Parallel Session

Ecology III

USING POST-INTRODUCTION DATA AND A MECHANISTIC-STATISTICAL APPROACH TO DATE AND LOCALIZE AN INVASION

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Keywords: Partial differential equation, Mechanistic-statistical approach, Bayesian inference, Biological invasions.

The spread of invasive alien species to new areas continues to be an appealing research topic, not only for biologists but also for mathematicians. In particular, many scientific investigations are carried out to reconstruct the past dynamics of the alien species. The purpose of this talk is to present a mechanistic-statistical framework [1] that will allow us to jointly estimate the introduction point (date and location of the invasive species arrival) and other parameters of the dynamics related to diffusion, reproduction and death. This approach is hinged on (i) a coupled reaction-absorption-diffusion sub-model that describes the invasive species dynamics in a heterogeneous domain, (ii) a stochastic sub-model that represents the observation process and (iii) a statistical inference procedure for estimating model parameters. Parameter estimation is performed in a Bayesian framework through an adaptive multiple importance sampling algorithm [2]. We will present the application of this framework to the invasion of *Xylella fastidiosa* in South Corsica, France, a bacterial plant pathogen detected there in 2015. To estimate the introduction point and the other model parameters, we exploited abundant post-introduction data collected from an intensive surveillance plan implemented after the first pathogen detection. Note finally that our generic approach could be applied to other invasive species for which post-introduction data are collected.

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Parallel Session

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OPTIMAL STRATEGIES TO PREVENT INVASIVE SPECIES TRANSPORT

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Joint work with Martina Beck (BC Ministry of Environment and Climate Change Strategy), Matthias Herborg (Institute of Ocean Science, Fisheries and Oceans Canada) and Mark Lewis (University of Alberta).

Keywords: Invasion Biology, Optimal Control.

Human transportation is a main vector for movement of invasive species. Therefore, screening along transportation routes can be a powerful tool to prevent new outbreaks of invasive species. One mode of human transportation is the movement of vehicles and trailers along road networks. These vehicles and trailers can transport infested goods (e.g. firewood containing invasive bark beetles) or can themselves be infested (e.g. aquatic invasive species attached to trailered boats).

In practice, constraints in financial budgets and other resources make it difficult to conduct inspections on comprehensive scales. This holds in particular for road networks, which are decentralized rather than hub-based. If only few pathways can be considered for inspection, managers must choose locations carefully.

A second challenge arises from traffic being around the clock whereas continual screening is costly and often infeasible. Thus, finding the optimal timing for inspections is a second essential component of successful invasive species management.

In this talk, we present a framework to allocate limited resources to the strategically best inspection times and locations so as to minimize the risk of new invasions. Our approach is based on a hierarchical spread model and involves linear integer programming methods.

We illustrate our approach by applying it to the fight against the introduction of zebra mussels (*Dreissena polymorpha*) to the Canadian province British Columbia. A major spread mechanism for zebra mussels is the traffic of recreational boaters transporting propagules from invaded to uninvaded lakes. Therefore, inspection stations have been set up on roads, where passing watercraft are screened for zebra mussels and cleaned, if contaminated. We show how our mathematical and computational methods yield strategies for the British Columbian watercraft inspection program so as to minimize the transport of zebra mussels into the province.

Wednesday, 25th, 11:10 Room: C8.2.19

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RANGE EXPANSION OF THE YELLOW-LEGGED HORNET IN EUROPE AND THE ROLE OF HUMAN-MEDIATED DISPERSAL

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Keywords: Asian hornet, Biological invasion, Dispersal, Model, Spread.

The invasive yellow-legged hornet, Vespa velutina, is native to Asia and was first discovered in Europe in 2005, in south-western France. Since then, it has established and spread very rapidly throughout France and neighboring countries (Spain, Portugal, Italy, Germany, Belgium, Switzerland and Great Britain). The Asian hornet causes serious ecological and economic problems as it kills domestic honeybees. It can also impact human health because of possible allergic reactions following the insect sting. It is thus important to understand the spread mechanism to develop strategies to limit its range expansion.

Rapid spread of invasive species is usually attributed to accidental transportation during human activities. Here, we present a model that describes the spread across France of Asian hornet accounting for active dispersal of the species and long distance jumps. We developed a reaction-diffusion model to describe the spread of the hornet due to active flight and population growth. We simulated long-distance jumps due to human activities by adding a stochastic component to the previous model. Mortality rate was included in the model to simulate the destruction of nests by humans. This model was calibrated using the invasion history in France between 2005 and 2009 and was validated using observations done in 2013. It was then extrapolated to the expansion in Europe.

This model was used to study the impact of human-mediated dispersal on the invasion of yellow-legged hornet in Europe and more particularly on different European islands (Corsica, Majorca, Channel Islands, etc...). Surprisingly, simulations show that human-mediated dispersal was not necessarily involved in the rapid spread of the invasive species across France [1] since the Asian hornet has very high dispersal capabilities by itself. On the other hand, long distance jumps due to human activities could be necessary to explain the invasion of some European islands.

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Parallel Session

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CONSERVATION MANAGEMENT IN THE FACE OF DISEASE-MEDIATED INVASION

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Joint work with Sally Bell, Peter Lurz and Mike Boots (UC Berkeley)

Keywords: Spatial Modelling, Invasion, Disease, Conservation, Squirrels.

Disease-mediated invasions, in which invading species carry a disease that is harmful to native species, are widespread across a range of vertebrate, invertebrate and plant systems. We therefore need a clear understanding of the role of disease to manage conservation threats due to introduced and invasive species. Here, we modify a general deterministic model framework that represents competition and disease interactions between native and invading species to include explicit spatial and stochastic processes. The model is used to assess the impact of disease-mediated invasion on the viability of conserving native species in refuges (priority conservation areas). Such refuges protect native species by excluding invasive species in the refuge and in a buffer zone that surrounds it. An important finding is that the disease can spread through the native species even when the invading species is prevented from establishing. Therefore control of invading species may protect native species from exclusion, but may not protect them from disease outbreaks. The model techniques are applied to the well-documented UK red and grey squirrel conservation system as a case study.

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POVERTY TRAPS AS A SOCIAL-ECOLOGICAL PHENOMENA: DYNAMICAL SYSTEM APPROACH

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Keywords: Poverty trap, Social-ecological system, Nonlinear ordinary differential equations, Feedback loop.

Poverty traps, as an observed phenomenon and as a theoretical concept, are a prime example of social-ecological systems, highlighting the idea of human-nature coupling. Some recent articles, see e.g. [1] and [2], suggest that in order to alleviate poverty, we need to include both human factor (through economy, habits, and decision making) and nature (by bringing in the ecological aspect of the environment). Theoretical understanding and practical problem solving rely on our ability to analyze and predict dynamic behavior of complex human-nature coupled systems. One of the possible approaches is to represent social-ecological systems by mathematical models and dynamical systems to identify and study drivers and mechanisms of the system. To this end, we formulate and analyze several models represented by nonlinear ordinary differential equations. We are looking for conditions of multistability, where different equilibrium points are identified with poor (unwanted) state of the system and non-poor (desired) state.

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ECOCULTURAL RANGE-EXPANSION MODEL OF MODERN HUMANS IN PALEOLITHIC

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Keywords: Reaction-diffusion system, Traveling wave solution, Niche, Cultural evolution.

Recent genetic and archaeological studies on the range expansion of modern humans and the demise of Neanderthals suggest 1) their interbreeding, that must have resulted from their co-existence, and 2) a diversity of cultures/behaviors in associations with the spread of modern humans. It was not a simple spread of homogeneous "modern human behaviors." This study aims to explain a possible relationship between the two aspects (i.e., demographic changes and cultural dynamics) through eco-cultural modeling. In our model, carrying capacities depend on their cultural levels. Both population densities and the densities of skilled individuals in Neanderthals and in modern humans are spatially distributed and subject to change by spatial diffusion, ecological competition, and cultural transmission within each species. Our model is formulated by reaction-diffusion equations. We analyze the resulting range expansion dynamics in one-dimensional space. Of special interest is the case of cognitive and intrinsic-demographic equivalence of the two species. The range expansion dynamics consist of multiple wave fronts of different speeds. Properties of these wave fronts are mathematically derived. Depending on the parameters, these traveling waves can result in replacement of Neanderthals by modern humans. The first wave of intrusive modern humans is characterized by a low population density and a low density of skilled individuals, with implications for archaeological visibility. The first invasion is due to weak interspecific competition (i.e., niche difference). The second wave of invasion may be induced by cultural differences between moderns and Neanderthals. Spatially and temporally extended coexistence of the two species, which would have facilitated the transfer of genes from Neanderthal into modern humans and vice versa, is observed in the traveling waves, except when niche overlap between the two species is extremely high. Our study proposes a complicated process of modern human range-expansion due to ecological and cultural factors.

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