PROVISIONAL PROGRAMME

The school aims to cover several themes on modelling in marine ecology and provide several courses within each theme. The currently negotiated themes include:

Theme 1: Marine population and community dynamics

Course 1 – Size-spectrum modelling
(Axel Rossberg: School of Biological and Chemical Science, Queen Mary University of Lodon, England)

The complexity of marine ecological communities calls their dynamics at some higher level of abstraction than food-web models that requires fewer parameters and is more robust to uncertainty. Ecologists therefore study the community size spectrum, defined as the distribution of community biomass over the logarithmic body mass axis. It tells us how many small and large individuals there are. The interesting mix of regularity and structure observed for this trait-based description suggests its amiability to modelling. However, attempts since the 1970s to formulate predictive size-spectrum models based on ad-hoc, heuristic considerations have regularly run into difficulties. I will show how mathematical approximation techniques can be used to derive simplified size-spectrum models from food web models for size-structure populations, and point to interesting open questions. A thus derived model provides a unified description of marine and freshwater pelagic size spectra and successfully explains observed structures and parameter dependencies. Drawing deeply from and extending the mathematical tool-box developed to study pattern-formation in non-linear dynamical systems (while swapping physical space by trait space—the logarithmic size axis), I will show how the dynamics of this simplified model can be understood, thus linking observed high-level ecological phenomenology mechanistically to the life-cycles of organisms.

Course 2 – Modelling size-structured interactions in marine ecosystems using physiologically structured population models (PSPMs)
(Andre de Roos: Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Netherlands)

One of the most prominent features of marine communities is the variation in body size both within as well as between species. This makes population models that recognise differences among individuals in survival, reproduction, growth, development, etc. as a function of size, age, or other life history states particularly important for modelling the dynamics of marine communities. Physiologically structured population models (PSPMs) constitute a class of structured models in which both the life histories of individuals and the emerging population dynamics unfold in continuous time, and individual states may be continuous (e.g., size) or discrete (e.g., juveniles vs. adults). PSPMs are particularly suited to account in detail for the interactions between individuals of the same and/or other populations and to describe individual life histories by bio-energetic models, such as in the Dynamic Energy Budget theory (DEB). PSPMs form a powerful tool for understanding how population and community dynamics emerge from individual life histories, and equally important, how population and community processes feed back to shape the life histories of individuals. This feedback loop between individual- and population-level processes often yields non-linear dynamics and can lead to counterintuitive results. The aim of this course is to provide participants with the conceptual background and technical skills to start formulating and analyzing PSPMs. Participants will get hands-on experience analysing PSPMs using the R-package 'PSPManalysis', which is a collection of numerical routines to perform demographic, equilibrium and evolutionary analysis of PSPMs. In addition, I will highlight some of the insights into population and community dynamics gained from the use of PSPMs, especially focusing on the interaction between different, size-structured fish populations.

Theme 2: Biogeochemistry and marine ecosystems

Course 1 – Ecological and evolutionary determinants of plankton dynamics
(Domenico d'Alelio: Integrative Marine Ecology Department, Stazione Zoologica Anton Dohrn, Naples, Italy)

Plankton are both unicellular and multicellular organisms drifting with water currents and playing a key role in the oceans. They regulate biogeochemical cycles and constitute the very first node of marine food webs. Plankton distribution is highly fragmented in the global ocean, following geographical and geomorphological gradients, such as latitude, distance from the continental shelfs and ocean depth. Physical processes induce strong oscillations in plankton activity, in both space and time. In addition, biological features, such as life-cycle organization and evolutionary plasticity, determine shifts in plankton abundances that are virtually disconnected to proximate environmental shifts. The relatively high intermittency in plankton data recommends studying trends and irregularity in plankton production in the frame of Long Term Ecological Researches, in which all physical and biological descriptors of ecosystem status are monitored at relatively high time resolution. Building on case studies focussing on LTERs, I will illustrate the interplay among different factors, from inorganic nutrients to biological interactions, in driving plankton dynamics in marine ecosystems.

Course 2 – Plankton interaction networks and their role in marine food-webs
(Domenico d'Alelio: Integrative Marine Ecology Department, Stazione Zoologica Anton Dohrn, Naples, Italy)

Plankton are both unicellular and multicellular organisms drifting with water currents and playing a key role in the oceans. They regulate biogeochemical cycles and constitute the very first node of marine food webs. Plankton include both prokaryotes (unicellular organisms without a nucleus), protists and protozoans (unicellular eukaryotes, or organisms with a proper nucleus) and metazoans (multicellular eukaryotes). Each group features a huge biological diversity cascading into a myriad of different sizes, forms, feeding behaviors and, ultimately, roles played in ecological communities, food webs and, ultimately, ecosystems. The interactions among different plankton produce complex ecological networks, in which the different organisms are entangled into multiple feeding connections, or trophic links. The complexity of interactions among plankton is an emergent property whose investigation is made possible by the new type of models now available, like ecological network ones, which allow linking plankton diversity, structure and function within a coherent food web context. Herein, by presenting key case studies and how they fit into more theoretical frameworks, I will illustrate to which extent Long Term Ecological Research provides dataset suitable to integrate the entangled plankton webs into wider ecosystem models.

Course 3 – Ecosystem models: from simplistic to overly complex
(Marcos Mateos: MARETEC, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal)

Complexity is an intrinsic feature of all living forms and ecosystems. The task of modelling the complexity of organisms and ecosystems remains a key challenge of the modelling community. Over the past decades many marine ecosystem models have been published and widely adopted by marine scientists, ranging from simple linear food chain models to extremely detailed models for complex food webs. Model complexity seems to go hand by hand with the increased knowledge on the function of marine biogeochemical cycles, as modelers try to reflect this knowledge on their models. However, complexity comes with a price. Complex models require significantly more computational power, specialized knowledge from the developers and user, as bigger data sets from the calibration and validation stages. As such, model complexity is an open discussion.
In this course I will address the basics of model complexity by using several examples on different degrees of complexity, stressing their major advantages and shortcomings. We will tackle issues such as the standard-organism approach, functional groups, variable stoichiometry and C:Chla ratios, multiple nutrient limitation, etc. Different algorithms will be examined and tested.

Course 4 – The challenges of modeling viruses in marine systems
(Marcos Mateos: MARETEC, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal)

Viruses are the most abundant biological entities in the world's oceans. They have an impact on the flow of energy and matter in food webs by controlling the dynamics and diversity of bacterioplankton and some phytoplankton groups. Over the past three decades numerous studies have shown their central role in marine biogeochemical cycles. However, they are either ignored or relegated to agents of less importance by marine modelers. Based on the current knowledge on the role of viruses on the ocean plankton dynamics, I will illustrate the way that viruses control the food webs and mass/energy flows, and present current paradigms on possible ways to include viruses in marine biogeochemical models. Profiting from the participants experience, this course will also promote the discussion on other possible approaches to incorporate viruses into marine ecosystem models, and their eventual limitations (knowledge gaps, computational requirements, etc.).

Theme 3: Fisheries and resource dynamics

Course 1 – Fisheries-induced evolution: an evolutionary ecology perspective
(David Boukal : Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic.)

Commercial fisheries exert strong fishing pressure on many marine fish stocks. This pressure often leads not only to overfishing but also to rapid evolutionary changes in life history and behavioural traits within the harvested populations. I will provide a brief introduction into the main evolutionary concepts that underlie the studies of fisheries-induced evolution (FIE), present main lines of direct and indirect evidence for FIE, and discuss various approaches used to model FIE. We will then explore simple life history models implemented in R to illustrate how different harvesting options affect the evolution of life history traits such as size and age at maturation.

Course 2 – The inherent parameter sensitivity of marine food-web models and how to deal with it in fisheries management
(Axel Rossberg: School of Biological and Chemical Science, Queen Mary University of Lodon, England)

Marine food web models exhibit a phenomenon known as ecological structural instability, a high sensitivity of equilibrium population sizes to changes in parameters or community composition. This, rather than being a weakness of the models, reflects a corresponding real property of marine communities. Thus, as tempting as it is to reduce structural instability by modifying models (as often done), this is unlikely to improve their utility. I will explain the mathematics underlying ecological structural instability and show how this understanding can be used to devise fisheries management strategies that achieve high yield while being robust to the inherent uncertainty. The analysis links matrix algebra to the choice of management strategies and exposes some interesting open theoretical questions. The theory explains, amongst others, why fisheries managers always fall back to using single-species models rather than multispecies models, believing these are more robust, and why they are often wrong.

Theme 4: Contaminants in marine systems and their impact on marine populations

Course 1 – Dynamic Energy Budget theory and applications in ecotoxicology
(Dina Lika: Department of Biology, University of Crete, Greece)

Dynamic Energy Budget (DEB) theory is a conceptual and quantitative framework for modeling individual metabolism throughout the entire life cycle of an organism in a variable environment, be it ectothermic or endothermic, autotrophic or heterotrophic, and is explicitly tied to food/substrate availability. Basic to DEB theory is the coherence between levels of biological organization, using the life cycle of an individual as primary focus, from which sub- and supra-organismic levels are considered. DEB models describe how individuals obtain resources from their environment and use them to fuel their life histories. If stressors, for instance toxicants, interfere with the acquisition and use of energy, there will be consequences in the physiological performance of individual organisms, and therefore, in population dynamics. I will provide an introduction to DEB theory (basic concepts, explore the dynamics of the standard DEB model and discuss its extensions) and explain how to mechanistically link external toxicant concentration to effects on life histories over time (toxicokinetic and toxicodynamic models) and discuss examples of lethal and sublethal effects. The evaluation of population consequences of effects of toxicants on organisms requires an explicit link between these two levels of organization. I will discuss different approaches to link DEB to population models.

Theme 5: Methods and tools in mathematical modelling

Course 1 – Fitting models to data

Introduction on Modeling and Identification of dynamic systems.
(Andrea De Gaetano: Istituto di Analisi dei Sistemi ed Informatica "A. Ruberti", CNR, Rome, Italy)

Modeling Dynamic Systems. Types of models (physical models/black box models, deterministic/stochastic). Purpose and evaluation of a model. Model identification in general. Calibration vs. Estimation. Modeling error. Parameter estimation by maximum likelihood for deterministic models. Parameter estimation for stochastic dynamical systems.

State reconstruction in deterministic systems.
(Costanzo Manes: Dip. di Ingegneria e Scienze dell'Informazione e Matematica, Università degli Studi dell'Aquila, L'Aquila, Italy)

The problem of state reconstruction from input-output measurements in dynamic systems. The concept of state observability. Design of asymptotic observers in linear systems (discrete-time, continuous-time). Design of interval observers. Observability of the state and design of asymptotic observers in nonlinear systems (discrete-time, continuous-time). Examples of application.

State estimation in stochastic systems.
(Costanzo Manes: Dip. di Ingegneria e Scienze dell'Informazione e Matematica, Università degli Studi dell'Aquila, L'Aquila, Italy)

The problem of state estimation from noisy measurements in stochastic dynamic systems. Optimal state estimation in linear stochastic systems (Kalman filter): the case of discrete-time measurement, for systems with continuous-time or discrete-time dynamics. State estimation for nonlinear stochastic systems: Extended Kalman Filter and Unscented Kalman Filter. Application to simultaneous state and parameters estimation. Examples of application.

Course 2 – Title and abstract to be defined
(Axel Rossberg: School of Biological and Chemical Science, Queen Mary University of Lodon, England)