IDAHO DEPARTMENT OF FISH AND GAME

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Progress Report

MODELING ELK & DEER POPULATION DYNAMICS IN IDAHO

July 1, 2003 to June 30, 2004

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PROGRESS REPORT
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MODELING ELK AND DEER POPULATION DYNAMICS IN IDAHO

Abstract

Elk and deer populations continue to exhibit large-scale changes in Idaho and throughout the western states. The preliminary results presented here are part of a larger study initiated to study the effects of competition and other factors on the dynamics of elk, mule deer, and white-tailed deer populations to predict population responses to inter- and intra-specific factors. This study is based on empirical long-term, spatial, and temporal datasets constructed from the Idaho Department of Fish and Game's (IDFG) population estimates for elk and mule deer. We are currently evaluating the efficacy of using harvest metrics and other landscape variables to predict sightability estimates and, thus bridge the gaps in the aerial survey dataset, thereby providing a long-term, spatial, and temporal dynamic dataset that can be used to study population responses to various factors, including effects of competition.

Introduction

Elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*O. virginianus*) populations extensively overlap throughout western North America. In Idaho and throughout the western states, their populations are experiencing large-scale changes (Unsworth et al. 1995), and numerous intrinsic and extrinsic factors can influence such population fluctuations. Our overall objective is to estimate competitive effects among these three species, examine the influence of intrinsic and extrinsic factors on competition, and to use this information to predict population responses to changes in these factors across their ranges in Idaho.

This study is based on empirical long-term, spatial, and temporal datasets. But, such datasets are often not available and inherently have gaps. IDFG has conducted aerial surveys for elk and mule deer over the past two decades that provide relatively accurate population estimates. However, logistics and budgets constrain surveys to only a sample of GMUs each year. Consequently, these datasets are incomplete, making population analyses difficult.

To achieve our objectives, we first have to bridge gaps in the aerial survey datasets. Hunter harvest data are an important and long-term source of information, and they are often used to monitor populations or sub-populations. For example, Roseberry and Woolf (1991:50) concluded that "trends in abundance, harvest, and effort might be indicative of a population's probable position on the growth curve." Here, we present preliminary results of employing mixed models to evaluate the efficacy of using hunter harvest to predict IDFG's aerial survey estimates. Predicted estimates are intended to bridge gaps in the aerial survey data, thereby providing long-term dynamic datasets for elk and mule deer.

Study Area

These preliminary analyses were performed on data collected in IDFG's Salmon Region, located in east-central Idaho. This area is divided into 12 Game Management Units (GMU) (Figure 1); encompasses 218,478 ha; ranges in elevation from 870 to 3,797 m; contains forest, shrub, and grassland vegetation; and supports livestock grazing, timber harvest, agriculture, and recreation.

Methods

Data

We obtained existing datasets of annual elk and mule deer hunter harvest levels (1981-2002) and aerial survey estimates (1992-2002) from IDFG. For these preliminary analyses, we used data recorded between 1992 and 2002. These data were collected at the resolution of GMUs, which represented sampling units. Harvest data, recorded via telephone surveys or mandatory reporting procedures during this same period, provided annual numbers of hunters, hunting days, and harvested males and females for each species during the general any-weapon hunting season. From these harvest metrics, four direct indices of harvest per unit effort were computed and used as predictors of population size (Table 1). Direct indices of harvest per unit effort assume that the harvest (e.g., number of harvested animals) per unit effort (e.g., number of hours hunted) is a function of the population size, and is a suitable index to the latter (Roseberry and Woolf 1991).

Estimates of annual elk and deer population sizes were collected during mid-winter (January-February) aerial surveys between 1992 and 2002 (Unsworth et al. 2002, IDFG 2003) and are unbiased estimates of actual population size and composition (Samuel et al. 1987). We used area (ha) of winter range in each GMU to standardize population size as a density per ha of winter range and considered density the response variable. This was intended to avoid biased low estimates that could occur if we used the area of GMUs. This is because GMU boundaries encompass summer, winter, transitional, and unsuitable habitats, and elk and deer are generally restricted to winter ranges during sightability counts. Furthermore, GMU boundaries may not correspond to population demography or spatial patterns exhibited by these large ungulates (Svancara et al. 2002). Area of winter range was computed by intersecting a polygon theme of GMUs with digitized boundaries of static winter ranges for mule deer (unpubl. data, Dr. Todd Black, Utah State University, Logan), and elk (Rocky Mountain Elk Foundation 1999). These winter ranges were digitized from 1:250,000 scale relief maps and are, therefore, appropriate for analyzing population-level responses across large spatial extents, such as those in this study.

Annual snow accumulation (cm) was also estimated in each GMU and used as a potential predictor of population size. It was estimated by randomly selecting 30 twelve km^2 plots across each GMU and obtaining daily estimates of precipitation (cm) and temperature (C) obtained from the DAYMET U.S. Data Center (http://www.daymet.org/) over the ten-year study period.

Specifically, annual snow accumulation was computed by summing the total amount of precipitation (cm) that fell on days that had a minimum temperature <0 C. Snow levels are believed to influence survival (Hepburn 1959, Verme and Ozoga 1971), density (Coughenour 1994), and harvest success (Mark Hurley, pers. comm.) of elk and deer and were, therefore, assumed to be important in relationships between harvest and population size.

Predictive model

For each species, we used harvest per unit effort and annual snow accumulation variables (Table 1) to develop ten mixed-effects regression models (Table 2), each representing a competing hypothesis, to predict sightability estimates of winter population densities. Sample sizes of harvest per unit effort were 84 and 50 for elk and mule deer, respectively. However, the size of sightability samples for elk (n = 12) and mule deer (n = 15) were small and necessitated pooling all years and GMUs in each model for each species. To avoid over-parameterized models, our models contained one or two parameters, had a single intercept for all GMUs, and did not test for the influence of year on variation of population density. Because GMUs were not identified as a factor in this design, we did not control for or test their effects as we will in the full analysis in the future. Hence, they represented environmental noise or random effects. For each set of models, we used Akaike's Information Criterion (AIC) (Akaike 1973) to evaluate their relative fit to the data and chose the model with the smallest AIC-value as the 'best' model.

We used a plot of innermost fitted values against observed responses to evaluate the explanatory power of the best model. We checked for normality of innermost residuals with a plot of innermost fitted values against the innermost (conditional) residuals. A qq-plot of the estimated random effects was developed to determine if effects of GMUs were normally distributed, and a box-plot of the innermost residuals by grouping variables was used to evaluate homoscedasticity of residuals. We used the intra-class correlation (ICC) value to describe the amount of variation among levels of the random effects (GMUs) explained by the best model. Since GMUs have a spatial context, the ICC computed from these models can be used as a measure of spatial autocorrelation. All statistical analyses and evaluations of model assumptions were performed with program R (Venables et al. 2003).

To bridge gaps in the datasets of aerial survey estimates, we predicted densities from the coefficients associated with the variable(s) representing harvest per unit effort and/or snow accumulation that were deemed important in the best model. Graphs of observed and predicted sightability estimates of winter densities were used to heuristically assess how well the predicted corresponded to the observed densities. Scope of inference and predictions are currently restricted to this study area, time period, and preliminary analyses.

Results and Discussion

There were four competing models (ΔAIC <2.0) that explained variation in winter density of elk (Table 2). Because each competing model contained a single and unique predictor of harvest per unit effort, and harvest metrics are typically correlated, it is plausible that any single harvest metric (i.e., model) may be appropriate to predict winter densities of elk. In order to construct a regression equation to predict densities, we chose the model with the smallest ΔAIC, which hypothesized density as a function of harvested males per hunter (Table 2). The ICC-value suggested that 30% of the variation differed among the GMUs and 70% within, thus indicating an absence of spatial autocorrelation. Further diagnostics indicated that this model met assumptions. The model equation:

$$\text{Winter elk density} = 3.67 + 0.23 * \text{harvested males per hunter}$$

predicted winter densities that were from 2-47% of observed sightability densities (Figure 2).

The best model that explained winter densities of mule deer suggested it to be an additive function of harvest per day and snow accumulation (Table 2). A second model hypothesizing mule deer density as a function of harvest of males per hunter and snow accumulation was also competing, but we considered the former model because it had the smallest ΔAIC. The ICC-value suggested that 95% of the variation differed among the GMUs and 15% within, suggesting that data were spatially auto-correlated. This spatial autocorrelation may be due to the small sample sizes and will be explored. Further diagnostics indicated that this model met assumptions. The model equation:

$$\text{Winter mule deer density} = 1.13 + 0.09 * \text{harvest per day} - 0.01 * \text{snow accumulation}$$

predicted winter densities that were from 1-80% of observed sightability densities (Figure 3). The predictions that were 80% off from observed aerial survey densities were in GMU 29 and are likely due to the spatial autocorrelation among GMUs that was not accounted for in these models. The average discrepancy between predicted and observed population estimates was 16%, and we anticipate it will improve with larger sample sizes and more complex models.

Modeling these relationships will continue through fall 2004. We developed simple mixed-effects regression models in this preliminary analysis because datasets were small. We intend to construct more complex mixed-effects and deterministic models once we have acquired a complete dataset. Future analyses into predicting sightability estimates will explore alternative criteria of grouping GMUs that incorporate time series methods, obtain estimates of confidence intervals for predicted lines, and use additional landscape metrics, such as road densities, vegetation type, ruggedness, etc. as categorical grouping variables as a means to groups GMUs.

Management Implications

A statistical model that predicts the effects of intrinsic and extrinsic factors on population growth rates of elk and deer will give wildlife managers the ability to predict the consequences of management decisions such as habitat alterations, harvest seasons, wolf introductions, and predator control, while considering the influence of competition. Using this model, managers will have the capability of predicting the outcome of various management scenarios within a given GMU prior to implementing a management activity. Such scientific information will foster a better understanding of wolf-big game relationships and aid in the effective management and conservation of elk, deer, and wolves.

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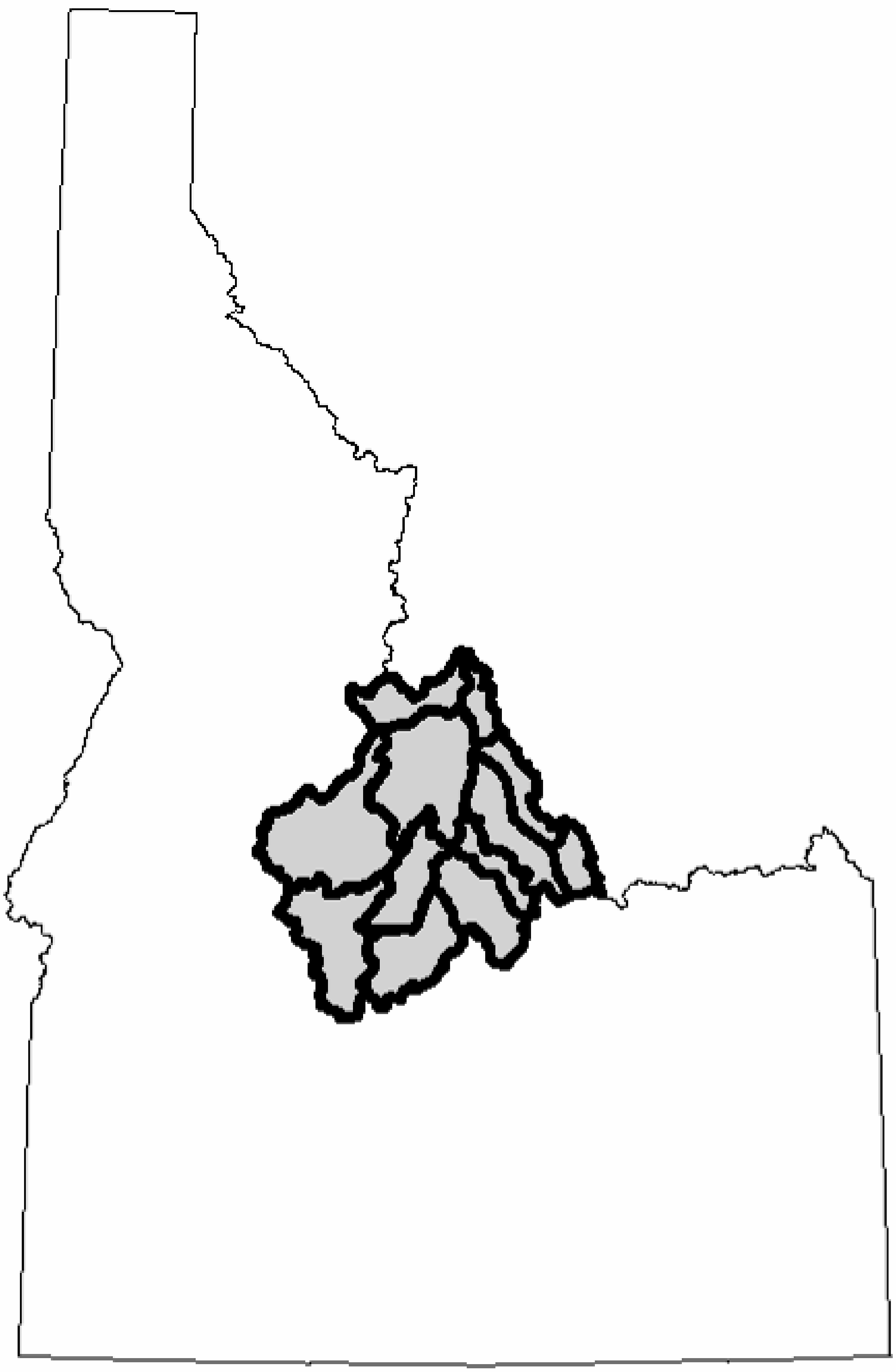


Figure 1. Study area.

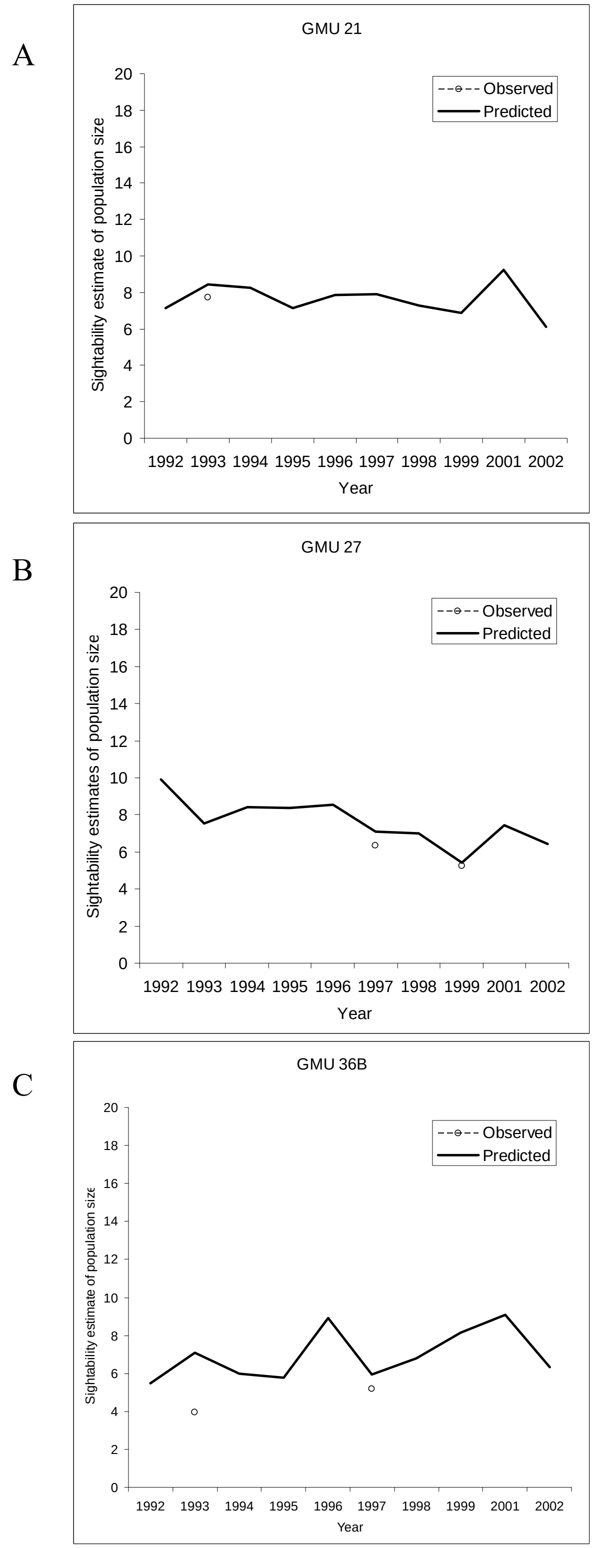
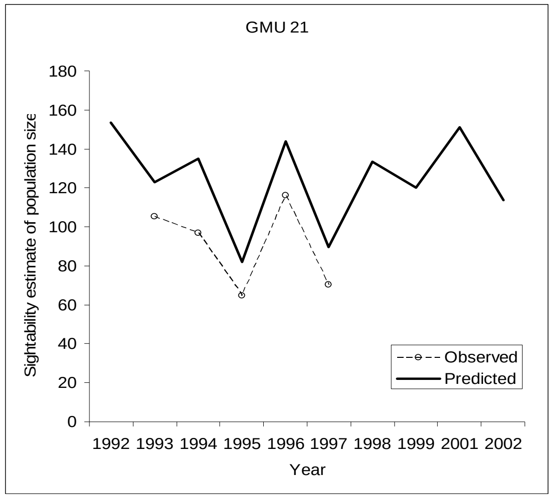


Figure 2. Predicted and observed winter population densities of elk in GMUs 21 (A), 27 (B), and 36B (C), Idaho.

A



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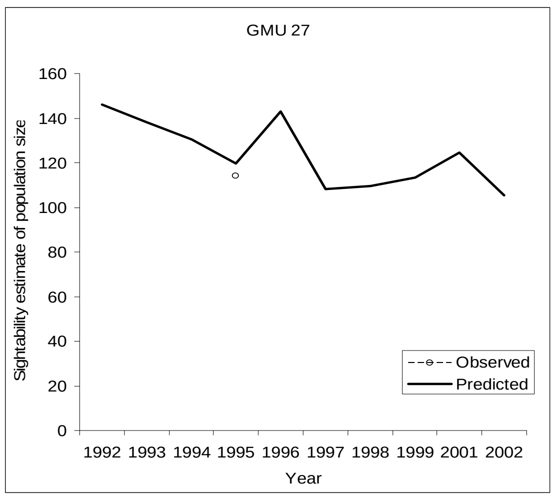

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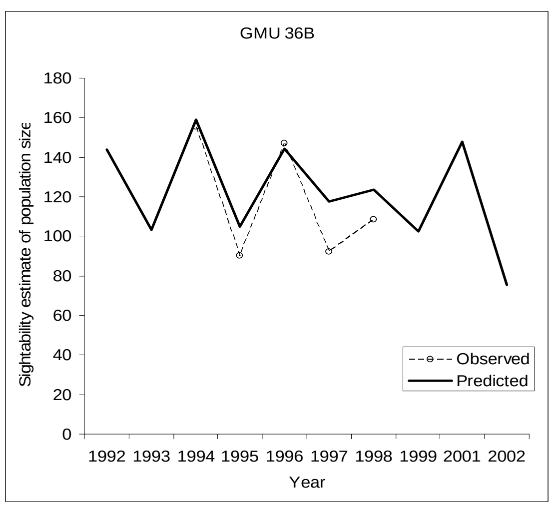

Figure 3. Predicted and observed winter population densities of mule deer in GMUs 21 (A), 27 (B), 36B (C), Idaho.

Table 1. Variables used for constructing mixed-effect regression models.

Variable	Type	Description[a]
Winter density	Continuous (response)	Estimated annual population size computed from midwinter aerial surveys divided by the area (ha) of winter range[b].
Harvest per hunter	Continuous (predictor)	Total male and female harvest during general harvest season divided by number of hunting licenses.
Harvest per hunter day	Continuous (predictor)	Total male and female harvest during general harvest season divided by number of hunter days.
Harvested males per hunter	Continuous (predictor)	Total male harvest during general harvest season divided by number of hunting licenses.
Harvested males per hunter day	Continuous (predictor)	Total male harvest during general harvest season divided by number of hunter days.
Snow accumulation	Continuous (predictor)	Average annual accumulation of daily snowfall (cm) across 30 random points.
GMU	Categorical (predictor)	IDFG game management unit.

[a] All variables were measured for each GMU.

[b] Mule deer (unpubl. Data, Dr. Todd Black at Utah State University, Logan); elk (Rocky Mountain Elk Foundation 1999).

Table 2. Mixed-effect regression models developed to predict aerial survey population estimates of elk and mule deer from hunter harvest and snow accumulation in East-central Idaho.

Model	d.f.	ΔAIC
Elk		
Density = harvested males per hunter + random effects	4	0.00
Density = harvest per hunter + random effects	4	0.49
Density = harvested males per hunter day + random effects	4	0.57
Density = harvest per hunter day + random effects	4	1.00
Density = harvested males per hunter + snow accum. + random effects	5	2.00
Density = harvest per hunter + snow accum. + random effects	5	2.48
Density = harvested males per hunter day + snow accum. + random effects	5	2.57
Density = snow accum. + random effects	4	2.75
Density = harvest per day + snow accum. + random effects	5	2.99
Mule deer		
Density = harvest per day + snow accum. + random effects	5	0.00
Density = harvested males per hunter day + snow accum. + random effects	5	1.56
Density = harvested males per hunter day + random effects	4	4.59
Density = harvest per hunter + snow accum. + random effects	5	4.69
Density = harvest per hunter day + random effects	4	5.19
Density = harvested males per hunter + snow accum. + random effects	5	6.12
Density = harvested males per hunter + random effects	4	6.80
Density = harvest per hunter + random effects	4	6.84
Density = snow accum. + random effects	4	12.23

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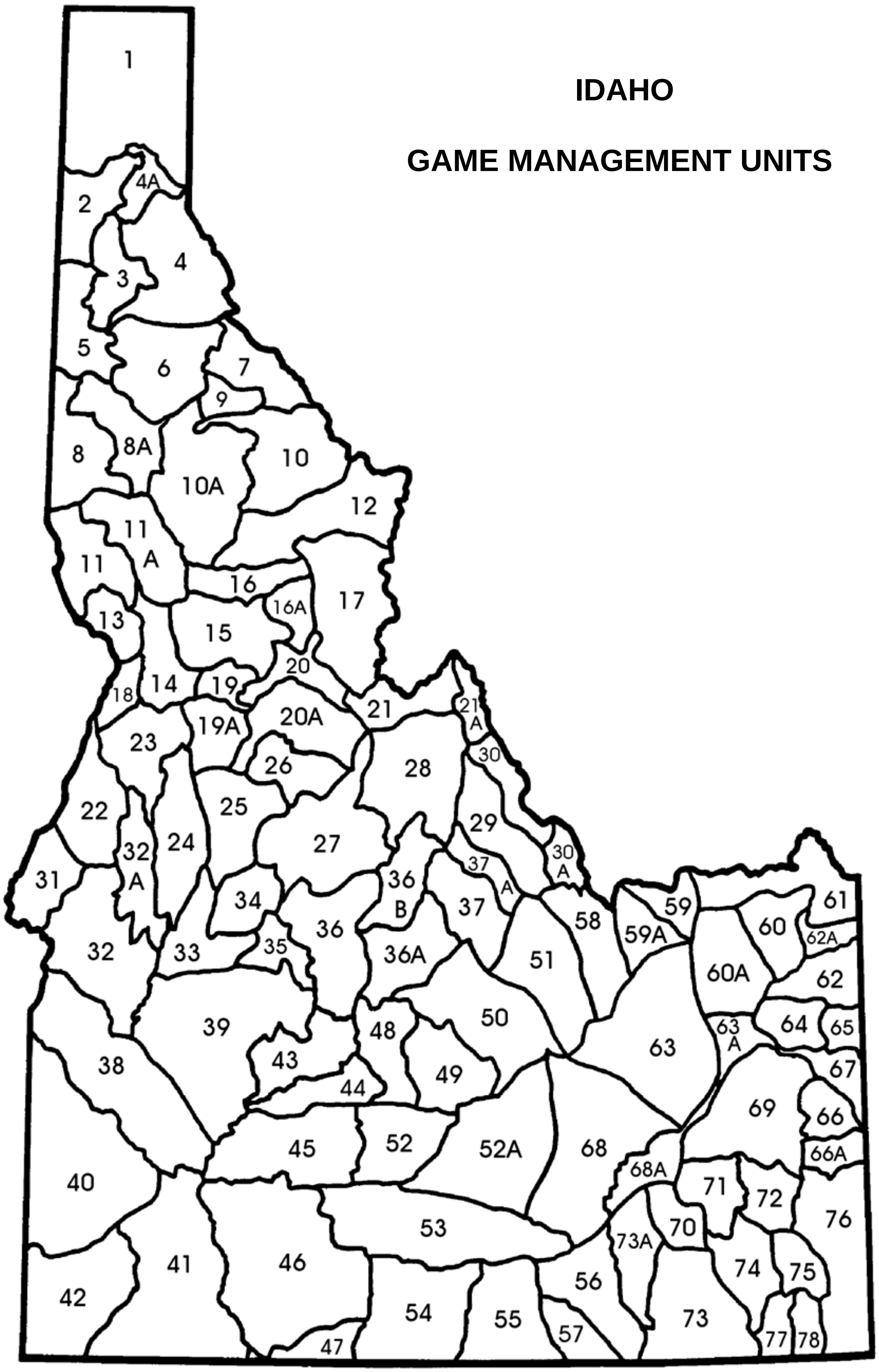
GAME MANAGEMENT UNITS



FEDERAL AID IN WILDLIFE RESTORATION

The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sale of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program then allots the funds back to states through a formula based on each state's geographic area and the number of paid hunting license holders in the state. The Idaho Department of Fish and Game uses the funds to help restore, conserve, manage, and enhance wild birds and mammals for the public benefit. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes necessary to be responsible, ethical hunters. Seventy-five percent of the funds for this project are from Federal Aid. The other 25% comes from license-generated funds.