Fisheries Biology, Assessment & Management

Lecture 2 (part 1)

How Many Fish in the Sea ?

(The Science of Fish Stock Assessment)

Remembering ...

- Processes
  - "Birth", Growth, Maturation, Reproduction, Death (due to fishing and natural causes)
- Stock abundance
  - as numbers, or as biomass
  - by age and by year (yearclasses/cohorts)
- Yield : catches and death rate due to fishing
  - the effect of fishing effort : $F = q E$
- Recruitment : dependence on spawning stock

Questions asked by "managers"

- The effects of current exploitation rates ?
- Potential for improvement ?
  - Increased yields and/or biomass
    - now (short-term) or future (long-term)
- Possibility of "Optimal" Exploitation ?
- Sustainability ?
- Desirable Conservation Measures ?
  - direct (controls on catch or effort)
  - "technical" (mesh sizes, closed areas)

What we would like to know

- The present Level of Exploitation
  - Fishing Mortality (depends on age/size)
- The Size of the Stock(s)
  - Biomass & Age/Size Composition
  - Trends with time ?
- The Risk of Collapse
  - Stock/Recruitment Relationships
- Catch Forecast (for TAC's)
  - Recent & Future Recruitment : Fluctuations

Stock Assessment (1)

- Analysis of biological samples
  - length & age compositions
  - catch curve analysis
- Analysis of fishing survey data
  - Abundance indices & total mortality rates
- Use of total international catch-at-age data
  - Virtual Population Analysis (VPA)
    - Cohort Analysis (simplified technique)

Stock Assessment (2)

- "Tuning" of VPA (using CPUE & Survey indices)
  - Extended Survivors Analysis
- Yield-per-Recruit Calculations
- Stock-Recruitment Relationships
- Catch Forecasts (for TAC's)

Data we can use

- Biological samples
  - length (and age ?) compositions
  - mortality rates (approximate, average)
- Catch & Effort data
  - mortality rates (reasonable)
  - stock sizes & trends
- Research Surveys
  - acoustic, plankton & fishing surveys
  - *** **fishery independent** ***

Biological Sampling

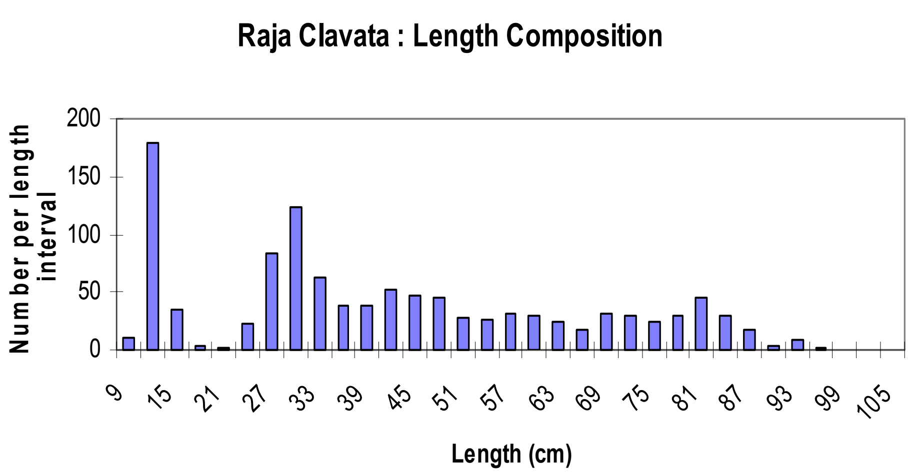
- Length Measurements
- Age determination (if possible)
  - count growth rings (otoliths or scales)
- Sample many landings
  - (areas, gears, seasons.....)
- Compare over several years
- Fair indication of mortality rates
  - ... over or under-exploited ??

Length compositions

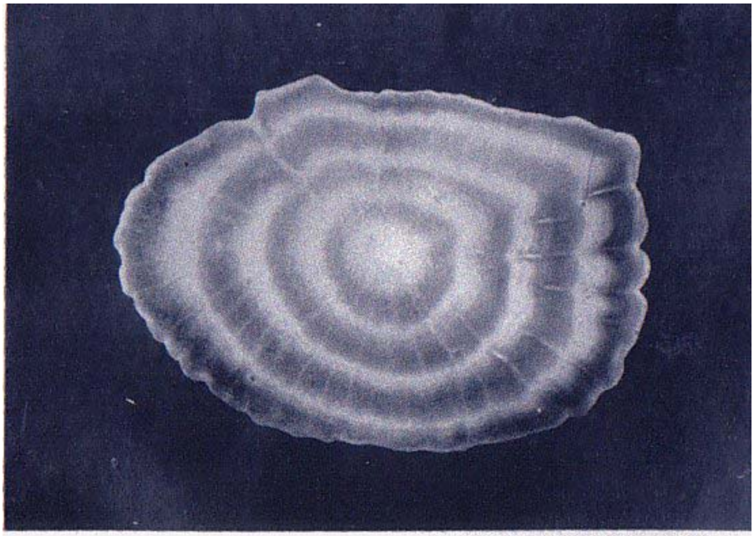
Raja Clavata : Irish Sea

length group min (cm)	Feb	Numbers July	Sept
9	10	0	2
12	180	4	62
15	35	15	2
18	4	2	0
21	2	0	11
24	23	2	56
27	84	3	176
30	124	18	108
33	63	34	43
36	39	21	29
39	39	16	58
42	52	14	65
45	47	31	56
48	46	18	44
51	28	27	29

Length compositions

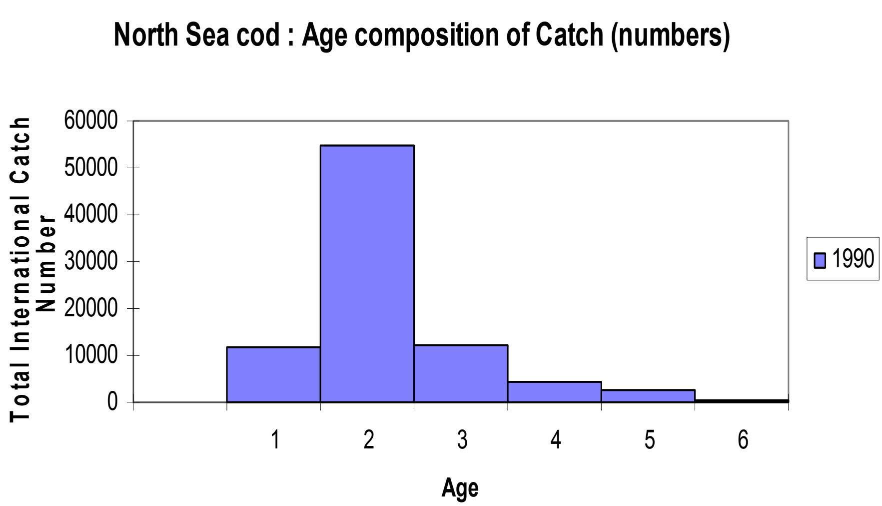


Plaice Otolith



EARSTONE OF PLAICE

Age compositions



"Catch Curve Analysis" by log catch ratios

- $C(y,a) = F(y,a)\, P_{bar}(y,a)$
- $C(y+1,a+1) = F(y+1,a+1)\, P_{bar}(y+1,a+1)$
- **<u>if</u>** F is constant (w.r.t. both time and age)
- $\ln\{ C(y,a) / C(y+1,a+1) \}$
- $= \ln\{ P_{bar}(y,a) / P_{bar}(y+1,a+1) \}$
- $= Z(y,a)$
- Fit (straight) lines to data points (on log scale)
- Or construct tables of log catch ratios

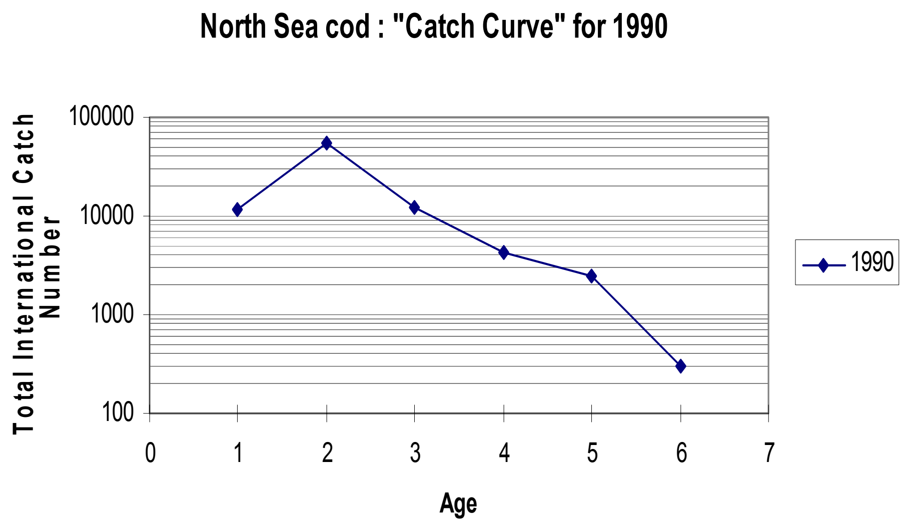
Catch-at age data :

North Sea Cod : Catch-at-age data

Catch Numbers **Year**

Age	1990	1991	1992	1993	1994	1995
1	11841	13628	27967	4814	16173	16465
2	54692	23571	32216	55560	25195	63654
3	11994	16840	8697	11409	21118	12932
4	4360	3319	4995	3211	3078	5296
5	2462	1393	1057	1578	862	800
6	304	1032	479	430	513	283

"Catch Curve" : for a single year



Problem : variable recruitment

- variable yearclass strength
  - causes "wiggles" in the catch curve in any single year
  - looks like (i.e. confounded with) variation of mortality with age
- solution : use data for separate cohorts
  - (not separate years)
- Calculate **log catch ratios**

log catch ratio spreadsheet

North Sea Cod : Catch-at-age and log catch ratios

Catch Numbers — **Year**

Age	1990	1991	1992	1993	1994	1995
1	11841	13628	27967	4814	16173	16465
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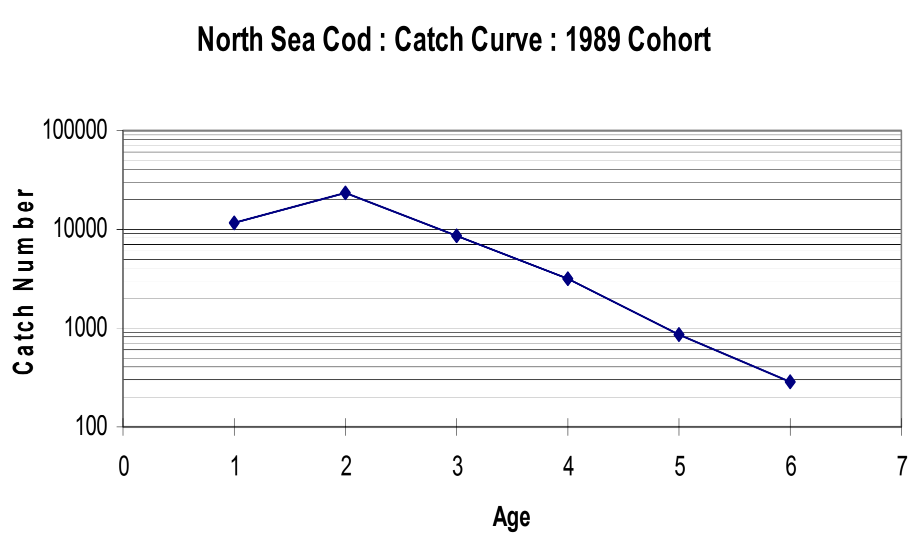
Log Catch Ratios (~ Z) — **Year (lower)**

Age (lower)	1990	1991	1992	1993	1994	
1	-0.69	-0.86	-0.69	-1.66	-1.37	**not fully exploited**
2	1.18	1.00	1.04	0.97	0.67	
3	1.28	1.22	1.00	1.31	1.38	
4	1.14	1.14	1.15	1.32	1.35	
5	0.87	1.07	0.90	1.12	1.11	

“Catch Curve” : for a single cohort



Problem : variable effort

- If effort varies from year to year, so does Fishing mortality
  - i.e. F(y,a) is not constant, causing errors
- but CPUE = q P_{bar} [not dependent on F]
- Better to use log CPUE ratios
  - still requires q(y,a+1) = q(y,a)
  - i.e. catchability independent of age & time
- a weaker assumption, but still not guaranteed
- needs catch & effort data (for individual fleets)

Catch & Effort Data

- From log-books, landings declarations
- Catch-per-unit-effort indices
  - are a valid indicator of stock size ...
  - **<u>if</u>** catchability is constant (w.r.t. age & time)
- Combine with age composition data (from biological samples) to get estimates of Z, and therefore also of F
- ??? are the basic data reliable ???
- ?? is catchability constant ??

Problem : partial selection

- younger (smaller) fish are not fully vulnerable
- so fishing mortality is not constant
- the “catch curve “ is not a straight line
- catches are not proportional to population size for these age groups

Virtual Population Analysis

- An alternative way (J. Gulland) to estimate :
  – population numbers (by age & year)
  – fishing mortaliy rates (by age & year)
- Uses total international catch data (**not** effort)
  – (N.B. : need other countries’ data)
- Requires catch numbers-at-age
  – does **not** assume F or q to be constant
- Based on the catch equation
- Need several years data (about 5, or more)

Cohort Analysis

- simplified approximate method (J. Pope)
- work with data for each cohort separately
- divide fish at beginning of year into
  - survivors (natural mortality only, full year)
  - victims (assume all caught at mid-year)
    - i.e. subject to M for half the year only
- P(y,a) = exp(M) P(y+1,a+1) (survivors)
- + exp(M/2) C(y,a) (victims)

Cohort Analysis (cont'd)

- P(y,a) = exp(M) P(y+1,a+1)
- + exp(M/2) C(y,a)
- apply sequentially, backwards
  - i.e. start with the oldest
  - need a starting value for the survivors
    - e.g. assume (guess) equal to last catch number
- also Z(y,a) = ln{ P(y,a) / P(y+1,a+1) }
- F(y,a) = Z(y,a) -M
- complete set of values for P(y,a) and F(y,a)

Cohort Analysis : single cohort

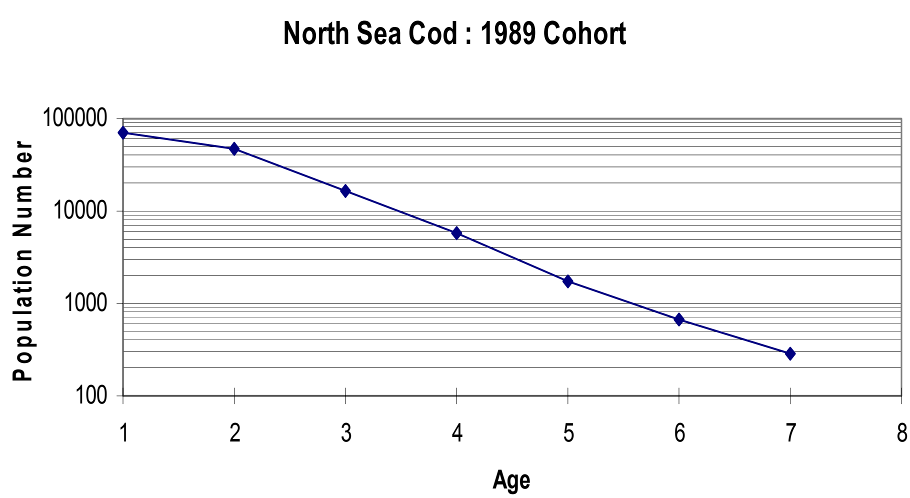
North Sea Cod : Cohort Analysis : Single Cohort :
1989 Yearclass

M = 0.2 **exp(M/2)=** 1.105

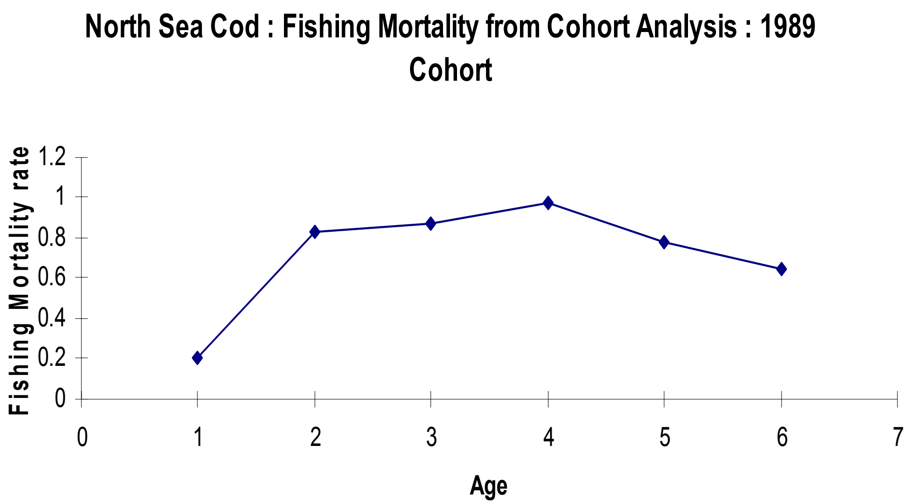
Age	Population	Catch	Z	F
1	69619	11841	0.408	0.208
2	46285	23571	1.027	0.827
3	16567	8697	1.068	0.868
4	5695	3211	1.176	0.976
5	1757	862	0.981	0.781
6	658	283	0.844	0.644
7	283	<<<<<<<<<<<<<<<<<<<<		**N.B. Start here assumed = final catch number**

work backwards from oldest age

Cohort Analysis : single cohort Population number at age



Cohort Analysis : single cohort
Fishing mortality at age



Cohort Analysis : multiple cohorts

Population Numbers **Year**

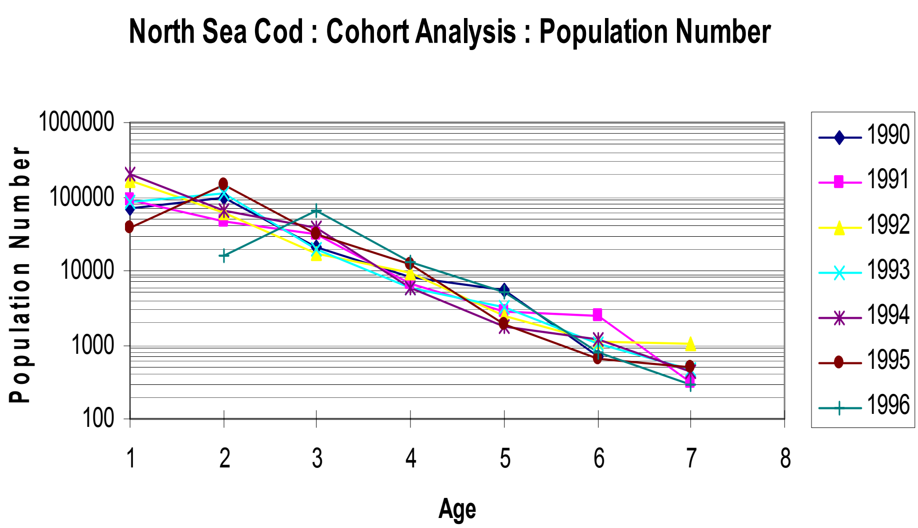
Age	1990	1991	1992	1993	1994	1995	1996
1	69619	87699	163175	84215	198758	38307	0
2	97245	46285	59471	108291	64593	148096	16465
3	21301	30130	16567	19540	38389	30087	63654
4	8361	6587	9431	5695	5675	12322	12932
5	5654	2901	2390	3202	1757	1861	5296
6	707	2401	1114	1000	1194	658	800
7		304	1032	479	430	513	283

Cohort Analysis : multiple cohorts

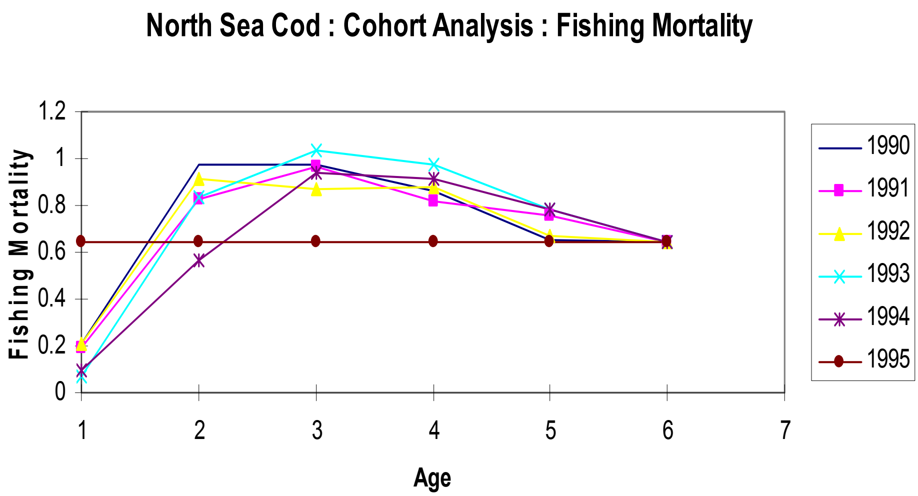
Fishing Mortality **Year**

Age	1990	1991	1992	1993	1994	1995
1	0.208	0.188	0.210	0.065	0.094	0.644
2	0.972	0.827	0.913	0.837	0.564	0.644
3	0.974	0.962	0.868	1.036	0.936	0.644
4	0.859	0.814	0.880	0.976	0.915	0.644
5	0.656	0.757	0.671	0.787	0.781	0.644
6	0.644	0.644	0.644	0.644	0.644	0.644

Cohort Analysis : multiple cohorts Population at age



Cohort Analysis : multiple cohorts
Fishing Mortality at age



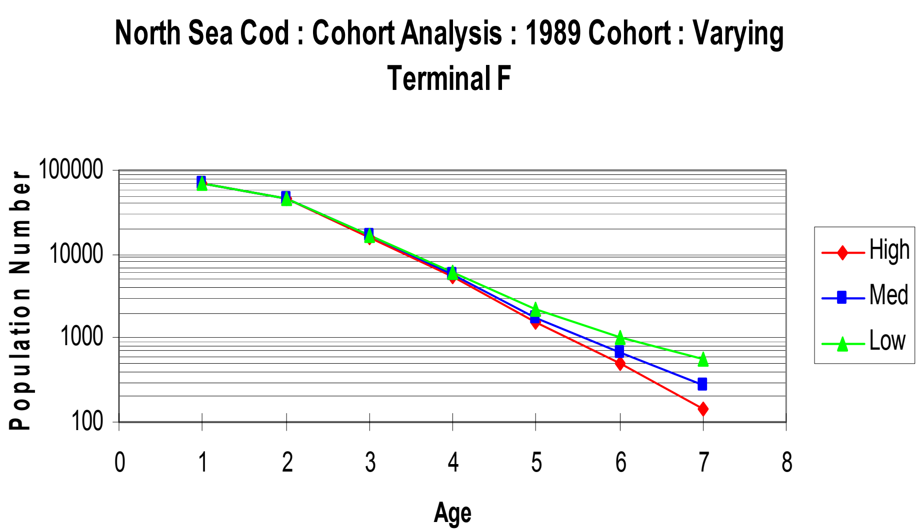
Practical Session

Cohort Analysis

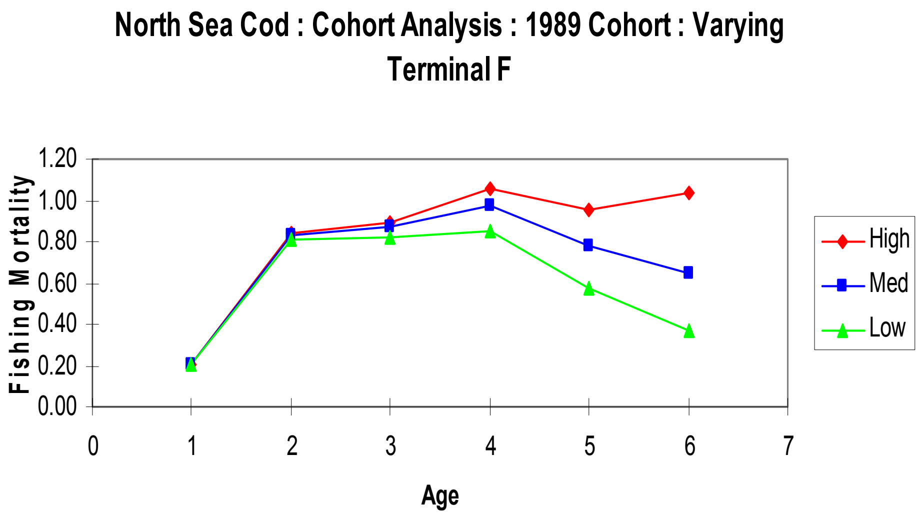
VPA & Cohort Analysis

- work with each cohort separately
  - hence the name of the method
- examples of Sequential Population Analysis
- need **total international** catch data
- need a sensible assumed value for the survivors ...
- i.e. one has to **assume** what one would most like to determine !
- good for retrospective analysis

VPA & Cohort Analysis
the "tuning" problem



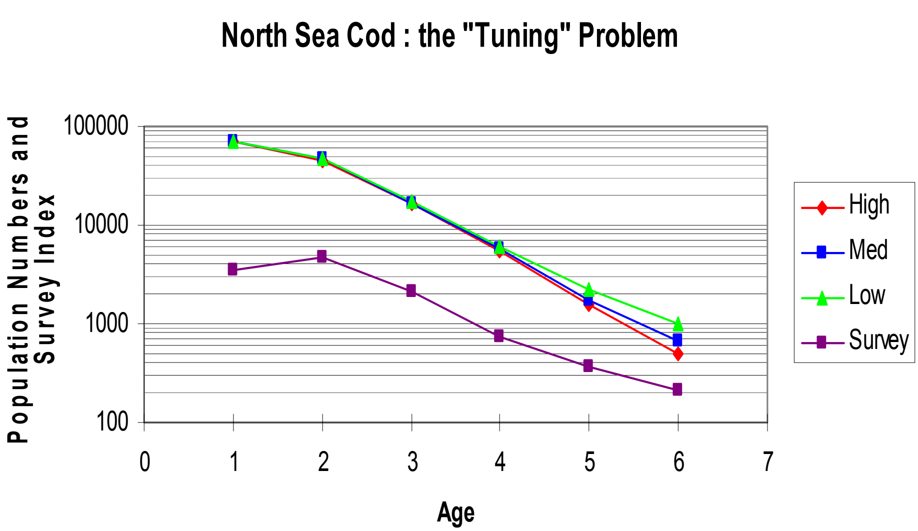
VPA & Cohort Analysis
the "tuning" problem



VPA & Cohort Analysis : the “tuning” problem

- Need independent estimates of abundance
  – but these can be relative, e.g.
- CPUE from effort data
  - ideally for **several** fleets
- CPUE from fishing surveys
  - preferably by research vessels
- Need to **combine** with VPA
  – many and various methods, including
  - <u>ad hoc</u>, ADAPT, Extended Survivors Analysis

VPA & Cohort Analysis
using abundance indices to solve the “tuning” problem



Research Survey Data

- Fishing Surveys (demersal fish)
  - data by species, size, age, maturity, etc
- Acoustic Surveys (pelagic fish)
  - species ???, sizes ??, calibration ?
- Plankton Surveys (of eggs & larvae)
  - spawning stock biomass only
- Cost (> £500 000 per survey)

Overview

- To assess the relative state of a stock (trends and fishing mortality) one needs :
  - catch & effort data for at least one fleet (or research survey)
  - plus biological samples (length & age compositions)
- To get absolute stock size one needs
  - total international catch (numbers-at-age)
  - more CPUE or survey data (for “tuning”)