Dynamic modeling

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In preparation for the Dynamic modeling section of my qualifying exam, Loo suggested I review notes from his course, his textbook, and other relevant papers.

0.1 Major points

- definitions of state and modeling philosophies
- need structure to build tactical models
- including different types of structure in models
- measuring replacement instead of local settlers
- cohort resonance
- MSY, stock-recruitment curves

0.2 Week I: Philosophical approach to population modeling

- Important science questions: what allows persistence, causes population cycles, the role of random environment, patchy habitats and individual movement
- Practical questions: how do you prevent extinction? What is a safe pop level? What are the effects of harvesting or other mortality? Role of habitat structure and populations?

0.2.1 Modeling approaches

- Levins [1966]
  - 3 characteristics: realism, generality, and precision
  - argued you could have only 2 of 3 of these
- Precision - closeness of measurements to one another
- Accuracy - how close measured value is to actual value
- Holling 1968 added the need for Holism
- May 1973 argued that most models were neither realistic, general, or precise
  - models range from simple to complex
- Strategic models are usually simpler and may yield a number of very general results
- Tactical models are often more complex and are used to attack a specific problem, such as those in management.
- models can be used for scientific, practical, or pedagogical purposes
- deductive (e.g. if a then b, try to reject hypotheses) vs inductive logic (if many observations of Z true, then Z is probably always true)

0.2.2 Other modeling concepts

- state - the information needed to predict the dynamics of the system. In a population, a system could consist of current population size, birth and death rates, and age or size distributions.

- i-state (information needed to predict individual state at next time) vs p-state (information needed to predict state of population at next time)
- IBMs important in situations where behavior, and possibility emergent properties, are important
- Uncertainty arises from process error, observational error, and structural error
- different scale of ecological organization

0.3 Week II: Simple population models

- Fibonacci and the rabbit problem
- assume all individuals the same in simple models
- exponential growth in continuous time and Malthus
- geometric growth
- simple linear models useful when density is low
- logistic growth is simple non linear model Ricker and Beverton-Holt versions in discrete time
- stability in ecology
- cobwebbing and stability

0.4 Week III: Linear, age-structured models

- The continuity equation (von Foerster 1959): PDE of age and time - solve by method of characteristics with boundary condition the birth process
- The renewal equation (Lotka 1907)
- The Leslie matrix - discrete time and discrete age
- eigenvalues, sensitivity, and elasticity
- replacement - important as it tells you about population growth and decay
- convergence to stable age distribution and transient responses

0.5 Week IV: Size-structured models

- stand (distribution of all cohorts at one time) or cohort (single cohort over time) distributions
- shows example of how larval duration, survival, and distance depends on temperature
- Integral projection model (Easterling et al. 2000) - discrete time but continuous size structure

0.6 Week V: Stage-structured models

- **Loo argues against stage-structured models as stage does not fulfill definition of state. You cannot predict where an indidivual will be in a stage structured model**

0.7 Week VI: Age-structured models with density-dependent recruitment

- what causes cycles in Dungeness crab? Environmental forcing, predator-prey dynamics, or density-dependent recruitment?
- can get cycles from cannibalism (as seen in Tribolium)
- multiple equilbria for populations, look at how many fish populations never rebounded
- cycles of period T, where T is generation time happens because of cohort resonance
- cohort resonance - a population's sensitivity to generational- or low-frequency cycles in environmental variables

0.8 Week VII: Linear age-structured models in a random environment

- three types of variability: environmental (random variability in reproduction or survival that affects all individuals similarly), demographic (different outcomes b/c of finiteness of individuals), and catastrophic (large single change in state)
- probability of extinction or quasi-extinction
- geometric growth rate
- role of correlated variability
- species at risk
  - estimate current risk of extinction
  - formulate delisting criteria
  - recovery planning
- Fieberg and Ellner (2000) - reliable predictions of extinction prob. are possible only over prediction period 10-20% of time series length
- Decision analysis - evaluation of all actions under various parameter values for various possible management actions

Week VIII: Models of populations distributed over space

- could use 1d renewal equation for continuous space or matrix model for discrete space (need dispersal matrix)
- Levins simple population model $\frac{dp}{dt} = mp(1-p) - ep$
- Hastings and Botsford [2006] - deterministic, n-patch model with movement between patches
  - persistence depends on all sources that contribute to persistence, not simple sources and sinks
  - all patches could have negative growth rates but dispersal allows metapopulation persistence
  - **people often measure fraction of settlers who originated locally, this is not a good measure**
  - **you need to measure replacement which depends on local dynamics and dispersal through loops**
- Botsford et al. 2001 - more realistic 1d coastline model with larval dispersal and scorched earth assumption
  - looked at sustainability of stock which depends on reserve size and spacing between reserves
  - want self persistence if one single large reserve or 35% of coastline in reserve networks
  - movement of larval stage is highly variable and hard to measure

Week IX: Models in conservation biology 9.1. Decision-making and model uses in population recovery 9.2. Early models: birth-death, MacArthur and Wilson (1967), Goodman (1987) 9.3. Ludwig's point: highly uncertain results 9.4. Following papers by Ellner's group 9.5 Spatial aspects – Population Diversity

0.9 Week X: Models in fishery management

- about 20% of stocks over fished, only 3% of stocks in recovering category
- logistic fishery model was used early on to project biomass $\frac{dB}{dt} = kB(1 - \frac{B}{B_\infty}) - Y$
- here $Y = qEB$, where q is catch ability and E is effort
- maximum sustainable yield, MSY $= B_\infty/2$
- many problems: 1 variable, few parameters, assuming CPUE is proportional to abundance, assuming population is at equilibrium
- in the 1990s the FAO went to more precautionary approach
- replacement is better measure to use when deciding how much to fish
- discusses reserves off of California
  - need to look at transient responses

- fishing management outside of reserves in important

0.10 Other important general fisheries papers

- Beverton and Holt (1957)
- Branch et al. 2010 - response to “fishing down food web paper"
  - found that the mean tropic level of fish was not decreasing over time
  - further they pointed out importance of certain stocks or certain spatial areas in altering this trend
  - point our that mean trophic level does not correlate well with actual abundance
- Worm et al. 2009 - assessment of fisheries around the world
  - examine large number of stocks using catch data and scientific surveys
  - point to a number of potential paths forward and what has worked in a select few locations (e.g. Alaska)

References

Louis W. Botsford, Alan Hastings, and William T. White. *Chapter Three: Linear, Age-Structured Models*.

Alan Hastings and Louis W Botsford. Persistence of spatial populations depends on returning home. *Proceedings of the National Academy of Sciences*, 103(15):6067–6072, 2006. ISSN 0027-8424. doi: 10.1073/pnas.0506651103. URL http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1458697{&}tool=pmcentrez{&}rendertype=abstract.

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