SCALE Annual Report – 2002-2003

Research and Education Activities

Research Objective 1: Case Study Synthesis and Comparisons
Objective: *Develop a state-of-knowledge publication on complexity, scale, and fragmentation.*

In this research objective the goal is to 1) synthesize what we know about the drivers of fragmentation, the nature of fragmented landscapes and how ecosystems and people respond to those changes within sites and across sites, 2) present what is known at a workshop, and; 3) publish the findings in an edited volume. To this end we organized a SCALE workshop at Ithala Game Reserve, South Africa, July 22-24, 2002. In the workshop, site level syntheses and site-level analyses were presented as potential book chapter outlines (they follow below). Before the workshop we were in contact with Kluwer Publishers and they were interested in publishing our book. In September we sent them a book proposal for review. The book proposal is currently under review and we should know in the next couple of months the outcome of their deliberations.

The book is titled: <u>Fragmentation in Semi-arid and Arid Landscapes: Consequences for Human and Natural Landscapes</u>. A summary of the book's main themes, arguments and objectives is below, with the book outline following.

One quarter of the earths land surface is composed of rangelands and the preponderance of these lands support pastoral economies. Historically, the use of rangelands by pastoral people and their livestock was communal, allowing wide-ranging movement of people and their herds under common property rules. More recently, global trends favoring exclusivity of use of land (e.g., land privatization) has fragmented these systems, compressing the scale of interaction between pastoralists, large herbivores, and plant communities. Fragmentation of arid and semiarid grazing lands is caused by a complex, but discordant, set of interactions involving ecosystem spatial properties, economic concepts and initiatives, and legal-political constraints on land tenure and land use. We develop the argument that the compression of interactions resulting from global fragmentation of drylands has fundamental consequences for the operation of pastoral economies and the ecosystems supporting them.

Arid and semi-arid land (ASAL) ecosystems are characterized by temporal and spatial heterogeneity in plant communities and production. Temporal heterogeneity arises from unusually large annual and seasonal variation in precipitation, which drives yearly and seasonal differences in plant production. Production of plant biomass during any one year in ASAL ecosystems can depart from the long-term average by orders of magnitude. Spatial heterogeneity in plants results from variable patterns of soil, precipitation, temperature, topography and land use. As a result of these patterns, ASAL ecosystems contain mosaics of vegetation, the diversity of which depend on the spatial variability in soils and the other variables above.

A central thesis of our book is that access to spatial heterogeneity in resources allows people and animals to respond to heterogeneity in time. Selective use of landscapes composed of diverse vegetation mosaics allows human and animal consumers (livestock and wildlife alike) to exploit pulses of plant growth when and where they occur. Exploitation of abundant resources, when they are available, creates a buffer against future adversity by allowing animals to grow and reproduce at an elevated rate. More importantly, pastoralists can partially compensate for episodic resource shortages by using areas of the landscape containing resources that are most stable in time—for example swamps and riparian areas during droughts. Restriction of movement by people and animals can prevent access to these key resources.

We show that ecosystem fragmentation and the ensuing restriction of access to heterogeneity can interfere with ecosystem function and can reduce the capacity of ASAL ecosystems to support ecological communities, social structures and economic activities. As a result, many of the world's ASAL ecosystems are dysfunctional to varying degrees. Dimensions of dysfunction vary from place to place, but include: increasing conflicts between wildlife and humans; wide-spread rangeland degradation in East Asia; increasing levels of poverty among pastoral people in Africa; the decline of rural livelihoods in the rangelands of Australia and the western US; wholesale collapse of grazed systems in Central Asia; and global-scale outbreaks of livestock diseases ('mad-cow,' foot and mouth disease) in confined industrial livestock enterprises.

Using information from 12 sites in Africa, Asia, Australia and North America we will examine how fragmentation occurs, the patterns that result, the consequences of fragmentation for ecosystems and the people who depend on them for their livelihoods. We begin the book with a discussion of the concept of fragmentation. The following four chapters bring together what is known about the human drivers of fragmentation, how to compare heterogeneity among sites, how pastoralists respond to land fragmentation, and finally, how large herbivores respond to landscape heterogeneity at multiple scales. The remaining chapters are case studies, providing detailed examples of the patterns discussed in the opening synthetic chapters.

Book Outline
Fragmentation in Semi-arid and Arid Landscapes: Consequences for Human and Natural Systems
Kathleen A. Galvin, Robin Reid, Roy H. Behnke and N. Thompson Hobbs, eds.

Part I. Framework

Chapter 1. Fragmentation of Arid and Semi-Arid Landscapes
N. Thompson Hobbs and Robin Reid

Humans have many impacts on the environment, but one of the most pervasive is fragmentation, the dissection of landscapes into spatially isolated parts. The central thesis of this book is that fragmentation of arid and semi-arid ecosystems has similar consequences caused by similar mechanisms throughout the world. This chapter will introduce a conceptual model (see Figure 1) of the operation of fragmenting forces in arid and semi-arid lands and their consequences for human and natural systems worldwide. This chapter will also introduce central concepts in the book, including fragmentation, landscape heterogeneity, and selectivity. Fragmentation has been a very useful concept when applied to conservation of populations of plants and animals worldwide. However, despite the importance of the fragmentation concept at the level of populations, there is very shallow understanding of the causes and consequences of fragmentation for ecosystem processes and for the interplay between those processes and human welfare. This book offers one of the first demonstrations of the effect of fragmentation on ecosystems and on people who are a part of those ecosystems.

Part II. Issues of Fragmentation and Complexity: A Synthetic Perspective

Chapter 2: The Drivers of Fragmentation Processes in Semi-arid and Arid Landscapes
Roy H. Behnke and Mark Stafford Smith

This chapter examines the institutional and economic factors that cause fragmentation and discusses the impact of fragmentation on economic inequality in pastoral societies. The investigation is organized around five hypotheses, three of which distinguish different trends for or against fragmentation in industrializing, post-industrial, or ex-socialist pastoral economies, and two which pertain to the conditions that limit fragmentation and the effects of fragmentation on economic inequality. The proximate drivers of fragmentation are diverse - pressure on resources, technical changes, price fluctuations, cultural aspirations, and warfare - to name a few examples. The manner in which these variables interact to drive fragmentation is complex; the variables are not commensurate in the way they influence fragmentation, and their importance shifts over time and from case to case. Developing a 'global' catalogue of these drivers is unlikely to yield a systematic understanding of fragmentation processes. It is instead useful to view fragmentation as driven by divergent interests and interest groups. These issues related to drivers of fragmentation will be discussed in this chapter.

Chapter 3: Comparing Landscape and Socioeconomic Heterogeneity Within and Between Ecosystems
Randall B. Boone and Shauna B. BurnSilver

There is a growing need to compare patches within ecosystems and ecosystems across continents. Analyses of ungulate movements within landscapes, and of settlement and sedentarization patterns, require useful measures of heterogeneity. Likewise, analyses of fragmentation (both landscape and economic) require comparisons that use standardized data layers. With the rapidly growing availability of ‘Earth observing’ data layers, especially global layers, quantitative comparisons of complexity across continents is becoming more inexpensive and thorough. This chapter will provide descriptions of how measures of heterogeneity (both landscape and socio-economic) may relate to ecosystem function, and how landscape heterogeneity contributes to socio-economic heterogeneity, and vise versa.

Chapter 4: Responses of Pastoralists to Land Fragmentation
Kathleen Galvin and Carol Kerven

This chapter discusses how societies respond to land fragmentation, namely how they continue to obtain plant resources in an environment that lacks spatial heterogeneity. Institutions that either constrain or enhance an individuals/social groups’ ability to deal with fragmentation will also be discussed. These issues will be discussed in a political economy and cultural capital framework. It is hypothesized that groups which borrow from a wide array of cultural traditions have a richer cultural capital, and therefore, a wider range of adaptive options to respond to feedback from the environment.

Chapter 5: The Importance of Spatial Scale, Movement, and Heterogeneity in Ecosystems with Large Herbivores
Michael Coughenour

This chapter seeks to explain how and why movement is important to herbivores, herbivore interactions with ecosystems, and ecosystem dynamics. The habitats of large herbivores are often spatially and temporally variable with respect to a variety of factors. This variability occurs at multiple scales. Large herbivores exhibit a variety of movement patterns at multiple spatial scales in order to find resources in temporally and spatially variable environments. These movements can be viewed as multi-scaled foraging behaviors, but other resources such as water and land cover are also important. Herbivore populations, and livestock production, are affected by the ways that spatially variable resources are utilized. The effects of herbivores on plants and soils are also affected by herbivore movement. Human population growth, land use, and land tenure have markedly altered both the spatial distributions of resources and herbivore movements. This has significant implications for wild herbivores, livestock-based food production systems, and ecosystems. This chapter will discuss large herbivore foraging at different scales, links between habitat selection and dietary selection, plant, soil, and ecosystem responses to herbivory, and responses of plants to climatic spatio-temporal variations. The chapter will conclude with a discussion of foraging and movement modeling approaches and challenges.

Part III. Case Studies

Each case study chapter will describe the drivers, processes, and patterns of land fragmentation (and reaggregation at some sites) at the site and the resultant ecological and human responses and consequences. A historical legacy of land use, land use change, and land tenure will enhance each chapter. Each chapter will be based on the same conceptual framework (Fig. 1), however, authors can draw in additional information where needed to fully explore relevant issues in each site.

Africa

Chapter 6: Fragmentation in Privatized Rangeland in the Kitengela Ecosystem, Kenya
Robin Reid, Patti Kristjanson, Nkedianye, Gichohi, Mrigesh Kshatriya

Chapter 7: Habitat Loss and Fragmentation in a Sub-humid Savanna on the Brink of Privatization, Mara, Kenya
Robin Reid, Lamprey, Ogutu, Mike Rainy, Suzanne Serneels, and Ole Kamuaro

Chapter 8: Amboseli
Shauna BurnSilver, Jeff Worden, Randall Boone

Chapter 9: Ngorongoro Conservation Area (NCA) and Loliondo, Tanzania
Kathleen Galvin

Chapter 10: South Africa
Kathleen Galvin

Australia

Chapter 11: Changing Patterns of Land Use in Dalrymple Shire, Australia
Chris Stokes, Ryan McAllister, Andrew Ash, D. Mark Stafford Smith

North America

Chapter 12: Northern Great Plains Land Tenure and Land Use Histories: A Case Study of Reaggregation of Rangelands
Jill Lackett and Kathleen Galvin

Chapter 13: A Case History of Land Tenure and Land Use in the Jackson Valley, USA
N. Thompson Hobbs

Asia

Chapter 14: The Shifting Balance Between Migratory and Settled Pastoralism: Land Tenure and Livestock Mobility in Kazakhstan
Ilya I. Alimaev and Roy H. Behnke

Chapter 15: Land-use Change in the Mongolian Landscapes: Consequences for Human and Natural Systems
Togtohyn Chuluun and Dennis Ojima

Part IV. Conclusions

Chapter 16: Do varying histories produce similar fragmentation outcomes (of scale of use and exclusivity of land use) for humans and ecosystems?

Literature Cited

Research Objective 2: Complexity Framework and Analysis
Objectives: *Develop a framework for complexity analysis, apply to all sites, and determine herbivore access to complexity for fragmented and un-fragmented grazing orbits (in conjunction with RO 4).*

Activities have focused upon creating a framework for allowing the heterogeneity of SCALE sites to be compared and contrasted, with some work done on herbivore access to heterogeneity based upon information from the literature. The boundaries of the bulk of the SCALE sites have been defined. Globally-available spatial data sets have been acquired and converted into an organized geographic information system. A new method of quantifying broad-scale access by ungulates to green forage was developed. A detailed outline of a book chapter reporting analyses has been written and reviewed by SCALE personnel. K. Price of Kansas Applied Remote Sensing, University of Kansas, is creating 1 km NDVI images of East Africa from 1990 to 1999. Lastly, following the failure of a hard drive containing the large spatial databases used in these analyses, a more rigorous backup procedure using multiple hard drives was implemented.

Research Objective 3: Herbivore Selection at the Paddock Scale
Objective: *Determine the effects of pasture size on animal diet quality and performance.*

The aim of the activities covered under this objective is to test whether seasonal variation in the diet quality of cattle is influenced by the sizes of paddocks and the complexity of vegetation enclosed within them. We hypothesize that large paddocks and complex mixes of vegetation provide greater opportunities for selectivity in animal diets allowing them to better regulate their nutrition, particularly during the dry season when dietary protein levels typically fall below maintenance levels.

To address this question we are using near infra-red spectroscopy (NIRS) analysis of fecal samples to quantify seasonal variation of diet quality in paddocks of differing sizes and vegetation complexity in the Dalrymple Shire, northeast Queensland, Australia. So far, we have selected 35 paddocks from 18 properties in the Shire (Fig. 2). Participating property managers have been providing fecal samples for analysis at two-monthly intervals since October 2002.

Paddocks have been selected according to the following criteria, in collaboration with property managers:

- the paddock must be managed as a discrete unit (with minimal transfers of stock in and out of paddocks and well-maintained boundaries that limit movement of stock between paddocks);
- the stock in the paddock should be of one type, preferably breeders;
- stocking rates within paddocks should also be as constant as possible;
- paddocks should preferably not have any introduced exotic forage species;
- paddocks should be accessible all year round for collection of fecal samples.

Within these constraints, a set of paddocks have been selected to cover a range of sizes (from 600 to 27,000 ha) and differing degrees of landscape complexity. Samples were further stratified across three broad geologic land types differing in their levels of soil fertility. We hope to build the number of paddocks in the study up to 50 over the coming year.

For each paddock we will develop measures of landscape heterogeneity from remotely-sensed data and use these to explore which elements of complexity in landscapes could be beneficial for animal diet selectivity.

Research Objective 4: Herbivore Movements in Fragmented vs. Intact Ecosystems
Objective: *Determine effects of fragmentation on herbivore access to ecosystem complexity.*

1. Assessment of the effects of landscape fragmentation on the movement of pastoral livestock herds in the Kitengela and Mara ecosystems (Kshatriya, Nkedianye, Reid) (fully funded by the NSF SCALE grant)

Research activities are related to determining the effects of habitat on the movement of pastoral livestock herds as a result of anthropic and natural modification of the environment. Here, fragmentation is taken to be some factor limiting access to vegetation. In particular, this study focuses on considering the effect of fragmentation with the presence/absence of fencing and the presence/absence of a high number of wildebeest on the movement patterns of cattle.

The two study sites are located in Kitengela and Maasai Mara ecosystem. Five herds are tracked in the Kitengela area, staring from March 2003 to present. The five herds range in size between 45-200 head of cattle. As of now a total of 200 grazing orbits have been recorded, for rangeland conditions related to late-dry season to early wet season. The grazing orbit data consists of the GPS location, recorded automatically every minute. In addition to position data, the herders recorded the location of the nearest fence and wildlife every ten minutes. At this study site the level of fragmentation is quantified by the rate of encountering fences. Preliminary results shows the grazing orbits are more convoluted and crossover more frequently in areas where fencing limits access to vegetation. In such areas, the velocity at which the herd moves over the landscape is much faster than in areas that are more open and less restrictive as to where the animals can move. We also show that the total distance covered by the herd decreases at the onset of the rains, when rangeland conditions begin to improve in both fragmented and un-fragmented areas.

2. The effects of pastoralism on the density and distribution of carnivores and their prey in the Mara Area of Kenya (Ogutu, Reid) (partially funded by the NSF SCALE grant)

In East Africa, grazing by pastoral people fragments landscapes for wildlife. Carnivores are particularly affected because people actively chase predators away from their flocks both at night and during the day. We conducted a playback survey of lions (*Panthera leo*), spotted hyenas (*Crocuta crocuta*) and black-backed jackals (*Canis mesomelas*), and a transect count of wild herbivores in the Maasai Mara National Reserve (non-fragmented landscape) and adjoining pastoral ranches (fragmented landscape) to assess the effect of pastoralism on the density, distribution and behavior of carnivores.

3. Census of the impacts of pastoralism and protection on the abundance and distribution of wildlife, livestock and people in the Mara ecosystem (partially funded by the NSF SCALE grant)

The objective of this research was to develop a fine-resolution understanding of the spatial interactions among people, livestock and wildlife in moderately fragmented pastoral landscapes (group ranches) and un-fragmented protected landscapes (the Mara National Reserve). Preliminary finding are discussed in the findings section below.

4. Synthesis paper of state of knowledge on fragmentation in East African pastoral systems (Reid, Thornton, Kruska) (partially funded by the NSF SCALE grant).

We wrote this paper to explore the relatively uncharted land of rangeland loss and fragmentation. In this paper, we discuss the causes and consequences of habitat loss and fragmentation from the perspective of people, their livestock, and wildlife (particularly charismatic mega-fauna). We do this first by developing a conceptual framework for rangeland loss and fragmentation and then by using three case studies to illustrate the ecological and economic consequences of these changes. We then present a preliminary map estimating where loss and fragmentation may be occurring in African rangelands today. We then highlight unresolved issues that require further thought and testing.

Research Objective 5: Typology of Actual Land Use Patterns
Objective: *Develop a standard format to differentiate and compare land use patterns and management scales within and across study sites.*
Research Objective 7: Factors Driving Contemporary Trends in Land Use Change

Objective: *Investigate how ecological, political, and socio-economic factors interact to influence individual land use decisions.*

Roy Behnke, Iliya I Alimaev and A Smaileov spent one month in Almaty, Kazakstan, in August and September 2002, reviewing historical and archival material in Russian on the changing scale of pastoral movement in Kazakstan from the period before Russian contact (circa 1700) to the present. Roy Behnke then spent an additional month analyzing this material and drafting a chapter for the up-coming SCALE book.

Roy Behnke, Carol Kerven, Iliya Alimaev and Sayat Temirbekov participated in the SCALE meeting in South Africa in July 2003. These discussions resulted in two chapter outlines for the SCALE book. One of the proposed chapters is a Kazakstan case study, "The shifting balance between migratory and settled pastoralism: Land tenure and livestock mobility in Kazakstan" by Alimaev and Behnke. A second overview chapter is titled "The drivers of fragmentation processes in semi-arid and arid landscapes" by Behnke and M Stafford Smith. Work on this chapter will begin in January 2004.

Research Objective 8: Economic Surveys and Analysis
Objectives: *Gather information on household economic performance and the economic dimensions of livestock production systems in relation to scale and resource access.*

Activities for this objective involve gathering data on household economic performance and the economic dimensions of livestock production in relation to scale and resource access. Survey data and secondary sources are being used to assess household economic viability, spatial resource access patterns and level of material subsidy. The major objective of this RO is to provide adequate information to enable relatively simple socio-economic modelling to be carried out in tandem with the Savanna ecosystem model. Scenario analyses can then be undertaken to look at the interactions between ecological complexity and household well-being in case-study environments.

Kajiado

During the year, data collection was essentially completed for the Kajiado case study. These data have contributed to a typology of households in the study area, each with access to different types and amounts of resources, and different levels of agricultural and non-agricultural enterprise diversification. Rules governing the allocation of resources at the household level, and the purchasing and selling of livestock, were derived from the survey data.

In early 2003, some additional information was collected from the group ranches in the study area concerning access to resources and household types, so that the entire study area could be classified in terms of the eight household types defined from the detailed household survey work. The information collected related particularly to group ranch membership and land use, and commodity prices in the local markets.

The PHEWS model for Kajiado was then reprogrammed, building on the version of the model constructed for the case study carried out in northern Tanzania earlier. Once the model had been calibrated, a series of scenario analyses was carried out to look at fragmentation issues, and these are currently being written up.

Kazakstan

The information from the questionnaire on household income sources was processed and analyzed, and this information will contribute towards a household model for this study area. The questionnaire was carried out as part of the Desertification and Regeneration: Modeling the impact of market reforms on Central Asian rangelands (DARCA) project.

Research Objective 9: PHEWS (Pastoralist Household Economic Welfare Simulator) Model Assessments
Objective: *Determine economic-ecological interactions resulting from alternative land use practices.*

Kajiado

The information collected in RO8 was used to specify the PHEWS model for Kajiado. PHEWS tracks both cash and calories in households. Depending on a household's activities and resources, dietary calories will be available in terms of milk and meat, bought tea and sugar, and maize, beans and vegetables produced on the household's own agricultural plots. If the household has cash, maize calories can be purchased from outside, if needed. If a household still has a need for calories, but does not have adequate cash, then these have to come from sources external to the household. These "external" calories, which may refer to gifts from friends and relatives, exchanges, or drought relief, are an important indicator of household food security in the model.

Cash flow is tracked in each of the 24 household types each month. Income arises from wage income, livestock trading, and any other business, and from sale of milk, of crops, and of livestock. In many households, some of these will not apply. Expenditures per month are assumed to be on tea/sugar, crop inputs, veterinary inputs, and general expenses, including school fees. All households' cash flow is calculated each month, and spare cash is stored for consumption in subsequent time periods.

Crop and livestock management are handled in a simple way in the model. All households have recurring monthly veterinary costs, which vary by wealth level, and the level of cropping inputs used also varies by wealth level. Animals are sold when there is a substantial cash need. If the cash need is relatively small, then a sheep or goat is sold. For a larger cash need, such as school fees, a large ruminant is sold, and a sheep or goat bought at the same time.

Once the model was built and data input files constructed, the model was calibrated. In this context, calibration refers to the process of balancing the model, because of the large uncertainty associated with many of the input data. It is clear that in reality, household expenditures generally have to balance household income fairly closely, and the model has to reflect this.

Research Objective 11: Spatial Complexity, Temporal Variability and Population Patterns
Objective: *Develop competing models linking animal populations to spatial complexity.*

Main question to address
How does spatial heterogeneity interact with density dependence and climate to affect the dynamics of ungulate populations?

Hypotheses
Increasing spatial heterogeneity would mitigate the adverse impacts of climate on ungulate population dynamics and reduce intra-specific competition of ungulates through spatial diversification of resource distribution.

Modeling approaches

1. Use the Gompertz population model to describe the dynamics of ungulate populations with average temperatures and precipitation of growing and dormant seasons as covariates.
2. Apply the Kalman filter, which is built on the basis of the Gompertz mode, to time series data to separate the process and measurement errors and correct for the bias in the estimates of the Gompertz model parameters caused by measurement errors.
3. Run multiple regressions of density dependent coefficients and weather coefficients over latitudes, coefficient of variation of topography of sites where data were collected, and of female body mass.

Collection of times series of ungulate
The database has a collection of 11 series of ungulate data from Europe, 18 from North America, and 14 from Africa (43 in total). Two criteria were applied to data collection:

1. At least 20 years of survey data
2. 2-3 missing data points

Research Objective 12: SAVANNA-PHEWS Complexity-Fragmentation Experiments
Objective: *Model effects of fragmentation on ecosystems and people.*

Great progress has been made on several fronts in using SAVANNA and PHEWS in modeling, with the focus on southern Kajiado District, Kenya. In southern Kajiado District, we assessed a series of questions of interest to land managers and pastoralists, most dealing with effects of fragmentation on wild or domestic ungulates and Maasai households. In Ngorongoro Conservation Area, Tanzania, effects of cultivation on ungulates were modeled. Finally, in the North-West Province of South Africa, effects of more variable climate on livestock production were assessed.

Research Objective 13: Complexity and Fragmentation in Theoretical Ecosystems
Objectives: *Study general responses of ASAL ecosystems to fragmentation.*

An application of the SAVANNA Modeling System was adapted to simplify it (and the interpretation of results) and detach the application from a spatially explicit location. The application was used to assess the effects of fragmenting a 300 km^2 block of land into parcels of decreasing size, down to thirty 10 km^2 parcels. In other activities, a method was developed to rigorously modify rainfall patterns to yield coefficients of variation of a desired percentage. Analyses using modified rainfall patterns will be important activities in the coming year.

We have also developed a strong mathematical argument that the isolating effects of fragmentation will reduce the abundance of populations of consumers in general, and large herbivores in particular. We are now drafting a manuscript reporting this work, a manuscript that will be submitted to *Science* before the first of the year. This manuscript will form the theoretical foundation for all of the results in the SCALE project.

Research Findings

Research Objective 1: Case Study Synthesis and Comparisons

Work in ongoing on writing book chapters for the SCALE synthesis book. Synthesis chapters are being written using information from the case study chapters.

Research Objective 2: Complexity Framework and Analysis

The 22 SCALE sites (Fig. 3) (21 as proposed plus the Central Plains Experimental Range, Colorado, which was added in 2003) were defined based on political boundaries (e.g., counties, conservation area boundaries, fenced paddocks, or ungulate ranges). The sites vary considerably in size, from the Central Plains Experimental Range and the Lowveld Game Ranches at less than 100 km^2 to five townships in the North-West Province, South Africa, totaling 49,222 km^2. Boundaries for Kazakhstan and Turkmenistan study areas are still in development, study areas within Mongolian aimags are being refined, and paddock fences for Australian sites are being digitized.

The USGS HYDRO1K digital elevation model database has been put in-place, with the GTOPO30 data used for Australia, where HYDRO1K was not prepared. We monitor the more highly resolved Shuttle Radar Topography Mission for progress on its release to the public, but as of now, only the western hemisphere is available. The 8 km resolution Pathfinder AVHRR Normalized Difference Vegetation Indices (NDVI) data have been merged into our GIS, but have become a secondary source. Instead, we now use the NASA Global Inventory Monitoring and Mapping data, which is based upon the same AVHRR data, but has multiple corrections applied and allows more appropriate comparisons of NDVI across years (1981 to 2003). The European Spot-VEGETATION consortium is providing valuable 1 km NDVI data, with images from its beginning in 1998 to spring 2003 that have been incorporated in our GIS. That higher quality dataset is reducing the usefulness of the mid-1990s 1 km resolution NDVI data set from USGS. Other data sets, such as those from the Global Land Cover Characterization project, were put in place in 2002.

The standard deviation in elevation (using standard errors of sampled locations) has been calculated for those areas with boundaries defined, along with the mean elevation. This reflects the landscape heterogeneity of each of the areas, and is closely correlated with the number of land cover types mapped for the areas. For some sites, we have calculated the coefficient of variation in NDVI across more than 20 years, representing in a uniform way the variation in greenness through time. The spatial coefficient of variation in greenness within 180 VEGETATION images has been calculated, and the mean recorded, reflecting the heterogeneity of forage resources through space.

The method created to represent the ability of vagile animals to access green forage is akin to a semivariogram in spatial statistics, but uses multiple NDVI images (or any other spatial layers showing resources important to animals or people, including SAVANNA output). Both the analysis and interpretation of results are straightforward. In general, a Monte Carlo method is used to place hundreds of animals randomly on a site of interest. The animals are then allowed to move within a given radius (e.g., 3 km) to access the most productive sites available (i.e., highest NDVI value, recognizing that NDVI is not a perfect representation of forage availability, and that masks to exclude unsuitable habitat may be needed). The radius is then increased (e.g., 5 km, 7 km, 9 km, … 30 km) with the improvement in access to forage noted. The results are then plotted, with distance on the x-axis and mean integrated NDVI score on the y-axis. The height of the line above the x-axis reflects the productivity of the site. The shape of the sloping line, which is usually non-linear, reflects the relative importance of fragmentation to animals. A flat line indicates that forage availability in an area is relatively homogeneous through space, whereas a steeply sloping line suggests a heterogeneous forage base.

Research Objective 3: Herbivore Selection at the Paddock Scale

The first year of data is sufficient to illustrate typical seasonal variation in cattle diet quality (Fig. 4). We intend to continue this data collection over the next three years to capture seasonal and inter-seasonal variation in diet quality from the different paddocks and relate this data to paddock size and measures of paddock heterogeneity currently being developed.

Research Objective 4: Herbivore Movements in Fragmented vs. Intact Ecosystems

1. Assessment of the effects of landscape fragmentation on the movement of pastoral livestock herds in the Kitengela and Mara ecosystems (Kshatriya, Nkedianye, Reid)

The study area in the Maasai Mara ecosystem sees an annual increase in wildebeest numbers during the mass migration of wildebeest from the Serengeti ecosystem in mid-August. This large perturbation results in the vegetation becoming patchy or fragmented due to selective and heavy grazing by these herbivores. At the Mara study site we wanted to document this effect on the grazing pattern of cattle before and during the migration. We collected data on grazing orbits of eight herds before and during the migration. The results show that herding practices change in response to the migration. The grazing orbits, in terms of the geometry and location, changed due to the presence of high number of wildebeests. The grazing orbits were longer and the velocity of movement faster in regions where there was little vegetation. The primary grazing area changed from open grassland, before the migration, to riverine habitat after the migration. Wildebeest often do not graze in such type of habitat due to high predation risk. The grazing orbit data will help to quantify how much time is spent in this habitat, which appears to be a feeding refuge area for cattle during the time of the wildebeest migration.

2. The effects of pastoralism on the density and distribution of carnivores and their prey in the Mara Area of Kenya (Ogutu, Reid)

Wild prey biomass density was 2.6 times higher in the ranches (14212 kg/km^2) than in the reserve (5472 kg/km^2). Hyena density was higher in the ranches (0.561 hyenas/km^2) than in the reserve (0.404 hyenas /km^2), in correspondence with the regional pattern of prey density. Jackal density was similar in both areas, whereas lion density was anomalously lower in the ranches (0.046 lions / km^2) than in the reserve (0.369 lions /km^2). Prey, lion and hyena densities did not differ between June 1991 (5172.273 kg/km^2) and June 2003 (5472 kg/km^2) in the reserve, but jackal density increased in the same period. Lion behavior apparently changed in the ranches, so the effectiveness of the playback technique for estimating their population size in pastoral systems requires evaluation. Lion populations in the pastoral ranches appeared headed for extinction due to conflicts with pastoralism, necessitating urgent conservation interventions that integrate pastoral economic welfare with large carnivore conservation goals to foster long-term viability of lion populations in pastoral systems.

3. Census of the impacts of pastoralism and protection on the abundance and distribution of wildlife, livestock and people in the Mara ecosystem

Our data show that pastoral communities, contrary to traditional views, can sometimes enhance biodiversity. These findings support other evidence that integrated livestock-wildlife systems are more productive than either livestock or wildlife systems alone, at least in East Africa. Conservation policy that excludes low to moderate levels of traditional pastoral use may inadvertently impoverish the very lands it was instituted to protect.

However, our data also show that many wildlife species need to live without people. Any positive effects of pastoralism on wildlife break down when the density of settlements passes a certain point, which has been reached around the small villages in the group ranches of the Mara. Settlement growth creates a patchy (or fragmented) landscape of heavily used patches, interspersed with more lightly used patches. If settlements become very numerous, the heavily used areas coalesce, creating a less fragmented, more uniformly used landscape. Thus, we expect that further growth in the number of settlements in the Mara will result in further negative consequences for wildlife.

Finally, land privatization may deplete wildlife. In the last 3 years, communities outside the reserve have begun to privatize the land and some families have split up in anticipation of land parcel allocation. We anticipate that this landscape fragmentation has and will have strong negative impacts on wildlife. If all the lands outside the reserve are privatized, we estimate that 40% of the wildlife will be lost, or 45,000 animals, and perhaps all the elephants and most carnivores.

4. Synthesis paper of state of knowledge on fragmentation in East African pastoral systems (Reid, Thornton, Kruska)

The causes of fragmentation can be bio-physical, social, or both, endogenous or exogenous in origin, and can be effective at a variety of scales. Many of the driving forces or causes originate at one level of scale and have consequences for another. The ecological and economic consequences of fragmentation include loss of whole populations or the genetic variation within populations of wildlife, changes in ecosystem function (water and nutrient cycling, carbon sequestration, 1^o and 2^o productivity), changes in the spread and distribution of pathogens, and changes in human welfare. There is some evidence that exclusion of people from protected areas reduces fragmentation, but may also reduce the populations of species that thrive in moderately fragmented landscapes. As land privatization occurs throughout the region, land owners often build fences, excluding wildlife. Fences can also impoverish pastoral peoples; for example, fewer than 10% of households in Kajiado were able to keep their animals within particular plots (after subdivision) without their suffering severe shortages of feed or without severely overstocking the land.

Research Objective 5: Typology of Actual Land Use Patterns
Research Objective 7: Factors Driving Contemporary Trends in Land Use Change

The objective of the Kazakstan case study on mobility was to examine the importance of land tenure in causing changes in the scale of livestock movement in one pastoral society. With few exceptions, in Kazakstan high levels of livestock mobility indicate an integrated system of land use, and restrictions on stock mobility amount to fragmentation. We concluded that:

a. In Kazakhstan in the 20th century extensive mobile pastoralism has flourished only when there were intermediate livestock numbers. At excessively high or very low stock numbers, mobility is retarded irrespective of the land tenure system.
b. Soviet land tenure policy was stable for six decades between 1930 and 1990. In this period, changes of mobility can be attributed to factors such as increases in irrigation and fodder production, water development and stock barns, and growing livestock populations. Agricultural intensification led to marginal restrictions in mobility in the late 1970s and1980s, but extensive mobile pastoralism based on industrial technology persisted up to the end of the Soviet period.
c. No type of land tenure system - state, private or common ownership or open access - is wholly incompatible with the maintenance of mobility. More important, it would seem, is the way in which these idealized tenure types have been interpreted and applied in practice. Collectivized Soviet agriculture was, for example, initially hostile to mobility, but eventually provided a suitable institutional basis and large scale units of land management compatible with extensive mobility.
d. Stock mobility in Kazakstan has been incompatible with radical, ideologically driven, and sudden changes in property systems. Mobility collapsed along with livestock numbers in the 1930s with the shift to state property ownership, and again in the 1990s with the attempted shift to private ownership.
e. There would appear to be a trend towards exclusive tenure over the last two centuries of Kazak history, but the evidence is equivocal. Privatization and restrictions on mobility were occurring prior to 1930, but these trends were reversed during the Soviet period. Following market reforms in the 1990s private (leasehold) control of rangeland is again possible. But low stock numbers have undermined the incentives for exclusive control since natural resources are not at present scarce relative to livestock numbers.

Research Objective 8: Economic Surveys and Analysis

Kajiado

For pastoral households in the Group Ranches in the southern part of Kajiado District, Kenya, survey results indicated that there are five basic types of economic activity:

- All households have some livestock (this may be all that some households do).
- Some households engage in other economic activity, including livestock trading.

- Some households engage in rainfed agriculture, growing mostly maize and beans for home consumption.
- Some households have irrigated plots of land near the swamps, where they may grow maize and beans, potatoes, and vegetables, such as onions and tomatoes, primarily for sale.
- Other households have access to larger agricultural land on the slopes of Kilimanjaro, where mostly maize and beans are grown for home consumption.

These five basic strategies are combined in various ways to produce eight livelihood strategies for the households in the study area. The decision-making unit in the model is the household associated with each Maasai elder, and there may be between 4 and 7 elders and their households per boma. The distribution of household type by group ranch area is highly variable.

In the model, each household type is stratified by wealth level. Detailed survey data indicated an average of 20.7 people (13.8 Adult Equivalents) per rich household, 14.4 people and 9.9 AE for medium households, and 9.8 people and 6.8 AE for poor households. In the study region, the split between rich, medium and poor households is approximately 23%, 29% and 48%, respectively. Using the 1999 census data for Kenya, we estimated a total of 3,820 households in the study area, with a mean size of 13.6 people per household. These households have access to various land and livestock resources. The size of rainfed, irrigated and Loitokitok agricultural plots averaged 0.66, 0.81 and 2.20 ha per household, respectively, with large and consistent variations between wealth levels. Similarly for herd sizes, herd sizes per household in the model average 62 for cattle, 26 for goats, and 28 for sheep.

These and many other result have been summarized in the form of input data files for the PHEWS modelling that is being carried out in RO9.

Research Objective 9: PHEWS (Pastoralist Household Economic Welfare Simulator) Model Assessments

Kajiado

The baseline or "control" run was carried out at 2.5 km resolution. Results from this run indicate that most households need some external calories at some stage, but for most households, the need for these occurs at specific times of the year, rather than a constant requirement, and are low anyway. For the landscape as a whole, between 30 and 46% of calories are home-produced. It is only the rich households who could in theory sustain a purely pastoral way of life, with 9 Tropical Livestock Units (TLU) per Adult Equivalent. The great majority of households (nearly 80%) have to do other things in addition to keeping livestock, as herd sizes are generally not large enough to sustain the large numbers of people per household. Model results indicate that, generally speaking, the more diversified the household, the better off the household is. Households with irrigated plots appear to have some room for maneuvering to meet financial obligations; yields on rainfed plots are highly variable, and generally low. Various scenarios were then simulated. To summarize the major results:

- *Effect of subdivision of group ranches on livestock and households*. For the group ranches simulated, all runs with subdivided areas showed substantial reductions in livestock numbers, mostly through households having to sell more animals to generate the cash needed, and this has a deleterious long-term impact on herd sizes and subsequent cash flow and food security. If subdivision were to occur, even to parcels as large as 196 km^2, then livelihood strategies would have to change markedly if current levels of household well-being were to be maintained. Alternatively, household numbers would have to be drastically reduced to levels where herd sizes could remain relatively stable. There are, however, substantial differences in the intrinsic productivity of the group ranches simulated; the more productive group ranches are generally more "resilient" to subdivision, but even for these, if plot size is reduced too much, then all succumb to crashing livestock populations.

- *Effect of reduced access by wildlife to private lands because of fragmentation*. In broad terms, the results suggest that if 75% or more of the land area is off-limits to wildlife, then cattle, sheep and goat TLU per AE start to increase, and do so substantially. Impacts on household well-being then become significant. The impacts on livestock numbers at lower levels of wildlife restriction appear to be relatively muted, possibly because of the delays in the system, and also possibly because the increases in off-take rates (more sales) are at least partially compensating for increased livestock numbers.

- *Effect of restricting dry-season access to key grazing resources.* The Chyulu Hills are seen in Kajiado as a key resource for pastoralists for dry-season grazing. In the model, a scenario was run to prevent access to these hills all year round. This results in a reduction in livestock numbers, declining TLU per AE for all households, an increase in the need by all households for external calories, slightly increased livestock sales to try to compensate for reduced household incomes, and a general decline in household well-being. Access to the Chyulu Hills for three months per year as a grazing reserve is of considerable importance to the long-term stability of the system and to household well-being. Without it, it appears that the number of cattle and sheep that could be supported would decline dramatically.

- *Effect of changing breed of cattle in the group ranches.* One scenario looked at the impacts of using heavier *Bos taurus* breeds in the group ranches, rather than the lighter local zebu breeds. In the scenario, all cattle were specified to be 50% crossbreds, with concomitant changes in potential milk and meat yields and cattle selling and purchase prices. Results of this model run indicate that cattle numbers decrease through time, compared with the control run; the number of TLU in rich livestock-only households is halved over a 24-year simulation period, while goat numbers increase substantially. Meat and milk calories increase in poor and medium households (as expected, from higher off-take rates), and there is somewhat more cash in the landscape (non-food consumption is slightly higher in the mixed breed scenario). Overall, however, food security suffers somewhat, and TLU per AE are declining through time, and at current population levels, this option does not look to be sustainable, unlike the control run. There are various issues here that need to be investigated further.

These and other model scenarios are currently being written up, and will be submitted to a journal for publication in due course.

Research Objective 11: Spatial Complexity, Temporal Variability and Population Patterns

Progress
We applied the Kalman filter to eight time series of ungulates in the Northwest and Midwest of the US and the southwest of Canada. The Kalman filter effectively removed sampling errors from the eight time series of ungulate populations. Measurement or sampling variance constituted 8 to 35 % of total variance in the eight time series. This result clearly suggests the necessity and importance of removing sampling errors for the statistical inference of population dynamics.

Plan for future work
We will continue to apply the state-space model to the rest of the time series and obtain bias-free estimates of the parameters of the Gompertz model. We will also work on a more general algorithm for the noise reduction of non-linear and non-normal time series using the Bayesian approach.

Research Objective 12: SAVANNA-PHEWS Complexity-Fragmentation Experiments

Two efforts were less central to the goals of the SCALE project, and findings will be briefly described:

Ngorongoro Conservation Area (NCA): Analyses of land fragmentation supported by the Global Livestock Collaborative Research Support Program, University of California, Davis, were repeated using randomization methods applied to climatic patterns. The analyses assess the effects of from 0 ac to 50,000 ac of cultivation in NCA on the wild and domestic herbivores of the area. Cultivation was represented as a loss of foraging habitat to herbivores. SAVANNA modeling did not show significant changes in any of the herbivores when cultivation was absent, at 10,000 ac – its current level – or up to 50,000 ac. When cultivation was placed into two large blocks of 5,000 ac or 10,000 ac each, herbivore populations changed (< 15%), but total biomass did not. Our findings suggest that any concerns about effects of current cultivation in NCA on large herbivores are unfounded.

North-West Province, South Africa: An existing application of SAVANNA that is merged with a mathematical programming model for optimizing profitability was used in analyses. Weather data for the site was modified so that the coefficient of variation in rainfall spanned from its observed 30% up to 46% (i.e., 30%, 32%, … 44%, 46%). The SAVANNA model and mathematical programming model were then run, using existing low Southern Oscillation Indices as substitutes for available seasonal weather forecasts predicting drought; livestock producers destocked animals when faced with forecasts of drought. Results were variable and dependent upon the rainfall pattern, but in general, climate that included higher coefficients of variation led to higher profits to producers, but greater variability in returns.

Southern Kajiado District, Kenya: Note — Modeling in Kajiado included socio-economic results from PHEWS, which are summarized under Research Objective 9. Here, effects on wild and domestic ungulates are highlighted.

In the late 1960s and early 1970s, the Kenyan government cooperated with international organizations in subdividing Kajiado District into what are now 52 group ranches, averaging about 31,000 ha. That process continues today, with group ranch councils voting to subdivide entire ranches into small parcels of perhaps 40 ha (100 ac) to be dispersed among group ranch members. Pastoralists use movement strategies to access variable green forage and water, and those movements may be prevented in subdivided lands. In that light, we sought to quantify the loss in livestock production and effects on households due to subdivision, and to quantify effects of parcel sharing through grazing associations. We used the Savanna Modeling System joined with the PHEWS model to quantify effects of fragmentation on livestock.

We modeled animals and households on four group ranches, and quantified changes in animal numbers and human well-being as ranches were subdivided into 196, 10, 5, 3, and 1 km^2 parcels – still larger than parcels typical in subdivision. Grazing associations were then represented by combining parcels into 3, 5, and 10 km^2 areas used in association, with neighboring and randomly dispersed parcels assessed. For analyses of parcels 10 km^2 or smaller, 20 randomly placed locations were simulated and the average response reported, and five 196 km^2 parcels were simulated. Simulations were run for 24 years, and livestock populations from the last 10 years were summarized.

About the same numbers of livestock could be supported on 196 km^2 parcels as on intact group ranches, but changes were clear when 10 km^2 parcels were modeled. In the most productive group ranch studied, Osilalei, the number of animals the ranch could support declined slowly or even increased as the land was subdivided (10 km^2 – 98%, 5 km^2 – 92%, 3 km^2 – 87%, 1 km^2 – 109%); populations may increase in productive parcels because animals do not compete with animals moving in from less productive areas for parts of the year. Eselengei Group Ranch showed a steady decline as land was subdivided, with 25% fewer livestock supported on the group ranch when it was fragmented to 1 km^2 parcels. Olgulului/Lolorashi was the least productive group ranch studied, and only 78% of the animals that could be supported on the intact group ranch could occur on the ranch when parcels were 10 km^2 or less. Declines in livestock could be partially offset by maintaining grazing associations. We found that maintaining associations with widely dispersed partners was important in moderately productive ranches, but less important in the most productive ranch and not helpful in the least productive ranch; productivity was either relatively high or low over the entire ranch, and whether associations were with immediate neighbors or more distant ranch members made little difference.

In other analyses, the suitability of areas outside Amboseli National Park were decreased progressively from 100% (suitability based only on ecological relationships) to 0% (entirely unsuitable), reflecting increasing fencing and other fragmentation of private lands outside the national park. The number of wildlife (represented with Large Herbivore Units) did not decline markedly in model results until the suitability of the private lands declined by about 75%, then there was a non-linear, dramatic decline in wildlife numbers. Based on the model, the number of wildlife would be less than 20% of the current population if private lands were entirely unsuitable or Amboseli was fenced.

Swamps in the Amboseli Ecosystem are important to elephants, cattle, and other ungulates as a short-term, dry season forage resource. We assessed what the effect of loss of access to swamps outside of Amboseli National Park would be to elephants, reflecting ongoing fragmentation of landscapes progressing until they were impermeable to elephants. We also assessed the effect of a loss of the entire swamp network, an extreme scenarios associated with the melting of Mount Kilimanjaro glaciers. There was little effect from the loss of access to swamps outside Amboseli National Park; currently there is little swamp habitat outside of the park available to elephants, and so its loss what not critical. Loss of all swamps caused severe declines, as expected, with the elephant population approaching zero as the 25 year modeling period ends.

Research Objective 13: Complexity and Fragmentation in Theoretical Ecosystems

Ecosystem Modeling

A hypothetical application was used for these analyses, but it was based upon an existing application of Savanna to the Vryburg area in the North-West Province of South Africa. Originally, five animal functional groups were defined, but herbivore populations show complex compensatory responses, making calculations of standardize metrics (e.g., tropical livestock units) complex and potentially misleading. Instead, a single herbivore functional group was parameterized, representing cattle.

A 300 km^2 block (20 km x 15 km) within Vryburg 1 Township was selected for modeling. All geographic data were generalized to 1 km x 1 km resolution cells. Carrying capacity is related to climate history in a complex way that was not the focus of these analyses. We therefore used a method within Savanna to generate a random weather history, where weather information for a year is drawn from the weather data randomly. Water was assumed to not be limiting. Parameters were set in the model, based upon an extensive literature review, previous Savanna applications, field work, and expert opinion. The initial stocking rate for the block was based on a recommendation from the Department of Agriculture, South Africa.

Analyses used a suite of fenced parcels, with parcels ranging from the entire 300 km^2 block modeled, to 30 parcels each 10 km^2. The model was run separately for each of the parcels, with cattle confined to the parcel in question. Each simulation was run for 30 years, and average stocking in the last 15 years of the simulation was the response of interest. Stocking rates were summed across parcels, so that in each case, the measure of interest was the number of cattle that could be supported on 300 km^2. Weather history affects stocking strongly in this arid region, so weather was kept the same for each analyses of the set parcels (i.e., 300 km^2 to 10 km^2), but the entire set was modeled 12 times, using a different randomly generated weather pattern for each set.

The carrying capacity of the 300 km^2 block declined steadily with increasing fragmentation, although capacity varied depending upon weather history, leading to variation in carrying capacity. In general, when the 300 km^2 block was fragmented into 10 km^2 parcels, the same 300 km^2 block supported 19% fewer cattle then when unfragmented. The implications of these results are profound, although this is a single example that frames our future research, rather than an end in itself. How does vegetation heterogeneity affect the relationship? Is the relationship similar for more productive sites? Is topographic complexity more important in determining the relationship than vegetation complexity? Is the relationship ameliorated by a larger herbivore community? If the species were migratory, and required more diverse resources, would the slope be steeper? These and other questions will be addressed by our ongoing studies.

Findings related to the work being done to develop a mathematical argument that the isolating effects of fragmentation will reduce the abundance of populations of consumers in general, and large herbivores in particular are discussed below.

Humans have modified the ecosystems of the earth in many ways, but one of the most pervasive effects of people on the environment is the dissection of natural systems into spatially distinct parts, a process generally known as fragmentation. Fragmentation has been implicated in loss of biological diversity worldwide because populations in fragmented habitats often decline to levels assuring local extinction. As habitats become increasingly fragmented, two things happen: the total area of habitat declines and habitat fragments become increasingly isolated as the area of unsuitable habitat separating them expands (Fig. 5A). It is not surprising that that the abundance organisms will decline over the long term as their habitat contracts. A more difficult, unanswered question asks "How does isolation of habitat affect population size in the absence of habitat loss?"

Habitat loss occurs when areas of landscape suitable for a species become unsuitable as a result of natural disturbance, community succession, or human-caused shifts in land cover. In contrast, isolation occurs whenever movements of individuals among habitats are restricted, as might occur, for example, when landscapes are subdivided by roads or fences or when corridors allowing movement among habitat patches are severed (Fig. 5B, C). Although loss of habitat often creates isolated habitat fragments, the converse is not true---isolation does not necessarily imply a reduction in the area of habitat available to a population. This distinction is important because human action may isolate habitats without reducing their area, and because the isolating effects of habitat fragmentation may add to the concomitant effects of habitat loss. That is, if the abundance of organisms declines as a result of isolation alone, then these declines are likely to amplify the effects of diminishing habitat area.

In Attachment A, we show that the effects of habitat isolation can reduce the abundance of consumers even when the area of their habitat remains constant. We show under a general set of assumptions that reducing access of individual consumers to variation in resources will cause declines in equilibrial abundance even when the total amount of habitat available to the population remains unchanged.

Opportunities for Training and Development

Hobbs, Boone, Galvin, Coughenour, and BurnSilver attended a two-day pre- International Rangeland Congress workshop in Durban, in July 2003. The workshop reviewed the literature on equilibrium and non-equilibrium dynamics within arid and semi-arid ecosystems. We then broke into small groups to discuss current and future challenges relating to ecosystem dynamics. The large group then reconvened, and attempted to reach agreements on the state of the paradigm in rangeland management, and future directions of research.

Boone cooperated in teaching an EY 590 seminar entitled "What in the World Is Biocomplexity?" led by Dr. N. Hanan in the spring of 2003.

Boone is assisting Dr. Michael Coughenour in training visiting scientist Mr. Wycliff Mutero, Head of the GIS Department, Kenya Wildlife Service. Mr. Mutero is interested in integrated assessments of conservation areas in Kenya, including exploring contentious issues of landscape fragmentation in Kitengela, south of Nairobi National Park.

Outreach

In July 2003, R. Boone joined S. BurnSilver and J. Worden, students associated with the SCALE project, in meeting with Maasai pastoral communities for a week. In a series of six meetings supported by the Global Livestock Collaborative Research Support Program, University of California, Davis, and affiliated with SCALE objectives, we presented field and modeling results to more than 500 pastoralists. Effects of fragmentation were described, and methods pastoralists may use to reduce harmful outcomes from fragmentation were cited.

A companion project, funded by the Belgian government, focuses on making sure the information that is generated by this NSF grant reaches the people who need it the most: pastoral community members, wildlife managers, scientists, and policy makers. It also supports 3 Ph.D. students that contribute directly to the subject of the SCALE grant. This project supports four community facilitators that identify community and policy maker needs for research and provide the needed information to the appropriate groups. The team holds community and policy maker meetings every 1-2 months. The team also produces posters, policy briefs and website updates of new research results.

Posters and Presentations

Ash, A., J. Gross, and M. Stafford Smith. 2003. Scale, heterogeneity, and secondary production in tropical rangelands. Invited paper for the 7th International Rangeland Congress, Durban, South Africa, August 1st.

Boone, R.B. and N.T. Hobbs. 2003. Lines around fragments: Effects of fencing on large herbivores. Fragmentation of rangelands: Ecological and economic implications. Invited paper for the 7th International Rangeland Congress, Durban, South Africa, August 1st.

BurnSilver, S.B. and R.B. Boone. 2003. Current land use and potential impacts of ongoing fragmentation of a pastoral landscape: An example from four Maasai group ranches, Kajiado District, Kenya. Poster, 7th International Rangeland Congress, Durban, South Africa.

Coughenour, M. 2003. The Ellis paradigm: Humans, herbivores, and rangeland systems. Invited paper for the 7th International Rangeland Congress, Durban, South Africa, August 1st.

Galvin, K.A., P.K. Thornton, R.B. Boone, and J. Sunderland. 2003. Climate variability and impacts on East African livestock herders. Fragmentation of rangelands: Ecological and economic implications. Invited paper for the 7th International Rangeland Congress, Durban, South Africa, August 1st.

Kerven, C, I. Alimaev, R. Behnke, G. Davidson, L. Franchois, N. Malmakov, E. Mathijs, A. Smailov, S. Temirbekov, I. Wright. 2003. Retraction and expansion of flock mobility in Central Asia: Costs and consequences. Invited paper for the 7th International Rangeland Congress, Durban, South Africa, August 1st.

Reid R S, Thornton P K and Kruska R L. 2003. Fragmentation and loss of habitat for pastoral people and wildlife in East Africa: Concepts and issues. Invited paper for the 7th International Rangeland Congress, Durban, South Africa, August 1st.

Thornton P K, Reid R S and Kruska R L. 2003. Adapting to global change in Africa: studying the implications for rangelands. Invited paper for the 7th International Rangeland Congress, Durban, South Africa, August 1st.

Journal Publications

Hobbs, N. T. 2003. Challenges and opportunities for integrating ecological knowledge across scales. Forest Ecology & Management 181:222-238.

Thornton P.K., K.A. Galvin, and R.B. Boone. 2003. An agro-pastoral household model for the rangelands of East Africa. Agricultural Systems 76:601-622.

Thornton P.K., S.B. BurnSilver, R.B. Boone, and K.A. Galvin. 2003. Modelling the impacts of group ranch subdivision on households in Kajiado, Kenya. *Agricultural Systems* (in preparation).

Other Publications

Ash, A., J. Gross, and M. Stafford Smith. 2003. Scale, heterogeneity, and secondary production in tropical rangelands. Proceedings of the VII International Rangeland Congress, Durban, South Africa *and* in review by African Journal of Range and Forage Science.

Boone, R.B., S.B. BurnSilver, J.S. Worden, K.A. Galvin, and N.T. Hobbs. In review. Large-scale movements of large herbivores: Livestock following seasonal changes in forage supply. Spatial ecology of large herbivores and pastoralists (H.H.T. Prins and F. van Langevelde, eds.).

Boone, R.B. and N.T. Hobbs. 2003. Lines around fragments: Effects of fencing on large herbivores. Proceedings of the VII International Rangeland Congress, Durban, South Africa *and* in review by African Journal of Range and Forage Science.

Boone, R.B. and S.B. BurnSilver. 2003. Subdivision of land in Kenya potentially devastating for pastoralists. Policy Brief by the Global Livestock Collaborative Research Support Program, University of California, Davis, California. (Citing partial support from NSF SCALE.)

Boone, R.B. and S.B. BurnSilver. 2003. Subdivision of group ranches can cause dramatic livestock declines. Policy Brief by the Global Livestock Collaborative Research Support Program, University of California, Davis, California. (Citing partial support from NSF SCALE.)

BurnSilver, S., R.B. Boone, and K.A. Galvin. 2003. Linking pastoralists to a heterogeneous landscape: The case of four Maasai group ranches in Kajiado District, Kenya. Pages 173-199 In Linking household and remotely sensed data: Methodological and practical problems (Fox, J., V. Mishra, R. Rindfuss, and S. Walsh, eds.). Kluwer Academic Publishing, Boston.

Galvin, K.A., P.K. Thornton, R.B. Boone, and J. Sunderland. 2003. Climate variability and impacts on East African livestock herders. Proceedings of the VII International Rangeland Congress, Durban, South Africa *and* in review by African Journal of Range and Forage Science.

Kerven, C., I. Alimaev, R. Behnke, G. Davidson, L. Franchois, N. Malmakov, E. Mathijs, A. Smailov, S. Temirbekov, I. Wright. 2003. Retraction and expansion of flock mobility in Central Asia: Costs and consequences. Proceedings of VII International Rangeland Congress, Durban, South Africa *and* in review by African Journal of Range and Forage Science.

Ogutu, J. and others. In preparation. The effects of pastoralism on the density and distribution of carnivores and their prey in the Mara Area of Kenya.

Reid, R.S., Ogutu, J., Rainy, M., Kruska, R.L., Nyabenge, M., McCartney, M., Worden, J., Wilson, C.J., Kshatriya, M., Kimani, K., and N'gan'ga, L. 2003. *Mara Count 2002: People Wildlife and Livestock in the Mara Ecosystem*. Report, Mara Count 2002, International Livestock Research Institute, Nairobi, Kenya.

Reid, R.S., Thornton, P.K. and Kruska, R.L. 2003. Loss and fragmentation of habitat for pastoral people and wildlife in East Africa: concepts and issues. Proceedings of VII International Rangeland Congress, Durban, South Africa *and* in review by African Journal of Range and Forage Science.

Other Products

R. Boone, in cooperation with N.T. Hobbs and G. Wang, has been creating metrics representing the spatial and temporal heterogeneity of landscapes included in a Large Herbivore Dynamics workshop hosted by the National Center for Ecological Analyses and Synthesis, University of California, Santa Barbara. Many of the techniques used in that workshop will be useful in analyses under Research Objective 2.

A website was created for the wildlife and livestock census work described in the discussion of research objective 4 (http:\www.maasaimaracount.org). This website includes the text of Reid et al. (2003) and more than 100 databases developed from the census data.

A computer program has been written by Kshatirya in GNU-C to determine the crossover points of a grazing track.

Other Participants

Kamau Kimani, Research Officer, International Livestock Research Institute, Nairobi, Kenya, socio-economic data collection and analysis.

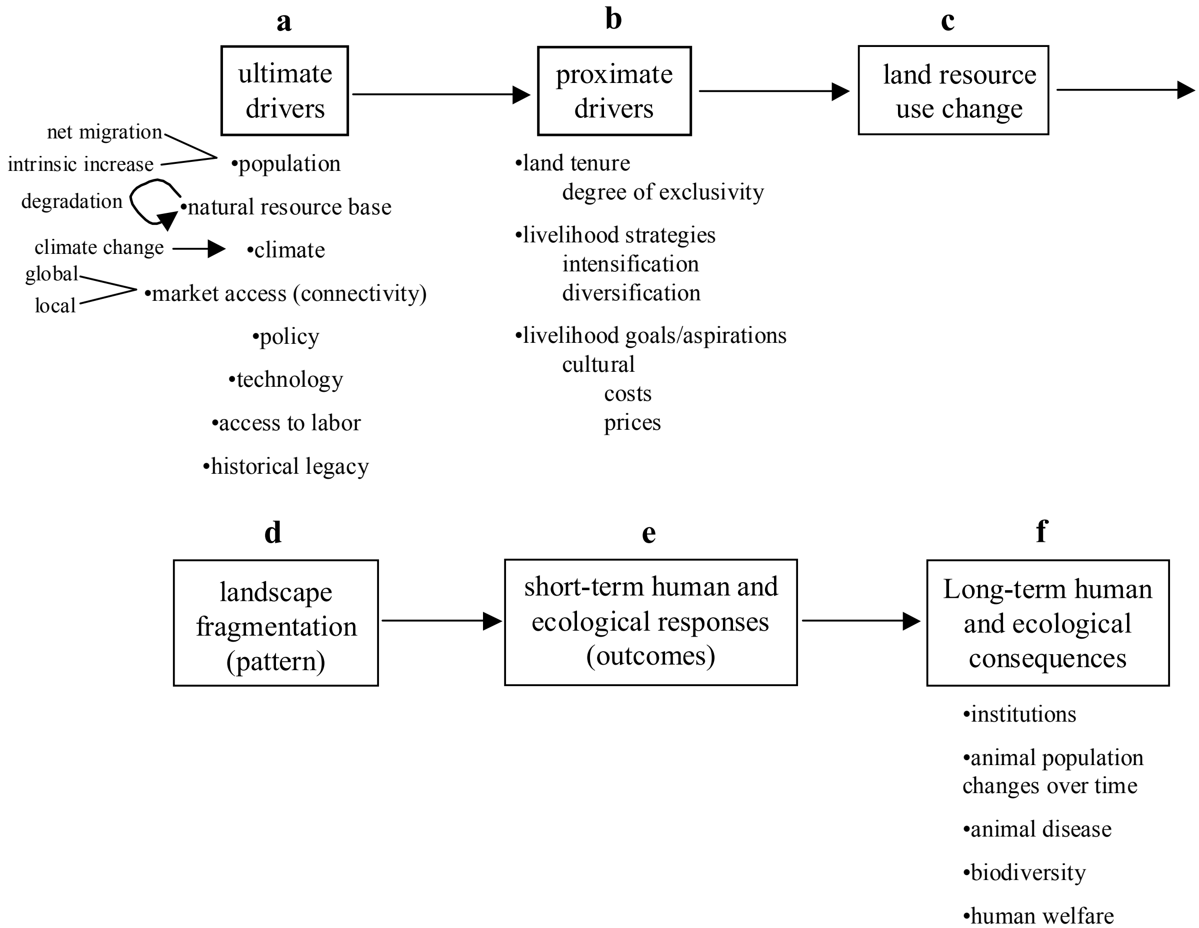

Figure 1: SCALE book conceptual framework

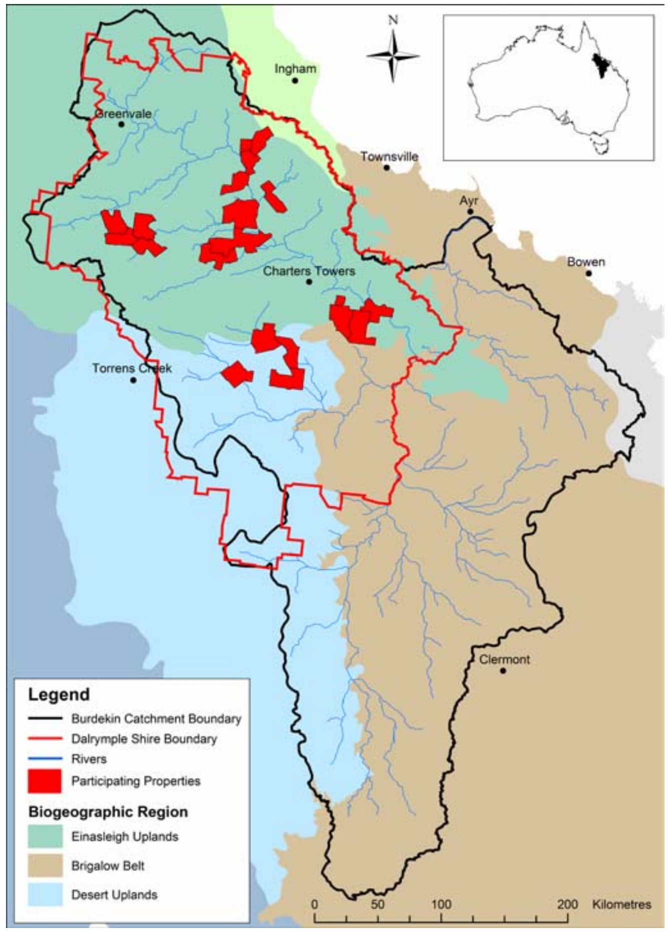

Figure 2: SCALE study area in northeast Queensland, showing the location of Dalrymple Shire and the participating pastoral properties in relation to biophysical features.

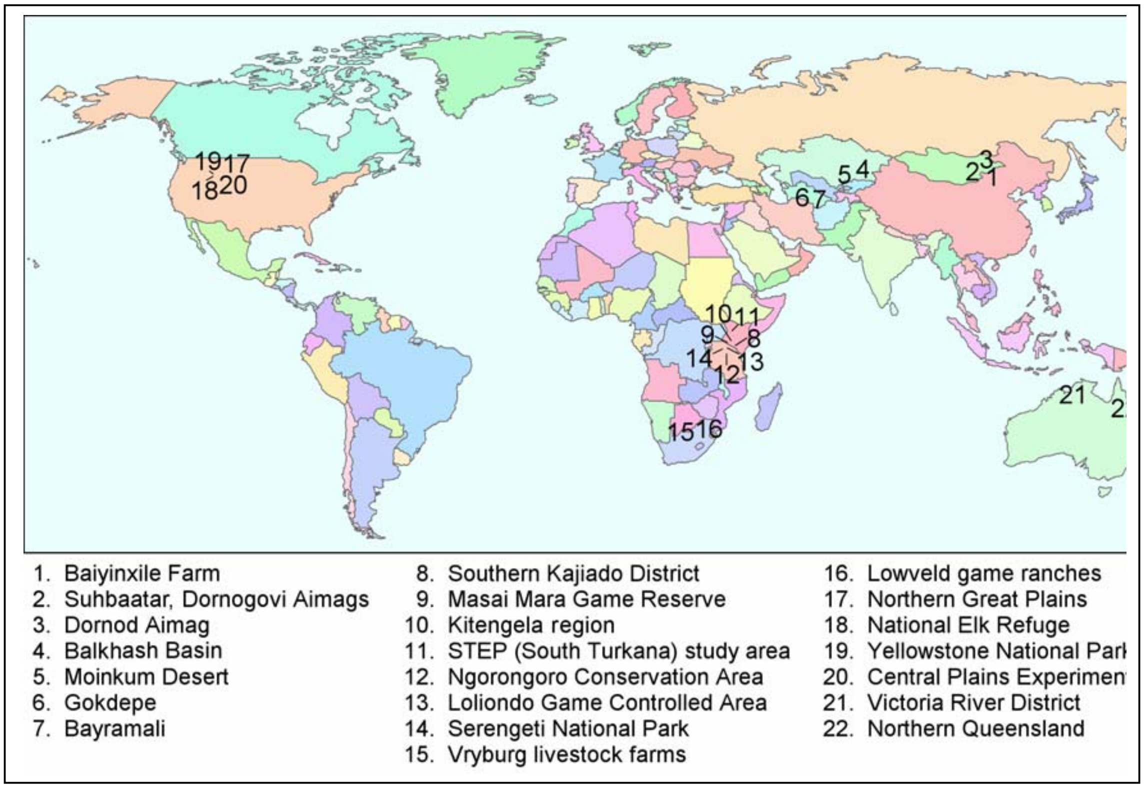

Figure 3: SCALE study sites

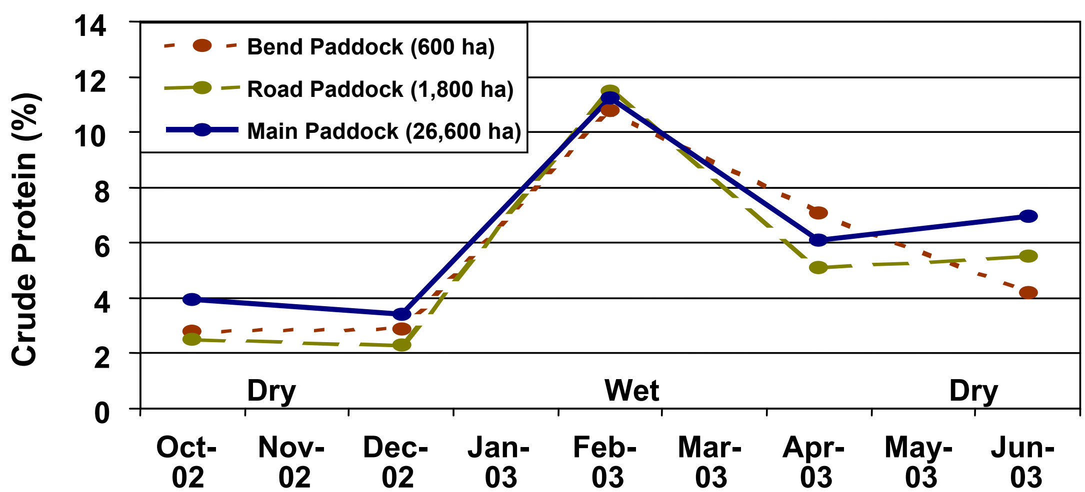

Figure 4: Variation in cattle diet quality as estimated from fecal NIRS analysis for three paddocks of different sizes on one of the properties in the study.

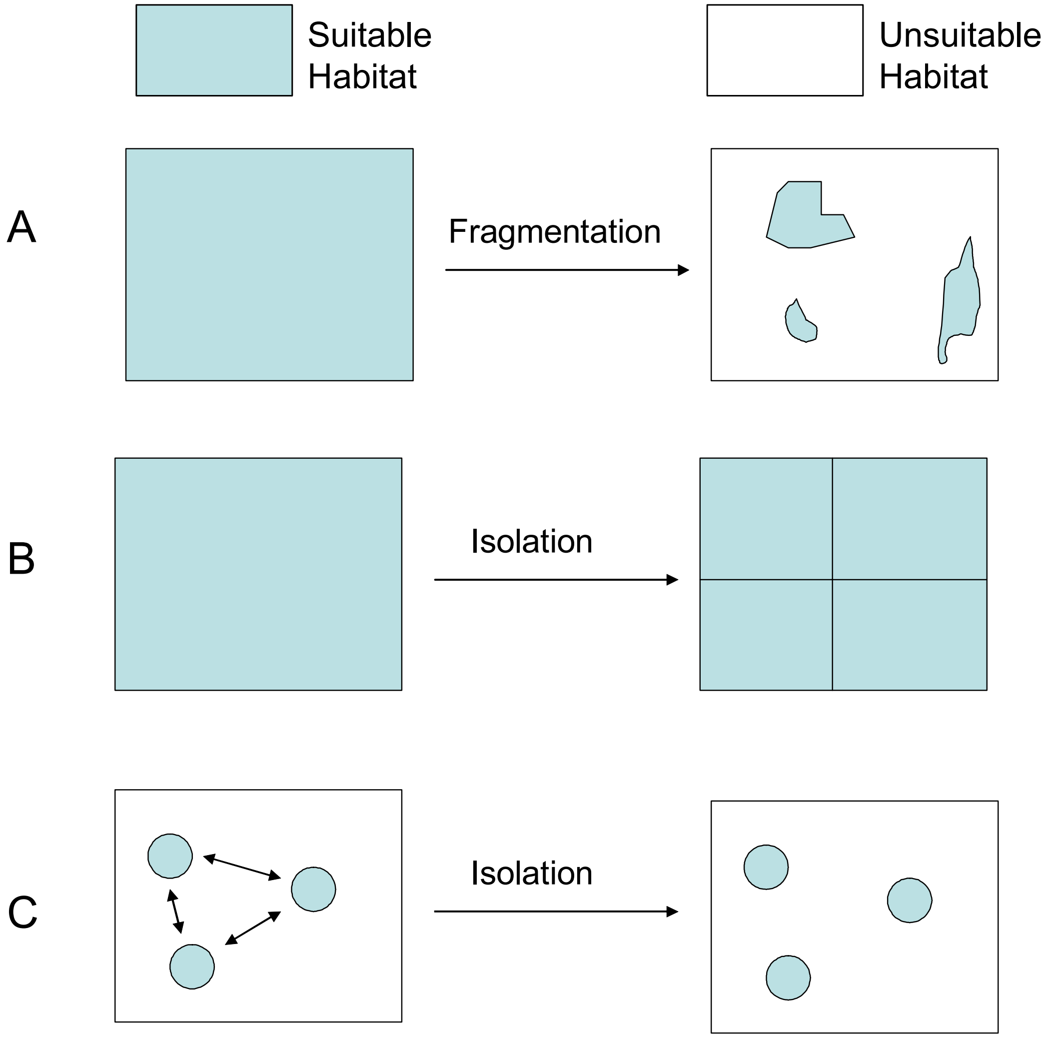

Figure 5: Habitat fragmentation (A) reduces the area of habitat available to a population and isolates individuals within habitat fragments. Isolation reduces the area of habitat available to an individual by its restricting access to resources, as might occur when landscapes are subdivided by roads or fences (B) or when corridors among patches are severed (C). Isolation does not reduce the area of habitat available to the population.