Introduction to Probability and Statistics for Ecosystem Managers

Simulation and Resampling

TIMOTHY C. HAAS

STATISTICS IN PRACTICE

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Dedicated to the next generation of ecosystem managers

Preface

This textbook will be useful for readers who are either in training for or are in positions having to do with the management of environmental systems and/or wildlife populations wherein one of the decreed management goals is the protection of some part of the ecosystem, for example, wildlife that is at threat from anthropogenic forces. Examples of such positions include being a member of a forestry, fish and game, national parks, or environmental protection agency – or a wildlife advocacy organization such as the African Wildlife Foundation or the World Wildlife Fund. The prerequisites needed for grasping the ideas presented in this textbook are some familiarity with natural resources and a precalculus course.

This textbook has the following pedagogical features:

1. Explanations of probabilistic and statistical concepts are intuitive. Probability is explained through simulations rather than mathematical derivations and statistics is presented through computer-based resampling methods rather than methods based on large sample approximations.

2. Almost all examples show how probability and statistics can be applied to ecosystem management challenges.

3. Exercises are plentiful and appear just after the associated content – making the textbook suitable for a lecture course in a natural resource and/or wildlife management department or as the main text in a program of self-study.

4. Detailed instructions for using the statistical program R are provided along with many complete R programs that generate the output of the textbook's many examples.

5. Enough mathematical programming details are given so that the reader can estimate statistical model parameters with minimum distance methods.

6. An introduction to Geographic Information Systems (GIS) appears that includes examples from quantum GIS (QGIS), a free GIS software package.

7. Spatial and spatio-temporal statistics are introduced and illustrated with examples from ecosystem management that make use of R's spatial statistics capabilities and JAVA® programs written by the author. The language of

vectors and matrices is introduced in enough detail to allow the reader to grasp spatial and spatio-temporal models that are expressed in this language.

8. A capstone case study is presented of how one might manage the rhino meta-population kept on private land in South Africa. This case study puts to use the textbook's material on probability, statistics, ecosystem stakeholder models, and individual-based models of wildlife populations.

9. An accompanying website (`www4.uwm.edu/people/haas/introtext`) contains all R and JAVA codes used in this textbook. It also contains all datasets used in the textbook's examples, a web-based ecosystem management tool (EMT) developed by the author in his previous book, *Improving Natural Resource Management: Ecological and Political Models* (Wiley-Blackwell), and answers to all of the textbook's exercises.

Several items are original to this textbook:

1. A new function to transform non-normal data to near-normality.

2. R codes to compute a spatial median filter, spatial cumulants, and spatial neural networks; along with codes that implement a probabilistic model of the spatial diffusion of an invasive species and an algorithm for constrained random search.

3. A learning algorithm that models how ecosystem stakeholders learn from experience as they reach ecosystem-affecting decisions.

4. Complete coverage of how to build and evaluate an individual-based model of a wildlife population that is to be managed.

5. An Online Intelligent Tutoring System (OITS) tied to the text that uses a learned model of a reader to deliver explanations that are focused on just those topics the reader is having difficulty with. This tutoring system can be found at the above-mentioned website.

Acknowledgments

The author appreciates comments made on an early version of Chapter 10 by the participants of the 7th International Wildlife Ranching Symposium, Kimberley, South Africa, October 10–13, 2011.

List of abbreviations

m-NN	*m*-nearest-neighbor
AER	actual error rate
ANOVA	analysis of variance
BLUP	best linear unbiased predictor
CDF	cumulative distribution function
CPT	conditional probability table
CRS	coordinate reference system
CSR	complete spatial randomness
d.o.f.	degrees of freedom
DAG	directed acyclic graph
DL	description length
DM-group	decision-making group
EMAT,	ecosystem management actions taxonomy
EMT	ecosystem management tool
EPA	Environment Protection Agency
ESA/NASA	European Space Agency/National Aeronautics and Space Administration
ESTDM	event-based spatio-temporal data model
FBLGDMD	feedback-based learning for group decision-making diagrams
FFT	fast Fourier transform
GIS	geographic information system
GLS	generalized least squares
GUI	graphical user interface
i.i.d.	independently and identically distributed
IBM	individual-based model
ICBEMP	Interior Columbia Basin Ecosystem Management Project
INTERCALV	intercalving interval
IQR	inter-quartile range
IUCN	International Union for Conservation of Nature
KECs	Key environmental correlates
LE	life expectancy
LOMAP	Local Model And Predictor
MA	maturation age
MCSTK	moving cylinder spatio-temporal kriging

MDLEP	minimum description length-evolutionary programming
MDL	minimum description length
MHD	minimum Hellinger distance
MLE	maximum likelihood estimate
MPEMP	most practical ecosystem management plan
MSHD	minimum simulated Hellinger distance
MSL	maximum simulated likelihood
MWRCK	moving window residual cokriging
MWRRK	moving window, regression, residual kriging
NEMBA	National Environmental Management: Biodiversity Act
NEMPAA	National Environmental Management: Protected Areas Act
NGO	nongovernmental organization
NP-hard	non-polynomial time hard
OC	operating characteristic
OGA	overall goal attainment
OITS	online intelligent tutoring system
OK	ordinary kriging
OLS	ordinary least squares
PAC	protected area complex
PA	protected area
PDF	probability density function
PDPF	probability density–probability function
PMF	probability mass function
POM	pattern-oriented modeling
Q-Q	Quantile–Quantile
QGIS	quantum GIS
SPPP	spatial Poisson point process
SSE	error sum of squares
SSR	regression sum of squares
SST	total sum of squares
TOPS	Threatened and Protected Species
USDA	US Department of Agriculture
WKT	well-known text

Contents