ECMTB 2014 Minisymposium on Cyclic Population Dynamics

Organiser:

Rebecca Tyson, Mathematics & Statistics, University of British Columbia Okanagan, Kelowna, BC, Canada

Abstract:

Population cycling is a ubiquitous phenomenon, applying across a number of animal, insect and bird populations in a wide variety of ecosystems. Furthermore, the dynamics of oscillating populations generate events of significant management and economic concern. For example, important cyclic events include periodic insect outbreaks, population lows in economically valuable fish stocks, and cycles in the observed effectiveness of biocontrol agents. Our ability to manage, anticipate, and mitigate the effects of these cyclic populations rests heavily on our mathematical understanding of the processes that generate or drive the observed cyclicity.

Substantial modelling effort has been expended to explain how population cycles form and persist. Nevertheless, definitive explanations for cycling have emerged only recently and only for some species. The cause of cycles remains unknown in many cases, and mathematical modelling has an important role to play in this ongoing work. The talks in this minisymposium will highlight mathematical modelling of cyclic population dynamics across a wide range of organisms in contexts ranging from predator-prey dynamics to the harnessing of chaotic dynamics to control population cycles. This minisymposium is a sequel to the highly successful international workshop “Current Challenges in Mathematical Modelling of Cyclic Populations” held at the Banff International Research Station in November 2013.

Schedule:

Time	**Speaker**
16:00 – 16:25	Frederic Barraquand (University of Tromso, Norway)
16:25 – 16:50	Frank Hilker (Osnabrueck University, Germany)
16:50 – 17:15	Gail Wolcowicz (McMaster University, Canada)
17:15 – 17:30	break
17:30 – 17:55	Christina Cobbold (University of Glasgow, Scotland)
17:55 – 18:20	Bret Elderd (Louisiana State University, USA)
18:20 – 18:45	Karen Abbott (Case Western Reserve University, USA)
18:45 – 19:00	break
19:00 – 20:00	working group on current challenges: review

Abstracts

1. Frederic Barraquand

Department of Arcitc and Marine Biology, University of Tromso, Tromso, Norway

Title: Revising the specialist and generalist predation hypotheses: examples from the Arctic

Abstract: A major hypothesis to explain when population cycles should be present or absent is the difference between generalist and specialist predation. Specialist predation is assumed to be largely destabilizing while generalist predation should be stabilizing. Using examples from the Arctic, notably the parametrised differential equation model of Gilg et al. 2003 [Science, 302:866-868], designed to explain lemming cycles in Greenland, we show that the role of generalist predation is more nuanced. In particular, we find that (1) generalist predators can initiate population declines and (2) short cycles persist in the absence of specialists. We then discuss the specialist-generalist predator dichotomy and its usefulness for population cycles theory.

2. Frank Hilker

   Institute of Environmental Systems Research, School of Mathematics/Computer Science, Osnabrueck University, Osnabrueck, Germany

   Title: Stabilizing population cycles with adaptive limiter control

   Abstract: As population cycles can lead to recurring outbreaks or increased extinction risk, many control methods aim at stabilizing fluctuations. Few of them, however, have been studied both empirically and theoretically. Here, we consider adaptive limiter control (ALC), a strategy recently proposed by Sah et al. and demonstrated in experimental fruit fly populations. The idea is to augment the population size whenever it falls below a certain fractions of its size in the previous generation. We thoroughly explain the mechanisms that allow ALC to reduce the magnitude of population fluctuations under certain conditions. While ALC is a control strategy with a number of useful properties, there are also some caveats that can turn ALC counterproductive and result in unintended outcomes.

3. Gail Wolcowicz

   Department of Mathematics, McMaster University, Hamilton, Ontario, Canada

   Title: A predator-prey model with time delay and the Mackey-Glass attractor

   Abstract: A delay is included in one of the simplest classical predator-prey models to model the time required for the predator to process the prey. We show that this introduces Hopf bifurcations, as well as sequences of period doubling bifurcations eventually leading to chaos, with a strange attractor that resembles the chaotic attractor of the Mackey-Glass equation.

   This is joint work with Daniel Franco (UNED, Madrid).

References:

Franco D, Hilker FM (2013) Adaptive limiter control of unimodal population maps. Journal of Theoretical Biology 337, 161-173.

Franco D, Hilker FM (2014) Stabilizing populations with adaptive limiters: prospects and fallacies. SIAM Journal on Applied Dynamical Systems 13, 447-465.

Sah P, Salve JP, Dey S (2013) Stabilizing biological populations and metapopulations through Adaptive Limiter Control. Journal of Theoretical Biology 320, 113-123.

4. Christina Cobbold

Department of Mathematics, University of Glasgow, Glasgow, Scotland

Title: Effects of dispersal and plant genotype on a cyclic herbivore population

Abstract: It has been shown that plant genotype can strongly affect not only individual herbivore performance, but also community composition and ecosystem function. Few studies, however, have addressed how plant genotype affects herbivore population dynamics. In this talk I will introduce a coupled patch model of herbivore dynamics and explore how the genetic composition of a forest influences herbivore population cycles in particular pest outbreak dynamics.

Specifically, I will show how plant genotype, the relative size of genotypic patches, and the rate of herbivore dispersal between them, affect the frequency, amplitude, and duration of outbreaks. We found that coupling two different genotypes does not necessarily result in an averaging of herbivore dynamics. Instead, depending on the ratio of patch sizes, when dispersal rates are moderate, outbreaks in the two- genotype case may be more or less severe than in forests of either genotype alone.

5. Bret Elderd

Department of Biological Sciences, Louisiana State University, Baton Rouge, Louisiana, USA

Title: The effects of biocontrol on cyclic pest populations and its unexpected outcomes

Abstract: The management of natural systems, while often meeting with success, has also led to unexpected and undesirable outcomes. Unfortunately, the ultimate result, desirable or undesirable, of such management programs may not be apparent until long after the control efforts have begun. This is particularly true for forest-defoliating species that exhibit long-period cycles such as the invasive gypsy moth, *Lymantria dispar*, which causes widespread damage in some years but is rare in others. We studied the effects of spraying biocontrol agents on gypsy moth population dynamics using a series of field-tested and empirically parameterized mathematical models. This allowed us to examine potential control strategies and assess long-term effects. In a non-spatial model, addition of biocontrol into the system decreases the amplitude

between boom and bust portions of the cycle. However, ill-planned biocontrol applications can help maintain pest populations at unexpectedly high numbers, which would result in constant forest defoliation. In a spatial two-patch model, where one patch is sprayed and the other is left untreated, there is considerable danger that migration between patches may drive the unsprayed population to levels that could also result in constant forest defoliation. It is often assumed that any control strategy that decreases pest populations in the short-term is beneficial, but our results show that undesirable outcomes over the long term may often occur. Thus, perturbations via management can have unexpected results, driving and maintaining populations at multiple levels including those far from desired management goals.

6. Frederic Barraquand

   Department of Arcitc and Marine Biology, University of Tromso, Tromso, Norway

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   Abstract: A major hypothesis to explain when population cycles should be present or absent is the difference between generalist and specialist predation. Specialist predation is assumed to be largely destabilizing while generalist predation should be stabilizing. Using examples from the Arctic, notably the parametrised differential equation model of Gilg et al. 2003 [Science, 302:866-868], designed to explain lemming cycles in Greenland, we show that the role of generalist predation is more nuanced. In particular, we find that (1) generalist predators can initiate population declines and (2) short cycles persist in the absence of specialists. We then discuss the specialist-generalist predator dichotomy and its usefulness for population cycles theory.

7. Karen Abbott

   Department of Biology, Case Western Reserve University, Cleveland, Ohio, USA

   Title: Where signal and noise collide: qualitative effects of stochasticity on population fluctuations

   Abstract: Population cycles are usually explained as a combination of deterministic mechanisms, such as predation, that drive density-dependent dynamics and stochastic forces that disrupt the neat patterns that would otherwise result. It is often convenient to apply the signal vs. noise dichotomy in this context, where a deterministic signal is blurred by stochastic noise. In some particularly fascinating situations, however, this dichotomy is unhelpful because the "signal" is inextricable from the "noise": stochasticity itself plays a role in shaping the overall pattern in the dynamics. In this way, stochasticity has a *qualitative* effect on the dynamics, such that the population fluctuations look quite different from what should result from the underlying deterministic factors alone. This creates quite a challenge: when we see patterns in ecological data, how can we tell if they were generated by mostly deterministic factors (with stochasticity simply adding some jitter) or if stochasticity played a key role in shaping the patterns themselves? This question is important, because the answer

determines whether stochasticity should be included explicitly in hypotheses for the observed patterns. By studying models that can show both of these outcomes and comparing their assumptions and behaviors, I begin to dissect what allows stochasticity to have a qualitative effect and become part of the “signal”. This study suggests that developing a more nuanced understanding of how stochasticity and nonlinearity interact in ecological systems will likely be more fruitful than viewing stochastic perturbations as “noise” to be filtered out.