Surplus Production models

- Logistic growth
- MSY
- Catch-effort
- How to fit, examples
- Alternatives
- Chapter 7 in text

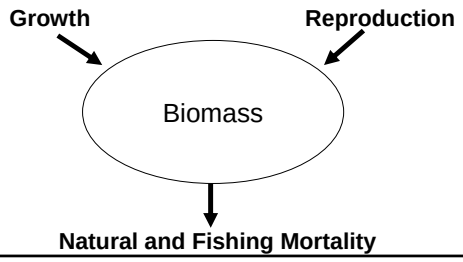
Surplus production models

- **View population as one unit of biomass, with all individuals having the same growth and mortality rates (no age structure)**
- **Conform to basic ideas of compensation and sustainable exploitation**
- **AKA….production models, stock production models, surplus yield models, biomass dynamic models**
- **Simplest stock assessment tool, peaked in popularity during the 1950's-1970's**

Surplus production models

Variation in population biomass results from:

- **increases due to growth and reproduction (termed production), and…..**
- **decreases from natural and fishing mortality**



Surplus production models

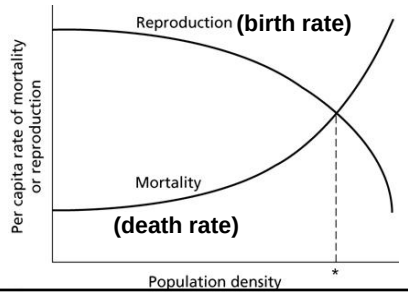
- Based on the principle that fish populations, on the average, produce more offspring than necessary to replenish themselves
- Therefore, on the average, fisheries should be able to harvest this excess (surplus) production without endangering the population
- In essence, no effect on the stock

Surplus production models

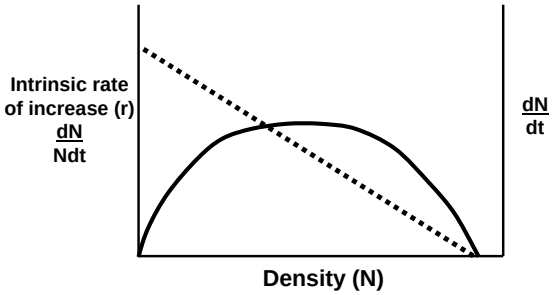
- In theory, we should be able to estimate the amount of surplus available, and….
- The population could be fished at a level that maximizes the surplus biomass harvested each year
- This is known as the maximum sustainable yield (MSY)

Surplus production models

- Remember, compensatory density dependence allows population to sustain additional mortality due to harvest

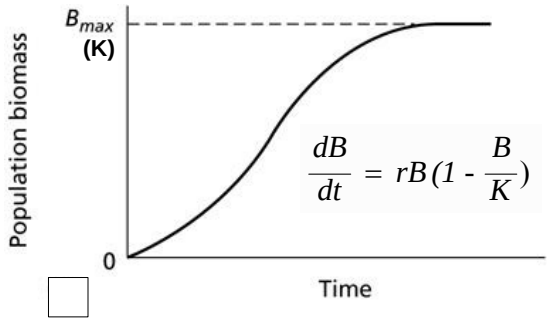


Surplus production models



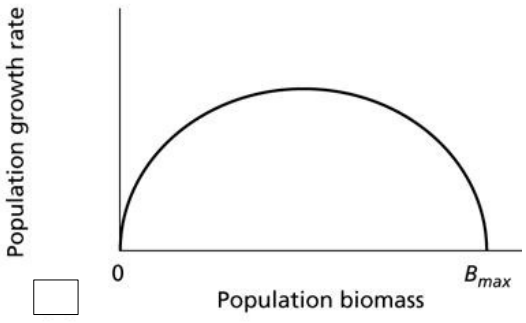
Surplus production models

- **Rooted in logistic population growth**

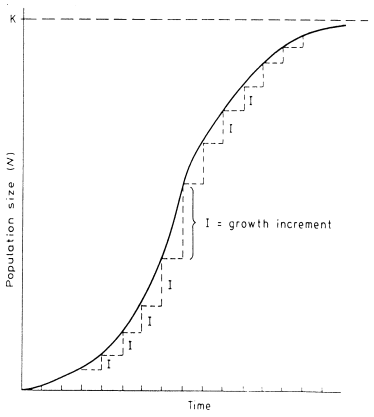


Surplus production models

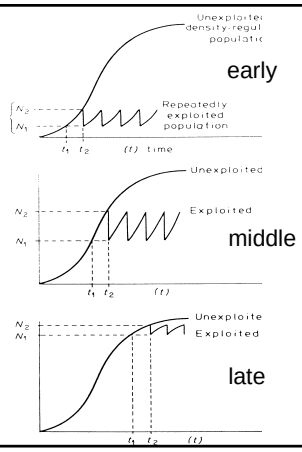
Population growth is max at intermediate levels



- Growth is max at intermediate levels



- Growth is max at intermediate levels

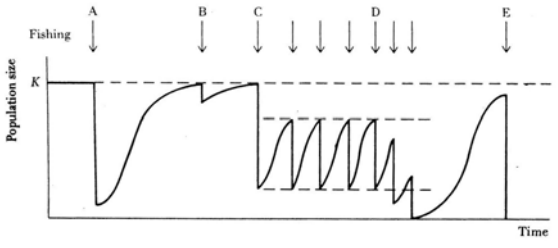


early

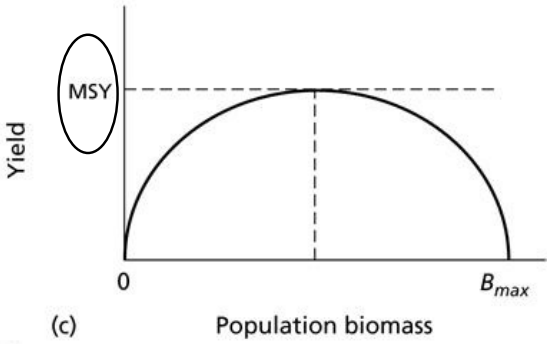
middle

late

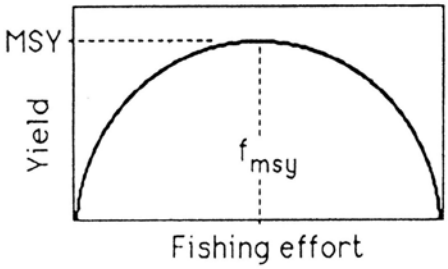
- **Growth is max at intermediate levels**



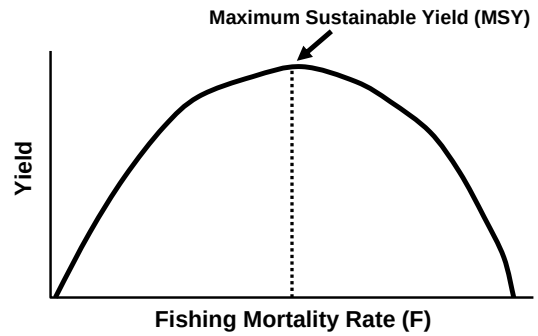
- **MSY at intermediate levels ($B_{max}/2$)**



- Note that since fishing mortality rate (F) and effort are assumed to be inversely proportional to biomass, either effort or F can be plotted against yield



So, $F_{opt} = F_{MSY}$



MSY from Catch-effort curves

The Schaefer (logistic) equation (rate of change of biomass):

$$dB/dt = r\,B\,[1-B/B_{max}]$$

The catch or yield (Y) is deducted:

$$dB/dt = r\,B\,[1-B/B_{max}] - Y$$

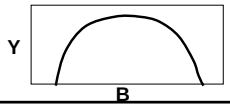
MSY from Catch-effort curves

$$dB/dt = r\,B\,[1-B/B_{max}] - Y$$

- At equilibrium, removals = growth, and dB/dt = 0:

$$Y = r\,B\,[1-B/B_{max}] \qquad (1)$$

This is the parabolic curve describing yield vs. biomass



MSY from Catch-effort curves

At equilibrium, removals = growth, (dB/dt=0):

$$Y = r\,B\,[1-B/B_{max}] \qquad (1)$$

Yield = catchability × effort × biomass

$$Y=qfB$$

sinceY/f = CPUE, then CPUE = qB

$$B = CPUE/q \qquad (2)$$

MSY from Catch-effort curves

$Y = r\,B\,[1-B/B_{max}]$ (1)

$B = CPUE/q$ (2)

Substituting (2) into (1) we get:

$Y = r(CPUE/q)\,[1-(CPUE/q/CPUE_{max}/q)]$

where $CPUE_{max}$ is CPUE at max biomass (B_{max}) of the stock

MSY from Catch-effort curves

$Y = r(CPUE/q)\,[1-(CPUE/q)/(CPUE_{max}/q)]$

$Y = rCPUE/q\,[1-CPUE/CPUE_{max}]$

Dividing by CPUE we get:

$Y/CPUE = f = r/q\,[1-CPUE/CPUE_{max}]$

Which after rearranging (trust me!) becomes:

$CPUE = CPUE_{max}-[CPUE_{max}q/r]\,f$

MSY from Catch-effort curves

$CPUE = CPUE_{max}-[CPUE_{max}q/r]\,f$

Multiplying by effort (f) and since $Y = f \times CPUE$

We get:

$$\mathbf{Y = af + bf^2}$$

This is Schaefer's model relating yield to fishing effort

MSY from Catch-effort curves

So we've just used algebra to go from:

$$dB/dt = r\,B\,[1-B/B_{max}] - Y$$

To this:

$$Y = af + bf^2$$

Schaefer's model relating yield to fishing effort

But, how do we get a and b?

MSY from Catch-effort curves

How do we get a and b?

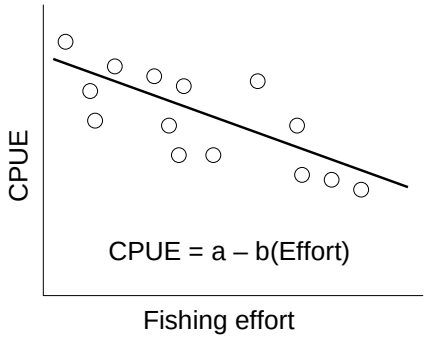
$$Y = af + bf^2$$

Dividing both sides by f gives us:

$$Y/f = a + bf$$

And Y/f = CPUE

Plot CPUE vs. Fishing Effort



Predicting Effort for MSY

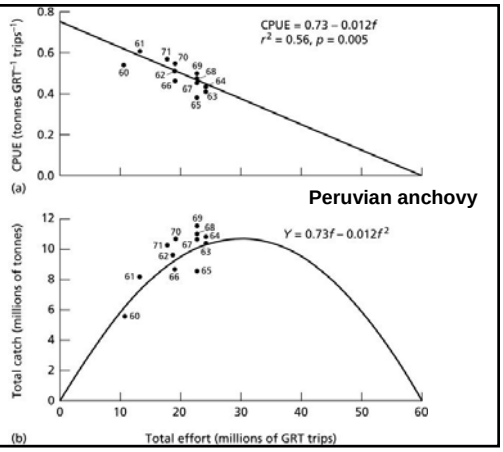
From plot of CPUE vs. Effort we have:

CPUE = a – b(Effort)

Plug a and b into:

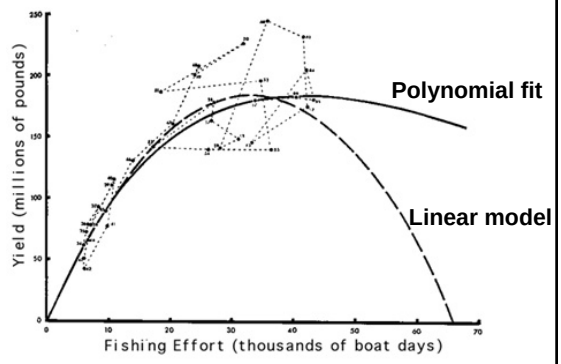
$$Y = af + bf^2$$

This will generate the predicted parabolic curve relating Y and f



Peruvian anchovy

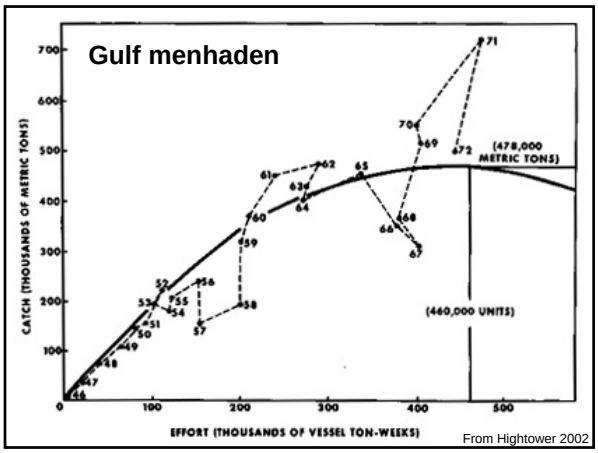
Eastern tropical Pacific yellowfin tuna

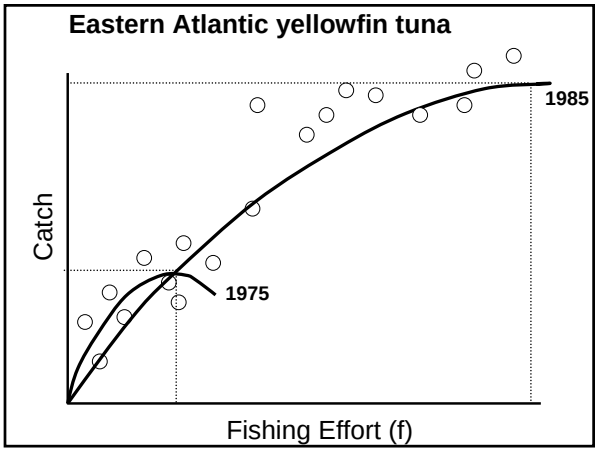


Polynomial fit

Linear model

From Hightower 2002





Catch-effort curves:
alternatives to Schaefer

- Fox curve (section 7.3) is more appropriate for biomass measurements (logistic curve usually with numbers)
- MSY to the left of logistic level

Catch-effort curves:
alternatives to Schaefer

- Pella-Tomlinson model (section 7.3) allows for flexibility in shape of production curve
- No longer has to be symmetric
- MSY to the left or right of logistic level ('based on third parameter = m')

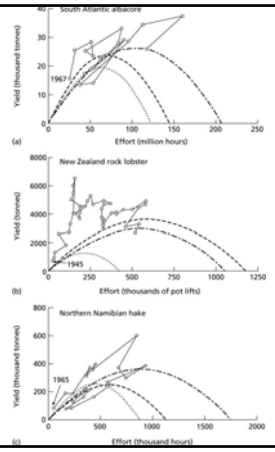
Surplus production approach:
Fitting models to data

- Equilibrium methods:
  - Assumes stock has stabilized at current rate of fishing
  - Basically, every year, catch = surplus production

Hilborn and Walters conclude: "…equilbrium-fitting methods are biased, unreliable, and simply should be thrown out."

Surplus production approach:
Fitting models to data

- Equilibrium methods:
  - Assumes stock has stabilized at current rate of fishing
- Non-equilibrium methods:
  - Process-error methods
    - No equilibrium assumption
    - All error in population growth relationship
    - Catch and effort data measured without error
  - Observation-error methods
    - All error in catch and effort data
    - Time series analysis of CPUE data



Observation error methods were most conservative

Data problems

Lack of contrast

- **Need high F's to observe r at low biomass**
- **Need low F's to detect K and any density-dependent changes in recruitment, growth, or mortality at high biomass**

Changes in catchability

- **Variation in gear, electronics, knowledge, fish distributions**
- **Violates CPUE = qB**

Surplus production approach:

Assumptions

- **abundance index (CPUE) is proportional to true abundance (Biomass)**
- **instantaneous reaction of stock**
- **symmetric parabola**
- **need large range of efforts (high and low)**
- **stock is self-contained**
- **any loss is mortality**
- **no interspecific interactions**
- **the environment is constant**
- **fishing is density-independent**

Surplus production approach:
Advantages

- calculate MSY and F_{opt} without catchability
- requires only catch and effort data
- don't need to know age structure
- inexpensive

Surplus production approach:
Disadvantages

- does not incorporate environmental factors
- excludes trophic linkages
- assumes stock has stabilized at current rate of fishing
- doesn't tell us much about the mechanisms affecting the population dynamics

Surplus production poetic humor

Hope from him had almost drained;
His children all had been entrained.
The last striped bass in Hudson River
Gave a pained, convulsive shiver.

His civil rights had been infringed-
On intake screen he hung impinged.
But yet one chance to outwit fate:
"I think I still can compensate!"

J. McFadden 1977

Surplus production poetic humor

Perhaps a fitting reply:

No need to compensate, old friend,
On the verge of your destruction.
We've double-checked our models and
Find you're just surplus production.

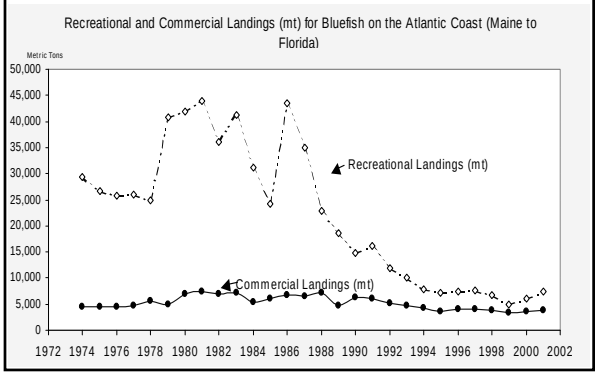
J. Boreman 1999

US bluefish fishery

- About 80% of the US Atlantic bluefish landings come from recreational fisheries mostly in state waters.
- Shore mode, private, and charter modes
- Commercial landings take the remaining 20% of harvest by floating traps, gillnets, and trawl.

➢ **Recent years commercial catches make up about 35-40%**

Landings



Fitting algorithm

The model estimates a beginning biomass from which a prediction of time series abundance indices is made (Ut). The parameters r, k, q, and Uo are adjusted until the best fit between the observed and predicted abundance is achieved

Minimize

Sum (Obs Ut – Pred Ut) ^{2}

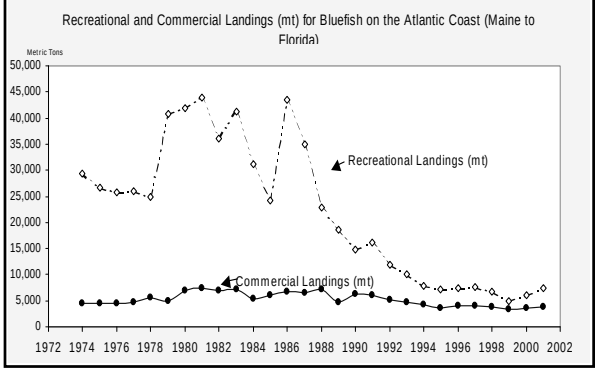
Management quantities

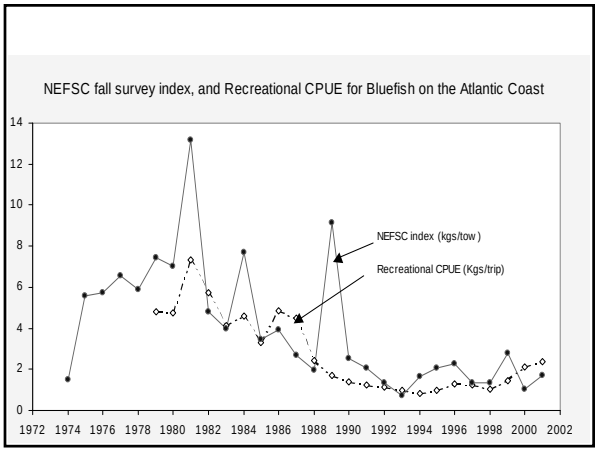
- Maximum Sustainable Yield MSY=rB_∞/4
- Biomass for MSY Bmsy=B_∞/2
- Fishing mortality rate at MSY Fmsy=r/2
- Effort at MSY fmsy=r/2q
- Maximum F near collapse Fcoll=r
- Effort at maximum fcoll=r/q

Input Data

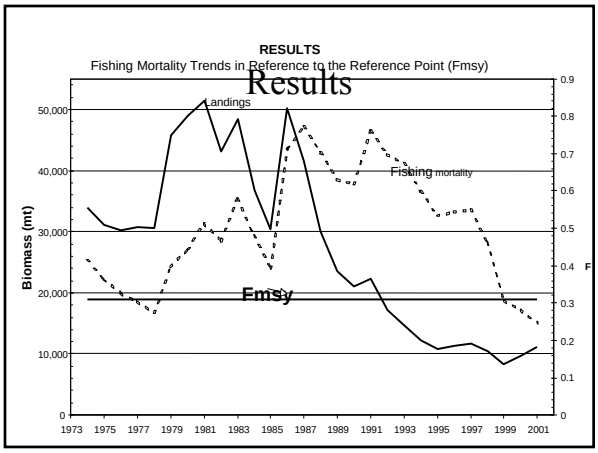
- Commercial landings 1974-2001 (NMFS)
- Recreational landings, and 15% of recreational discards.
  - 81-01 from MRFSS
  - 79-80 from MRFSS reports
  - 74-78 from Boreman (1983) adjusted by 0.5
- CPUE is calculated as the catch in trips identified as targeting bluefish in the Atlantic Coast (1979-2001)
- Biomass index from the NEFSC inshore trawl survey index (1974-2001)

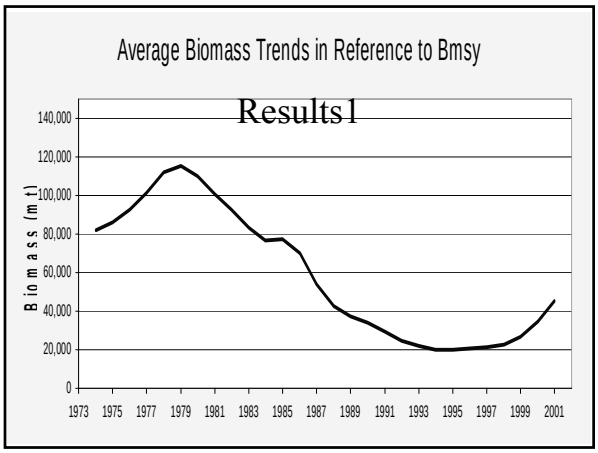
Landings

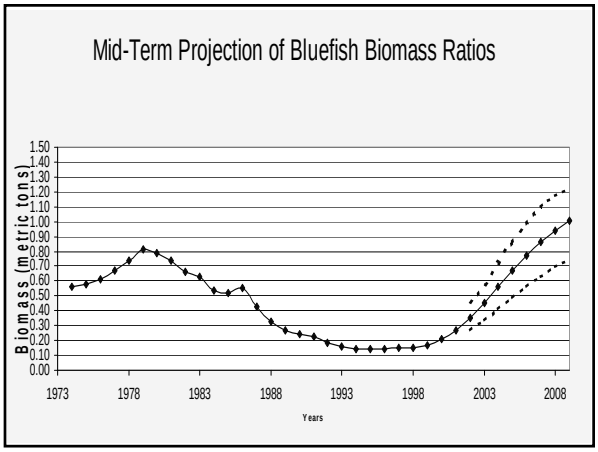




Results







Conclusions

- Bluefish stock is overfished but overfishing is not occurring.
- F2001 is estimated below the reference point Fmsy=0.4
- Biomass has increased in recent years but remains below Bmsy (73% of the threshhold)
- Mid-term Projections show stock might be restored by 2007 if F is maintained below Fmsy