From: A J
To: Grizzle, Betty
Subject: Re: Snow in Swedish denning site
Date: Wednesday, April 26, 2017 2:49:56 PM

A very young wolverine could have had a January birth. This den is quite unusual and may not actually be a den. It may have been a place where she moved her kit temporarily on the way to a new den. So hard to tell with these old accounts. The hunters may have begun digging up a den and the female moved the kit as a consequence. It is unlikely that she would have kept the kit there very long.

On Wed, Apr 26, 2017 at 11:50 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Thanks for sending the photo and den information.
>
> Just a follow-up to this message. I noticed in Pulliainen's (1968) discussion of wolverine dens in Finland, that at least one was reported as not having any snow (pp. 340, 342). I don't see an exact date (looks like the roman numerals represent month, so this would be January), but, from his summary (see below), it appears to be a very young wolverine.
>
> "*Den No 25*. I. 1950. Savukoski, Naltiotunturi. One unsexed blind cub was found at the butt of a spruce in a spruce peat-bog (about 3 km from the nearest fell). There was no snow at the butt of the tree. The cub was covered by spruce brush. The lowest spruce twigs were covered with snow. Many tracks of a female wolverine were seen around the spruce. (Onni Mukkala)"
>
> On Tue, Apr 18, 2017 at 3:58 PM, A J <222wsheridan@gmail.com> wrote:
>
>> Jens is standing just above an occupied wolverine den under boulders; note how little snow is on the ground and boulders; kits verified on camera; this is in Early March
>>
>> Sent from my iPhone
>
> --
>
> Betty J. Grizzle, D.Env.
> Fish and Wildlife Biologist
> U.S. Fish and Wildlife Service
> Carlsbad Fish and Wildlife Office
> 2177 Salk Ave, Suite 250
> Carlsbad, CA 92008
> 760-431-9440, ext. 215

760-431-5901 fax

From:	Inman, Bob
To:	Grizzle, Betty; 222wsheridan@gmail.com
Subject:	RE: Looking for wolverine photo
Date:	Thursday, April 27, 2017 10:46:19 AM
Attachments:	F121 & Cubs credit M. Packila Montana.JPG

You are welcome to use this one, credit Mark Packila. A female with 2 young from sw Montana. I have a note out to a guy who has some really good new photos too. We will have a bunch from the survey if that is of interest.

-Bob Inman

Robert M. Inman, PhD
Carnivore-Furbearer Coordinator
Montana Fish, Wildlife and Parks
1420 East 6th Ave., PO Box 200701,
Helena, MT 59620-0701
406-444-0042 (o)
406-570-5326 (c)
bobinman@mt.gov

From: Grizzle, Betty [mailto:betty_grizzle@fws.gov]
Sent: Wednesday, April 26, 2017 12:14 PM
To: 222wsheridan@gmail.com; Inman, Bob <bobinman@mt.gov>
Subject: Looking for wolverine photo

Hi Bob and Audrey - I am writing to ask if either of you has a nice adult wolverine photo that our agency can add to the cover of our Species Status Assessment Report. We will add a photo credit, but we need to have permission for its use in our administrative record.
No rush, however.

Thank you,
Betty
--

Betty J. Grizzle, D.Env.
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
Carlsbad Fish and Wildlife Office
2177 Salk Ave, Suite 250
Carlsbad, CA 92008
760-431-9440, ext. 215
760-431-5901 fax

From:	Grizzle, Betty
To:	Inman, Bob
Cc:	222wsheridan@gmail.com
Subject:	Re: Looking for wolverine photo
Date:	Thursday, April 27, 2017 10:51:36 AM

Thanks Bob! Very nice. I like this one because it also shows their habitat.

On Thu, Apr 27, 2017 at 9:45 AM, Inman, Bob <bobinman@mt.gov> wrote:

> You are welcome to use this one, credit Mark Packila. A female with 2 young from sw Montana. I have a note out to a guy who has some really good new photos too. We will have a bunch from the survey if that is of interest.
>
> -Bob Inman
>
> Robert M. Inman, PhD
>
> Carnivore-Furbearer Coordinator
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> bobinman@mt.gov
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> **From:** Grizzle, Betty [mailto:betty_grizzle@fws.gov]
> **Sent:** Wednesday, April 26, 2017 12:14 PM
> **To:** 222wsheridan@gmail.com; Inman, Bob <bobinman@mt.gov>
> **Subject:** Looking for wolverine photo
>
> Hi Bob and Audrey - I am writing to ask if either of you has a nice adult wolverine photo that our agency can add to the cover of our Species Status Assessment Report. We will add a photo credit, but we need to have permission for its use in our administrative record.

> No rush, however.
>
> Thank you,
>
> Betty
>
> --
>
> Betty J. Grizzle, D.Env.
>
> Fish and Wildlife Biologist
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760-431-9440, ext. 215
760-431-5901 fax

From:	Guinotte, John
To:	Kevin Doherty
Subject:	Fwd: Update on Wolverine
Date:	Friday, April 28, 2017 4:27:46 PM
Attachments:	MODIS_Elevation_with_Den_Elevs_May1_June1.png MODIS_Elevation_with_Den_Elevs_May1_May15.png SCA_1500-2300mband_MODIS_timeseries_May1_May15.png MODIS_snowcovered_areas_elevation_and_aspect_analysis.xlsx

Hey Kevin, I haven't looked at this yet. Maybe you and I can regroup on Monday on this.

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

---------- Forwarded message ----------
From: **Joe Barsugli** <joseph.barsugli@noaa.gov>
Date: Fri, Apr 28, 2017 at 4:12 PM
Subject: Update on Wolverine
To: "Guinotte, John" <john_guinotte@fws.gov>
Cc: Andrea Ray <Andrea.Ray@noaa.gov>

John,

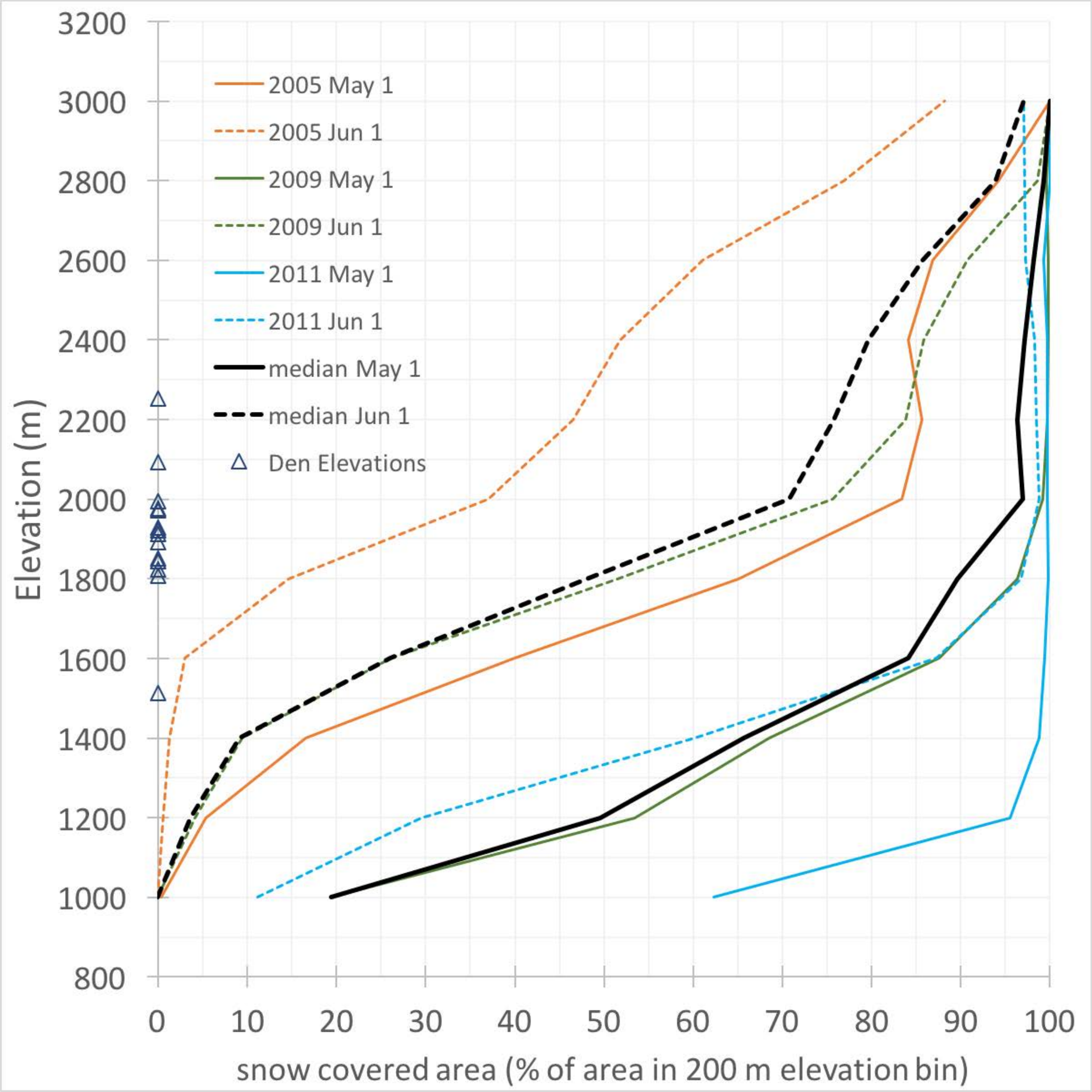
I've still been fighting this respiratory thing off an on -- so haven't been able to work on this as much as I had hoped. Candida gave me the spreadsheet by elevation and I produced some new plots. I am also attaching the spreadsheet of MODIS snow covered area by elevation band and by aspect sector as this will allow more flexibility if you wanted to delve in to this data at some later date.

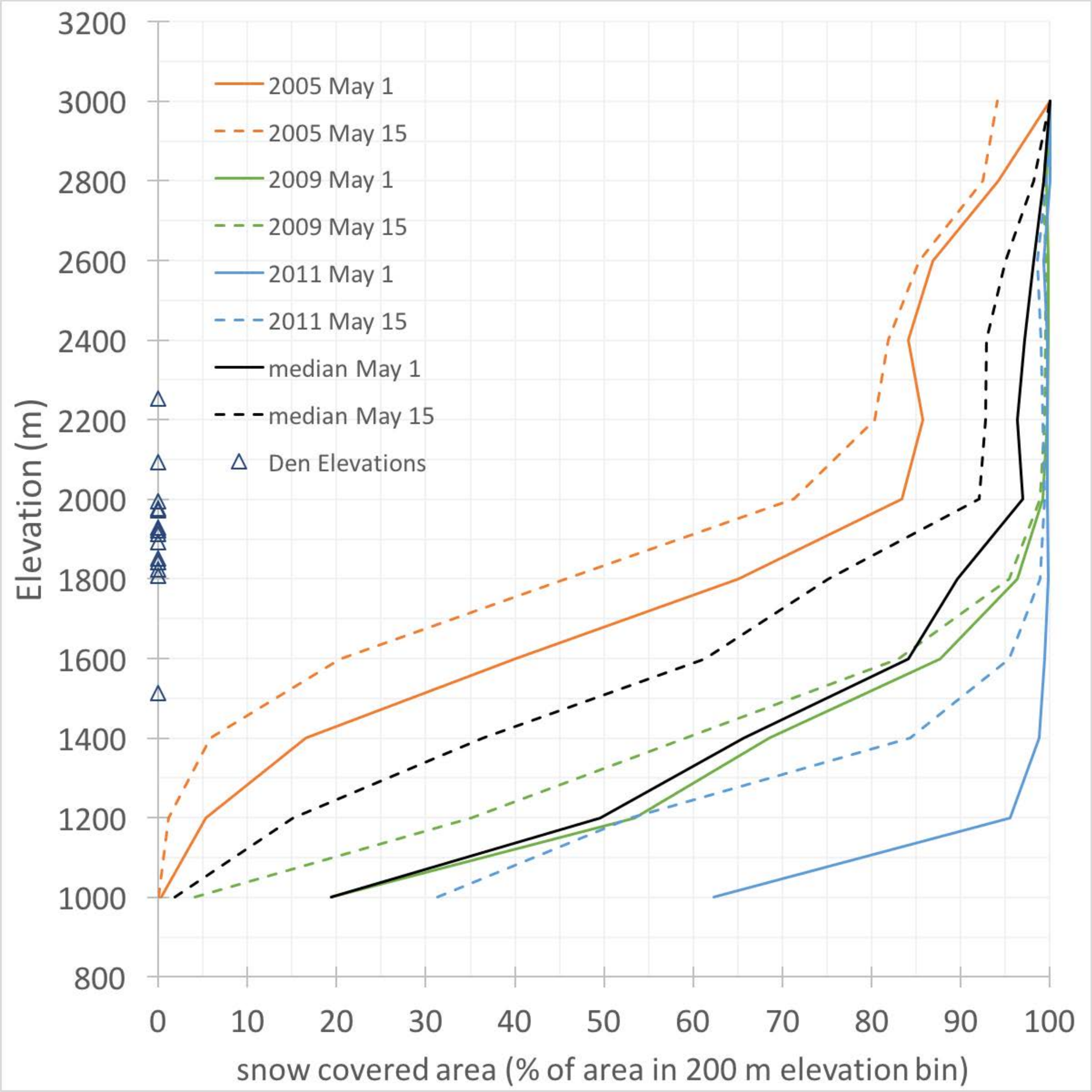
Here are some of the graphics you were interested in for the MODIS analysis.   The Area v. Elevation plot was redone with two options regarding the calendar date that is chosen. IN the first, "May1_June1" is as before.   As you suggested, I redid this for May1 and May 15 instead of June1.   There is really only room on this plot for two target dates. Keep in mind that this is the MODIS product that only detects the presence/absence of snow. One reason we chose June 1 initially is that a snow disappearance date of June 1 or later indicates substantial snow earlier in May (or else the replenishment of snow by snowfall during May).

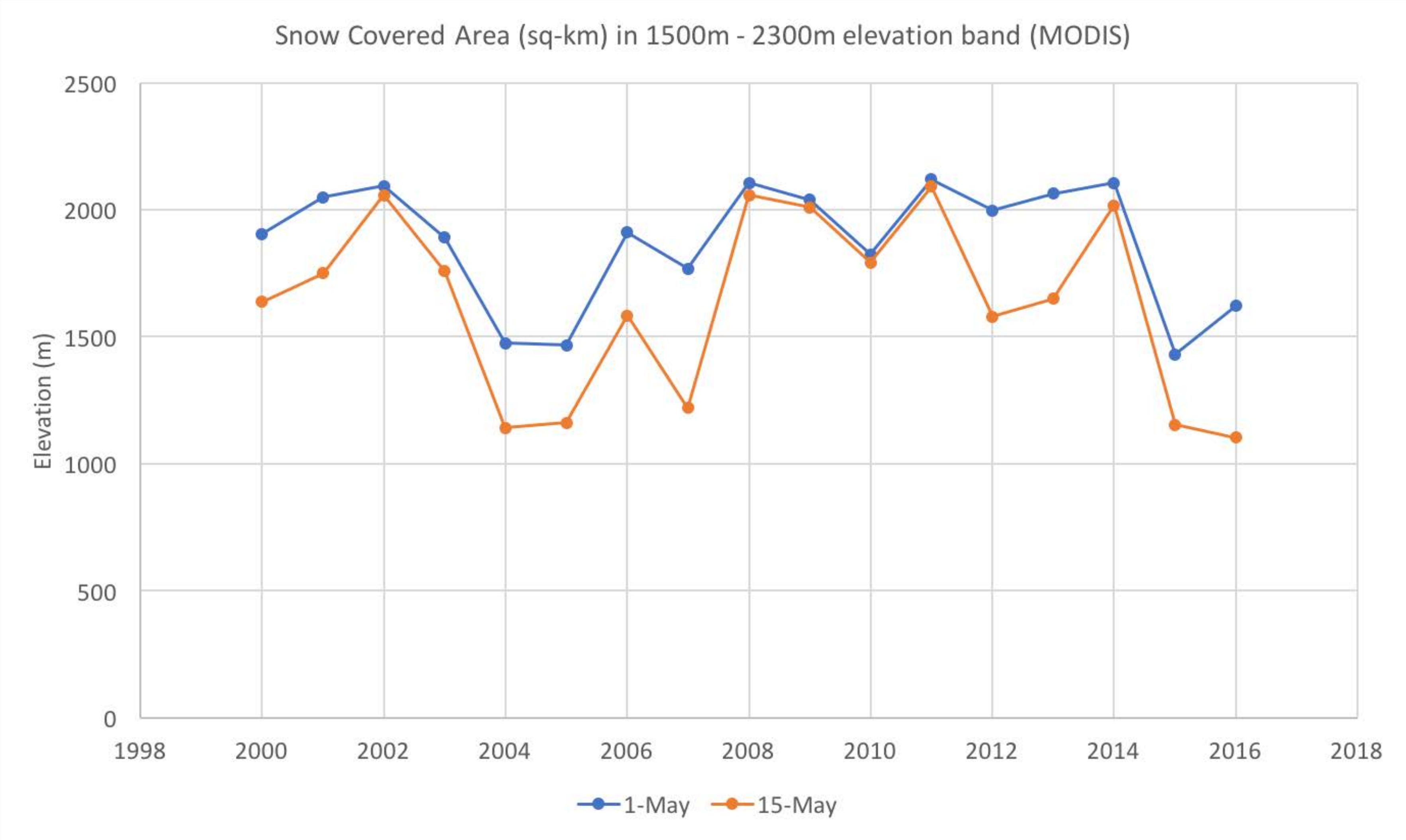
I am also attaching the spreadsheet of MODIS snow covered area by elevation band and by aspect sector as this will allow more flexibility if you wanted to delve in to this data at some later date.

Joe

--
Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309
303-497-6042
PSD Science Board and
Attribution and Predictability Assessments Team Member


3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
Elevation (m)
0
10
20
30
40
50
60
70
80
90
100
snow covered area (% of area in 200 m elevation bin)
2005 May 1
2005 Jun 1
2009 May 1
2009 Jun 1
2011 May 1
2011 Jun 1
median May 1
median Jun 1
Den Elevations


2005 May 1
2005 May 15
2009 May 1
2009 May 15
2011 May 1
2011 May 15
median May 1
median May 15
Den Elevations
Elevation (m)
snow covered area (% of area in 200 m elevation bin)
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
0
10
20
30
40
50
60
70
80
90
100


Snow Covered Area (sq-km) in 1500m - 2300m elevation band (MODIS)
2500
2000
1500
1000
500
0
Elevation (m)
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
1-May
15-May

total area		elevation bin	May 1 2000	2001	2002	2003
16,750,000	**1**	**1000**	4.94	5.44	5.63	2.63
112,562,496	**2**	**1200**	62.31	75.63	90.81	43.63
282,437,504	**3**	**1400**	201.50	239.38	259.19	166.50
482,312,512	**4**	**1600**	405.56	453.25	468.19	373.50
589,437,504	**5**	**1800**	525.56	573.56	583.31	519.31
599,312,512	**6**	**2000**	555.37	582.75	593.50	564.81
456,375,008	**7**	**2200**	419.00	439.50	449.50	433.50
256,624,992	**8**	**2400**	235.06	245.00	253.06	246.56
85,687,504	**9**	**2600**	80.38	81.88	85.06	83.13
17,312,500	**10**	**2800**	16.69	16.19	17.19	17.00
2,125,000	**11**	**3000**	1.94	2.00	2.13	2.13
			2,441.06	**2,633.50**	**2,711.13**	**2,406.44**
		1500-2300	1,905.50	2,049.06	2,094.50	1,891.12
16.75	**1**	**1000**	29.48	32.46	33.58	15.67
112.56	**2**	**1200**	55.36	67.18	80.68	38.76
282.44	**3**	**1400**	71.34	84.75	91.77	58.95
482.31	**4**	**1600**	84.09	93.97	97.07	77.44
589.44	**5**	**1800**	89.16	97.31	98.96	88.10
599.31	**6**	**2000**	92.67	97.24	99.03	94.24
456.38	**7**	**2200**	91.81	96.30	98.49	94.99
256.62	**8**	**2400**	91.60	95.47	98.61	96.08
85.69	**9**	**2600**	93.80	95.55	99.27	97.01
17.31	**10**	**2800**	96.39	93.50	99.28	98.19
2.13	**11**	**3000**	91.18	94.12	100.00	100.00

total area		elevation bin	May 15 2000	2001	2002	2003
16,750,000	**1**	**1000**	1.13	0.69	4.06	0.75
112,562,496	**2**	**1200**	29.88	23.75	52.50	21.69
282,437,504	**3**	**1400**	116.94	103.25	209.50	118.88
482,312,512	**4**	**1600**	300.69	295.38	438.94	299.25
589,437,504	**5**	**1800**	442.75	478.56	577.00	473.56
599,312,512	**6**	**2000**	508.06	551.88	593.00	553.69
456,375,008	**7**	**2200**	385.06	423.25	449.44	431.00
256,624,992	**8**	**2400**	216.88	237.19	253.00	245.88
85,687,504	**9**	**2600**	76.50	81.31	85.06	83.13
17,312,500	**10**	**2800**	16.44	16.19	17.19	17.00
2,125,000	**11**	**3000**	1.94	2.00	2.13	2.13

			2,065.25	**2,189.00**	**2,625.25**	**2,224.50**
		1500-2300	1,636.56	1,749.06	2,058.38	1,757.50
16.75	**1**	**1000**	6.72	4.10	24.25	4.48
112.56	**2**	**1200**	26.54	21.10	46.64	19.27
282.44	**3**	**1400**	41.40	36.56	74.18	42.09
482.31	**4**	**1600**	62.34	61.24	91.01	62.04
589.44	**5**	**1800**	75.11	81.19	97.89	80.34
599.31	**6**	**2000**	84.77	92.08	98.95	92.39
456.38	**7**	**2200**	84.37	92.74	98.48	94.44
256.62	**8**	**2400**	84.51	92.43	98.59	95.81
85.69	**9**	**2600**	89.28	94.89	99.27	97.01
17.31	**10**	**2800**	94.95	93.50	99.28	98.19
2.13	**11**	**3000**	91.18	94.12	100.00	100.00

total area		**elevation**	**Jun 1**			
		bin	**2000**	**2001**	**2002**	**2003**
16,750,000	**1**	**1000**	0.50	0.13	1.94	0.00
112,562,496	**2**	**1200**	8.13	4.44	30.19	5.00
282,437,504	**3**	**1400**	34.00	6.69	125.69	25.88
482,312,512	**4**	**1600**	125.81	35.25	318.38	125.44
589,437,504	**5**	**1800**	275.19	139.12	494.12	283.19
599,312,512	**6**	**2000**	382.75	261.00	565.06	424.25
456,375,008	**7**	**2200**	301.12	225.25	437.00	345.62
256,624,992	**8**	**2400**	166.62	127.19	247.62	196.19
85,687,504	**9**	**2600**	61.56	49.31	84.69	70.25
17,312,500	**10**	**2800**	14.75	12.19	17.19	16.63
2,125,000	**11**	**3000**	1.94	1.88	2.13	2.13
			1,363.75	**857.87**	**2,291.88**	**1,489.56**
		1500-2300	1,084.87	660.62	1,814.56	1,178.50
16.75	**1**	**1000**	2.99	0.75	11.57	0.00
112.56	**2**	**1200**	7.22	3.94	26.82	4.44
282.44	**3**	**1400**	12.04	2.37	44.50	9.16
482.31	**4**	**1600**	26.09	7.31	66.01	26.01
589.44	**5**	**1800**	46.69	23.60	83.83	48.04
599.31	**6**	**2000**	63.86	43.55	94.29	70.79
456.38	**7**	**2200**	65.98	49.36	95.75	75.73
256.62	**8**	**2400**	64.93	49.56	96.49	76.45
85.69	**9**	**2600**	71.85	57.55	98.83	81.98
17.31	**10**	**2800**	85.20	70.40	99.28	96.03
2.13	**11**	**3000**	91.18	88.24	100.00	100.00

Den Elevations	x-position	Den Elevations
1514	0	1514
1807	0	1807
1823	0	1823
1843	0	1843
1851	0	1851
1893	0	1893
1912	0	1912
1922	0	1922
1928	0	1928
1973	0	1973
1977	0	1977
1995	0	1995
2093	0	2093
2252	0	2252

Elevation (m

1500-2300m Snow Covered Area (MODIS)

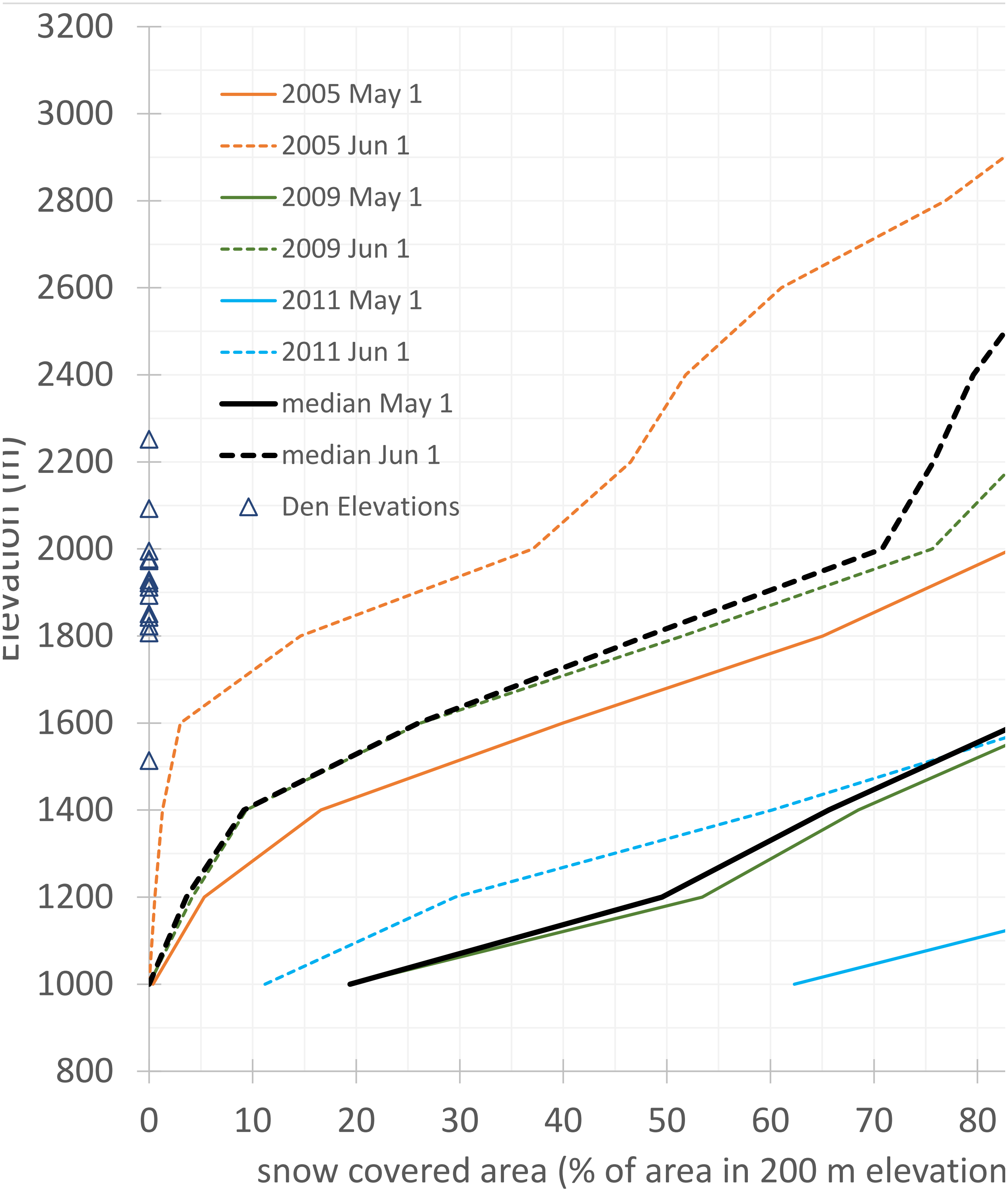
	2000	**2001**	**2002**	**2003**
1-May	1905.50	2049.06	2094.50	1891.12
15-May	1636.56	1749.06	2058.38	1757.50
1-Jun	1084.875	660.625	1814.563	1178.500

2004	2005	2006	2007	2008	2009	2010
0.50	0.06	2.50	1.88	8.69	3.25	0.69
10.69	6.00	34.13	34.88	101.50	60.13	29.38
57.56	46.81	148.44	127.31	273.50	193.44	121.50
204.81	192.69	360.50	314.00	473.69	422.62	319.31
382.00	383.50	528.12	468.50	583.56	567.69	498.00
494.50	499.75	581.00	553.56	595.63	594.19	567.50
392.81	391.06	441.69	432.75	453.38	454.81	438.88
222.25	215.88	249.44	248.69	253.50	256.19	248.75
78.06	74.44	83.13	83.38	84.88	85.50	84.69
16.38	16.31	17.00	17.19	17.31	17.25	17.06
2.06	2.13	2.13	2.13	2.13	2.13	2.06
1,850.44	**1,822.56**	**2,411.44**	**2,247.50**	**2,737.56**	**2,593.81**	**2,297.75**
1,474.13	1,467.00	1,911.31	1,768.81	2,106.25	2,039.31	1,823.69
2.99	0.37	14.93	11.19	51.87	19.40	4.10
9.49	5.33	30.32	30.98	90.17	53.41	26.10
20.38	16.57	52.56	45.08	96.84	68.49	43.02
42.46	39.95	74.74	65.10	98.21	87.62	66.20
64.81	65.06	89.60	79.48	99.00	96.31	84.49
82.51	83.39	96.94	92.37	99.38	99.14	94.69
86.07	85.69	96.78	94.82	99.34	99.66	96.17
86.60	84.12	97.20	96.91	98.78	99.83	96.93
91.10	86.87	97.01	97.30	99.05	99.78	98.83
94.58	94.22	98.19	99.28	100.00	99.64	98.56
97.06	100.00	100.00	100.00	100.00	100.00	97.06

2004	2005	2006	2007	2008	2009	2010
0.00	0.00	0.25	0.00	6.13	0.69	0.31
4.13	1.31	7.00	4.25	82.63	39.50	17.06
20.69	16.56	55.75	27.88	250.00	167.00	102.94
114.00	98.69	214.81	127.94	450.00	400.44	300.06
273.56	269.12	416.31	297.75	568.50	562.31	487.75
411.06	427.00	533.62	437.69	588.81	592.37	565.88
341.69	366.81	418.44	356.31	449.50	453.50	438.38
196.88	210.12	238.44	207.31	250.44	255.31	248.00
73.75	73.13	81.44	73.88	83.81	85.25	84.38
16.25	16.00	17.00	16.81	17.19	17.19	17.06
2.06	2.00	2.13	2.13	2.13	2.13	2.06

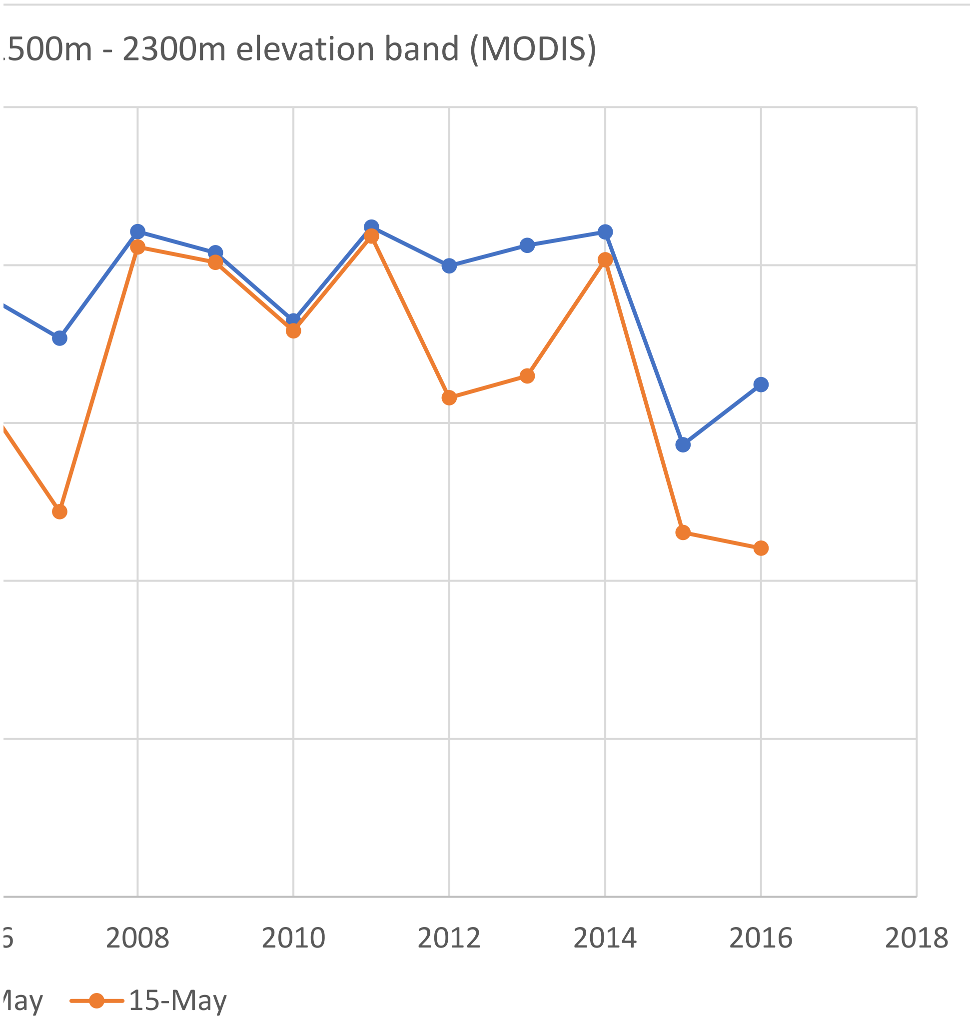
1,449.94	**1,479.44**	**1,977.94**	**1,547.69**	**2,660.37**	**2,535.50**	**2,246.50**
1,140.31	1,161.63	1,583.19	1,219.69	2,056.81	2,008.62	1,792.06
0.00	0.00	1.49	0.00	36.57	4.10	1.87
3.66	1.17	6.22	3.78	73.40	35.09	15.16
7.32	5.86	19.74	9.87	88.52	59.13	36.45
23.64	20.46	44.54	26.53	93.30	83.02	62.21
46.41	45.66	70.63	50.51	96.45	95.40	82.75
68.59	71.25	89.04	73.03	98.25	98.84	94.42
74.87	80.38	91.69	78.07	98.49	99.37	96.06
76.72	81.88	92.91	80.78	97.59	99.49	96.64
86.07	85.34	95.04	86.21	97.81	99.49	98.47
93.86	92.42	98.19	97.11	99.28	99.28	98.56
97.06	94.12	100.00	100.00	100.00	100.00	97.06

2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
0.00	0.00	0.00	0.00	0.38	0.00	0.06
2.75	0.63	1.81	2.44	12.38	4.69	8.69
13.00	3.63	11.56	7.50	67.44	26.50	56.25
95.94	14.56	77.44	43.31	210.00	126.31	200.62
251.69	86.13	228.56	167.62	400.75	303.62	382.88
392.69	222.12	384.25	314.06	526.25	453.25	515.56
335.75	212.19	321.12	284.62	418.75	382.31	418.06
195.94	133.00	182.06	170.06	234.44	220.25	239.50
73.44	52.31	65.63	65.75	81.00	77.75	83.31
16.25	13.31	15.50	16.13	17.19	17.06	16.69
2.06	1.88	2.00	2.13	2.13	2.13	2.06
1,376.75	**739.12**	**1,288.12**	**1,071.19**	**1,957.94**	**1,609.19**	**1,914.94**
1,076.06	535.00	1,011.37	809.62	1,555.75	1,265.50	1,517.12
0.00	0.00	0.00	0.00	2.24	0.00	0.37
2.44	0.56	1.61	2.17	10.99	4.16	7.72
4.60	1.28	4.09	2.66	23.88	9.38	19.92
19.89	3.02	16.06	8.98	43.54	26.19	41.60
42.70	14.61	38.78	28.44	67.99	51.51	64.96
65.52	37.06	64.12	52.40	87.81	75.63	86.03
73.57	46.49	70.36	62.37	91.76	83.77	91.61
76.35	51.83	70.94	66.27	91.35	85.83	93.33
85.70	61.05	76.59	76.73	94.53	90.74	97.23
93.86	76.90	89.53	93.14	99.28	98.56	96.39
97.06	88.24	94.12	100.00	100.00	100.00	97.06



3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
2005 May 1
2005 Jun 1
2009 May 1
2009 Jun 1
2011 May 1
2011 Jun 1
median May 1
median Jun 1
Den Elevations
0
10
20
30
40
50
60
70
80
snow covered area (% of area in 200 m elevation

2004	2005	2006	2007	2008	2009	2010
1474.13	1467.00	1911.31	1768.81	2106.25	2039.31	1823.69
1140.31	1161.63	1583.19	1219.69	2056.81	2008.62	1792.06
1076.063	535.000	1011.375	809.625	1555.750	1265.500	1517.125

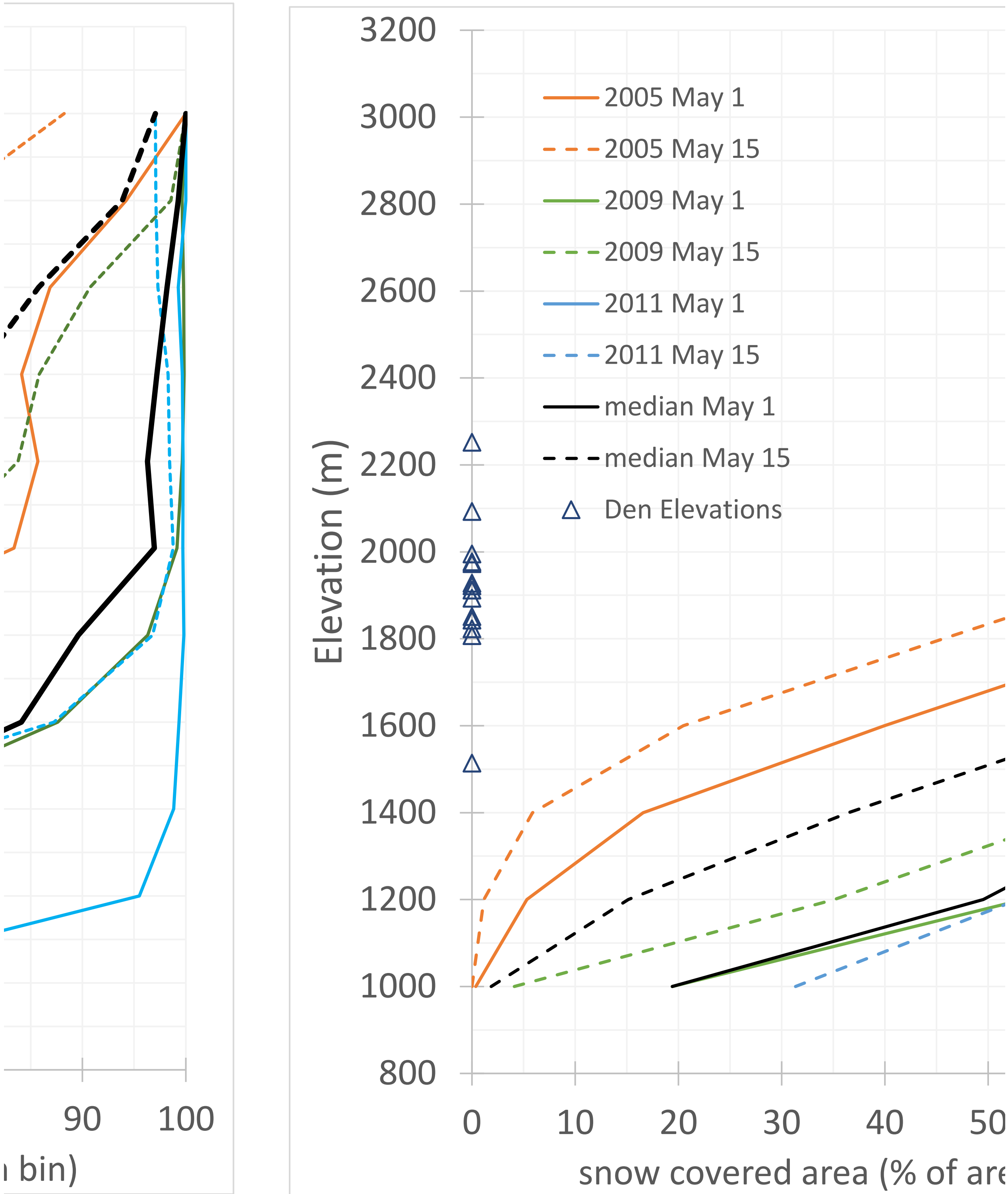


2011	2012	2013	2014	2015	2016	median
10.44	4.63	6.75	5.06	0.06	0.38	3.25
107.50	55.75	60.13	81.56	5.19	9.81	55.75
279.12	185.38	210.75	256.44	27.13	55.06	185.38
479.19	411.19	442.62	470.81	139.81	215.12	405.56
588.31	553.37	572.19	585.37	348.50	422.19	528.12
597.50	586.69	594.75	595.75	514.31	548.37	581.00
455.12	446.19	452.94	453.50	428.94	435.75	439.50
255.75	251.81	254.00	254.06	246.12	250.12	249.44
85.06	84.13	84.88	84.81	85.06	83.94	84.13
17.31	17.25	17.25	17.31	17.31	16.69	17.19
2.13	2.13	2.13	2.13	2.13	2.13	2.13
2,759.50	**2,538.12**	**2,631.50**	**2,720.19**	**1,809.31**	**2,029.37**	**2441.06**
2,120.13	1,997.44	2,062.50	2,105.44	1,431.56	1,621.44	1,954.19
62.31	27.61	40.30	30.22	0.37	2.24	19.40
95.50	49.53	53.41	72.46	4.61	8.72	49.53
98.83	65.63	74.62	90.79	9.60	19.50	65.63
99.35	85.25	91.77	97.62	28.99	44.60	84.09
99.81	93.88	97.07	99.31	59.12	71.63	89.60
99.70	97.89	99.24	99.41	85.82	91.50	96.94
99.73	97.77	99.25	99.37	93.99	95.48	96.30
99.66	98.12	98.98	99.00	95.91	97.47	97.20
99.27	98.18	99.05	98.98	99.27	97.96	98.18
100.00	99.64	99.64	100.00	100.00	96.39	99.28
100.00	100.00	100.00	100.00	100.00	100.00	100.00

2011	2012	2013	2014	2015	2016	median
5.25	0.19	0.06	2.06	0.00	0.00	0.31
59.56	5.81	4.88	32.56	1.81	1.31	17.06
238.25	53.38	52.94	159.38	8.19	11.63	102.94
460.31	224.00	224.56	410.38	77.25	90.31	295.38
582.94	421.00	436.44	563.25	257.19	246.31	442.75
595.75	528.38	553.88	592.25	435.75	409.19	551.88
452.69	406.50	433.75	451.38	382.81	357.62	423.25
254.06	223.06	246.88	252.56	225.50	211.69	238.44
84.50	76.81	84.50	83.25	80.63	75.81	81.44
17.25	17.06	17.25	16.44	17.00	16.31	17.00
2.13	2.13	2.13	2.00	2.13	2.13	2.13

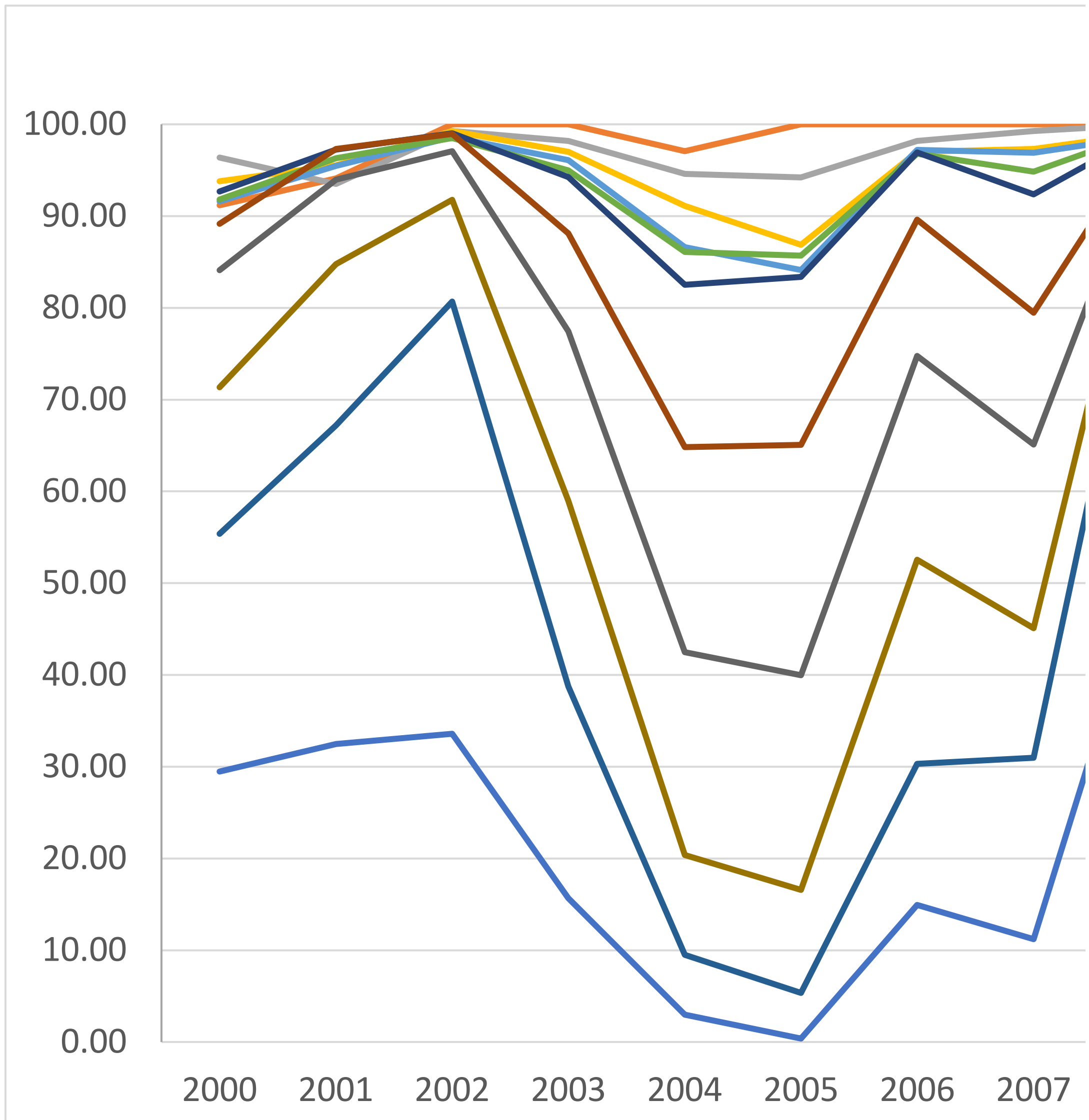
2,687.87	**1,952.31**	**2,052.31**	**2,530.87**	**1,486.44**	**1,421.00**	**2065.25**
2,091.69	1,579.88	1,648.63	2,017.25	1,153.00	1,103.44	1,713.25
31.34	1.12	0.37	12.31	0.00	0.00	1.87
52.92	5.16	4.33	28.93	1.61	1.17	15.16
84.35	18.90	18.74	56.43	2.90	4.12	36.45
95.44	46.44	46.56	85.08	16.02	18.72	61.24
98.90	71.42	74.04	95.56	43.63	41.79	75.11
99.41	88.16	92.42	98.82	72.71	68.28	92.08
99.19	89.07	95.04	98.90	83.88	78.36	92.74
99.00	86.92	96.20	98.42	87.87	82.49	92.91
98.61	89.64	98.61	97.16	94.09	88.48	95.04
99.64	98.56	99.64	94.95	98.19	94.22	98.19
100.00	100.00	100.00	94.12	100.00	100.00	100.00

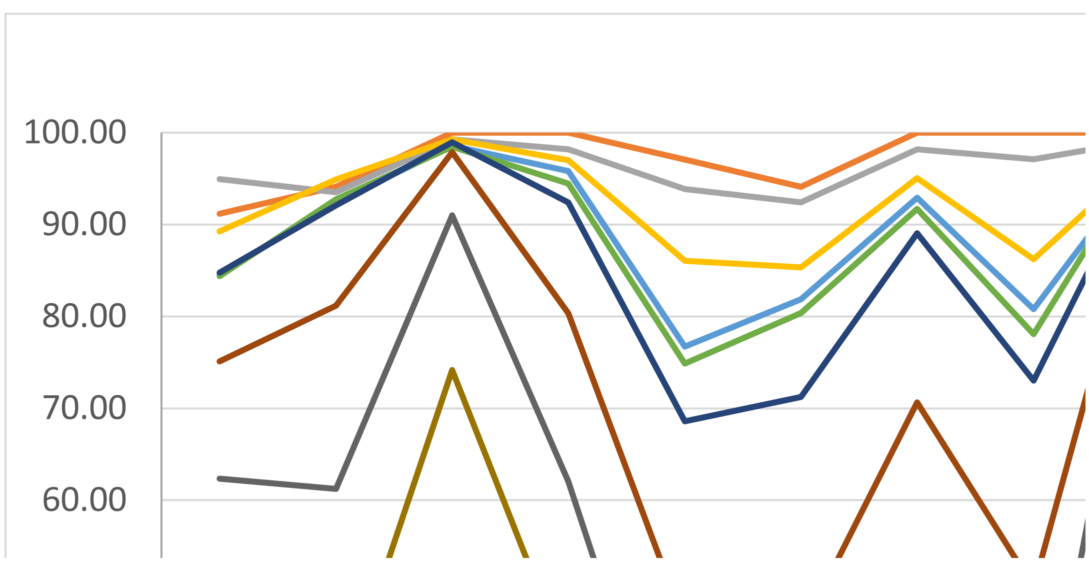
2011	**2012**	**2013**	**2014**	**2015**	**2016**	**median**
1.88	0.13	0.00	0.00	0.00	0.00	0.00
33.25	2.44	2.13	4.06	0.81	0.94	4.06
169.94	38.75	16.19	29.88	2.13	6.69	25.88
420.75	182.56	113.44	158.56	16.44	61.44	125.44
570.50	373.56	303.50	343.19	126.56	208.25	283.19
592.00	501.69	449.94	474.56	312.69	372.38	424.25
449.25	391.69	364.38	383.44	308.88	336.94	345.62
252.19	214.19	210.50	212.38	192.56	204.25	204.25
83.38	73.81	76.50	73.50	72.38	74.56	73.50
16.81	16.94	16.56	15.88	16.19	16.25	16.25
2.06	2.13	2.13	2.00	2.06	2.13	2.06
2,556.87	**1,795.31**	**1,553.13**	**1,693.37**	**1,049.87**	**1,282.88**	**1489.56**
2,032.50	1,449.50	1,231.25	1,359.75	764.56	979.00	1,178.50
11.19	0.75	0.00	0.00	0.00	0.00	0.00
29.54	2.17	1.89	3.61	0.72	0.83	3.61
60.17	13.72	5.73	10.58	0.75	2.37	9.16
87.24	37.85	23.52	32.88	3.41	12.74	26.01
96.79	63.38	51.49	58.22	21.47	35.33	48.04
98.78	83.71	75.08	79.18	52.17	62.13	70.79
98.44	85.83	79.84	84.02	67.68	73.83	75.73
98.27	83.46	82.03	82.76	75.04	79.59	79.59
97.30	86.14	89.28	85.78	84.46	87.02	85.78
97.11	97.83	95.67	91.70	93.50	93.86	93.86
97.06	100.00	100.00	94.12	97.06	100.00	97.06

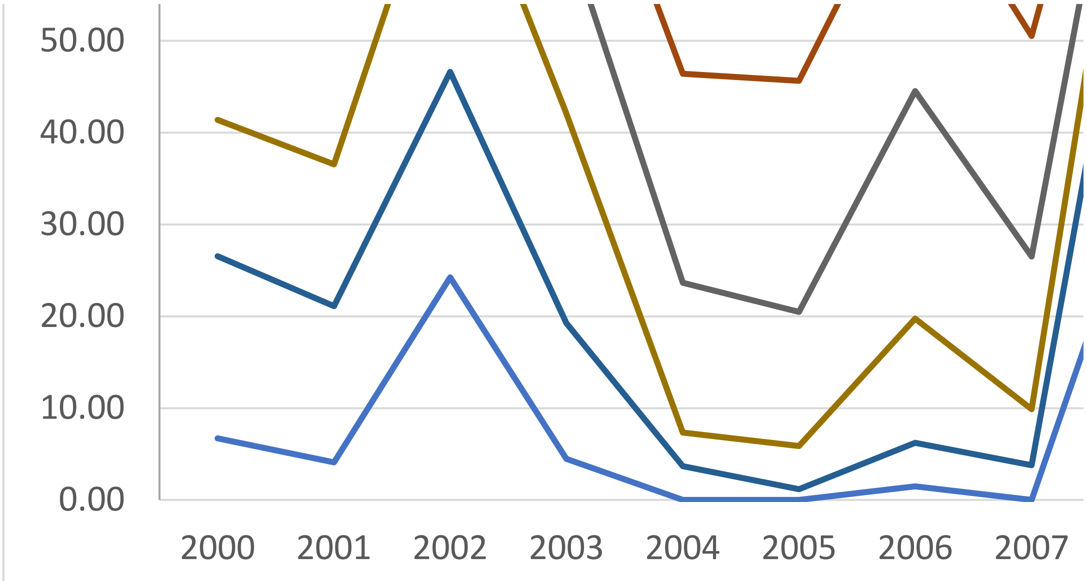


90
100
bin)
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
Elevation (m)
2005 May 1
2005 May 15
2009 May 1
2009 May 15
2011 May 1
2011 May 15
median May 1
median May 15
Den Elevations
0
10
20
30
40
50
snow covered area (% of are

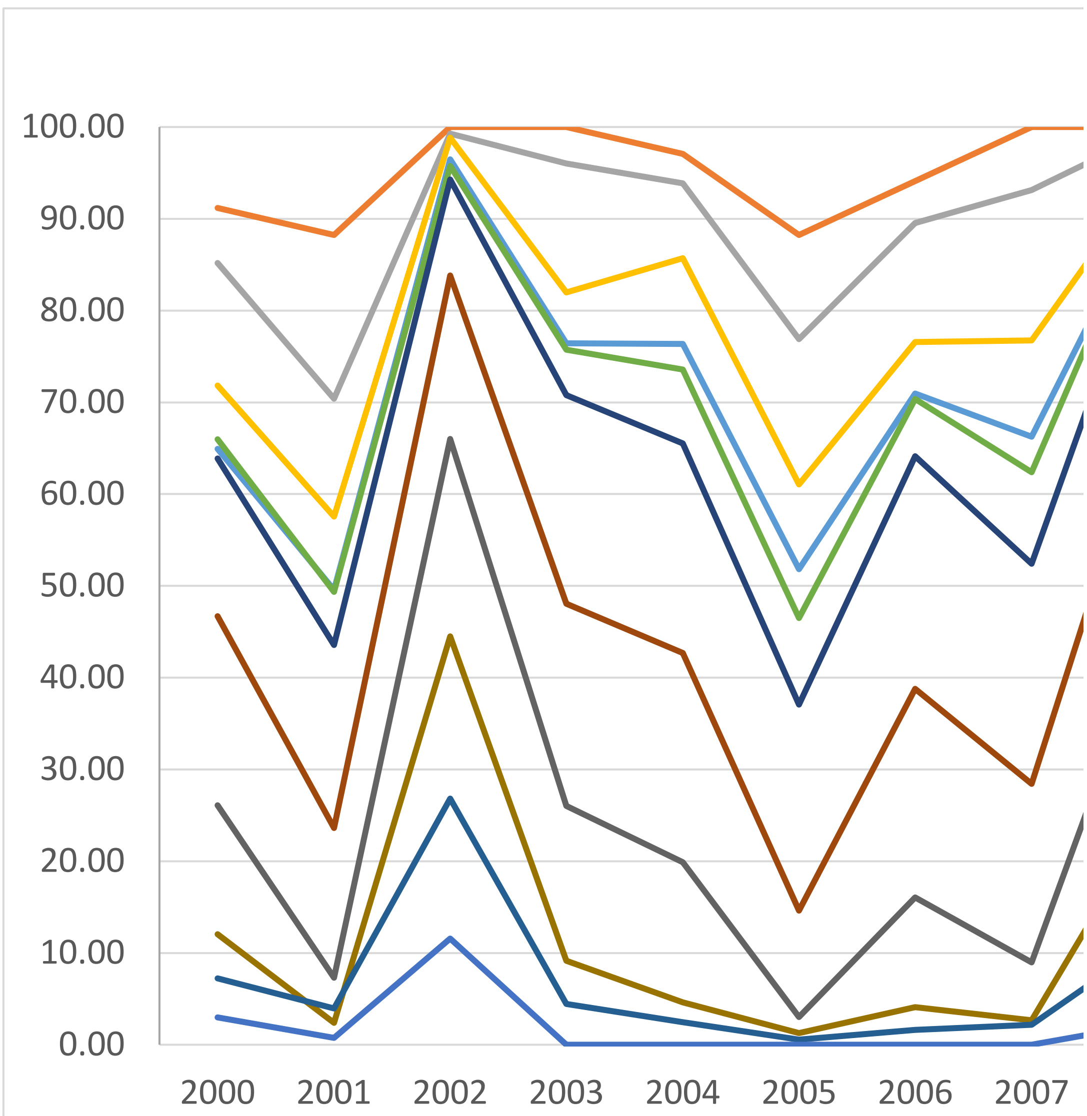
2011	2012	2013	2014	2015	2016
2120.13	1997.44	2062.50	2105.44	1431.56	1621.44
2091.69	1579.88	1648.63	2017.25	1153.00	1103.44
2032.500	1449.500	1231.250	1359.750	764.562	979.000


100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2000
2001
2002
2003
2004
2005
2006
2007

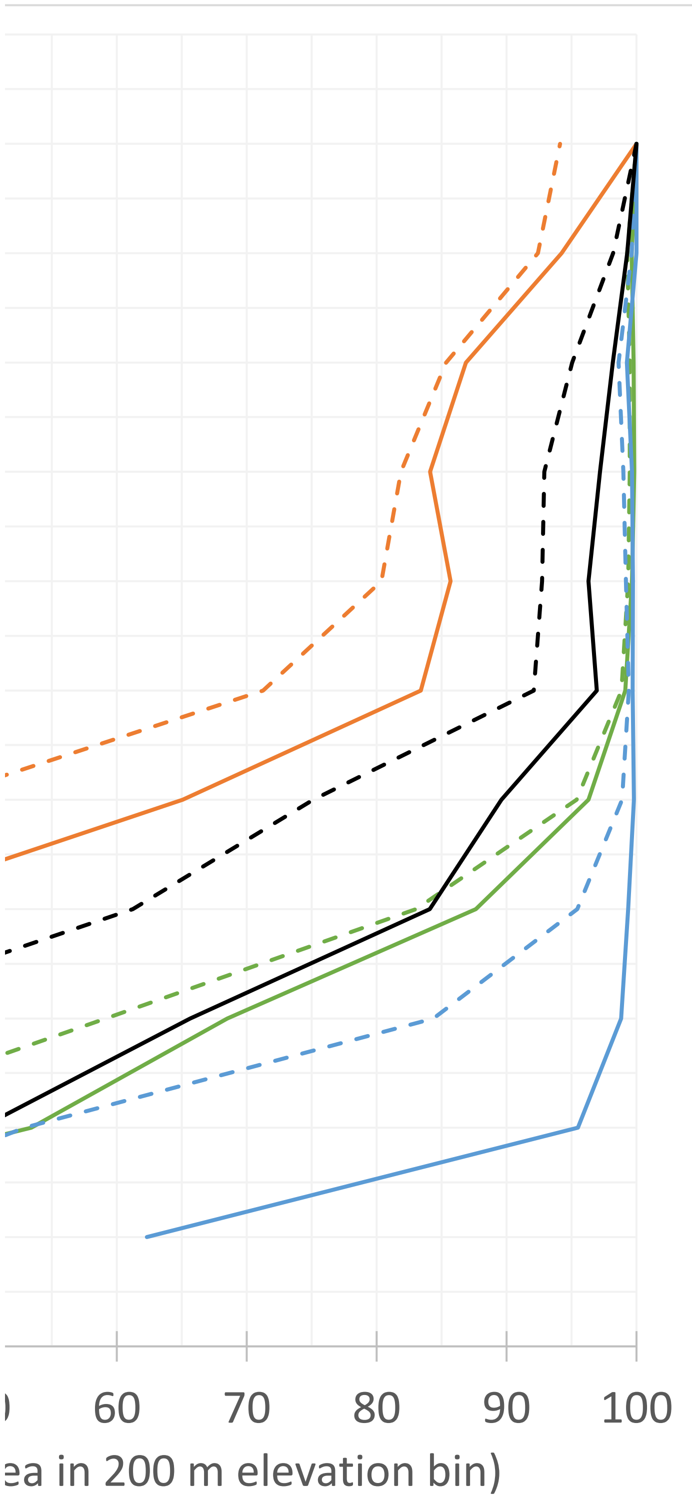

100.00
90.00
80.00
70.00
60.00



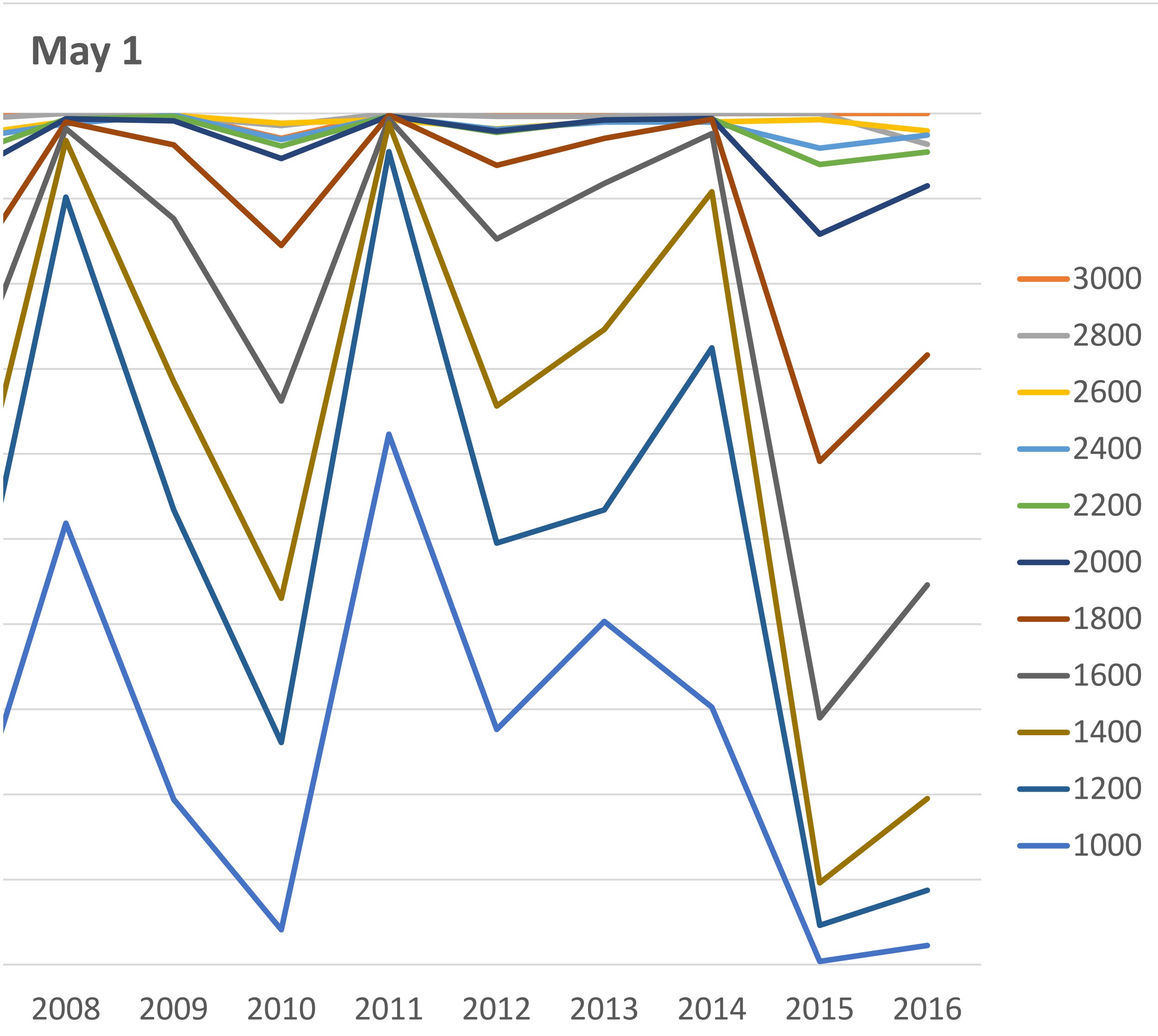
50.00
40.00
30.00
20.00
10.00
0.00
2000
2001
2002
2003
2004
2005
2006
2007

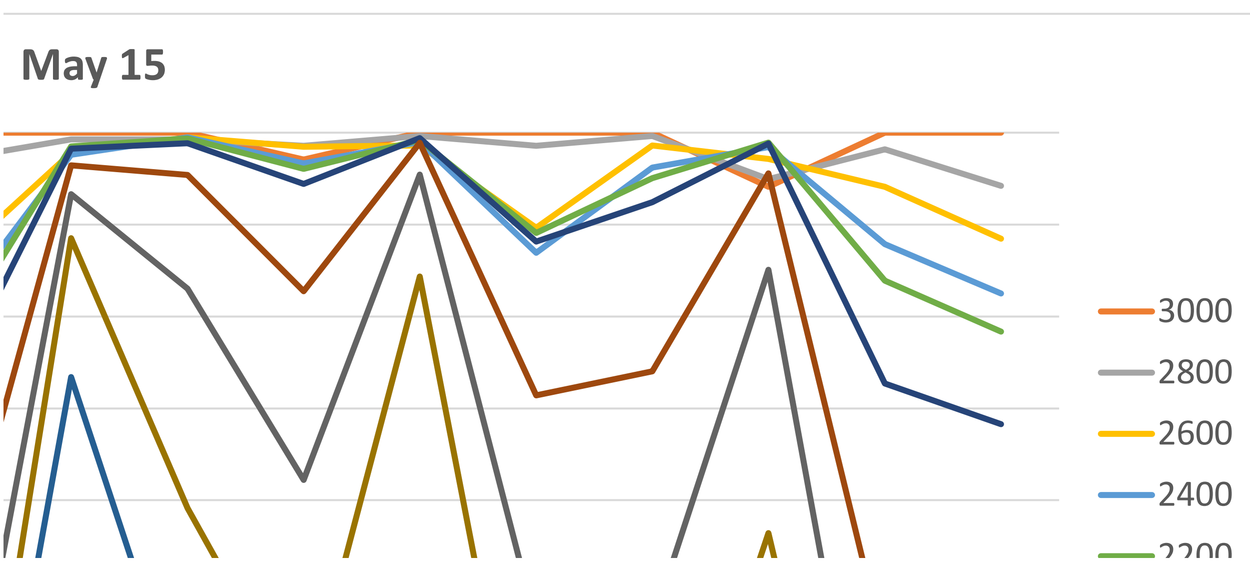


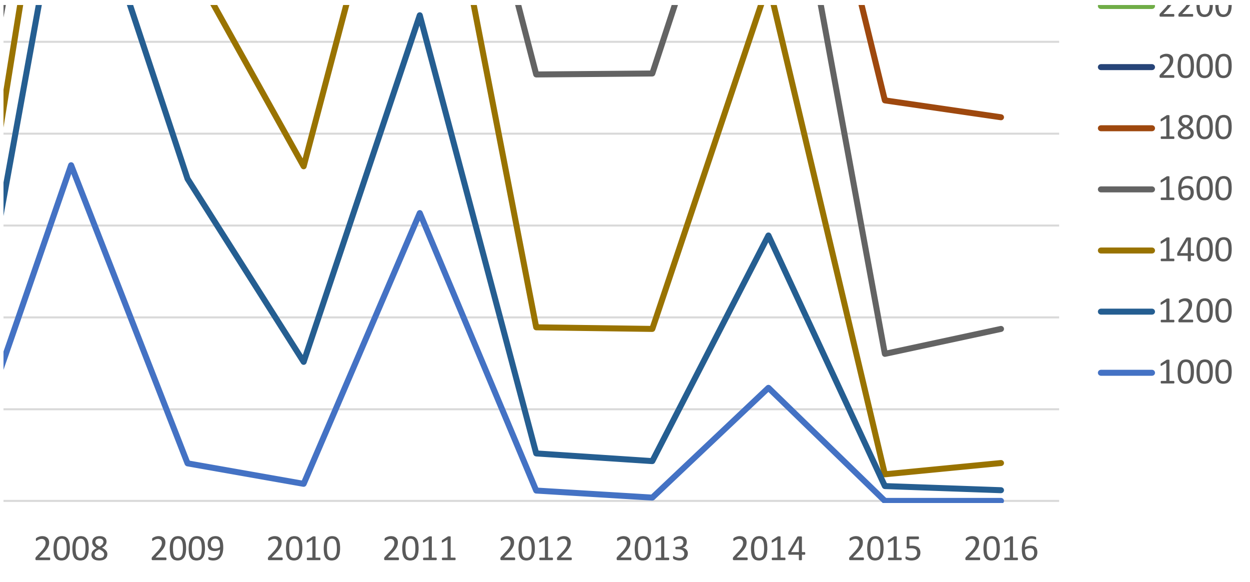
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2000
2001
2002
2003
2004
2005
2006
2007

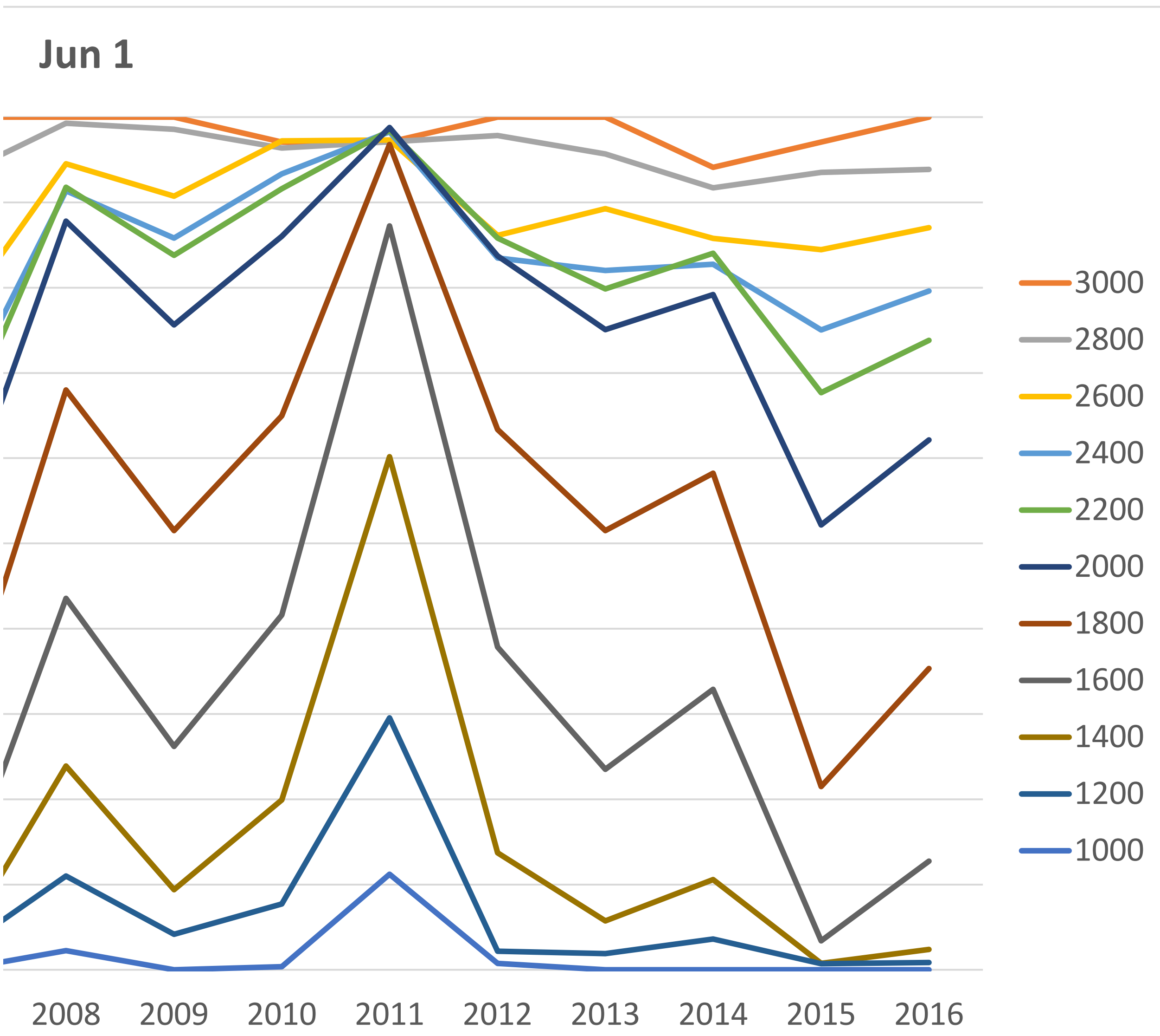


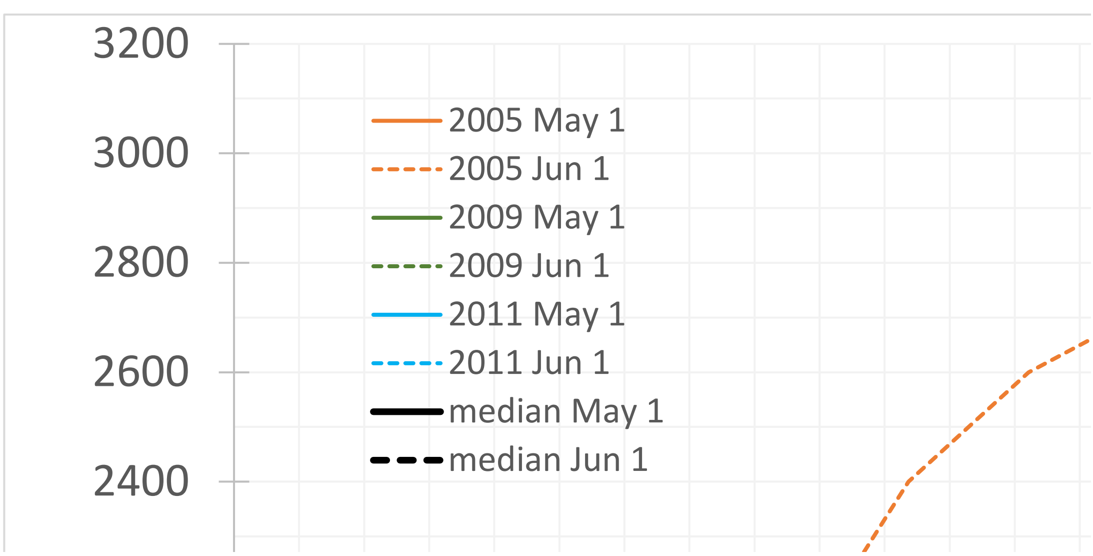
60
70
80
90
100
ea in 200 m elevation bin)

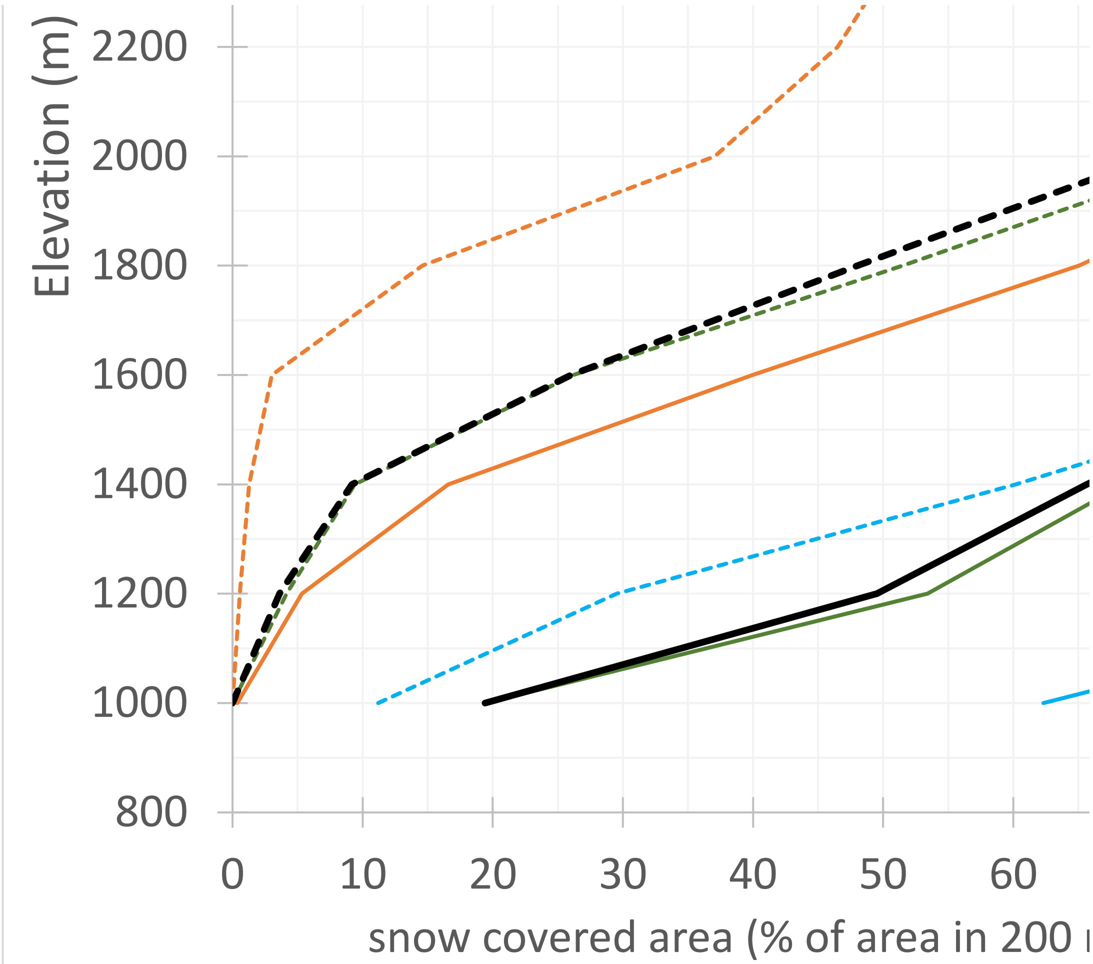

May 1
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
2008
2009
2010
2011
2012
2013
2014
2015
2016

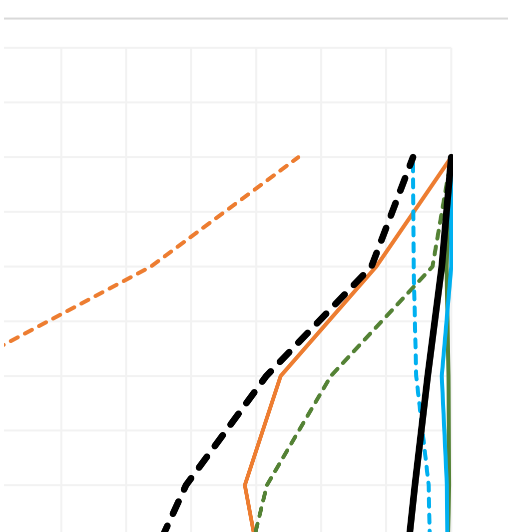

May 15
3000
2800
2600
2400

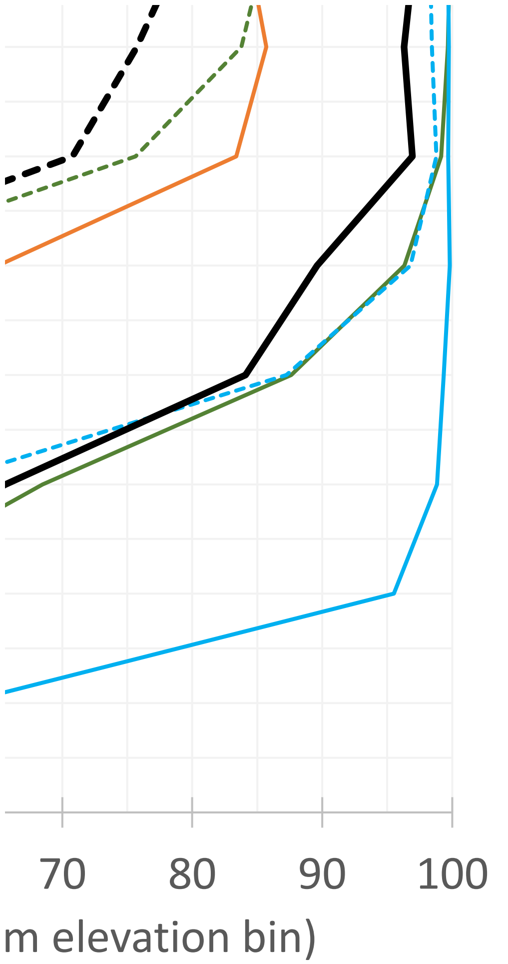

2200
2000
1800
1600
1400
1200
1000
2008
2009
2010
2011
2012
2013
2014
2015
2016


Jun 1
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
2008
2009
2010
2011
2012
2013
2014
2015
2016


3200
3000
2800
2600
2400
2005 May 1
2005 Jun 1
2009 May 1
2009 Jun 1
2011 May 1
2011 Jun 1
median May 1
median Jun 1


Elevation (m)
2200
2000
1800
1600
1400
1200
1000
800
0
10
20
30
40
50
60
snow covered area (% of area in 200




70
80
90
100
m elevation bin)

From:	Joe Barsugli
To:	Guinotte, John
Subject:	Re: Update on Wolverine
Date:	Friday, April 28, 2017 4:53:35 PM

I'm at 2 1/2 weeks. Will see the doc on monday. Joe

On 4/28/2017 4:28 PM, Guinotte, John wrote:

> Thanks Joe, I'll have a look at this on Monday. Hope you feel better soon. That stuff is no fun. My entire family had it for 2+ weeks recently.
> Best, John
>
> John Guinotte
> Fish and Wildlife Biologist
> Ecological Services
> U.S. Fish and Wildlife Service
> Mountain Prairie Region 6
> 134 Union Blvd., Lakewood, CO 80228
> 303-236-4264
> john_guinotte@fws.gov
>
> On Fri, Apr 28, 2017 at 4:12 PM, Joe Barsugli <joseph.barsugli@noaa.gov> wrote:
>
> > John,
> >
> > I've still been fighting this respiratory thing off an on -- so haven't been able to work on this as much as I had hoped. Candida gave me the spreadsheet by elevation and I produced some new plots. I am also attaching the spreadsheet of MODIS snow covered area by elevation band and by aspect sector as this will allow more flexibility if you wanted to delve in to this data at some later date.
> >
> > Here are some of the graphics you were interested in for the MODIS analysis. The Area v. Elevation plot was redone with two options regarding the calendar date that is chosen. IN the first, "May1_June1" is as before. As you suggested, I redid this for May1 and May 15 instead of June1. There is really only room on this plot for two target dates. Keep in mind that this is the MODIS product that only detects the presence/absence of snow. One reason we chose June 1 initially is that a snow disappearance date of June 1 or later indicates substantial snow earlier in May (or else the replenishment of snow by snowfall during May).
> >
> > I am also attaching the spreadsheet of MODIS snow covered area by elevation band and by aspect sector as this will allow more flexibility if you wanted to delve in to this data at some later date.
> >
> > Joe

--
Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309
303-497-6042
PSD Science Board and
Attribution and Predictability Assessments Team Member

--
Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309
303-497-6042
PSD Science Board and
Attribution and Predictability Assessments Team Member

From: Guinotte, John
To: Doherty, Kevin
Subject: Re: Update on Wolverine
Date: Monday, May 1, 2017 7:40:37 AM

Yeah I noticed that too. There is no axis label for km2 in the 3rd fig. I spoke to Joe about the June 1 issue before and explained it was too late, if anything we need April 15, May 1 and May 15. He said that the original plan was for CU to run those dates but for some reason we ended up with June 1. I'm in my office, give me a shout when you get back from the bus.

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

On Mon, May 1, 2017 at 7:21 AM, Doherty, Kevin <kevin_doherty@fws.gov> wrote:

> John,
>
> Give me a ring when you get in. The third figure makes no sense??? If we are looking at Wolverine Den's June 1st has no relevance, I am not sure why it was even made.
>
> I have to take the kids to the bus this morning because Melissa is still out of town until tonight. Leaving 7:45, back at 8:10.
>
> Cheers
> Kevin
>
> On Fri, Apr 28, 2017 at 4:27 PM, Guinotte, John <john_guinotte@fws.gov> wrote:
>
>> Hey Kevin, I haven't looked at this yet. Maybe you and I can regroup on Monday on this.
>>
>> John Guinotte
>> Fish and Wildlife Biologist
>> Ecological Services
>> U.S. Fish and Wildlife Service
>> Mountain Prairie Region 6
>> 134 Union Blvd., Lakewood, CO 80228
>> 303-236-4264
>> john_guinotte@fws.gov
>>
>> ---------- Forwarded message ----------
>> From: **Joe Barsugli** <joseph.barsugli@noaa.gov>
>> Date: Fri, Apr 28, 2017 at 4:12 PM
>> Subject: Update on Wolverine
>> To: "Guinotte, John" <john_guinotte@fws.gov>
>> Cc: Andrea Ray <Andrea.Ray@noaa.gov>

John,

I've still been fighting this respiratory thing off an on -- so haven't been able to work on this as much as I had hoped. Candida gave me the spreadsheet by elevation and I produced some new plots. I am also attaching the spreadsheet of MODIS snow covered area by elevation band and by aspect sector as this will allow more flexibility if you wanted to delve in to this data at some later date.

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I am also attaching the spreadsheet of MODIS snow covered area by elevation band and by aspect sector as this will allow more flexibility if you wanted to delve in to this data at some later date.

Joe

--

Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309
303-497-6042
PSD Science Board and
Attribution and Predictability Assessments Team Member

--

Kevin Doherty, PhD
Spatial Ecologist
USFWS Region 6 --Science Applications
134 Union Blvd, Lakewood, CO 80228
Phone: (303) 921-0524
Email: kevin_doherty@fws.gov

From:	Shoemaker, Justin
To:	Bryon Holt; Caitlin Snyder; Jacobsen, Dana; Grizzle, Betty; Guinotte, John; Jodi Bush; Stephen Torbit; Gregg Kurz; Kit Hershey; Madeline Drake; Josh Hull
Subject:	Wolverine SSA team call
Date:	Tuesday, May 2, 2017 1:56:14 PM
Attachments:	Wolverine_Curent_Range_EPA_EcoReg.pdf Wolverine_Curent_Range.pdf Wolverine_Inman_Habitat_Obs.pdf

---

Wolverine Team,

Agenda for today's call:

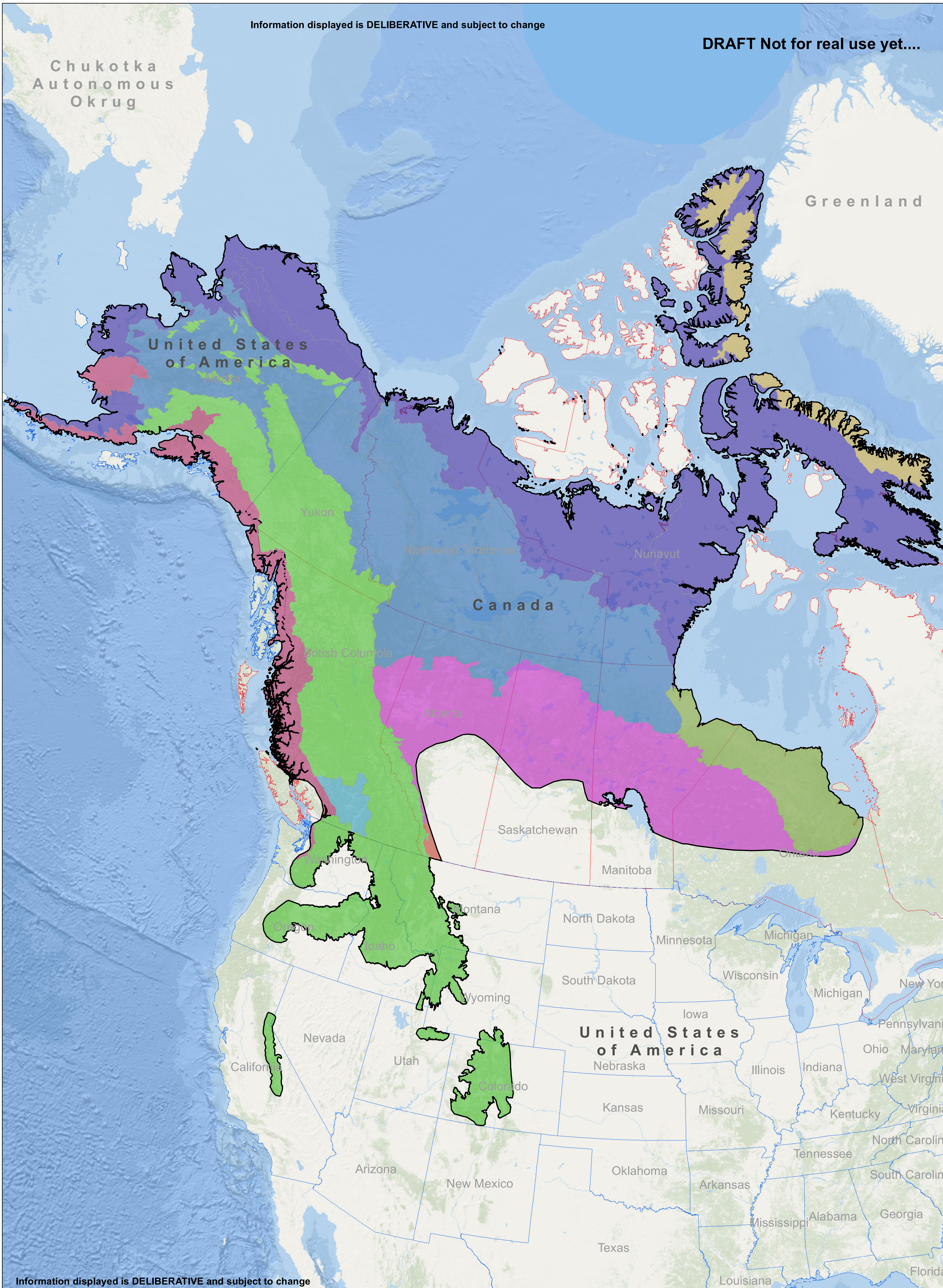
-Update on SSA progress from Betty
  -Range maps
-NOAA report, John
-PVA
-Genetics study effort

Attached are maps for discussion on today's call and a table of acreages based on the current range map.

Sum of Acres			
FeatureNam	**Zone**	**Total**	Percent
Wolverine - Range	Alaska	380,050,540.22	18.5
	Canada	1,548,989,734.70	75.36
	Lower 48	126,272,764.73	6.14
Wolverine - Range Total		**2,055,313,039.66**	
Grand Total		**2,055,313,039.66**	

Justin Shoemaker
Classification Biologist
U.S. Fish and Wildlife Service, Region 6
Phone: 309-757-5800 x214
Email: justin_shoemaker@fws.gov

U.S. Fish & Wildlife Service
Carlsbad Fish and Wildlife Office
2177 Salk Ave. Suite 250, Carlsbad, California 92008



DRAFT Not for real use yet....

Legend

- North American Wolverine (*Gulo gulo luscus*) Current Range
- ARCTIC CORDILLERA
- GREAT PLAINS
- HUDSON PLAIN
- MARINE WEST COAST FOREST
- NORTH AMERICAN DESERTS
- NORTHERN FORESTS
- NORTHWESTERN FORESTED MOUNTAINS
- TAIGA
- TUNDRA

N

0 90 180 360 Miles

Kilometers 0 90 180 360

PRODUCED BY GIS SERVICES
CARLSBAD FIELD OFFICE
GIS CONTACT: ED TURNER
BIOLOGY CONTACT: BETTY GRIZZLE
(760) 431-9440
DATA SOURCE: USFWS, EPA Eco-Level2, USCB, ESRI
IMAGE SOURCE: ESRI Online Mapper
Apr 27, 2017
S:\stem\edstemp\American_wolverine\MXDs\SSA_FINAL\Wolverine_Curent_Range_EPA_EcoReg.mxd

U.S. Fish & Wildlife Service
Carlsbad Fish and Wildlife Office
2177 Salk Ave. Suite 250, Carlsbad, California 92008

DRAFT Not for real use yet....

Legend

North American Wolverine (*Gulo gulo luscus*) Current Range

PRODUCED BY GIS SERVICES
CARLSBAD FIELD OFFICE
GIS CONTACT: ED TURNER
BIOLOGY CONTACT: BETTY GRIZZLE
(760) 431-9440
DATA SOURCE: USFWS, NWT, USCB, ESRI
IMAGE SOURCE: ESRI Online Mapper
Apr 27, 2017
S:\stem\edstemp\American_wolverine\MXDs\SSA_FINAL\Wolverine_Curent_Range_Portrait.mxd

N

0 90 180 360 Miles

0 90 180 360 Kilometers

U.S. Fish & Wildlife Service

Carlsbad Fish and Wildlife Office
2177 Salk Ave. Suite 250, Carlsbad, California 92008

Information displayed is DELIBERATIVE and subject to change

Wolverine Observations and Inman Modeled Habitats

PRODUCED BY GIS SERVICES
CARLSBAD FIELD OFFICE
GIS CONTACT: ED TURNER
BIOLOGY CONTACT: BETTY GRIZZLE
(760) 431-9440
DATA SOURCE: USFWS, INMAN (WCS),
IMAGE SOURCE: ESRI Online Mapper
Apr 27, 2017
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N

0 55 110 220 Miles

0 55 110 220 Kilometers

Legend

▲ Wolverine Observations
Compiled by USFWS-CFWO in the 2017 effort.

Primary Habitat

Female Dispersal

Male Dispersal

Map is a reproduction of Figure 4., from Robert Inman's Doctoral Thesis No. 2013:4, Wolverine Ecology and Conservation in the Western United States

Wolverine study's plan preferred to endangered species listing

GreatFalls Published 1:28 p.m. MT May 2, 2017 | **Updated 3:56 p.m. MT May 2, 2017**

(Photo: Photo courtesy of Montana Fish, Wildlife and Parks)

During a multi-state survey this winter to establish a baseline of where wolverines live in the U.S., one of the solitary mountaineers was photographed by a motion-detecting camera 65 miles southeast of Great Falls in the Little Belt Mountains.

Nicknamed "mountain devils" with a misleading reputation as mean, the largest land-dwelling member of the weasel family are primarily carnivorous scavengers, dig up dead animals to eat. It's not uncommon for wolverines to dig 20 to 30 feet into the snowpack to find animals that died in avalanches.

Wolverines were wiped out in the U.S. by hunting, trapping and poisoning by the early 1900s. In the 1930s, they began to return from Canada and have since reoccupied portions of their historic range in Washington, Oregon, Idaho, Montana and Wyoming. There are 250-300 in the U.S.

Wolverines are not a threat to humans or livestock, unless you and your horse are stuck up to your waists on a snow-covered mountain slope, unable to move. You might even welcome a death by wolverine at that point.

But for some, the "mountain devil" is a scary species.

On Aug. 13, 2014, the U.S. Fish and Wildlife Service withdrew a previous proposal to list the North American wolverine as a threatened species under the Endangered Species Act. The initial proposal had cited climate change as a factor in the proposed listing. Later the agency determined that the effects of climate change were not likely to place the wolverine in danger of extinction now or in the foreseeable future

Earthjustice, representing conservation groups, sued the Fish and Wildlife Service.

In 2016, a federal district court judge in Montana sided with the environmental groups and invalidated the withdrawal of the proposed listing. A decision on listing the wolverine is now pending.

That sent the Fish and Wildlife Service back to the drawing board and a decision on federal protections is pending.

In the past, wolverines have been studied in single regions, with differing techniques used in those individual efforts.

A wolverine checks out meat hanging from a tree in the Pintler Mountains. Photographs and DNA samples are being being collected at bait stations in four states as part of a study of wolverine population and habitat that could lead to conservation measures. "They are kind of like solitary mountaineers," Wendy Cole, a wildlife biologist, says of wolverines. *(Photo: Photo courtesy of Montana Fish, Wildlife and Parks)*

The current study, which includes the Little Belts, stands out because uniform data collection techniques are being used across the entire range of the wolverine, with participation from state wildlife agencies in 11 western states, federal land managers, the U.S. Fish and Wildlife Service and a couple of universities.

It's always preferable to create conservation plans with buy-in from landowners, public land user groups, scientists and states rather than have such plans mandated by a court after a lawsuit.

The current wolverine study is remarkable for the simple fact that multiple government groups and scientists are participating, and cooperating in the effort.

"I think one of the coolest things about this project is it's on such a large scale," said Wendy Cole of Montana Fish, Wildlife and Parks, noting that scientists who usually guard data closely are sharing information for this project.

As a wolverine climbs, it rubs against brushes sticking out of a tree leaving behind hairs and DNA. *(Photo: Photo courtesy Montana Fish, Wildlife and Parks)*

Right now the study is establishing whether wolverines are, in fact, living in areas that are "wolveriney" — rugged, mountainous, snowy areas.

States' end goal is to craft a conservation plan for wolverines that will help to avert a federal listing and the land and other restrictions that come with that.

"Colorado and California are places where there are big chunks of wolverine habitat that we know are not occupied at this time and haven't been for 100 years," said Bob Inman, FWP's carnivore-furbearer coordinator and one of the leaders of the study. "So we're working with the U.S. and Wildlife Service to try and develop policies that would facilitate reintroductions into those big chunks of habitat."

We like that option, if Colorado and California are agreeable of course, a lot better than an unknown mandate crafted mostly by a court after an environmental-group backed lawsuit.

This wolverine visited a bait station on Rocky Mountain Front on April 4. Montana Fish, Wildlife and Parks says a wolverine also visited a bait station in the Little Belt Mountains. *(Photo: Photo courtesy of Montana Fish, Wildlife and Parks)*

And we also like the perks of the study.

"'Oh my gosh, there's a wolverine, there's a wolverine!'" has been Cole's reaction when she and other researchers have discovered pictures of wolverines on the cameras.

The photos are pretty cool.

—*Tribune edit board*

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From: Grizzle, Betty
To: A J
Subject: Re: WSB snow at den-site scale
Date: Wednesday, May 3, 2017 12:29:51 PM

Thanks for the update. Will make sure to check for this.

On Wed, May 3, 2017 at 11:20 AM, A J <222wsheridan@gmail.com> wrote:

> Hi
> This paper should be out by end of next week or early the week after as Early View in Wildlife Society Bulletin. It can then be cited with the DOI and be available for distribution.

--

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From: Grizzle, Betty
To: Shoemaker, Justin; John Guinotte; Stephen Torbit; Bush, Jodi
Subject: News article re multi-state wolverine surveys
Date: Thursday, May 4, 2017 10:29:53 AM

FYI

Wolverine study's plan preferred to endangered species listing

GreatFalls Tribune/Opinion
May 2, 2017

During a multi-state survey this winter to establish a baseline of where wolverines live in the U.S., one of the solitary mountaineers was photographed by a motion-detecting camera 65 miles southeast of Great Falls in the Little Belt Mountains.... http://www.greatfallstribune.com/story/opinion/2017/05/02/wolverine-studys-plan-preferred-endangered-species-listing/101208748/

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From:	Grizzle, Betty
To:	A J
Subject:	Re: Wolverine and white markings
Date:	Thursday, May 4, 2017 1:15:29 PM
Attachments:	Novikov 1962 selected pages.pdf

Here are selected pages from Novikov (front matter and Gulo account, which starts on page 30 of pdf file).

I also had my sister help me translate Henri de Puyjalon's 1900 wolverine discussion (Labrador area of Canada) and also found (online) Seton's Life Histories of Northern Animals 1909 and wolverine account, which includes a range map (at that time) for the 3 "races." This was was modified by van Zyll de Jong (1975), which is where I found the Novikov citation!

On Thu, May 4, 2017 at 12:02 PM, A J <222wsheridan@gmail.com> wrote:

> yes, I'd like to see them; I'm not sure if that is in my library!
> It seems the Scandinavian, Finnish, Russian wolverines tend towards the coloration you described. But there are certainly exceptions and I'm not sure anyone has looked at this objectively across broad areas.
>
> On Thu, May 4, 2017 at 10:56 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>
>> FYI - I found Novikov's book - Fauna of USSR, Carnivorous Mammals (translation) from used bookseller. I was looking for the foot loading discussion for wolverines.
>> He states that predominant color of trunk is dark cinnamon brown, or light reddish brown, and that tips of paws are almost black.
>> Also, he says that dens usually built in clefts in rocks, among stones, or under roots of upturned trees.
>> I can send a scanned copy of the pages if you're interested.
>>
>> On Thu, May 4, 2017 at 11:38 AM, A J <222wsheridan@gmail.com> wrote:
>>
>>> Yes, and we could get samples from trappers in AK. Jens is capturing wolverines right now. I assume they photograph their animals but doesn't hurt to ask. He should have lots from northern Sweden and a few from southern Sweden. And then there are the Norwegians and the Finnish researchers. Rebecca Watters may be able to help with the Mongolian animals but I don't know if she has photos that match DNA samples. I could inquire with the fur buyer here if he still goes to Russia for pelts.
>>>
>>> Sent from my iPhone
>>>
>>> On May 4, 2017, at 10:21 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>>>
>>> Thanks Audrey. Seems like this would be an interesting part of a larger and more comprehensive genetic study.
>>> I will send message to Jens today.
>>>
>>> On Thu, May 4, 2017 at 11:04 AM, A J <222wsheridan@gmail.com> wrote:
>>>
>>>> Hi Betty
>>>> I don't think anyone has looked at white traits in wolverines on a global scale, either prevalence or genetic markers. White markings on the feet

are common (but not dominant) in Alaska, at least on the North Slope and Southeast Alaska where I have worked. I have attached an unusual individual, which I believe was caught in Alaska. One trapper I know in NE Alaska showed me a "white" wolverine he captured. Not an albino, but white with cream highlights where black would occur on a "normal" wolverine. From what I know of wolverines in Scandinavia, there is much less white even in the chest pattern. Jens could speak to whether they have ever gotten a white-footed wolverine. There may be regional differences in the occurrence rate and prominence of white markings, which suggests a genetic marker that runs in the population until something changes it. I once asked a fur buyer in Fairbanks about regional differences, and he said there were differences in the size and color of the diamond on wolverines across Alaska.We didn't discuss white feet. Some wolverines, almost as rare as white ones, are nearly completely black. It would be interesting to see if there are genetic differences and if they change over time regionally. The "white-less" wolverines in Scandinavia may be because the population may have descended from a few dark individuals and could change over time as the population increases and expands and dispersers arrive from Russia. The local buyer has purchased wolverines from Russia. I will have to talk to him again to see if white feet occurred on the hides he purchases. It seems to me I recall Jeff Copeland mentioning that he thinks a dominant male in an area can determine the coloration of the individuals in an area and perhaps he has worked with genetics along these lines. It does seem that wolverines from Montana more commonly had larger areas of white on chest, legs, and feet than in other areas. Bob Inman certainly has captured individuals like this.

On another subject, did you hear from Jens in response to your email? Did you ask him about the number of dens outside the snow model that they now have? He is going to try to photograph some of these den sites in the coming week.
Audrey

On Thu, May 4, 2017 at 9:28 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

Hi Audrey - You may have seen this OpEd from the Great Falls Tribune.

Wolverine study's plan preferred to endangered species listing

GreatFalls Tribune/Opinion

May 2, 2017

During a multi-state survey this winter to establish a baseline of where wolverines live in the U.S., one of the solitary mountaineers was photographed by a motion-detecting camera 65 miles southeast of Great Falls in the Little Belt Mountains.... http://www.greatfallstribune.com/story/opinion

/2017/05/02/wolverine-studys-plan-preferred-endangered-species-listing/101208748/

I noticed that one of the photographs (Pintler Mtns) shows a wolverine with white on its front paws. I had read (somewhere) about this interesting characteristic and ask Bob Inman if he knew whether this was unique to North America or Montana, and whether this has been observed in wolverines in Scandinavia. He said that they have seen fairly extensive white markings, often on the foot, in GYE and Montana, but did not know about other populations.

I also read the following account of almost all-white wolverines from Cardinal's report:

From Cardinal 2004 *Aboriginal Traditional Knowledge COSEWIC Status Report on Wolverine Gulo gulo Qavvik*: (page 7)
"A nearly all-white variant of wolverine has been trapped by hunters in the Kitikmeot region. Knowledge holders in the region state that this variety is very rare; in all of the other regions, only one other knowledge holder reported catching a wolverine that had a significant amount of white on it. Knowledge holders also mentioned that this variant has always occurred in this one area and reported their parents had caught this variety in the past. A pelt was also on display at the local HTC."

Question for you: Do you know if anyone has looked at these traits (on global scale) and how prevalent they are? And whether anyone has investigated the genetic markers for this?

Thanks.

--

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Academy of Sciences of the USSR

Keys to the fauna of the USSR
published by the Zoological Institute of the
Academy of Sciences of the USSR
No 62

G. A. Novikov

CARNIVOROUS MAMMALS of the FAUNA of the USSR

Translation of the Russian book:

Akademiya Nauk Soyuza Sovetskikh Sotsialisticheskikh Respublik

Opredeliteli po faune SSSR, izdavaemye Zoologicheskim institutom Akademii Nauk SSSR
62

G.A. Novikov

KHISHCHNYE MLEKOPITAYUSHCHIE FAUNY SSSR

Izdatel'stvo Akademii Nauk SSSR
Moskva 1956 Leningrad

Israel Program for Scientific Translations
Jerusalem 1962

OTS 61-11403

Published by
THE ISRAEL PROGRAM FOR SCIENTIFIC TRANSLATIONS
pursuant to an agreement with
THE NATIONAL SCIENCE FOUNDATION, WASHINGTON, D.C.
and the
DEPARTMENT OF THE INTERIOR, USA

Translated by: Dr. A. Birron and Z.S. Cole

Printed in Jerusalem by S. Monson

PST Cat. No 447

Price: $3.00

Available from the Office of Technical Services,
U.S. Department of Commerce, Washington 25, D.C.

CONTENTS

NOTE: Page numbers of the Russian original appear in the left-hand margin of the translated text.

INTRODUCTION

BRIEF DESCRIPTION OF THE ORDER CARNIVORA

Carnivorous mammals constitute an order (Carnivora) closely associated phylogenetically with the order of pinnipeds (Pinnipedia) and the extinct Creodonta. The phylogenetic relationships of these orders are so close that a number of authors (Simpson, 1945) regard them as suborders of the single order Carnivora. According to these opinions the terrestrial carnivores constitute the suborder Fissipedia.

The order Carnivora includes mammals differing widely in their external appearance as well as in their mode of life, but related by a common origin and a number of general morphological features.

The dimensions and external appearance of these animals vary from the small and slender weasel to the huge and powerfully built bear. The feet are plantigrade, subplantigrade or digitigrade. Each foot has not less than four digits, and in some (bears, dogs) five. The thumbs of the two pairs of limbs are not opposable to the other digits. The digits are armed with claws, which in cats (with the exception of the cheetah), are retractile and extremely sharp. The tail in the majority of cases is long and entirely covered with hair, sometimes furry; in some (bears) the tail is short and hidden by the pelage. The head varies in form: round in cats, elongated in dogs and some martens, flat and blunt-muzzled in the kolinsky (mink) and otter, and broad at its base and sharp-nosed in raccoons and bears. The ears may be large and pointed (corsac fox, etc), short and round (cats), or underdeveloped and with a closing auditory meatus (kolinsky). The hair cover varies from relatively short (weasels, ermine, otter) to furry and dense (sable, marten) or shaggy and long (bear, glutton), and from coarse and bristly (ratel, badger) to fine and silky (sable). The guard hair and underfur are well marked in the winter pelage; the underfur reaches the maximum density in amphibious carnivores (kolinsky, otter).

The dentition is heterodont, i.e., it consists of a number of groups of teeth of varying form and function. However, the dentition is also diphyodont, i.e., the milk teeth are replaced by permanent ones. The teeth have roots. The incisors are relatively small. Most species contain three incisors in each half of both jaws, the sole exception being sea otters (genus <u>Enhydra</u>), which have only two incisors occurring on each side of the lower jaw. The canines are always well developed and of typical form, but they vary in length, thickness and degree of curvature. The premolar and molar teeth have masticating surfaces varying somewhat in structure, ranging

from tuberculate-sectorial (tuberculo-sectorial) to blunt tuberculate-tetra-
10 and multituberculate. The upper posterior premolar (pm^4) and the lower first molar (m_1) are particularly well developed as a rule, and are conspicuous by their size and by bearing sharp cutting tubercles; they are known as carnassial teeth. The hard palate is entire. The tympanic chambers (bullae osseae) are usually ossified. The lower jaw articulates with the skull by means of semicylindrical condyles pivoting in deep transversely elongated glenoid cavities. The angular process of the lower jaw is generally small and uncurved. The clavicle is rudimentary or absent. The brain attains a high degree of development. The cerebral hemispheres are well-developed with three sulci or grooves and a large number of convolutions, and are macrosmatic, i.e., possessing large olfactory lobes. The testes are situated outside the abdominal cavity behind the genital organ in the scrotum. All male carnivores except hyenas possess a bone in the genital organ (os penis = baculum). The uterus is bicornuate. The placenta is deciduate, discoidal. Young are born helpless, and in most cases blind, their number varying from 1 to 21.

The majority of carnivores are terrestrial; some, however, are adapted to an amphibious existence. The terrestrial carnivores include species adapted to climbing trees. This group inhabits all kinds of habitats throughout the world, occupying haunts in burrows, dens, and natural retreats on the surface of the earth or in hollows of trees. Carnivores predominate; omnivores and herbivores are rare among them. Many carnivores which are typically flesh-eating consume herbaceous food regularly. Feeding on carrion is widespread. They are active mainly during the night and the dawn hours. Molting occurs twice annually in the majority of species, but in hibernating ones it takes place only once, in summer.

SKULL STRUCTURE AND ITS MODIFICATION WITH AGE

The peculiarities of the skull structure and its individual parts and their proportions play a highly important role in identifying the species of the animal. Thus, a knowledge of the main details of skull structure is absolutely essential. Without dwelling on a detailed description of the carnivore skull, we shall confine ourselves to a brief description of its most important elements and present figures of the skull in three views (Figures 1-3) that may contribute to the clarity of the description.

As a result of the mode of life and feeding peculiarities, the skull of predatory animals is, as a rule, distinguished by the powerful development of crests, by strong and widely separated zygomatic arches, and in some species, in addition, by large mastoid and lateral occipital processes.

The anterior (face) portion of the skull is formed laterally by the premaxillary and maxillary bones and superiorly, by elongated nasals lying over the large nasal aperture opening behind it. The zygomatic processes extend from the maxillary bones posteriorly to form the zygomatic arches in conjunction with the zygomatic processes of the squamosal bones extending anteriorly and the jugal bone situated between them. A small lacrimal bone is adjacent to the posterior edge of the anterior branch of the zygomatic arch and of the anterolateral portion of the frontal bone. The infraorbital foramina lie in front and at the base of the zygomatic processes of the maxillary bones. The facial trunks of the trigeminal nerve pass through their lower portions and the anterior rami of the masticatory muscles through their upper parts.

The nasal and maxillary bones are bounded posteriorly by the frontals. The portion of the frontal which is constricted above the orbits is called the
11 interorbital constriction or interorbital space. Postorbital processes extend from the anterior portion of the frontal bones. In some species they are so long that they join the processes of the zygomatic arches to close the orbit from behind. The skull is more or less constricted behind the postorbital processes and then again expands in the region of the braincase. The vault of the latter is formed anteriorly by the frontals, posteriorly by the parietals and the unpaired interparietal bone. The sagittal crest, which is most developed in its posterior part, where it sometimes forms a powerful bulge protruding over the occipital region of the skull, extends along the medial line of the braincase. In a number of species, as well as in young specimens and sometimes in females, the sagittal crest is either not pronounced or is altogether absent. The occipital crest lies along the posterior edge of the braincase from the mastoid processes to the upper edge of the occipital bone, reaching a considerable degree of development in old individuals of some species.

The facial portion of the brain is limited inferiorly by the hard or osseous palate, formed of the premaxillary, a process of the maxillary, and the palatine bones. The incisors are situated on the anterior section of the premaxillary bones in deep alveoli, behind which lies the elongated foramen incisivum (anterior palatine foramen). The rest of the teeth (canines, premolars and molars) follow immediately behind the incisors, with no diastema of the kind occurring in rodents, and are situated in the sockets of the maxillary bones. A more or less extensive postpalatine incisure is present behind the hard palate, delimited laterally by the processes of the pterygoid, bones which terminate posteriorly in hooklike processes. The pterygoid, vomer and sphenoid bones are visible in the postpalatine incisure. The lower side of the posterior section of the zygomatic arch bears the glenoid fossa for the articulation of the mandibular condyles. This fossa is so deep and is so shaped in some carnivores that the lower jaw cannot be separated even from a detached skull. A number of bones forming the auditory region of the skull lie in the posterior portion of the lower surface of the skull, lateral to the basioccipital bones. These include the paired petrous bones, which extend into the brain cavity and contain the auditory labyrinth. The mastoid bone, bearing a mastoid process visible exteriorly, and lying adjacent to the paroccipital processes of the occipital bones, fuses with this (petrous) bone. The tympanic bone, which is expanded like a vesicle and forms a tympanic chamber with the external auditory passage, the edges of which form a tube, fuses with these bones from outside.

The occipital portion of the skull consists of a fusion between the basioccipital, two lateral occipital and one upper occipital bone. The skull articulates with the vertebral column by means of the occipital condyles which lie laterally to the great occipital foramen (foramen magnum), through which the brain passes to join the spinal cord.

The lower jaw consists of paired branches connecting anteriorly by means of a symphysis. The posterior portion of the lower jaw bears three processes on each side, the coronoid above, the articular, which serves to connect the lower jaw with the skull below, and finally the angular.

When dealing with skulls one must bear in mind the considerable changes occurring with age. Briefly these consist of the following: As a result of the slight development of the teeth the nasal region of the skull in young carnivores is extremely short. In young badgers, for instance, the ratio
12 of the braincase to the length of the facial region is 1.65 : 1, while in adults it is 1.3 : 1. The entire posterior skull region is much larger and broader. The skull in the occipital region is markedly higher than in the nasal region. The crests and processes serving for the attachment of muscles are either absent or slightly developed. The zygomatic arches are slender and slightly spread. The postorbital constriction is not very pronounced. The tympanic chambers are much more rounded, dilated and broad. The postpalatine incisure is markedly broader. With age, the progresseive growth of the facial region takes place, as well as the growth and enlargement of the zygomatic arches and of the sagittal and paroccipital processes. Especially quick growth of the crests and processes sets in upon the young animal's changing over to a carnivorous diet. At the same time the gradual fusion of sutures occurs; these are considerably less visible in adults than in young animals. The relative rate of development in adult and young animals, as, for example, in the arctic fox, is clearly seen in Figure 4. The further development of crests and processes continues even after the animal attains full growth and sexual maturity, but the basic proportions of the skull sections are maintained without any substantial change.

DENTITION AND ITS MODIFICATION WITH AGE

Independently of the form of the tooth, the distinguishing characters comprise the crown, which protrudes from the jaw; at the edge of the alveolus the crown sometimes displays a small constriction or groove – the neck of the tooth. All carnivore teeth possess roots sunken in the alveoli.

As indicated above the dentition of carnivores is heterodont. All groups of teeth are represented: incisors, canines, premolars and molars. The number of each kind of tooth is highly important in the determination of species. For brevity and convenience the number of teeth is presented in formula form, where i (incisivi) indicates incisors, c (canini) canines, pm (praemolares) premolars, and m (molares) the molars. The numerator indicates the number of teeth in the upper jaw, the denominator the number in the lower. As the teeth are disposed symmetrically only the number of teeth contained in one half of the upper and lower jaw is shown, but following the sign of equality the total number in both jaws is given. The dentition of the wolf, for example, is given by: $i\,\frac{3}{3}\ c\,\frac{1}{1}\ pm\,\frac{4}{4}\ m\,\frac{2}{3} = 42$.

13 The dentition undergoes rather great changes with age, and dental condition is one of the most reliable features for the determination of the relative and sometimes even the absolute age of carnivorous animals. These changes are primarily expressed in the gradual appearance of milk teeth, followed by their replacement by the permanent teeth, and finally by the trituration of the denticles and tubercles of the latter. The rate of such changes may, of course, vary in different individuals as a result of the condition of

Key to Figure 1

1–Incisors (incisivi); 2–premaxilla (os praemaxillare = intermaxillare = incisivum); 3–intermaxillary suture (sutura intermaxillaris); 4–canine (caninus); 5– incisive foramen (foramen incisivum); 6–nasal process of nasal bone (processus nasalis ossis nasilis); 7–palatine process of premaxilla (processus palatinus ossis intermaxillaris); 8–nasal process of premaxilla (processus nasalis ossis intermaxillaris); 9–nasal bone (os nasale); 10–nasal suture (sutura internasalis); 11–maxillary bone (os maxillare); 12–maxillary-premaxillary suture, (sutura maxillo-intermaxillaris); 13–infraorbital foramen (foramen infraorbitale); 14–maxillary-nasal suture (sutura maxillo-nasalis); 15–nasal process of frontal bone (processus nasalis ossis frontalis); 16–frontal process of maxilla (processus frontalis ossis maxillaris); 17–maxillary-frontal suture (sutura maxillo-frontalis); 18–maxillary-zygomatic (sutura maxillo-jugularis); 19–frontal process of nasal bone (processus frontalis ossis nasalis); 20–lacrimal foramen (foramen lacrymale); 21–frontal branch of zygomatic bone (ramus frontalis ossid zygomatici); 22–lacrimal bone (os lacrymale); 23–zygomatic bone (os zygomaticum = jugale); 24–margin of orbit (margo orbitalis); 25–orbit (orbita); 26–frontal bone (os frontale); 27–frontal suture (sutura frontalis); 28–frontal process of zygomatic bone (processus frontalis ossis zygomatici); 29–temporal process of zygomatic bone (processus temporalis ossis zygomatici); 30–zygomatic process of squamosal bone (processus zygomaticus ossis squamosis); 31–postorbital process (processus postorbitalis); 32–semicircular line of frontal bone (linea semicircularis ossis frontalis); 33–frontal sulcus (sulcus frontalis); 34–coronal suture (sutura coronalis); 35–squamosal bone (os squamosum); 36– parietal-squamosal suture (sutura parietale-squamosis); 37–parietal bone (os parietale); 38–sagittal crest (crista sagittalis); 39–mastoid process (processus mastoideus); 40–interparietal bone (os interparietale); 41–supraoccipital crest (crista supraoccipitalis); 42–lambdoidal suture (sutura lamboidalis); 43–occipital bone (os occipitale).

Key to Figure 2

1–Incisors (incisivi); 2–canine (caninus); 3–premaxilla (os praemaxillare = intermaxillare = incisivum); 4–incisive foramen (foramen incisivum); 5–first premolar tooth (dens praemolaris –pm^1); 6–alveolar process of maxilla (processus alveolaris ossis maxillaris); 7–palatine process of maxilla (processus palatinus ossis maxillaris); 8–second premolar tooth (pm^2); 9–third premolar tooth (pm^3); 10–postpalatine foramen (foramen palatinum posterius); 11–palatine sulcus (sulcus palatinus); 12–carnassial tooth (dens sectorius –pm^4); 13–first molar tooth (dens molaris –m^1); 14–second molar tooth (m^2); 15–ventral palato-maxillary suture (sutura palato-maxillaris ventralis); 16–palatine suture (sutura palatina); 17–anterior edge of postorbital incisure; 18–pterygoid process of maxilla (processus pterygoidus ossis maxillaris); 19–palatine bone (os palatinum); 20–vomer (vomer); 21–mesopterygoid fossa (fossa mesopterygoidea); 22–frontal bone (os frontale); 23–postorbital process of frontal bone (processus postorbitalis = processus zygomaticus ossis frontalis); 24–zygomatic bone (os zygomaticum = jugale); 25–frontal process of zygomatic bone (processus frontalis ossis zygomatici); 26–hook of process of pterygoid bone (hamulus pterygoideus = processus hamulares); 27–presphenoid bone (os praesphenoideum); 28–orbital portion of sphenoid bone (orbito-sphenoideum); 29–pterygoid bone (os pterygoideum); 30–round foramen (foramen rotundum); 31–basisphenoid bone (os basisphenoideum); 32–oval foramen (foramen ovale); 33–Eustachian tube (tuba eustachii); 34–lateral pharyngeal tubercle (tuberculum pharyngeum laterale); 35–postglenoid process (processus postglenoideus); 36–carotid canal (canalis caroticum); 37–glenoid fossa (fossa glenoidea-articularis); 38–jugal process of squamosal bone (processus zygomaticus ossis squamosis); 39–external auditory meatus (meatus auditorius externus); 40–stylomastoid foramen (foramen stylo-mastoideum); 41–petroso-occipital groove (fissura petroso-occipitalis); 42–tympanic chamber (bulla tympani = b. ossea = b. auditoria); 43–basioccipital bone (os basioccipitale); 44–anterior condylar foramen (foramen condyloideum anterius); 45–condylar fossa (fossa condyloidea); 46–occipital condyle (condylus occipitales); 47– mastoid process (processus mastoideus); 48–paroccipital process (processus paroccipitalis = jugularis); 49–jugular foramen (foramen jugulare = f. lacerum posterius); 50–occipital foramen (foramen magnum); 51–occipital tubercle (tuberculum nuchalum ossis supraoccipitalis); 52–supraoccipital bone (os supraoccipitale); 53–occipital bone (os occipitale).

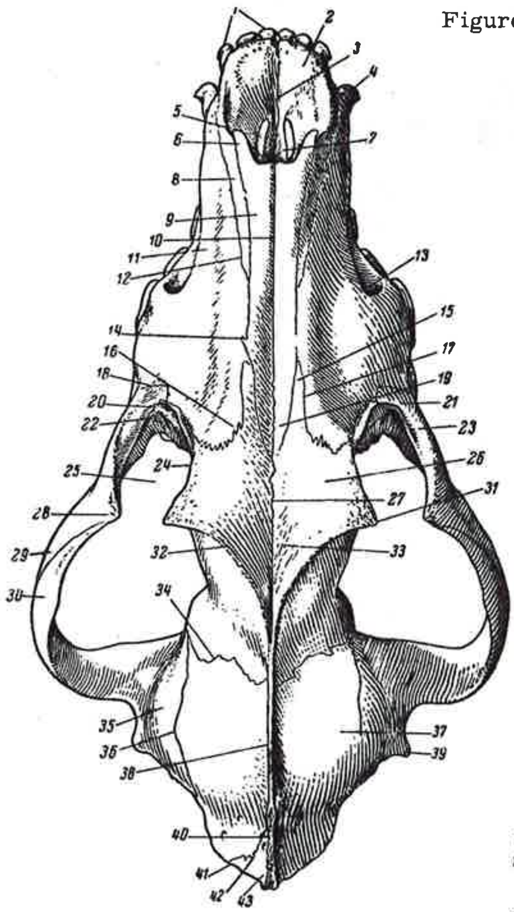

Figure 1. Skull of wolf (Canis lupus L.)
Dorsal view

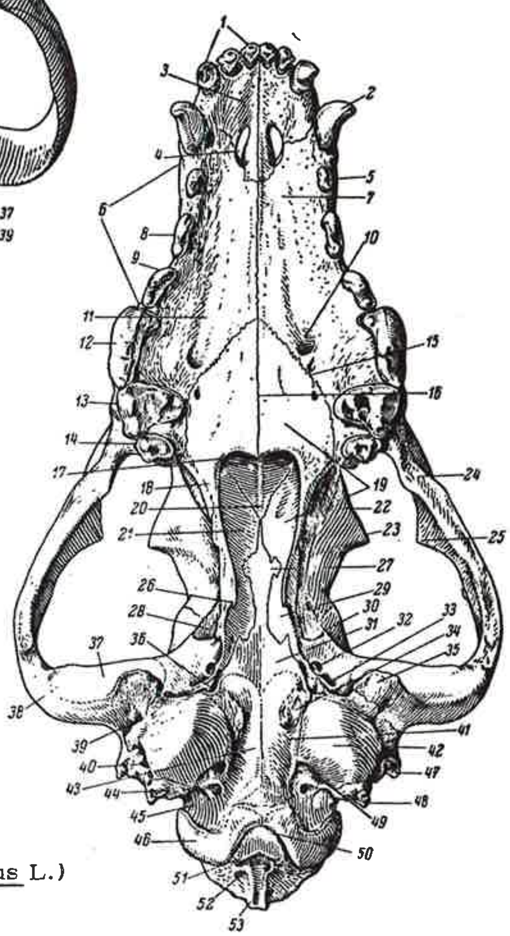

Figure 2. Skull of wolf (Canis lupus L.)
Ventral view

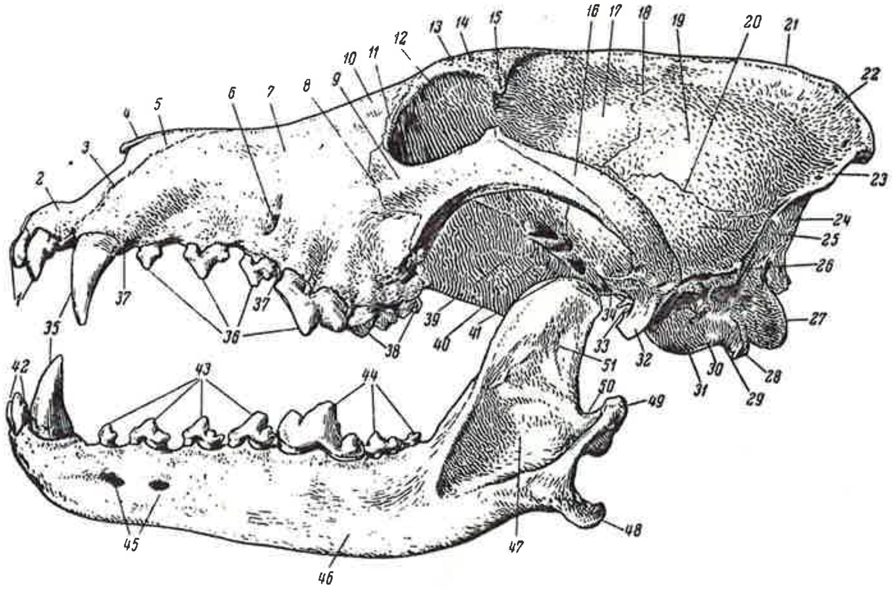

Figure 3. Skull of wolf (Canis lupus L.) Lateral view

Key to Figure 3

1–Upper incisors (incisivi); 2–premaxilla (os praemaxillare = intermaxillare = incisivum); 3–maxillo- intermaxillary suture (sutura maxillo-intermaxillaris); 4–nasal bone (os nasale); 5— nasal process of pre- maxilla (processus nasalis ossis intermaxillaris); 6–infraorbital foramen (foramen infraorbitale); 7–maxilla (os maxillare); 8–maxillo-jugal suture (sutura maxillo-jugale); 9–zygomatic bone (os zygomaticum = ju- gale); 10–frontal process (processus frontalis); 11–lacrimal bone (os lacrymale); 12–orbit (orbita); 13– superciliary arch (arcus superciliaris); 14–frontal bone (os frontale); 15–postorbital process (processus post- orbitalis = p. zygomaticus ossis frontalis); 16–zygomatic process of squamosal bone (processus zygomaticus ossis squamosi); 17–parieto-temporal part of frontal bone (pars parieto-temporalis ossis frontalis); 18–coro- nal suture (sutura coronalis); 19–parietal bone (os parietale); 20–squamosal suture (sutura squamosum); 21– sagittal crest (crista sagittalis); 22–interparietal bone (os interparietale); 23–supraoccipital crest (crists su- praoccipitalis); 24–supraoccipital bone (os supraoccipitale); 25–squamosal bone (os squamosum); 26–mas- toid process (processus mastoideus); 27–occipital condyle (condylus occipitalis); 28–paroccipital process (processus paroccipitalis = jugularis); 29–stylomastoid foramen (foramen stylo-mastoideum); 30–external auditory meatus (meatus auditorius externus); 31–tympanic chamber (bulla tympani); 32–postglenoid process (processus postglenoideus); 33–glenoid fossa (fossa glenoidea); 34–posterior pterygoid foramen (foramen pterygoideum posterius); 35–canines (dentes canini); 36–upper premolar teeth (dentes praemolares); 37– alveolar process (processus alveolaris); 38–upper molar teeth (dentes molares); 39–optic foramen (foramen opticum); 40–orbital fissure (fissura orbitalis); 41–anterior pterygoidal foramen (foramen pterygoideum an- terius); 42–lower incisors (dentes incisivi); 43–lower premolar teeth (dentes praemolares); 44–lower molars (dentes molares); 45–chin apertures (foramina mentalia); 46–lower jaw (mandibula); 47–masseter fossa (fossa masseterica); 48–angular process (processus angularis); 49–condylar process (processus articularis = processus condyloideus); 50–mandibular incisure (incisure mandibulae); 51–coronoid process (processus coronoideus).

14 the organism, type of food, and other factors, but as a general rule, it is subject to certain regularities. Milk teeth predecessors are present for the canines, incisors and premolars (except for the first premolar). First to emerge are the lower milk incisors and canines, followed by the upper incisors and canines, then the lower premolars, and finally the upper premolars. This is also the order of the replacement of milk teeth by the permanent teeth. The dental trituration in wolves, dogs, and foxes is particularly well displayed, first in the incisors, then in the premolars and molars. It is by the degree of wearing away of the crowns of these teeth that the age of the animal is determined.

Thus, the determination of the age of dogs, foxes and certain other members of the dog family is based chiefly on the regular wear of the cutting edges of the incisors. These are initially not uniform but possess three festoons or bulges (the so-called trifolium); moreover, in young animals (foxes up to the age of 10 months) all teeth are intact, their surface being a bright, shining white. In animals aged 1 year 7 months to 1 year 10 months, i.e., obtained in the hunting season of the second year of their life, the trituration of the first incisors or "hook-teeth" of the lower jaw (i.e., i_1) is observed; in individual specimens the upper "hooks" (i^1) are also worn away. In addition, the first molar of both jaws begin to undergo trituration. In foxes aged 2 years 7 months to 2 years 10 months not only are the lower "hooks" but the lower middle incisors also (i_2) are worn away. The "edges" of the lower jaw (i_3) are beginning to wear away. The trifolium is still visible on the upper "hooks". The middle incisors of the upper jaw are already affected by trituration in almost half of the specimens. The upper "edges" are always intact, but at the same time the process of trituration is beginning to involve the first and fourth upper premolars and is observed in some 40 % of individuals on the same teeth of the lower jaw. The teeth acquire a yellowish tinge. Foxes aged 3 years 7 months to 3 years 10 months are characterized by marked trituration of the lower incisors, among them the "edges" are also considerably worn away. Traces of wear are visible
15 in the canines. On the upper jaw the "hooks" are somewhat worn; the middle incisors and premolars as well as the fourth premolar and the first and second molar are slightly affected. Finally, in the sixth winter of the fox's life the incisors of both jaws are markedly worn and shortened, and all other teeth, except for the second and third premolars, which are worn away more slowly, are considerably worn away (Grigor'ev and Popov, 1940).

16

MEASUREMENTS OF BODY AND SKULL

An important role is played by the dimensions of body and skull in identifying the species and studying the taxonomy of an animal. The following measurements are most widely applied (Figure 5):

1) Length of body – overall length of head and body – from tip of nose to root of tail – is measured in a straight line on the unextended carcass of the animal.

2) Length of tail – from root to end of tail, excluding terminal hairs.

3) Length of posterior paw – from protruding posterior portion of heel to end of longest digit, excluding claw.

17 4) Height of ear – from lower edge of ear aperture to tip of ear conch, not taking into consideration the ear tufts in the lynx, caracal and similar animals, nor the terminal hairs in other animals.

When measuring skulls the following basic dimensions are taken:

1) Condylobasal length – from most anterior point of maxilla (between incisors) to posterior surface of occipital condyles.

2) Overall length – from most anterior point of skull (incisors, maxilla, and nasal bones) to most protruding posterior part (occipital condyles, occipital bone, etc).

3) Basal length – from posterior end of alveoli of medial upper incisors to lowest point of foramen magnum.

4) Length of facial region – from most protruding point of maxilla between incisors to middle of line joining points of greatest postorbital constriction of skull*.

5) Length of braincase region – from middle of line joining points of greatest postorbital constriction of skull to posterior part of occipital condyles.

6) Length of nasal bones – measured along medial suture between these bones.

7) Maximum length of nasal bones – from anterior end of nasal process of one of nasal bones to its posterior end.

8) Length of hard palate – from posterior edge of alveoli of medial incisors to anterior edge of postpalatine incisure.

9) Length of postpalatine incisure – from its anterior edge to posterior ends of hooks of pterygoid bones.

10) Width over canines – maximum width between exterior edges of alveoli of upper canines measured from above.

11) Zygomatic width – between exterior edges of those parts of zygomatic arches which are at maximum distance from skull.

12) Interorbital distance (width) – minimum width of frontal bones between orbits.

13) Postorbital width – maximal postorbital constriction, i.e., minimum distance between external edges of skull posterior to postorbital processes.

18 14) Mastoid width – maximum distance between mastoid processes.

15) Height of skull in region of tympanic bullae – from highest point of parietal region to lowest point of tympanic chamber.

16) Height of nasal section, with jaws clenched – from lower edge of mandible in region of symphysis to upper edge of skull over upper canines.

In individual cases in this key some duly explained additional measurements are used.

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* It should be borne in mind that the length of the facial and brain sections is measured in various ways by different authors.

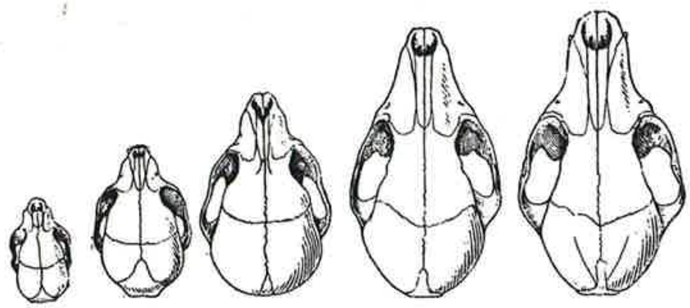

Figure 4. Age variations of skull of arctic fox (Alopex lagopus L.) (after V.I. Tsalkin)

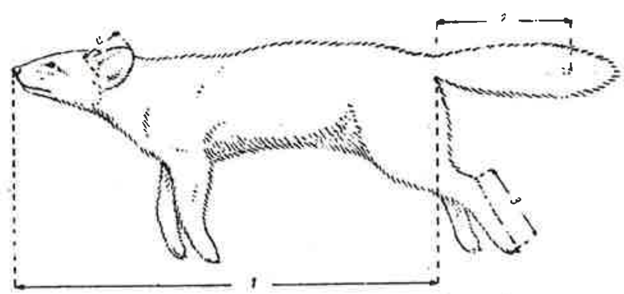

Figure 5. Diagram of body measurements

1-length of body; 2-length of tail (excluding terminal hairs); 3-length of foot (excluding claws); 4-height of ear

GEOGRAPHICAL DISTRIBUTION OF CARNIVORES

Existing carnivores are divided into seven families comprising 93
genera (dogs 12; bears 4; raccoons 8; mustelids 28; viverrids 36; hyenas
3; cats 2). Six families are represented in the USSR fauna, including the
acclimatized raccoon (family Procyonidae). Forty-one species of endemic
19 carnivores and two acclimatized ones (raccoon and American mink) occur
in the territory of the Soviet Union. The numbers of the species are distributed in the following manner according to families:

Mustelids (Mustelidae)	18	Bears (Ursidae)	3
Cats (Felidae)	12	Hyenas (Hyaenidae)	1
Dogs (Canidae)	8	Raccoons (Procyonidae)	1

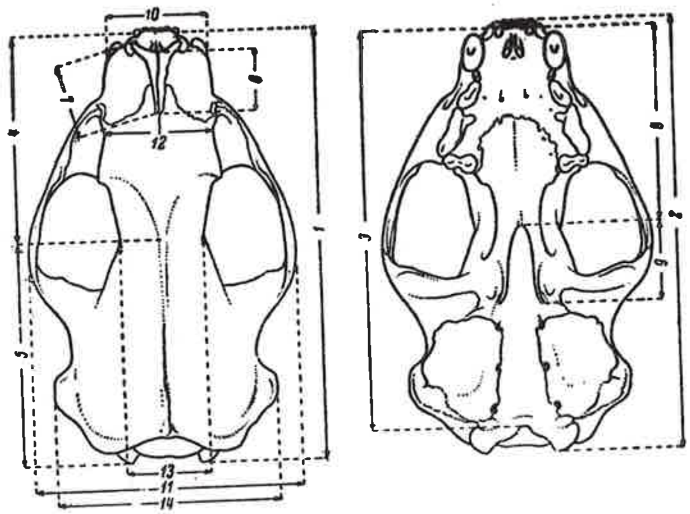

Figure 6. Diagram of skull measurements

1-condylobasal length; 2-overall length; 3-basal length; 4-length of facial region; 5-length of brain region; 6-length of nasals; 7-maximal length of nasals; 8-length of hard palate; 9-length of postpalatine incisure; 10-width over canines; 11-zygomatic width; 12-interorbital width; 13-postorbital width; 14-mastoid width

Thus, the mustelid family is the most abundantly represented in number of species, totaling 40 % of all USSR carnivorous fauna in number of species, and together with the cat family including almost 75 % of all USSR species.

Owing to peculiarities of nutrition and other biological characters, the carnivores are equipped for survival under a variety of conditions and are therefore very widely distributed, from the extreme Arctic to tropical regions. They are absent only in Australia (disregarding the dingo) and on the small oceanic islands. The most widespread are species of canids, mustelids, and bear families. Of these, the polar bear and the arctic fox are permanent inhabitants of the Arctic; many genera are associated with the temperate zones of Eurasia and America and large numbers are distributed in the subtropical and tropical regions of Asia, Africa and America. The cats are particularly well represented in many forms in South America and South Asia; the viverrids mainly inhabit southern Asia and Africa, only two of their species being encountered in southern Europe, but they are the sole representatives of the carnivores of Madagascar, where seven endemic ge-
20 nera of these animals are known to occur. The small family of hyenas (three genera) is limited in its areal to Africa and Asia. The raccoons belong almost exclusively to the fauna of South and, to some extent, North
America, only two genera inhabiting southern Asia. Thus, none of the fa- 21
milies of Carnivora are endemic to one continent or zoogeographical region.

A few genera only are endemic; particularly numerous are the endemic genera of Asia (26), mainly of the viverrids and mustelids, and also of Africa (22, disregarding the seven genera endemic for Madagascar). Eleven endemic genera are known in South America and only four in North America. Europe is without any.

The distribution of carnivores in the geographical regions within the boundaries of the USSR has the following character:

Zone of polar ice and tundra: only the white polar bear constantly inhabits the extreme north, while the arctic fox, although breeding in the tundra zone, winters in the northern part of the taiga. The wolf, glutton and fox, which are widespread in the tundra, also carry out seasonal migrations. The first two species trail migrating reindeer herds. The ermine and snow weasel are quite common in the tundra. Following the mass multiplication of lemmings, there is a marked increase in the number of arctic foxes. and other foxes and carnivores feeding on them, but after the dying off of the rodents, the fox population decreases accordingly.

Forest tundra: this occupies a relatively narrow belt south of the tundra. This transitional belt lacks any specific carnivore species; snow weasels, ermines and foxes are common here. The arctic fox, wolf and glutton frequently migrate to the forest tundra in winter.

Forest zone: this is divided into the subzones of the taiga and the broadleaf and mixed forests. Most characteristic of this zone are the European brown bear, sable, glutton and lynx. In the past these animals were considerably more widespread than at present; they could be encountered not only in the taiga but also far to the south and west – in mixed forests. They disappeared from these areas in recorded time as a result of direct extermination and marked changes in environmental conditions. The pine marten, European mink and common polecat are highly typical of the forest zone of the European part of the USSR. The marten and European mink penetrate a certain distance east of the Urals. The polecat is particularly abundant in the southern half of the zone, but is gradually settling in more northerly zones as a result of the agricultural development of areas previously covered by dense forests. The kolinsky (mink) is common in the Siberian taiga, and is also encountered in the forest steppe, during recent decades having spread throughout the eastern parts of the European section of the country [USSR]. In addition to the above-mentioned animals, such species as wolf, fox, ermine, snow weasel, badger and otter are widespread in the forest zone. The otter finds the most suitable living conditions in the forest rivers, rich in fish. The other carnivores keep to the edges of the forest massifs or forest belts and forest coppices in fields, meadows and river flood plains.

A number of endemic species of carnivores are indigenous to the mixed and broadleaf forests peculiar to the Far East south: raccoon dog, Asiatic black bear, yellow-throated marten, Far East forest cat, and peculiar subspecies of the tiger and leopard. Some carnivores with a wide range are also encountered here: wolf, fox, European brown bear, ermine, snow weasel, badger, otter and glutton.

The *forest steppe* does not have any endemic carnivore species, but some find here quite favorable conditions and multiply considerably, for
21 example, wolf, fox, ermine, polecat and badger. The stone marten and the light polecat also occur in the forest steppe of the European part of the USSR.

The steppe zone. The corsac fox, the light polecat, the sarmatier (mottled polecat) and to some extent the steppe cat and the manul are typical of steppes, while the jungle cat is typical of the regularly flooded lands of steppe rivers. Here, wolves, foxes, snow weasels, and ermine are widely distributed, while the badger is sometimes encountered. These animals are well represented in the steppes of the eastern part of the zone, as the steppe landscape in the European portion of the USSR has been greatly altered by human activities.

The desert zone possesses a number of specific carnivores, including the hoary fox, hyena, steppe cat, caracal, manul cat, sand-dune cat and cheetah. Some of them, it is true, such as the hoary fox, hyena, caracal and cheetah, are very rare in the USSR, but together with other more common animals they impart a certain color to the fauna of this geographical zone. In addition, the wolf, fox, weasel and sarmatier, represented here by peculiar subspecies, are distinguishable (with the exception of the sarmatier) by a dull adaptive coloration. The animal world of the impenetrable reed thickets and bush along the shores of large rivers flowing through the desert is of a considerably different nature. Jackals and jungle cats abound here; tigers were once common here, too, but today they are found in only a few places in the Amu-Dar'ya basin.

Mountain regions. These have only few species peculiar to them. Practically only the snow leopard, red wolf and to some extent the leopard may be included in this group. The ratel is encountered only in the mountains (Kopet Dagh). All other species of carnivores are denizens of the forest zone or belong to widely distributed forms. In the mountains they live in characteristic forest habitats, some surviving only in the mountains, as the mountain landscape provides better protective conditions than the plains, where animals are dying off at a much more rapid rate. Thus, in the Caucasus Mountains the wolf, European brown bear, forest and stone marten, European wildcat and others are still quite abundant. The wolf, European brown bear and stone marten are also common in the mountains of Central Asia and Kazakhstan. The European lynx is not uncommon in many mountain forest regions.

In discussing the peculiarities of the geographical distribution of animals one must bear in mind that these have been markedly affected by human activity. The changes occurring in the areals of some species have already been mentioned. In addition, the results of acclimatization must be considered, such as the wide dissemination in the European part of the USSR of the endemic Far Eastern raccoon dog and the introduction of the American mink into the fauna of a number of regions of the forest zone.

Finally, it should be noted that some carnivore species appear to be closely associated with man. This is particularly true of the wolf and to some extent the common polecat. The jackal, fox, ermine, snow weasel and, sometimes, the kolinsky and stone marten stay close to human habitations, while some carnivores settle right inside villages and even in cities (snow weasel, stone marten, etc).

ECOLOGICAL SURVEY OF CARNIVORES

The rather extensive geographical distribution of carnivorous mammals and their existence in all geographical zones demonstrate the good
22 adaptive capacities of these animals. Even representatives of the same species often inhabit completely different types of habitat. The common fox, for example, ranges from the tundra to the desert zone and from western Europe to the shores of the Pacific, while it often ascends to quite high altitudes in the mountains. Aside from such widespread ecologically plastic species, there are a number of more rigorously specialized ones, capable of existing solely under well-defined ecological conditions, and therefore occurring in relatively limited areas, e.g., the snow leopard and cheetah. However, the limits of the areal are not always conditioned by the ecology of the animals, as historical causes often play an important role. An obvious example is the raccoon dog; its natural areal is limited to a portion of the Maritime Territory, but this animal has manifested a high degree of ecological plasticity in its acclimatization in the western parts of the country.

The methods of adaptation of carnivores to various environmental factors may be indicated by a number of examples. They are displayed in the morphological features, ecology and behavior of animals. But it must be borne in mind, that the formation of these or other features or properties is generally associated not with any single factor, but with a complex of physical and biotic ones.

Temperature is of the utmost importance among the physical factors of the environment. In winter, animals are subjected to the effects of very low temperatures, sometimes dropping to -40 to -50°, not only in the north, but in numerous southern regions as well. The most important adaptive feature for survival is the thick pelage which develops toward winter. Thus, in the Yenisei sable's pelage on the back there are 22 underfur hairs for each bristle hair in summer, while in winter the number rises to 44. Not only does the density of the hair cover, particularly of the underfur, increase in winter, but even its height. In the forest marten of the Moscow region, the length of the guard hairs is 31.1 mm in summer and 46.2 mm in winter. The bristle hairs measure 23.8 and 36.8 mm respectively, while the underfur measures 12.0 and 22.4 mm (Kuznetsov, 1952). As a result, the layer of air enclosed between the hairs increases and the thermoinsulation properties of the fur are enhanced accordingly. The whitening of the fur in some northern carnivores (arctic fox, ermine, snow weasel), or its growing lighter, (wolf), also contribute to the decrease of heat loss. In the arctic fox the decoloration is accompanied by the formation of air-filled cavities within the hair, which also increase the thermoinsulation properties of the hair cover. In winter, very little of the body remains unprotected by fur. The soles of the feet in particular become covered with dense harsh hair, completely covering the heel pads. Profuse fat deposits which form in numerous animals in the fall also promote protection against the cold. Subcutaneous and internal fat deposits during the periods of hunger during the winter are an addtional source of energy, and constitute the main source for hibernating species. Various retreats in which the animals stay during the most intense frosts and storms play an important role in the lives of many species. The sable, for instance, does not leave its burrow under the snow for days on end, as the temperature there never drops as low as on the surface. The snow also provides a reliable protection against the frost for the weasel, ermine and numerous other small carnivores. The inhabitants of snowless deserts are exposed to more unfavorable conditions in this respect, as in winter they can only take refuge in burrows.

In summer the animals possess a sparse hair cover, almost devoid of underfur, this being retained only in species which lead an aquatic or am-
23 phibious mode of life (sea otter, otter, polar bear, mink), as life in the water, which possesses high heat conductivity, necessitates a reliable protection against chilling. Thinning of the hair cover in summer is accompanied by a corresponding thickening of the skin. In the fox, for example, the skin in winter is approximately 1.5 mm thick, while in summer it increases to 2.2 mm (Leshchinskaya, 1952). Animals avoid the negative influence of high temperature mainly by taking refuge during the hottest part of the day in burrows, dens or thick vegetation, leaving them to hunt only at sunset. This diurnal rhythm is also favored because of the greater security offered by the night. It is noteworthy that the soles of the paws of the sand-dune cat are densely covered with hair during the summer, an adaptation similar to that described for the arctic fox and other northern animals, but in the present case serving to protect the paws from contact with the sun-baked sands.

The direct influence of humidity on carnivorous mammals is relatively small, many of them inhabiting deserts where there is 100 mm of precipitation annually and where sources of water are quite rare or even absent. The sand-dune cat, for example, survives in such completely waterless deserts. Apparently, that moisture acquired with the food suffices for him. On the other hand, the reed cat, raccoon and to some extent the arctic fox live in rather moist environments along the shores of pools and streams. Finally, carnivores include a group of species (sea otter, river otter, mink, etc) which are more or less closely associated with aqueous habitats, which will be described more fully later (see p 26).

The snow constitutes the most important form of precipitation for terrestrial carnivores, especially where it forms a deep cover. The role of snow as an insulating agent has already been mentioned above. Snow also exerts an important influence on the ability to locomote and obtain food. In species living constantly in regions abounding in snow, the supportive areas of the paws are considerably larger, which reduces the weight per unit of the paw's surface and increases the chances of successful passage by these animals over loose snow. In this connection, the difference between the corsac fox living in snowless regions and the common fox is quite apparent. Despite the small dimensions of the corsac fox each cm^2 of paw surface bears a considerably larger load in comparison to the larger fox, as a result of the small area of the load-bearing surfaces of the corsac's paws. An adult corsac male obtained in October 1945 in the Daur steppes weighed 2,580 g, and the overall supporting surface of the paws was 42 cm^2, giving 61 g of load per cm^2. However, the paws of the common fox from the Moscow region bear a load of 42 g, those of the Pechora taiga, which is marked by an extremely dense snow cover, 28 g, and finally, those of the mountain forest regions of the Kola Peninsula, which also have a fairly deep snow cover, bear 27 to 30 g, the area of the paws being 148 cm^2 and the body weight 3.6 to 4.8 kg (Nasimovich, 1951). The glutton is also distinguished by a high degree of mobility. In specimens of this species from the Altai the load is

only 27 to 35 g/cm^2 (Dulkeit, 1953). Nor is it by chance that the lynx, the sole species of cat spreading far to the north of the taiga subzone, possesses such long feet and broad paws, which serve these carnivores as a sort of ski when traversing deep loose snow. In the Altai lynx the load per cm^2 of paw ranges from 40 to 60 g (Dulkeit, 1953). The wolf, on the other hand,
24 in which the load exceeds 100 g/cm^2 (Merts, 1953), sinks deep in the snow and thus avoids extremely snowy regions where it is difficult to obtain food. Only toward spring, with the formation of a thick crust, does the wolf acquire the means of readily overtaking roe deer, elk and deer, which sink into and injure their feet in the crust. A deep snow cover makes hunting for murine rodents difficult. Some of the carnivores, such as snow weasel and ermine, plunge directly into the snow, dig through it, and thus reach the rodents living in winter on the surface of the earth under cover of the snow. Others, such as the common fox and arctic fox, obtain small animals by listening for them, rapidly stamping on them with their paws under the snow, and then excavating them.

The nature of the influence of light on carnivores has not been adequately studied. It is known that maintaining silver foxes in darkened cages leads to a considerable increase in the number of dark-colored individuals. A darkening of the pelt under these conditions is also observed in the sable and blue arctic fox (Il'ina, 1952). The diurnal cycles of illumination exert a profound effect on the diurnal rhythm of the animal's activity. Among the carnivores are many that are active at night. However, their daily lives are determined not so much by the direct influence of illumination as by the diurnal cycle of the animals they live on, as well as by the degree of safety afforded by the hour. It is not by chance that in areas where they are relatively free from persecution the nocturnal carnivores are commonly observed during the daylight hours as well. Seasonal changes in illumination also apparently exert a profound influence on the reproductive biology of some carnivores. By changing the character of the illumination in winter months, for instance, the latent period of pregnancy in sables has been shortened by 2 to 3 months (Belyaev, Perel'dik and Portnova, 1951).

The terrain and soil conditions play a role of no lesser importance among the environmental factors affecting the animal. The nature of the relief directly determines whether certain species of carnivores in a given locality can continue to exist, depending on whether they are inhabitants of the mountains or the plains. A rough topography usually affords better protection, as there are more sites safe for the construction of dens and burrows, which in the plains are usually located on the slopes of low hills or in ravines, and in mountains – in canyons, clefts of rocks and stone-strewn stretches. The type of ground is also important. Carnivores prefer to dig burrows on dry, well-drained sandy soils in areas with a low level of ground waters, which is of particular importance in northern areas. The relief also exerts a profound indirect influence on the distribution of large carnivores, as it is on this that the snow cover, and thus the distribution of wintering sites of ungulates, depends.

As to biological factors, the vegetation plays an important role in the life of the carnivores, as of other animals. The conditions of nutrition of the carnivores depend directly and indirectly on this factor, as does the possibility of constructing dens and burrows. In other words, the vegetation is one of the chief factors determining the distribution and mode of life of predatory animals. Even if a given species of carnivore does not itself feed on herbaceous food, its existence nevertheless depends on the distribution and number of herbivorous rodents, ungulates and birds. The degree of development of the vegetation is clearly reflected in the protective conditions of the landscape, and the majority of carnivorous animals construct burrows and dens in the thickest stands of vegetation which to other animals and humans are accessible only with difficulty.

Depending on the mode of life and nature of adaptations to various éco-
25 logical conditions, particularly conditions of movement and feeding, a number of habitational types or adaptive types may be distinguished among the carnivores.

Typical ground [terrestrial] forms predominate among them. The majority inhabit the forest. However, they include almost no species completely adapted to life in trees, as is observed in rodents (flying squirrel, tree squirrel). Even the pine marten and yellow-throated marten, which climb trees with agility and execute great leaps from one treetop to another and successfully hunt squirrels there, nevertheless feel no less at ease on the ground. The marten only rarely climbs trees in the sparse northern forests, obtaining its food solely on the ground. The rest of the carnivores of the forest, even those that climb trees, live in hollows high in the trees, and eat fruits directly from branches, nevertheless cannot be included among species living an arboreal mode of life. This group of semiarboreal and semiterrestrial forms include black bears, raccoons, sables, European and Far East forest cat. The brown bear, lynx and leopard also climb trees with ease, and sometimes the kolinsky, ermine, etc. Carnivores which climb with agility are primarily distinguished by somewhat longer limbs than the related purely terrestrial forms. As measurements conducted by O.V. Petrov have shown, the forest marten has limbs which are relatively longer than those of the snow weasel, polecat and ermine, and even the sable. Different proportions of the parts of the limbs are observed in the marten and the sable from the other animals mentioned. A short humerus and long radial bones are characteristic of the anterior limbs, while the posterior limbs have a rather long femur and a relatively short tibia. In contrast to this, the ermine possesses a longer humerus and tibia. The climbing forms of carnivores are also distinguished by longer, sharp and bent claws. The tail is of great assistance in jumping from one tree to another. In the forest marten and yellow-throated marten it is markedly longer than in the sable.

Peculiar adaptations have developed in a number of carnivores which obtain their food by pursuing their prey and are capable of long, rapid runs. They are distinguished by long, slender limbs and a relatively short body. The wolf is a typical example. The peculiarities of its exterior are particularly obvious when compared to other members of the dog family, which may be arranged in the following biological series according to the degree of their adaptation for rapid running: raccoon dog, arctic fox, corsak fox, common fox, jackal, red wolf, common wolf. The wolf is surpassed in this respect by the borzoi hunting dog, specially bred by man. The family of cats also includes good runners with long slender limbs (cheetah, caracal, lynx), while the majority of species possess shorter, massive legs.

The ermine and the snow weasel are characteristic representatives of a certain habitational type. They obtain their food not only on the surface of the earth but frequently penetrate into the burrows of murine rodents and catch them there. For this purpose, the ermine and, even more so, the weasel, possesses an extremely thin and agile body. This character is less marked in other martens – polecat, Altai mink, kolinsky, and others. Of these only the steppe polecat regularly catches susliks in their burrows.

26 Leaping forms are completely lacking among carnivores and burrowing types are not well represented, as they are in the orders of Rodentia and Insectivora. Only the badger and ratel, with their powerful forelimbs armed with large, strong claws, their massive physical structure, and their bristly hair cover, are to a certain measure adapted to a burrowing mode of existence. But these animals also dig their underground passages exclusively for the purpose of constructing habitations, and in obtaining their food, make only shallow excavations. Other carnivores (arctic fox, sometimes the common fox and the wolf, and some small cats) may also dig burrows, but more frequently they utilize existing ones. The use of other animals' burrows is widespread among the carnivores, as is the use of various natural retreats or simple lairs above the surface of the ground. Relatively few species exclusively inhabit burrows during the breeding period. These are: badger, ratel, arctic fox, common fox, corsac fox, light polecat, sarmatier, steppe cat, manul and sand-dune cat. In addition, some eight species dwell irregularly in burrows and only when natural retreats are lacking (wolf, jackal, raccoon dog, hyena, ermine, weasel and others). Various natural retreats are particularly widely employed by carnivores. In the majority of cases, various shelters in depressions in the soil, fissures in rocks, caves, overhanging rocks, under roots of fallen trees, stony stretches, etc, may serve as such retreats. At least five or six animal species exclusively inhabit such sites (brown and polar bears, tigers, leopards, and snow leopard), many of them using almost exclusively covered retreats on the ground. Some species are even content with the most primitive surface dens; the jungle cat, for instance, often contrives something resembling a nest from dry grass among reed and brush thickets and raises its young in it. A number of small rodents (sable, marten, European and Far East forest cats, raccoons), as well as the Asiatic black bear, occupy hollows in trees sometimes quite high above the ground.

Burrows and other dens are particularly necessary for animals raising young. The survival of the newborn to a great extent depends on their quality and location. Thus, the breeding burrows and dens are constructed most carefully, well camouflaged, in spots difficult to reach. Very secure dens are often occupied by animals year after year, even those carnivore species that lead a nomadic type of existence, e.g., large cats, wolves, etc.

Some carnivores require satisfactory abodes for the hibernation period as well (bear, raccoon dog, badger, raccoon). For the rest of the year some species, usually the large animals, content themselves with the most casual dens, without any special modifications so long as they provide the minimum of safety and protection against inclement weather. Other species, e.g., small martens and cats, continue to employ burrows, hollow trees, etc, not merely a single residence, but a number throughout their hunting ranges. Such abodes may sometimes be dispersed over considerable distances. One of the reasons which may cause an animal to change its den is its severe infestation with fleas and other parasites. Only during periods of intense frost and storms do the sable, marten, polecat and others live for extended periods in a single burrow, hardly ever leaving it.

Animals more or less adapted to an aquatic form of life constitute a rather peculiar ecological group. There are four such species among USSR fauna – sea otter, otter, European and American mink. The sea otter and
27 the otter are the most specialized of these. The entire form of the body indicates their aquatic form of life, while minks differ relatively little in this respect from other small martens, constituting a kind of transitional stage from the purely terrestrial to the amphibious types. The head and body of the mink assumed a somewhat more streamlined appearance, the ear conches became shorter, swimming membranes developed on the paws and the hair cover became denser, thicker and waterproof, changing but little with the seasons. These and several other details of the body structure permit minks to swim well and to dive. Nevertheless, minks have remianed largely terrestrial animals, for example, obtaining their food as frequently on the land as in the water. The appearance of the otter has changed more markedly in all respects. Its nimble, flat body with its long muscular tail and short but strong limbs, equipped with wide membranes, is excellently adapted for rapid swimming and diving. The external auditory meatus and nostrils are closed by special valves during diving. The hair cover consists of coarse, glossy bristles and, in a healthy animal, the delicate, extremely dense underfur remains completely dry under water. The otter moves less quickly, but nevertheless fairly rapidly, on land than in the water, not infrequently undertaking long journeys across water divides from one river to another. Fish, frogs and other aquatic animals predominate in the otter's diet. Finally, the sea otter approaches the pinnipeds in degree of specialization. This is seen not only in the body form, but particularly in the structure and disposition of the posterior limbs, these being displaced posteriorly, twisted externally, and possessing a markedly elongated distal portion and an enormous swimming web. In contrast to this, the anterior paws have developed in a different direction, the digits shortened to such a degree as to be almost imperceptible from outside, the paws in the form of a stump, their agility almost entirely lost and their function limited to holding the food while it is being eaten. The sea otter feeds exclusively on marine animals, chiefly those of the bottom, procuring them by diving. It passes even its daily rest periods in the water, emerging on land only at night and for the time of parturition. Its connections with the land are thus minimal.

The variety of the diet of the carnivores is quite large, as are the methods of obtaining it and the corresponding morphological adaptations. Most species of Carnivora being flesh-eaters, the characteristic dentition is developed in accordance with this, with large canines, sharply tuberculated shearing crowns on the premolar and molar teeth, and markedly pronounced teeth. These characteristics are most clearly manifested in the cats, in some canids and in the martens, and is also accompanied by a marked increase in the development of the crests and processes of the skull. The skull of the hyena – an animal feeding mainly on large carrion and capable of gnawing even large-shafted bones – is particularly noteworthy. Some typical carnivores even feed regularly on insects, other invertebrates and plants. Feeding on cedar nuts, berries and insects is of almost equal importance to the sable as feeding on murine rodents. The pine and stone martens in the south also feed on berries, fruits and insects to a large extent. However, feeding on plants and invertebrates is particularly characteristic

of the badger, in which the dentition has correspondingly altered, so that the masticatory surfaces of the molars are broadened and the carnassial
28 teeth are not pronounced. Finally, the food and dentition of the sea otter are particularly characteristic. Its molar teeth assume the form of broad bluntly tuberculated grinders, which are suitable for the trituration of the hard armor of sea urchins, etc.

The development of such an important organ as the claws proceeded parallel to the dentition. In the most highly specialized carnivores – cats – the claws are retractile, thus ensuring their extreme sharpness and effectiveness for use as offensive weapons. In other carnivores (the wolves and foxes, for example) the claws play a different role; in the badger they serve for digging, having consequently become thicker and straighter. Finally, as the claws are not important for the sea otter, they have to a certain degree become reduced.

It goes without saying that the type of diet is reflected directly in the digestive apparatus particularly in the length of the intestine. The carnivore species which devour herbaceous food more frequently possess markedly longer intestines.

Methods of obtaining food vary considerably among the carnivores. The principal methods are: stalking of prey (cats); ambushing animals near their burrows, trails, and waterholes (cats); pursuit (wolf, cheetah); direct entrance into the retreat (ermine, snow weasel, steppe polecat); and seizure on the ground (black polecat, raccoon dog). The majority of carnivores are solitary hunters, except for the training periods of the young, when the adults teach them how to hunt. Some species (wolves) systematically hunt in packs, sometimes resorting to a division of function among drivers and ambushers.

The irregularity of food provision among carnivores has brought about a number of peculiarities in behavior and ecology. When the opportunity offers, numerous carnivores destroy many more animals than are immediately consumable. Some hide the food remnants in stores, using them at a later date. When the usual food is lacking, for example, murine rodents, the carnivores resort widely to reserve foods, eating other vertebrates, insects, fruits, berries and even carrion and refuse. Such phenomena are observed in even the most specialized species, e.g., ermines, which in the Kola Peninsula during food shortages feed on juniper berries. The ability of carnivores to endure more or less prolonged hunger assists them in their struggle for survival during hunger periods – a biological feature which appeared during the process of evolution and is absent in insectivores and small rodents with their extremely high metabolic rate.

Hibernation is a means of survival during unfavorable periods used by the badger, all three species of bears, raccoon dog and raccoon. These eat heavily in the autumn, storing up large amounts of subcutaneous and internal fat, which must serve as the chief sources of energy during the winter. The weight of the raccoon dog, for example, increases towards winter from 4-6 kg to 6-10 kg. Animals insufficiently fattened fail to enter their hibernation. The winter sleep of carnivores differs considerably from the hibernation of rodents, insectivores and chiropters in that their body temperature drops insignificantly and complete quiescence does not set in, the animal sleeping in a state of alert, and in case of danger often leaving its retreat. Raccoon dogs frequently awaken during hot spells and go outside; in the south, raccoon dogs and badgers do not hibernate at all, but remain active throughout the winter.

29 Monogamy (wolf, arctic fox, frequently common fox, etc), as well as polygamy (martens and cats), occurs among the carnivores, although the ratio of sexes in nature in the majority of species is approximately 1 : 1. In various species the mating season occurs at altogether different times of year: in wolves and foxes toward the end of winter, in small cats during spring, in the sable, marten and European brown bear in the middle of summer. Oestrus in some species is not synchronized with any special season of the year, e.g., sea otter, tiger, probably otter and perhaps snow weasel. In numerous carnivores the rutting season is accompanied by fierce battles between males and by strange calls. The length of gestation varies greatly. In the polecat, kolinsky and others it lasts approximately 38 to 40 days; in the wolf, common fox, arctic fox and small cats approximately 60; in the lynx 70 to 74; in the leopard 90 to 105; in the tiger 98 to 110; in the bear 180 days. The period of gestation is rather protracted in a number of mustelids: ermine 210 to 240 days; badger 240 to 250; pine marten 230 to 270; sable 253 to 297 days. Such a long period of gestation is explained by the long rest period (latent period) in which the fertilized egg is present, although its development takes only $1\frac{1}{2}$ months, as in the case of the polecat. A brief but quite irregular latent period (from the point of view of time) is observed in the American mink, and as a result, the gestation period varies from 36 to 74 days. The number of young in a litter in large carnivores is usually 1 to 2; in European brown bears rarely 3 to 4; small and medium carnivores 3 to 6. The arctic fox is marked by the highest fecundity, up to 21 young being observed in it in captivity. The number of young depends on the age and condition of fatness of the female. Young and poorly nourished females are less fecund. In almost all carnivores with the exception of the sea otter the young are born completely helpless, blind and with a closed auditory passage. Their eyes open after $1\frac{1}{2}$ to 4 weeks; the young remain a longer or shorter period in the burrow or den, being fed first on milk and then on regular food. In the small species the litters disperse as early as the fall. The wolves remain together also during the following year. Female polar bears and tigresses, which give birth once in three years, roam with the young until the following period of heat. Sexual maturity in the majority of species is achieved in the second year. A large percentage of young animals perish long before this time as a result of unfavorable weather conditions, disease, hunger, extermination by larger carnivores, and other causes. Thus, only few individuals attain the maximum age, which in the large carnivores is 15 to 20 years.

Due to the uneven influence of environmental factors on the mortality and fertility of the carnivores, the numbers of the numerous species are subject to considerable yearly fluctuations. The population of small mustelids, foxes, arctic foxes and other carnivores, whose existence, as already indicated, depends to a large extent on the abundance of small rodents, is particularly unstable. Mass multiplication of rodents is followed by an increase in the numbers of carnivores, while the dying off of rodents leads to hunger and exhaustion, and is accompanied by the spread of devastating epizootic diseases among the increased carnivore populations, compelling them sometimes to migrate, so that finally their numbers drop to a minimum. In the same way the lynx population in some areas depends on the dynamics of the population of the white hare, and the pine marten population in the north on forest animals and birds on which it preys.

The relations between the species of carnivores are demonstrated in
30 different ways. Carnivores frequently attack one another. For example, tigers attack bears, wolves attack bears and foxes, and gluttons attack foxes, otters and martens, etc. However, while the above-mentioned are of a sporadic nature, the relationship between some species is stably antagonistic. Thus, the tiger in the Far East, for example, is a great exterminator of wolves, and its disappearance in some regions has led to an increase in the number of wolves; the sable on the Altai persistently hunts the kolinsky and devours it when caught. The otter displaces the mink. Another type of interspecies relationship is the use by some carnivores of the food remnants of others. Most typical in this respect is the glutton, which regularly feeds at the expense of the wolves. When food is lacking, not only the ermine but even the fox becomes a "sponger" on the forest marten in the northern taiga, pilfering the remnants of its catch which is has stored away. Under conditions of high numbers of carnivores and a scarcity of murine rodents, for example, rivalry inevitably flares up between those consuming such foods including even individuals of the same species. Peculiar relationships occur in connection with the use of burrows, particularly in the tundra, marshy taiga, and other habitats where the number of suitable sites for constructing dens is limited. The most energetically burrowing animals in the tundra are the arctic foxes, and in the forest – badgers. Other species also make use of the burrows dug by these animals: fox, raccoon dog, occasionally wolves, etc. In some cases the latter occupy old burrows and in others they drive out the original hosts, while badgers and foxes sometimes simultaneously inhabit the widely ramified "badger cities" and raise their young there.

Finally, natural hybridization by some species is observed in nature, such as between the pine marten and sable and the common polecat and European mink.

In conclusion, the high degree of development of the higher nervous activity among numerous carnivorous mammals is to be noted. The wolf, jackal and fox are particularly noteworthy in this respect. An important factor in the perfection of the higher nervous activity and the appearance of complex types of reflexes (particularly defensive ones), in these predators has apparently been the pursuit of large, wary animals and their systematic pursuit by man, and the correspondingly directed influence of natural selection.

PRACTICAL IMPORTANCE OF CARNIVORES

Carnivorous mammals are of manifold importance in the life of man. In some cases they are beneficial, in others – destructive, while a single species may be both, depending on the conditions of its life. This emphasizes the complexity of evaluating the practical importance of some species.

It should first be noted that almost all species of carnivorous mammals of the USSR are included among the fur-bearing animals. The pelts of the sable, sea otter, otter, pine marten, blue arctic fox and others are the most valuable of all furs procurable not only in the Soviet Union but throughout the world. Only a few species of carnivores are without interest to the fur trade, either because of their scarcity (hoary fox, etc) or their poor quality skins (hyena).

Hunting carnivores for fur, and sometimes for meat, fat and other
31 valuable products at the same time, is one of the most ancient methods of exploiting natural resources practised by man. The fur trade has always flourished on the present territory of the USSR and has played a highly important role in the national economy. Pelts of a number of fur animals, e.g., martens, were used in old Russia not only for their intrinsic value as fur, but functioned as money, and as a result some of the silver coins which later appeared were called "kun" [kunitsa = mustelid]. "Soft goods" were the most important part of the levies collected in ancient Russia and served as the chief export item. At the same time the pelts of sables, martens, foxes, arctic foxes and "sea beavers" (sea otters) were of prime importance. It will suffice to mention that in 1594, when Russia was making preparations, in alliance with Austria, for war against Turkey, 40,360 sables were dispatched to Vienna as a subsidy.

The extent of fur hunting during the Middle Ages was extremely great. In the first 4 years following the union with Siberia, for example, the Treasury alone received yearly from that area 200,000 sable skins, 10,000 black-brown foxes, etc. Fur hunting was practically uncontrolled and, together with forest fires and lumbering, had a highly deleterious effect, above all, on the populations of sables, martens and other highly valuable animals.

The exploitation of the fur riches of the country was even more rampant during the period of capitalism. The resources of the fur-bearing animals and the region of their distribution shrank markedly under the influence of predacious trade practices. Some fur animals (sea otter, sable) were on the verge of almost complete destruction.

This prompted the Soviet Government shortly after the Great October Socialistic Revolution to effectuate immediate measures to bring about radical reforms in the fur trade, methods of protection, and artificial dissemination and breeding of fur animals. The results quickly became apparent. Today, the population of sable in a number of areas has attained the same high levels existing many decades back. They also reappeared in a number of areas where they had been exterminated. Temporary bans on pine marten trading also led to a considerable growth of the population. A less satisfactory situation exists in the rehabilitation and growth of numbers of otters, European mink and sea otters. The changeover by the trade to less valuable species previously completely unexploited (mole, water vole, hamster, etc) or to those traded in insignificant numbers (kolinsky, Altai mink) also helped to increase the numbers of valuable fur animals.

Among the most effective organizational measures for increasing the productivity of the hunting grounds, particular success has been achieved by the extensive network of large government-owned preserves and the mass acclimatization and reacclimitization of fur animals in various areas. In the 1927-1948 period alone, for example, 700 sables were captured and transferred to previous regions of their distribution, in the majority of cases with most promising results. The greatest economic effect exerted by the experimental acclimatization of wild fur-bearing animals was that of the release of the raccoon dog in numerous regions of the European part of the USSR, where it multiplied abundantly, became widely distributed, and became one of the most important fur trade species; it is now obtained in

large numbers. The introduction of the raccoon dog, incidentally, was without success in the most northerly and southerly regions of the country, while in some southeastern regions the species proved to be an undesir-
32 able element from the epidemiological point of view. Moreover, the raccoon dog became one of the chief foes of game fowl. Attempts to acclimatization were launched in new regions of distribution with some other nation al fur animals – kolinsky, steppe polecat, stone marten, sea otter – but these experiments have failed to produce the desired practical results. The acclimatization in Tataria, Bashkiria, Altai and the Far East of the American mink, and in Azerbaijan and, to some extent, in Kirgizia of the American raccoon, have proved much more successful. Attempts at acclimatizing skunks and the release of domestic silver foxes to breed freely in the open have proved unsuccessful.

The cage breeding of silver foxes, blue arctic foxes, sables, pine martens, raccoon dogs and American minks has become widely developed in the USSR simultaneously with the utilization of wild fur-bearing animals. Government fur-breeding sovkhozes (state farms) and kolkhozes (collective farms) not only raise large numbers of valuable fur-bearing animals but carry out extensive selection work, creating a number of completely new breeds of foxes and American minks distinguished by original fur colors and high fertility. Due to the discoveries of Soviet scientists the large-scale breeding of sables and martens has become organized for the first time anywhere in the world, these animals never before having multiplied in captivity. The free natural breeding of blue arctic foxes on the Commander Islands is meeting with great success. The population of fur animals in animal sovkhozes is one of the sources of breeding material for acclimatization in nature, although animals captured in the wild state are of course more viable.

The carnivorous mammals were the initial materials for the breeding of domestic animals in the distant past, for example the dog and the cat. Dogs are the most ancient domestic animals known. The various breeds have originated from various wild ancestors – wolves and jackals. As a result of continuous selection, numerous and extremely varied breeds have been created, many of which differ quite distinctly from the original wild ancestors. The dog plays an important role in the life of man, performing various tasks in peace as well as in military life.

The domestic cat also apparently originated from various wild cat species, particularly from the spotted steppe cat, European forest cat, and other species. Cats were domesticated considerably later than dogs. The number of their breeds is smaller than that of dogs, which is partly owing to the somewhat greater difficulties in their breeding and selection. Animals similar in color to wild ones, either existing or having existed in the past in the given locality, usually predominate among domestic cats. Thus, impure breeds of the central belt of Europe are very similar to the European wildcat, domestic cats in Kazakhstan are frequently of a similar appearance to the steppe cat, etc. Domestic cats readily revert to the wild state and often mate with wild cats.

Domestication experiments are also known with other animals in addition to the dog and cat. In southeastern Europe and north Africa, for example, the ferret* (Mustela furo) are bred to exterminate rats and to hunt

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* [Called in Russian the African or white polecat]

wild rabbit. The mongoose (Herpestes mungo) is used in South Asia to combat rodents and snakes. The use of trained cheetahs was once resorted to in Asia for hunting ungulates.

Wild carnivorous mammals play a considerable role in the extermination of animal pests of agriculture and forestry (snow weasels, ermine,
33 light polecat). The steppe polecat exterminates susliks on such a scale that hunting it is banned in certain areas and temporary reserves have been created for its protection and propagation. The snow weasel is undoubtedly of greater service to agriculture by exterminating murine rodents than to the fur trade as a game animal.

Some carnivores, however, are exclusively destructive, as they inflict great losses on animal and poultry farms, exterminating numerous game birds and animals and sometimes damaging agricultural crops. The common fox and the red wolf clearly belong to this category, and unquestionably should be completely annihilated. Despite the intensive fight being waged against it, the wolf inflicts considerable losses on animals, particularly in the tundra, steppe and forest steppe, destroying large numbers of reindeer, sheep, calves, foals, etc. The struggle against it constitutes to be a serious problem. The bear inflicts considerable losses on cattle and horses in some taiga areas of the European part of the USSR, where they pasture in the forest. Under these conditions it is of course to be exterminated, but in most of its areal the bear not only does not attack domestic animals, but does not very frequently hunt even wild ungulates. The jackal, glutton, reed cat and yellow-throated marten also undoubtedly belong to the destructive category. The glutton is noxious not only because it kills valuable animals and birds but also because it attacks animals in traps, as well as in hunters' catches in the forest. Domestic cattle, and dogs and wild ungulates sometimes suffer in the southern mountainous regions from attacks by leopards and snow leopards, but these predators are today so rare that the losses inflicted by them are small. It is hardly correct to include them unreservedly among the species which must be systematically hunted. It would be much more expedient to capture them alive for zoos and shoot them only in cases of extreme need. This is even more valid with regard to the tiger, which has been preserved on the territory of the USSR in numbers hardly exceeding a few dozen, and is thus on the verge of complete extinction.

Some predators (common polecat, fox, etc) become pests only under certain conditions. Sometimes, individual animals become pests – a common phenomenon among carnivores. In such cases, individuals which prove to be noxious should be exterminated. However, this conclusion should not be applied to the entire species, for instance, to all foxes and polecats, as they feed chiefly on noxious rodents and are thus extremely useful.

The mink and otter are never desireable in the ponds of the fish-breeding farms and in reserves of particularly valuable species of fish.

The negative influence of carnivorous mammals is also manifest in epidemiological and epizootiological respects. Representatives of the dog family are sometimes the principal carriers of rabies virus, constituting a serious menace to man and domestic animals. The complete extermination of the wolf in a number of West European countries has resulted in the almost complete elimination of dog rabies in these countries. Carnivores participate in the transmission of a number of infectious diseases, both directly and as hosts to ticks, fleas and other external parasites, and may also spread helminthological invasions, being the intermediate hosts of a number of endoparasites. Finally, some carnivores which feed on carrion may promote the spread of infection by dragging around the carcasses of dead Siberian marmots, susliks and other rodents, as well as ungulates.

34 The danger of direct attack by even the large carnivores on man is usually greatly exaggerated. On sensing man, the animal usually takes cover in time, and only when wounded or caught unaware, particularly near its catch or its young, or else when extremely hungry, launches an attack. Rabid animals which lose all sense of caution are extremely dangerous. Sometimes man-eating tendencies become manifest in individual tigers, wolves, bears and other large predators.

As almost all carnivores, including the most destructive, are fur bearers, the restriction of their numbers should primarily be effected by means of maximal increase of hunting during the open season, which simultaneously provides the government with an additional amount of valuable (export) fur. This measure should prove quite sufficient if applied to the majority of noxious predators. However, bearing in mind the extreme destructiveness of wolves, and the difficulty of hunting them, all possible extermination measures should be enforced during the whole year round, particularly the extermination of litters in dens and the use of poison, traps and all possible methods of rifle hunting. Hunting from light planes and sometimes from aerogliders is most effective under conditions of an open terrain.

after spawning, mollusks, grasshoppers, cedar nuts and berries. It hunts ungulates with particular success in the fall and in spring, when the litters have not yet disbanded. It usually hunts its prey by stalking it, trying to drive it to the river ice, and sometimes leaps on musk deer from above or by stealth. It often takes squirrels and flying squirrels in tree hollows. It may feed on a musk deer for 2 or 3 days while living somewhere in the neighborhood. The yellow-throated marten usually leads a nomadic existence. It is active chiefly at night, but often during the day, too. It runs rapidly over the ground and climbs trees excellently, leaping from the crown of one tree to another.

The biology of reproduction has not been studied. All that is known is that the litter consists of up to five young.

Spring molt occurs in March, fall molt in October. The pelt is of low quality fur and is not classified into categories. It is obtained in small numbers incidental to the hunting of other fur animals. It is one of the most destructive animals of Far Eastern forests, killing enormous numbers of ungulates and fur-bearing animals. The yellow-throated marten is host to ticks, with which it is often heavily infested.

4. Genus GULO Frisch – GLUTTONS

Frisch. Natursystem vierfüss. Thiere in Tabellen: 17. 1775. – Gulo Satunin. 104. 1914. – Gulo Ognev. III: 84. 1935.

DENTITION: $i\frac{3}{3}\ c\frac{1}{1}\ pm\frac{4}{4}\ m\frac{1}{2} = 38.$

The genus comprises one species, represented in the USSR fauna.

1. Gulo gulo L. – Glutton

Linnaeus. S.N. ed. X, I: 45 (Mustela gulo). 1758. – Pallas. Spicilegia Zool., XIV: 35 (G. sibiricus). 1767. – Kerr. Animal Kingdom: 190 (Ursus gulo albus). 1792. – Pallas. Zoogr. Rosso-Asiat.: 73 (Meles gulo). 1811. – Oken. Lehrb. Naturgesch., III: 1004 (G. vulgaris). 1816. – Desmarest. Mammologie ou description d. espèces d. Mammifères: 174 (G. arcticus). 1820. – Nilsson. Skand. Fauna Daggdjur., I: 95 (G. borealis). 1820. – Kaup. Entw. Geschichte Nat. Syst. Europ. Thierwelt., I: 68 (G. arctos). 1829. – Blasius. Allgem. Encyclopedie gesammt. Forst'und Jagdwissensch., VIII: 1 (G. gulo). 1892. – Trouessart. 202
201 Faune de Mammifères d'Europe: 71 (G. luscus). 1910. – Matschie. Sitzungsberichte Gesellsch. Nat. Freunde Berlin: 147 (G. biedermanni, G. wachei). 1918. – Pocock. Proc. Zool. Soc. London: 180 (G. gulo). 1920. – Dybowsky. Archiv Tow. Nauk Lwow, I: 349 (G. kamtschaticus). 1922.

BIOLOGY: Seton. Live Game Animals, II, 2: 403. 1929. – Prell. Zool. Anzeiger, 97, 5-6: 113. 1932. – Grinberg. Rys' i rossomakha (Lynx and Glutton), 23. 1933. – Adlerberg. Zveri Arktiki (Animals of the Arctic), 325. 1935. – Ognev. III, 85. 1935. – Naumov and Lavrov. 117. 1941. – Bobrinskii. 130. 1944. – Nasimovich. Trudy Laplandskogo Gosudarstvennogo zapovednika, III, 107. 1948. – Naumov and Lavrov. 72. 1948. – Kuznetsov. 268. 1952. – Dul'keit. Preobrazovaniya fauny pozvonochnykh nashei 203
strany, sbornik, 147. 1953. – Sludskii. Byulleten' Moskovskogo obshchestva ispytatelei prirody, otdel biologii, LVIII, 2, 18. 1953. – Wright a. Rausch. Journ. Mammol., 36, 3: 346. 1955.

Rather large animal. Body length 76-86 cm; tail approximately 18 cm; height at shoulders 35-45 cm; weight 11-14 kg, occasionally up to 32 kg. Body bulky, squat, on short, thick, semiplantigrade limbs with strong semiretractile claws (Figure 127). Muzzle somewhat elongate. Ears short and rounded. Tail short and shaggy. Pelage dense and long, with coarse guard hair. Predominant color of trunk dark cinnamon brown; in some specimens light reddish brown. **Broad patch on back ("saddle" or shabrack), neck, chest, belly, tip of tail and limbs – dark cinnamon or dark brown, darker than rest of fur.** More or less broad reddish or yellowish band (so-called breechclout) extends from root of tail along flanks. Tips of paws almost black.

Figure 127. Glutton (Gulo gulo L.) (Illustration by A. N. Komarov)

Skull bulky and large (Figure 128). Condylobasal length ♂♂ 144-152 mm, ♀♀ 134-136 mm; zygomatic width ♂♂ 95-107 mm, ♀♀ 89-90 mm; height in region of tympanic bullae ♂♂ 73-82 mm, ♀♀ 68-77 mm. Upper profile of skull markedly elevated in frontal region, from where it descends steeply to nasal apertures. Rostrum short and broad. Distance from alveoli of middle incisors to middle of line connecting ends of postorbital processes is 65 to 70% the distance from the last point to extreme posterior protru-
202 sion of sagittal crest. Distance between posterior edge of alveolus of upper canine and infraorbital foramen almost one half the width of the skull above the canines. Nasal bones short and broad; length along middle suture shorter than distance from anterior end of suture to alveoli of middle incisors. The nasal aperture is large, bending markedly posteriorly, so that when the skull is examined dorsally the anterior ends of the premaxillary bone protrude greatly anteriad from upper edge of nasal aperture. Zygomatic arch-
203 es very large, widely separated posteriorly. Postorbital processes short and broad. Region of postorbital distance elongated, with almost parallel sides, considerably narrower than width of skull over canines. Braincase relatively high and narrow, broadening evenly behind point of maximum postorbital constriction. Sagittal crest well developed, forming large protrusion which overhangs occipital region of skull. Occipital crest fairly well developed. Mastoid processes large, in the form of massive protrusions directed anteriorly and inferiorly (Figure 69e). Width of skull between mastoid processes $1\frac{1}{2}$ times the distance between lower edge of

occipital foramen and anterior edge of palatine incisure. Lateral occipital foramina large and serrated. Infraorbital foramina very small, disposed vertically. Diameter of foramen one half that of upper canine (Figure 68e). Tympanic bullae relatively small, lying at an angle to each other, expanded internally, short, broadened, and gently descending toward the auditory apertures. Auditory tubes well developed. Space between posterior portions of tympanic bullae very uneven. Bony palate very broad. Width between posterior edges of alveoli of carnassial teeth exceeds 75 % the length of the palate, measured from tip of palatine incisure to alveoli of middle incisors. Teeth large, quite powerful. Longitudinal diameter of base of

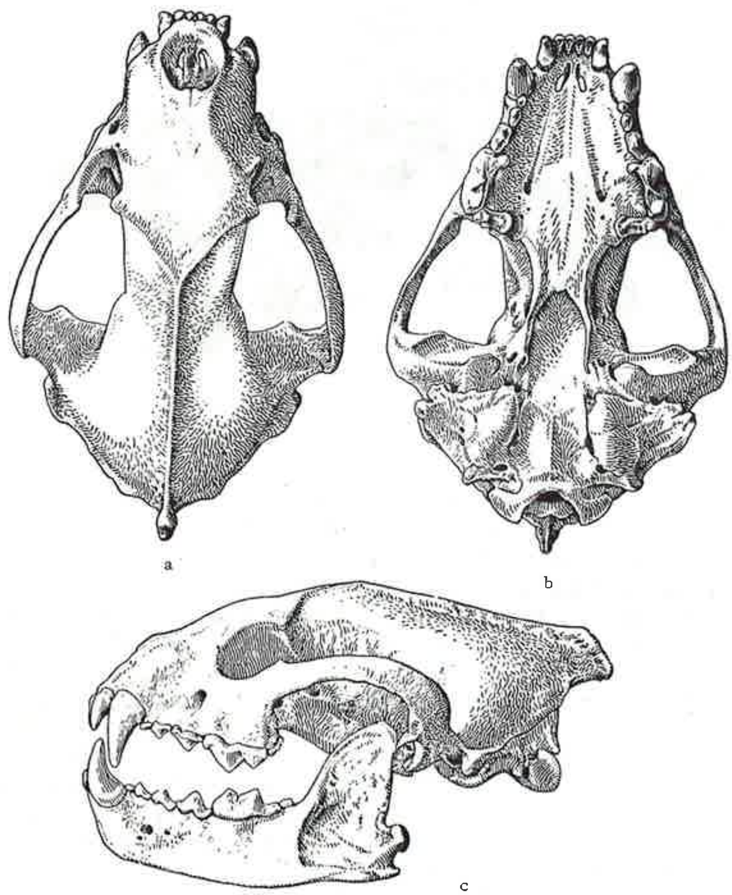

Figure 128. Skull of glutton (Gulo gulo L.)

a-dorsal view; b-ventral view; c-lateral view

upper canine over 10 mm. When the jaws are closed the two upper premolars do not touch the lower ones. Longitudinal axis of upper carnassial tooth (pm^4) almost 4 times that of first molar (m^1). Internal protrusion of upper carnassial tooth relatively small; main denticle very large with clear-
204 ly defined lateral edges. Upper molar of typical "mustelid" structure. First

premolar of both jaws slightly developed, displaced internally from row of teeth. Lower carnassial with two large cusps. Last lower molar very small, with rounded crown.

Os penis rather large, markedly bent almost in the center, with broad base and tuberculated tip (Figure 129).

Figure 129. Os penis of glutton (Gulo gulo L.) (After photograph by V. P. Teplov)

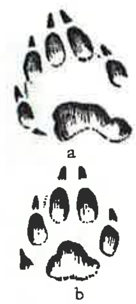

Figure 130. Footprints of glutton (Gulo gulo L.) (After A. N. Formozov)

a-anterior; b-posterior

It is distributed chiefly in forest zones, and to some extent in forest-tundra and tundra zones. In the last century it still existed far to the south in the region of the broadleaf forests of the Ukraine. Today the southern boundary of its range in the European part of the USSR passes approximately through Leningrad, Vologda, Kirov, Molotov, and north of Sverdlovsk. Individuals occasionally enter the southern regions, appearing in Belorussia, Mari ASSR, in the Zlatoust District. East of the Urals the range passes Egorshino and Irbit, Sverdlovsk Region, and further east, at approximately the same latitude; it then descends sharply south and enters Altai. In recent years the glutton has appeared regularly in western Siberia in ty-
205 pical forest-steppe regions. It is frequently observed in Vengerovo and the Kuibyshev District of Novosibirsk Region, located somewhat north of Lake Chana, near Chagly Lake (Krasnoarmeisk District, Kokchetav Region, Kazakh SSR, 54° N. lat.), and finally in the Kokpekty District of the Semipalatinsk Region, 20 km north of Lake Zaisan, i. e., in the semidesert zone, which it obviously entered from the southern Altai. It is fairly widespread in Altai. Farther east, it is found throughout the taiga to the Pacific coast, except for southernmost regions. It is encountered on Sakhalin and the Shantarskie Islands.

In the north, it extends to the shore of Barents Sea on Kola Peninsula. In summer, it is seen more or less along the entire shore of Arctic Ocean,
206 individuals being seen even in winter on the northern tip of Yamal, Gyda Peninsula, Chelyuskin Peninsula (77° 43' N. lat.), and in the tundra of Lena-Khatanga Territory to 72° 48' N. lat. In Anadyr it has survived in the western

portion, and is very rarely encountered in the maritime belt. It ranges on Kamchatka.

Has already been exterminated in western Europe, surviving only in Sweden, Norway and Finland. In Mongolia it inhabits only taiga regions of Kentei and the Lake Kosogol area.

Characteristic of large forest, plain and mountain stretches far from inhabited areas. Often lives in unforested mountain zones, tundra and forest tundra. Den usually built in clefts in rocks, among stones, or under roots of upturned trees.

Figure 131. Footprints of glutton (Gulo gulo L.) in shallow snow. Teletskoe Lake, February 1951 (Photograph by F. D. Shaposhnikov)

Attacks reindeer, roe deer, musk deer, young elk, and wapiti, either by stealth or after a long chase over deep snow, in which it moves easily. However, it most often feeds on carcasses of animals killed but not eaten by wolves. Also captures small rodents and birds (chiefly forest game birds), destroying their nests; occasionally even takes river beavers and sometimes other predators, including foxes and otters. Systematically loots prey from traps and often plunders food in taiga winter quarters of hunters. Eats small quantities of bilberries, crowberries, etc. In Siberia, Altai and Kamchatka, it feeds on cedar nuts, and sometimes eats bracket fungus.

When there is a sizeable catch, several gluttons sometimes gather around it, remaining in the vicinity for a number of days until it is completely devoured. The rest of the time it migrates extensively, often covering some dozens of kilometers per day. In the tundra it makes seasonal migrations, in the winter migrating southward in large numbers in pursuit of reindeer. Single footprints sometimes resemble those of wolf (Figure 130), but they are considerably broader, and the track is not so straight (Figures 131, 132).

Figure 132. Footprints of glutton (Gulo gulo L.) in deep snow. Altai, January 1950 (Photograph by F. D. Shaposhnikov)

The biology of reproduction has not been adequately studied. Mating occurs in fall, around September, but according to certain reports (Prell, 1932) – in summer. The period of gestation, as in other mustelids, is prolonged. The young, one to five in number, appear in spring. According to American data (Seton, 1929), the pelage of newborn is white, and by 3 to 4 weeks, the coloration becomes like that of adults, but duller. According to certain observations, not only the female but also the male participates in training the young. Litters disband toward rutting time, but even then young animals remain close to one another, sometimes hunting together.

Molt occurs twice yearly. Spring molt begins on flanks and withers, extends gradually rearward.

Diseases have not been studied. Indications exist that in the 80's of last century mass extermination of predatory animals (including gluttons) occurred in Anadyr.

The pelt is of relatively little value, being prepared in small numbers and not divided into categories. No special glutton trade exists; it is usually obtained incidentally while hunting with guns or by means of traps or wooden snares. Gluttons are destructive animals, and their extermination is permissible throughout the year.

207 Individual variations are quite extensive. Geographical variability is slight, and has not been adequately studied. Only one subspecies – *G. gulo gulo* L. (1758) – exists in the USSR.

5. Genus *MELLIVORA* Storr — RATELS or HONEY BADGERS

Storr. Prodromus methodi Mammalium et Avium: 34. 1780. – *Ratellus* Gray. Griffith's Cuvier Animal Kingdom, 5: 118. 1827. – *Ursitaxus* Hodgson. Journ. Asiat. Soc. Bengal, IV, 45: 522, 564. 1835. – *Ursotaxus* Blyt, in Cuvier Animal Kingdom, arranged according to its organisation; 86. 1840. – *Melitoryx* Gloger. Gemeinnütz. Hand-und Hilfsbuch Naturgesch., I: 57. 1841. – *Mellivora* Satunin. 103. 1914. – *Mellivora* Ognev. II: 496. 1931.

Dentition: $i\,\frac{3}{3}\ c\,\frac{1}{1}\ pm\,\frac{3}{3}\ m\,\frac{1}{1} = 32.$

There are several species; one is distributed in the USSR, others in Africa, Anterior Asia and India.

1. *Mellivora indica* Kerr – Ratel or honey badger*

Kerr. Animal Kingdom: 188 (*Ursus indicus*). 1792. – Fischer. Synopsis Mammalium: 151 (*Meles indica*). 1829. – Hodgson. Journ. Asiat. Soc. Bengal., IV, 45: 522, 564 (*Ursitaxus inauritus*). 1835. – Gray. Catalogue carnivorous British Mus.: 132 (*Meles indica*). 1869. – Pocock. Proc. Zool. Soc. London: 180 (*M. capensis*). 1920. – Pocock. Fauna British India, Mamm., II: 456 (*M. capensis*). 1941. – Ellerman. 268 (*M. capensis*). 1951.

BIOLOGY: Zarudnyi and Bikhner. Zapiski Akademii nauk, XIX, 2, 73. 1892. – Barentsov. Fauna Zakaspiiskoi oblasti (The Fauna of the Trancaspian Region), 9. 1894. – Greve. Geogr. Verbreit. Raubthiere: 160. 1894. – Bikhner. Ezhegodnik Zoologicheskogo muzeya imperatorskoi Akademii nauk, 1, XV. 1896. – Bil'kevich. Izvestiya Zakaspiiskogo muzeya, 1, 3. 1918. – Ognev. II, 497. 1931. – Flerov. Trudy Soveta po izucheniyu proizvoditel'nykh sil, seriya Turkmenskaya, 2, 247. 1932. – Ognev. III, 635. 1935. – Naumov and Lavrov. 72. 1948. – Sukhinin i Shcherbina. Priroda, 5, 117. 1955.

Externally similar to badger, but differing in smaller size and a number of morphological features. Body length 70-75 cm; tail 18-20 cm; hind paw approximately 12 cm; height of ear approximately 2 cm. Weight of male obtained in Badkhyz in September 1952 – 12 kg**. Body awkward and squat, on short, bulky plantigrade limbs with large strong fossorial claws (Figure 133). Muzzle elongate, with small ear conches. Tail very short, covered with rough fur. Pelage coarse, and rather long on back. Very
208 peculiar coloration. Back, from head to tail, whitish, distinctly outlined from dark brown color of rest of body, head, limbs and tail (Figure 134).

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* Pocock (1920, 1941) and Ellerman and Morrison-Scott (1951) consider Indian and African ratels to be a single species, *M. capensis* Schreber (1776). Owing to a lack of comparative material we shall not touch on this problem.

** Pocock (1941: 460-462) gives the following dimensions for Indian ratels: body length ♂♂ 69-82.5 cm, ♀♀ 62.5-65 cm; length of tail ♂♂ 12.5-17.6 cm, ♀♀ 15-17.5 cm; length of hind foot ♂♂ 11.2-12 cm; weight ♂♂ approximately 9 kg, ♀♀ approximately 7 kg.

From:	Grizzle, Betty
To:	A J
Subject:	Re: Wolverine and white markings
Date:	Thursday, May 4, 2017 2:01:48 PM
Attachments:	Pages from de Puyjalon 1900.pdf

I have not seen the Captain Cartwright document. What year was that?

Here are de Puyjalon pages just for wolverine (in French). The entire publication is just over 20MB, so let me know if you want everything.
The reason for locating this was because it was cited in Fortin (2005) and I wanted to check his 66th parallel notation (page 4), about wolverines found at that range or perhaps further, which is correct (page 144 of de Puyjalon). de Puyjalon also says they inhabit Labrador (earlier in document), but are rare below the 47th parallel (p. 126). Based on her translation of his discussion, my sister said that he really hated wolverines!

Full citation from Fortin: De Puyjalon, H. 1900. Histoire naturelle à l'usage des chasseurs canadiens et des éleveurs d'animaux à fourrures. Imprimerie du Soleil, Québec. 428 pp.

On Thu, May 4, 2017 at 12:26 PM, A J <222wsheridan@gmail.com> wrote:

> I would love to see the Labrador material you referred to. I have a special interest in Labrador having looked for wolverines there. Have you looked at "Captain Cartwright and his Labrador Journal" (edited by Charles Wendell Townsend M.D.)." He mentions wolverines (he trapped) on pages 73, 93, 98, 197, 202, 210, 228, 255, 261, and 268.
>
> On Thu, May 4, 2017 at 11:15 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>
>> Here are selected pages from Novikov (front matter and Gulo account, which starts on page 30 of pdf file).
>>
>> I also had my sister help me translate Henri de Puyjalon's 1900 wolverine discussion (Labrador area of Canada) and also found (online) Seton's Life Histories of Northern Animals 1909 and wolverine account, which includes a range map (at that time) for the 3 "races." This was was modified by van Zyll de Jong (1975), which is where I found the Novikov citation!
>>
>> On Thu, May 4, 2017 at 12:02 PM, A J <222wsheridan@gmail.com> wrote:
>>
>>> yes, I'd like to see them; I'm not sure if that is in my library!
>>> It seems the Scandinavian, Finnish, Russian wolverines tend towards the coloration you described. But there are certainly exceptions and I'm not sure anyone has looked at this objectively across broad areas.
>>>
>>> On Thu, May 4, 2017 at 10:56 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>>>
>>>> FYI - I found Novikov's book - Fauna of USSR, Carnivorous Mammals (translation) from used bookseller. I was looking for the foot loading discussion for wolverines.
>>>> He states that predominant color of trunk is dark cinnamon brown, or light reddish brown, and that tips of paws are almost black.
>>>> Also, he says that dens usually built in clefts in rocks, among stones, or under roots of upturned trees.
>>>> I can send a scanned copy of the pages if you're interested.

On Thu, May 4, 2017 at 11:38 AM, A J <222wsheridan@gmail.com> wrote:

Yes, and we could get samples from trappers in AK. Jens is capturing wolverines right now. I assume they photograph their animals but doesn't hurt to ask. He should have lots from northern Sweden and a few from southern Sweden. And then there are the Norwegians and the Finnish researchers. Rebecca Watters may be able to help with the Mongolian animals but I don't know if she has photos that match DNA samples. I could inquire with the fur buyer here if he still goes to Russia for pelts.

Sent from my iPhone

On May 4, 2017, at 10:21 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

Thanks Audrey. Seems like this would be an interesting part of a larger and more comprehensive genetic study.
I will send message to Jens today.

On Thu, May 4, 2017 at 11:04 AM, A J <222wsheridan@gmail.com> wrote:

Hi Betty
I don't think anyone has looked at white traits in wolverines on a global scale, either prevalence or genetic markers. White markings on the feet are common (but not dominant) in Alaska, at least on the North Slope and Southeast Alaska where I have worked. I have attached an unusual individual, which I believe was caught in Alaska. One trapper I know in NE Alaska showed me a "white" wolverine he captured. Not an albino, but white with cream highlights where black would occur on a "normal" wolverine. From what I know of wolverines in Scandinavia, there is much less white even in the chest pattern. Jens could speak to whether they have ever gotten a white-footed wolverine. There may be regional differences in the occurrence rate and prominence of white markings, which suggests a genetic marker that runs in the population until something changes it. I once asked a fur buyer in Fairbanks about regional differences, and he said there were differences in the size and color of the diamond on wolverines across Alaska.We didn't discuss white feet. Some wolverines, almost as rare as white ones, are nearly completely black. It would be interesting to see if there are genetic differences and if they change over time regionally. The "white-less" wolverines in Scandinavia may be because the population may have descended from a few dark individuals and could change over time as the population increases and expands and dispersers arrive from Russia. The local buyer has purchased wolverines from Russia. I will have to talk to him again to see if white feet occurred on the hides he purchases. It seems to me I recall Jeff Copeland mentioning that he thinks a dominant male in an area can determine the coloration of the individuals in an area and perhaps he has worked with genetics along these lines. It does seem that wolverines from Montana more commonly had larger areas of white on chest, legs, and feet than in other areas. Bob Inman certainly has captured individuals like this.

On another subject, did you hear from Jens in response to your email? Did you ask him about the number of dens outside the snow model that they now have? He is going to try to photograph some of these den sites in the coming week.
Audrey

On Thu, May 4, 2017 at 9:28 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

Hi Audrey - You may have seen this OpEd from the Great Falls Tribune.

Wolverine study's plan preferred to endangered species listing

GreatFalls Tribune/Opinion

May 2, 2017

During a multi-state survey this winter to establish a baseline of where wolverines live in the U.S., one of the solitary mountaineers was photographed by a motion-detecting camera 65 miles southeast of Great Falls in the Little Belt Mountains.... http://www.greatfallstribune.com/story/opinion/2017/05/02/wolverine-studys-plan-preferred-endangered-species-listing/101208748/

I noticed that one of the photographs (Pintler Mtns) shows a wolverine with white on its front paws. I had read (somewhere) about this interesting characteristic and ask Bob Inman if he knew whether this was unique to North America or Montana, and whether this has been observed in wolverines in Scandinavia. He said that they have seen fairly extensive white markings, often on the foot, in GYE and Montana, but did not know about other populations.

I also read the following account of almost all-white wolverines from Cardinal's report:

From Cardinal 2004 *Aboriginal Traditional Knowledge COSEWIC Status Report on Wolverine Gulo gulo Qavvik*: (page 7)
"A nearly all-white variant of wolverine has been trapped by hunters in the Kitikmeot region. Knowledge holders in the region state that this variety is very rare; in all of the other regions, only one other knowledge holder reported catching a wolverine that had a significant amount of white on it. Knowledge holders also mentioned that this variant has always occurred in this one area and reported their parents had caught this variety in the past. A pelt was also on display at the local HTC."

Question for you: Do you know if anyone has looked at these traits (on global scale) and how prevalent they are? And whether anyone has investigated the genetic markers for this?

Thanks.

--

Betty J. Grizzle, D.Env.
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U.S. Fish and Wildlife Service
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Carlsbad, CA 92008
760-431-9440, ext. 215
760-431-5901 fax

Son parcours géographique est très étendu. Dans la province, on rencontre la variété noire, surtout dans le nord des comtés de l'ouest, où l'attirent les grands fauves ; mais elle y est rare au-dessous du 47ème parallèlle.

Sur les territoires du nord-est du Labrador Canadien, c'est la variété grise qui domine. On prétend qu'elle s'y accouple quelquefois avec les chiens de la région (chiens de Cométic ou Esquimaux), et il est certain qu'il est des chiens de Cométic qui ressemblent prodigieusement à des loups.

Une esquisse de cet animal si connu était inutile. Sa forme de chien à museau pointu et à front élargi ; ses oreilles droites et son œil oblique à reflets d'un jaune fauve ; sa queue rectiligne et touffue, sont présents à toutes les mémoires.

Il a de physique de l'emploi : C'est un bandit et il en a l'air.

***

LE CARCAJOU (GULO VULGARIS, CUVIER.— GULO LUCUS, SABINE.)

Voici ce que je disais de cet animal dans mon " Guide du chasseur de pelleterie ", publié en 1893. C'est l'expression de ce que je considère comme la vérité, malgré la forme un peu humoristique que l'on voudra bien me pardonner ; je n'ai rien à y retrancher. Bien au contraire, je me permettrai d'y ajouter : 1° L'opinion exprimée par Monsieur T. T. Payne, naturaliste-observateur, à la baie Stupart, détroit d'Hudson ; 2o Le témoignage donné au comité du sénat, en 1888, par Monseigneur Clut, O. M. I., évêque d'Arindel, dans les territoires du Nord-Ouest, Mackenzie.

Ce sont les sauvages qui l'ont nommé " karka-joo ", mais ils le désignent plus souvent sous le nom de " qua-quâ-sut "—" le diable des bois "—et, tout pillard, tout voleur qu'il soit, on ne saurait l'accuser d'avoir dérobé cette épithète qui lui convient à tous égards. Aucun animal n'a été plus travesti par les naturalistes de tous les temps. Les uns lui ont prêté toutes les diableries, les autres les lui nient à peu près toutes et mettent en doute celles qui restent. Cette divergence d'opinion tient à la différence très considérable du développement de l'intelligence ou de l'instinct pour chaque individu d'une même variété. Les naturalistes de l'ancien régime ont observé des animaux très roués, très intelligents, car, à ces dates anciennes et bénies, les hommes de science étaient encore quelquefois des hommes de chasse et observaient de temps en temps, eux-mêmes, les animaux qu'ils se proposaient de décrire. Chasseurs, ils ajoutaient foi aux récits des chasseurs, dont ils appréciaient la vérité connue. Incrédules, ils accordaient néanmoins quelque créance à leurs récits, lorsque ces derniers se reproduisaient identiques sous des latitudes diverses et dans des circonstances différentes ; tout au moins faisaient-ils une petite part au vrai, se gardant bien de le sacrifier à tout propos au stupide tyran moderne que l'on appelle le vraisemblable.

Aujourd'hui, le naturaliste ne décrit plus les animaux, il les empaille. Il simplifie l'examen et l'étude sur le vif par la négation qui dispense de travail et de fatigue et lui donne une structure savante aux yeux du vulgaire ignare, abêti par le doute systématique. Bien plus, comme ceux qui l'ont précédé dans la science lui ont laissé peu de chose à faire, il trouve commode de saper ou de nier les faits établis par ses devanciers.

Il complique leurs découvertes et leurs études de celles qu'il croit avoir faites et qui, la plupart du temps, n'existent que pour lui. Il modifie les classifications adoptées, tronçonne les ordres, multiplie les familles, gaspille les espèces pour en faire des variétés et les variétés pour en constituer des espèces, croyant avoir gravi les hauteurs les plus élancées des sciences naturelles, lorsqu'il a donné son nom au " rat à trompe " de joyeuse mémoire, ou à une coquille de " bigorneau " abandonné par un celte amateur de mollusques.

Me voilà, il me semble, un peu loin du Carcajou. J'y reviens.—J'avais besoin avant de parler de l'être invraisemblable dont je veux vous entretenir aujourd'hui, de m'attirer les sympathies de nos naturalistes modernes.

Les sauvages montagnais qui le connaissent bien lui trouvent une ressemblance saisissante de mœurs et d'allures avec le diable, qu'ils connaissent non moins bien, paraît-il. Je ne surprendrai donc personne en disant qu'auprès de lui, le renard, dont les vertus laissent cependant considérablement à désirer, est un saint doublé d'un imbécile. Le Carcajou, j'entends le Carcajou digne de ce nom, ne respire et n'agit que pour satisfaire ses passions et entraver celles des autres. Pour atteindre ce but, tous les moyens lui sont bons. Il n'est pas un habitant des bois, qui ne devienne plus ou moins sa victime, mais sa victime préférée, entre tous, c'est le chasseur. C'est avec une persistance infatigable, avec un acharnement endiablé servi par une force et une intelligence peu commune qu'il moleste ce dernier, qu'il le persécute, qu'il l'ahurit au point de le contraindre à démolir ses dernières " tentures ", à fermer ses pièges et à changer de territoire de chasse.

L'odorat de cet animal tient du prodige. Tout le monde a entendu dire que son passetemps favori consistait dans le pillage et la destruction des chemins de chasse des trappeurs. Ce que l'on sait moins, c'est qu'il atteint ce but, lors même que les " tentures ", en automne, ont été recouvertes plus tard par deux ou trois pieds de neige, et que tout a contribué à dissimuler les émanations personnelles du chasseur et celles de ses appâts ou de ses pièges.

Sa manière de procéder prouve une sagacité et une perversité inouïes, j'allais dire une instruction très soignée, s'il ne s'était agi d'un animal. Lorsque son odorat, ou une faculté spéciale que l'on ne saurait définir, lui a signalé la présence d'un piège sous la neige, il calcule à peu près la longueur que peut avoir la chaîne qui relie celle-ci au " piquet de garde ", puis il décrit un cercle ayant pour rayon une longueur un peu moindre que la longueur calculée, creuse une tranchée en suivant la circonférence du cercle, et, si son calcul a été juste, tombe sur une partie de la chaîne dont il se saisit pour attirer le piège et le détendre.

Lorsque son appréciation primitive lui a donné un rayon trop grand, il creuse une nouvelle tranchée circulaire concentrique intérieurement à la première, et ainsi de suite jusqu'à ce qu'il ait atteint le piège. Abandonner ce dernier sur le théâtre du vol, serait donner au chasseur une chance de le retrouver et de s'en servir encore.

Le Carcajou se garde bien d'agir ainsi : sa mansuétude ne veut pas se contenter des joies inachevées d'une vengeance incomplète. Alors, il emporte le piège et, s'éloignant le plus possible du chemin des " tentures ", il grimpe sur un arbre, aussi haut qu'il peut monter,—il connait les lois de la pesanteur—et le laisse tomber dans le banc de neige le plus épais qui soit au pied du tronc.

En voyant et en étudiant les vestiges du travail de Quà-Qu'à-Sut, bien loin de lui en vouloir, j'ai souvent été près du désir immodéré de lui demander où il avait puisé les notions si précises qu'il possède sur le rapport de la circonférence au diamètre et sur les lois de la chute des corps. Il eut sans doute, dédaigné de me répondre, car il connait les hommes et sait le prix qu'ils attachent au tégument poilu qui sert d'enveloppe à son " instinct ", mais s'il m'eut répondu, il l'eut fait, j'en suis convaincu, avec toute l'érudition d'un géomètre de profession.

Pour lui tout ce qui est propriété humaine est dissipable, brisable et salissable à merci ! Il en agit avec les " tentures " de bois comme avec les tentures de pièges ; avec le mobilier rustique et primitif d'un " camp " comme avec les provisions, et les armes du chasseur.

Il ne lui suffit pas de briser les pièges, de disperser les provisions, de voler les vêtements; il aime encore à laisser les marques les moins discutables de son passage détesté. Il semble tenir absolument à dissiper tous les doutes et, pour cet objet, il laisse sur le lieu de son crime les plus abominables de ses " laissées ". Les premières qui m'ait été donné d'étudier avaient été déposées précieusement par lui exactement au centre d'un baril à demi plein de farine, dont il avait su enlever le couvercle, sans rien répandre du contenu et sans renverser le contenant. A quel entraînement ironique obéissait-il en accomplissant cet acte d'un goût douteux, surtout pour une bête née si loin de la Sprée ? Inexplicable, n'est-ce pas?

J'ai pu constater aussi le respect profond qu'il a pour son épiderme, le sang-froid et l'habileté qu'il apporte à le préserver de toutes les atteintes du plomb.

Il y a bien des années, hélas ! j'étais campé près d'une petite rivière de la côte nord du fleuve, la Mistassini. La nuit était complète et je dormais du sommeil d'un juste depuis plusieurs heures, lorsque je fus réveillé par un bruit inattendu dans ces parages. Un grognement se faisait entendre presque à mes oreilles et les cordes qui s'attachaient aux piquets de ma tente étaient, tour à tour, violemment secouées. Mettre la main sur mon fusil, réveiller mon engagé, l'armer d'une torche de bouleau et sortir, furent l'affaire d'un instant. En arrière de la tente prenait naissance la forêt, la mer était en avant.

Dès les premières lueurs jetées par la torche, l'animal avait pris le bois, néanmoins je l'avais vu assez distinctement pour le reconnaître. Je le voyais encore, ou plutôt je voyais la moitié de son œil. Abrité derrière un gros sapin, il n'exposait de cette partie précieuse de sa personne que juste ce qu'il en fallait pour observer mes mouvements. Je marchais sur lui le fusil à l'épaule, chaque arbre me forçant à faire un détour.

A tous mes mouvements correspondait un mouvement symétriquement inverse du carcajou, qui parvenait ainsi à gagner l'abri du sapin suivant,sans avoir présenté à mes plombs d'autre partie de sa personne que cette section d'œil, dont l'expression me parut bien plus celle de la gouaillerie que celle de la crainte. Peu à peu il gagna les bois épais, sans m'avoir donné une seule fois l'occasion de lui envoyer un coup de fusil ; cependant, quelques pas à peine me séparaient de lui. J'ai fait la guerre de partisan et retraité sous bois avec toute l'habilité que me donnait l'amour particulier que j'éprouve pour une peau qui m'est chère —je veux parler de la mienne—mais, je l'avoue, à ma honte et à celle des armées modernes, je ne vis jamais un tirailleur quitter un abri pour en gagner un autre, sous le feu de l'ennemi, avec un calme, une précision et un sang-froid comparables à ceux du carcajou.

On le croit peu agile. Il n'a point, il est vrai, la rapidité du lévrier, mais son intelligence lui en tient lieu. Jamais il ne se presse. La peur semble lui être étrangère. Il bat en retraite et ne fuit pas. Sa force est peu commune, extraordinaire même, si on la compare à l'exiguité relative de sa taille, qui atteint à peine celle d'un chien de moyenne grosseur ; il brise assez facilement les chaînes des gros pièges. Il a trente-huit dents, dont douze incisives, quatre canines et le reste en molaires. Il perfore les cabanes de castor, détruit leurs digues pour faire assécher leur demeure et s'emparer de leur personne. Il mange de tous et de tout. Il s'attaque aussi aux animaux de forte taille et il est incontestable qu'il sait arrêter, tuer et manger les jeunes caribous.

Pour cette chasse, qu'il pratique en hiver, il met à profit les théorèmes d'Euclide et la connaissance approfondie des mœurs de l'animal qu'il convoite. Il sait que, dans sa fuite, le caribou ne suit jamais une ligne droite et qu'il décrit toujours une courbe plus ou moins allongée : une randonnée. Il sait encore qu'on le rencontre en hiver sur les lacs recouverts de glace et de neige.

Lorsque les hasards de la chasse le mettent en présence d'une harde de ces animaux dans de semblables conditions, il se montre à l'improviste sur les bords du lac. Les caribous effrayés, prennent sur le champ leur course en décrivant la courbe habituelle. Lui, coupe au plus court, va se placer à l'extrémité de l'arc, sur un tronc d'arbre penché au-dessus du lac et lorsque les fugitifs passent au-dessous de l'arbre, il se laisse cheoir sur un jeune caribou, et le tue en lui coupant l'artère carotide.

Le fait que je viens de narrer, je ne l'ignore pas, est repoussé par certains naturalistes en chambre. Je ne puis, pour leur plaire, récuser le témoignage de mes yeux, et s'il était nécessaire, je pourrais en appeler au témoignage de quelques officiers de la Baie d'Hudson et de beaucoup de chasseurs très expérimentés, qui, ayant vu comme moi, ne sauraient hésiter à soutenir la rigoureuse vérité de mon récit.

Le carcajou n'est que bien peu sensible aux charmes des boulettes empoisonnées. Il s'en défie même extraordinairement et lorsque, en dépit de son odorat subtil et de sa prudence achevée, il s'y laisse prendre, ça n'est jamais qu'à demi. Puis, s'il échappe aux effets de l'intoxication, il prévient ses congénères, et le lieu du théâtre de l'empoisonnement d'un frère est réprouvé et abandonné de tous les carcajous qui, lorsqu'une impitoyable nécessité les contraint à le traverser, le franchissent sans s'arrêter un seul instant et le plus rapidement possible.

A propos de cette faculté singulière, voici ce que me contait Th., vieux trappeur qui, depuis 45 ans, promène ses tentures un peu partout sur la côte et dont le caractère rigide se prête peu aux fumisteries sportives. Je donne son récit tel que je l'ai reçu, en lui conservant tout son laconisme.

" Un jour, je montai du poison, afin de me débarrasser d'un carcajou, qui mettait mes chemins de tentures au pillage. Je déposai de suite quelques boulettes. Il vint à l'appât et ne voulut en manger que la moitié. Aussitôt qu'il l'eût avalé, il se mit à faire des efforts pour vomir en reculant, laissant sur un espace d'au moins cinquante pas les résidus expulsés par ses viscères, puis, débarrassé du poison, il prit le bois et s'enfuit. Pendant deux ans, je ne vis plus un seul de ces animaux au même lieu, et plus tard, si j'en trouvais une piste, je distinguai que l'animal traversait sans s'arrêter le plus vite possible l'endroit où j'avais autrefois jeté mes appâts empoisonnés. Ils doivent se prévenir entre eux. D'ailleurs, je ne suis pas le seul à qui pareille aventure soit arrivée. Demandez à M. de Godbout, il lui est arrivé la même chose."

T. . a-il vu le carcajou agir ainsi ? non, peut-être, mais il est inutile à un chasseur d'assister aux faits et gestes d'un animal pour savoir qu'elles ont été ses attitudes, ses actions ou ses allures. Les pistes et les traces laissées par ce dernier suffisent, dans la plupart des cas, pour donner des certitudes ; et je ne mets pas en doute un instant que les choses ne se soient passées ainsi que les contait mon vieux chasseur.

D'après ce récit, " qu'à-qu'à-sut " est doué d'une faculté spéciale qui lui permet de restituer à l'occasion ce qu'il avale, quand le saveur lui en paraît indiscrète, et, il n'est pas douteux, qu'il ne sache, que le plus sûr remède contre l'ingestion d'une substance toxique, est le vomissement.

A quoi doit-il ses notions d'une thérapeutique si bien conçue ? En est-il redevable à l'expérience, au raisonnement ou aux leçons de ceux qui le précédèrent dans la vie ? Obéit-il simplement aux impulsions de l'étrange moteur auquel on a donné si improprement, à mon avis, le nom "d'instinct ?" Doit-on attribuer également à ce dernier l'abstention de ses congénères et leur répugnance, si nettement accusée, pour un lieu témoin de tant d'angoisses et de tant d'efforts ? Quels pouvaient être les mobiles et les causes d'une semblable attitude, que l'on ne saurait sans ânerie, rapporter à un développement anormal de l'odorat ? Je ne jouis pas de l'instinct du carcajou, aussi, ne vois-je que deux solutions à ce problème. Sans doute, il y en a bien d'autres, mais ce sont les seules, je l'avoue à ma honte, qui me soient fournies par mon intelligence humaine.

Ou j'ai été victime d'un vaste mensonge, ce que je me refuserai toujours à croire, les faits m'ayant été exposés par un chasseur ; ou, le carcajou est très fort en toxicologie et possède un langage très éloquent, dont il se sert, au lieu d'en faire mauvais usage, pour avertir ses amis de même poil des dangers qu'il a courus et de ceux qu'ils sont exposés à courir.

Après tout ce que je viens de dire, il semblerait que s'enparer d'un carcajou, soit une œuvre impossible. Il n'en est rien cependant. Il est même assez facile d'en capturer une grande quantité d'instinct moyen ou touchant à l'idiotisme. Car, ainsi que pour le renard et pour toutes les bêtes du bois, l'étiage " instinctectuel "— puisse la Postérité me pardonner ce néologisme ! —de cet animal varie à l'infini. " Quâ-quâ-sut " ne se prend jamais.

Voici ce que dit Monsieur Payne :

" C'est le plus grand ennemi des Esquimaux, et s'il en parait un en aucun temps près de leur camp, ils ne prendront pas de repos qu'ils ne l'aient tué. Et quand il en est rapporté un, il y a toujours grande réjouissance. C'est le plus ingénieux voleur qui existe dans cette région et il n'est aucune cache à son épreuve tant il est fort. Il roulera de gros cailloux, et une fois dans la cache il ne perd pas son temps à détacher les sacs en peau de phoque, mais il fait bientôt un trou, et en véritable Esquimau, il vit d'huile et de graisse de phoque jusqu'à ce que le sac soit vide ; alors il tourne son attention vers une autre cache.

" Les dispositions au vol de cet animal sont tellement semblables à celles d'un être humain malhonnête, qu'un Esquimau connu pour voleur est toujours appelé " Kubvie " par ses compatriotes.

" Heureusement cet animal est peu nombreux dans cette localité, quoiqu'on en prenne souvent dans des trappes à quelques milles à l'ouest, où il existe, comme le loup, pendant l'année entière."

Voici ce qu'ajoute Monseigneur Clut :

" Les pékans, les martres se prennent généralement au moyen de pièges en bois et en fer. Le carcajou est l'ennemi du pays et des pauvres Indiens, parce qu'il détruit les pièges en bois tendus pour les pékans, les martres et les visons, et sans se faire prendre. C'est l'animal le plus rusé que je connaisse ; mais il a des instincts de malice immonde sans pareils."

Tous les animaux se chassent au fusil. On peut donc tuer un carcajou tout comme on tuerait un lapin. Mais il n'est pas toujours aisé de l'apercevoir. Cependant, le cas se présente, quoique bien rarement ; aussi, tuer un carcajou au fusil est une aventure, rien qu'une aventure, et il n'existe pas de coutume spéciale qui régisse cette sorte de chasse. Au piège, il est plusieurs manières de procéder. En voici une.

On érige une attrape assez grande et on l'amorce avec un lambeau d'étoffe, dernier vestige d'un vêtement que vous avez abandonné. Derrière la cabane de l'attrape, — (je suppose que l'on n'a pas oublié qu'une trappe est toujours protégée en arrière par une clôture en piquets solidement enfoncés et solidement recouverts qu'on appelle " la cabane ", cabane qui empêche l'animal d'atteindre l'appât autrement que par le côté où peut jouer le piège ou la " tombe "),—on plante sur un espace de quelques verges carrées un bois factice, en enfonçant en terre des branches vertes assez grosses et garnies de leurs feuilles. Puis au milieu de ce petit bois improvisé, on place deux ou trois pièges soigneusement dissimulés, comme on le fait pour le renard et en prenant plus de précautions encore, s'il est possible. Le carcajou, qui voit la possibilité de priver le chasseur d'un vêtement qu'il lui croit indispensable, mais aussi qui connaît les effets de l'attrape ou du piège, se garde bien de se présenter de front, il contourne la cabane afin d'en briser la clôture et s'emparer sans danger, croit-il, de l'objet de sa convoitise ; et pour y parvenir, il pénètre dans le petit bois et se prend quelquefois, pas toujours, dans les pièges que vous avez disposés à cet effet.

Voici une autre méthode : On suspend à un arbre un paletot ou un pantalon, une poire à poudre ou un fusil, des provisions ou des bottes. Cela doit être fait sans prendre aucune précaution, de la façon la plus naturelle possible, puis, avec toute la ruse dont vous êtes capable, avec toute l'habileté dont vous êtes certainement susceptible, vous placez plusieurs pièges autour de l'arbre. L'animal lorsqu'il a connaissance de vos armes, de vos vêtements ou de vos provisions, se met en frais de s'en approcher afin de vous jouer un mauvais tour. Mais il ne se presse pas, il connaît trop le chasseur pour cela. Il tourne autour de l'arbre, il flaire, il inspecte et il finit toujours par rencontrer quelques-uns de vos pièges dont il saisit la chaîne et qu'il fait partir.

Quelquefois, il les découvre tous, alors vous avez perdu, ou bien peu s'en faut, vos effets, vos pièges et votre temps. D'autres fois, tranquilisé par l'exécution de quelques-uns de vos pièges, il compose avec son astuce habituelle, s'approche trop vite et se prend dans l'un de ceux qu'il a dédaigné de découvrir. En dehors de ces deux moyens, applicables à la capture d'un carcajou d'intellect ordinaire, il y a l'attrape et le piège tendus dans un tout autre but que celui de le prendre J'en ai vu fuyant avec un piège à la patte, se reprendre dans la même journée, un peu plus loin, dans un autre piège tendu pour l'ours. Ce carcajou, de la variété imbécile, se rencontre plus souvent qu'on ne le croit, et c'est lui qui a fait douter des aptitudes de " Quâ-quâ-sut." Mais, à quelque variété qu'il appartienne, je ne saurais trop recommander de bien choisir le piège destiné à le prendre. Il faut le choisir très solide, le munir d'une chaîne à toute épreuve et passer dans l'organeau un long bâton de mascamina (cormier) bois très dur qui résiste plus longtemps que les autres aux terribles mâchoires de l'animal. Un carcajou pris n'a plus qu'un seul désir en ce monde, s'échapper, et vous pouvez arriver sur lui, sans qu'il interrompe une minute le travail destiné à lui rendre la liberté.

Le carcajou ne se terre pas.

D'après les aborigènes, la femelle conçoit en avril ou commencement de mai et met bas d'avril en mai l'année suivante, deux ou quatre petits, qu'elle soigne avec assez de sollicitude. Elle porterait donc 12 mois. Si ce fait, que je n'ai pu contrôler encore, était exact, il battrait en brèche la loi qui veut que la durée de la gestation des animaux soit en raison directe de leur taille.

La fourrure du carcajou est marron foncé, très épaisse et croisée sur le dos d'une nuance plus pâle. C'est une belle fourrure qui vaut toujours un bon prix

Le parcours géographique du carcajou s'étend jusqu'au 66ème parallèle et peut-être un peu plus loin. Il n'est que trop abondant dans notre province.

On a calomnié l'ours, mais on a trop ménagé le carcajou. Il est, avec le loup, et à un titre plus élevé encore, la désolation des bois et des chasseurs.

La destruction de ces deux animaux doit être encouragée par tous les moyens possibles.

Tuer un loup est une bonne affaire. Tuer un carcajou est non seulement une bonne affaire, mais encore une bonne action.

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LE LOUP-CERVIER.—Gravure du "Chasseur Illustré," Paris.

From: A J
To: Grizzle, Betty
Subject: Re: Wolverine and white markings
Date: Thursday, May 4, 2017 2:20:01 PM

You can find Cartwright's book on Amazon; I have the paperback edited by Townsend originally published in 1911, but I see there is a new book out in 2013 that I will have to get. By the way, take any data on wolverines gathered by Fortin with a grain of salt. OK if he cites other data but I would consider his own observations of wolverine tracks with some reservation. I worked with him in Ontario.

On Thu, May 4, 2017 at 12:01 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> I have not seen the Captain Cartwright document. What year was that?
>
> Here are de Puyjalon pages just for wolverine (in French). The entire publication is just over 20MB, so let me know if you want everything.
> The reason for locating this was because it was cited in Fortin (2005) and I wanted to check his 66th parallel notation (page 4), about wolverines found at that range or perhaps further, which is correct (page 144 of de Puyjalon). de Puyjalon also says they inhabit Labrador (earlier in document), but are rare below the 47th parallel (p. 126). Based on her translation of his discussion, my sister said that he really hated wolverines!
>
> Full citation from Fortin: De Puyjalon, H. 1900. Histoire naturelle à l'usage des chasseurs canadiens et des éleveurs d'animaux à fourrures. Imprimerie du Soleil, Québec. 428 pp.
>
> On Thu, May 4, 2017 at 12:26 PM, A J <222wsheridan@gmail.com> wrote:
>
>> I would love to see the Labrador material you referred to. I have a special interest in Labrador having looked for wolverines there. Have you looked at "Captain Cartwright and his Labrador Journal" (edited by Charles Wendell Townsend M.D.)." He mentions wolverines (he trapped) on pages 73, 93, 98, 197, 202, 210, 228, 255, 261, and 268.
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>> On Thu, May 4, 2017 at 11:15 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>>
>>> Here are selected pages from Novikov (front matter and Gulo account, which starts on page 30 of pdf file).
>>>
>>> I also had my sister help me translate Henri de Puyjalon's 1900 wolverine discussion (Labrador area of Canada) and also found (online) Seton's Life Histories of Northern Animals 1909 and wolverine account, which includes a range map (at that time) for the 3 "races." This was was modified by van Zyll de Jong (1975), which is where I found the Novikov citation!
>>>
>>> On Thu, May 4, 2017 at 12:02 PM, A J <222wsheridan@gmail.com> wrote:
>>>
>>>> yes, I'd like to see them; I'm not sure if that is in my library!
>>>> It seems the Scandinavian, Finnish, Russian wolverines tend towards the coloration you described. But there are certainly exceptions and I'm not sure anyone has looked at this objectively across broad areas.
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>>>> On Thu, May 4, 2017 at 10:56 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>>>>
>>>>> FYI - I found Novikov's book - Fauna of USSR, Carnivorous Mammals (translation)

from used bookseller. I was looking for the foot loading discussion for wolverines. He states that predominant color of trunk is dark cinnamon brown, or light reddish brown, and that tips of paws are almost black.
Also, he says that dens usually built in clefts in rocks, among stones, or under roots of upturned trees.
I can send a scanned copy of the pages if you're interested.

On Thu, May 4, 2017 at 11:38 AM, A J <222wsheridan@gmail.com> wrote:

> Yes, and we could get samples from trappers in AK. Jens is capturing wolverines right now. I assume they photograph their animals but doesn't hurt to ask. He should have lots from northern Sweden and a few from southern Sweden. And then there are the Norwegians and the Finnish researchers. Rebecca Watters may be able to help with the Mongolian animals but I don't know if she has photos that match DNA samples. I could inquire with the fur buyer here if he still goes to Russia for pelts.
>
> Sent from my iPhone
>
> On May 4, 2017, at 10:21 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>
> Thanks Audrey. Seems like this would be an interesting part of a larger and more comprehensive genetic study.
> I will send message to Jens today.
>
> On Thu, May 4, 2017 at 11:04 AM, A J <222wsheridan@gmail.com> wrote:
>
>> Hi Betty
>> I don't think anyone has looked at white traits in wolverines on a global scale, either prevalence or genetic markers. White markings on the feet are common (but not dominant) in Alaska, at least on the North Slope and Southeast Alaska where I have worked. I have attached an unusual individual, which I believe was caught in Alaska. One trapper I know in NE Alaska showed me a "white" wolverine he captured. Not an albino, but white with cream highlights where black would occur on a "normal" wolverine. From what I know of wolverines in Scandinavia, there is much less white even in the chest pattern. Jens could speak to whether they have ever gotten a white-footed wolverine. There may be regional differences in the occurrence rate and prominence of white markings, which suggests a genetic marker that runs in the population until something changes it. I once asked a fur buyer in Fairbanks about regional differences, and he said there were differences in the size and color of the diamond on wolverines across Alaska.We didn't discuss white feet. Some wolverines, almost as rare as white ones, are nearly completely black. It would be interesting to see if there are genetic differences and if they change over time regionally. The "white-less" wolverines in Scandinavia may be because the population may have descended from a few dark individuals and could change over time as the

population increases and expands and dispersers arrive from Russia. The local buyer has purchased wolverines from Russia. I will have to talk to him again to see if white feet occurred on the hides he purchases. It seems to me I recall Jeff Copeland mentioning that he thinks a dominant male in an area can determine the coloration of the individuals in an area and perhaps he has worked with genetics along these lines. It does seem that wolverines from Montana more commonly had larger areas of white on chest, legs, and feet than in other areas. Bob Inman certainly has captured individuals like this.

On another subject, did you hear from Jens in response to your email? Did you ask him about the number of dens outside the snow model that they now have? He is going to try to photograph some of these den sites in the coming week.
Audrey

On Thu, May 4, 2017 at 9:28 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Hi Audrey - You may have seen this OpEd from the Great Falls Tribune.
>
> ## Wolverine study's plan preferred to endangered species listing
>
> GreatFalls Tribune/Opinion
>
> May 2, 2017
>
> During a multi-state survey this winter to establish a baseline of where wolverines live in the U.S., one of the solitary mountaineers was photographed by a motion-detecting camera 65 miles southeast of Great Falls in the Little Belt Mountains.... http://www.greatfallstribune.com/story/opinion/2017/05/02/wolverine-studys-plan-preferred-endangered-species-listing/101208748/
>
> I noticed that one of the photographs (Pintler Mtns) shows a wolverine with white on its front paws. I had read (somewhere) about this interesting characteristic and ask Bob Inman if he knew whether this was unique to North America or Montana, and whether this has been observed in wolverines in Scandinavia. He said that they have seen fairly extensive white markings, often on the foot, in GYE and Montana, but did not know about other populations.
>
> I also read the following account of almost all-white wolverines from Cardinal's report:
>
> From Cardinal 2004 *Aboriginal Traditional Knowledge COSEWIC Status Report on Wolverine Gulo gulo Qavvik*: (page

7)
"A nearly all-white variant of wolverine has been trapped by hunters in the Kitikmeot region. Knowledge holders in the region state that this variety is very rare; in all of the other regions, only one other knowledge holder reported catching a wolverine that had a significant amount of white on it. Knowledge holders also mentioned that this variant has always occurred in this one area and reported their parents had caught this variety in the past. A pelt was also on display at the local HTC."

Question for you: Do you know if anyone has looked at these traits (on global scale) and how prevalent they are? And whether anyone has investigated the genetic markers for this?

Thanks.
--

Betty J. Grizzle, D.Env.
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
Carlsbad Fish and Wildlife Office
2177 Salk Ave, Suite 250
Carlsbad, CA 92008
760-431-9440, ext. 215
760-431-5901 fax

From:	Conor McGowan
To:	Grizzle, Betty; Justin Shoemaker/R6/FWS/DOI; Conor McGowan; Guinotte, John
Subject:	Wolverine Prototype model
Date:	Monday, May 8, 2017 3:37:43 PM
Attachments:	Wloverine1.xlsx

Hi folks,

I've put together a pretty simple deterministic model for Wolverines. I converted the basic demographic rates from the scandanavian life table and input them on the spread sheet. I also incorporated functions to allow a population ceiling that can be annually reduced to reflect habitat loss, a function to lower adult male survival to capture the effects of possible road construction and disturbance on male survival, and function to reduce productivity to relect the possible effects of snow of denning success.

If you want to schedule a call to look at this I'd be happy to go through it. I think it is a good start, capturing most of our thoughts on the issues faced by wolverines, but it would require stochasticity and a better capturing of uncertainty.

Thanks,

Conor

--
//---
Conor P. McGowan, Ph.D.
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USGS, Alabama Cooperative Fish and Wildlife Research Unit
School of Forestry and Wildlife Sciences,
Auburn University
Auburn, AL 36849-5418

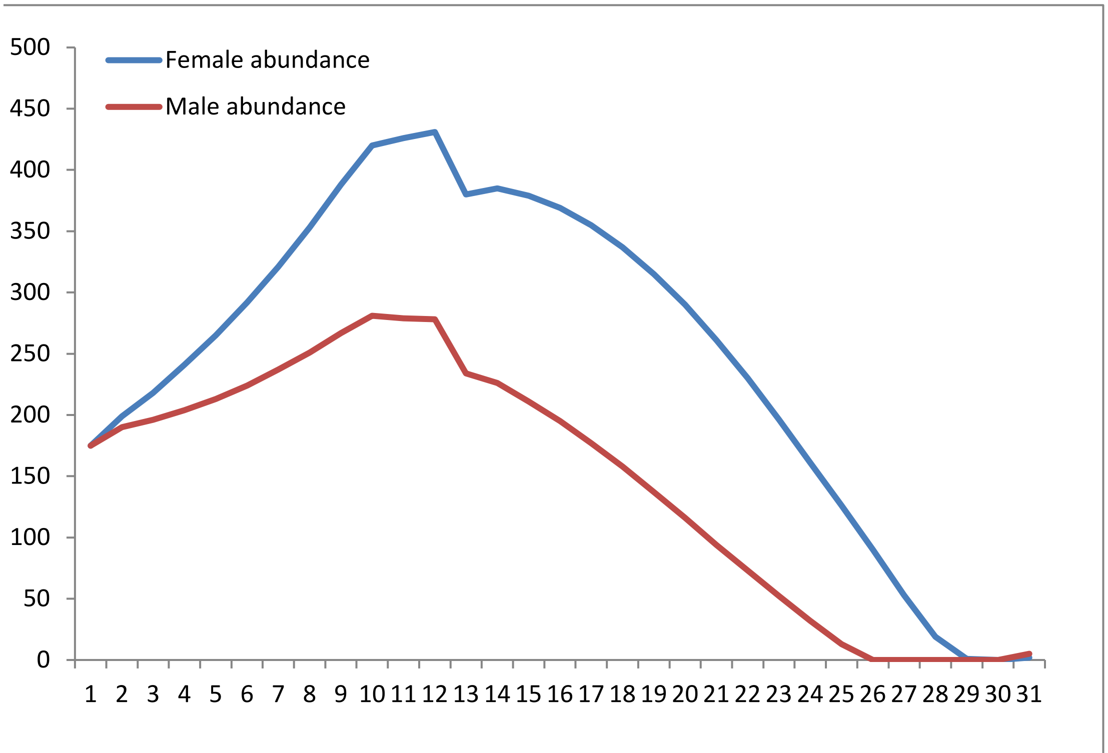
EM:cmcgowan@usgs.gov
Ph:334 844 9231
www.auburn.edu/~cpm0014
//---

Wolverine

Ni	350	initial abundance	
Sri	0.5		
Sam	0.84	0.005	Male survival decline due to dispersal
Saf	0.89		
Si	0.861		
Sy	0.79		
Ff	0.913	0.1	Fertility decline due to snow loss
Fm	0.74	0.1	Fertility decline due to snow loss
csr	0.4		
Max pop	700	0.01	decline in K due to habitat loss
Fim	2		
Mim	5		

	female	male
0	175	175
1	199	190
2	218	196
3	241	204
4	265	213
5	292	224
6	321	237
7	353	251
8	388	267
9	420	281
10	426	279
11	431	278
12	380	234
13	385	226
14	379	211
15	369	195
16	355	177
17	337	158
18	315	137
19	290	116
20	261	94
21	230	73
22	196	52
23	161	32
24	126	13
25	90	0
26	53	0
27	19	0
28	1	0
29	0	0
30	2	5

P-preg	sex ratio	MaxPop	Sam	tot pop	Lambda		
0.39	0.5	700	0.84	350			
0.39	0.488432	693	0.8358	389	1.111429	0.561328	-0.43867
0.39	0.47343	686	0.831621	414	1.064267	0.603499	-0.3965
0.39	0.458427	679	0.827463	445	1.074879	0.655376	-0.34462
0.39	0.445607	672	0.823326	478	1.074157	0.71131	-0.28869
0.39	0.434109	665	0.819209	516	1.079498	0.77594	-0.22406
0.39	0.424731	658	0.815113	558	1.081395	0.848024	-0.15198
0.39	0.415563	651	0.811037	604	1.082437	0.927803	-0.0722
0.39	0.407634	644	0.806982	655	1.084437	1.017081	0.017081
0.39	0.400856	638	0.802947	701	1.070229	1.098746	0.098746
0.181489	0.395745	632	0.798933	705	1.005706	1.115506	0.115506
0.174203	0.392102	626	0.794938	709	1.005674	1.132588	0.132588
0.152215	0.381107	620	0.790963	614	0.866008	0.990323	-0.00968
0.129771	0.369885	614	0.787008	611	0.995114	0.995114	-0.00489
0.105254	0.357627	608	0.783073	590	0.96563	0.970395	-0.02961
0.081489	0.345745	602	0.779158	564	0.955932	0.936877	-0.06312
0.055414	0.332707	596	0.775262	532	0.943262	0.892617	-0.10738
0.028384	0.319192	590	0.771386	495	0.930451	0.838983	-0.16102
0	0.303097	584	0.767529	452	0.913131	0.773973	-0.22603
0	0.285714	578	0.763691	406	0.89823	0.702422	-0.29758
0	0.264789	572	0.759873	355	0.874384	0.620629	-0.37937
0	0.240924	566	0.756073	303	0.853521	0.535336	-0.46466
0	0.209677	560	0.752293	248	0.818482	0.442857	-0.55714
0	0.165803	554	0.748532	193	0.778226	0.348375	-0.65162
0	0.093525	548	0.744789	139	0.720207	0.25365	-0.74635
0	0	543	0.741065	90	0.647482	0.165746	-0.83425
0	0	538	0.73736	53	0.588889	0.098513	-0.90149
0	0	533	0.733673	19	0.358491	0.035647	-0.96435
0	0	528	0.730005	1	0.052632	0.001894	-0.99811
#DIV/0!	#DIV/0!	523	0.726354	0	0	0	-1
0.39	0.714286	518	0.722723	7	#DIV/0!	0.013514	-0.98649



Female abundance
Male abundance
500
450
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

From:	Guinotte, John
To:	Kevin Doherty
Subject:	Fwd: Wolverine Report 5MAY 2017 -- including Exec. Summary
Date:	Monday, May 8, 2017 9:28:49 AM
Attachments:	Wolverine Report Text FINAL DRAFT 5May17.pdf Wolverine Report Text FINAL DRAFT 5May17.docx

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

---------- Forwarded message ----------
From: **Joe Barsugli** <joseph.barsugli@noaa.gov>
Date: Fri, May 5, 2017 at 2:55 PM
Subject: Wolverine Report 5MAY 2017 -- including Exec. Summary
To: Stephen Torbit <Stephen_Torbit@fws.gov>, "Guinotte, John" <john_guinotte@fws.gov>, Andrea Ray <Andrea.Ray@noaa.gov>, Candida Dewes <Candida.Dewes@noaa.gov>, Imtiaz Rangwala <Imtiaz.Rangwala@noaa.gov>, Ben Livneh <ben.livneh@colorado.edu>, Aaron Joseph Heldmyer <Aaron.Heldmyer@colorado.edu>

Steve, John (and the team)

It has been hectic with me sick and Andrea at a conference, but A new version of the Text and figures have been uploaded to the drive.

Numerous changes:

- Figures have been updated/fixed, and a couple of figures added to the elevation dependence discussion for the model output.
- Executive Summary has been added to the text.
- Numerous comments from John and Kevin were addressed.

The main substantive changes are an expansion of the elevation-dependence discussion in the modeling section and the addition of the Executive summary. Other changes were either fixes to figures, or clarifications/re-writing to address comments from John and Kevin. There are many of these, and a few sections were re-organized to lead to better flow, but without changing the underlying content.

I am attaching a PDF and DOCX versions of the text here, but the .docx and .pdf version of text and figures are on the drive. I have ALSO included a "track changes" .docx file for those interested.

We have not gone through this with a fine toothed comb, so there may still be a few small things. But Better to get this to you now.

Joe

--
Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309
303-497-6042
PSD Science Board and
Attribution and Predictability Assessments Team Member

Wolverine Snow Refugia Study: An analysis of future climate risks

A Report to the U.S. Fish and Wildlife Service Region 6

Andrea J. Ray[1], Joseph J. Barsugli[2], Ben Livneh[3] Candida F. Dewes[2], Imtiaz Rangwala[2], Aaron Heldmyer[3], Jenna Stewart[3]

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Executive Summary

Overview: This study is a fine-scale assessment of snow extent and depth at two areas in and in the vicinity of Glacier (GLAC) and Rocky Mountain (ROMO) National Parks. The analysis was done for both the recent past, using MODIS satellite-based remote sensing, and in historic simulations and projections of future snowpack using a high-resolution hydrologic model. The fine scale hydrologic modeling allows for the consideration of snow processes such as dependence on terrain slope and aspect that are important to understanding high elevation snow persistence in a changing climate and were not considered in previous work.

Methods: The report intentionally builds on previous work by McKelvey et al. (2011) extending that work by providing a higher resolution spatial scale analysis for two case study areas, and a broader range of future scenarios. Two areas were studied: a high latitude, low elevation area within Glacier National Park (Figure 2-1) that is currently occupied by wolverines and a lower latitude, high elevation area within Rocky Mountain National Park (Figure 2-2).A detailed comparison of their methodologies and ours is provided in Table 2-1. The project uses methods from the peer-reviewed, published literature to:

- Explicitly model the effects of slope and aspect, using fine-scale spatial models to analyze topographic effects on snow
- Better represent the range of plausible future changes (climate scenarios)
- Analyze extremes: we selected representative wet, dry, and near normal years from the historic record and assessed how these might change in the future
    - Representative years for GLAC: 2011 (cool wet), 2005 (warm dry), 2009 (near normal).
    - Representative years for ROMO: 2011 (cool wet), 2002 (warm dry), 2007 (near normal).
- Assessing change in snow by elevation.

MODIS Observed Historic Snowpack Variability Analysis: Satellite-based MODIS snow cover data was used to assess the historical variability of snow cover in the study areas and as a basis for the spatial evaluation of the hydrologic model simulations. The historical observed snow cover was analyzed for its dependence on terrain elevation and aspect (compass direction that the slope faces).

- In GLAC, snow covered areavaries considerably by year, including "wet" years such as 2011 with very persistent snow, years with strong melt in early May, such as 2012, or in late May (2009, 2001), and "dry" years (2004, 2005). The period of the modeling study in Section 5 ends in 2013 due to dataset limitations, but it is worth noting that the last two years of the MODIS record, 2015 and 2016 show low snowcover (Section 4.3).
- Even in dry years, NE-facing slopes in GLAC tend to hold more snow and melt later in the season. There is > 80% snow cover above ~2000 m elevation on May 1 during dry years, and > 95% snow cover above ~1200 m during wet years. Snow conditions on June 1 during wet years resemble those for May 1 during near-normal years.
- In ROMO, snow covered area also varies considerably by year (Section 4.4).
- NW-facing slopes in ROMO tend to hold more snow even during dry years. In very dry years, snow cover peaks at intermediate elevations, suggesting that the high-altitude snowpack may be particularly vulnerable in this region under warm/dry conditions.

Future Snowpack Projections: The Distributed Hydrology Soil Vegetation (DHSVM) was run in historical simulations of the period 1998-2013. The model was validated against SNOTEL in-situ snow observations and MODIS snow cover. The model was then run for five scenarios of the future which represent a nominal 2055 climate. Scenarios were selected from CMIP5 global climate model (GCM) projections, and were chosen to span a large fraction of the range of the CMIP5 ensemble projections in each study area in terms of precipitation and temperature changes. Representative Wet, Near Normal, and Dry years were analyzed for the historical simulations and how each of these years plays out under these five future scenarios. The number of years (out of 16) with snow above 0.5m depth was also analyzed as was the change in Snow Covered Area (SCA) with depth greater than 0.5m. The average change in SCA and Snow Water Equivalent (SWE) was analyzed as a function of elevation, and for GLAC was overlayed with the elevations of wolverine den sites. (Section 5)

For the study area in Glacier National Park (GLAC), projections for May 15th Snow Covered Area and area with snow depth greater than 0.5 meters declines on average in all scenarios and for almost all years (Section 5-11). This is a12-42 percent decline in snow covered area, and a 15-68 percent decline in area with snow depth > 0.5 meters for the scenarios considered.

- The Warm/Wet scenario shows the least change compared to the historic snow cover in terms of the area of significant (0.5 meter) snowpack, comparable to only a small shift in time. In contrast, under the Hot/Wet scenario, on May 1 the area covered by >0.5 snowpack is smaller than the area covered on June 1 in the historic record – a shift of a month earlier.
- All projections show declines in the number of years with significant snow. The areas with frequent (14-16 years) availability of significant snow become concentrated in smaller high elevation areas.
- For wet years, the high elevations of the study areas result in little loss of snowpack under most scenarios of change.
- For high elevation areas, there is little change in SCA for 4 of the 5 scenarios above 2200m. As in a mirror image there is greater than 95 % loss of SCA below 1400m for 4 of the 5 scenarios. Between these two elevations – and in the regions where most observations of dens have been noted – the snowpack change is very sensitive to elevation and to the particular future climate scenario.

For the study area in and around Rocky Mountain National Park (ROMO), projections of May 15th Snow Covered Area in ROMO (13mm threshold on May 15) declines on average in all scenarios and for almost all years. (Section 5-12)

- There is a 12-52 percent decline in snow covered area, and a 7-64 percent decline in area with snow depth > 0.5 meters for the scenarios considered.
- Snow Covered Area in ROMO (0.5 m threshold on May 15) generally declines in wet years, but may increase in dry years in those scenarios with increased precipitation.
- Some scenarios with increased precipitation show increases in May 15 snowpack at the higher elevations in both study areas, but decreases in snowpack at lower elevations. This can lead to an increase in the area of > 0.5 meters of snow for "dry" years.
- ROMO exhibited more uncertainty in projections than GLAC

- ROMO has more uncertainty as to whether precipitation will increase or decrease.
- The beneficial effect of increased precipitation on snowpack is more prominent earlier in the Spring. In the Warm/Wet scenario, the area of significant snow on May1 increases on average, though it decreases on May 15.
- For wet years, the high elevations of the study areas result in only modest loss of snow cover under all scenarios of change. However even in wet years, the area of significant snowpack can decline by almost 50% for the Hot/Dry climate change scenario. (Section 5-X)

Elevation dependence of change (Section 5.13): In general, and supported by the literature, the snowpack at the higher elevations of both areas is more responsive to precipitation change, while at lower elevations it is more responsive to temperature change. For GLAC, most of the observed den sites are located just below the precipitation-dominated zone, and therefore at elevations where the changes in snowpack are highly dependent on the climate scenario and also on elevation. For high elevation areas there is loss of SCA for four of the five future scenarios, with an increase only in the Warm/Wet (giss) scenario. The climate of ROMO is, on average drier than that of GLAC, and the regions of the model simulations that have significant snow in most years is restricted to the two smaller areas within the domain (Figure 5-21). As a result the characteristics of the present-day climate does not act to buffer changes in the area of significant snow on May 1st as it does in GLAC.

Comparison with McKelvey's results (Section 6): There are challenges in making a direct comparison between the studies due to differences in the goals and spatial scale. McKelvey investigated persistence of even a light snow cover to May 15th as a correlate of wolverine habitat, as noted in Aubry et al (2008). This study focuses on high-elevation terrain and on the persistence of deeper snowpack. However, the following comparisons are valid:

- Snow cover persists in our study areas, even for the hotter scenario of change in the McKelvey study (miroc "2080's). The greatest loss of snow cover in McKelvey occurs at lower elevations that were deliberately not included in the GLAC or ROMO study areas.
- McKelvey focused exclusively on the persistence of even light snow cover on May 15th. Because of the increased resolution of our study we are able to consider whether any pockets of snow with depth greater than 0.5 meters will persist in these areas. Results vary according to scenario, but generally show declines in SCA with depth greater than 0.5 meters by the 2050s, as noted above.
- Our results may reasonably be generalized to the high mountain ranges within the Rockies that lie between GLAC and ROMO, with projections on average wetter in GLAC. However, without further study we cannot reasonably extend our results to say whether or not snow refugia may persist in the Central Rockies at lower elevations where McKelvey indicates the greatest snowpack losses, nor to the Cascades with its very different maritime climate.

[Intentionally Left Blank]

1 Introduction

1.1 Motivation

This report responds to the United States Fish and Wildlife Service (FWS) need for information on potential climate impacts to snow persistence. The North American wolverine (*Gulo gulo luscus*) is currently being evaluated for listing as a threatened or endangered species under the Endangered Species Act (ESA) and climate change effects on snow persistence was identified as an important factor for the future viability of the wolverine. The species was considered for listing in 2014, but FWS concluded that it did not warrant listing. They further concluded that there is significant uncertainty about how the effects of climate change will affect wolverines and their habitat in the foreseeable future, and that this uncertainty includes information on how fine-scale changes in snow cover and persistence might affect denning site selection.

This report provides FWS with a finer scale assessment of snow extent and depth at which extends previous work by McKelvey et al. (2011). We believe the inclusion of finer scale analyses as well as additional snow processes such as slope and aspect are critical to understanding high elevation snow persistence in a changing climate.

ADD By design, our methods are from the peer-reviewed, published literature, etc. What we find is consistent with past research

Funding was provided by the U.S. Fish and Wildlife Service, Region 6 and the NOAA/Earth System Research Lab/Physical Sciences Division. This effort builds on work underway by the project team at NOAA/ESRL/PSD, the NOAA-University of Colorado (CU) Cooperative Institute for Research in Environmental Sciences (CIRES), and CU Department of Civil, Environmental & Architectural Engineering.

1.2 Project Objectives

Persistent spring snowpack has been described as an important factor in determining suitable habitat for the wolverine, including Northern boreal forests and subarctic and alpine tundra (Aubry et al, 2007, Peacock et al, 2011). This relationship was the basis for the analysis by Copeland et al. (2010) and McKelvey et al. (2011) used in the previous FWS decision. In both studies, climate change projections of snowpack were used to characterize potential future wolverine habitat.

The goal of this effort is to identify the depth and persistence of spring snow in the future. Our primary objective is to advance scientific understanding of the current spatial extent of spring snow retention on the landscape, and the future temporal and spatial extent of snow retention through a thirty-year period, 2041-2070, centered on the year 2055. We aim to advance snow analysis and modeling to better support assessment of snow-related species, in the following ways:

- Explicitly model the effects of slope and aspect, using fine-scale spatial models to analyze topographic effects on snow

- Better represent the range of plausible future changes (climate scenarios)
- Analyze extremes: wet and dry years from the historic record and how these might change in the future

Our strategy was to build on previous methods where possible to be comparable to work by McKelvey et al. (2011) and Copeland et al. (2010). We departed from their methods where necessary to take advantage of analysis techniques not feasible at the large scales used in the studies done by those authors. These include new scientific data and tools that are now available, including the following:

- Use of a longer time series of satellite and in situ observations
- Analysis of historic snowpack variability to investigate the influences of topography on snow cover
- Use of more recent climate model output and improved criteria for choice of climate change scenarios
- Use of hydrologic modeling at highly resolved (250m) spatial scale for simulation and future projection of snow cover and depth for two case study areas in Glacier National Park and Rocky Mountain National Park.

2 Project Overview and Background

2.1 Overview

We first reviewed the observed climate and variability, in order to provide context for future changes (Section 3). We next analyzed historic snow variability from satellite remote sensing of snow extent from the year 2000 to present to determine areas of greater and lesser sensitivity to climate drivers (temperature and precipitation), and identify possible snow refugia. Prior studies also show a relationship between terrain (slope and aspect) and persistence of snow (e.g. Lundquist and Flint, 2006) and thus this factor is potentially important under in a changed climate. (Section 4). We then did an intercomparison of the satellite observations of snow with that from the DHSVM hydrologic modeling study that includes a representation of slope and aspect (the compass direction that the slope faces) of the terrain and shading on the snowpack. Finally, the DSHVM hydrologic model was forced with five future scenarios of climate change for each of the two study regions (Section 5). These future climate scenarios were derived from the latest Coupled Model Inter-comparison Project Phase-5 runs (CMIP5, Taylor et al., 2012) which informed the latest Intergovernmental Panel on Climate Change (IPCC) report (IPCC AR5, 2013).

All methodologies were chosen to be consistent with those used in existing peer-reviewed work.

2.2 Study Areas

High-resolution hydrologic modeling was needed to provide fine scale analysis of snow. However, given time, funding and computational constraints, it was necessary to limit the study domain to two areas of about 1,500-3,000km^2 for high-resolution analysis. Two study areas representing core and peripheral habitat regions in the northern and central Rocky Mountains were identified in consultation with FWS Region 6 personnel (Figures 2-1 and 2-2). We bracketed the range of wolverine habitat conditions in the lower 48 habitat conditions, because we were restricted to smaller areas for analysis. The two sites chosen included a high latitude, low elevation area within Glacier National Park (Figure 2-1) that is currently occupied by wolverines and a lower latitude, high elevation area within Rocky Mountain National Park (Figure 2-2) that has had recent documented wolverine occurrence and could be a potential reintroduction site for wolverines. Both model areas encompassed elevations from ~250m below treeline to maximum elevation.

The analysis for the GLAC and ROMO study areas is presented in separate sections, repeating descriptions to make the material self-contained for the reader who may read about only one area; similarly, complete captions are given for each area.

2.3 The West-wide context of future climate

Global climate models (GCMs) are the primary tools used by climate science to examine the nature of climate change during the 21st century. These models reveal both the uncertainty of climate projections as well as underlying regional patterns of change. This section provides a west-wide context for the specific choices of future climate scenarios that will be discussed later in the report.

Understanding the uncertainty of climate projections is commonly approached through comparison of the results from multiple climate models (e.g. IPCC, 2013). There are currently about 20 modeling centers worldwide that provide output from their best model or models to be considered in the Coupled Model Inter-comparison Project Phase-5 (CMIP5, Taylor et al., 2012), an international, coordinated modeling project which informed the most recent Intergovernmental Panel on Climate Change (IPCC) assessment report (IPCC AR5, 2013). When we quantify regional changes in climate variables such as temperature and precipitation by a particular time horizon in the 21st century, we find a large spread in the extent of warming and changes in precipitation, including both increases and decreases in precipitation, as shown in regional maps (Figure 2-4) and described later in Section 5. For temperature change, much of this spread (or uncertainty) is a result of the difference among the formulations of the GCMs (e.g., their climate sensitivities), whereas for precipitation it is both the differences among GCMs and internal climate variability. Some difference also comes out of the choice of future greenhouse gases (GHG) emission scenario. However, the differences among greenhouse gas emissions scenarios is less at mid-21st century compared to later in the century, and is much smaller than other sources of uncertainty at the regional scale (IPCC,2013).

In addition to uncertainty, the CMIP5 climate models also reveal regional patterns of change. Figure 2-4 shows projected annual and seasonal temperature and precipitation changes by 2050 (2035–2064) over the western U.S., including the northern and central Rocky Mountains, from an ensemble of the 34 climate models used for this study under the RCP 8.5, a high-end emissions scenario. The large maps show the average change for all of the models (n=34) for that season, and the small maps show the average changes of the highest 20% and lowest 20% of the models, based on the statewide change for Colorado in temperature or precipitation. For much of the central and northern Rockies, all models show a substantial warming (of +2.5°F to +5.5°F). While fewer models agree about the direction of precipitation change west-wide, even the lower (drier) models show an increase in winter precipitation for the area around Glacier National Park, although there is less agreement for the central Rockies area including Rocky Mountain National Park.

The uncertainty of climate change motivates the choice of several future climate scenarios for each study region. The regional patterns of change indicate that the range of the climate scenarios chosen will differ somewhat from region to region. The GCM output, and the specific selection of future climate scenarios for this study are discussed further in Section 5.

2.4 Comparison between our analysis and that of Copeland and McKelvey

The Copeland et al. (2010) and McKelvey et al. (2011) studies were an integral part of the previous FWS decision process. Therefore, we present here a detailed comparison of their methodologies and ours, to establish both how our methodologies followed theirs when appropriate, and diverged where new data or updated methods were available. A summary of the most salient similarities and differences between our work and the studies used previously is presented in Table 2-1.

Table 2-1: Modeling Methods Compared to McKelvey

	McKelvey (Littell)	This Study
Spatial Resolution (modeling)	VIC model – 1/16 degree (~5km x 7 km, ~37km^2 cell)	DHSVM model - 250m x 250m UTM grid (~0.0625 km^2 cell)
Spatial Extent	Westwide except California and Great Basin	ROMO and GLAC study areas, near and above treeline
Process differences	Slope and aspect were not modeled and the mountains were assumed to be flat from a solar radiation process, implicit elevation bands.	Slope, aspect, shading, explicit fine scale elevation effects.
Validation	None specific to snow	Comparison to SNOTEL (ground stations) and MODIS (satellite)
Future Scenarios	Delta Method; "2045";"2085"; from 3 GCMs selected to span westwide temperature changes.	Delta Method: "2055" from 5 GCMs spanning regional changes in temperature and precipitation
Analysis	Changes in long-term mean snowpack only	Means and variability, including wet, near normal and dry years.
Snow representation	Binary snow/no snow at 13 cm snow depth	Analyzed snow depth at two thresholds: 13mm of SWE ('light snow') and 0.5m depth ('significant snow')

Both Copeland et al (2010; hereafter, simply Copeland or the Copeland study) and McKelvey present analysis based on satellite remotely-sensed snow cover from the MODIS . For example, Copeland calculated the number of years with snowcover on May 15th as detected in the MODIS snowcover dataset, by calculating a snow disappearance date. They found that most (45 of 75) North American den sites were in areas that snow cover persisted with 6 or 7 out of 7 years on May 15th. We also provide a historical analysis of remotely sensed snow cover from MODIS.

We also investigated the of number of years of snow persistence for our study areas, however, the new MODIS product has two advantages over that available at the time of their study, 1) improved snow detection (snow covered area, SCA), and 2) 17 years of MODIS data is now available vs the 7 available to Copeland and McKelvey. Furthermore, we investigated the relationships between snow cover persistence and both elevation and aspect (the compass direction of the slope face).

Both McKelvey and the present study investigate projections of snow cover using a distributed hydrologic model. McKelvey et al. (2011) (hereafter, simply McKelvey or the McKelvey study) focused their analysis on May 1st snow depth simulated by the Variable Infiltration Capacity hydrologic (VIC) hydrology model (1/16 degree, ~5km x 7 km), "flat" gridboxes, or cells, with no slope aspect dependence). The May 1st snow depth was then converted into a proxy for May 15th snow disappearance by applying a threshold of 13 cm – a procedure they refer to as "cross-walking". All subsequent calculations of theirs were done using the May 15th snow cover proxy. The VIC model runs were documented in Littell et al. (2011) and were based on meteorological inputs from Elsner et al. (2010). The present study uses the Distributed Hydrology Soil Vegetation (DHSVM) model, which was developed by the same group at the University of Washington for fine-scale simulations, and shares many model components with the VIC model. The primary output of DHSVM is snow water equivalent (SWE). We investigate several thresholds for converting SWE to "snow cover". Conversion of SWE to snow depth is done using empirically derived conversion factor relevant to late Spring.

To generate future climate scenarios, Littell (on which McKelvey results are based) used the "delta method" (described later in Section 5) for the projected changes in climate compared to present day. This study also uses the "delta method," applied in a similar manner. The McKelvey study used a range of temperature change to select GCMs representing the range or spread of future scenarios. As shown below in Section 5.10 and Figure 5.7, their chosen future scenarios reflect a range of precipitation in GLAC, but in ROMO, the three scenarios have similar precipitation changes. This project selected a larger number of future scenarios selected based on changes in both temperature and precipitation, to be consistent with recommended strategies for incorporation of uncertainties into the assessment of impacts and developing adaptation strategies (e.g. Fisichelli et al, 2016 a,b, see Section 5-8).

Analysis metrics, including the time frames of the projections differ somewhat between the two studies. The McKelvey study calculated a metric for a historic period (1915-2005 average) and two futures, 30-year averages around "2045" and" 2085." This study focused on a 30-year period around mid-century, "2055" to focus on FWS' time horizons for the wolverine and due to time and computational constraints given the project budget. We also reproduce a single future scenario using one of the Littell (2011) "2080's scenarios for direct comparison. Calculations for a later period using the CMIP5 climate models (e.g. ~2100) could easily be made, but were beyond the scope of this project. We provide analysis for two thresholds of snow amount, a "light" snow cover (13mm of snow water equivalent [SWE]), and significant, or "heavy" snow cover (equivalent to 0.5 m of snow depth). Because McKelvey only had access to May 1st snow depth simulation from Littell (2011), they chose to use a 13 cm snow depth on May1st as a proxy for snow disappearance by May 15th. We instead chose to use a much lighter threshold of snow on May 15th itself. Note that SWE is a measure of the water content in the snowpack; to estimate depth, a density of the snow must be assumed, i.e. an approximation of whether the snow is heavy or light. Our threshold of 13mm SWE was originally chosen to be comparable to McKelvey's snow depth. Our assumptions are discussed further in Sec. 5.6.

An important difference between this study and prior work by Copeland et al. (2010) and McKelvey et al. (2011) is the spatial scale of results. McKelvey and Copeland both presented results on a regular 1/16 degree latitude-longitude grid, in which each cell, or gridbox is ~5-7 km on a side. These cells were assumed to be flat in the model-- that is they do not incorporate slope or aspect information in their surface energy balance. The result of this is north-facing slopes are treated identically to south-facing slopes. Our study uses the Distributed Hydrology Soil Vegetation Model (DHSVM) originally developed by Wigmosta et al. (1994)[1] for simulating the snowpack at 250m x 250m resolution that incorporates other physical drivers of snowpack (a complete energy balance at the surface, a 2-layer snow model, and a 2-layer vegetation canopy model) and allows analysis of snow at different slopes and aspects (slope directions). The VIC modeling included the option for elevational snow bands within the VIC grid (Jeremy Littell, pers. comm.) but the snow band information was not explicitly used. Therefore, sub-grid scale elevational effects are implicit and approximate in the VIC model whereas it is explicitly modeled at the 250m-scale in DHSVM. A visual comparison of the gridbox sizes is shown in Figure 2-3, for further description of the terminology used to describe spatial resolution, see "resolution" in the Glossary.

It should be noted there are tradeoffs between our strategies and the methods of Copeland and McKelvey. The finer scale analysis presented in this report integrates slope and aspect with respect to snow accumulation and retention that are thought to be important for maintaining snow refugia for denning sites (see Fig 2 in McKelvey et al 2011). The disadvantage of this improvement in spatial resolution is we were only able to analyze two study areas due to time and computational constraints. The Copeland and McKelvey projects analyzed a much larger domain, including most of the wolverine range in the continental US, but does not provide detailed analysis of any habitat area.

[1] The most up-to-date documentation of the DHSVM model, including changes to the model subsequent to the original reference, is available from the following website: http://www.hydro.washington.edu/Lettenmaier/Models/DHSVM/documentation.shtml)

3 Observed Climate and Variability

Comment [GJM1]: In general, we think section 3 should be shortened if possible.

1-2 Intro paragraphs up front that give context on why the climate scenarios were chosen and why the specific years were used.

We can still discuss this. I marked the "background material" as such.

Key Points:

- Both study areas show upward trends in both temperature and freezing level.
- Surface Air Temperature and Atmospheric freezing level are related, with a stronger relationship in ROMO (that is, a greater change in freezing level for a given surface air temperature change)
- Representative years chosen for GLAC: 2011 (wet), 2005 (dry), 2009 (near normal).
- Representative years chosen for ROMO: 2011 (wet), 2002 (dry), 2007 (near normal).

3.1 Introduction

This section presents a historical analysis of the winter and spring climate variability for the two study regions, GLAC and ROMO, in order to provide context for future changes. This section includes a discussion of trends in temperature and freezing level; historical variability in cool season (October – May) temperature and precipitation for the study areas, choice of representative years during the simulation period for cool/wet, warm/dry, and near normal conditions for the two areas; and a ranking of the representative years in a longer climate record. A complete description of regional climate is beyond the scope of this project, but may be found in e.g. McWethy et al (2010), Garfin et al (2014), Lukas et al (2014), Shafer et al (2014), and citations therein.

3.2 Background Material: Trends in Surface Temperature and Freezing Level in the Study Areas

Temperature strongly influences hydrologic processes such as snowpack accumulation, and timing of snowmelt. Here we present some background material on observed trends in surface air temperature and on the freezing level in the atmosphere, and how these two quantities are related.

Both the Glacier and Rocky Mountain areas show a trend of increasing surface air temperature in the winter season (October-May, Figure 3-1), consistent with trends that have been observed west-wide (Garfin et al 2014; Lukas et al 2014; Shafer et al 2014). While winter season temperatures vary inter-annually, linear regression of these data (not shown) indicates about a 1.4 ^{o}C increase in temperature from 1948-2015 for an area around Glacier, and about a 1.2 ^{o}C increase around Rocky Mountain National Park.

Atmospheric freezing level height (FLH) represents the altitude in the free atmosphere (that is, away from the surface and its immediate influence) where the temperature is 0 °C. Above this level, the temperature of the air is typically below freezing. Freezing in the free atmosphere is indicative of the level above which precipitation falls as snow rather than rain. Freezing level height can have a strong influence on freeze-thaw processes in high-elevation regions (Bradley et al 2009). As with winter season temperatures, freezing level varies over time (Figures 3-2, 3-3), but linear regression (not shown) indicates about a 160m increase in the freezing level for Glacier (Fig 3-2), and about a 170 m increase in the freezing level for Rocky Mountain (Fig 3-3).

Figure 3-4 illustrates a strong relationship between freezing levels and surface air temperature change for both regions in October-May with explained variance (R^2) close to 0.8. For GLAC (3-1, left), a 1°C anomaly in temperature equates to about a 115 m increase in the freezing level, over the period. For ROMO, for 1°C increase in temperature there has been about a 180 m increase in the freezing level (3-1, right). If these historical relationships hold in the future, the larger change in freezing level for the ROMO study area could indicate a greater sensitivity of snow covered area to rising temperatures.

3.3 Exploring Weather Variability through the Choice of Representative Years for Detailed Analysis

One of the primary study goals is to extend the analysis to include the effects of climate change on extreme years – both for years with high- and low- spring snowpack. This is in contrast to McKelvey et al (2011) who studied only the effect of climate change on the *long-term average* snowpack. Our historical snowpack analysis (Section 4) was performed for the entire period 2000-2013 and the hydrologic modeling (Section 5) for 1998-2013, and for the counterparts for these years under various climate change scenarios. To capture the weather variability within these periods we focus some of our analysis in Sections 4 and 5 on a representative wet, dry, and near normal year for each study area. Nonetheless, results from all years were computed.

Table 3-1: Historical Percentiles of precipitation and temperature for the representative dry, near normal, and wet years for GLAC and ROMO study areas.

	Year Type	Year	Oct. - May Precipitation Percentile	Oct. - May Temperature Percentile
GLAC	Dry	2005	6	83
	Near Normal	2009	45	42
	Wet	2011	98	6
ROMO	Dry	2002	4	45
	Near Normal	2007	56	69
	Wet	2011	96	36

To drive our choice of representative years, we investigated historical cold-season (October-May) temperature and precipitation anomalies and MODIS-based snow covered area for 2000-2013. Years were chosen within that range to represent a cool/wet year with high spring snowpack, a "near normal" year, and a "dry" year with low snowpack. Figure 3-5 shows scatterplots of the anomalous precipitation (as % of average) and temperature (degrees Celsius) for each year of the primary study period (2000-2013) for the two study areas. For both study areas, the 2011 winter stands out as a particularly large (cool/wet) anomaly.

The choice a dry year for GLAC points to 2005. Examination of the time series of Snow Covered Area (SCA) derived from the MODIS satellite product (Figure 3-6) corroborates this choice. For ROMO the hot/dry year 2012 with exceptionally low snow cover was first chosen. However modeling difficulties encountered in the model validation procedure described in section 5.4.2 led to the need to find an alternative "dry" year for ROMO. The scatter plot in Figure 3-5 indicates that 2004 or 2002 might both be good alternatives, and both of these years had adequate modeling success. Because 2002 had lower Spring snow cover (figure 3-6), and because it was a widely agreed upon drought year in Colorado, we chose to use 2002 as the representative "dry" year for ROMO.

For the choice of near-normal year, 2007 is indicated for ROMO, as that is closest to the center of the scatterplot in Figure 3-5. A number of choices would seem plausible for GLAC, however as no one year stands out as "most normal." To further guide our choices of representative years, we looked at the elevation profiles of SCA for the various years, and 2009 was chosen. We show the SCA as a function of elevation within the study areas (Figure 3-6cd) for the representative years. These plots indicate that the elevation profile of observed snow cover in our chosen near-normal years closely follow the median profile for 2000-2013.

3.4 The Study Period in the Longer Climate Record

Because the study period is 14 years long, the question arises as to how "extreme" the wet and dry years are in the longer climatological record. To address this we analyze how often the temperature and precipitation anomalies for the study years are likely to occur in the longer (1950-2013) climatological record by computing their percentiles. Percentiles were calculated by ranking the data and using the following formula: percentile = (rank – 0.5)/(total number of years). Note that the exact rankings and percentiles may differ based on the underlying dataset and interpolation methods used, as the study areas have relatively few observing stations. However, percentiles calculated from the PRISM dataset (not shown) yield qualitatively similar results to those found below.

The percentiles of October – May precipitation and temperature averaged over the study areas are shown for the representative wet, near normal and dry in Table 3-1 for both study areas. The percentiles are calculated based on the 63 total years in the 1951-2013 period of the Livneh (2014) dataset. For GLAC, October – May 2011 was at the 98th percentile of precipitation and the 6th percentile of temperature, while 2005 was at the 6th percentile of precipitation and 83rd percentile of temperature. For ROMO, 2011 was in the 96th percentile of October – May precipitation, but only the 36th percentile of temperature, and while anomalously cold was not extreme in temperature. 2002 was in the 4th percentile of precipitation, but only near the median in temperature.

For further reference, Tables 3-2 (GLAC) and 3-3 (ROMO) show the percentiles of precipitation and temperature for the entire study period, 2000-2013, as well as the percentiles for the April – June melt season. Even though the low precipitation was more extreme in 2002 than in 2012, the temperature was not. This is reflected in the MODIS spring snowcover (Figure 3-6), where 2002 was low, but not as nearly extreme as in 2012.

Table 3-2: Percentile of temperature and precipitation anomalies for GLAC study area based on the 1951-2013 period. Percentiles are shown for both the October – May cold season and for the April – June melt season.

GLAC	Percentile 1951-2013			
	Oct. - May Precipitation	Oct. - May Temperature	Apr. - June Precipitation	Apr. - June Temperature
2000	31	96	7	66
2001	2	37	47	58
2002	61	31	91	12
2003	33	87	13	69
2004	13	63	33	61
2005	6	83	80	47
2006	37	82	53	93
2007	21	72	6	75
2008	39	47	60	17
2009	45	42	12	34
2010	12	55	85	13
2011	98	6	87	4
2012	40	74	72	53
2013	60	66	56	29

Table 3-3: Percentile of temperature and precipitation anomalies for ROMO study area based on the 1951-2013 period. Percentiles are shown for both the October – May cold season and for the April – June melt season.

ROMO	Percentile 1951-2013			
	Oct. - May Precipitation	Oct. - May Temperature	Apr. - June Precipitation	Apr. - June Temperature
2000	45	98	40	98
2001	29	33	23	91
2002	4	45	2	96
2003	75	80	77	64
2004	21	91	75	77
2005	50	82	82	53
2006	28	74	4	94
2007	56	69	6	75
2008	80	12	45	13
2009	77	93	88	44
2010	48	13	87	37
2011	96	36	93	25
2012	10	94	7	99
2013	64	26	79	42

4 MODIS Observed Historic Snowpack Variability Analysis

Key points

- In GLAC, even in dry years, NE-facing slopes tend to hold more snow and melt later in the season. There is > 80% snow cover above ~2000 m elevation on May 1 during dry years, and > 95% snow cover above ~1200 m during wet years. Snow conditions on June 1 during wet years resemble those for May 1 during near-normal years.
- In ROMO, NW-facing slopes tend to hold more snow even during dry years. In very dry years, snow cover peaks at intermediate elevations, suggesting that the high-altitude snowpack may be particularly vulnerable in this region under warm/dry conditions.

Comment [GJM2]: Agree, it was used as validation for dhsvm, should come after. If you don't agree, you could break it up and keep the historical variability piece here and put the validation piece after chap 5

Comment [JJB3R2]: I don't mention validation here. We cover that briefly elsewhere and it distracts here.

4.1 Introduction

In this section we perform an analysis of the variability of snow cover in the historical period 2000-2016 using gridded snow cover data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the Terra satellite. The dataset and methodology of analysis is first described. The analysis for the GLAC and ROMO study areas are then presented in separate sections, repeating descriptions to make the material self-contained for the reader who may read about only one area. Each section consists of analysis of the following: a) total snow covered area (SCA), b) SCA fractional area as a function of eight compass directions of slope aspect (octants), and c) elevation dependence.

4.2 Dataset and Methods

4.2.1 Data sub-setting and re-projection

We downloaded selected MODIS/Terra daily snow cover data on a 500m grid from the recently released version 6 (MOD10A1.006) (Hall and Riggs, 2016). All data from geographic tiles h09v04 (ROMO) and h10v04 (GLAC) were downloaded for days between March 1 and July 1 for all years from 2000 to 2016.

The data are available in daily files, one for each tile, and georeferenced to an equal-area sinusoidal projection. Each tile covers 10° x 10° at the equator or approximately 1200 km by 1200 km, with a nominal pixel resolution of 500 m (actual resolution 463.313 m). To bring the data to the same grid as used in the hydrologic modeling necessitated re-projection of the data onto a Universal Transverse Mercator Grid. We used the MODIS Reprojection Tool (https://lpdaac.usgs.gov/tools/modis_reprojection_tool) to subset the daily tiles to the areas of interest and re-project the subsetted areas to UTM grids with a pixel resolution of 250 m using nearest-neighbor resampling. The ROMO study area perimeter falls at the corner of tile h09v04, and extends slightly beyond the tile boundaries at its southern tip. We excluded this extension of the study from our analysis. Parameters for the MODIS data reprojection are provided in Table S4-1.

4.2.2 Converting Normalized Difference Snow Index to Binary (yes/no) Snow Cover

To better align our analysis with that in Copeland and McKelvey's work we wanted to use a daily binary (yes/no) snow cover value. However, one main obstacle had to be overcome -- snow cover was characterized differently in the versions of the MODIS data that Copeland used and in the current version. The prior work by McKelvey and Copeland both used Collection 4 of the MODIS data which provided them with a binary snow cover classification for each pixel on each day (clouds permitting). Collection 4 data are only available for the years 2000-2007, necessitating the use of the more recent MODIS Collection 6 products for the present study. However, Collection 6 does not include a binary daily snow cover product. Instead, snow cover is identified using the Normalized Difference Snow Index (NDSI).

NDSI is reported as a ratio, with values ranging from 0.00 to 1.00 (scaled and reported as 0 to 100 in the data files). The NASA guidance on conversion was not definitive: "If a user wants to make a binary SCA [Snow Covered Area] from the C6 [Collection 6] product they can set their own NDSI threshold for snow using the NDSI_Snow_Cover or the NDSI data or a combination of those data." (NASA, 2016). In lieu of a prescription, we chose to follow the procedure used by NASA to produce the 8-day composite snowcover product; we applied a threshold of NDSI > 0.1 to the daily MODIS NDSI values to indicate the presence of snow in a pixel on a given day.

4.2.3 Snow disappearance date and snow cover on a given date

As in Copeland et al (2010), we calculate a snow disappearance date for each year at each pixel. We define the Snow Disappearance Date (SDD) as the first day after March 1 in which NDSI/100 was less or equal to 0.1 (Cite NASA). The SDD is denoted by the Day of Year value, in which January 1 is 1, February 1 is 32, March 1 is 60 (or 61 in leap years), etc. Once SDD was defined at each grid point for each year (resulting in 17 annual maps of SDD for the period of record), we were able to derive snow cover maps for any given date. For example, snow cover on May 1 was inferred by marking grid points as "snow-covered" if their SDD was equal or greater than 121 (or 122 for leap years). We repeated the process to infer snow cover maps for May 15 and June 1. This indirect method to infer snow cover allowed us to circumvent the reality of several missing data points due to cloud cover, and offered a conservative estimate of snow disappearance.

4.2.4 Snow cover by elevation and aspect

A 250-m digital elevation model (DEM) was created using bilinear interpolation from the National Elevation Dataset (NED)10-m DEM products (USGS, 2009). Using this we obtained grids for elevation and aspect octants in both study regions. We reclassified the elevation values into 200 m bins. The elevation bins range from 1000 to 3000 m in GLAC and 2600 to 4200 m in ROMO. Both the slope magnitude and the aspect of the slope (that is the compass direction that the slope faces) were analyzed using functionality in the open source Quantum GIS software. We reclassified the aspect grids into eight 45°-wide directional bins (hereafter, octants) centered on the points of the compass. In both types of analyses (elevation and aspect), we computed snow covered area (SCA) on May1, May15, and June1, in terms of the total area in square kilometers and also in terms of the percentage of snow covered area in several elevation bands and aspect octants.

4.3 MODIS analysis for GLAC

This section presents some summary statistics of snow cover, including total snow covered area, and number of years during the period of study with snow cover on a given date. MODIS snow cover data was analyzed for March1 – July1 for all years 2000-2016. For more in depth analysis including aspect and elevation-based analyses the report focuses on the representative years defined in Section 3: 2011 ("wet"), 2009 ("near normal"), and 2005 ("dry").

4.3.1 Total Snow Covered Area

Total snow covered area was the primary metric that was analyzed in McKelvey et al (2011) and provides an overall summary of availability of snow. Figure 4-1 presents maps of May 15 snow cover for the GLAC study area and vicinity from MODIS. These maps clearly depict the regional character of the year-to-year variations in snowcover. Figure 4-2 shows the total snow covered area within the study area polygon, which is depicted in red on the previous figure. The year-to-year variations are shown for snowcover on three different dates during the melt season. The behavior in individual year varies considerably, including "wet" years such as 2011 with very persistent snow, years with strong melt in early May, such as 2012, or in late May (2009, 2001), and "dry" years (2004, 2005). The period of the modeling study in Section 5 ends in 2013 due to dataset limitations, but it is worth noting that the last two years of the MODIS record, 2015 and 2016 show low snowcover. Both these years had near-normal precipitation, but had anomalously warm temperatures. These years would be good candidates for future analysis.

To summarize all 17 years of the record, Figure 4-3 presents maps of the number of years with snow cover on May 1, May 15, and June 1. These are similar to the analysis done by the Copeland and McKelvey studies. The primary difference is in the use of the newer MODIS products and the extension of the analysis from seven to seventeen years.

Figure 4-4 quantifies the maps in Figure 4-3, showing the area within the GLAC study area polygon with different numbers of years of snow cover. The three colored bars designate different days of the year. Because the study areas were chosen to be in the vicinity of tree line, it is no surprise that in the present climate there are large areas that see snow every year on May 1st.

4.3.2 Aspect Dependence of Snowpack: Total Area

One of the primary goals of this study is to investigate topographic factors that influence the persistence of snow during the melt season. One such factor is the "slope aspect" or simply "aspect" – the compass direction that the slope faces. Figure 4-5 presents the dependence of total snow covered area (km^2) on aspect for each of the 17 years in the MODIS dataset, for May 1, May 15, and June 1. The shape of the curves for individual years is strongly determined by the topography of the region, with more land area located in the northwest and southeast octants. Upon closer inspection, other features become apparent. Comparing the SW and NE octants we see that there is greater year-to-year variability in the SW, indicating a greater sensitivity of SW-facing slopes to variations in the historical climate. Two representative years, 2011 and 2005, illustrate the progression of total snow covered area from May 1 to June 1 (Figure 4-6). In the dry year, 2005, snow cover declines faster on S, SW, and W slopes, as one would expect; this analysis quantifies the magnitude of this effect.

Comment [GJM4]: Why didn't you includes analysis for 2015 and 2016?
AJR: not in the Livneh dataset, say that the first place (here I think) – John also commented on this at beginning of 5, ~p 18

Comment [KED5]: If it is not standardized I am not sure what this means beyond, the the direction of the mountain chain. Maps show you were the snow is.

Comment [Office6R5]: Talk to Steve – we can take these out. We note that this is mainly the due to the land area itself.

4.3.3 Aspect Dependence of Snowpack: Fractional area

The total land area within each aspect octant varies due to the orientation of ridges and valleys in the study area. As a result, the analysis of total snow covered area is dominated by the topography itself. To focus on the *relative* importance of the snow processes related to aspect, we calculated the fraction of the total land area within each octant that is snow covered for each of the 17 years in the historical record, while in Figure 4-8 we focus on the representative wet and dry years. For example, in Figure 4-7, the asymmetric shape clearly shows that in GLAC, the NE directions ranging from E to N have much larger fractional area covered by snow. Even in dry years, over 60 % of the NE facing slopes are snow-covered on May 15th.

4.3.4 Elevation Dependence

Figure 4-9 shows the elevation dependence of MODIS snow cover for the wet, near-normal and dry years, with the median of all years as reference. The results are shown as a percentage of the total area within each 200-meter elevation band within the study area boundaries.

Comment [GJM7]: We should put the dens on the y axis in fig 4-9. I also think fig 4-9 data should be changed; all jun 1 should be replaced with may 15. I can talk with you on phone about this.

Also, I think we need an additional bar chart that shows all years may 1 and may 15, snow covered area only for elevations where we have dens (~1500m-2300m). This would show historic SCA for the elevation bands that wolverines have used for denning.

Comment [Office8R7]: I was able to do most of this, but replacing June 1 with May 15 obscures some of the features we want to show – particularly since this is for MODIS, which responds to very light snow cover.

4.4 MODIS analysis for ROMO

MODIS snow cover data was analyzed for March1 – July 1 for the years 2000-2016. Data for all years was analyzed. We present here some summary statistics of snow cover, including total snow covered area, and number of years during the period of study with snow cover on a given date. For more in depth analysis including aspect and elevation-based analyses the report focuses on the representative years defined in Section 3: 2011 (“wet”), 2007 (“near normal”), and 2012 (“dry”).

4.4.1 Total Snow Covered Area

Total snow covered area was the primary metric that was analyzed in McKelvey et al (2011) and provides an overall summary of availability of snow. Figure 4-10 presents maps of May 15 snow cover for the ROMO study area and vicinity from MODIS. These maps clearly depict the regional character of the year-to-year variations in snowcover. Figure 4-11 shows the total snow covered area within the study area polygon, which is depicted in red on the previous figure. The year-to-year variations are shown for snowcover on three different dates during the melt season. The behavior in individual year varies considerably, including “wet” years such as 2011 with very persistent snow, years with strong melt in early May, such as 2004, or in late May (2001, 2013), and “dry” years (2002, 2012).

To summarize all 17 years of the record, Figure 4-12 presents maps of the number of years with snow cover on May 1, May 15, and June 1. These are similar to the analysis done by Copeland and McKelvey studies. The primary difference is in the use of the newer MODIS products and the extension of the analysis from seven to seventeen years.

Figure 4-13 quantifies the maps shown in Figure 4-12, showing the area within the GLAC study area polygon with different numbers of years of snow cover. The three colored bars designate different days of the year. Because the study areas were chosen to be in the vicinity of tree line, it is no surprise that in the present climate there are large areas that see snow every year on May 1.

4.4.2 Slope Aspect Dependence of Snowpack: Total Area

One of the primary goals of this study is to investigate topographic factors the influence the persistence of snow during the melt season. One such factor is the "slope aspect" or simply "aspect" – the compass direction that the slope faces. Figure 4-14 presents the dependence of total snow covered area (km^2) on aspect for each of the 17 years in the MODIS dataset for May 1, May 15, and June 1. The shape of the curves for individual years is strongly determined by the topography of the region, with less land area available in the NW octant, and more in the NE. Compared to GLAC, the ROMO study area shows more year-to-year variation in the shape of the curves, likely indicating stronger meteorological controls on the directionality of the snowpack compared to the topographic control seen in GLAC. Comparing the SW and NE octants we see that there is greater year-to-year variability in the SW, indicating a greater sensitivity of SW-facing slopes to variations in the historical climate. Two representative years, 2002 and 2011, illustrate the progression of total snow covered area from May 1 to June 1 (Figure 4-15).The dry year, 2002, shows that snow cover starts out lower on May1 and declines faster on SE, S and SW slopes. The year 2012 is also shown and exhibits similar behavior to 2002 but with less overall magnitude.

4.4.3 Slope Aspect Dependence of Snowpack: Fractional Area

The total land area within each aspect octant varies due to the orientation of ridges and valleys in the study area. As a result, the analysis of total snow covered area is dominated by the topography itself. To focus on the *relative* importance of the snow processes related to aspect, Figure 4-16 presents an analysis of the fraction of the total land area within each directional "bin" that is snow covered. The asymmetric shape shows that the NW-facing slopes have larger fractional area covered by snow. With the exception of 2012, even in dry years over 60 % of the NW facing slopes are snow-covered on May 15th. Figure 4-17 indicates that for the dry year 2012, snow cover was retained preferentially on NW-facing slopes.

4.4.4 Elevation Dependence

Figure 4-18 shows the elevation dependence of MODIS snow cover for the wet, near-normal and dry years, with the median of all years as reference. The results are shown as a percentage of the total elevation within each 200-meter elevation band within the study area boundaries. The ROMO area shows that the dry year, 2002 (as well as the other very dry year during the period, 2012), was significantly different from the other two, with a fractional area declining with altitude above 3400m. This may indicate that the meteorology in this region interacts differently with the topography in extremely dry years than in wetter years. The high-altitude snowpack may be particularly vulnerable in this region if conditions like those in 2002 recur.

5 Future Snowpack Projections: DHSVM Modeling

Key Points - Methods

- We conducted this analyses to………….
- The Distributed Hydrology Soil Vegetation (DHSVM) model was run for the historic period 1998-2013 and validated against available SNOTEL observing stations. The spatial patterns of snow were validated against MODIS satellite remotely sensed snow cover.
- Five scenarios of the future – a thirty year period centered on 2055 -- were selected from CMIP5 global climate model (GCM) projections based on a moderate (RCP 4.5) and high (RCP 8.5) emissions scenarios. These were chosen to represent a large fraction of the range of the CMIP5 ensemble projections in each study area in terms of precipitation and temperature changes. The scenarios differ somewhat between the two study areas to better represent the range of climate projections in each area.
- The selected GCM projections were downscaled using the "delta method" which applies change factors from the climate models to the historic temperature and precipitation that are used as inputs to the DHSVM model.
- Analysis is presented for light snow cover (Snow Water Equivalent > 13mm) for comparison with MODIS and McKelvey, and for 0.5 m of snow depth.
- To capture climate variability, Wet, Near Normal, and Dry representative case study years are shown for the historical simulations and how each of these years plays out under these five future scenarios.

Key Points – GLAC study area.

- Snow Covered Area in GLAC and area with snow depth greater than 0.5 meters on May 15 declines on average in all scenarios on average and for almost all years.
- On average, projections for the May 15 snowpack in the GLAC study area show a 12-42 percent decline in snow covered area, and a 15-68 percent decline in area with snow depth > 0.5 meters for the scenarios considered.
    - This resulted in X to X km2 in snow covered areas with > 0.5 meter snow cover
- All projections show declines in the number of years with significant snow. The areas with frequent (14-16 years) availability of significant snow become concentrated in smaller high elevation areas.
- For wet years, the high elevations of the study areas result in little loss of snowpack under most scenarios of change.
- For GLAC the Warm/Wet scenario shows the least change compared to the historic snow cover in terms of the area of significant (0.5 meter) snowpack. Under the Hot/Wet scenario, the May 1st significant snowpack diminishes to below the level of the historic June 1 snowpack.

Key Points – ROMO study area.

- Snow Covered Area in ROMO (13mm threshold on May 15) declines on average in all scenarios on average and for almost all years.

- On average, projections for the May 15 snowpack in the ROMO study area show a 12-52 percent decline in snow covered area, and a 7-64 percent decline in area with snow depth > 0.5 meters for the scenarios considered.
    - This resulted in X to X km2 in snow covered areas with > 0.5 meter snow cover
- Snow Covered Area in ROMO (0.5 m threshold on May 15) generally declines in wet years, but may increase in dry years in those scenarios with increased precipitation.
- Scenarios with increased precipitation may show increases in May 15 snowpack at the higher elevations in both study areas, but decreases in snowpack at lower elevations. This can lead to an increase in the area of > 0.5 meters of snow for dry years.
- ROMO exhibited more uncertainty in projections than GLAC
    - The beneficial effect of increased precipitation on snowpack is more prominent earlier in the Spring. In the Warm/Wet scenario, the area of significant snow on May1 increases on average, though it decreases on May 15.
    - For wet years, the high elevations of the study areas result in only modest loss of snow cover in the under all scenarios of change. However even in wet years, the area of significant snowpack can decline by almost 50% for the Hot/Dry climate change scenario.

5.1 Introduction

In this section we describe the hydrologic model along with various modeling assumptions, validation of the model, the choice of risk-spanning future climate scenarios, and present results of historical and projected snowpack for the two study areas.

To determine the projected effects of a changing climate on snowpack we ran a physically-based hydrology model. The physical basis of the model – using a full energy and water balance of the snowpack rather than a simple temperature-index model -- is critical to evaluate change in a non-stationary climate. While ambient temperature is a critical factor in whether precipitation falls as rain or snow, the subsequent evolution of the snowpack, and in particular the melt season, is driven primarily by the energy balance at the surface. The energy balance is the result of several processes, including solar and longwave radiation, sensible and latent heat fluxes, and heat flux into the ground, as well as storage of heat in the snowpack. Therefore, including a realistic energy balance helps to understand how the perturbations to climate will affect the snowpack.

5.2 Model Description

The Distributed Hydrology Soil Vegetation Model (DHSVM) provides a physically-based simulation of land surface hydrology, including snowpack. The physical processes include a full surface water and energy balance model, a 2-layer canopy model, a multi-layer soil model, a 2-layer snowpack model (Wigmosta et al. 1994). It has been used in many studies that have provided realistic hydrologic simulations in topographically complex areas (e.g. Livneh et al. 2015). The model has explicit treatment of topographic slope, and aspect (the compass direction that the slope faces).

The model was selected for developing snowpack projections because it can be run at a fine spatial scale (250 m x 250m pixels) yet is able to be run over extensive domains. There are both finer-scale snow models, for which it would have been impractical to simulate such a large domain, and coarser-scale models, such as the 1/16 degree grid of the VIC model that the McKelvey study used (see section 2.3). Coarser-scale models do not explicitly model the effects of slope and aspect, which is one of the primary goals of this study. Both DHSVM and VIC were primarily developed at the University of Washington, and are available as open-source community models. The two models share many components in common, including similar snow and canopy models. As such it supports the project goal of building on McKelvey study by modelling at a finer scale and treating slope and aspect explicitly.

The model was set up for both study domains on a 250m grid in Universal Transverse Mercator (UTM) coordinates within the modeling domain defined within the polygons shown in Section 2. Soil properties and vegetation type as well as a digital elevation model (DEM) were adapted to the model grid. A soil hydraulic routing network was also determined from the DEM, though in this project we do not investigate the runoff. The effect of slope and aspect on incoming solar radiation is implemented through a computation of the degree of shading for each 250-m pixel that was variable throughout the day and differed from month to month based on the solar angle in the sky and from the DEM. The model requires inputs of time-varying meteorological fields on sub-daily time scales. Snow water equivalent was output on May 1, May 15, and June 1 for every year of the simulation. As noted below, snow depth was estimated using a typical snowpack density for late Spring.

More details of the model will be included in the Section 5 Supplementary Material.

5.3 Meteorological Inputs

The DHSVM model inputs were derived in a multi-step process. First, values of daily minimum temperature, daily maximum temperature, and precipitation were extracted from the Livneh (2015) dataset, which has a grid resolution of 1/16th degree in latitude and longitude. These daily values were disaggregated in time. Other forcing variables needed by the model, solar radiation, downwelling longwave radiation, specific humidity were derived from empirical relationships using the MTCLIM algorithms which were evaluated by Livneh et al. (2014) finding small overall biases. The Livneh et al (2015) data was then interpolated to the 250m DHSVM grid using an inverse-distance weighting algorithm along with assumed lapse rates (elevation dependence) in temperature and in precipitation. More details of the Livneh 2015 dataset will be included in the Section 5 Supplementary Material.

5.4 DHSVM Historical Validation

The goal of the model validation is to assess the overall magnitude, temporal, and spatial aspects of the modeled snowpack in the Spring and how these differ from observational estimates. Observational estimate of snow depth or snow water equivalent at the scales that we simulated are not available, leading to uncertainty about the "true" snowpack. For the overall magnitude and temporal aspects of the snow simulation, we compared the historical model simulation to point observations at the few available SNOTEL sites, focusing on the duration and melt-out date of the snowpack. The spatial aspect of bias was evaluated by comparing the model output to the observed spatial patterns of snow cover obtained from the MODIS analysis (see Section 4), qualitatively for GLAC and quantitatively for ROMO. When interpreting the projections, future model biases are typically assumed to be similar to historical biases. With this assumption, the calculation of, for example, percentage change is less sensitive to biases and uncertainties in the historical simulation.

5.4.1 Comparison to SNOTEL

The DHSVM historical simulation was compared against the snow data from nine SNOTEL sites in the ROMO study area that were in operation during the full time-period of interest, and the 3 SNOTEL sites in and adjacent to the GLAC study area (Table 5-1). Validation against SNOTEL snow data was performed by running the DHSVM model in "point" mode so that it simulated the conditions at the SNOTEL locations only. Because the SNOTEL stations are deliberately sited in clearings, the canopy was assumed to be open for the validation runs, while the actual 250m grid canopy values were used for the production runs. Two metrics were chosen: the meltout day of year (defined as the date when SWE fell to less than 1mm), and the duration of snow cover (total number of days during the water year (October-September) when SWE > 10cm). Figure 5-1a shows the modeled and observed meltout dates for the GLAC and ROMO SNOTEL sites, and Figure 5-1b shows the duration of snowpack. One does not expect exact reproduction of the snowpack at the SNOTEL sites, but rather a scatter about the 1-to-1 line, which is seen. The Copeland Lake, and to some extent the Many Glacier SNOTEL sites are outliers, with the model retaining snowpack significantly longer than in observations. Both these sites are at relatively low elevations, and are quite sensitive to potential temperature biases in the input data. The Livneh (2015) dataset is known to have a cool bias relative to other datasets, which may influence these sites disproportionately.

Table 5-1 SNOTEL Sites at Study Areas. Maps with SNOTEL sites are shown in Figs 2-1 and 2-2.

	SNOTEL SITE NAME (Site Number, Abbreviation)
Glacier Study Area	Flattop Mountain (482, flat), Many Glacier (613, many), Pike Creek (693, pike)
Rocky Mountain Study Area (used for Validation)	Bear Lake (322, bear), Copeland Lake (412, cope), Joe Wright (551, joew), Lake Eldora (564, eldo), Lake Irene (565, iren), Niwot (663, niwo), Phantom Valley (688, phan), University Camp (838, univ), Willow Park (870, will)
Rocky Mountain Study Area (installed after 1997, not used)	Never Summer (1031), Wild Basin (1042), Hourglass Lake (1122), Long Draw Reservoir (1123), High Lonesome (1187), Sawtooth (1251)

The year-to-year variations of peak snowpack at the GLAC SNOTEL sites are well captured, as illustrated in Figure 5-2 that shows simulated and observed time series of SWE at these stations.

Figure 5-3 shows selected SNOTEL sites in the ROMO area. As can be seen in Figure 5-2, the Copeland Lake site is less well simulated than other sites. We attribute this to being located at a lower elevation than other sites, and hence susceptible to small biases in temperature in the meteorological inputs. Other sites in ROMO are well simulated.

Based on this evaluation of DHSVM performance, the standard set of model parameters was adopted for the GLAC domain without modification.

The question arises of the independence of the SNOTEL data from the Livneh (2015) forcing data. The primary observing station data that were used for interpolation by Livneh (2015) did not include SNOTEL. However, a monthly adjustment factor was applied to the interpolated precipitation to reproduce the 1981-2000 climatology of PRISM. The temperature data in Livneh et al (2015) were entirely independent of SNOTEL data. Therefore, we expect that the errors revealed at the SNOTEL sites should be representative of errors at other, unobserved sites in the domain.

5.4.2 Comparison to MODIS Snow Cover

The spatial distribution of snow cover was assessed by comparison with MODIS data. Some care must be taken to compare observed NDSI, which indicated fractional snow cover, with modeled SWE, which does not account for fractional snow cover within a pixel. For this evaluation, a threshold to determine "snow covered ground" was chosen for both the MODIS NDSI (0.1) and for the DHSVM SWE. Figures 5-4 and 5-5 snow spatial overlays of the DHSVM simulated snow cover and the MODIS observed snow cover for the representative "dry" years in ROMO and GLAC. In terms of snow cover, dry years were more difficult to simulate than wet years, and the spatial agreement is good for these two examples.

However, initial attempts to model ROMO indicated biases in the spatial patterns of snow cover compared to MODIS. To overcome model errors at ROMO, an adjustment of two DHSVM snow parameters was conducted. The representative values of the physical quantities of these parameters can span a fairly large range, and hence an experiment was conducted to evaluate the appropriate settings of the model for ROMO based on minimizing differences between simulated and MODIS SCA for the historical period, as well as reducing biases with SNOTEL SWE.

The first parameter modified was the snow-surface roughness (SR), which affects the amount of turbulent heat fluxes that occur between the snow and the atmosphere, whereby a small number corresponds to a smoother snowpack that has less heat exchange with the overlying air, while the opposite is true for a large value. The second parameter was the liquid water capacity (LWC) that describes the volume of water that the snowpack can hold before water will leach out of the snowpack. This parameter is important, since it is common for snow to melt during the day and then for liquid water to refreeze at night.

Adjustments were made to SR and LWC within reasonable physical ranges and the DHSVM simulated SCA was compared with MODIS via a threat score. The threat score used, referred to as the Critical Success Index (CSI) by Zappa (2010), is defined as:

$$CSI = \frac{a}{a + b + c}$$

Where a indicates a snow-covered pixel in both the simulation and observed data, b indicates a snow-covered pixel in the simulation but a bare pixel in the observed ("false positive"), and c is a bare pixel for the simulation and a snow-covered pixel shown by the observed data ("false negative"). The objective was to maximize the threat score. Approximately ten unique parameter settings were tested. Additionally, for each parameter setting the mean bias in meltout day and duration of snow cover between DHSVM simulated and SNOTEL SWE was calculated with the objective being a minimization of the bias between the two (bias = simulated – observed). The final DHSVM settings for ROMO were identified by the parameter values that corresponded with a combination of a high threat score and a low bias. The table and figure showing the parameter settings and ensuing objective values are included in the supplementary material (Figure S5.X).

5.5 Determination of Snow Depth from DHSVM model output

DHSVM does not compute snow depth as a separate quantity, but instead returns snow water equivalent (SWE). To estimate the snow depth from SWE, a bulk density of the snowpack must be assumed. We adopt a density of 0.4 (or equivalently, at 2.5-to-1 ratio of snow depth to SWE, further discussion can be found in the Section 5 Supplementary Material) appropriate for the May snowpack in the study areas. Several lines of evidence point to the reasonableness of this assumption. First, SNOTEL stations where both depth and SWE are measured show similar ratios for the two study areas. Second, we investigated the ratio of density from the SNODAS (Snow Data Assimilation System) product from the NOAA National Operational Hydrologic Remote Sensing Center, which points to a very narrow range around 2.6-2.7 for the ratio. Finally, for comparison with the McKelvey et al (2011) work we compared the May 1 Snow Depth and SWE products from the Littell et al (2011) hydrologic model runs (obtained separately from https://cig.uw.edu/datasets/wus/). These all point to an approximate value consistent with a density between 0.35 and 0.4. The results of this study do not depend on a precise value for snow density.

5.6 Choice of thresholds for analysis

While the the McKelvey study analysis was for the presence or absence of snowcover, this modeling effort produces results in terms of SWE. This allows greater flexibility in evaluation of the depth of the snowpack, but presents a problem in comparison. To compare the model-generated SWE with both the McKelvey study results and our own MODIS historical snow cover analysis we investigated several threshold values of SWE: 1mm, 5mm, 13mm. For the purposes of this section we use the 13mm SWE threshold. We also were concerned with analyzing the presence of "significant snow" which we defined as 0.5 m of snow depth, or 0.2 m of snow water equivalent using our assumed May snow density. The value of 0.5 m was arrived at by an analysis of the modeled snow depth at known wolverine denning sites in Glacier National Park (Table 5-2). With the exception of one site that had melted out by May 15th, the other sites all have snowpack between 0.4 and 1.4 m.

Table 5-2: Modeled Snow Depth on May 15 at reported den sites in the Glacier Study Area (source: John Guinotte, FWS)

Den site	Date observed (month-yr)	Meltout Date (MODIS)	May 15 snow depth dhsvm (m)	Notes
1	Apr-03	5/25/2003	1.036	
2	May-03	5/25/2003	1.045	
3	Apr-04	6/4/2004	0.407	
4	Apr-04	6/29/2004	0.539	
5	May-04	6/29/2004	0.653	
6	Mar-05	6/11/2005	0.531	
7	Apr-05	6/11/2005	0.531	
8	May-05	6/11/2005	0.468	
9	Mar-06	5/25/2006	1.435	
10	Apr-06	5/14/2006	0	meltout occurred before may 15
11	Apr-06	6/7/2006	1.233	
12	May-06	5/31/2006	0.611	
13	May-06	5/31/2006	0.611	duplicate

5.7 Delta Method for Future Scenarios

The advantages and disadvantages of the delta method have been discussed extensively in the literature (e.g. Sofaer et al, 2016, for a recent review). The primary advantages of this method are its long history of use, its simplicity, and its use of the historical observed weather as the baseline. The simplicity allowed for the study to be completed in a short time-frame, while still reaching our primary objectives of finer spatial scale and a more complete exploration of future climate scenarios. The use of the historical baseline allows us to explore how wet, near normal, and dry "representative years" would play out under the different climate futures. However, it is important to keep in mind that we are "parameterizing the future variability in terms of the historical variability." This treatment of daily variability also leads to the primary disadvantage of the delta method: the assumptions that the changes in extremes follow the changes in the means, and that the pattern of daily weather is simply shifted without changing the sequences of weather. This aspect is less of a concern for this study, as snow accumulation and ablation are cumulative processes, so that the daily sequences of storms is less critical to simulate than the monthly and seasonal totals. Another assumption of the delta method is that the large-scale changes in temperature and precipitation apply uniformly to the study area. Equivalently we assume that change factors in ambient (free-air) temperature and precipitation will not depend on the small scale spatial detail. Because we explicitly compute the surface energy balance, we are able to simulate surface temperature differences that depend on fine-scale terrain, mitigating to some extent this limitation of the delta method.

Following McKelvey (2011), we use the “delta method” to downscale the climate model data to the 250m modeling grid.

The steps in this method are as follows:

- Start with historical daily meteorological forcings (inputs to the DSHVM model) for the historical baseline period (1998-2013)
- Run DHSVM with the historical forcings to produce the simulated historical snow and hydrology.
- From climate model output, compute the change in 30-year average temperature for each calendar month over the time frame of interest. Do the same for the percent change in precipitation
- Apply these change factors to the historical daily meteorological inputs to DHSVM to generate future scenarios of meteorological inputs.
- Run DHSVM with these new inputs to generate the projected snow and hydrology.
- Compare the projected snow to the historic DHSVM model simulations to infer changes in snowpack.
- Repeat for a set of change factors from different climate models that adequately sample the uncertainty in climate projections.

The result of the delta method is a continuous-in-time simulation of the historical period (1998-2013), and an equal length simulation of how this sequence of years would play out in the future under five different scenarios of climate change. Figure 5-6 illustrates typical DHSVM model output using the delta method. Figure 5-6a shows a map of May 15, 2011 Snow Water Equivalent for the Glacier Study Area from the historical simulation, while Figure 5-6b shows a single projected future for what that year’s SWE would look like under a particular scenario of climate change. The future scenario represents a year similar to 2011, that is, a relatively wet and cool year in the sequence, however the temperature and precipitation have been adjusted to be consistent with the 2041-2070 projected climate from the MIROC climate model.

5.8 GCM Uncertainty and Scenario Planning Approach

As noted in Section 2, global climate models (GCMs) are our primary tools to examine the nature of climate change during the 21st century. There are currently about 20 modeling centers worldwide which provided output from their best model(s) to be considered in the Coupled Model Inter-comparison Project Phase-5 (CMIP5, Taylor et al., 2012) which informed the latest Intergovernmental Panel on Climate Change (IPCC) report (IPCC AR5). Here we quantify changes in temperature and precipitation for the two study areas for the 2014-2070 time frame. We find a large spread in the extent of warming and changes in precipitation, including both increases and decreases in precipitation, as shown in Figure 5-7. The McKelvey study chose GCMs based on the range of temperature change (see Sec 2.2, also shown in Figure 5-7). For temperature, much of this spread (or uncertainty) is a result of the difference between GCMs (e.g., their climate sensitivities), whereas for precipitation it is both the difference between GCMs and internal climate variability. Some difference also comes from the choice of future greenhouse gases (GHG) emission scenario. However, these differences among mid-21st century climate responses are limited compared to later in the century (see a discussion in Ray et al., 2010).

For more robust planning and climate adaptation, experts recommend incorporation of these uncertainties into the assessment of impacts and developing adaptation strategies. The scenario planning approach has been one method that has been recommend and promoted by different entities and experts (National Park Service, 2013; Rowland et al., 2014; Maier et al., 2016; Murphy et al. 2016; Star et al., 2016, Fisichelli et al, 2016 a,b). Therefore, we adopted a strategy of selecting multiple divergent future scenarios challenging to the system of interest, following that in Fisichelli et al (2016 a, b).

5.9 Climate Projections Evaluation and Scenarios Selection

We compiled output for temperature and precipitation projections for 34 CMIP5 GCMs from the Reclamation (2013; http://gdo-dcp.ucllnl.org/) archive of 1-degree Regridded GCM dataset for Representative Concentration Pathways (RCP) 4.5 and 8.5, which are respectively the moderate and high GHG emissions scenarios --- therefore, a total of 68 GCM projections described in Supplementary Material. These data were then analyzed to quantify broad-scale projections for the two study regions by 2055 (i.e. a mid-point centered on the 2041-2070 period) – primarily changes in the cold season (Oct-May) temperature and precipitation by 2055 relative to the 1986-2015 period. Figures 5-7 show these changes for Rocky Mountain and Glacier National Parks, respectively, which are bounded by rectangular latitude/longitude values. As mentioned earlier, we found a large range in temperature increases (1-4 ^{o}C) and changes in precipitation (-5% to +20%) for these regions by 2055. Table 5-3 shows GCM names, numbers and colors coded in later figures, and relative changes in temperature and precipitation. To incorporate the large range in climate projections, we worked with the ensemble of 68 CMIP5 temperature & precipitation projections, described by the red filled-circles in Figure 5-7, to select five future climate scenarios (black circles) that span the different parts of this projection space. Five GCMs representing these scenarios were identified for both RMNP and GNP. For each of these GCMs, we calculated changes in temperature and precipitation by 2055 for each month of the year, which we call the “monthly delta”. These monthly deltas were used to perturb the hydrological models to simulate snow response in RMNP and GNP by 2055.

Table 5-3. The six future scenarios used (five for each area) with changes in temperature and precipitation relative to other scenarios (See also Fig 5-7 for an alternate visualization of these changes), and the GCM used as the basis for the deltas for this scenario. More details on the GCMs are in the Glossary.

Future Scenario Name and #	Scenario Change in GLAC relative to other scenarios	Scenario Change in ROMO relative to other scenarios	Code and color for GCM used for this scenario
Central (#1)	+~2.2 ^{o}C increase in temperature (close to the ensemble mean) and +~5% increase in precipitation	+~2.5 ^{o}C increase in temperature (close to the ensemble mean) and +~8% increase in precipitation	cnrm, red
GLAC: **Hot/ Very Wet (**#2)	relatively higher increase in temperature (+~3.2 C) and the highest increase in precipitation (+20%) for the GLAC scenarios	N/A	canesm, green
ROMO: **Hot/Dry (**#2)	N/A	relatively higher temperature increase (+~ 3.5 ^{o}C) and -~5% decrease in precipitation. This scenario results in the greatest change (reduction) in snow pack and snowcover.	hadgem, green
Hot/ Wet (#3)	the highest temperature increase of the GLAC scenarios (+~4.2 ^{o}C) and +~10% increase in precipitation	the highest temperature increase of the ROMO scenarios (+~3.7 ^{o}C) and the highest increase in precipitation (+~18%).	miroc, purple
Warm/ Wet (#4)	relatively lower temperature increase (+~1 ^{o}C) and +~10% increase in precipitation	relatively lower temperature increase (+~1.3 ^{o}C) and +~7% increase in precipitation that appears to partially offset the impacts of the temperature increase. This scenario results in the least change in snow pack and snowcover.	giss, aqua
Warm/ Dry (#5)	relatively lower temperature increase (+~1.6 ^{o}C) and -~5% decrease in precipitation	relatively lower temperature increase (+~0.8 ^{o}C) and -~5% decrease in precipitation	fio, orange

5.10 Modeling Caveats

Some processes which may be of relevance not represented in the model include wind and avalanche re-distribution of snowpack. Snow depth is not explicitly modeled, and must be inferred (see below). The meteorological forcing does not take into account cold air pooling or how this may change in the future. Cold air pooling – the anomalously cold air that can collect in valley bottoms, particularly in Winter, could also act to prolong the duration of snow cover in those locations. While Curtis et al (2014) identify this as a potential process, they do not physically model cold air pooling, but merely include it in their present-day climatology as a simple “offset” from their unadjusted data. Nonetheless their work provides a complementary approach to the identification of potential snow refugia, though more work would need to be done to study the geographic and seasonal aspects for the study areas.

5.11 GLAC Study Area Results

5.11.1 SWE and Snow Covered Area for representative years

Figures 5-8 shows DHSVM model simulated snow water equivalent (SWE) on May 15 for the wet (2011) representative year. Maps of snow cover derived from SWE by applying a threshold of 13 mm are available in the Supplementary material. Results for thresholds of 1 mm and 5 mm of SWE were also investigated and show similar patterns. Snow covered area with a “light snow cover” threshold was computed primarily for comparison with both the MODIS results from Section 4, and with McKelvey. In Figure 5-8, the historical simulation is shown along with three of the five future scenarios, chosen to represent the central scenario (cnrm), the greatest change in snowpack on average (Hot/Wet (miroc) scenario) and the least change (Warm/Wet (giss) scenario). The projected snow maps answer the question “what would the snowpack in a wet year like 2011 look like in the 2040’s through 2070’s under these scenarios of climate change.”

Figures 5-9 and 5-10 show SWE for the Near Normal (2009) and Dry (2005) representative years. The historical simulation and future scenarios are as in Figure 5-8. Figure 5-11 summarizes the results for snow covered area in terms of the total snow covered area (km^2) within the study area polygon. The numerical values of snow covered area for all years in the simulation, as well as percent changes for these quantities are shown in Table 5-4. Table 5-4 indicates that the snowcovered area decreases for all scenarios. **On average, the GLAC study area exhibits a 12-42 percent decline in snow covered area on May 15 for the scenarios considered.**

- **Elevation at den graph should be incorporated here instead of an add on section later in the report.**
- Comparing the Wet and Dry representative years we see that dry years are more vulnerable to climate change in terms of percent loss of snow covered area.
- For the Wet year, the high elevations of the study area result in little loss of snowpack in the study areas under most scenarios of change.
- However, in Figures 5-10 and 5-11 we notice an anomaly – for the dry year, the Hot/Wet scenario does not have the greatest loss of snow covered area. The increase in precipitation in this scenario has somewhat compensated for the loss of snowpack due to warming.

Comment [GJM9]: We should run this by Steve to see what he thinks re displaying maps using SWE vs snow depth. Swe is much less understandable to the avg reader whereas snow depth is clear.

Comment [Office10R9]: For the paper we will probably have to stick to SWE as much as possible. Snow depth was derived using our empirical formula, which is fine for our purposes – denoting areas of a significant amount of snow--. But showing maps it is probably less risky to snow them in terms of SWE – that is what snow/hydrologic modelers mainly think in terms of anyway as it is more close

APPENDIX????

GLAC Area (km^2)	Snow Covered Area (13mm SWE threshold) Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	historical	2552	2793	2655	2802	2890	2753	2533	2408	2636	2491	2883	2901	2524	2901	2758	2851	2708	2756
	Central (cnrm)	1768	2329	2030	2459	2816	2326	1812	1509	1959	1816	2742	2880	1886	2885	2179	2561	2247	2253
	Hot/Very Wet (canesm)	1394	1956	1707	1955	2595	1858	1303	1171	1510	1174	2436	2764	1293	2817	1723	2127	1862	1790
	Hot/Wet (miroc)	1573	1646	1604	1637	1518	2122	998	2275	1527	1517	2608	2037	1618	2481	1157	2165	1780	1627
	Warm/Wet (giss)	2197	2583	2388	2599	2856	2486	2191	2017	2312	2109	2842	2895	2170	2901	2485	2705	2484	2486
	Warm/Dry (fio)	2112	2440	2184	2586	2830	2555	2089	1776	2231	2070	2806	2891	2127	2900	2486	2659	2421	2463
15-May	historical	1452	2718	2433	2352	2873	2636	2287	2087	2373	1741	2807	2825	2393	2900	2557	2548	2436	2490
	Central (cnrm)	636	2114	1703	1780	2661	2068	1409	1104	1555	963	2367	2479	1664	2817	1763	1733	1801	1748
	Hot/Very Wet (canesm)	650	1835	1447	1419	2449	1652	1083	887	1255	657	2174	2218	1118	2697	1473	1584	1537	1460
	Hot/Wet (miroc)	1079	1440	977	1051	1230	1958	784	1451	1152	1026	2307	1677	1499	2305	879	1760	1411	1335
	Warm/Wet (giss)	1079	2483	2098	2062	2800	2332	1963	1667	1981	1299	2638	2672	2034	2882	2203	2247	2152	2151
	Warm/Dry (fio)	883	2274	1913	1910	2712	2372	1722	1397	1851	1138	2515	2600	1918	2864	2125	1943	2009	1931
1-Jun	historical	863	2360	1759	1114	2599	1932	1864	1375	1446	1061	1923	2205	1907	2863	2171	2035	1842	1915
	Central (cnrm)	250	1512	948	628	2049	1099	897	560	663	417	1005	1397	1025	2600	1281	1114	1090	1015
	Hot/Very Wet (canesm)	328	1393	909	590	1923	966	742	514	689	347	1172	1414	794	2455	1118	1134	1030	937
	Hot/Wet (miroc)	496	813	359	282	682	1109	417	552	267	511	1008	682	831	1862	527	786	699	617
	Warm/Wet (giss)	613	2046	1392	883	2401	1507	1473	1046	1063	759	1574	1893	1580	2789	1763	1747	1533	1541
	Warm/Dry (fio)	401	1723	1137	623	2217	1410	1196	735	810	527	1222	1606	1178	2691	1611	1291	1274	1209

% change	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	Central (cnrm)	-31	-17	-24	-12	-3	-16	-28	-37	-26	-27	-5	-1	-25	-1	-21	-10	-17	-18
	Hot/Very Wet (canesm)	-45	-30	-36	-30	-10	-33	-49	-51	-43	-53	-15	-5	-49	-3	-38	-25	-31	-35
	Hot/Wet (miroc)	-38	-41	-40	-42	-47	-23	-61	-6	-42	-39	-10	-30	-36	-15	-58	-24	-34	-41
	Warm/Wet (giss)	-14	-8	-10	-7	-1	-10	-13	-16	-12	-15	-1	0	-14	0	-10	-5	-8	-10
	Warm/Dry (fio)	-17	-13	-18	-8	-2	-7	-18	-26	-15	-17	-3	0	-16	0	-10	-7	-11	-11
15-May	Central (cnrm)	-56	-22	-30	-24	-7	-22	-38	-47	-34	-45	-16	-12	-30	-3	-31	-32	-26	-30
	Hot/Very Wet (canesm)	-55	-32	-41	-40	-15	-37	-53	-58	-47	-62	-23	-22	-53	-7	-42	-38	-37	-41
	Hot/Wet (miroc)	-26	-47	-60	-55	-57	-26	-66	-30	-51	-41	-18	-41	-37	-21	-66	-31	-42	-46
	Warm/Wet (giss)	-26	-9	-14	-12	-3	-12	-14	-20	-17	-25	-6	-5	-15	-1	-14	-12	-12	-14
	Warm/Dry (fio)	-39	-16	-21	-19	-6	-10	-25	-33	-22	-35	-10	-8	-20	-1	-17	-24	-18	-22
1-Jun	Central (cnrm)	-71	-36	-46	-44	-21	-43	-52	-59	-54	-61	-48	-37	-46	-9	-41	-45	-41	-47
	Hot/Very Wet (canesm)	-62	-41	-48	-47	-26	-50	-60	-63	-52	-67	-39	-36	-58	-14	-49	-44	-44	-51
	Hot/Wet (miroc)	-42	-66	-80	-75	-74	-43	-78	-60	-82	-52	-48	-69	-56	-35	-76	-61	-62	-68
	Warm/Wet (giss)	-29	-13	-21	-21	-8	-22	-21	-24	-27	-28	-18	-14	-17	-3	-19	-14	-17	-20
	Warm/Dry (fio)	-54	-27	-35	-44	-15	-27	-36	-47	-44	-50	-36	-27	-38	-6	-26	-37	-31	-37

Table 5-4: GLAC Snow Covered Area (13mm SWE threshold) Top: Area (km^2) in historical and five future scenarios. Bottom: percent change in future simulations compared to historical. Average and Median values also shown.

5.11.2 Area and Number of years with 0.5 m Snow Depth

Because of interest in wolverine denning sites, we analyze snow depth > 0.5 m, which we will also refer to as "significant snow" to contrast with the emphasis on light snow in McKelvey et al (2011) and in the previous section. Figure 5-12 shows the area with snow depth > 0.5 m on May 15 within the study area for the dry, near normal, and wet years. Because of the higher threshold for snow, the effects are somewhat larger than for the light snow threshold. This is particularly evident in the dry year, which has a 50% decline on May 15 for four of the future scenarios. The numerical values of snow covered area at the > 0.5 m threshold are shown in Table 5-5 for all years, as well as percent changes for these quantities. **On average, the GLAC study area exhibits a 15 – 68 percent decline in the area of snow depth > 0.5 meters for the scenarios considered.**
Figure 5-22 here, plus text to accompany the results from this figure. Also include the X to X km^2 area that correspond to the 15-68 declines.

Figure 5-13 shows a map of the number of years (out of 16 possible) where each model pixel had at least 0.5 m of snow depth on May 15. This number-of-years statistic is analogous to that used by the Copeland study, except that there are more years of data, and these maps use a much higher threshold of snow. The projections show declines in the number of years with significant snow. The areas with frequent (14-16 years) availability of significant snow become concentrated in smaller high elevation areas.

The effects of climate change on snow melt have been presented as analogous to a "time shifting" of the melt season earlier in the year. For example, McKelvey used the May 31 vs. May 15 snow covered area as a proxy for a 2-week shift in the melt season. Figure 5-14 contrasts the evolution of the snowpack from May 1 to June 1 in the historical simulations (Top Row) with the Warm/Wet scenario (Middle Row) and Hot/Wet (Bottom Row) scenarios. We see that the Warm/Wet scenario, shows the least change compared to the historic snow cover in terms of the availability of significant snow. In contrast, under the Hot/Wet scenario, the May 1st significant snowpack has been diminished below the level of the historic June 1 snowpack – greater than a month shift.

Snow Covered Area (0.5 m depth threshold)

Area (km^2)	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	historical	1594	2545	2204	2326	2844	2392	2032	1800	2124	1571	2613	2731	1692	2901	2453	2625	2278	2359
	Central (cnrm)	770	1826	1477	1912	2530	1766	1137	912	1283	951	2160	2383	965	2847	1630	1893	1653	1698
	Hot/Very Wet (canesm)	733	1587	1234	1399	2283	1336	826	732	1075	578	1992	2070	677	2721	1316	1650	1388	1326
	Hot/Wet (miroc)	474	526	633	425	458	1538	395	614	364	541	1321	1236	332	2029	436	1018	771	533
	Warm/Wet (giss)	1154	2242	1810	2012	2681	1968	1590	1400	1660	1112	2389	2525	1360	2890	2017	2328	1946	1990
	Warm/Dry (fio)	974	1938	1594	1877	2586	2054	1368	1058	1471	969	2169	2418	897	2873	1944	2046	1765	1907
15-May	historical	550	2496	1937	1417	2749	2201	1673	1308	1805	804	2317	2537	1647	2881	2135	2035	1906	1986
	Central (cnrm)	140	1731	1161	1007	2329	1453	792	566	961	328	1585	1957	911	2692	1284	1139	1252	1150
	Hot/Very Wet (canesm)	247	1537	1048	835	2128	1176	648	509	900	274	1632	1797	662	2538	1087	1155	1136	1068
	Hot/Wet (miroc)	302	508	346	217	439	1447	203	531	290	302	1053	878	565	1733	352	634	612	473
	Warm/Wet (giss)	380	2199	1546	1166	2560	1782	1287	995	1362	567	2051	2286	1355	2825	1693	1745	1612	1620
	Warm/Dry (fio)	199	1873	1301	890	2438	1781	986	659	1106	328	1692	2096	879	2765	1559	1208	1360	1255
1-Jun	historical	337	1903	1089	428	2156	1192	1199	723	845	486	1140	1590	1144	2782	1625	1534	1261	1168
	Central (cnrm)	52	1052	494	202	1473	563	435	227	310	145	462	810	514	2353	827	738	666	504
	Hot/Very Wet (canesm)	113	1024	572	238	1476	585	437	262	398	145	667	956	429	2254	781	847	699	579
	Hot/Wet (miroc)	90	220	100	36	194	542	104	103	43	158	284	194	185	1319	194	250	251	190
	Warm/Wet (giss)	221	1545	817	321	1895	870	928	534	589	346	859	1262	973	2646	1246	1298	1022	899
	Warm/Dry (fio)	97	1139	567	164	1598	724	602	294	377	157	552	876	522	2457	1049	817	749	584

% change	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	Central (cnrm)	-52	-28	-33	-18	-11	-26	-44	-49	-40	-39	-17	-13	-43	-2	-34	-28	-27	-28
	Hot/Very Wet (canesm)	-54	-38	-44	-40	-20	-44	-59	-59	-49	-63	-24	-24	-60	-6	-46	-37	-39	-44
	Hot/Wet (miroc)	-70	-79	-71	-82	-84	-36	-81	-66	-83	-66	-49	-55	-80	-30	-82	-61	-66	-77
	Warm/Wet (giss)	-28	-12	-18	-13	-6	-18	-22	-22	-22	-29	-9	-8	-20	0	-18	-11	-15	-16
	Warm/Dry (fio)	-39	-24	-28	-19	-9	-14	-33	-41	-31	-38	-17	-11	-47	-1	-21	-22	-23	-19
15-May	Central (cnrm)	-75	-31	-40	-29	-15	-34	-53	-57	-47	-59	-32	-23	-45	-7	-40	-44	-34	-42
	Hot/Very Wet (canesm)	-55	-38	-46	-41	-23	-47	-61	-61	-50	-66	-30	-29	-60	-12	-49	-43	-40	-46
	Hot/Wet (miroc)	-45	-80	-82	-85	-84	-34	-88	-59	-84	-62	-55	-65	-66	-40	-84	-69	-68	-76
	Warm/Wet (giss)	-31	-12	-20	-18	-7	-19	-23	-24	-25	-29	-11	-10	-18	-2	-21	-14	-15	-18
	Warm/Dry (fio)	-64	-25	-33	-37	-11	-19	-41	-50	-39	-59	-27	-17	-47	-4	-27	-41	-29	-37
1-Jun	Central (cnrm)	-85	-45	-55	-53	-32	-53	-64	-69	-63	-70	-59	-49	-55	-15	-49	-52	-47	-57
	Hot/Very Wet (canesm)	-66	-46	-47	-44	-32	-51	-64	-64	-53	-70	-42	-40	-63	-19	-52	-45	-45	-50
	Hot/Wet (miroc)	-73	-88	-91	-92	-91	-55	-91	-86	-95	-67	-75	-88	-84	-53	-88	-84	-80	-84
	Warm/Wet (giss)	-34	-19	-25	-25	-12	-27	-23	-26	-30	-29	-25	-21	-15	-5	-23	-15	-19	-23
	Warm/Dry (fio)	-71	-40	-48	-62	-26	-39	-50	-59	-55	-68	-52	-45	-54	-12	-35	-47	-41	-50

Table 5-5: GLAC Snow Covered Area (0.5 m snow depth threshold) Top: Area (km^2) in historical and five future scenarios. Bottom: percent change in future simulations compared to historical. Average and Median values also shown.

5.12 ROMO Study Area

On average, the ROMO study area exhibits a 7 – 64 percent decline in the area of snow depth > 0.5 meters on May 15 for the scenarios considered. Note that the Warm/Wet scenario projects a slight increase in the area of significant snowpack on May 1.

5.12.1 SWE and Snow Covered Area for representative years

Figure 5-15 shows DHSVM model simulated SWE on May 15th for the wet representative year (2011). The historical simulation is shown along with three of the five future scenarios, chosen to represent the central scenario (cnrm), the greatest change in snowpack on average (Hot/Dry (hadgem2) scenario) and the least change (Warm/Wet (giss) scenario). The future scenarios answer the question "what would the snowpack in a wet year (like 2011) look like in the 2040's through 2070's under these scenarios of climate change." Note that the "greatest snowpack change" scenario is different for ROMO than for GLAC. We have included Hot/Dry in the choice of scenarios for ROMO because a significant number of climate models project drying conditions in ROMO, whereas in GLAC, the vast majority of climate models predict a wetter future.

Figures 5-16 and 5-17 shows SWE for the "Near Normal" (2009) and "Dry" (2002) year. One can see that in the dry year, the snow cover is already very sparse even in the historical simulation.

Figure 5-18 summarizes the results in terms of the total snow covered area (km^2) within the study area polygon. In this case, the threshold used is 13mm of SWE, representing a light snow cover, and comparable to the results in McKelvey. Comparing the Wet and Dry years we see, as with GLAC, that dry years are more vulnerable to climate change in terms of percentage of area lost. For the Wet year, the high elevations of the study area result in little loss of snowpack in the study areas under most scenarios of change. The numerical values of snow covered area for all years, as well as percent changes for these quantities are shown in Table 5-7. **On average, the ROMO study area exhibits a 12-52 percent decline in snow covered area on May 15 for the scenarios considered.**

ROMO — Snow Covered Area sq-km (13mm SWE threshold)

	Scenario	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	historical	1567	1514	1574	1523	1245	1594	1248	1580	1573	1555	1595	1578	1439	1593	779	1594	1472	1570
	Central (cnrm)	1380	1216	1424	1112	786	1571	655	1470	1376	1195	1593	1396	1091	1553	379	1547	1234	1378
	Hot/Dry (hadgem2)	1127	971	1079	844	418	1498	429	1114	1188	1081	1587	1267	763	1507	185	1462	1033	1097
	Hot/Very Wet (miroc)	963	569	1045	773	501	1425	293	1280	1215	701	1582	1003	837	1444	112	1382	945	983
	Warm/Wet (giss)	1498	1429	1510	1373	944	1589	964	1522	1528	1461	1595	1547	1335	1586	583	1587	1378	1504
	Warm/Dry (fio)	1462	1392	1546	1353	981	1584	828	1519	1518	1433	1595	1533	1234	1584	481	1580	1351	1490
15-May	historical	1427	1467	1146	1064	989	1592	831	1519	1490	1421	1593	1449	1372	1587	588	1566	1319	1438
	Central (cnrm)	1012	1076	728	495	526	1546	340	1206	982	872	1563	953	951	1485	245	1366	959	967
	Hot/Dry (hadgem2)	530	688	250	221	213	1395	119	671	650	569	1410	470	562	1320	80	846	625	565
	Hot/Very Wet (miroc)	637	483	457	385	327	1346	141	948	858	491	1510	615	742	1355	78	1193	723	626
	Warm/Wet (giss)	1235	1315	877	814	693	1583	554	1346	1312	1242	1585	1246	1228	1559	396	1515	1156	1244
	Warm/Dry (fio)	1227	1311	928	755	695	1573	504	1361	1302	1200	1588	1279	1141	1556	344	1505	1142	1253

Snow Covered Area % change (13mm SWE threshold)

	Scenario	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	Central (cnrm)	-12	-20	-10	-27	-37	-1	-48	-7	-13	-23	0	-12	-24	-2	-51	-3	-16	-12
	Hot/Dry (hadgem2)	-28	-36	-31	-45	-66	-6	-66	-30	-24	-30	-1	-20	-47	-5	-76	-8	-30	-30
	Hot/Very Wet (miroc)	-39	-62	-34	-49	-60	-11	-77	-19	-23	-55	-1	-36	-42	-9	-86	-13	-36	-37
	Warm/Wet (giss)	-4	-6	-4	-10	-24	0	-23	-4	-3	-6	0	-2	-7	0	-25	0	-6	-4
	Warm/Dry (fio)	-7	-8	-2	-11	-21	-1	-34	-4	-3	-8	0	-3	-14	-1	-38	-1	-8	-5
15-May	Central (cnrm)	-29	-27	-37	-53	-47	-3	-59	-21	-34	-39	-2	-34	-31	-6	-58	-13	-27	-33
	Hot/Dry (hadgem2)	-63	-53	-78	-79	-78	-12	-86	-56	-56	-60	-12	-68	-59	-17	-86	-46	-53	-61
	Hot/Very Wet (miroc)	-55	-67	-60	-64	-67	-15	-83	-38	-42	-65	-5	-58	-46	-15	-87	-24	-45	-56
	Warm/Wet (giss)	-13	-10	-23	-23	-30	-1	-33	-11	-12	-13	-1	-14	-11	-2	-33	-3	-12	-13
	Warm/Dry (fio)	-14	-11	-19	-29	-30	-1	-39	-10	-13	-16	0	-12	-17	-2	-41	-4	-13	-13

Table 5-6: ROMO Snow Covered Area (13 mm SWE threshold) Top: Area (km^2) in historical and five future scenarios. Bottom: percent change in future simulations compared to historical. Average and Median values also shown.

5.12.2 Area and Number of years with 0.5 m Snow Depth

Because of interest in wolverine denning sites, we analyze snow depth > 0.5 m, which we will refer to here as "significant snow." Figure 5-19 shows the area with snow depth > 0.5 m within the study area. Because of the more stringent threshold for snow, the effects are somewhat larger than for the light snow cover. The numerical values of snow covered area at the > 0.5 m threshold are shown in Table 5-7 for all years, as well as percent changes for these quantities. In this table, we note that dry years such as 2002 see increases in snow covered area for the Hot/Very Wet and Warm/Wet scenarios. As in GLAC, dry years are somewhat buffered against change, and in fact can see increases in high-altitude "significant" snow for scenarios with increased precipitation. This is a result of the elevational dependence of snowpack change that will be discussed in the next sub-section. **On average, the ROMO study area exhibits a 7 – 64 percent decline in the area of snow depth > 0.5 meters on May 15 for the scenarios considered. Note that the Warm/Wet scenario projects a slight increase in the area of significant snowpack on May 1.**

Figure 5-20 shows a map of the number of years (out of 16 possible) where each model pixel had at least 0.5 m of snow depth on May 15th. This summary statistic is analogous to that used by the Copeland study, except that there are more years of data, and these maps use a much higher threshold of snow. The projections show declines in the number of years with significant snow. The areas with frequent (14-16 years) availability of significant snow become concentrated in smaller high elevation areas. The Hot/Dry "greatest change" scenario, illustrates that the combination of drying and warming leads to very large declines in the persistence of snow.

The effects of climate change on snow melt have been presented as analogous to a "time shifting" of the melt season earlier in the year. For example, McKelvey (2011) used the May 31st vs. May 15th snow covered area as a proxy for a 2-week shift in the melt season. Figure 5-21 contrasts the evolution of the snowpack from May 1 to June 1 in the historical simulations (Top Row) with the Warm/Wet scenario (giss, Middle Row) and Hot/Dry (hadgem, Bottom Row) scenarios [Graphics being re-done].

5.13 Elevation Dependence of Snowpack Change in the DHSVM model

Snowpack accumulation and melt depends critically on temperature and hence on elevation. In the Warm/Dry and Hot/Dry scenarios, both the precipitation decrease and the warming act to reduce Spring snowpack. For the scenarios with warming and increased precipitation there are two countervailing forces that play out along an elevational gradient. A warmer, wetter future is one in which the freezing level and snow line tends to be higher, but with the potential for greater snowpack accumulation during the cold season at high elevations. The warming also tends to lead to an earlier snowmelt, so that the increased high-elevation snowpack is more evident early in the Springtime than later.

Figures 5-22 shows the percent change in May 1st snow covered area (SCA; 0.5 meters depth) for GLAC, computed for 200 m elevation bands. The elevation of observed den sites is noted by triangles, with den sites ranging from approximately 1500m to 2300 m. There is little change in SCA for 4 of the 5 scenarios above 2200m. As in a mirror image there is greater than 95 % loss of SCA below 1400m for 4 of the 5 scenarios. Between these two elevations – and in the regions where most observations of dens have been noted – the snowpack change is very sensitive to elevation and to the particular future climate scenario. Figure 5-23 shows the elevation dependence of the May 1st snowpack measured in terms of snow water equivalent (SWE). Viewing snowpack in terms of SWE illustrates more clearly that the Hot/Very Wet future scenario has a greater snowpack at high elevations despite completely losing its snowpack at 100m elevation. Figure 5-23 also illustrates that SWE can have modest declines without affecting the area with significant snow depth. The implications is that wet, cold climate of the GLAC study area can act as a "buffer" to change in the area of 0.5 meter deep snow on May 1st, at least at high elevations.

Figure 5-24 shown the May 1st SCA (0.5 meter depth) for ROMO. The high elevation areas show a loss of SCA for four of the five future scenarios, which an increase only in the Warm/Wet (giss) scenario. The climate of ROMO is, on average drier than that of GLAC, and the regions of the model simulations that have significant snow in most years is restricted to the two smaller areas within the domain (Figure 5-21). As a result the climate does not act to buffer change in the area of significant snow on May 1st.

This phenomenon of elevation-dependent snowpack change in the Western US is well supported in the literature. Regonda et al. (2005) found little historical change in snowpack in the Western United States above approximately 2500m elevation despite observed warming trends. Christensen and Lettenmaier (2007) considered VIC hydrology model projections and reported as strong elevation dependence for snowpack loss in the Colorado River basin below 2500 m elevation (their data was visualized in Ray et al. 2008). Two recent studies are of special interest because they focus on areas near those considered here. Sospendra-Alfonso et al (2015), on an area near the GLAC study area, find that historically, temperature has been a larger driver of April 1st snowpack only below about 1560 m elevation, with precipitation the main driver of variability above that elevation. Scalzitti et al. (2016) investigated a single climate change scenario using a high-resolution weather model and found that the critical elevation below which temperature dominates snowpack rises by about 250m in the Colorado Rockies, and rises by about 191 m in the Northern Rockies hear the GLAC study area. While it is difficult to these results directly to the present study due to differences in methodology, the qualitative picture remains – projected warming has a larger effect at lower elevations whereas projected precipitation changes may dominate the Springtime snowpack in the high country.

ROMO

Snow Covered Area sq-km (0.5 meter snow depth threshold)

	Scenario	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	historical	468	249	734	180	26	1578	90	422	418	746	1334	594	70	1356	22	381	542	420
	Central (cnrm)	421	185	607	95	38	1470	102	375	208	398	1199	451	55	1293	16	402	457	386
	Hot/Dry (hadgem2)	166	57	232	64	10	1245	33	137	278	314	984	231	14	1096	2	125	312	152
	Hot/Very Wet (miroc)	275	135	375	155	40	1133	59	320	397	259	1200	350	130	1164	3	719	419	297
	Warm/Wet (giss)	453	256	601	210	38	1552	118	375	514	753	1417	572	104	1374	23	481	552	467
	Warm/Dry (fio)	187	99	483	45	4	1510	16	172	159	475	946	374	14	1201	5	176	367	174
15-May	historical	429	277	288	105	29	1568	37	474	416	593	1341	403	227	1289	25	436	496	409
	Central (cnrm)	263	169	177	35	27	1385	22	352	161	248	988	216	174	1066	13	267	348	196
	Hot/Dry (hadgem2)	56	44	32	12	4	990	3	96	133	114	586	54	35	677	0	45	180	50
	Hot/Very Wet (miroc)	174	122	106	58	33	1061	18	276	263	173	970	184	217	922	4	395	311	179
	Warm/Wet (giss)	351	257	208	94	35	1519	33	403	433	530	1292	338	241	1239	23	404	462	345
	Warm/Dry (fio)	208	120	168	31	4	1481	10	211	167	373	1053	244	87	1064	6	239	342	188

Snow Covered Area % change (0.5 meter snow depth threshold)

	Scenario	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	Central (cnrm)	-10	-25	-17	-47	44	-7	13	-11	-50	-47	-10	-24	-21	-5	-27	5	-16	-8
	Hot/Dry (hadgem2)	-64	-77	-68	-65	-61	-21	-63	-68	-33	-58	-26	-61	-80	-19	-91	-67	-42	-64
	Hot/Very Wet (miroc)	-41	-46	-49	-14	53	-28	-35	-24	-5	-65	-10	-41	85	-14	-85	88	-23	-29
	Warm/Wet (giss)	-3	3	-18	16	44	-2	31	-11	23	1	6	-4	48	1	6	26	2	11
	Warm/Dry (fio)	-60	-60	-34	-75	-85	-4	-82	-59	-62	-36	-29	-37	-79	-11	-79	-54	-32	-59
15-May	Central (cnrm)	-39	-39	-38	-67	-5	-12	-42	-26	-61	-58	-26	-47	-23	-17	-48	-39	-30	-52
	Hot/Dry (hadgem2)	-87	-84	-89	-88	-85	-37	-93	-80	-68	-81	-56	-87	-85	-47	-98	-90	-64	-88
	Hot/Very Wet (miroc)	-60	-56	-63	-44	13	-32	-53	-42	-37	-71	-28	-54	-4	-28	-86	-9	-37	-56
	Warm/Wet (giss)	-18	-7	-28	-10	20	-3	-13	-15	4	-11	-4	-16	6	-4	-8	-7	-7	-16
	Warm/Dry (fio)	-52	-56	-42	-71	-85	-6	-74	-55	-60	-37	-22	-39	-62	-17	-78	-45	-31	-54

Table 5-7: ROMO Snow Covered Area (0.5 m snow depth threshold) Top: Area (km^2) in historical and five future scenarios. Bottom: percent change in future simulations compared to historical. Average and Median values also shown.

6 Comparing results with McKelvey

An overview of the methodological similarities and differences between this study and McKelvey et al (2011) was presented in section 2.2. The differences in aims of these studies leads to challenges in making a direct comparison. McKelvey investigated persistence of even a snow cover to May 15th as a correlate of wolverine habitat, as noted in Aubry et al (2008). This study focuses on high-elevation terrain and on the persistence of deeper snowpack. Nonetheless some general statements can be made relating the two studies. Figure 5-24 shows snowcover under McKelvey's historic and "miroc 2080's" (or hotter) scenario. The GLAC and ROMO areas have been outlined. A close examination of this figure shows that snow cover persists in our study areas, even for their hotter scenario of change (miroc "2080's). The greatest loss of snow cover in McKelvey occurs at lower elevations than were included in GLAC or ROMO. Because of the increased resolution of our study we are able to consider whether any pockets of snow with depth greater than 0.5 meters will persist.

Comment [GJM11]: Explain this was their worst case. AJR – they don't use use the term "Worst Case" – they just use miroc, We coul say the warm/warmer and hot/hotter scenarios, but I'm not comfortable calling them "worst case" and definitely not best case.

The choice of future climate scenarios differs somewhat from McKelvey. We have intentionally included scenarios that represent the range of possibilities indicated by the CMIP5 climate models. McKelvey used climate model output from Littell, who chose scenarios based solely on projected warming. For GLAC, this choice fortuitously included a range of precipitation changes as well. For ROMO, however, McKelvey's scenarios include only a narrow range of precipitation change, where we include scenarios with significantly increased wintertime precipitation as well as scenarios with drying. This is a significant factor, given the buffering effect that increased precipitation has on snowpack loss at high elevations.

While McKelvey focused snowpack projections entirely on the long-term average, we investigate how climate variability – the sequences of wet and dry years -- intersects with scenarios of change. For ROMO in particular we find that dry years behave differently than wet years, with dry years benefitting from the increased precipitation in several of our future scenarios. This emphasizes the importance of planning for a range of possible climate scenarios, particularly regarding the direction of change in wintertime precipitation.

The question arises as to how the fine-scale projections of snow persistence in other areas might reasonably be inferred from the two study areas considered here. Figure 5-24 indicates many areas in the western United States that show persistence of snow cover in McKelvey's scenarios, even in the more extreme scenarios. We have investigated two study areas: a northern, relatively wet and low-elevation area GLAC, and a southern, relatively dry, and very high elevation area (ROMO). In both areas we find general declines in snow covered area under most future scenarios. The GLAC study area is broadly similar in its climate to much of the high northern Rockies, while ROMO shares features with the high mountain ranges of the Central Rockies. For areas in the McKelvey maps that show retention of snow on the higher mountain ranges it is physically reasonable to presume that a finer scale simulation would show the retention of areas of snow > 0.5 m on May 15th. Extending this beyond the general area of the Rocky Mountains is problematic. Even within the Rockies, in regions where McKelvey's results show widespread loss of snowpack it is probably not reasonable to conclude one way or the other whether a finer scale analysis would identify snow refugia.

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8 Glossary

- **Aspect:** compass direction that slope faces
- **Baseline period 1916-2000**: Deltas (changes) computed (monthly average delta) for "2040's and "2080's" compared to the 1916-2000 baseline.
- **CanESM:** A CMIP5 climate model the Canadian Centre for Climate Modeling and Analysis (canesm2.1.rcp85), forced with the RCP 8.5 higher emissions pathway, used in this report as a future scenario (Hot/Dry scenario for GLAC only) that has relatively higher increase in temperature (+~4.5 C) and about +20% increase in precipitation (See Figure 5-7)
- **Climate Sensitivity:** Regionally speaking, it is the response of a climate model for a given amount of greenhouse gas increase. More narrowly defined it is the global average temperature increase that results from a doubling of carbon dioxide over pre-industrial values.
- **CMIP3, CMIP5:** Coupled Model Intercomparison Project Phases 3 and 5. "Foundational" collections of climate model projections, used in the Intergovernmental panel on Climate Change (IPCC) 2007 and IPCC 2013 reports, respectively
- **CNRM:** A CMIP5 climate model from the French National Centre of Meteorological Research (cnrm-cm5.1.rcp85),used in this report as a future scenario (Central scenario for both GLAC and ROMO) that is relatively close to the ensemble mean in temperature increase (+~2.5 ^{o}C) and +~5-8% increase in precipitation (See Figure 5-7).
- **DEM:** Digital elevation model
- **DSHVM:** Distributed Hydrology Soil Vegetation Model
- **ESM:** earth system models, see GCM.
- **FIO:** A CMIP5 earth system model from the First Institute of Oceanography, State Oceanic Administration of China (fio-esm.1.rcp85), used in this report as a future scenario (Warm/Dry scenario for both areas) that is relatively lower in temperature increase (+~0.8-1.6 ^{o}C) and -~5% decrease in precipitation (See Figure 5-7).
- **FLH:** Atmospheric freezing level height is the altitude in the free atmosphere at which the temperature is 0 °C
- **GCM:** Global Climate Model, 6 were used for this report from the IPCC 2013 class of models; X of these are actually earth system models (ESM), an advanced type of GCM which have the added capability to explicitly represent biogeochemical processes that interact with the physical climate. GCM is used as a general term referring to both kinds of models, ESM is used specifically for earth system models.

- **GISS:** A CMIP5 climate model from the NASA Goddard Institute for Space Studies (giss-e2-r.1.rcp45), used in this report as a future scenario (Warm/Wet scenario for both areas). Referred to as the "Least Change" scenario because it that is relatively lower temperature increase (+~1-1.3 ^{o}C) and +~7-10% increase in precipitation (See Figure 5-7).
- **GLAC:** An area in Glacier National Park used as a spatial unit of analysis in this report
- **HADGEM:** A CMIP5 earth system model from the United Kingdom Meteorological Office Hadley Center (hadgem2-es.1.rcp85) used in this report as a future scenario (Hot/Very Wet scenario for ROMO only) that has relatively higher temperature increase (+~ 3.5 ^{o}C) and -~5% decrease in precipitation.
- **Internal climate variability**: The variations in the climate, even for 30-year and longer averages, that can occur due to the interactions of the atmosphere, ocean, inland surface and cryosphere. This occurs even in the absence of anthropogenic climate change.
- **MODIS:** Moderate Resolution Imaging Spectroradiometer, a satellite remote sensing instrument carried on the Terra satellite
- **MIROC:** A CMIP5 earth system model from the Japanese Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies (miroc-esm-chem.1.rcp85), used in this report as a future scenario (Hot/Wet scenario for both areas). Referred to as the "Greatest Change" scenario because it has the highest temperature increase of the scenarios (+~4 ^{o}C) and +~10-18% increase in precipitation (see Figure 5-7). This ESM has an atmospheric chemistry (CHEM) component coupled to the MIROC-ESM (http://maca.northwestknowledge.net/GCMs.php).
- **NDSI:** Normalized Difference Snow Index, a measure of snow cover, has a has a linear relationship to fractional snow cover (FSC)
- **North American Freezing Level Tracker**: NCEP/NCAR Global Reanalysis 2.5^{o} x 2.5^{o} grid data (http://www.wrcc.dri.edu/cwd/products/)
- **Octants:** Topographic aspect, or compass direction, was classified into eight directional bins, each representing 45° of compass arc, e.g; NW, N, NE, E, SE, S, SW, and W
- **Resolution:** The VIC modeling that was the basis for McKelvey was performed on a regular grid in latitude and longitude, with a grid size of 1/16 degree on a side. The distance between degrees of longitude varies due to the curvature of the Earth, and the east-west dimension of a gridbox is smaller than the north-south distance by a factor of the cosine of latitude. At 40°N latitude, the southern extent of Rocky Mountain National Park, the gridbox is ~5km by 7 km (~37km^2). Grid boxes at Glacier National Park (~48°N) are slightly smaller. When referring to the McKelvey study we will use the "1/16 degree" notation. The DHSVM modeling used in this study was performed on a uniform grid in the Universal Transverse Mercator (UTM) map projection, which allows a near-uniform grid size of 250m by 250m (0.0625 km^2) in both of the study areas.
- **ROMO:** An area in and around Rocky Mountain NP used as a spatial unit of analysis in this report
- **SCA:** Snow Covered Area (km^2)
- **SDD:** Snow Disappearance Date, the first Day of Year after March 1 where pixel is snow-free, defined as the date which NDSI/100 was less or equal to 0.1.
- **SNODAS:** Snow Data Assimilation System, a product of the NOAA National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC)

- **SWE:** Snow water equivalent (mm). For May, snow depth is assumed to be ~ 2.5 *SWE
- **TopoWx:**
- **Snow covered area, total:**Total area covered by snow within the study boundaries in square kilometers (km^2)
- **Snow covered area, fractional:** Percentage of the total land area that is covered by snow; this can be within the study boundaries, aspect area, or elevation bands
- **VIC:** Variable Infiltration Capacity hydrologic model
- **UTM:** Universal Transverse Mercator spatial coordinates

FIGURES – see separate file

Wolverine Snow Refugia Study: An analysis of future climate risks

A Report to the U.S. Fish and Wildlife Service Region 6

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Executive Summary

Overview: This study is a fine-scale assessment of snow extent and depth at two areas in and in the vicinity of Glacier (GLAC) and Rocky Mountain (ROMO) National Parks. The analysis was done for both the recent past, using MODIS satellite-based remote sensing, and in historic simulations and projections of future snowpack using a high-resolution hydrologic model. The fine scale hydrologic modeling allows for the consideration of snow processes such as dependence on terrain slope and aspect that are important to understanding high elevation snow persistence in a changing climate and were not considered in previous work.

Methods: The report intentionally builds on previous work by McKelvey et al. (2011) extending that work by providing a higher resolution spatial scale analysis for two case study areas, and a broader range of future scenarios. Two areas were studied: a high latitude, low elevation area within Glacier National Park (Figure 2-1) that is currently occupied by wolverines and a lower latitude, high elevation area within Rocky Mountain National Park (Figure 2-2).A detailed comparison of their methodologies and ours is provided in Table 2-1. The project uses methods from the peer-reviewed, published literature to:

- Explicitly model the effects of slope and aspect, using fine-scale spatial models to analyze topographic effects on snow
- Better represent the range of plausible future changes (climate scenarios)
- Analyze extremes: we selected representative wet, dry, and near normal years from the historic record and assessed how these might change in the future
    - Representative years for GLAC: 2011 (cool wet), 2005 (warm dry), 2009 (near normal).
    - Representative years for ROMO: 2011 (cool wet), 2002 (warm dry), 2007 (near normal).
- Assessing change in snow by elevation.

MODIS Observed Historic Snowpack Variability Analysis: Satellite-based MODIS snow cover data was used to assess the historical variability of snow cover in the study areas and as a basis for the spatial evaluation of the hydrologic model simulations. The historical observed snow cover was analyzed for its dependence on terrain elevation and aspect (compass direction that the slope faces).

- In GLAC, snow covered areavaries considerably by year, including "wet" years such as 2011 with very persistent snow, years with strong melt in early May, such as 2012, or in late May (2009, 2001), and "dry" years (2004, 2005). The period of the modeling study in Section 5 ends in 2013 due to dataset limitations, but it is worth noting that the last two years of the MODIS record, 2015 and 2016 show low snowcover (Section 4.3).
- Even in dry years, NE-facing slopes in GLAC tend to hold more snow and melt later in the season. There is > 80% snow cover above ~2000 m elevation on May 1 during dry years, and > 95% snow cover above ~1200 m during wet years. Snow conditions on June 1 during wet years resemble those for May 1 during near-normal years.
- In ROMO, snow covered area also varies considerably by year (Section 4.4).
- NW-facing slopes in ROMO tend to hold more snow even during dry years. In very dry years, snow cover peaks at intermediate elevations, suggesting that the high-altitude snowpack may be particularly vulnerable in this region under warm/dry conditions.

Future Snowpack Projections: The Distributed Hydrology Soil Vegetation (DHSVM) was run in historical simulations of the period 1998-2013. The model was validated against SNOTEL in-situ snow observations and MODIS snow cover. The model was then run for five scenarios of the future which represent a nominal 2055 climate. Scenarios were selected from CMIP5 global climate model (GCM) projections, and were chosen to span a large fraction of the range of the CMIP5 ensemble projections in each study area in terms of precipitation and temperature changes. Representative Wet, Near Normal, and Dry years were analyzed for the historical simulations and how each of these years plays out under these five future scenarios. The number of years (out of 16) with snow above 0.5m depth was also analyzed as was the change in Snow Covered Area (SCA) with depth greater than 0.5m. The average change in SCA and Snow Water Equivalent (SWE) was analyzed as a function of elevation, and for GLAC was overlayed with the elevations of wolverine den sites. (Section 5)

For the study area in Glacier National Park (GLAC), projections for May 15th Snow Covered Area and area with snow depth greater than 0.5 meters declines on average in all scenarios and for almost all years (Section 5-11). This is a12-42 percent decline in snow covered area, and a 15-68 percent decline in area with snow depth > 0.5 meters for the scenarios considered.

- The Warm/Wet scenario shows the least change compared to the historic snow cover in terms of the area of significant (0.5 meter) snowpack, comparable to only a small shift in time. In contrast, under the Hot/Wet scenario, on May 1 the area covered by >0.5 snowpack is smaller than the area covered on June 1 in the historic record – a shift of a month earlier.
- All projections show declines in the number of years with significant snow. The areas with frequent (14-16 years) availability of significant snow become concentrated in smaller high elevation areas.
- For wet years, the high elevations of the study areas result in little loss of snowpack under most scenarios of change.
- For high elevation areas, there is little change in SCA for 4 of the 5 scenarios above 2200m. As in a mirror image there is greater than 95 % loss of SCA below 1400m for 4 of the 5 scenarios. Between these two elevations – and in the regions where most observations of dens have been noted – the snowpack change is very sensitive to elevation and to the particular future climate scenario.

For the study area in and around Rocky Mountain National Park (ROMO), projections of May 15th Snow Covered Area in ROMO (13mm threshold on May 15) declines on average in all scenarios and for almost all years. (Section 5-12)

- There is a 12-52 percent decline in snow covered area, and a 7-64 percent decline in area with snow depth > 0.5 meters for the scenarios considered.
- Snow Covered Area in ROMO (0.5 m threshold on May 15) generally declines in wet years, but may increase in dry years in those scenarios with increased precipitation.
- Some scenarios with increased precipitation show increases in May 15 snowpack at the higher elevations in both study areas, but decreases in snowpack at lower elevations. This can lead to an increase in the area of > 0.5 meters of snow for "dry" years.
- ROMO exhibited more uncertainty in projections than GLAC

- ROMO has more uncertainty as to whether precipitation will increase or decrease.
- The beneficial effect of increased precipitation on snowpack is more prominent earlier in the Spring. In the Warm/Wet scenario, the area of significant snow on May1 increases on average, though it decreases on May 15.
- For wet years, the high elevations of the study areas result in only modest loss of snow cover under all scenarios of change. However even in wet years, the area of significant snowpack can decline by almost 50% for the Hot/Dry climate change scenario. (Section 5-X)

Elevation dependence of change (Section 5.13): In general, and supported by the literature, the snowpack at the higher elevations of both areas is more responsive to precipitation change, while at lower elevations it is more responsive to temperature change. For GLAC, most of the observed den sites are located just below the precipitation-dominated zone, and therefore at elevations where the changes in snowpack are highly dependent on the climate scenario and also on elevation. For high elevation areas there is loss of SCA for four of the five future scenarios, with an increase only in the Warm/Wet (giss) scenario. The climate of ROMO is, on average drier than that of GLAC, and the regions of the model simulations that have significant snow in most years is restricted to the two smaller areas within the domain (Figure 5-21). As a result the characteristics of the present-day climate does not act to buffer changes in the area of significant snow on May 1st as it does in GLAC.

Comparison with McKelvey's results (Section 6): There are challenges in making a direct comparison between the studies due to differences in the goals and spatial scale. McKelvey investigated persistence of even a light snow cover to May 15th as a correlate of wolverine habitat, as noted in Aubry et al (2008). This study focuses on high-elevation terrain and on the persistence of deeper snowpack. However, the following comparisons are valid:

- Snow cover persists in our study areas, even for the hotter scenario of change in the McKelvey study (miroc "2080's). The greatest loss of snow cover in McKelvey occurs at lower elevations that were deliberately not included in the GLAC or ROMO study areas.
- McKelvey focused exclusively on the persistence of even light snow cover on May 15th. Because of the increased resolution of our study we are able to consider whether any pockets of snow with depth greater than 0.5 meters will persist in these areas. Results vary according to scenario, but generally show declines in SCA with depth greater than 0.5 meters by the 2050s, as noted above.
- Our results may reasonably be generalized to the high mountain ranges within the Rockies that lie between GLAC and ROMO, with projections on average wetter in GLAC. However, without further study we cannot reasonably extend our results to say whether or not snow refugia may persist in the Central Rockies at lower elevations where McKelvey indicates the greatest snowpack losses, nor to the Cascades with its very different maritime climate.

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1 Introduction

1.1 Motivation

This report responds to the United States Fish and Wildlife Service (FWS) need for information on potential climate impacts to snow persistence. The North American wolverine (*Gulo gulo luscus*) is currently being evaluated for listing as a threatened or endangered species under the Endangered Species Act (ESA) and climate change effects on snow persistence was identified as an important factor for the future viability of the wolverine. The species was considered for listing in 2014, but FWS concluded that it did not warrant listing. They further concluded that there is significant uncertainty about how the effects of climate change will affect wolverines and their habitat in the foreseeable future, and that this uncertainty includes information on how fine-scale changes in snow cover and persistence might affect denning site selection.

This report provides FWS with a finer scale assessment of snow extent and depth at which extends previous work by McKelvey et al. (2011). We believe the inclusion of finer scale analyses as well as additional snow processes such as slope and aspect are critical to understanding high elevation snow persistence in a changing climate.

ADD By design, our methods are from the peer-reviewed, published literature, etc. What we find is consistent with past research

Funding was provided by the U.S. Fish and Wildlife Service, Region 6 and the NOAA/Earth System Research Lab/Physical Sciences Division. This effort builds on work underway by the project team at NOAA/ESRL/PSD, the NOAA-University of Colorado (CU) Cooperative Institute for Research in Environmental Sciences (CIRES), and CU Department of Civil, Environmental & Architectural Engineering.

1.2 Project Objectives

Persistent spring snowpack has been described as an important factor in determining suitable habitat for the wolverine, including Northern boreal forests and subarctic and alpine tundra (Aubry et al, 2007, Peacock et al, 2011). This relationship was the basis for the analysis by Copeland et al. (2010) and McKelvey et al. (2011) used in the previous FWS decision. In both studies, climate change projections of snowpack were used to characterize potential future wolverine habitat.

The goal of this effort is to identify the depth and persistence of spring snow in the future. Our primary objective is to advance scientific understanding of the current spatial extent of spring snow retention on the landscape, and the future temporal and spatial extent of snow retention through a thirty-year period, 2041-2070, centered on the year 2055. We aim to advance snow analysis and modeling to better support assessment of snow-related species, in the following ways:

- Explicitly model the effects of slope and aspect, using fine-scale spatial models to analyze topographic effects on snow

- Better represent the range of plausible future changes (climate scenarios)
- Analyze extremes: wet and dry years from the historic record and how these might change in the future

Our strategy was to build on previous methods where possible to be comparable to work by McKelvey et al. (2011) and Copeland et al. (2010). We departed from their methods where necessary to take advantage of analysis techniques not feasible at the large scales used in the studies done by those authors. These include new scientific data and tools that are now available, including the following:

- Use of a longer time series of satellite and in situ observations
- Analysis of historic snowpack variability to investigate the influences of topography on snow cover
- Use of more recent climate model output and improved criteria for choice of climate change scenarios
- Use of hydrologic modeling at highly resolved (250m) spatial scale for simulation and future projection of snow cover and depth for two case study areas in Glacier National Park and Rocky Mountain National Park.

2 Project Overview and Background

2.1 Overview

We first reviewed the observed climate and variability, in order to provide context for future changes (Section 3). We next analyzed historic snow variability from satellite remote sensing of snow extent from the year 2000 to present to determine areas of greater and lesser sensitivity to climate drivers (temperature and precipitation), and identify possible snow refugia. Prior studies also show a relationship between terrain (slope and aspect) and persistence of snow (e.g. Lundquist and Flint, 2006) and thus this factor is potentially important under in a changed climate. (Section 4). We then did an intercomparison of the satellite observations of snow with that from the DHSVM hydrologic modeling study that includes a representation of slope and aspect (the compass direction that the slope faces) of the terrain and shading on the snowpack. Finally, the DSHVM hydrologic model was forced with five future scenarios of climate change for each of the two study regions (Section 5). These future climate scenarios were derived from the latest Coupled Model Inter-comparison Project Phase-5 runs (CMIP5, Taylor et al., 2012) which informed the latest Intergovernmental Panel on Climate Change (IPCC) report (IPCC AR5, 2013).

All methodologies were chosen to be consistent with those used in existing peer-reviewed work.

2.2 Study Areas

High-resolution hydrologic modeling was needed to provide fine scale analysis of snow. However, given time, funding and computational constraints, it was necessary to limit the study domain to two areas of about 1,500-3,000km^2 for high-resolution analysis. Two study areas representing core and peripheral habitat regions in the northern and central Rocky Mountains were identified in consultation with FWS Region 6 personnel (Figures 2-1 and 2-2). We bracketed the range of wolverine habitat conditions in the lower 48 habitat conditions, because we were restricted to smaller areas for analysis. The two sites chosen included a high latitude, low elevation area within Glacier National Park (Figure 2-1) that is currently occupied by wolverines and a lower latitude, high elevation area within Rocky Mountain National Park (Figure 2-2) that has had recent documented wolverine occurrence and could be a potential reintroduction site for wolverines. Both model areas encompassed elevations from ~250m below treeline to maximum elevation.

The analysis for the GLAC and ROMO study areas is presented in separate sections, repeating descriptions to make the material self-contained for the reader who may read about only one area; similarly, complete captions are given for each area.

2.3 The West-wide context of future climate

Global climate models (GCMs) are the primary tools used by climate science to examine the nature of climate change during the 21st century. These models reveal both the uncertainty of climate projections as well as underlying regional patterns of change. This section provides a west-wide context for the specific choices of future climate scenarios that will be discussed later in the report.

Understanding the uncertainty of climate projections is commonly approached through comparison of the results from multiple climate models (e.g. IPCC, 2013). There are currently about 20 modeling centers worldwide that provide output from their best model or models to be considered in the Coupled Model Inter-comparison Project Phase-5 (CMIP5, Taylor et al., 2012), an international, coordinated modeling project which informed the most recent Intergovernmental Panel on Climate Change (IPCC) assessment report (IPCC AR5, 2013). When we quantify regional changes in climate variables such as temperature and precipitation by a particular time horizon in the 21st century, we find a large spread in the extent of warming and changes in precipitation, including both increases and decreases in precipitation, as shown in regional maps (Figure 2-4) and described later in Section 5. For temperature change, much of this spread (or uncertainty) is a result of the difference among the formulations of the GCMs (e.g., their climate sensitivities), whereas for precipitation it is both the differences among GCMs and internal climate variability. Some difference also comes out of the choice of future greenhouse gases (GHG) emission scenario. However, the differences among greenhouse gas emissions scenarios is less at mid-21st century compared to later in the century, and is much smaller than other sources of uncertainty at the regional scale (IPCC,2013).

In addition to uncertainty, the CMIP5 climate models also reveal regional patterns of change. Figure 2-4 shows projected annual and seasonal temperature and precipitation changes by 2050 (2035–2064) over the western U.S., including the northern and central Rocky Mountains, from an ensemble of the 34 climate models used for this study under the RCP 8.5, a high-end emissions scenario. The large maps show the average change for all of the models (n=34) for that season, and the small maps show the average changes of the highest 20% and lowest 20% of the models, based on the statewide change for Colorado in temperature or precipitation. For much of the central and northern Rockies, all models show a substantial warming (of +2.5°F to +5.5°F). While fewer models agree about the direction of precipitation change west-wide, even the lower (drier) models show an increase in winter precipitation for the area around Glacier National Park, although there is less agreement for the central Rockies area including Rocky Mountain National Park.

The uncertainty of climate change motivates the choice of several future climate scenarios for each study region. The regional patterns of change indicate that the range of the climate scenarios chosen will differ somewhat from region to region. The GCM output, and the specific selection of future climate scenarios for this study are discussed further in Section 5.

2.4 Comparison between our analysis and that of Copeland and McKelvey

The Copeland et al. (2010) and McKelvey et al. (2011) studies were an integral part of the previous FWS decision process. Therefore, we present here a detailed comparison of their methodologies and ours, to establish both how our methodologies followed theirs when appropriate, and diverged where new data or updated methods were available. A summary of the most salient similarities and differences between our work and the studies used previously is presented in Table 2-1.

Table 2-1: Modeling Methods Compared to McKelvey

	McKelvey (Littell)	**This Study**
Spatial Resolution (modeling)	VIC model – 1/16 degree (~5km x 7 km, ~37km^2 cell)	DHSVM model - 250m x 250m UTM grid (~0.0625 km^2 cell)
Spatial Extent	Westwide except California and Great Basin	ROMO and GLAC study areas, near and above treeline
Process differences	Slope and aspect were not modeled and the mountains were assumed to be flat from a solar radiation process, implicit elevation bands.	Slope, aspect, shading, explicit fine scale elevation effects.
Validation	None specific to snow	Comparison to SNOTEL (ground stations) and MODIS (satellite)
Future Scenarios	Delta Method; "2045";"2085"; from 3 GCMs selected to span westwide temperature changes.	Delta Method: "2055" from 5 GCMs spanning regional changes in temperature and precipitation
Analysis	Changes in long-term mean snowpack only	Means and variability, including wet, near normal and dry years.
Snow representation	Binary snow/no snow at 13 cm snow depth	Analyzed snow depth at two thresholds: 13mm of SWE ('light snow') and 0.5m depth ('significant snow')

Both Copeland et al (2010; hereafter, simply Copeland or the Copeland study) and McKelvey present analysis based on satellite remotely-sensed snow cover from the MODIS . For example, Copeland calculated the number of years with snowcover on May 15th as detected in the MODIS snowcover dataset, by calculating a snow disappearance date. They found that most (45 of 75) North American den sites were in areas that snow cover persisted with 6 or 7 out of 7 years on May 15th. We also provide a historical analysis of remotely sensed snow cover from MODIS.

We also investigated the of number of years of snow persistence for our study areas, however, the new MODIS product has two advantages over that available at the time of their study, 1) improved snow detection (snow covered area, SCA), and 2) 17 years of MODIS data is now available vs the 7 available to Copeland and McKelvey. Furthermore, we investigated the relationships between snow cover persistence and both elevation and aspect (the compass direction of the slope face).

Both McKelvey and the present study investigate projections of snow cover using a distributed hydrologic model.   McKelvey et al. (2011) (hereafter, simply McKelvey or the McKelvey study) focused their analysis on May 1st snow depth simulated by the Variable Infiltration Capacity hydrologic (VIC) hydrology model (1/16 degree, ~5km x 7 km), "flat" gridboxes, or cells, with no slope aspect dependence). The May 1st snow depth was then converted into a proxy for May 15th snow disappearance by applying a threshold of 13 cm – a procedure they refer to as "cross-walking". All subsequent calculations of theirs were done using the May 15th snow cover proxy.   The VIC model runs were documented in Littell et al. (2011) and were based on meteorological inputs from Elsner et al. (2010). The present study uses the Distributed Hydrology Soil Vegetation (DHSVM) model, which was developed by the same group at the University of Washington for fine-scale simulations, and shares many model components with the VIC model. The primary output of DHSVM is snow water equivalent (SWE). We investigate several thresholds for converting SWE to "snow cover". Conversion of SWE to snow depth is done using empirically derived conversion factor relevant to late Spring.

To generate future climate scenarios, Littell (on which McKelvey results are based) used the "delta method" (described later in Section 5) for the projected changes in climate compared to present day. This study also uses the "delta method," applied in a similar manner. The McKelvey study used a range of temperature change to select GCMs representing the range or spread of future scenarios. As shown below in Section 5.10 and Figure 5.7, their chosen future scenarios reflect a range of precipitation in GLAC, but in ROMO, the three scenarios have similar precipitation changes. This project selected a larger number of future scenarios selected based on changes in both temperature and precipitation, to be consistent with recommended strategies for incorporation of uncertainties into the assessment of impacts and developing adaptation strategies (e.g. Fisichelli et al, 2016 a,b, see Section 5-8).

Analysis metrics, including the time frames of the projections differ somewhat between the two studies.   The McKelvey study calculated a metric for a historic period (1915-2005 average) and two futures, 30-year averages around "2045" and" 2085." This study focused on a 30-year period around mid-century, "2055" to focus on FWS' time horizons for the wolverine and due to time and computational constraints given the project budget. We also reproduce a single future scenario using one of the Littell (2011) "2080's scenarios for direct comparison. Calculations for a later period using the CMIP5 climate models (e.g. ~2100) could easily be made, but were beyond the scope of this project. We provide analysis for two thresholds of snow amount, a "light" snow cover (13mm of snow water equivalent [SWE]), and significant, or "heavy" snow cover (equivalent to 0.5 m of snow depth). Because McKelvey only had access to May 1st snow depth simulation from Littell (2011), they chose to use a 13 cm snow depth on May1st as a proxy for snow disappearance by May 15th. We instead chose to use a much lighter threshold of snow on May 15th itself. Note that SWE is a measure of the water content in the snowpack; to estimate depth, a density of the snow must be assumed, i.e. an approximation of whether the snow is heavy or light. Our threshold of 13mm SWE was originally chosen to be comparable to McKelvey's snow depth. Our assumptions are discussed further in Sec. 5.6.

An important difference between this study and prior work by Copeland et al. (2010) and McKelvey et al. (2011) is the spatial scale of results. McKelvey and Copeland both presented results on a regular 1/16 degree latitude-longitude grid, in which each cell, or gridbox is ~5-7 km on a side. These cells were assumed to be flat in the model-- that is they do not incorporate slope or aspect information in their surface energy balance. The result of this is north-facing slopes are treated identically to south-facing slopes. Our study uses the Distributed Hydrology Soil Vegetation Model (DHSVM) originally developed by Wigmosta et al. (1994)[1] for simulating the snowpack at 250m x 250m resolution that incorporates other physical drivers of snowpack (a complete energy balance at the surface, a 2-layer snow model, and a 2-layer vegetation canopy model) and allows analysis of snow at different slopes and aspects (slope directions). The VIC modeling included the option for elevational snow bands within the VIC grid (Jeremy Littell, pers. comm.) but the snow band information was not explicitly used. Therefore, sub-grid scale elevational effects are implicit and approximate in the VIC model whereas it is explicitly modeled at the 250m-scale in DHSVM. A visual comparison of the gridbox sizes is shown in Figure 2-3, for further description of the terminology used to describe spatial resolution, see "resolution" in the Glossary.

It should be noted there are tradeoffs between our strategies and the methods of Copeland and McKelvey. The finer scale analysis presented in this report integrates slope and aspect with respect to snow accumulation and retention that are thought to be important for maintaining snow refugia for denning sites (see Fig 2 in McKelvey et al 2011). The disadvantage of this improvement in spatial resolution is we were only able to analyze two study areas due to time and computational constraints. The Copeland and McKelvey projects analyzed a much larger domain, including most of the wolverine range in the continental US, but does not provide detailed analysis of any habitat area.

[1] The most up-to-date documentation of the DHSVM model, including changes to the model subsequent to the original reference, is available from the following website: http://www.hydro.washington.edu/Lettenmaier/Models/DHSVM/documentation.shtml)

3 Observed Climate and Variability

Commented [GJM1]: In general, we think section 3 should be shortened if possible.

1-2 Intro paragraphs up front that give context on why the climate scenarios were chosen and why the specific years were used.

We can still discuss this. I marked the "background material" as such.

Key Points:

- Both study areas show upward trends in both temperature and freezing level.
- Surface Air Temperature and Atmospheric freezing level are related, with a stronger relationship in ROMO (that is, a greater change in freezing level for a given surface air temperature change)
- Representative years chosen for GLAC: 2011 (wet), 2005 (dry), 2009 (near normal).
- Representative years chosen for ROMO: 2011 (wet), 2002 (dry), 2007 (near normal).

3.1 Introduction

This section presents a historical analysis of the winter and spring climate variability for the two study regions, GLAC and ROMO, in order to provide context for future changes. This section includes a discussion of trends in temperature and freezing level; historical variability in cool season (October – May) temperature and precipitation for the study areas, choice of representative years during the simulation period for cool/wet, warm/dry, and near normal conditions for the two areas; and a ranking of the representative years in a longer climate record. A complete description of regional climate is beyond the scope of this project, but may be found in e.g. McWethy et al (2010), Garfin et al (2014), Lukas et al (2014), Shafer et al (2014), and citations therein.

3.2 Background Material: Trends in Surface Temperature and Freezing Level in the Study Areas

Temperature strongly influences hydrologic processes such as snowpack accumulation, and timing of snowmelt. Here we present some background material on observed trends in surface air temperature and on the freezing level in the atmosphere, and how these two quantities are related.

Both the Glacier and Rocky Mountain areas show a trend of increasing surface air temperature in the winter season (October-May, Figure 3-1), consistent with trends that have been observed west-wide (Garfin et al 2014; Lukas et al 2014; Shafer et al 2014). While winter season temperatures vary inter-annually, linear regression of these data (not shown) indicates about a 1.4 ^{o}C increase in temperature from 1948-2015 for an area around Glacier, and about a 1.2 ^{o}C increase around Rocky Mountain National Park.

Atmospheric freezing level height (FLH) represents the altitude in the free atmosphere (that is, away from the surface and its immediate influence) where the temperature is 0 °C. Above this level, the temperature of the air is typically below freezing. Freezing in the free atmosphere is indicative of the level above which precipitation falls as snow rather than rain. Freezing level height can have a strong influence on freeze-thaw processes in high-elevation regions (Bradley et al 2009). As with winter season temperatures, freezing level varies over time (Figures 3-2, 3-3), but linear regression (not shown) indicates about a 160m increase in the freezing level for Glacier (Fig 3-2), and about a 170 m increase in the freezing level for Rocky Mountain (Fig 3-3).

Figure 3-4 illustrates a strong relationship between freezing levels and surface air temperature change for both regions in October-May with explained variance (R^2) close to 0.8. For GLAC (3-1, left), a 1ºC anomaly in temperature equates to about a 115 m increase in the freezing level, over the period. For ROMO, for 1ºC increase in temperature there has been about a 180 m increase in the freezing level (3-1, right). If these historical relationships hold in the future, the larger change in freezing level for the ROMO study area could indicate a greater sensitivity of snow covered area to rising temperatures.

3.3 Exploring Weather Variability through the Choice of Representative Years for Detailed Analysis

One of the primary study goals is to extend the analysis to include the effects of climate change on extreme years – both for years with high- and low- spring snowpack. This is in contrast to McKelvey et al (2011) who studied only the effect of climate change on the *long-term average* snowpack. Our historical snowpack analysis (Section 4) was performed for the entire period 2000-2013 and the hydrologic modeling (Section 5) for 1998-2013, and for the counterparts for these years under various climate change scenarios. To capture the weather variability within these periods we focus some of our analysis in Sections 4 and 5 on a representative wet, dry, and near normal year for each study area. Nonetheless, results from all years were computed.

Table 3-1: Historical Percentiles of precipitation and temperature for the representative dry, near normal, and wet years for GLAC and ROMO study areas.

	Year Type	Year	Oct. - May Precipitation Percentile	Oct. - May Temperature Percentile
GLAC	Dry	2005	6	83
	Near Normal	2009	45	42
	Wet	2011	98	6
ROMO	Dry	2002	4	45
	Near Normal	2007	56	69
	Wet	2011	96	36

To drive our choice of representative years, we investigated historical cold-season (October-May) temperature and precipitation anomalies and MODIS-based snow covered area for 2000-2013. Years were chosen within that range to represent a cool/wet year with high spring snowpack, a "near normal" year, and a "dry" year with low snowpack. Figure 3-5 shows scatterplots of the anomalous precipitation (as % of average) and temperature (degrees Celsius) for each year of the primary study period (2000-2013) for the two study areas. For both study areas, the 2011 winter stands out as a particularly large (cool/wet) anomaly.

The choice a dry year for GLAC points to 2005. Examination of the time series of Snow Covered Area (SCA) derived from the MODIS satellite product (Figure 3-6) corroborates this choice. For ROMO the hot/dry year 2012 with exceptionally low snow cover was first chosen. However modeling difficulties encountered in the model validation procedure described in section 5.4.2 led to the need to find an alternative "dry" year for ROMO. The scatter plot in Figure 3-5 indicates that 2004 or 2002 might both be good alternatives, and both of these years had adequate modeling success. Because 2002 had lower Spring snow cover (figure 3-6), and because it was a widely agreed upon drought year in Colorado, we chose to use 2002 as the representative "dry" year for ROMO.

For the choice of near-normal year, 2007 is indicated for ROMO, as that is closest to the center of the scatterplot in Figure 3-5. A number of choices would seem plausible for GLAC, however as no one year stands out as "most normal." To further guide our choices of representative years, we looked at the elevation profiles of SCA for the various years, and 2009 was chosen. We show the SCA as a function of elevation within the study areas (Figure 3-6cd) for the representative years. These plots indicate that the elevation profile of observed snow cover in our chosen near-normal years closely follow the median profile for 2000-2013.

3.4 The Study Period in the Longer Climate Record

Because the study period is 14 years long, the question arises as to how "extreme" the wet and dry years are in the longer climatological record. To address this we analyze how often the temperature and precipitation anomalies for the study years are likely to occur in the longer (1950-2013) climatological record by computing their percentiles. Percentiles were calculated by ranking the data and using the following formula: percentile = (rank – 0.5)/(total number of years). Note that the exact rankings and percentiles may differ based on the underlying dataset and interpolation methods used, as the study areas have relatively few observing stations. However, percentiles calculated from the PRISM dataset (not shown) yield qualitatively similar results to those found below.

The percentiles of October – May precipitation and temperature averaged over the study areas are shown for the representative wet, near normal and dry in Table 3-1 for both study areas. The percentiles are calculated based on the 63 total years in the 1951-2013 period of the Livneh (2014) dataset. For GLAC, October – May 2011 was at the 98th percentile of precipitation and the 6th percentile of temperature, while 2005 was at the 6th percentile of precipitation and 83rd percentile of temperature. For ROMO, 2011 was in the 96th percentile of October – May precipitation, but only the 36th percentile of temperature, and while anomalously cold was not extreme in temperature. 2002 was in the 4th percentile of precipitation, but only near the median in temperature.

For further reference, Tables 3-2 (GLAC) and 3-3 (ROMO) show the percentiles of precipitation and temperature for the entire study period, 2000-2013, as well as the percentiles for the April – June melt season. Even though the low precipitation was more extreme in 2002 than in 2012, the temperature was not. This is reflected in the MODIS spring snowcover (Figure 3-6), where 2002 was low, but not as nearly extreme as in 2012.

Table 3-2: Percentile of temperature and precipitation anomalies for GLAC study area based on the 1951-2013 period. Percentiles are shown for both the October – May cold season and for the April – June melt season.

GLAC	Percentile 1951-2013			
	Oct. - May Precipitation	Oct. - May Temperature	Apr. - June Precipitation	Apr. - June Temperature
2000	31	96	7	66
2001	2	37	47	58
2002	61	31	91	12
2003	33	87	13	69
2004	13	63	33	61
2005	6	83	80	47
2006	37	82	53	93
2007	21	72	6	75
2008	39	47	60	17
2009	45	42	12	34
2010	12	55	85	13
2011	98	6	87	4
2012	40	74	72	53
2013	60	66	56	29

Table 3-3: Percentile of temperature and precipitation anomalies for ROMO study area based on the 1951-2013 period. Percentiles are shown for both the October – May cold season and for the April – June melt season.

ROMO	Percentile 1951-2013			
	Oct. - May Precipitation	Oct. - May Temperature	Apr. - June Precipitation	Apr. - June Temperature
2000	45	98	40	98
2001	29	33	23	91
2002	4	45	2	96
2003	75	80	77	64
2004	21	91	75	77
2005	50	82	82	53
2006	28	74	4	94
2007	56	69	6	75
2008	80	12	45	13
2009	77	93	88	44
2010	48	13	87	37
2011	96	36	93	25
2012	10	94	7	99
2013	64	26	79	42

4 MODIS Observed Historic Snowpack Variability Analysis

Commented [GJM2]: Agree, it was used as validation for dhsvm, should come after. If you don't agree, you could break it up and keep the historical variability piece here and put the validation piece after chap 5

Commented [JJB3R2]: I don't mention validation here. We cover that briefly elsewhere and it distracts here.

Key points

- In GLAC, even in dry years, NE-facing slopes tend to hold more snow and melt later in the season. There is > 80% snow cover above ~2000 m elevation on May 1 during dry years, and > 95% snow cover above ~1200 m during wet years. Snow conditions on June 1 during wet years resemble those for May 1 during near-normal years.
- In ROMO, NW-facing slopes tend to hold more snow even during dry years. In very dry years, snow cover peaks at intermediate elevations, suggesting that the high-altitude snowpack may be particularly vulnerable in this region under warm/dry conditions.

4.1 Introduction

In this section we perform an analysis of the variability of snow cover in the historical period 2000-2016 using gridded snow cover data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the Terra satellite. The dataset and methodology of analysis is first described. The analysis for the GLAC and ROMO study areas are then presented in separate sections, repeating descriptions to make the material self-contained for the reader who may read about only one area. Each section consists of analysis of the following: a) total snow covered area (SCA), b) SCA fractional area as a function of eight compass directions of slope aspect (octants), and c) elevation dependence.

4.2 Dataset and Methods

4.2.1 Data sub-setting and re-projection

We downloaded selected MODIS/Terra daily snow cover data on a 500m grid from the recently released version 6 (MOD10A1.006) (Hall and Riggs, 2016). All data from geographic tiles h09v04 (ROMO) and h10v04 (GLAC) were downloaded for days between March 1 and July 1 for all years from 2000 to 2016.

The data are available in daily files, one for each tile, and georeferenced to an equal-area sinusoidal projection. Each tile covers 10° x 10° at the equator or approximately 1200 km by 1200 km, with a nominal pixel resolution of 500 m (actual resolution 463.313 m). To bring the data to the same grid as used in the hydrologic modeling necessitated re-projection of the data onto a Universal Transverse Mercator Grid. We used the MODIS Reprojection Tool (https://lpdaac.usgs.gov/tools/modis_reprojection_tool) to subset the daily tiles to the areas of interest and re-project the subsetted areas to UTM grids with a pixel resolution of 250 m using nearest-neighbor resampling. The ROMO study area perimeter falls at the corner of tile h09v04, and extends slightly beyond the tile boundaries at its southern tip. We excluded this extension of the study from our analysis. Parameters for the MODIS data reprojection are provided in Table S4-1.

4.2.2 Converting Normalized Difference Snow Index to Binary (yes/no) Snow Cover

To better align our analysis with that in Copeland and McKelvey's work we wanted to use a daily binary (yes/no) snow cover value. However, one main obstacle had to be overcome -- snow cover was characterized differently in the versions of the MODIS data that Copeland used and in the current version. The prior work by McKelvey and Copeland both used Collection 4 of the MODIS data which provided them with a binary snow cover classification for each pixel on each day (clouds permitting). Collection 4 data are only available for the years 2000-2007, necessitating the use of the more recent MODIS Collection 6 products for the present study. However, Collection 6 does not include a binary daily snow cover product. Instead, snow cover is identified using the Normalized Difference Snow Index (NDSI).

NDSI is reported as a ratio, with values ranging from 0.00 to 1.00 (scaled and reported as 0 to 100 in the data files). The NASA guidance on conversion was not definitive: "If a user wants to make a binary SCA [Snow Covered Area] from the C6 [Collection 6] product they can set their own NDSI threshold for snow using the NDSI_Snow_Cover or the NDSI data or a combination of those data." (NASA, 2016). In lieu of a prescription, we chose to follow the procedure used by NASA to produce the 8-day composite snowcover product; we applied a threshold of NDSI > 0.1 to the daily MODIS NDSI values to indicate the presence of snow in a pixel on a given day.

4.2.3 Snow disappearance date and snow cover on a given date

As in Copeland et al (2010), we calculate a snow disappearance date for each year at each pixel. We define the Snow Disappearance Date (SDD) as the first day after March 1 in which NDSI/100 was less or equal to 0.1 (Cite NASA). The SDD is denoted by the Day of Year value, in which January 1 is 1, February 1 is 32, March 1 is 60 (or 61 in leap years), etc. Once SDD was defined at each grid point for each year (resulting in 17 annual maps of SDD for the period of record), we were able to derive snow cover maps for any given date. For example, snow cover on May 1 was inferred by marking grid points as "snow-covered" if their SDD was equal or greater than 121 (or 122 for leap years). We repeated the process to infer snow cover maps for May 15 and June 1. This indirect method to infer snow cover allowed us to circumvent the reality of several missing data points due to cloud cover, and offered a conservative estimate of snow disappearance.

4.2.4 Snow cover by elevation and aspect

A 250-m digital elevation model (DEM) was created using bilinear interpolation from the National Elevation Dataset (NED)10-m DEM products (USGS, 2009). Using this we obtained grids for elevation and aspect octants in both study regions. We reclassified the elevation values into 200 m bins. The elevation bins range from 1000 to 3000 m in GLAC and 2600 to 4200 m in ROMO. Both the slope magnitude and the aspect of the slope (that is the compass direction that the slope faces) were analyzed using functionality in the open source Quantum GIS software. We reclassified the aspect grids into eight 45°-wide directional bins (hereafter, octants) centered on the points of the compass. In both types of analyses (elevation and aspect), we computed snow covered area (SCA) on May1, May15, and June1, in terms of the total area in square kilometers and also in terms of the percentage of snow covered area in several elevation bands and aspect octants.

4.3 MODIS analysis for GLAC

This section presents some summary statistics of snow cover, including total snow covered area, and number of years during the period of study with snow cover on a given date. MODIS snow cover data was analyzed for March1 – July1 for all years 2000-2016. For more in depth analysis including aspect and elevation-based analyses the report focuses on the representative years defined in Section 3: 2011 (“wet”), 2009 (“near normal”), and 2005 (“dry”).

4.3.1 Total Snow Covered Area

Total snow covered area was the primary metric that was analyzed in McKelvey et al (2011) and provides an overall summary of availability of snow. Figure 4-1 presents maps of May 15 snow cover for the GLAC study area and vicinity from MODIS. These maps clearly depict the regional character of the year-to-year variations in snowcover. Figure 4-2 shows the total snow covered area within the study area polygon, which is depicted in red on the previous figure. The year-to-year variations are shown for snowcover on three different dates during the melt season. The behavior in individual year varies considerably, including “wet” years such as 2011 with very persistent snow, years with strong melt in early May, such as 2012, or in late May (2009, 2001), and “dry” years (2004, 2005). The period of the modeling study in Section 5 ends in 2013 due to dataset limitations, but it is worth noting that the last two years of the MODIS record, 2015 and 2016 show low snowcover. Both these years had near-normal precipitation, but had anomalously warm temperatures. These years would be good candidates for future analysis.

To summarize all 17 years of the record, Figure 4-3 presents maps of the number of years with snow cover on May 1, May 15, and June 1. These are similar to the analysis done by the Copeland and McKelvey studies. The primary difference is in the use of the newer MODIS products and the extension of the analysis from seven to seventeen years.

Figure 4-4 quantifies the maps in Figure 4-3, showing the area within the GLAC study area polygon with different numbers of years of snow cover. The three colored bars designate different days of the year. Because the study areas were chosen to be in the vicinity of tree line, it is no surprise that in the present climate there are large areas that see snow every year on May 1st.

4.3.2 Aspect Dependence of Snowpack: Total Area

One of the primary goals of this study is to investigate topographic factors that influence the persistence of snow during the melt season. One such factor is the “slope aspect” or simply “aspect” – the compass direction that the slope faces. Figure 4-5 presents the dependence of total snow covered area (km^2) on aspect for each of the 17 years in the MODIS dataset, for May 1, May 15, and June 1. The shape of the curves for individual years is strongly determined by the topography of the region, with more land area located in the northwest and southeast octants. Upon closer inspection, other features become apparent. Comparing the SW and NE octants we see that there is greater year-to-year variability in the SW, indicating a greater sensitivity of SW-facing slopes to variations in the historical climate. Two representative years, 2011 and 2005, illustrate the progression of total snow covered area from May 1 to June 1 (Figure 4-6). In the dry year, 2005, snow cover declines faster on S, SW, and W slopes, as one would expect; this analysis quantifies the magnitude of this effect.

Commented [GJM4]: Why didn’t you includes analysis for 2015 and 2016?
AJR: not in the Livneh dataset, say that the first place (here I think) – John also commented on this at beginning of 5, ~p 18

Commented [KED5]: If it is not standardized I am not sure what this means beyond, the the direction of the mountain chain. Maps show you were the snow is.

Commented [Office6R5]: Talk to Steve – we can take these out. We note that this is mainly the due to the land area itself.

4.3.3 Aspect Dependence of Snowpack: Fractional area

The total land area within each aspect octant varies due to the orientation of ridges and valleys in the study area. As a result, the analysis of total snow covered area is dominated by the topography itself. To focus on the *relative* importance of the snow processes related to aspect, we calculated the fraction of the total land area within each octant that is snow covered for each of the 17 years in the historical record, while in Figure 4-8 we focus on the representative wet and dry years. For example, in Figure 4-7, the asymmetric shape clearly shows that in GLAC, the NE directions ranging from E to N have much larger fractional area covered by snow. Even in dry years, over 60 % of the NE facing slopes are snow-covered on May 15th.

4.3.4 Elevation Dependence

Figure 4-9 shows the elevation dependence of MODIS snow cover for the wet, near-normal and dry years, with the median of all years as reference. The results are shown as a percentage of the total area within each 200-meter elevation band within the study area boundaries.

Commented [GJM7]: We should put the dens on the y axis in fig 4-9. I also think fig 4-9 data should be changed; all jun 1 should be replaced with may 15. I can talk with you on phone about this.

Also, I think we need an additional bar chart that shows all years may 1 and may 15, snow covered area only for elevations where we have dens (~1500m-2300m). This would show historic SCA for the elevation bands that wolverines have used for denning.

Commented [Office8R7]: I was able to do most of this, but replacing June 1 with May 15 obscures some of the features we want to show – particularly since this is for MODIS, which responds to very light snow cover.

4.4 MODIS analysis for ROMO

MODIS snow cover data was analyzed for March1 – July 1 for the years 2000-2016. Data for all years was analyzed. We present here some summary statistics of snow cover, including total snow covered area, and number of years during the period of study with snow cover on a given date. For more in depth analysis including aspect and elevation-based analyses the report focuses on the representative years defined in Section 3: 2011 (“wet”), 2007 (“near normal”), and 2012 (“dry”).

4.4.1 Total Snow Covered Area

Total snow covered area was the primary metric that was analyzed in McKelvey et al (2011) and provides an overall summary of availability of snow. Figure 4-10 presents maps of May 15 snow cover for the ROMO study area and vicinity from MODIS. These maps clearly depict the regional character of the year-to-year variations in snowcover. Figure 4-11 shows the total snow covered area within the study area polygon, which is depicted in red on the previous figure. The year-to-year variations are shown for snowcover on three different dates during the melt season. The behavior in individual year varies considerably, including “wet” years such as 2011 with very persistent snow, years with strong melt in early May, such as 2004, or in late May (2001, 2013), and “dry” years (2002, 2012).

To summarize all 17 years of the record, Figure 4-12 presents maps of the number of years with snow cover on May 1, May 15, and June 1. These are similar to the analysis done by Copeland and McKelvey studies. The primary difference is in the use of the newer MODIS products and the extension of the analysis from seven to seventeen years.

Figure 4-13 quantifies the maps shown in Figure 4-12, showing the area within the GLAC study area polygon with different numbers of years of snow cover. The three colored bars designate different days of the year. Because the study areas were chosen to be in the vicinity of tree line, it is no surprise that in the present climate there are large areas that see snow every year on May 1.

4.4.2 Slope Aspect Dependence of Snowpack: Total Area

One of the primary goals of this study is to investigate topographic factors the influence the persistence of snow during the melt season. One such factor is the "slope aspect" or simply "aspect" – the compass direction that the slope faces. Figure 4-14 presents the dependence of total snow covered area (km^2) on aspect for each of the 17 years in the MODIS dataset for May 1, May 15, and June 1. The shape of the curves for individual years is strongly determined by the topography of the region, with less land area available in the NW octant, and more in the NE. Compared to GLAC, the ROMO study area shows more year-to-year variation in the shape of the curves, likely indicating stronger meteorological controls on the directionality of the snowpack compared to the topographic control seen in GLAC. Comparing the SW and NE octants we see that there is greater year-to-year variability in the SW, indicating a greater sensitivity of SW-facing slopes to variations in the historical climate. Two representative years, 2002 and 2011, illustrate the progression of total snow covered area from May 1 to June 1 (Figure 4-15).The dry year, 2002, shows that snow cover starts out lower on May1 and declines faster on SE, S and SW slopes. The year 2012 is also shown and exhibits similar behavior to 2002 but with less overall magnitude.

4.4.3 Slope Aspect Dependence of Snowpack: Fractional Area

The total land area within each aspect octant varies due to the orientation of ridges and valleys in the study area. As a result, the analysis of total snow covered area is dominated by the topography itself. To focus on the *relative* importance of the snow processes related to aspect, Figure 4-16 presents an analysis of the fraction of the total land area within each directional "bin" that is snow covered. The asymmetric shape shows that the NW-facing slopes have larger fractional area covered by snow. With the exception of 2012, even in dry years over 60 % of the NW facing slopes are snow-covered on May 15th. Figure 4-17 indicates that for the dry year 2012, snow cover was retained preferentially on NW-facing slopes.

4.4.4 Elevation Dependence

Figure 4-18 shows the elevation dependence of MODIS snow cover for the wet, near-normal and dry years, with the median of all years as reference. The results are shown as a percentage of the total elevation within each 200-meter elevation band within the study area boundaries. The ROMO area shows that the dry year, 2002 (as well as the other very dry year during the period, 2012), was significantly different from the other two, with a fractional area declining with altitude above 3400m. This may indicate that the meteorology in this region interacts differently with the topography in extremely dry years than in wetter years. The high-altitude snowpack may be particularly vulnerable in this region if conditions like those in 2002 recur.

5 Future Snowpack Projections: DHSVM Modeling

Key Points - Methods

- We conducted this analyses to…………
- The Distributed Hydrology Soil Vegetation (DHSVM) model was run for the historic period 1998-2013 and validated against available SNOTEL observing stations. The spatial patterns of snow were validated against MODIS satellite remotely sensed snow cover.
- Five scenarios of the future – a thirty year period centered on 2055 -- were selected from CMIP5 global climate model (GCM) projections based on a moderate (RCP 4.5) and high (RCP 8.5) emissions scenarios. These were chosen to represent a large fraction of the range of the CMIP5 ensemble projections in each study area in terms of precipitation and temperature changes. The scenarios differ somewhat between the two study areas to better represent the range of climate projections in each area.
- The selected GCM projections were downscaled using the "delta method" which applies change factors from the climate models to the historic temperature and precipitation that are used as inputs to the DHSVM model.
- Analysis is presented for light snow cover (Snow Water Equivalent > 13mm) for comparison with MODIS and McKelvey, and for 0.5 m of snow depth.
- To capture climate variability, Wet, Near Normal, and Dry representative case study years are shown for the historical simulations and how each of these years plays out under these five future scenarios.

Key Points – GLAC study area.

- Snow Covered Area in GLAC and area with snow depth greater than 0.5 meters on May 15 declines on average in all scenarios on average and for almost all years.
- On average, projections for the May 15 snowpack in the GLAC study area show a 12-42 percent decline in snow covered area, and a 15-68 percent decline in area with snow depth > 0.5 meters for the scenarios considered.
    - This resulted in X to X km2 in snow covered areas with > 0.5 meter snow cover
- All projections show declines in the number of years with significant snow. The areas with frequent (14-16 years) availability of significant snow become concentrated in smaller high elevation areas.
- For wet years, the high elevations of the study areas result in little loss of snowpack under most scenarios of change.
- For GLAC the Warm/Wet scenario shows the least change compared to the historic snow cover in terms of the area of significant (0.5 meter) snowpack. Under the Hot/Wet scenario, the May 1st significant snowpack diminishes to below the level of the historic June 1 snowpack.

Key Points – ROMO study area.

- Snow Covered Area in ROMO (13mm threshold on May 15) declines on average in all scenarios on average and for almost all years.

- On average, projections for the May 15 snowpack in the ROMO study area show a 12-52 percent decline in snow covered area, and a 7-64 percent decline in area with snow depth > 0.5 meters for the scenarios considered.
    - This resulted in X to X km2 in snow covered areas with > 0.5 meter snow cover
- Snow Covered Area in ROMO (0.5 m threshold on May 15) generally declines in wet years, but may increase in dry years in those scenarios with increased precipitation.
- Scenarios with increased precipitation may show increases in May 15 snowpack at the higher elevations in both study areas, but decreases in snowpack at lower elevations. This can lead to an increase in the area of > 0.5 meters of snow for dry years.
- ROMO exhibited more uncertainty in projections than GLAC
    - The beneficial effect of increased precipitation on snowpack is more prominent earlier in the Spring. In the Warm/Wet scenario, the area of significant snow on May1 increases on average, though it decreases on May 15.
    - For wet years, the high elevations of the study areas result in only modest loss of snow cover in the under all scenarios of change. However even in wet years, the area of significant snowpack can decline by almost 50% for the Hot/Dry climate change scenario.

5.1 Introduction

In this section we describe the hydrologic model along with various modeling assumptions, validation of the model, the choice of risk-spanning future climate scenarios, and present results of historical and projected snowpack for the two study areas.

To determine the projected effects of a changing climate on snowpack we ran a physically-based hydrology model. The physical basis of the model – using a full energy and water balance of the snowpack rather than a simple temperature-index model -- is critical to evaluate change in a non-stationary climate. While ambient temperature is a critical factor in whether precipitation falls as rain or snow, the subsequent evolution of the snowpack, and in particular the melt season, is driven primarily by the energy balance at the surface. The energy balance is the result of several processes, including solar and longwave radiation, sensible and latent heat fluxes, and heat flux into the ground, as well as storage of heat in the snowpack. Therefore, including a realistic energy balance helps to understand how the perturbations to climate will affect the snowpack.

5.2 Model Description

The Distributed Hydrology Soil Vegetation Model (DHSVM) provides a physically-based simulation of land surface hydrology, including snowpack. The physical processes include a full surface water and energy balance model, a 2-layer canopy model, a multi-layer soil model, a 2-layer snowpack model (Wigmosta et al. 1994). It has been used in many studies that have provided realistic hydrologic simulations in topographically complex areas (e.g. Livneh et al. 2015). The model has explicit treatment of topographic slope, and aspect (the compass direction that the slope faces).

The model was selected for developing snowpack projections because it can be run at a fine spatial scale (250 m x 250m pixels) yet is able to be run over extensive domains. There are both finer-scale snow models, for which it would have been impractical to simulate such a large domain, and coarser-scale models, such as the 1/16 degree grid of the VIC model that the McKelvey study used (see section 2.3). Coarser-scale models do not explicitly model the effects of slope and aspect, which is one of the primary goals of this study. Both DHSVM and VIC were primarily developed at the University of Washington, and are available as open-source community models. The two models share many components in common, including similar snow and canopy models. As such it supports the project goal of building on McKelvey study by modelling at a finer scale and treating slope and aspect explicitly.

The model was set up for both study domains on a 250m grid in Universal Transverse Mercator (UTM) coordinates within the modeling domain defined within the polygons shown in Section 2. Soil properties and vegetation type as well as a digital elevation model (DEM) were adapted to the model grid. A soil hydraulic routing network was also determined from the DEM, though in this project we do not investigate the runoff. The effect of slope and aspect on incoming solar radiation is implemented through a computation of the degree of shading for each 250-m pixel that was variable throughout the day and differed from month to month based on the solar angle in the sky and from the DEM. The model requires inputs of time-varying meteorological fields on sub-daily time scales. Snow water equivalent was output on May 1, May 15, and June 1 for every year of the simulation. As noted below, snow depth was estimated using a typical snowpack density for late Spring.

More details of the model will be included in the Section 5 Supplementary Material.

5.3 Meteorological Inputs

The DHSVM model inputs were derived in a multi-step process. First, values of daily minimum temperature, daily maximum temperature, and precipitation were extracted from the Livneh (2015) dataset, which has a grid resolution of $1/16^{th}$ degree in latitude and longitude. These daily values were disaggregated in time. Other forcing variables needed by the model, solar radiation, downwelling longwave radiation, specific humidity were derived from empirical relationships using the MTCLIM algorithms which were evaluated by Livneh et al. (2014) finding small overall biases. The Livneh et al (2015) data was then interpolated to the 250m DHSVM grid using an inverse-distance weighting algorithm along with assumed lapse rates (elevation dependence) in temperature and in precipitation. More details of the Livneh 2015 dataset will be included in the Section 5 Supplementary Material.

5.4 DHSVM Historical Validation

The goal of the model validation is to assess the overall magnitude, temporal, and spatial aspects of the modeled snowpack in the Spring and how these differ from observational estimates. Observational estimate of snow depth or snow water equivalent at the scales that we simulated are not available, leading to uncertainty about the "true" snowpack. For the overall magnitude and temporal aspects of the snow simulation, we compared the historical model simulation to point observations at the few available SNOTEL sites, focusing on the duration and melt-out date of the snowpack. The spatial aspect of bias was evaluated by comparing the model output to the observed spatial patterns of snow cover obtained from the MODIS analysis (see Section 4), qualitatively for GLAC and quantitatively for ROMO. When interpreting the projections, future model biases are typically assumed to be similar to historical biases. With this assumption, the calculation of, for example, percentage change is less sensitive to biases and uncertainties in the historical simulation.

5.4.1 Comparison to SNOTEL

The DHSVM historical simulation was compared against the snow data from nine SNOTEL sites in the ROMO study area that were in operation during the full time-period of interest, and the 3 SNOTEL sites in and adjacent to the GLAC study area (Table 5-1). Validation against SNOTEL snow data was performed by running the DHSVM model in "point" mode so that it simulated the conditions at the SNOTEL locations only. Because the SNOTEL stations are deliberately sited in clearings, the canopy was assumed to be open for the validation runs, while the actual 250m grid canopy values were used for the production runs. Two metrics were chosen: the meltout day of year (defined as the date when SWE fell to less than 1mm), and the duration of snow cover (total number of days during the water year (October-September) when SWE > 10cm). Figure 5-1a shows the modeled and observed meltout dates for the GLAC and ROMO SNOTEL sites, and Figure 5-1b shows the duration of snowpack. One does not expect exact reproduction of the snowpack at the SNOTEL sites, but rather a scatter about the 1-to-1 line, which is seen. The Copeland Lake, and to some extent the Many Glacier SNOTEL sites are outliers, with the model retaining snowpack significantly longer than in observations. Both these sites are at relatively low elevations, and are quite sensitive to potential temperature biases in the input data. The Livneh (2015) dataset is known to have a cool bias relative to other datasets, which may influence these sites disproportionately.

Table 5-1 SNOTEL Sites at Study Areas. Maps with SNOTEL sites are shown in Figs 2-1 and 2-2.

	SNOTEL SITE NAME (Site Number, Abbreviation)
Glacier Study Area	Flattop Mountain (482, flat), Many Glacier (613, many), Pike Creek (693, pike)
Rocky Mountain Study Area (used for Validation)	Bear Lake (322, bear), Copeland Lake (412, cope), Joe Wright (551, joew), Lake Eldora (564, eldo), Lake Irene (565, iren), Niwot (663, niwo), Phantom Valley (688, phan), University Camp (838, univ), Willow Park (870, will)
Rocky Mountain Study Area (installed after 1997, not used)	Never Summer (1031), Wild Basin (1042), Hourglass Lake (1122), Long Draw Reservoir (1123), High Lonesome (1187), Sawtooth (1251)

The year-to-year variations of peak snowpack at the GLAC SNOTEL sites are well captured, as illustrated in Figure 5-2 that shows simulated and observed time series of SWE at these stations.

Figure 5-3 shows selected SNOTEL sites in the ROMO area. As can be seen in Figure 5-2, the Copeland Lake site is less well simulated than other sites. We attribute this to being located at a lower elevation than other sites, and hence susceptible to small biases in temperature in the meteorological inputs. Other sites in ROMO are well simulated.

Based on this evaluation of DHSVM performance, the standard set of model parameters was adopted for the GLAC domain without modification.

The question arises of the independence of the SNOTEL data from the Livneh (2015) forcing data. The primary observing station data that were used for interpolation by Livneh (2015) did not include SNOTEL. However, a monthly adjustment factor was applied to the interpolated precipitation to reproduce the 1981-2000 climatology of PRISM. The temperature data in Livneh et al (2015) were entirely independent of SNOTEL data. Therefore, we expect that the errors revealed at the SNOTEL sites should be representative of errors at other, unobserved sites in the domain.

5.4.2 Comparison to MODIS Snow Cover

The spatial distribution of snow cover was assessed by comparison with MODIS data. Some care must be taken to compare observed NDSI, which indicated fractional snow cover, with modeled SWE, which does not account for fractional snow cover within a pixel. For this evaluation, a threshold to determine "snow covered ground" was chosen for both the MODIS NDSI (0.1) and for the DHSVM SWE. Figures 5-4 and 5-5 snow spatial overlays of the DHSVM simulated snow cover and the MODIS observed snow cover for the representative "dry" years in ROMO and GLAC. In terms of snow cover, dry years were more difficult to simulate than wet years, and the spatial agreement is good for these two examples.

However, initial attempts to model ROMO indicated biases in the spatial patterns of snow cover compared to MODIS. To overcome model errors at ROMO, an adjustment of two DHSVM snow parameters was conducted. The representative values of the physical quantities of these parameters can span a fairly large range, and hence an experiment was conducted to evaluate the appropriate settings of the model for ROMO based on minimizing differences between simulated and MODIS SCA for the historical period, as well as reducing biases with SNOTEL SWE.

The first parameter modified was the snow-surface roughness (SR), which affects the amount of turbulent heat fluxes that occur between the snow and the atmosphere, whereby a small number corresponds to a smoother snowpack that has less heat exchange with the overlying air, while the opposite is true for a large value. The second parameter was the liquid water capacity (LWC) that describes the volume of water that the snowpack can hold before water will leach out of the snowpack. This parameter is important, since it is common for snow to melt during the day and then for liquid water to refreeze at night.

Adjustments were made to SR and LWC within reasonable physical ranges and the DHSVM simulated SCA was compared with MODIS via a threat score. The threat score used, referred to as the Critical Success Index (CSI) by Zappa (2010), is defined as:

$$CSI = \frac{a}{a + b + c}$$

Where a indicates a snow-covered pixel in both the simulation and observed data, b indicates a snow-covered pixel in the simulation but a bare pixel in the observed (“false positive”), and c is a bare pixel for the simulation and a snow-covered pixel shown by the observed data (“false negative”). The objective was to maximize the threat score. Approximately ten unique parameter settings were tested. Additionally, for each parameter setting the mean bias in meltout day and duration of snow cover between DHSVM simulated and SNOTEL SWE was calculated with the objective being a minimization of the bias between the two (bias = simulated – observed). The final DHSVM settings for ROMO were identified by the parameter values that corresponded with a combination of a high threat score and a low bias. The table and figure showing the parameter settings and ensuing objective values are included in the supplementary material (Figure S5.X).

5.5 Determination of Snow Depth from DHSVM model output

DHSVM does not compute snow depth as a separate quantity, but instead returns snow water equivalent (SWE). To estimate the snow depth from SWE, a bulk density of the snowpack must be assumed. We adopt a density of 0.4 (or equivalently, at 2.5-to-1 ratio of snow depth to SWE, further discussion can be found in the Section 5 Supplementary Material) appropriate for the May snowpack in the study areas. Several lines of evidence point to the reasonableness of this assumption. First, SNOTEL stations where both depth and SWE are measured show similar ratios for the two study areas. Second, we investigated the ratio of density from the SNODAS (Snow Data Assimilation System) product from the NOAA National Operational Hydrologic Remote Sensing Center, which points to a very narrow range around 2.6-2.7 for the ratio. Finally, for comparison with the McKelvey et al (2011) work we compared the May 1 Snow Depth and SWE products from the Littell et al (2011) hydrologic model runs (obtained separately from https://cig.uw.edu/datasets/wus/). These all point to an approximate value consistent with a density between 0.35 and 0.4. The results of this study do not depend on a precise value for snow density.

5.6 Choice of thresholds for analysis

While the the McKelvey study analysis was for the presence or absence of snowcover, this modeling effort produces results in terms of SWE. This allows greater flexibility in evaluation of the depth of the snowpack, but presents a problem in comparison. To compare the model-generated SWE with both the McKelvey study results and our own MODIS historical snow cover analysis we investigated several threshold values of SWE: 1mm, 5mm, 13mm. For the purposes of this section we use the 13mm SWE threshold. We also were concerned with analyzing the presence of “significant snow” which we defined as 0.5 m of snow depth, or 0.2 m of snow water equivalent using our assumed May snow density. The value of 0.5 m was arrived at by an analysis of the modeled snow depth at known wolverine denning sites in Glacier National Park (Table 5-2). With the exception of one site that had melted out by May 15^{th}, the other sites all have snowpack between 0.4 and 1.4 m.

Table 5-2: Modeled Snow Depth on May 15 at reported den sites in the Glacier Study Area (source: John Guinotte, FWS)

Den site	Date observed (month-yr)	Meltout Date (MODIS)	May 15 snow depth dhsvm (m)	Notes
1	Apr-03	5/25/2003	1.036	
2	May-03	5/25/2003	1.045	
3	Apr-04	6/4/2004	0.407	
4	Apr-04	6/29/2004	0.539	
5	May-04	6/29/2004	0.653	
6	Mar-05	6/11/2005	0.531	
7	Apr-05	6/11/2005	0.531	
8	May-05	6/11/2005	0.468	
9	Mar-06	5/25/2006	1.435	
10	Apr-06	5/14/2006	0	meltout occurred before may 15
11	Apr-06	6/7/2006	1.233	
12	May-06	5/31/2006	0.611	
13	May-06	5/31/2006	0.611	duplicate

5.7 Delta Method for Future Scenarios

The advantages and disadvantages of the delta method have been discussed extensively in the literature (e.g. Sofaer et al, 2016, for a recent review). The primary advantages of this method are its long history of use, its simplicity, and its use of the historical observed weather as the baseline. The simplicity allowed for the study to be completed in a short time-frame, while still reaching our primary objectives of finer spatial scale and a more complete exploration of future climate scenarios. The use of the historical baseline allows us to explore how wet, near normal, and dry "representative years" would play out under the different climate futures. However, it is important to keep in mind that we are "parameterizing the future variability in terms of the historical variability." This treatment of daily variability also leads to the primary disadvantage of the delta method: the assumptions that the changes in extremes follow the changes in the means, and that the pattern of daily weather is simply shifted without changing the sequences of weather. This aspect is less of a concern for this study, as snow accumulation and ablation are cumulative processes, so that the daily sequences of storms is less critical to simulate than the monthly and seasonal totals. Another assumption of the delta method is that the large-scale changes in temperature and precipitation apply uniformly to the study area. Equivalently we assume that change factors in ambient (free-air) temperature and precipitation will not depend on the small scale spatial detail. Because we explicitly compute the surface energy balance, we are able to simulate surface temperature differences that depend on fine-scale terrain, mitigating to some extent this limitation of the delta method.

Following McKelvey (2011), we use the “delta method” to downscale the climate model data to the 250m modeling grid.

The steps in this method are as follows:

- Start with historical daily meteorological forcings (inputs to the DSHVM model) for the historical baseline period (1998-2013)
- Run DHSVM with the historical forcings to produce the simulated historical snow and hydrology.
- From climate model output, compute the change in 30-year average temperature for each calendar month over the time frame of interest. Do the same for the percent change in precipitation
- Apply these change factors to the historical daily meteorological inputs to DHSVM to generate future scenarios of meteorological inputs.
- Run DHSVM with these new inputs to generate the projected snow and hydrology.
- Compare the projected snow to the historic DHSVM model simulations to infer changes in snowpack.
- Repeat for a set of change factors from different climate models that adequately sample the uncertainty in climate projections.

The result of the delta method is a continuous-in-time simulation of the historical period (1998-2013), and an equal length simulation of how this sequence of years would play out in the future under five different scenarios of climate change. Figure 5-6 illustrates typical DHSVM model output using the delta method. Figure 5-6a shows a map of May 15, 2011 Snow Water Equivalent for the Glacier Study Area from the historical simulation, while Figure 5-6b shows a single projected future for what that year’s SWE would look like under a particular scenario of climate change. The future scenario represents a year similar to 2011, that is, a relatively wet and cool year in the sequence, however the temperature and precipitation have been adjusted to be consistent with the 2041-2070 projected climate from the MIROC climate model.

5.8 GCM Uncertainty and Scenario Planning Approach

As noted in Section 2, global climate models (GCMs) are our primary tools to examine the nature of climate change during the 21st century. There are currently about 20 modeling centers worldwide which provided output from their best model(s) to be considered in the Coupled Model Inter-comparison Project Phase-5 (CMIP5, Taylor et al., 2012) which informed the latest Intergovernmental Panel on Climate Change (IPCC) report (IPCC AR5). Here we quantify changes in temperature and precipitation for the two study areas for the 2014-2070 time frame. We find a large spread in the extent of warming and changes in precipitation, including both increases and decreases in precipitation, as shown in Figure 5-7. The McKelvey study chose GCMs based on the range of temperature change (see Sec 2.2, also shown in Figure 5-7). For temperature, much of this spread (or uncertainty) is a result of the difference between GCMs (e.g., their climate sensitivities), whereas for precipitation it is both the difference between GCMs and internal climate variability. Some difference also comes from the choice of future greenhouse gases (GHG) emission scenario. However, these differences among mid-21st century climate responses are limited compared to later in the century (see a discussion in Ray et al., 2010).

For more robust planning and climate adaptation, experts recommend incorporation of these uncertainties into the assessment of impacts and developing adaptation strategies. The scenario planning approach has been one method that has been recommend and promoted by different entities and experts (National Park Service, 2013; Rowland et al., 2014; Maier et al., 2016; Murphy et al. 2016; Star et al., 2016, Fisichelli et al, 2016 a,b). Therefore, we adopted a strategy of selecting multiple divergent future scenarios challenging to the system of interest, following that in Fisichelli et al (2016 a, b).

5.9 Climate Projections Evaluation and Scenarios Selection

We compiled output for temperature and precipitation projections for 34 CMIP5 GCMs from the Reclamation (2013; http://gdo-dcp.ucllnl.org/) archive of 1-degree Regridded GCM dataset for Representative Concentration Pathways (RCP) 4.5 and 8.5, which are respectively the moderate and high GHG emissions scenarios --- therefore, a total of 68 GCM projections described in Supplementary Material. These data were then analyzed to quantify broad-scale projections for the two study regions by 2055 (i.e. a mid-point centered on the 2041-2070 period) – primarily changes in the cold season (Oct-May) temperature and precipitation by 2055 relative to the 1986-2015 period. Figures 5-7 show these changes for Rocky Mountain and Glacier National Parks, respectively, which are bounded by rectangular latitude/longitude values. As mentioned earlier, we found a large range in temperature increases (1-4 ºC) and changes in precipitation (-5% to +20%) for these regions by 2055. Table 5-3 shows GCM names, numbers and colors coded in later figures, and relative changes in temperature and precipitation. To incorporate the large range in climate projections, we worked with the ensemble of 68 CMIP5 temperature & precipitation projections, described by the red filled-circles in Figure 5-7, to select five future climate scenarios (black circles) that span the different parts of this projection space. Five GCMs representing these scenarios were identified for both RMNP and GNP. For each of these GCMs, we calculated changes in temperature and precipitation by 2055 for each month of the year, which we call the "monthly delta". These monthly deltas were used to perturb the hydrological models to simulate snow response in RMNP and GNP by 2055.

Table 5-3. The six future scenarios used (five for each area) with changes in temperature and precipitation relative to other scenarios (See also Fig 5-7 for an alternate visualization of these changes), and the GCM used as the basis for the deltas for this scenario. More details on the GCMs are in the Glossary.

Future Scenario Name and #	Scenario Change in GLAC relative to other scenarios	Scenario Change in ROMO relative to other scenarios	Code and color for GCM used for this scenario
Central (#1)	+~2.2 °C increase in temperature (close to the ensemble mean) and +~5% increase in precipitation	+~2.5 °C increase in temperature (close to the ensemble mean) and +~8% increase in precipitation	cnrm, red
GLAC: **Hot/ Very Wet** (#2)	relatively higher increase in temperature (+~3.2 C) and the highest increase in precipitation (+20%) for the GLAC scenarios	N/A	canesm, green
ROMO: **Hot/Dry** (#2)	N/A	relatively higher temperature increase (+~ 3.5 °C) and -~5% decrease in precipitation. This scenario results in the greatest change (reduction) in snow pack and snowcover.	hadgem, green
Hot/ Wet (#3)	the highest temperature increase of the GLAC scenarios (+~4.2 °C) and +~10% increase in precipitation	the highest temperature increase of the ROMO scenarios (+~3.7 °C) and the highest increase in precipitation (+~18%).	miroc, purple
Warm/ Wet (#4)	relatively lower temperature increase (+~1 °C) and +~10% increase in precipitation	relatively lower temperature increase (+~1.3 °C) and +~7% increase in precipitation that appears to partially offset the impacts of the temperature increase. This scenario results in the least change in snow pack and snowcover.	giss, aqua
Warm/ Dry (#5)	relatively lower temperature increase (+~1.6 °C) and -~5% decrease in precipitation	relatively lower temperature increase (+~0.8 °C) and -~5% decrease in precipitation	fio, orange

5.10 Modeling Caveats

Some processes which may be of relevance not represented in the model include wind and avalanche re-distribution of snowpack. Snow depth is not explicitly modeled, and must be inferred (see below). The meteorological forcing does not take into account cold air pooling or how this may change in the future. Cold air pooling – the anomalously cold air that can collect in valley bottoms, particularly in Winter, could also act to prolong the duration of snow cover in those locations. While Curtis et al (2014) identify this as a potential process, they do not physically model cold air pooling, but merely include it in their present-day climatology as a simple "offset" from their unadjusted data. Nonetheless their work provides a complementary approach to the identification of potential snow refugia, though more work would need to be done to study the geographic and seasonal aspects for the study areas.

5.11 GLAC Study Area Results

5.11.1 SWE and Snow Covered Area for representative years

Figures 5-8 shows DHSVM model simulated snow water equivalent (SWE) on May 15 for the wet (2011) representative year. Maps of snow cover derived from SWE by applying a threshold of 13 mm are available in the Supplementary material. Results for thresholds of 1 mm and 5 mm of SWE were also investigated and show similar patterns. Snow covered area with a "light snow cover" threshold was computed primarily for comparison with both the MODIS results from Section 4, and with McKelvey. In Figure 5-8, the historical simulation is shown along with three of the five future scenarios, chosen to represent the central scenario (cnrm), the greatest change in snowpack on average (Hot/Wet (miroc) scenario) and the least change (Warm/Wet (giss) scenario). The projected snow maps answer the question "what would the snowpack in a wet year like 2011 look like in the 2040's through 2070's under these scenarios of climate change."

Figures 5-9 and 5-10 show SWE for the Near Normal (2009) and Dry (2005) representative years. The historical simulation and future scenarios are as in Figure 5-8. Figure 5-11 summarizes the results for snow covered area in terms of the total snow covered area (km^2) within the study area polygon. The numerical values of snow covered area for all years in the simulation, as well as percent changes for these quantities are shown in Table 5-4. Table 5-4 indicates that the snowcovered area decreases for all scenarios. **On average, the GLAC study area exhibits a 12-42 percent decline in snow covered area on May 15 for the scenarios considered.**

- **Elevation at den graph should be incorporated here instead of an add on section later in the report.**
- Comparing the Wet and Dry representative years we see that dry years are more vulnerable to climate change in terms of percent loss of snow covered area.
- For the Wet year, the high elevations of the study area result in little loss of snowpack in the study areas under most scenarios of change.
- However, in Figures 5-10 and 5-11 we notice an anomaly – for the dry year, the Hot/Wet scenario does not have the greatest loss of snow covered area. The increase in precipitation in this scenario has somewhat compensated for the loss of snowpack due to warming.

Commented [GJM9]: We should run this by Steve to see what he thinks re displaying maps using SWE vs snow depth. Swe is much less understandable to the avg reader whereas snow depth is clear.

Commented [Office10R9]: For the paper we will probably have to stick to SWE as much as possible. Snow depth was derived using our empirical formula, which is fine for our purposes – denoting areas of a significant amount of snow--. But showing maps it is probably less risky to snow them in terms of SWE – that is what snow/hydrologic modelers mainly think in terms of anyway as it is more close

GLAC Area (km^2)	Snow Covered Area (13mm SWE threshold) Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	historical	2552	2793	2655	2802	2890	2753	2533	2408	2636	2491	2883	2901	2524	2901	2758	2851	2708	2756
	Central (cnrm)	1768	2329	2030	2459	2816	2326	1812	1509	1959	1816	2742	2880	1886	2885	2179	2561	2247	2253
	Hot/Very Wet (canesm)	1394	1956	1707	1955	2595	1858	1303	1171	1510	1174	2436	2764	1293	2817	1723	2127	1862	1790
	Hot/Wet (miroc)	1573	1646	1604	1637	1518	2122	998	2275	1527	1517	2608	2037	1618	2481	1157	2165	1780	1627
	Warm/Wet (giss)	2197	2583	2388	2599	2856	2486	2191	2017	2312	2109	2842	2895	2170	2901	2485	2705	2484	2486
	Warm/Dry (bio)	2112	2440	2184	2586	2830	2555	2089	1776	2231	2070	2806	2891	2127	2900	2486	2659	2421	2463
15-May	historical	1452	2718	2433	2352	2873	2636	2287	2087	2373	1741	2807	2825	2393	2900	2557	2548	2436	2490
	Central (cnrm)	636	2114	1703	1780	2661	2068	1409	1104	1555	963	2367	2479	1664	2817	1763	1733	1801	1748
	Hot/Very Wet (canesm)	650	1835	1447	1419	2449	1652	1083	887	1255	657	2174	2218	1118	2697	1473	1584	1537	1460
	Hot/Wet (miroc)	1079	1440	977	1051	1230	1958	784	1451	1152	1026	2307	1677	1499	2305	879	1760	1411	1335
	Warm/Wet (giss)	1079	2483	2098	2062	2800	2332	1963	1667	1981	1299	2638	2672	2034	2882	2203	2247	2152	2151
	Warm/Dry (bio)	883	2274	1913	1910	2712	2372	1722	1397	1851	1138	2515	2600	1918	2864	2125	1943	2009	1931
1-Jun	historical	863	2360	1759	1114	2599	1932	1864	1375	1446	1061	1923	2205	1907	2863	2171	2035	1842	1915
	Central (cnrm)	250	1512	948	628	2049	1099	897	560	663	417	1005	1397	1025	2600	1281	1114	1090	1015
	Hot/Very Wet (canesm)	328	1393	909	590	1923	966	742	514	689	347	1172	1414	794	2455	1118	1134	1030	937
	Hot/Wet (miroc)	496	813	359	282	682	1109	417	552	267	511	1008	682	831	1862	527	786	699	617
	Warm/Wet (giss)	613	2046	1392	883	2401	1507	1473	1046	1063	759	1574	1893	1580	2789	1763	1747	1533	1541
	Warm/Dry (bio)	401	1723	1137	623	2217	1410	1196	735	810	527	1222	1606	1178	2691	1611	1291	1274	1209

% change	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	Central (cnrm)	-31	-17	-24	-12	-3	-16	-28	-37	-26	-27	-5	-1	-25	-1	-21	-10	-17	-18
	Hot/Very Wet (canesm)	-45	-30	-36	-30	-10	-33	-49	-51	-43	-53	-15	-5	-49	-3	-38	-25	-31	-35
	Hot/Wet (miroc)	-38	-41	-40	-42	-47	-23	-61	-6	-42	-39	-10	-30	-36	-15	-58	-24	-34	-41
	Warm/Wet (giss)	-14	-8	-10	-7	-1	-10	-13	-16	-12	-15	-1	0	-14	0	-10	-5	-8	-10
	Warm/Dry (bio)	-17	-13	-18	-8	-2	-7	-18	-26	-15	-17	-3	0	-16	0	-10	-7	-11	-11
15-May	Central (cnrm)	-56	-22	-30	-24	-7	-22	-38	-47	-34	-45	-16	-12	-30	-3	-31	-32	-26	-30
	Hot/Very Wet (canesm)	-55	-32	-41	-40	-15	-37	-53	-58	-47	-62	-23	-22	-53	-7	-42	-38	-37	-41
	Hot/Wet (miroc)	-26	-47	-60	-55	-57	-26	-66	-30	-51	-41	-18	-41	-37	-21	-66	-31	-42	-46
	Warm/Wet (giss)	-26	-9	-14	-12	-3	-12	-14	-20	-17	-25	-6	-5	-15	-1	-14	-12	-12	-14
	Warm/Dry (bio)	-39	-16	-21	-19	-6	-10	-25	-33	-22	-35	-10	-8	-20	-1	-17	-24	-18	-22
1-Jun	Central (cnrm)	-71	-36	-46	-44	-21	-43	-52	-59	-54	-61	-48	-37	-46	-9	-41	-45	-41	-47
	Hot/Very Wet (canesm)	-62	-41	-48	-47	-26	-50	-60	-63	-52	-67	-39	-36	-58	-14	-49	-44	-44	-51
	Hot/Wet (miroc)	-42	-66	-80	-75	-74	-43	-78	-60	-82	-52	-48	-69	-56	-35	-76	-61	-62	-68
	Warm/Wet (giss)	-29	-13	-21	-21	-8	-22	-21	-24	-27	-28	-18	-14	-17	-3	-19	-14	-17	-20
	Warm/Dry (bio)	-54	-27	-35	-44	-15	-27	-36	-47	-44	-50	-36	-27	-38	-6	-26	-37	-31	-37

Table 5-4: GLAC Snow Covered Area (13mm SWE threshold) Top: Area (km^2) in historical and five future scenarios. Bottom: percent change in future simulations compared to historical. Average and Median values also shown.

5.11.2 Area and Number of years with 0.5 m Snow Depth

Because of interest in wolverine denning sites, we analyze snow depth > 0.5 m, which we will also refer to as "significant snow" to contrast with the emphasis on light snow in McKelvey et al (2011) and in the previous section. Figure 5-12 shows the area with snow depth > 0.5 m on May 15 within the study area for the dry, near normal, and wet years. Because of the higher threshold for snow, the effects are somewhat larger than for the light snow threshold. This is particularly evident in the dry year, which has a 50% decline on May 15 for four of the future scenarios. The numerical values of snow covered area at the > 0.5 m threshold are shown in Table 5-5 for all years, as well as percent changes for these quantities. **On average, the GLAC study area exhibits a 15 – 68 percent decline in the area of snow depth > 0.5 meters for the scenarios considered.**
Figure 5-22 here, plus text to accompany the results from this figure. Also include the X to X km^2 area that correspond to the 15-68 declines.

Figure 5-13 shows a map of the number of years (out of 16 possible) where each model pixel had at least 0.5 m of snow depth on May 15. This number-of-years statistic is analogous to that used by the Copeland study, except that there are more years of data, and these maps use a much higher threshold of snow. The projections show declines in the number of years with significant snow. The areas with frequent (14-16 years) availability of significant snow become concentrated in smaller high elevation areas.

The effects of climate change on snow melt have been presented as analogous to a "time shifting" of the melt season earlier in the year. For example, McKelvey used the May 31 vs. May 15 snow covered area as a proxy for a 2-week shift in the melt season. Figure 5-14 contrasts the evolution of the snowpack from May 1 to June 1 in the historical simulations (Top Row) with the Warm/Wet scenario (Middle Row) and Hot/Wet (Bottom Row) scenarios. We see that the Warm/Wet scenario, shows the least change compared to the historic snow cover in terms of the availability of significant snow. In contrast, under the Hot/Wet scenario, the May 1st significant snowpack has been diminished below the level of the historic June 1 snowpack – greater than a month shift.

Snow Covered Area (0.5 m depth threshold)																			
Area (km^2)	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	historical	1594	2545	2204	2326	2844	2392	2032	1800	2124	1571	2613	2731	1692	2901	2453	2625	2278	2359
	Central (cnrm)	770	1826	1477	1912	2530	1766	1137	912	1283	951	2160	2383	965	2847	1630	1893	1653	1698
	Hot/Very Wet (canesm)	733	1587	1234	1399	2283	1336	826	732	1075	578	1992	2070	677	2721	1316	1650	1388	1326
	Hot/Wet (miroc)	474	526	633	425	458	1538	395	614	364	541	1321	1236	332	2029	436	1018	771	533
	Warm/Wet (giss)	1154	2242	1810	2012	2681	1968	1590	1400	1660	1112	2389	2525	1360	2890	2017	2328	1946	1990
	Warm/Dry (fio)	974	1938	1594	1877	2586	2054	1368	1058	1471	969	2169	2418	897	2873	1944	2046	1765	1907
15-May	historical	550	2496	1937	1417	2749	2201	1673	1308	1805	804	2317	2537	1647	2881	2135	2035	1906	1986
	Central (cnrm)	140	1731	1161	1007	2329	1453	792	566	961	328	1585	1957	911	2692	1284	1139	1252	1150
	Hot/Very Wet (canesm)	247	1537	1048	835	2128	1176	648	509	900	274	1632	1797	662	2538	1087	1155	1136	1068
	Hot/Wet (miroc)	302	508	346	217	439	1447	203	531	290	302	1053	878	565	1733	352	634	612	473
	Warm/Wet (giss)	380	2199	1546	1166	2560	1782	1287	995	1362	567	2051	2286	1355	2825	1693	1745	1612	1620
	Warm/Dry (fio)	199	1873	1301	880	2438	1781	986	659	1106	328	1692	2096	879	2765	1559	1208	1360	1255
1-Jun	historical	337	1903	1089	428	2156	1192	1199	723	845	486	1140	1590	1144	2782	1625	1534	1261	1168
	Central (cnrm)	52	1052	494	202	1473	563	435	227	310	145	462	810	514	2353	827	738	666	504
	Hot/Very Wet (canesm)	113	1024	572	238	1476	585	437	262	398	145	667	956	429	2254	781	847	699	579
	Hot/Wet (miroc)	90	220	100	36	194	542	104	103	43	158	284	194	185	1319	194	250	251	190
	Warm/Wet (giss)	221	1545	817	321	1895	870	928	534	589	346	859	1262	973	2646	1246	1298	1022	899
	Warm/Dry (fio)	97	1139	567	164	1598	724	602	294	377	157	552	876	522	2457	1049	817	749	584

% change	Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	Central (cnrm)	-52	-28	-33	-18	-11	-26	-44	-49	-40	-39	-17	-13	-43	-2	-34	-28	-27	-28
	Hot/Very Wet (canesm)	-54	-38	-44	-40	-20	-44	-59	-59	-49	-63	-24	-24	-60	-6	-46	-37	-39	-44
	Hot/Wet (miroc)	-70	-79	-71	-82	-84	-36	-81	-66	-83	-66	-49	-55	-80	-30	-82	-61	-66	-77
	Warm/Wet (giss)	-28	-12	-18	-13	-6	-18	-22	-22	-22	-29	-9	-8	-20	0	-18	-11	-15	-16
	Warm/Dry (fio)	-39	-24	-28	-19	-9	-14	-33	-41	-31	-38	-17	-11	-47	-1	-21	-22	-23	-19
15-May	Central (cnrm)	-75	-31	-40	-29	-15	-34	-53	-57	-47	-59	-32	-23	-45	-7	-40	-44	-34	-42
	Hot/Very Wet (canesm)	-55	-38	-46	-41	-23	-47	-61	-61	-50	-66	-30	-29	-60	-12	-49	-43	-40	-46
	Hot/Wet (miroc)	-45	-80	-82	-85	-84	-34	-88	-59	-84	-62	-55	-65	-66	-40	-84	-69	-68	-76
	Warm/Wet (giss)	-31	-12	-20	-18	-7	-19	-23	-24	-25	-29	-11	-10	-18	-2	-21	-14	-15	-18
	Warm/Dry (fio)	-64	-25	-33	-37	-11	-19	-41	-50	-39	-59	-27	-17	-47	-4	-27	-41	-29	-37
1-Jun	Central (cnrm)	-85	-45	-55	-53	-32	-53	-64	-69	-63	-70	-59	-49	-55	-15	-49	-52	-47	-57
	Hot/Very Wet (canesm)	-66	-46	-47	-44	-32	-51	-64	-64	-53	-70	-42	-40	-63	-19	-52	-45	-45	-50
	Hot/Wet (miroc)	-73	-88	-91	-92	-91	-55	-91	-86	-95	-67	-75	-88	-84	-53	-88	-84	-80	-84
	Warm/Wet (giss)	-34	-19	-25	-25	-12	-27	-23	-26	-30	-29	-25	-21	-15	-5	-23	-15	-19	-23
	Warm/Dry (fio)	-71	-40	-48	-62	-26	-39	-50	-59	-55	-68	-52	-45	-54	-12	-35	-47	-41	-50

Table 5-5: GLAC Snow Covered Area (0.5 m snow depth threshold) Top: Area (km^2) in historical and five future scenarios. Bottom: percent change in future simulations compared to historical. Average and Median values also shown.

5.12 ROMO Study Area

On average, the ROMO study area exhibits a 7 – 64 percent decline in the area of snow depth > 0.5 meters on May 15 for the scenarios considered. Note that the Warm/Wet scenario projects a slight increase in the area of significant snowpack on May 1.

5.12.1 SWE and Snow Covered Area for representative years

Figure 5-15 shows DHSVM model simulated SWE on May 15th for the wet representative year (2011). The historical simulation is shown along with three of the five future scenarios, chosen to represent the central scenario (cnrm), the greatest change in snowpack on average (Hot/Dry (hadgem2) scenario) and the least change (Warm/Wet (giss) scenario). The future scenarios answer the question "what would the snowpack in a wet year (like 2011) look like in the 2040's through 2070's under these scenarios of climate change." Note that the "greatest snowpack change" scenario is different for ROMO than for GLAC. We have included Hot/Dry in the choice of scenarios for ROMO because a significant number of climate models project drying conditions in ROMO, whereas in GLAC, the vast majority of climate models predict a wetter future.

Figures 5-16 and 5-17 shows SWE for the "Near Normal" (2009) and "Dry" (2002) year. One can see that in the dry year, the snow cover is already very sparse even in the historical simulation.

Figure 5-18 summarizes the results in terms of the total snow covered area (km^2) within the study area polygon. In this case, the threshold used is 13mm of SWE, representing a light snow cover, and comparable to the results in McKelvey. Comparing the Wet and Dry years we see, as with GLAC, that dry years are more vulnerable to climate change in terms of percentage of area lost. For the Wet year, the high elevations of the study area result in little loss of snowpack in the study areas under most scenarios of change. The numerical values of snow covered area for all years, as well as percent changes for these quantities are shown in Table 5-7. **On average, the ROMO study area exhibits a 12-52 percent decline in snow covered area on May 15 for the scenarios considered.**

ROMO Snow Covered Area sq-km [13mm SWE threshold]

ROMO	Scenario	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	historical	1567	1514	1574	1523	1245	1594	1248	1580	1573	1555	1595	1578	1439	1593	779	1594	1472	1570
	Central [ccsm]	1380	1216	1424	1112	786	1571	655	1470	1376	1195	1593	1396	1091	1553	379	1547	1234	1378
	Hot/Dry [hadgem2]	1127	971	1079	844	418	1498	429	1114	1188	1081	1587	1267	763	1507	185	1462	1033	1097
	Hot/Very Wet [miroc]	963	569	1045	773	501	1425	293	1280	1215	701	1582	1003	837	1444	112	1382	945	983
	Warm/Wet [giss]	1498	1429	1510	1373	944	1589	964	1522	1528	1461	1595	1547	1335	1586	583	1587	1378	1504
	Warm/Dry [fio]	1462	1392	1546	1363	981	1584	828	1519	1518	1433	1595	1533	1234	1584	481	1580	1351	1490
15-May	historical	1427	1467	1146	1064	989	1592	831	1519	1490	1421	1593	1449	1372	1587	588	1566	1319	1438
	Central [ccsm]	1012	1076	728	495	526	1546	340	1206	982	872	1563	953	951	1485	245	1366	959	967
	Hot/Dry [hadgem2]	530	688	250	221	213	1385	119	671	650	569	1410	470	562	1320	80	846	625	565
	Hot/Very Wet [miroc]	637	483	457	385	327	1346	141	948	858	491	1510	615	742	1355	78	1193	723	626
	Warm/Wet [giss]	1235	1315	877	814	693	1583	554	1346	1312	1242	1585	1246	1228	1559	396	1515	1156	1244
	Warm/Dry [fio]	1227	1311	928	755	695	1573	504	1361	1302	1200	1588	1279	1141	1556	344	1505	1142	1253

Snow Covered Area % change [13mm SWE threshold]

	Scenario	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	Central [ccsm]	-12	-20	-10	-27	-37	-1	-48	-7	-13	-23	0	-12	-24	-2	-51	-3	-16	-12
	Hot/Dry [hadgem2]	-28	-36	-31	-45	-66	-6	-66	-30	-24	-30	-1	-20	-47	-5	-76	-8	-30	-30
	Hot/Very Wet [miroc]	-39	-62	-34	-49	-60	-11	-77	-19	-23	-55	-1	-36	-42	-9	-86	-13	-36	-37
	Warm/Wet [giss]	-4	-6	-4	-10	-24	0	-23	-4	-3	-6	0	-2	-7	0	-25	0	-6	-4
	Warm/Dry [fio]	-7	-8	-2	-11	-21	-1	-34	-4	-3	-8	0	-3	-14	-1	-38	-1	-8	-5
15-May	Central [ccsm]	-29	-27	-37	-53	-47	-3	-59	-21	-34	-39	-2	-34	-31	-6	-58	-13	-27	-33
	Hot/Dry [hadgem2]	-63	-53	-78	-79	-78	-12	-86	-56	-56	-60	-12	-68	-59	-17	-86	-46	-53	-61
	Hot/Very Wet [miroc]	-55	-67	-60	-64	-67	-15	-83	-38	-42	-65	-5	-58	-46	-15	-87	-24	-45	-56
	Warm/Wet [giss]	-13	-10	-23	-23	-30	-1	-33	-11	-12	-13	-1	-14	-11	-2	-33	-3	-12	-13
	Warm/Dry [fio]	-14	-11	-19	-29	-30	-1	-39	-10	-13	-16	0	-12	-17	-2	-41	-4	-13	-13

Table 5-6: ROMO Snow Covered Area (13 mm SWE threshold) Top: Area (km^2) in historical and five future scenarios. Bottom: percent change in future simulations compared to historical. Average and Median values also shown.

5.12.2 Area and Number of years with 0.5 m Snow Depth

Because of interest in wolverine denning sites, we analyze snow depth > 0.5 m, which we will refer to here as "significant snow." Figure 5-19 shows the area with snow depth > 0.5 m within the study area. Because of the more stringent threshold for snow, the effects are somewhat larger than for the light snow cover. The numerical values of snow covered area at the > 0.5 m threshold are shown in Table 5-7 for all years, as well as percent changes for these quantities. In this table, we note that dry years such as 2002 see increases in snow covered area for the Hot/Very Wet and Warm/Wet scenarios. As in GLAC, dry years are somewhat buffered against change, and in fact can see increases in high-altitude "significant" snow for scenarios with increased precipitation. This is a result of the elevational dependence of snowpack change that will be discussed in the next sub-section. **On average, the ROMO study area exhibits a 7 – 64 percent decline in the area of snow depth > 0.5 meters on May 15 for the scenarios considered. Note that the Warm/Wet scenario projects a slight increase in the area of significant snowpack on May 1.**

Figure 5-20 shows a map of the number of years (out of 16 possible) where each model pixel had at least 0.5 m of snow depth on May 15th. This summary statistic is analogous to that used by the Copeland study, except that there are more years of data, and these maps use a much higher threshold of snow. The projections show declines in the number of years with significant snow. The areas with frequent (14-16 years) availability of significant snow become concentrated in smaller high elevation areas. The Hot/Dry "greatest change" scenario, illustrates that the combination of drying and warming leads to very large declines in the persistence of snow.

The effects of climate change on snow melt have been presented as analogous to a "time shifting" of the melt season earlier in the year. For example, McKelvey (2011) used the May 31st vs. May 15th snow covered area as a proxy for a 2-week shift in the melt season. Figure 5-21 contrasts the evolution of the snowpack from May 1 to June 1 in the historical simulations (Top Row) with the Warm/Wet scenario (giss, Middle Row) and Hot/Dry (hadgem, Bottom Row) scenarios [Graphics being re-done].

5.13 Elevation Dependence of Snowpack Change in the DHSVM model

Snowpack accumulation and melt depends critically on temperature and hence on elevation. In the Warm/Dry and Hot/Dry scenarios, both the precipitation decrease and the warming act to reduce Spring snowpack. For the scenarios with warming and increased precipitation there are two countervailing forces that play out along an elevational gradient. A warmer, wetter future is one in which the freezing level and snow line tends to be higher, but with the potential for greater snowpack accumulation during the cold season at high elevations. The warming also tends to lead to an earlier snowmelt, so that the increased high-elevation snowpack is more evident early in the Springtime than later.

Figures 5-22 shows the percent change in May 1st snow covered area (SCA; 0.5 meters depth) for GLAC, computed for 200 m elevation bands. The elevation of observed den sites is noted by triangles, with den sites ranging from approximately 1500m to 2300 m. There is little change in SCA for 4 of the 5 scenarios above 2200m. As in a mirror image there is greater than 95 % loss of SCA below 1400m for 4 of the 5 scenarios. Between these two elevations – and in the regions where most observations of dens have been noted – the snowpack change is very sensitive to elevation and to the particular future climate scenario. Figure 5-23 shows the elevation dependence of the May 1st snowpack measured in terms of snow water equivalent (SWE). Viewing snowpack in terms of SWE illustrates more clearly that the Hot/Very Wet future scenario has a greater snowpack at high elevations despite completely losing its snowpack at 100m elevation. Figure 5-23 also illustrates that SWE can have modest declines without affecting the area with significant snow depth. The implications is that wet, cold climate of the GLAC study area can act as a "buffer" to change in the area of 0.5 meter deep snow on May 1st, at least at high elevations.

Figure 5-24 shown the May 1st SCA (0.5 meter depth) for ROMO. The high elevation areas show a loss of SCA for four of the five future scenarios, which an increase only in the Warm/Wet (giss) scenario. The climate of ROMO is, on average drier than that of GLAC, and the regions of the model simulations that have significant snow in most years is restricted to the two smaller areas within the domain (Figure 5-21). As a result the climate does not act to buffer change in the area of significant snow on May 1st.

This phenomenon of elevation-dependent snowpack change in the Western US is well supported in the literature. Regonda et al. (2005) found little historical change in snowpack in the Western United States above approximately 2500m elevation despite observed warming trends. Christensen and Lettenmaier (2007) considered VIC hydrology model projections and reported as strong elevation dependence for snowpack loss in the Colorado River basin below 2500 m elevation (their data was visualized in Ray et al. 2008). Two recent studies are of special interest because they focus on areas near those considered here. Sospendra-Alfonso et al (2015), on an area near the GLAC study area, find that historically, temperature has been a larger driver of April 1st snowpack only below about 1560 m elevation, with precipitation the main driver of variability above that elevation. Scalzitti et al. (2016) investigated a single climate change scenario using a high-resolution weather model and found that the critical elevation below which temperature dominates snowpack rises by about 250m in the Colorado Rockies, and rises by about 191 m in the Northern Rockies hear the GLAC study area. While it is difficult to these results directly to the present study due to differences in methodology, the qualitative picture remains – projected warming has a larger effect at lower elevations whereas projected precipitation changes may dominate the Springtime snowpack in the high country.

ROMO	Snow Covered Area sq-km (0.5 meter snow depth threshold)																		
	Scenario	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	historical	468	249	734	180	26	1578	90	422	418	746	1334	594	70	1366	22	381	542	420
	Central [cnrm]	421	185	607	95	38	1470	102	375	208	398	1199	451	55	1293	16	402	457	386
	Hot/Dry [hadgem2]	166	57	232	64	10	1245	33	137	278	314	984	231	14	1096	2	125	312	152
	Hot/Very Wet [miroc]	275	135	375	155	40	1133	59	320	397	259	1200	390	130	1164	3	719	419	297
	Warm/Wet [giss]	453	256	601	210	38	1552	118	375	514	753	1417	572	104	1374	23	481	552	467
	Warm/Dry [fio]	187	99	483	45	4	1510	16	172	159	475	946	374	14	1201	5	176	367	174
15-May	historical	429	277	288	105	29	1568	37	474	416	593	1341	403	227	1289	25	436	496	409
	Central [cnrm]	263	169	177	35	27	1385	22	352	161	248	988	216	174	1066	13	267	348	196
	Hot/Dry [hadgem2]	56	44	32	12	4	990	3	96	133	114	586	54	35	677	0	45	180	50
	Hot/Very Wet [miroc]	174	122	106	58	33	1061	18	276	263	173	970	184	217	922	4	395	311	179
	Warm/Wet [giss]	351	257	208	94	35	1519	33	403	433	530	1292	338	241	1239	23	404	462	345
	Warm/Dry [fio]	208	120	168	31	4	1481	10	211	167	373	1053	244	87	1064	6	239	342	188

	Snow Covered Area % change (0.5 meter snow depth threshold)																		
	Scenario	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average	Median
1-May	Central [cnrm]	-10	-25	-17	-47	44	-7	13	-11	-50	-47	-10	-24	-21	-5	-27	5	-16	-8
	Hot/Dry [hadgem2]	-64	-77	-68	-65	-61	-21	-63	-68	-33	-58	-26	-61	-80	-19	-91	-67	-42	-64
	Hot/Very Wet [miroc]	-41	-46	-49	-14	53	-28	-35	-24	-5	-65	-10	-41	85	-14	-85	88	-23	-29
	Warm/Wet [giss]	-3	3	-18	16	44	-2	31	-11	23	1	6	-4	48	1	6	26	2	11
	Warm/Dry [fio]	-60	-60	-34	-75	-85	-4	-82	-59	-62	-36	-29	-37	-79	-11	-79	-54	-32	-59
15-May	Central [cnrm]	-39	-39	-38	-67	-5	-12	-42	-26	-61	-58	-26	-47	-23	-17	-48	-39	-30	-52
	Hot/Dry [hadgem2]	-87	-84	-89	-88	-85	-37	-93	-80	-68	-81	-56	-87	-85	-47	-98	-90	-64	-88
	Hot/Very Wet [miroc]	-60	-56	-63	-44	13	-32	-53	-42	-37	-71	-28	-54	-4	-28	-86	-9	-37	-56
	Warm/Wet [giss]	-18	-7	-28	-10	20	-3	-13	-15	4	-11	-4	-16	6	-4	-8	-7	-7	-16
	Warm/Dry [fio]	-52	-56	-42	-71	-85	-6	-74	-55	-60	-37	-22	-39	-62	-17	-78	-45	-31	-54

Table 5-7: ROMO Snow Covered Area (0.5 m snow depth threshold) Top: Area (km^2) in historical and five future scenarios. Bottom: percent change in future simulations compared to historical. Average and Median values also shown.

6 Comparing results with McKelvey

An overview of the methodological similarities and differences between this study and McKelvey et al (2011) was presented in section 2.2. The differences in aims of these studies leads to challenges in making a direct comparison. McKelvey investigated persistence of even a snow cover to May 15th as a correlate of wolverine habitat, as noted in Aubry et al (2008). This study focuses on high-elevation terrain and on the persistence of deeper snowpack. Nonetheless some general statements can be made relating the two studies. Figure 5-24 shows snowcover under McKelvey's historic and "miroc 2080's" (or hotter) scenario. The GLAC and ROMO areas have been outlined. A close examination of this figure shows that snow cover persists in our study areas, even for their hotter scenario of change (miroc "2080's). The greatest loss of snow cover in McKelvey occurs at lower elevations than were included in GLAC or ROMO. Because of the increased resolution of our study we are able to consider whether any pockets of snow with depth greater than 0.5 meters will persist.

Commented [GJM11]: Explain this was their worst case. AJR – they don't use use the term "Worst Case" – they just use miroc, We coul say the warm/warmer and hot/hotter scenarios, but I'm not comfortable calling them "worst case" and definitely not best case.

The choice of future climate scenarios differs somewhat from McKelvey. We have intentionally included scenarios that represent the range of possibilities indicated by the CMIP5 climate models. McKelvey used climate model output from Littell, who chose scenarios based solely on projected warming. For GLAC, this choice fortuitously included a range of precipitation changes as well. For ROMO, however, McKelvey's scenarios include only a narrow range of precipitation change, where we include scenarios with significantly increased wintertime precipitation as well as scenarios with drying. This is a significant factor, given the buffering effect that increased precipitation has on snowpack loss at high elevations.

While McKelvey focused snowpack projections entirely on the long-term average, we investigate how climate variability – the sequences of wet and dry years -- intersects with scenarios of change. For ROMO in particular we find that dry years behave differently than wet years, with dry years benefitting from the increased precipitation in several of our future scenarios. This emphasizes the importance of planning for a range of possible climate scenarios, particularly regarding the direction of change in wintertime precipitation.

The question arises as to how the fine-scale projections of snow persistence in other areas might reasonably be inferred from the two study areas considered here. Figure 5-24 indicates many areas in the western United States that show persistence of snow cover in McKelvey's scenarios, even in the more extreme scenarios. We have investigated two study areas: a northern, relatively wet and low-elevation area GLAC, and a southern, relatively dry, and very high elevation area (ROMO). In both areas we find general declines in snow covered area under most future scenarios. The GLAC study area is broadly similar in its climate to much of the high northern Rockies, while ROMO shares features with the high mountain ranges of the Central Rockies. For areas in the McKelvey maps that show retention of snow on the higher mountain ranges it is physically reasonable to presume that a finer scale simulation would show the retention of areas of snow > 0.5 m on May 15th. Extending this beyond the general area of the Rocky Mountains is problematic. Even within the Rockies, in regions where McKelvey's results show widespread loss of snowpack it is probably not reasonable to conclude one way or the other whether a finer scale analysis would identify snow refugia.

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8 Glossary

- **Aspect:** compass direction that slope faces
- **Baseline period 1916-2000**: Deltas (changes) computed (monthly average delta) for "2040's and "2080's" compared to the 1916-2000 baseline.
- **CanESM:** A CMIP5 climate model the Canadian Centre for Climate Modeling and Analysis (canesm2.1.rcp85), forced with the RCP 8.5 higher emissions pathway, used in this report as a future scenario (Hot/Dry scenario for GLAC only) that has relatively higher increase in temperature (+~4.5 C) and about +20% increase in precipitation (See Figure 5-7)
- **Climate Sensitivity:** Regionally speaking, it is the response of a climate model for a given amount of greenhouse gas increase. More narrowly defined it is the global average temperature increase that results from a doubling of carbon dioxide over pre-industrial values.
- **CMIP3, CMIP5:** Coupled Model Intercomparison Project Phases 3 and 5. "Foundational" collections of climate model projections, used in the Intergovernmental panel on Climate Change (IPCC) 2007 and IPCC 2013 reports, respectively
- **CNRM:** A CMIP5 climate model from the French National Centre of Meteorological Research (cnrm-cm5.1.rcp85),used in this report as a future scenario (Central scenario for both GLAC and ROMO) that is relatively close to the ensemble mean in temperature increase (+~2.5 ºC) and +~5-8% increase in precipitation (See Figure 5-7).
- **DEM:** Digital elevation model
- **DSHVM:** Distributed Hydrology Soil Vegetation Model
- **ESM:** earth system models, see GCM.
- **FIO:** A CMIP5 earth system model from the First Institute of Oceanography, State Oceanic Administration of China (fio-esm.1.rcp85), used in this report as a future scenario (Warm/Dry scenario for both areas) that is relatively lower in temperature increase (+~0.8-1.6 ºC) and -~5% decrease in precipitation (See Figure 5-7).
- **FLH:** Atmospheric freezing level height is the altitude in the free atmosphere at which the temperature is 0 °C
- **GCM:** Global Climate Model, 6 were used for this report from the IPCC 2013 class of models; X of these are actually earth system models (ESM), an advanced type of GCM which have the added capability to explicitly represent biogeochemical processes that interact with the physical climate. GCM is used as a general term referring to both kinds of models, ESM is used specifically for earth system models.

- **GISS:** A CMIP5 climate model from the NASA Goddard Institute for Space Studies (giss-e2-r.1.rcp45), used in this report as a future scenario (Warm/Wet scenario for both areas). Referred to as the "Least Change" scenario because it that is relatively lower temperature increase (+~1-1.3 ºC) and +~7-10% increase in precipitation (See Figure 5-7).
- **GLAC:** An area in Glacier National Park used as a spatial unit of analysis in this report
- **HADGEM:** A CMIP5 earth system model from the United Kingdom Meteorological Office Hadley Center (hadgem2-es.1.rcp85) used in this report as a future scenario (Hot/Very Wet scenario for ROMO only) that has relatively higher temperature increase (+~ 3.5 ºC) and -~5% decrease in precipitation.
- **Internal climate variability**: The variations in the climate, even for 30-year and longer averages, that can occur due to the interactions of the atmosphere, ocean, inland surface and cryosphere. This occurs even in the absence of anthropogenic climate change.
- **MODIS:** Moderate Resolution Imaging Spectroradiometer, a satellite remote sensing instrument carried on the Terra satellite
- **MIROC:** A CMIP5 earth system model from the Japanese Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies (miroc-esm-chem.1.rcp85), used in this report as a future scenario (Hot/Wet scenario for both areas). Referred to as the "Greatest Change" scenario because it has the highest temperature increase of the scenarios (+~4 ºC) and +~10-18% increase in precipitation (see Figure 5-7). This ESM has an atmospheric chemistry (CHEM) component coupled to the MIROC-ESM (http://maca.northwestknowledge.net/GCMs.php).
- **NDSI:** Normalized Difference Snow Index, a measure of snow cover, has a has a linear relationship to fractional snow cover (FSC)
- **North American Freezing Level Tracker**: NCEP/NCAR Global Reanalysis 2.5º x 2.5º grid data (http://www.wrcc.dri.edu/cwd/products/)
- **Octants:** Topographic aspect, or compass direction, was classified into eight directional bins, each representing 45° of compass arc, e.g; NW, N, NE, E, SE, S, SW, and W
- **Resolution:** The VIC modeling that was the basis for McKelvey was performed on a regular grid in latitude and longitude, with a grid size of 1/16 degree on a side. The distance between degrees of longitude varies due to the curvature of the Earth, and the east-west dimension of a gridbox is smaller than the north-south distance by a factor of the cosine of latitude. At 40°N latitude, the southern extent of Rocky Mountain National Park, the gridbox is ~5km by 7 km (~37km^2). Grid boxes at Glacier National Park (~48°N) are slightly smaller. When referring to the McKelvey study we will use the "1/16 degree" notation. The DHSVM modeling used in this study was performed on a uniform grid in the Universal Transverse Mercator (UTM) map projection, which allows a near-uniform grid size of 250m by 250m (0.0625 km^2) in both of the study areas.
- **ROMO:** An area in and around Rocky Mountain NP used as a spatial unit of analysis in this report
- **SCA:** Snow Covered Area (km^2)
- **SDD:** Snow Disappearance Date, the first Day of Year after March 1 where pixel is snow-free, defined as the date which NDSI/100 was less or equal to 0.1.
- **SNODAS:** Snow Data Assimilation System, a product of the NOAA National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC)

- **SWE:** Snow water equivalent (mm). For May, snow depth is assumed to be ~ 2.5 *SWE
- **TopoWx:**
- **Snow covered area, total:**Total area covered by snow within the study boundaries in square kilometers (km^2)
- **Snow covered area, fractional:** Percentage of the total land area that is covered by snow; this can be within the study boundaries, aspect area, or elevation bands
- **VIC:** Variable Infiltration Capacity hydrologic model
- **UTM:** Universal Transverse Mercator spatial coordinates

FIGURES – see separate file

From:	A J
To:	Grizzle, Betty
Subject:	Re: Wolverine and white markings
Date:	Monday, May 8, 2017 12:27:44 PM

I don't know what he means by more variation in Scandinavia. My impression is just the opposite. I'm not sure that Jens is familiar with all the different color patterns in NA wolverines, from very light to almost black and all the variations in between. Then again, maybe he meant to say less instead of more.

On Mon, May 8, 2017 at 9:00 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Audrey - Here is response from Jens regarding my questions about coloration:
>
> *Regarding coloration of wolverines in Sweden: In general it seems like there is more variation in coloration of Scandinavian wolverines compared to North American. I cannot recall that I have seen any wolverines with white paws or "extra coloration" over here. They are generally dark with varying levels of light chest pattern, in addition to the typical light band along the side of the body.*
>
> On Thu, May 4, 2017 at 11:04 AM, A J <222wsheridan@gmail.com> wrote:
>
>> Hi Betty
>> I don't think anyone has looked at white traits in wolverines on a global scale, either prevalence or genetic markers. White markings on the feet are common (but not dominant) in Alaska, at least on the North Slope and Southeast Alaska where I have worked. I have attached an unusual individual, which I believe was caught in Alaska. One trapper I know in NE Alaska showed me a "white" wolverine he captured. Not an albino, but white with cream highlights where black would occur on a "normal" wolverine. From what I know of wolverines in Scandinavia, there is much less white even in the chest pattern. Jens could speak to whether they have ever gotten a white-footed wolverine. There may be regional differences in the occurrence rate and prominence of white markings, which suggests a genetic marker that runs in the population until something changes it. I once asked a fur buyer in Fairbanks about regional differences, and he said there were differences in the size and color of the diamond on wolverines across Alaska.We didn't discuss white feet. Some wolverines, almost as rare as white ones, are nearly completely black. It would be interesting to see if there are genetic differences and if they change over time regionally. The "white-less" wolverines in Scandinavia may be because the population may have descended from a few dark individuals and could change over time as the population increases and expands and dispersers arrive from Russia. The local buyer has purchased wolverines from Russia. I will have to talk to him again to see if white feet occurred on the hides he purchases. It seems to me I recall Jeff Copeland mentioning that he thinks a dominant male in an area can determine the coloration of the individuals in an area and perhaps he has worked with genetics along these lines. It does seem that wolverines from Montana more commonly had larger areas of white on chest, legs, and feet than in other areas. Bob Inman certainly has captured individuals like this.
>>
>> On another subject, did you hear from Jens in response to your email? Did you ask him about the number of dens outside the snow model that they now have? He is going to try to photograph some of these den sites in the coming week.
>> Audrey
>>
>> On Thu, May 4, 2017 at 9:28 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>>
>>> Hi Audrey - You may have seen this OpEd from the Great Falls Tribune.

Wolverine study’s plan preferred to endangered species listing

GreatFalls Tribune/Opinion

May 2, 2017

During a multi-state survey this winter to establish a baseline of where wolverines live in the U.S., one of the solitary mountaineers was photographed by a motion-detecting camera 65 miles southeast of Great Falls in the Little Belt Mountains.... http://www.greatfallstribune.com/story/opinion/2017/05/02/wolverine-studys-plan-preferred-endangered-species-listing/101208748/

I noticed that one of the photographs (Pintler Mtns) shows a wolverine with white on its front paws. I had read (somewhere) about this interesting characteristic and ask Bob Inman if he knew whether this was unique to North America or Montana, and whether this has been observed in wolverines in Scandinavia. He said that they have seen fairly extensive white markings, often on the foot, in GYE and Montana, but did not know about other populations.

I also read the following account of almost all-white wolverines from Cardinal's report:

From Cardinal 2004 *Aboriginal Traditional Knowledge COSEWIC Status Report on Wolverine Gulo gulo Qavvik*: (page 7)
"A nearly all-white variant of wolverine has been trapped by hunters in the Kitikmeot region. Knowledge holders in the region state that this variety is very rare; in all of the other regions, only one other knowledge holder reported catching a wolverine that had a significant amount of white on it. Knowledge holders also mentioned that this variant has always occurred in this one area and reported their parents had caught this variety in the past. A pelt was also on display at the local HTC."

Question for you: Do you know if anyone has looked at these traits (on global scale) and how prevalent they are? And whether anyone has investigated the genetic markers for this?

Thanks.
--

Betty J. Grizzle, D.Env.
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
Carlsbad Fish and Wildlife Office
2177 Salk Ave, Suite 250
Carlsbad, CA 92008
760-431-9440, ext. 215
760-431-5901 fax

--

Betty J. Grizzle, D.Env.
Fish and Wildlife Biologist
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2177 Salk Ave, Suite 250
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From:	Doherty, Kevin
To:	Guinotte, John
Subject:	Re: Wolverine Report 5MAY 2017 -- including Exec. Summary
Date:	Tuesday, May 9, 2017 8:29:08 AM

are the figures the same?

On Mon, May 8, 2017 at 9:28 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
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134 Union Blvd., Lakewood, CO 80228
303-236-4264
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---------- Forwarded message ----------
From: **Joe Barsugli** <joseph.barsugli@noaa.gov>
Date: Fri, May 5, 2017 at 2:55 PM
Subject: Wolverine Report 5MAY 2017 -- including Exec. Summary
To: Stephen Torbit <Stephen_Torbit@fws.gov>, "Guinotte, John" <john_guinotte@fws.gov>, Andrea Ray <Andrea.Ray@noaa.gov>, Candida Dewes <Candida.Dewes@noaa.gov>, Imtiaz Rangwala <Imtiaz.Rangwala@noaa.gov>, Ben Livneh <ben.livneh@colorado.edu>, Aaron Joseph Heldmyer <Aaron.Heldmyer@colorado.edu>

Steve, John (and the team)

It has been hectic with me sick and Andrea at a conference, but A new version of the Text and figures have been uploaded to the drive.

Numerous changes:

- Figures have been updated/fixed, and a couple of figures added to the elevation dependence discussion for the model output.
- Executive Summary has been added to the text.
- Numerous comments from John and Kevin were addressed.

The main substantive changes are an expansion of the elevation-dependence discussion in the modeling section and the addition of the Executive summary. Other changes were either fixes to figures, or clarifications/re-writing to address comments from John and Kevin. There are many of these, and a few sections were re-organized to lead to better flow, but without changing the underlying content.

I am attaching a PDF and DOCX versions of the text here, but the .docx and .pdf version of text and figures are on the drive. I have ALSO included a "track changes" .docx file for those interested.

We have not gone through this with a fine toothed comb, so there may still be a few small things. But Better to get this to you now.

Joe

--
Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309
303-497-6042
PSD Science Board and
Attribution and Predictability Assessments Team Member

--

Kevin Doherty, PhD
Spatial Ecologist
USFWS Region 6 --Science Applications
134 Union Blvd, Lakewood, CO 80228
Phone: (303) 921-0524
Email: kevin_doherty@fws.gov

From:	Guinotte, John
To:	Stephen Torbit
Subject:	Re: Wolverine Report 5MAY 2017 -- including Exec. Summary
Date:	Wednesday, May 10, 2017 8:36:26 AM

Hey Steve, I'm out of the office next Friday, but Thurs would work. Can you give me a call on cell when you get a minute this am? cell is 206-915-2037. Thanks John

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

On Wed, May 10, 2017 at 8:28 AM, Stephen Torbit <Stephen_Torbit@fws.gov> wrote:

> Morning everyone. FWS was hit hard by the hail on Monday afternoon. We lost big parts of the roof of our building and the 6th floor, where all of us work, was flooded. We had to spend some time yesterday mopping up and clearing out electronics. No one can occupy their offices until we get electricity and fire alarms back on for the 6th floor. So, John, Kevin and I are working from home. I may get a temporary office next week.
>
> This has slowed down our review of your draft report a bit and John, Kevin and I need to review and huddle here soon. I suggest that we try and arrange a 2 hour meeting for later next week in Boulder at your offices to review the report and make decisions and recommendations regarding the final version.
>
> I am thinking Thursday or Friday. Please let us know what day and time might work best for you all up there and we will see what we can schedule.
>
> Thanks
>
> Steve
>
> Stephen C. Torbit
>
> Assistant Regional Director
>
> Science Applications

U.S. Fish and Wildlife Service

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Lakewood, Colorado 80228

303-236-4602 – Office

720-626-7504 – Cell

From: Joe Barsugli [mailto:joseph.barsugli@noaa.gov]
Sent: Friday, May 05, 2017 2:56 PM
To: Stephen Torbit; Guinotte, John; Andrea Ray; Candida Dewes; Imtiaz Rangwala; Ben Livneh; Aaron Joseph Heldmyer
Subject: Wolverine Report 5MAY 2017 -- including Exec. Summary

Steve, John (and the team)

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Joe

--

Joseph Barsugli, Research Scientist III

CIRES, UCB216

University of Colorado Boulder

Boulder CO 80309

303-497-6042

PSD Science Board and

Attribution and Predictability Assessments Team Member

From: Guinotte, John
To: Stephen Torbit
Subject: Re: Wolverine Report 5MAY 2017 -- including Exec. Summary
Date: Wednesday, May 10, 2017 8:38:14 AM

Scratch that last email. I was looking at the wrong week. I could do Friday next week in Boulder, but Thurs afternoon from 1-5pm wont work. We have a meeting w the WY field office all afternoon.

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
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> Stephen C. Torbit
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> Assistant Regional Director

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To: Stephen Torbit; Guinotte, John; Andrea Ray; Candida Dewes; Imtiaz Rangwala; Ben Livneh; Aaron Joseph Heldmyer
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University of Colorado Boulder

Boulder CO 80309

303-497-6042

PSD Science Board and

Attribution and Predictability Assessments Team Member

From:	Stephen Torbit
To:	Andrea Ray - NOAA Federal
Cc:	Joseph Barsugli; John Guinotte; Candida Dewes; Imtiaz Rangwala; Ben Livneh; Aaron Joseph Heldmyer; Kevin Doherty
Subject:	RE: Wolverine Report 5MAY 2017 -- including Exec. Summary
Date:	Wednesday, May 10, 2017 11:07:37 AM

Lets plan on Friday morning in your shop Maybe we could start about 9:30 and go until 11:30 or so.

Stephen C. Torbit
Assistant Regional Director
Science Applications
U.S. Fish and Wildlife Service
134 Union Blvd.
Lakewood, Colorado 80228
303-236-4602 – Office
720-626-7504 – Cell

From: Andrea Ray - NOAA Federal [mailto:andrea.ray@noaa.gov]
Sent: Wednesday, May 10, 2017 11:06 AM
To: Stephen Torbit
Cc: Joseph Barsugli; John Guinotte; Candida Dewes; Imtiaz Rangwala; Ben Livneh; Aaron Joseph Heldmyer; Kevin Doherty
Subject: Re: Wolverine Report 5MAY 2017 -- including Exec. Summary

Hi Steve, I'm sorry to hear about the building, what a mess! Next Thursday/Friday is fine with me, and we'll coordinate among ourselves and get back to you about times. I can tell you that Thursday afternoon, 18 May from 1-6p is a CIRES science symposium event that will involve most of the team, so it would be better to do it in the morning or Friday.

and -- welcome back. Andrea

On Wed, May 10, 2017 at 8:28 AM, Stephen Torbit <Stephen_Torbit@fws.gov> wrote:
Morning everyone. FWS was hit hard by the hail on Monday afternoon. We lost big parts of the roof of our building and the 6th floor, where all of us work, was flooded. We had to spend some time yesterday mopping up and clearing out electronics.   No one can occupy their offices until we get electricity and fire alarms back on for the 6th floor. So, John, Kevin and I are working from home. I may get a temporary office next week.

This has slowed down our review of your draft report a bit and John, Kevin and I need to review and huddle here soon. I suggest that we try and arrange a 2 hour meeting for later next week in Boulder at your offices to review the report and make decisions and recommendations regarding the final version.

I am thinking Thursday or Friday.   Please let us know what day and time might work best for you all up there and we will see what we can schedule.

Thanks
Steve

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Assistant Regional Director
Science Applications
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Lakewood, Colorado 80228
303-236-4602 – Office
720-626-7504 – Cell

From: Joe Barsugli [mailto:joseph.barsugli@noaa.gov]
Sent: Friday, May 05, 2017 2:56 PM
To: Stephen Torbit; Guinotte, John; Andrea Ray; Candida Dewes; Imtiaz Rangwala; Ben Livneh; Aaron Joseph Heldmyer
Subject: Wolverine Report 5MAY 2017 -- including Exec. Summary

Steve, John (and the team)

It has been hectic with me sick and Andrea at a conference, but A new version of the Text and figures have been uploaded to the drive.

Numerous changes:

- Figures have been updated/fixed, and a couple of figures added to the elevation dependence discussion for the model output.
- Executive Summary has been added to the text.
- Numerous comments from John and Kevin were addressed.

The main substantive changes are an expansion of the elevation-dependence discussion in the modeling section and the addition of the Executive summary. Other changes were either fixes to figures, or clarifications/re-writing to address comments from John and Kevin. There are many of these, and a few sections were re-organized to lead to better flow, but without changing the underlying content.

I am attaching a PDF and DOCX versions of the text here, but the .docx and .pdf version of text and figures are on the drive. I have ALSO included a "track changes" .docx file for those interested.

We have not gone through this with a fine toothed comb, so there may still be a few small things. But Better to get this to you now.

Joe

--
Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309

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PSD Science Board and
Attribution and Predictability Assessments Team Member

--
--
Andrea J. Ray, Ph.D.
NOAA Earth System Research Lab, Mailcode R/PSD1
325 Broadway, Boulder, CO 80305-3328
(tel) 303-497-6434
(fax) 303-497-6449
andrea.ray@noaa.gov
www.researchgate.net/profile/Andrea_Ray2

From: Guinotte, John
To: Kevin Doherty
Subject: Fwd: april 15 dhsvm outputs?
Date: Friday, May 12, 2017 8:15:06 AM

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

---------- Forwarded message ----------
From: **Joe Barsugli** <joseph.barsugli@noaa.gov>
Date: Thu, May 11, 2017 at 1:24 PM
Subject: Re: april 15 dhsvm outputs?
To: "Guinotte, John" <john_guinotte@fws.gov>, Stephen Torbit <Stephen_Torbit@fws.gov>, Andrea Ray <Andrea.Ray@noaa.gov>, Aaron Joseph Heldmyer <Aaron.Heldmyer@colorado.edu>, Ben Livneh <ben.livneh@colorado.edu>

John,

These outputs are not available from the current runs that Ben and Aaron produced, and would take some effort to produce on their part. Have you heard more information from the Wolverine biologists as to whether this is critical, or whether the May 1 output is sufficient? I am including Ben and Aaron on this e-mail thread in case they have more information to add.

Joe

On 5/11/2017 9:32 AM, Guinotte, John wrote:

> Hi Joe and Andrea,
>
> Do you have any updates on this from Ben or Aaron? I checked the google drive today and don't see any dhsvm outputs for April 15.
>
> Thanks John
>
> John Guinotte
> Fish and Wildlife Biologist
> Ecological Services
> U.S. Fish and Wildlife Service
> Mountain Prairie Region 6
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> 303-236-4264

john_guinotte@fws.gov

--
Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309
303-497-6042
PSD Science Board and
Attribution and Predictability Assessments Team Member

From:	Andrea Ray - NOAA Federal
To:	Stephen Torbit
Cc:	John Guinotte; Imtiaz Rangwala; Kevin Doherty
Subject:	Does 1:30 Friday 19th work? Re: Wolverine Report 5MAY 2017 -- including Exec. Summary
Date:	Friday, May 12, 2017 10:54:20 AM

That's the best time -- Ben isn't available in the morning, and I've got a noon-1:30 (that I'll put a hard stop on). Imtiaz and Ben aren't available at the same times, and we agreed that Ben is more critical for this meeting, we can call or email Imtiaz with questions.

once you confirm, I'll send out a calendar invitation
Thanks, Andrea

On Wed, May 10, 2017 at 11:17 AM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

> Hi Steve -- hold off until I've heard from people -- I have a separate email going around about schedules. Ben may not be available on Friday.
>
> I'll get back to you ASAP. Also, we're working on a list of reviewers.
>
> Andre
>
> On Wed, May 10, 2017 at 11:07 AM, Stephen Torbit <Stephen_Torbit@fws.gov> wrote:
>
>> Lets plan on Friday morning in your shop Maybe we could start about 9:30 and go until 11:30 or so.
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To: Stephen Torbit; Guinotte, John; Andrea Ray; Candida Dewes; Imtiaz Rangwala; Ben Livneh; Aaron Joseph Heldmyer
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Joseph Barsugli, Research Scientist III

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www.researchgate.net/profile/Andrea_Ray2

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andrea.ray@noaa.gov
www.researchgate.net/profile/Andrea_Ray2

From:	Guinotte, John
To:	Joseph Barsugli - NOAA Affiliate
Cc:	Stephen Torbit; Andrea Ray; Aaron Joseph Heldmyer; Ben Livneh
Subject:	Re: april 15 dhsvm outputs?
Date:	Friday, May 12, 2017 11:48:36 AM

Hi Joe, I confirmed with Betty that April 15 is needed.
Thanks John

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

On Thu, May 11, 2017 at 1:24 PM, Joe Barsugli <joseph.barsugli@noaa.gov> wrote:

> John,
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> > john_guinotte@fws.gov
>
> --

Joseph Barsugli, Research Scientist III
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Boulder CO 80309
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From:	Google Calendar on behalf of andrea.ray@noaa.gov
To:	john_guinotte@fws.gov; kevin_doherty@fws.gov; imtiaz.rangwala@noaa.gov; joseph.barsugli@noaa.gov; beli1098@colorado.edu; candida.dewes@noaa.gov; aahe1976@colorado.edu; jest6889@colorado.edu; stephen_torbit@fws.gov
Subject:	FWS Wolverine project meeting
Attachments:	invite.ics

This event has been changed.

more details » <https://www.google.com/calendar/event?
action=VIEW&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>

Changed: FWS Wolverine project meeting

Changed:
Let me know if anyone needs to be on via Go-to-meeting, I haven't set that up yet.

When
Changed: Fri May 19, 2017 1:30pm – 3:30pm Mountain Time
Where
Changed: DSRC - 1D708 (map <https://maps.google.com/maps?q=DSRC+-+1D708&hl=en>)
Calendar
john_guinotte@fws.gov
Who
• andrea.ray@noaa.gov
- organizer
• kevin_doherty@fws.gov
• imtiaz.rangwala@noaa.gov
• joseph.barsugli@noaa.gov
• john_guinotte@fws.gov
• beli1098@colorado.edu
• candida.dewes@noaa.gov
• aahe1976@colorado.edu
• jest6889@colorado.edu
• stephen_torbit@fws.gov

Going?
Yes <https://www.google.com/calendar/event?
action=RESPOND&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&rst=1&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>
-
Maybe <https://www.google.com/calendar/event?
action=RESPOND&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&rst=3&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>
-
No <https://www.google.com/calendar/event?
action=RESPOND&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&rst=2&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>
more options » <https://www.google.com/calendar/event?
action=VIEW&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>

Attachment 20170512 131859_EM_FWS Wolverine project meeting.ics (3103 Bytes) cannot be converted to PDF format.

From:	Jodi Bush
To:	Grizzle, Betty
Cc:	Guinotte, John; Shoemaker, Justin; Conor McGowan
Subject:	Re: Wolverine PVA call
Date:	Monday, May 15, 2017 9:48:07 AM

Call in the info? JB

Sent from my iPhone

On Apr 27, 2017, at 2:24 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Yes, that's fine.
>
> On Thu, Apr 27, 2017 at 1:21 PM, Guinotte, John <john_guinotte@fws.gov> wrote:
>
> > Works for me Justin.
> >
> > John Guinotte
> > Fish and Wildlife Biologist
> > Ecological Services
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> > Mountain Prairie Region 6
> > 134 Union Blvd., Lakewood, CO 80228
> > 303-236-4264
> > john_guinotte@fws.gov
> >
> > On Thu, Apr 27, 2017 at 2:19 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:
> >
> > > All,
> > >
> > > How about a call tomorrow at 1:00 Central to catch up on the PVA effort? Let me know if that works and I'll set it up.
> > >
> > > Justin Shoemaker
> > > Classification Biologist
> > > U.S. Fish and Wildlife Service, Region 6
> > > Phone: 309-757-5800 x214
> > > Email: justin_shoemaker@fws.gov
>
> --
>
> Betty J. Grizzle, D.Env.
> Fish and Wildlife Biologist
> U.S. Fish and Wildlife Service
> Carlsbad Fish and Wildlife Office

2177 Salk Ave, Suite 250
Carlsbad, CA 92008
760-431-9440, ext. 215
760-431-5901 fax

From:	Guinotte, John
To:	McGowan, Conor
Cc:	Jodi Bush; Conor McGowan; Grizzle, Betty; Shoemaker, Justin
Subject:	Re: Wolverine PVA call
Date:	Monday, May 15, 2017 10:21:37 AM

Hi Conor, I think there is some confusion here. The call at 11am mountain today is on wolverine genetics, not PVA. No need for you to be on.
Best, John

John Guinotte
Fish and Wildlife Biologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

On Mon, May 15, 2017 at 10:15 AM, McGowan, Conor <cmcgowan@usgs.gov> wrote:

> This is the first I have heard of any call.   It seems that neither of my email addresses we cc'd. What day and time are we having a call, and do I need to be on the line?
>
> On Mon, May 15, 2017 at 10:48 AM, Jodi Bush <jodi_bush@fws.gov> wrote:
>
>> Call in the info? JB
>>
>> Sent from my iPhone
>>
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Betty J. Grizzle, D.Env.
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
Carlsbad Fish and Wildlife Office
2177 Salk Ave, Suite 250
Carlsbad, CA 92008
760-431-9440, ext. 215
760-431-5901 fax

--

Conor P. McGowan, Ph.D.
Assistant Leader and Associate Research Professor
USGS, Alabama Cooperative Fish and Wildlife Research Unit
School of Forestry and Wildlife Sciences,
Auburn University
Auburn, AL 36849-5418

EM:cmcgowan@usgs.gov
Ph:334 844 9231
www.auburn.edu/~cpm0014

From:	Google Calendar on behalf of andrea.ray@noaa.gov
To:	john_guinotte@fws.gov; imtiaz.rangwala@noaa.gov; don.murray@noaa.gov; jest6889@colorado.edu; aahe1976@colorado.edu; coury.ditch@noaa.gov; beli1098@colorado.edu; joseph.barsugli@noaa.gov; candida.dewes@noaa.gov; kevin_doherty@fws.gov; stephen_torbit@fws.gov
Subject:	FWS Wolverine project meeting - updated time 2pm
Start:	Friday, May 19, 2017 2:00:00 PM
End:	Friday, May 19, 2017 4:00:00 PM
Location:	DSRC - 1D708 and go-to meeting
Attachments:	invite.ics

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action=VIEW&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>

Changed: FWS Wolverine project meeting - updated time 2pm

Changed: Please join my meeting from your computer, tablet or smartphone.
https://global.gotomeeting.com/join/925942125 <https://www.google.com/url?q=https%3A%2F%2Fglobal.gotomeeting.com%2Fjoin%2F925942125&sa=D&ust=1494889819730000&usg=AFQjCNGVWCxlbjP6rF_SRYnodN1TTietUQ>

You can also dial in using your phone.
United States +1 (408) 650-3123

Access Code: 925-942-125

When
Changed: Fri May 19, 2017 2pm – 4pm Mountain Time
Where
Changed: DSRC - 1D708 and go-to meeting (map <https://maps.google.com/maps?q=DSRC+-+1D708+and+go-to+meeting&hl=en>)
Calendar
john_guinotte@fws.gov
Who
• andrea.ray@noaa.gov
- organizer
• imtiaz.rangwala@noaa.gov
• don.murray@noaa.gov
• jest6889@colorado.edu
• aahe1976@colorado.edu
• coury.ditch@noaa.gov
• beli1098@colorado.edu
• joseph.barsugli@noaa.gov
• john_guinotte@fws.gov
• candida.dewes@noaa.gov
• kevin_doherty@fws.gov
• stephen_torbit@fws.gov

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-
Maybe <https://www.google.com/calendar/event?
action=RESPOND&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&rst=3&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>
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action=RESPOND&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&rst=2&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>
more options » <https://www.google.com/calendar/event?
action=VIEW&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>

hment 20170515 151427_EM_FWS Wolverine project meeting - updated time .ics (3595 Bytes) cannot be converted to PDF fo

From: Andrea Ray - NOAA Federal
To: Stephen Torbit
Cc: John Guinotte; Joseph Barsugli
Subject: Re: Friday 19 May 1:30-3:30 Re: Wolverine Report 5MAY 2017 -- including Exec. Summary
Date: Tuesday, May 16, 2017 11:15:14 AM

We have people to ask about this :) ... we'll keep it in mind and let you know that the snow gurus here say. my guess is that the roads are now so warm that anything that falls over night will have melted by afternoon. But safety will rule!

If we can't meet Friday, would our usual time Monday 3-5 work? I'll make a back up plan.

On Tue, May 16, 2017 at 10:42 AM, Stephen Torbit <Stephen_Torbit@fws.gov> wrote:

> Sooo I am sure you NOAA folks are totally up on the storm that is coming, but we may have to postpone the meeting on Friday depending on how much snow we get and what the wind/temps are like on 93. Don't want to decide yet, just putting it out there.
>
> ST
>
> Stephen C. Torbit
>
> Assistant Regional Director
>
> Science Applications
>
> U.S. Fish and Wildlife Service
>
> 134 Union Blvd.
>
> Lakewood, Colorado 80228
>
> 303-236-4602 – Office
>
> 720-626-7504 – Cell
>
> **From:** Andrea Ray - NOAA Federal [mailto:andrea.ray@noaa.gov]
> **Sent:** Monday, May 15, 2017 3:08 PM
> **To:** Guinotte, John
> **Cc:** Stephen Torbit; Joseph Barsugli
>
> **Subject:** Re: Friday 19 May 1:30-3:30 Re: Wolverine Report 5MAY 2017 -- including Exec. Summary

thanks! we'll cover a few things and Ben will join by phone when he's done with his other meeting at 2:30

On Mon, May 15, 2017 at 2:55 PM, Guinotte, John <john_guinotte@fws.gov> wrote:

Yes, that will work for me.

Best, John

John Guinotte
Fish and Wildlife Biologist

Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6

134 Union Blvd., Lakewood, CO 80228

303-236-4264
john_guinotte@fws.gov

On Mon, May 15, 2017 at 2:22 PM, Stephen Torbit <Stephen_Torbit@fws.gov> wrote:

Andrea, I can start later, prefer 2 pm if possible. But I think we might go a bit late and know how long it takes to get back to Golden area on 93 on Friday afternoons.

John, we may need to have dinner in Boulder after the NOAA meeting so that traffic can run its course. Can you meet later as Andrea has suggested?

Steve

Stephen C. Torbit

Assistant Regional Director

Science Applications

U.S. Fish and Wildlife Service

134 Union Blvd.

Lakewood, Colorado 80228

303-236-4602 – Office

720-626-7504 – Cell

From: Andrea Ray - NOAA Federal [mailto:andrea.ray@noaa.gov]
Sent: Saturday, May 13, 2017 12:36 PM
To: Stephen Torbit; John Guinotte; Joseph Barsugli
Subject: Re: Friday 19 May 1:30-3:30 Re: Wolverine Report 5MAY 2017 -- including Exec. Summary

Turns out that Ben scheduled something until 2:30 while we were sorting out time. So -- could we start a little later? He can join us by phone at 2:30, but I worry that his other meeting may run late. Could we start at 2 or 2:30? we'll have a few things to go over that don't include Ben, but we'll need him for part of this.

Let me know, thanks for patience with herding cats. Andrea

On Fri, May 12, 2017 at 2:26 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

Hi All, we'll have a FWS Wolverine project meeting next Friday 19 May 1:30-3:30 in the usual room, 1D708. You should have a googlecal invitation too.

Let me know if anyone will not be here in person and needs to be on via Go-to-meeting, I haven't set that up, but I can.

Andrea

On Wed, May 10, 2017 at 11:05 AM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

Hi Steve, I'm sorry to hear about the building, what a mess! Next Thursday/Friday is fine with me, and we'll coordinate among ourselves and get back to you about times. I can tell you that Thursday afternoon, 18 May from 1-6p is a CIRES science symposium event that will involve most of the team, so it would be better to do it in the morning or Friday.

and -- welcome back. Andrea

On Wed, May 10, 2017 at 8:28 AM, Stephen Torbit <Stephen_Torbit@fws.gov> wrote:

Morning everyone. FWS was hit hard by the hail on Monday afternoon. We lost big parts of the roof of our building and the 6th floor, where all of us work, was flooded. We had to spend some time yesterday mopping up and clearing out electronics. No one can occupy their offices until we get electricity and fire alarms back on for the 6th floor. So, John, Kevin and I are working from home. I may get a temporary office next week.

This has slowed down our review of your draft report a bit and John, Kevin and I need to review and huddle here soon. I suggest that we try and arrange a 2 hour meeting for later next week in Boulder at your offices to review the report and make decisions and recommendations regarding the final version.

I am thinking Thursday or Friday. Please let us know what day and time might work best for you all up there and we will see what we can schedule.

Thanks

Steve

Stephen C. Torbit

Assistant Regional Director

Science Applications

U.S. Fish and Wildlife Service

134 Union Blvd.

Lakewood, Colorado 80228

303-236-4602 – Office

720-626-7504 – Cell

From: Joe Barsugli [mailto:joseph.barsugli@noaa.gov]
Sent: Friday, May 05, 2017 2:56 PM
To: Stephen Torbit; Guinotte, John; Andrea Ray; Candida Dewes; Imtiaz Rangwala; Ben Livneh; Aaron Joseph Heldmyer
Subject: Wolverine Report 5MAY 2017 -- including Exec. Summary

Steve, John (and the team)

It has been hectic with me sick and Andrea at a conference, but A new version of the Text and figures have been uploaded to the drive.

Numerous changes:

- Figures have been updated/fixed, and a couple of figures added to the elevation dependence discussion for the model output.
- Executive Summary has been added to the text.
- Numerous comments from John and Kevin were addressed.

The main substantive changes are an expansion of the elevation-dependence discussion in the modeling section and the addition of the Executive summary. Other changes were either fixes to figures, or clarifications/re-writing to address comments from John and Kevin. There are many of these, and a few sections were re-organized to lead to better flow, but without changing the underlying content.

I am attaching a PDF and DOCX versions of the text here, but the .docx and .pdf version of text and figures are on the drive. I have ALSO included a "track changes" .docx file for those interested.

We have not gone through this with a fine toothed comb, so there may still be a few small things. But Better to get this to you now.

Joe

--

Joseph Barsugli, Research Scientist III

CIRES, UCB216

University of Colorado Boulder

Boulder CO 80309

303-497-6042

PSD Science Board and

Attribution and Predictability Assessments Team Member

--

--

Andrea J. Ray, Ph.D.
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325 Broadway, Boulder, CO 80305-3328
(tel) 303-497-6434
(fax) 303-497-6449
andrea.ray@noaa.gov

www.researchgate.net/profile/Andrea_Ray2

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Andrea J. Ray, Ph.D.
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325 Broadway, Boulder, CO 80305-3328
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andrea.ray@noaa.gov

www.researchgate.net/profile/Andrea_Ray2

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Andrea J. Ray, Ph.D.

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325 Broadway, Boulder, CO 80305-3328
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(fax) 303-497-6449
andrea.ray@noaa.gov

www.researchgate.net/profile/Andrea_Ray2

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325 Broadway, Boulder, CO 80305-3328
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(fax) 303-497-6449
andrea.ray@noaa.gov

www.researchgate.net/profile/Andrea_Ray2

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325 Broadway, Boulder, CO 80305-3328
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(fax) 303-497-6449
andrea.ray@noaa.gov
www.researchgate.net/profile/Andrea_Ray2

From:	Google Calendar on behalf of andrea.ray@noaa.gov
To:	john_guinotte@fws.gov; joseph.barsugli@noaa.gov; jest6889@colorado.edu; candida.dewes@noaa.gov; beli1098@colorado.edu; stephen_torbit@fws.gov; don.murray@noaa.gov; aahe1976@colorado.edu; kevin_doherty@fws.gov; coury.ditch@noaa.gov; imtiaz.rangwala@noaa.gov
Subject:	FWS Wolverine project meeting - now in 1D403 & updated time 2pm
Attachments:	invite.ics

This event has been changed.

more details » <https://www.google.com/calendar/event?
action=VIEW&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>

Changed: FWS Wolverine project meeting - now in 1D403 & updated time 2pm

Changed: We've been bumped to 1D403, which is on a side hall before you get to the usual room

Please join my meeting from your computer, tablet or smartphone.
https://global.gotomeeting.com/join/925942125 <https://www.google.com/url?q=https%3A%2F%2Fglobal.gotomeeting.com%2Fjoin%2F925942125&sa=D&ust=1494968909247000&usg=AFQjCNEWwewRD8gAlvk-ZHVrMvi3ZfcrCg>

You can also dial in using your phone.
United States +1 (408) 650-3123

Access Code: 925-942-125

When
Fri May 19, 2017 2pm – 4pm Mountain Time
Where
Changed: DSRC 1D403 go-to meeting (map <https://maps.google.com/maps?q=DSRC+1D403+go-to+meeting&hl=en>)
Calendar
john_guinotte@fws.gov
Who
• andrea.ray@noaa.gov
- organizer
• joseph.barsugli@noaa.gov
• jest6889@colorado.edu
• candida.dewes@noaa.gov
• beli1098@colorado.edu
• john_guinotte@fws.gov
• stephen_torbit@fws.gov
• don.murray@noaa.gov
• aahe1976@colorado.edu
• kevin_doherty@fws.gov
• coury.ditch@noaa.gov
• imtiaz.rangwala@noaa.gov

Going?
Yes <https://www.google.com/calendar/event?
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Maybe <https://www.google.com/calendar/event?
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No <https://www.google.com/calendar/event?
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more options » <https://www.google.com/calendar/event?
action=VIEW&eid=MnE2M3R1NHFkcHBmOXRyM2w1Mmt1ZThhaG9fMjAxNzA0MTdUMjEwMDAwWiBqb2huX2d1aW5vdHRlQGZ3cy5nb3Y&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjJmYjJiOTJkMjQ3ODc0M2E3ZjVmMTZkY2ZhZDY5NTQ5MjI2ZmE2NDA&ctz=America/Denver&hl=en>

nment 20170516 130846_EM_FWS Wolverine project meeting - now in 1D403 .ics (3492 Bytes) cannot be converted to PDF fo

From: Andrea Ray - NOAA Federal
To: Steve Torbit; John Guinotte; Ben Livneh; Joseph Barsugli; Candida Dewes - NOAA Affiliate; Imtiaz Rangwala; Aaron Joseph Heldmyer
Subject: Friday 19 May 2-4 Wolverine & possible "snow date" Wolverine
Date: Tuesday, May 16, 2017 4:33:39 PM

Hi all, just wanted to confirm that we're on for a slightly later time, 2p, to discuss the wolverine report with FWS , and we'll be in 1D708 instead of the usual room. John and Steve will be here in person, barring weather...

And speaking of weather -- there's a chance of a fair amount of snow on thurs night into Friday. I just checked in with Klaus Wolter, and he's working up a forecast now. He says it could be "historic" -- the NOAA people will know that this is partly Klaus' enthusiasm for snow, but also the risks he's seeing in the models. the area had 19" of snow in late may1931 he says, so its not without precedent! (FWS, I'll forward the message from Klaus when I get it). NWS isn't saying anything yet. I'd caution that any snow that does fall will land on warm pavement, and the low thursday night is a little above freezing - it will take a bit of snow for it to stick and persist until Friday afternoon. But I'm not the expert!

if weather cancels this, we might have the meeting anyway by go-to meeting (its reserved)-- but I'd like to hold our usual time, 3-5p on Monday, as a back up -- let me know if that doesnt work for you or if you could only be in the meeting part of the time,

Thanks, Andrea
--
--
Andrea J. Ray, Ph.D.
NOAA Earth System Research Lab, Mailcode R/PSD1
325 Broadway, Boulder, CO 80305-3328
(tel) 303-497-6434
(fax) 303-497-6449
andrea.ray@noaa.gov
www.researchgate.net/profile/Andrea_Ray2

From: Google Calendar on behalf of andrea.ray@noaa.gov
To: john_guinotte@fws.gov; jest6889@colorado.edu; stephen_torbit@fws.gov; beli1098@colorado.edu; don.murray@noaa.gov; aahe1976@colorado.edu; joseph.barsugli@noaa.gov; candida.dewes@noaa.gov; imtiaz.rangwala@noaa.gov; coury.ditch@noaa.gov
Subject: HOLD alt FWS Wolverine meeting -- in case Friday is snowed out
Attachments: invite.ics

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more details » <https://www.google.com/calendar/event?
action=VIEW&eid=dTVnb3N1NXRmODliMmdyOGlhY3NpMmU4NDAgam9obl9ndWlub3R0ZUBmd3MuZ292&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjI5YTk4MTdkODljNzI1NmUzOWFjYzAzODRhOTk5OTc0N2ZlOWFlNGY&ctz=America/Denver&hl=en>

HOLD alt FWS Wolverine meeting -- in case Friday is snowed out

Holding this time in case Steve and John can't make it here on Friday afternoon

https://global.gotomeeting.com/join/925942125 <https://www.google.com/url?q=https%3A%2F%2Fglobal.gotomeeting.com%2Fjoin%2F925942125&sa=D&ust=1494984230360000&usg=AFQjCNEFr3C0T3NKu53QR6k2SkjEH0o__Q>
You can also dial in using your phone.
United States +1 (408) 650-3123
Access Code: 925-942-125

When
Mon May 22, 2017 3pm – 4pm Mountain Time
Where
DSRC - 1D708 (map <https://maps.google.com/maps?q=DSRC+-+1D708&hl=en>)
Calendar
john_guinotte@fws.gov
Who
• andrea.ray@noaa.gov
- organizer
• jest6889@colorado.edu
• john_guinotte@fws.gov
• stephen_torbit@fws.gov
• beli1098@colorado.edu
• don.murray@noaa.gov
• aahe1976@colorado.edu
• joseph.barsugli@noaa.gov
• candida.dewes@noaa.gov
• imtiaz.rangwala@noaa.gov
• coury.ditch@noaa.gov

Going?
Yes <https://www.google.com/calendar/event?
action=RESPOND&eid=dTVnb3N1NXRmODliMmdyOGlhY3NpMmU4NDAgam9obl9ndWlub3R0ZUBmd3MuZ292&rst=1&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjI5YTk4MTdkODljNzI1NmUzOWFjYzAzODRhOTk5OTc0N2ZlOWFlNGY&ctz=America/Denver&hl=en>
-
Maybe <https://www.google.com/calendar/event?
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-
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more options » <https://www.google.com/calendar/event?
action=VIEW&eid=dTVnb3N1NXRmODliMmdyOGlhY3NpMmU4NDAgam9obl9ndWlub3R0ZUBmd3MuZ292&tok=MTkjYW5kcmVhLnJheUBub2FhLmdvdjI5YTk4MTdkODljNzI1NmUzOWFjYzAzODRhOTk5OTc0N2ZlOWFlNGY&ctz=America/Denver&hl=en>

hment 20170516 172410_EM_HOLD alt FWS Wolverine meeting -- in case Fri.ics (2954 Bytes) cannot be converted to PDF fo

From:	Google Calendar on behalf of andrea.ray@noaa.gov
To:	john_guinotte@fws.gov
Subject:	HOLD alt FWS Wolverine meeting -- in case Friday is snowed out
Attachments:	invite.ics

This event has been canceled and removed from your calendar.

HOLD alt FWS Wolverine meeting -- in case Friday is snowed out

Holding this time in case Steve and John can't make it here on Friday afternoon

https://global.gotomeeting.com/join/925942125 <https://www.google.com/url?q=https%3A%2F%2Fglobal.gotomeeting.com%2Fjoin%2F925942125&sa=D&ust=1495050980297000&usg=AFQjCNHdzxoExR7qCpRuAru8cINTXbzF-g>
You can also dial in using your phone.
United States +1 (408) 650-3123
Access Code: 925-942-125

When
Mon May 22, 2017 3pm – 4pm Mountain Time
Where
DSRC - 1D708 (map <https://maps.google.com/maps?q=DSRC+-+1D708&hl=en>)
Calendar
john_guinotte@fws.gov
Who
• andrea.ray@noaa.gov
- organizer
• jest6889@colorado.edu
• candida.dewes@noaa.gov
• coury.ditch@noaa.gov
• don.murray@noaa.gov
• beli1098@colorado.edu
• john_guinotte@fws.gov
• joseph.barsugli@noaa.gov
• imtiaz.rangwala@noaa.gov
• aahe1976@colorado.edu
• stephen_torbit@fws.gov
Invitation from Google Calendar <https://www.google.com/calendar/>

hment 20170517 115631_EM_HOLD alt FWS Wolverine meeting -- in case Fri.ics (2559 Bytes) cannot be converted to PDF fo

From: Bush, Jodi
To: Stephen Torbit
Cc: Betty Grizzle; Justin Shoemaker
Subject: Re: Information on the Wolverine Genetic research
Date: Thursday, May 18, 2017 2:23:54 PM

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ok. I sent on the questions with a little explanation so they can likely wait a little bit.

Snow missed us in Helena but hit missoula and elsewhere - it just rained like heck. Be safe.
JB

Jodi L. Bush
Office Supervisor
Montana State Ecological Services Office
585 Shepard Way, Suite 1
Helena, MT 59601
(406) 449-5225, ext.205

On Thu, May 18, 2017 at 2:13 PM, Stephen Torbit <Stephen_Torbit@fws.gov> wrote:

> I can send some info from Betty that I edited, but there have been developments we should talk about. I am jammed up with wolverine climate stuff for the next couple of days, so maybe we can discuss next week when Betty is in Denver. Glad she is coming next week, we are getting slammed with snow.
>
> Stephen Torbit Ph.D.
> ARD - Science Applications
> Region 6
> Fish and Wildlife Service
> Office: 303-236-4602
> Cell: 720-626-7504
> stephen_torbit@fws.gov
>
> **From:** Bush, Jodi [mailto:jodi_bush@fws.gov]
> **Sent:** Thursday, May 18, 2017 2:10 PM
> **To:** Betty Grizzle; Stephen Torbit
> **Cc:** Justin Shoemaker
> **Subject:** Information on the Wolverine Genetic research
>
> Hey folks- do we have a short writeup on what we are trying to do for the Wolverine genetic work? I'm getting asked questions by our other regions (Noreen has asked for money and they want to know what they are paying for), and want to provide them with a succinct response. Thanks. JB

Jodi L. Bush

Office Supervisor

Montana State Ecological Services Office

585 Shepard Way, Suite 1

Helena, MT 59601

(406) 449-5225, ext.205

From:	Andrea Ray - NOAA Federal
To:	Guinotte, John
Cc:	Stephen Torbit
Subject:	Re: Invitation: HOLD alt FWS Wolverine meeting -- in case Friday is snowe... @ Mon May 22, 2017 3pm - 4pm (john_guinotte@fws.gov)
Date:	Thursday, May 18, 2017 8:14:48 PM

Hi John and Steve, I'm more optimistic about meeting Friday afternoon, so lets check in mid morning when we've got a better sense of things.

NWS has backed off the winter storm warning to end earlier tomorrow, around noon, and they're now saying "Snowfall intensity is expected to decrease overnight with light to occasional moderate snow at times late tonight Friday morning." It's barely going to get below freezing tonight.

Safety should be the priority of course! If you can't come up, I'd suggest we go ahead using the go-to meeting, b/c its going to be tricky to get everyone together. I haven't checked others' schedules yet. I'm out of the office Wed-Fri next week, although there's some times when I could call in on Wednesday, and in the morning on Thursday and Friday.

So lets see how the weather is tomorrow, and hopefully this will work!

Andrea

On Wed, May 17, 2017 at 6:01 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Hi Andrea,
> If we get snowed out on Friday, Mon and Tues are bad for Steve and I as we have Betty Grizzle, the lead wolverine biologist, here for a briefing. Lets hope we are fine for Friday.
> Best, John
>
> John Guinotte
> Fish and Wildlife Biologist
> Ecological Services
> U.S. Fish and Wildlife Service
> Mountain Prairie Region 6
> 134 Union Blvd., Lakewood, CO 80228
> 303-236-4264
> john_guinotte@fws.gov
>
> On Tue, May 16, 2017 at 5:23 PM, <andrea.ray@noaa.gov> wrote:
>
> > **HOLD alt FWS Wolverine meeting -- in case Friday is snowed out** **more details »**
> >
> > Holding this time in case Steve and John can't make it here on Friday afternoon
> >
> > https://global.gotomeeting.com/join/925942125
> > You can also dial in using your phone.
> > United States +1 (408) 650-3123
> > Access Code: 925-942-125

When Mon May 22, 2017 3pm – 4pm Mountain Time

Where DSRC - 1D708 (map)

Calendar john_guinotte@fws.gov

Who
- andrea.ray@noaa.gov - organizer
- jest6889@colorado.edu
- john_guinotte@fws.gov
- stephen_torbit@fws.gov
- beli1098@colorado.edu
- don.murray@noaa.gov
- aahe1976@colorado.edu
- joseph.barsugli@noaa.gov
- candida.dewes@noaa.gov
- imtiaz.rangwala@noaa.gov
- coury.ditch@noaa.gov

Going? **Yes** - **Maybe** - **No** more options »

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Andrea J. Ray, Ph.D.
NOAA Earth System Research Lab, Mailcode R/PSD1
325 Broadway, Boulder, CO 80305-3328
(tel) 303-497-6434
(fax) 303-497-6449
andrea.ray@noaa.gov
www.researchgate.net/profile/Andrea_Ray2

From:	Stephen Torbit
To:	Andrea Ray - NOAA Federal
Cc:	Guinotte, John
Subject:	Re: Invitation: HOLD alt FWS Wolverine meeting -- in case Friday is snowe... @ Mon May 22, 2017 3pm - 4pm (john_guinotte@fws.gov)
Date:	Thursday, May 18, 2017 9:10:14 PM

I think we will be good. There was a big mtn. lion meeting in Estes today and I talked to the wolverine guy from Montana that was in Estes. He made it down just fine tonight, so I think we will be fine, but will check in at mid-morning.

Sent from my iPad

On May 18, 2017, at 8:14 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

> Hi John and Steve, I'm more optimistic about meeting Friday afternoon, so lets check in mid morning when we've got a better sense of things.
>
> NWS has backed off the winter storm warning to end earlier tomorrow, around noon, and they're now saying "Snowfall intensity is expected to decrease overnight with light to occasional moderate snow at times late tonight Friday morning." It's barely going to get below freezing tonight.
>
> Safety should be the priority of course! If you can't come up, I'd suggest we go ahead using the go-to meeting, b/c its going to be tricky to get everyone together. I haven't checked others' schedules yet. I'm out of the office Wed-Fri next week, although there's some times when I could call in on Wednesday, and in the morning on Thursday and Friday.
>
> So lets see how the weather is tomorrow, and hopefully this will work!
>
> Andrea
>
> On Wed, May 17, 2017 at 6:01 AM, Guinotte, John <john_guinotte@fws.gov> wrote:
>
>> Hi Andrea,
>> If we get snowed out on Friday, Mon and Tues are bad for Steve and I as we have Betty Grizzle, the lead wolverine biologist, here for a briefing. Lets hope we are fine for Friday.
>> Best, John
>>
>> John Guinotte
>> Fish and Wildlife Biologist
>> Ecological Services
>> U.S. Fish and Wildlife Service
>> Mountain Prairie Region 6
>> 134 Union Blvd., Lakewood, CO 80228
>> 303-236-4264
>> john_guinotte@fws.gov

On Tue, May 16, 2017 at 5:23 PM, <andrea.ray@noaa.gov> wrote:

HOLD alt FWS Wolverine meeting -- in case Friday is snowed out **more details »**

Holding this time in case Steve and John can't make it here on Friday afternoon

https://global.gotomeeting.com/join/925942125
You can also dial in using your phone.
United States +1 (408) 650-3123
Access Code: 925-942-125

When	Mon May 22, 2017 3pm – 4pm Mountain Time
Where	DSRC - 1D708 (map)
Calendar	john_guinotte@fws.gov
Who	• andrea.ray@noaa.gov - organizer • jest6889@colorado.edu • john_guinotte@fws.gov • stephen_torbit@fws.gov • beli1098@colorado.edu • don.murray@noaa.gov • aahe1976@colorado.edu • joseph.barsugli@noaa.gov • candida.dewes@noaa.gov • imtiaz.rangwala@noaa.gov • coury.ditch@noaa.gov

Going? **Yes** - **Maybe** - **No** more options »

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--
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From:	Andrea Ray - NOAA Federal
To:	Stephen Torbit
Cc:	Guinotte, John
Subject:	Re: Invitation: HOLD alt FWS Wolverine meeting -- in case Friday is snowe... @ Mon May 22, 2017 3pm - 4pm (john_guinotte@fws.gov)
Date:	Friday, May 19, 2017 11:18:00 AM

Confirming we're on?? no indication that roads are an issue up here, although there's places where there's a lot of water running off. I thought we might have a lot of branches/trees down, but doesnt look bad -- it got warm enough while it was snowing yesterday that a lot of the snow on leaves fell off.

thanks, Andrea

On Thu, May 18, 2017 at 9:10 PM, Stephen Torbit <stephen_torbit@fws.gov> wrote:

> I think we will be good. There was a big mtn. lion meeting in Estes today and I talked to the wolverine guy from Montana that was in Estes. He made it down just fine tonight, so I think we will be fine, but will check in at mid-morning.
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Going? **Yes** - **Maybe** - **No** more options »

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To:	Andrea Ray - NOAA Federal
Cc:	John Guinotte
Subject:	RE: Invitation: HOLD alt FWS Wolverine meeting -- in case Friday is snowe... @ Mon May 22, 2017 3pm - 4pm (john_guinotte@fws.gov)
Date:	Friday, May 19, 2017 12:03:57 PM

We are on, we will be leaving at 1 to get to Boulder. We will see you soon.

Stephen C. Torbit
Assistant Regional Director
Science Applications
U.S. Fish and Wildlife Service
134 Union Blvd.
Lakewood, Colorado 80228
303-236-4602 – Office
720-626-7504 – Cell

From: Andrea Ray - NOAA Federal [mailto:andrea.ray@noaa.gov]
Sent: Friday, May 19, 2017 11:18 AM
To: Stephen Torbit
Cc: Guinotte, John
Subject: Re: Invitation: HOLD alt FWS Wolverine meeting -- in case Friday is snowe... @ Mon May 22, 2017 3pm - 4pm (john_guinotte@fws.gov)

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From:	Joe Barsugli
To:	Guinotte, John; Stephen Torbit; kevin_doherty@fws.gov
Subject:	Fwd: Re: DHSVM earlier output (Mar1, MAr15, Arp1 Apr15)
Date:	Friday, May 19, 2017 3:06:20 PM

-------- Forwarded Message --------
Subject: Re: DHSVM earlier output
Date: Tue, 16 May 2017 12:15:02 -0600
From: Aaron Joseph Heldmyer <Aaron.Heldmyer@colorado.edu>
Reply-To: Aaron.Heldmyer@colorado.edu
To: Ben Livneh <Ben.Livneh@colorado.edu>
CC: Joe Barsugli <joseph.barsugli@noaa.gov>, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov>

Hi everyone,

Hot off the presses - ASCII rasters for GLAC and ROMO for Mar 1, Mar 15, Apr 1, and Apr 15 from 1998-2013. I checked over a few maps and they appear reasonable, but please let me know if there's anything that seems off.

Find them at: FWS - Wolverine > Data and Maps > DHSVM_Delta_Maps > .Mar+Apr

On Sat, May 13, 2017 at 9:10 AM, Aaron Joseph Heldmyer <Aaron.Heldmyer@colorado.edu> wrote:

> Hi all,
>
> I can have these prepared by early next week. Let me know if there are any additional items you need!
>
> On May 13, 2017 7:31 AM, "Ben Livneh" <Ben.Livneh@colorado.edu> wrote:
>
>> Aaron et al.,
>>
>> I agree we should stick with SWE maps for the sake of the report and publication. Therefore, I think 1 Mar, 15 Mar, 1 Apr, and 15 Apr should do.
>>
>> Ben
>>
>> On Fri, May 12, 2017 at 5:11 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:
>>
>>> I think April 1st would be a useful comparison b/c so many decisions, and many other projects are targetted to the 1st of the month. So April 1 might also bolster our paper (s)
>>>
>>> would other months be useful for Aaron's MS or dissertation?
>>>
>>> And while I agree with considering what would be useful for other projects -- I don't

want to do too much ahead on a project that's already at the tail end of funded time

On Fri, May 12, 2017 at 4:19 PM, Joe Barsugli <joseph.barsugli@noaa.gov> wrote:

> Ben,
>
> What do you think is needed?
>
> For this project, outputting every two weeks from 1MAR onwards is probably fine. However, that doesn't capture the snow disappearance date very well if we want to do more quantitative comparison to MODIS. I hesitate to output every day, though.
>
> We could think about other future applications of this snow data including the Lynx, and the Ptarmigan, though I think the Ptarmigan is problematic as it is really alpine/ above treeline. Earlier dates might be useful for other projects, -- maybe for the Lynx -- as that probably needs more of a duration of snowpack metric, and initiation as well as melt of the snowpack. .. just speculating. Actually re-running again for another project with significantly more outputs is not out of the question.... just get what we need for this paper....
>
> What other variables are we interested in besides SWE for more sophisticated diagnosis? Perhaps snow temperature? Perhaps energy balance terms?
>
> Joe
>
> On 5/12/2017 4:01 PM, Ben Livneh wrote:
>
> > Joe
> > I am OK with asking Aaron to rerun the model, as I agree that it will really help the publication. However, let's try to be sure that we capture all the outputs/dates we may need.
> > Ben
> >
> > Sent from my phone. Please forgive the brevity, the typos, and the lack of nuance
> >
> > On May 12, 2017 3:14 PM, "Joe Barsugli" <joseph.barsugli@noaa.gov> wrote:
> >
> > > Talking to Andrea and just thinking some about this... I think having the earlier output will help in writing the paper for publication.
> > >
> > > Joe

--
Joseph Barsugli, Research Scientist III
CIRES, UCB216
University of Colorado Boulder
Boulder CO 80309
303-497-6042
PSD Science Board and
Attribution and Predictability Assessments Team Member

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Ben Livneh, Ph.D
Assistant Professor, Department of Civil, Environmental, and Architectural Engineering
&
Fellow, Cooperative Institute for Research in Environmental Sciences (CIRES)
Campus Box 216 UCB, Ekeley S250C, University of Colorado, Boulder 80309, USA
Phone: 303-735-0288 | http://www.colorado.edu/lab/livneh/

--
Aaron Heldmyer

Ph.D. Student, Cooperative Institute for Research in Environmental Sciences (CIRES)
University of Colorado - Boulder
SEEC S263, 4001 Discovery Dr, Boulder, CO 80303

Phone: 970-361-8406 | E-mail: aaron.heldmyer@colorado.edu

--
Joseph Barsugli
Research Scientist III
CIRES, UCB 216
University of Colorado at Boulder
cell:720-244-5922

From:	A J
To:	Grizzle, Betty
Subject:	Re: Wolverine life expectancy
Date:	Monday, May 22, 2017 10:11:59 AM

Hi Betty
I assume you have Rauset, Low, and Persson 2015. That is the paper I was referring to in my last email.
All the best
Audrey

Sent from my iPhone

On May 19, 2017, at 9:33 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Thanks. There are several life history demographics (including age of 1st offspring, maximum age of reproduction, etc.-Table 1) in Nilsson's 2013 PVA model for Scandinavian populations of bear, lynx, and wolverine, which I have (and those values are largely derived from Persson). I will ask Malin specifically about life expectancy, but it does appear to be variable.
>
> On Thu, May 18, 2017 at 1:44 PM, A J <222wsheridan@gmail.com> wrote:
>
>> Hi Betty
>> I guess the average age of breeding females would depend on what population you are talking about since trapped populations would have a lower average age. But for a protected population like most of the western states, I assume that it might be similar to what Jens had in the mountains in Sweden,although there were not as many predators so lifespan may be longer there than in the western states. I know Jens had at least 12-year-olds denning, but I don't know what would be an average age of breeding females. Not sure what generation time means specifically. I would assume (roughly) first breeding at 3 years and continue breeding through age 12. But I have found fetuses in a 15 year old. However, Jens would be a much better reference for this statistic. I suggest writing to Jens or Malin; they will have the best data on this. There is one paper, which I don't have with me here, that was done in Scandinavia on declining reproduction in older animals but that does not refer to average age of breeding females. You probably have that paper but I will look for it and send it when I find it.
>>
>> On Thu, May 18, 2017 at 8:06 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>>
>>> Hi Audrey - I have been looking for more recent references regarding the life expectancy of wolverines than the fairly old citations from Pasitschniak-Arts and Lariviere (1995).
>>> The 2014 COSEWIC report provides a generation time of 7.5, but that is an estimate of the average age of breeding females in the population.
>>> Do you know of any other published estimates?
>>>
>>> --

Betty J. Grizzle, D.Env.
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
Carlsbad Fish and Wildlife Office
2177 Salk Ave, Suite 250
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From:	Guinotte, John
To:	Stephen Torbit
Subject:	Fwd: emails discussions
Date:	Tuesday, May 23, 2017 1:57:31 PM
Attachments:	Attachment B.pdf Attachment C.pdf Attachment D.pdf Attachment E.pdf Attachment F.pdf Attachment G.pdf Attachment H.pdf Attachment I.pdf Attachment J.pdf Attachment L.pdf Attachment M.pdf Attachment N.pdf Attachment O.pdf Attachment Q.pdf Attachment S.pdf Attachment T.pdf Attachment U.pdf Attachment V.pdf Attachment W.pdf Attachment X.pdf Attachment Y.pdf Attachment Z.pdf

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---------- Forwarded message ----------
From: **Grizzle, Betty** <betty_grizzle@fws.gov>
Date: Wed, Apr 19, 2017 at 9:59 AM
Subject: Fwd: emails discussions
To: John Guinotte <john_guinotte@fws.gov>

---------- Forwarded message ----------
From: **A J** <222wsheridan@gmail.com>
Date: Tue, Apr 18, 2017 at 3:39 PM
Subject: Re: emails discussions
To: "Grizzle, Betty" <betty_grizzle@fws.gov>

attachments; I don't know how to zip them!

On Tue, Apr 18, 2017 at 2:34 PM, A J <222wsheridan@gmail.com> wrote:

> the copy I got did not have the signature page showing it was signed off
>
> On Tue, Apr 18, 2017 at 2:32 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

It's cited in Zigouris et al. 2013 publication and in her 2014 dissertation from Trent, but that's a good question as to whether it was actually finished.

On Tue, Apr 18, 2017 at 3:23 PM, A J <222wsheridan@gmail.com> wrote:

> i'm not sure Frances ever completed that thesis; I got that draft from his advisor Dr. Cook
>
> On Tue, Apr 18, 2017 at 2:20 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>
> > Thanks again. Also, just wanted to let you know that the photos in your "Associations and Movement Patterns of Reproductive Female Wolverines (*Gulo gulo luscus*) on the Southeast Alaska Mainland" (Final Report February 2010) were very interesting. But more importantly, I had been searching (without success) for the Frances 2008 MS Thesis that is included in that document as an Appendix (the UNM library said it was missing from their collection!).
> >
> > On Tue, Apr 18, 2017 at 3:15 PM, A J <222wsheridan@gmail.com> wrote:
> >
> > > here it is
> > >
> > > On Tue, Apr 18, 2017 at 2:08 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
> > >
> > > > Looking for Attachment (appendix?) A right now.
> > > >
> > > > On Tue, Apr 18, 2017 at 3:05 PM, A J <222wsheridan@gmail.com> wrote:
> > > >
> > > > > Here Attachment B; do you need any others?
> > > > >
> > > > > On Tue, Apr 18, 2017 at 1:33 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
> > > > >
> > > > > > Thanks Audrey. I found a few things, but not these (yet). I am looking at your peer review comments on previous proposed rule and haven't found your "Attachment B" yet....will keep looking.
> > > > > >
> > > > > > I apologize for having you search for and resend your earlier comments; I am trying to be thorough in this new assessment and have many questions about several analyses.
> > > > > > Betty
> > > > > >
> > > > > > On Tue, Apr 18, 2017 at 2:20 PM, A J <222wsheridan@gmail.com> wrote:
> > > > > >
> > > > > > > Betty
> > > > > > > I don't know if you have already seen these from Shawn's files, but these emails contain a discussion I had with Copeland and McKelvey after some reluctance on my part to get into such an exchange post-status review. I was pretty burned out by then on the whole subject. But you may find parts help answer some of the questions you recently sent. The McKelvey Email file is emails between Jeff and I until it became apparent that it was better to talk directly to Kevin and so his responses to me are in blue type in that email. The McKelvey Email Response file holds my answers back to him in black type. As you will see, there is little consensus on the matters under discussion. I had permission from both to share these emails and Shawn received copies. He had encouraged us to discuss these issues (and others) hoping to get some resolution of the differences of opinion, but as I suspected from the start, I don't think anyone changed their minds on

anything.

--

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ATTACHMENT B

Excerpt from comments by Justina Ray as a reviewer for the Canadian Journal of Zoology on the draft of Copeland et al. (2010) submitted for publication on 17 June 2009 (by permission from Justina Ray, personal communication, April 2013).

2. Climate and Wolverine Data used for Analyses

I have multiple concerns about the data used for the analyses, most of which can likely be addressed by adding explanations/justifications.

a. Date of snow data appears somewhat arbitrary (April 24-May 15) and is actually at some odds with previously published dates of wolverine den emergence (Magoun & Copeland paper) which suggest that most kits have emerged a good deal earlier than May 15---- nearly all den abandonment (n=18 total dens both natal and maternal) occurred before May. Hence, more justification is required for why these dates were used for the snow cover. There should also be some direct correspondence between the dates of the actual den data used for this analysis and the dates of the climate data. Instead, the justification for the dates is a general statement ("generally corresponds to the period of wolverine den abandonment" lines 150-151). As the first time compilation of 500 den sites, it presents a terrific opportunity to collate the known dates of emergence. Also, since the den data cover a large latitudinal range it would be useful to know if there is latitudinal variation in post-weaning den abandonment.

From: "Jeff Copeland" <jcopeland224@gmail.com>
Subject: Re: FW: 2007 paper
Date: Fri, February 15, 2013 12:13 pm
To: amagoun@ptialaska.net

Myrberget suggests the 10th of May for abandonment but reports den use as late as the 12th. I attached the paper but found that for some reason my pdf is missing the first page? Not sure what that's about.

The Aubry et al. paper states that we choose those dates to represent snow distribution during the "latter portion of the denning period," while the Copeland et al. paper equivocated even more by stating that this period "generally corresponds to the period of wolverine den abandonment." The citations, in both cases, were added to direct the reader to references for the time of den abandonment. They were not to suggest that our dates corresponded precisely with the time of den abandonment. I think that is pretty clear in both papers.

jeff

On Fri, Feb 15, 2013 at 1:44 PM, <amagoun@ptialaska.net> wrote:

Thanks, Jeff. Just wanted to know how the dates were arrived at because both the
Aubry et al. 2007 and the Copeland et al. 2010 paper cited the Magoun and Copeland
1998 paper (and Keith also cited the Myrberget 1968 paper) as the source of the
dates and the Magoun and Copeland 1998 paper does not appear to suggest a May 15
date for either Alaska or Idaho. I do not have my hard copy of Myrberget with me in
Oregon? Would you happen to have that one in electronic form that you could send to
me?
Thanks
Audrey

> When we developed this, we considered that weaning occurs 9-10 weeks
> post-parturition. If parturition occurs late Feb to early Mar, on average,
> then that puts weaning out towards mid-May. In Glacier we always planned
> our kit capture attempts for around the end of the first week of May. We
> always found the female and kits still in the den at that time. The 14 or
> 15th of May date was a bit arbitrary but I think it generally matches the
> time of den abandonment. As I mentioned earlier, if I was going to error,
> I wanted to do so toward estimating too late rather than too early and I
> did consider this as inclusive of both natal and maternal. Are you
> concerned that we should have went with a later date?
>
> On Fri, Feb 15, 2013 at 1:18 PM, <amagoun@ptialaska.net> wrote:
>
>>
>>
>> Thanks for the reply and explanation, Jeff. I realize the need for using
>> multiple
>> days because of cloud cover but what I was hoping to understand better was
>> why
>> start at 14 May and work backwards from there. You stated below that: "we
>> wanted to
>> go as late as we felt comfortable that females might still be associated
>> with the
>> reproductive den." This is actually the crux of why I initially asked the
>> question
>> of Keith. Why were you comfortable with the May 14 (May 15) date as the
>> latest date
>> that females would be associated with the reproductive den (I assume you
>> mean both
>> natal and maternal combined?). What was the source of this date? I can't
>> find any
>> reference for a reproductive den that was used until May 14, with the
>> possible

>> exception of remnant snow drifts used as maternal dens (or rendezvous
>> sites) and
>> since they were "remnant" snowdrifts/snow patches, one can assume that
>> snow was not
>> completely covering all the area that was around the den. So how did you
>> specifically arrive at 14 May (or 15 May as is stated in the Copeland et
>> al. 2010
>> paper)?
>>
>>
>> > The beginning and ending dates have no specific link to wolverine ecology
>> > other than they were meant to be inclusive of when we would expect the
>> > cessation of denning. We tended toward choosing a relatively late date
>> on
>> > the latter end (May 14) because doing so would provide a more
>> conservative
>> > estimate for the distribution of snow. The earlier the ending date the
>> > more snow would be represented and the better the model would fit so we
>> > wanted to go as late as we felt comfortable that females might still be
>> > associated with the reproductive den.
>> >
>> > When using snow data you cannot select a specific date for the analysis
>> > because of the potential for cloud cover. A cloudy day will obscure the
>> > satellites view of the earth's surface and as such will leave data gaps.
>> > Although most of my experience is with MODIS data as I did not do the
>> snow
>> > cover analysis for the historical distribution paper I would assume the
>> > same would be true for the EASE data. As such, you have to develop the
>> > snow layer (or at least we had to at the time) from a multi-day time
>> period
>> > in order to avoid the cloud cover issue.
>> >
>> > Jeff
>> >
>> > On Wed, Feb 13, 2013 at 6:27 PM, Aubry, Keith -FS <kaubry@fs.fed.us>
>> wrote:
>> >
>> >> Jeff or Kevin,
>> >> Can you provide the information that Audrey is looking for here??
>> Thanks,
>> >> k .
>> >>
>> >> ****************************
>> >> Keith B. Aubry, Ph.D.
>> >> Research Wildlife Biologist
>> >> USDA Forest Service
>> >> Pacific Northwest Research Station
>> >> 3625 93rd Ave. SW
>> >> Olympia, WA 98512
>> >>
>> >> e-mail: kaubry@fs.fed.us
>> >> Phone/voicemail: (360) 753-7685
>> >> FAX: (360) 753-7737
>> >> **
>> >>
>> >>
>> >> -----Original Message-----
>> >> From: Aubry, Keith -FS
>> >> Sent: Wednesday, February 13, 2013 5:26 PM
>> >> To: 'amagoun@ptialaska.net'
>> >> Subject: RE: 2007 paper

\>> >>
\>> >> Audrey
\>> >> Actually, I think Jeff was primarily responsible for selecting the final
\>> >> dates, so I will have to check with him to answer your question. Also,
\>> I'm
\>> >> away from home right now and am leaving for Hawaii early tomorrow
\>> morning,
\>> >> returning on Wed the 20th, so I really can't answer your question right
\>> >> now, anyway. I'll be back in touch with you on this next week.
\>> Aloha...
\>> >> k.
\>> >>
\>> >> ****************************
\>> >> Keith B. Aubry, Ph.D.
\>> >> Research Wildlife Biologist
\>> >> USDA Forest Service
\>> >> Pacific Northwest Research Station
\>> >> 3625 93rd Ave. SWv
\>> >> Olympia, WA 98512
\>> >>
\>> >> e-mail: kaubry@fs.fed.us
\>> >> Phone/voicemail: (360) 753-7685
\>> >> FAX: (360) 753-7737
\>> >> ***************************************
\>> >>
\>> >> -----Original Message-----
\>> >> From: amagoun@ptialaska.net [/src/compose.phpamagoun@ptialaska.net]
\>> >> Sent: Wednesday, February 13, 2013 2:10 PM
\>> >> To: Aubry, Keith -FS
\>> >> Subject: 2007 paper
\>> >>
\>> >> Hi Keith
\>> >> I am reviewing the proposed rule for listing the wolverine that you sent
\>> >> to me. I have a question regarding the Aubry et al 2007 paper. In that
\>> >> paper the authors
\>> >> state:
\>> >>
\>> >> "We chose the time period from 15 April to 14 May to represent snow
\>> cover
\>> >> present during the latter portion of the wolverine denning period
\>> >> (Myrberget 1968, Magoun and Copeland 1998)."
\>> >>
\>> >> I can't see where you (others?) arrived at the 14 May date from the
\>> >> literature that you cited here. Can you tell me specifically why you
\>> used
\>> >> 15 April to 14 May, especially the latter part of that period, 1 May -
\>> 14
\>> >> May?
\>> >> Thanks as always
\>> >> Audrey
\>> >>
\>> >>
\>> >>
\>> >>
\>> >>
\>> >>

>> >>
>> >>
>> >
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>>
>

Attachments:

untitled-[1.1]	
Size:	7.9 k
Type:	text/plain

myrberget_breeding den of the wolverine.PDF	
Size:	1.4 M
Type:	application/pdf

Environment Canada Environnement Canada

Canada

Daily Data Report for February 2004

RED LAKE A
ONTARIO

Latitude: 51°04'01.000" N **Longitude**: 93°47'35.000" W **Elevation**: 385.90 m

Climate ID: 6016975 **WMO ID**: 71854 **TC ID**: YRL

Daily Data Report for February 2004

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days	Cool Deg Days	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10s deg	Spd of Max Gust km/h
01	-9.9	-17.2	-13.6	31.6	0.0	0.0	T	T	46		<31
02	-13.2	-25.2	-19.2	37.2	0.0	0.0	T	T	45		<31
03	-17.6	-28.7	-23.2	41.2	0.0	0.0	0.6	0.6	45		<31
04	-12.5	-28.4	-20.5	38.5	0.0	0.0	T	T	45		<31
05	-6.0	-16.4	-11.2	29.2	0.0	0.0	5.8	3.6	46		<31
06	-9.9	-21.0	-15.5	33.5	0.0	0.0	3.2	1.4	53		<31
07	-9.0	-31.8	-20.4	38.4	0.0	0.0	T	T	51	19	43
08	-4.3	-9.6	-7.0	25.0	0.0	0.0	0.6	0.3	49	20	32
09	-6.0	-19.0	-12.5	30.5	0.0	0.0	0.8	0.4	49	32	33
10	-9.2	-27.7	-18.5	36.5	0.0	0.0	T	T	47		<31
11	-12.7	-26.5	-19.6	37.6	0.0	0.0	0.4	0.2	47		<31
12	-8.5	-27.6	-18.1	36.1	0.0	0.0	0.0	0.0	46	25	41
13	-9.5	-22.0	-15.8	33.8	0.0	0.0	T	T	46	31	43
14	-19.8	-30.1	-25.0	43.0	0.0	0.0	0.0	0.0	46		<31
15	-14.5	-31.6	-23.1	41.1	0.0	0.0	T	T	46		<31
16	-10.5	-18.5	-14.5	32.5	0.0	0.0	0.6	0.6	45		<31
17	-5.5	-23.5	-14.5	32.5	0.0	0.0	T	T	46	15	44
18	-2.8	-6.5	-4.7	22.7	0.0	0.0	0.6	0.4	46	21	37
19	-1.6	-8.1	-4.9	22.9	0.0	0.0	T	T	45		<31
20	0.1	-6.2	-3.1	21.1	0.0	0.0	2.4	1.7	45		<31
21	-4.8	-14.5	-9.7	27.7	0.0	0.0	0.2	0.2	45		<31
22	-0.8	-14.5	-7.7	25.7	0.0	0.0	1.0	0.4	44		<31
23	1.3	-6.9	-2.8	20.8	0.0	0.0	T	T	44		<31
24	0.1	-11.4	-5.7	23.7	0.0	0.0	0.0	0.0	44		<31
25	-2.2	-6.1	-4.2	22.2	0.0	0.0	T	T	44		<31
26	-0.1	-5.5	-2.8	20.8	0.0	0.0	0.0	0.0	44		<31
27	4.7	-6.7	-1.0	19.0	0.0	0.0	0.0	0.0	44		<31
28	2.3	0.0	1.2	16.8	0.0	T	T	T	44	20	37
29	1.0	-1.5	-0.3	18.3	0.0	0.0	T	T	43		<31
Sum				**859.9**	**0.0**	**T**	**16.2**	**9.8**			
Avg	**-6.3**	**-17.0**	**-11.7**								
Xtrm	**4.7**	**-31.8**								**15**	**44**

Summary, average and extreme values are based on the data above.

Legend
[empty] = No data available
M = Missing
E = Estimated
A = Accumulated
C = Precipitation occurred, amount uncertain
L = Precipitation may or may not have occurred
F = Accumulated and estimated
N = Temperature missing but known to be > 0
Y = Temperature missing but known to be < 0
S = More than one occurrence
T = Trace
* = The value displayed is based on incomplete data
† = Data for this day has undergone only preliminary quality checking
‡ = Partner data that is not subject to review by the National Climate Archives

We'd like to hear from you! Please click "Contact Us" to share your comments and suggestions.

Date Modified: 2013-02-04

Environment Canada Environnement Canada Canada

Daily Data Report for March 2004

RED LAKE A
ONTARIO

Latitude: 51°04'01.000" N **Longitude**: 93°47'35.000" W **Elevation**: 385.90 m

Climate ID: 6016975 **WMO ID**: 71854 **TC ID**: YRL

Daily Data Report for March 2004

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days	Cool Deg Days	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10s deg	Spd of Max Gust km/h
01	0.8	-2.0	-0.6	18.6	0.0	0.0	7.4	6.6	42		<31
02	-1.7	-5.4	-3.6	21.6	0.0	0.0	1.2	1.2	51		<31
03	-5.4	-22.5	-14.0	32.0	0.0	0.0	1.4	0.6	53		<31
04	-6.2	-27.2	-16.7	34.7	0.0	0.0	0.6	0.2	51		<31
05	-1.1	-12.0	-6.6	24.6	0.0	0.0	T	T	51		<31
06	0.1	-7.1	-3.5	21.5	0.0	0.0	0.4	0.2	50	15	33
07	-2.7	-11.5	-7.1	25.1	0.0	T	2.8	2.2	51	29	35
08	0.0	-17.8	-8.9	26.9	0.0	T	T	T	50		<31
09	7.3	-12.4	-2.6	20.6	0.0	0.0	0.0	0.0	49	18	48
10	3.8	-16.8	-6.5	24.5	0.0	T	4.2	3.8	43	27	44
11	-13.7	-22.0	-17.9	35.9	0.0	0.0	5.8	4.8	46	36	44
12	-3.9	-24.3	-14.1	32.1	0.0	0.0	0.0	0.0	46		<31
13	-3.9	-12.7	-8.3	26.3	0.0	T	10.2	7.0	46	9	39
14	-3.7	-18.0	-10.9	28.9	0.0	0.0	2.4	2.0	53	34	43
15	-1.0	-24.4	-12.7	30.7	0.0	0.0	0.0	0.0	53		<31
16	0.5	-10.7	-5.1	23.1	0.0	1.0	1.2	1.0	53	16	48
17	-0.7	-5.0	-2.9	20.9	0.0	0.0	5.0	3.0	55	26	32
18	-2.1	-14.0	-8.1	26.1	0.0	0.0	0.2	T	53		<31
19	3.7	-14.3	-5.3	23.3	0.0	0.4	17.4	12.4	52	12	82
20	-3.0	-15.0	-9.0	27.0	0.0	0.2	1.4	0.8	58	34	50
21	-6.9	-26.8	-16.9	34.9	0.0	0.0	T	T	56		<31
22	-1.9	-14.7	-8.3	26.3	0.0	0.0	1.8	1.0	57	31	46
23	-2.9	-26.8	-14.9	32.9	0.0	0.0	0.0	0.0	59	20	41
24	9.2	-3.0	3.1	14.9	0.0	0.0	0.0	0.0	57		<31
25	13.2	-5.5	3.9	14.1	0.0	0.0	0.0	0.0	45	23	37
26	-4.0	-13.4	-8.7	26.7	0.0	0.0	T	T	45	8	33
27	4.0	-7.2	-1.6	19.6	0.0	2.8	0.0	2.8	45	11	50
28	8.2	0.5	4.4	13.6	0.0	11.4	T	11.4	43		<31
29	0.5	-9.0	-4.3	22.3	0.0	0.0	12.6	11.1	40	31	54
30	3.5	-13.2	-4.9	22.9	0.0	0.0	0.0	0.0	42		<31
Sum				**769.2**	**0.0**	**15.8**	**76.0**	**72.1**			
Avg	**0.0**	**-13.6**	**-6.8**								
Xtrm	**13.2**	**-27.2**								**12**	**82**

Summary, average and extreme values are based on the data above.

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days	Cool Deg Days	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10s deg	Spd of Max Gust km/h
31	9.9	-7.2	1.4	16.6	0.0	0.0	0.0	0.0	41		<31
Sum				**769.2**	**0.0**	**15.8**	**76.0**	**72.1**			
Avg	**0.0**	**-13.6**	**-6.8**								
Xtrm	**13.2**	**-27.2**								**12**	**82**

Summary, average and extreme values are based on the data above.

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We'd like to hear from you! Please click "Contact Us" to share your comments and suggestions.

Date Modified: 2013-02-04

Environment Canada Environnement Canada Canada

Daily Data Report for April 2004

RED LAKE A
ONTARIO

Latitude: 51°04'01.000" N **Longitude**: 93°47'35.000" W **Elevation**: 385.90 m

Climate ID: 6016975 **WMO ID**: 71854 **TC ID**: YRL

Daily Data Report for April 2004

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days	Cool Deg Days	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10s deg	Spd of Max Gust km/h
01	10.8	-1.2	4.8	13.2	0.0	0.0	0.0	0.0	37		<31
02	9.1	-3.9	2.6	15.4	0.0	1.6	T	1.6	36		<31
03	0.3	-4.5	-2.1	20.1	0.0	T	0.8	0.6	35	34	44
04	6.9	-6.5	0.2	17.8	0.0	0.0	0.0	0.0	34		<31
05	6.7	-1.7	2.5	15.5	0.0	0.6	T	0.6	30		<31
06	12.6	-2.0	5.3	12.7	0.0	0.0	0.0	0.0	30		<31
07	11.8	-4.3	3.8	14.2	0.0	0.0	T	T	28	31	33
08	1.3	-3.5	-1.1	19.1	0.0	0.0	T	T	19		<31
09	0.3	-7.0	-3.4	21.4	0.0	0.0	0.0	0.0	17		<31
10	-1.8	-9.3	-5.6	23.6	0.0	0.0	0.2	T	13		<31
11	3.5	-12.1	-4.3	22.3	0.0	0.0	0.0	0.0	12	M	M
12	4.1	-4.6	-0.3	18.3	0.0	0.0	T	T	9	21	37
13	6.2	-2.5	1.9	16.1	0.0	0.0	0.0	0.0	8	28	35
14	4.9	-8.0	-1.6	19.6	0.0	0.0	0.0	0.0	6		<31
15	2.8	-4.4	-0.8	18.8	0.0	T	6.6	6.4	6	8	48
16	3.7	-0.8	1.5	16.5	0.0	T	0.8	0.7	9	29	32
17	5.8	-1.5	2.2	15.8	0.0	0.0	T	T	6		<31
18	4.1	-0.5	1.8	16.2	0.0	3.0	T	3.0	4		<31
19	8.2	0.5	4.4	13.6	0.0	T	T	T	T	33	35
20	12.9	0.5	6.7	11.3	0.0	1.4	0.0	1.4	T	17	50
21	5.0	-3.0	1.0	17.0	0.0	T	T	T	T	33	37
22	10.4	-7.3	1.6	16.4	0.0	0.0	0.0	0.0	T	23	44
23	4.0	-4.0	0.0	18.0	0.0	0.8	T	0.8	T	29	56
24	13.7	-4.3	4.7	13.3	0.0	0.0	0.0	0.0	0	17	56
25	8.4	-0.5	4.0	14.0	0.0	0.2	T	0.2	0	25	46
26	4.1	-6.2	-1.1	19.1	0.0	0.0	1.8	1.3	T	31	46
27	7.2	-7.3	-0.1	18.1	0.0	T	T	T	0	13	39
28	16.2	-2.0	7.1	10.9	0.0	0.6	T	0.6	0	33	44
29	5.2	-6.4	-0.6	18.6	0.0	0.0	T	T	0	35	37
30	3.9	-3.5	0.2	17.8	0.0	0.0	10.0	7.2	0	33	41
Sum				**504.7**	**0.0**	**8.2**	**20.2**	**24.4**			
Avg	**6.4**	**-4.1**	**1.2**								
Xtrm											

Summary, average and extreme values are based on the data above.

Legend
[empty] = No data available
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† = Data for this day has undergone only preliminary quality checking
‡ = Partner data that is not subject to review by the National Climate Archives

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Date Modified: 2013-02-04

Environment Canada Environnement Canada

Canada

Daily Data Report for February 2004

PICKLE LAKE A
ONTARIO

Latitude: 51°26'47.000" N **Longitude**: 90°12'51.000" W **Elevation**: 386.20 m

Climate ID: 6016527 **WMO ID**: 71845 **TC ID**: YPL

Daily Data Report for February 2004

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days	Cool Deg Days	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10s deg	Spd of Max Gust km/h
01	-11.7	-25.4	-18.6	36.6	0.0	0.0	0.8	0.6	37		<31
02	-9.0	-16.3	-12.7	30.7	0.0	0.0	1.0	0.8	38		<31
03	-13.0	-24.5	-18.8	36.8	0.0	0.0	T	T	38	28	37
04	-13.2	-22.8	-18.0	36.0	0.0	0.0	0.4	0.2	37	28	32
05	-5.8	-20.8	-13.3	31.3	0.0	0.0	5.4	5.4	38		<31
06	-14.3	-25.0	-19.7	37.7	0.0	0.0	3.4	2.8	41	4	33
07	-10.7	-30.6	-20.7	38.7	0.0	0.0	T	T	41	21	44
08	-6.7	-10.7	-8.7	26.7	0.0	0.0	1.4	1.0	40		<31
09	-6.9	-21.0	-14.0	32.0	0.0	0.0	3.2	2.4	42	2	35
10	-11.1	-26.6	-18.9	36.9	0.0	0.0	0.0	0.0	42		<31
11	-15.3	-24.8	-20.1	38.1	0.0	0.0	0.8	0.6	42		<31
12	-10.3	-27.9	-19.1	37.1	0.0	0.0	T	T	42	22	54
13	-10.3	-28.5	-19.4	37.4	0.0	0.0	1.2	1.0	37	34	46
14	-23.0	-33.2	-28.1	46.1	0.0	0.0	T	T	37	29	43
15	-17.3	-30.0	-23.7	41.7	0.0	0.0	0.0	0.0	35		<31
16	-10.6	-24.2	-17.4	35.4	0.0	0.0	1.8	1.4	35	16	37
17	-8.7	-18.6	-13.7	31.7	0.0	0.0	T	T	36	27	32
18	-2.8	-12.1	-7.5	25.5	0.0	0.0	1.8	1.4	36	16	33
19	-4.8	-20.9	-12.9	30.9	0.0	0.0	T	T	37		<31
20	-3.6	-11.5	-7.6	25.6	0.0	0.0	0.6	0.4	37		<31
21	-8.4	-20.9	-14.7	32.7	0.0	0.0	T	T	38	33	32
22	-6.4	-26.4	-16.4	34.4	0.0	0.0	T	T	38		<31
23	-0.4	-11.8	-6.1	24.1	0.0	0.0	T	T	38		<31
24	3.1	-7.9	-2.4	20.4	0.0	0.0	0.0	0.0	38		<31
25	3.3	-12.4	-4.6	22.6	0.0	0.0	0.0	0.0	38	21	33
26	-2.8	-8.5	-5.7	23.7	0.0	0.0	T	T	37		<31
27	4.9	-4.8	0.1	17.9	0.0	0.0	0.0	0.0	37		<31
28	2.2	-1.8	0.2	17.8	0.0	T	T	T	36	32	33
29	1.9	-0.5	0.7	17.3	0.0	0.0	T	T	36		<31
Sum				**903.8**	**0.0**	**T**	**21.8**	**18.0**			
Avg	**-7.3**	**-19.0**	**-13.2**								
Xtrm	**4.9**	**-33.2**								**22**	**54**

Summary, average and extreme values are based on the data above.

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N = Temperature missing but known to be > 0
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We'd like to hear from you! Please click "Contact Us" to share your comments and suggestions.

Date Modified: 2013-02-04

Environment Canada Environnement Canada

Canada

Daily Data Report for March 2004

PICKLE LAKE A
ONTARIO

Latitude: 51°26'47.000" N **Longitude**: 90°12'51.000" W **Elevation**: 386.20 m

Climate ID: 6016527 **WMO ID**: 71845 **TC ID**: YPL

Daily Data Report for March 2004

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days	Cool Deg Days	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10s deg	Spd of Max Gust km/h
01	-0.1	-2.5	-1.3	19.3	0.0	0.0	5.6	5.2	36		<31
02	-2.5	-11.2	-6.9	24.9	0.0	0.0	1.6	1.4	41	36	32
03	-9.4	-17.3	-13.4	31.4	0.0	0.0	0.6	0.4	41		<31
04	-7.7	-24.5	-16.1	34.1	0.0	0.0	0.0	0.0	41		<31
05	-2.8	-18.0	-10.4	28.4	0.0	0.0	0.0	0.0	41		<31
06	-1.1	-13.3	-7.2	25.2	0.0	0.0	0.0	0.0	41	17	35
07	-0.4	-9.0	-4.7	22.7	0.0	0.0	1.4	1.4	41	32	35
08	0.6	-10.2	-4.8	22.8	0.0	0.0	T	T	40		<31
09	4.7	-8.7	-2.0	20.0	0.0	0.0	0.0	0.0	40	20	44
10	5.1	-16.6	-5.8	23.8	0.0	3.6	5.6	9.0	39	3	56
11	-16.0	-24.0	-20.0	38.0	0.0	0.0	8.8	8.2	41	2	50
12	-9.2	-26.8	-18.0	36.0	0.0	0.0	0.0	0.0	39		<31
13	-3.2	-18.7	-11.0	29.0	0.0	0.0	10.4	7.2	39	14	46
14	-5.6	-15.4	-10.5	28.5	0.0	0.0	14.0	10.0	55	2	57
15	-1.9	-21.3	-11.6	29.6	0.0	0.0	0.0	0.0	55	27	32
16	0.5	-13.2	-6.4	24.4	0.0	0.0	0.0	0.0	54	19	52
17	0.5	-5.7	-2.6	20.6	0.0	0.0	3.6	3.0	52	18	33
18	-3.7	-8.6	-6.2	24.2	0.0	0.0	T	T	53		<31
19	-2.7	-8.7	-5.7	23.7	0.0	0.0	15.4	12.8	53	14	63
20	-3.8	-19.1	-11.5	29.5	0.0	0.0	5.6	3.4	69	36	59
21	-9.8	-24.6	-17.2	35.2	0.0	0.0	0.0	0.0	68		<31
22	-5.0	-20.0	-12.5	30.5	0.0	0.0	1.2	0.6	66	34	57
23	-4.2	-24.1	-14.2	32.2	0.0	0.0	0.0	0.0	66	21	39
24	8.7	-4.4	2.2	15.8	0.0	0.0	0.0	0.0	64	20	41
25	12.8	-12.4	0.2	17.8	0.0	T	0.0	T	61	36	54
26	-6.7	-19.0	-12.9	30.9	0.0	0.0	0.0	0.0	45	2	46
27	2.6	-12.2	-4.8	22.8	0.0	T	0.0	T	45	14	48
28	4.7	2.0	3.4	14.6	0.0	4.4	0.0	4.4	40	16	48
29	2.5	-8.5	-3.0	21.0	0.0	2.4	2.0	4.4	33	32	65
30	1.3	-9.7	-4.2	22.2	0.0	0.0	0.8	0.4	30		<31
Sum				**797.7**	**0.0**	**10.4**	**76.6**	**71.8**			
Avg	**-1.4**	**-14.0**	**-7.7**								
Xtrm	**12.8**	**-26.8**								**32**	**65**

Summary, average and extreme values are based on the data above.

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days	Cool Deg Days	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10s deg	Spd of Max Gust km/h
31	8.2	-9.4	-0.6	18.6	0.0	0.0	0.0	0.0	30		<31
Sum				**797.7**	**0.0**	**10.4**	**76.6**	**71.8**			
Avg	**-1.4**	**-14.0**	**-7.7**								
Xtrm	**12.8**	**-26.8**								**32**	**65**

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Date Modified: 2013-02-04

Environment Canada Environnement Canada Canada

Daily Data Report for April 2004

PICKLE LAKE A
ONTARIO

Latitude: 51°26'47.000" N Longitude: 90°12'51.000" W Elevation: 386.20 m

Climate ID: 6016527 WMO ID: 71845 TC ID: YPL

Daily Data Report for April 2004

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days	Cool Deg Days	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10s deg	Spd of Max Gust km/h
01	10.1	-3.6	3.3	14.7	0.0	0.0	0.0	0.0	28	20	32
02	11.7	-2.3	4.7	13.3	0.0	0.0	3.0	2.6	25	2	46
03	-1.4	-10.8	-6.1	24.1	0.0	0.0	3.8	2.8	24	2	43
04	1.8	-13.3	-5.8	23.8	0.0	0.0	0.0	0.0	24		<31
05	8.7	-4.3	2.2	15.8	0.0	2.0	0.2	2.2	24	18	52
06	12.0	0.8	6.4	11.6	0.0	0.0	0.0	0.0	17	30	43
07	12.1	-4.0	4.1	13.9	0.0	0.0	0.0	0.0	10		<31
08	2.6	-6.9	-2.2	20.2	0.0	0.0	1.4	1.4	T		<31
09	-3.6	-10.6	-7.1	25.1	0.0	0.0	2.6	1.8	T	35	33
10	-3.0	-10.9	-7.0	25.0	0.0	0.0	4.2	2.6	9		<31
11	1.9	-13.2	-5.7	23.7	0.0	0.0	0.0	0.0	8		<31
12	4.3	-10.1	-2.9	20.9	0.0	0.0	T	T	4	20	48
13	2.8	-5.0	-1.1	19.1	0.0	0.0	1.0	0.4	4	33	37
14	2.5	-8.6	-3.1	21.1	0.0	0.0	0.0	0.0	T	30	37
15	3.1	-10.2	-3.6	21.6	0.0	0.0	5.0	5.0	T	12	52
16	2.3	-0.2	1.1	16.9	0.0	0.0	2.6	2.6	T	30	43
17	4.2	-2.3	1.0	17.0	0.0	0.0	T	T	T	32	37
18	3.0	-2.5	0.3	17.7	0.0	0.0	5.2	5.0	T	11	44
19	2.6	-2.9	-0.2	18.2	0.0	0.0	0.0	0.0	3	35	41
20	10.6	-3.2	3.7	14.3	0.0	0.0	0.0	0.0	T	18	43
21	3.2	-6.2	-1.5	19.5	0.0	T	T	T	T	32	48
22	8.1	-9.4	-0.7	18.7	0.0	0.0	0.0	0.0	T	22	43
23	3.2	-7.0	-1.9	19.9	0.0	T	T	T	T	33	57
24	10.6	-8.1	1.3	16.7	0.0	0.0	0.0	0.0	T	18	56
25	8.4	-2.1	3.2	14.8	0.0	T	T	T	T	26	41
26	-0.7	-8.8	-4.8	22.8	0.0	0.0	3.0	2.6	T	34	65
27	6.3	-10.0	-1.9	19.9	0.0	0.0	0.0	0.0	T		<31
28	13.2	-2.6	5.3	12.7	0.0	0.3	5.0	5.1	T	36	39
29	3.4	-6.9	-1.8	19.8	0.0	0.0	3.0	2.8	3	35	52
30	7.0	-5.9	0.6	17.4	0.0	0.0	0.2	0.2	T	34	44
Sum				**560.2**	**0.0**	**2.3**	**40.2**	**37.1**			
Avg	**5.0**	**-6.4**	**-0.7**								
Xtrm	**13.2**	**-13.3**								**34**	**65**

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Date Modified: 2013-02-04


Wolverine den site in Ontario, Canada – 2004
30 March
25 June

Rendezvous site in northwestern Alaska where a female wolverine kept her two kits in late June 1979. The kits were kept under this remnant snowdrift where melt water formed a cavern under the length of the snowdrift (spotting scope on a tripod for size comparison). Remnant snowdrifts were commonly used as maternal den sites or rendezvous sites (Magoun 1985, p. 73).

Audrey Magoun

From: "Audrey Magoun" <amagoun@ptialaska.net>
To: "Dorothy Hall" <dorothy.k.hall@nasa.gov>
Sent: Monday, April 01, 2013 4:33 PM
Subject: Re: MODIS guide

Thanks, Dorothy. I think the reason they used V4 was that, even though the paper was published in 2010, they actually began analyzing the data in at least 2007, maybe earlier. In a recent email the lead author stated "It was MODIS Terra version 4 and some version 5 as I recall." When was V5 available? Could it be that it was so recent that they got started on their analysis before it was available? I will try to find out why they used V4. What kind of error would V4 have created, e.g., more pixels or less pixels classified as snow-covered? I know they had to look at the pixels over a 21-day period to try to eliminate cloud cover in order to come up with the snow cover on 15 May for the study area.

----- Original Message -----
From: "Dorothy Hall" <dorothy.k.hall@nasa.gov>
To: "Audrey Magoun" <amagoun@ptialaska.net>
Sent: Monday, April 01, 2013 3:16 PM
Subject: Re: MODIS guide

> Hi Audrey,
>
> I've sent an email to double check on that. I hope to find out sooner
> than Thursday.
>
> The real issue is that a user should *not* be using V4 products. There
> were some issues in V4 that were fixed in V5. I can't remember all of the
> issues, but since V5 is available why would he/she use V4? In fact you
> can't even get V4 anymore. I would suggest to the user to re-do the study
> using V5. In fact I wouldn't accept a paper, as a reviewer, if V4 was
> used. It really doesn't make sense to use an old product when a newer,
> better one is available.
>
> Dorothy
>
>
> On 4/1/2013 6:59 PM, Audrey Magoun wrote:
>> Thursday or even longer will be fine; I'd really appreciate it if you
>> would
>> check
>> thanks
>> ----- Original Message -----
>> From: "Dorothy Hall" <dorothy.k.hall@nasa.gov>
>> To: "Audrey Magoun" <amagoun@ptialaska.net>
>> Sent: Monday, April 01, 2013 2:06 PM
>> Subject: Re: MODIS guide

>>
>>
>>> Hi Audrey,
>>>
>>> Wow, I don't remember, but I don't think so. I don't think V4 had
>>> fractional snow cover. I could find out for sure but I won't be back at
>>> the office until Thursday.
>>>
>>> Dorothy
>>>
>>>
>>> On 4/1/2013 5:01 PM, Audrey Magoun wrote:
>>>> Final question then, just to be absolutely sure I understand, would the
>>>> version used by these authors "MODIS/Terra snow cover daily L3 global
>>>> 500m grid. Version 4, 24 April - 21 May 2000-2006" have included
>>>> fractional snow, as I thought that some snow products don't include
>>>> fractional snow? Thanks again so much.
>>>>   ----- Original Message -----
>>>>
>>>>   *From:* Dorothy Hall <mailto:Dorothy.K.Hall@nasa.gov>
>>>>   *To:* Audrey Magoun <mailto:amagoun@ptialaska.net>
>>>>   *Sent:* Monday, April 01, 2013 12:28 PM
>>>>   *Subject:* Re: MODIS guide
>>>>
>>>>   Hi Audrey,
>>>>
>>>>   I think you've got it. Below a fractional snow cover of around
>>>> 20%
>>>>   we really aren't certain at all. As you point out, even from 20 -
>>>>   100% it can be iffy, and it's really not possible to validate with
>>>>   any accuracy. Sometimes we're measuring snow in trees and that's
>>>>   counted. So it's more of a guide than an actual number.
>>>>
>>>>   Dorothy
>>>>
>>>>
>>>>
>>>>   On 4/1/2013 4:25 PM, Audrey Magoun wrote:
>>>>>   Thanks, Dorothy. In the paper I am reviewing, the authors only
>>>>>   state that they used the MODIS daily snow data (500 m spatial
>>>>>   resolution) from the Terra satellite and they cite Hall et al.
>>>>>   2006--MODIS/Terra snow cover daily L3 global 500m grid. Version
>>>>> 4,
>>>>>   24 April - 21 May 2000-2006. This is for the Northern Hemisphere
>>>>>   as the paper is about wolverines (attached). I read through the
>>>>>   guide quickly but I still am trying to determine how accurate
>>>>> this
>>>>>   snow cover data would be in detecting snow, in this case, if
>>>>>   snowmelt had progressed far enough that snow occurred only in
>>>>>   patches, both in mountains and in the flatter boreal forest of
>>>>>   Canada. The pixels were classified as snow, bare ground, cloud,

>>>>> or
>>>>> night. Specifically, I'm trying to determine what really is in a
>>>>> pixel classified as snow vs. bare ground. Would the specific snow
>>>>> product they used classify fractional snow of less than 20% as
>>>>> bare ground and pixels with >20% classified as snow-covered? Or
>>>>> would the authors have had the % of fractional snow from 0-100%
>>>>> available to them and they then made the determination of
>>>>> snow-covered or bare themselves? And would these authors have
>>>>> even
>>>>> used the fractional snow product given the description above? (I
>>>>> am trying to find out from them what snow product they used but
>>>>> haven't heard back yet.) From your email below, it appears that
>>>>> with up to 20% of fractional snow in a pixel, which then may have
>>>>> been classified as bare, the authors might not have had
>>>>> information on snowbeds that occurred in those pixels, is that
>>>>> correct? And would it matter, for example, if there was only one
>>>>> snowbed in the pixel that covered about 15% of the pixel vs 3
>>>>> smaller snowbeds separated by bare ground? Also, I've been
>>>>> reading
>>>>> the literature on fractional snow and it appears there are still
>>>>> problems with classifying it, say in mountains vs. boreal forest.
>>>>> Would that have been true for the data these authors used?
>>>>> Thanks so much and I hope you don't mind my questions.
>>>>> Audrey
>>>>> ----- Original Message -----
>>>>>
>>>>> *From:* Dorothy Hall <mailto:Dorothy.K.Hall@nasa.gov>
>>>>> *To:* Audrey Magoun <mailto:amagoun@ptialaska.net>
>>>>> *Sent:* Monday, April 01, 2013 11:45 AM
>>>>> *Subject:* Re: MODIS guide
>>>>>
>>>>> Hi Audrey,
>>>>>
>>>>> Yes, it's the most recent but George Riggs is updating it now
>>>>> for Collection 6. It won't be done for a few months. Some
>>>>> things have changed, but it's still pretty accurate for
>>>>> Collection 5. Let me know if you have any specific
>>>>> questions.
>>>>>
>>>>> Dorothy
>>>>>
>>>>>
>>>>>
>>>>> On 4/1/2013 3:20 PM, Audrey Magoun wrote:
>>>>>> Hi Dorothy
>>>>>> One more question for you--is the MODIS Snow Products User
>>>>>> Guide to Collection 5 by George A. Riggs, Dorothy K. Hall,
>>>>>> Vincent V. Salomonson, November 2006 the most current guide
>>>>>> and would it be the best explanation of MODIS Snow Products
>>>>>> used for 2000-2007 ?
>>>>>> Thanks so much for your time.

>>>>>> Audrey
>>>>>> ----- Original Message -----
>>>>>>
>>>>>> *From:* Dorothy Hall <mailto:Dorothy.K.Hall@nasa.gov>
>>>>>> *To:* Audrey Magoun <mailto:amagoun@ptialaska.net>
>>>>>> *Sent:* Monday, April 01, 2013 4:07 AM
>>>>>> *Subject:* Re: MODIS resolution and ability to detect
>>>>>> snow patches at the 500 m resolution
>>>>>>
>>>>>> Hi Audrey,
>>>>>>
>>>>>> I am really sorry but I missed your email. This morning
>>>>>> I was going through old emails in my inbox and
>>>>>> discovered
>>>>>> this. I hope it's not too late.
>>>>>>
>>>>>> When the fractional snow cover (which is provided as
>>>>>> part
>>>>>> of the product) gets to less than 20%, I think you can
>>>>>> safely say that the pixel is largely "bare." I hope
>>>>>> this
>>>>>> is helpful.
>>>>>>
>>>>>> Dorothy
>>>>>>
>>>>>>
>>>>>>
>>>>>> On 3/25/2013 9:06 PM, Audrey Magoun wrote:
>>>>>>> Hello Dorothy
>>>>>>> I am reviewing a paper that used MODIS snow cover data
>>>>>>> to determine the snow cover (globally) in the northern
>>>>>>> hemisphere in the years 2000-2006 for the period 24
>>>>>>> April to 15 May for the purpose of evaluating the
>>>>>>> extent
>>>>>>> of wolverine denning habitat. During this period, some
>>>>>>> areas are beginning to melt and snow becomes patchy.
>>>>>>> What I am hoping you can tell me is at what point will
>>>>>>> the MODIS data show a pixel as "bare" even if it has
>>>>>>> snow patches distributed across the pixel? What
>>>>>>> distribution, size, and perhaps shape of snow patches
>>>>>>> would still produce a pixel that was considered "bare"
>>>>>>> even though some snow is present? I have not used MODIS
>>>>>>> data myself so I am not familiar with the process for
>>>>>>> determining bare vs. snow-covered.
>>>>>>> Thank you so much for considering this request.
>>>>>>> Audrey Magoun
>>>>>>> Wildlife Biologist
>>>>>>
>>>>>> --
>>>>>> Dorothy K. Hall
>>>>>> Cryospheric Sciences Laboratory

>>>>>> Code 615
>>>>>> NASA Goddard Space Flight Center
>>>>>> Greenbelt, MD 20771
>>>>>> USA
>>>>>>
>>>>>> dorothy.k.hall@nasa.gov
>>>>>> Phone: 301-614-5771
>>>>>>
>>>>>> No virus found in this message.
>>>>>> Checked by AVG - www.avg.com <http://www.avg.com>
>>>>>> Version: 2013.0.3267 / Virus Database: 3161/6218 -
>>>>>> Release Date: 04/01/13
>>>>>>
>>>>>
>>>>> --
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> No virus found in this message.
> Checked by AVG - www.avg.com
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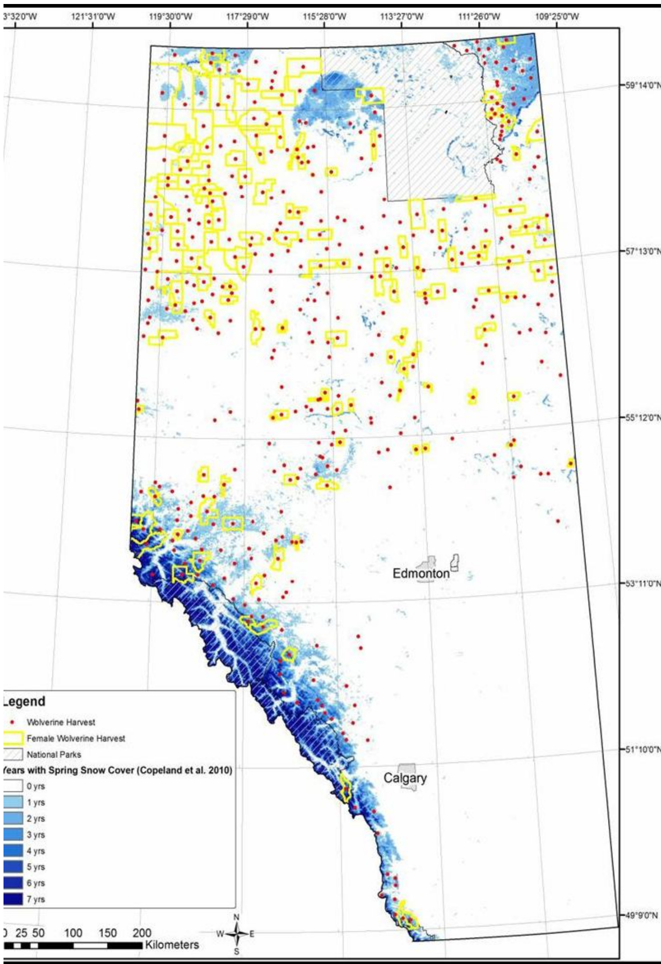
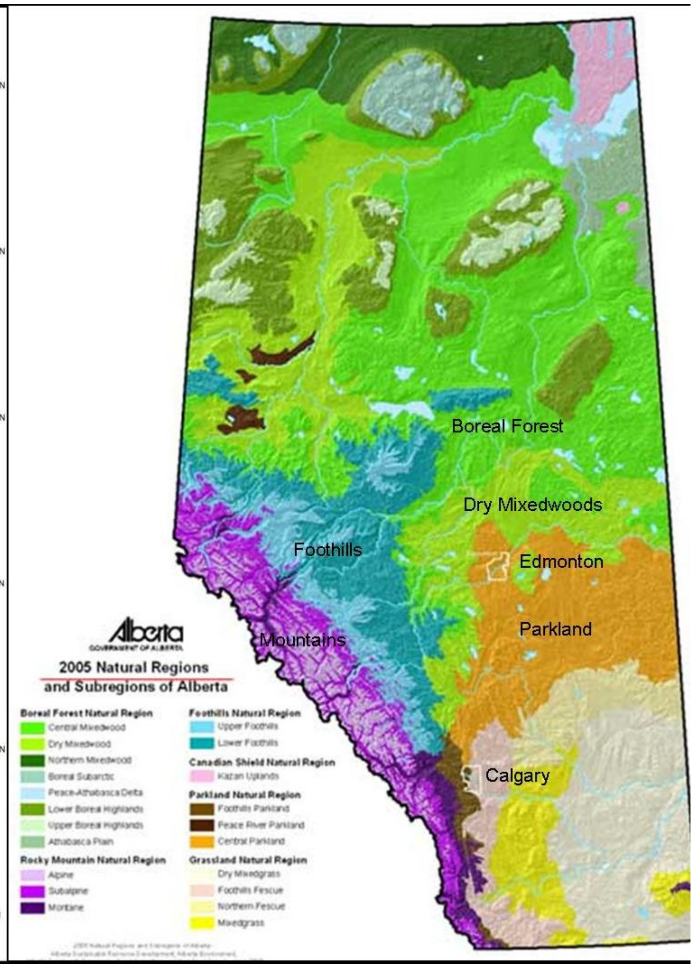
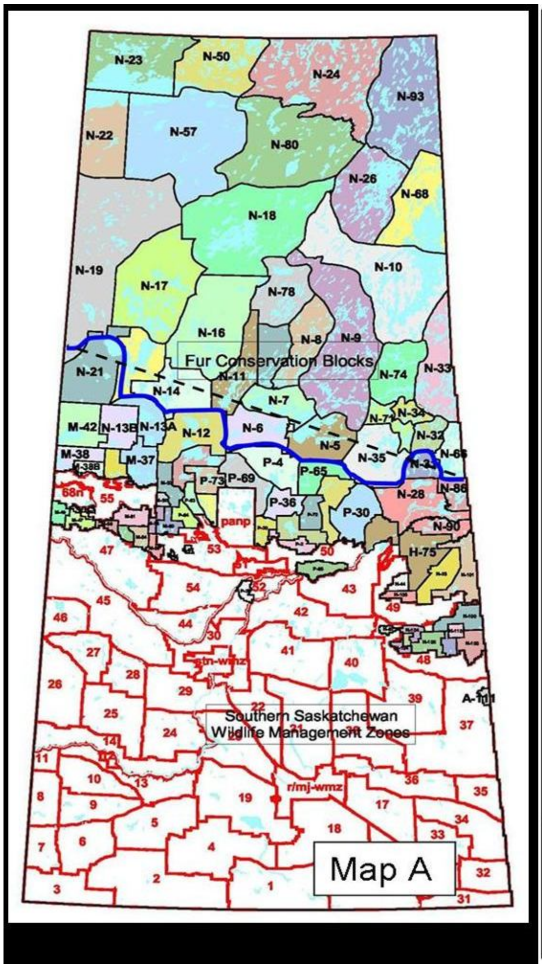
>

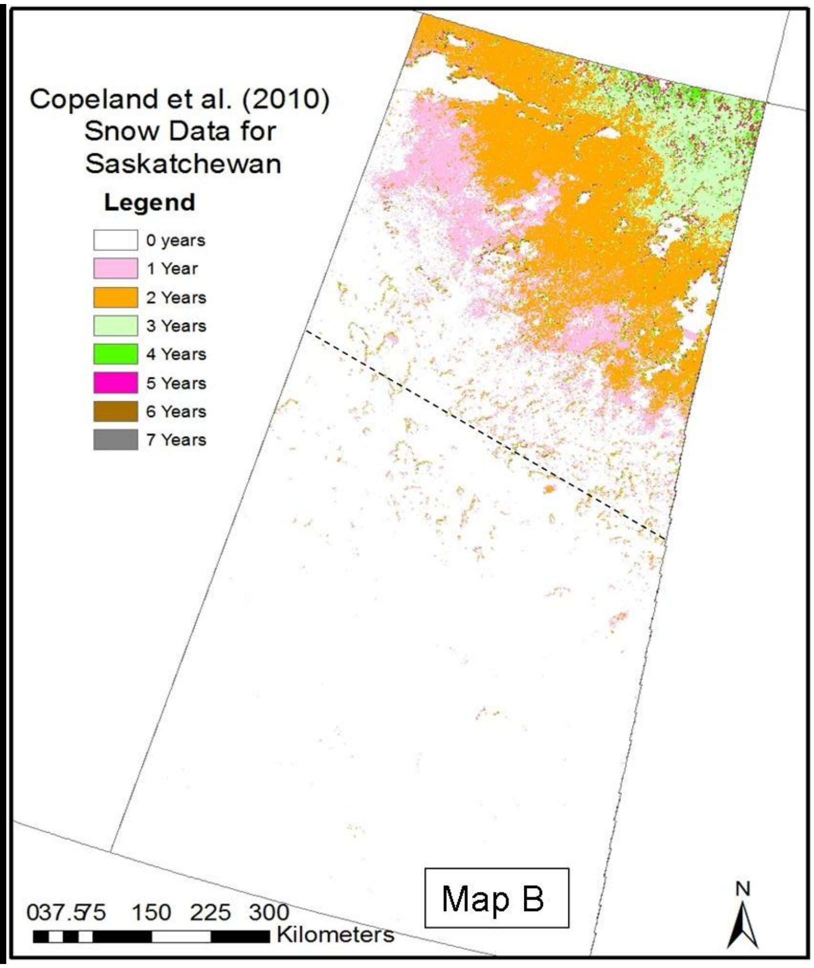
Snowbeds in the Wallowa Mountains, northeast Oregon on 4 August 2012

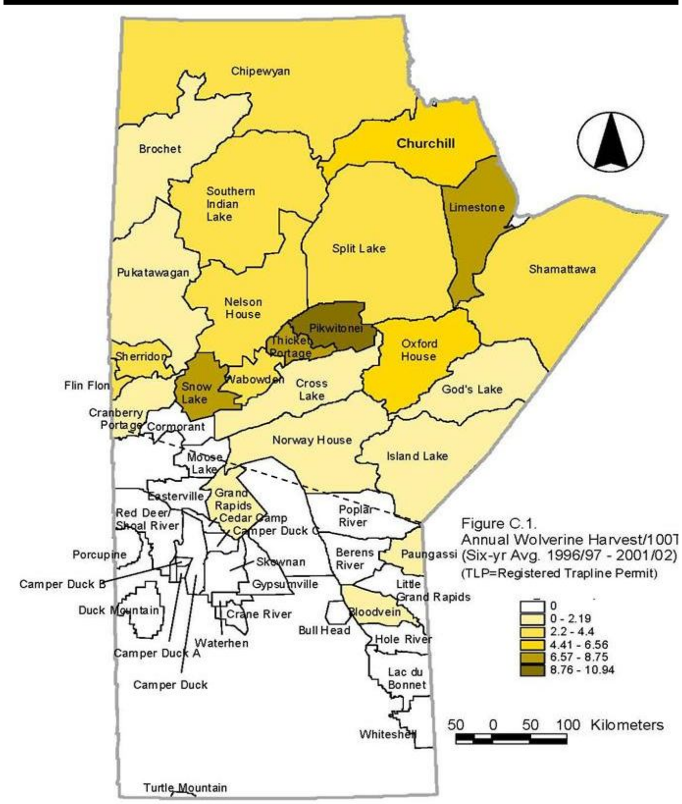

newborn
1 week
Copyright © Dale Pedersen
8 weeks
10 weeks

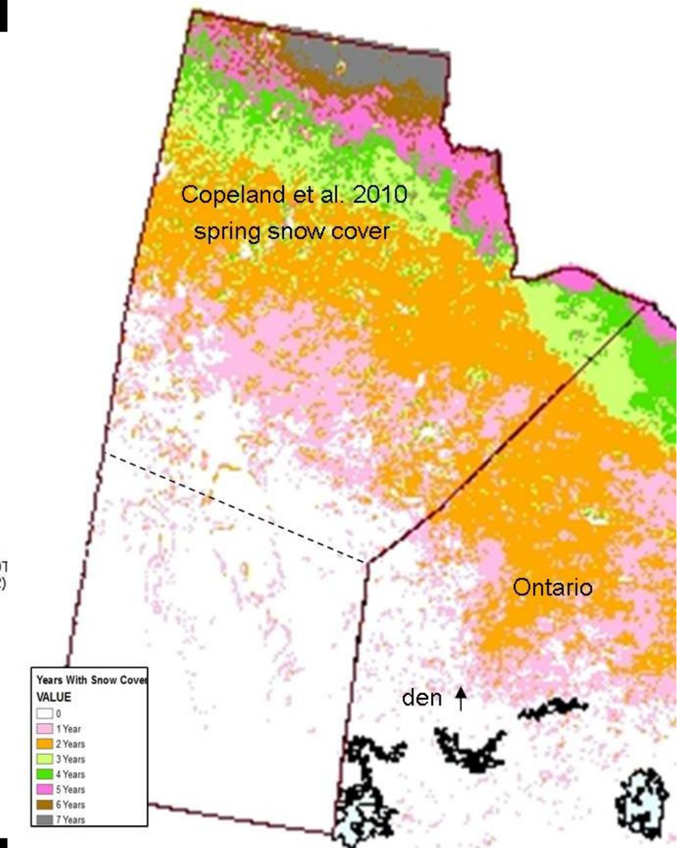

121°31'0"W
119°30'0"W
117°29'0"W
115°28'0"W
113°27'0"W
111°26'0"W
109°25'0"W
59°14'0"N
57°13'0"N
55°12'0"N
53°11'0"N
51°10'0"N
49°9'0"N
Edmonton
Calgary
Legend
Wolverine Harvest
Female Wolverine Harvest
National Parks
Years with Spring Snow Cover (Copeland et al. 2010)
0 yrs
1 yrs
2 yrs
3 yrs
4 yrs
5 yrs
6 yrs
7 yrs
25 50 100 150 200
Kilometers
N
W
E
S


Boreal Forest
Dry Mixedwoods
Foothills
Edmonton
Mountains
Parkland
Calgary
2005 Natural Regions
and Subregions of Alberta
Boreal Forest Natural Region
Central Mixedwood
Dry Mixedwood
Northern Mixedwood
Boreal Subarctic
Peace-Athabasca Delta
Lower Boreal Highlands
Upper Boreal Highlands
Athabasca Plain
Rocky Mountain Natural Region
Alpine
Subalpine
Montane
Foothills Natural Region
Upper Foothills
Lower Foothills
Canadian Shield Natural Region
Kazan Uplands
Parkland Natural Region
Foothills Parkland
Peace River Parkland
Central Parkland
Grassland Natural Region
Dry Mixedgrass
Foothills Fescue
Northern Fescue
Mixedgrass

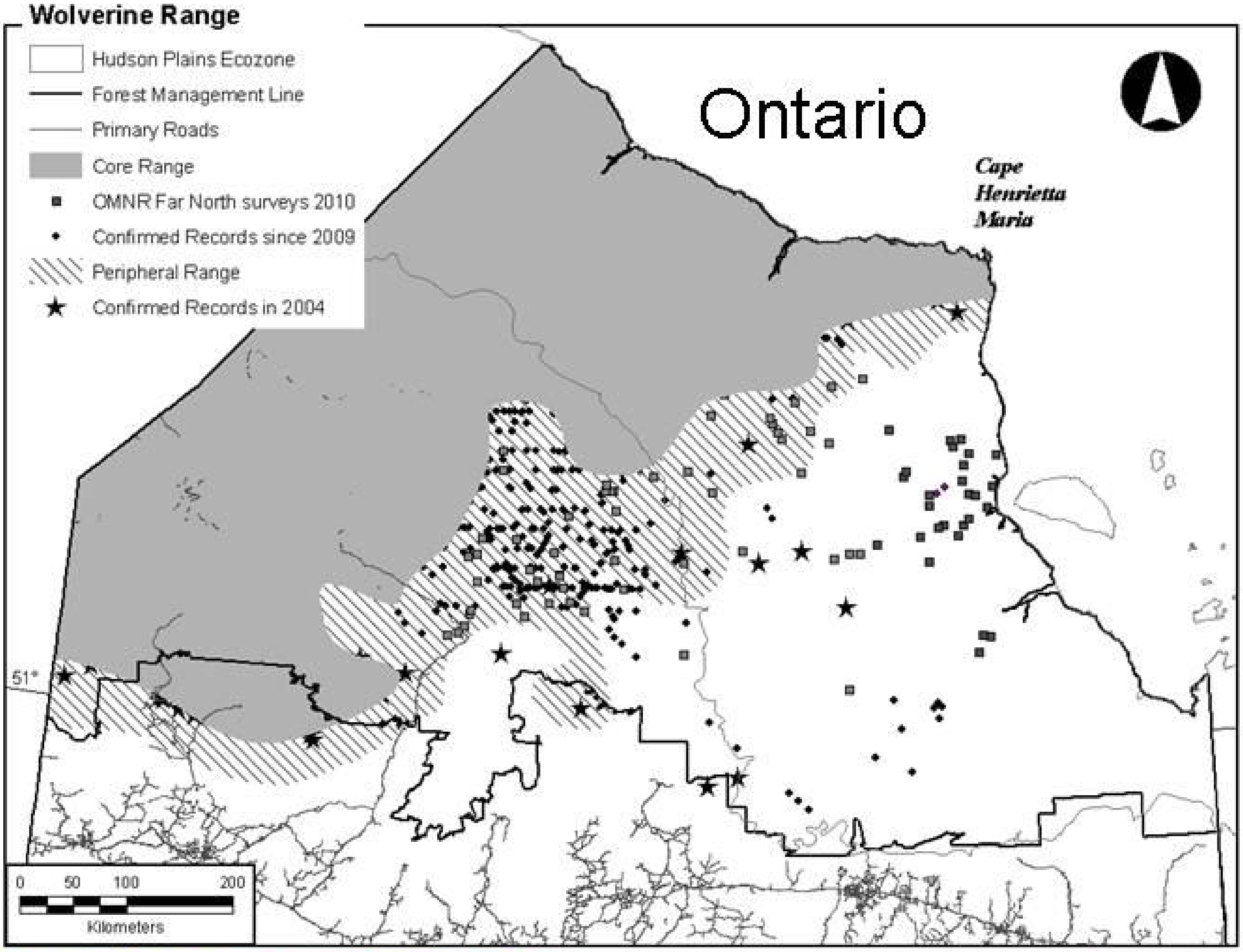

Fur Conservation Blocks
Southern Saskatchewan Wildlife Management Zones
Map A

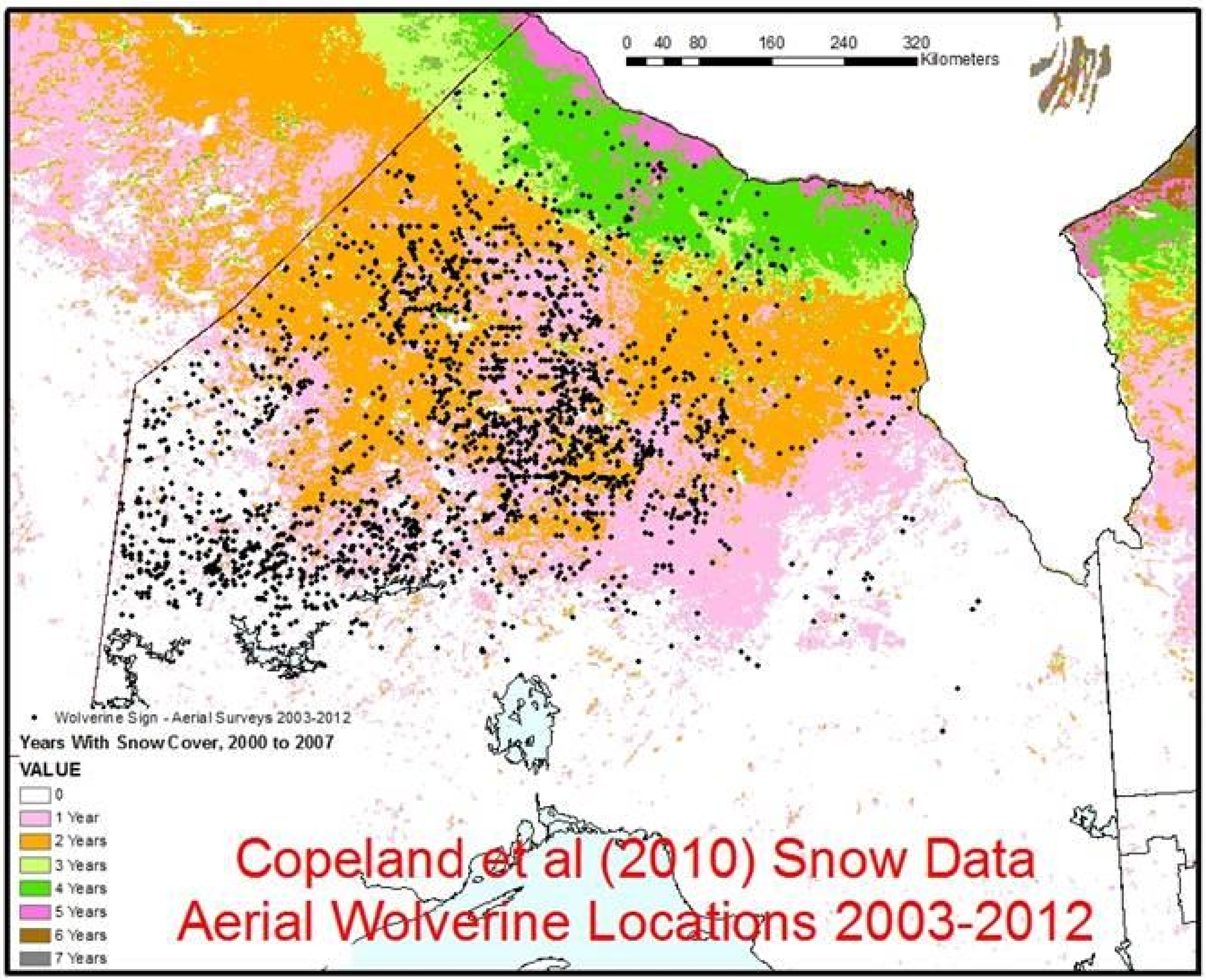

Copeland et al. (2010)
Snow Data for
Saskatchewan
Legend
0 years
1 Year
2 Years
3 Years
4 Years
5 Years
6 Years
7 Years
037.575 150 225 300
Kilometers
Map B
N





Most harvested wolverines occur above the dashed line but some have been harvested south of the line particularly in recent years (Dean Berezanski, personal communication).


Wolverine Range
Hudson Plains Ecozone
Forest Management Line
Primary Roads
Core Range
OMNR Far North surveys 2010
Confirmed Records since 2009
Peripheral Range
Confirmed Records in 2004
Ontario
Cape Henrietta Maria
51°
0 50 100 200
Kilometers


0 40 80 160 240 320 Kilometers
Wolverine Sign - Aerial Surveys 2003-2012
Years With Snow Cover, 2000 to 2007
VALUE
0
1 Year
2 Years
3 Years
4 Years
5 Years
6 Years
7 Years
Copeland et al (2010) Snow Data
Aerial Wolverine Locations 2003-2012

Audrey Magoun

From: "Malin Aronsson" <malin.aronsson@slu.se>
To: "Audrey Magoun" <amagoun@ptialaska.net>; <222wsheridan@gmail.com>
Cc: "Malin Aronsson" <malin.aronsson@slu.se>
Sent: Monday, March 25, 2013 9:20 AM
Attach: 2011 Perssonomslagside,1-44.pdf
Subject: Second try...

Here is the old email... Sending one report in this email and the other one in a new email.

Hi Audrey,

There are den sites found outside of “the snow model” during the last years. Every year there is an extensive search for wolverine dens within the reindeer husbandry area (northern half of Sweden) because the number of den sites is the base for the compensation payment system to the reindeer herders for damages caused by wolverines and the den inventory are also the basis for the population estimation. This den-site inventory has been going on since 1996. I attached to reports (both in Swedish unfortunately) that show the distribution of wolverine den sites in Sweden (we usually report den sites over a three year period because of the varying reproductive success for females). The first document (Persson and Broseth) reports the population development 1996 – 2010 and you find the den sites (with a 20 km buffer zone) in figure 1a-e. The red colour just means that there are more den sites within the buffer zones. The second document (Aronsson and Persson) is a report where we try to summarise the information we have about wolverines in the “forest areas” outside of “traditional wolverine area” (mountains and forest close to the mountains). Figure 2 shows the documented den sites (from the national inventory) with a 20 km buffer zone (blue). The red line is our definition of the limit for “traditional wolverine areas” based on land use, vegetation, the mountain range and reindeer herding practices. We classify the den sites found to the east of that line as being outside of traditional wolverine areas. Our red line matches “the snow model” pretty well in the southern half of the Swedish wolverine distribution and if you compare Copelands paper with the maps in the two reports you can see that there area quite a few den sites outside of the snow model in resent years. The blue triangles in figure 3 shows the number of documented den sites east of our red line, most of these den sites are found the southern half of the wolverine distribution and hence outside of the snow model. From 2008 and to today 12-15% of the den sites have been found east of the red line (10-18/year and it looks like a majority of those are outside of the snow model, in the area where it says “Sweden” in figure 4 in Copelands paper). But still a majority of the total den sites (90-110/year) are found inside the snow model. As for distances den sites are found from just outside the snow model to approximately 140 km outside of the snow model (rough estimates because I don´t have a GIS layer of the snow model).

We have not captured any wolverines yet . But they have visited the traps a couple of times so we area still hoping. We finished setting up 6 camera stations last week and they will be on until we get back from fieldwork in the north in the end of April. So far I have some photos of one big wolverine (think it is a male). He has spots on the right side of his chest and photos I have got from local people shows that he has been in the area since at least 2010. We are at a carnivore conference in Sweden right now and there area lots of participants from the County Administrative Boards (that manages wildlife in Sweden) and I have to tell you that you have a fan club here from the field personnel from the County Administrative Boards. Some of them have your book and have tried your camera-stations on their own. We had a meeting yesterday to try to coordinate the use of camera-stations in 2 counties and today Jens said that one more county wants to join.

/Malin
****
Malin Aronsson
Grimsö forskningsstation / Grimsö Wildlife Research Station
Institutionen för ecology / Dept. of Ecology
Sveriges lantbruksuniversitet / Swedish University of Agricultural Sciences
SE-730 91 Riddarhyttan
Sweden

+46 (0) 581-697312

Från: Audrey Magoun [amagoun@ptialaska.net]
Skickat: den 25 mars 2013 17:14
Till: Malin Aronsson
Ämne: Re: Getting close...

No, I didn't get them. Perhaps send them to both of my emails
amagoun@ptialaska.net
222wsheridan@gmail.com

thanks much

----- Original Message -----
From: "Malin Aronsson" <malin.aronsson@slu.se>
To: "Audrey Magoun" <amagoun@ptialaska.net>
Sent: Monday, March 25, 2013 12:07 AM
Subject: Re: Getting close...

There is just one, the black on the side is rubber as snow and ice protection.

I did send the papers the day after I sent the first email (1,5 weeks agoe), you did not get them??? They are big files, I'll send them again, separate emails this time.

/Malin

Skickat från min iPhone

25 mar 2013 kl. 01:16 skrev "Audrey Magoun" <amagoun@ptialaska.net>:

> Hope one of them don't trigger it while the other is up on the side like
> that!!! Have you tried putting a few small pieces of bait outside the
> trap, tied down with cable?
>
> Did you try to resend those papers you told me about?
> thanks

> Audrey
> ----- Original Message ----- From: "Malin Aronsson"
> <malin.aronsson@slu.se>
> To: <amagoun@ptialaska.net>
> Sent: Sunday, March 24, 2013 2:30 PM
> Subject: Getting close...
>
>
> ... Very close...
>
> / Malin and Jens
>
>
>
>
> --
>
>
> -----
> No virus found in this message.
> Checked by AVG - www.avg.com
> Version: 2013.0.2904 / Virus Database: 2641/6202 - Release Date: 03/24/13

No virus found in this message.
Checked by AVG - www.avg.com
Version: 2013.0.2904 / Virus Database: 2641/6202 - Release Date: 03/24/13

No virus found in this message.
Checked by AVG - www.avg.com
Version: 2013.0.2904 / Virus Database: 2641/6202 - Release Date: 03/24/13


GREATER YELLOWSTONE
WOLVERINE STUDY
patagonia

Audrey Magoun

From: "TWF" <gulogulo@mindspring.com>
To: "Magoun Audrey" <amagoun@ptialaska.net>
Sent: Thursday, March 28, 2013 3:35 PM
Subject: Re: tooth eruption

Audrey,

What a gorgeous little *Gulo*!

After gleaning as much insight as I could from Bob's kit photo, I would offer the following comments:

First, I am basing my age estimate on the photo solely, not only because of Bob's qualifiers, but also as a result of his statement that their records indicated, "no incisors were erupted".

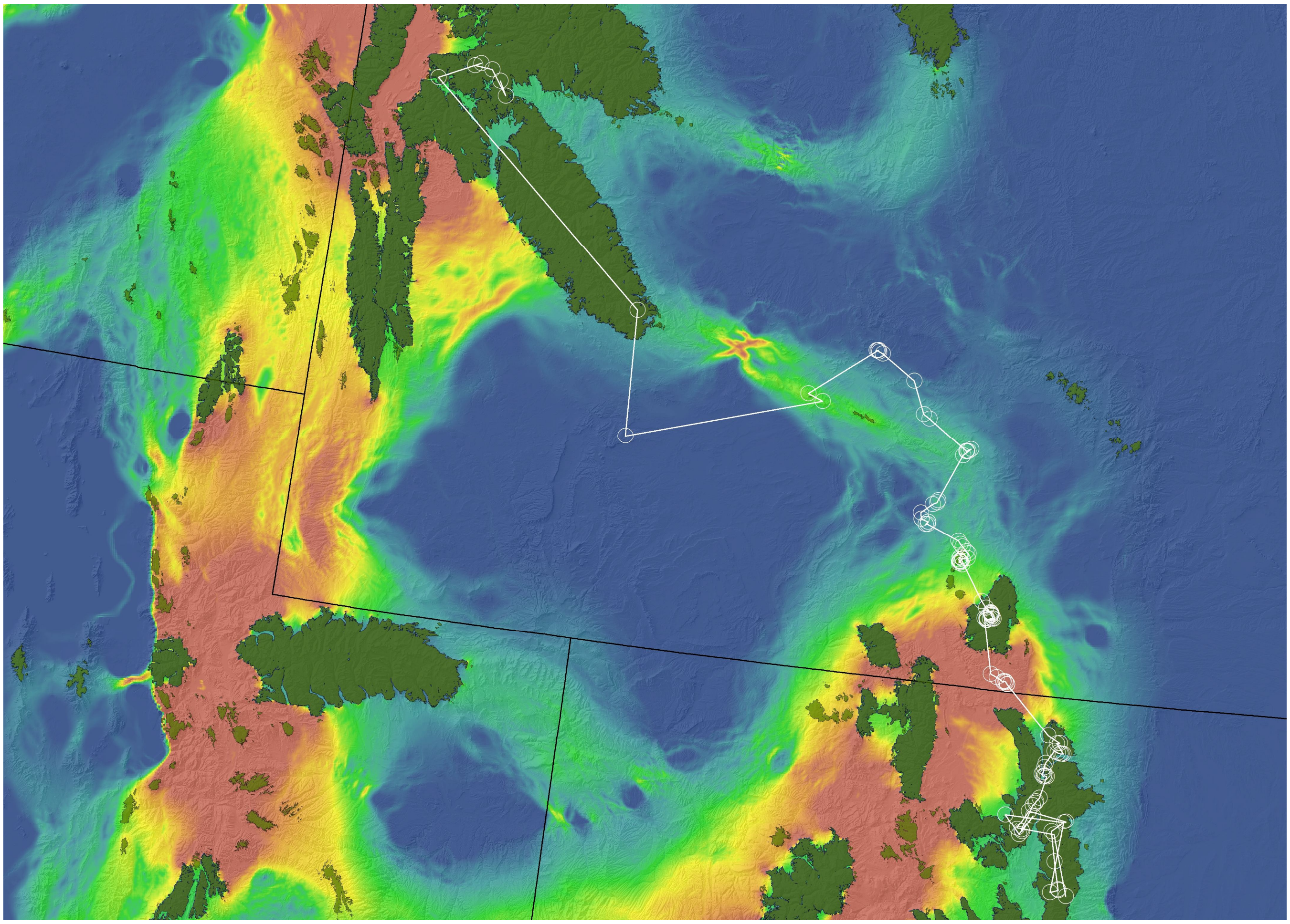
From my data, I^3 were fully in place at 49 days. Dale's (Sue) limited observation data is also consistent with I^3 erupted by 7 weeks. Although the photo of the lower dentition is certainly not at the quality level needed to feel certain of the dentition status, I would suggest this individual was 11-12 weeks old at the time of the photo. This is based on what appears to be the lower canines, PM_3, PM_4, and M_1 fully in place.

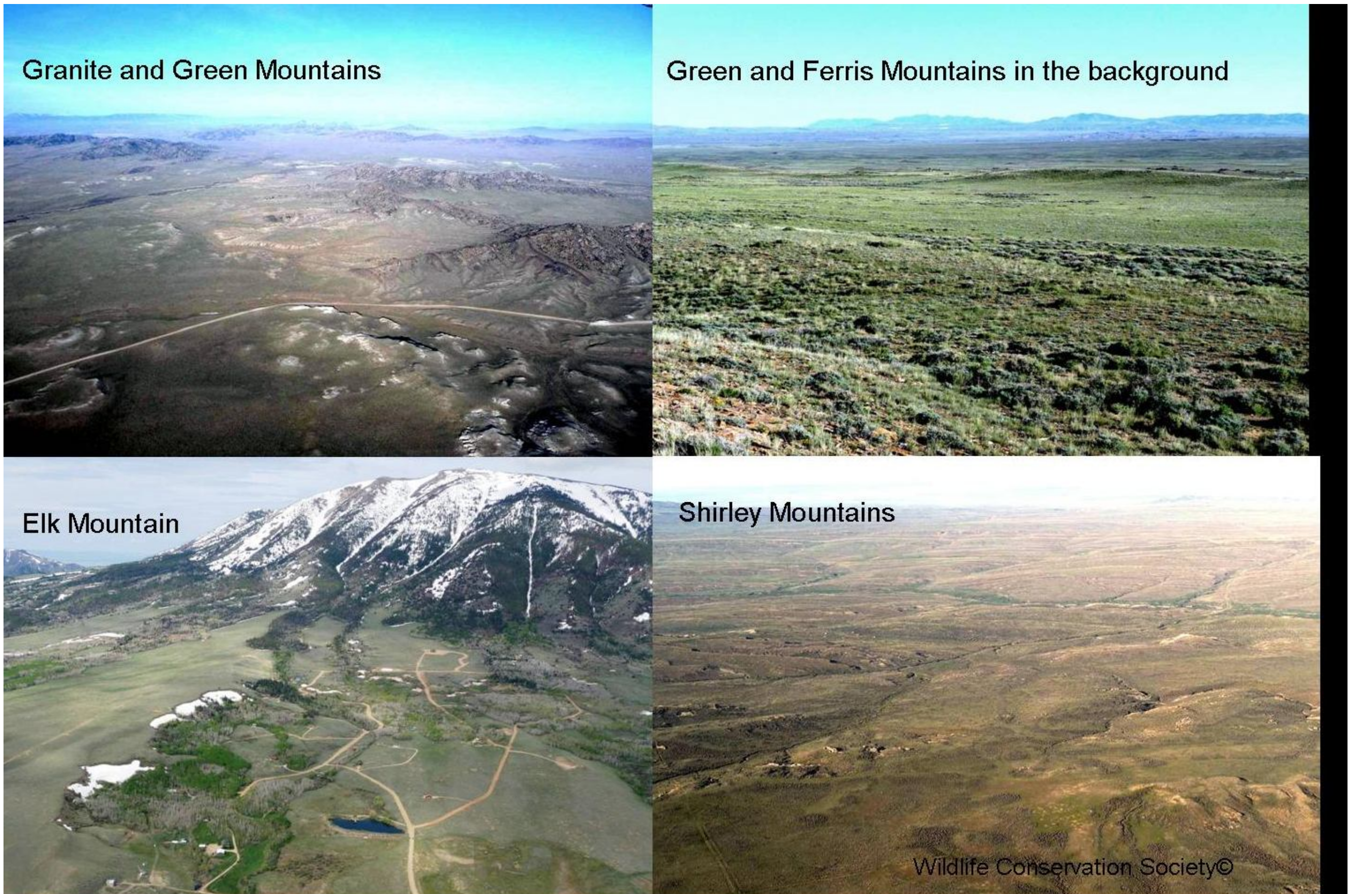
By our data, there is a period of 2+ weeks (70-83+ days) that this formula would be in place before I_1 erupts (I_1 eruption 83-90 days).

Also, from my experience with *Gulo* kits I would further <u>guess</u> that this kit is probably closer to 12 weeks than 11 weeks. This is subjectively based on the individual's pelage and gross appearance. I don't know if this kit's locomotion was reasonably developed at the time of the capture, but our kits were uncoordinated when running and their climbing ability was very limited at 11 weeks. By 12 weeks it had definitely improved.

It would have been interesting to palpate the incisal line, as it appears small "white bumps" are present.

Clint





Habitat used by a male wolverine while dispersing from Wyoming to Colorado

From:	Bush, Jodi
To:	Marjorie Nelson; Stephen Torbit (Stephen Torbit/R6/FWS/DOI); Justin Shoemaker
Cc:	Betty Grizzle
Subject:	Additional Genetic work for wolverine
Date:	Wednesday, May 24, 2017 4:04:12 PM

Folks - Sorry I missed the call today. I was tied up back at NCTC. Betty caught me up and as we talked I thought it would probably be advantageous to us all if we came up with a preliminary scope of work for what we are looking for with the genetic work. This would help make sure that we are all on the same page and we could share it with the other Regions to facilitate understanding of what we intend to do.

Steve. Do you think you could take the first stab at drafting up something? I know you have talked to many different entities regarding the genetics issue and it might be useful to start with what you see as our preliminary tasks. Justin and Betty would weigh in too but your initial efforts would really help to get us what we need to make progress on this task. Let me know if you are okay with attempting to come up with the first draft. After that we can send it around for adds or changes and get something that we can share and all speak to with one voice. Thanks for all your help on this fun topic. JB

Jodi L. Bush
Office Supervisor
Montana State Ecological Services Office
585 Shepard Way, Suite 1
Helena, MT 59601
(406) 449-5225, ext.205

From:	Shoemaker, Justin
To:	Caitlin Snyder
Cc:	Grizzle, Betty
Subject:	Revised wolverine timeline-draft
Date:	Wednesday, May 24, 2017 11:56:47 AM
Attachments:	Wolverine Detailed Timeline_05242017.docx

Caitlin,

Here's my attempt at a revised schedule for wolverine. Can you look over the HQ review time frames for this schedule?

I still need to go over the dates currently in there to make sure they don't fall on weekends or holidays.

Justin Shoemaker
Classification Biologist
U.S. Fish and Wildlife Service, Region 6
Phone: 309-757-5800 x214
Email: justin_shoemaker@fws.gov

Wolverine Listing Determination Timeline
5/19/17 version

Task	Responsible Parties	Dates	Length of time
Species Status Assessment (SSA) Phase			
FR notice opening comment period on 2013 proposed listing rule	MTFO	Oct 18 2016	done
DIP letters sent out to States and partners	MTFO	Oct	done
Public comment period, input from States, partners, etc.		Oct 18-Nov 17	30 days, done
Conduct science analysis (SSA)	SSA core team	By Sept 15 2017	in process
Draft SSA report	Betty Grizzle (FO Lead Bio)	By Oct 7	in process
SSA core team meeting in Denver	Core team, R6 management and decision support staff	Feb 15-16	2 days, done
SSA report check-in	SSA core team, management	Early-mid Sept (TBD)	half day
Peer review planning and contracting	Justin Shoemaker (ULT lead), Caitlin Snyder (ULT assist)	Aug - Oct	2 months to get contracted peer reviewers in place
SSA report core team review	SSA core team	Oct 7-14	1 week
Edit SSA report based on core team review	Betty Grizzle	Oct 14-Oct 21	1 week
SSA report to peer reviewers and partners*	Justin Shoemaker, Jodi Bush (MTFO Project Leader)	Oct 21-Nov 21	1 month
Edit and finalize SSA report	Betty Grizzle	Nov 21-Dec 19	4 weeks
Listing Decision Analysis Phase			
SSA report to recommendation team	Justin Shoemaker, Jodi Bush	Dec 19	At least 2 weeks prior to recommendation team meeting
Decision meeting	RDs or delegates, ARDs, other management, SSA core team	First or second week of Jan **2018**	2 days
Draft decision summary for the record or certify decision meeting notes	R6 RD or delegate	early Jan	3 days (after recommendation team meeting)
Process for final withdrawal of proposed listing (if decision is to not list) - or revised proposed listing rule (if decision is to list)			
Draft final withdrawal (not-warranted) FR notice or revised proposed listing rule (and if necessary, proposed 10(j), 4(d))	Justin Shoemaker	Jan 15-Feb 12	4 weeks
Core team reviews FR notice,	SSA core team,	Feb 12-Feb 26	2 weeks

*Includes States, Tribes, Federal Agencies

make revisions	Justin Shoemaker		
Regional Office Surnames and concurrence	Marjorie Nelson, Mike Thabault, Matt Hogan, Noreen Walsh, and concurring regional RDs/ARDs or delegates	Feb 26-March 12	2 weeks
SOL surname	DOI SOL	Feb 26-March 12	2 weeks
PPM and HQ ES surname	PPM, HQ ES	Feb 26-March 12	2 weeks
Revise based on RO/SOL/PPM comments	Justin Shoemaker	March 12-March 26	2 weeks
HQ review	Sarah Quamme, Bridget Fahey	March 26-?	6 weeks prior to FR date
Asst. Director for ES Surname	Asst. Director for ES	?	4 business days
FWS Director Surname	Director of FWS	?	5 business days
Fish, Wildlife, and Parks Surname	FWP	?	10 business days
Executive Secretary Surname	Executive Secretary's Office	?	3 business days
Deliver to FR	HQ	May 7	
Publication of withdrawal or proposed rule	Federal Register	May 14	
Public comment period on revised proposed listing (only if decision is to list)		May 14-June 12	30 days
Process for final listing Federal Register document			
Comment and response strategy meeting – develop plan to review and address comments received	SSA core team, management	Mid May (TBD)	half day
Review and address public comments on proposed listing	SSA core team, support staffing as needed from R6 RO	June 12-July 16	1 month
Meeting with decision team to discuss public comment and any new info, revisit decision	Marjorie Nelson, Mike Thabault, Matt Hogan, Noreen Walsh, and concurring regional RDs/ARDs or delegates	Early July 2018	half day
Draft final listing FR doc (if necessary 10(j), 4(d))	Justin Shoemaker and Betty Grizzle	by July 16	2 months from proposed listing publication
SSA core team reviews FR notice, make revisions	SSA core team	July 16-July 23	1 week
Regional Office Surnames and concurrence	Marjorie Nelson, Mike Thabault, Matt Hogan, Noreen Walsh, and concurring regional	July 23-Aug 6	2 weeks

*Includes States, Tribes, Federal Agencies

Commented [SJ1]: Could use Caitlin's input on HQ review/surnames, length of time for each step.

	RDs/ARDs or delegates		
SOL surname	DOI SOL	July 23-Aug 6	2 weeks
PPM and HQ ES surname	PPM, HQ ES	July 23-Aug 6	2 weeks
Revise based on RO/SOL/PPM comments	Justin Shoemaker and Betty Grizzle	Aug 6-Aug 13	1 week
HQ review	Sarah Quamme, Bridget Fahey	Aug 13	6 weeks prior to FR date
FWS Director Surname	Director of FWS	?	?
Fish, Wildlife, and Parks Surname	FWP	?	?
Executive Secretary Surname	Executive Secretary's Office	?	?
Deliver to FR	HQ	Sep 24	
Publication of final rule	Federal Register	Sep 28, 2018	Note: We've committed to final rule in FY 18 in the work plan

Commented [SJ2]: Caitlin?

*Includes States, Tribes, Federal Agencies

From: Snyder, Caitlin
To: Shoemaker, Justin
Cc: Grizzle, Betty
Subject: Re: Revised wolverine timeline-draft
Date: Wednesday, May 24, 2017 2:27:58 PM
Attachments: Wolverine Detailed Timeline_05242017_cs.docx

Hi Justin,

I changed a few of the dates in the HQ review chain based on the FR submittal dates. Let me know if you have any questions. (I did account for the public holiday in September for the final action when calculating dates.)

Thanks,
Caitlin

Caitlin Snyder
Unified Listing Team
U.S. Fish & Wildlife Service
MS: ES
5275 Leesburg Pike
Falls Church, VA 22041-3803
phone: 703 358 2673

On Wed, May 24, 2017 at 1:56 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> Caitlin,
>
> Here's my attempt at a revised schedule for wolverine. Can you look over the HQ review time frames for this schedule?
>
> I still need to go over the dates currently in there to make sure they don't fall on weekends or holidays.
>
> Justin Shoemaker
> Classification Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov

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5/19/17 version

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Draft final withdrawal (not-warranted) FR notice or revised proposed listing rule (and if necessary, proposed 10(j), 4(d))	Justin Shoemaker	Jan 15-Feb 12	4 weeks

*Includes States, Tribes, Federal Agencies

Core team reviews FR notice, make revisions	SSA core team, Justin Shoemaker	Feb 12-Feb 26	2 weeks
Regional Office Surnames and concurrence	Marjorie Nelson, Mike Thabault, Matt Hogan, Noreen Walsh, and concurring regional RDs/ARDs or delegates	Feb 26-March 12	2 weeks
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PPM ~~and HQ ES surname~~	PPM~~, HQ ES~~	Feb 26-March 12	2 weeks
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HQ review	Sarah Quamme, Bridget Fahey	March ~~26~~21-~~?~~	2 weeks (submit 6 weeks prior to FR submittal date)
Asst. Director for ES Surname	Asst. Director for ES	April 4~~?~~	~~5~~4 business days
FWS Director Surname	Director of FWS	April 11~~?~~	5 business days
Fish, Wildlife, and Parks Surname	FWP	~~?~~April 18	10 business days
Executive Secretary Surname	Executive Secretary's Office	May 2~~?~~	3 business days
Deliver to FR	HQ	May 7	
Publication of withdrawal or proposed rule	Federal Register	May 14	
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SSA core team reviews FR notice, make revisions	SSA core team	July 16-July 23	1 week

*Includes States, Tribes, Federal Agencies

Commented [SJ1]: Could use Caitlin's input on HQ review/surnames, length of time for each step.

Commented [SC2R1]: Counting back from the FR date of May 14, the document will need to come in here on March 21. If you want to calculate the dates from submitting HQ on March 26, you'll get a slightly later FR date in May.

Commented [SC3]: I think this needs to be 60 days. The CFR requires us to open the comment period for 60 days on a rule proposing listing, but we might want to confirm if a revised proposed listing is considered a "new" listing (and thus requiring 60 days), or another sort of proposed rule (and only requiring 30 days).

Regional Office Surnames and concurrence	Marjorie Nelson, Mike Thabault, Matt Hogan, Noreen Walsh, and concurring regional RDs/ARDs or delegates	July 23-Aug 6	2 weeks
SOL surname	DOI SOL	July 23-Aug 6	2 weeks
PPM ~~and HQ ES surname~~	PPM~~, HQ ES~~	July 23-Aug 6	2 weeks
Revise based on RO/SOL/PPM comments	Justin Shoemaker and Betty Grizzle	Aug 6-Aug 13	1 week
HQ review	Sarah Quamme, Bridget Fahey	Aug 7~~13~~	6 weeks prior to FR date
AES Surname	Assistant Director Ecological Services	Aug 21	5 business days
FWS Director ~~Surname~~Signature	Director of FWS	Aug 28~~?~~	?5 business days
Fish, Wildlife, and Parks Surname	FWP	Sep 5~~?~~	?10 business days
Executive Secretary Surname	Executive Secretary's Office	Sep 19~~?~~	3 business days~~?~~
Deliver to FR	HQ	Sep 24	
Publication of final rule	Federal Register	Sep 28, 2018	Note: We've committed to final rule in FY 18 in the work plan

*Includes States, Tribes, Federal Agencies

Commented [SJ4]: Caitlin?

Commented [SC5R4]: Inserted dates based on Sep 24 submittal to FR. Did not count Labor Day (holiday)

From:	Shoemaker, Justin
To:	Grizzle, Betty
Subject:	Re: DRAFT talking points for RO call next week
Date:	Friday, May 26, 2017 9:42:03 AM
Attachments:	Talking Points_JS.docx

Looks good. I added a bit about DPS, feel free to take it or leave it.

Justin Shoemaker
Classification Biologist
U.S. Fish and Wildlife Service, Region 6
Phone: 309-757-5800 x214
Email: justin_shoemaker@fws.gov

On Fri, May 26, 2017 at 9:39 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Hi Justin - I prepared this fairly quickly yesterday afternoon. Please take a look and add/edit. I will try to contact WGI today.
> Thanks.
>
> --
>
> Betty J. Grizzle, D.Env.
> Fish and Wildlife Biologist
> U.S. Fish and Wildlife Service
> Carlsbad Fish and Wildlife Office
> 2177 Salk Ave, Suite 250
> Carlsbad, CA 92008
> 760-431-9440, ext. 215
> 760-431-5901 fax

Talking Points – Funding Request for Wolverine Genetic Analyses

Background

In the U.S. District Court decision (April 4, 2016), the court remanded our withdrawal of the wolverine proposed rule for further consideration based on two primary issues: 1) ignoring best available science in dismissing the threat to wolverine from climate change and 2) ignoring best available science by dismissing the **threat to wolverine from genetic isolation and small population size**. Specifically, the court said that, in our 2014 withdrawal, we failed to articulate how our statements regarding the following did not constitute adverse effects to wolverine:

- Apparent loss of connectivity between Rocky Mountains and Canada prevented influx of genetic material needed to maintain or increase the genetic diversity in contiguous U.S.
- Effective population size is too low to support the subpopulations in contiguous U.S.
- Genetic drift has already occurred in subpopulations in contiguous U.S. as compared to Canada, and a continued loss of genetic diversity may lead to inbreeding depression and inability of wolverines in contiguous U.S. to persist

Thus, we need to evaluate our statements that there is "good evidence" that genetic diversity is lower in wolverines in the contiguous U.S. as compared to Canada and Alaska. We also need to determine whether there is a threat for inbreeding depression based on small population.

The following talking points provide potential pathways for addressing the court's remand.

Microsatellite analysis

- Provide funding to USFS genomics lab (Missoula) to prepare microsatellite loci analyses using existing samples provided to this lab (by western States) to examine current genetic structure of wolverines in contiguous U.S. Costs are estimated at $60,000 based approximately 300 samples collected already submitted, at $200/sample.
- Provide funding to independent lab (e.g., Wildlife Genetics International, British Columbia) for this analysis. This will require that the USFS lab release collected samples. WGI has previously run genetic analyses for wolverines. [*Betty is requesting cost estimate*]
- Provide funding to FWS Conservation Genetics Laboratory in Alaska. This would also require that samples be retrieved from USFS lab. Cost estimated at $100/sample and several months (estimate) to complete. However, the costs may, in the long run, be similar to USFS as they have not previously run any genetic testing for wolverine and therefore would require lead time and materials (additional costs).

Commented [SJ1]: I thought $60k was for microsatellite and mitochondrial analysis. Just microsatellite might be less? Steve might know.

If the microsatellite analysis is funded, conduct independent review of USFS results

- Provide funding to FWS Alaska lab to either 1) obtain from USFS lab 50 samples and analyze this subsample to verify USFS lab results. Cost likely to be $100/sample.
- Provide funding to independent lab to prepare review and interpretation of the results of USFS analysis to assess current genetic structure of populations of wolverines across North America (not just the contiguous U.S.) using results from other studies in GenBank that includes wolverines in Canada.

Commented [SJ2]: Is there a 2)?

Effective population size analysis (if funds available)

Provide funding for independent assessment of minimum viable population size following methods from Koskela (Finland) using results from USFS lab

DPS

Preliminary interpretation by the FWS Alaska lab of recent genetic studies indicate that wolverines in the lower 48 States are likely decedents of wolverines that migrated from Canada years ago to repopulate the area after persecution of predators ceased. As such, wolverines in the lower 48 do not represent distinct genetics (no unique alleles) as it may apply to discreteness in our DPS policy. Genetically speaking, recent studies show nothing significant in the lower 48, also as it may apply to the DPS policy. Any additional knowledge gained through a more thorough and complete comparison of genetics of wolverines in the lower 48 compared to Canada would provide a more legally and scientifically robust basis on which to base our DPS determination.

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From:	Grizzle, Betty
To:	Guinotte, John
Subject:	Re: DRAFT talking points for RO call next week
Date:	Tuesday, May 30, 2017 8:27:26 AM

John - I wasn't sure if we were submitting 20 or more than this. I will make the change.
FYI - I spoke with WGI on Friday. Give me a call if you want to discuss.

On Tue, May 30, 2017 at 6:57 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Hi Betty and Justin. I was out Friday and just read this. Looks good to me. I thought be were only going to send 20 samples to the FWS Alaska lab for the independent review of USFS result? In the document it is listed as 50.
>
> Also, I noticed Mike has not accepted the invite for the call this am. Do we know if he is going to be on? If not, we probably need to reschedule. I'm in the office today, but have not seen him.
>
> Best, John
>
> John Guinotte
> Fish and Wildlife Biologist
> Ecological Services
> U.S. Fish and Wildlife Service
> Mountain Prairie Region 6
> 134 Union Blvd., Lakewood, CO 80228
> 303-236-4264
> john_guinotte@fws.gov
>
> On Fri, May 26, 2017 at 11:50 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>
>> Justin - Here is my second edited version (so ignore previous email and attachment). I renamed the file name, and left one response to your comment in this draft.
>>
>> On Fri, May 26, 2017 at 8:41 AM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:
>>
>>> Looks good. I added a bit about DPS, feel free to take it or leave it.
>>>
>>> Justin Shoemaker
>>> Classification Biologist
>>> U.S. Fish and Wildlife Service, Region 6
>>> Phone: 309-757-5800 x214
>>> Email: justin_shoemaker@fws.gov
>>>
>>> On Fri, May 26, 2017 at 9:39 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>>>
>>>> Hi Justin - I prepared this fairly quickly yesterday afternoon. Please take a look and add/edit. I will try to contact WGI today.
>>>> Thanks.
>>>>
>>>> --
>>>>
>>>> Betty J. Grizzle, D.Env.
>>>> Fish and Wildlife Biologist

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From:	Guinotte, John
To:	Shoemaker, Justin; Betty Grizzle
Subject:	Fwd: draft email to steve.
Date:	Tuesday, May 30, 2017 12:10:39 PM

I just spoke to Steve. Question #2 isn't possible. The states only paid for 1. Identification of whether or not it is a wolverine and 2. The gender of the wolverine. Have to run the microsat on all 300 samples to get the individuals.

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john_guinotte@fws.gov

---------- Forwarded message ----------
From: **Guinotte, John** <john_guinotte@fws.gov>
Date: Tue, May 30, 2017 at 11:47 AM
Subject: draft email to steve.
To: "Shoemaker, Justin" <justin_shoemaker@fws.gov>, Betty Grizzle <betty_grizzle@fws.gov>

Hi Justin and Betty, Can you both take a look at these and let me know if I missed something, etc. here? If not, I will send to Steve and cc Mike.
thanks John

Hi Steve,

We talked about what is needed cost estimate wise after you jumped off.

We need to know the following from Schwartz:

1. What is the total cost to run microsatellites only on the 300 samples he has in hand?

2. Could he run a sub-sample of the 300 samples and still get us the answers we need? If the answer is yes, how many samples would he have to run to give us a statistically rigorous result and what is the total cost?

3. What is the cost of doing the blinds and who would do them? This doesn't seem very doable to me now.

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john_guinotte@fws.gov

From:	Grizzle, Betty
To:	Guinotte, John
Cc:	Shoemaker, Justin
Subject:	Re: draft email to steve.
Date:	Tuesday, May 30, 2017 12:11:01 PM

#1 and #2 look fine. I think #3 is not relevant at this point.
One other thing, we need to make sure that the total cost includes preparing appropriate statistical analyses and interpretation of those results.

On Tue, May 30, 2017 at 10:47 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Hi Justin and Betty, Can you both take a look at these and let me know if I missed something, etc. here? If not, I will send to Steve and cc Mike.
> thanks John
>
> Hi Steve,
>
> We talked about what is needed cost estimate wise after you jumped off.
>
> We need to know the following from Schwartz:
>
> 1. What is the total cost to run microsatellites only on the 300 samples he has in hand?
>
> 2. Could he run a sub-sample of the 300 samples and still get us the answers we need? If the answer is yes, how many samples would he have to run to give us a statistically rigorous result and what is the total cost?
>
> 3. What is the cost of doing the blinds and who would do them? This doesn't seem very doable to me now.
>
> John Guinotte
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From:	Grizzle, Betty
To:	Guinotte, John
Cc:	Shoemaker, Justin
Subject:	Re: draft email to steve.
Date:	Tuesday, May 30, 2017 1:13:01 PM

Looks fine. Thanks, John.

On Tue, May 30, 2017 at 12:11 PM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Hi, After talking w Steve and Betty again today, I reworked the questions. I think this should be final. Please let me know and I'll send to Steve and Mike. thanks John
>
> > Hi Steve,
> >
> > We talked about what is needed cost estimate wise after you jumped off.
> >
> > We need to know the following from Schwartz:
> >
> > 1. Does Schwartz know how many wolverine samples there are in the 300 total hair samples he has in hand? Is it 100, 150?
> > 2. What is the total cost to run microsatellites only on the wolverine samples? When will he have the results?
>
> 3. Need to make sure his cost estimate includes appropriate statistical analyses and interpretation of those results.
>
> > John Guinotte
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From:	Guinotte, John
To:	Joseph Barsugli - NOAA Affiliate
Cc:	Stephen Torbit; Betty Grizzle
Subject:	Re: Fwd: snowpack projections?
Date:	Thursday, June 1, 2017 3:00:41 PM

Thanks Joe. Appreciate the feedback.
Best, J

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john_guinotte@fws.gov

On Thu, Jun 1, 2017 at 1:46 PM, Joe Barsugli <joseph.barsugli@noaa.gov> wrote:

> At the elvel of spatial scale it is similar to the McKelvey/Littell data. Perhaps it could be used as a replacement for the Littell data.
>
> The snow model is...not physically based. I am hesitant to say much more without reading the papers (beyond the abstract) -- but it is a statistical model based on the Nov-Mar average precip and mov-mar average minimum temperature. The regressions based on SNOTEL data are then applied to the Tmin and Precip values at the unobserved grids. I mean, why not just run a temperature-index snow model at each grid (as Candida has done for another project?) Or in our case a full energy and water balance snow model?
>
> All in all
>
> a) I prefer full energy balance snow models for climate change work. (statistical realationships may not be stationary)
>
> b) the selective siting of SNOTEL sites makes the regressions unrepresentative. (they may have dealt with this in the deatils I haven't read..)
>
> Joe
>
> On 6/1/2017 8:22 AM, Guinotte, John wrote:
>
>> Hi Joe,
>>
>> When Betty was here we spoke about potential projections for snowpack across the rest of the wolverine range. I had a quick look at this site this am. If you go to the "raster layers for the continental US" link there are several snow raster

layers available, including a "Future April 1 SWE" product. The metadata says:

"April 1 SWE and snow residence time were modeled using the spatial analog models of Luce et al., [2014] (see also Lute and Luce, in review). These models are built on precipitation and snow data from Snowpack Telemetry (SNOTEL) stations across the western United States and temperature data from the TopoWx dataset [Oyler et al., 2014]. To simulate historical and future gridded snow, the models ingest gridded winter cumulative precipitation and winter average temperature (from the MACAv2-Metdata dataset described above). While the snow models have been rigorously validated [Lute and Luce, in review], their application to gridded climate model data has not been evaluated"

I'm wondering what you think of this. It looks like the spatial resolution of the model data is approx 4km x 4km. The "Future April 1 SWE" product is RCP8.5 for 2080. If it looks like this is something we could use, I can get in touch with Luce and ask if they have a product for 2050.

Thanks John

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---------- Forwarded message ----------
From: **Luce, Charlie -FS** <cluce@fs.fed.us>
Date: Wed, May 31, 2017 at 10:12 PM
Subject: RE: snowpack projections?
To: "Isaak, Daniel -FS" <disaak@fs.fed.us>, "Guinotte, John" <john_guinotte@fws.gov>

Hi John,

I'm glad you are interested in snow! We do have some maps up on the web. They are pretty strictly focused on Forest Service lands at this time, but there is a link for full CONUS arcgis coverage (TIFF) at the bottom of the page.

https://www.fs.fed.us/rm/boise/AWAE/projects/national-forest-climate-change-maps.html

I'd be interested in the utility of these for snow-dependent species and if any additional information might be useful.

Best,

Charlie

Charles Luce, PhD
Research Hydrologist
Forest Service

Research and Development

Rocky Mountain Research Station

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cluce@fs.fed.us

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Caring for the land and serving people

From: Isaak, Daniel -FS
Sent: Wednesday, May 31, 2017 10:47 AM
To: Guinotte, John <john_guinotte@fws.gov>
Cc: Luce, Charlie -FS <cluce@fs.fed.us>
Subject: RE: snowpack projections?

Hi John, I'm not an expert on snow but I work with one, Charlie Luce who's a research hydrologist here in our lab (ResearchGate profile: https://www.researchgate.net/profile/Charles_Luce). I've cc'd him on this & he'll know what exists for snow cover projections and datasets relevant to wolverines in the west. Best, Dan

From: Guinotte, John [mailto:john_guinotte@fws.gov]
Sent: Wednesday, May 31, 2017 7:20 AM
To: Isaak, Daniel -FS <disaak@fs.fed.us>
Subject: snowpack projections?

Hi Dan,

I'm working on the wolverine species status assessment and I'm wondering if you have future snowpack projections across the west? I thought you might have this as part of the Climate Shield project.

Thanks John

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--
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PSD Science Board and
Attribution and Predictability Assessments Team Member

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Here comes the judge

By Greg Walcher
Friday, June 2, 2017

The Great Falls Tribune reported, "Wolverine study's plan preferred to endangered species listing." That is a common sentiment in the West, where almost anything is preferable to endangered species listings, and the accompanying federal control over private land.

When I started as director of the Colorado Department of Natural Resources, we were just beginning our state's wildly successful reintroduction of lynx into the southern Rockies. It is among the great success stories in conservation history, with a thriving lynx population, and new births outnumbering mortality every year. As originally planned several years earlier, the program would have reintroduced both lynx and wolverines.

The wolverine part of the program was very controversial. Animal rights activists claimed it was cruel, ranchers worried about livestock, and outdoor groups thought wolverines dangerous. As children, my brothers and I were fascinated by animal books, and the main word always used to describe wolverines was "ferocious." It has powerful jaws, sharp claws, can kill prey as large as a moose, and will steal food from bears and wolves.

Several legislators opposed Colorado's reintroduction program, and even tried to cut our budget to stop it. By separating the two, we were able to proceed with the lynx, and permanently postpone the wolverine. History has proven that decision popular and successful.

Now we are again faced with the prospect of wolverine reintroduction into Colorado, not because the public or their elected officials have changed their minds, but because of lawsuits and judges.

The U.S. Fish and Wildlife Service was forced to reopen the entire process on a 6-year-old proposal to list wolverines under the Endangered Species Act. The agency studied it for several years, but ultimately withdrew the listing plan after concluding that the animal is not in danger as previously thought. That didn't suit environmental groups who prefer federal control, so they sued, and a federal judge with very little discussion overturned the withdrawal, effectively restarting the listing process. Under the law, that means the judge had decided the wolverine “is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.”

How would a federal district judge know that? He was not present for any of the analysis undertaken by the agency, nor the scores of meetings held with other experts. Judges are not scientists, yet they dictate to the agency charged with administering the law based on “the best available scientific” information. Court orders are now so numerous that Fish and Wildlife has little discretion over its own budget and priorities.

The Obama Administration devised a system for prioritizing listings, so limited resources could be used on the most at-risk species, but that also resulted in a lawsuit — and a court order disallowing such prioritization. Almost in exasperation, Obama asked Congress (in vain) to cap the amount of money that can be spent to process petitions. The agency has completely lost control of the process Congress intended it to manage for the benefit of endangered species.

Will wolverines now be added to the threatened and endangered list despite the best efforts of 11 western states to conserve their habitat and population? That question now awaits a new multi-state survey to determine exactly where wolverines live. We know at least 300 occupy their historic range in Washington, Oregon, Idaho, Montana and Wyoming. They are occasionally seen in California and Colorado, too, though probably not in significant numbers. We cannot guess; we need to know. Thus, this new survey should form the basis for all decision-making on the animal’s potential listing. But will it?

To be clear, this is not about whether wolverines can peacefully coexist in a state with 5.6 million people and 4,000 sheep and cattle. That is a topic for legitimate debate among Coloradans. Rather, this is about who should make that decision — the national environmental lobby, federal judges, or the people of Colorado?

Conservation plans adopted by state and local governments, landowners, and local user groups always enjoy broader support than federal judicial mandates. So the 11 states plan to write conservation plans that will avert the federal listing of wolverines. We know from experience (i.e. Gunnison sage grouse) that the federal government cannot be trusted to keep that promise, so a survey documenting the “best available science” and an agreement on how many wolverines ought to live where, is the only sensible approach.

The left frequently complains that science should not be manipulated by appointees with political agendas. It should not be manipulated by lawsuits with political agendas, either.

Greg Walcher is president of the Natural Resources Group and author of “Smoking Them Out: The Theft of the Environment and How to Take it Back.” He is a Western Slope native.

COMMENTS

Page 1 of 1

By *ROBERT LAITRES* - Tuesday, June 6, 2017

Mr. Walcher criticizes judges and lawyers because they are not scientists and know little about the environment. He would rather let the citizens of Colorado make those decisions. Somehow, the gentleman neglects the fact that most Colorado citizens are no more informed as to those subjects than the judges and attorneys who oppose his position. If fact, many of them are even less informed. So, what will they use as basis for their judgment? It will certainly not be based on any type of scientific findings, but on something else, usually on some personal agenda, or an agenda determined by “political ideology, and not on any type of scientific findings, as most such questions usually are.

Page 1 of 1