Participatory Modeling of Endangered Wildlife Systems: Simulating the Sage-grouse and Land Use in Central Washington

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Abstract: The Greater sage-grouse (Centrocercus urophasianus) occupies the sage brush habitats of Western North America. Large population declines in the last several decades have made it a candidate for possible listing under the Endangered Species Act. Listing was recently avoided in part because seventy local working groups are developing long-range management plans in conjunction with federal and local agencies. The Foster Creek Conservation District, a working group in Douglas County, Washington, saw the potential for system dynamics to synthesize known sage-grouse dynamics and local land use patterns to support development of their Habitat Conservation Plan and subsequent land management decisions. The resulting model is providing insights into the cropland and shrub steppe ecosystems of Douglas County and the management scenarios which may prevent the sage-grouse from an endangered status. The model is designed to facilitate and support land use management decisions through the collaborative exploration of model parameters and simulated scenarios.

Key words: participatory modeling, wildlife modeling, sage-grouse, collaboration, system dynamics, land use modeling, endangered species.

Introduction

The Sage-grouse

The Greater sage-grouse (*Centrocercus urophasianus*) is a unique western North American gallinaceous species that lives in the sagebrush (*Artemisia*) habitats of the western United States and adjacent Canada (Figure 1). Sage-grouse are known as a sage brush obligate species because they depend on sagebrush for food, shelter and nesting. The sagebrush areas of Douglas County, Washington (Figure 2) and other North American locales have been greatly changed by agricultural conversion, fire, invasion of exotic annuals, fragmentation, urbanization and inappropriate livestock management (Connelly et al. 2004, Schroeder et al. 1999) to the extent that sagebrush habitat is now found in patches of varying size and condition (Quigley and Arbelbide 1997). In Douglas County alone, about 75% of the natural habitat has been converted to agricultural land (Douglas County Draft MSHCP 2005). Anthropogenic change and fragmentation of habitat have been the major driving forces in the decline of sage-grouse populations which no longer exist across their former extensive historical range (Connelly et al. 2004, Stinson et al. 2004). Concern across the US West about this decline has caused the sage-grouse to be considered for inclusion in the U.S. federal threatened and endangered species list by the US Department of Fish and Wildlife (USFW). Listing will likely result in changes in the management of the remaining sagebrush lands that harbor populations of sage-grouse and consequently affect the activities and livelihoods of those dependent on sage-grouse lands (Wambolt et al. 2002). Due to the controversy over this potential listing, and in lieu of listing at this time, federal land management agencies have agreed to participate with local working groups to develop long-range management plans that address sage-grouse population declines and habitat needs.

Figure 1. Greater sage-grouse (*Centrocercus urophasianus)*

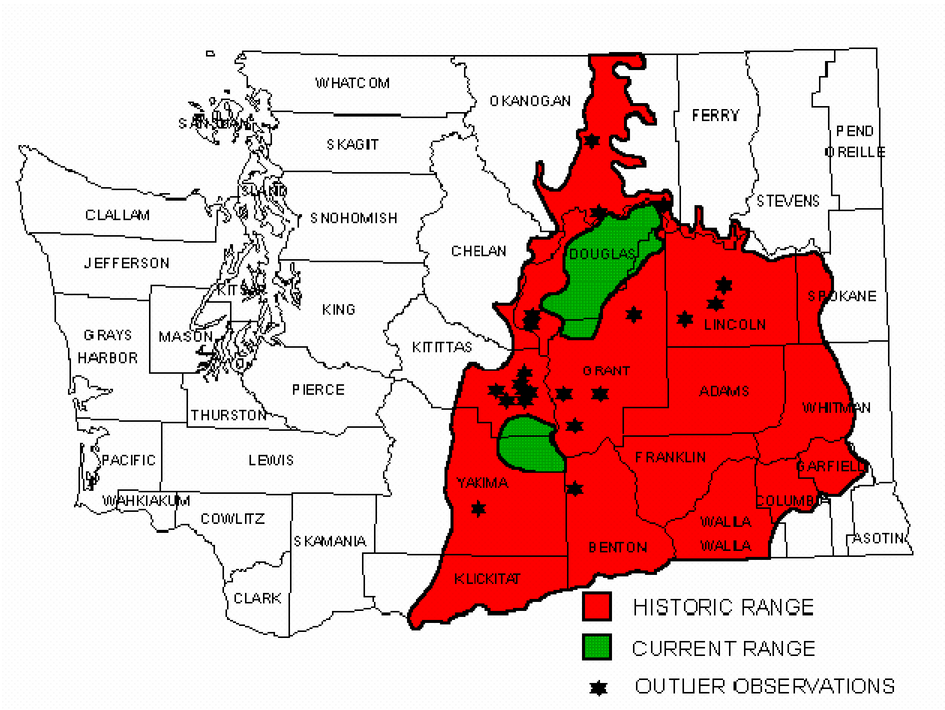

Figure 2. Current and historic range of the Greater sage-grouse in Washington State. (Douglas County Multi Species Habitat Conservation Plan (MSHCP)).

The Foster Creek Conservation District

Aside from the potential of federal listing, the sage grouse is listed as threatened in the State of Washington (Washington Department of Fish and Wildlife 2005). To help address the sage-grouse and other species of concern, the Foster Creek Conservation District (FCCD), Douglas County, Washington is presently developing a Multiple Species Habitat Conservation Plan (MSHCP, hereafter referred to as HCP). A large percentage of the land in Douglas County is privately owned. Federal and state listings both have the potential to regulate private property management. "It is the expressed desire of the private agricultural land owners in Douglas County to reverse the declining population trends of FESA Species as well as other key fish and wildlife species within the County"(Douglas County Draft MSHCP 2005). As part of this effort, the District saw the potential for system dynamics to synthesize sage-grouse biology with land use patterns to form a system-wide perspective of local impacts on the sage-grouse population. The subsequent model has been named the Integrated Sage-Grouse and Human Systems Model to indicate the broad scope of the FCCD's management agenda.

Development of this model has been guided by a belief that sound ecological management happens only with respectful coordination and communication between land management agencies and land owners. Part of this coordination includes data sharing. The management agency-land owner relationship may be strained, perhaps not so much by the data itself, but by the data collection processes and types of data which either party considers important when making decisions. Agency biologists are bound to scientific protocol, such as Population Viability Analysis (PVA), and peer review that produces reports that may be difficult to understand or hard to access by the general public. Land owners use historical information handed down through generations, personal observations, and instinct developed by their intimate knowledge of the land. Local knowledge is typically not offered in a format that will withstand scientific peer review. However they differ, both scientific and local knowledge are valid and useful. Conversely, both types of knowledge may contain inconsistencies brought about by lack of information, misinformation, or an inadequate understanding of system complexity and dynamics. Furthermore, landowners may feel that issues concerning their livelihoods should be more prominently included in the process. Melding local and scientific information into a system dynamics model offers a unique venue for data verification, shared learning, and improvements in communication and trust (van den Belt 2005, Stave 2002 p.139). This in turn increases the likelihood that land use decisions will lead to improved stewardship.

The role of system dynamics

We believe system dynamics modeling can help the sage-grouse working groups better understand land management challenges posed by declining sage-grouse populations. This method has the greatest potential when used in a participatory fashion by scientists and managers working together with others who also have a stake in land management decisions. Using group system dynamics modeling for participatory environmental problem solving is a relatively new process which has been used on a variety of environmental problems such as air quality, water quality and quantity, and biological conservation management. Marjan van den Belt, describes five case studies, their models and the lessons learned from the processes (van den Belt 2004). Other published case studies include that of Kris Stave who used group system dynamics modeling to help the citizens of Las Vegas explore remedies to air quality problems (Stave 2002, p. 139). Tidwell et. al. used system dynamics modeling to assist citizens with watershed planning in the Middle Rio Grand River valley (Tidwell et al 2004, p.357). Wildlife models have been developed for bear management (Siemer and Otto 2005, Faust et al. 2004) and fishery management (Otto and Struben 2004 p. 287). Videira et al. modeled “tourism, eco-tourism, aquaculture, fishing, wildlife protection and nature conservation, effluent discharge and navigation of fishing and recreation boats” (Videira et al. 2004, Videira 2005 p. 27). Spatial-Dynamics were used by BenDor et al. in a decision support tool for ash borer eradication (BenDor et al. 2005).

The Integrated Sage-Grouse and Human Systems Model was developed in collaboration with land owners, agency representatives[1] which included scientific experts, and representation from The Nature Conservancy. The FCCD group had worked together for many years prior to this modeling effort. The landowner committee and the technical committee had been working on the HCP prior to the federal mandate to develop sage grouse plans due to the fact that sage-grouse are listed as threatened in Washington State. This group was well into a participatory process and they have developed respectful relationships and a sense of cohesiveness. After USFW approval of the HCP, the next challenge that awaits the group is convincing land owners to sign on to the plan. One of the goals of the model was to help FCCD get the “best bang for the buck” when targeting landowners for HCP sign-on. Signing on to an HCP requires that landowners develop a farm or ranch plan which must be approved as being within the guidelines of the HCP. Land owners also agree to be monitored for compliance with their plan. In return, the land owner is covered under the blanket of the HCP’s, ESA section 10, incidental take permit[2] and assured a level of regulatory certainty.

The intention of the Integrated Sage-Grouse and Human Systems Model is to further develop insights into the cropland and shrub steppe ecosystems of Douglas County to facilitate and support land use management decisions affecting the Greater sage-grouse and other obligate species. The model was designed to help FCCD understand which land types and conservation efforts are most important for the recovery of the sage-grouse and within reasonable reach of local landowners. Additionally, because sage-grouse are sage brush obligates, improving sage-grouse habitat should also assist with the conservation of other species of concern.

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[1] Washington Fish and Wildlife (WDFW), US Fish and Wildlife (USFW), Bureau of Land Management (BLM), Natural Resources Conservation Service (NRCS), WA Department of Natural Resources (WDNR), Douglas County Farm Service Agency, and an “at large” range expert.

[2] “In 1982, Congress adopted Section 10 of the Endangered Species Act [(16 U.S.C. §1539(a)(2A)] as a way to promote, "creative partnerships between the public and private sectors...in the interest of species and habitat conservation." Section 10 authorized Habitat Conservation Plans (HCPs) to give landowners a means by which they could "incidentally take" listed species or their habitats only after the landowners have identified what will be done to "minimize and mitigate" the impact of the permitted take on the listed species.” www.fostercreek.net/esa.html

The Group Modeling Process

The model was constructed with Vensim PLE plus (Ventana Systems) over 12 weeks. The FCCD participants provided all of the data and insights as to the operation of the sage-grouse system in Douglas County. After the initial meeting, FCCD met as a group with the modelers on two other occasions to provide feedback on model structure. Frequent contacts via phone and email were also used to confirm important relationships within the model. Additional contact with Mike Schroeder, Washington Department of Fish and Wildlife (WDFW) was needed to confirm sage-grouse parameters. FCCD is very fortunate to have Schroeder as their official state biologist. He has spent of good deal of his life devoted to the study of shrub steppe species and is one of the most highly published experts on sage-grouse biology.

The model was developed in an iterative fashion. The land use portion went through two major iterations, and the sage-grouse life history sector was developed in three major iterations. A unique feature of the model is the integration of the sage-grouse life cycle with the land use sector. The feedbacks between land use and sage-grouse were perhaps the most important part of the project. These feedback relationships were developed through four major iterations. And finally, the interface views went through multiple modifications as model building progressed. Many insights into the model were gained in these iterations, and others were gained by experimentation with the completed model. This led to another major iteration of the interface (that occurred after the contract period but before final presentation to the group) in the interests of making these insights available and the model more accessible and usable by all stakeholders. The sources of the model constants and reasoning behind the quantitative links have been thoroughly documented in the comment window of each variable.

Parameter values were estimated in one-at-a-time fashion using a wide range of information from the FCCD participants. Ford (1999 p.174) encourages modelers to take advantage of information from across the information spectrum shown in Figure 3, and the FCCD participants were encouraged when we explained that we would follow this approach. They were especially encouraged by our willingness to make use of the expert judgment and personal intuition of the members of the FCCD.

Physical laws	**Controlled physical experiments**	**Uncontrolled physical experiments**	**Social system data**	**Social system cases**	**Expert judgment**	**Personal intuition**

Figure 3. The information spectrum. (Ford 1999 p. 175).

The participants provided a great deal of data and statistical estimates that had been acquired through peer reviewable processes. The most current data available on land cover had been translated from aerial photos to GIS which FCCD used to delineate Douglas County into 16 land types as part of their HCP. The range of each species of concern was then overlaid on the GIS. Figure 4 illustrates the Douglas County sage-grouse area which covers 292,030 hectares and includes 11 of the 16 land categories. Suitability indices were assigned to each category and include consideration for sage-grouse density in any particular land type.

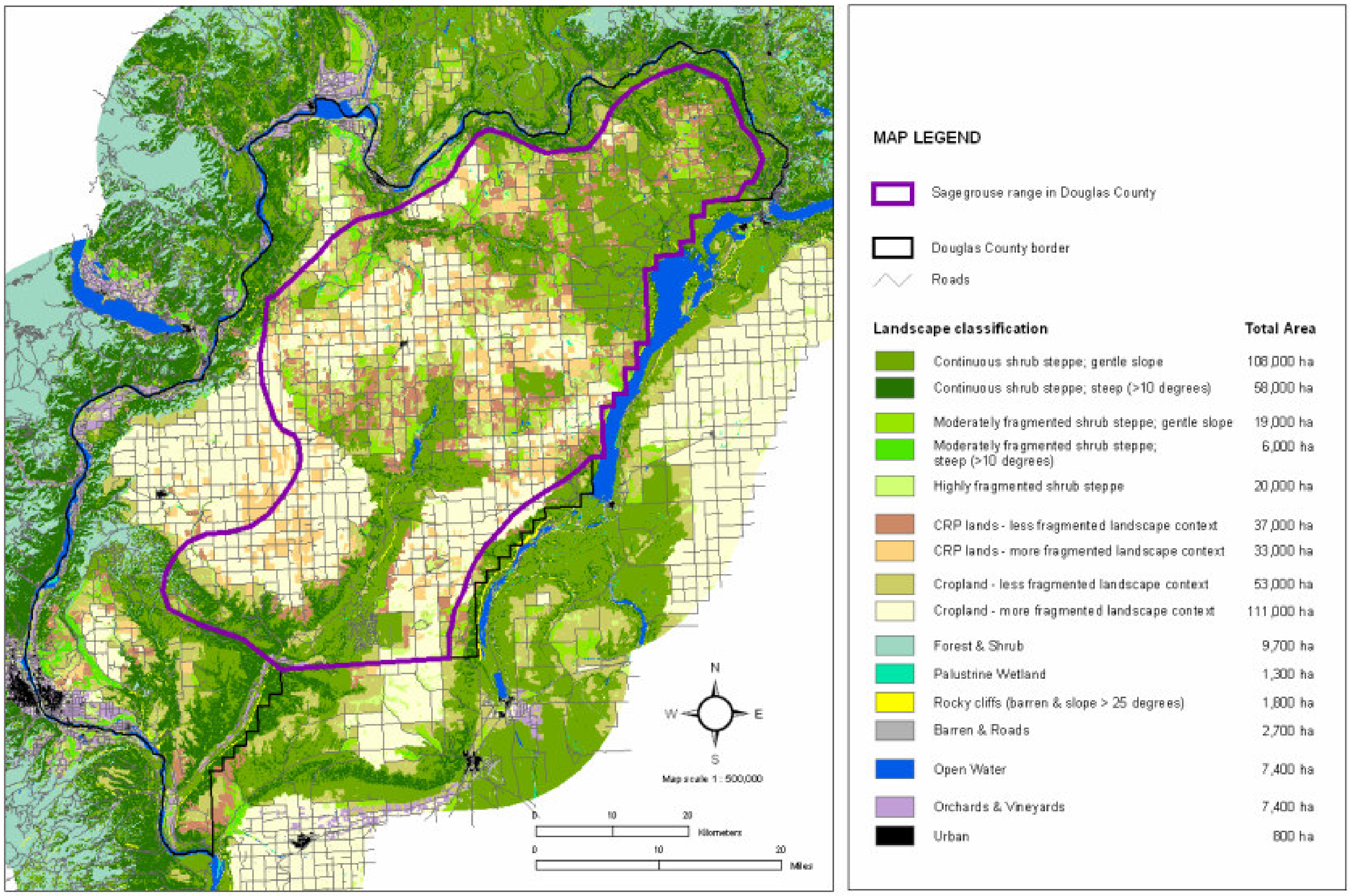

Figure 4. Douglas County GIS with sage-grouse range delineated. Legend indicates land category totals for the entire county.

Sage-grouse population estimates had been acquired by Schroeder through the use of peer reviewed sage-grouse estimation procedures. Sage-grouse life history parameters were derived from data provided by Schroeder, and from peer reviewed journal articles and reports about sage-grouse, many authored or co-authored by Schroeder. The structure of the life history portion of the model follows a life-stage transition form familiar to population biologists.

The parameters that linked sage-grouse density with land use were based on assumptions made by the modelers, that are easy to follow, and are similar to those used in other types of biological models. The parameters that are most uncertain are the relative values of habitat suitability. The debate about these parameters and more importantly, what land use change will improve suitability, is presently being discussed outside of the model. The model simply condenses data into one format so that questions about original data assumptions may be tested. It has taken the best science available to FCCD and placed it in a form that is accessible to both scientists and non scientists. It has also made the concerns of landowners accessible to agency representatives and scientists. FCCD realizes that ecosystem management is a holistic endeavor and must include the concerns of the ecosystem's human occupants as well as concern for the non human occupants.

The Model Structure

Clearly, the model is a work in progress. As of March 2006, the model is comprised of 10 stocks and 18 flows. The diagrams and results are spread across 26 views. Time is simulated in months, and a typical simulation runs for 50 years to encompass the habitat planning horizon. There are over 200 input parameters which are specified in the model. Spatial aspects have been included through the aggregation of land categories and through the suitability indices which include consideration for sage-grouse density (Schroeder per. com. 2005).

Land Use and Suitability Indices

Aggregate land categories include cropland, Conservation Reserve Program (CRP)[3] and shrub steppe designations which are further delineated by their proximity to one another, steepness of slope, and their degree of fragmentation.[4] Shrub Steppe designations cannot be changed through modified land use; however, Wheatland and CRP land categories have been integrated into stock and flow variables to allow the user to change percentages of CRP contracts in the sage-grouse area (Figure 5). Additionally, the proximity of Wheatland and CRP to shrub steppe was also considered.

This population of sage-grouse is migratory and uses different parts of its range for winter and breeding, therefore each of the land use categories has an assigned suitability index for both winter and breeding use. This effectively splits land designation into 22 categories each with a unique suitability index. For example the highly fragmented shrub steppe has a suitability of 0.65 for breeding (out of 1) and 0.05 for winter habitat, while gentle and continuous shrub steppe has a breeding suitability of 0.1 and a winter suitability of 0.6.

The habitat suitability index for any land category, multiplied by hectares of land in that category, creates a parameter called "habitat units". The assumption made is that, given a positive rate[5] of increase in the sage-grouse population, more habitat units whether acquired by expanding habitat through restoration, or by improving existing habitat, should be able to support more birds. Due to the potential for controversy over the suitability indices, user interfaces provides sliders to manipulate the indices.

[3] "The Conservation Reserve Program (CRP) is a voluntary program for agricultural landowners. Through CRP, [a farmer] can receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible farmland. The Commodity Credit Corporation (CCC) makes annual rental payments based on the agriculture rental value of the land, and it provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. Participants enroll in CRP contracts for 10 to 15 years." (Farm Service Agency)

[4] Land designations: cropland in crop landscape, cropland in shrub steppe (ss) landscape, CRP in crop landscape, CRP in shrub steppe landscape, shrub steppe gentle and continuous, shrub steppe steep and continuous, shrub steppe gentle and moderate, shrub steppe steep and moderate, shrub steppe fragmented, palustrine wetland and barren.

[5] A positive rate of increase is necessary for improved population numbers. A negative rate would indicate that the population is in a long term decline and will not recover without intervention. Negative rates for sage-grouse could be caused such things as inbreeding depression (lowers productivity) or a breakdown in the social structure of the lek mating system. (also see foot note 6)

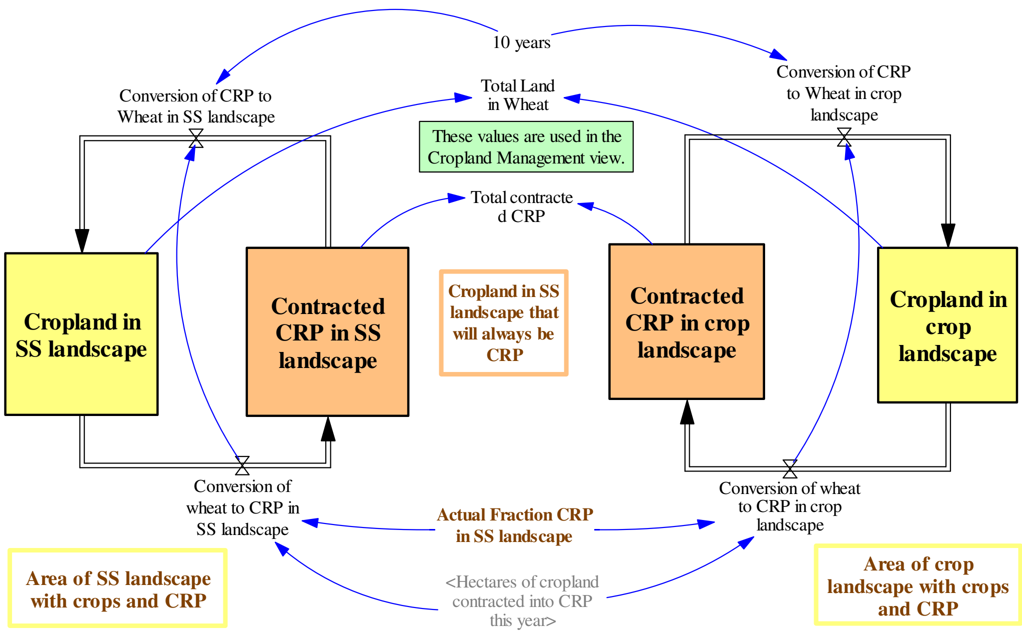

Figure 5. Cropland and CRP View of the systems model

Economics and Local Knowledge

Gathering local information in Douglas County was limited due to the time constraints of the model building period; however, the model offers a starting point for discussion and continued discovery of the potential impacts of both land and sage-grouse management upon land owners and sage-grouse. Sliders are available that allow the user to estimate the cost of improvements per acre that landowners may incur for inclusion in the HCP. Additional concerns include those of wheat growers who are likely to be impacted by the 2007 Farm Bill. After a review of an early version of the model, Wade Troutman (per. com. 2005) suggested a “switch” that would remove CRP from the system (a potential outcome of a farm bill which removed conservation support). This was subsequently added, and the model now simulates the impact of this potential loss of all CRP upon sage-grouse populations and area economics.

A simple economic model that contrasts area-wide net CRP income with wheat income and production costs has been included (Figure 6). Considerable time has been spent on a “cattle economics and potential land impacts of grazing” component of the model. At present this has not been integrated into the sage-grouse model due to the lack of verification from ranchers. This is a complex system in of itself and there are many assumptions and parameters that require consensus as to both their impacts and usefulness to the sage-grouse model. However, the model presently offers ranchers a platform to discover potential impacts to sage-grouse through the improvement of shrub steppe suitability. Ranchers will no doubt begin to describe how the improvements should or will take place, and the benefits, costs and impacts to ranching operations. As this discovery develops, FCCD may find it useful to include these items in a future version of the model.

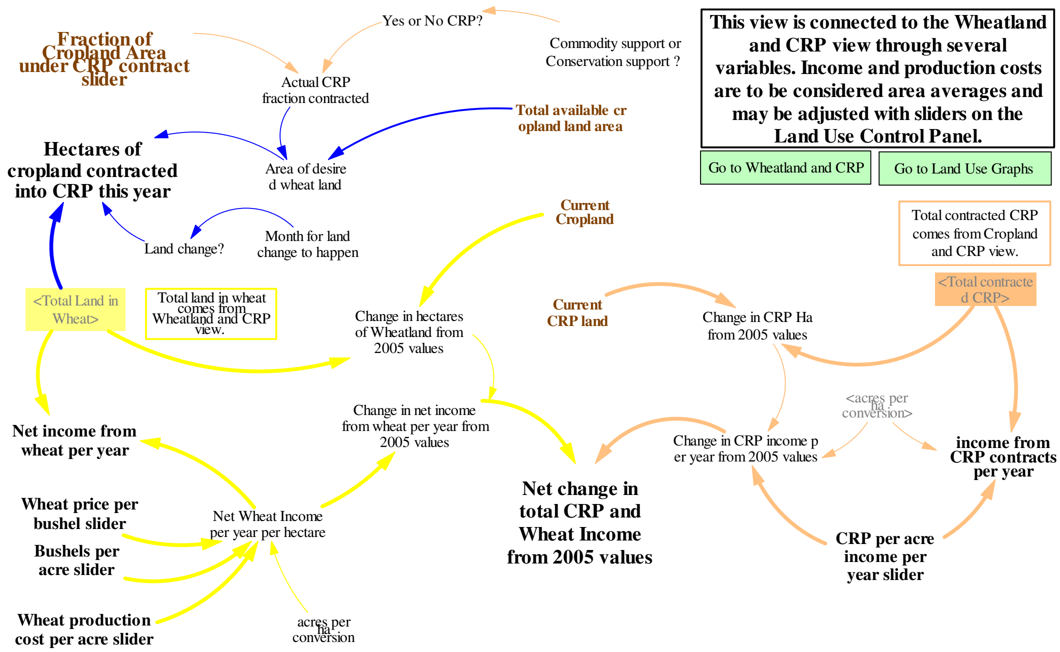

Figure 6. Cropland Management View

Sage-grouse Demographics

Important life stages and demographic rates of the greater sage-grouse have been identified from current literature (Schroeder 1997, Schroeder et al. 1999, Stinson et al. 2004) and with information provided by Schroeder. Life stages appear in the model (Figure 7) as stocks for eggs in nests, chicks, adult female birds, and adult male birds. Demographic rates appear as the flows between the stocks and include variables such as "successful hatches".

It is not known how density dependence limits sage-grouse populations; however, it does occur. Biologists have indicated that the current Douglas County population of approximately 650 birds is most likely at carrying capacity (Connelly et al. 2004). Schroeder (per. com.), notes that breeding and winter habitat may both be equally limiting at this time. Therefore, population limits have been set in the model by dividing the current estimated population into the total breeding and winter habitat units. This establishes a density dependent relationship between the birds and both types of habitat units. Another density dependant relationship is established through the major feedback loop highlighted with the darkened blue line on the "Female Life History" view of the model. This relationship limits the number of nests in available breeding habitat to a default amount based on the current conditions. In other words, to establish more nests, more habitat units are needed. Other feedback loops operate through mortality rates of both chicks and adults and appear on their associated life history views.

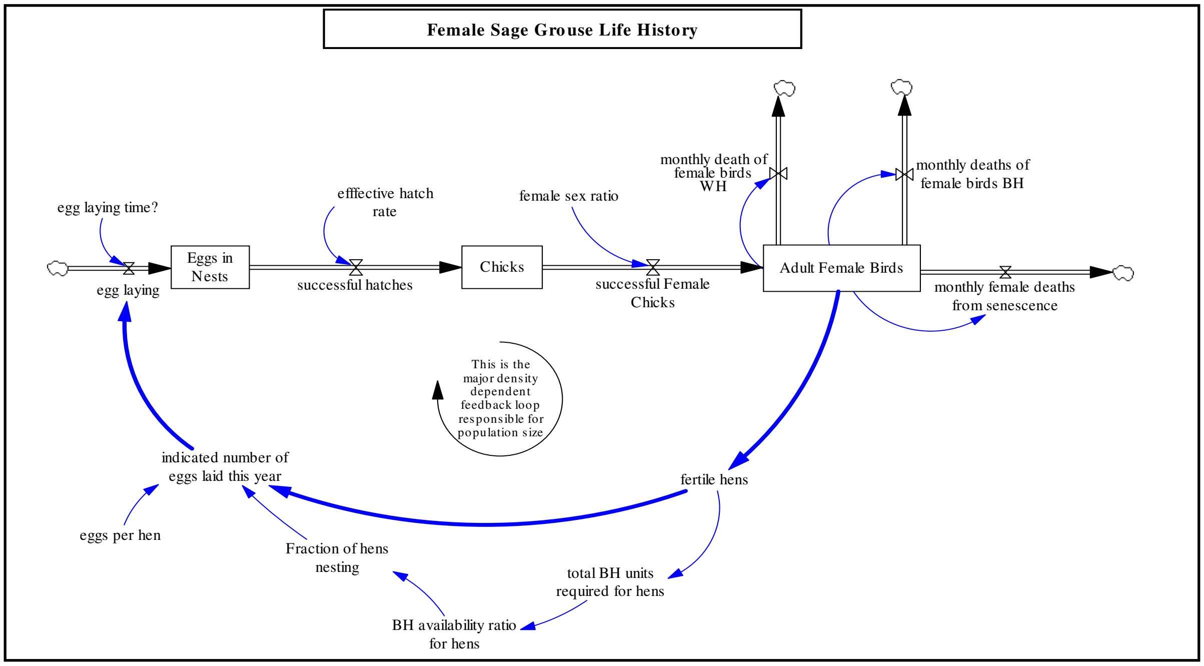

Figure 7. Female Bird Life History and Reproduction

Illustrative Results

Exploring Sage-grouse Demographics

Current demographic rates in Douglas County are favorable for the continued persistence and growth of the sage-grouse population. Productivity is high and female mortality is low compared to other studies (Connelly et al. 2004). The model population responds positively to increases in habitat quantity or quality. However, demographic parameters are not givens, but rather they are estimates with an associated standard deviation and may change over time with changing environmental or other conditions, such as an Allee effect[6]. Sensitivity analysis has shown that the model is sensitive to changes in certain demographic rates. Sensitive parameters are chick survival, female mortality, percent of successful females (*i.e.*, females that have more than 1 chick) and eggs/nest. The systems analysis of these parameters was conducted by discovering a critical or threshold value for each, defined as the value at which the sage-grouse

[6] Allee effects are an inverse density dependence that influences reproduction when a population falls below a critical density that is required for the stimulation of breeding (Akcakaya et al. 1999). It can be very important in species that have a socially structured mating system (Ebenhard 2000). It is also inclusive of any combination of factors that cause the growth rate of a population to decline as it gets smaller. Several things can occur in small populations including an inability to find mates or not enough animals to stimulate a breeding response. Also, if predation is constant, species in a declining population are subjected to greater and greater risk. At some point, reduced fitness and inbreeding depression can also occur. Declines in breeding success can cause further declines in population size and coupled with demographic stochasticity, leading to what is termed the extinction vortex. In sage-grouse, the social structure associated with the lek mating system might begin to break down in a declining population causing a lower percentage of females to be successful.

population began to decline. Each sensitive parameter was explored independently of the others. For example, the annual chick survival rate is 0.167. Chick survival is an adjustable slider set at the default position of 0.167 on the Sage Grouse Life History interface. By decreasing chick survival in small increments, it was found that the trajectory of the grouse population began to decline at a value of 0.128 (see Figure 8). This is a very small downward change in the survival rate (approximately .04) and shows the sensitive nature of this parameter. The specified amount of change is well within the standard deviation assigned to that rate, and therefore, this threshold value should be considered as a possible annual rate for any year. Chick survival is the only parameter with a threshold value that falls within the standard deviation of its rate, although eggs/nest is very close. The model indicates that chick survival is the most critical parameter, which coincides with other analysis, with the literature cited above and expert opinion (Schroeder, per.com. 2005). The same type of analysis was done for the other 3 sensitive parameters. Results are in Table 1.

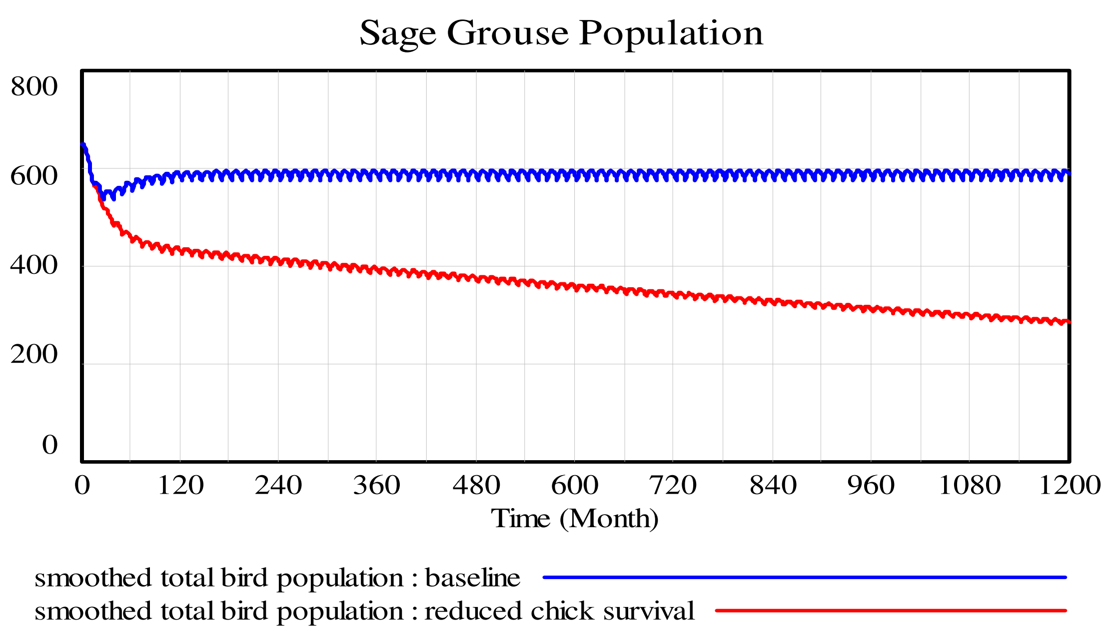

Figure 8. Response of the Douglas County Greater sage-grouse population to a downward change in the annual chick survival rate from the baseline model value of 0.167 to a critical value of 0.128. The critical or threshold value was found by experimentally decreasing the survival rate until the population trajectory began to go negative.

Parameter	Model Value	Threshold Value	Difference	Standard Deviation
Chick Survival	0.167	0.128	~0.04	0.10
Female Mortality	0.25	0.36	.09	0.068
Fraction of Successful Females	0.59	0.45	0.14	0.10
Eggs/nest	9.1	7.0	2.1	2

Table 1. Threshold values for sensitive parameters in the systems model of the Douglas County Greater sage-grouse population**.**

There are also synergistic effects when more than one demographic rate changes at the same time. Small (and declining) populations are subject to an inverse density dependence known as the Allee effect which is any factor, or more likely, combination of factors that cause the growth rate of a population to decline as it gets smaller. The systems model allows the user to change several demographic rates at the same time to simulate the decrease in productivity and survival normally associated with declining populations. For example, the 4 sensitive demographic rates were reduced concurrently by 10%. Results are in Figure 9 and show the population in serious decline.

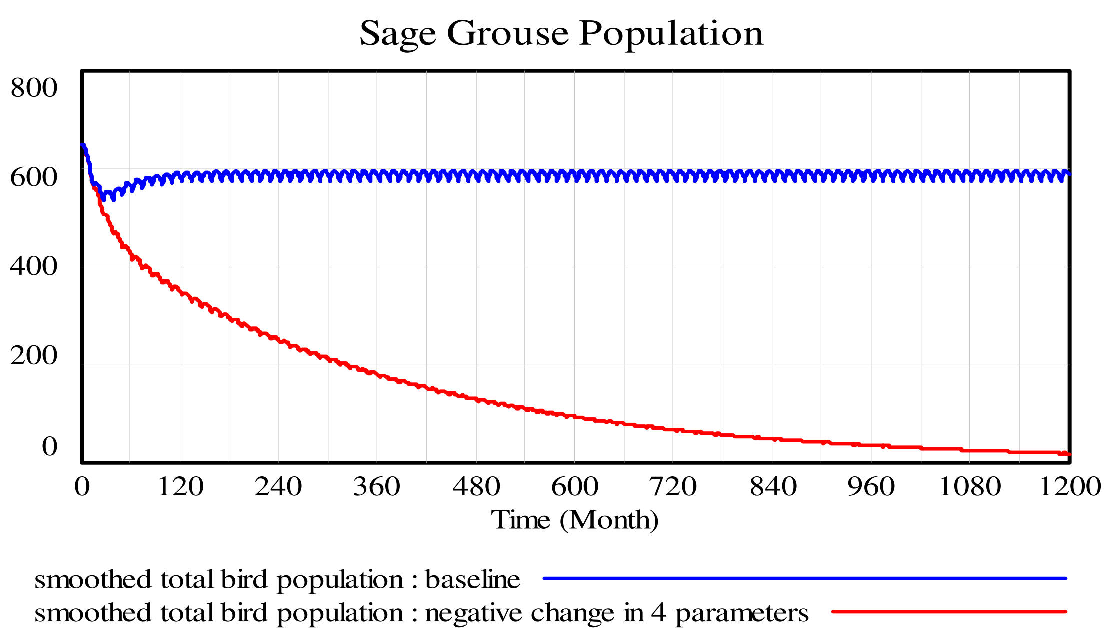

Figure 9. Synergistic response of the Douglas County Greater sage-grouse population to a negative change of 10% in the four sensitive parameters, chick survival at 0.15, female mortality at 0.275, fraction of successful females at .53, and eggs/nest at 8.2.

Exploring Land Use Changes

The systems model allows users to investigate the effects of potential land use changes on the sage-grouse population. Model users have been supplied with sliders for many parameters that can be used alone or in combination to investigate possible future scenarios. Population projections resulting from the inclusion of land in the HCP are shown in Figure 10.

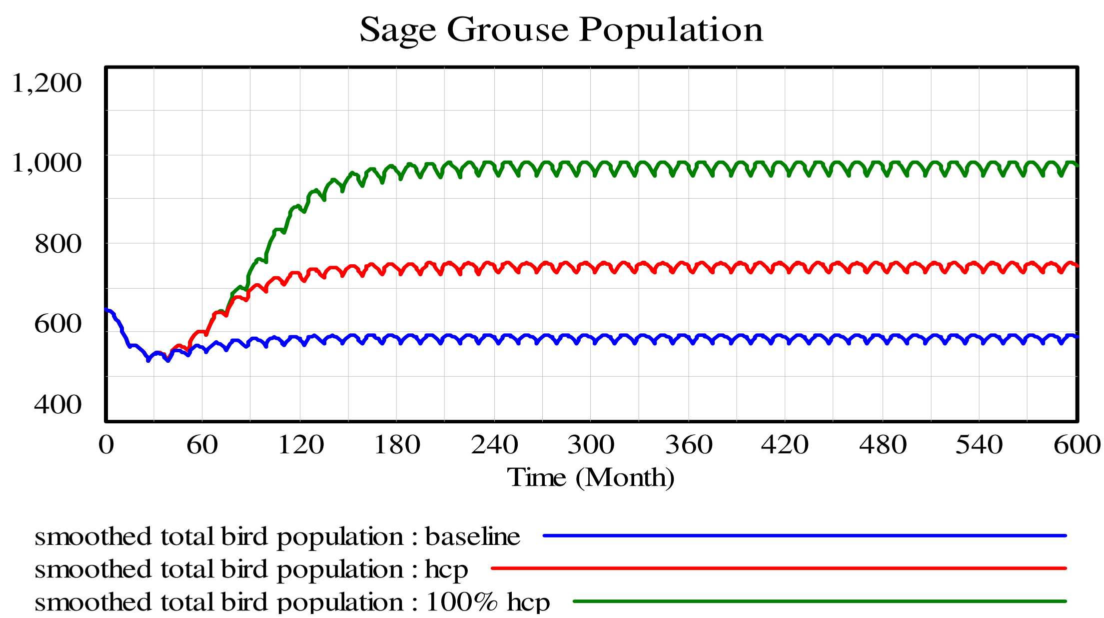

Figure 10. The effect of HCP inclusion on sage-grouse population showing a potential population of up to 1,000 birds. (HCP 0%, is equivalent to a baseline sometime in the future[7]).

One of the biggest concerns voiced by FCCD was related to losses in the amount of land under CRP contract. A specific 8% of CRP land has become critical nesting habitat for sage-grouse and is under threat of removal from the CRP program. We used the model to simulate these losses. It also simulates potential mitigation for these losses with inclusion of land in the HCP. The blue line is again the baseline or current condition in Figure 11. The green line illustrates an 8% loss range wide (includes CRP in cropland). The grey line illustrates an 8% loss just in shrub steppe landscape CRP. And, finally the red line is total loss of CRP. Figure 12 illustrates that a loss of 100% of the CRP can be more than offset by inclusion of half the land in HCP.

[7] HCP 0% is equivalent to a baseline sometime in the future for two reasons. 1) Recently improved management practices in the shrub steppe will provide for better habitat suitability. And 2), CRP contracts were initiated in 1997 and 1998. Additional time will allow the habitat in these areas to mature, again improving suitability.

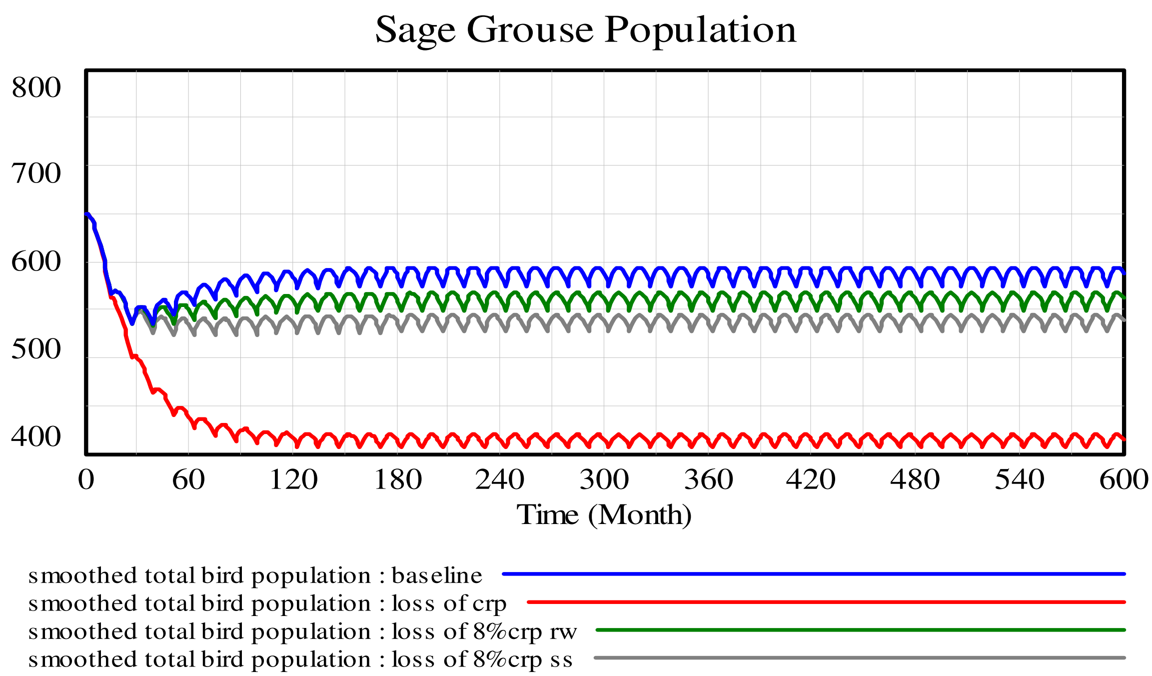

Figure 11. An illustration of the effect of CRP loss on sage-grouse population. RW is rangewide, SS is shrub steppe.

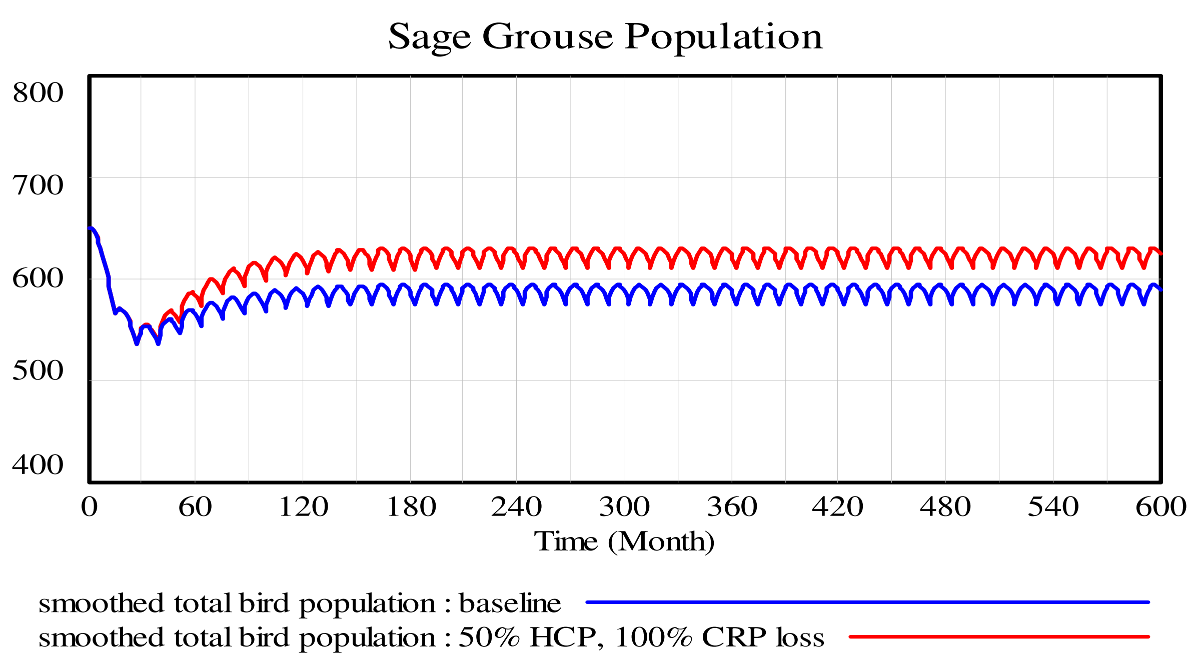

Figure 12. 50% inclusion in HCP can offset the effect of 100% loss in CRP on sage-grouse population.

Environmental Variation

Biologists, managers and people who make their living from the land know that productivity of land and therefore its carrying capacity changes from year to year, in large part due to variations in local weather patterns. Sage-grouse populations tend to fluctuate in approximately 10 year cycles (Connelly et al. 2004). The FCCD group requested that this type of variability be included to add more realism to the model. Due to the lack of data on these cycles, variability was determined by a loose correlation with historic rainfall which did not specifically show a ten year cycle. We took the high and low values over a 100 year period, and added a random function to select a value within that range for any given year. The rainfall value was linked to habitat by causing the number of habitat units to expand when rainfall was above the long-term average and to shrink when it was below that average. The resulting output did show a cyclic behavior in the sage-grouse population, but not at the expected interval (Figure 13). It was decided by the group that such added complexity did not really aid in understanding their system at this time. Other forms of adding variability are being considered for future work.

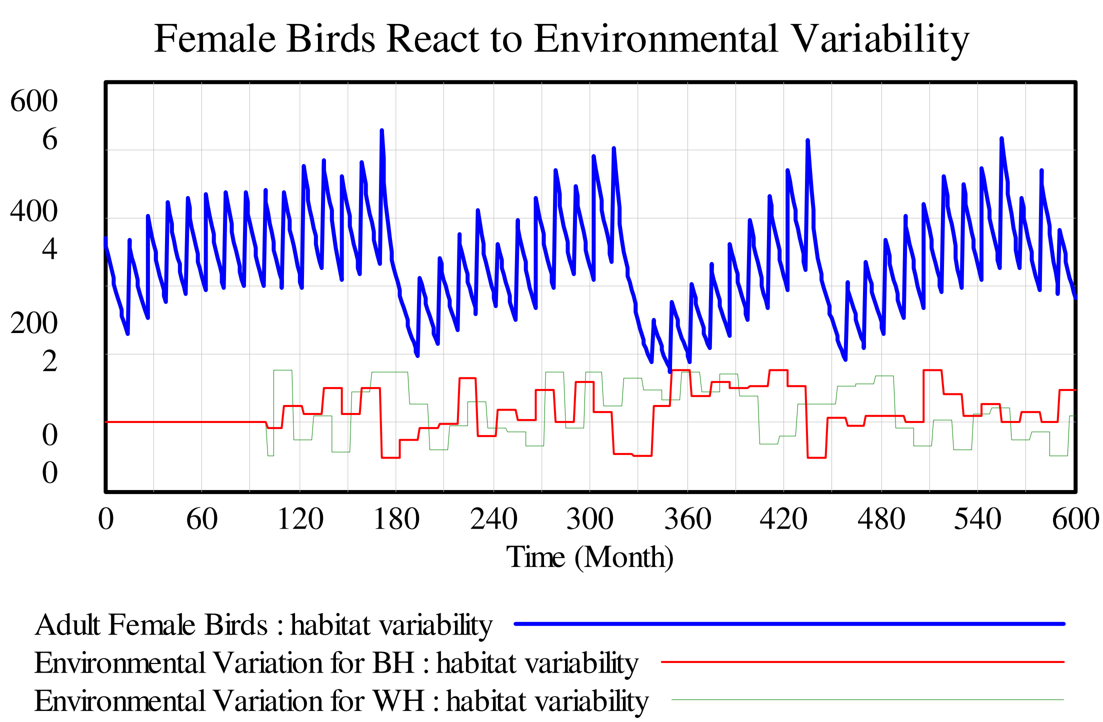

Figure 13. Environmental variability was added to both breeding habitat (BH) and winter habitat (WH).

Concluding Discussion

When we arrived at our first meeting with the FCCD, we had very little knowledge of Douglas County or the problems faced by landowners. We only knew that FCCD was concerned about their sage-grouse. Throughout the next 12 weeks, group members educated us about the nuances of their concerns, provided expert data and the context in which it was gathered and analyzed, and they gave us a look inside the lives of the people who call the sage-grouse country of

Douglas County home. They invited us to use our skills as model builders to help them synthesize a variety of data types into one context which would allow them to investigate the connections and feedbacks in their system. Furthermore, they understood that a variety of concerns must be addressed for ecosystem management to be successful.

The model was delivered in its present form to the Foster Creek Conservation District in November of 2005. It has been designed to help develop instincts for adaptive management of the complex sage brush steppe and cropland ecosystems that are home to the sage-grouse of Douglas County. It combines sage-grouse biology with land use patterns to simulate the response of the birds to current and future management decisions. It was designed to be self contained and available to all interested parties in the sense that users do not need the modelers present to operate the model. The FCCD participants appreciate that the model is not designed to predict any specific values or points in time. Rather, the goal is to indicate potential trends in the sage-grouse population based on past and present data. The model is designed and should be used for combining and computing data into an illustrative representation of a complex system. Models are valuable because they simultaneously compute a myriad of parameters and relationships and can simulate system trajectories under various conditions. Models also offer a step up from decisions made on "gut feeling" by allowing those feelings to be tested and evaluated.

As we assimilated FCCD data into the systems model we tried to anticipate the questions that would be asked of the model as well as the reactions of the working group. Experience tells us that as users explore a model they will inevitably want to start making improvements. Potential improvements suggest that we have encouraged people to better understand a system that is important to them. Adaptive management suggests that humanity take a holistic view of its surroundings, to learn about the parts as they are related to the whole, and to understand the dynamic interactions of those parts as they work together in a system. It also suggests that when new information is gained, and better options discovered, that better management should follow.

This well tested model structure offers a base on which additional concerns may be layered; it may be easily updated as new information becomes available. We have discussed adding additional economic components, more ranching concerns, and a "more methodical process to quantify suitability indices" (Dudek pers. com.). FCCD is also working on a remote sensing project to help them monitor habitat. This data may be used to update the model as habitat changes occur. Additionally, the land use template of the model may be adapted and applied to other species of concern in Douglas County.

We will soon be conducting interviews with FCCD members to assess the model and modeling process to date. We will continue to document the model, the process and its usefulness to the management objectives of the Foster Creek Conservation District Multi Species Habitat Conservation Plan.

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