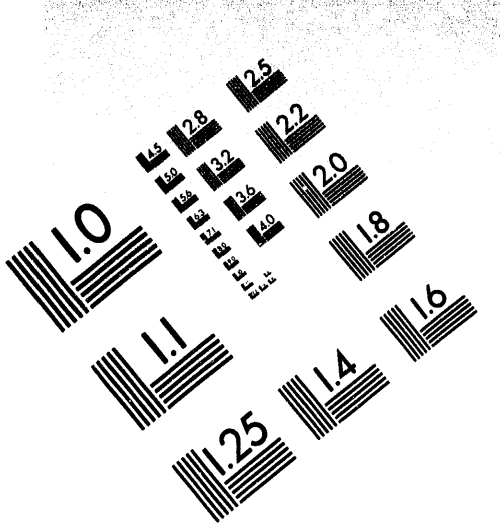


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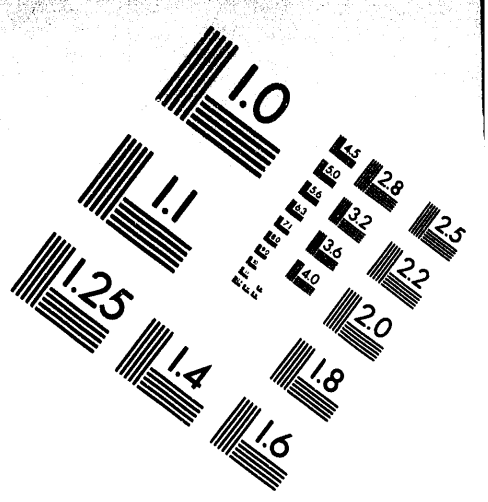
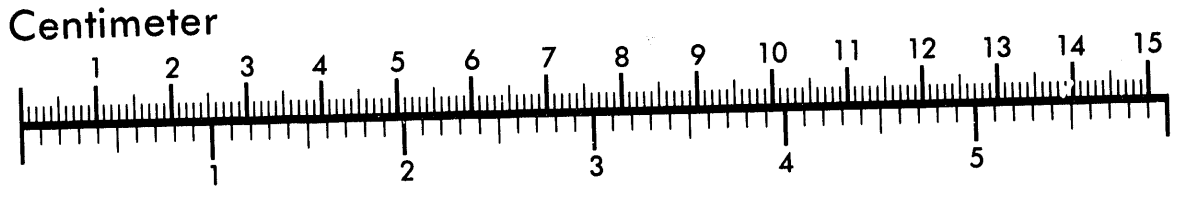

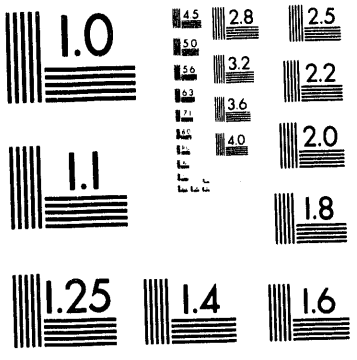
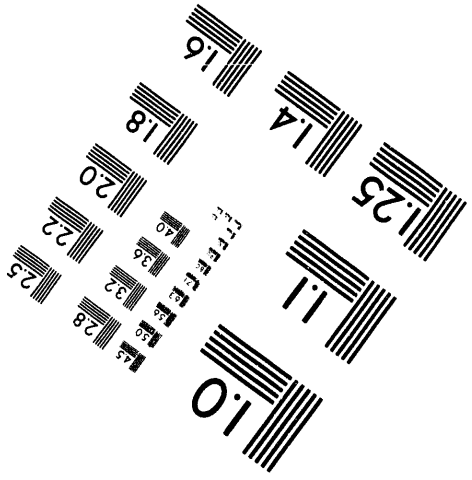
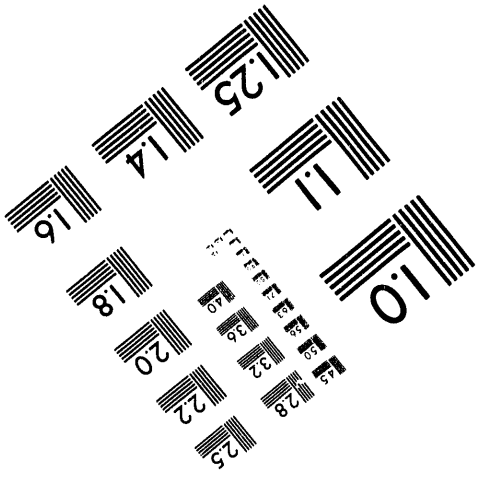

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Abstracts and Program Proceedings of the 1994 Meeting of the International Society for Ecological Modelling North American Chapter

J.R. Kercher
Program Chair
Health and Ecological Assessment Division
P.O. Box 808, L-524
Livermore, CA 94550

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Introduction

The 1994 Annual Meeting for the International Society for Ecological Modelling-North American Chapter (ISEM) is scheduled for August 7 through 11 in Knoxville, Tennessee. The meeting is convened in conjunction with the American Institute of Biological Sciences annual meeting and its member societies including the Ecological Society of America, the Botanical Society of America, and others.

The ISEM meeting has a program of six symposia and one contributed session. The sessions cover a range of topics in population modeling, zoological modeling, vegetation modeling, risk assessment, plant physiological modeling, and large scale systems. The rapidly developing area of individual-based models is well covered at the meeting. Implications of models for use in ecological management is explicit in the symposia on risk assessment and at least implicit in the symposia addressing plant physiology and the acquisition of large-scale data sets to drive large scale models.

The Society has a headquarters office in the Knoxville Convention Center, Meeting Room 8. There is a DOS machine and a MacIntosh available there for use by the Society's members.

ISEM is maintaining a job and applicant listing for ISEM members or for any prospective employer with a position open in ecological modeling. Files on applicants and positions is maintained in the Society's headquarters, Meeting Room 8, Knoxville Convention Center.

Purpose and Officers of the INTERNATIONAL SOCIETY FOR ECOLOGICAL MODELLING-North American Chapter

The International Society for Ecological Modelling (ISEM) promotes the international exchange of ideas, scientific results, and general knowledge in the area of application of systems analysis and simulation in ecology and natural resource management. The Society was formed in Denmark in 1975, and today has chapters in Germany, Italy, Japan, and North America. The North American Chapter was formed in 1982. ISEM sponsors conferences, symposia, and workshops that promote the systems philosophy and the use of mathematical analysis and modeling in ecological research and teaching, and in the management of natural resources. The Chapter publishes the newsletter ECOMOD, and *Ecological Modelling* is the official scientific journal of the Society.

President: WILLIAM E. GRANT, Department of Wildlife and Fisheries Science, Texas A&M University, College Station, Texas 77843-2258 (409/845-5777)

Secretary-General: EDWARD J. RYKIEL, JR., Center for Biosystems Modelling, Department of Industrial Engineering, Texas A&M University, College Station, Texas 77843 (409/845-9573).

Vice-Presidents: JON D. HANSON, (Editor of ECOMOD), USDA ARS, Great Plains Systems Research, 301 S. Howes, P.O. Box E, Fort Collins, Colorado 80522 (303/490-8323).

JAMES R. KERCHER, (Program Chairman), L-524, Health and Ecological Assessment Division, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550 (510/422-1416)

JOHN L. SCHNASE, Advanced Technology Group, Washington University School of Medicine, 660 South Euclid Ave., St. Louis, MO 63110 (314/362-3117)

Acknowledgments

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

Program

Society headquarters will be Meeting Room 8, Knoxville Convention Center.

MONDAY MORNING AUGUST 8, 1994

Sess 1: ISEM Symposium: Theoretical Developments in Structured Populations and Communities. Organized by THOMAS HALLAM, Department of Mathematics and Graduate Program in Ecology, University of Tennessee, Knoxville, TN 37996-1300 (615/974-4293). **Knoxville Convention Center, Meeting Room 6.**

8:00 CASWELL, HAL. Comparative demography with structured population models: untangling environmental effects

8:30 CROWE, KATHLEEN. Asymmetric competition and competitive outcome

9:00 CUSHING, JAMES. Models for hierarchically structured populations

9:30 HASTINGS, ALAN. Structured models of metapopulations --focus on local population sizes

10:00 RECESS

10:15 HENSON, SHANDELLE M and THOMAS G. HALLAM. Asymptotic competitive exclusion in structured populations

10:45 KOOIJMAN, BAS. Constraint population dynamics and the entropy of biomass

11:15 NISBET, ROGER M., EDWARD MCCAULEY, WILLIAM W. MURDOCH, ANDRE M. DE ROOS, and WILLIAM S.C. GURNEY. Structured population models for zooplankton

MONDAY AFTERNOON, AUGUST 8, 1994

Sess 2: **ISEM Symposium: Individual-Based Models of Animal Populations.** Organized by DONALD L. DEANGELIS, Environmental Sciences Division, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee 37831 (615/574-7823). **Knoxville Convention Center, Meeting Room 6**

1:00 WU, YEGANG, LOUIS J. GROSS, D. MARTIN FLEMING, JANE COMISKEY, and HANG-KWANG LUH. SIMPDEL: a spatially explicit individual-based model for white-tailed deer and Florida panther on Everglades landscapes.

1:30 COOKE, JERRY L. and K.L. RISENHOOVER. An individual-based model of mule deer habitat relationships in a self fragmenting system: the Chihuahan Desert.

2:00 RISENHOOVER, K.L., W. YAN, J.H. ROESE, P.D. TEEL, and J.L. COOKE. Modeling tick-host-landscape interactions: an individual-based approach.

2:30 WALLACE, LINDA L., MONICA G. TURNER, and WILLIAM H. ROMME, and YEGANG WU. Modeling ungulates, snow, and fire on Yellowstone's winter range.

3:00 RECESS

3:15 PROVENCHER, LOUIS. Simplified individual-based simulations designed as experiments.

3:45 DONG, QUAN and DONALD L. DEANGELIS. Modeling population consequences of cannibalism and competition for food in smallmouth bass.

4:15 ROSE, KENNETH A. Numerical considerations in individual-based modeling.

MONDAY EVENING, AUGUST 8, 1994

5:30 Mixer. (Cash bar). International Society for Ecological Modeling. **Holiday Inn World's Fair, LeConte Room.**

TUESDAY MORNING, AUGUST 9, 1994

Sess 3: **ISEM Contributed Papers: Ecological Modelling.** JEFFREY S. AMTHOR, Health and Ecological Assessment Division, L-256, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550 (510/422-7471), presiding. **Knoxville Convention Center, Meeting Room 6**

8:15 HART, DEBORAH R., and ROBERT H. GARDNER. Models for the spread of invading organisms subject to competition.

8:30 HERENDEEN, ROBERT. Bottom-up:top-down and trophic cascade paradigms: 1. Qualitative differences between food chains and webs. 2. Quantitative effects in chains.

8:45 BAVECO, HANS M., ANDRE M. DE ROOS, and C. KLOK. Predicting the impact of pesticides on earthworm population dynamics using stage-structured and individual-based models.

9:00 WU, XINYUAN and WILLIAM J. MITSCH. Hydrology and nutrient loading and retention models for constructed riparian wetlands.

9:15 VAN DER PEIJL, MARIANNE. Simulation of nutrient and carbon dynamics in European wetlands, testing a spatial modelling approach.

9:30 JOHNSON, ALAN R. and BRUCE T. MILNE. A gradient percolation model of vegetative phase transitions.

9:45 ACEVEDO, M.F., W.T. WALLER, and D.P. SMITH. Cladoceran population response to stress: switch to sexual reproduction.

10:00 RECESS

10:15 KIRCHNER, THOMAS B., WILLIAM ALLDREDGE, and TERRY MCLENDON. An object-oriented toolkit for creating site-specific models for ecological risk assessments.

10:30 MARSHALL, JOHN D. and RONDA L. KOROL. Stable carbon isotope ratios as a test of the intermediate calculation of a biogeochemical forest ecosystem model. Forest-BGC.

10:45 SAMPSON, DAVID A., PHILIP M. DOUGHERTY, and ELLEN J. COOTER. Regional variation in loblolly pine production response to climate change in the southeastern United States.

11:00 DUNGAN, J.L. and R.M. KELLER. SIGMA: a knowledge-based simulation tool applied to ecosystem modeling.

11:15 HINCKLEY, S., A. HERMANN, and B.A. MEGREY. Coupled bio-physical modeling of recruitment dynamics of a marine fish: a spatially explicit, individual-based approach.

11:30 SCHEFFER, M. and E.H. VAN NES. LABDA, new perspectives for an old approach to ecological prediction.

11:45 ODUM, HOWARD T. and ELISABETH C. ODUM. Simulating energy systems language models and eMpower with symbol-icons, object programmed for the MacIntosh program EXTEND.

TUESDAY AFTERNOON, AUGUST 9,1994

Sess 4: **ISEM Symposium: Ecological Risk Assessment.** Organized by ROBERT A. GOLDSTEIN, Environment Division, EPRI, P.O. Box 10412, Palo Alto, CA 94303 (415/855-2593). **Knoxville Convention Center, Meeting Room 6**

1:00 GOLDSTEIN, ROBERT A. Introduction to ecological risk assessment.

1:30 BARTELL, STEVEN M. DOUGLAS B. CHAMBERS, DENNIS K. KROCHAK, and MARK B. WITTRUP. Ecological risk analysis of uranium exploration mining in northern Saskatchewan, Canada.

2:00 AKCAKAYA, RESIT. A method for integrating habitat data into models for extinction risk assessment.

2:30 MILLS, WILLIAM B and GEORGE L. BOWIE. Potential impacts on aquatic organisms from steam-generated power plant riverine releases.

3:00 RECESS

3:15 DALE, VIRGINIA H., and ANTHONY W. KING. Implications of uncertainty in land-use change on global terrestrial CO_2 flux.

3:45 GINZBURG, LEV R. and SCOTT FERSON. Integrating objective and subjective uncertainties in ecological risk: an example of the spotted owl.

4:15 SPEAKERS' PANEL and AUDIENCE. What will the future of ecological risk assessment look like?

WEDNESDAY MORNING, AUGUST 10, 1994

Sess 5: ISEM Symposium. Towards rigorous validation and broad application of process-based terrestrial ecosystem models: deriving necessary model input from commonly available data. Organized by XIWEI YIN, Canadian Forest Service Sault Ste. Marie, Ontario, Canada P6A 5M7. (705/949-9461). **Knoxville Convention Center, Meeting Room 6**

8:00 YIN, XIWEI. Introductory remarks.

8:15 RASTETTER, EDWARD B. Validating ecosystem models of long-term responses to global change and other forms of self-delusion.

8:45 YIN, XIWEI. Input variables for the physical environment: reconstructing time series of global solar radiation, fog frequency, forest water fluxes, soil moisture, and soil temperature from air temperature and precipitation records.

9:15 LOVETT, GARY M, SCOTT V. OLLINGER, and JOHN D. ABER. Calculating regional-scale patterns of atmospheric deposition from available data.

9:45 RECESS

10:00 SIMPSON, LLOYD G., ROBERT A. NISBET and DANIEL B. BOTKIN. Input variables for biomass: estimating biomass and carbon storage from simple forest inventory variables.

10:30 POST, W.M. Soil data requirements for global change studies.

11:00 KIMMINS, J.P. and DANIEL MAILLY. Overcoming some of the problems of input data limitations by the hybrid simulation approach.

WEDNESDAY NOON, AUGUST 10, 1994

12:00 Business Meeting Luncheon. International Society for Ecological Modeling. Open meeting. **Holiday Inn World's Fair, Dogwood Room.**

WEDNESDAY AFTERNOON, AUGUST 10, 1994

Sess 6: ISEM Symposium: Facilitation, Nurse Plants, and Nucleation: Vegetation Cluster Processes Driving Plant Succession. Organized by EDWARD J. RYKIEL JR., Biosystems Group, Department of Industrial Engineering, Texas A&M University, College Station, TX 77843. (409/845-9573). **Knoxville Convention Center, Meeting Room 6**

1:15 RYKIEL JR., EDWARD J., Introduction.

1:30 ARCHER, STEVEN R. and EDWARD J. RYKIEL JR. Similarities in vegetation cluster formation processes in contrasting savanna ecosystems

2:00 MCPHERSON, GUY R. Environmental influences on facilitation and interference in semi-desert grasslands.

2:30 CALLAWAY, RAGAN M. and MARK D. BERTNESS. Gradients of physical stress and the relative importance of facilitation and interference

3:00 RECESS

3:15 YEATON, RICHARD. The role of cluster-phase dynamics in the rehabilitation of succulent Karoo rangelands "

3:45 WALKER, LAWRENCE R. Facilitation in primary succession.

4:15 BELSKY, A. JOY and CHARLES D. CANHAM. Inverted gaps? Savanna gaps? Grassland gaps? Are isolated trees in savannas comparable to tree-fall gaps in forests?

4:45 RYKIEL JR., EDWARD J. Summary.

THURSDAY MORNING, AUGUST 11, 1994

Sess 7: ISEM Symposium. Modularity in Models of Plant Growth. Organized by JAMES F. REYNOLDS, Department of Botany, Phytotron Bldg., Box 90340, Duke University, Durham, NC 27608-0340. (919/-660-7404) and BASIL. ACOCK, Systems Research Laboratory, USDA, Bldg. 011A, Room 165B, BARC-W, Beltsville, MD 20705. **Knoxville Convention Center, Meeting Room 6**

8:00 REYNOLDS, JAMES F. and BASIL ACOCK. Modularity in models of plant growth.

8:15 WHITNEY, ROGER . Linking plant growth modeling and software engineering concepts in object-oriented programming.

8:45 SEQUEIRA, RONALDO A. Implementation of object-oriented simulation models: advantages, disadvantages, and biological implications.

9:15 REDDY, V.R. and BASIL ACOCK. An object-oriented structure for crop models.

9:45 BREAK

10:00 PACHEPSKY, YAKOV and DENNIS TIMLIN A modular, two-dimensional soil and root process simulator: Design and examples.

10:30 CHEN, JIA-LIN and JAMES F. REYNOLDS. GEPSI: A *GE*neral *P*lant *SI*mulator based on object-oriented principles.

11:00 LUO, YIQI, HAROLD MOONEY, CHRISTOPHER B. FIELD, JIA-LIN CHEN, and JAMES F. REYNOLDS. Applying GEPSI to annual grasslands: A test of its generality.

11:30 PANEL DISCUSSION

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Abstracts

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ACEVEDO M.F., W.T. WALLER, and D.P.SMITH. Institute of Applied Sciences, University of North Texas, Denton, TX 76203.
Cladoceran population response to stress: switch to sexual reproduction.

We describe a model developed for assessing the potential population-level consequences of physical and chemical stressors acting on cladoceran populations; specifically, *Ceriodaphnia dubia* is selected for this modeling effort due to their extensive use in toxicity testing. The model is based on the dynamics of the life-cycle and focuses on the switching to sexual reproduction due to environmental stress. Hatching, maturation, mortality, food ingestion and growth are included. The density of males, sexual eggs, neonates and mature individuals are calculated. The switching to sexual reproduction is triggered by reduction of ingestion rate, which in turn is conditioned by physical, e.g. temperature and photoperiod, and/or chemical stress as well as to a reduction in food quantity and/or quality.

Key Words: *C. dubia*, model, population, risk assessments, stress, cladoceran.

AKÇAKAYA, H. RESIT. Applied Biomathematics, Setauket, NY 11733-1345.
A method for integrating habitat data into models for extinction risk assessment.

Habitats used by most species are becoming increasingly fragmented, requiring a metapopulation modelling approach to assessment of species extinction risks. Recognizing habitat patchiness from an endangered species' point of view requires utilization of spatial information on habitat suitability. A model for extinction risk assessment that meets both of these requirements is presented. The model has three components. The first component analyzes habitat data exported from a GIS, and identifies the patches of habitat that can support a population. The structure of these patches, including their locations, sizes and distances from each other, define the spatial structure of the metapopulation. The second component combines this spatial structure with demographic data and other information on the ecology of the species to complete a metapopulation model, which incorporates age or stage structure and density dependence for each population, spatial correlation and dispersal among populations, environmental and demographic stochasticity and catastrophes. The third component performs a risk analysis, and runs multiple simulations, automatically changing parameters to analyze the sensitivity of risks to input data.

ARCHER, STEVEN R. and EDWARD J. RYKIEL, JR. Texas A&M University, College Station, TX 77843. Similarities in vegetation cluster formation processes in contrasting savanna ecosystems

The formation, structure and dynamics of vegetation clusters has been quantified in the Post Oak savanna and the Rio Grande Plains of central and south Texas. The sites contrast in cluster-forming species, *Quercus stellata - Juniperus virginiana* and *Prosopis glandulosa* - mixed-shrubs respectively. *Quercus* (non-legume) and *Prosopis* (legume) are the nucleating species which establish in grassland patches and serve as an attractor for animal dispersed seeds. Subsequent changes in soils and microclimate facilitate germination and/or establishment of subordinate shrubs. Analysis of multi-temporal aerial photographs suggests that landscape succession from grassland to park land to woodland occurs as new clusters are initiated and existing clusters expand and coalesce. After a phase of co-existence, asymmetric competition develops as understory shrubs increase in size and density. In the *Quercus* savanna, *Juniperus* eventually grows through the canopy of the nucleating hardwood. However, in southern Texas, decadal frosts prevent cold sensitive subtropical understory shrubs from over-topping *Prosopis*. At this site, high densities of understory shrub roots in upper soil horizons reduce growth and seed production of the overstory *Prosopis*. Mortality of deciduous nucleating trees and persistence of the evergreen species eventually occurs at both sites. Despite the species differences, the same ecological processes of cluster formation and landscape change seem to be operating in both these ecosystems, indicating that the process may be general.

BARTELL, STEVEN M.[1], DOUGLAS B. CHAMBERS[2], DENNIS K. KROCHAK[3], and MARK B. WITTRUP[4]. [1]SENES Oak Ridge, Inc., Oak Ridge, TN 37830, [2]SENES Consultants, Ltd., Richland, Ontario, Canada, [3]TAEM Ltd., Saskatoon, Saskatchewan, Canada, and [4]Cameco Corporation, Saskatoon, Saskatchewan, Canada. Ecological risk analysis of uranium exploration mining in northern Saskatchewan, Canada.

A screening-level ecological risk analysis addressed potential mining impacts at Yak Creek, McDonald Lake, and McArthur River. Impacts on populations of six aquatic and nine terrestrial valued ecosystem components (VECs) were evaluated in relation to expected exposures to five radionuclides and eleven toxic metals. Risks associated with possible changes in pH, alkalinity, total dissolved solids, and ammonia were also examined. The results of the screening calculations suggested that copper, cadmium, iron, and ammonia posed potential risks to many of the aquatic plants, invertebrates, and fish. Risks posed by radionuclides appeared to be negligible for terrestrial and aquatic VECs.

BAVECO, HANS M., ANDRE M. DE ROOS AND C. KLOK. Institute for Forestry and Nature Research, Postbox 23, 6700 AA Wageningen, The Netherlands. Predicting the impact of pesticides on earthworm population dynamics, using stage-structured and individual-based models.

To arrive at criteria for pesticide application, based on the side-effects (in a non-target area), an approach for predicting the impact of contaminants on populations is being developed. Because of their importance in terrestrial foodchains, earthworms (Lumbricidae, i.e. Lumbricus rubellus) are chosen as the primary target of modeling. As most experimental information is available at the level of the individual, growth, maturation and reproduction of individuals are explicitly modeled. Simple rules are applied for the partitioning of energy between growth, reproduction and maintenance. The population models derived from this individual model, are essentially size- or staged-structured. As little is known about regulatory mechanisms, models assuming predator-regulation as well as models assuming food-regulation are developed. The impact of toxic substances on the population, via the individual energetic parameters, is assessed in the stage-structured models. Recovery rates under more realistic conditions including environmental stochasticity, are estimated from individual-based models. The results refer to relatively simple theoretical models. They show how different the impact of toxic substances can be depending on the regulatory mechanisms operating in de population. They illustrate how the effects on individual life-history parameters relate to effects observed on the population level.

BELSKY, A. JOY[1] and CHARLES D. CANHAM[2]. [1]Oregon Natural Resources Council, 522 S.W. 5th Ave., Suite 1050, Portland, OR 87204, USA and [2]Institute of Ecosystem Studies, Millbrook, NY, 12545. Inverted Gaps? Savanna Gaps? Grassland Gaps? Are isolated trees in savannas comparable to tree-fall gaps in forests?

Tree-fall gaps create understory patches that are warmer, lighter, and drier than the surrounding forest matrix. Conversely, trees in savannas create understory patches that are cooler, darker, and wetter than the surrounding grassland matrix. The patches below both forest gaps and savanna tree crowns are associated with unique species compositions, altered successional patterns, and altered soil properties. With so many similarities between forest gaps and savanna trees, the question is whether savannas, like forests, can profitably be described and studied in terms of patch dynamics. And if so, why haven't they?

CALLAWAY, RAGAN M.[1] and MARK D. BERTNESS[2]. [1]University of Montana, Missoula, MT 59812, and [2]Brown University, Providence, RI 02912. Gradients of physical stress and the relative importance of facilitation and interference.

Most of the interactions between plant species that have been reported in the literature fall into one of two categories: facilitation or interference. However, many recent researchers have emphasized that multiple, interacting mechanisms including facilitation, competition, and allelopathy determine overall effects of plant species on each another, and that these mechanisms may shift in relative importance in space and time. In habitats characterized by high consumer pressure or by extreme physical stress, buffering of negative effects by neighbors is often the dominant mechanism in associations that might otherwise be competitive. We propose a hypothesis, which emphasizes the cumulative effects of positive and negative interactions, as a framework for incorporating facilitation into models of community organization. We hypothesize that positive interactions among plants should be particularly important in driving community structure and dynamics in systems characterized by physical stress or by high consumer pressure, whereas interference should predominate in systems where the physical environment is relatively benign and consumer pressure is less severe. As a test of the "physical-stress" component of this hypothesis, we examined spatial associations between whitebark pine "nurse plants" and subalpine fir along a gradient of productivity and stress in subalpine forests of the Northern Rockies. In highly productive sheltered sites, which we assume to be less physically stressful, spatial associations between whitebark pine and subalpine fir were random, suggesting that no positive interactions exist. However, in exposed, physically stressful sites with much lower productivity, subalpine fir is strongly associated with whitebark pine, suggesting that facilitation is important.

CASWELL, HAL. Biology Department, Woods Hole Oceanographic Institution, Woods Hole MA 02543. Comparative demography with structured population models: untangling environmental effects.

The environment affects population growth only through its effects on the vital rates. The vital rates vary with the age, size, and developmental stage of the individual. So do the sensitivities of the vital rates to any given environmental factor. Thus, comparative demography using structured population models is a powerful tool for studying the effects of environmental factors on population growth. In this paper I will present a general framework for such analyses, with specific examples from fixed, random, and regression designs.

CHEN, JIA-LIN and JAMES F. REYNOLDS. Duke University, Durham, NC 27708. GEPSI: A *GE*neric *P*lant *SI*mulator based on object-oriented principles.

Object-oriented programming is an ideal tool for modular design of large, complex systems. We present a generic plant growth model (GEPSI) designed and programmed in C++. GEPSI is generic in the sense that new models of any plant species can be developed by adding specific subclasses to existing classes, while the overall structure and existing classes of GEPSI remain the same. The current version of the model contains two blocks, ENVIRONMENT and PLANT. The ENVIRONMENT block has classes Weather, MicroWeather and Soil. Weather defines and updates hourly conditions above a canopy based either on measurements or theoretical formulas. MicroWeather incorporates a radiation transfer model and updates hourly micro-meteorological profiles within a canopy. Soil defines and updates profiles of soil temperature, water content and nitrogen concentrations. All profiles are based on first principles equations of physical and chemical processes. In the PLANT block, the classes are designed to parallel "true" hierarchical ownership structures of a plant. The classes are Plant, Canopy and RootSystem, and Stem, Leaf, Fruit, and Root. Each class defines and updates daily, hourly or subhourly attribute variables based on physiological processes. The hierarchical inheritance structure of classes is the basis from which new subclasses can be added.

COOKE, JERRY L. and KEN L. RISENHOOVER. Texas A&M University, College Station, Texas 77843. An Individual-based Model of Mule Deer-Habitat Relationships in a Self-Fragmenting System: the Chihuahuan Desert.

An individual-based modelling approach was used to examine mechanisms affecting mule deer distributions in the Chihuahuan desert. We combined edaphic data and measurements of rainfall to model spatial-temporal patterns of vegetative productivity. The accumulation of soil moisture across the landscape matrix was a function of rainfall pattern coupled with each sites infiltration, evapo-transpiration, and position on the landscape. Extant soil moisture and temperature was used to predict vegetative growth for the soil type found at each site. The seasonal nature of rainfall in the Chihuahuan desert, and the variable efficiency of soils to absorb and retain water, produced varying degrees of resource fragmentation among seasons and between years. Model output was used to simulate deer movements, allowing deer population behavior to emerge from the landscape's constraints.

CROWE, KATHLEEN M., Cornell University, Ithaca, NY 14853. Asymmetric competition and competitive outcome.

Recent experimental and theoretical studies of various ecological systems have suggested that asymmetric, or intra-class, competition may have a significant effect on competition between species. These asymmetries typically take the form of extra competitive or predation effects among a small subset of the size classes of the population. This talk presents a simple model of asymmetric competition among two size-structured species, studies the effects of the asymmetries and compares the results with relevant examples from the biological literature.

CUSHING, J. M. Department of Mathematics, University of Arizona, Tucson, AZ 85721. Models for hierarchically structured populations.

Hierarchical models are those in which the vital rates of an individual are functions of the total population densities of all individuals of higher and/or lower rank as determined by some scalar hierarchy. In an age-structured hierarchical population the ranking is based upon chronological age and age-specific birth and death rate of an individual are functions of the total number of individuals older than and/or younger than the individual. It can be shown, rather surprisingly, that from the complicated nonlinear, integro-differential, hyperbolic partial differential equations for the age-specific density distribution which arise from the basic McKendrick equations there can be derived a decoupled ordinary differential equation for total population size. We will show how this methodology can be used to study the effects that various kinds of intra-specific interactions can have on a species' success in inter-specific competition interactions. The theoretical questions that will be addressed include: is intra-specific contest competition advantageous or disadvantageous to a species when it competes with other species for a common resource? What about cannibalism? Can the presence in a population of such intra-specific interactions make the difference between its survival or its competitive exclusion by other species?

DALE, VIRGINIA H., and KING, ANTHONY W., Oak Ridge National Laboratory, Oak Ridge, TN 37830. Implications of uncertainty in land-use change on global terrestrial CO_2 flux.

The major sources of uncertainty in global terrestrial CO_2 flux arise from estimates of biomass, land use change, and fate of carbon. The range and source of variability in existing data on these three factors is examined. For global analyses, information is typically used from major biomes for each continent, and the degree of variability in the estimates is not clear. A factorial analysis of uncertainty and error of a global carbon model is also used to discern between the implications of variability in these three factors. The model results suggest that land-use change contributes the greatest uncertainty in projections of carbon flux. These implications are discussed with relevance to land-management decisions and their effects upon the global carbon flux from terrestrial systems. This research provides a case study of the components of ecological risk analysis: evaluating the variability in the data, performing a error analysis of a model, and considering the implications of the model results to the ecological system and resource management.

DONG, QUAN[1] and DONALD L. DeANGELIS. Vanderbilt University, Nashville, TN 37235, Oak Ridge National Laboratory, Oak Ridge, TN 37831. Modeling population consequences of cannibalism and competition for food in smallmouth bass.

We use an individual-based modeling approach to study the consequences of cannibalism and competition for food on recruitment of the young of the year (y-o-y) smallmouth bass. Our model simulates many y-o-y and older immature fish of a sample population simultaneously. These older fish are potential cannibals on and competitors with y-o-y. For each fish, foraging, growth and survival are simulated daily for a growing season. Cannibalism occurs as a part of a foraging process. Our modeling results are listed below. 1) The increase of recruitment decelerates with the increase of initial density of y-o-y and may approach to a certain level as the initial density of y-o-y continues to increase. 2) The initial density of immatures adds another dimension to the density relationship, changes the shape of the curves on the y-o-y recruitment plane into a more Ricker type curve. 3) There is a strong interaction between initial density of y-o-y and density of immatures. Existence of high density of these immatures and therefore sharing food among the y-o-y and immatures in same habitat are responsible for much overcompensation. 4) Cannibalism intensifies the changes that were soly determined by competition for food and generally reduces the recruitment. 5) Growth decreases with overall density and the portion of potential cannibals. Variation in the length of y-o-y increases with density. 6) Cannibalism improves average growth of cannibals. 7) The daily rate of cannibalism varies. Empirical studies of different species showed similar results.

DUNGAN, J.L. and R.M. KELLER. NASA Ames Research Center, Moffett Field, CA 94035. SIGMA: A knowledge-based simulation tool applied to ecosystem modeling.

The need for better technology to facilitate building, sharing and reusing models is generally recognized within the ecosystem modeling community. The Scientists' Intelligent Graphical Modelling Assistant (SIGMA) creates an environment for model building, sharing and reuse which provides an alternative to more conventional approaches which too often yield poorly documented, awkwardly structured model code. The SIGMA interface presents the user a list of model quantities which can be selected for computation. Equations to calculate the model quantities may be chosen from an existing library of ecosystem modeling equations, or built using a specialized equation editor. Inputs for these equations may be supplied by data or by calculation from other equations. Each variable and equation is expressed using ecological terminology and scientific units, and is documented with explanatory descriptions and optional literature citations. Automatic scientific unit conversion is supported and only physically-consistent equations are accepted by the system. The system uses knowledge-based semantic conditions to decide which equations in its library make sense to apply in a given situation, and supplies these to the user for selection. The equations and variables are graphically represented as a flow diagram which provides a complete summary of the model. Forest-BGC (Running and Coughlan 1988), a stand-level model that simulates photosynthesis and evapotranspiration for conifer canopies, was originally implemented in Fortran and subsequently reimplemented using SIGMA. The SIGMA version reproduces daily results and also provides a knowledge base which greatly facilitates inspection, modification and extension of Forest-BGC.

GINZBURG, LEV R.[1] and SCOTT FERSON[2]. [1]State University of New York, Stony Brook, NY 11794, and [2]Applied Biomathematics, Setauket, NY 11733. Integrating objective and subjective uncertainties in ecological risk: an example of the Spotted Owl.

It has only recently been recognized that there are two distinct kinds of uncertainty in ecological risk analyses. Objective uncertainty (also known as variability, heterogeneity or 'Type A' uncertainty) arises from temporal and spatial stochasticity, genetic novelty, and inter-individual variation. Subjective uncertainty (also known as ignorance, or 'Type B' uncertainty) arises from measurement error and indecision about the form of the mathematical model. Since subjective uncertainty depends on our own ignorance, it can be reduced by empirical study, but additional investigation will not generally reduce the magnitude of objective uncertainty (although we may get better estimates of its size) since it exists independently of human observation. These two kinds of uncertainty are confounded when a single technique such as Monte Carlo analysis is used to propagate uncertainty through a model. Some workers have suggested that the two kinds of errors should be propagated separately. But even this strategy may be insufficient since subjective uncertainty need not obey the axioms of probability theory. We give an example from a population viability analysis for Spotted Owl in which subjective uncertainty plays a substantial role.

HART, DEBORAH R.[1] and ROBERT H. GARDNER[2]. [1]Knox College, Galesburg, IL 61401 and [2]Oak Ridge National Laboratory, Oak Ridge, TN 37831.
Models for the spread of invading organisms subject to competition.

We have developed and analyzed a spatially explicit model of the effect of competition on the rate and extent of invasion. The model assumes a mobile immature stage followed by a sessile adult stage. Competition for space is based on a seed lottery, with the probability of success dependent on species specific habitat preferences. Analytical results using integrodifference equations shows that, on a homogeneous landscape, the speed of invasion depends on the level of competition and the form of the dispersal density function. Competition can considerably slow the invasion speed and, when the mean dispersal distance is fixed, the invasion speed is the fastest for dispersal functions with a relatively large tail. Cellular automata simulations of invasion under competition on complex heterogeneous landscapes confirms these results and allows an evaluation of the combined effect of competition and landscape fragmentation on the characteristics of species invasion.

HASTINGS, ALAN. Division of Environmental Studies and Institute for Theoretical Dynamics, University of California, Davis, CA 95616. Structured models of metapopulations -- focus on local population sizes.

I have developed models for metapopulations which include a description of local population sizes. I will begin by reviewing results for models where the population dynamics are described in continuous time, using a continuous description of population sizes. I will then describe an alternate formulation based on a discrete time (and discrete size) description of the dynamics. I will use this description to determine the conditions under which the population as a whole cycles. This will then be used to understand the conditions that lead to some insect species exhibiting outbreaks which are widespread, whereas other species typically have outbreaks only at local spatial scales.

HENSON, SHANDELLE M.[1] and THOMAS G. HALLAM[2]. [1]University of Tennessee, Knoxville, TN 37996, and [2]University of Tennessee, Knoxville, TN 37996. Asymptotic competitive exclusion in structured populations.

McKendrick-von Foerster physiologically structured partial differential equation models are used to investigate asymptotic competitive exclusion, a nongenetic "survival of the fittest" for ecological morphs which are closed under reproduction. We consider both the age structured and the individual-based age-size structured settings, and allow birth, death, and individual growth rates to be time and density dependent in the general cases. Results suggest that a good measure of "ecotypic fitness" is the product βL of the birth rate function β and survivorship function L. Density dependence in mortality that uniformly affects the different morphs does not modify the characteristic behavior.

HERENDEEN, ROBERT. Illinois Natural History Survey, Champaign, IL 61820. Bottom-up:top-down and trophic cascade paradigms: 1. Qualitative differences between food chains and webs. 2. Quantitative effects in chains.

Trophic cascade (TC) and bottom-up:top-down (BU:TD) hypotheses of ecosystem response to perturbation are special, but widely applicable, instances of more general ecosystem model considerations. 1. Qualitative, webs v. chains: The TC's prediction of the sign of compartmental stock changes in a perturbed ecosystem is based on a linear food chain model and does not necessarily hold for food webs. 2. Quantitative, chains: For a wide range of ratio-dependent functional relationships between trophic levels in a food chain, BU:TD predicts that perturbation effects should propagate up the chain with the same sign and roughly constant strength, but down the chain with alternating sign and diminishing strength. I illustrate by simulating perturbation responses in models of three ecosystems (one chain and two webs). I also develop an analytical approach to justify the quantitative conclusion for the chain. The approach can be used for any form of functional response connecting trophic levels.

HINCKLEY, S.[1], A. HERMANN[2], and B. A. MEGREY[1]. [1] NOAA, Alaska Fisheries Science Center, Seattle, WA 98115, and [2] University of Washington, Seattle, WA 98195. Coupled Bio-physical Modeling of Recruitment Dynamics of a Marine Fish: A Spatially Explicit, Individual-based Approach.

Biotic and abiotic controls on population regulation processes in marine fish species are believed to act most strongly on the earliest life stages, such as planktonic eggs and larvae. Complex and interacting factors affecting growth and survival of these stages may be explored with models which couple biological processes and ocean physics. Individual-based approaches (IBMs) which treat organisms as separate entities may be preferable to aggregated models for situations where individuals do not experience the same history of exposure to environmental conditions throughout their lives. For planktonic marine populations in areas with strong, variable currents, spatial trajectories may in fact diverge widely among individuals, hence each animal will experience different temperatures, salinities, prey and predator fields over its life. Growth histories and survival probabilities may therefore also differ widely among individuals. Few IBMs to date have explicitly included spatial factors and their effect on population regulation and recruitment through effects on individuals. For example, workable techniques for coupling hydrodynamic models with biological process models are not well established. Although many approaches are theoretically viable, current computer speed and storage limitations set practical limits on efficient alternatives. In this presentation we describe a successful approach at coupling a regional circulation model with an individual-based biological process model. Our framework is intended to capture fundamental biological and physical processes, resolve the appropriate spatial and temporal scales, and satisfy practical limits on computation. The two primary model components are: (1) the physical model, which is a wind and buoyancy forced 3-D eddy-resolving hydrodynamic model (the Semispectral Primitive Equation Model of Haidvogel, Wilkin, and Young), and (2) the population dynamics model, which is a spatially explicit, stochastic, individual-based biological process model of egg and larval fish development. Specific examples are presented in which model-generated spatial distributions and measures of individual growth compare quite favorably with measured distributions. We conclude by drawing generalizations which should benefit anyone attempting to work with large-scale physical-biological coupled models. In addition, we discuss possibilities for incorporating additional trophic linkages such as zooplankton prey fields.

JOHNSON, ALAN R. and BRUCE T. MILNE. University of New Mexico, Albuquerque, NM 87131. A gradient percolation model of vegetative phase transitions.

Standard percolation has been suggested as a neutral model of heterogeneous landscapes. In the standard percolation model, each site in a regular lattice is randomly assigned to an "occupied" status, with probability p, or to an "unoccupied" status, with probability $1-p$. For the standard model p is assumed to be the same for all sites in the lattice. In gradient percolation, on the other hand, p is allowed to vary with spatial location as specified by an underlying gradient function. For both standard and gradient percolation models, a second-order phase transition occurs at a critical p value ($p_c \approx 0.5928$ for a square lattice). This phase transition is characterized by power-law scaling of (1) mean cluster size, (2) correlation length and (3) proportion of the landscape covered by a spanning cluster. The utility of gradient percolation as a model of vegetative transition zones (ecotones) will be tested by evaluating the power-law scaling of these variables in digitized aerial photographs of woodland/grassland ecotones in New Mexico.

KIMMINS, JAMES P. and DANIEL MAILLY. University of British Columbia, Vancouver, BC, V6T 1Z4, Canada. Overcoming some of the problems of input data limitations by the hybrid simulation approach.

The paper will discuss an alternative ecosystem modelling strategy - hybrid simulation - in which estimates of certain process rates, coefficients or ratios are obtained from relatively easy-to-obtain empirical field data. The hybrid simulation approach is a combination of process simulation and historical-bioassay empirical modelling strategies specifically designed to address problems of input data availability. Results of sensitivity analyses will be presented to illustrate the sensitivity of this modelling approach to the quality of input data.

Kirchner,Thomas B., William Alldredge and Terry McLendon. An Object-Oriented Toolkit for Creating Site Specific Models for Ecological Risk Assessments. Colorado State University, Fort Collins, Colorado.

Models are an essential component of most ecological risk assessments. These models often need to consider individual, population, community and ecosystem level effects. Site specific factors are often of critical importance in defining endpoints for the analysis and for identifying processes and components to be considered in the models. A range of models, from simple screening models to dynamic, spatially explicit models, are needed for many analyses. In addition, the results of analyses need to be presented in such a way that decision makers can understand what was considered in the assessment, what assumptions were made, what are the uncertainties in the results, and what are the impacts of management decisions on the environment. To facilitate an ecological risk assessment at the Los Alamos National Laboratory we have developed a library of C++ classes. These classes enable one to construct models easily from verified components. The library supports interprocess communication(IPC) using several protocols. IPC classes can be used to create distributed model systems and to link models to database systems. Components for assembling graphical user interfaces are included for DOS and UNIX Motif. Verification is enhanced by compile-time options that include code to perform dimensional analysis on computations during the execution of the model. The library, advantages and disadvantages of IPC and an example of a risk assessment model will be described.

KOOIJMAN, BAS. Dept. Theor. Biol., Vrije Universiteit, de Boelelaan 1087, 1081 HV Amsterdam. Contraint population dynamics and the entropy of biomass.

The zero-th trophic level in models of food chains or food webs is often assumed to grow exponentially or logistically. Since the resources of the zero-th trophic level are not included, these models do not obey mass and/or energy conservation laws. Simulation studies indicate that the typical wild oscillatory behaviour of these models disappears when the zero-th trophic level is inert and supplied from outside the system in a way that is consistent with conservation laws. Incorporation of maintenance requirements and reserve pools also have stabilizing effects. The necessity to include both these traits to obtain realism is illustrated in the glucose-bacteria-myxamoebae chain in a chemostat. It will be shown how dynamic models for uptake and use of resources can be made consistent with mass and energy conservation laws for micro-organisms without introducing new parameters. The essence is in the coupling of mass fluxes and dissipating heat to the processes of assimilation, growth and maintenance. This approach allows a unique decomposition of biomass into a structural and a reserve component on the basis of measurements of the elemental composition of biomass. The reasoning can be simply extended to include product formation (such as penicellin) and fermentation. Application of the conservation law for free energy offers an indirect access to the free energy content of structural biomass and reserves, and via Gibbs relationship, to the entropy of biomass. This elusive parameter is of vital importance to the rigorous definition of the concept 'energy' and knowledge about its value might contribute to funtamental issues in molecular biology.

LOVETT, GARY M.[1], SCOTT V. OLLINGER[2], and JOHN D. ABER[2]. [1]Institute of Ecosystem Sudies, Box AB, Millbrook, NY 12545, and [2]Complex Systems Research Center, University of New Hampshire, Durham, NH 03824. Calculating regional-scale patterns of atmospheric deposition from available data.

Regional-scale simulations of terrestrial biogeochemical processes require regional-scale specifications of atmospheric inputs. Regional averages of atmospheric deposition or coarse-resolution isopleths based on continental-scale monitoring programs are insufficient because spatial variability of atmosphericdeposition can be higher within a landscape than across a region. This extreme variability results from spatially variable rainfall amounts and the sensitivity of dry deposition and cloud water deposition to local meteorology and vegetation structure. We have developed a spatial model of wet and dry deposition patterns in the northeastern U.S. which incorporates some of the major features of atmospheric deposition patterns. This talk will discuss the strengths and limitations of the model and an extension of the approach to better define variability in atmospheric deposition due to elevation and land use.

YIQI LUO[1], HAROLD A. MOONEY[1], CHRISTOPHER B. FIELD[2], JIA-LIN CHEN[3], and JAMES F. REYNOLDS.[3] [1]Stanford University, Stanford, CA 94305, [2]Carnegie Institution of Washington, Stanford, CA 94305, and [3]Duke University, Durham, NC 27708. Applying GEPSI to annual grasslands: A test of its generality.

GEPSI is a modular, *ge*neric *p*lant *si*mulator, designed and programmed in C++, that models soil and aerial environments, photosynthesis, respiration, carbon partitioning, and growth. In principle, GEPSI is designed to be generic so new models of any plant species can be readily developed by adding specific subclasses to existing classes, while the overall structure and existing classes of GEPSI remain unaltered. To date, GEPSI has been parameterized for two woody species, loblolly pine (*Pinus taeda*) and creosotebush (*Larrea tridentata*). We present results -- both successes and failures -- from a test case of the application of GEPSI to model the growth of species in a California annual grassland.

MARSHALL, JOHN D.[1] and RONDA L. KOROL[2]. [1]University of Idaho, Moscow, ID 83844- 1133, and [2]Intermountain Research Station, USDA Forest Service, Moscow, ID 83843. Stable carbon isotope ratios as a test of the intermediate calculations of a biogeochemical forest ecosystem model, Forest-BGC.

Complex ecosystem models are often tested by comparing their final predictions of, e.g., NPP, to measurements. However, a test of such a model's mechanistic basis would require verification of its intermediate calculations. Here we present such a test using stable carbon isotope ratios of foliage to verify the photosynthetic gas exchange calculations of Forest-BGC, biogeochemical forest ecosystem model. Foliage samples were gathered from seven conifer tree species growing in diverse ecosystems, including *Pinus elliottii* from Florida, *Pinus resinosa* from Wisconsin, *Pinus ponderosa* from Montana, *Pseudotsuga menziesii* from British Columbia, *Tsuga heterophylla* from Oregon, and *Pinus contorta* from Colorado. Forest-BGC was run after being modified to produce an estimate of the stable carbon isotope ratio; predictions were subsequently compared to the isotope measurements. In a separate experiment the model was modified to accept carbon isotope ratios as inputs; photosynthetic rates were then calculated using a new algorithm and the isotopic data. Old and new photosynthetic algorithms were compared in terms of their ability to predict measured NPP.

McPHERSON, GUY R. University of Arizona, Tucson, AZ 85721. Environmental influences on facilitation and interference in semi-desert grasslands.

Facilitation and interference between woody plants were examined in semi-desert grasslands of western Texas. *Prosopis glandulosa* facilitated establishment of *Juniperus pinchotii* in the southern High Plains but not in the nearby Rolling Plains. The relationship between *Prosopis* and *Juniperus* shifted from facilitation to competition as *Juniperus* plants became large on the High Plains, apparently contributing to mortality of *Prosopis* plants. Large *Juniperus* plants facilitated establishment of other woody species (*Berberis trifoliolata, Rhus microphylla, Mimosa biuncifera*) in the High Plains and Rolling Plains. Interactions between plants were clearly dependent on the environment: facilitation was observed, and contributed to cluster-phase successional dynamics to varying degrees in both regions, whereas interference was observed more frequently and with more species on the Rolling Plains than on the High Plains.

MILLS, WILLIAM B. and GEORGE L. BOWIE. Tetra Tech, Inc., Lafayette, CA 94549.
Potential impacts on aquatic organisms from steam-generated power plant riverine releases

Power plants release excess heat and chemicals to rivers both by permitted NPDES discharges and inadvertently by pond leachate, fuel spills, and atmospheric deposition. A wide variety of constituents such as selenium, copper, benzo(a)pyrene and pesticides are associated with power plant operations and therefore can be potentially transported to rivers. The objective of this work is to evaluate the potential impacts of power plant releases on organisms in rivers. Chemical concentrations and excess heat distribution in rivers are predicted using the Electric Power Research Institute's RIVRISK model. Ecological risks are estimated for fish and invertebrate communities using predicted exposure concentrations and reference toxicity values from the literature for selected contaminants. Habitat differences (water column vs. sediments) and spatial and temporal differences in exposure are included in the assessment. Because the model's algorithms are embedded within a Monte Carlo framework, the predicted results are interpreted probabilistically and examined to identify conditions that lead to excessive ecological exposures. Because RIVRISK can also calculate human health risks, ecological and human health risks are compared.

NISBET, ROGER M.[1], EDWARD MCCAULEY[2], WILLIAM W. MURDOCH[1], ANDRE M. DE ROOS[3] AND WILLIAM .S.C. GURNEY[4]. [1]Department of Biological Sciences, University of California, Santa Barbara, CA 93106, USA. [2]Department of Biological Sciences, University of Calgary, Calgary, Alberta T2N 1N4, Canada. [3]Department of Pure and Applied Biology, University of Amsterdam, Kruislaaan 318, 1098 SM Amsterdam, The Netherlands. [4]Department of Statistics and Modelling Science, University of Strathclyde, Glasgow G1 1XH, U.K. Structured population models for zooplankton.

Structured population models aim to relate the properties of individuals and populations, yet there are very few systems for which population dynamics have been predicted from experiments on individuals, with the results subjected to experimental test. We have performed experiments to determine the effect of food supply on individual growth, reproduction and mortality of the water flea *Daphnia* in laboratory batch culture, and also on population dynamics under similar conditions. We construct a stage structured model describing *Daphnia* population dynamics in terms of five delay-differential equations, in which *all* functions and parameters are obtained from the experiments on individuals. The model predictions of equilibrium juvenile and adult populations, juvenile stage duration, and adult fecundity are compared with experiment.

ODUM, HOWARD T. and ELISABETH C. ODUM. Environmental Engineering Sciences, University of Florida, and Santa Fe Community College, Gainesville, Fl 32611. **Simulating energy systems language models and eMpower with symbol-icons, object programmed for the Macintosh program EXTEND.**

Following a several year development & testing period, symbol-icons of the general systems energy language have been object programmed for automatic simulation using the Macintosh program EXTEND. When the blocks are pulled to the screen and connected, the system of symbols sets up the system of equations for simulation and output graphs. Information is passed back and forth between blocks with 4 position arrays ("force", flow, handling code, and transformity). Five plotter icons allow different kinds of graphs depending on the purpose (Quantity, Flow, EMergy, empower, and Transformity). The process of programming has helped define eMergy, empower, and transformity mathematically. Examples will include ecosystems and ecological economic systems. We will also demonstrate EXTEND models for elementary teaching which start with pictorial icons. One of these "Environmental Decision Making" is part of the published software BioQUEST and another was prepared for schools studying Biosphere 2.

PACHEPSKY, YAKOV A.[1] and DENNIS TIMLIN[2]. [1]Duke University, Durham, NC 27710, and [2]Systems Research Laboratory, USDA, Beltsville, MD 20705. A modular two-dimensional soil and root process simulator: Design and examples.

We proposed the design of a generic two-dimensional soil simulator for use in crop modeling. Decoupling of processes and rearrangement of boundary condition formulations was used to facilitate independence of modules. Encapsulation of information was consistently implemented to provide simplicity of replacement, amendment and addition of modules. Interaction of modules on the spatial grid was enhanced by the possibility to consider both nodal and cellular values. Asyncronous coupling of modules allowed modules to have different internal time steps. Modules of various management practices could be easily incorporated into simulator. The representative 2DSOIL simulator is written in FORTRAN. Examples demonstrate its effectiness both for simulation of two-dimensional soil phenomena and for incorporation into crop models.

POST, WILFRED M. Oak Ridge National Laboratory, Oak Ridge, TN 37831 and University of Tennessee, Knoxville, TN 37996. Soil data requirements for global change studies.

Process models and methods of analysis for use in assessments and impact analyses of global change require information about soils. These global change studies require soil information for various applications including climate and land-use impacts on terrestrial vegetation dynamics, carbon cycle dynamics, trace gas exchange, and the interactions among these processes. Soils information including water holding capacity, carbon and nutrient content, depth to impermeable layer, is needed for determining soil moisture, hydrologic regime, organic matter decomposition, CO_2 return to the atmosphere, and nutrient dynamics. Additionally, texture, pH, redox potential, and hydrologic regime are important soil properties useful in developing more process based models of trace gas fluxes from terrestrial systems. A great deal of soils data has been assembled by soil scientists. These are in two forms: (1) measurements and laboratory analyses performed on samples taken from soil profiles and (2) maps of soil taxonomic units at various scales of spatial resolution including global. Combining these two forms of soils information is essential for modeling population and ecosystem processes at broad spatial scales. However, because of the spatial heterogeneity of soil properties and the sensitivity of ecosystem models to these properties, such a synthesis is difficult and must be done with specific objectives in mind.

PROVENCHER, LOUIS. The Nature Conservancy, P. O. Box 875, Niceville, FL 32588-0875, USA. Simplified individual-based simulations designed as experiments.

Although individual-based models (I-BM) can easily incorporate vast amounts of detail and realism, simplified and interpretable structures should first be attempted to answer precise questions. A model may be considered simple if its code structure can directly translate into a feasible experimental design and can be expressed as a system of analytically intractable partial and ordinary differential equations. Using spiders, I will give simple examples of tools for model simplification using allometric theory, sampling theory, and experimental hypothesis testing. I will also discuss one difficulty of correctly imitating differential equations, especially spatial ones, with I-BMs. A method and example focused on shortest-events will be presented to deal with this difficulty.

RASTETTER, EDWARD B. The Marine Biological Laboratory, Woods Hole, MA 02543. Validating ecosystem models of long-term responses to global change and other forms of self-delusion.

Models are now being built to predict long-term responses of terrestrial ecosystems to changes in CO_2 and Climate. To be realistic, these models must incorporate processes like soil development and succession that can take centuries to unfold. These slow processes typically constrain the long-term dynamics of the models. Because of these slow-to-develop constraints, are tests against data derived form short-term experiments (decade or less) even relevant to the long-term projections by these models? Are longer-term, reconstructed data from the past of high enough quality to adequately test these models? Can space-for-time substitutions tell us much about responses to CO_2? I believe the answers to all these questions is "No" and conclude that the only way to evaluate long-term model projections, other than waiting the requisite amount of time, is to compare them against other models with widely different underlying assumptions.

REDDY, VANGIMALLA R. and BASIL ACOCK. USDA, ARS, Systems Research Lab., Beltsville, MD 20705-2350. An object-oriented structure for crop models.

Object-oriented design (OOD) and programming (OOP) appear to offer many advantages for modular crop modeling. The model structure is modular and well-defined, reuse of code is facilitated through inheritance, and data can be hidden (encapsulated) inside the objects. However, OOD is best suited to describing the relationships between freely interacting objects. Plant models are not like the ATM software used so frequently in examples of OOD. The organs, i.e. objects, on a plant do not wait passively for input from other organs, but they all grow in response to their environment and interact with each other simultaneously and continuously. Also, our ignorance of the processes controlling plant growth forces us to use devices like the limiting-factor model to handle these interactions. Many plant models therefore calculate potential growth, limitations imposed by various factors and then actual growth. In short, there are procedural elements in plant models that do not easily fit an OOD. These and other considerations that have gone into an OOD structure for crop models will be described.

REYNOLDS, JAMES F.[1] and BASIL ACOCK[2]. [1]Duke University, Durham, NC 27608-0340, and [2]USDA, ARS, Systems Research Lab., Beltsville, MD 20705-2350.
Modularity in models of plant growth

Most plant growth models are created monolithic and idiosyncratic, only to have a very limited life. Modularity offers a way of opening up model structures to contributions from many authors. This will facilitate the comparison of various hypotheses about plant growth and greatly extend the life and utility of models. Models are collections of hypotheses and should be continuously advanced as our collective understanding advances. A generic modular structure - accepted by the modeling community - could be populated with modules by scientists with the relevant expertise. Alternative hypotheses could be readily tested by replacing modules, and the models would advance as our collective understanding increased. Is a "generic" structure feasible? Do general principles of modularity exist? Is object-oriented programming the answer?

RISENHOOVER, KEN L.[1], WEN YAN[1], JOHN H. ROESE[2], PETE D. TEEL[1], and JERRY L. COOKE[1]. [1]Texas A&M University, College Station, Texas, 77843, and [2]Lake Superior State University, Sault Ste. Marie, Michigan 49783. Modelling Tick-Host-Landscape Interactions: An Individual-Based Approach.

We develop a rule-based, event-driven model of ruminant foraging behavior and use it to evaluate how resource abundance and heterogeneity influence deer and cattle movements and other processes responsible for the spread and maintenance of "cattle fever" tick populations on the landscape. Forage resources were modelled as individual plant objects and subdivided into 5 forage classes (1 forb, 1 grass and 3 browse). Individual forager objects were characterized in terms of the physical, physiological and cognitive attributes of either white-tailed deer (Odocoileus virginianus) or cattle. Animal movements were modelled as a sequence of steps in response to perceived resources. Tick dispersion was a function of host-mediated dispersal on the landscape. As predicted, forage abundance and heterogeneity strongly influenced deer and cattle movements and residence patterns on the landscape. Areas providing forage resources attractive to both deer and cattle are "hot spots" for tick attachment and disease transmission. Results demonstrate that temporal and spatial attributes of tick detachment from one host and the likelihood of new host encounter at that location determine rates of tick dispersal and population size.

ROSE, KENNETH A. Oak Ridge National Laboratory, Oak Ridge, TN 37831-6036. Numerical considerations in individual-based modeling.

As individual-based modeling of ecological systems increases in popularity, models become more complex and numerical issues become important and, at times, limiting. Numerical issues include execution speed, memory requirements, and prediction accuracy. Some solutions to these numerical issues can affect the biological assumptions of the model. Fish models of population dynamics under high mortality and protracted spawning, explicit representation of spatial heterogeneity, and two species interacting via resource competition and predation are used to illustrate some common numerical issues that arise. For each issue, possible solutions are discussed and selected examples of their accuracy, efficiency, and effects on the biology of the models are provided. Some facts, but mostly opinions, are offered concerning the merits of the different proposed solutions, and the utility of alternative solutions such as object oriented programming and parallel processing.

SAMPSON, DAVID A.[1], PHILIP M. DOUGHERTY[2], and ELLEN J. COOTER[3]. [1]North Carolina State University, Raleigh, NC 27965, [2]USDA Forest Service, Southeast Forest Experiment Station, Research Triangle Park, NC 27709, and [3]NOAA ARL, on assignment to US Environmental Protection Agency AREAL, Research Triangle Park, NC 27711. Regional variation in loblolly pine production response to climate change in the southeastern United States.

Regional patterns of loblolly pine production response to climate changes projected for the southeastern United States were explored using an adaptation of the forest growth process model BIOMASS. Forty years of historical climate data were modified to reflect the projections of 4 general circulation models (GCM's); GISS, GFDL, OSU, and UKMO. Annual net primary productivity (NPP) of a modal loblolly pine stand was simulated under these climate scenarios using low and high leaf area index (LAI) and poor and good soil water holding capacities. NPP varied between 0 and 18 Mg C ha^{-1} yr^{-1}, with much of the variation in NPP attributed to climate variability and the particular GCM used. LAI and soil water holding capacity were of equal or lesser importance. NPP increased with increasing LAI and under all GCM scenarios. The largest and most consistent increases in NPP were simulated under the GISS scenario. NPP simulation results were the most dynamic using the UKMO scenario, with radical shifts in NPP predicted in response to climate, LAI, and soil water holding capacities.

SCHEFFER, M. and E. H. VAN NES. RIZA, P.O.box 17, 8200 AA Lelystad, THE NETHERLANDS.
LABDA, new perspectives for an old approach to ecological prediction.

Experts tend to do better than simulation models in predicting the response of ecosystems to measurements. The reasoning behind expert prognosis is often based on information on comparable cases that is subsequently adjusted to account for the expected effects of known differences in the situation. We formalized this procedure and coined it the LABDA approach ('Large Analogous But Differences Also'). An automated procedure to find analogous cases from a data base and an algorithm to use this information for prognoses are described. An example of the application in lake management is given.

RONALDO A. SEQUEIRA. USDA-ARS-Crop Simulation Research Unit, Mississippi State, MS, 39762. Implementation of object-oriented simulation models: advantages, disadvantages, and biological implications

For biological scientists the ideas of object-oriented design, based on the notions of taxonomy, discrete structures, behavior, and scale make the object-oriented approach intrinsically familiar and thus, attractive. More importantly, the implementation of object oriented simulations may have mechanistic implications for process representation that result in increased mechanistic realism. The ideas embodied in object-oriented programming have resulted in a change in the methods of software development and the administration of software projects. More than 75% of a software project's time is spent on maintenance. Object-oriented programming provides advantages in this area unavailable using other approaches. Key ideas regarding system design are presented: inheritance relations and hierarchies provide the keys to system architecture but it is 'parts-of' links or hierarchies that determine the distribution of control. This paper describes object-oriented programming in terms relevant to the modeling of biological systems. First, the characteristics of polymorphism, encapsulation, data hiding, abstraction, and hierarchy are explained from the point of view of a biosystems modeler; then, the building of simulation models using object-oriented design ideas is described.

SIMPSON, LLOYD G., ROBERT A. NISBET, and DANIEL B. BOTKIN. The Center for the Study of the Environment, 301 E. Carrillo St., Santa Barbara, CA 93101. Input variables for biomass: estimating biomass and carbon storage from simple forest inventory variables.

We are developing a spatial approach to the use of JABOWA-II forest growth model toproject changes in forest biomass over a large landscape. The model uses simple diameter at breast height and total height measures with biomass equations collected from the literature or developed directly by us to estimate biomass. Using a GIS, forests sites are characterized in each elevation band of a landscape and each is modeled with JABOWA-II under normal and global warming climatic conditions. The results are then mapped into the GIS to show changes in biomass quantity and distribution over the landscape. An example will be presented that uses a hypothetical landscape and forest in the boreal forest biome. The discussion that follows will demonstrate the process and importance of incorporating reliable biomass estimates into the model.

MARIANNE VAN DER PEIJL. Utrecht University, Sorbonnelaan 16, 3584 CA Utrecht, The Netherlands. Simulation of Nutrient and Carbon Dynamics in European Wetlands, testing a spatial modelling approach.

A model describing the nutrient dynamics in riparian wetlands has been developed. The model forms an integral part of a multi-disciplinary, international, EC-STEP-funded research project 'Functional Analysis of European Wetland Ecosystems'.
The main objectives of the model are to analyze wetland functioning in terms of nutrient dynamics and to predict the consequences of human impacts.
The model consists of submodels of C, N and P dynamics. Spatial aspects are implemented by defining separate models of dynamics in the various hydro-geomorphic units within the wetland and by connecting these through mass flows.
Hydro-geomorphic units are defined as areas of homogeneous geomorphology or landform, hydrology/hydrogeology and soil type.
The validity of this modelling approach is demonstrated by comparing model behaviour and simulation results of the model and a 'lumped model' of the same site.

WALKER, LAWRENCE R., University of Nevada, Las Vegas, NV 89154. Facilitation in primary succession.

Facilitation has long been suggested as an important process altering or even determining species replacements in plant succession. However, experimental evidence of facilitation is minimal, even in primary succession where facilitation was presumed to be most important. Comparisons of several primary seres suggest the relative importance of facilitation by colonizers associated with symbiotic nitrogen-fixing bacteria increases with decreasing soil nitrogen. However, competitive interactions between plant species frequently offset facultative effects. The relative importance of facilitation and competition varies temporally depending on growth rates and relative sizes of the interacting species, and spatially depending on the relative age and densities of the species. Species interactions are most likely to determine the rate of succession; environmental factors and species life histories are most likely to determine the actual sequence of species replacements.

WALLACE, LINDA L.[1], MONICA G. TURNER[2], WILLIAM H. ROMME[3], and YEGANG WU[4]. [1]University of Oklahoma, Norman, OK 73019, [2]Oak Ridge National Laboratory, Oak Ridge, TN 37831-6038, [3]Fort Lewis College, Durango, CO 81301, [4]South Florida Water Management District, West Palm Beach, FL 33416. Modeling ungulates, snow and fire on Yellowstone's northern winter range.

An individual-based, spatially-explicit model was developed to examine the effects of landscape patchiness due to fire in Yellowstone National Park on bison and elk survival. We also modeled differential snow accumulation during winters of varying severity. Probabilistic ungulate movement rules were developed and the model maintained an energy balance sheet on each animal in each of three different age/sex classes. Survival depended upon the balance of energy expenditures and energy intake that each animal was able to maintain. Analysis of the output of multiple model runs indicated that survival was primarily dependent upon winter survival, followed by effects of population size and fire size.

WHITNEY, ROGER. Dept. of Mathematical Sciences and Computer Science, San Diego State University, San Diego, CA 92182. **Linking plant growth modeling and software engineering concepts in object-oriented programming.**

We are using object-oriented software concepts to guide implementation of plant growth models implemented with object-oriented programming languages. These concepts include guidelines for improving the understandability and modifiability of objects, increasing the use of inheritance, improving the ability to reuse code in other plant models, and the identification of hidden objects in the models. Application of these software engineering concepts improves the modularity of the plant growth models.

WU, XINYUAN and WILLIAM J. MITSCH. The Ohio State University, Columbus, OH 43210. Hydrology and nutrient loading and retention models for constructed riparian wetlands.

Hydrology and nutrient loading and retention models have been developed in STELLA for the constructed riparian wetlands at two sites in the Midwest. A simple phosphorus retention model was developed based on three years of data on wetlands of the Des Plaines River Wetland Demonstration Project near Chicago and used as the first estimation of the phosphorus retention process in the wetlands of the Olentangy River Wetland Research Park in Columbus. A deterministic hydrology and nutrient loading model was developed based on historical weather and river hydrology and chemistry data and the wetland basin design. This model has been used to design the operational hydrology control regime according to wetland design parameters and to test the effect of different hydrologic operational regimes on the hydrology and nutrient dynamics of the wetland. Simulation studies show that the predictions of hydrologic loading and turnover time and phosphorus loading and retention by the simulation with mean historical river flow are considerably different from the means of the predictions by the simulations with actual historical river flows in the same years. Such deviation can lead to errors in the research design and operational planning. A stochastic hydrology model is being developed to achieve a more realistic representation of the system.

WU, YEGANG[1,2], LOUIS J. GROSS[2], D. MARTIN FLEMING[3], JANE COMISKEY[2], and HANG-KWANG LUH[2]. [1]South Florida Water Management District, West Palm Beach, FL 33416, Phone (407)686-8800, FAX (407)687-6436, yegang.wu@sfwmd.gov, [2]University of Tennessee, Knoxville, TN 37996, Phone (615)974-4295, FAX (615)974-6576, gross@math.utk.edu, and [3]Everglades National Park, Homestead, FL 33030, Phone (305)242-7832, FAX (305)242-7836. SIMPDEL: A spatially explicit individual-based model for white-tailed deer/Florida panther on Everglades landscapes..

SIMPDEL simulates individual white-tailed deer (*Odocoileus virginianus seminolus*) and Florida panther (*Felis concolor corvi*) throughout their lifespan on the South Florida landscape. The model includes behavioral changes in individuals induced by spatial and temporal vegetational responses to foraging and hydrology. One objective of the model is to investigate the population-scale effects of alternative hydrologic scenarios. To accomplish this, the model includes fawn and kitten production and growth, foraging and associated bioenergetics models for both deer and panther, activity range dynamics, panther-deer interactions, and various mortality factors for both deer and panther. The model is run on a landscape with spatial resolution as small as 100 m, and on time scales of up to 25 years. It is coupled to a hydrology model that supplies daily water-level changes, and to GIS data on vegetation cover types for Florida south of Lake Okeechobee.

YEATON, RICHARD I., University of Natal, Pietermaritzburg 3200, South Africa. The role of cluster-phase dynamics in the rehabilitation of succulent karoo rangelands.

The cluster-phase successional process in the succulent Karoo begins with the establishment in open sites of low-growing, multiple-stemmed species of the *Mesembryanthemacease*, which trap organic debris and soil at their bases. These plants serve as sites of establishment for seedlings of woody shrub species. Heavy overgrazing has resulted in the dominance of an unpalatable species, *Pteronia pallens*, which inhibits the establishment of more palatable species. Fifty seedlings per 100 m^2 germinated ten months after cutting *P. pallens* from a series of plots while only 0.1 seedlings per 100 m^2 were found on control plots. Hand-plantings of seedlings of the palatable woody shrub, *Osteospermum sinuatum*, under the skeletons of *P. pallens* were significantly more successful ten days after planting (89%) than those planted under live *P. pallens* (70%) and those planted in open sites (41%). Knowledge of the cluster-phase dynamics of this rangeland enables the planning of strategies for its restoration and indicates how this rangeland will respond to global warming. Grasses will enter the cluster and replace woody shrubs.

YIN, XIWEI. Canadian Forest Service, Sault Ste. Marie, Ontario, Canada P6A 5M7. Input variables for the physical environment: reconstructing time series of global solar radiation, fog frequency, forest water fluxes, soil moisture, and soil temperature from air temperature and precipitation records.

Light, temperature and water supply represent the major physical constraints to the function of terrestrial plant ecosystems. A series of mathematical modules are summarized which project global solar radiation, fog water input, soil water content and soil temperature. Model input data are limited to air temperature, precipitation, and rudimentary site information (latitude, elevation, slope, aspect, vegetative cover, soil texture and depth). Without site-specific calibration, model projections are compared favorably with available time-series data for diverse sites.

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