Journal of Environmental Management 218 (2018) 103–117

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Economic analysis of threatened species conservation: The case of woodland caribou and oilsands development in Alberta, Canada

Grant Hauer [a,*], W.L. (Vic) Adamowicz [a], Stan Boutin [b]

[a] Resource Economics and Environmental Sociology, University of Alberta, Canada
[b] Biological Sciences, University of Alberta, Canada

A R T I C L E I N F O

Article history:
Received 23 January 2017
Received in revised form
9 March 2018
Accepted 10 March 2018

Keywords:
Economics
Conservation planning
Woodland caribou
Species at risk
Dynamic mathematical modelling
Cost curve for threatened species recovery

A B S T R A C T

Tradeoffs between cost and recovery targets for boreal caribou herds, threatened species in Alberta, Canada, are examined using a dynamic cost minimization model. Unlike most approaches used for minimizing costs of achieving threatened species targets, we incorporate opportunity costs of surface (forests) and subsurface resources (energy) as well as direct costs of conservation (habitat restoration and direct predator control), into a forward looking model of species protection. Opportunity costs of conservation over time are minimized with an explicit target date for meeting species recovery targets; defined as the number of self-sustaining caribou herds, which requires that both habitat and population targets are met by a set date. The model was run under various scenarios including three species recovery criteria, two oil and gas price regimes, and targets for the number of herds to recover from 1 to 12. The derived cost curve follows a typical pattern as costs of recovery per herd increase as the number of herds targeted for recovery increases. The results also show that the opportunity costs for direct predator control are small compared to habitat restoration and protection costs. However, direct predator control is essential for meeting caribou population targets and reducing the risk of extirpation while habitat is recovered over time.

1. Introduction

Woodland caribou are listed as a threatened species in Canada and Alberta and almost all herds are well below self-sustaining growth rates (Environment Canada, 2011; Festa-Bianchet et al., 2011; Hervieux et al., 2013). Actions to protect caribou are challenging because of the potential for significant impact on economic sectors and the long term nature of the problem. Caribou are a low population density species that rely on old forest habitats. Caribou populations have been increasingly preyed upon by wolf species because of recent increases in deer and moose populations within the caribou ranges in Alberta (Latham et al., 2011b; Dawe et al., 2014). This has occurred for several reasons. Young forest area has increased (decrease in old forest) because of large fires and increased forest harvesting (Sorensen et al., 2008). Increased energy industry activity over the last 30 years in Alberta has led to the creation of linear corridors associated with roads, pipelines and seismic lines, which has in turn led to increased access by wolves and thus higher rates of wolf predation (Schneider et al., 2010; Latham et al. 2011a, 2013; Boutin et al., 2012). Finally, changing climatic conditions also appear to have generated increased threats to caribou through the arrival of deer and predators (Schneider et al., 2011; Dawe et al., 2014).

Caribou recovery strategies typically include the following management actions aimed at reducing wolf predation either indirectly by: (1) creating or retaining mature habitat for caribou by limiting industrial activities in areas occupied by caribou; (2) reducing linear features through forest restoration; or directly by (3) directly reducing wolf populations (and in some cases reducing alternate prey for wolves) (Hervieux et al., 2014; Environment Canada, 2011). Each of the proposed management actions has widely variable direct and/or indirect opportunity costs. Indirect opportunity costs arise from policies that restrict or defer development of high value energy resource areas that would otherwise be developed in the near future. In contrast, reducing wolf population through hunting is a direct cost that is relatively inexpensive but may have high political costs (Hervieux et al., 2014).

In 2003 boreal woodland caribou were listed as a threatened species under Canada's Species at Risk Act. The act requires that

* Corresponding author.
E-mail address: ghauer@ualberta.ca (G. Hauer).

https://doi.org/10.1016/j.jenvman.2018.03.039
0301-4797/

species listed as either threatened or endangered must have a recovery plan that will ensure that the listed species will be restored to a naturally self-sustaining population. A proposed federal recovery plan was provided in 2011. In Alberta responsibility for developing the recovery plan lay with the Fish and Wildlife division of the Alberta Department of Sustainable Development. A caribou recovery plan document for Alberta was completed in 2004.

The specific case of woodland caribou leads us to incorporate considerations in this paper beyond those normally examined in the literature on cost effective conservation. First, the population is characterized by several spatially distinct units (herds). Defining what recovery means in this context is challenging. Effort could be placed into guaranteeing that selected herds reach a self-sustaining level, or effort could be spread across the herds to increase the chances that all the herds are self-sustaining. Does "recovery" in this context mean that all herds exceed some threshold level of self-sustaining status, or does it mean that some number of herds achieve this status? The number of herds we require to attain self-sustaining status will affect cost estimates. There may also be tradeoffs between the number of self-sustaining units, their locations, and the confidence that self-sustaining status of the species (rather than the herd) has been achieved. In the Alberta, the policy goals as stated in the Woodland Caribou Recovery Plan (2005) makes this tradeoff in the direction of conserving all herds. Yet caribou populations in most herds have continued to decline. Also, absent from the recovery plan is discussion of the time frame over which caribou should be recovered. Timing is important for caribou because delaying recovery actions increases risk of extirpation and for cost because earlier recovery actions result in higher costs than deferred actions. In this paper, we construct a curve that estimates the costs of fully recovering given numbers of caribou herds by a specific target date, from one herd to all herds.

1.1. Modelling approach

The conservation planning literature contains analyses of the opportunity costs of achieving varying levels of conservation effectiveness (species survival probabilities, maintenance of biodiversity), implicitly defining least-cost conservation strategies (Naidoo et al., 2006). Static analyses (i.e., no time element) that minimize costs of achieving habitat targets are common in the conservation biology literature (e.g. applications of Marxan; Game and Granthan, 2008) while approaches that incorporate the dynamics of species populations and/or underlying habitats (e.g. forest dynamics) are more common in the economics literature and emerging conservation literature (e.g. Nalle et al., 2004; Polasky et al., 2005; Montgomery et al., 1999; Hauer et al., 2010a,b). In most cases the land use activities examined are based on private lands and include agriculture or forestry activities. Most dynamic analyses assess the tradeoff between economic outcomes and species populations (e.g. Nalle et al., 2004) or metrics of species or conservation outcomes (e.g. Polasky et al., 2008). In this paper we focus on the tradeoffs associated with recovery programs for boreal caribou (*Rangifer tarandus caribou)* in Alberta, Canada. The least cost approach to achieve endangered species recovery, or implicitly the opportunity cost of alternate levels of recovery, provides important information for recovery planning.

We believe this paper contributes to the literature in two ways. First, the approach is dynamic with a long time horizon that enables comparison of optimal energy extraction and forest harvesting regimes across a large region over time, under different conservation target levels. This has advantages over static cost models because cost minimizing strategies that either substitute development activity from one place to another and/or delay or defer development activities over varying time spans, can be modeled, which is not possible in a static approach. Within the model, opportunity costs are minimized subject to additional constraints which include land and capital constraints and forest growth and yield functions. Underlying the model is a database on energy reserves and forest inventory. With respect to caribou conservation, a dynamic approach is especially useful in that an explicit target date for meeting conservation targets and then sustaining them beyond the target date can be defined. Comparison of model runs with and without conservation constraints or with different levels of conservation can be conducted to find the minimum cost of achieving various targets and timing options. Second, this dynamic approach enables us to consider multiple activities that can be used to enhance species populations that (a) include predator control and habitat restoration activities that are difficult to incorporate in static optimization approaches which tend to focus on habitat protection only, (b) examine the risk of extirpation over the time required to achieve targets for alternative approaches to predator control (including a "habitat only" focus to species recovery), and (c) examine the costs of conservation when the dynamics of a wildlife species at risk (woodland caribou), forest resources, and subsurface energy resources are integrated into the analysis. The application also provides us with the opportunity to compare and contrast static versus dynamic analysis of conservation options (Schneider et al., 2012, 2011).

2. Model Formulation

2.1. Study area

Our study region is approximately 560,000km2 and is shown in Fig. 1. The caribou herd boundaries were obtained from the Alberta Caribou Committee (ACC) and Alberta Sustainable Resource Development. Industrial activity in both the forest and energy sectors is modeled over the entire region, both inside and outside the herd ranges. Our model includes forest and energy sectors (oil and gas and bitumen resources) within and outside the caribou ranges. The area contains mountain and foothill forest regions in the southwest and a large area of boreal forest plains in the central portions of the region. There is a small area of boreal canadian shield in the northeastern corner of the province. The oil and gas potential in the province is in the foothills region (where the Ala Peche, Narraway, Red Rock Prairie Creek and Little Smokey herds are located) and the boreal plains regions which encompasses the rest of the caribou herds in the region. Forestry potential exists in most parts of the region. The primary area of bitumen potential intersects the Cold Lake, East Side Athabasca, West Side Athabasca River, and Red Earth caribou herds. The study region includes 15 caribou ranges shown in Table 1. However, the 3 mountain herds (Narraway, Red Rock Prairie Ceek and Ala Peche) are removed from the analysis because the model used to estimate caribou growth rates may not be valid for these herds.[1] Therefore, our modeled study region contains 12 caribou herds (NC) and 1 large area outside the caribou ranges for a total of 13 regions (N). Forest resources inventory and energy resources are aggregated into classes within each of these areas as described below. The model has a 100 year time horizon divided into 5 year periods.

2.2. Criteria for caribou recovery

We consider a caribou herd to be recovered when two criteria

[1] An analysis for 15 herds has been conducted, under the assumption that the growth rate processes are the same. The analysis with 15 herds produces qualitatively similar results and is available from the authors upon request.