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Linking resource selection and mortality modeling for population estimation of mountain lions in Montana

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ABSTRACT

To be most effective, the scale of wildlife management practices should match the range of a particular species' movements. For this reason, combined with our inability to rigorously or regularly census mountain lion populations, several authors have suggested that mountain lions be managed in a source-sink or metapopulation framework. We used a combination of resource selection functions, mortality estimation, and dispersal modeling to estimate cougar population levels in Montana statewide and potential population level effects of planned harvest levels. Between 1980 and 2012, 236 independent mountain lions were collared and monitored for research in Montana. From these data we used 18,695 GPS locations collected during winter from 85 animals to develop a resource selection function (RSF), and 11,726 VHF and GPS locations from 142 animals along with the locations of 6343 mountain lions harvested from 1988–2011 to validate the RSF model. Our RSF model validated well in all portions of the State, although it appeared to perform better in Montana Fish, Wildlife and Parks (MFWP) Regions 1, 2, 4 and 6, than in Regions 3, 5, and 7. Our mean RSF based population estimate for the total population (kittens, juveniles, and adults) of mountain lions in Montana in 2005 was 3926, with almost 25% of the entire population in MFWP Region 1. Estimates based on a high and low reference population estimates produce a possible range of 2784 to 5156 mountain lions statewide. Based on a range of possible survival rates we estimated the mountain lion population in Montana to be stable to slightly increasing between 2005 and 2010 with lambda ranging from 0.999 (SD = 0.05) to 1.02 (SD = 0.03). We believe these population growth rates to be a conservative estimate of true population growth. Our model suggests that proposed changes to female harvest quotas for 2013–2015 will result in an annual statewide population decline of 3% and shows that, due to reduced dispersal, changes to harvest in one management unit may affect population growth in neighboring units where smaller or even no changes were made. Uncertainty regarding dispersal levels and initial population density may have a significant effect on predictions at a management unit scale (i.e. 2000 km^2), while at a regional scale (i.e. 50,000 km^2) large differences in initial population density result in relatively small changes in population growth rate, and uncertainty about dispersal may not be as influential. Doubling the presumed initial density from a low estimation of 2.19 total animals per 100 km^2 resulted in a difference in annual population growth rate of only 2.6% statewide when

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compared to high density of 4.04 total animals per 100 km^2 (low initial population estimate λ = 0.99, while high initial population estimate λ = 1.03). We suggest modeling tools such as this may be useful in harvest planning at a regional and statewide level.

1. Introduction

In North America, the mountain lion (*Puma concolor*) is hunted throughout much of its range. Wildlife managers generally apply 1 of 3 models in the harvest of mountain lions: general season (unlimited numbers of either sex may be harvested), limited entry (harvest is limited by restricting the number of licenses sold), and quota system (harvest is limited by season closure once a prescribed number of animals are taken). A fourth "zone management" (Logan and Sweanor, 2001) or "metapopulation" model (Laundre and Clark, 2003) has been proposed but has seen limited application to date. These harvest strategies are thought to reduce the risk of overharvest by ensuring a sustainable loss of the total population (limited entry), reduction of female mortality (quota system), or preservation of source populations that sustain hunted areas (metapopulation model).

To be effective in conserving mountain lion populations, both the limited entry and quota systems require managers have some knowledge of the true mountain lion population level or its possible range. Overestimation of total population, and therefore quotas or tags issued, can quickly lead to overkill and a rapidly declining population (Lambert et al., 2006). Conversely, underestimation of the true population may lead to unnecessary limitations of public recreational opportunities. To date, no accurate method exists to broadly estimate mountain lion populations (Choate et al., 2006). Intensive collaring programs have been employed to estimate density; however these techniques are labor intensive, costly, and impractical for estimation of populations at broad geographic scales. As a result, most jurisdictions rely on hunter effort and harvest trends, expert opinion, hunter testimony, or other indices to determine population and harvest levels (Anderson and Lindzey, 2005; McBride et al., 2008). The metapopulation model requires no estimation of population level, but does require knowledge of immigration rates between hunted and unhunted areas, with the number of new emigrants representing the sustainable harvest (Cougar Management Guidelines Working Group, 2005). Few studies have rigorously estimated immigration rates between hunted and unhunted areas however, and as a result the efficacy of the metapopulation model approach to harvest remains untested.

In Montana a combination of limited entry and quotas are used by the Montana Fish Wildlife and Parks (MFWP) to allow recreational opportunities for the public, while maintaining viable mountain lion populations, thus creating a need for accurate and defensible population estimates. MFWP has proposed basing population estimates on mean densities from past research, extrapolated to forested areas in the western portion of the state. This method seems preferable to relying simply on opinion or public perception, which can run contrary to true density or trend (Freddy et al., 2004; Lambert et al., 2006). However, it does not take into account the variation in populations caused by resource availability, local mortality factors, and levels of immigration and emigration, which may ultimately control mountain lion density (Cooley et al., 2009b; Robinson et al., 2014).

Like most long lived vertebrate species, mountain lion population growth is sensitive to changes in adult female survival, and harvest-induced mortality of adult females is additive (Cooley et al., 2011; Robinson et al., 2014). The effect of any harvest program is dependent on its resultant mortality rate (i.e. animals harvested/animals available), yet the size of most lion populations is unknown. In fact, after more than 40 years of research, a method to estimate the size or trend of lion populations is still the most pressing research need for mountain lion management (McKinney, 2011). Mountain lion densities observed in field-based census projects, where researchers have tried to capture or otherwise account for every individual, have tended to range from approximately 1 to 2 adults and/or 2 to 4 total animals per 100 km^2 (Quigley and Hornocker, 2010).

Both male and female juvenile cougars are capable of long distance dispersals (Stoner et al., 2008; Elbroch et al., 2009), with noteworthy accounts of individuals traveling >1000 km (Thompson and Jenks, 2005; Abhat, 2011). In Montana, mean male and female dispersal distances were recently found to be 43 km and 24 km, respectively (Newby, 2011). Cooley et al. (2009b) showed that dispersal may have a dampening effect on population change induced by harvest; reducing population growth in lightly hunted areas through emigration, and increasing population growth in heavily hunted areas do to immigration. While harvest can induce source-sink dynamics by altering local demographic rates (Dias, 1996; Novaro et al., 2005; Andreasen et al., 2012), the innate ability of mountain lions to disperse long distances may frustrate management goals of population reduction, may lead to unexpected impacts of harvest in neighboring management units, or even provide a level of cushion or margin of error causing population growth in a particular area to tend toward 1.0 regardless of management programs.

While survival and dispersal are known to have large effects on mountain lion populations, much uncertainty remains about their effects in a harvest management context. The functional form of dispersal effects on mountain lion populations is not entirely clear and as such has been largely ignored in harvest planning. Whether connectivity among management units is best modeled as a function of distance or needs to include a measure of habitat quality (i.e. ecological distance or friction) is unclear in a population modeling context, let alone in a harvest management context. Most mountain lion harvest strategies do not directly account for dispersal among management units.

Here we use a combination of resource selection functions (RSFs), mortality estimation, and dispersal modeling to develop a cougar metapopulation model for Montana. This model incorporates available data, our current state of knowledge regarding mountain lion habitat selection and population dynamics, and explicitly considers major uncertainties including unknown population sizes and various possible functional forms of dispersal among management units (including no dispersal). We demonstrate how predictions from this model might be used to inform decisions about harvest management programs by predicting the effects of lion hunting regulations implemented in Montana.

2. Materials and methods

2.1. Study area

Our study area was the state of Montana (381,154 km^2), the 4th largest and 3rd least populated state (behind only Wyoming and Alaska) in the USA. The state is bisected by the continental divide, approximately 1/3rd of the way across the state from the western