Effects of lingcod predation on copper rockfish recovery in marine reserves

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Agenda

- Purpose
- Model Structure
  - Population dynamics
  - Predation model
- Proposed Investigations

Purpose

- Rockfish decline
  - Ecologically and commercially important fish

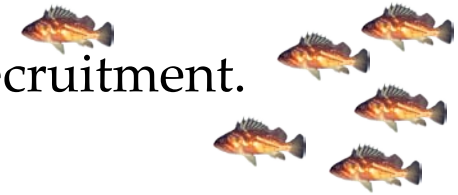
- Marine Protected Areas
  - Also protects lingcod

- Efficacy of MPAs concerning rockfish

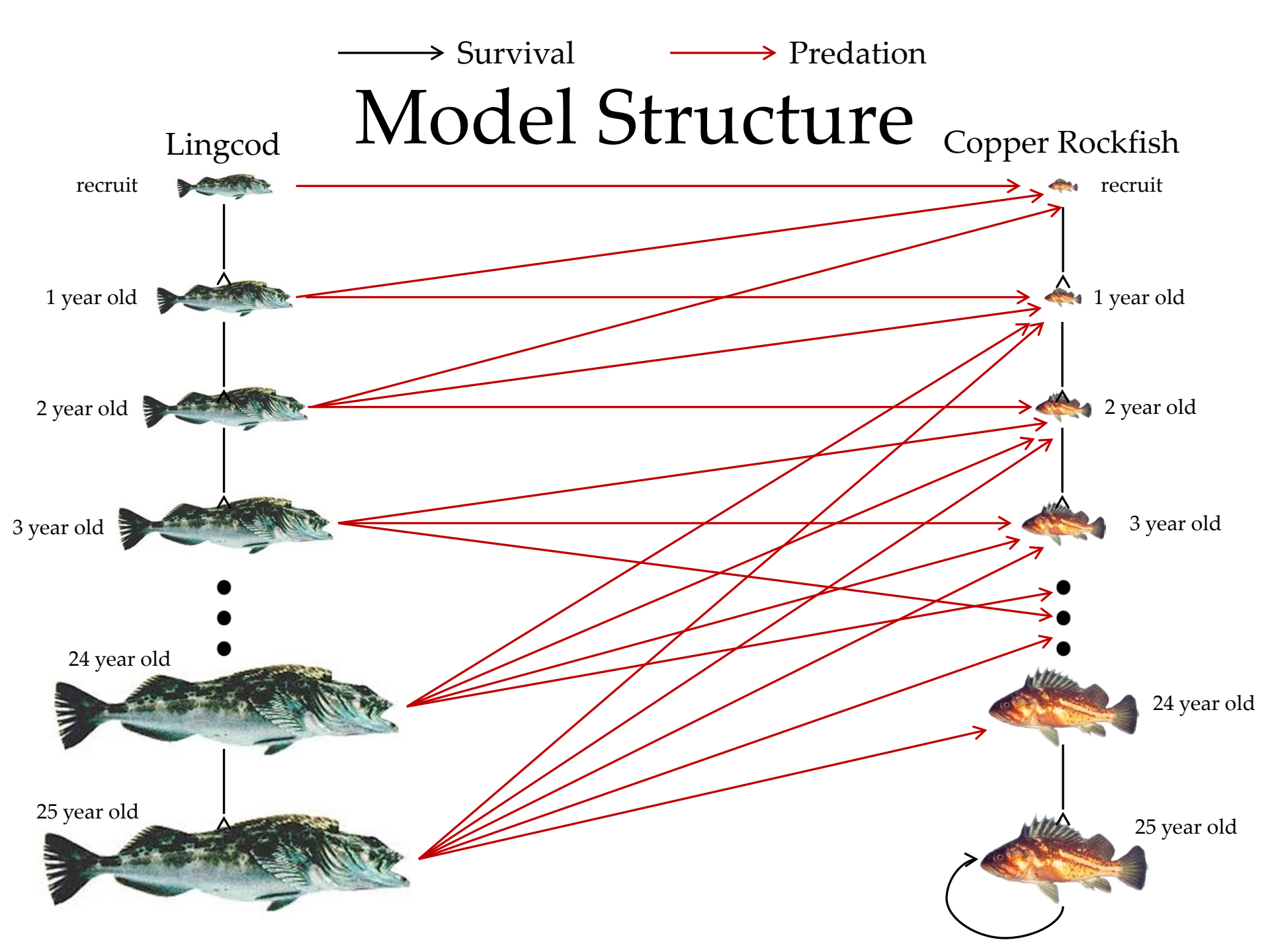
Model Structure

- Systems of annually updating difference equations featuring:
  - Length/growth-dependent natural mortality (Gislason et al., 2010)

  - Fixed recruitment.



  - Density- and length-dependent predation of rockfish by lingcod.
    - Derived from empirical observations of size structure in lingcod-rockfish predation within the San Juan Archipelago (Beaudreau and Essington, 2009).


Survival
Predation
Model Structure
Lingcod
Copper Rockfish
recruit
1 year old
2 year old
3 year old
24 year old
25 year old
recruit
1 year old
2 year old
3 year old
24 year old
25 year old

Model Structure

Recruits:

$$R_0(t) = r_R$$

$$LF_0(t) = \frac{r_L}{2}$$

$$LM_0(t) = \frac{r_L}{2}$$

Juveniles and Adults:

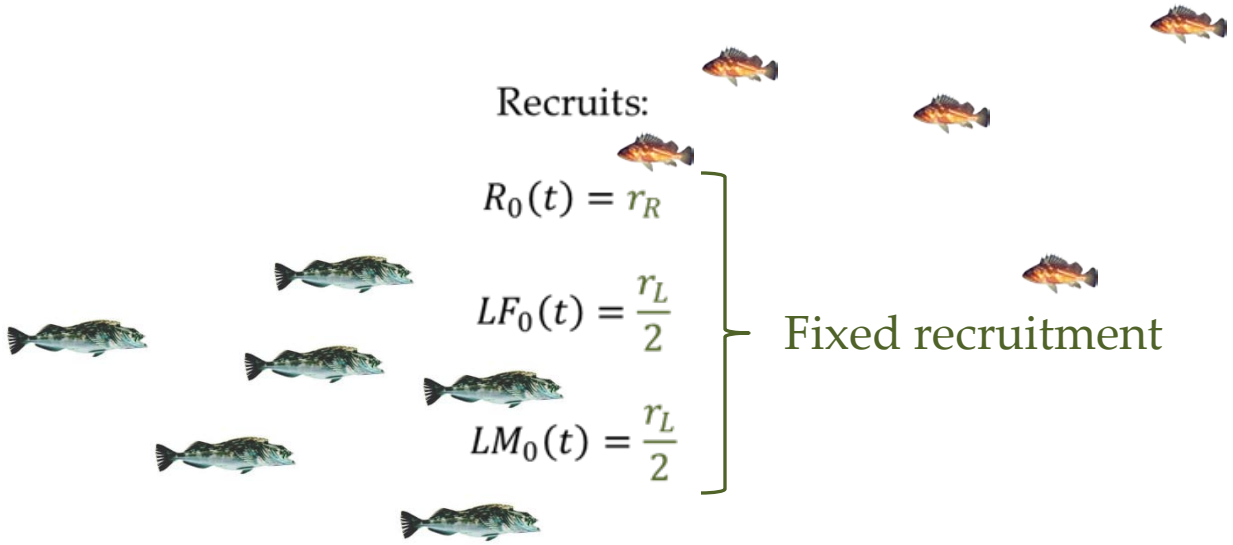
$$R_i(t+1) = S_{i-1}(R_{i-1}(t) - D_{i-1}(t)), \qquad for\ i = 1, 2, \dots, 24$$

$$R_{25}(t+1) = S_{24}(R_{24}(t) - D_{24}(t)) + \underbrace{S_{25}(R_{25}(t) - D_{25}(t))}_{\text{Self-loop}}$$

$$LF_i(t+1) = PF_{i-1}LF_{i-1}(t), \qquad for\ i = 1, 2, \dots, 25$$

$$LM_i(t+1) = PM_{i-1}LM_{i-1}(t), \qquad for\ i = 1, 2, \dots, 25$$

Model Structure



Recruits:

$$R_0(t) = r_R$$

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Fixed recruitment

Juveniles and Adults:

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Rockfish survival

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Female lingcod survival → PF_{i-1}

$$LF_i(t+1) = PF_{i-1}LF_{i-1}(t), \qquad for\ i = 1, 2, \dots, 25$$

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Model Structure

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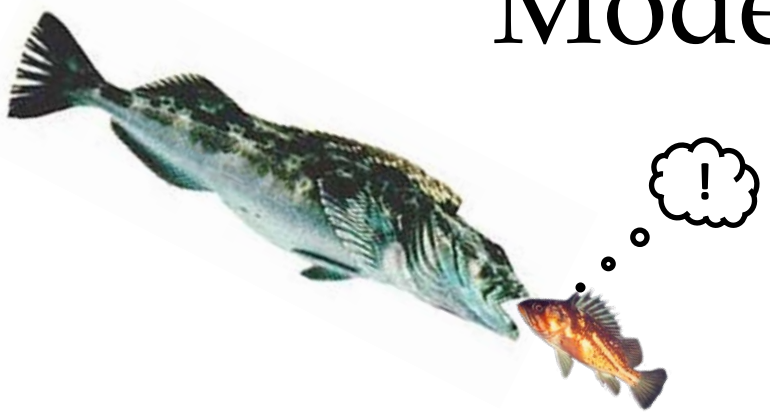
Male lingcod survival

Model Structure



Recruits:

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Lingcod predation on rockfish

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Model Structure

Predation Model

- Dynamic components:
  - Functional response*✦
  - Lingcod density
- Fixed relationships:
  - Prey weight†
  - Consumption (bioenergetics model*)
  - Prey length preference‡*

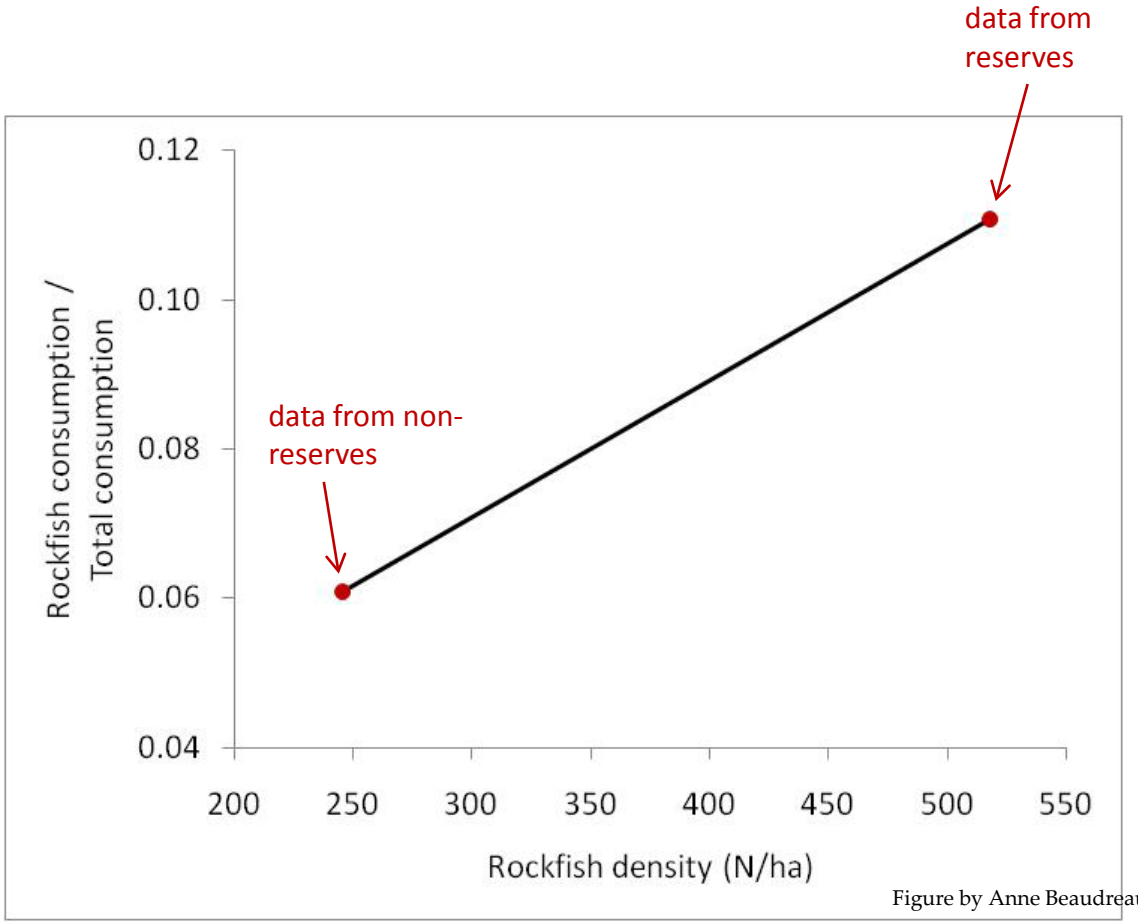
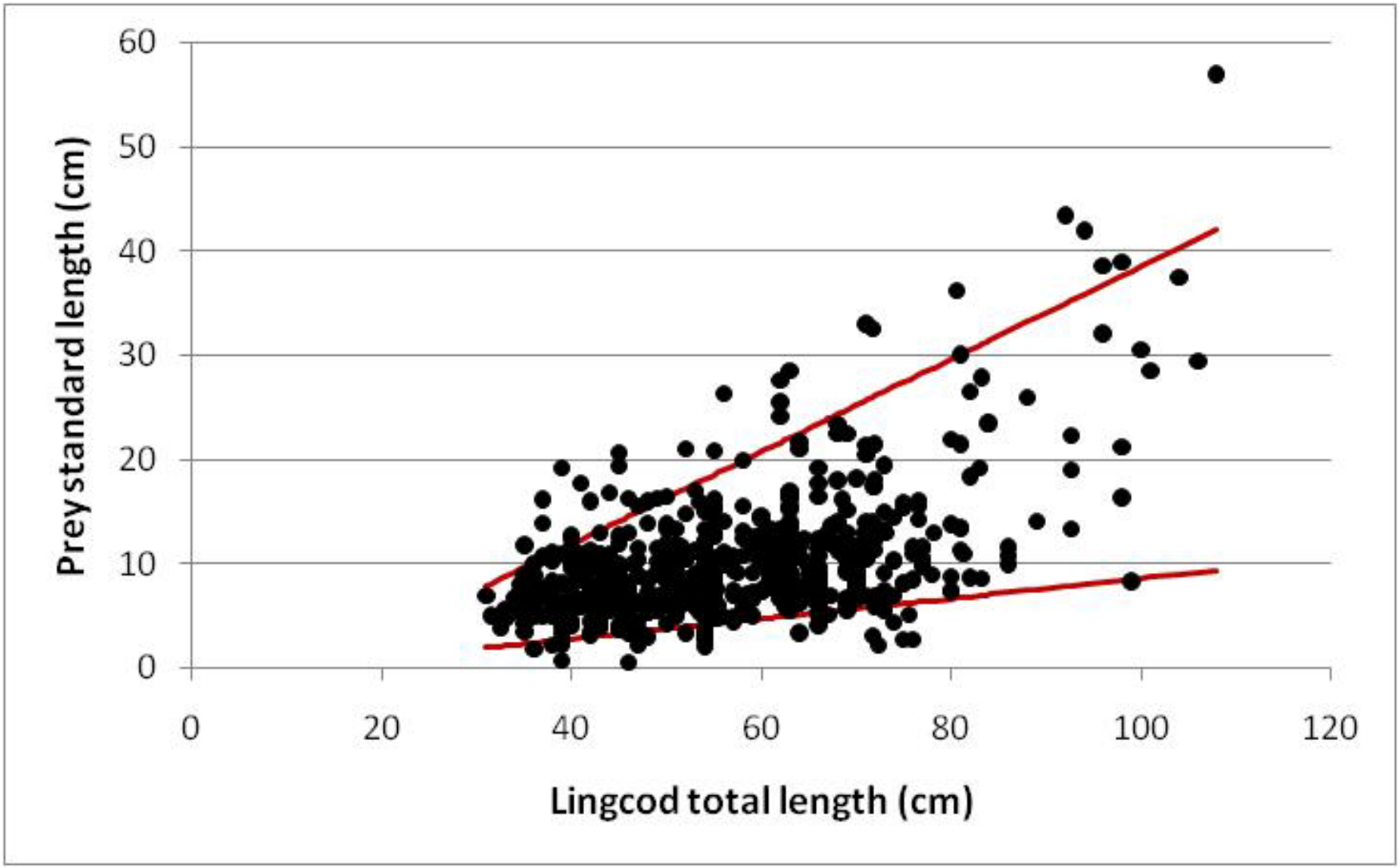


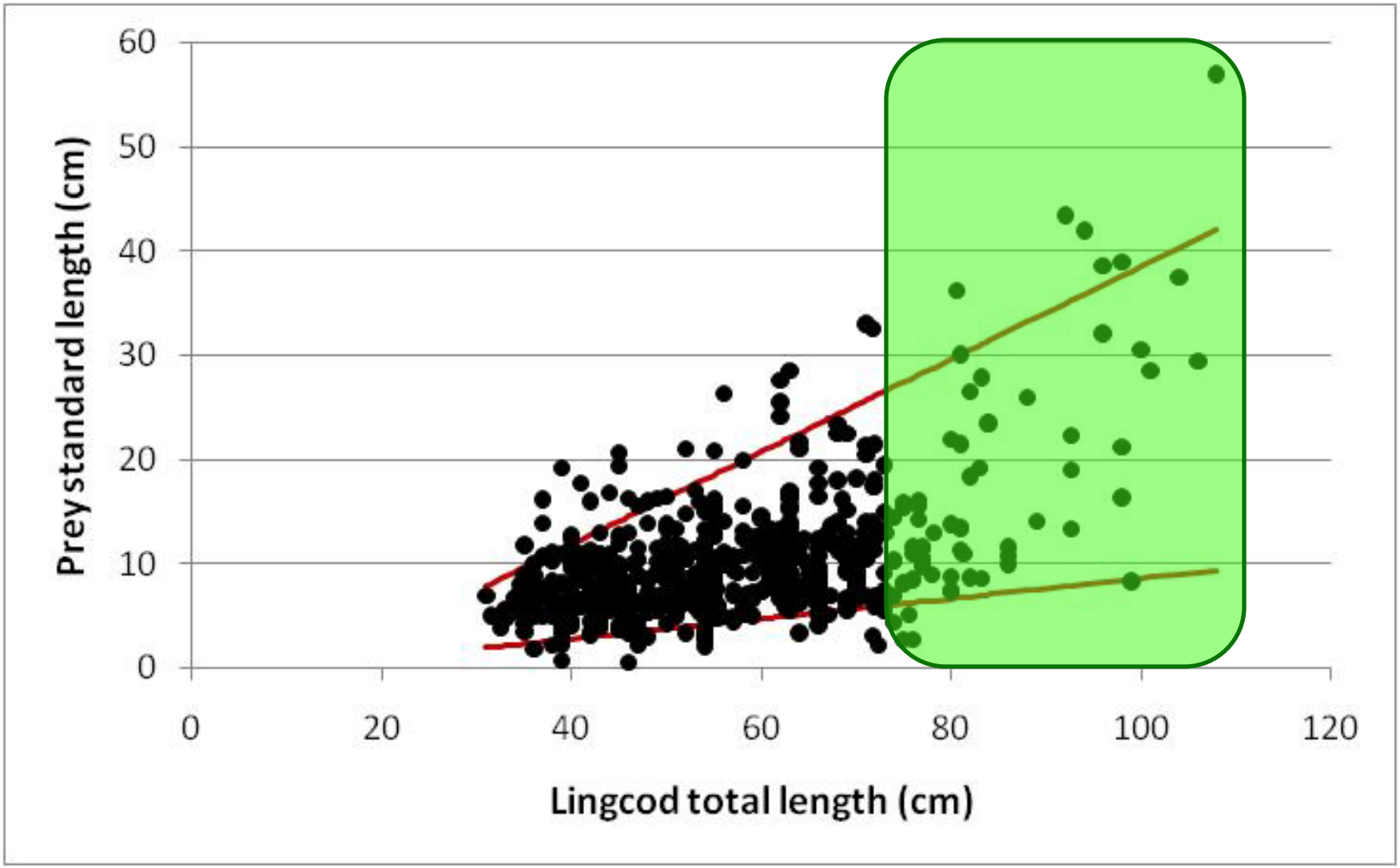
Figure by Anne Beaudreau

‡ Beaudreau and Essington, 2007
* Beaudreau and Essington, 2009
✦ Eisenhardt, 2001
† Gowan, 1983

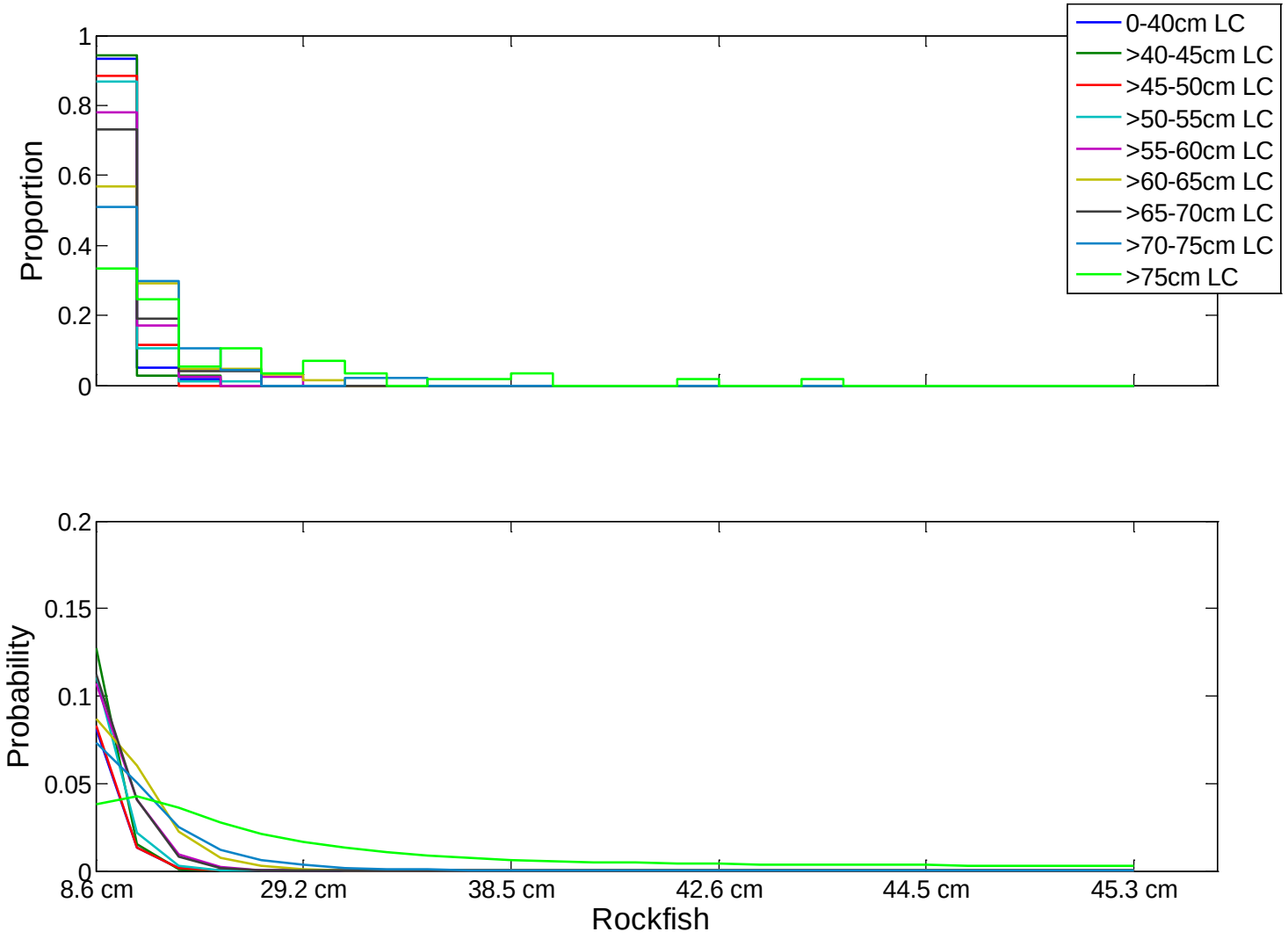
Model Structure



Model Structure



Model Structure



Model Structure

Predation

$$D_i(t) = \sum_{j=0}^{25} CR_{ratio}(t)\left(PRM_{i,j} \cdot \frac{CM_j}{W_i} \cdot LM_j(t) + PRF_{i,j} \cdot \frac{CF_j}{W_i} \cdot LF_j(t)\right), \qquad for\ i = 0, 1, 2, \ldots, 25$$

Model Structure

Predation

$$D_i(t) = \sum_{j=0}^{25} CR_{ratio}(t)\left(PRM_{i,j} \cdot \frac{CM_j}{W_i} \cdot LM_j(t) + PRF_{i,j} \cdot \frac{CF_j}{W_i} \cdot LF_j(t)\right), \qquad for\ i = 0, 1, 2, \ldots, 25$$

Functional response

Model Structure

Predation

$$D_i(t) = \sum_{j=0}^{25} CR_{ratio}(t)\left(PRM_{i,j} \cdot \frac{CM_j}{W_i} \cdot LM_j(t) + PRF_{i,j} \cdot \frac{CF_j}{W_i} \cdot LF_j(t)\right), \qquad for\ i = 0, 1, 2, \ldots, 25$$

Rockfish eaten by male lingcod

Model Structure

Predation

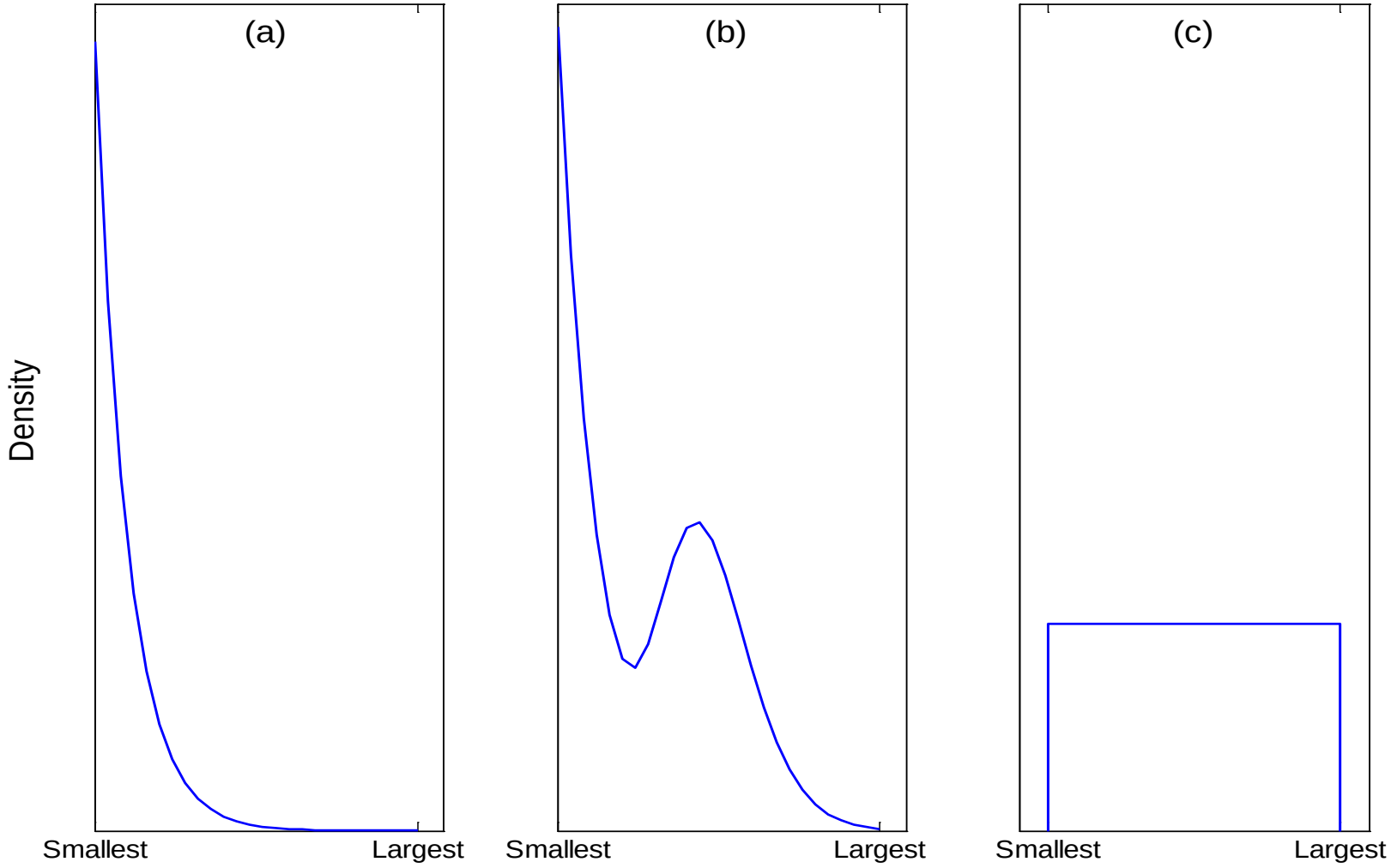
$$D_i(t) = \sum_{j=0}^{25} CR_{ratio}(t)\left(PRM_{i,j} \cdot \frac{CM_j}{W_i} \cdot LM_j(t) + PRF_{i,j} \cdot \frac{CF_j}{W_i} \cdot LF_j(t)\right), \qquad for\ i = 0, 1, 2, \dots, 25$$

Rockfish eaten by female lingcod

Proposed Investigations

- Distinct initial size distributions for different types of reserves:
  - "New"
  - "Old"

Proposed Investigations



Proposed Investigations

- What do we expect?
  - New reserve may offer faster, short term recovery (if any) for rockfish.

- If the rockfish do not recover?
  - Selective removal of lingcod

http://wn.com/spearfishing_sea_bass

Stay tuned!
Jim Lyle 9/20/2008 Long Beach

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