THE COMMUNITY ECOLOGICAL MONITORING PROGRAM ANNUAL REPORT 2013

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Executive Summary

The Community Ecological Monitoring Program (CEMP) arose in 2005 as an extension of the Kluane monitoring project to begin a regional assessment of the health of the Yukon boreal forest ecosystem. This is the seventh 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 in all areas in 2013 except at Faro where cone crops were high. Ground berries in the forest were moderate in 2013 with some variability from site to site. Watson Lake and Faro had very low ground berry counts. Red-backed voles remained at low numbers in 2013 at most sites and were moderately common only at Kluane and Whitehorse. Snowshoe hares began their increase phase, particularly at Kluane and Faro, recovering from their cyclic low of 2010-2012. The next hare peak in the Yukon will probably occur in 2016 or 2017. Mushroom production was low at Kluane and Mayo but moderate at all other sites in 2013. Soapberries were abundant in 2013 at Whitehorse and Kluane, but moderate to low at Mayo. Snow track counts in winter for mammalian predators are being done at Kluane, Mayo, Whitehorse, Watson Lake, and Faro. At all CEMP sites lynx remained low or declined slightly during 2012-2013. Marten increased to high numbers at Mayo, moderate numbers at Kluane, and decreased dramatically in Whitehorse and Faro. In a separate study local knowledge interviews were completed at Mayo by Mark O'Donoghue in early 2013 and are summarized briefly here, an important step in bringing local knowledge of trends together with our CEMP data. As additional data are added in the years to come, the regional patterns of ecosystem changes will become more evident.

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. 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.

There are two approaches ecologists are using to answer the broad question about changes in ecosystem integrity over time. First, sit and count, wait and see. This is the simplest approach to describe the system as it changes and it is useful as a first step. By itself it does not permit any management actions to thwart changes, since, by the time you see changes, it is often too late to do very much about them. Nevertheless, this approach is important because we carefully document what is happening here and now. Second, we can identify key components of the ecosystem that appear to be responding rapidly to climate change and target them for both model building and experimental attack to try to understand the underlying ecosystem complexity. This requires intense multi-year research, carried out by university students, regional biologists, and Parks personnel. This is our approach. We have picked ecosystem variables like ground berry production and spruce cone production that are commonly thought to be under the control of weather, and we are building predictive models that we can test to predict (for example) the abundance of ground berries from temperature and rainfall data in particular months of the previous year. We can then test these models from year to year to see if they are accurate and to change them as needed. By itself this approach will not solve the broad problem of ecosystem change, but it is a start and in combination with the first approach we will gradually improve our understanding of where we are headed with climate change.

This monitoring program has several interrelated objectives. First, it provides long-term monitoring data that provide important baseline information on undisturbed forest sites, and this information is of value to many research programs as well as providing control data for assessing impacts of industrial developments, and for park and forest management in the Kluane region. Second, it constitutes an early warning system of significant changes taking place in the central and southern Yukon boreal forest ecosystem. The early detection of these changes should guide medium to long-term planning and biodiversity management and research. Third, CEMP monitors the long-term processes that drive the boreal forest ecosystem. The Kluane Boreal Forest Ecosystem Project documented important interactions and ecological processes during the ten years of its existence, 1986 to 1996 (Krebs, Boutin and Boonstra 2001). However, we still do not understand the longer cycles and processes that drive boreal forest ecosystems on a landscape scale and help to protect its biodiversity. CEMP is helping to document some of those patterns and processes.

Data from our CEMP monitoring are supplemented by local knowledge gathered in interviews carried out each year at Mayo, and we will report on this work briefly in this report as well.

Why Monitoring is needed

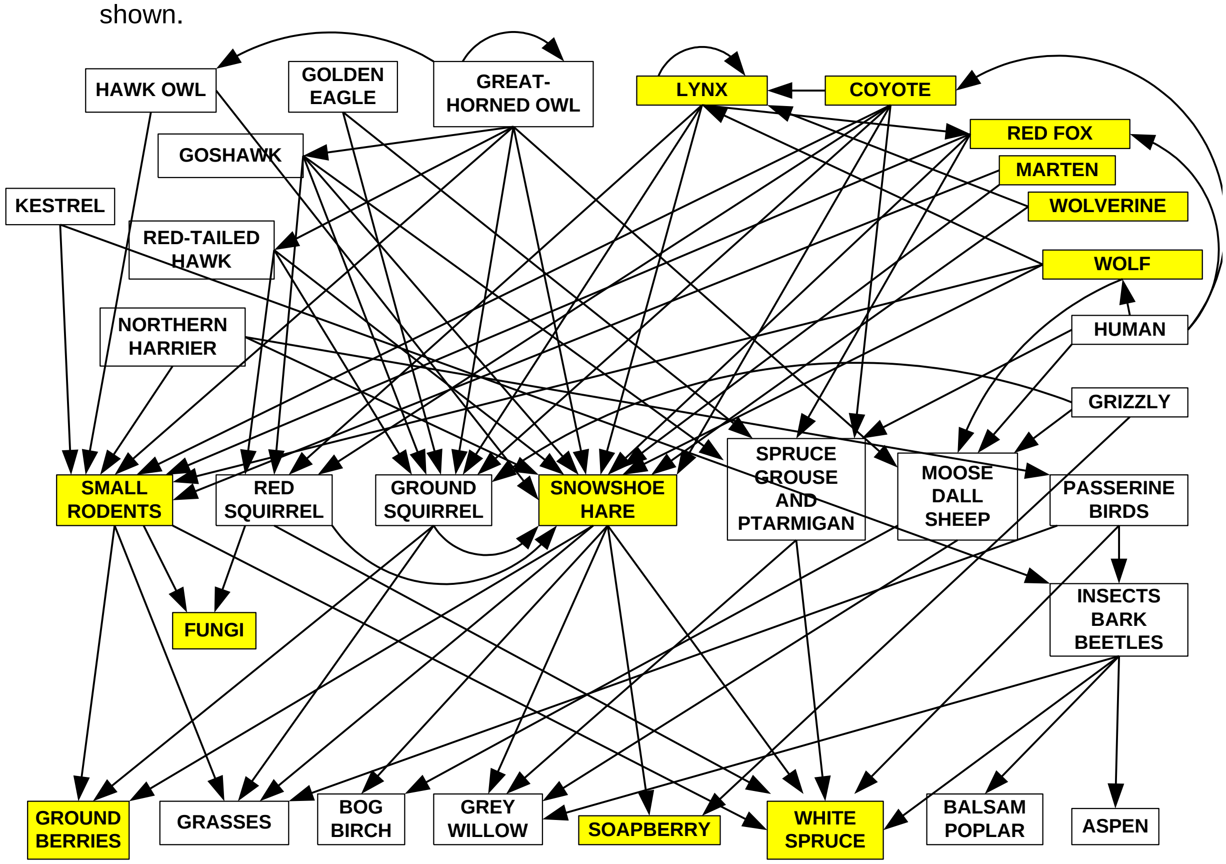
What are the goals of this monitoring program? It is important to keep in mind where we are headed in any monitoring design. The key question we need to be able to answer is *how will the Yukon's ecosystems respond to climate change*? The answer to this simple question is not simple. Some parts of our 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 that 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 7 indicators that are being monitored are listed below. The species that are being monitored are indicated by shading in Figure 1. Note that 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.



A brief description of what we measure in each protocol and why we measure it is given below:

1. **White Spruce Cone Production.** Measurements: annual rates of cone production are documented. Rationale: major food for red squirrels, passerine birds, and mice.
2. **Ground Berry and Soapberry Production.** Measurements: berry production is recorded each year for the major berry producers in the Yukon boreal forests – crowberry, bearberry, red bearberry, toadflax, cranberry, and soapberry. Rationale: major food supplies for small mammals, bears and birds.
3. **Mushroom Production:** Measurements: standing crop of mushrooms is recorded in early August each year as an index of mushroom fruiting. Rationale: important food for red squirrels and other mammals, highly variable in production from year to year.
4. **Small Mammal Abundance.** Measurements: population density estimates calculated from live trapping mice and voles twice per year at Kluane and Whitehorse, and once per summer at other CEMP sites. Rationale: major prey for many predators; these small mammals create a 3-4 year population cycle as well as major irruptions in the area.
5. **Arctic Ground Squirrel Abundance:** Measurements: population density estimates from live trapping once or twice per year at Kluane. Ground squirrels do not occur in forested areas at the other CEMP sites, and are most common in alpine areas that we do not sample. Rationale: major prey item for many predators.
6. **Snowshoe Hare Abundance.** Measurements: population density estimates calculated from live trapping hares twice per year at Kluane and by counting fecal pellets once per year at all CEMP sites. Rationale: the keystone species of the boreal forest with a 9-10 year population cycle.
7. **Predator Abundance**. Measurements: index of relative abundance of coyotes, lynx, marten, and other predators from winter track transect is being carried out annually in the Kluane Lake area, at Mayo and at Whitehorse, Watson Lake and Faro. Rationale: an index of major terrestrial predators in the system.

We have prepared a separate handbook of the details of the monitoring protocols for each of the species groups listed above (CEMP Monitoring, 2013, available on the web at http://www.zoology.ubc.ca/~krebs/kluane.html).

In addition to these 7 protocols, a number of research and management projects are being conducted in the Yukon (e.g. the Breeding Bird Survey, Christmas Bird Counts, Owl Surveys). Through cooperation and partnerships, these projects contribute important additional information that is valuable for long-term monitoring in the Yukon.

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.

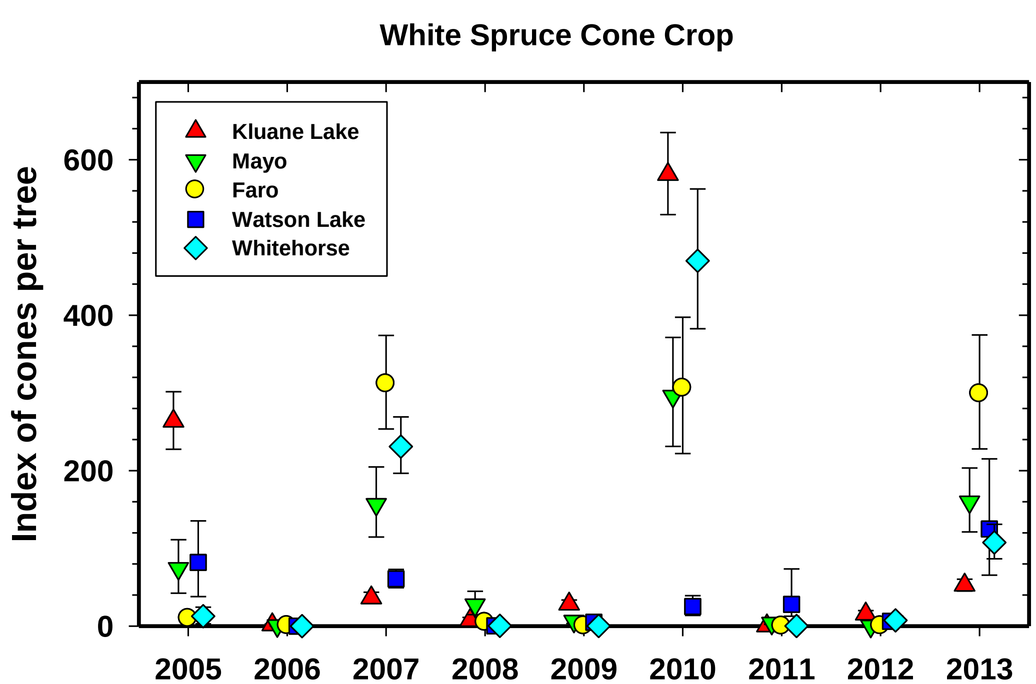
Results and Discussion

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. As indicated in Table 1, many of the protocols have been developed for CEMP only since 2004 and thus regional comparisons within CEMP are limited to the years 2005 to 2013. 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 over the CEMP sampling sites since 2005. The 2005 and 2007 cone crops were moderate, but the 2006, 2008, 2009, 2011, and 2012 cone crops were nearly a complete failure at Kluane, Mayo, Watson Lake, Faro, and Whitehorse. Cone counts in 2013 were moderate on all sites with Kluane being the lowest and Faro the highest. If years of high cone production are driven by weather variables, we should soon be able to correlate our weather data with these cone production events. There is a suggestion of a cycle in cone crops in the Kluane area, but this cyclic interval is so variable it does

Figure 2. Average white spruce cone counts on CEMP sites for 2005 to 2013. Green cones are counted from the top 3 m of a tagged set of trees each August. Only the cones visible from one side of the tree are counted, so this is an index of cone production, not an absolute measure. There was a complete cone failure in 2006, 2008, 2009, 2011 and 2012 at all sites. The 2010 count was the largest we have seen during the last 25 years.



not allow for prediction of when the next large cone crop should be expected. We have data on cone crops at Kluane Lake since 1987 and we have recently developed a statistical model to predict cone crops in the Kluane region from summer temperature and rainfall of the previous 2 years (Krebs et al. 2012). In future years we will be able to check this statistical model with further data, and develop comparable models for the other sites. So far the model for spruce cone production has operated well. It utilizes weather data from years (*t-1*) and (*t-2*) to predict cones in year *t.* For 2013 the predicted cone crop index per tree for Kluane Lake was 63 cones and the observed crop was 53. Similar data for the 2012 cone crop were 27 and 16 cones. Further data are needed.

What is surprising about Figure 2 is that all the 5 regional counts show the same pattern of high and low years, and there were very high crops in summer 2010 at all sites except Watson Lake. The suggestion from this is that the regional climate of the southern and central Yukon may coordinate years of high and low cone counts. Further data are required to quantify the regional synchrony in cone crops. Cone counts are highly variable, as Figure 2 shows, and different sites within a region can be quite variable. Some of this variability will be reduced when we can achieve larger sample sizes. Because of this variability in cone production, it will take a series of several poor years (> 7) in a row for us to conclude that cone production is falling due to some external factor such as climate change. Red squirrels and seed-eating birds might provide a more responsive index of detrimental cone crop changes.

(b) Ground Berry Production

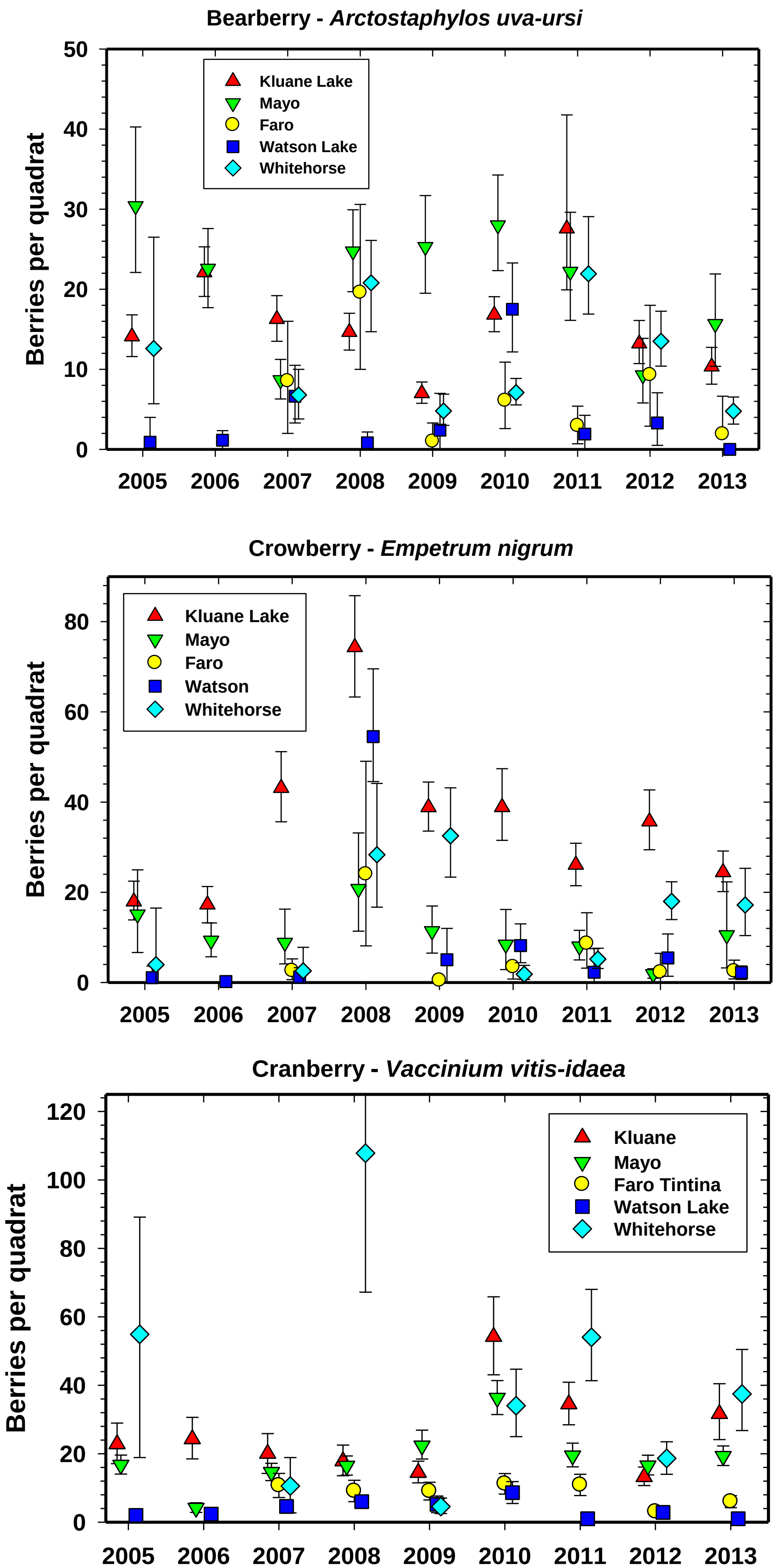
Five species of ground berries are counted in permanent quadrats each year. The major berry-producing plants are bearberry (*Arctostaphylos uva-ursi*), red bearberry (*A. rubra*), crowberry (*Empetrum nigrum*), toadflax (*Geocaulon lividum*), and cranberry (*Vaccinium vitis-idaea*). For each of these species green berries are counted in late July or early August before the berries are harvested by bears, mice, and chipmunks. 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 for all these years. Mayo had consistently high counts of bearberries from 2005 to 2011 (which could account for the stability of small rodent numbers) but in the last 2 years Mayo counts of bearberries have declined. There was considerable variation in bearberry numbers between sites and years in 2010 and 2011, but less among sites in 2012 and 2013. The variation is large enough to require more data to see if there is a clear pattern or if local processes (e.g. at Mayo) determine berry production in this species. At the present time it looks like local processes determine bearberry crops.

Crowberry counts show a clearer pattern of agreement among most of the sites with a high production year only in 2008 and low counts in the other 7 years. The average production of crowberries at Kluane is 2-3 times that of each of the other 4 sites for these nine years of data. Crowberry counts on all sites except Kluane and Whitehorse were very low in 2013. Crowberry counts at Mayo appear to be more constant than those at other CEMP sites.

Cranberry counts show yet a different pattern with low to very low production at all sites in 2012 and increasing counts in 2013 in Whitehorse and Kluane. In 2013 Faro and Watson Lake had very few cranberries, while Mayo was nearly the same in 2012 and 2013. Mayo berry counts appear to be more consistent from year to year and lack the boom-bust dynamics of the other sites. There has been no repeat of the 2008 high cranberry counts in Whitehorse.

Figure 3. Average berry counts for 3 species of ground berries at CEMP sites from 2005 to 2013. Quadrat size is 40 by 40 cm. Error bars are 95% confidence intervals.

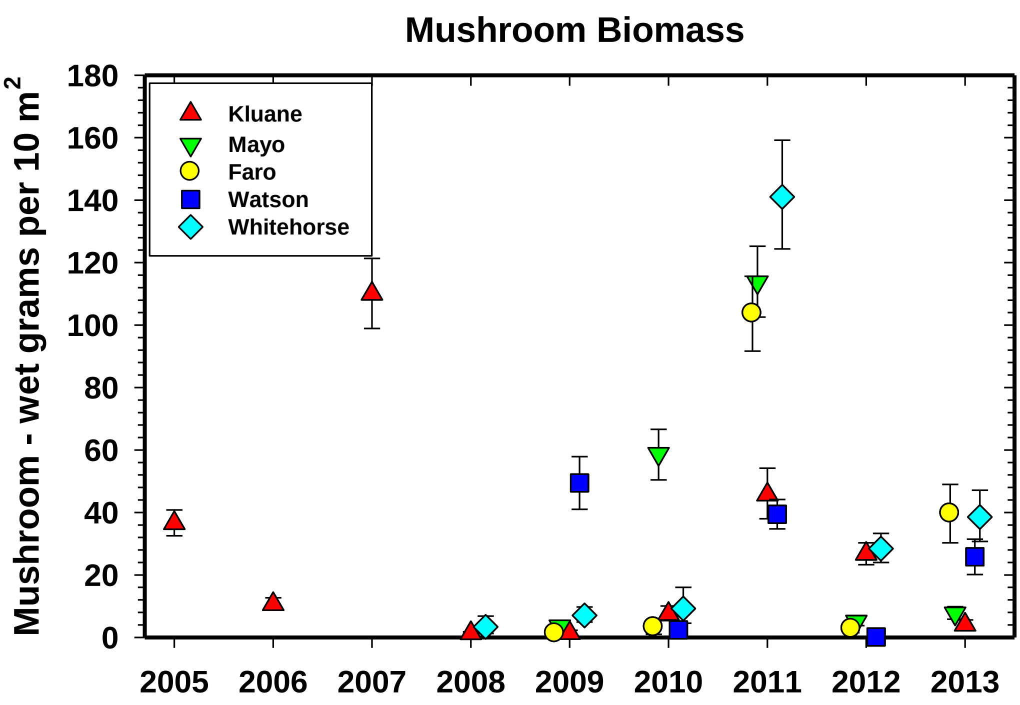


We have analyzed the climatic controls of ground berry production in the Kluane region from data gathered over 1994 to 2008 resulting in equations relating berry production to climate (Krebs et al. 2009). Each species of ground berry in the Kluane area responded to different signals of temperature and rainfall, and there was no general climate pattern to which all the species of ground berries responded. Future data will permit us to evaluate whether these predictive climatic equations that seem to operate well in the Kluane area also apply to the other CEMP sites. Our working hypothesis is that ground berries respond to regional 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) Mushroom Production

Since 2008 we have begun monitoring aboveground mushroom production on several of the CEMP sites. Data on mushroom production from Kluane Lake has been collected since 1995 and we have published a climate model to predict mushroom crops (Krebs et al. 2008). Figure 4 shows the aboveground biomass of mushrooms for the CEMP sites. Mushrooms were extremely abundant at all sites in 2011, but low in abundance in 2012 and low to moderate in 2013. Our statistical model for mushroom abundance uses June rainfall of the current year and May rainfall of the previous year to predict production. As we accumulate more data from all the CEMP sites in the next few years we will be able to test the climate model developed for Kluane to determine its generality for other sites in the southern and central Yukon.

Figure 4. Aboveground mushroom production measured in early August (g wet weight per 10 m^2). Mushroom production was low to moderate in 2013.



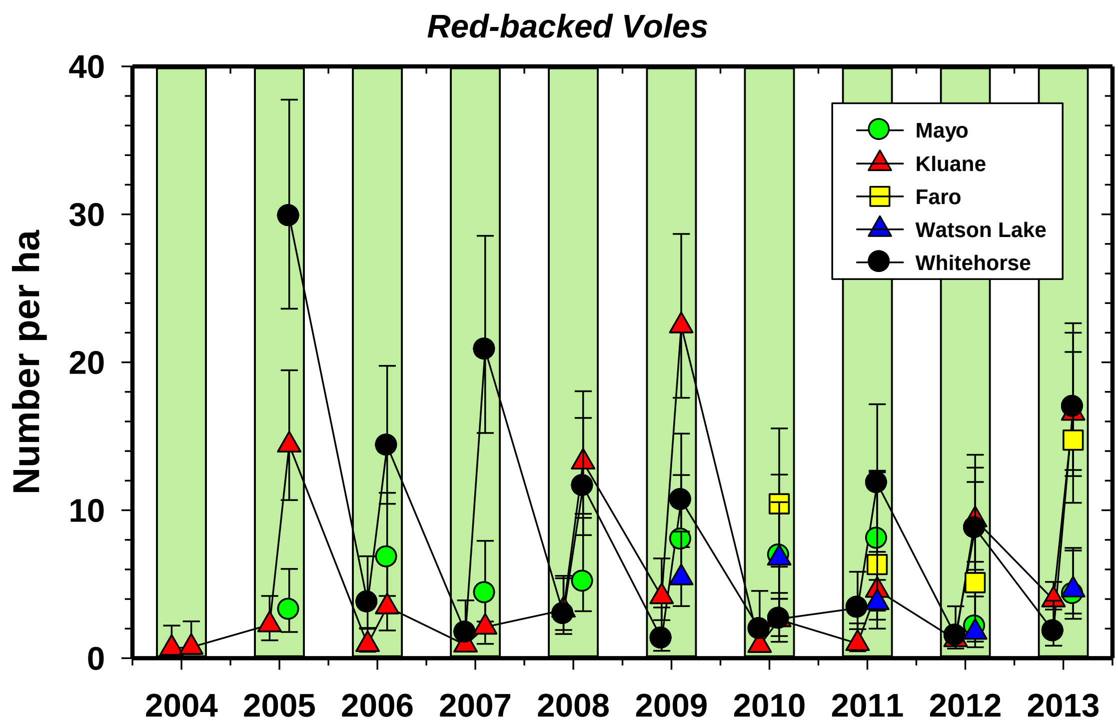
(d) Small Rodent Numbers

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 5 shows the changes in red-backed vole numbers for the period 2004 to 2012.

Red-backed voles at Kluane have fluctuated in 3-4 year cycles for the past 25 years and this pattern is shown in Figure 5 with peak years of 2005 and 2009. But Mayo populations have been nearly stable from 2005 to 2011, dropping to a low point in 2012. Whitehorse populations were extremely high in the late summer of 2005 and again in late summer 2007, moderately abundant in 2008 and 2009, at low ebb in 2010, and

Figure 5. Population estimates for red-backed voles in five CEMP areas, 2004-2013. 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 only late summer estimates.



rising again in the last 3 years. The pattern to date does not suggest any clear synchrony in fluctuations of red-backed vole numbers in the southern and central Yukon. Further data are needed to determine if this asynchrony continues in red-backed vole populations at the different CEMP sites in subsequent years.

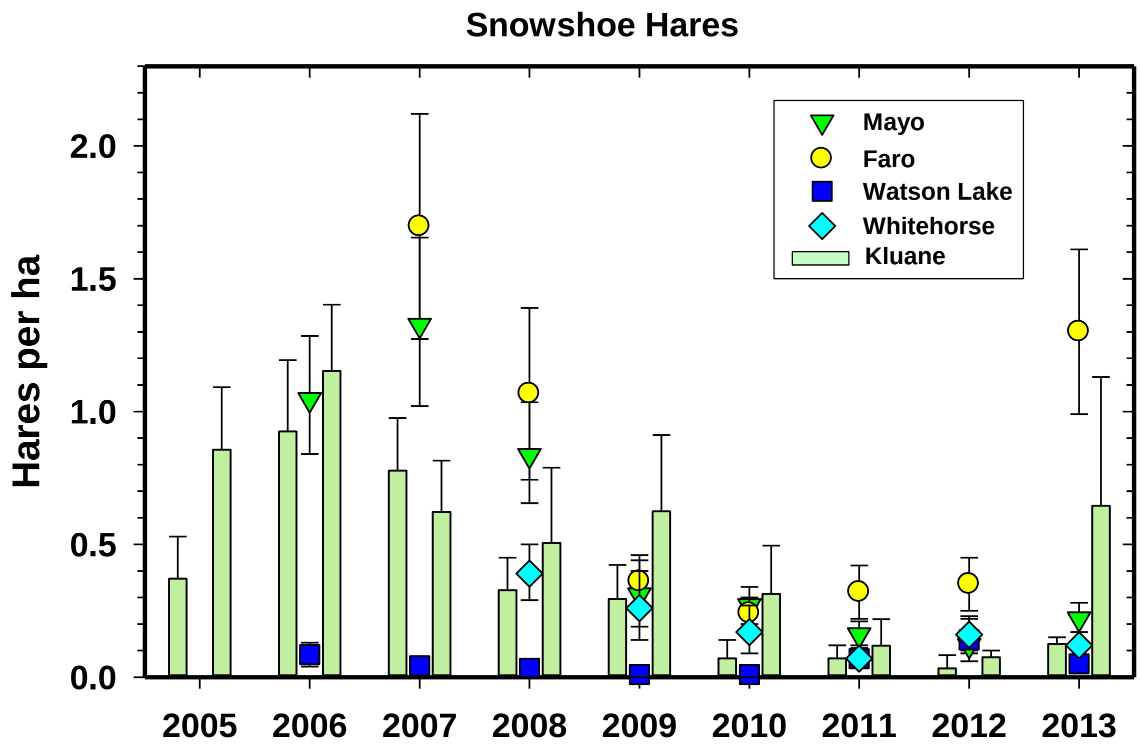
The only other small mammal that is common to many of the CEMP sites is the deer mouse, *Peromyscus maniculatus*. At present the number of captures of this rodent species is too low on most of the sites to discuss any common patterns of population change. Deer mice remained between 1-3 per ha on all sites from 2005 to 2012, and in general tend to be stable in numbers from year to year.

(e) 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 6 shows the changes in hare numbers since 2005 at the CEMP sites.

Two points stand out in Figure 6. First, Watson Lake sites had almost no snowshoe hares in any of the eight years for which we have data. There is clear natural history information for Watson Lake that the hare cycle exists, and we need to explore the possibility that the amplitude of the Watson Lake cycle is low relative to other Yukon sites. Second, all other CEMP sites are following the Kluane hare cycle closely, with peak populations in 2006-7 and declining populations in 2008, 2009, and 2010. The hare population at Kluane showed a strong increase over the summer of 2009, but this increase was trimmed back to low numbers by the spring of 2010, and the same pattern occurred in 2011 and 2012. The summer of 2013 showed increasing trends on most

Figure 6. Population density estimates for snowshoe hares in CEMP areas, 2005-2012. Mark-recapture data from Kluane are given as histogram bars, 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.



areas, suggesting that the increase phase of the hare cycle has begun. If this is the case the next hare peak should be in 2016.

Figure 6 shows that Mayo and Faro reached a peak in 2006-7 at the same time as Kluane. 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 are in phase. We have summarized the hare data from the Yukon, Alaska, northern BC and the NWT in Krebs et al. (2013). This analysis of regional synchrony strongly suggests a travelling wave of hare peaks that moves from northern BC into the Yukon and then north and west into Alaska. For example, in southern interior Alaska hare numbers were at a peak in 2008 and 2009, when Kluane and Mayo hares were declining. Inuvik populations were at a peak in 2009 when Mayo and Kluane hares had already finished declining. On the Kenai Peninsula hares were high in 2010 and at a peak in 2011, completely out of phase with Kluane and Mayo hares that were low.

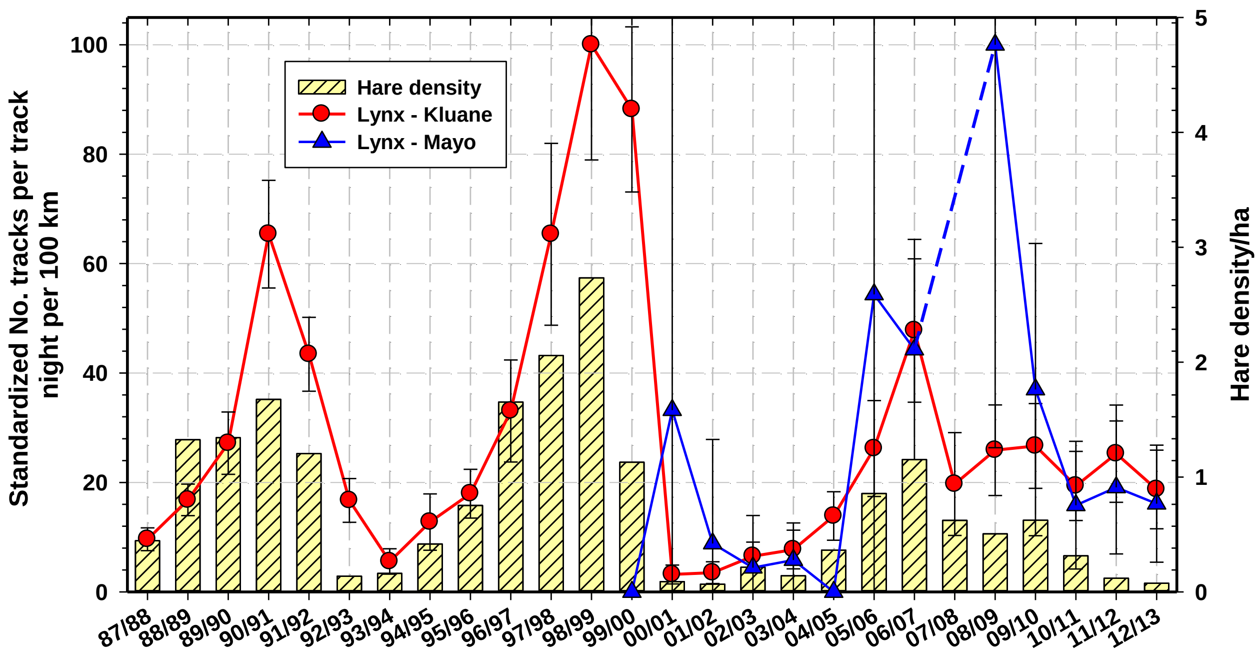
The significance of these regional differences in the hare cycle lies in the movements of predators like lynx and great-horned owls from one high hare area to adjacent ones that are low or starting to recover. The most promising explanation for regional synchrony involves predator movements, and depending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

(f) 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. 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.

Figure 8 shows the changes in abundance of lynx in Mayo and Kluane 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 .Consequently we have standardized track counts by setting the maximum count observed (per 100 km) in each area to 100 tracks per 100 km on Figure 8. Three points are quite striking in this graph. First, the

Figure 8. Snow tracking abundance estimates for Canada lynx at Kluane and Mayo, 1987 to 2013. Lynx abundance was standardized for each area to a maximum of 100 to indicate trends in numbers. Hare data are from Kluane in the autumn preceding the winter predator data.



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 5 years is higher than we have seen in a hare low previously. There are more lynx in the Kluane area during the last several years than could ever be supported on the existing hare population. These lynx must be transients headed for starvation or have been able to switch to alternate prey like red squirrels. We do not know which of these scenarios is correct but we suspect that they are feeding mainly on red squirrels. O'Donoghue et al. (1997) showed that radio-collared lynx moved up to 830 km from their home range once the hare cycle collapsed.

We also have snow tracking data for predators from Whitehorse, Faro, and Watson Lake. These data currently cover shorter time periods than those in Figure 8, and I list them in Table 1.

Table 1. Predator snow tracking data of Canada lynx for Whitehorse, Faro and Watson Lake. Data are lynx tracks per 100 km tracked with 1 S.E.

Region	Winter 2009-2010	Winter 2010-2011	Winter 2011-2012	Winter 2012-2013
Whitehorse			22.3 ± 8.1	23.0 ± 7.7
Faro	0.0[a]	3.7 ± 2.5	4.7 ± 3.5	1.54 ± 1.4
Watson Lake	8.0 ±	12.0 ± 3.7	6.8 ± 3.0	9.62 ± 4.9

[a] Based on 52 km of tracking, no lynx tracks found.

Lynx appear to be more abundant in the Whitehorse area than in the other CEMP sites and we will follow these apparent differences in the coming hare cycle. Lynx in the last three winters have been low at Faro and Watson Lake.

(g) Brief Notes on Other Monitoring Measurements

We are in the process of coordinating the monitoring at each of the five CEMP sites. Changes in personnel have complicated keeping the protocols for data collection in the field completely standardized. Fortunately 2012 was a time of improvement in coordination of the monitoring program, and in 2013 we were adjusting to the differences among the sites and the data needs of each site.

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 make this a challenge. In 2013 soapberries were at moderate to low abundance at Mayo but were abundant on bushes at Kluane and Whitehorse.

Red squirrel numbers have been studied extensively at Kluane for years by Stan Boutin's group, and we are evaluating the possibility of using midden counts or call counts as indices on the other CEMP sites.

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. More information is being gathered from the other CEMP monitoring sites on predator numbers by means of snow tracking 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.

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. This could be achieved with satellite radio collars or possibly by geolocators (Bachler et al. 2010, Stutchbury et al. 2009). 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 (the passive approach), to monitor changes and try to explain them ecologically, and to develop and use models which include climatic variables to predict what will happen (our active approach). Long-term data sets are essential to this endeavour and we learn as we go along from year to year.

(h) Local Knowledge Interviews

We summarize here a complementary set of data from Mark O'Donoghue gathered under another YTG program that involves local knowledge interviews in Mayo. Unfortunately these local knowledge data are not systematically obtained from other sites within the CEMP monitoring region. Mark O'Donoghue has summarized the data from these local knowledge interviews (O'Donoghue 2014). The strength of the local knowledge interviews is that they give insight into many environmental changes that we best monitor by local knowledge and on the impacts of these changes on rural people. They also place the results we find from our technical monitoring in the larger context of the whole regional landscape. Many examples are illustrated in the Mayo report – changes in the abundance of wolves, wolverine, moose and deer, as well as changes in the availability of fish and berries for the local population. Changes in winter ice conditions in relation to climate change can be evaluated, as well as general human impacts on wildlife. The summary taken from the Mayo document from interviews in February and March 2013 about conditions in the previous year illustrates the additional information that can be obtained by local knowledge interviews about a variety of topics of interest:

Most people interviewed noted that late winter and spring 2012 were about average with quite a bit of snowfall and wind, but overall average temperatures and rainfall. In general, people interviewed have said that most springs have been windier than usual during the past nine years. Most people interviewed noted that summer 2012 was an average year with a nice mix of sun and rain, not too windy, and with an average number of storms without too much lightning. June was the driest month of the summer. There was also less smoke in the air than in most summers.

Weather during the winter of 2012-13 was quite varied. November and December 2012 were cold with several cold snaps in the -50s and little snowfall. January and February 2013, however, were unseasonably warm with lots of snow.

Winds were average to above normal.

The past year 2012 saw an end to the latest boom in mining exploration and associated aircraft activity, although activities remained high in some areas. The use of ATVs and sport hunting also generally increased. Most people interviewed noted less highway tourism than usual for the fifth year in a row. Use of ATVs, sport hunting, and mining exploration caused the biggest concerns about their effects on wildlife and subsistence activities of all the activities considered. Most people interviewed thought that there were cumulative effects of all human activities on wildlife in the Mayo area.

Most people interviewed noted about the same number of spruce cones in 2012 compared to other years. The infestation of leaf miners in aspen trees continued to affect most trees in 2012, but it seemed less severe than at its peak in 2008. Most people interviewed noted at least a few more trees dying, and some birch trees also now seem to be affected. People interviewed varied in their responses about mushrooms in 2012. Generally, more mushrooms grow in wet years, and there was an average amount of rainfall in summer 2012, so mushroom crops varied locally.

Cranberries and blueberries are consistently the most frequently picked berries in the Mayo area but a wide variety of others including raspberries, strawberries, black and red currants, high-bush cranberries, cloudberries, soapberries, blackberries (crowberries), bearberries, bog cranberries, and Saskatoon berries are also picked. Half of the people interviewed who picked berries in 2012 did not meet their berry needs, mostly because of a very poor blueberry crop.

Four fish species—Chinook salmon, grayling, lake trout, and pike—are consistently the species most harvested in the Mayo area, but there has been a noticeable decline in the percentage of people fishing for salmon in recent years. In the last three years, more people have also been fishing for burbot (ling cod). Salmon are the main subsistence species for First Nations people, harvested using nets. The other species are harvested by angling and ice fishing. In 2012-13, six of the nine people interviewed who fished did not meet their fish needs, and said that a lack of enough salmon, low numbers of other fish, and lack of time to go fishing were the reasons they came up short. The percentage of people interviewed who have not been able to meet their fish needs has increased over the nine years of these interviews.

Moose are an important source of food for people in Mayo. Most hunters saw fewer moose and fewer bulls than usual in fall 2012; and the percentage of hunters seeing fewer animals has been increasing during the past nine years. We saw the highest percentage of hunters unable to meet their needs for moose in 2012 as well. Most moose harvested were in good shape. Low numbers of moose in the area, high numbers of other hunters, the warm weather in late September, and high predator numbers were listed as the main factors affecting numbers of moose seen. Most people noted that the timing of this year's rut was later than usual. Bulls seen were average sized to smaller than usual, as has been the case in the previous eight years. People interviewed saw relatively few calves in the fall compared to what they usually see.

Similar to 2011-2012, most people interviewed noted that they had seen more or the same numbers of spruce and ruffed grouse in the last year compared to other years. Most people saw the same number or fewer ptarmigan and blue grouse. As in most years, people interviewed gave variable responses about the number of ducks and geese they saw in 2012, depending on where they spent their time on the land. Most thought that numbers of ducks had stayed the same or decreased and that numbers of geese had stayed the same. Numbers of swans and cranes stayed the same or increased, consistent with the trend we've seen the past few years.

Numbers of kestrels are declining throughout North America. Most people interviewed saw few or some kestrels in 2012 and most felt that there were about the same number of birds compared to other years.

Numbers of rusty blackbirds have declined by about 85% since the mid-1960s in North America. Most people interviewed saw few blackbirds in 2012, but some people saw some or lots, especially people spending time along the rivers. Most people saw about the same number as in previous years. These birds are most frequently seen in the spring and fall when they are grouping for migration.

We also asked people interviewed about the numbers and trends in numbers of common bird species—chickadees and gray jays—so that we have a baseline to compare their trends with those of the species of concern. People interviewed consistently saw some or lots of chickadees and gray jays in all years and mostly indicated they saw about the same numbers from year to year.

Most people interviewed saw lots of mice and voles and saw about the same number or more than the year before. This is the second year in a row of abundant mice and voles in the Mayo area. Most people interviewed reported seeing some or lots of red squirrels in 2012-13, and the same number as the year before. Red squirrels do not seem to have declined much in response to two years of cone crop failure after the boom year in spruce cones in 2010.

Numbers of hares seem to have started to increase again in the region, although there are localised spots where there are still very few or no animals. The last cyclical peak in hare numbers was around 2006. People interviewed were mixed in their observations of number of muskrats, and fewer people reported increasing numbers compared to the past two years. Most people interviewed saw about the same number of beavers as usual in 2012-2013. As in other years, Talbot Creek and several others were identified as being blocked for fish movements by beaver dams. Most people interviewed reported that they had seen lots of and more porcupines in 2012-13, maintaining the high numbers we have seen since 2004.

Most people interviewed saw some marten in 2012-2013, but numbers seemed to vary locally and there was no widespread increase as was seen in 2011-2012. Most people interviewed said there were few or some wolverines during the past year and most thought numbers had stayed about the same or declined compared to the year before that. There were some local hotspots of activity though. Most people interviewed said there were some or lots of weasels and that that they had seen about the same number as the previous year. Weasel numbers mostly respond to numbers of mice and voles which have been good in the Mayo area for the past two years. People interviewed saw few or some lynx, and their numbers seem to be starting to increase in some places in response to rising numbers of hares. However, the increase in hare numbers is slow and numbers of lynx remain low or have declined in some other local areas. Relatively few coyotes are seen in most years in the Mayo area. People interviewed gave variable responses as to how many coyotes they had seen in 2012-2013 and most thought numbers had stayed about the same or declined since the previous year.

This year, nine of the people interviewed trapped. Most trappers had difficulty getting access to their lines early in the season because of a lack of snow and cold temperatures, while deep snow and warm temperatures in January-February also caused some difficulties. Lynx numbers were low and marten numbers varied by area, so a number of trappers found animals hard to find. However, the price of fur was the best it has been in years and this helped compensate for the difficult conditions.

These local knowledge interviews can help to provide the larger picture of changes in Yukon's ecosystems as the climate continues to warm and thus complement the data we are gathering in the CEMP program.

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 9 years of data, our conclusions to date must be tentative, but we have a firm foundation for coordinating these regional data sets. We need to proceed to answer two 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, mushroom abundance (Figure 4) can vary greatly between sites, yet snowshoe hare numbers (Figure 6) 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 and precipitation data that will apply across all CEMP sites?

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.

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References Cited

Bächler, E., S. Hahn, M. Schaub, R. Arlettaz, L. Jenni, J.W. Fox, V. Afanasyev, and F. Liechti. 2010. Year-round tracking of small Trans-Saharan migrants using light-level geolocators. *PLoS One 5.*

Krebs, C.J., R. Boonstra, V.O. Nams, M. O'Donoghue, K.E. Hodges, and S. Boutin. 2001. Estimating snowshoe hare population density from pellet plots: a further evaluation. *Canadian Journal of Zoology* **79**:1-4.

Krebs, C.J., S. Boutin and R. Boonstra (editors). 2001. *Ecosystem Dynamics of the Boreal Forest: The Kluane Project.* Oxford University Press. Oxford, England. 511 pp.

Krebs, C.J., Carrier, P., Boutin, S., Boonstra, R., and Hofer, E.J. 2008. Mushroom crops in relation to weather in the southwestern Yukon. *Botany* **86**: 1497-1502.

Krebs, C.J., Boonstra, R., Cowcill, K. and Kenney, A.J. 2009. Climatic determinants of berry crops in the boreal forest of the southwestern Yukon. *Botany* **87**: 401-408.

Krebs, C.J., Cowcill, K., Boonstra, R., and Kenney, A.J. 2010. Do changes in berry crops drive population fluctuations in small rodents in the southwestern Yukon? *Journal of Mammalogy* **91**(2): 500-509.

Krebs, C.J., LaMontagne, J.M., Kenney, A.J., and Boutin, S. 2012. Climatic determinants of white spruce cone crops in the boreal forest of the southwestern Yukon. Botany **90**(2): 113-119.

Krebs, C.J., Kielland, K., Bryant, J., O'Donoghue, M., Doyle, F., McIntyre, C., DiFolco, D., Berg, N., Carrier, S., Boonstra, R., Boutin, S., Kenney, A.J., Bodony, K., Putera, J., and Burke, T. 2013. Synchrony in the Snowshoe Hare Cycle in Northwestern North America, 1970-2012. *Canadian Journal of Zoology* **91**: 562-572.

O'Donoghue, M., S. Boutin, C. J. Krebs, and E. J. Hofer. 1997. Numerical responses of coyotes and lynx to the snowshoe hare cycle. *Oikos* **80**:150-162.

O'Donoghue, M. 2014. Mayo Community Ecological Monitoring Project Local Knowledge Interviews: 2012-2013 Summary. Available from mark.odonoghue@gov.yk.ca.

Stutchbury, B.J.M., S.A. Tarof, T. Done, E. Gow, P.M. Kramer, J. Tautin, J.W. Fox, and V. Afanasyev. 2009. Tracking long-distance songbird migration by using geolocators. *Science* **323**: 896-897.