NSERC-ACR Industrial Research Chair

in

Integrated Landscape Management

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Stan Boutin
Professor
Department of Biological Sciences
University of Alberta
Edmonton
780 492-1297
fax: 780 492-9234
email: Stan.Boutin@ualberta.ca

http://www.biosci.ualberta.ca/People/Faculty/B/StanBoutin.aspx

Executive summary

The ILM Chair has the long-term objective of producing a toolkit that will form the core of ecologically informed land use planning. At the heart of this toolkit will be Integrated Landscape Management Models (ILMMs) capable of integrating multiple land use activities over broad space and long time scales to allow managers to explore the economic, ecological, and social implications of strategic land use decisions. The core of such models will be based on strong science that reduces key uncertainties allowing us to link human actions (land use practices, planning, and policy) to indicators (ecological, economic, and social). ILMMs form the basis for stakeholders (public, government, and industry) to understand and explore important trade-offs and devise more robust solutions to managing the risk of meeting longterm societal objectives around economic growth and ecological sustainability.

In Phase II the Chair worked to have "Integration" result from a multi-sector land use plan unfolding in space and time rather than as an outcome of cumulative independent activities clashing on a shared landbase. As a consequence the ILM lab developed innovative models and studies to provide timely input into the Alberta Landuse Secretariat and Regional Landuse plans, understand the cause of declines in woodland caribou and propose innovative province-wide conservation strategies, understand the trade-offs between multiple cumulative effects and terrestrial biodiversity, and to promote the Alberta Biodiversity Monitoring Institute as a world class monitoring system.

The ILM lab has produced over 50 peer-reviewed publications in the last 5 years and trained 21 graduate students and post-doctoral fellows. All publications and student theses can be found at:

http://www.biosci.ualberta.ca/People/Faculty/B/StanBoutin.aspx

Background

To date, Canadians have been able to have "their cake and eat it too" as natural resource use has grown while many wilderness areas and their attendant ecosystems have remained largely intact, particularly in boreal and arctic regions. However, unprecedented growth in development is now producing signs of resource use conflict and ecosystem stress. Conflicts between resource sectors in many jurisdictions have resulted in the creation of new government departments for coordinating the activities of different land uses, multi-stakeholder consultations, and regional land use strategies to prevent or mitigate such conflicts. While laudable in their intent, few efforts have delivered an effective means to deal with an exceptionally complex range of environmental, economic, and social issues. **The ILM Chair has the long-term objective of producing an ILM toolkit that will form the core of ecologically informed land use planning.** At the heart of this toolkit will be **Integrated Landscape Management Models** (ILMMs) capable of integrating multiple land use activities over broad space and long time scales to allow managers to explore the economic, ecological, and social implications of strategic land use decisions. The core of such models will be based on strong science that **reduces key uncertainties to allow us to link human actions (land use practices, planning, and policy) to indicators (ecological, economic, and social).** ILMMs form the basis for stakeholders (public, government, and industry) to understand and explore important trade-offs and **devise more**

robust solutions to managing the risk of meeting longterm societal objectives around economic growth and ecological sustainability.

In Phase II the Chair worked to have "Integration" result from a multi-sector land use plan unfolding in space and time rather than as an outcome of cumulative independent activities clashing on a shared landbase. The short-term objectives of Phase II were to:

1. **Resolve key uncertainties around the causes and consequences of non-native species invasions in forested systems.** In Phase I we found strong relationships between increased levels of human activities (forest cutblocks, roads, well sites, pipelines, seismic lines) and changes in vertebrate communities in the boreal forest that favoured invasive non-native species at the expense of natives. In Phase II the Chair examined the mechanisms that promote these shifts and consequences of these changes to ecosystem function including maintenance of woodland caribou and forest songbird populations.
2. **Develop and explore strategic land use scenarios through the use of Integrated Landscape Management Models**. In collaboration with industry and government partners the Chair moved to the next phase of development and use of ILMMs in the land use planning process to enable exploration of a broader array of alternative real-world management and policy options.

Research Program Summary

1. Reducing key uncertainties that prevent us from linking human actions to ecosystem function: the introduction of non-native vertebrates

We had 5 projects that examined the interaction between human landuse and the effects of invasives (ranging from earthworms to cowbirds to white-tailed deer and coyotes) on forest birds, woodland caribou, and biodiversity of plants, mosses, and lichens. Some highlights include:

Woodland caribou, deer, and wolves. **Dave Latham (PhD)** provided detailed evidence for woodland caribou representing a case of apparent competition in northeastern Alberta. Increased deer abundance in caribou range has increased wolf abundance which has led to increased caribou mortality and population declines (15). Wolves also hunt more efficiently and penetrate farther into caribou range due to the presence of linear features created by oil and gas exploration (7,15). **Kim Dawe (PhD)** showed that the increased deer numbers have resulted from changes in land cover caused by human activity and changes in climate; the latter being most important (5,10). Caribou work originating in the ILM lab has been fundamental in driving caribou conservation plans at the provincial and federal levels. Boutin has served as a member of the Scientific Advisory Group that produced the Environment Canada document "Scientific Review for the Identification of Critical Habitat for Woodland Caribou Boreal Population in Canada" released in 2010. He also served on the Board and the Research and Monitoring Sub-committee of the Alberta Caribou Committee. Richard Schneider (Research Associate) served on the Advisory Team for the Athabasca Caribou Landscape Planning team that produced the Athabasca Caribou Management Options Report (May 2009). Research has expanded to

include woodland caribou populations in the Revelstoke area of BC (**Robert Serrouya PhD candidate** studying effects of experimental manipulations of moose density on caribou population dynamics; see 1,2,16,27) and the Horn River Basin of northeastern BC (**Craig DeMars PhD candidate** studying identification of calving habitat and factors affecting calf survival).

Source sink dynamics of boreal forest songbirds. The goal of this project was to clarify the effect of edges on songbirds in the northern boreal forest by quantifying habitat quality with respect to edge proximity, and by relating the nesting success of individuals to this edge-related environmental variation. The rationale was that the ubiquitous nature of linear features such as seismic lines and pipelines in northeastern Alberta, renders the potential for edge effects to dominate songbird dynamics. **Jeff Ball (PhD candidate)** found that forest edges created by energy sector pipelines and seismic lines do not negatively affect nesting success of forest songbirds. Instead, reproductive success of ground nesting birds was higher near edges (28,29). This contradicts the findings of studies conducted elsewhere, which suggests boreal forest dissection may not reduce nesting habitat quality near edges. Negative edge effects are often related to increased rates of nest predation and nest parasitism in edge habitats, most commonly due to the movement of non-forest associated nest predators and brood parasites along linear features into the once contiguous forest. The publication of our video nest-surveillance data clearly shows this does not occur in northern areas of the boreal forest. We identified only forest-associated species destroying nests. Red squirrels and, to a lesser extent, sharp-shinned hawks were the main predators (29).

Earthworms and invasion meltdown. **Erin Cameron (MSc and PhD candidate)** built an honors project into a full doctoral program involving the pattern of invasion my earthworms which are non-native to the boreal forest (see 8,9,31,32,40,44). She examined the spread of non-native earthworms and plants in addition to birds, as these groups may all be influenced by anthropogenic disturbances but could also affect each other's spread. For instance, earthworms are thought to facilitate the spread and establishment of non-native plants and may act as a key source of prey for non-native or generalist birds such as robins. Birds are also often vectors of spread for plant propagules and may be important for spread of earthworms or their cocoons. Based on co-occurrence of several earthworm species in the field, it has been suggested that earthworm invasions are an example of an invasional meltdown (i.e. an accelerating increase in the number of species invading or their effects). After observing this pattern at our field sites in the boreal forest, we tested this hypothesis using a laboratory experiment and found no evidence of synergistic effects or facilitation between litter dwelling and mineral soil dwelling species.

Biodiversity responses to a gradient in human activity. **Diane Haughland (PhD) and Stephen Mayor (PhD candidate)** are studying how vascular plant, moss, and lichen diversity change in response to gradients in human landuse. They have taken advantage of the extensive database collected by ABMI to chart the distribution and abundance of 100's of species and how this changes in response to a full gradient of landuse disturbance. Both students have publications in preparation. Diane defended her thesis in April and Stephen will defend in autumn 2012.

Seismic line recovery as determined by wildlife use. The rapid pace of new development has led to concerns regarding how exploration, extraction, and transportation of energy resources can be

done in an economically-viable yet ecologically-sustainable manner. A broad range of stakeholders have suggested this balance can be best met using management thresholds, or development limits, for the density and extent of the energy sector's physical disturbance footprint (a strategy recently adopted in the Federal Draft Recovery Strategy for Woodland Caribou). Linear features, and specifically seismic lines, are proportionately the largest component of the industry's footprint and consequently the most commonly suggested metric with which to measure thresholds. While management thresholds constitute an important step in boreal land use planning, there are two key uncertainties limiting the efficacy of this tool. First, it is not clear which seismic lines constitute disturbances that merit inclusion in a threshold calculation. To date, it is not known how most mammals respond to seismic lines at all. Further, in the northern boreal several types of seismic lines exist including wide conventional lines and narrower low impact lines, and these lines exist across a range of recovery states. Second, there is no research available to support where actual threshold density targets should be set. It is unclear how or if species' occupancy rates or population densities are influenced by seismic line density making it impossible to set meaningful targets. **Jesse Tigner (MSc)** examined how various mammals respond to different types of seismic lines, which lines constitute disturbances that should be included in threshold calculations, and measured changes in species' occupancy rates relative to increasing line density to develop threshold targets that are meaningful biologically. Jesse has two manuscripts in preparation and will defend his thesis in summer 2012.

2: In collaboration with industry and government partners, the Chair will develop and use ILMMs to provide decision support for a range of regional land-use planning initiatives.

Strategic land-use planning beyond the scale of individual projects must integrate diverse human activities and ecological interactions at a variety of spatial and temporal scales. Individual land-use decisions made today often do not display their full ecological effects until some years later. In Phase II we used ILMMs to explore alternative scenarios in order to identify optimal strategies for managing future risks to economic and ecological sustainability. Some highlights include:

Modeling a Provincial Woodland Caribou Conservation Strategy. The recovery of woodland caribou is a major concern for industry and government, given the high profile of this species and the fact that population declines have been linked to industrial development. The objective of this project was to explore alternative recovery strategies, including triage and habitat protection. Our emphasis was on the strategic allocation of conservation resources, designed to maximize long-term conservation outcomes at the provincial scale, in contrast to the existing approach of giving priority to herds with the highest near-term risk of extirpation. Our aim was to provide land managers with efficient and effective reserve design options and a clear understanding of the economic trade-offs inherent in decisions concerning reserve design and other recovery efforts. A herd-level analysis was conducted to rank herds on the basis of cost of recovery and several measures of viability in collaboration with Drs. Vic Adamowicz and Grant Hauer. The estimation of cost of recovery was based on a caribou population model that included components for habitat regeneration and wolf control (24). This work has produced two novel assessments of caribou conservation strategies (3,24) that has sparked widespread interest by government and industry. It has played a fundamental role in formulation of the

Federal Draft Recovery Strategy for woodland caribou (2011) and it prompted a personal "thank-you" to Boutin from Paul Boothe, DM Environment Canada. A second study involved the use of optimization, via the Marxan model, to identify efficient and effective reserve design options, at the regional (Oil Sands Region) and the provincial scale, as a component of caribou recovery efforts. This study included an analysis of the cost of protection as a function of the amount of overall habitat protected. The results are now published in PLoS One (3).

Regional and Provincial Protected Area Selection. A conceptual and technical framework was developed to link a conservation planning tool (Marxan) to develop land use zoning strategies with a simulation model (ALCES) to evaluate such strategies. The framework was submitted to Alberta's Oil Sands Branch as part of a regional land use planning report (2008) that included scenarios, zoning and market instruments, and presented at three government workshops (2008). Building on earlier work for the Oil Sands Branch, optimized conservation area designs were developed for the Lower Athabasca Regional Plan (LARP), part of the Alberta Landuse Framework, using Marxan and presented to the Alberta Land-Use Secretariat and the LARP Regional Advisory Council (July 2009). These designs helped guide the selection of conservation areas in northeastern Alberta by the government (2011). The scope of the Marxan modelling was later expanded to all of Alberta's public lands. Modelling efforts were focused on identifying optimal conservation designs, incorporating both ecological and economic trade-offs (13).

Cross-boundary Conservation Planning for Boreal Forest Songbirds. This is an ongoing project to create songbird management plans for areas across the boreal forest of Canada. As related to the ILM chair we have used NE Alberta as a test ground for our ideas on how to convert point count data in density estimates and use this information to track and predict future changes in bird populations based on land-use trajectories. We have a database of over 50,000 point counts at more than 15,000 locations. To use these data we have developed novel statistical techniques to convert disparate point count data to density estimator (20). The density estimates created by this project have become part of the ALCES program through the Alberta Landuse Secretariat. The database is called Alberta Songbird Information System and will be released as an online tool in the next 6 months through www.borealbirds.ca. The objective of this project is to create a series of regional habitat association models, integrate them into a land use simulation model, and explore management scenarios across boundaries that consider the level of responsibility that different jurisdictions have in maintaining a particular species.

Modeling forest management responses to a mountain pine beetle epidemic. With the spread of British Columbia's pine beetle epidemic east of the Rocky Mountains, the pine beetle has become the dominant concern for forest managers in Alberta, both within industry and government. The objective of our beetle modeling project was to work with our forest industry partners to investigate the potential impacts of the beetle epidemic and explore alternative management strategies for responding to it. We simulated the effects of a severe pine beetle epidemic in western Alberta, in terms of changes to a suite of forest management outcome measures, under two management scenarios: conventional harvest and a preventive pine reduction strategy. Our objective was to describe the potential outcomes of these alternative management approaches over the medium and longer-term. We initiated an industry working group to develop an approach for modeling the effects of pine beetles in ALCES. We also

worked closely with government staff to incorporate their perspectives on the epidemic. Brad Stelfox worked with the lab to make changes to ALCES that allowed it to capture some of the features of a pine beetle outbreak that we felt were important to incorporate (e.g., to enable the simulation of multiple regeneration trajectories following disturbance by pine beetle. A summary of final model runs were published by Natural Resources Canada in 2009 and a peer-reviewed paper was published in 2010 (26). Our simulations showed that the government's pine beetle strategy could not be effectively implemented, even if the onset of the beetle outbreak was delayed for 20 years. Alternative management approaches and avenues for future research are discussed in our report. For example, in place of the pine beetle strategy as currently articulated, consideration should be given to focusing all control and preventative harvest efforts on pure pine stands only, and regenerating these stands as mixedwoods.

Climate Change Modeling. A growing body of scientific literature suggests prairie climates will undergo significant changes over the course of this century as a consequence of global warming, even if steps are taken to limit future carbon emissions. Given that climate has a large effect on ecological processes and the distribution of vegetative communities it can be expected that climatic changes over the coming decades will increasingly affect many land-use outcomes. It follows that models used as decision support tools for land-use planning should incorporate climate change, at least as an external driver. Some of the ILM lab's modeling efforts were directed to this issue. Our approach was based on the development of bioclimatic envelope models which we modified such that they could be used in the context of land use planning and adaptation under climate change. In our approach, the trajectory of vegetation change is set by a bioclimatic envelope model, but the rate of transition from one vegetation type to another is determined by a disturbance model. The working assumption is that changes in the vegetative composition of a given site will not manifest without a disturbance event, which is likely to hold true for at least the next few decades. We used this new approach to explore potential shifts in vegetation in Alberta under alternative climate and disturbance scenarios and we reported the implications of these changes for land use planners and those charged with developing adaptation strategies. We also developed an approach for incorporating climate change into the regional land-use planning process now underway in Alberta. We developed a natural and human-caused disturbance model, parameterized for Alberta ecosystems, and linked it to the envelope models generated in collaboration with Dr. Andreas Hamann. We used this composite modeling system to explore potential shifts in Alberta's major biomes over the next 50 years (35). The disturbance model slowed the rate of ecosystem transition, relative to the raw projections of the bioclimatic envelope model. But even with these transition lags in place, a northward shift of grasslands into much of the existing parkland occurred over the 50 years of our simulation. There was also a conversion of 12-21% of Alberta's boreal region to parkland. In addition to aspatial projections our simulations provide testable predictions about where ecosystem changes due to climate change are most likely to be initially observed. We also conducted an investigation of model uncertainty that provides an indication of the robustness of our findings and identifies fruitful avenues for future research. In late 2008, the ILM lab hosted a climate modeling workshop on behalf of interested government personnel. The workshop, involving scientists and managers with experience in multiple areas of climate research, was designed to be a technical discussion of practical issues surrounding the modeling of changes in terrestrial ecosystems as a result of climate change. Based on the findings from this workshop we published a report that described a recommended approach for how to incorporate climate

change into ALCES, in the context of regional land-use planning. This report covered both methodological issues and model parameterization.

Deviations from the Original Proposal

Changes from the Phase II proposal are relatively minor. We had planned to have a student study the effects of coyotes as a boreal forest invasive species. We did not find a student to date but we do have a reasonable telemetry database on 9 coyotes collared by Dave Latham plus and extensive database available from the ABMI winter tracking program. Results have been summarized and presented to partners at various meetings. Other changes largely involved additions that arose through student ideas and opportunities.

Scientific significance of the results

The ILM lab has produced 50 peer-reviewed publications since 2006. A number of these have been published in top ranked journals such as PLOS One, Frontiers in Ecology and Environment, and Biological Conservation. Results have provided core scientific information for woodland caribou conservation in Alberta and Canada. Further, our results, and collaboration with ABMI, are providing a comprehensive assessment of the potential effects of energy sector activities on birds and mammals in the boreal forest. Finally, our incorporation of climate change components to ILMM models such as ALCES is unique.

Potential benefits to Canada

The Oil Sands of Alberta are a globally significant energy resource that drives the economic engine of Alberta and Canada. Oil produced in the region has been subject to wide criticism because of the environmental cost associated with its extraction. The ILM Chair has been instrumental in providing sound scientific information outlining the actual local and regional terrestrial environmental effects as well as providing the tools to conduct effective ecologically informed landuse planning. ILM results have had a clear imprint on the federal and provincial conservation strategy for woodland

Refereed Journal Articles, Submitted

1. McLellan, M.L., R. Serrouya, B.N. McLellan, K. Furk, D. Heard, and H.U. Wittmer. In review. Implications of body condition on the unsustainable predation rates of endangered mountain caribou. Oecologia.
2. Dawe, K., E. Bayne, and S. Boutin. Submitted. Factors driving white tail deer distribution in the western boreal-implications for woodland caribou conservation. Ecological Applications

Refereed Journal Articles, Accepted or Published

1. Habib, T.J., D.R. Farr, R.R., Schneider, and S. Boutin. *In Press.* Economic and ecological outcomes of flexible biodiversity offset systems. Conservation Biology
2. Serrouya, R., D. Paetkau, B.N. McLellan, S. Boutin, D. Jenkins, and M. Campbell. *In Press*. Population size and major valleys explain microsatellite variation better than subspecies or ecotype for caribou in western Canada. Molecular Ecology.
3. Schneider, R, G. Hauer, K. Dawe, W.L. Adamowicz, and S. Boutin. 2012. Selection of reserves for woodland caribou using an optimization approach. PloS ONE 7(2): e31672
4. Boutin, S., M.S. Boyce, M. Hebblewhite, D. Hervieux, K.H. Knopff, M.C. Latham, A.D.M. Latham, J. Nagy, D. Seip, and R. Serrouya. 2012. Why are caribou declining in the Oil Sands? Frontiers in Ecology and the Environment.
5. Latham, A.D.M. and S. Boutin. 2011. Wolf, *Canis lupus*, pup mortality: interspecific predation or non-parental infanticide? Canadian Field-Naturalist 125:158-161
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10. Kardynal, K. J., J. L. Morissette, S. L Van Wilgenburg, K. A. Hobson, and E. M. Bayne. 2011. Avian responses to experimental harvest in southern boreal mixedwood shoreline forests: Is there an alternative to conventional boreal riparian buffer management? Canadian Journal of Forest Research 41:2375-2388
11. Festa-Bianchet, M., S.A. Boutin, S.D. Cote, and A. Gunn. 2011. Conservation of caribou (Rangifer tarandus) in Canadian uncertain future. Canadian Journal of Zoology 89:419-434.
12. Schneider, R., G. Hauer, D. Farr, W.L. Adamowicz, W.L., and S. Boutin. 2011. Achieving conservation when opportunity costs are high: optimizing reserve design in Alberta's oil sands region. PLoS One 6: e23254
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15. Serrouya, R., B.N. McLellan, S. Boutin, D.R., Seip, and S.E. Nielsen. 2011. Developing a population target for an overabundant ungulate for ecosystem restoration. Journal of Applied Ecology 48: 935–942.
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Conferences Presentations and Posters

The ILM Lab has made over 120 presentations at venues including Society for Conservation Biology Meetings, Alberta Chapter of the Wildlife Society, Petroleum Technology Alliance Conference, Wildlife Society meetings, American Ornithological Union, Alberta Chamber of Resources, Canadian Association of Petroleum Producers, Alberta Caribou Committee

Other (Technical Reports, Non-Refereed Articles, etc.) - 36 reports