hunting success of predators like lynx, so the question then becomes will climate change affect lynx hunting success and if so how?

The key to these approaches is to have a comprehensive monitoring program in place that gathers data year after year. We cannot start and stop monitoring programs for a few years any more than we can stop and start reporting on the stock market for a few years. The need is thus for a commitment in funding and in people to carry these goals forward. This is what we have begun in the CEMP program and we summarize here what we have so far achieved.

Protocols Monitored and Cooperating Research Programs

Figure 1 shows the food web of the southern and central Yukon boreal forest region. If we wish to monitor ecological integrity, we need to measure key components in each of the levels of this food web. However, we cannot monitor everything, and we have concentrated our efforts on 7 significant indicators. We believe that these indicators constitute a start for obtaining early warning of ecosystem change, establishing baseline data on the natural range of variation of key ecosystem components, evaluating forest management practices, and advancing our understanding of the dynamics of boreal ecosystems. The species that are being monitored are indicated by shading in Figure 1. We do not have the funding to monitor large mammals like bears, moose, caribou, and Dall sheep, and these large mammals are monitored by other programs in Environment Yukon and by First Nations.

Figure 1. Food web for the boreal forest in the southern and central Yukon. The species being monitored in at least two of the CEMP sites are shaded. Only the major feeding linkages are shown.



We have prepared a separate handbook of the details of the monitoring protocols for each of the species groups listed above (CEMP Monitoring Handbook, available on the web at http://www.zoology.ubc.ca/~krebs/kluane.html).

Two general questions underlie this monitoring program. First, *is there synchrony among sites in these indicators?* Regional synchrony can be achieved by ecological indicators responding to weather variation that has a widespread regional signature, or by large-scale dispersal of animals like lynx and coyotes. Second, *are there regional patterns of variation in the density or productivity of indicators?* For example, snowshoe hares may be on average more abundant in some areas than they are in others. In turn, all these regional similarities or differences need to be explained ecologically.

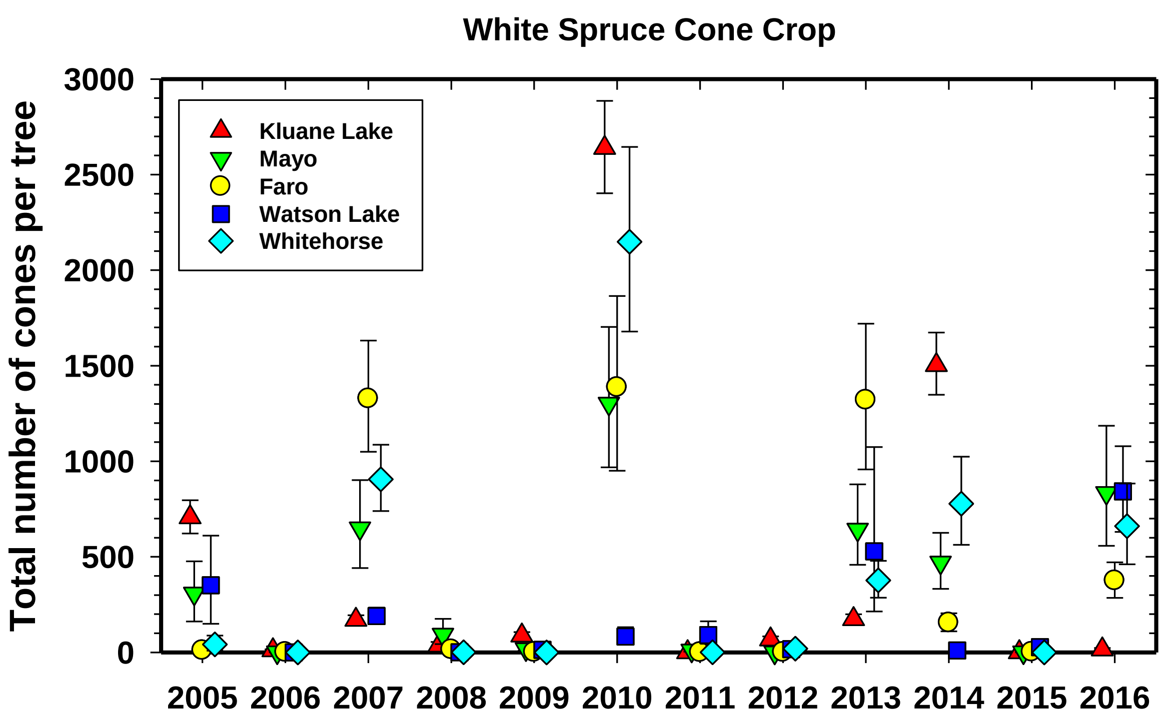
Results and Discussion

For the purpose of this Annual Report, we would like to discuss some of the findings from 7 of the protocols. We maintain on the web site http://www.zoology.ubc.ca/~krebs/kluane.html a detailed EXCEL file (*monitor.xlsx*) that has all the summarized data from all our monitoring efforts at Kluane since 1973. In the figures that follow we report means and 95 % confidence limits unless indicated otherwise.

(a) White Spruce Cone Production

White spruce trees produce a variable number of cones each year, and at irregular intervals very large crops are produced in mast years. We have been counting cones on spruce in the Kluane area since 1987, and Figure 2 shows the cone counts

Figure 2. Average white spruce cone counts on CEMP sites for 2005 to 2016. Green cones are counted from the top 3 m of a tagged set of trees each August. These index counts are converted to total cones per tree by the LaMontagne conversion (LaMontagne et al. 2005). There was a complete cone failure in 2006, 2008, 2009, 2011, 2012 and 2015 at all sites. Moderately high cone counts occurred in 2016 on all areas except Kluane.



over the CEMP sampling sites since 2005. The 2005 and 2007 cone crops were moderate, but the 2006, 2008, 2009, 2011, 2012, and 2015 cone crops were nearly a complete failure at all our study sites. Cone counts reached a moderate peak in 2016 on all sites except Kluane. If years of high cone production are driven by weather variables, we should be able to correlate our weather data with these cone production events.

There is a suggestion that large cone crops in white spruce are occurring more frequently in recent years. Cone crops since 2006 have tended to occur at intervals of 2-4 years while those prior to 2006 were 5-7 years apart. If this pattern holds we should expect high cone counts on many sites in 2017 or 2018. Red squirrels and seed-eating birds should provide a responsive index of more frequent cone crops.

We recalculated the predictive regression for white spruce cone counts in 2016 (Krebs et al. 2017). The two key variables remain as the temperature in July of 1 and 2 years prior to the actual cone crop. No rainfall variable was a significant predictor. We used this regression to predict cone counts for 2017 from the weather data of 2015 and 2016 (see Table 1).

(b) Ground Berry Production

Five species of ground berries are counted in permanent quadrats each year. The major berry-producing plants are bearberry (*Arctostaphylos uva-ursi*), red bearberry (*A. rubra*), crowberry (*Empetrum nigrum*), toadflax (*Geocaulon lividum*), and cranberry (*Vaccinium vitis-idaea*). We use permanent quadrats for our counts because in any particular area it is possible for some small patches of berries to be abundant when the general landscape has few berries overall. Figure 3 shows the data we have accumulated on three of the species of ground berries since 2005.

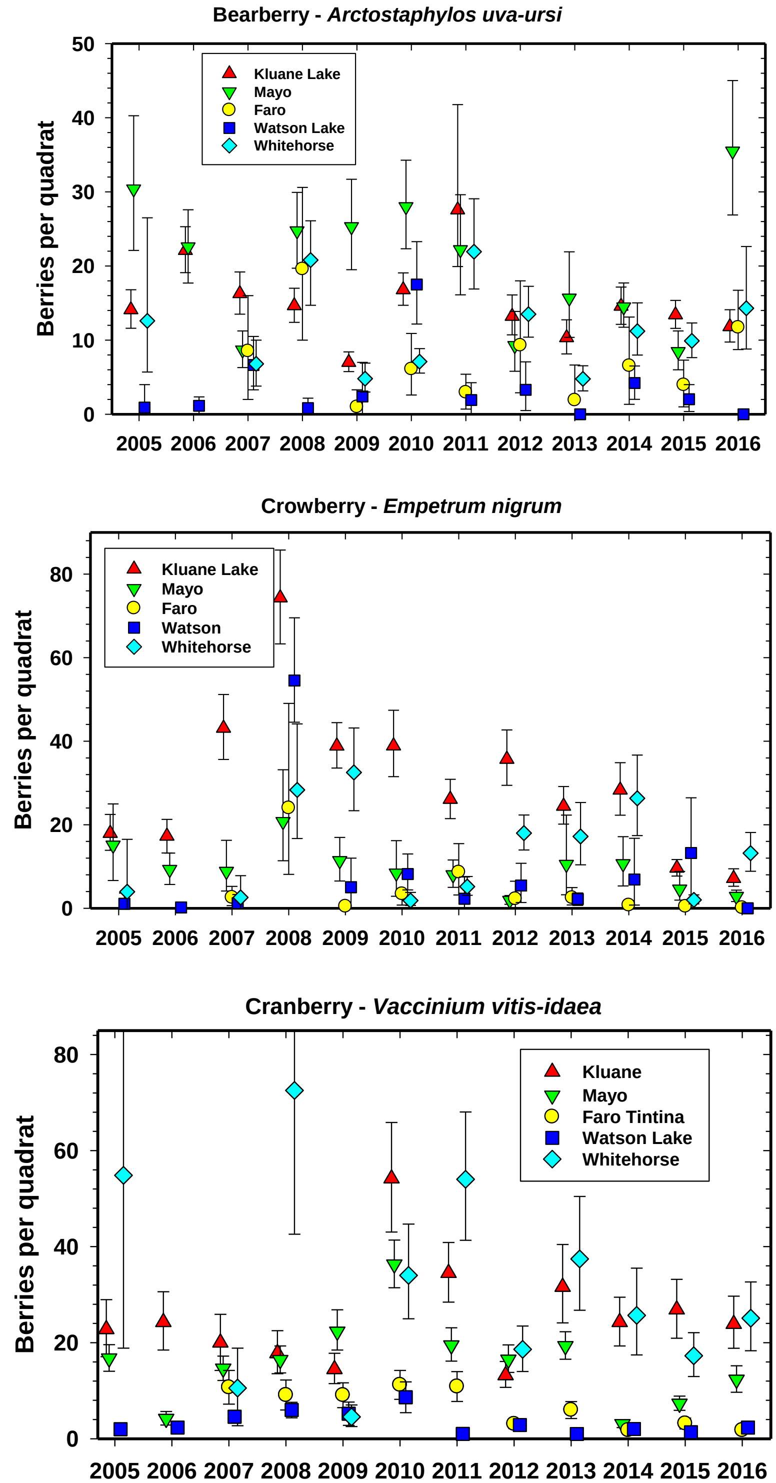
Bearberry counts are highly variable among the five monitoring areas. In particular Watson Lake sites had very few bearberries in all these years. The variation is large enough to require more data to see if the suggestion that bearberry crops in general have been declining since 2011 indicates the start of a long-term trend.

Crowberry counts show a clearer pattern of agreement among most of the sites with a high production year only in 2008 and lower counts in the last 7 years with a suggested continuing decrease in production in recent years all over the southern Yukon. Crowberry counts on all sites except perhaps Watson Lake were very low in 2015.

Cranberry counts show yet a different pattern with moderate production at Whitehorse and Kluane in 2016, lower counts at Mayo. In 2016 Faro and Watson Lake had virtually no cranberries. There is no clear general regional pattern to these cranberry counts. We have seen no repeat of the 2008 high cranberry counts in Whitehorse, and moderate counts were found only at Whitehorse and Kluane in 2014, 2015, and 2016. The only regional pattern for all these three species is the trend to lower counts over the last 4-5 years, compared with the previous 5 years, with an occasional good year in only one species at one site (like bearberry at Mayo in 2016).

We have re-analyzed the climatic controls of ground berry production in the Kluane region from data gathered over 1994 to 2016 resulting in equations relating berry production to climate that update those given in Krebs et al. (2009). Each species of ground berry in the Kluane area responded to different signals of temperature and rainfall, and there was no general climate pattern to which all the species of ground berries responded. Our working hypothesis is that ground berries respond to regional

Figure 3. Average berry counts for 3 species of ground berries at CEMP sites from 2005 to 2016. Quadrat size is 40 by 40 cm. Error bars are 95% confidence intervals.



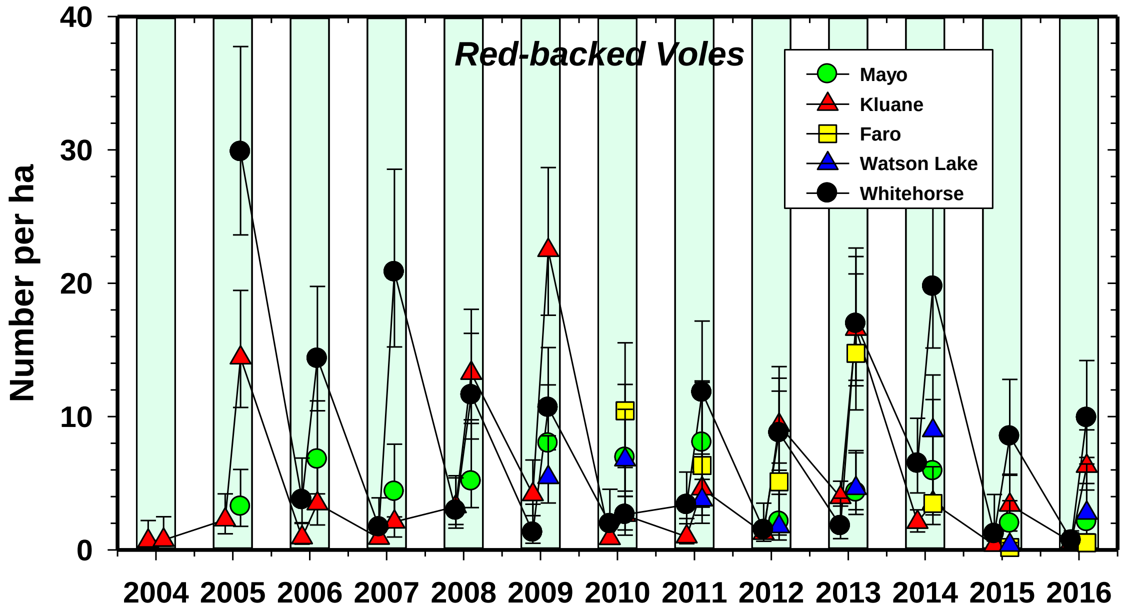
weather patterns but that individual berry species require a different suite of weather variables (monthly temperatures, monthly rainfall) from the current and previous years in order to produce a large berry crop.

(c) Small Rodent Numbers

The most common rodent on all of the CEMP sites is the red-backed vole (*Myodes* = *Clethrionomys rutilus*), and we have estimated the abundance of this species by live trapping, marking, and releasing individuals. Live trapping at Kluane and Whitehorse is done in spring and late summer, and at Mayo, Faro, and Watson Lake only in late summer. Figure 4 shows the changes in red-backed vole numbers for the period 2004 to 2016. All populations were low in 2015 and 2016, with most (except Whitehorse) failing to rise above 5 per ha.

Red-backed voles at Kluane have fluctuated in 3-4 year cycles for the past 25 years and this pattern is shown in Figure 4 with peak years of 2005, 2009, and 2013. Whitehorse populations fluctuate considerably but not in a clear 3-4 year cycle. Mayo, Faro, and Watson Lake populations were low in summer 2016. The pattern to date does

Figure 4. Population estimates for red-backed voles in five CEMP areas, 2004-2016. Trapping grids have an effective trapping area of about 3 ha. Summer months are shaded green. Spring and late summer estimates are available only for Whitehorse and Kluane. Other areas have late summer estimates only.



not suggest any close synchrony in fluctuations of red-backed vole numbers in the southern and central Yukon. Mayo populations have only rarely exceeded 6 per ha since 2005, and were very low in 2016.

The only other small mammal that is common to many of the CEMP sites is the deer mouse, *Peromyscus maniculatus*. At present the number of captures of this rodent species is too low on most of the sites to discuss any common patterns of population change. Deer mice remained between 1-4 per ha on all sites from 2005 to 2016, and in general tend to be stable in numbers from year to year.

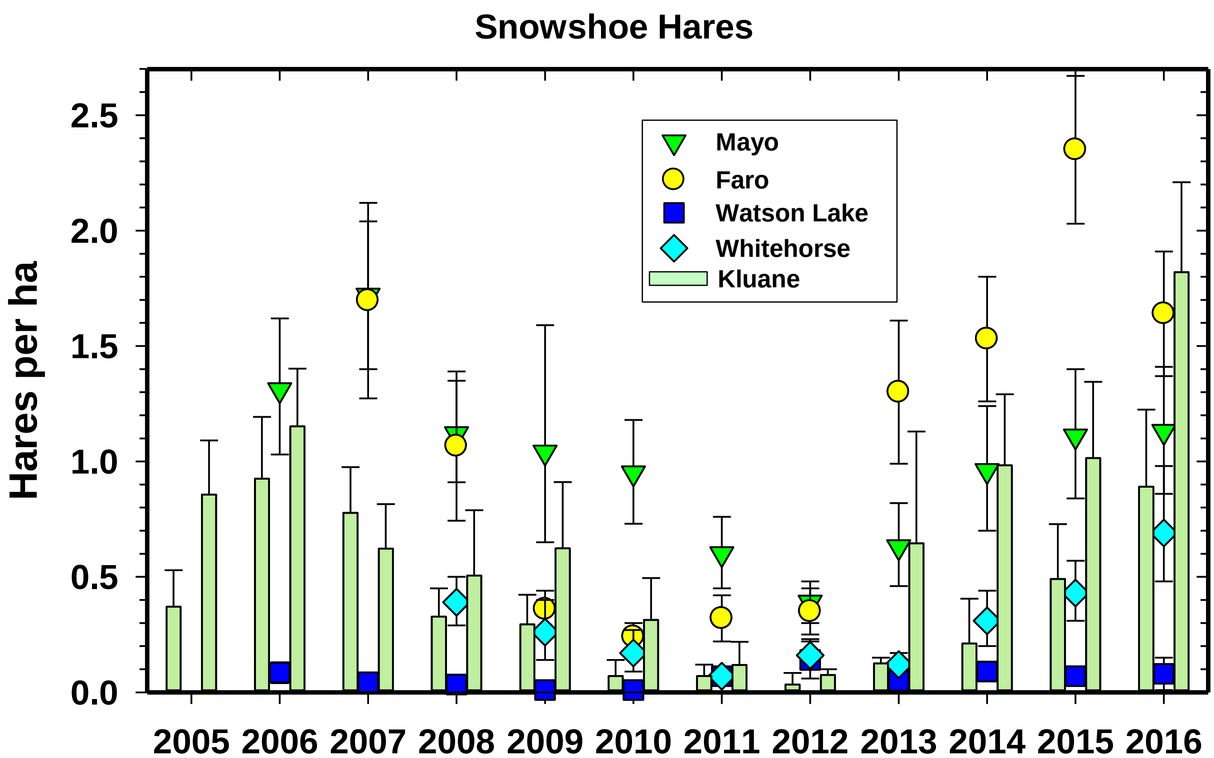
Since most of these mice and voles weight approximately 25 g, a density of 5/ha would provide a predator with only 125 g of potential food per day, assuming the predator could catch and eat all of them in 5 ha of habitat. A hypothetical coyote would in this simple model clean off all the small rodents in 1.5 km^2 per month. Simple calculations of this type suggest that predators in the boreal forest cannot make a living on small rodents which must be an incidental part of their diet.

(d) Snowshoe Hare Numbers

The snowshoe hare is a keystone species in much of the boreal forest because it is the prey of so many predators (see Figure 1). Snowshoe hares fluctuate in 9-10 year cycles throughout the boreal zone. At Kluane we have estimated the abundance of snowshoe hares by live trapping, marking, and releasing individuals. We developed a simple census method for hares by the use of fecal pellet counts carried out once a year in summer (Krebs et al. 2001) and this technique has been used at all the CEMP sites for comparative data. Figure 5 shows the changes in hare numbers since 2005 at the CEMP sites.

Two points stand out in Figure 5. First, Watson Lake sites had almost no snowshoe hares in any of the nine years for which we have data. There is clear natural history information for Watson Lake that the hare cycle exists and that hares are increasing rapidly in that area, so the problem is that the current hare monitoring sites

Figure 5. Population density estimates for snowshoe hares in CEMP areas, 2005-2016. Mark-recapture data from Kluane are given as a bar graph, and estimates from fecal pellet counts at CEMP sites are given as points (95% confidence limits). Note that the data from fecal pellet counts integrate hare density over the previous year. Mayo data from Rusty Creek site only.



are in poor hare habitat and need to be repositioned. Second, all other CEMP sites are following the Kluane hare cycle closely, with peak populations in 2006-7 and declining populations from 2008 to 2011. Faro hare numbers increased rapidly in the summers of 2013 to 2015 and were at a peak in 2015. Mayo hares (Rusty Creek site) have increased in close correlation to those at Kluane Lake and reached a peak in 2015 and 2016. Slower rates of growth at Whitehorse occurred in 2014 and 2015, and hares around Whitehorse appeared to be still increasing in 2016. The increase phase of the hare cycle has been similar to the 2006-7 peak in Whitehorse and Mayo, and if these trends continue we could have a low hare peak in 2016-17 in all areas except for a higher peak at Faro.

Regional synchrony is well established in snowshoe hares in much of the Yukon, but as we get more regional details we find that not all areas in western Canada and Alaska tend to be in phase. We have summarized the hare data from the Yukon, Alaska, northern BC and the NWT in Krebs et al. (2013, 2014). This analysis of regional synchrony strongly suggests a travelling wave of hare peaks that moves from northern BC into the Yukon one year later and then moves north in the Yukon with a further one year delay and west into Alaska to peak 2 years later than BC. As far as we can determine, this travelling wave is also occurring in the current hare peak of 2015 - 2017, and our colleagues in Alaska and the NWT are gathering hare data comparable to ours to answer this question whether the cyclic peak migrates west into Alaska.

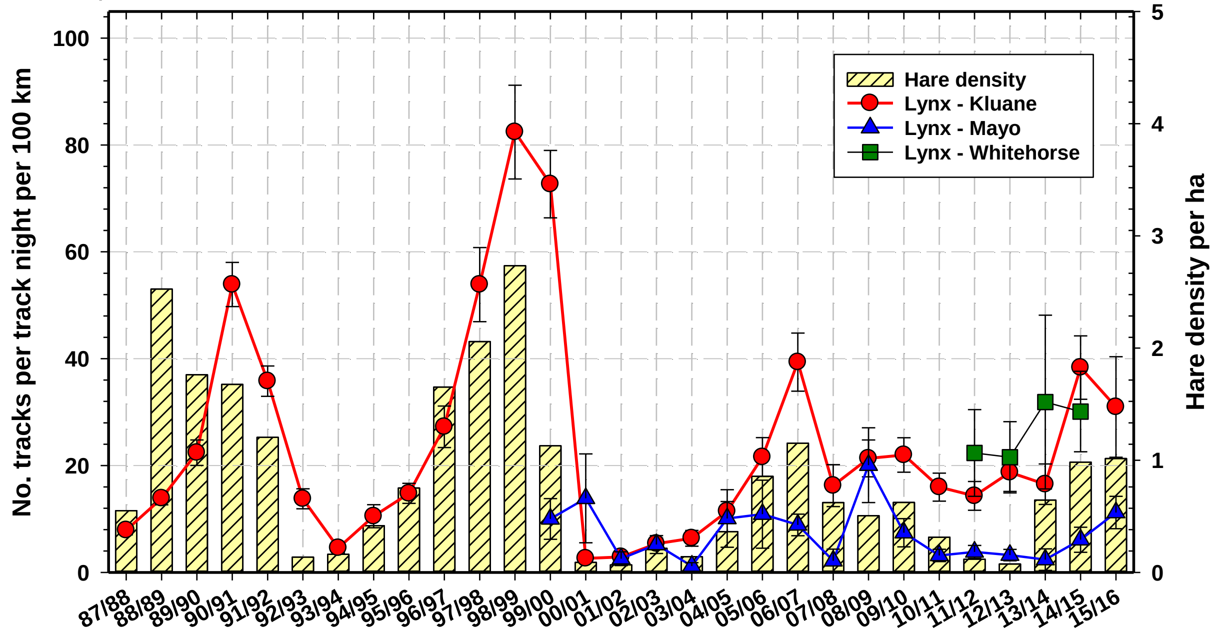
The significance of these regional differences in the hare cycle lies in the movements of predators like lynx and great-horned owls from one high hare area to adjacent ones that are low or starting to recover. The most promising explanation for regional synchrony involves predator movements, and depending on the geometry of the highs, such movements could produce a travelling wave of density changes.

(e) Lynx Abundance

We have been following lynx abundance in the Kluane region since 1987 by means of winter snow track counts along established routes. We expanded this predator tracking to Mayo in 1999 and to Whitehorse, Faro, and Watson Lake in 2009. We count lynx tracks crossing snowmobile routes after fresh snowfalls each winter, depending on wind conditions. On average about 300 km are tracked each winter at Kluane and about 125 km at Mayo. But during the last 2 years snow conditions in winter have limited our ability to use snow tracking for predator counts.

Figure 6 shows the changes in abundance of lynx in Mayo, Kluane and Whitehorse as measured by snow tracks. Because our winter snow tracking cannot be done in identical habitats in all areas, we do not expect the absolute number of tracks to directly indicate lynx density but only trends in density. Three points are quite striking in this graph. First, the last lynx peak at Kluane in 2006-07 was the lowest we have seen, coincidental with the lowest hare peak we have seen at Kluane. Second, lynx at Mayo appear to be out of phase with lynx at Kluane by a delay of 1-2 years. Third, lynx abundance during the low of the hare cycle at Kluane during the last 6 years is higher than we have seen in a hare low previously. There are more lynx in the Kluane area (and at Whitehorse) during the last several years than could ever be supported on the existing hare population. These lynx must be transients headed for starvation (unlikely) or have been able to switch to alternate prey like red squirrels (more likely). We suspect

Figure 6. Snow tracking abundance estimates for Canada lynx at Kluane, Mayo, and Whitehorse, 1987 to 2016. Hare data are from Kluane in the autumn preceding the winter predator data.

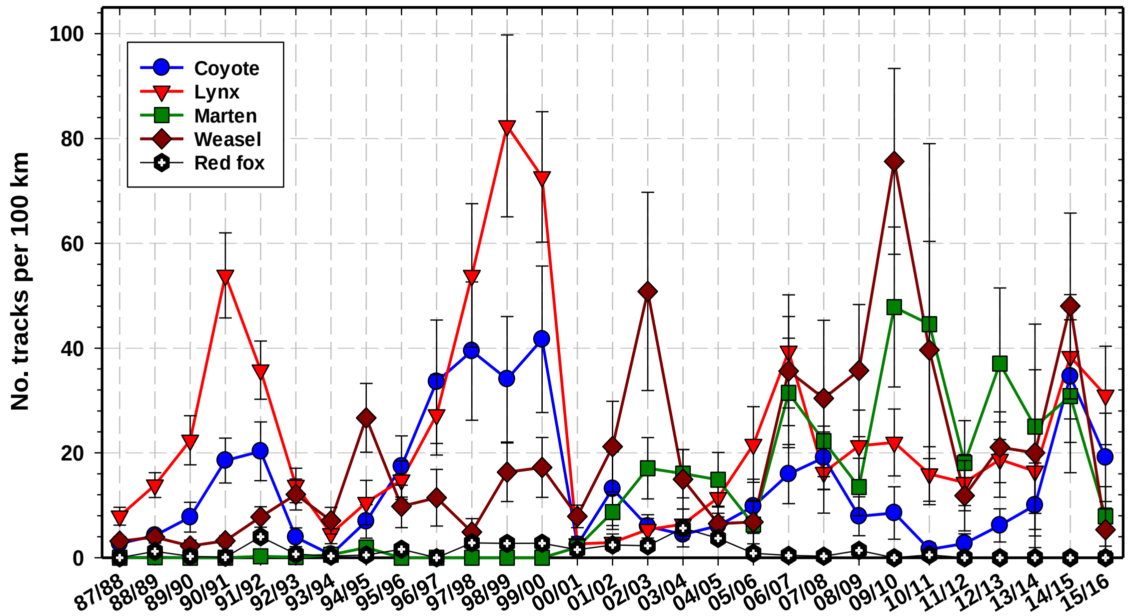


that lynx have been feeding mainly on red squirrels from 2008 to 2013. O'Donoghue et al. (1998) showed that lynx fed extensively on red squirrels in the low phase of the hare cycle, and the data suggest that this prey switching was very strong during the low phase from 2008 to 2013, which allowed lynx to maintain a relatively high density during low phase.

We do not have any snow tracking data from Faro or Watson Lake for winter 2015-2016 because of a shortage of snow. Because this may become a more serious problem in future years, we began in autumn 2015 to install a set of trail cameras in the Kluane area to take automatic photos from October to January of animals moving along game trails and paths. We will determine in the next 3 winters if this use of game cameras can potentially replace snow tracking in winter to obtain an index of predator abundance. Our preliminary results are very promising

Lynx have been increasing in numbers on all areas as the hare cycle has been at a peak from 2014 to 2016, but it does not appear that they will reach the high levels they were at in 1998-99.

Figure 7. Snow tracking abundance estimates for coyote, Canada lynx, marten, weasel and red fox at Kluane, 1987 to 2016. Track counts are affected by activity as well as by abundance, so must be considered an index of abundance.



(f) Brief Notes on Other Monitoring Measurements

Soapberries are a favourite food of grizzly bears, and are being counted at Kluane, Mayo, and Whitehorse. We place a high priority on counting soapberries in all sites but there are few soapberries on some of our sites which makes this a challenge. In 2016 soapberries were at very low abundance at Kluane Lake but were moderately high on bushes at Whitehorse and Mayo. Mushrooms were abundant at Mayo in 2016 but very scarce at all other CEMP sites in 2016.

Red squirrel numbers have been studied extensively at Kluane for years by Stan Boutin's group. In general red squirrel numbers are relatively stable in the boreal forest but they have increased at Kluane in the last 3 years in response to good spruce cone crops and have remained high in 2016.

Coyotes and lynx follow the hare cycle closely. Marten and weasels have become much more abundant since 2000 at Kluane and may be affecting the dynamics of the hare cycle. In winter 2015-2016 marten and weasel numbers at Kluane fell dramatically below 2014-2015 levels (Figure 7). More information is being gathered from the other CEMP monitoring sites on predator numbers by means of snow tracking or camera trapping and this will give us regional patterns in the coming years.

Bird surveys in the Yukon are being done by other groups, but we would like to coordinate owl survey counts with the BC Owl Survey in future years to get coverage at all CEMP sites. Other bird surveys would be desirable to put in place to obtain a better picture of regional trends for the southern Yukon. Natural history observations suggest increasing grouse populations at many of the CEMP sites in 2015 and high grouse numbers in 2016.

There is general interest among Yukon and Alaskan biologists to implement a program of regional monitoring of the major mammal and bird predators of the boreal forest. It would require a large investment of time and money to analyze this large-scale monitoring of movements of major predators.

Our goal in this monitoring program is to develop statistical methods of estimating the abundance and productivity of our seven indicators of ecosystem health for the Yukon boreal forest. We expect all of these to change as the climate alters, and we need to be able to predict how climatic variables do or do not affect our indicators. There are three ways to determine the impact of climate change – to observe what happens, to monitor changes and try to explain them ecologically, and to develop and use models which include climatic variables to predict what will happen. Long-term data sets are essential to this endeavour and we learn as we go along from year to year.

(g) Predictions for Indicator Species in 2017

We have combined the statistical models we have for plant species and the patterns we have seen for mammals to produce these predictions of trends for the coming year. Testing all these models as the years go by will allow us to determine how reliable these predictions are.

Table 1. Predictions for 2017 for Monitored Species at all CEMP Sites

Species / Group	**Kluane**	**Faro**	**Mayo**	**Watson Lake**	**Whitehorse**	
White spruce cone crop[1]	268	320	321	315	100	Low to moderate crop in all sites. Range has been 0 to 2000 cones per tree
Above-ground mushrooms[2]	53	41	36	50	**185**	Grams per 10 m^2 Small crop except Whitehorse. Range has been 1 to 100 $g/10m^2$
Soapberries[3]	32	–	29	–	33	Berries per 10 mm stem. Relatively low crop. Range has been 16 to 141
Small mammals	peak ~ 15/ha	low ~ 5/ha	increasing < 5/ha	low - increase ~ 5-10/ha	**peak** ~ 15-20/ha	Red-backed voles only; deer mice low except Whitehorse, *Microtus* scarce everywhere
Snowshoe hares	decline	decline	decline	slight increase	**peak**	Peaks are traveling north and west
Lynx and other predators	**peak**	**peak**	**peak**	low	near a peak	All predators should be declining in 2017 and breeding may cease or be unproductive

[1] Expected mean total number of cones for the entire tree
[2] Very large crop expected for Whitehorse
[3] Tentative predictions from a new statistical model

Conclusion

In this report we have presented a few of the time series of monitoring results that we have obtained from the CEMP program since it was begun in 2005. With only 12 years of data for some of our indicators, our conclusions to date must be tentative, but we have a firm foundation for coordinating these regional data sets. The boreal forest ecosystem is a boom-bust ecosystem with all the major components showing strong fluctuations in abundance. Determining the associations between these fluctuating components of the ecosystem is underway, and in the same way that we have needed a long time series of weather data to recognize climate change, achieving an understanding of this northern ecosystem will require long-term ecological data.

We need to proceed in the short term to answer three questions:

1. How much correlation is there between the Kluane Lake sites and other sites at Mayo, Faro, Watson Lake, and Whitehorse? We have seen that, for example, bearberry production (Figure 3) can vary greatly between sites, yet snowshoe hare numbers (Figure 5) are highly correlated among sites.
2. How much correlation is there between climatic measurements and biological measurements? For example, can we develop a predictive equation for cone crops from temperature data that will apply across all CEMP sites? So far we have achieved this for spruce cones and mushrooms.
3. How can we get a better index of changes in predator populations in a time when snowfall and winter conditions have become so variable? Can we utilize remote camera trapping (Meek et al. 2014) as one way of spreading our sampling and overcoming weather changes?

The database management system for CEMP is well set up, and we have developed a good group of workers with skills to make the needed measurements. With the data we have gathered and will continue to gather, we can begin to address the important management issues for the southern and central Yukon and to provide a detailed assessment of how climate change is affecting biodiversity in the boreal forest ecosystem in this part of the Yukon. In connection with local knowledge interviews a broad picture of how the environment is changing will emerge from these efforts.

Acknowledgements

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