Yield Per Recruit

Reading:

See Jennings et al. 2001, section 7.7

Haddon et al. 2011, section 2.8

Yield Per Recruit (YPR) models

Main questions:

- How hard should we fish to optimize harvest?
- What is the optimum age (or size) at first capture?
  - Lots of small fish or fewer big fish?

YPR is called a "**dynamic pool model**"

What are Dynamic Pool Models?

- Simple age-structured models
- Deterministic models
- Include mortality and growth models
- Widely used to develop reference points used to manage fisheries
- Common Types :
  - **Yield per recruit (YPR) → TODAY**
  - Spawning Stock Biomass per Recruit (SSB/R, S/R)
  - Egg per recruit

YPR – In class exercise

- See hand out
- Explanation of exercise
- Preliminary questions
  - If your goal is to maximize your yield, what fishing strategy do you think will be best: u=80%, 50%, 40%, 30%, 20%, 10%?

- Break up into groups and calculate the values. Then, fill in the summary table on the board.

Example

- *values rounded to 1 decimal place

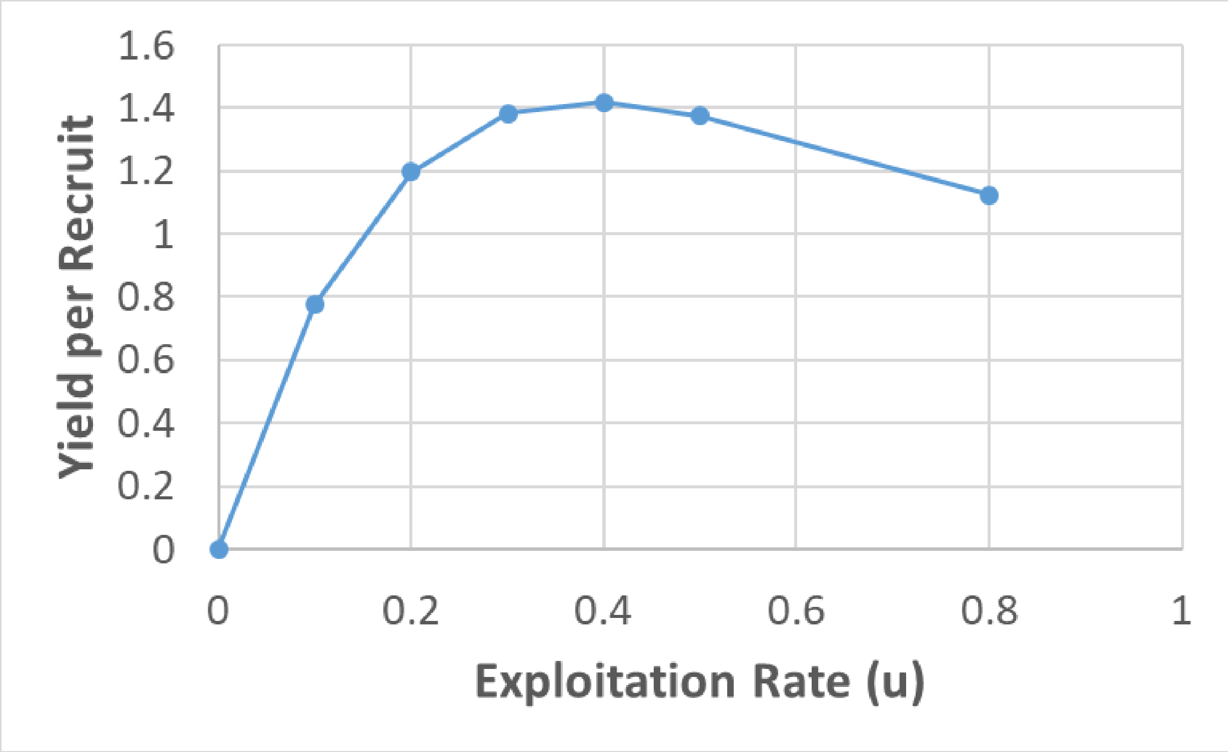
		Exploitation rate of 80% (u=0.8)		
Age (a)	Weight (W, in kg)	Stock Size (N)	Catch (C)	Catch Wt (kg)
1	--	1000	--	--
2	1	200 ($(1-u)*N_{a-1}$)	800 ($u*N_{a-1}$)	800 ($C*W_a$)
3	1.5	40.0	160.0	240.0
4	2	8.0	32.0	64.0
5	2.5	1.6	6.4	16.0
6	3	0.3	1.3	3.8
		TOTAL	1000	1124
			YPR	**1.124**

Write your YPR Results on the board

Fishing Scenario	Total Catch (# of fish)	Total Catch (kg)	Initial Recruits	Yield per recruit
u=0.8			1000	
u=0.5			1000	
u=0.4			1000	
u=0.3			1000	
u=0.2			1000	
u=0.1			1000	

- What do the results mean?
- Did the results match your prediction? Why or why not?
- What were the tradeoffs with the different strategies?
- What would happen if we introduced natural mortality?

YPR Results

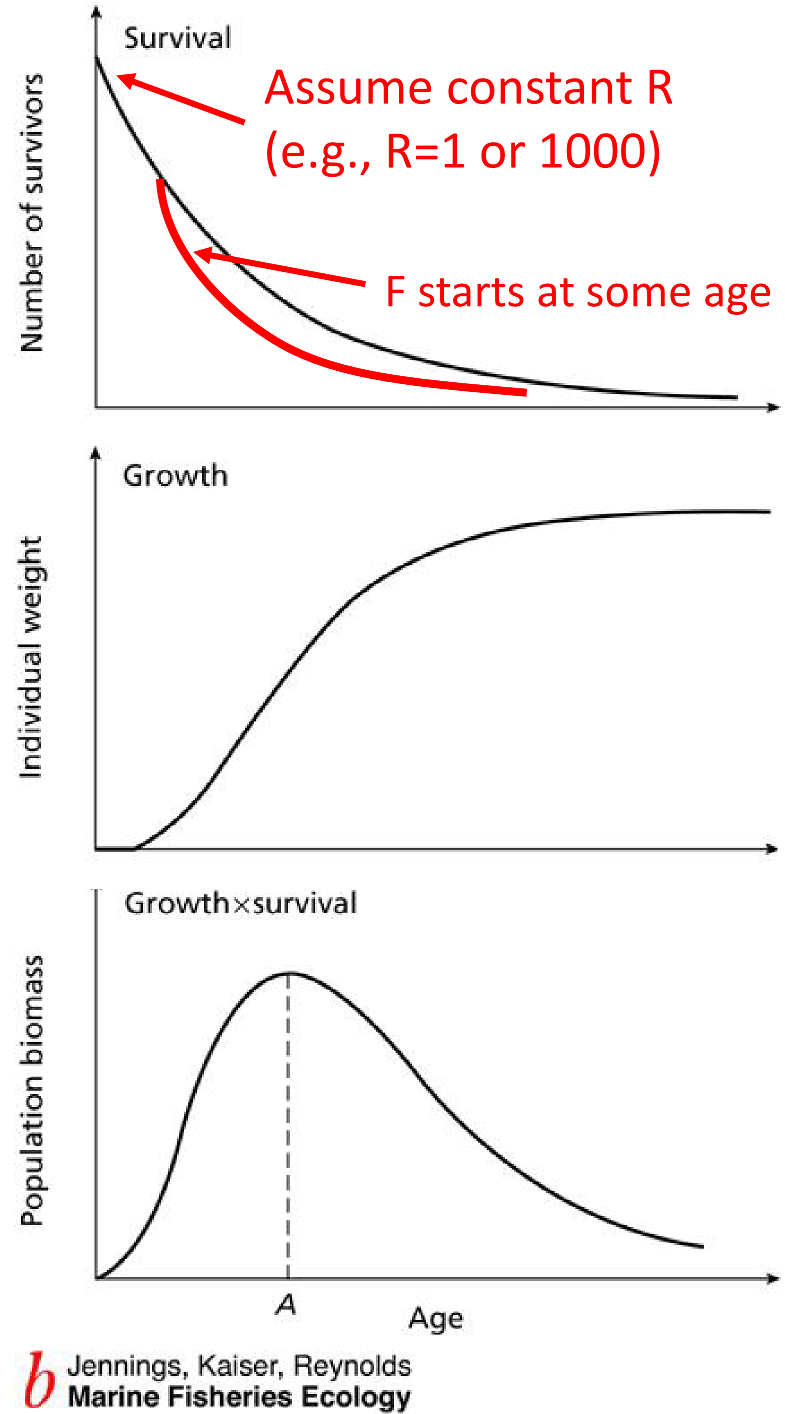


Fishing Scenario	Total Catch (# of fish)	Total Catch (kg)	Initial Recruits	Yield per recruit
u=0.1	410	776	1000	0.776
u=0.2	672	1198	1000	1.198
u=0.3	832	1382	1000	1.382
u=0.4	922	1420	1000	1.420
u=0.5	969	1375	1000	1.375
u=0.8	1000	1124	1000	1.124

Yield Per Recruit (YPR)

Fishing yield affected by a tradeoff between growth and mortality

- Basic Idea
    - Assume constant R
    - Simulate declines in N by age
    - Account for increases in W at age
    - Calculate Biomass at age
    - Estimate yield
        - given F and age at capture
    - Repeat for different fishing scenarios to find the optimum yield



YPR

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How do we express this as an equation?

Yield Per Recruit (YPR)

- Model biomass and yield of a cohort over time, accounting for growth and mortality:

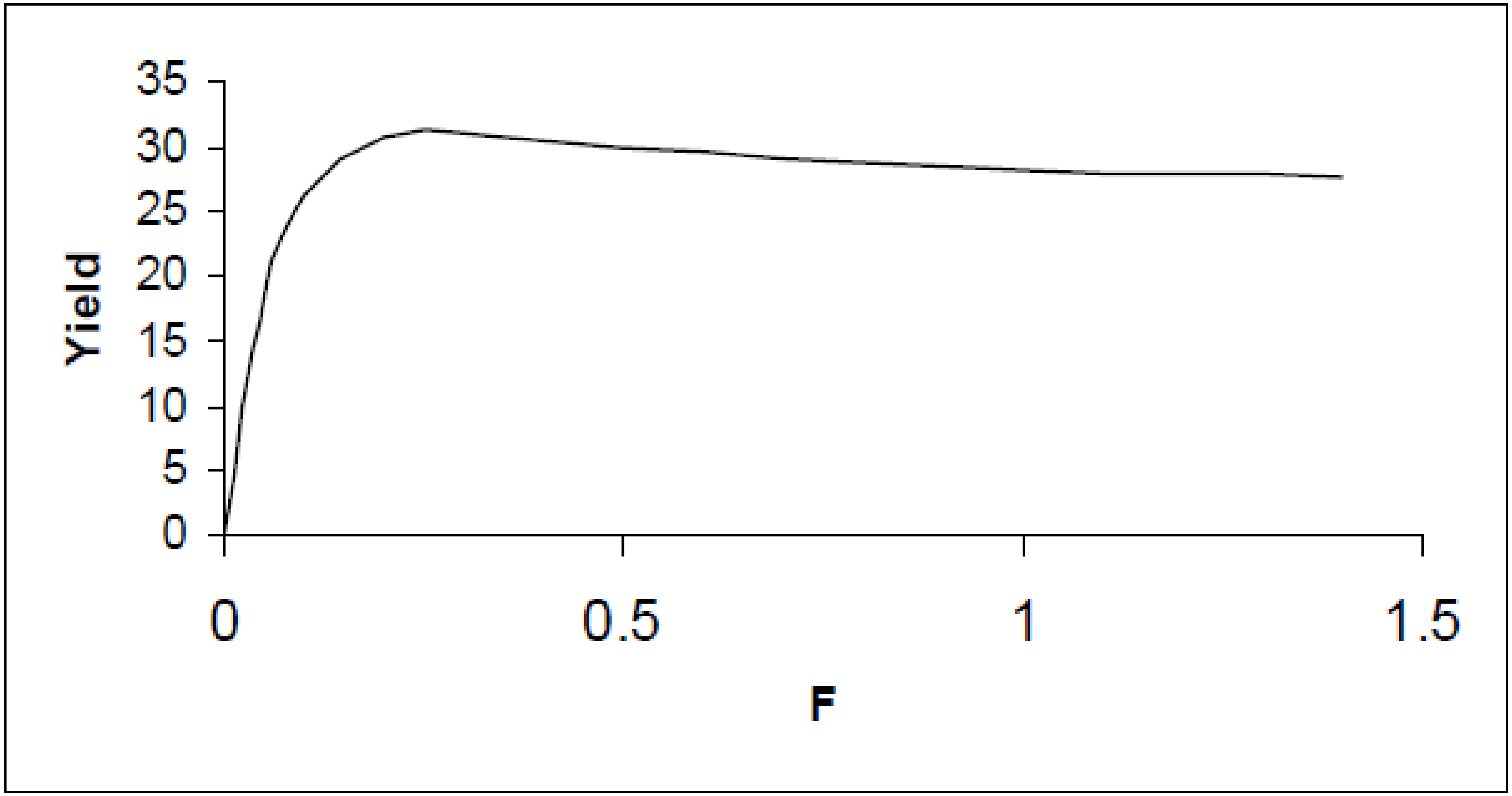
$$Y = \sum_{t=t_c}^{t_{max}} \frac{F_t}{Z_t}(1 - e^{-Z_t})N_t W_t \qquad Y = \sum_{t=t_c}^{t_{max}} u_t N_t W_t$$

  - Y = yield (in biomass) per fish recruited to fishery
  - t_c = age at first capture
  - t_{max} = max age that is captured
  - F_t = instantaneous fishing mortality rate at age t
  - Z_t = instantaneous total mortality rate
  - u_t = exploitation rate at age t (proportion harvested)
  - N_t = abundance at age t
  - W_t = weight at age t

How do we model Nt and Wt?

Yield (per recruit) vs. F

- Yield per recruit curve
  - Model is run for different values of F (e.g. our 6 scenarios)
- What do the different parts of this curve represent?



*Not uncommon to have a flat top to these curves

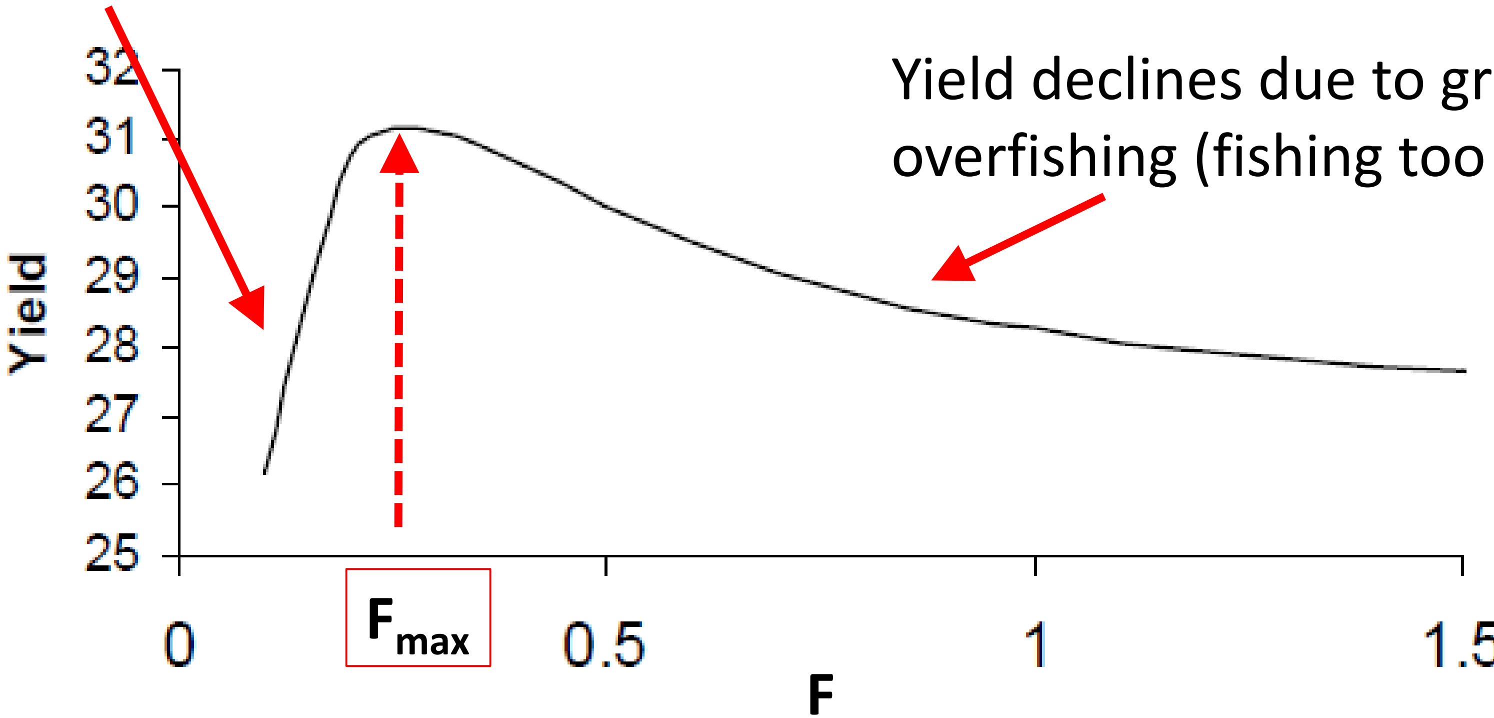
Yield (per recruit) vs. F

<u>Growth overfishing</u> – when fishing rates are too high, preventing the maximum yield being caught (b/c fish are prevented from growing to larger sizes)

Yield declines due to low fishing (not fishing hard enough)

Yield declines due to growth overfishing (fishing too hard)

*Change in Y-axis scale for viewing

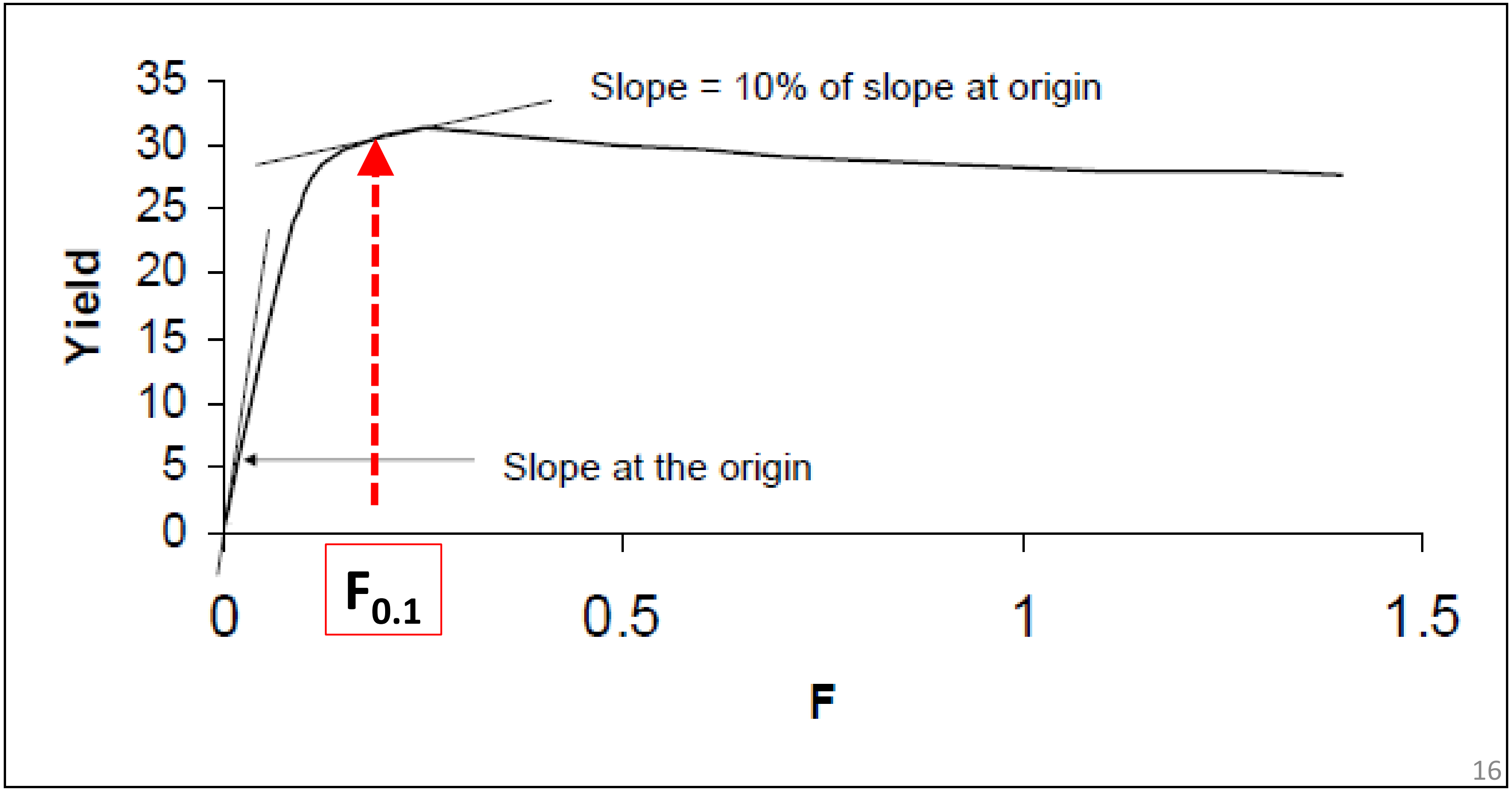


F_{max} = Fishing mortality rate that maximizes the yield per recruit

Use optimization function to find Fmax

$F_{0.1}$

- **$F_{0.1}$ = F where slope of YPR curve is 10% of slope at the origin**
- Conservative alternative to Fmax

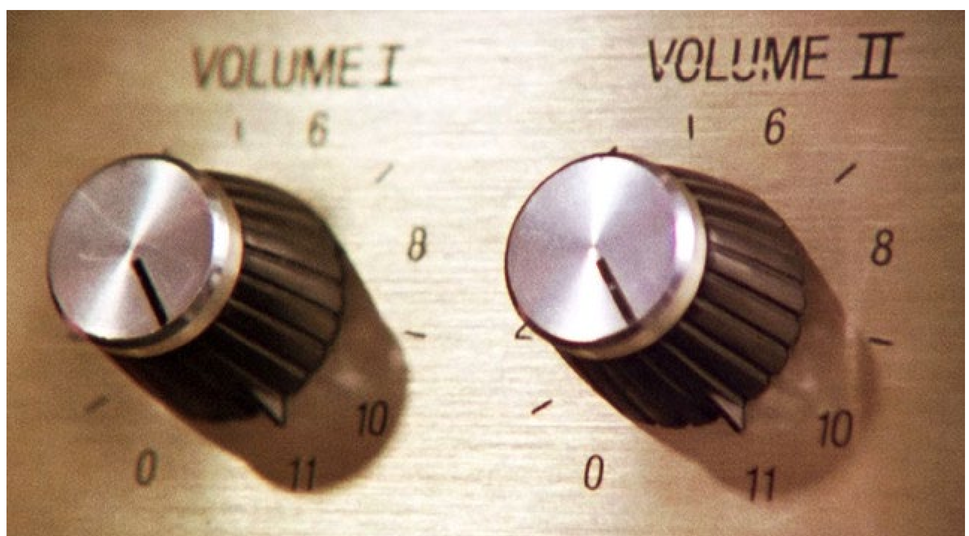


Comments on F_{max} and $F_{0.1}$

- **Biological reference points** – quantitative, biologically-based metric for a stock to inform management
- $F_{0.1}$
  - Ad hoc with no theoretical justification
  - More conservative
  - Greater stock stability with slightly lower yields
- Fmax ≠ Fmsy (don't confuse the two…)
- Usage
  - Still used somewhat in Europe and Canada
  - In US: Spawning Stock Biomass per Recruit favored

Yield per recruit models

- 2 main control variables:
  - Age at first capture, t_c (ie, selectivity pattern)
  - Fishing Mortality, F
- Try different combinations of t_c and F to maximize yield



Age at first capture (t_c)

- Assume constant M, but F only starts at t_c
- But we can change how abruptly F increases by changing the “selectivity”

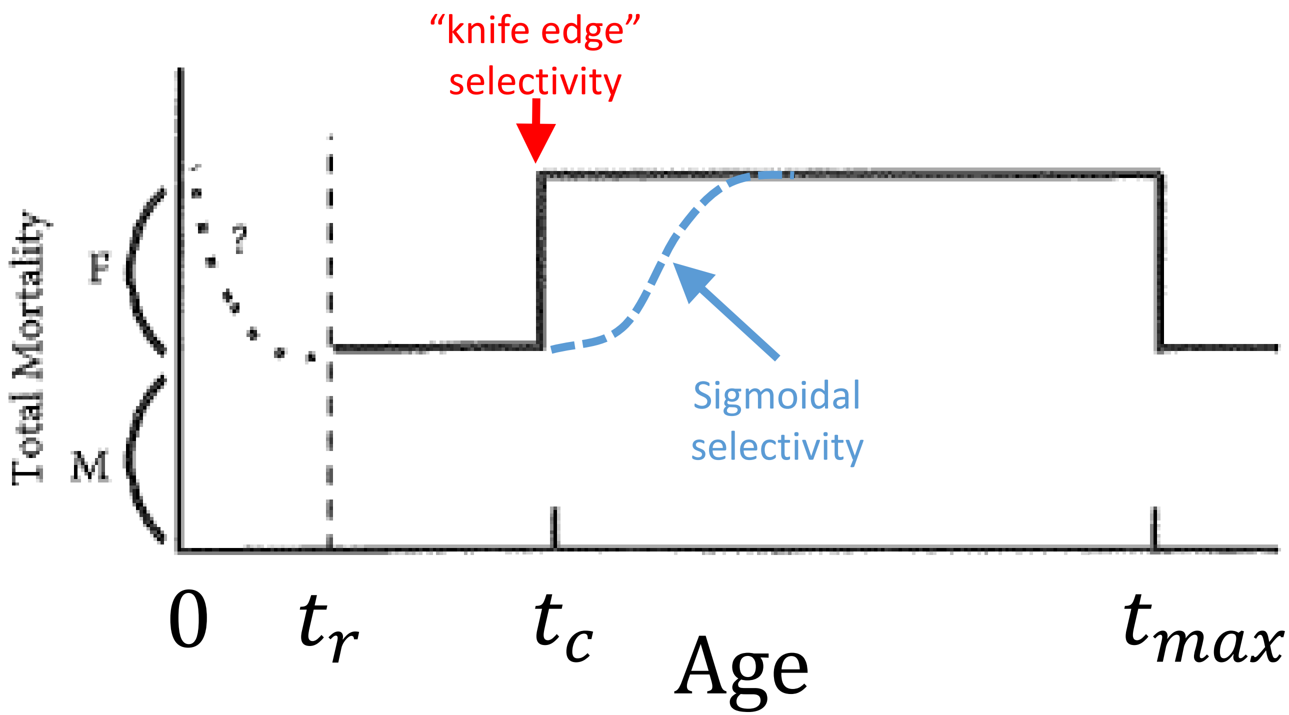
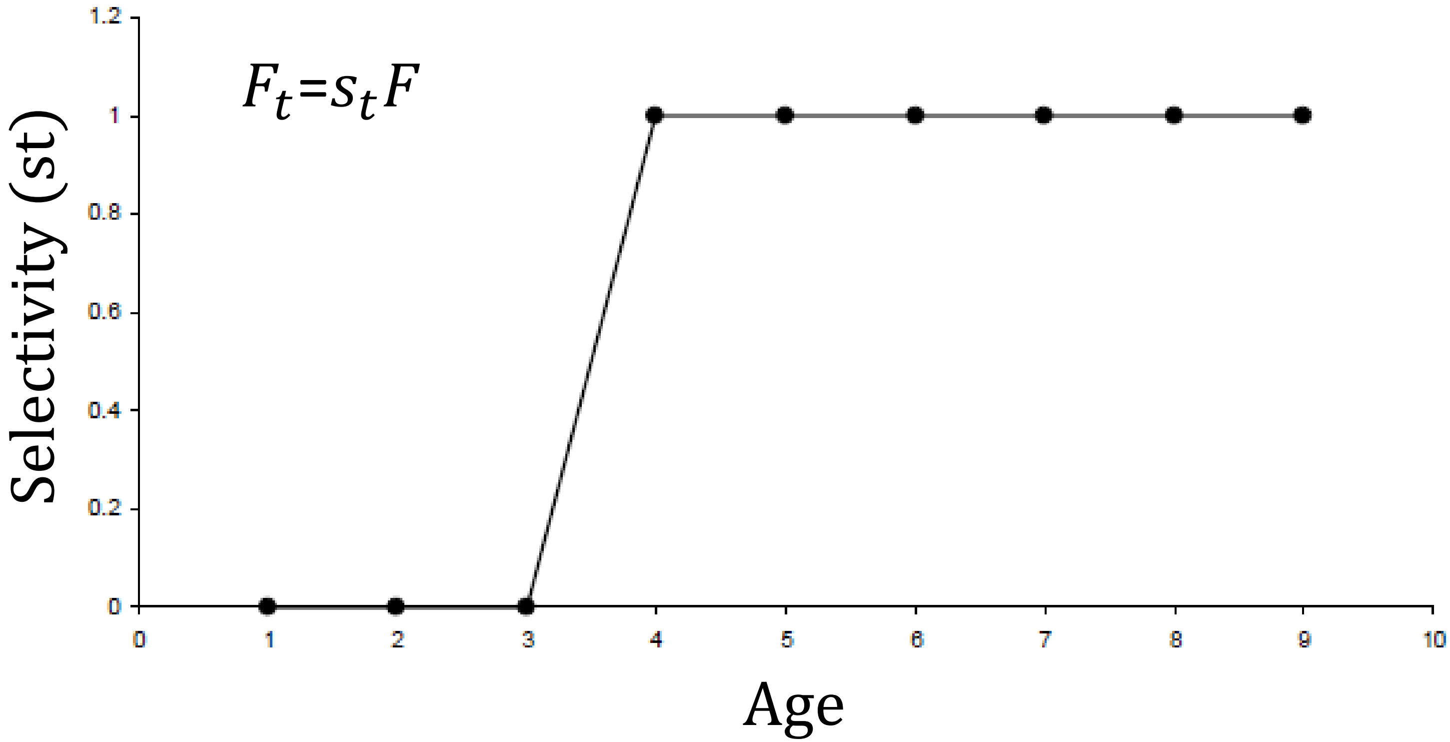


FIGURE 2.14
A diagram of the assumptions made in simple yield-per-recruit analysis. Here t_r is the age at recruitment, t_c is the age at first possible capture, and t_{max} is the age at which fish cease to be vulnerable to fishing. The model does not consider the dynamics of individuals younger than t_r years of age but simply assumes that there are R recruits of this age entering the stock each breeding period. M and F are the constant instantaneous rates of natural and fishing mortality, respectively. Knife-edge selection is shown by the vertical rise in mortality at t_c.

Fishing mortality by age

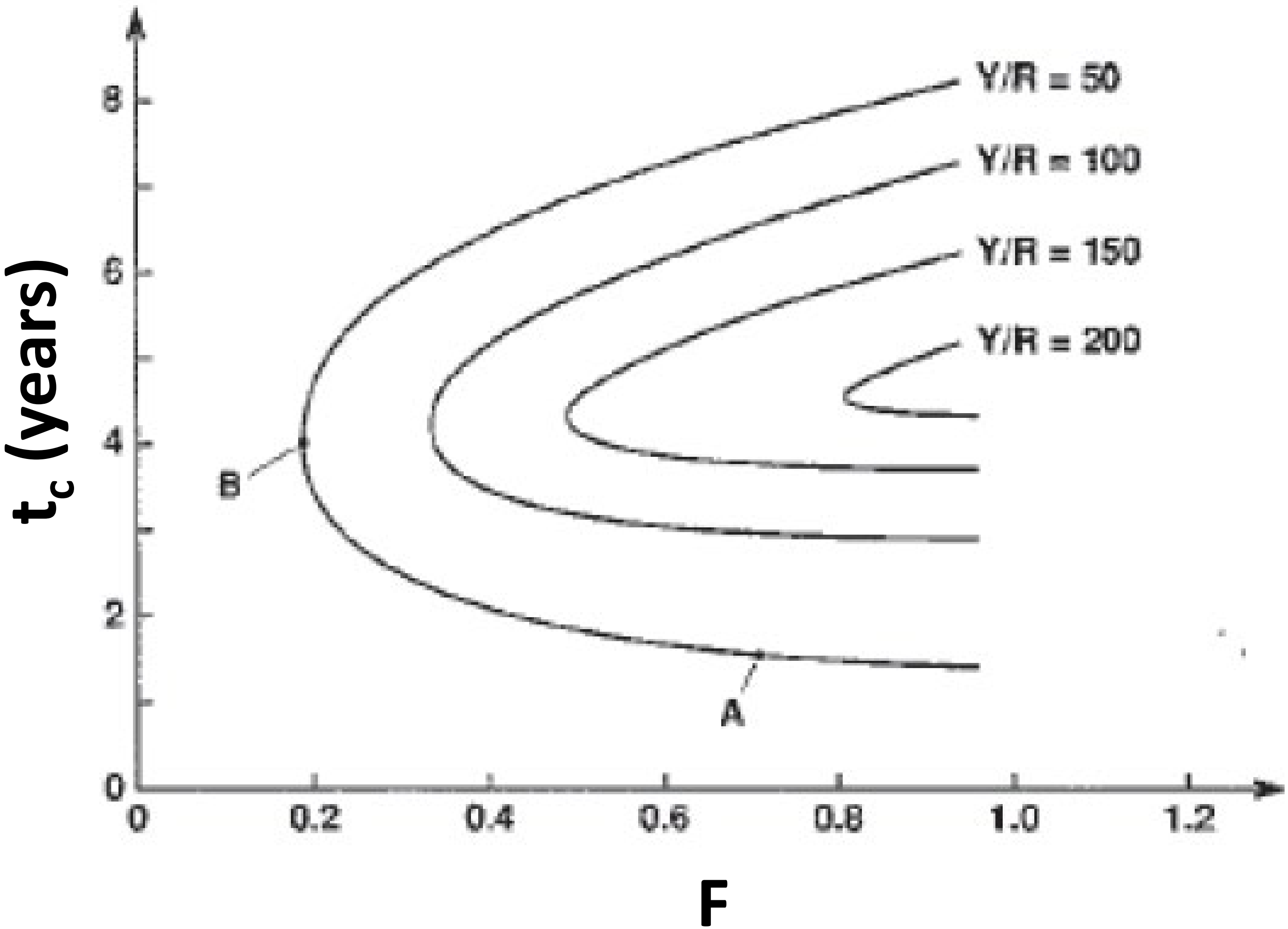
- **Age-specific selectivity** (s_t) = the probability of being vulnerable to fishing at age t (or some size)
  - This is known as "partial recruitment" for the **ypr()** function in R
- Simple model assumes knife-edge selectivity (but can have different shapes):



YPR Surface

Side: Beverton & Holt with cardboard cutout for YPR surface

YPR contour plot



Assumptions of YPR Models

- Constant recruitment (ie age-structure is at equilibrium or steady state)

- Constant mortality schedule

- Constant growth schedule

"I'm afarid we need someone with a little more backbone for this position."

Uses of YPR Models

- Develop reference points (F_{max}, $F_{0.1}$) for fisheries management (constant fishing rate harvest strategy)
  - Prevent growth overfishing
  - Evaluates things we can control (F, t_c)
- Determine optimal age at first capture
  - Gear regulations (e.g., mesh sizes, hook sizes, escapement holes, minimum sizes)
  - Season start date

Limitations of YPR Models

In what setting may some of these be more appropriate?

- Constant assumptions
  - Assumes steady state (e.g., constant R & age structure)
  - Constant mortality, selection, size at age schedules
  - This means no density dependence
- Used as a relative measure
  - does not estimate total yield which is of greater interest to fishers. (Total yield requires info on amount of R)
- Ignores effects of harvest on recruitment (no SR model)
  - No indication of whether F_{max} or $F_{0.1}$ is sustainable!
    - E.g., Some could predict t_c for juveniles; some predict infinite Fmax

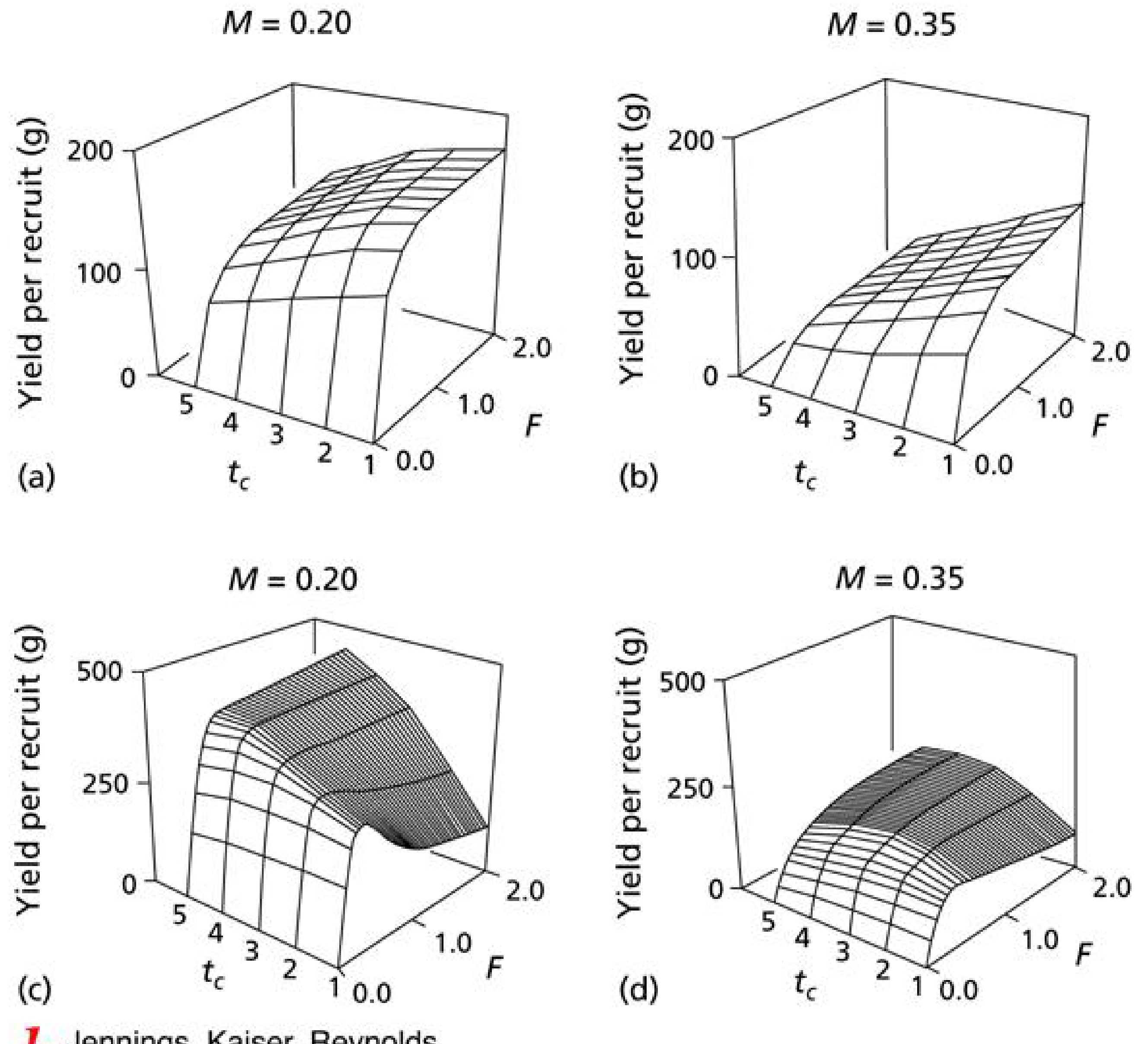
YPR example – Atlantic croaker

- Effect of region and M assumption?

- CB
  - Tc=age-2
  - Z~0.6
  - 1988-91 data
- NC
  - Tc=age-1
  - Z~1.3
  - 1979-81 data

Chesapeake Bay

North Carolina



Summary - YPR

$$Y = \sum_{t=t_c}^{t_{max}} \frac{F_t}{Z_t}(1 - e^{-Z_t})N_t W_t$$
$$or\ (u_t N_t W_t)$$

- **Yield per Recruit (YPR)**
  - **YPR** = estimate of the weight that each recruit contributes to fishery harvest over its lifetime (on average)
  - Goal of YPR models: evaluate fishing rates & age at capture (t_c) to maximize YPR
- YPR models account for:
  - age-structure
  - growth and mortality
- YPR models don't account for:
  - Recruitment, changes in growth or mortality schedules, or density dependence
- Provide info and reference points for management
  - Deals with **growth overfishing**
  - $\mathbf{F_{max}}$ and $\mathbf{F_{0.1}}$ (or $\mathbf{u_{max}}$ and $\mathbf{u_{0.1}}$)
  - Provides info on optimal **age at first capture**

know definitions & graphical representation