

Ecological Modelling

An introduction

S.E. Jørgensen

University of Copenhagen, Denmark

WITPRESS Southampton, Boston



Contents

| | |
|--|-----------|
| Preface | ix |
| Chapter 1 | |
| Ecological models | 1 |
| 1.1 Why go modelling?..... | 1 |
| 1.2 History of ecological modelling..... | 3 |
| 1.3 Modelling components..... | 6 |
| 1.4 Modelling procedure..... | 8 |
| 1.5 Selection of model complexity | 19 |
| 1.6 Model uncertainty | 21 |
| 1.7 Mediated modelling | 22 |
| Chapter 2 | |
| Model types | 29 |
| 2.1 Classification of models..... | 29 |
| 2.2 Model types – an overview | 29 |
| 2.3 Characteristics of the model types | 33 |
| 2.3.1 Dynamic biogeochemical and bioenergetic models..... | 33 |
| 2.3.2 Steady state biogeochemical models..... | 34 |
| 2.3.3 Population dynamic models..... | 34 |
| 2.3.4 Structurally dynamic models | 35 |
| 2.3.5 Fuzzy models..... | 35 |
| 2.3.6 Artificial neural networks | 36 |
| 2.3.7 Spatial models..... | 37 |
| 2.3.8 Individual based models and cellular automata | 37 |
| 2.3.9 Ecotoxicological models..... | 38 |
| 2.3.10 Stochastic models | 39 |
| 2.3.11 Hybrid models | 39 |
| 2.4 Applicability of the different model types. | 40 |
| Chapter 3 | |
| Biogeochemical models | 45 |
| 3.1 Biogeochemical and bioenergetic models have wide applications | 45 |
| 3.2 A chemo-state model to illustrate a steady state biogeochemical model . | 48 |
| 3.3 An eutrophication model based on 2–4 state variables and statistic correlations to find additional state variables..... | 49 |

| | |
|---|------------|
| 3.4 An eutrophication model of medium to high complexity | 54 |
| 3.5 Model of subsurface wetland | 66 |
| 3.5.1 Process equations..... | 69 |
| 3.5.2 Parameters..... | 70 |
| 3.5.3 Differential equations | 71 |
| 3.5.4 Model results | 72 |
| 3.5.5 Practical information about forcing functions and parameters | 73 |
| 3.5.6 Use of the model for wetland design | 73 |
| 3.6 River models..... | 73 |
| | |
| Chapter 4 | |
| Population dynamic models..... | 87 |
| 4.1 Introduction..... | 87 |
| 4.2 Basic concepts..... | 87 |
| 4.3 Growth models in population dynamics | 88 |
| 4.4 Interaction between populations | 93 |
| 4.5 Matrix models | 99 |
| 4.6 Metapopulation models..... | 101 |
| 4.7 Modelling infectious diseases | 102 |
| | |
| Chapter 5 | |
| Ecotoxicological models..... | 109 |
| 5.1 Introduction..... | 109 |
| 5.2 Five classes of ecotoxicological models | 111 |
| 5.2.1 Food chain or food web dynamic models | 111 |
| 5.2.2 Static models of the mass flows of toxic substances..... | 111 |
| 5.2.3 A dynamic model of a toxic substance in one trophic level..... | 112 |
| 5.2.4 Ecotoxicological models in population dynamics..... | 113 |
| 5.2.5 Ecotoxicological models with effect components..... | 113 |
| 5.3 The application of parameter estimation methods in ecotoxicological modelling..... | 116 |
| 5.4 Biogeochemical and ecotoxicological model example: contamination of an agricultural field..... | 120 |
| 5.5 Uptake of toxic substances by plants | 125 |
| | |
| Chapter 6 | |
| Spatial models | 133 |
| 6.1 Introduction..... | 133 |
| 6.2 2D and 3D models | 134 |
| 6.3 An example of distance as independent variable: chromium pollution in a Danish Fjord..... | 135 |
| 6.3.1 Model description | 136 |
| 6.4 Application of GIS..... | 141 |
| 6.5 Use of cellular automata or lattice models in spatial modelling | 141 |
| 6.6 Surface modelling | 143 |
| 6.7 Use of IBM in research: determination of the role of conjugation in the evolution | 144 |
| 6.7.1 The model | 145 |

| | |
|---|-----|
| 6.7.2 State variables..... | 146 |
| 6.7.3 Model structure..... | 147 |
| 6.7.4 Parameters and forcing functions..... | 147 |
| 6.7.5 Model results | 148 |
| 6.7.6 Discussion and conclusions | 150 |

Chapter 7

Structurally dynamic models (SDMs)..... 153

| | |
|--|-----|
| 7.1 Basic concepts of structurally dynamic modelling | 153 |
| 7.2 Ecosystem characteristics | 154 |
| 7.3 The thermodynamic concept of eco-exergy | 159 |
| 7.4 Structurally dynamic models | 163 |
| 7.5 Development of SDM for Darwin’s finches | 168 |
| 7.6 Model of the ectoparasites–birds interactions..... | 169 |
| 7.7 A structurally dynamic eutrophication model developed by use of STELLA..... | 170 |
| 7.8 SDM developed for Lake Fure..... | 173 |

**Appendix 1: Table of oxygen solubility as function of temperature
and salinity..... 185**

Index 187