11-18-2011

Spatial Population Models in Spatiotemporally Structured Environments

David Hiebeler
Principal Investigator; University of Maine, Orono, david.hiebeler@maine.edu

Final Report for Period: 09/2010 - 08/2011
Submitted on: 11/18/2011
Principal Investigator: Hiebeler, David .
Award ID: 0718786
Organization: University of Maine
Submitted By:
Hiebeler, David - Principal Investigator
Title:
Spatial Population Models in Spatiotemporally Structured Environments

Project Participants

Senior Personnel

Name: Hiebeler, David
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Name: Johnson, Andrew
Worked for more than 160 Hours: Yes
Contribution to Project:
Andrew was a grad student in the Ecology and Environmental Sciences master's program at UMaine. For his thesis research, he explored a spatial lattice population model incorporating interactions between dormancy and the spatial scale of disturbances.

Undergraduate Student

Name: Michaud, Isaac
Worked for more than 160 Hours: Yes
Contribution to Project:
Primary research assistant, working on simulation and mathematical models; Isaac also helped in training most of the new undergraduate research assistants. Isaac attended the 2008 MTBI summer REU program. Isaac was involved in many/most of the sub-projects related to this award, and helped train many of the other students.

Name: Millett, Nicholas
Worked for more than 160 Hours: Yes
Contribution to Project:
Nick worked on simulation and mathematical models, and contributed to training new undergraduate research assistants. He also attended the 2008 MTBI summer REU program. Nick did a project involving a population model in which sites dispersed to neighboring sites and second-nearest-neighboring sites; he wrote his Undergraduate Honors Thesis on this model.

Name: Coe, Ashley
Worked for more than 160 Hours: No
Contribution to Project:
Ashley worked on developing a spatial computer simulation model of Asian woodwasp population spread.

Name: Rigazio, Tyler
Worked for more than 160 Hours: No
Contribution to Project:

After working through my training materials, Tyler participated in the MTBI summer REU program (with financial support from that program). He then developed some R computer code to measure the sizes of contiguous habitat patches in lattice models.

Name: Wasserman, Ben

Worked for more than 160 Hours: No

Contribution to Project:

Ben was supported partially with work-study funds, then later (after a hiatus due to involvement with other projects) worked on the project via an indepdent-study Capstone project. We developed a spatial population model on heterogeneous landscapes with continuous habitat quality.

Name: Morrill, Andrea

Worked for more than 160 Hours: No

Contribution to Project:

Andrea was an undergraduate studying to become a high-school teacher. She worked through some of my training materials, helped coordinate training of other future K-12 teachers I involved in my group, and participated in related K-12 outreach efforts.

Name: Juntura, Jamie

Worked for more than 160 Hours: No

Contribution to Project:

Jamie is a future K-12 teacher. He worked through through some of my training materials, and was later involved in related K-12 outreach efforts. Demographic info: Jamie is half Filipino.

Name: LaFountain, Bethany

Worked for more than 160 Hours: No

Contribution to Project:

Bethany was an undergraduate planning to become a K-12 teacher. She worked through some of my training materials, until leaving the University of Maine and moving to another region in early summer for personal reasons. Demographic info: Beth is one-quarter Native American (Maliseet).

Name: Krause, Sarah

Worked for more than 160 Hours: No

Contribution to Project:

Sarah was studying to be K-12 teacher. In year 1 of the project, she worked through some of my training materials; in year 2, she was involved in related K-12 outreach efforts.

Name: Merckens, Jeff

Worked for more than 160 Hours: Yes

Contribution to Project:

Jeff joined the project in the 2008-2009 academic year; he worked through my training materials, and participated in the 2009 MTBI summer REU program. During 2009-2010, Jeff worked on a model of a locally dispersing population on dynamic landscapes, representing a system where pesticide is applied to contiguous groups of sites on a landscape at a given spatial scale. He did both programming of the simulation model, and development and analysis of mathematical approximations.

Name: Chiu, Yin

Worked for more than 160 Hours: Yes

Contribution to Project:

Yin joined the project in the 2008-2009 academic year, and worked through my training materials. (She spent Spring 2009 studying abroad, and participated in a summer REU program at NCSU in mathematical biology, on an unrelated project). She worked on the 'dynamic landscapes' model.

Name: Millios, Robert

Worked for more than 160 Hours: Yes

Contribution to Project:

The student explored dynamics of a spatial epidemiological model with clustered distributions of vaccinated individuals. He primarily did programming of the simulation model, and some supporting visualization software.

Technician, Programmer

Name: Hill, Jack

Worked for more than 160 Hours: Yes

Contribution to Project:

Jack was essentially a nontraditional undergraduate student on leave; he has finished his degree requirements but not yet received his degree (due to financial difficulties). He worked through my training materials on his own in early 2009 (without support as I was unable to hire him as a standard undergraduate employee because he was not registered for classes in Spring 2009). In summer 2009, I have hired him as a Temporary professional employee to assist with developing Java applets demonstrating the models for outreach efforts. He has since received his degree, is working on finishing a Master's degree in Math, and will likely pursue an interdisciplinary PhD (he's working as a research assistant for another grant-supported project in Marine Sciences).

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

Young S. Lee, Dept. of Mathematics and Computer Science, Manchester College, N. Manchester, IN 46962

Tae S. Do, Department of Mathematics Education, Kwandong University, Kangneung, South Korea, 210-701

Frank Drummond, School of Biology and Ecology, University of Maine, Orono ME, 04469

Tod Shockey, Dept of Mathematics and Statistics, University of Maine, Orono ME 04469

Young Lee and Tae Do have collaborated via e-mail on the Dynamic Landscapes model.

Frank Drummond has interacted with the PI and two undergraduates (Ashley Coe and Isaac Michaud) on the Asian Woodwasps model, and is a committee member (practically co-chair) of graduate student Andrew Johnson.

Tod Shockey interacted with the PI in developing related outreach efforts to teachers and 7th- and 8th-grade students at the Beatrice Rafferty school, a Native American K-8 tribal school on the Passamaquoddy Reservation in Pleasant Point, ME. Shockey and the PI discussed basic mathematical models related to this project; Shockey then (together with some of the future K-12 teachers previously trained via this grant) developed other spatial models for the outreach efforts, using the Netlogo software platform.

Activities and Findings

Research and Education Activities:

Together with my undergraduate research assistants and with a bit of interaction with other collaborators, we have primarily explored the following lattice-based spatial population models:

I. 'Block Disturbances 2': Several variations of a model of spatially correlated disturbances (i.e. groups of multiple sites being simultaneously disturbed). This was a follow-up to previous work: D. Hiebeler, ?Spatially Correlated Disturbances in a Locally Dispersing Population Model,? Journal of Theoretical Biology, 232, 143?149 (2005). Goals of this part of the project were to better understand why increasing the scale of disturbances while controlling the overall disturbance rate has a negative effect on equilibrium population density (as seen in the previous study), by developing several variations of the model intended to separate the effects of temporal variability and spatial correlations, as well as ways of quantifying/describing temporal and spatial variability. These two features were confounded in the original model. This work was done with students Isaac Michaud (undergrad/grad) and Nick Millett (grad).

II. 'Dynamic Landscapes': A model of a locally-dispersing population on dynamic landscapes with spatial clustering and temporal autocorrelation of habitat types. This work continued development of a model ﬁrst developed by Jennifer Houle, a former undergraduate research assistant of the PI. Collaborators Young Lee and Tae Do were for a time loosely involved in trying to bring this project to publishable status. Students Isaac Michaud (undergrad/grad), Yin Chiu (undergrad), and Jeff Merckens (undergrad) have been involved to varying extents as well.

III. 'Continuous Habitat Quality': undergraduate Ben Wasserman, as part of two course projects and the focus of an independent-study Capstone course, explored the effects of variability in habitat quality in a population model. Tim Buchak also worked on the model, first as a high-school student and then as an undergraduate. We have explored versions of the model with local dispersal and long-distance dispersal, and are focusing primarily on the latter as we move the project toward publishable results. The project involves differential equations for moments of the conditional distribution of habitat qualities of occupied sites.

IV. 'Asian Woodwasps' A simulation-based spatial lattice model of Asian woodwasps, a recent invasive species in the U.S. This work was done by Ashley Coe and Isaac Michaud, with participation by Frank Drummond. This was a lattice-based model falling loosely within the scope of this grant. Preliminary exploration was done, with the intention of later pursuing separate funding for the project with Frank Drummond (most likely from the U.S. Dept. of Agriculture) if the work looked promising.

V. 'Second-nearest neighbors'. A lattice population model was studied where reproducing occupied sites disperse offspring to neighboring sites as well as site 2 units away. One main goal of the project was to develop techniques which could then be applied to more general models. Undergraduate Nick Millett worked on the project, including writing his Undergraduate Honors Thesis on the topic.

VI. 'Dormancy in dynamic heterogeneous habitat'. A population model based on model II (Dynamic Landscapes) above was studied, with the additional feature that the population includes dormant organisms which can persist in unsuitable habitat, and then later re-emerge after habitat has become suitable again. Interactions between various parameters are being studied. This was the topic of graduate student Andrew Johnson's master's thesis.

VII. 'Urn models'. Together with a collaborator from Mexico, we applied urn probability models to dispersal in a lattice population model. This was motivated by some of the analysis of the 'second-nearest neighbors' model; the techniques we developed here should be easily applicable to models with structured heterogeneous habitat, which we hope to explore (though after the grant has finished).

Findings:

I. Block Disturbances 2: When describing the temporal variability of disturbances, one must specify the spatial scale at which such variability is measured. Similarly, when describing spatial autocorrelations of disturbances, one must specify the temporal scale over which measurements are taken. Spatial and temporal effects cannot be separated. We developed metrics to quantify spatial and temporal structure of disturbances in a lattice population model. Analytical results were obtained for temporal and spatial variability, respectively defined in terms of the coefficient of variation of times between disturbance events within a particular region, and the probability of or coefficient of variation of number of disturbances within a given region and within a fixed time interval.

Both types of variability increase as the spatial scale of disturbance events increases in a locally-dispersing population model (where the overall disturbance rate is held fixed). This helps to explain why increasing the size of disturbances decreases the equilibrium density of the population.

One should be more aware of (if not explicitly describe) correlations at various spatial and temporal scales when investigating spatial population models. This result should promote more careful attention to the link between spatial and temporal structure in models and in studies of natural populations. We also developed algorithms for more efficiently simulating spatial lattice models with certain types of interactions.

A paper based on these results has been submitted to Ecological Modelling for publication and is currently under review.

II. Dynamic Landscapes: For a locally-dispersing population in dynamic heterogeneous habitat, where e.g. a pesticide is applied which renders a contiguous block of habitat temporarily unsuitable, a choice may be made between frequently applying pesticide to small blocks of sites or occasionally applying pesticide to larger blocks of sites (but in such a way that the total rate of pesticide application is held fixed).
Two contrary effects arise: we know that increasing the spatial scale of disturbances reduces population density (from model I, 'Block Disturbances 2', described above); but the larger disturbances also lead to larger spatial correlations in habitat types, which are known

to increase population density (based on PI's previous work).

Because the dynamics of habitat types are driven by exogenous disturbances, rather than spreading locally, the dynamics may be described without need for moment-closure approximations typically used with lattice population models. In fact, differential equations describing the dynamics of habitat structure can be written for any desired spatial scale; we explored pairs and triplets.

Two different approximations (using information at the pair and triplet scales for habitat types) were used with a lattice population model (moment-closure approximations were used with the population model itself). These models show that for a relatively small portion of the parameter space, increasing the spatial scale of disturbances may first increase and then decrease equilibrium population density, as these two contrary effects interact. Population density is typically maximized for intermediate disturbance sizes near the extinction threshold in the model.

Findings from this model are being prepared for submission for publication.

III. Continuous Habitat Quality: Increasing the variability of habitat quality (while keeping the mean quality unchanged) increases population density, by causing some sites to become sources and others to become sinks (at least for the particular version of the model we are exploring). Various moment-closure approximations were tried, which seem to make different extreme assumptions about the kurtosis of the distribution of habitat quality, e.g. all sites are equally distant from the mean, or most sites are at the mean but rare sites have quality very far from the mean. An improved mathematical model was attempted by using a weighted average of different 'extreme' approximations of the above types, where the weights were chosen by determining how to obtain the kurtosis of the actual landscape using the kurtosis of the 'extreme' landscapes assumed by the different approximations. We were able to obtain analytical results, however, by considering population densities within small ranges of habitat quality and taking appropriate limits. This allowed for calculation of equilibrium population density as well as the distribution of habitat quality of occupied sites, for a variety of cases of marginal habitat quality distributions.

Findings from this model are being prepared for submission for publication.

IV. Asian Woodwasps

No significant results were obtained from this minor project.

V. Second-nearest neighbors:

Spatial correlations among neighboring sites can be used to approximate correlations over longer distances, by constructing spatial Markov processes using the shorter-range correlation information present within the population model. Pair approximations fail to predict qualitative results for a population with dispersal to second-nearest sites due to the disparity in correlations between pairs of adjacent sites and pairs of second-nearest neighboring sites. Triplet approximations, which incorporate spatial information among groups of three sites, do a much better job at predicting the behavior of the model over a variety of parameter settings, and helping to explain just why the pair approximations do poorly.

This project demonstrating the method of estimating correlations over longer distances via spatial Markov processes for this model; similar techniques should work with populations with more general dispersal distributions and on heterogeneous landscapes.

A paper describing this model has been published.

VI. Dormancy in dynamic heterogeneous habitat:

In a population on heterogeneous landscapes with dormancy, where dormant organisms are able to persist in unsuitable habitat, and later emerge after the habitat becomes suitable:

Even in a spatial population with only long-distance interactions (i.e. no local spatial structure), there is a complex interplay between various parameters in the model such as the emergence rate of dormant organisms, the proportion of reproductive effort allocated to dormant vs active reproduction, habitat turnover rate, etc.

Dormant offspring face three costs: (1) a dormant individual on an unsuitable site may die before its site becomes suitable (and therefore before it has an opportunity to become reproductively active); (2) a dormant individual on a suitable site also faces the possibility of mortality before becoming reproductively active, and (3) furthermore it may be out-competed by active individuals colonizing its site.

On the other hand, the benefit of having some dormant offspring is that it allows a population to take advantage of unsuitable habitat, keeping a 'seed bank' in such sites which may then become active once the habitat is again suitable.

As mortality increases from low levels, the optimal level of dormancy first decreases as the population first uses more active reproduction to rapidly colonize the increasing number of empty suitable sites available. As mortality continues to increase, the eventual depression in active occupied sites eventually reduces the third cost of dormancy mentioned above, and the optimal dormancy level again increases.

These effects are seen in a system with a changing environment, but at times are contrary to basic prior results in dormancy theory due to the fact that our model takes place in a spatially extended system where environmental fluctuations are not synchronized across the landscape. Because of this, things such as the temporal variability of environmental variability do not play a significant role on the effects of dormancy.

When spatial correlations in habitat type are introduced into the model, dispersal gains an additional benefit for a locally-dispersing population: the ability for the population to recolonize a large disturbed region from an already-existing seed bank, rather than growing in slowly from the edges of the disturbance. In such a model, surprisingly, more rapid emergence from dormancy once the habitat has become suitable is not always beneficial, because rapid emergence mitigates the above benefits of the spatially distributed seed bank.

A master's thesis in Ecology & Environmental Sciences was written based on these results; findings from this model are being prepared for submission for publication.

VII. Urn models:

Using urn probability models (calculating the number of white balls drawn from an urn containing balls of multiple colors) to study dispersal in a lattice population model allows one to separate out the mean versus the variance in the number of offspring produced by an occupied site in a lattice model, two factors that are often conflated in population models based on the basic contact process. This model was an offshoot based on analysis of the 'second-nearest neighbors' model above, but the techniques should be very applicable (together with the spatial Markov chain approximations also from the 'second-nearest neighbors' work) to allow for further analysis of the effects of spatially structured habitat quality.

A paper describing this work has been accepted for publication.

Training and Development:

Significant time and effort has been spent training many undergraduate research assistants. They have gained skills in writing spatially explicit population lattice simulation models (in Matlab, R, and a bit of C), and basic mathematical models of such systems. Four of the students attended the MTBI summer REU program, where they received very intensive training in mathematical modeling, including many presentations of their group research projects. The undergraduate students trained at UMaine include four future K-12 teachers.

In addition, a graduate student completed his thesis in the Ecology and Environmental Sciences program. He had no prior experience in mathematical and computational modeling, but his thesis was a theoretical population model using both techniques.

Outreach Activities:

Efforts were made to begin outreach to high school students, K-12 teachers, as well as preservice K-12 teachers (current undergraduates planning to go into teaching).

* Jan 18, 2008: I met with 4 high-school teachers (Heather Holmes, Chris Libby, Hala Nazmy, Margie Innis) and a preservice teacher (Sarah Judkins) at Orono High School, to plan outreach eﬀorts at their school.

* Feb 8, 2008: I met with Meghan Southworth, a Mathematics Specialist with the Maine Mathematics and Science Alliance, to discuss future high-school outreach eﬀorts.

* Feb 14, 2008: Spoke with Steve Godsoe (chair of Math Dept) and Cary James (chair of Science Dept) at Bangor High School about future high-school outreach eﬀorts.

* Mar 18, 2008: Gave a presentation at the Cross-Tier Team Teaching meeting held at the University of Maine campus (by Bob Franzosa), attended by various educators, administrators, and teachers-in-training. I demonstrated several of my spatial simulations and mentioned plans for future high-school outreach.

* Mar 28, 2008: met with Henry Chai and Andrew Audibert, both sophomores at Bangor High School. I presented many of my models to them, and provided them with my training materials for undergraduate research assistants, which they have slowly been working through. (I was not planning to begin direct involvement of high-school students at this stage, but teachers at Bangor High School were so enthusiastic they wanted to send a couple of students to me early.) Andrew Audibert subsequently worked with me on another NSF-funded project.

* Apr 18, 2008: Gave presentation (twice) on ?Simulation and Modeling in Mathematical Biology? at Orono High School, to two groups of sophomores, juniors, and seniors (roughly 35 students).

* Jun 19, 2008: Gave my presentation on ?Simulation and Modeling in Mathematical Biology? at SUMS (Strengthening Understanding of Mathematics and Science) on the Arizona State University campus, to about 9 Arizona high-school students as well as several K-12 teachers, many from underrepresented groups (Latino).

* Nov 16, 2008: undergraduates Isaac Michaud and Nicholas Millett gave poster presentations at the UMaine System Board of Trustees meeting, of their summer 2008 MTBI projects. Attending were: Umaine Board of Trustees Members, UMaine Farmington Board of Visitors Members, Chief executive officers (campus presidents from 7 UMaine campuses), Chief academic officers (provosts) from the UMaine system, Chief financial officers from the UMaine system, the Chancellor and two vice-chancellors from the UMaine System office, and two students from each of the seven UMaine campuses as well as some faculty members.

* March 28, 2009: Gave an invited poster presentation on 'Modeling Outbreaks in Agricultural Systems, Human Communities, and Computer Networks' at the exhibition of the Coalition for National Science Funding in Washington, DC (to Congressional members & staffers). Earlier that day, I met with staffers in the office of Maine's two Senators (Collins and Snowe) and state Representative Michaud, telling them how NSF funding benefits the University of Maine as well as the state, and how it contributes to training students.

* June 12, 2009: Held an interactive session on 'Emergent Dynamics in Spatial Models' in Orono, ME. The participants were a group of 24 7th-graders from the Columbia Secondary School for Math, Science, and Engineering in New York City. Many of the students were from underrepresented groups.

* June/July 2009: a news blurb about the above March 28 presentation

was published in the Notices of the AMS (vol. 56, no. 6, 2009, page 747). From the AMS web site, 'The Notices is the world's most widely read magazine aimed at professional mathematicians. ... the Notices is sent to the approximately 30,000 AMS members worldwide, one-third of whom reside outside the United States.'

* April 2010: visited the Universe of Maine Presque Isle campus for 'Imagine Math Day 2010', on 'Mathematical Methods in Ecology'. There were 11 high-school students and 2 teachers present, from the Caribou Alternative School (which includes students from Caribou and Fort Fairfield, ME) and Ashland High School. We explored computational population models for a half-day.

* July 2010: met with Luke Shorty, a teacher from the Maine School of Science and Mathematics (a high school in Limestone, ME) to discuss outreach possibilities. He also recommended a just-graduated MSSM student, who later worked with me with support from my CAREER award.

* May 2011: Ran 2 sessions of a workshop on 'Simulating and modeling the natural world with math and computers' for K-12 students on the UMaine campus via the 4-H organization. There were 12 students between grades 6 and 12 (3 female, 9 male). Written feedback after the workshop included comments such as 'very interesting!' and 'I never thought of this way to use math'. A pre- and post-workshop survey showed that the 100% of participants agreed that 'computer simulations can be useful for understanding biology and the natural world' after completing the workshop, compared with 54% agreement with the statement before the workshop.

* May 2011: Released the iOS app 'Spatial Population Ecological and Epidemiological Dynamics Simulator (SPEED Sim)' on Apple's iTunes App Store, which includes the 'Block Disturbances 2' model. I hope to add some of the other models supported by this grant to the app, as they are published.

* Java applets which can be run in a web browser have been written for two of the models: 'dynamic landscapes' and 'dormancy'. They will be publicly linked to when papers describing the models have been accepted for publication; meanwhile, they can be seen on the (non-publicly linked) web site
http://www.math.umaine.edu/~hiebeler/4H.html

Journal Publications

Hiebeler, DE; Millett, NE, "Pair and triplet approximation of a spatial lattice population model with multiscale dispersal using Markov chains for estimating spatial autocorrelation", JOURNAL OF THEORETICAL BIOLOGY, p. 74, vol. 279, (2011). Published, 10.1016/j.jtbi.2011.03.02

Carlos Hernandez-Suarez and David Hiebeler, "Modeling Species Dispersal with Occupancy Urn Models", Theoretical Ecology, p. , vol. , (2011). Accepted,

David E. Hiebeler and Isaac J. Michaud, "Quantifying Spatial and Temporal Variability of Spatially Correlated Disturbances", Ecological Modelling, p. , vol. , (2011). Submitted,

Books or Other One-time Publications

Web/Internet Site

URL(s):

http://www.math.umaine.edu/~hiebeler/4H.html

Description:

This web site is for a 4-H workshop the PI gave for K-12 students, and contains several Java applets implementing simulation models interactively explored by the students during the workshop.

Two of the simulation models on the page were from the project supported by this NSF award. There are currently no other public web site which link to this 4-H workshop page, i.e. the page is not "publicly discoverable" at this time (though attendees of the various K-12 outreach workshops run by the PI are all given links/access to the models). As papers describing the research are published, the simulation applets will be moved over to a public web site, with more documentation.

Other Specific Products

Product Type:

Software (or netware)

Product Description:

An iOS application "Spatial Population Ecological and Epidemiological Dynamics Simulator (SPEED Sim)" distributed on Apple's iTunes App Store, able to be installed (for free) on iPhone/iPad/iPod Touch devices.

Sharing Information:

The application is distributed via Apple's distribution mechanism; it is also demonstrated during K-12 outreach efforts by the PI.

Contributions

Contributions within Discipline:

We have developed quantitative measurements which can be used to describe both the spatial and temporal variability of events (such as application of a pesticide) impacting a population. We were able to obtain analytical mathematical results for these measurements with our specific population model involving large-scale disturbances to a population, but the same measurements could be used with empirical field data, or numerically computed for simulation models.

We have shown that it's impossible to separate spatial and temporal effects even within theoretical models, and that measurements of either aspect of variability depend on the scale used for the other aspect. Both the spatial and temporal structure of events interact to affect population dynamics.

When habitat quality is dynamic (again resulting from application of pesticides, in our model systems), increasing the spatial scale of disturbances may either increase or decrease the prevalence of the invasive species one is trying to control. Again, spatial and temporal features interact, with e.g. the spatial scale of disturbances having either positive or negative effect on population density depending on the timescale of pesticide application and dissipation relative to population birth/death dynamics.

Increasing variability in habitat quality (while maintaining the same overall mean quality) can provide refugia -- pockets of high-quality habitat in a sea of otherwise low-quality sites, allowing a population to persist where it otherwise may not. However, for certain distributions of habitat quality, a population may actually do worse (persist at lower density) as variability in habitat quality increases, if the high-quality sites are sufficiently rare.
Analytical results describing population densities and the conditional probability distribution of habitat quality of sites exploited by a population were obtained for particular habitat quality (marginal, i.e. unconditional) distributions.

Even populations which disperse over very short distances produce emergent spatial correlations at much larger distances as time goes by. We used spatial correlations at very short distances to estimate correlations at larger spatial scales, as a way to demonstrate why the technique of pair approximation (commonly used with lattice population models) can do very poorly in some cases. This was demonstrated by using triplet probabilities and including additional correlations within our model.

Finally, dormancy, the ability of an organism to persist in unsuitable habitat before re-emerging and potentially reproducing, was shown to interact in complex ways with dynamic habitat quality and spatial structure (of both the population and habitat). Some degree of dormancy is generally useful, to mitigate risks of offspring landing in unsuitable habitat; dormant offspring may simply wait around until the habitat becomes suitable again (with some risk of mortality while waiting).

In nonspatial systems, we found that the optimal level of dormancy in offspring first decreases and then increases as the mortality rate of active site increases, reflecting the interaction between colonization of empty sites and replacement of dormant individuals by newly dispersing active offspring. For emergence from the dormant state to active reproduction (once a site is suitable), a faster emergence rate generally increases population density (by reducing the risk of mortality of dormant organisms and reducing the delay until reproduction). However, with a population using short-distance dispersal and with large-scale disturbances creating clustered habitat distributions, delayed emergence may be beneficial, as it maintains a more spatially distributed seed bank which allows for more rapid recolonization of large disturbed regions.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

The PI participated in the Mathematical and Theoretical Biology Institute (MTBI, http://mtbi.asu.edu) in summer 2008 as an instructor and research mentor. This includes presenting the PI's research (including aspects of this NSF-funded project) to undergraduate and graduate students, many from underrepresented groups (Latino, African-American, Native American), in an environment designed to encourage the undergraduates to pursue graduate degrees.

Four of the PI's undergraduate research assistants (Isaac Michaud, Nicholas Millett, Tyler Rigazio, and Jeff Merckens) have also attended MTBI.

The PI mentored one group's project on household epidemiological models. The group includes Isaac Michaud from UMaine.

See other sections of this report for various K-12 student/teacher outreach efforts.

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Organizational Partners

Any Book

Contributions: To Any Other Disciplines

Contributions: To Any Resources for Research and Education

Contributions: To Any Beyond Science and Engineering

Any Conference

Inside the AMS

AMS Announces Congressional Fellow

The American Mathematical Society (AMS) is pleased to announce that Katherine Crowley of Washington and Lee University has been chosen as the AMS Congressional Fellow for 2009–10.

The AMS will sponsor Crowley's fellowship through the Congressional Fellowship Program administered by the American Association for the Advancement of Science (AAAS). The fellowship is designed to provide a unique public policy learning experience, to demonstrate the value of science-government interaction, and to bring a technical background and external perspective to the decision-making process in Congress.

Katherine Crowley

Fellows spend a year on the staff of a member of Congress or a congressional committee, working as a special legislative assistant in legislative and policy areas requiring scientific and technical input. The fellowship program includes an orientation on congressional and executive branch operations and a year-long seminar series on issues involving science, technology, and public policy.

Katherine Crowley was chosen from among several very competitive applicants. She earned her Ph.D. in mathematics from Rice University after completing her thesis, titled *Discrete Morse Theory and the Geometry of Nonpositively Curved Simplicial Complexes.*

For more information on the AAAS Congressional Fellowship Program, visit the website `http://www.fellowships.aaas.org`.

—AMS Washington Office

AMS Announces Mass Media Fellowship Award

The American Mathematical Society (AMS) is pleased to announce that Baldur Hedinsson has been awarded its 2009 Mass Media Fellowship. Hedinsson is a Ph.D. student in mathematics at Boston University. He will be working at the *Milwaukee Journal Sentinel* for ten weeks over the summer under the sponsorship of the AMS.

The Mass Media Fellowship program is organized by the American Association for the Advancement of Science (AAAS) and is intended to strengthen the connections between science and the media, to improve public understanding of science, and to sharpen the ability of the fellows to communicate complex scientific issues to nonspecialists. The program is available to college or university students (in their senior years or on any graduate or postgraduate level) in the natural, physical, health, engineering, computer, or social sciences or mathematics with outstanding written and oral communication skills and a strong interest in learning about the media. It is a highly competitive program, and the AMS wishes to congratulate Baldur Hedinsson on his accomplishment.

Baldur Hedinsson

The program is in its thirty-fifth year and has supported more than five hundred fellows.

—AMS Washington Office

AMS Testifies Before House Appropriations Subcommittee

American Mathematical Society Past President James Glimm testified on April 2, 2009, before the House Appropriations Subcommittee on Commerce, Justice, Science and Related Agencies. The testimony was part of a joint statement by the American Mathematical Society, the American Chemical Society, the American Physical Society, and the Federation of American Societies for Experimental Biology urging a federal investment of $7 billion for the National Science Foundation (NSF) for fiscal year 2010.

James Glimm

Glimm emphasized that this level of support "would allow the NSF to continue innovative and transformational scientific research that fuels the American economy, upholds national security, maintains our global competitiveness, and improves health and quality of life for millions of Americans." The full text of the testimony can be read at http://www.ams.org/government/testimony-approp-april2009.pdf.

—AMS Washington Office

Erdős Memorial Lecture

The Erdős Memorial Lecture is an annual invited address named for the prolific mathematician Paul Erdős (1913–1996). The lectures are supported by a fund created by Andrew Beal, a Dallas banker and mathematics enthusiast. The Beal Prize Fund, now US$100,000, is being held by the AMS until it is awarded for a correct solution to the Beal Conjecture (see http://www.math.unt.edu/~mauldin/beal.html). At Beal's request, the interest from the fund is used to support the Erdős Memorial Lecture.

The Erdős Memorial Lecturer for 2009 was Jeffrey Lagarias of the University of Michigan. He delivered a lecture titled "From Apollonian Circle Packings to Fibonacci Numbers" at the Spring Central Section Meeting at the University of Illinois at Urbana-Champaign in March 2009. In 2008 the Erdős Memorial Lecturer was William Timothy Gowers of the University of Cambridge, who spoke on "Decomposing Bounded Functions" at the Courant Institute of Mathematical Sciences, New York University, during the Spring Northeast Section Meeting in March 2008.

—AMS announcement

AMS Sponsors Exhibit on Mathematical Modeling

David Hiebeler of the University of Maine represented the AMS at the fifteenth annual Coalition for National Science Funding (CNSF) Exhibition on Capitol Hill held March 24, 2009. Hiebeler's research, funded by the National Science Foundation, was presented to members of Congress, congressional staff, administration representatives, and members of the scientific community in an exhibit titled "Modeling Outbreaks in Agricultural Systems, Human Communities and Computer Networks".

Hiebeler's exhibit used information and computer simulations to describe his work in three different areas: (1) determining the best strategy for applying pesticides or other measures to control invasive insect species in Maine's agriculture while using fewer chemicals; (2) using epidemiological models to explore the implications of clustering within certain socioeconomic groups of people who choose not to be vaccinated or to have their children vaccinated against infectious diseases; and (3) modeling the effectiveness of new biological dispersal strategies in the spread of computer viruses and "worms" by malicious software and also exploring methods for helping to control such outbreaks.

David Hiebeler with Rep. Rush Holt (NJ-12).

The annual CNSF exhibition highlights research made possible through funding by the National Science Foundation. The 2009 exhibition included thirty-four exhibit booths displaying a wide range of scientific research and education projects. For more information, see http://www.ams.org/government/cnsfex09.html.

—Anita Benjamin, AMS Washington Office

AMS Holds Workshop for Department Chairs

The AMS hosted its annual one-day workshop for mathematical sciences department chairs at the 2009 Joint Mathematics Meetings in Washington, D.C. This session is organized in a workshop format so as to stimulate discussion among attendees. The workshop focused on mentoring faculty through the professional life cycle; on the mission of the mathematics department within the context of the institution's mission; on positioning the mathematics department for the future in an environment of budget cuts; and on creating a productive, positive collegial environment.

Workshop leaders included Guillermo Ferreyra, dean of the College of Arts and Sciences, Louisiana State University; Lawrence Gray, former head and director of undergraduate studies at the School of Mathematics, University of Minnesota; and Stephen Robinson, chair, Department of Mathematics, Wake Forest University.

The Department Chairs Workshop is an annual event hosted by the AMS prior to the start of the Joint Meetings. Past workshop sessions have focused on a range of issues facing departments today, including personnel issues (staff and faculty); long-range planning; hiring, promotion, and tenure; budget management; assessments; outreach; stewardship; junior faculty development; communication; departmental leadership; and undergraduate and graduate education.

If you are interested in attending a future workshop, please look for registration information sent out in advance of the Joint Meetings or contact the AMS Washington Office at amsdc@ams.org.

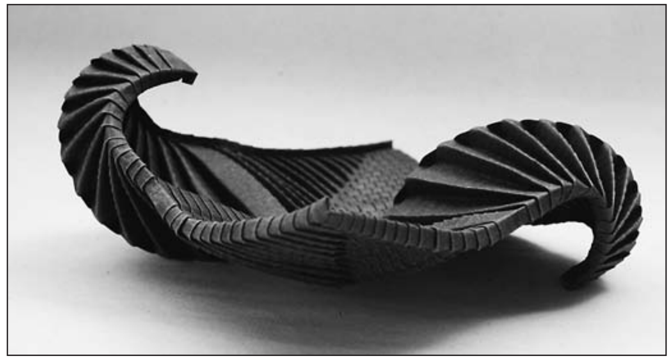
—Anita Benjamin, AMS Washington Office

From the AMS Public Awareness Office

• **AMS Graduate Student Blog**. The AMS Graduate Student Blog is a new blog by and for math graduate students, managed by Frank Morgan, AMS vice-president and professor of mathematics at Williams College. "Graduate students are the future of the AMS, and they have a lot to talk about," says Morgan. The Graduate Student Editorial Board members are Asher Auel, Adam Boocher, Diana Davis, Daniel Erman, Fernando Galaz, Brian Katz, Alex Levin, Kathryn Lindsey, Andrew Obus, David Shea Vela-Vick, Clay Shonkwiler, Annalies Z. Vuong, and Tom Wright, and Morgan hopes that more grad students from around the country will be interested in joining the board. The blog entries to date concern organizing a reading seminar, how to give a good mathematics talk, advice for beginning teaching assistants, navigating seminars, and finding an advisor—topics of great importance to graduate students, who are all are invited to join the community by posting comments, questions and advice on the blog. The American Mathematical Society encourages all graduate students in the mathematical sciences to visit and use the AMS Graduate Student Blog, hosted by Williams College, at `http://mathgradblog.williams.edu/`.

• **Math in the Media**. Recent media coverage of mathematics and mathematicians includes the winner of the 2009 Intel Science Talent Search competition (Eric Larson of Eugene, Oregon "for his classification of new fusion categories, a type of algebraic structure with applications in string theory and quantum computation"); a profile of Ken Golden ("Cold Equations," by Dana Mackenzie, *Science*, April 3); the 2009 Abel Prize awarded to Mikhail Gromov; a series of articles on mathematics by Arvind Gupta (MITACS) published in the *Vancouver Sun*. View the most recent issue of Math in the Media and explore the archive of "Tony Phillips' Take" and Math Digest summaries at `http://www.ams.org/mathmedia/`.

• ***2009 Mathematical Art Exhibition* album on Mathematical Imagery**. The Mathematical Art Exhibition held at the 2009 Joint Mathematics Meetings in Washington, DC, included 49 works in various media by 36 artists. Images of these works—which can be sent as e-postcards—are now posted as an album on Mathematical Imagery. Robert Fathauer was the curator of the exhibition, and the exhibition was juried by Fathauer, Anne Burns, Nat Friedman, and Reza Sarhangi. The album includes winners of the inaugural Mathematical Art Exhibition Prizes: first prize to Goran Konjevod, for his origami work, "Wave (32)", 2006 (pictured here); second prize to Carlo Séquin, for his sculpture, "Figure-8 Knot", 2007; and third prize to Robert Fathauer, for "Twice Iterated Knot No. 1", 2008. The prize "for aesthetically pleasing works that combine mathematics and art" was established in 2008 through an endowment provided to the AMS by an anonymous donor who wishes to acknowledge those whose works demonstrate the beauty and elegance of mathematics expressed in a visual art form. See `http://www.ams.org/mathimagery/thumbnails.php?album=22`.



"Wave (32)", by Goran Konjevod, 2006.

—Annette Emerson and Mike Breen
AMS Public Awareness Officers
`paoffice@ams.org`

Deaths of AMS Members

VLADO CIGIC, professor, Strojarski Fakultet, Bosnia-Herzegovina, died on November 22, 2008. Born on August 21, 1946, he was a member of the Society for 7 years.

KARL WALTER GRUENBERG, professor, Queen Mary University of London, died on October 10, 2007. Born on June 3, 1928, he was a member of the Society for 50 years.

JOHN R. KUCHER, from Quincy, MA, died on July 28, 2008. Born on September 28, 1946, he was a member of the Society for one year.

JACK LORELL, professor, Caltech, died on March 13, 2008. Born on October 7, 1916, he was a member of the Society for 68 years.

CHARLES E. RICKART, from North Branford, CT, died on April 17, 2002. Born on June 28, 1913, he was a member of the Society for 63 years.

ANDREW J. TERZUOLI, from Brooklyn, NY, died on January 23, 2008. Born on October 5, 1914, he was a member of the Society for 60 years.

EUGENE R. TOMER, from San Francisco, CA, died on July 2, 2007. Born on June 15, 1932, he was a member of the Society for 47 years.

BENNIE B. WILLIAMS, University of Texas at Arlington, died on September 9, 2007. Born on January 16, 1922, he was a member of the Society for 40 years.

RHODA WOOD, from Pasadena, CA, died on June 22, 2006. Born on July 2, 1912, she was a member of the Society for 67 years.