From:	Grizzle, Betty
To:	Shoemaker, Justin
Cc:	Guinotte, John
Subject:	Re: cosewic range map
Date:	Wednesday, January 17, 2018 2:22:39 PM
Attachments:	Wolverine_Current_Potential_Extent_Final.jpg Wolverine_COSEWIC_CPE_Dec 19.jpg Wolverine_MExO_revised.jpg

---

Justin - Here are jpg versions of the CPE maps (contiguous US and North America) and the MEO map.

On Wed, Jan 17, 2018 at 1:17 PM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Here is the updated map for current, historical, etc. for NA. Is this all you need Justin? You have the map w the DPS 2013 layer that Nick and Shawn came up with. Was there another one you need that you don't have? You have Betty's map for current range right.
> best, J
>
> John Guinotte
> Spatial Ecologist
> 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

--

Betty J. Grizzle, D.Env.
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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

PRODUCED BY GIS SERVICES
CARLSBAD FIELD OFFICE
GIS CONTACT: ED TURNER
BIOLOGY CONTACT: BETTY GRIZZLE
(760) 431-9440
DATA SOURCE: USFWS, EPA, NOT, USCB, ESRI
IMAGE SOURCE: ESRI Online Mapper
Dec 19, 2017
S:\cfo\mxds\temp\American_wolverine\MXDs\SSA_FINAL\SSA_FINAL_MXDs\Wolverine_COSEWIC_CPE.mxd

N

0 115 230 460 Miles
0 162.5 325 650 Kilometers

North American Wolverine (*Gulo gulo luscus*) Current Potential Extent

PRODUCED BY GIS SERVICES
CARLSBAD FIELD OFFICE
GIS CONTACT: ED TURNER
BIOLOGY CONTACT: BETTY GRIZZLE
(760) 431-9440
DATA SOURCE: USFWS, EPA, NOT, USCB, ESRI
IMAGE SOURCE: ESRI Online Mapper
Dec 12, 2017
S:\cfo\mled\temp\American_wolverine\MXDs\SSA_FINAL\SSA_FINAL_MXDs\Wolverine_MEx0.mxd

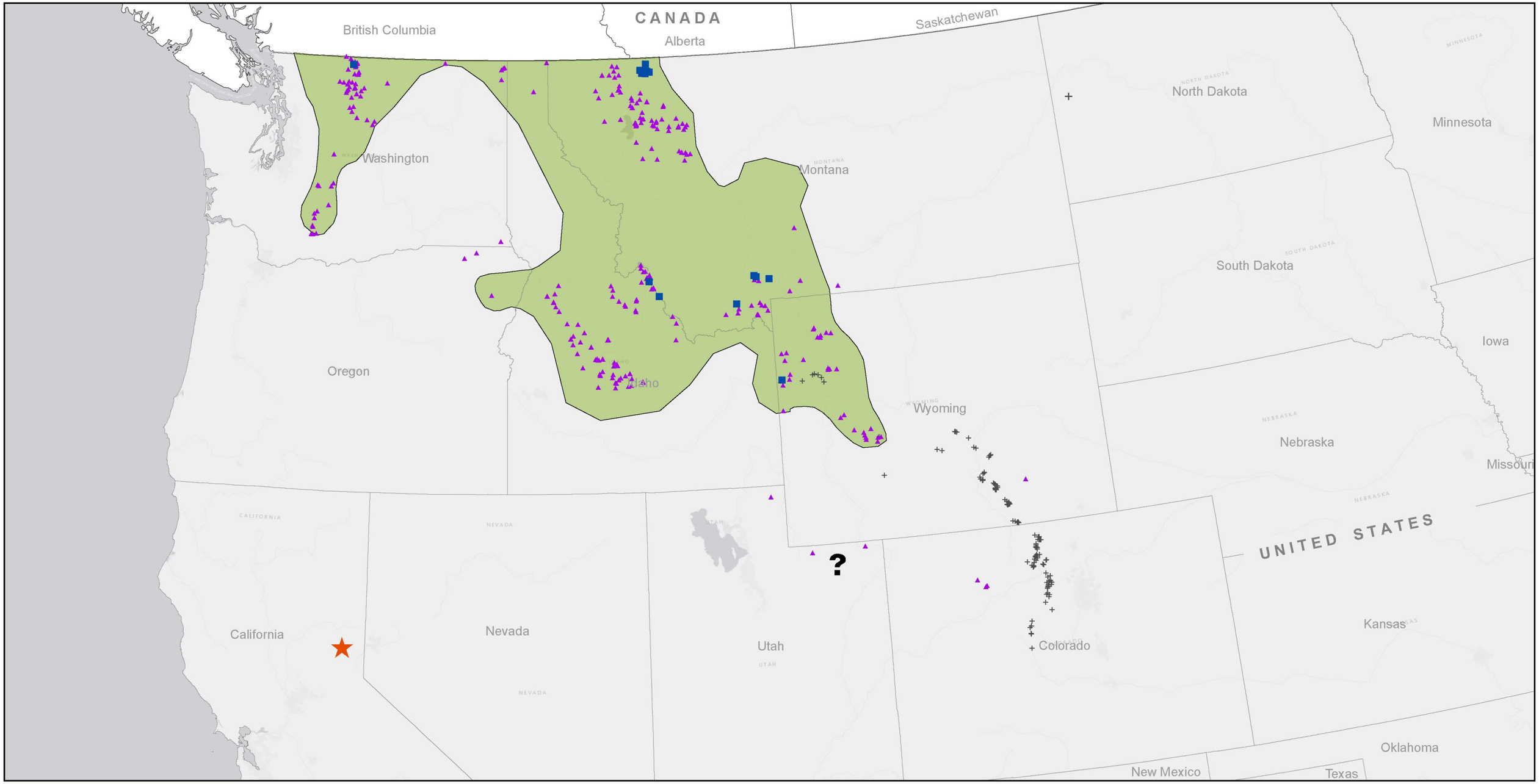
N

0 115 230 460 Miles

0 162.5 325 650 Kilometers

▲ Wolverine Observations in the Contiguous United States, 1827 – 2017; Compiled by USFWS

North American Wolverine (*Gulo gulo luscus*) Maximum Extent of Occurrences



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
Dec 19, 2017
S:\stem\edstemp\American_wolverine\MXDs\SSA_FINAL\SSA_FINAL_MXDs\Wolverine_Current_Potential_Extent.mxd

N

0 50 100 200 Miles

0 45 90 180 Kilometers

North American Wolverine (*Gulo gulo luscus*) Current Potential Extent

Wolverine Observations 2004 - 2017

Wolverine Den Observations 2002 - 2015

Wolverine Observation M56 2016

California Wolverine Observations 2008 – 2016

From: Shoemaker, Justin
To: Grizzle, Betty
Cc: Guinotte, John
Subject: Re: cosewic range map
Date: Wednesday, January 17, 2018 2:27:46 PM

Thanks all. If I need anything else I'll let you know.

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

On Wed, Jan 17, 2018 at 3:22 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Justin - Here are jpg versions of the CPE maps (contiguous US and North America) and the MEO map.
>
> On Wed, Jan 17, 2018 at 1:17 PM, Guinotte, John <john_guinotte@fws.gov> wrote:
>
> > Here is the updated map for current, historical, etc. for NA. Is this all you need Justin? You have the map w the DPS 2013 layer that Nick and Shawn came up with. Was there another one you need that you don't have? You have Betty's map for current range right. best, J
> >
> > John Guinotte
> > Spatial Ecologist
> > 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
>
> --
>
> 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: Kurz, Gregg
To: Hershey, Kit
Cc: Bryon Holt
Subject: Re: Wolverine prebrief today
Date: Thursday, January 18, 2018 11:14:14 AM

Thanks Kit and thanks to Bryon for taking the lead with the well pointed explanation.

Gregg

On Thu, Jan 18, 2018 at 11:11 AM, Hershey, Kit <kit_hershey@fws.gov> wrote:

> Bryon and Gregg,
> Thanks so much for your time today. The briefing was exactly what Rollie and Terry were hoping for: succinct and to the point. I also want to reiterate my thanks for your participation on the core team. R1 has been well represented by all your efforts. Kit
> --
> Kit Hershey, Regional Listing Coordinator
> Pacific Regional Office, Region 1
> US Fish and Wildlife Service
> 911 NE 11th Avenue
> Portland, OR 97232
> (503) 231-6869

--
Gregg Kurz
Branch Manager for Listing and Recovery
Carnivore Specialist
Central Washington Field Office
215 Melody Lane, Suite 103
Wenatchee, WA 98801-8122

509-665-3508 ex:2007
cell: 509-393-5880

From: Grizzle, Betty
To: Shoemaker, Justin
Cc: Norman, Kate; Guinotte, John
Subject: Re: DPS packet
Date: Thursday, January 18, 2018 11:15:12 AM

Not sure if the trapping map is needed (this might require more detailed explanation) or the current maps (since these are in the SSA Report). In other words, I would keep the focus for this set of materials on the previous DPS discussion/determination. Also, suggest clarifying/defining the term "conservation status" (as used in the 2010 12-month finding), where first used.

On Thu, Jan 18, 2018 at 9:59 AM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> Is this too much stuff to give them? Please take a look.
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov

--

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Carlsbad, CA 92008
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760-431-5901 fax

From:	Turner, Ed
To:	Betty Grizzle
Subject:	Nick"s DPS work
Date:	Thursday, January 18, 2018 12:58:37 PM
Attachments:	Looks like Nick did this.docx CFWO_Run_Nicks_Range_model_NO_SNOW.pdf Range_DPS_explain_model.pdf

---

--

Edwin Turner, Geographer
GIS Mapping and Analysis Branch

DOI-R8-CFWO
USFWS Carlsbad Fish and Wildlife Office
2177 Salk Ave. Suite 250
Carlsbad, CA 92008
760.431.9440 x266

Ed_Turner@fws.gov
760.431.9440 x266

Looks like Nick did this: **Nick will be looking at this soon and will get the complete process to me **

1. Took all cells from Copeland snow data 2000-2006 where grid values were 1 or larger (did not keep nodata = 0) and extracted those to new Raster. I found a few versions of this that very in cell size and projection. There are two raster sets, Snow and a PH that both have 500x500 cells, but different projections. Nick's output raster used for remaining process data has 1000x1000 cells, thus his "out_1k" raster name.
2. Took the grid of Inman PH model combined that with the Snow and looks like combined that with Female Dispersal (FD) (I did not have a grid for this so I don't know the size I can measure in ArcMap if needed).
3. Combined all and looks like he clipped it to the US border.
4. All data regardless if Snow, PH was a grid core 1, but he still had to retrain FD unique contiguous area ID or Grid value. This would allow calculations of area to determine if patch meets > 100km2 limits to keep and push forward to the "Out_1k" raster product.
5. Next looks like he, used Expand on Out_1k to give a buffer area of 20 units, which would equal 20km, as his raster cell is 1000x1000.
6. Next looks like he converted raster to polygon retaining cell edge.
7. I assumed he used edit function to run a smooth on the output polygon data from the Out_1k raster and based on his filename I assume he used a 20 input for Maximum allowable offset, but that never worked for me. I never received the same shapes.
8. Next, it looks like he took his smooth 20 product and clipped it to the USA boundary and then ran a smooth at 50 units. Again, that never worked for me. I never received the same shapes.
9. After all that it looks like he removed some of those Oregon, Washington, Nevada, etc. polygons that would not seem like wolverine areas. Betty has Shawn's email that explains which DPS polygons to drop.

Note: I only attempted step # 6, 7, & 8, assuming I was using the right stuff. I have Nick's out_1k_expand20 raster, so I could quickly test out to a poly data, and then try the smooth's.

I did not try the raster "Merge", or possibly take to command line GRID and run stacks, but to do so I first have to get the snow and PH raster's in the same projection and raster form as one is an Unsigned and the other is signed and I'm having difficulties combining those. The other issue is that I only have the FD as a polygon set from Nick's folders and I would need to convert that to a raster or grid and must match the other raster's for it to work.

CFWO RUN

We chose to just take the Bob Inman models data (PH, FD) and the Copeland Snow as 2000-2007 blended from Nick's folder and run all that as polygons.

Here is what I have to work with in polys:

1. Took Inman's PH and FD data from Nick's "Inman" folder and projected to Wolverine range-wide Alb projection.
2. Took Copeland's Snow 2000-2006 as one class from Nick's "Snow" folder and projected to Wolverine range-wide Alb projection.
3. Unioned the Snow and PH
4. Coded Snow or PH as value = 1
5. Dissolved the data on value = 1
6. Unioned the Snow/PH with the FD
7. Clip product by USA to limit size
8. Selected only Snow/PH code = 1
9. Dissolved product by FD code and Snow/PH code (this will group all patches by the FD area on which they reside) *** Some areas of Snow/PH that will meet the > 100km2 size requirements will fall outside of FD areas. To match closer to what Nick did, we too will look at these non-FD areas and use the size limitations.
10. Select only FD = 0 and run explode. (FD = 0 are areas of Snow/PH that fall outside of the FD areas. (Because all those patches area grouped as Fd = 0, those must be exploded into unique patches to use the size limits).
11. Calculate Hectares as double
12. Select Hectares > 10,000 and code "GT_100km2" = 1 (for areas > 100km2); Select Hectares < 10,000 code as "GT_100km2" = 2 (for areas < 100km2).
13. Select just those that meet size requirement "GT_100km2" = 1, dissolve on the Snow_PH = 1 and output the data so it can be buffered as one record feature (this extra step may help speed up the buffering process as these data are complex in shape).
14. Buffer the output from step #12 by 20km
15. Clip buffer by USA

*** I think in the end, Nick's habitat differs in some areas because he resampled from the original grid cell size that based on the data I could locate, was very small to 500x500. By going to 1000x1000 some of the gaps between original data patches were filled. I used the original polygon files and thus I had areas where the Snow or the PH or the Female Dispersal would not touch. That gives me a slightly different buffered area because I did not have some of the cell area that Nick picked up. See map where I show Nicks data and our data for Habitat output or where I show zoomed in specific area.

Data:

Nick_Wolv_DPS – Nick's output product

WestUSstates – From Nick's folder and is just western US and I used to clip data.

Copeland_Snow_2000_2006 – From Nick's folders and this is just Copeland's snow with only values of 1-7 combined as one grid value to a 1.

Inman_WCS (FD, MD, MH, PH) – Data from Nick's Inman folder that represents Male, Female Dispersal, Maternal Habitat, Primary Habitat.

Snow_PH – Union of Snow and PH

Snow_PH_Diss – All data that is snow or PH gets a value 1 and dissolves on that to create one simple feature record.

Snow_PH_FD – The above unioned with Female Dispersal. This gives areas of FD with unique ID's and snow/ph patches with value 1.

Snow_PH_FD_Clip – Above clipped to the West US data Nick had.

Snow_PH_FD_Clip_Dis – Above dissolved by the FD unique number and the snow/ph value 1. This will group all unique FD areas and the patches within those.

Snow_PH_FD_Clip_Dis_Exp – Above but select FD areas = 0 so we can explode the snow/ph polys that fall outside of female dispersal areas. We needed these because Nick had areas of snow and PH outside of Female Dispersal that are > 100km2 in his final product and I need to capture that too. *** This is the actual output Habitat data area and you must select and use on GT_100km2 = 1.

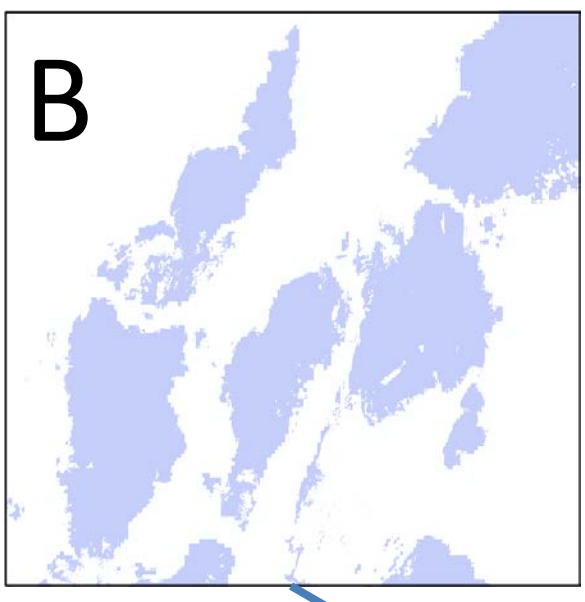
Snow_PH_FD_Clip_Exp_Dis_4_buf – Above selected for just areas that had snow/ph > 100km2 and dissolved into one blob feature for a simple buffer to 20km. This just made buffering the data quicker.

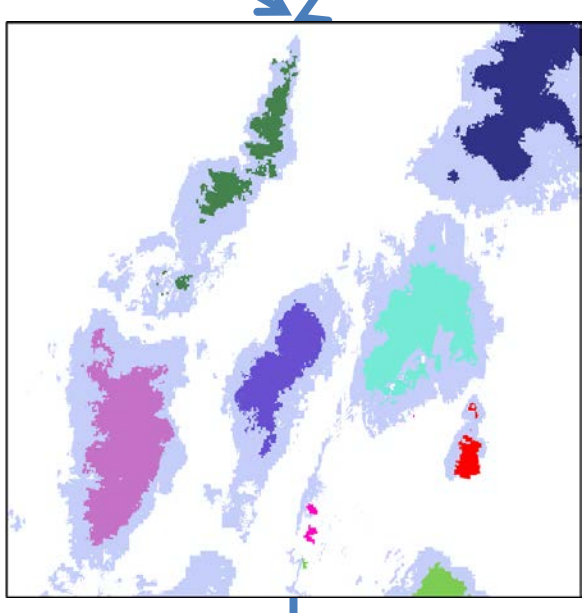
Snow_PH_FD_buf20km_Clip – Final range (like Nick's DPS) prior to me removing that areas that Shawn had Nick pull. See pdf's they show what polys to drop out. Note not exact match to Nick's smooth50 output, but that's because of 1000x1000 cells and I had smaller data area overall.

Primary Wolverine Habitat (WCS)

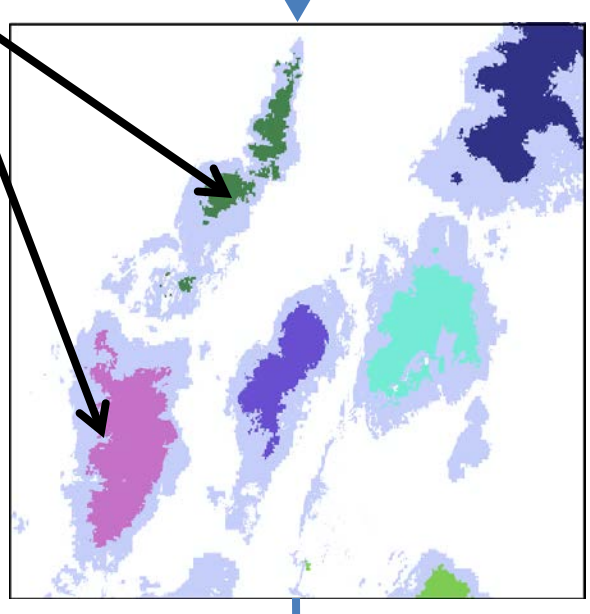
Combined

Female Dispersal layer (WCS)

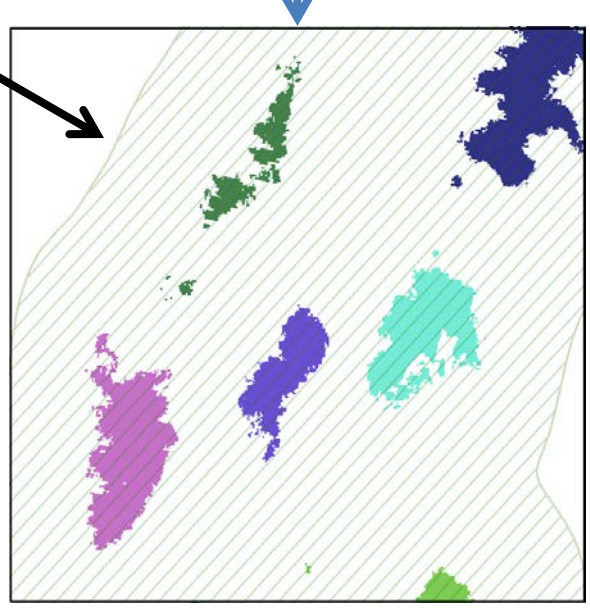




Modeled Habitat



Geographic Range



1. Calculate FD_NUM value for each individual or contiguous polygon in the Female Dispersal data.

2. Calculate FD Base Acres and Hectares and select only those areas that are >= 10,000 hectares. Reason being if a female dispersal area is less than 100km2 (10k hectares) then we would not retain Inman's PH model anyway.

3. Limit attributes in each data to reduce clutter, just turn off those unwanted and then Identity the PH model to the >= 10k FD areas.

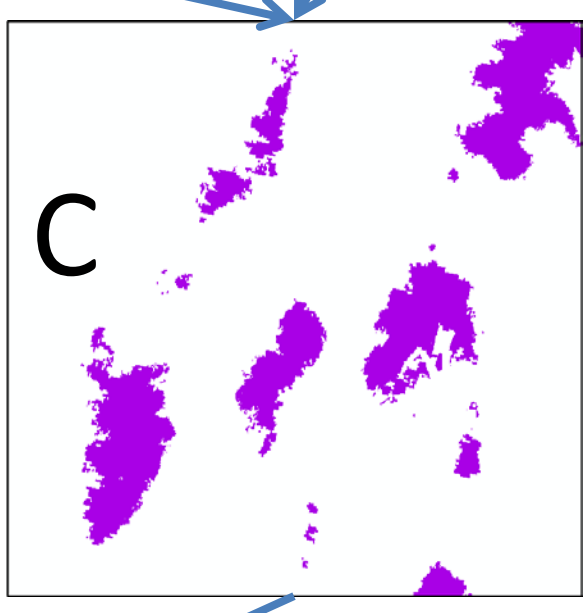
4. The output from the step "3" provides data that are PH model on areas of FD >= 10k, now select only the areas that are coded as "Primary Habitat" from the PH model. This will remove any areas of FD that do not have PH contained within. Now dissolve those selected PH areas, as they could be various PH polys that contain the same FD area value. Ex. You may end up with a few hundred or few thousand small PH polys in one contiguous FD area. Dissolving merged all those disjoined polygons into one record for the FD area with which they reside.

5. Added PH Output acres and hectares values to the dissolved product from step "4" and add a field to carry data forward that meets the >= 10,000 hectare rule. Select all records that are >= 10k and buffer only those areas by 20km to follow what Nick Hardy had done with his run.

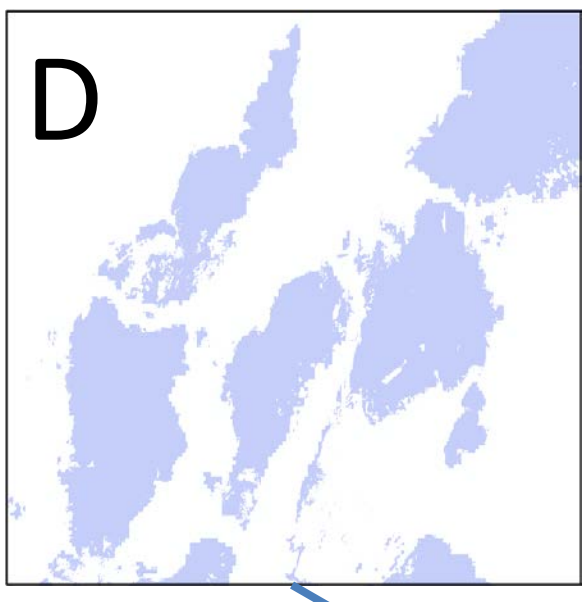
Late spring snow in >= 1 year of those surveyed

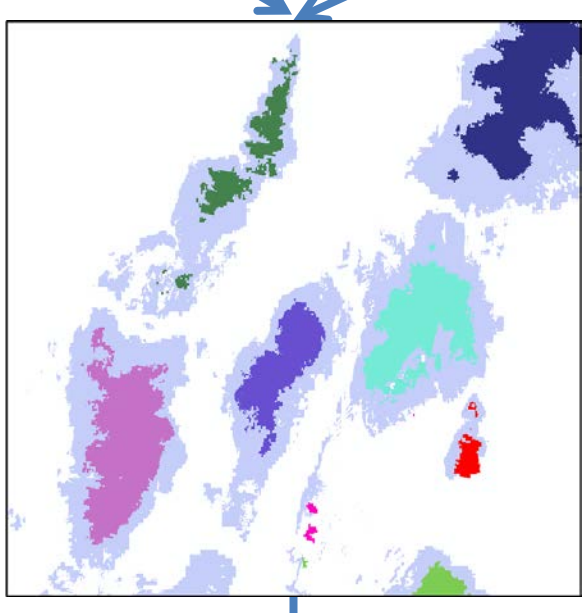
Primary Wolverine Habitat (WCS)

Combined



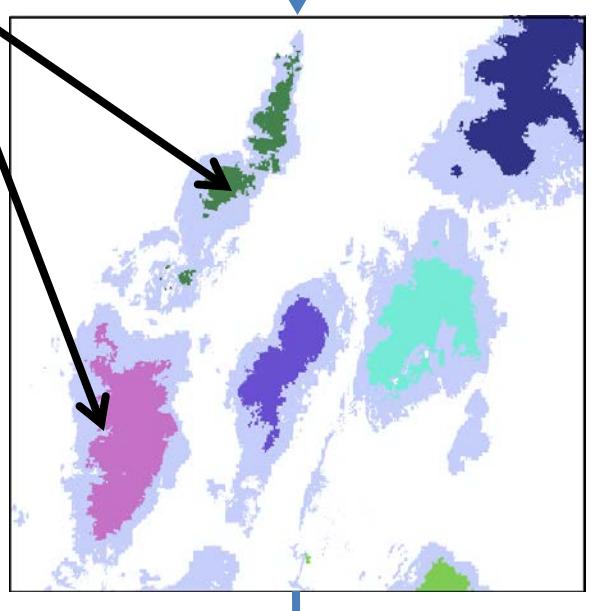
Female Dispersal layer (WCS)





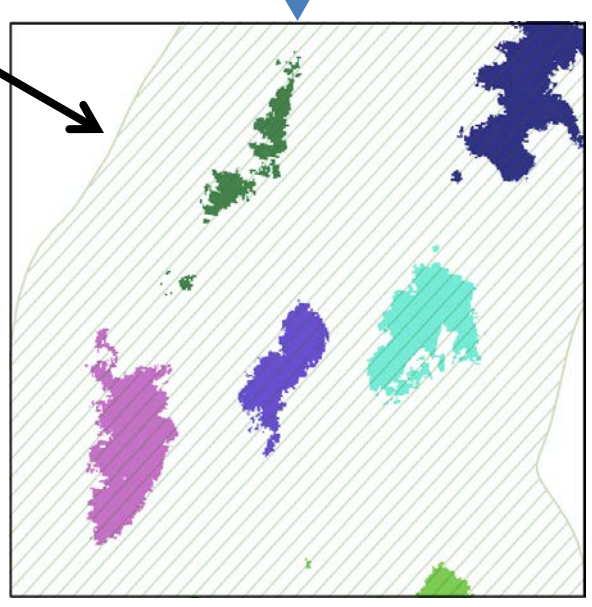
Overlay ‘C’ with ‘D’.
Group C by contiguous areas of ‘D’.
Each color represents a joined area of habitat.
e.g. the dark green areas show areas of ‘C’ that are connected by the same female dispersal polygon, even though they do not touch each other

Modeled Habitat



Discard all joined habitat (‘E’) with a total area < 100 km^2.
e.g. the dark green area is made up of individual polygons <100km^2, however since they are connected into the same habitat group by the female dispersal layer (and so are the same color) and the total are is >100km^2 they are kept.
e.g. the red area shows multiple polygons joined by the female dispersal layer. Because the total area of joined habitat (red) is <100km^2 they are discarded.

Geographic Range



Buffer modeled habitat by 20km and smooth output to create the geographic range

From:	Turner, Ed
To:	Betty Grizzle
Subject:	More Nick"s work that I tried to recreate
Date:	Thursday, January 18, 2018 1:00:30 PM
Attachments:	Models_CFWO_Snow_PH_Run.pdf Models_CFWO_Snow_PH_Run_Drops.pdf Models_CFWO_Snow_PH_Run_vs_nicks_Hab.pdf Models_CFWO_Snow_PH_Run_with_Habitat_Nicks_DPS.pdf Models_CFWO_Snow_PH_Run_with_Habitat_Nicks_DPS_and_Data_we_did_notget.pdf N ICKs_Out_Expand20_poly_Smooth50.pdf NICKs_fr_wolverine_distribution_HIRES.pdf

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On first email. Find Nick's model explained, then see what I added to try and explain his model. Plus my notes of what i attempted.

In this email, Images of what I could make and how it does not come out like his work.

--

Edwin Turner, Geographer
GIS Mapping and Analysis Branch

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Ed_Turner@fws.gov
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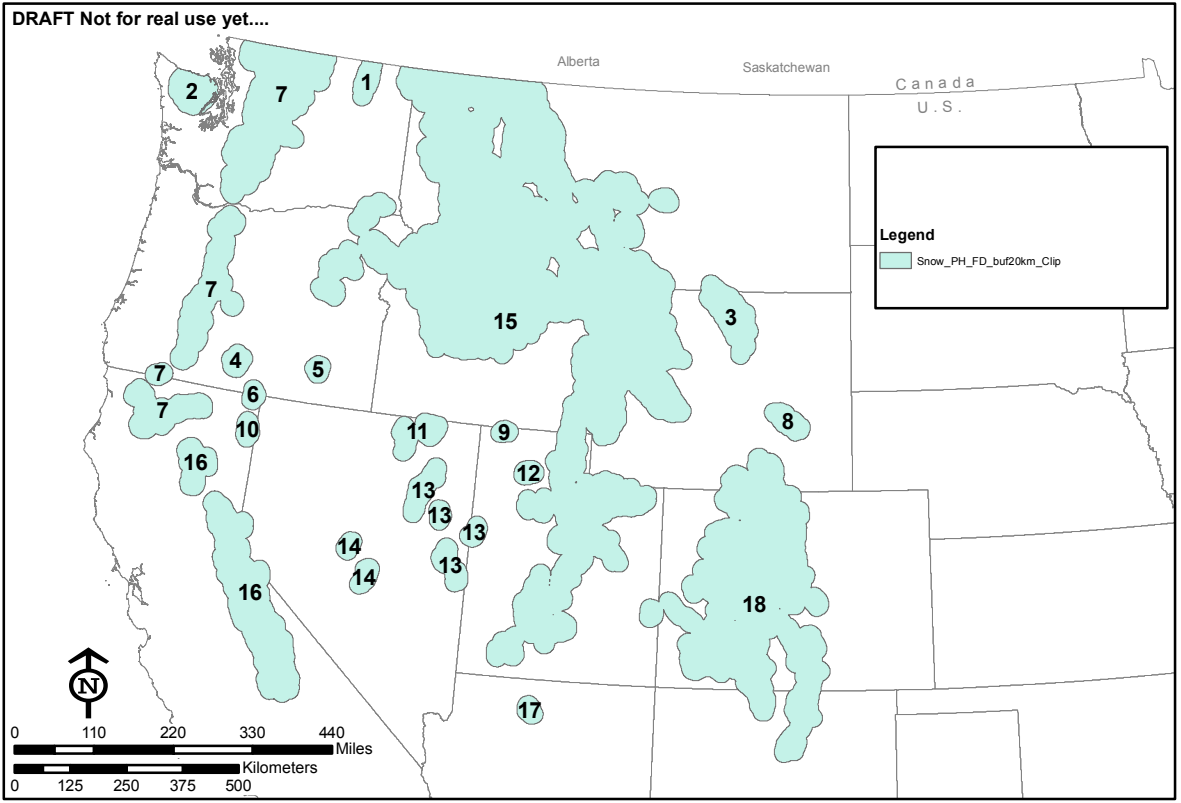
DRAFT Not for real use yet....
Alberta
Saskatchewan
Canada
U.S.
Legend
Snow_PH_FD_buf20km_Clip
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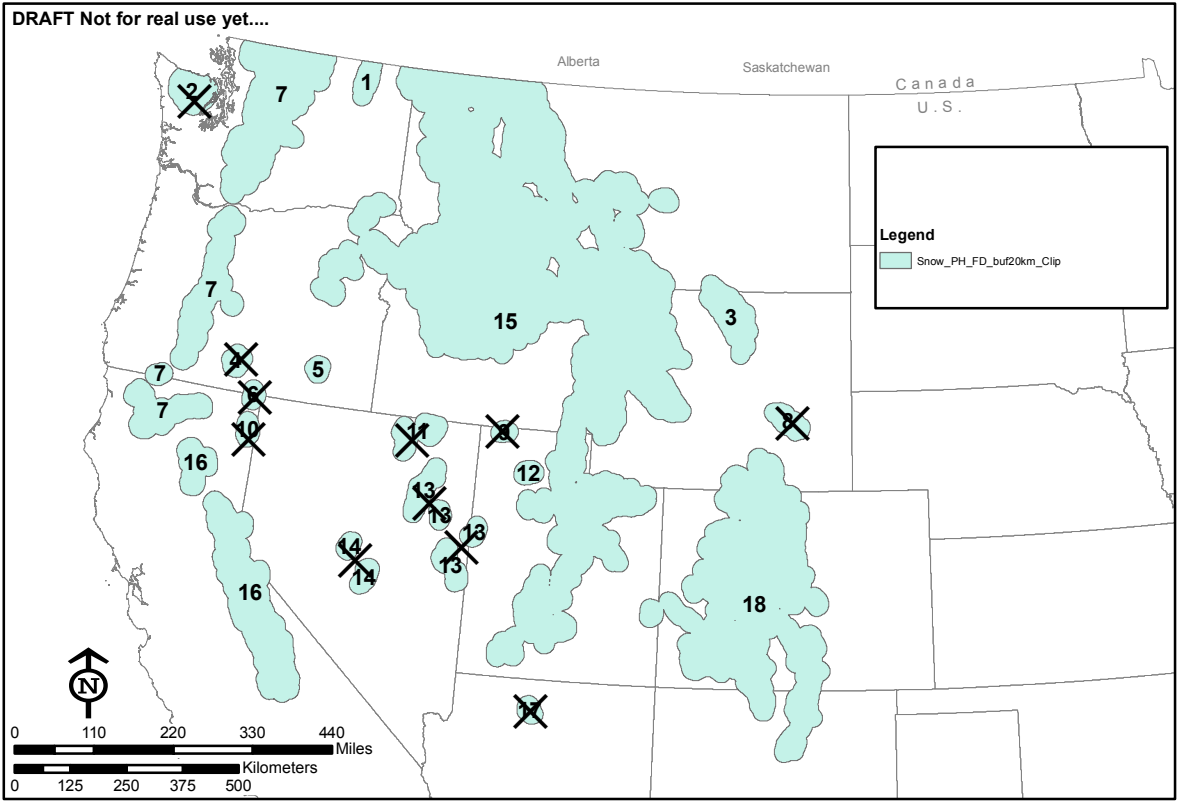
Kilometers


DRAFT Not for real use yet....
Alberta
Saskatchewan
Canada
U.S.
Legend
Snow_PH_FD_buf20km_Clip
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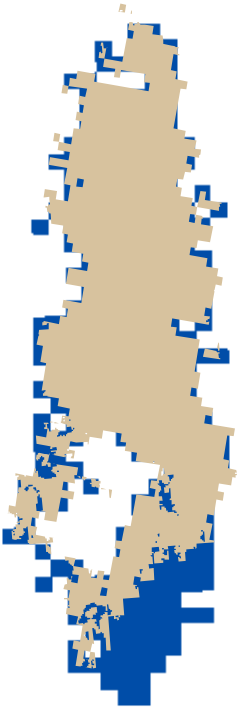
Miles
0 125 250 375 500
Kilometers

DRAFT Not for real use yet....



Legend USFS NRIS

Snow or PH on FD that meets requirements
Area of Snow or PH that fell on areas of FD that size out > 100km2. I retained these and Buffered to 20km.

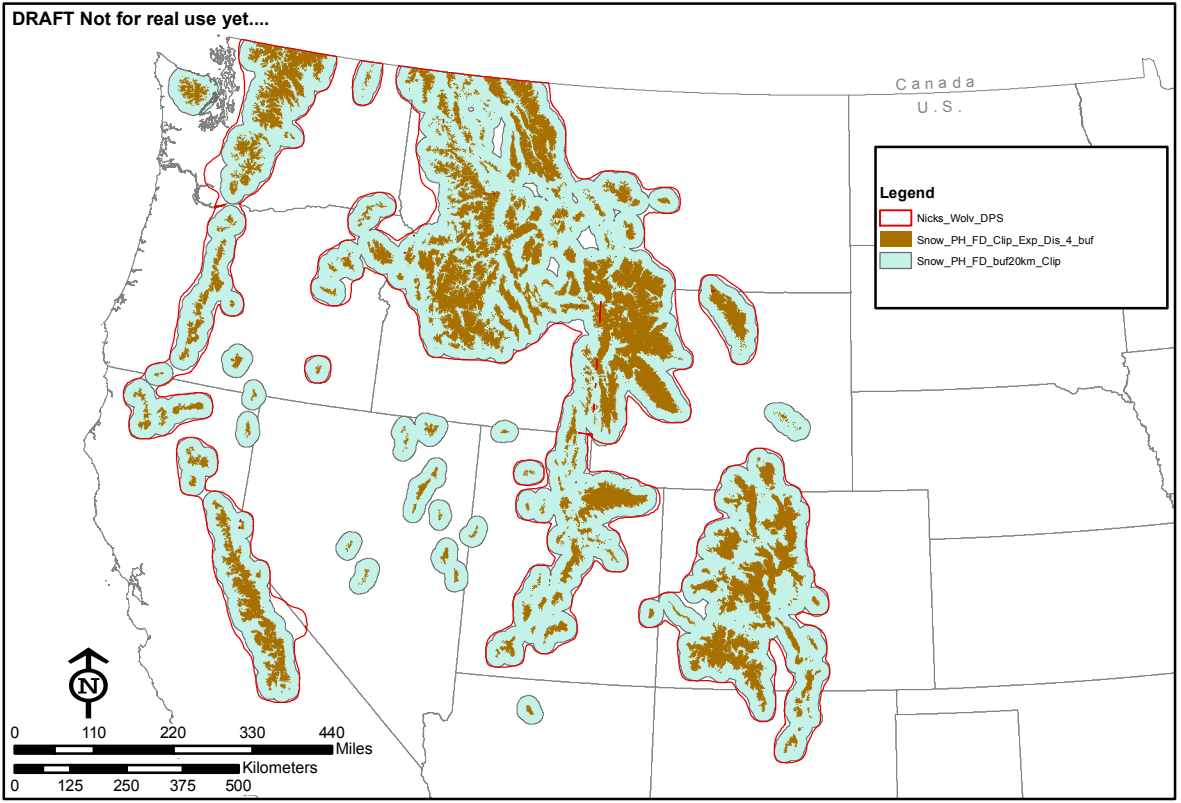
** Note to match his work closer, we also selected snow and PH outside of FD, but only if it was > 100km2.
This does not follow his instructions, and the question would be why include it?

Snow or PH outside of FD that does not meet requirements
Area of Snow or PH that fell outside areas of FD that size < 100km2. Under the rule these should drop.
It could be that his grid process grabbed these because they are neighbor cells. But still they are outside of the limits and should be removed based on instructions.

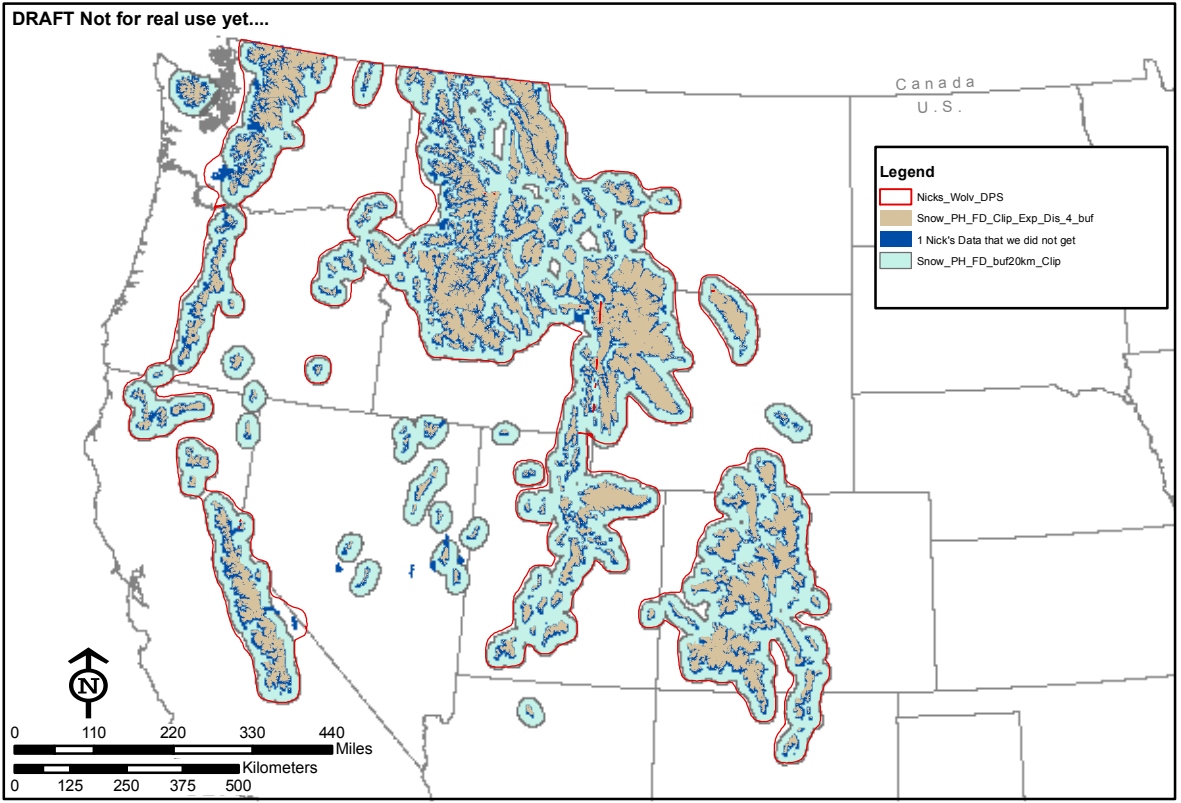
N

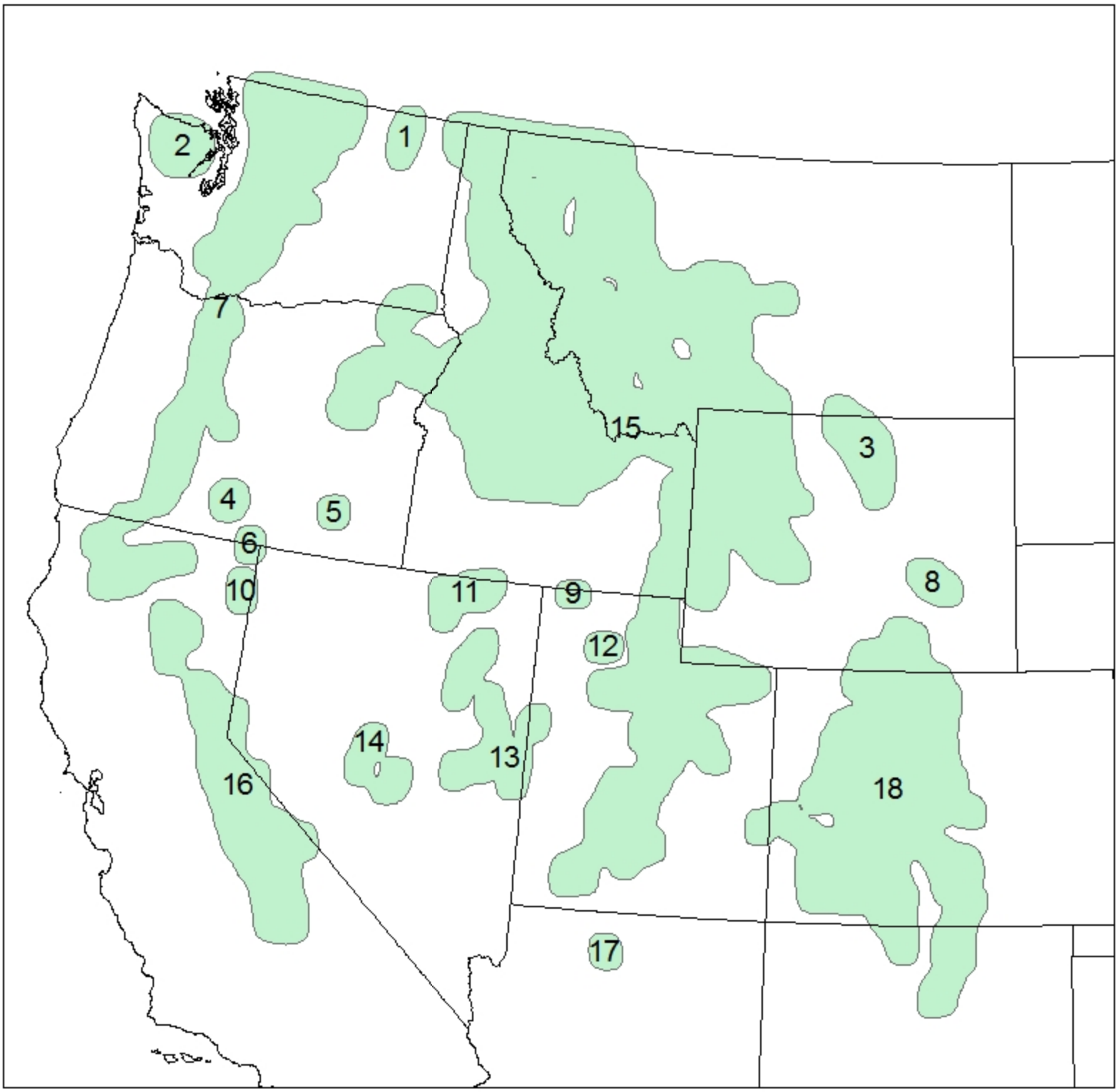
0 3 6 9 12 Miles

0 3 6 9 12 Kilometers

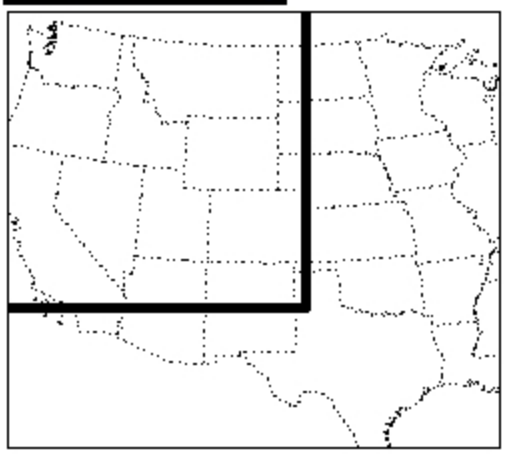

DRAFT Not for real use yet....
Canada
U.S.
Legend
Nicks_Wolv_DPS
Snow_PH_FD_Clip_Exp_Dis_4_buf
Snow_PH_FD_buf20km_Clip
N
0 110 220 330 440
Miles
Kilometers
0 125 250 375 500

DRAFT Not for real use yet....





Locator Map



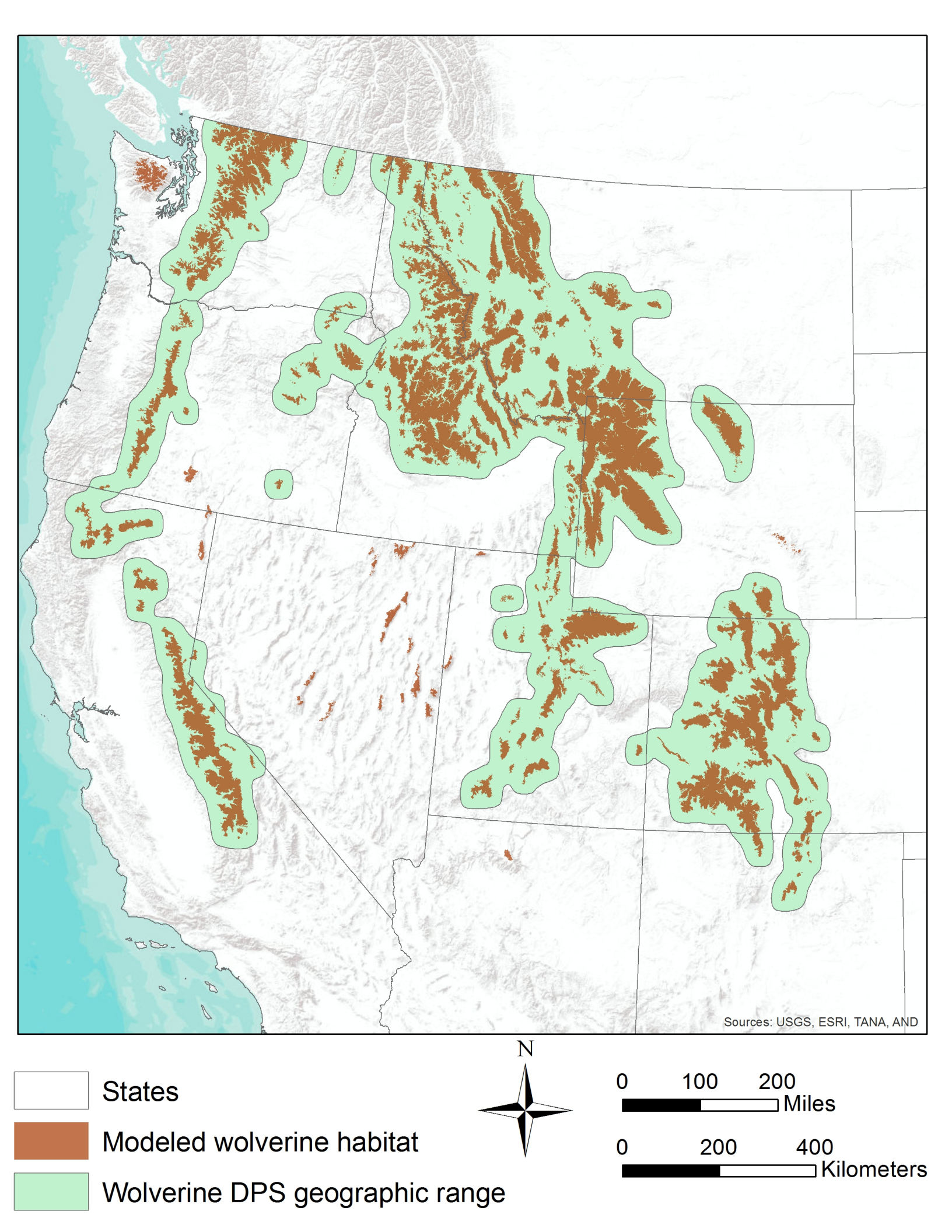
N

0 112.5 225 450
Miles

0 112.5225 450
Kilometers

out_expand20_poly_smooth50

States


Sources: USGS, ESRI, TANA, AND
States
Modeled wolverine habitat
Wolverine DPS geographic range
N
0 100 200
Miles
0 200 400
Kilometers

From: Norman, Kate
To: Guinotte, John
Cc: Shoemaker, Justin; Grizzle, Betty
Subject: Re: DPS packet
Date: Thursday, January 18, 2018 4:54:58 PM

I echo the concern over the maps. I think folks may anchor on those.

Thanks,
K

On Thu, Jan 18, 2018 at 11:58 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Hey Justin, I think those maps as is without text explaining what is going on in them, might do more harm than good. Especially true for the 'dps 2013" and 'trapping' map. I'd do one of two things: 1/keep the maps in there and provide text explaining them, or 2/ remove the maps entirely and wait to explain them in detail at the meeting.
>
> As is, I think you leave it up to them to draw their own conclusions about what is going on, which could be wrong, and could make it hard to counter pre-conceived ideas in the meeting.
>
> John Guinotte
> Spatial Ecologist
> 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, Jan 18, 2018 at 10:59 AM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:
>
> > Is this too much stuff to give them? Please take a look.
> >
> > Justin Shoemaker
> > Classification and Recovery Biologist
> > U.S. Fish and Wildlife Service, Region 6
> > Phone: 309-757-5800 x214
> > Email: justin_shoemaker@fws.gov

--

Kate Norman, U.S. Fish and Wildlife Service
Chief, Decision Support Branch, Ecological Services, Region 6
Office: 303-236-4214
kate_norman@fws.gov
The Mission of Decision Support: Our multidisciplinary team supports Region 6 conservation delivery through applied science, responsive collaboration, and effective communication.
To submit a help request, please visit the Region 6 SharePoint site: http://bit.ly/2a6sOCv

From: Norman, Kate
To: Shoemaker, Justin
Subject: Re: Invitation: Wolverine - final details @ Fri Jan 19, 2018 2pm - 2:30pm (CST) (justin_shoemaker@fws.gov)
Date: Friday, January 19, 2018 8:59:56 AM

Yeppers!
K

On Fri, Jan 19, 2018 at 7:33 AM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> Can we move this call to 30 min earlier?
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov
>
> On Thu, Jan 18, 2018 at 3:55 PM, Kate Norman <kate_norman@fws.gov> wrote:
>
> **Wolverine - final details** **more details »**
>
> When Fri Jan 19, 2018 2pm – 2:30pm Central Time
>
> Where Justin will call Kate 303-236-4214 (map)
>
> Video call https://plus.google.com/hangouts/_/doi.gov/justin-shoemake
>
> Calendar justin_shoemaker@fws.gov
>
> Who
> - kate_norman@fws.gov - organizer
> - justin_shoemaker@fws.gov
>
> Going? **Yes** - **Maybe** - **No** more options »
>
> Invitation from Google Calendar
>
> You are receiving this email at the account justin_shoemaker@fws.gov because you are subscribed for invitations on calendar justin_shoemaker@fws.gov.
>
> To stop receiving these emails, please log in to https://www.google.com/calendar/ and change your notification settings for this calendar.
>
> Forwarding this invitation could allow any recipient to modify your RSVP response. Learn More.

--
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From: Norman, Kate
To: Trina Vigil
Cc: Shoemaker, Justin
Subject: QUESTION for TRINA: Could you assist with the wolverine meeting (1/24/18)
Date: Friday, January 19, 2018 3:41:18 PM

Hi Trina-

We may need some help with the wolverine meeting next week.

1. **TENT CARDS:** Could you make name tents for the folks who will be attending? https://docs.google.com/spreadsheets/d/1n0Ho57gZGW4R4u3Zr61nzZzwVfdwEzSYxRL410Xietg/edit#gid=0
2. **LUNCH ORDERS:** Could you please help with lunch? I'm thinking Jason's deli where everyone orders there own and we have it delivered would be the easiest. Just for Wednesday, 1/24/18
3. **SCORE PAPERS:** I've asked Trinity to help cut up the scoring papers on Tuesday, but I may need your assistance last minute if it looks like that's not feasible.
4. **SET UP:** Day of meeting set-up? If you're around on Wednesday, I ALWAYS appreciate your help with meeting set up.
5. **KEY CARDS:** Could you get a handful (say 6) key cards for folks to use temporarily? Do those still exist?

Thanks!
K

--
Kate Norman, U.S. Fish and Wildlife Service
Chief, Decision Support Branch, Ecological Services, Region 6
Office: 303-236-4214
kate_norman@fws.gov
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To submit a help request, please visit the Region 6 SharePoint site: http://bit.ly/2a6sOCv

From: Noreen Walsh
To: Shoemaker, Justin
Subject: Re: Wolverine Recommendation Team Meeting Materials
Date: Friday, January 19, 2018 7:13:58 PM

Thank you Justin. Have a good weekend.

On Jan 19, 2018, at 6:54 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> In preparation for the wolverine recommendation team meeting next week, please see the attached materials. Included is the latest draft of the agenda, a policy and definitions handout, and information on past application of the DPS policy to wolverine in the contiguous U.S.
>
> Note that we have condensed the agenda with the decision team into one full day on 1/24 now. The SSA core team will meet on the morning of 1/25.
>
> See the agenda for more details as well as a link for the webinar and conference line number.
>
> The meeting materials attached and additional information (including the SSA Report) can be found on the drive folder.
>
> Wolverine meeting folder on Google Drive: https://drive.google.com/drive/folders/14fAdJj20mu9RlRiy91ktqxjX5K-yhKnz?usp=sharing
>
> If you have problems accessing the folder, please let me know.
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov
>
> <Policy and definition handouts _01052018.docx>
>
> <2018-01-24_WolverineMtgAgenda.docx>
>
> <Wolverine DPS packet for RTM_01242018.pdf>

From: Grizzle, Betty
To: John Guinotte
Subject: slide
Date: Friday, January 19, 2018 8:56:30 AM
Attachments: slide.docx

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see attached

--

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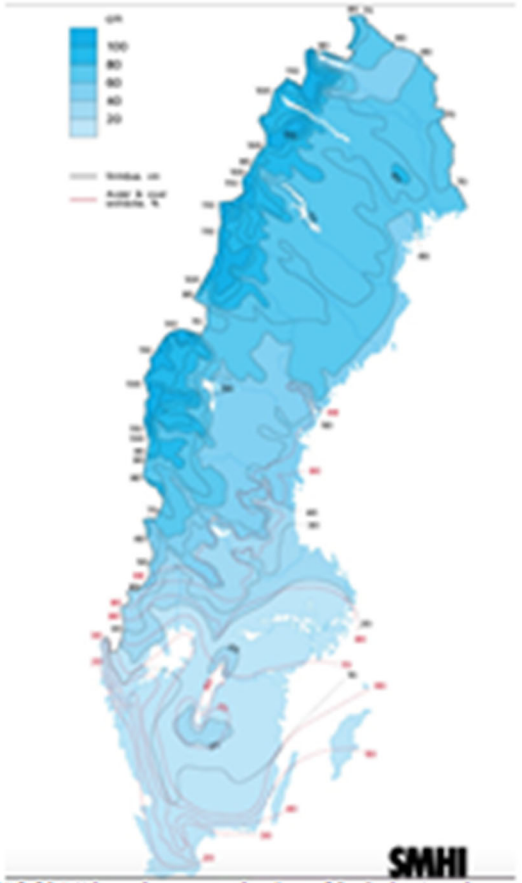
Carlsbad Fish and Wildlife Office
2177 Salk Ave, Suite 250
Carlsbad, CA 92008
760-431-9440, ext. 215
760-431-5901 fax

From Aronsson and Persson 2016:



Left. Wolverine population distribution trend in Sweden (2012-2014) based on reproductions (black dots) and observations (grey dots) registered within the national monitoring programme. Shaded area shows the reindeer husbandry area and black line shows the border used to differentiate alpine areas and boreal forest landscape.

Right. Mean snow depth in cm ('snödjup' in the map, cm, black lines) and proportion of years with snow cover ('andel år med snötäcke' in the map, %, red lines) in Sweden March 15th. (from the measurement period 1961-1990, as defined by the World Meteorological Organization).

Note: Reproductions found in areas with 50 centimeters (19.69 inches) of snow on March 15.

From: Grizzle, Betty
To: Guinotte, John
Subject: Re: paper with supplemental info
Date: Friday, January 19, 2018 9:32:38 AM
Attachments: Slide 2.docx

Attached is slide I prepared for Alberta.

On Fri, Jan 19, 2018 at 8:22 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

> if you do an eyeball comparison betweeen fig 2c in aronsson and persson and fig 1 in copeland 2010, it looks like most of those wolverine reproduction dots are outside copelands snow layer.
>
> John Guinotte
> Spatial Ecologist
> 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, Jan 19, 2018 at 9:05 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>
> > see attached
> >
> > --
> >
> > 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
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--

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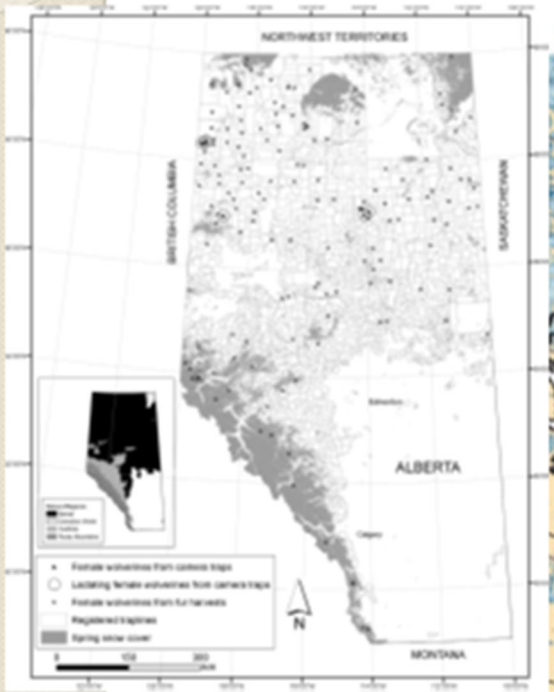
Results from Webb et al. compared to Copeland et al.



From: Grizzle, Betty
To: Guinotte, John
Subject: Re: paper with supplemental info
Date: Friday, January 19, 2018 9:50:36 AM
Attachments: Slide 2.docx

Does this work?

On Fri, Jan 19, 2018 at 8:42 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

> It will be important to note that webb didn't map dens, but did map lactating females, which are difficult to see in the map. You might want to put some big colored dots on the webb map to show where those lactating females are.
>
> John Guinotte
> Spatial Ecologist
> 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
>
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> > > > see attached
> > > >
> > > > --
> > > >
> > > > Betty J. Grizzle, D.Env.
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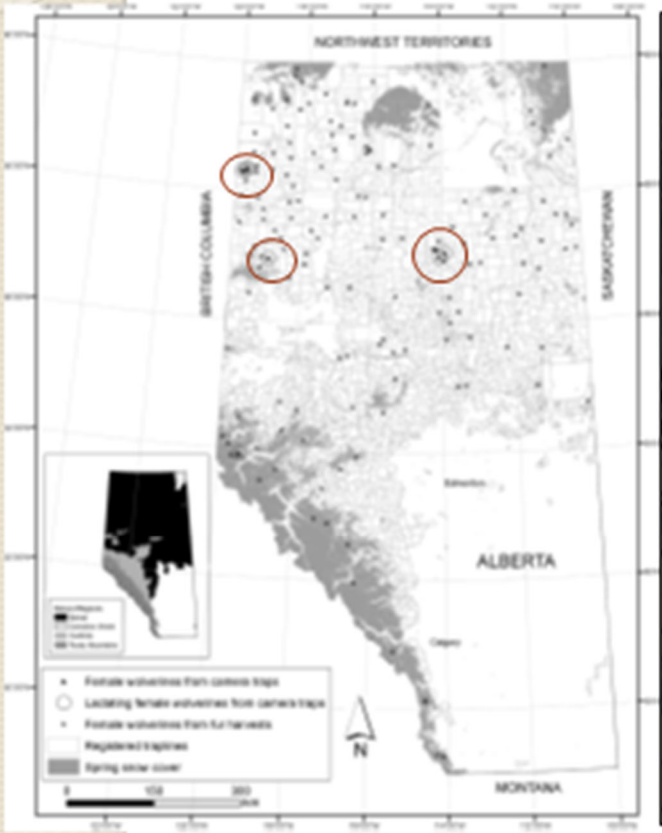
Canada: Results from Webb et al. compared to Copeland et al.



From: Grizzle, Betty
To: Shoemaker, Justin; Bush, Jodi
Subject: Revised PowerPoint
Date: Friday, January 19, 2018 10:41:12 AM
Attachments: 20180119_North American Wolverine PPT.pdf

I haven't received any comments on the draft I sent out earlier. I added a few more slides (see #16 and 17) and an overall assessment slide. I did my best to trim down text/words.

Let me know if you have any comments/changes. Assuming we are still meeting next week, I can also make changes when I see you next Tuesday.

--

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North American Wolverine

Gulo gulo luscus

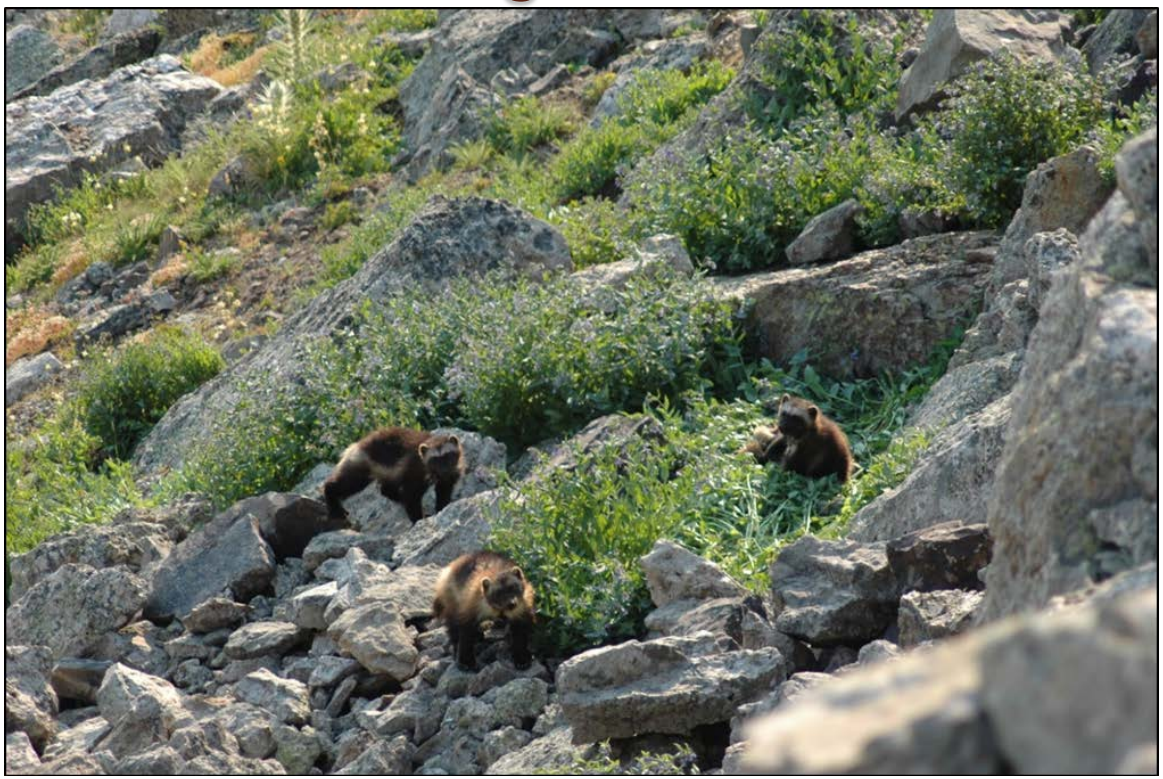


Photo credit: Mark Packila; used with permission.

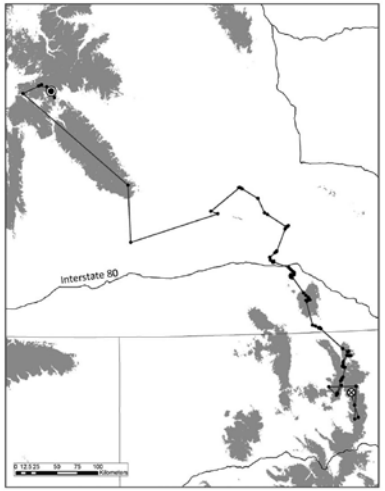
Prepared for Recommendation Team Meeting
Mountain Prairie Regional Office
January 24-25, 2017

Species Description & Needs

- Taxonomy of No American & Eurasian wolverines – same species, *subspecies* unclear
- Culturally important to Aboriginal Peoples and Native Americans
- Curious, cautious, learned behaviors (e.g., avalanche rescue)
- Unique fur properties – valuable for trade
  - Other morphological/physiological adaptations

Species Description & Needs (cont.)

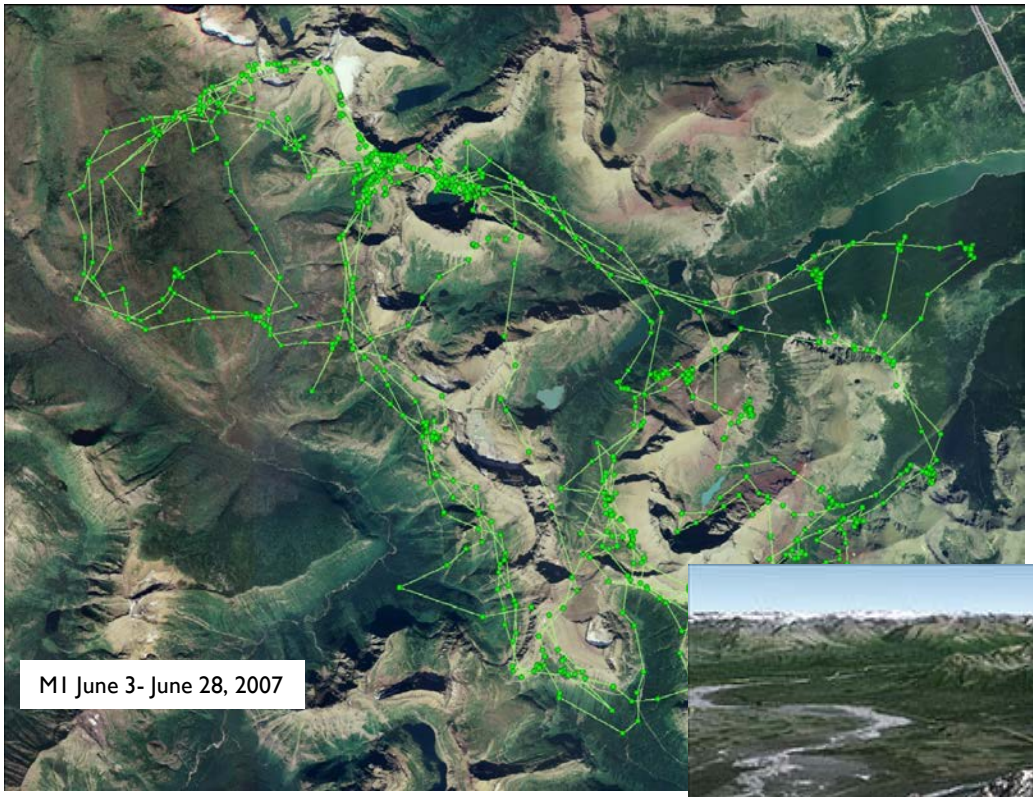
- Key physical/ecological needs
  - Large territories, remote areas, high elevations
  - Access to variety of food, seasonal variability
  - Physical/Structural habitat features (e.g., talus slopes)
- Extensive movement and dispersal capabilities



Map of VHF locations of M56 - 2008 to 2009

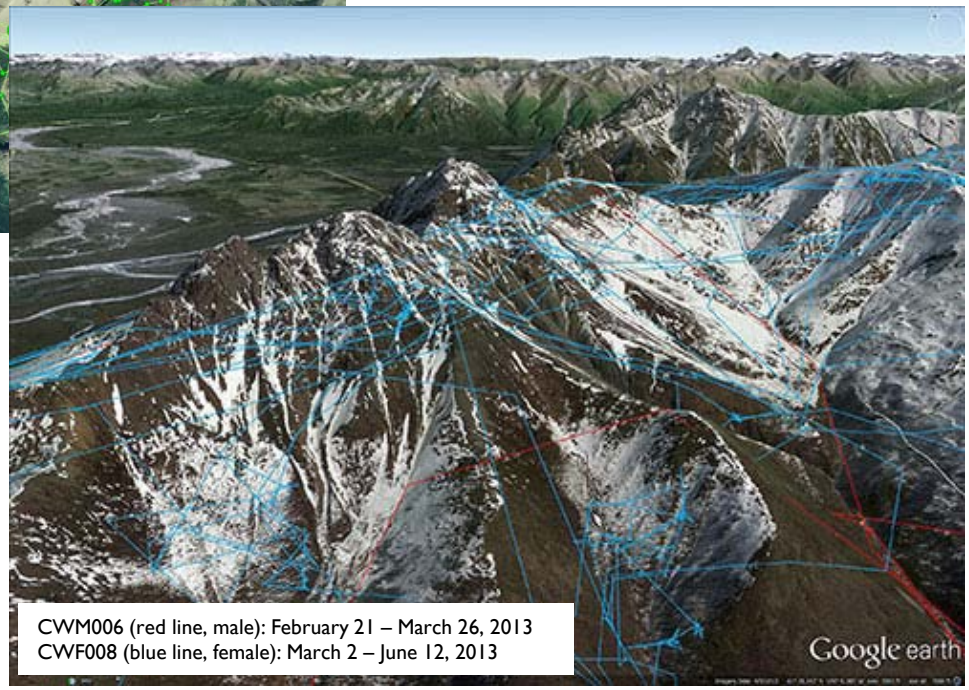
Suspected wolverine M56, from Packila et al. 2017

Other Examples of Movement Patterns



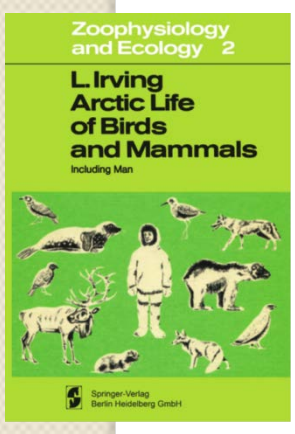
Glacier NP; Copeland and Yates 2008

Southern Alaska; Woodford 2014



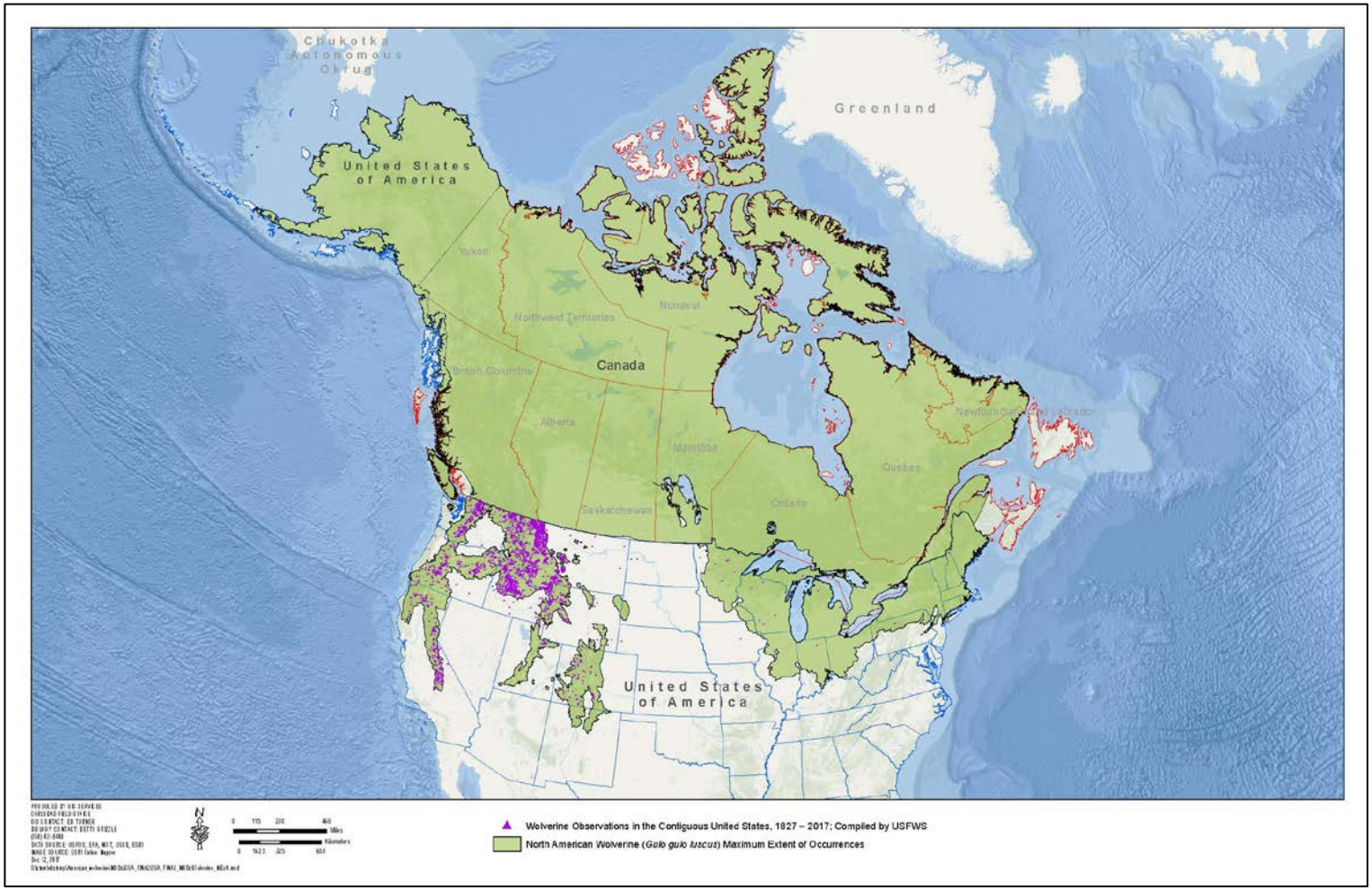
Species Description & Needs (cont.)

- *However*, still many unknowns
  - Difficult animal to survey/study
    - Most studies conducted in winter months
  - Recent Scandinavian & Canadian studies providing new insights
- Physiology (Arctic studies, 1950s-1970s) not well-documented in previous rules
  - Important to describe critical temperature ranges and elements of thermoneutrality for evaluating effects of climate change
  - But limited studies; none on wild populations



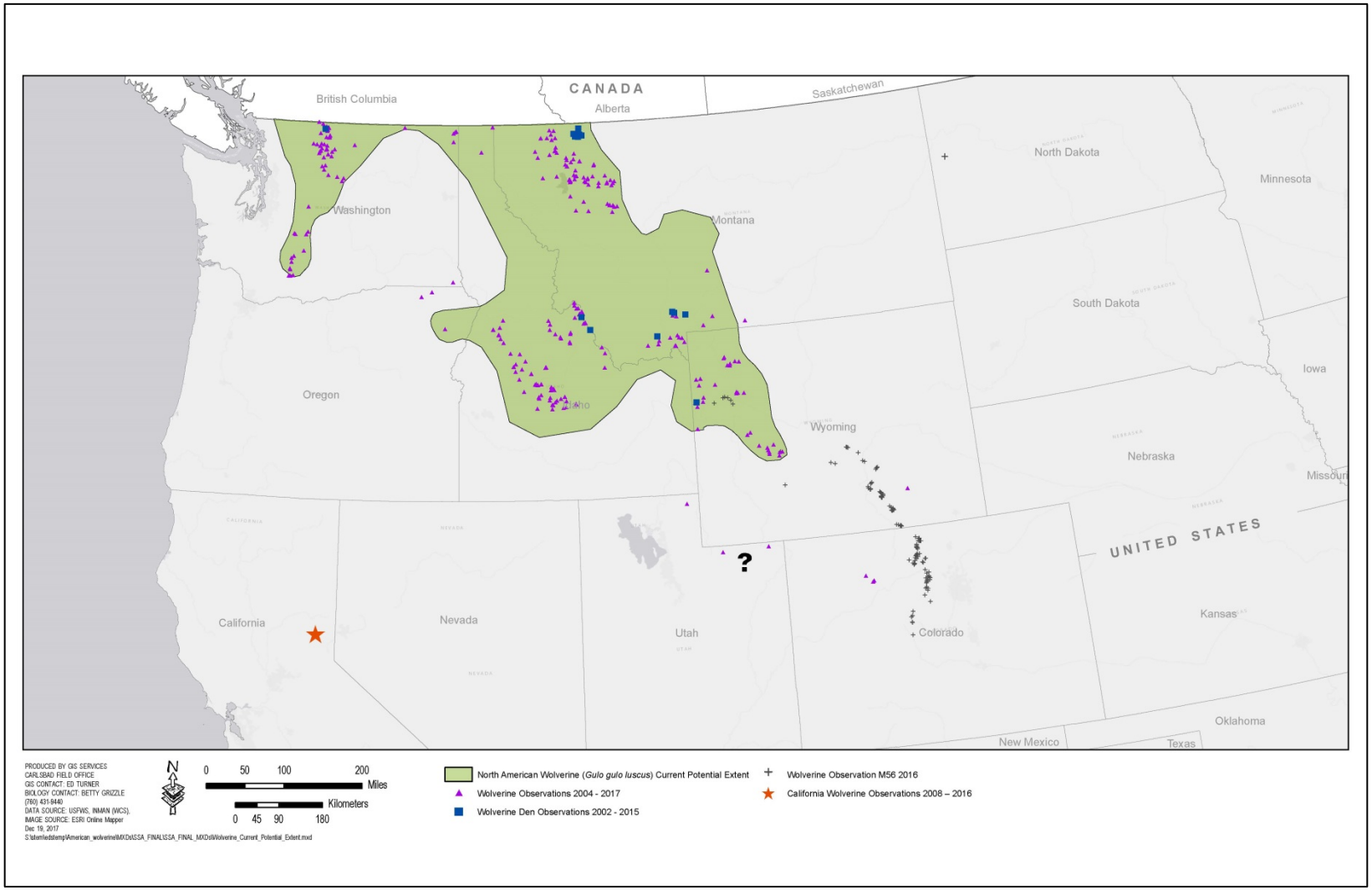
Maximum Extent of Occurrences

- Using all available records
  - West-northwestern U.S. (several sources); Midwest/Eastern U.S. (from Aubry); Canada and AK from COSEWIC report (2014)



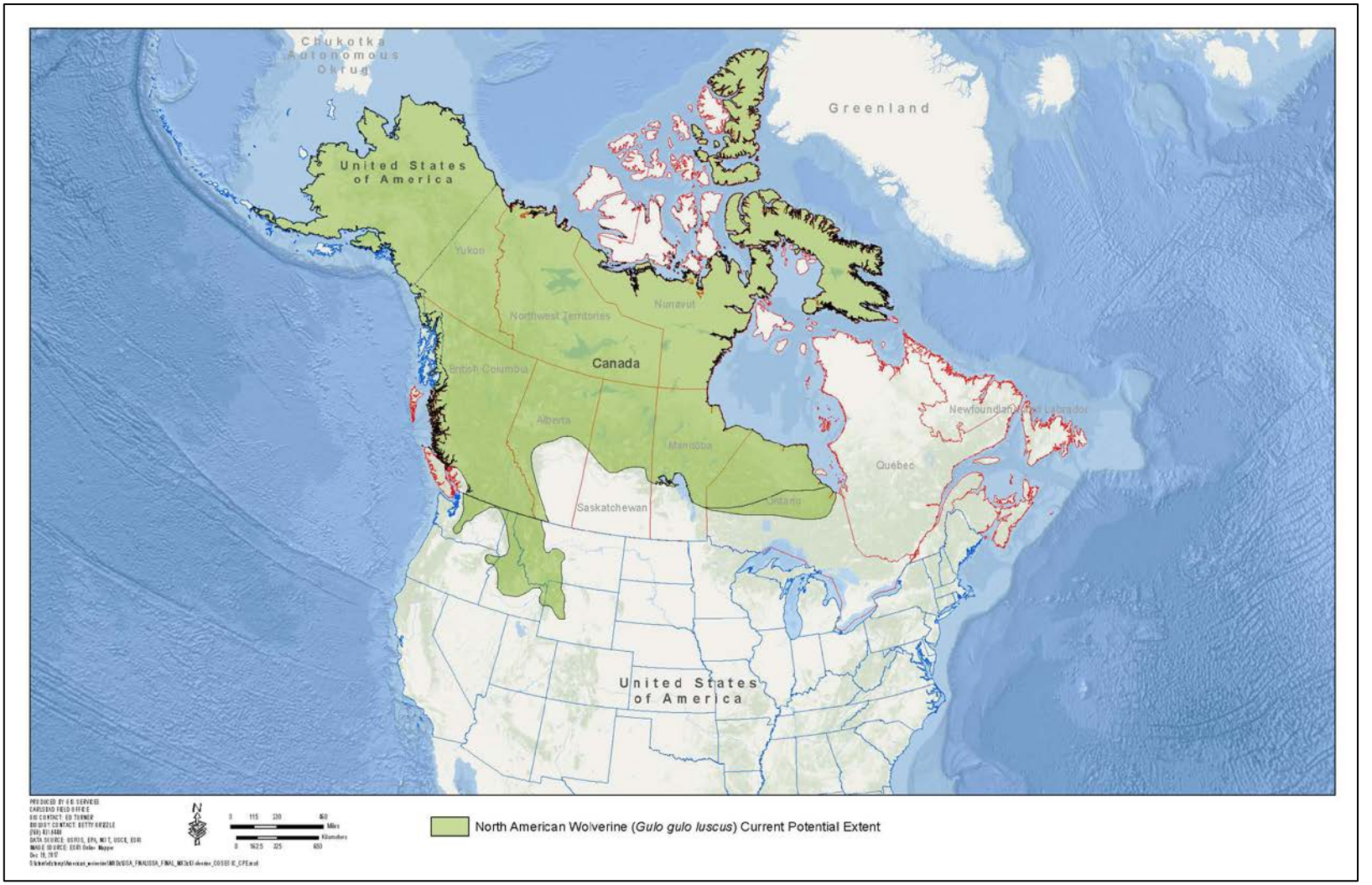
Current Potential Extent – Contiguous U.S.

- Developed from ecological regions mapping (EPA); Fed/State agencies; additional records from researchers



Current Potential Extent – North America

- Developed from ecological regions mapping (EPA); COSEWIC; Fed/State agencies



Comparison with previous range map (not published)

Habitat Use

WAFWA 2017

Clevenger et al. 2017

Copeland and Yates 2008

Heinemeyer and Squires 2015

wolverinepedia.zaxtor.net

Summary of Habitat Use related to Life History

- Vegetation associations
  - Arctic tundra, boreal forests, mixed forests
- Other habitat associations
  - High elevations (esp. in lower 48), with talus slopes
  - "Ruggedness" element (topographic heterogeneity)
  - Away from human footprint & predators (esp. while raising young)
  - Available food, including caching areas
  - Access to water (esp. in summer)
- Large, exclusive territories
  - 54-148 mi^2 for females (lower U.S.)
  - 201-610 mi^2 for males (lower U.S.)

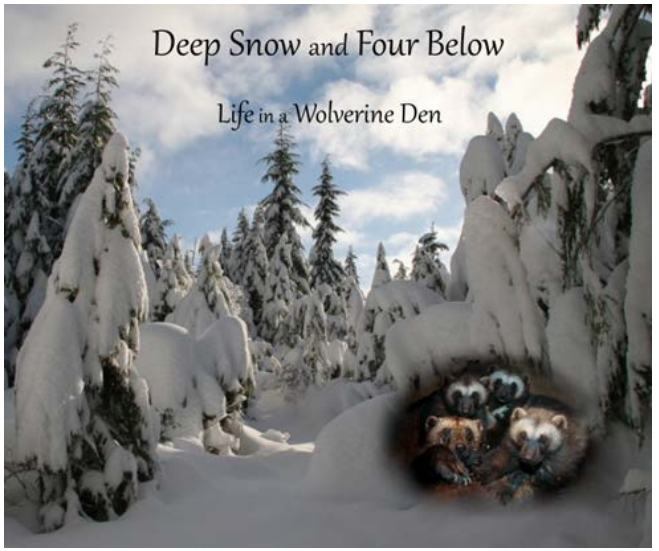
Heinemeyer et al. 2017

Reproduction and Growth

- Polygamous behavior
- Delayed implantation
- Low reproductive rate (less than 1 young per adult female per year)
- Short gestation period
- Denning behavior, altricial young
- Extended period of maternal care, but young grow rapidly (fully grown at 8 months)

Magoun 2010

Use of Dens & Denning Habitat



Denning "habitat" in Glacier NP, from Copeland and Yates 2008

Entrance to natal den, Glacier NP, from Copeland and Yates 2008

March 2 2017 den, Sweden (lower left, under boulder)

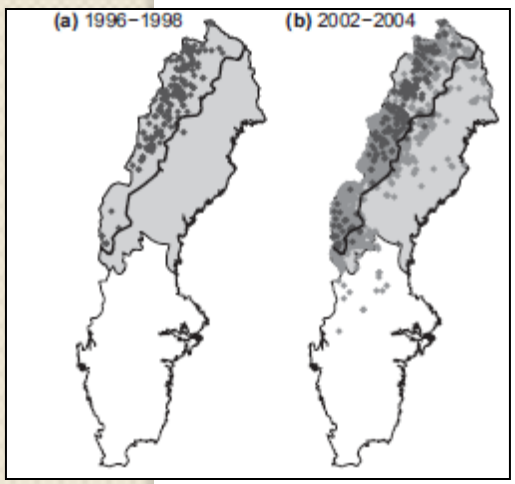
Wolverine habitat, denning, & snow – only one piece of the puzzle

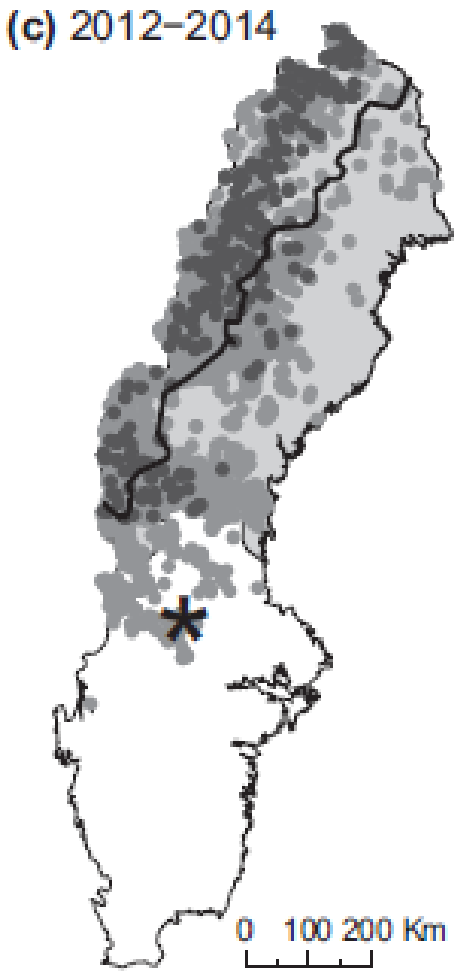
- Copeland *et al.* 2010 – ***assumed*** persistent of wolverine populations is linked to availability of suitable reproductive den sites
  - And snow cover that persists throughout the denning period ***may be*** a critical habitat component limiting their geographic distribution
- This (now 8-year old paper) was good, first effort to model where wolverines might be found; inherent limitations
- Snow cover depths and (late) dates of snow cover persistence used to predict wolverine distributions and population-level effects from CC (McKelvey *et al.* 2011)
  - To note: May 15 date has no biological basis
- ➢ Results presented in these two publications became narrative for evaluating effects of CC to wolverines

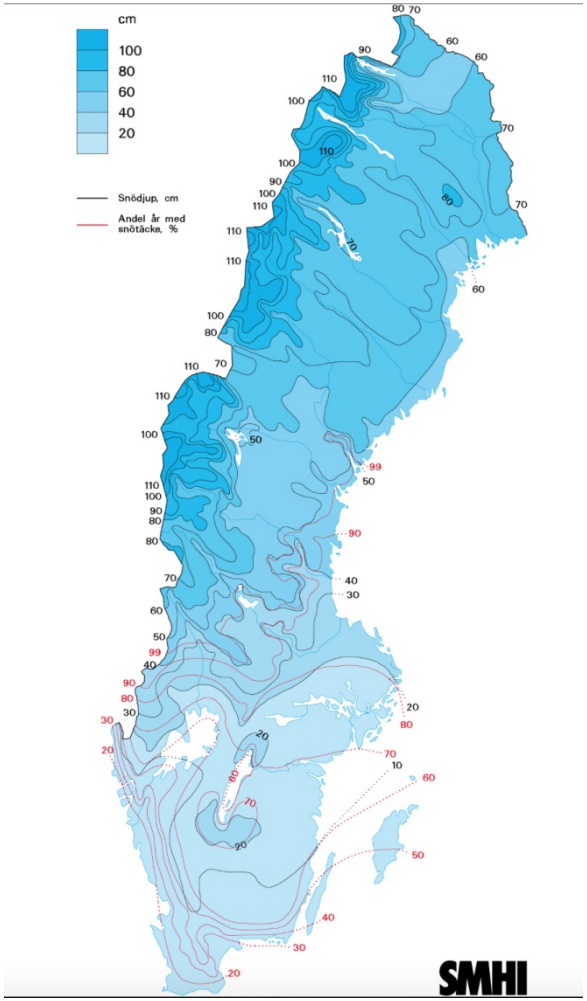
Wolverine habitat, denning, & snow – only one piece of the puzzle

- Two peer reviewers of 2013 proposed rule raised substantive concerns on this issue and the Service's interpretation
- New studies – Copeland et al. model does not always predict either wolverine occurrences or den sites
  - At least 80 dens in Scandinavia now recorded outside model
- ➢ To discuss later – results of new CC modeling

From Aronsson and Persson 2016:





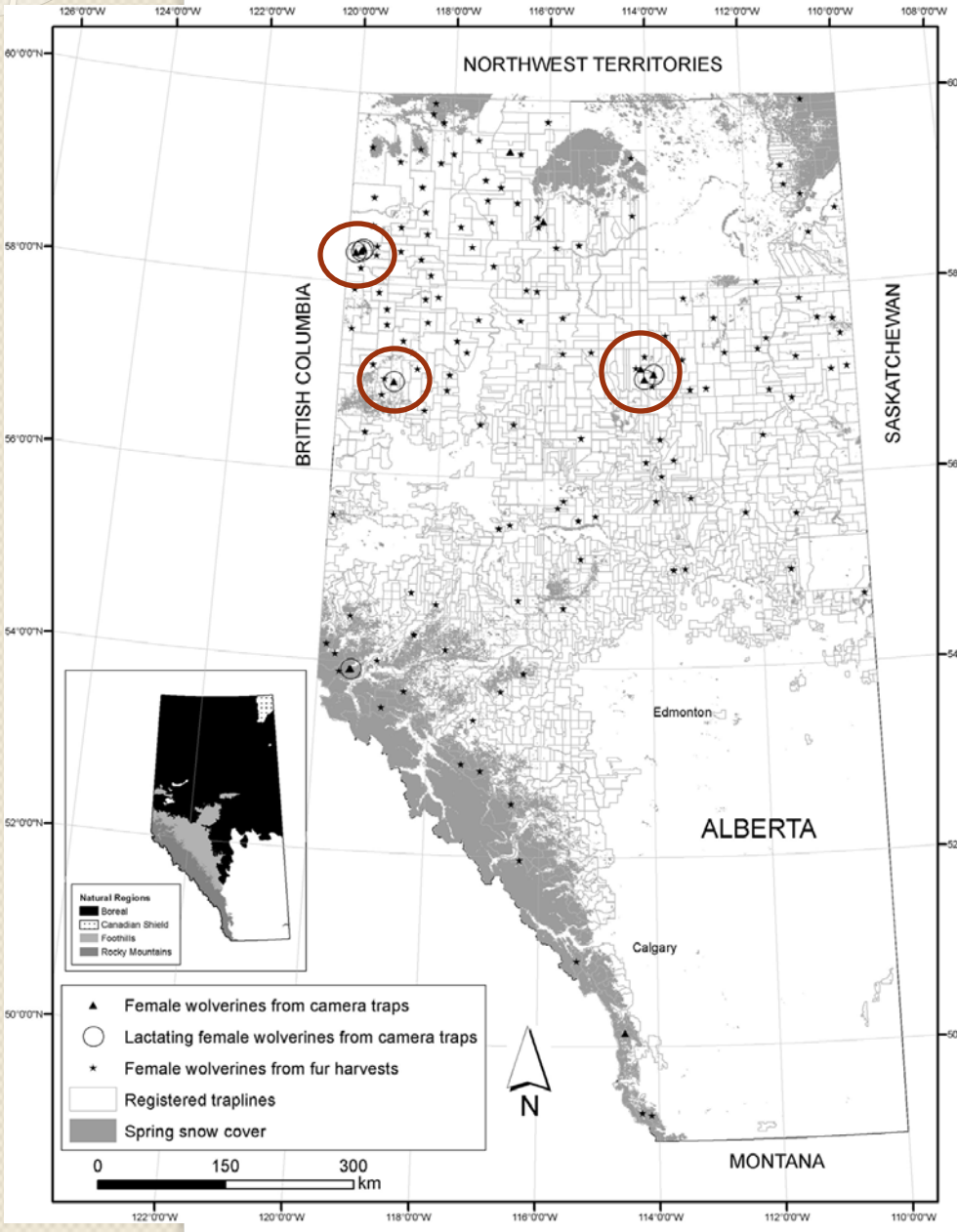


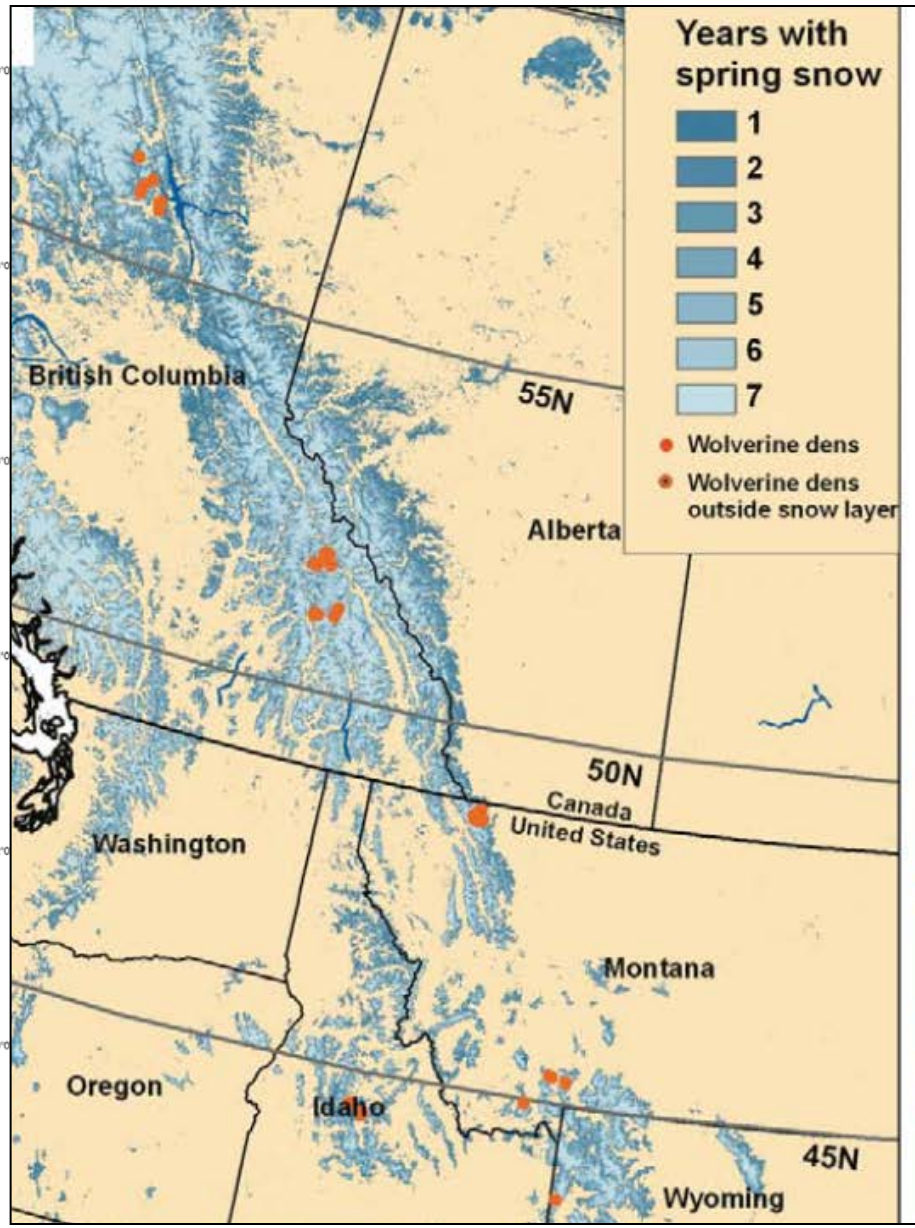
Left: Wolverine population distribution trend in Sweden (2012-2014) based on reproductions (black dots) and observations (grey dots) registered within the national monitoring programme. Shaded area shows the reindeer husbandry area and black line shows the border used to differentiate alpine areas and boreal forest landscape.

Right: Mean snow depth in cm ('snödjup' in the map, cm; black lines) and proportion of years with snow cover ('andel år med snötäcke' in the map, %; red lines) in Sweden **March 15th**. (from the measurement period 1961-1990, as defined by the World Meteorological Organization).

Note: Reproductions found in areas with 50 centimeters (19.69 inches) of snow on March 15.

Alberta, Canada: Webb et al. (lactating females) vs Copeland et al.





Summary points re denning

- Limited information on relationship of denning habitat with reproductive success
- Denning habitat varies across Holarctic range
- Young moved from natal den in late April
- Many factors influence den locations and shifts in den locations (not just temp/snow depth or persistence)
- Our analysis of "melt-out" dates for natal den sites in U.S. – earliest was May 14

Other Life History Elements

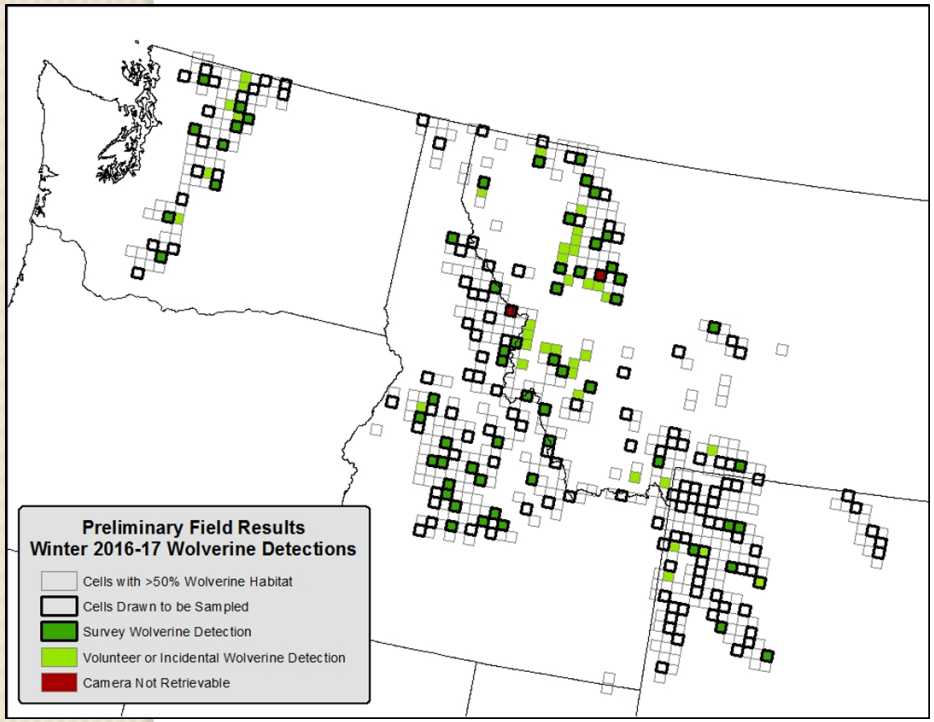
- Diet and Feeding
  - Both scavengers and predators
  - Diet varies regionally, seasonally, yearly
  - Commonly "switch" food sources
- Population Structure
  - Metapopulation in lower 48
  - Panmictic population in Canada
  - Naturally low densities across No America
- Genetic diversity/structure – unclear
  - Wolverines still recovering from many decades of hunting and trapping pressures
  - Newer/more complete sampling/analysis and demographic studies needed

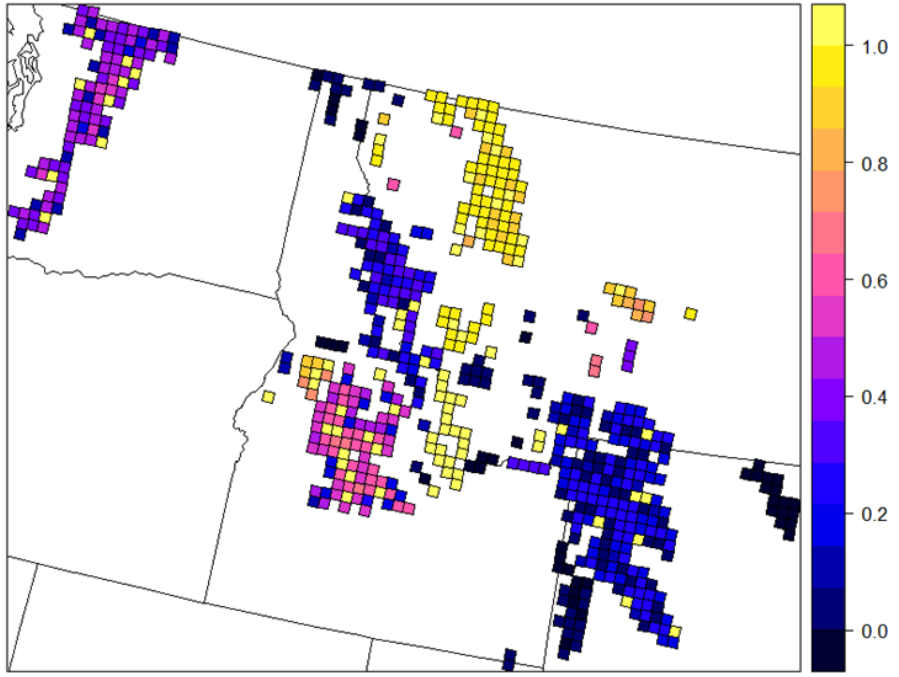
Biological Status (current conditions)

- Population size
  - In No America: uncommon and at naturally low densities
  - Lower 48: model estimate of 318 individuals (range 249 to 626)
    - Wolverine working group developing occupancy analysis
  - Canada – over 10,000 adults
    - Stable or increasing in this northern part of No Am range
  - AK uses density estimates (5-10 per 386 mi^2)
- Movement between AK and Canada, and between lower 48 and Canada

Wolverine detections, Winter 2015-2016 (WY) and Winter 2016-2017 from 4 Western States Occupancy Study

- 95 cells (as of 12/2017)
- 157 genetic samples
- Avg. estimated probability of occupancy – 42%





Potential Stressors Evaluated

- Effects from roads
- Effects from wildland fire
- Disturbance – winter recreational activity, other infrastructure
- Disease and Predation
- Overutilization
  - Research activities
  - Harvesting and incidental trapping
- For Future Conditions
  - Effects of Climate Change
  - Cumulative Effects

Effects from roads

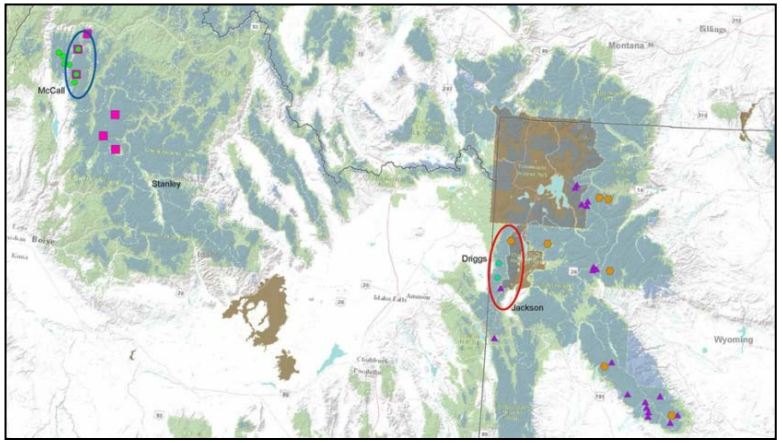
US287, MT: road-kill death of M204 as he utilized a road-killed elk carcass; from Packila *et al.* 2007

- Mortalities
  - 1972 to 2001: 4 (No America)
  - 2004 to 2016: 7 (lower 48 States)
  - 2013 to 2015: 10 (Alberta, Canada)
- Road miles/density
  - > 7,500 ft elevation: 85% local roads (CPE area)
  - Inman's modeled primary habitat: higher density in Southern Rockies
- Norway study
  - Higher tolerance to proximity of roads at home range scale vs. den site scale

Disturbance

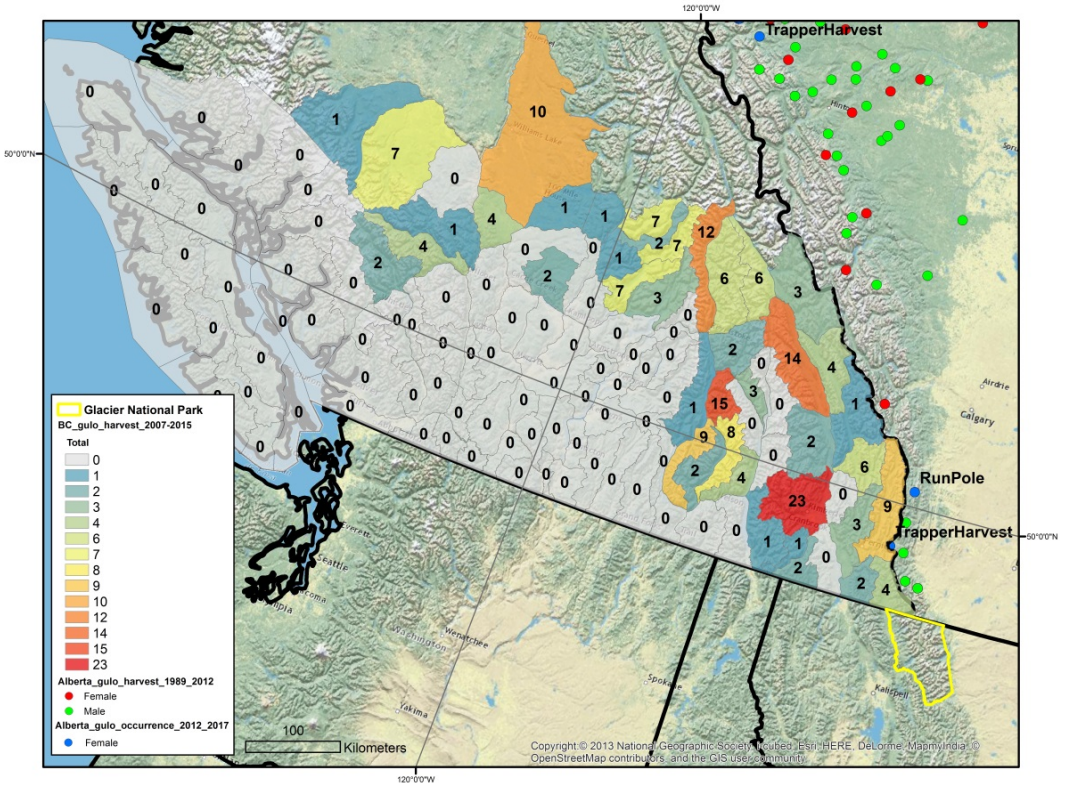
- Winter Recreation
  - 2010-2015 Study: Wolverines maintained home ranges within high use areas, over several years
    - No evidence re effects on reproductive success
  - Winter road closures
  - Recent detections (2016, 2017) in some recreational study areas

Heinemeyer and Squires 2013



Overutilization (e.g., trapping)

- No current trapping in lower 48
  - Incidental trapping: most recent in ID and MT (w/ some mortalities)
  - Both States implementing mandatory trapping education programs
- U.S.-Canada border (68 mi, avg max. dispersal distance)
  - Alberta (2007-2015): Avg < 1.0 animals/yr
  - B.C. (1989-2017): Avg 8.5 animals/yr
  - Trapping pressure & genetic structure being studied in Canada



Additional stressors evaluated

- Other human disturbance
  - Mixed results – associated with some roads & infrastructure, but avoid others
    - More likely related to avoiding predation risk
    - Wolverine dens found in clear cut areas (Canada)
- Wildland fire – no empirical studies
  - Likely not a positive or negative
  - USFS implementing fire mgt practices
- Disease and Predation
    - No evidence that these act as stressors beyond few individuals

Future "Scenario": Most likely condition

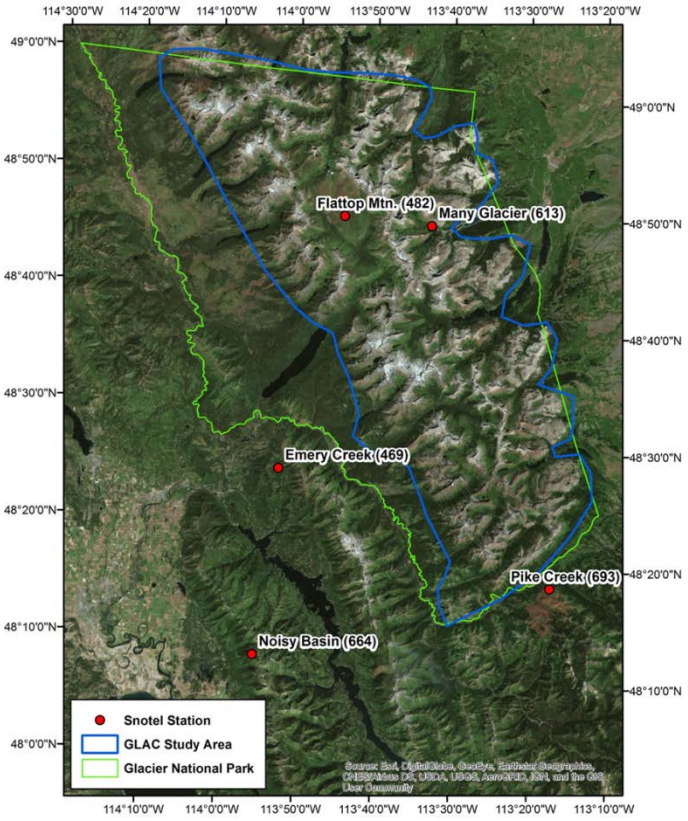
- Effects of climate change
  - Elevated temperature
  - Decline in snowpack
  - Potential increase in wildland fire
- No change expected in levels of other stressors

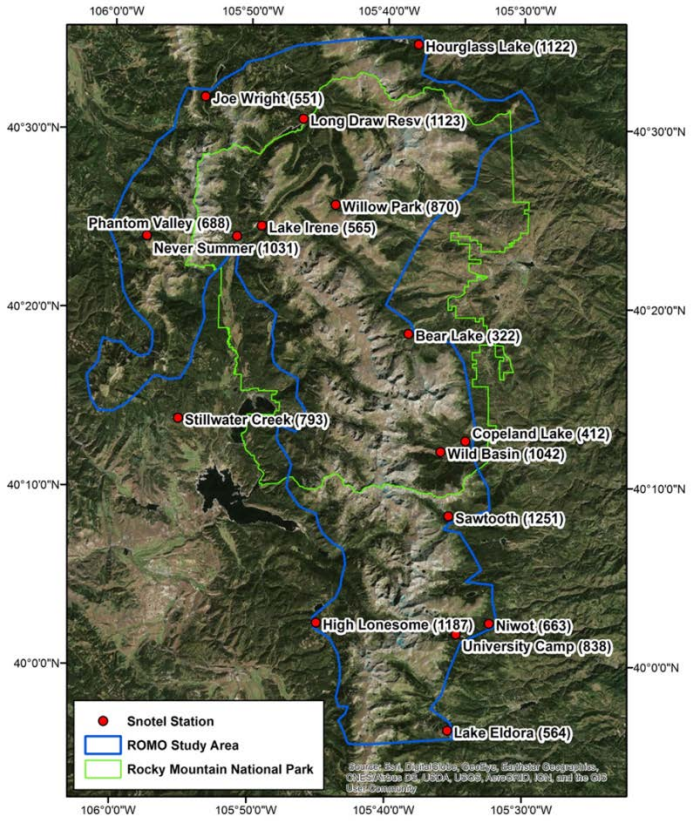
Future Conditions: Climate Change Effects – Summary by Region

Region	Observed trend : Temperature	Observed trend: Precipitation	Projected trend: Temperature	Projected trend: Precipitation
California (Tahoe area)	↑1.66°F since 1895; ↑3.94°F since 1975	No trend	↑3.8 to 5.8° F (by 2060s)	↑in winter; but 3% ↓ yearly
Columbia River Basin	↑ 1.3°F (Pacific NW), 1895-2011	No trend; decline in amount of snow	↑ 2.34°F (2010-2039); ↑ 5.04°F (2070-2099)	↑up to 8.5% (less than annual variability)
Upper Snake River Basin	↑ 0.5 to 1.0°F, 1895-2014	No trend	↑5.0°F (2100)	Small ↑
Southern Rocky Mtns	↑ 2.0°F, past 30 years	No trend (more severe drought conditions)	↑2.5 to 5.0°F (2050s)	↑ in winter (2050s)
Northern Rockies (MT)	↑0.5°F/decade, over past 68 years	No trend in annual mean (decline in winter months)	↑3.0 to 7.0°F (2050s)	↑in some areas, ↓ statewide in summer (increased variability)

Cumulative Effects with Climate Change – Snowpack/Snow Cover

- Northern and Southern Rocky Mountains (NOAA/CU study): 2 study areas to assess snow extent and depth (to evaluate snow persistence/CC)



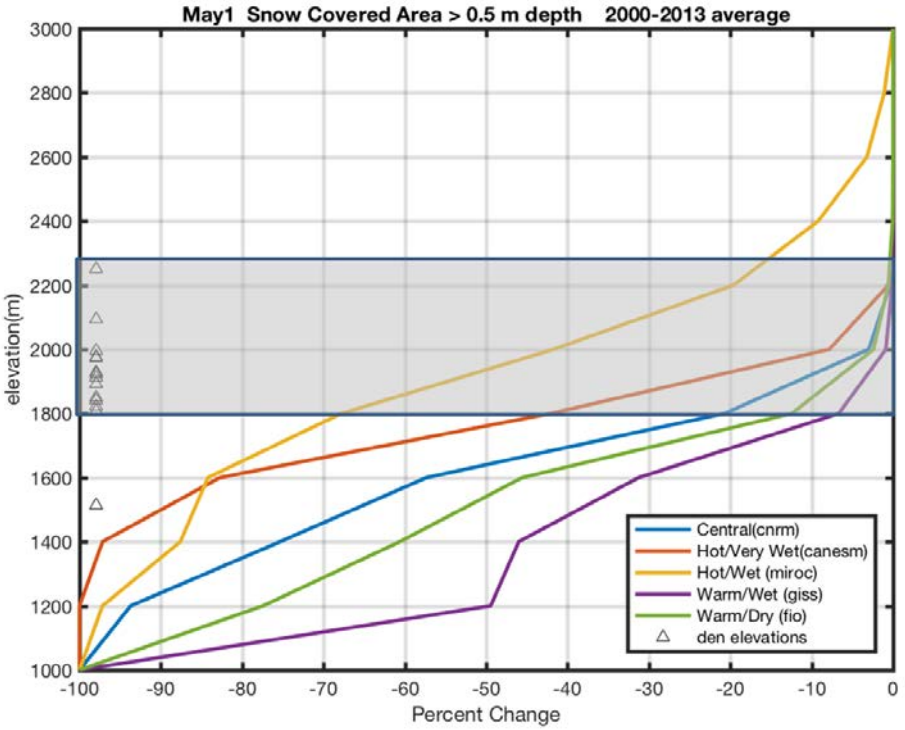


Comparison of Methods

Ray et al. (2017)	Copeland et al. (2010); McKelvey et al. (2011)
0.24 mi^2 spatial resolution ◦ Glacier and Rocky Mtn NP	14.29 mi^2 spatial resolution ◦ Western U.S. (except CA, GB)
Topographic features used (slope, aspect, shading)	No topo features used
Validated with SNOTEL and MODIS	No validation for snow
17 years of MODIS data	7 years of MODIS data
Snow cover dates include April 15, May 1, May 15 (better aligns w/ life history)	Snow cover dates include May 15 and May 29 (both derived)
Snow presence defined: 1.25 cm (0.5 in) snow depth on May 15	Snow presence defined: 13 cm (5.12 in) snow depth on May 1

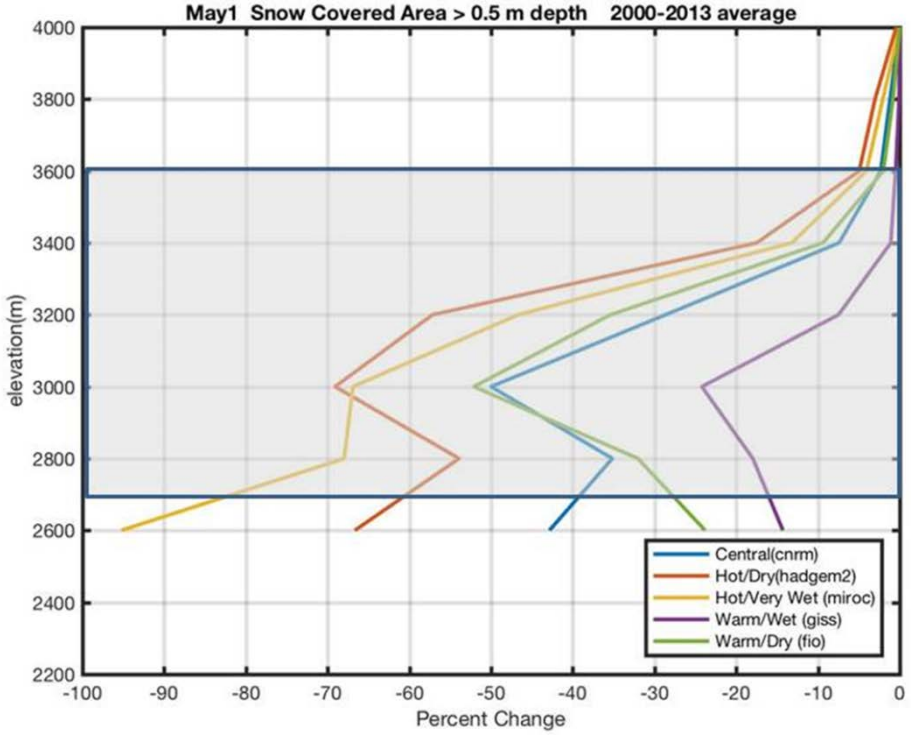
Key Results – Glacier NP

- Average Snow Covered Area (depth ≥ 0.5 m or 20 in) percent change at elevation bands for five future scenarios on May 1st



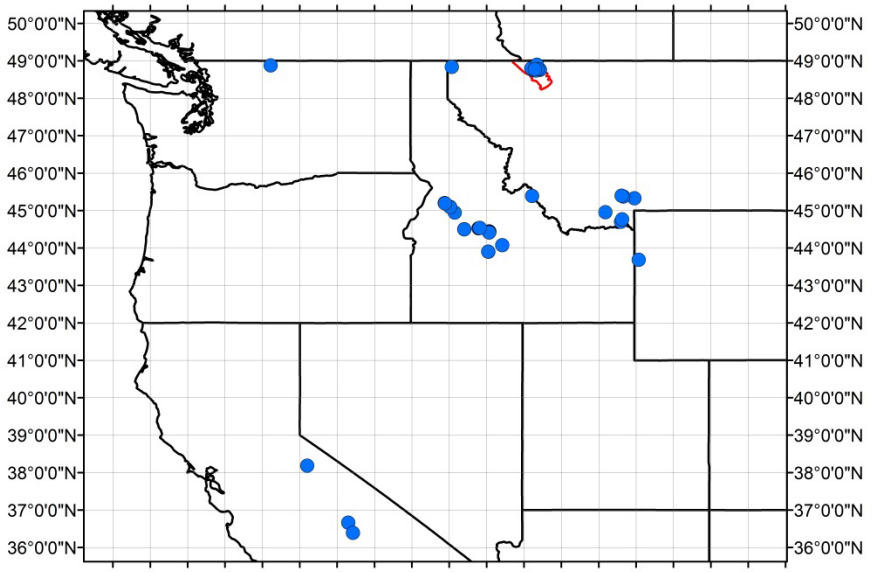
Key Results – Rocky Mtn NP

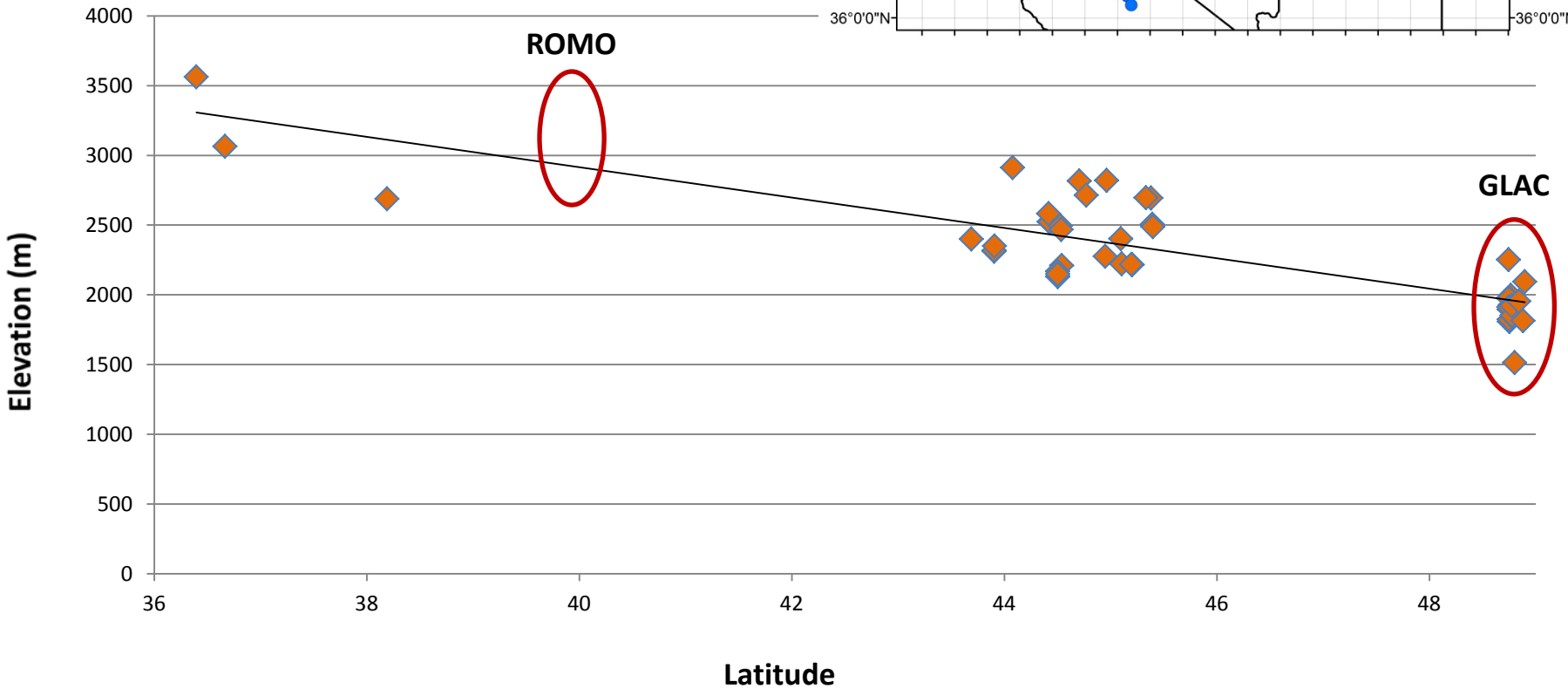
- Average Snow Covered Area (depth ≥ 0.5 m or 20 in) percent change at elevation bands for five future scenarios on May 1st



Den Sites in Lower 48 (n=47)

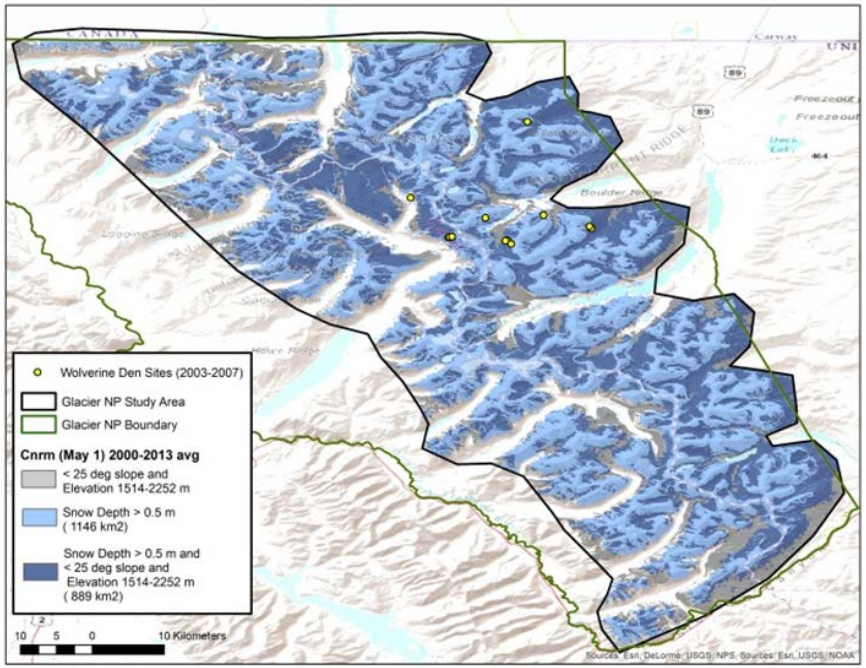
Residual standard error: 219.7 on 45 degrees of freedom
Multiple R-squared: 0.6925, **Adjusted R-squared: 0.6856**
F-statistic: 101.3 on 1 and 45 DF, p-value: 4.23e-13
Slope is different than zero, $p = 4.23 * 10^{-13}$





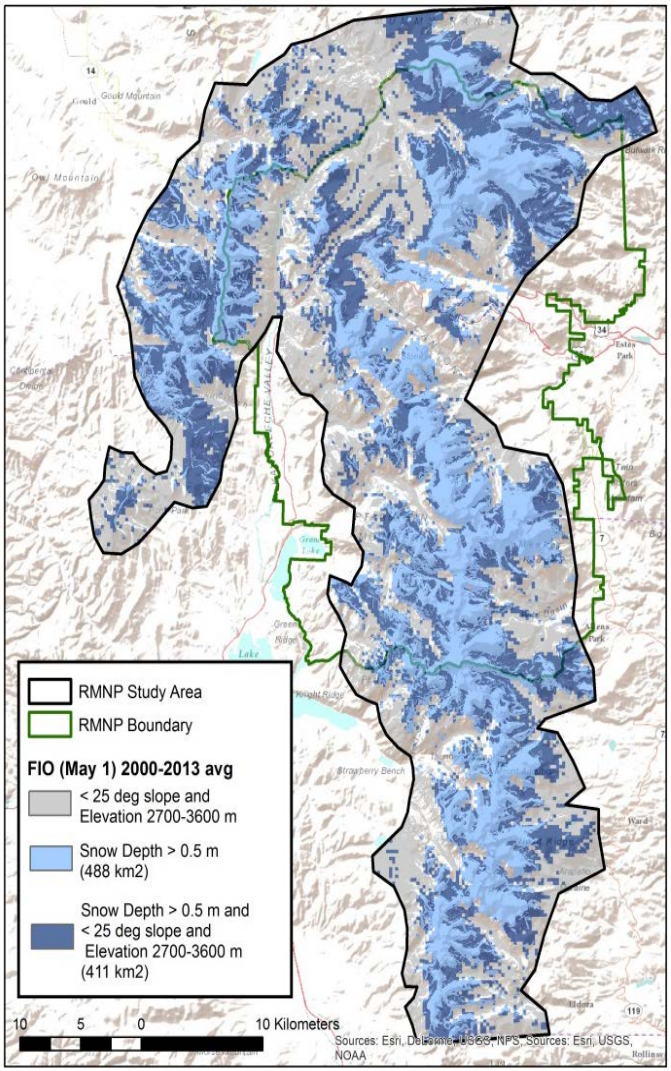
Key Results – Glacier NP

- Distribution of averaged projected Snow Covered Area (depth ≥ 0.5 m (20 in)) for May 1; Central scenario.
- Map identifies where slopes < 25° and elevations 1514–2252 m (4,968–7,389 ft) (where dens have been documented).



Key Results – Rocky Mtn NP

- Distribution of averaged projected Snow Covered Area (depth ≥ 0.5 m (20 in)) for May 1; Central scenario.
- Map identifies where slopes < 25° and elevations 2,700-3,600 m (8,858–11,811 ft) (inferred elevations where dens would be expected).



Snowpack/Snow Cover:

General Conclusions for Northern & Southern Rocky Mtns

- Large portions of the study areas meet all three criteria in future (Year 2055):
  - Greater than 0.5 m (20 in) snow depth on May 1;
  - At elevation 4,967–7,389 ft for Glacier NP or 8,858 to 11,811 ft for Rocky Mtn NP; and
  - With a slope less than 25 degrees
- Large tracts of significant snow-covered area are projected in close proximity to documented historical den sites across all three scenarios

Summary of Future Conditions

- CC model projections for areas within wolverine's range in contiguous U.S.
  - Increases in temperature by the mid-21st century
  - Drought duration/intensity could be worse with increase temperatures
  - Snow cover projected to decline, but will vary by elevation, topography, region
    - Higher elevations more resilient
- Wildland fire risk is site-specific, but likely to increase

Overall Assessment

- Known or likely potential stressors represent low risk to the species
- Climate change effects: increase temperature and reduced snowpack
  - Model results: higher elevations (where wolverines are found) retain more snow than lower elevations
  - Modeled study areas: large portions have snow > 20" on May 1
- Legal protections in several western states
  - Threatened, Candidate, or Non-game Species
- Legal trapping currently prohibited in contiguous U.S.
  - Some incidental trapping still occurring
  - Trapping in Canada & Alaska appears to be sustainable
- No population trend information for contiguous U.S.
  - Winter surveys indicate 0.42 probability of occupancy
  - Wolverines now found in areas previously extirpated
    - Continue to move into US from Canada, and move across intl. borders

Peer Review Comments
(AMEC mgt oversight)

- **Reviewer 1**: good job pulling info together, highlighted uncertainties; additional references provided; some technical comments
- **Reviewer 2**: very negative; claim of "pervasive" bias in use and interpretation of info; concern over CC projections past 50 years
- **Reviewer 3**: technical comments provided (e.g., N_e); uncertainty re CC modeling
- **Reviewer 4**: complete, comprehensive, well-organized summary; identified omissions and oversights; e.g., effects of human-caused mortality on viability of contiguous U.S. wolverine population

Public, Agency, Other Parties' Concerns

- Response to Oct 2016 NOI (proposed rule/status review)
  - Over 200 comments posted (from several States, Canada, U.K.)
  - Most, but not all, general public comments favored listing
    - CC effects (need for deep snow) and rarity/small population size as primary concerns
      - "Indiscriminate" trapping, winter recreation, loss of genetic diversity, and loss of 2/3 of habitat (due to reduction in areas w/ deep snow; McKelvey et al. 2011 estimate)
    - Am. Society of Mammalogists; Shoshone-Bannock Tribes, NGOs and their members support listing
  - State agencies/industry groups – generally, reaffirmed previously submitted comments (2013 proposed rule), criticism of DPS
    - Criticisms of Copeland et al. 2010 model and Service's reliance on this as basis for listing
    - Montana and Wyoming: extensive comments/documents

Public, Agency, Other Parties' Concerns

- SSA Report review:
  - Common comments – Range maps not clear (maps revised and retitled); update WAFWA winter 2016-2017 survey results
  - **Wyoming Game & Fish** – update survey info; contact Tribes for any other detections/survey results
  - **Idaho Fish & Game** – technical comments; clarify denning habitat discussion; include den info from researcher (added); revise winter recreation study discussion (new report)
  - **Montana Fish Wildlife & Parks** – many technical comments and clarifications; most incorporated
  - **Washington Fish & Game** – highlighted lack of complete info on wolverine biology/ecology; concerned about expressed "doubt" about association w/ snow; technical comments also provided

Public, Agency, Other Parties' Concerns

- SSA Report review:
  - **Colorado Parks & Wildlife** – Questioned inclusion of State in current range; maps revised
  - **California Dept. Fish & Wildlife** – unlikely to have viable reproductive population (recovery) w/o translocation
  - **Oregon Dept. Fish & Wildlife**– comment on range maps, some areas do not have reproducing populations
  - **Utah DNR** – add State protections/conservation actions
  - **New Mexico F&G** – clarify status; no protections since presence (current or historic) not verified
  - **USFS** – general and technical comments (esp. from one reviewer; addressed where appropriate
    - Focused on climate change and deep snow requirement (may or may not be adaptable)
  - **BLM** – few comments submitted

Federal and State Mechanisms

- National Forest Management Act
  - USFS – Forest Plans
- Wilderness Act
- Federal Land Policy and Management Act
  - BLM – Land Use and Resource Mgt Plans
  - BLM Manual 6840 (Special Status Species Mgt)
- State permitting regulations for research
- State Wildlife Action Plans
  - Wolverine is *Species of Greatest Conservation Need* (all western States)
  - Idaho Wolverine Conservation Plan

Federal and State Mechanisms (cont.)

- State Protections (currently, no legal trapping in lower 48)
  - Threatened – CA, OR
  - Endangered – CO
  - Candidate – WA
  - Non-game (protected) species – ID, WY
  - Furbearer and species of concern – MT
  - Protected from collection, possession, import – UT
- Canada: varying provincial designations, from 'E' to 'T' (eastern areas), sensitive/special concern, or no ranking
- AK and Canada regulate trapping/hunting
- Recent settlements or agreements w/ Wildlife Services for predator control devices

Other Conservation Mechanisms

- Nez Perce Tribe
  - Wolverine – species of conservation concern in 3 draft conservation plans
    - IRMP, Plant and Wildlife Conservation Strategy, & Forest Mgt Plan
- Shoshone-Bannock Tribes
  - Preparing Climate Change Adaptation Plan
    - To be used for developing adaptation actions and monitoring
- No Tribal Nations submitted SSA Report review comments

Acknowledgements

- Many thanks to Core Team members for their participation and review of drafts!
- Spatial Analysis and GIS Support – John Guinotte and Ed Turner (CFWO)
- Literature procurement – Wayne Nuckols (CFWO)
- Funding support for NOAA study
- And wolverine researchers, Federal/State agency and Canadian biologists

"Buddy" in California, May 2016; Photo credit: Chris Stermer, CDFW

From: Bush, Jodi
To: Grizzle, Betty
Cc: Shoemaker, Justin
Subject: Re: Revised PowerPoint
Date: Friday, January 19, 2018 10:44:27 AM

Hey Betty. Thanks I got tied up with some other work. If I find some time, I will finish my review and get back to you on this new version asap. 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 Fri, Jan 19, 2018 at 10:41 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> I haven't received any comments on the draft I sent out earlier. I added a few more slides (see #16 and 17) and an overall assessment slide. I did my best to trim down text/words.
>
> Let me know if you have any comments/changes. Assuming we are still meeting next week, I can also make changes when I see you next Tuesday.
>
> --
>
> 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: Grizzle, Betty
Subject: Re: paper with supplemental info
Date: Friday, January 19, 2018 12:12:14 PM

---

yeah, there is one more though close to the BC border in the snow layer

John Guinotte
Spatial Ecologist
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, Jan 19, 2018 at 9:50 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Does this work?
>
> On Fri, Jan 19, 2018 at 8:42 AM, Guinotte, John <john_guinotte@fws.gov> wrote:
>
> > It will be important to note that webb didn't map dens, but did map lactating females, which are difficult to see in the map. You might want to put some big colored dots on the webb map to show where those lactating females are.
> >
> > John Guinotte
> > Spatial Ecologist
> > 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, Jan 19, 2018 at 9:32 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
> >
> > > Attached is slide I prepared for Alberta.
> > >
> > > On Fri, Jan 19, 2018 at 8:22 AM, Guinotte, John <john_guinotte@fws.gov> wrote:
> > >
> > > > if you do an eyeball comparison betweeen fig 2c in aronsson and persson and fig 1 in copeland 2010, it looks like most of those wolverine reproduction dots are outside copelands snow layer.
> > > >
> > > > John Guinotte
> > > > Spatial Ecologist
> > > > 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, Jan 19, 2018 at 9:05 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> see attached
>
> --
>
> 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

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760-431-5901 fax

From: Grizzle, Betty
To: John Guinotte
Subject: Luce paper
Date: Friday, January 19, 2018 1:50:37 PM
Attachments: Luce et al 2014 sup-1.pdf
Luce et al 2014.pdf

John - Have you seen this 2014 paper? It was cited and maps included in the (still draft) 2016 USFS climate vulnerability/adaptation assessment for Northern Rocky Mountains.

--

Betty J. Grizzle, D.Env.
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Auxiliary material for

Sensitivity of snowpack storage to precipitation and temperature using spatial and temporal analog models

Charles H. Luce[1], Viviana Lopez-Burgos[1], and Zachary Holden[2]

1. U.S. Forest Service Research and Development, Rocky Mountain Research Station, Boise, Idaho, USA
2. U.S. Forest Service Region 1, Missoula, Montana, USA

Water Resources Research

Introduction

The State of California Department of Water Resources (CADWR) maintains a separate automated snowpack monitoring network similar to the SNOTEL network analyzed in the accompanying paper. While the SNOTEL network provides coverage for primarily eastward draining basins, the CADWR system has greater North-South coverage and includes basins draining to the west slope of the Sierra Nevada. Despite basic similarities in purpose between the two networks there are slight differences in equipment and protocols that make direct inclusion of the CADWR data into our analysis questionable. Here we provide some analysis of the two data sets to help other researchers see the differences, and potentially provoke further discussion on whether the differences are equipment/protocol related or demonstrate some unique behaviors not accounted for in the SNOTEL data. Data for the CADWR network are available at http://cdec.water.ca.gov/cgi-progs/queryCSV. Some of the stations in the network are operated by CADWR and others by the U.S. Bureau of Reclamation (USBR) so may have different instruments or instrument placement.

Results

We screened the initial list of 75 stations by looking at the number of missing days of temperature and precipitation data in each year. With a limit of no more than 10 missing temperature or precipitation values in a given year (temperature data seemed generally to be limiting), we reduced the available data to water years 2006-2013 at 7 stations (Table S1). We calculated the Nov-Mar temperature and precipitation as was done for the SNOTEL stations and found the April 1 SWE value. The CADWR data plotted somewhat colder and wetter than most of the other stations, including the SNOTEL stations from California (Figure S1).

Table S1: CADWR Stations with less than 10 days of missing P and T data and at least 8 years of data.

Code	Name	Operator
BLC	Blue Canyon	USBR
CWD	Cottonwood Lakes	CA DWR
GRV	Graveyard Meadow	USBR
HNT	Huntington Lake	USBR
SIL	Silver Lake	USBR
TMR	Tamarack Summit	USBR
TUM	Tuolumne Meadows	CA DWR

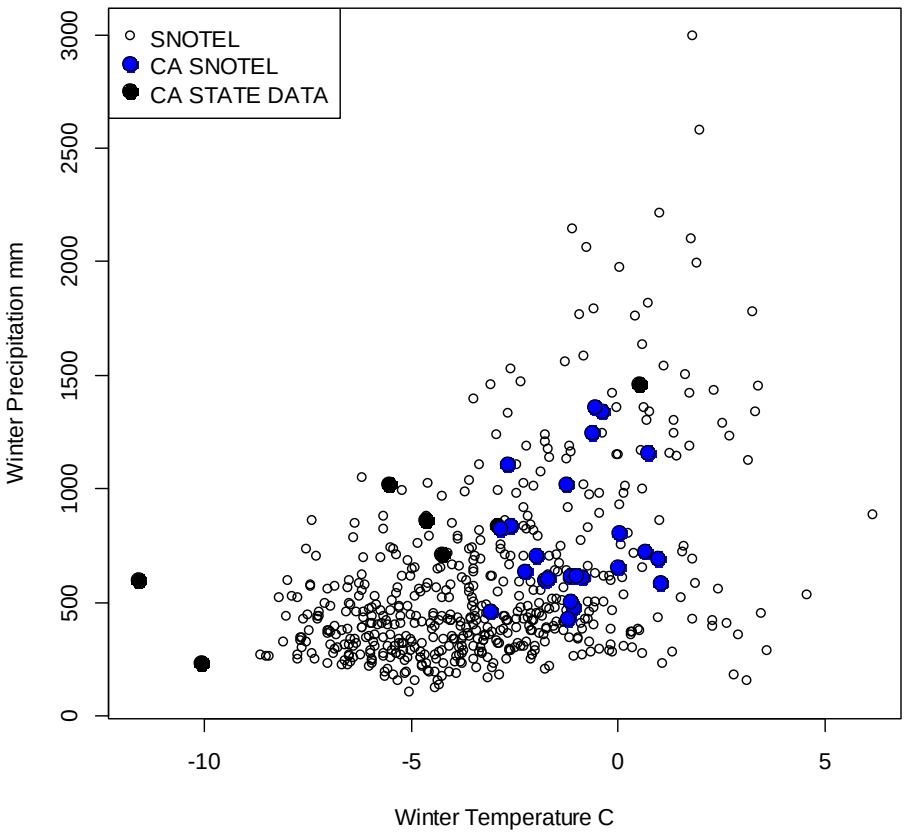

Figure S1: Precipitation versus temperature for the CADWR data (black), California SNOTEL stations (blue) and the full set of SNOTEL stations analyzed in the paper (open).

The CADWR stations record generally colder temperatures than SNOTEL stations at an equivalent elevation in California. To an extent, they are relatively cold for their elevation even within the greater SNOTEL data (Figure S2), which has a substantial range of latitude and influence from arctic air. The coldest of the CADWR stations is the Tuolumne Meadows (TUM) station, which is known to be in a

location with cold air pooling [*Lundquist and Cayan*, 2007], and the other very cold station (Cottonwood Lakes) is at 3096 m. At TUM about 0.14% of the days in November-March have a daily average temperature greater than 0°C. At CWD it is about 1.4%. In contrast at Leavitt Lake (SNOTEL station in CA at 2931 m), the average temperature is -1.8 C, with 40% of the days in Nov-Mar having a positive average temperature (in °C). Note that TUM and CWD are both operated by the State of California while the other 5 stations in the CADWR network are operated by USBR.

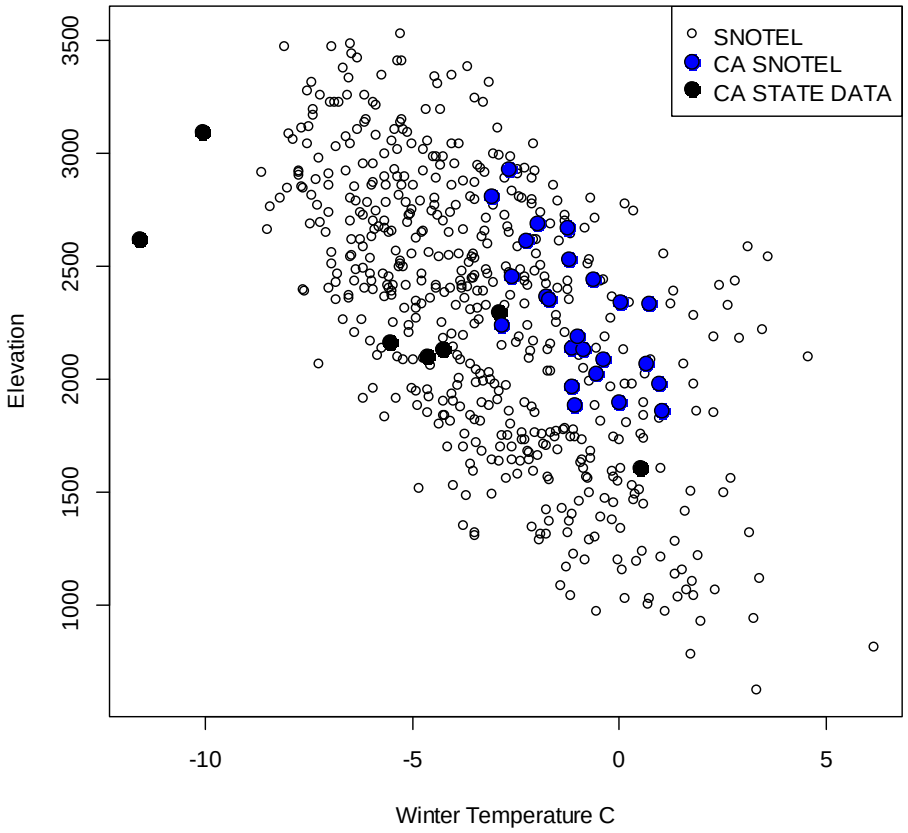

Figure S2: Temperature and elevation for the new data (black), California SNOTEL stations (blue) and the full set of SNOTEL stations analyzed in the paper (open).

Using the CADWR data as a validation data set for the spatial model built on the SNOTEL data yields an RMSE of 345 mm, mostly overpredicting April 1 SWE. Application of a local fit polynomial to predict values well outside of the range of observed temperatures would be expected to yield poor predictions. Since many of these stations are relatively cold, we examined the ratio of Apr 1 SWE on the pillow to the Nov-Mar precipitation as a function of temperature. Most of the CADWR stations fell below both the bulk of the SNOTEL stations (Figure S3) at an equal temperature, but particularly so relative to the California SNOTEL data. This could indicate any of a number of differences in the CADWR data relative to the SNOTEL data, whether it be differences in measurements or siting of the stations. The cold

temperatures could be an indication of persistent cold air drainage or pooling, for example. This aspect would be of particular interest to us if it is a broad disconnect from the SNOTEL results, as cold air drainage effects may be captured based on topographic information [*Holden et al.*, 2011], providing some potential basis for modeling differences.

Unfortunately, it may be more likely that the discrepancy results from differences in the measurement systems used by SNOTEL and CADWR stations. Differences in temperature could simply result from the heights of the temperature sensors above the ground, for instance. Alternatively, the lower SWE/P ratios could result from a different degree of undercatch in the precipitation gauge, a greater proportion of precipitation as rain, more melt, or a different amount of drift or scour on the snow pillow. Just for reference, the Leavitt Lake site mentioned earlier with the warmer temperature at high elevation had a SWE/P ratio of 1.4. A value greater than one represents a combination of gage undercatch, drifting on the pillow, snow accumulation starting before November, little melt before Apr 1, and a large fraction of the precipitation as snow instead of rain.

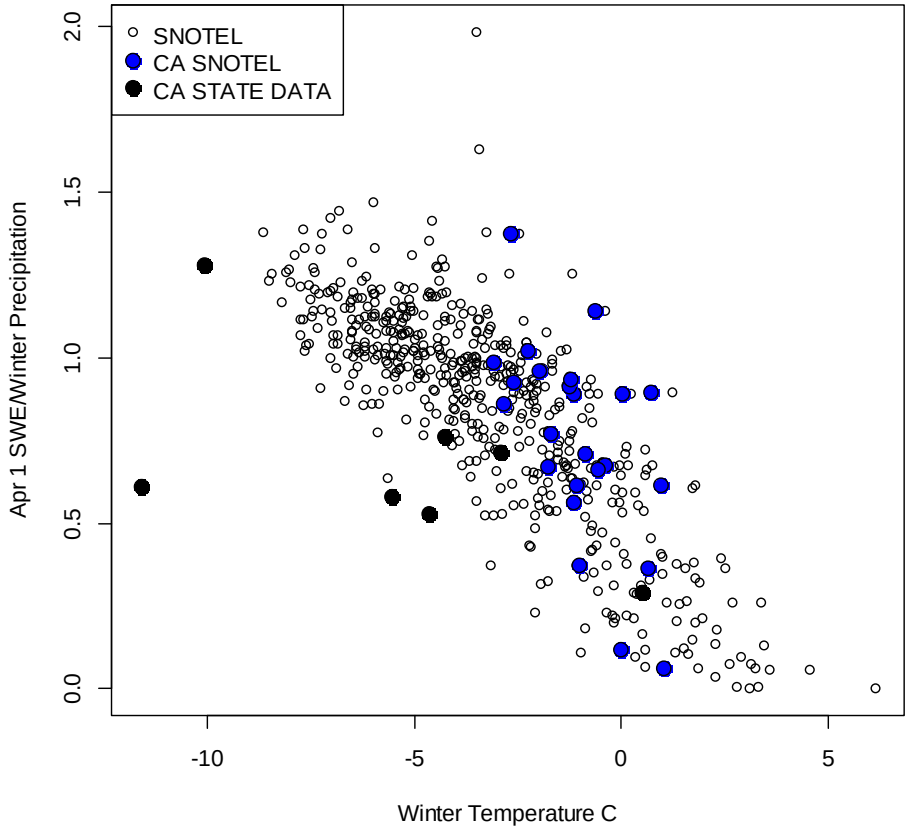

Figure S3: Ratio of April 1 SWE to Nov-Mar Precip against temperature. Most of the CADWR has SWE/P ratios less than those observed at SNOTEL stations for an equivalent temperature. This can result from differences in site selection or differences in meteorological equipment.

While some variability in gage catch, drifting, and cold air drainage would also be expected within the SNOTEL station data, they do not seem as apparent as they are in the CADWR data set. The cold temperatures could argue for the CADWR stations as being situated in particularly cold air pooling or drainage sites, which could be taken to suggest that a model fit to the SNOTEL network does not work well for sites with strong cold air drainage, a viable hypothesis. However, the departures of the spatial analog model at CADWR stations seem to be strongly related to the SWE/P ratios. At these cold stations, there is an expectation of a relatively high SWE/P, but most of these stations report a relatively low SWE/P (compared to SNOTEL stations), even for temperatures a few degrees warmer. The magnitude of error seems to be a fairly strong function of SWE/P (Figure S4), which could argue that different precipitation measurements, or local scouring of snow from the pillow could be a source of disagreement, as could a cold bias in temperature measurement. It could also result from different data curation that makes corrections for precipitation gage undercatch (although one of the CADWR stations still has a SWE/P greater than 1).

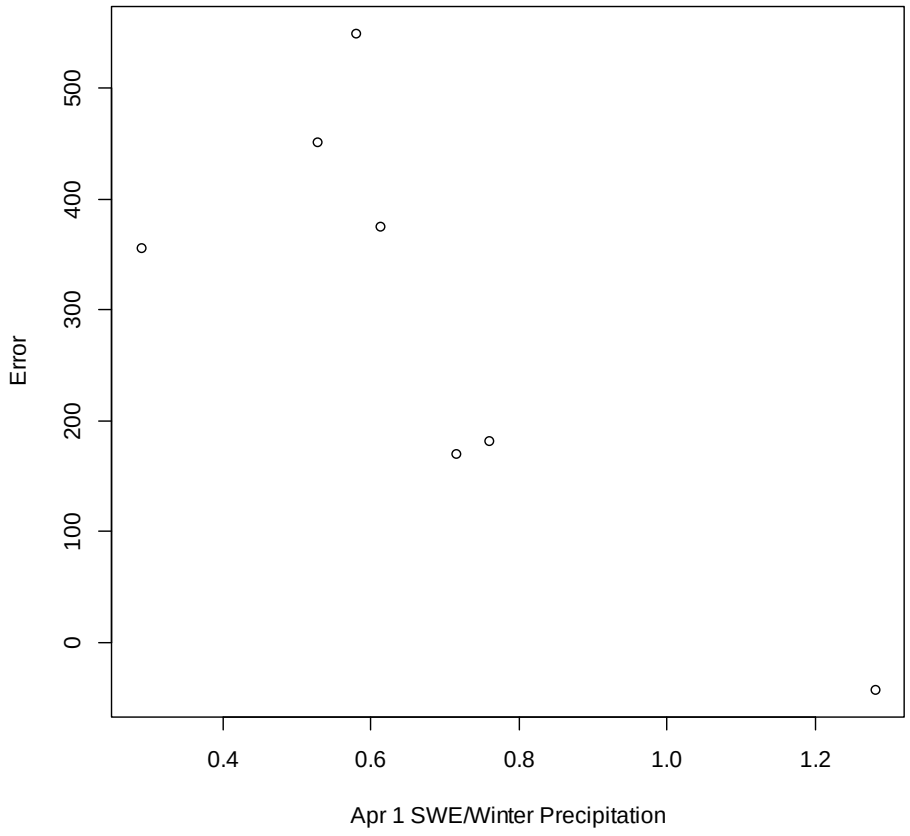

Figure S4: Error (model tends toward overprediction of these data so most values are positive) as a function of the ratio of Apr 1 SWE to Nov-Mar Precipitation.

Without clearly knowing whether these represent unique snow environments not sampled by SNOTEL or there is some difference in equipment or protocols, we can only speculate about causes of

differences. Without substantial additional information it is not fruitful to compare these data from apparently different networks with potentially different equipment and data curation. In particular the fact that several of the sites could be somewhat biased in their SWE/P ratio relative to sites with similar temperatures is a concern, as is the possibility that two of the sites have cold biases in temperature measurements. The measured values could well be correct, but comparisons with other sites would need assurances of equivalent equipment and lack of scouring.

The exercise of comparing to the CADWR data, however, raises some good questions about additional factors that should be considered. In particular, the cold air pooling might be expected to generate a different relationship between P, T, and SWE (assuming it is not present in the SNOTEL data). Presumably, then, topographic metrics that indicate cold air pooling might be useful in tightening the relationship found at the SNOTEL stations.

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AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE
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Key Points:
- Different inference paths for climate effects on snow have different outcomes
- Season average P and T predict April 1 SWE and snow residence time well
- Snowpack sensitivity to climate greater than previously thought in some areas

Supporting Information:
- Auxillary material for snow sensitivity

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Sensitivity of snowpack storage to precipitation and temperature using spatial and temporal analog models

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Abstract Empirical sensitivity analyses are important for evaluation of the effects of a changing climate on water resources and ecosystems. Although mechanistic models are commonly applied for evaluation of climate effects for snowmelt, empirical relationships provide a first-order validation of the various postulates required for their implementation. Previous studies of empirical sensitivity for April 1 snow water equivalent (SWE) in the western United States were developed by regressing interannual variations in SWE to winter precipitation and temperature. This offers a temporal analog for climate change, positing that a warmer future looks like warmer years. Spatial analogs are used to hypothesize that a warmer future may look like warmer places, and are frequently applied alternatives for complex processes, or states/metrics that show little interannual variability (e.g., forest cover). We contrast spatial and temporal analogs for sensitivity of April 1 SWE and the mean residence time of snow (SRT) using data from 524 Snowpack Telemetry (SNOTEL) stations across the western U.S. We built relatively strong models using spatial analogs to relate temperature and precipitation climatology to snowpack climatology (April 1 SWE, $R^2=0.87$, and SRT, $R^2=0.81$). Although the poorest temporal analog relationships were in areas showing the highest sensitivity to warming, spatial analog models showed consistent performance throughout the range of temperature and precipitation. Generally, slopes from the spatial relationships showed greater thermal sensitivity than the temporal analogs, and high elevation stations showed greater vulnerability using a spatial analog than shown in previous modeling and sensitivity studies. The spatial analog models provide a simple perspective to evaluate potential futures and may be useful in further evaluation of snowpack with warming.

1. Introduction

One of the more critical sensitivities affecting the water resources and ecology of western U.S. mountains is changes in snowpack storage of water [*Barnett et al.*, 2008; *Holden et al.*, 2012; *McKelvey et al.*, 2011; *Westerling et al.*, 2006]. Storage has two dimensions, how much water is held, and how long it is held. The Snow Water Equivalent (SWE) on 1 April is a commonly applied metric describing the depth of stored water for the spring and summer runoff season, as it is a metric with a long record of measurement at many sites [e.g., *Mote*, 2003; *Regonda et al.*, 2005]. Storage time metrics are less well developed for snowpacks because there are a limited number of stations with relatively short records (e.g., Snowpack Telemetry stations, SNOTEL) where such measurements can be made [*Clow*, 2010; *Serreze et al.*, 1999]. The timing of streamflow has been applied as a related metric [e.g., *Cayan et al.*, 2001; *Stewart et al.*, 2005], and similar metrics of timing have been applied for center of melt timing [*Clow*, 2010] and the center of mass of SWE [*Kapnick and Hall*, 2012]. Hydrologists commonly apply the idea of mean residence time with respect to water in soil or other reservoirs [e.g., *Kirchner*, 2009; *McGuire et al.*, 2005; *McNamara et al.*, 2011; *Soulsby et al.*, 2009]; however, the metric has not been applied to snowpacks despite the advantage of snow's comparatively short-tailed (and finite) residence time distribution. There has been substantial discussion of trends and sensitivity of April 1 SWE as well as future projections [*Casola et al.*, 2009; *Hamlet et al.*, 2005; *Mote*, 2003, 2006]. Although there has been discussion of trends of timing aspects of snowmelt [*Cayan et al.*, 2001; *Clow*, 2010; *Kapnick and Hall*, 2012; *Stewart et al.*, 2005], quantitative evaluation of the sensitivity of timing to seasonal precipitation and temperature metrics has been limited [*Hamlet et al.*, 2005; *Stewart et al.*, 2005].

Three primary sources of information have informed our understanding of the potential impacts of climate change on water resources and ecology: temporal analogs, spatial analogs, and simulation models.

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Temporal analogs show the sensitivity of processes to shifts in climate by reasoning that warmer futures look like warmer years or warmer days do now [*Mohseni et al*., 1998; *Mote*, 2006; *Sankarasubramanian et al*., 2001; *Sawicz et al*., 2011]. Temporal analogs are usually constructed using time series, say interannual data, of weather data regressed against outcomes of interest, for example April 1 SWE.

Spatial analogs rely on a logic that a warmer future may look like warmer places do now; they are sometimes called "space-for-time" substitutions. Spatial analogs are constructed by regressing climatological averages of weather data against outcomes of interest, for example species presence-absence data. In the absence of longtime-series of fluxes or states, spatial analogs are commonly used to develop models of sensitivity to climate [e.g., *Tchebakova et al*., 1994; *Vose et al*., 2012; *Wenger et al*., 2011]. With respect to snow, this would look like examining how average April 1 SWE changed from place-to-place as a function of the climate of those locations.

Mechanistic simulation models are applied when there is concern that climate futures may not look like any temporal or spatial analogs available to us now or in the recent past, and that the empiricism inherent in them may break down under altered climates [*Williams and Jackson*, 2007]. Though there may be substantial reliance on simulation models for relatively simple processes like snowmelt [*Casola et al*., 2009; *Elsner et al*., 2010; *Hamlet et al*., 2005; *Minder*, 2010; *Sproles et al*., 2013], there is still some need for calibration and model improvement. Even in the relatively low parameter-dimensionality of physically based snowmelt models, some suppositions must be made that may not be practical to simulate from first principles and common weather data but that could lead to substantial divergence in estimates [e.g., *Dai*, 2008; *Marks et al*., 2013; *Rutter et al*., 2009]. Among these are estimating the phase, solid versus liquid, of precipitation during a given event, and not the least of the uncertainties is temporal downscaling from a "2°C warmer" climate to the distributions of temperatures on wet versus dry days in particular months. Ultimately, simulation models do what modelers tell them to do, and having empirical analogs to inform, guide, and validate sensitivity estimates is valuable for constraining modeling choices.

Empirical evaluation of snowpack sensitivity to climate has used temporal analogs, for example through regression of interannual variability of April 1 SWE to interannual variability in precipitation and temperature [*Mote*, 2006]. These empirical correlations and temporal trend analyses have been contrasted with simulation models like the Variable Infiltration Capacity (VIC) model [*Liang et al*., 1994] to show similar qualitative expectations from independent lines of reasoning [e.g., *Casola et al*., 2009; *Elsner et al*., 2010; *Hamlet et al*., 2005; *Mote et al*., 2005].

Some uncertainties remain from these analyses. One of the findings regarding snowpack sensitivity to climate in this context is that temporal model fits may not be the strongest in the locations with the seemingly most vulnerable snowpacks [*Casola et al*., 2009; *Mote*, 2006]. In addition, some higher elevation locations show increased April 1 SWE with increasing temperature (even when precipitation is specified as constant) [*Hamlet et al*., 2005; *Mote*, 2006]. An important caveat regarding these studies, one expressed by their authors, is that in both simulation model experiments and empirical analyses, temperature, and precipitation inputs were derived from predominantly low elevation stations, sometimes far from the actual SWE observations [*Hamlet et al*., 2005; *Mote*, 2006]. This required simplifying assumptions about how those inputs vary across space and with elevation [*Minder*, 2010], and unfortunately, interannual variations in high elevation weather are not always well captured by nearby low elevation stations [e.g., *Dettinger et al*., 2004; *Luce et al*., 2013]. Validations of snowmelt timing simulations compared to streamflow data show pronounced bias [*Wenger et al*., 2010], suggesting some need for further evaluation of timing sensitivity as well.

The reasoning behind spatial analogs has been one of the underpinnings for a movement toward observatory networks for ecological and hydrological sciences [e.g., *Schimel et al*., 2007]. While quantitative spatial analogs have been applied to model the sensitivity of ecological systems [e.g., *Monserud et al*., 1993; *Wenger et al*., 2013], they have not been applied for snowpacks. Considering just the simple utility of being able to compare snowpack sensitivity to ecological sensitivity in some settings, there is value in contrasting spatial and temporal analogs for modeling snowpack sensitivity to climate variations. The potential for improving sensitivity estimates in locations where the temporal analog performs poorly is another justification for exploring the spatial alternative, as is the potential to test more complex model formulations with a larger sample size. There are certainly conceptual challenges to applying spatially referenced sensitivities when temporal ones are available. One potential worry is that stations in different geographic locations do not

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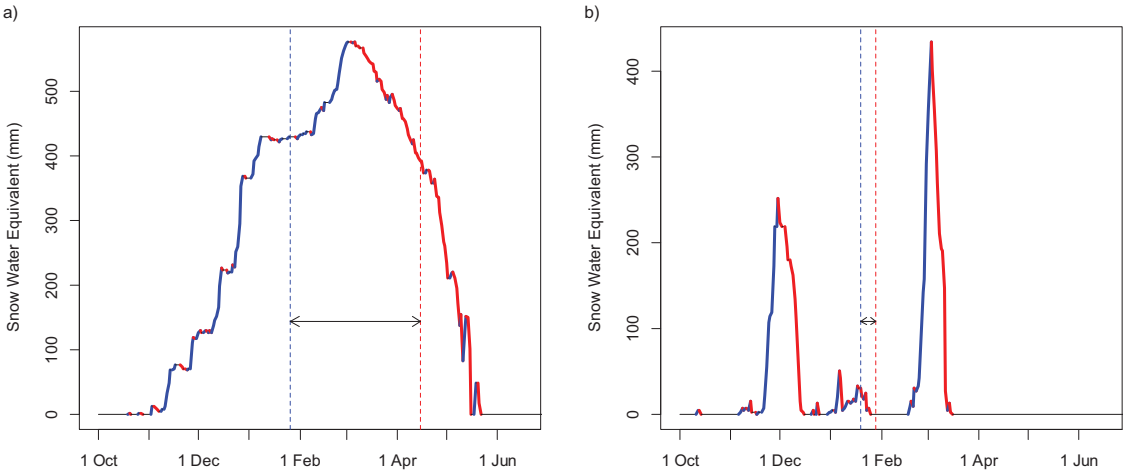

Figure 1. Example traces of snow water equivalent (SWE) for water year 2007 contrasting places with short-snow and long-snow residence times. The plots show two stations in Oregon at (a) 1645 m elevation and (b) 950 m elevation. Blue indicates days when accumulation occurs, while red indicates days of melt, and black is a day with no change. The blue vertical-dashed line is the center of timing (first moment) of accumulation; the red vertical-dashed line is the center of timing of melt; and the arrow indicates the difference between them, the mean snow residence time (SRT). SRT is 79 days for (a) and 9.6 days for (b).

necessarily share similar weather sequences, variations in the jet stream path, and seasonal timing of storms, and solar azimuth angles in spring could conceptually overwhelm any signal due to simple metrics of winter climate. While such issues might cloud interpretation of poor-fitting models, they only represent sources of residual variance when models have strong relationships. Resolving these questions would support ongoing design and investment in observatory networks.

We address several of these issues through examination of SNOw TELemetry (SNOTEL) network records, where daily precipitation, temperature, and snow water equivalent data are collected at each location. We have four objectives: (1) reexamine the temporal analog sensitivities using stations where weather information and snowpack information are collected in the same location, (2) consider the sensitivity of snowpack mean residence time as a metric of storage duration, (3) develop and test spatial analog models to further explore climatic sensitivity, and (4) contrast the temporal and spatial analog approaches for these sites with relatively rich information.

2. Methods

2.1. Data

Daily precipitation, temperature, and snow water equivalent data were obtained from the U.S. Department of Agriculture's Natural Resources Conservation Service SNOw TELemetry (SNOTEL) sites (http://www.wcc.nrcs.usda.gov/snow/). We used all stations in western United States (excluding Alaska) with data between Water Years 1991–2011, which comprised 524 stations. These stations were spread across the 11 western states plus one station in extreme western South Dakota. Although some stations have data extending into the early 1980s, we used a later period to allow inclusion of more stations. April 1 SWE was taken directly from the SNOTEL record each year.

Mean snow residence time (SRT) was estimated as the difference between the center of timing of snow accumulation (CT_{acc}) and the center of timing of melt (CT_{melt}) each year (Figure 1). Snow accumulation for each day was taken as any positive increment in SWE, and melt was taken as any decrement in SWE. They were calculated as:

$$CT_{\mathrm{acc}} = \frac{\sum t_i acc_i}{\sum acc_i} \tag{1}$$

$$CT_{\mathrm{melt}} = \frac{\sum t_i melt_i}{\sum melt_i} \tag{2}$$

where t_i is the number of days passed since 1 October, acc_i is the increase in SWE on day i and $melt_i$ is the decrease in snow on day i, following the approach of *Stewart et al.* [2005]. CT_{acc} and CT_{melt} are the depth

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weighted mean dates of accumulation and melt, respectively. The difference in the mean accumulation and mean melt dates is the mean residence time, SRT

$$\mathrm{SRT} = CT_{\mathrm{melt}} - CT_{\mathrm{acc}} \tag{3}$$

Data from the California Department of Water Resources (CADWR) snow sensor station network were also examined, but we did not use them because of differences in protocol for temperature and SWE measurements between the CADWR and SNOTEL networks and among stations within the CADWR network. Although differences were slight, even seemingly minor differences in selection or placement of instruments can lead to inconsistencies when comparing among stations (see supporting information).

2.2. Temporal Analog Analysis

The temporal analog analysis parallels that of *Mote* [2006] in applying multiple linear regression to find a model that estimates the dependent variable (April 1 SWE or SRT) for each year at a site using the precipitation and temperature from each year. We found the parameters for the least squares fit to the following equations at each site

$$\mathrm{Apr1SWE}(t) = \mathrm{a_{Pa}Prcp}(t) + \mathrm{a_{Ta}T_{min}}(t) + \varepsilon_{\mathrm{a}}(t) \tag{4}$$

$$\mathrm{SRT}(t) = \mathrm{a_{Pr}Prcp}(t) + \mathrm{a_{Tr}T_{min}}(t) + \varepsilon_{\mathrm{r}}(t), \tag{5}$$

where Prcp(t) is the annual time series of total November through March precipitation taken from the precipitation gage at each site, and $\mathrm{T_{min}}(t)$ is the annual time series of the November through March average of the daily minimum temperature. We used the daily minimum temperature because the correlations were stronger using that metric than when using $\mathrm{T_{avg}}$. $\mathrm{a_{Pa}}$ and $\mathrm{a_{Ta}}$ are the regression coefficients for precipitation and minimum temperature for predicting April 1 SWE, and $\mathrm{a_{Pr}}$ and $\mathrm{a_{Tr}}$ are the regression coefficients for SRT. ε is the residual at year t. Data were assessed for normality and were not obviously skewed.

Standardized beta coefficients were also obtained to determine the relative effect of the independent variables on the dependent variable:

$$\beta_{Pa} = \mathrm{a_{Pa}} \cdot \frac{sd(Prcp)}{sd(Apr1SWE)} \tag{6a}$$

$$\beta_{Ta} = \mathrm{a_{Ta}} \cdot \frac{sd(Tmin)}{sd(Apr1SWE)} \tag{6b}$$

$$\beta_{Pr} = \mathrm{a_{Pr}} \cdot \frac{sd(Prcp)}{sd(SRT)} \tag{6c}$$

$$\beta_{Tr} = \mathrm{a_{Tr}} \cdot \frac{sd(Tmin)}{sd(SRT)} \tag{6d}$$

where *sd* denotes standard deviation.

2.3. Spatial Analog Analysis

For the spatial analogs, we examined nonlinear response surfaces of snow climatology (April 1 SWE and SRT) to precipitation and temperature climatology. We used local polynomial regression of the average response variable at each site to average winter temperature and precipitation at each site. This model does not represent the temporal variation at sites, but differences in climates across sites.

Analyzing climatic differences among 524 stations allowed for consideration of more complex functional relationships between temperature, precipitation, and the dependent variables than was appropriate with time series of 21 years or less. Using short-time series in the temporal analog, it is difficult to identify significant interaction terms, for instance, or allow for nonlinear responses in temperature or precipitation. There was no theoretical expectation of the functional form of the relationship, other than considering the potential importance of an interaction term between temperature and precipitation. Such an interaction term would suggest that one would have less snow as a result of either warm temperatures *or* low precipitation, and that colder temperatures *and* greater precipitation are required for deeper snowpacks. This would also

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be intuitive in the case of the interannual analysis, but it is often difficult to identify significant interaction terms from short, noisy time series.

Without specific knowledge of the functional form, but also without the need to explicitly find parameters for that form, we applied a local fit algorithm to describe the shape of the surface. We used the locfit package [*Loader*, 1999] in R to plot a smooth surface through the data. Local regression finds a fit for the data points that resembles the unknown function $\mu(x_i)$, which describes the relationship between y (e.g., April 1 SWE or SRT) and x (Temperature and Precipitation).

$$y_i = \mu(x_i) + \epsilon_i \tag{7}$$

It does so by locally fitting a polynomial model of degree 2 to each pair of observations (x_i and y_i) by way of approximation (using Taylor's theorem) to data from observation pairs that are inside a user defined window. These neighborhood observations are weighted by a proximity function, the observations with the most similar independent variable values are more important. We specified the model in R as, for example:

$$\text{locfit}(\text{swe} \sim \text{lp}(\text{Tavg}, \text{Precip}, \text{nn}=0.8, \ \text{scale}=\text{T})) \tag{8}$$

where nn is a user defined bandwidth (with values 0 to 1) that controls the smoothness of the fit and states how many observation pairs (nearest neighbors) will be used for the approximation. Bandwidth selection was initially guided by a generalized cross validation, which indicated optimal bandwidths at nn=0.65 for April 1 SWE and nn=0.6 for SRT, though with relatively flat response. Stronger smoothing was applied to remove visually obvious local variations that were physically unrealistic, yielding a more monotonic relationship, at a slight expense for the overall goodness of fit (see below). We used nn=0.8 for both April 1 SWE and SRT, which means the approximation used the closest 80% of observation pairs to point x_i,y_i.

For the spatial analog approach, our two explanatory variables (x's) were total November through March precipitation and the average November through March daily average temperature. In this case, the daily average temperatures gave a better fit than did the minimum temperatures used in the temporal analog models described above. November-March precipitation and average daily temperature were averaged over the years with complete data at each station. Temporal coverage ranged from 8 to 21 years, with 50% of the stations having 18 or more years of complete data, and 95% having 13 or more years. Our dependent variables were SRT and April 1 SWE. We also examined fits to CT_{melt} and CT_{acc} individually to better understand results for SRT.

We assessed the fit between the smoothed/fitted surface and the observed data using the Nash-Sutcliffe model efficiency coefficient:

$$R^2 = 1 - \frac{V_r}{V} \tag{9}$$

Where V_r is the mean square error, and V is the variance of the response variable.

We also used locfit to identify the partial derivatives with respect to each explanatory variable. These partial derivatives of the smoothed surface are a measure of the local sensitivity to precipitation and temperature:

$$\textit{Sensitivity to Precipitation} = \frac{\partial \textit{Response Variable}}{\partial \textit{Precipitation}} \tag{10a}$$

$$\textit{Sensitivity to Tavg} = \frac{\partial \textit{Response Variable}}{\partial \textit{Tavg}} \tag{10b}$$

Bandwidths for derivatives must commonly be set higher than for the original variable [*Newell and Einbeck*, 2007], and we used nn=0.9 for the April 1 SWE temperature derivative and nn=1 for all other derivatives.

Besides identifying the local slopes, we further offer an example of how the spatial analog model could be applied to estimate the change in the response variable if the average temperature were to rise 3°C, accounting for potential nonlinearities in sensitivity. This hypothetic temperature rise is based on *Dettinger* [2013] and *Solomon et al.* [2007]. We estimated the changed snowpack by first evaluating the empirical response surface for P and T_{avg}, and then evaluating the same surface with P unchanged and T_{avg} + 3°C, and taking the difference. Negative estimated future values were set to zero, since all response variables were positive

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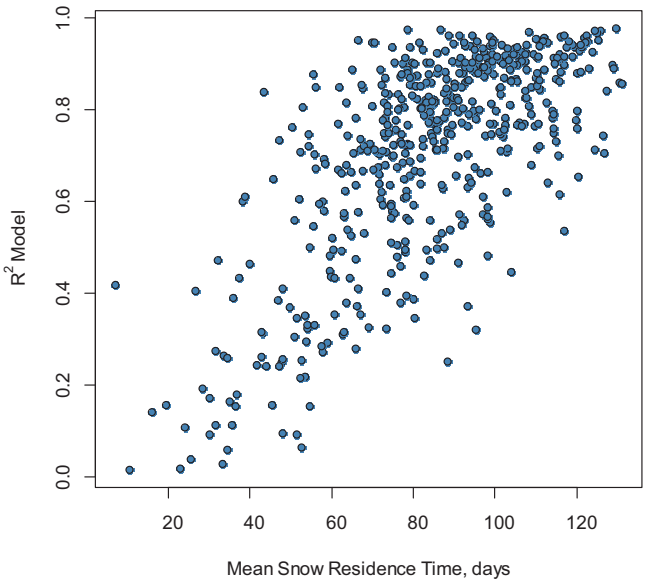

Figure 2. Relationship of at-a-station (temporal analog) regression quality to the station's mean snow residence time (SRT).

valued. We did not show an equivalent map for precipitation change, because it is estimated to be substantially uncertain across this region [*IPCC*, 2013]; precipitation is not well modeled by GCMs [*Blöschl and Montanari*, 2010], and there are substantial unresolved uncertainties for future precipitation in the mountains of the western United States [*Luce et al.*, 2013]. While these are not actual deterrents to making the computations, it might add confusion, and our intention is just to show a simple example that could be compared to similar analyses of change in temperature. Clearly more site-specific estimates of temperature change could be applied at each station.

3. Results

3.1. Temporal Analog

The overall goodness of fit (R^2) of the temporal analog models varies substantially across stations, from 0.015 to 0.98, although 75% of the stations have an R^2 greater than 0.6. Ninety-three percent of the p values for the models were less than 0.1. The R^2 of each station's temporal analog fit is strongly related to the square of the precipitation correlation with SWE (ρ_p^2) at that site (R^2=0.87, $p < 1 \times 10^{-15}$) while the correlation with temperature had no bearing on the overall quality of the model at each site (R^2=0.001, $p = 0.42$). Elevation is a relatively weak predictor of model quality (R^2= 0.27, $p < 1 \times 10^{-15}$); stations with poorer quality fits tend to be at lower elevations. Winter-averaged minimum temperatures have a slightly better relationship ($R^2 = 0.32$, $p < 1 \times 10^{-15}$), and again stations with poorer quality fits tend to be the warmer stations. This can be interpreted to say that what are broadly perceived to be the most vulnerable snowpacks are the ones with the poorest temporal analog fits. SRT was a reasonably strong predictor of the quality of fit ($R^2 = 0.50$, $p < 1 \times 10^{-15}$, Figure 2) offering a little further insight. One interpretation is that the season long temperature and precipitation averages may not be particularly informative of the year-to-year variations in April 1 SWE in places where the snowpack only lasts a few weeks and may nearly completely melt a few times each winter (see e.g., Figure 1b). If the effect of within-season timing of accumulation becomes a large source of variability in April 1 SWE, then the temporal analog will be poorer in places where snow accumulation and melt are shorter than seasonal scale. The number of years of complete data had an insubstantial influence on goodness of fit at each station (R^2=0.05, $p = 5 \times 10^{-8}$), and 71% of stations with less than 13 years of data had greater than average R^2 values.

Broadly, precipitation seemed to be more influential than temperature on an interannual basis at the SNOTEL stations, and correlations between April 1 SWE and precipitation tended to be greater than those for temperature (Figure 3a). In addition, only 12% of the temperature coefficients had a p value less than 0.1 (suggesting that most were not statistically differentiable from 0), while 95% of the precipitation coefficients were significant ($p < 0.1$). Standardized beta coefficients are stronger for precipitation than temperature at a substantial majority of stations (Figure 3b), indicating that variations in April 1 SWE for the period of the SNOTEL records were dominated by variations in precipitation. There are a few stations where temperature was more influential, however. These few stations were in the lower half of the elevation distribution.

SRT integrates weather across longer time scales, building some expectation that the fits might be better. However, SRT fits were generally poorer with a mean R^2 of 0.44 and half of the values between 0.31 and

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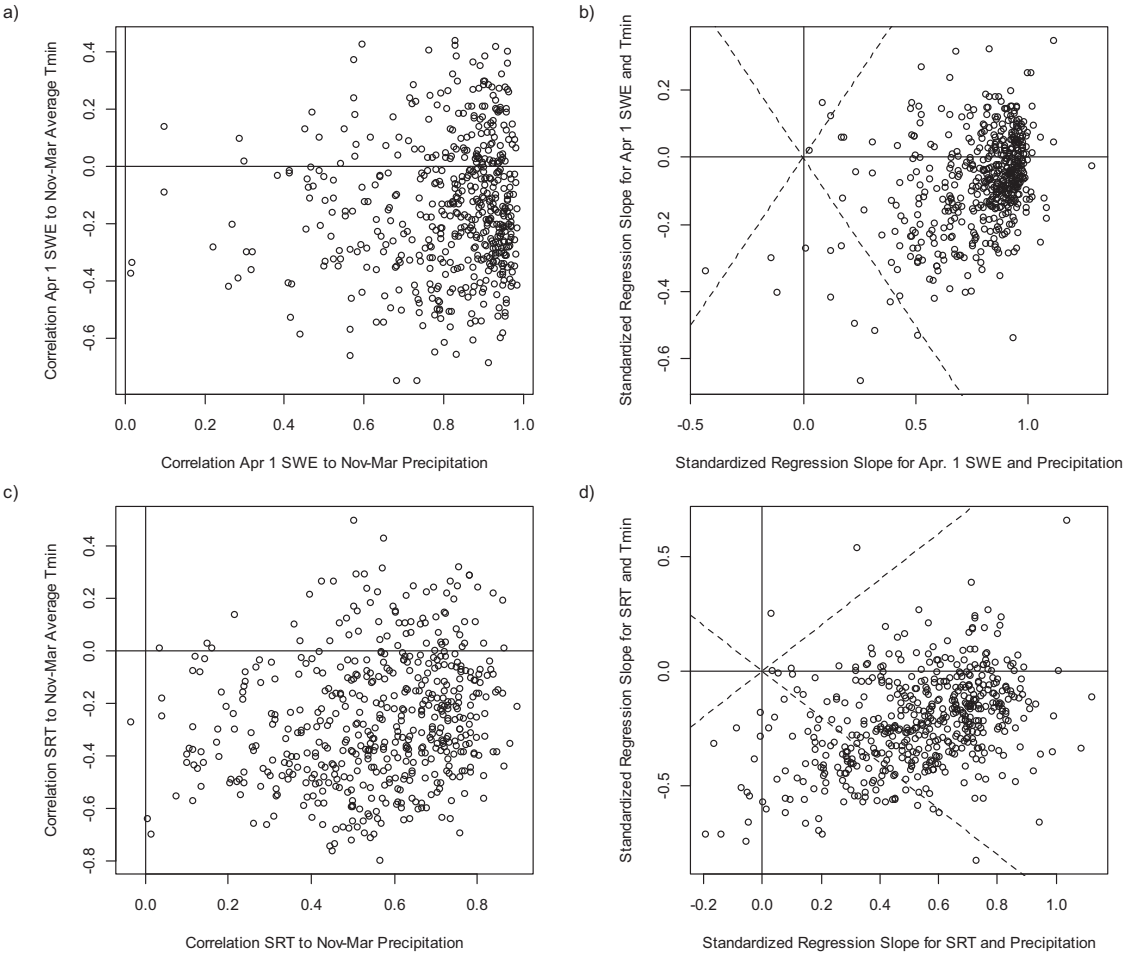

Figure 3. Correlations and standardized correlation coefficients for temporal analog models of (a and b) April 1 SWE and (c and d) mean snow residence time (SRT) at western U.S. SNOTEL stations. Dashed lines on standardized regression plots (b and d) are 1:1 lines showing where the relative influence of precipitation and temperature are equal.

0.57. Seventy-eight percent of the *p* values were less than 0.05. In contrast to the April 1 SWE fits, the precipitation correlations were not substantially and consistently greater than the temperature correlations, and the contributions of both the temperature and the precipitation correlations to the overall goodness of fit were more equal (Figures 3c and 3d). There was no relationship between the quality of fit for SRT and metrics like elevation or winter temperatures.

This study and that of *Mote* [2006] use different periods of record (1991–2011 versus 1960–2002), so it is difficult to quantitatively attribute differences between the two studies to methods. Nonetheless, the similarity of approach requires a brief comparison of findings. *Mote* [2006] used snow course records from the U.S. Natural Resources Conservation Service and offsite temperature and precipitation data from the U.S. Historical Climate Network, a subset of the National Weather Service's cooperative observer program, as well as a few stations from a Canadian counterpart. Fits for the interannual linear model of April 1 SWE appear somewhat improved in quality to those of *Mote* [2006] comparing Figure 3 therein to Figure 3a here. The mean correlation between April 1 SWE and precipitation is 0.82, and half of the values are between 0.76 and 0.93, higher than in *Mote* [2006], who reported a mean of 0.65 with half of the values between 0.53 and 0.81. The mean correlation with temperature was −0.15 with half of the values between −0.31 and 0.02. These temperature correlations are weaker than in *Mote* [2006], who reported a mean of −0.22 and half of the values between −0.36 and −0.10. Although some of these differences could be related to climate differences between the periods of analysis, the differences are also consistent with having collocated precipitation, temperature, and SWE data at SNOTEL stations and the fact that SNOTEL stations have a slightly higher elevation distribution than snow courses.

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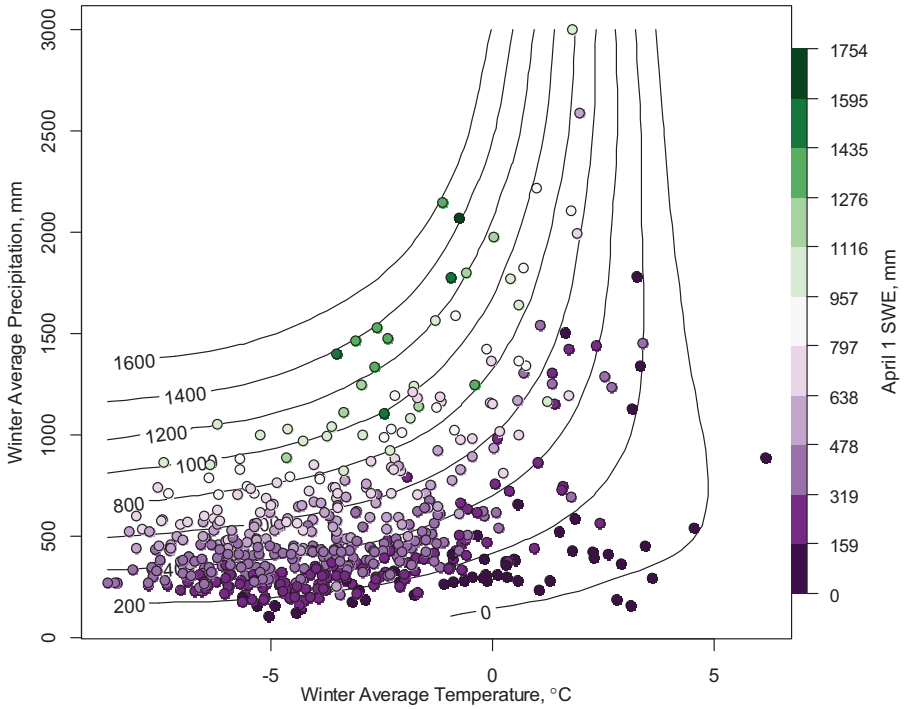

Figure 4. April 1 SWE (in color) as a function of winter average temperature and precipitation. Contours are a fitted surface using local polynomial regression. Units of contour levels are millimeter. Winter denotes November through March.

3.2. Spatial Analog and Contrast to Temporal Analog Results

3.2.1. April 1 SWE

The spatial analog for April 1 SWE on November–March precipitation and average temperature provided a strong fit (Nash-Sutcliffe R^2=0.87, RMSE=101 mm, Figure 4). The squared error at each station was unrelated to the number of years of record at the station (R^2=0.004, p = 0.14). The curved contour lines show a strong interaction between precipitation and temperature in their effect on April 1 SWE, which is reinforced by the sensitivity plots (Figure 5) where temperature sensitivity is primarily a function of precipitation and precipitation sensitivity is predominantly a function of temperature. A simple linear model with an interaction term of the form:

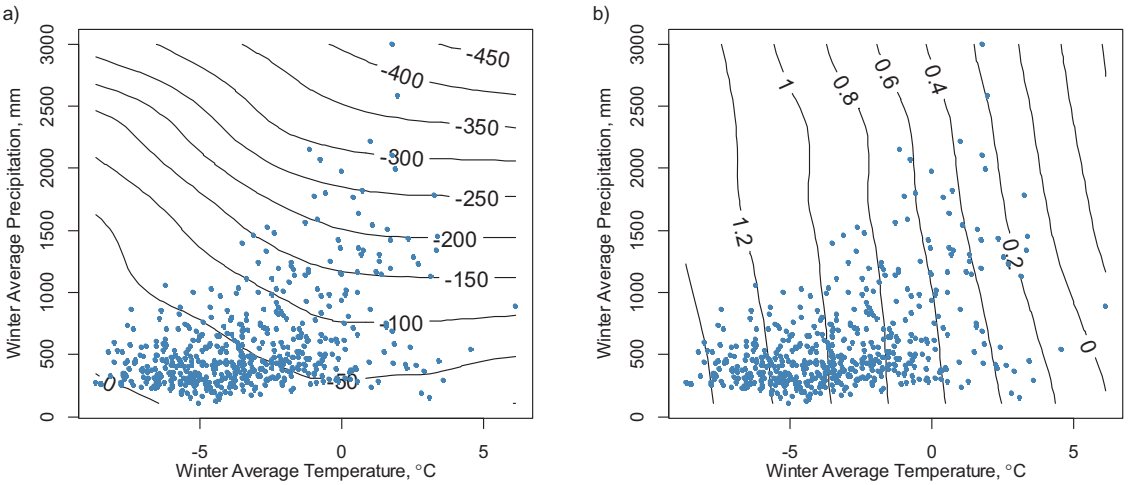

Figure 5. Spatial analog (a) temperature and (b) precipitation sensitivity of April 1 SWE as partial derivatives of the contours shown in Figure 4. Dots are for reference to show where the stations plot in T-P. Units on contour are mm/°C in (a) and mm-SWE/mm-P in (b). Winter denotes November through March.

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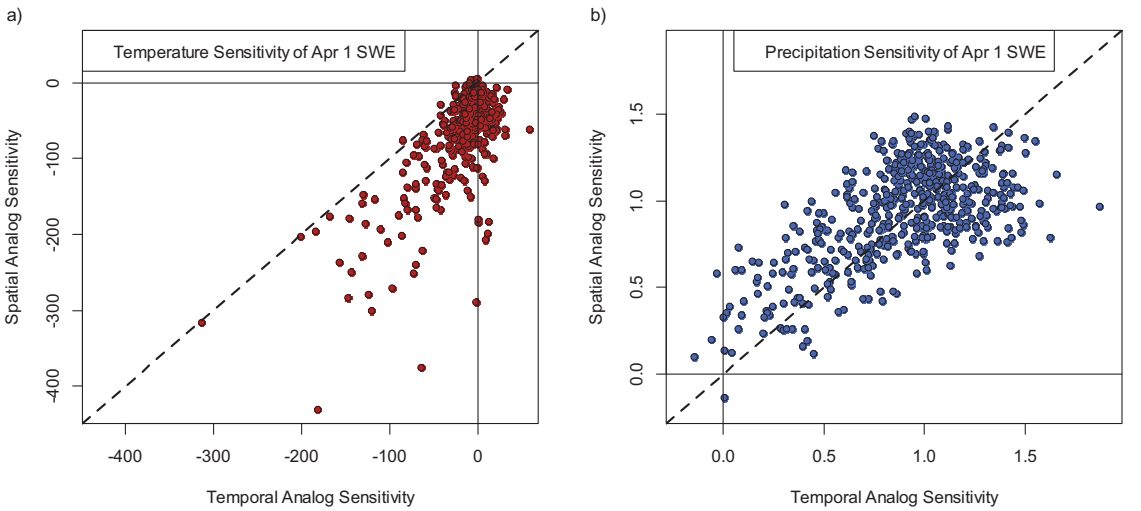

Figure 6. Comparison of (a) thermal and (b) precipitation sensitivity of April 1 SWE derived from temporal versus spatial analogs. Within each plot, axes have the same range, with lines drawn for 0 sensitivity and a dashed line showing where sensitivities are equal.

$$SWE = aTavg + bPrcp + c(Tavg\ x\ Prcp) + \epsilon_i \tag{11}$$

would yield an R^2 of 0.85, but would miss some of the nonlinearity in the local polynomial fit (other than that implied by the interaction itself). As might be expected from the general patterns noted in the analysis of temporal analogs and earlier analyses [*Mote*, 2006; *Mote et al.*, 2005], temperature sensitivity declines as precipitation sensitivity increases.

Differences between the spatial and temporal analog estimates of thermal sensitivity are substantial (Figure 6a). The mean temperature coefficient for the temporal analog was −14 mm/°C, while the mean partial derivative for the spatial analog was −58 mm/°C. While the temporal analog sometimes yielded physically

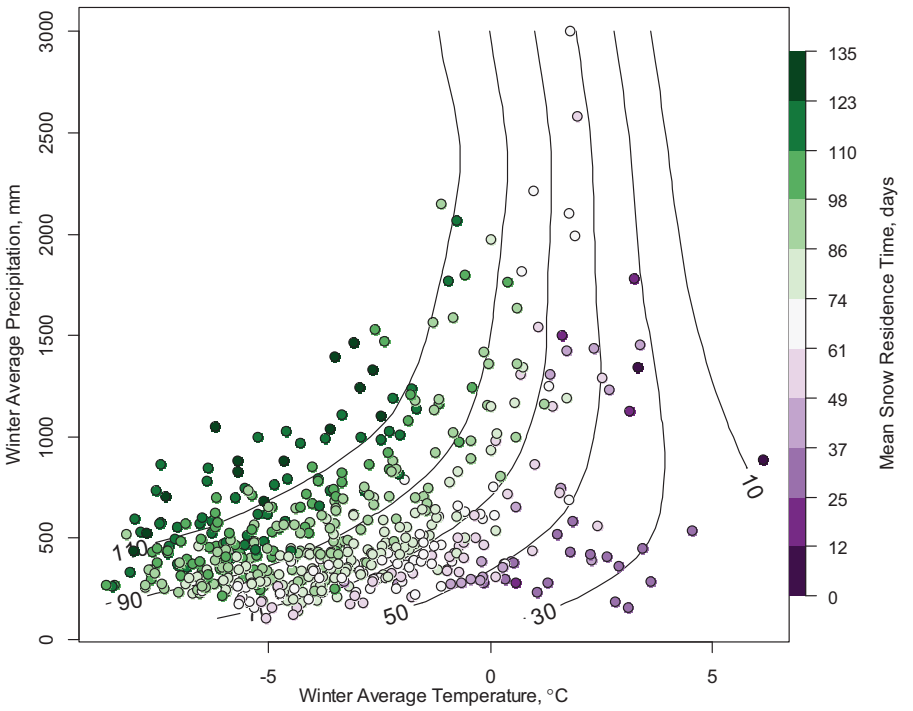

Figure 7. Mean snow residence time (SRT) as a function of winter average temperature and precipitation. Contours are a fitted surface using local polynomial regression. Units of contour levels are days. Winter denotes November through March.

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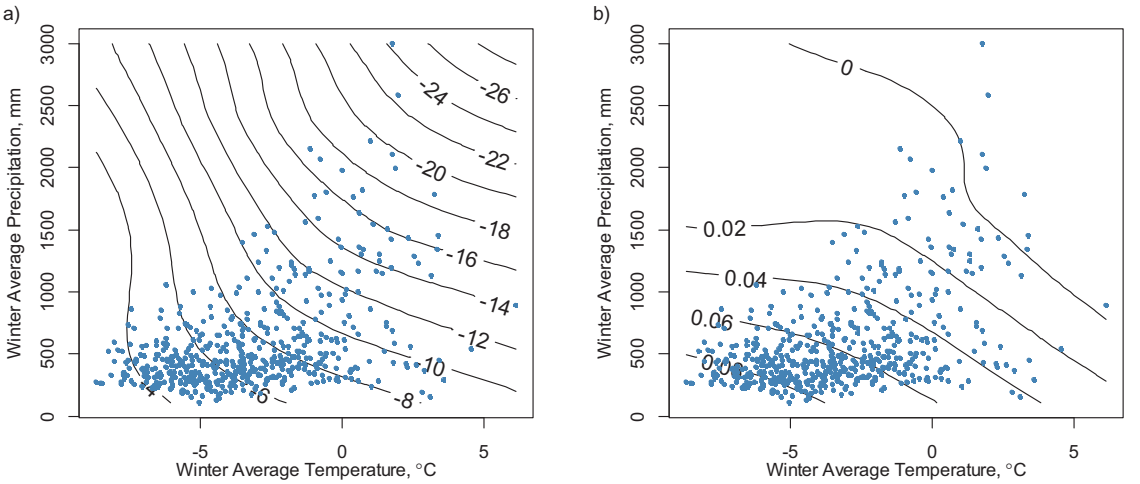

Figure 8. Spatial analog (a) temperature and (b) precipitation sensitivity of mean snow residence time (SRT) as partial derivatives of the contours shown in Figure 7. Dots are for reference to show where the stations plot in T-P. Units on contour on (a) are days/°C and on (b) are days/mm. Winter denotes November through March.

unreasonable positive coefficients, the spatial analog almost universally had negative coefficients. There were only three stations where the temporal analog predicts a greater thermal sensitivity than the spatial analog.

Differences in precipitation sensitivity for April 1 SWE are less pronounced, with no obvious bias and a slight degree of correlation (Figure 6b, $R^2=0.39$, $p < 2.2 \times 10^{-16}$). The mean precipitation coefficient was 0.89 for the temporal analog and the mean partial derivative for the spatial analog was 0.94.

3.2.2. Snow Residence Time

The spatial analog fit for SRT is almost as good as that for the April 1 SWE (Nash-Sutcliffe $R^2=0.81$, RMSE=10.1 days, Figure 7). The squared error at each station was very weakly related to the number of years of record at the station ($R^2=0.019$, $p = 0.002$). The fit of SRT shows interacting effects between precipitation and temperature similar to those for SWE, but with partial derivatives that are somewhat more sloped across the T-P plane than those of April 1 SWE (Figure 8). Warm-wet places show the greatest sensitivity to temperature change, and for a given precipitation level, warm places show greater temperature sensitivity. The precipitation partial derivatives have more of a joint sensitivity to T and P than do the precipitation partial derivatives of April 1 SWE.

As for April 1 SWE, the SRT thermal sensitivity estimated by spatial analog is generally greater, with a mean of −7.4 days/°C compared with −2.8 days/°C for the temporal analog. None of the spatial analog estimates

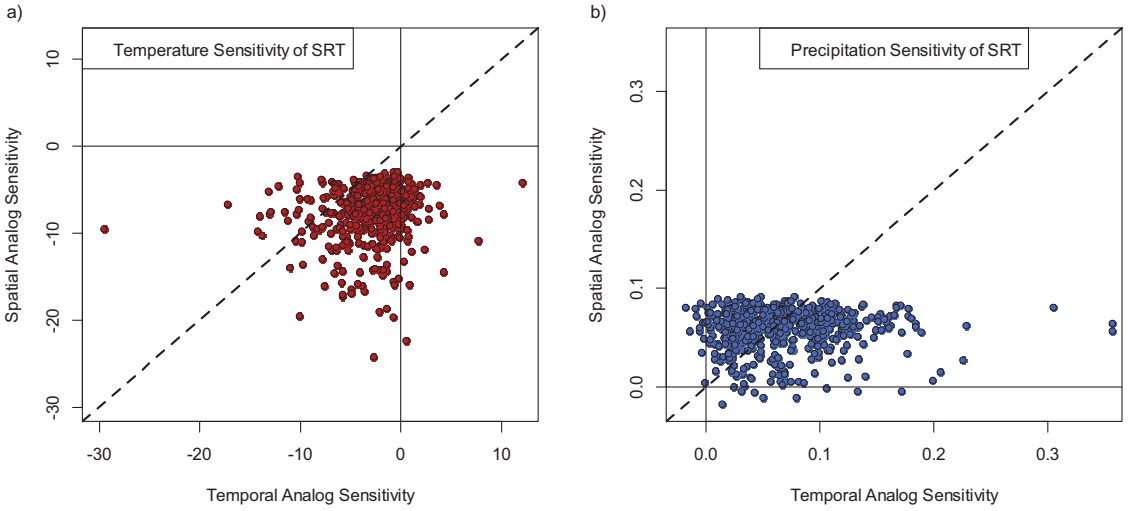

Figure 9. Comparison of (a) thermal and (b) precipitation sensitivity of mean snow residence time (SRT) derived from temporal versus spatial analogs. Within each plot, axes have the same range, with lines drawn for 0 sensitivity and a dashed line showing where sensitivities are equal.

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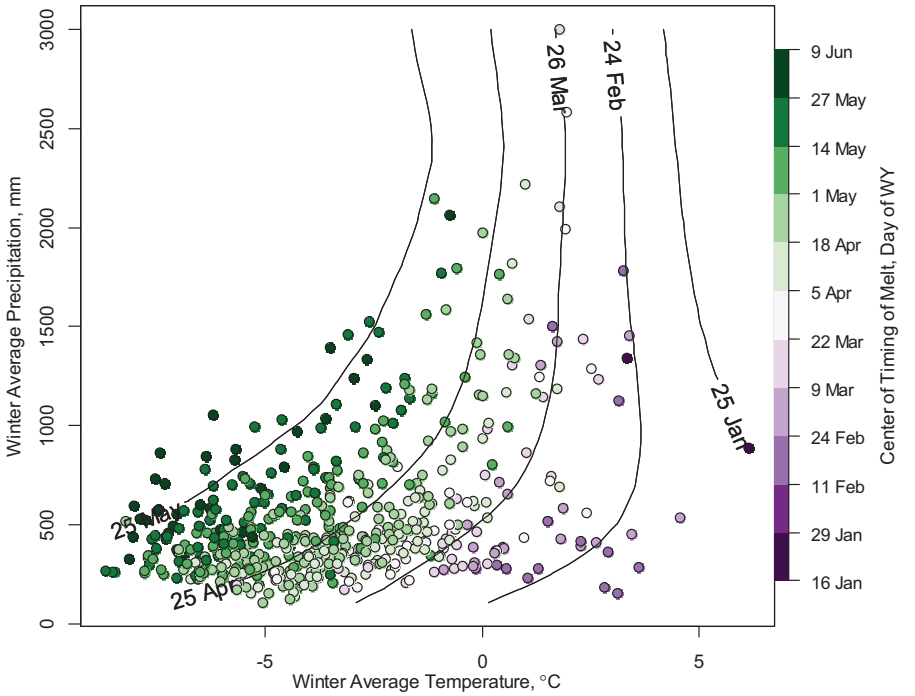

Figure 10. Center of timing of melt (CT_{melt}) as a function of winter average temperature and precipitation. Contours are a fitted surface using local polynomial regression. Contours are spaced 30 days apart. Winter denotes November through March.

show a positive sensitivity, while many of the temporal analogs do (Figure 9a). Although there is little difference in the mean precipitation sensitivity, 0.066 days/mm for the temporal analog and 0.058 days/mm for the spatial, there is no relationship between estimates from the two approaches (R^2=0.002, $p = 0.28$, Figure 9b).

The SRT at a station is strongly a function of CT_{melt} (R^2=0.9, slope=0.87 days/day, $p < 10^{-15}$), with a negligible contribution from variations in CT_{acc} (R^2=0.01, slope=0.28 days/day, $p = 0.026$). Although conceptually, the "accumulation season" is longer than the "melt season" for most seasonal snowpacks, the variance in CT_{acc} across SNOTEL sites is relatively small, with a standard deviation of just 8 days around a mean of 28 January (day of WY 120). A local fit surface using temperature and precipitation does not model the variability in CT of accumulation well, with a Nash-Sutcliffe R^2 of 0.26 and RMSE of 6.9 days. Elevation provides a slightly better estimate of CT of accumulation (R^2=0.35, $p < 10^{-15}$), although the slope is in the opposite direction of what might be expected if one were contemplating a strong effect of a later start to the accumulation season at lower elevations.

The CT_{mlt} has a variance of 25 days around a mean date of 22 April. The variability in CT_{mlt} can be reasonably well modeled with a local fit surface on temperature and precipitation (Nash-Sutcliffe R^2=0.78, RMSE = 12 days, Figure 10), with a pattern that appears primarily temperature related, with some precipitation contribution at colder temperatures. The fit of CT_{mlt} with elevation is poor (R^2=0.17, $p < 2.2 \times 10^{-16}$).

3.3. Comparison of Projected Responses to a Temperature Increase

Differences in performance and relative sensitivity of temporal and spatial analog models lead logically to the question of how the models might affect conclusions about the effects of projected warming on snow accumulation and melt. We examined differences in sensitivity of the spatial and temporal analog models to warming using a 3°C increase in winter temperature applied to each model. Although warming is not expected to be uniform across the western United States, applying a single temperature change to all sites allows comparisons of sensitivity more easily without confounding them with differences in exposure across sites.

Although the temporal analog only supports a linear application of the coefficient because the fit is a plane with no variations in temperature sensitivity, the spatial analog models have nonlinearities. We first checked whether the nonlinearities apparent in the spatial analogs were of consequence for a 3°C temperature change by comparing the amount of change estimated by a partial derivative versus that estimated by

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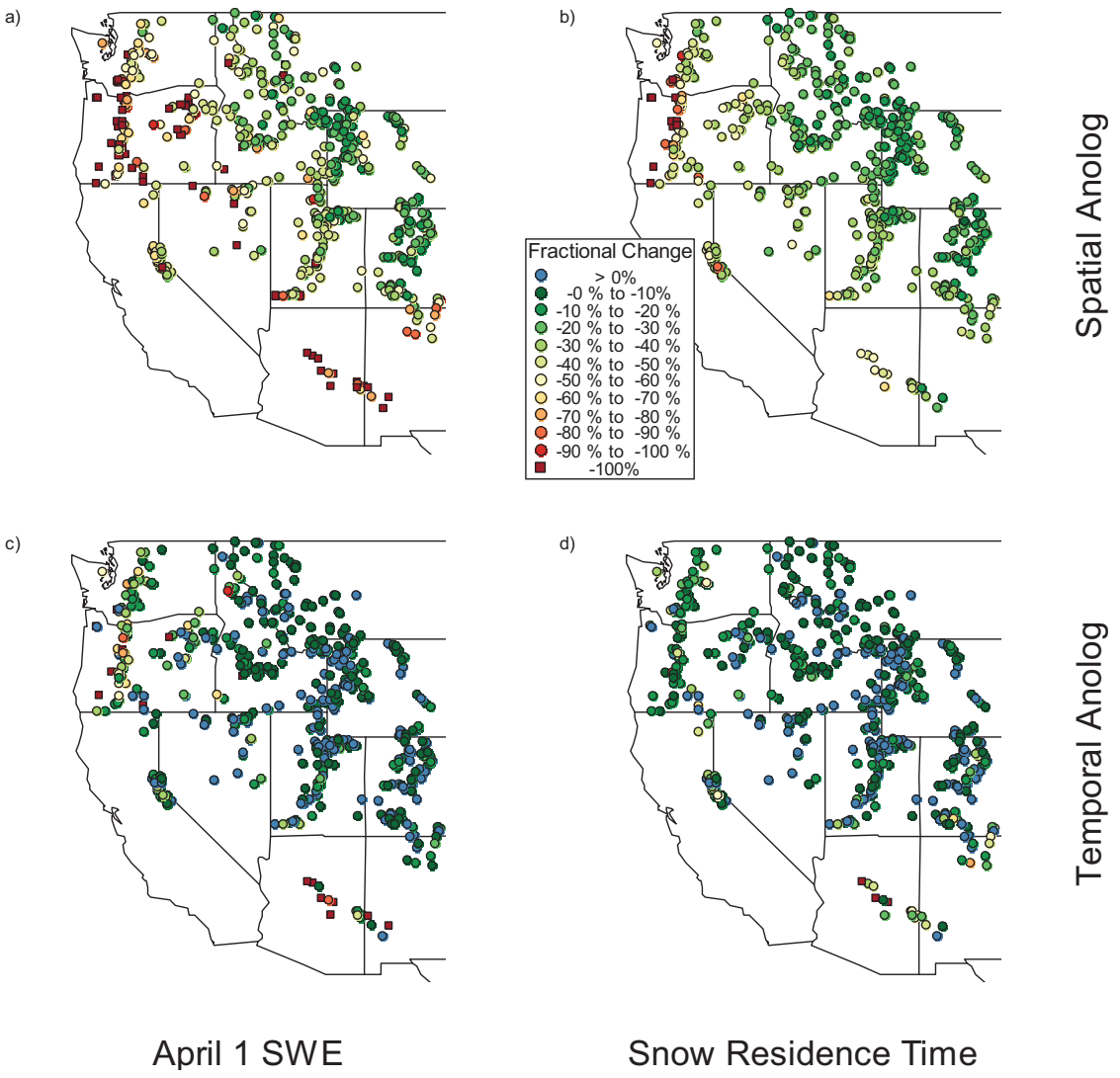

Figure 11. Comparison of fractional declines derived from spatial (a and b) versus temporal (c and d) analogs considering a 3°C increase in winter average temperature at each SNOTEL station. Left hand (a and c) maps are for April 1 SWE and right hand (b and d) maps are for mean snow residence time (SRT). Blue points denote projected increases.

directly calculating the difference in snow metrics between the observed T_{avg} and $T_{avg}+3°C$. Nonlinearities of response to temperature are modest but present, and the local sensitivity (from partial derivatives) generally underestimates the modeled change for a 3°C temperature increase by 21% for April 1 SWE and 10% for SRT. Differences tended to be more consistent and pronounced for less sensitive locations, with underestimates averaging 35% for April 1 SWE and 21% for SRT for the least sensitive half of the sites (as indicated by their partial derivatives). The nonlinear behavior is hinted at by Figure 5a, where there is temperature dependency of temperature sensitivity (the sensitivity contours have a slight slope through the blue points). Rather than using the partial derivatives to linearly estimate snowpack changes due to temperature changes, we used the local polynomial fits directly to incorporate the effect of these nonlinearities in maps of fractional decline using the spatial sensitivity (Figures 11a and 11b).

Using the spatial analog, estimated fractional changes in April 1 SWE with a 3°C warming are substantial at SNOTEL gages across the west (Figure 11a). The smallest decline was 9%, while some sites are expected to become snow free (100% reduction) on 1 April. The average decline projected across the SNOTEL sites is 46% with a median 40% decline. Coastal and southern mountains show the largest changes, with more modest declines predicted in interior mountains. Projected declines in SRT are not as severe, with an average decline of 33%, a median decline of 30% and a minimum decline of 8%. Fewer sites are expected to

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show nearly complete loss of seasonal snow (SRT declining 100%) than are expected to regularly see no snow on 1 April (Figure 11b). These patterns are consistent with the general findings of *Karl et al.* [1993] predicting decreased snow cover.

Contrasting the spatial analog change (top row in Figure 11) with the temporal analog change (bottom row) demonstrates substantial differences in estimated effects between the two approaches. The temporal analog model shows substantially lesser declines estimated for SWE and SRT using the temporal model, with average declines of 10% and 12% and median declines of 5% and 8%, respectively. With the temporal model, many stations (30% and 13% of stations, respectively) are projected to have increases despite specifying no increase in precipitation. In contrast the spatial model estimates no increases for either. Most of the stations projecting increases in the temporal analog model are at high elevations in the interior, but some of the stations with intermittent snow also show increases, likely due to uncertain temperature coefficients, which were largely (89% for April 1 SWE and 72% for SRT) not statistically different from 0 at $\alpha=0.1$. This finding suggests utility in comparison of model uncertainty in a similar set of maps, but the magnitude of differences in the expected values between approaches is itself important.

4. Discussion

Temporal model correlations estimated from local data at SNOTEL stations were generally greater than those presented by *Mote* [2006] where extrapolated weather data were used. Our fits also had substantially stronger correlation between precipitation and April 1 SWE. There are a few differences between the studies that could explain the differences, for example the period of record being different, a slightly higher elevation distribution for SNOTEL stations, or the difference between having and not-having collocated precipitation data. This final factor is related to the dynamic interplay between circulation patterns and terrain that moderate orographic precipitation and making projecting precipitation into mountains from low elevation stations difficult [*Colle*, 2004; *Dettinger et al*., 2004; *Luce et al*., 2013; *Yuter et al*., 2011]. Mean snow residence time distinguishes among stations with relatively poor and relatively strong fits of temporal sensitivity.

The models built in the context of a spatial analog provide a different picture of sensitivity than do the temporal analogs. Models of April 1 SWE and SRT based on climatological averages of P and T are relatively strong, so that spatial analogies of sensitivity to climatological warming seem reasonable. The spatial models, derived from SNOTEL stations distributed across a broad range of both T and P reveal expected interactions between T and P in generating snowpack. Deep and long-lived snowpacks are a function of both cold temperatures and high precipitation, so that shallow and short-lived snowpacks result from either low precipitation or warm temperatures. Thus, relatively wet warm locations where winter temperatures are near the rain-snow transition are more sensitive to even small increases in temperature than colder sites.

Thermal sensitivities derived from spatial differences are generally stronger than those derived from time series, and they also show very few positive sensitivities. A positive sensitivity, where there was more snow in warmer years, was more common among temporally derived sensitivities at cold stations, although only a few of the positive sensitivities were statistically significant. Such behavior has also been displayed for VIC simulations at higher elevations by *Hamlet et al*. [2005] even with precipitation fixed. The difference in thermal sensitivity is more pronounced for SRT than April 1 SWE. If some interannual variability is due to within-season timing of events (see Figure 1b), and this is not explained by T and P in the interannual models, the slope of the relationship is flatter than would be expected. The comparatively poor correlation coefficients on temporally derived thermal sensitivities highlight concerns about interpreting trends. For example, at a station such as the one illustrated in Figure 1b, a 2 week delay in the snow event would have resulted in a dramatically different April 1 SWE reading. When substantial noise in April 1 SWE is introduced that is related to the random timing of events, trends or correlations could appear as nonsignificant because of the timing-related noise. In contrast, the slower declines and rises in Figure 1a yield a situation that is less sensitive to snowfall event timing. To apply the spatial analog in this study, we first built a climatological model of differences in snowpack storage across locations. Similar work has been done for accumulation and snow cover duration [*Hantel and Hirtl-Wielke*, 2007; *Woods*, 2009]. Although the approach of *Woods* [2009] uses a subseasonal-scale simulation to develop and melt a snowpack, it uses climatological constructs affecting snow accumulation and melt, as opposed to actual time series. In that sense, this study supports the broad connection between season-scale precipitation and temperature climatology and both the depth and duration of snowpack storage found by *Woods* [2009]. A symmetric sensitivity of snow

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accumulation start and end to shifts in the dimensionless temperature proposed by *Woods* [2009] would help explain the small variance in CT_{acc} across the large diversity of sites and its relative insensitivity to temperature-related predictors. It may be that some variance could be explained by the differences in season-scale phase correlation of precipitation with temperature. The strength of the relationship between snowpack duration and both precipitation and temperature suggests that adding precipitation information to the model of *Hantel and Hirtl-Wielke* [2007] could improve its fit. The importance of CT_{mlt} to the overall SRT combined with the point that deeper snowpacks take longer to melt offers a mechanism for the importance of precipitation on snowpack duration.

Contrasting expected changes in April 1 SWE and SRT between the spatial and temporal analog approaches yielded much greater change projections using the spatial model than the temporal. Temperature coefficients for the temporal model were generally smaller and less certain than the precipitation coefficients for the temporal models, and the majority were not statistically significant, despite models that were mostly significant overall (considering variations in both T and P). It is possible that on an interannual basis, other factors besides November–March temperature and precipitation perturb SWE and SRT responses sufficiently to disrupt estimates of the temperature coefficient. The spatial analysis would suggest that chief among these might be interactions between temperature and precipitation, but unfortunately such a model is not well supported by the relatively short time series. This final result might suggest that temporal analogs are less trustworthy than generally accepted for purposes of projections, with a tendency to underestimate temperature effects. Comparison of both approaches to physically based snowpack modeling would have value for further understanding seasonal snow dynamics in a warmer world.

5. Conclusions

We contrasted two approaches to empirically determining sensitivity of snowpacks to climatic variations: one using variations from year-to-year at each station, and the other using variations in temporally averaged climate across stations. Our findings on temporally derived correlations were similar to previous studies [*Mote*, 2006], but with stronger model fits. The climatologically based spatial analog approach yielded stronger sensitivities of both April 1 SWE and SRT to variations in temperature and precipitation, and ultimately, greater projected changes. Sensitivities from the spatial analog were more consistently physically reasonable, in contrast to the time series approach, which gave unrealistic mean estimates of sensitivity in some locations, though we acknowledge that zero sensitivity was within the range of most temperature coefficient estimates from the temporal analogs.

Additionally, the spatial analog models captured the interaction between precipitation and temperature in forming snowpacks, where either warm conditions or low precipitation could yield a shallow, short-lived snowpack. Consequently, temperature sensitivity was highest in places that are already relatively warm, and warm snowpacks with high precipitation are likely to suffer some of the largest changes in snow storage as the climate warms. The spatial analog models also exhibited stronger sensitivity of cold, high elevation snowpacks to both temperature, and precipitation variations than previously noted. Given some of these differences, it is worthwhile to add the use of this simple climatological snowpack model in assessments of climate change impacts to water resources.

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Published 2014. This article is a U.S. Government work and is in the public domain in the USA.

From:	Bush, Jodi
To:	Thabault, Michael; Marjorie Nelson
Cc:	Justin Shoemaker; Betty Grizzle
Subject:	Fwd: Wolverine Recommendation Team Meeting Materials
Date:	Monday, January 22, 2018 8:19:43 AM
Attachments:	Policy and definition handouts_01052018.docx 2018-01-24_WolverineMtgAgenda.docx Wolverine DPS packet for RTM_01242018.pdf

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Mike/Marj. Wondering who is going to make the call on cancelling or not the wolverine decision meeting? I am supposed to fly out tomorrow am. Assuming I should hold off cancelling til after this afternoon's vote.

Mostly I'm concerned about inability to reach folks quickly after today as folks won't have access to computers although I'm sure those that have them will be checking phones. Looking for advice... JB

Jodi L. Bush
Office Supervisor
Montana State Ecological Services Office
585 Shepard Way, Suite 1
Helena, MT 59601
(406) 449-5225, ext.205

---------- Forwarded message ----------
From: **Shoemaker, Justin** <justin_shoemaker@fws.gov>
Date: Fri, Jan 19, 2018 at 6:54 PM
Subject: Wolverine Recommendation Team Meeting Materials
To: Michael Thabault <michael_thabault@fws.gov>, Marjorie Nelson <marjorie_nelson@fws.gov>, Kit Hershey <kit_hershey@fws.gov>, Michael Fris <michael_fris@fws.gov>, Paul Souza <paul_souza@fws.gov>, Noreen Walsh <noreen_walsh@fws.gov>, Matt Hogan <matt_hogan@fws.gov>, "Jacobsen, Dana" <Dana.Jacobsen@sol.doi.gov>, Kathryn Williams-shuck <kate.williams-shuck@sol.doi.gov>, Stephen Torbit <stephen_torbit@fws.gov>, Rollie White <rollie_white@fws.gov>, Gregg Kurz <gregg_kurz@fws.gov>, Bryon Holt <bryon_holt@fws.gov>, Madeline Drake <madeline_drake@fws.gov>, Josh Hull <josh_hull@fws.gov>, Jodi Bush <jodi_bush@fws.gov>, Caitlin Snyder <caitlin_snyder@fws.gov>, Sarah Fierce <sarah_backsen@fws.gov>, "Norman, Kate" <kate_norman@fws.gov>, "Guinotte, John" <john_guinotte@fws.gov>, Kurt Broderdorp <kurt_broderdorp@fws.gov>, "Grizzle, Betty" <betty_grizzle@fws.gov>

In preparation for the wolverine recommendation team meeting next week, please see the attached materials. Included is the latest draft of the agenda, a policy and definitions handout, and information on past application of the DPS policy to wolverine in the contiguous U.S.

Note that we have condensed the agenda with the decision team into one full day on 1/24 now. The SSA core team will meet on the morning of 1/25.

See the agenda for more details as well as a link for the webinar and conference line number.

The meeting materials attached and additional information (including the SSA Report) can be found on the drive folder.

Wolverine meeting folder on Google Drive:
https://drive.google.com/drive/folders/14fAdJj20mu9RlRiy91ktqxjX5K-yhKnz?usp=sharing

If you have problems accessing the folder, please let me know.

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

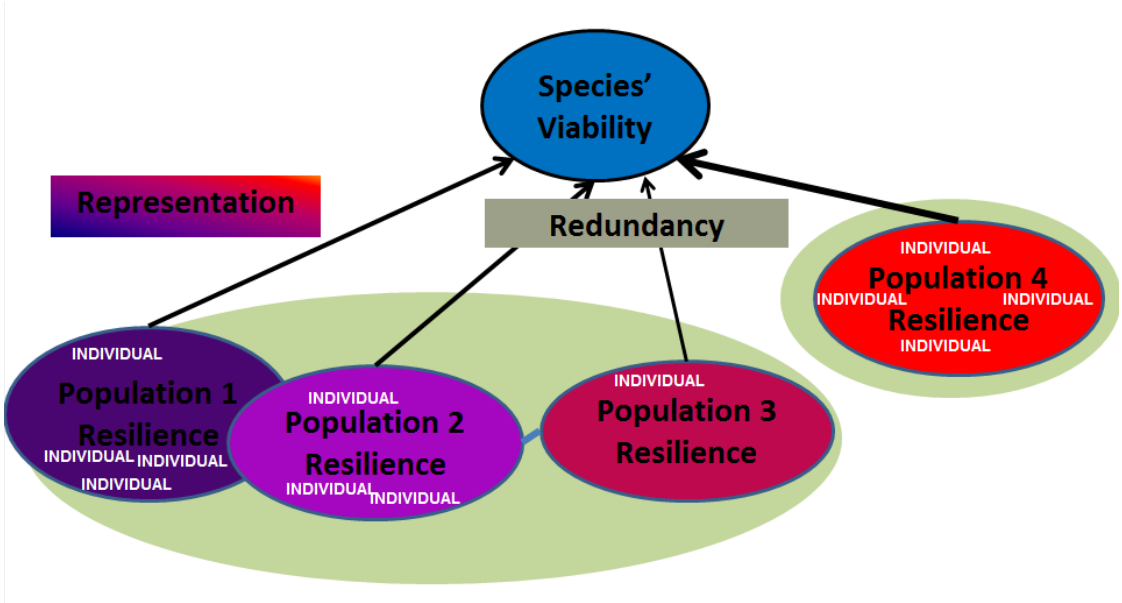
The 3 Rs

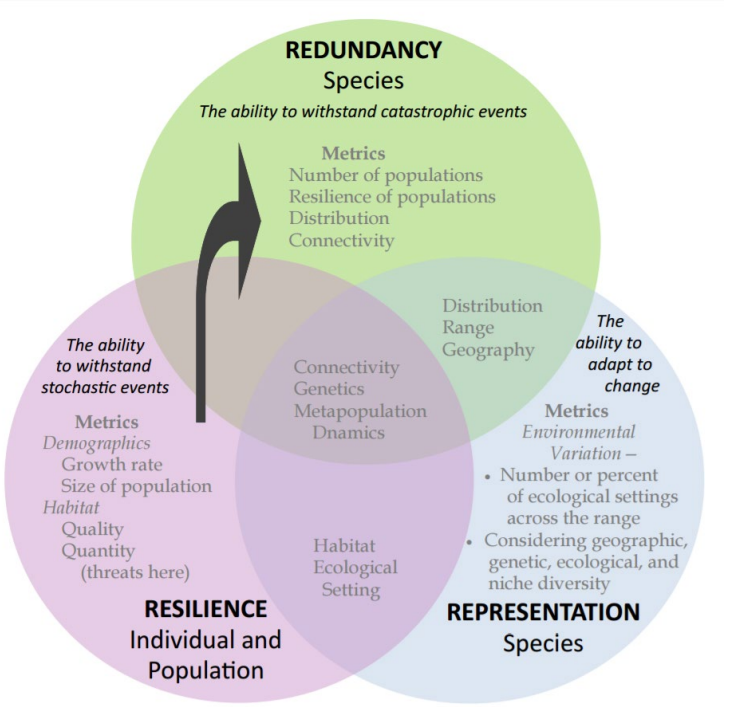
Viability is sustaining a sufficient number (redundancy) and distribution of healthy populations (resiliency) to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and changes in environmental conditions (representation); OR the ability or likelihood of the species to maintain populations over time, i.e., likelihood of avoiding extinction.

Resiliency—the ability of the species' populations to withstand annual environmental variation & stochastic events; influenced by # and distribution of healthy populations across spatially heterogeneous areas.

Representation—the ability of a species to adapt to changing environmental conditions; the breadth of genetic, ecological, demographic, and behavioral diversity across a species' range that contribute to its capacity to adapt over time.

Redundancy—the ability of a species to withstand catastrophic events; influenced by the # of populations and the distribution of populations relative to the spatial extent of catastrophic events that are germane to the species.





DPS – Distinct Population Segment

The DPS Policy identifies principles that guide the Services' listing, delisting, and reclassification of DPSs of vertebrate species. (Joint FWS/NMFS policy published February 7, 1996 (61 FR 4722))

Three Elements:

- **Discreteness -** Discreteness of the population segment in relation to the remainder of the species to which it belongs;
- **Significance -** The significance of the population segment to the species to which it belongs;
- **Conservation Status -** The population segment's conservation status in relation to the ESA standards for listing (i.e., is the population segment, when treated as if it were a species, endangered or threatened?).

Discreteness

1. It is **markedly separate from other populations of the same taxon** as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
2. It is **delimited by international governmental boundaries** within which **differences** in control of exploitation, management of habitat, conservation status, or regulatory mechanisms **exist that are significant** in light of section 4(a)(1)(D) of the Act.

Significance

- If discrete, we consider biological and ecological significance.
- This consideration may include, but is not limited to, the following:
    1. Persistence of the discrete population segment in an ecological setting **unusual or unique** for the taxon,
    2. Evidence that loss of the discrete population segment would result in a **significant gap** in the range of the taxon,
    3. Evidence that the discrete population segment represents the **only surviving natural occurrence** of a taxon that may be more abundant elsewhere as an introduced population outside its historical range, or
    4. Evidence that the discrete population segment **differs markedly** from other populations of the species in its **genetic characteristics**.

Conservation Status

- Does it meet the Act's definitions of "endangered species" or "threatened species"?

Status Under the ESA: Definitions

Endangered Species – a species which is in danger of extinction throughout all or a significant portion of its range.

"In Danger of Extinction": currently on the brink of extinction in the wild (Service's supplemental explanation for the polar bear listing (12/22/2010))

- Does not necessarily mean that extinction is imminent or inevitable, or even more likely than not;
- Nor must the actual extinction event (death of last individual), if it occurs, occur in a short period of time;
- Depends on life history and ecology of the species, nature of the threats, and the species' response.

4 Categories of Endangered determinations from the Polar Bear memo:

1. Species facing a catastrophic threat from which the risk of extinction is imminent and certain. Example: snail darter
2. Narrowly restricted endemics that, as a result of their limited range or population size, are vulnerable to extinction from elevated threats. Examples: Devil's Hole pupfish, *Phyllostegia hispida* (Hawaii)
3. Species formerly more widespread that have been reduced to such critically low numbers or restricted ranges that they are at a high risk of extinction due to threats that would not otherwise imperil the species. Examples: California condor, black-footed ferret, whooping crane
4. Species with still relatively widespread distribution that have nevertheless suffered ongoing major reductions in its numbers, range, or both, as a result of factors that have not been abated. Examples: red-cockaded woodpecker, longleaf pine.
    - Threatened species typically have some of the characteristics of the fourth category above, in that they too have generally suffered some recent decline in numbers, range, or both, but to a less severe extent than endangered species. Whether a species in this situation is ultimately an endangered species or a threatened species depends on the specific life history and ecology of the species, the nature of the threats, and population numbers and trends. Even species that have suffered fairly substantial declines in numbers or range are sometimes listed as threatened rather than endangered, such as the desert tortoise, northern spotted owl, and the southwest distinct population segment of the northern sea otter.

Threatened Species – a species which is likely to become an endangered species [in danger of extinction] within the *foreseeable future* throughout all or a significant portion of its range.

"Foreseeable future" is not specifically defined in the ESA, regulations, or policy.

- Guidance found in 2009 Solicitor's M-Opinion, "The Meaning of 'Foreseeable Future' in Section 3(20) of the Endangered Species Act."
- "a key statutory difference between a threatened and endangered species is the timing of when a species may be in danger of extinction…, either now (endangered) or in the foreseeable future (threatened)."

- How far we can reasonably project into the future the threats acting on the species and the species' response to those threats (how far is reasonable based on our confidence in the data).
- Observable population-level trends may indicate how the species is responding to those threats.
- Threatened is not simply a little less imperiled than endangered; it's all about the future.

SPR - Significant Portion of its Range

- SPR analysis only conducted when the status of the species "throughout all" of its range is **neither** T nor E.
- To list a species based on its status in an SPR, a portion must be both *significant* and *T or E*.
- SPR analysis has 2 parts:
    - Analyze whether the portion is significant.
    - Analyze the status of that portion. (sequence is not important)

"Significant" -- A portion of the range of a species is defined as "significant" if the species is not currently endangered or threatened throughout all of its range, but the portion's contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range.

Considerations:

Significant portion of the range—are there geographic differences in level of threat/risk of extinction?
Is any portion of any of the species range at greater risk of extinction (i.e., experiencing elevated levels of stressors or a concentration of threats)?

1. NO—listing is not warranted; explain why.
2. YES—where and why?

a. Are any of these geographic areas experiencing impacts from a stressor that is sufficient to cause the species to be in danger of extinction currently, or likely to become so in the foreseeable future, in that portion?

b. Is that portion a significant portion of the species range (i.e., what is the importance of that portion to ensure the species' viability in the long-term)? In other words, would the hypothetical loss of that portion cause the species to become in danger of extinction, or likely to become so?

**Consider Redundancy, Resiliency, and Representation (abundance, spatial distribution, productivity, and diversity).

i. NO to both (a) and (b)—listing is not warranted; explain why.
ii. If YES only to either (a) or (b)—listing is not warranted; explain why.
iii. YES to both (a) and (b)—listing the entire species is warranted; explain why.

Wolverine Meeting Agenda

January 24, 2018; Lakewood, Colorado

Purpose

The goal of this meeting is to help our Decision Team, including regional leadership from all three regions supporting wolverine, to make a well-informed and defensible recommendation to the Acting Director of the U.S. Fish and Wildlife Service (Acting Director) on the following policy questions:

- **Distinct Population Segment:** In 2013, the listable entity was defined as a DPS. Given new information, does this segment still meet the definition of a DPS based upon discreteness and significance?
- **Status:** Does the listable entity (possibly a DPS; possibly the entire species range) warrant listing as either endangered or threatened? We will address this question by looking at the species risk of extinction now and under three, different future scenarios.
- **Significant Portion of the Range:** If the listable entity does NOT warrant listing, do any portions which meet the definition of SPR warrant listing?

Logistics

Date and Time:

January 24, 2018 (8:00 am to 5:00 pm)

Location:

Region 6 Regional Office - Wolf Conference Room: 134 Union Boulevard, Lakewood, Colorado 80228
Please call Trina Vigil at 303-236-4253 for building access.

Webinar Link: http://www.mymeetings.com/nc/join.php?i=742652114&p=&t=c
Phone Line: 866-916-4854, participant code: 49134589

Participants[1]

Decision Makers

The Decision Makers will be charged with making decision recommendations to the Acting Director on all policy question. They will participate in all discussions and exercises.

- Rollie White,* Noreen Walsh,* Paul Souza (by phone)
- *Decision Maker Support: Matt Hogan,* Mike Thabault,* Marj Nelson,* Mike Fris**

Core Team Members

Core Team members will participate in discussions and may be asked to engage in exercises, but will not be responsible for making any recommendations to the Acting Director.

- Justin Shoemaker,* Jodi Bush,* John Guinotte,* Steve Torbit,* Betty Grizzle,* Caitlin Snyder, Dana Jacobsen(SOL),* Bryon Holt,* Kit Hershey (by phone), Madeline Drake,* Josh Hull, Gregg Kurz

[1] Individuals identified with an asterisk are anticipated to attend

- *Core Team Support: Kate Williams-Shuck* (SOL)*

Meeting Support

- Kate Norman, Facilitator
- Sarah Backsen, Scribe

Meeting Materials:

https://drive.google.com/drive/u/0/folders/14fAdJj20mu9RlRiy91ktqxjX5K-yhKnz

Exercises:

To help reduce any potential cognitive biases during the decision-making discussions, you will remain anonymous during any exercises. The exercises are not meant to be "votes" and they are not recorded. You may be asked to divide, or "spread" 100 points between two alternatives, which allows you to express your certainty or uncertainty with your answers. You will also be asked to provide rationale in bullets for discussion.

Example Exercise: Is it going to rain?
Each participant has 100 points to distribute between: "Yes, it will rain today" and "No, it will not rain today."

- *I may believe it will rain and have very little doubt about that outcome (I could allocate 90 points to Yes and 10 to No; my rationale might be that I saw a weather report for my area indicating a strong possibility of rain).*
- *However, my colleague may perceive the certainty differently; he may still believe that it's likely to rain, but have less certainty (He may distribute only 60 points to Yes and 40 to No citing a different weather report and the fact that he lives in a different part of the city).*

The allocation of points indicates both the overall feeling about the potential for rain today as well as the associated certainty of the outcome. Discussing the results and talking about the different reports (data) and slightly different locations (variables) can lead to a better understanding of everyone's perspectives.

Agenda

Wednesday - January 24, 2018			
Start	**Time**	**Agenda Item**	**Lead**
8:00 am	15 min	**Introductions and Logistics** *Identify Roles & Decision Context; Restrooms, Exits, Breaks, etc.*	Mike Thabault
8:15 am	45 min	**Regulatory and Litigation History** *Including DPS*	Justin Shoemaker, Dana Jacobsen
9:00 am	60 min (1 hr)	**Species Status Assessment (SSA) Presentation** *Species Needs, Current Status, Future Scenarios*	Betty Grizzle
10:00 am	15 min	BREAK	
10:15 am	60 min (1 hr)	**Species Status Assessment (SSA) Presentation Continued** *Species Needs, Current Status, Future Scenarios*	Betty Grizzle
11:15 am	15 min	**Introduction to Exercises** *To reduce cognitive biases, you will remain anonymous during discussion exercises.*	Kate Norman
11:30 am	15	BREAK (food will be delivered for a working lunch)	
11:45 am	75 min (1:15 h)	**Recap of DPS - Exercise and Discussion (DPS)** *Distinctness, Significance (scoring and rationale bullets)*	Justin Shoemaker, Kate Norman
1:00 pm	15 min	BREAK	
1:15 pm	45 min	**Snowpack Model Overview**	Steve Torbit, John Guinotte
1:45 pm	10 min	**Introduction to remaining Exercises** Setting the stage for the final exercises; Brief recap of major takeaways from SSA	Kate Norman, Justin Shoemaker
1:55 pm	75 min (1:15 h)	**Current Status Exercise and Discussion** *We will work through additional questions and exercises to address the current status.*	Kate Norman
3:10 pm	15 min	BREAK	
3:25 pm	75 min (1:15 h)	**Future Status Exercise and Discussion** *We will work through additional questions and exercises to address the future status.*	Kate Norman
4:40 pm	50 min	**Final Discussion and Wrap up** *What have we agreed upon? Do we need to meet Thursday morning? If so, when? Next steps?*	Kate Norman
5:30 pm		ADJOURN and OPTIONAL SOCIAL HOUR	

Thursday - January 25, 2018

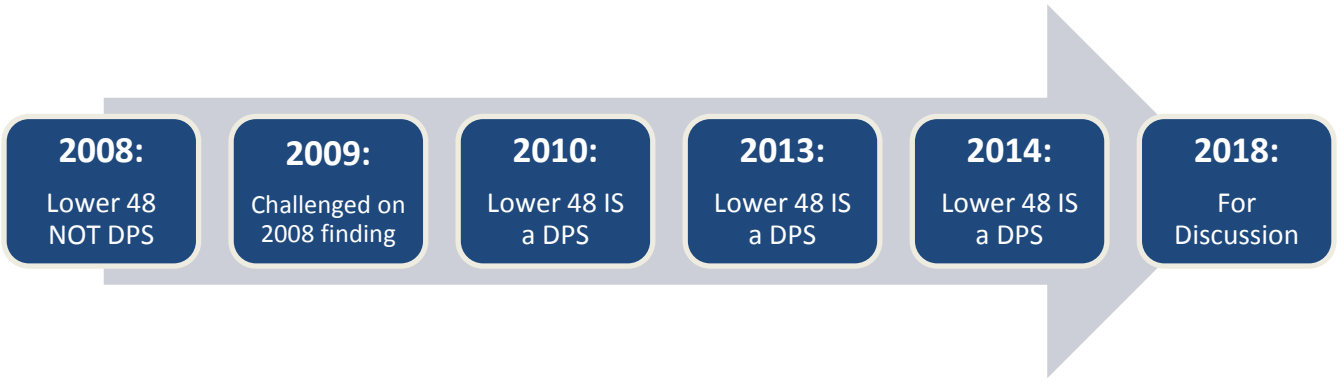
If additional conversation is needed, those who are available can meet in person at a time determined on the previous day. If people need to return home on Wednesday night, we will use the phone line and webinar to conference people in.

The conference room will be available to Core Team members who wish to use this time for work.

Wolverine Meeting - DPS History 2008 - 2014

January 24 - 25, 2018; Lakewood, Colorado

The following is a discussion of the past assessments of the contiguous United States population of wolverine as that population relates to the Distinct Population Segment (DPS)



2008 (12-mo finding)

Discreteness = NO

1. Markedly Separated = NO

- U.S. population connected to populations in Canada and likely dependent on them to some degree to maintain genetic diversity.

2. International Governmental Boundary per 4(a)(1)D = NO

- No difference in biological conservation status
- Difference in exploitation (e.g. trapping) not significant due to adequate regulation.

Overall

Not discrete, so not a DPS. We did not explore significance.

2009 Litigation

- We were quickly challenged by Defenders of Wildlife, Center for Biological Diversity, and others.
- In 2009, we entered into a settlement agreement to reconsider our 12-mo finding.
- Record reflects a last minute change in 2008 DPS determination.

2010 (warranted but precluded); 2013 (proposed listing rule), 2014 (vacated withdrawal)

All of the above findings used the following rationale for assessing the contiguous United States wolverine population under the DPS policy.

Discreteness = YES

1. Markedly Separated = NO

- We provided no analysis of this discreteness condition,
- Evidently conceded that criterion is not met.

2. International Governmental Boundary per 4(a)(1)D = YES

- **Population Size:**
  - Canada = large populations;
  - Contiguous US = population numbers so low continued existence at risk
- **Effective Population Size:**
  - Canada = in good shape with sufficient genetic diversity;
  - Contiguous US = small with poor genetic diversity
- **Habitat Connectivity:**
  - Canada = well-distributed and interconnected;
  - Contiguous US =fragmented habitat.
- **Exploitation**
  - Did not rely on control of exploitation to establish discreteness

Differences in conservation status of the wolverine between the U.S. and Canada are substantial and significant in light of Section 4(a)(1)(D) of the Act.

Significance = YES

Criteria #2 (Evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon) = YES

- Contiguous US = southernmost reach of the wolverine's range. Loss of this portion would substantially reduce southern range terminus approximately 15 degrees of latitude (40 percent of the latitudinal extent of the wolverine range); and loss of 205,942 km2 (79,515 mi2) of habitat (based on Copeland et al 2010 model)
- Loss of Contiguous US would result in a significant gap in the range of the taxon.

Criteria #1 (persistence of the discrete population segment in an ecological setting unusual or unique for the taxon) = NO

- Habitat attributes used by wolverines in both Canada and contiguous U.S. appear similar
- Contiguous US wolverines do not appear to exist in an unusual or unique ecological setting. Thus, we did not rely on this factor when determining that the wolverine in the U.S. is significant to the taxon as a whole.

Criteria #3 (only remaining occurrence of a taxon) = NO

- Does not apply (wolverines still found in Canada and Alaska)

Criteria #4 (…discrete population segment differs markedly from other populations of the species in its genetic characteristics) = NO

- Genetic difference: Reduced in contiguous US as compared with Canada so that the contiguous U.S. populations contain a subset of the genetics of the Canada-Alaska population….
- Genetic differences between the U.S. and Canadian wolverine populations are the result of loss of genetic diversity.
  This is not the kind of genetic difference that would lead us to conclude that a population is significant under our DPS policy.

vulnerable kits from predation by large carnivores, including other wolverines (Pulliainen 1968, p. 342; Zyryanov 1989, pp. 3–12), but may also have physiological benefits for kits by buffering them from extreme cold, wind, and desiccation (Pullianen 1968, p. 342, Bjärvall *et al.* 1978, p. 23). Wolverines live in low-temperature conditions and appear to select habitats in part to avoid high summer temperatures (Copeland *et al.* 2010, p. 242). Wolverine distribution is likely affected by climatic conditions at two different scales. Wolverines require deep persistent snow for denning, and this likely determines where wolverine populations can be found at the grossest range-wide scale (Copeland *et al.* 2010, p. 244). At smaller scales, wolverines likely select habitats to avoid high summer temperatures. These cool habitats also tend to retain snow late into spring, leading to wolverines' year-round association with areas of persistent spring snow (Copeland *et al.* 2010, p. 244).

All of the areas in the contiguous United States for which good evidence of persistent wolverine populations (either present or historic) exists (i.e., North Cascades, Sierra Nevada, northern and southern Rocky Mountains) contain large and well-distributed areas of deep snow cover that persists through the wolverine denning period (Brock *et al.* 2007, pp. 36–53; Aubry *et al.* 2007, p. 2154; Copeland *et al.* 2010, Figure 1). The Great Plains, Great Lakes, Midwest, and Northeast lack the spring snow conditions and low summer temperatures thought to be required by wolverines for successful reproduction and year-round occupancy (Aubry *et al.* 2007, p. 2154; Copeland *et al.* 2010, Figure 1). The lack of persistent spring snow conditions in the Great Plains, Great Lakes, Midwest, and Northeast supports the exclusion of these areas from the current range of wolverines. Whether wolverines once existed as established populations in any of these regions is uncertain, but the current climate appears to preclude their presence as reproducing populations now, and the sparse historical record of wolverine presence in this area makes historic occupation of these areas by wolverine populations doubtful. It is our conclusion that the ecosystem that supports wolverines does not exist in these areas currently, and may never have existed in the past.

Large areas of habitat with characteristics suitable for wolverines still occur in the southern Rocky Mountains and Sierra Nevada, despite the extirpation of wolverines from those areas (Aubry *et al.* 2007, p. 2154, Brock *et al.* 2007, p. 26; Copeland *et al.* 2010, Figure 1). Wolverine extirpations in these areas were coincident with systematic predator eradication efforts in the early 1900s, which have been discontinued for many years. Each of these areas has received at least one and possibly more migrants from adjacent populations in the northern Rocky Mountains; however, there is no evidence that females have migrated to these areas or that populations of wolverines exist in them (Aubry *et al.* 2007, Table 1; Moriarty *et al.* 2009, entire; Inman *et al.* 2009, entire).

We conclude that areas of wolverine historical occurrence can be placed in one of three categories: (1) Areas where wolverines are extant as reproducing and potentially self-sustaining populations (North Cascades, northern Rocky Mountains); (2) areas where wolverines historically existed as reproducing and potentially self-sustaining populations prior to human-induced extirpation, and where reestablishment of those populations is possible given current habitat condition and management (the Sierra Nevada Mountains in California and southern Rocky Mountains in Colorado, New Mexico, Wyoming, and Utah); and (3) areas where historical presence of wolverines in reproducing and potentially self-sustaining populations is doubtful, and where the current habitat conditions preclude the establishment of populations (Great Plains, Midwest, Great Lakes, and Northeast). We, therefore, consider the current range of wolverines to include suitable habitat in the North Cascades of Washington and possibly Oregon, the northern Rocky Mountains of Idaho, Wyoming, and Montana, the southern Rocky Mountains of Colorado, Utah, and Wyoming, and the Sierra Nevada of California. We here include the Sierra Nevada and southern Rocky Mountains in the current range of wolverines despite the probability that functional populations do not exist in these areas. They are included due to the known existence of one individual in each area and the possibility that more, as yet undetected, individuals inhabit these areas.

Distinct Population Segment

Pursuant to the Act, we must consider for listing any species, subspecies, or, for vertebrates, any Distinct Population Segment (DPS) of these taxa, if there is sufficient information to indicate that such action may be warranted. To interpret and implement the DPS provision of the Act and Congressional guidance, the Service and the National Marine Fisheries Service published, on February 7, 1996, an interagency Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Act (61 FR 4722). This policy addresses the recognition of DPSs for potential listing actions. The policy allows for more refined application of the Act that better reflects the biological needs of the taxon being considered, and avoids the inclusion of entities that do not require its protective measures.

Under our DPS policy, three elements are considered in a decision regarding the status of a possible DPS as endangered or threatened under the Act. These are applied similarly for additions to the list of endangered and threatened species, reclassification, and removal from the list. They are: (1) Discreteness of the population segment in relation to the remainder of the taxon; (2) the biological or ecological significance of the population segment to the taxon to which it belongs; and (3) the population segment's conservation status in relation to the Act's standards for listing (*i.e.,* whether the population segment is, when treated as if it were a species or subspecies, endangered or threatened). Discreteness refers to the degree of isolation of a population from other members of the species, and we evaluate this based on specific criteria. If a population segment is considered discrete, we must consider whether the discrete segment is "significant" to the taxon to which it belongs by using the best available scientific and commercial information. If we determine that a population segment is both discrete and significant, we then evaluate it for endangered or threatened status based on the Act's standards. The DPS evaluation in this finding concerns the segment of the wolverine species occurring within the 48 States, including the northern and southern Rocky Mountain physiographic provinces, Sierra Nevada Range, and North Cascades Range.

Distinct Population Segment Analysis for Wolverine in the Contiguous United States

Analysis of Discreteness

Under our DPS Policy, a population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions: (1) It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors (quantitative measures of genetic or morphological discontinuity may provide evidence of this separation); or (2) it is delimited by international governmental boundaries within which

differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act (inadequacy of existing regulatory mechanisms). The wolverine within the contiguous United States meets the second DPS discreteness condition because of differences in conservation status as delimited by the Canadian-U.S. international governmental boundary.

Discreteness Based on the International Border—Differences in Conservation Status

We find that differences in conservation status of the wolverine between the United States and Canada are substantial and significant in light of section 4(a)(1)(D) of the Act. In the remaining current range in Canada-Alaska, wolverines exist in well-distributed, interconnected, large populations. Conversely, wolverine populations in the remaining U.S. range appear to be at numbers so low that their continued existence could be at risk, especially as considered in light of the five threat factors discussed below. These risks come from three main factors: (1) Small total population size; (2) effective population size below that needed to maintain genetic diversity and demographic stability; and (3) the fragmented nature of wolverine habitat in the contiguous United States that results in smaller, isolated "sky island" patches separated by unsuitable habitats. It is apparent that maintaining wolverines within their native range in the contiguous United States into the future is likely to require regulatory mechanisms that are not currently in place. These three factors are explained in more detail below.

The total population sizes for Canada-Alaska and the contiguous United States differ by more than an order of magnitude. The contiguous U.S. population likely numbers approximately 250 to 300 individuals (Inman 2010b, pers. comm.). This contrasts with western Canada, where wolverine populations are estimated at 15,089 to 18,967 individuals (COSEWIC 2003, p. 22). Wolverine population size in Alaska is unknown; however, the average annual harvest exceeds 500 individuals and the population does not appear to be in decline (Alaska Department of Fish and Game 2004, entire), indicating that the population is likely to number over ten thousand individuals (calculated using demographic data in Lofroth and Ott 2007, pp. 2196–2198; assumes sustainable harvest). The difference in total population size coincides with the international boundary between the contiguous United States and Canada. Wolverine populations number 2,089–3,567 in British Columbia and 1,500–2,000 in Alberta (COSEWIC 2003, p. 22), the two provinces immediately adjacent to the contiguous U.S. wolverine population. The difference in total population sizes is significant because critically small populations such as those in the contiguous United States face higher extinction risk than large ones such as the Canada-Alaska population. Therefore, the contiguous U.S. population is more vulnerable to extinction, and thus of poor conservation status, relative to the more secure Canada-Alaska population.

Wolverines in Canada's eastern provinces are listed under the Species at Risk Act of Canada. Wolverines in the eastern provinces appear to have been extirpated by the early 20th century (COSEWIC 2003, p. 20). There is a general lack of reliable historic information on wolverines in this area, and significant doubt exists about whether a population ever occurred there historically (COSEWIC 2003, p. 20). For the purposes of this finding, we considered the Canadian wolverine population to include only wolverines from Ontario west to the Pacific coast and Alaska, and assumed that wolverines in eastern Canada were either extirpated or are at such low numbers as not to be part of a functioning population. It is our determination that the conservation status of the eastern population, if it does indeed exist, is not relevant to the discreteness analysis for this DPS for the following reasons: (1) If wolverines currently reside in the eastern Canadian Provinces, they are likely disjunct from wolverines in western Canada (COSEWIC 2003, Figure 3); and (2) there is significant doubt that wolverine populations existed in this part of Canada historically, so the current lack of evidence of a population may not represent a degradation of species status in this area (COSEWIC 2003, pp. 20–21).

The second substantial difference in wolverine status between the contiguous United States and Canada is reflected in the size of the effective populations. Population ecologists use the concept of a population's "effective" size as a measure of the proportion of the actual population that contributes to future generations (for a review of effective population size, see Schwartz *et al.* 1998, entire). In a population where all of the individuals contribute offspring equally, effective population size would equal true population size. For populations where contribution to the next generations is often unequal, effective population size will be smaller than the true or "census" population size. The smaller the effective population size, the more reproduction is dominated by a few individuals. Effective population size is important because it determines rates of loss of genetic variation, fixation of deleterious alleles and the rate of inbreeding. Populations with small effective population sizes show reductions in population growth rates and increases in extinction probabilities (Leberg 1990, p. 194; Jimenez *et al.* 1994, pp. 272–273; Newman and Pilson 1997, p. 360; Saccheri *et al.* 1998, p. 492; Reed and Bryant 2000, p. 11; Schwartz and Mills 2005, p. 419; Hogg *et al.* 2006, p. 1495, 1498; Allendorf and Luikart 2007, pp. 338–342). Franklin (1980, as cited in Allendorf and Luikart 2007, p. 359) proposed an empirically based rule suggesting that for short-term (a few generations) maintenance of genetic diversity, effective population size should not be less than 50. For long-term (hundreds of generations) maintenance of genetic diversity, effective population size should not be less than 500 (for appropriate use of this rule and its limitations see Allendorf and Luikart 2007, pp. 359–360). Others suggest that even higher numbers are required to ensure that populations remain viable, suggesting that long-term connectivity to the reservoir of genetic resources in the Canadian population of wolverines will be required (Traill *et al.* 2010, p. 32).

Wolverine effective population size in the largest extant population in the contiguous United States is exceptionally low (Schwartz personal communication 2007, entire) and is below what is thought necessary for short-term maintenance of genetic diversity. Effective population size for wolverines in the Rocky Mountains averaged 39 (Schwartz personal communication 2007, entire) (this study excluded the small population from the Crazy and Belt Mountains (hereafter "CrazyBelts") as they may be an isolated population, which could bias the estimate using the methods of Tallmon *et al.* (2007, entire)). Measures of the effective population sizes of the other populations in the contiguous United States have not been completed, but given their small census sizes, their effective sizes are expected to be smaller than for the northern Rocky Mountain population. Thus, wolverine effective population sizes are very low. For comparison, estimates of wolverine effective population size are bracketed by critically endangered species like the black-footed ferret (4.10) (Wisely *et al.*

2007, p. 3) and ocelots (2.9 to 13.9) (Janecka *et al.* 2007, p. 1), but substantially smaller than estimates for the Yellowstone Grizzly bear (greater than 100), which has reached the level of recovery under the Act (Miller and Waits 2003, p. 4338). Therefore, we conclude that effective population size estimates for wolverines do not suggest that populations are currently critically endangered, but they do suggest that populations are low enough that they could be vulnerable to loss of genetic diversity, and may require intervention in the future to remain viable.

The concern with the low effective population size is highlighted in recent research that determined that, absent immigration, at least 400 breeding pairs would be necessary to sustain long-term genetic viability of the contiguous U.S. wolverine population (Cegelski *et al.* 2006, p. 197). However, the entire population is likely 250–300 (Inman 2010b, pers. comm.), with a substantial number of these being nonbreeding subadults. Furthermore, the U.S. population appears to be split into at least five smaller subpopulations (Northern Cascades, CrazyBelts, Idaho, Greater Yellowstone Ecosystem, and Northern Montana) that are semi-isolated from each other, meaning that genetic exchange does not occur frequently enough to prevent genetic drift (changes in genetic composition due to random sampling in small populations) and loss of genetic diversity (Cegelski *et al.* 2006, p. 206) further reducing the effective population size. Based on available scientific and commercial information, it does not appear that any of the wolverine populations that historically existed in the contiguous United States would have had effective population sizes approaching 400 animals. Therefore, it is likely that connectivity to Canadian populations to the north would have been necessary to maintain genetic diversity in these populations prior to European settlement.

The concern that low effective population size may result in negative effects is already being realized for the contiguous U.S. population of wolverine. Genetic drift has occurred in the remaining populations in the contiguous United States: wolverines here contain 3 of 13 haplotypes (sets of closely linked genetic markers that are inherited together) found in Canadian populations (Kyle and Strobeck 2001, p. 343; Cegelski *et al.* 2003, pp. 2914–2915; Cegelski *et al.* 2006, p. 208; Schwartz *et al.* 2007, p. 2176; Schwartz *et al.* 2009, p. 3229). The haplotypes found in these populations are a subset of those in the larger Canadian population, indicating that genetic drift had caused a loss of genetic diversity. A single haplotype dominates the northern Rocky Mountain wolverine population, with 71 of 73 wolverine sampled expressing that haplotype (Schwartz *et al.* 2007, p. 2176). The reduced number of haplotypes indicates not only that genetic drift is occurring, but also that there is some level of genetic separation; if these populations were freely interbreeding, they would share more haplotypes. The reduction of haplotypes is likely a result of small population size and the fragmented nature of wolverine habitat in the United States and is consistent with an emerging pattern of reduced genetic variation at the southern edge of the range documented in a suite of boreal forest carnivores (Schwartz *et al.* 2007, p. 2177). Whether or not the wolverine population in the contiguous United States has suffered any deleterious effects due to this reduction in genetic diversity is unknown. However, based on principles of conservation genetics, we do expect that reduced genetic diversity would make this population more vulnerable to other threats due to reduced genetic resiliency and reduced ability to adapt to change (Allendorf and Luikart 2007, pp. 338–342).

No effective population size estimate exists for populations in Canada or Alaska; however, because of the large and contiguous nature of the population and the relatively high genetic diversity in Canada and Alaska, there is a reasonable scientific basis to conclude that the effective population size is large enough that it is not a cause for conservation concern. None of the Canadian or Alaskan populations tested show signs of genetic drift or inbreeding. This information indicates that the population does not have a low effective population size.

Reduced genetic diversity and low effective population sizes result in high extinction risk in animal populations (Frankham 1995, p. 795). The fragile nature of wolverine populations in the contiguous United States contrasts with Canada and Alaska where wolverines are relatively abundant and exist in habitats with a high level of connectivity (COSEWIC 2003, p.8; Slough 2007, p. 78).

The third substantial difference in wolverine status between the contiguous United States and Canada is reflected by the amount and distribution of available habitat for the species. Habitat in the contiguous United States consists of small isolated "islands" of high-elevation alpine habitats separated from each other by low valleys of unsuitable habitats. Habitat islands are represented by areas containing spring snow (Copeland *et al.* 2010, Figure 2). Wolverine range in the contiguous United States is characterized by isolated mountain habitats dissected by lower-elevation valleys, while habitat in adjoining Canada comprises mostly large blocks of contiguous habitat (Copeland *et al.* 2010, Figure 2; Copeland 2010, pers. comm.). Wolverines occupy habitat at high elevations, generally above 2,100 m (6,888 ft), in the mountains of the contiguous United States. The intervening valleys in this area range from 975 m to 1,500 m (3,198 ft to 4,920 ft), and are dominated by ecosystems that are unsuitable for long-term wolverine presence, but do serve as routes for wolverine movement between suitable habitat patches. Intermountain valleys are increasingly becoming the sites of human residential and commercial developments and transportation corridors. The large distances between suitable wolverine habitats results in wolverines existing on an archipelago of suitable habitats in a sea of unsuitable habitat. The low population density and genetic diversity of wolverines in this area requires that exchange of individual wolverines between islands of habitat occurs to avoid inbreeding or local extinction due to demographic stochasticity.

Wolverine populations in the Canadian Rocky Mountains also exist on habitat islands, but the islands are much larger, so that exchange of individuals is less critical for demographic and genetic stability. Further north in Canada, where cold snowy conditions occur at lower elevations, wolverines inhabit lower elevations and valley bottom habitats (COSEWIC 2003, pp. 7–8). In the far north of Canada, wolverine habitat extends into low-elevation valleys and the vast expanses of low-elevation boreal forest and tundra. For these reasons, exchange of wolverines between habitat islands in the Canadian Rocky Mountains is both more likely to occur and less critical for the long-term maintenance of those populations.

In the contiguous United States, wolverines must cross unsuitable habitats to achieve connectivity among subpopulations, which is required to avert further genetic drift and loss of genetic diversity (Kyle and Strobeck 2002, p. 1148; Cegelski *et al.* 2006, pp. 208–209; Schwartz *et al.* 2009, p. 3230). The highly fragmented nature of the habitat in the contiguous United States contributes to the low effective population size for wolverines in this area, making the continued persistence of the population precarious relative to the Canadian-Alaskan population.

Habitats in Canada and Alaska exist in larger contiguous blocks that have few or no impediments to demographic or genetic connectivity with peripheral smaller blocks (Copeland *et al.* 2010, Figure 2). The fragmented nature and distribution of wolverine habitat in the contiguous United States results in a population that is highly vulnerable to extirpation because of lack of connectivity between subpopulations, it also makes them more vulnerable to external threats such as those analyzed under the five threat factors below.

Conservation status of wolverines in the contiguous United States differs significantly with that of the Canada-Alaska population. The Canada-Alaska population is large, well-connected, and exists in large blocks of contiguous habitat. In contrast, the population in the contiguous United States is small in total size and is fragmented on small patches of suitable habitat that are separated by large areas of unsuitable habitat. These differences result in a Canada-Alaska population that is robust and better able to respond to habitat changes, while the contiguous United States population is vulnerable to changes in habitat or management. We believe that the differences in conservation status between the contiguous United States and Canada are significant in light of section 4(a)(1)(D) of the Act (inadequacy of existing regulatory mechanisms) because they reveal that the existing mechanisms in Canada are sufficient to maintain wolverine, while in the United States, the existing regulatory mechanisms are not sufficient to address the biological conservation concerns.

Legal Status Conveyed by National, State, and Provincial Governments

The United States currently confers no Federal status on the wolverine. Each State regulates the species relative to its existing populations. In Washington, the wolverine is listed as State Endangered (Washington Department of Fish and Wildlife 2010, entire). Idaho and Wyoming designate it as a protected nongame species (Idaho Fish and Game 2010, p. 4; Wyoming Game and Fish 2005, p. 4), and Montana regulates it as a furbearer (Montana Department of Fish, Wildlife, and Parks 2010, entire). Oregon, while currently not considered to have any individuals other than possible unsuccessful dispersers, has a closed season on trapping of wolverines. California and Colorado currently each have only one confirmed wolverine, and the States do not allow harvest.

The Canadian Government has listed its Eastern population of wolverine as Endangered under the Species at Risk Act (SARA) in Quebec and Labrador, where it may be extirpated due to trapping and hunting and declining caribou herds (Government of Canada 2010, entire). Because wolverines appear to have been extirpated from this area since the early part of the century and their historical status as a viable population is uncertain, we do not consider it to be in the current range, and thus consider the species' status there not relevant to the question of whether significant differences in status exist between the two countries. The Western population of wolverines occurs in eight Provinces, two of which (British Columbia and Alberta) are contiguous to the wolverine range in the United States. This population in Canada has no status under SARA, but has a designation of Special Concern (Vulnerable) under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Government of Canada 2010, entire), a status that does not provide legal protections. British Columbia and Alberta have Provincial species conservation lists, which are priority-setting tools for establishing baseline ranks and conservation activities (Province of British Columbia 2002, p. 1). Both Provinces include the wolverine on their provincial "blue list," indicating that it may be at risk (Peterson 1997, p. 1), except on Vancouver Island where the wolverine is possibly extirpated and is "red listed" (threatened, endangered, or candidate; not harvested) (Lofroth and Ott 2007, p. 2193; Province of British Columbia 2002, p. 2).

In our 2008 12-month finding, we determined that differences in management status conveyed by the States and Provinces that regulate wolverine management were not significantly different from each other, as States and Provinces both allowed regulated harvest and there were a variety of regulatory mechanisms in each. Regulatory status in the Canadian Provinces and U.S. States regulatory status remains unchanged, and we continue to find no significant difference between the legal status of wolverines between Canada and the United States.

While similarities exist in the legal conservation statuses bestowed on the wolverine in the four U.S. States where it currently persists, and the two adjacent Canadian Provinces, the differences in biological conservation status are significant and affect the future of the species. In western Canada, the wolverine has no protection under SARA; in the United States the wolverine currently has no status under the Act. This allows piecemeal management by States and Provinces with little regard for regional management directed at the continued existence of the species in the contiguous United States.

Because British Columbia and Alberta are contiguous to a larger, and more robust, portion of the wolverine's range in northwestern Canada, documented declines in wolverine populations (likely due to harvest levels) in the southern portions of both Provinces have not raised the status of the species to a level of concern that would result in its consideration for status under SARA (Lofroth and Krebs 2007, pp. 2164–2165; Lofroth and Ott 2007, p. 2193; Peterson 1997, pp. 4–5).

Differences in Control of Exploitation

Significant differences exist in control of exploitation between the United States and Canadian wolverine populations. U.S. populations are largely not harvested, with the exception of a carefully controlled and very limited harvest in Montana; while in Canada, harvest is widespread throughout the provinces within the current range. British Columbia has a 3- to 4-month trapping season with no provincial quota, while adjacent Washington considers the species State Endangered and allows no trapping. Alberta allows a 3-month trapping season with quotas in 6 of its 8 fur management zones for an annual average harvest of 37 (zones 7 and 8 in Alberta are closed to trapping but are outside the species' normal range and so the closure is of little conservation consequence (Province of Alberta 2007, entire)), while adjacent Montana allows up to a 2.5-month hunting and trapping season with a total quota of 5 wolverines (maximum of 3 females).

Although we do not have comprehensive numbers of the annual wolverine harvest in Canada, we have estimated a total annual harvest of 719 animals (see Table 2) based upon the best information available to us. Based on available information, we presume this to be an underestimate, because it is based upon reported harvests, which, for Canadian territories, likely accounts for only one-fifth to one-third of the total harvest because of heavy unreported harvest and use by local communities (Melchoir *et al.* 1987 as cited in Banci 1994, p. 101).

TABLE 2—ESTIMATED ANNUAL WOLVERINE HARVEST IN CANADA

Province or territory	Estimated annual harvest	Source
British Columbia	175	Lofroth and Ott, 2007, pp. 2196–2197.
Alberta	37	Province of Alberta 2006, p. 14.
Saskatchewan	10	COSEWIC 2007, Table 1
Manitoba	48	COSEWIC 2007, Table 1
Ontario	8	COSEWIC 2007, Table 1
Yukon	150	COSEWIC 2007, Table 1
Northwest Territories	209	COSEWIC 2007, Table 1 *
Nunavut	82	COSEWIC 2007, Table 1 ^
Total	719	

* Corrected to adjust for majority being unreported in pelt production statistics.
^ Corrected using Dumond and Krizan 2002 as cited in COSEWIC 2007 p. 17.

Based upon these numbers, we conservatively estimate that harvest in Canada is a minimum of 4.7 percent of the population annually. This estimate is nearly three times the amount of harvest in the United States, which is approximately 5 animals of 300, or 1.6 percent. We find that this nearly 300 percent difference is significant, because the wolverine is sensitive to even small increases in mortality rates (Squires *et al.* 2007, p. 2218). Human-caused mortality of wolverines is likely additive to natural mortality due to the low reproductive rate and relatively long life expectancy of wolverines (Krebs *et al.* 2004, p. 499; Lofroth and Ott 2007, pp. 2197–2198; Squires *et al.* 2007, pp. 2218–2219).

These differences may be significant in light of section 4(a)(1)(D) of the Act, because they show that regulatory mechanisms are necessary in the United States and Canada to ensure that the contiguous U.S. population continues to receive migrants from the genetically richer Canadian population. However, the differences in control of exploitation favor the U.S. population, which is the population that is potentially at risk. In Canada, no such mechanisms are currently needed to protect the species. About 15,000 to 19,000 wolverines occur in western Canada where suitable habitat is plentiful (COSEWIC 2003, pp. 14–21). Because of this abundance of habitat, conservative management and careful geographic control of harvest are not necessary to conserve wolverines in western Canada. This situation contrasts with the situation in the United States, where habitat is fragmented and wolverine populations are limited to high elevations over portions of four States (Washington, Idaho, Montana, and Wyoming). Because differences in control of exploitation exist, but control favors the at-risk population, we do not rely on control of exploitation to establish discreteness.

Summary for Discreteness

The international boundary between Canada and the United States currently leads to division of the control of exploitation and conservation status of the wolverine. This division is significant because it allows for potential extirpation of the species within the contiguous United States through loss of small populations and lack of demographic and genetic connectivity of the two populations. This difference in conservation status is likely to become more significant in light of threats discussed in the five factors analyzed below. Therefore, we find that the difference in the conservation statuses in Canada and the United States result in vulnerability to the significant threats (discussed below) in the U.S. wolverine population but not for the Canadian population. Existing regulatory mechanisms are inadequate to ensure the continued existence of wolverines in the contiguous United States in the face of these threats. Therefore, it is our determination that the difference in conservation status between the two populations is significant in light of section 4(a)(1)(D) of the Act, because existing regulatory mechanisms appear sufficient to maintain the robust conservation status of the Canada-Alaska population, while existing regulatory mechanisms in the contiguous United States are insufficient to protect the wolverine from threats due to its depleted conservation status. As a result, the contiguous United States population of the wolverine meets the discreteness criterion in our DPS Policy (61 FR 4725). Consequently, we use the international border between the United States and Canada to define the northern boundary of the North American wolverine DPS.

Analysis for Significance

If we determine a population segment is discrete, its biological and ecological significance will then be considered in light of Congressional guidance that the authority to list DPS's be used sparingly while encouraging the conservation of genetic diversity. In carrying out this examination, we consider available scientific evidence of the population's importance to the taxon to which it belongs (*i.e.,* the North American wolverine (*Gulo gulo luscus*). Our DPS policy states that this consideration may include, but is not limited to: (1) Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon; (2) evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon; (3) evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range; or (4) evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics. Below we address Factors 1, 2, and 4. Factor 3 does not apply to the continental U.S. wolverine population because North American wolverines are distributed widely across Alaska and Canada.

Significant Gap in the Range of the Taxon

Loss of wolverines in the contiguous United States would represent a significant gap in the range of the taxon. Wolverines once lived throughout the North American Rocky Mountains from Alaska and Canada, south through Colorado and into New Mexico, and in the North Cascades of Washington and the Sierra Nevada Range of California—an extent covering approximately 38° of latitude. Wolverines were extirpated

from most of the southern portions of their historic range, including all of the Sierra Nevada in California and all of Colorado, and possibly even the North Cascades and northern Rocky Mountains in the early 20th century (Aubry *et al.* 2007, Table 1), a loss of approximately 15° of latitude. The wolverines that have moved to California and Colorado in the past 2 years (Moriarty *et al.* 2009, Figure 1; Inman *et al* 2009, pp. 22–25) may represent the initial attempts to recolonize the southernmost extent of the species' historic range and a continuation of a recolonization of the contiguous United States that began in the 1930s (Aubry *et al.* 2007, Table 1). Based on the current scientific information, we conclude that there is at least one wolverine each in the Sierra Nevada and southern Rocky Mountains. Both of these animals are males that dispersed from known populations rather than being from undiscovered remnant populations native to the regions in question, and there is no reason to believe that functional populations exist in these areas. Today, the contiguous United States represents the southernmost reach of the wolverine's range. The loss of this population would be significant because it would substantially curtail the range of the wolverine by moving the southern range terminus approximately 15° of latitude to the north (or approximately 40 percent of the latitudinal extent of wolverine range) and eliminate wolverines from the fauna of the contiguous United States. Therefore, the loss of this population would result in a significant gap in the range of the taxon. The estimated area that would be lost from wolverine range in North America if the contiguous U.S. population was extirpated is 205,942 km^2 (79,515 mi^2) based on the habitat model developed by Copeland *et al.* (2010, entire; Copeland 2010, pers. comm.).

Given the wolverine's historic occupancy of the contiguous United States and the portion of the historic range they represent, maintenance and recovery of wolverines in their current range would provide some security for the rest of the taxon if conditions in Canada and Alaska deteriorated to the point that wolverines become endangered there. Populations on the periphery of species' ranges tend to be given lower conservation priority because they are thought to exist in low-quality habitats, and are also thought to be the populations that are least likely to survive a reduction in range (Wolf *et al.* 1996, p. 1147). However, this tendency presumes that the ultimate cause of the species' extinction will be one that operates by eroding away the species' range beginning at the periphery and progressing to the center. This presumption is based on biogeographical information that habitat and population densities of species are highest near the center of the species' range, and decline near the edge (Brown and Lomolino 1998, Figure 4.16). Data from real range collapses of species from around the world illustrate that species' ranges tend to collapse to peripheral areas rather than to the center of their historic ranges (Lomolino and Channell 1995, p. 342; Channell and Lomomolino 2000, pp. 84–86). Of 96 species whose last remnant populations were found either in the core or periphery of their historic range (rather than some in both core and periphery), 91 (95 percent) of the species were found to exist only in the periphery, and 5 (5 percent) existed solely in the center (Channell and Lomolino 2000, p. 85). Available scientific data support the importance of peripheral populations for conservation (Fraser 1999, entire; Lesica and Allendorf 1995, entire).

Based upon the 15 degree latitude gap that would result in the range of the wolverine if the U.S. population was lost, we determine that the loss of the contiguous U.S. wolverine population would result in a significant gap in the range of the taxon. Thus, the DPS meets the definition of significant in our DPS policy.

Unusual or Unique Ecological Setting

Wolverines in the contiguous United States exist in an ecosystem that requires extensive movements between habitats to maintain demographic viability and genetic diversity. Within the range of North American wolverines, the northern Rocky Mountains and North Cascades have the highest diversity of large predators and native ungulate prey species, which results in complex ecological interaction among ungulate prey, predators, scavenger groups, and vegetation (Smith *et al.* 2003, pp. 330–339). In the proposed DPS area, wolverines share habitats with gray wolves (*Canis lupus*), black bears (*Ursus americanus*), grizzly bears (*Ursus arctos horribilis*), puma (*Felis concolor*), lynx (*Lynx canadensis),* coyotes (*Canis latrans*), badgers (*Taxidea taxus*), bobcats (*Felis rufus*), fishers (*Martes pennanti*), and martens (*Martes americana*). The unique and diverse assemblage of native prey, and sources of carrion, for these carnivores include elk (*Cervus elaphus*), mule deer *(Odocoileus hemionus),* white-tailed deer (*Odocoileus virginianus*), moose (*Alces alces*), woodland caribou (*Rangifer caribou),* bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*), pronghorn (*Antilocapra americana*), bison (*Bison bison*) (only in the Greater Yellowstone Area), and beaver (*Castor canadensis*).

Despite the fragmented nature of the habitat and the high diversity of prey, wolverines in the contiguous United States appear to use habitat attributes that are similar to wolverine populations range-wide (Copeland *et al.* 2010, entire), and do not appear to exist in an unusual or unique ecological setting. Thus, we did not rely on this factor when determining that the wolverine in the United States is significant to the taxon as a whole.

Marked Genetic Differences

Several genetics studies have confirmed genetic differentiation between wolverines in the contiguous United States and those in Canada and Alaska (Cegelski *et al.* 2006, pp. 203–205; Kyle and Strobeck 2002, p. 342; Schwartz *et al.* 2007, p. 2175). The U.S. Rocky Mountain populations group together in mitochondrial DNA (mtDNA) analyses (Schwartz *et al.* 2007, p. 2176). The primary genetic difference is a reduction of diversity in the United States as compared with Canada so that the contiguous U.S. populations contain a subset of the genetics of the Canada-Alaska population (Cegelski *et al.* 2006, p. 200; Schwartz *et al.* 2007, p. 2172). The contiguous U.S. populations contain 3 mtDNA haplotypes and Canada-Alaska samples also contain those three haplotypes plus ten more. Idaho has substantially lower heterozygosity (a measure of the genetic variation in a population) (42 percent) than the nearest Canadian population (61 percent) sampled only 700 km (435 mi) away (Kyle and Strobeck, 2001, p. 341, 345). Genetic structure in the contiguous United States indicates that population fragmentation caused by either natural or anthropogenic factors, has reduced gene flow between populations, and that genetic drift has occurred and may still be occurring (Kyle and Strobeck 2001, p. 343; Cegelski *et al.* 2003, pp. 2914–2915; Cegelski *et al.* 2006, p. 208). This reduced genetic diversity and gene flow coincides with the international border and indicates that individuals are not passing freely between Canadian and U.S. populations (Schwartz *et al.* 2009, pp. 3229–3230). Four wolverine subpopulations have been identified within Montana based on genetic data (Cegelski *et al.* 2003, p. 2913; Guillot *et al.* 2005, p. 1274). Subsequent work suggests that Montana may contain a

single population that is genetically structured by both distance and ecological factors meaning that wolverines across their range in Montana occasionally exchange individuals but do not freely interbreed because of the great distances and frequent unsuitable habitat that separates populations (Schwartz *et al.* 2009, p. 3227).

The levels of gene flow in the contiguous United States are low compared to wolverines in Alaska and Northern Canada (Kyle and Strobeck 2001; 2002, pp. 343–345), indicating that habitat in the contiguous United States is much more fragmented than habitats further north in Canada and Alaska (Schwartz *et al.* 2009, p. 3227). A distinct break was identified between the U.S. population and the Canadian populations (Cegelski *et al.* 2006, p. 203; Schwartz *et al.* 2009, pp. 3229–3230). Similarly, Schwartz *et al.* (2007, p. 2176) found that wolverines in Idaho, Montana, and Wyoming have few haplotypes (2 in the main Rocky Mountain group, plus 1 identified by Cegelski *et al.* 2006 in north-central Montana) compared to 13 distinct haplotypes in Canada, despite greater numbers of samples collected in the contiguous United States. Of these two haplotypes found by Schwartz, one is predominant, with 71 of 73 samples containing this haplotype (Schwartz *et al.* 2007, p. 2176).

The genetic differences between the U.S. and Canadian wolverine populations identified above are the result of loss of genetic diversity, either through genetic drift or founder effects. The differences consist of lower genetic diversity in the United States, a difference that is of conservation concern because it reflects loss of genetic diversity through inbreeding. This is not the kind of genetic difference that would lead us to conclude that a population is significant under our DPS policy. That policy is designed to ensure the protection of rare or unique biological diversity rather than mere differences in gene frequencies. Therefore, we do not rely on marked genetic differences in our determination of significance for this DPS.

Summary for Significance

We conclude that the wolverine population in the contiguous United States is significant because its loss would result in a significant gap in the range of the taxon.

Summary of the Distinct Population Segment Analysis

We conclude that the wolverine population in the contiguous United States is both discrete and significant under our DPS policy. Conservation status of wolverines in the contiguous United States is less secure than wolverines in adjacent Canada due to fragmented habitat, small population size, reduced genetic diversity, and their vulnerability to threats analyzed in this finding. Loss of the contiguous U.S. wolverines would result in a significant gap in the range of the taxon. Therefore, we determine that the wolverine in the 48 States, as currently described, meets both the discreteness and significance criteria of our DPS policy, and is a listable entity under the Act. We now consider the conservation status of this DPS.

Summary of Information Pertaining to the Five Factors

Section 4 of the Act (16 U.S.C. 1533) and implementing regulations (50 CFR part 424) set forth procedures for adding species to the Federal Lists of Endangered and Threatened Wildlife and Plants. Under section 4(a)(1) of the Act, a species may be determined to be endangered or threatened based on any of the following five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence. In making this finding, information pertaining to the U.S. DPS of the wolverine in relation to the five factors provided in section 4(a)(1) of the Act is discussed below.

We are required by the Act to assess threats information that may occur within the foreseeable future. We define foreseeable future as a timeframe in which impacts can be reasonably expected to occur. As discussed below, we have identified one primary threat to the wolverine DPS: climate change. Other threats are secondary and only rise to the level of threats to the DPS as they may work in concert with climate changes to affect the conservation status of the species. For this reason we use a foreseeable future identified for climate change (out to 2099) for all of the threat factors. For most threat factors, future projections are not available and it is assumed that current trends will continue unless information exists to the contrary.

Factor A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Under Factor A we will discuss a variety of impacts to wolverine habitat including: (1) Climate change, (2) human use and disturbance, (3) dispersed recreational activities, (4) infrastructure development, (5) transportation corridors, and (6) land management. Many of these impact categories overlap or act in concert with each other to affect wolverine habitat. Climate change is discussed under Factor A because although climate change may affect wolverines directly by creating physiological stress, the primary impact of climate change on wolverines is expected to be through changes to the availability and distribution of wolverine habitat.

Two efforts to map wolverine habitat in the contiguous United States have been completed, although only one has been peer-reviewed (Brock *et al.* 2007, entire; Copeland *et al.* 2010, entire). As the single peer reviewed source, we rely on Copeland *et al.* (2010, entire) and supplemental information about that publication supplied in Copeland (pers. comm. 2010, p. 1) unless specified otherwise. We also report some statistics from the Brock *et al.* (2007) analysis because the authors report habitat broken down by land ownership whereas Copeland *et al.* (2010) do not. Both the Copeland *et al.* (2010) and Brock *et al.* (2007) analyses largely agree on the location of wolverine habitat within their geographic area of overlap; however, Brock *et al.* (2007) tends to be more inclusive and hence habitat area estimates for their model tend to be somewhat larger than for Copeland *et al.* (2010). Within the three States that currently harbor wolverines in the northern Rocky Mountains (Montana, Idaho, and Wyoming), an estimated 104,363 km^2 (40,295 mi^2) of wolverine habitat exists (Copeland 2010, pers. comm.). Based on the habitat model developed by Brock *et al.* (2007), 95 percent (120,000 km^2; 46,332 mi^2) is in Federal ownership with the largest portion of that (108,969 km^2; 42,073 mi^2) managed by the U.S. Forest Service (Forest Service) (Inman 2007b, pers. comm.).

Reduction in Habitat Due to Climate Change

Department of the Interior Secretarial Order Number 3289, issued September 14, 2009 (Department of the Interior (DOI) 2009), provides guidance that DOI bureaus and offices shall "* * * [c]onsider and analyze potential climate change impacts when undertaking long-

From: Thabault, Michael
To: Bush, Jodi
Cc: Marjorie Nelson; Justin Shoemaker; Betty Grizzle
Subject: Re: Wolverine Recommendation Team Meeting Materials
Date: Monday, January 22, 2018 8:23:18 AM

I have staff meeting in about 10 minutes. Hopefully will have more direction after that. Stand by

Michael Thabault
Assistant Regional Director
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region
303-236-4210
michael_thabault@fws.gov

On Mon, Jan 22, 2018 at 8:19 AM, Bush, Jodi <jodi_bush@fws.gov> wrote:

> Mike/Marj. Wondering who is going to make the call on cancelling or not the wolverine decision meeting? I am supposed to fly out tomorrow am. Assuming I should hold off cancelling til after this afternoon's vote.
>
> Mostly I'm concerned about inability to reach folks quickly after today as folks won't have access to computers although I'm sure those that have them will be checking phones. Looking for advice... JB
>
> Jodi L. Bush
> Office Supervisor
> Montana State Ecological Services Office
> 585 Shepard Way, Suite 1
> Helena, MT 59601
> (406) 449-5225, ext.205
>
> ---------- Forwarded message ----------
> From: **Shoemaker, Justin** <justin_shoemaker@fws.gov>
> Date: Fri, Jan 19, 2018 at 6:54 PM
> Subject: Wolverine Recommendation Team Meeting Materials
> To: Michael Thabault <michael_thabault@fws.gov>, Marjorie Nelson <marjorie_nelson@fws.gov>, Kit Hershey <kit_hershey@fws.gov>, Michael Fris <michael_fris@fws.gov>, Paul Souza <paul_souza@fws.gov>, Noreen Walsh <noreen_walsh@fws.gov>, Matt Hogan <matt_hogan@fws.gov>, "Jacobsen, Dana" <Dana.Jacobsen@sol.doi.gov>, Kathryn Williams-shuck <kate.williams-shuck@sol.doi.gov>, Stephen Torbit <stephen_torbit@fws.gov>, Rollie White <rollie_white@fws.gov>, Gregg Kurz <gregg_kurz@fws.gov>, Bryon Holt <bryon_holt@fws.gov>, Madeline Drake <madeline_drake@fws.gov>, Josh Hull <josh_hull@fws.gov>, Jodi Bush <jodi_bush@fws.gov>, Caitlin Snyder <caitlin_snyder@fws.gov>, Sarah Fierce <sarah_backsen@fws.gov>, "Norman, Kate" <kate_norman@fws.gov>, "Guinotte, John" <john_guinotte@fws.gov>, Kurt Broderdorp <kurt_broderdorp@fws.gov>, "Grizzle, Betty"

<betty_grizzle@fws.gov>

In preparation for the wolverine recommendation team meeting next week, please see the attached materials. Included is the latest draft of the agenda, a policy and definitions handout, and information on past application of the DPS policy to wolverine in the contiguous U.S.

Note that we have condensed the agenda with the decision team into one full day on 1/24 now. The SSA core team will meet on the morning of 1/25.

See the agenda for more details as well as a link for the webinar and conference line number.

The meeting materials attached and additional information (including the SSA Report) can be found on the drive folder.

Wolverine meeting folder on Google Drive:
https://drive.google.com/drive/folders/14fAdJj20mu9RlRiy91ktqxjX5K-yhKnz?usp=sharing

If you have problems accessing the folder, please let me know.

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

From:	Shoemaker, Justin
To:	Michael Thabault; Marjorie Nelson; Kit Hershey; Michael Fris; Paul Souza; Noreen Walsh; Matt Hogan; Jacobsen, Dana; Kathryn Williams-shuck; Stephen Torbit; Rollie White; Gregg Kurz; Bryon Holt; Madeline Drake; Josh Hull; Jodi Bush; Caitlin Snyder; Sarah Fierce; Norman, Kate; Guinotte, John; Kurt Broderdorp; Grizzle, Betty
Subject:	Re: Wolverine Recommendation Team Meeting Materials
Date:	Monday, January 22, 2018 9:30:55 AM

Team,

Stand by on canceling your travel plans until we see if we're recalled back this morning.

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

On Fri, Jan 19, 2018 at 7:54 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

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

From: Shoemaker, Justin
To: Hershey, Kit
Subject: Re: Wolverine Recommendation Team Meeting Materials
Date: Monday, January 22, 2018 10:00:18 AM

I'll revise. Thanks.

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

On Mon, Jan 22, 2018 at 10:54 AM, Hershey, Kit <kit_hershey@fws.gov> wrote:

> Rollie will stay tuned - for me could you correct agenda that reads I am on core team (as you know I wasn't on the core team; am just POC for R1 as Regional Liaison) thanks
>
> On Mon, Jan 22, 2018 at 8:30 AM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:
>
> > Team,
> >
> > Stand by on canceling your travel plans until we see if we're recalled back this morning.
> >
> > Justin Shoemaker
> > Classification and Recovery Biologist
> > U.S. Fish and Wildlife Service, Region 6
> > Phone: 309-757-5800 x214
> > Email: justin_shoemaker@fws.gov
> >
> > On Fri, Jan 19, 2018 at 7:54 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:
> >
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> > >
> > > If you have problems accessing the folder, please let me know.
> > >
> > > Justin Shoemaker
> > > Classification and Recovery Biologist

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

--
Kit Hershey, Regional Listing Coordinator
Pacific Regional Office, Region 1
US Fish and Wildlife Service
911 NE 11th Avenue
Portland, OR 97232
(503) 231-6869

From: Hull, Josh
To: Shoemaker, Justin
Subject: Wolverine RTM
Date: Tuesday, January 23, 2018 9:04:32 AM

Hi Justin,
Is the RTM for wolverine still on for the 24th and 25th? Thanks.
Josh

****

Josh Hull
Listing and Recovery Division Chief
Sacramento Fish and Wildlife Office
2800 Cottage Way, W-2605
Sacramento, CA 95825

916-414-6742

From: Hershey, Kit
To: Shoemaker, Justin
Subject: Re: Wolverine Recommendation Team Meeting Materials
Date: Tuesday, January 23, 2018 10:42:55 AM

Hi Justin,
I will try to call in by 8 AM (7 PST) but may be late - is that OK? Also, as Decision Maker "support" what is my expected role? thanks

On Mon, Jan 22, 2018 at 8:30 AM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> Team,
>
> Stand by on canceling your travel plans until we see if we're recalled back this morning.
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov
>
> On Fri, Jan 19, 2018 at 7:54 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:
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> > In preparation for the wolverine recommendation team meeting next week, please see the attached materials. Included is the latest draft of the agenda, a policy and definitions handout, and information on past application of the DPS policy to wolverine in the contiguous U.S.
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> > If you have problems accessing the folder, please let me know.
> >
> > Justin Shoemaker
> > Classification and Recovery Biologist
> > U.S. Fish and Wildlife Service, Region 6
> > Phone: 309-757-5800 x214
> > Email: justin_shoemaker@fws.gov

--

Kit Hershey, Regional Listing Coordinator
Pacific Regional Office, Region 1
US Fish and Wildlife Service
911 NE 11th Avenue
Portland, OR 97232
(503) 231-6869

From: Shoemaker, Justin
To: Holt, Bryon
Subject: Re: wolverine meeting
Date: Tuesday, January 23, 2018 3:19:52 PM

Yes. Will you be attending in person?

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

On Tue, Jan 23, 2018 at 10:37 AM, Holt, Bryon <bryon_holt@fws.gov> wrote:

> Is the meeting still on this week???
>
> --
> **********
> Bryon Holt
> U.S. Fish and Wildlife Service
> Northern Idaho Field Office, Spokane, WA
> Telephone: (509) 893-8014
> Fax: (509) 891-6748
> email: bryon_holt@fws.gov
>
> **********

From: Snyder, Caitlin
To: Shoemaker, Justin
Subject: Re: Wolverine meeting
Date: Tuesday, January 23, 2018 3:22:37 PM

Okay, thanks. I'll get on the phone/webinar tomorrow AM.

Caitlin Snyder
Endangered Species Listing Program
U.S. Fish & Wildlife Service
MS: ES
5275 Leesburg Pike
Falls Church, VA 22041-3803
phone: 703 358 2673

On Tue, Jan 23, 2018 at 5:19 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> Sounds good. Yes, 8 am MT tomorrow.
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov
>
> On Tue, Jan 23, 2018 at 11:29 AM, Snyder, Caitlin <caitlin_snyder@fws.gov> wrote:
>
> > Hi Justin,
> >
> > My training was canceled, so I'm planning to sit in on the wolverine meeting to listen.
> >
> > I'll use the webinar info that's listed on the agenda.
> >
> > To confirm, the meeting will start at 8:00 AM Mountain time (so 10:00 AM Eastern time)?
> >
> > Thanks,
> > Caitlin
> >
> > Caitlin Snyder
> > Endangered Species Listing Program
> > U.S. Fish & Wildlife Service
> > MS: ES
> > 5275 Leesburg Pike
> > Falls Church, VA 22041-3803
> > phone: 703 358 2673

From: Shoemaker, Justin
To: Thabault, Michael; Nelson, Marjorie; Hershey, Kit; Fris, Michael; Souza, Paul; Walsh, Noreen; Hogan, Matt; Jacobsen, Dana E; Williams-shuck, Kathryn L; Torbit, Stephen; White, Rollie; Kurz, Gregg; Bryon Holt; Drake, Madeline K; Hull, Josh; Bush, Jodi; Snyder, Caitlin; Backsen, Sarah; Norman, Kate; Guinotte, John M; Broderdorp, Kurt; Grizzle, Betty
Subject: Re: Wolverine Recommendation Team Meeting Materials
Date: Tuesday, January 23, 2018 3:23:42 PM

Team,

The wolverine meeting is still on for tomorrow. Some folks will be participating via the webinar and phone line (in the agenda). If you were planning to come to Denver before the shutdown and are not attending in person now, please let me know.

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

On Fri, Jan 19, 2018 at 7:54 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

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> If you have problems accessing the folder, please let me know.
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov

From: Rollie White
To: Shoemaker, Justin
Subject: Re: Wolverine Recommendation Team Meeting Materials
Date: Tuesday, January 23, 2018 3:43:04 PM

Hi Justin,
I am still coming to Denver. About to board my flight. See you tomorrow.
-Rollie

Sent from my iPhone

On Jan 23, 2018, at 2:23 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> Team,
>
> The wolverine meeting is still on for tomorrow. Some folks will be participating via the webinar and phone line (in the agenda). If you were planning to come to Denver before the shutdown and are not attending in person now, please let me know.
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
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> >
> > If you have problems accessing the folder, please let me know.
> >
> > Justin Shoemaker

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

From: Shoemaker, Justin
To: Thabault, Michael
Subject: Re: Wolverine Recommendation Team Meeting Materials
Date: Tuesday, January 23, 2018 3:46:58 PM

The plan is to do a working lunch, ordering through Jason's Deli.

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

On Tue, Jan 23, 2018 at 4:32 PM, Thabault, Michael <michael_thabault@fws.gov> wrote:

> Justin, Are we working through lunch or will there be a break?
>
> Michael Thabault
> Assistant Regional Director
> Ecological Services
> U.S. Fish and Wildlife Service
> Mountain Prairie Region
> 303-236-4210
> michael_thabault@fws.gov
>
> On Tue, Jan 23, 2018 at 3:23 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:
>
> > Team,
> >
> > The wolverine meeting is still on for tomorrow. Some folks will be participating via the webinar and phone line (in the agenda). If you were planning to come to Denver before the shutdown and are not attending in person now, please let me know.
> >
> > Justin Shoemaker
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Justin Shoemaker
Classification and Recovery Biologist
U.S. Fish and Wildlife Service, Region 6
Phone: 309-757-5800 x214
Email: justin_shoemaker@fws.gov

From: Bush, Jodi
To: Grizzle, Betty
Subject: Re: Draft PowerPoint presentation for RMT next week
Date: Tuesday, January 23, 2018 4:24:47 PM

Couple of things..

Talk about what you did to get here...Who we talked to and how, generally what information and who you talked to and why you focused on getting additional information that you did not have before...

Can you add a slide that gives an overview of what you are going to talk about? Taking a stab here...:

Species Description (taxonomy)
Distribution
LIFE HISTORY INFO (reproduction and growth?)
Habitat use
Biological Information ??
Stressors
Future Scenarios

Jodi L. Bush
Office Supervisor
Montana State Ecological Services Office
585 Shepard Way, Suite 1
Helena, MT 59601
(406) 449-5225, ext.205

On Wed, Jan 17, 2018 at 10:05 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> For discussion today on Core Team call, please see attached pdf file (ppt format is too large to send).
>
> --
>
> 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: Drake, Madeline
To: Shoemaker, Justin
Subject: Re: Wolverine Recommendation Team Meeting Materials
Date: Wednesday, January 24, 2018 6:32:25 AM

Hi Justin,

I am pretty sure Mike Fris is coming too, our office made the decision to still send me based on the fact that he was still coming.

Thanks,
Madeline

On Tue, Jan 23, 2018 at 2:18 PM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> Is Mike Fris coming w/ you?
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov
>
> On Tue, Jan 23, 2018 at 1:21 PM, Drake, Madeline <madeline_drake@fws.gov> wrote:
>
> > Hi Justin,
> >
> > We were able to re-book everything, so I will see you tomorrow for the meeting.
> >
> > Best,
> > Madeline
> >
> > On Mon, Jan 22, 2018 at 8:52 AM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:
> >
> > > I totally understand. Thanks for letting me know.
> > >
> > > Justin Shoemaker
> > > Classification and Recovery Biologist
> > > U.S. Fish and Wildlife Service, Region 6
> > > Phone: 309-757-5800 x214
> > > Email: justin_shoemaker@fws.gov
> > >
> > > On Mon, Jan 22, 2018 at 10:50 AM, Drake, Madeline <madeline_drake@fws.gov> wrote:
> > >
> > > > Hi Justin,
> > > >
> > > > I talked with my supervisor, Josh Hull, and our field supervisor, Jennifer Norris, and it was decided to go ahead and cancel the trip since I will not have my computer or any resources to cancel the trip if the government remains shut down. If the meeting continues as planned, I will no longer be able to attend. I apologize for the inconvenience.
> > > >
> > > > Best,
> > > > Madeline

On Mon, Jan 22, 2018 at 8:30 AM, Shoemaker, Justin <justin_shoemaker@fws.gov> wrote:

> Team,
>
> Stand by on canceling your travel plans until we see if we're recalled back this morning.
>
> Justin Shoemaker
> Classification and Recovery Biologist
> U.S. Fish and Wildlife Service, Region 6
> Phone: 309-757-5800 x214
> Email: justin_shoemaker@fws.gov
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> > Justin Shoemaker
> > Classification and Recovery Biologist
> > U.S. Fish and Wildlife Service, Region 6
> > Phone: 309-757-5800 x214
> > Email: justin_shoemaker@fws.gov

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Madeline Drake
Listing and Recovery Division
Sacramento Fish and Wildlife Office
2800 Cottage Way, W-2605
Sacramento, CA 95825

916-414-6685

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From:	Rollie White
To:	betty_grizzle@fws.gov
Subject:	Here is the CBD letter
Date:	Wednesday, January 24, 2018 10:08:35 AM
Attachments:	Untitled attachment 02555.htm IDFG-re-Wolverine-Incidental-Capture-Jan-2018.pdf

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http://www.biologicaldiversity.org/species/mammals/American_wolverine/pdfs/IDFG-re-Wolverine-Incidental-Capture-Jan-2018.pdf

Rollie White
Assistant Regional Director - Ecological Services
Pacific Region
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Portland, OR 97232
O: (503) 231-6151
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Rollie_White@fws.gov

CENTER for BIOLOGICAL DIVERSITY Because life is good.

January 16, 2018

Virgil Moore, Director
virgilmoore@idfg.idaho.gov
Greg Wooten
greg.wooten@idfg.idaho.gov
P.O. Box 25
Boise, ID 83707

Re: Wolverine Incidental Trapping on December 8, 2017

Dear Director Moore and Mr. Wooten,

On approximately December 8, 2017, an adult female wolverine was captured and killed in GMU 21A in the Fourth of July Creek drainage in a snare trap set to capture fox. The trapper reported the incident and spoke with Idaho Department of Fish and Game personnel regarding the incident.

The wolverine was captured in a snare trap baited with beef scraps. The snare height was 10 inches and the snare loop was 8 inches. Despite state requirements, the trapper reported and IDFG recorded that there was no stop on the snare loop. Despite noting the trapping violation, IDFG has not taken any enforcement action against the trapper.

The wolverine was captured and killed in an area frequented by wolverines. In 2008, IDFG documented a wolverine maternal den just two miles from the site of the incidental capture, and the agency has collected and confirmed wolverine DNA from tracks in the Fourth of July Creek drainage and adjacent drainages over the past 8 years. The area is an important travel corridor for wolverines and is high suitability modeled habitat for the species.

As you are aware, wolverines have been protected under Idaho state law since 1965 and are a species proposed for listing under the Endangered Species Act. In order to avoid future incidents of wolverine trapping and mortality in Idaho, we request that IDFG prohibit trapping by snares, conibears, and other lethal devices in known wolverine habitat, including the Beaverhead Mountains. Moreover, to avoid the death of wolverines caused by illegal traps, we request that IDFG take enforcement action against this trapper for failure to include a stop on this snare.

I look forward to a response on these requests and will be happy to answer any questions you may have. I can be reached by phone at (303) 854-7748, or by email at asantarsiere@biologicaldiversity.org.

Sincerely,

Andrea Santarsiere
Senior Attorney, Center for Biological Diversity

Cc: IDFG Salmon Region, U.S. Fish and Wildlife Service

From: Snyder, Caitlin
To: Justin Shoemaker
Subject: Assist with FR document for wolverine
Date: Friday, January 26, 2018 1:06:40 PM

Hi Justin,

How are you? I gave Q a download of the wolverine meeting this afternoon. I wanted to pass along that I am available to assist with writing/reviewing the FR document as needed. I took notes during the meeting, so tried to capture the rationale behind the recommendations discussed.

Thanks,
Caitlin

Caitlin Snyder
Endangered Species Listing Program
U.S. Fish & Wildlife Service
MS: ES
5275 Leesburg Pike
Falls Church, VA 22041-3803
phone: 703 358 2673

From: Guinotte, John
To: Stephen Torbit
Subject: Fwd: text for ssa
Date: Monday, January 29, 2018 2:59:25 PM

---

give me a ring if you want to talk about this.

---------- Forwarded message ----------
From: **Andrea Ray - NOAA Federal** <andrea.ray@noaa.gov>
Date: Mon, Jan 29, 2018 at 2:53 PM
Subject: Re: text for ssa
To: "Guinotte, John" <john_guinotte@fws.gov>

John -- easier if you give me a call, 303-497-6434. but here's a quick response: We represented a large part of the range of uncertainty (shown in Fig 5-7) in the selection of the 5 scenarios, so our results reflect that for the 30 year period averaged around 2055. the range of the 5 results we present *is* the extension of that to the uncertainty of temp/precip changes on snowpack in this time period.

I thought mid-century was selected more b/c of FWS' idea of forseeable future and time/resources (including computational), and less about uncertainty among emissions. Uncertainty among the two RCP's (4.5 and 8.5) is considered in that both are included in the GCM output shown in Fig 5-7, we didn't distinguish between them in selecting the 5 scenarios. by "mid-century" the three commonly analyzed RCPs are just beginning to diverge. We could have chosen the lower one commonly analyzed (2.5? 2.6?) but again, we needed to make some choices due to resources, and even later, choices in what was presented to avoid cognitive overload.

We *might* be able to quickly produce a version of Fig 5-7 that shows the last 30 years of the century (~2071-2100) of you wanted a comparison. I think the models end in 2100 or maybe CMIP5 ends in 2110.

I know its been argued for other SSA's that FWS is ignoring end of the century impacts, but you gotta get thru mid-century first has always been the response, I think.

as for uncertainty across the RCPs, here's text from the USGCRP resilience toolkit/climate explorer that sums it up, and elswhere I've seen it said that they're not forecasting which is more likely: "According to the Intergovernmental Panel on Climate Change, the Representative Concentration Pathways (RCPs) should not be considered policy-prescriptive because they were developed to support scientific research on various possible climate change futures, without making any judgment as to their desirability or probability. These scenarios reflect choices individuals and society will make over coming decades, so there is uncertainty regarding the actual year-to-year change in greenhouse gases. RCPs are not considered to be forecasts, nor do they represent absolute bounds on the realm of possibility. While they all represent plausible scenarios for the future, none of the RCPs are intended to serve as predictions, best guesses, most likely, or more plausible pathways than the others.

In 2015, at the United Nations Framework on Climate Change (UNFCCC) 21st Annual Conference of the Parties (COP21) in Paris, many nations agreed to pursue efforts to limit global average temperature increase to 1.5°C above pre-industrial levels. Climate modelers suggest this is only possible if we strive to reach RCP 2.6, a pathway that calls for immediate action to achieve drastic reductions in greenhouse gas emissions."

Andrea

On Mon, Jan 29, 2018 at 2:20 PM, Guinotte, John <john_guinotte@fws.gov> wrote:

Hi Andrea,

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Below is what is in your report. Do you have any text or citations specifically about the uncertainty of emissions 2050-2100 and by extension the uncertainty of temp/precip changes on snowpack in this time period?

Betty needs to add some text to this section in the SSA.

thanks John

"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. 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. "

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(fax) 303-497-6449
andrea.ray@noaa.gov
www.researchgate.net/profile/Andrea_Ray2

From: Guinotte, John
To: Betty Grizzle; Stephen Torbit
Subject: Fwd: text for ssa
Date: Monday, January 29, 2018 3:18:22 PM

Hi Betty and Steve, I just spoke to Andrea about this. She's going to create a scatter plot like fig 5-7 for 2071-2100. I think this will be useful. She is also going to send us some more detailed text on what we have in hand, (2055 projection). She reminded me that these results are for a nominal 2055, they ran a 30 year average around 2055 to take out the interannual variability, so that is where the 2041-2070 number comes from. These aren't strictly projections for 2055. Hopefully the text she provides will explain this more clearly than I did.

---------- Forwarded message ----------
From: **Andrea Ray - NOAA Federal** <andrea.ray@noaa.gov>
Date: Mon, Jan 29, 2018 at 3:01 PM
Subject: Fwd: text for ssa
To: John Guinotte <john_guinotte@fws.gov>, Joe Barsugli <joseph.barsugli@colorado.edu>, Steve Torbit <Stephen_Torbit@fws.gov>

now copying Steve and Joe

John -- easier if you give me a call, 303-497-6434. but here's a quick response: We represented a large part of the range of uncertainty (shown in Fig 5-7) in the selection of the 5 scenarios, so our results reflect that for the 30 year period averaged around 2055. the range of the 5 results we present *is* the extension of that to the uncertainty of temp/precip changes on snowpack in this time period.

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From: Grizzle, Betty
To: John Guinotte; Stephen Torbit
Subject: Draft text
Date: Monday, January 29, 2018 3:35:53 PM
Attachments: Language for Snow Discussion.docx

John and Steve - This is still very much a draft, but I wanted to get your input, and also have you pull a little more from Ray et al. regarding their analysis of snow persistence related to topography, slope. aspect, etc. (see blue highlighted sentence at end).

Let me know if you want to discuss on a call (I am teleworking tomorrow).
Thanks,
Betty

--

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

Potential Language for "not all snow is equal" addition to SSA Report
Some text below from Ray *et al*. 2017, with paraphrasing after reviewing cited articles:

Intro paragraphs (from Sospedra-Alfonso *et al*. 2015 and Luce 2017): (NOTE – still need to locate citations from these sources)

The properties of the snowpack are generally inferred from temperature, solar radiation, and precipitation (Sospedra-Alfonso *et al*. 2015, p. 4,429). The key conditions for the accumulation of snow are sufficiently cold air temperature to support precipitation in the form of snow, and the persistence of temperature below freezing to preserve the snowpack (Sospedra-Alfonso *et al*. 2015, p. 4,429). Several studies have used air temperature and precipitation to explain snowpack (e.g., Cayan 1996; Hamlet *et al*. 2005; Mote 2006; Brown and Mote 2008; Beniston 2012; Morán-Tejeda *et al*. 2013), in part because air temperature is considered a good proxy indicator of snowmelt (Anderson 2002) and the general lack of radiation observations, while air temperature and precipitation are more readily available from climatological and hydro-meteorological networks (Sospedra-Alfonso *et al*. 2015, p. 4,429).

Elevational relationships with snowpack with temperature and precipitation have also been examined. In a study of the mountainous region of Switzerland, a linear relationship was found between elevation and temperature and precipitation, such that the elevation at which these influences are equal defines a threshold below (above) which temperature (precipitation) is the main driver of the snowpack; for the Swiss mountains, this threshold elevation was 1400 meters (± 200 meters) (4,593 ft (± 656 ft)) (Morán-Tejeda *et al*. 2013). This is because, in general, higher elevations are less sensitive to temperature than lower elevations.

In the western United States, Regonda *et al*. (2005, p. 377) found little historical change in snowpack (measured as snow water equivalent) above approximately 2500 m (8,202 ft) in elevation despite observed warming trends. In a more recent study, Sospedra-Alfonso *et al*. (2015, entire) evaluated snowpack variability relative to elevation in the Rocky Mountain region of northern Idaho and northwestern Montana. The authors found that, historically, temperature has been a larger driver of April (aggregated months) snowpack below about 1,560 m (5,118 ft) elevation, with precipitation the main driver of variability above that elevation (Sospedra-Alfonso *et al*. 2015, p. 4,436). Another study, using a single climate change scenario and a high-resolution weather model, found that the threshold elevation below which temperature dominates snowpack rises by about 250 m (820 ft) in the Colorado (Southern) Rockies, and about 191 m (627 ft) in the Northern Rockies (near Glacier National Park) (Scalzitti *et al*. 2016, p. 5,364). However, results from a spatial analog model presented by Luce *et al*. (2014, p. 9,460) found that cold, high elevation snowpacks were more sensitive to both temperature and precipitation variations than previously noted.

Topography is also an important factor affecting effecting seasonality, precipitation amount, and potential trends in snow cover (Luce 2017, p. 70). The range of potential changes to climate is complex, particularly for the Northern Rockies, since current climatological settings vary over the landscape at both macroscales and fine scales (Luce 2017, p. 70). In this region, there are broad east to west changes in precipitation seasonality and amount, and thus local differences are found between nearby mountain and valley weather stations; therefore, the trends and drivers for

climate variations will differ greatly from east to west. In general, the interior parts of the Northern Rockies (higher elevations) are thought to be cold enough to be relatively insensitive to warming temperatures but strongly sensitive to variation in precipitation (Luce *et al*. 2017, p. 70). In contrast, the lower elevation mountains found in northern Idaho, which are heavily influenced by a maritime snow climate (Armstrong and Armstrong 1987; Mock and Birkeland 2000; Roch 1949), are sensitive to temperature variability, particularly with respect to snow durability (Luce *et al*. 2014; Figure 11).

[Below for internal reference/review only – will not be able to include in final report due to copyright issues]

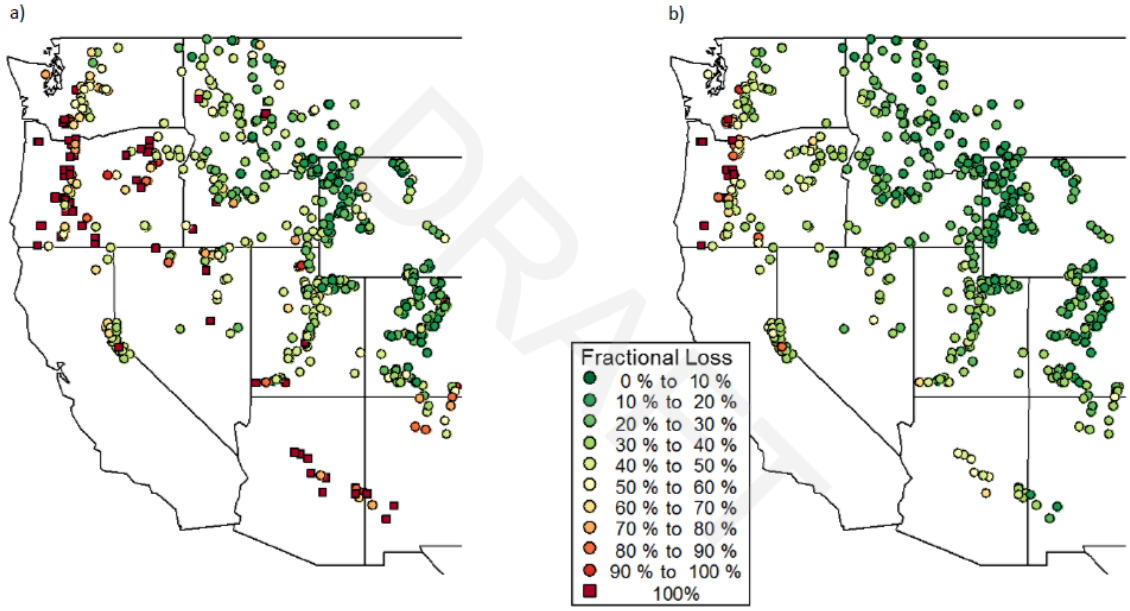

Figure 4.5—Estimated loss of a) April 1 snow water equivalent and b) mean snow residence time as related to warming of 5.4 °F (from Luce et al. 2014).

Although these studies may not be directly comparable to our modeled projections due to differences in methodology, the results from our projections of snow cover at lower elevations (Glacier National Park) versus higher elevations (Rocky Mountain National Park) also confirm this elevation-dependent change in snowpack. Thus, in summary, the qualitative picture indicates that projected warming has a larger effect at lower elevations whereas projected precipitation changes are likely to dominate spring snowpack in the high country (Ray *et al*. 2017, p. 45). Need to add language from Ray et al. relative to aspect (east-west, etc.) and/or microscale differences.

CITATIONS to add (see also *in litt* from Sospedra-Alfonso and Luce 2017):

Morán-Tejeda, E., J. I. López-Moreno, and M. Beniston. 2013. The changing roles of temperature and precipitation on snowpack variability in Switzerland as a function of altitude. Geophys. Res. Lett., 40, 2131–2136, doi:10.1002/grl.50463.

Regonda, S. K. , B. Rajagopalan, M. Clark, and J. Pitlick. 2005. Seasonal Cycle Shifts in Hydroclimatology over the Western United States. J. Climate18, 372–384.

Scalzitti J, Strong C, Kochanski A. 2016. Climate change impact on the roles of temperature and precipitation in Western U.S. snowpack variability. Geophys Res Lett 43 5361-5369.

Sospedra-Alfonso, R., J. R. Melton, and W. J. Merryfield. 2015. Effects of temperature and precipitation on snowpack variability in the central Rocky Mountains as a function of elevation. Geophys. Res. Lett., 42, 4429–4438.

From: Guinotte, John
To: Betty Grizzle
Subject: Fwd: text for ssa
Date: Tuesday, January 30, 2018 7:04:56 AM

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useful explanation of the 30 year average.

John Guinotte
Spatial Ecologist
Ecological Services
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Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

---------- Forwarded message ----------
From: **Andrea Ray - NOAA Federal** <andrea.ray@noaa.gov>
Date: Mon, Jan 29, 2018 at 5:08 PM
Subject: Re: text for ssa
To: John Guinotte <john_guinotte@fws.gov>
Cc: Joe Barsugli <joseph.barsugli@colorado.edu>, Steve Torbit <Stephen_Torbit@fws.gov>, Imtiaz Rangwala <imtiaz.rangwala@noaa.gov>

John, Following up on our call a few minutes ago, I'll get back to you on whether Imtiaz can easily do scatter plots like Fig 5-7 for end of century.

On why use a 30 year average period, We mention that we used a "thirty-year period, 2041-2070, centered on 2055" on the bottom of p.7. But we don't say why. Here's text you can use, and two places I could quickly find it described are p 60-61 in Lukas et al 2014 (cite: Lukas, J., Barsugli, J., Doesken, N., Rangwala, I., and K. Wolter (2014). Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A Report for the Colorado Water Conservation Board. Western Water Assessment. 108 pp, available at: http://wwa.colorado.edu/climate/co2014report/). An article on 30 years as a "climate normal" is here, Arguez et al: https://www1.ncdc.noaa.gov/pub/data/normals/1981-2010/documentation/1981-2010-normals-overview.pdf

"We chose a 30-year averaging period for two reasons: First, a 30 year period is commonly used to characterize the background state of observed climate about which anomalous conditions and even extremes occur (Arguez, D, et al. 2012). We planned to compare projections to an observed period, so we chose a 30 year period around mid-century, with a similar intent to characterize the average state around the anomalies and extremes which are also in the climate models. GCM climate projections include simulated natural variability, to more clearly distinguish the the anthropogenic future change we need to compare to a future period that is long enough so that the natural variability is at least partly averaged out (Lukas et al, 2014). In this report, the projected changes described for 2055 are based on the projected conditions averaged over the period 2041–2070, and compared with the conditions for the historical period of 1971–2000 (except where otherwise noted). Because the climate continues to change throughout that future period, the changes described for 2055 are like a snapshot of

a moving target."

If Imtiaz can do those plots, they'll likely be 2070-2099 or 2071-2100, so they'll follow on from the period we used.

A couple of other points from Lukas et al: "For the same emissions scenario, the climate models produce different projected future climate changes because (1) the representation of some key climate processes differs from model to model, and (2) the multi-decadal natural variability simulated by the models is still present in the 30-year average and is not synchronized from model to model." sidebar 3.1 gives more info if you're interested.

On Mon, Jan 29, 2018 at 3:01 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

> now copying Steve and Joe
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From: Guinotte, John
To: Betty Grizzle
Subject: Fwd: text for ssa
Date: Tuesday, January 30, 2018 7:05:33 AM
Attachments: image.png

---

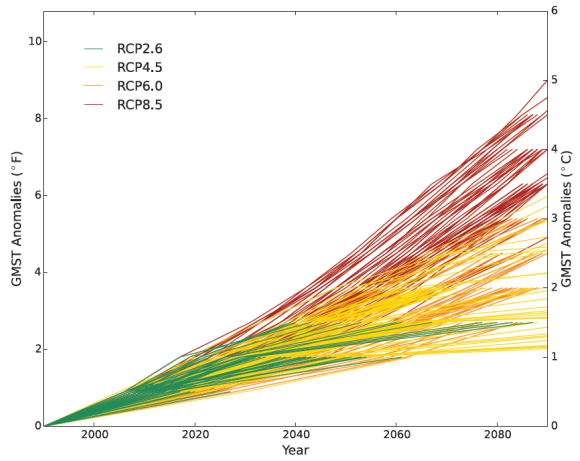
nice graphic, not sure we can use it.

---------- Forwarded message ----------
From: **Andrea Ray - NOAA Federal** <andrea.ray@noaa.gov>
Date: Mon, Jan 29, 2018 at 5:15 PM
Subject: Re: text for ssa
To: John Guinotte <john_guinotte@fws.gov>
Cc: Joe Barsugli <joseph.barsugli@colorado.edu>, Steve Torbit <Stephen_Torbit@fws.gov>, Imtiaz Rangwala <imtiaz.rangwala@noaa.gov>

also, there might be something in the 4th National climate assessment, about what periods they used. WE might be able to say that we used a similar period.

Here's a graphic from the review draft in the fall -- by 2055, the two RCPs we used are beginning to separate. But we used 34 models from each of those RCPs to select the scenarios. So we've reflected the range of both of them

Andrea



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FINAL

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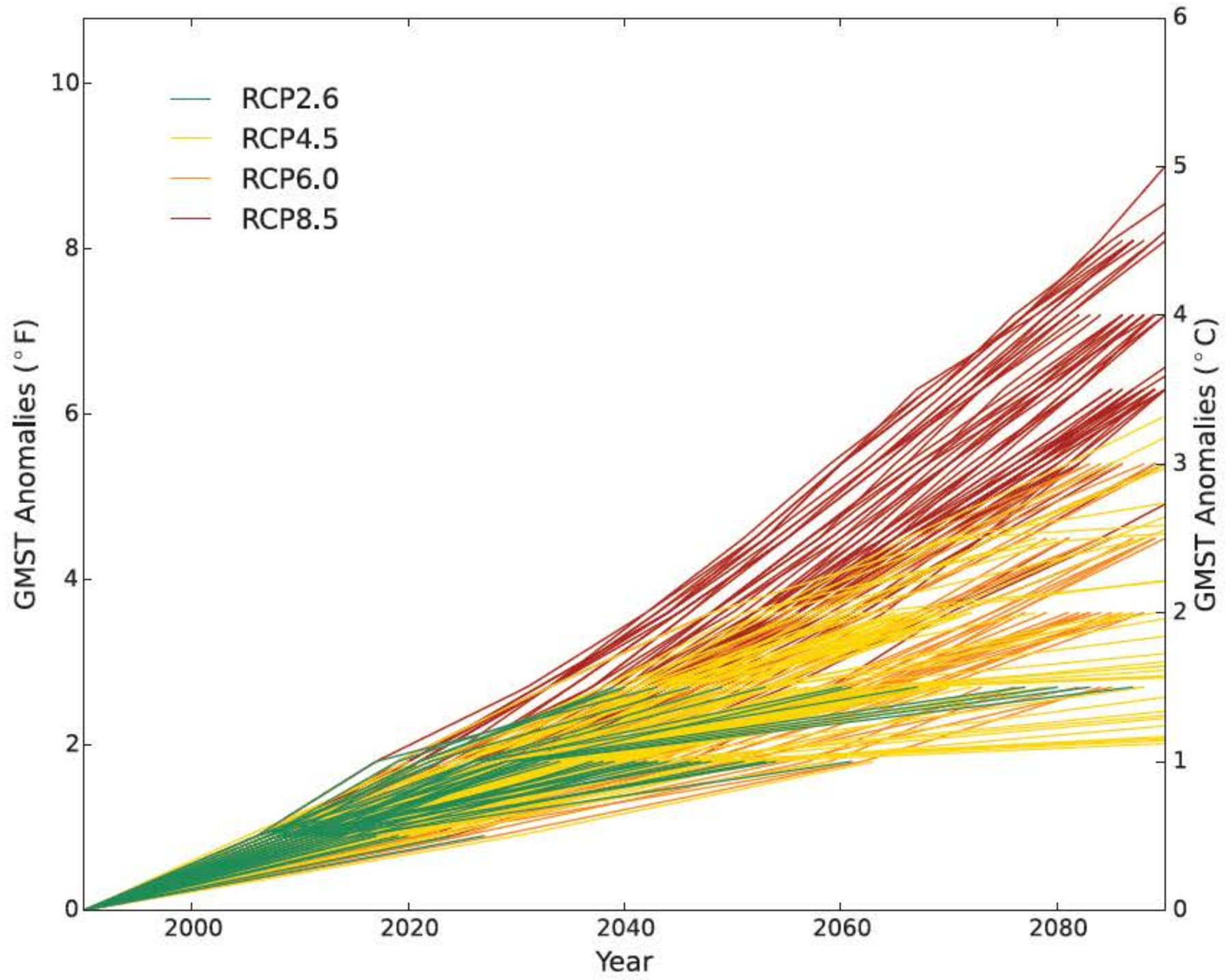

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From: Guinotte, John
To: Andrea Ray - NOAA Federal
Cc: Joe Barsugli; Steve Torbit; Imtiaz Rangwala
Subject: Re: text for ssa
Date: Tuesday, January 30, 2018 8:31:36 AM
Attachments: image.png

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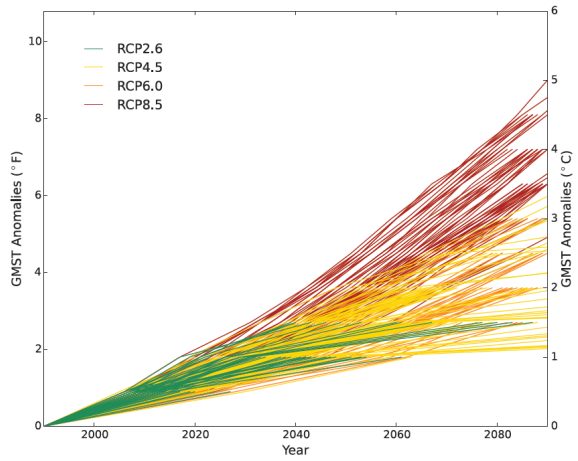

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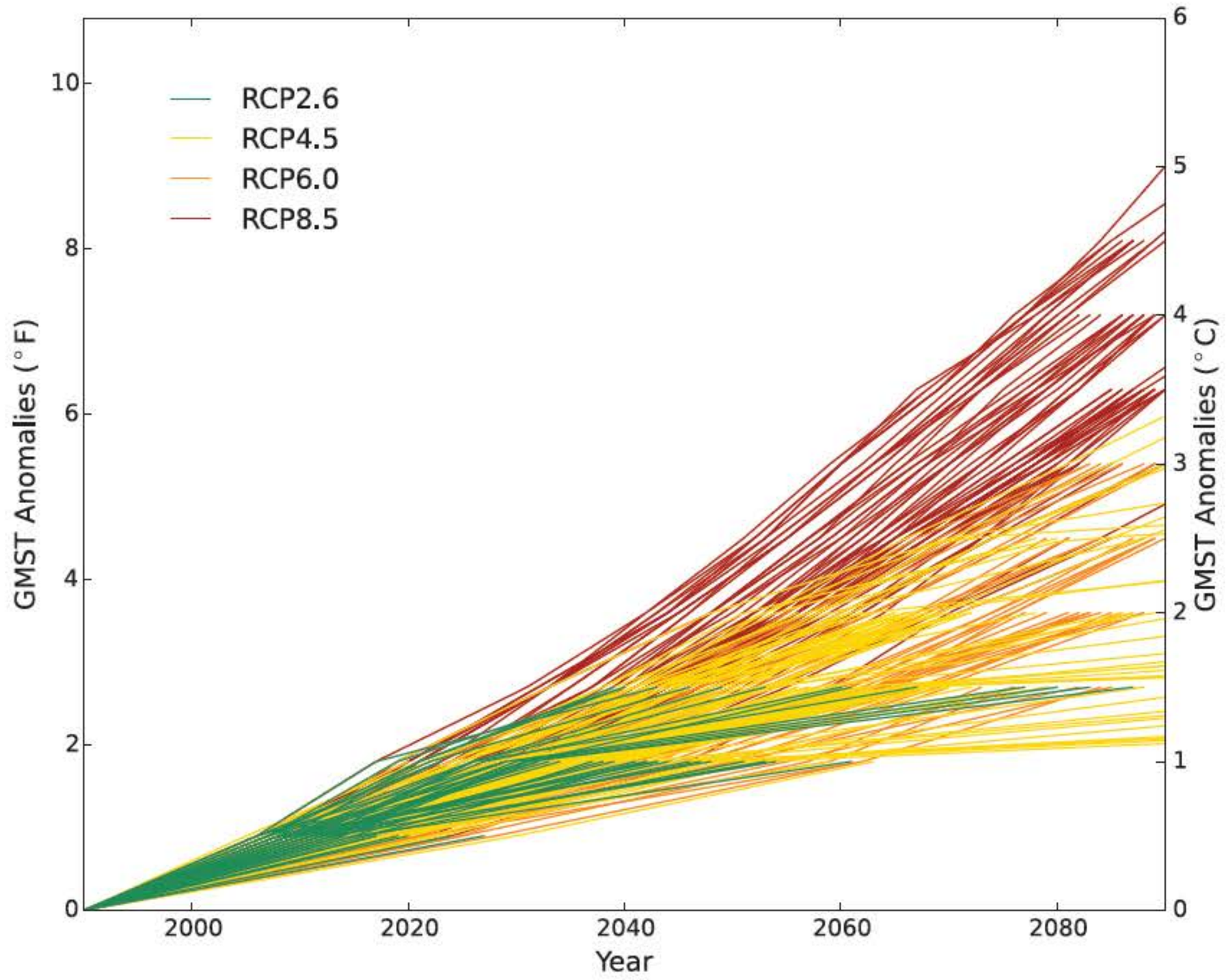

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From: Guinotte, John
To: Betty Grizzle
Subject: Fwd: update on Fig 4.2 from NCA4 CCSA Re: text for ssa
Date: Tuesday, January 30, 2018 9:10:03 AM
Attachments: image.png
NCA4_CCSA_figure4_2.png

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we can use this graphic.

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---------- Forwarded message ----------
From: **Andrea Ray - NOAA Federal** <andrea.ray@noaa.gov>
Date: Tue, Jan 30, 2018 at 8:56 AM
Subject: update on Fig 4.2 from NCA4 CCSA Re: text for ssa
To: "Guinotte, John" <john_guinotte@fws.gov>, Joseph Barsugli <joseph.barsugli@noaa.gov>
Cc: Steve Torbit <Stephen_Torbit@fws.gov>, Imtiaz Rangwala <imtiaz.rangwala@noaa.gov>

update -- that NCA4 "Climate Science Special Report" is officially out, as I was thinking (it was in the press last fall). The final graphic is attached. The report and pdf are available from here; https://science2017.globalchange.gov/ (click chapter for for this figure and text)

the citation is: USGCRP, 2017: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp, doi: 10.7930/J0J964J6.

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> Hi John, That figure was from the "Final Clearance 28 June 2017 Fifth-Order Draft (5OD)" I think that's now officially out. I'll look for the latest version of Fig 4.2 in NCA right now & get back to you. I think you could say that its from the X order draft.
>
> Imtiaz downloaded the data overnight and expects to have figures later this morning that will be a 2070-99. the CMIP5 archive only goes out to 2099. We wanted the 30y period to be consistent, so the year 2070 is in both, but that's not an issue for this.
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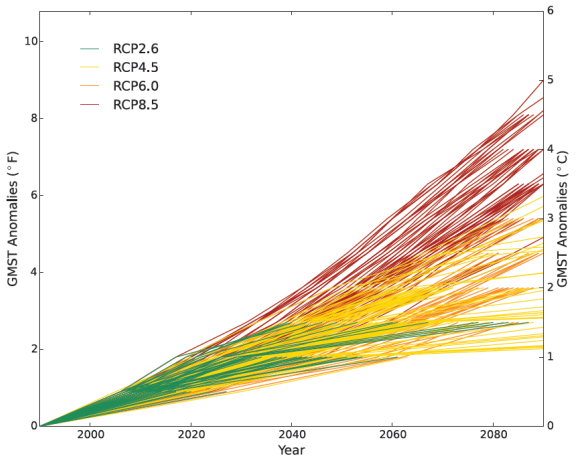

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In 2015, at the United Nations Framework on Climate Change (UNFCCC) 21st Annual Conference of the Parties (COP21) in Paris, many nations agreed to pursue efforts to limit global average temperature increase to 1.5°C above pre-industrial levels. Climate modelers suggest this is only possible if we strive to reach RCP 2.6, a pathway that calls for immediate action to achieve drastic reductions in greenhouse gas emissions."

Andrea

On Mon, Jan 29, 2018 at 2:20 PM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Hi Andrea,
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> We had some questions about why 2055 was chosen as the end point for the snow projections. We explained it was a combination of computational (time/money), uncertainty of emissions 2050-2100, and FWS time horizons.
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> Ecological Services
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> john_guinotte@fws.gov

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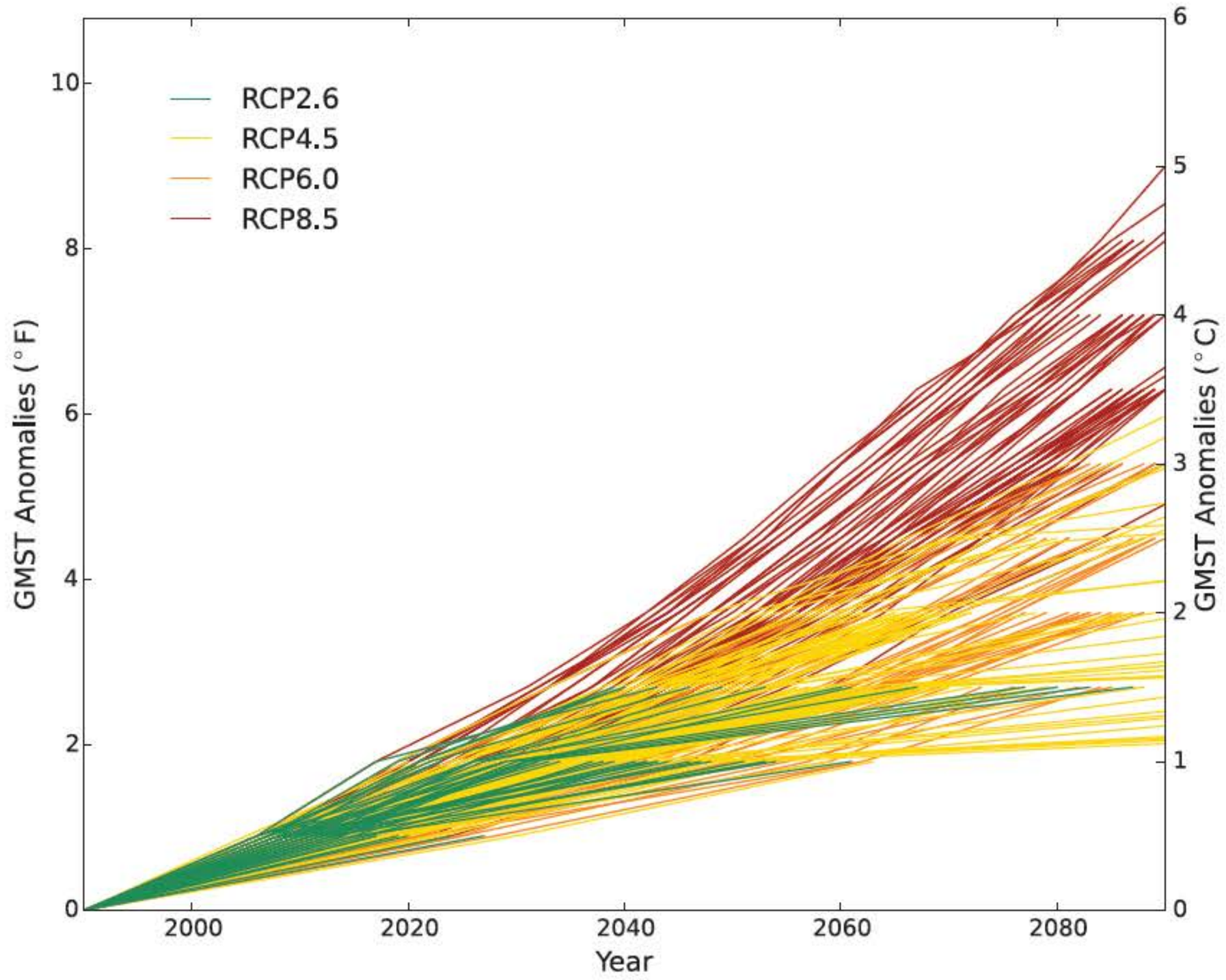


Figure 4.2: Global mean surface temperature anomalies (°F) relative to 1976–2005 for four RCP scenarios, 2.6 (green), 4.5 (yellow), 6.0 (orange), and 8.5 (red). Each line represents an individual simulation from the CMIP5 archive. Every RCP-based simulation with annual or monthly temperature outputs available was used here. The values shown here were calculated in 0.5°C increments; since not every simulation reaches the next 0.5°C increment before end of century, many lines terminate before 2100. (Figure source: adapted from Swain and Hayhoe 2015).

FINAL

RCP2.6
RCP4.5
RCP6.0
RCP8.5

GMT Anomalies (ºF)

10
8
6
4
2
0

GMT Anomalies (ºC)

6
5
4
3
2
1
0

2000
2020
2040
2060
2080

Year

From: Grizzle, Betty
To: Shoemaker, Justin; John Guinotte
Subject: Follow-up from meeting: Sky Island information
Date: Tuesday, January 30, 2018 9:43:01 AM

Information on "Sky Islands:" (as I mentioned, this is the only area of No America I have found using this terminology)

From USFS:

"Sky Islands" are isolated mountain ranges **in southeastern Arizona and northern Mexico**. Some of the mountains rise more than 6,000 feet above the surrounding desert floor making the lowlands and high peaks drastically different. Plants and animals living in the mountains could never survive in the surrounding deserts. Thus by analogy, the mountains are "islands" surrounded by deserts that are "seas."

https://www.fs.fed.us/wildflowers/beauty/Sky_Islands/index.shtml

From Sky Island Alliance:

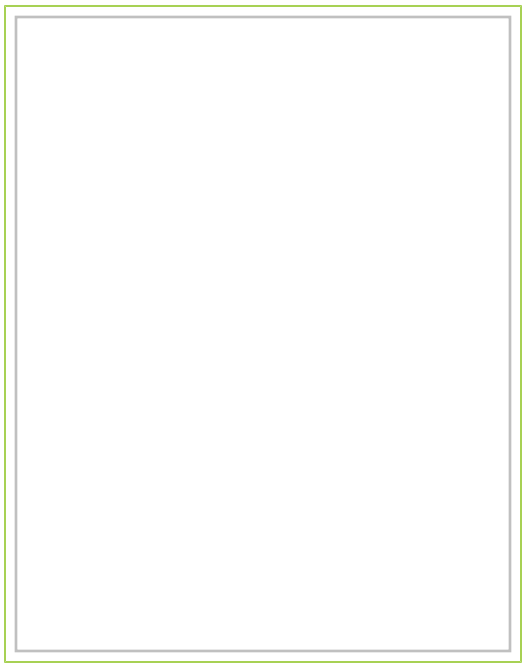
Biogeography of the Sky Islands

One hundred miles north of Tucson, Arizona, the massive bulk of high country called the Colorado Plateau and Rocky Mountains jut into central Arizona and western New Mexico with iconic snow capped peaks and montane rivers. These thick forests and deep canyons form the Mogollon Rim, which signifies the abrupt edge found on the Plateau's southern flank. The largest continuous stand of ponderosa pine in the world is found there, hosting the last bulwark of temperately inclined constituents before precipitously giving way to a more broken country of mountains and valleys below.

In the opposite direction—150 miles southeast of Tucson—the *other* mountainous spine of North America, the mighty Sierra Madre Occidental and its subtropical forests of pines and parrots gives way just before reaching the Arizona-New Mexico border. Here, an entirely different set of ecosystems have evolved over the millennia, adapting to warmer temperatures and strong connections to the western Hemisphere's tropical latitudes.

Between and connecting these two massive continental backbones, 40 distinct mountain ranges form the Sky Island region of North America. This globally unique convergence—the north-south overlap of two major cordilleras spanning the temperate and subtropical latitudes—begins to form the foundation for ecological interactions found nowhere else on earth.

https://www.terrain.org/articles/21/skroch.htm



Biogeographic influences on the Sky Island region.
Graphic courtesy Sky Island Alliance.

--

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: Guinotte, John
Subject: Re: update on Fig 4.2 from NCA4 CCSA Re: text for ssa
Date: Tuesday, January 30, 2018 9:56:24 AM
Attachments: image.png

FYI - From the report:

Some figures and images are copyright protected. Permission of the copyright owner must be obtained before making use of copyrighted material.

For this figure:

This figure, "*Global Mean Temperature Anomalies (RCPs)*", is an adapted figure provided by Katharine Hayhoe.

The figure version presented here was adapted from the original as follows:

1. The figure includes more lines (where each line corresponds to an individual CMIP5 global model simulation), including data for RCP2.6 that was not included in the original figure, such that it now has one line for every RCP-based simulation that has annual or monthly mean temperature available in the CMIP5 archive as of August 2016. 2. The data has been re-scaled to a base period of 1976-2005 instead of the original 1971-2000, for consistency with the NCA4 base period. 3. The axes have been re-drawn to begin at zero rather than 1oC. 4. A secondary axis in degrees F has been added.

The original figure is found in:

Swain, S. and K. Hayhoe. 2015. CMIP5 projected changes in spring and summer drought and wet conditions over North America. Climate Dynamics, 44(9), 2737-2750. doi: 10.1007/s00382-014-2255-9

So, it looks like the original figure is likely copyrighted.

On Tue, Jan 30, 2018 at 8:09 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

> we can use this graphic.
>
> John Guinotte
> Spatial Ecologist
> 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: **Andrea Ray - NOAA Federal** <andrea.ray@noaa.gov>
> Date: Tue, Jan 30, 2018 at 8:56 AM
> Subject: update on Fig 4.2 from NCA4 CCSA Re: text for ssa
> To: "Guinotte, John" <john_guinotte@fws.gov>, Joseph Barsugli <joseph.barsugli@noaa.gov>

Cc: Steve Torbit <Stephen_Torbit@fws.gov>, Imtiaz Rangwala <imtiaz.rangwala@noaa.gov>

update -- that NCA4 "Climate Science Special Report" is officially out, as I was thinking (it was in the press last fall). The final graphic is attached. The report and pdf are available from here; https://science2017.globalchange.gov/ (click chapter for for this figure and text)

the citation is: USGCRP, 2017: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 470 pp, doi: 10.7930/J0J964J6.

Andrea

On Tue, Jan 30, 2018 at 8:41 AM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

> Hi John, That figure was from the "Final Clearance 28 June 2017 Fifth-Order Draft (5OD)" I think that's now officially out. I'll look for the latest version of Fig 4.2 in NCA right now & get back to you. I think you could say that its from the X order draft.
>
> Imtiaz downloaded the data overnight and expects to have figures later this morning that will be a 2070-99. the CMIP5 archive only goes out to 2099. We wanted the 30y period to be consistent, so the year 2070 is in both, but that's not an issue for this.
>
> its in the captions that the period is 2041-2070, but we could quickly overlay a new figure title to emphazise that? or Betty can just emphasize that in the text?
>
> Andrea
>
> On Tue, Jan 30, 2018 at 8:31 AM, Guinotte, John <john_guinotte@fws.gov> wrote:
>
> > Thanks Andrea. I passed this all on to Betty. I assume we can't use fig 4.2 below since it is draft?
> > thanks John
> >
> > John Guinotte
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> > Ecological Services
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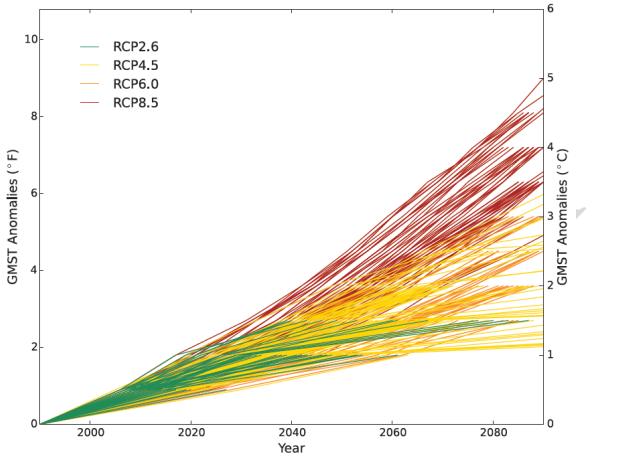
> >
> > On Mon, Jan 29, 2018 at 5:15 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:
> >
> > > also, there might be something in the 4th National climate assessment, about what periods they used. WE might be able to say that we used a similar period.

Here's a graphic from the review draft in the fall -- by 2055, the two RCPs we used are beginning to separate. But we used 34 models from each of those RCPs to select the scenarios. So we've reflected the range of both of them

Andrea



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FINAL

On Mon, Jan 29, 2018 at 5:08 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

> John, Following up on our call a few minutes ago, I'll get back to you on whether Imtiaz can easily do scatter plots like Fig 5-7 for end of century.
>
> On why use a 30 year average period, We mention that we used a "thirty-year period, 2041-2070, centered on 2055" on the bottom of p.7. But we don't say why. Here's text you can use, and two places I could quickly find it described are p 60-61 in Lukas et al 2014 (cite: Lukas, J., Barsugli, J., Doesken, N., Rangwala, I., and K. Wolter (2014). Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A Report for the Colorado Water Conservation Board. Western Water Assessment. 108 pp, available at: http://wwa.colorado.edu/climate/co2014report/). An article on 30 years as a "climate normal" is here, Arguez et al: https://www1.ncdc.noaa.gov/pub/data/normals/1981-

2010/documentation/1981-2010-normals-overview.pdf

"We chose a 30-year averaging period for two reasons: First, a 30 year period is commonly used to characterize the background state of observed climate about which anomalous conditions and even extremes occur (Arguez, D, et al. 2012). We planned to compare projections to an observed period, so we chose a 30 year period around mid-century, with a similar intent to characterize the average state around the anomalies and extremes which are also in the climate models. GCM climate projections include simulated natural variability, to more clearly distinguish the the anthropogenic future change we need to compare to a future period that is long enough so that the natural variability is at least partly averaged out (Lukas et al, 2014). In this report, the projected changes described for 2055 are based on the projected conditions averaged over the period 2041–2070, and compared with the conditions for the historical period of 1971–2000 (except where otherwise noted). Because the climate continues to change throughout that future period, the changes described for 2055 are like a snapshot of a moving target."

If Imtiaz can do those plots, they'll likely be 2070-2099 or 2071-2100, so they'll follow on from the period we used.

A couple of other points from Lukas et al: "For the same emissions scenario, the climate models produce different projected future climate changes because (1) the representation of some key climate processes differs from model to model, and (2) the multi-decadal natural variability simulated by the models is still present in the 30-year average and is not synchronized from model to model." sidebar 3.1 gives more info if you're interested.

On Mon, Jan 29, 2018 at 3:01 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

> now copying Steve and Joe
>
> John -- easier if you give me a call, 303-497-6434. but here's a quick response: We represented a large part of the range of uncertainty (shown in Fig 5-7) in the selection of the 5 scenarios, so our results reflect that for the 30 year period averaged around 2055. the range of the 5 results we present *is* the extension of that to the uncertainty of temp/precip changes on snowpack in this time period.
>
> I thought mid-century was selected more b/c of FWS' idea of forseeable future and time/resources (including computational), and less about uncertainty among emissions. Uncertainty among the two RCP's (4.5 and 8.5) is considered in that both are included in the GCM output shown in Fig 5-7, we didn't distinguish between them in selecting the 5 scenarios. by "mid-century" the three commonly analyzed RCPs are just beginning to diverge. We could have chosen the lower one commonly analyzed (2.5? 2.6?) but again, we needed to make some choices due to resources, and even later, choices in what was presented to avoid cognitive overload.
>
> We *might* be able to quickly produce a version of Fig 5-7 that shows the last 30 years of the century (~2071-2100) of you wanted a comparison. I think the models end in 2100 or maybe CMIP5 ends in 2110.
>
> I know its been argued for other SSA's that FWS is ignoring end of the century impacts, but you gotta get thru mid-century first has always been the response, I think.
>
> as for uncertainty across the RCPs, here's text from the USGCRP resilience toolkit/climate explorer that sums it up, and elswhere I've seen it said that they're

not forecasting which is more likely: "According to the Intergovernmental Panel on Climate Change, the Representative Concentration Pathways (RCPs) should not be considered policy-prescriptive because they were developed to support scientific research on various possible climate change futures, without making any judgment as to their desirability or probability. These scenarios reflect choices individuals and society will make over coming decades, so there is uncertainty regarding the actual year-to-year change in greenhouse gases. RCPs are not considered to be forecasts, nor do they represent absolute bounds on the realm of possibility. While they all represent plausible scenarios for the future, none of the RCPs are intended to serve as predictions, best guesses, most likely, or more plausible pathways than the others.

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760-431-5901 fax

From: Shevenell Webb
To: Grizzle, Betty
Subject: Re: Request to use map (from your 2016 paper)
Date: Tuesday, January 30, 2018 9:57:09 AM
Attachments: SnowManuscriptMapFinal_Fig1_ver2Color.jpg

Hi Betty,

I have attached a color map version showing spring snow cover and wolverine locations in Alberta. We are working on a manuscript right now on Characteristics of wolverine dens in the lowland boreal forest of north-central Alberta. We visited 8 unique wolverine dens outside Copeland et al. spring snow cover layer. I don't know when USFWS will be making final recommendations, but we should have a decent draft available in ~1 month if that is at all useful?

cheers, Shevenell

_____
Shevenell Webb, Wildlife Biologist

Alberta Conservation Association
phone: 207-242-2875
email: shevenell.webb@ab-conservation.com

**I am in the office Tuesday, Thursday, and Friday.

From: Grizzle, Betty <betty_grizzle@fws.gov>
Sent: Friday, January 26, 2018 10:54 AM
To: Shevenell Webb
Subject: Request to use map (from your 2016 paper)

Hi Shevenell - We are addressing a few final comments on our wolverine status review. Regarding your 2016 paper in The Journal of Wildlife Management, would it be possible for our agency to use Figure 1 from that paper in our status review document? If so, do you have a better quality image than what is presented in the published paper?

Thanks so much and let me know if you have questions about this request,
Betty

--

Betty J. Grizzle, D.Env.

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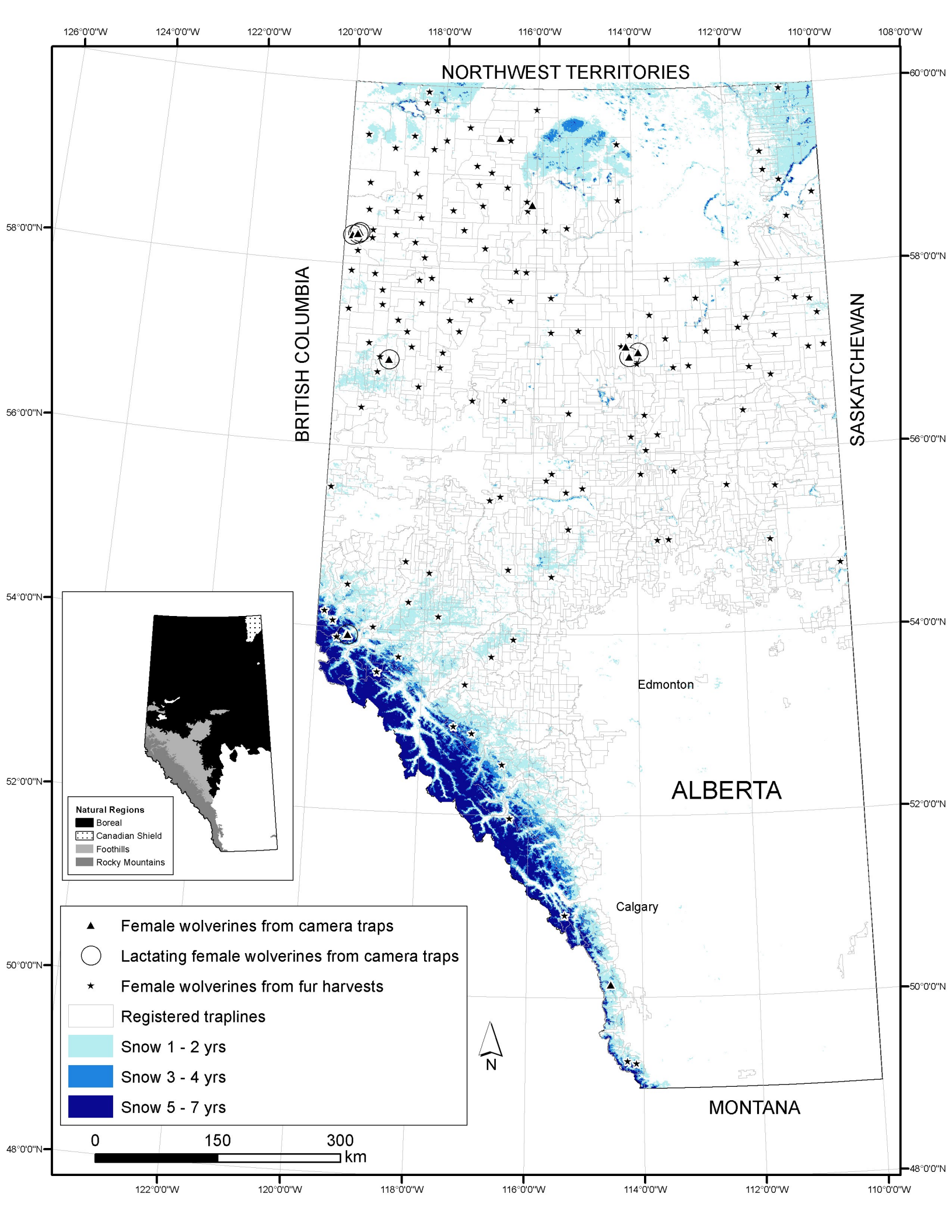
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NORTHWEST TERRITORIES
BRITISH COLUMBIA
SASKATCHEWAN
ALBERTA
MONTANA
Edmonton
Calgary
Natural Regions
Boreal
Canadian Shield
Foothills
Rocky Mountains
Female wolverines from camera traps
Lactating female wolverines from camera traps
Female wolverines from fur harvests
Registered traplines
Snow 1 - 2 yrs
Snow 3 - 4 yrs
Snow 5 - 7 yrs
N
0
150
300
km

From: Grizzle, Betty
To: Shoemaker, Justin; John Guinotte; Bush, Jodi; Stephen Torbit
Subject: Fwd: Request to use map (from your 2016 paper)
Date: Tuesday, January 30, 2018 10:01:02 AM
Attachments: SnowManuscriptMapFinal_Fig1_ver2Color.jpg

FYI - Looks like we can use the map Shevenell provided in her email (with accompanying credit). I recommend placing this directly in the SSA Report rather than in another appendix. Thoughts?

---------- Forwarded message ----------
From: **Shevenell Webb** <Shevenell.Webb@ab-conservation.com>
Date: Tue, Jan 30, 2018 at 8:55 AM
Subject: Re: Request to use map (from your 2016 paper)
To: "Grizzle, Betty" <betty_grizzle@fws.gov>

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cheers, Shevenell

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Shevenell Webb, Wildlife Biologist

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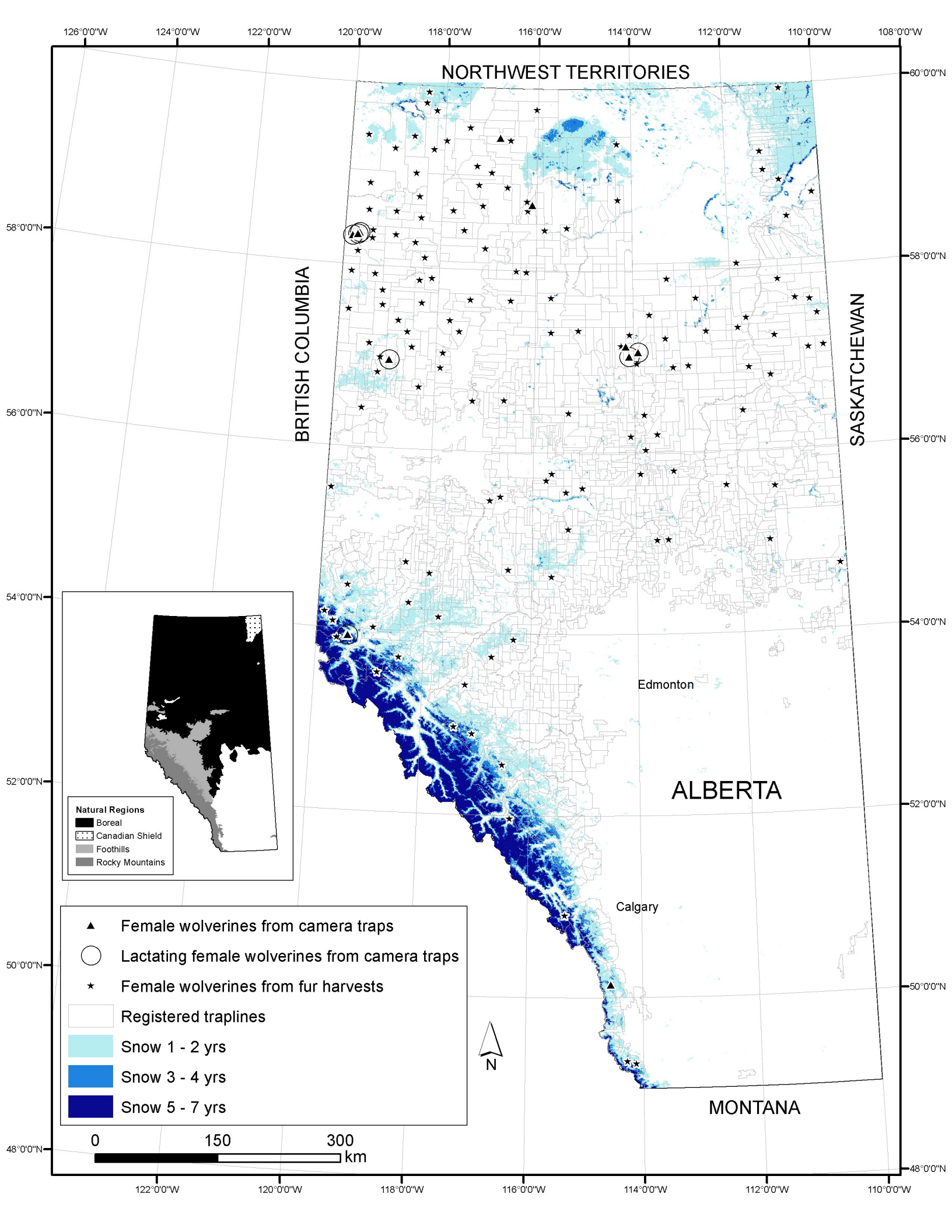
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118°0'0"W
116°0'0"W
114°0'0"W
112°0'0"W
110°0'0"W
108°0'0"W
60°0'0"N
58°0'0"N
56°0'0"N
54°0'0"N
52°0'0"N
50°0'0"N
48°0'0"N
NORTHWEST TERRITORIES
BRITISH COLUMBIA
SASKATCHEWAN
ALBERTA
MONTANA
Edmonton
Calgary
Natural Regions
Boreal
Canadian Shield
Foothills
Rocky Mountains
Female wolverines from camera traps
Lactating female wolverines from camera traps
Female wolverines from fur harvests
Registered traplines
Snow 1 - 2 yrs
Snow 3 - 4 yrs
Snow 5 - 7 yrs
N
0
150
300
km

From: Grizzle, Betty
To: Guinotte, John
Subject: Re: text for ssa
Date: Tuesday, January 30, 2018 10:09:26 AM
Attachments: image.png

From the National Assessment: I think this language could be used along with the text in the NOAA/CU report that Andrea sent ("We chose a 30-year average.."). Thoughts?

Future projections are most commonly summarized for a given future scenario (for example, RCP8.5 or 4.5) over a range of future climatological time periods (for example, temperature change in 2040–2079 or 2070–2099 relative to 1980–2009). While this approach has the advantage of developing projections for a specific time horizon, uncertainty in future projections is relatively high, incorporating both the uncertainty due to multiple scenarios as well as uncertainty regarding the response of the climate system to human emissions. These uncertainties increase the further out in time the projections go. Using these same transient, scenario-based simulations, however, it is possible to analyze the projected changes for a given global mean temperature (GMT) threshold by extracting a time slice (typically 20 years) centered around the point in time at which that change is reached (Figure 4.2).

On Tue, Jan 30, 2018 at 8:14 AM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Yes, this is a little confusing. She's talking about the 2055 projections only when she says the stuff in bold below. basically we covered the range of temp/precip projections for the 2055 data by selecting 5 models (red dots in fig 5-7). Doesn't have anything to do with projections beyond 2070.
>
> On Tue, Jan 30, 2018 at 9:09 AM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:
>
> > Thanks John. Do you know if the 4th National Assessment is available online (I haven't looked yet)? If we want to include this, we can talk about the figure relative to the uncertainty it presents, and/or describe by text what the figure means and cite the figure number.
> > Not sure I understand the connection to Figure 5-7 (plots of temp vs. precip, at least in my version of the document).
> > Can you explain her statement above and how this changes the uncertainty in the scenarios? **"But we used 34 models from each of those RCPs to select the scenarios. So we've reflected the range of both of them"**
> >
> > On Tue, Jan 30, 2018 at 6:05 AM, Guinotte, John <john_guinotte@fws.gov> wrote:
> >
> > > nice graphic, not sure we can use it.
> > >
> > > ---------- Forwarded message ----------
> > > From: **Andrea Ray - NOAA Federal** <andrea.ray@noaa.gov>
> > > Date: Mon, Jan 29, 2018 at 5:15 PM
> > > Subject: Re: text for ssa
> > > To: John Guinotte <john_guinotte@fws.gov>
> > > Cc: Joe Barsugli <joseph.barsugli@colorado.edu>, Steve Torbit <Stephen_Torbit@fws.gov>, Imtiaz Rangwala <imtiaz.rangwala@noaa.gov>

also, there might be something in the 4th National climate assessment, about what periods they used. WE might be able to say that we used a similar period.

Here's a graphic from the review draft in the fall -- by 2055, the two RCPs we used are beginning to separate. But we used 34 models from each of those RCPs to select the scenarios. So we've reflected the range of both of them

Andrea

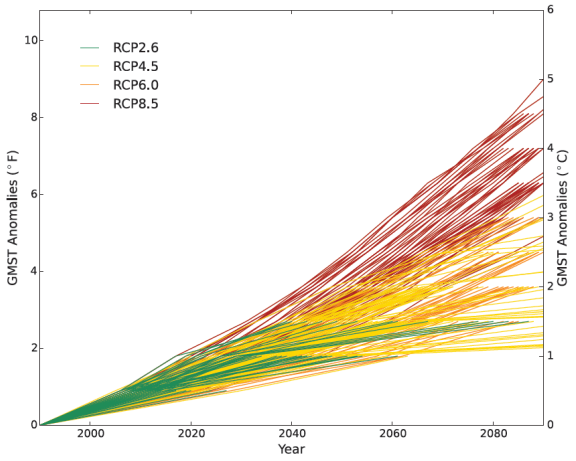

Figure 4.2: Global mean surface temperature anomalies (°F) relative to 1976–2005 for four RCP scenarios, 2.6 (green), 4.5 (yellow), 6.0 (orange), and 8.5 (red). Each line represents an individual simulation from the CMIP5 archive. Every RCP-based simulation with annual or monthly temperature outputs available was used here. The values shown here were calculated in 0.5°C increments; since not every simulation reaches the next 0.5°C increment before end of century, many lines terminate before 2100. (Figure source: adapted from Swain and Hayhoe 2015).

FINAL

On Mon, Jan 29, 2018 at 5:08 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

> John, Following up on our call a few minutes ago, I'll get back to you on whether Imtiaz can easily do scatter plots like Fig 5-7 for end of century.
>
> On why use a 30 year average period, We mention that we used a "thirty-year period, 2041-2070, centered on 2055" on the bottom of p.7. But we don't say why. Here's text you can use, and two places I could quickly find it described are p 60-61 in Lukas et al 2014 (cite: Lukas, J., Barsugli, J., Doesken, N., Rangwala, I., and K. Wolter (2014).

Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation. A Report for the Colorado Water Conservation Board. Western Water Assessment. 108 pp, available at: http://wwa.colorado.edu/climate/co2014report/). An article on 30 years as a "climate normal" is here, Arguez et al: https://www1.ncdc.noaa.gov/pub/data/normals/1981-2010/documentation/1981-2010-normals-overview.pdf

"We chose a 30-year averaging period for two reasons: First, a 30 year period is commonly used to characterize the background state of observed climate about which anomalous conditions and even extremes occur (Arguez, D, et al. 2012). We planned to compare projections to an observed period, so we chose a 30 year period around mid-century, with a similar intent to characterize the average state around the anomalies and extremes which are also in the climate models. GCM climate projections include simulated natural variability, to more clearly distinguish the the anthropogenic future change we need to compare to a future period that is long enough so that the natural variability is at least partly averaged out (Lukas et al, 2014). In this report, the projected changes described for 2055 are based on the projected conditions averaged over the period 2041–2070, and compared with the conditions for the historical period of 1971–2000 (except where otherwise noted). Because the climate continues to change throughout that future period, the changes described for 2055 are like a snapshot of a moving target."

If Imtiaz can do those plots, they'll likely be 2070-2099 or 2071-2100, so they'll follow on from the period we used.

A couple of other points from Lukas et al: "For the same emissions scenario, the climate models produce different projected future climate changes because (1) the representation of some key climate processes differs from model to model, and (2) the multi-decadal natural variability simulated by the models is still present in the 30-year average and is not synchronized from model to model." sidebar 3.1 gives more info if you're interested.

On Mon, Jan 29, 2018 at 3:01 PM, Andrea Ray - NOAA Federal <andrea.ray@noaa.gov> wrote:

> now copying Steve and Joe
>
> John -- easier if you give me a call, 303-497-6434. but here's a quick response: We represented a large part of the range of uncertainty (shown in Fig 5-7) in the selection of the 5 scenarios, so our results reflect that for the 30 year period averaged around 2055. the range of the 5 results we present *is* the extension of that to the uncertainty of temp/precip changes on snowpack in this time period.
>
> I thought mid-century was selected more b/c of FWS' idea of forseeable future and time/resources (including computational), and less about uncertainty among emissions. Uncertainty among the two RCP's (4.5 and 8.5) is considered in that both are included in the GCM output shown in Fig 5-7, we didn't distinguish between them in selecting the 5 scenarios. by "mid-century" the three commonly analyzed RCPs are just beginning to diverge. We could have chosen the lower one commonly analyzed (2.5? 2.6?) but again, we needed to make some choices due to resources, and even later, choices in what was presented to avoid cognitive overload.
>
> We *might* be able to quickly produce a version of Fig 5-7 that shows the last 30 years of the century (~2071-2100) of you wanted a comparison. I think the models end in 2100 or maybe CMIP5 ends in 2110.

I know its been argued for other SSA's that FWS is ignoring end of the century impacts, but you gotta get thru mid-century first has always been the response, I think.

as for uncertainty across the RCPs, here's text from the USGCRP resilience toolkit/climate explorer that sums it up, and elswhere I've seen it said that they're not forecasting which is more likely: "According to the Intergovernmental Panel on Climate Change, the Representative Concentration Pathways (RCPs) should not be considered policy-prescriptive because they were developed to support scientific research on various possible climate change futures, without making any judgment as to their desirability or probability. These scenarios reflect choices individuals and society will make over coming decades, so there is uncertainty regarding the actual year-to-year change in greenhouse gases. RCPs are not considered to be forecasts, nor do they represent absolute bounds on the realm of possibility. While they all represent plausible scenarios for the future, none of the RCPs are intended to serve as predictions, best guesses, most likely, or more plausible pathways than the others.

In 2015, at the United Nations Framework on Climate Change (UNFCCC) 21st Annual Conference of the Parties (COP21) in Paris, many nations agreed to pursue efforts to limit global average temperature increase to 1.5°C above pre-industrial levels. Climate modelers suggest this is only possible if we strive to reach RCP 2.6, a pathway that calls for immediate action to achieve drastic reductions in greenhouse gas emissions."

Andrea

On Mon, Jan 29, 2018 at 2:20 PM, Guinotte, John <john_guinotte@fws.gov> wrote:

> Hi Andrea,
>
> We had some questions about why 2055 was chosen as the end point for the snow projections. We explained it was a combination of computational (time/money), uncertainty of emissions 2050-2100, and FWS time horizons.
>
> Below is what is in your report. Do you have any text or citations specifically about the uncertainty of emissions 2050-2100 and by extension the uncertainty of temp/precip changes on snowpack in this time period?
>
> Betty needs to add some text to this section in the SSA.
>
> thanks John
>
> "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. 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. "
>
> John Guinotte
> Spatial Ecologist
> 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

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From: Grizzle, Betty
To: John Guinotte
Subject: new paper
Date: Tuesday, January 30, 2018 10:59:35 AM
Attachments: Aronsson_2018_EJWR_breeding dispersal wolverines.pdf

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see attached

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ORIGINAL ARTICLE

Female breeding dispersal in wolverines, a solitary carnivore with high territorial fidelity

Malin Aronsson[1] · Jens Persson[1]

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Abstract
Individuals' fidelity to an area provides insight into the stability of the spatial and temporal organisation of animals. Territorial fidelity is often influenced by reproductive success, age, the dispersion and predictability of resources, and intraspecific competition. We examined between-year territorial fidelity in wolverines (*Gulo gulo*), using location data from 47 individuals collected during 1993–2013 in northern Sweden, to assess the stability of the spatial organisation of this solitary carnivore. For females, we also determined residency status from 1 year to the next. The study population is characterized by a stable distribution of resident individuals, with both males and females showing higher fidelity at the total territory level compared to more intensively used core areas. In 86% of the yearly residency status estimates ($n = 122$), the female remained stationary. In the remaining 14% of the cases, females either vacated their territory (8% of residency statuses), or expanded into a neighbouring territory (6% of residency statuses). We documented six cases of breeding dispersal, representing one of the few known cases of breeding dispersal in long-lived large mammals. We suggest that this high territorial fidelity is enabled by wolverines' caching and scavenging behaviours, which buffer the unpredictable and large spatiotemporal variation in resource abundance in this low-productivity area. Breeding dispersal may occur due to competition for high-quality territories in this saturated population, where females are forced to abandon their territory by competitors or bequeath territories to offspring. This study further highlights the complexity of the social and spatial dynamics for solitary carnivores.

Keywords Floater · Social system · Territoriality · Space use · Home range

Introduction

Individuals' fidelity to an area reflects the stability of the spatial organisation of animals (Switzer 1993; Adams 2001), and interannual variation in space use patterns can influence both population structure and dynamics (Terraube et al. 2015; Uboni et al. 2015). Home range fidelity is generally associated to dispersion, predictability and depletion rate of resources, as well as reproductive success, age and competition (Moorhouse and Macdonald 2005, Kirk et al. 2008; Edwards et al. 2009; Terraube et al. 2015). In solitary territorial species, space use is primarily driven by resource competition over access to food or the opposite sex (Sandell 1989; Aronsson et al. 2016). Territorial fidelity is beneficial because it allows individuals to become familiar with resources in an area, enhancing survival and reproductive success (Switzer 1993; Kirk et al. 2008). Furthermore, for species that aggressively defend territories, movement into unfamiliar areas increases mortality risk (Isbell et al. 1990; Stamps and Krishnan 2001). Despite this, some individuals may vacate an established territory and perform breeding dispersal, defined as the permanent movement of individuals, which have reproduced, between subsequent breeding sites (Greenwood 1980). Breeding dispersal has mostly been documented in birds (e.g. Greenwood and Harvey 1982; Terraube et al. 2015), and although it occurs in mammals (e.g. Berteaux and Boutin 2000; Jerina et al. 2014), it has rarely been documented in larger long-lived mammals (Jerina et al. 2014).

Breeding dispersal may be a consequence of reproductive failure, mate loss or an attempt to acquire a higher-quality territory (Wauters et al. 1995; Forero et al. 1999; Pasinelli et al. 2007). It can also result from intraspecific competition,

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when resident individuals are evicted or disperse to take over a new territory (Pasinelli et al. 2007; Mattisson et al. 2013). Breeding dispersal has also been considered as a form of parental investment when the territory is bequeathed to an offspring to enhance offspring survival and reproductive success (Lindström 1986; Berteaux and Boutin 2000). Moreover, some individuals that vacate a territory may become floaters (Smith 1978), forming a reservoir of individuals that can occupy vacant territories when they become available and thus influence population dynamics (Penteriani et al. 2011).

Long-term, individual-based ecological studies are essential to obtain information about between-year variation in space use and spatial organisation (Pelton and van Manen 1996; Clutton-Brock and Sheldon 2010). In this study, we use location data from 47 adult wolverines *(Gulo gulo)* monitored during 20 years (1993–2013) in northern Sweden. The wolverine is a solitary carnivore with a polygamous mating system (Hedmark et al. 2007), intrasexual territoriality (Persson et al. 2010; Inman et al. 2012a) and male-biased natal dispersal (Vangen et al. 2001; Flagstad et al. 2004). Wolverines occupy arctic tundra and boreal forest zones of Eurasia and North America (Copeland et al. 2010) and are adapted to harsh environmental conditions with low productivity by being an opportunistic generalist predator and scavenger that caches food for later use (Inman et al. 2012b; Mattisson et al. 2016). Wolverine female reproductive success is influenced by winter food availability as well as age-related reproductive costs, where the probability to successfully reproduce 2 years in a row declines with age (Persson 2005; Rauset et al. 2015). In northern Sweden, wolverines primarily feed on migratory, semi-domestic reindeer *(Rangifer tarandus)* (Mattisson et al. 2011; Mattisson et al. 2016) managed by indigenous Sámi reindeer herding communities (Persson et al. 2009).

The aim of this study was to assess the stability of wolverine spatial organisation by examining individual territorial fidelity from 1 year to the next. To account for the possibility that factors determining space use differ between intensively used areas compared to the total territory (Aronsson et al. 2016), we measured site fidelity at two spatial scales: (i) total territory and (ii) core area. We also examined between-year changes in female residency status, i.e. did they remain resident or did they permanently leave an established territory. Breeding dispersal may occur to enhance future reproductive success (Wauters et al. 1995; Pasinelli et al. 2007), or as a consequence of decreased reproductive potential with age (Berteaux and Boutin 2000). Therefore, we considered the influence of previous reproductive performance and age on fidelity for wolverine females. Territorial fidelity is generally predicted to be low in unpredictable environments with low and variable resource abundance (Switzer 1993; Maher and Lott 2000; Moorhouse and Macdonald 2005; Edwards et al. 2009). Still, we predict that wolverines exhibit high territorial fidelity because of their food-caching behaviour that buffers temporal fluctuations in food availability and thus, promotes territoriality and site fidelity even when resources in the environment are unpredictable (Tye 1986; Maher and Lott 2000; Eide et al. 2004).

Material and methods

Study area and animal capture

The study was carried out in a 7000-km^2 area in and around Sarek National Park in northern Sweden (Kvikkjokk 67° 00′ N, 17° 40′ E). The climate is continental with cold winters (−13 °C in January) and medium warm summers (14 °C in July) and the ground is usually snow covered from November to May. The area is characterized by deep valleys, glaciers and high alpine plateaus with peaks up to 2000 m a.s.l.. Mountain birch (*Betula pubescens*) forms the tree line at 600–700 m a.s.l. (for a detailed description of the study area, see Rauset et al. (2015)). The area consists of important spring and summer grazing pastures for semi-domestic reindeer. During winter, most reindeers are moved to winter grazing grounds to the east of the study area (Danell et al. 2006), resulting in a large temporal and spatial variation in reindeer density.

We used wolverine location and reproductive data collected from 1993 to 2013. Wolverines were captured and immobilized using ethics-approved handling protocols (see Persson et al. 2010). Animals were fitted with VHF collars (1993–1995: MOD315, Telonics. USA), intraperitoneal VHF transmitters (1996–2013: IMP/210/L, IMP/300/L or IMP/400/L, Telonics. USA) or GPS collars (2003–2006: Televilt PosrecTM C300, TVP positioning AB, Sweden; 2008–2013 GPS plus mini, Vectronics Aerospace, Germany). Female reproductive status and location of natal den sites (hereafter dens) was confirmed using a combination of radio tracking, snow tracking and visual observations (see Persson et al. 2006). Reproductions were classified as successful if the cubs survived until June (3–4 months old) and unsuccessful if the female showed denning behaviour but did not have cubs in June or did not reproduce. We aimed to capture and equip all cubs with intraperitoneal transmitters and monitor them throughout their life; consequently, a large part of the individuals were of known age.

Spatial analysis

Only resident animals ≥ 3 years old were included in the analysis because wolverines in the study population rarely breed prior to 3 years (Rauset et al. 2015). We estimated annual space use for each individual as the annual utilization distribution (UD) using the fixed-kernel method with the reference bandwidth (Worton 1989) within the "adehabitatHR" package

(Calenge 2006) for R (R Core Team 2014). Years were defined as calendar years. The number of locations acquired per individual and year varied extensively during the study period as telemetry technology developed. To reduce biases from different sampling frequencies (Börger et al. 2006), we randomly sampled one location/day for individuals with multiple daily locations. We only calculated UDs for individuals monitored for ≥ 6 months during ≥ 2 years with ≥ 20 yearly locations (Persson et al. 2010; Rauset et al. 2015); in this study, mean (±SE) of annual locations per individual was 146 ± 15. From the UD, a specific proportion (isopleth) of the animal's use of space can be retained; we used the 90% isopleth as the annual territory and the 50% isopleth as the core area (Rauset et al. 2015). We quantified fidelity by estimating the overlap between annual UDs using the volume of intersection index (VI) for both the territory and core area levels (Millspaugh et al. 2004). VI values range from 0 (no overlap) to 1 (identical UDs). We calculated VI for subsequent years, or year t and $t + 2$ if location data from year $t + 1$ was missing (5 out of 62 VI estimates). Because annual territory sizes do not differ for females with or without cubs (Persson et al. 2010), we calculated VI between years independent of female reproductive status. During part of the study period (i.e. 1999–2004), the focus of the project was to monitor yearly survival, reproductive success and denning behaviour of the resident females within the study area. Hence, females were intensively monitored during the denning period (Feb–May; cf. Rauset et al. 2015) while there are relatively infrequent locations from ≥ 6 months/year for these females. Consequently, for females, we also used distances between den sites as a measurement of fidelity. We calculated distances between den sites in subsequent years or year t and $t + 2$ if the female did not reproduce in year $t + 1$ (22 out of 90 den distances). In total, we obtained 129 interannual fidelity estimates for 5 males (7 VI) monitored for an average of 2.6 years ± 0.6 SE (range 2–5) and 42 females (55 VI and 90 den distances) monitored for 4.5 ± 0.4 years (range 2–11).

The closest distance between neighbouring females' den sites used in the same year was 4.6 km (Aronsson 2017). Consequently, we considered females to have conducted breeding dispersal if the VI estimate or locations showed that she moved from her territory, she reproduced again > 4.5 km from her previous den site and her previous territory was occupied by a new individual. Furthermore, females that did not reproduce after moving were considered to have re-established when subsequent space use pattern showed that they became stationary in a new area. We used reproductive success to obtain a measurement of territory quality (Garshelis 2000; Stephens et al. 2015). For this, we used the locations of all den sites for collared individuals and den sites from the national monitoring program (i.e. since 1996, wolverine den sites have been recorded in the Swedish national monitoring program for large carnivores, see Aronsson and Persson (2016)). For each female, we calculated the total number of den sites that had been documented within 2.1 km of her current den site (i.e. 2.1 km is the mean distance between consecutive den sites for stationary females in this study area, see "Results" section) or centre point of locations for females that did not reproduce ($n = 2$). We calculated local denning frequency for each area and year (local denning frequency (LDF)) as the total number of den sites divided by the time the area had been monitored (i.e. 18 years; 1996–2013). Because this measurement is based on successful reproductions, an important fitness component, within the territory, we argue that this is a good measurement of territory quality.

Statistical analysis

We used generalized linear mixed models with a beta error distribution in the glmmADMB package (Skaug et al. 2014) in R with VI as the response variable. Individual identity was fitted as a random effect in all models to account for repeated measurements. We used isopleth level as a covariate to test if fidelity differed between territory and core area level. Due to the low sample size for males ($n = 7$), we did not conduct any statistical analysis for differences between sexes. For females, we included age and reproductive success in year t (two-level factor; successful and unsuccessful reproduction) as covariates. Candidate models were compared using the sample size-corrected Akaike Information Criterion (AIC_c) and AIC_c weights (w_i). Means are presented with standard errors unless otherwise stated.

Results

Female and male wolverines had similar overlap (volume of intersection; VI) patterns and showed higher between-year fidelity for the annual territory compared to core areas (Fig. 1; 0.60 ± 0.03 vs. 0.44 ± 0.03 for females, and 0.55 ± 0.03 vs. 0.42 ± 0.1 for males, respectively; improvement in AIC_c for overlap model including isopleth level [i.e. 90 and 50%] compared to model without: females = 18 and males = 3.2). We determined female residency status from 1 year to the next in 122 territories, and in 105 (86%) of these, the female remained stationary; hence, wolverine females showed high territorial fidelity. Eight of the 42 females vacated an established territory once ($n = 7$) or twice ($n = 1$), resulting in a total of nine occasions when a resident female moved from her territory (Table 1, Fig. 2). These moving females re-established in a new territory in seven of these nine cases (Table 1). In all but one of these, the female reproduced in the new territory and thus conducted breeding dispersal (Figs. 2 and 3). Floating behaviour was exhibited by the two females that did not re-establish and one breeding dispersal female before she re-established (Table 1, Fig. 2). Five

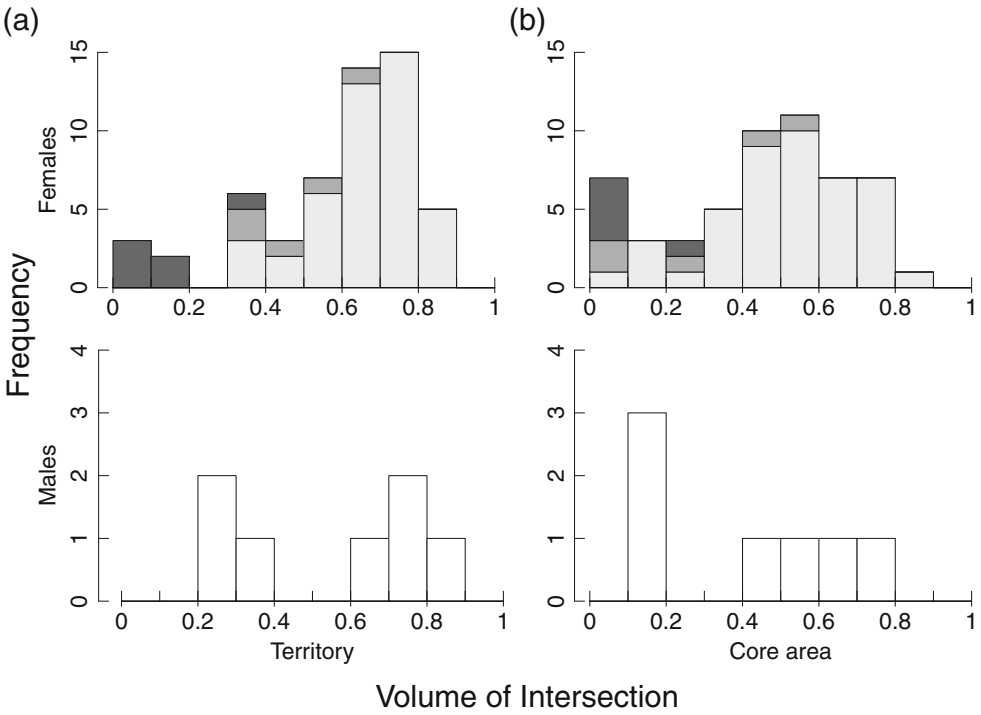

Fig. 1 Frequency distributions of volume of intersection (VI) values showing: territory (a) and core area (b) fidelity for female and male wolverines in northern Sweden during 1993–2013. VI represents how similar space use was between years (i.e. VI value of 0 represents no overlap and VI represents identical space use). Females are divided depending on residency status; stationary (light grey), expanding (medium grey) and breeding dispersing or floating (dark grey)

additional females expanded their territory once ($n = 3$) or twice ($n = 2$) into a neighbouring territory after the neighbouring female died, resulting in reduced overlap. Thus, they subsequently occupied an area previously occupied by two or three females (hereafter called "expanding;" Fig. 4(a, c)).

The mean distance between consecutive natal den sites for stationary females (excluding expanding females) was 2.1 ± 0.2 km ($n = 79$), for breeding dispersing females 9.8 ± 0.8 km ($n = 6$) and for expanding females 9.1 ± 2.3 ($n = 5$) (Fig. 5). Mean local denning frequency (LDF) for stationary females was 0.21 ± 0.02. To obtain a relative quality estimate for territories that were vacated in relation to where females re-established, we used the difference in LDF for these sites from the mean for stationary females (Table 1). Of the seven females that re-established, there was no consistent pattern in how their LDF changed from before and after re-establishment: the LDF of three females improved; for three females, it diminished; and for one female, LDF did not change. However, only two females re-established in a territory with better quality than the mean for stationary females (Table 1). The mean territory and core area VI for stationary females was

Table 1 Individual females that moved from an established territory during the study period (1993–2013), total time they were monitored, age when moving, residency status (floater (F), breeding dispersal (BD) or re-established (R)), reproductive performance before and after move and time from move to first reproduction in second territory. Relative local denning frequency (LDF) shows the difference in LDF for the first and second territory from the mean LDF for stationary females (0.21 ± 0.022)

ID	Years monitored	Age when moving	Residency status	Reproductive performance before moving	Reproduction in new territory	Time (years)	Relative LDF first territory	Relative LDF second territory
F9530*	5	4	F[a]	Success		3*	0.35	
F9530	"	5	BD[a]		Yes			−0.15
F9530	"	6	BD	Fail	Yes	1	−0.15	−0.04
F9646	2	7	BD	Fail	Yes	1	−0.09	0.02
F9870	5	6	BD	Success	Yes	1	0.02	−0.15
F03167	3	?	BD	Success	Yes	2	−0.15	0.02
F05202	3	?	BD	Success	Yes	2	−0.15	−0.15
F9525	7	9	R	Success	No	–	0.02	−0.21
F9312	2	6	F	Success	–	–	−0.15	–
F9315	2	4	F	Success	–	–	0.35	–

[a] F9530 showed were classified as floater after more before establishing and reproducing in a new territory (see Fig. 2)

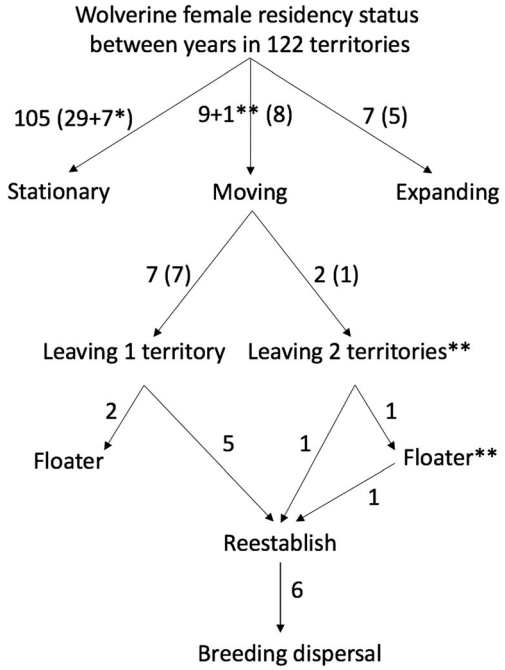

Fig. 2 Summary of residency status from 1 year to the next in 122 territories for a total of 42 adult wolverine females monitored for ≥ 2 years during 1993–2013 in northern Sweden. Next to each arrow are indicated number of territories and (number of females). Seven females* were stationary before and/or after moving/expanding, hence these are included in both the stationary and moving female categories. One female moved from two territories during the study period, and before re-establishing the first time, she was defined as floater during 1 year**. Consequently, although only nine territories were vacated during the study period residency status were classified as moving in (9 + 1)** occasions (+ 1 due to floating followed by breeding dispersal in one territory)

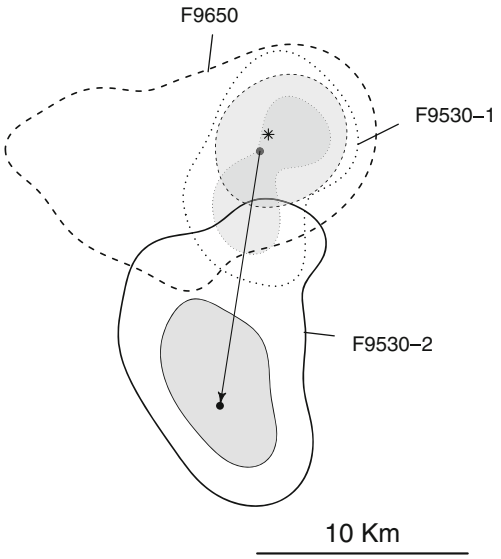

Fig. 3 Breeding dispersal by wolverine female F9530. F9530 reproduced successfully in a territory (F9530–1; dotted line) in year 1. She subsequently left her first territory and re-established and reproduced in a new territory (F9530–2; solid line) in year 2. Den sites of F9530 are represented by filled circle (•); arrow shows dispersal direction. Simultaneously, F9650 established a territory (dashed line) and reproduced (✳) in the former area of F9530. Core areas are shown in grey with the same outline as corresponding territory

0.66 ± 0.02 and 0.52 ± 0.03, respectively, and VI for moving and expanding females was 0.21 ± 0.05 and 0.09 ± 0.03, respectively (Fig. 1). By including all females in the analysis, we found that both territory and core are fidelity was negatively affected by previous reproductive performance (i.e. females that successfully reproduced the first year included in the overlap measurement had lower VI values than females that did not reproduce the first year; Table 2a). However, excluding females that dispersed or showed floating behaviour from the analysis removed this effect of reproductive success on fidelity (Table 2b). There was no effect of female age on territory or core area overlap (Table 2c).

Discussion

As predicted, wolverines showed high territorial fidelity, as females remained stationary in their territory between years in 86% of the residency status estimates ($n = 122$). This suggests that the population is characterized by a stable spatial distribution of resident individuals. However, we found six occasions of breeding dispersal, representing the first documentation of wolverine female breeding dispersal, and one of the few in long-lived, large mammals (Jerina et al. 2014). This behaviour creates infrequent exceptions to the stable spatial organisation and adds important knowledge regarding the complexity of spacing behaviour in large mammals in general and wolverines in particular.

Territorial fidelity is predicted to be low in habitats where food resources are low, variable and unpredictable and deplete fast (Wauters et al. 1995; Kirk et al. 2008; Edwards et al. 2009). This corresponds to the characterization of wolverine habitat in general (Persson 2005; Inman et al. 2012b), and particularly in northern Scandinavia where wolverines are highly dependent on migrating reindeer. Reindeer movements are influenced by seasonal snow conditions and Sámi reindeer herding practices (Persson 2005). Thus, prey availability is unpredictable and varies both within and among years, resulting in large territory sizes with high individual variation (Persson et al. 2010). However, food caching is an integral part of wolverine biology (Inman et al. 2012b; Mattisson et al. 2016), which buffers against depletion, unpredictability and variation in prey availability. As a consequence, food caching can be an important factor promoting the observed high territorial fidelity in wolverines despite the unpredictable environment (Tye 1986; Eide et al. 2004). In addition, occurrence of more efficient predators, such as the Eurasian lynx (*Lynx lynx*), provides wolverines with a relatively consistent availability of carcasses for direct consumption and caching (Mattisson et al. 2011). This decreases the variation and

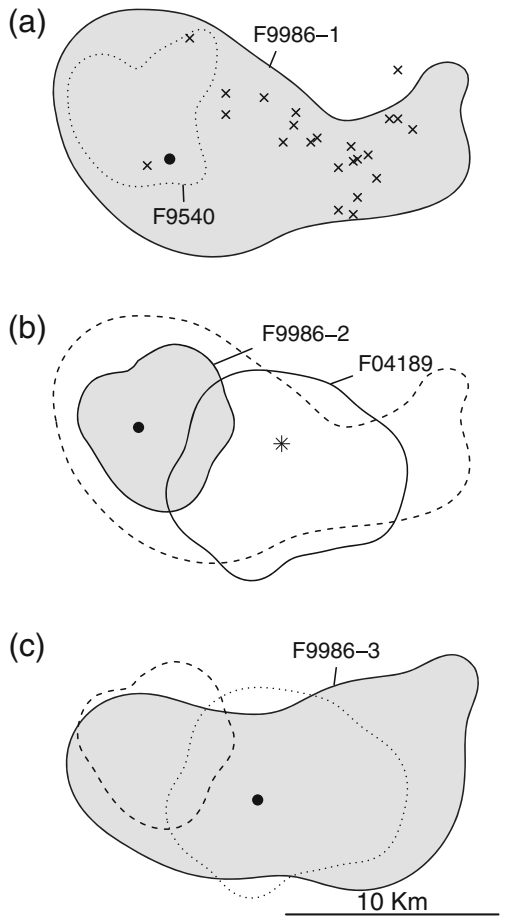

Fig. 4 Territory expansion and split by wolverine female F9986. (a) F9986 expanded her territory after the death of the neighbouring female F9540 in 2003; telemetry locations for F9986 before expansion are represented by crosses (x). Consequently, the new territory of F9986 (F9986–1; grey) covers an area previously containing two female territories. Filled circle (•) represents the den site of F9986 in 2004 where she gave birth to a female offspring (F04189). (b) In 2007, the area is split between mother (F9986–2; grey) and daughter (F04189); they are both reproducing in 2008. Filled circle (•) represents den site of F9986 and star (✳) den site of F4189. (c) After the death of F04189 (lethal control June 2008), F9986 expands again (F9986–3; grey). Filled circle (•) represents the den site of F9986 in 2009, and she is poached later that same year

unpredictability in food availability and enhances wolverine reproductive success (Rauset et al. 2015; Mattisson et al. 2016). Our study area is largely saturated with wolverine territories, resulting in few available areas to settle (Persson et al. 2010; Aronsson 2017). Territories are maintained by patrolling in combination with marking and aggressive behaviour during encounters (Persson et al. 2003, 2009, 2010), and both subadult and adult wolverines are killed by conspecifics (Krebs et al. 2004; Persson et al. 2009). Consequently, the high potential cost associated with exploratory movements might contribute to the high territorial fidelity. Furthermore, the area is characterized by distinct features, such as mountains, deep valleys and rivers, which form natural territory borders that might facilitate territorial defence (Eason et al. 1999). This could confine individuals to established territories and thus further promote territorial stability in time and space.

Fidelity was lower at the core area level than at the territory level for both males and females, suggesting that it is critical to maintain the outer territory boundary to secure long-term resources (Aronsson et al. 2016). In contrast, the extent of the most used area within the territory (i.e. core area) presumably varies among years because of spatial fluctuations in key resources. For instance, the spatial distribution of live reindeer and carcasses could greatly vary within and among years due to the nomadic behaviour of reindeer (Mattisson et al. 2016). In addition, female core areas could vary among years depending on their reproductive status and interannual variation in den site location. Male wolverines have territories that are several times larger than females (Persson et al. 2010). Larger areas are more difficult to defend from intrusion, which could decrease territorial fidelity (Jetz et al. 2004). However, both males and females in our study showed high mean overlap values between years. For males, this could be a result of our low sample size (i.e. five unique individuals). Of the monitored males, three individuals showed lower overlap than the other two (Fig. 1). One male retreated from parts of his territory when a neighbouring male moved in, indicating that the former might have been actively pushed away by the latter (i.e. resulting in low overlap values for both males). The third male appeared to be abandoning his territory at the end of his monitoring period.

Although wolverine females generally exhibit high territorial fidelity, we found that 8% of territories were vacated between years and 6% of territories were expanded (Fig. 2). If insufficient resources were the main reason for females to vacate a territory, we would expect them to have low reproductive success prior to moving (Pasinelli et al. 2007). Yet, on seven of nine occasions, the moving females reproduced successfully the last year monitored before vacating her territory (Table 1), which suggests that reproductive failure is not the main factor causing established females to abandon a territory. That most females successfully reproduced before vacating their territory also explains the overall negative effect of reproductive success on both territory and core area fidelity (i.e. lower VI for females that successfully reproduced; Table 2a), as this effect was considerably diminished when dispersing, expanding and floating females were excluded (Table 2b). Five of the seven females that re-established reproduced the first year in the new territory. Considering the high reproductive frequency before and after dispersal (78 and 71%, respectively) compared to the average reproductive frequency in the population (53%; Persson et al. 2006) suggests that most females that moved were in prime condition (Rauset et al. 2015) (Table 1). Thus, possible reasons for their dispersal are to obtain a territory of higher quality (cf. Wauters et al. 1995). Our measure of relative quality of territories that were vacated

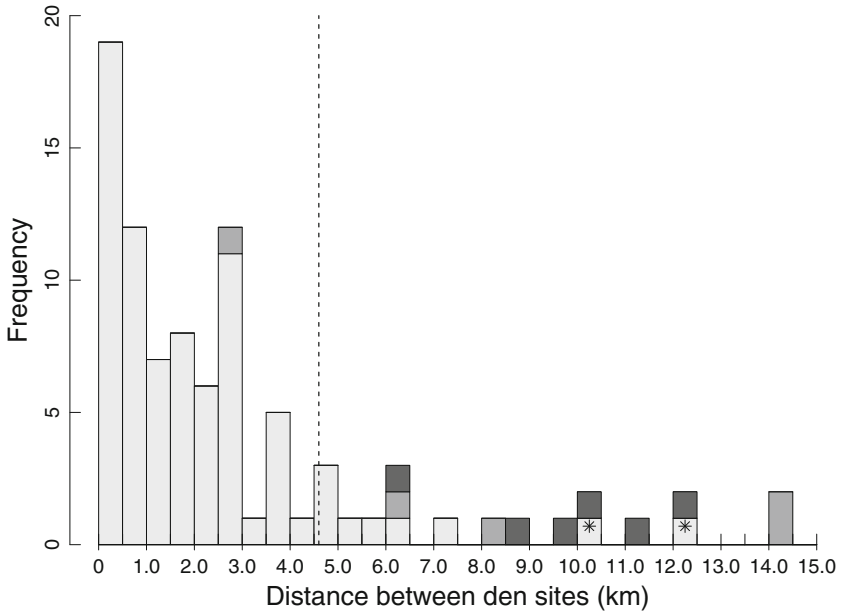

Fig. 5 Frequency distribution of distances (km; $n = 90$) between yearly den sites for wolverine females in northern Sweden during 1993–2013. Females are divided into stationary ($n = 79$; light grey), expanding ($n = 5$; medium grey) and breeding dispersing ($n = 6$; dark grey). One female repeatedly used den sites at opposite ends of a large and elongated territory resulting in two large den distances (indicated by ✳). By removing these distances, the mean (±SE) distance between den sites for stationary females was reduced to 1.8 ± 0.2 km ($n = 77$), compared to 2.1 ± 0.2 km ($n = 79$). The dashed line indicates the closest distance between neighbouring females den sites used the same year within the study area during the study period (Aronsson 2017)

and re-established, respectively, showed an inconsistent pattern (Table 1). If territorial abandonment and re-establishments is the result of a takeover, the inconsistent pattern in LDF is expected, as the focal female could be either an intruding or evicted individual, which was unknown to us in most cases. The latter is supported by the fact that three females that abandoned a territory subsequently exhibited floating behaviour, suggesting that they did not leave because they had the opportunity to obtain a territory of higher quality. Instead, it is likely that they were forced to abandon their territory, possibly because their competitive ability had decreased (Smith 1978), especially considering that two of these females abandoned an area with very high LDF value. Consequently, abandonment of established territories could be related a combination of searching for better territories and social interactions caused by competition for territories.

Table 2 Candidate models relating wolverine female interannual territory and core area volume of intersection (VI) to reproductive success (Repro; difference of successful reproduction from unsuccessful reproduction) for all VI ($n = 55$) (a), only VI for stationary females (i.e. excluding breeding dispersal, expanding and floating; $n = 46$) (b), and age for females with known age ($n = 21$) (c). Models are ranked based on sample size-corrected AIC (AIC_c), difference in AIC_c relative to the highest-ranked model (ΔAIC_c) and AIC_c weights (w_i)

	VI territory level		VI core area level	
Model	ΔAIC_c	w_i	AIC_c	w_i
(a)				
Repro[a]	0.00	0.78	0.00	0.86
Null model	2.54	0.22	3.56	0.14
(b)				
Repro[b]	0.00	0.5	0.98	0.38
Null model	0.01	0.5	0.00	0.62
(c)				
Null model	0.0	0.82	0.00	0.82
Age	3.09	0.18	3.09	0.18

[a] Model predictions territory level: VI = 0.53 for females that successfully reproduced the first year included in overlap estimate, VI = 0.64 for females that did not reproduce

[b] Model prediction territory level: VI = 0.64 for females that successfully reproduced the first year included in overlap estimate, VI = 0.69 for females that did not reproduce

Another potential explanation for abandonment of territories by adult females is parental investment (Lindström 1986; Berteaux and Boutin 2000). Wolverine natal dispersal pattern is male-biased, where females tend to remain close their natal territory and age at natal dispersal varies more among females than males (Vangen et al. 2001). Young, inexperienced animals that have not settled are often subject to higher mortality than resident animals (Waser 1996; Blankenship et al. 2006). Juvenile wolverine females are killed when they explore areas outside their natal territory after independence, presumably by territorial neighbours (Persson et al. 2003), suggesting that territorial competition can be fierce for young inexperienced females in this saturated area. Hence, parental investment could explain why females vacate

established territories after a successful reproduction, i.e. they bequeath their territory to a daughter. One of the moving females (F9525) was replaced by her young daughter. Although we did not find any overall effect of age on female fidelity to territory or core area (Table 2c), F9525 was older than all other moving females, and although she was monitored for 3 years after re-establishment, she did not reproduce again (Table 1). Furthermore, females that expanded their territory subsequently covered an area that previously contained two reproducing females, indicating that there are resources for > 1 female. This could be to secure an area that can later be bequeathed to a female offspring (c.f. budding dispersal in social species; Gardner and West 2006; Nichols et al. 2012). One female (F9986) maintained her expanded territory for 4 years before her adult daughter (F04189) gained possession of half the area. F9986 regained the area again after her daughter died (Fig. 4). In another observation, one subadult daughter established in part of her mother's expanded territory although we could not determine her residency status because she died in an avalanche before first reproduction (27 months of age). The remaining three expanding females did not reproduce ($n = 1$) or only produced male offspring between the expansion and their death or end of the study period ($n = 2$, monitored for 2 and 5 years following territory expansion).

To fully understand the causes and consequences of breeding dispersal in wolverine females requires detailed location data to determine the timing and interactions leading up to the dispersal event (i.e. if it is a result of an aggressive interaction). In addition, concurrent data are needed on habitat quality and the reproductive success of stationary versus dispersing adult females. Due to the low reproductive rate of wolverines (Persson et al. 2006) and the rarity of this behaviour, we could not fully disentangle the potential causes despite 20 years of individual-based data.

We suggest that the high territorial fidelity in wolverines in this study is a result of intrasexual territoriality in a saturated population with intense competition for high-quality territories. This is facilitated by scavenging and caching, which increase predictability in resource abundance, decrease depletion rate and create a valuable resource (cache sites) to defend. In addition, distinct terrain features may assist territorial defence, which promote territorial stability in time and space. Our results concur with the findings of Bischof et al. (2016) who investigated spatiotemporal patterns in wolverines using non-invasive genetic sampling to reveal that wolverines tended to stay in the same general area from year to year. We suggest that the ultimate driver of the observed breeding dispersal is high competition for territories, translated through social interactions between competitors (aggressive forcing) and mother-offspring (territory bequeathal). This demonstration of the complexity in carnivore spatial behaviour provides a stronger foundation for science-based management of wolverine populations that are subject to strong conservation and management concerns in many parts of its distribution (Sæther et al. 2005; Persson et al. 2009; Inman et al. 2013). Our results have implications for the design and interpretation of population monitoring schemes (Ellis et al. 2014; Aronsson and Persson 2016), harvest strategies (Sæther et al. 2005) and conflict mitigation (Persson et al. 2015; Aronsson and Persson 2016).

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Wauters LA, Lens L, Dhondt AA (1995) Variation in territory fidelity and territory shift among red squirrel, Sciurus vulgaris, females. Anim Behav 49:187–193

Worton BJ (1989) Kernel methods for estimating the utilization distribution in home range studies. Ecology 70(1):164–168. https://doi.org/10.2307/1938423

From: Guinotte, John
To: Grizzle, Betty
Cc: Stephen Torbit
Subject: Re: Draft text
Date: Tuesday, January 30, 2018 2:13:39 PM

Looks pretty good Betty. The Luce paragraph is the most useful in my opinion. Not sure about the Switzerland example. There should be a citation for the Rockies showing a similar relationship. I thought I saw one in either the NOAA report or the MSU climate study. I'll read your latest one now.

John Guinotte
Spatial Ecologist
Ecological Services
U.S. Fish and Wildlife Service
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134 Union Blvd., Lakewood, CO 80228
303-236-4264
john_guinotte@fws.gov

On Mon, Jan 29, 2018 at 3:35 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> John and Steve - This is still very much a draft, but I wanted to get your input, and also have you pull a little more from Ray et al. regarding their analysis of snow persistence related to topography, slope. aspect, etc. (see blue highlighted sentence at end).
>
> Let me know if you want to discuss on a call (I am teleworking tomorrow).
> Thanks,
> 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: Guinotte, John
To: Grizzle, Betty
Subject: Re: Excerpts from USFS Northern Rocky Mtns climate assessment
Date: Tuesday, January 30, 2018 2:17:06 PM

I would go ahead and add it.

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On Tue, Jan 30, 2018 at 12:56 PM, Grizzle, Betty <betty_grizzle@fws.gov> wrote:

> Here is another section related to snowpack modeling that I sent earlier to Justin. The second paragraph could be included with what I sent you yesterday.
>
> ---------- Forwarded message ----------
> From: **Grizzle, Betty** <betty_grizzle@fws.gov>
> Date: Fri, Jan 19, 2018 at 1:41 PM
> Subject: Excerpts from USFS Northern Rocky Mtns climate assessment
> To: "Shoemaker, Justin" <justin_shoemaker@fws.gov>
>
> See attached.
>
> --
>
> Betty J. Grizzle, D.Env.
> Fish and Wildlife Biologist
> U.S. Fish and Wildlife Service
> Carlsbad Fish and Wildlife Office
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> Carlsbad, CA 92008
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>
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From: Guinotte, John
To: Betty Grizzle; Stephen Torbit; Shoemaker, Justin
Subject: female home range and RMNP
Date: Tuesday, January 30, 2018 3:06:26 PM
Attachments: romo_range_female.jpg

Hi, See map. This is what I was talking about in the rec meeting re small number of females that could 'fit' in ROMO. This is rough, but gives you an idea. For the ROMO snow study area, you might be able to get 5 females, probably closer to 4. If you were only looking to reintroduce in RMNP, you would be hard pressed to reintroduce more than 2 females.

Betty and I spoke about female home range size for romo. She recommended 303 km2 for females and 797 km2 for males. That would equate to only one male in RMNP.

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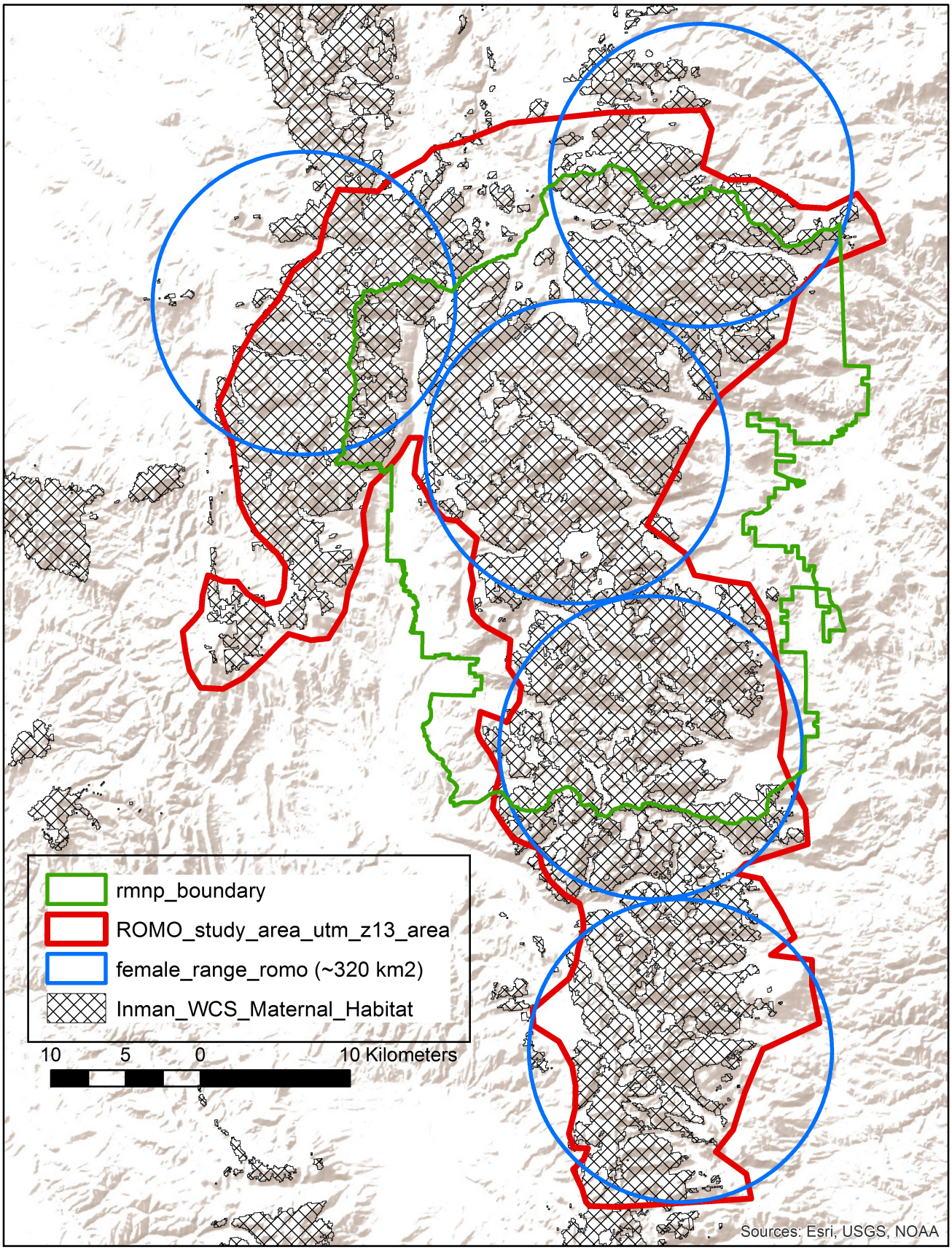
rmnp_boundary
ROMO_study_area_utm_z13_area
female_range_romo (~320 km2)
Inman_WCS_Maternal_Habitat
10 5 0 10 Kilometers
Sources: Esri, USGS, NOAA

From: Grizzle, Betty
To: bobinman@mt.gov
Subject: Home range mapping
Date: Tuesday, January 30, 2018 4:18:33 PM
Attachments: Female Home Range Map_Rocky Mtn.docx

Hi Bob - We did a quick spatial analysis to estimate the potential number of female wolverines that could occupy the Rocky Mountain National Park area. This is one area included in our climate change/snow persistence modeling analysis. We used home range estimates from your Greater Yellowstone study (approximate) and your maternal habitat layer. I am attaching a Word version of the map my colleague in Region 6 prepared (original jpg is too large to send).

What are your thoughts on this? It seems to show that you might be able to have (at most) 5 females in this study area, but maybe only 1 male. Does that make sense?

I am teleworking today, but back in the office tomorrow, if you have questions.
Thanks for your time,
Betty

--

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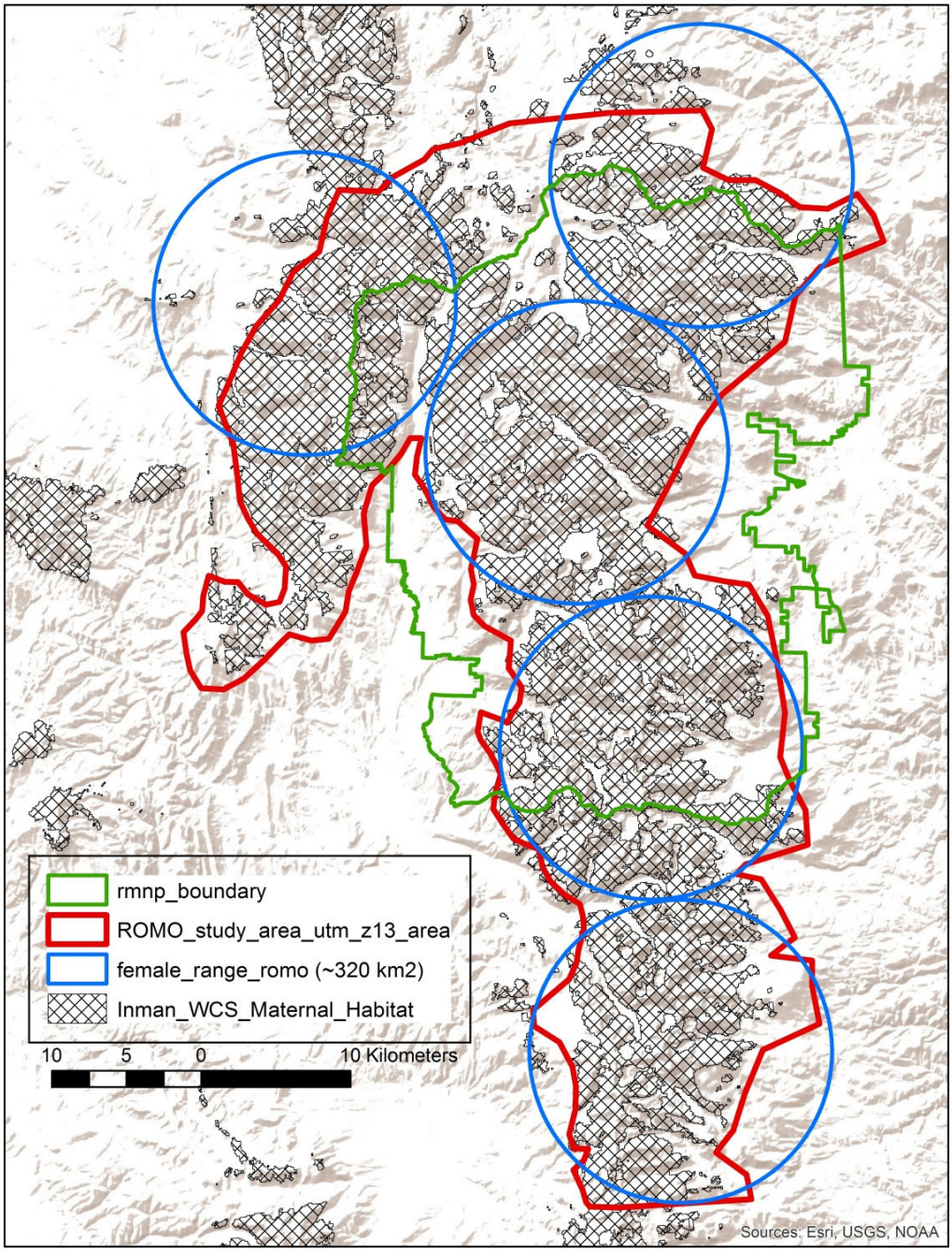
rmnp_boundary
ROMO_study_area_utm_z13_area
female_range_romo (~320 km2)
Inman_WCS_Maternal_Habitat
10 5 0 10 Kilometers
Sources: Esri, USGS, NOAA

From: Grizzle, Betty
To: John Guinotte
Subject: Fwd: Home range mapping
Date: Wednesday, January 31, 2018 7:27:31 AM

See message below from Bob Inman, recommending adding his PH.

---------- Forwarded message ----------
From: **Inman, Bob** <bobinman@mt.gov>
Date: Tue, Jan 30, 2018 at 3:46 PM
Subject: RE: Home range mapping
To: "Grizzle, Betty" <betty_grizzle@fws.gov>

Hey Betty,

I would like to see primary habitat on there too. Might be able to get a better feel of how they might spread themselves out that way.

Five females and one male is a ratio that I have not heard of before. 2-3 females per male is typical, so if 5 females are in the area, I would think 2 males would be appropriate. In Grand Teton Park, we essentially had 2 pairs, a male and female in the south end and the same in the north end.

Hope you are well.

-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: Tuesday, January 30, 2018 4:19 PM
To: Inman, Bob <bobinman@mt.gov>
Subject: Home range mapping

Hi Bob - We did a quick spatial analysis to estimate the potential number of female wolverines that could occupy the Rocky Mountain National Park area. This is one area included in our climate change/snow persistence modeling analysis. We used home range estimates from your Greater Yellowstone study (approximate) and your maternal habitat layer. I am attaching a Word version of the map my colleague in Region 6 prepared (original jpg is too large to send).

What are your thoughts on this? It seems to show that you might be able to have (at most) 5 females in this study area, but maybe only 1 male. Does that make sense?

I am teleworking today, but back in the office tomorrow, if you have questions.

Thanks for your time,

Betty

--

Betty J. Grizzle, D.Env.

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