Report on
Scaling from individuals to group dynamics in heterogeneous physical environments

4-5 SEPTEMBER 2000

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c/o Danish Institute for Fisheries Research
Charlottenlund Slot
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REPORT ON
SCALING FROM INDIVIDUALS TO GROUP DYNAMICS IN HETEROGENEOUS PHYSICAL ENVIRONMENTS, CHARLOTTENLUND CASTLE, SEPTEMBER 4-5, 2000

Background

DIFRES and other Danish research institutions have applied for funding from the Danish Research Agency's programme "Creating foundation for Research in Fisheries and Aquaculture" to establish a network "Scaling from Individuals to Populations (SLIP)". To get a head start on the activities in the network, and as a result of arrangements made last spring we organised a research seminar on scaling in heterogeneous environments.

Time and Venue

The seminar was held over two days, on Monday the 4th of September and Tuesday the 5th of September 2000, at the Danish Institute for Fisheries Research, Charlottenlund Castle.

Guests Lecturers

We invited Simon Levin (Princeton), Glenn Flierl (MIT), and Danny Grünbaum (U. of Washington, Seattle) to give inspiring lectures on

?? Scaling in ecosystems (Levin)
?? Coupling between behaviour and physics (Flierl)
?? Group dynamics (Grünbaum)

PROGRAMME

Monday, September 4

09:00 – 09:30	Coffee
09:30 – 09:40	Welcome - Jan E. Beyer (DIFRES)
09:40 – 10:30	**Ecosystems as Complex Adaptive Systems -** Simon Levin (Princeton)
10:40 – 11:30	**Fluid flow and biological movement -** Glenn R. Flierl (MIT)
11:40 – 12:30	**Dynamics of Grouping I: Translating from individual behaviours to aggregation characteristics -** Danny Grünbaum (U. of Washington)
12:30 – 13:30	Lunch
13:30 – 13:45	**Overview of the SLIP network -** Henrik Gislason (U. of Copenhagen)
13:45 – 14:05	~~TBA (Measuring energy budgets of swimming fish in the field) - Niels Gerner Andersen (DIFRES)~~ (Cancelled)
14:05 – 14:20	**Bank specific availability of sandeels for predators and fishery - how individual fitness optimisation scale to population dynamics -** Henrik Mosegaard (DIFRES)
14:20 – 14:50	**Implementing behaviour in individual-based models using neural networks -** Geir Huse (U. of Bergen)
14:50 – 15:30	Coffee
15:30 – 16:15	**Conservation genetics of an exploited marine species, Atlantic cod** Daniel Ruzzante (DIFRES)
16:15 – 16:30	**Phenotype -environment interactions and selective processes in early life history of fish -** Peter Grønkjær (U. of Aarhus)
17:00 – 18:30	Reception

Tuesday, September 4

09:00 – 09:30	Coffee
09:30 – 09:40	Opening remarks - Jan E. Beyer (DIFRES)
09:40 – 10:30	**Scaling from individuals to ecosystems -** Simon Levin (Princeton)
10:40 – 11:30	**Flow, Taxis, and Kinesis (see the complete online presentation, including animations) -** Glenn R. Flierl (MIT)
11:40 – 12:30	**Dynamics of Grouping II: Predicting distributions of social populations in marine environments -** Danny Grünbaum (U. of Washington)
12:20 – 13:30	Lunch
13:30 – 13:45	**Estimating point process parameters with applications to the modelling of predator-prey interactions in a marine environment -** Bo Friis Nielsen (Tech. U. of Denmark)
13:45 – 14:00	**IBMs of Spatial and Temporal Dynamics in Marine Ecosystems -** Uffe Høgsbro Thygesen (DIFRES)
14:00 – 14:30	**Application of structural dynamic models -** Svend-Erik Jørgensen (Danish School of Pharmacy)
14:30 – 15:00	**Temporal and spatial scale invariant patterns of population dynamics -** Per Lundberg (U. of Lund)
15:00 – 15:30	Coffee
15:30 – 16:00	**Sensory motile behaviour of microbes and effects at the population level -** Tom Fenchel (U. of Copenhagen)
16:00 – 16:30	**LIFECO: Linking hydrographic Frontal activity and ECOsystem dynamics in the North Sea & Skagerrak: Impact on fish stock recruitment. An Overview -** Mike St. John (DIFRES)
16:30 – 16:45	**Spatial variability in the marine plankton - respective influence from hydrography and individual behaviour -** Peter Munk (DIFRES)
16:45 – 17:00	Concluding remarks - Jan E. Beyer (DIFRES)

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ABSTRACTS

Dynamics of Grouping I: Translating from individual behaviors to aggregation characteristics
Danny Grünbaum, U. of Washington

Most marine populations are highly aggregated in time and space. Spatial and temporal structures have profound impacts on the dynamics of these populations and of marine ecosystems in general. Understanding the origins of aggregation in behavioral, demographic, and physical mechanisms constitutes one of the primary challenges in biological oceanography. In this first of two talks, I will discuss theoretical approaches that integrate these three aggregation mechanisms to predict the timing, size, and location of aggregations of marine organisms. In particular, I will emphasize how individual-level responses to conspecifics and to environmental variation relate to the characteristics of groups. I will survey new modeling approaches that attempt to more accurately describe the diversity of social and asocial behaviors, to incorporate experimental observations of behavior in the lab and field, and to deduce trophic dynamics from population distributions.

Dynamics of Grouping II: Predicting distributions of social populations in marine environments
Danny Grünbaum, U. of Washington

Marine populations are typically heterogeneously distributed at a hierarchy of spatio-temporal scales. At local scales, variability in the distribution of many species takes the form of aggregations, within which individuals interact by responding socially to other members of the aggregation as well as asocially to their local environment. Predicting population-level fluxes in such species requires translating from microscopic individual- and group-level descriptions to macroscopic models of population density. In the marine setting, these population models must be compatible in form and computational requirements with geophysical scale fluid dynamical simulations. However, social interactions are inherently non-linear, and tractable mathematical descriptions of population fluxes arising from social behaviors are still the subject of active research. In this talk, I will discuss theoretical approaches to predict population fluxes from characteristics of social groups (e.g. group size, speed, cohesion, directional persistence, etc.) as well as large-scale ocean circulation patterns and resource distributions.

Implementing behaviour in individual-based models using neural networks
Geir Huse, U. of Bergen

Individual-based models (IBMs) have become very popular in ecology during the last decade. The focus of most studies using IBMs has been problems where behaviour is unimportant or simply enforced through rules made by the modeller. There have been few attempts to address more complex behavioural problems, partly due to a lack of appropriate modelling techniques. However, behavioural and life history aspects can be implemented in IBMs through adaptive models based on genetic algorithms and neural networks. I will present some examples of how this approach can be used to model fish behaviour at different space and time scales along with a comparison between the neural network approach and alternative approaches. The pros and cons of the different modelling approaches in behavioural ecology will be discussed.

Fluid flow and biological movement
Glenn R. Flierl, MIT

We will discuss continuum dynamics as applied to both fluids and distributions of the biota. While both systems can be expressed in Lagrangian form using basic Newtonian dynamics, such a description may not be very usedul when we consider large numbers of particles. We can instead examine the Boltzmann equation which predicts the probable number of particles having particular velocities at particular spatial/ temporal points. We can derive approximate density and velocity equations -- in the case of fluids, the Navier-Stokes equations and in the case of organisms, density equations which include the effects of the fluid flow and response to environmental conditions (including social processes involving the presence or absence of congeners).

Secondly, we will discuss the basics of fluid transport of passive and active tracers (i.e. populations which respond to environmental conditions). Fluctuations in the fluid flow give both mean drifts of material and eddy diffusion. Both, however, depend upon the biological response rates as well as the properties of the flow.

Flow, Taxis, and Kinesis

Glenn R. Flierl, MIT

We describe the principal components of fluid motion – translation, strain, vorticity, and divergence -- and the effects on the densities of the biota. We consider the instabilities that allow a smooth field to break into patches. Next we consider some specific examples such as (1) concentrations at fronts, (2) group formation in sheared flows and turbulent flows, (3) tidal convergences.

LIFECO: LInking hydrographic Frontal activity and ECOsystem dynamics in the North Sea & Skagerrak: Impact on fish stock recruitment

Mike St. John, DIFRES/HØK

At present resolution of processes involved in fish stock collapses remains speculative due to in part to the lack of research directed to the impact of environmental processes on stock dynamics. LIFECO is a major step in this direction, taking a holistic approach to the understanding of the effects of frontal processes (h/U3 and shelf break), key organising processes in the North Sea ecosystem, on fish stock recruitment and trophic interactions. Unlike most fisheries programs LIFECO addresses the effects of a key process on the dynamics of the ecosystem in a holistic manner rather than following a single species approach. The approach utilised is mechanistic, resolving links and key processes, a strategy, which is necessary to understand the effects of environmental variability on the ecosystem. The approach employed necessitates the utilisation and integration of a multidisciplinary research strategy typically not utilised in fisheries science. The program consists of 9 work packages wherein the first two consist of the development and application of simulation techniques to;

- ?? identify key climatic processes influencing frontal manifestation,
- ?? develop long term indices of frontal manifestation,
- ?? resolve the effects of frontal processes on the production and aggregation of lower trophic levels.

The third work package consists of the assemblage and application of remote sensing data to ground-truth the modelling components and to develop real time indices of frontal occurrence. The next three work packages are concerned with in situ measurement of organism distribution and trophodynamics relative to frontal processes following both bottom up and top down approaches. The next two work packages involve the development of a common database for utilisation by all participants to resolve distributional patterns using GIS data analysis and visualisation techniques. These work packages are designed to allow the statistical examination of distributional patterns of fish species relative to frontal occurrence.

The final component is the synthesis work package where we:

- ?? examine the effects of climatic processes and their variability on the dynamics of North Sea commercial fish population dynamics and develop environmentally sensitive recruitment models.
- ?? resolve the key regimes influencing ecosystem dynamics, distributional patterns and recruitment success. The successful comp letion of this activity will identify potential ecological reserves for the development of area specific management strategies
- ?? identify the necessity to adapt surveys assessing commercial fish stock abundance and recruitment to address variations in abundance relative to hydrographic features,
- ?? evaluate if prey suitability coefficients utilised in existing multi- species models of North Sea fish stocks are appropriate considering a heterogeneous distribution of prey organisms due to hydrographic features and develop alternative approaches.

Due to the diversity of research activities performed in LIFECO, the presentation will give a brief overview of the program and then focus on potential areas of interest to SLIPS participants.

Ecosystems as Complex Adaptive Systems
Simon Levin, Princeton

Understanding how to protect biodiversity requires understanding how it arose, and how it is maintained. The biosphere is a complex adaptive system, which is self-organized through the collective activities of many players-plants, animals, and microbes. The dynamics of the global commons emerges from the selfish actions of individuals, and the enlightened self-interest that results in altruism, coalitions and communities. This lecture will explore these features, and lessons to be learned for achieving a sustainable future. Spatial stochastic and agent- based models of animal and plant assemblages will play a central role, as will game-theoretic approaches to evolutionary dynamics. Fundamental issues will involve the relationships between microscopic and macroscopic phenomena.

Scaling from individuals to ecosystems
Simon Levin, Princeton

A fundamental problem in ecology is to understand how patterns and processes at the level of ecosystems emerge from the responses of individuals to environmental factors and to each other. Landscape patterns in forest and grassland plant distributions are governed by the physiological attributes of individuals, but nonlinearities arising from how individuals affect one another make the problem of integration of individualistic responses, and specifically of what the consequences will be for the distributions of species and effects on ecosystem processes, nontrivial. Conceptually similar, but mathematically distinct, problems arise in the analysis of how grouping patterns in animals are governed by the responses of individuals to local cues. In this talk, I will explore a variety of marine and terrestrial examples.

Application of structural dynamic models
Svend-Erik Jørgensen, Danish School of Pharmacy

Ecosystems are flexible and adaptable, while our model is rigid as if ecosystems were physical systems. When models are used as tool for development of prognoses, it is a fatal disadvantage that our model reflects the structure that was in the ecosystem when we developed the model and not the structure that is going to be a result of the changed circumstances in the future.

Structural dynamic models can be developed either by use of expert knowledge or by use of goal functions which are optimised. It is important the goal functions are able to describe the development of the ecosystems under new prevailing conditions. The thermodynamic variable exergy has been used in ten case studies to develop structural dynamic models. One of the models will be presented to illustrate this approach.

IBMs of Spatial and Temporal Dynamics in Marine Ecosystems
Uffe Høgsbro Thygesen, DIFRES/HFI

This talk presents the ideas behind my post.doc.-project in the SLIP network. I will investigate IBMs which are based on stochastic differential equations governing the state of individuals. I intend to construct a simulation environment which includes 1) solution of these SDEs, 2) computational fluid dynamics and 3) discrete events (birth and death). I intend to look into model reduction in this type of models, using techniques from system theory and statistical mechanics. Finally I am interested in matching models with empirical data using statistics of point patterns.