DOWNLOAD PDF MODELING SPATIOTEMPORAL DYNAMICS IN ECOLOGY

Chapter 1 : CiteSeerX â€" Citation Query Modelling spatiotemporal dynamics in ecology

This book reviews one of the newest and most important areas of theoretical ecology: the study of spatiotemporal dynamics by means of a spatially explicit approximation that allows the investigation of the effects of real space.

Scale Invariance in Biology: Coincidence Or Footprint of a Universal Mechanism? Gisiger , " In this article, we present a self-contained review of recent work on complex biological systems which exhibit no characteristic scale. A hypothesis recently put forward to explain these scale-free phenomomena is criticality, a notion introduced by physicists while studying phase transitions in materials, where systems spontaneously arrange themselves in an unstable manner similar, for instance, to a row of dominoes. Here, we review in a critical manner work which investigates to what extent this idea can be generalized to biology. We then review typical mathematical models exhibiting such properties: These notions are then brought together to see to what extent they can account for the scale invariance observed in ecology, evolution of species, type III epidemics and some aspects of the central nervous system. This article also discusses how the notion of scale invariance can give important insights into the workings of biological systems. B , " Why are some ecosystems so rich, yet contain so many rare species? High species diversity, together with rarity, is a general trend in neotropical forests and coral reefs. However, the origin of such diversity and the consequences of food web complexity in both species abundances and temporal fluctu However, the origin of such diversity and the consequences of food web complexity in both species abundances and temporal fluctuations are not well understood. Several regularities are observed in complex, multispecies ecosystems that suggest that these ecologies might be organized close to points of instability. We explore, in greater depth, a recent stochastic model of population dynamics that is shown to reproduce: It is conjectured that the conflict between the natural tendency towards higher diversity due to immigration, and the ecosystem level constraints derived from an increasing number of links, leaves the system poised at a critical boundary separating stable from unstable communities, where large fluctuations are expected to occur. We suggest that the patterns displayed by species-rich communities, including rarity, would result from such a spontaneous tendency towards instability. Bad Genes or Weak Chaos? Using a simple model of large-scale evolution, we show how an n-species ecosystem evolves towards a critical state where extinctions of all sizes are generated. This state involves a situation where high unpredictability This state involves a situation where high unpredictability is present. The basic properties of the overall macroevolutionary pattern are well reproduced and a new interpretation for this process is suggested. Pandolfi - American Zoologist , " TWO studies from the Pleistocene coral reef fossil record demonstrate the sensitivity of reef communities to both local environmental parameters and habitat reduction. In the first study, Pleistocene reef coral assemblages from Papua New Guinea show pronounced constancy in taxonomic compos In the first study, Pleistocene reef coral assemblages from Papua New Guinea show pronounced constancy in taxonomic composition and species diversity between and 30 ka thousand years. Spatial differences in reef coral community composition during successive high stands of sea level were greater among sites of the same age than among reefs of different ages, even though global changes in sea level, atmospheric CO_2 concentration, tropical benthic habitat area, and temperature varied at each high sea level stand. Thus, local environmental variation associated with runoff from the land had greater influence on reef coral community composition than variation in global climate and sea level. Proportional sampling from a regional species pool does not explain the temporal persistence and local factors likely played a major role. Examination of coral reef response to global change should not only involve regional diversity patterns but also local ecological factors, and the interactive effects of local and global environmental The DivGame Simulator: The dynamic properties of a stochastic cellular automata model for rainforest dynamics are studied by computer simulation. This model integrates forest growth, species diversity and canopy gap formation and expansion. It is able to account for a wide spectrum of field observations. In particular it suggests two mechanisms controling species abundances in rich ecosystems: According to the model, rarity and species richness are both consequence of internal dynamics in ecosystems driven by low immigration rates. Some theoretical consequences are then outlined. As early indicated by Charles Darwin, languages behave and change very much like living species. They display high diversity, differentiate in space and time, emerge and disappear. A large body of literature has explored the role of information exchanges and communicative constraints in groups of ag A large body of literature has explored the role of information exchanges and communicative constraints in groups of agents under selective scenarios. These models have been very helpful in providing a rationale on how complex forms of communication emerge under evolutionary pressures. However, other patterns of large-scale organization can be described using mathematical methods ignoring communicative traits. These approaches consider shorter time scales and have been developed by exploiting both theoretical ecology and statistical physics methods. The models are reviewed here and include extinction, invasion, origination, spatial organization, coexistence and diversity as key concepts and are very simple in their defining rules. Such simplicity is used in order to catch the most fundamental laws of organization and those universal ingredients responsible for qualitative traits. The similarities between observed and predicted patterns indicate that an ecological theory of language is emerging, supporting on a quantitative basis its ecological nature, although key differences are also present. Here we critically review some recent advances lying and outline their implications and limitations as well as open problems for future research. Perry - Progress in Physical Geography , " Over the last 30 years ecologists and biogeographers have rejected the view that ecological systems are inherently stable or a Over the last 30 years ecologists and biogeographers have rejected the view that ecological systems are inherently stable or at some sort of equilibrium. Instead a nonequilibrium view, emphasizing the role of chance events such as disturbance in ecological dynamics, has become dominant. Alongside this change, the way in which the roles of space and spatial heterogeneity in ecological dynamics are viewed has shifted. Classical ecological theory tended to ignore spatial dynamics and heterogeneity and focused instead on temporal pattern. Over the last 20 years this view has also changed and the importance of spatial pattern has been emphasized. Through the explicit consideration of space and spatial pattern it has been shown that spatial heterogeneity may act to either stabilize or destabilize ecological systems and processes. This paper reviews these two changes in the way ecological systems are conceptualized and explores how they are inter-related. Advances in our understanding of the role of space and the nature of equilibrium in ecological systems are discussed within the context of both modelling and empirical studies, as are the problems involved with experimentally testing the large body of spatial theory developed. Show Context Citation Context Modelling the spread of invasive species: The research presented in this paper uses a GIS-based cellular automata CA framework to study and create an applied and ecologically significant model of spread for invasive plant species. Cellular automata CA coded within a Geographic Information System GIS are employed to test the ability of studied parameters of vegetation dynamics to represent spatial growth patterns. This method combines the well-established spatial data management and presentation capabilities of GIS with the spatial and temporal modeling capabilities of CA theory, creating the ideal tool for applied, data rich modeling. Instead of conventionally testing a previously created model, parameters are examined through simulation for their contribution to spread and the resulting spatial pattern. Initial simulation runs focus on the different effects of stochastic versus deterministic parameter values. Further studies examine the effect of different relationships, conditions and interactions between parameters. Upper and lower bounds to parameters, the interactions between parameters, and the relative importance of each parameter are examined in a number of combinations. Each parameter is then accepted or declined to create a conceptual model outlining the ecologically most significant features of the species. The authors show how models of invasion and vegetation dynamics can effectively be transposed into a contextually rich environment through a GIS-CA framework of model creation. In this respect,sanother research characteristic of CAs becomes important, i. CAs are dynamic systems tha Interactions of ecosystem processes with spatial heterogeneity in the puzzle of nitrogen limitation by G. Darrel Jenerette, Jianguo Wu " We examined the potential effects of spatial heterogeneity and its development on the distribution, abundance, and functioning of nitrogen fixing and non-fixing components of a model ecosystem. CAECO, a spatially explicit ind CAECO, a spatially explicit individual based model approach, simulated the interactions between nitrogen fluxes and plant species community dynamics. Self-organized spatial patterns of nitrogen concentrations and plant occupancy were observed as the system approached an apparently meta-stable state. Nitrogen limitation was tested using chronic and gradient nitrogen amendments to the landscape. The dynamic arrangement of ecosystem components was sufficient to maintain indefinite nitrogen limitation at a local scale. However, landscape scale productivity was not similarly increased with nitrogen amendments. Landscape productivity was independent of nitrogen additions while fixers were present in the ecosystem. The probability of fixer loss from the system responded non-linearly to increasing nitrogen addition. The results of these model experiments suggest local and landscape constraints of primary productivity may be fundamentally distinct. However, the function of spatial self-organization for an ecosystem is not well understood. Evaluating the role of self-organizing spatial patte

Chapter 2 : Frontiers | Grand challenges in population dynamics | Ecology and Evolution

In the past few years, part of theoretical ecology has focused on the spatiotemporal dynamics generated by simple ecological models. To a large extent, the results obtained have changed our view of complexity.

Show Context Citation Context Present address for PJR: Stabilization through spatial pattern formation in metapopulations with long-range dispersal by Michael Doebeli, Graeme D. Many studies of metapopulation models assume that spatially extended populations occupy a network of identical habitat patches, each coupled to its nearest neighbouring patches by density-independent dispersal. Much previous work has focused on the temporal stability of spatially homogeneous equilib Much previous work has focused on the temporal stability of spatially homogeneous equilibrium states of the metapopulation, and one of the main predictions of such models is that the stability of equilibrium states in the local patches in the absence of migration determines the stability of spatially homogeneous equilibrium states of the whole metapopulation when migration is added. In particular, heterogeneity in local habitat quality in combination with long-range dispersal can induce a stable equilibrium for the metapopulation dynamics, even when within-patch processes would produce very complex behaviour in each patch in the absence of migration. This new global equilibrium is characterized by a standing spatial wave of population abundances. Such standing spatial waves can also be observed in metapopulations consisting of identical habitat patches, i. Spatial pattern formation after destabilization of spatially homogeneous equilibrium states is The DivGame Simulator: The dynamic properties of a stochastic cellular automata model for rainforest dynamics are studied by computer simulation. This model integrates forest growth, species diversity and canopy gap formation and expansion. It is able to account for a wide spectrum of field observations. In particular it suggests two mechanisms controling species abundances in rich ecosystems: According to the model, rarity and species richness are both consequence of internal dynamics in ecosystems driven by low immigration rates. Some theoretical consequences are then outlined. Local population renewal is governed by the Ricker model and we also consider asymmetrical dispersal as well as the presence of environmen Local population renewal is governed by the Ricker model and we also consider asymmetrical dispersal as well as the presence of environmental heterogeneity. Our results show that both population dynamics and the level of synchrony di! For two patches di! However, for a larger number of local populations the dynamics are similar irrespective of the dispersal rule. For example, for the parameter values yielding stable or periodic dynamics in a single population, the dynamics do not change when the patches are coupled with dispersal. High intensity of dispersal does not guarantee synchrony between local populations. The level of synchrony depends also on dispersal rule, the number of local populations, and the intrinsic rate of increase. In our study, the e! The results call for caution when drawing general conclusions from models of only two interacting populations and question the applicability of a large number of theoretical papers dealing with two local populations Host mobility drives pathogen competition in spatially structured populations by Chiara Poletto, Ro Meloni, Vittoria Colizza, Yamir Moreno, Ro Vespignani - PLOS Comp Bio , " Interactions among multiple infectious agents are increasingly recognized as a fundamental issue in the understanding of key questions in public health regarding pathogen emergence, maintenance, and evolution. The full description of host-multipathogen systems is, however, challenged by the multipli The full description of host-multipathogen systems is, however, challenged by the multiplicity of factors affecting the interaction dynamics and the resulting competition that may occur at different scales, from the within-host scale to the spatial structure and mobility of the host population. Here we study the dynamics of two competing pathogens in a structured host population and assess the impact of the mobility pattern of hosts on the pathogen competition. We model the spatial structure of the host population in terms of a metapopulation network and focus on two strains imported locally in the system and having the same transmission potential but different infectious periods. We find different scenarios leading to competitive success of either one of the strain or to the codominance of both strains in the system. The dominance of the strain characterized by the shorter or longer infectious period depends exclusively on the structure of the population and on the the mobility of hosts across patches. The proposed modeling framework allows the integration of other relevant epidemiological, environmental and demographic factors, opening the path to further mathematical and computational studies of the Is Chaos Due to Over-simplification in Models of Population Dynamics? Scheuring , " Theoretical ecologists have observed chaotic behavior in population models for decades. However, in the past few years, several studies indicate that complex dynamics, including chaos, become less probable in biologically more sophisticated models. For example, the inclusion of either sexual reprodu For example, the inclusion of either sexual reproduction, population structure or dis-persal generally increases stability. These results can explain the difference between the dynamical complexity of most theoretical models and the relative stability found within real time series. A geostatistical analysis of the geographical distribution of lymphatic filariasis prevalence in southern India by A. Gaining a better understanding of the spatial population structure of infectious agents is increasingly recognized as being key to their more effective mapping and to improving knowledge of their overall population dynamics and control. Here, we investigate the spatial structure of bancrof Here, we investigate the spatial structure of bancroftian filariasis distribution using geostatistical methods in an endemic region in Southern India. A major finding from the analysis was that once large-scale spatial trends were removed, the antigenemia data did not show evidence for the existence of any small-scale dependency at the study sampling interval of 25 km. By contrast, analysis of the randomly sampled microfilaraemia data indicated strong spatial contagion in prevalence up to a distance of approximately 6.

DOWNLOAD PDF MODELING SPATIOTEMPORAL DYNAMICS IN ECOLOGY

Chapter 3 : CiteSeerX â€” Citation Query Rethinking complexity: modelling spatiotemporal dynamics in eco

A review of one of the most important areas of theoretical ecology: the study of spatiotemporal dynamics by means of a spatially explicit approximation, allowing investigation of the effects of real Models are provided to calculate development of populations in time and ecological niches.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution CC-BY license http: This article has been cited by other articles in PMC. Abstract The prevention and control of dengue are great public health challenges for many countries, particularly since , as other arboviruses have been observed to interact significantly with dengue virus. Different approaches and methodologies have been proposed and discussed by the research community. An important tool widely used is modeling and simulation, which help us to understand epidemic dynamics and create scenarios to support planning and decision making processes. It supports compartmental and individual-based models, implemented over a GIS database, that represent Aedes aegypti population dynamics, human demography, human mobility, urban landscape and dengue transmission mediated by human and mosquito encounters. A user-friendly graphical interface was developed to facilitate model configuration and data input, and a library of models was developed to support teaching-learning activities. DengueME was applied in study cases and evaluated by specialists. Other improvements will be made in future work, to enhance its extensibility and usability. Introduction Dengue incidence increased rapidly in the last two decades [1 , 2 , 3]. However, problems with under-reporting and case misclassification suggest that the full impact of the disease is unknown and that new approaches for surveillance are required [4]. More recently, the emergence of other arboviruses, such as chikungunya [5] and zika [6], particularly in South America, have posed new challenges for surveillance and control. Dengue is a viral infection transmitted between humans and mosquitoes, with four serotypes that are rapidly spreading worldwide [4]. Until recently, its primary vector, the Aedes aegypti mosquito, which is well adapted to urban areas, was distributed mainly across tropical and subtropical regions [4 , 7]. However, now, it has spread to North America and Europe [8]. A secondary vector, Aedes albopictus, also expanded its geographic range in recent years [8 , 9]. The risk of dengue outbreaks and endemicity occurs mainly in tropical and subtropical regions [3]. However, the disease is spreading to North America and Europe [10 , 11 , 12], due to the presence of Aedes and the introduction of the virus. Dengue transmission is a complex process that involves the interaction of multiple agents humans, mosquitoes and virus in a heterogeneous space. The space itself is complex enough to provide many challenges for dengue transmission studies. The current pandemic was favored by a combination of several factors [4]. These included the global movement of hosts and vectors that speed up virus circulation [13 , 14 , 15] , urban crowding which favored multiple transmissions by a single infectious mosquito and loss of effect of previously efficient vector control strategies [16]. To map and describe global patterns of vulnerability to dengue transmission, some researchers have created risk maps and estimated the global distribution of dengue from notification and environmental data [3 , 17 , 18 , 19 , 20]. Although knowledge about the global situation of the disease is essential, it is also important to understand its dynamics at a local scale, where the encounters between vectors and hosts happen. Microclimate conditions, such as temperature, rainfall and humidity, interfere with all vector development stages, from egg viability to adult longevity and dispersal, among other aspects of dengue transmission [21 , 22 , 23 , 24 , 25]. Sociodemographic and environmental factors that contribute to increased dengue incidence [26 , 27] include: Other candidates are in different stages of development and evaluation [40 , 41]. However, none of them can be an immediate global panacea [4]. Besides, a dengue vaccine does not prevent the spread of zika and chikungunya viruses. Therefore, improvements in treatment and innovative approaches to understand and prevent transmission should continue. Several other control strategies have been proposed, studied and tested. They include reducing the abundance of the vector [42], introducing genetically-modified mosquitoes [43], infecting vectors with other pathogens [44 , 45 , 46 , 47] and preventing mosquito-human contact [48]. An improved understanding of the current epidemiology of the disease and its potential for future spread can assist policy makers in allocating resources to face this global public health challenge [4]. Several dynamic models have been developed to describe dengue transmission dynamics in space and time [49 , 50 , 51 , 52] and the behavior of its primary vector, Ae. They are fundamental tools for comparing different control methods and can evaluate what-if scenarios, but creating computational models accounting for several populations metapopulation models , heterogeneity e. DengueME is an open source tool that supports the development of spatiotemporal models for simulating dengue and its vector, integrated with a Geographic Information System GIS. The pre-compiled software is available for Windows, and source code is available for users to compile in Linux and OS X. DengueME was developed as a tool to assist the design of site-specific and vector population-specific control strategies for dengue. To reach this goal, DengueME provides: Computational models are useful for understanding the determinants of disease transmission processes and to analyze the impact of control strategies. Figure 1 shows the exponential growth of the number of scientific articles on dengue in general blue circles and articles on dengue models red squares , in the last two decades source: The number of articles on dengue models has grown faster than the number of articles on dengue in general. The increased interest in modeling shows the potential demand for frameworks that feature fast implementation, selection and testing of alternative dengue models in a single environment.

Chapter 4 : DengueME: A Tool for the Modeling and Simulation of Dengue Spatiotemporal Dynamics

In the past few years, part of theoretical ecology has focused on the spatiotemporal dynamics generated by simple ecological models. To a large extent, the results obtained have changed our view.

These aggregationsâ€”the size of which fluctuates in space and timeâ€”are called populations. Despite the fact that population dynamics has historically attracted the interest of many scientists, we are still far from understanding how and why populations fluctuate in natural ecosystems. The main reason is that populations are complex systems, with emergent properties that are impossible to determine by the sum of their parts. The components of population dynamics, including processes and patterns, are numerous and have multifaceted dimensions. Here, I will highlight some of themâ€”unavoidably, in a subjective manner. The Multidimensionality of Population Dynamics The size of a population integrates many factors, from the individual to the ecosystem levels, such as behavior, physiology, host-parasite and predator-prey interactions, diseases, nutrients, among others. Those processes also interact with physical drivers e. In most cases, these topics have been studied independently and in a simple manner; for instance, can the dynamics of a population be understood from pairwise interactions between two competing species? Thus, disentangling the influence of each of the numerous factors influencing population fluctuations remains a great challenge, due to the complexity of integrating the genetic, biotic and physical interactions giving raise to population dynamics. Working directly with fitness components, together with their variance, and simultaneously having robust estimates of population size over time may partially overcome those challenges, but the challenge is then shifted to time-consuming field monitoring work. Experiments at the microcosm-level are a valid alternative mainly to test specific hypotheses, but they do not solve the challenge of understanding population fluctuations in a holistic manner, given that experiments represent a simplified and altered version of reality. The Spatial Dimension of Population Dynamics Compared to population fluctuations over time, the spatial scale of population dynamics has historically been ignored because it can greatly complicate research. Collecting spatially-structured population data is highly demanding, but studying population processes that are inherent to the spatial scale are crucial, because the world is unavoidably spatially heterogeneous Tilman and Kareiva, Pioneering studies on simple predator-prey systems already stressed that a patchy, subdivided environment is necessary to maintain coexistence between two species Huffaker et al. The study of dispersal and connectivity between populations has much advanced in recent decades, particularly with the development of island biogeography and metapopulation theory MacArthur and Wilson, ; Hanski, There is still a considerable lag between theoretical advances and empirical results testing specific hypothesis, though new approaches and technologies, such as individual mark-recapture and telemetry e. For example, we are now aware of the importance of disturbances both natural and anthropogenic in dispersal, or of the many individual traits associated to dispersal such as morphology, behavior, physiology or life-history , but some issues still remain little-known, such as the role of trophic level, mating strategy, niche breath and plasticity of organisms on dispersal. Theoretical Models and Empirical Studies Many of the challenges described above have been solved by working with theoretical modeling. One paradigmatic example is the logistic curve of population growth first described by Verhulst back in Even for this broadly accepted pattern of population growth, the empirical evidences of this pattern are few, because of the difficulty of studying a population since its foundation colonization and over a sufficient amount of time, and also because not all the assumptions of the model can be properly tested in nature. The growth of theoretical models in population dynamics has been huge in recent decades, favored by the enormous capacities of computers to simulate complex scenarios. But, in general, theoretical and empirical ecologists working on population dynamics seldom engage in interdisciplinary studies and hence are not taking advantage of potential collaborations and inputs. This remains an issue that should be tackled in the future. At the same time, some models in widespread use, such as biogeographical models e. Some Properties of Population Dynamics Why do populations remain relatively stable or able to persist over time? This is one of the most difficult challenges confronting ecologists Cappuccino and Price, The role of density-dependence, age composition, competition at intra- and inter-specific levels, predation, dispersal between local populations, and other drivers and processes are still far from being understood as a whole, ever since the founding works on population regulation by Hutchinson We know that populations have resilient properties that allow them to rebound after perturbations have ceased, and maintain numbers around a dynamic equilibrium. But we also know that populations can crash and collapse following extreme values of environmental and demographic stochasticities or due to deterministic factors. What are the factors allowing population resilience? The roles played by the hidden components of populations e. Population Dynamics in Applied Disciplines The bridge between population dynamics and conservation biology still remains weak. Some processes, like extinction and colonization of empty patches, or concepts, like habitat quality heterogeneity, are commonly misunderstood in conservation. Thus, there is a need for a stronger background in population dynamics properties for the curricula of conservation practitioners. Concepts such as the minimum viable population or quasi-extinction probabilities in forecasting population trajectories see below still remain vague and allow for an extra dose of scientific subjectivity. Another important application of population dynamics is on the harvesting of populations and their sustainability. Some fisheries collapses recorded in the literature are important examples of non-linear population dynamics that challenge our knowledge on these dynamics, and highlight once again the importance and potential of interdisciplinary work between biologists and other scientists, including physicists or oceanographers. The influence of ecosystem maturity on harvested fish populations and in general in the study of natural populations and communities was already pointed out by Margalef but has been seldom considered in studies on anthropogenic perturbed systems and their resilient capacity. From an applied point of view, forecasting the fate of a population threatened or exploited is one of the greatest challenges for scientists, and crucial in the contexts of both sustainable exploitation and biodiversity conservation. Predictions increase their reliability with the amount of data available, but collecting robust data sets is consuming especially at large spatio-temporal scales. When data on population size is available, application of time series analysis, including data mining, pattern recognition and machine learning can be a fruitful pathway, together with the identification of non-linear behaviors, time-lags, extinction vortices associated to Allee effects, and regime shifts among others. There is an interest also from theoretical studies to understand and predict the dynamics of populations and communities, thus encouraging once again interdisciplinary work with field ecologists. Modeling Spatiotemporal Dynamics in Ecology. Individual variation and population dynamics. New Approaches and Synthesis. Dispersal Ecology and Evolution. Experimental studies on predation: Circular causal systems in ecology. The Theory of Island Biogeography. On certain unifying principles in ecology. Oro D Grand challenges in population dynamics.