Contrasting Native and Introduced Mountain Goat Populations in Montana

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ABSTRACT Mountain goat (*Oreamnos americanus*) distributions in Montana include historic, native ranges as well as mountainous areas into which mountain goats have expanded from introductions to non-native habitat. We synthesized population survey and harvest data collected by Montana Fish, Wildlife and Parks (MFWP) during 1960–2015 and received responses from 18 MFWP biologists to a questionnaire regarding status, trends, and management of mountain goats across the state. In 2016 an estimated 3,685 mountain goats were managed by MFWP, 2,526 (69%) in introduced populations, and 1,159 (31%) in native populations. Compared with population estimates from the 1940s, numbers of mountain goats in native ranges (outside national parks) were currently 3–4 times fewer than the 4,100 native mountain goats estimated then. Responses by MFWP biologists supported this decline of native mountain goats and highlighted a current pattern of many small and isolated mountain goat populations. Furthermore, both hunting licenses issued for and annual harvests of native populations have declined nearly 10-fold from the 1960s to present. To the contrary, mountain goat numbers in introduced populations have generally increased and provided 84% of Montana's hunting opportunity in 2015. Biologists identified a wide range of management and research actions that would benefit management and conservation of mountain goats. These included: 1) evaluation of statistical power associated with various monitoring protocols, 2) continued maintenance of centralized databases, 3) design of monitoring approaches for long-term consistency, 4) potential development of a statewide species management plan, and 5) research into habitat factors, population dynamics, and causes of mortality of mountain goats.

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Among North American ungulates, mountain goats (*Oreamnos americanus*) present many challenges for wildlife management and conservation. They live in remote and harsh environments where traditional monitoring techniques are challenging (Gonzalez-Voyer et al. 2001); they often occur in small isolated populations which are more difficult to monitor and face increased risk of extirpation (Fagan and Holmes 2006); and they exhibit life history characteristics that make them particularly susceptible to over-harvest and slow to recover from population declines (Gonzalez-Voyer et al. 2003, Hamel et al. 2006, Toweill et al. 2004, Festa-Bianchet and Côté 2008). Potentially as a result of some of these challenges, mountain goats have suffered recent population declines across much of the southern portion of the species' native range over the past 50–70 years (Côté and Festa-Bianchet 2003, Festa-Bianchet and Côté 2008, Smith 2014). For example, mountain goat populations in British Columbia have declined by half from an estimated 100,000 in 1960 to 39,000–63,000 in 2010 (Mountain Goat Management Team 2010). Abundance of mountain goats in Washington has declined by 60 percent since 1950 (Rice and Gay 2010). Due to concerns about declines in Alberta, wildlife officials closed the entire province to mountain goat hunting in 1987; only in 2001 were conservative harvest quotas reinstated there (Hamel et al. 2006).

In Montana, the status of mountain goats is complicated. The western portion of the state supports native populations. To the east, additional populations were established by translocating mountain goats into prehistorically unoccupied habitat (Figure 1). License numbers to hunt native mountain goats have generally been reduced over the past three or four decades in response to population declines in some areas. Carlsen and Erickson (2008) concluded, "The decline in mountain goat populations is alarming and deserves investigation by [MFWP]. When goat populations decline, it appears they don't recover." Contrary to the decline of Montana's native mountain goats, substantial increases have been observed in some introduced populations (Williams 1999, Lemke 2004, Flesch et al. 2016). The transplanting of mountain goats into southwestern and central Montana began over 70 years ago. From 1941 to 2008, 495 animals were transplanted to 27 different sites, with some ranges receiving multiple introductions (Picton and Lonner 2008). Introduced herds in some locations have grown in both numbers and geographic range, while other introductions appeared to have failed, whether immediately or after a period of time. Carlsen and Erickson (2008) reported that the statewide total mountain goat harvest has been relatively stable over the past 30 years, yet this summary may mask markedly different trends occurring among native and introduced populations.

Montana has a rich history of research into the biology, ecology, and conservation requirements of mountain goats, beginning with the work of Casebeer et al. (1950). Studies during the 1970s and '80s provided the most comprehensive biological information on Montana's native mountain goat populations (Chadwick 1973, Rideout 1974, Smith 1976, Thompson 1980, Joslin 1986). Several studies in the Crazy Mountains provided information on that introduced population's ecology and growth during the 1950s and 1960s (Lentfer 1955, Saunders 1955, Foss 1962). Changes in numbers and distributions of other introduced populations were closely monitored in recent years by MFWP (Swenson 1985, Williams 1999, Lemke 2004). Most recently, Flesch et al. (2016) described range expansion and population growth of introduced mountain goats in the Greater Yellowstone Area.

The aim of this study was to compile and synthesize mountain goat harvest and population information at a statewide scale across Montana during 1960–2015, with particular attention to comparing and contrasting dynamics of native and introduced mountain goat populations. We also developed and distributed an expert-opinion questionnaire to solicit the insights and opinions of MFWP personnel (area biologists and/or regional wildlife managers whose jurisdictions include mountain goats) regarding population

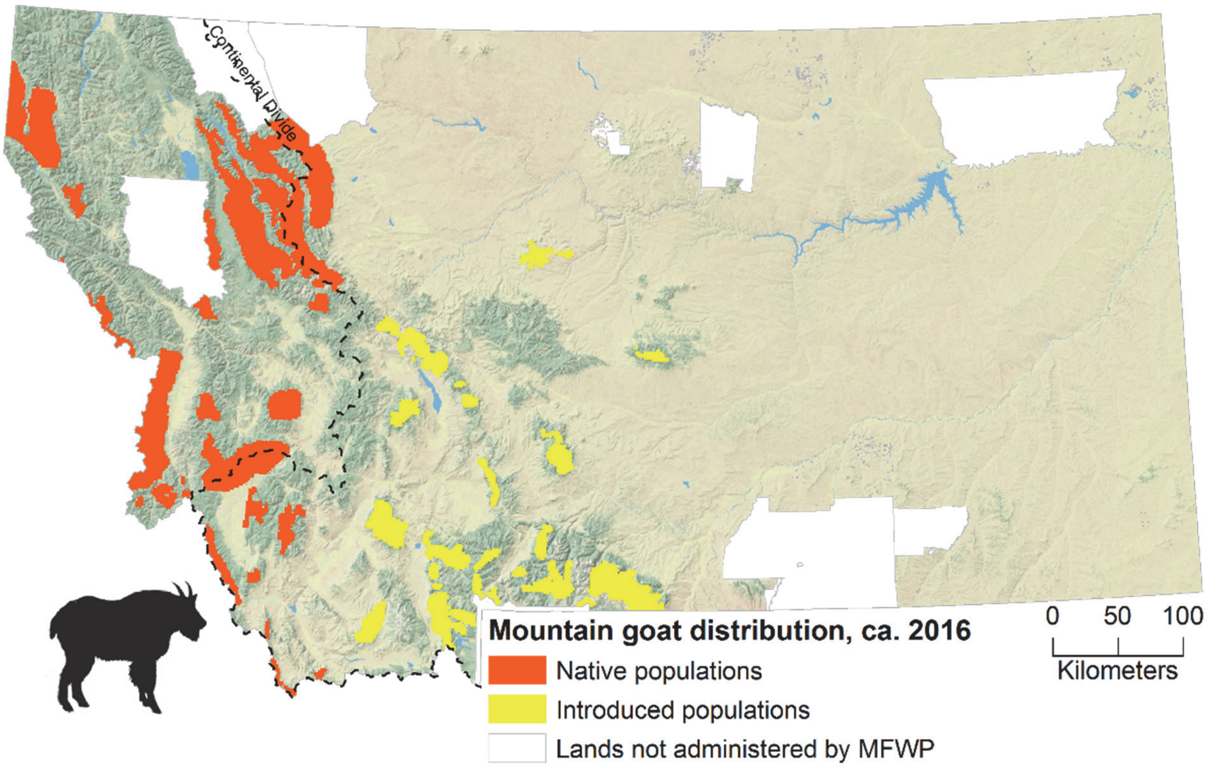

Figure 1. Distribution of extant native and introduced populations of mountain goats in Montana, 2016.

trends, limiting factors, monitoring practices, and future research and management needs. Summarized results from this survey of MFWP biologists represent the current state of knowledge about Montana's mountain goats, with potential to guide future research, monitoring, and planning efforts aimed at filling information gaps and sustaining or enhancing mountain goat populations and hunting opportunity.

STUDY AREA

Our study was in Montana, USA, during 1960–2015. Montana is 380,832 km^2 in area and ranges in elevation from 555–3,904 m. The western portion of the state consists predominately of a portion of the Rocky Mountains, whereas the eastern portion includes smaller island mountain ranges surrounded by large expanses of prairie-badlands and prairie-agricultural lands mixed with timbered river drainages. January temperatures average -12° to -6°C and July temperatures average 18° to 23°C. Precipitation varies widely depending on location and elevation, with average annual precipitation ranging from 17–88 cm/year. Large mammal carnivore species sympatric with mountain goats in all or portions of the state during all or portions of the study period included mountain lions (*Puma concolor*), wolves (*Canis lupus*), black bears (*Ursus americanus*), grizzly bears (*Ursus arctos*), and wolverine (*Gulo gulo*). Ungulate species present on the landscape included bighorn sheep (*Ovis canadensis*), elk (*Cervus canadensis*), deer (*Odocoileus* spp.), and moose (*Alces alces*).

METHODS

Data collection

We began this project by compiling and digitizing as much historical data as we could find regarding mountain goat harvest and population monitoring. Data were retrieved from a range of sources including department-wide online databases, electronic files provided for local areas by MFWP biologists, and from paper copies of historic survey and inventory reports housed within library archives of 5 different MFWP offices. After compiling data into a single database, we sent data subsets to each area biologist for them to review and rectify with local records.

Hunter harvest. — During the early portion of the study period, 1960–1987, mountain goat harvest was monitored with a paper questionnaire mailed to all license-holders. A correction was applied to harvest estimates to account for imperfect response rates. During 1988–2004, mountain goat harvest was estimated using a mix of both phone calls and mail surveys in a continued attempt to reach all license-holders, and since 2005 phone calls have been used exclusively. Response rates for mountain goat surveys are typically high (>90% annually), and corrections of estimates for imperfect response rates during the entire study period assumed that the relatively small proportion of non-respondents were missing at random from the sample (Lohr 2009). Information on the sex, age, and horn measurements for harvested mountain goats was also available via a separate data stream provided by the mandatory checking of such, which was instituted in 1983 and continued to the present. In total, the compilation of mountain goat harvest data spanned 69 hunting districts (HDs) and 56 years, for a total of 2,229 district-years of data concerning quantities of licenses issued, total numbers of mountain goats harvested, and numbers harvested according to sex.

Due to the challenge of accurately identifying the sex of mountain goats in field settings, MFWP exclusively offered either-sex licenses during this study period that allowed hunters to legally harvest either a male or female. Harvest of male mountain goats is typically the goal for both wildlife managers (e.g., to harvest animals with lower reproductive value) and for hunters (e.g., to harvest animals with larger trophy scores). To support this goal, MFWP currently offers information and videos on their website as a voluntary educational opportunity for hunters.

Population trend surveys. —Population survey data presented challenges to compile because they were not necessarily collected or summarized in a consistent manner across the state and over time. In fact, our questionnaire to MFWP biologists (described below) revealed many differences in the manner with which mountain goat population surveys were conducted, which we will describe here. Survey platforms have included a combination of rotary and fixed-wing aircraft as well as ground surveys. The timing of surveys varies widely by jurisdiction, with 25% of aerial surveys conducted during winter or early spring, 21% during mid-summer, 33% during late summer, and 21% during fall. The frequency of surveys ranged from annually (28%), to every other (19%) or every few years (19%), to “rare” (33%) among HDs. Survey results provide a minimum count and age ratios specific to various times of year. Count data are not sightabilty-corrected population estimates but instead are treated as minimum counts for monitoring of population trend (Humbert et al. 2009). In total, we compiled >700 individual mountain goat population surveys spanning 1960–2016.

Data analysis

Hunter harvest. —We used descriptive plots and statistics to characterize trends in mountain goat hunter harvest data across the study period. These included summaries of the availability of licenses, total harvest, hunter success rates (total harvest/licenses issued), and sex ratio of harvested mountain goats. We also compared summaries of each of these statistics to assess differences in native vs. introduced populations. We used a *t*-test to compare the proportional harvest of females among native and introduced populations and used linear regression of this proportion over time to assess the potential for a trend during the study period.

To compare harvest data among regional populations, we grouped 69 different mountain goat HDs that have been designated during various portions of the period 1960–2015 into 28 regional "population units" (Table 1). The area and number of animals encompassed by each population unit were not consistent because we attempted to delineate populations according to biologically meaningful topographic or ecological boundaries. These groupings included 14 native population units and 14 introduced population units. We estimated the 2015 harvest rates of mountain goats by combining hunter harvest data presented here with population estimates developed below via questionnaires to FWP area biologists (described below). Specifically, we estimated the "harvest rate" as the estimated total harvest of mountain goats in 2015 divided by the estimated population size. We estimated the "license rate" as the number of licenses issued in 2015 divided by the estimated population size of mountain goats within a given population unit. Because population estimates used in the derivation of harvest rates came from expert opinion questionnaire rather than repeatable statistical population estimation procedures, these harvest rates have important and unknown degrees of accuracy and precision.

Population trend surveys. —Population trends from aerial survey data spanning our full study period of 1960–2015 were difficult to interpret primarily because the frequency and locality of surveys were not consistent enough to meet the assumptions of an analysis of trend (Harris 1986). Thus, we focused our analysis on recent survey data collected during the 21st century (2000–2015) and identified 52 survey areas (typically HDs) with at least one survey during this period, for a total of 171 surveys.

To estimate annual population growth rates, λ, from survey count data, we used exponential growth state-space models developed by Humbert et al. (2009). These models have been shown to more rigorously measure uncertainty surrounding estimates of trend by accounting for process variance (i.e., biological variation) in annual growth rates as well as observation error that induces additional sampling noise around annual count data. Flesch et al. (2016) also used these methods in a recent analysis of mountain goat population trends from survey count data in the Greater

Table 1. Population estimates (from expert opinion), hunting licenses offered, total harvest, and estimated license rate (licenses/population size) and harvest rate (harvest/population size) of mountain goats among regional populations in Montana, 2015.

	Regional population	Population estimate (Range)	Licenses	Total harvest	License rate	Harvest rate
Native populations	Cabinet	135 (125-155)	8	7	5.9%	5.2%
	Bob Marshall	360 (322-367)	13	10	3.6%	2.8%
	Mission	17 (16-18)	2	0	11.8%	0%
	Whitefish (extirpated)	0	0	0	--	--
	Anaconda	20 (0-40)	0	0	0%	0%
	Blackfoot	40 (20-55)	0	0	0%	0%
	Flint Creek	25 (0-70)	0	0	0%	0%
	Great Burn	23 (20-25)	0	0	0%	0%
	West Bitterroot	100 (80-120)	2	1	2.0%	1.0%
	Sapphire	10 (0-40)	0	0	0%	0%
	West Fork	30 (10-100)	0	0	0%	0%
	Beaverhead	51 (36-66)	0	0	0%	0%
	Pioneer	125 (75-150)	9	3	7.2%	2.4%
	East Front	223 (165-315)	5	4	2.2%	1.8%
Introduced populations	Absaroka	470 (355-538)	58	38	12.3%	8.0%
	Bridger	78 (56-98)	5	4	6.4%	5.1%
	Crazy	450 (330-550)	50	42	11.1%	9.4%
	Elkhorn	20 (9-30)	0	0	0%	0%
	Gallatin	250 (140-275)	30	28	12.0%	11.2%
	Highland	10 (10-15)	0	0	0%	0%
	Madison	617 (447-760)	24	19	3.9%	3.1%
	Sleeping Giant	0 (0-1)	0	0	0%	0%
	Snowcrest	48 (22-48)	3	3	6.3%	6.3%
	Tobacco Root	27 (11-44)	3	3	11.1%	11.1%
	Big Belt	105 (81-130)	2	1	1.9%	1.0%
	Square Butte-Highwood	105 (90-135)	6	5	5.7%	4.8%
	Big Snowy	1 (1-2)	0	0	0%	0%
	Beartooth	345 (290-422)	21	12	6.1%	3.5%

Yellowstone Area. Our analysis includes some of the same HDs as those studied by Flesch et al. (2016), although we focus only on a recent time period, 2000–2016. This statistical approach has been shown to perform well with a minimum of 5 data points spanning a ten-year survey period (Humbert et al. 2009, Flesch et al. 2016). For our analyses we identified a set of 21 survey areas for which at least 5 surveys were conducted during unique years of a 16-year period. After estimating trends and statistical uncertainty for each area, we used linear-log regression to test for a curvilinear relationship between the standard errors of growth rate estimates and the respective average number of individuals counted in each area.

Expert opinion questionnaire

We developed an original, standardized questionnaire for completion by MFWP area biologists. We emailed this 25-question survey to eighteen MFWP biologists in Regions 1–5 who have management responsibility for currently delineated mountain goat HDs. Responses were compiled and summarized separately for native and introduced mountain goat HDs. We treated HDs as population sample units for summarizing results, because population surveys are typically conducted on a HD basis. Populations not currently within an administrative HD were included as independent samples. For a subset of questions, we asked respondents to rank a set of possible answers by their relative importance within each HD. In these cases, respondents were free to select and rank as many or as few options as were applicable, with their top choice receiving at rank of 1. We summarized answers to these questions in 2 ways: 1) first we recorded the number of times (the count) a given answer was selected, and 2) we scored rankings in reverse order such that ranks of 1 received the most points. For example, in a question with 7 possible answers, a ranking of 1 received a score of 7, a ranking of 2 received a score of 6, and so on. Scores were then summed for each possible answer across all responses.

With our first question (Question 1), we asked biologists to provide population estimates for a total of 58 population units, including 26 HDs with native populations, 26 HDs with introduced populations, and 6 populations (4 native and 2 introduced) not currently within an HD. These were not statistical estimates, but expert opinion estimates derived from the best available information, including aerial and ground surveys, knowledge of sightability corrections from populations elsewhere (Cichowski et al. 1994, Gonzalez-Voyer et al. 2001), and professional judgment. We also asked biologists to provide a “range of confidence” surrounding each population estimate, which was not a statistical confidence interval but rather a “best guess” at the range of possible values of true abundance. When pooling estimates for summary purposes across multiple HDs, we used the sum of point estimates, low range of confidence boundaries, and high range of confidence boundaries to characterize total estimates and range of confidence boundaries for the pooled area.

The second suite of questions (Questions 2–8) concerned biologists’ impressions of the historic (1960–2010) and current (2010–2015) status of each population (per HD) and the relative roles of various potential limiting factors during each time period. The third suite of questions (Questions 9–16) were focused on the goals and means with which biologists set harvest quotas. This section also included questions about biologists’ perceptions of the interest and ability of hunters to correctly identify the sex of targeted mountain goats in the field. The fourth suite of questions (Questions 17–19) concerned the methodology (e.g., aircraft platform, time of year, and frequency) used to conduct population trend counts. Next we asked questions about habitat concerns specific to mountain goat populations (Question 20–21), interest in translocation as a management tool (Question 22), and the most pressing management and research needs (Question 23–25). Details concerning this questionnaire and biologist responses beyond what is presented here are available in an unpublished report (Smith and DeCesare 2017; found online at: http://fwp.mt.gov/fwpDoc.html?id=81144).

RESULTS

Hunter harvest

The availability of hunting licenses during 1960–2015 peaked in 1963 at 1,371 licenses, primarily for hunting of native populations (Figure 2a). Unlimited licenses were available for several native populations at the beginning of the study period in 1960, although regulations for these HDs were gradually switched to limited, draw-based licensing during the subsequent decade. The last unlimited hunting occurred in 1971 in a portion of the Bob Marshall Wilderness, after which only limited licenses were offered in all HDs. In 2015, 16,643 hunters applied to the lottery for 241 mountain goat licenses, with a 1.4% chance of successfully drawing.

Mirroring trends in license availability, total harvest of mountain goats was highest during the early 1960s, peaking at 513 animals in 1963. By the late 1970s and throughout the 1980s, total harvest became somewhat stable, averaging 216 (range 170–242) mountain goats per year during 1977–1989. Similar harvests have been achieved since, including during the 1990s (mean=212, range=197–228), the 2000s (mean=221, range=184–250), and most recently 2010–2015 (mean=198, range=174–214). Less visible during this 40-year period of stability in total harvest has been a dramatic shift in harvest from native to introduced populations. In the early 1960s, 87–88% of harvested animals were from native populations, averaging 377 native mountain goats harvested per year compared to 55 introduced mountain goats. Since that time, the proportionate harvest of native mountain goats has declined substantially as a result of both reduced licenses in native populations and increased licenses in introduced populations. In 2015, 25 mountain goats were harvested from native ranges compared to 155 from introduced ranges.

The success rates of hunters, measured as kills per license sold, were lowest during the beginning of this study period, averaging 34% for native populations and 41% for introduced populations during the 1960s (Figure 2b). During subsequent decades, as licenses were reduced in native ranges and increased in introduced ranges, success rates for both increased. Throughout this period, hunter success in introduced range has remained consistently higher than in native range. Thus far during the 21st century (2000–2015), success rates have averaged 65% for hunters of native populations and 74% for hunters of introduced populations.

There was no statistical difference in proportionate harvest of females among native and introduced populations (t_{110}=0.543, P=0.588; Figure 3). A decreasing trend in the annual proportion of females in the harvest was evident among both native (β=-0.002, P=0.001) and introduced (β=-0.002, P=0.001) subsets of the statewide harvest, showing an average decrease of 0.2% per year (Figure 3). For example, an average of 42.2% of the annual harvest was females during the 1960s

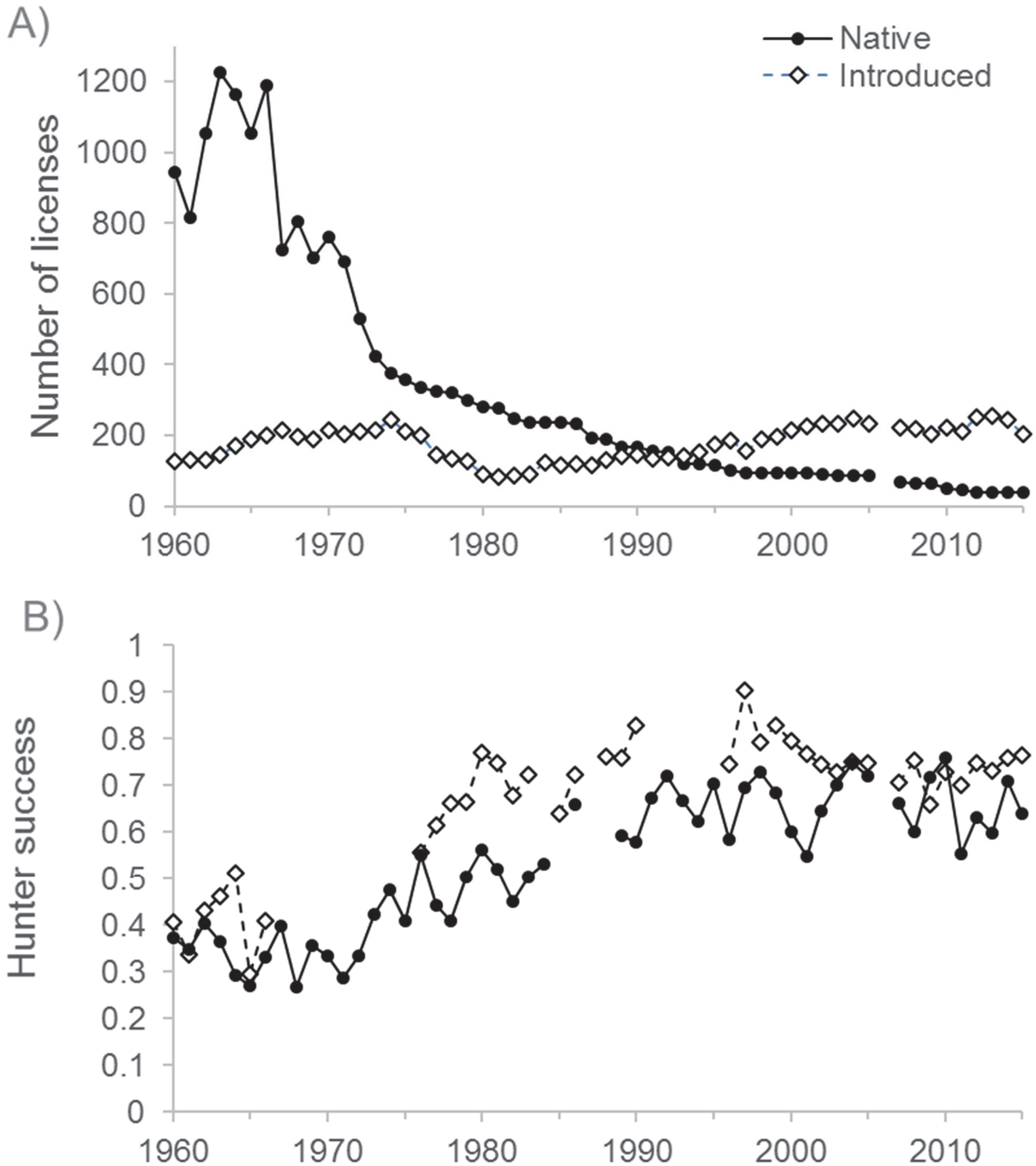

Figure 2. Trends in A) the availability of hunting licenses and B) hunter success rates (kills per license) for native and introduced populations of mountain goats in Montana, 1960–2015.

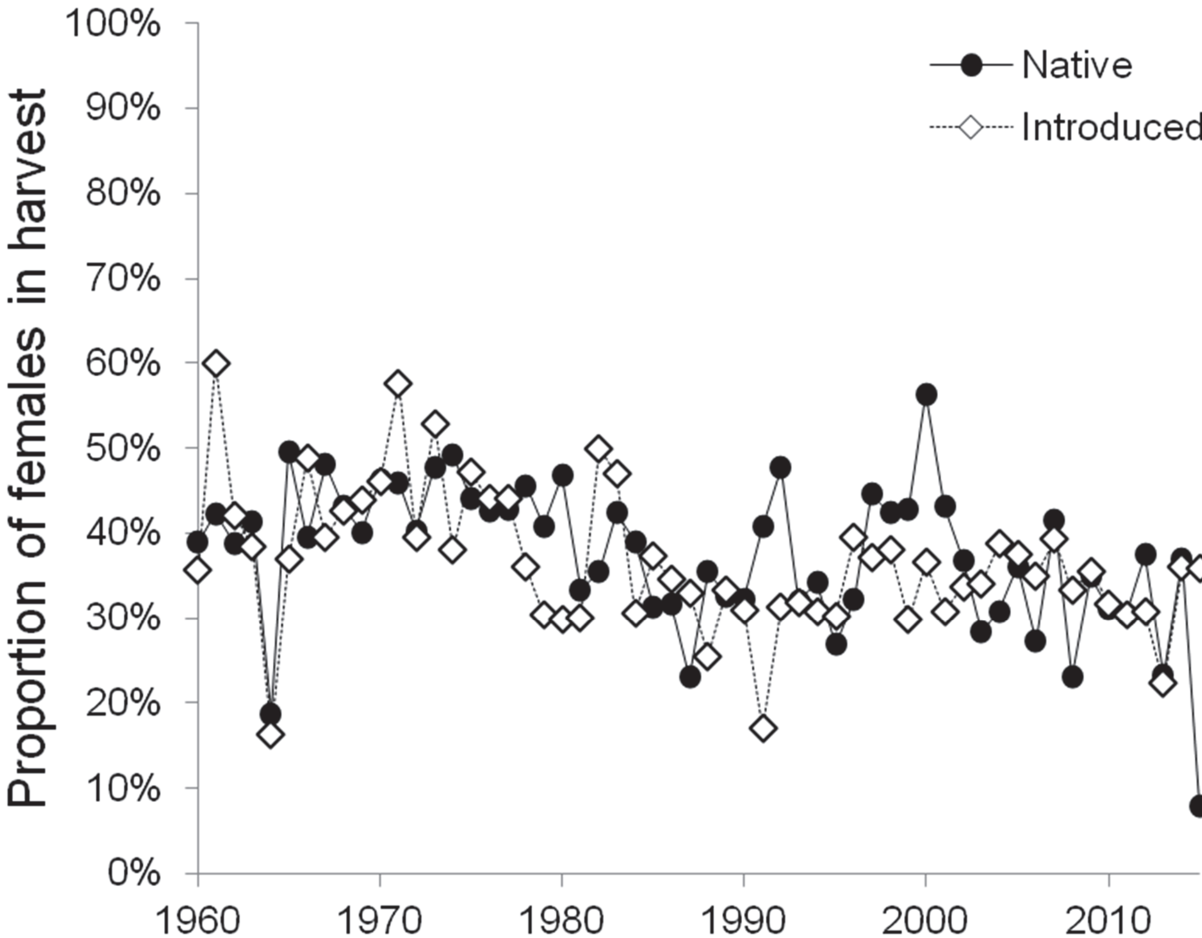

Figure 3. Proportion of females within the annual harvest of mountain goats, among native and introduced populations, in Montana, 1960–2015

(excluding an outlier value of 18% from 1964), while an average of 30.7% of the harvest was females during 2010–2015.

Among 13 extant native regional population units (groups of HDs), 7 were closed to hunting and 6 provided hunting opportunity in 2015. The average license rate (using population estimates derived from expert opinion questionnaires) among the hunted native population units was 5.5%, and the harvest rate averaged 2.0% (Table 1). Among the 14 introduced population units, 4 were closed to hunting and 10 provided hunting opportunity in 2015. The average license rate among the hunted introduced population units was 7.7%, and the harvest rate averaged 6.3% (Table 1).

Population trend surveys

We estimated survey-based population growth rates for 5 native HDs and 16 introduced HDs during 2000–2015 (Figure 4). For native HDs, point estimates of λ were <1 for 4 of 5 populations. However, 95% confidence intervals of λ overlapped 1.0 for all native HDs except HD 101, West Cabinet Mountains where λ was significantly <1.0. Among introduced HDs, point estimates of λ were <1.0 for half (8 of

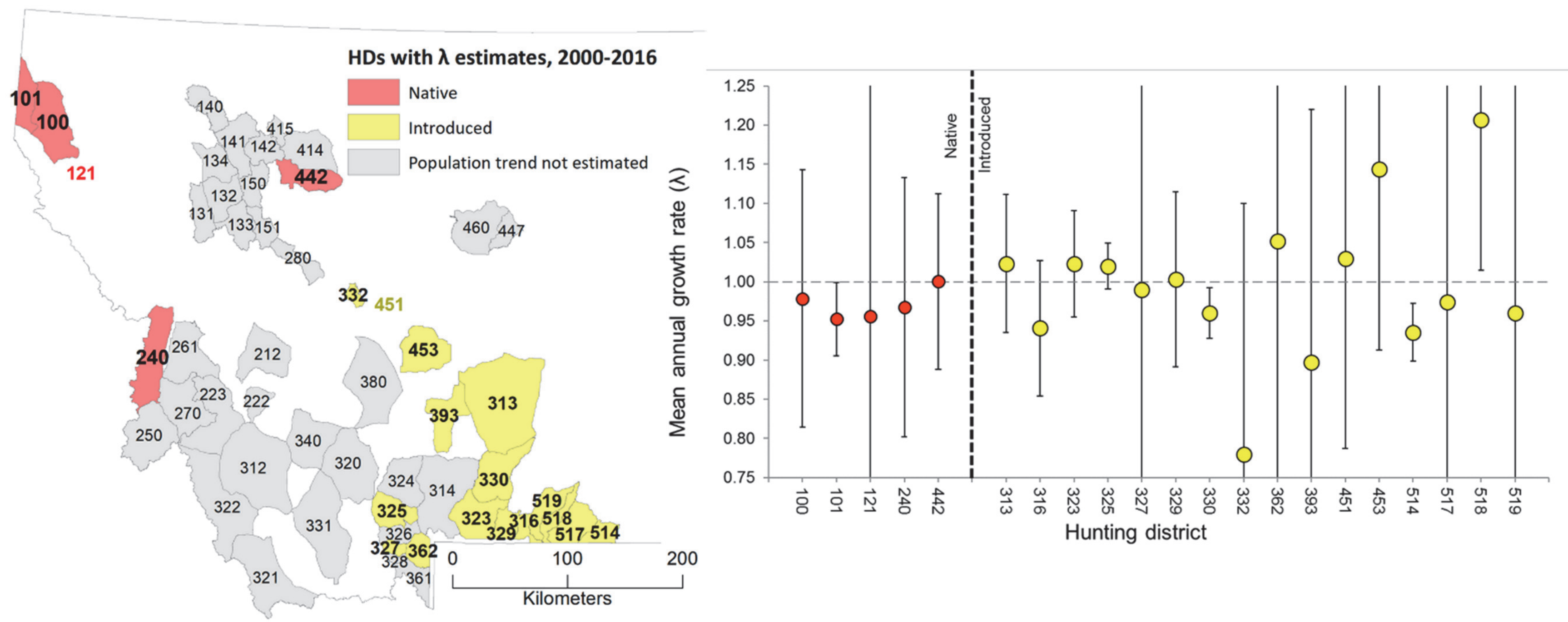

Figure 4. Mean annual population growth rates and 95% confidence intervals for 21 mountain goat HDs in Montana, 2000–2016. Note, these results include 2 former HDs (121, 451) that have since been closed and thus are not represented with polygon boundaries.

16) of populations and >1.0 for the other half. Confidence intervals of λ overlapped 1.0 for 14 of 16 introduced HDs, while confidence intervals for the remaining 2 (HD 330, North Absaroka, and HD 514, Line Creek) indicated estimates of λ that were significantly <1.0. Given the wide confidence intervals surrounding most estimates of λ, little can be said with statistical certainty about trends in survey data for many of these mountain goat HDs using survey data alone. Linear-log regression of the standard errors of λ estimates relative to the log (number of individuals counted per survey area) suggested a negative relationship between the magnitude of counts and the subsequent estimate's standard error (β=-0.034, P=0.021; Figure 5). Thus, statistically rigorous estimates of trends are more difficult to attain under survey conditions of small populations and infrequent surveys.

Among all mountain goat survey areas (including HDs as well as populations outside of HD boundaries) with at least one survey during 2000–2015, the average count was 39 animals. For the subset of 21 survey areas with >5 surveys the average count was 56 animals. When comparing the standard error of estimates of lambda by the magnitude of these counts per area, it appears that there is potential for a high amount of uncertainty (i.e., SE estimates >0.05 would lead to confidence intervals >0.2 units wide surrounding λ) when the average number of mountain goats counted is <100 animals. This would apply to 48 of all 52 survey areas flown during 2000–2015, unless surveys were designed such that data could be pooled among multiple

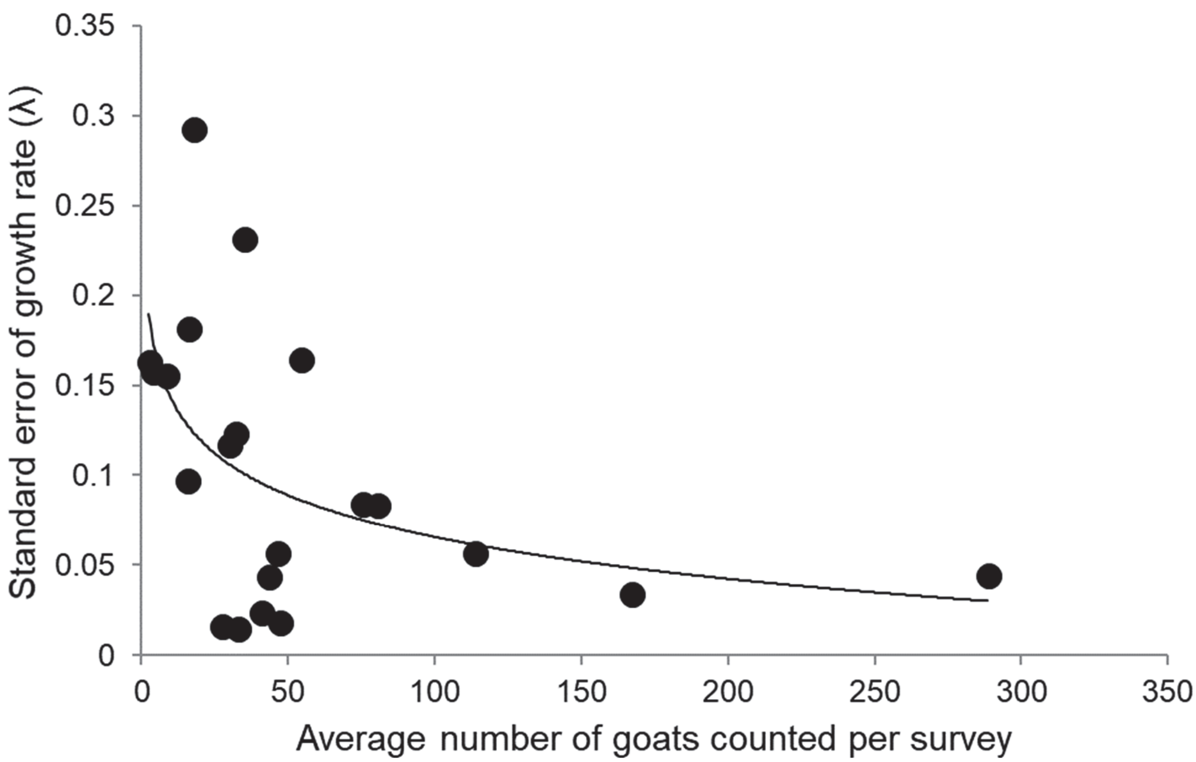

Figure 5. Standard error of mountain goat population growth rate estimates as a function of the average number of individuals counted during trend surveys in 21 survey areas across Montana, 2000–2015. The fitted line was derived from a linear-log regression showing a significant negative effect of log (mean number counted) on the resulting standard error.

survey areas prior to interpretation. However, a formal power analysis of simulated mountain goat survey data would provide an improved depiction of the precision of trend estimates under various scenarios of monitoring goats with aerial surveys.

Expert opinion questionnaire

Population estimates. —According to results from this questionnaire, the estimated total population (and range of confidence) of mountain goats in 2016 in native populations was 1,159 (885–1,537), and in introduced populations was 2,526 mountain goats (1,842–2,958). The combined statewide population (excluding the 2 national parks) was 3,685 (2,727–4,495). An additional 2,000 (1,700–2,300) mountain goats are estimated to live in native populations within Glacier National Park (Belt and Krausman 2012, J. Belt pers. comm.), and 225 (200–250) mountain goats from introduced populations inhabiting northern Yellowstone National Park, either year-round or seasonally (Flesch et al. 2016). Including animals within national parks yields statewide estimates of 3,159 native mountain goats and 2,751 introduced mountain goats totaling 5,910 in all.

Trends and limiting factors. —Area biologists estimated that 77% (23 of 30) of native mountain goat HDs have declined between 1960 and 2010, including 1 extirpated population. An additional 13% (4 of 30) were judged to be stable and 10% (3 of 30) had uncertain trends over this period. For introduced HDs, biologists estimated that 43% (12 of 28) declined during this 50-year period, 11% (3 of 28) remained stable, 43% (12 of 28) increased, and trend for the remaining HD was uncertain. The most commonly cited factors limiting mountain goat numbers over this historic period of 1960–2010 were total hunter harvest followed by unknown reasons, harvest of female mountain goats, habitat changes, and predation (Table 2). That ranking was very similar for both native and introduced populations of mountain goats, with ORV/snowmobile use a concern in several HDs of native mountain goats, and predation a greater concern for introduced populations. Several respondents noted a high degree of uncertainty surrounding declines in native mountain goat populations, sometimes as a consequence of insufficient population data needed to assess changes.

With regards to the more recent period of 2010–2015, biologists responded that 75% of native HDs declined during this time or their status was uncertain; whereas 75% of introduced HDs were judged to be stable or increasing, with the remainder judged as declining or of uncertain trend. The most commonly cited factors currently limiting mountain goat numbers were habitat changes, followed by harvest of female mountain goats, total mountain goat harvest, predation, small population risks, and ORV/snowmobile disturbance (Table 3). There were marked differences between perceived factors limiting contemporary mountain goats in native versus introduced HDs. For introduced HDs, predation, harvest of females, total harvest, and habitat changes ranked similarly as most important. For native mountain goats, habitat changes were most important, followed by small population risks, ORV/snowmobile disturbance, and climate change concerns. Regarding native mountain goat populations, several biologists noted that the cumulative effects

Table 2. Relative importance of factors limiting mountain goat populations historically (1960–2010) in 29 native and 27 introduced HDs (as well as local populations outside of HD boundaries) in Montana. Count data indicate the number of populations to which a limiting factor applies. Weighted scores reflect both the number of populations to which a factor applies and the relative rankings of that factor among others selected.

		Disease	Predation	Hunter harvest (total # animals)	Hunter harvest (proportion of females)	Habitat changes (non-anthropogenic)	ORV/Snowmobile disturbance	Energy exploration	Logging and/or road construction	Non-motorized recreation	Climate change	Small population risks (inbreeding, …)	Other (describe in Q4)	Unknown
Native	Count	7	10	21	10	17	14			3	10	9		21
	Weighted score	23	49	126	70	78	79			15	13	52		123
Introduced	Count	4	12	11	10	10				1		4	5	8
	Weighted score	14	63	56	54	43				3		23	30	54
Total	Count	11	22	32	20	27	14			4	10	13	5	29
	Weighted score	37	112	182	124	121	79			18	33	75	30	177

of specific factors may be perpetuating suppression of mountain goat numbers that may have begun prior to 2010. Regarding introduced populations, biologists raised concerns about suspected predation on mountain goats as well as the need for careful monitoring of harvest rates and potential overuse of available range by mountain goats.

Harvest management. —In response to a question about the goals of harvest management, biologists managing native populations took an almost unanimously conservative approach to harvest, with the goal of minimizing impact on populations in 94% of HDs. To the contrary, biologists managing introduced populations had more varied objectives, including the goal of minimizing impact in 42% of HDs but also goals of limiting or decreasing population growth in 58% of HDs. Survey minimum counts and survey recruitment ratios were the two types of data on which biologists place the greatest reliance in setting harvest regulations. The next two factors most relied on to set regulations were FWP harvest data (number of animals harvested relative to number of licenses issued) and hunter effort data (number of days/animal harvested). With mandatory reporting of mountain goat kills and consistent annual hunter harvest surveys, these may be the most consistently available data at biologists' disposal.

We also asked biologists 2 questions regarding how considerations of the sex of animals entered hunters' decisions when targeting a mountain goat. Responses indicated that an average of 55% (range 0–

Table 3. Relative importance of factors limiting mountain goat populations in recent times (2010–2015) in 29 native and 27 introduced HDs (as well as local populations outside of HD boundaries) in Montana. Count data indicate the number of populations to which a limiting factor applies. Weighted scores reflect both the number of populations to which a factor applies and the relative rankings of that factor among others selected.

		Disease	Predation	Hunter harvest (total # animals)	Hunter harvest (proportion of females)	Habitat changes (non-anthropogenic)	ORV/Snowmobile disturbance	Energy exploration	Logging and/or road construction	Non-motorized recreation	Climate change	Small population risks (inbreeding, …)	Other (please describe in Q4)	Ltd Available Habitat
Native	Count	10	14	14	13	18	21			4	20	16	4	
	Weighted score	50	66	74	81	101	95			20	91	99	15	
Introduced	Count	6	13	11	11	12	3			3		3		2
	Weighted score	41	69	62	67	60	17			11		17		14
Total	Count	16	27	25	24	30	24			7	20	19	4	2
	Weighted score	91	135	136	148	161	112			31	91	116	15	14

90%) of hunters intend to harvest a male rather than a female; and biologists estimated that an average of 52% (range 0–90%) of hunters can correctly identify a mountain goat's sex under field hunting conditions. These results suggested that approximately half of license-holders may be as likely to kill a female as a male, particularly with female-biased sex ratios being typical in the adult cohort of mountain goat populations (Chadwick 1973, Rideout 1974, Gonzalez-Voyer et al. 2003).

Biologists identified a wide array of research needs that would benefit their understanding and management of mountain goat populations. Of 12 topics mentioned, 3 research themes or areas of study captured 62% of all topics respondents offered: assessments of habitat condition, use, and carrying capacity (9 responses); population demographics: productivity, recruitment, kid survival, and adult survival (7); and causes of mortality (5). The other 9 topics were each mentioned 3 times or less. Biologists also identified 8 management or monitoring needs that would assist mountain goat management. The 2 topics most often mentioned, and constituting 68% of all responses, were: better/more frequent monitoring of populations (10 responses); and sightability correction models and improved, standardized, survey methodology (5). Ten additional topics of relevance to mountain goat management and conservation in Montana were mentioned 1 or 2 times each by questionnaire respondents.

DISCUSSION

Population estimates and trends

To put current numbers in historical perspective, Casebeer et al. (1950) reviewed estimates of the statewide mountain goat population during 1919–1942, as recorded by the US Forest Service, and during 1943–1948 from estimates made by the Montana Fish and Game Department (Rognrud and Lancaster 1947). From these records it appears that about 4,100 mountain goats occupied native ranges across Montana during 1943–1946 (excluding national parks), a figure 3.5 times larger than the 1,159 native mountain goats estimated by Montana's biologists in 2016 in our study (Figure 6). Establishment of new herds in previously unoccupied mountain ranges began in 1941 (Picton and Lonner 2008). While the program to expand mountain goat distributions to unoccupied ranges was still in its infancy, Casebeer et al. (1950) recorded an annual maximum of 97 mountain goats among all introduced populations during 1943–1946. Additional translocations and growth of introduced populations resulted in our estimate of 2,526 in 2016 (Figure 6).

For native mountain goat populations, numbers of licenses and harvested mountain goats have plummeted from an average of 967 licenses and 329 harvested annually during the decade of the 1960s to an average of 50 licenses and 33 mountain goats harvested during 2007–2015 (39 licenses and 25 mountain goats harvested in 2015). In contrast, licenses and mountain goats harvested from introduced populations have increased from an average 169 licenses and 71 mountain goats harvested annually during the 1960s to an average of 225 licenses and 165 mountain goats harvested during 2007–2015 (202 licenses and 155 mountain goats harvested from introduced populations in 2015).

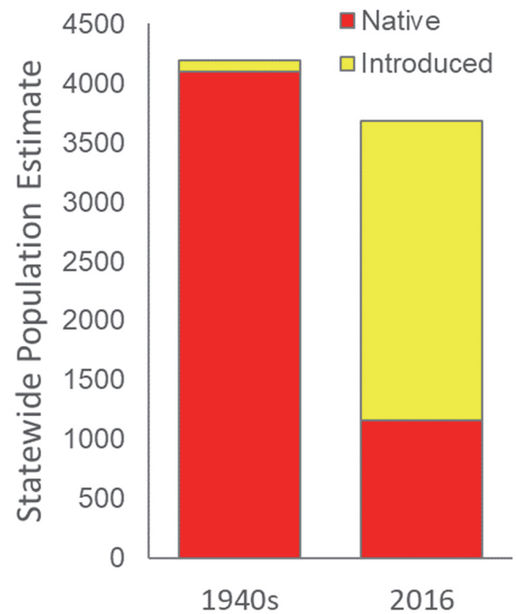

Figure 6. Comparison of 1940s estimates of mountain goat abundance in native and introduced populations of Montana, excluding national parks, by Casebeer et al. (1950) with those of this study for 2016.

Harvest management of mountain goats has been a topic of much interest and debate. Corroborating our questionnaire results concerning the important role that hunter harvest played in reducing historic mountain goat populations (Table 2), overharvest has been implicated as a source of population declines in native mountain goats in other parts of their range. Rice and Gay (2010) used population modeling to evaluate historical trends of mountain goats in Washington and found that population declines were primarily attributable to harvest. Mountain goat populations, numbering less than 100 animals, are generally no longer hunted in Washington (Rice and Gay 2010). Hamel et al. (2006) modeled population dynamics of mountain goats in Alberta and showed high sensitivity of population dynamics to adult female survival and a subsequently detrimental role of female harvest in affecting population trends. As a result of these findings, the authors recommended closure of hunting in populations numbering <50 total individuals, and conservative harvest rates of 1–4% for larger populations depending on the population size and proportionate female harvest (Hamel et al. 2006, Rice and Gay 2010). In our study, the average license rates were 5.5% across hunted native population units and 7.7% across hunted introduced populations, while harvest rates averaged 2.0% for native and 6.3% for introduced populations. It is important to note that these estimates rely on population estimates from expert opinion rather than from repeatable, statistical population estimation procedures, and thus have unknown accuracy and precision. Twelve of the state's 52 currently delineated HDs have been closed to hunting, ostensibly due to populations too small to support harvest (note: following the completion of this study an additional 7 native populations were closed to hunting for the 2018 season).

Harvest rates of introduced population units have typically been higher, including cases of harvesting as many as 7.5–20% of the population in some areas (reviewed by Williams 1999 and Côté et al. 2001). Williams (1999) noted that introduced mountain goat populations likely occur in different stages of Caughley's (1970) 4 states of an ungulate irruption, as regulated by density-dependent quality of habitat. Because introductions began as early as the 1940s, it is evident that some of Montana's introduced herds have already experienced multiple cycles of increase and decline. Thus, a single optimal harvest rate prescription may not apply to all populations after accounting for other limiting factors such as density dependence or predation rates. However, all authors have recommended caution with harvest of mountain goats in particular due to the difficulties of limiting harvest to males as well as their generally modest reproductive capacity.

Population monitoring

Our results suggested that current monitoring practices using aerial surveys alone have not, for the most part, been adequate to reasonably distinguish increasing vs. decreasing population trends with statistical rigor over the most recent 15-year time period. Biologists offered that better and more frequent monitoring of populations was their top management need and suggested research leading to a better understanding of population demographics of mountain goats was a high priority. Minimum counts documented during population surveys are a valid means of monitoring trend, even with annual variation in sightability of animals, provided the average sightability over long periods of time does not change (reviewed by DeCesare et al. 2016). In other words, an equal proportion of the population is assumed to be within the survey area and mean sightability of those within the area is assumed to be constant. While these counts provide a means of estimating trend, they cannot be used to estimate abundance without specific estimates of sightability. Measured sightability rates of marked mountain goats have varied from ~40% to 80% in studies in British Columbia, Idaho, and Washington (Poole et al. 2000, Pauley and Crenshaw 2006, Rice et al. 2009). Sightability likely varies among mountain goat populations and habitats in Montana, making it unlikely that a single sightability model would apply across the state (Harris et al. 2015). Accounting for sightability bias across would Montana would likely require multiple studies and multiple models to fit varying conditions.

Managers of species that tend to occur in small populations commonly face an additional challenge of lacking statistical power when interpreting trend surveys. The precision of population estimates is known to decrease as the size of the population being monitored decreases (Taylor and Gerrodette 1993, Barnes 2002, DeCesare et al. 2016). For example, Barnes (2002) found that the confidence intervals for estimates for a West African elephant monitoring program were likely to be >100% of the point estimates when the population was below 600 animals. While this threshold doesn't necessarily apply directly to mountain goat monitoring in Montana, our results do suggest a positive relationship between the magnitude of counts and their precision (Figure 5). Thus, lumping subpopulations together into larger groups whether during surveys or during data analysis may increase our power to detect trends if done so consistently over time and if population dynamics can be assumed to be the same across the larger group. A formal power analysis of simulated and empirical mountain goat survey data would offer an improved depiction of how various survey sampling designs might affect the strength of results. Additionally, review of other survey techniques or monitoring practices (such as monitoring of trend via survival and reproductive rates of marked individuals or non-invasive DNA-based population estimation) may aid in evaluating current practices compared to those employed for mountain goats in other jurisdictions (Poole et al. 2011).

In addition to minimum counts, biologists indicated frequent use of recruitment ratios when monitoring mountain goat populations. These ratios are typically formulated as young/adult ratios, though the definition of the adult denominator appeared to vary across surveys depending on efforts to distinguish yearling or 2-year-old mountain goats from older animals. Of significance to interpretation of these data is the important life history detail that the age of first reproduction for female mountain goats is 3 years of age (Rideout 1975) and primiparity can average >4 years-old for native populations (Festa-Bianchet and Côté 2008). It is likely that many of the adults counted in recruitment ratios are not in fact breeding-aged adults. Thus, variation in age structure of adults across years or populations should be expected to confound interpretation of recruitment ratio data.

Area biologists also indicated that other data, in addition to survey data, are used when managing mountain goats. These included hunter harvest data, hunter effort data, and data concerning the age and sex of harvested individuals. Statistical modeling of these forms of data is not typically employed, and it is currently unclear if catch-effort or age-at-harvest data would be sufficient to glean meaningful patterns statistically, whether as a stand-alone analysis or incorporated into an integrated population model (Skalski et al. 2007, Udevitz and Gogan 2012). Hunter success, in particular, may be of limited value in assessing the population status of mountain goats, particularly native mountain goats in Montana. Over the past 60 years as harvest success has increased (Figure 2), we found that Montana's native mountain goats have clearly been in decline as have the number of licenses issued annually. In HDs where only one or two licenses are issued annually, hunter success of 100% or 50% in a HD is difficult to interpret, and potentially misleading. Fidelity of mountain goats to preferred areas of their ranges contributes to the ability of hunters to find and harvest mountain goats, even when populations are small (Chadwick 1973, Smith 1976, Taylor et al. 2006, Festa-Bianchet and Côté 2008). This natural history trait may predispose hunted mountain goat populations to apparent “hyperstability” when monitored with hunter statistics alone (Hatter 2001). In such cases, hunter harvest statistics may convey a deceptively stable trend even for declining populations, because hunters continue to find and harvest mountain goats in the same areas and with the same efficiency regardless of decreased numbers overall (Hatter 2001). Survey responses suggested that Montana’s mountain goat managers recognize the limited value of harvest success compared to biological data obtained from population surveys on which they place greater importance when establishing annual regulations. Consequently, population monitoring ranked highest among management priorities.

Limiting factors

Concerns about small population effects raised by several biologists are justified, given the small and potentially isolated nature of many of Montana’s mountain goat populations. Biologists estimated that >50% of the state’s HDs (and 69% of extant native HDs) may support fewer than 50 mountain goats. Such populations risk heightened consequences of stochastic events and inbreeding depression, compared to large populations or metapopulations (Hebblewhite et al. 2010, Johnson et al. 2011). Effective conservation of mountain goats may require additional understanding of the extent to which populations face such risks. Research on movement and yearlong distributional patterns are needed for some of Montana’s larger landscapes to determine where populations may now be reproductively isolated.

Unique among large mammal species, the mountain goat’s distribution in Montana is almost completely on federally or state-managed lands, including national forest multiple-use lands, national forest wilderness areas, two national parks, state lands, and tribal land. Because of their high, rugged nature, mountain goat ranges tend to be less subject to human development and alteration than habitats of the state’s other big game species. Yet, the biologists we surveyed offered a range of direct or indirect effects, both natural and anthropogenic, that are either suspected or known to be affecting mountain goats. Road construction into mountain goat habitat to facilitate mining, energy and timber extraction, and motorized recreation can alter habitat with implications for mountain goat distributions and demography (Fox et al. 1989, White and Gregovich 2017), and increased vulnerability of mountain goats to harvest (Mountain Goat Management Team 2010). Numerous studies in Canada and the U.S. have demonstrated that mountain goats are particularly sensitive to helicopter disturbance (Foster and Rahs 1983, Côté, 1996, Gordon and Wilson, 2004).

In Montana, some of the most pertinent research conducted on habitat-mediated impacts on mountain goats includes documentation of how helicopter over-flights associated with seismic testing affects population dynamics (Joslin 1986), and how road intrusion and timber harvest alter mountain goat behavior and distribution (Chadwick 1973). However, little is known about the effects of commercial and recreational activities on most mountain goat populations in the state, or about the condition and carrying capacity of most mountain goat ranges and how that may relate to population performance. Likewise, the effects of wildfire, or contrarily fire suppression, on mountain goats through changes in habitat structure, plant succession, and forage are little known. These are noteworthy areas for research regarding the differing status and trends we identified of native versus introduced populations generally. Mountain goats may also be among those species most sensitive to climate change because of their cold-adapted nature and because the climate is warming (and cascading environmental changes occurring) twice as rapidly at high elevations compared to the global mean rate of warming (Beever and Belant 2011).

Future directions

Montana is unique among the 8 U.S. and Canadian jurisdictions within the native range of the mountain goat by now supporting greater numbers of mountain goats in introduced populations than those in the state's native populations. Clearly one size fits all prescriptions for management would not serve the state's mountain goat populations well. Management and conservation efforts require consideration of the wide range of habitats Montana's mountain goats occupy with special attention to differences between native and introduced mountain goats. However, statewide coordination of management planning and research prioritization may serve to leverage resources to address needs and answer questions for broad landscapes and multiple populations of mountain goats.

From our findings, important topics deserving of future attention in comprehensive planning for Montana's mountain goats include:

1) Recommendations for harvest of mountain goats: These may well differ for native and introduced populations. Not only population harvest rates, but sex-specific harvest prescriptions dependent on maintaining viable population size could be addressed. Wildlife managers can influence mountain goat conservation largely through regulation of public harvest in comparison to other factors beyond their control.

2) Evaluation of monitoring practices: MFWP biologists rely heavily on population survey data to establish harvest levels of populations. Improved survey techniques, sightability modeling, and informed/optimal monitoring frequencies are all important management needs. Although biologists overwhelmingly felt that monitoring needed to be herd or hunting district specific because of local conditions, some consensus on data collected may be important for comparing populations and analyzing multi-year trends. The most difficult task in this study was analysis of population survey data due to inconsistencies in monitoring frequency and protocols. A formal power analysis of simulated and

empirical mountain goat survey data would offer an improved depiction of how various survey sampling designs might affect the strength of results.

3) Local monitoring protocols: We support area biologists' efforts to formally design, prescribe, and document monitoring protocols for mountain goats in their respective areas with the goal of detecting changes in population status that require management actions. These would greatly benefit future area biologists in their jurisdictions and efforts such as this study by collecting comparable data streams over time.

4) Species management plan: MFWP does not currently have a statewide management plan for mountain goats. Examples of such plans exist for other species in Montana, and for mountain goats in neighboring jurisdictions (e.g., Alberta, British Columbia, Idaho, Oregon, Utah, and Washington). Those state and provincial plans have brought together much of the pertinent literature and identified key planning elements, some unique to mountain goat conservation. Development of such a plan has been previously identified as a priority by MFWP, yet has not occurred in the face of limited time and resources. Relative to other ungulate species in Montana, a management plan for mountain goats may be particularly useful for a variety of reasons. First, various life history traits make them more sensitive to harvest management than other ungulates, which justifies a unique approach to harvest management of this species. Second, some of the variation in monitoring practices and/or harvest rates identified in this report might benefit from regional or statewide coordination or guidelines. Third, the reproductive isolation of many populations may render mountain goats more vulnerable to natural and anthropogenic changes in their environment across broad areas of their distribution. Lastly, individual biologists have less funding and time to devote to this species relative to other more abundant and/or controversial species, which might increase the value of a statewide resource for information and guidance.

5) Ecological research: In addition to the monitoring-based research questions we identified above, our questionnaire indicated a variety of potential avenues for important research into mountain goat ecology. These included, but were not limited to, assessments of mountain goat foraging ecology and habitat condition, demographic vital rates and population dynamics, and causes of mortality.

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LITERATURE CITED

Barnes, R.F.W. 2002. The problem of precision and trend detection posed by small elephant populations in West Africa. African Journal of Ecology 40:179–185.

Beever, E.A., and J. Belant, editors. 2011. Ecological Consequences of Climate Change: Mechanisms, Conservation, and Management. CRC Press, Boca Raton, FL.

Belt, J.J., and P.R. Krausman. 2012. Evaluating population estimates of mountain goats based on citizen science. Wildlife Society Bulletin 36:264–276.

Carlsen, T. and G. Erickson. 2008. Status of Rocky Mountain bighorn sheep and mountain goats in Montana. Proceedings of the Northern Wildlife Sheep and Goat Council 16:7–18.

Casebeer, R.L., M.J. Rognrud, and S. Brandborg. 1950. The Rocky Mountain goat in Montana. Bulletin 5, Montana Fish and Game Commission, Helena.

Caughley, G. 1970. Eruption of ungulate populations, with emphasis on Himalayan thar in New Zealand. Ecology 51:53–72.

Chadwick, D.H. 1973. Mountain goat ecology-logging relationships in the Bunker Creek drainage of western Montana. M.S. Thesis, University of Montana, Missoula.

Cichowski, D. B., D. Haas, and G. Schultze. 1994. A method used for estimating mountain goat numbers in the Babine Mountains Recreation Area, British Columbia. Proceedings of the Northern Wild Sheep and Goat Council 6:56–64.

Côté, S.D. 1996. Mountain goat responses to helicopter disturbance. Wildlife Society Bulletin 24:681–685.

Côté, S.D. and M. Festa-Bianchet. 2003. Mountain goat, *Oreamnos americanus*. Pages 1,061–1,075 in Wild mammals of North America: biology, management, and conservation. G.A. Feldhammer, B. Thompson, and J. Chapman, eds. John Hopkins University Press, Baltimore, MD.

Côté, S.D., M. Festa-Bianchet, and K.G. Smith. 2001. Compensatory reproduction in harvested mountain goat populations: a word of caution. Wildlife Society Bulletin 29:726–730.

DeCesare, N.J., J.R. Newby, V.J. Boccadori, T. Chilton-Radandt, T. Thier, D. Waltee, K. Podruzny, and J.A. Gude. 2016. Calibrating minimum counts and catch-per-unit-effort as indices of moose population trend. Wildlife Society Bulletin 40:537–547.

Fagan, W.F., and E.E. Holmes. 2006. Quantifying the extinction vortex. Ecology Letters 9:51–60.

Festa-Bianchet, M. and S.D. Côté. 2008. Mountain Goats: ecology, behavior, and conservation of an alpine ungulate. Island Press, Washington, DC.

Flesch, E.P., R.A. Garrott, P.J. White, D. Brimeyer, A.B. Courtemanch, J.A. Cunningham, S.R. Dewey, G.L. Fralick, K. Loveless, D.E. McWhirter, H. Miyasaki, A. Pils, M.A. Sawaya, and S.T. Stewart. 2016. Range expansion and population growth of nonnative mountain goats in the Greater Yellowstone Area: Challenges for Management. Wildlife Society Bulletin 40: 241–250.

Foss, A.J. 1962. A study of the Rocky Mountain goat in Montana. M.S. Thesis, Montana State University, Bozeman.

Foster, B.R., and E.Y. Rahs. 1983. Mountain goat response to hydroelectric exploration in northwestern British Columbia. Environmental Management 7:189–197.

Fox, J.L., C.A. Smith, and J.W. Schoen. 1989. Relation between mountain goats and their habitat in southeastern Alaska. General Technical Report PNW-GTR-246. USDA-USFS, Pacific Northwest Research Station, Portland, Oregon.

Gonzalez-Voyer, A., M. Festa-Bianchet, and K.G. Smith. 2001. Efficiency of aerial surveys of mountain goats. Wildlife Society Bulletin 29:140–144.

Gonzalez-Voyer, A., K.G., Smith, and M. Festa-Bianchet. 2003. Dynamics of hunted and unhunted mountain goat Oreamnos americanus populations. Wildlife Biology 9:213–218.

Gordon, S.M., and S.F. Wilson. 2004. Effect of helicopter logging on mountain goat behavior in coastal British Columbia. Proceedings of the Northern Wildlife Sheep and Goat Council 14:49–63.

Hamel, S., S.D. Côté, K.G. Smith, M. Festa-Bianchet. 2006. Population dynamics and harvest potential of mountain goat herds in Alberta. Journal of Wildlife Management 70:1044–1053.

Harris, R. B. 1986. Reliability of trend lines obtained from variable counts. Journal of Wildlife Management 50:165–171.

Harris, R. B., M. Atamian, H. Ferguson, and I. Karen. 2015. Estimating moose abundance and trends in northeastern Washington state: index counts, sightability models, and reducing uncertainty. Alces 51:57–69.

Hatter, I.W. 2001. An assessment of catch-per-unit-effort to estimate rate of change in deer and moose populations. Alces 37:71–77.

Hebblewhite, M., C. White, and M. Musiani. 2010. Revisiting extinction in national parks: mountain caribou in Banff. Conservation Biology 24:341–344.

Humbert, J.-Y., L.S. Mills, J. S. Horne, and B. Dennis. 2009. A better way to estimate population trends. Oikos 118:1940–1946.

Johnson, H.E., L. S. Mills, J.D. Wehausen, T.R. Stephenson, and G. Luikart. 2011. Translating effects of inbreeding depression on component vital rates to overall population growth in endangered bighorn sheep. Conservation Biology 25:1240–1249.

Joslin, G. 1986. Mountain goat population changes in relation to energy exploration along Montana's Rocky Mountain Front. Proceedings of the Northern Wildlife Sheep and Goat Council 5:253–271.

Lemke, T.O. 2004. Origin, expansion, and status of mountain goats in Yellowstone National Park. Wildlife Society Bulletin 32:532–541.

Lentfer, J.W. 1955. A two-year study of the Rocky Mountain goat in the Crazy Mountains, Montana. Journal of Wildlife Management 19:417–429.

Lohr, S. L. 2009. Sampling: design and analysis. Second edition. Brooks/Cole, Boston, Massachusetts, USA.

Mountain Goat Management Team. 2010. Management plan for the mountain goat (*Oreamnos americanus*) in British Columbia. British Columbia Management Plan Series, Ministry of Environment, Victoria.

Pauley, G.R., and J.G. Crenshaw. 2006. Evaluation of paintball, mark-resight surveys for estimating mountain goat abundance. Wildlife Society Bulletin 34:1350–1355.

Picton, H.D., and T.N. Lonner. 2008. Montana's Wildlife Legacy: Decimation to Restoration. Media Works Publishing, Bozeman, Montana.

Poole, K.G., D.C. Heard, and G.S. Watts. 2000. Mountain goat inventory in the Robson Valley, British Columbia. Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council 12:114–124.

Poole, K.G., D.M. Reynolds, G. Mowat, and D. Paetkau. 2011. Estimating mountain goat abundance using DNA from fecal pellets. Wildlife Society Bulletin 75:1527–1534.

Rice, C.G., K.J. Jenkins, and W.-Y. Chang. 2009. A sightability model for mountain goats. Journal of Wildlife Management 73:468–478.

Rice, C.G., and D. Gay. 2010. Effects of mountain goat harvest on historic and contemporary populations. Northwestern Naturalist 91:40–57.

Rideout, C.B. 1974. A radio-telemetry study of the ecology and behavior of the Rocky Mountain goat in western Montana. Dissertation, University of Kansas, Lawrence.

Rideout, C.B. 1975. *Oreamnos americanus*. Mammalian Species No. 63: 1–6.

Rognrud, M., and F. Lancaster. 1947. Montana mountain goat distribution and census survey. Project 1-R, Wildlife Restoration Division, Montana Fish and Game Commission, Helena.

Saunders, J.K., Jr. 1955. Food habits and range use of the Rocky Mountain goat in the Crazy Mountains, Montana. Journal of Wildlife Management 19:429–437.

Skalski, J.R., R.L. Townsend, and B.A. Gilbert. 2007. Calibrating statistical population reconstruction models using catch-effort and index data. Journal of Wildlife Management 71:1309–1316.

Smith, B.L. 1976. Ecology of Rocky Mountain goats in the Bitterroot Mountains, Montana. M.S. Thesis, University of Montana, Missoula.

Smith, B.L. 2014. Life on the Rocks: A Portrait of the American Mountain Goat. University Press of Colorado, Boulder.

Smith, B. L., and N. J. DeCesare. 2017. Status of Montana's mountain goats: A synthesis of management data (1960–2015) and field biologists' perspectives. Unpublished report, Montana Fish, Wildlife and Parks, Missoula.

Swenson, J.E. 1985. Compensatory reproduction in an introduced mountain goat population in the Absaroka Mountains, Montana. Journal of Wildlife Management 49:837–843.

Taylor, B. L., and T. Gerrodette. 1993. The uses of statistical power in conservation biology: the vaquita and northern spotted owl. Conservation Biology 7:489–500.

Taylor, S., W. Wall, and Y. Kulis. 2006. Habitat selection by mountain goats in south coastal British Columbia. Proceedings of the Northern Wild Sheep and Goat Council 15:141–157.

Thompson, M.J. 1980. Mountain goat distribution, population characteristics, and habitat use in the Sawtooth Range, Montana. M.S. Thesis, Montana State University, Bozeman.

Toweill, D.E., S. Gordon, E. Jenkins, T. Kreeger, and D. McWhirter. 2004. A working hypothesis for the management of mountain goats. Proceedings of the Northern Wild Sheep and Goat Council 14:5–45.

Udevitz, M.S., and P.J. P. Gogan. 2012. Estimating survival rates with time series of standing age-structure data. Ecology 93:726–732.

White, K.S., and D.P. Gregovich. 2017. Mountain goat resource selection in relation to mining-related disturbance. Wildlife Biology 2017:wlb.00277.

Williams, J.S. 1999. Compensatory reproduction and dispersal in an introduced mountain goat population in central Montana. Wildlife Society Bulletin 27:1019–1024.