Fishery Stock Assessment

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Russell's Equation

\[ B_{t+1} - B_t = (R + G) - (D + Y) \]

- Biomass at \( t+1 \)
- Biomass at \( t \)
- Recruitment
- Growth
- Natural Mortality
- Yield
Monitoring of Fish Population

- Catch trends sometimes disagree to the fish population trends because fishery is not scientific survey but economic activity.
- Fish population is not obvious as the number of trees on a mountain, because fish under water can not be seen directly.
- Scientific assessment is important to know the fish population
Population Estimation Methods
Population Estimation Method

- **Direct Method**
  - Sighting Counting (Line transect Method)
  - Acoustic Method (Echo sounder)
  - Scientific Trawl Survey
  - Mark & Recapture Method

- **Indirect Method**
  - Depletion Method (DeLury Method)
  - Virtual Population Analysis (VPA)
Examples of direct methods
Line Transect Method

- Data: distance from vessel, angle from course, survey line length
- Output: search width, population density

\[ N = n \times \frac{A}{2W\ell} \]
Population Estimation of Mink Whale in Antarctic Sea

*Population: over 760 thousand*

*1991 IWC*

*Balaenoptera acutorostrata*
Acoustic Method by using echo sounder
Target strength

Length (cm)

Target Strength (dB/kg)
Direct methods

- Scientific and precise
- Cruse by the research vessel is must
- Very expensive to get data
- Can not estimate population before starting scientific cruses.
Examples of indirect methods
Catch per unit effort (CPUE)

Notation:  
- \( C \): Catch in Number  
- \( N \): Population in Number  
- \( E \): Fishing Effort  
- \( q \): Vulnerability  

\[ C \propto N \quad (\text{Effort}=\text{const.}) \]
\[ C \propto E \quad (\text{Population}=\text{cont.}) \]

\[ C = q N E \]
\[ \frac{C}{E} = q N \]

**CPUE** \( \propto N \)
DeLury Method

- **Data:** Catch, Fishing Effort
- **Estimators:** Population, Vulnerability
- **Assumption:** CPUE $\propto$ Population

![Graph showing CPUE vs. Cumulative Catch]
Abalone Diving Fishery in Goto islands

![Graph showing CPUE (kg/d) vs. Cumulative Catch (t)]

- ■ "Black" Abalone
- + "Red" Abalone
Virtual Population Analysis
VPA (Corhort Analysis)

- An population estimation method from catch at age
  - by stock by year class
  - no need to use fishing information

- Internationally most standard population estimation method
  - in International committees
  - for Total Allowable catch

- Theoretical development going on
  - ADAPT
  - SVPA
  - Length / weight based VPA
Age based model in population estimation papers

Megrey (1989)
Standard VPA
Virtual Population Analysis (VPA)

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Population at the beginning of age 2

Population at the beginning of age 3

Population at the beginning of age 4

Population at the beginning of age 5

Death

Death

Death
Basic equations

\[ N_{a,y} = N_{a+1,y+1} e^M + C_{a,y} e^{M/2} \]

\[ F_{a,y} = \ln \frac{N_{a,y}}{N_{a+1,y+1}} - M \]

\[ N_{A,Y} = \frac{C_{A,Y}}{1-e^{-F_A}} e^{M/2} \]

\[ F_{A,y} = F_{A-1,y} \]

**N**: Population at age

**F**: Fishing Mortality

**C**: Catch at age

**M**: Natural Mortality
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For Recent Year

- If fishery is stable, selectivity, will be stable.
- In this situation, $F$ would be assumed as recent average value

$$F_{a-1, y} = \frac{1}{3}(F_{a-1, y-1} + F_{a-1, y-2} + F_{a-1, y-3})$$
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An Example of Application
## TAC controlled stocks in Japan

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Walleye Pollock Pacific Stock

- Habitat: Pacific coast of Northern Japan
- Spawning Ground: Funka Bay
- Migration: younger age in Tohoku area, matured fish migrate to Doto area and spawning fish in Funakabay area
- Fishery: Trawl net (younger), Gillnet (older)
- Age at mature: 3 years
SSB - Recruitment Relationship

Recruitment (Age 0, 100 million)

Spawning Stock Biomass (10,000 t)
VPA

- ADAPT VPA
- Tuned by Acoustic Survey and CPUE of trawl fishery

\[
SSQ = \sum_y \left( \ln(I_{1,y}) - \ln(qN_{1,y}) \right)^2 / 7 \\
+ \sum_y \left( \ln(X_{a,y}) - \ln(bN_{a,y}) \right)^2 / 5 / 14
\]
Difference between Tuned or not

Without Tuning

Tuned
Limitation and Potentials
Limitations of VPA

- Low reliability from little information
- Can not apply automatically
- Natural mortality and catch at age are must
- Difficult to use short lived sp.
- Use only for separate stock
Potentials of VPA

- Most reliable now
- Utilize maximum informations
- Flexible (eq. age dependence of M)
- Possibility for estimating M by using separable VPA
- Flexibly incorporate other informations (Integrated VPA)
- Know limitation and Use widely
Perspective for the Future
Stock Assessment
Perspective for the Future Stock Assessment

- Direct method for estimating recent population and Indirect method for estimating productivity of the stock
- Combination of various data available to use more information to the population estimation
- Simulation study for examining the validation of the method
- Age-based model for the precise assessment and length- or weight-based model for quick assessment, especially for tropical fish