

Discard Mortality Workshop August 7-8, 2006

Importance of Bycatch Discard Mortality

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Inaccurate Discard Mortality

- Two typical assumptions:
 - 100% mortality: all discards are assumed to die, regardless of gear, size, age, season, area, depth, etc.
 - 0% mortality: the implicit assumption when discards are not estimated or not included in population modeling.
- A complete range of reality:
 - Near 100% mortality: river herring in mid-water trawls (discarded on shore).
 - Near 0% mortality: lobsters (in trap fisheries).
 - Somewhere between: the most likely reality.

Effect of Inaccurate 'Defaults'

- Bad Data:
 - Under/overestimate total catch – effects perceptions about stock productivity.
 - Biased age distribution of catch (usually under/overestimate the portion of small, young fish).
 - Biased catch rates from fishery.
- Modeling Problems:
 - Scaling errors: under/overestimate recruitment and biomass.
 - 'Process error:' bias causes disagreement between catch estimates and other information (age structure, relative abundance, selectivity)
 - Biased reference points (F_{msy} , B_{msy})
 - Over/underestimated removals will be subsumed in other estimates (fishing mortality, natural mortality, total mortality)
- Management Errors:
 - Uncertain or incorrect status determination (overfishing, overfished).
 - Misleading information on catch of immature fish.
 - Inaccurate evaluation of the contribution of different gear types to total catch, catch per effort and catch at age.

Presentation Approach

- Review 'construction' of catch at age
- Review two categories of stock assessment models (with different sensitivities to discard mortality)
 - Virtual Population Analysis (VPA)
 - 'Forward Projection' Models (biomass dynamics, delay-difference, Collie-Sissenwine, statistical catch-at-age).
- Review MSY estimation

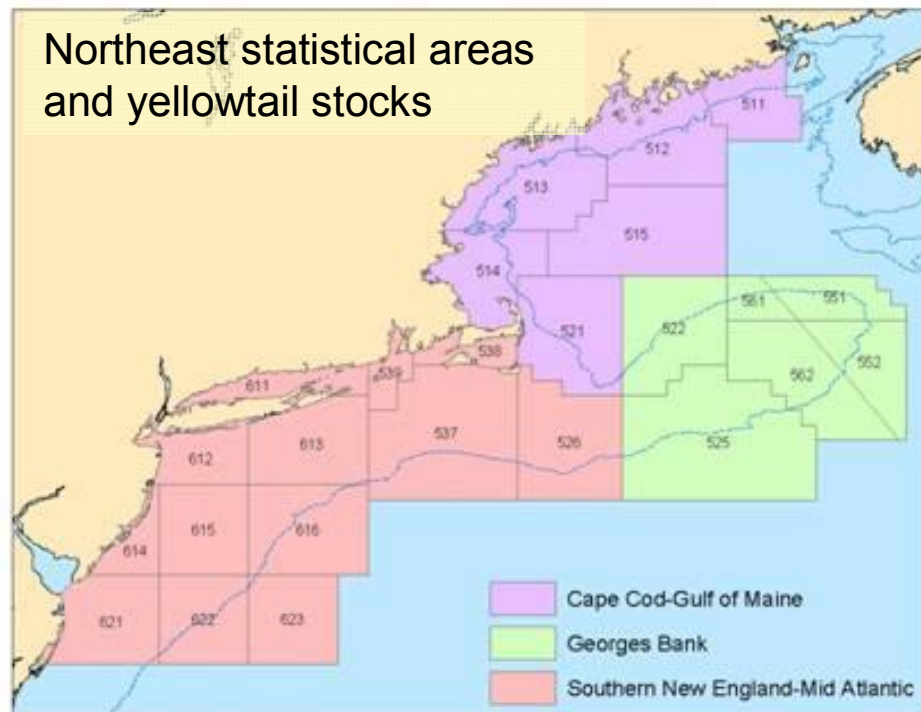
Estimating Removals (Catch)

- Census Methods
 - Seafood Dealer Transactions
 - Fisherman logbooks
- Survey Sampling Methods
 - Creel Surveys
 - Intercept Sampling
 - **Discard Estimation**



Vessel Logbook System

- All landings, discards and effort are reported (a census of effort and catch).
- Used to derive estimates of landings, by geographic area (statistical area, stock) and time period (month, quarter or year)



Northeast Logbook Data

- Trip Information

- hull number, permit, date sailed, duration, number of crew, port landed, state, date landed, time landed, captain

- Fishing Gear Information:

- gear type, mesh size, number deployed, gear size, area fished, latitude, longitude, loran, number of hauls, soak time, depth

- Catch Information:

- Species, quantity kept, quantity discarded, dealer number, dealer name, date sold

100830

FISHING VESSEL TRIP REPORT

XXXXXXX
 DID NOT FISH DURING MONTH/YEAR _____

RECEIVED

JUL 1 1994

1. VESSEL NAME <i>Four Girls</i>		2. USCG. DOC. or STATE REG. NO. <i>538910</i>		3. VESSEL PERMIT NUMBER <i>240185</i>	
4. DATE/TIME SAILED DATE (mm/dd/yy) <i>6/1/94</i> TIME (24 hrs) <i>0800 - 00/0800</i>		5. TRIP TYPE (CHECK ONE) <input checked="" type="checkbox"/> COMMERCIAL <input type="checkbox"/> PARTY <input type="checkbox"/> CHARTER		6. NO. OF CREW <i>3</i>	
FILL OUT A NEW PAGE FOR EACH CHART AREA OR GEAR OR MESH/RING SIZE FISHED					
8. GEAR TYPE <i>PVE</i>		9. MESH/RING SIZE <i>5</i>		10. QUANTITY OF GEAR <i>50</i>	
12. CHART AREA <i>513</i>		14. LATITUDE/LONGITUDE OF LORAN LATITUDE <i>13</i> LONGITUDE		11. SIZE OF GEAR <i>6</i>	
13. AVG DEPTH <i>110</i> fath		15. NO. OF HAULS <i>1</i>		16. AVERAGE TOW/SOAK TIME <i>120</i> min	
17. SPECIES CODE NAME		18. KEPT COUNT (Comm)		19. DISCARDED COUNT (Comm)	
<i>HAL</i>		<i>5000</i>		<i>0</i>	
20. DEALER PERMIT NO.		21. DEALER NAME		22. DATE SOLD (mm/dd/yy)	
<i>00000</i>		<i>C.B. MERCER</i>		<i>6/2/94</i>	
23. PORT AND STATE LANDED <i>Portland, ME</i>				24. DATE LANDED (mm/dd/yy) <i>6/1/94</i>	
				TIME LANDED <i>18.30</i>	

I certify that the information provided on this form is true, complete and correct to the best of my knowledge.

Recreational Catch Surveys

- Complementary survey methods:
 - Intercept Survey (relatively small **sample**)
 - Number, weights and lengths of fish caught by species
 - State and county of residence
 - Trips per year
 - Mode of fishing
 - Primary area of fishing
 - Telephone Household Survey (larger sample)
 - Presence of marine recreational anglers in the household
 - Number of anglers per household
 - Fishing trips in 2-month period
 - Mode of each trip
 - Location (county) of each trip



Discards

- Several approaches to expanding **samples** to entire fishery discards:
 - Based on landings: discard to kept ratios (from sea samplers or logbooks) are expanded based on total landings within a gear group:

Total Discards=Total Landings x

(sum of observed discards /sum of observed kept)

- $D/L=d/k$
- $D=L(d/k)$

Based on effort: discard per unit effort observations (from sea samplers or logbooks) are expanded based on total effort within a gear group:

Total Discards=Total Effort x

(sum of observed discards /sum of observed effort)

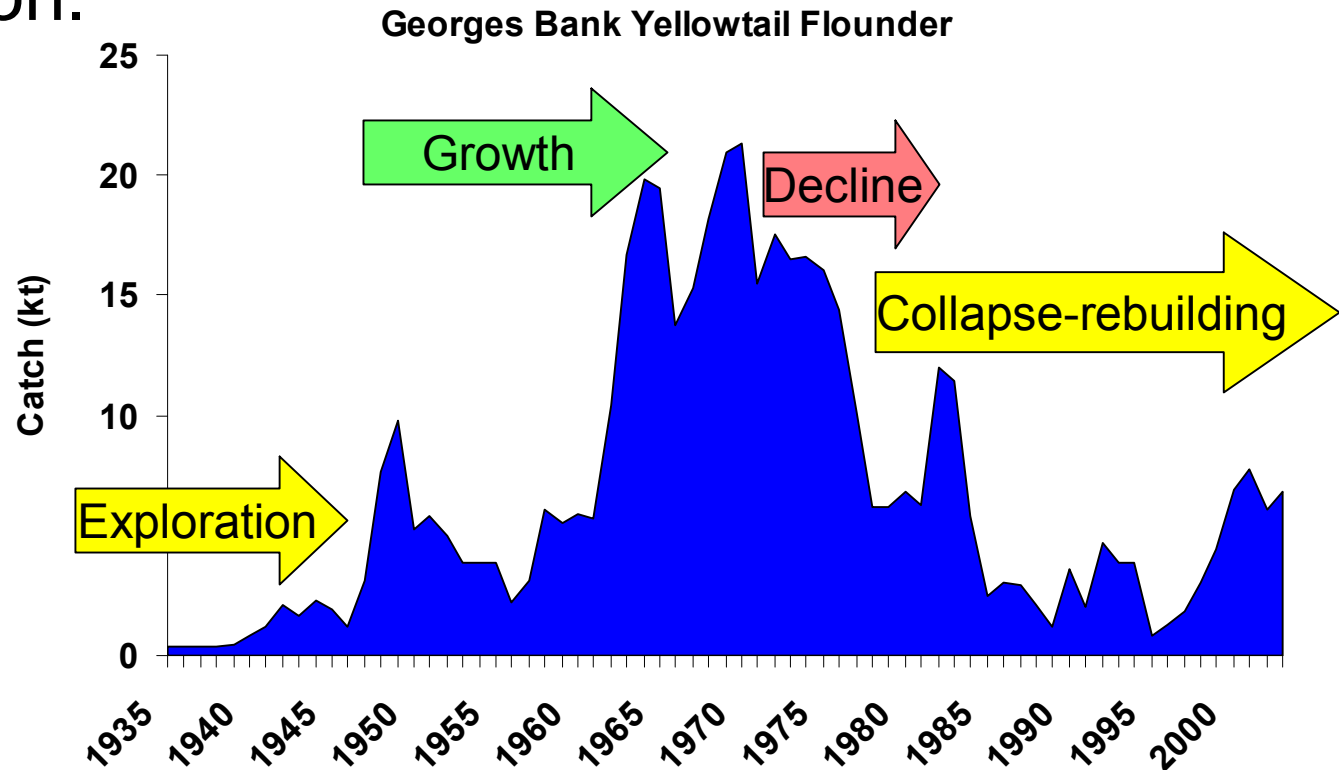
- $D/E=d/e$
- $D=E(d/e)$

- Achieving representative estimates relies on an adequate sampling design for observer data or analytical design for logbook data.



Fishery Development

- Historical series of catch shows stages of exploitation.



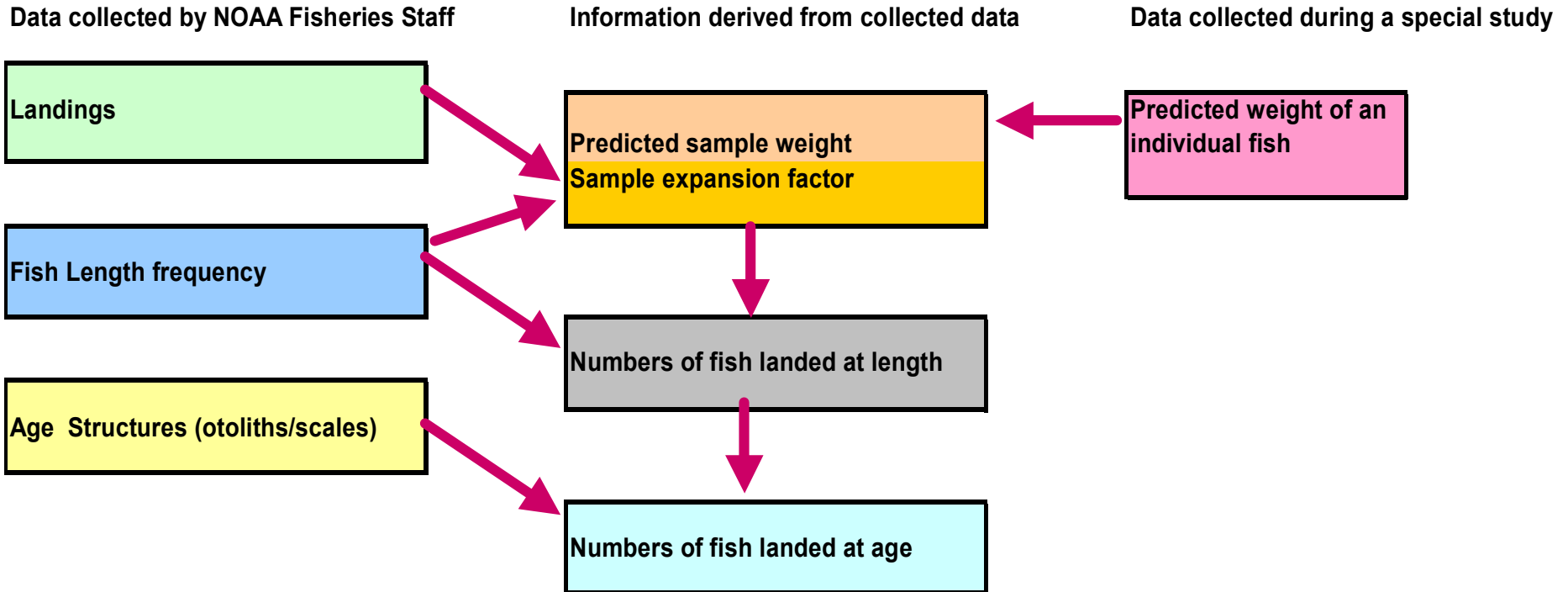
- The initial development of the fishery may have valuable baseline information.

Biological Characteristics

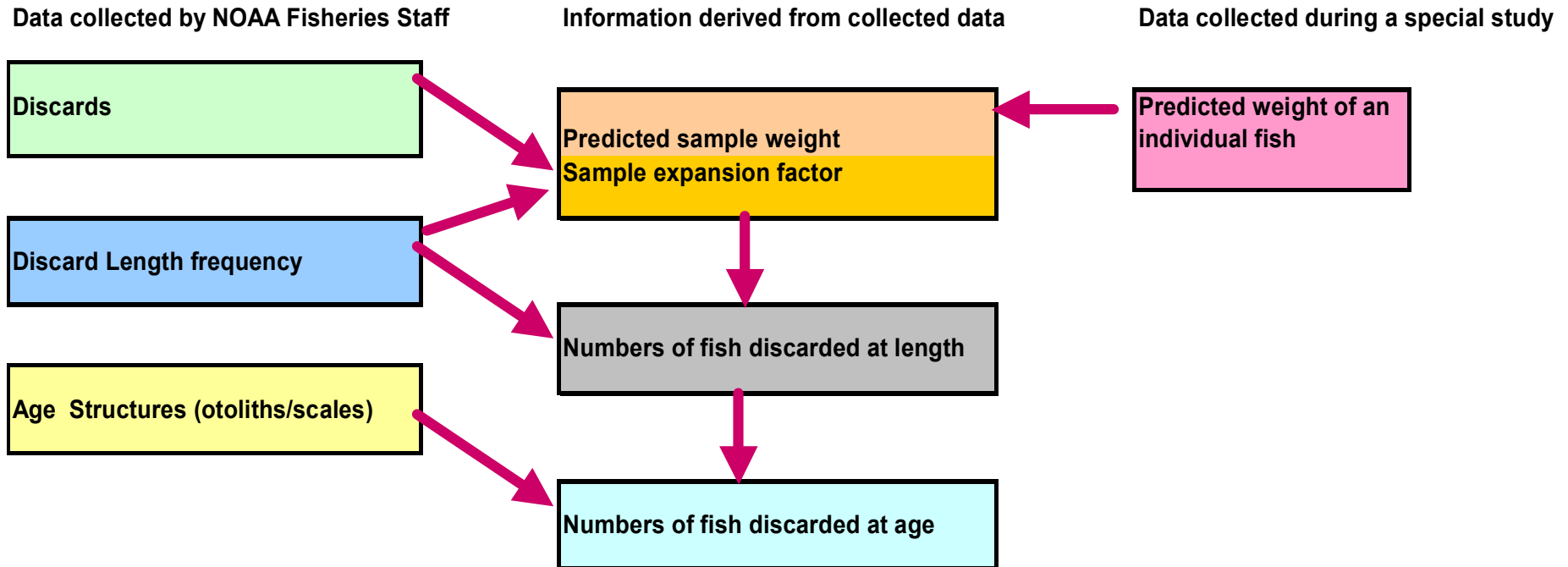
- Demographic attributes of fishery removals (size, age, sex) are also valuable for stock assessment.



Landings at Age



Discards at Age

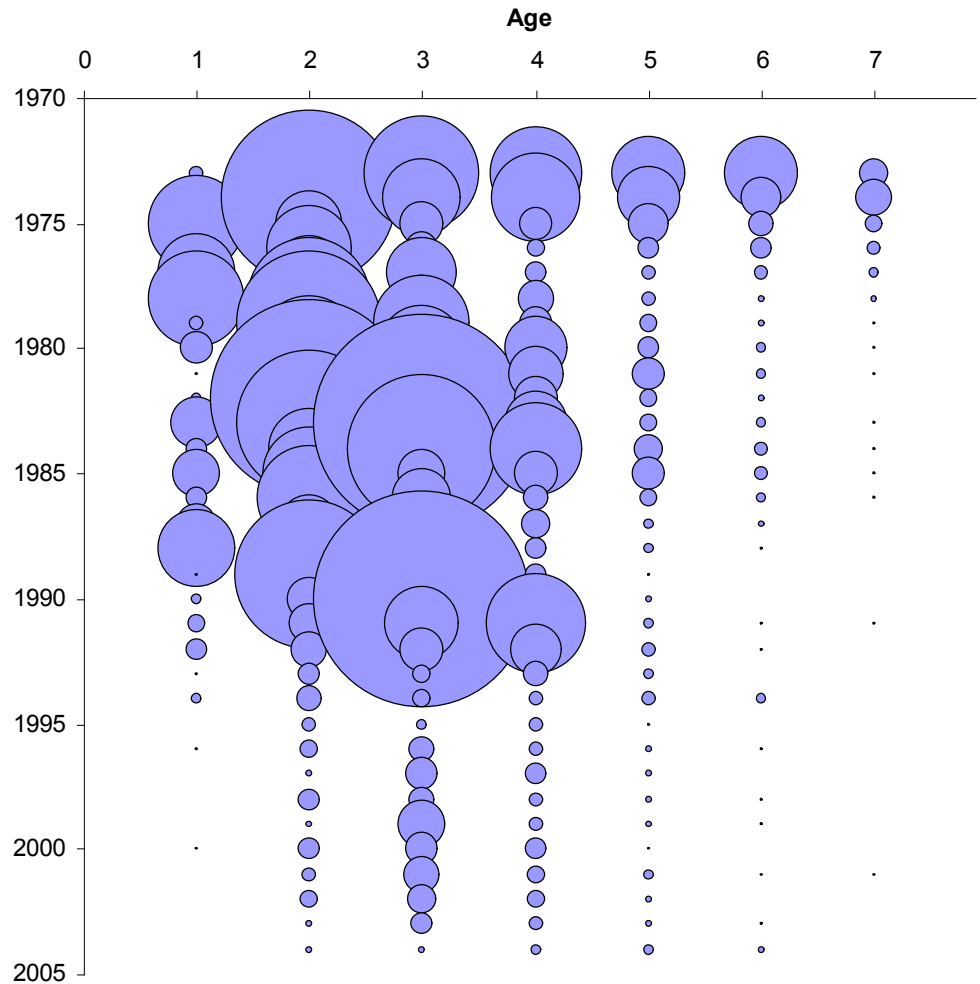


Total Catch at Age

- Total catch at age = landings at age + discards at age + ...
- Input to age-based assessment model (virtual population analysis reconstructs abundance at age from catch at age)
- Derived from census of landings (and effort), samples of length and age of landings and discards **and an estimate of discard mortality**.
- Samples must represent the population to produce a reliable estimate of catch at age (and reliable assessment results).

Catch at Age

- Southern New England Yellowtail Flounder:
 - Most catch is age-2 and age-3
 - Wider age distribution in the early 1970s than since
 - Abundant yearclasses in 1981 and 1987
- Input for age-based assessment models.



Virtual Population Analysis

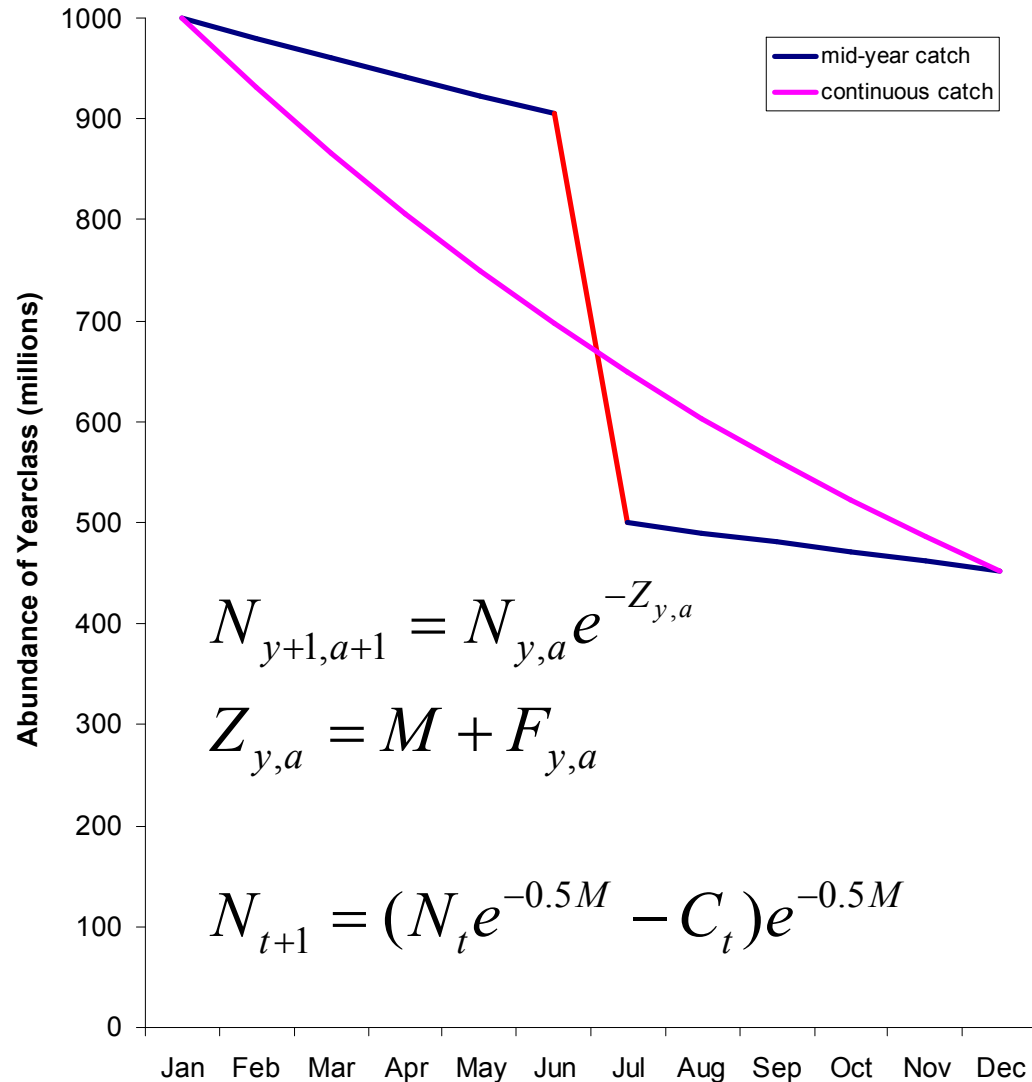
A simple, but informative
population process

Yearclass abundance (N) over
time:

N at the end of the year =
N at start of year
- natural mortality
- catch

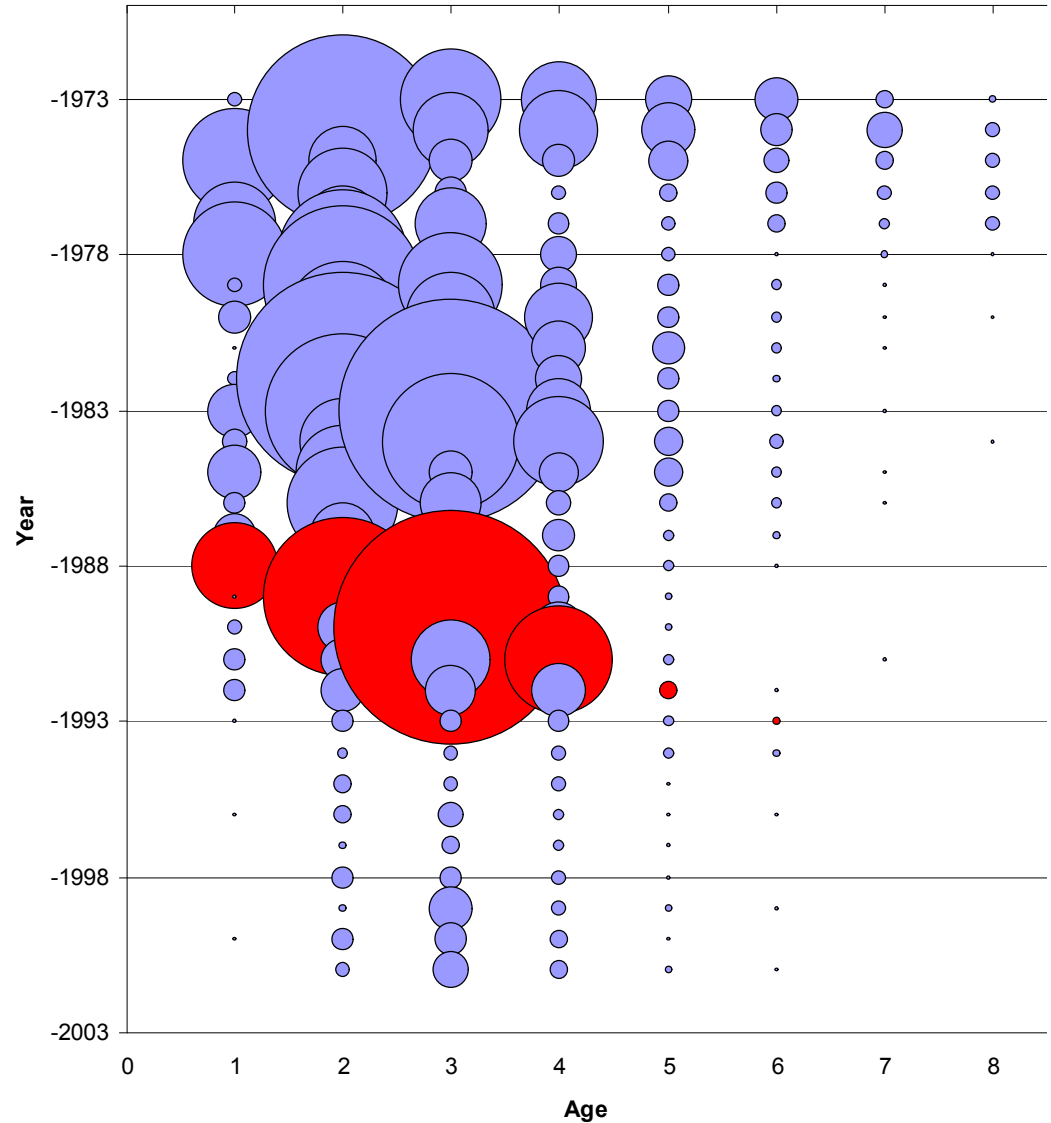
Or *reconstruction of abundance
back in time*

N at the start of the year =
N at end of year
+ natural mortality
+ catch



VPA

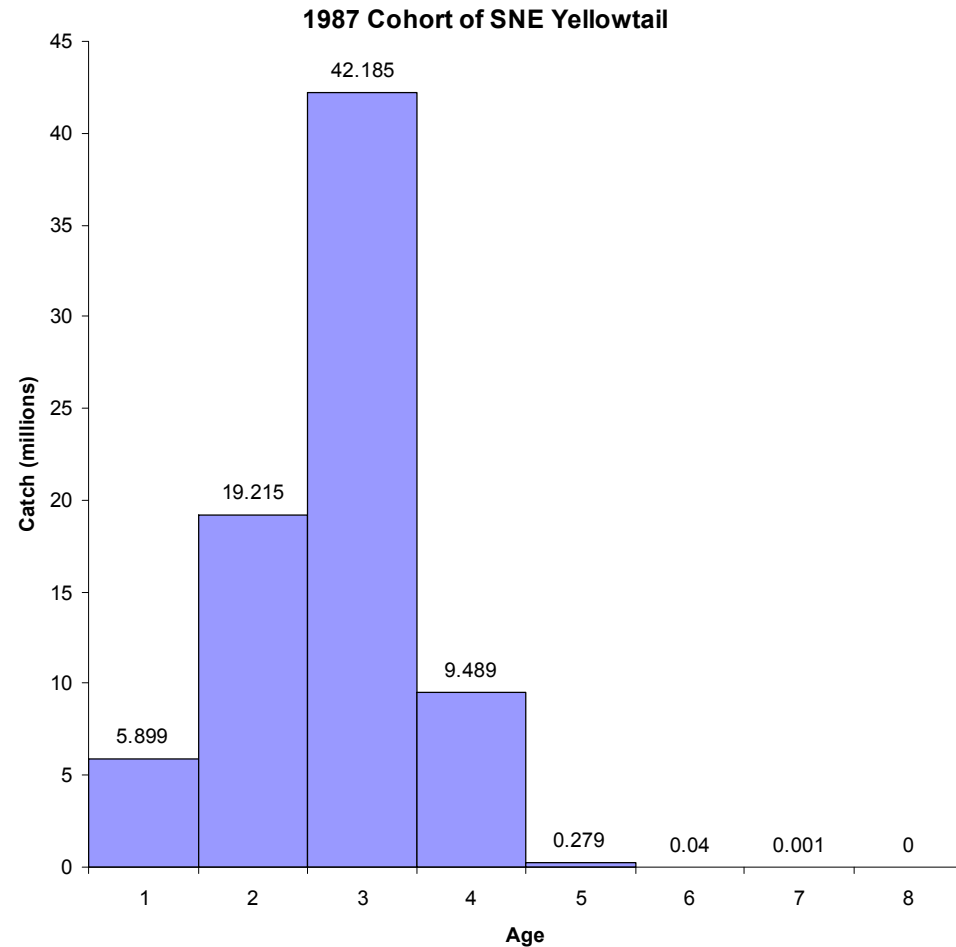
Southern New England Yellowtail Catch



- Age distribution of the catch.
 - From census of total catch biomass and port samples.
 - SNE yellowtail example:
 - 1987 yearclass dominated the catch in the late 80s early 90s.

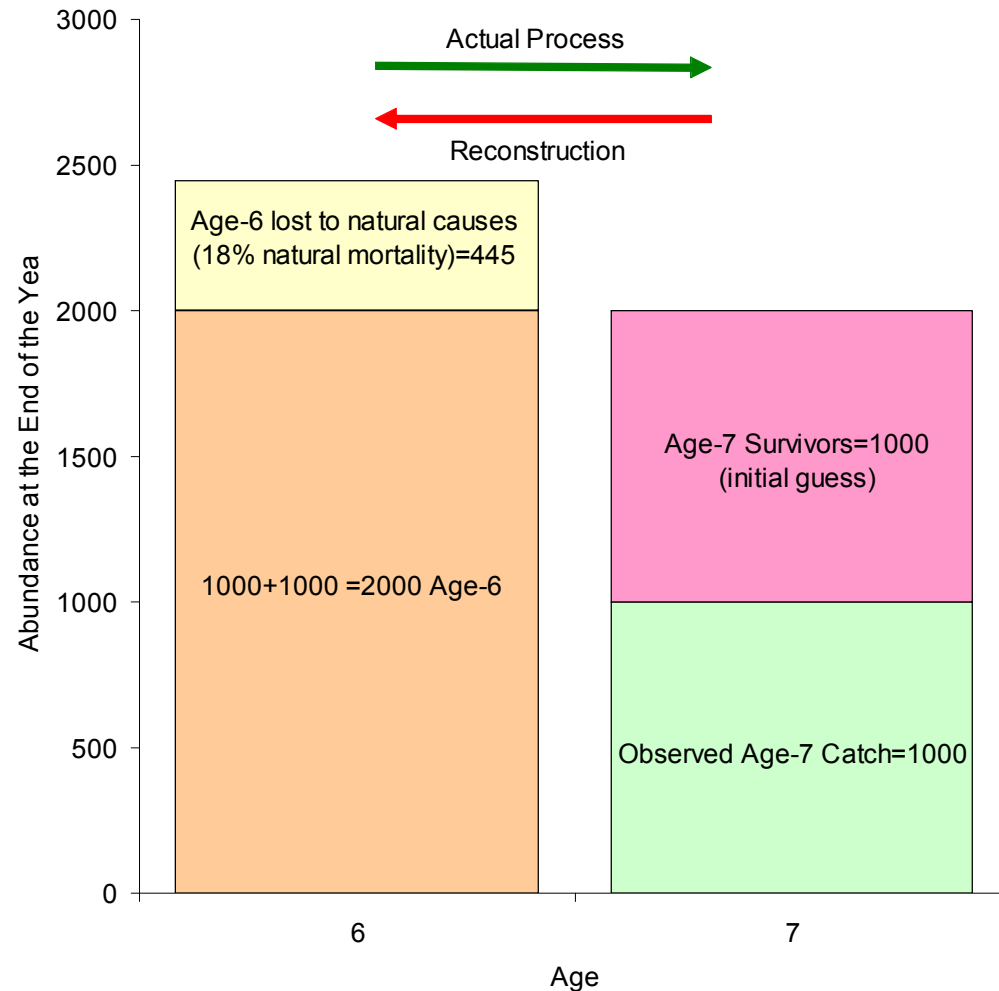
Virtual Population Analysis

- Over the lifespan of the 1987 yearclass, 77 million fish were caught.
- We also know that some fish died from natural mortality.
- So, *at a minimum*, there were 77 million fish when they were 1 year olds.
- But this is just the population we “saw” (*the virtual population*) from the underlying true population.
- *VPA* reconstructs the true population from the virtual population.



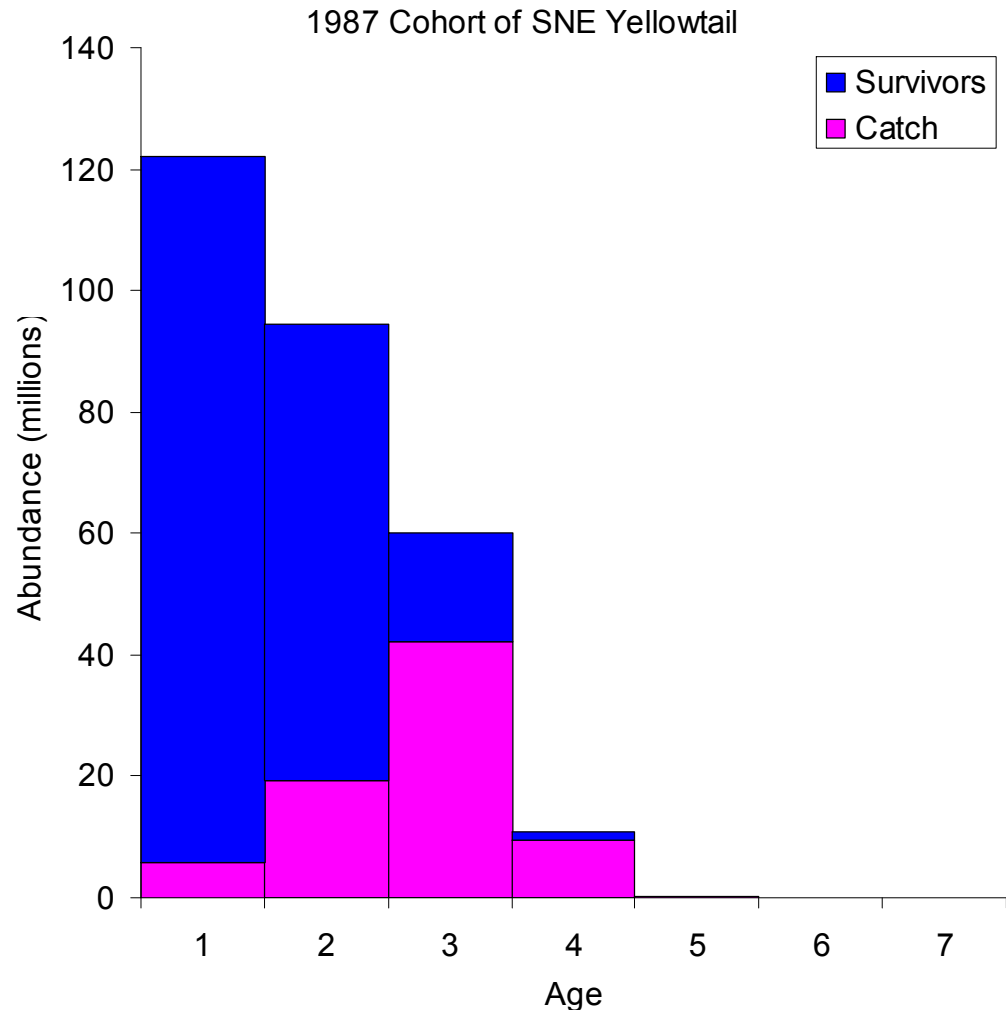
Virtual Population Analysis

- 1987 yearclass of SNE yellowtail
- 1,000 fish caught at age-7 (none at age 8).
- *For now*, suppose those 1,000 fish came from a population of 2,000 fish.
- Using the population process, and an estimate of natural mortality, we can reconstruct abundance at age-6:
$$N_{\text{age 6}} = N_{\text{age 7}} + \text{natural mortality} + \text{age 7 catch}$$
- Then reconstruct the abundance at age-5, etc. back to age-1.



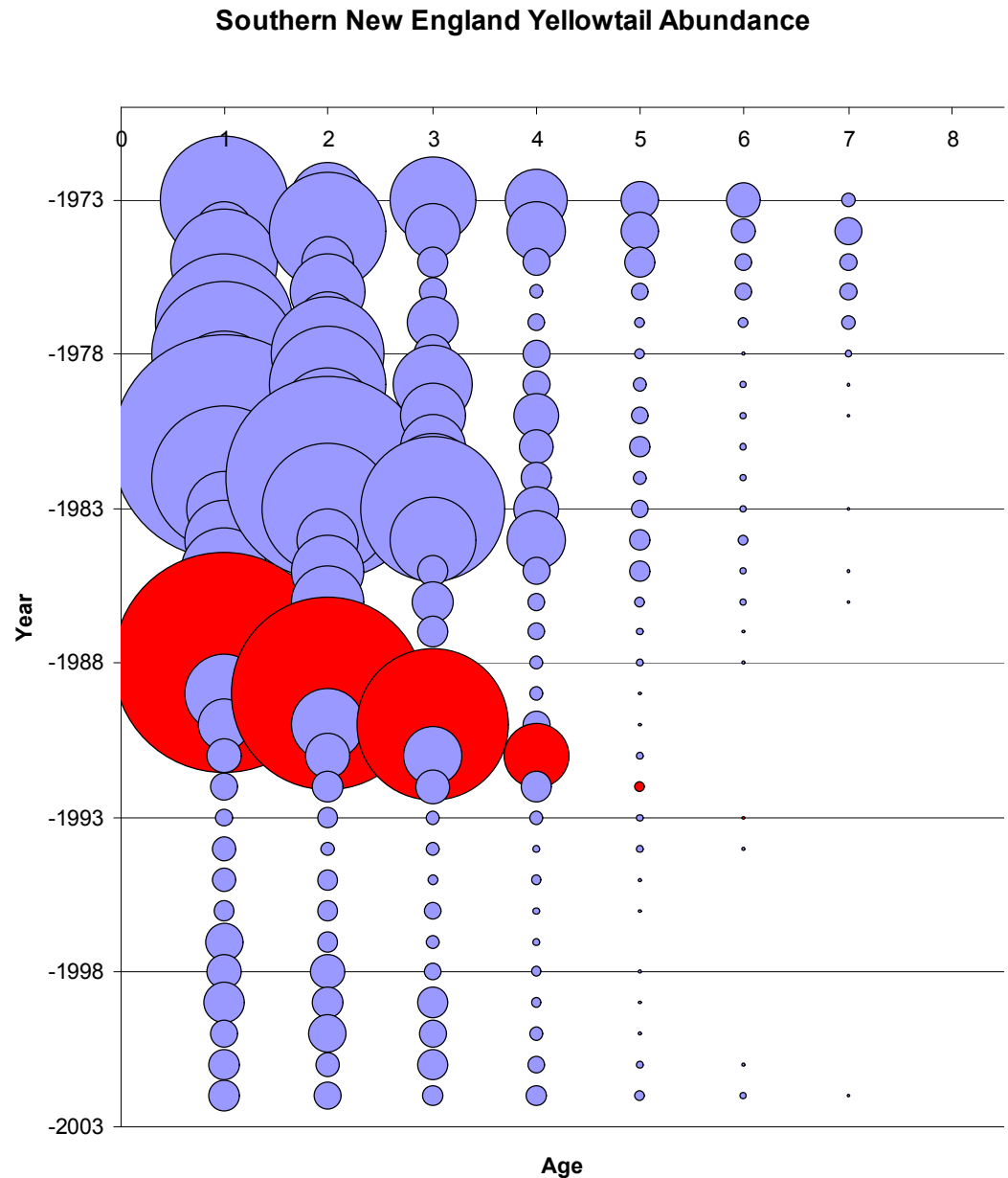
Virtual Population Analysis

- By accounting for observed catch over the lifetime of the cohort (77 million) and natural mortality (*with an initial guess about age-7 survivors*), the age-1 abundance estimate is 122 million.



VPA

- Reconstruction of all yearclasses gives a total population estimate.
- Input Data:
 - catch at age
 - estimate of natural mortality
 - *initial guess* about abundance of survivors at the oldest age.



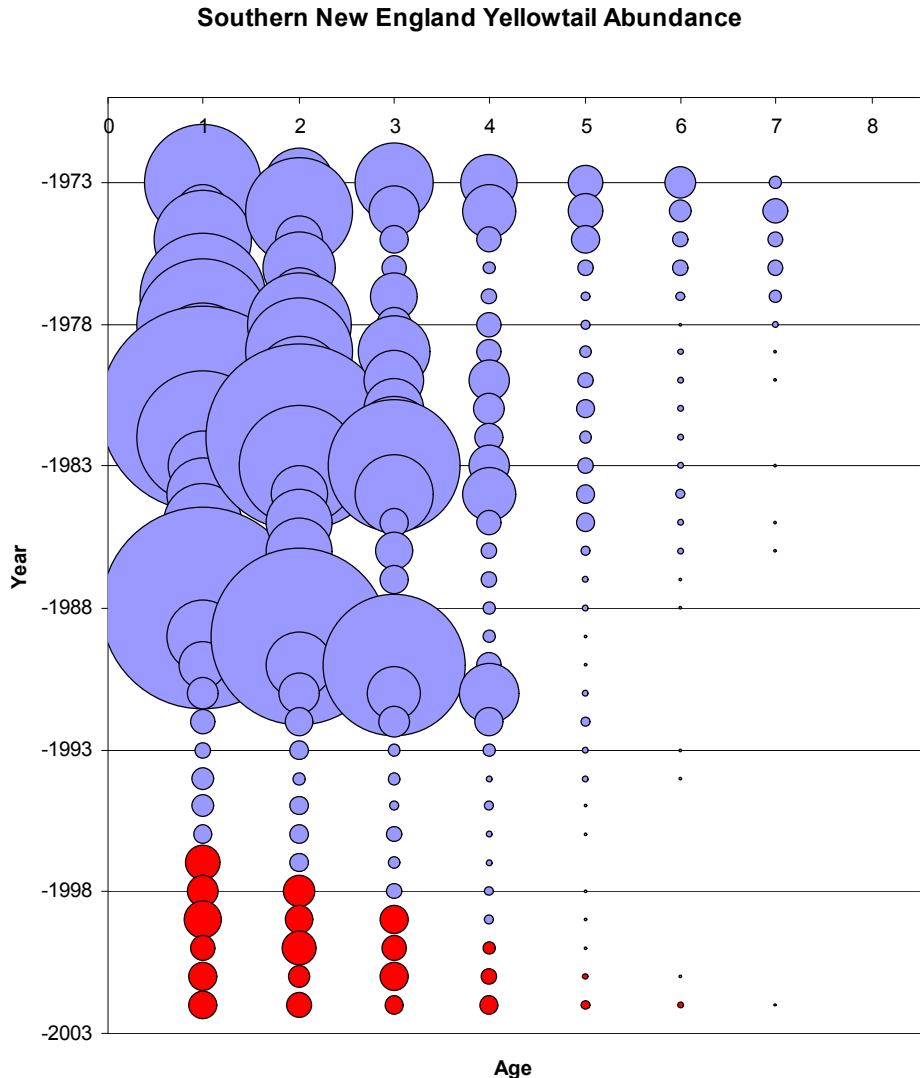
VPA Calibration

- Initial guesses are replaced with estimates:

- oldest age of historical yearclasses estimated by assuming that age-7 fish have the same vulnerability to the fishery as ages 4-6:

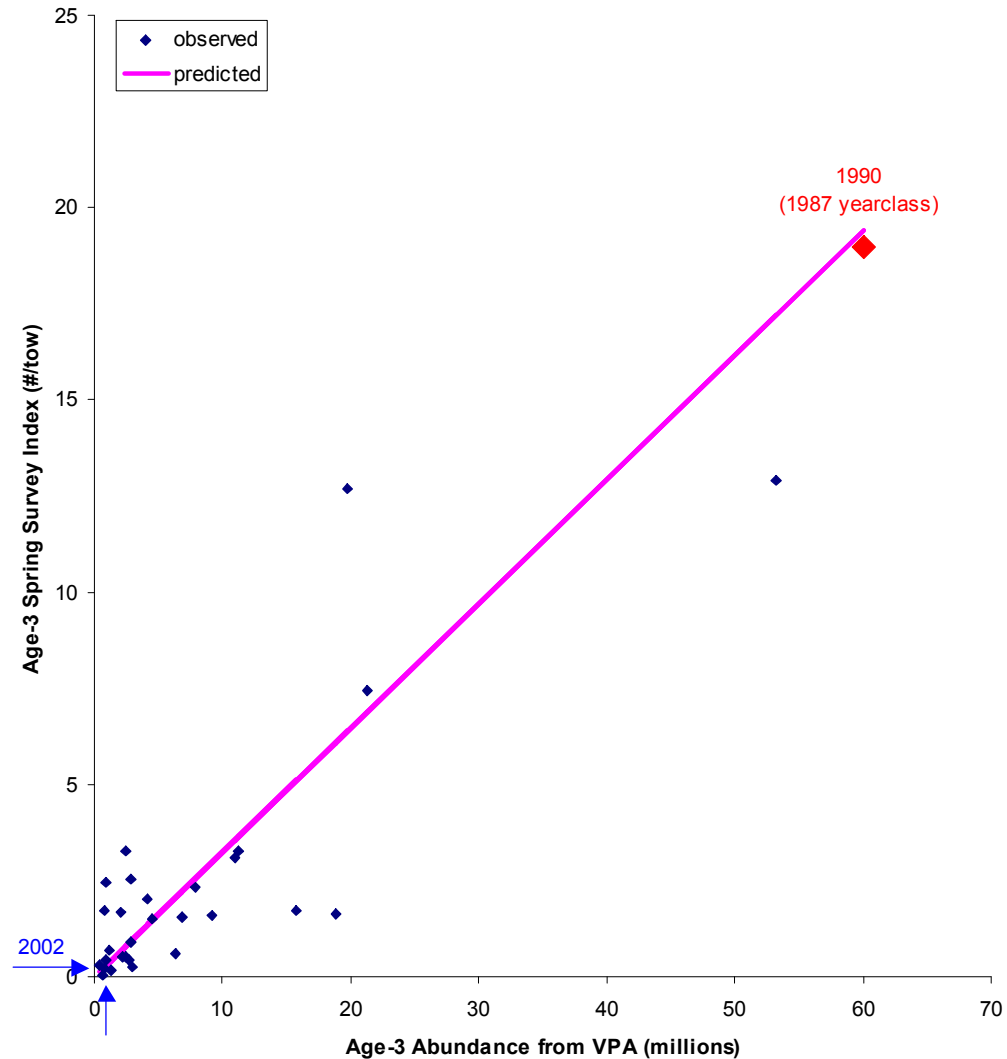
$$N_t = \frac{C_t Z_t}{F_t (1 - e^{-Z_t})}$$

- yearclasses that are alive now require more information.
 - need an independent index of relative abundance over time.



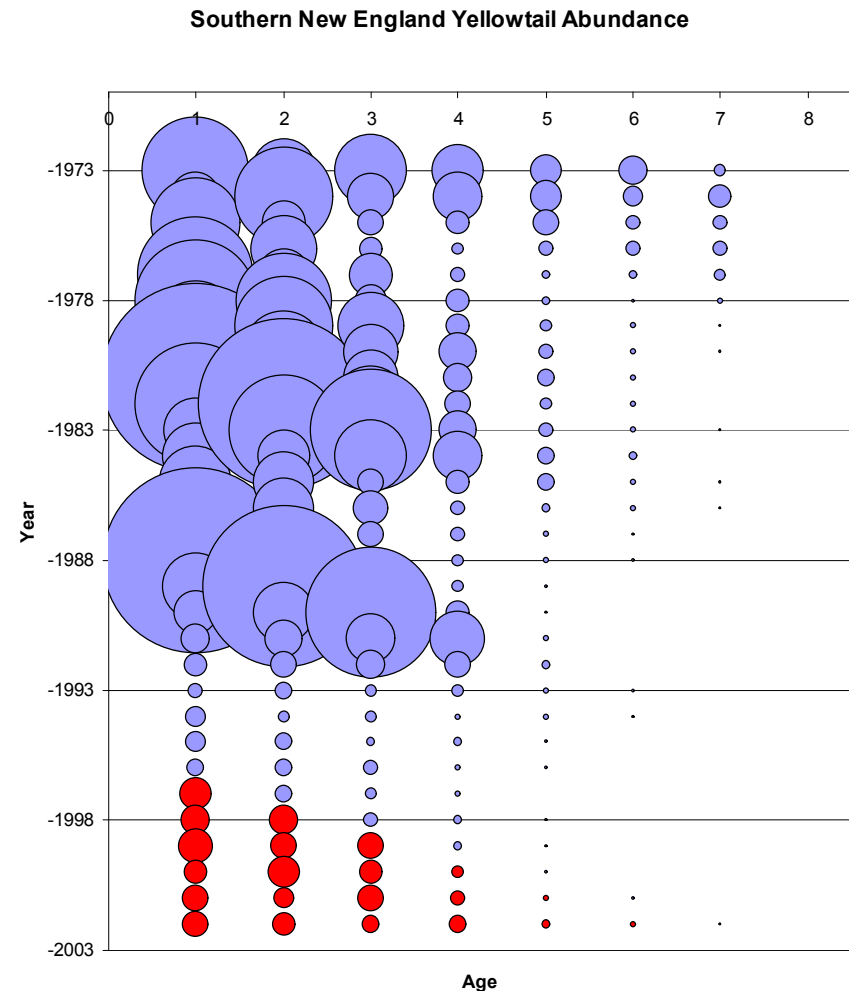
VPA Calibration

- Abundance of living yearclasses in 2002 are estimated using a predictive relationship between historical VPA abundance and survey indices.
- $I_{t,a} = q_a N_{t,a}$
- $N_{2003,age-3} = q_{age-3} N_{t2002,age-3}$



Effect of Inaccurate Discard Mortality on VPA

- Over/under estimation of discard mortality will produce a proportional, cumulative and exponential bias in estimates of historical recruitment.
- Disagreements between VPA abundance calculations and survey relative abundance at age will produce calibration errors and uncertainty in current abundance estimates.



Forward Projection Models

- With a population production process, stock size can be modeled to match observed catch, abundance indices, and age or stage structure in some.

- Biomass dynamics (aggregate population):

$$B_{t+1} = B_t + rB_t \left(1 - \frac{B_t}{K} \right) - C_t$$

- Delay Difference (recruitment)

$$B_t = \frac{s_{t-1} \alpha B_{t-1}}{\bar{w}_{t-1}} + s_{t-1} \rho B_{t-1} + w_k R_t$$

- Catch-Survey (stages)

$$P_{t+1} = \left[(P_t + R_t) e^{-MT_t} - C_t \right] e^{-M(1-T_t)}$$

- Statistical Catch-at-Age (full age structure)

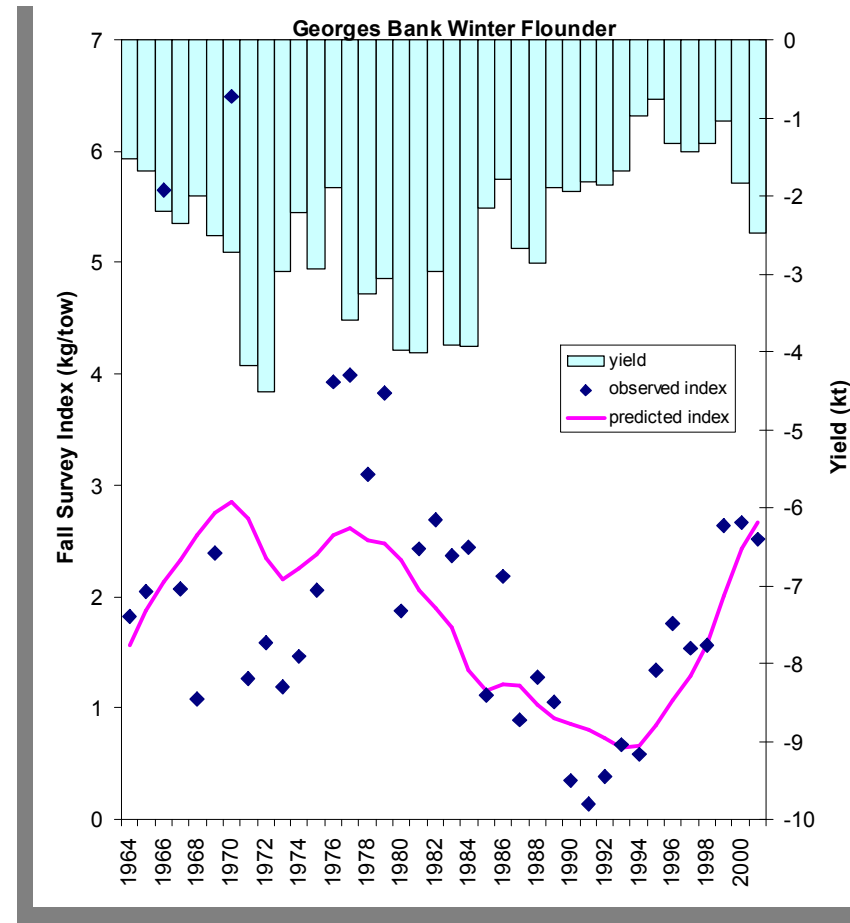
$$B_{t+1} = \left[\sum_{a=k+1}^{\infty} N_{a,t} e^{-(F_{a,t}+M)} w_a \right] + w_k R_{t+1}$$

Forward Projection & Estimating Absolute Biomass

- Biomass Dynamics Model:

- *Smoothing*: stock size estimates are fit to survey data using the simple population process.
- *And scaling*: survey observations are scaled to absolute biomass estimates by evaluating the response in survey data to absolute removals.

$$B_{t+1} = B_t + rB_t \left(1 - \frac{B_t}{K} \right) - C_t$$

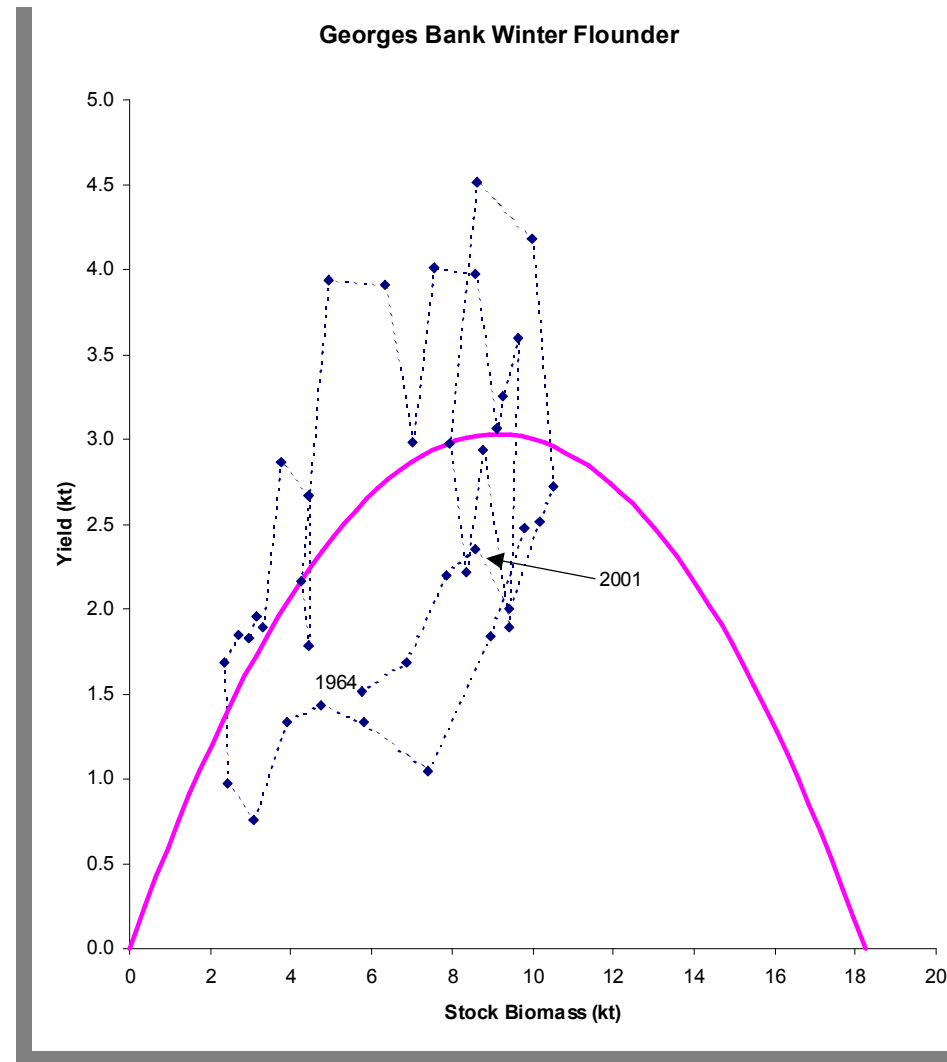


Biomass Dynamics Models

- Stock Status

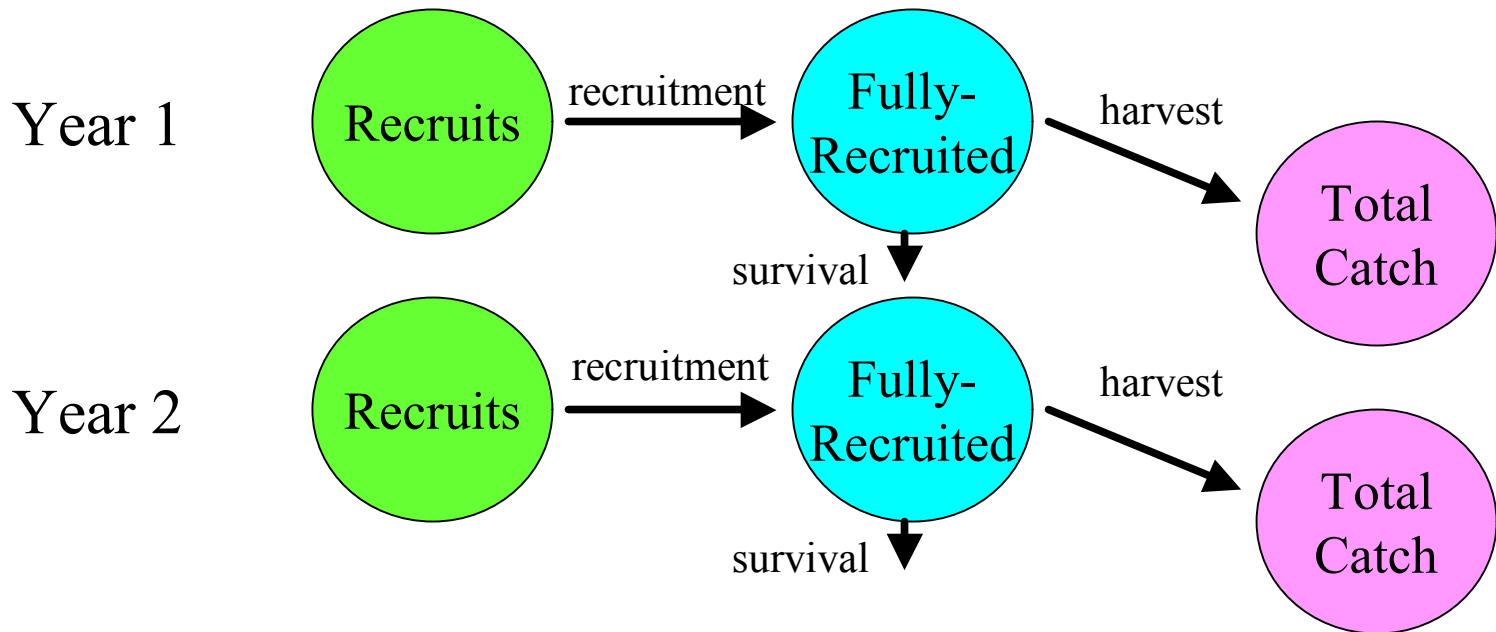
- *Scaling:*

- When catch was not sustainable, stock decreased (1970s-1980s).
- When catch was less than potential production, stock increased (1960s, 1990s).



Stage-Based Methods

- Use life-history stage or size-group as a proxy for age:
 - Collie-Sissenwine (=Catch-Survey Analysis, CSA)



$$P_{t+1} = \left[(P_t + R_t) e^{-MT_t} - C_t \right] e^{-M(1-T_t)}$$

Statistical Catch-at-Age

(from Chris Legault)

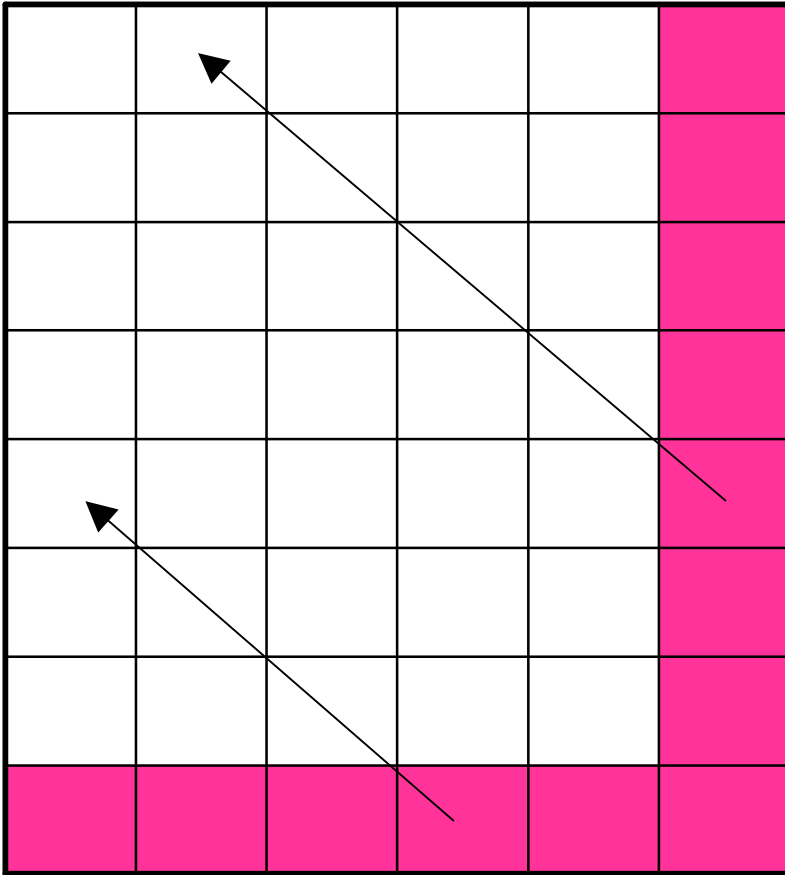
- VPA
 - Estimates abundance of the oldest age and current cohorts
 - Calculates abundance back in time
 - Assumes no error in the catch at age
- SCAA
 - Estimates initial abundance at age, recruitments, fishing mortality, selectivity
 - Calculates abundance forward in time
 - Assumes error in the catch at age

Trade-off between assumptions and number of estimated parameters.

VPA

Age ->

Year
|
v



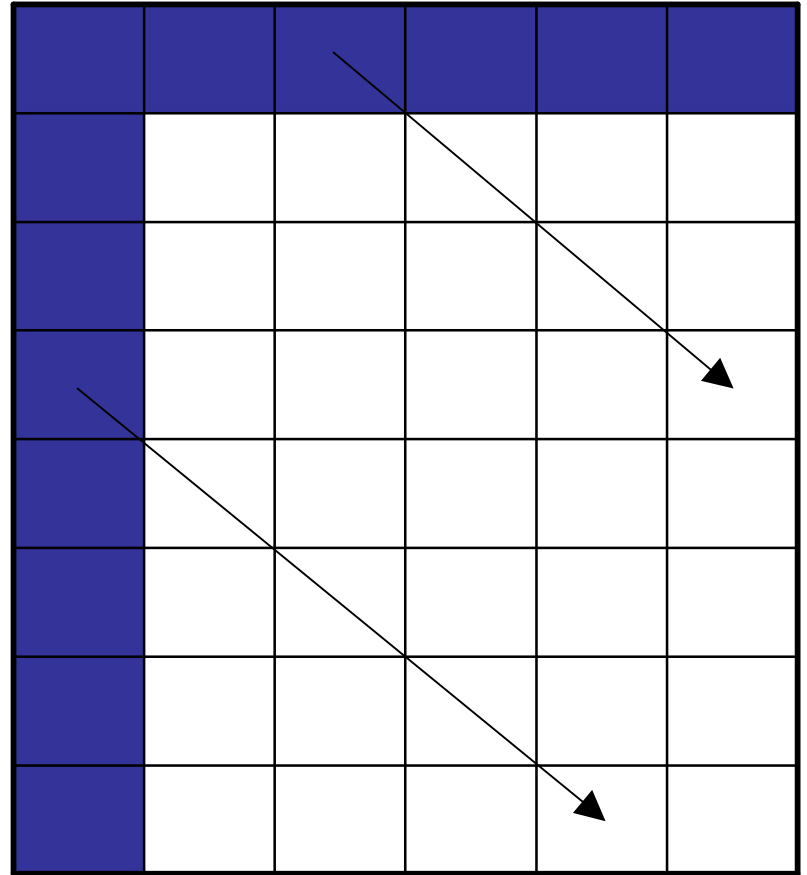
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Importance of Discard Mortality

SCAA

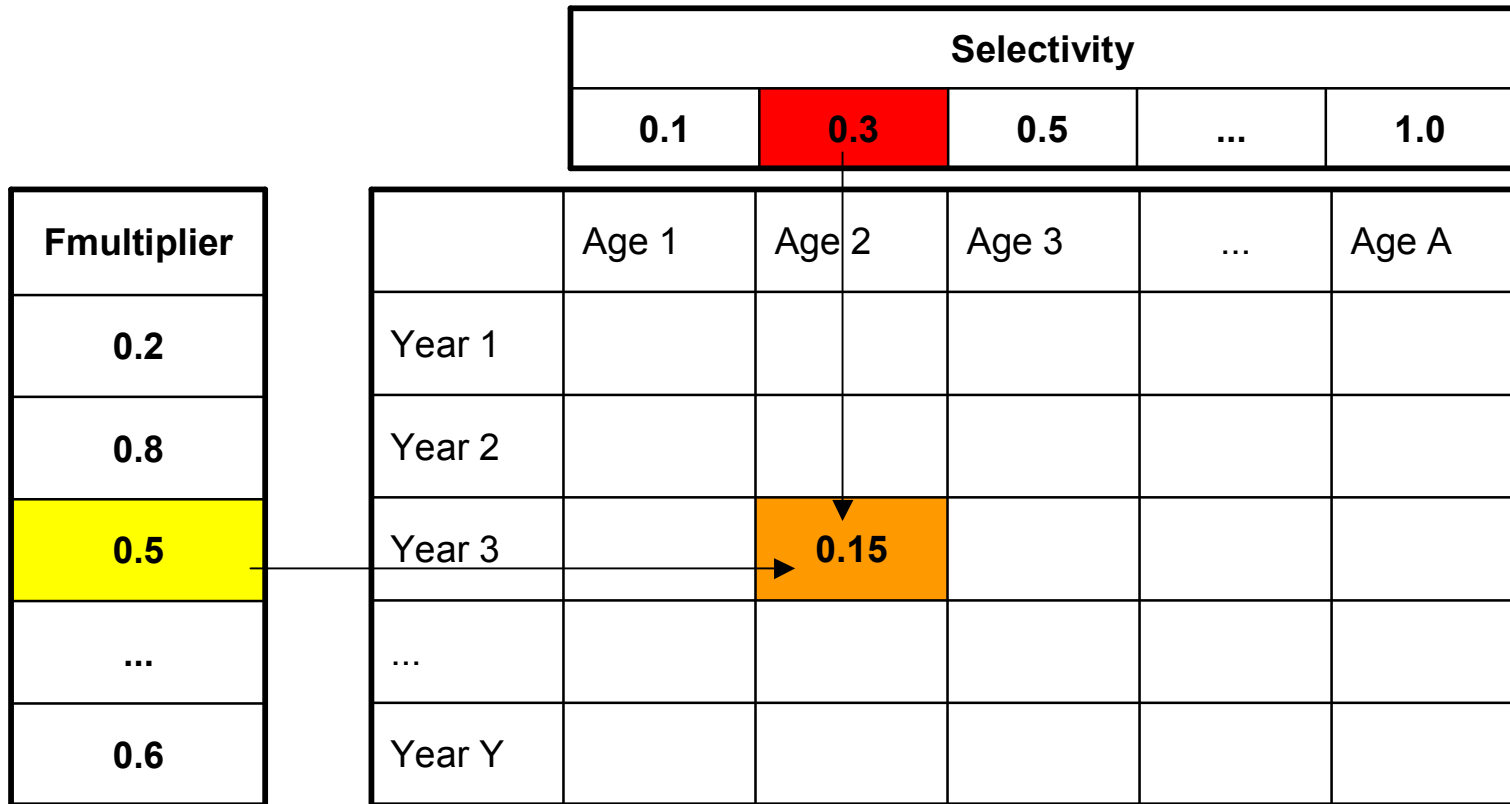
Age ->

Year
|
v



30

Separability of F



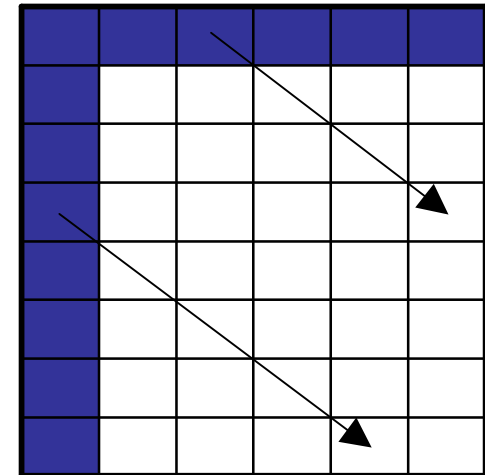
$$F_{y,a} = F_{mult,y} P_a$$

$$Z_{y,a} = F_{y,a} + M$$

Population

- Conventional age-based population dynamics formulas
- Need initial age structure and recruitments
- Rest of matrix filled given Z matrix

$$N_{y,a} = N_{y-1,a-1} e^{(-Z_{y-1,a-1})}$$



Catch

- Catch equation for whole matrix

$$C_{y,a} = N_{y,a} F_{y,a} (1 - e^{-Z_{y,a}}) / Z_{y,a}$$

- Now compare to observed catch 2 ways
 - Total catch in weight (yield)

$$Y_y = \sum_a (C_{y,a} * Wt_{y,a})$$

- Catch at age proportions

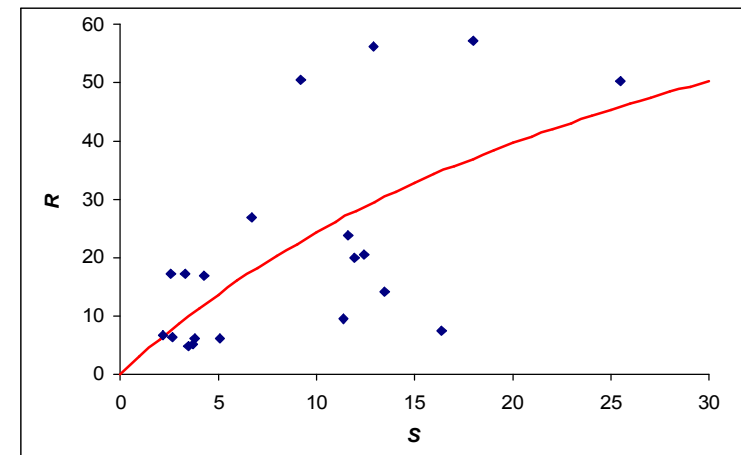
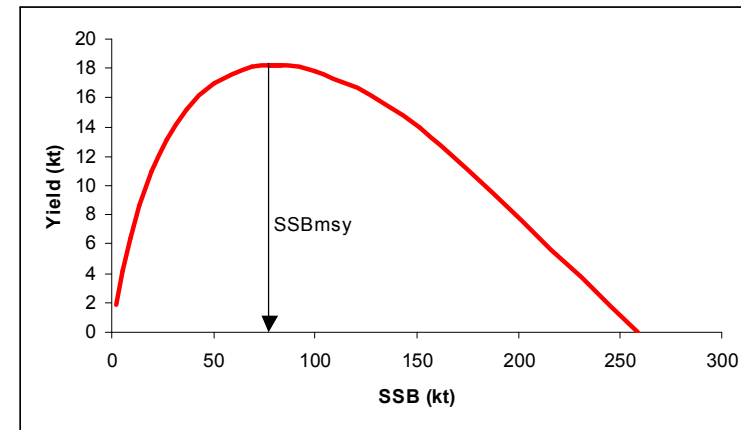
$$CP_{y,a} = \frac{C_{y,a}}{\sum_a C_{y,a}}$$

Effect of Inaccurate Discard Mortality on Forward Projection Models

- Biased removals add process error (changes in relative abundance don't match estimated catch).
- Under/over estimated catch usually will produce a proportional and cumulative bias in stock size in all years, but it may also lead to unpredictable inaccuracies associated with incorrect model solutions.
- Discard mortality can be added as an estimable parameter, but requires prior information from field estimation, good selectivity data and precise information on relative abundance at age.

Effect of Inaccurate Discard Mortality on MSY Reference Points

- Under/overestimated catch will bias observed production, typically causing a proportional bias in MSY and Bmsy and disproportional bias in Fmsy, but it may also lead to unpredictable inaccuracies associated with incorrect model solutions.
- Under/overestimated recruitment will produce a proportional bias in MSY and Bmsy.
- Inaccurate recruitment and stock size estimates will alter the stock-recruit relationship producing unpredictable bias in all MSY reference points
- Inaccurate selectivity at age will produce a disproportional bias in Fmsy.



Summary

- Accurate estimates of discard mortality are important to derive reliable total catch and catch at age.
- Stock assessment models will produce biased results in predictable and unpredictable ways, depending on the model.
- Inaccurate estimates of discard mortality may cause considerable uncertainty for fishery management.