**Indicators of regime shifts in freshwater ecosystems**

**Lead Supervisor Name**

Dr Christopher Clements

**Lead Supervisor Contact Details**

c.clements@bristol.ac.uk

**Lead Supervisor Location/Student Home Institution**

Institution: Bristol

School: Biological Sciences

**Full Project Description**

Regime shifts, characterised by sudden, often irreversible, changes in the composition of biological communities, can have catastrophic impacts on the ecosystem services which society relies on. Classic examples of this phenomenon originate from freshwater ecosystems, where shifts in the structure of a community can lead to cyanobacteria-dominated ecosystems, with potential negative impacts on human and livestock health. Being able to predict impending regime shifts in time to avert them is consequently a critical goal with significant implications for the management of scarce freshwater resources. This project will use long-term monitoring data in combination with advanced modelling techniques to characterise how community composition can change prior to and during a regime shift, and test and develop generalisable methods to predict and prevent such shifts in the future. A key goal in predictive ecology is forecasting the potential for rapid changes in ecosystems, leading to the development of “early warning signals”. These are generalisable methods which aim to predict changes in the composition of a community by detecting signals in time series data which are symptomatic of an approaching regime shift. The potential efficacy of such signals has been widely shown in simulation studies, but remains largely untested on real-world data, in part due to the lack of long-term monitoring before and after observed regime shifts. This has raised questions about their suitability to inform management strategies for natural capital. This project will tackle this knowledge gap using a two-pronged approach: analysis of long-term monitoring data from a well-studied lake ecosystem which has undergone a regime shift, and complementary theoretical modelling of the lake community. The Sea of Galilee is the only natural freshwater lake in Israel, and consequently a key resource. Its importance has meant extensive monitoring has been carried out for nearly 50 years, providing exceptional data on the abundances, biomasses, and densities of fish, zooplankton, and phytoplankton species from 1969 until 2018, as well as changes in the lake’s chemical composition. The lake’s community underwent a major shift in 1994-1995, resulting in a severe deterioration in water quality and an increase in harmful algal blooms. Consequently, data on multiple species and trophic levels are available prior to, during, and after a known regime shift, making it ideal for testing and developing warning signal methods. These exceptional data will be used to parameterise a size-spectra model of the lake community, allowing multiple simulated outcomes of perturbations on the system to be assessed. This project will: (1) assess whether the regime shift in the Sea of Galilee could have been predicted prior to its occurrence, (2) determine how far in advance such warning signals are detectable, (3) examine whether it is better to focus on specific species, trophic levels, or look at the community dynamics as a whole when trying to predict a system’s future dynamics, and (4) identify what data should be collected in the future to predict regime shifts. In addition to the specialist training provided by the supervisors, the student will undertake a full range of general courses to enhance their employability and personal development, including training on Statistics, Computing, Research Ethics, Intellectual Property and Enterprise, Bioinformatics, Sampling Methodology, and Research Skills.

**Real Life challenges this project will address**

The ability of human societies to persist in their current form is intimately linked to the services ecosystems provide. Freshwater resources are of particular concern as increasing populations rely on dwindling water to drink, irrigate crops, water livestock, and as key sites for recreation and other cultural services. Changes in the ecology of freshwater bodies can have significant impacts on the availability of drinking water, with regime shifts to cyanobacterial-dominated communities posing a risk to human and livestock health, and other resources such as fisheries. Cyanobacterial blooms can be caused by preventable stressors such eutrophication, however, to avoid shifts to cyanobacterial-dominated communities we must first be able to predict whether a regime shift is at risk of occurring, and thus whether intervention is required. This project will test and develop methods to predict approaching regime shifts based on alternate stable states theory, with a focus on providing reliable indicators which can be used to inform the management of at-risk freshwater ecosystems, and determine what data are needed to make reliable predictions, thus informing future monitoring programmes.

**What you should know about this project**

The project will be the first to take an ecosystem-wide approach to assessing whether we can predict ecosystem-scale regime shifts between healthy and cyanobacteria-dominated states in freshwater systems, using recently developed early warning signal methods. The student will take an interdisciplinary approach, analysing an exceptionally detailed 50-year dataset from the Sea of Galilee on the abundance, biomass, and sizes of the phytoplankton, zooplankton, and fish community, as well as the chemical composition of the lake. Uniquely, this dataset contains high resolution, multi-trophic level information prior to, during, and after an observed regime shift in the lake’s biotic community. This will allow us, for the first time, to test and develop current and novel early warning signals methods on a real-world regime shift. Moreover, the resolution of this long-term data set provides the data required to adapt, parameterise, and perturb size spectra community models to develop causal understanding of the processes at work during the detected ecological transitions. The project will be computer-based, and so the candidate must have a strong analytical background, a working understanding of computer programming, and an ecological background or strong interest in ecology. The supervisory team have complimentary skills and excellent track records in areas directly related to the research to be carried out during this project: Clements’ expertise developing and testing indicators of regime shifts in ecological systems, Thackeray’s expertise in the responses of lake ecosystems to environmental change and analysis of data from freshwater systems, Blanchard’s expertise in the development and use of size spectra models to simulate and assess the collapse of ecological communities, and Gal’s expertise in the Sea of Galilee, the pressures being exerted upon it, and the data available and their limitations.

**What expertise you will develop**

The student will gain expertise in the causes and consequences of regime shifts in ecological systems, from an ecological and sociological perspective. The student will develop a range of transferable skills, including cutting edge analytical and statistical skills, computer coding, the ability to work with large data sets (“big data”), communication skills to liaise with stakeholders, researchers, and the public, and a deep understanding of how models of ecological systems are constructed, perturbed, and used to make management decisions. The student will have ample opportunity to shape and influence the direction of the research carried out within the project, and in doing so will be able to develop as an independent science leader and forge their own unique research path.

**Why this project is novel**

Whilst a handful of previous studies have looked for early warning signals of regime shifts in fresh water systems, they have been limited in their scope to experimental manipulations of small lakes, modelling exercises, or studies of palaeoecological dynamics. This project will go far beyond the current scope of this work by analysing long-term high-resolution monitoring data from the Sea of Galilee which includes information on the whole lake community (including biomass, trait, and abundance data on phytoplankton, zooplankton, and fish) as well as changes in the chemical composition of the lake prior to, during, and after a recently observed regime shift. This data will be analysed to determine: (1) whether recently proposed early warning signals methods can reliably and accurately predict the observed regime shift in this natural system, (2) in what data are warning signals most reliably detected (e.g. nutrient concentrations, phytoplankton, zooplankton, or fish abundances/biomass), and (3) what are the minimum data requirements to make reliable predictions. To further enhance the scope of this project, the Sea of Galilee data will be used to parameterise a size spectra model of the lake community, allowing different community dynamic outcomes to be simulated under a range of environmental change scenarios. This studentship will therefore tackle a fundamental question regarding the reliability and applicability of early warning signals, specifically: at what ecological scale (species, community, ecosystem) should we search for such warning signals? Thus, whilst this project has a significant applied angle to the research, it will also help answer broad questions about the nature of ecosystem collapse, and how best we can predict and thus prevent such catastrophic changes.

**Rest of Supervisory Team:**

**Stakeholder Organisation** Israel Water Authority

**Stakeholder Supervisor** Firas Talhami

**Co-Supervisor 1** Dr Stephen Thackeray

Affiliation: CEH

Email: sjtr@ceh.ac.uk

**Co-Supervisor 2** Dr Gideon Gal

Affiliation: Israel Oceanographic & Limnological Research

Email: gal@ocean.org.il

**Co-Supervisor 3** Professor Julia Blanchard

Affiliation: University of Tasmania

Email: julia.blanchard@utas.edu.au