Index

Note: Page numbers followed by *b* indicate boxes, *f* indicate figures and *t* indicate tables.

Α

Adaptability, 296 Adjacency matrix digraph-based, 165-167, 166f graph, 165–167, 165f modeling procedure and, 25f, 26, 27tweighted digraph, 165-167, 166f Age distribution blue whale illustration of, 149-150 matrix models and, 147-149 Agricultural landscape succession example amoeba diagram used in, 365fbackground, 363 spatial distribution of ecosystem types in, 363, 364f of spatial model, 363-364 WAMOD used in, 363-364 Agricultural products case study cadmium/lead balance and, 279, 280f cadmium/lead contamination, 278-284 conceptual diagram, 281f model equations, 281, 282t, 283 model results, 283-284 model used in, 279-283, 281f AIC. See Akaike's Information Criterion Akaike's Information Criterion (AIC), 59 Algal culture illustration, of growth models, 134-135 Allometric estimation methods, 268 Allometric principles, 77 Amoeba diagram, 365f Analysis, 10

ANN. See Artificial neural networks Artificial neural networks (ANN) advantages/disadvantages, 112 applicability of, 116–118, 117t, 118tpercentage application of, 98–99, 98t, 99fquestion answered by, 97 Autonomous models, 44t, 47

В

 β values, for various organisms, 329–330, 331*t* Base model, 51–52 Benthic fauna, 276, 277-278 Biodegradation rate, 266-267 Biodemographic models, 48, 48t Bioenergetic models, 95-96 advantages/disadvantages, 108 overview of, 48, 48t Biogeochemical models, 95-96. See also Dynamic biogeochemical models; Steady-state biogeochemical models advantages/disadvantages, 108 applicability of, 116-118, 117t, 118t of ecosystems, 17–18, 17t of environmental problems, 18, 18*t* management problems solved by, 176 - 177overview of, 48, 48t Biological magnification, 85, 85t **Biological** parameters biochemical feedback mechanisms and, 68

Biological parameters (Continued) discrepancies regarding, 67–68 environmental factors and, 67 indirect determinations of, 67 Biomanipulation, 335–342, 339*f*, 340*f* hysteresis reaction and, 335–336, 335f model variables/forcing functions and, 336-337 phytoplankton growth rate and, 338, 338f zooplankton growth rate and, 338, 339f Black-box models, 44t, 47, 104–105 Blue whale age distribution illustration of matrix models, 149-150 problem conditions, 149 problem solution, 149–150 Box conceptual models, 104

С

Calibration automatic, 38-39 data regarding, 39–40, 61–62, 61f of eutrophication models, 61 explanation of need for, 37-38 goal of, 37 recommendations, 40-41 requirement of, 61 step, 23, 25f, 37-41 trial-and-error, 38, 39 weights and, 39 Causal models overview of, 44t, 47 parameters found in literature for, 60-61 Chemo-state model to illustrate steady-state biogeochemical models, 160-162 as mixed flow reactor, 160, 160f one component considered in, 160, 161*f* pesticide in lake illustration of, 162 Chlorophyll concentration, 190 Chromium distribution, Danish fjord case study, 271-278

Clementsian concept, 9 Climate. See also Global warming model infection models and, 155f, 156 Coexistence, 296 Compartment models, 44t, 45 Competition equations, four cases of, 136, 136f, 136t Complementarity theory, 81 Complex river models, 14f, 15 Complexity, 13 conceptual diagrams and, 100-101 functional, 13 structural, 13 Complexity, model AIC and, 59 balance tempering, 51 base model and, 51–52 ecological buffer capacity and, 58, 58f, 59f effectiveness vs. articulation revealing, 53-54, 53f excessive, 51 knowledge regarding, 52-53, 52f, 54 lakes example and, 56–57, 56*f*, 57*f* map analogy illuminating, 54 mass/energy flow diagrams and, 55-56 selection of, 51-60 Conceptual diagram agricultural products case study, 281f complexity regarding, 100-101 of copper ecotoxicological model/ SDM example, 343*f* energy circuit, 106–107, 107f feedback dynamics, 105–106, 106f fish habitat along river corridor example, 366, 367f fugacity fate model, 286f of global warming model, 219f infection models, 155–156, 155*f* Lake Glumsø model, 23f, 187f modeling elements and, 22, 23f modeling procedure and, 23f, 25f, 27 of nitrogen cycle, 23f

in oyster reef example, 170–171, 170f savanna succession example, 360f of Streeter-Phelps river model, 182-183, 183f subsurface wetland model, 209-210, 211f, 212f, 213f of yeast anaerobic cultivation illustration, 141–142, 141f Conceptual models, 95-96, 100-107 black-/white-box, 104-105 box, 104 diagrams and, 100-101 energy circuit diagram and, 106–107, 107ffeedback dynamics diagrams and, 105-106, 106f focal level and, 101, 102*f* function of, 100 input/output, 105, 105*f* picture, 103, 104f submodels and, 103, 103f with three hierarchical levels, 101, 102*f* Condition index, 144-145 Conservation law of mass, 84 principle, 83, 138 Conservation of energy biomass to energy conversion and, 88, 89t discovery of, 86 herbivorous animals and, 87-88 plants/solar energy and, 86–87, 88f population dynamic model and, 138 Conservation of matter biological magnification and, 85, 85t constraints and, 83 law of mass conservation and, 84 mass flow through food chain and, 85 net efficiency and, 85 Streeter-Phelps model and, 84 Constant flow rate equation, 29 Constraints, modeling, 82-92 conservation of energy and, 86

conservation of matter and, 83 conservation principles and, 83 considerations of using, 91*f*, 92 degrees of freedom and, 90 entropy and, 88 hierarchy of regulation mechanisms and, 90 parameter estimation and, 77–78 system properties and, 82–83 Copper ecotoxicological model/SDM example, 343–346 conceptual diagram of, 343*f* overview, 343–344 results of model run, 344*f*, 345, 345*f*

D

Danish fjord case study, 273f, 274f, 274t background, 271 benthic fauna and, 276, 277-278 on chromium distribution, 271-278 models used in, 271 parameters, 275, 275t prognosis validation, 278, 278t settling rates, 275–276, 276t statistical analysis results, 274-275, 275tDarwin's finches, SDM for, 333–334, 335f DDT biological magnification and, 85, 85t concentrations, 85, 87t fish weight and, 85, 86f Definition of problem step, 24, 25*f* Deterministic models, 44t, 45, 45f Detritus settling velocity, 70t Differential equations for simple eutrophication models, 191 subsurface wetland model, 215-216 Distributed models overview of, 44t, 46-47 SDMs as, 49-50 Dynamic biogeochemical models. See also Lake Glumsø model

advantages/disadvantages, 108

Dynamic biogeochemical models (Continued) applicability of, 116–118, 117t, 118t application of, 177–178 eutrophication models, complex, 192 - 208eutrophication models, simple, 184 - 192global warming model, 218-225 overview of, 175-176 percentage application of, 98-99, 98t, 99f Streeter-Phelps river BOD/DO model using STELLA and, 179-183 subsurface wetland model, 208-218 Dynamic models, 95-96. See also Dynamic biogeochemical models; Population dynamics models; Structurally dynamic models advantages/disadvantages, 108 choice of, 48-49, 49f food chain/food web, 246, 248f overview of, 44*t*, 46, 46*f* of toxic substance in one trophic level, 247, 249f, 250f

Ε

EAU. *See* Equivalent animal units Ecoexergy, 330, 332–333. *See also* Exergy Ecological buffer capacity, 58, 58*f*, 59*f* Ecological modeling. *See also specific subject* advantages of, 5–6 application of, state of art in, 16–18 development of, 13–16, 14*f* factors in evolution of, 2–3 growth in field of, 10 holism and, 7–11 hypotheses regarding, 6, 8*f* as management tool, 3–4, 4*f*, 5*f* physical/mathematical models and, 1–3

quantum theory and, 78-82 as research tool, 4–7, 8f Ecological network analysis (ENA) description of, 163, 164-165 digraph-based adjacency matrix and, 165–167, 166f EcoNet software and, 168–169 flow model elements and, 165 graph adjacency matrix and, 165–167, 165fgraph theory/matrix algebra and, 165-167 path proliferation and, 168 reachability matrix and, 168 steady-state models and, 163-174 weighted digraph adjacency matrix and, 165-167, 166f EcoNet software analysis of values in, 171, 173t ENA and, 168-169 integral flow matrix and, 173 integral storage matrix and, 173 mutualism relations and, 174 nondimensional direct flow matrix and, 172 numerical methods used in, 170-171 ovster reef example using, 169–171, 170f partial turnover rate matrix and, 173 system-wide properties calculated in, 171, 172b utility analysis and, 174 Ecopath models example of, 163, 164f input ratios and, 163 steady-state models and, 162-163 Ecopath software, 162 Ecosystems. See also Exergy; specific topic agricultural landscape succession example regarding, 363, 364f approaches to study of, 12 biogeochemical models of, 17–18, 17t characteristics, 3-4

concepts explaining functioning of, 7 definitions of, 11, 12 ecology, 9 evolution of, 317-321 heterogeneity regarding, 316-317 as irreducible, 81-82 models. 231 natural selection and, 317, 319 as object of research, 11-13 reductionism and, 2, 6, 312-313 regulating mechanisms and, hierarchy of, 4, 311*t* species composition/external factors and, 317, 318–319, 318f synthesis and, 6 Ecotoxicological models. See also Copper ecotoxicological model/SDM example advantages/disadvantages, 114 agricultural products case study, 278 - 284applicability of, 116–118, 117*t*, 118*t* approach to developing, 246 characteristics/structure of, 244-258 classification of, 229-233 Danish fjord case study, 271-278 dynamic model of toxic substance in one trophic level, 247, 249*f*, 250*f* with effect components, 251, 253f effect models and, 254, 254f ERA and, 233–244, 255–256, 257–258 estimation of parameters of, 261-271 examples of, 259t fate models and, 229, 230, 253, 254f food chain/food web dynamic models, 246, 248f fugacity fate models, 284–287 human evaluation processes models and, 254, 254f human perception processes models and, 254, 254f other models vs., 245-246 overview of, 97

percentage application of, 98-99, 98t, 99f in population dynamics, 250 practical application of, 229–233, 258 - 261static models of toxic substance mass flows, 247, 248f submodels of, 253–255, 254f EEP software, estimation and, 269, 270-271, 270f Effect components, ecotoxicological models with, 251, 253f Effect models applied, 231-232 classification of, 231 ecotoxicological models and, 254, 254f overview of, 229, 230-231 Effectiveness, 296 EIA. See Environmental impact assessment Elements, modeling, 20-24 conceptual diagram and, 22, 23f forcing functions/external variables, 20 mathematical equations, 21 parameters, 21 state variables, 20 universal constants, 22 ENA. See Ecological network analysis Energy circuit conceptual diagram, 106–107, 107f Energy flow diagrams lakes example, 56–57, 56f, 57f model complexity selection and, 55-56 Silver Spring example, 55–56, 55f Entropy, 88 Environ, 82 Environment, properties of, 296-297 Environmental management, 4, 5f modeling, 13-16, 14f problems, 18, 18t Environmental impact assessment (EIA), 234, 235 Environmental risk assessment (ERA)

Environmental risk assessment (ERA) (Continued) assessments factors and, 237, 237t basic assumptions of, 234 ecotoxicological models and, 233-244, 255-256, 257-258 EIA and, 234, 235 handbooks, 243 medicinal products and, 244 spatial/time scale for various hazards, 236, 236f steps in, 238-244, 239f, 242f uncertainty and, 237, 238 Equivalent animal units (EAU), 144 ERA. See Environmental risk assessment Eutrophication chlorophyll concentration and, 190 defined, 186-187 events sequences leading to, 189-190 of lakes, 186 nitrogen and, 187-188 nutrient concentrations predicting, 190 - 192phosphorus concentration and, 190, 191*t* phosphorus cycle and, 187, 187f phytoplankton and, 188–189, 188t plant tissue and, 187, 188t Eutrophication models. See also Lake Glumsø model calibration of, 61 complex, 192–208 core questions for, 184–185 development of, 14f, 15 differential equations for simple, 191 overview, 192-208 sampling frequency and, 62 simple, 184-192 various, 193t, 194 Eutrophy, 186 Exergy. See also Ecoexergy β values for various organisms and, 329-330, 331t

defined, 327 explained, 323, 324 as goal function, 323 natural selection and, 324 nutrient concentration increase/ decrease and, 324, 325, 325f Existence, 296 External variables, 20

F

Fate models, 229, 230. See also Fugacity fate models classes of, 230 ecotoxicological models and, 229, 230, 253, 254f fugacity, 284-287 overview of, 229-230 Fate-transport-effect-models (FTEmodels), 230, 231 Fecundity, 131–132 Feedback dynamics conceptual diagram, 105-106, 106f Finches. See Darwin's finches, SDM for First-order rate expression, 29, 30. See also Logistic growth equation with regulation, 30 Fish growth example, parameters and, 65 Fish habitat along river corridor example conceptual diagram, 366, 367f dredging fill and, 366, 366f results, 366–368, 368f of spatial model, 364–368 Fish weight, DDT and, 85, 86f Fishery models growth rate vs. number for logistic growth equation in, 150, 151fmortality and, 151*f* one vs. several species and, 153 optimum yield and, 152, 152f population dynamics models and, 150 - 153Food chain/food web dynamic models, 246, 248f

Forcing functions, 20 biomanipulation and, 336-337 global warming model, 223 subsurface wetland model, 210-211, 217 - 218Forest succession after blowdown example background, 356–357, 357t modified original model, 357, 358f results, 357-359, 358f of spatial model, 356-359 Freedom of action, 296 FTE-models. See Fate-transport-effectmodels Fugacity fate models, 284–287 applied on four levels, 286 conceptual diagram of, 286f fugacity capacity and, 285-286, 286t illustrations, 287-290 solutions, example, 287-288, 289-290 Functional complexity, 13 Fuzzy models, 97 advantages/disadvantages, 111 applicability of, 116–118, 117t, 118t percentage application of, 98–99, 98t, 99f

G

GBM. See Grid-based model
Gene-individual-population example, of IBM, 304–307, 306f, 307f
Geographical Information System (GIS), 97, 353
GIS. See Geographical Information System
Gleasonian concept, 9
Global models, 231
Global warming model diagram, 219f
as dynamic biogeochemical model, 218–225
features/processes, 224–225
forcing functions, 223

overview regarding, 218-223 results, 223-224, 224f state variables, 223 STELLA equations, 220t Gödel's Theorem, 81 Graph adjacency matrix, 165–167, 165f Grid-based model (GBM), 301, 302f Groupiness, 122-123 Growth models algal culture illustration, 134-135 carrying capacity and, 132-134 density dependence and, 132-134 fecundity and, 131-132 herbivores population dynamics illustration of, 142–146 interaction between populations and, 135 - 141intrinsic rate of natural increase and, 132 logistic growth equation assumptions and, 132-134 net reproductive rate and, 131-132 in population dynamics, 131-134 r_{max} and, 132, 133t seasonal changes and, 135 simplest, 131 survivorship curve in, 132, 132f yeast anaerobic cultivation illustration of. 141-142

Н

Handbooks of environmental chemical properties, ERA, 243 Herbivores population dynamics illustration background of, 142–143 birth considerations in, 145 condition index and, 144–145 EAU and, 144 food preferences and, 144–145, 144*t* formulation of problem in, 143*f*, 144 Kudu *vs.* number of years plotted in, 147*f* Herbivores population dynamics illustration (*Continued*) number of species classes needed in, 144 palatable browse vs. number of years plotted in, 146, 147*f* of population dynamics models, 142 - 146rain and, 143*f*, 146 subclasses used in, 145 vegetation considerations in, 145 Herbivorous animals, energy conservation and, 87-88 Hierarchy theory, 9 Holism, 7–11 Holistic models, 44t, 45 Human evaluation processes models, 254, 254f Human perception processes models, 254, 254f Hybrid models, 116 Hydrodynamic models, 177-178 Hysteresis reaction, 335–336, 335f

I

IBE. See Individual-Based Ecology IBMs. See Individual-based models IMM. See Institutionalized or mediated modeling Individual-Based Ecology (IBE), 293 Individual-based models (IBMs) advantages/disadvantages, 114 applicability of, 116-118, 117t, 118t conclusions about, 308 designing, 293-294 emergent vs. imposed behaviors and, 294 - 295gene-individual-population example of, 304-307, 306f, 307f history of, 291-293 IBE and, 293 implementing, 297-299 ODD protocol and, 297-299, 298f, 299f

orientors and, 295-297 other models vs., 292-293 overview, 291 for parameterizing models, 301-302, 302*f* percentage application of, 98-99, 98t, 99f POM, 299-301, 300f population models vs., 292 questions answered by, 96, 97 spatial models and, 302-304, 303f Individualistic concept, 9 Infection models climate influence and, 155*f*, 156 conceptual diagram of, 155-156, 155f equations used in, 156, 157t population dynamics models and, 131 simulation results, 156, 158f Infon, 82 Input/output conceptual models, 105, 105fInstitutionalized or mediated modeling (IMM) advantages of, 122 first step in, 123 follow-up workshop recommendations, 125 "groupiness" increased by, 122–123 introduction of objectives stage of, 123 main idea of, 122 problem definition stage of, 123-124 process, 123-125 qualitative model building stage of, 124 quantitative model building stage of, 124 scenario testing stage of, 125 when to apply, 125-127 why we need, 25*f*, 121–122 Integral flow matrix, 173 Integral storage matrix, 173 Intensive measuring program dense observations and, 64

example results, 66t parameter estimation via, 62-64, 63fperturbation of set and, 64-65 Interaction between populations conservation principle and, 138 equation criticisms, 138, 139f, 140 four cases of competition equations and, 136, 136f, 136t in growth models, 135–141 herbivores population dynamics illustration of, 142-146 Lotka-Volterra equation and, 135, 138, 140 parasitism and, 139-140 predation equations, 136–137 prey-predator relationship and, 137–138, 137*f* stability concept and, 140-141 steady-state situation and, 136 symbiotic relationships and, 140 yeast anaerobic cultivation illustration of. 141-142 Intrinsic rate of natural increase, 132 Irreducible systems, 9, 81-82

Κ

Kudu, herbivores population dynamics illustration and, 147*f*

L

Lake Glumsø model advantages of, 194 changes in (1979-1983), 201–202 characteristic features of, 195 conceptual diagrams used in, 23f, 187fgrowth rate limiting factors in, 196 intensive measuring period applied to, 202 as management tool, 205–207 modified applications of, 205, 206tnitrogen release submodel and, 200 parameters regarding, 205

phosphorus exchange submodel and, 198–199, 198*f*, 199*f*, 200 prediction vs. observation and, 207, 208, 208t sediment submodel and, 198 success of, 194-195, 207 validation of, 202–204, 203t Lakes. See also Lake Glumsø model: Pesticide in lake illustration eutrophication of, 186 model complexity example about, 56–57, 56f, 57f Landsat program, US, 350–351, 350t Landscape models, 231 Law of energy conservation, 73, 73f. See also Conservation of energy Law of mass conservation, 84 Law of the minimum, 189 Linear models, 44t Logistic growth equation algal culture illustration, 134-135 first order rate expression and, 29 fishery models and, 150, 151f growth model assumptions, 132-134 time lag and, 135 Lotka-Volterra equation criticism of, 138, 140 four cases of competition equations regarding, 136, 136f, 136t interaction between populations and, 135, 138, 140 predation equations and, 136–137 Lotka-Volterra model, 13–14, 14f Lumped models, 44t, 46-47 Luxury uptake, 189

М

Management models, 3–4, 4*f*, 5*f*, 44–45, 44*t* Map analogy, 54 Mathematical equations, 21, 25*f*, 29–31 Mathematical models, 1–3 elements used in, 20–24 Mathematical models (Continued) hypotheses regarding, 6, 8f as management tool, 3-4 as research tool, 4–7 Matrix. See also Adjacency matrix algebra, 165–167 integral flow, 173 integral storage, 173 nondimensional direct flow, 172 partial turnover rate, 173 reachability, 168 Matrix models age distribution and, 147-149 blue whale age distribution illustration of, 149-150 overview of, 44t, 45 PMM and, 301, 302f Maximal rate of natural increase (r_{max}) , 132, 133t Mediated modeling. See Institutionalized or mediated modeling Medicinal products, ERA and, 244 Metapopulation models application of, 154–155 dispersal movements and, 153-154, 153f with disturbances, 154-155, 154flandscape fragmentation and, 154 population dynamics models and, 153-155 Michaelis-Menton expression, 30 Mississippi Delta, satellite remote sensing of, 352f Mixed flow reactor, 160, 160f Model types advantages/disadvantages of, 108-116 applicability of different, 116-118, 117*t*, 118*t* conceptual models, 100-107 introduction, 95-96 overview of, 96-100 percentage application of, 98–99, 98t, 99f questions prompting new, 96-97

questions solved by new, 97 Modeling elements. See Elements, modeling Modeling procedure. See Procedure, modeling Models. See also specific subject/model application of, state of art in, 16 - 18classification of, 44-50, 44t, 48t defined, 1 holism and, 7-11 hypothesis regarding, 6, 8f irreducible systems and, 9 as management tool, 3–4, 4f, 5f mathematical, 1–7 physical, 1-3 as research tool, 4–7, 8f selection of complexity of, 51-60 Monte Carlo simulation, 77 Mortality defined, 130 fishery models and, 151f MSS. See Multi-Spectral Scanner Multi-Spectral Scanner (MSS), 350-351, 351*t* Mutations, 82 Mutualism relations, in oyster reef example, 174

Ν

Natality, 130 Natural selection ecosystems and, 317, 319 exergy and, 324 Net efficiency, 85 Net reproductive rate, 131–132 Nitrogen cycle diagram, 23*f* eutrophication and, 187–188 release submodel, 200 Non-autonomous models, 44*t*, 47 Nonlinear models, 44*t* Normal environmental state, 296

ο

ODD protocol, 297-299, 298f, 299f Oligotrophy, 186 Order, 13 Organic compounds, 263t Organism models, 231 Organization, 13 Orientors, 295-297 Other systems, 297 Oyster reef example analysis of values in, 171, 173t formulation, 169–170 input throughflow/residence time values in, 171, 171*t* integral flow matrix in, 173 integral storage matrix and, 173 model diagram, 170-171, 170f mutualism relations in, 174 nondimensional direct flow matrix in, 172 numerical methods used in. 170–171 partial turnover rate matrix in, 173 results in, 171 system-wide properties calculated in, 171, 172b utility analysis in, 174

Ρ

Parameters, 21. *See also* Biological parameters allometric principles and, 77 biochemical mechanisms estimating, 72 Danish fjord case study, 275, 275*t* energy conservation law and, 73, 73*f* estimation, 60–78, 261–271 estimation methods summary, 78 estimation of ecotoxicological model, 261–271 fish growth example regarding, 65 found in literature, 60–61, 67–68, 71 general relationships and, 71, 73–74 IBMs and, 301–302, 302*f*

intensive measuring program and, 62-64, 63f Lake Glumsø model and, 205 model constraints and, 77-78 Monte Carlo simulation and, 77 organism size regarding, 73 sampling frequency and, 62 settling velocity, 68-69 size/concentration factor and, 75, 77f size/excretion rate and, 75, 76f size/generation time and, 73-74, 74f, 75f size/uptake rate and, 75, 76f subsurface wetland model, 214-215 Parasitism, 139-140 Patch-matrix model (PMM), 301, 302f Pattern-oriented modeling (POM), 299-301, 300f Pesticide in lake illustration of chemo-state model, 162 conditions laid out in, 162 problem solution, 162 Phosphorus concentration, 190, 191t cycle, 187, 187f exchange submodels, 198-199, 198f, 199*f*, 200 Physical models, 1-3 Phytoplankton biomanipulation and, 338, 338f eutrophication and, 188-189, 188t settling velocities, 68–69, 69t Picture conceptual models, 103, 104f Plant tissue, essential elements in, 187, 188*t* PMM. See Patch-matrix model POM. See Pattern-oriented modeling Population dynamics. See also Herbivores population dynamics illustration ecotoxicological models in, 250 Population dynamics models, 95–96. See also Interaction between populations

Population dynamics models (Continued) advantages/disadvantages, 109 algal culture illustration, 134–135 applicability of, 116–118, 117t, 118t basic concepts, 129-130 blue whale age distribution illustration of. 149-150 conservation of energy and, 138 development of, 13–14, 14f fishery models and, 150-153 growth models in, 131-134 herbivores population dynamics illustration of, 142-146 infection models and, 131 interaction between populations in, 135-141 matrix models and, 147-149 metapopulation models and, 153-155 mortality defined, 130 natality defined, 130 percentage application of, 98–99, 98t, 99f population defined, 130 yeast anaerobic cultivation illustration of, 141-142 Population models, 231. See also Metapopulation models; Population dynamics models IBMs vs., 292 Predation equations, 136–137 Prey-predator relationship, 137–138, 137*f* Procedure, modeling, 24–31, 25f adjacency matrix in, 25f, 26, 27t calibration step of, 23, 25f, 37-41 complexity and, 25-26, 27 conceptual diagram and, 23f, 25f, 27 data and, 26 definition of problem step in, 24, 25*f* mathematical equations step in, 25f, 29 - 31SDMs, 326-327, 326f sensitivity analysis step of, 25f, 34–37

STELLA and, 28, 28*f* steps in, 22–24 validation step of, 23, 41–43 verification step of, 22, 25*f*, 31–34

Q

Quantum theory complementarity theory and, 81 ecological modeling and, 78–82 environ and, 82 infon and, 82 irreducible systems and, 81–82 mutations and, 82 pluralistic view and, 81 practical number of observations and, 79–80 practical uncertainty relation and, 79 uncertainty principle, 79

R

r_{max}. *See* Maximal rate of natural increase Randomness, 13 Rate governed by diffusion, 30 Reachability matrix, 168 Reductionism, 6, 312–313 Reductionistic models, 44*t*, 45 Reliability, 296 Research models, 44–45, 44*t* Risk assessment. *See* Environmental risk assessment River models, 13–14, 14*f*

S

Satellite remote sensing GIS and, 353 image of Mississippi Delta, 352*f* image of Washington D.C, 352*f* Landsat program, US, 350–351, 350*t* MSS and, 350–351, 351*t* spatial models and, 350, 350*t* TM and, 350–351, 351*t* Savanna succession example application regarding, 362-363 conceptual diagram, 360f model process flow chart, 360-361, 361f overview of, 359-360 regions applied to, 360 of spatial model, 359-363 Scarce resources, 296 Science analysis/synthesis and, 10 development of, 8-11 irreducible systems and, 9 uncertainty and, 9 world equation and, 10 Scientific models, 44-45, 44t SDMs. See Structurally dynamic models Second order rate expression, 30 Security, 296 Sediment submodel, 198 Sensitivity analysis carrying out, 34–35 high- vs. low-leverage variables in, 35-36, 35t step, 25f, 34-37 submodels and, 36 Settling rates, Danish fjord case study, 275-276, 276t Settling velocity detritus ranges of, 70t phytoplankton concentration and, 68 - 69phytoplankton ranges of, 69t ways to determine, 69-71 Silver Spring example, 55–56, 55f Spatial autocorrelation, 349 Spatial models advantages/disadvantages, 113 agricultural landscape succession example, 363-364 applicability of, 116–118, 117*t*, 118*t* concepts/terms used with, 349-353 condition warranting use of, 348-349

early days of, 353-355, 355t fish habitat along river corridor example, 364-368 forest succession after blowdown example, 356-359 GIS and, 353 IBMs and, 302–304, 303f introduction, 347-353 patterns and, 349 percentage application of, 98–99, 98t, 99f question answered by, 96, 97 satellite remote sensing and, 350, 350t savanna succession example, 359–363 scale and, 349 spatial autocorrelation and, 349 state-of-the-art of, 356-368 Stability concept, 140–141 State variables, 20 global warming model, 223 subsurface wetland model, 209-210 Static models, 48-49 overview of, 44t, 46, 46f of toxic substance mass flows, 247, 248f Steady-state biogeochemical models advantages/disadvantages, 109 applicability of, 116–118, 117t, 118t chemo-state model to illustrate, 160-162 percentage application of, 98–99, 98t, 99f pesticide in lake illustration of, 162 Steady-state models, 95-96. See also Steady-state biogeochemical models applicability of, 116–118, 117*t*, 118*t* chemo-state model and, 160-162 Ecopath models and, 162-163 ENA and, 163-174 environmental problems and, 18, 18t pesticide in lake illustration of, 162 presumptions of, 159

STELLA agricultural products case study and, 278-284, 281f global warming model using, 220t river BOD/DO model using, 179-183 Streeter-Phelps model and, 179–183, 186t symbols used in, 27, 28f Stochastic models, 97 advantages/disadvantages, 115 applicability of, 116-118, 117t, 118t overview of, 44*t*, 45, 45*f* Streeter-Phelps model conceptual diagram, 182–183, 183f conservation of matter and, 84 development of, 13-14, 14f equation applied in, 183, 186t results of running, 184f, 185t using STELLA, 179-183 Structural complexity, 13 Structurally dynamic models (SDMs). See also Copper ecotoxicological model/SDM example; Exergy advantages/disadvantages, 110, 321 applicability of, 116–118, 117t, 118t β values for various organisms and, 329-330, 331t biomanipulation and, 335-342 for Darwin's finches, 333–334, 335f as distributed models, 49-50 ecoexergy and, 330, 332-333 ecotoxicological example of, 343-346 how to construct, 321-333 maximization of biomass and, 323 percentage application of, 98–99, 98t, 99f procedure development, 326-327, 326f question answered by, 96, 97 six orientors and, 322 twenty-one case studies regarding, 309-310 Submodels conceptual models and, 103, 103f

of ecotoxicological models, 253-255, 254f nitrogen release, 200 phosphorus exchange, 198–199, 198f, 199*f*, 200 sediment, 198 sensitivity analysis and, 36 Subsurface wetland model conceptual diagrams of, 209-210, 211f, 212f, 213f delay values and, 213-214 differential equations, 215–216 as dynamic biogeochemical model, 208-218 forcing functions in, 210–211, 217–218 origins of, 208-209 parameters, 214-215 process equations, 211–214, 211f, 212f, 213fremoval efficiencies and, 214 results, 217 scope of, 209 state variables in, 209-210 wetland design using, 218 Superorganism concept, 9 Survivorship curve, 132, 132f Symbiotic relationships, 140 Synthesis, 6, 10

Т

Thematic Mapper (TM), 350–351, 351*t* TM. *See* Thematic Mapper Toxic substance in one trophic level dynamic models, 247, 249*f*, 250*f* Toxic substance mass flows static models, 247, 248*f*

U

Uncertainty ecology and, 9 ERA and, 237, 238 quantum theory and, 79 validation and, 42–43 Universal constants, 22 Utility analysis, 174

V

Validation criteria formulation, 42 Danish fjord case study, 278, 278t data used for, 41-42 ideal model regarding, 43 Lake Glumsø model, 202-204, 203t requirement of, 41-42 revision questions for, 43 step, 23, 41-43 uncertainty and, 42-43 Variables. See also External variables; State variables biomanipulation and, 336-337 high- vs. low-leverage, 35-36, 35t Variety, 296 Verification defined. 31 model reaction and, 32 model stability and, 32 multiple scenario analysis for, 34

step, 22, 25*f*, 31–34 unit checking and, 33

w

WAMOD. See Water and Substance Simulation Model
Washington D.C., satellite remote sensing of, 352*f*Water and Substance Simulation Model (WAMOD), 363–364
Weighted digraph adjacency matrix, 165–167, 166*f*White-box conceptual models, 104–105

Υ

Yeast anaerobic cultivation illustration conceptual diagram of, 141–142, 141*f* observed/calculated values used in, 141–142, 142*t* of population interaction, 141–142

Ζ

Zooplankton growth rate, 338, 339f