Fish Conservation and Management

CONS 486

Traditional management use of life history information

Ross Chapter 3
Traditional management use of life history information

• Escapement models
• Surplus production models
Major theme: Linking science to conservation & management

- Physiology
- Behaviour
- Population ecology
- Ecosystem ecology
- Habitat data (limnology, oceanography)
- Life history

- Managing fisheries & habitats
- Protecting populations & habitats
- Restoring populations & habitats
- Fisheries exploitation data
- Applied life history data
- Human dimensions: socio-economic data
- Harvest regulations
- Managing fisheries & habitats

Basic science
Applied science
Conservation
Management

Life history

Applied science

Conservation

Management

Basic science
Definitions

• Population recruitment: production of offspring that survive to sexual maturity and reproduce

• Fisheries recruitment: production of offspring that reach a harvestable body size

• Stock size: the number of individuals (or biomass) that support a fishery

• Spawner stock: biomass of reproducing adults aka spawners

• Stock-recruitment models: predict recruitment based on number (or biomass) of adult fish
How are stock-recruitment models used?

• ‘Models’ are mathematical equations
  – Need to know stock size
  – Population growth rate
  – Population carrying capacity
  – And must assume DENSITY DEPENDENT population growth

• Then...you can forecast future abundance!
  – i.e., predict # of recruits in next generation

• Use results to inform management decisions
  • E.g., fisheries opening/closures, quotas
Assumes high recruitment at low spawner abundance

**BUT** density dependence limits mature progeny when spawner stock size is high

- Eg food limitation
- At carrying capacity there would be no change in mature progeny numbers despite increasing spawners
The model predicts that recruitment will increase with stock size and peak at *mid-level* abundance *THEN* decline at high abundances due to density dependent factors (more than just food limitation).

Factors include:
- Food limitation
- Cannibalism
- Disease
- Damage/competition for spawning sites/redds

Carrying capacity

1:1 line
Plaice... not known for their looks
Plaice data fit with Beverton-Holt model

- Carrying capacity ~15-20 spawning biomass
- Spawning biomass >40 do not increase recruits and could be harvested as surplus
- Note each data point is from a different year

Fig 3.11 from Ross
Chum salmon data fit with Ricker model

- Carrying capacity ~1000 spawning biomass

- Spawning biomass >1200 depress recruits and could be harvested as surplus

- Note each data point is from a different year

Fig 3.11 from Ross
Limitation 1: Poor fit to some data points!

• Models account for **density dependent** processes
  – Residual variation results from **independent** processes

• So residuals reflect **density independent** factors!

• Large variance away from model predictions reflect something unique that year
  – E.g., a stochastic climate event

• So residuals help managers understand **other factors** that control recruitment
Plaice data: Density independent effects

- Large density independent effect
- Small density independent effect

*Note each data point is from a different year*
Haddock (*Melanogrammus aeglefinus*)
Limitation 2: Ricker model for haddock

Fig 3.9 from Ross.
Limitation 2: Ricker model for haddock

• Recent recruitment of haddock is well below historically normal
• Low spawning biomass and low recruitment
  – Result of overfishing
  – Recruitment driven well below carrying capacity
• Heavily fished stocks never reach carrying capacity in a given year
Stock-recruit models: Applications

• Problems associated with density independent factors and fisheries pressure
  – Ricker and BH tend to work best in oceanic fisheries that exhibit strong density dependence
    • And resilience to density independence factors

• Work well in Pacific Salmon mgmt because fisheries occur primarily on mature progeny
  – E.g., fisheries exclusively target 4-5 y.o. sockeye during return migrations
  – And it is possible to get reliable stock estimates on the spawning grounds
Surplus production models
Surplus Production Models: Background

A population in a new environment will grow following logistic growth – which is regulated by density dependent processes.

- **Rate of population growth** in an unexploited population is greatest at **mid-level abundance**.
- Mid-level population abundance represents the **highest rate of replacement per year**.
- **Surplus production models** assume that fish can produce more offspring than necessary to sustain the population.
- In theory, fisheries can take advantage of this!

- **Maximum Sustainable Yield (MSY)** of fisheries would therefore theoretically occur at **mid-level abundance of a population**.
- **MSY**: Population can be harvested sustainably at mid-level abundance because the spawning biomass is most likely to replace itself with recruits by the following year.

Fig 3.8 from Ross
- **Biomass production VS stock size:** provides parabolic curve
- Biomass production is greatest at $\frac{1}{2}$ the biomass that habitat supports
Surplus production curve

• This framework can be taken one step further if:
  1. You know stock size
  2. The probability of capture (fishing harvest rate) is constant over all stock sizes
     – If so, fishing effort is a surrogate variable for stock size
     • Higher effort means higher capture

• **Surplus production curves** show theoretical proportion of a stock that can be removed without causing a change in stock abundance
• Yield to the fishery VS stock size
• Yield is greatest (MSY) at $\frac{1}{2}$ the biomass that habitat supports: so fisheries should be able to maintain population at this level and receive max benefits

Maximum Sustainable Yield (MSY)
Limitations: Surplus production models

• Hilborn and Walters 1992:
  1. Error/uncertainty in stock size data
     • No accounting for individual size/reproductive status
  2. Capture probability is rarely constant
     • Fish spatially aggregate differently at different stock sizes
  3. Humans now find and harvest individuals or aggregations very efficiently

• **MSY** still used to manage many fisheries
  – But often considered ‘upper bounds’ of exploitation
  – Philosophy shifted away from *maximizing* catch!
Fisheries OVERexploitation