KRSP Cone Counts

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Figure 1: Caption

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## Warning: package 'dplyr' was built under R version 3.4.4
## Warning: package 'tidyr' was built under R version 3.4.4
## Warning: package 'knitr' was built under R version 3.4.3
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To Do

1. Format the Count_date field in cone-counts.csv consistently.

Motivation

The goals of this document are to:

1. Provide consistent and transparent calculations of cone abundance that can be used by KRSP personnel for their research.
2. Explain the different ways that cone abundance can be reported, so we can be consistent in our terminology and usage.
3. Provide code that will allow us to easily update data summaries when new data become available.

NOTE that key KRSP citations are inlcluded within this document.

Spruce seed as food for red squirrels

A large proportion of the diet of red squirrels is composed on the seeds of white spruce cones (Fletcher et al. 2013) and the production of spruce cones has been documented to flutuate widely from one year to the next (LaMontagne and Boutin 2007; Krebs et al. 2012). Since 1989 we have been measuring the number of cones produced by many trees throughout the study areas as a measure of the availability of food resources for that year.

Protocol

This protocol is described and calibrated in LaMontagne et al. (2005).

Cones are counted at grid stations when they are fully formed and visible but harvesting by squirrels has not yet begun (usually mid-July to Aug 10). This was initially started in collaboration with the Kluane Boreal Forest Ecosystem Project. On Sulphur, Lloyd, Joe, and Agnes, cone counts are performed at hare trapping stations. On Kloo, and Chitty a different sampling scheme is used (e.g., Kloo –3 to J, odd #s between 1-12). Refer to the cone file or sheets in the grid binders for locations. At each station, the closest spruce tree to the grid stake that has a DBH greater than 5 cm should already be marked with red flagging (and usually have CONE COUNT written on the flagging). Use the recorded DBH from previous years to help relocate trees that do not have flagging on them.

Count the number of new cones in the top 3 metres (10 ft) of the tree using a pair of binoculars and estimate the percent cover of cones from a location where you have a clear view of one side of the tree. If any datum is missing, enter it as "-1" in the computer file. Beginning in 2009, the number of old cones (cones from previous years that are open but still on the tree in the top three metres.

If the total number of cones exceeds 100, take a photograph of the top of the tree using a telephoto lens, ensuring that the contrast and lighting is optimal. This was originally done with a telephoto lens, with cones counted from the photograph using a magnifying glass and fine black marker to keep track of those cones already counted (or prick cones with a pin and count the pin pricks on the reverse). In recent years this has been done with a digital camera. Detailed instructions for extracting cone count data from digital photographs is provided below (see Taking Photographs).

IMPORTANT Special Note about Cone Counts in 1989

Note that no data were recorded in 1989 because there were no cones on any trees (observed in the field). In 2016, McAdam entered data for 1989 as all zero cones for all trees on KL and SU that were counted in 1990. It is important to note that these data were not collected in the field for each individual tree. Instead it was obserevd that there were no cones on any tree in 1989 and no cone counts were performed. It is worth noting that in 2015 there were also zero cones on all 561 trees counted.

Meta-Data

Variables:

Grid - Study are from which the data were collected

Year - Year in which the data were collected

Stake - Grid stake closest to the tree (not collected in all years)

LocX - Grid location for the tree

LocY - Grid location for the tree

DBH - Diameter at breast hieght (cm) for the tree. Not updated each year.

Distance - Distance of the tree from the grid stake.

Direction - Direction of the tree from the grid stake.

Per - Percent cover of cones in top 3m of tree

New_Tree (Y/N) - Is this a new tree counted for the first time?

Status - Bark beetle status (Need coding here)

Count_Date - Date on which the cones were counted (this field needs to be formatted consistently)

NumNew - Number of cones in top 3m of tree

Comments - Comments

#Number of Cone Count Observations Per Year

Year	AG	CH	JO	KL	LL	SU
1988	NA	NA	NA	133	NA	83
1989	NA	NA	NA	144	NA	87
1990	NA	NA	NA	143	NA	87
1991	83	86	NA	168	79	85
1992	84	84	NA	164	74	86
1993	83	86	NA	167	79	86
1994	86	86	NA	166	86	86
1995	85	86	NA	168	86	85
1996	NA	NA	NA	168	86	86
1997	NA	NA	NA	167	78	86
1998	NA	NA	NA	84	78	86

Year	AG	CH	JO	KL	LL	SU
1999	NA	NA	NA	84	78	86
2000	NA	NA	NA	84	85	86
2001	NA	NA	NA	85	85	86
2002	NA	NA	NA	85	86	86
2003	NA	NA	NA	85	86	86
2004	NA	NA	NA	84	86	86
2005	126	NA	183	84	86	86
2006	126	127	200	84	86	86
2007	126	127	200	84	86	86
2008	126	127	200	84	86	86
2009	126	125	187	84	149	86
2010	126	126	192	81	147	86
2011	126	126	185	84	145	86
2012	122	76	190	84	102	77
2013	125	80	190	84	102	83
2014	126	81	85	80	102	79
2015	126	81	85	84	102	83
2016	126	81	85	84	102	83
2017	126	100	85	84	102	86

Cone Count Measurements

Cone counts can be reported in three possible ways:

1. Raw counts as observed in the field.
2. Cones Index - ln-transformed cone counts (ln[x+1] transformed).
3. Counts of the actual number of cones per tree.

1. Raw Cone Counts

These are the raw cone counts as recorded in the field and entered in the datafile. These should be referred to as '*cone counts*'. For example, 'The average number of spruce cones counted per tree was 126.'. These are the raw data but I am not aware of any specific case where these data are particularly useful. They are just an index of the number of cones on each tree and are also not statistically very well behaved. In the `cone-counts.csv` file the raw cone counts are represented by the `NumNew` variable. Historically only new cones were counted as `Num`. Between 2009 and 2015, new cones and old cones were differentiated as `NumNew` and `NumOld`.

Year	AG	CH	JO	KL	LL	SU
1988	NA	NA	NA	51.782	NA	38.711
1989	NA	NA	NA	0.000	NA	0.000
1990	NA	NA	NA	41.322	NA	28.379
1991	0.795	1.581	NA	1.452	4.139	0.153
1992	67.560	39.631	NA	100.768	70.824	51.442
1993	7.241	12.081	NA	300.497	159.152	140.965
1994	3.814	6.500	NA	1.801	1.279	0.558
1995	82.271	151.047	NA	133.875	100.302	77.400
1996	NA	NA	NA	82.054	19.953	55.279
1997	NA	NA	NA	52.431	37.141	25.186
1998	NA	NA	NA	343.155	293.910	225.105

Year	AG	CH	JO	KL	LL	SU
1999	NA	NA	NA	60.524	13.064	8.674
2000	NA	NA	NA	2.298	1.271	1.767
2001	NA	NA	NA	27.459	14.576	12.337
2002	NA	NA	NA	49.353	33.953	21.349
2003	NA	NA	NA	12.765	10.105	4.721
2004	NA	NA	NA	15.060	9.372	10.209
2005	0.278	NA	240.093	207.869	23.035	113.581
2006	6.635	2.803	0.090	1.452	6.535	1.128
2007	42.214	39.803	14.270	38.536	70.488	15.663
2008	2.294	5.102	8.620	12.083	2.605	3.058
2009	11.683	13.232	22.674	29.250	28.718	12.535
2010	231.063	264.865	396.151	415.765	492.823	269.651
2011	0.032	1.111	0.011	0.024	0.317	0.047
2012	10.820	30.289	15.489	39.595	31.118	12.429
2013	16.512	54.625	29.242	46.810	46.520	20.627
2014	138.571	304.457	260.918	345.587	316.235	79.797
2015	0.000	0.000	0.000	0.000	0.000	0.000
2016	1.563	3.654	0.294	1.143	3.961	1.542
2017	20.817	19.150	15.682	21.429	31.245	15.465

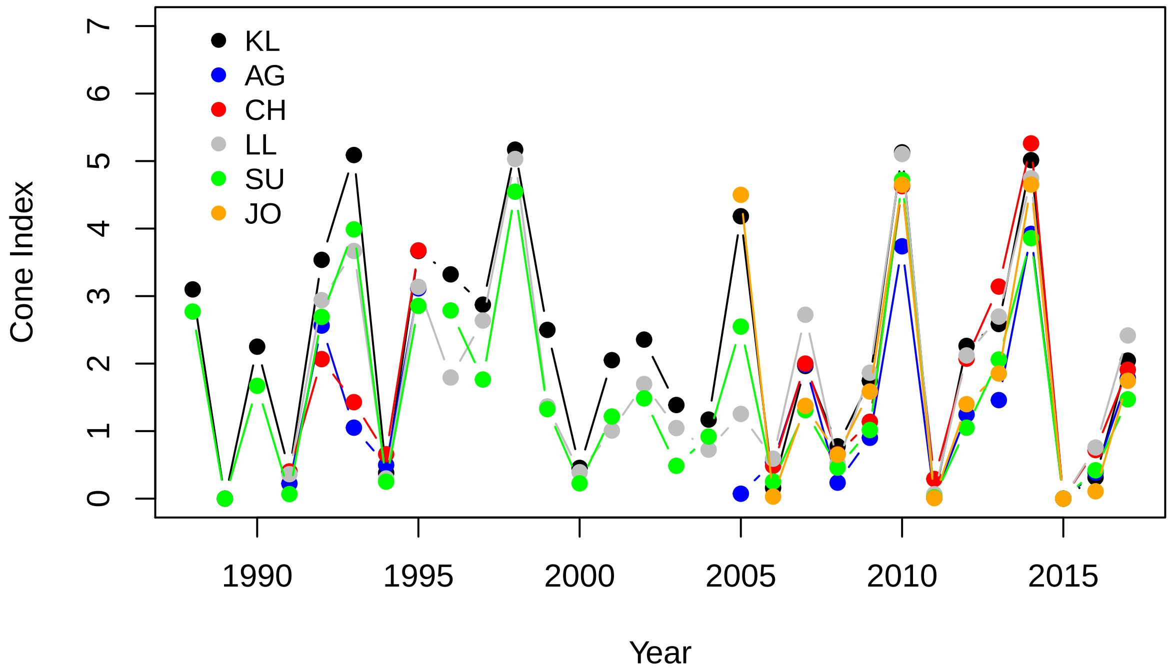
2. Cone Index

The '*cone index*' is a simple transformation of the *cone count*. The raw *cone count* data are ln (x+1) transformed. In R the notation for the natural logarithm is `log()`. 1 is added to each observation before transforming to make an observation of 0 identifiable.

The *cone index*, is truly an index of cone abduance, so it does not have a direct biological interpretation. Also, since the index is on a log scale it can be hard to assess the magnitude of effects and readers are often not impressed by the magnitude of mast events when the data are depicted on this scale. Despite these limitations, these data are statistically very well behaved (normally distributed), so **this is the best measure to include in statistical analyses (i.e. as a predictor of some aspect of red squirrel biology)**.

Year	AG	CH	JO	KL	LL	SU
1988	NA	NA	NA	3.099	NA	2.771
1989	NA	NA	NA	0.000	NA	0.000
1990	NA	NA	NA	2.251	NA	1.671
1991	0.223	0.403	NA	0.396	0.362	0.067
1992	2.563	2.066	NA	3.537	2.940	2.692
1993	1.051	1.429	NA	5.089	3.668	3.988
1994	0.497	0.658	NA	0.380	0.298	0.250
1995	3.114	3.677	NA	3.668	3.137	2.855
1996	NA	NA	NA	3.322	1.794	2.787
1997	NA	NA	NA	2.873	2.637	1.764
1998	NA	NA	NA	5.169	5.031	4.546
1999	NA	NA	NA	2.499	1.365	1.326
2000	NA	NA	NA	0.455	0.391	0.226
2001	NA	NA	NA	2.051	1.008	1.216
2002	NA	NA	NA	2.355	1.697	1.485
2003	NA	NA	NA	1.387	1.045	0.486
2004	NA	NA	NA	1.171	0.725	0.919

Year	AG	CH	JO	KL	LL	SU
2005	0.072	NA	4.500	4.183	1.255	2.548
2006	0.536	0.487	0.030	0.159	0.591	0.253
2007	1.984	2.000	1.374	1.965	2.724	1.310
2008	0.236	0.658	0.651	0.775	0.521	0.458
2009	0.900	1.138	1.586	1.746	1.865	1.016
2010	3.737	4.629	4.650	5.130	5.104	4.720
2011	0.013	0.291	0.007	0.017	0.065	0.019
2012	1.245	2.073	1.399	2.262	2.121	1.050
2013	1.459	3.141	1.854	2.586	2.696	2.060
2014	3.922	5.262	4.652	5.014	4.745	3.858
2015	0.000	0.000	0.000	0.000	0.000	0.000
2016	0.385	0.719	0.108	0.314	0.757	0.420
2017	1.784	1.909	1.746	2.045	2.416	1.471



3. Total Number of Cones Per Tree

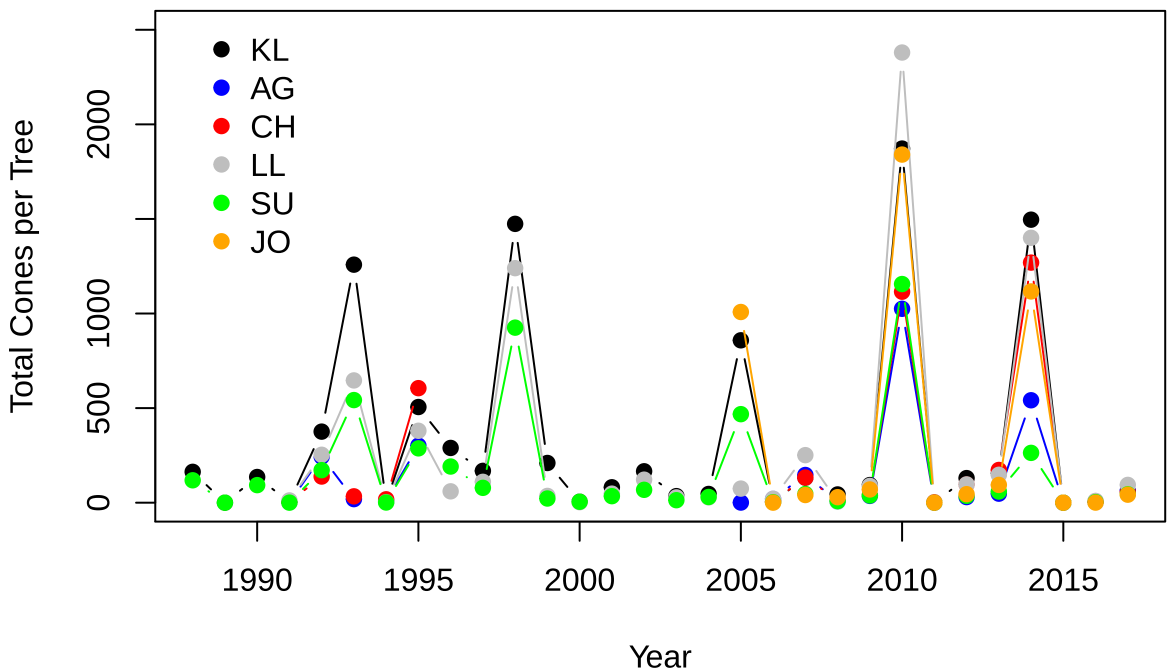
Krebs et al. (2012) provide an equation for converting cone counts to *total number of cones per tree* based on the calibration from LaMontagne et al. (2005).

This is the biologically most relevant measure of cone production and is useful for depicting how dramatic the mast years are on an intuitove scale, but these data are very skewed both within and across years so they can be tricky to include in statistical models.

$$TotalNumberOfCones = 1.11568 * exp(0.1681 + 1.1891 * log(ConeCount + 0.01))$$

Year	AG	CH	JO	KL	LL	SU
1988	NA	NA	NA	163.023	NA	118.379
1989	NA	NA	NA	0.006	NA	0.006

Year	AG	CH	JO	KL	LL	SU
1990	NA	NA	NA	135.653	NA	92.826
1991	1.667	3.299	NA	3.110	11.970	0.262
1992	243.550	138.272	NA	375.681	253.320	171.999
1993	18.822	33.523	NA	1258.262	646.303	542.483
1994	9.997	17.921	NA	4.057	2.750	0.935
1995	301.518	605.391	NA	505.712	380.214	287.222
1996	NA	NA	NA	289.393	59.990	191.163
1997	NA	NA	NA	168.252	110.229	78.474
1998	NA	NA	NA	1474.074	1239.813	925.272
1999	NA	NA	NA	209.839	35.797	22.025
2000	NA	NA	NA	5.344	2.627	4.918
2001	NA	NA	NA	81.405	47.697	34.465
2002	NA	NA	NA	165.992	121.599	68.024
2003	NA	NA	NA	34.665	27.981	13.203
2004	NA	NA	NA	46.097	28.211	30.067
2005	0.598	NA	1008.143	858.347	74.580	468.052
2006	20.146	6.726	0.177	3.929	20.622	2.426
2007	146.429	132.811	40.555	132.088	251.370	45.728
2008	6.509	13.650	29.193	43.465	6.024	8.211
2009	35.893	39.582	69.829	93.163	88.634	38.197
2010	1024.966	1115.418	1840.246	1871.957	2379.756	1155.840
2011	0.060	2.353	0.020	0.037	0.707	0.085
2012	29.754	96.543	44.948	129.998	96.650	36.241
2013	47.753	172.953	93.921	152.574	147.401	59.005
2014	541.498	1269.146	1116.737	1496.201	1400.280	263.342
2015	0.006	0.006	0.006	0.006	0.006	0.006
2016	3.372	8.206	0.537	2.342	9.065	3.118
2017	62.975	55.116	42.411	60.190	93.937	44.479



Annual measures across all grids

In many instances we are not interested in grid-specifc cone abundances but only in annual values. Here I will compile the annual average cone count, cone index and total cones across all six grids (AG, CH, JO, KL, LL, SU). Note that this is potentially problematic because as you can see from the figure of GridYear averages there is considereable variation in cone production among grids in some years (e.g. low cones on AG and CH in 2005).

Year	num_trees	cone_counts	cone_index_t	cone_index_tm1	total_cones	mast
1988	216	46.759	2.973	NA	145.868	n
1989	231	0.000	0.000	2.973	0.006	n
1989	0	0.000	0.000	2.973	0.006	n
1990	230	36.426	2.031	0.000	119.453	n
1990	230	36.426	2.031	0.000	119.453	n
1991	501	1.569	0.307	2.031	3.817	n
1992	492	71.535	2.882	0.307	258.582	n
1993	501	152.733	3.379	2.882	623.326	y
1994	510	2.635	0.411	3.379	6.650	n
1995	510	113.096	3.352	0.411	430.911	n
1996	340	59.574	2.800	3.352	206.521	n
1997	331	41.749	2.529	2.800	131.253	n
1998	248	286.730	4.910	2.529	1210.085	y
1999	248	27.617	1.736	4.910	89.971	n
2000	255	1.776	0.357	1.736	4.295	n
2001	256	18.102	1.424	0.357	54.444	n
2002	257	34.829	1.844	1.424	118.354	n
2003	257	9.183	0.971	1.844	25.247	n
2004	256	11.520	0.936	0.971	34.703	n
2005	565	129.526	2.674	0.936	536.873	y
2006	709	2.808	0.312	2.674	8.096	n
2007	709	33.673	1.821	0.312	112.939	n
2008	709	5.872	0.554	1.821	18.713	n
2009	757	20.053	1.406	0.554	61.883	n
2010	758	353.377	4.642	1.406	1614.605	y
2011	752	0.263	0.069	4.642	0.560	n
2012	651	21.539	1.632	0.069	66.169	n
2013	664	33.703	2.182	1.632	106.023	n
2014	553	235.996	4.531	2.182	993.275	y
2015	561	0.000	0.000	4.531	0.006	n
2016	561	2.043	0.454	0.000	4.484	n
2017	583	20.906	1.902	0.454	60.916	n

Annual measures for KL and SU only

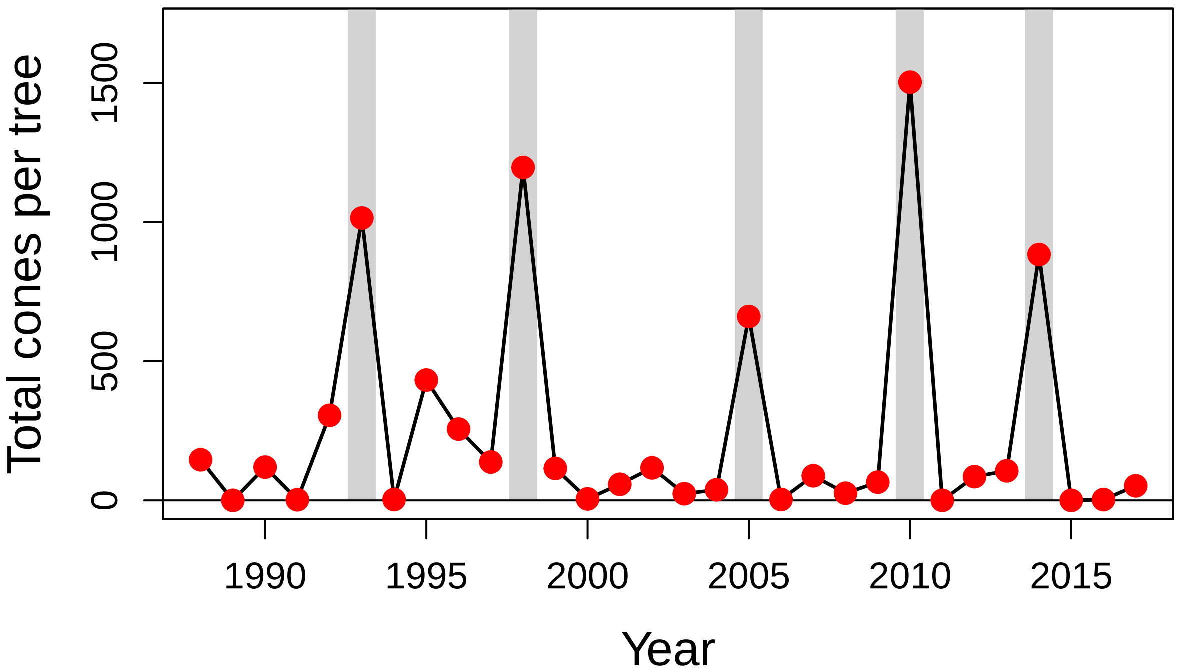
We often are interested in only the long-term control grids in which case the average cone abundance on KL and SU is probably the best measure.

Year	num_trees	cone_counts	cone_index_t	cone_index_tm1	total_cones	mast
1988	216	46.759	2.973	NA	145.868	n
1989	231	0.000	0.000	2.973	0.006	n
1990	230	36.426	2.031	0.000	119.453	n

Year	num_trees	cone_counts	cone_index_t	cone_index_tm1	total_cones	mast
1991	253	1.016	0.285	2.031	2.153	n
1992	250	83.800	3.246	0.285	305.615	n
1993	253	246.269	4.715	3.246	1014.954	y
1994	252	1.377	0.336	4.715	2.992	n
1995	253	114.901	3.395	0.336	432.306	n
1996	254	72.988	3.141	3.395	256.134	n
1997	253	43.170	2.496	3.141	137.734	n
1998	170	283.435	4.854	2.496	1196.445	y
1999	170	34.294	1.906	4.854	114.827	n
2000	170	2.029	0.339	1.906	5.129	n
2001	171	19.854	1.631	0.339	57.798	n
2002	171	35.269	1.917	1.631	116.722	n
2003	171	8.719	0.934	1.917	23.872	n
2004	170	12.606	1.043	0.934	37.988	n
2005	170	160.171	3.356	1.043	660.904	y
2006	170	1.288	0.207	3.356	3.168	n
2007	170	26.965	1.633	0.207	88.400	n
2008	170	7.518	0.615	1.633	25.631	n
2009	170	20.794	1.377	0.615	65.357	n
2010	167	340.521	4.919	1.377	1503.178	y
2011	170	0.035	0.018	4.919	0.062	n
2012	161	26.602	1.683	0.018	85.158	n
2013	167	33.796	2.325	1.683	106.070	n
2014	159	213.528	4.440	2.325	883.648	y
2015	167	0.000	0.000	4.440	0.006	n
2016	167	1.341	0.367	0.000	2.727	n
2017	170	18.412	1.754	0.367	52.242	n

Plot for Presentations

I often use the following plot for presentations. I will display this plot in the PDF as well as exporting a PDF of the plot alone.




```
## pdf
##   2
```

Taking Photographs

Photographs need to be high resolution and clear in order to be able to count cones from them. This means that photos should be taken from a location where the top of the tree is clearly visible and with the sun shining on that side of the tree. Back-lit or poorly lit photos will be extremely difficult to count. Adjust the settings on the camera so that the file name is visible on the image once the picture is taken. Write the file name in your data book on the cone count for trees with more than 100 cones visible from one side.

Practice taking a few unofficial photos and try counting cones on them following the protocol below to get a sense of the appropriate settings for the clearest image. Counting Cones from Digital Images ImageJ is probably the easiest program for counting cones from digital images. The software can be downloaded from http://rsbweb.nih.gov/ij/. Make sure that the "Cell Counter" plugin is installed. If not, it can be obtained from http://rsb.info.nih.gov/ij/plugins/cell-counter.html.

1. Open the ImageJ software.
2. Open the digital image (File>Open>) making sure you are opening the correct image (always check which folder the image is in, since photo names are not individually unique, e.g. CHP2 is a photo in both the Pre harvest folder and the Post harvest folder).
3. Open the "Cell Counter" plugin (Plugins>Analyze>Cell counter)
4. Click "Initialize" (you only need to do this once to get started on a photo, don't click it again while counting cones in the same photo or it will reset everything).
5. Rotate the photo if necessary (Image>Rotate).
6. Some photos may have trees in the background, count only the tree in the center of the photo, but make a comment in the data file indicating there was more than 1 tree in the photo.
7. The photo should be zoomed in or out to get the appropriate magnification so that cones can be clearly seen (Image>Zoom>In).
8. Select counter "Type 1".
9. Click once on each visible OLD OPENED CONE in the photo. Each click will add one to the running tally of the total number of cones on the photo and will add a mark to the image so that you know the

cone has been counted.

10. To delete an unwanted mark simply select the "Delete Mode" check box. When selected, clicking a mark will delete it. To go back to counting cones unclick the "Delete mode" check box. Alternatively you can also click on the "Delete" button, but this will only delete the last marker that was added.
11. Then select counter "Type 2".
12. Click once on each visible NEW CONE in the photo (as above).
13. To move the photo around once it's zoomed in to see other areas of the tree, click on the hand tool in the Image J toolbar. To go back to the cell counter click on the rectangle in the Image J toolbar.
14. When you have counted all of the cones on the image, record the total tally for old (Type 1) and new cones (Type 2) in the designated excel file along with the date and your initials (observer).
15. When you are done counting cones for the day, backup your excel file in the backup folder in the 2010 cone photos folder on the desktop. Save the excel file with the date in the file name, e.g. Ariel 2010 Cone picture counts Nov 1.docx.

Key References

Fletcher, Quinn E, Manuelle Landry-Cuerrier, Stan Boutin, Andrew G McAdam, John R Speakman, and Murray M Humphries. 2013. "Reproductive timing and reliance on hoarded capital resources by lactating red squirrels." *Oecologia* 173 (4): 1203–15.

Krebs, C J, J.M. LaMontagne, A J Kenney, and Stan Boutin. 2012. "Climatic determinants of white spruce cone crops in the boreal forest of southwestern Yukon." *Botany* 90 (2): 113–19.

LaMontagne, Jalene M, and Stan Boutin. 2007. "Local-scale synchrony and variability in mast seed production patterns of Picea glauca." *Journal of Ecology* 95 (5): 991–1000.

LaMontagne, Jalene M, Susan Peters, and Stan Boutin. 2005. "A visual index for estimating cone production for individual white spruce trees." *Canadian Journal of Forest Research* 35 (June): 3020–6.