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Object-oriented Simulation Model of Rangeland Grasshopper Population Dynamics

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Introduction

The Grasshopper IPM Project has brought together many talented scientists for the purpose of enhancing the management and control of rangeland grasshoppers. These individual scientists have produced important advances in basic grasshopper ecology during the project. The project also provides a valuable opportunity to assimilate current knowledge into a framework to better understand grasshopper ecology for prediction and management. One method of using and testing this knowledge is to develop a simulation model. Object-oriented programming can be used to model individual grasshopper cohorts, habitats, parasites, and predators in substantial detail, and then aggregate them at the landscape level. Such a spatio-temporal model may provide insight into new grasshopper management strategies, prediction of outbreaks, and responses of populations to selective management tactics.

Materials and Methods

In March 1992 the modeling team (Berry, Onsager, Kemp, Belovsky and Joern) met in Bozeman for two days to formulate an initial model. The team met again in October to refine the current version. The model was structured from an object-oriented perspective. With this approach, each entity in the model functions in an autonomous fashion. At a higher level of abstraction, objects serve as templates to build specific instances of that type of object. For example, a generic grasshopper object can be defined. This object can contain the general attributes (size, age, location, etc.) and functions (movement, feeding, starvation, oviposition, etc.) of a grasshopper. Then the attributes and functions can be inherited and slightly modified to simulate any species.

Once each object is defined, any number of copies (with different ages, body sizes, etc.) can be created in a simulation. For example, new instances of grasshoppers would be created each day during spring egg hatch. In the same way, grasshopper habitats and predators or parasites can be abstracted and modeled. Because each entity is autonomous, the model is very flexible and can handle numerous and different types of habitats, predators and grasshoppers.

The model was originally written in SmallTalk V for Windows and converted to Turbo Pascal 6.0. Turbo Pascal, like SmallTalk, provides true object oriented features, but produces much faster execution times for the model. Some SmallTalk data structures were created from a third party library (Object Professional).

Results

The modeling team has successfully defined and implemented a high level grasshopper object. This generic grasshopper has several attributes: age, life stage, body mass, maximum body mass, egg pod size, etc. In addition, each grasshopper can feed, grow, age, produce eggs, resorb eggs, oviposit, lose body mass and die. Loss of body mass and egg resorption is caused by inadequate nutrition. Adult females will resorb eggs from their current clutch before they lose body mass. If remaining eggs in the clutch reach a specified mass, the entire clutch will be deposited in the patch where the grasshopper is located.

Habitat is partitioned into objects called patches. Each patch is considered to be homogenous to a grasshopper. Grasshoppers can move into and out of patches. Competition mortality for the grasshoppers is handled at the patch level. Food is preferentially allocated first to the grasshoppers with larger body sizes. Therefore, large grasshoppers will out compete smaller grasshoppers when food is limited. The model can be run with any number of grasshopper cohorts and patches. Each cohort and patch may be unique. A sample run with a single patch is shown in Fig. 1. and 2.

Discussion

Model development with the modeling team has lead to some very interesting discussions about grasshopper ecology. Often, data gaps have been discovered and experiments conceived. There has probably never been such a formalization of grasshopper ecology. In a sense, the model provides an uncompromising framework to formalize and assimilate current theory about grasshopper biology and population dynamics.

Object-oriented modelling has allowed this model to contain much more detail about grasshopper species differences and spatial dynamics. The ability to easily model many species in a heterogenous environment (many different patches) may help to unravel the mysteries of rangeland grasshopper outbreaks, and to evaluate selective management strategies such as baits, range management and biological control in an IPM framework. The modeling team intends to incorporate response to parasitism, predation, and forage quality into the model before termination of the project.

Summary

An object-oriented simulation model of rangeland grasshoppers has been designed and developed. This model captures and assimilates current knowledge of grasshopper ecology that might otherwise be lost at the end of the Grasshopper IPM Project. Details of individual grasshopper species and habitat are included easily using object-oriented programming techniques. The ability to easily model many species in a heterogenous environment (many different patches) may help to unravel the mysteries of rangeland grasshopper outbreaks, and to evaluate alternative management strategies such as baits, range management and biological control in an IPM framework. The modeling team intends to incorporate response to parasitism, predation, and forage quality into the model before termination of the project.

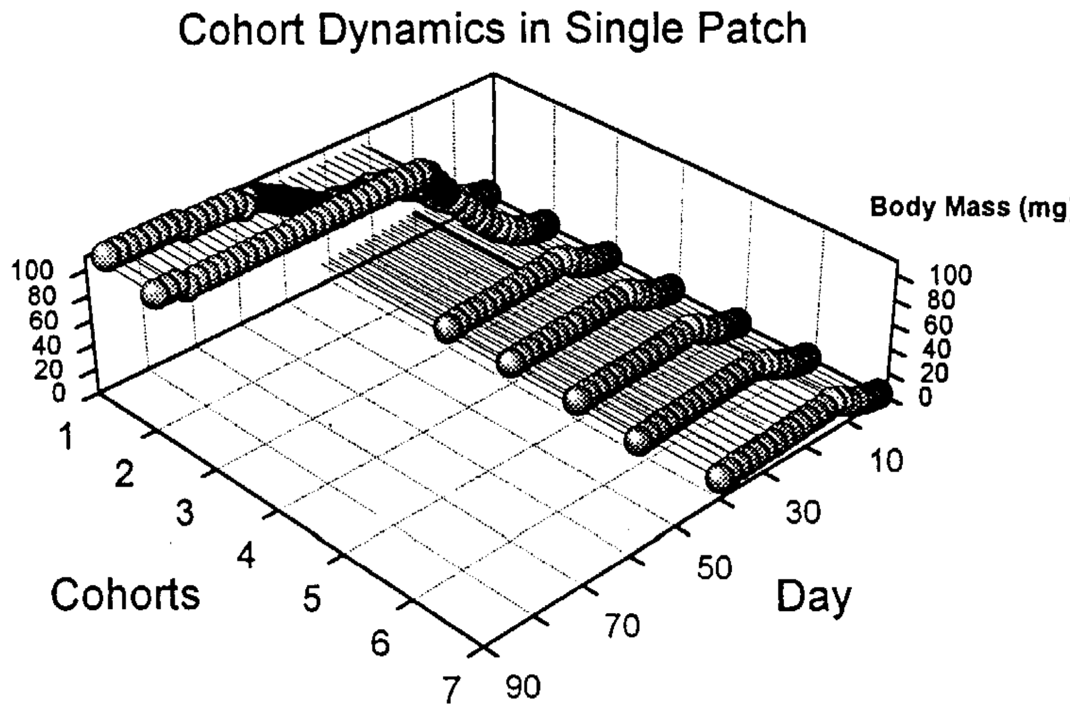

Figure 1. Simulation of seven grasshopper cohorts growing in a patch. All cohorts begin as newly hatched first instars with equal body mass. Food becomes limiting and the two uppermost cohorts gain more mass on about day 10, the first day when food became deficient. Thereafter, these two cohorts out-compete the others. The five smallest cohorts finally starve, and all food is then available to the remaining chorts. Removal of certain cohorts by parasites, predators, or selective control tactics can also generate surprising responses among the survivors.

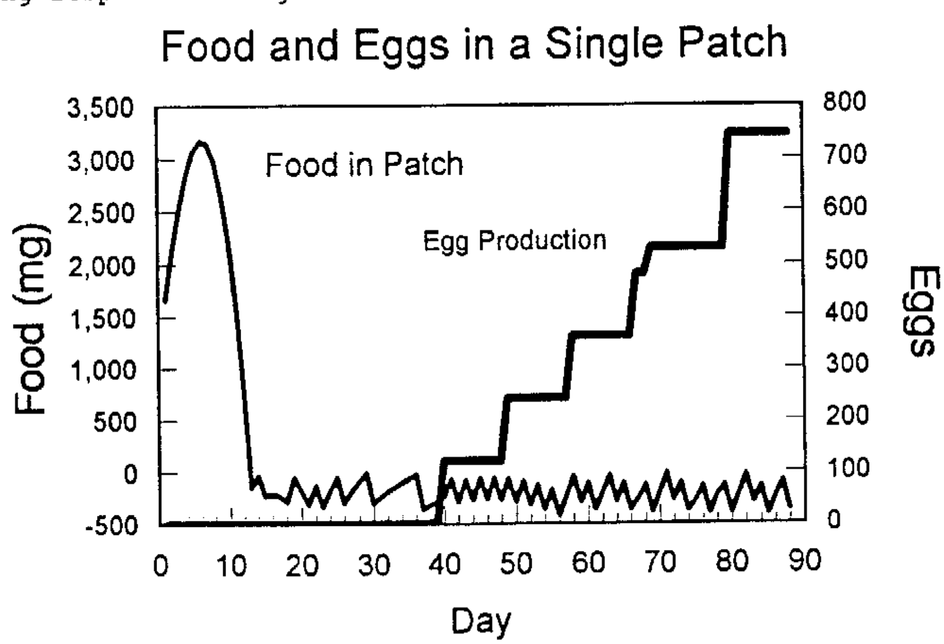

Figure 2. Same simulation as Fig. 1, but, shows the amount of food in the patch and oviposition. Negative food for any given day means that some grasshoppers lost body mass or starved. The stair-step oviposition results from laying pods, instead of individual eggs.