Handbook of Ecological Modelling and Informatics
Handbook of Ecological Modelling and Informatics

Editors:

S.E. Jørgensen
The University of Pharmaceutical Science, Denmark

T-S. Chon
Pusan National University, Korea

F. Recknagel
University of Adelaide, Australia
**Contents**

Preface ................................................................................................................................... xiii

Model examples, software, homepages and contact person for the various model types .................................................................................................................................... xv

Chapter 1  
**Introduction: sub-disciplines of ecology and the history of ecological modeling** ....... 1  
*S.E. Jørgensen*

1 History of the ecological sub-disciplines ................................................................. 1  
2 The development of ecological modeling ....................................................... 5

Chapter 2  
**Overview of the model types available for ecological modeling** ....................... 9  
*S.E. Jørgensen & T.-S. Chon*

1 Issues in model development ................................................................. 9  
1.1 Presentation of spatial distribution .......................................................... 11  
1.2 Computational realization of biological properties ................................... 15  
1.3 Revealing environmental factors .......................................................... 17  
1.4 Data handling and model construction ............................................. 18  
2 Increasing number of model types .......................................................... 19  
3 Characteristics of the model types available today ........................................ 21  
3.1 Dynamic models: Chapters 5 and 11 .................................................. 22  
3.2 Static models: Chapters 5 and 11 ....................................................... 23  
3.3 Population dynamic model: Chapter 12 ............................................ 24  
3.4 Structurally dynamic models: Chapter 13 ......................................... 25  
3.5 Fuzzy models: Chapter 8 ................................................................. 26  
3.6 Models in ecological informatics: Chapter 9 ....................................... 27  
3.7 Individual-based models and cellular automata: Chapters 7 and 16 ....... 28  
3.8 Spatial models: Chapters 6 and 20 .................................................... 30  
3.9 Ecotoxicological models: Chapters 14 and 15 ................................... 31  
3.10 Stochastic models: Chapter 12 ......................................................... 33  
3.11 Rule-based models: Chapter 17 ....................................................... 34  
3.12 Hybrid models: Chapter 10 .............................................................. 35
Chapter 3
Ecological informatics: current scope and feature areas .................................................. 41
F. Recknagel
1 Introduction ................................................................................................................ ...... 41
2 Feature areas ............................................................................................................... ...... 43
3 Future directions ........................................................................................................... .... 44

Chapter 4
Model making ....................................................................................................................... 49
S.E. Jørgensen
1 Modelling procedure ......................................................................................................... 49
2 Institutionalized modeling ................................................................................................. 51
2.1 The institutionalized modelling process ......................................................................... 52
3 When to apply IMM?....................................................................................................... 53

Chapter 5
Ecopath with Ecosim: linking fisheries and ecology ........................................................ 55
V. Christensen
1 Why ecosystem modeling in fisheries? ............................................................................ 55
2 The Ecopath with Ecosim (EwE) modeling approach ..................................................... 56
2.1 Model overview.............................................................................................................. 56
2.2 Mass-balance .............................................................................................................. 56
2.3 The foraging arena ...................................................................................................... 58
2.4 Ecosim ...................................................................................................................... 59
3 EwE modules and applications ...................................................................................... 60
5 EwE applications ......................................................................................................... 61
6 Getting hold of the EwE software ................................................................................ 62
7 Exercise: trawling cultivates the ocean bottom for squid ................................................ 63

Chapter 6
Surface modelling of population distribution ................................................................... 71
T.-X. Yue, Y.-A. Wang & Z.-M. Fan
1 Introduction ...................................................................................................................... 71
2 YUE-SMPD .................................................................................................................. 72
2.1 Approaches to population distribution analyses ...................................................... 72
2.2 YUE-SMPD formulation ......................................................................................... 73
3 An application of YUE-SMPD .................................................................................. 74
3.1 Major data layers ...................................................................................................... 74
3.2 YUE-SMPD operation ............................................................................................. 86
3.3 Change trend of population distribution in China .................................................... 87
3.4 Scenarios of population distribution in China ......................................................... 90
4 Discussion ................................................................................................................... 92
Chapter 7
Individual-based models ................................................................. 99

1 Introduction ......................................................................................... 99
2 Properties of individuals ..................................................................... 100
3 Model construction ........................................................................... 101
   3.1 Program outline and system environment ........................................... 101
   3.2 Variables ........................................................................................ 102
   3.3 Model structure and interaction ......................................................... 102
   3.4 Parameters and input data ................................................................. 102
   3.5 Output and model results ................................................................. 102
4 Case study 1: flocking behavior .......................................................... 103
   4.1 Program outline and system environment ........................................... 103
   4.2 Variables ........................................................................................ 103
   4.3 Model structure and interaction ......................................................... 105
   4.4 Parameters and input data ................................................................. 107
   4.5 Output and results ........................................................................... 107
5 Case study 2: population dispersal ....................................................... 109
   5.1 Program outline and system environment ........................................... 109
   5.2 Variables ........................................................................................ 111
   5.3 Model structure and interaction ......................................................... 113
   5.4 Parameters and input data ................................................................. 113
   5.5 Output and results ........................................................................... 114

Chapter 8
A fuzzy approach to ecological modelling and data analysis .................... 125
A. Salski, B. Holsten & M. Trepel

1 Imprecision, uncertainty and heterogeneity of environmental data ............ 125
2 Fuzzy sets and fuzzy logic in ecological applications ................................ 126
   2.1 Fuzzy classification and spatial data analysis ...................................... 126
   2.2 Fuzzy modelling, decision making and ecosystem management ............ 127
   2.3 Hybrid approaches to data analysis and ecological modelling ............. 127
3 Fuzzy classification: a fuzzy clustering approach .................................... 127
   3.1 An application example: fuzzy classification of wetlands for determination of water quality improvement potentials .......................... 129
4 Fuzzy modelling .................................................................................. 132
   4.1 An application example: a fuzzy and neuro-fuzzy approach to modelling cattle grazing in Western Europe ................................. 134
5 Final remarks .................................................................................... 138

Chapter 9
Ecological informatics by means of neural, evolutionary and object-oriented computation ...................................................... 141
F. Recknagel & H. Cao

1 Introduction ......................................................................................... 141
2 Artificial neural networks ................................................................... 141
   2.1 Supervised feedforward ANN ......................................................... 143
   2.2 Supervised feedback ANN .............................................................. 144
   2.3 Non-supervised ANN ................................................................. 145
Chapter 18
Network calculations II: a user’s manual for EcoNet ......................................................... 325
C. Kazanci

1 Introduction ................................................................................................................ ...... 325
2 How to create an EcoNet model .................................................................................... 327
  2.1 EcoNet model structure ....................................................................................... 327
  2.2 EcoNet model flexibility ..................................................................................... 328
  2.3 A few rules about EcoNet models ....................................................................... 329
3 How to run an EcoNet model ....................................................................................... 330
  3.1 Fourth-order Runge–Kutta method ................................................................. 331
  3.2 Numerical solution methods ............................................................................. 332
  3.3 Stochastic method ............................................................................................ 333
  3.4 From model to differential equation .................................................................. 334
4 Simulation and analysis results ................................................................................... 335
  4.1 Network diagram ............................................................................................... 335
  4.2 Time-course plot and data of compartment storage values ................................ 336
  4.3 Model information ............................................................................................ 338
  4.4 Adjacency matrix .............................................................................................. 338
  4.5 Flow coefficient matrix ..................................................................................... 338
  4.6 Flow matrix ....................................................................................................... 340
  4.7 Network analysis .............................................................................................. 341
  4.8 Storage analysis ............................................................................................... 341
  4.9 Throughflow analysis ....................................................................................... 342
  4.10 Utility analysis ............................................................................................... 344
5 Study of an EcoNet model ......................................................................................... 345
  5.1 Model description .............................................................................................. 345
  5.2 Flow analysis ..................................................................................................... 346
  5.3 Storage and utility analysis ............................................................................... 348
  5.4 Further analysis ............................................................................................... 349

Chapter 19
Mediating conceptual knowledge using qualitative reasoning ........................................... 351
B. Bredeweg & P. Salles

1 Introduction ................................................................................................................ ...... 351
2 Background and principles .......................................................................................... 352
  2.1 How does it work? ............................................................................................. 352
  2.2 Model ingredients ............................................................................................. 353
  2.3 Qualitativeness ................................................................................................... 354
  2.4 Causality ........................................................................................................... 355
  2.5 Inequality reasoning .......................................................................................... 356
  2.6 Correspondences ............................................................................................... 357
  2.7 Model fragments: reusing partial models ......................................................... 357
  2.8 Generating a state-graph .................................................................................. 358
3 Garp3: QR workbench ............................................................................................... 359
  3.1 Build environment ............................................................................................. 361
  3.2 Simulate environment ....................................................................................... 365
  3.3 Special features and support ............................................................................ 368
  3.4 Support and getting started ............................................................................. 373
4 Examples of QR models ............................................................................................ 373
  4.1 Binary population interactions ....................................................................... 373
Preface

During the last two decades the development in computer technology has been enormous. Two decades ago, we were probably working with our first personal computers, which may have had a memory of 512 kb or 1024 kb and storage capacity was 30 or 50 Mb. The laptops of today have 1000 or 2000 times as much memory and capacity and the price of computers is 25-50 times lower, when we consider the level of incomes. This development has of course also influenced the development of ecological models. The models of today are much larger. For instance 3D-models that were hardly used twenty years ago due to the required computer time are generally in use to day. Models considering the spatial distribution are now regularly used whenever a spatial distribution is of importance for the modelling results; it was impossible to run most spatial distribution models on personal computers twenty years ago. As a result, several new model types have emerged, and they are able to solve modeling problems formulated in the 1970s.

- How do we deal with the individuality of the organisms?
- How do we consider the change in properties of the organisms due to adaptation? How do we consider a shift in the species composition, which we know may take place?
- How can we build a model based on a very heterogeneous data base?
- How can we develop a model, when our data base is fuzzy?
- How can we describe the spatial distribution?
- How can we ensure that we get the best model description based on our data?
- Can we combine several ecosystem models to a landscape model?

The modelling tool box available to day, year 2008, contains many more tools than twenty years ago. The more comprehensive tool box has made it easier to achieve good model results, but it has also made it more difficult to select the right tool or combination of tools to solve a specific problem. We have therefore found that there was a need for a “Handbook in Ecological Modelling” with the scope to present to the readers all the available model tools of today. To facilitate the selection of the right model type for a specific problem, we have included on a CD a typical example of all the available model types. Such an easy-to-go test of a model example, will demonstrate the advantages and disadvantages of the model type for the readers and thereby give a better basis for the right model type selection.

The development of the computer technology has offered two other advantages for the ecological modellers, namely that it is more easy to have access to and to apply big data bases and
that an enormous amount of ecologically relevant information including genetic information is available on internet. Due to this development a new ecological sub-discipline called ecological informatics was born in Adelaide in year 2000, when it was agreed at a conference in ecological informatics to launch ISEI, International Society of Ecological Informatics. We found it therefore of interest for the readers to include also this development of applied ecology in the handbook and we have therefore decided to use the title “Handbook of Ecological Modelling and Informatics”. What ecological informatics covers is presented in details in Chapter 3 and also the minor overlap it has with ecological modelling, while the field of ecological modelling is presented in Chapter 2. The chapters 4-20 present the up-to-date tool box of ecological modelling and informatics. In the last chapter, we attempt to predict in which direction these two rapid growing sub-disciplines of ecology will develop.

Ecological modelling and informatics are two very recent sub-disciplines of ecology. They have opened-up a number of new possibilities for synthesizing and quantifying knowledge in ecology, which is urgently needed in modern environmental management. With the ecological crisis that can be foreseen in the 21st century due to a rapidly expanding population in many countries, rapidly decreasing natural resources in all countries and significant global climate changes, there will be a growing need for ecological modelling and informatics. This handbook will contribute to wider development and application of quantitative ecological approaches.

The Editors, 2008