Factors Predicting Success of Mountain Goat Reintroductions

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ABSTRACT We adopted a retrospective approach to assess factors associated with success of mountain goat (*Oreamnos americanus*) reintroductions into native habitats during 1950-2010. We excluded translocations into areas not historically inhabited by mountain goats, as well as projects best considered augmentations. To supplement published and unpublished literature, we requested data on translocations from staff at state and provincial wildlife agencies likely to have access to information otherwise unavailable. Where data allowed, we estimated post-translocation growth rates, *r*. Because most projects did not allow the quantification of growth, we also categorized reintroduction projects as successful or not, reintroduced populations as extant or extirpated, and released animals as having displayed site fidelity or dispersing soon after release. We examined a suite of hypothesized explanatory variables for these outcomes, including number of males, females, juveniles, and kids, as well as number of separate releases, number of source populations (assumed a proxy for genetic variation), and whether source populations themselves originated as translocations. In contrast to earlier work that suggested no demographic predictor of mountain goat translocation success (Guenzel 1980), we found that the number of adult founders was strongly predictive of long-term success. Releases of just a few animals were relatively likely to have been extirpated within the time duration studied. Evidence suggested that releasing juveniles and kids along with adults produced no improvement in probability of a successful outcome.

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Translocations, augmentations, and reintroductions all have long histories of use in wildlife conservation but assessing determinants of their effectiveness is problematic. Case-study approaches (e.g., Jorgenson and Quinlan 1996, Whiting et al. 2011) reveal details that apply in any given situation but it is often challenging to find generalizations that are widely applicable. Instead, most studies of translocations and reintroductions have been retrospective, gathering existing data on a number of individual projects, and making inferences based on selected characteristics of the projects and quantitative or qualitative measures of success (Griffith et al. 1989; Wolf et al. 1996, 1998).

Translocations of large mammals began shortly after wildlife management emerged as a serious profession (Bolen and Robinson 2003) but projects during the first few decades were often poorly documented. The work of Griffith et al. (1989) spurred a renewed interest in quantitative analyses of wildlife translocations, generally across a wide range of taxa (Singer et al. 2000, Armstrong and Seddon 2007). Although details have differed, most analyses

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have broadly concluded, not surprisingly, that translocations and reintroductions are more likely to succeed when: 1) wild, rather than captive animals are used as the source; 2) more, rather than fewer animals, are released; 3) genetic variation among founders is higher rather than lower; 4) habitat quality at the release site is higher rather than lower; and 5) patch area in which animals are released is larger rather than smaller (Wolf et al. 1996, 1998; Fischer and Lindenmayer 2000).

In North America, mountain goats (*Oreamnos americanus*) have been among the more commonly translocated large mammals (Hurley and Clark 1996), both within portions of their native range where populations had become depressed and outside their native range into mountains that appeared suitable and where public interest was strong. To date, however, the only published evaluation of mountain goat translocations remains that of Guenzel (1980). Working with 11 projects that were considered successful, Guenzel (1980) found that no demographic factors from the released animals predicted subsequent population growth. This surprising finding would seem at odds with prevailing wisdom that the number and possibly sex or age composition of founders would influence success or rate of growth. Of particular relevance for mountain goats, Komers and Curman (2000) observed that founder size, proportion of mature individuals, and proportion of males among adults were all positively associated with growth rates among 33 reintroductions involving Northern Hemisphere artiodactyls. In an evaluation of bighorn sheep (*Ovis canadensis*) translocations, Singer et al. (2000) found that, in addition to habitat characteristics particular to bighorns, founder size was positively associated with eventual success, though number of source populations for founders was not.

Our study was motivated by the question: Do the results obtained by Guenzel (1980) indicate that mountain goats are an exception to the expected patterns in wildlife translocations? Alternatively, might the failure of Guenzel (1980) to find any relationships between source populations and subsequent success have resulted from choice of metric (instantaneous rate of growth), choice of populations (successful, largely released in non-native mountain ranges), or lack of statistical power (i.e., low sample size)? Our objective was to revisit the question of whether certain characteristics of mountain goat releases made them more or less likely to succeed. Our approach was a retrospective analysis, similar conceptually to those of Guenzel (1980), Griffith (1989), Komers and Curman (2000) and others, in which we applied simple statistical tests to existing documentation of mountain goat releases and subsequent population performance. We limited our focus to releases of mountain goats into native habitat.

METHODS

Data Sources

We reviewed published and unpublished literature for reports on mountain goat translocations, augmentations, and reintroductions. We supplemented this search with e-mails to wildlife agency staff in western US states and Canadian provinces likely to have access to unpublished records. In these cases, we sent a blank database to respondents and asked them to enter the following information for each project: dates and location of releases, number of released animals by age and sex, information on source populations, as well as any information on size and quality of the targeted release area. We also requested data on any and all follow-up surveys on released animals.

Definitions

We defined any deliberate release of mountain goats into non-captive settings as a translocation. Regardless of the language used

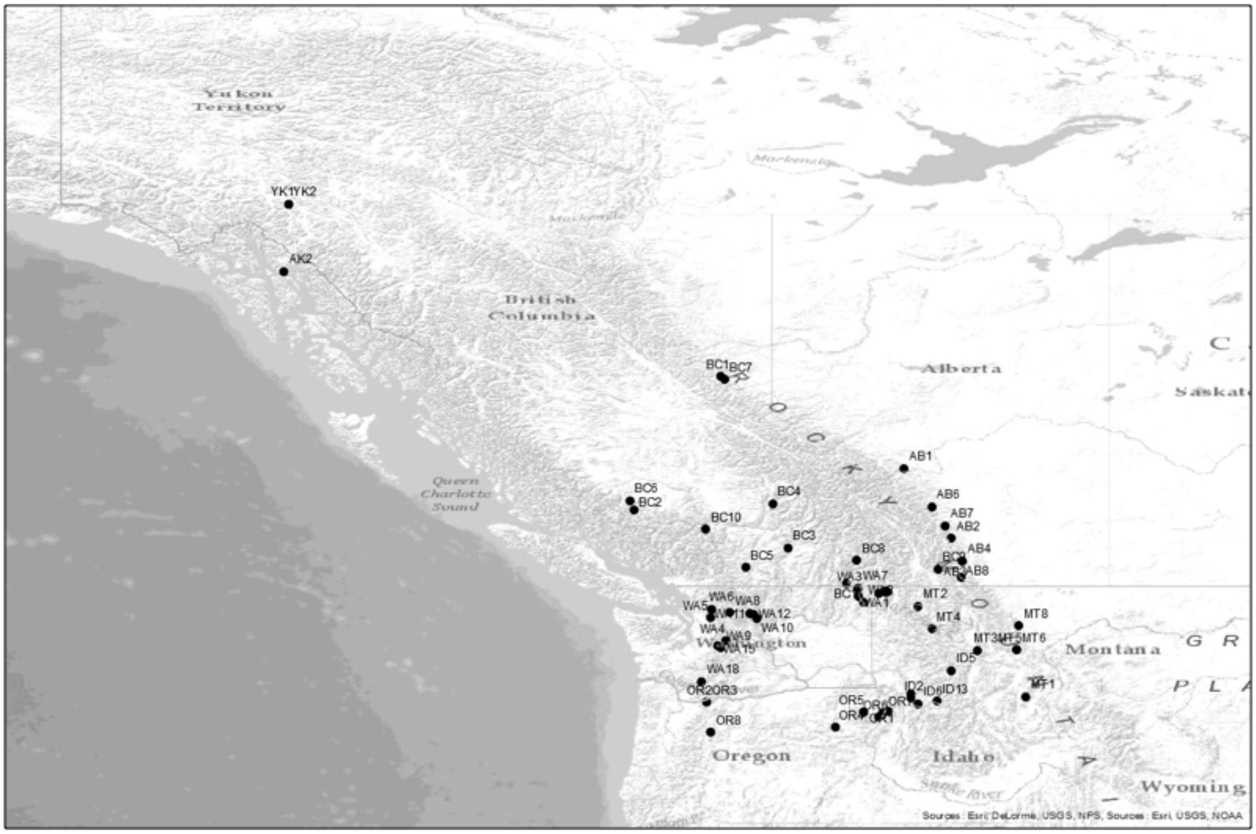

Figure 1. Sketch map showing approximate locations of mountain goat reintroduction projects considered in this analysis, 1950-2010. Some projects not shown to reduce clutter; projects in Alaska not shown. Project codes refer to Appendices.

in the source documentation, we considered any translocation in which some goats were known or suspected to exist in the target area at the time of the translocation as an augmentation. Following Armstrong and Seddon (2007), we reserved the term reintroduction for projects in which mountain goats were moved to areas known to be part of their historic range but from which they were known or suspected to have been extirpated.

Releases for a single project often spanned >1 year. In these cases, we considered multiple releases in adjacent years in nearby areas to constitute a single reintroduction. Releases separated by >5 years, even if at a single site, were considered independent projects.

In addition to quantitative measures of post-release population trajectory (below), we developed 3 binary categories to summarize each project. We defined "extant" as documented evidence that, at the most recent report, some released animals or their offspring were still present (this contrasted with "extirpated," which was when all evidence suggested that no animals remained). In some cases this categorization could not be confidently made. Based on text in the original documentation, we distinguished reintroductions in which most or all animals remained at or near the intended site ("site fidelity") from those in which many or all animals, though perhaps surviving and even reproducing, scattered widely. Finally, we defined each reintroduction as successful or unsuccessful. Successful reintroductions were those that were: 1) defined that way in writing by an agency-employed author of a report; 2) subsequent surveys across >6 years suggested a positive rate of growth and the population had at least doubled in size; or 3) notwithstanding lack of data, the population was clearly known

Table 1. Mountain goat reintroductions (by jurisdiction), 1950-2010, categorized by two criteria: A) assessed as a success or failure and B) known to be extant or extirpated.

	A			B			
Jurisdiction	**Success**	**Failure**	**Undetermined**	**Extant**	**Extirpated**	**Unknown**	**Total**
Washington	2	7	9	5	5	8	18
British Columbia	4	4	3	7	2	2	11
Montana	2	1	5	3	0	5	8
Idaho	1	5	7	2	5	6	13
Oregon	4	2	2	5	2	1	8
Alberta	1	6	1	6	1	1	8
Yukon	1	1	0	2	0	0	2
Alaska	1	1	0	1	0	1	2
Total	16	27	27	31	15	24	70

to be thriving by the responsible agency. Unsuccessful reintroductions were those: 1) described as such by agency documentation; 2) known to be extirpated; or 3) displaying negative trajectory >10 years since release. If none of these conditions applied, we categorized the reintroduction success as undetermined.

Analyses

When existing documentation was sufficient, we calculated the instantaneous rate of change, *r*, as $\ln\left(\frac{Ns}{Nr} / t\right)$, where *Nr* was the number of reintroduced animals surviving the initial reintroduction effort; *Ns* was the number counted in a subsequent survey; and *t* was the number of years elapsed between the two. When multiple post-reintroduction surveys were documented, we examined trends visually and selected surveys that appeared to reflect the trajectory post-release (i.e., before hunting was initiated or major habitat changes took place). To examine correlates of population trajectory, we examined a suite of multiple regression models in which *r* was the response variable, and predictor variables were total number of animals released, number of adults released, number of adult females and males released, sex ratio of adults released, number of separate releases (within an individual reintroduction), number of separate sources (which we used as a proxy for genetic variation), and whether sources were themselves native or resulted from previous translocations.

Because relatively few projects provided sufficient information to estimate *r*, and because *r* was itself an imperfect metric as a response variable (see Discussion), we also examined the 3 binary response variables (extant and extirpated, site fidelity and scattered, successful and unsuccessful) with multiple logistic regression, using the same suite of explanatory variables. We examined the

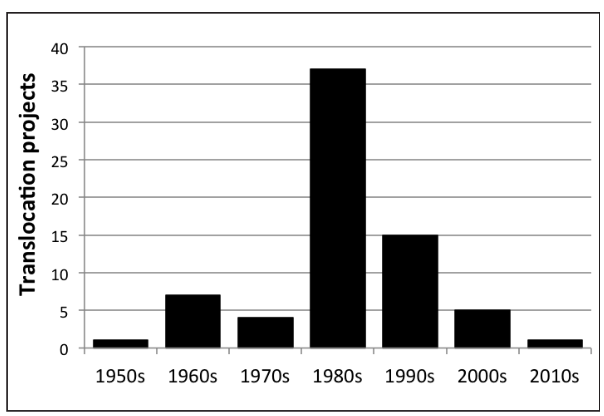

Figure 2. Frequency of mountain goat translocations into native habitat in North America by decade.

strength of evidence among competing logistic regression models with Akaike Information Criterion corrected for sample size (AIC_c) but also examined whether individual regression coefficients overlapped zero. Because the sex of all adult founder goats was missing in 10% of cases, and the sex or age were missing in some of the founder goats in a separate 18% of cases (i.e., the total number of founders exceeded the sum of known sex/age goats), we conducted logistic regression models using the missing data imputation approach contained in Program AMELIA (http://gking.harvard.edu/amelia; see also Honaker and King 2010, Nakagawa and Frecklton 2011) when models contained these variables. For this approach, we reasoned that missing data may have been related to the level of detail recorded by the project staff which, in turn, may have affected success; thus, we could not assume that data were missing at random across the entire data-set. However, within cases that were independently classified as having the same outcome (i.e., successful, unsuccessful, undetermined), we found it reasonable to assume that variables were missing at random.

Few translocation projects documented the size or quality of the habitat in which releases took place and our attempts to systematize recording of these when following-up with respondents in writing were unsatisfactory. Thus, we had no direct way to examine habitat size, quality, or configuration as predictors of reintroduction success.

We conducted linear regressions and computed Student's t-tests using STATISTIX 7.1 (Analytical Software, Tallahassee, FL) and multiple logistic regression analysis to assess the strength of competing models explaining binary outcomes using R (version 3.01, R Development Core Team 2008). When we tested hypotheses, we used $\alpha = 0.05$. Because the normal approximation may be unreliable when interpreting results from logistic regression, we examined percentiles from bootstrapping ($n = 500$) to examine confidence bounds.

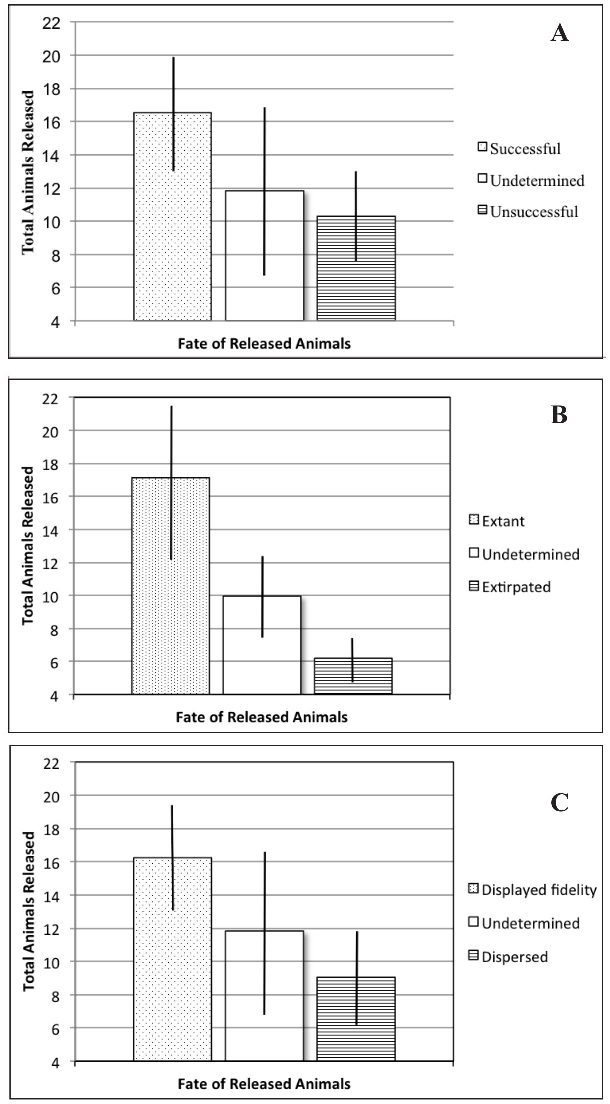

Figure 3. Mean (boxes) and 95% confidence intervals (vertical lines) of the total number of mountain goats released during 1950-2010 within native habitat in North America, among projects categorized as A) successful, unsuccessful, or undetermined; B) goats extant, extirpated, or undetermined; and C) released goat displaying site fidelity, dispersing, or undetermined.

RESULTS

We obtained information on a total of 108 mountain goat translocations within historically occupied range in North America during 1950-2010. Of these, 28 occurred where mountain goats were not considered native and thus

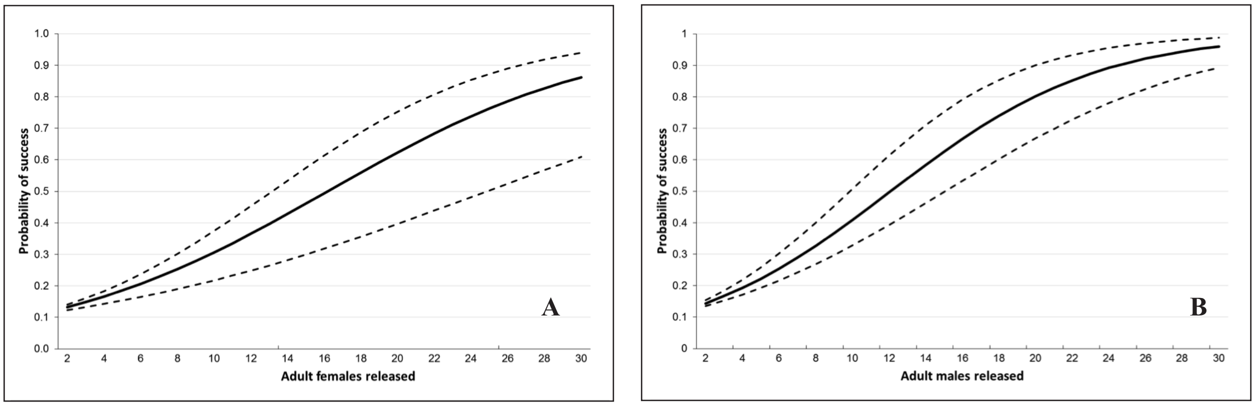

Figure 4. Estimated probability of a mountain goat reintroduction during 1950-2010 within native habitat in North America being successful (see text for definition) as a function of (A) the number of adult females released, and (B) the number of adult males released. Approximate 95% confidence intervals for the probability of success are shown as dashed lines. Models that included the number of juveniles and/or kids did not yield statistically significant improvements in model fit relative to the adult-only models.

were excluded from further analyses. Of the remaining 76 translocations, 6 occurred where a remnant population of native goats existed at the time and were thus best viewed as efforts to augment an existing population. Thus, we categorized 70 projects as reintroductions (Fig. 1, Appendix A). Documentation for all 70 reintroductions included the number of goats released, but we were only able to obtain complete age and sex data of released animals for 46 of these. The remaining 24 projects included various combinations of animals with known sex and age and unclassified animals. A total of 863 goats were reintroduced in these 70 projects, of which 374 were classified as adult females, 193 as adult males, 45 as yearling females, 32 as yearling males, and 51 as kids or undifferentiated "juveniles." Goats reintroduced by each project varied from 1 to 69 ($\bar{x}$ = 12.3, SD = 9.7), with the most common releases being 6 to 10 animals. Frequency of mountain goat reintroduction projects peaked in the 1980s (Fig. 2).

We categorized 15 of the 70 reintroductions as successful and 27 as unsuccessful; 27 others could not be categorized with confidence (Table 1, Appendix B). Fifteen of the 70 reintroduced populations were known to have been extirpated, 31 were known to be extant when most recently surveyed, and 24 were unknown (Table 1). In 21 of the 70 reintroductions, goats were characterized as displaying fidelity to the intended reintroduction area, whereas considerable dispersing from the area characterized 20 others, and 29 could not be categorized.

Only 20 of the 70 projects were documented sufficiently to allow an estimate of growth rate over time (12 of which we categorized as successful, 5 as unsuccessful, and 3 as undetermined). The time elapsed between reintroduction and surveys used for estimation of r varied from 6 to 29 years ($\bar{x}$ = 14.5, SD = 7.3). Growth rates ($\lambda = e^r$) varied from 0.89 to 1.19.

Predictors of Population Growth Rate

We found no evidence that population trajectory (r) following reintroduction was related to the total number of animals released, total number of adult females released, total number of adult males released, or adult sex ratio (all $P > 0.50$ and $r^2 < 0.03$). Similarly, population trajectory was unrelated to the number of separate releases (1-4) involved in each reintroduction ($F = 1.0$, df = 1,19, $P = 0.33$); the number of sources (up to 3 when multiple releases were made; $F = 1.09$, df = 1,19, $P = 0.31$); or whether source populations were native or themselves resulted from previous translocations ($F = 1.78$, df = 1,19, $P = 0.20$).

Predictors of Reintroduction Success

Reintroductions with larger numbers of goats released were more successful than those with fewer (Fig. 3). Among reintroductions judged successful, total number of goats released averaged 16.8 (SD = 6.9), compared with a mean of 9.6 (SD = 6.1) goats released in unsuccessful projects ($t = 2.92$, $P = 0.006$). Similarly, among reintroductions displaying area-specific fidelity, mean number of goats released averaged 16.2 (SD = 6.9), compared with 9.1 goats (SD = 6.2) for those characterized by extensive dispersal ($t = 3.49$, $P = 0.001$). Reintroductions characterized as extant averaged 15.0 (SD = 7.4) goats compared with 6.2 (SD = 2.4) goats among those that had been extirpated ($t = 4.67$, $P < 0.001$). Logistic regressions indicated that neither the probabilities of reintroduction success, extirpation, nor animals remaining near the release site were predicted by the number of founding populations represented in the release (success on number of sources $\beta = 0.163$, SE = 0.530, $P = 0.759$; extant on number of sources $\beta = 0.670$, SE = 0.667, $P = 0.315$; resident on number of sources $\beta = 0.122$, SE = 0.579, $P = 0.833$).

Logistic regressions indicated that reintroduction success was a positive function of the number of released animals. The best-supported model predicting success included only the number of adult males released, though strength of evidence was almost the same for models with the number of adult females released and with the total number of adults released (Table 2). We felt justified in examining a model including both number of adult males and adult female founders because the correlation among these predictor variables was not strong (Pearson's $r = 0.41$, $n = 39$). In all models, the explanatory variables were positively related to success (Table 3) but the effect magnitudes were greatest for models including only adult goats. The model relating total number of goats (including juveniles and kids) released to success had much weaker support and the confidence intervals around the coefficient that included juveniles overlapped zero (Table 3). Odds-ratios similarly indicated that the probability of a successful reintroduction increased with both the number of adult females and adult males released (Fig. 4). Our model relating the number of adult males and females released to success suggested that, on average, 25 males and 33 females were required to achieve a 50% probability of success. All other things being equal, any given future reintroduction project would have to release somewhat more than this number to attain a high probability of success.

Table 2. Strength of evidence of top logistic regression models relating success of mountain goat reintroductions, 1950-2010 in native habitat within North America (see text for definition) to candidate explanatory variables. Shown are Akaike's Information Criterion corrected for small sample size (AIC_c) and number of parameters (*k*).

Model	Deviance	*k*	AIC_c	ΔAIC_c
Number of adult males released	48.147	3	52.15	0.00
Number of adult females released	48.851	3	52.85	0.70
Number of adult males and females released	49.401	4	53.40	1.25

Table 3. Coefficients of best fitting models, top logistic regression models relating success of mountain goat reintroductions, 1950-2010 in native habitat within North America (see text for definition) to candidate explanatory variables.

Model	β	Lower 95%	Upper 95%
Total animals released (all ages)	0.141	0.056	2.524
Adult females released	0.130	0.086	0.162
Adult and juvenile females released	0.139	0.078	0.194
Adult males released	0.178	0.144	0.218
Adult and juvenile males released	0.199	0.035	0.301
Juveniles released	0.020	-0.003	0.049

DISCUSSION

Guenzel (1980) concluded that demographic variables characterizing mountain goat releases did not explain subsequent population growth, and speculated that habitat quality and environmental factors would have been better predictors. We similarly lacked data that could be used to address differences in habitat quality among mountain goat reintroductions but, unlike Guenzel (1980), found that success of reintroductions was predicted, at least in part, by demographic characteristics of the founders. As Guenzel (1980) had done, we examined population trajectories following reintroduction, finding – as he had – no meaningful relationships. However, using our binary response variable of reintroduction success, we found that the number of adult females and males, but not the number of juveniles and kids, were significant predictors of success.

Although population trajectory (quantified either by r or λ) would seem intuitively to be an objective assessment metric, we argue that our use of the qualitative measure "success" is more likely to be meaningful. First, the monitoring of goat populations varied considerably and few goat surveys included corrections for imperfect detection or incomplete coverage of the area actually occupied. Thus, reported goat numbers almost certainly contained a great deal of unacknowledged sampling variation, such that analyses with trajectory as the response variable reflected false precision. More critically, goat populations receiving follow-up surveys were unlikely to have been a random sample of all reintroduction efforts. Rather, translocations known or believed to be failing were less likely to be surveyed formally than those doing well, or if a survey was conducted of a failing population, it may not have been documented. Such a bias is suggested in the greater proportion of projects categorized as successful (12 of 20 projects, with 5 unsuccessful) among those allowing estimation of trajectory than among those lacking quantitative follow-up surveys (3 of 50 projects, with 23 unsuccessful).

We failed to find evidence that the number of source populations represented in the reintroduction was a significant predictor of subsequent population trajectory or of any of our binary measures of success. This might seem to suggest that genetic variability among founders was unimportant, contrary to the findings of Biebach and Keller (2012) for reintroduced alpine ibex (*Capra ibex*). We would caution against this interpretation for a number of reasons. First, we found that size of founder populations was a reliable predictor of success (even if not of growth rate) and was likely to incorporate both demographic and genetic benefits (Allendorf and Luikart 2007). Second, though one would intuitively imagine that genetic diversity of founders from >1 source ought to be greater than that from a single source, this may not be true if separate founder populations are highly related to one another. Third, the number of sources for goat reintroductions considered here may have been too coarse a measure of the genetic diversity actually passed on to subsequent generations. We suspect that genetic diversity does play a role in determining reintroduction success, even if our data failed to capture that information.

MANAGEMENT IMPLICATIONS

Despite the frequency with which mountain goats have been the objects of translocation efforts, many releases into historical native habitat (i.e., reintroductions) have failed. Determinants of success are no doubt complex, and probably include factors beyond the biological (e.g., agency management capacity, support of local communities), and even within the realm of biology, factors we could not evaluate with data at hand (e.g., habitat quality). It goes without saying that managers wishing to restore mountain goat populations where they have been depleted need to carefully consider the habitat suitability of target release areas, as well as social, organizational, and economic factors that ultimately will play large roles. However, it appears that programs are likely to fail, regardless of other issues, when only a few goats are released. This retrospective analysis provides evidence that reintroduced mountain goats are likely to persist and expand when >30 females older than yearling class are released. Further, though a sex ratio favoring females is supported, releasing too few adult males can also reduce the chance of success. We recommend that no fewer than 15 adult males also form the nucleus of the new herd (Fig. 4b). Although not specifically supported by our data, we believe it is likely that efforts to enhance the genetic diversity of founders are also worthwhile.

Our quantitative analysis was not designed to unearth the ultimate factors causing small mountain goat reintroductions to fail. It seems reasonable to expect, as with any taxon, that initial survivorship will be lower than expected from individuals with established home ranges (e.g., Smith and Nichols 1984, Paul 2009). Specifically for mountain goats, where documentation has been sufficient (e.g., Fielder and Keesee 1988, Jorgenson and Quinlan 1996), it has often been noted that released goats are prone to dispersing widely. Thus, even if individuals experience high initial survival, they may fail to establish the social cohesion evidently needed to ensure recruitment of future adults (Komers and Curman 2000, Armstrong and Seddon 2007) and thus long-term population persistence and growth.

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Appendix A. Mountain goat reintroductions used in analyses, 1950-2010. Shown are reintroduction site, numbers of released animals by sex and age (M = male, F = female), number of releases, number of source populations, and whether source population was native or reintroduced.

State or Prov		Mountain range	Population name	Year	Total released	Age 2+		Yrlg		Kid		Unaged		Unsexed kid	Unknown	Releases	Sources	Native?
						M	F	M	F	M	F	M	F					
Alaska																		
	1	Kenai	Cecil Rhode Mtn	1983	16	3	6	1	6							1	1	Y
	2	Mt Juneau		1989	11	2	8	1								1	1	Y
Alberta																		
	1	Shunda Mtn	near Nordegg	1972	7	2	5									1	1	Y
	2	Highwood	Picklejar Lakes I	1986	2		2									1	1	Y
	3	Livingstone I	Livingstone I	1987	13	5	4	1	1						2	3	2	Y
	4	Livingstone II	Livingstone II	1993	13	2	9		2							4	2	Y
	5	Highwood	Picklejar Lakes II	1993	21	2	11	4	4							1	1	Y
	6	Highwood	Head Mt/Trap Ck	1995	20	4	9	4	3							2	2	Y
	7	Highwood	Nihahi Ridge	1995	20	3	14		3							2	2	Y
	8	Highwood	Barnaby Ridge	1995	6	1	5									1	1	Y
British Columbia																		
	1	Peace	Bullmoose Mtn	1983	20	3	7								10	1	1	Y
	2	Cariboo	Potato Mtn	1984	5	1	4									1	2	Y
	3	Okanogan	Shorts Ck	1984	5	2	3									1	1	Y
	4	Thompson	Dunn Pk	1985	30	7	23									4	4	Y
	5	Okanogan	Snass Mtn/ Tulameen	1986	8										8	1	1	Y
	6	Cariboo	Nemaea/ Tsuniah	1988	13	2	3							1	7	2	1	Y
	7	Peace	Mt Spieker	1989	8	4	4									1	3	Y
	8	Kootenay	Slocan Valley	1990	20	3	10							1	6	3	1	Y
	9	Kootenay	Mt Broadwood	1990	17	3	10							4		3	3	Y

Appendix A — Cont.

State or Prov		Mountain range	Population name	Year	Total released	Age 2+		Yrlg		Kid		Unaged		Unsexed kid	Unknown	Releases	Sources	Native?
						M	F	M	F	M	F	M	F					
	10	Thompson	Fountain Ridge	1994	8	2	6									1	1	Y
	11	Kootenay	Trail	1999	15										15	1	1	Y
Idaho																		
	1	Clearwater	Seven Devils	1962	17	4	9			2	2					2	1	Y
	2	Clearwater	Dome Hill	1966	11	5	6									2	1	Y
	3	Selkirk	Lion Ck	1981	2	1	1									1	1	Y
	4	Selkirk	Bugle Ck	1985	2	2										1	1	N
	5	Clearwater	Boulder Ck	1986	7	2	5									1	1	Y
	6	Clearwater	Oregon Butte	1987	12	2	10									1	1	Y
	7	Clearwater	Seven Devils II	1989	8	8										1	1	N
	8	Selkirk	Parker Ck	1989	6		6									2	1	Y
	9	Clearwater	Big Squaw	1994	12	5	7									3	1	Y
	10	Selkirk	Ball Ck	1994	3	3										1	1	Y
	11	Clearwater	Johns Ck	1998	1	1										1	1	Y
	12	Clearwater	Big Mallard Falls	1999	18	9	9									2	1	Y
	13	Clearwater	Sheep Hill	2003	16	5	5			2	4					1	1	Y
Montana																		
	1	Silver Bow	Highlands	1962	7										7	1	1	Y
	2	Cabinets	Drift Ck	1980	7										7	1	1	?
	3	Rattlesnake	Rattlesnake	1984	18	1	6	1	3	1	6				0	2	1	N
	4	Cabinets	Cube Iron/Mt. Headley	1985	26	4	4	2	2	1	1				12	3	2	N
	5	Red Mtn	Helena NF	1989	18	8	10									2	2	N
	6	Red Mtn II	Lewis and Clark County	1990	10	1	7		2						0	1	1	N
	7	Front Range	Red Mountain	2002	15	1	4								10	2	2	N
	8	Front Range	Ear Mountain	2008	10										10	1	1	N

Appendix A — Cont.

State or Prov		Mountain range	Population name	Year	Total released	Age 2+		Yrlg		Kid		Unaged		Unsexed kid	Unknown	Releases	Sources	Native?
						M	F	M	F	M	F	M	F					
Oregon																		
	1	Wallowa	Chief Joseph Peak	1950	5						1	3	1			1	1	Y
	2	Columbia Gorge	Tanner Butte	1969	8							2	6			1	1	N
	3	Columbia Gorge	Tanner Butte	1975	7							3	4			2	1	N
	4	Elkhorn	Pine Ck	1983	21							9	12			3	3	Y, N, Y
	5	Wallowa	Hurricane	1985	33							13	20			3	2	N, Y
	6	Snake River	Hat Point	2000	16		7	3	2					4		1	1	N
	7	Snake River	Steamboat Ck	2003	18	3	7	1	3	3	1					1	1	N
	8	Oregon Cascades	Mt Jefferson	2010	69	1	14		6	1	2				45	2	1	N
Washington																		
	1	Selkirk	Cato Ck	1962	7	2	5									1	1	Y
	2	Selkirk	Le Clerc Ck	1964	6	2	4									1	1	Y
	3	Selkirk	Flume Ck (Linton)	1965	7	2	4				1					1	1	Y
	4	S Cascades	Mt Margaret (GPNF)	1972	8		1	3							4	2	1	N
	5	N Cascades	Mt Pilchuck (Darrington RD)	1975	7	1	1								5	2	1	N
	6	N Cascades	Higgins Mtn	1981	10	1	6	2		1						1	1	N
	7	Selkirk	Hooknose	1981	11	3	4	2	2							1	1	N
	8	N Cascades	Lime Mtn	1981	10	5	4			1						1	1	N
	9	S Cascades	Kelly Butte	1983	10	5	3	1	1							2	1	N
	10	N Cascades	Lake Chelan Corral Ck	1983	5	1	2			2						1	1	N

Appendix A — Cont.

State or Prov		Mountain range	Population name	Year	Total released	Age 2+		Yrlg		Kid		Unaged		Unsexed kid	Unknown	Releases	Sources	Native?
						M	F	M	F	M	F	M	F					
	11	N Cascades	Lake Chelan Domke Mtn	1983	1		1									1	1	N
	12	N Cascades	Lake Chelan Rex Ck	1983	5	2	1	1	1							1	1	N
	13	N Cascades	Lake Chelan Round Mtn	1983	5		2	1	1		1					1	1	N
	14	N Cascades	Lake Chelan Still/Box	1983	13	3	7	1	2							1	1	N
	15	S Cascades	Rooster Comb	1983	28	5	13	3	1	3	3					2	1	N
	16	N Cascades	Lake Chelan Canoe Ck	1984	10	6	3							1		1	1	N
	17	N Cascades	Lake Chelan Pyramid Ck	1984	5	2	3									1	1	N
	18	S Cascades	Smith Ck	1985	12										12	1	1	N
Yukon																		
	1	Mt White I	BC Yukon border	1983	12	4	7			1						2	1	Y
	2	Mt White II	BC Yukon border	1990	10	2									8	2	1	Y

Appendix B. Information about mountain goat reintroductions used in analyses, 1950-2010, including whether or not population remained extant; if extant, last known population size; years of change population size monitored; estimated instantaneous rate of growth (r), whether or not population stayed resident, whether or not reintroduction was judged successful (see text), and source of information.

State/Prov		Mountain range	Population name	Year	Extant?	Pop Size	Years of change	*r*	Stayed resident	Success	Reference
Alaska											
	1	Kenai	Cecil Rhode Mtn	1983	Y	53	9	0.133	Y	Y	a,b,c,d,e,f
	2	Mt Juneau		1989	?	?			N	?	c
Alberta											
	1	Shunda Mtn	near Nordegg	1972	Y	11	27	0.017	Y	N	g,h
	2	Highwood	Picklejar Lakes I	1986	Y	2			N	N	g,h
	3	Livingstone I	Livingstone I	1987	Y	12	6	0.048	Y	N	g,j
	4	Livingstone II	Livingstone II	1993	Y	14	13	0.006	N	Y	g,h,i,j
	5	Highwood	Picklejar Lakes II	1993	Y	?			N	N	g,h,j
	6	Highwood	Head Mt/ Trap Ck	1995	?	?			N	N	g,h,j
	7	Highwood	Nihahi Ridge	1995	?	?			N	?	g,h,j
	8	Highwood	Barnaby Ridge	1995	N	0			N	N	g,h,j
British Columbia									?		
	1	Peace	Bullmoose Mtn	1983	Y	44	6	0.131	Y	Y	k,l,m
	2	Cariboo	Potato Mtn	1984	Y	70	15	0.176	Y	Y	k,l,m
	3	Okanagan	Shorts Ck	1984	N	0			N	N	k,l,m
	4	Thompson	Dunn Pk	1985	Y	?			?	?	
	5	Okanagan	Snass Mtn/ Tulameen	1986	?	?			?	?	k,l,m
	6	Cariboo	Nemaea/ Tsuniah	1988	Y	10	11	-0.024	Y	N	k,l,m
	7	Peace	Mt Spieker	1989	N	0			?	N	k,l,m
	8	Kootenay	Slocan Valley	1990	Y	38	8	0.080	Y	Y	k,l,m
	9	Kootenay	Mt Broadwood	1990	?	?			N	N	
	10	Thompson	Fountain Ridge	1994	Y	?			?	?	k,l,m
	11	Kootenay	Trail	1999		35	8	0.106	Y	Y	m

Appendix B — Cont.

State/Prov	Mountain range	Population name	Year	Extant?	Pop Size	Years of change	*r*	Stayed resident	Success	Reference
Idaho										
1	Clearwater	Seven Devils	1962	Y	71	17	0.084	Y	Y	n,o
2	Clearwater	Dome Hill	1966	?	?			?	?	n,o
3	Selkirk	Lion Ck	1981	N	0			N	N	n,o
3	Selkirk	Lion Ck	1981	N	0			N	N	n,o
4	Selkirk	Bugle Ck	1985	N	0			?	N	n,o
5	Clearwater	Boulder Ck	1986	N	0			N	N	n,o
6	Clearwater	Oregon Butte	1987	?	?			?	?	n,o
7	Clearwater	Seven Devils II	1989	Y	?			?	?	n,o
8	Selkirk	Parker Ck	1989	N	0			?	N	n,o
9	Clearwater	Big Squaw	1994	?	?			?	?	n,o
10	Selkirk	Ball Ck	1994	N	0			?	N	n,o
11	Clearwater	Johns Ck	1998	?	?			?	?	n,o
12	Clearwater	Big Mallard Falls	1999	?	?			?	?	n,o,p,q
13	Clearwater	Sheep Hill	2003	?	?			?	?	n,o,p,q
Montana										
1	Silver Bow	Highlands	1962	?	?			?	?	r
2	Cabinets	Drift Ck	1980	?	?			?	?	r
3	Rattlesnake	Rattlesnake	1984	Y	10	29	-0.020	Y	N	r, s, t
4	Cabinets	Cube Iron/ Mt. Headley	1985	?	32.5	25	0.009	Y	Y	u
5	Red Mtn	Helena NF	1989	?	?			?	?	V
6	Red Mtn II	Lewis and Clark County	1990	Y	28	18	0.057	Y	?	r,s,t
7	Front Range	Red Mountain	2002	?	?			?	?	w,x
8	Front Range	Ear Mountain	2008	?	?			?	?	
Oregon										
1	Wallowa	Chief Joseph Peak	1950		?					y,z,aa
2	Columbia Gorge	Tanner Butte	1969	N	0			N	N	y,z
3	Columbia Gorge	Tanner Butte	1975	N	0			N	N	y,z,aa
4	Elkhorn	Pine Ck	1983	Y	301	25	0.107	Y	Y	y,z,aa,ab

Appendix B — Cont.

State/Prov	Mountain range	Population name	Year	Extant?	Pop Size	Years of change	*r*	Stayed resident	Success	Reference
5	Wallowa	Hurricane	1985	Y	106	9	0.130	Y	Y	y,z,aa,ab
6	Snake River	Hat Point	2000	Y	?			Y	Y	aa,ab
7	Snake River	Steamboat Ck	2003	Y	?			Y	Y	aa,ab
8	Oregon Cascades	Mt Jefferson	2010	?	?			?	N	ac
Washington										
1	Selkirk	Cato Ck	1962	N	0			?	N	ad,ae
2	Selkirk	Le Clerc Ck	1964	N	0			?	N	ad,ae,af
3	Selkirk	Flume Ck (Linton)	1965	N	0			?	N	ad,ae,af,ai
4	S Cascades	Mt Margaret (GPNF)	1972	N	?			?	N	ad,af,aj
5	N Cascades	Mt Pilchuck (Darrington RD)	1975	Y	small			?	?	ad,af
6	N Cascades	Higgins Mtn	1981	?	?			?	N	af,ah
7	Selkirk	Hooknose	1981	N	0			N	N	ad,ak
8	N Cascades	Lime Mtn	1981	?	?			?	?	ad,af
9	S Cascades	Kelly Butte	1983	Y	34	15	0.082	Y	?	af,al, am,an
10	N Cascades	Lake Chelan Corral Ck	1983	?	?			N	?	ag,ah,ao
11	N Cascades	Lake Chelan Domke Mtn	1983	?	?			N	?	ag,ah,ao
12	N Cascades	Lake Chelan Rex Ck	1983	?	?			N	?	ag,ah,ao
13	N Cascades	Lake Chelan Round Mtn	1983	?	?			N	?	ag,ah,ao
14	N Cascades	Lake Chelan Still/Box	1983	Y	?			Y	Y	af
15	S Cascades	Rooster Comb	1983	Y	17	15	-0.033	Y	N	af,am,an
16	N Cascades	Lake Chelan Canoe Ck	1984	?	?			N	?	ag,ah,ao

Appendix B — Cont.

State/Prov	Mountain range	Population name	Year	Extant?	Pop Size	Years of change	*r*	Stayed resident	Success	Reference
17	N Cascades	Lake Chelan Pyramid Ck	1984	?	?			N	?	ag,ah,ao
18	S Cascades	Smith Ck	1985	Y	30	18	0.051	?	Y	af,ap,aq
Yukon										
1	Mt White I	BC Yukon border	1983	Y	6	6	-0.116	Y	N	ar,as
2	Mt White II	BC Yukon border	1990	Y	27	10	0.099	Y	Y	as

[a]Smith and Nichols 1984; [b]ADFG 2010; [c]Paul 2009; [d]ADFG 2011; [e]McDonough and Selinger 2008; [f]T. J. McDonough, Alaska Department of Fish and Game, Homer, AK, January 2013; [g]Smith et al. 1996; [h]Alberta Fish and Wildlife Division 2003; [i]Smith 2008; [j]Jorgenson and Quinlan 1996; [k]Mountain Goat Management Team 2010; [l]Hatter and Blower 1996; [m]Blood 2001; [n]Oldenburg 1996; [o]Toweill 2009; [p]Toweill 2010; [q]Toweill 2012; [r]McCarthy 1996; [s]Firebaugh et al. 1991; [t]Firebaugh et al. 2003; [u]Sterling, pers. comm; [v]Gadbow 2005; [w]Nielsen et al 1986; [x]Nielsen et al 1987; [y]Coggins et al. 1996; [z]Matthews and Coggins 1994; [aa]ODFW 2009; [ab]ODFW 2010; [ac]ODFW and CTWS 2010; [ad]Johnson 1983; [ae]Base and Zender 2007; [af]Johnson 1996; [ag]Fielder and Keesee 1988; Fielder 2001; [ah]Shirk, pers. comm; [ai]Anon 1975; [aj]Wadkins 1985; [ak]Zender 1985; [al]Spencer 1998; [am]Spencer 1986; [an]Vales, pers. comm; [ao]Moorhead 1989; [ap]Miller 2003; [aq]Miller 2004; [ar]Carey 1996; [as]Yukon Wildlife Branch 2006.