# WF4313/6413-Fisheries Management

Class 9


In the news &
announcements

# Refining Crappie (*Pomoxis spp.*) Aquaculture Techniques

Christian Shirley, M.S. candidate

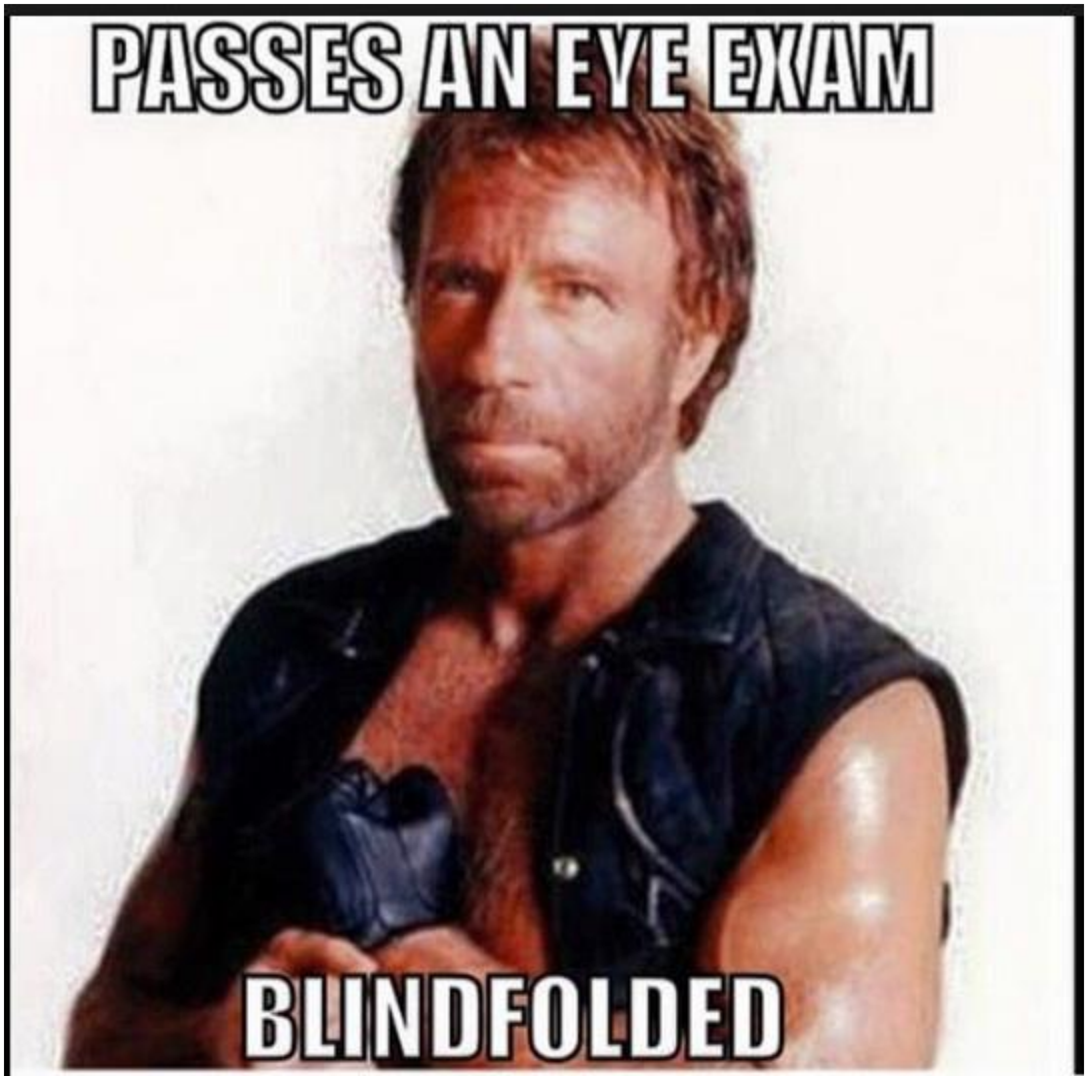
Thesis seminar

Department of Wildlife, Fisheries and Aquaculture

September 26, 2018 12:30 p.m.

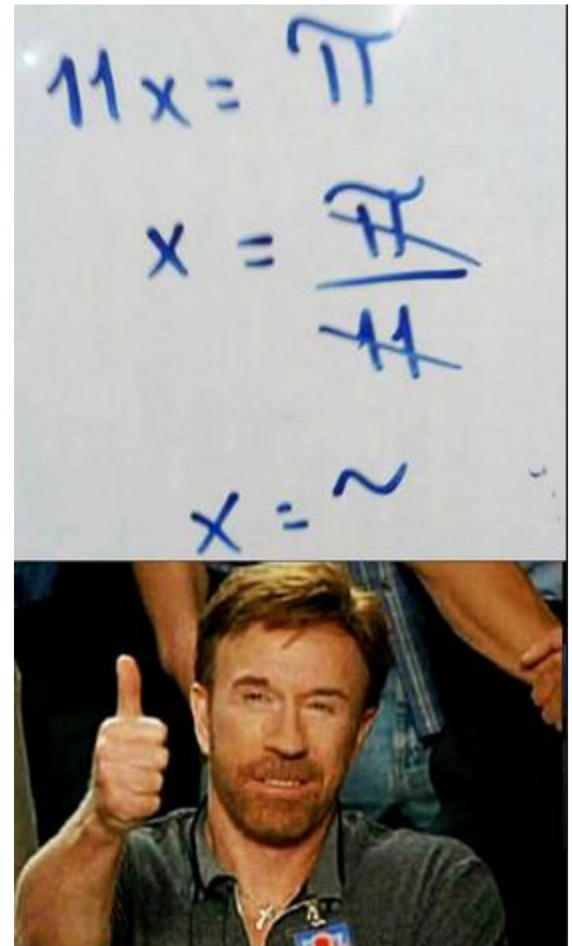
Tully Auditorium

# Exam 1: Monday October 1$^{st}$ @ 8am



# Some things to consider

- Do not memorize equations
- Know how to interpret a graph (e.g., length-weight, age-length).
- If you see things on slides in several places it is likely important!



FW4313 Fisheries Management Exam I September XX$^{th}$, 20XX

Name: ___________________________

Print your name at the top of each page (1 point deduction of you do not). Answer each question clearly and concisely. If you need additional space, please use the back of the exam. Make sure that your answers are clearly marked. You have a maximum of 50 minutes to complete the exam. This exam is worth a total of 125 points.

Remember to abide by the Mississippi State University Honor Code at all times.

1) Circle the most correct answer below. What is part of the conceptual process of fisheries management? (2 point)

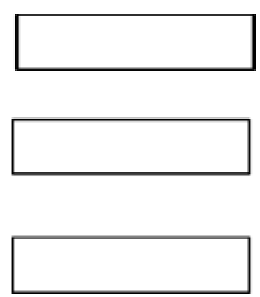
a) Internet marketing
b) Fishing license sales
c) Decision making
d) Fish sampling

2) Circle the most correct answer below. What is a necessary component of fisheries management? (2 point)

a) Fishing
b) Trophy fish
c) Total angler satisfaction
d) Allocation of resources

3) Is monitoring fish fishery management? (2 point)

4) Fill in the boxes with names and arrows representing the conceptual model of fisheries. (4 points)

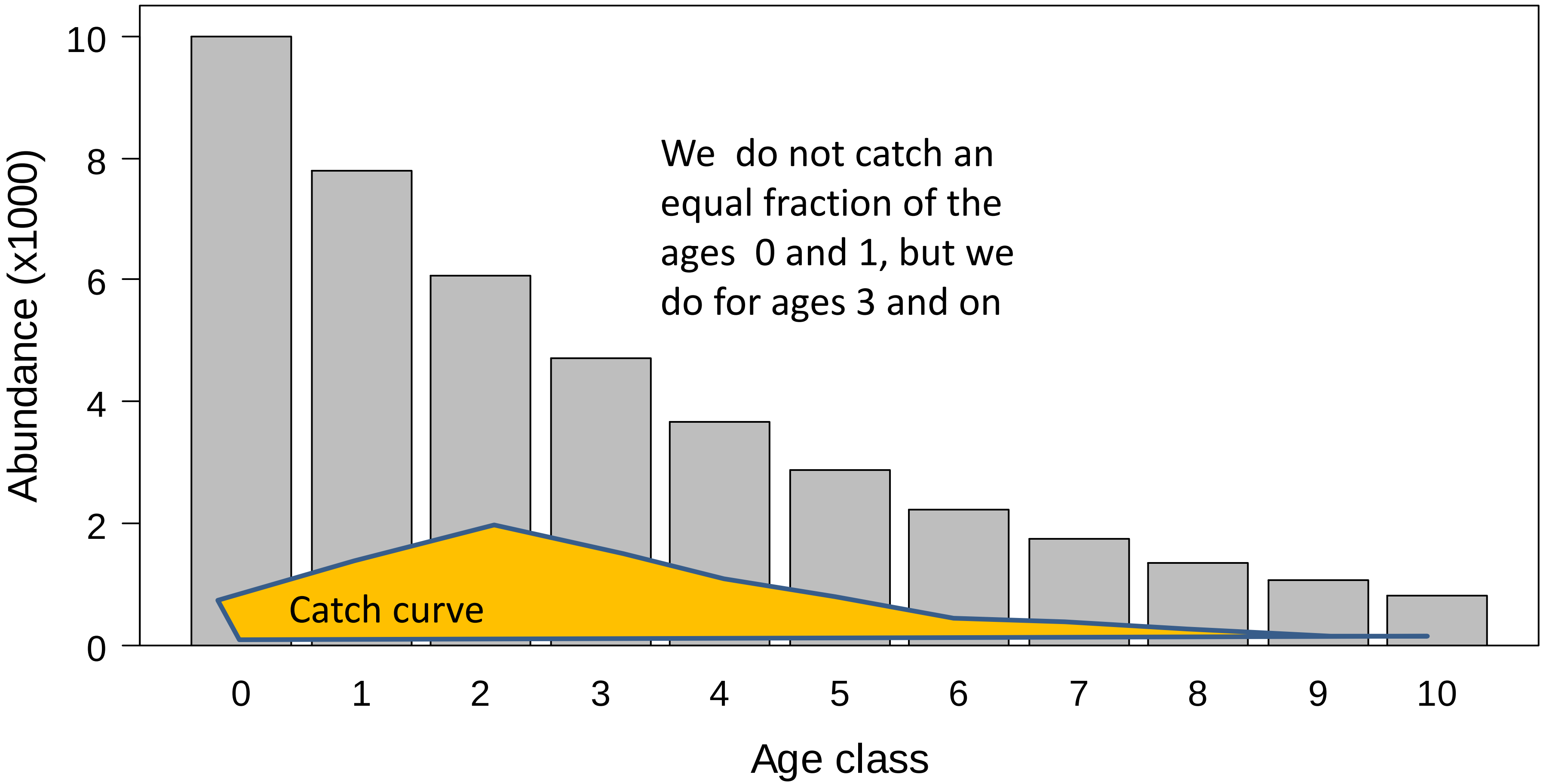


5) Circle the most correct answer below. How much is the seafood industry worth? (2 point)

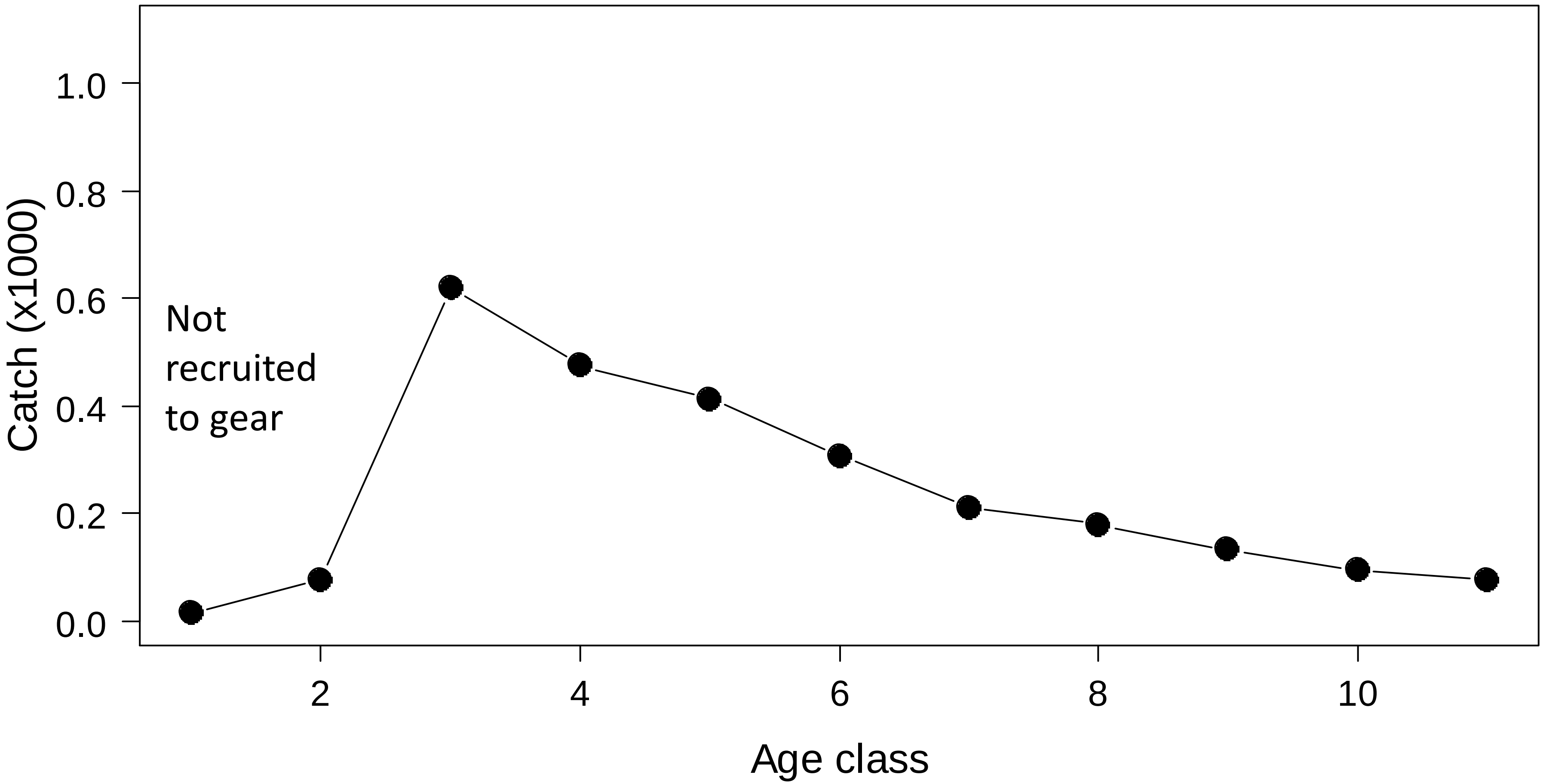
a) 37 dollars
b) 37 thousand dollars
c) 37 million dollars
d) 37 billion dollars

# ESTIMATING TOTAL MORTALITY (*Z*)

# The practical realities



# Practical realities: catch curve



# Practical realities: catch curve

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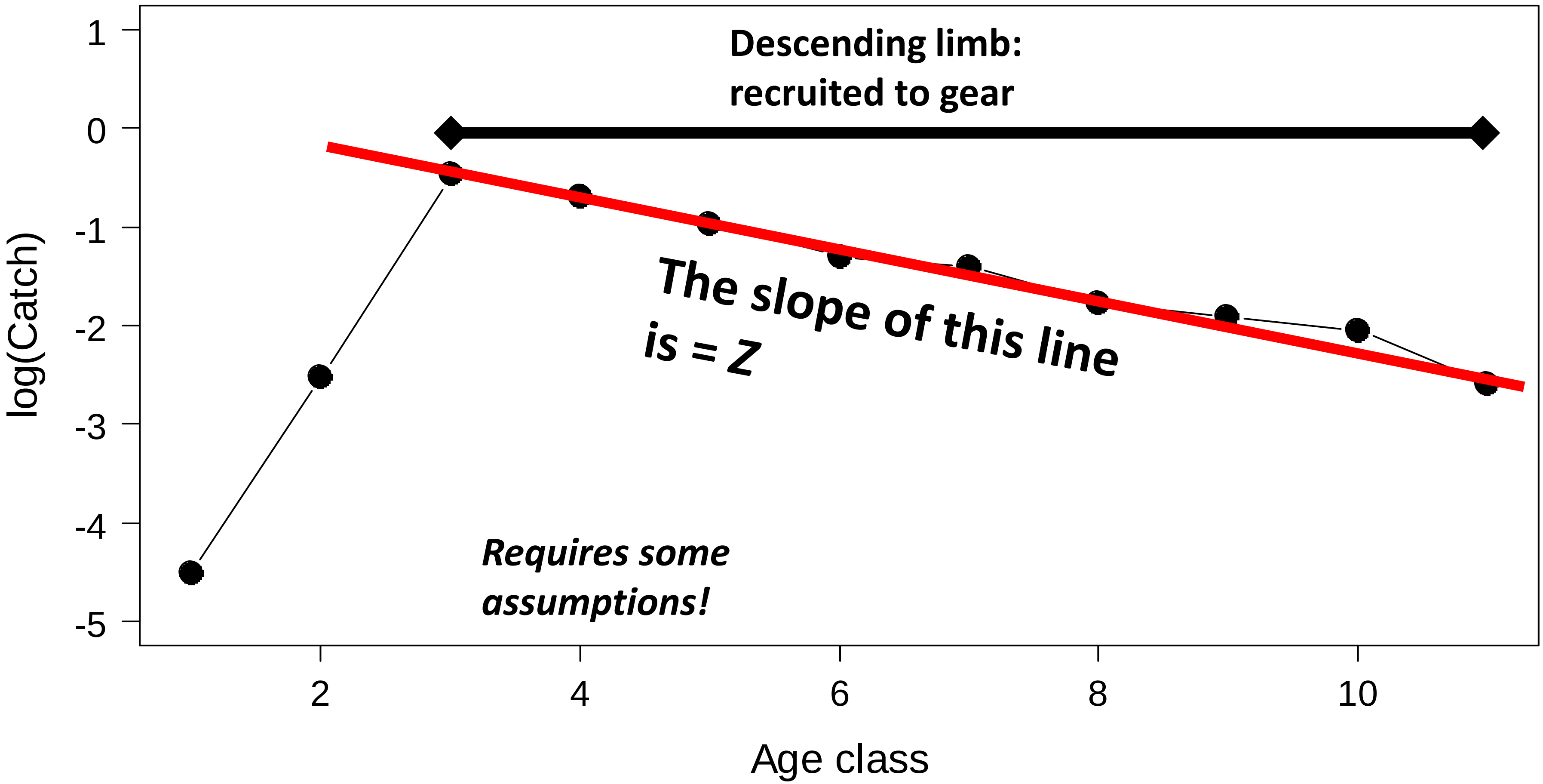


# Catchability?

$$Z = F + M$$

$$F = Catchability \cdot Effort$$

Links effort and catch

Hard to estimate!

# Lets talk about rates

- Instantaneous
- Finite

$$\frac{Abundance}{dt} = r \cdot Abundance - M \cdot Abundance$$

$$\frac{dN}{dt} = -Z \cdot N$$

# Types of rates: Instantaneous

Instantaneous mortality rates are used in many fisheries models. They represent the rate of change over a time period. So, if you could chop up a year into very small increments the instantaneous rate would get applied to that very small time step. In essence the time step would be 0.

# Types of rates: Finite

<u>Finite mortality rates</u> are the fraction of fish stock that dies in  timeframe (e.g., a year).

Example: annual total mortality rate (*A*) of 0.2 means that 20% of the fish stock dies over one year.  So if we have 100 fish 20 of those fish would die and 80 would survive.

# 10% off per day late!

- 10% off your assignment per day after due date
- What if you are 15 hours late?
- Should you get a full 10% off?
- If 24 hours (1 day) gets 10% off what should 15 hours get you?

# If 24 hours (1 day) gets 10% off what should 15 hours get you?

- 10% finite rate (100*(1-0.1))=90 if you got all the points but was 1 day late
- 90*(1-0.1) = 81 if you got all the points but was 1 day late
- 15 hours?
- Convert 10% from finite to instantaneous… actually (1-0.1)

# Finite→ Instantaneous

- Convert finite to instantaneous

$$S = -\log(0.9)$$

$$S = 0.10536$$

- We can divide *S* into time intervals

$$S = 0.10536 \cdot \frac{15}{24}$$

$$S = 0.0658$$

- The <u>instantaneous</u> survival rate for 15 hours is 0.0658

# Instantaneous→ Finite

- Now we can convert the instantaneous rate to a finite rate

$$s = \exp(-1 \cdot 0.0658)$$

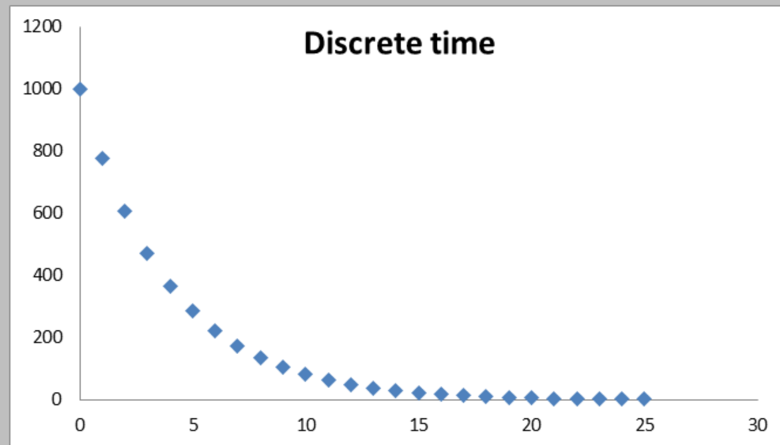
$$s = 0.936271$$

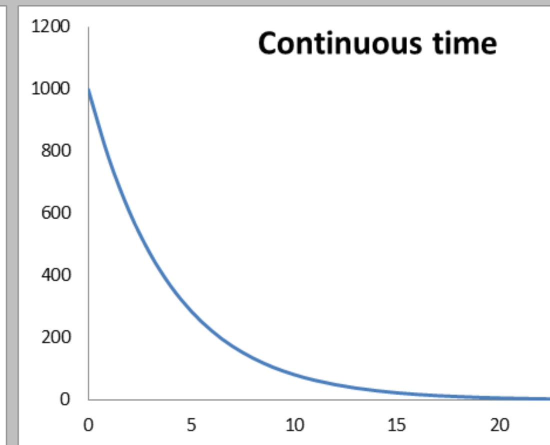
- So if you were 15 hours late on an assignment but you got all 100 points you would get a 93.6271
- That seems much better than getting a 90!

# Types of rates

| | Exponential | Discrete |
|---|---|---|
| Z | -0.25 | 0.778801 |
| $B_0$ | 1000 | 1000 |

| t | Exponential | Discrete |
|---|---|---|
| 0 | 1000 | 1000 |
| 1 | 778.8007831 | 778.8008 |
| 2 | 606.5306597 | 606.5307 |
| 3 | 472.3665527 | 472.3666 |
| 4 | 367.8794412 | 367.8794 |
| 5 | 286.5047969 | 286.5048 |
| 6 | 223.1301601 | 223.1302 |
| 7 | 173.7739435 | 173.7739 |
| 8 | 135.3352832 | 135.3353 |
| 9 | 105.3992246 | 105.3992 |
| 10 | 82.08499862 | 82.085 |
| 11 | 63.92786121 | 63.92786 |
| 12 | 49.78706837 | 49.78707 |
| 13 | 38.77420783 | 38.77421 |
| 14 | 30.19738342 | 30.19738 |
| 15 | 23.51774586 | 23.51775 |
| 16 | 18.31563889 | 18.31564 |
| 17 | 14.26423391 | 14.26423 |
| 18 | 11.10899654 | 11.109 |
| 19 | 8.651695203 | 8.651695 |
| 20 | 6.737946999 | 6.737947 |
| 21 | 5.247518399 | 5.247518 |
| 22 | 4.086771438 | 4.086771 |
| 23 | 3.182780707 | 3.182781 |



# Worked example

Suppose we had 1000 fish and 700 survive to the next year, the finite morality rate *A* is be 0.3 over the 12 month interval

Suppose we wanted to know what the morality rate was at 4 & 8 months.

To determine this the easy way we need to know instantaneous mortality

# Worked example

First we convert our **finite morality rate *A*** to an instantaneous rate

$$Z = -\log_e(1-(N_t - N_{t+dt})/N_t)$$

$$Z = -\log_e(1-(1000-700)/1000)$$

$$Z = -\log_e(1-0.3)$$

$$Z = 0.356$$

$$Z = -\log_e(1-A)$$

$$A = 1-e^{-Z}$$

# Worked example

**One of the nice properties of instantaneous rates is that we can simply divide them by time to get varying interval rates.** For example, 1 month

$$Z_{1months} = \frac{0.356}{12}$$

$$Z_{1months} = 0.0297$$

$$A_{1months} = 1 - e^{-0.238}$$

$$A_{1months} = 0.0292$$

# Worked example

Similarly we can do the same thing for an 3 month interval

$$Z_{3months} = \frac{0.356}{4}$$

$$Z_{3months} = 0.119$$

$$A_{3months} = 1 - e^{-0.119}$$

$$A_{3months} = 0.112$$

There are 4 3 month periods in 12 months

# A worked example

So at 1 months past June 1 we would expect the population abundance to be:

$$N_{1months} = 1000 - (1000 \cdot 0.0292)$$

$$N_{1months} = 971$$

And for 3 months

$$N_{3months} = 1000 - (1000 \cdot 0.112)$$

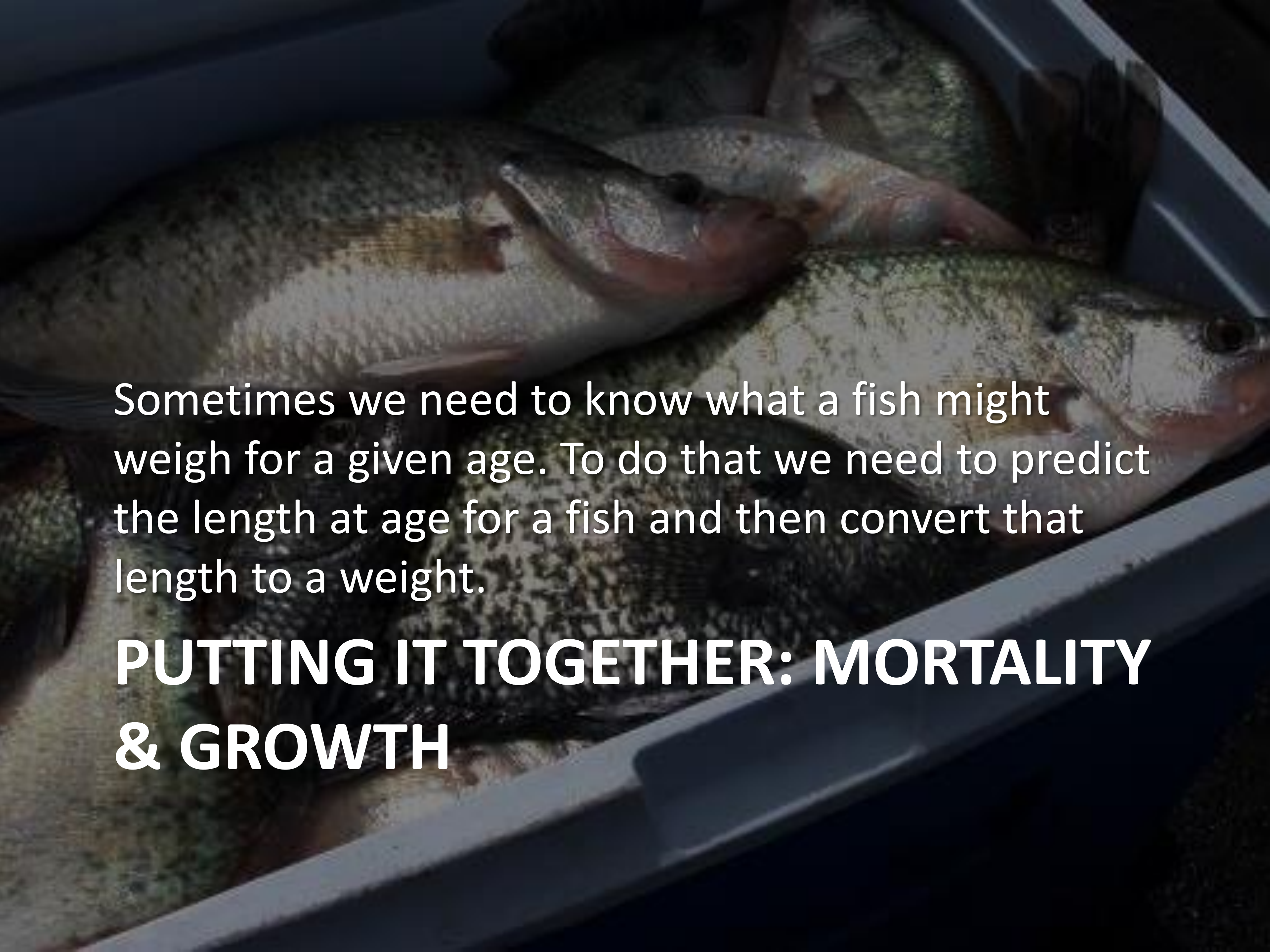
$$N_{3months} = 888$$

So there were 29 mortalities in the first month and 112 in the first 3 months

# When would these rates make sense?

- Finite?

- Instantaneous?



Sometimes we need to know what a fish might weigh for a given age. To do that we need to predict the length at age for a fish and then convert that length to a weight.

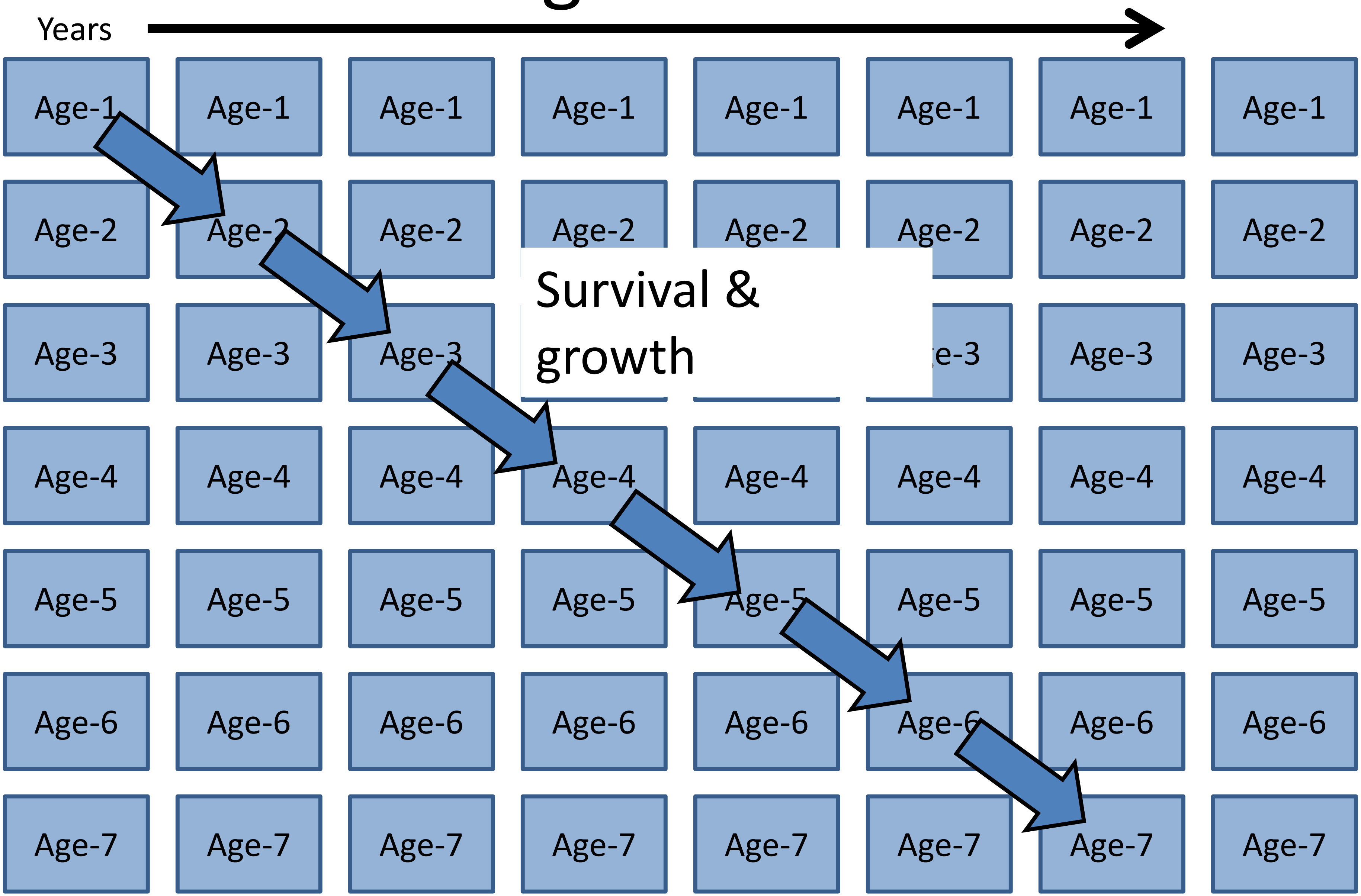
# PUTTING IT TOGETHER: MORTALITY & GROWTH

# Age & time

Years

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Age-1 | Age-1 | Age-1 | Age-1 | Age-1 | Age-1 | Age-1 | Age-1 |
| Age-2 | Age-2 | Age-2 | Age-2 | Age-2 | Age-2 | Age-2 | Age-2 |
| Age-3 | Age-3 | Age-3 | Age-3 | Age-3 | Age-3 | Age-3 | Age-3 |
| Age-4 | Age-4 | Age-4 | Age-4 | Age-4 | Age-4 | Age-4 | Age-4 |
| Age-5 | Age-5 | Age-5 | Age-5 | Age-5 | Age-5 | Age-5 | Age-5 |
| Age-6 | Age-6 | Age-6 | Age-6 | Age-6 | Age-6 | Age-6 | Age-6 |
| Age-7 | Age-7 | Age-7 | Age-7 | Age-7 | Age-7 | Age-7 | Age-7 |

# Age & time


Years
Age-1 Age-1 Age-1 Age-1 Age-1 Age-1 Age-1 Age-1
Age-2 Age-2 Age-2 Age-2 Age-2 Age-2 Age-2 Age-2
Survival & growth
Age-3 Age-3 Age-3 Age-3 Age-3
Age-4 Age-4 Age-4 Age-4 Age-4 Age-4 Age-4 Age-4
Age-5 Age-5 Age-5 Age-5 Age-5 Age-5 Age-5 Age-5
Age-6 Age-6 Age-6 Age-6 Age-6 Age-6 Age-6 Age-6
Age-7 Age-7 Age-7 Age-7 Age-7 Age-7 Age-7 Age-7

# Trade off

1. Harvesting a lot of fish
2. Harvesting fewer, but larger fish

Lets look at this

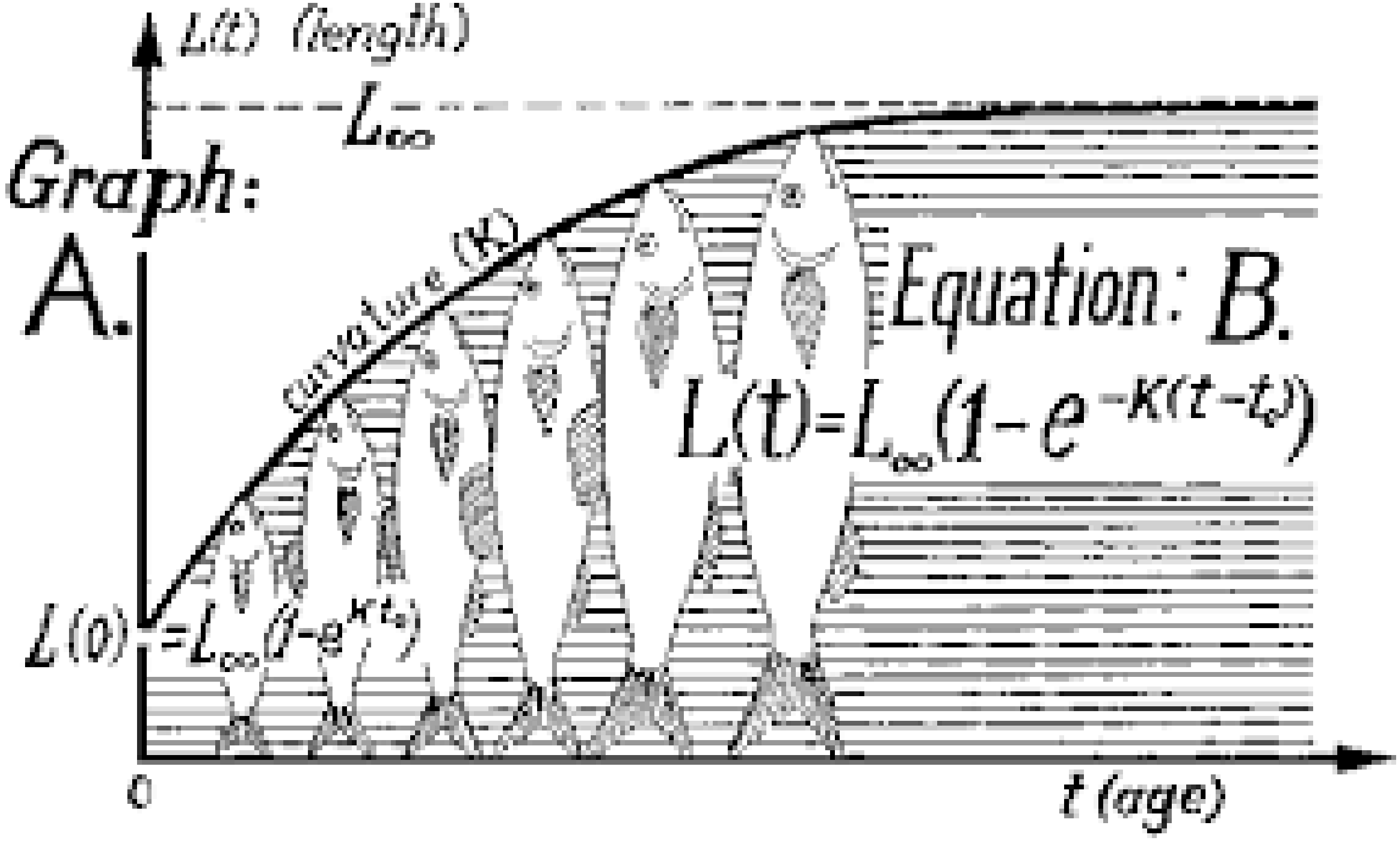
# Some management parameters

Management can control*

- Gear-catchability
- Effort
- **Harvested fish size-Minimum length limit**

*Not a complete list

# Why set a minimum length limit (MLL)



# Cohort based

Follow a cohort over its lifetime

- Recruits: defined by age
- Maximum age (longevity)
- Survival (finite) = 0.20 (0.222 instantaneous)

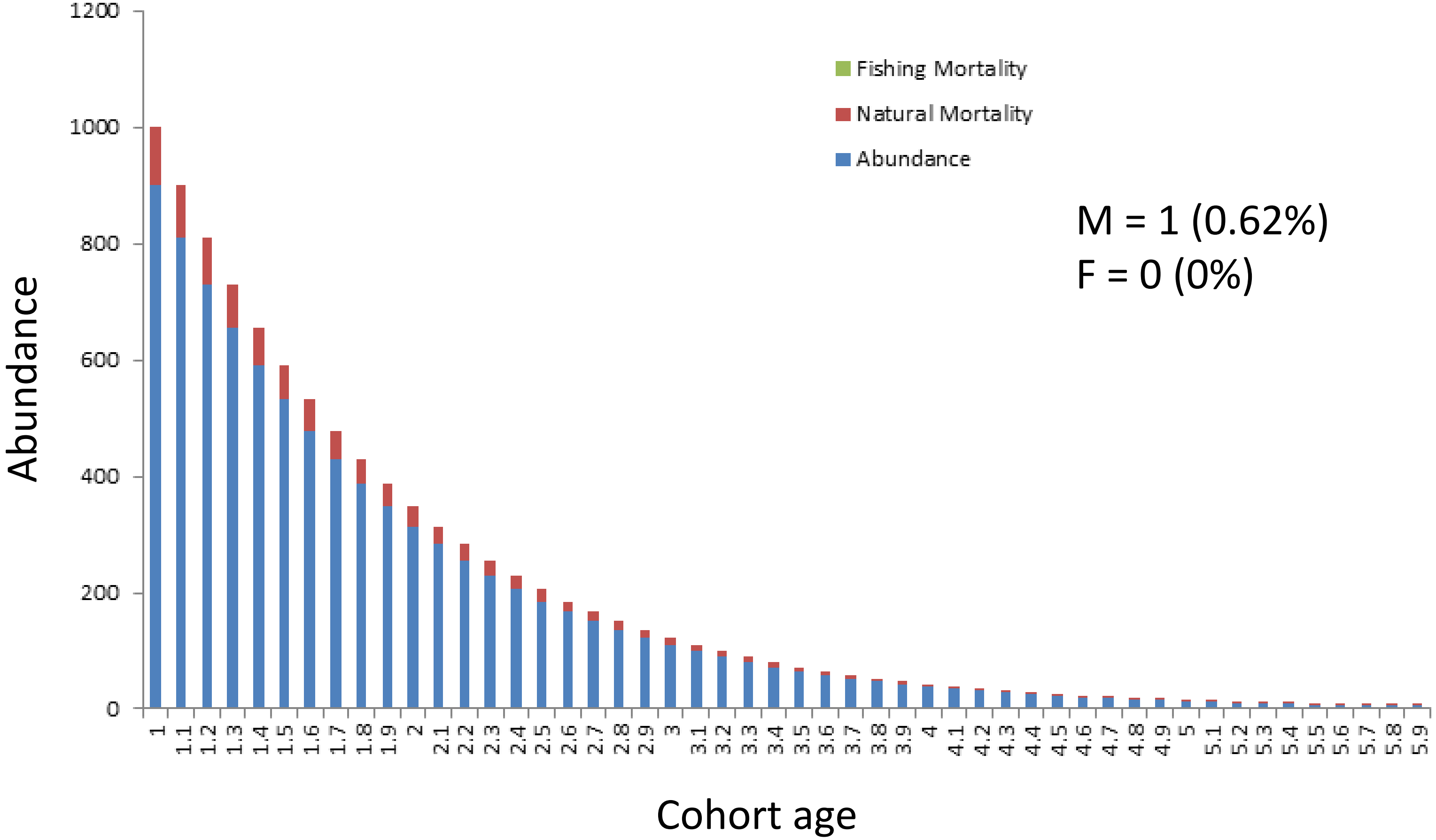
| Age-1 | Age-2 | Age-3 | Age-4 | Age-5 |
|---|---|---|---|---|
| 1000 → | 200 → | 40 → | 8 → | 2 |

# Cohort recruited

| Age-1 | Age-2 | Age-3 | Age-4 | Age-5 |
|---|---|---|---|---|
| 1000 → | 200 → | 40 → | 8 → | 2 |

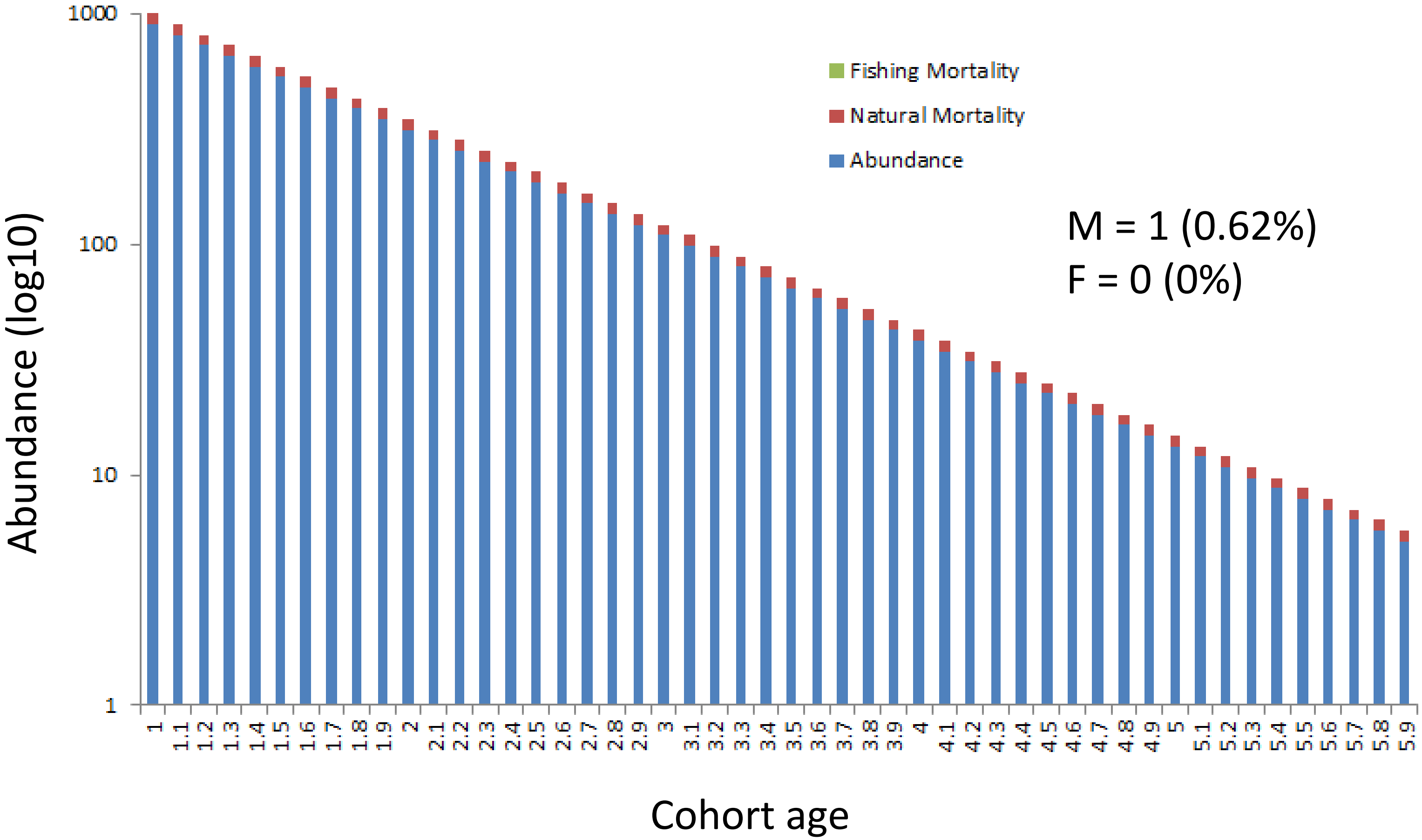
1000 age-1 fish recruited

# No fishing mortality




M = 1 (0.62%)
F = 0 (0%)

# No fishing mortality



# Fishing mortality

Minimum length limit-Applies to certain size fish and above

Slot limit-applies to a fish within a minimum and maximum size limits

ISSUE:  Cohort dynamics a function of age (or time)…How do we relate length limits to age?

# Flip the VBGF

Recall, the VBGF predicts length at age

$$Length_{age} = Length_{\infty} \cdot (1 - e^{-K \cdot (age - t_0)})$$

Can rearrange equation to predict age given length

# Proof

$$Length_{age} = Length_{\infty} \cdot (1 - e^{-K\cdot(age - t_0)})$$

$$\frac{Length_{age}}{Length_{\infty}} = (1 - e^{-K\cdot(age - t_0)})$$

$$-1 + \frac{Length_{age}}{Length_{\infty}} = -e^{-K\cdot(age - t_0)}$$

$$1 - \frac{Length_{age}}{Length_{\infty}} = e^{-K\cdot(age - t_0)}$$

$$\log\left(1 - \frac{Length_{age}}{Length_{\infty}}\right) = -K \cdot (age - t_0)$$

$$\frac{\log\left(1 - \frac{Length_{age}}{Length_{\infty}}\right)}{-K} = (age - t_0)$$

$$t_0 + \frac{\log\left(1 - \frac{Length_{age}}{Length_{\infty}}\right)}{-K} = age$$

# Example

Proposed minimum length limit

1. 8 inches (203 mm)
2. 12 inches (304 mm)
3. 14 inches (356 mm)
4. 15 inches (381 mm)

$$Length_{\infty} = 400$$

$$K = 0.3$$

$$t_0 = 0.1$$

# 8 inch limit

$$t_0 + \frac{\log\left(1 - \frac{Length_{age}}{Length_{\infty}}\right)}{-K} = age$$

$$0.1 + \frac{\log\left(1 - \frac{203}{400}\right)}{-0.3} = age$$

$$0.1 + \frac{-3.05}{-0.3} = age$$

$$0.1 + 10.16 = age$$

$$2.46 = age$$

# 12 inch limit

$$t_0 + \frac{\log\left(1 - \frac{Length_{age}}{Length_{\infty}}\right)}{-K} = age$$

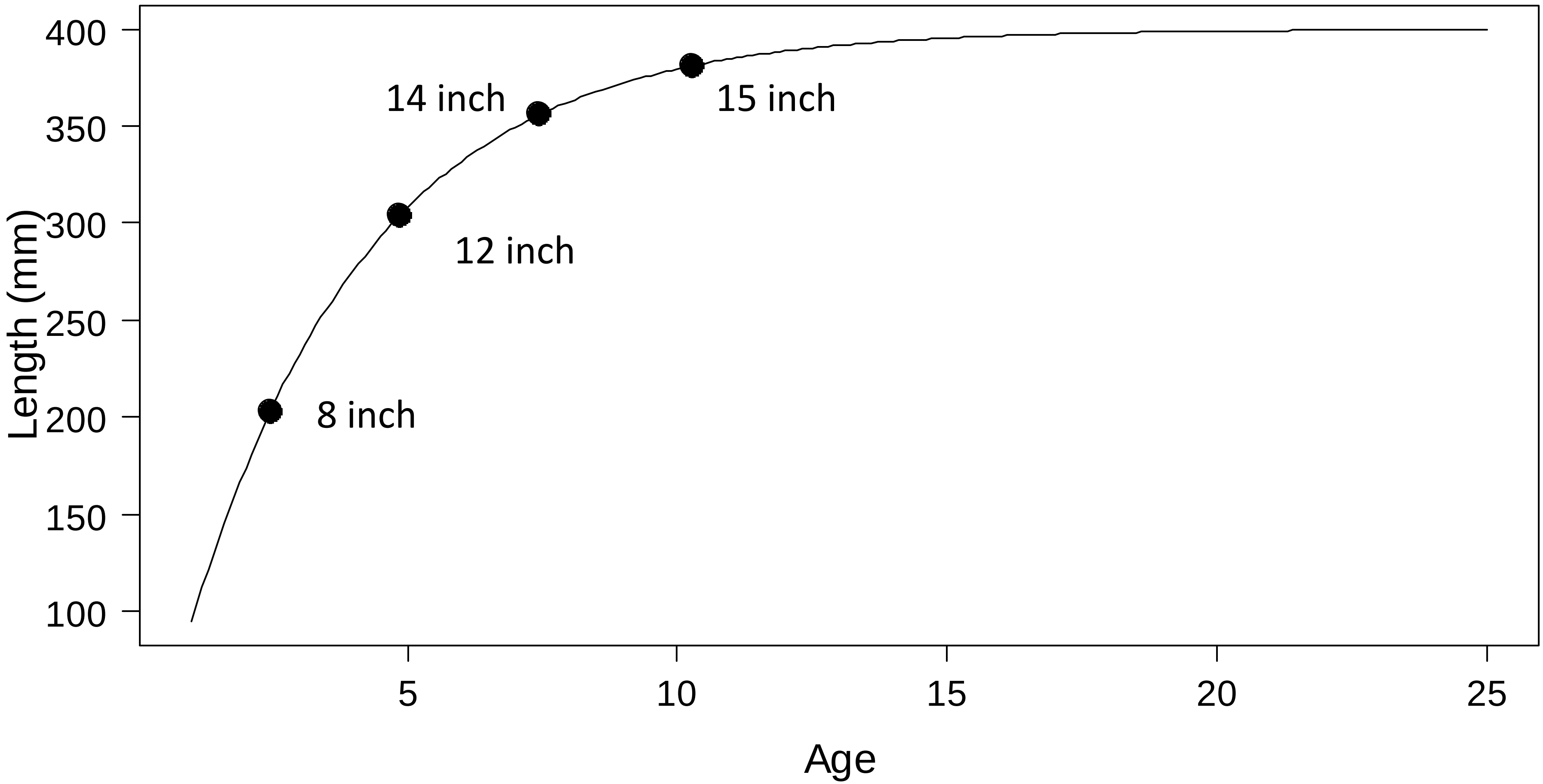
$$0.1 + \frac{\log\left(1 - \frac{304}{400}\right)}{-0.3} = age$$

$$0.1 + \frac{-1.427}{-0.3} = age$$

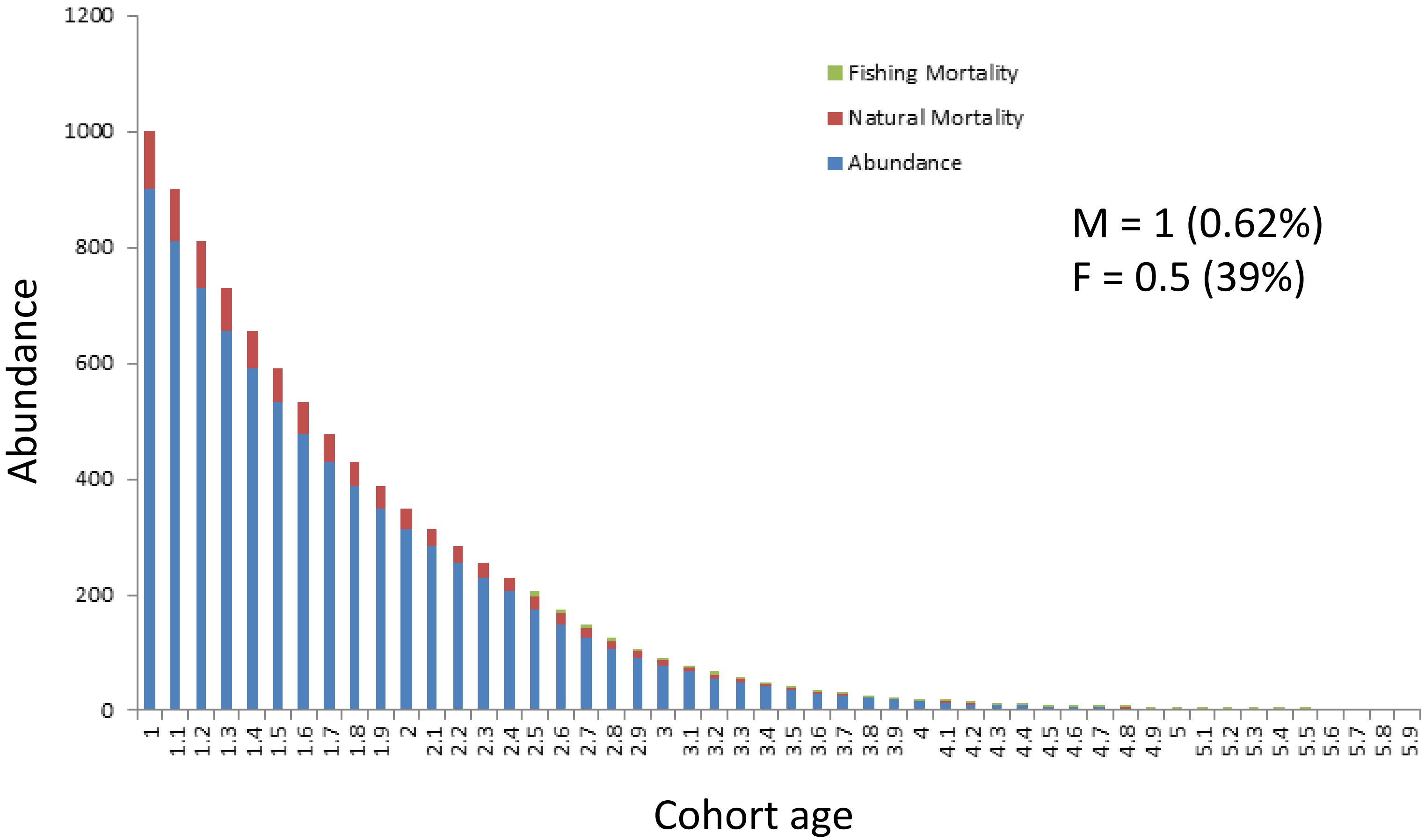
$$0.1 + 4.757 = age$$

$$4.857 = age$$

# Length limit & growth

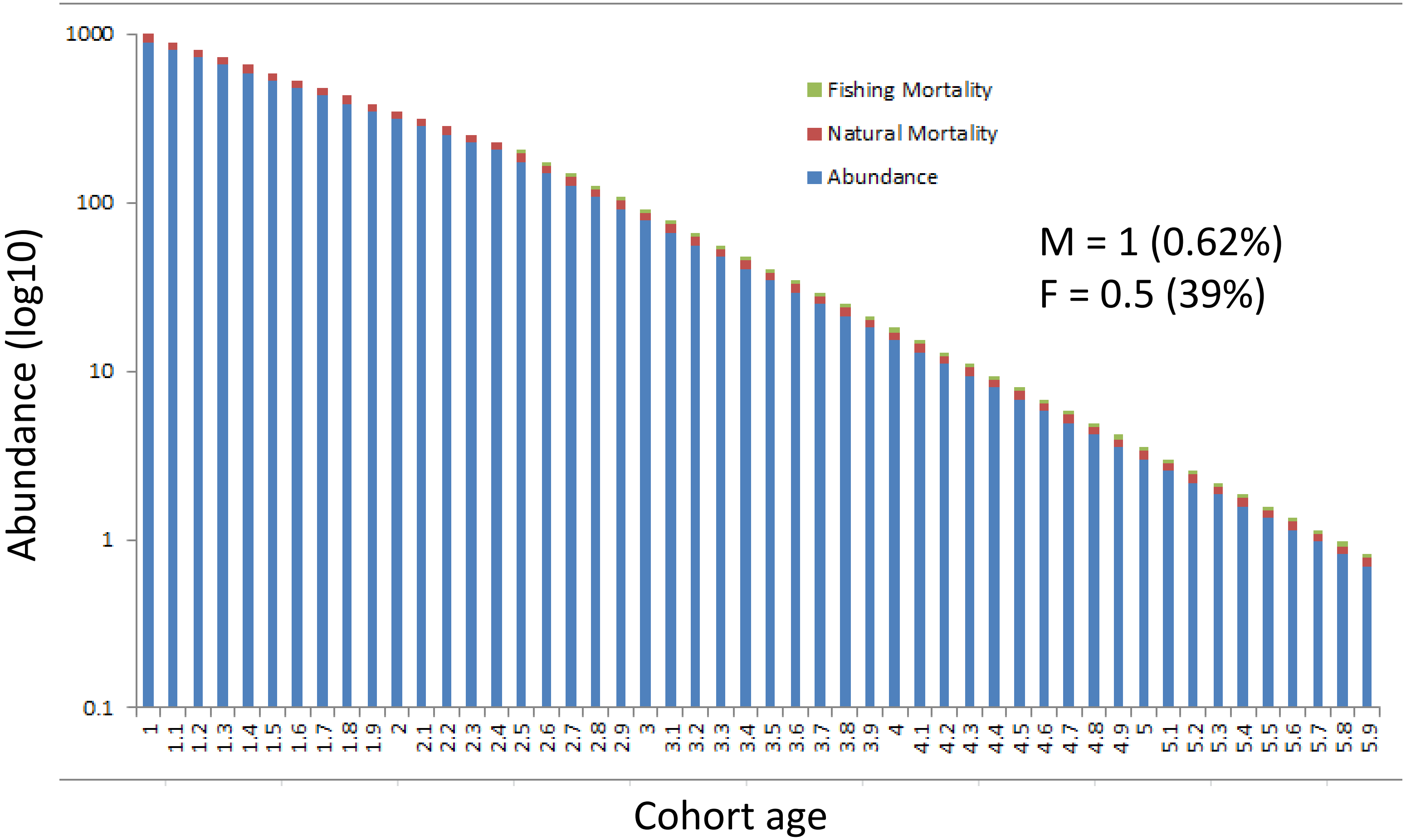


# 8 inch limit




M = 1 (0.62%)
F = 0.5 (39%)

# 8 inch limit



Fishing Mortality
Natural Mortality
Abundance
M = 1 (0.62%)
F = 0.5 (39%)
Abundance (log10)
1000
100
10
1
0.1
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2
2.3
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4.7
4.8
4.9
5
5.1
5.2
5.3
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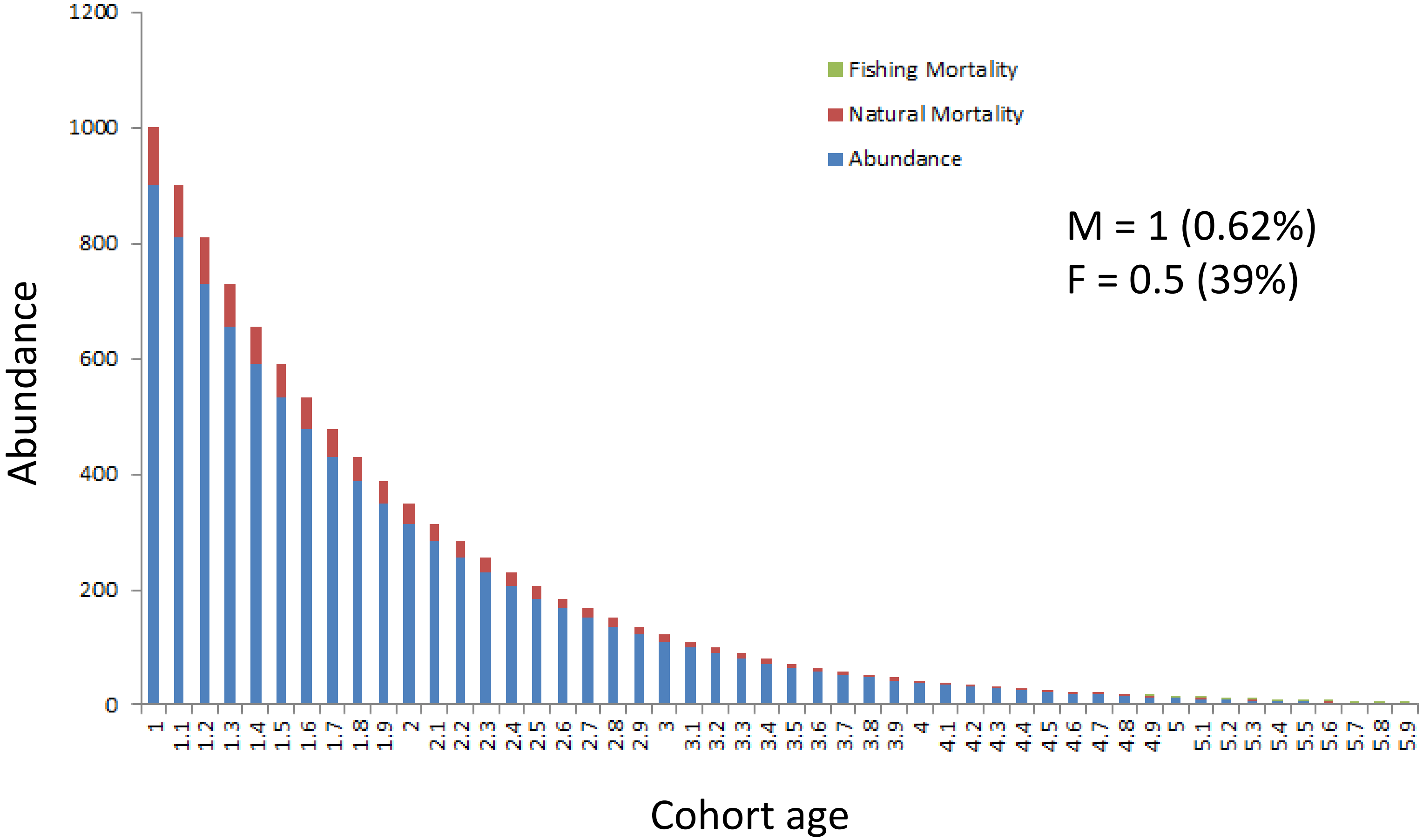
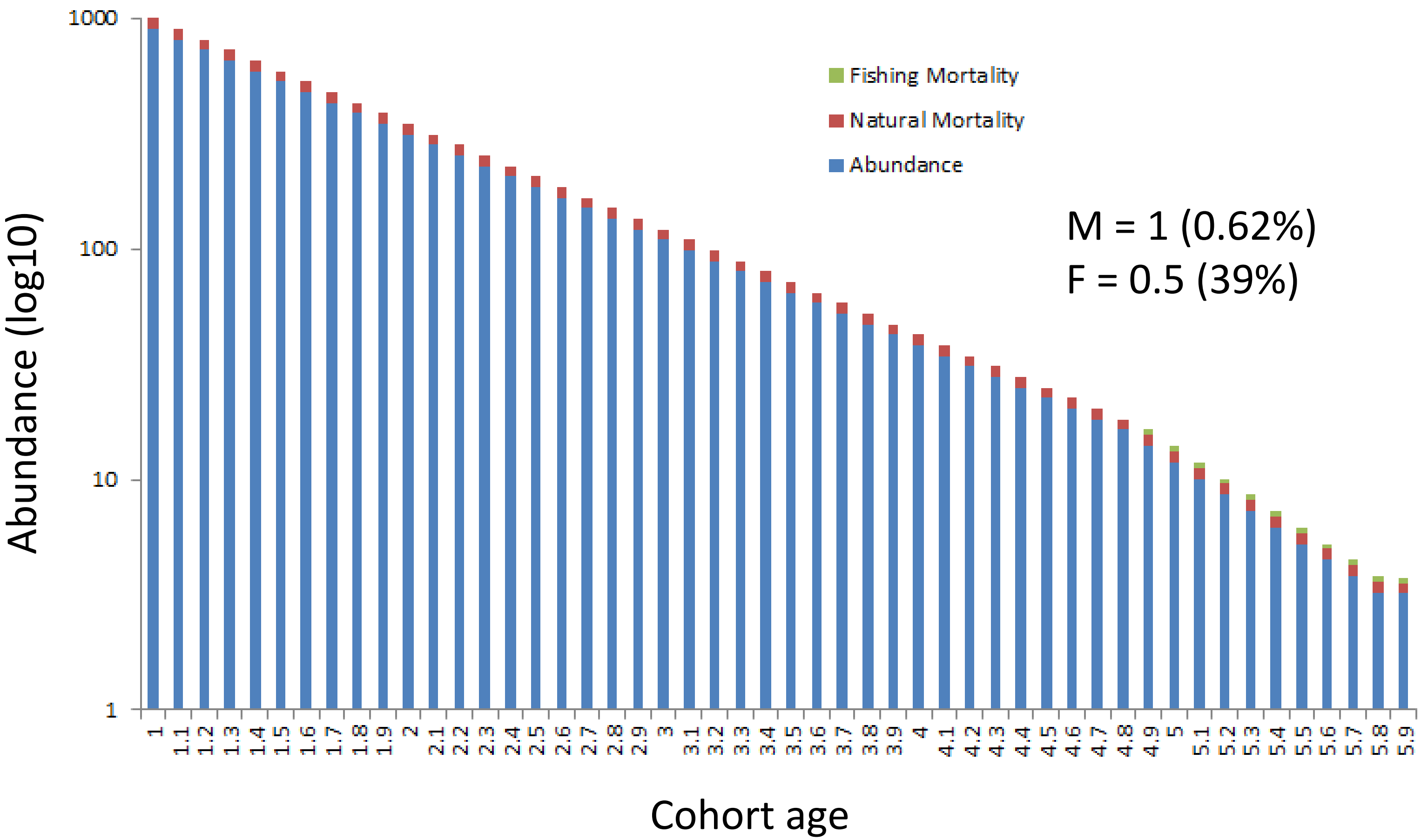
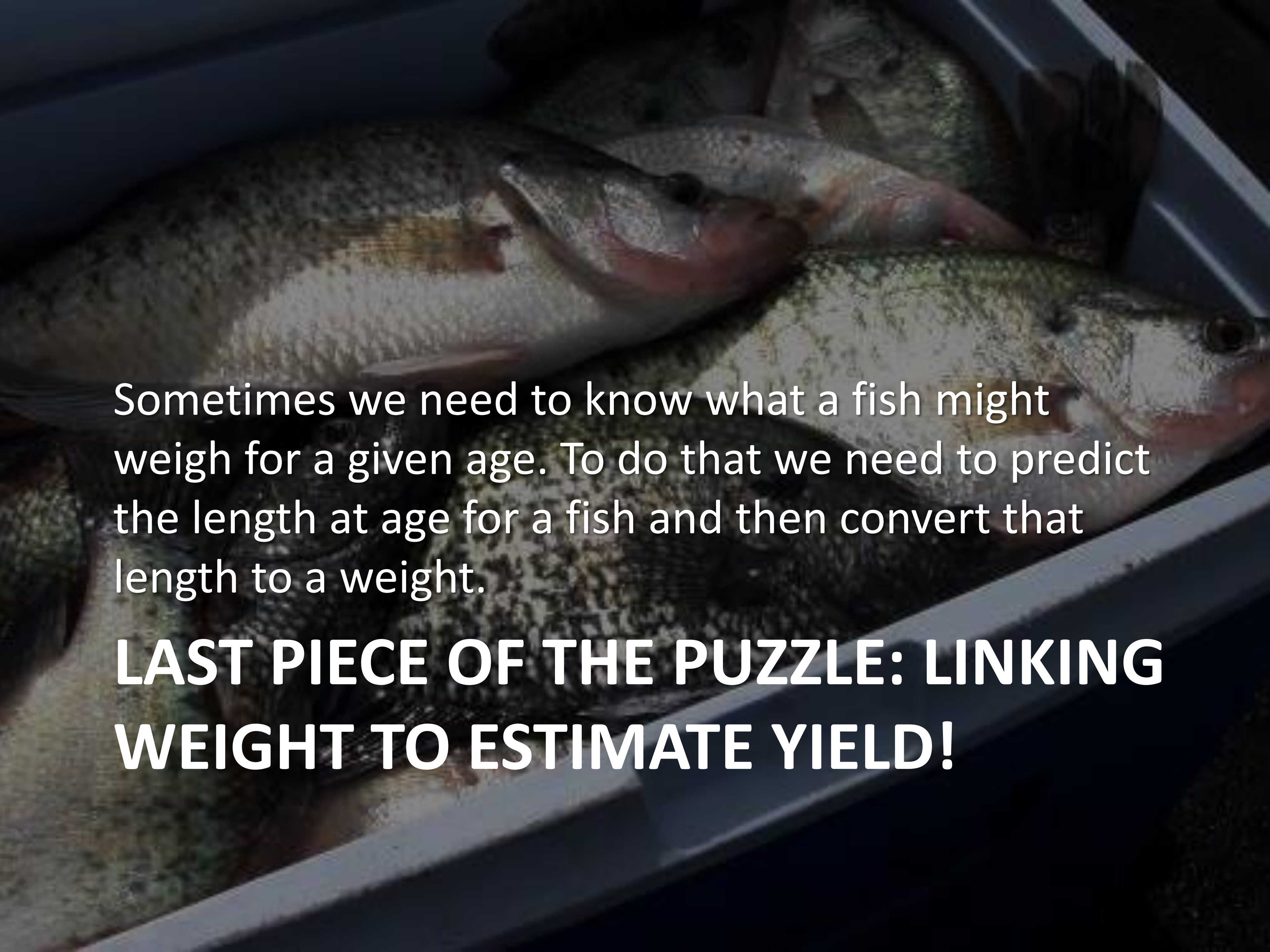
5.5
5.6
5.7
5.8
5.9
Cohort age

# 12 inch limit



# 12 inch limit

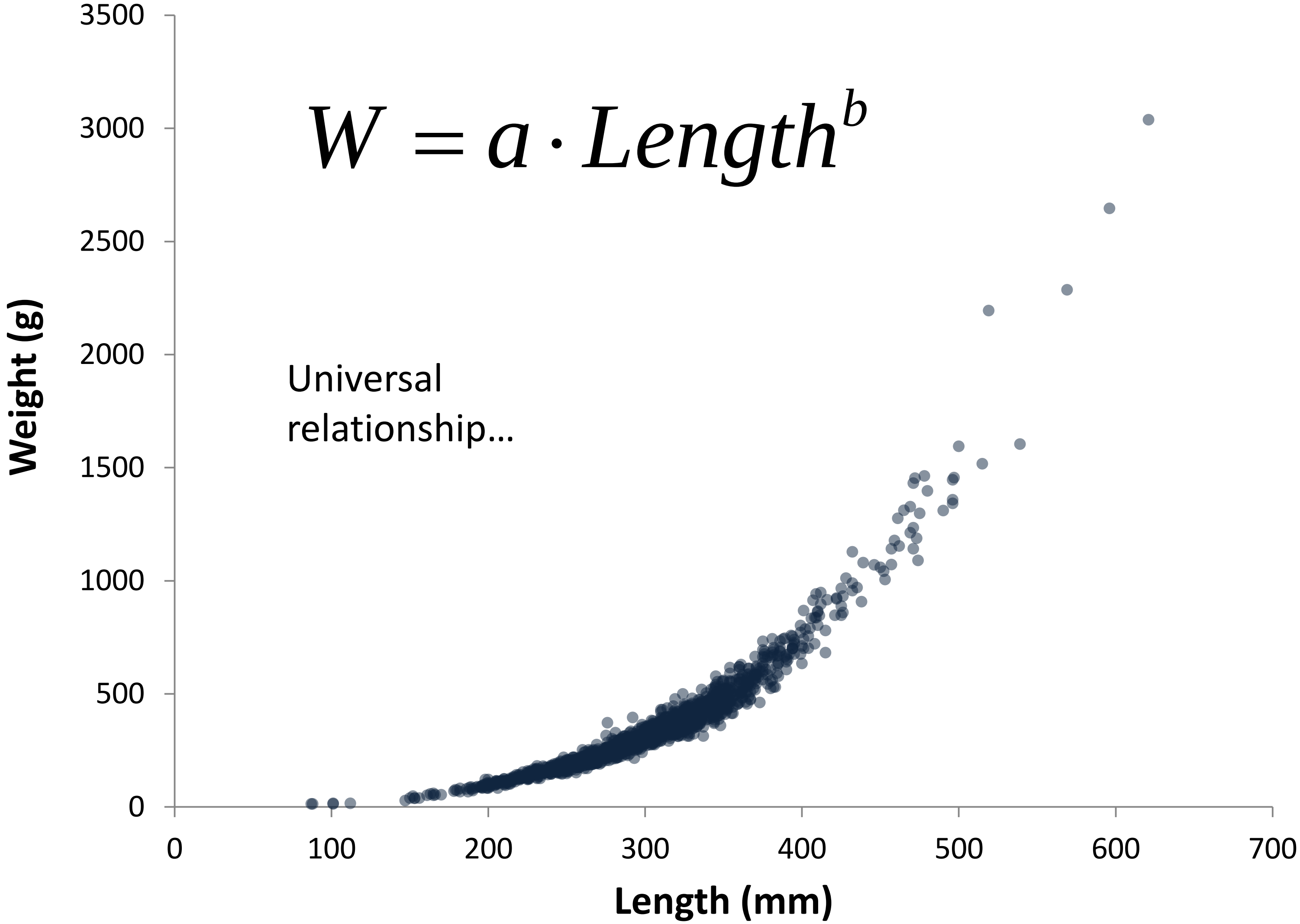




Sometimes we need to know what a fish might weigh for a given age. To do that we need to predict the length at age for a fish and then convert that length to a weight.

# LAST PIECE OF THE PUZZLE: LINKING WEIGHT TO ESTIMATE YIELD!

# Length-weight relationship



# Straightening the curve

Law of logarithms

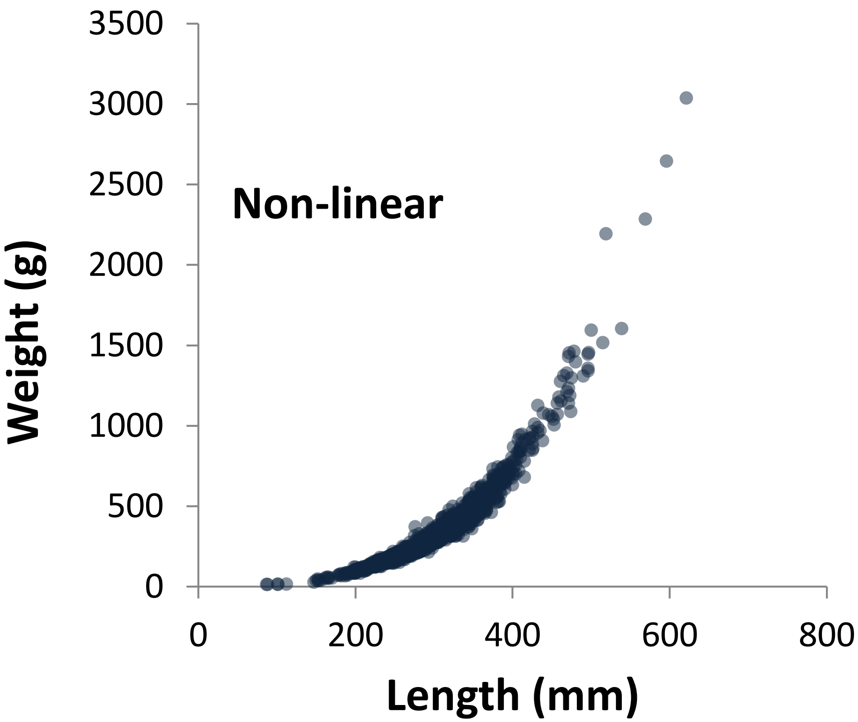
$$W = a \cdot L^b$$

$$\log_{10}(W) = \log_{10}(a \cdot L^b)$$

$$\log_{10}(W) = \log_{10}(a) + b \cdot \log_{10}(L)$$

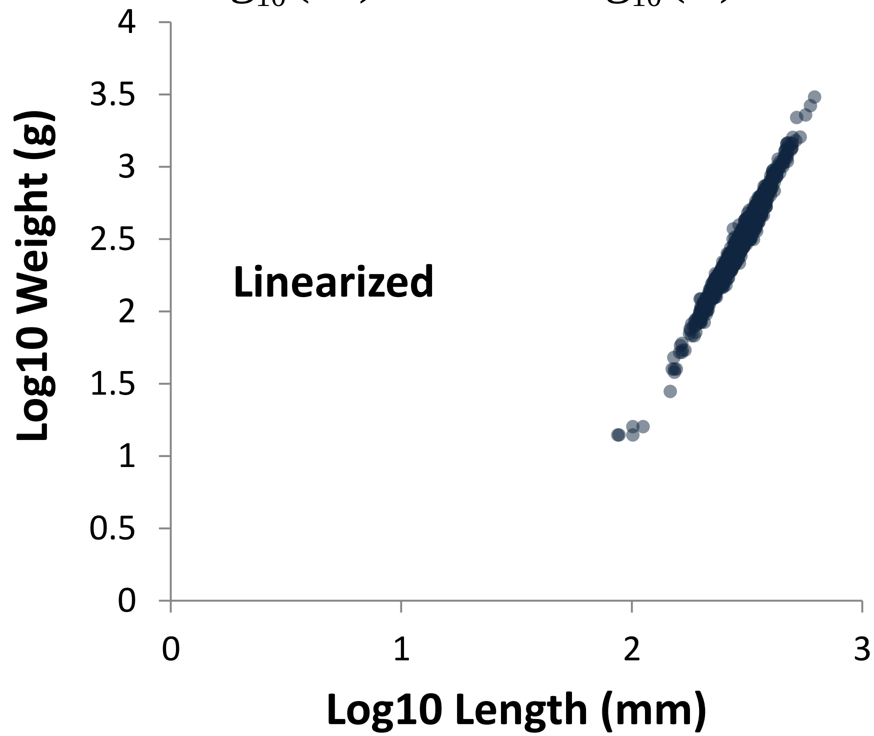
# Estimating weight from length

$$W = a \cdot Length^{b}$$




$$\log_{10}(W) = \log_{10}(a) + b \cdot \log_{10}(L)$$

$$\log_{10}(W) = a' + b \cdot \log_{10}(L)$$

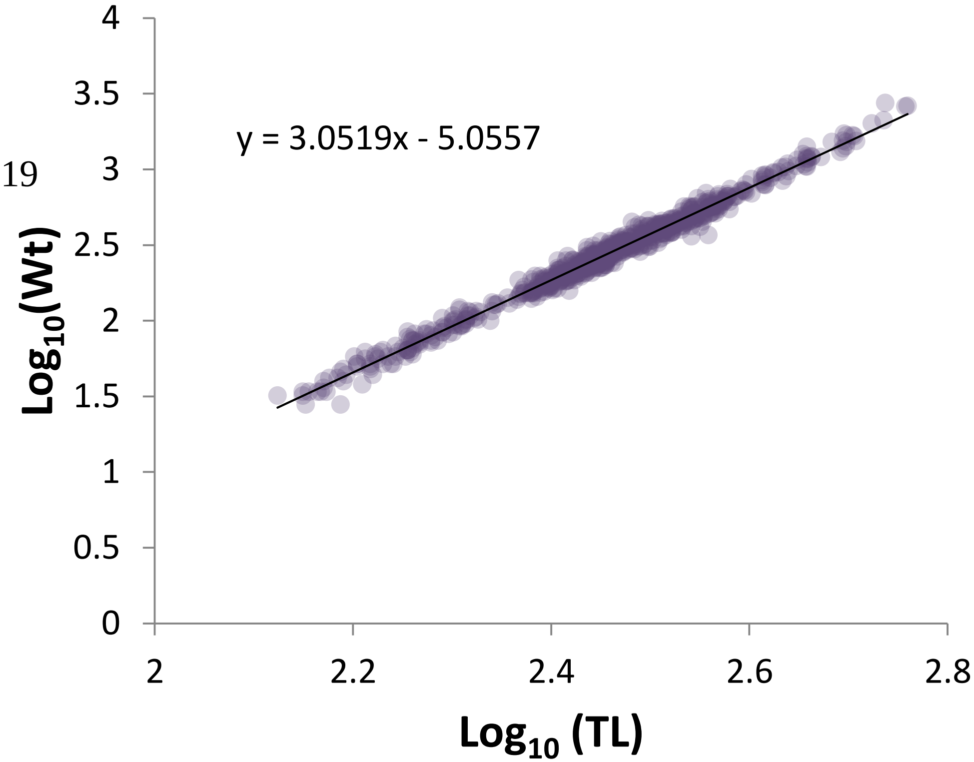


# Can estimate weight from length!

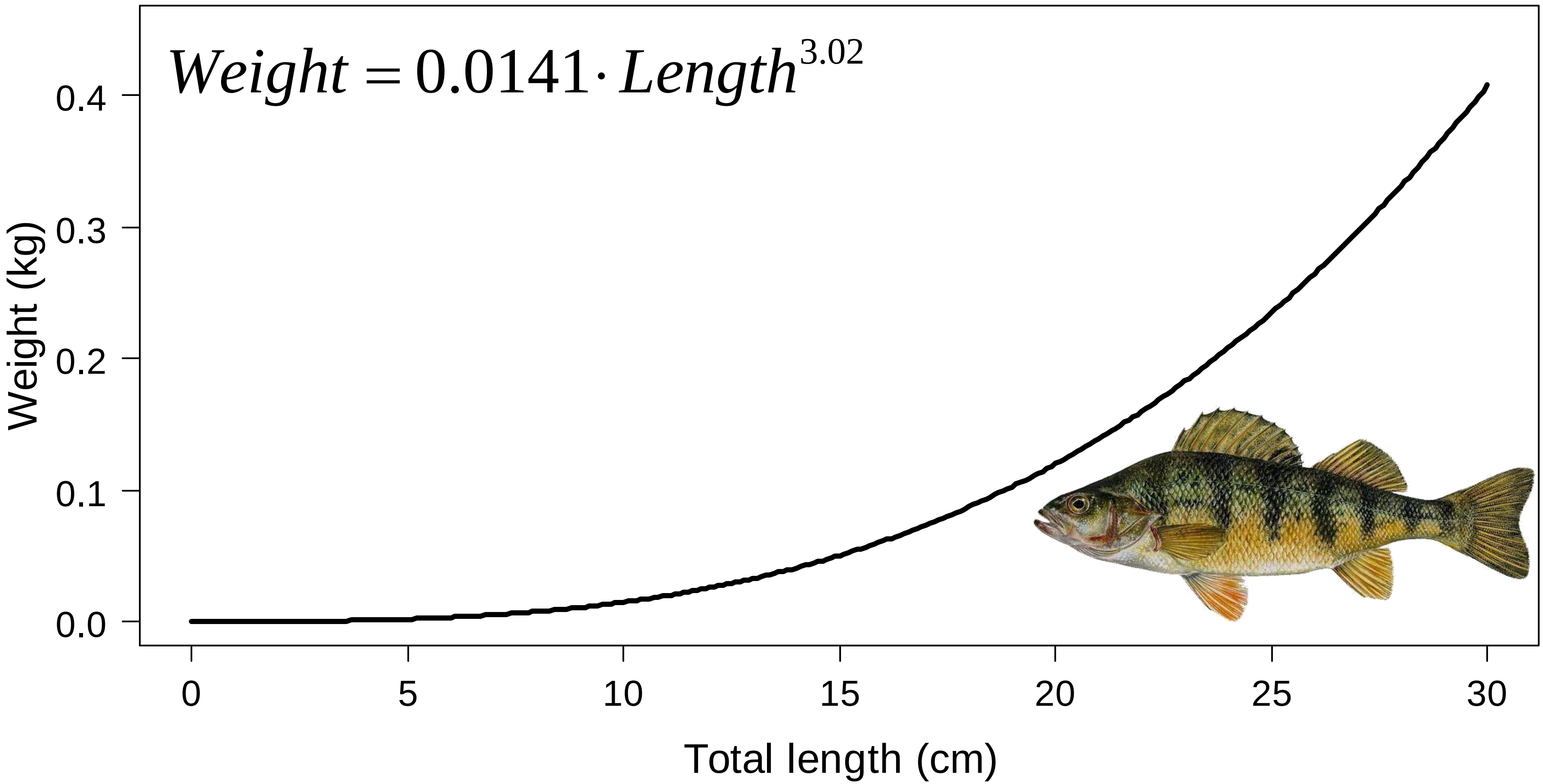
$$Weight = 10^{-5.0557} \cdot Length^{3.0519}$$

$$Weight = 10^{-5.0557} \cdot 400^{3.0519}$$

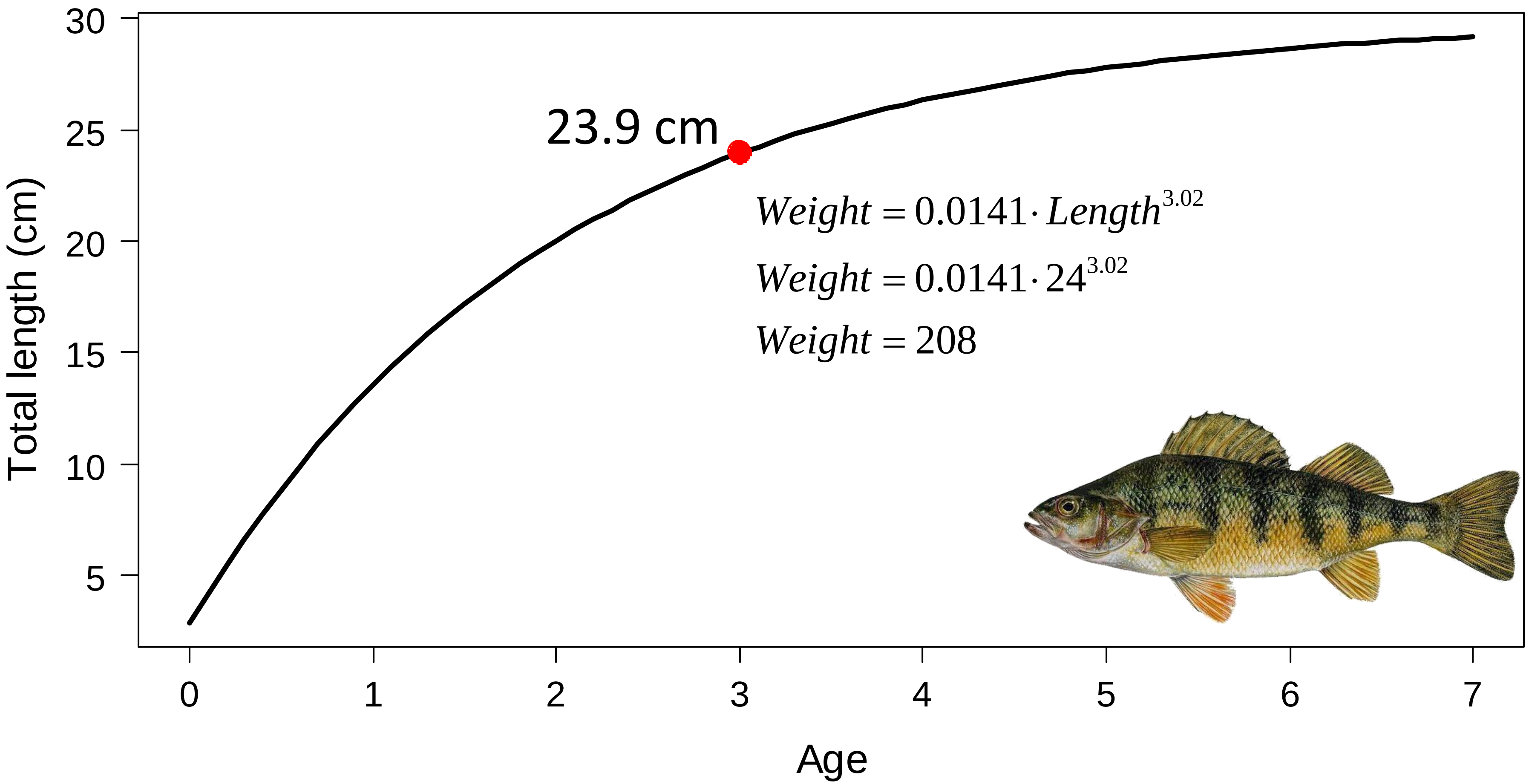
$$Weight = 768\,g$$



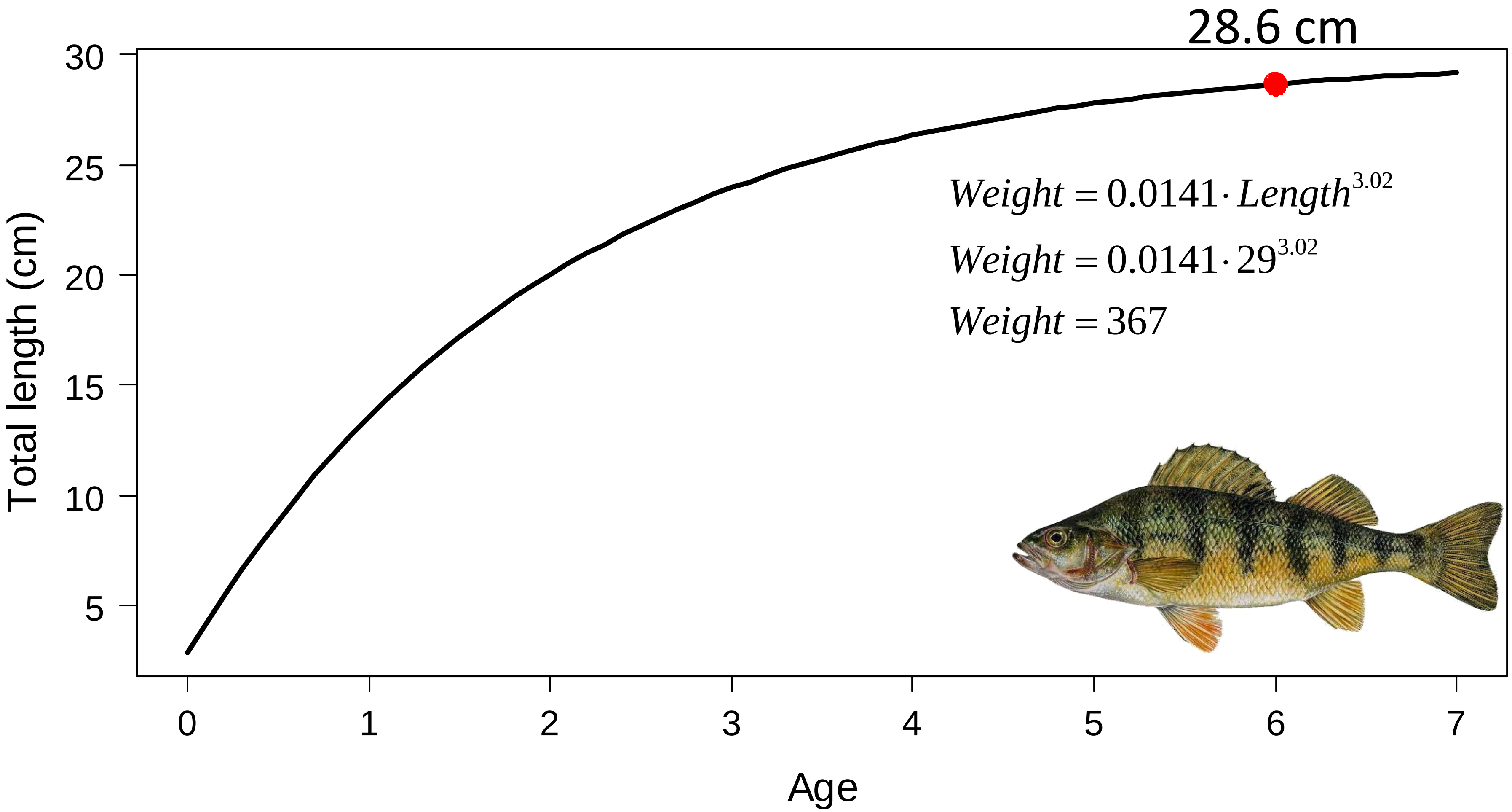
# Length-weight



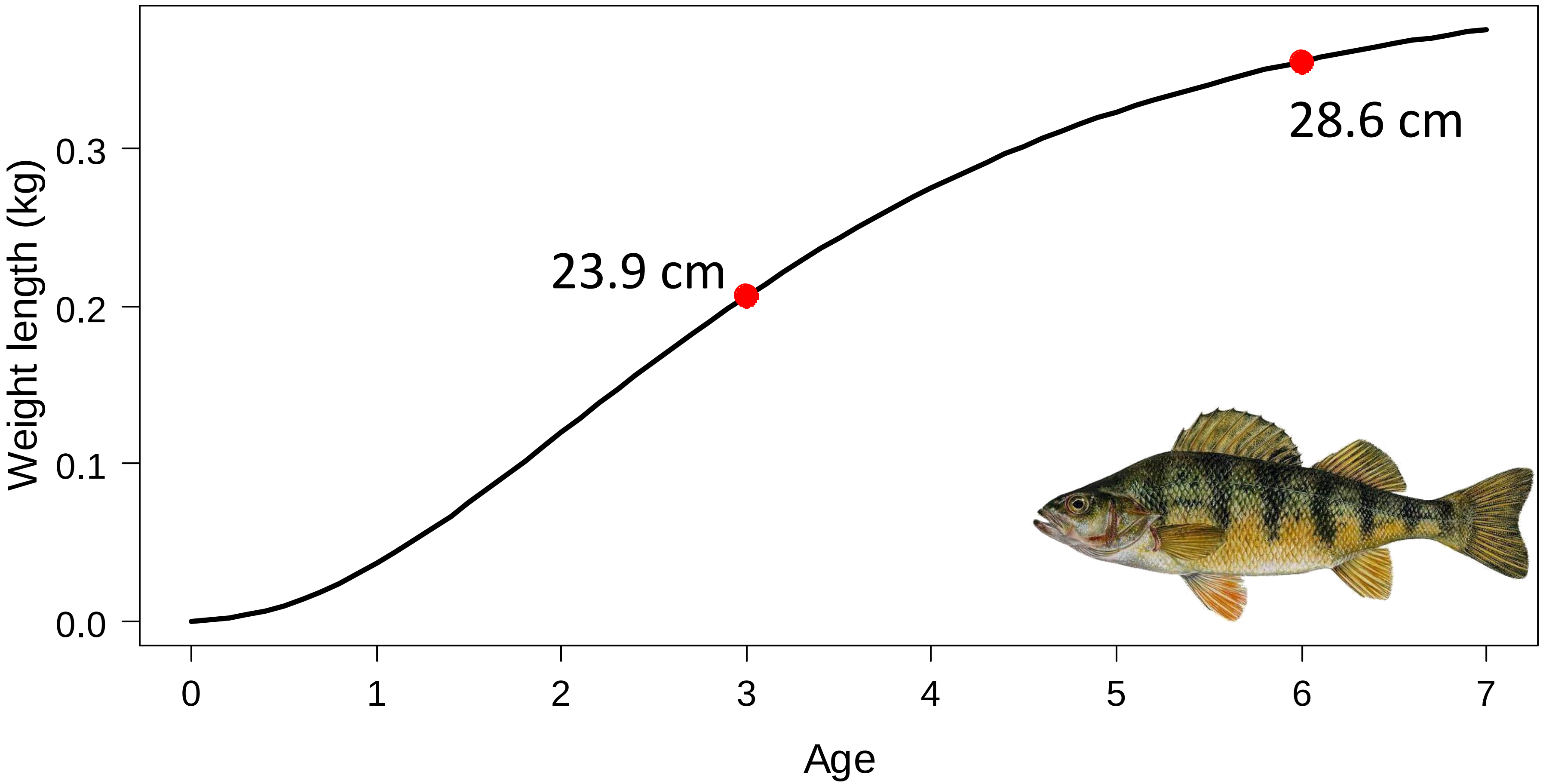
# Weight for an age-3 fish



# Weight for an age-6 fish



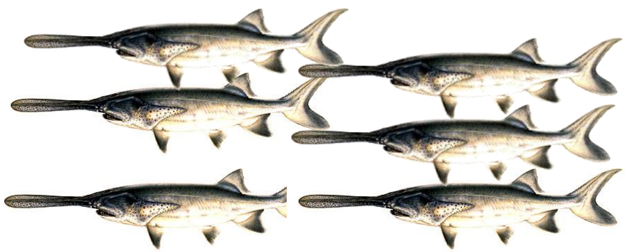
# Age-weight



# A yield predicting primer

Yield(age) = Harvested(age)•Weight(age)

Harvested (age=3.5)



X

Weight(age=3.5)

50 kg

=

Yield(age=3.5)

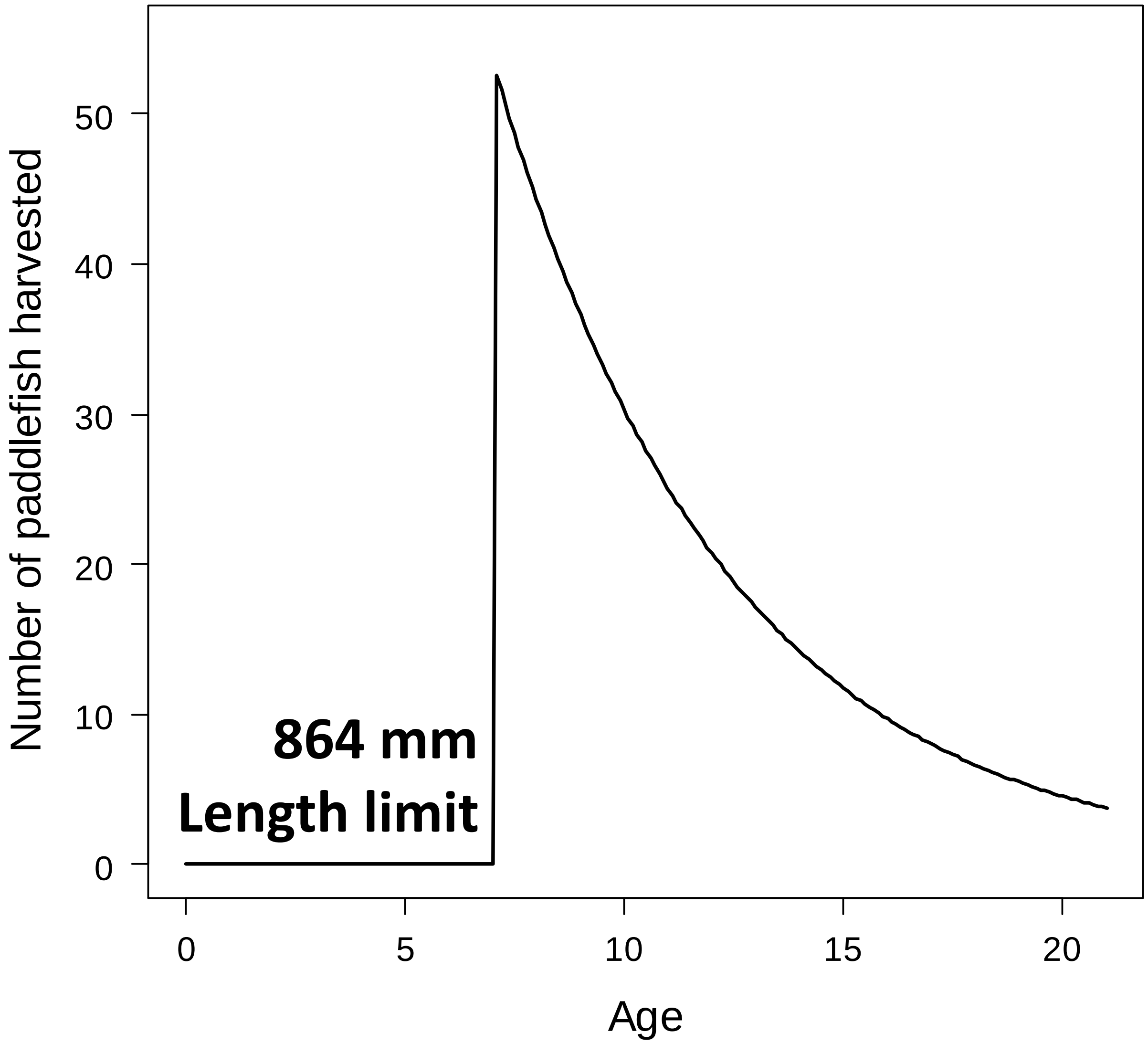
300 kg

*Paddlefish can live up to 21 years ($\lambda_{max}$)…So how is total cohort yield calculated?*

# Catch-at-age

Convert length limit to years

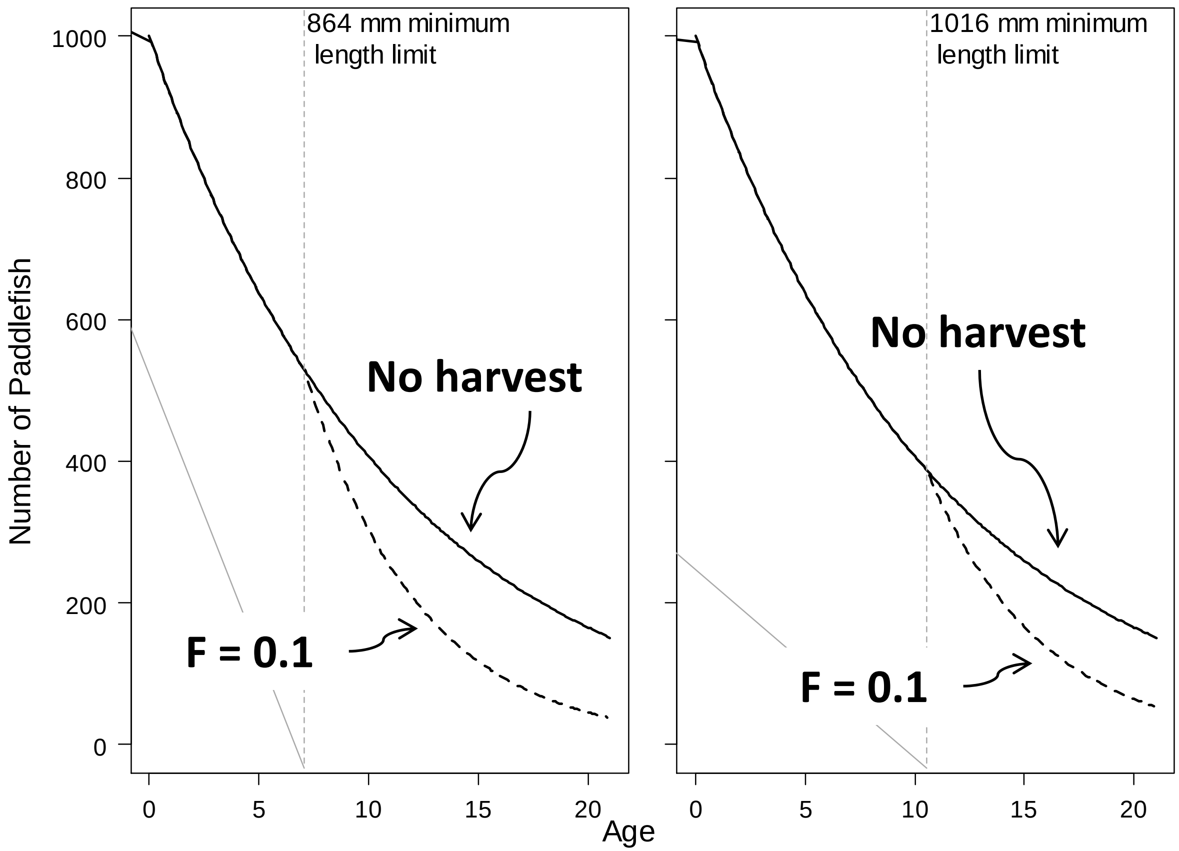
- vonBertalanffy growth function



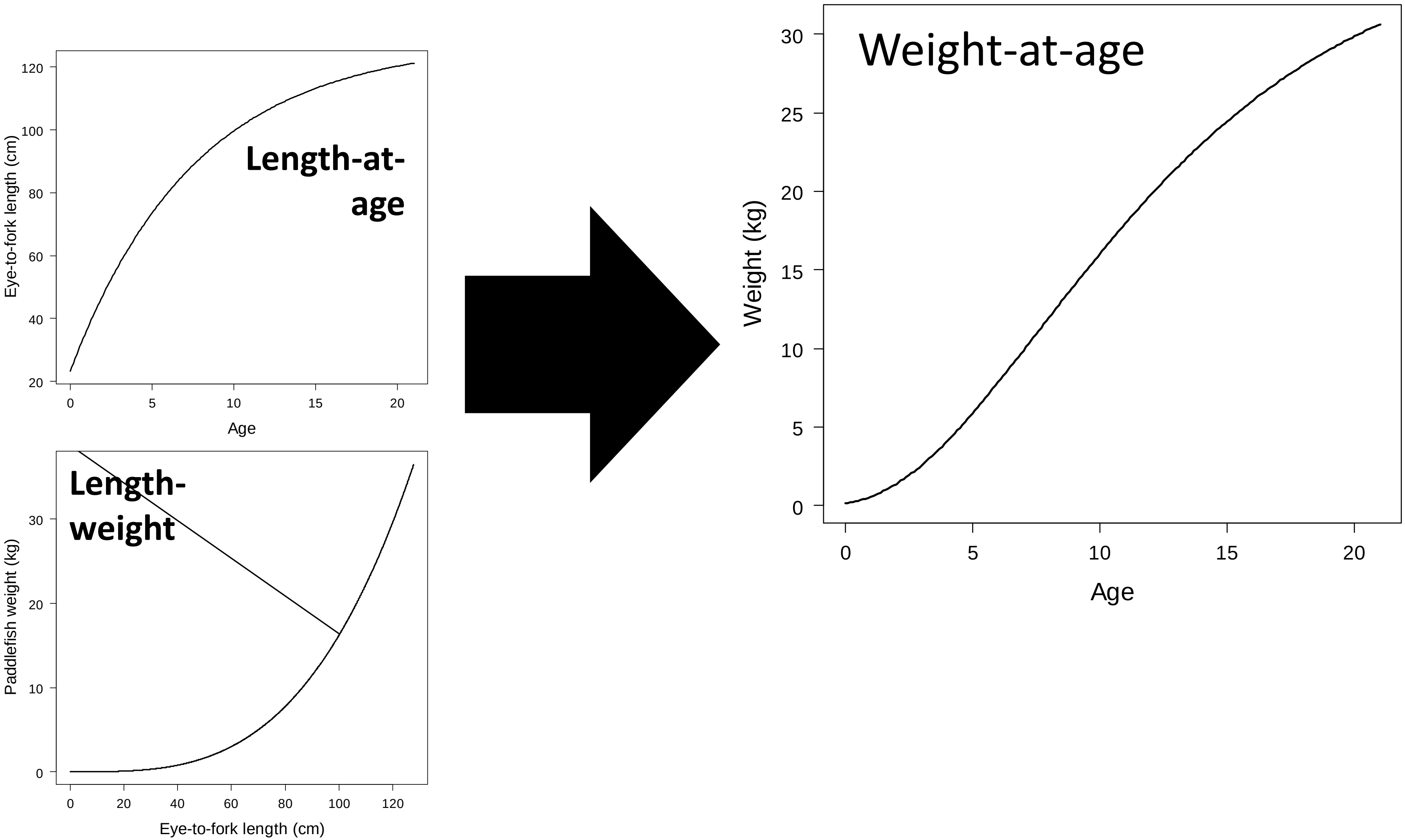
# A yield predicting primer

Need 2 parts for simulated cohort

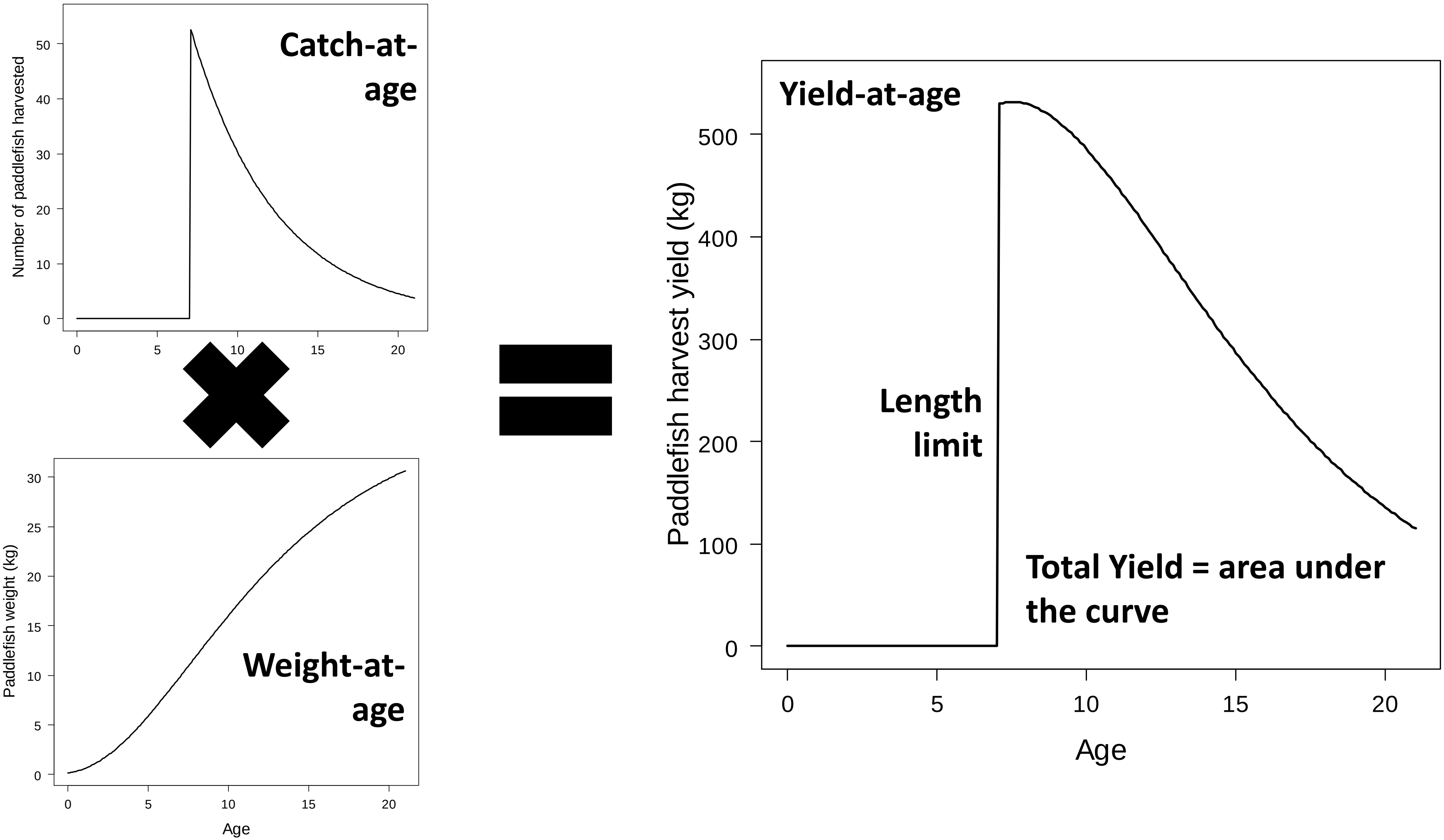
1. Catch-at-age
2. Weight-at-age



# Weight-at-age



# Putting it all together



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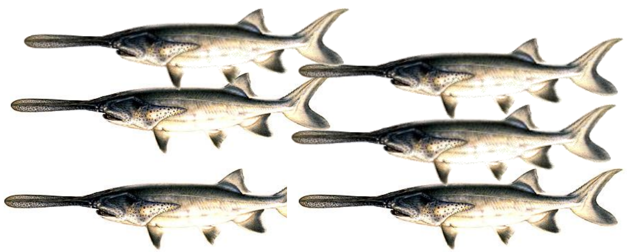
Harvested (age=3.5)



X

Weight(age=3.5)

50 kg

=

Yield(age=3.5)

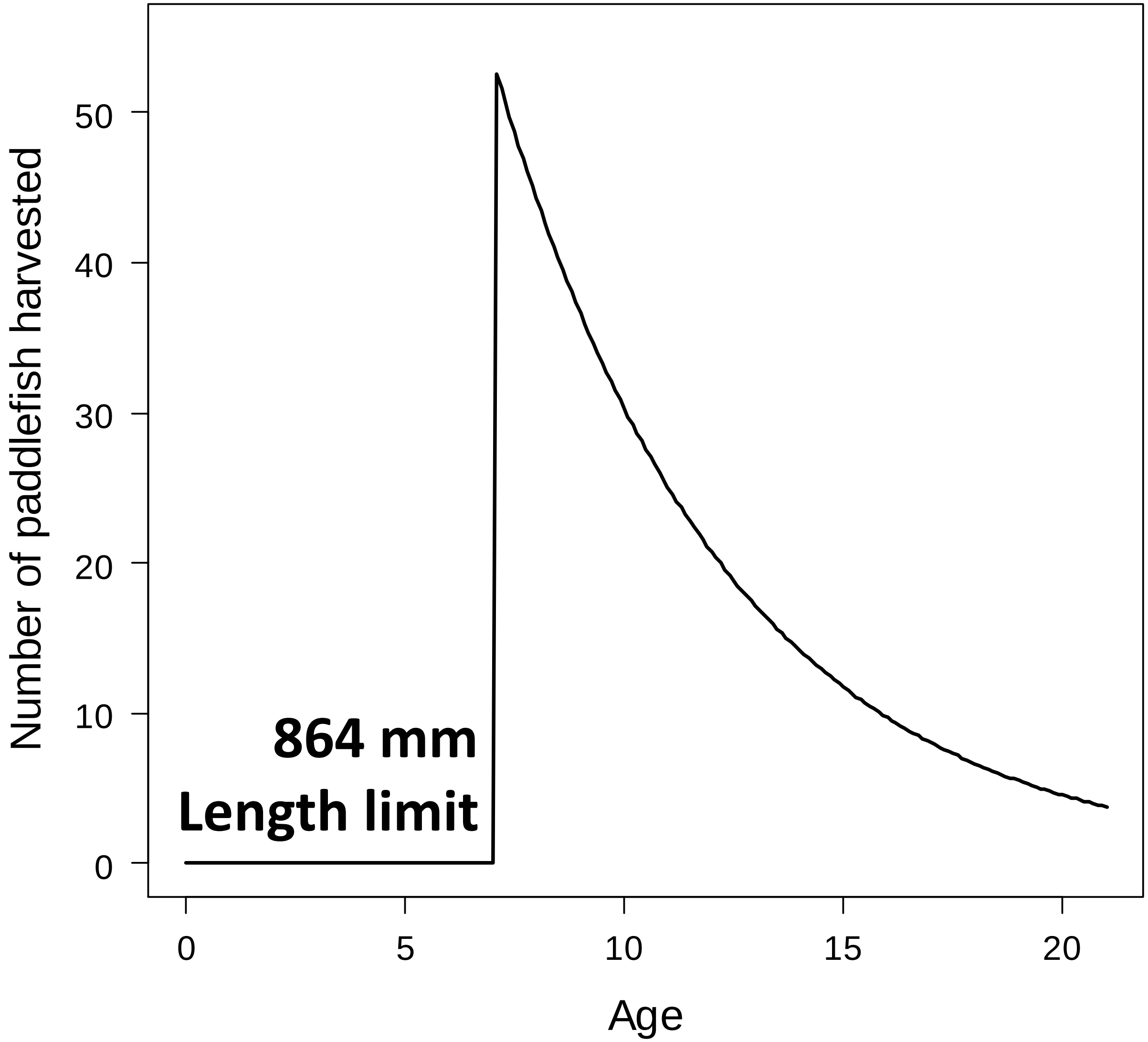
300 kg

*Paddlefish can live up to 21 years ($\lambda_{max}$)…So how is total cohort yield calculated?*

# Catch-at-age

Convert length limit to years

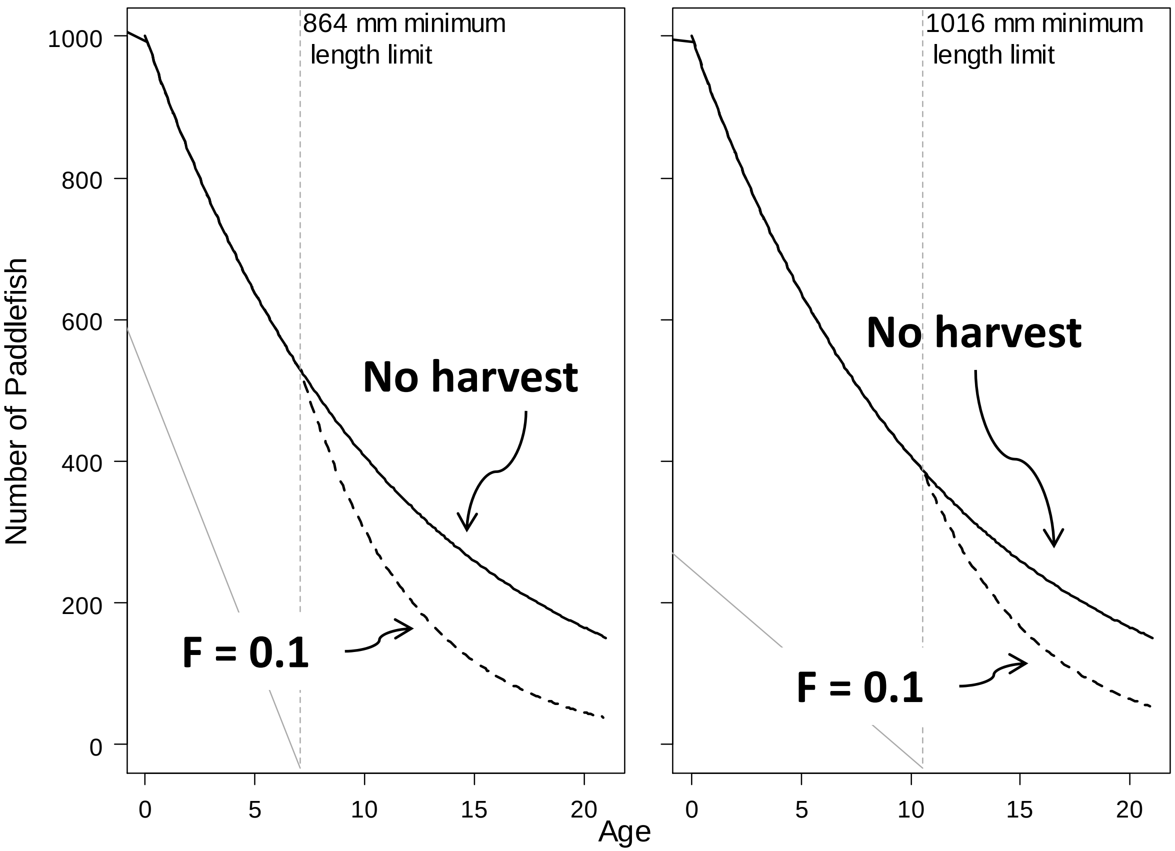
- vonBertalanffy growth function



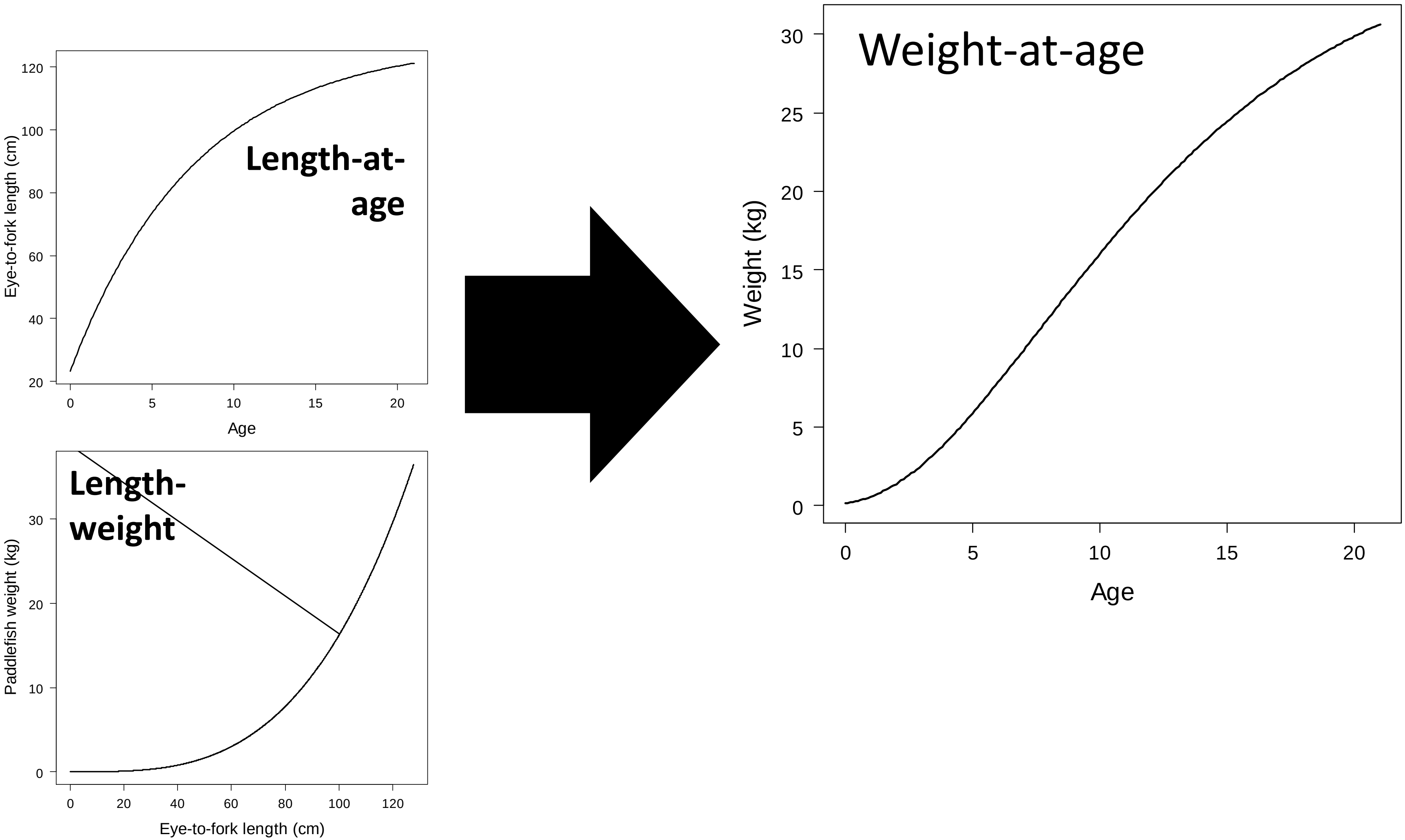
# A yield predicting primer

Need 2 parts for simulated cohort

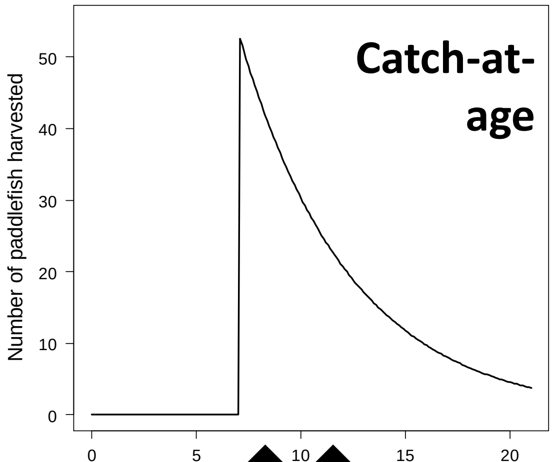
1. Catch-at-age
2. Weight-at-age

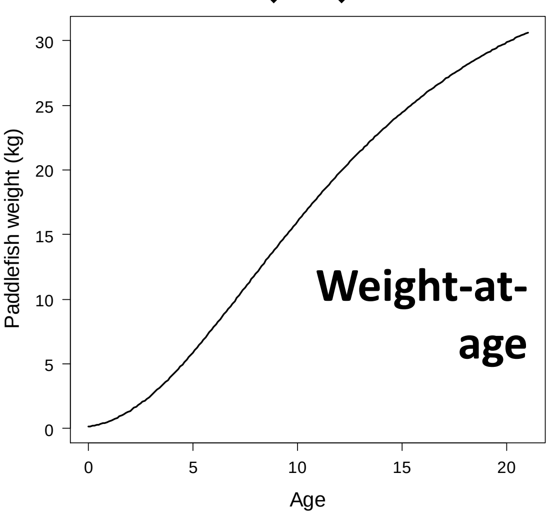


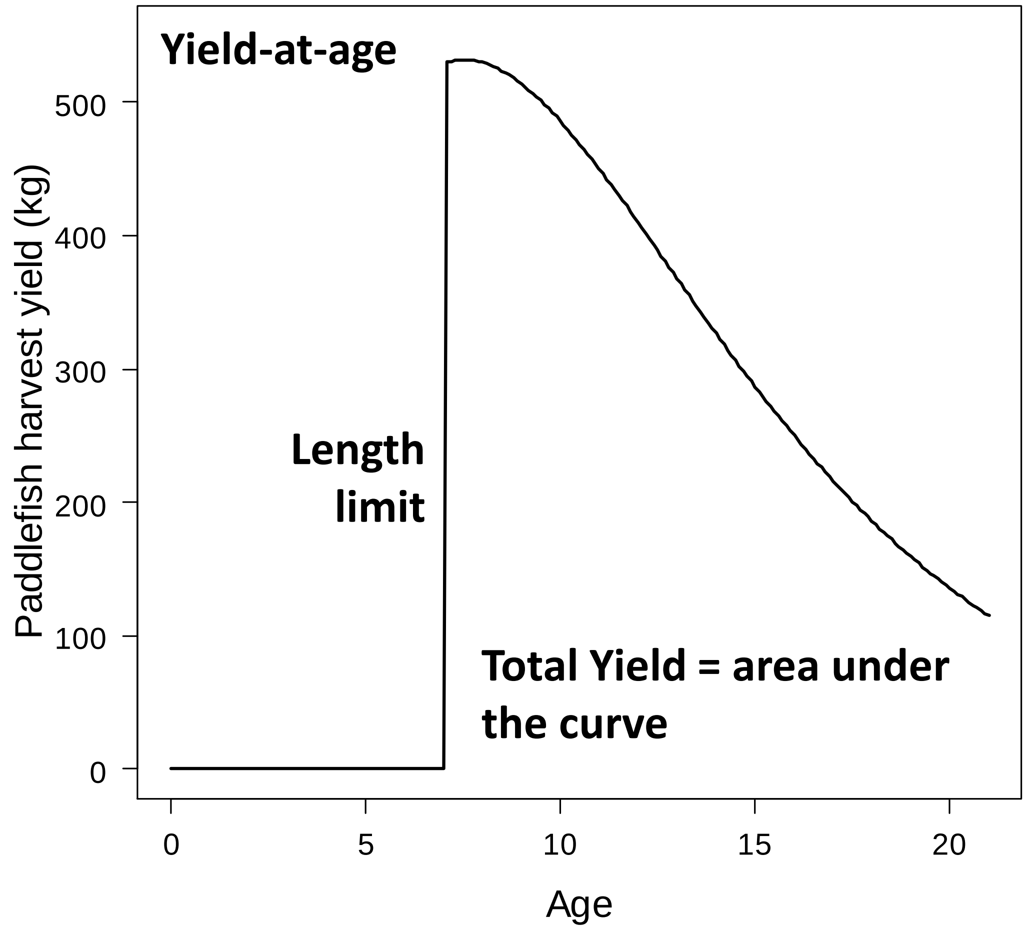
# Weight-at-age



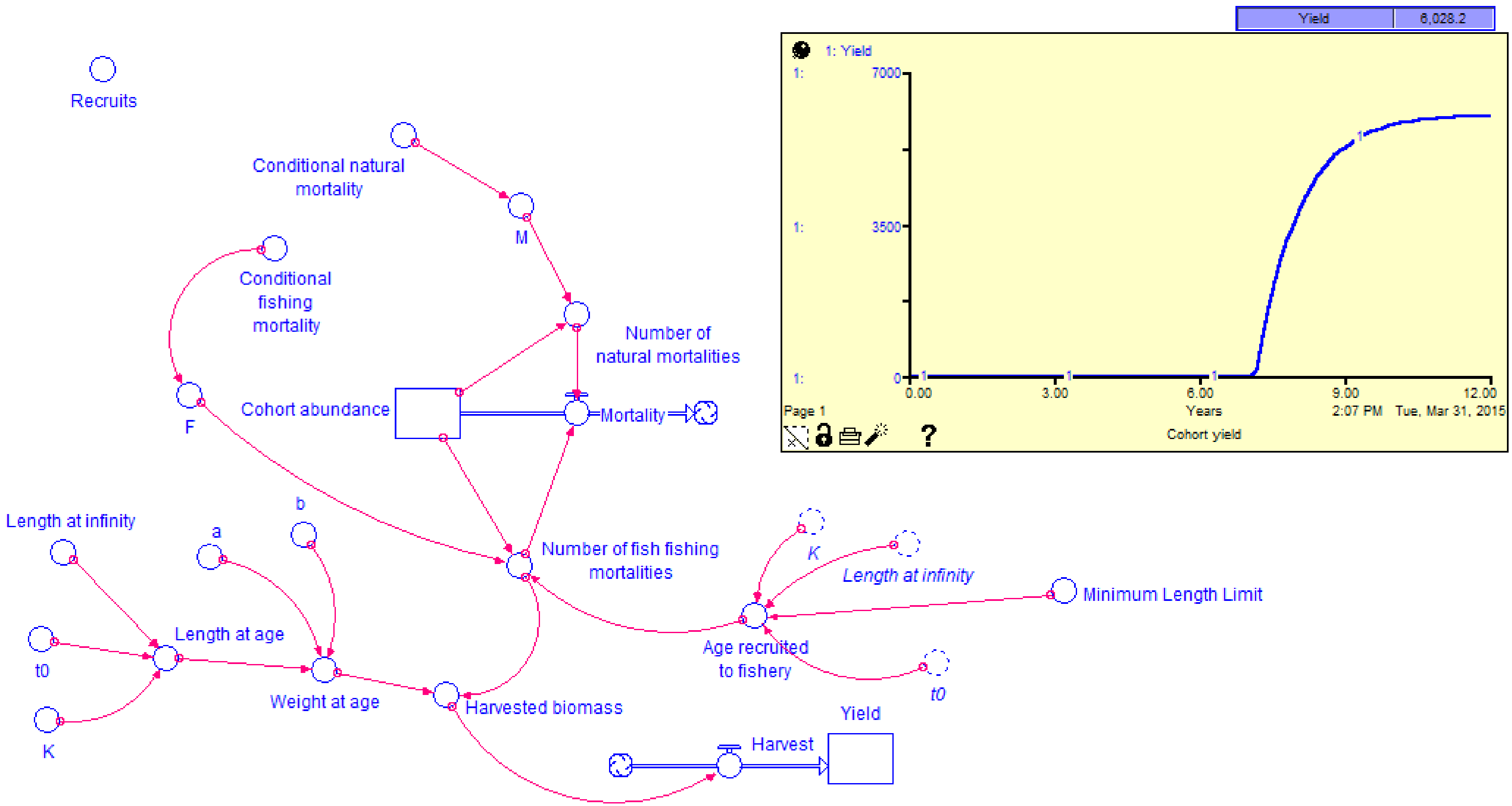
# Putting it all together



# Yield per recruit

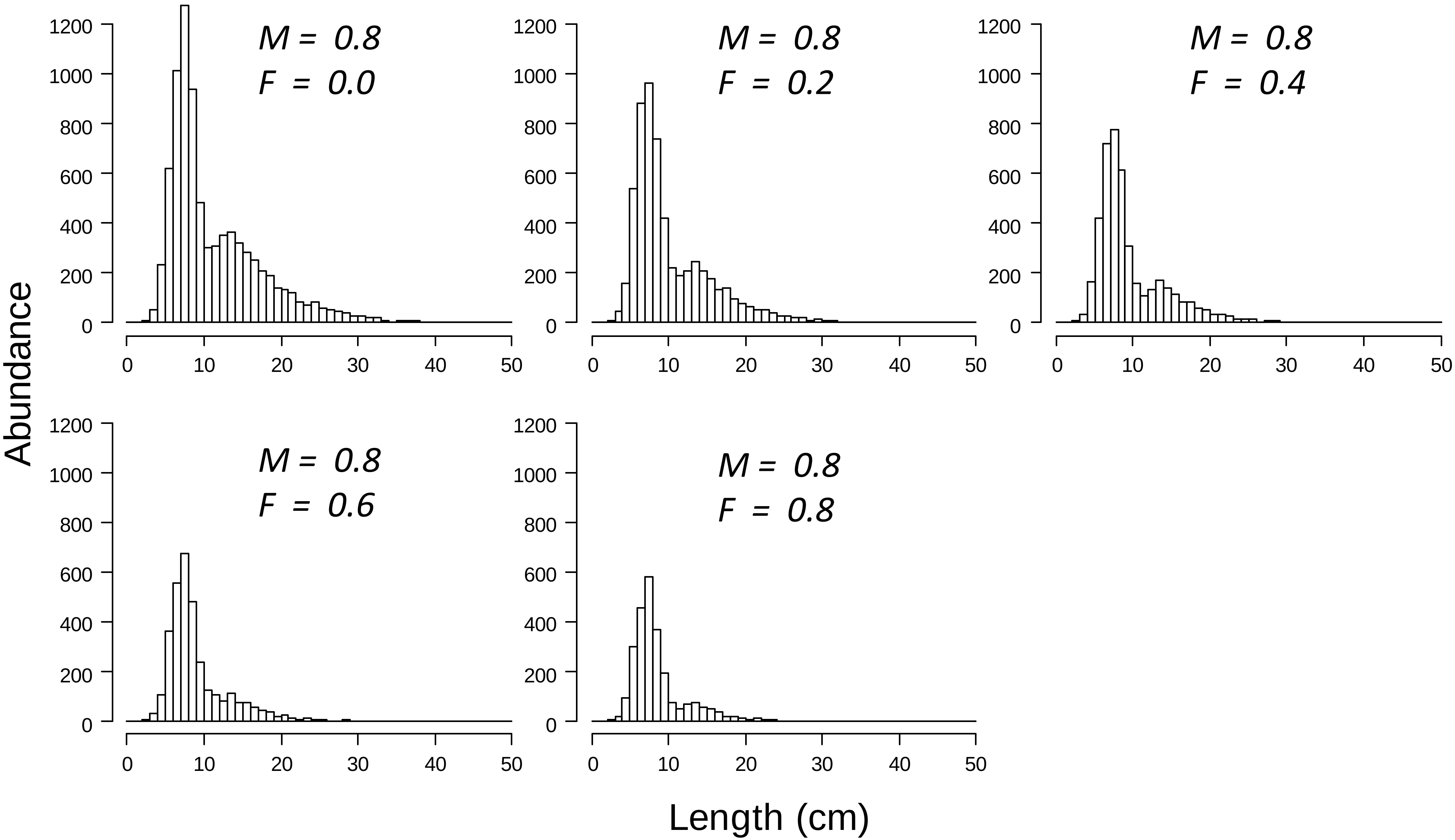


# Commercial versus Recreational

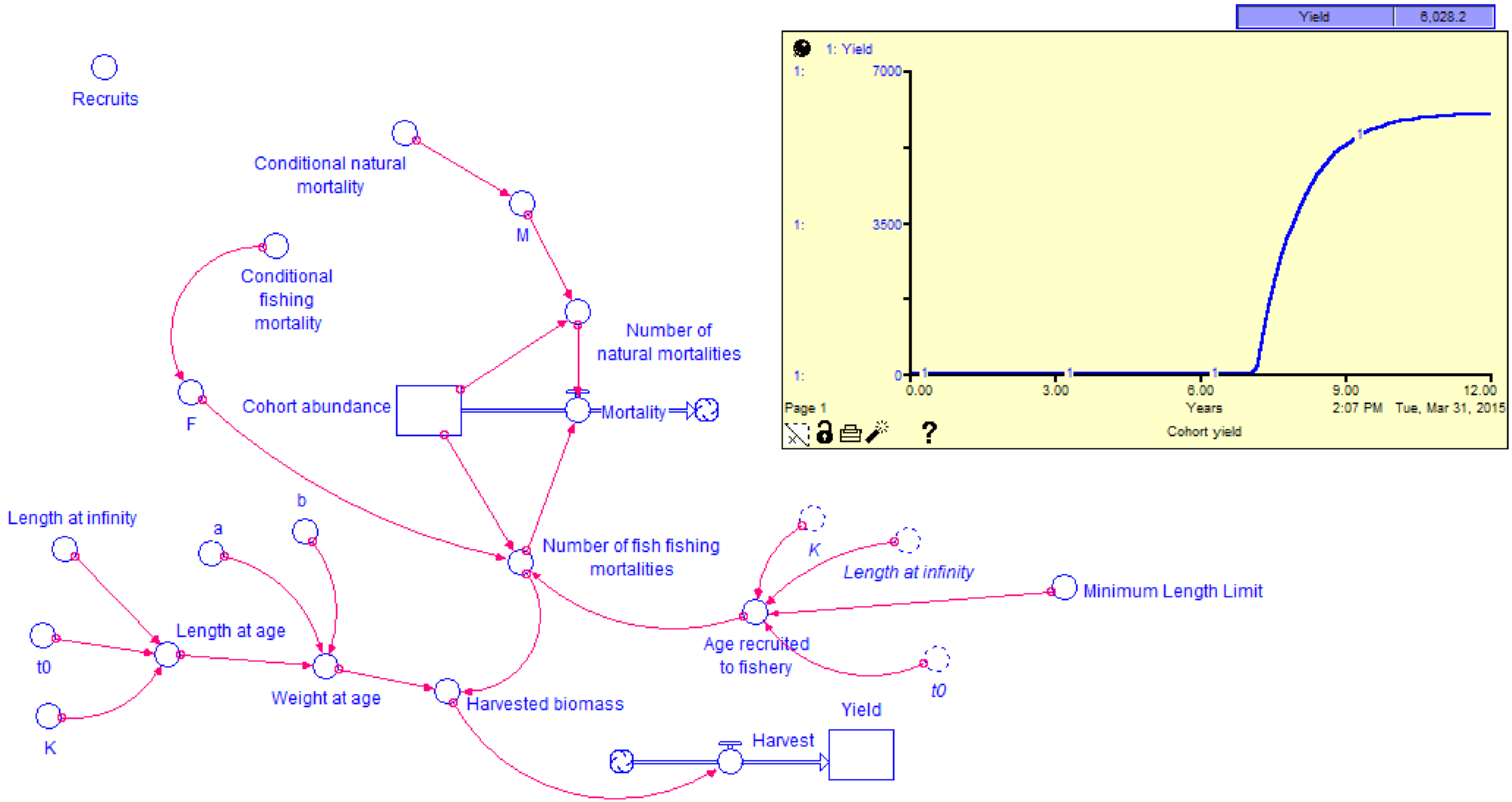
Value: Biomass

Value: Size

# Size structure erodes with *F*



# Yield per recruit & size structure

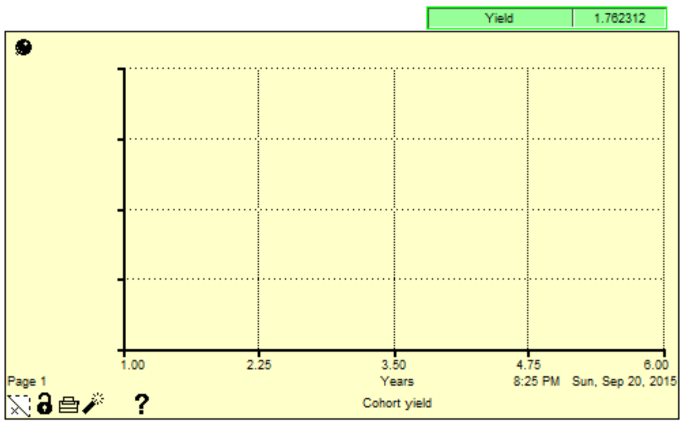


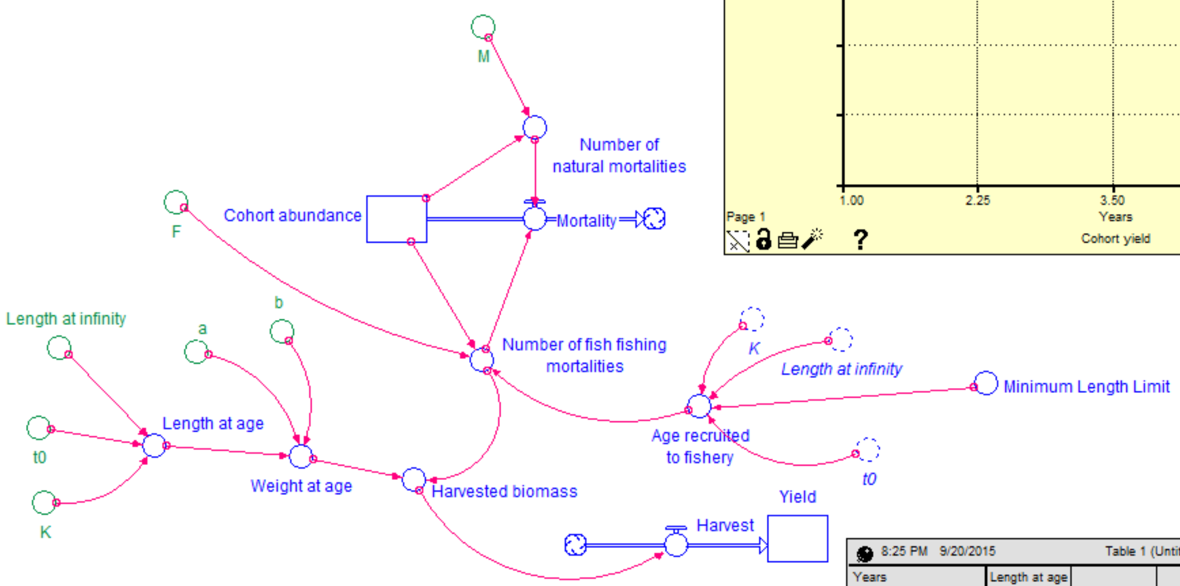
# Stock density indices

PSD (which specifically indicates Quality/Stock) is a basic measure of size structure, and thus, balance within fish populations. “Balance” suggests a stable predator prey dynamic with adequate recruitment and growth of both predator and prey.

# Yield and PSD

Largemouth Bass Yield Per Recruit Model




8:25 PM 9/20/2015 Table 1 (Untitled Table)

| Years | Length at age |
|---|---|
| Initial | 94.65 |
| 1 | 173.79 |
| 2 | 232.42 |
| 3 | 275.85 |
| 4 | 308.03 |
| 5 | 331.87 |

# Largemouth Bass PSD Values

| Stock | 200 |
|---|---|
| Quality | 300 |
| Preferred | 380 |
| Memorable | 510 |
| Trophy | 630 |

# Predicted number at length

10 Inch Minimum Length Limit

| | | F | | | |
|---|---|---|---|---|---|
| Initial | Length | 0 | 0.1 | 0.3 | 0.5 |
| 0 | 106.77 | 1,000 | 1,000 | 1,000 | 1,000 |
| 1 | 194.18 | 175 | 175 | 175 | 175 |
| 2 | 265.75 | **31** | **30** | **30** | **29** |
| 3 | 324.35 | **5** | **5** | **4** | **3** |
| 4 | 372.32 | **1** | **1** | **0** | **0** |
| 5 | 411.6 | **0** | **0** | **0** | **0** |
| 6 | 443.75 | **0** | **0** | **0** | **0** |
| 7 | 470.08 | **0** | **0** | **0** | **0** |
| 8 | 491.64 | **0** | **0** | **0** | **0** |
| 9 | 509.29 | **0** | **0** | **0** | **0** |
| 10 | 523.74 | **0** | **0** | **0** | **0** |
| 11 | 535.57 | **0** | **0** | **0** | **0** |

# Predicted number at length

12 Inch Minimum Length Limit

| | | F | | | |
|---|---|---|---|---|---|
| Initial | Length | 0 | 0.1 | 0.3 | 0.5 |
| 0 | 106.77 | 1,000 | 1,000 | 1,000 | 1,000 |
| 1 | 194.18 | 175 | 175 | 175 | 175 |
| 2 | 265.75 | **31** | **31** | **31** | **31** |
| 3 | 324.35 | **5** | **5** | **5** | **4** |
| 4 | 372.32 | **1** | **1** | **1** | **0** |
| 5 | 411.6 | **0** | **0** | **0** | **0** |
| 6 | 443.75 | **0** | **0** | **0** | **0** |
| 7 | 470.08 | **0** | **0** | **0** | **0** |
| 8 | 491.64 | **0** | **0** | **0** | **0** |
| 9 | 509.29 | **0** | **0** | **0** | **0** |
| 10 | 523.74 | **0** | **0** | **0** | **0** |
| 11 | 535.57 | **0** | **0** | **0** | **0** |

# PSD Values-Traditional

| F | Stock | Quality | PSD |
|---|---|---|---|
| 0.00 | 37 | 6 | 18 |
| 0.10 | 37 | 6 | 16 |
| 0.30 | 34 | 1 | 12 |
| 0.50 | 32 | 0 | 1 |

10 Inch Minimum Length Limit

| F | Stock | Quality | PSD |
|---|---|---|---|
| 0.00 | 37 | 6 | 18 |
| 0.10 | 37 | 6 | 17 |
| 0.30 | 36 | 5 | 15 |
| 0.50 | 5 | 0 | 9 |

12 Inch Minimum Length Limit

# PSD Values-Incremental

| F | Stock | Quality | PSD |
|---|---|---|---|
| 0.00 | 37 | 6 | 82 |
| 0.10 | 37 | 6 | 83 |
| 0.30 | 34 | 1 | 88 |
| 0.50 | 32 | 0 | 99 |

10 Inch Minimum Length Limit

| F | Stock | Quality | PSD |
|---|---|---|---|
| 0.00 | 37 | 6 | 82 |
| 0.10 | 37 | 6 | 83 |
| 0.30 | 36 | 5 | 85 |
| 0.50 | 5 | 0 | 99 |

12 Inch Minimum Length Limit

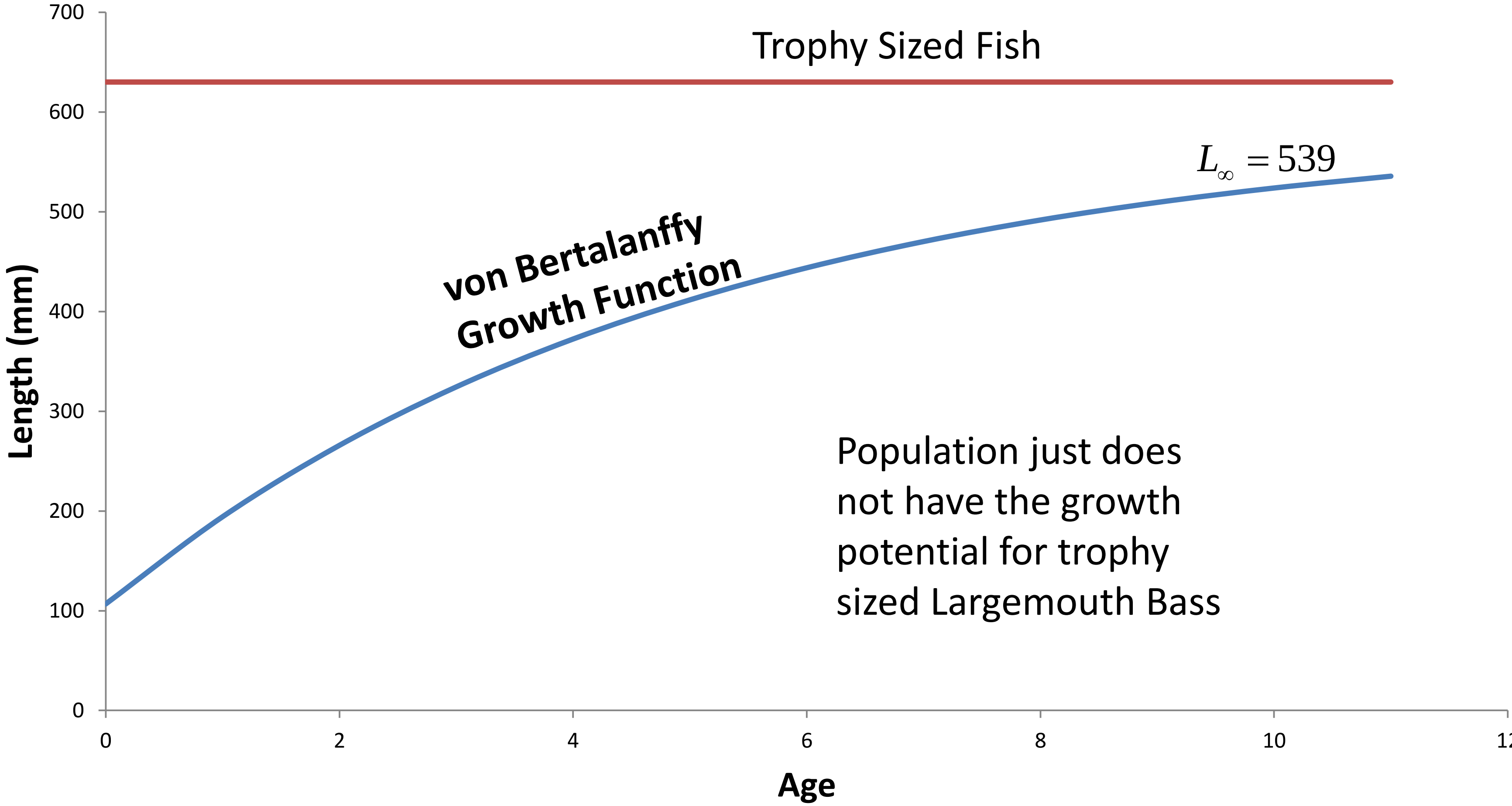
# Where are the trophy fish?

12 Inch Minimum Length Limit

| | | F | | | |
|---|---|---|---|---|---|
| Initial | Length | 0 | 0.1 | 0.3 | 0.5 |
| 0 | 106.77 | 1,000 | 1,000 | 1,000 | 1,000 |
| 1 | 194.18 | 175 | 175 | 175 | 175 |
| 2 | 265.75 | **31** | **31** | **31** | **31** |
| 3 | 324.35 | **5** | **5** | **5** | **4** |
| 4 | 372.32 | **1** | **1** | **1** | **0** |
| 5 | 411.6 | **0** | **0** | **0** | **0** |
| 6 | 443.75 | **0** | **0** | **0** | **0** |
| 7 | 470.08 | **0** | **0** | **0** | **0** |
| 8 | 491.64 | **0** | **0** | **0** | **0** |
| 9 | 509.29 | **0** | **0** | **0** | **0** |
| 10 | 523.74 | **0** | **0** | **0** | **0** |
| 11 | 535.57 | **0** | **0** | **0** | **0** |

630 mm!

# Where are the trophy fish?



# Management Case Study

## New regulations displease some Oregon bass fishermen

**GEORGE PLAVEN, East Oregonian** *7:21 a.m. PDT September 8, 2015*

*(Photo: Special to the Statesman Journal)*

PENDLETON, Ore. (AP) — Bud Hartman can sense 55 years of progress beginning to unravel.

As one of the original members of the Oregon Bass and Panfish Club in 1958, Hartman, of Portland, fought for the state's first ever bag limits on bass fishing to protect the species from overharvest.

The Oregon Fish and Wildlife Commission last week approved sport fishing regulations for 2016 that includes removing bag limits on all warmwater fish — including bass, walleye, crappie, panfish and catfish — in the Columbia, John Day and Umpqua rivers, leaving Hartman deflated.

"I've been at the forefront of making sure these fish have the right to exist in Oregon," he said. "As of last Friday, I felt like all of these efforts we put in have all been in vain."

Hartman, who attended the commission's meeting in Seaside, said he felt his arguments against ending bag limits on warmwater fish fell on deaf ears. He isn't worried the fisheries will become overly degraded, but said it simply sends the wrong message to anglers.

"To me, it devalues the resource," Hartman said. "It says to the angling public that (these fish) don't mean anything."

STATESMAN JOURNAL

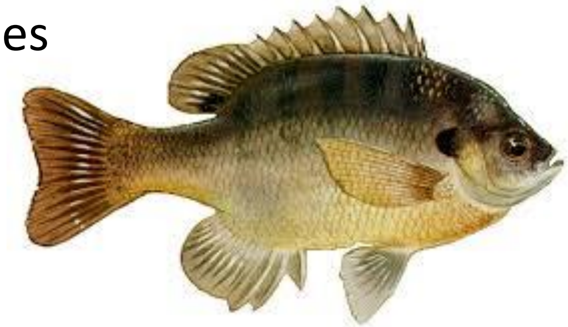
Commission approves 2016 fishing rules

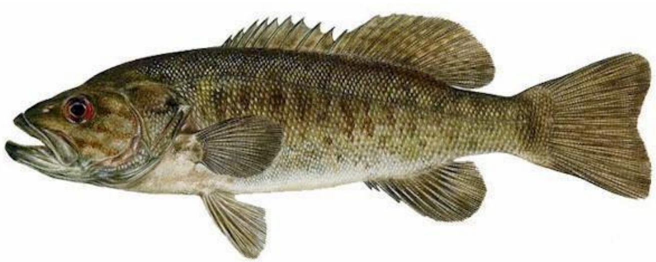
(http://www.statesmanjournal.com/story/travel/outdoors/hunting-fishing/2015/09/04/commission-approves-2016-fishing-rules/71726808/?from=global&sessionKey=&autologin=)

Eighteen percent of Oregon fishermen said they consider themselves primarily warmwater anglers, according to a 2006 survey by the state Department of Fish & Wildlife. Another 26 percent said they fished for warmwater species at some point during the past year.

# Management case study

Management Decision to Remove
Bag Limits on Warmwater Fishes





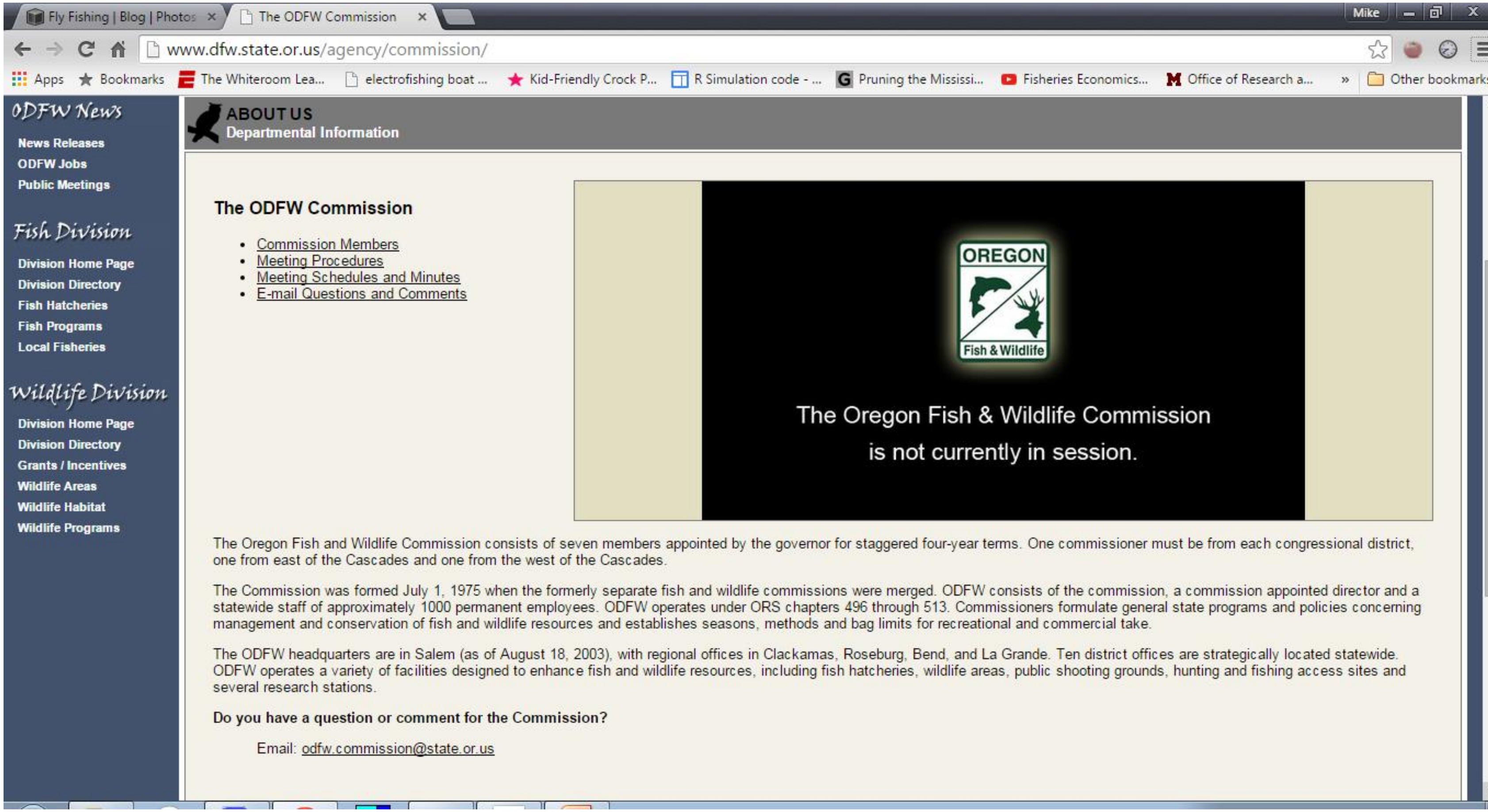
# Governance

*"The Oregon Fish and Wildlife Commission consists of <u>seven members appointed by the governor for staggered four-year terms</u>. One commissioner must be from each congressional district, one from east of the Cascades and one from the west of the Cascades."*

*"The Commission was formed July 1, 1975 when the formerly separate fish and wildlife commissions were merged. ODFW consists of the commission, a commission appointed director and a statewide staff of approximately 1000 permanent employees. ODFW operates under ORS chapters 496 through 513. Commissioners formulate general state programs and policies concerning management and conservation of fish and wildlife resources and establishes seasons, methods and bag limits for recreational and commercial take.*

*"The ODFW headquarters are in Salem (as of August 18, 2003), with regional offices in Clackamas, Roseburg, Bend, and La Grande. Ten district offices are strategically located statewide. ODFW operates a variety of facilities designed to enhance fish and wildlife resources, including fish hatcheries, wildlife areas, public shooting grounds, hunting and fishing access sites and several research stations."*

# Transparency



# Visibility


FRESH CHUM | OLD CHUM | CHUM TOPICS | SLAB OF THE YEAR

« Man says he likes feel of sharks | Main | DJI Phantom 3 & Inspire 1 Add Auto Flight Modes »

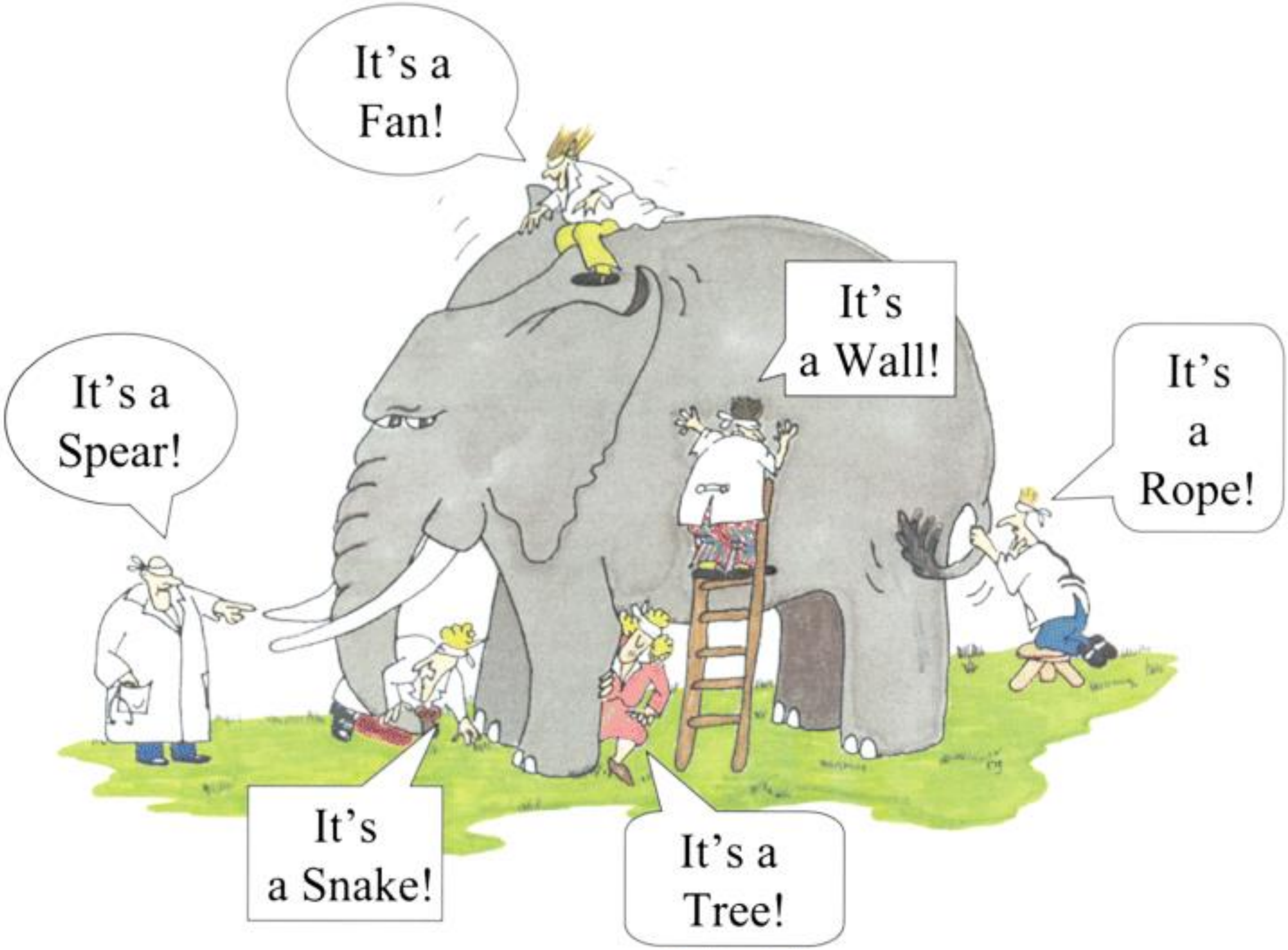
## New regulations displease some Oregon bass fishermen

Wednesday, September 9, 2015 At 12:00AM

It's not just the trout contituency that is upset over the ODFW's new 2016 rules proposals.

LINK (via: The Statesmen Journal)

# Only part of the picture



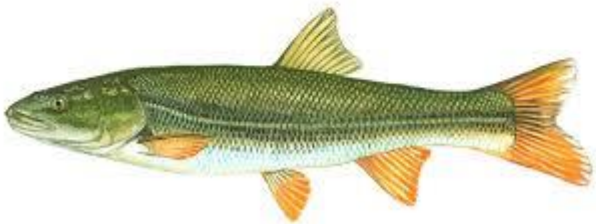
# Geographic Scope

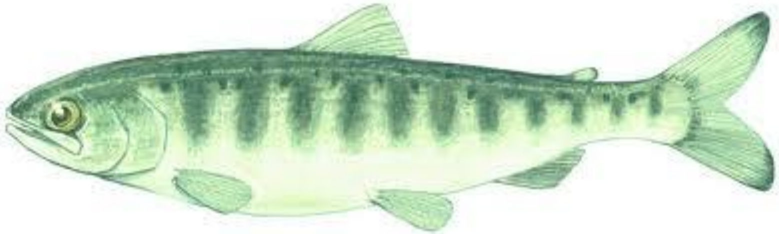
# More of the picture

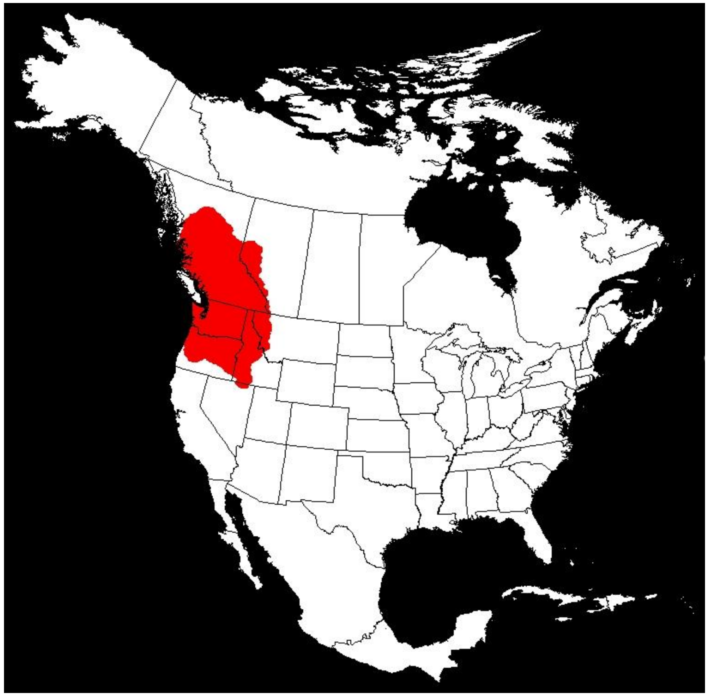


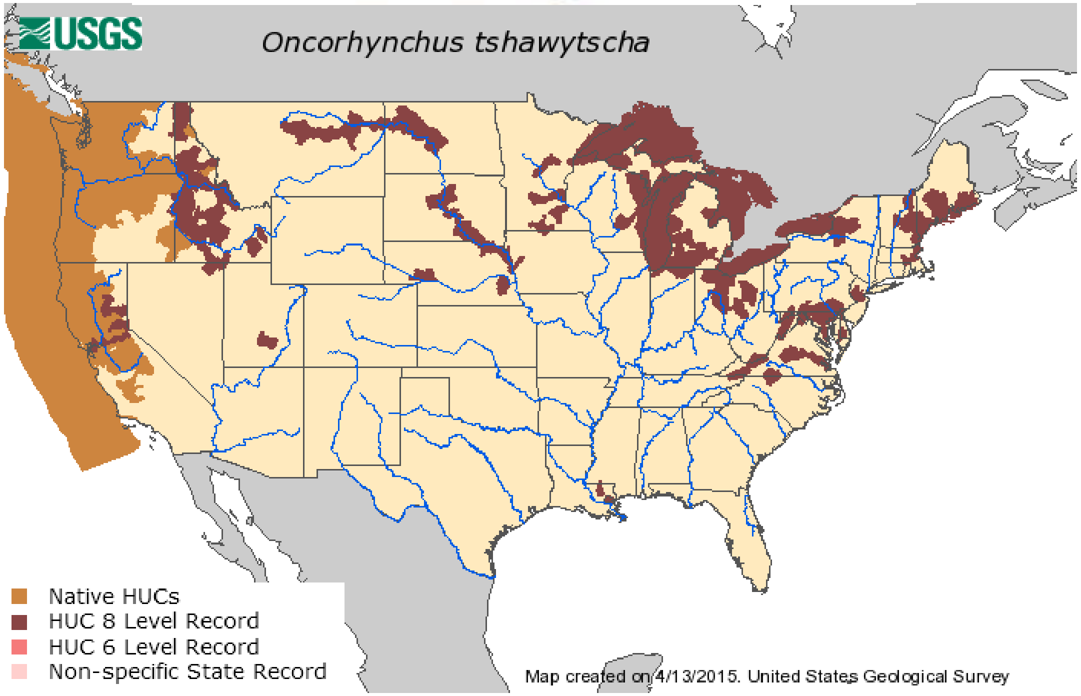
The Elwaha River

# Native fish

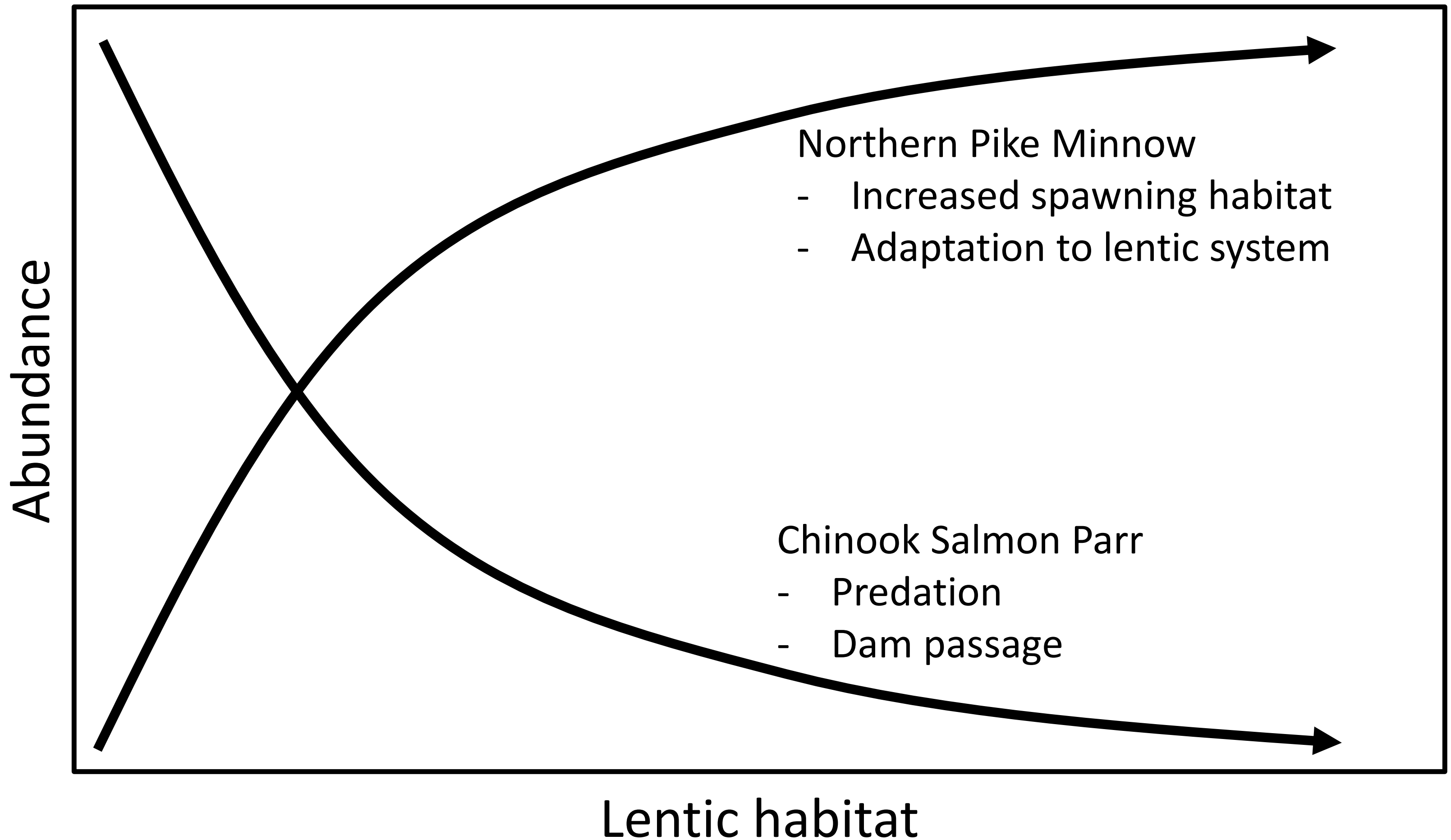




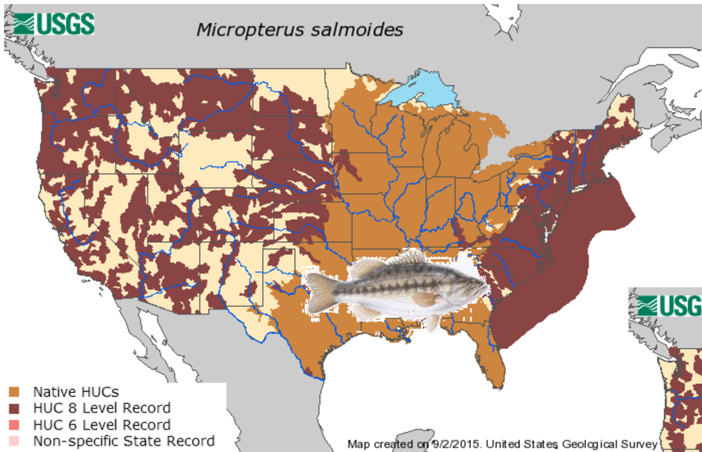


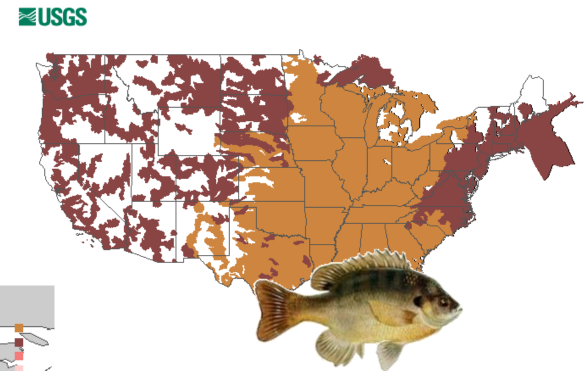

USGS
Oncorhynchus tshawytscha
Native HUCs
HUC 8 Level Record
HUC 6 Level Record
Non-specific State Record
Map created on 4/13/2015. United States Geological Survey

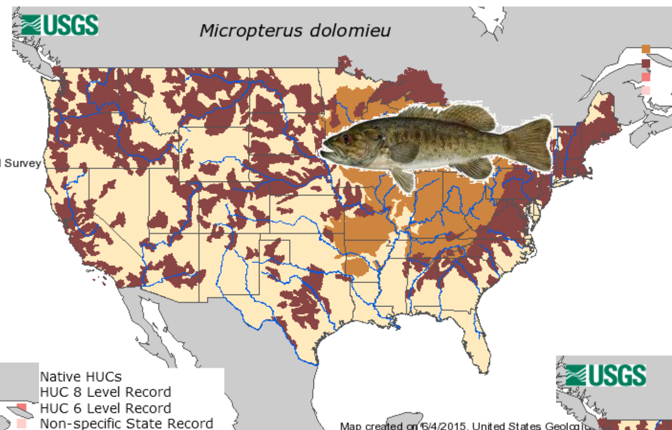
# Functional model

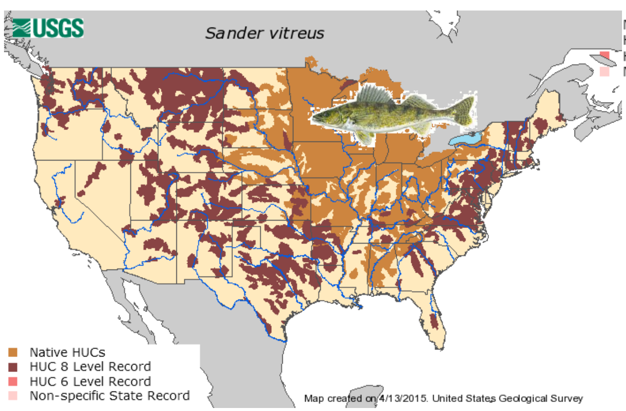


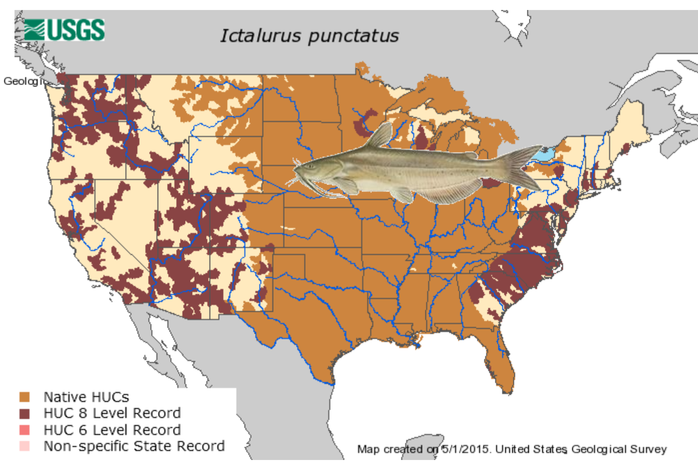
# Non-Native Fish



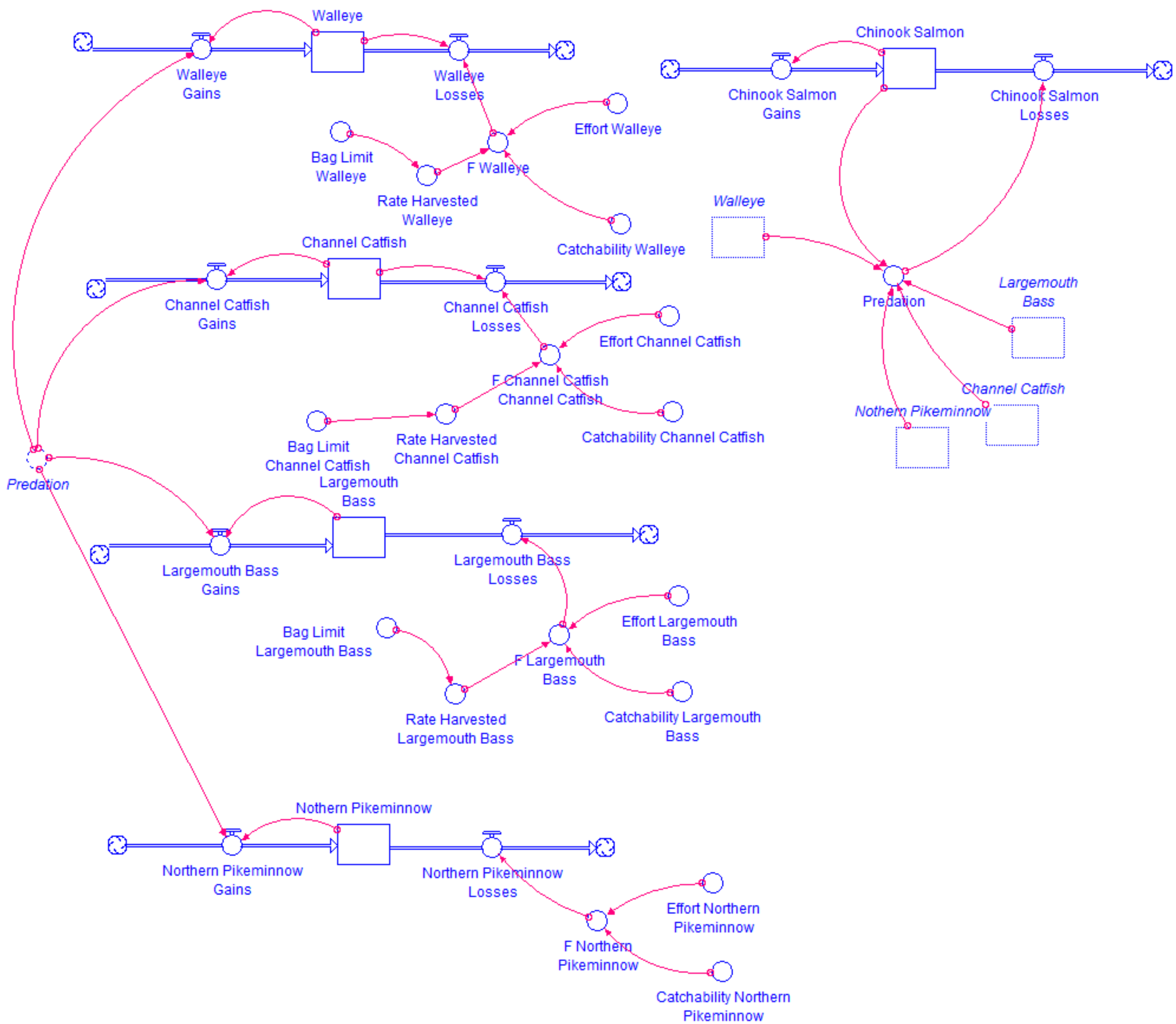




http://nas.er.usgs.gov/

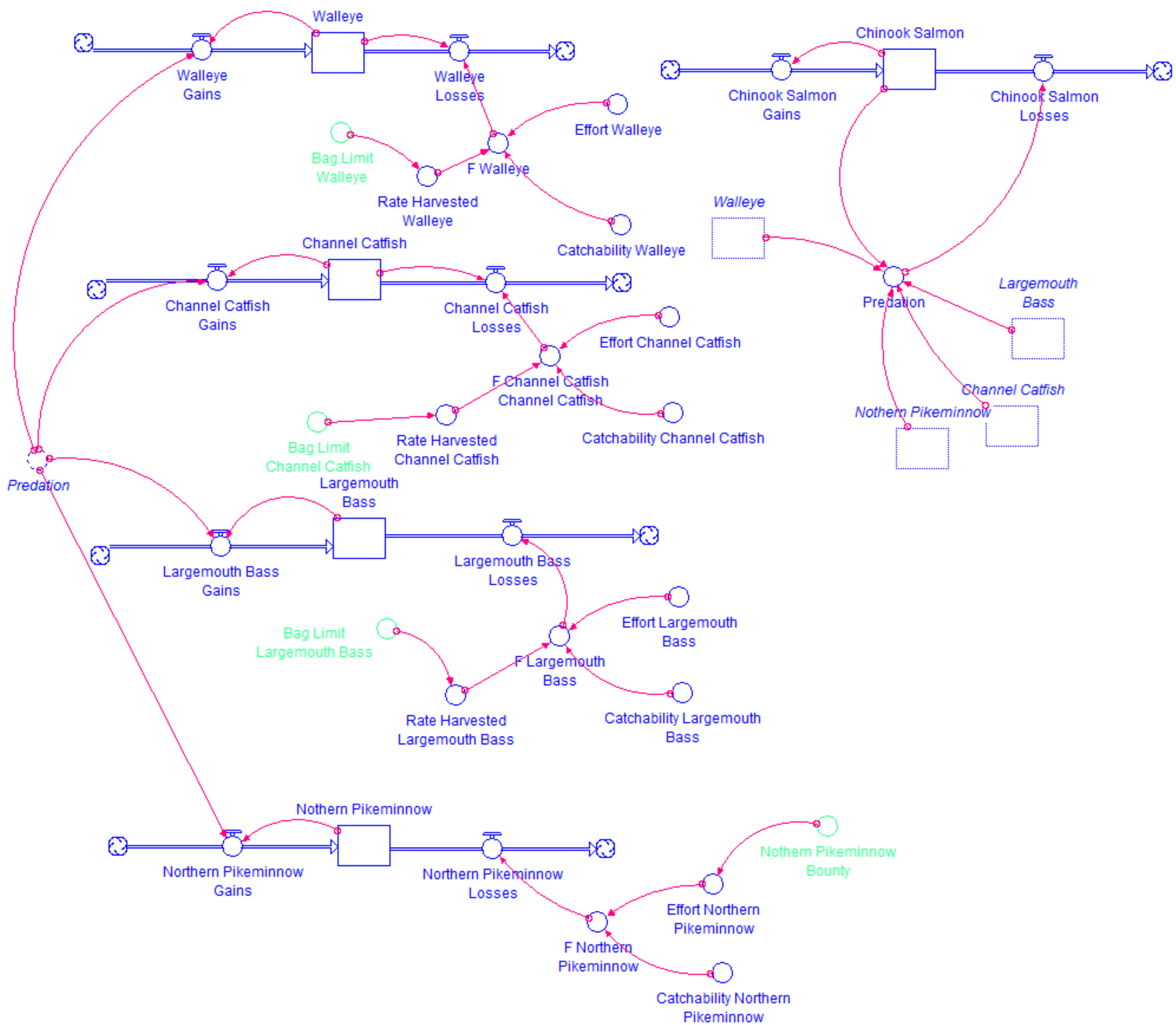
# The System-Conceptually I



# N. Pikeminnow Bounty



# The System-Conceptually II



# Some points to consider

- Impoundment of Columbia River created more lentic habitat
- Introduction of non-native species for recreational and subsistence fishing
- Increased native and non-native piscivore abundance

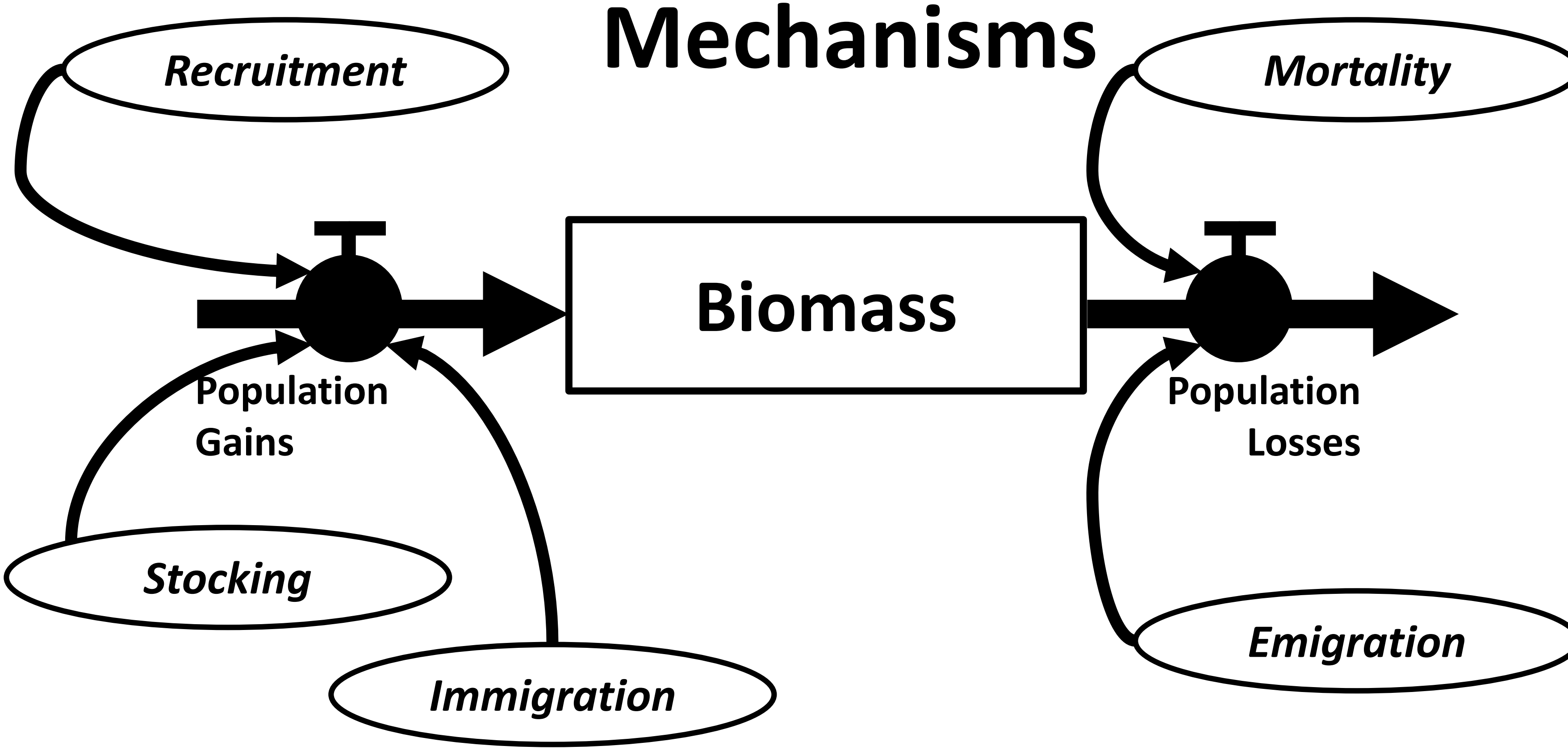
# Management implications

1. Bounty on native fish
2. No bag limits on non-native fish

What is right? Is it the role of the management agency to protect native species?

- How do you value native and non-native fishes to make decisions?

# Fish dynamics: States, Processes, & Mechanisms




$$\frac{dAbundance}{dt} = \left(recruitment + stocking + immigration\right) - \left(mortality + emigration\right)$$

# Understand the system

- Processes:  Gains & Losses
- Mechanisms:  growth, mortality, predation,
- States:  Abundance, Biomass
- Interactions among system components
- Formal representation of the system

# Advantages & *Disadvantages*

1. Transparent representation of the system
2. Communication with stakeholders
3. Prediction and forecasting
4. Unintended consequences
5. Guide monitoring and research
6. *Complex?*
7. *Unrealistic assumptions?*

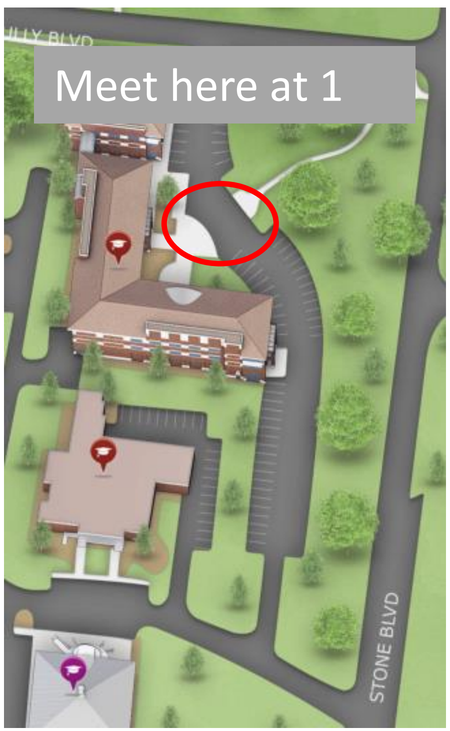
# WF4313/6613-Fisheries Management

Class 13– Yield Management & Management Case Study

# Announcements

# Announcement

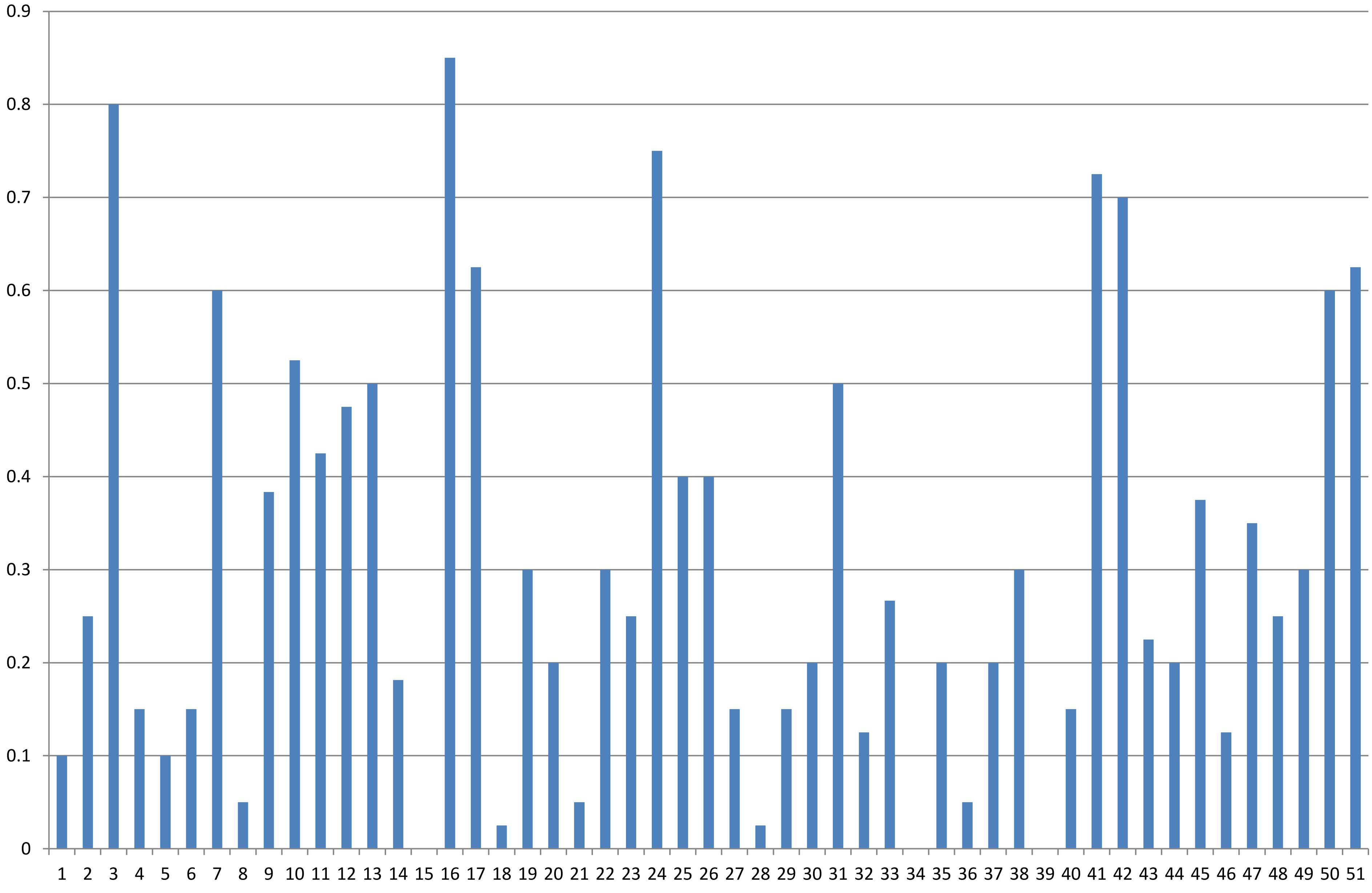
1. Lab tomorrow 10/3-Stream electrofishing
2. Waders, bug repellent, sunscreen, water




**10/3-Group 1**
Yasko, S
Rush, H
Gerhart, B.
Yarber, C.
Shannon, A.
Wilson, A.
Lundy, F.
Woodyard, E.
Munter, Z.
Tipton, J.

**10/10-Group 2**
McAllister, B.
Cook, M.
Pigott, W.
Thompson, W.
Lucore, A.
Virden, M.
Hopson, E.
Pettigrew, C.
Roberson, H.
Gammon, T.

# Exam 1



0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51

# Class Topics

## Yield and biomass management

## Management case study

Management objectives:

1. Maximize yield

Unstructured & structured populations

# HOW DO MANAGERS DETERMINE HOW MUCH TO HARVEST?

$$\frac{dB}{dt} = r \cdot B \frac{K - B}{K} - F \cdot B$$

**BIOMASS: GRAHAM SCHAEFER**

# Concept: equilibrium & non-equilibrium

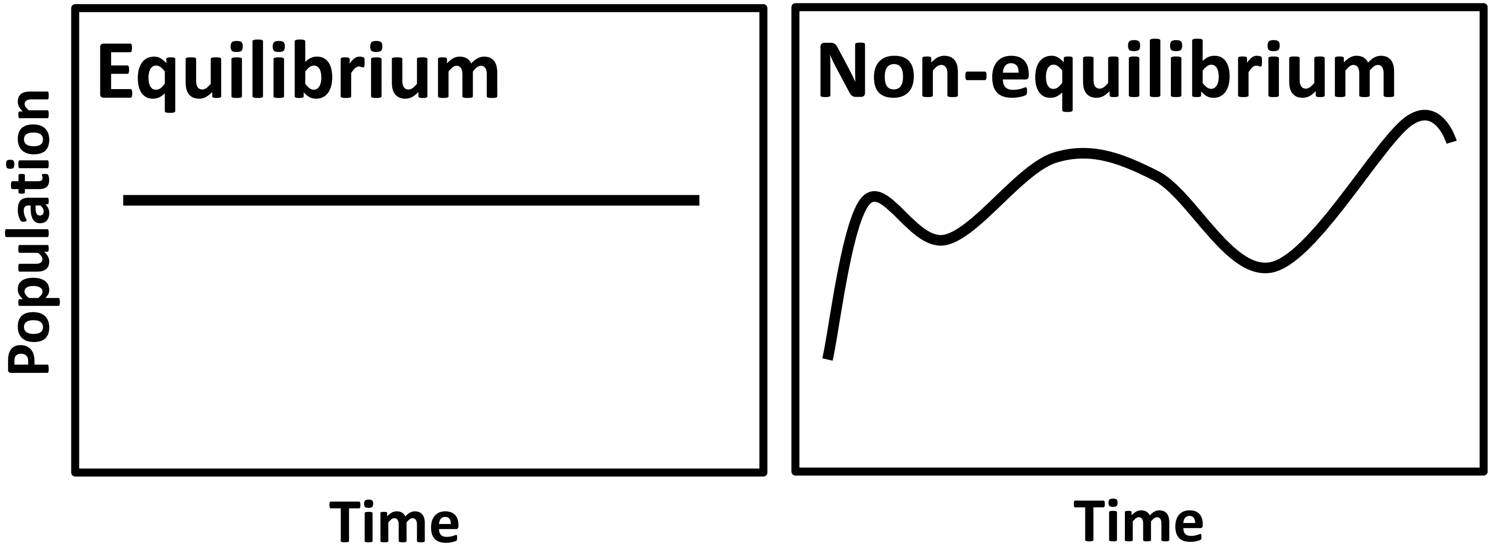
$$0 = \frac{dBiomss}{dt}$$

Population does not change over time.

$$0 \neq \frac{dBiomss}{dt}$$

Population is changing over time.

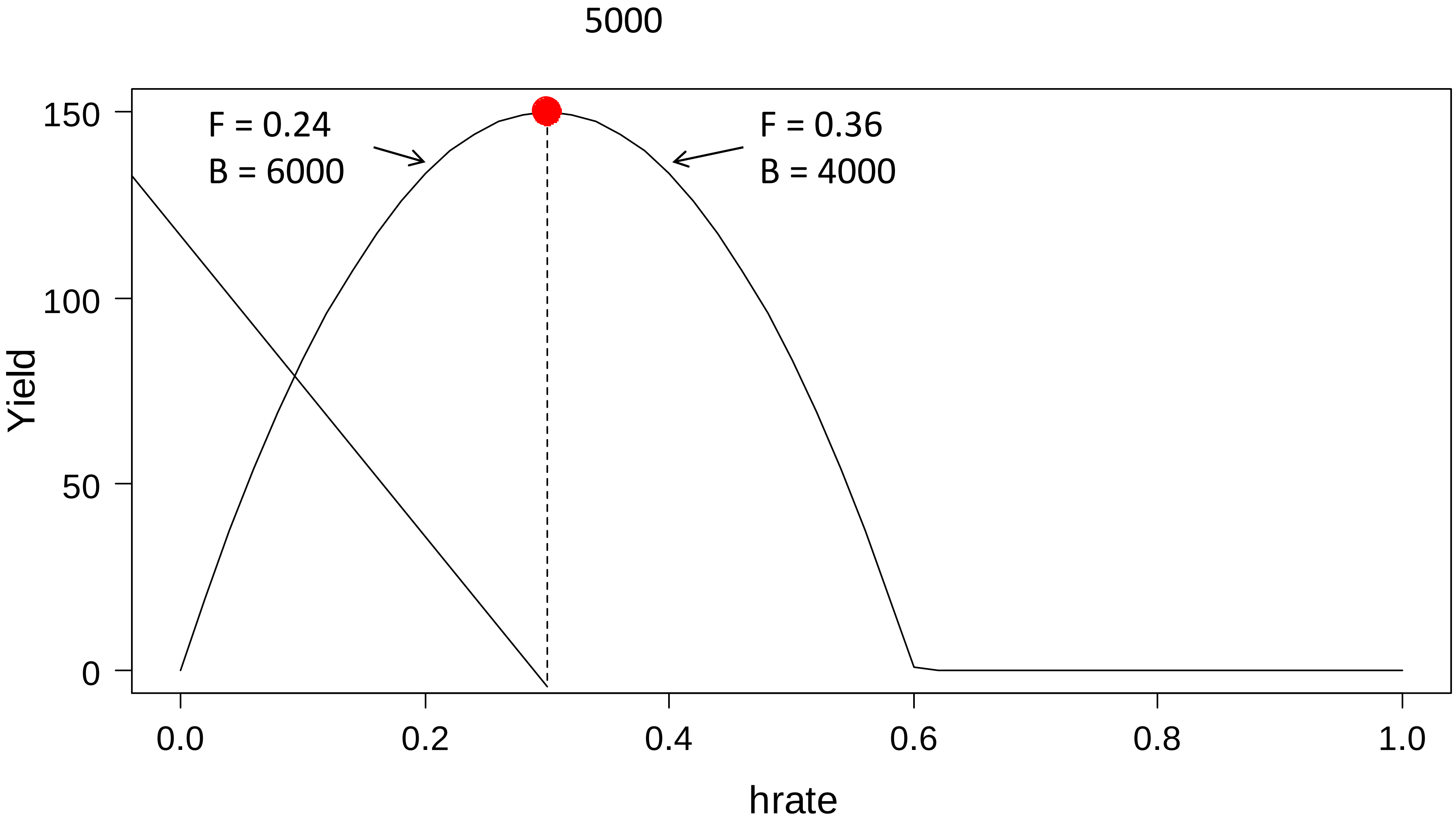
# Concept: equilibrium & non-equilibrium




$$0 = \frac{dBiomss}{dt}$$

$$0 \neq \frac{dBiomss}{dt}$$

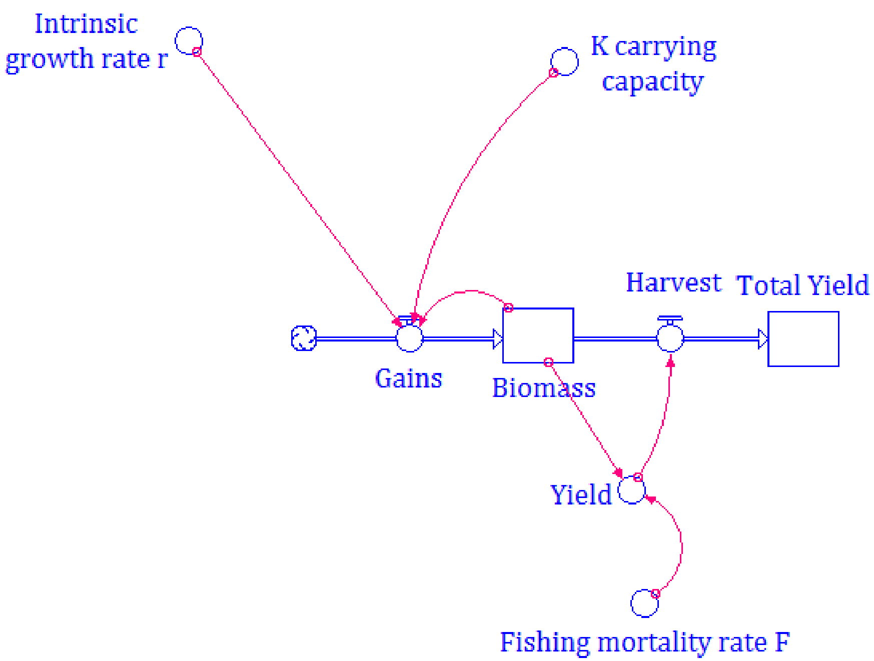
# Equilibrium sustained yield



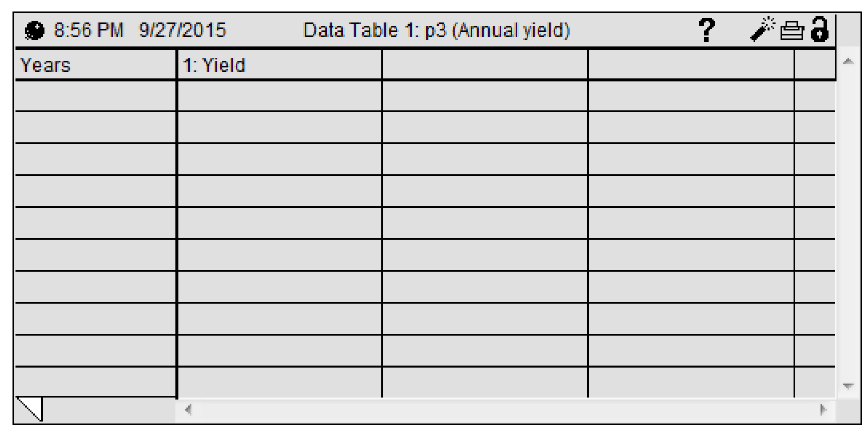
# Why is this important?

- Most harvest model evaluate equilibrium yield!
- Why? Lets explore this!

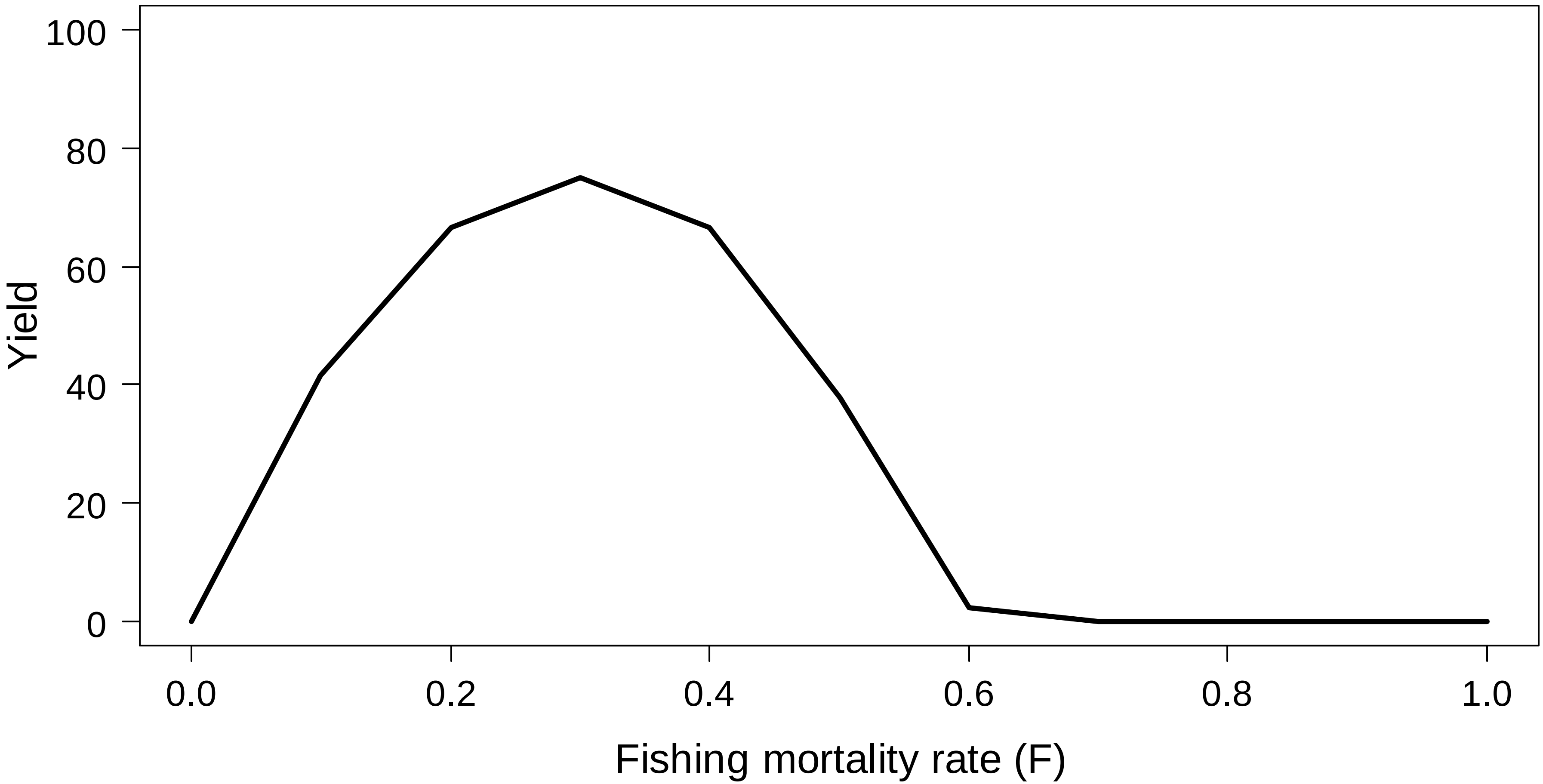
# Biomass dynamics







# Equilibrium conditions

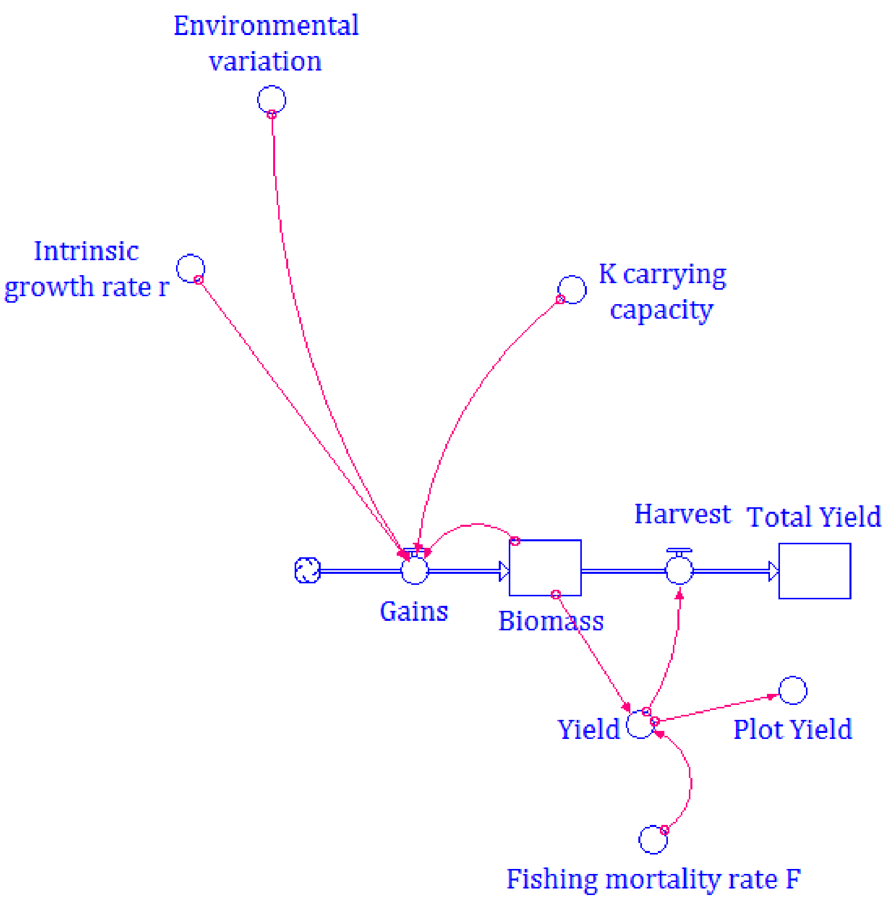


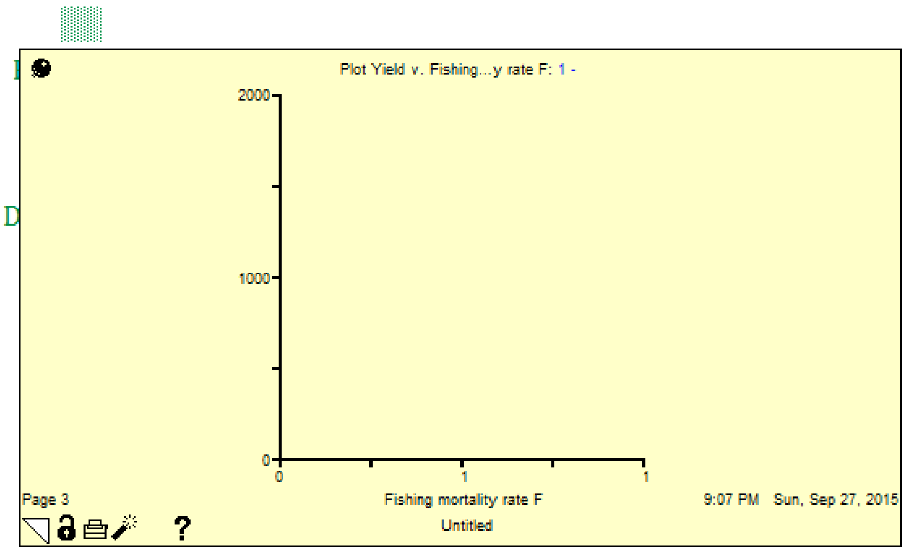
# Biomass dynamics model assumptions

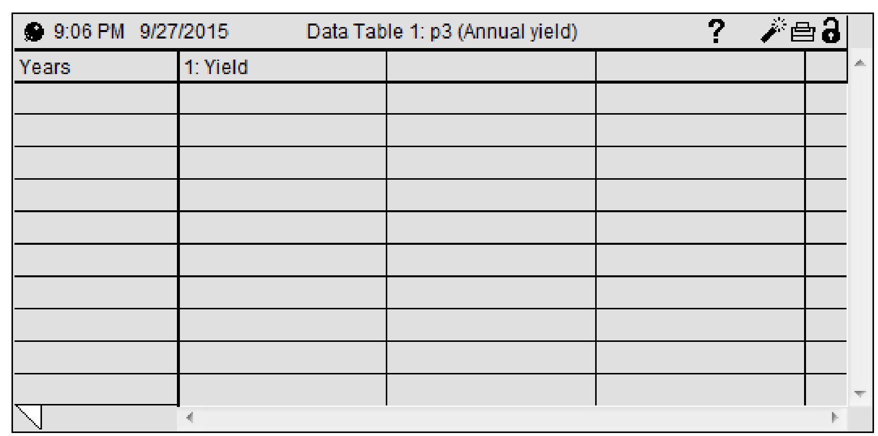
- Rates are constant
- Parameters are constant

Lets explore these

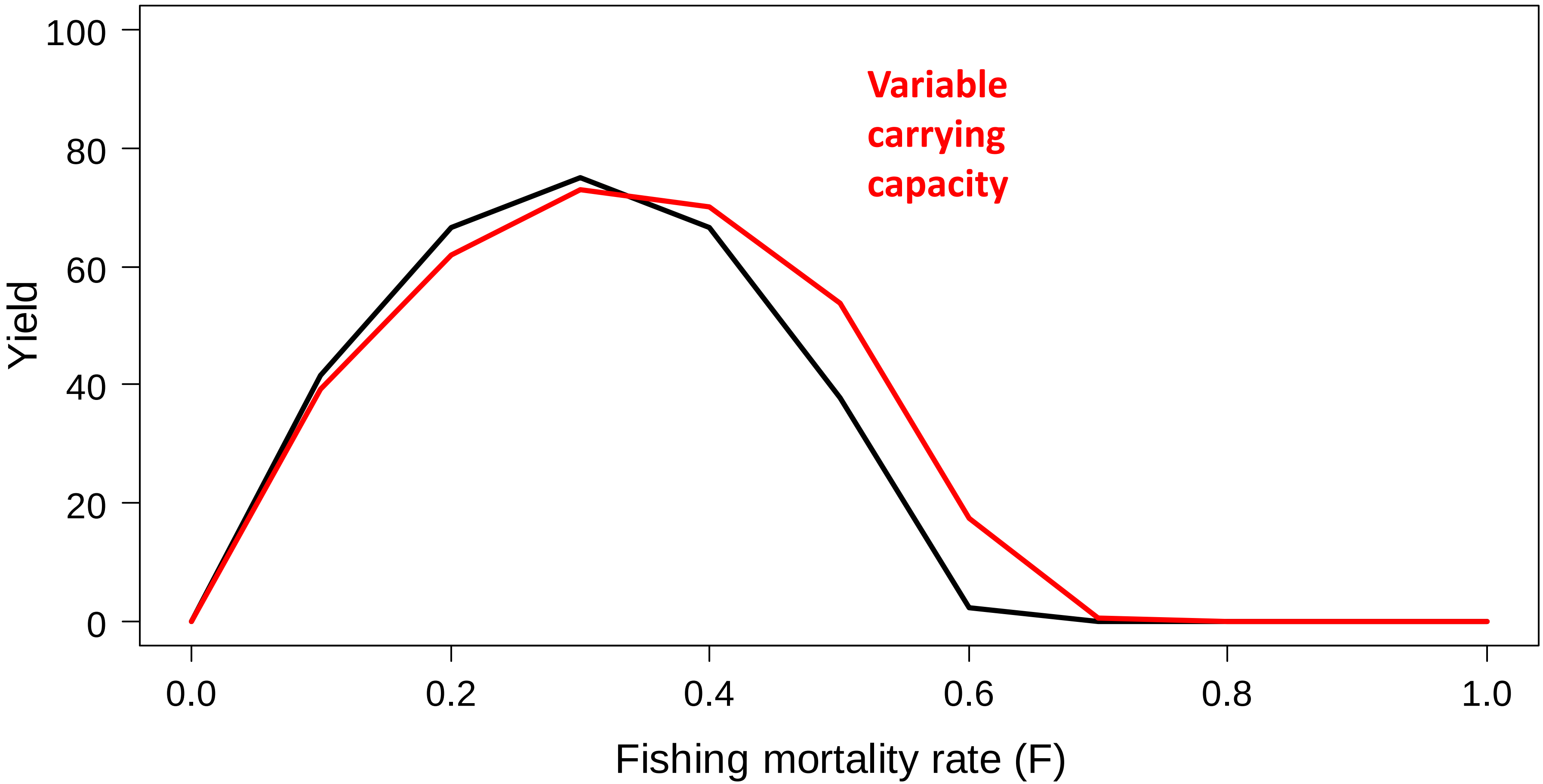
# Varying carrying capacity



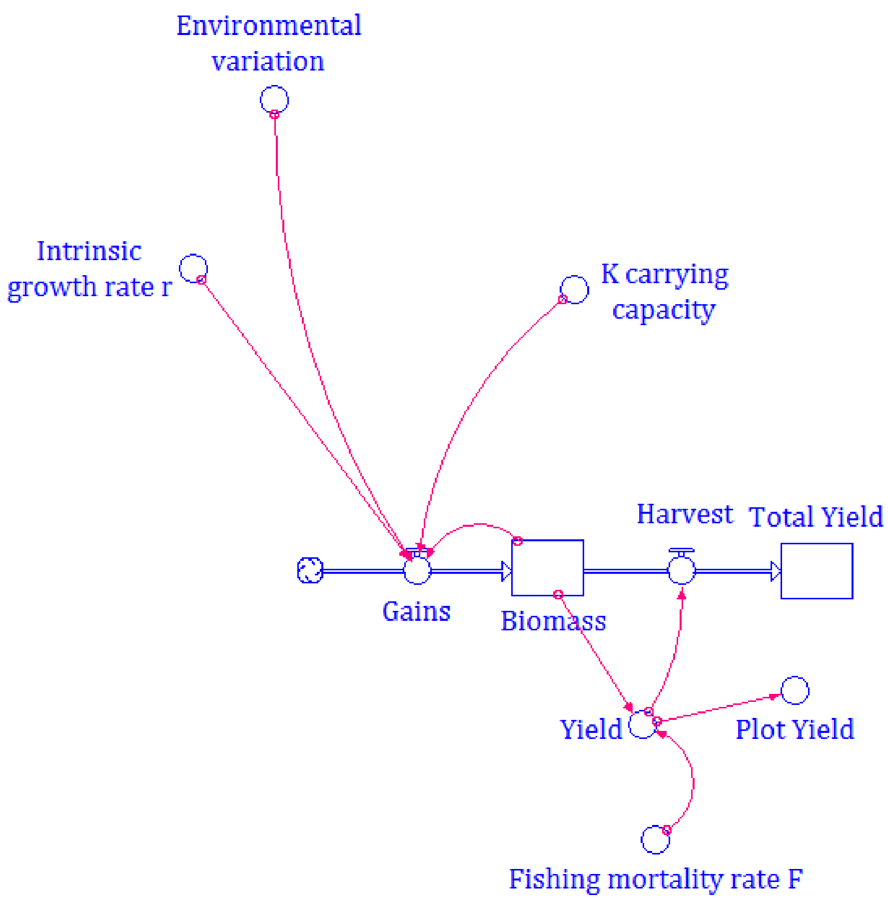



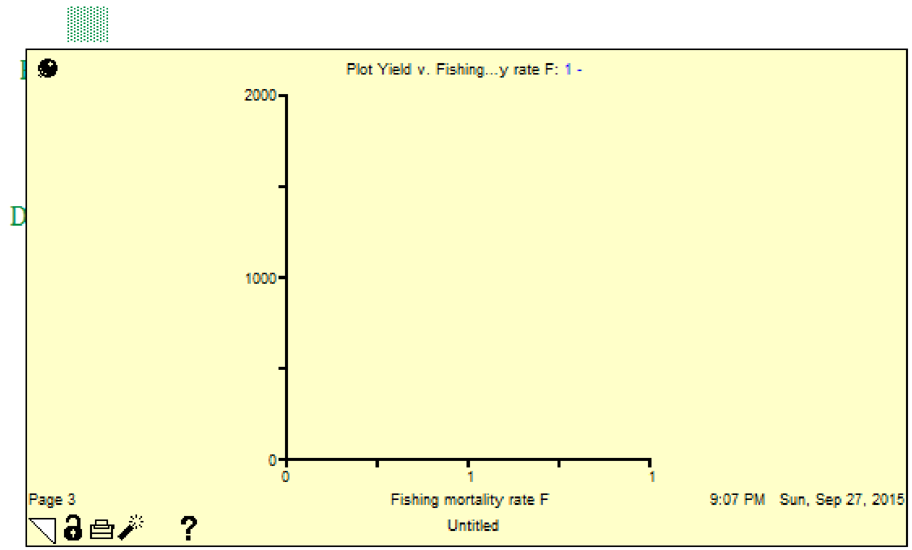



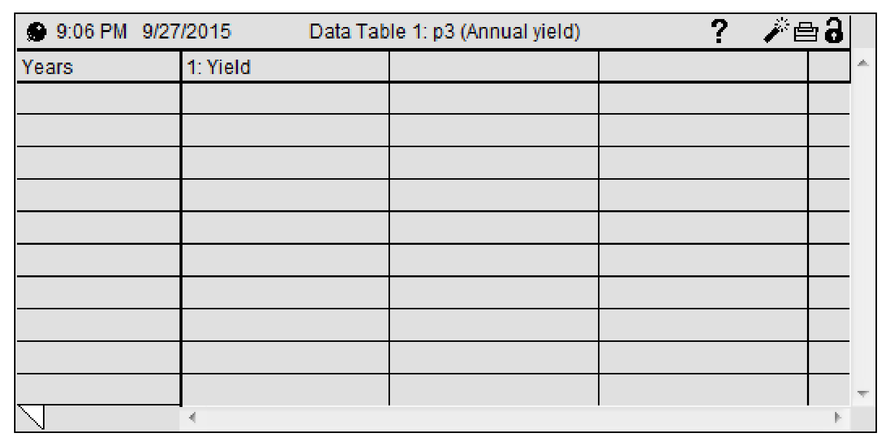
# Variation in carrying capacity



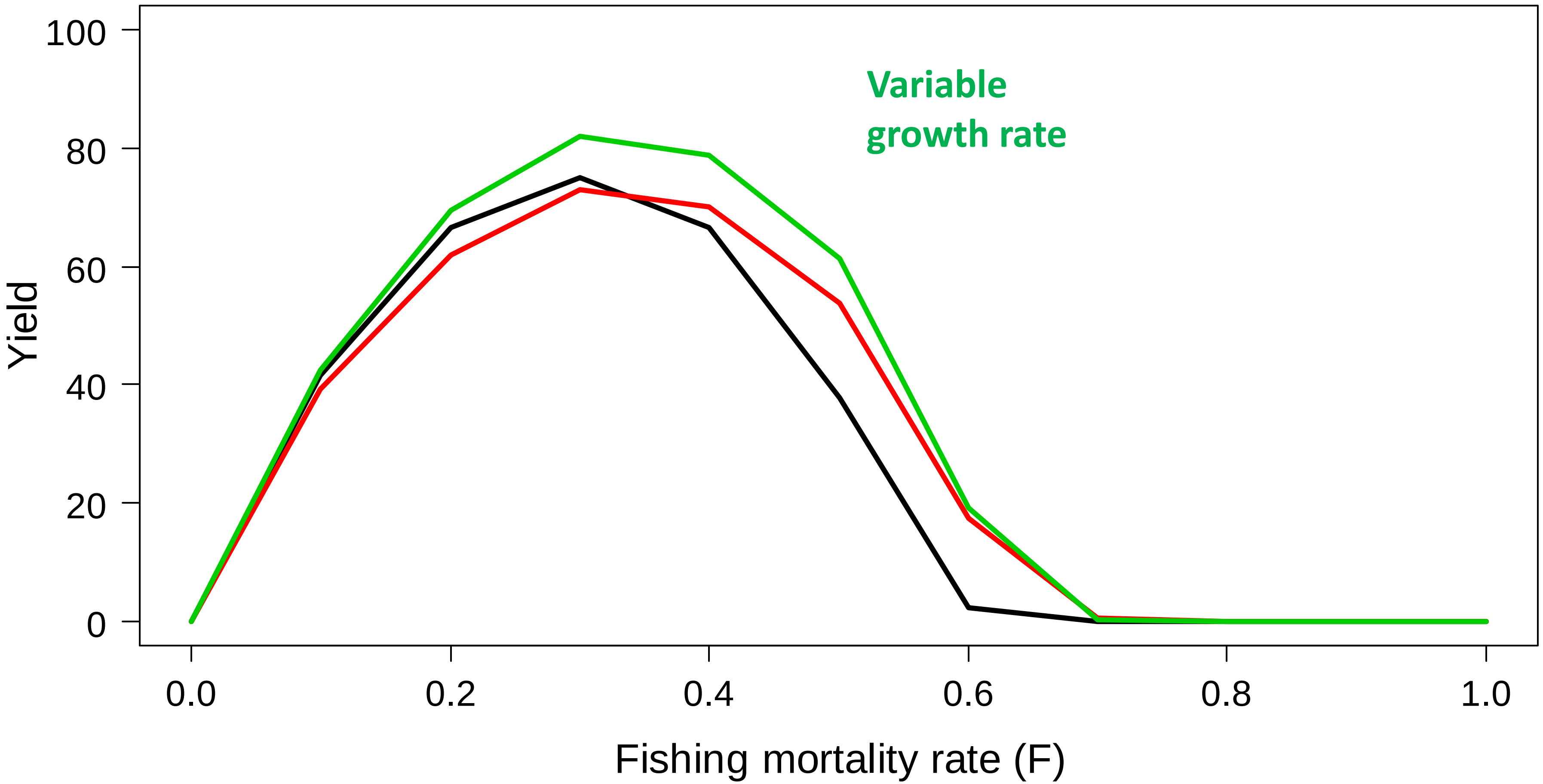
# Varying intrinsic growth rates



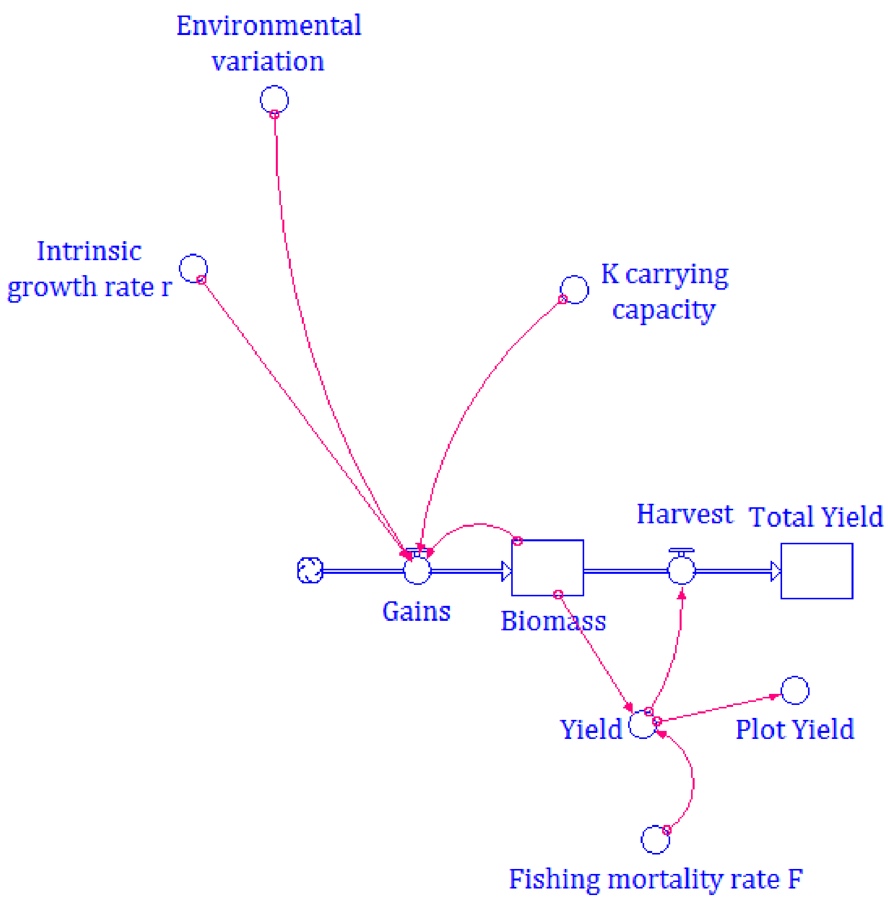



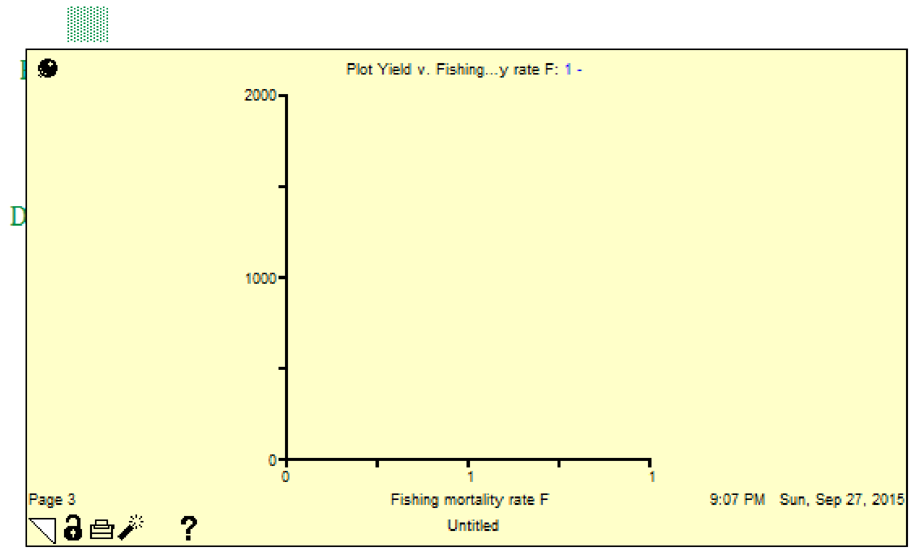
# Variable r

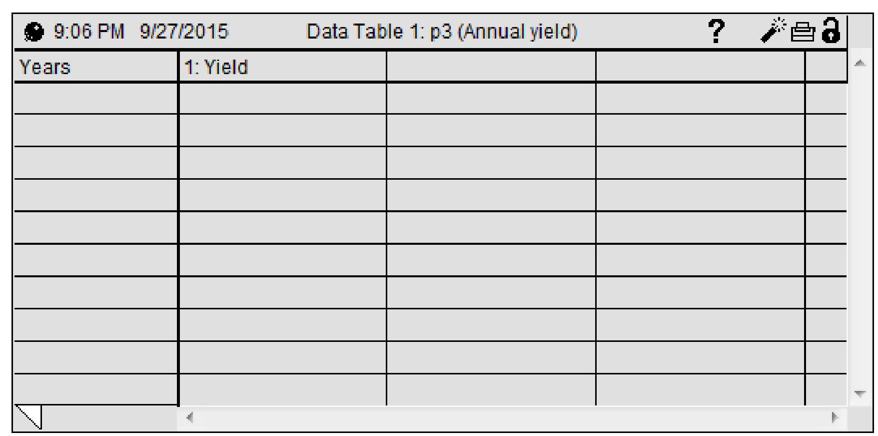


Variable
growth rate
Yield
Fishing mortality rate (F)
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0

# Variable K and r?



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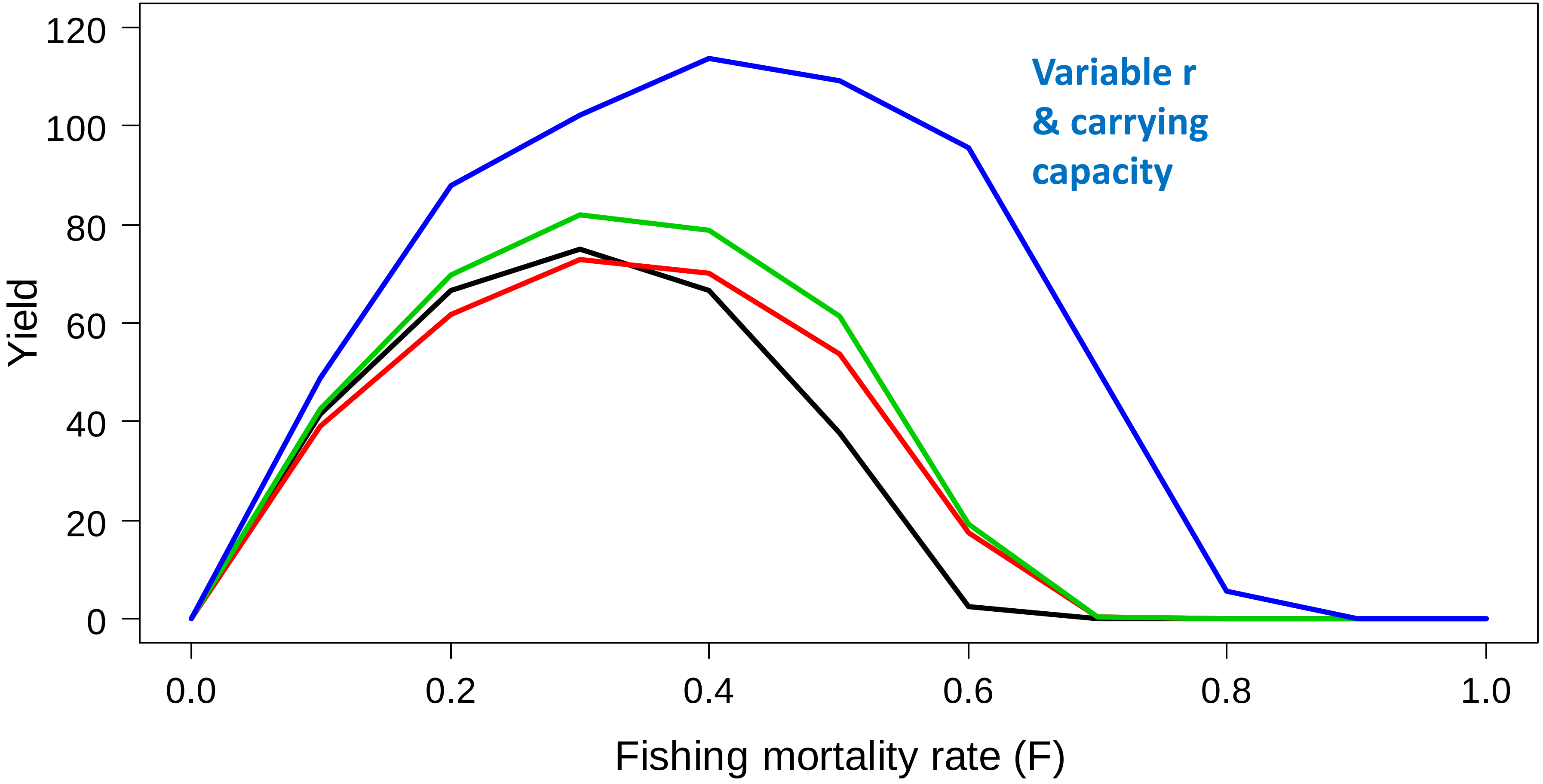


# Managing biomass yield of aquatic resources is not easy!

# Dealing with these issues

- Precautionary approach
- Abandon MSY

# Epitaph for MSY

TRANSACTIONS of the AMERICAN FISHERIES SOCIETY

*January 1977*

VOLUME 106

NUMBER 1

## An Epitaph for the Concept of Maximum Sustained Yield[1]

P. A. LARKIN

*Institute of Animal Resource Ecology, University of British Columbia Vancouver, British Columbia V6T 1W5*

About 30 years ago, when I was a graduate student, the idea of managing fisheries for maximum sustained yield was just beginning to really catch on. Of course, the ideas had already been around for quite a while. Baranov (1918) was the first to combine information on growth and abundance to develop famous "green book," the first version of his handbook (Ricker 1958); Fry (1947) developed the virtual population idea; and Schaefer (1954) proposed his method for estimating surplus production under nonequilibrium conditions. The literature crackled with new information and new ideas. The solidification

# $F_{0.1}$

*The use of $F_{0.1}$ has emerged as a useful "rule of thumb" for managing fisheries, but according to Hilborn and Walters (1992) this is an arbitrary, ad hoc strategy with no theoretical basis.*

# How do we figure out $F_{0.1}$

1. Find slope at origin
2. Plot line with 10% of this slope
3. Find tangent of curve at this slope

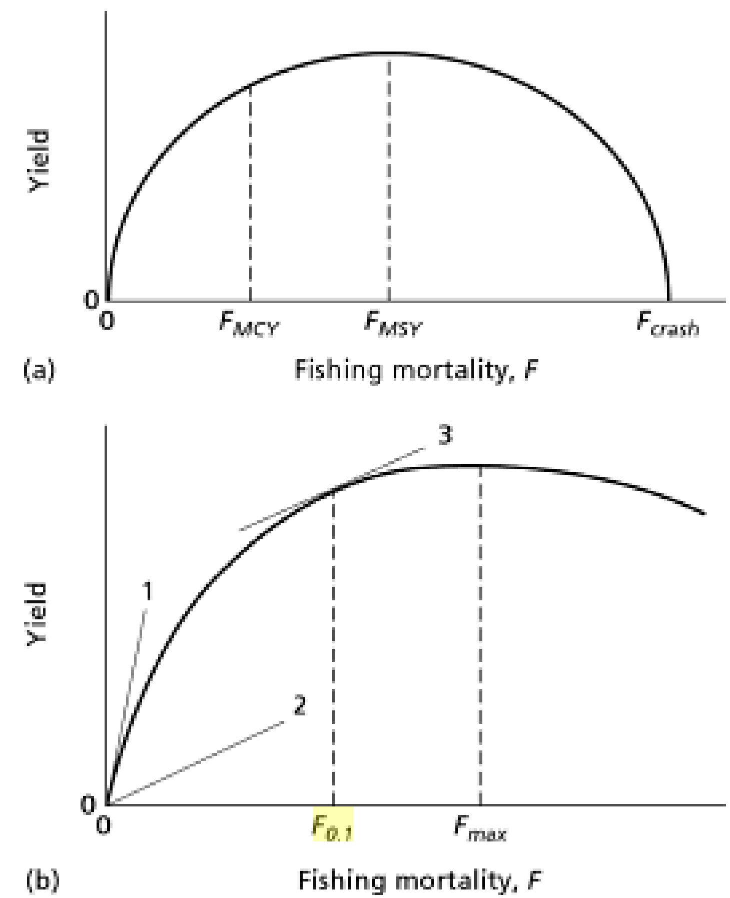
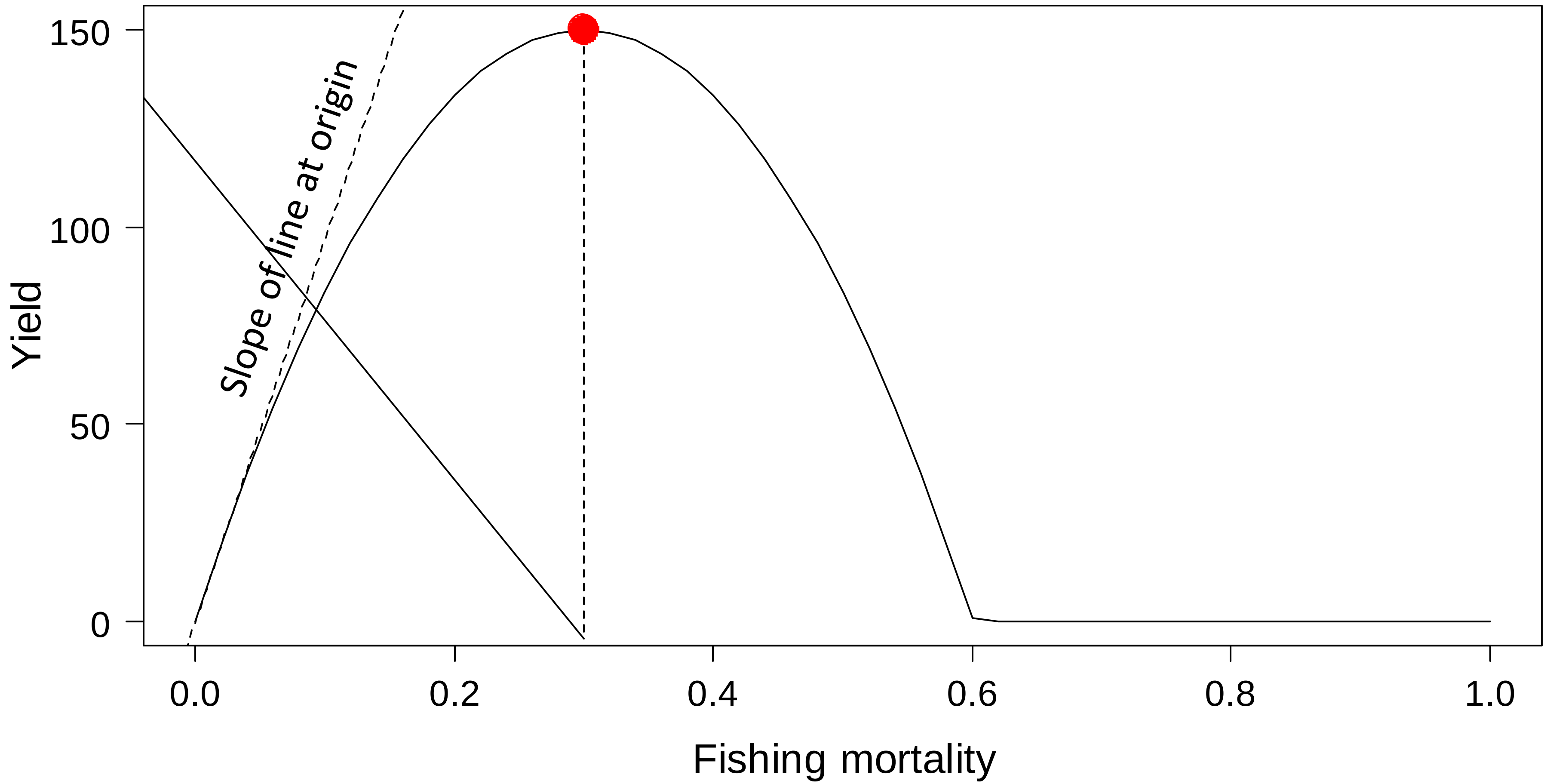
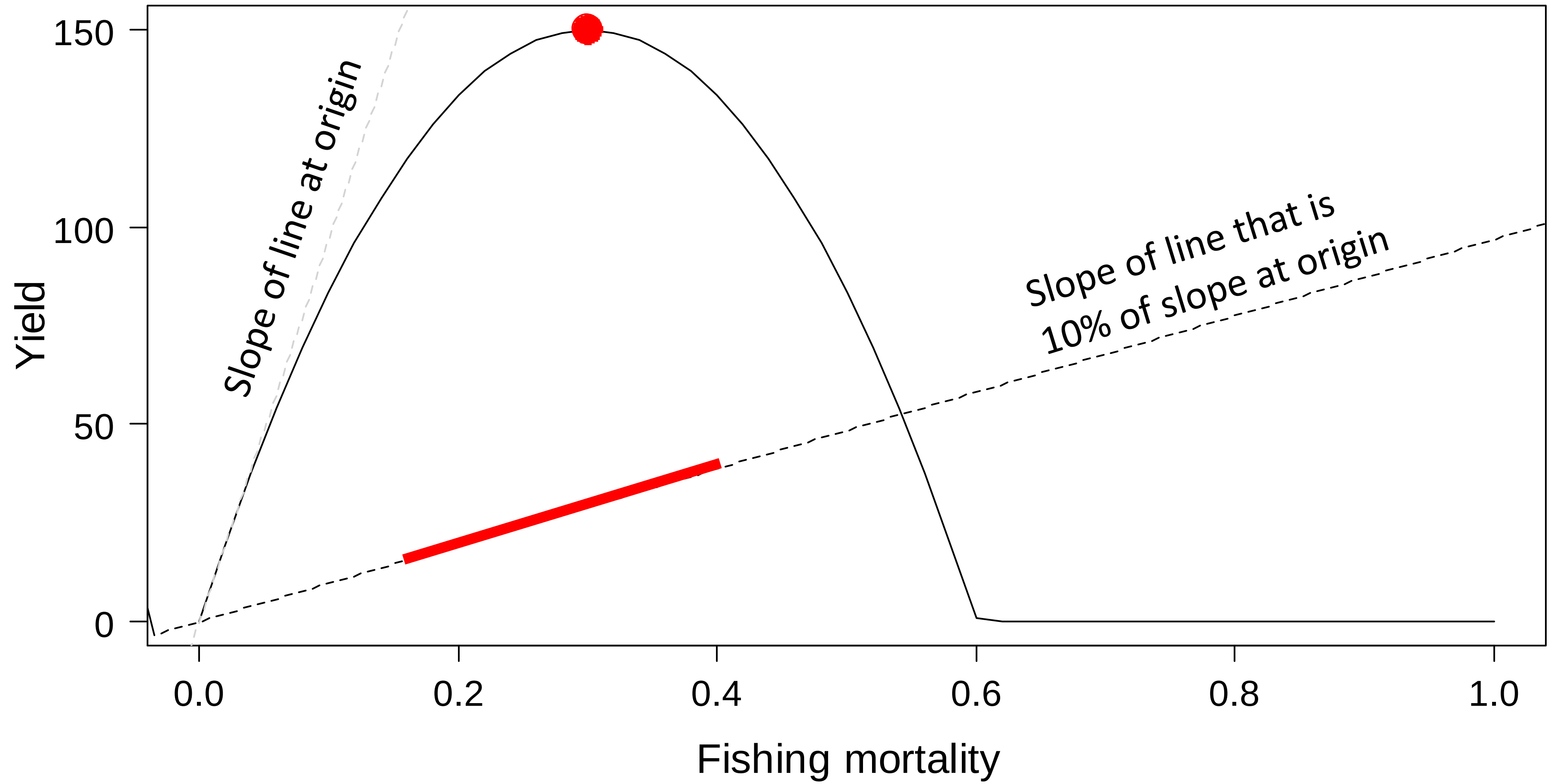



*Fig. 7.20* Biological reference points. (a) Surplus production model; (b) yield-per-recruit model. $F_{0.1}$ is found by following the numbered steps indicated: (1) find slope at origin; (2) plot line with 10% of this slope; (3) find tangent to curve at this slope.

# Slope at origin



# 10% of slope at origin



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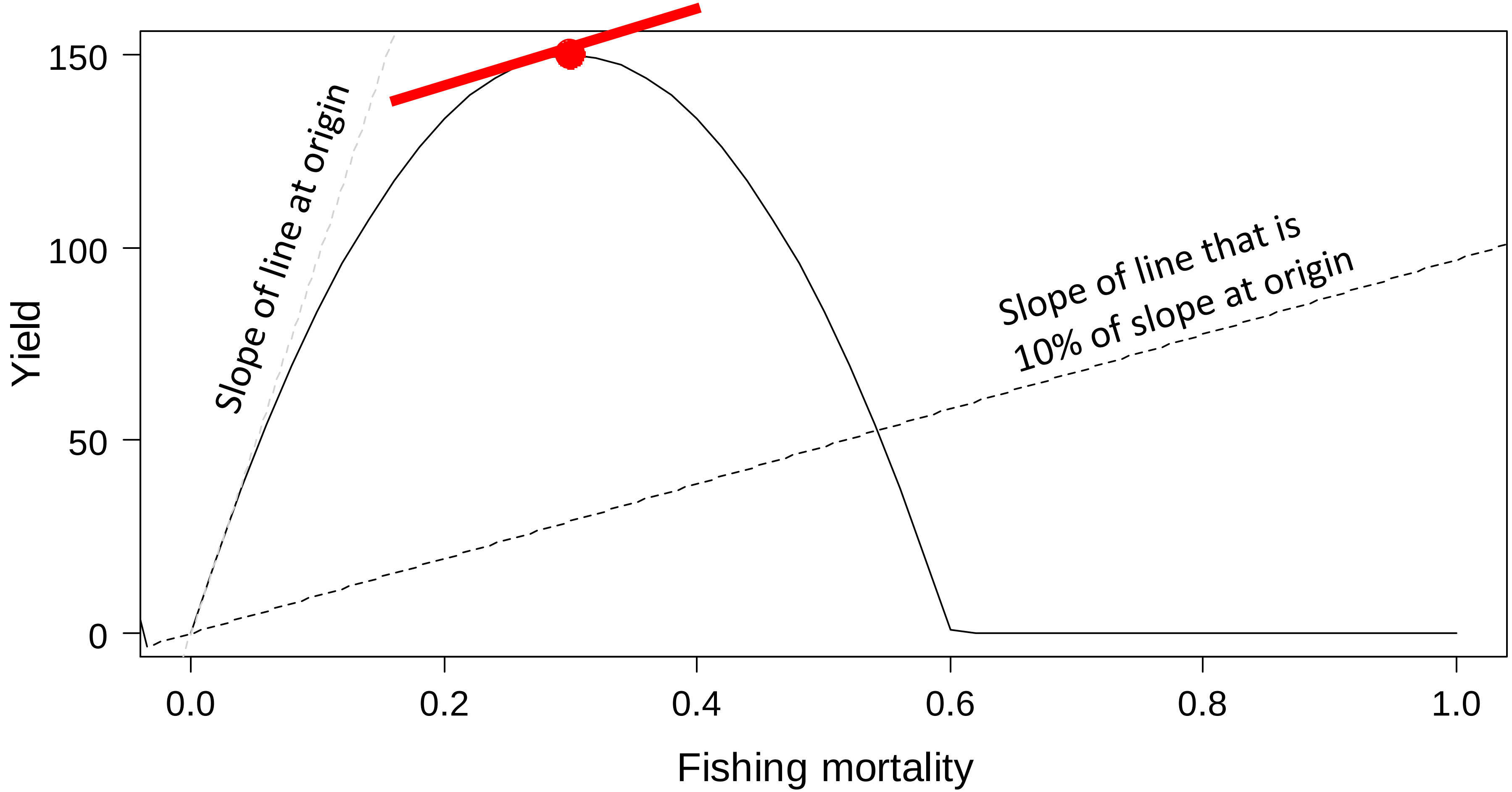
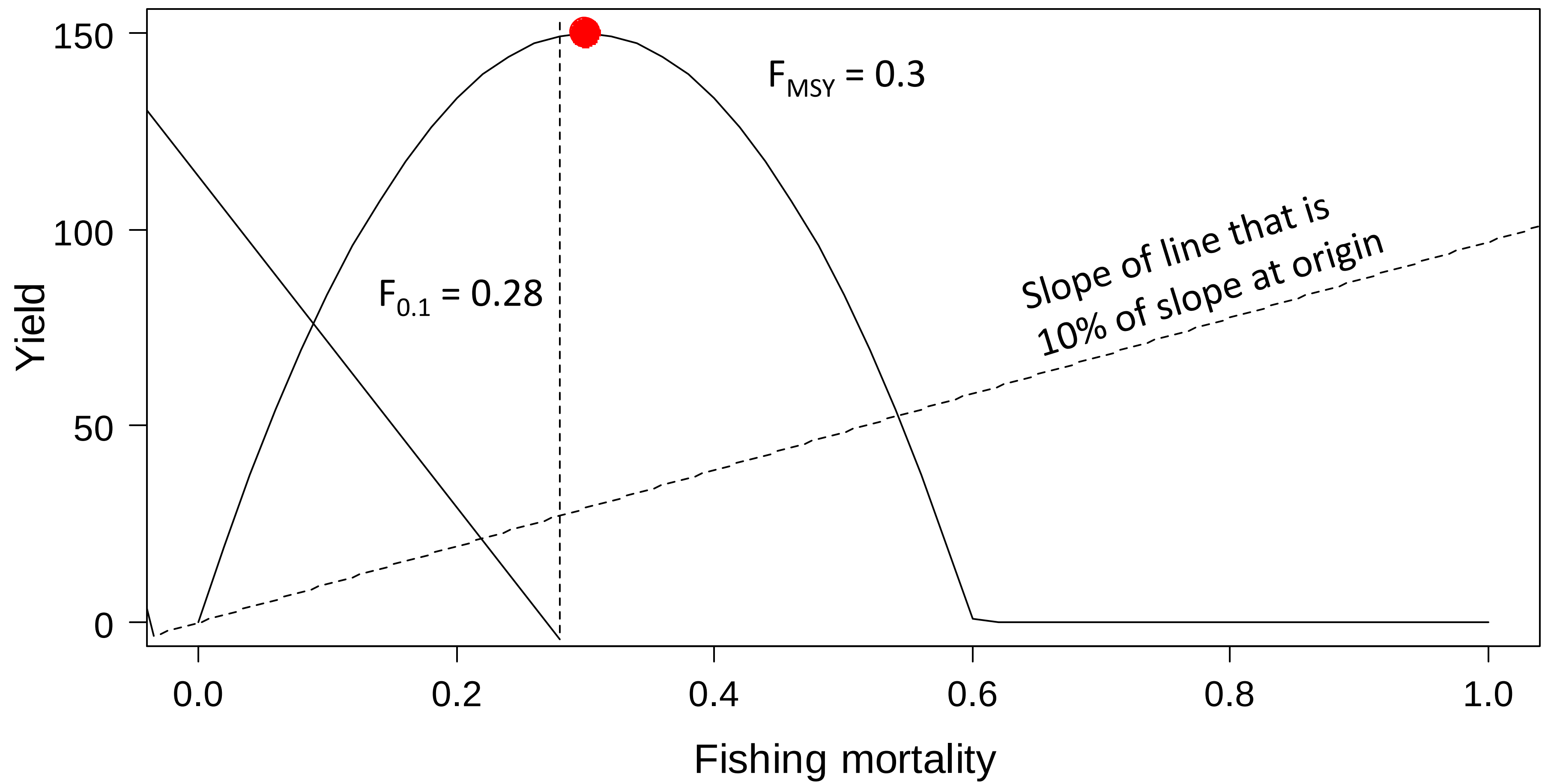


# $F_{0.1}$



150
100
50
0
0.0
0.2
0.4
0.6
0.8
1.0
Yield
Fishing mortality
$F_{MSY}$ = 0.3
$F_{0.1}$ = 0.28
Slope of line that is
10% of slope at origin

# Continuous harvest

Suppose harvest does not occur continuously…

Is this realistic?

Examples?

# Continuous harvest?

## *Finfish*

### Mississippi Red Snapper 2015

All vessels (private and for-hire) landing Red Snapper in Mississippi must use the Tails n' Scales electronic reporting system regardless of harvest area (federal waters, Mississippi state waters, adjacent states' waters, etc.) There are no exemptions. Mississippi Department of Marine Resources (MDMR) requires one report per trip per vessel.

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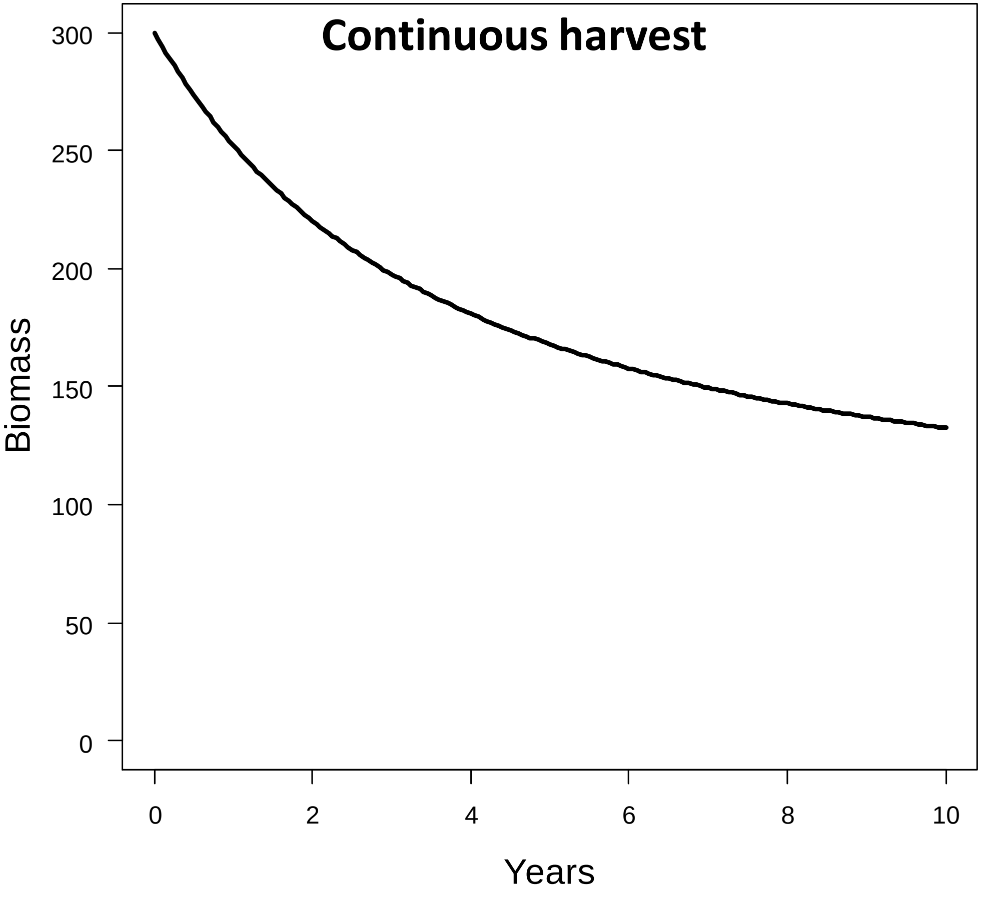
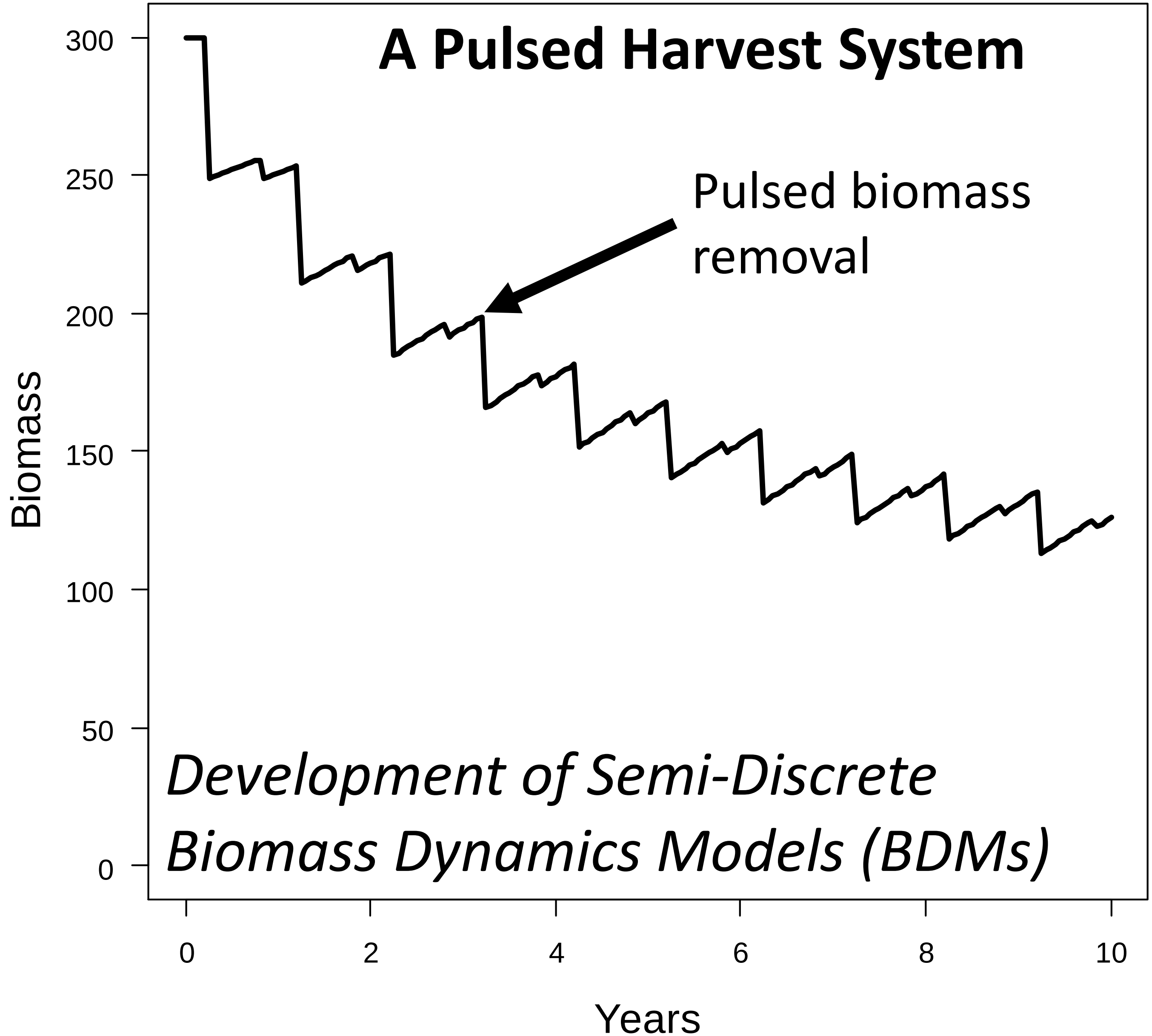


# *Pulsed harvest & biomass dynamics*



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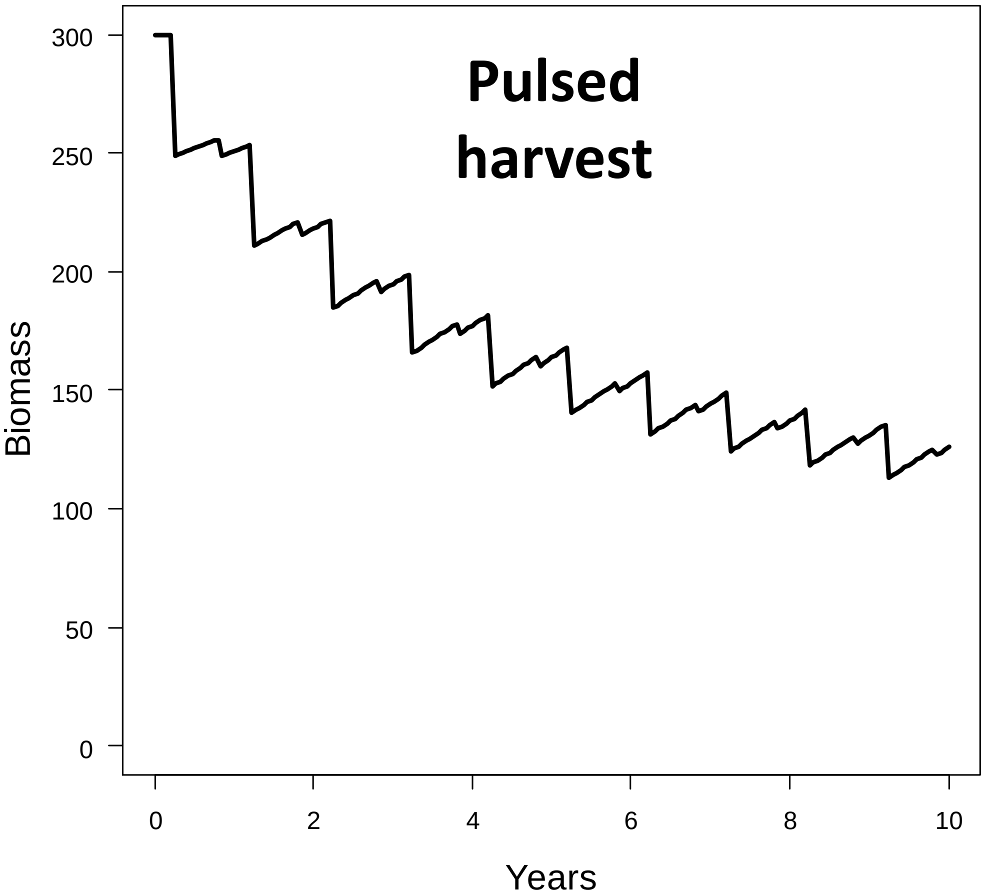

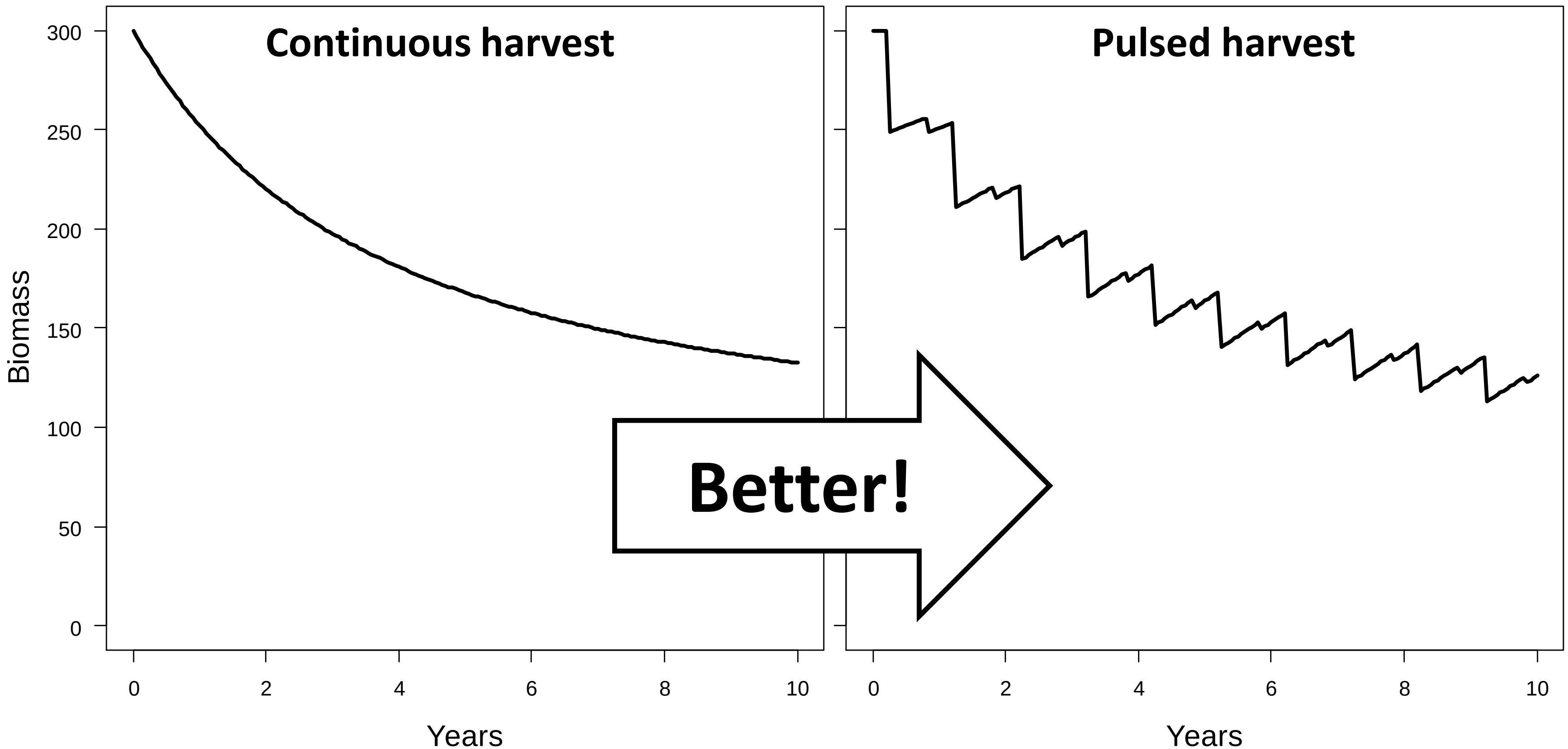


***Can biomass dynamics models be improved by accounting for pulsed harvests? YES***

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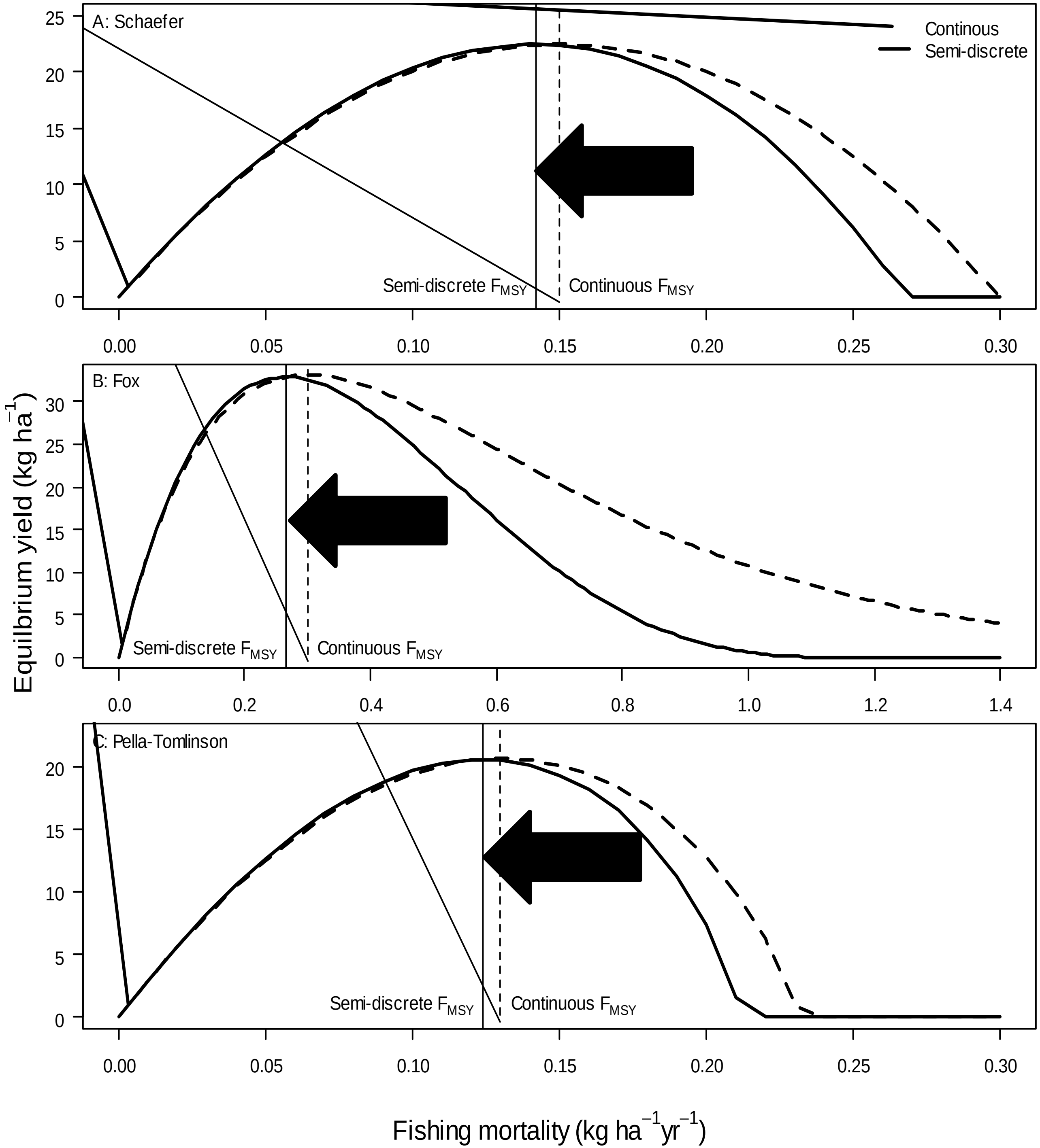

# MANAGING COMMON CARP BIOMASS

*North American Journal of Fisheries Management* 32:1251–1264, 2012

ISSN: 0275-5947 print / 1548-8675 online
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ARTICLE

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*Department of Natural Resource Ecology and Management, Iowa State University, 339 Science II, Ames, Iowa 50011-3221, USA*

**Clay L. Pierce**
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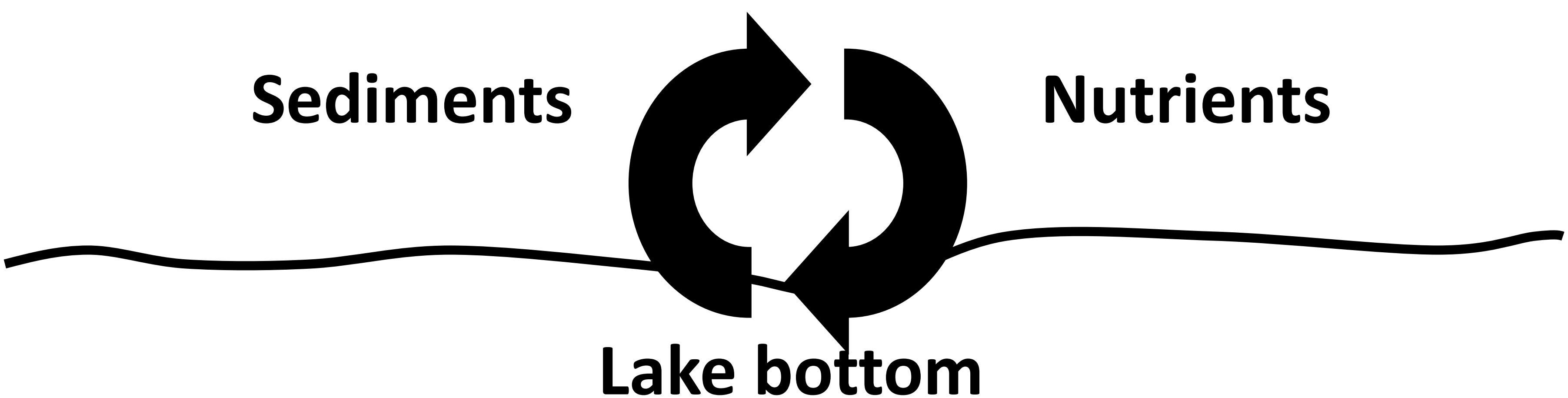
Carp effects on water quality


# Carp effects on water quality

# Water quality: internal processes

**Water column**



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- Averaged **432,312** visitors annually
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http://www.card.iastate.edu/lakes/

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- Objectives: 100 kg carp per hectare
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  - Biomanipulation (removal of 75% of biomass)
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$$\left.\begin{aligned} \frac{dB(t)}{dt} &= rB(t), & t &\neq \tau_k \\ B(\tau_k^+) &= B(\tau_k) - C(\tau_k), & t &= \tau_k \end{aligned}\right\}$$

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**Fit to data by maximum likelihood to estimate *r* & *q*, given B, I, and C**

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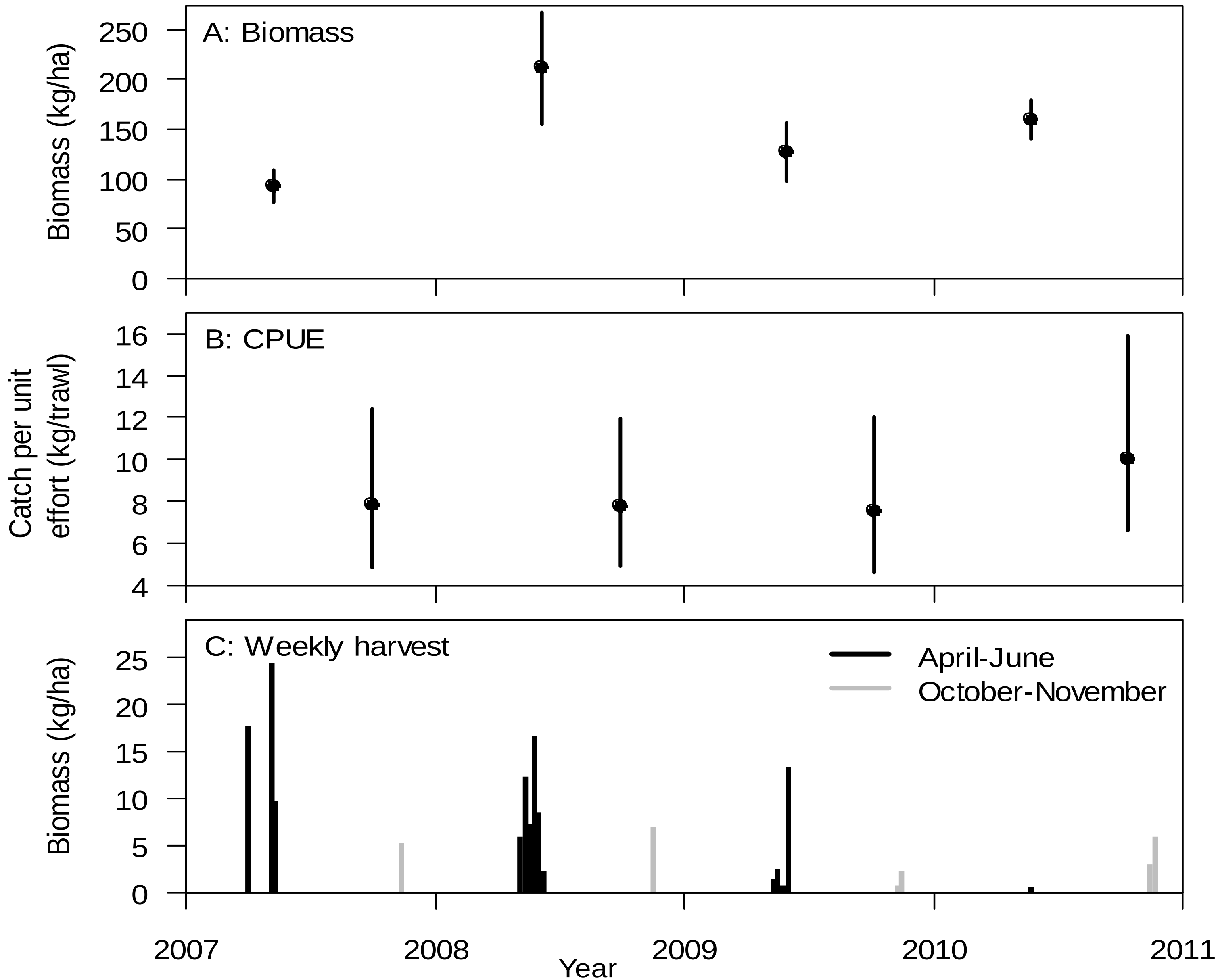

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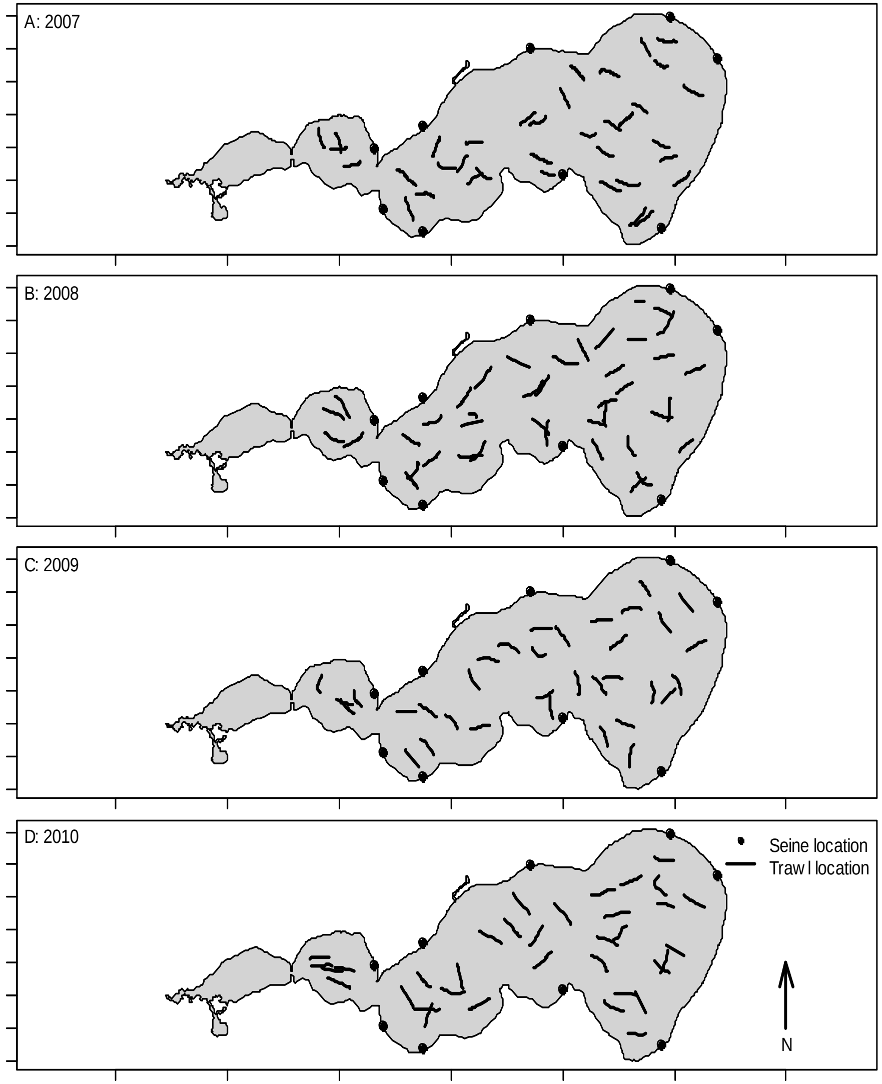



# Tracking carp biomass harvested

## When & how much biomass is harvested

# Clear Lake Carp Roundup

### New Tools Give Biologists an Edge Over 20 Tons of Carp

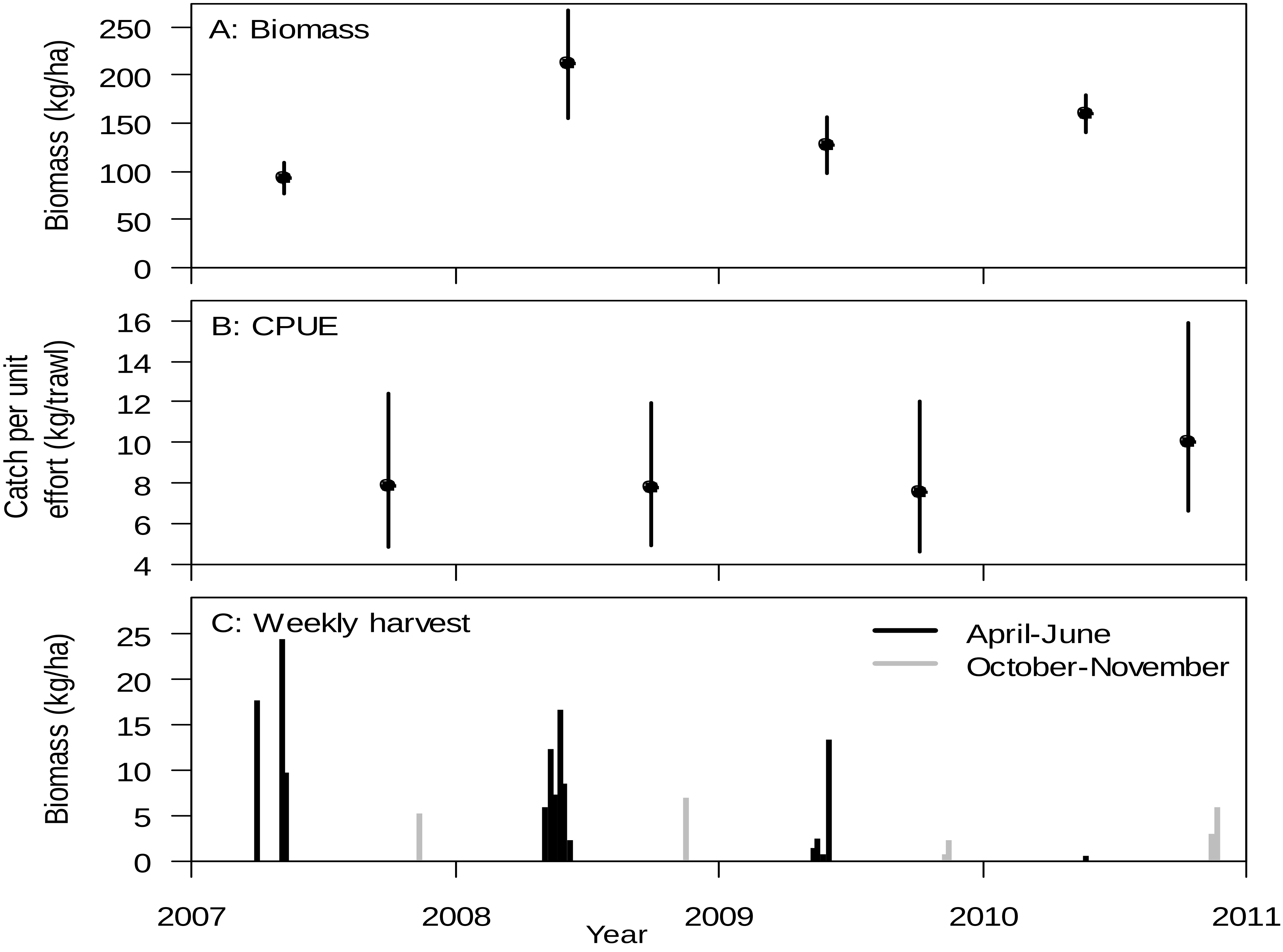
STORY AND PHOTOS BY LOWELL WASHBURN

If you're a card-carrying member of Carp Haters Inc., don't worry about it. You've got plenty of company and, in this particular case, your emotions are completely justified.

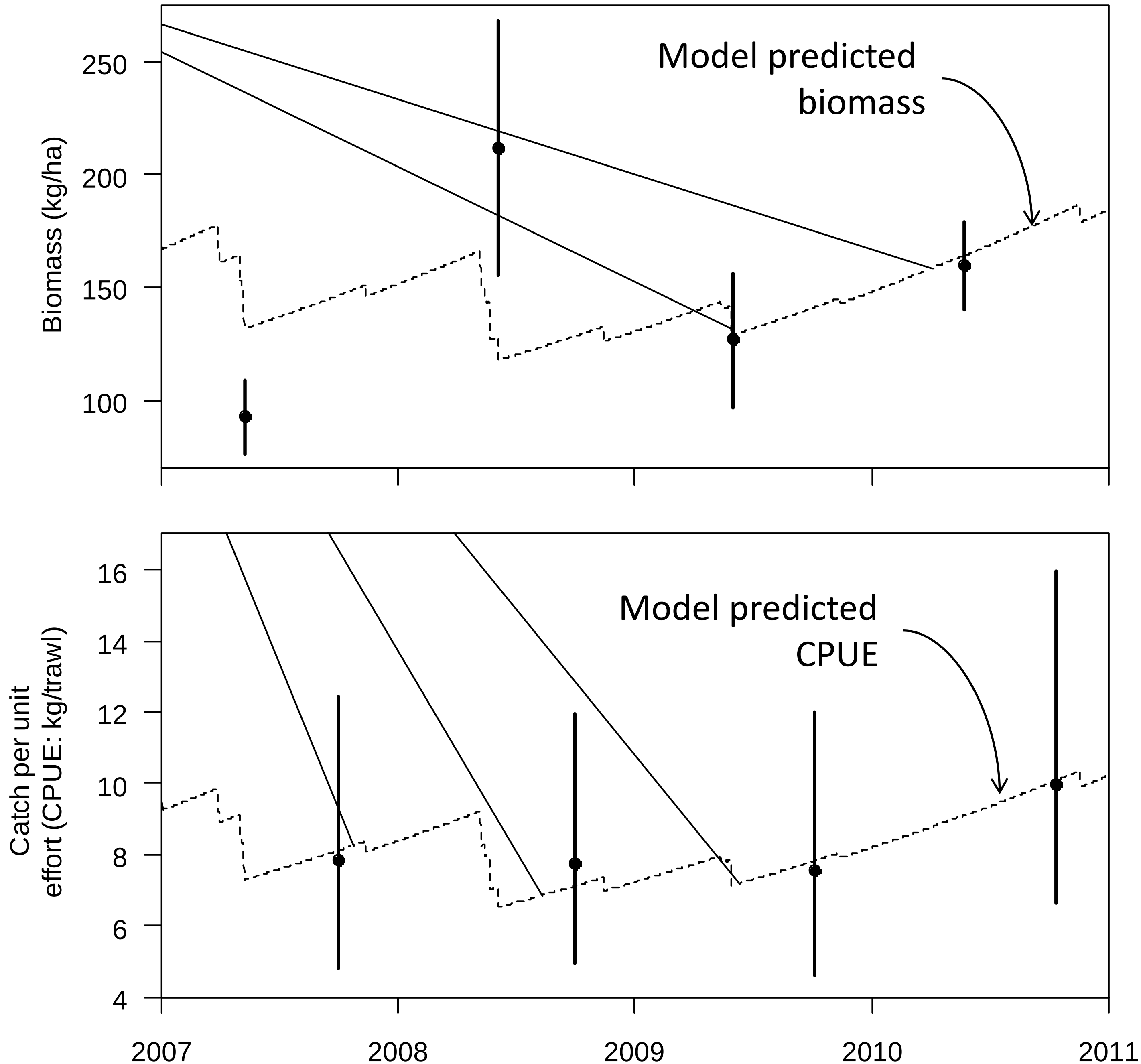
Although common carp were introduced in the 1800s with the very best intentions, few blunders have had greater negative consequences to aquatic ecosystems and native sport fisheries. Carp uproot and destroy valuable aquatic plant communities, reduce water clarity, out-compete and displace native game and forage fish, and drastically contribute to increased phosphorus levels. But let's skip all the sugar and tell it like it is. When it comes to American waters, the common carp is just plain evil—period.

As is the case with most natural resource agencies, the DNR has been battling carp for decades. Fisheries workers have installed mechanical barriers to restrict carp movement, poisoned lakes and fish nurseries,

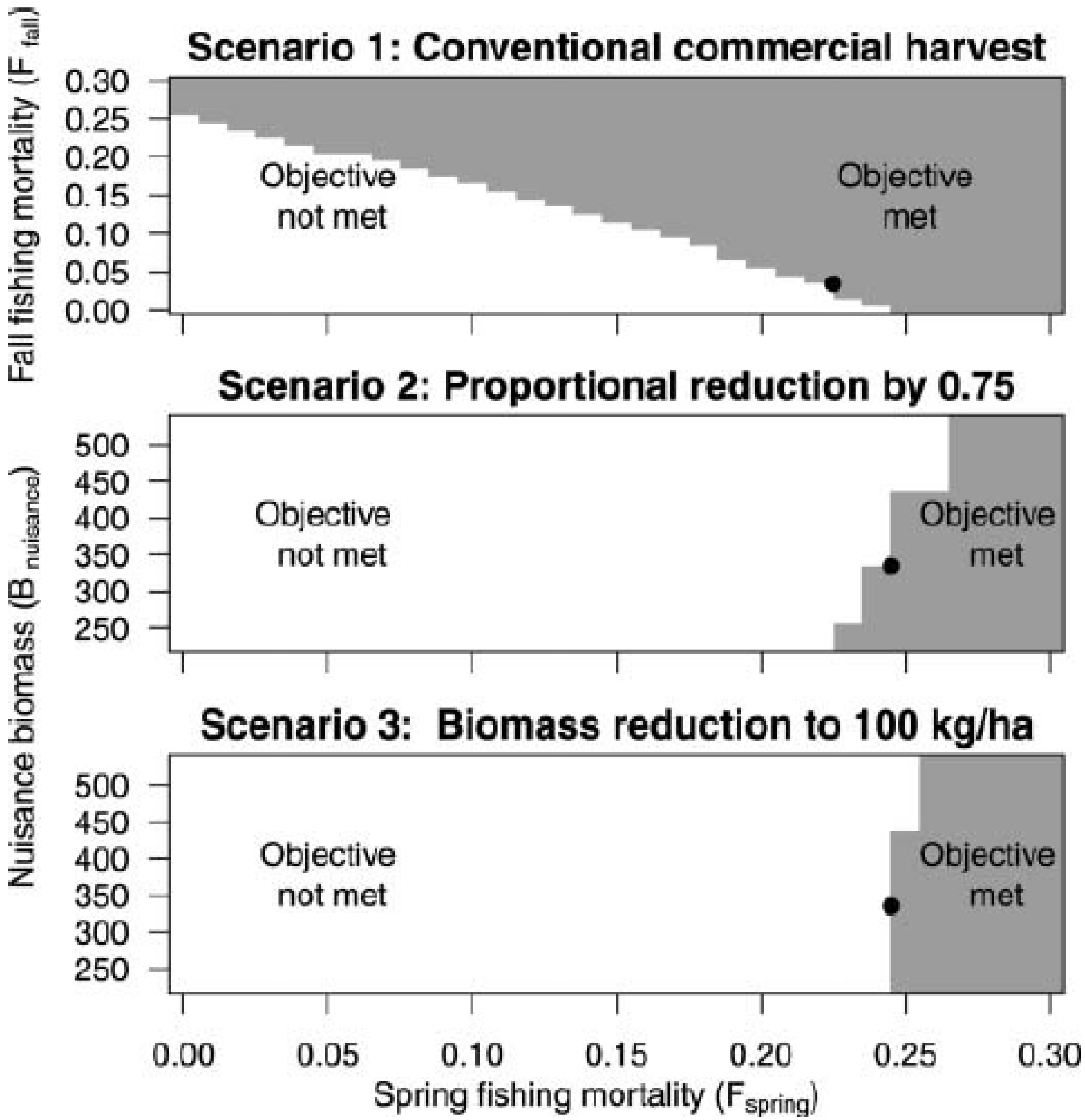
WWW.IOWADNR.GOV 51


A: Biomass
Biomass (kg/ha)
0
50
100
150
200
250
B: CPUE
Catch per unit effort (kg/trawl)
4
6
8
10
12
14
16
C: Weekly harvest
Biomass (kg/ha)
0
5
10
15
20
25
April-June
October-November
2007
2008
2009
2010
2011
Year

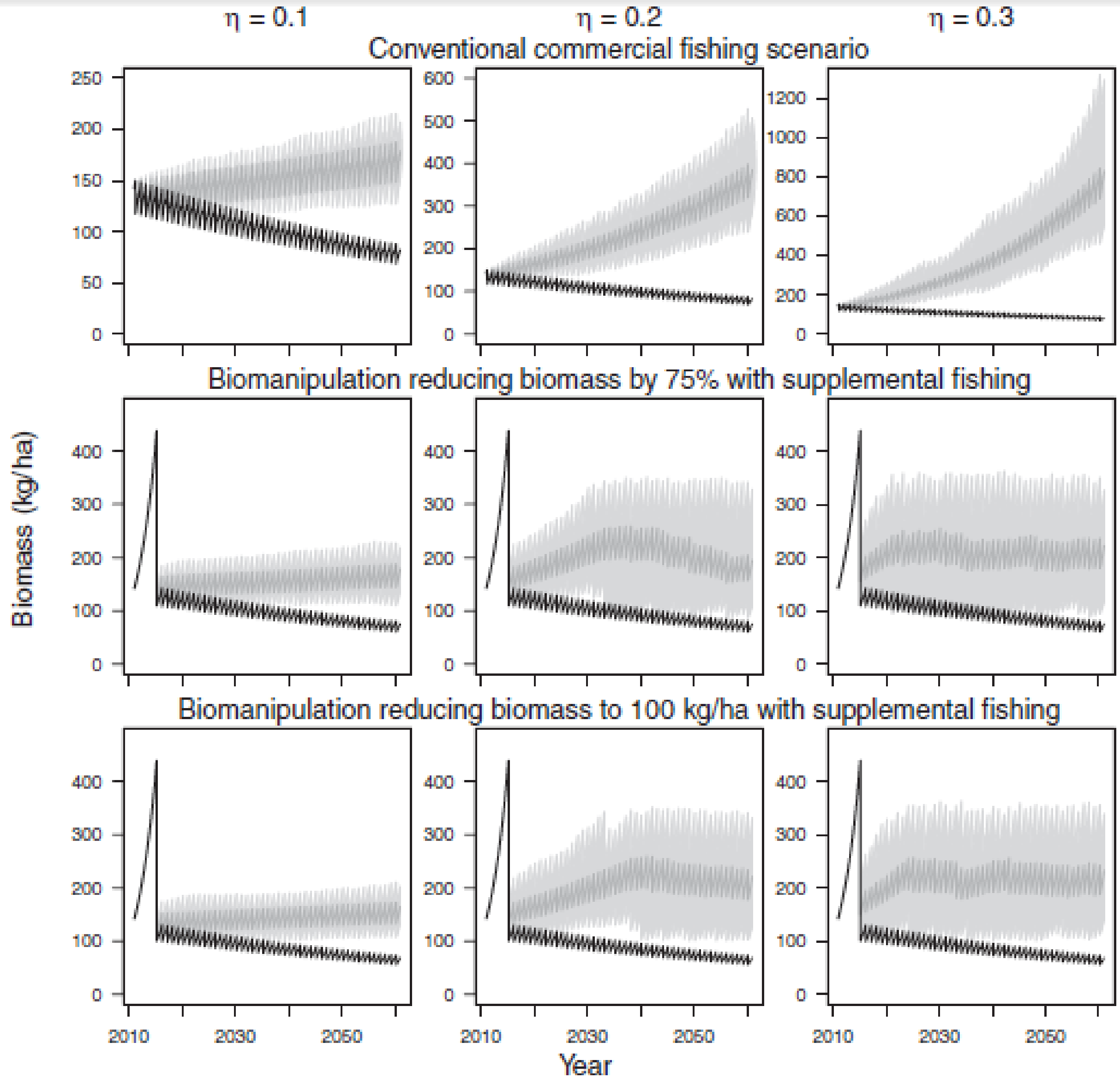
# *Fitted model*



# Meeting management objectives



# Partial Controllability



# CarpBioDyn

**SCENARIOS OVERVIEW-**
**+++++Scenario 1: Continued spring and fall commercial fishing**
**+++++Scenario 2: Pulsed spring harvest of 75% of biomass if biomass exceeds nuisance levels. Supplemental spring commercial fishing occurs when biomass is below nuiscance levels**
**+++++Scenario 3: Pulsed spring harvest of of biomass to 100 kg/ha if biomass exceeds nuisance levels. Supplemental spring commercial fishing occurs when biomass is below nuiscance levels.**

Scenario
2
U 1 2 3

**Scenario 1: Continued spring and fall commercial fishing**

U 0.25

**SCENARIOS 2 and 3: Nuisance biomass level**

Nuisance Biomass Threshold
U 400

F supplemental
0.00

**Unintentional underharvest due to uncontrolable factors such as weather, personnel, and markets can effect common carp dynamics. Ideally management strategies to control common carp are robust to unintentional underharvest. This slider input can be used to evaluate the impacts of underharvest on common carp biomass dynamics.**

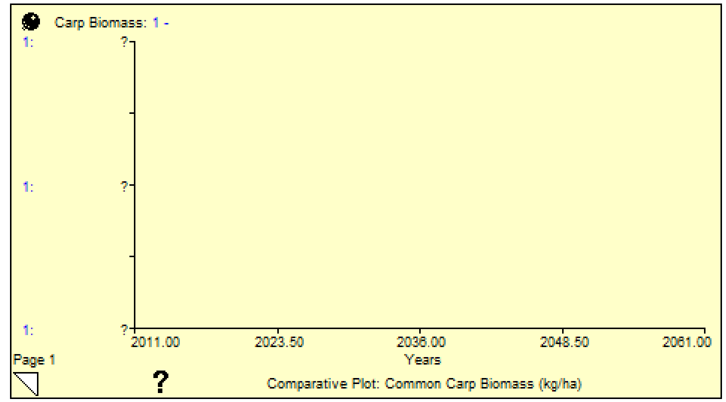
**Setting the slider to 0 simulates perfect harvest (i.e., no under harvest). The slider can be increased to 0.1, 0.2, 0.3, and 0.4 to stocastically simulate underharvest of 10% to 40%. Default value is 0.**

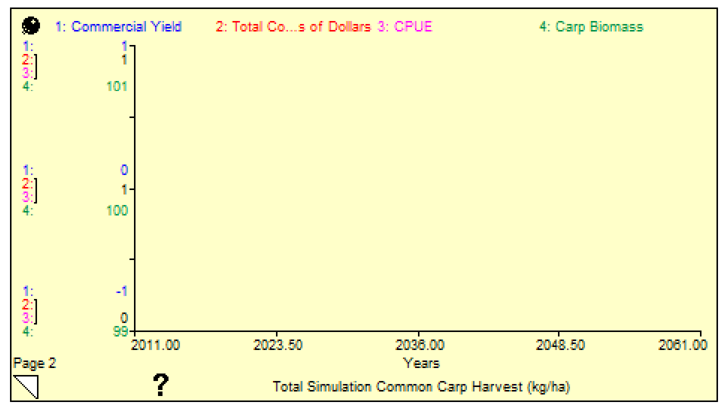
Under harvest
0.0

**Subsidy Evaluation- Use this slider to set a subsidy amount in cents/kg. The total cost of the subsidy over time is then calculated.**

Subsidy amount
U 0.23

| Total cost | $0 |
| --- | --- |




Return to introduction page

Restore Sliders and Knobs to Defaults

Clear Graphs & Tables

Run The Carp Model!

Press to move to table of model output

# WF4313/6613-Fisheries Management

Class 14– Yield Management & Management Case Study

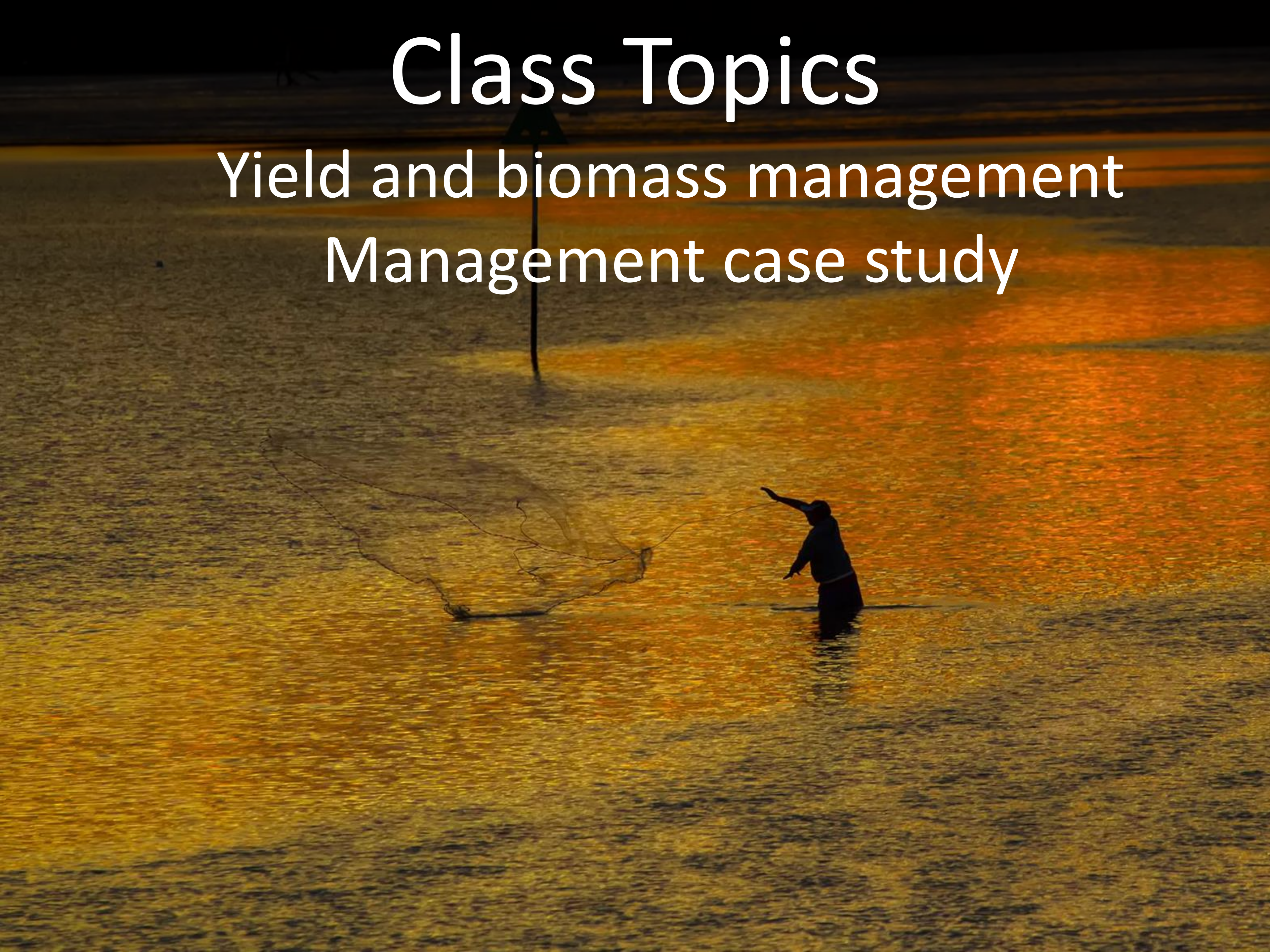
# Announcements


HAILSTATE
HAILSTATE
STATE

# Class Topics

Yield and biomass management

Management case study



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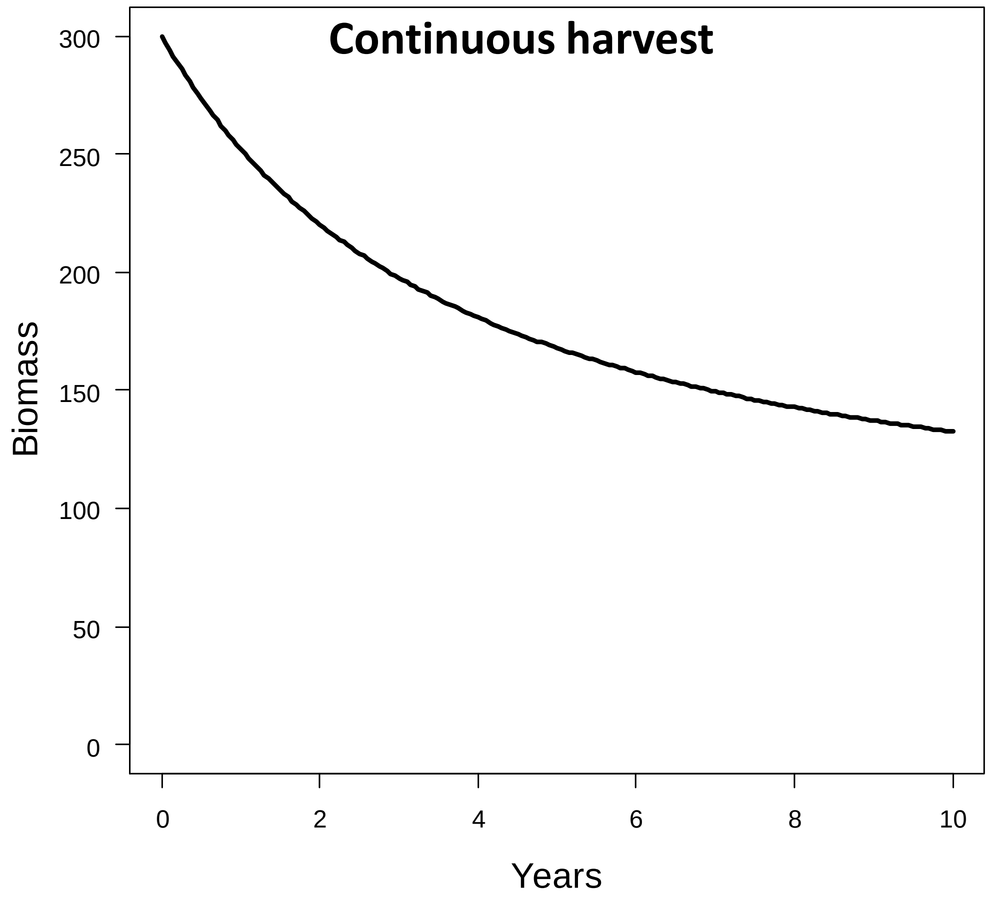

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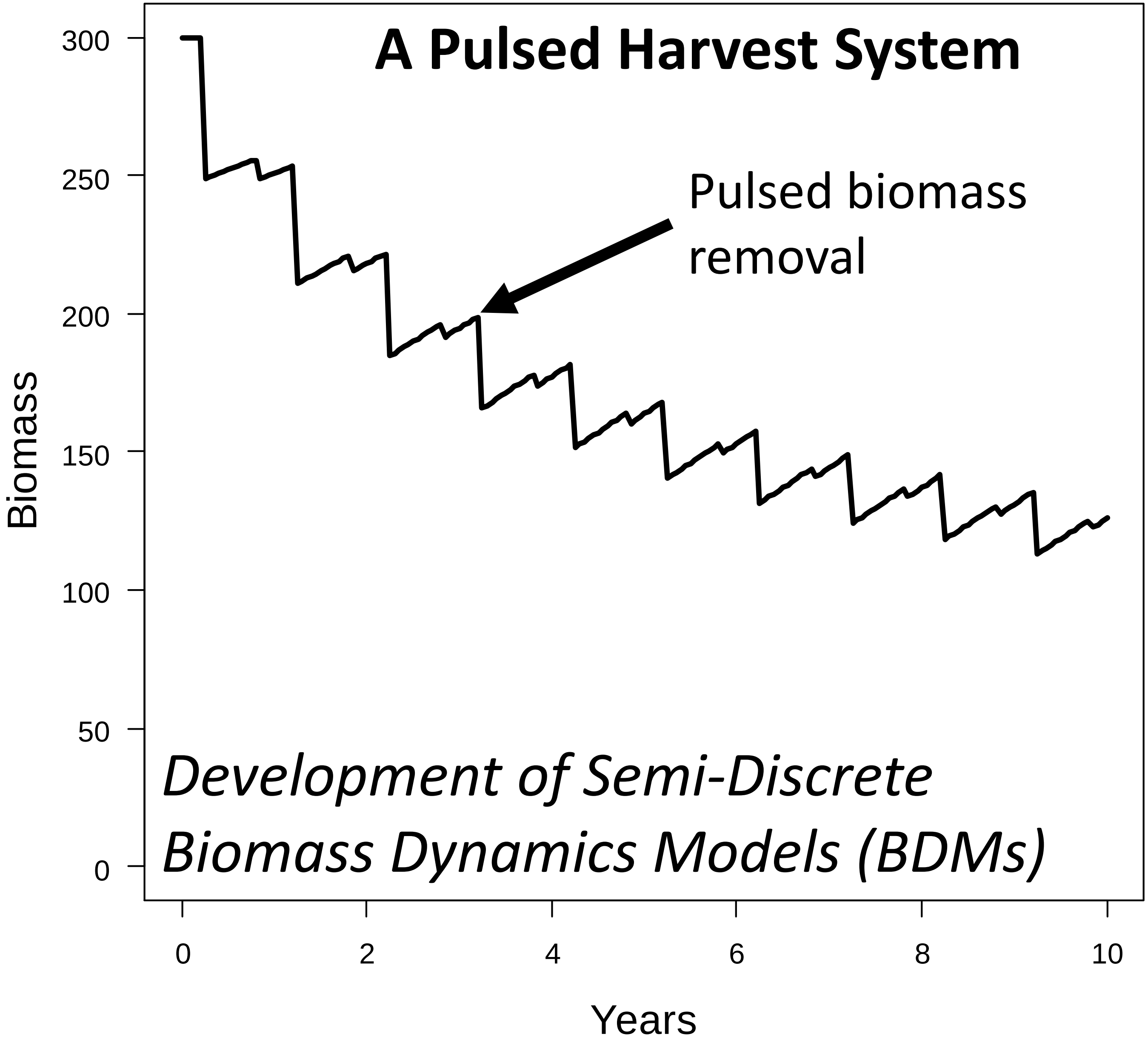

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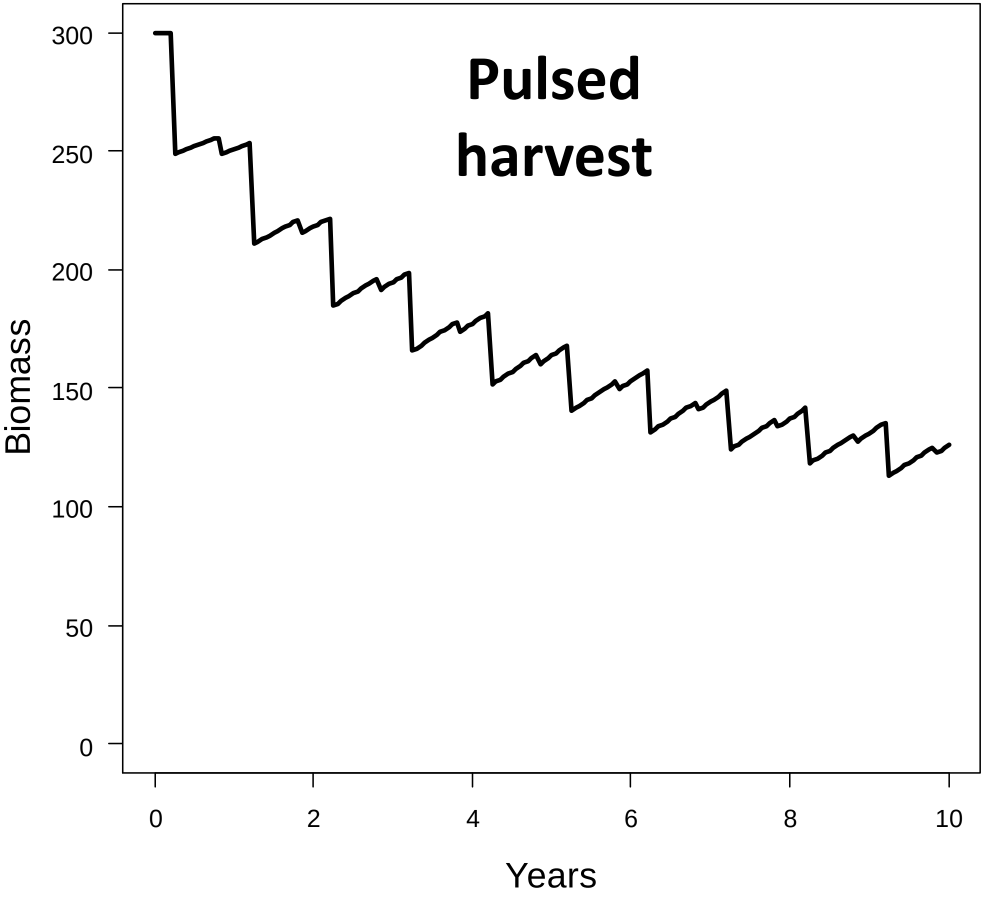

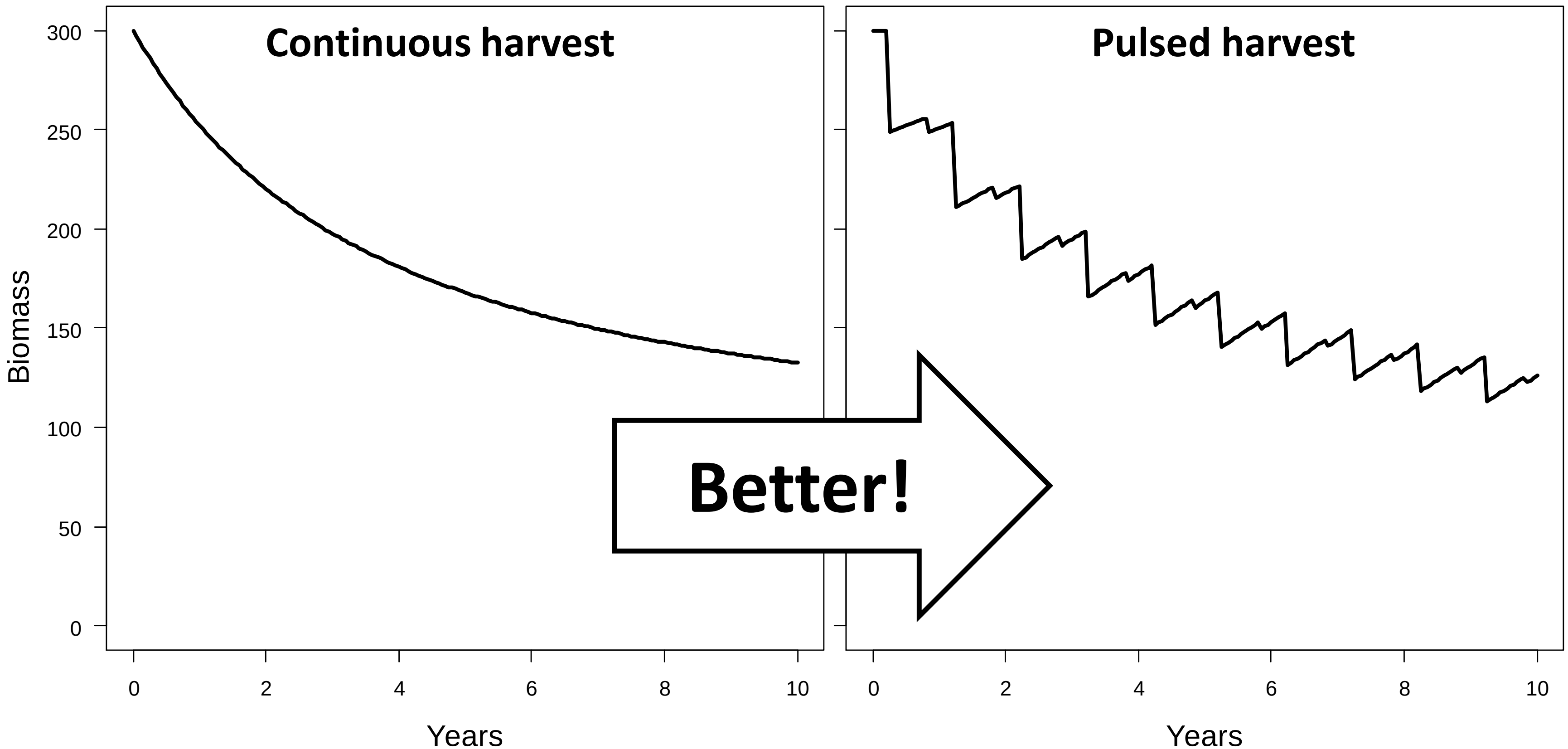


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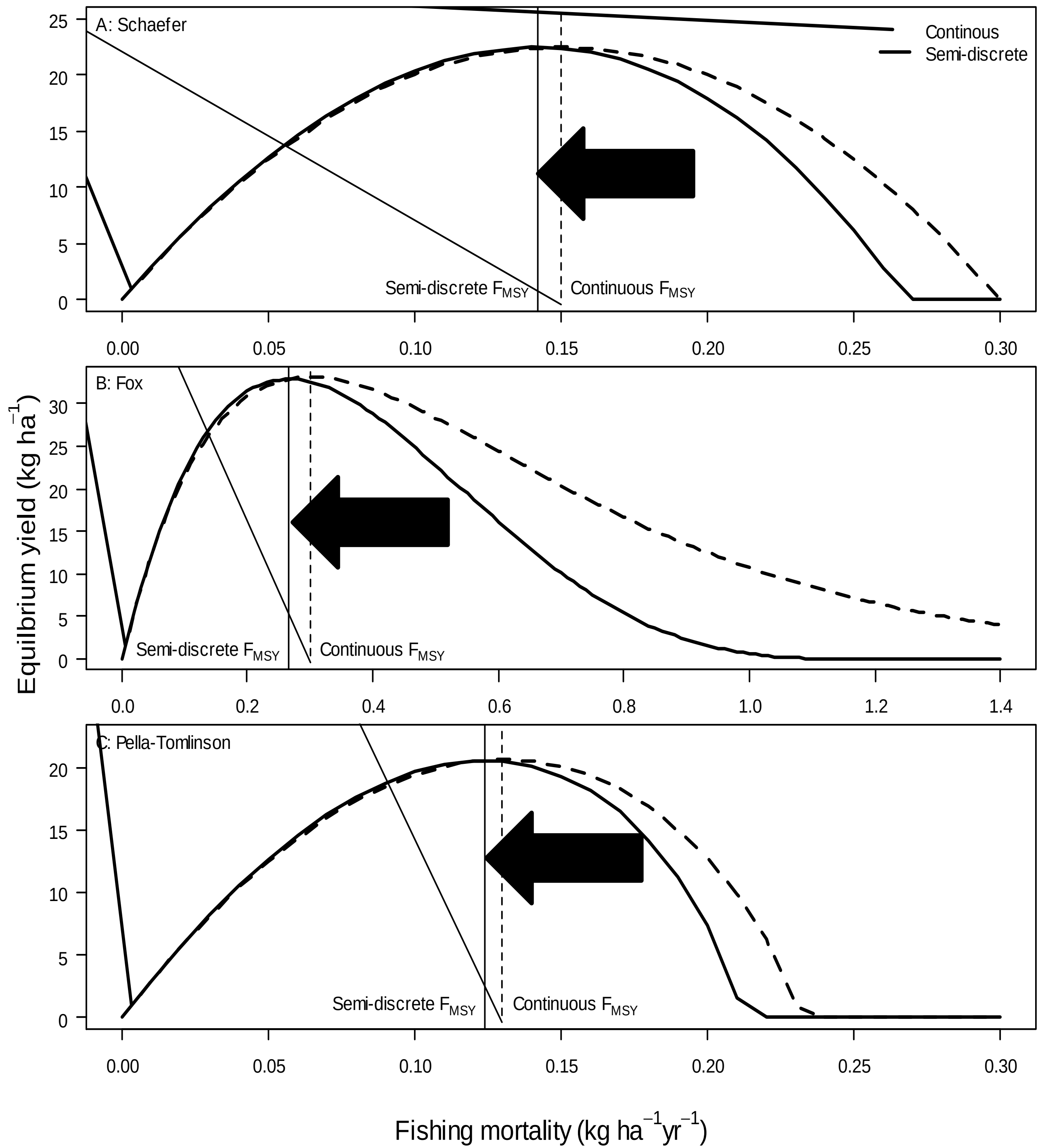

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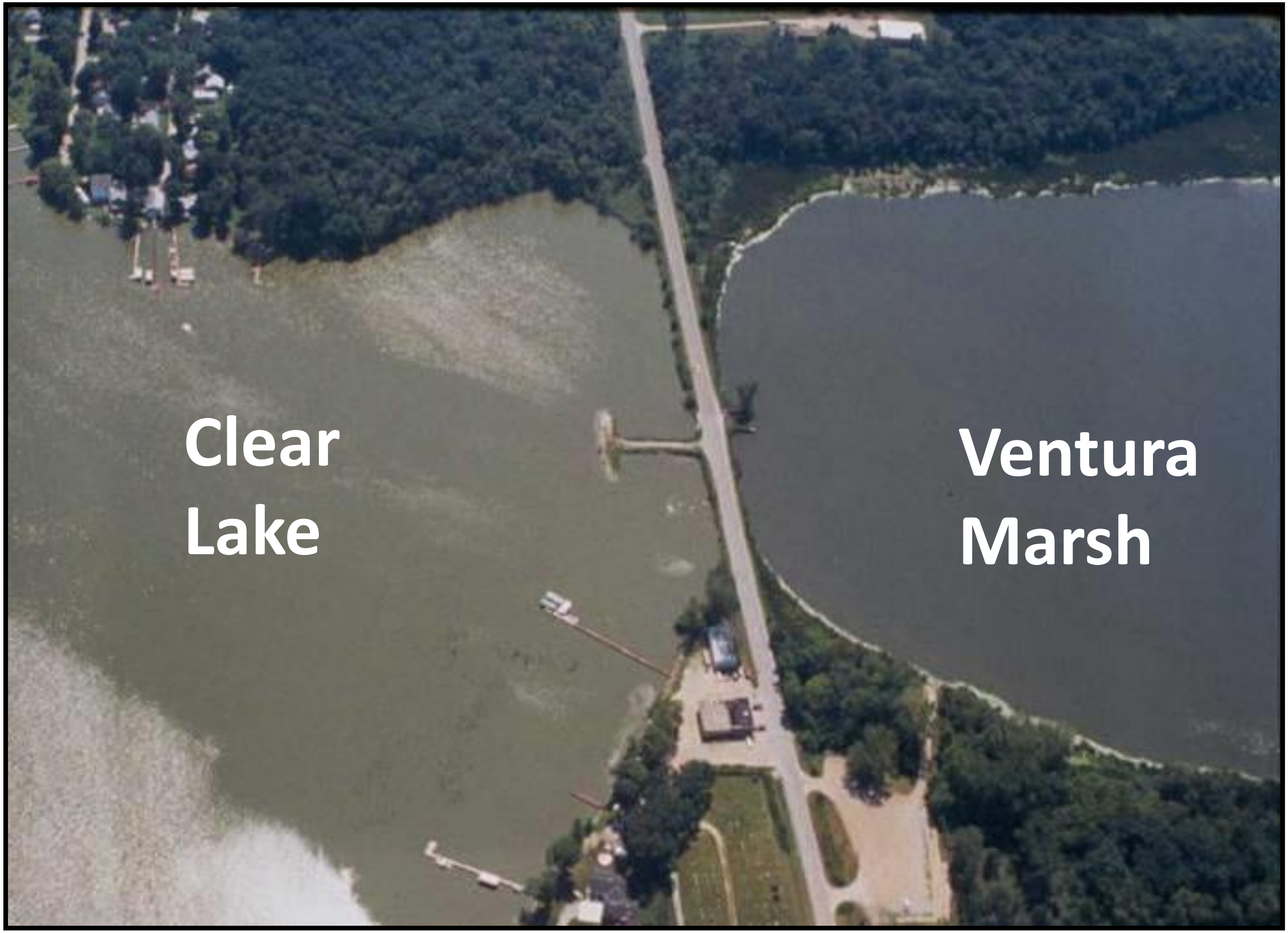


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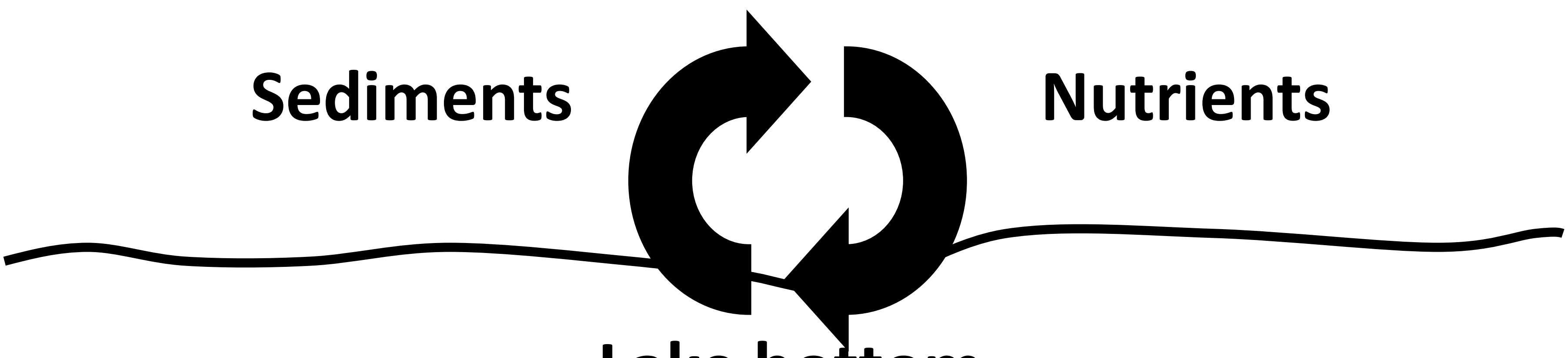
**Sediments**



**Nutrients**

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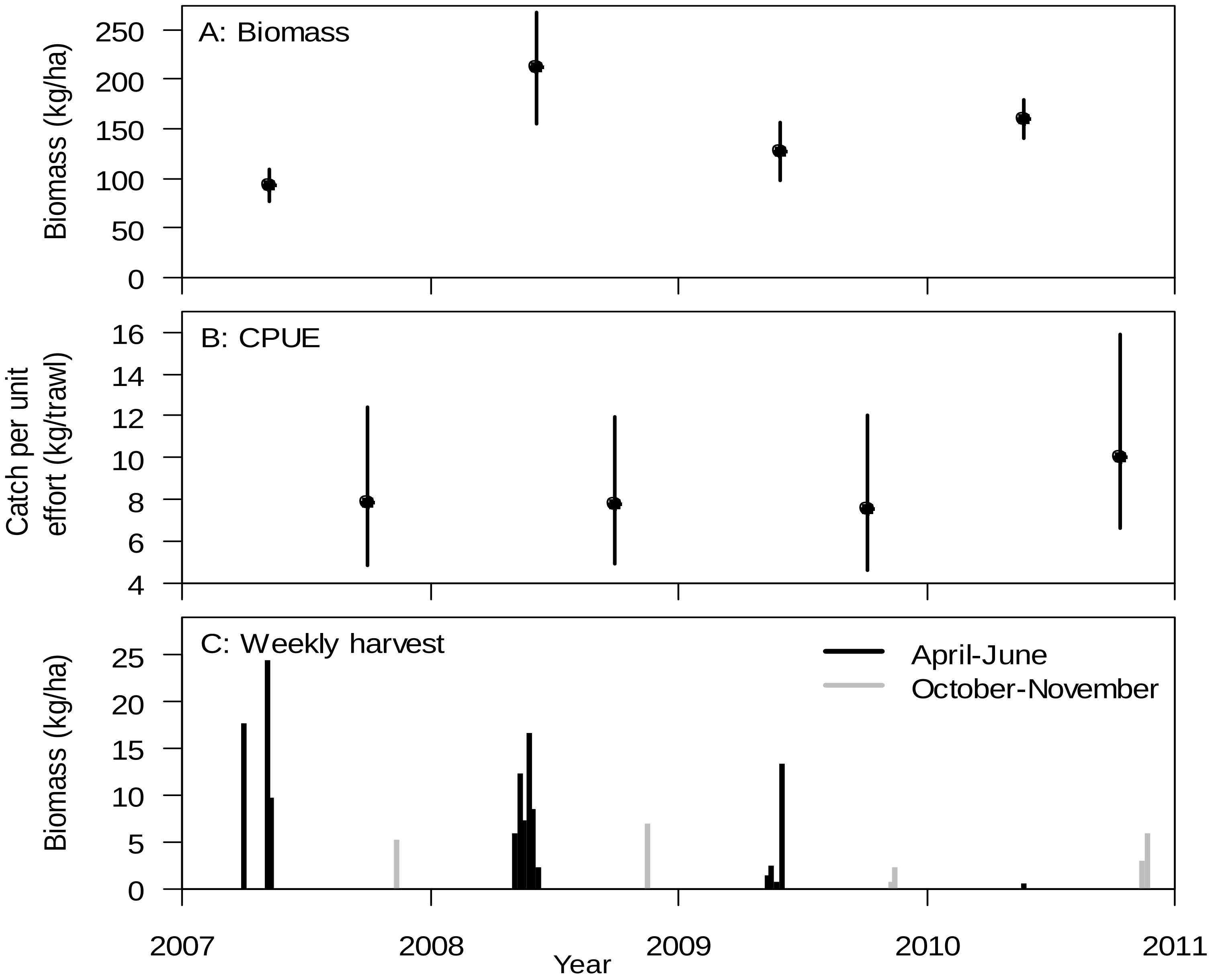

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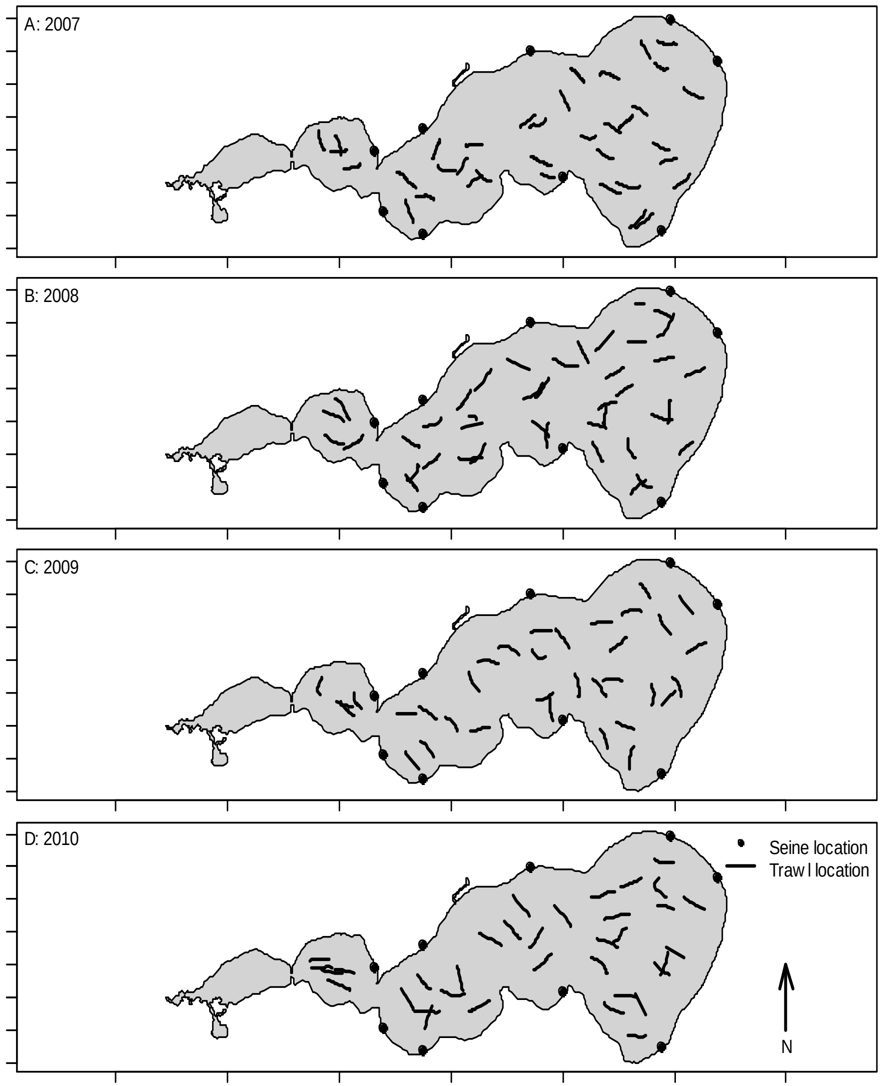


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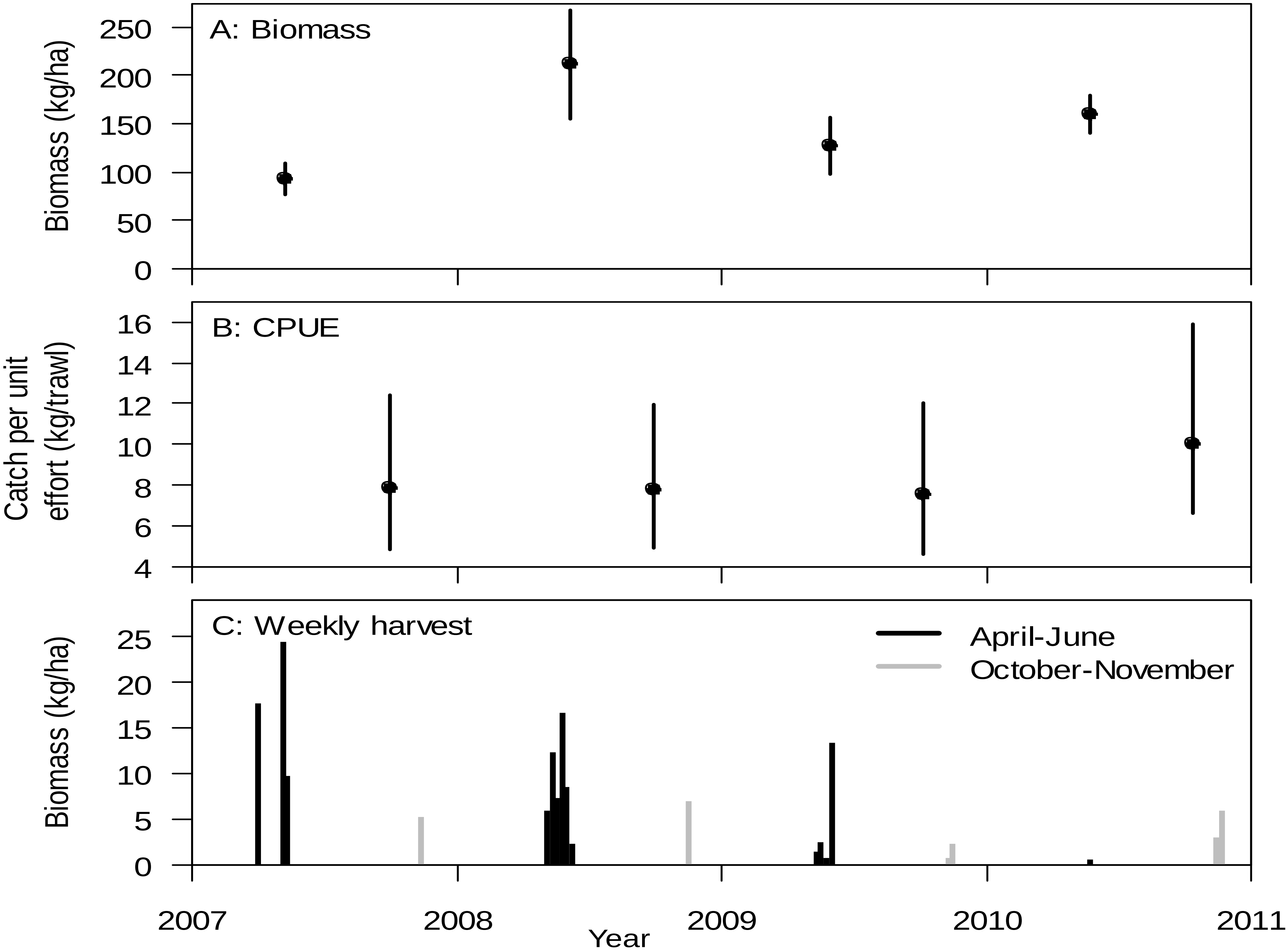
STORY AND PHOTOS BY LOWELL WASHBURN

If you're a card-carrying member of Carp Haters Inc., don't worry about it. You've got plenty of company and, in this particular case, your emotions are completely justified.

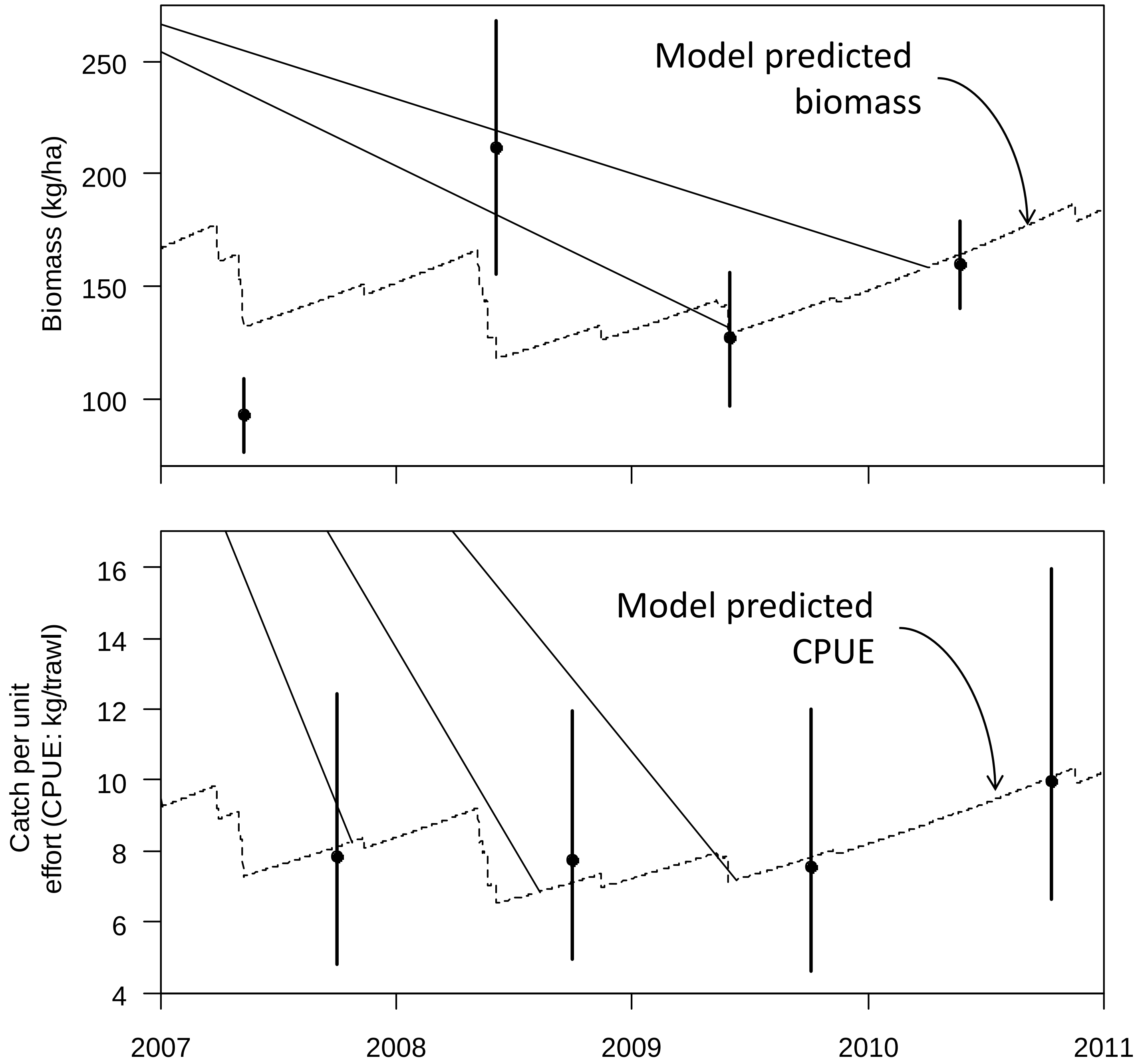
Although common carp were introduced in the 1800s with the very best intentions, few blunders have had greater negative consequences to aquatic ecosystems and native sport fisheries. Carp uproot and destroy valuable aquatic plant communities, reduce water clarity, out-compete and displace native game and forage fish, and drastically contribute to increased phosphorus levels. But let's skip all the sugar and tell it like it is. When it comes to American waters, the common carp is just plain evil—period.

As is the case with most natural resource agencies, the DNR has been battling carp for decades. Fisheries workers have installed mechanical barriers to restrict carp movement, poisoned lakes and fish nurseries,

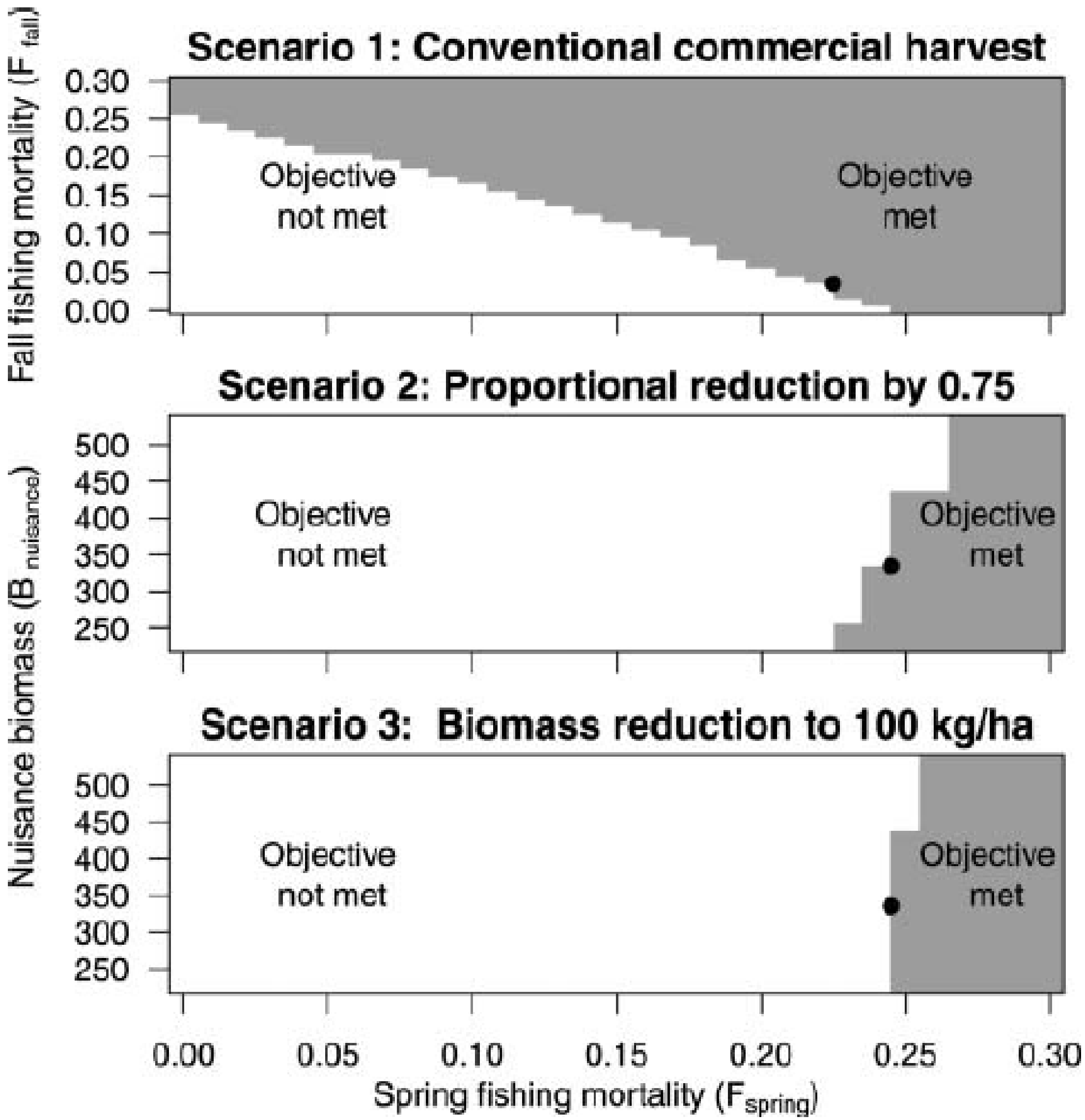
WWW.IOWADNR.GOV 51


A: Biomass
Biomass (kg/ha)
250
200
150
100
50
0
B: CPUE
Catch per unit effort (kg/trawl)
16
14
12
10
8
6
4
C: Weekly harvest
Biomass (kg/ha)
25
20
15
10
5
0
April-June
October-November
2007
2008
2009
2010
2011
Year

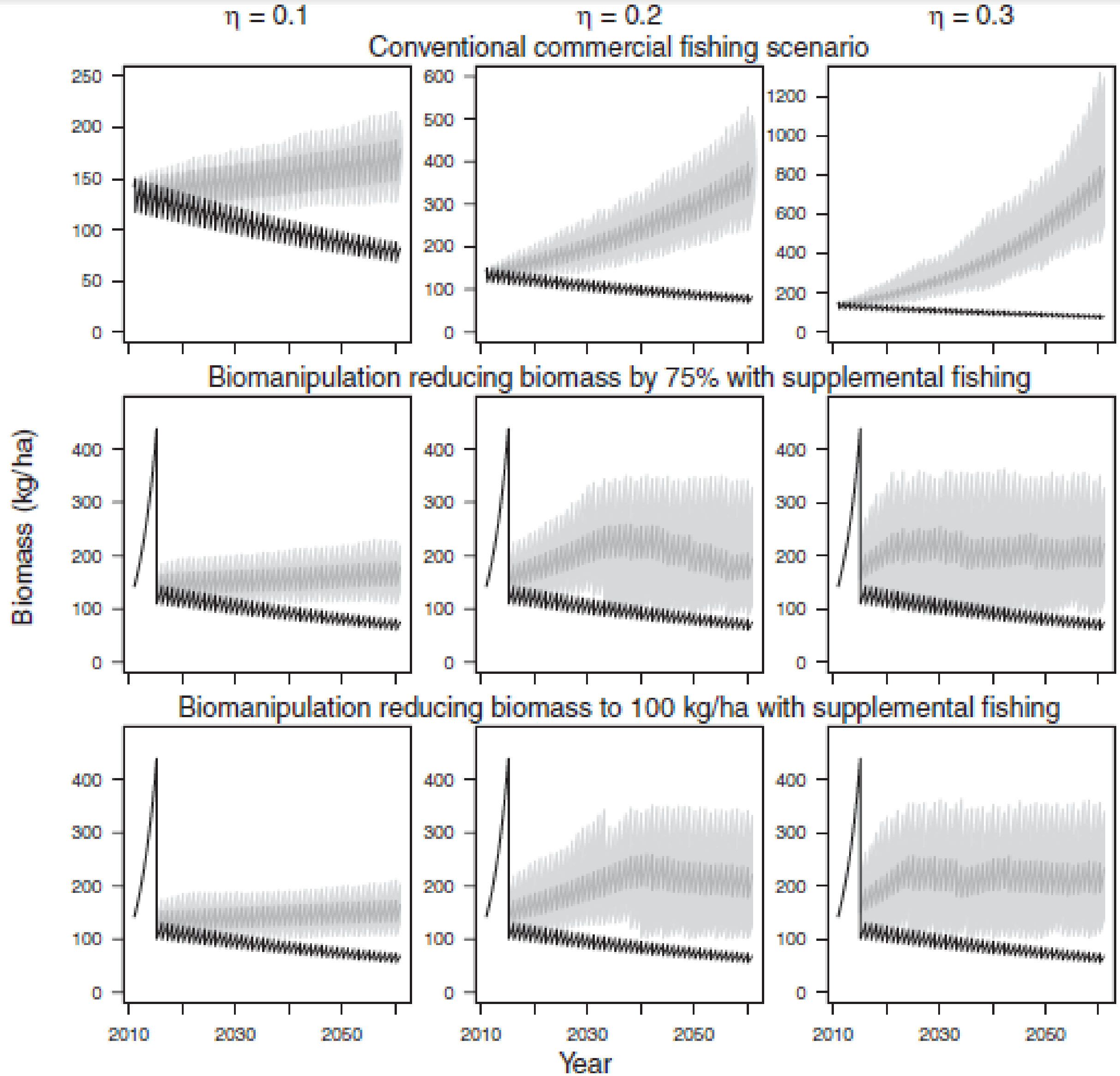
# Fitted model



# Meeting management objectives



# Partial Controllability



# CarpBioDyn

**SCENARIOS OVERVIEW-**
**+++++Scenario 1: Continued spring and fall commercial fishing**
**+++++Scenario 2: Pulsed spring harvest of 75% of biomass if biomass exceeds nuisance levels. Supplemental spring commercial fishing occurs when biomass is below nuiscance levels**
**+++++Scenario 3: Pulsed spring harvest of of biomass to 100 kg/ha if biomass exceeds nuisance levels. Supplemental spring commercial fishing occurs when biomass is below nuiscance levels.**

Scenario

2

2

1 3

**Scenario 1: Continued spring and fall commercial fishing**

0.25

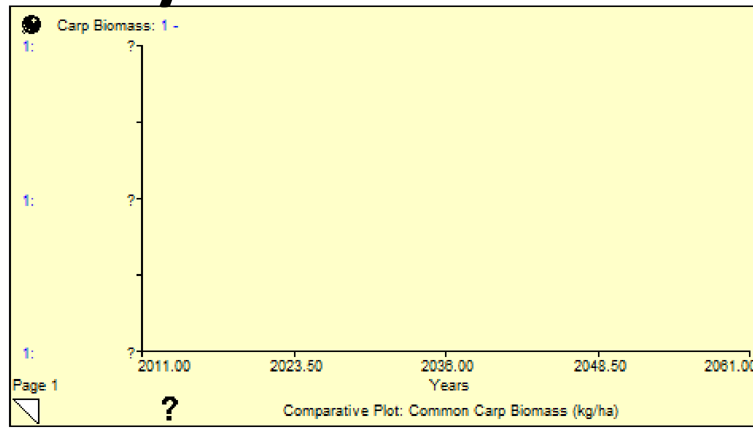
**SCENARIOS 2 and 3: Nuisance biomass level**

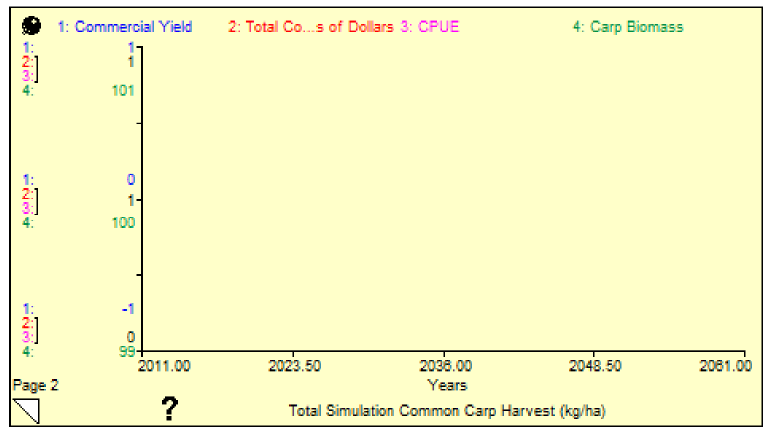
Nuisance Biomass Threshold

400

F supplemental

0.00




**Unintentional underharvest due to uncontrolable factors such as weather, personnel, and markets can effect common carp dynamics. Ideally management strategies to control common carp are robust to unintentional underharvest. This slider input can be used to evaluate the impacts of underharvest on common carp biomass dynamics.**

**Setting the slider to 0 simulates perfect harvest (i.e., no under harvest). The slider can be increased to 0.1, 0.2, 0.3, and 0.4 to stocastically simulate underharvest of 10% to 40%. Default value is 0.**

Under harvest

0.0

Return to introduction page

Restore Sliders and Knobs to Defaults

Clear Graphs & Tables

Run The Carp Model!

Press to move to table of model output

**Subsidy Evaluation- Use this slider to set a subsidy amount in cents/kg. The total cost of the subsidy over time is then calculated.**

Subsidy amount

0.23

| Total cost | $0 |
|---|---|

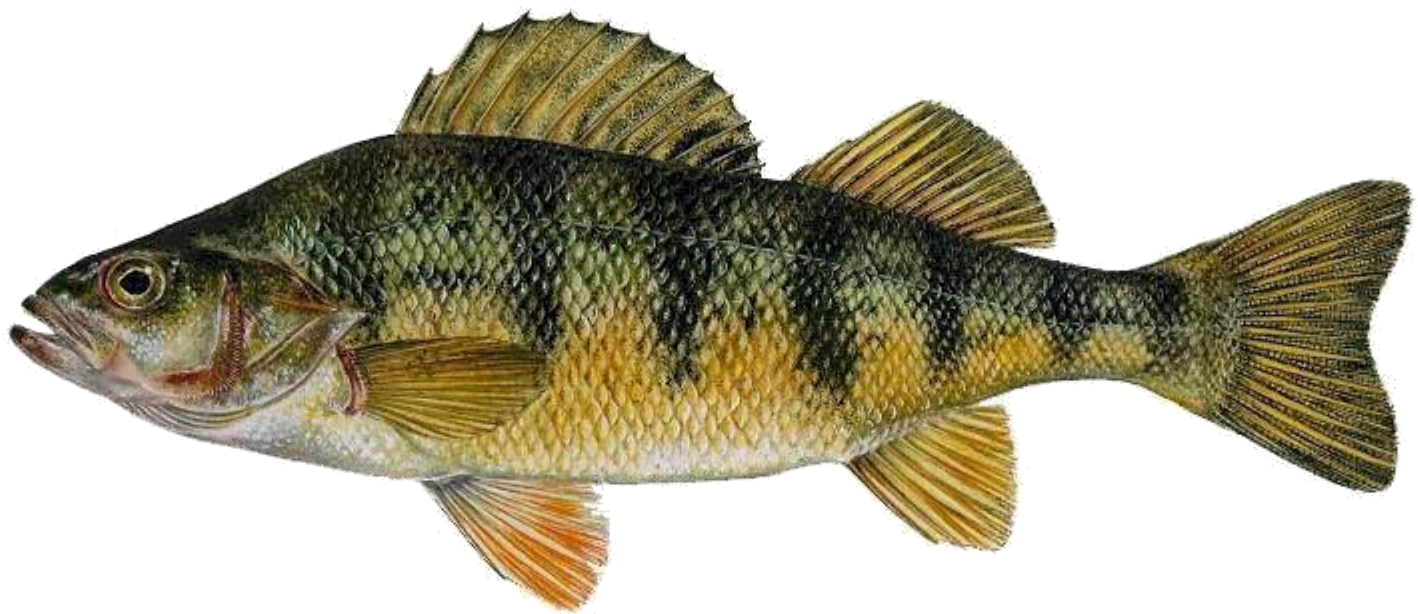
In a nutshell-preventing or minimizing growth overfishing!

# MANAGING YIELD IN AGE STRUCTURED POPULATIONS

# What is growth overfishing?

**Harvest fish before they have time to grow**

**Example:**

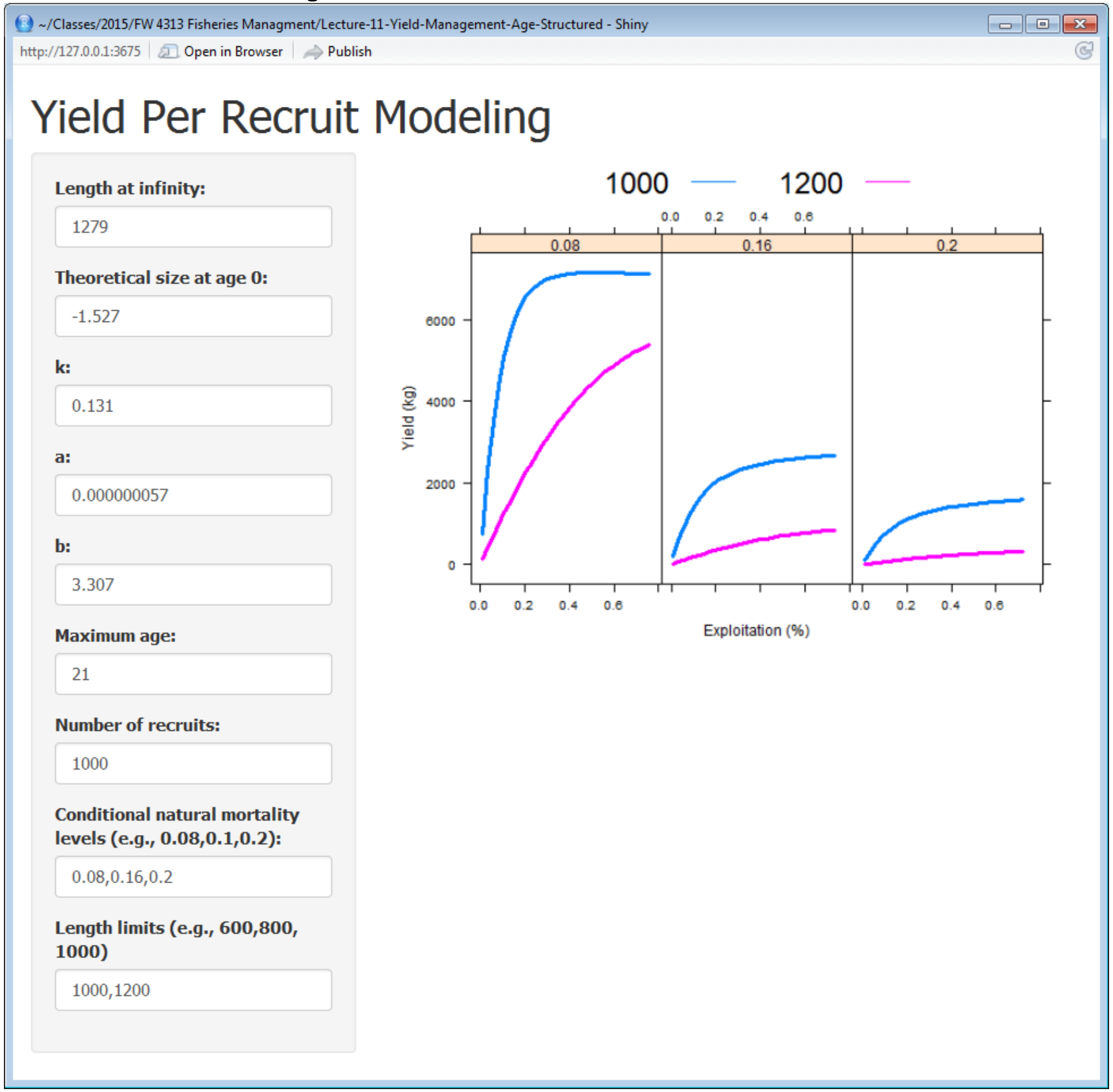


# Growth process in fish

The assimilation of food as biomass (i.e., tissue). Primarily refers to somatic tissue but also includes gonad tissue.

- Fish adding **weight** over **time**
    1. **Relate time (age) to length**
    2. **Relate length to weight**

# Yield per recruit model!



# Diagnosing growth overfishing

Growth overfishing

No growth overfishing

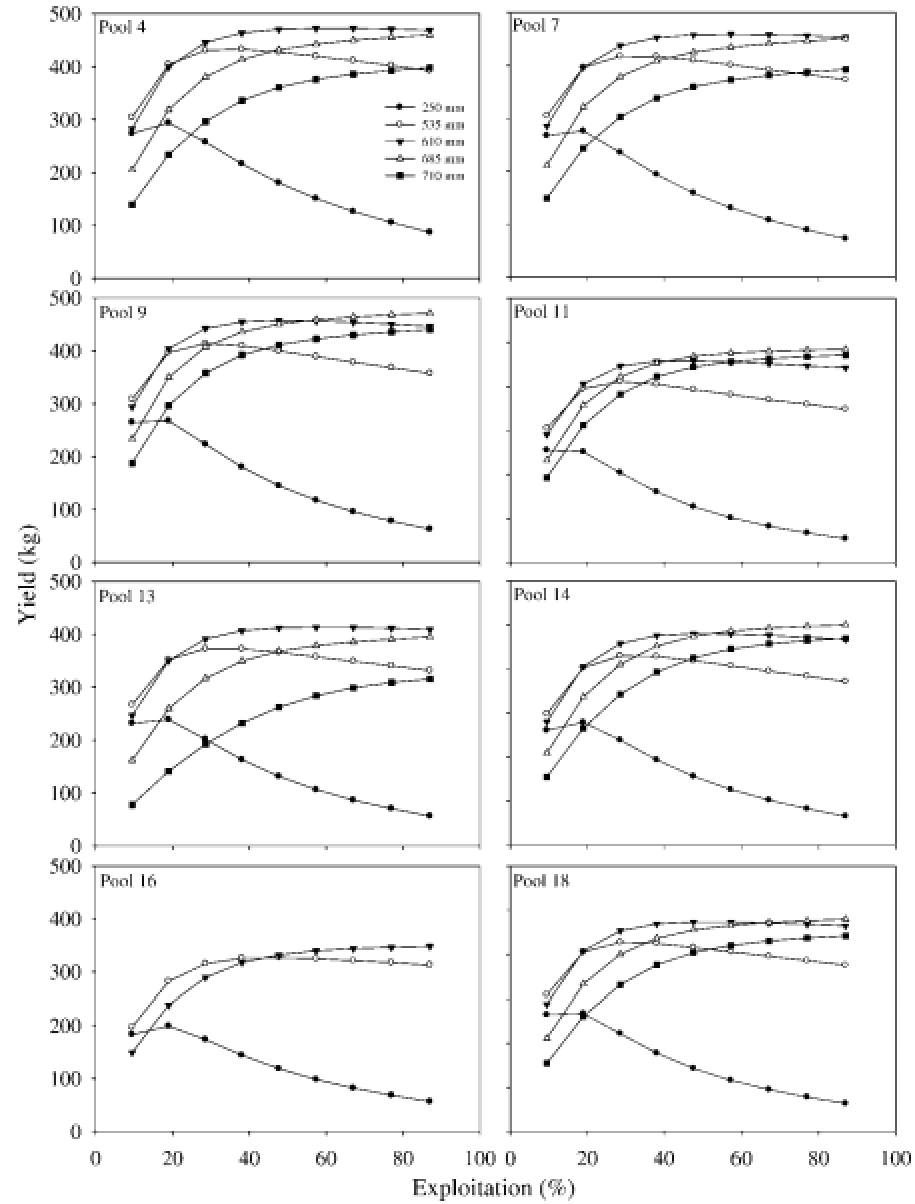
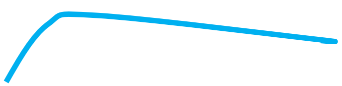



FIGURE 3.—Simulated yields for selected shovelnose sturgeon populations in the upper Mississippi River with a conditional natural mortality of 10%. The simulations were conducted with five different minimum length limits except in the case of Pool 16, for which only three minimum length limits were simulated because the 685- and 710-mm length limits exceeded the asymptotic maximum length of the fish in the pool.

# Diagnosing growth overfishing



Growth overfishing

No growth overfishing

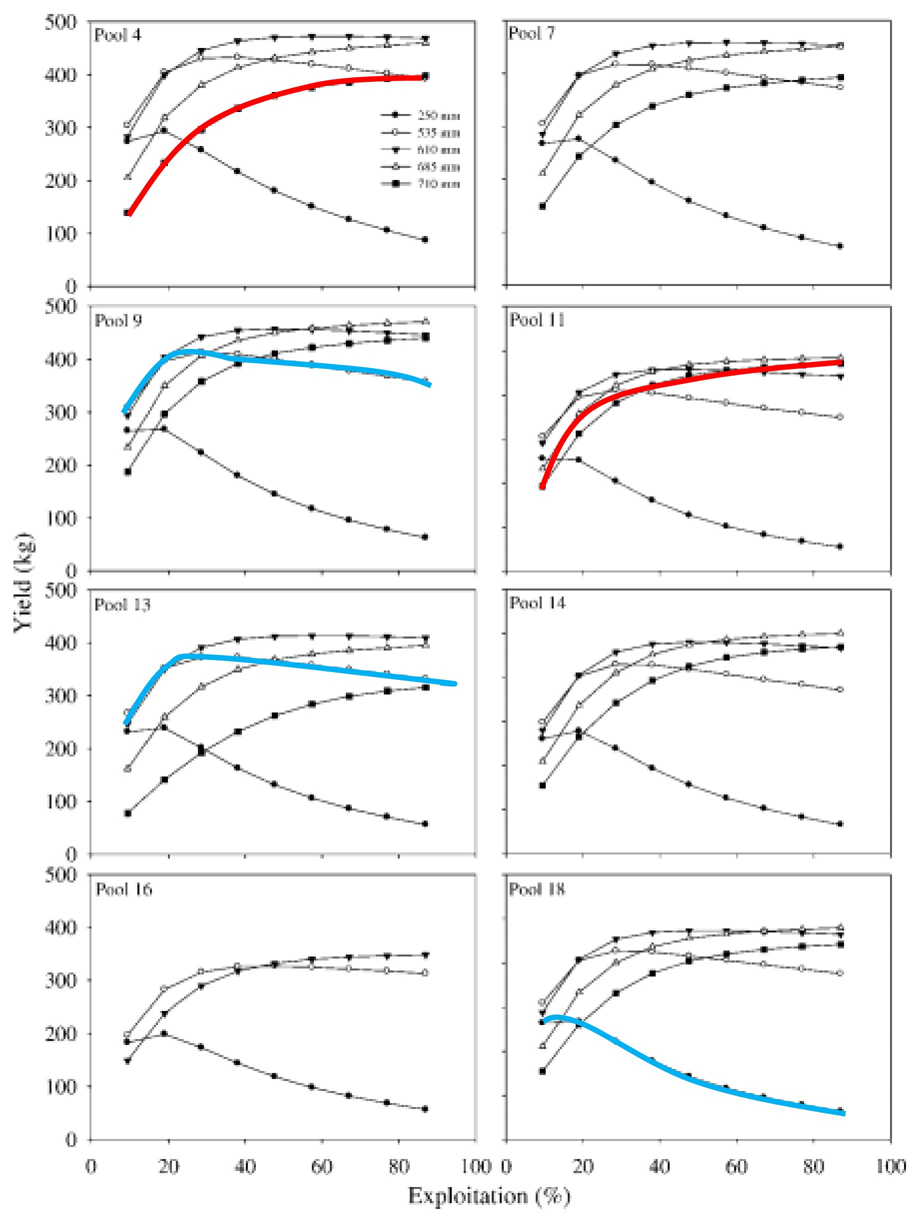



FIGURE 3.—Simulated yields for selected shovelnose sturgeon populations in the upper Mississippi River with a conditional natural mortality of 10%. The simulations were conducted with five different minimum length limits except in the case of Pool 16, for which only three minimum length limits were simulated because the 685- and 710-mm length limits exceeded the asymptotic maximum length of the fish in the pool.

# PADDLEFISH ROE HARVEST

*Co-authors:*

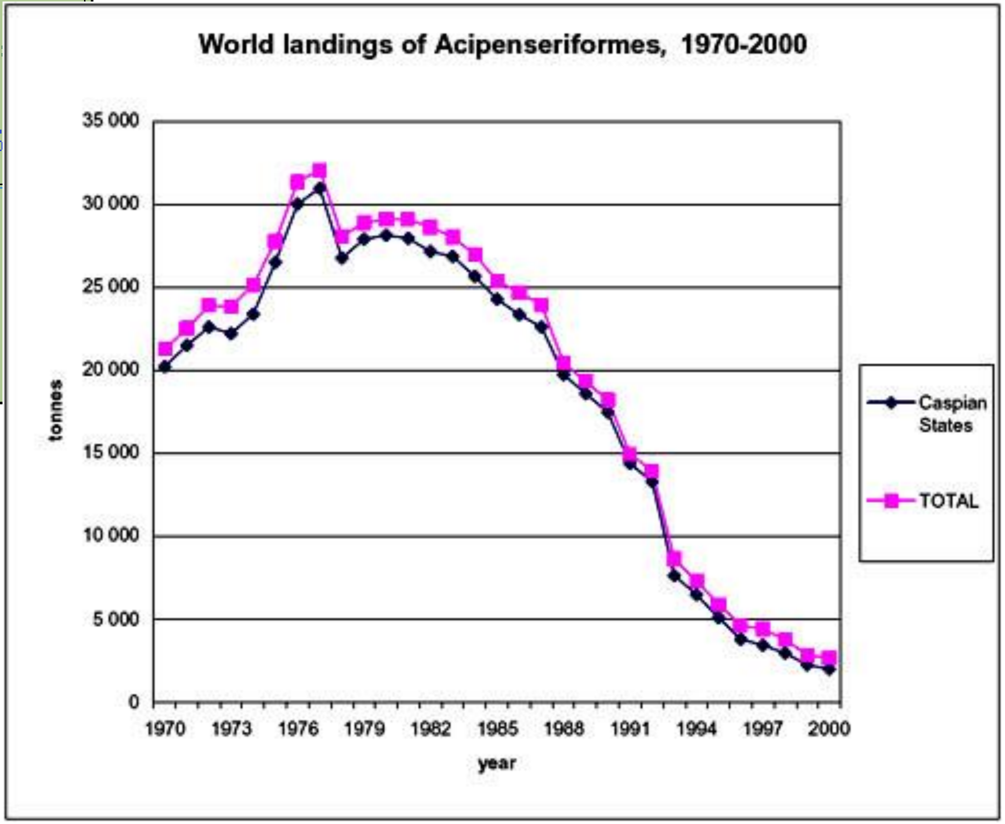
*P.W. Betolli - Tennessee Cooperative Fish and Wildlife Research Unit*

*G.D. Scholten – Iowa Department of Natural Resources*

# Caviar sources

- Salmon
- Mullet
- Herring
- Carp
- Bowfin
- Acipenseriformes
  - Sturgeon
  - Paddlefish

# Eurasian caviar stocks decline


*http://www.fao.org/docrep/006/Y5261E/y5261e06.htm*

# NA Acipensiformes harvest

- High market price
- Increased harvest in North America
- At-risk to overfishing?

npr

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## Caviar Ban Threatens Mississippi Paddlefish

by JOHN NIELSEN

**Listen**
*Day to Day*

Add to Playlist
Download

*November 1, 2005*

text size A A A

Some fishermen on the Mississippi remember using buckets of paddlefish eggs as pig slop. Then the U.S. government banned caviar imports from the Caspian Sea. NPR environmental correspondent John Nielsen reports on how that ban made paddlefish caviar the preferred alternative, and led to overfishing that now threatens the species.

220 $/kg roe; 500-650$ per fish

# Yield-per-recruit (YPR) models

- Predicts fishery yield
- Age structured
- Evaluate varying:
  - Fishing mortality
  - Length limits
  - Natural mortality

North American Journal of Fisheries Management 32:731–744, 2012

ISSN: 0275-5947 print / 1548-8675 online
DOI: 10.1080/02755947.2012.686956

ARTICLE

**Differences in Paddlefish Populations among Impoundments of the Arkansas River, Arkansas**

**Frank J. Leone**
*Arkansas Game and Fish Commission, 2 Natural Resources Drive, Little Rock, Arkansas 72205, USA*

**Joseph N. Stoeckel**
*...ussellville,*
*...72205, USA*

North American Journal of Fisheries Management 22:537–549, 2002


**Potential Influence of Harvest on Shovelnose Sturgeon Populations in the Missouri River System**

J. Appl. Ichthyol. 23 (2007), 465–475

ISSN 0175–8659
*Received: June 15, 2006*
*Accepted: December 20, 2006*
doi: 10.1111/j.1439-0426.2007.00886.x

**Effects of harvest and length limits on shovelnose sturgeon in the upper Wabash River, Indiana**

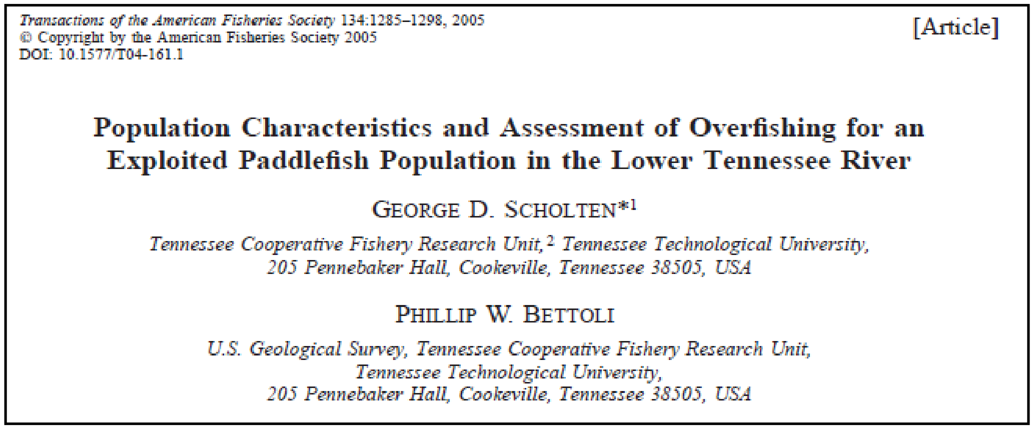
By A. J. Kennedy and T. M. Sutton

North American Journal of Fisheries Management 29:84–100, 2009

DOI: 10.1577/M08-115.1

**Effects of Commercial Harvest on Shovelnose Sturgeon Populations in the Upper Mississippi River**

# Paddlefish harvest



*Transactions of the American Fisheries Society* 134:1285–1298, 2005

DOI: 10.1577/T04-161.1

[Article]

**Population Characteristics and Assessment of Overfishing for an Exploited Paddlefish Population in the Lower Tennessee River**

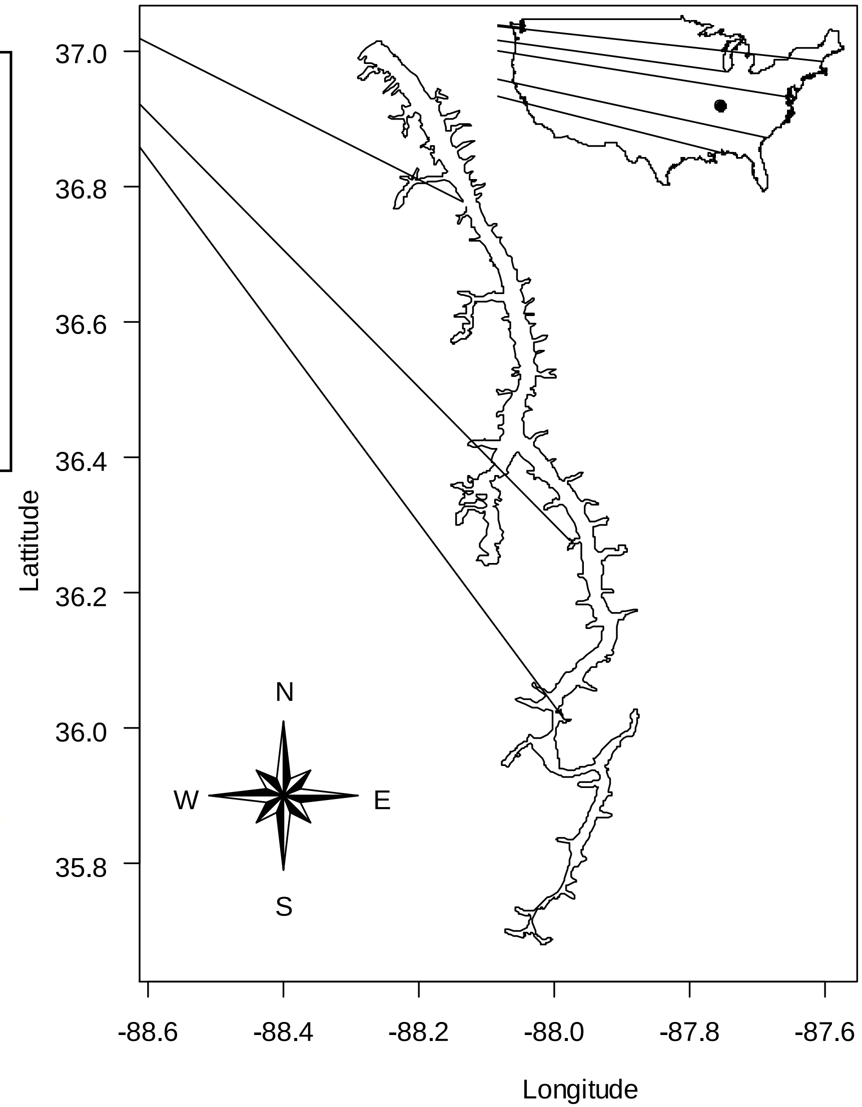
GEORGE D. SCHOLTEN*[1]

*Tennessee Cooperative Fishery Research Unit,[2] Tennessee Technological University, 205 Pennebaker Hall, Cookeville, Tennessee 38505, USA*

PHILLIP W. BETTOLI

*U.S. Geological Survey, Tennessee Cooperative Fishery Research Unit, Tennessee Technological University, 205 Pennebaker Hall, Cookeville, Tennessee 38505, USA*

*Can roe yield be increased by delaying recruitment to the fishery?*



# Potential for overfishing?

- Growth overfishing
  - 864-mm
  - Exploitation > 30%
  - Weak at 965
- Suggests increasing length limit

***<u>But, commercial fishery targets ovarian tissue not biomass!</u>***

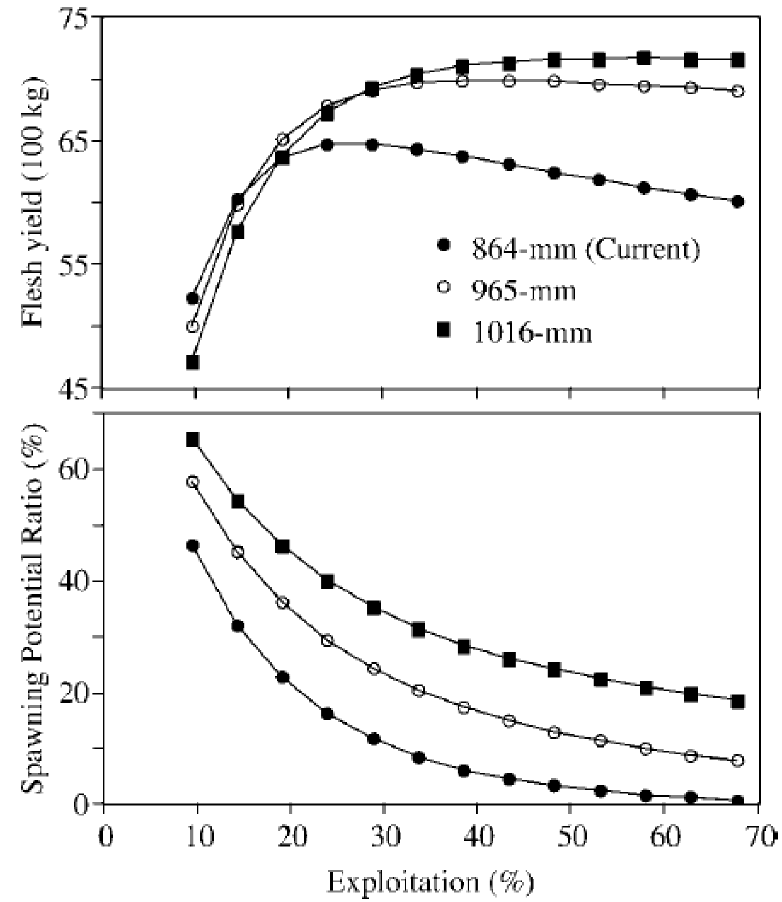
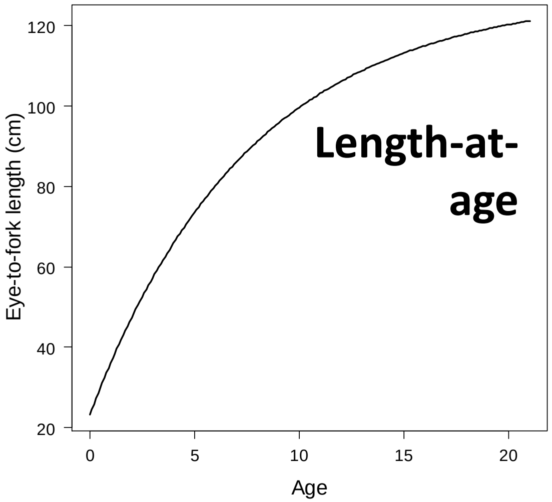
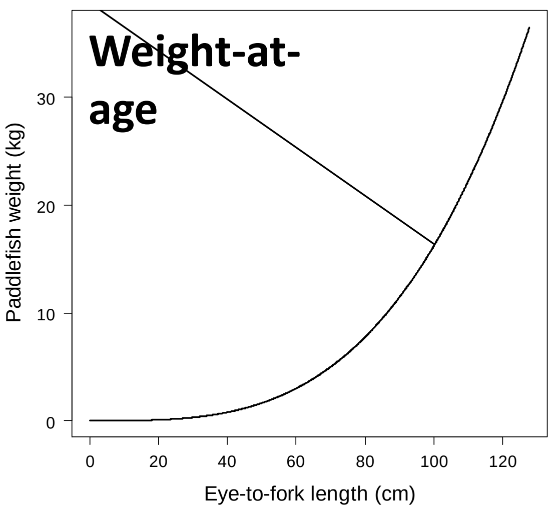
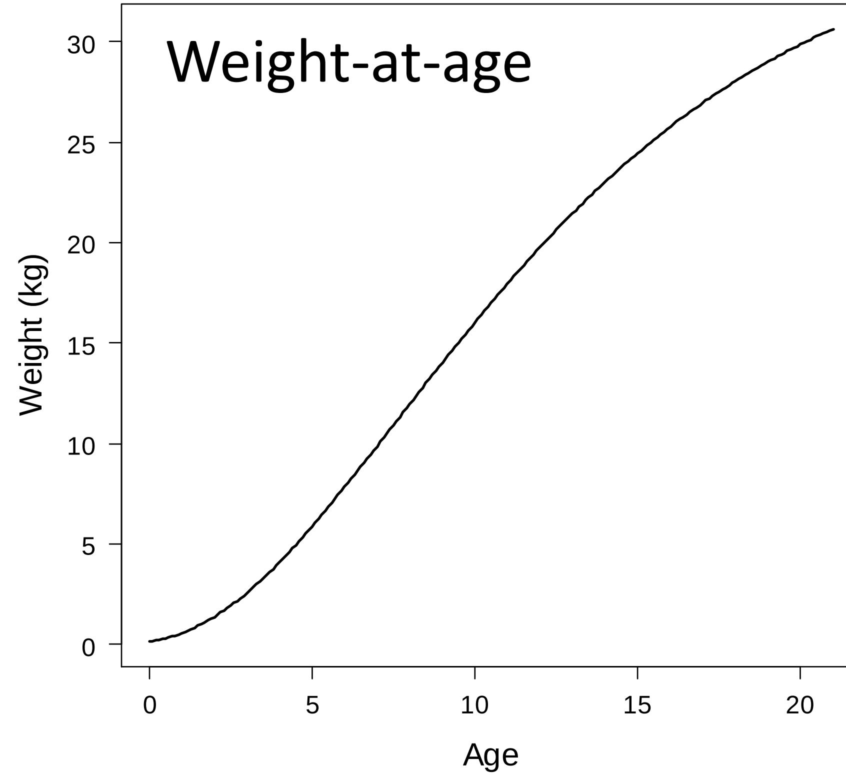



FIGURE 6.—Predicted paddlefish flesh yield (per 1,000 recruits; top) and spawning potential ratio (bottom) versus exploitation for three different minimum length limits in Kentucky Lake in 2003–2004.

# Weight-at-age

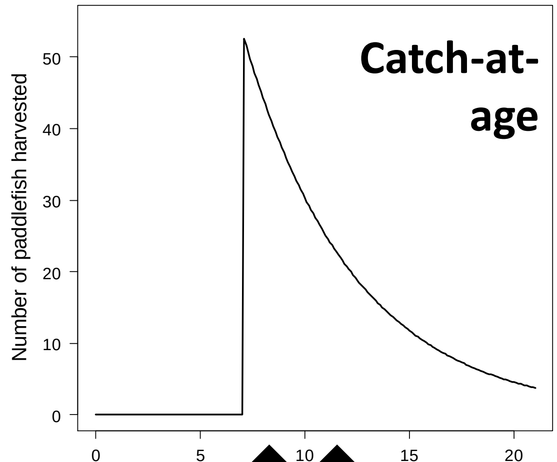


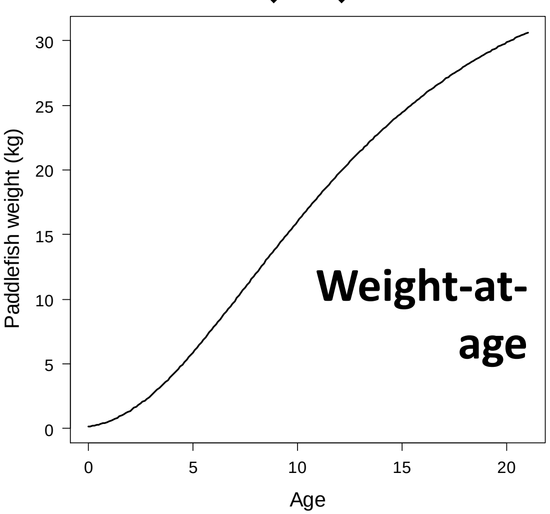



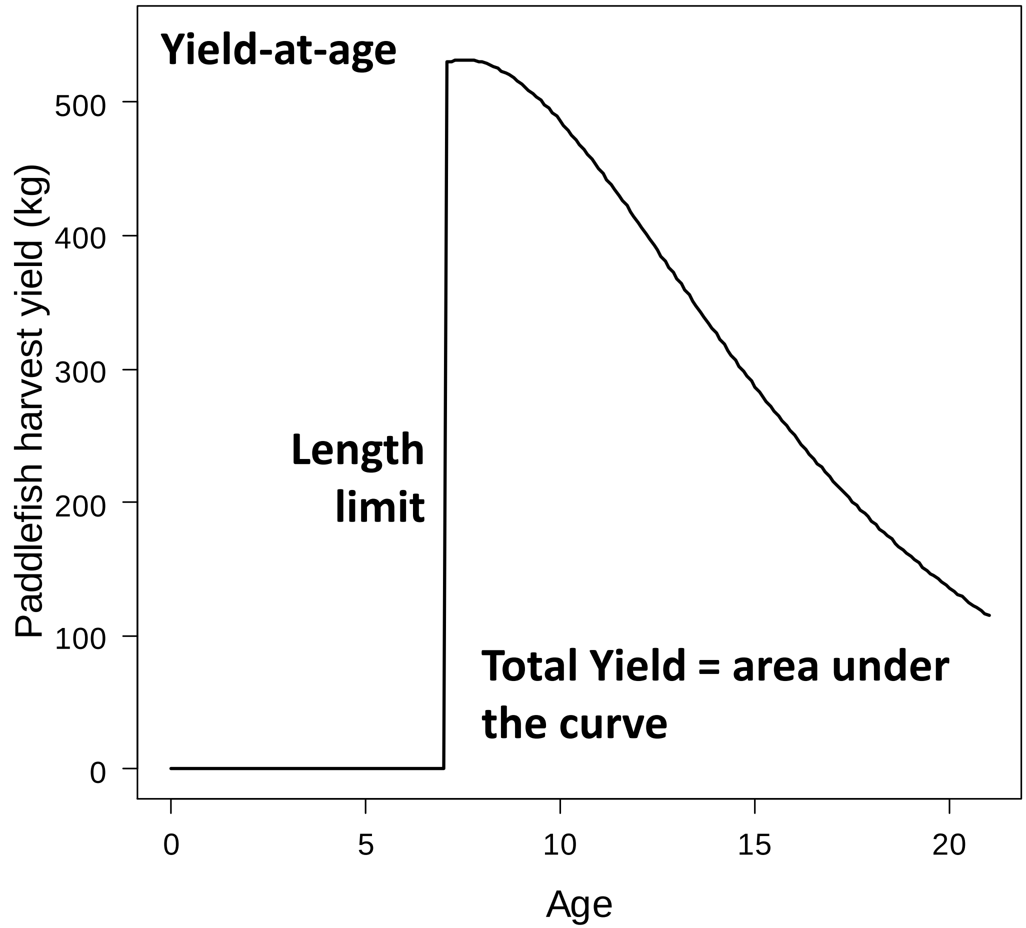




$$W_{fish}(age) = 10^{-5.711} \bullet (1{,}279 \bullet (1 - e^{-0.131 \bullet (age+1.527)}))^{3.307}$$

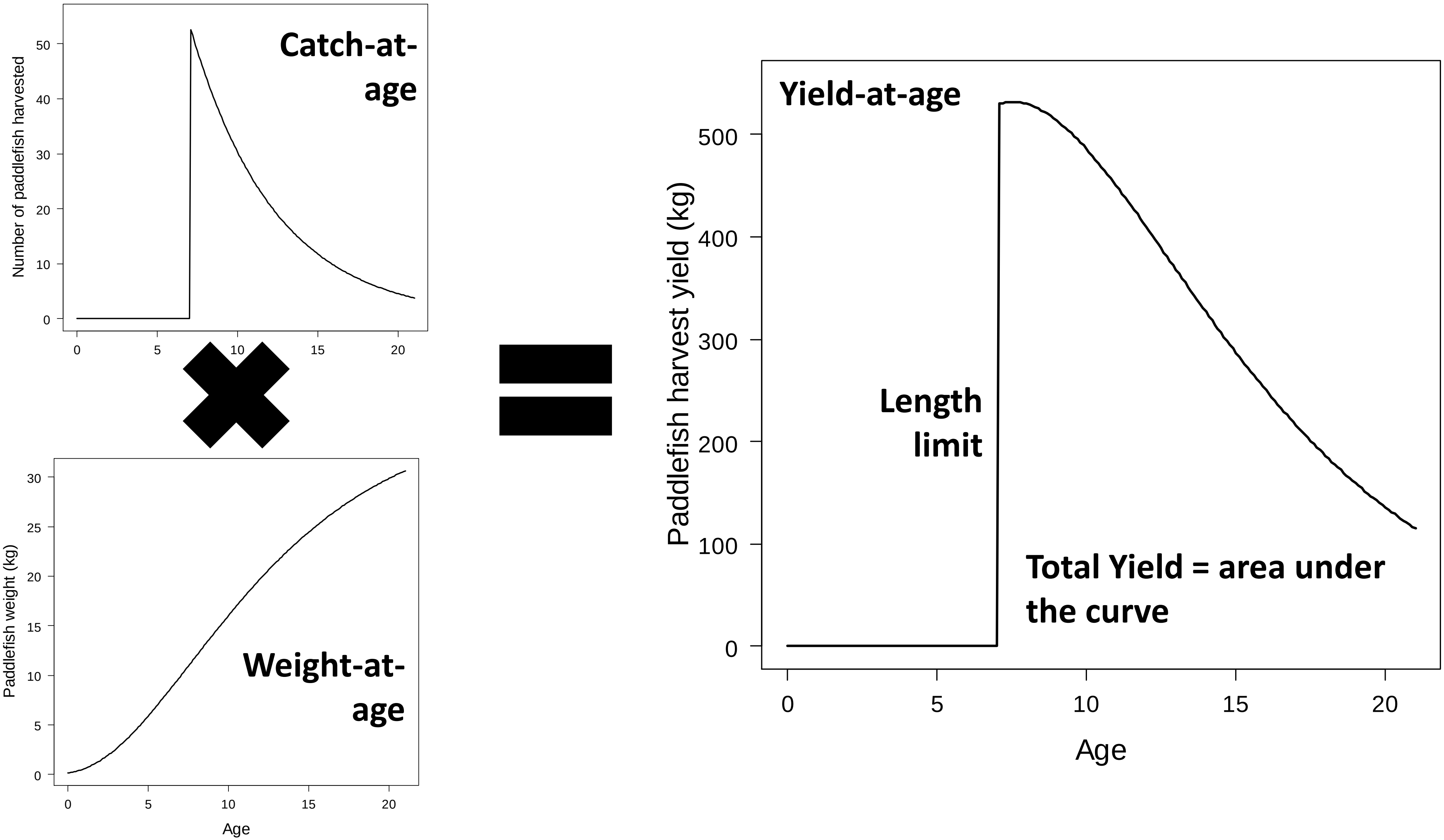
# Putting it all together



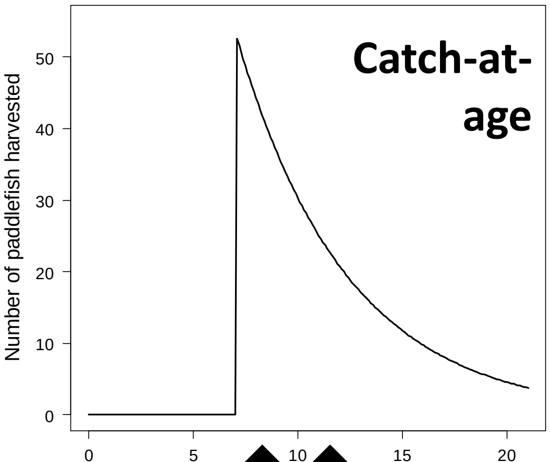



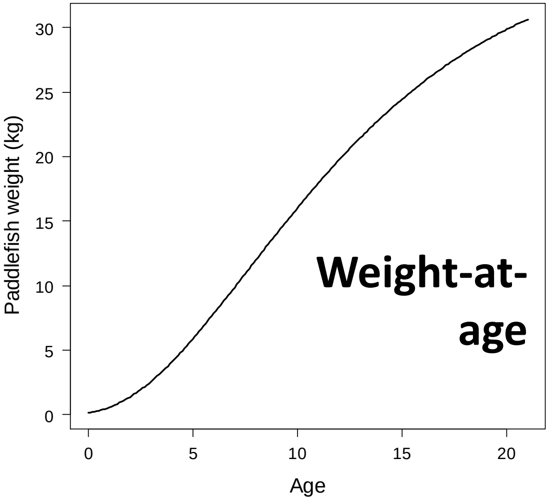



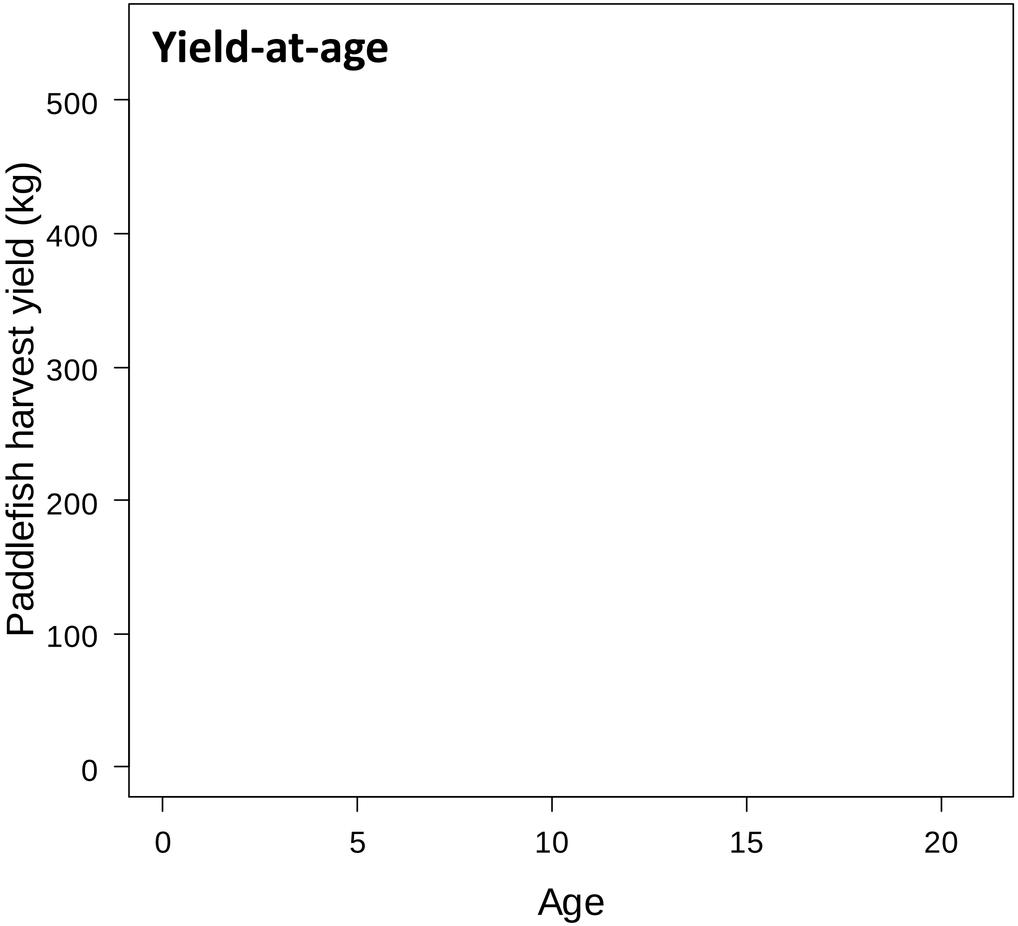
# Putting it all together



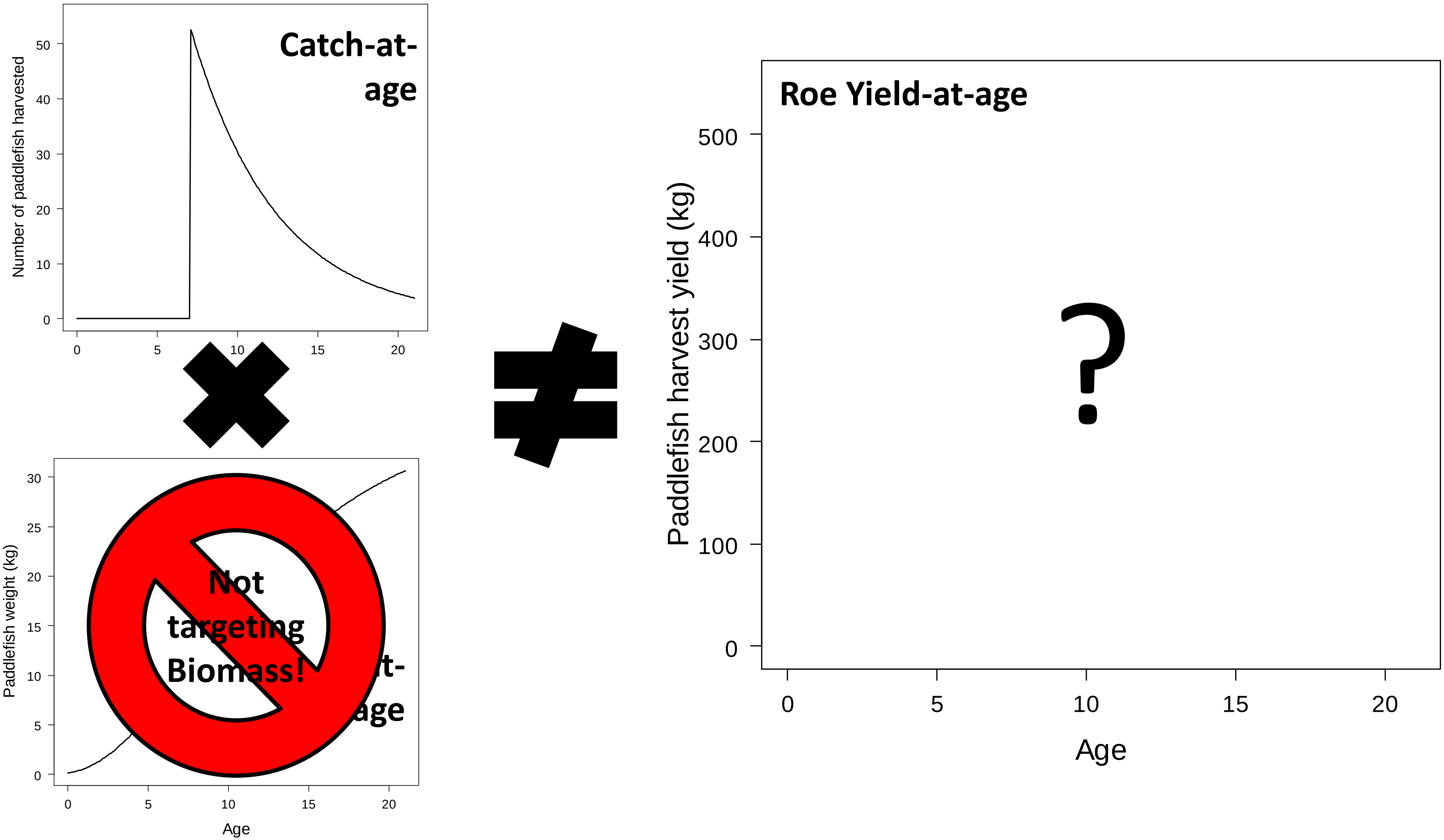
# Roe yield?


Catch-at-age
Number of paddlefish harvested
0
10
20
30
40
50
0
5
10
15
20


Weight-at-age
Paddlefish weight (kg)
0
5
10
15
20
25
30
0
5
10
15
20
Age


Yield-at-age
Paddlefish harvest yield (kg)
0
100
200
300
400
500
0
5
10
15
20
Age

# Putting it all together

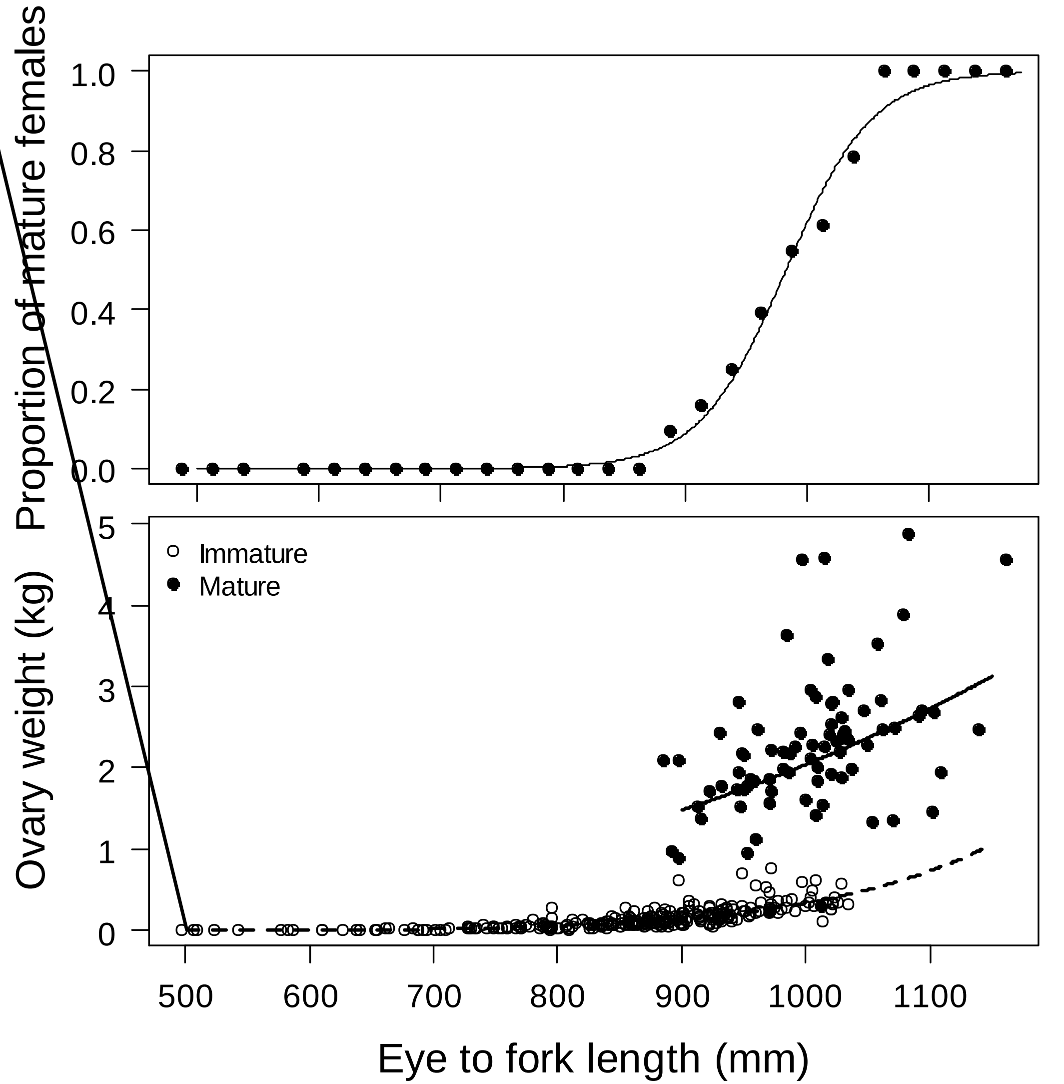


# Simulating roe yield

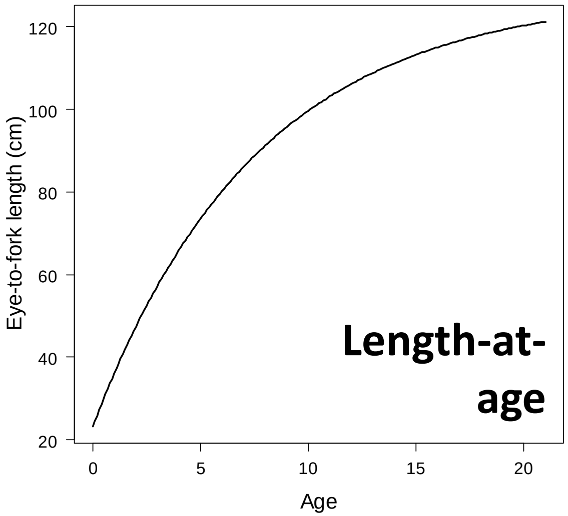
*Ovary weight-at-EFL*

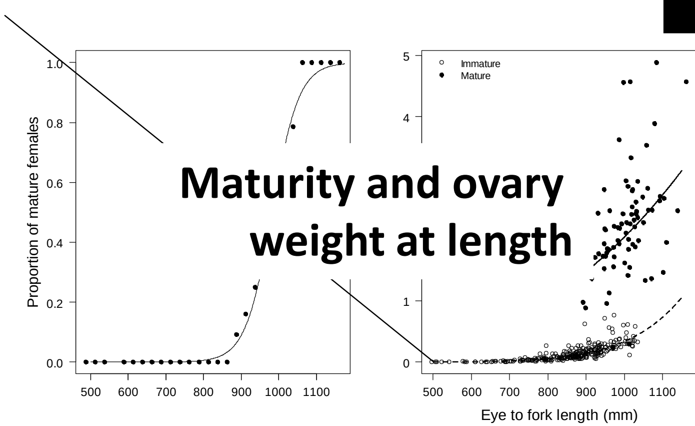
Account for:

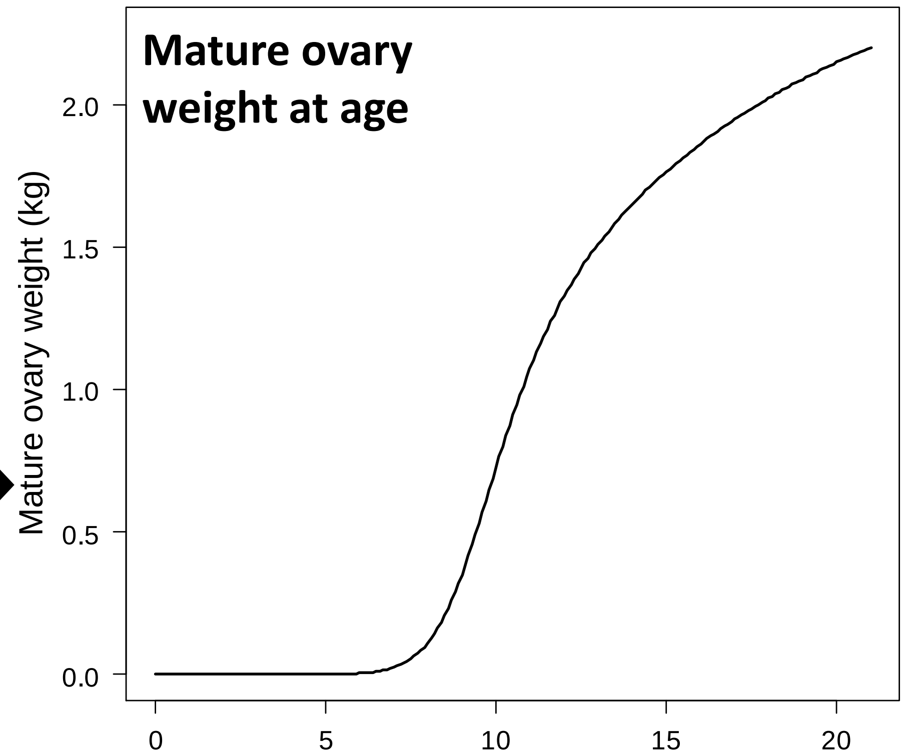
- Maturity
- Ovary weight



# Simulating roe yield

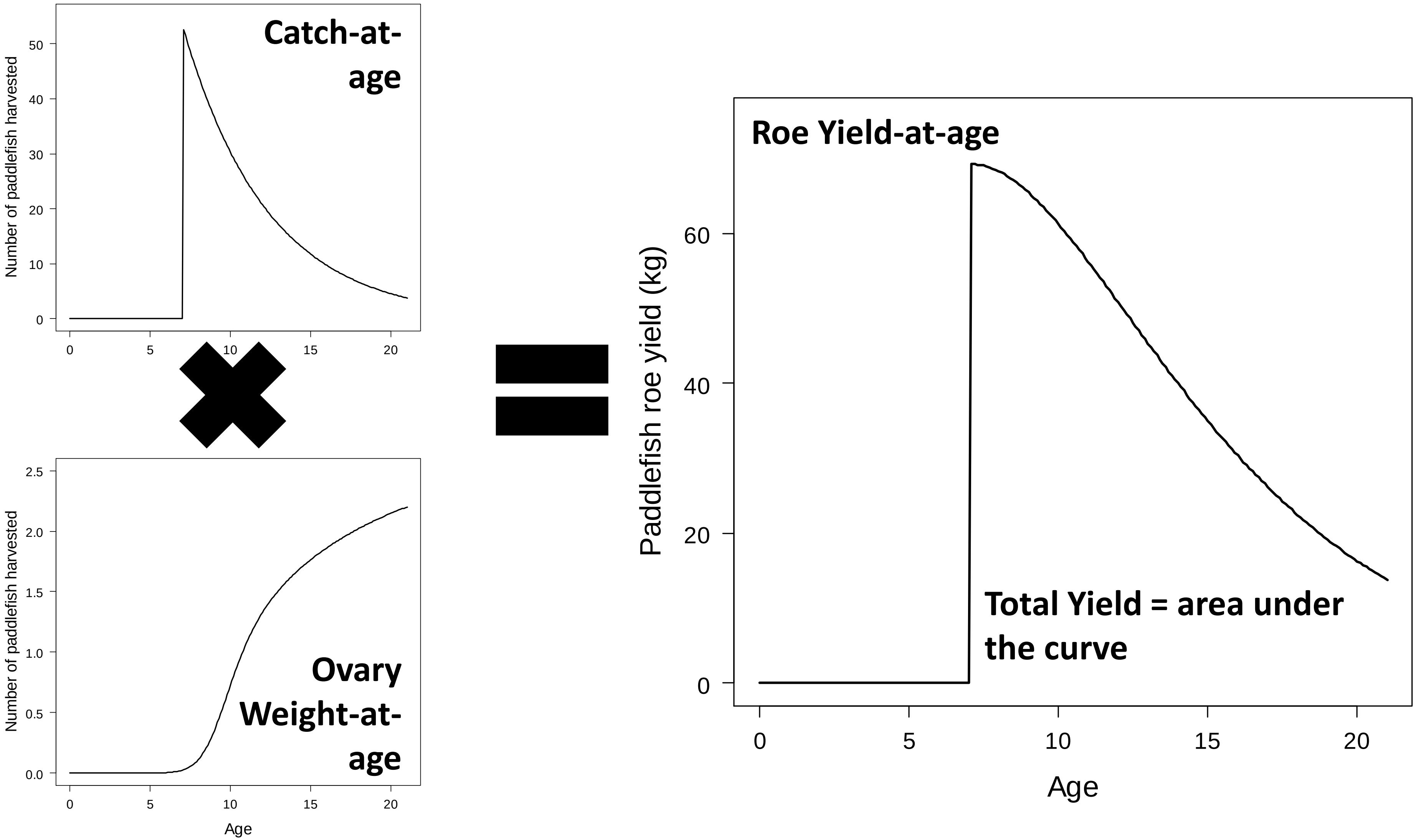


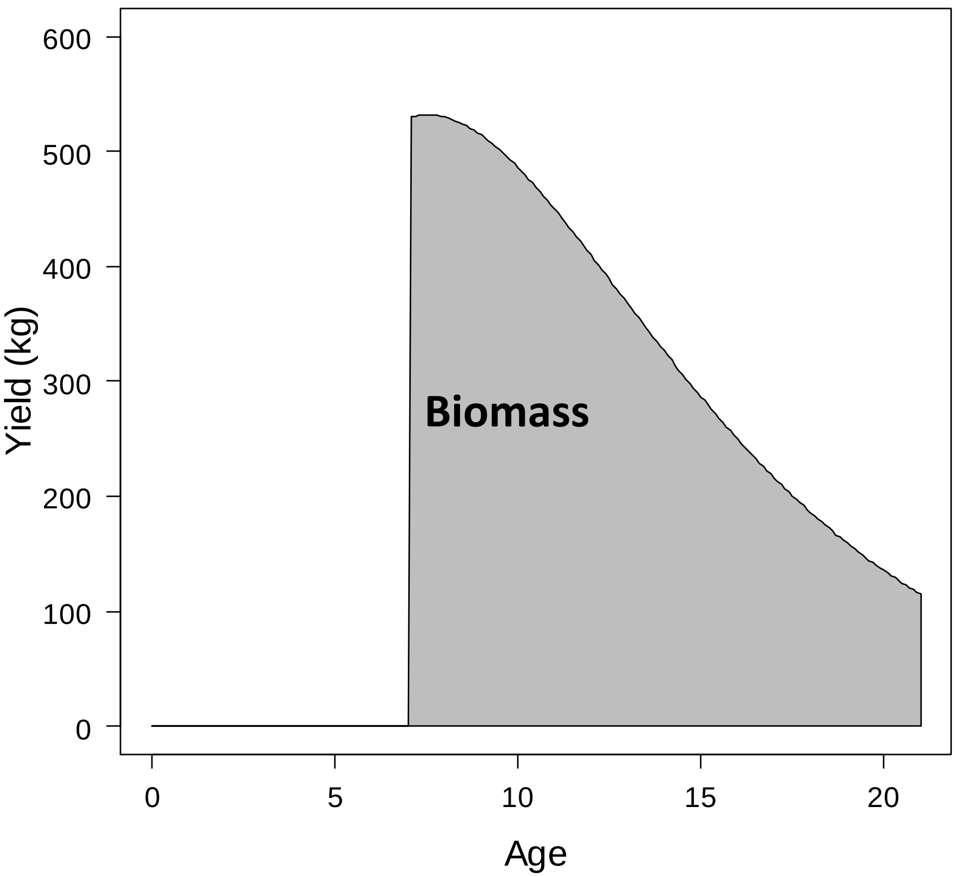

$$W_{ovary}(t) = 0.6 \bullet \left( \frac{e^{-27.78+0.028 \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (t+1.527)})}}{e^{-27.78+0.028 \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (t+1.527)})} + 1} \right) \bullet \left(0.0000014 \bullet (1{,}279 \bullet (1 - e^{-0.131 \bullet (t+1.527)})^{3.0529}\right)$$

# Finally…roe yield!

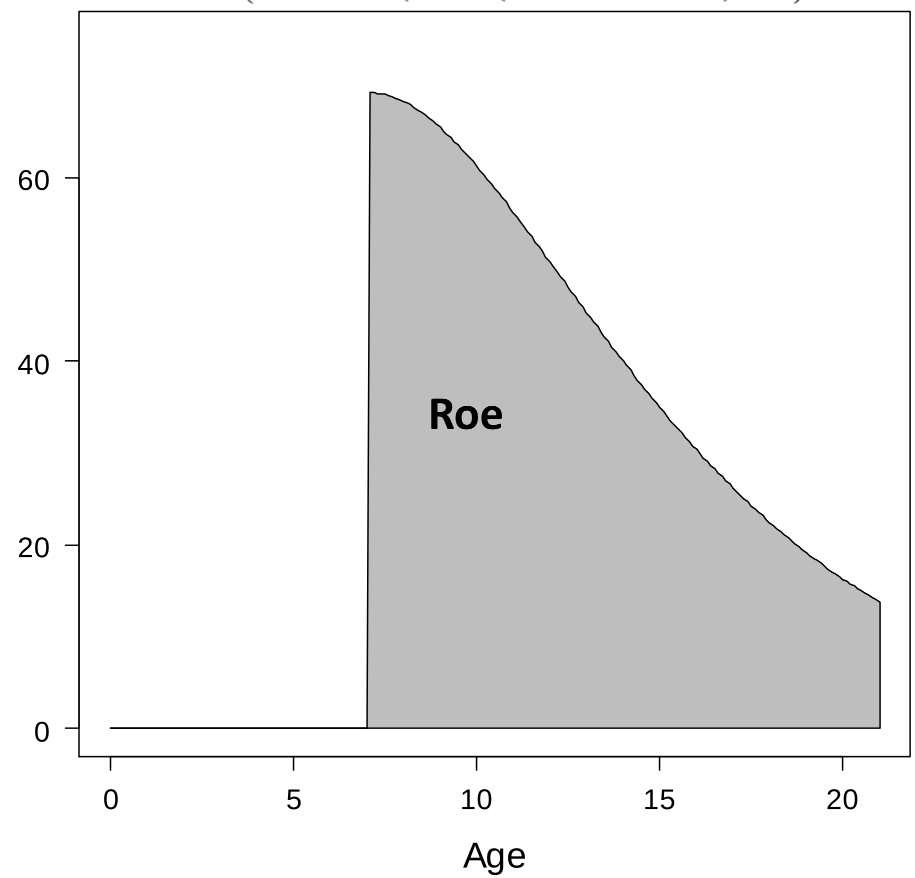


# Finally…yield!

$$Y_{fish} = \int_{t_r}^{t_\lambda} F \bullet R \bullet e^{-(M \bullet t_r)} \bullet e^{-(M+F) \bullet (t-t_r)} \bullet 10^{-5.71} \bullet \left(1{,}279 \bullet \left(1 - e^{-0.131 \bullet (t+1.527)}\right)\right)^{3.307} \bullet dt$$




$$Y_{roe} = \int_{t_r}^{t_\lambda} F \bullet R \bullet e^{-(M \bullet t_r)} \bullet e^{-(M+F) \bullet (t-t_r)} \bullet 0.6 \bullet \left(\frac{e^{-27.78+0.028 \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (t+1.527)})}}{e^{-27.78+0.028 \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (t+1.527)})} + 1}\right) \bullet \left(0.0000014 \bullet (1{,}279 \bullet (1 - e^{-0.131 \bullet (t+1.527)})^{3.0529}\right) \bullet dt$$



# Predicting total yield

Analytical?

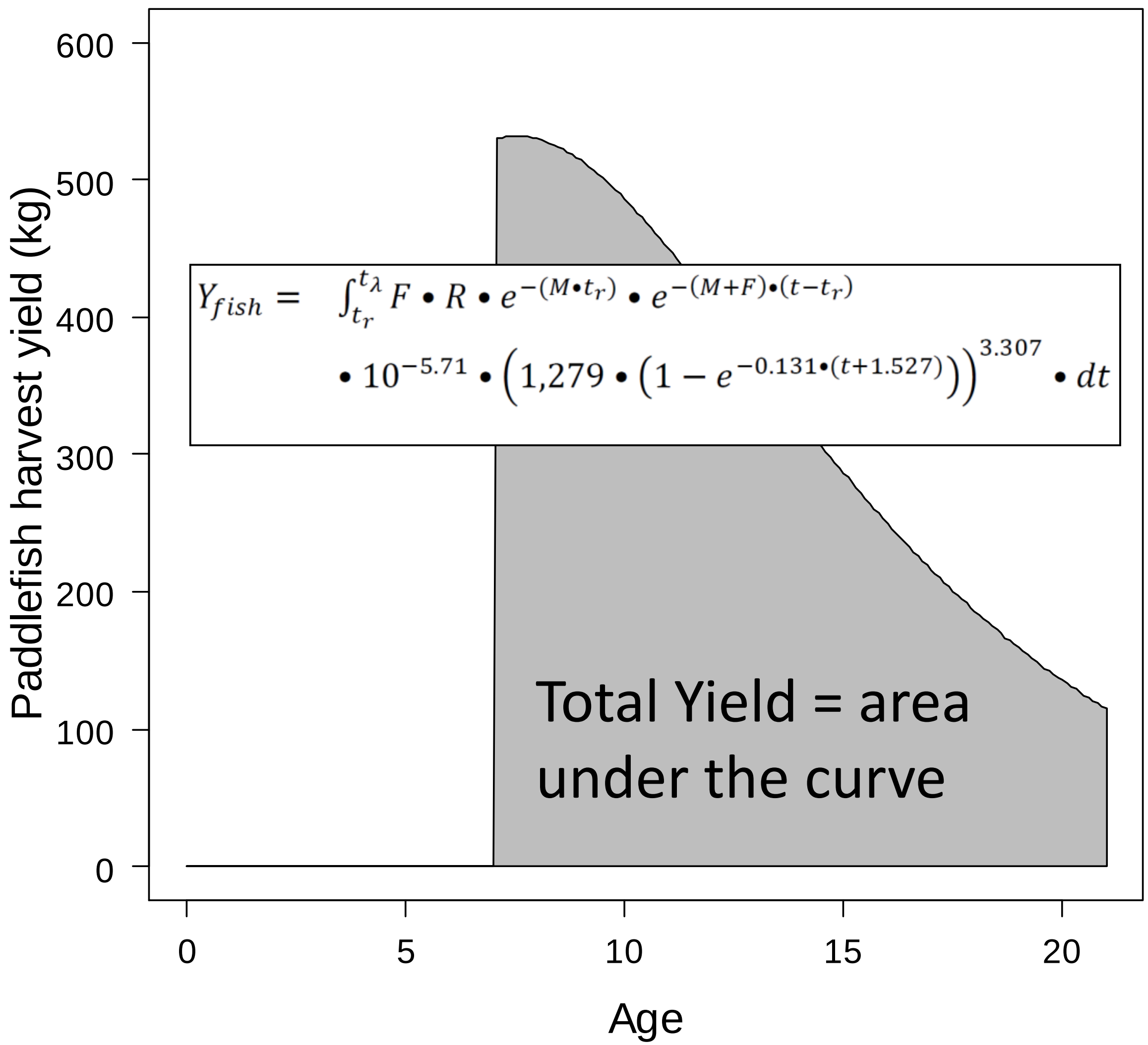
Approximate?

Jones (1957)

– Incomplete β function

— FAST

— FAMS

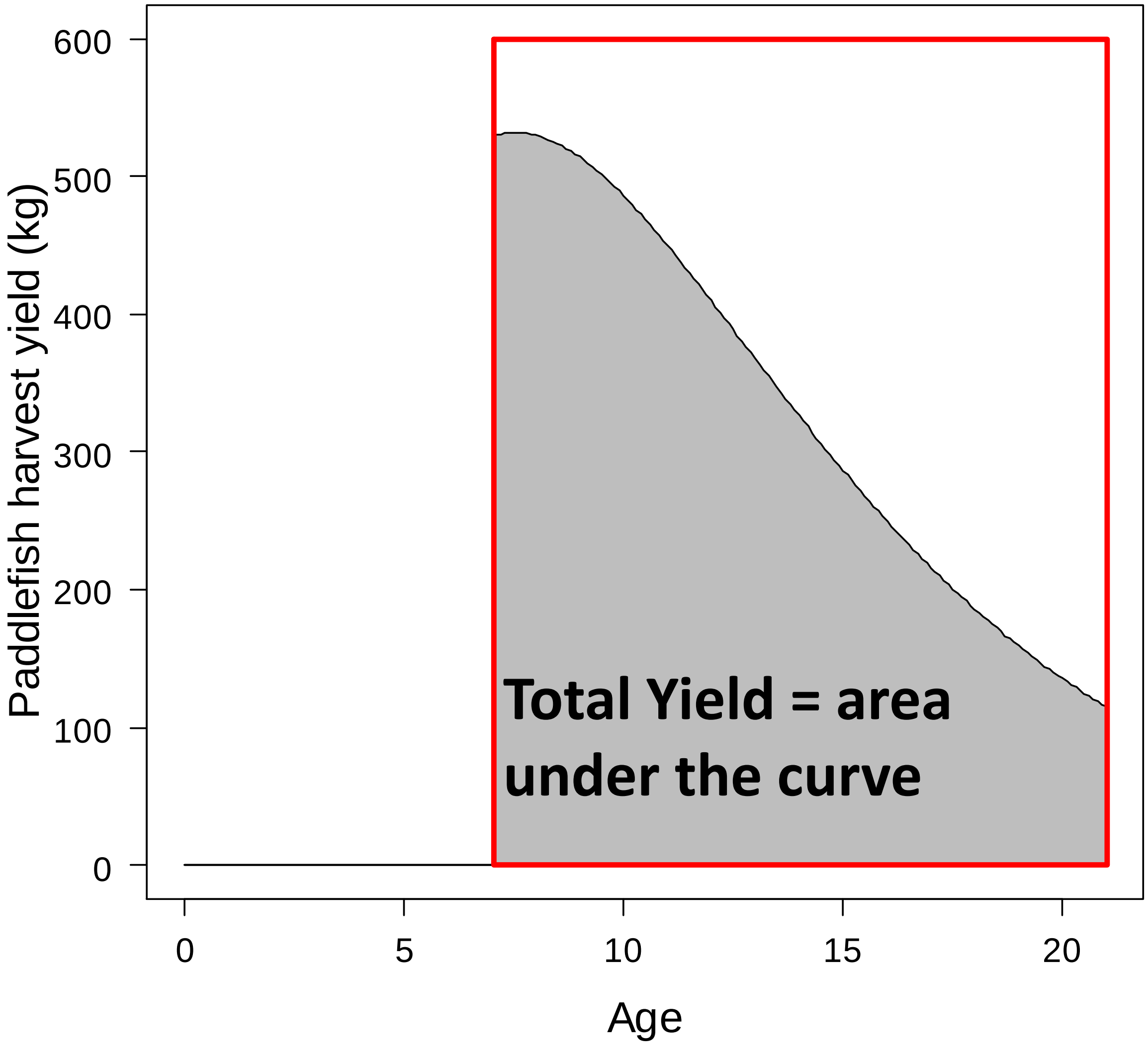



$$Y_{fish} = \int_{t_r}^{t_\lambda} F \bullet R \bullet e^{-(M \bullet t_r)} \bullet e^{-(M+F) \bullet (t-t_r)} \bullet 10^{-5.71} \bullet \left(1{,}279 \bullet \left(1 - e^{-0.131 \bullet (t+1.527)}\right)\right)^{3.307} \bullet dt$$

# Numerical approaches

Box the region

- Age recruited to fishery
- Maximum age
- Known area

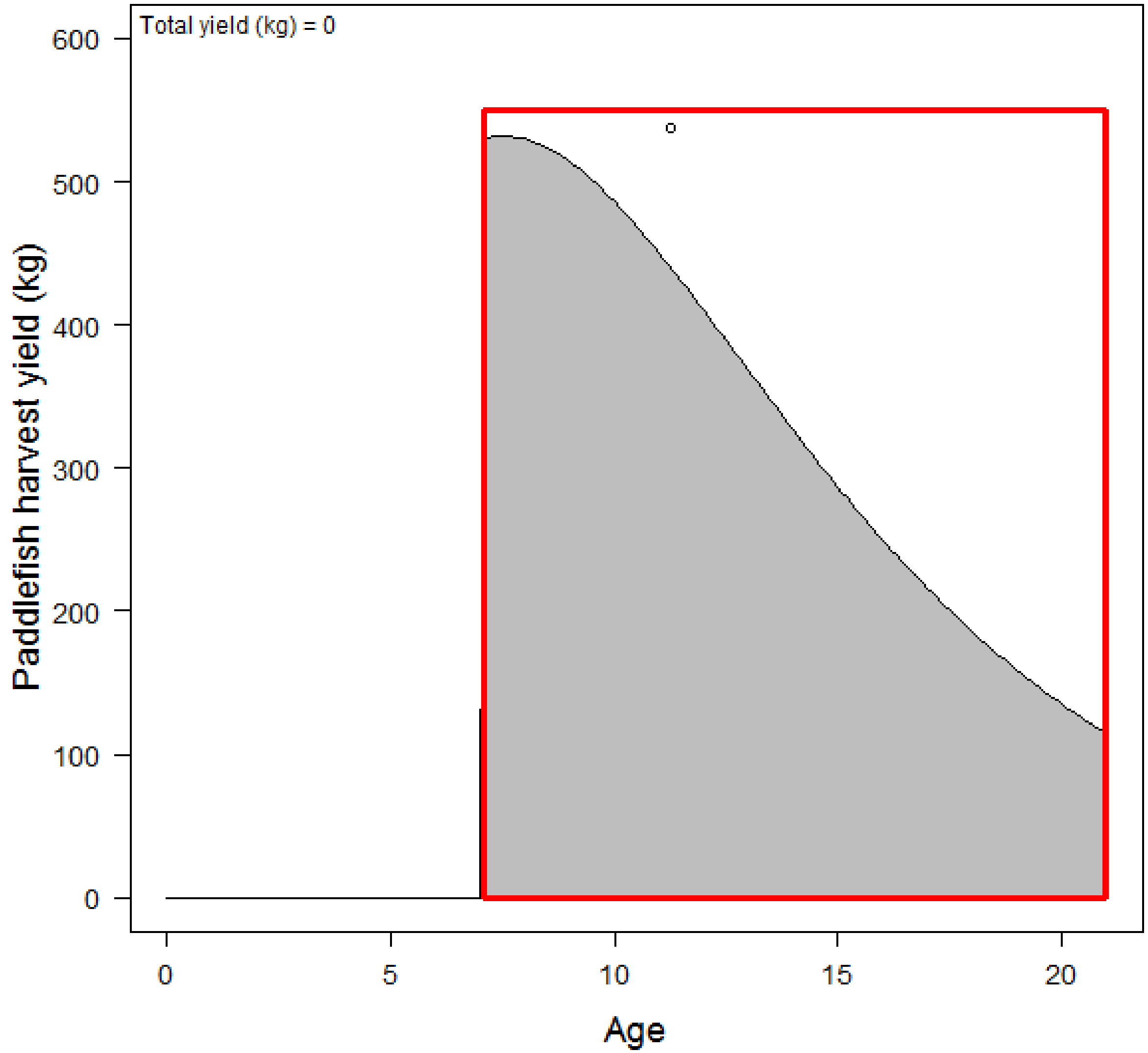


# Illustration of numerical integration

Monte Carlo numerical integration

- Do for many random draws within box

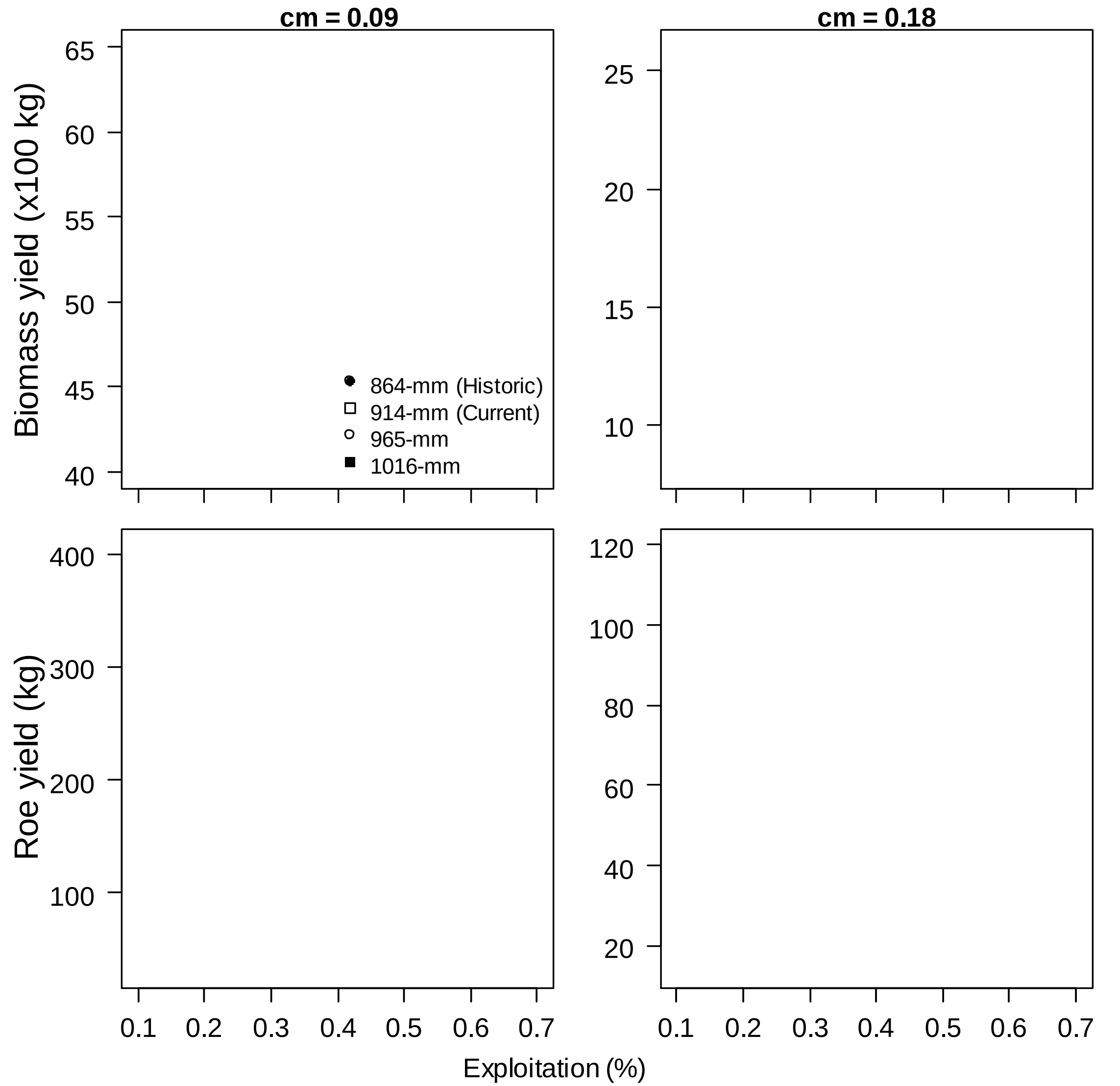
- Very Flexible



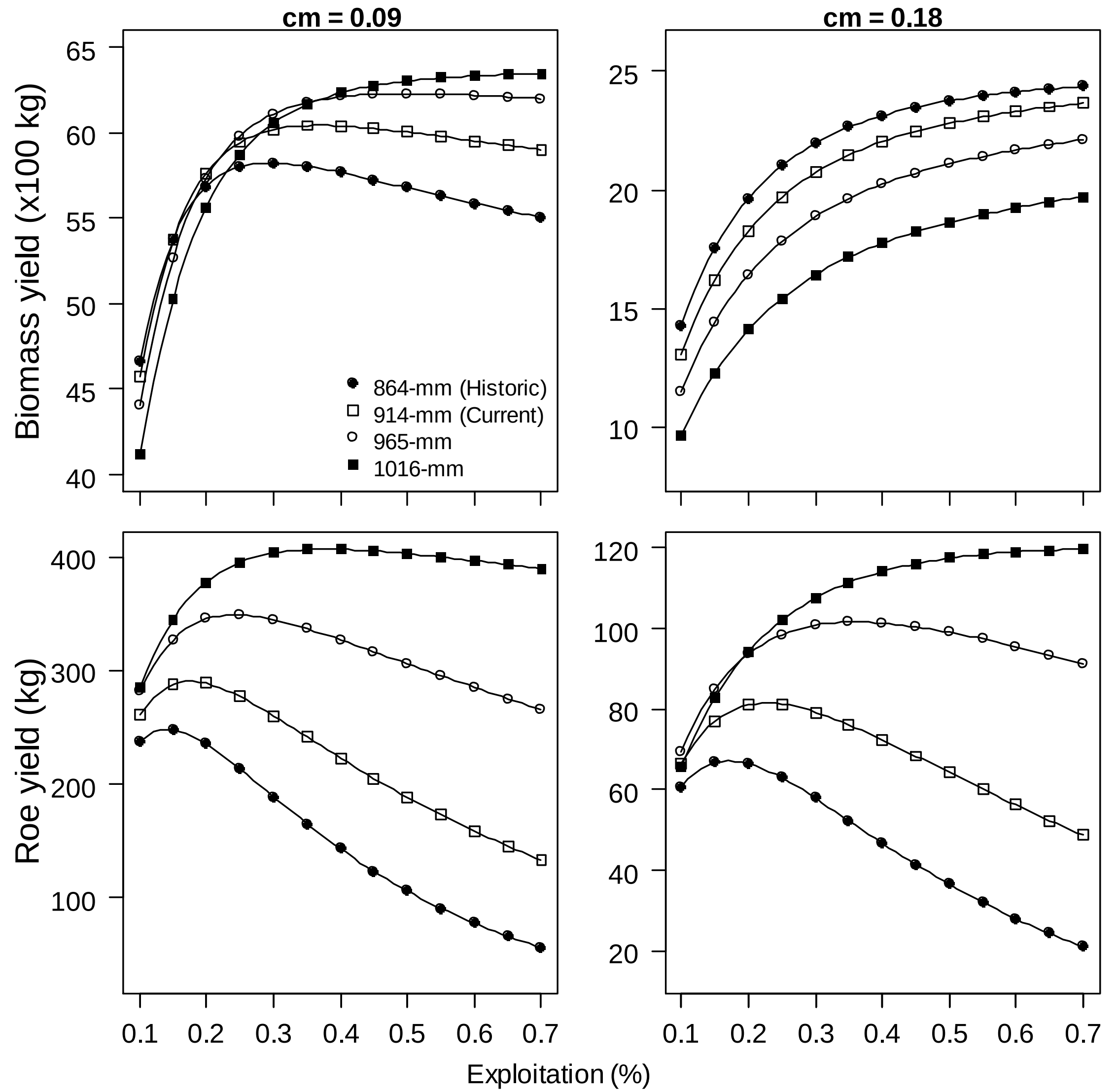
# Predicted biomass and roe yields

Varying:

- Exploitation
- Natural Mortality
- Length limit



# Predicted biomass and roe yields



# Key points

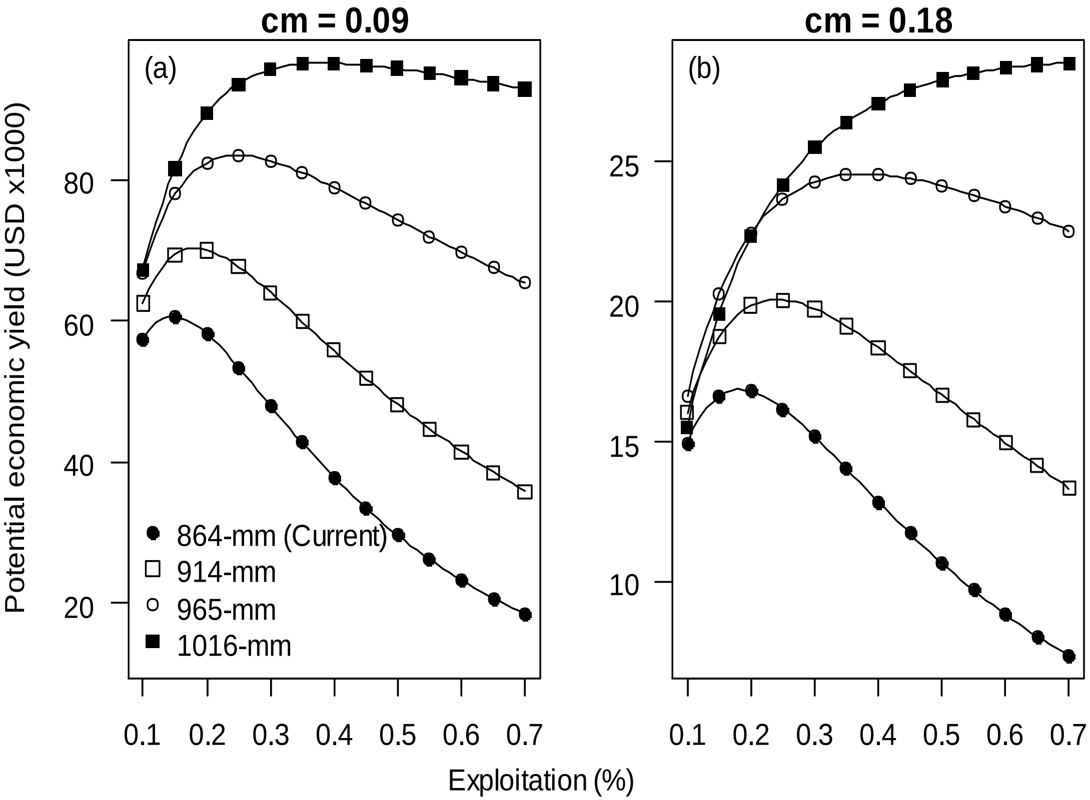
- Growth overfishing (roe)
  - Occurs at **<u>lower</u>** exploitation rates
  - **<u>More severe</u>** in terms of roe
  - Suggests higher minimum length limits
- Less sensitive to uncertainty to natural mortality

*Multiple tissue harvest?*


# Multiple tissue harvest

Economic yield

- Roe (200 $/ounce)
- Flesh (1 $/pound)
- Domestic culture?

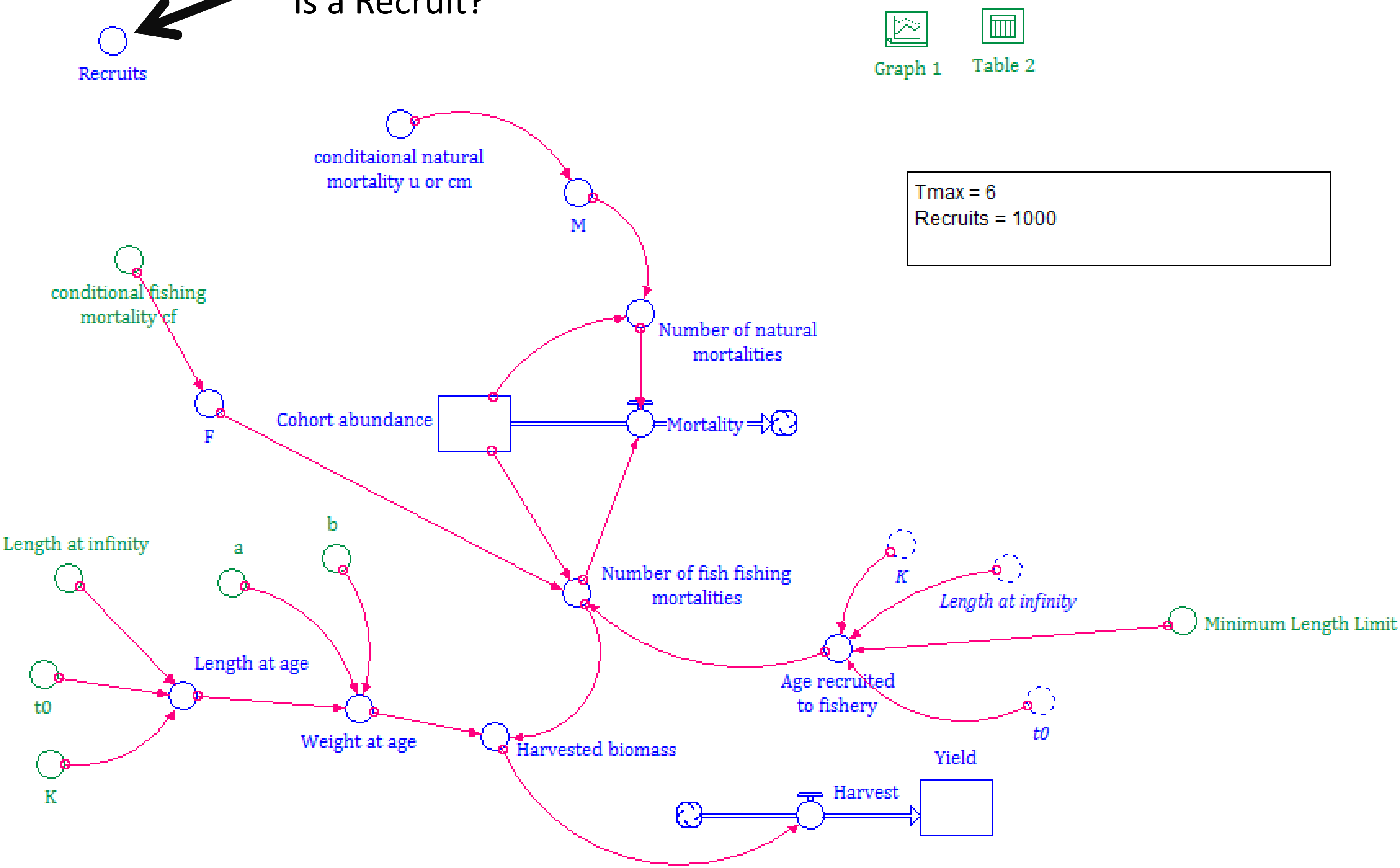



# RECRUITMENT MANAGEMENT

# What is *recruitment*?

*The addition of new fish into the catchable, harvestable, or adult populations.*

What exactly
is a Recruit?



# Catchable, harvestable, or adult?

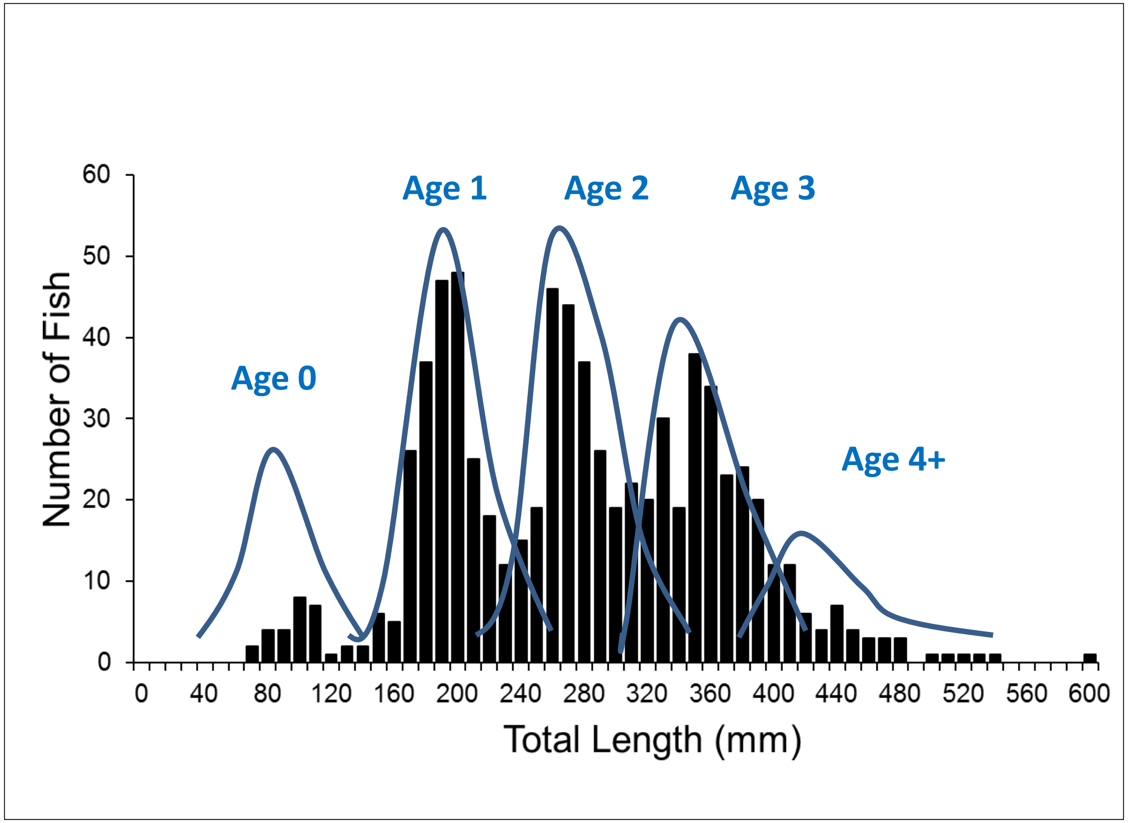
- Varies among fish
  - Species
  - Locations
  - Studies

The definition of a recruit is vague!

# Defining a "recruit"

Typically defined by fish length or age

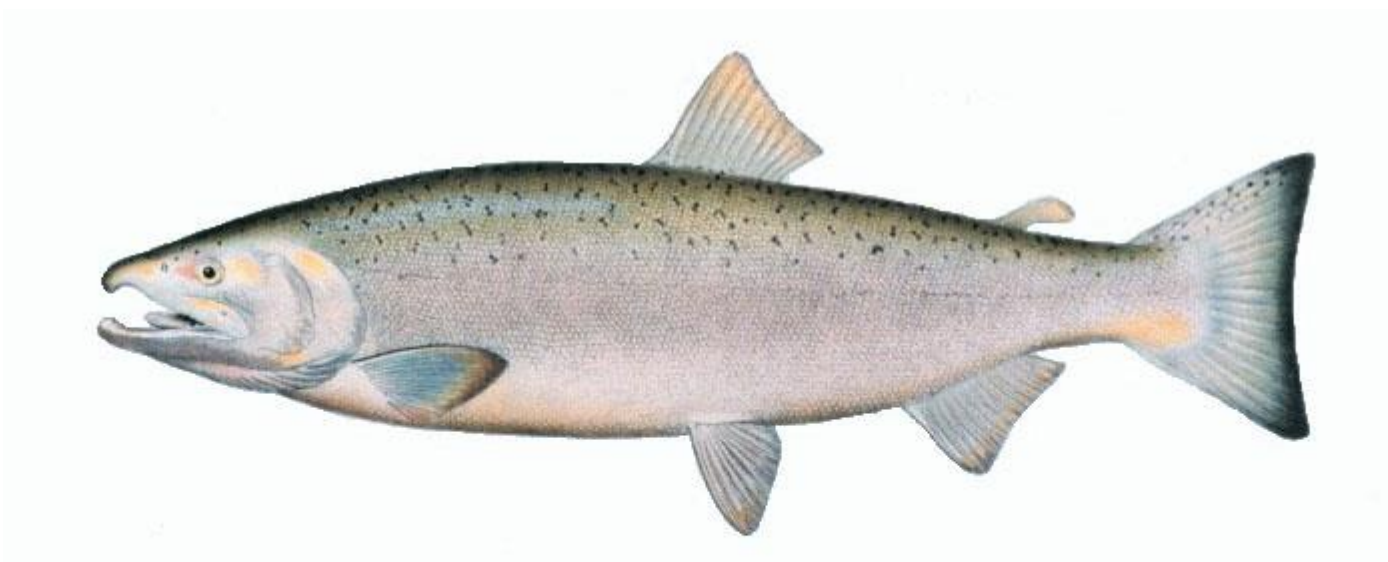
- Length: stock-size (200 mm) largemouth bass
- Age: age-1 white crappie



# Recruit definitions

Froese (2004) – Coho salmon, OR

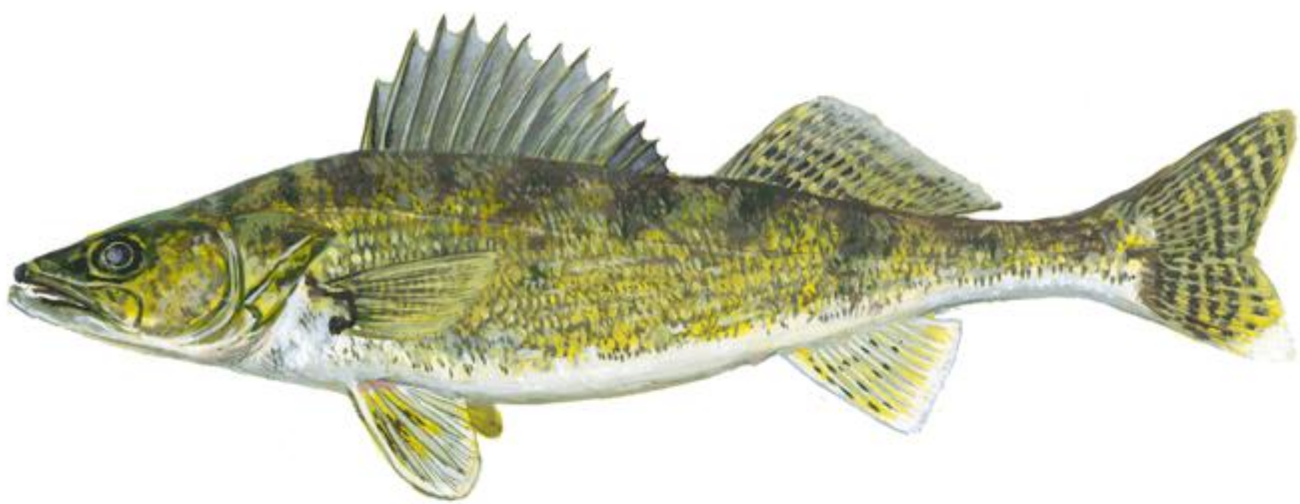
The data represent females migrating upstream to spawn (S), and the resulting female smolts migrating downstream approximately 1.5 years later (R).



# Recruit definitions

- Beard et al. (2003) – Walleye, WI

where $R$ is the number of age-0 recruits per kilometer, $S$ is the number of adult walleyes per hectare,



# Recruit definitions

- Belcher & Jennings (2004) – White shrimp, GA

The total pounds of white shrimp caught during May–June represented spawners, whereas the total pounds of white shrimp caught during August–January represented recruits.

# Recruit definitions

- Allen & Miranda (2001) – Black crappie, MS

  where $R$ is recruits (number of age-1 fish), $S$ is stock (number of fish older than age 1),

# Recruit definitions

- Richards et al. (2004) – Lake Trout, MI

and Sitar 2000). To account for the time lag between spawning and recruitment at age 7, spawning stock CPE measured during 1970–1990 was matched with CPE of age-7 recruits during 1978–1998 to model recruitment of the 1971–1991 year-classes.

# Factors influencing recruitment

<u>Density Independent</u>

- Changes in water level or flow
- Aquatic plant abundance or species composition
- Water temperature

<u>Density Dependent</u>

- Spawning stock abundance
- Year-class strength
- Can stabilize recruitment

# IMPORTANT:

Recruitment is not determined solely by how many young-of-year (YOY = baby) fish are produced.  You can have low recruitment in a year when YOY production is very high, or high recruitment when YOY production is relatively low.

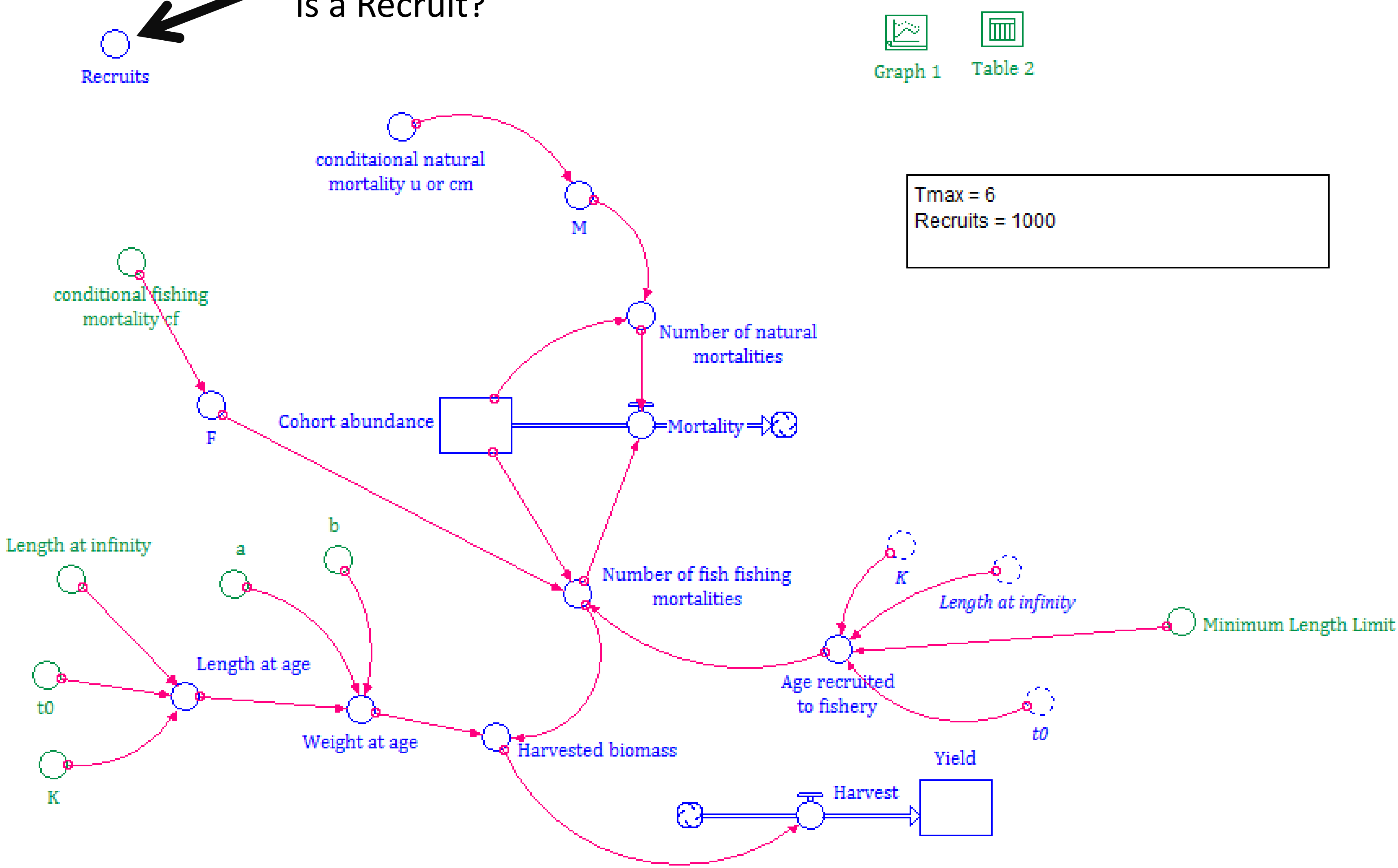
**Why do you think this is?**

In a nutshell-preventing or minimizing recruitment overfishing!

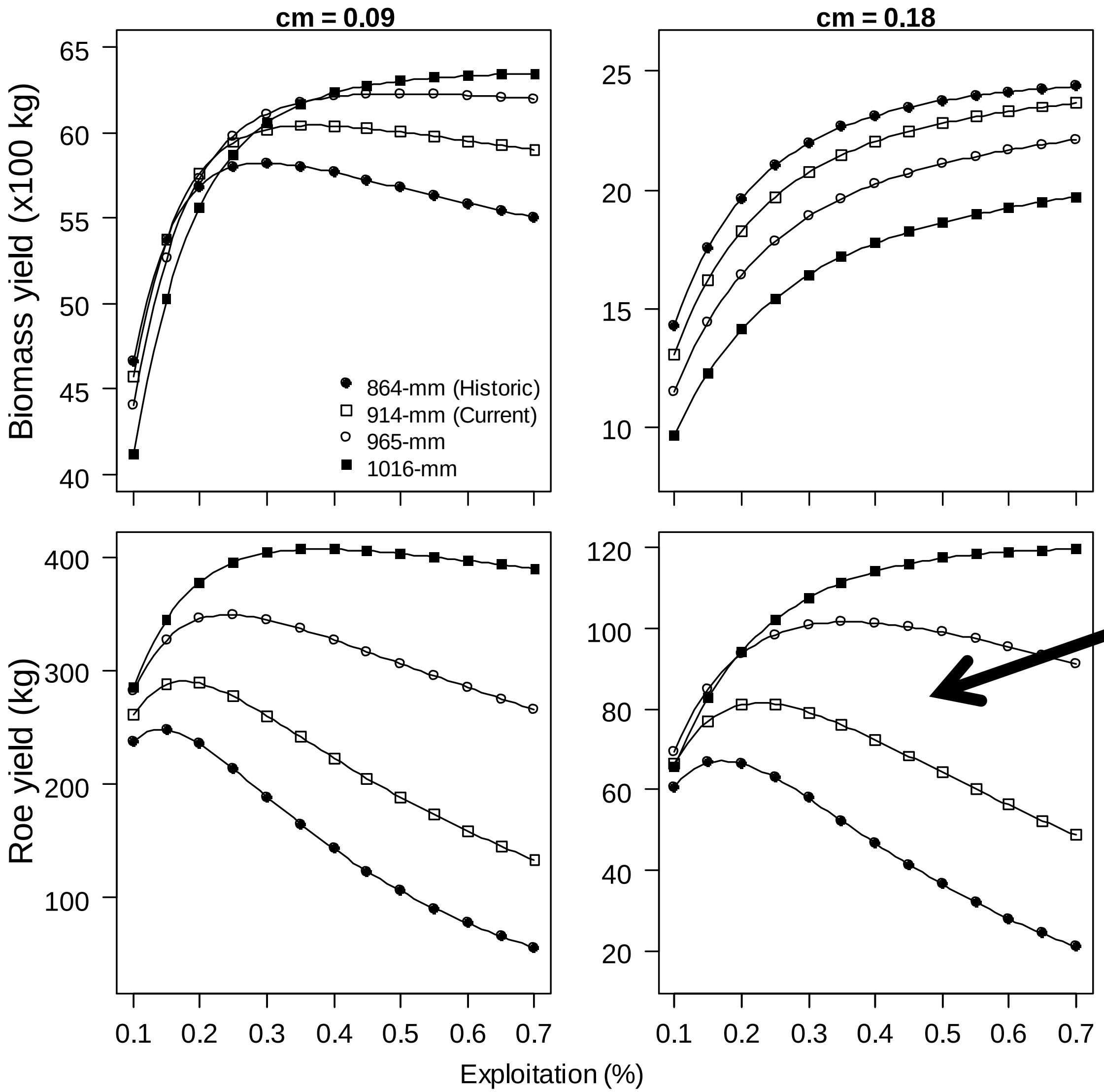
*You need old fish to make new fish and you need new fish to make old fish*

# MANAGING RECRUITMENT IN AGE STRUCTURED POPULATIONS

What exactly is a Recruit?



# Predicted biomass and roe yields




Eggs related to recruits….

But young of year ≠ recruits

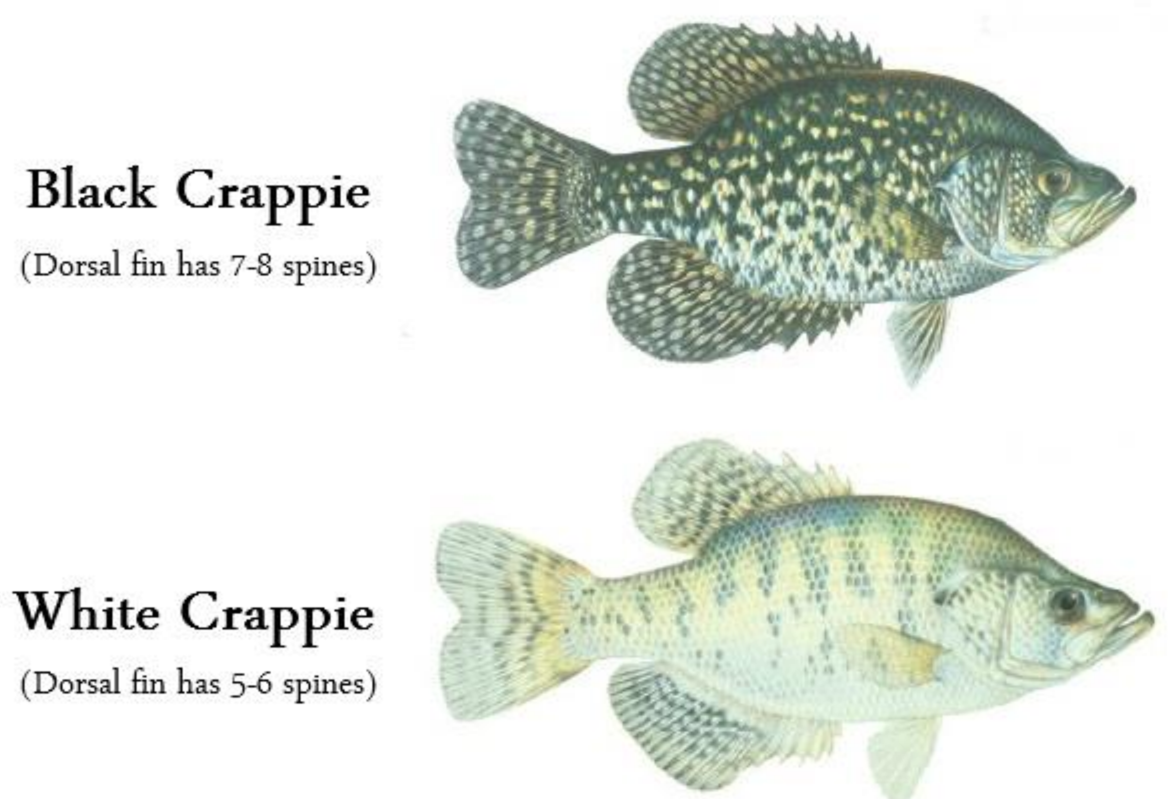
# Recruit definitions

- Allen & Miranda (2001) – Black crappie, MS

  where $R$ is recruits (number of age-1 fish), $S$ is stock (number of fish older than age 1),

# Crappie (White & Black)

- Typically co-managed as 1 species
- Most anglers cannot tell difference



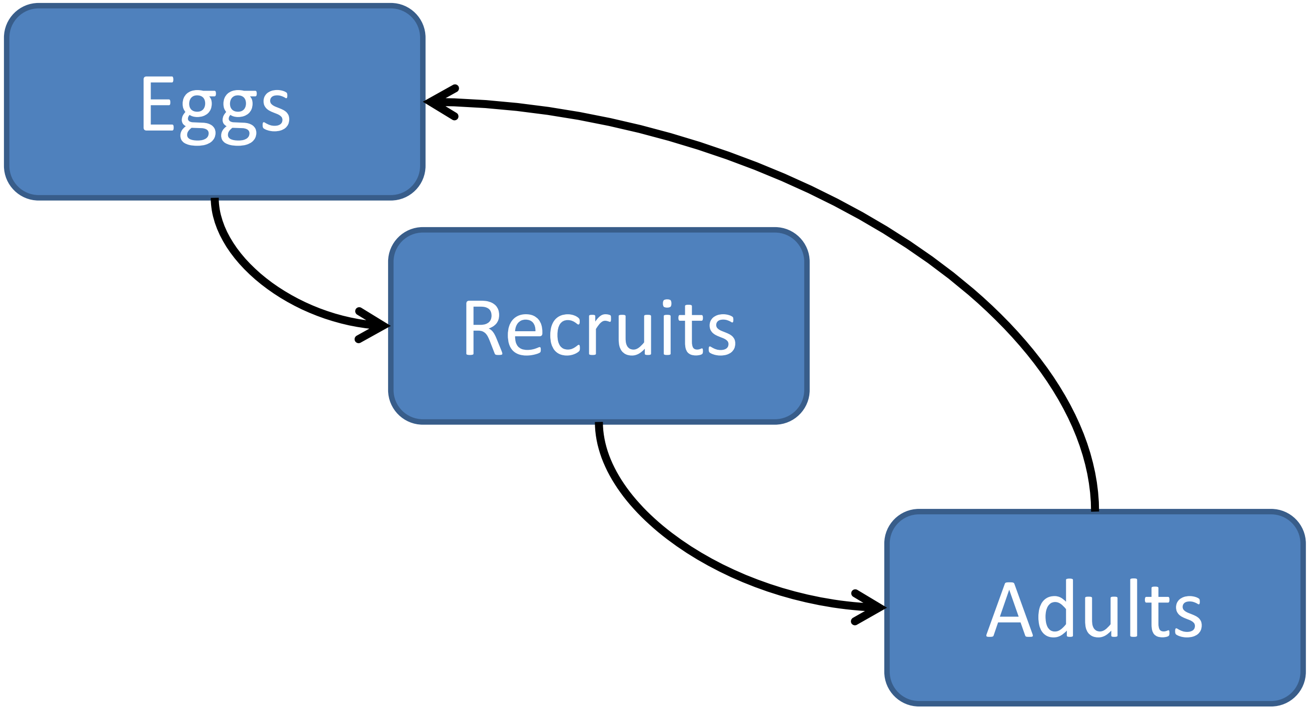
Recruits

# RECRUITMENT MANAGEMENT

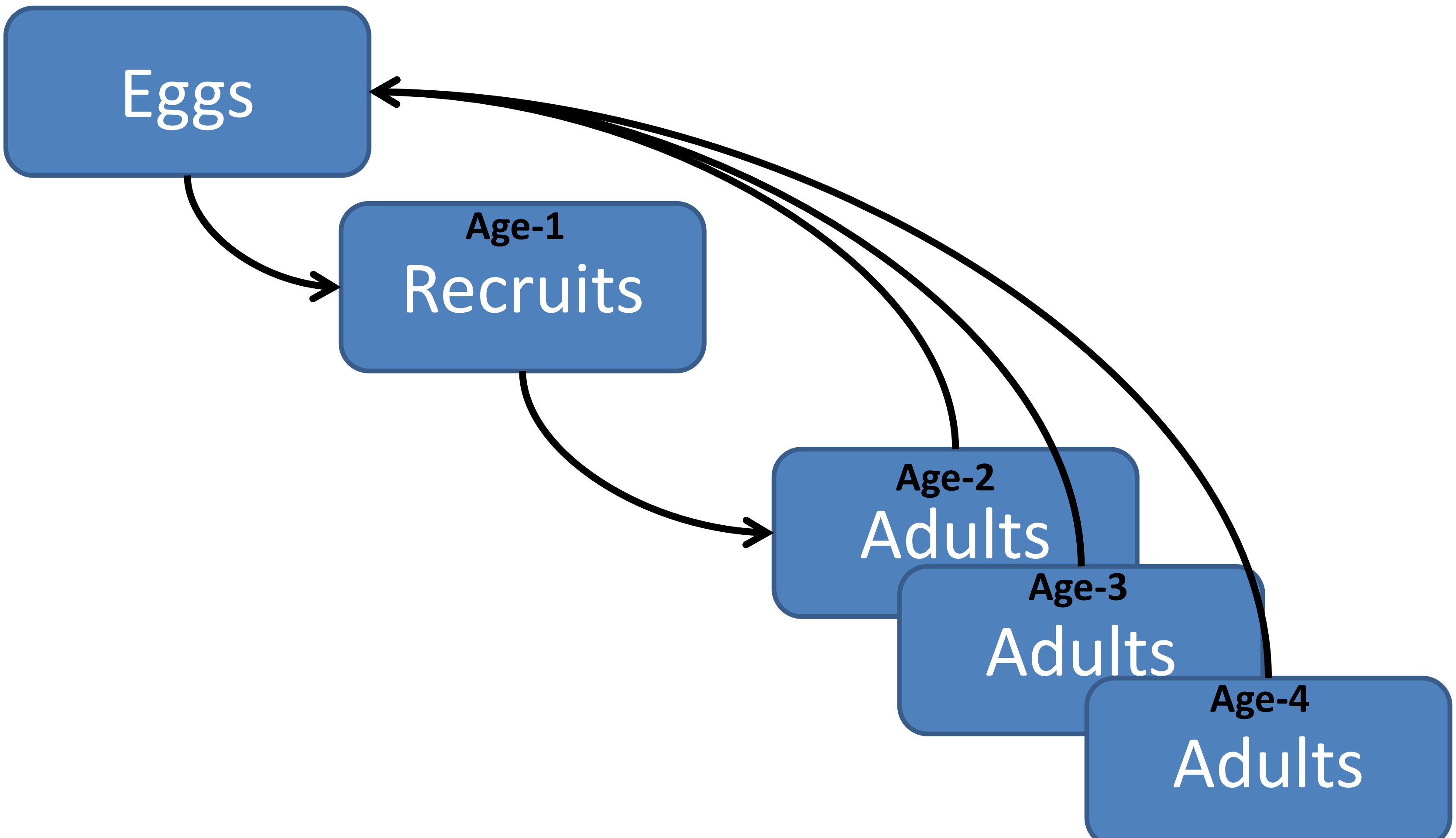
WHAT IS IT?

HOW DO WE DO IT?

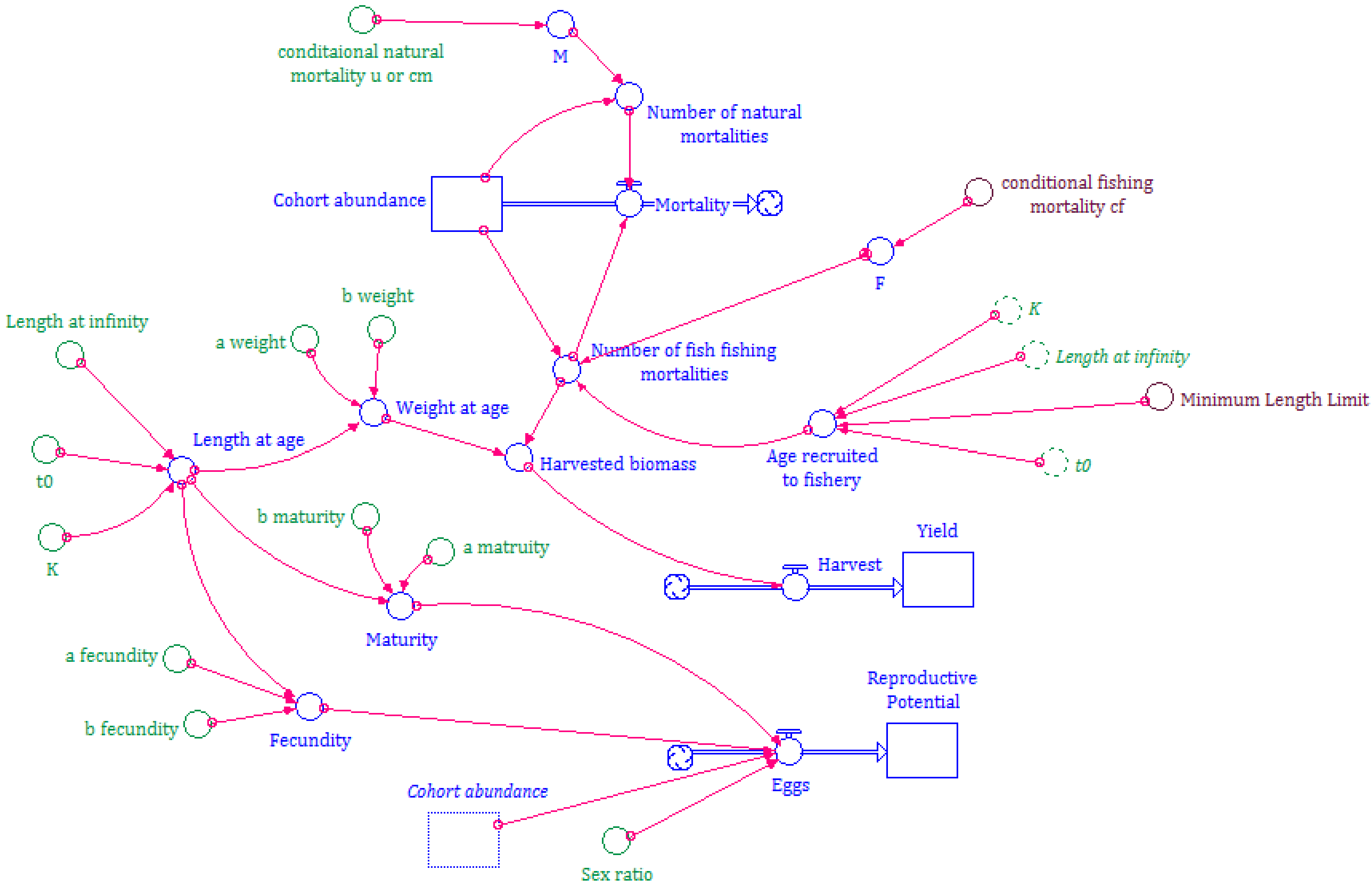
# Conceptually



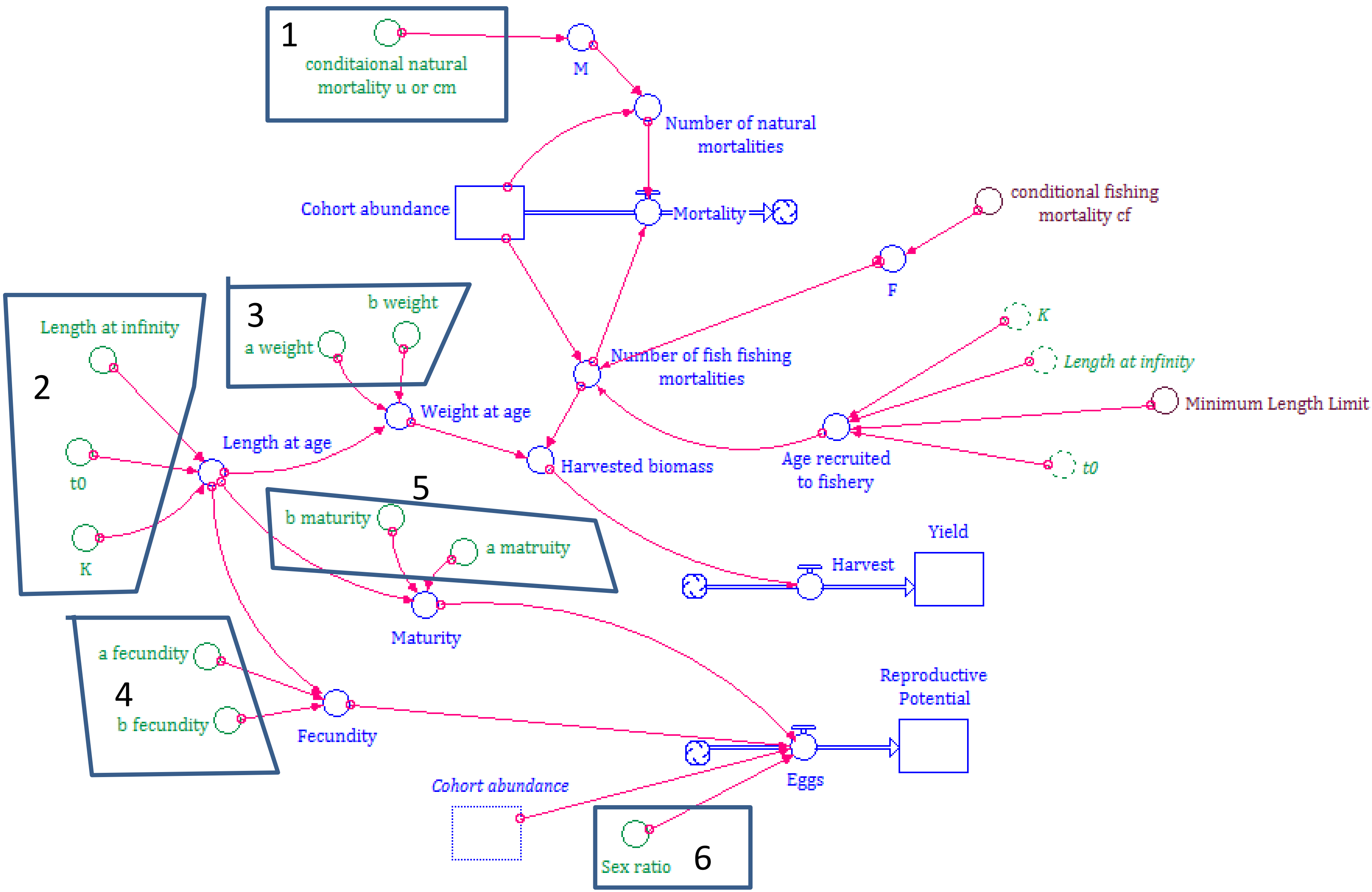
# Adding age structure



# Conceptually



# Bits of information needed



# Bits of information needed

1. Natural Mortality
2. Length-Age
3. Weight-Length
4. Fecundity
5. Maturity
6. Sex ratio

# Management parameters

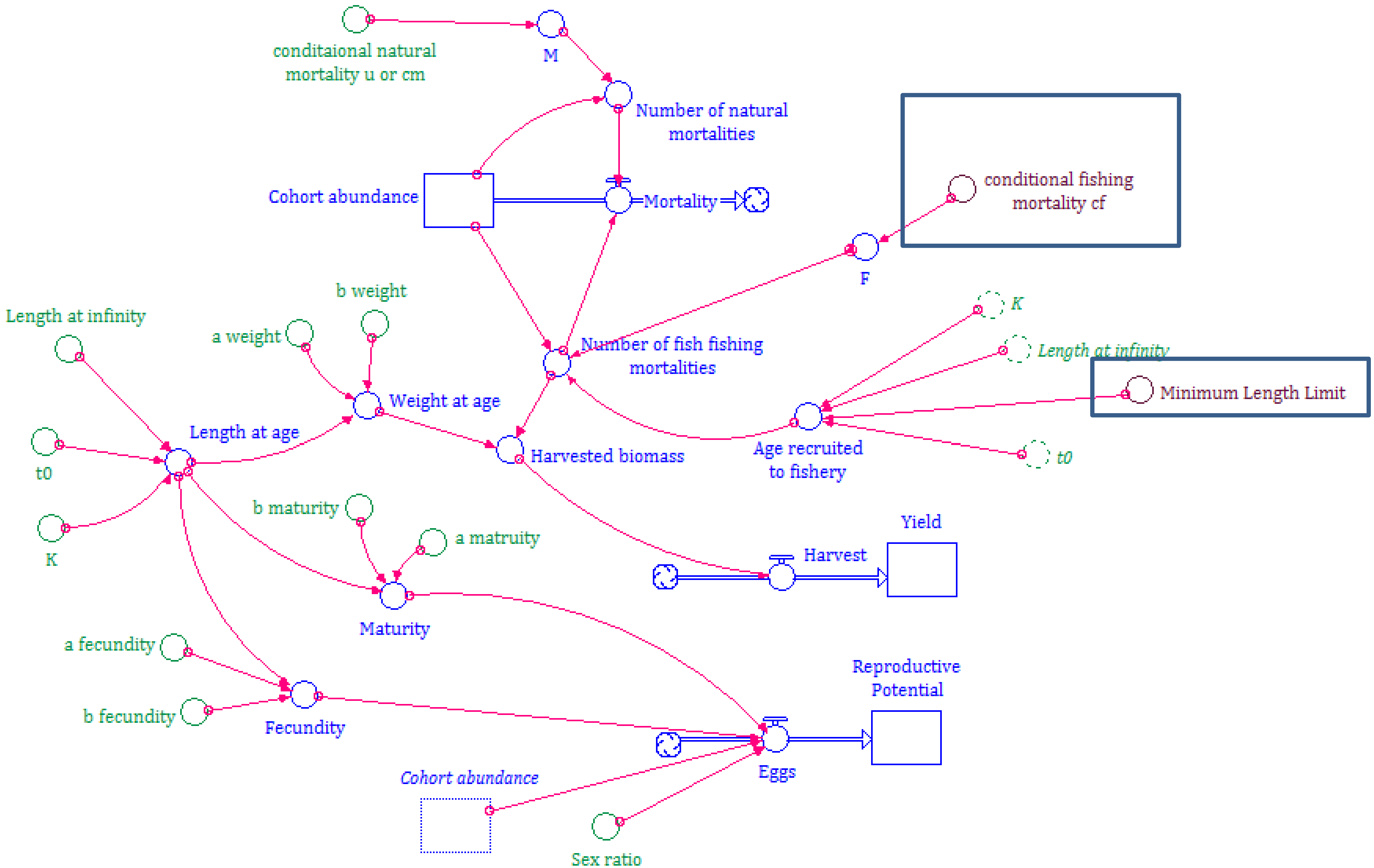
**Fecundity is a function of spawning stock abundance or biomass**

Minimize recruitment overfishing

- Maintain enough spawning abundance or biomass in system
- Reproductive potential

**Fishing mortality & Length limit**

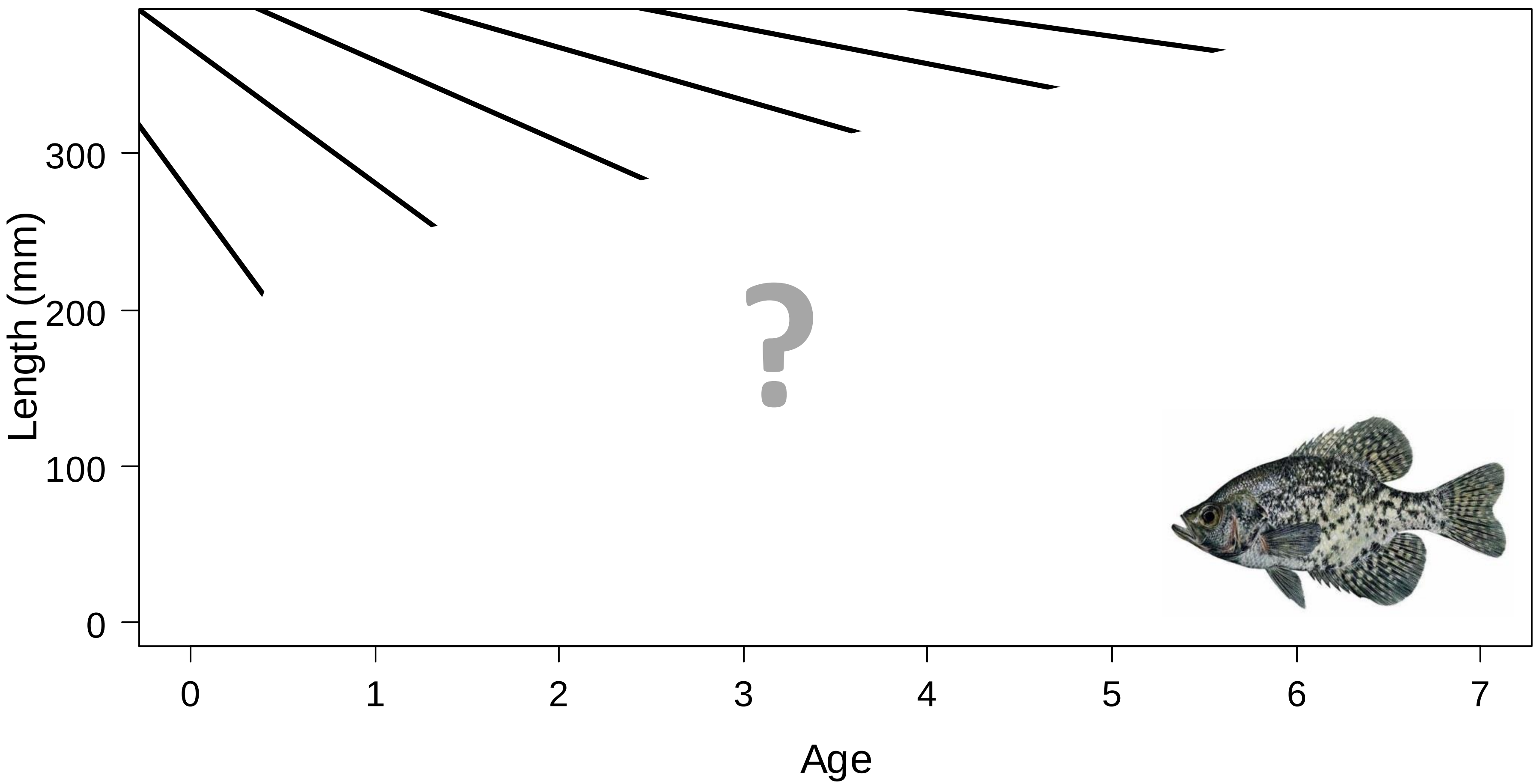
# Management parameters



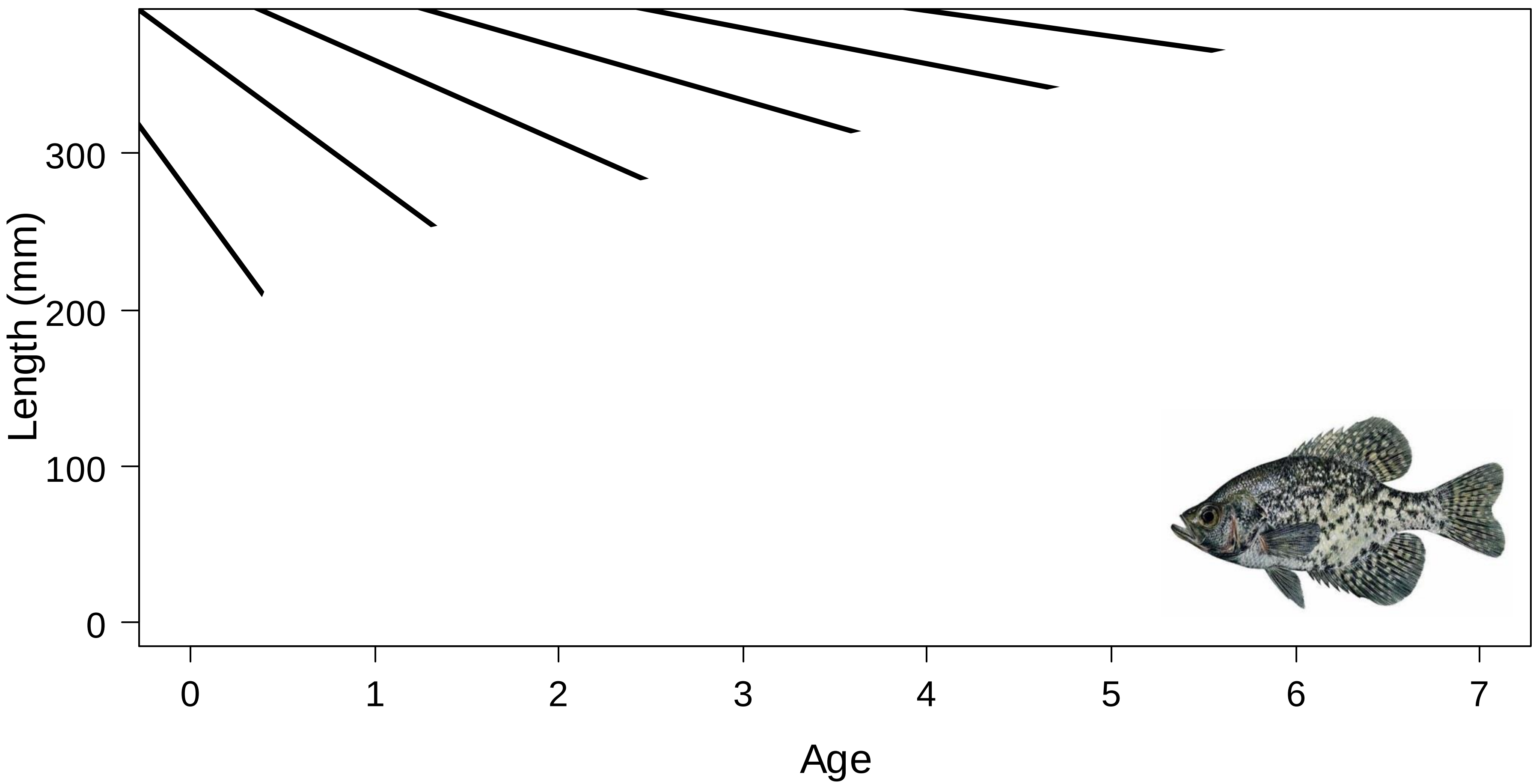
# We do we want to manage recruitment?

- Angler satisfaction
  - Recruitment drives year to year variability in abundance and biomass
  - Recruitment drives fish abundance and biomass

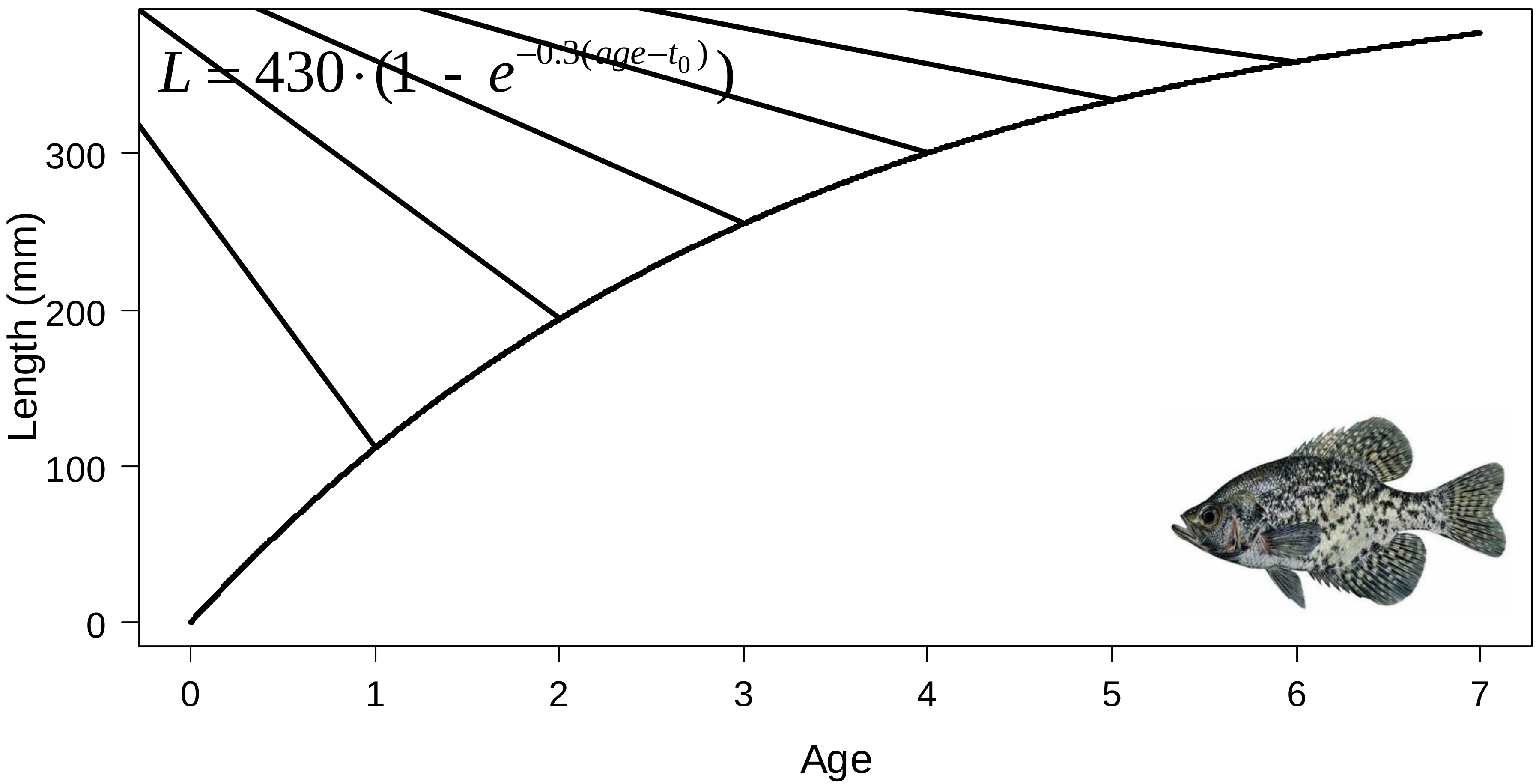
# Age-Length



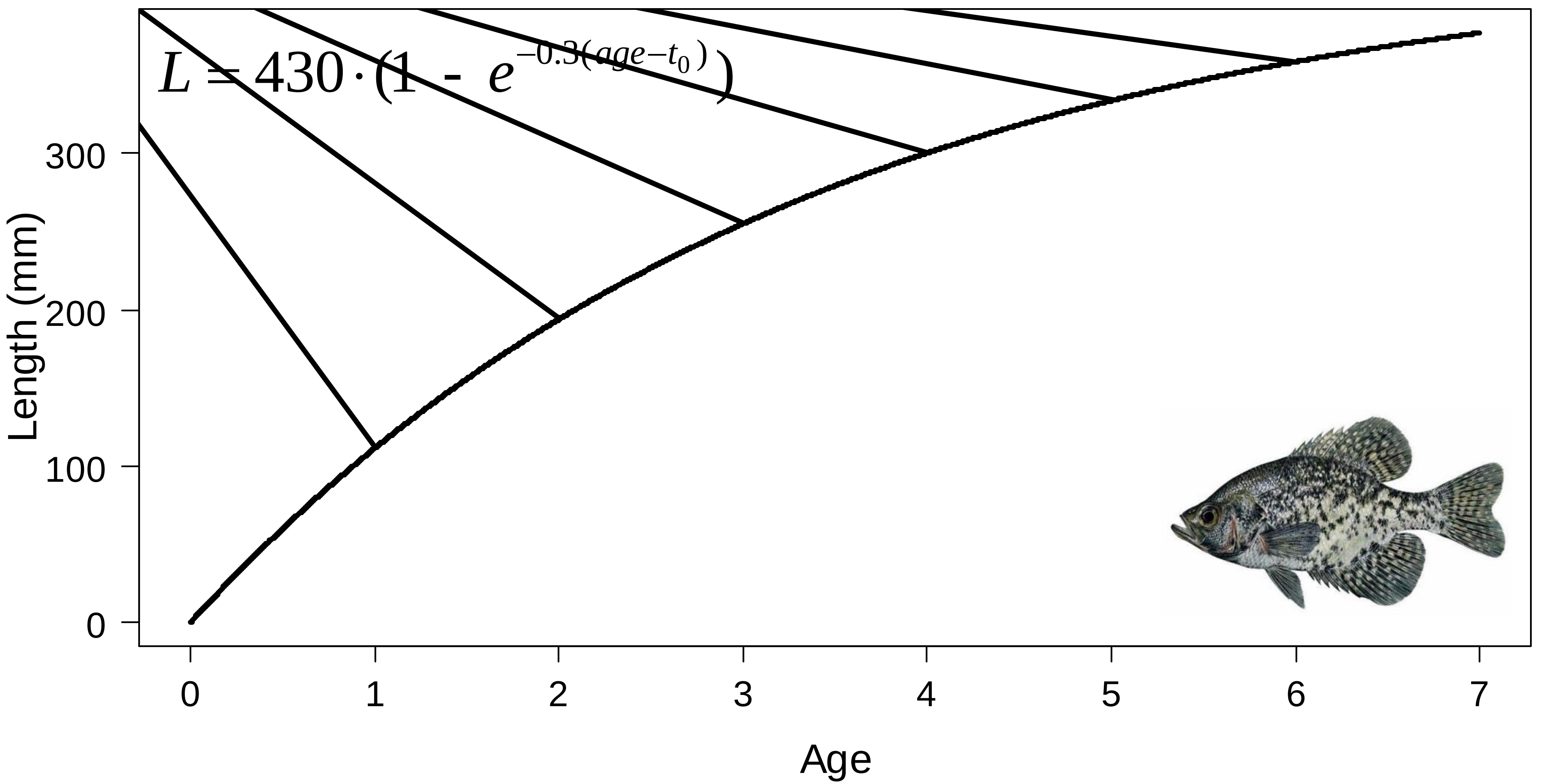
# Age-Length



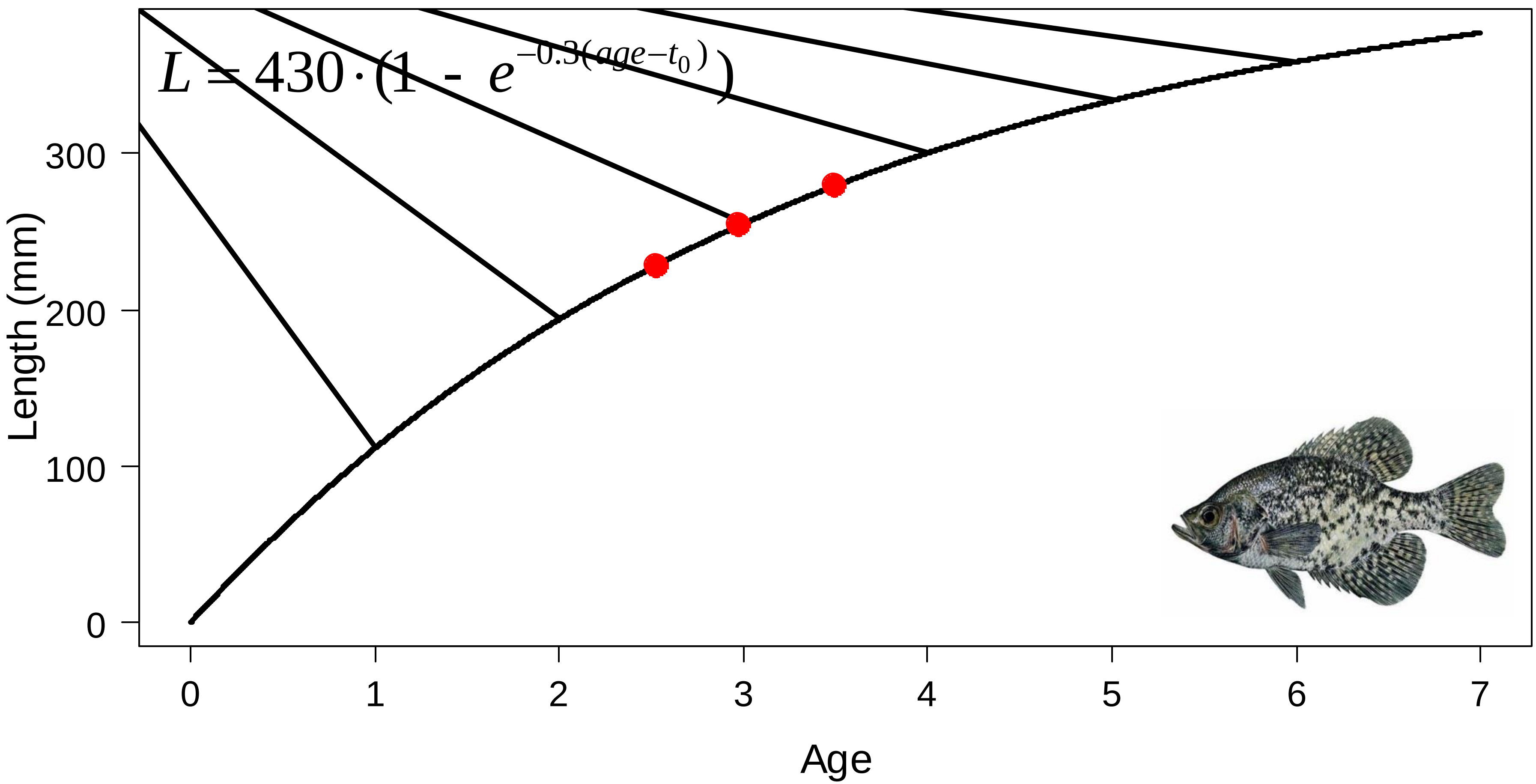
# Age-Length



# Age-Length



# Age-Length

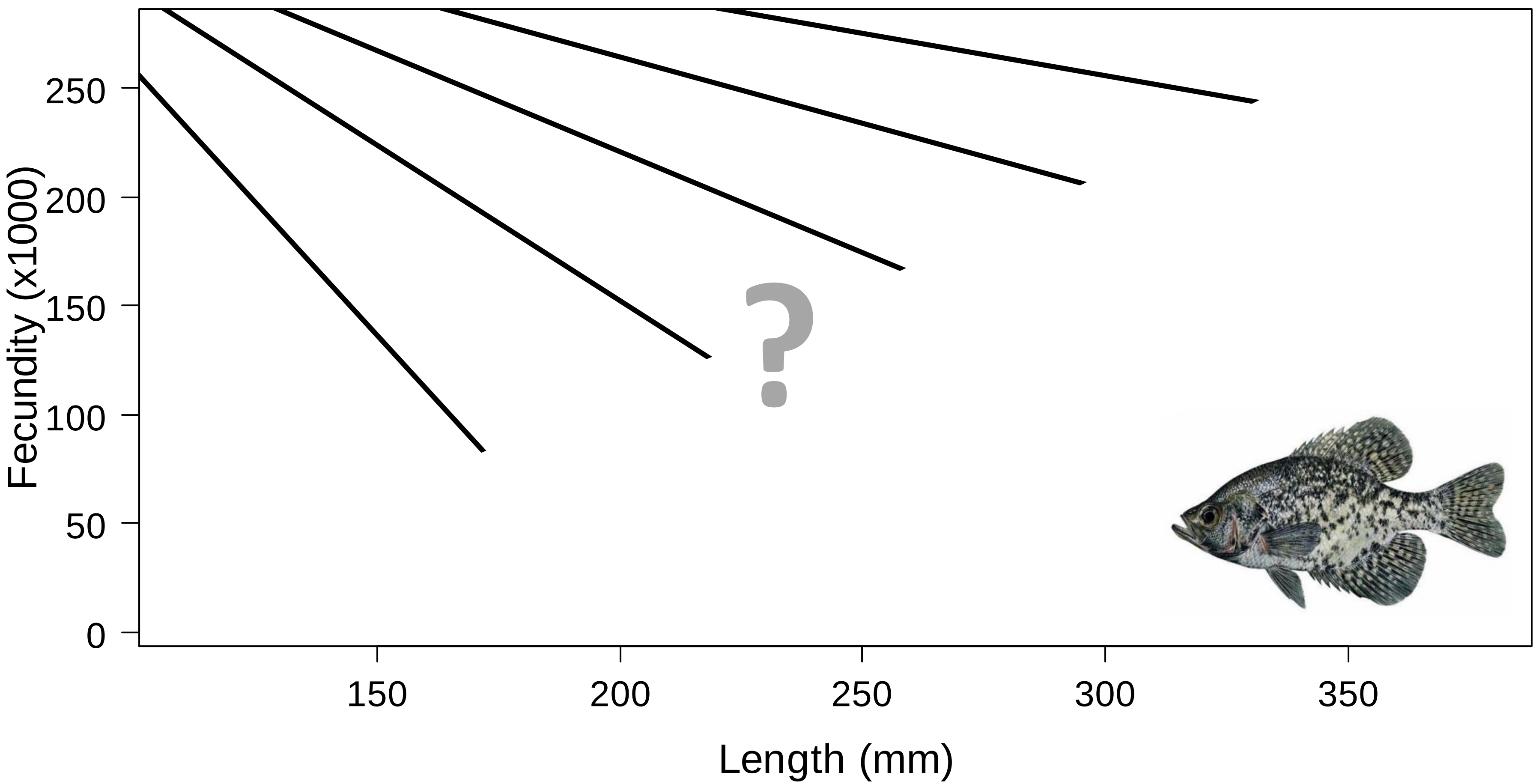


# Fecundity

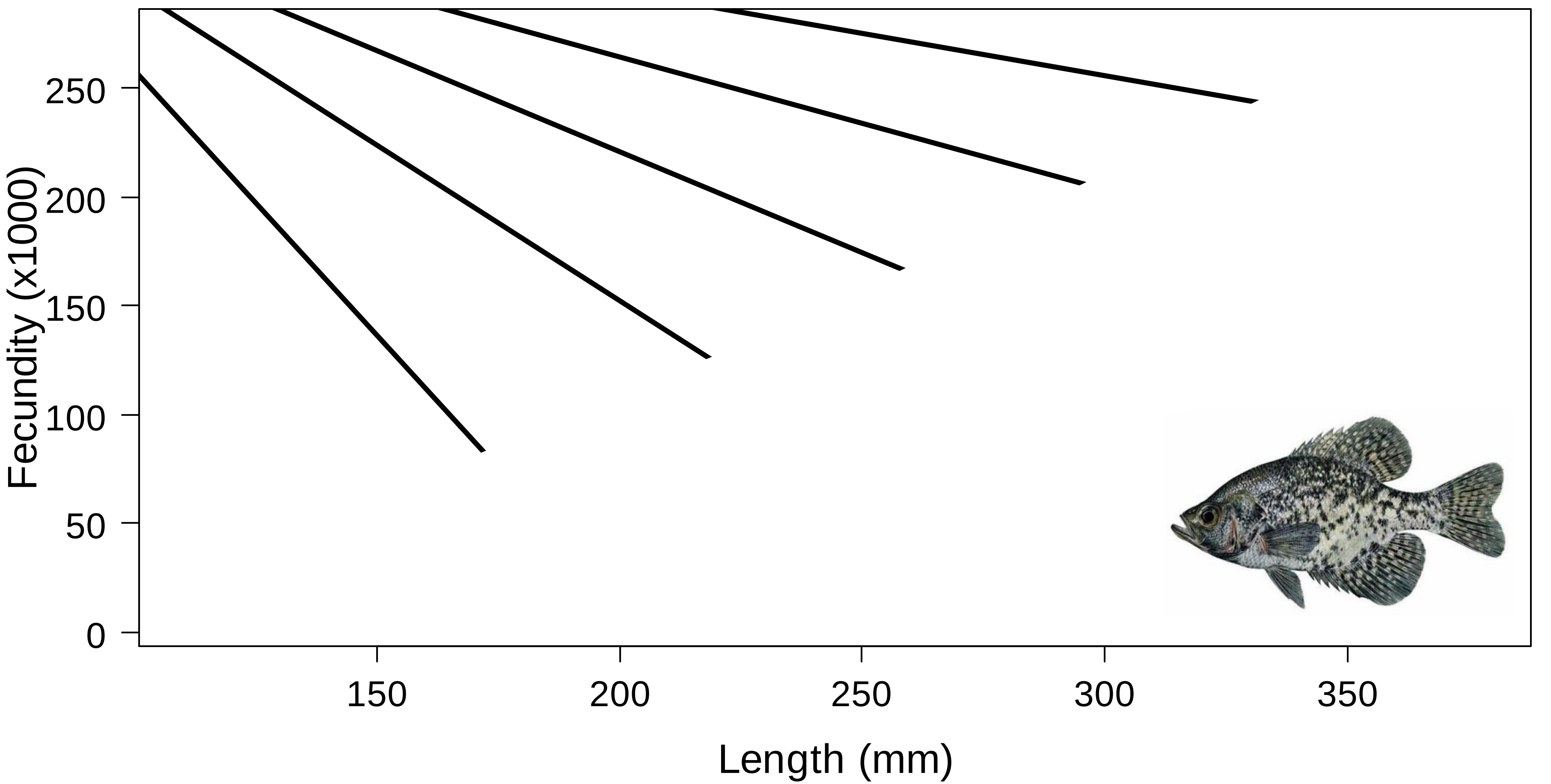
*Number of eggs an animal produces during each reproductive cycle; the potential reproductive capacity of an organism or population. Usually increases with age and size*

http://www.fishbase.org/Glossary/Glossary.php?q=fecundity&language=english&sc=is

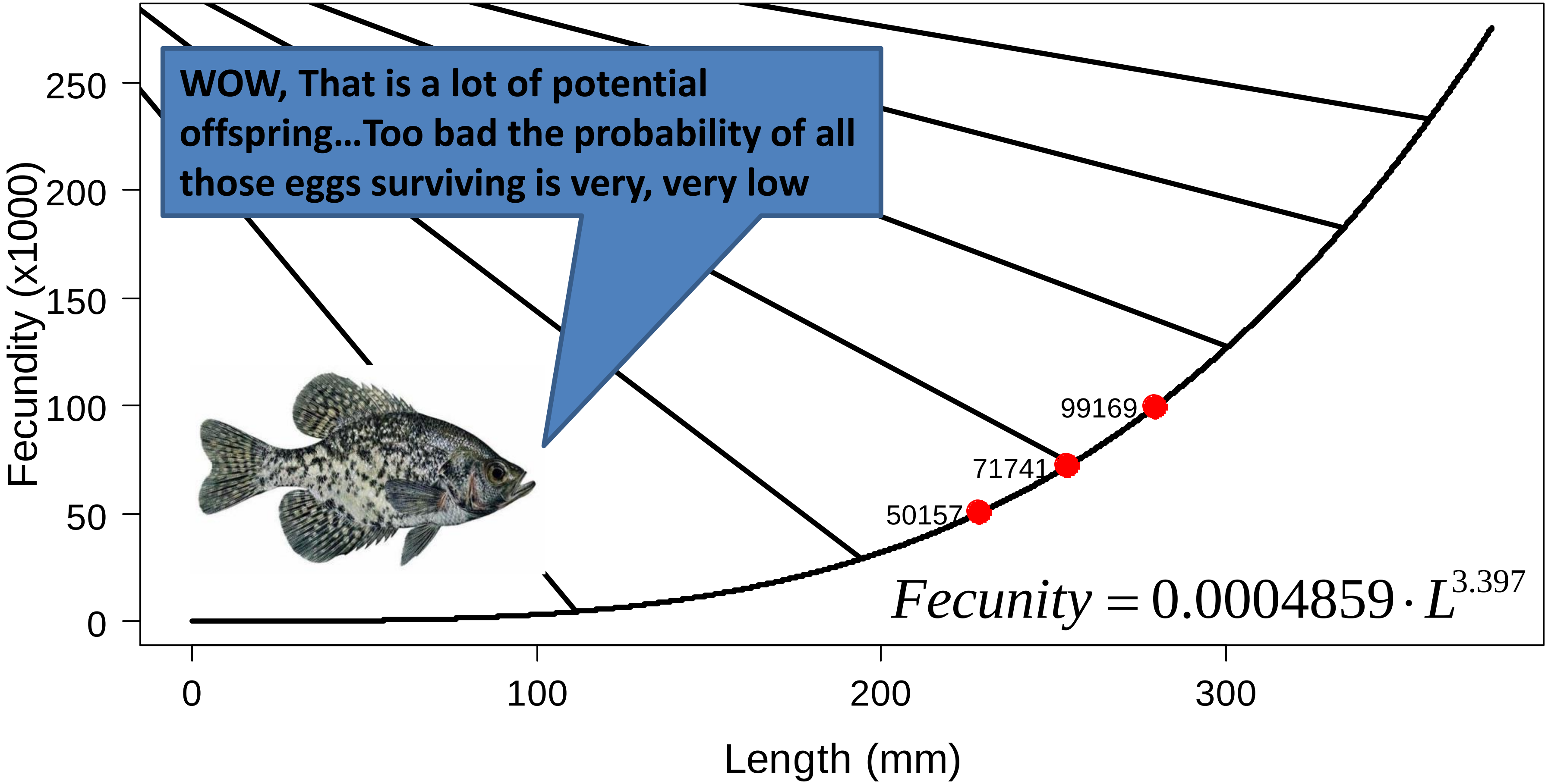
# Black Crappie Fecundity



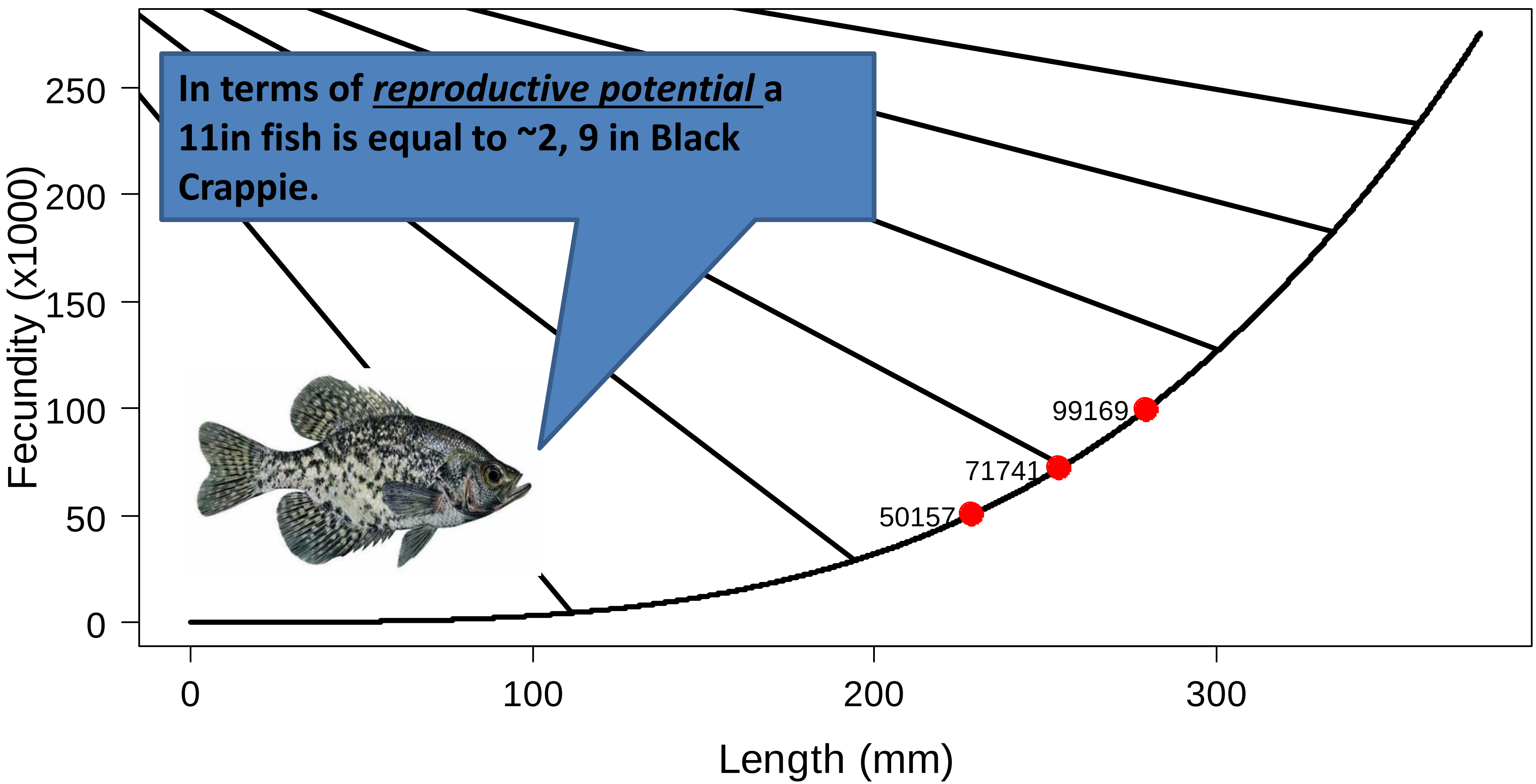
# Black Crappie Fecundity



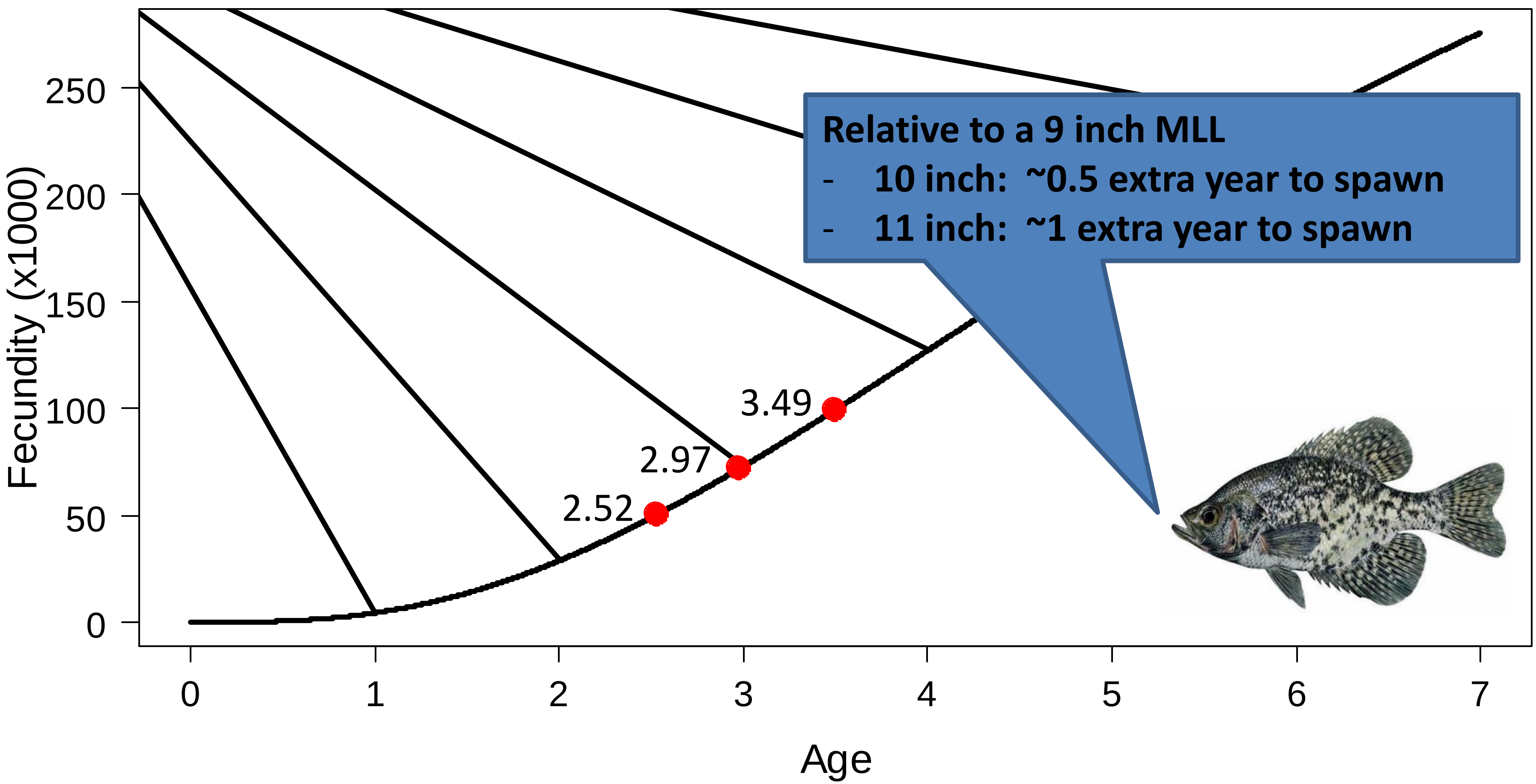
# Black Crappie Fecundity



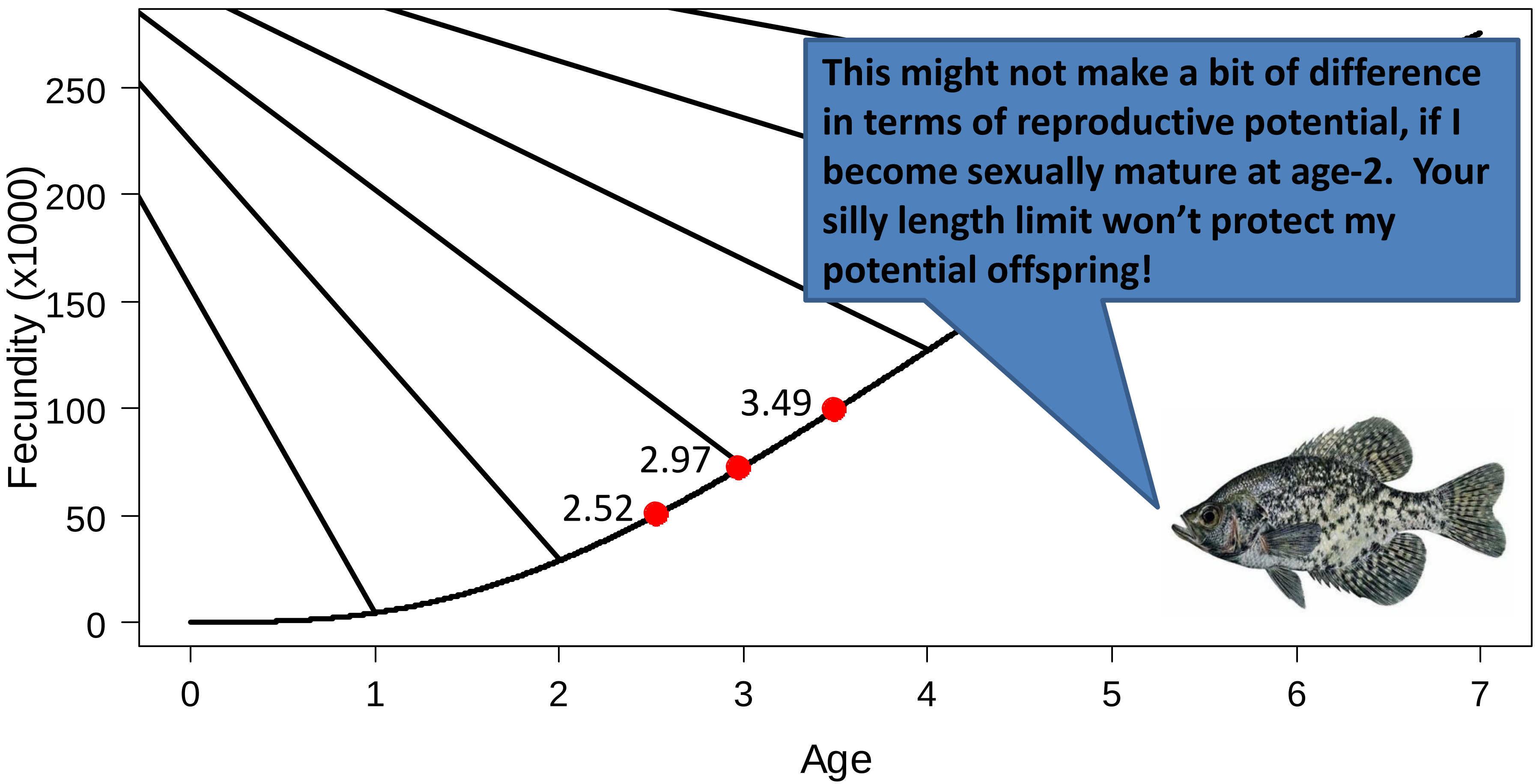
# Black Crappie Fecundity



# Fecundity & Age



# Fecundity & Age



# Maturity

*A stage at which fish are able to develop ripe gonads and to participate in spawning.*

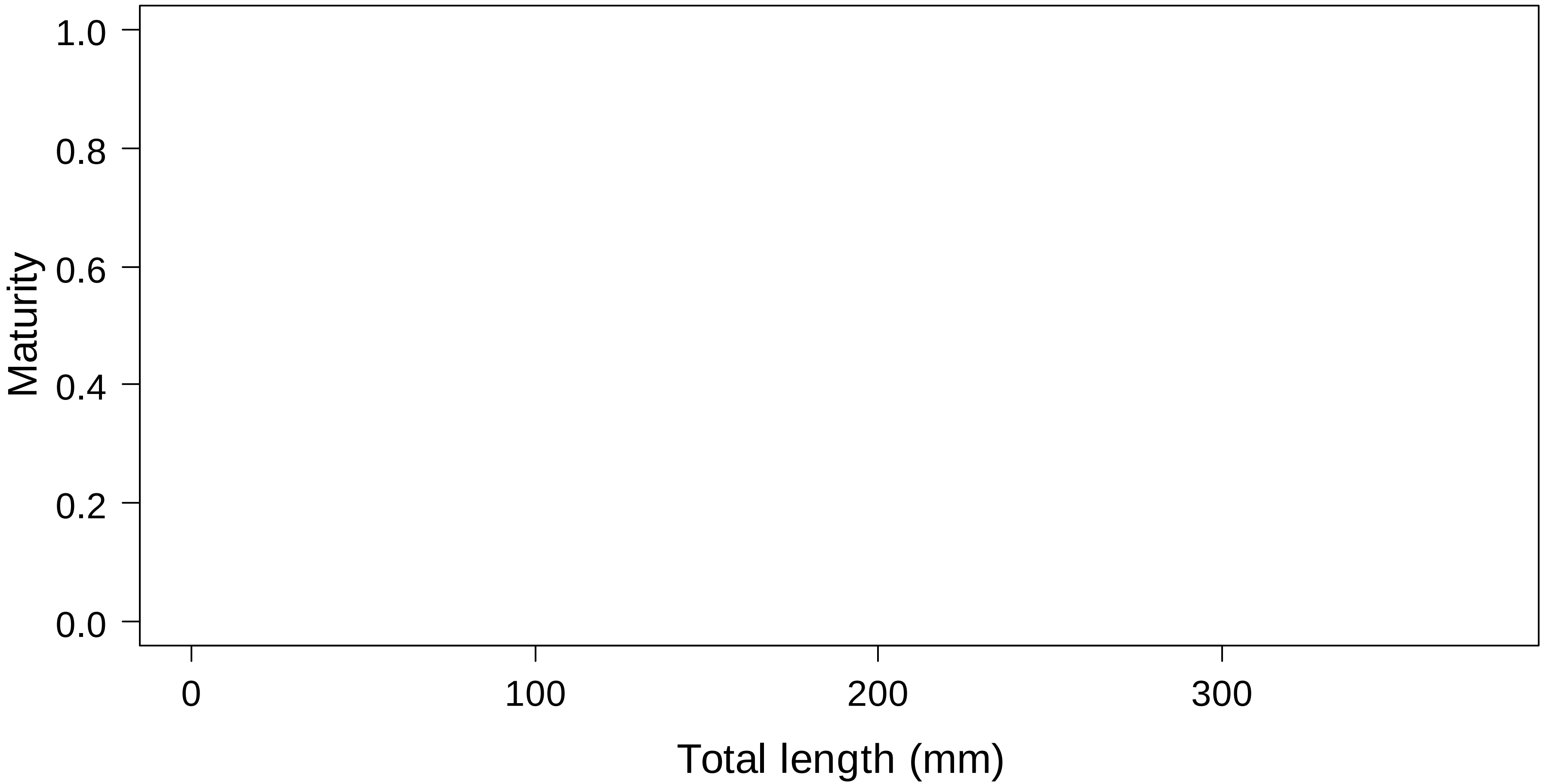
**Length at first maturity**

*Mean length at which fish of a given population develop ripe gonads for the first time.*

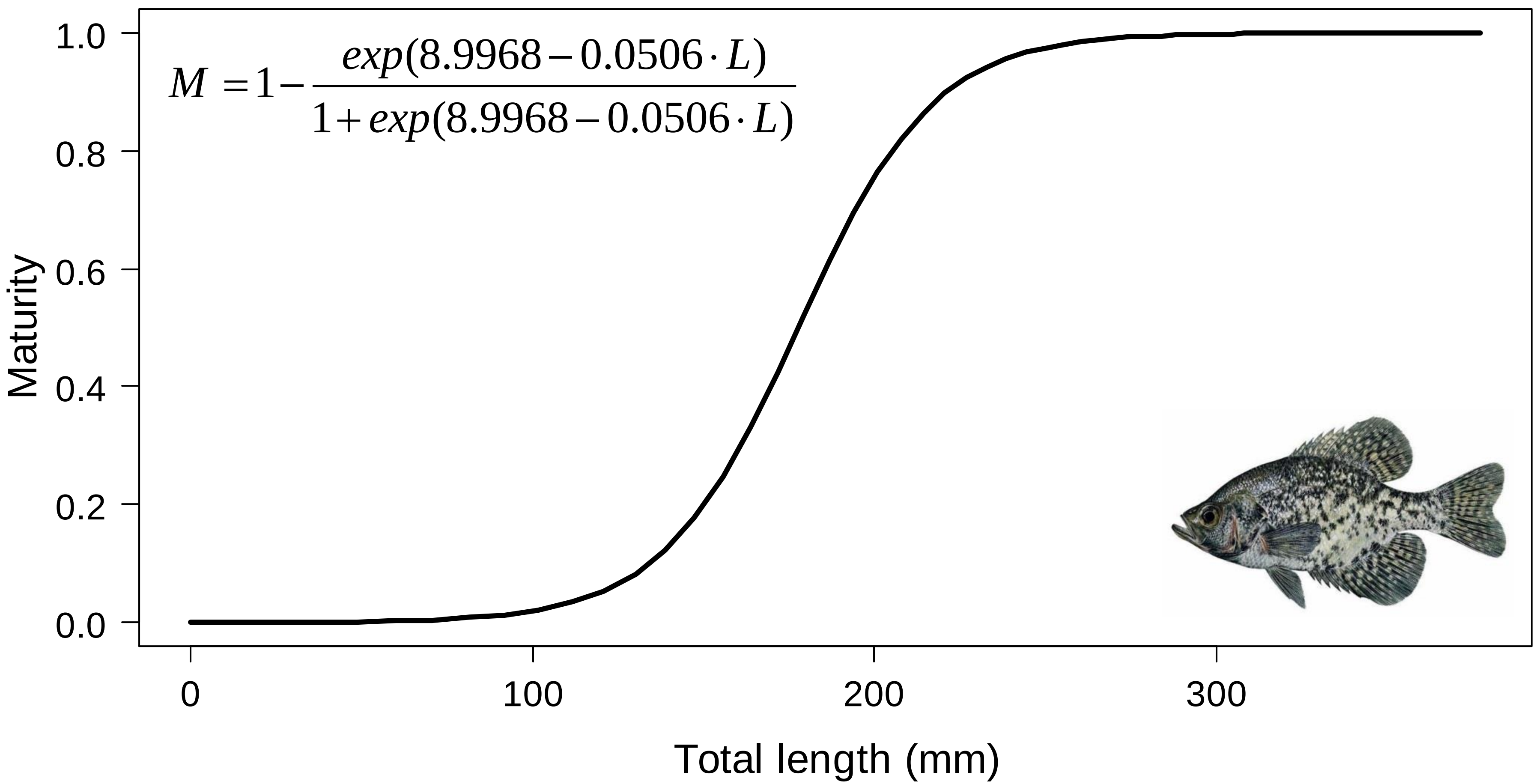
# Determining sexual maturity & ratio

- Link maturity (yes or no) to length
- Sex ratio

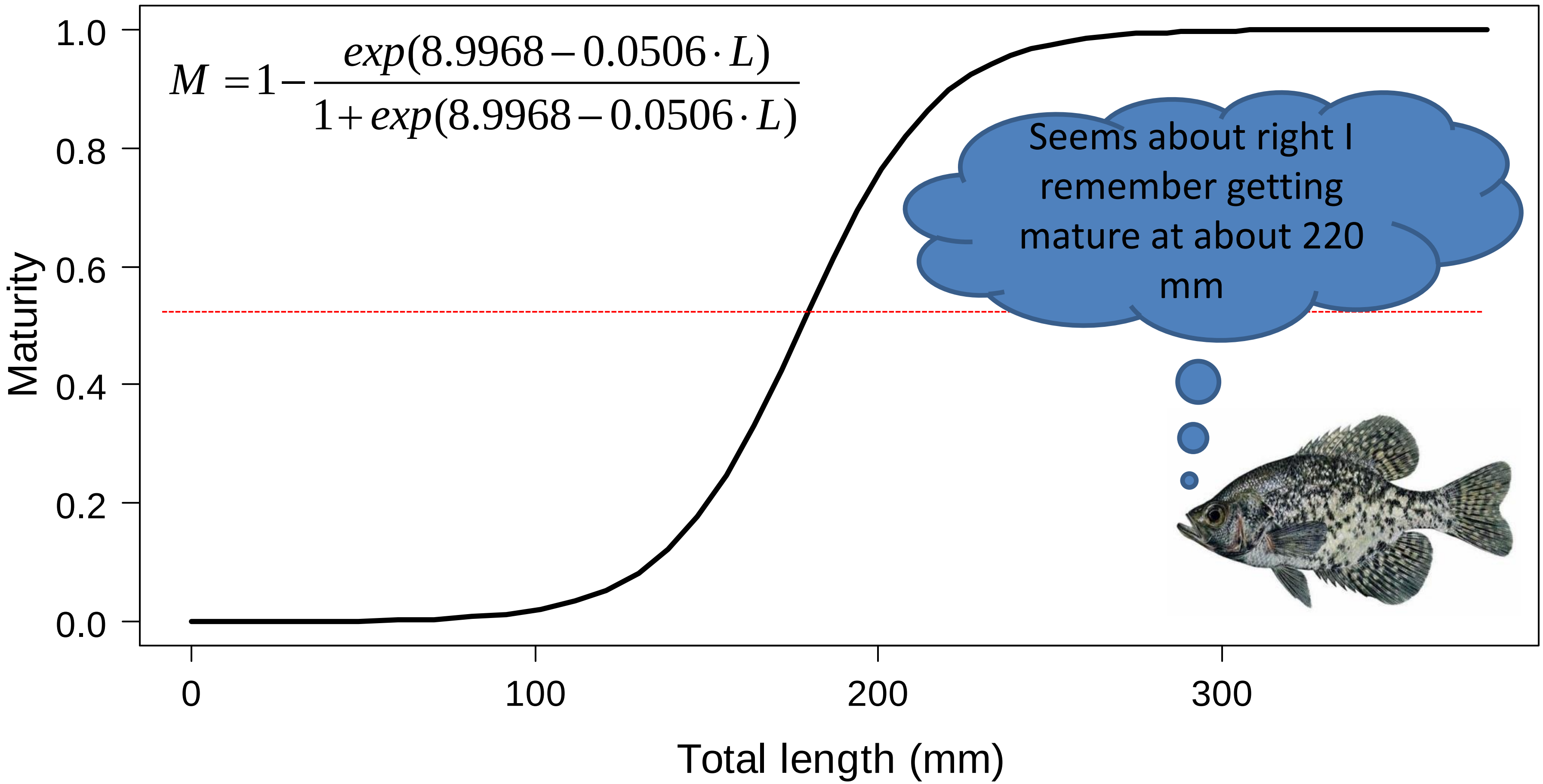
# Maturity function



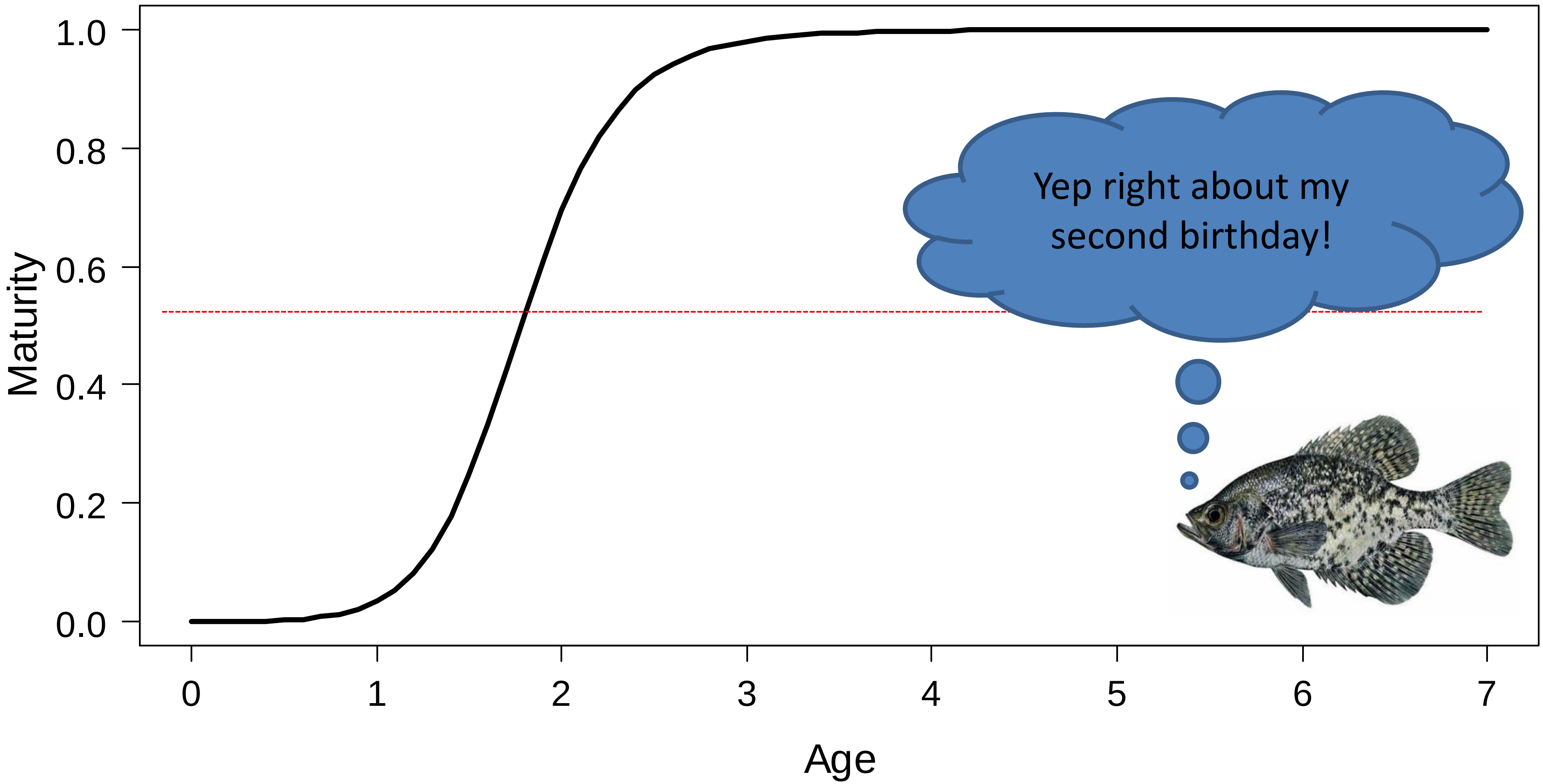
# Maturity function



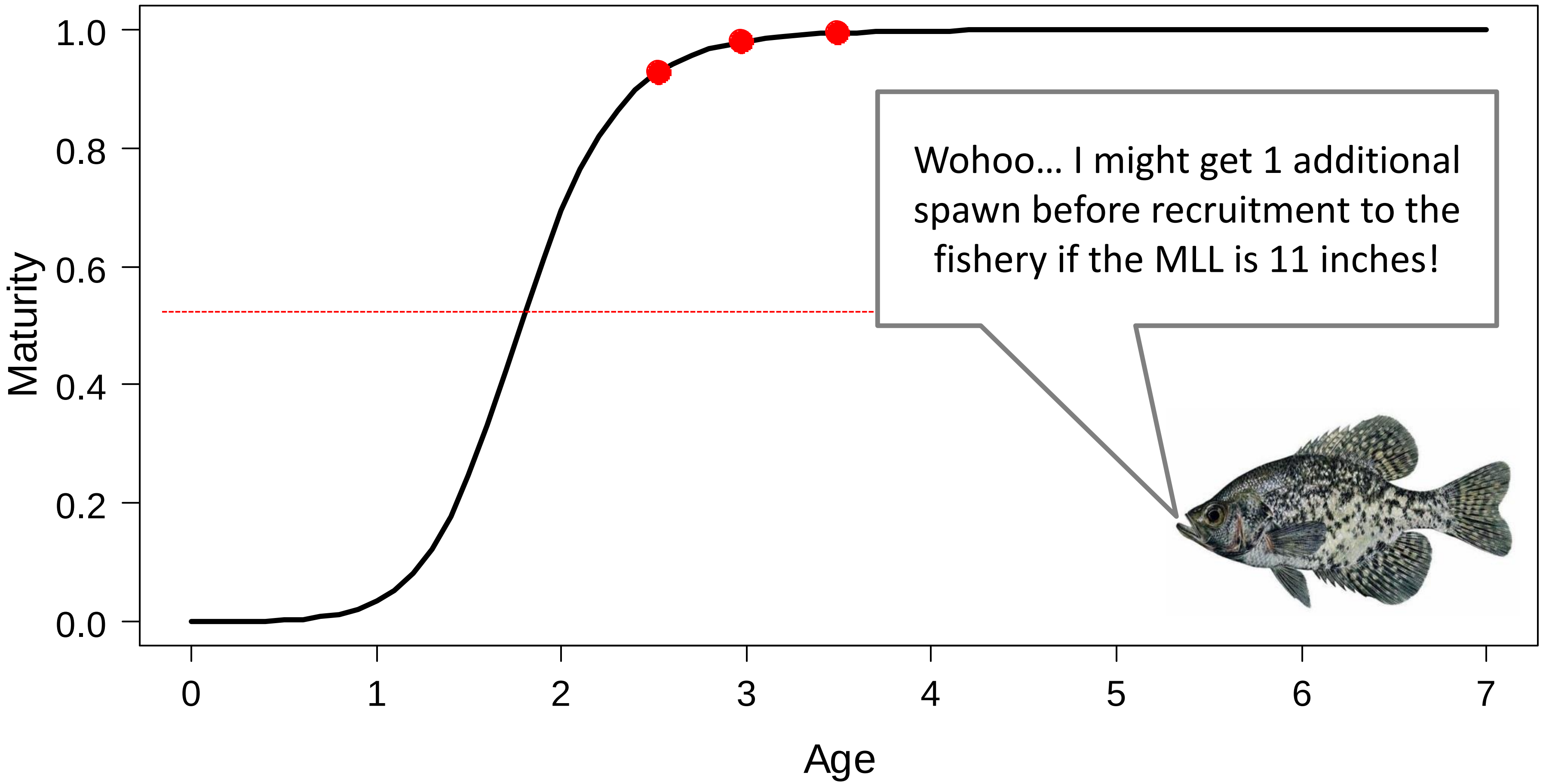
# Maturity function



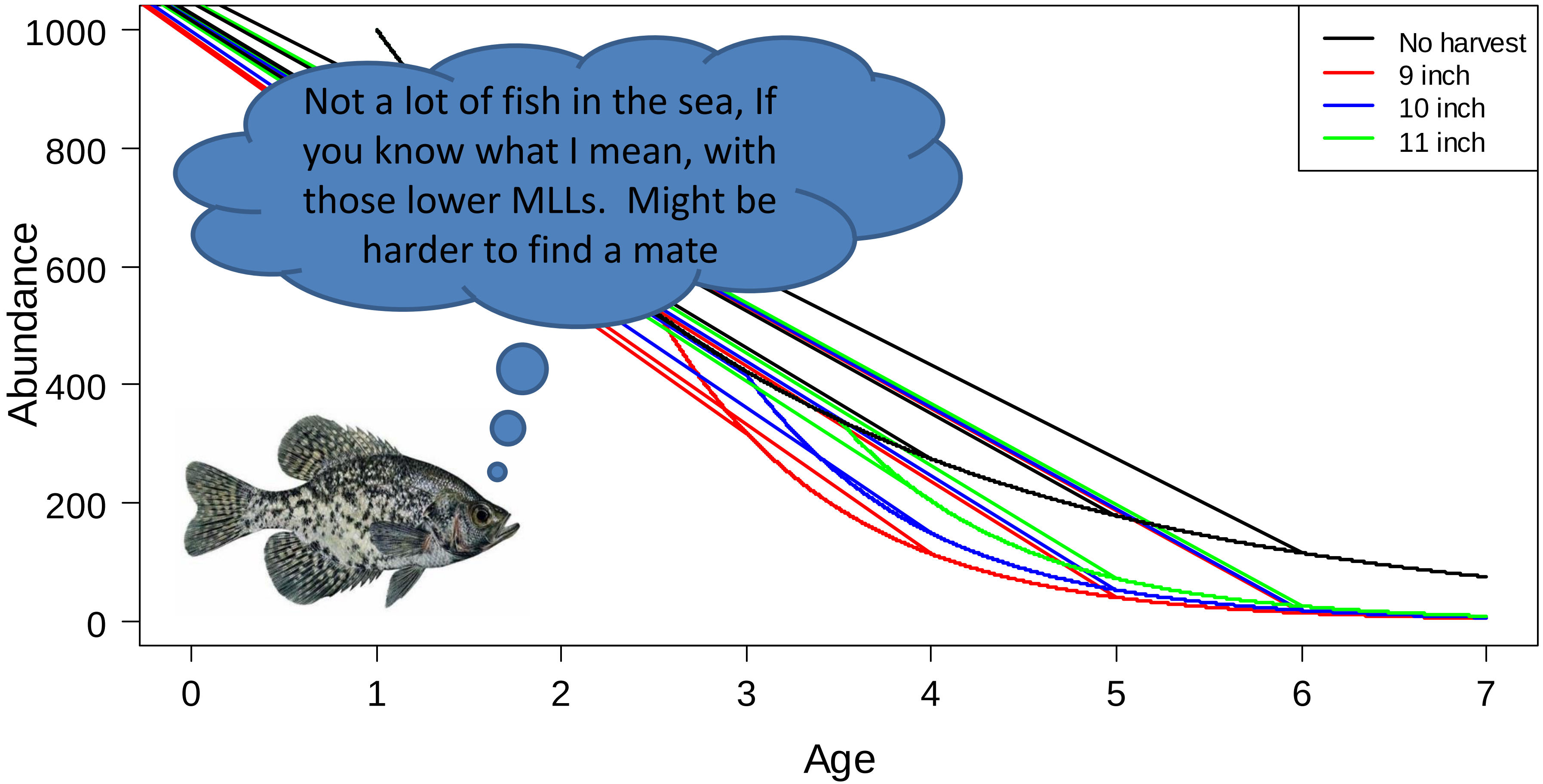
# Maturity function



# Maturity function & MLL

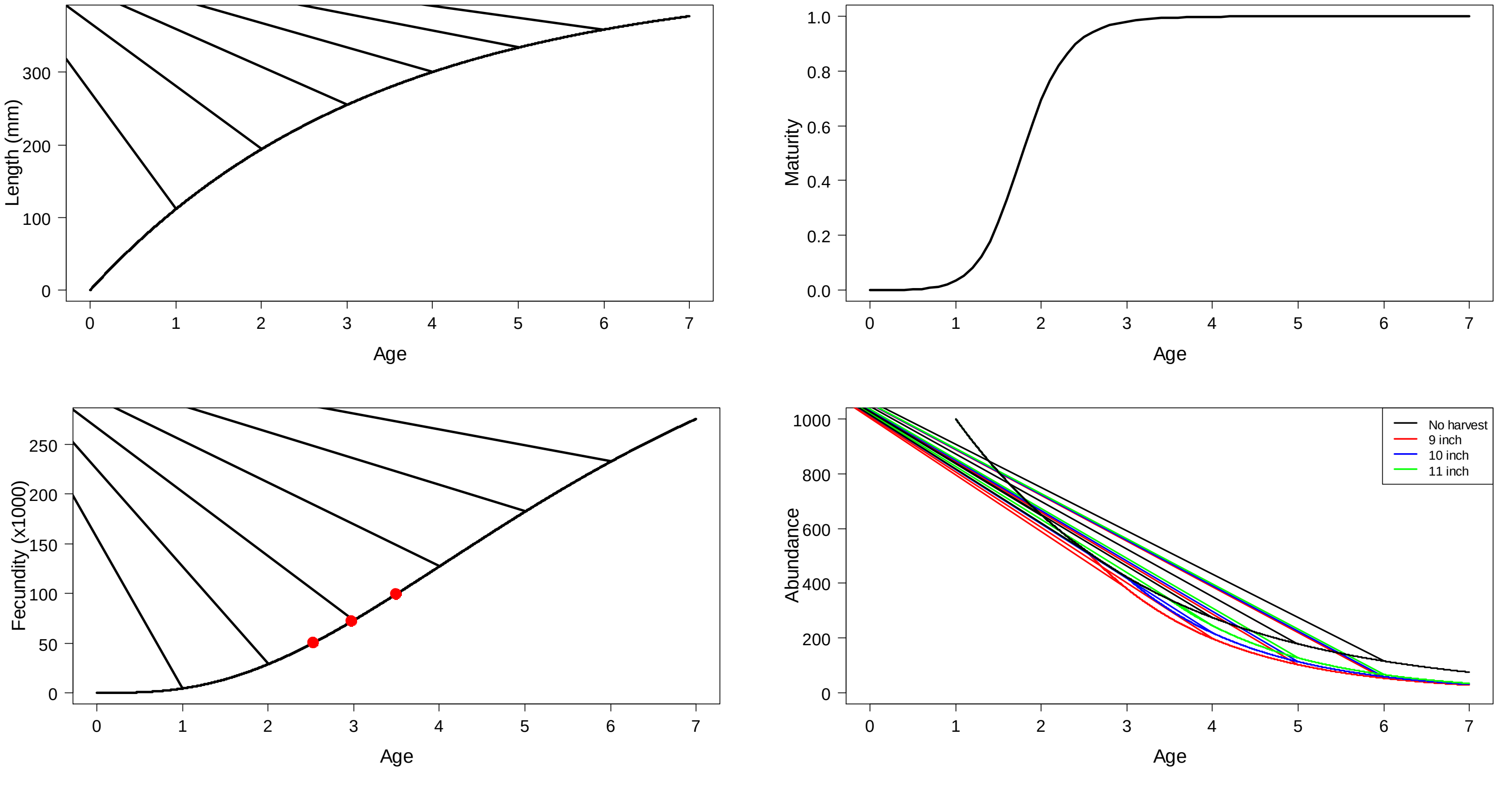


# Abundance



Not a lot of fish in the sea, If you know what I mean, with those lower MLLs. Might be harder to find a mate
No harvest
9 inch
10 inch
11 inch
Abundance
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
Age

# Complex interactions? You bet!



# Evaluation of recruitment overfishing

- Limited in practice
- Set regulations that are **robust** to recruitment overfishing
  - Ratio of spawning biomass to unfished biomass (SSR)
  - Ratio of spawning potential to unfished potential (SPR)

# Spawning potential ratio

- **Spawning potential:** The number of eggs that could be produced by an average recruit over its lifetime
- **Ratio:** the fished stock is divided by the number of eggs that could be produced by an average recruit over its lifetime when the stock is unfished.
- Compares the spawning ability of a stock in the fished condition to the stock's spawning ability in the unfished condition.

# Example

- 10 fish survive the first couple of years of life and are now large enough to be caught (recruited) in the fishery.
- Four are caught before they spawn (no eggs produced)
- Three others are caught after they spawn once (some eggs produced),
- The last three live to spawn three times (many eggs produced) before dying of old age.
- During their lifetime, the 10 fish produced 1 million eggs and the average recruit produced 100,000 eggs (1 million divided by 10).
- Unfished population, 10 fish survive as before. Three die of natural causes after spawning (some eggs produced) and the other seven spawn three times (very many eggs produced) before dying of old age.
- During their lifetime, these 10 fish produced 5 million eggs and the average recruit produced 500,000 eggs (5 million divided by 10).
- The spawning potential ratio is:  100,000 eggs produced by the average fished recruit divided by the 500,000 eggs produced by the average unfished recruit and is equal to 0.20 or 20 percent.

# Spawning stock biomass (SSB) & Spawning stock biomass per recruit (SSBR)

- Biomass (weight):
  – entire adult stock,
  – mature females in the stock,
  – eggs they produce. These measures are called

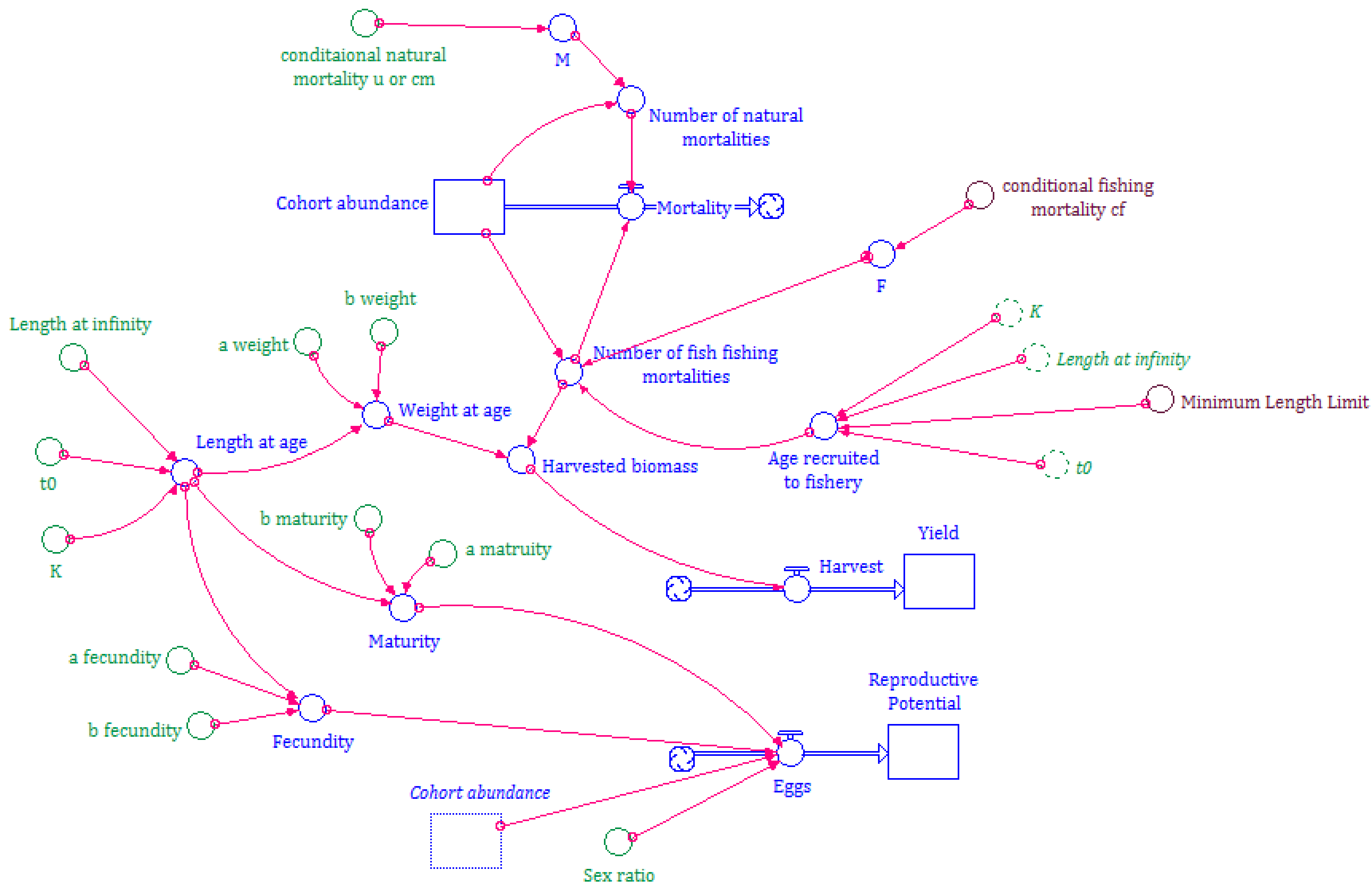
*Spawning stock biomass (SSB) or spawning stock biomass per recruit (SSBR)*

# What is the SPR for Crappie?

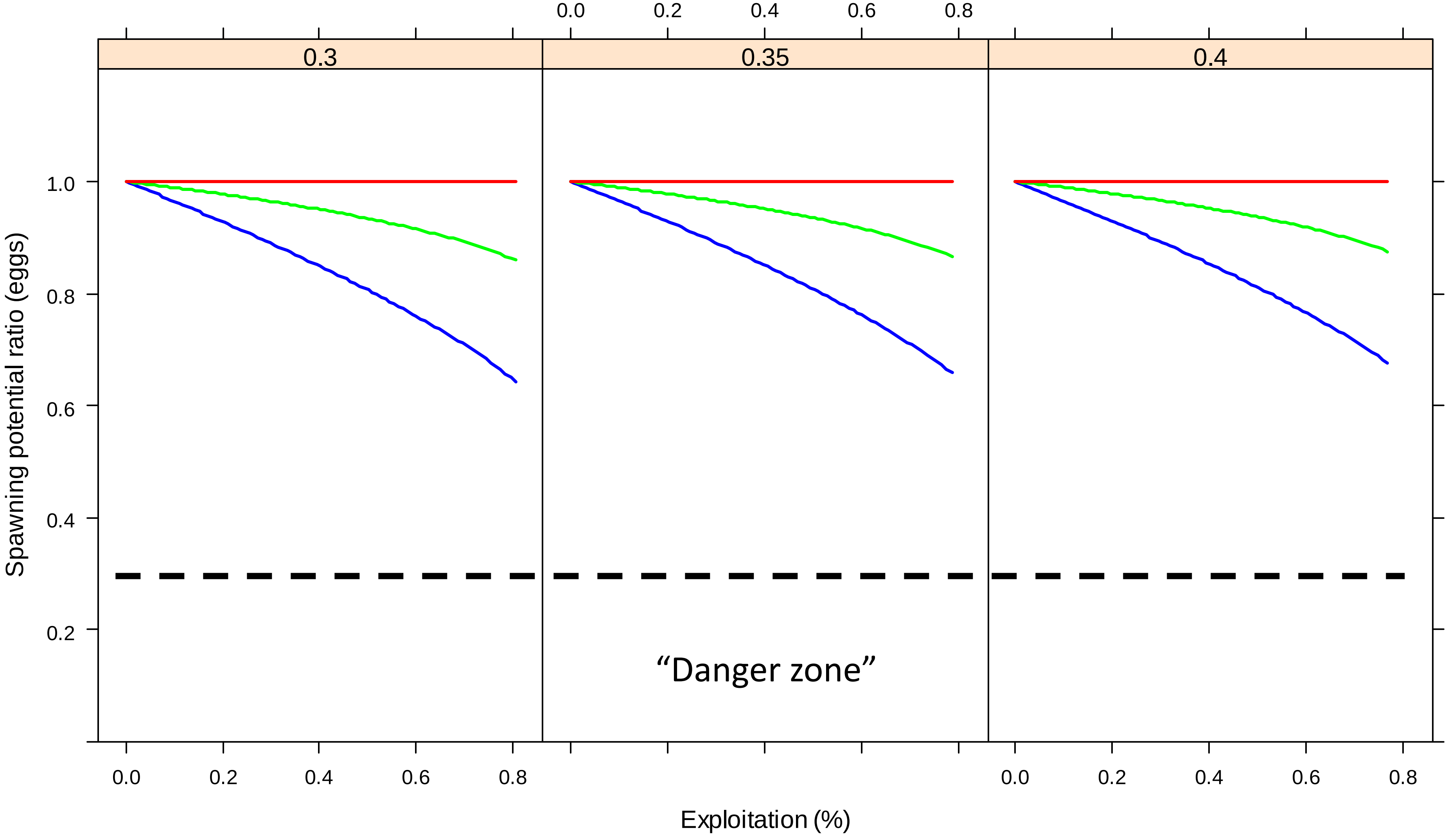
# Stock specific SPR?

- Studies show that some stocks (depending on the species of fish) can maintain themselves if the spawning stock biomass per recruit can be kept at 20 to 35% (or more) of what it was in the unfished stock.
- Lower values of SPR may lead to severe stock declines.

# Conceptually

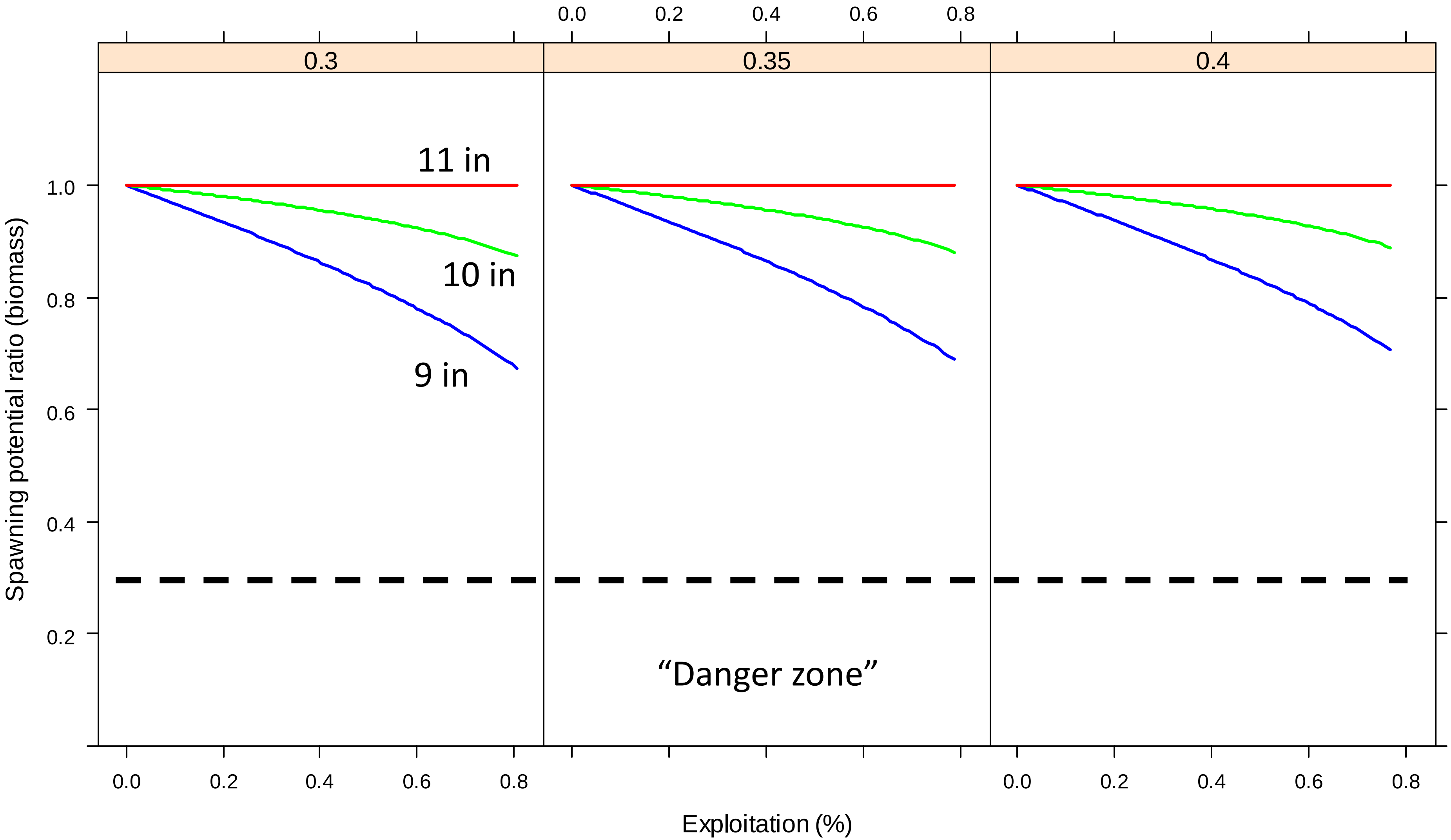


# SPR-Eggs

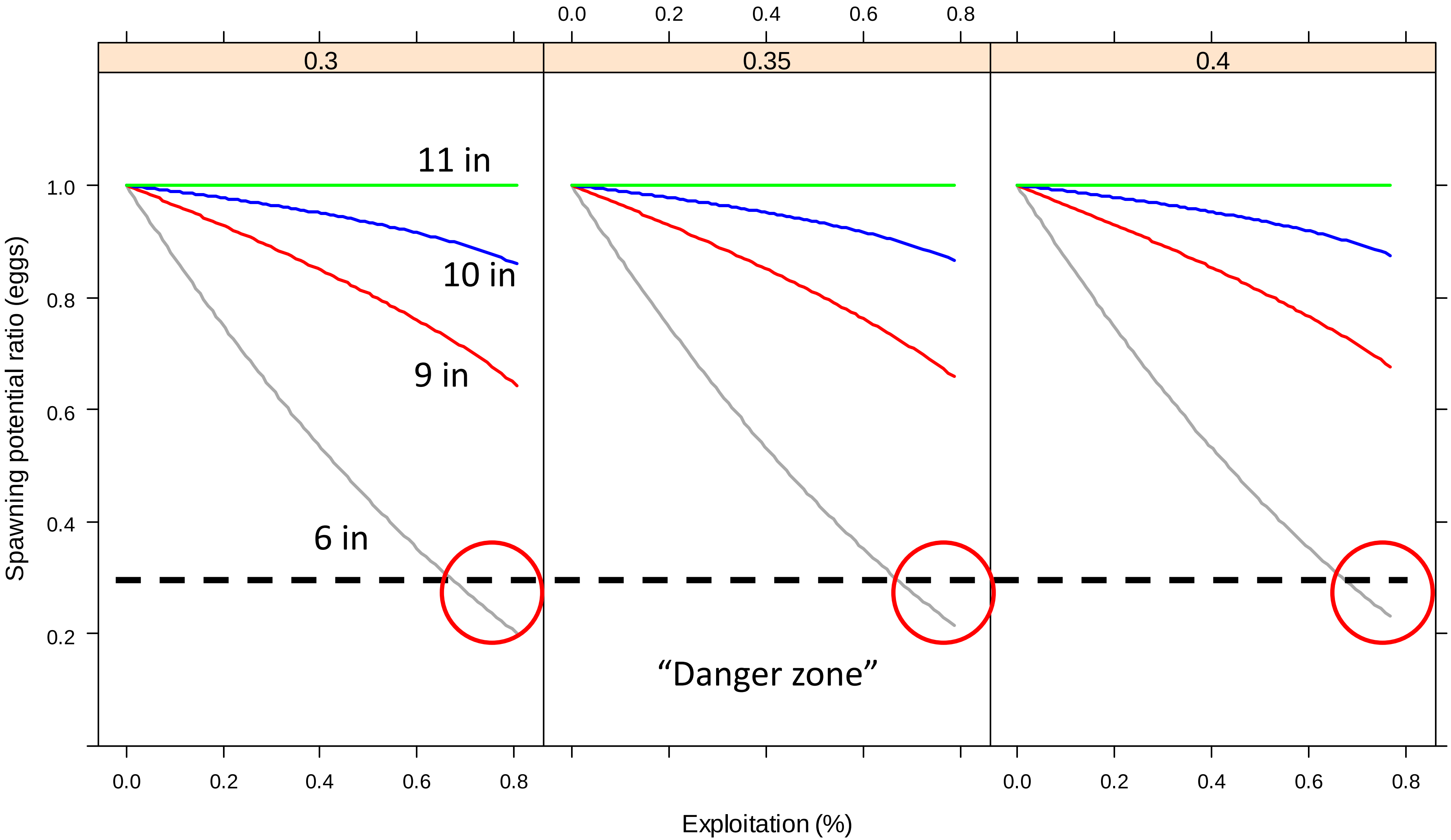


0.3
0.35
0.4
Spawning potential ratio (eggs)
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
Exploitation (%)
"Danger zone"

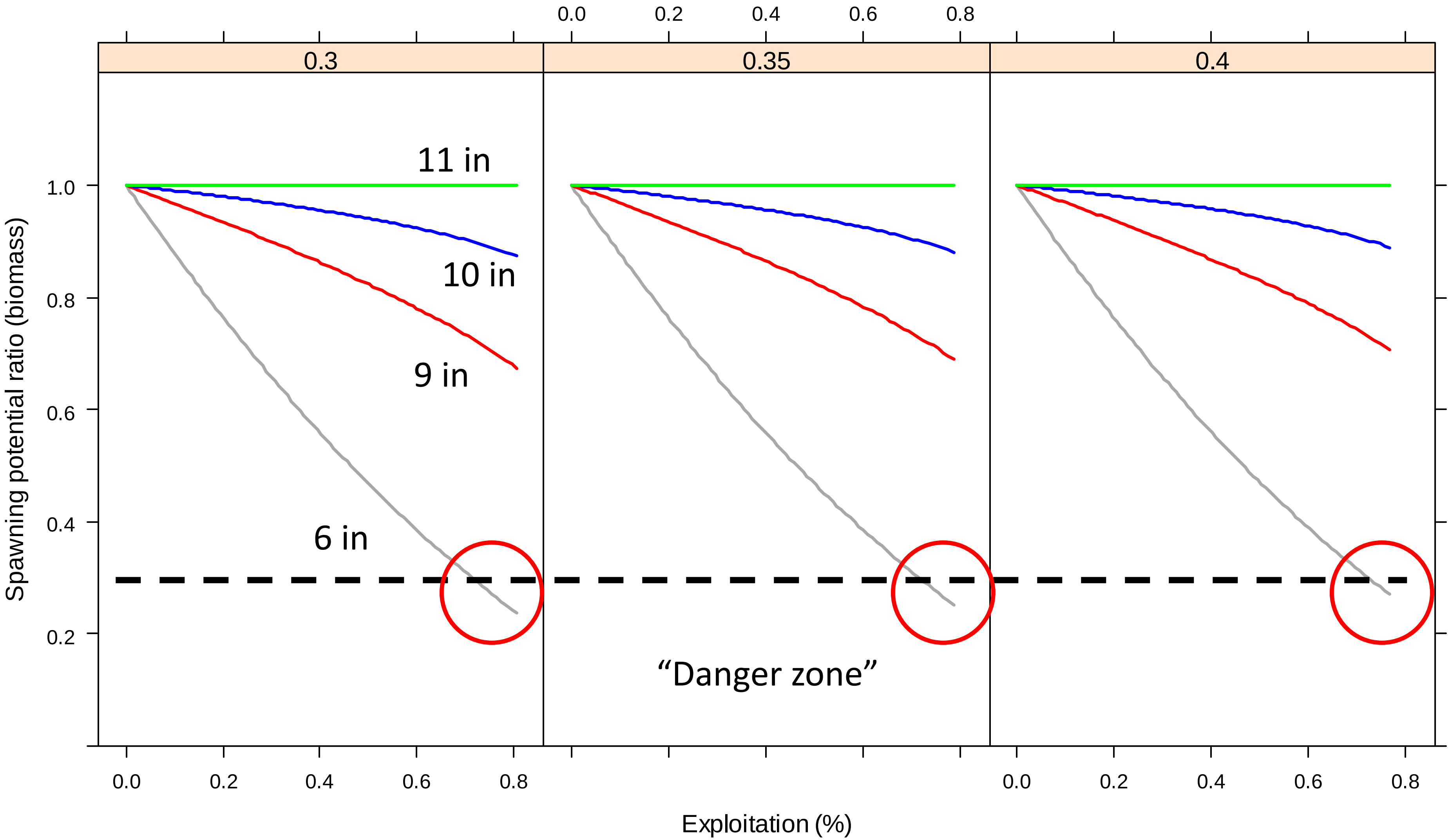
# SPR-Mature female biomass



# Adding a 6 inch MLL



# Adding a 6 inch MLL



# WF4313/6613-Fisheries Management

Class 15– Yield Management Case Studies

# In the news

# Share your bay scallop input with the FWC; workshops scheduled for October

**News Release**

Thursday, October 05, 2017

Media contact: Amanda Nalley, 850-410-4943 or Amanda.Nalley@MyFWC.com

This summer, the Florida Fish and Wildlife Conservation Commission (FWC) implemented staggered season start and end dates for bay scallop harvest. The FWC needs your feedback on this staggered season structure before determining how to manage the season in the future.

The FWC will be hosting five public workshops including areas of the state where scallop harvest is allowed as well as in Pasco County, where harvest currently is not allowed. The goal of these workshops will be to gather input on the bay scallop fishery, including whether this year's staggered season made for a more enjoyable time on the water and whether it had any economic impact on the coastal communities that depend upon this fishery. Input from these workshops will be discussed at a future Commission meeting and will help the FWC determine what the bay scallop season structure should be in future years.

Upcoming in-person workshops are scheduled as follows (scheduled 6 to 8 p.m. local time except for Port St. Joe):

- Oct. 12: Port St. Joe, Gulf County Board of County Commissioners, Robert M. Moore Administration Building, 1000 Cecil G. Costin Sr. Blvd. (this meeting only is from 5:30 to 7:30 p.m. ET).
- Oct. 16: Steinhatchee, Steinhatchee Landing Resort, 219 NE Highway 51.
- Oct. 17: Land O' Lakes, Land O' Lakes Recreation Complex, Meeting Rooms 3 & 4, 3032 Collier Parkway.
- Oct. 18: Crystal River, City Council Chambers, 123 NW Highway 19.
- Oct. 26: Carrabelle, Franklin County Senior Center, 201 NW Ave. F.

# Goliath grouper in-person workshops scheduled for October; online workshops also available

**News Release**

Thursday, October 05, 2017

Media contact: Amanda Nalley, 850-410-4943 or Amanda.Nalley@MyFWC.com

The Florida Fish and Wildlife Conservation Commission (FWC) will continue gathering public input on the management of goliath grouper this month at several in-person workshops scheduled across the state. The FWC is seeking input on goliath grouper management, including the possibility of a limited harvest in Florida state waters.

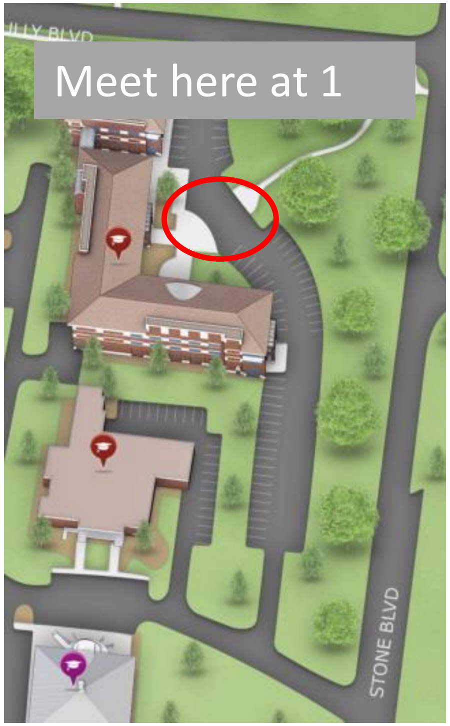
A total of 16 in-person workshops will be held altogether, including workshops held previously in July and August.

For those who missed a workshop in their area or cannot make an in-person workshop, an on-demand virtual workshop is available. This newly-added online feature can be found on the public workshops webpage at MyFWC.com/Fishing by clicking on "Saltwater Fishing," "Public Comments/Workshops" and "Workshops." Once you've viewed the workshop, you can take a workshop survey, which is identical to a survey given at the in-person workshops. Additional written comments may be submitted online at MyFWC.com/SaltwaterComments.

# Announcements

# Announcement

1. Lab tomorrow 10/3-Stream electrofishing
2. Waders, bug repellent, sunscreen, water




| **10/3-Group 1** | **10/10-Group 2** |
|---|---|
| Yasko, S | McAllister, B. |
| Rush, H | Cook, M. |
| Gerhart, B. | Pigott, W. |
| Yarber, C. | Thompson, W. |
| Shannon, A. | Lucore, A. |
| Wilson, A. | Virden, M. |
| Lundy, F. | Hopson, E. |
| Woodyard, E. | Pettigrew, C. |
| Munter, Z. | Roberson, H. |
| Tipton, J. | Gammon, T. |

# Class Topics

Yield and biomass management

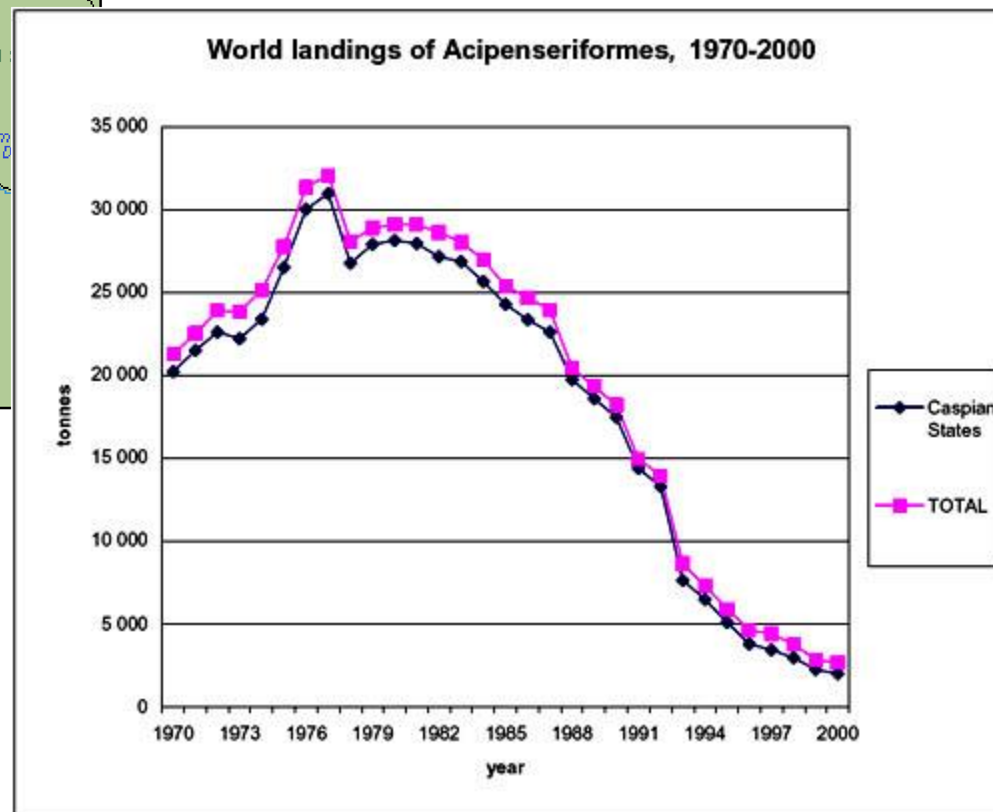
Management case study

# MANAGEMENT CASE STUDY
# PADDLEFISH ROE HARVEST

# Caviar sources

- Salmon
- Mullet
- Herring
- Carp
- Bowfin
- Acipenseriformes
  - Sturgeon
  - Paddlefish

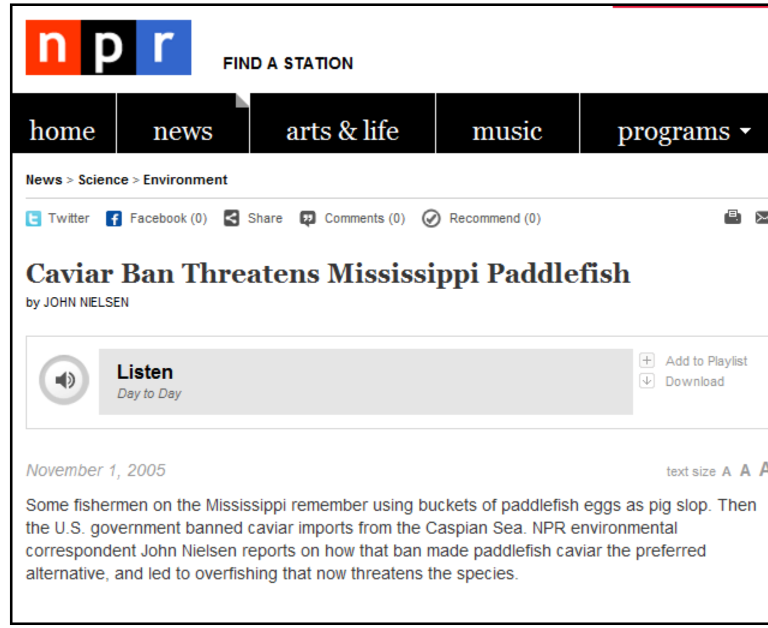
# Eurasian caviar stocks decline


http://www.fao.org/docrep/006/Y5261E/y5261e06.htm

# NA Acipensiformes harvest

- High market price
- Increased harvest in North America
- At-risk to overfishing?



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## Caviar Ban Threatens Mississippi Paddlefish

by JOHN NIELSEN

Listen
*Day to Day*

Add to Playlist
Download

*November 1, 2005*

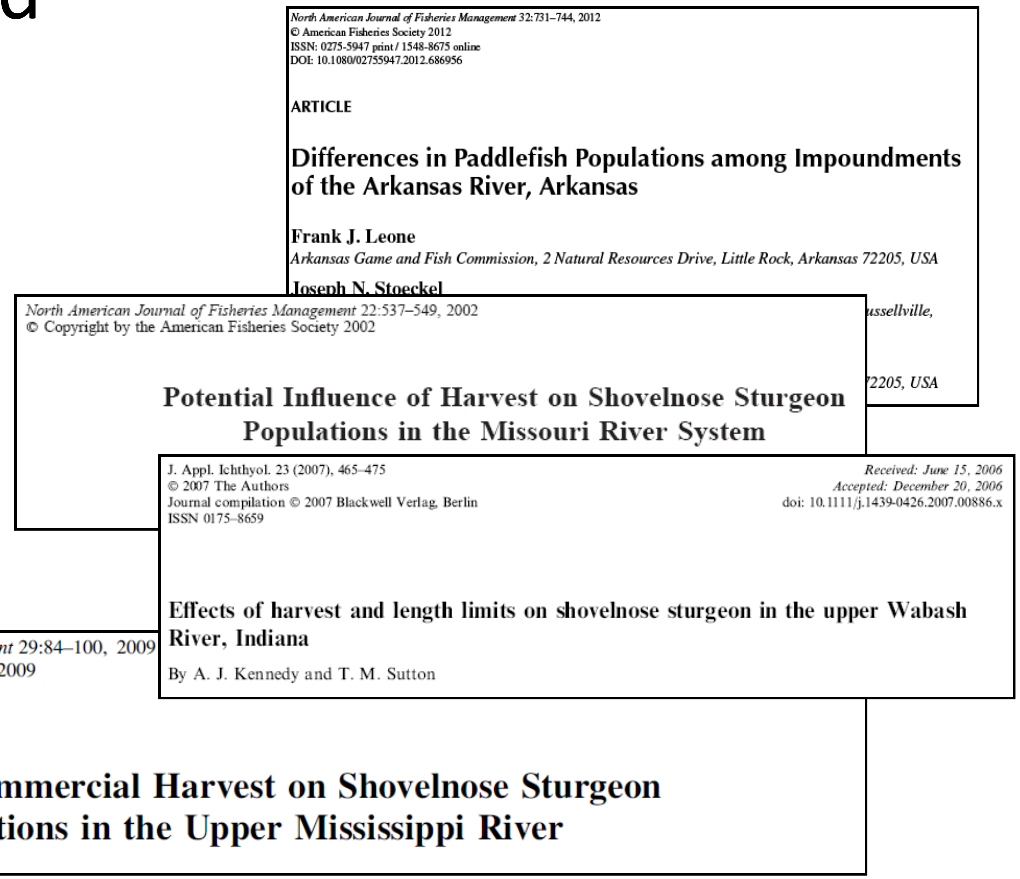
text size A A A

Some fishermen on the Mississippi remember using buckets of paddlefish eggs as pig slop. Then the U.S. government banned caviar imports from the Caspian Sea. NPR environmental correspondent John Nielsen reports on how that ban made paddlefish caviar the preferred alternative, and led to overfishing that now threatens the species.

220 $/kg roe; 500-650$ per fish

# Yield-per-recruit (YPR) models

- Predicts fishery yield
- Age structured
- Evaluate varying:
  - Fishing mortality
  - Length limits
  - Natural mortality



North American Journal of Fisheries Management 32:731–744, 2012
© American Fisheries Society 2012
ISSN: 0275-5947 print / 1548-8675 online
DOI: 10.1080/02755947.2012.686956

ARTICLE

**Differences in Paddlefish Populations among Impoundments of the Arkansas River, Arkansas**

Frank J. Leone
*Arkansas Game and Fish Commission, 2 Natural Resources Drive, Little Rock, Arkansas 72205, USA*

Joseph N. Stoeckel

*ussellville,*

*72205, USA*

*North American Journal of Fisheries Management* 22:537–549, 2002
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**Potential Influence of Harvest on Shovelnose Sturgeon Populations in the Missouri River System**

J. Appl. Ichthyol. 23 (2007), 465–475
© 2007 The Authors
Journal compilation © 2007 Blackwell Verlag, Berlin
ISSN 0175–8659

*Received: June 15, 2006*
*Accepted: December 20, 2006*
doi: 10.1111/j.1439-0426.2007.00886.x

**Effects of harvest and length limits on shovelnose sturgeon in the upper Wabash River, Indiana**

By A. J. Kennedy and T. M. Sutton

*North American Journal of Fisheries Management* 29:84–100, 2009
© Copyright by the American Fisheries Society 2009
DOI: 10.1577/M08-115.1

**Effects of Commercial Harvest on Shovelnose Sturgeon Populations in the Upper Mississippi River**

# Paddlefish harvest

*Transactions of the American Fisheries Society* 134:1285–1298, 2005

DOI: 10.1577/T04-161.1

[Article]

**Population Characteristics and Assessment of Overfishing for an Exploited Paddlefish Population in the Lower Tennessee River**

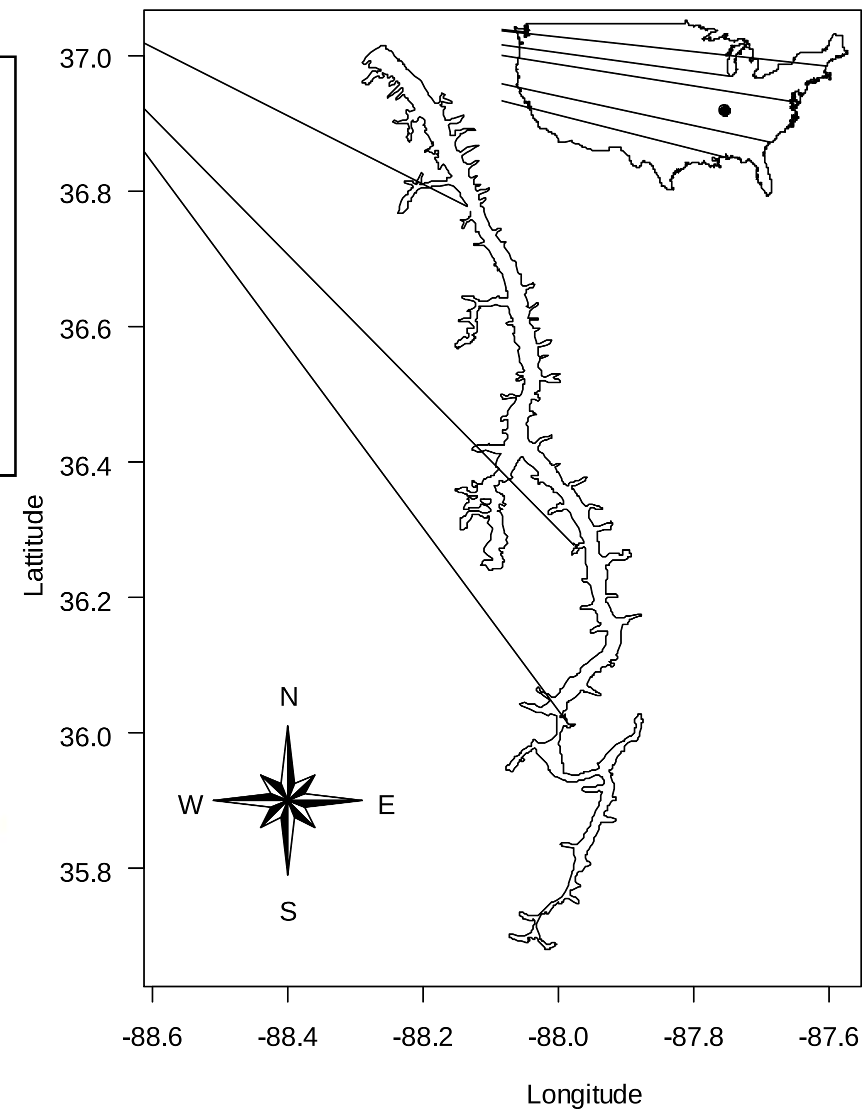
George D. Scholten*[1]

*Tennessee Cooperative Fishery Research Unit,[2] Tennessee Technological University, 205 Pennebaker Hall, Cookeville, Tennessee 38505, USA*

Phillip W. Bettoli

*U.S. Geological Survey, Tennessee Cooperative Fishery Research Unit, Tennessee Technological University, 205 Pennebaker Hall, Cookeville, Tennessee 38505, USA*

*Can roe yield be increased by delaying recruitment to the fishery?*



# Potential for overfishing?

- Growth overfishing
  - 864-mm
  - Exploitation > 30%
  - Weak at 965
- Suggests increasing length limit

***<u>But, commercial fishery targets ovarian tissue not biomass!</u>***

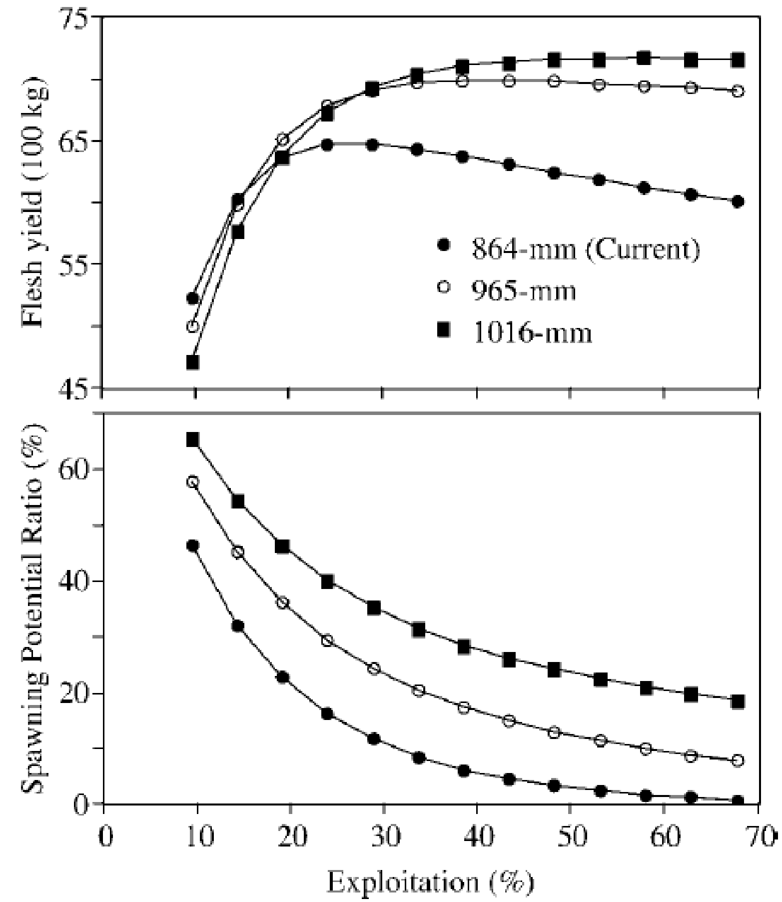
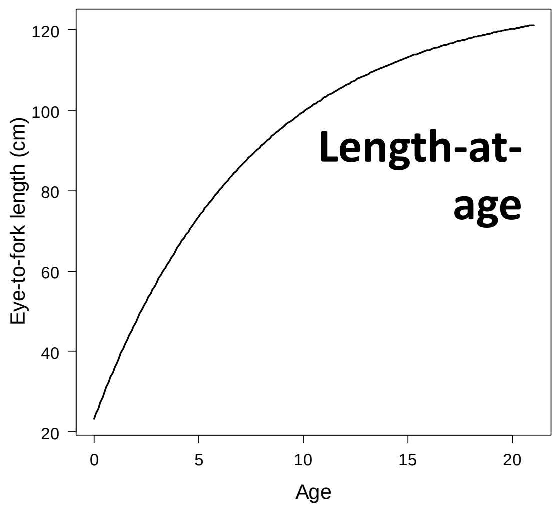
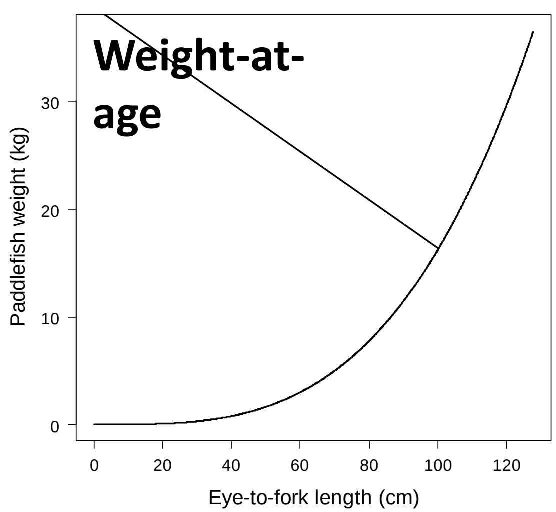
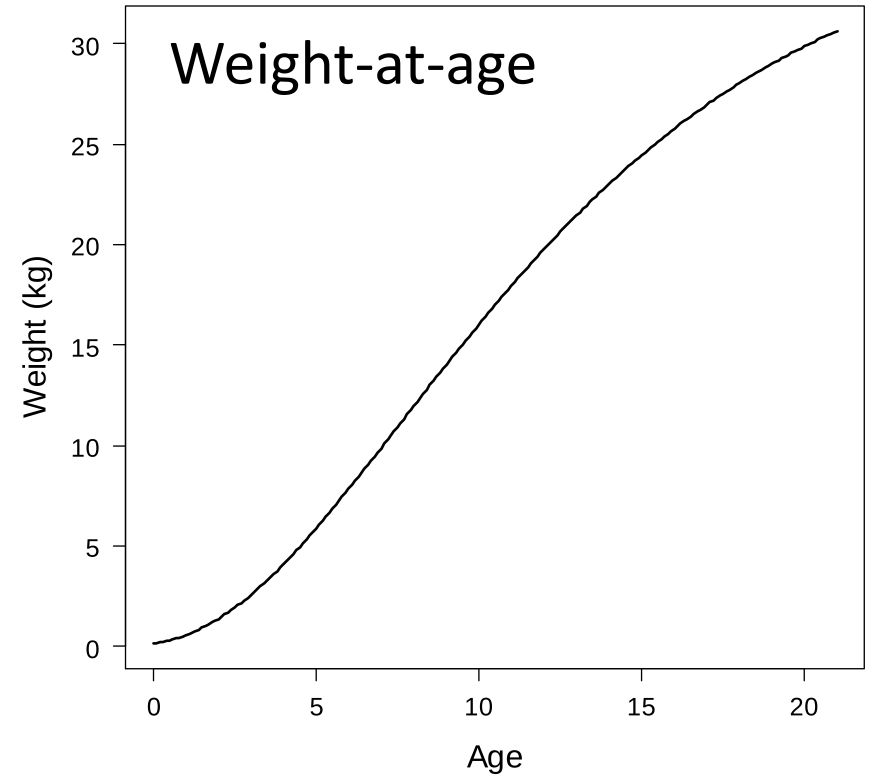



FIGURE 6.—Predicted paddlefish flesh yield (per 1,000 recruits; top) and spawning potential ratio (bottom) versus exploitation for three different minimum length limits in Kentucky Lake in 2003–2004.

# Weight-at-age

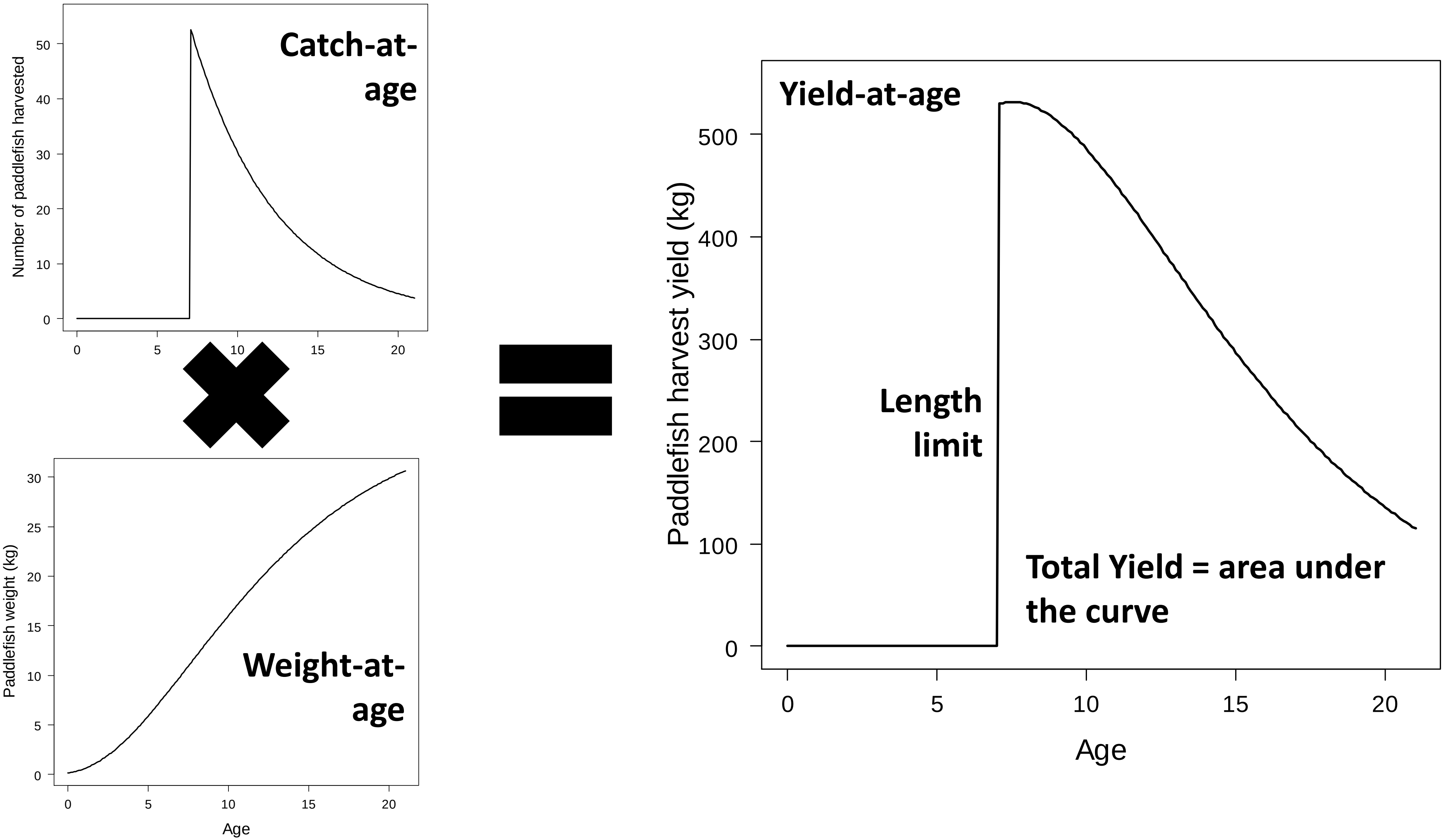


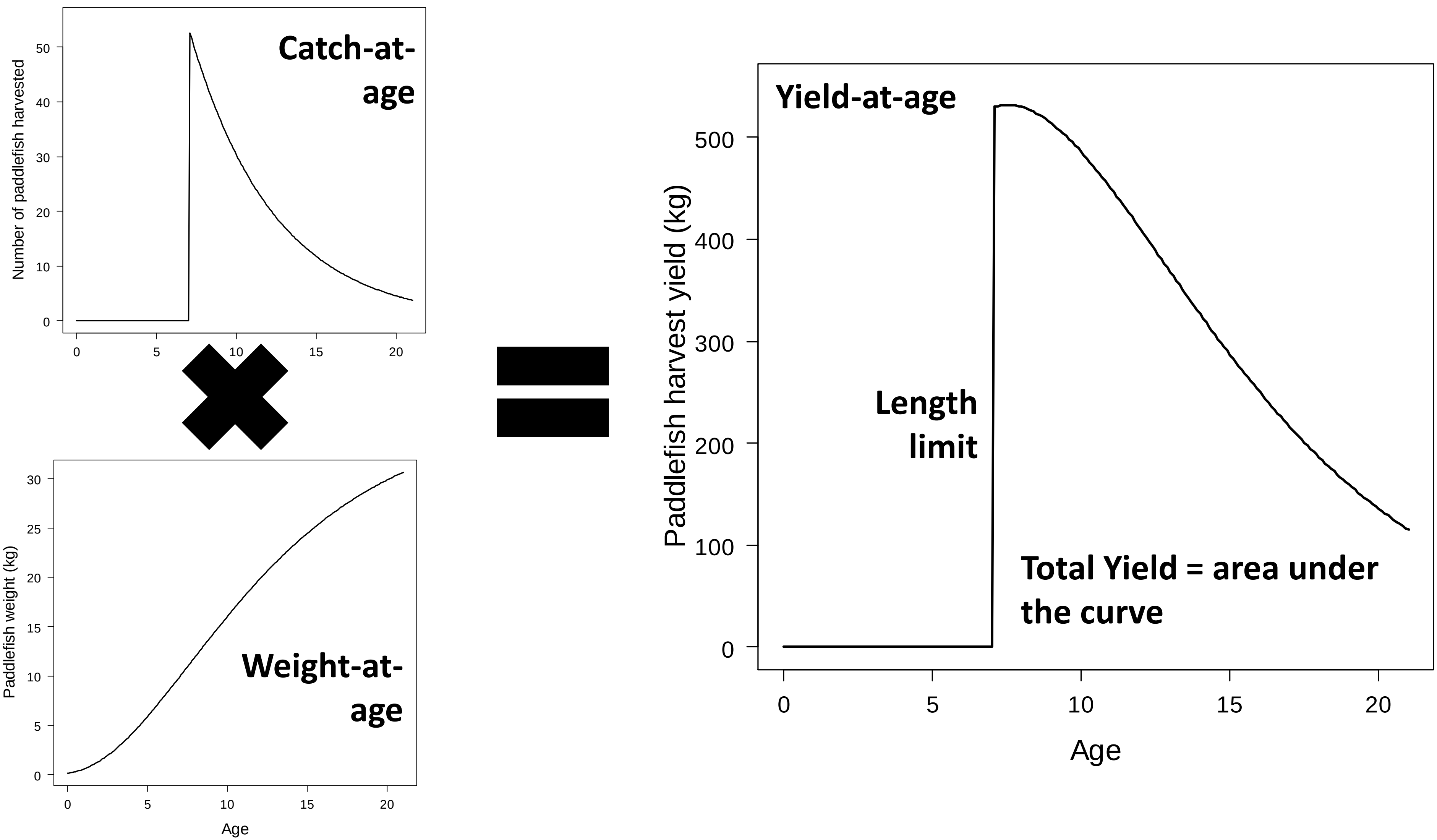




$$W_{fish}(age) = 10^{-5.711} \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (age+1.527)}))^{3.307}$$

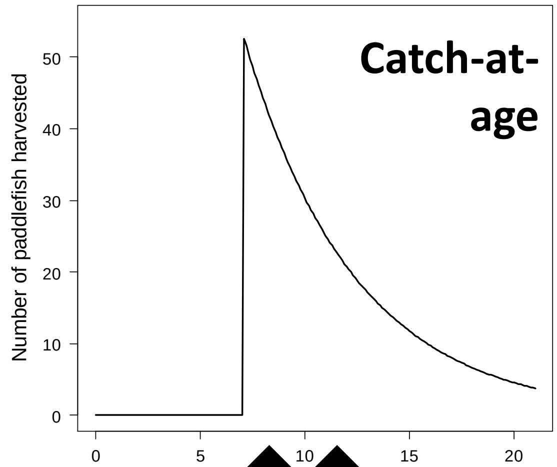
# Putting it all together

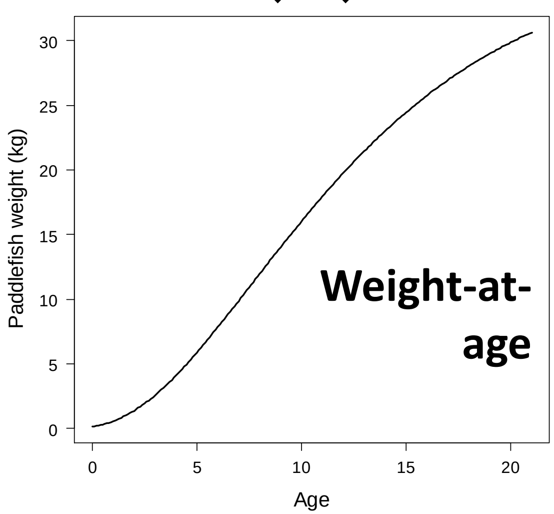


# Putting it all together



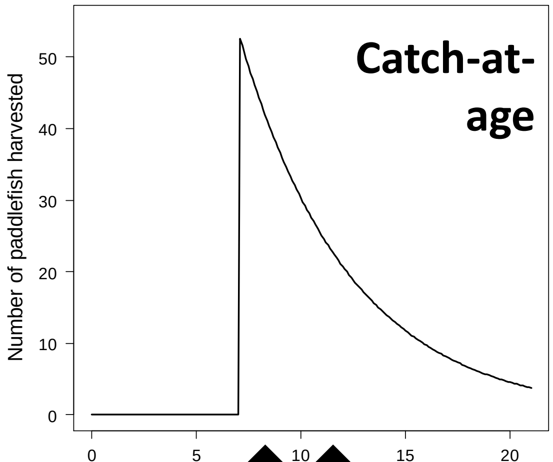
# Roe yield?

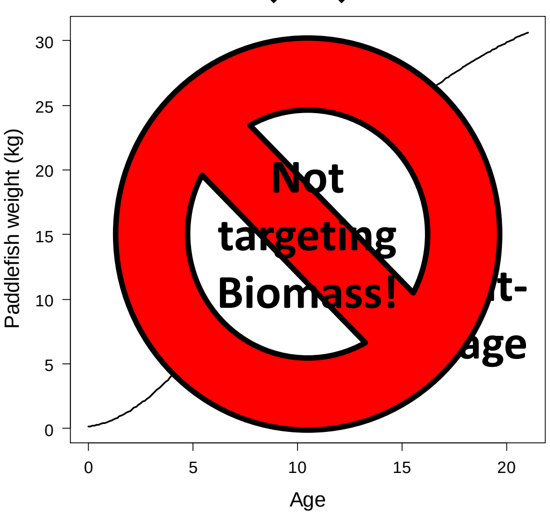

Catch-at-age
Number of paddlefish harvested
0
10
20
30
40
50
0
5
10
15
20

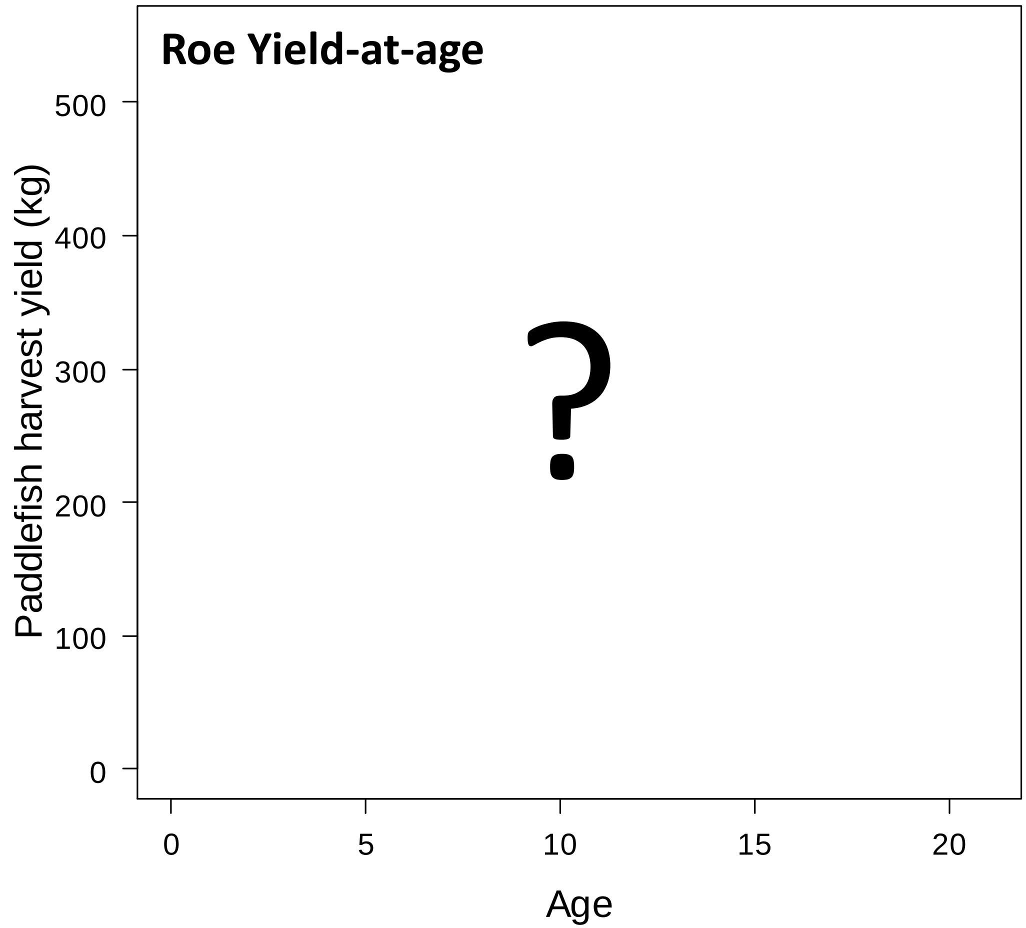

Weight-at-age
Paddlefish weight (kg)
0
5
10
15
20
25
30
0
5
10
15
20
Age


Yield-at-age
Paddlefish harvest yield (kg)
0
100
200
300
400
500
0
5
10
15
20
Age

# Putting it all together



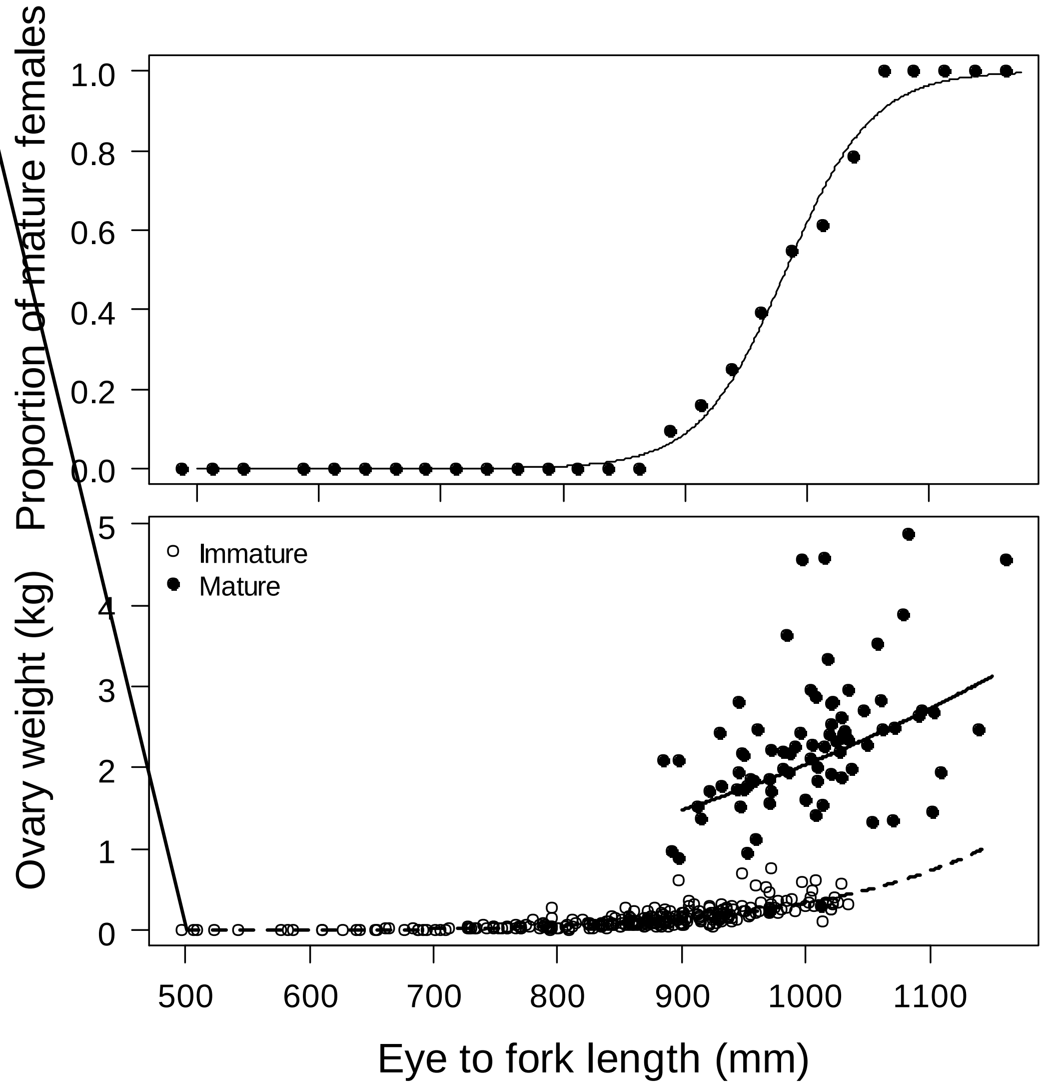



# Simulating roe yield

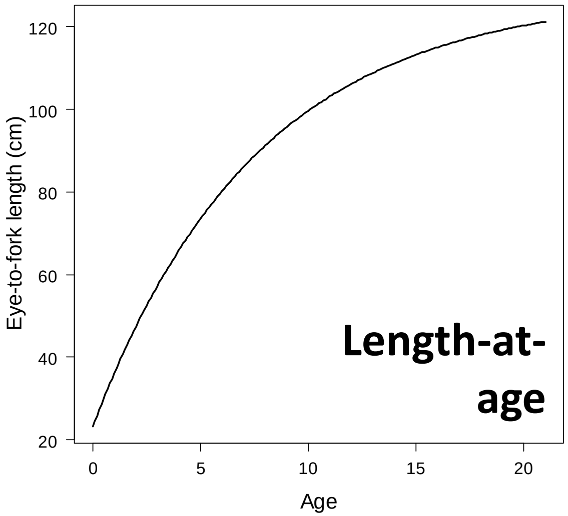
*Ovary weight-at-EFL*

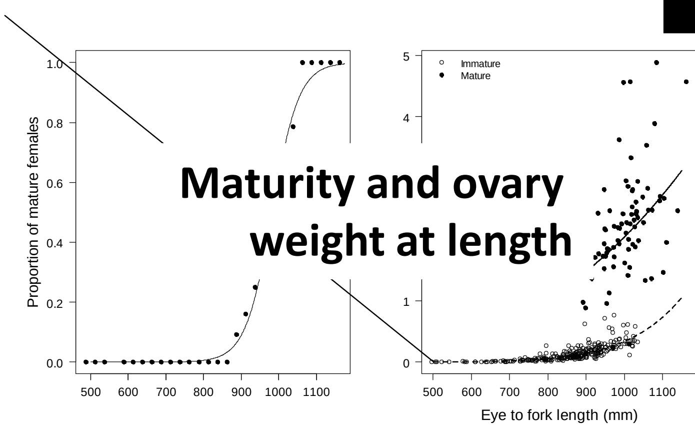
Account for:

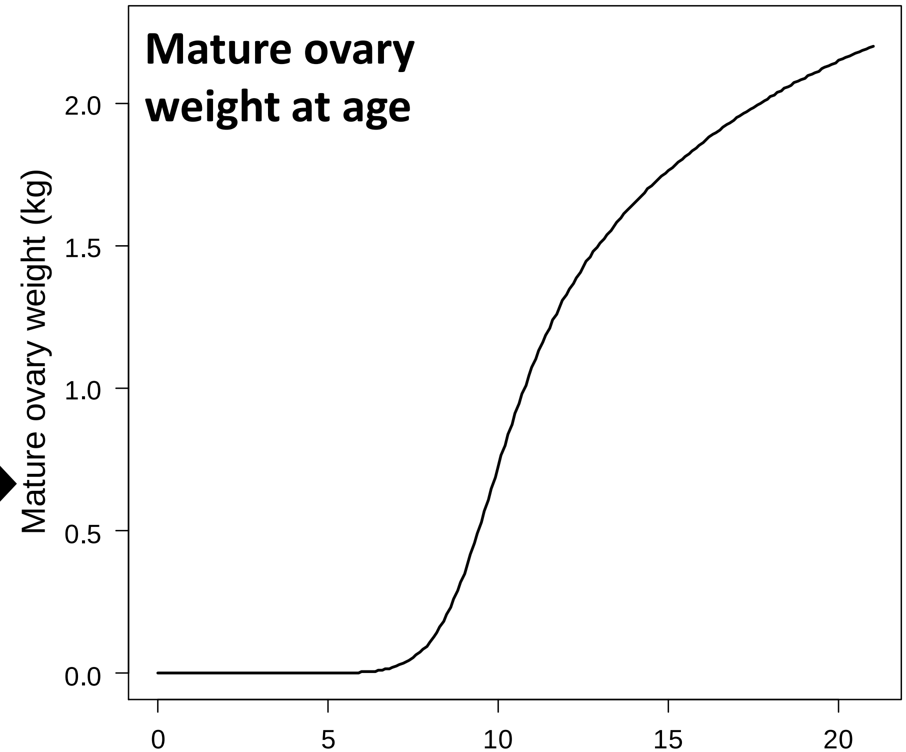
- Maturity
- Ovary weight



# Simulating roe yield

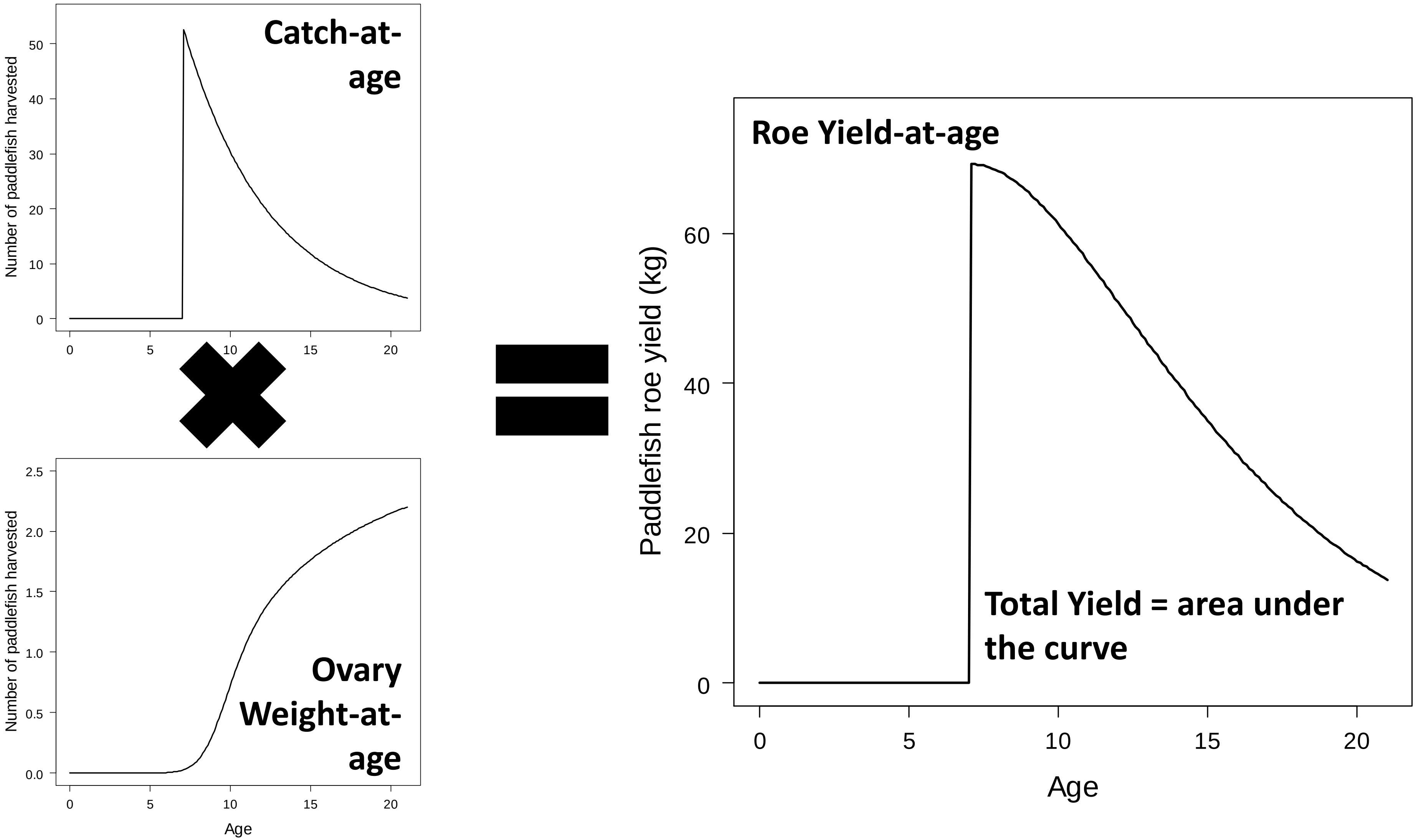


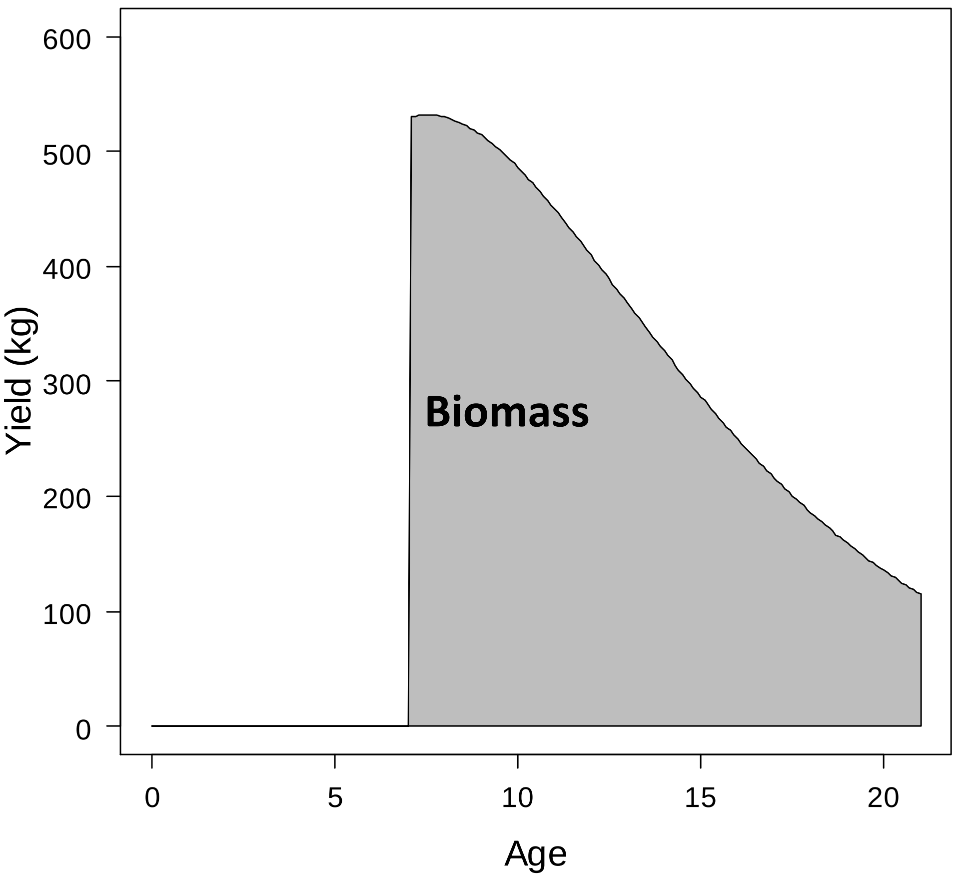

$$W_{ovary}(t) = 0.6 \bullet \left( \frac{e^{-27.78+0.028 \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (t+1.527)})}}{e^{-27.78+0.028 \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (t+1.527)})} + 1} \right) \bullet \left(0.0000014 \bullet (1{,}279 \bullet (1 - e^{-0.131 \bullet (t+1.527)})^{3.0529}\right)$$

# Finally…roe yield!

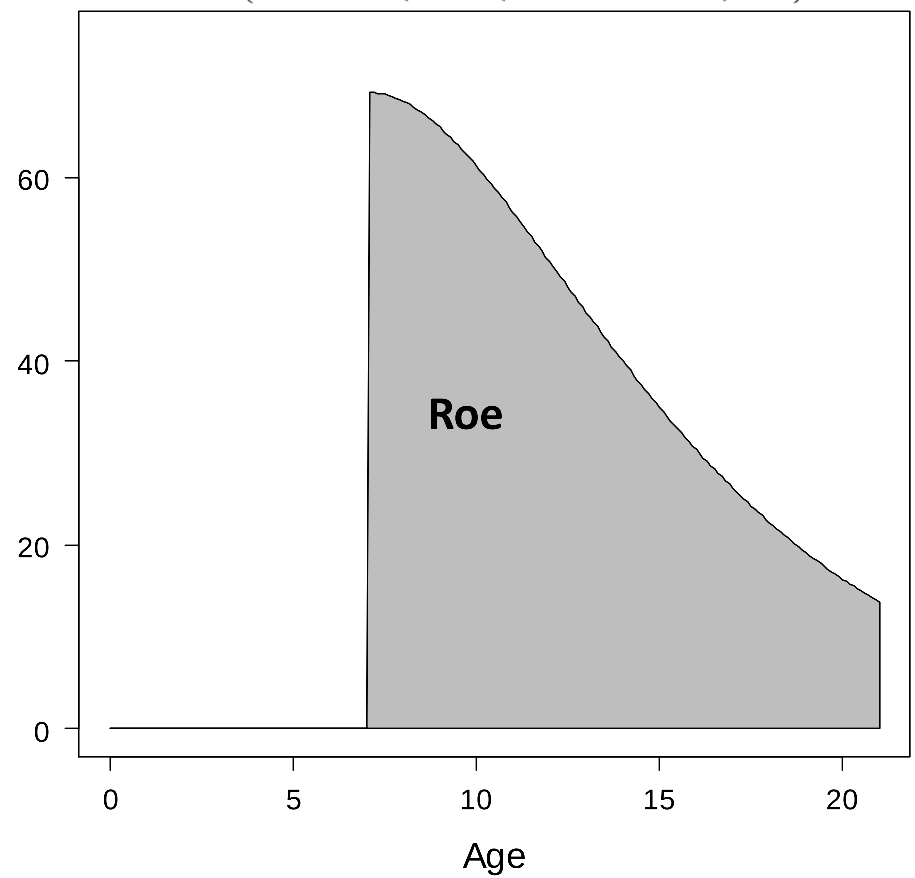


# Finally…yield!

$$Y_{fish} = \int_{t_r}^{t_\lambda} F \bullet R \bullet e^{-(M \bullet t_r)} \bullet e^{-(M+F) \bullet (t-t_r)} \bullet 10^{-5.71} \bullet \left(1{,}279 \bullet \left(1 - e^{-0.131 \bullet (t+1.527)}\right)\right)^{3.307} \bullet dt$$




$$Y_{roe} = \int_{t_r}^{t_\lambda} F \bullet R \bullet e^{-(M \bullet t_r)} \bullet e^{-(M+F) \bullet (t-t_r)} \bullet 0.6 \bullet \left(\frac{e^{-27.78+0.028 \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (t+1.527)})}}{e^{-27.78+0.028 \bullet (1{,}279 \bullet (1-e^{-0.131 \bullet (t+1.527)})} + 1}\right) \bullet \left(0.0000014 \bullet (1{,}279 \bullet (1 - e^{-0.131 \bullet (t+1.527)})^{3.0529}\right) \bullet dt$$



# Predicting total yield

Analytical?

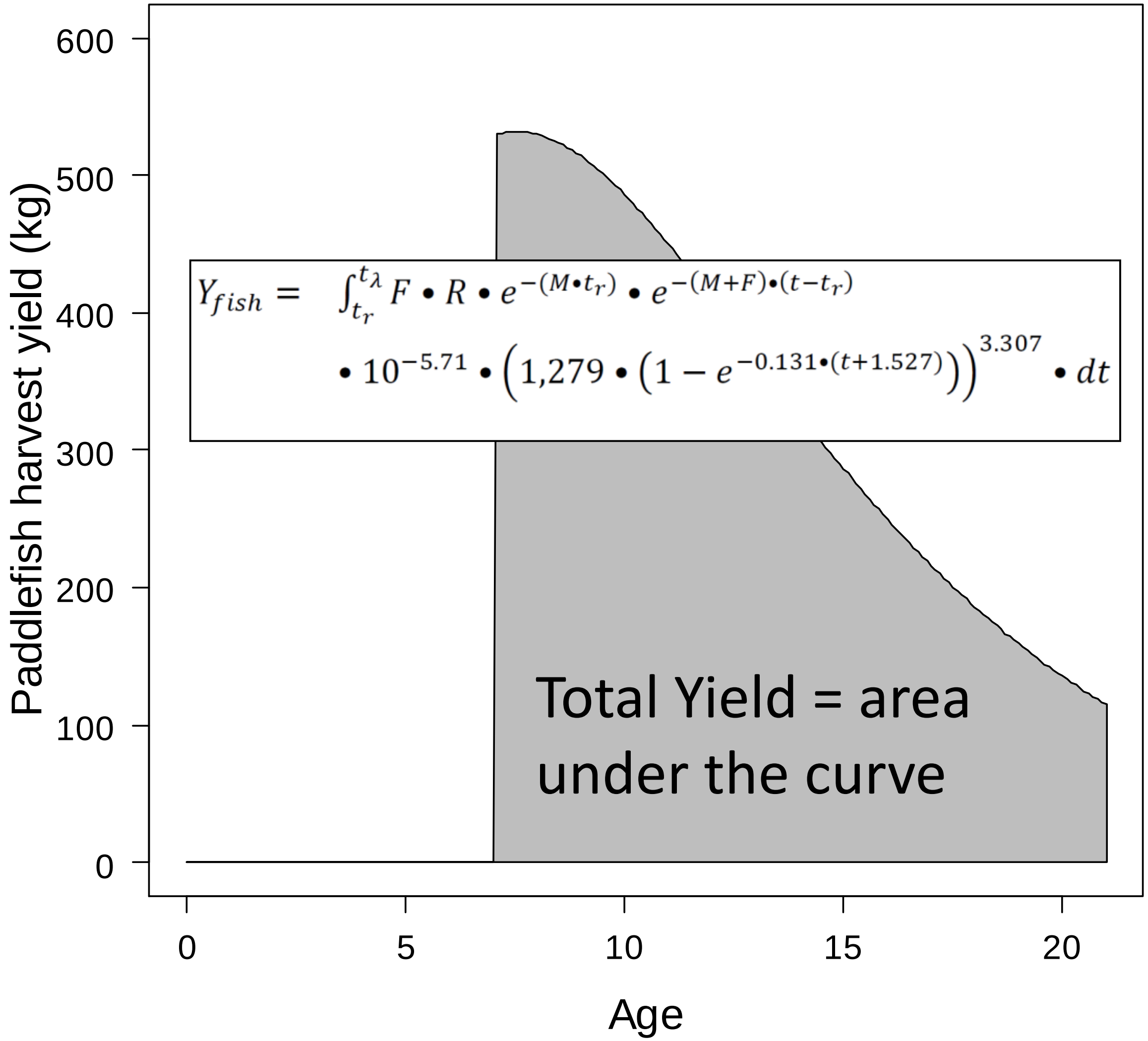
Approximate?

Jones (1957)

– Incomplete β function

— FAST

— FAMS

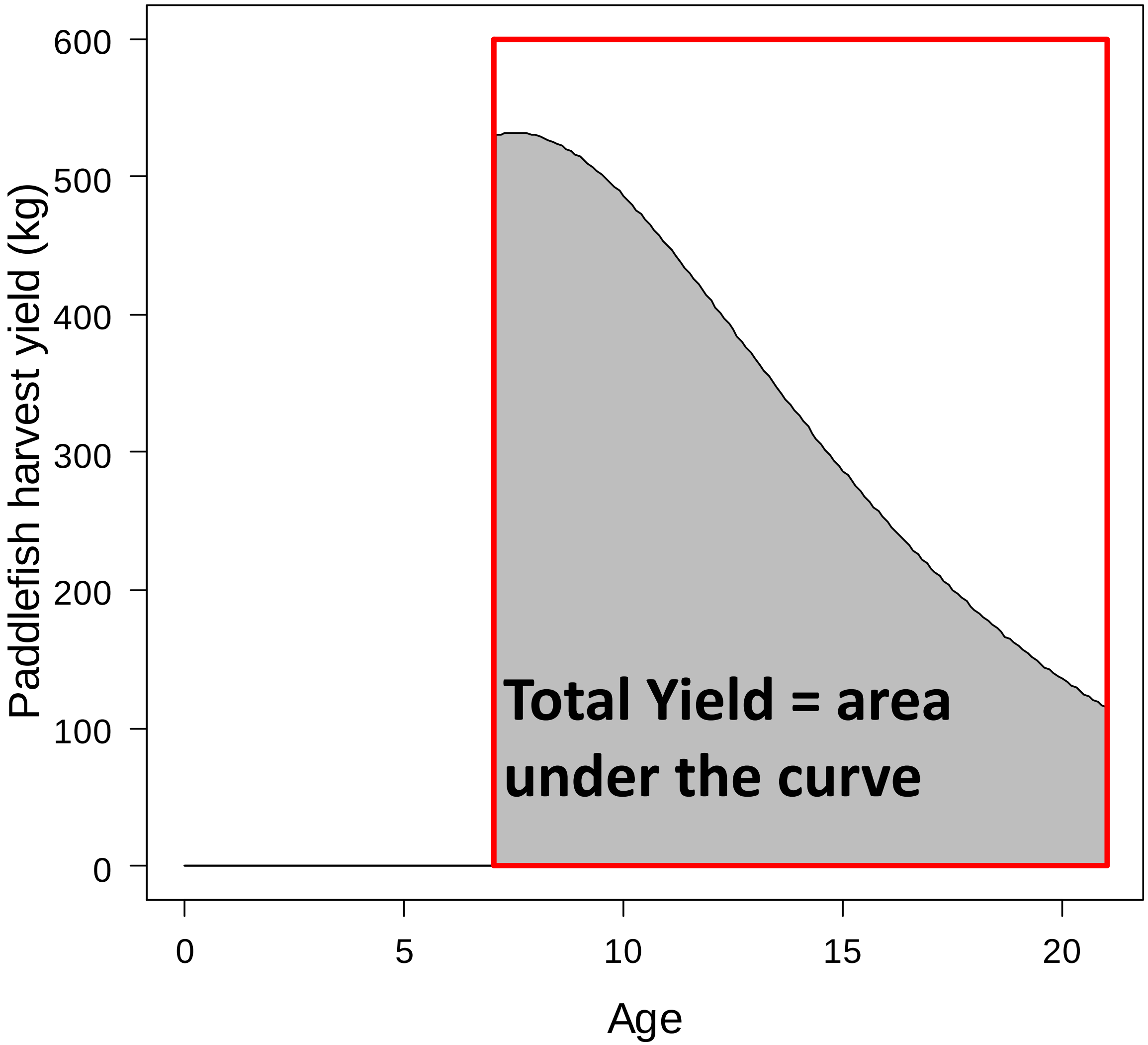



$$Y_{fish} = \int_{t_r}^{t_\lambda} F \bullet R \bullet e^{-(M \bullet t_r)} \bullet e^{-(M+F)\bullet(t-t_r)} \bullet 10^{-5.71} \bullet \left(1{,}279 \bullet \left(1 - e^{-0.131\bullet(t+1.527)}\right)\right)^{3.307} \bullet dt$$

# Numerical approaches

Box the region

- Age recruited to fishery
- Maximum age
- Known area

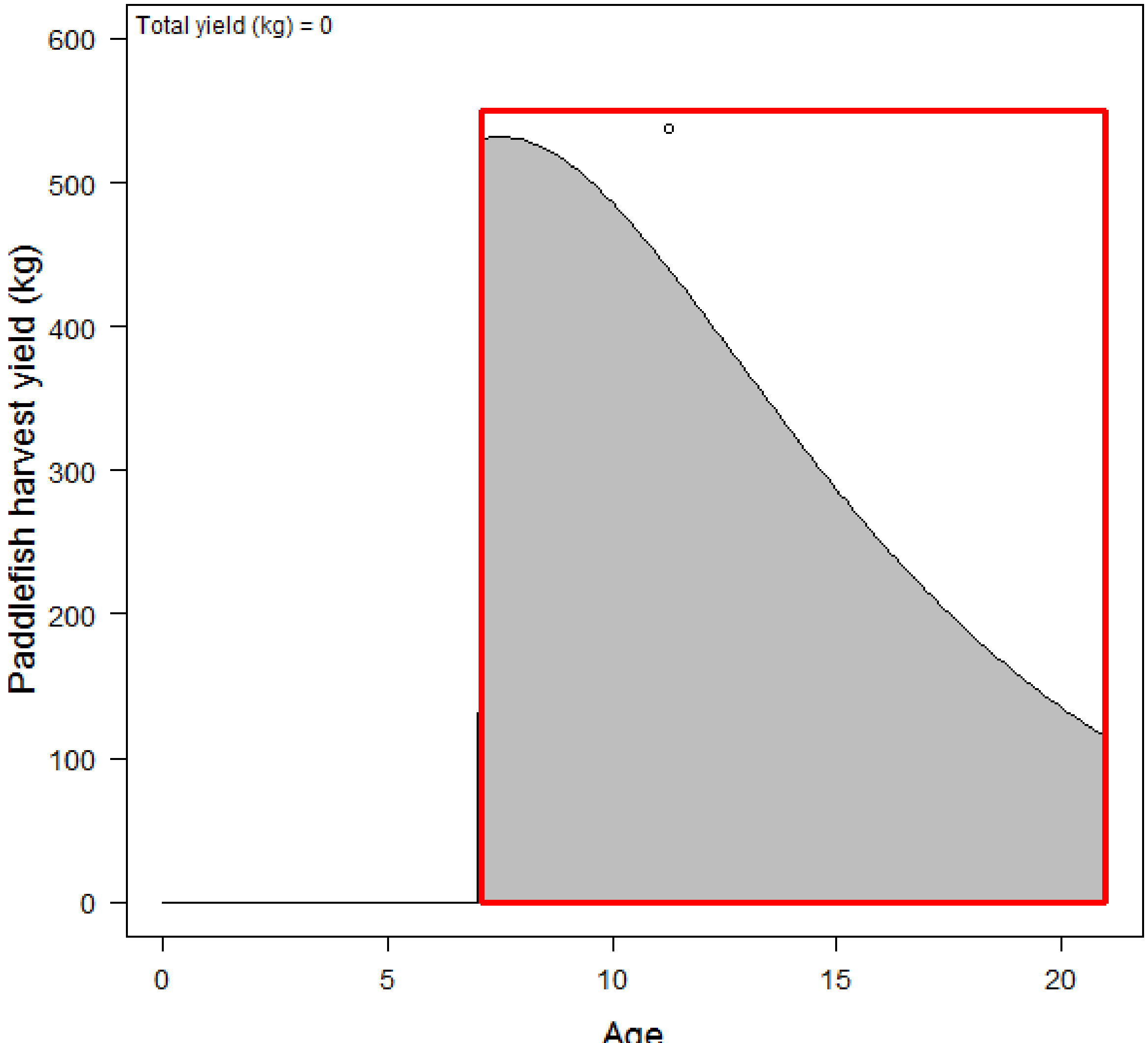


# Illustration of numerical integration

Monte Carlo numerical integration

- Do for many random draws within box

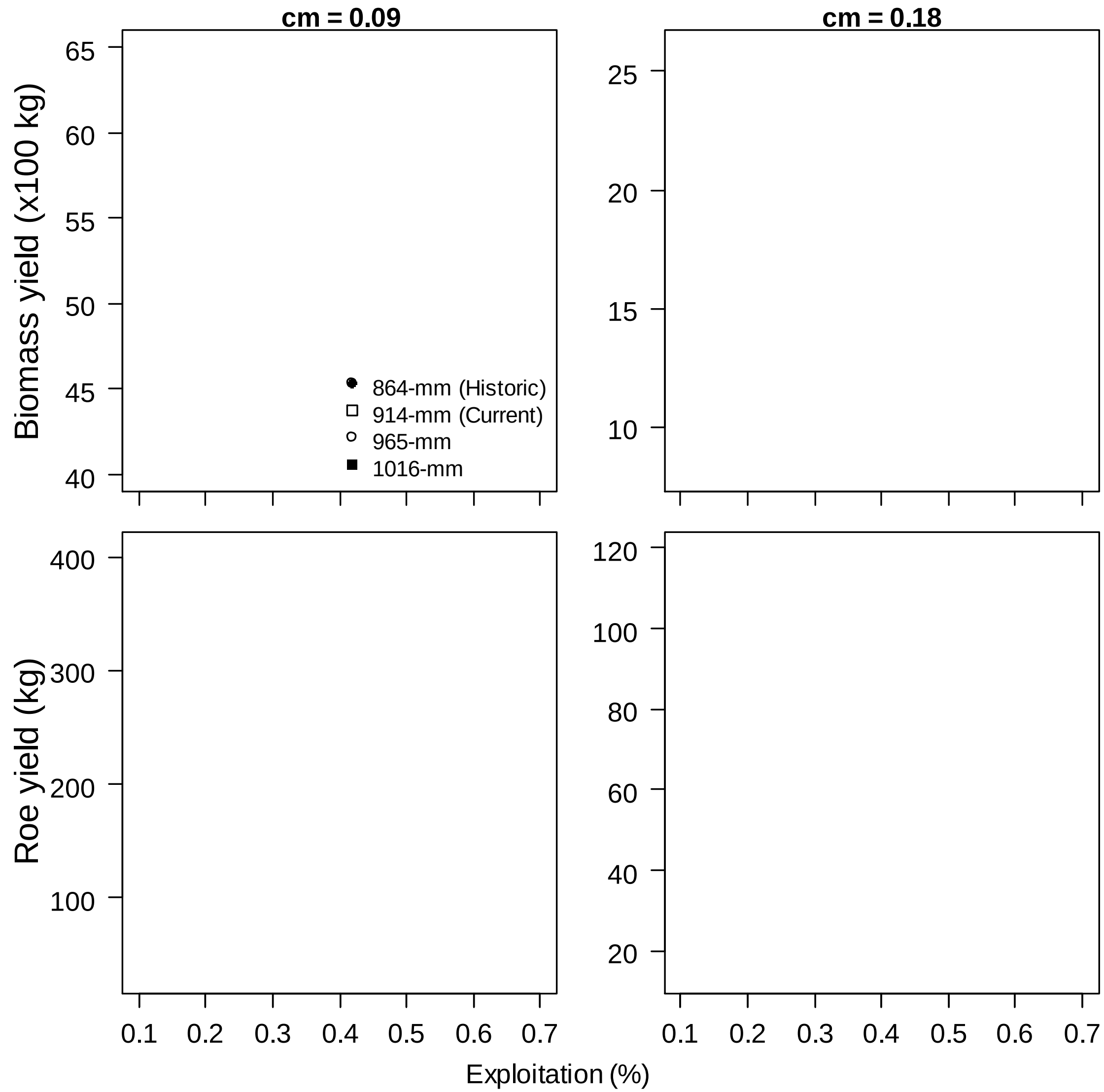
- Very Flexible



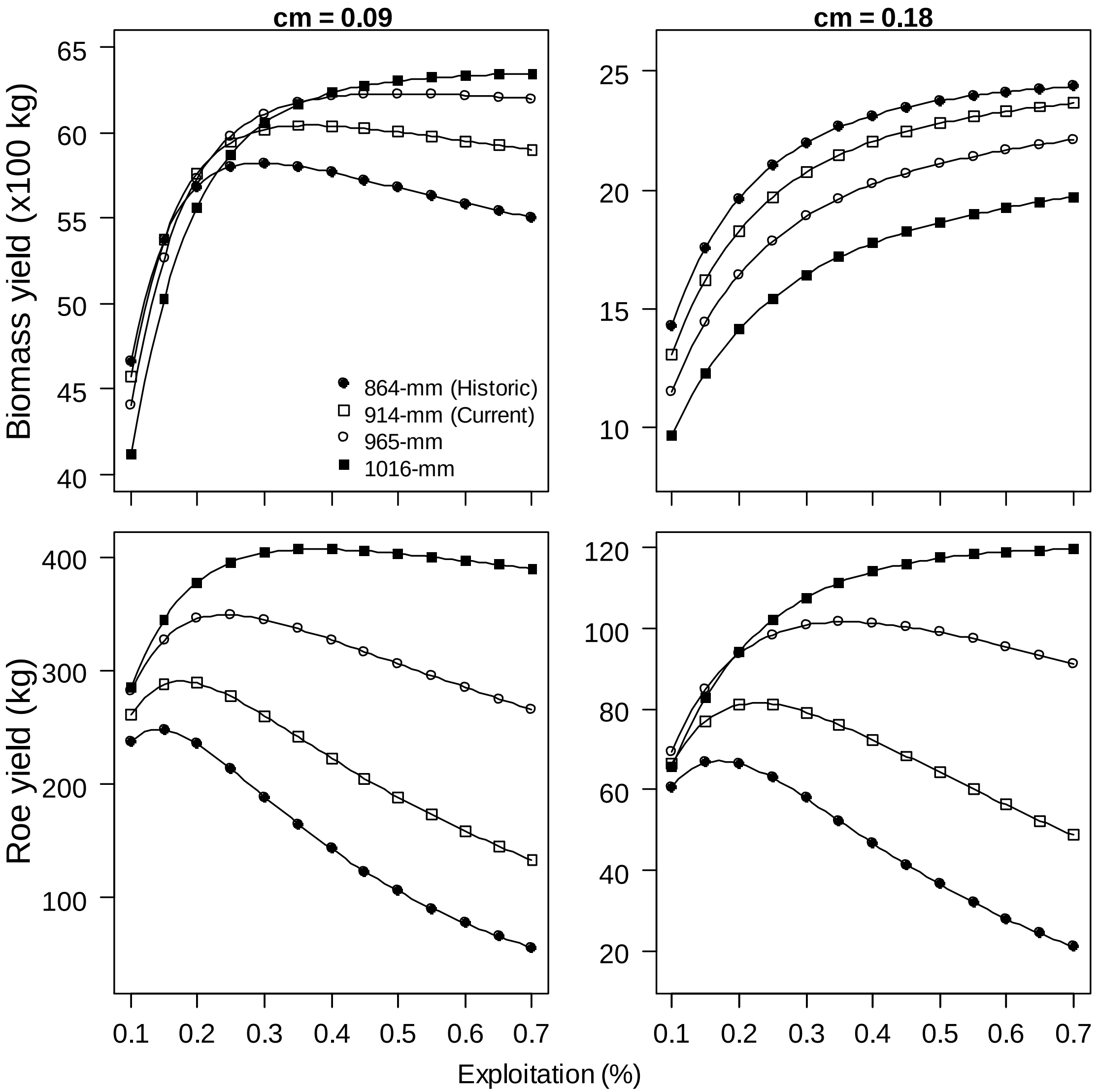
# Predicted biomass and roe yields

Varying:

- Exploitation
- Natural Mortality
- Length limit



# Predicted biomass and roe yields



# Key points

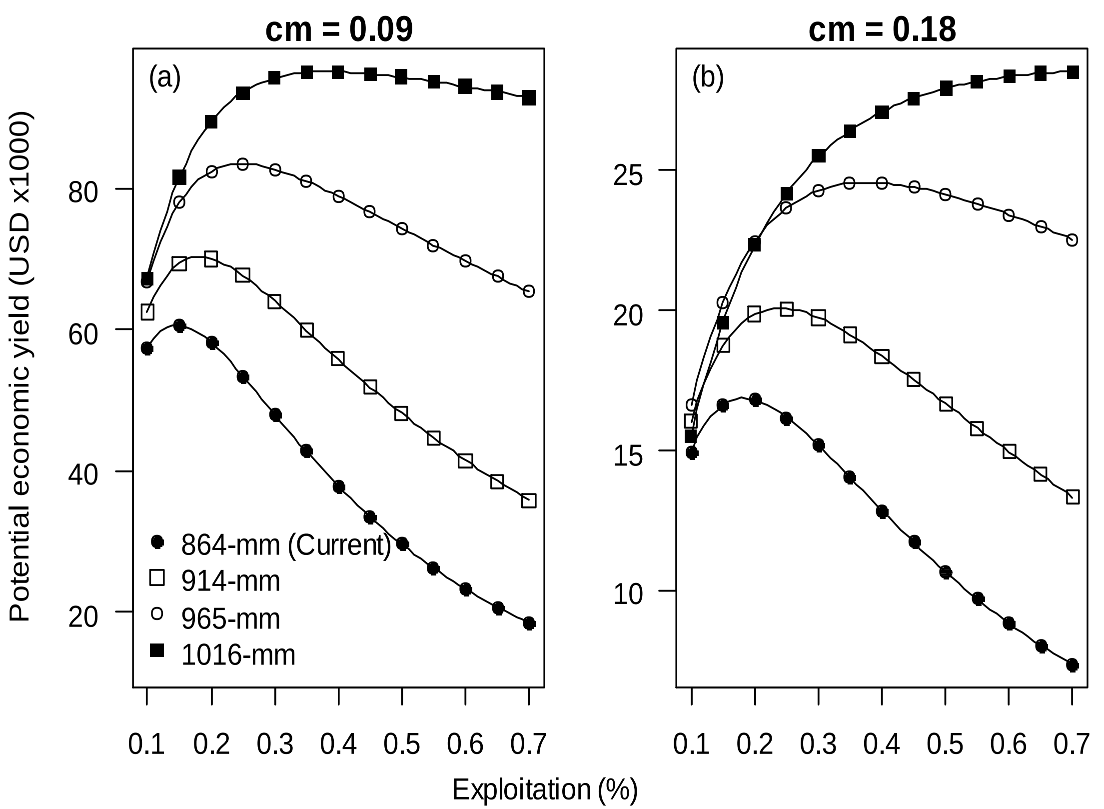
- Growth overfishing (roe)
  - Occurs at **<u>lower</u>** exploitation rates
  - **<u>More severe</u>** in terms of roe
  - Suggests higher minimum length limits
- Less sensitive to uncertainty to natural mortality

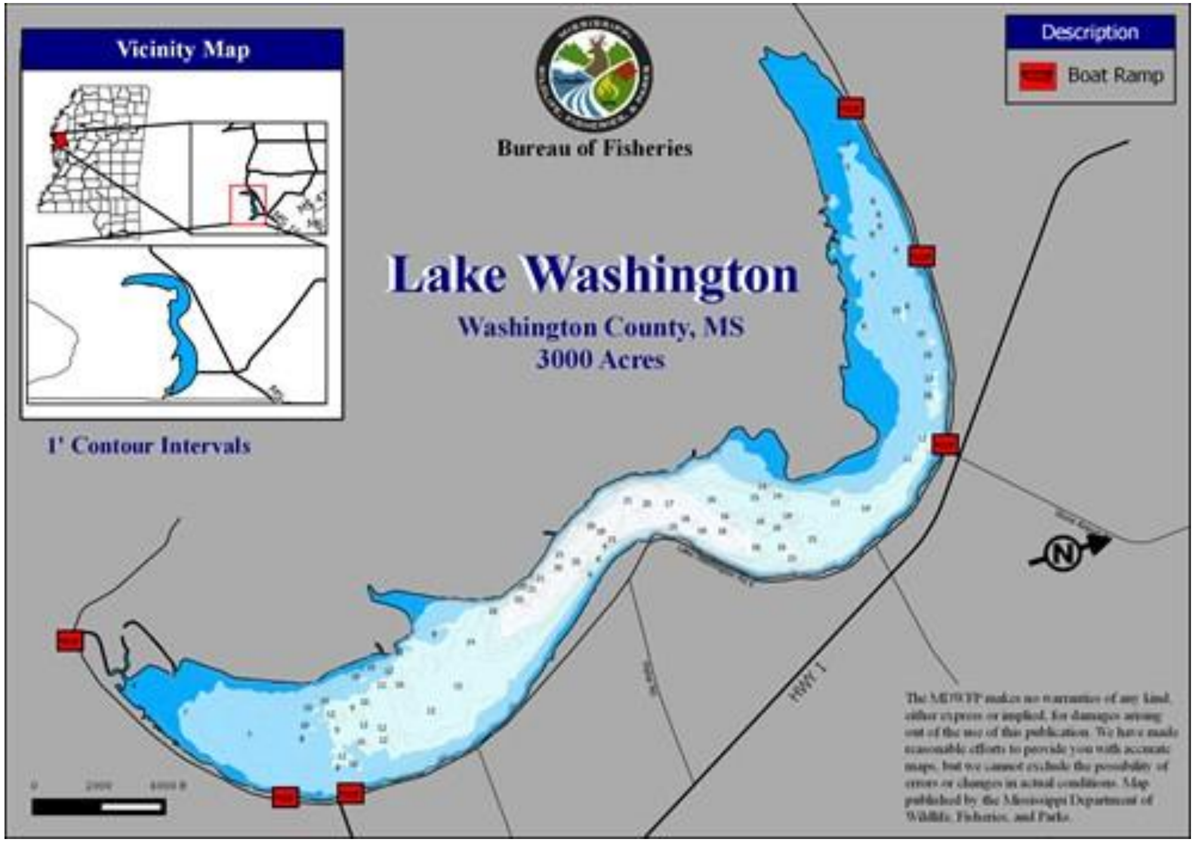
*Multiple tissue harvest?*


# Multiple tissue harvest

Economic yield

- Roe (200 $/ounce)
- Flesh (1 $/pound)
- Domestic culture?

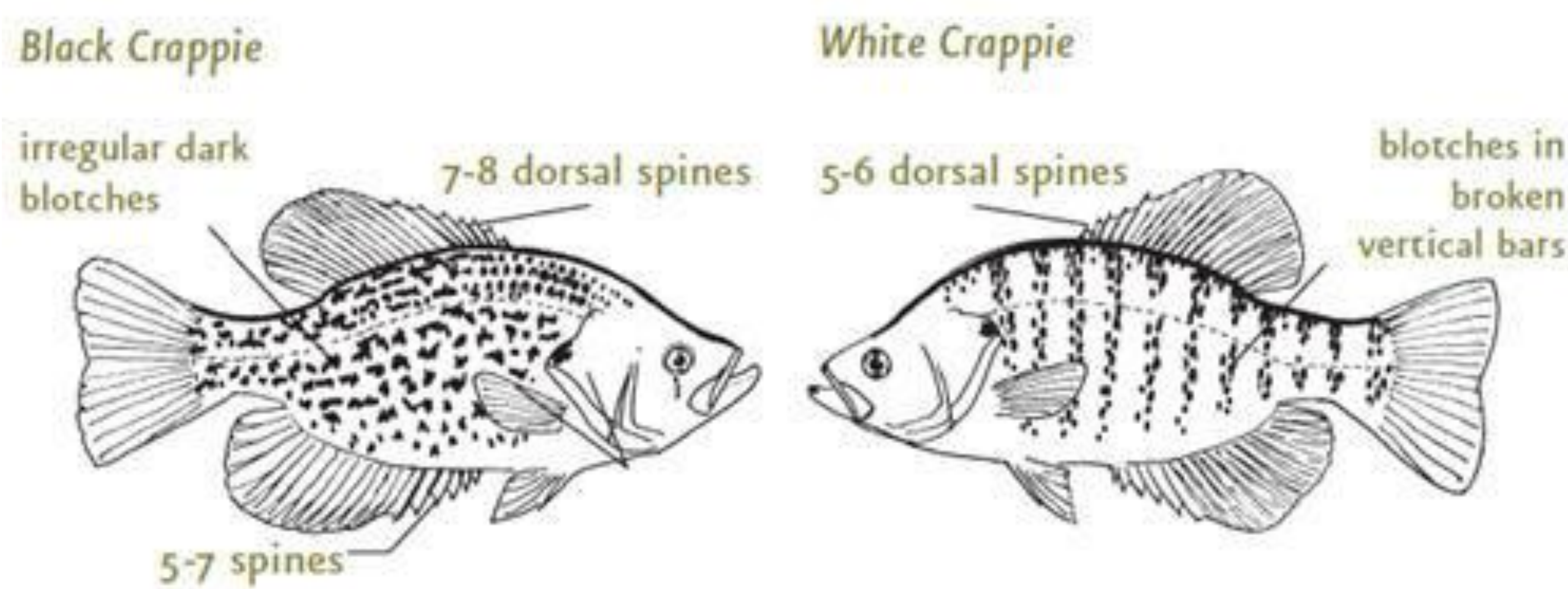



# MANAGEMENT CASE STUDY
# LAKE WASHINGTON CRAPPIE HARVEST

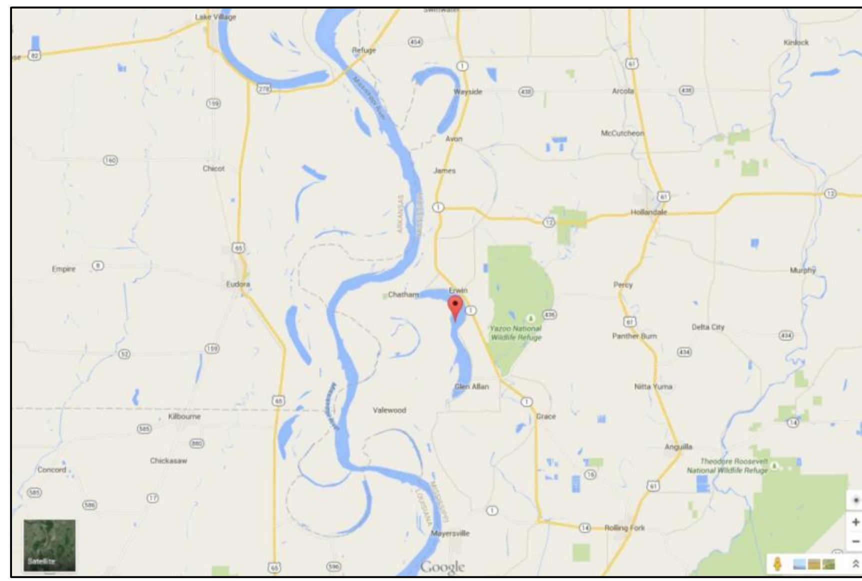
# Species Description

- Black and White Crappie
- Managed as one species



# Study Area

- 25 miles from Greenville MS in Washington County
- One of state's largest natural lakes (5,000 acres)
- World renowned crappie fishing



# Current Regulations

- Minimum length limit was 10”
  - 30 fish bag limit
  - 5 fish under 10”

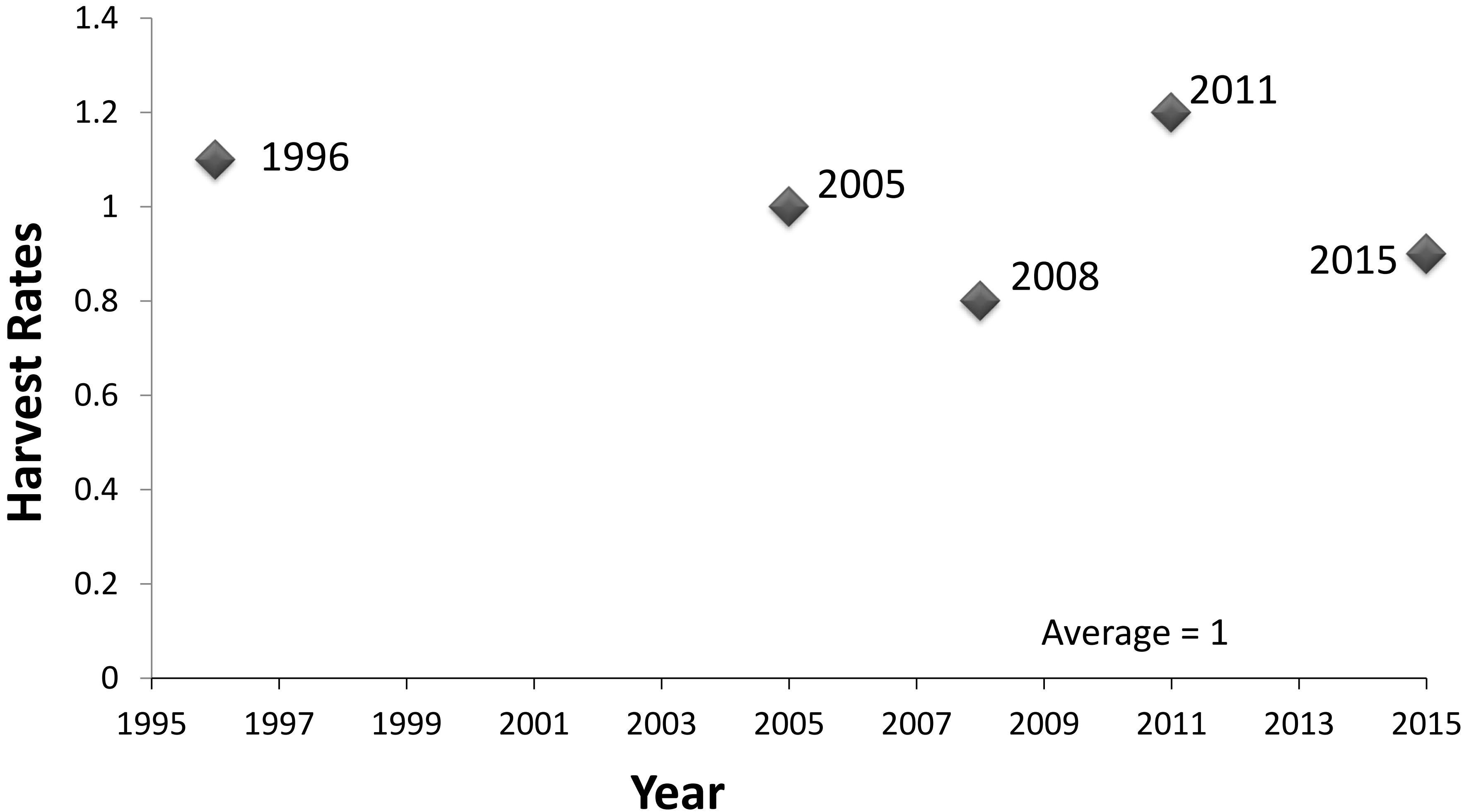
# “5 Under Rule”

- Anglers allowed to keep 5 crappie under 10” limit
- Most say they would keep an 8” or above fish
- Provides subsistence

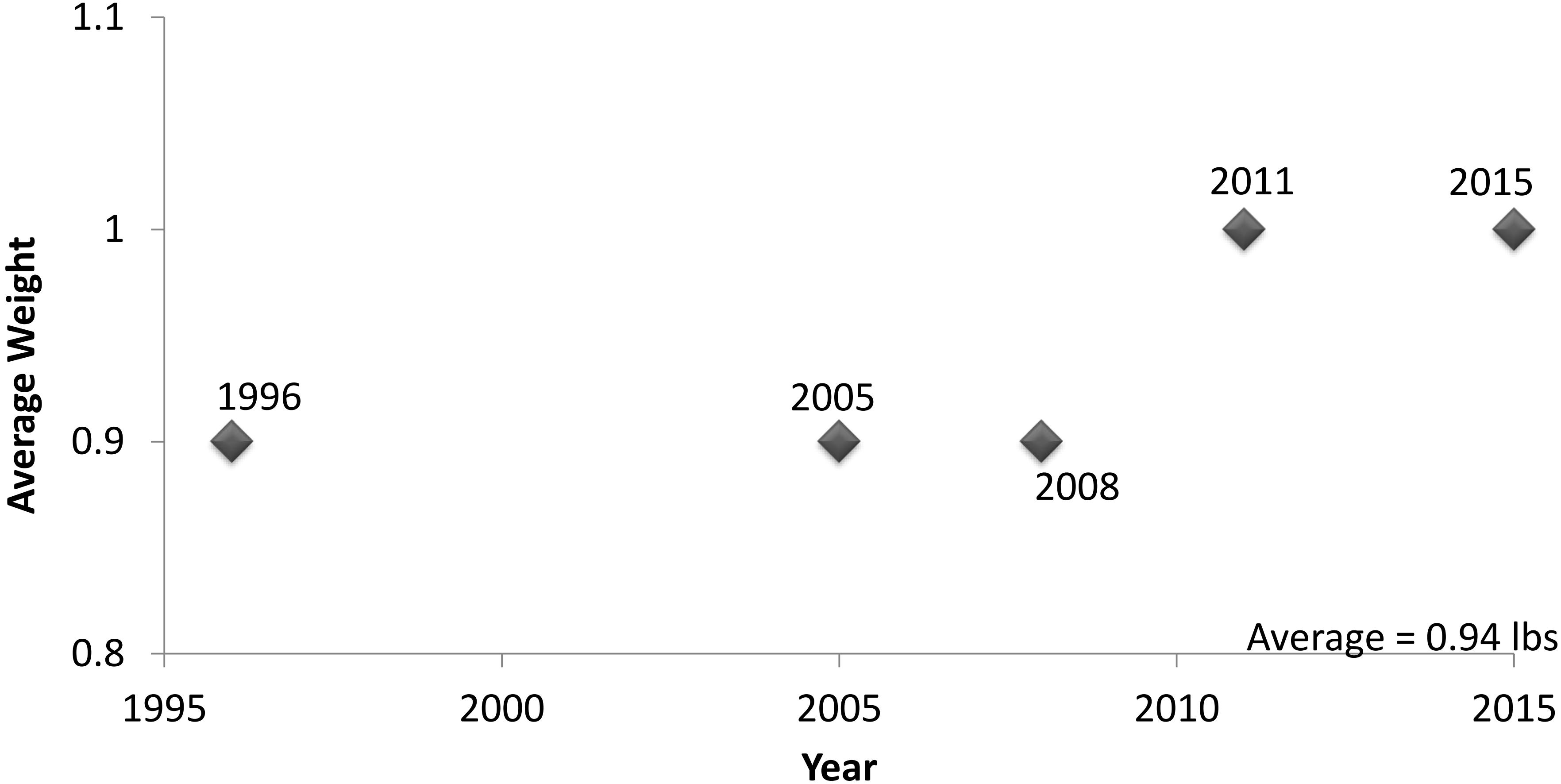
# What is the problem?

- 595 anglers sign petition
  - Increase length limit to 12”
  - Claimed catch rates and size had decreased
- Recreational anglers and subsistence anglers

# Harvest per Hour



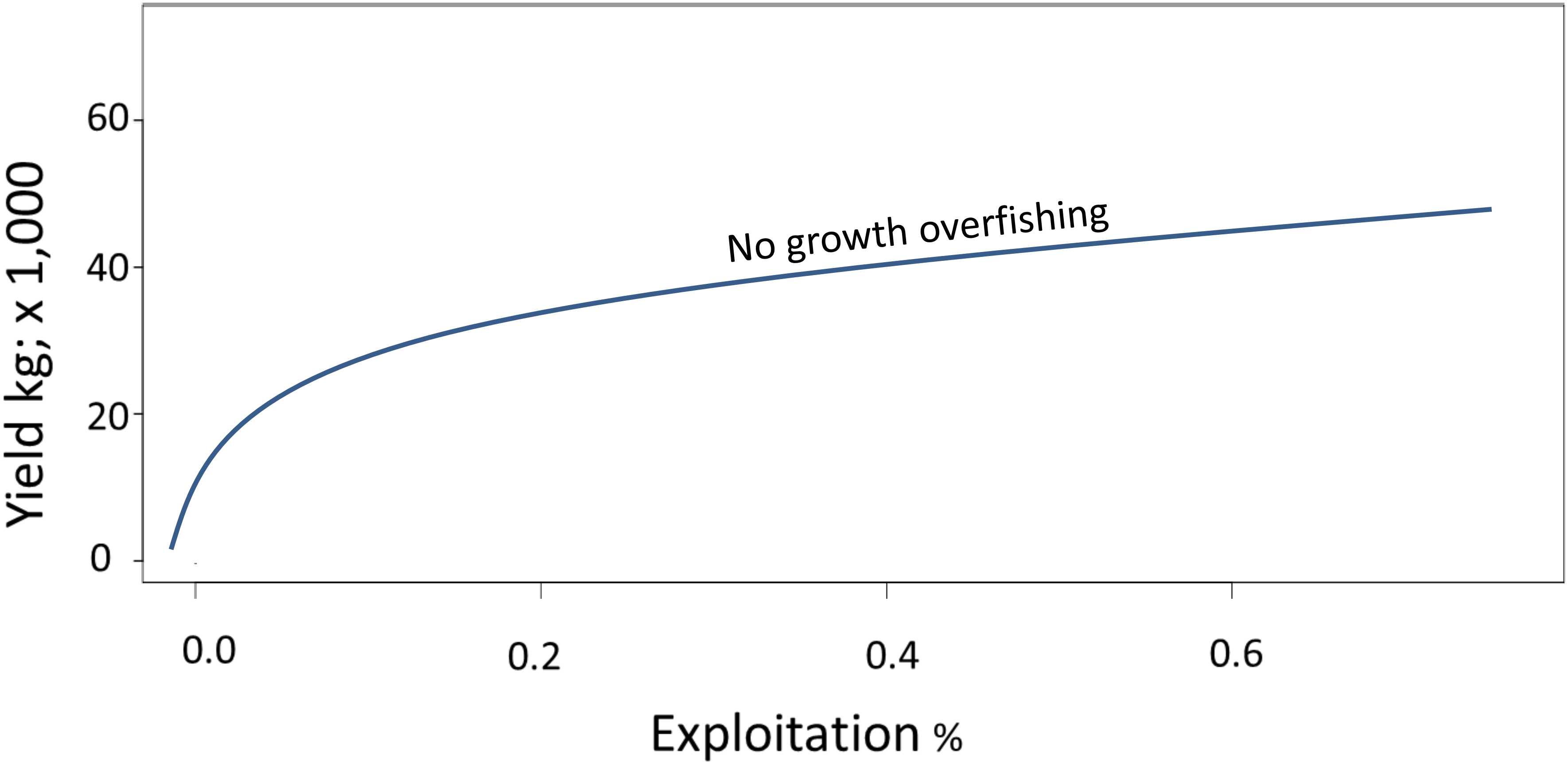
# Average Weight



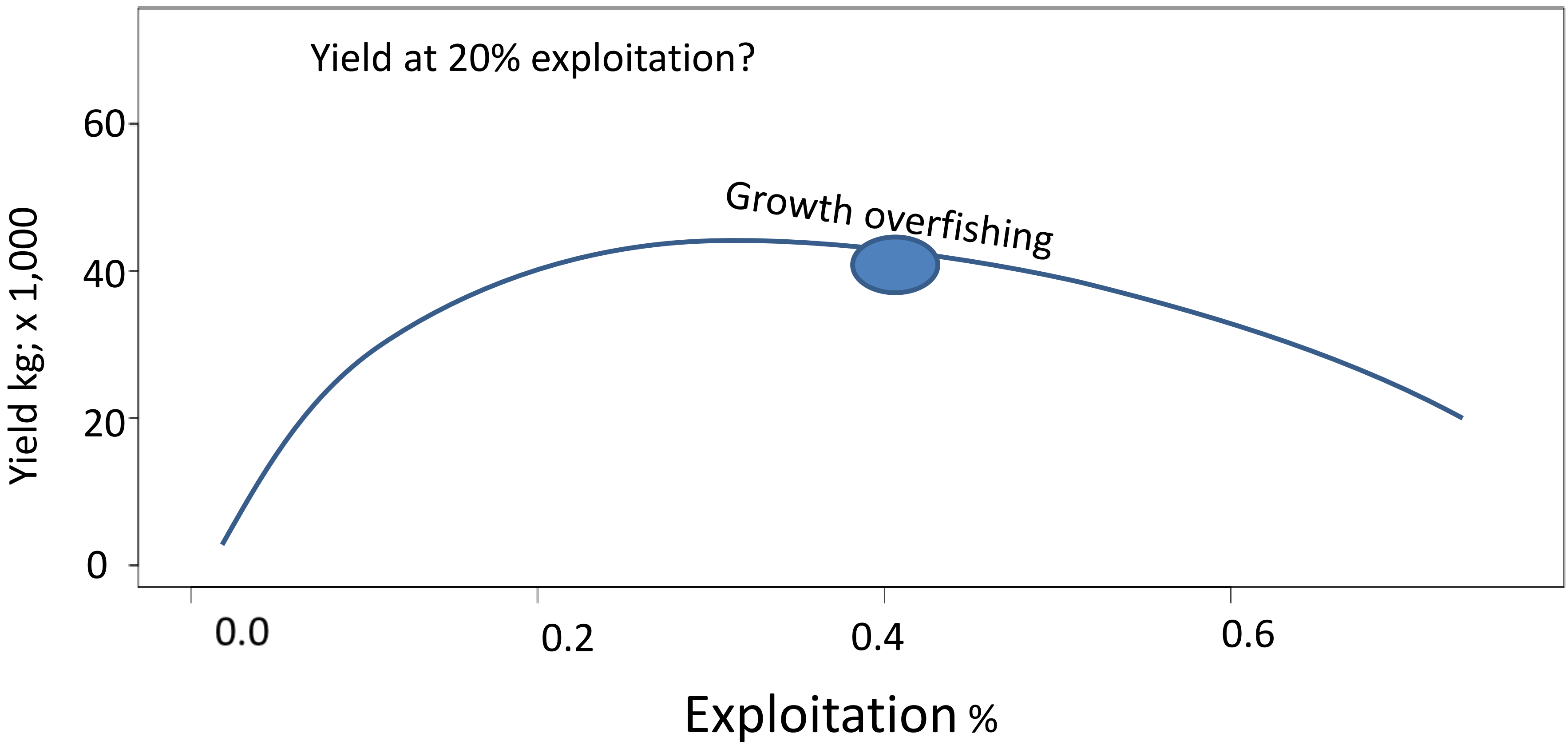
# Objectives

- Evaluate potential for growth overfishing at current and proposed length limits
- Evaluate at different mortality rates between 8” and MLL
  - “5 under” rule

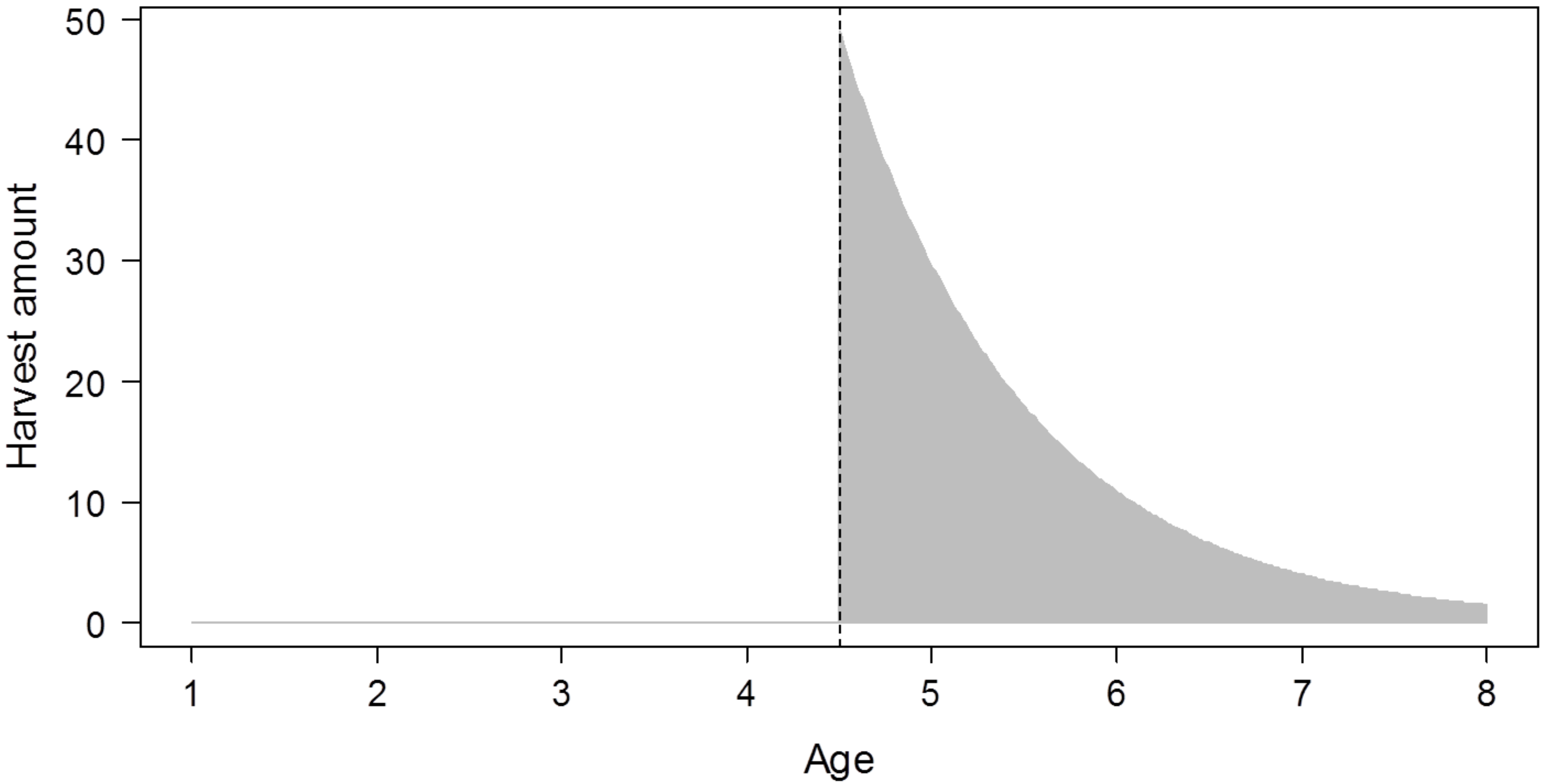
# What are we looking for?

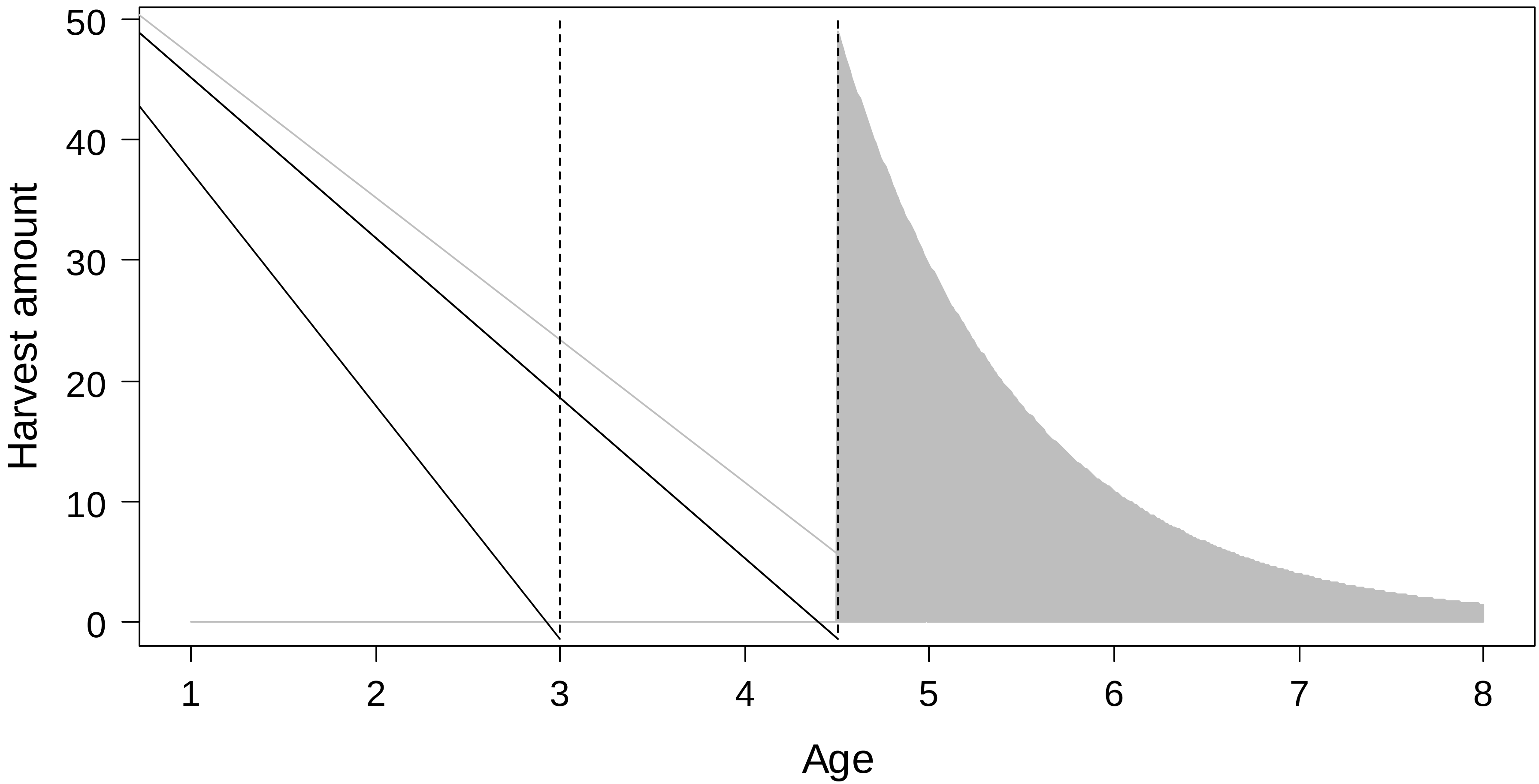


# What are we looking for?



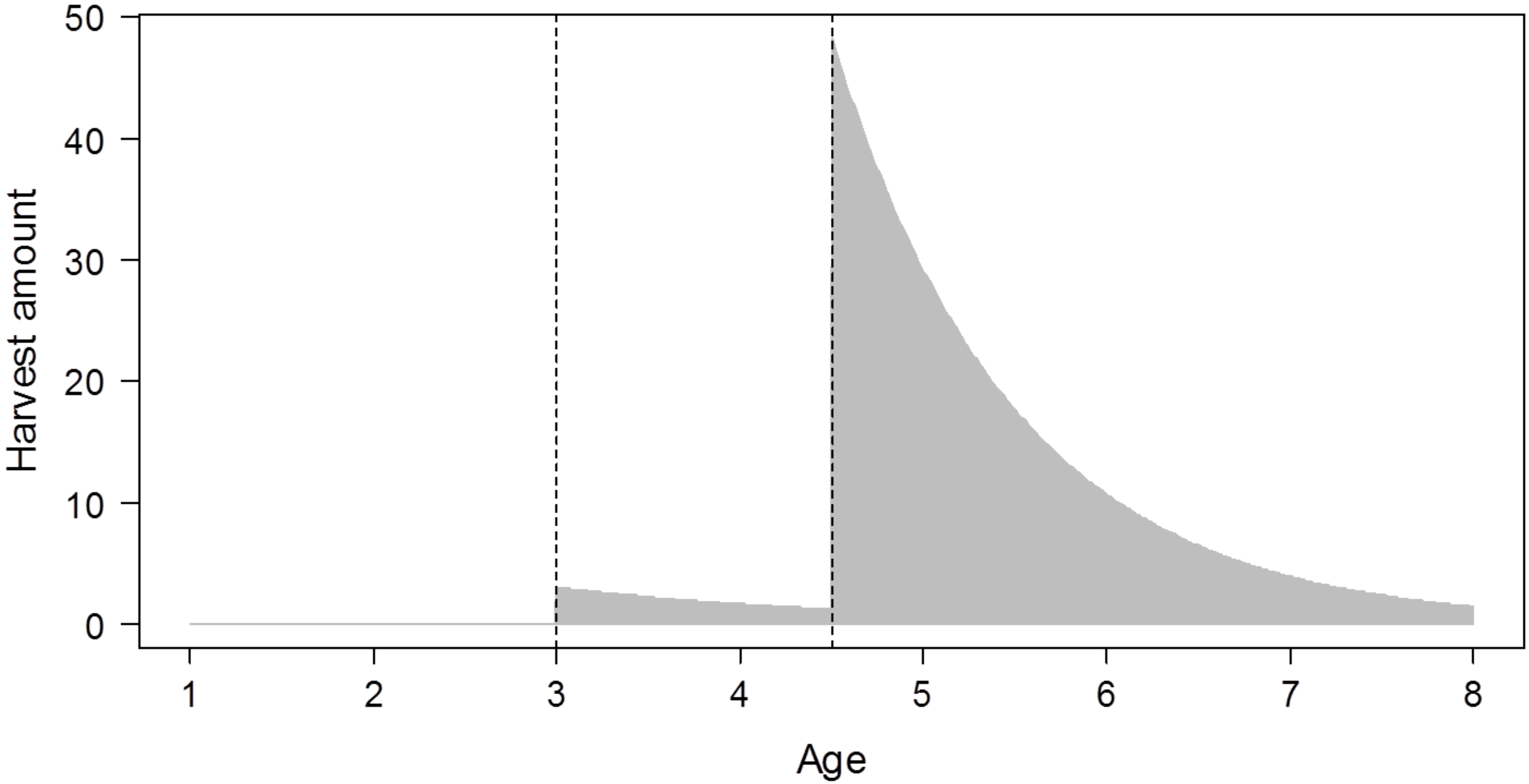
# Traditional YPR





50
40
30
20
10
0
Harvest amount
1
2
3
4
5
6
7
8
Age

# New and improved



# What we need?

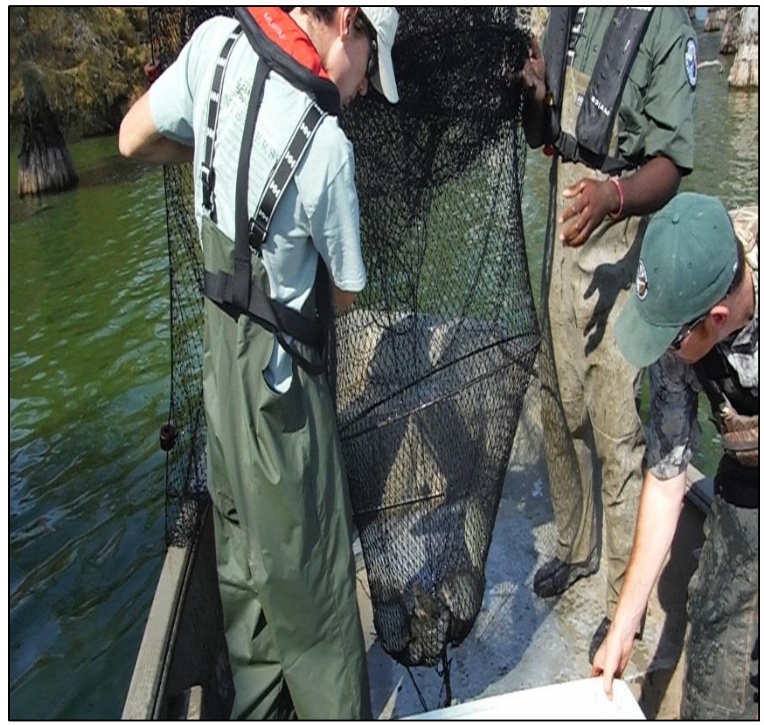
1. Mortality
2. Length Weight Relationship
3. VBGF (Age & Growth)
4. Yield per Recruit Models

# 1. Mortality

- 66% annual mortality
  - Weighted catch curve done in 2012
- 41% annual exploitation rate
  - 400 tagged fish > 10”

# 2. Lengths & Weights

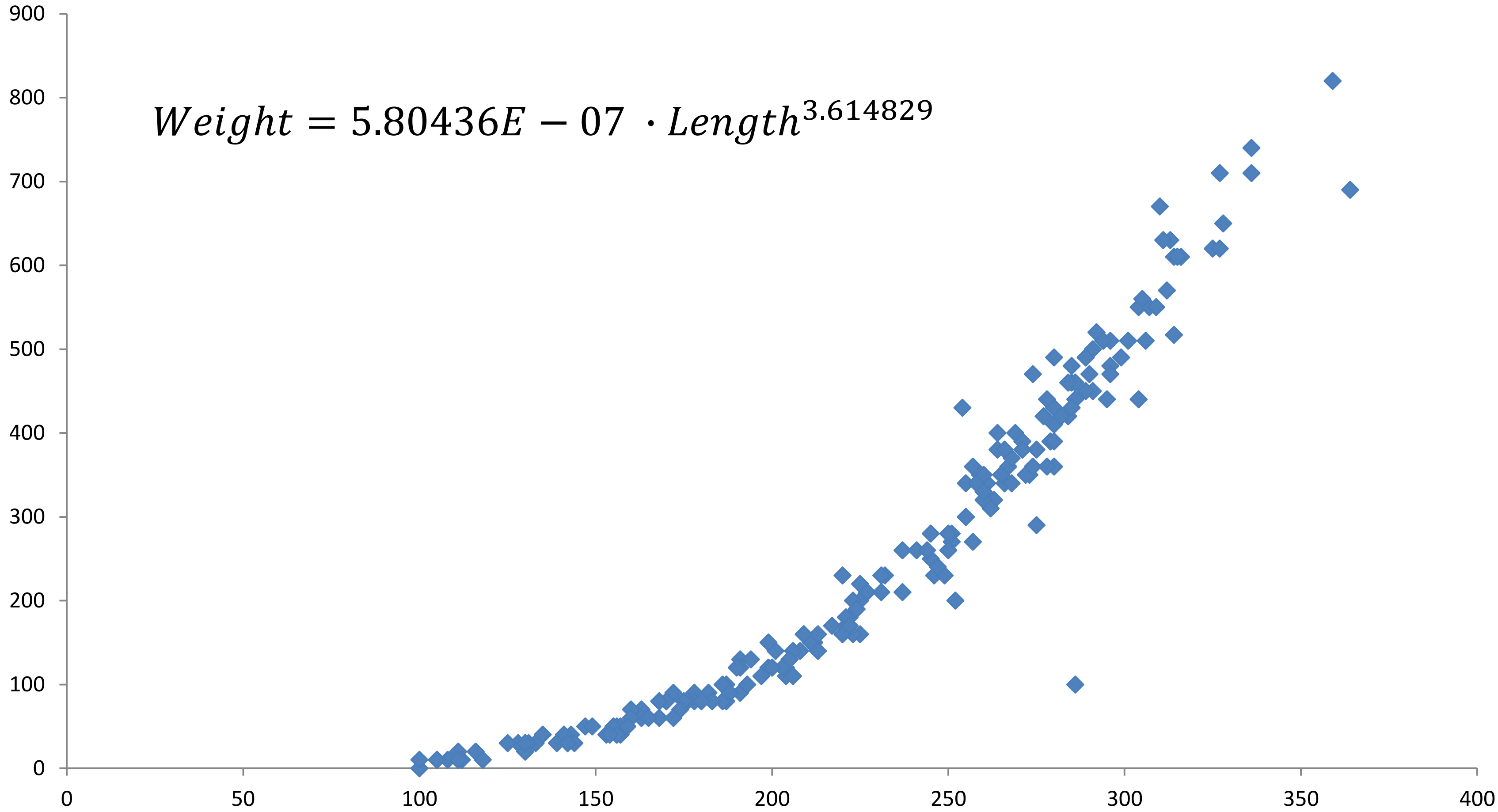
- Lead nets and trap nets
- 12 of each at 24 different locations



# 2. Lengths & Weights

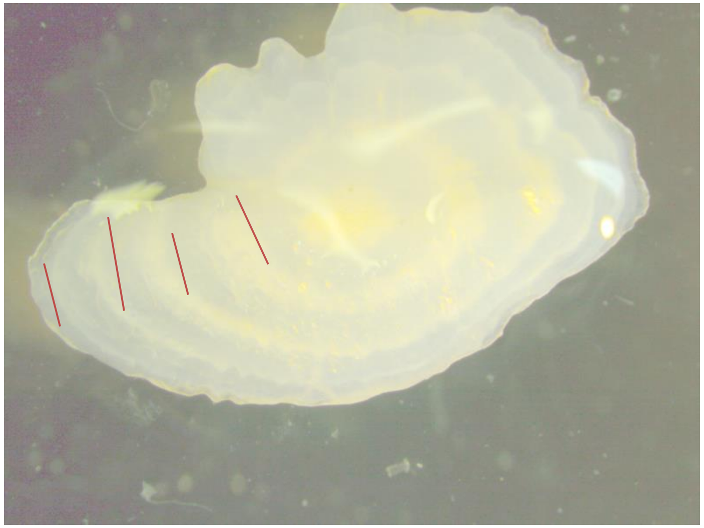
- Every fish caught was measured
- Species other than crappie were released
- 5 crappie from each cm bin kept to be weighed

# 2. Length-Weight Relationship

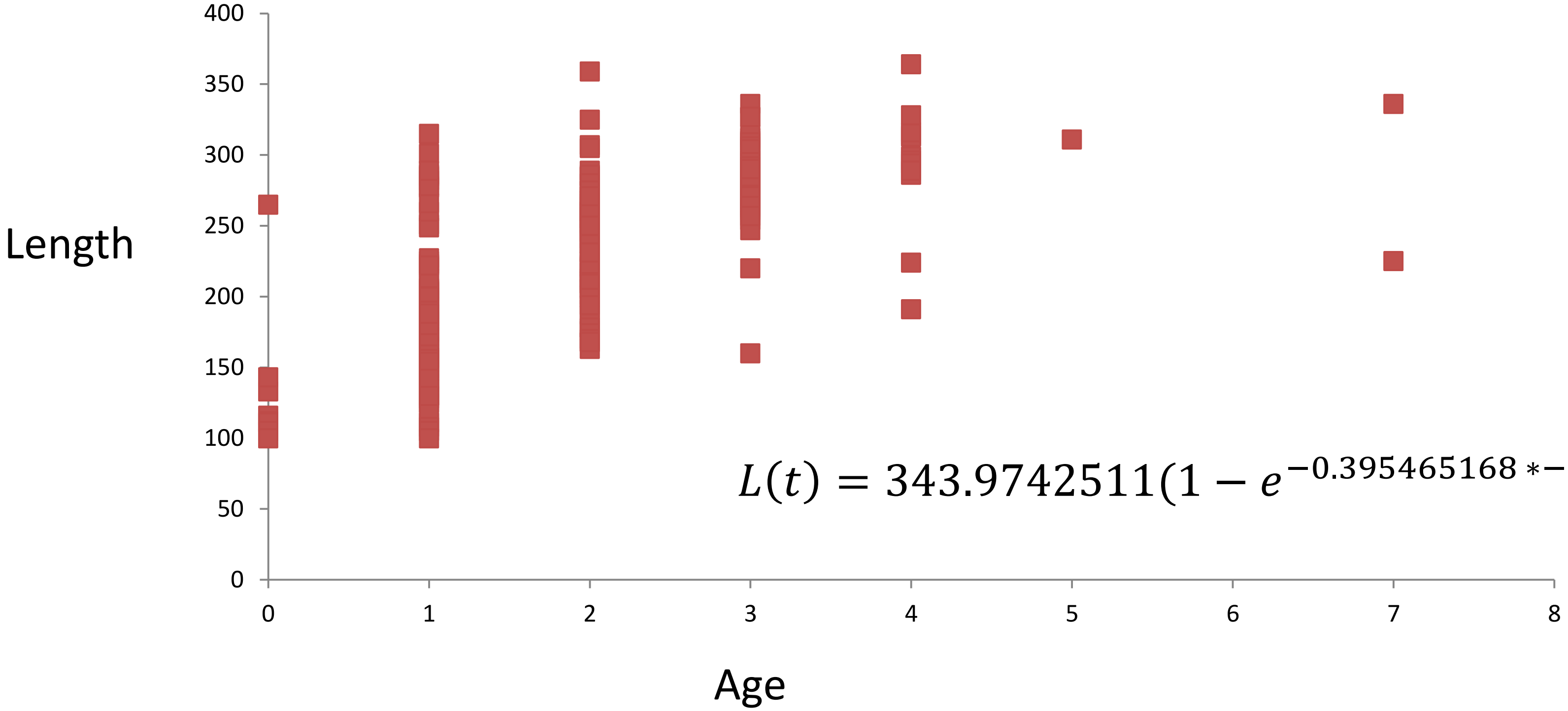


# 3. VBGF

- Aged by 2 technicians and consensus reach when a disagreement occurred
- Ages used to make VBGF



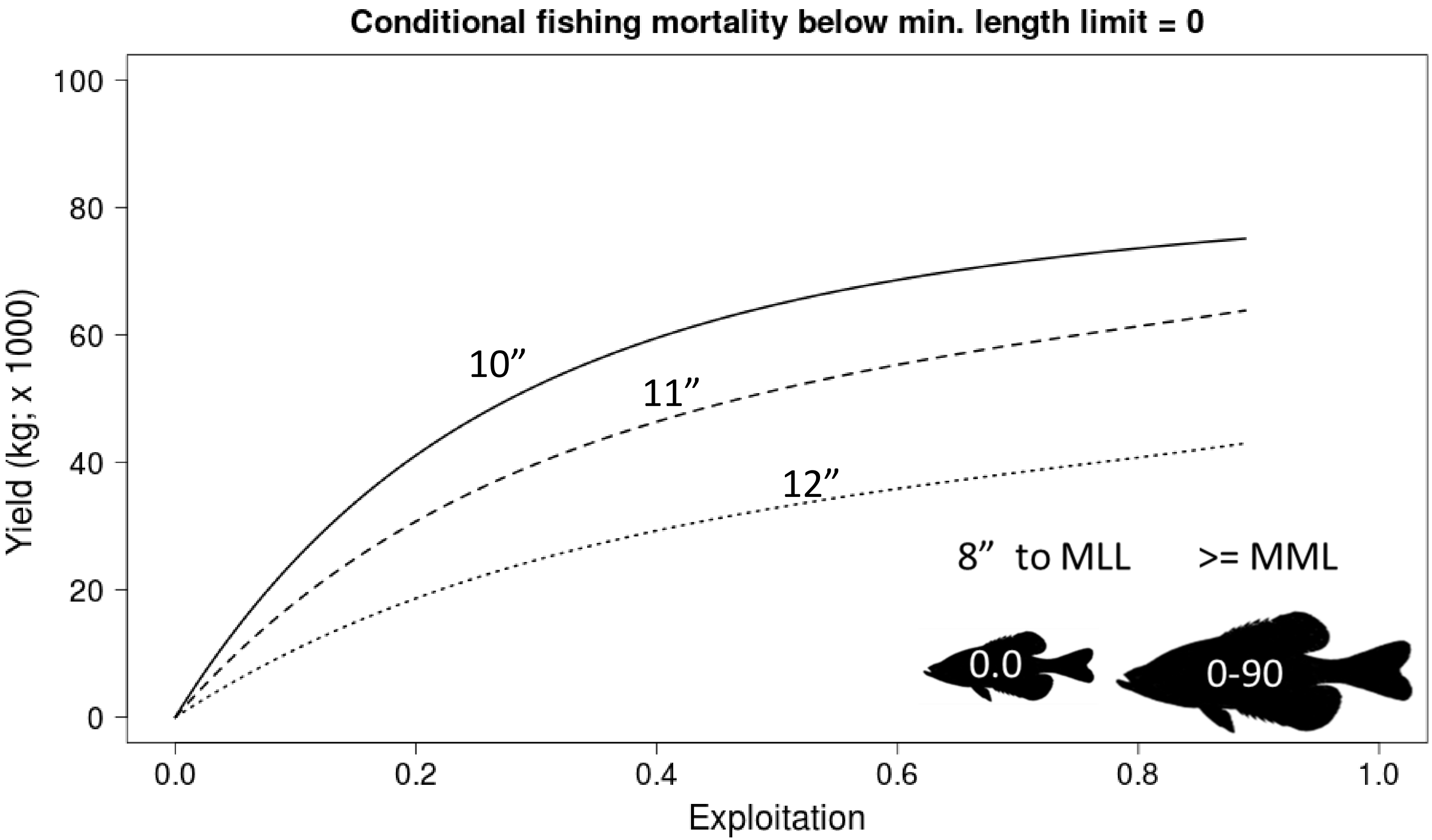
# VBGF



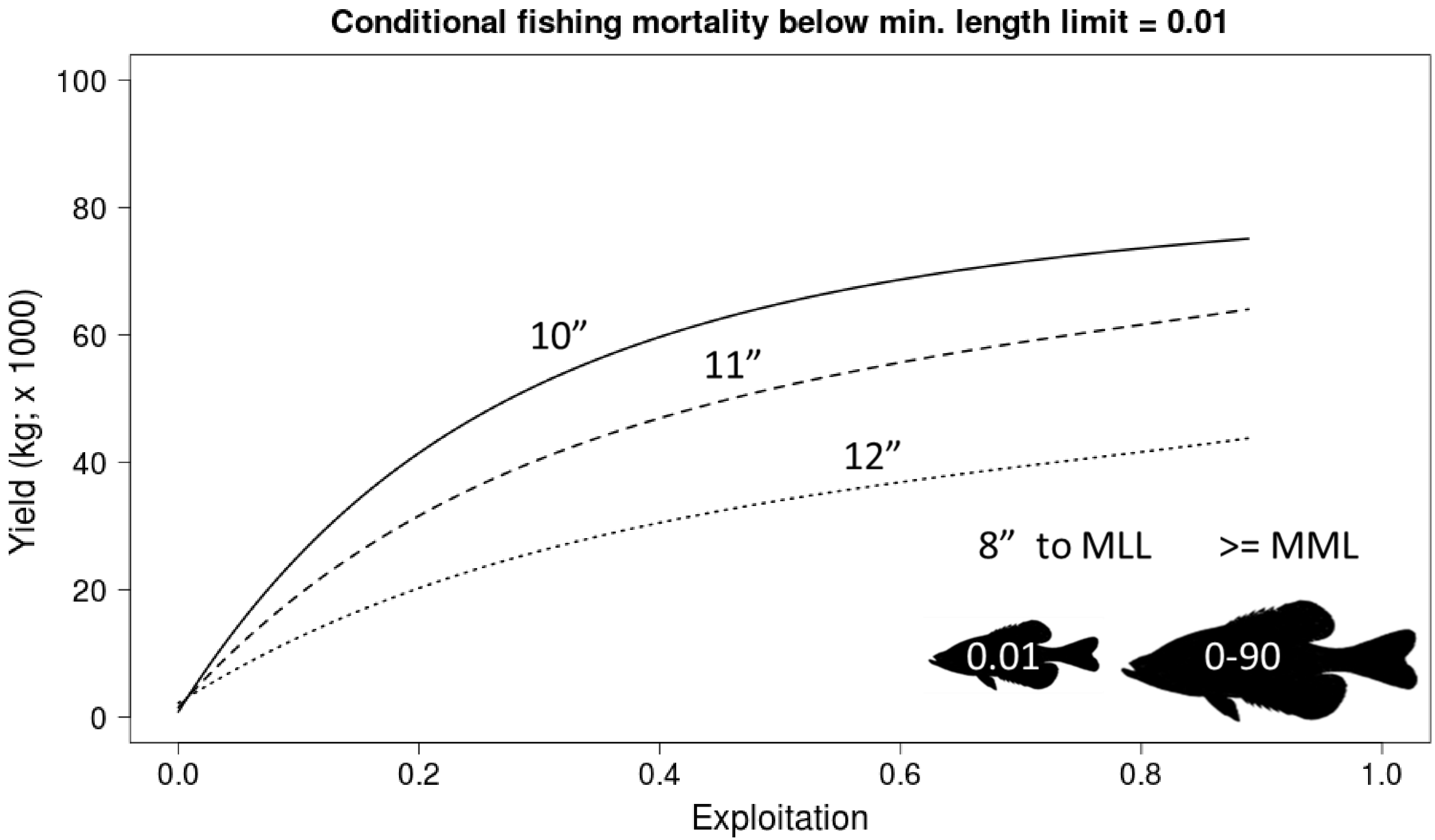

$$L(t) = 343.9742511(1 - e^{-0.395465168 * -1.025572642})$$

# 4. Models

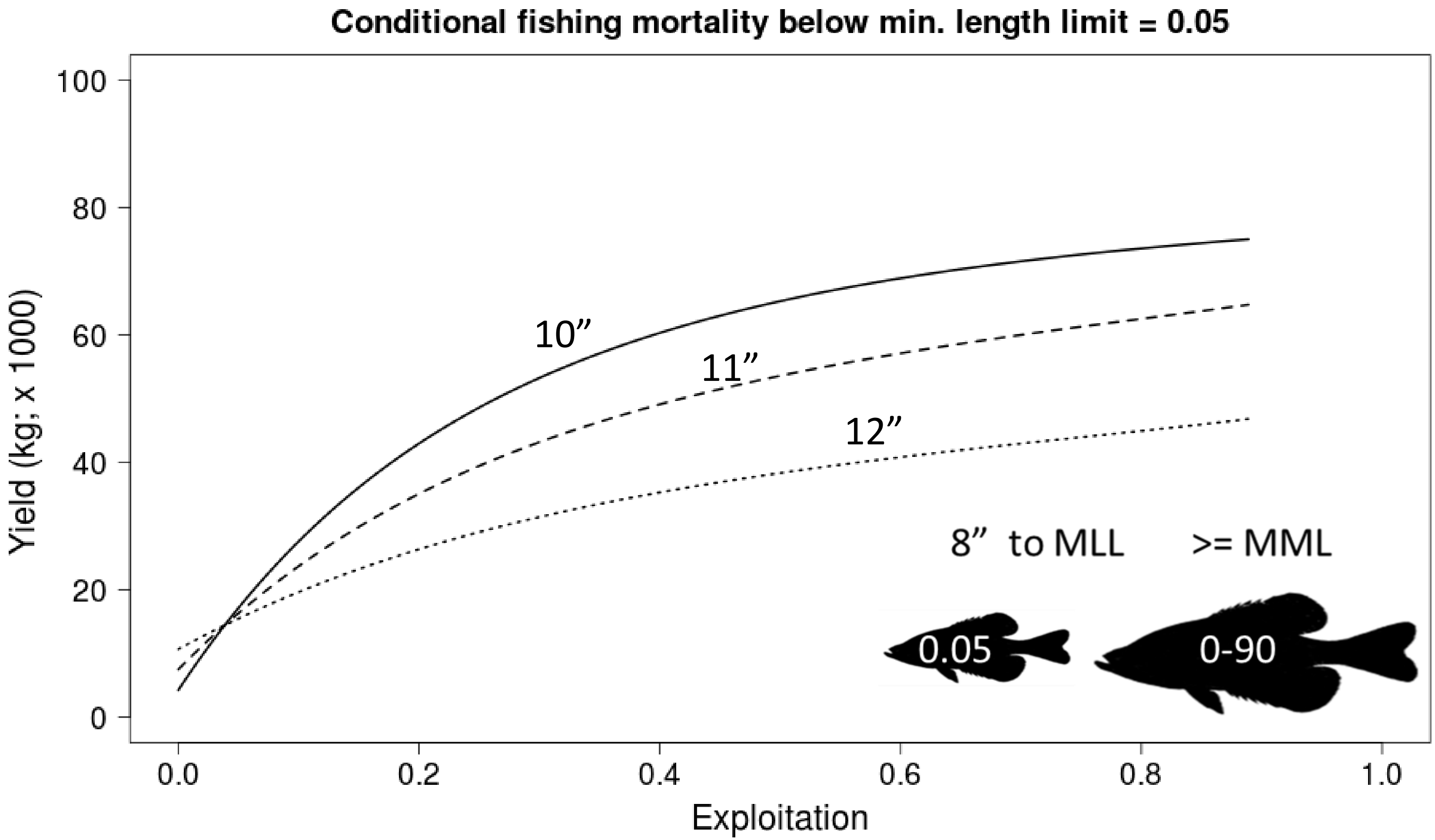
- Using length limits 10”, 11”, and 12”
- 5 models showing different rates of conditional fishing mortality below MLL
  - 0, 0.01, 0.05, 0.1, and 0.2
- Evaluate potential for growth overfishing



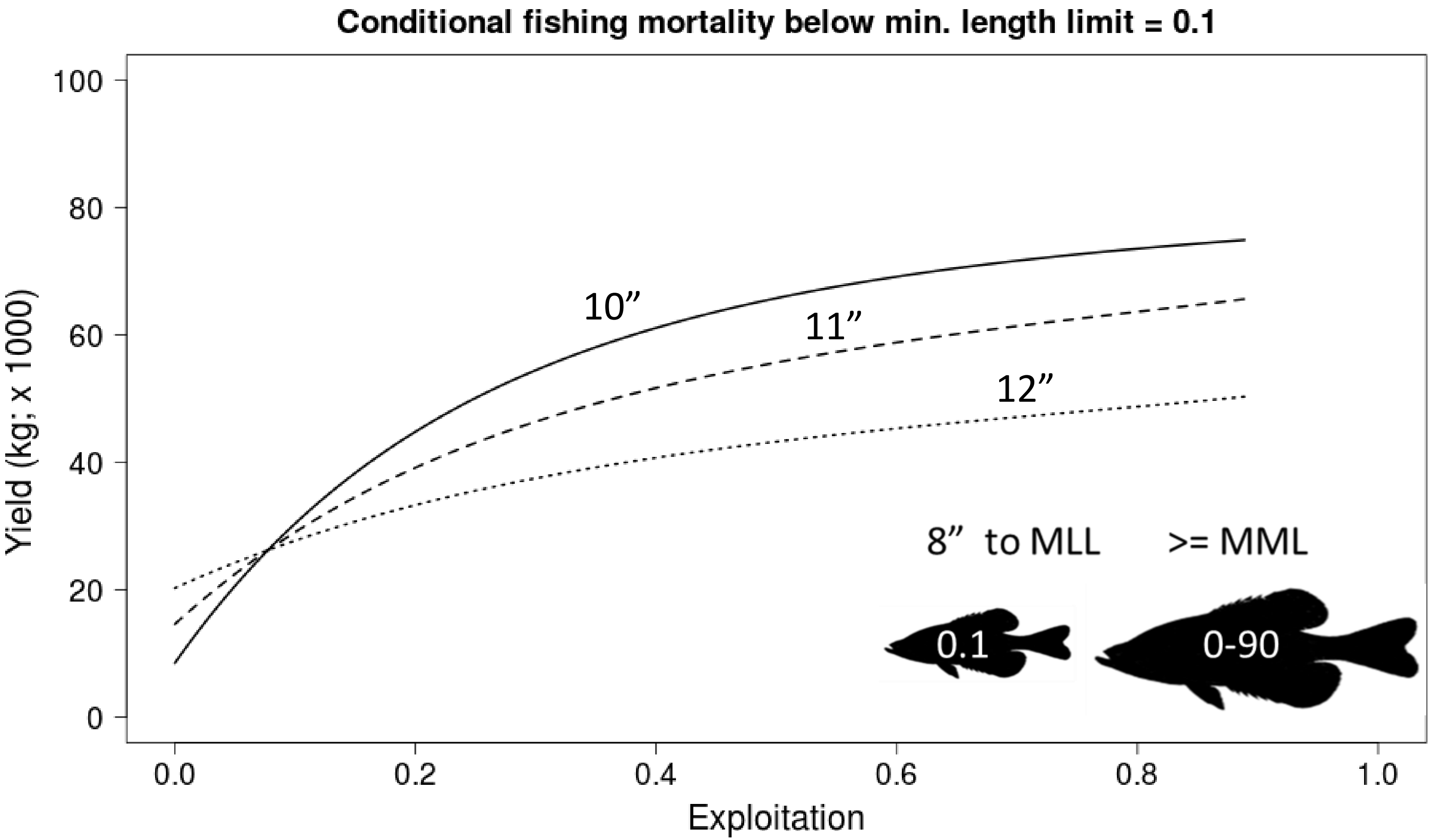

# YPR: No harvest under MLL



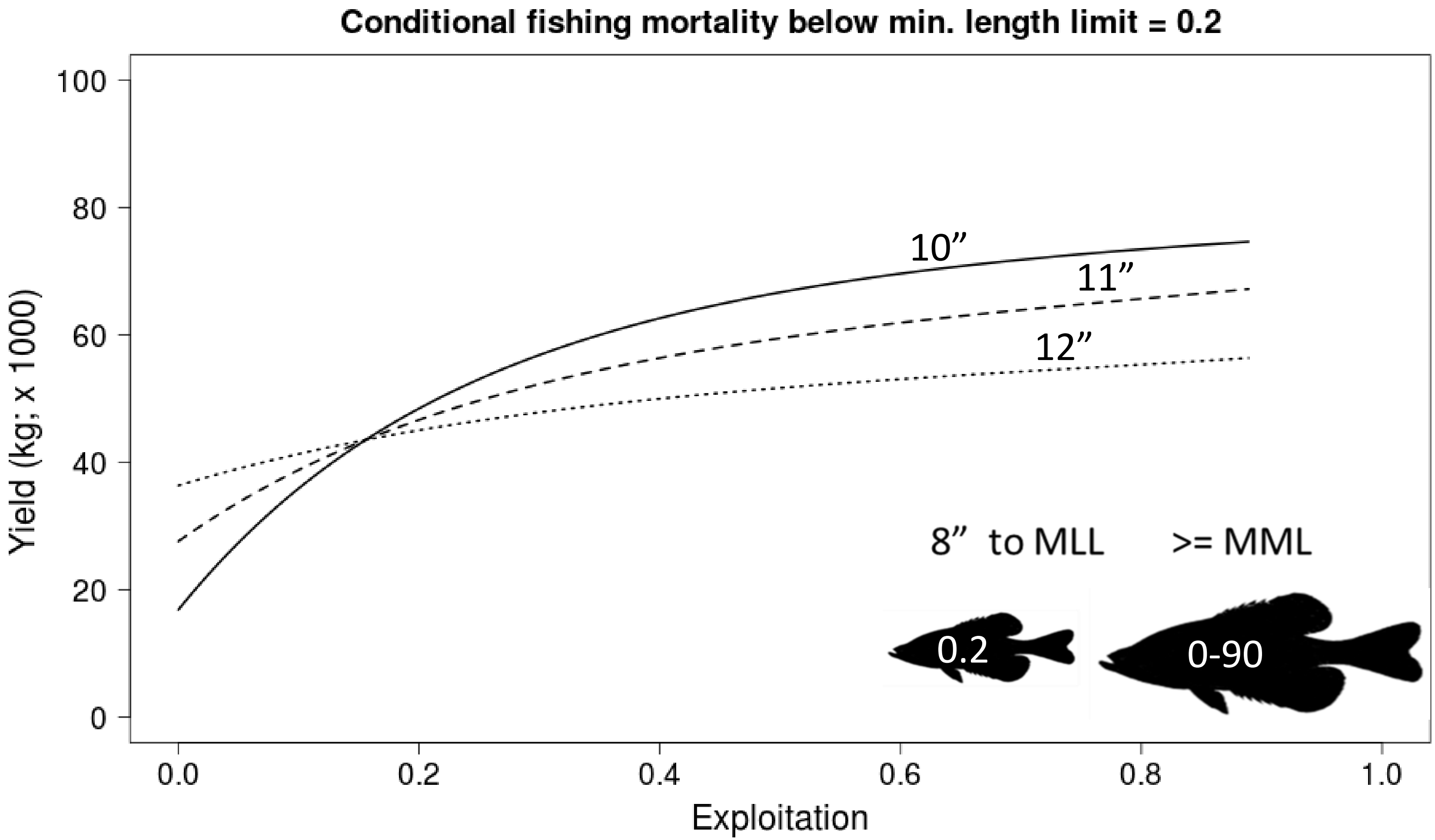

# YPR: Fishing Mortality under MLL = 0.01




# YPR: Fishing Mortality under MLL = 0.05




# YPR: Fishing Mortality under MLL = 0.1




# YPR: Fishing Mortality under MLL = 0.2

- Potential for growth overfishing
- “Free for all” on 8” to 12” fish

# In a nutshell

- Growth overfishing potential-NO
- Supports data from MDWFP
  - Harvest rates and Average Weight
- Effect of “5 under” is minimal when MLL is low
- Management impact?

# Press Release

Thursday, May 26, 2016

**Mississippi Wildlife, Fisheries, and Parks**
1505 Eastover Drive, Jackson, MS, 39211
Phone: 601-432-2400

## Fishing Regulation Changes Approved for Lake Washington

JACKSON - The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) Fisheries Bureau announced new fishing regulations on Lake Washington. The new regulation sets the minimum length limit for crappie at 11 inches, but anglers will be allowed to harvest five fish under the length limit each day. The daily creel limit for crappie will remain 30 per angler. The new crappie regulations and the current black bass regulations will include the outlet channel from Lake Washington to the weir at Paul Love Park.

In addition, anglers fishing with yo-yos are required to attend these fishing devices at all times. Attend means that the anglers must remain in sight of the yo-yos if the gears are set and baited or set and tripped. Anglers will be allowed to leave their yo-yos unattended between 11 a.m. to 1 p.m. Yo-yos must be tripped with the hook out of the water during this two hour time period. MDWFP Law Enforcement officers have the authority to seize or confiscate unattended untripped yo-yos during this two hour period and unattended yo-yos other times of the day.

The new regulations become effective on June 23, 2016.

For more information regarding fishing in Mississippi, visit our website at www.mdwfp.com or call us at (601) 432-2212.

Find us on Facebook & follow us on Twitter

**Share with your friends!**

# *Caveat emptor*

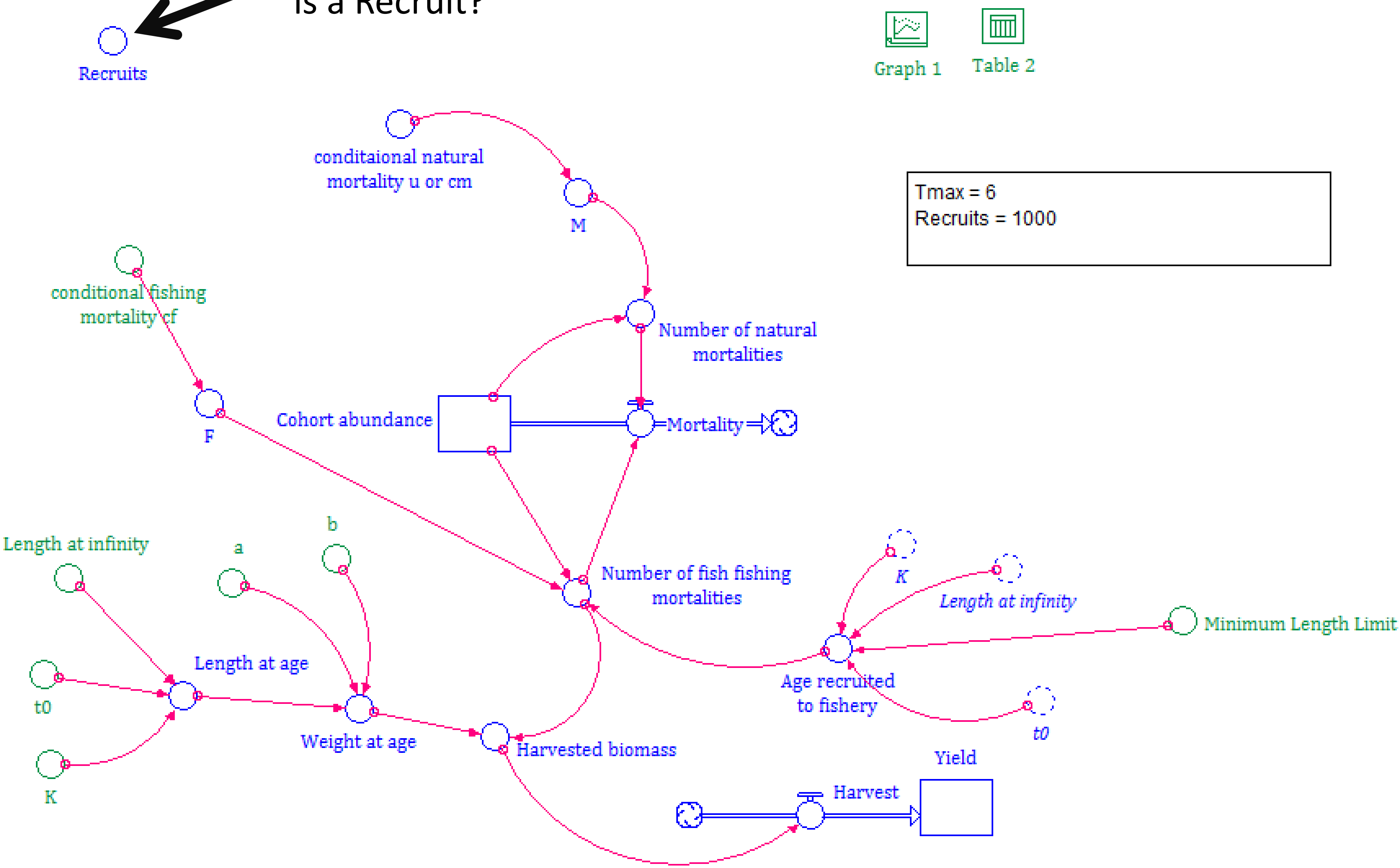
- But on growth overfishing….

# RECRUITMENT MANAGEMENT

# What is *recruitment*?

*The addition of new fish into the catchable, harvestable, or adult populations.*

What exactly is a Recruit?



# Catchable, harvestable, or adult?

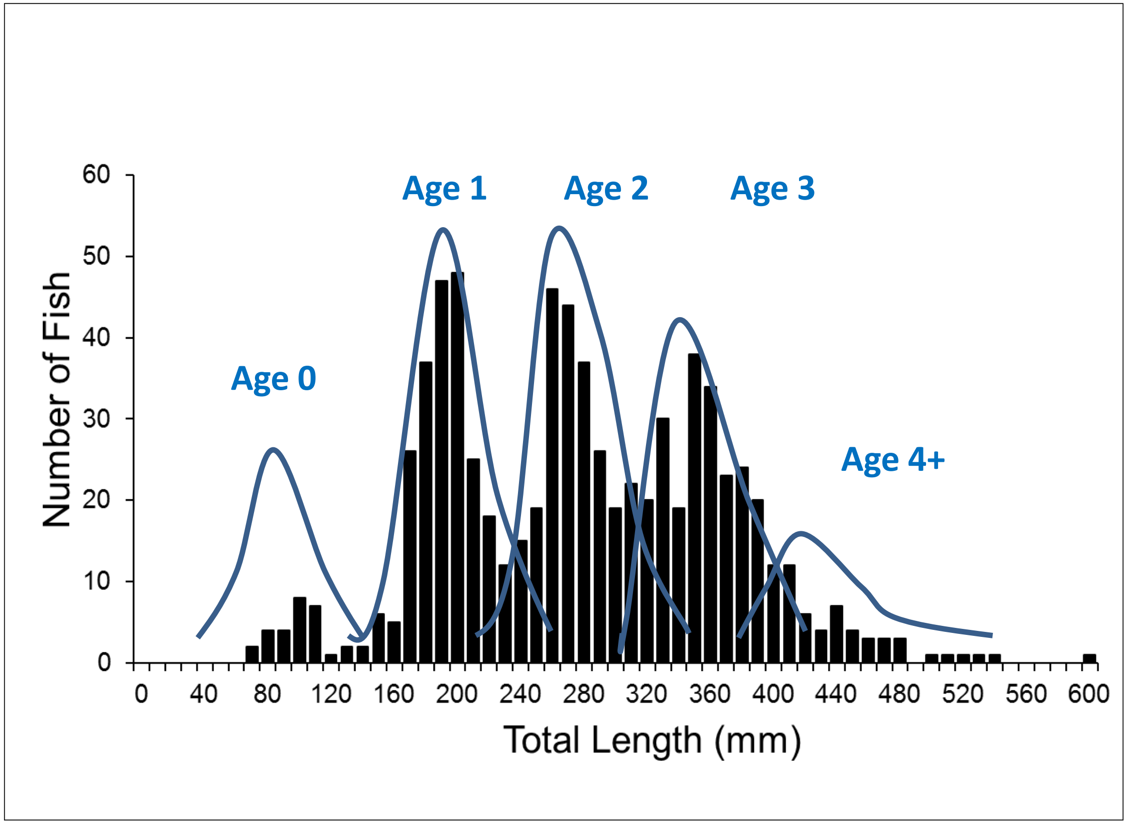
- Varies among fish
  - Species
  - Locations
  - Studies

The definition of a recruit is vague!

# Defining a "recruit"

Typically defined by fish length or age

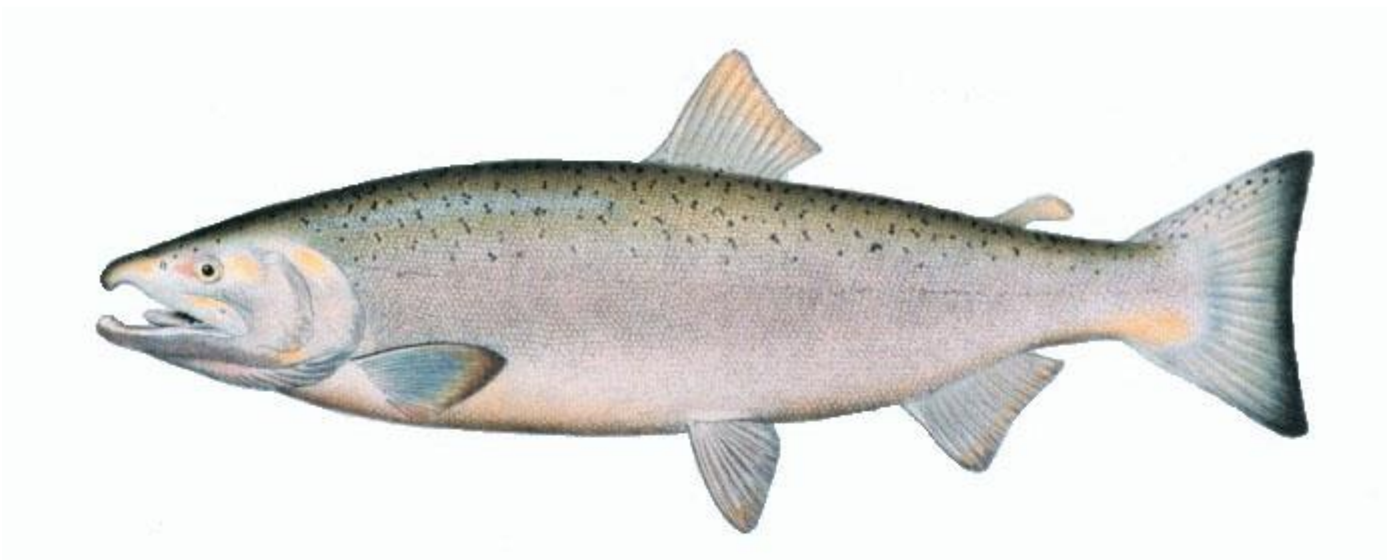
- Length: stock-size (200 mm) largemouth bass
- Age: age-1 white crappie



# Recruit definitions

Froese (2004) – Coho salmon, OR

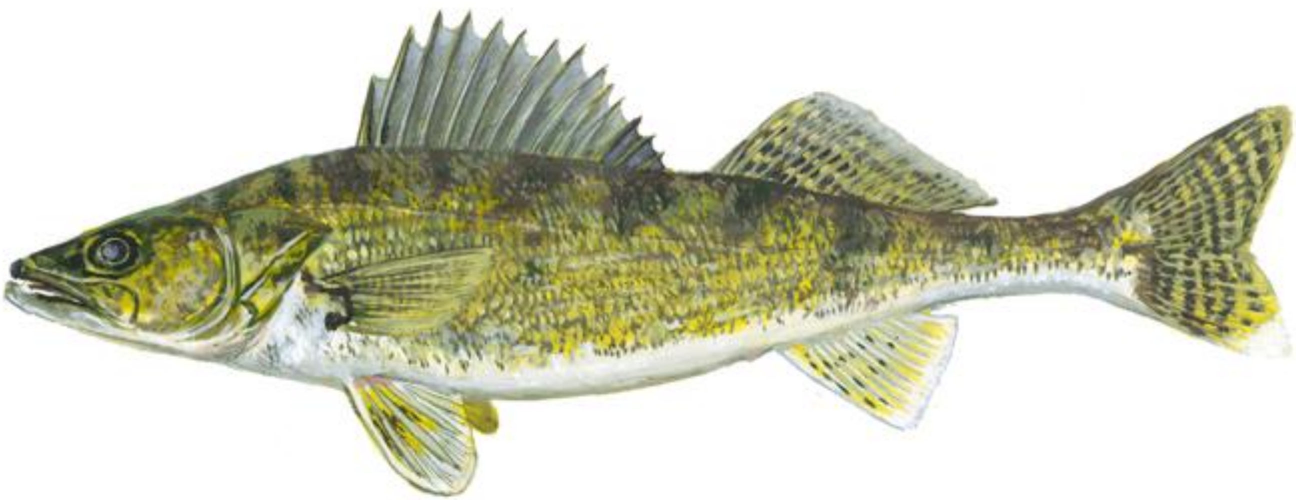
The data represent females migrating upstream to spawn (S), and the resulting female smolts migrating downstream approximately 1.5 years later (R).



# Recruit definitions

- Beard et al. (2003) – Walleye, WI

where $R$ is the number of age-0 recruits per kilometer, $S$ is the number of adult walleyes per hectare,



# Recruit definitions

- Belcher & Jennings (2004) – White shrimp, GA

The total pounds of white shrimp caught during May–June represented spawners, whereas the total pounds of white shrimp caught during August–January represented recruits.

# Recruit definitions

- Allen & Miranda (2001) – Black crappie, MS

  where $R$ is recruits (number of age-1 fish), $S$ is stock (number of fish older than age 1),

# Recruit definitions

- Richards et al. (2004) – Lake Trout, MI

and Sitar 2000). To account for the time lag between spawning and recruitment at age 7, spawning stock CPE measured during 1970–1990 was matched with CPE of age-7 recruits during 1978–1998 to model recruitment of the 1971–1991 year-classes.

# Factors influencing recruitment

<u>Density Independent</u>

- Changes in water level or flow
- Aquatic plant abundance or species composition
- Water temperature

<u>Density Dependent</u>

- Spawning stock abundance
- Year-class strength
- Can stabilize recruitment

# IMPORTANT:

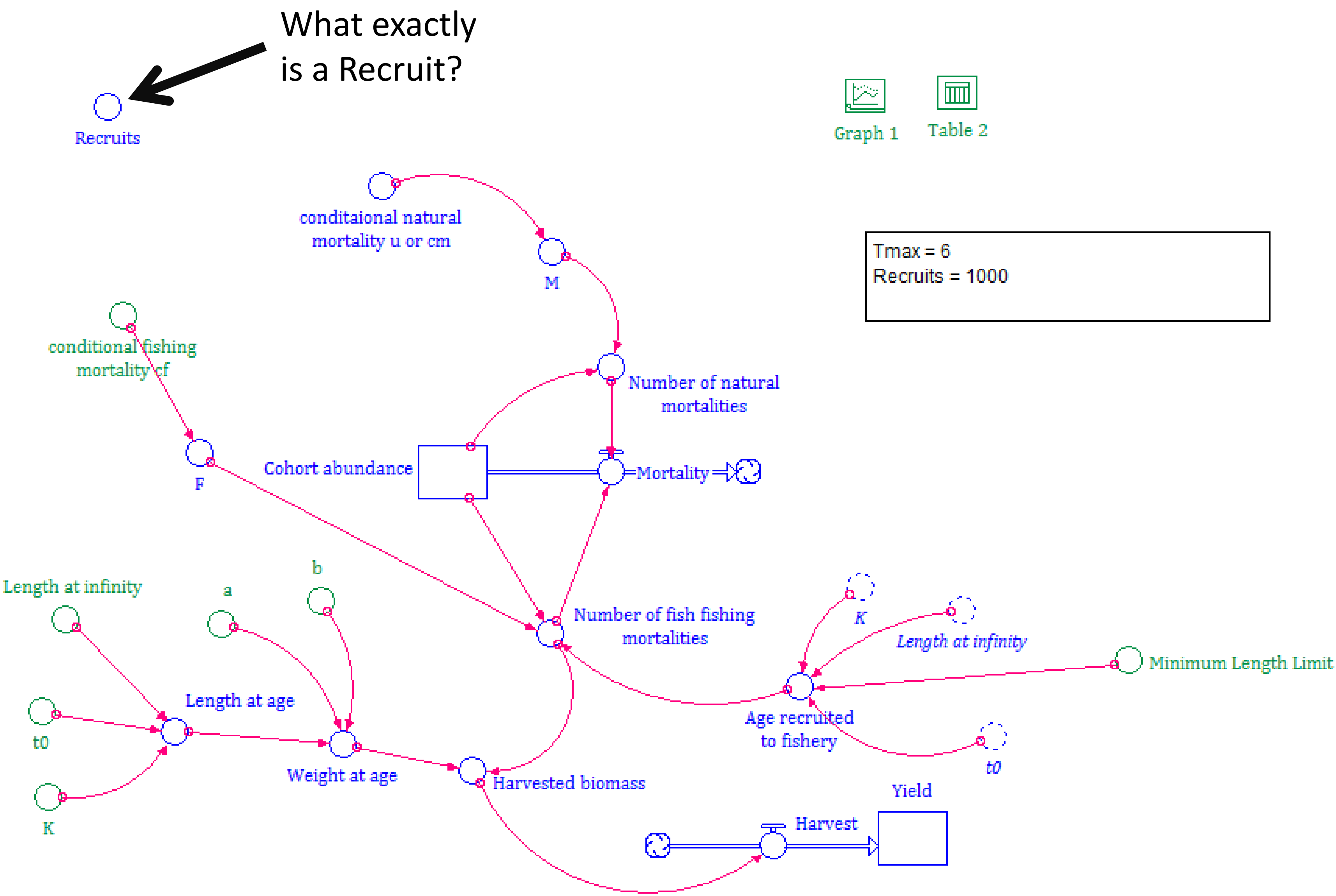
Recruitment is not determined solely by how many young-of-year (YOY = baby) fish are produced.  You can have low recruitment in a year when YOY production is very high, or high recruitment when YOY production is relatively low.

**Why do you think this is?**

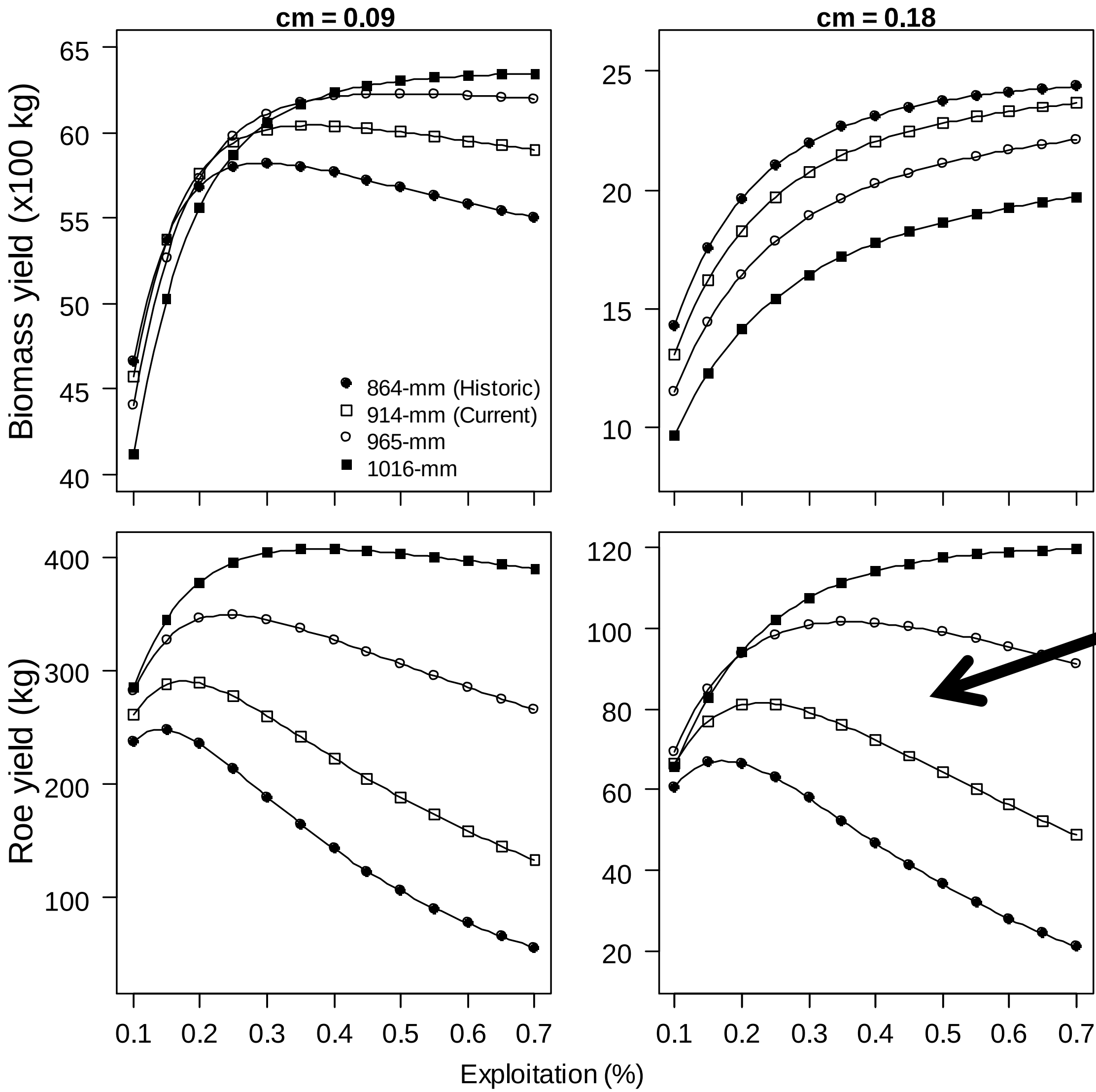
In a nutshell-preventing or minimizing recruitment overfishing!

*You need old fish to make new fish and you need new fish to make old fish*

# MANAGING RECRUITMENT IN AGE STRUCTURED POPULATIONS


What exactly is a Recruit?
Recruits
Graph 1
Table 2
Tmax = 6
Recruits = 1000
conditaional natural mortality u or cm
M
conditional fishing mortality cf
Number of natural mortalities
F
Cohort abundance
Mortality
Length at infinity
a
b
Number of fish fishing mortalities
K
Length at infinity
Minimum Length Limit
Length at age
t0
Weight at age
Age recruited to fishery
K
Harvested biomass
t0
Yield
Harvest

# Predicted biomass and roe yields




Eggs related to recruits….

But young of year ≠ recruits

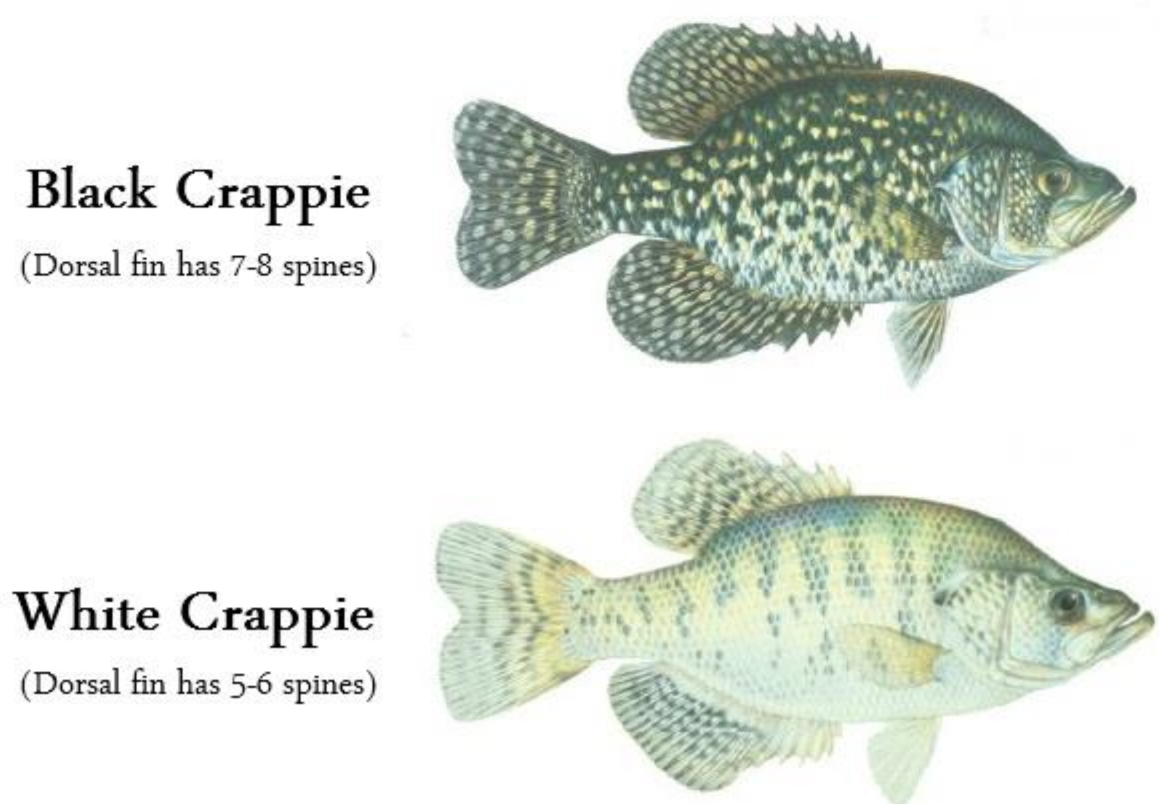
# Recruit definitions

- Allen & Miranda (2001) – Black crappie, MS

  where $R$ is recruits (number of age-1 fish), $S$ is stock (number of fish older than age 1),

# Crappie (White & Black)

- Typically co-managed as 1 species
- Most anglers cannot tell difference



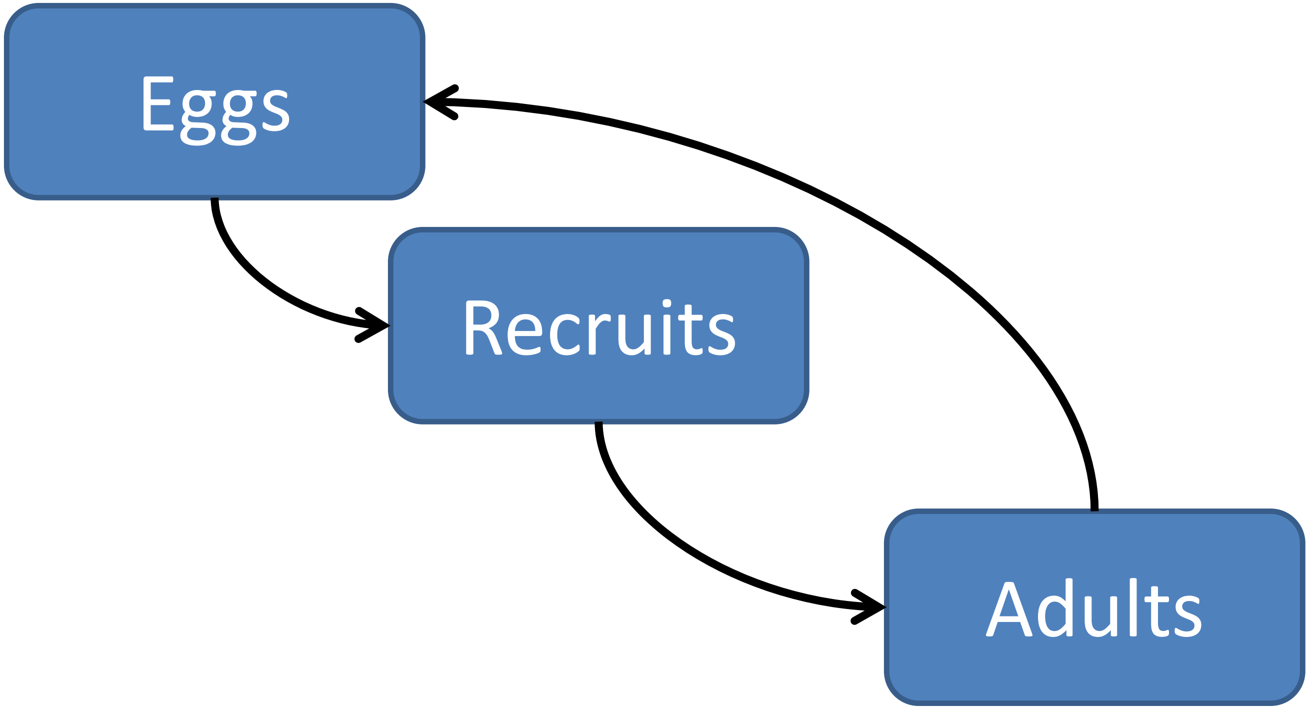
Recruits

# RECRUITMENT MANAGEMENT

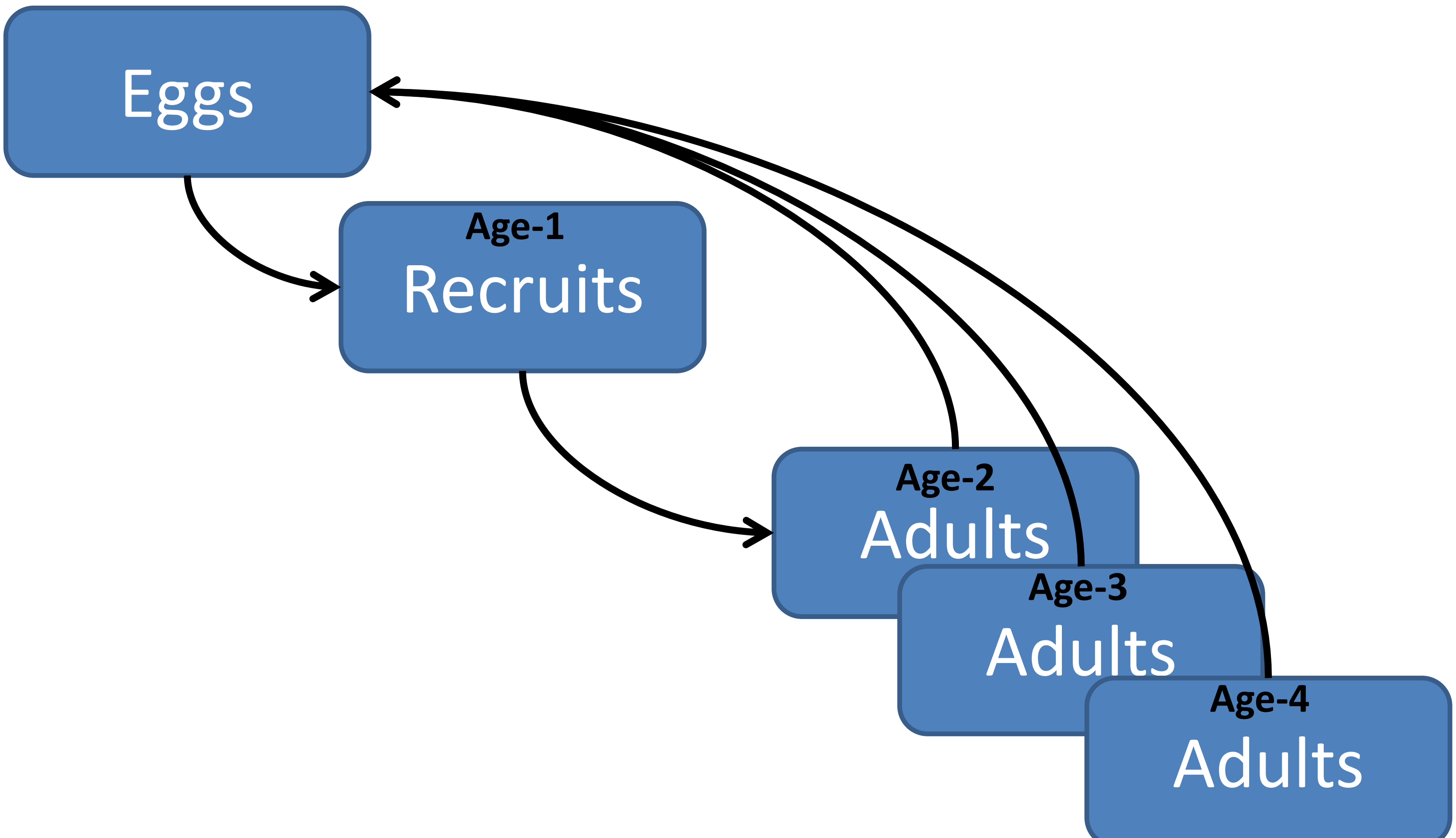
WHAT IS IT?

HOW DO WE DO IT?

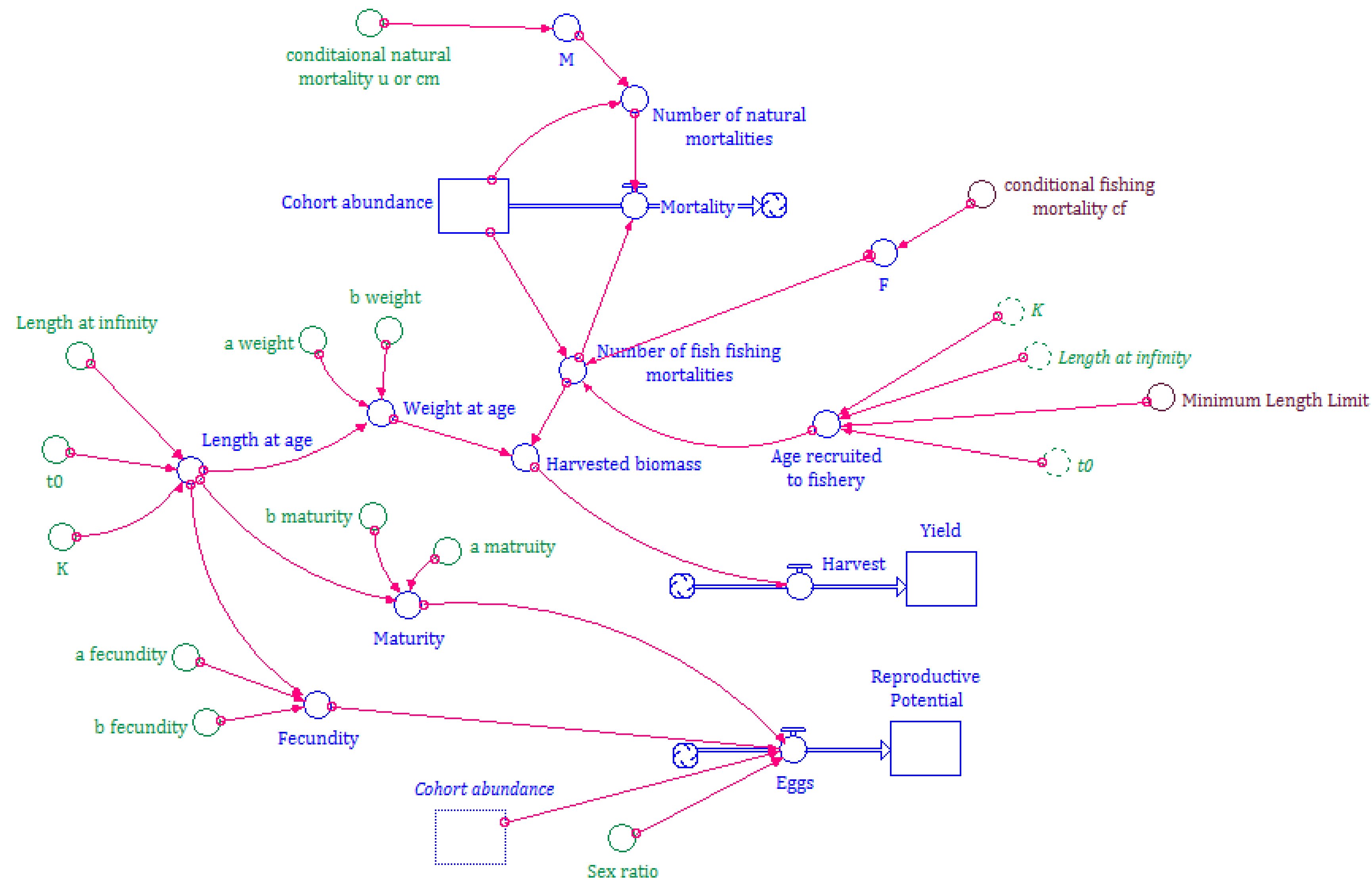
# Conceptually



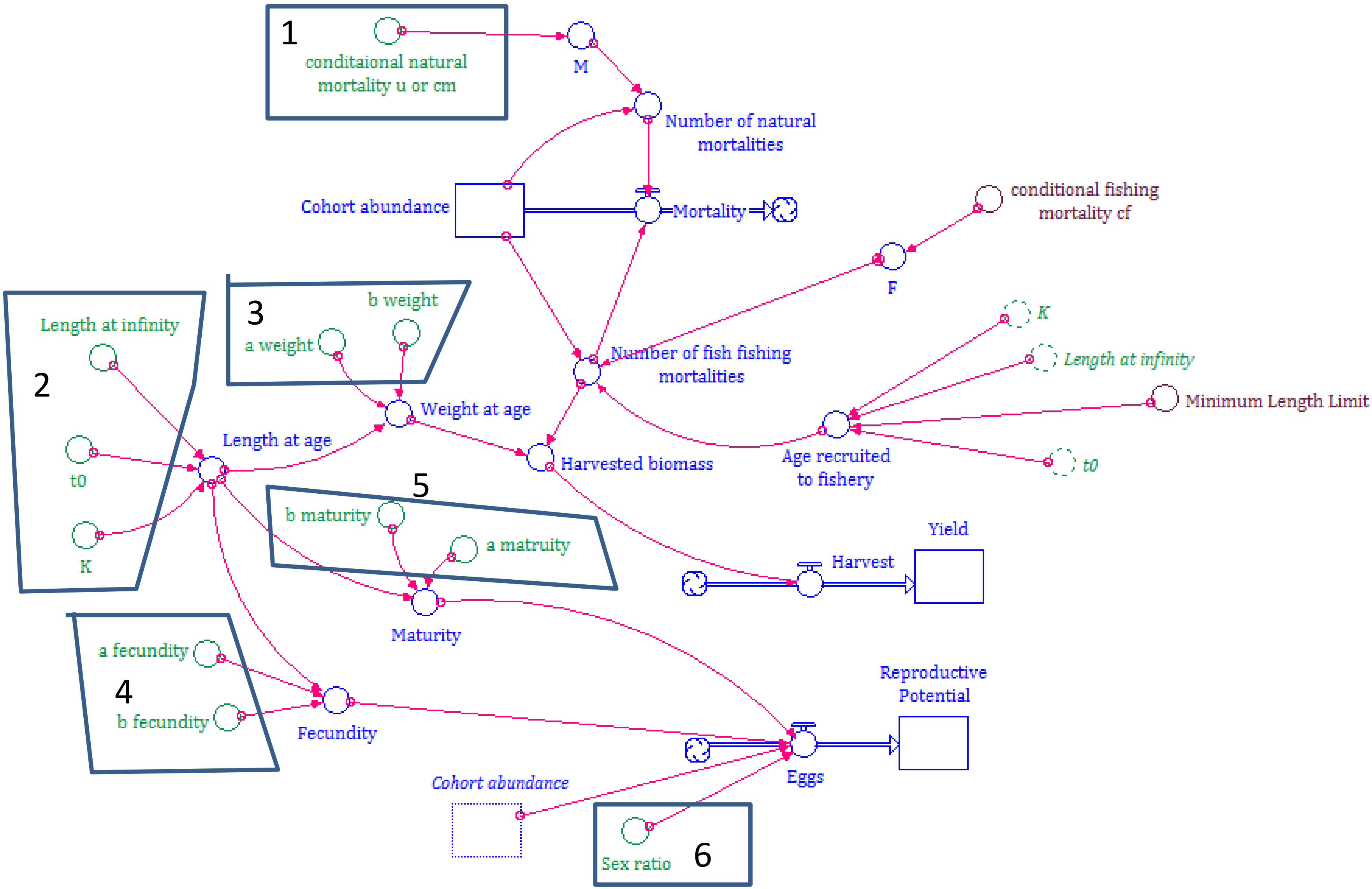
# Adding age structure



# Conceptually



# Bits of information needed



# Bits of information needed

1. Natural Mortality
2. Length-Age
3. Weight-Length
4. Fecundity
5. Maturity
6. Sex ratio

# Management parameters

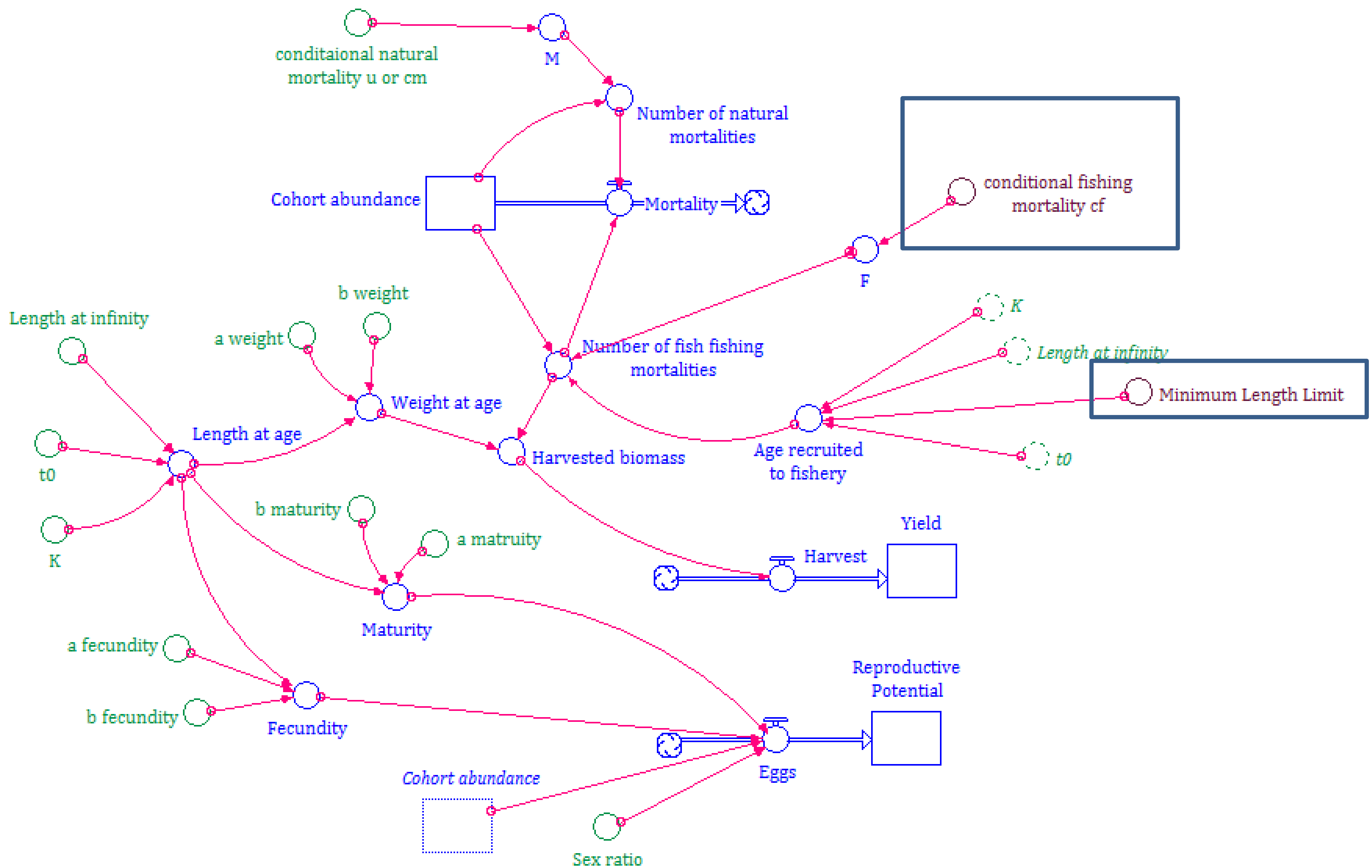
**Fecundity is a function of spawning stock abundance or biomass**

Minimize recruitment overfishing

- Maintain enough spawning abundance or biomass in system
- Reproductive potential

**Fishing mortality & Length limit**

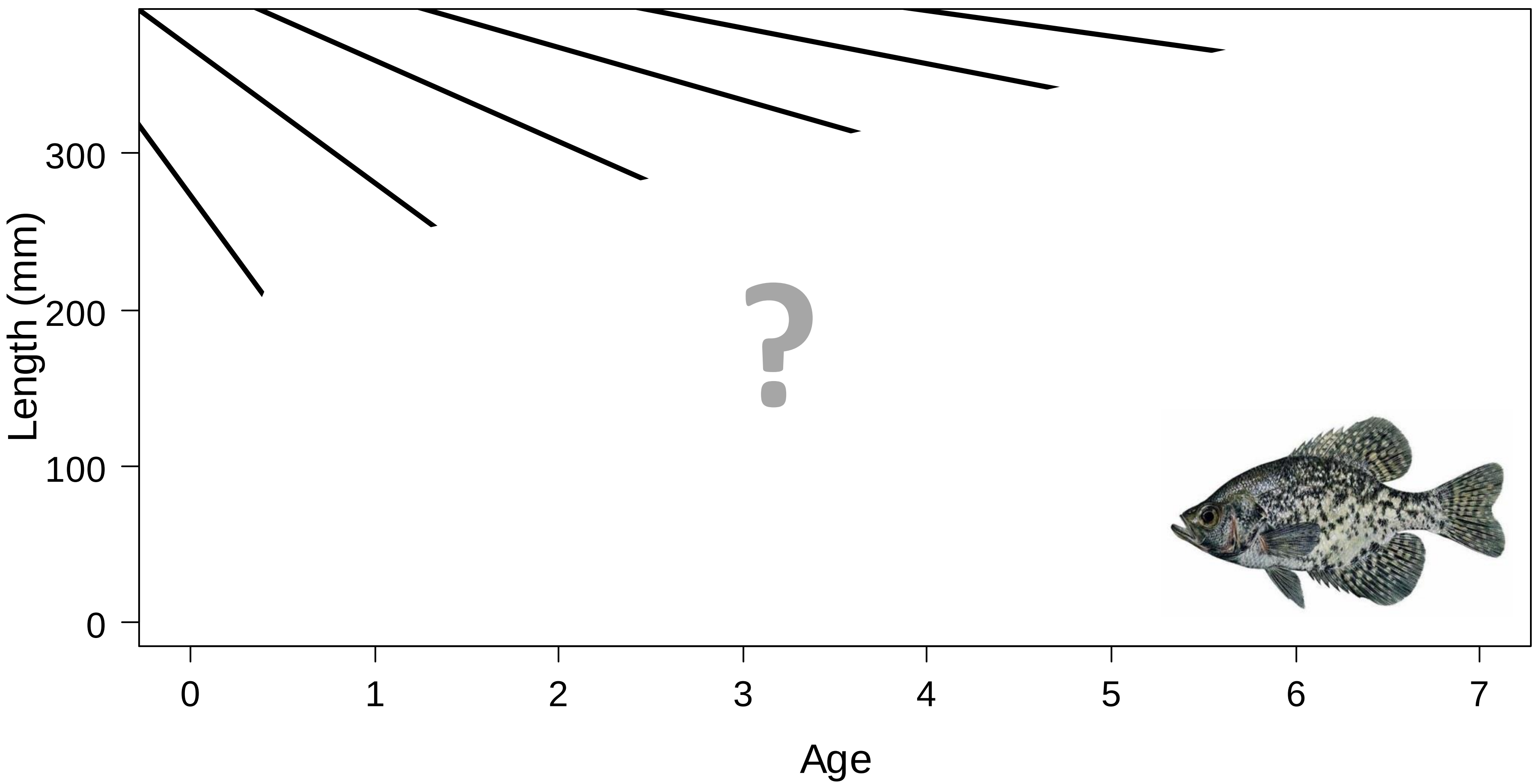
# Management parameters



# We do we want to manage recruitment?

- Angler satisfaction
  - Recruitment drives year to year variability in abundance and biomass
  - Recruitment drives fish abundance and biomass

# Age-Length



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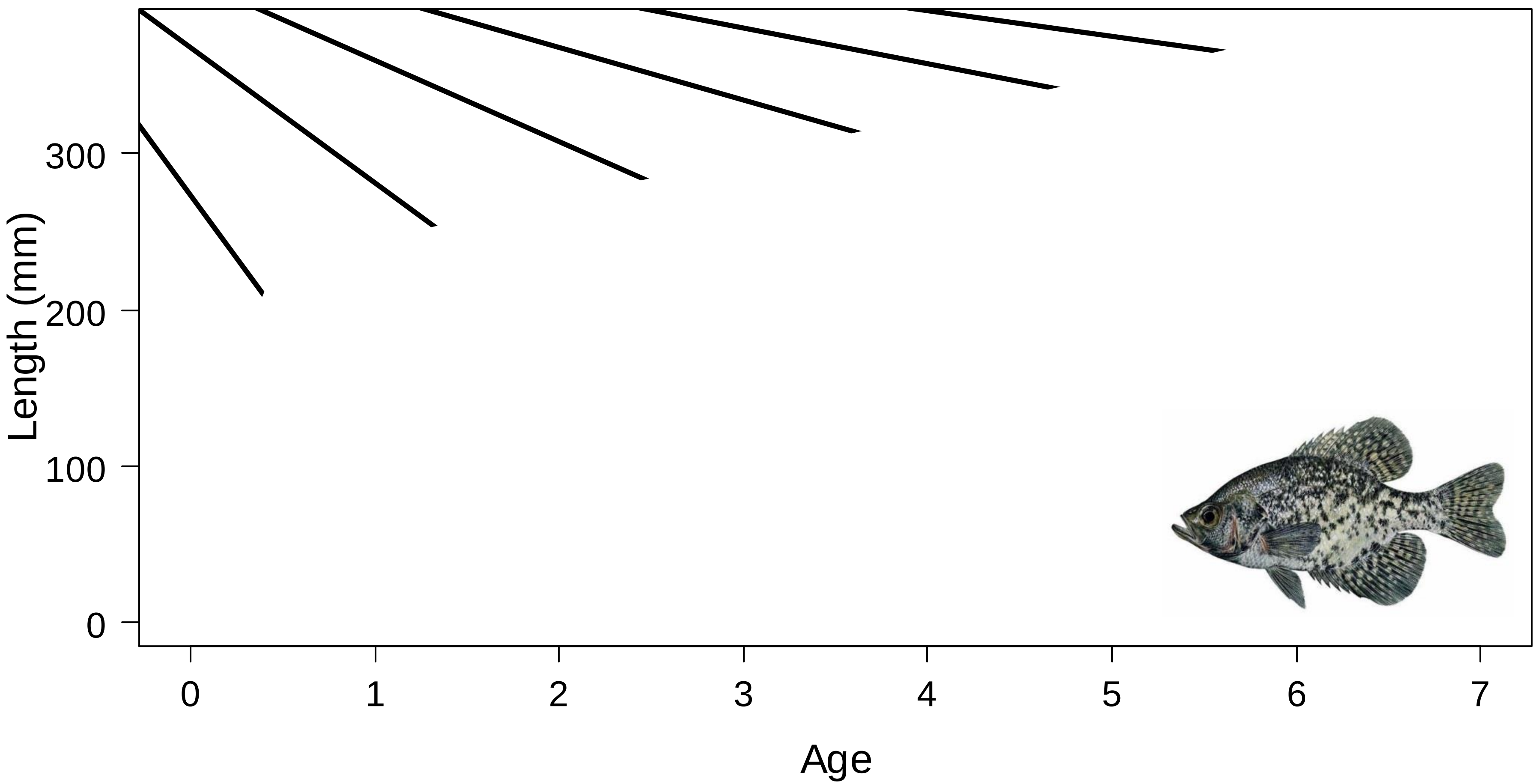

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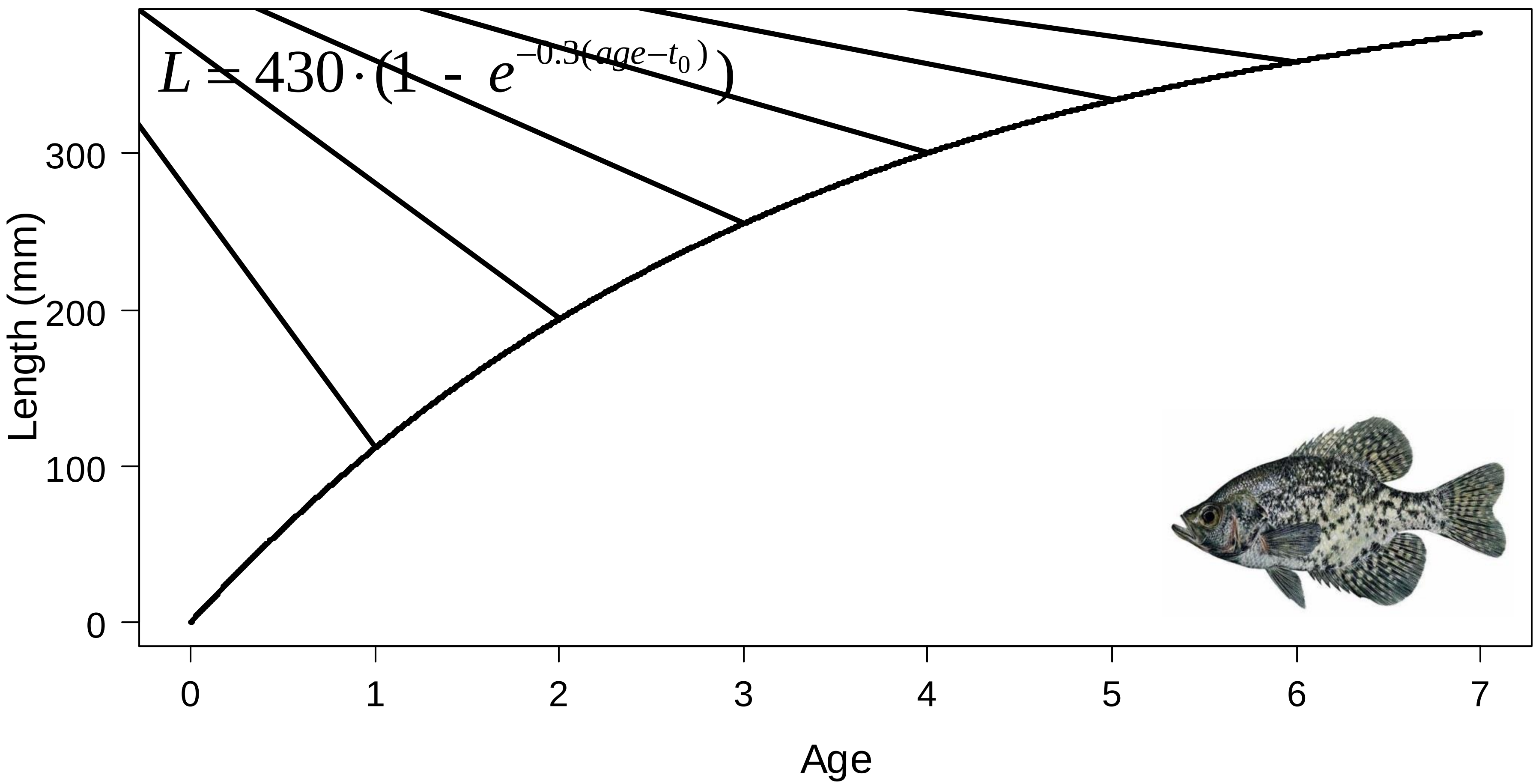

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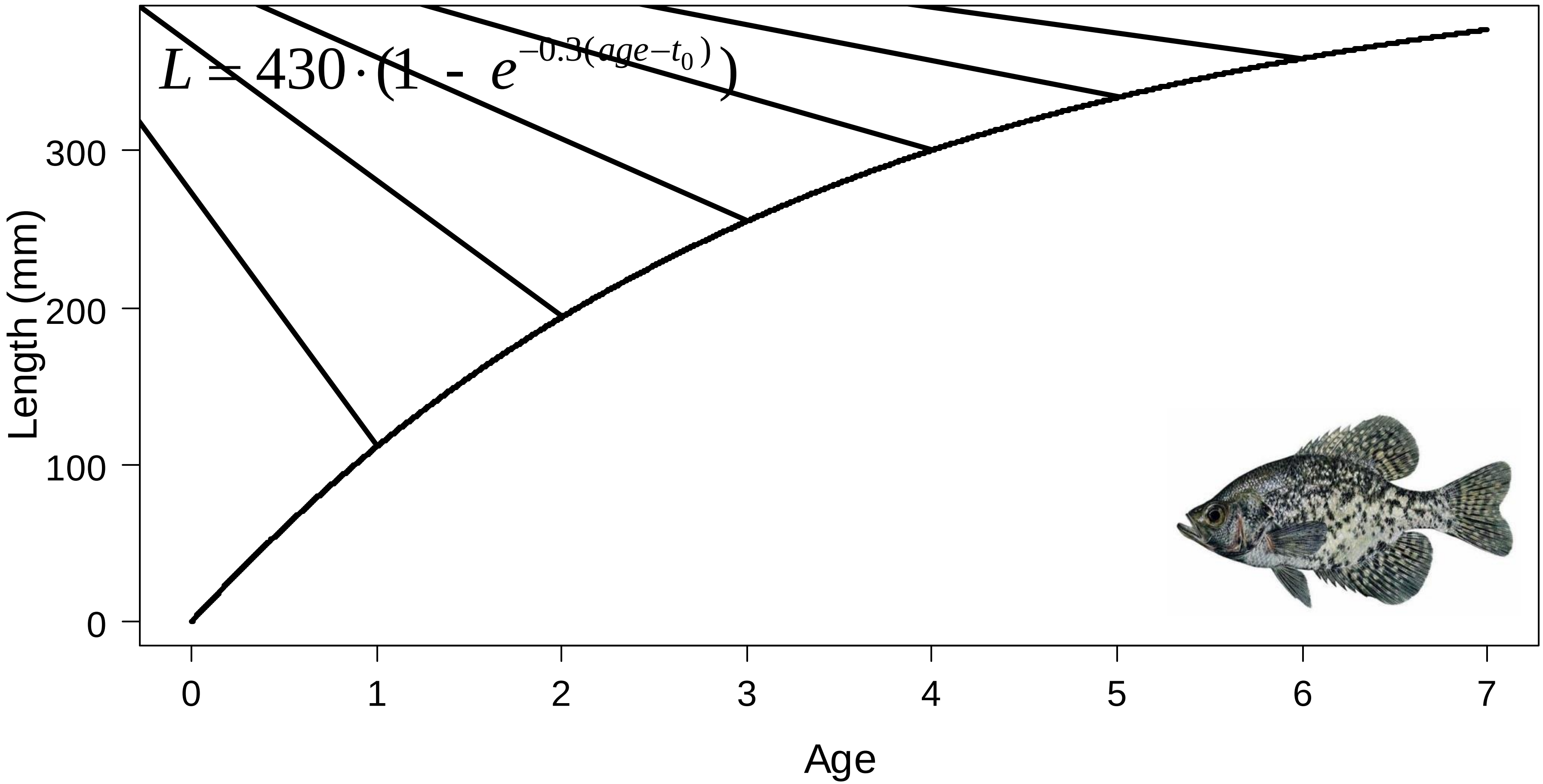
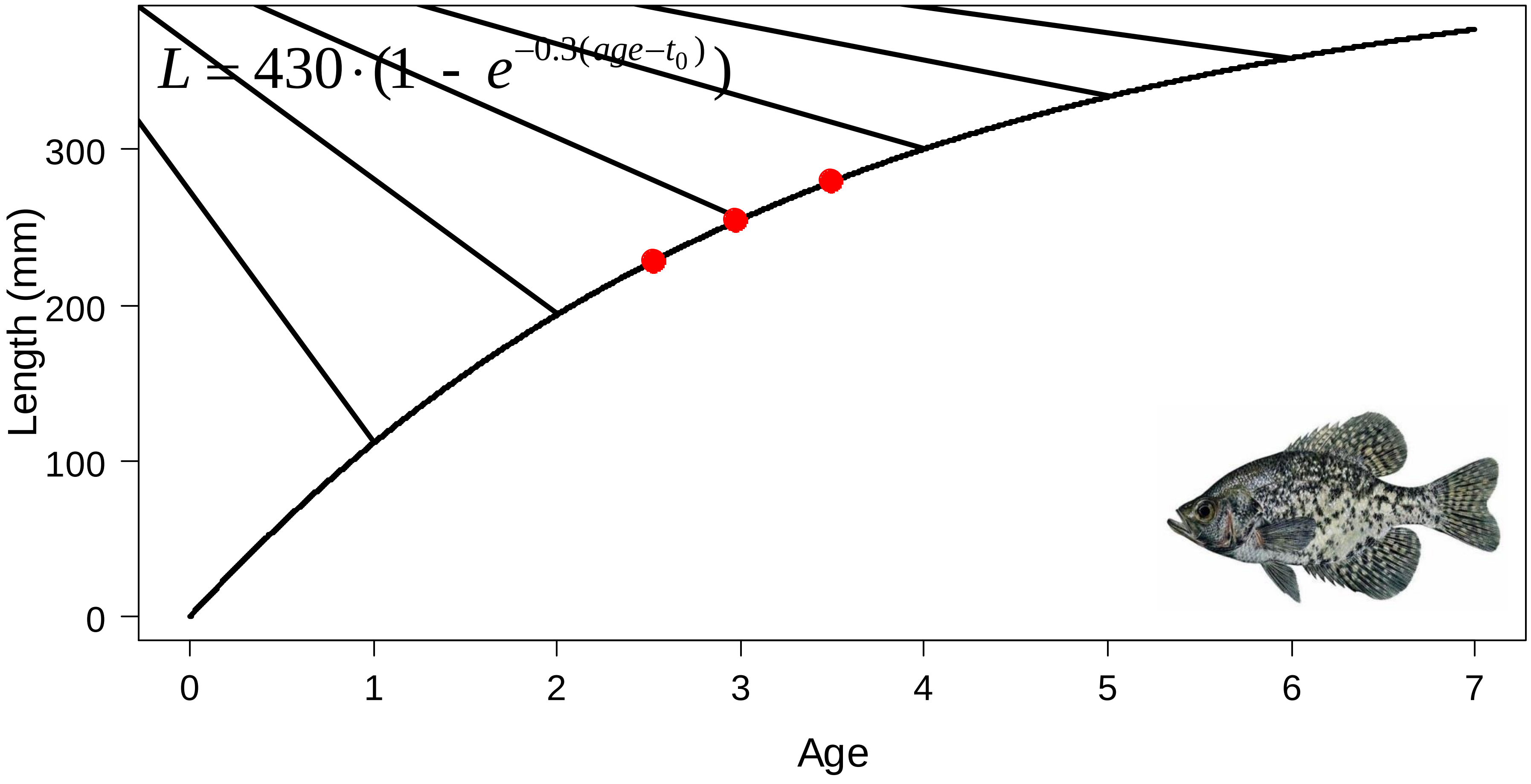


# Age-Length

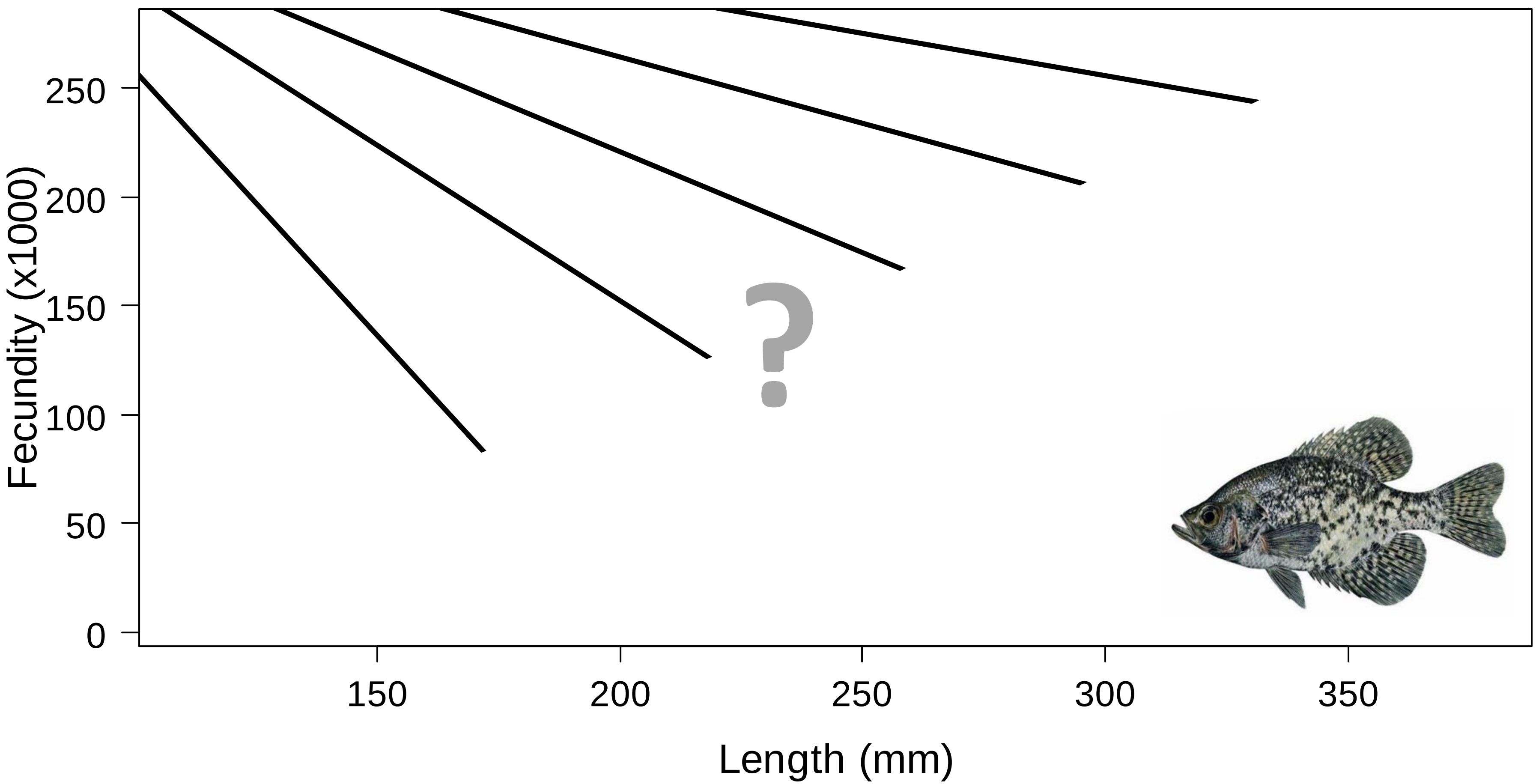


# Fecundity

*Number of eggs an animal produces during each reproductive cycle; the potential reproductive capacity of an organism or population. Usually increases with age and size*

http://www.fishbase.org/Glossary/Glossary.php?q=fecundity&language=english&sc=is

# Black Crappie Fecundity



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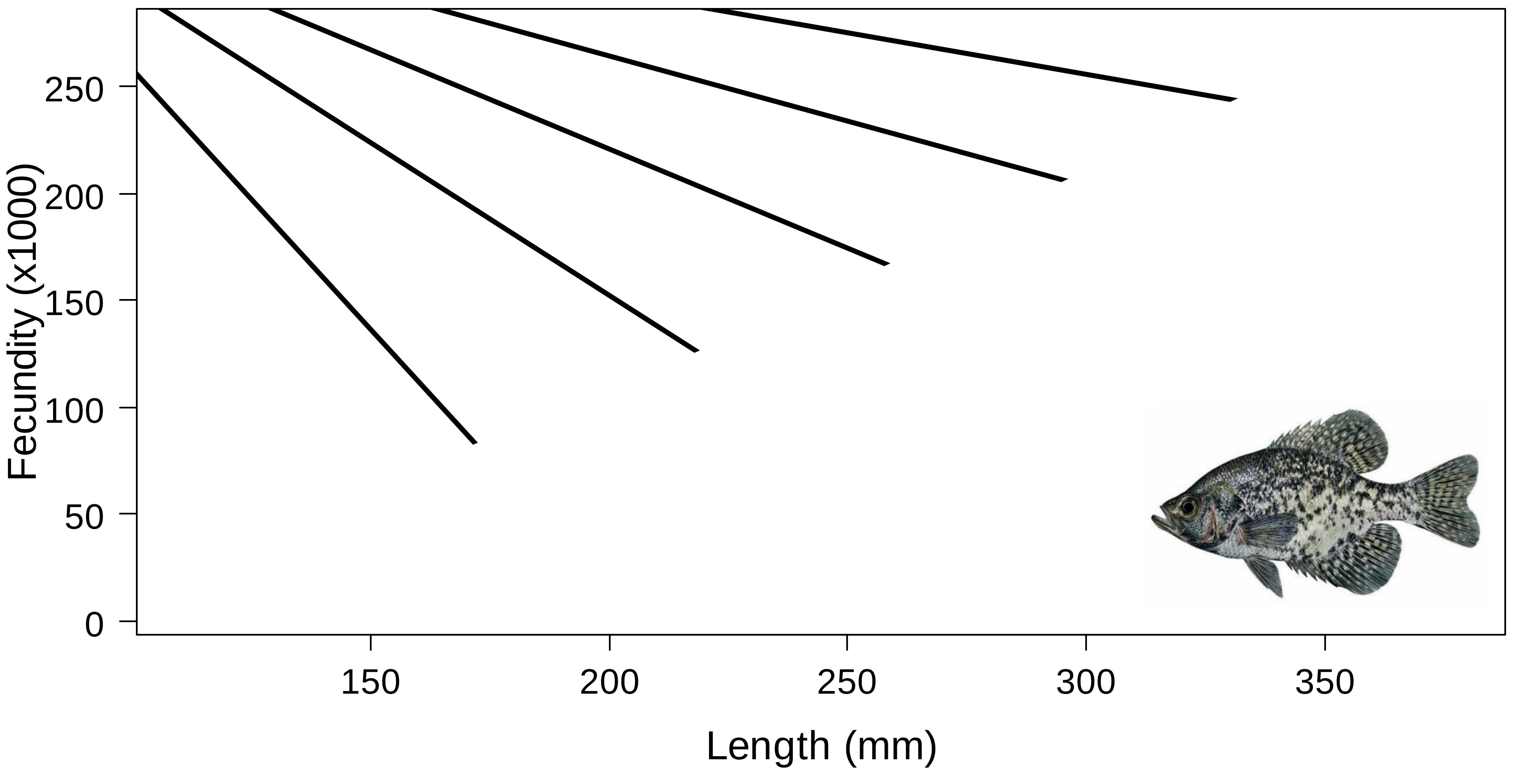

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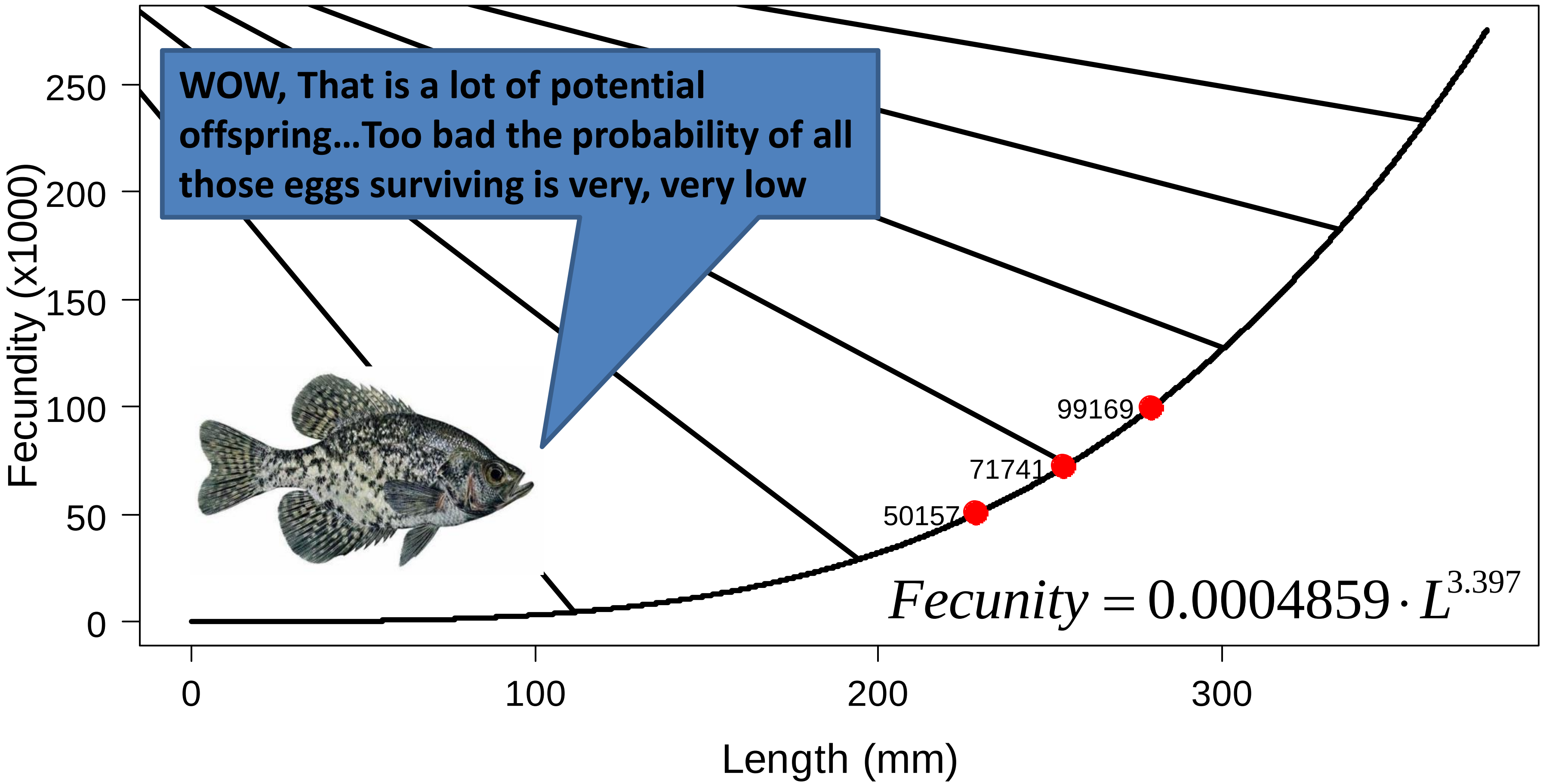

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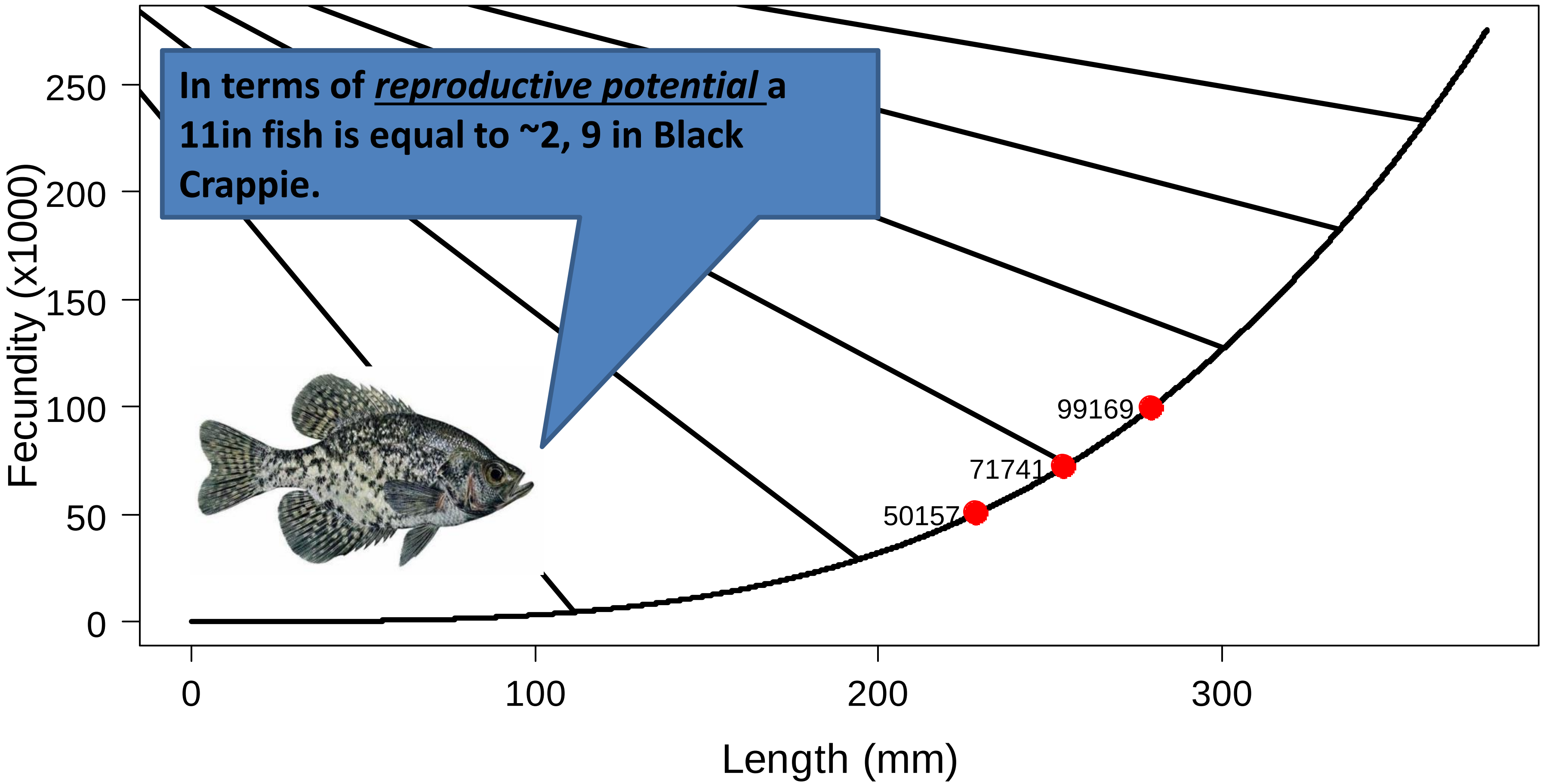
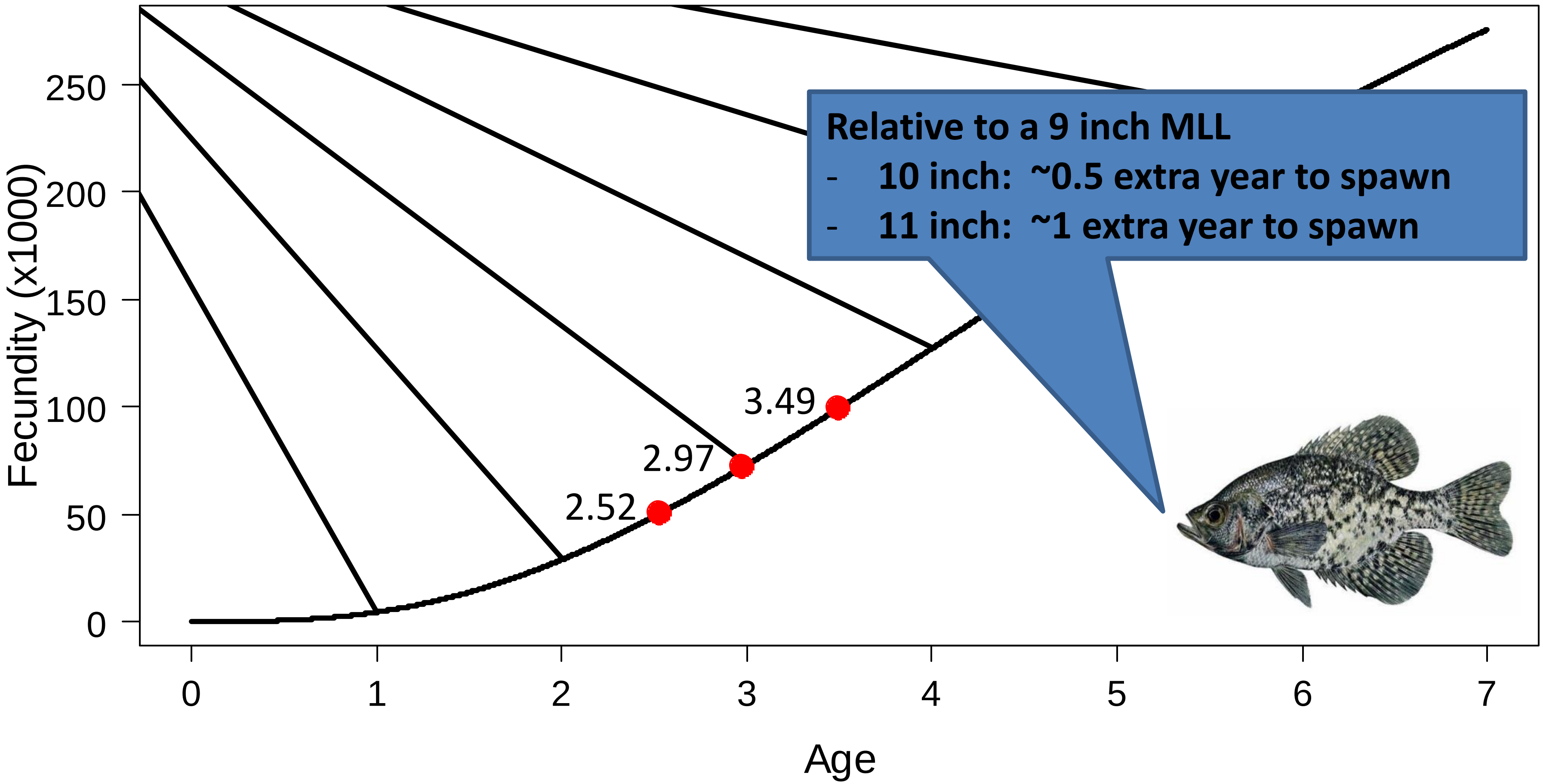


# Fecundity & Age



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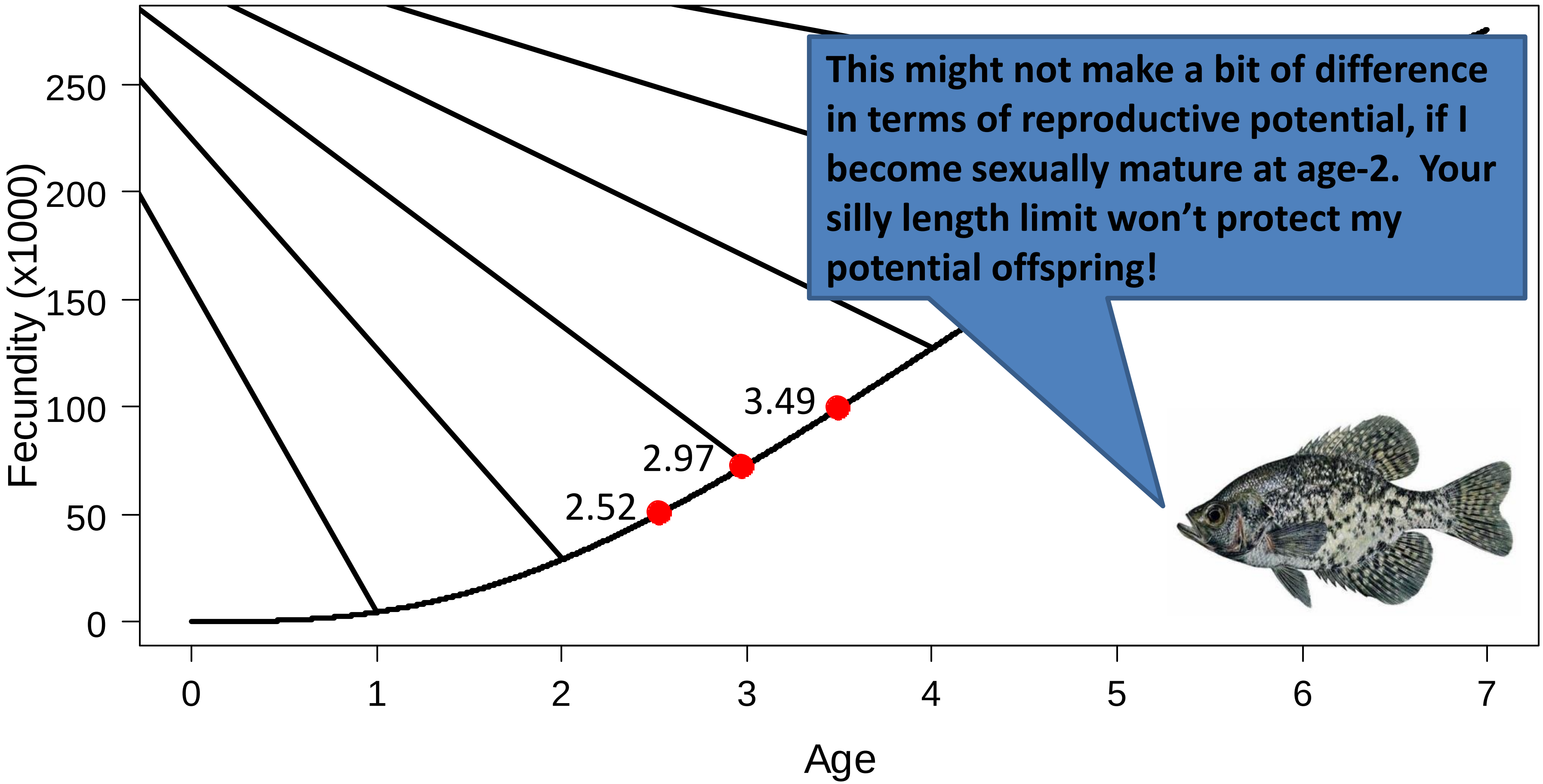


# Maturity

*A stage at which fish are able to develop ripe gonads and to participate in spawning.*

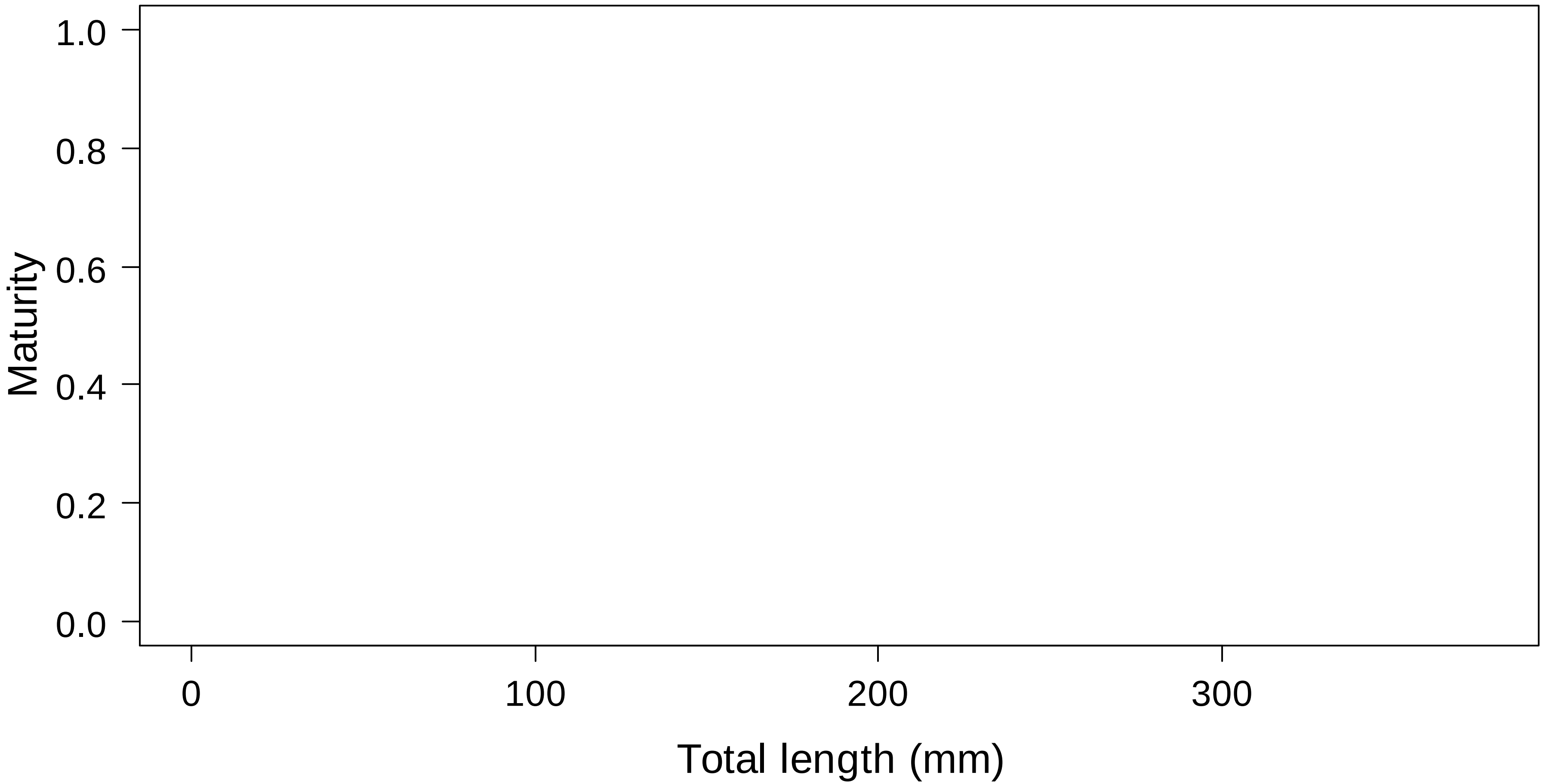
**Length at first maturity**

*Mean length at which fish of a given population develop ripe gonads for the first time.*

# Determining sexual maturity & ratio

- Link maturity (yes or no) to length
- Sex ratio

# Maturity function



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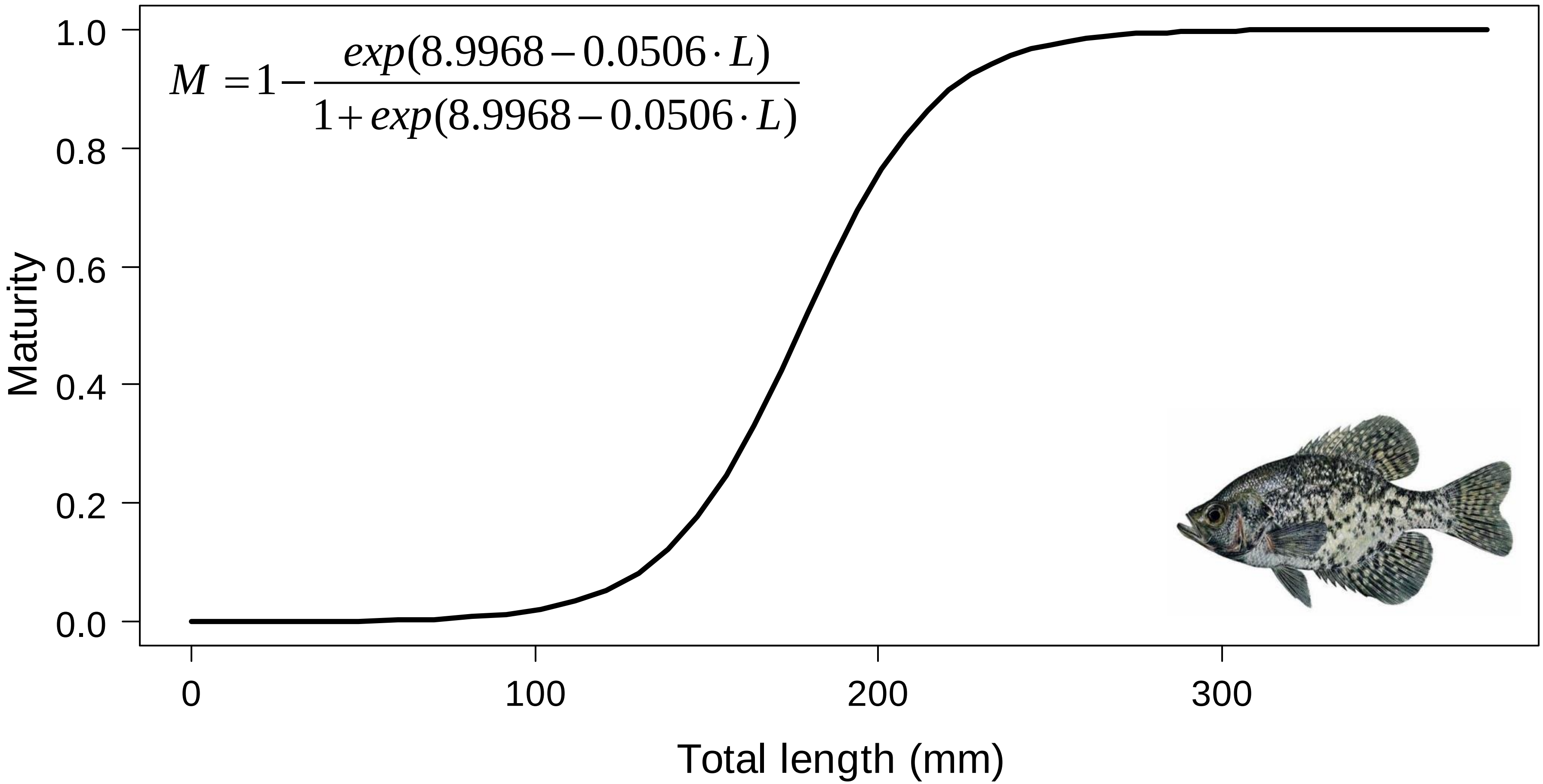

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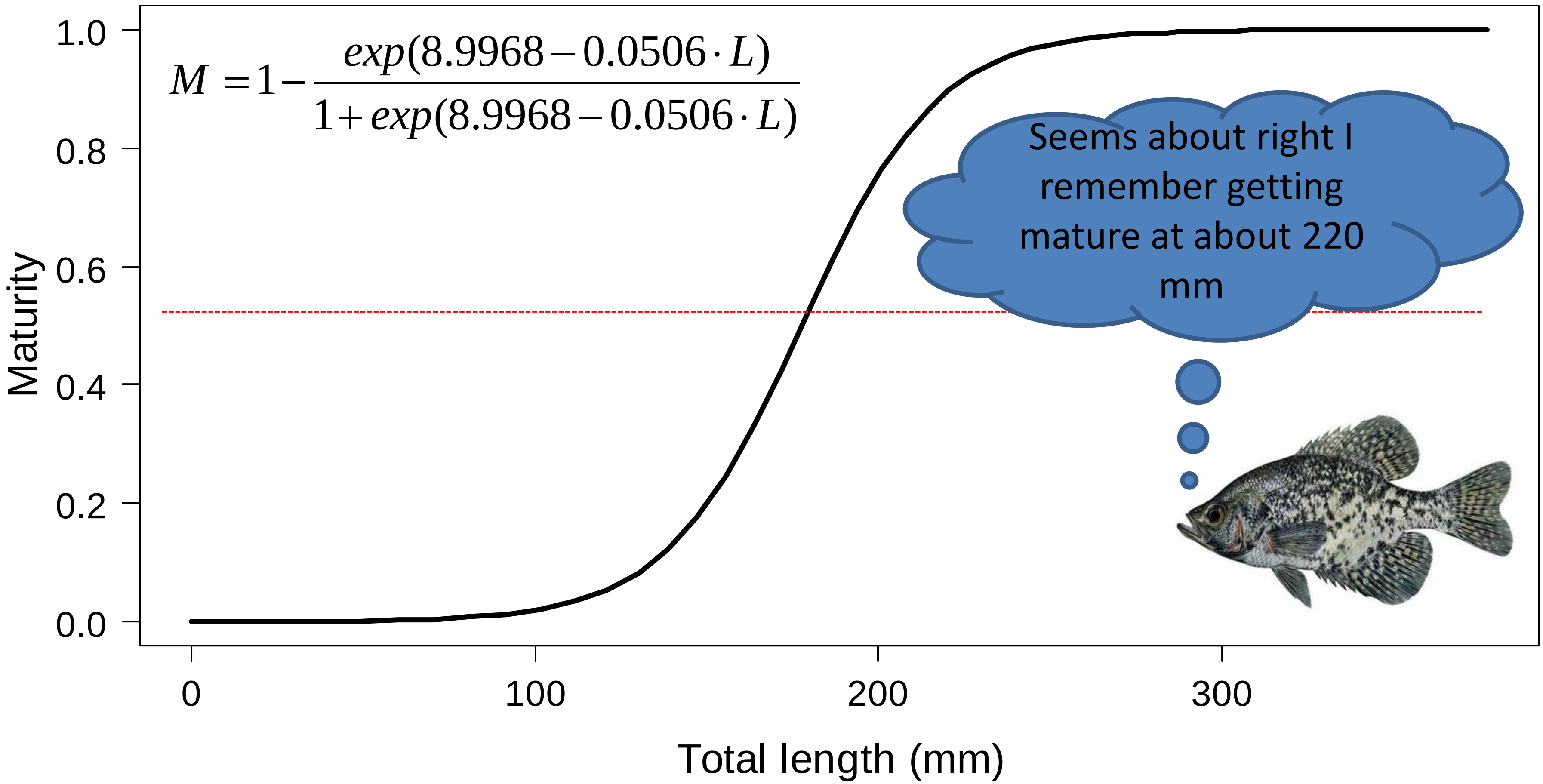

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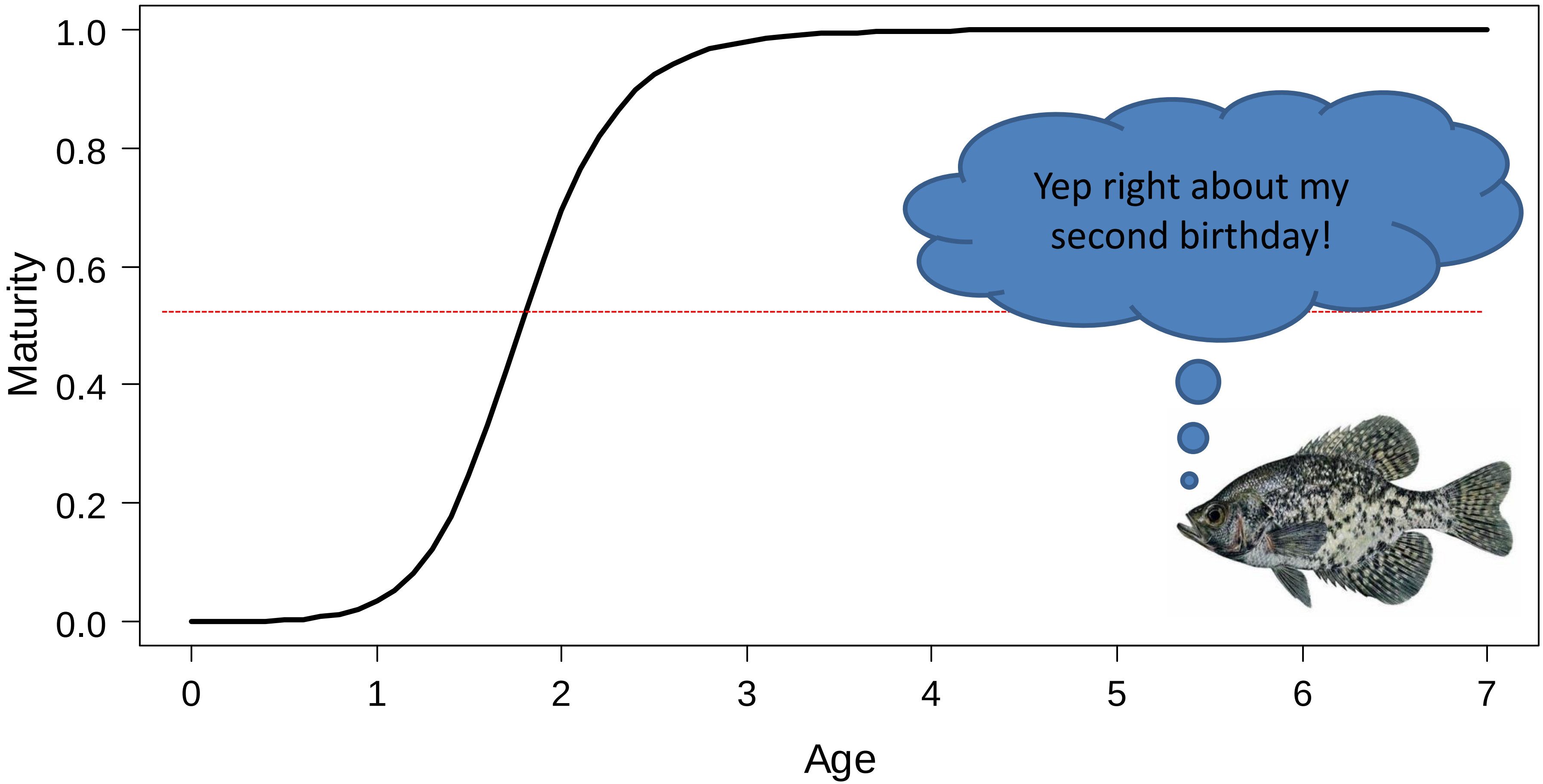
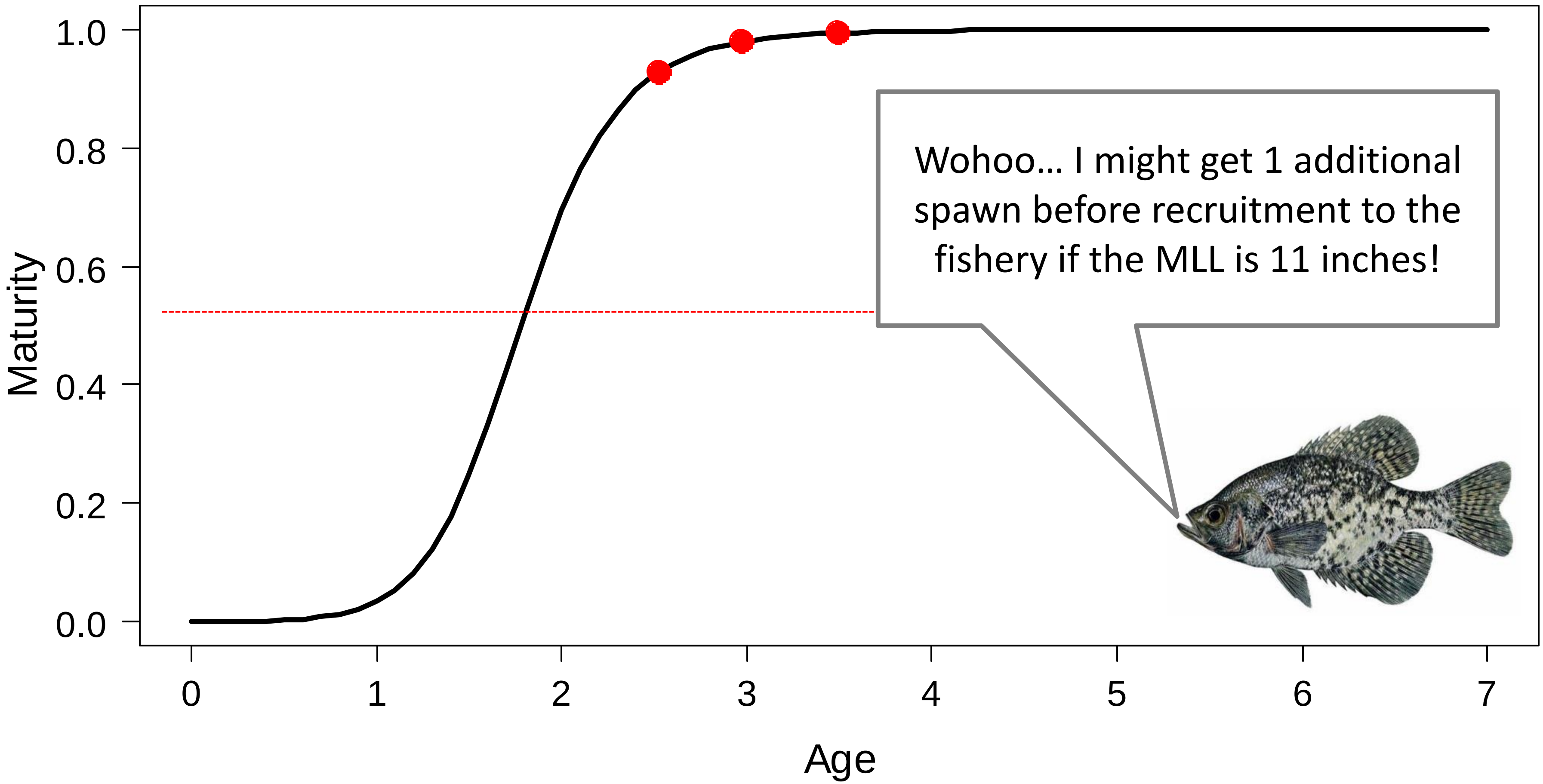
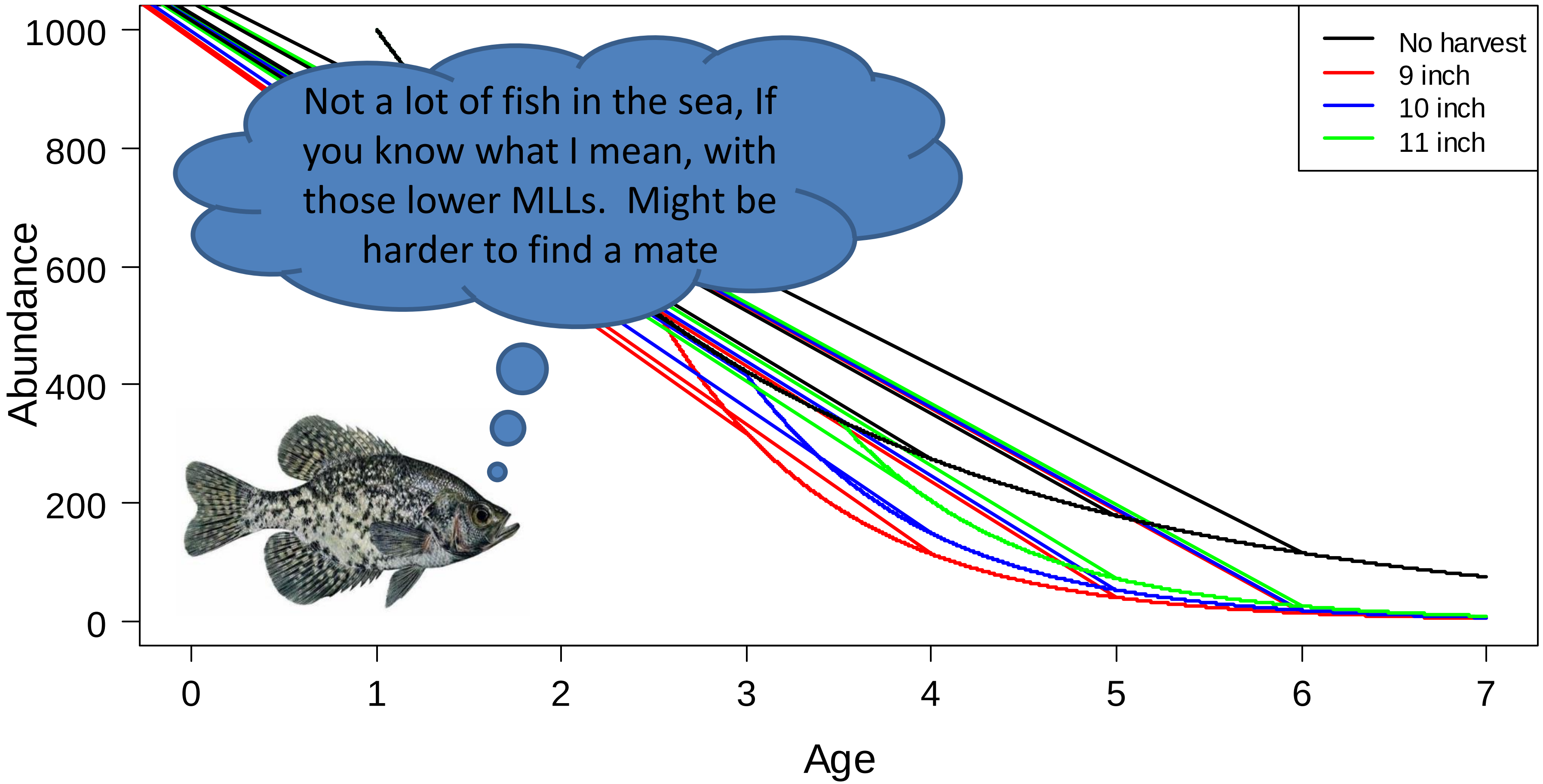


# Maturity function & MLL

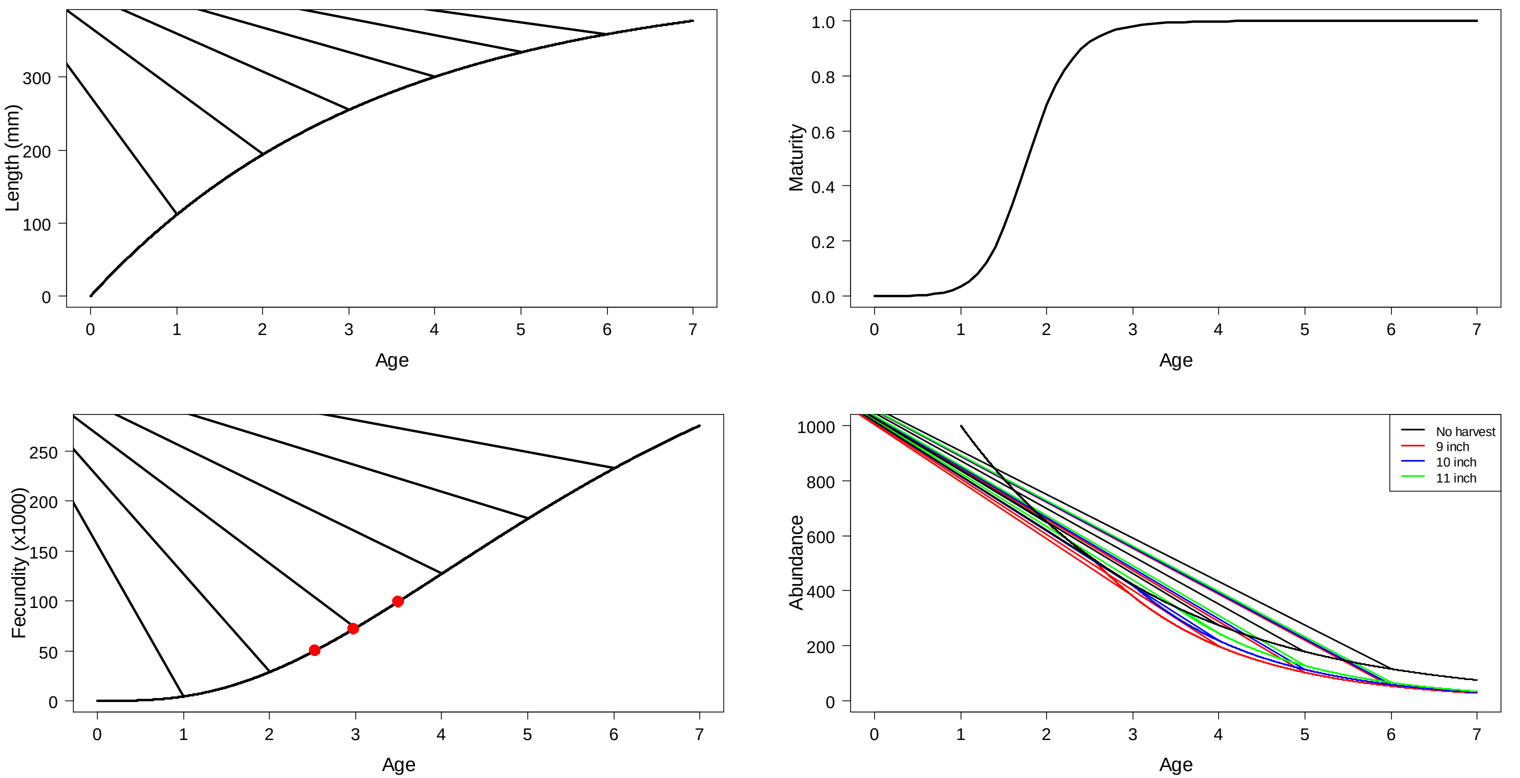


# Abundance



No harvest
9 inch
10 inch
11 inch
Not a lot of fish in the sea, If you know what I mean, with those lower MLLs. Might be harder to find a mate
Abundance
1000
800
600
400
200
0
Age
0
1
2
3
4
5
6
7

# Complex interactions? You bet!



# Evaluation of recruitment overfishing

- Limited in practice
- Set regulations that are **robust** to recruitment overfishing
  - Ratio of spawning biomass to unfished biomass (SSR)
  - Ratio of spawning potential to unfished potential (SPR)

# Spawning potential ratio

- **Spawning potential:** The number of eggs that could be produced by an average recruit over its lifetime
- **Ratio:** the fished stock is divided by the number of eggs that could be produced by an average recruit over its lifetime when the stock is unfished.
- Compares the spawning ability of a stock in the fished condition to the stock's spawning ability in the unfished condition.

# Example

- 10 fish survive the first couple of years of life and are now large enough to be caught (recruited) in the fishery.
- Four are caught before they spawn (no eggs produced)
- Three others are caught after they spawn once (some eggs produced),
- The last three live to spawn three times (many eggs produced) before dying of old age.
- During their lifetime, the 10 fish produced 1 million eggs and the average recruit produced 100,000 eggs (1 million divided by 10).
- Unfished population, 10 fish survive as before. Three die of natural causes after spawning (some eggs produced) and the other seven spawn three times (very many eggs produced) before dying of old age.
- During their lifetime, these 10 fish produced 5 million eggs and the average recruit produced 500,000 eggs (5 million divided by 10).
- The spawning potential ratio is: 100,000 eggs produced by the average fished recruit divided by the 500,000 eggs produced by the average unfished recruit and is equal to 0.20 or 20 percent.

# Spawning stock biomass (SSB) & Spawning stock biomass per recruit (SSBR)

- Biomass (weight):
  - entire adult stock,
  - mature females in the stock,
  - eggs they produce. These measures are called

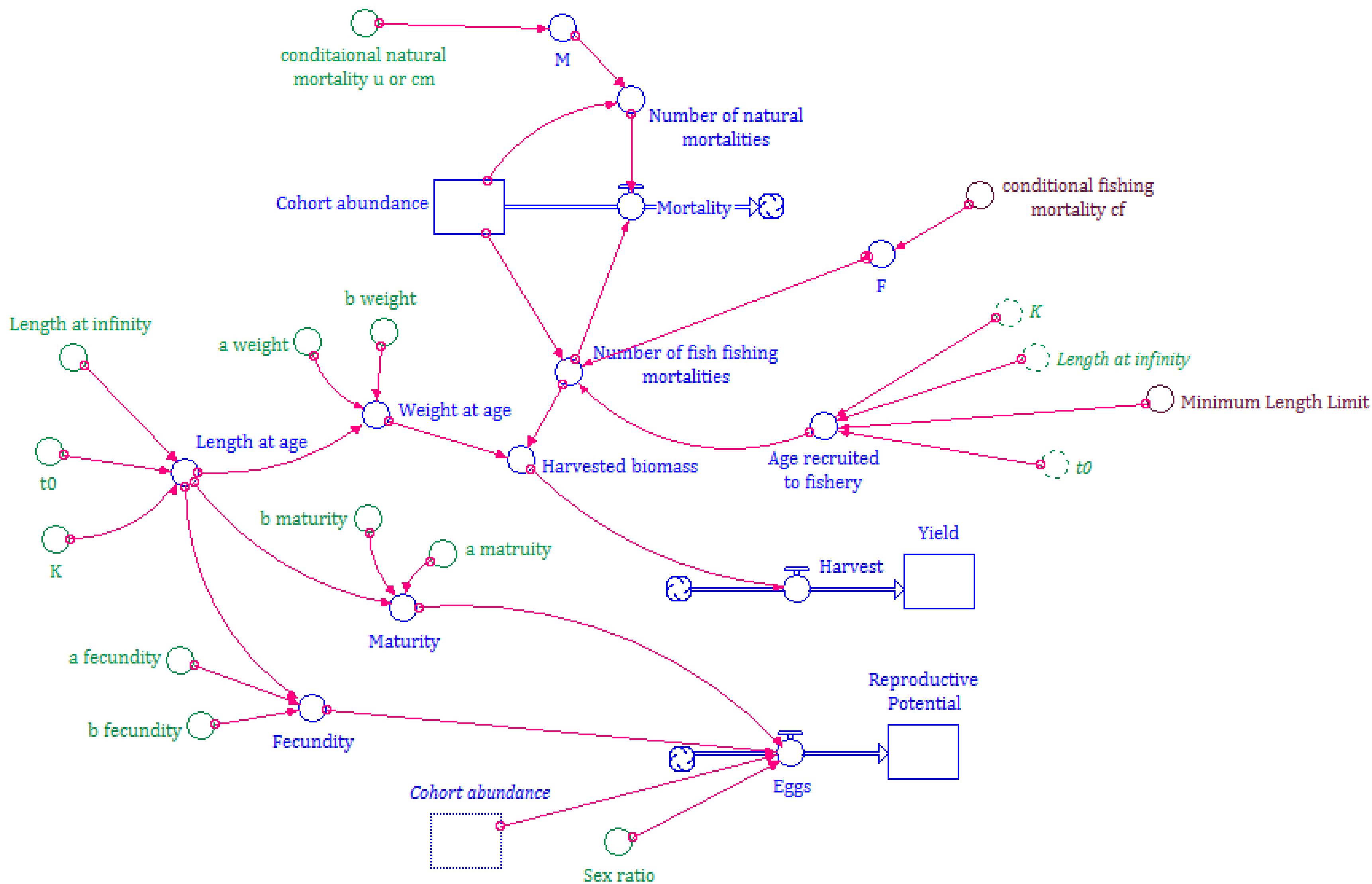
*Spawning stock biomass (SSB) or spawning stock biomass per recruit (SSBR)*

# What is the SPR for Crappie?

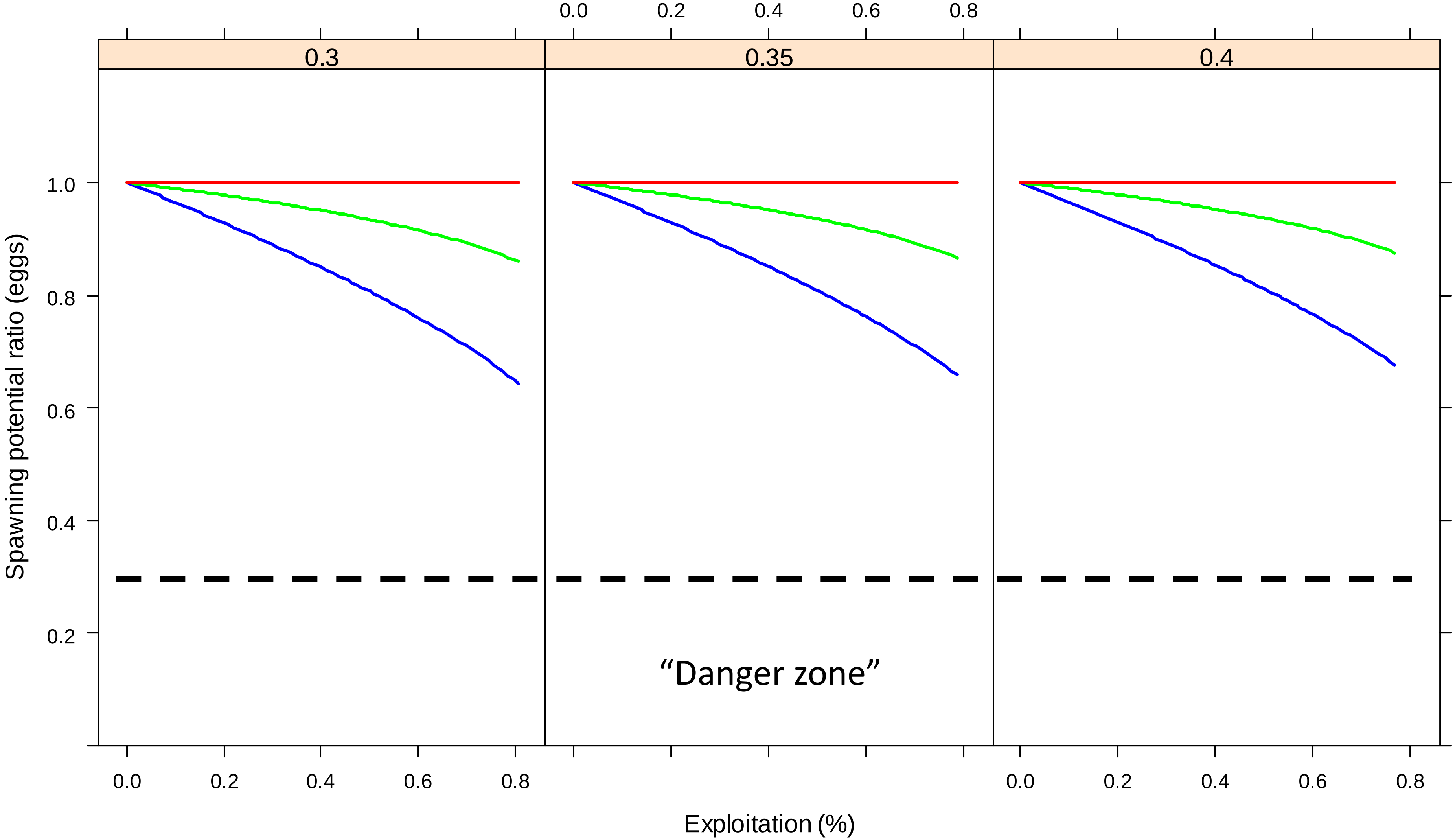
# Stock specific SPR?

- Studies show that some stocks (depending on the species of fish) can maintain themselves if the spawning stock biomass per recruit can be kept at 20 to 35% (or more) of what it was in the unfished stock.
- Lower values of SPR may lead to severe stock declines.

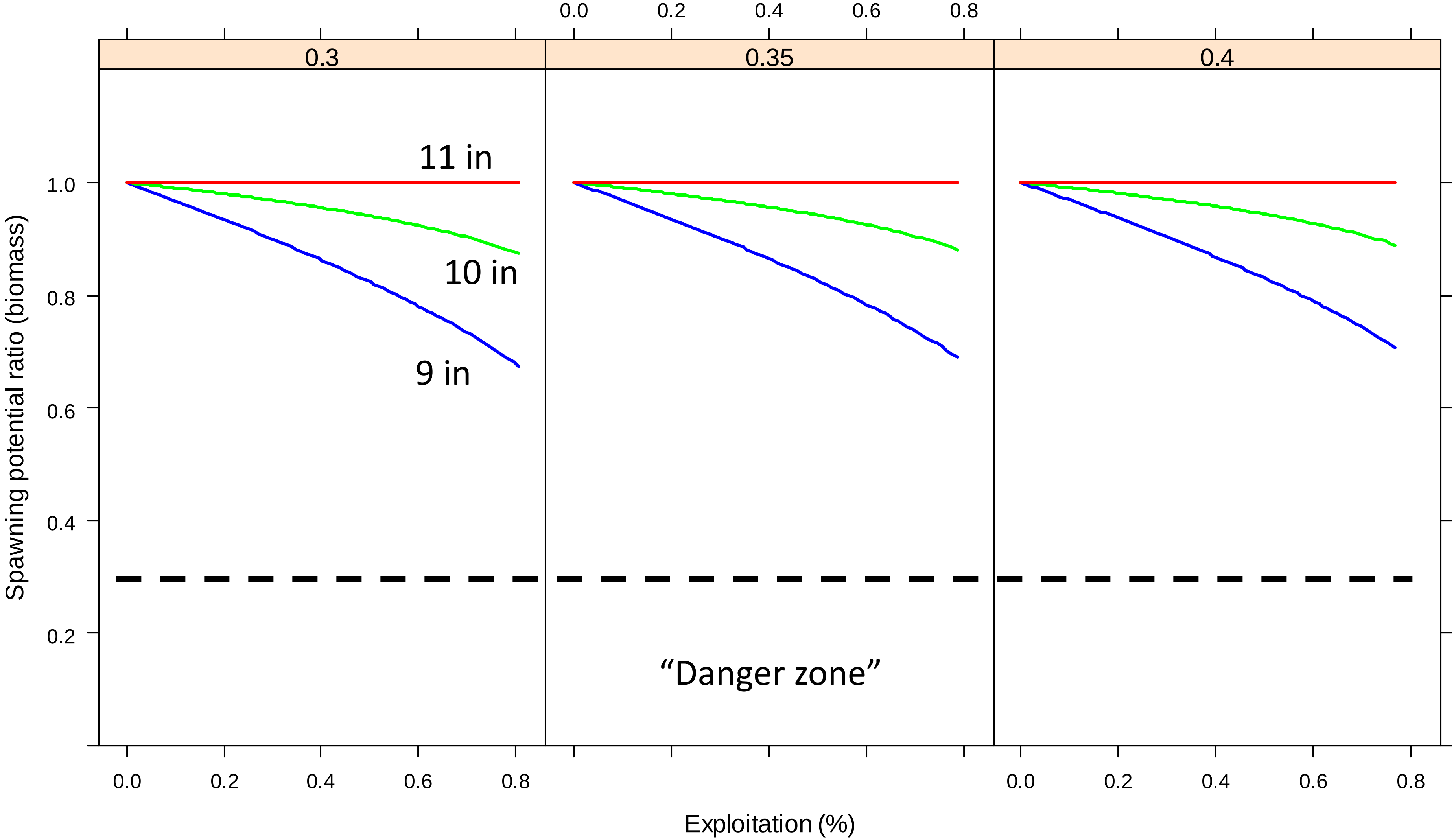
# Conceptually



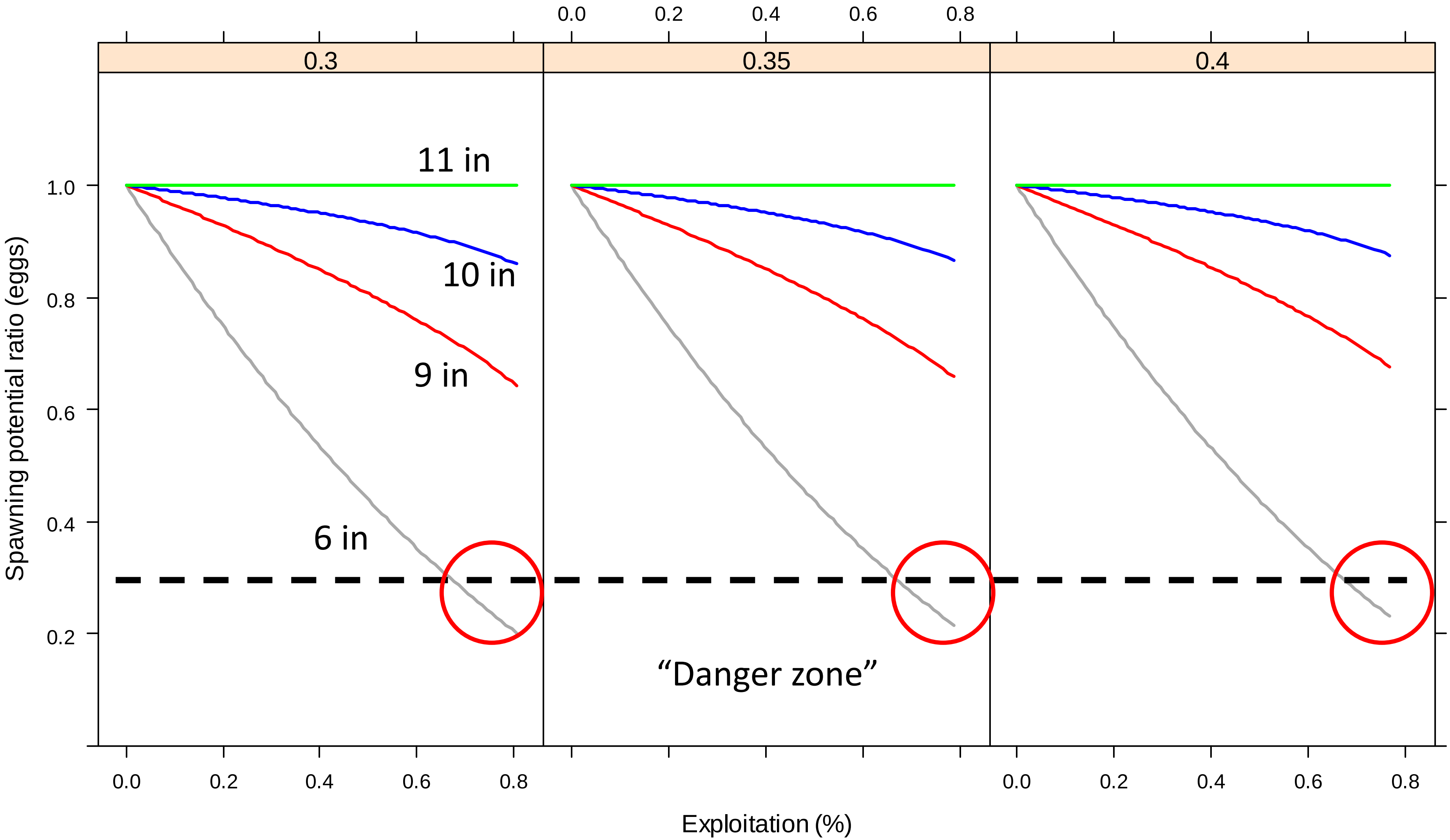
# SPR-Eggs


0.3
0.35
0.4
Spawning potential ratio (eggs)
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
"Danger zone"
Exploitation (%)

# SPR-Mature female biomass



# Adding a 6 inch MLL



# Adding a 6 inch MLL