MATHEMATICAL MODELS IN POPULATION BIOLOGY AND EPIDEMIOLOGY

Mathematical Models in Population Biology and Epidemiology: Understanding Life and Disease Through Numbers

mathematical models in population biology and epidemiology provide powerful frameworks to understand the dynamics of living organisms and the spread of diseases within populations. These models serve as essential tools for ecologists, epidemiologists, and public health officials by transforming complex biological processes into quantitative terms. Through them, we gain insights into population growth, species interactions, and the transmission patterns of infectious diseases, which in turn inform effective management and intervention strategies.

In this exploration, we'll dive into the core concepts behind these mathematical models, their practical applications, and how they continue to evolve in response to new scientific challenges. Whether you're a student, researcher, or simply curious about how math connects to biology and health, this article aims to offer a clear, engaging overview.

Understanding the Basics: What Are Mathematical Models in Population Biology and Epidemiology?

At their core, mathematical models in population biology and epidemiology are simplified representations of real-world biological systems. By using equations and computational simulations, these models describe how populations change over time and how diseases spread among individuals. They help answer fundamental questions like: How fast will a population grow? What factors cause population decline? How does an infectious disease transmit and persist within a community?

These models usually rely on parameters derived from empirical data—such as birth and death rates, transmission probabilities, or recovery times—which are used in mathematical expressions like differential equations or difference equations. The goal is to capture the essence of biological processes while maintaining enough simplicity for analysis and prediction.

Population Biology Models: Tracking Life's Numbers

Population biology focuses on the dynamics of groups of organisms, whether it's a herd of deer, a colony of bacteria, or a forest of trees. Here, mathematical models help in predicting changes in population size and structure over time, influenced by births, deaths, immigration, and emigration.

One of the most fundamental models is the **exponential growth model**, which assumes unlimited resources and no constraints. It's described by the equation:

$$\frac{dN}{dt} = rN$$

where N is the population size, t is time, and r is the intrinsic growth rate. Although simple, this model is rarely sustainable in real ecosystems, as resources are finite.

To capture real-world limitations, the **logistic growth model** introduces the concept of carrying capacity K:

$$\frac{dN}{dt} = rN \left(1 - \frac{N}{K}\right)$$

This model reflects how growth slows as the population approaches the environment's capacity, producing a characteristic S-shaped curve. It's widely used in ecology to understand how populations stabilize or fluctuate.

Beyond single-species models, there are **multi-species interaction models** that explore predator-prey dynamics, competition, and symbiosis. For example, the famous Lotka-Volterra equations model the oscillations between predators and their prey, highlighting the cyclical nature of these relationships.

The Role of Stochasticity and Spatial Structure

In reality, population dynamics are influenced by random events and spatial heterogeneity. Incorporating **stochasticity**—random fluctuations due to birth, death, or environmental variability—adds realism to models, especially for small populations where chance events can have large effects.

Additionally, spatial models consider how individuals move and interact across landscapes. **Metapopulation models** divide populations into discrete patches connected by migration, which helps explain phenomena like local extinction and recolonization.

Mathematical Models in Epidemiology: Mapping the Spread of Disease

Epidemiology uses mathematical models to understand how infectious diseases propagate through populations. These models are crucial for predicting outbreaks, evaluating control measures, and guiding public health decisions.

Compartmental Models: The SIR Framework

The most widely used approach in epidemiological modeling is compartmental models, which divide the population into categories based on disease status. The classic example is the **SIR model**, which categorizes individuals as:

- **S**: Susceptible (not yet infected but vulnerable)
- **I**: Infectious (currently carrying and transmitting the disease)
- **R**: Recovered (immune or removed from the population)

The model is governed by differential equations that describe the rates at which individuals move between compartments:

$$
\begin{aligned}
\frac{dS}{dt} &= -\beta SI \\
\frac{dI}{dt} &= \beta SI - \gamma I \\
\frac{dR}{dt} &= \gamma I
\end{aligned}
$$

Here, β represents the transmission rate, and γ the recovery rate. This framework elegantly captures the progression of many infectious diseases, from influenza to measles.

Extensions to the SIR model include:

- **SEIR models**, which add an exposed but not yet infectious compartment.
- **SIS models**, where recovered individuals return to the susceptible state.
- Models incorporating births, deaths, vaccinations, or varying infectiousness.

Basic Reproduction Number R_0: A Key Epidemiological Metric

A pivotal concept derived from epidemiological models is the **basic reproduction number**, R_0, which represents the average number of secondary infections caused by one infected individual in a fully susceptible population. If $R_0 > 1$, the disease can spread and potentially cause an epidemic; if $R_0 < 1$, the disease will eventually die out.

Estimating R_0 helps public health officials assess outbreak potential and the level of immunity required to achieve **herd immunity**.

Incorporating Real-World Complexity

Modern epidemiological models often account for additional factors to better reflect reality, such as:

- **Age structure**, since transmission and susceptibility can vary by age.
- **Network dynamics**, modeling how social connections influence spread.
- **Behavioral changes**, where individuals alter their behavior in response to an outbreak.
- **Spatial spread**, integrating geographic information to track disease hotspots.

Agent-based models simulate individuals with distinct behaviors and interactions, providing fine-grained insights but requiring significant computational power.

Applications and Impact of Mathematical Models in Population Biology and Epidemiology

These mathematical frameworks are not just theoretical exercises—they have tangible impacts on conservation, agriculture, and public health.

Informing Conservation and Wildlife Management

Population models help predict the viability of endangered species, assess the effects of habitat loss, and design protected areas. For example, understanding predator-prey dynamics can guide interventions to maintain ecosystem balance.

Guiding Epidemic Response and Policy

During outbreaks—like the COVID-19 pandemic—epidemiological models have been central to forecasting case numbers, hospitalizations, and mortality. They assist in evaluating the effectiveness of interventions such as social distancing, vaccination campaigns, and travel restrictions.

Optimizing Vaccination Strategies

Models can simulate how different vaccination coverages and timings affect disease spread. This enables policymakers to allocate limited resources efficiently, target high-risk groups, and minimize outbreaks.

Challenges and Future Directions

Despite their utility, mathematical models in population biology and epidemiology face challenges:

- **Data quality and availability**: Accurate parameters require reliable data, which can be scarce or uncertain.
- **Model complexity vs. interpretability**: More detailed models may be realistic but harder to analyze and communicate.
- **Changing environments**: Climate change, urbanization, and evolving pathogens introduce new variables that models must adapt to.

Advances in computational power, machine learning, and data collection (like genomic surveillance) are opening new horizons. Hybrid models combining mechanistic equations with data-driven approaches promise to improve predictions and responsiveness.

Mathematical models in population biology and epidemiology offer a fascinating window into the dynamics of life and disease. They blend biology, mathematics, and computer science, providing critical insights that shape our understanding of natural systems and public health. As we continue to face emerging challenges, these models remain indispensable tools for navigating an ever-changing biological landscape.

Frequently Asked Questions

What are mathematical models in population biology and epidemiology?

Mathematical models in population biology and epidemiology are quantitative frameworks that use mathematical equations and computational simulations to describe and predict the dynamics of populations and the spread of diseases within those populations.

How do SIR models help in understanding disease spread?

SIR models categorize a population into Susceptible, Infected, and Recovered compartments, using differential equations to simulate how an infectious disease spreads, peaks, and eventually declines, helping in predicting outbreak dynamics and evaluating control strategies.

What role do mathematical models play in managing epidemics like COVID-19?

Mathematical models help estimate crucial epidemiological parameters, project future case numbers, assess the impact of interventions like vaccination and social distancing, and guide public health policies to mitigate the spread of diseases such as COVID-19.

How do population biology models inform conservation efforts?

Population biology models analyze factors affecting species population dynamics such as birth rates, death rates, competition, and environmental changes, enabling conservationists to predict population viability and design effective management strategies to preserve biodiversity.

What are the limitations of mathematical models in epidemiology?

Limitations include reliance on accurate data, simplifications that may overlook complex biological and social factors, assumptions that may not hold in real-world scenarios, and uncertainties in parameter estimation, which can affect the precision and applicability of the model predictions.

Additional Resources

Mathematical Models in Population Biology and Epidemiology: Bridging Theory and Real-World Applications

mathematical models in population biology and epidemiology serve as crucial tools for understanding complex biological systems and the spread of diseases. By translating biological phenomena into quantitative frameworks, these models enable scientists, policymakers, and healthcare professionals to predict trends, assess intervention strategies, and ultimately make informed decisions. As the fields of population biology and epidemiology continue to evolve with advances in computational power and data availability, the role of mathematical modeling becomes ever more indispensable.

Understanding Mathematical Models in Population Biology and Epidemiology

Mathematical models in population biology and epidemiology are structured representations of natural processes through mathematical expressions. These models typically encompass differential equations, stochastic processes, or agent-based simulations that describe how populations or diseases change over time and space. The primary objective is to capture essential dynamics such as birth and death rates, species interactions, or infection transmission without requiring exhaustive empirical observation.

In population biology, models examine factors influencing population growth, competition, predation, and migration. Epidemiological models, on the other hand, focus on disease transmission, recovery rates, immunity, and public health interventions. Both disciplines intersect in the study of infectious diseases that affect host populations, bringing together ecological and medical perspectives.

Key Types of Mathematical Models

Several foundational models form the backbone of population biology and epidemiology:

- **Deterministic Models:** These models use fixed parameters and initial conditions to predict outcomes. They often take the form of ordinary differential equations (ODEs) representing average behaviors over time.
- **Stochastic Models:** Incorporating randomness, these models account for unpredictable variations in biological systems, such as random mutation or chance infection events.
- **Agent-Based Models (ABMs):** ABMs simulate individuals or agents with distinct behaviors and interactions, providing nuanced insights into heterogeneous populations and spatial structures.
- **Network Models:** These models focus on the connections between individuals or species, particularly relevant in epidemiology for mapping transmission pathways.

Applications and Implications in Population Biology

In population biology, mathematical models are used to decipher the complex interactions that regulate species abundance and diversity. The classic logistic growth model, for example, describes how populations grow rapidly when resources are abundant but slow as they approach carrying capacity. This model has been extended to incorporate interspecies interactions through Lotka-Volterra equations, which model predator-prey dynamics and competitive exclusion.

More sophisticated models incorporate age structure, spatial distribution, and environmental variability, which reflect real-world population heterogeneity. For instance, metapopulation models examine how local populations interact through migration, shedding light on species persistence despite local extinctions.

The predictive power of these models aids conservation biology by identifying critical thresholds that prevent population collapse and by assessing the impact of human activities on ecosystems. They also serve in managing fisheries, controlling invasive species, and understanding evolutionary processes.

Strengths and Limitations in Population Modeling

Mathematical models in population biology offer several advantages:

- They provide a theoretical framework to test hypotheses that are difficult or impossible to examine empirically.
- Models can integrate diverse data sources to generate comprehensive predictions.
- They facilitate scenario analysis, such as assessing the impact of climate change or habitat fragmentation.

However, these models also face limitations:

- Parameter estimation can be challenging due to limited or noisy data.
- Oversimplification may overlook critical biological details, reducing model accuracy.
- Complex models may require significant computational resources and expertise.

Mathematical Modeling in Epidemiology: Tracking and Controlling Disease Spread

Epidemiological models have gained substantial prominence, especially amid global health crises such as the COVID-19 pandemic. These models enable researchers to forecast disease outbreaks, estimate reproduction numbers (R0), and evaluate intervention strategies like vaccination, quarantine, or social distancing.

One of the foundational epidemiological frameworks is the SIR model, which divides the population into susceptible (S), infected (I), and recovered (R) compartments. Variants such as SEIR (including an exposed phase) and SIS (without lasting immunity) adapt to specific diseases and conditions.

Incorporating Complexity: Beyond Basic Models

Modern epidemiological models often integrate additional factors:

- **Heterogeneous Mixing:** Accounting for differences in contact rates among age groups or communities.
- **Spatial Dynamics:** Modeling disease spread across geographic regions using partial differential equations or network approaches.
- **Stochasticity:** Capturing random fluctuations, especially important in emerging outbreaks or small populations.
- **Behavioral Responses:** Including changes in human behavior in response to the epidemic or policies.

These enhancements improve the model's realism and predictive accuracy, supporting tailored public health responses.

Challenges in Epidemiological Modeling

Despite their utility, epidemiological models confront several challenges:

- **Data Quality and Availability:** Accurate modeling requires timely and comprehensive data, which can be hindered by underreporting or diagnostic delays.
- **Parameter Uncertainty:** Key parameters such as transmission rates can vary widely and are often estimated indirectly.
- **Dynamic Environments:** Changing pathogen characteristics and population behaviors complicate long-term predictions.

Addressing these challenges often involves sensitivity analyses and real-time model updates as new data emerge.

Interdisciplinary Integration and Future Directions

Mathematical models in population biology and epidemiology increasingly benefit from interdisciplinary collaboration, incorporating insights from genetics, ecology, sociology, and computer science. Advances in machine learning and big data analytics complement traditional modeling approaches, enabling more refined and adaptive frameworks.

For example, integrating genomic data with epidemiological models can trace pathogen evolution and transmission chains with unprecedented precision. Similarly, real-time mobility data enhance spatial models' ability to predict disease spread.

As global challenges like climate change, urbanization, and emerging infectious diseases intensify, the development of robust, flexible, and interpretable mathematical models will be pivotal. These tools not only facilitate scientific understanding but also inform policy decisions that protect public health and biodiversity.

In sum, mathematical models in population biology and epidemiology represent powerful instruments that bridge theoretical constructs and practical solutions. Their continued refinement and application promise to deepen our grasp of biological complexity and improve responses to ecological and health-related challenges.

[Mathematical Models In Population Biology And Epidemiology]

mathematical models in population biology and epidemiology: Mathematical Models in Population Biology and Epidemiology Fred Brauer, Carlos Castillo-Chavez, 2001-03-30 The goal of this book is to search for a balance between simple and analyzable models and unsolvable models which are capable of addressing important questions on population biology. Part I focusses on single species simple models including those which have been used to predict the growth of human and animal population in the past. Single population models are, in some sense, the building blocks of more realistic models -- the subject of Part II. Their role is fundamental to the study of ecological and demographic processes including the role of population structure and spatial heterogeneity -- the subject of Part III. This book, which will include both examples and exercises, is of use to practitioners, graduate students, and scientists working in the field.

mathematical models in population biology and epidemiology: Mathematical Models in Population Biology and Epidemiology Fred Brauer, Dawn BIes, 2011-11-08 The goal of this book is to search for a balance between simple and analyzable models and unsolvable models which are capable of addressing important questions on population biology. Part I focusses on single species simple models including those which have been used to predict the growth of human and animal population in the past. Single population models are, in some sense, the building blocks of more realistic models -- the subject of Part II. Their role is fundamental to the study of ecological and demographic processes including the role of population structure and spatial heterogeneity -- the subject of Part III. This book, which will include both examples and exercises, is of use to practitioners, graduate students, and scientists working in the field.

mathematical models in population biology and epidemiology: *Mathematical Models in Population Biology and Epidemiology* Fred Brauer, Carlos Castillo-Chavez, 2011-11-09 The goal of this book is to search for a balance between simple and analyzable models and unsolvable models which are capable of addressing important questions on population biology. Part I focusses on single species simple models including those which have been used to predict the growth of human and animal population in the past. Single population models are, in some sense, the building blocks of more realistic models -- the subject of Part II. Their role is fundamental to the study of ecological and demographic processes including the role of population structure and spatial heterogeneity -- the subject of Part III. This book, which will include both examples and exercises, is of use to practitioners, graduate students, and scientists working in the field.

mathematical models in population biology and epidemiology: Mathematical Approaches for Emerging and Reemerging Infectious Diseases: An Introduction Carlos Castillo-Chavez, 2002-05-02 This book grew out of the discussions and presentations that began during the Workshop on Emerging and Reemerging Diseases (May 17-21, 1999) sponsored by the Institute for Mathematics and its Application (IMA) at the University of Minnesota with the support of NIH and NSF. The workshop started with a two-day tutorial session directed at ecologists, epidemiologists, immunologists, mathematicians, and scientists interested in the study of disease dynamics. The core of this first volume, Volume 125, covers tutorial and research contributions on the use of dynamical systems (deterministic discrete, delay, PDEs, and ODEs models) and stochastic models in disease dynamics. The volume includes the study of cancer, HIV, pertussis, and tuberculosis. Beginning graduate students in applied mathematics, scientists in the natural, social, or health sciences or mathematicians who want to enter the fields of mathematical and theoretical epidemiology will find this book useful.

mathematical models in population biology and epidemiology: *Mathematical Models in Population Biology* Maira Aguiar, 2018-08-15 The aim of this book is to build a fundamental understanding in Mathematical Biology, Epidemiology and Ecology. Written for biologists, mathematicians, applied statisticians and physicists, Mathematical Models in Population Biology: Essential Concepts in Biomathematicsprovides a coverage of different topics in mathematical biology from vector-borne diseases, fractional calculus, and stochastic differential equations to neuro-dynamics, illustrating some important models used for real data.

mathematical models in population biology and epidemiology: *Discrete Mathematical Models in Population Biology* Saber N. Elaydi, Jim M. Cushing, 2025-01-03 This text lays the foundation for understanding the beauty and power of discrete-time models. It covers rich mathematical modeling landscapes, each offering deep insights into the dynamics of biological systems. A harmonious balance is achieved between theoretical principles, mathematical rigor, and practical applications. Illustrative examples, numerical simulations, and empirical case studies are provided to enhance mastery of the subject and facilitate the translation of discrete-time mathematical biology into real-world challenges. Mainly geared to upper undergraduates, the text may also be used in graduate courses focusing on discrete-time modeling. Chapters 1–4 constitute the core of the text. Instructors will find the dependence chart quite useful when designing their particular course. This invaluable resource begins with an exploration of single-species models where frameworks for discrete-time modeling are established. Competition models and Predator-prey interactions are examined next followed by evolutionary models, structured population models, and models of infectious diseases. The consequences of periodic variations, seasonal changes, and cyclic environmental factors on population dynamics and ecological interactions are investigated within the realm of periodically forced biological models. This indispensable resource is structured to support educational settings: A first course in biomathematics, introducing students to the fundamental mathematical techniques essential for biological research. A modeling course with a concentration on developing and analyzing mathematical models that encapsulate biological phenomena. An advanced mathematical biology course that offers an in-depth exploration of complex models and sophisticated mathematical frameworks designed to tackle advanced problems in biology. With its clear exposition and methodical approach, this text educates and inspires students and professionals to apply mathematical biology to real-world situations. While minimal knowledge of calculus is required, the reader should have a solid mathematical background in linear algebra.

mathematical models in population biology and epidemiology: Mathematical Models in Epidemiology Fred Brauer, Carlos Castillo-Chavez, Zhilan Feng, 2019-10-10 The book is a comprehensive, self-contained introduction to the mathematical modeling and analysis of disease transmission models. It includes (i) an introduction to the main concepts of compartmental models including models with heterogeneous mixing of individuals and models for vector-transmitted diseases, (ii) a detailed analysis of models for important specific diseases, including tuberculosis, HIV/AIDS, influenza, Ebola virus disease, malaria, dengue fever and the Zika virus, (iii) an introduction to more advanced mathematical topics, including age structure, spatial structure, and mobility, and (iv) some challenges and opportunities for the future. There are exercises of varying degrees of difficulty, and projects leading to new research directions. For the benefit of public health professionals whose contact with mathematics may not be recent, there is an appendix covering the necessary mathematical background. There are indications which sections require a strong mathematical background so that the book can be useful for both mathematical modelers and public health professionals.

mathematical models in population biology and epidemiology: Mathematical Models for Communicable Diseases Fred Brauer, Carlos Castillo-Chavez, 2013-02-07 A self-contained and comprehensive guide to the mathematical modeling of disease transmission, appropriate for graduate students.

mathematical models in population biology and epidemiology: Mathematical Epidemiology of Infectious Diseases O. Diekmann, J. A. P. Heesterbeek, 2000-04-07 Mathematical Epidemiology of Infectious Diseases Model Building, Analysis and Interpretation O. Diekmann University of Utrecht, The Netherlands J. A. P. Heesterbeek Centre for Biometry Wageningen, The Netherlands The mathematical modelling of epidemics in populations is a vast and important area of study. It is about translating biological assumptions into mathematics, about mathematical analysis aided by interpretation and about obtaining insight into epidemic phenomena when translating mathematical results back into population biology. Model assumptions are formulated in terms of, usually stochastic, behaviour of individuals and then the resulting phenomena, at the population level, are unravelled. Conceptual clarity is attained, assumptions are stated clearly, hidden working hypotheses are attained and mechanistic links between different observables are exposed. Features: * Model construction, analysis and interpretation receive detailed attention * Uniquely covers both deterministic and stochastic viewpoints * Examples of applications given throughout * Extensive coverage of the latest research into the mathematical modelling of epidemics of infectious diseases * Provides a solid foundation of modelling skills The reader will learn to translate, model, analyse and interpret, with the help of the numerous exercises. In literally working through this text, the reader acquires modelling skills that are also valuable outside of epidemiology, certainly within population dynamics, but even beyond that. In addition, the reader receives training in mathematical argumentation. The text is aimed at applied mathematicians with an interest in population biology and epidemiology, at theoretical biologists and epidemiologists. Previous exposure to epidemic concepts is not required, as all background information is given. The book is primarily aimed at self-study and ideally suited for small discussion groups, or for use as a course text.

mathematical models in population biology and epidemiology: Mathematical Population Dynamics and Epidemiology in Temporal and Spatio-Temporal Domains Harkaran Singh, Joydip Dhar, 2018-12-07 Mankind now faces even more challenging environment- and health-related problems than ever before. Readily available transportation systems facilitate the swift spread of diseases as large populations migrate from one part of the world to another. Studies on the spread of the communicable diseases are very important. This book, Mathematical Population Dynamics and Epidemiology in Temporal and Spatio-Temporal Domains, provides a useful experimental tool for making practical predictions, building and testing theories, answering specific questions, determining sensitivities of the parameters, forming control strategies, and much more. This volume focuses on the study of population dynamics with special emphasis on the migration of populations and the spreading of epidemics among human and animal populations. It also provides the background needed to interpret, construct, and analyze a wide variety of mathematical models. Most of the techniques presented in the book can be readily applied to model other phenomena, in biology as well as in other disciplines.

mathematical models in population biology and epidemiology: Population Biology Alan Hastings, 1996-12-13 Population biology has been investigated quantitatively for many decades, resulting in a rich body of scientific literature. Ecologists often avoid this literature, put off by its apparently formidable mathematics. This textbook provides an introduction to the biology and ecology of populations by emphasizing the roles of simple mathematical models in explaining the growth and behavior of populations. The author only assumes acquaintance with elementary calculus, and provides tutorial explanations where needed to develop mathematical concepts. Examples, problems, extensive marginal notes and numerous graphs enhance the book's value to students in classes ranging from population biology and population ecology to mathematical biology and mathematical ecology. The book will also be useful as a supplement to introductory courses in ecology.

mathematical models in population biology and epidemiology: Structured Population Models in Biology and Epidemiology Pierre Magal, Shigui Ruan, 2008-04-30 In this new century mankind faces ever more challenging environmental and publichealthproblems,suchaspollution,invasionbyexoticspecies,theem- gence of new diseases or the emergence of diseases into new regions (West Nile virus,SARS,Anthrax,etc.),andtheresurgenceofexistingdiseases(in?uenza, malaria, TB, HIV/AIDS, etc.). Mathematical models have been successfully used to study many biological, epidemiological and medical problems, and nonlinear and complex dynamics have been observed in all of those contexts. Mathematical studies have helped us not only to better understand these problems but also to ?nd solutions in some cases, such as the prediction and control of SARS outbreaks, understanding HIV infection, and the investi- tion of antibiotic-resistant infections in hospitals. Structuredpopulationmodelsdistinguishindividualsfromoneanother- cording to characteristics such as age, size, location, status, and movement, to determine the birth, growth and death rates, interaction with each other and with environment, infectivity, etc. The goal of structured population models is to understand how these characteristics a?ect the dynamics of these models and thus the outcomes and consequences of the biological and epidemiolo- cal processes. There is a very large and growing body of literature on these topics. This book deals with the recent and important advances in the study of structured population models in biology and epidemiology. There are six chapters in this book, written by leading researchers in these areas.

mathematical models in population biology and epidemiology: An Introduction to Mathematical Epidemiology Maia Martcheva, 2015-10-20 The book is a comprehensive, self-contained introduction to the mathematical modeling and analysis of infectious diseases. It includes model building, fitting to data, local and global analysis techniques. Various types of deterministic dynamical models are considered: ordinary differential equation models, delay-differential equation models, difference equation models, age-structured PDE models and diffusion models. It includes various techniques for the computation of the basic reproduction number as well as approaches to the epidemiological interpretation of the reproduction number. MATLAB code is included to facilitate the data fitting and the simulation with age-structured models.

mathematical models in population biology and epidemiology: Mathematical Approaches for Emerging and Reemerging Infectious Diseases: Models, Methods, and Theory Carlos Castillo-Chavez, Sally Blower, Pauline van den Driessche, Denise Kirschner, Abdul-Aziz Yakubu, 2012-12-06 This IMA Volume in Mathematics and its Applications MATHEMATICAL APPROACHES FOR EMERGING AND REEMERGING INFECTIOUS DISEASES: MODELS, AND THEORY METHODS is based on the proceedings of a successful one week workshop. The pro ceedings of the two-day tutorial which preceded the workshop Introduction to Epidemiology and Immunology appears as IMA Volume 125: Math ematical Approaches for Emerging and Reemerging Infectious Diseases: An Introduction. The tutorial and the workshop are integral parts of the September 1998 to June 1999 IMA program on MATHEMATICS IN BI OLOGY. I would like to thank Carlos Castillo-Chavez (Director of the Math ematical and Theoretical Biology Institute and a member of the Depart ments of Biometrics, Statistics and Theoretical and Applied Mechanics, Cornell University), Sally M. Blower (Biomathematics, UCLA School of Medicine), Pauline van den Driessche (Mathematics and Statistics, Uni versity of Victoria), and Denise Kirschner (Microbiology and Immunology, University of Michigan Medical School) for their superb roles as organizers of the meetings and editors of the proceedings. Carlos Castillo-Chavez, es pecially, made a major contribution by spearheading the editing process. I am also grateful to Kenneth L. Cooke (Mathematics, Pomona College), for being one of the workshop organizers and to Abdul-Aziz Yakubu (Mathe matics, Howard University) for serving as co-editor of the proceedings. I thank Simon A. Levin (Ecology and Evolutionary Biology, Princeton Uni versity) for providing an introduction.

mathematical models in population biology and epidemiology: *Mathematical Modeling of Biological Systems, Volume II* Andreas Deutsch, Rafael Bravo de la Parra, Rob J. de Boer, Odo Diekmann, Peter Jagers, Eva Kisdi, Mirjam Kretzschmar, Petr Lansky, Hans Metz, 2007-10-12 Volume II of this two-volume, interdisciplinary work is a unified presentation of a broad range of state-of-the-art topics in the rapidly growing field of mathematical modeling in the biological sciences. Highlighted throughout are mathematical and computational apporaches to examine central problems in the life sciences, ranging from the organization principles of individual cells to the dynamics of large populations. The chapters are thematically organized into the following main areas: epidemiology, evolution and ecology, immunology, neural systems and the brain, and innovative mathematical methods and education. The work will be an excellent reference text for a broad audience of researchers, practitioners, and advanced students in this rapidly growing field at the intersection of applied mathematics, experimental biology and medicine, computational biology, biochemistry, computer science, and physics.

mathematical models in population biology and epidemiology: Mathematical Modeling in Physical Sciences Dimitrios Vlachos, 2024-05-23 This volume gathers selected papers presented at the ICMSQUARE 2023 - 12th International Conference on Mathematical Modeling in Physical Sciences held in Belgrade, Serbia from August 28–31, 2023. This proceedings offers a compilation of cutting-edge research, which aims to advance the knowledge and development of high-quality research in mathematical fields related to physics, chemistry, biology, medicine, economics, environmental sciences, and more. Annually held since 2012, the ICMSQUARE conference serves as a platform for the exchange of ideas and discussions on the latest technological trends in these fields. This book is an invaluable resource for researchers, academicians, and professionals in these areas seeking to stay up-to-date with the latest developments in mathematical modeling.

mathematical models in population biology and epidemiology: Mathematical Modelling in Engineering & Human Behaviour 2018 Lucas Jódar, Juan Carlos Cortés, Luis Acedo Rodríguez, 2019-04-15 This book includes papers in cross-disciplinary applications of mathematical modelling: from medicine to linguistics, social problems, and more. Based on cutting-edge research, each chapter is focused on a different problem of modelling human behaviour or engineering problems at different levels. The reader would find this book to be a useful reference in identifying problems of interest in social, medicine and engineering sciences, and in developing mathematical models that could be used to successfully predict behaviours and obtain practical information for specialised practitioners. This book is a must-read for anyone interested in the new developments of applied mathematics in connection with epidemics, medical modelling, social issues, random differential equations and numerical methods.

mathematical models in population biology and epidemiology: *Dynamical Systems with Applications using MATLAB®* Stephen Lynch, 2014-07-22 This textbook, now in its second edition, provides a broad introduction to both continuous and discrete dynamical systems, the theory of which is motivated by examples from a wide range of disciplines. It emphasizes applications and simulation utilizing MATLAB®, Simulink®, the Image Processing Toolbox® and the Symbolic Math toolbox®, including MuPAD. Features new to the second edition include · sections on series solutions of ordinary differential equations, perturbation methods, normal forms, Gröbner bases, and chaos synchronization; · chapters on image processing and binary oscillator computing; · hundreds of new illustrations, examples, and exercises with solutions; and · over eighty up-to-date MATLAB program files and Simulink model files available online. These files were voted MATLAB Central Pick of the Week in July 2013. The hands-on approach of Dynamical Systems with Applications using MATLAB, Second Edition, has minimal prerequisites, only requiring familiarity with ordinary differential equations. It will appeal to advanced undergraduate and graduate students, applied mathematicians, engineers, and researchers in a broad range of disciplines such as population dynamics, biology, chemistry, computing, economics, nonlinear optics, neural networks, and physics. Praise for the first edition Summing up, it can be said that this text allows the reader to have an easy and quick start to the huge field of dynamical systems theory. MATLAB/SIMULINK facilitate this approach under the aspect of learning by doing. —OR News/Operations Research Spectrum The MATLAB programs are kept as simple as possible and the author's experience has shown that this method of teaching using MATLAB works well with computer laboratory classes of small sizes.... I recommend 'Dynamical Systems with Applications using MATLAB' as a good handbook for a diverse readership: graduates and professionals in mathematics, physics, science and engineering. —Mathematica

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