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

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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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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

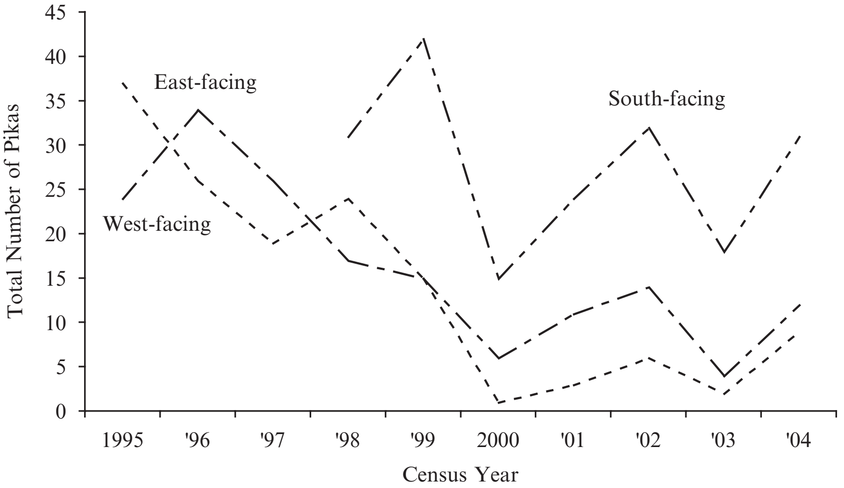

Fig. 1 Late summer total abundance of collared pikas (adults and juveniles) in southwestern Yukon from 1995 to 2004. Estimates were derived from complete census data of live-trapped individuals in three subpopulations

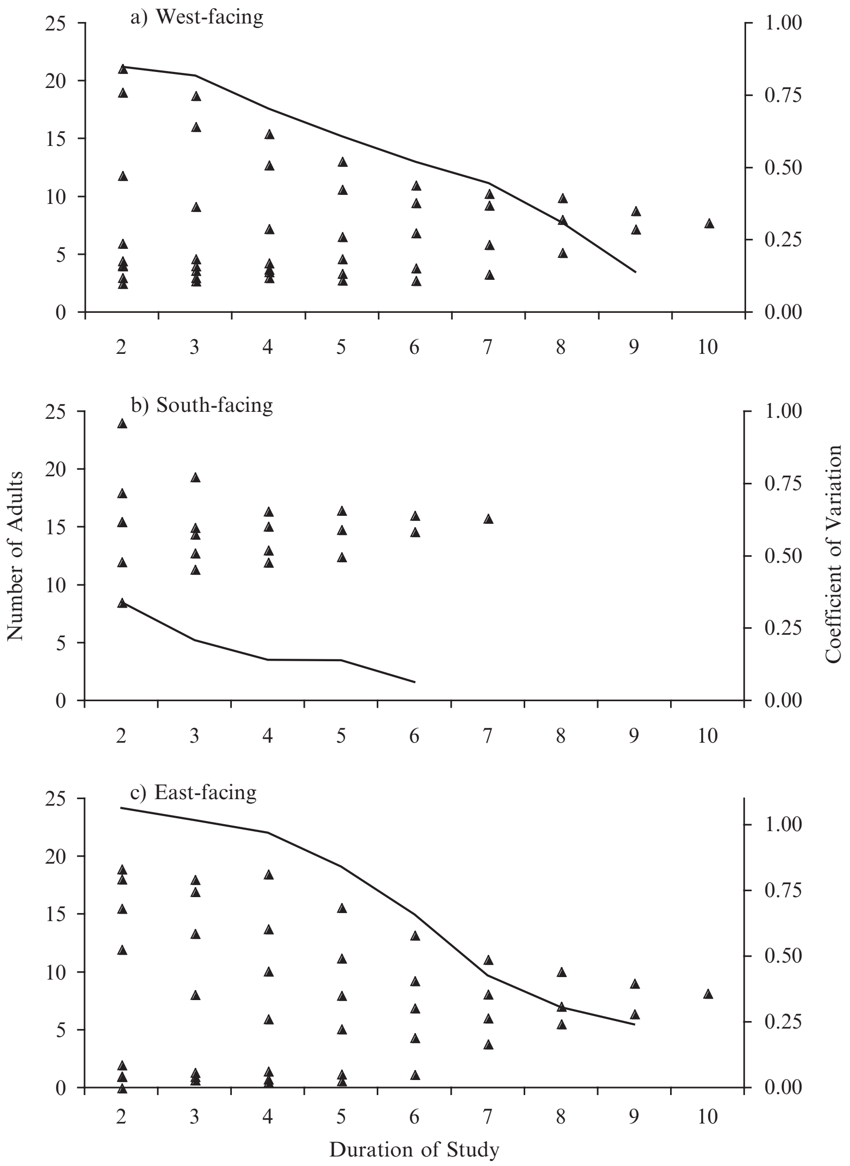

Fig. 2 Bootstrapped estimates of adult pika abundance using 2–10 years of census data. *Triangular symbols* represent bootstrapped mean number of adults in three subpopulations for hypothetical studies of 2–10 years in duration. The *solid line* indicates the coefficient of variation

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.

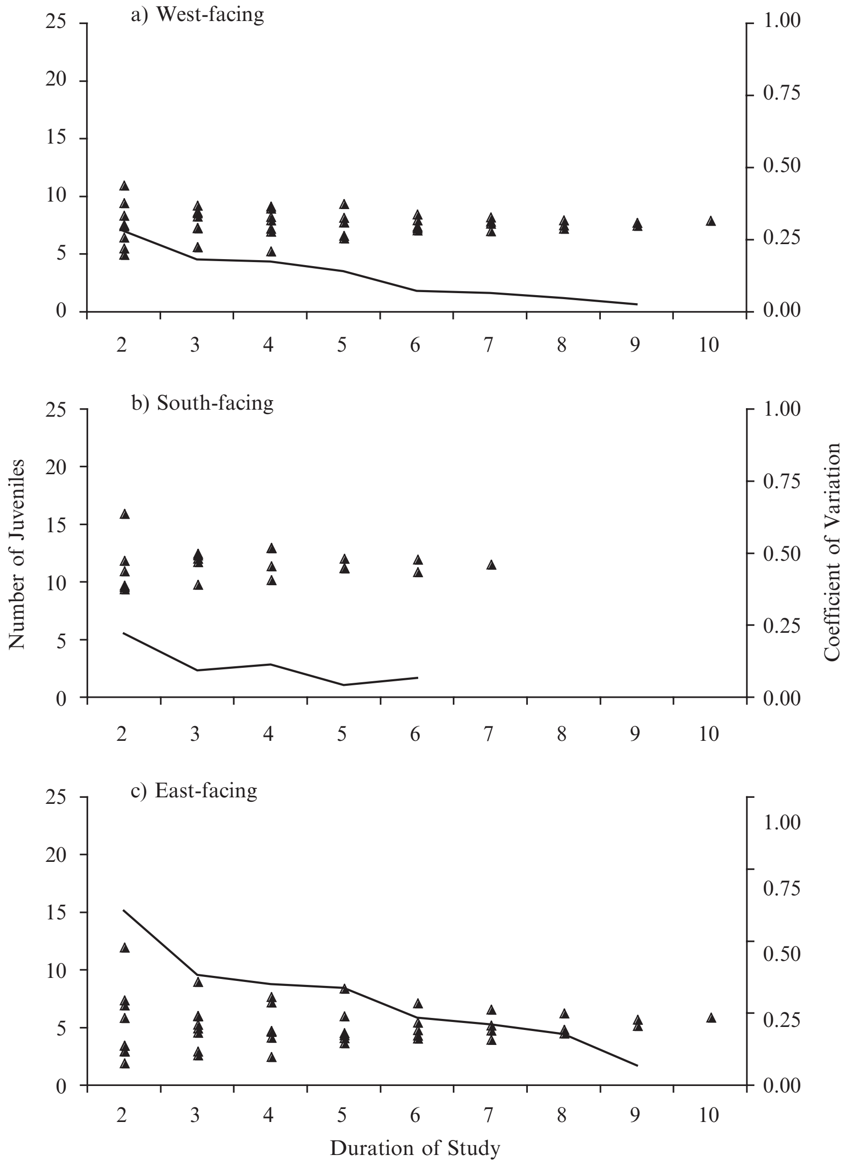

Fig. 3 Bootstrapped estimates of juvenile pika abundance using 2–10 years of census data. *Triangular symbols* represent bootstrapped mean number of juveniles in three subpopulations for hypothetical studies of 2–10 years in duration. The *solid line* indicates the coefficient of variation

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

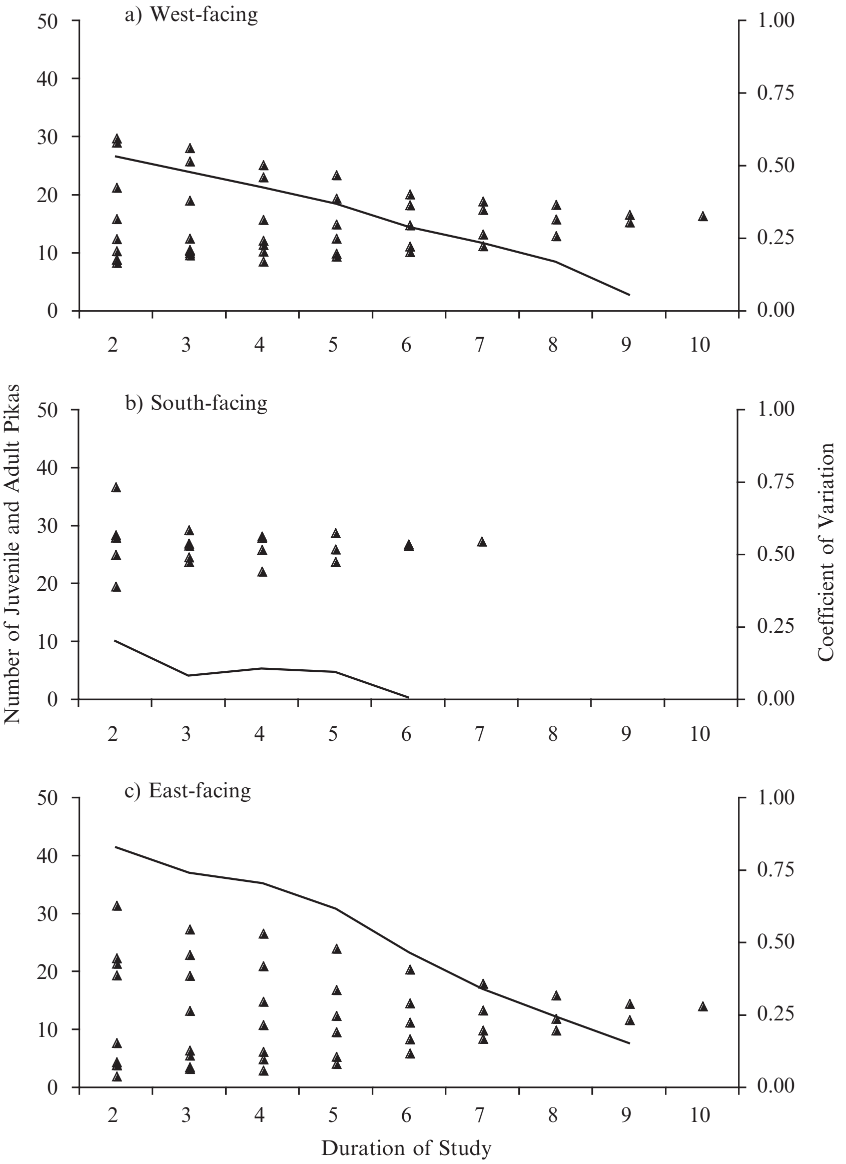

Fig. 4 Bootstrapped estimates of juvenile and adult pika abundance using 2–10 years of census data. *Triangular symbols* represent bootstrapped mean number of individuals (juveniles + adults) in three subpopulations for hypothetical studies of 2–10 years in duration. The *solid line* indicates the coefficient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

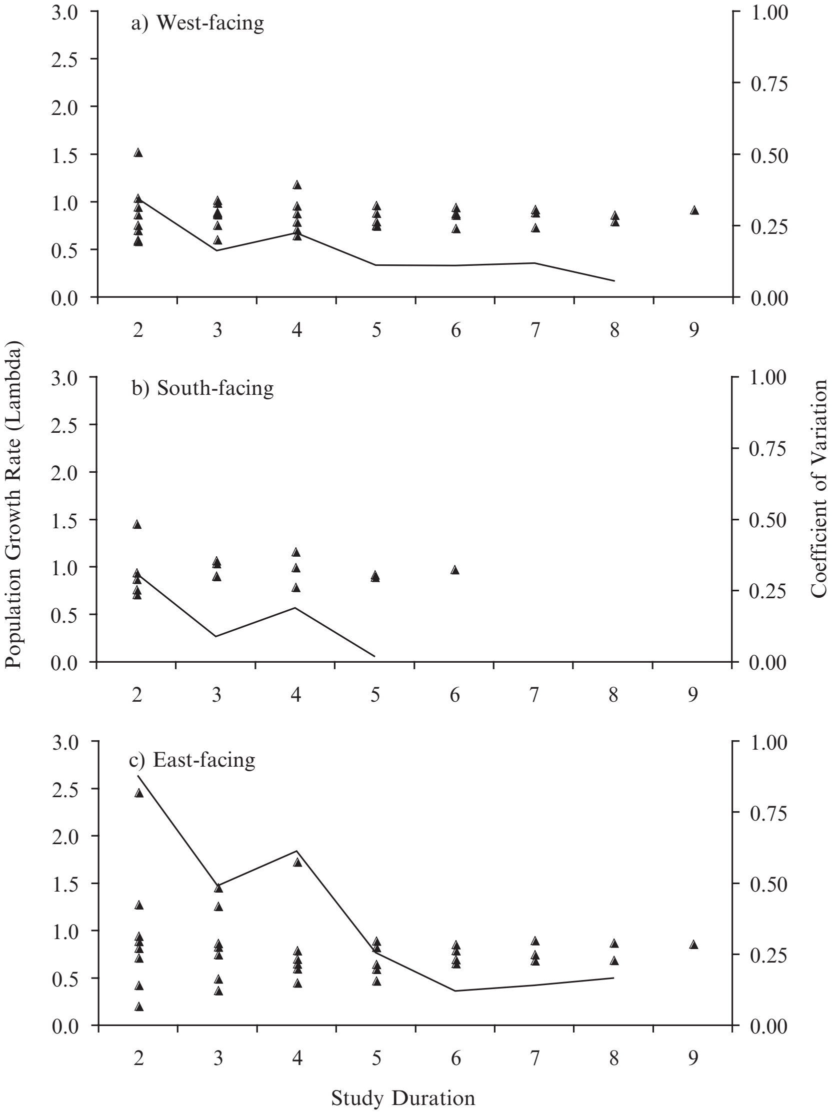

Fig. 5 Bootstrapped estimates of pika population growth rates using 2–10 years of census data. *Triangular symbols* represent bootstrapped mean growth rate in three subpopulations for hypothetical studies of 2–10 years in duration. The *solid line* indicates the coefficient of variation

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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