Sharon Tiemann - Pika documents for April Commission meeting

From:	Brian Nowicki <bnowicki@biologicaldiversity.org>
To:	"'Jon Fischer'" <JFischer@fgc.ca.gov>, <fgc@fgc.ca.gov>, <ashea@fgc.ca.gov>
Date:	4/8/2008 10:04 AM
Subject:	Pika documents for April Commission meeting
Attachments:	Final SRLoarie 2008.pdf; SRLoarie Resume.pdf; PikaMap[1].pdf; Morrison & Hik 2008_When, where, & 4 how long_census designconsider'ns_Lagomorph book.pdf

Jon and John,

Attached are a few additional documents to include in the record and offer to the Commission for their consideration in deciding on the peition to list the American pika. These include:

1) PikaMap. A map of the geographic distribution of American pika under present day and future (2100) conditions.
2) Final SR Loarie. A description of the methods used by the researcher to develop the maps.
3) SR Loarie Resume. The CV for the researcher who developed the maps.
4) Morrison and Hik 2008. A very recent article in "Lagomorph Biology:Evolution, Ecology, and Conservation" that describes the particular vulnerability of pikas to the impacts of global warming.

We ask that these items be included in the packet of recent correspondence provided to the Commissioners. I will call Jon this morning, and I can bring over hard and electronic copies if necessary.

Also, I would like to check to make sure that the pika petition is still scheduled for Thursday morning in the most recent agenda for the Commission meeting, and to make sure there will be time for the Center to present in support of the petition. The author of the petition, Shaye Wolf, PhD, will be presenting for the Center.

Thank you very much for your time.

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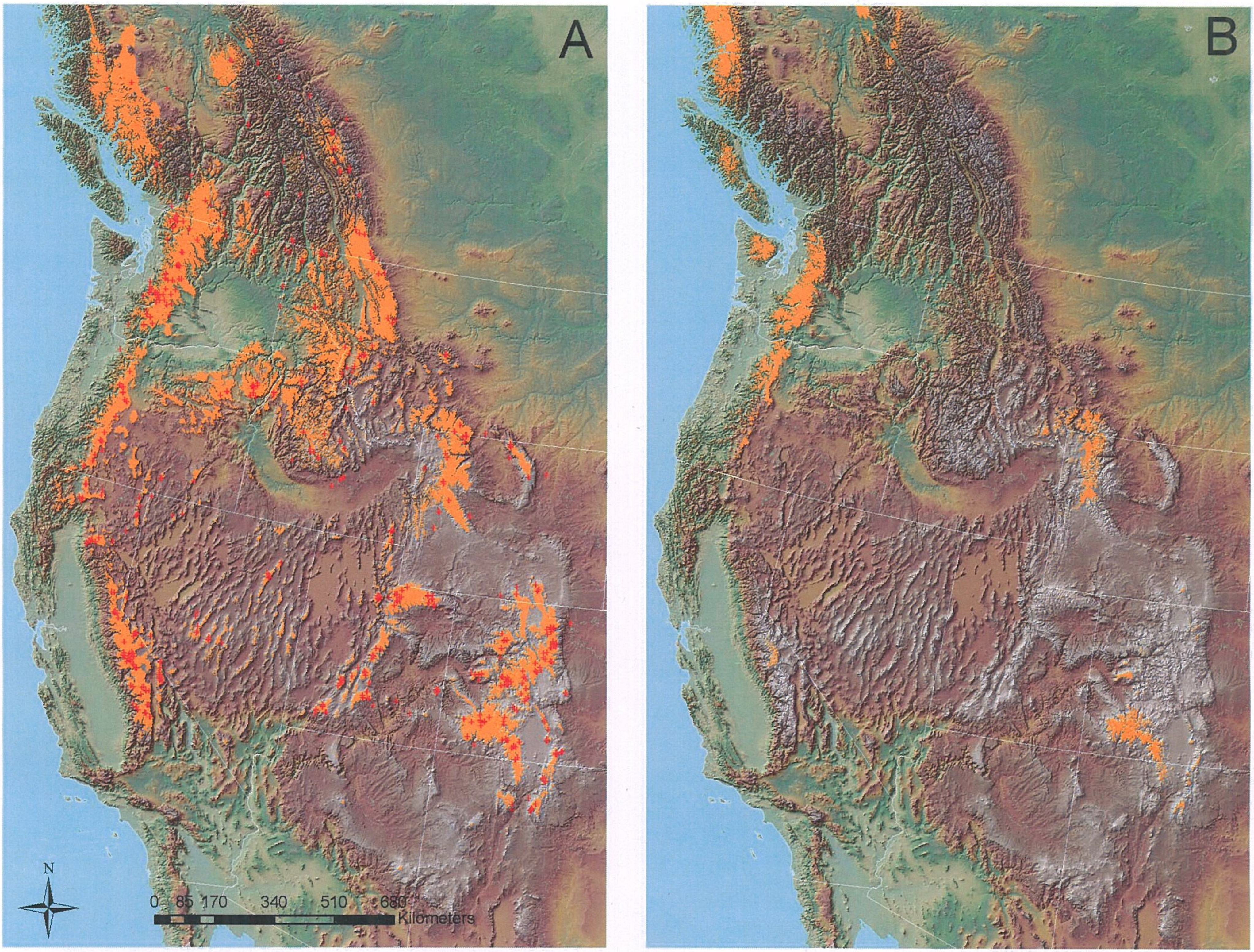
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Distribution of the American Pika (*Ochotona princeps*)
under Present-day and Future Climate Conditions

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Environmental Science and Policy
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Duke University

April 2008

Introduction

I am a Ph.D. candidate at the Nicholas School of the Environment and Earth Sciences at Duke University specializing in research involving the response of species distribution to climate change. I expect to receive my Ph.D. in the spring of 2008, and I have accepted a post-doctoral position as a climate change researcher at the Carnegie Institution of Washington, Department of Global Ecology, based in Stanford California. My resume is attached.

This analysis is part of an ongoing study to predict the impacts of climate change on the distribution of the American Pika (*Ochotona princeps*) throughout its range in the western United States. This analysis uses an ecological niche modeling approach to model habitat suitability as a function of climate conditions. More specifically, this analysis models habitat suitability for American pika under both present-day climate conditions and climate conditions projected for the end of this century (2100). This work is intended for publication.

Methods

The distribution of the American pika was modeled as a function of present-day climate conditions to create an ecological niche model that projects suitable habitat for pikas. The ecological niche model was then projected into future climate conditions in order to predict the area of suitable habitat for pikas in 2100.

Environmental data

Present-day (~1950-2000) and future climate data were used to create climate layers for use in the ecological niche model. Present-day monthly climate data were taken from the WorldClim database [1] at 30" spatial resolution. Future climate data for 2100 were drawn from general circulation model (GCM) simulations from the Community Climate System Model 3.0 [2], downloaded from the Earth System Grid website (http://www.earthsystemgrid.org) with a spatial resolution of 1.4°, or roughly 125×125 km. I used the B1 emission scenario from the 2007 International Panel on Climate Change Fourth Assessment Report (Special Report on Emissions Scenarios - SRES). The B1 scenario is a relatively low emission scenario resulting from a "more integrated, and more ecologically friendly world."

I created future monthly climate surfaces at 30" spatial resolution as follows. First, I calculated the differences between climate conditions in 2100 and pre-industrial climate conditions. These differences were then interpolated to 30" spatial resolution using the spline function in ArcInfo (ESRI, Redlands, CA) with the tension option. Finally, these monthly difference maps were added to the WorldClim present-day climate data maps to produce future monthly climate maps at 30" spatial resolution. This procedure had the dual advantage of producing data at a spatial resolution (30") relevant to the analysis and of calibrating the downscaled 2100 climate data to actual observed climate conditions.

American pika occurrence data

I obtained 2556 geo-referenced museum specimens for *Ochotona princeps* from the Global Biodiversity Information Facility website (http://www.gbif.org). The analysis area was a 1.6 million km x 2.7 million km region that encompassed all non-fossil specimens and most of western North America.

Ecological niche model

An ecological niche model for the American pika was created using the program Maxent [3] by modeling pika distribution as a function of present-day climate conditions using the recent pika occurrence data (described above) and present-day climate data. The Maxent program generates ecological niche models using only presence records, contrasting them with pseudo-absence data sampled from the remainder of the study area. I developed present-day ecological niche models based on the 2556 occurrences, and projected the ecological niche model into both present-day and 2100 climate conditions across the study area. The ecological niche model used 19 bioclimatic variables in the WorldClim data set. These variables represent summaries of means and variation in temperature and precipitation relevant to determining species distributions.

Results

Figure 1 shows the distribution of the American pika, depicted in orange shading, modeled under present-day (Figure 1A) and future (2100) (Figure 1B) climate conditions. The red "+"s represent the 2556 recent pika occurrence records. The background depicts elevation. The modeled distributions represent habitat suitability for the pika using our ecological niche modeling approach. Thus, these maps show changes in habitat suitability for the American pika under the present-day climate conditions versus future climate conditions under the low-emissions B1 scenario.

These results indicate that habitat suitability for the pika will be significantly reduced throughout its range in the western United States. Remnant suitable habitat is predicted to remain only in a few small regions of the Rocky Mountains, the Cascades and the Sierra Nevada. Suitable habitat the American pika in California will be virtually eliminated except for a tiny fragment of habitat in the central Sierra Nevada.

References

1. Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978.

2. Collins WD, Blackmon M, Bitz C, Bonan G, Bretherton CS, et al. (2004) The community climate system model: CCSM3. Journal of Climate 19: 2122–2143.

3. Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. Ecological Modelling 190: 231–259.

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EDUCATION

Duke University, Durham, NC
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Ph.D. Candidate in Environmental Science and Policy (degree expected Spring 2008)
Major Advisor, Dr. Stuart L. Pimm
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Stanford University, Stanford, CA
MS in Biological Sciences (2002)
BS in Earth Systems Science and Biological Sciences (2001)
Minor in Physics

MAJOR FIELD RESEARCH

Southern Africa, 2004 to present
Spent 18 months studying the influence of climate on elephant movements and ecology

Central America, 1999 to 2000
Spent 9 months studying bird dispersal

Caribbean, 1998 to 1999
Spent 6 months studying *Anolis* lizard ecology

PUBLICATIONS

SR Loarie, MJ Suitor, RS Schick, C Loucks, P Jones, C Gates, JSClark, A mechanistic model for pronghorn movement and habitat selection. *In prep.*

SR Loarie, JS Clark, BD Best, LN Joppa, PN Halpin, Dealing with species detection in distribution models – a new role for range maps. *In prep.*

RS Schick, JS Clark, **SR Loarie**, F Colchero, BD Best, A Boustany, DA Conde, PN Halpin, LN Joppa, CM McClellan, Understanding movement data and movement processes: what is the state of the art? *In review.*

SR Loarie, R van Aarde, SL Pimm, Fences and artificial water distort elephant movements across wet and dry savannahs. *In review.*

SR Loarie, B Carter, CA. Knight, KA Hayhoe, DD Ackerly, Climate change and the fate of the California flora. *In review.*

AE Zanne, M Westoby, DS Falster, DD Ackerly, **SR Loarie**, DA Coomes, Angiosperm trait spectra: variation in xylem anatomy and ecological function. *In review.*

S.R. Loarie, L.N. Joppa, S.L. Pimm, 2007. Satellites miss environmental priorities. *Trends Ecol. Evol.* **22**, 630-632.

S.R. Loarie, L.N. Joppa, S.L. Pimm, 2008. Satellites miss environmental priorities: Response to Loveland et al. and Kark et al. *Trends Ecol. Evol.* **23**, 283-184.

LN Joppa, **SR Loarie**, SL Pimm, On the protection of protected areas. *In press , Proc Natl Acad Sci USA.*

CH Sekercioglu, SH Schneider, JP Fay, **SR Loarie**, 2008. Climate change, elevational range shifts, and bird extinctions. *Cons. Bio.* **22**, 140-150.

SR Loarie, S Chakraborty, K Dexter, A Fleming-Davies, A Gronewold, J Liu, A McBride, E Pollina. 2006. Density dependence and population growth: evaluating classical and Bayesian approaches to parameter estimation and model selection. In J.S. Clark, "Statistical computation for environmental sciences in R". Princeton University Press. 2007.

CH Sekercioglu, **S.R. Loarie**, F Oviendo Brenes, PR Ehrlich, GC Daily, 2007. Persistence of Forest Birds in the Costa Rican Agricultural Countryside. *Cons. Bio.*, **21**, 482-494.

EE Cleland, NR Chiariello, **SR Loarie**, HA Mooney, CB Field, 2006. Diverse responses of phenology to global changes in a grassland ecosystem. *Proc Natl Acad Sci USA* **103**:13740–13744.

Konstant, WR, D Taylor, DA Wake, R Bittman, B Ertter and **SR Loarie**. 2004. *California Floristic Province*. In: Hotspots Revisited: Earth's Biologically Richest and Most Threatened Ecoregions. RA. Mittermeier, P Robles Gil, M Hoffman, J Pilgrim, T Brooks, CG Mittermeier, JL Lamoreux and GAB da Fonseca (eds.). CEMEX, Mexico City, Mexico.

HR Pereira, **SR Loarie**, J Roughgarden, 2002. Monogamy, polygyny and interspecific interactions in the lizards Anolis gingivinusand Anolis pogus. *Caribbean Journal of Science*, **38**:132-136.

SELECTED PRESENTATIONS

SR Loarie, R van Aarde, SL Pimm, 2007. Seasonal vegetation preferences drive elephant migrations across seven southern African countries. The Society for Conservation Biology Annual Meeting Abstract/presentation. Port Elizabeth, South Africa

SR Loarie, R van Aarde, SL Pimm, 2006. Using remotely sensed data to model african elephant movement. NASA Biodiversity and Ecological Forecasting Team Meeting. Washington DC, United States

SR Loarie, R van Aarde, SL Pimm, 2006. The Influence of water, vegetation, and human activity on African elephant movement. The Society for Conservation Biology Annual Meeting Abstract/presentation. San Jose, California, United States

SR Loarie, SM Ferreira, 2005. Movements and meta-population dynamics. Southern African Wildlife Managers Association Symposium Abstract/presentation. Limpopo Province, South Africa

SR Loarie, R van Aarde, SL Pimm, 2005. Water and land-use influence elephant movements in Botswana- implications for wildlife management. The Ecological Society of America Annual Meeting Abstract/presentation. Montreal, Canada

SR Loarie, B Carter, CA Knight, DD Ackerly, 2004. Extinction sinks in the California flora. The Ecological Society of America Annual Meeting Abstract/presentation. Portland, Oregon, United States

PROFESSIONAL ACTIVITIES

Memberships
Ecological Society of America
Society for Conservation Biology

Journals
Reviewer for *Biological Conservation*

Working Group Participation
Wood Anatomy: from phylogenies to climate envelopes. NESCent, Durham, NC
Phyloinformatics Hackathon: Comparative Methods in R. NESCent, Durham, NC

When? Where? and for How Long? Census Design Considerations for an Alpine Lagomorph, the Collared Pika (*Ochotona collaris*)

SHAWN F. MORRISON* AND DAVID S. HIK

Introduction

Talus-dwelling pikas (*Ochotona* spp.) live in alpine areas on naturally fragmented patches of talus habitat separated by an inhospitable matrix of meadow or forest. Consequently, pikas have been studied to examine dispersal behavior (Peacock and Smith 1997) and to test predictions of metapopulation theory (Clinchy et al. 2002; Moilanen et al. 1998; Smith 1980). Their small territories, diurnal behavior, and high levels of activity have also made them the focus of studies investigating foraging behavior (Dearing 1996; Holmes 1991; Morrison et al. 2004), nutrient cycling (Aho et al. 1998), and plant community composition (Huntly 1987; Mcintire and Hik 2002), among others.

Pikas have been recognized as being particularly vulnerable to the effects of climate warming because of their sensitivity to high temperatures (MacArthur and Wang 1973; Smith 1974). This sensitivity had led to pikas being proposed as climate-change indicators for alpine ecosystems (Beever et al. 2003; McDonald and Brown 1992; Smith et al. 2004), in part because alpine and high latitude ecosystems are predicted to be most affected by global warming (Källén et al. 2001). Some negative effects of climate change on high-latitude wildlife populations are already being observed (Derocher et al. 2004; Hik 2001), however the overall implications of climate warming remain unknown for most species (Hofgaard et al. 1999).

Testing ecological theory in the field and managing wildlife populations and their habitat requires reliable estimates of population density among sites and over time, and both direct enumeration techniques and population indices are widely used (Caughley and Sinclair 1994; Karels et al. 2004; McArdle et al. 1990; Wilson et al. 1996). Indeed, for pikas to be useful as an indicator species, long-term population census data are essential for detecting changes in pika abundance, population growth rates, and the range of natural variation. Long-term data will also permit accurate parameterization of population models for determining the future viability of pikas at local, regional and population scales (e.g., Beissinger and McCullough 2002).

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P.C. Alves, N. Ferrand, and K. Hackländer (Eds.)
Lagomorph Biology: Evolution, Ecology, and Conservation: 103–113

This, in turn, will allow for an assessment of the alpine ecosystem as a whole as reflected by pika populations. Unfortunately, there are few long-term population census datasets available for this genus.

In this study, we used data from a continuous 10-year (1995–2004) live-trapping census for collared pikas (*Ochotona collaris*) to examine the effects of (1) census duration, (2) location of the study area, and (3) timing of study initiation on estimates of population size and the yearly rate of population growth (λ). Our primary objective was to determine the number of years of census data required to quantify the population dynamics of this species.

Study Area

The study was conducted in a 4-km^2 alpine valley that consisted of a meadow interspersed with patches of talus in the Ruby Range, east of Kluane Lake, Yukon, Canada (61°13′N, 138°16′W; 1,700–2,200 a.s.l.) between 1995 and 2004. The talus patches were separated by a matrix of *Dryas octopetala*, *Salix* spp. and several graminoid species (e.g., *Carex consimilis*). *Cassiope tetragona* was common along the talus margins in some areas. See McIntire (1999) and Hik et al. (2001) for additional details.

The valley was segregated into three subpopulations based on dominant aspects: east-, west-, and south-facing. Collared pikas, hoary marmots (*Marmota caligata*) and arctic ground squirrels (*Spermophilus parryii plesius*) were the dominant herbivores in the valley. Potential predators of pikas include raptors, foxes (*Vulpes vulpes*), and weasels (predominately short-tailed weasels, *Mustela erminea*) (Hik et al. 2001). The snow-free season generally extends from mid-June to early September.

Methods

We used a 10-year census dataset of >400 collared pikas where the entire population was uniquely marked and trapped each summer. Capture methods were described in detail by Franken and Hik (2004). Briefly, pikas were live-trapped using Tomahawk live-traps baited with fresh native vegetation. Pikas are quite active within their small (<25-m radius) territories, have distinctive territorial calls, and have distinguishable haypiles (Smith 1974, 1980), permitting us to locate and capture all pikas resident within the study area.

Individuals trapped for the first time were marked with numbered metal ear tags (Monel #1) and a unique color combination of thin wire to allow identification from a distance without requiring subsequent recaptures. Individuals were sexed following Duke (1951) and classified as juvenile or adult based on mass and molt pattern.

Bootstrapped mean population sizes and population growth rates ($\lambda_t = N_{t+1}/N_t$, where N_t is the number of pikas in year t) (Efron 1982) were calculated for 2–10 years of consecutive data for as many study-durations as possible for each subpopulation. For example, we had 7 years of consecutive census data available for the south-facing subpopulation (1998–2004), which allowed us to calculate bootstrapped means for six possible 2-year studies (1998–1999, 1999–2000, . . . , 2003–2004), five 3-year studies, four 4-year studies, and so on. Coefficients of variation (CV; Zar 1999) were used to indicate variability in the mean values. In the above example, the CV for studies of 2-year duration was based on six bootstrapped means. We present examples of state variables (N_t) and transition probabilities (λ_t); similar analyses could be conducted on other population variables such as survival or reproduction.

Results

Population estimates and growth rates varied considerably and depended on study duration, year of initiation, and location within the valley (subpopulation). All three subpopulations were variable from 1995 to 2004 (Fig. 1). The east-facing and west-facing subpopulation declined from 1995 to 2004, with short periods of moderate increase (e.g., 2000–2002). The west-facing subpopulation declined to extinction in winter 1999–2000 and was not recolonized until 2001. The east-facing subpopulation went extinct during winter 2003–2004 but was recolonized by juveniles during summer 2004. The south-facing

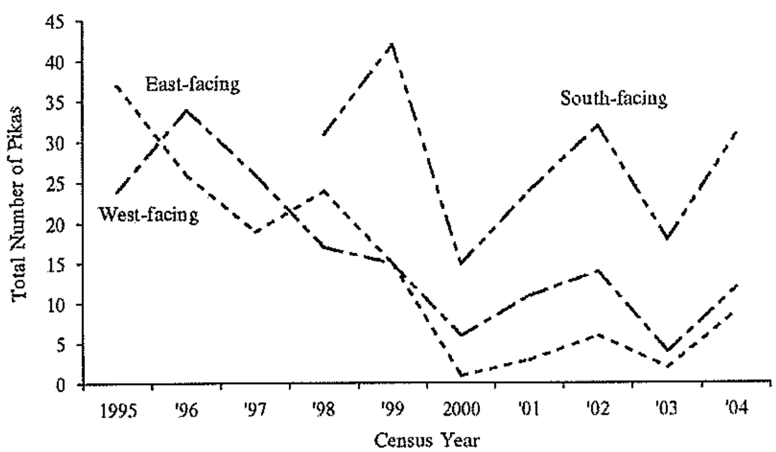

Fig. 1 Late summer total abundance of collared pikas (adults and juveniles) in southwestern Yukon from 1995 to 2004. Estimates were derived from complete census data of live-trapped individuals in three subpopulations

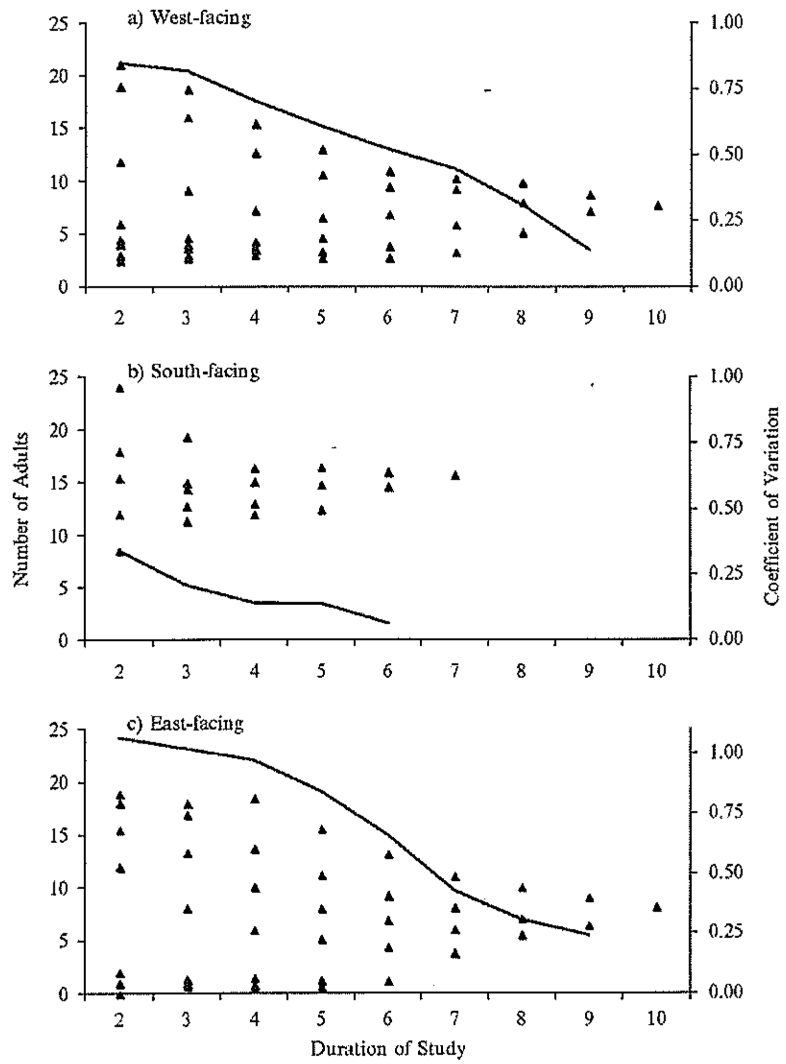

Fig. 2 Bootstrapped estimates of adult pika abundance using 2–10 years of census data. *Triangular symbols* represent bootstrapped mean number of adults in three subpopulations for hypothetical studies of 2–10 years in duration. The *solid line* indicates the coefficient of variation

subpopulation was consistently larger than either the east-facing or west-facing subpopulations and did not go extinct at any time during our study (Fig. 1). Based on trapping data, only 4 of 400 pikas moved between these three subpopulations from 1995–2004 following their first capture, suggesting these areas were largely independent despite being <300 m apart.

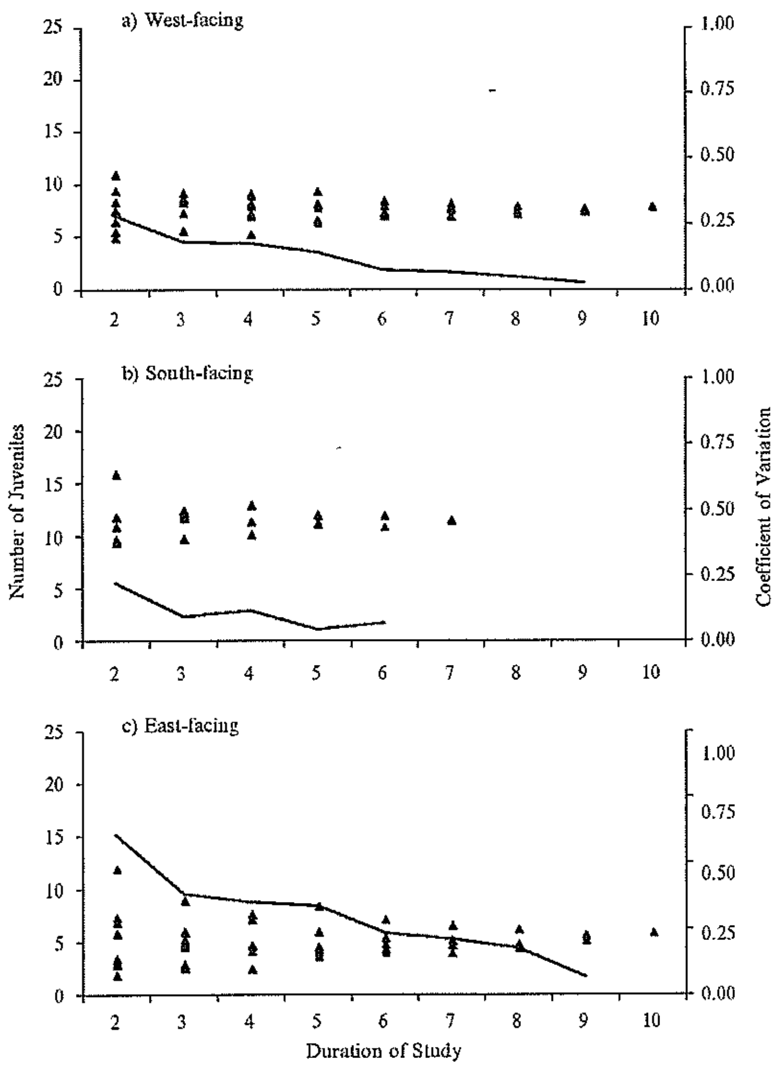

Fig. 3 Bootstrapped estimates of juvenile pika abundance using 2–10 years of census data. *Triangular symbols* represent bootstrapped mean number of juveniles in three subpopulations for hypothetical studies of 2–10 years in duration. The *solid line* indicates the coefficient of variation

The coefficients of variation (CVs) for population size were lowest for the south-facing subpopulation for all possible study durations. They (CVs) were remarkably small (<25%) for 2-year studies (Figs. 2–4), in marked contrast to the east-facing or west-facing subpopulations that required 5–6 years of data before CV declined to 25%. The CV continued to decline with additional

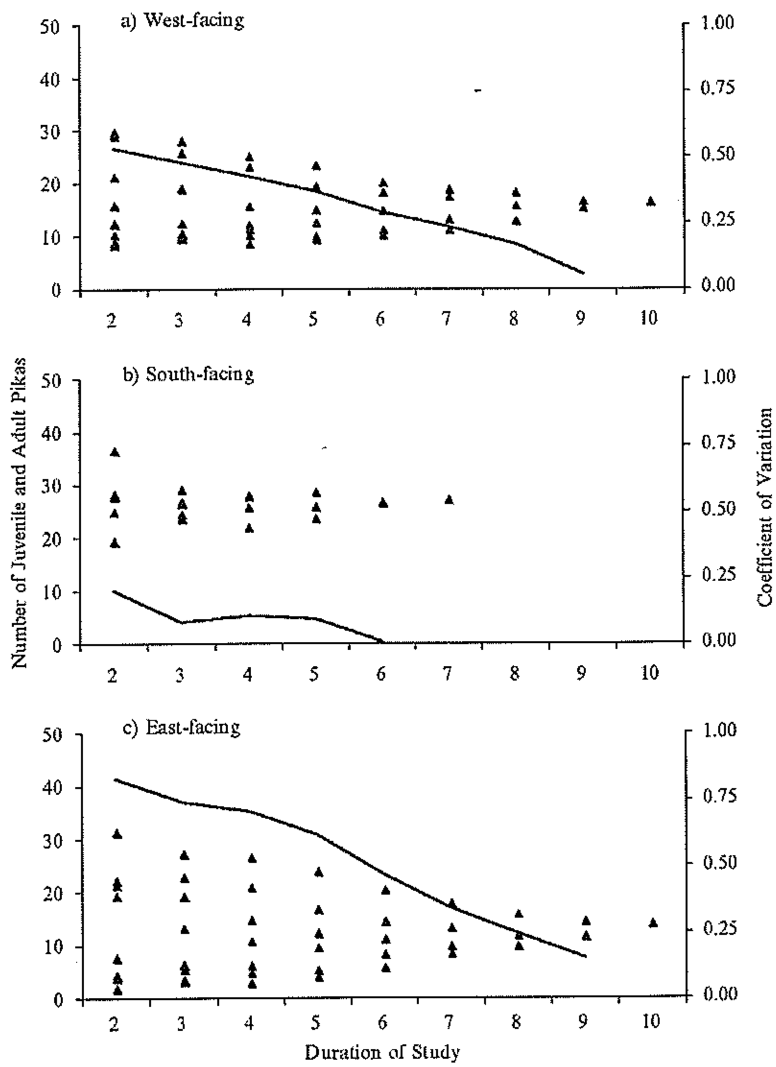

Fig. 4 Bootstrapped estimates of juvenile and adult pika abundance using 2–10 years of census data. *Triangular symbols* represent bootstrapped mean number of individuals (juveniles + adults) in three subpopulations for hypothetical studies of 2–10 years in duration. The *solid line* indicates the coefficient of variation

years of continuous data for east-facing and west-facing suggesting, not surprisingly, that a greater number of years were necessary to reliably estimate mean population size and variability.

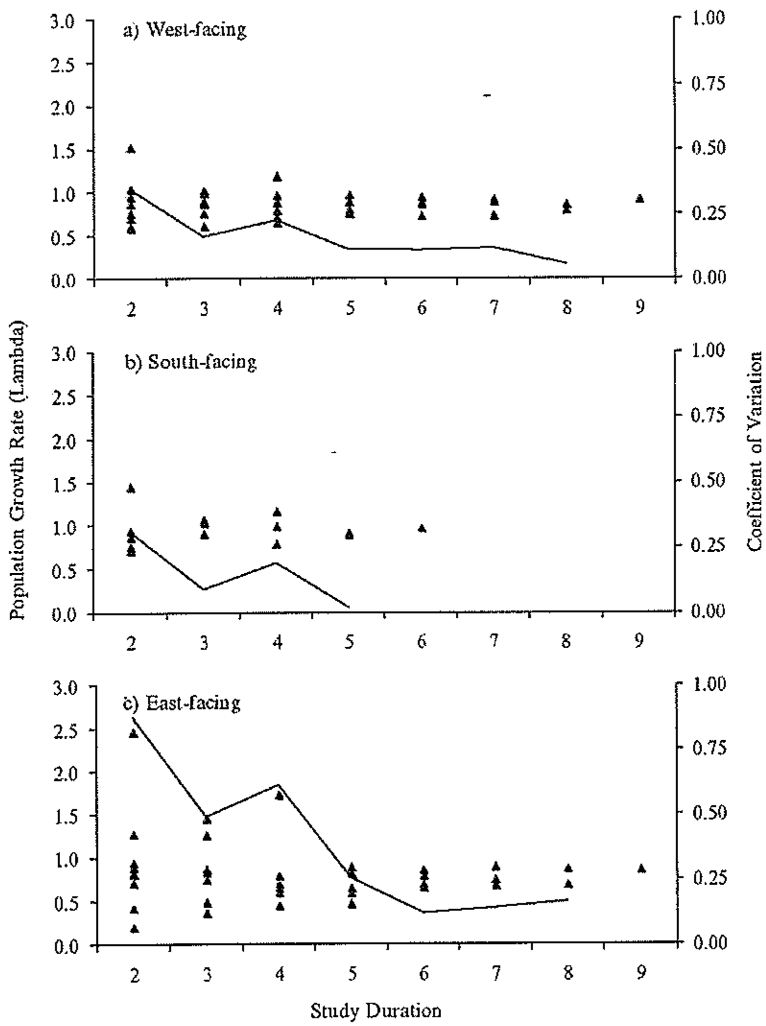

Fig. 5 Bootstrapped estimates of pika population growth rates using 2–10 years of census data. *Triangular symbols* represent bootstrapped mean growth rate in three subpopulations for hypothetical studies of 2–10 years in duration. The *solid line* indicates the coefficient of variation

The CVs for yearly subpopulation growth rates (Fig. 5) were lowest for the south- and east-facing subpopulations for all possible study durations, and declined to <25% with 3 years or more of census data. This result is in marked contrast to the east-facing subpopulation that required 5–6 years of data before the CV declined to less than 25%. The CV continued to decline with additional years of continuous census data for all areas suggesting again and, not surprisingly, a greater number of years were necessary to reliably estimate mean population size and variability.

Discussion

Collared pika populations in Yukon are variable across time and space, presumably in response to unpredictable environmental conditions (Smith 1978). This explanation for high variability may apply to our population that collapsed by 90% from 1998 to 2000. The decline occurred across the entire study area and does not appear to be related to biotic factors such as disease, food resources, or predation. Instead, we hypothesize that the decline is related to warmer winters that resulted in low snow accumulation (and therefore poor insulation value), increased frequency of freeze-thaw events, icing following winter rains, and late winter snowfall which delays the start of the growing season (Kreuzer and Huntly 2003; Smith 1978). If this hypothesis is correct, we predict that pikas at our study area will experience future population declines as a result of increased frequency of these adverse weather events as predicted by current climate change models (Houghton et al. 2001). In addition, climate warming is predicted to force pika populations to higher altitudes to maintain thermoregulation and could cause localized extinctions, particularly for lower altitude populations (McDonald and Brown 1992).

Population models created to understand pika population dynamics will require reliable parameter estimates (Beissinger 2002). This is particularly important when pikas are being used as a climate-change indicator species and are used to gauge the state of the surrounding alpine ecosystem. Further, accurate parameter estimates are essential when investigating the effects of stochastic environmental events (Lande 2002), that are predicted to increase in frequency by current climate models (Houghton et al. 2001).

Our study underscores the usefulness of long-term population monitoring. Although we presented 10 years of continuous census data, this may still not be of sufficient duration to determine the full range of natural population variability. Population size was relatively high in 1995 when the study was initiated but has declined since then with no indication of a recovery to previous numbers. This parallels declining trends reported for other species of pika such as *Ochotona princeps* (Beever et al. 2003) and *Ochotona iliensis* (Smith et al. 2004). There is no evidence to suggest that the high densities in 1995, or the low densities in 2000, are typical or anomalous. The maximum number of pikas is limited by territory availability, however, not all known territories, as indicated by old haypile remains, were occupied at the same time (DS Hik et al. unpublished data).

The low levels of observed movement between the three dominant aspects in our study site are consistent with other reports of pika philopatry

(McDonald and Brown 1992; Smith and Ivins 1983). Inter-patch movement rates of marked juveniles within a given aspect are higher than between aspects, as expected for individuals searching for vacant territories (Franken 2002). However, movement rates between patches and dominant aspects may be underestimated because juveniles are most trappable once they have established territories and are no longer moving between patches. Nevertheless, subpopulations were separated by non-talus habitat (streams and 100 to 200-m stretches of meadow), and these features likely serve as movement barriers to dispersing pikas, which are known to have poor dispersal abilities (Hafner and Sullivan 1995; Smith 1974).

Our results show that the year in which a study is initiated, its duration, and the sampling location within relatively small study areas are of great importance in inferring long-term population means and natural levels of variability. Conclusions based on short-term studies (<5 years) regarding longer-term population dynamics should be tentative, and extrapolation to nearby populations is cautioned. Given a choice, we recommend future monitoring studies give priority to sampling from multiple populations rather than collecting exhaustive census data on a single population. Population estimates could be obtained quickly and relatively inexpensively by searching for active hay piles in late summer as an indication of pika presence. These data could then be incorporated into a count-based population viability analysis (PVA) to determine extinction risk (Morris and Doak 2002). Alternatively, and given additional time or funding, live-trapping and ear-tagging should be added to provide useful information on age structure and survival. This would allow for the construction of detailed demographic PVAs that more accurately portrays population dynamics than count-based methods (Morris and Doak 2002).

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References

Aho K, Huntly N, Moen J, Oksanen T (1998) Pikas (*Ochotona princeps* : Lagomorpha) as allogenic engineers in an alpine ecosystem. Oecologia 114:405–409

Beever EA, Brussard PE, Berger J (2003) Patterns of apparent extirpation among isolated populations of pikas (*Ochotona princeps*) in the Great Basin. J Mammal 84:37–54

Beissinger SR (2002) Population viability analysis: past, present and future. In: Beissinger SR, McCullough DR (eds) Population viability analysis. University of Chicago Press, Chicago, pp 5–17

Beissinger SR, McCullough DR (2002) Population viability analysis. University of Chicago Press, Chicago

Caughley G, Sinclair ARE (1994) Wildlife ecology and management. Blackwell Science, Cambridge

Clinchy M, Haydon DT, Smith AT (2002) Pattern does not equal process: what does patch occupancy really tell us about metapopulation dynamics? Am Nat 159:351–362

Dearing MD (1996) Disparate determinants of summer and winter diet selection of a generalist herbivore, *Ochotona princeps*. Oecologia 108:467–478

Derocher AE, Lunn NJ, Stirling I (2004) Polar bears in a warming climate. Integr Comp Biol 44:163–176

Duke KL (1951) The external genitalia of the pika, *Ochotona princeps*. J Mammal 32:169–173

Efron B (1982) The jackknife, the bootstrap, and other resampling plans. Monogr Soc Industr Appl Math 38:1–92

Franken RJ (2002) Demography and metapopulation dynamics of collared pikas (*Ochotona collaris*) in the southwest Yukon. MSc Thesis, University of Alberta, Edmonton, Alberta

Franken RJ, Hik DS (2004) Influence of habitat quality, patch size, and connectivity on colonization and extinction dynamics of collared pikas (*Ochotona collaris*). J Anim Ecol 73:889–896

Hafner DJ, Sullivan RM (1995) Historical and ecological biogeography of Nearctic pikas (Lagomorpha, Ochotonidae). J Mammal 76:302–321

Hik DS (2001) State of knowledge: impacts of climate change on biophysical systems. In: Gap analysis project. Northern Climate Exchange, Whitehorse, Yukon

Hik DS, McColl CJ, Boonstra R (2001) Why are Arctic ground squirrels more stressed in the boreal forest than in alpine meadows? Ecoscience 8:275–288

Hofgaard A, Ball JP, Danell K, Callaghan TV (1999) Animal responses to global change in the north. Ecol Bull 47:54

Holmes WG (1991) Predator risk affects foraging behavior of pikas—observational and experimental evidence. Anim Behav 42:111–119

Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Dai X, Maskell K, Johnson CA (2001) Climate Change 2001: the scientific basis third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Huntly NJ (1987) Influence of refuging consumers (pikas - *Ochotona princeps*) on sub-alpine meadow vegetation. Ecology 68:274–283

Källén E, Kattsov V, Walsh J, Weatherhead E (2001) Report from the arctic climate impact assessment modeling and scenarios workshop. Arctic Climate Impact Assessment Secretariat, Stockholm, Sweden

Karels TJ, Koppel L, Hik DS (2004) Fecal pellet counts as a technique for monitoring an alpine dwelling social rodent, the hoary marmot (*Marmota caligata*). Arctic Antarctic Alp Res 36:490–494

Kreuzer MP, Huntly NJ (2003) Habitat-specific demography: evidence for source-sink population structure in a mammal, the pika. Oecologia 134:343–349

Lande R (2002) Incorporation stochasticity in population viability analysis. In: Beissinger SR McCullough DR (eds) Population viability analysis. University of Chicago Press, Chicago, pp 18–40

MacArthur RA, Wang LCH (1973) Physiology of thermoregulation in pika, *Ochotona princeps*. Can J Zool 51:11–16

McArdle BH, Gaston KJ, Lawton JH (1990) Variation in the size of animal populations: patterns, problems and artifacts. J Anim Ecol 59:439–454

McDonald KA, Brown JH (1992) Using montane mammals to model extinctions due to climate change. Conserv Biol 6:409–415

Mcintire EJB (1999) The effects of collared pika grazing on alpine tundra vegetation in southwestern Yukon, Canada. Graduate Department of Botany. University of Toronto, Toronto, Ontario

Mcintire EJB, Hik DS (2002) Grazing history versus current grazing: leaf demography and compensatory growth of three alpine plants in response to a native herbivore (*Ochotona collaris*). J Ecol 90:348–359

Moilanen A, Smith AT, Hanski I (1998) Long-term dynamics in a metapopulation of the American pika. Am Nat 152:530–542

Morris WF, Doak DF (2002) Quantitative conservation biology. Sinauer Associates, Sunderland, MA

Morrison S, Barton L, Caputa P, Hik DS (2004) Forage selection by collared pikas, *Ochotona collaris*, under varying degrees of predation risk. Can J Zool 82:533–540

Peacock MM, Smith AT (1997) The effect of habitat fragmentation on dispersal patterns, mating behavior, and genetic variation in a pika (*Ochotona princeps*) metapopulation. Oecologia 112:524–533

Smith AT (1974) The distribution and dispersal of pikas: influences of behavior and climate. Ecology 55:1368–1376

Smith AT (1978) Comparative demography of pikas (*Ochotona*) - effect of spatial and temporal age-specific mortality. Ecology 59:133–139

Smith AT (1980) Temporal changes in insular populations of the pika (*Ochotona princeps*). Ecology 61:8–13

Smith AT, Ivins BL (1983) Colonization in a pika population: dispersal vs. philopatry. Behav Ecol Sociobiol 13:37–47

Smith AT, Weidong L, Hik DS (2004) Pikas as harbingers of global warming. Species 41:4–5

Wilson DE, Cole FR, Nichols JD, Rudran R, Foster MS (1996) Measuring and monitoring biological diversity: standard methods for mammals. Smithsonian Institution Press, Washington, DC

Zar JH (1999) Biostatistical analysis, 4th edn. Prentice Hall, Englewood Cliffs, NJ