Population Modeling and Management
for Fisheries Science and Conservation Biology

MBF 614 -- Fall 2010

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Hours: T-Th 0900-1015, RSMAS S/A-120
with computer-intensive laboratory

Pre-requisites: Differential & Integral Calculus, Multivariable Calculus, Linear Algebra,
Biometrics (MBF 508), Marine Population Dynamics (MBF613) or
permission of instructor.

Useful Courses: Advanced Biometrics (MBF 615), Computer Simulation Systems (MAS
547), Ordinary Differential Equations, Partial Differential Equations,

Brief Course Description.- A synthesis of mathematical and computer-intensive models to
assess and manage population (i.e., fish, shellfish, marine mammals and sea turtles) responses
to exploitation and environmental changes. Rigorous quantitative development of modeling
concepts and stock assessment techniques including: stock surplus production; structured
analytical yields (yield-per-recruit and age-size structured assessments); stock and recruitment;
and, dynamic structured assessment methods. Equilibrium and non-equilibrium approaches
will be evaluated with respect to data assimilation and parameter estimation. Simulation
modeling tools will highlight concepts in decision theory, adaptive control, and risk assessment.
Specific population modeling and resource allocation case studies from regional, federal and
international fishery management institutions. Lecture and computer-based laboratory using R
Project for Statistical Computing, Excel, FORTRAN (or C++), AD Model Builder and other
software packages.

Grades.- Grades are based on: 20% Mid-term; 20% Final; 55% computer-intensive laboratories;
and, 5% for class participation.
Key Reference Books on Library Reserve


Population Modeling and Management
Jerald S. Ault
University of Miami RSMAS

Chapter 1.0 Population Modeling and Resource Management
1.1 Why manage fish stocks?
1.2 Aims of modeling and management.
1.3 Resource management in the United States.
1.4 Conceptual framework, goals and objectives of stock assessment.
1.5 Characteristics of stocks under exploitation.
1.6 General approaches to fishery management.
  1.6.1 Comparison of Surplus production and Analytical yield theory.
  1.6.2 Resource persistence, economic measures and optimal harvests.
1.7 Providing scientific advice.
1.8 Fisheries management, benchmarks and risk assessment.
  1.8.1 Population-dynamic and environmental variability.
1.9 References

Chapter 2.0 Stock Production Models
2.1 Basic concepts of surplus production.
2.2 Model characteristics.
2.3 Assumptions.
2.4 Historical developments in density-dependent modeling.
  2.4.1 Derivation of logistic population growth.
  2.4.2 Analytical properties of the logistic model.
2.5 Relationship between surplus yield (production) and dN/dt.
2.6 Types of models for stock production and stock biomass dynamics.
  2.6.1 Logistic model of Graham-Schaefer.
  2.6.2 Exponential model of Gulland-Fox.
  2.6.3 Generalized model of Pella & Tomlinson.
2.7 Analytical determination of model benchmarks.
  2.7.1 Maximum population size ($B_0$).
  2.7.2 Optimum fishing effort ($F_{opt}$) and population size ($B$).
  2.7.3 Maximum sustainable yield (MSY).
2.8 Performing a production model analysis.
  2.8.1 Data requirements for reliable parameter estimation.
  2.8.2 Common violations of model assumptions.
2.9 Computer algorithms for production model parameter estimation.
  2.9.1 Model developments and implementation.
  2.9.2 Generalized stock production (GENPROD model).
  2.9.3 Equilibrium approximation (PRODFIT model).
  2.9.4 Models incorporating environmental variability.
2.10 Non-equilibrium stock production models.
  2.10.1 Gulland’s equilibrium approximation based on fishing effort.
2.10.2 Catchability \( q \) known and unknown.
2.10.3 Linear and exponential models.
2.11 Density-dependent catchability model.
2.12 Extensions to non-equilibrium surplus production models.
2.13 A stock production model incorporating covariates (ASPIC model).
  2.13.1 “Tuning” to a biomass index.
  2.13.2 Partitioning fishing mortality by gear, time or area.
  2.13.3 Making projections of stock biomass.
2.14 Uncertainty of parameter estimates.
  2.14.1 Likelihood profiles.
  2.14.2 Bootstrap confidence intervals and estimates of bias.
2.15 Multispecies (predator-prey) community production models.
2.16 References.

Chapter 3.0 Structured (Age-Length) Analytical Yield Models
3.1 Background and overview.
3.2 Analytical yield and dynamic pool models.
3.3 Conceptual framework for analytical yield versus VPA models.
3.4 Principal assumptions of the deterministic model.
3.5 Exponential mortality and stock survivorship.
3.6 Average population size and fishery yield (catch).
3.7 Assessment with analytical yield models
  3.7.1 Basic modeling concepts and strategies.
  3.7.2 Management objectives.
3.8 Formal derivation of the yield-per-recruit (YPR) model.
  3.8.1 Yield in numbers (\( Y_N \)).
  3.8.2 Yield in weight (\( Y_W \)).
3.9 Isometric and allometric growth forms.
3.10 Discrete step-wise growth (e.g., crustaceans).
3.11 Biological community models.
  3.11.1 Yield-per-prey recruit using exponential growth.
3.12 Piecewise integration of equilibrium yield curves.
  3.12.1 Arithmetic model.
3.13 Ricker’s modification of the arithmetic model.
  3.13.1 Exponential model.
3.14 No growth model (observations only) of Thompson and Bell.
3.15 Effects of changes in gear selection on population size and yields.
  3.15.1 Gulland’s selection model.
3.16 Multiple gear fisheries (heterogeneous fishing).
3.17 Transitional behavior of YPR models.
3.18 YPR analysis and advice.
  3.18.1 Model properties and interpretation.
  3.18.2 Management benchmark analysis.
3.19 Biological reference points and fishery sustainability.
3.19.1 Fishery yields and YPR.
3.19.2 Spawning potential ratio (SPR).
3.19.3 Limit control rules and the precautionary approach.

3.20 Computer algorithms.
3.20.1 YPR point analysis and surfaces (BHYIELD).
3.20.2 Probabilistic yield-per-recruit (YPER).

3.21 References.

Chapter 4.0 Stock and Recruitment Models
4.1 Purpose, principals, assumptions and data requirements.
4.2 Family of decreasing nonlinear survivorship functions.
   4.2.1 Beverton-Holt, Ricker, Schaefer, power function, and depensation.
4.3 Types of stock-recruitment (S-R) relationships.
4.4 Beverton-Holt (competition) S-R theory.
   4.4.1 First principle derivation.
4.5 Ricker (density-dependence) S-R theory.
   4.5.1 First principle derivation.
   4.5.2 Stability conditions.
   4.5.3 Relationship to logistic stock production model.
4.6 Attributes of the model(s) and MSY exploitation.
4.7 Getz S-R model.
4.8 Deriso’s generalized S-R model.
4.9 S-R model fitting using advanced statistical methods.
   4.9.1 Impacts of measurement errors.
4.10 Adaptive analyses.
4.11 Environmental influences and biological-physical coupling.
4.12 Marine recruitment processes and hypotheses.
   4.12.1 Events intervening between stock spawning and recruitment.
4.13 Cushing-Shepherd model.
4.14 Response to exploitation in “saturation” spawners.
4.15 Recruitment in age-structured models.
   4.15.1 Strategies for including S-R relationships.
   4.15.2 Steepness.
4.16 References.

Chapter 5.0 Analytical Modeling and Parameter Estimation
5.1 Steps in model building and validation.
5.2 Nonlinear model estimation.
   5.2.1 Parameter estimation techniques.
   5.2.2 Graphical searches for optimal parameter values.
   5.2.3 Parameter correlation and confounding effects.
   5.2.4 Automated directed and heuristic searches.
5.3 Likelihood
   5.3.1 Maximum likelihood criterion of fit.
5.3.2 Probability density and likelihood definition.
5.3.3 Maximum likelihood criterion.
5.3.4 Likelihoods with normal probability distribution.
5.3.5 Fitting a curve with normal likelihoods.
5.3.6 Likelihoods with lognormal probability distribution.
5.3.7 Fitting a curve with lognormal likelihoods.
5.3.8 Likelihoods with the binomial distribution.
5.3.9 Percentile confidence intervals using likelihoods.
5.3.10 Likelihood profile confidence intervals.
5.3.11 Likelihoods from poisson and gamma distributions.
5.3.12 Likelihoods from the multinomial distribution.

5.4 Bayesian Analyses
5.4.1 Introduction to Bayes’ theorem.
5.4.2 Prior probabilities.
5.4.3 Informative and non-informative priors.

5.5 Computer intensive methods
5.5.1 Resampling.
5.5.2 Randomization tests.
5.5.3 Jackknife methods.
5.5.4 Bootstrap methods.
5.5.5 Monte Carlo methods.

5.6 Relationship between methods.

5.7 References.

Chapter 6.0 Dynamic Structured Assessments
6.1 Systems analysis and simulation models.
6.1 Fishery population simulation and assessment models.
6.1.1 Generalized exploited population simulation (GXPOPS).
6.1.2 Discrete stochastic population simulation (DSPOPS).
6.1.3 Reef-fish experimental exploitation fishery simulator (REEFS).

6.2 Statistical catch-at-age and integrated cohort analyses models.
6.2.1 Fitting catch-at-age data.
6.2.2 Adding a stock-recruitment relationship.
6.2.3 Auxiliary data and different criteria of fit.
6.2.4 Relative weight to different contributions.
6.2.5 Characterization of uncertainty.
6.2.6 Model projections and risk assessment.

6.3 Stock Synthesis models.
6.3.1 Age- and size structured models.
6.3.2 Tuning with auxiliary covariates.

6.4 Stock reduction analyses (Kimura).
6.5 Decision making under uncertainty.
6.6 Population viability analysis.
6.7 Risk-based fishery stock assessment and management.
6.8 Multispecies models.
6.9 Spatial- and age-structured models.
6.10 Ecosystem management and fishery systems science.
6.11 References.

Chapter 7.0 Case Studies
7.1 International Commission for Conservation of Atlantic Tunas (ICCAT)
7.2 Regional Fishery Management Councils (i.e., SAFMC and GMFMC)
7.3 Florida Fish & Wildlife Conservation Commission

2010 Computer Laboratories

(1) Computer Programming & Model-Building

(2) Production Models 1: PRODFIT and Maximum Sustained Yield

(3) Maximum Economic Yields from Fishery Production

(4) Production Models 2: ASPIC and Biomass Dynamic (Non-equilibrium) Modeling

(5) Analytical Yield Model Analysis and Advice (e.g, BHYIELD and YPR)

(6) Generalized Yield-per-Recruit Model Analysis & Advice (e.g., YPER)

(7) Stock-Recruitment: Stability dynamics, steepness estimation & resulting productivity

(8) Multispecies YPR/VPA – Objective functions & parameter estimation

(9) Transitional Fishery Dynamics (e.g., DSPOPS) – Risk analysis

(10) Final Integrated Laboratory: Tropical Tuna or Reef Fish Assessment (e.g., XSA, REEFS)