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Human Dimensions

Deer and Elk Hunter Recruitment, Retention, and Participation Trends in Montana

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ABSTRACT Big game hunting is the most popular type of hunting in the United States, and deer and elk hunting are the most popular type of hunting in Montana. Similar to other states, deer and elk hunting also generates most of the revenue spent on wildlife conservation by the state of Montana. Although nationwide trends indicate a concerning decline in hunter participation, the trends in license sales and hunter participation within most states have not received as much attention. We investigated trends in resident deer and elk license sales in Montana using existing licensing databases. We then estimated hunter recruitment, hunter participation, and license purchasing probabilities using hunter education and licensing databases. We employed a multi-state mark–recapture model and 248,819 records of deer and elk license purchasing habits for individual Montana residents during 2002–2007. We used matrix population models to examine the relative influence of these parameters on trends in license sales and hunter participation. Resident deer and elk license sales increased 4% in Montana during 2002–2007. We found that males had greater recruitment rates, retention rates, and license purchasing probabilities than females, and that young adults had lesser license purchasing probabilities than other age classes. Based on analyses of matrix population models, trends in license sales in Montana are most influenced by middle-aged and baby boomer male license purchase probabilities. Trends in hunter participation are positively influenced by recruitment and retention in all male age classes, with the smallest predicted effects arising from recruitment of young adult males. Our results suggest that a focus on older age class males with programs designed to increase hunter recruitment, retention, and license purchase probabilities may have similar or larger effects on trends in license sales and hunter participation in Montana than programs directed at youth. Our analyses also provide a framework by which trends in hunter recruitment, retention, and license purchasing habits can be objectively quantified in order to inform and evaluate hunter recruitment, retention, and license purchase habit programs.

KEY WORDS deer, elk, hunters, hunter participation, hunter recruitment, hunter retention, license purchase probability, mark–recapture, Montana.

Hunting is a primary form of direct engagement with wildlife and natural resources for a significant portion of the public. The social and cultural benefits of hunting are numerous and are well engrained in the American democracy (Kallman 1987). Hunting provides an avenue for recreation and the expression of tradition and culture (Enck et al. 2000), provides tremendous economic influx to local communities and businesses (U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau 2006), is a primary means of wildlife population management (Carpenter 2000, Riley et al. 2003), and is the primary economic engine supporting wildlife conservation in North America (Peterson 2004). By far, most hunting activity and related expenditures in the United States are focused on big game, including deer and elk (U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau 2006).

The centrality of hunting to Montanans is illustrated by the state consistently having one of the highest per capita participation rates in the nation (U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau 2006). Hunter participation in Montana, like other areas, is focused on big game, primarily deer and elk (Montana Department of Fish, Wildlife and Parks 2011). Deer and elk hunting are part of the cultural fabric in Montana (Eliason 2008). Deer and elk hunting also provide most of the substantial economic impact of hunting in the state (R. Brooks and Z. King, Montana Fish, Wildlife and Parks, unpublished report). Hunting provides the primary means of controlling deer and elk population sizes in Montana (Montana Department of Fish, Wildlife and

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Parks 2001, 2004), while simultaneously providing 64% of the wildlife conservation revenues for the state, totaling approximately $50 million annually (Montana Department of Fish, Wildlife and Parks, unpublished data). Because of the flexibility of these funds, they can be spent on all wildlife, hunted and non-hunted.

Declining hunter participation in Montana could have cultural, political, economic, and wildlife management and conservation implications. Several authors have noted that participation in hunting in the United States and Canada is declining (e.g., Enck et al. 2000, Riley et al. 2003, Schultz et al. 2003, Zinn 2003, U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau 2006). In all but the most populous states, however, sampling error alone is too large for robust inferences about the trend in hunter participation at the level of individual states (U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau 2006). References to declines in hunter participation speak primarily to states with the largest populations, or regional or national trends. These trends are disconnected from decision authority and processes in many cases, because a large fraction of the responsibility for wildlife conservation and management rests with the states. States are responsible for managing the harvest and hunting seasons for most wildlife, especially deer and elk. Therefore, states also have a large portion of the responsibility for managing hunter participation, recruitment, and retention. Reliable estimates of state-specific patterns of hunter participation trends are needed so that states can build programs to manage hunter participation in their jurisdictions.

The purposes of this study are to provide a summary of deer and elk hunting trends in Montana and to obtain estimates of the roles that recruitment, retention, and license purchasing probabilities play in hunting participation and license sale trends in Montana. Using databases similar to those employed by most states and provinces in North America, we provide a detailed analysis of the deer and elk hunter population in Montana. We provide elasticity and sensitivity analyses of deer and elk hunting parameters to determine which rates are most likely to influence the trend in deer and elk hunter participation, and therefore which rates might be targeted to affect this trend. Through these analyses, we also provide some insights to other jurisdictions on the use of licensing databases for determining and analyzing the trends in hunter participation and demographics of hunters.

METHODS

Big game hunters in Montana must be at least 12 yr old and can buy more than 1 license to harvest mule deer, white-tailed deer, or elk either through a general (over-the-counter) or limited-entry (drawing) process. Most limited-entry permits in Montana require a general license as a pre-requisite. Limited-entry licenses are available for several antlerless hunts, and individuals have the ability to obtain such licenses without a general license. Licenses are either specific to a certain area, species, and/or age–sex class, or are generally valid across a wide area, for more than 1 species, or for more than 1 age–sex class, depending on the specificity of the hunting regulations in a particular area. The number of non-residents that purchase deer or elk hunting licenses in Montana is controlled by state law. The number of residents that can purchase deer or elk licenses in Montana is unlimited. For our analyses, we solely considered Montana residents because only resident hunter trends are uninhibited by current laws.

Beginning in 2002, Montana Fish, Wildlife and Parks (MFWP) launched the Automated Licensing System (ALS), which is a computer-based, point-of-sale software and database system. Data on individual license purchasers and license types is entered into a database at the time of sale in this system. At the time of this analysis, MFWP License Year 2007 was the latest year for which data had been finalized. Prior to 2002, all license sales to hunters were completed using a paper-based system. Data from paper licenses were entered into electronic format dating back to 1989, but were omitted from analysis because of recording errors and logistical complications.

Additionally, since 2001, MFWP has tracked hunter education graduates using a hunter education database. All individuals under the age of 18 have been required to complete MFWP hunter education prior to purchasing a Montana hunting license during this time. Participation for older individuals is permitted but only regulated by a Montana state law passed in 2003. The 2003 law dictates that everyone born after 1985 is required to complete hunter education prior to obtaining a hunting license. This infers that in our licensing dataset, some, but not all, individuals age 18–22 were required to complete hunter education. Individuals in the MFWP hunter education database are tracked with unique identifiers and can be cross-referenced with license buyers in the ALS system.

Trends in the Hunter Population

For each year, we created a summary of the number of individual Montana residents that purchased at least 1 deer or elk license. We estimated the annual rate of change in this time series using a log-linear regression model of the natural-log transformed count data against time (Skalski et al. 2005). From the estimated instantaneous rate of change, r, resulting from this regression, we obtained an estimate of the annual rate of population change, λ using $\hat{\lambda} = e^{\hat{r}}$ (Skalski et al. 2005). These analyses were performed in R (R version 2.5.0, http://www.R-project.org, accessed 12 Sep 2011).

Hunter Retention and Recruitment Rates

We used records on individual resident license purchasing patterns across years to estimate hunter retention rates. For this analysis, we built encounter histories for all individual residents existing in the MFWP licensing databases, where a resident was coded as 1 if they purchased at least 1 deer or elk license in a given year and 0 if not, consistent with mark–recapture data formatting (Williams et al. 2002). In this dataset, we attached information about the sex and age class of each individual resident that purchased at least 1 deer or elk license during 2002–2007 from the ALS system. For age classes, we considered 12–18 yr old (minors), 19–30 yr old (young adults), 31–42 yr old (middle-aged adults), 43–59 (baby boomers), and age 60+ (seniors). We chose the breaks in these classes to correspond generally to traditional life stages of adolescence, young adulthood, adulthood, and old age (Kail and Cavanaugh 2006). The minor age class represents individuals that live at home and are under the care of adults. The young adult age class represents the life stage where individuals are prone to leave home for university, careers, military, or other life pursuits. The middle-aged adult and baby boomer age classes represent the life stages when individuals tend to become established in careers and other pursuits that may facilitate stability. Rather than treating this life stage as a single age class, we chose to treat individuals belonging to the baby boomer generation as a separate class. Several authors have highlighted the characteristics of this group to trends in hunter participation (e.g., Leonard 2007, Winkler et al. 2008). Finally, the senior age class represents individuals that are eligible for retirement and that may have more free time and ability to pursue recreational activities.

Using this dataset, we estimated Montana deer and elk hunter retention rates, annual license purchasing probabilities, and age-class transition rates using a multi-state, mark–recapture model (Schwarz 2005). In this model, we treated hunter retention as analogous to apparent survival, annual license purchasing probability as analogous to detection probability, and age-class transition rates as analogous to state transition rates in the typical multi-state model formulation (Schwarz 2005). Although detection probabilities in wildlife studies and license purchases are not directly analogous because the ALS database afforded us a complete census of license purchases, coding and analyzing the data in this manner allowed formal estimation of license purchasing probabilities in standard software. This model formulation explicitly accounted for the fact that hunters can remain hunters without purchasing a license in a given year (Enck et al. 2000). We developed an a priori model list that included all additive combinations for the effects of predictor variables on hunter retention, license purchasing probability, and age-class transition rates. We used Program MARK (White and Burnham 1999) to complete the analysis and Akaike's Information Criterion (AIC) to select between models (Burnham and Anderson 2002).

We calculated recruitment into the youngest age class as the ratio of hunter education graduates to the total number of individuals in the minor age class in the ALS database. We could not estimate recruitment into the older age classes for 2 reasons. First, most hunters in our database were not subject to laws requiring hunter education, so they were not included in the hunter education database. Second, the time series of ALS data available for this analysis only included 6 yr (2002–2007). Previous work indicated that 60% of individual license buyers skipped 1 or more years between purchasing hunting licenses (Montana Department of Fish, Wildlife, and Parks, D. J. Case and Associates, and Southwick Associates, unpublished report). Due to this propensity, hunters that had previously purchased licenses would have been considered new recruits in an open population capture–recapture modeling framework that used the ALS information to assign "marking" and "recapture" encounters to individual license buyers. Such an error would lead to overestimates of recruitment rates.

Perturbation Analyses

We constructed 2 Leslie matrix population models (Caswell 2001) to estimate the relative influence of hunter retention, recruitment of young hunters, and license purchase probability on trends in license sales and hunter numbers. We populated both models with the vital rates estimated as described above, with estimated vital rates for males and females treated separately in 2-sex matrix models. We constructed the first of these models with diagonal elements containing terms for hunter retention rates, license purchase probabilities, and recruitment rates for each age–sex class. The off-diagonal elements contained terms for transition rates between age classes, within each sex. We held recruitment rates into age classes other than minors constant at 0.10 to reflect our general a priori understanding of the recruitment rates into the minor age class. This projection matrix represents trends in license sales, and therefore has implications for the fiscal consequences of trends in hunter participation. We then constructed our hunter participation matrix as above, but without the terms for license purchase probabilities. As hunters can remain hunters without purchasing licenses (Enck et al. 2000), this matrix reflected the dynamics of hunters irrespective of license purchases, which has direct bearing on the social consequences of trends in hunter participation.

For both of these matrices, we conducted elasticity and sensitivity analyses using Program R (R version 2.5.0, http://www.R-project.org, accessed 12 Sep 2011). Elasticity analysis refers to the impact of proportional increases in vital rates on the population growth rate, λ, which we determined using the dominant eigenvalue of each matrix (Caswell 2001). We examined the elasticity of hunter retention rates, license purchase probabilities, and recruitment rates by increasing each rate by 10% and examining the resulting effect on λ in each matrix. We did not examine the elasticity of the age class transition rates because these rates are affected by loss due to hunter drop-outs as well as the age distribution within each age class, which is unlikely to be affected by management actions.

Sensitivity analysis refers to the impact of absolute increases in vital rates on λ (Caswell 2001). We used sensitivity analysis to examine the impact on λ of recruiting a similar number of new hunters into older age classes as are currently recruited into the minor age class via hunter education efforts. We expressed the absolute number of males and females recruited into the minor age class by hunter recruitment annually as a percentage of the number of males and females currently in each of the older age classes in the ALS system. We examined the impact on λ that this proportional recruitment into each age class would have, while holding recruitment into all other age classes constant at zero, for both projection matrices described above.

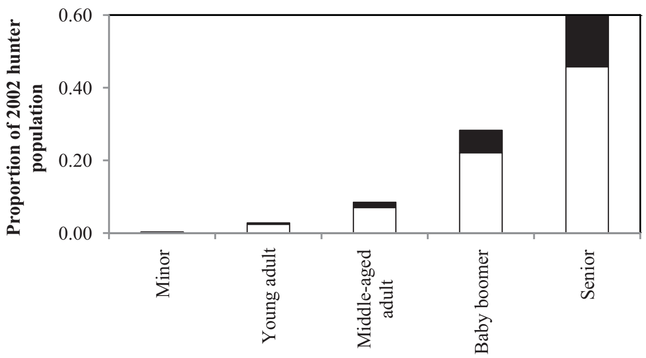

Figure 1. Population of deer and elk license holders in Montana in the Automated Licensing System (ALS) using license holder ages in 2002, the first year of data we considered. Females are the black portion of bars and males are the open portion of bars.

RESULTS

Trends in the Hunter Population

We estimated λ for Montana residents as 1.006 during 2002–2007. In 2002, 151,661 residents purchased at least 1 deer or elk hunting license, and in 2007, 157,729 residents purchased at least 1 deer or elk hunting license, representing a 4% increase during this 6 yr period. The number of residents purchasing at least 1 deer or elk hunting license increased every year from 2002 to 2007.

Hunter Retention and Recruitment Rates

The ALS database contained individual deer and elk license purchasing records of 248,819 Montana residents. The makeup of the deer and elk license holder population in the ALS database was heavily skewed toward males and older age classes (Fig. 1).

We included hunter age class, sex, and year as predictor variables in the final model selection analysis. The most parsimonious model based on AIC was by far the most parameterized model, with 140 estimated parameters (Table 1). This model represented the situation where hunter retention, license purchase probabilities, and age class transition rates were all influenced by age class, sex, and year.

Based on the most supported model, hunter retention rates were estimated precisely, as 43 of 50 estimated hunter retention rates were estimated with a coefficient of variation (CV) <1% (Fig. 2). Estimated hunter retention rates were greater for males than for females in general. For males, across all years and all age classes, 19 of 25 estimated hunter retention rates were >90% (Fig. 2). In contrast, 24 of 25 estimated hunter retention rates for females were <90% (Fig. 2). Variability among years and age classes, within sexes, was minor compared to the difference in estimated retention rates between sexes (Fig. 2).

License purchase probabilities were estimated precisely in the most supported model, with 38 of 50 estimated parameters having a CV <1% (Fig. 3). Estimated license purchase probabilities were greater for males than for females. Estimated license purchase probabilities were lesser for the young adult age class, for both males and females, than for the other age classes (Fig. 3). In this age class, 5 of 5 license purchase probability estimates for males were <90%, whereas outside of this age class, 14 of 20 license purchase probability estimates for males were >90% (Fig. 3). Similarly, in this age class 4 of 5 license purchase probability estimates for females were <80%, whereas outside of the young adult age class, 17 of 20 license purchase probability estimates for females were >80% (Fig. 3).

Transition rates were not as precisely estimated in the most supported model, and only 6 of 40 estimated transition rates had a CV <1% (Fig. 4). This is likely because of the paucity of age class transitions in our dataset. The minor, young adult, middle-aged adult, and baby boomer age classes span 7 yr, 12 yr, 12 yr, and 17 yr, respectively, and our dataset spans 6 yr. The potential for transition between age classes was therefore low in this analysis. Estimated age class transition rates were similar for males and females, except for the transition from minors to young adults, which was greater for males than for females (Fig. 4). The estimated transition rate from the baby boomer to the senior age class was also lesser than the estimated transition rates for the other age classes (Fig. 4).

On average, 1,301 females and 3,500 males under age 18 have graduated from MFWP hunter education courses

Table 1. Model selection results for a priori models of hunter retention, license purchase probability, and age class transition rates for Montana deer and elk hunters, 2002–2007.

Model[a,b]	ΔAIC[c]	w_i[d]	K[e]
{Phi(stage[f] + sex + time), *P*(stage + sex + time), Psi(stage + sex + time)}	0	1	140
{Phi(sex + stage), *P*(sex + stage), Psi(sex + stage)}	1,435	0	28
{Phi(sex + time), *P*(sex + time), Psi(sex + stage + time)}	5,746	0	60
{Phi(sex), *P*(sex), Psi(sex + stage)}	7,631	0	12
{Phi(stage + time), *P*(stage + time), Psi(stage + time)}	15,257	0	70
{Phi(stage + time), *P*(stage + time), Psi(stage + time)}	15,257	0	70
{Phi(stage), *P*(stage), Psi(stage)}	17,245	0	14

[a] Covariates evaluated included age class (stage), sex, and year (time).
[b] Phi refers to the hunter retention rate parameter, *P* refers to the license purchase probability parameter, and Psi refers to the age class transition probability parameter.
[c] Change in Akaike's Information Criterion (AIC) value from the top model. The AIC value for the top ranked model was 1,285,432.
[d] Akaike weights.
[e] No. of parameters.
[f] Age class was a categorical covariate that included classes for minors (12–18 yr old), young adults (19–30 yr old), middle-aged adults (31–42 yr old), baby boomers (43–59 yr old), and seniors (60+ yr old).

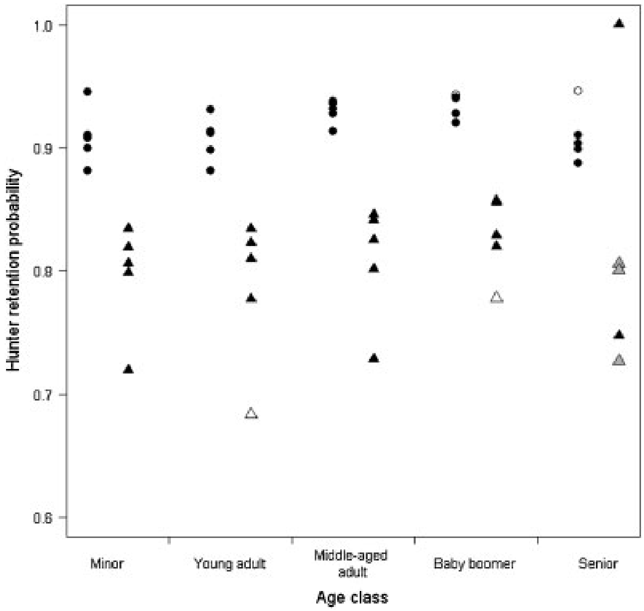

Figure 2. Estimated deer and elk hunter retention rates in Montana based on the most parsimonious model. Estimates for individual years (2002–2007) are plotted. Circles are estimated parameters for males, and triangles are estimated parameters for females. Within each age class, estimates for males and females are offset for visual clarity. Estimates with a coefficient of variation (CV; standard error divided by the estimate) less than 1% are solid, estimates with a CV between 1% and 5% are gray, and estimates with a CV greater than 5% are open.

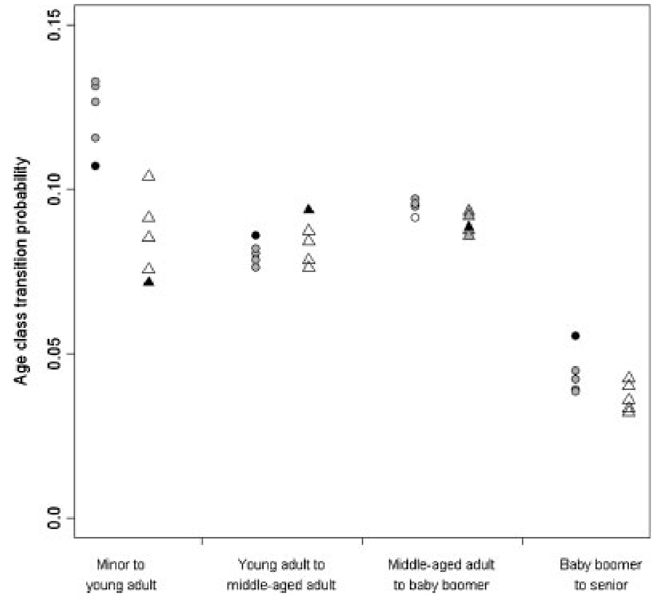

Figure 4. Estimated age class transition rates of deer and elk hunters in Montana based on the most parsimonious model. Estimates for individual years (2002–2007) are plotted. Circles are estimated parameters for males, and triangles are estimated parameters for females. Within each age class transition, estimates for males and females are offset for visual clarity. Estimates with a coefficient of variation (CV; standard error divided by the estimate) less than 1% are solid, estimates with a CV between 1% and 5% are gray, and estimates with a CV greater than 5% are open.

annually since 2001. By cross-referencing post-2002 data from the hunter education database with the ALS database, we found that 23% of the females and 14% of the males in the hunter education database did not purchase deer or elk hunting licenses in the ALS system. Adjusting for this loss, we estimated that the MFWP hunter education program graduates an average of 1,001 females and 3,019 males under age 18 that purchase at least 1 deer or elk hunting license annually. We estimated recruitment rates into the minor age class as 16.7% and 8.8% annually for females and males, respectively.

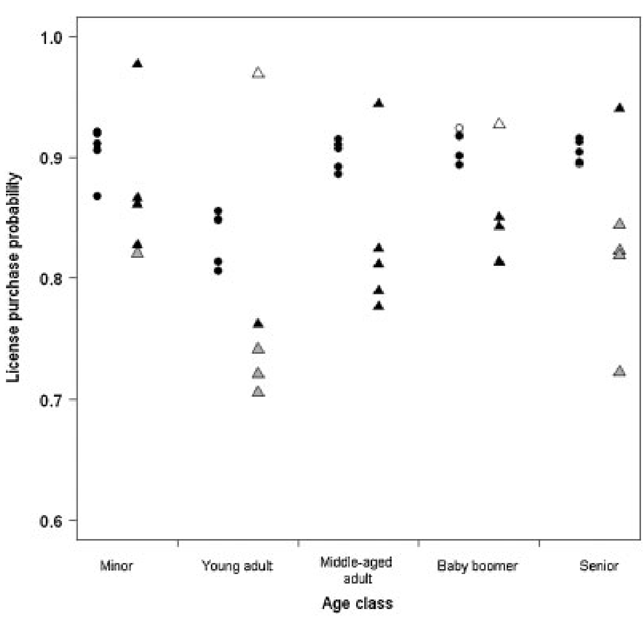

Figure 3. Estimated deer and elk license purchase probabilities in Montana based on the most parsimonious model. Estimates for individual years (2002–2007) are plotted. Circles are estimated parameters for males, and triangles are estimated parameters for females. Within each age class, estimates for males and females are offset for visual clarity. Estimates with a coefficient of variation (CV; standard error divided by the estimate) less than 1% are solid, estimates with a CV between 1% and 5% are gray, and estimates with a CV greater than 5% are open.

Perturbation Analyses

In no case did increasing any female hunter parameter result in a measurable expected change in λ for either license sales or hunter participation. Elasticity analyses of the license sales matrix model suggested that license sales are more influenced by male license purchase probabilities than male hunter retention in the middle-aged adult and baby-boomer age classes, more influenced by male hunter retention than male license purchase probability in the minor age class, and equally influenced by male hunter retention and male license purchase probability in the senior age class (Fig. 5). Increasing male recruitment into the minor age class by 10% had little effect on λ for license sales. Elasticity analyses of the license sales model suggested that male license purchase rates in the middle-aged adult and baby boomer age classes had the largest effects on λ for license sales (Fig. 5). In contrast, elasticity analysis of the hunter participation matrix suggested that increasing the male hunter retention rate by 10% in any age class would have roughly the same theoretical (i.e., asymptotic at the stable age distribution; Mills 2007) effect of a 5–6% increase in λ for hunter participation, including for the young adult age class.

To conduct sensitivity analyses, we estimated that 1,001 females and 3,019 males would represent increases of 6% and

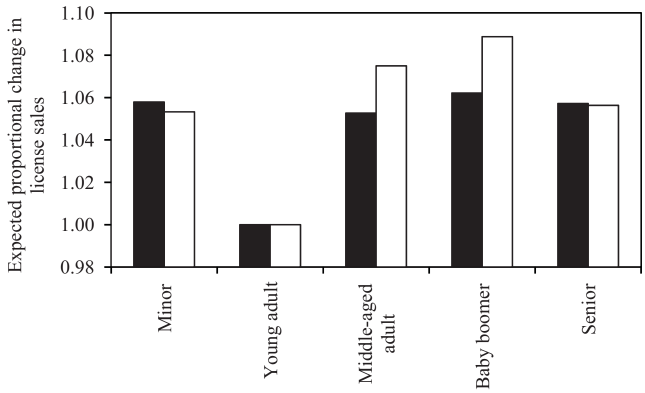

Figure 5. Expected proportional change in the annual growth rate, λ, for deer and elk license sales based on elasticity analyses of male hunter retention rates (black bars) and license purchase probabilities (open bars) in Montana, 2002–2007. We also considered recruitment into the minor age class in this elasticity analysis, but the expected effect on λ was too small to be represented on this figure.

5% to young adult females and males, 9% and 8% of middle-aged adult females and males, 8% and 7% of baby boomer females and males, and 12% and 13% of senior females and males. Assuming no recruitment into any age class except the minor age class resulted in a λ for hunter participation of 0.99, near stability. Adding the same number of females and males into older age classes as are recruited into the minor age class annually would result in larger effects on λ for both license sales and hunter participation (Table 2). In some cases, growth in hunter participation could be achieved solely by the addition of this number of females and males into a single older age class (Table 2). Adding females and males to the minor, middle-aged adult, baby boomer, and senior age classes would result in a roughly equivalent proportional increase in λ for license sales of approximately 7–12%, but adding females and males to the young adult age class would not result in a measurable increase in λ for license sales. Adding females and males to the middle-aged adult, baby boomer, and senior age classes would result in a roughly equivalent proportional increase in λ for hunter participation of 8–11%, whereas adding females and males to the minor and young adult age classes would results in smaller increases in λ for hunter participation of 6% and 2%, respectively.

DISCUSSION

Recent publications have pointed to declining trends in hunter participation at the nationwide level (Enck et al. 2000, Peterson 2004, U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau 2006) and in some states (e.g., Winkler et al. 2008). However, during 2002–2007, when dependable records of license sales were kept by MFWP, the number of resident hunters purchasing at least 1 deer or elk hunting license increased by 4% in 6 yr. Although United States Census Bureau estimates indicate that the Montana population grew by approximately 5% during this same period, this is a relatively small difference in growth in licensed hunters and the projected growth in the Montana population. Nevertheless, an increasing trend in licensed hunters provides a positive perspective. This result has positive implications for agency revenues and for the cultural importance of deer and elk hunting. This increasing trend in deer and elk hunter numbers may have been masked when considering data on license sales from prior to the implementation of the electronic point-of-sale license system in 2002. The early, paper-based system was prone to data collection and data entry error, producing replicate individual records and inflated figures on license sales that made inclusion into this analysis impossible. We therefore urge caution in use and interpretation of these sorts of data in other jurisdictions.

An increasing trend in license sales does not obviate concern over funding shortfalls in Montana in the future. The cost of doing business has increased because of inflation and market-driven commodity prices. For example, the cost of crude oil in the United States roughly tripled during 2004–2008. This has clear implications for wildlife conservation activities; the same wildlife survey activities were more expensive in 2008 as compared to 2004 if they relied on oil-based fuel. In addition to increasing costs, public demands for services on state wildlife agencies are broadening and increasing (Jacobson and Decker 2006, Jacobson et al. 2007).

We agree with Jacobson et al. (2010) and Regan (2010) that the funding base for state wildlife agencies must be expanded to include more constituencies than hunters and anglers, so as to broaden the base of support and increase the overall funding for wildlife conservation. Our analyses do not provide insight into this topic or how best to address this need.

Table 2. Sensitivity of deer and elk license sales and hunter participation to the addition of 1,001 females and 3,019 males (the average number of hunter education graduates recruited into the minor age class annually) to each age class in Montana. The base model refers to a model assuming no recruitment into any age class. λ refers to the annual rate of change expected with recruitment only into a particular age class, and Δλ refers to the expected proportional increase in λ, versus the base model, with the addition of individuals into each age class.

	License sales		Hunter participation	
	λ	Δλ	λ	Δλ
Base	0.851	—	0.935	—
Minor	0.913	1.074	0.991	1.060
Young adult	0.851	1.000	0.957	1.024
Middle-aged adult	0.918	1.079	1.010	1.081
Baby boomer	0.921	1.082	1.005	1.075
Senior	0.953	1.120	1.034	1.106

Relevant to our analyses, we also think it will remain necessary to ensure continuing, or even increasing, funding contributions from hunters and anglers to pay for the conservation of game species. Funding contributions from hunters and anglers have been focused on game and sport fish conservation for more than a century (McCabe 1931, Leopold 1932). These funding sources have been hugely successful at achieving conservation of game animals (Williams 2010) and enabling a scientific basis for wildlife conservation (White and Bishop 2010). We argue that continued funding directed at game species conservation will be necessary, so as not to risk a relapse to the funding shortfalls, and therefore stymied progress, in game conservation and wildlife science that existed prior to the inception of the current user-pay system (Mussehl and Howell 1971, Kallman 1987). Our results provide insights into the most effective ways to ensure continued or increasing funding contributions for conservation from deer and elk hunters in Montana.

Maintaining or increasing interest in deer and elk hunting is also important for maintaining a valuable public connection to wildlife. Approximately 75% of the Montana public can be characterized into value orientations that attach importance to traditional methods of interacting with wildlife, such as hunting and fishing (Teel and Manfredo 2010). Correspondingly, Montana has the lowest proportion of public that is disengaged from wildlife conservation values and issues in the west, followed closely by the other Rocky Mountain and northern prairie states that also have high proportions of traditional wildlife value orientations (Teel and Manfredo 2010). It is not surprising that deer and elk hunting are a central part of the culture in Montana (Eliason 2008). Given that traditional activities such as deer and elk hunting are the method by which a large portion of Montanans interact with wildlife, we believe it is important to maintain or enhance this base of public involvement and support for wildlife conservation. Our results provide insights into the most effective parameters to target in order to maintain the close tie between Montana deer and elk hunters and the wildlife they pursue through hunter recruitment and retention efforts.

Our analysis methods formally separated hunter retention from license purchase probabilities, thereby providing inferences concerning both hunter retention and license sales. Males had greater hunter retention rates and license purchase probabilities than females, in every age class (Figs. 2 and 3). In fact, Montana deer and elk hunter retention rates for males of every age class are on par with the highest survival rates for K-selected wildlife that depend on adult survival for long-term population persistence (Eberhardt 2002). This means that efforts aimed at increasing female hunter retention rates and license purchase probabilities would need to result in proportionally larger effects than the same sort of efforts directed at males, in order to bring the female parameters on par with male parameters. Correspondingly, perturbation analyses of matrix models representing both license sales and hunter participation indicated that increases in male parameters would theoretically have much larger effects on λ than increases in female parameters. Further, the ALS data set that we employed in this analysis is composed of 77% males (Fig. 1). This means that even smaller changes in male parameters would have larger absolute impacts on deer and elk hunter numbers than correspondingly larger changes in female parameters.

These results indicate that efforts designed to have the largest possible effect on deer and elk license sales and hunter participation in Montana should be focused on males. This does not mean that similar efforts should not be directed at females; there are many social, political, economic, and other reasons to have programs directed at female deer and elk hunters. For example, our results do not consider hunter associates that provide cultural and social support for hunting in ways other than purchasing hunting licenses (Enck et al. 2000). Our inferences do not have bearing on the need to retain the female segment of the hunter associate population. In this context, we believe that female hunters who hunt infrequently (or maybe never) may provide a strong voice for the future of hunting, not only through their individual participation but also by serving as role models, hunting advocates, and social support with a range of influences potentially larger than their male counterparts. Further, females are a growing segment of the national hunting population (U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau 2006). In Montana hunter education programs, female participation has grown from 20% in the 1990s to more than 30% today. Our quantitative results are contingent on observed patterns through 2007, and they may not be relevant if the female hunter population continues to grow to levels far above those observed in our data.

Interpretation of our estimated transition rates requires care because of the differing numbers of years in the various age classes. Transition rates between age classes are affected by dropout of deer and elk hunters between age classes, the number of years in the age classes, and the age structure of individuals within those age classes. With no hunter dropout between age classes and an even age structure within age classes, we should expect transition rates of 14%, 8%, 8%, and 6% for the minor to young adult, young adult to middle-aged adult, middle-aged adult to baby boomer, and baby boomer to senior age class transitions, respectively. Our estimated transition rates were lesser than expected in the minor to young adult and baby boomer to senior transitions (Fig. 4). Upon close examination of the age structure of hunters within age classes, the lesser than expected baby boomer to senior transition can be explained by an age structure that was biased toward more individuals in the early years of the baby boomer age class in our dataset. Based on the age structure of minors in our dataset, the lesser than expected minor to young adult transition rate stems at least partially from hunter dropout at this transition point. This transition may offer an opportunity to focus on youth hunter retention, though efforts focused on this parameter may not be productive for consistently increasing deer and elk hunter participation or license sales in Montana. Minors are prone to leave home for college or other life pursuits at age 18, which may not be affected by hunter retention programs. "Dispersal" of minors away from home as they become young adults may reduce the impact of traditional hunter recruitment tactics in Montana that are focused on youth under age 18. However, if these individuals are retained as hunters in their new states of residency, then the national hunter population may be affected. Due to the small portion of nationwide hunters that each state manages, hunter recruitment tactics that are focused on youth under age 18 would likely need to be coordinated nationally for effects to be noticeable.

Elasticity analyses of the license sales and hunter participation matrix models showed a key difference. Analyses of the license sales model suggested that increasing the male hunter retention rate or license purchase probability in the young adult age class resulted in limited impact on λ for license sales. Elasticity analyses of the hunter participation model indicated that increasing the young adult male retention rate would result in an increase in λ for hunter participation similar to that expected by increasing the hunter retention rate for males in any age class. The disparity is due to the special dynamics of the young adult age class. We estimated that this age class has a retention rate similar to the other male age classes (Fig. 2), but has a low comparative license purchase probability (Fig. 3). Males in this age group are likely to remain hunters; they are just not as likely to purchase a license as males in the other age categories. They contribute as much as other age classes to a hunter participation growth model, but not to a license sales growth model. This inference was only possible because of the quantitative separation of hunter retention rates and license purchase probabilities in our analyses.

A major limitation of inferences from our perturbation analyses stems from the focus on theoretical effects and analytical calculations. Analytical perturbation analyses are valid asymptotically at the stable age distribution, and they do not account for the range of possible or observed variation in vital rates (Mills 2007). Alternative approaches focus on the range of possible, real-world variation in vital rates, and the impact that management actions may have on those vital rates, to identify the most effective targets for population growth (Mills 2007). We are unaware of other studies that simultaneously quantify recruitment rates, retention rates, and license purchasing probabilities within a state jurisdiction, so the range of possible variation is not yet well established. We view the results of our perturbation analyses as entry points for consideration and development of strategies designed to affect license sales or hunter participation. Future work should confirm or revamp our conclusions. Our limited results indicate more among-year variation in retention rates and license purchase probabilities may exist for the minor and young adult age classes than the other age classes (Figs. 2 and 3). If retention rates and license purchase probabilities for these age classes are more plastic, they may in fact be the most appropriate targets at which to focus efforts (Mills 2007).

In contrast to the focus of most hunter recruitment programs on youth, our perturbation analysis results highlight the importance of the middle-aged and baby boomer male age classes for hunter participation and license sales. However, our choice of a 0.10 recruitment rate for older age classes was somewhat arbitrary because the actual rates are unknown and inestimable with our dataset. Our results may have been affected by this choice, and future work should focus on obtaining data-based estimates of these rates. Nevertheless, focus on recruitment, retention, and license purchase probabilities for middle-aged and baby boomer male age classes should have comparable or stronger effects on λ for deer and elk license sales and hunter participation in Montana, compared to other age–sex classes. The importance of these age classes for trends in deer and elk license sales and hunter participation in Montana may be due to characteristics of the baby boomer cohort rather than these age classes, which are partially comprised of baby boomer individuals. Several authors have hypothesized that the baby boomer cohort is critical to trends in hunter participation (e.g., Leonard 2007, Winkler et al. 2008). In our analysis, we only had 6 yr of license data available, whereas the age classes we considered ranged in length from 7 yr to 17 yr. We therefore observed relatively few transitions of individuals between age classes, as evidenced by the relative imprecision of the transition rate estimates from our most supported model (Fig. 4). Revisiting this analysis in the future, with more years of data, would allow us to estimate whether the characteristics of middle-aged and baby boomer individuals shift as they enter new age classes, or remain consistent with the cohort that individuals were born into.

MANAGEMENT IMPLICATIONS

Our results have three major management implications. First, we highlight the importance of a recruitment and retention program focus on males age 31 and older, to have the largest possible positive effects on λ for deer and elk license sales and hunter participation in Montana. Currently, most hunter recruitment efforts in Montana, as in other states, are focused on youth, and refocusing on older age classes would be a break from this paradigm. Second, our results highlight the importance of license purchasing habits of middle-aged adult and baby boomer males to trends in license sales. Efforts directed at identifying individuals or classes of deer and elk license holders that will not purchase licenses in the future, identifying the reasons why, and taking action to increase the probability they will purchase a license annually might result in increases in license sales. Several statistical machine-learning and data-mining tools are available to accurately predict these individuals in the extremely large and complex licensing databases (e.g., Hastie et al. 2003). Lastly, our analysis methodology and the point-of-sale license data we used could serve as the foundation for more effective modeling, monitoring, and evaluation of hunter recruitment and retention programs. Few agencies evaluate the effectiveness of hunter recruitment and retention efforts, and our work provides an example of how agencies might track the effectiveness of these programs. Replication of these analyses in other states would also offer the potential to compare the details of deer and elk hunter populations, and perhaps the degree to which similar methods designed to increase license sales or hunter participation might work in multiple jurisdictions.

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