Anatomy of a decline: *persistence*

- **6 extirpations from historic to end of my 1st sampling (once / 268.5 site-yrs)**
  (every 10.74 yrs)
- **4 add'l extirpations from 1st to end of my 2nd sampling (once / 41.3 site-yrs)**
  (every 2.2 yrs)
  - ***~5x faster than 20th-century rate; ~8.7x, if 1996 is demarcation point***
- **All but 2 sites still had (old) evidences**
- **Pinchot Creek functionally extirpated; other extirpations likely (vaguely defined sites)**

<u>3 periods of sampling</u>

Historic	**1898-1956, 1990**
Recent_1	**1994-1999**
Recent_2	**2003-2008**

Results

First surveys (1994-1999)

- **6 of 25 sites (24%) reported from 1898 to 1990 appeared currently extirpated**

Of the 6 apparent extirpations, …

  - all 6 occurred within grazed areas
  - all 6 in ranges with little talus habitat or not in ranges
  - 4 on BLM-administered lands
  - 1 site detected, but assumed to be 'functionally extirpated'

- **Extirpated populations**: at lower absolute and maximum elevations; nearer to primary roads; at slightly warmer and drier sites; northernmost sites

Results – ***Recent extirpations***

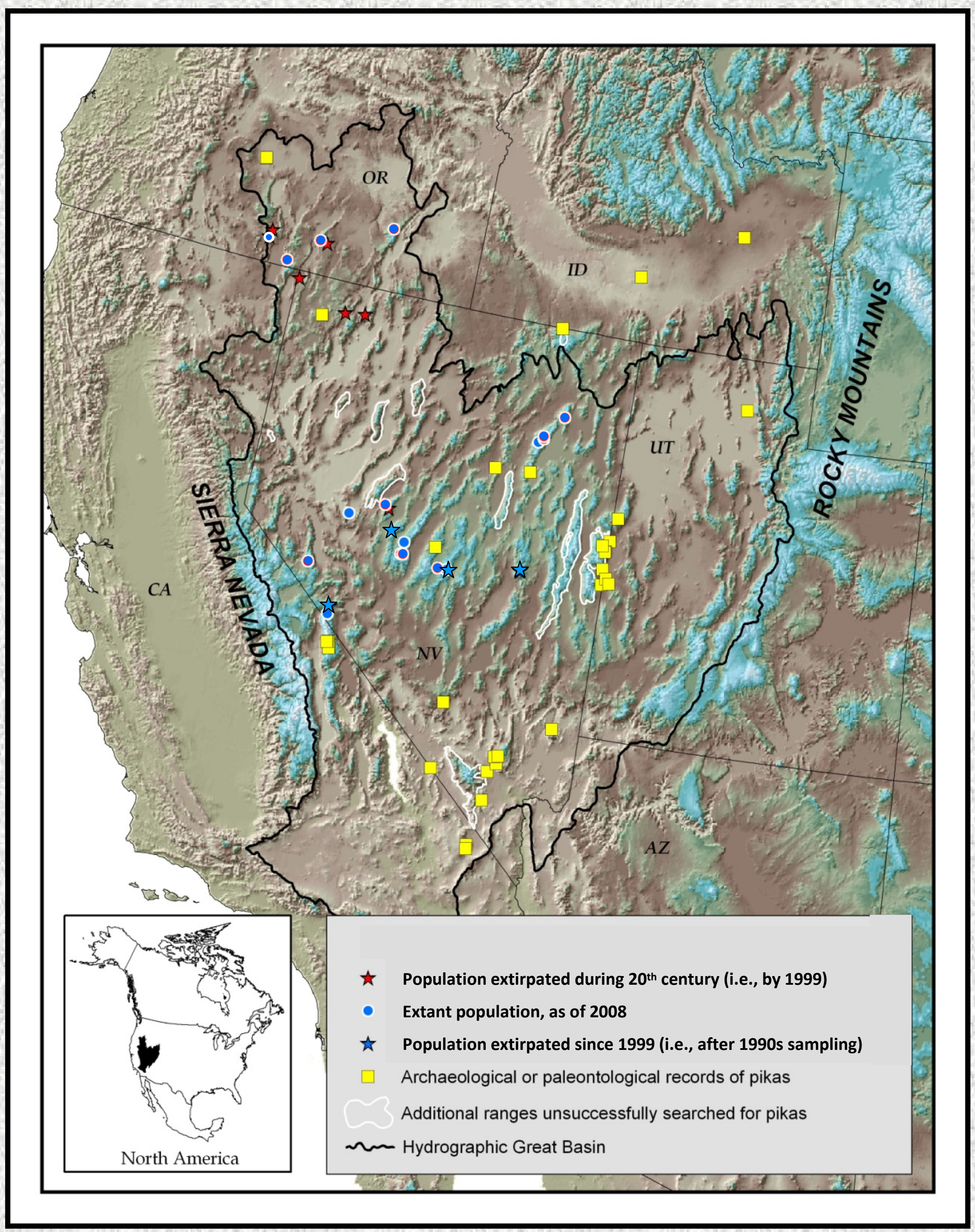
2003-08 confirmatory surveys

- **Now 10 of 25 sites (40%) reported from 1898 to 1990 appear currently extirpated**
  - Pikas have never been detected at any of 6 extirpated sites**

Of the 4 additional extirpations, …

  - 1 of 4 extirpations occurred on BLM-administered lands
  - 1 of 4 in ranges with little talus habitat or not in ranges
  - 3 of 4 occurred within grazed areas
  - 2 of 4 in wilderness designation

- **Extirpated populations**: at more-southern sites



Study sites

within the Great Basin

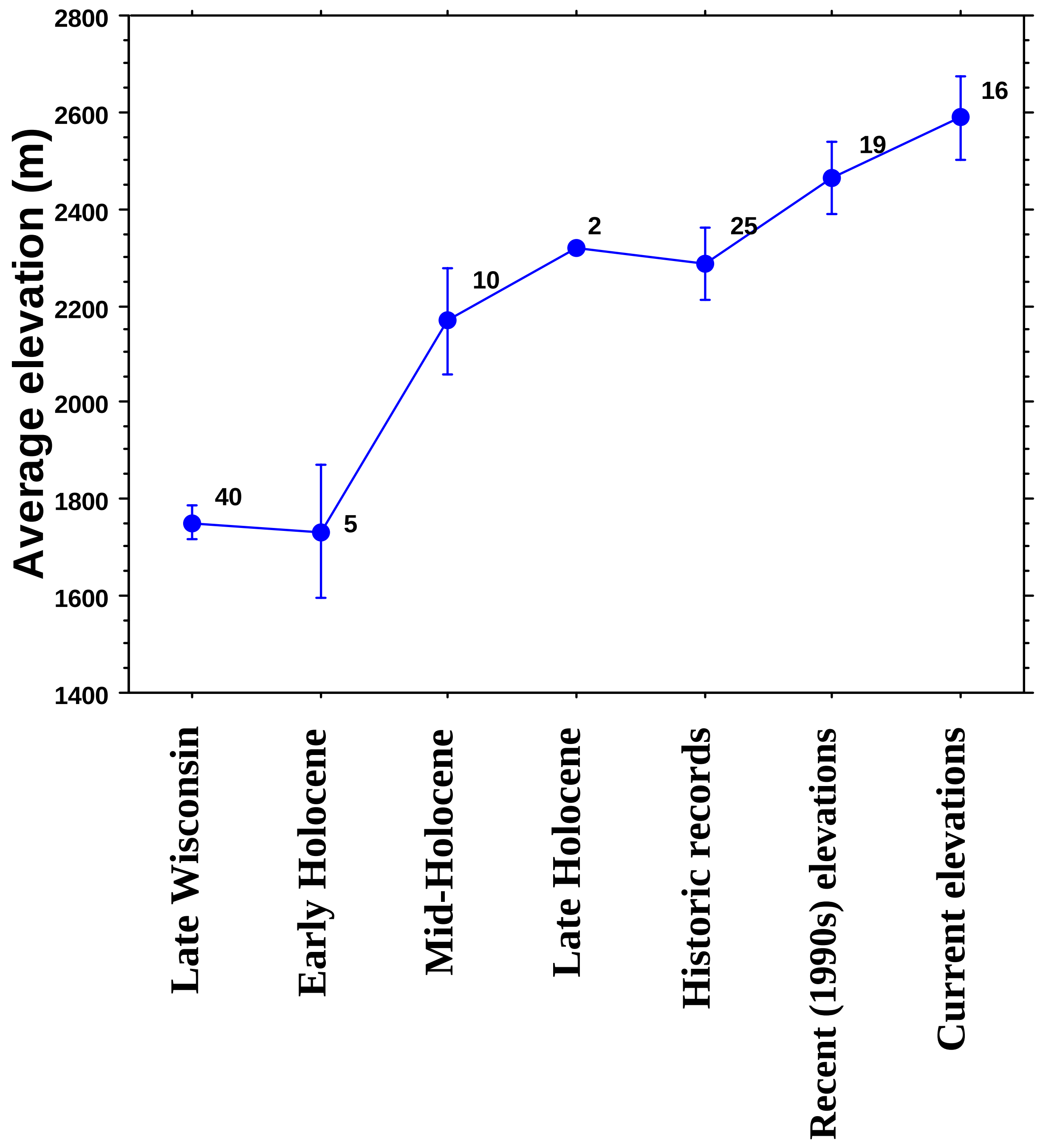
(blue areas: >2,286 m)

Anatomy of a decline: *upslope migrations*

- **Minimum elev. of detections (Basin-wide avg.), Historical to my first sampling: 13.2 m per decade**
- **Minimum elev. of detections, (Basin-wide avg.) 1st to 2nd sampling: ~145 m per decade**
  - **Parmesan & Yohe (2003) meta-analysis: 6.1 m per decade**
- ***Average*** **elev. of detections also rose, at 3 add'l sites**
- **Not parsimonious to posit rapid evolution of reduced *p***

Anatomy of a decline:

upslope migrations, over time



Evidence of climatic influence on pikas

- **Within mixed-occupancy sites, extirpated patches averaged 2.51˚C warmer during summer than did occupied patches**
- **Extant sites received PRISM-estimated 1.43x greater PPT during 1961-1990 than did 6 sites initially extirpated, & 1.75x greater PPT during 1971-2000 than 4 sites of recent loss**
- **Loss of pikas from low-elevation sites in 4 ranges even though higher-elevation populations in the same range persisted; retractions > 100 m in 6 ranges**

Evidence of climatic influence on pikas

- **<u>EXP'MENTAL</u>: Vulnerability to direct heat stress** (Smith 1974)

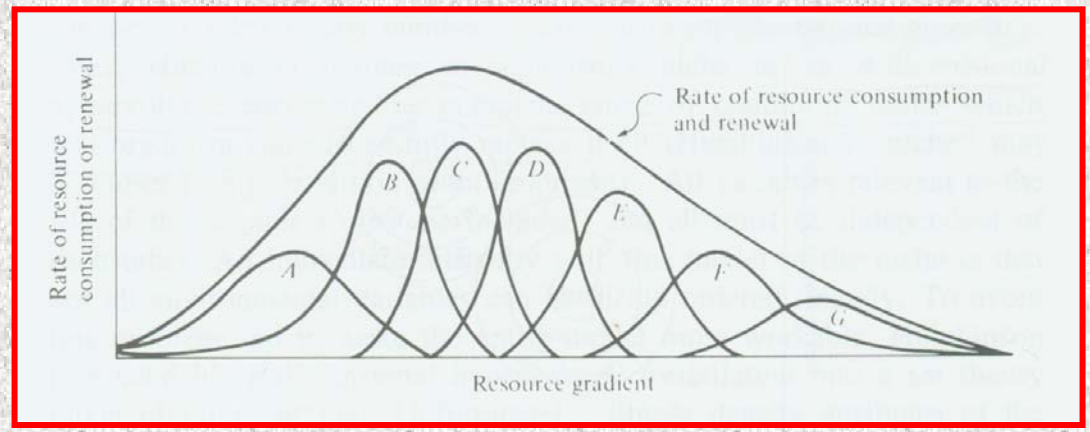
- **Hotter, drier macroclimates at extirpated vs. extant sites**
  - **PRISM-modeled data, AND i-Buttons in taluses across Basin**

- **Excellent ability of our climatic surrogate to predict persistence in univariate and AIC analyses (>95% of total weight), 1990s analyses**

	iButton field data, 2005-2006			
	# Days > 28?C	Avg summer temperature (?C)	# Days < 0?C	# Days < -5?C
Pika-extant sites (*N* = 15 sites)	2.8 + 1.0	12.05 + 1.01	204.4 + 13.2	15.0 + 4.6
Pika-extirpated sites (*N* = 10)	10.9 + 4.0	17.02 + 0.72	159.6 + 9.7	28.7 + 7.8

Bioclimatic envelope models

- **Forecasting future responses to GCC**
- **Relate to niche concept: *fundamental*, *realized***

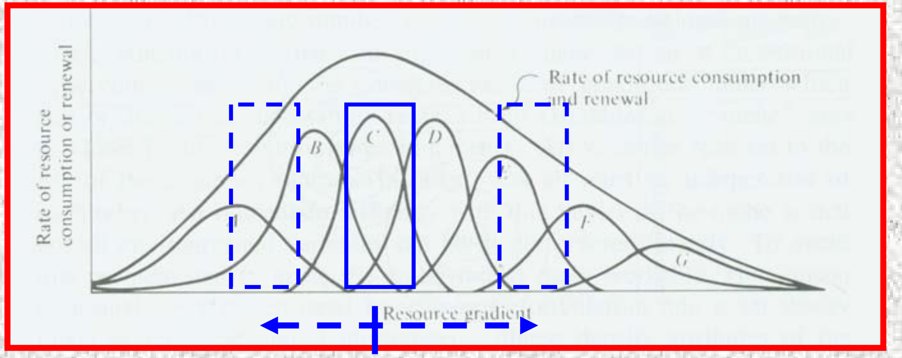


- **Many sources of uncertainty**
- **Often rely on coarse-scale data, analysis**
- **Frequently presence-only data, modeling**

Modeling changes in species distributions

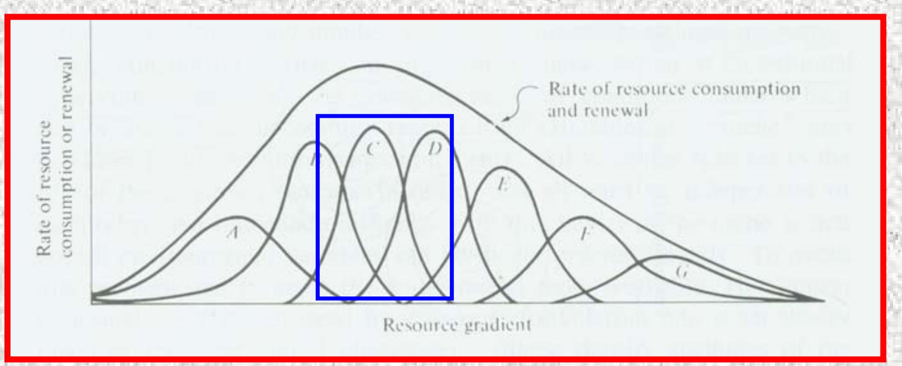
- Observed evol'n in thermal performance
- Sufficient genetic diversity for local adapt'n
- Pika extirpations latitudinally distributed

<u>Local adaptation</u>:
Losses determined by *magnitude of* climatic *change*



Modeling changes in species distributions

- Observed evol'n in thermal performance
- Sufficient genetic diversity for local adapt'n
- Pika extirpations latitudinally distributed
- ***HOWEVER …***

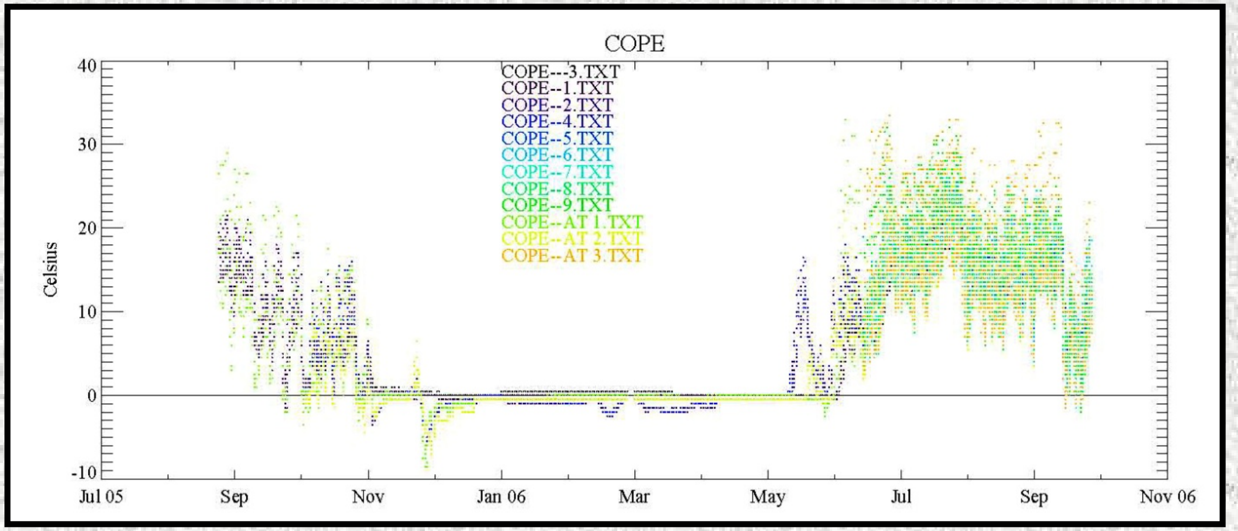


- **Most species' losses at S. edge of range**
- **Rate of climatic change has been RAPID**
- **Energetic, physiological constraints**

<u>Fixed-dimensions niche</u>: Losses determined by *proximity to edge of bio-climatic envelope* (i.e., relative status)

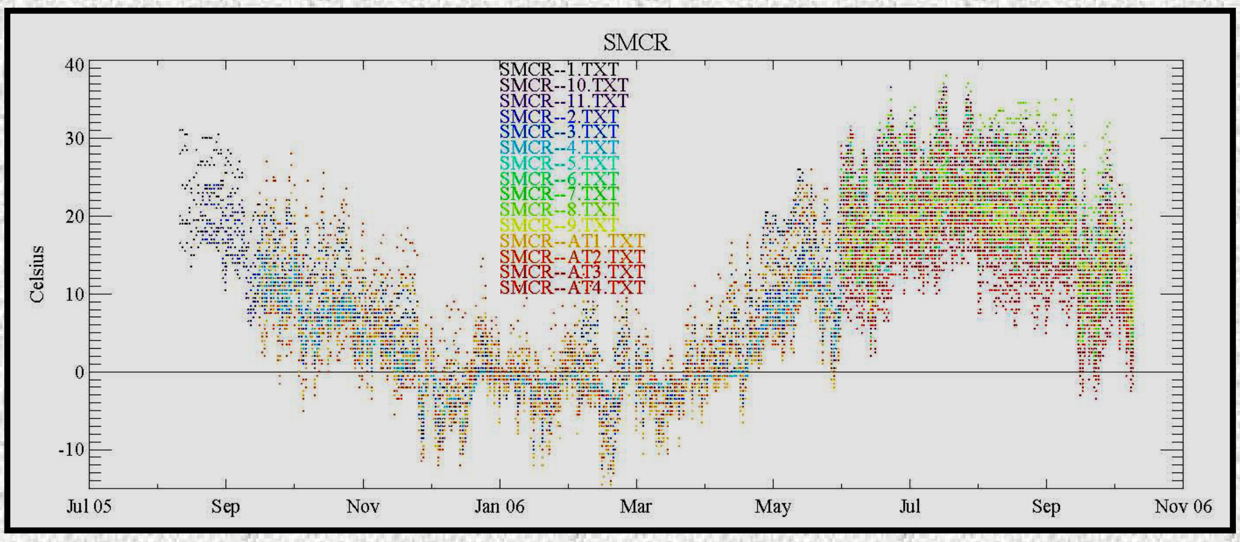
Potential mechanisms of GCC on montane spp.: *winter cold stress*

- All **extant** sites snow-covered >2 wks, ***except*** one low-density (vulnerable) site, and 1 other site



- 8 of 10 **extirpated** sites never had snow cover >2 wks (except DUPE, PECR)

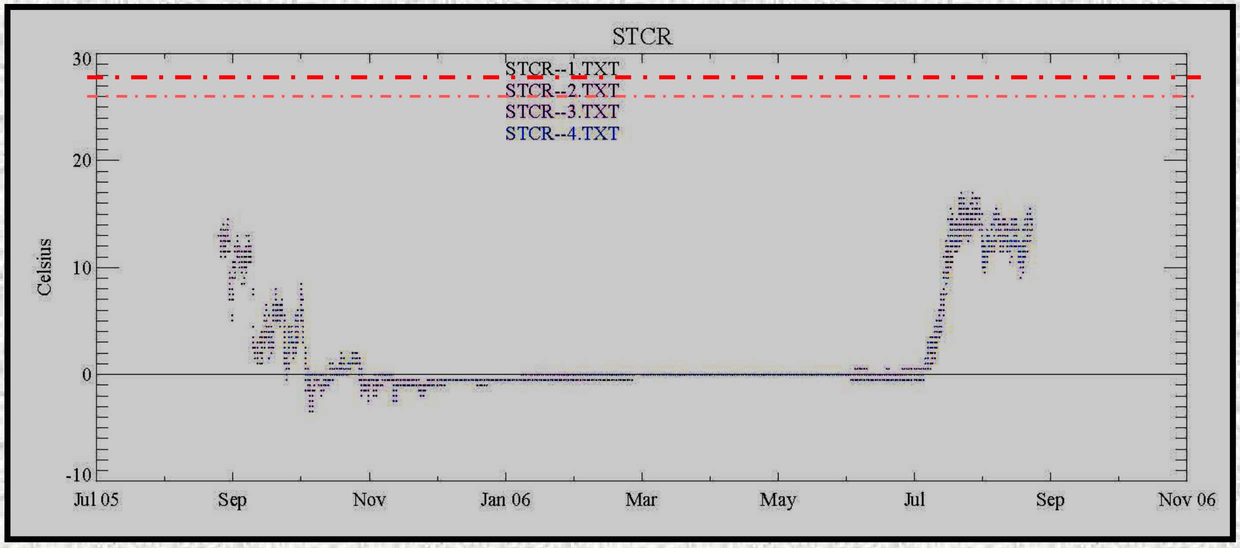
Interstices reached -22 °C



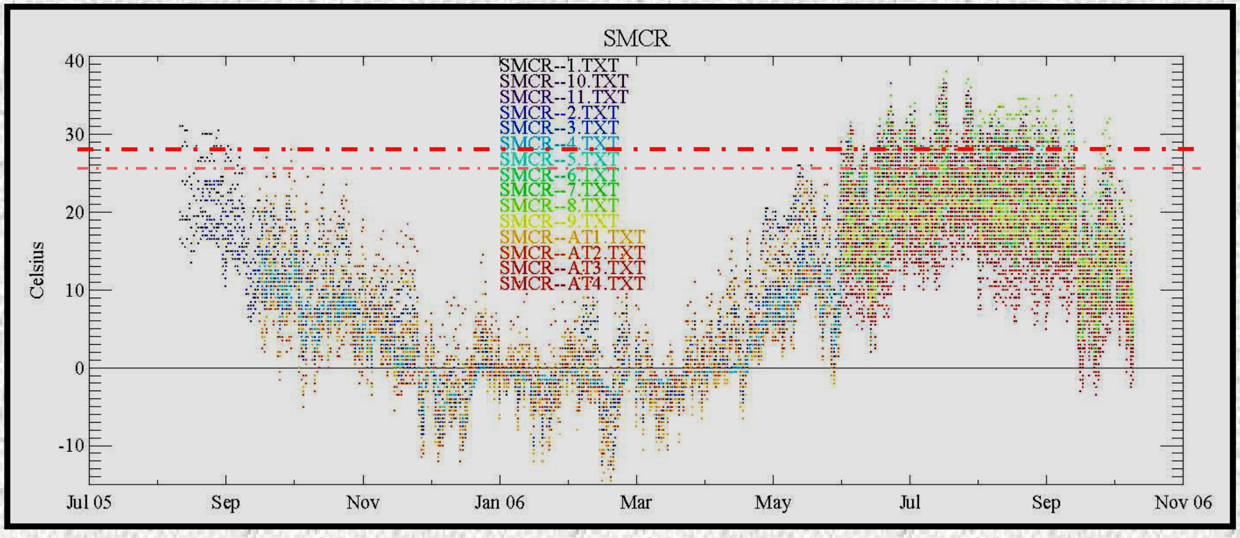
Potential mechanisms of GCC on montane spp.: *summer heat stress*

- **Extant** sites tended to rarely have within-talus temps above pika-lethal thresholds

  (Smith 1974, MacArthur & Wang 1974)



- **Extirpated** sites more frequently had within-talus temps above pika-lethal thresholds



Information-theoretic analyses *vs*. null-hypothesis testing

I-T analyses (e.g., AICc)

- Requires more critical thinking beforehand
- Compares strength of evidence for numerous plausible explanations
- Allows incorporation of past info and predictive ability
- Allows comparison of models of different complexity

N-H Significance Testing

- **Only possible answers**: reject H_o , fail to reject H_o
- Torturous logic
  - H_o usu. trivial, uninformative
- Not useful for prediction or incorporating past info
- Subjective definition of 'significance' ($\alpha = 0.05$)
- *P*-value is f(*N*), and does not provide effect size or precision
  - Reflects data sets never collected more than the observed data

Utility of BOTH approaches compromised by indiscriminate use (Bonferroni)

Information-theoretic results: *top models*

Model	$-2 \times \log(L)$	K	AIC_c	ΔAIC_c	Akaike weight	Evidence ratio^{-1}
Mean summer temperature (2005–2006)	22.559	2	27.104	0.000	0.148	1.000
Days below −5°C (1945–2006) and mean summer temperature (1945–2006)	20.330	3	27.473	0.368	0.123	0.832
Days above 28°C (2005–2006)	23.337	2	27.883	0.779	0.100	0.677
Mean summer temperature (2005–2006) and days above 28°C (2005–2006)	20.774	3	27.916	0.812	0.099	0.666
Mean summer temperature (1945–2006)	23.954	2	28.500	1.396	0.074	0.498

- **Importance of types of stress not previously well appreciated**
- **Acute heat stress a relatively poor predictor (behavior)**
- **Recent variables prominent among models with AIC_c < 2**

Information-theoretic results: *variable wts*

Predictor	Mean Akaike weight per model	Sign of effect
Recent mean summer temperature (°C)	0.0629	6−
Long-term mean summer temperature (°C)	0.0530	6−
Recent no. days above 28°C	0.0530	6−
Cumulative no. days below −5°C	0.0491	4−
Recent no. days below 0°C	0.0271	2−, 2 +
Cumulative no. days above 28°C	0.0263	6−
Recent no. days below −5°C	0.0252	3−, 1+
Cumulative no. days below 0°C	0.0207	3−, 1+
Change in no. days above 28°C	0.0037	6−
Change in no. days below 0°C	0.0034	4−
Change in mean summer temperature (°C)	0.0022	1−, 5+
Change in no. days below −5°C	0.0014	3−, 1+

- **Importance of types of stress not previously well appreciated**
- **Acute heat stress a relatively poor predictor (behavior)**
- **Concern @ historic low-temp vars; exploratory analyses w/ -10˚C (95%)**

Altered extinction dynamics: *the rules ain't the same*

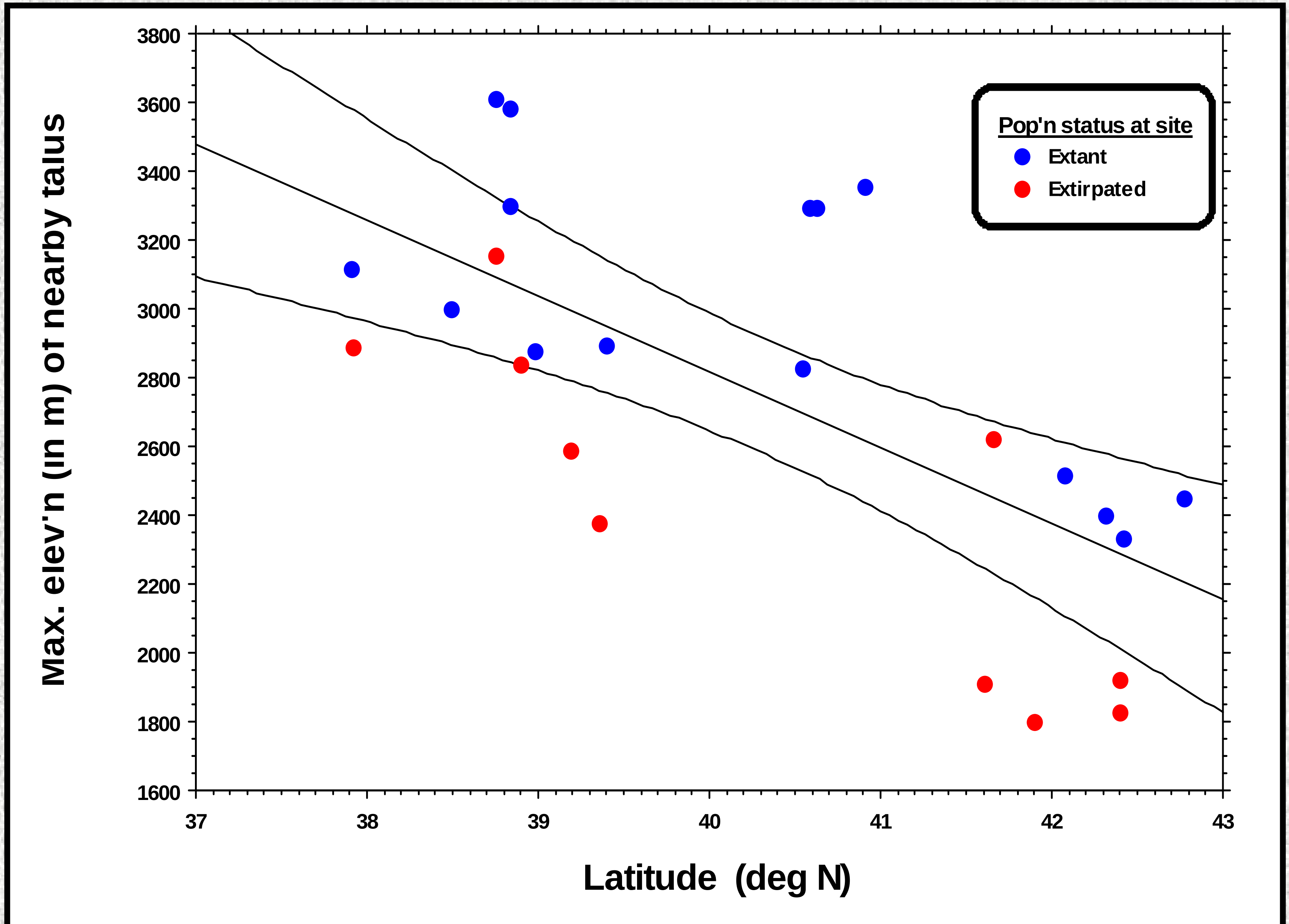
- **More-rapid rates of site-level extirpation, upslope retraction**
- **Different relative roles of extirpation determinants, 20th Century vs. last decade**
- **Test using model-averaged probabilities of persistence from 1990s sampling, to predict losses since 1999 => utter failure (p = 0.86)**
- **North vs. southern latitude of pika-extirpated sites (purging of extinction debt?)**
- **Proximity to primary roads no longer appeared important**
- **Populations now being lost even from large mountain ranges and protected areas**

Information-theoretic results: *paradigm shift*

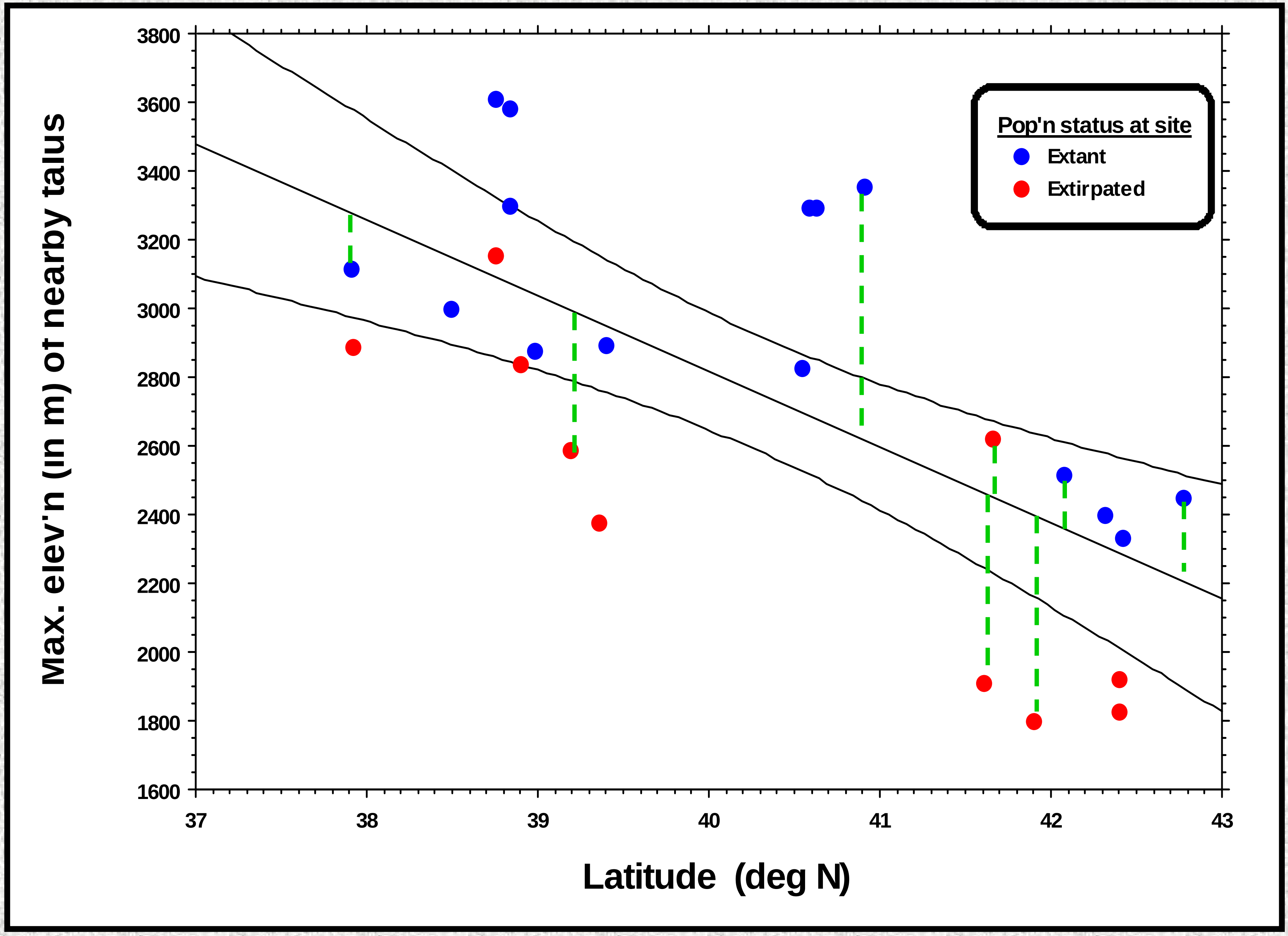
Maximum elevation of local habitat (high-elevation refugium; Beever et al. 2003)

	'20th-Century' (historic to 1999)	'Recent' (1999 to 2009)
Predictor variable (listed in order of decreasing weight per model	**MaxElev**	**AugMaxT**
	RngHab	RngHab
	AugMaxT	DistRd
	DistRd	GrzPost99
	GrzPre99	**MaxElev**
Sites correctly classified	24/25	16/19
Average of |(weighted P[occ] - occupancy status)|	0.123	0.276

- **Climatic-stress surrogate appears to have dropped in importance**
- **Model fit (ability to predict persistence) was much worse, recently**



Beever (1999): latitude-adjusted local migrational ceiling (*sensu* Grinnell 1917)



Beever (1999): ***integrative*****, latitude-adjusted local migrational ceiling**

CPC Mtg: Feb 2011

Information-theoretic results: *paradigm shift*

Maximum-elevation residual (latitude-corrected; Beever et al. *in review*)

	'20th-Century' (historic to 1999)	'Recent' (1999 to 2009)
Predictor variable (listed in order of decreasing weight per model	RngHab **MaxElevR** DistRd GrzPre99 **AugMaxT**	**MaxElevR** **AugMaxT** RngHab GrzPost99 DistRd
Sites correctly classified	22/25	18/19
Average of |(weighted P[occ] - occupancy status)|	0.185	0.169

- **Both climatic-stress vars increased in importance, and now are two most-important determinants of persistence**
- **Model fit (ability to predict persistence) was much better, recently**

Information-theoretic results: *top models* (3 periods)

Persistence period	Maximum elevation of habitat within upperbound of dispersal distance: Model	Log likelihood	K	AIC_c	Δ_i	w_i	R^2	Residual of maximum elevation of local habitat on latitude: Model	Log likelihood	K	AIC_c	Δ_i	w_i	R^2
Historical through 1990s ('20thCentury')	MaxElev	−5.240	2	15.025	0.000	0.2714	0.7410	MaxElevR + RngHab	−6.574	3	20.292	0.000	0.2034	0.6558
	MaxElev + RngHab	−4.379	3	15.902	0.876	0.1751	0.7913	MaxElevR	−8.329	2	21.204	0.912	0.1289	0.5290
	MaxElev + AugMaxT	−4.704	3	16.551	1.526	0.1265	0.7727	MaxElevR + RngHab + DistRd	−5.604	4	21.207	0.916	0.1287	0.7187
	MaxElev + DistRd	−5.038	3	17.220	2.195	0.0906	0.7531	RngHab + DistRd	−7.532	3	22.207	1.915	0.0781	0.5888
	MaxElev + GrzPre99	−5.221	3	17.585	2.560	0.0755	0.7422	MaxElevR + RngHab + GrzPre99	−6.138	4	22.275	1.983	0.0755	0.6847
	MaxElev + RngHab + DistRd	−4.031	4	18.063	3.038	0.0594	0.8107	MaxElevR + GrzPre99	−7.746	3	22.634	2.342	0.0631	0.5731
	MaxElev + RngHab + AugMaxT	−4.127	4	18.254	3.228	0.0540	0.8055	MaxElevR + DistRd	−7.866	3	22.874	2.582	0.0559	0.5642
	MaxElev + RngHab + GrzPre99	−4.366	4	18.732	3.707	0.0425	0.7921	MaxElevR + RngHab + AugMaxT	−6.560	4	23.120	2.828	0.0495	0.6568
								RngHab + AugMaxT	−8.216	3	23.574	3.282	0.0394	0.5377
								MaxElevR + AugMaxT	−8.233	3	23.610	3.318	0.0387	0.5364
1990s through 2000s ('Recent')	AugMaxT	−7.628	2	20.005	0.000	0.2618	0.3152	MaxElevR	−5.475	2	15.700	0.000	0.2538	0.5667
	Null	−9.778	1	21.792	1.787	0.1071	0.0000	MaxElevR + RngHab	−4.605	3	16.811	1.111	0.1457	0.6533
								MaxElevR + GrzPost99	−4.718	3	17.036	1.336	0.1301	0.6425
								MaxElevR + AugMaxT	−4.837	3	17.274	1.574	0.1155	0.6310
								MaxElevR + DistRd	−5.445	3	18.489	2.789	0.0629	0.5699
								MaxElevR + RngHab + GrzPost99	−4.152	4	19.162	3.462	0.0450	0.6953
								MaxElevR + RngHab + AugMaxT	−4.257	4	19.372	3.672	0.0405	0.6857
								MaxElevR + RngHab + DistRd	−4.343	4	19.543	3.843	0.0372	0.6779
Historical through 2000s ('Overall')	RngHab + AugMaxT	−10.356	3	27.856	0.000	0.1311	0.5461	MaxElevR + RngHab + GrzPre99	−5.215	4	20.430	0.000	0.2216	0.8178
	RngHab + GrzPre99	−10.526	3	28.195	0.340	0.1106	0.5351	MaxElevR + GrzPre99	−6.726	3	20.594	0.164	0.2042	0.7492
	MaxElev + AugMaxT	−10.834	3	28.810	0.954	0.0814	0.5148	MaxElevR + RngHab	−7.018	3	21.179	0.749	0.1524	0.7350
	MaxElev + GrzPre99	−11.043	3	29.229	1.373	0.0660	0.5007	MaxElevR	−8.642	2	21.829	1.399	0.1101	0.6494
	GrzPre99	−12.365	2	29.276	1.421	0.0645	0.4057	MaxElevR + RngHab + DistRd	−6.338	4	22.676	2.246	0.0721	0.7676
	MaxElev	−12.422	2	29.389	1.533	0.0609	0.4014	MaxElevR + GrzPre99 + AugMaxT	−6.663	4	23.325	2.895	0.0521	0.7523
	DistRd + AugMaxT	−11.159	3	29.461	1.606	0.0588	0.4927	MaxElevR + DistRd + GrzPre99	−6.725	4	23.450	3.020	0.0490	0.7493
	DistRd + GrzPre99	−11.215	3	29.574	1.718	0.0555	0.4888	MaxElevR + RngHab + AugMaxT	−6.993	4	23.986	3.556	0.0374	0.7362
	MaxElev + RngHab + AugMaxT	−9.886	4	29.773	1.917	0.0503	0.5759	MaxElevR + AugMaxT	−8.438	3	24.019	3.589	0.0368	0.6608
	AugMaxT	−12.672	2	29.889	2.034	0.0474	0.3822	MaxElevR + DistRd	−8.570	3	24.282	3.852	0.0323	0.6535
	MaxElev + GrzPre99 + AugMaxT	−10.075	4	30.150	2.294	0.0416	0.5641							
	MaxElev + RngHab	−11.529	3	30.200	2.345	0.0406	0.4669							
	MaxElev + RngHab + GrzPre99	−10.161	4	30.322	2.466	0.0382	0.5586							
	RngHab + DistRd	−11.696	3	30.535	2.679	0.0344	0.4550							
	MaxElev + DistRd + AugMaxT	−10.367	4	30.733	2.878	0.0311	0.5455							
	RngHab	−13.346	2	31.237	3.382	0.0242	0.3284							
	MaxElev + DistRd + GrzPre99	−10.754	4	31.508	3.653	0.0211	0.5201							
	MaxElev + DistRd	−12.258	3	31.659	3.803	0.0196	0.4138							

Information-theoretic results: *top models* (3 periods)

Persistence period	Maximum elevation of habitat within upperbound of dispersal distance: Model	Log likelihood	K	AIC_c	Δ_i	w_i	R^2	Residual of maximum elevation of local habitat on latitude: Model	Log likelihood	K	AIC_c	Δ_i	w_i	R^2
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	MaxElev + RngHab	−4.379	3	15.902	0.876	0.1751	0.7913	MaxElevR	−8.329	2	21.204	0.912	0.1289	0.5290
	MaxElev + AugMaxT	−4.704	3	16.551	1.526	0.1265	0.7727	MaxElevR + RngHab + DistRd	−5.604	4	21.207	0.916	0.1287	0.7187
	MaxElev + DistRd	−5.038	3	17.220	2.195	0.0906	0.7531	RngHab + DistRd	−7.532	3	22.207	1.915	0.0781	0.5888
	MaxElev + GrzPre99	−5.221	3	17.585	2.560	0.0755	0.7422	MaxElevR + RngHab + GrzPre99	−6.138	4	22.275	1.983	0.0755	0.6847
	MaxElev + RngHab + DistRd	−4.031	4	18.063	3.038	0.0594	0.8107	MaxElevR + GrzPre99	−7.746	3	22.634	2.342	0.0631	0.5731
	MaxElev + RngHab + AugMaxT	−4.127	4	18.254	3.228	0.0540	0.8055	MaxElevR + DistRd	−7.866	3	22.874	2.582	0.0559	0.5642
	MaxElev + RngHab + GrzPre99	−4.366	4	18.732	3.707	0.0425	0.7921	MaxElevR + RngHab + AugMaxT	−6.560	4	23.120	2.828	0.0495	0.6568
								RngHab + AugMaxT	−8.216	3	23.574	3.282	0.0394	0.5377
								MaxElevR + AugMaxT	−8.233	3	23.610	3.318	0.0387	0.5364
1990s through 2000s ('Recent')	AugMaxT	−7.628	2	20.005	0.000	0.2618	0.3152	MaxElevR	−5.475	2	15.700	0.000	0.2538	0.5667
	Null	−9.778	1	21.792	1.787	0.1071	0.0000	MaxElevR + RngHab	−4.605	3	16.811	1.111	0.1457	0.6533
								MaxElevR + GrzPost99	−4.718	3	17.036	1.336	0.1301	0.6425
								MaxElevR + AugMaxT	−4.837	3	17.274	1.574	0.1155	0.6310
								MaxElevR + DistRd	−5.445	3	18.489	2.789	0.0629	0.5699
								MaxElevR + RngHab + GrzPost99	−4.152	4	19.162	3.462	0.0450	0.6953
								MaxElevR + RngHab + AugMaxT	−4.257	4	19.372	3.672	0.0405	0.6857
								MaxElevR + RngHab + DistRd	−4.343	4	19.543	3.843	0.0372	0.6779
Historical through 2000s ('Overall')	RngHab + AugMaxT	−10.356	3	27.856	0.000	0.1311	0.5461	MaxElevR + RngHab + GrzPre99	−5.215	4	20.430	0.000	0.2216	0.8178
	RngHab + GrzPre99	−10.526	3	28.195	0.340	0.1106	0.5351	MaxElevR + GrzPre99	−6.726	3	20.594	0.164	0.2042	0.7492
	MaxElev + AugMaxT	−10.834	3	28.810	0.954	0.0814	0.5148	MaxElevR + RngHab	−7.018	3	21.179	0.749	0.1524	0.7350
	MaxElev + GrzPre99	−11.043	3	29.229	1.373	0.0660	0.5007	MaxElevR	−8.642	2	21.829	1.399	0.1101	0.6494
	GrzPre99	−12.365	2	29.276	1.421	0.0645	0.4057	MaxElevR + RngHab + DistRd	−6.338	4	22.676	2.246	0.0721	0.7676
	MaxElev	−12.422	2	29.389	1.533	0.0609	0.4014	MaxElevR + GrzPre99 + AugMaxT	−6.663	4	23.325	2.895	0.0521	0.7523
	DistRd + AugMaxT	−11.159	3	29.461	1.606	0.0588	0.4927	MaxElevR + DistRd + GrzPre99	−6.725	4	23.450	3.020	0.0490	0.7493
	DistRd + GrzPre99	−11.215	3	29.574	1.718	0.0555	0.4888	MaxElevR + RngHab + AugMaxT	−6.993	4	23.986	3.556	0.0374	0.7362
	MaxElev + RngHab + AugMaxT	−9.886	4	29.773	1.917	0.0503	0.5759	MaxElevR + AugMaxT	−8.438	3	24.019	3.589	0.0368	0.6608
	AugMaxT	−12.672	2	29.889	2.034	0.0474	0.3822	MaxElevR + DistRd	−8.570	3	24.282	3.852	0.0323	0.6535
	MaxElev + GrzPre99 + AugMaxT	−10.075	4	30.150	2.294	0.0416	0.5641							
	MaxElev + RngHab	−11.529	3	30.200	2.345	0.0406	0.4669							
	MaxElev + RngHab + GrzPre99	−10.161	4	30.322	2.466	0.0382	0.5586							
	RngHab + DistRd	−11.696	3	30.535	2.679	0.0344	0.4550							
	MaxElev + DistRd + AugMaxT	−10.367	4	30.733	2.878	0.0311	0.5455							
	RngHab	−13.346	2	31.237	3.382	0.0242	0.3284							
	MaxElev + DistRd + GrzPre99	−10.754	4	31.508	3.653	0.0211	0.5201							
	MaxElev + DistRd	−12.258	3	31.659	3.803	0.0196	0.4138							

Information-theoretic results: *top models* (3 periods)

Maximum elevation of habitat within upperbound of dispersal distance

Persistence period	Model	Log likelihood	K	AIC_c	Δ_i	w_i	R^2
Historical through 1990s ('20thCentury')	MaxElev	−5.240	2	15.025	0.000	0.2714	0.7410
	MaxElev + RngHab	−4.379	3	15.902	0.876	0.1751	0.7913
	MaxElev + AugMaxT	−4.704	3	16.551	1.526	0.1265	0.7727
	MaxElev + DistRd	−5.038	3	17.220	2.195	0.0906	0.7531
	MaxElev + GrzPre99	−5.221	3	17.585	2.560	0.0755	0.7422
	MaxElev + RngHab + DistRd	−4.031	4	18.063	3.038	0.0594	0.8107
	MaxElev + RngHab + AugMaxT	−4.127	4	18.254	3.228	0.0540	0.8055
	MaxElev + RngHab + GrzPre99	−4.366	4	18.732	3.707	0.0425	0.7921
1990s through 2000s ('Recent')	AugMaxT	−7.628	2	20.005	0.000	0.2618	0.3152
	Null	−9.778	1	21.792	1.787	0.1071	0.0000
Historical through 2000s ('Overall')	RngHab + AugMaxT	−10.356	3	27.856	0.000	0.1311	0.5461
	RngHab + GrzPre99	−10.526	3	28.195	0.340	0.1106	0.5351
	MaxElev + AugMaxT	−10.834	3	28.810	0.954	0.0814	0.5148
	MaxElev + GrzPre99	−11.043	3	29.229	1.373	0.0660	0.5007
	GrzPre99	−12.365	2	29.276	1.421	0.0645	0.4057
	MaxElev	−12.422	2	29.389	1.533	0.0609	0.4014
	DistRd + AugMaxT	−11.159	3	29.461	1.606	0.0588	0.4927
	DistRd + GrzPre99	−11.215	3	29.574	1.718	0.0555	0.4888
	MaxElev + RngHab + AugMaxT	−9.886	4	29.773	1.917	0.0503	0.5759
	AugMaxT	−12.672	2	29.889	2.034	0.0474	0.3822
	MaxElev + GrzPre99 + AugMaxT	−10.075	4	30.150	2.294	0.0416	0.5641
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Residual of maximum elevation of local habitat on latitude

Persistence period	Model	Log likelihood	K	AIC_c	Δ_i	w_i	R^2
Historical through 1990s ('20thCentury')	MaxElevR + RngHab	−6.574	3	20.292	0.000	0.2034	0.6558
	MaxElevR	−8.329	2	21.204	0.912	0.1289	0.5290
	MaxElevR + RngHab + DistRd	−5.604	4	21.207	0.916	0.1287	0.7187
	RngHab + DistRd	−7.532	3	22.207	1.915	0.0781	0.5888
	MaxElevR + RngHab + GrzPre99	−6.138	4	22.275	1.983	0.0755	0.6847
	MaxElevR + GrzPre99	−7.746	3	22.634	2.342	0.0631	0.5731
	MaxElevR + DistRd	−7.866	3	22.874	2.582	0.0559	0.5642
	MaxElevR + RngHab + AugMaxT	−6.560	4	23.120	2.828	0.0495	0.6568
	RngHab + AugMaxT	−8.216	3	23.574	3.282	0.0394	0.5377
	MaxElevR + AugMaxT	−8.233	3	23.610	3.318	0.0387	0.5364
1990s through 2000s ('Recent')	MaxElevR	−5.475	2	15.700	0.000	0.2538	0.5667
	MaxElevR + RngHab	−4.605	3	16.811	1.111	0.1457	0.6533
	MaxElevR + GrzPost99	−4.718	3	17.036	1.336	0.1301	0.6425
	MaxElevR + AugMaxT	−4.837	3	17.274	1.574	0.1155	0.6310
	MaxElevR + DistRd	−5.445	3	18.489	2.789	0.0629	0.5699
	MaxElevR + RngHab + GrzPost99	−4.152	4	19.162	3.462	0.0450	0.6953
	MaxElevR + RngHab + AugMaxT	−4.257	4	19.372	3.672	0.0405	0.6857
	MaxElevR + RngHab + DistRd	−4.343	4	19.543	3.843	0.0372	0.6779
Historical through 2000s ('Overall')	MaxElevR + RngHab + GrzPre99	−5.215	4	20.430	0.000	0.2216	0.8178
	MaxElevR + GrzPre99	−6.726	3	20.594	0.164	0.2042	0.7492
	MaxElevR + RngHab	−7.018	3	21.179	0.749	0.1524	0.7350
	MaxElevR	−8.642	2	21.829	1.399	0.1101	0.6494
	MaxElevR + RngHab + DistRd	−6.338	4	22.676	2.246	0.0721	0.7676
	MaxElevR + GrzPre99 + AugMaxT	−6.663	4	23.325	2.895	0.0521	0.7523
	MaxElevR + DistRd + GrzPre99	−6.725	4	23.450	3.020	0.0490	0.7493
	MaxElevR + RngHab + AugMaxT	−6.993	4	23.986	3.556	0.0374	0.7362
	MaxElevR + AugMaxT	−8.438	3	24.019	3.589	0.0368	0.6608
	MaxElevR + DistRd	−8.570	3	24.282	3.852	0.0323	0.6535

Information-theoretic results: *top models* (3 periods)

Maximum elevation of habitat within upperbound of dispersal distance

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	GrzPre99	−12.365	2	29.276	1.421	0.0645	0.4057
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	RngHab + DistRd	−7.532	3	22.207	1.915	0.0781	0.5888
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	MaxElevR + GrzPre99	−7.746	3	22.634	2.342	0.0631	0.5731
	MaxElevR + DistRd	−7.866	3	22.874	2.582	0.0559	0.5642
	MaxElevR + RngHab + AugMaxT	−6.560	4	23.120	2.828	0.0495	0.6568
	RngHab + AugMaxT	−8.216	3	23.574	3.282	0.0394	0.5377
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	MaxElevR + GrzPost99	−4.718	3	17.036	1.336	0.1301	0.6425
	MaxElevR + AugMaxT	−4.837	3	17.274	1.574	0.1155	0.6310
	MaxElevR + DistRd	−5.445	3	18.489	2.789	0.0629	0.5699
	MaxElevR + RngHab + GrzPost99	−4.152	4	19.162	3.462	0.0450	0.6953
	MaxElevR + RngHab + AugMaxT	−4.257	4	19.372	3.672	0.0405	0.6857
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I-T results: 1999-2008 & Overall; integrated climatic- and non-climatic-variable models

Table 1 Information on individual predictors and top models, for persistence since 1990s surveys (a) or from historic records to the present (b)

Predictor	w_j	w_j/model	# Coeffs > 0	# Coeffs < 0	Coeff CV	Model	Log likelihood	K	AIC_c	Δ_i	w_i
(a) Persistence from 1990s through 2000s surveys ('Recent')											
DaysNeg10	**0.6980**	**0.1396**	**1**	**4**	**2.6522**	*MaxElevR + DaysNeg10*	*−1.80E-09*	*3*	*7.714*	*0.000*	*0.4385*
MaxElevR	**0.7018**	**0.0877**	**8**	**0**	**1.7520**	MaxElevR + DaysNeg10 + GrzPost99	−5.60E-10	4	11.077	3.363	0.0816
Pop1990s	0.2727	0.0545	5	0	0.9220	MaxElevR + DaysNeg10 + LocalHRs	−4.95E-10	4	11.077	3.363	0.0816
GrzPost99	0.1675	0.0419	2	2	1.6273	AveSumT + Pop1990s + Latitude	−8.90E-09	4	11.077	3.363	0.0816
Latitude	0.1649	0.0412	4	0	1.4855	Pop1990s + Latitude + GrzPost99	−1.28E-08	4	11.077	3.363	0.0816
LocalHRs	0.1723	0.0287	6	0	2.0035	MaxElevR + Pop1990s + LocalHRs	−1.59E-08	4	11.077	3.363	0.0816
AveSumT	**0.1977**	**0.0282**	**1**	**6**	**2.7152**	AveSumT + DaysNeg10 + RngHab	−2.10E-07	4	11.077	3.363	0.0816
RngHab	0.0876	0.0219	4	0	1.9925						
(b) Persistence from historic records through 2000s surveys ('Overall')											
DaysNeg10	**0.7033**	**0.1407**	**0**	**5**	**0.3468**	*MaxElevR + DaysNeg10 + LocalHRs*	*−3.212675*	*4*	*16.531*	*0.000*	*0.2884*
MaxElevR	**0.6317**	**0.1053**	**6**	**0**	**0.1916**	*MaxElevR + DaysNeg10*	*−5.350031*	*3*	*17.900*	*1.369*	*0.1454*
AveSumT	**0.2973**	**0.0595**	**0**	**5**	**0.2153**	*AveSumT + DaysNeg10 + RngHab*	*−4.118848*	*4*	*18.343*	*1.812*	*0.1165*
RngHab	0.4201	0.0467	9	0	0.2930	*MaxElevR + DaysNeg10 + RngHab*	*−4.188762*	*4*	*18.483*	*1.952*	*0.1087*
LocalHRs	0.3803	0.0423	9	0	0.5801	AveSumT + RngHab	−5.843907	3	18.888	2.357	0.0887
GrzPre99	0.0632	0.0158	0	4	0.0267	AveSumT + DaysNeg10	−6.537314	3	20.275	3.744	0.0444
AveAnnPPT	**0.0702**	**0.0117**	**6**	**0**	**0.3235**	MaxElevR + RngHab + GrzPre99	−5.199007	4	20.503	3.973	0.0396

- ***Models were created before 2000s sampling, represent collection of best-guess hypotheses***
- **Closer to 'truth' = models more predictive of pattern than original (2003) suite**
- **Amount of talus area in the mtn. range is decreasing in importance**
- **Apparent importance of types of stress not previously widely recognized as drivers**
- **Climate interacting with non-climatic vars, in some cases**

DONE !!

So what ???

- Mammals worldwide typically have been endangered primarily by habitat loss, over-exploitation, lg. body size
- Climate is the single-strongest factor effecting distributional change (increasingly so), yet interacts with other factors to affect population dynamics
- When microclimate data are lacking, the residual measure can provide a first estimate of site vulnerability
- Early-warning signs of change are valuable
- Population loss can occur without detectable change in (talus) habitat extent or configuration
  - empirical verification of trend necessary for some wildlife spp.

Conclusions (cont'd)

- **Upper, mean, and median elevation didn't change, at most sites – solely seeing a low-elev'n concatenation**
- **Distributional changes have been observed in ne CA, NV, se OR, the Cascades, UT, CO, s. ID, YOSE, & other locations.**
- **Ultimately, concern for alpine ecosystems will be more efficient than concern for a single species**
- **Population loss can occur without detectable change in (talus) habitat extent or configuration**
  - **empirical verification of trend necessary for some wildlife spp.**

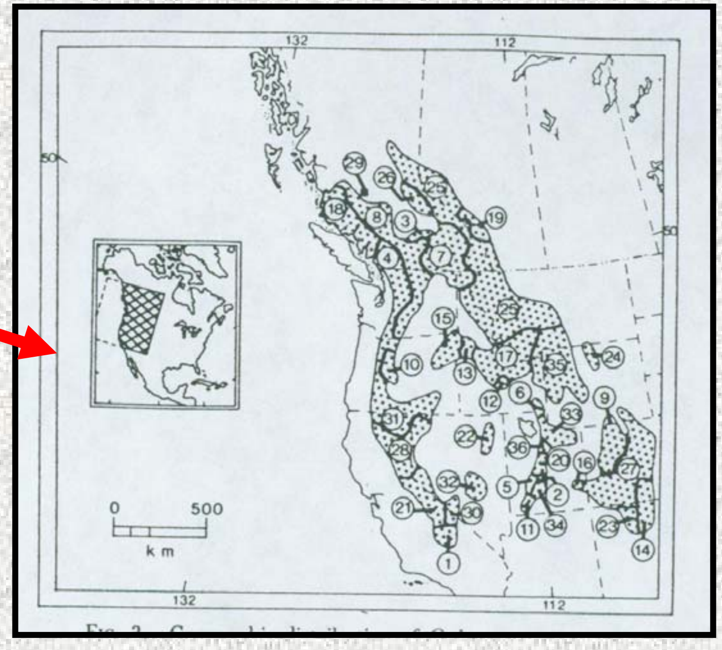
Multi-scale dynamics, processes

Scale	Proposed investigations		Processes associated with this scale		Factors driving dynamics
Local (patch)	1) Patch-occupancy via multi-model inference (resource-selection functions)		Patch occupancy, extinction/recolonization, territoriality, competition for copulations (mating)		Patch quality (spatial extent, rock diameter, %slope, vegetative characteristics) and isolation; anthropogenic influences; effects of individual animals
Within-range	1) Alternative scale for 1) above		[[*In the Great Basin, probably only exist within the Ruby-East Humboldt, White, Toiyabe, and perhaps Steens Mtns.*]]		Anthropogenic influences (proximity of rds, sympatric grazing); infrequent long-range dispersal;
Eco-regional (GB)	1) information-theoretic and predictive modeling of site-level persistence; 2) intensive thermal characterization of sites; 3) application of population-size metric as index of site vulnerability to future extirpation		Currently, apparent local extinctions w/o concomitant colonizations; latitudinal and longitudinal gradients in elevational distributions (Hafner 1993)		Anthropogenic influences; climate (temp and PPT); extent and elevational distribution of talus habitat at local and mtn-range scales
Conti-nental (N. Am.)	1) Multivariate (or multiple logistic) comparison of prehistoric, recently extirpated, and currently extant sites; 2) comparison of thermal niches and population-loss rates among regions		Subspeciation; latitudinal gradients in elevational niche; long-term expansion & contraction of geographic range		Broad (temporal)-scale climate (e.g., latitude, aspect, elevation), biogeographic dynamics (e.g., mainland vs. island, stepping-stone proximity and dispersal barriers, site area)

Pikas as model sp. for bioclimatic-niche testing

Theoretical considerations

- Large geographic range (18˚ of latitude – clinal variation)
- 36 subspp. (short dispersal distances)
- Complete paleo record (↑ & ↓ over time)
- Known vulnerability to high-heat stress



Genus : persisted since Pliocene
Species: ~ last 500,000 yrs (WIan glacial period)

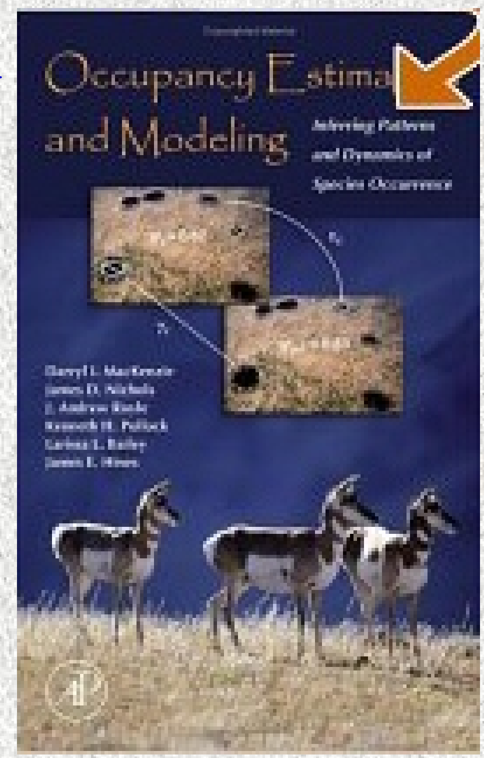
Pikas as model sp. for bioclimatic-niche testing$_2$

Practical considerations

- Locally abundant, unlike most mammal spp.
- Relatively stable pop'n sizes
- Highly detectable (HPs, calls)
  - Means monitoring is less expensive
- Easily defined habitat, NOT changing over time
  - losses ***not*** confounded by habitat change
- HSTal records & 15 yrs of recent data indicate a changing distribution
  - Site extirpations; upslope migration

Model sp. for bioclimatic-niche testing: high detectability

Location	$p \pm 1$ SE
sw, central, & ne UT	0.89 ± 0.03 (>0.85 @ most sites)
Craters o' Moon NM, s ID	0.92 (95% CI: 0.74-0.98)
Lava Beds NM, ne CA	0.97 ± 0.03
Great Basin, ↓ experience	0.85 ± 0.05
Hays Cnyn Range, nw NV	0.93
Great Basin, ↑ experience	0.96 ± 0.02



MacKenzie et al. (2006)

Obs'vdGB site-level occupancy histories

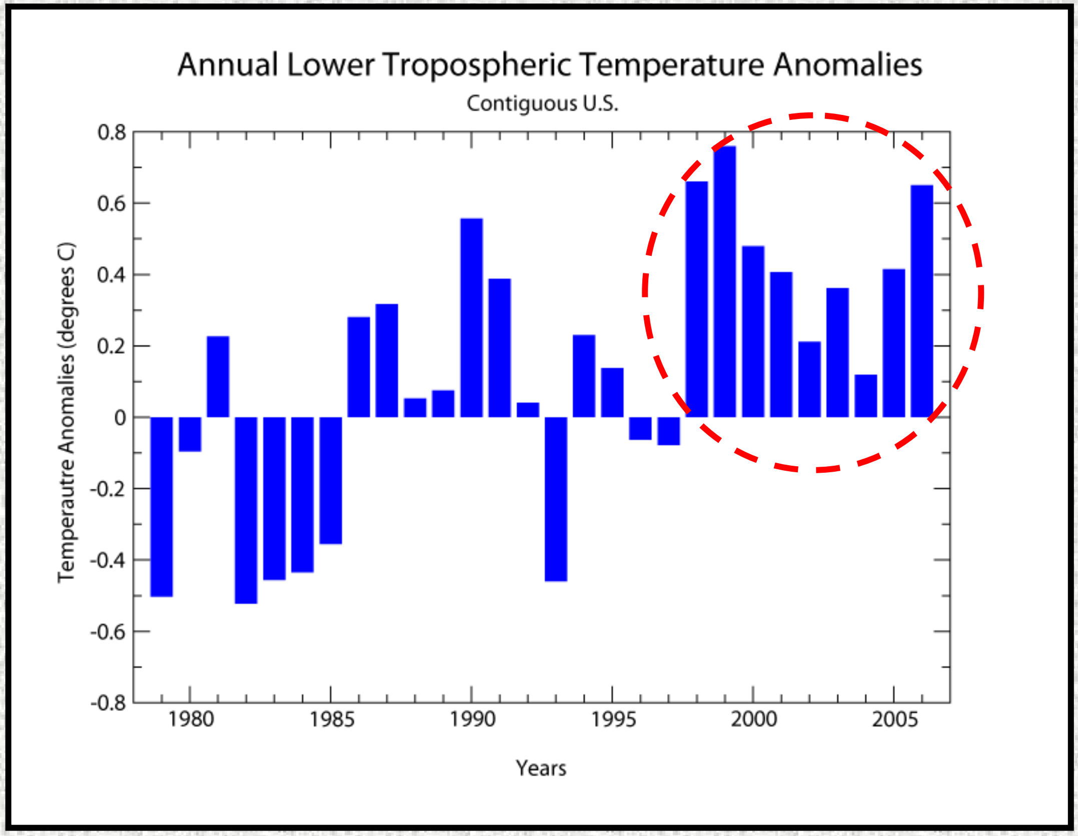
111111 … **always occupied**

000000 … **always unoccupied**

110000 … **pvsly occup'd; 'extirpated'**

Interpretation$_1$

- Importance of Recent thermal influences was predicted to be greater, consistent with inflection point in atmospheric data



Data collected by NOAA's TIROS-N polar-orbiting satellites; adjusted for time-dependent biases by NASA (troposphere = lowest 8 km of atmosphere)

What can be done?

- **Must proceed from solid understanding of life- and natural history**
- **Behavioral <u>mechanisms</u> to accommodate climate stress need to be understood and incorporated**
- **Empirical verification of trend necessary for some wildlife spp.**
- **Knowing past dynamics may not help forecast future**
- **Take data on early-warning signs of change**
- **When microclimate data are lacking, the residual measure can provide a first estimate of site vulnerability**
- **Multi-pronged approaches will provide best insights into specific mechanisms by which GCC acts upon species**
- **Ultimately, concern for alpine ecosystems will be more efficient than concern for a single species**

What can be done? (*actions*)

- If talus areas are no longer habitable, relocation efforts in vain
- Belwether, relatively common, and high-*p* spp. cheap to study
- Mitigation of other synergistic drivers, stressors (grazing contexts, preferential harvest of lg. boulders, etc., etc.)
- Conserv'n or acquisition of potential corridors (e.g., newly created habitats from glacial recession, N), to increase connectivity
- Be wary of emerging diseases; testing; disease management
- Conserve genetic diversity (hair, scat), esp. for poorly dispersing spp.
- Assisted migrations ?