Stock-recruitment and reference points

Simulation based Fmsy

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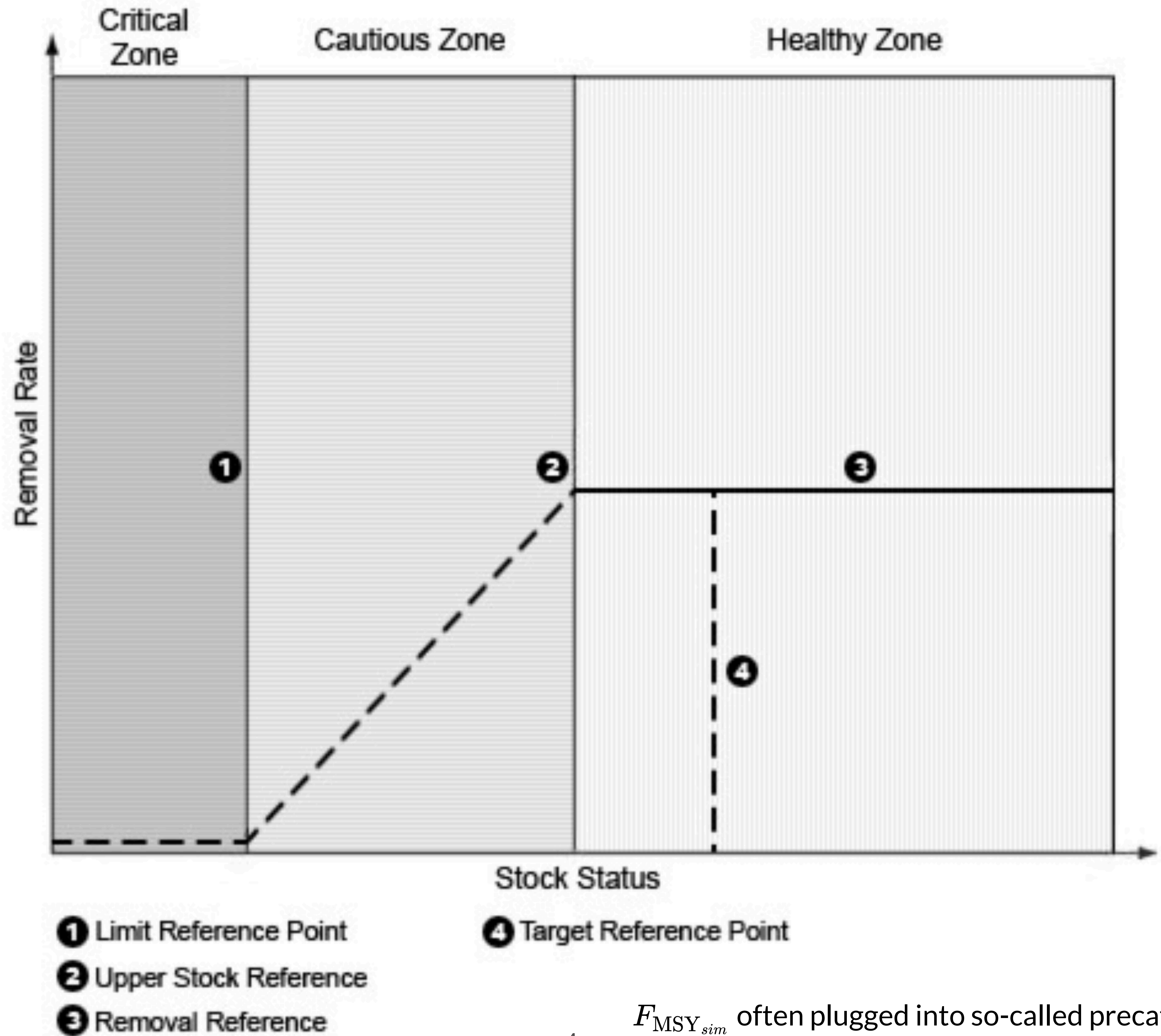
Bill Murray in *Groundhog Day*; Refinement through iteration

Objectives

- Extend equilibrium F_{MSY} calculations for age-structured models to non-equilibrium settings via simulation
    - Primarily by adding recruitment variability around a stock-recruitment relationship, though many alternatives exist
- Compare $F_{\mathrm{MSY}_{sim}}$ to $F_{\mathrm{MSY}_{eq}}$
- Become fluent in a standard age-structured fisheries model à la Cahill



$F_{\mathrm{MSY}_{sim}}$ often plugged into so-called precatuionary rules

The Good, *The Bad*, *and the Ugly* of this lecture

Age-structured population dynamics (log scale)

$$\log N_{t+1,a} = \begin{cases} \log\alpha + \log SSB_t - \log(1+\beta\cdot SSB_t) + w_t, & a = 1 \\ \log N_{t,a-1} - Z_{t,a-1}, & 2 \le a < a_{\max} \\ \log\left(e^{\log N_{t,a_{\max}-1} - Z_{t,a_{\max}-1}} + e^{\log N_{t,a_{\max}} - Z_{t,a_{\max}}}\right), & a = a_{\max} \text{ (plus group)} \end{cases}$$

Where:

$N_{1,a} = N_{\text{init},a}$

$SSB_1 = \sum_a N_{1,a}\cdot m_a\cdot w_a$

$w_t \sim \text{Normal}(0,\sigma_r^2)$

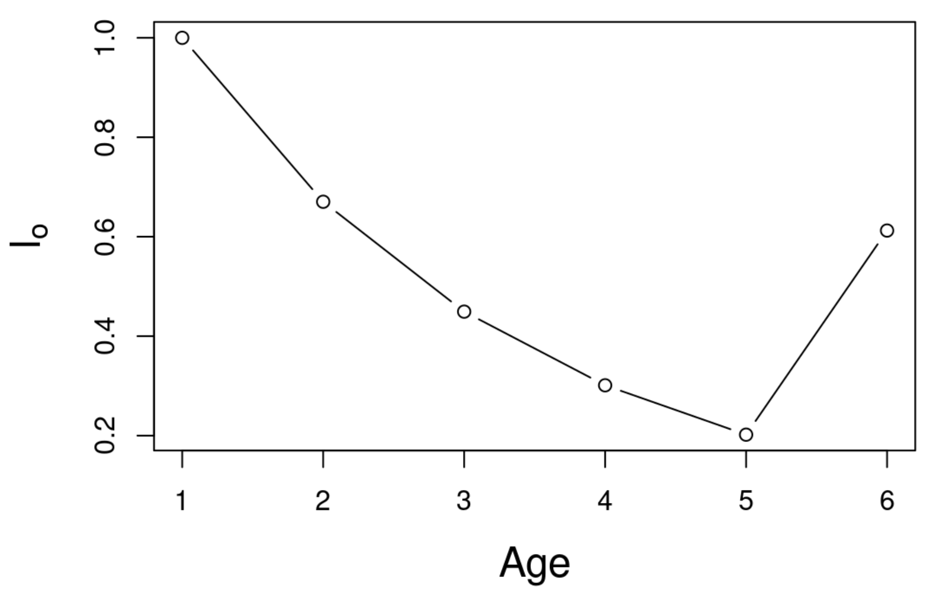
$Z_{t,a} = F\cdot v_a + M$

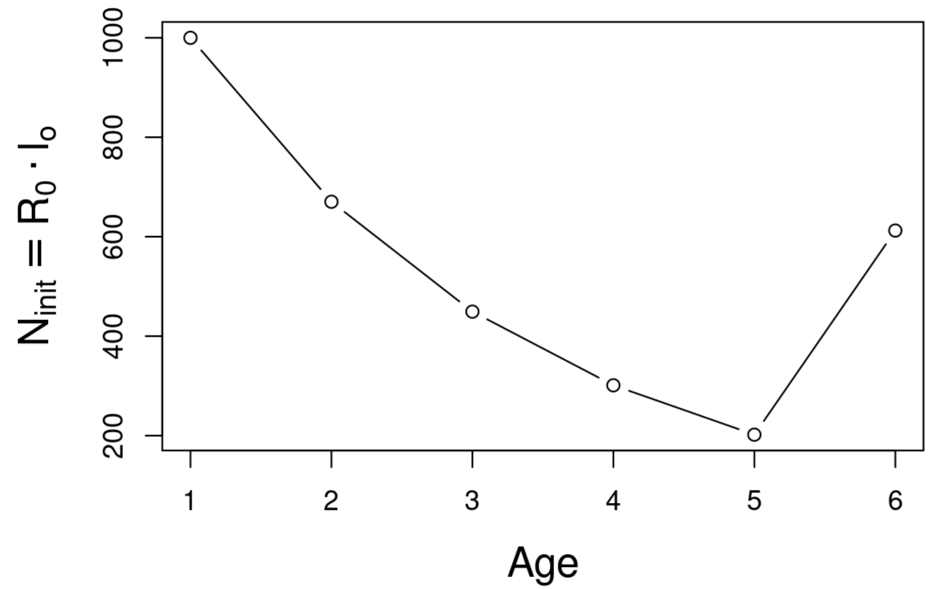
$SSB_t = \sum_a N_{t,a}\cdot m_a\cdot w_a$

$Y_t = \sum_a N_{t,a}\cdot w_a\cdot \frac{F\cdot v_a}{Z_{t,a}}\cdot\left(1 - e^{-Z_{t,a}}\right)$

Initializing an age-structured model

- Botsford incidence functions and survivorship vectors (l_o, l_x) make it easy to initialize a population dynamics model
- In an unfished population, the age structure is simply $R_0 \cdot l_o$





- Can also initialize at a fished equilibrium or at terminal abundance at age estimated by a model

Walters and Martell 2004

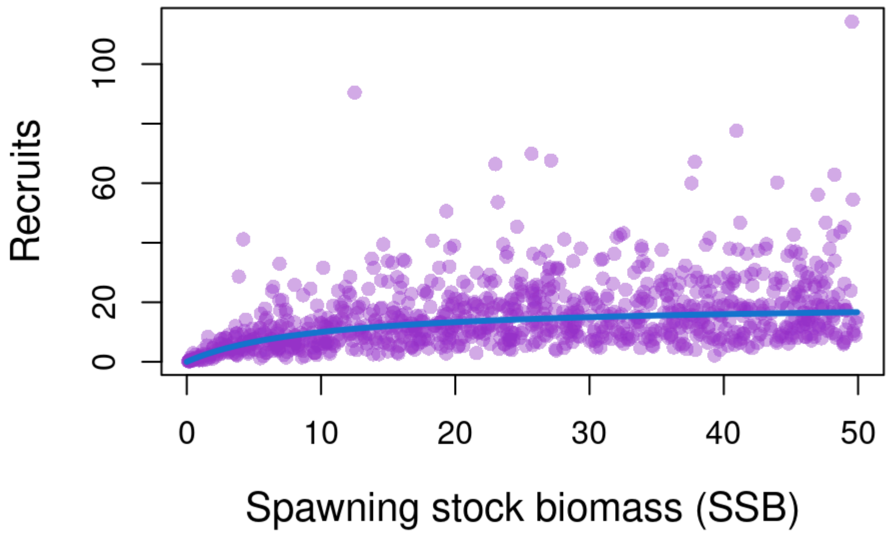
Age-structured model in log-space

$$\log N_{t+1,a} = \begin{cases} \log \alpha + \log SSB_t - \log(1 + \beta \cdot SSB_t) + w_t, & a = 1 \\ \log N_{t,a-1} - Z_{t,a-1}, & 2 \leq a < a_{\max} \\ \log\left(e^{\log N_{t,a_{\max}-1} - Z_{t,a_{\max}-1}} + e^{\log N_{t,a_{\max}} - Z_{t,a_{\max}}}\right), & a = a_{\max} \end{cases}$$

- This formulation:
  1. Improves numerical stability
  2. Simplifies the recursion
  3. Easier computation

Simulation based $\mathrm{F}_{\mathrm{MSY}}$: stochasticity

- Recruitment variability is often a key source of uncertainty in fish populations
- Ignored in the equilibrium reference point calculations :(



- $w_t \sim \mathrm{Normal}(0, \sigma_r^2 = 0.6)$

Beverton and Holt 1957

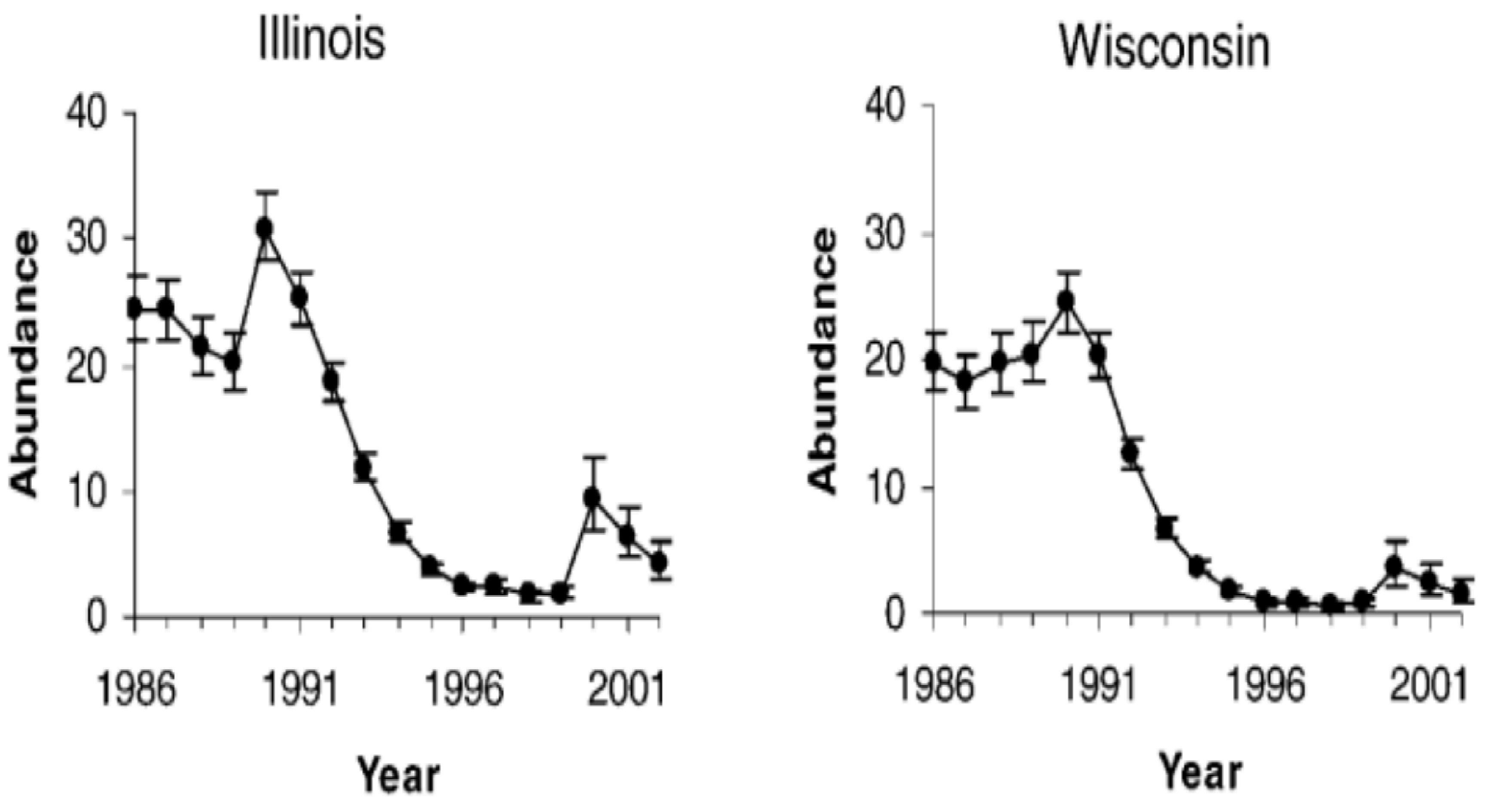
Simulation-based $\mathrm{F}_{\mathrm{MSY}}$: roadmap

- We want to understand how recruitment **stochasticity** affects F_{MSY}
- Parameterize our age-structured model using Ro and recK
- Simulate **population dynamics** over a long time horizon with random recruitment deviations
- Use **numerical optimization** to find the value of F that maximizes average annual yield
- Repeat across many replicates with different w_t sequences, and **summarize** the resulting distribution of F_{MSY} estimates

- Be careful!
  - $F_{\mathrm{MSY}_{sim}}$ is sometimes called F_{MAY} or even just F_{MSY}
  - $F_{\mathrm{MSY}_{sim}}$ is not the same quantity as $F_{\mathrm{MSY}_{eq}}$ from last lecture, though both are sometimes called F_{MSY} (misery)

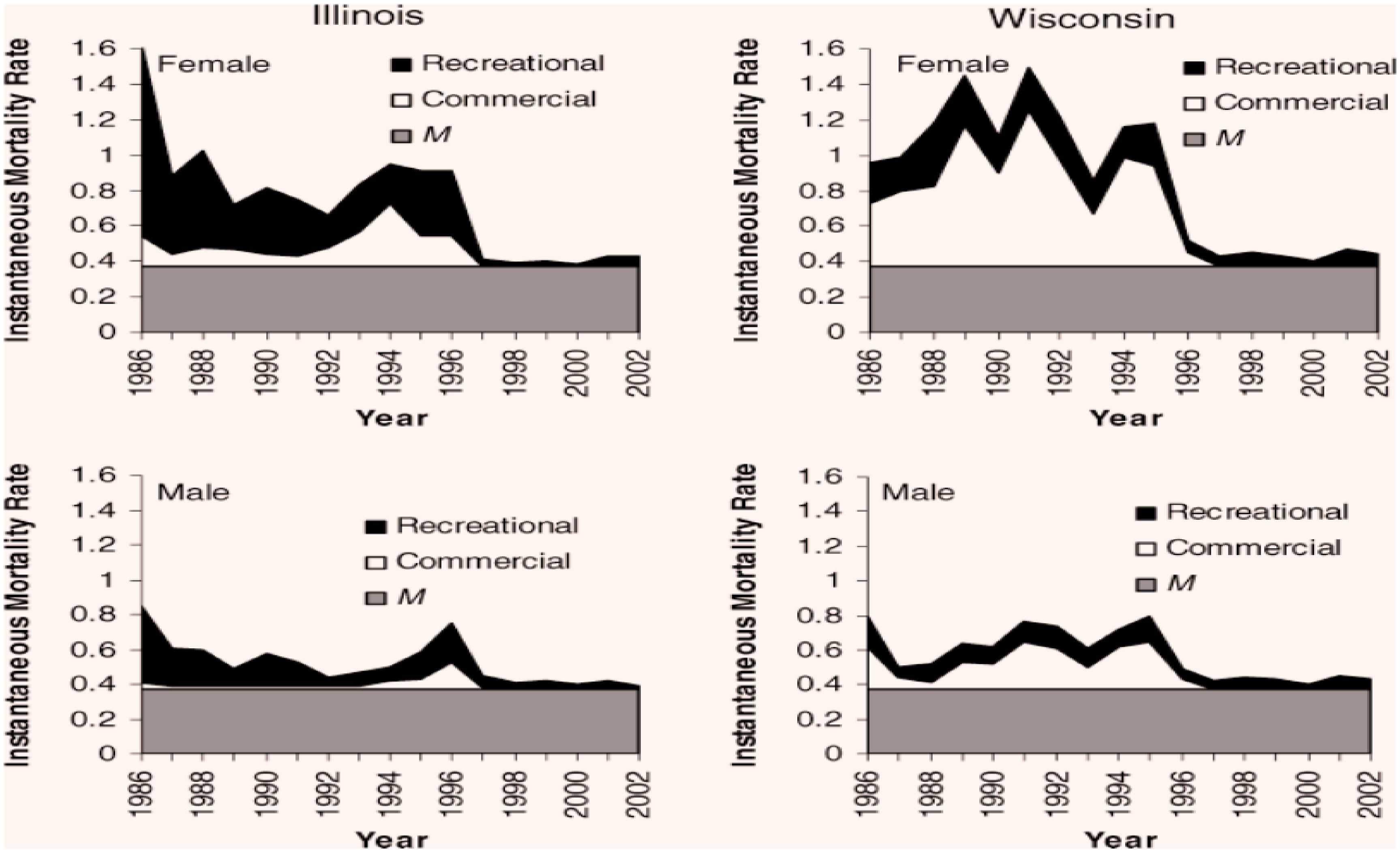
Hilborn and Walters 1992

The Saga of Lake Michigan Yellow Perch



Wilberg et al. 2005

The Saga of Lake Michigan Yellow Perch



Wilberg et al. 2005

Exercise

- Go through `fmsy_sim_bh.R` as a group
- Explore how recruitment stochasticity affects reference points
- Does your analysis lend any insights into the collapse of Lake Michigan Yellow Perch?
- Play!

  1. recK and Ro
  2. Ricker vs. BH (already coded for you)
  3. Compare with equilibrium solutions
  4. life history + other leading parameters

  - Note that your data are based loosely off Lake Erie Yellow Perch
- My advice: approach the problem with strategic and experimental thinking

References

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