Effects of Climate and Gadid Predation on Red King Crab Population Dynamics in Alaska

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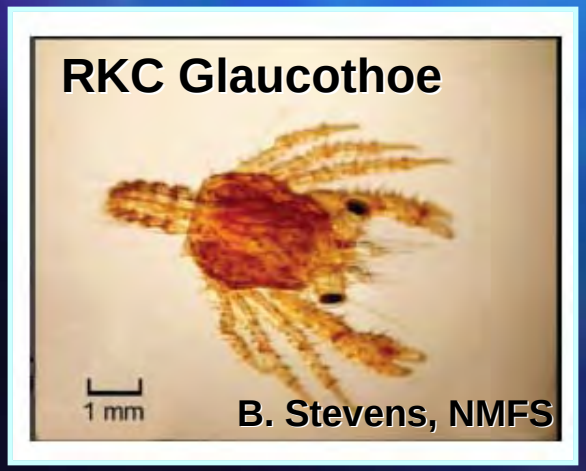
Outline of Presentation

- Red king crab biology and life history
- Fishery and management history
- Consider evidence for effects of:
  - Fishing
  - Parental stock size
  - Climate
  - Predation
- General conclusions

Reproductive Biology of Red King Crab

- Mating immediately after the female annual molt in spring
- Females carry up to 500,000 embryos

Early Life History



- Larvae hatch in April to June in Bristol Bay (eastern Bering Sea) and go through four pelagic zoeal stages
- They transform to glaucothoe while searching for suitable nursery habitat < 50 m depth
- Then, they molt into benthic juveniles

Later Life History

- Young molt several times per year through age 3, then molting is annual
- Aggregations (pods) are formed as juveniles through adulthood


Photo: L. Barr, Auke Bay, AK


Photo: www.afsc.noaa.gov

- After maturity, females molt annually, but males molt with declining probability
- Males are recruited to fishery at ~8-9 yr
- Longevity > 20 years

Overview of Fishery Management

- 3-S (Size-Sex-Season) Management:
  - Sex – Only males are legal for harvest
  - Size – Minimum legal size
  - Season – No fishing during spring molting & mating periods
- Former harvest rate:
  - 20-60% of legal males, depending on population size, pre-recruit abundance and post-recruit abundance (half these rates applied to Norton Sd.)
- Current harvest rate:
  - Kodiak: 20% of mature males
  - Bristol Bay: 10-15% of mature males
  - Norton Sound: 5-10% of legal males

Crab Stock Assessments

Assessment Surveys

- Kodiak – pots during 1972-1986, trawls since 1986
- Bristol Bay – annual trawls since 1968
- Norton Sound – sporadic trawls & pots since 1976

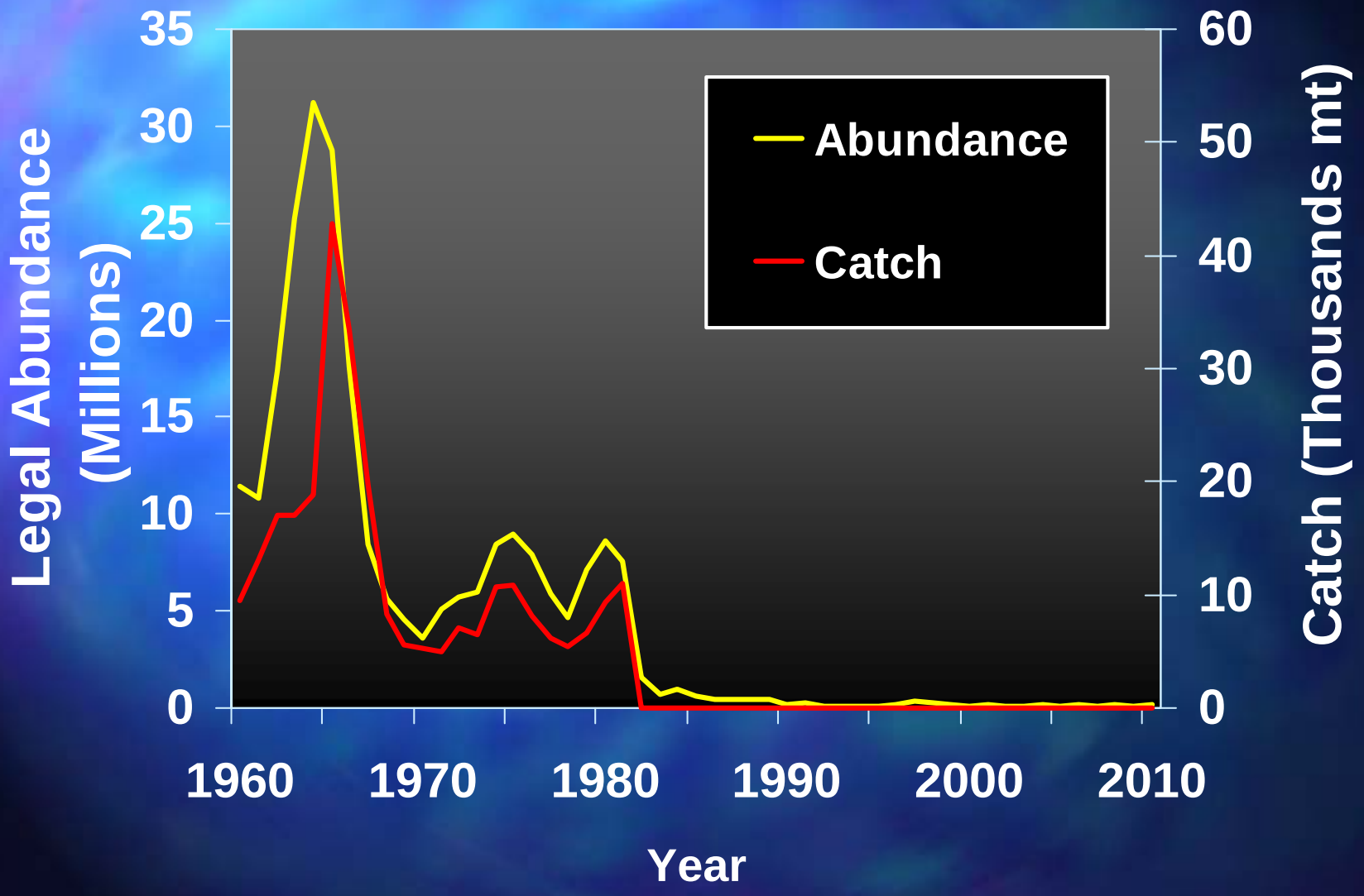
Other Monitoring Data

- Onboard observers – Bristol Bay
- Dockside sampling – all areas

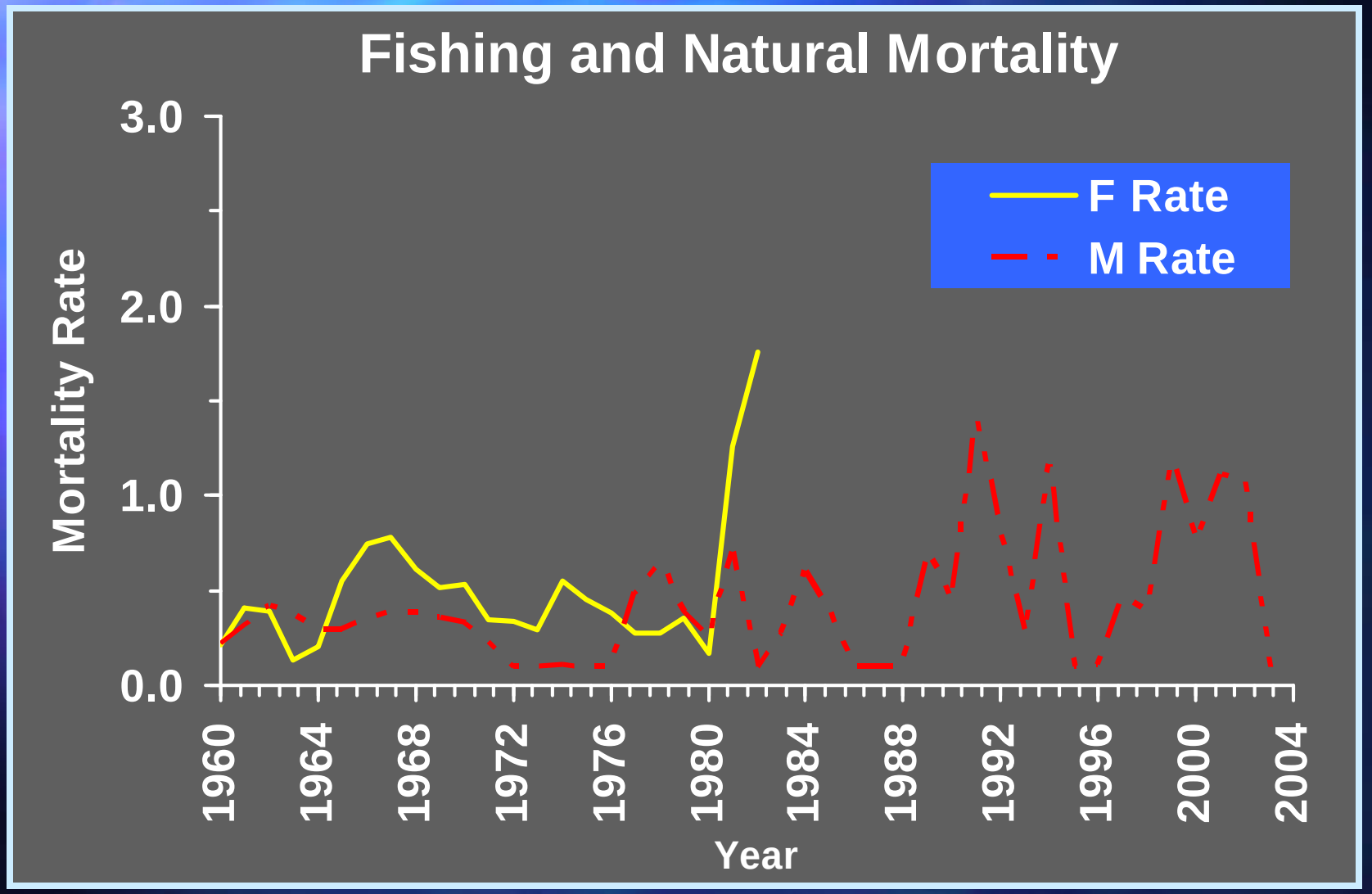
Stock assessment models

- Kodiak – Catch-survey analysis
- Bristol Bay – Length-based analysis
- Norton Sound – Length-based stock-synthesis analysis

Abundance & Catch: Kodiak

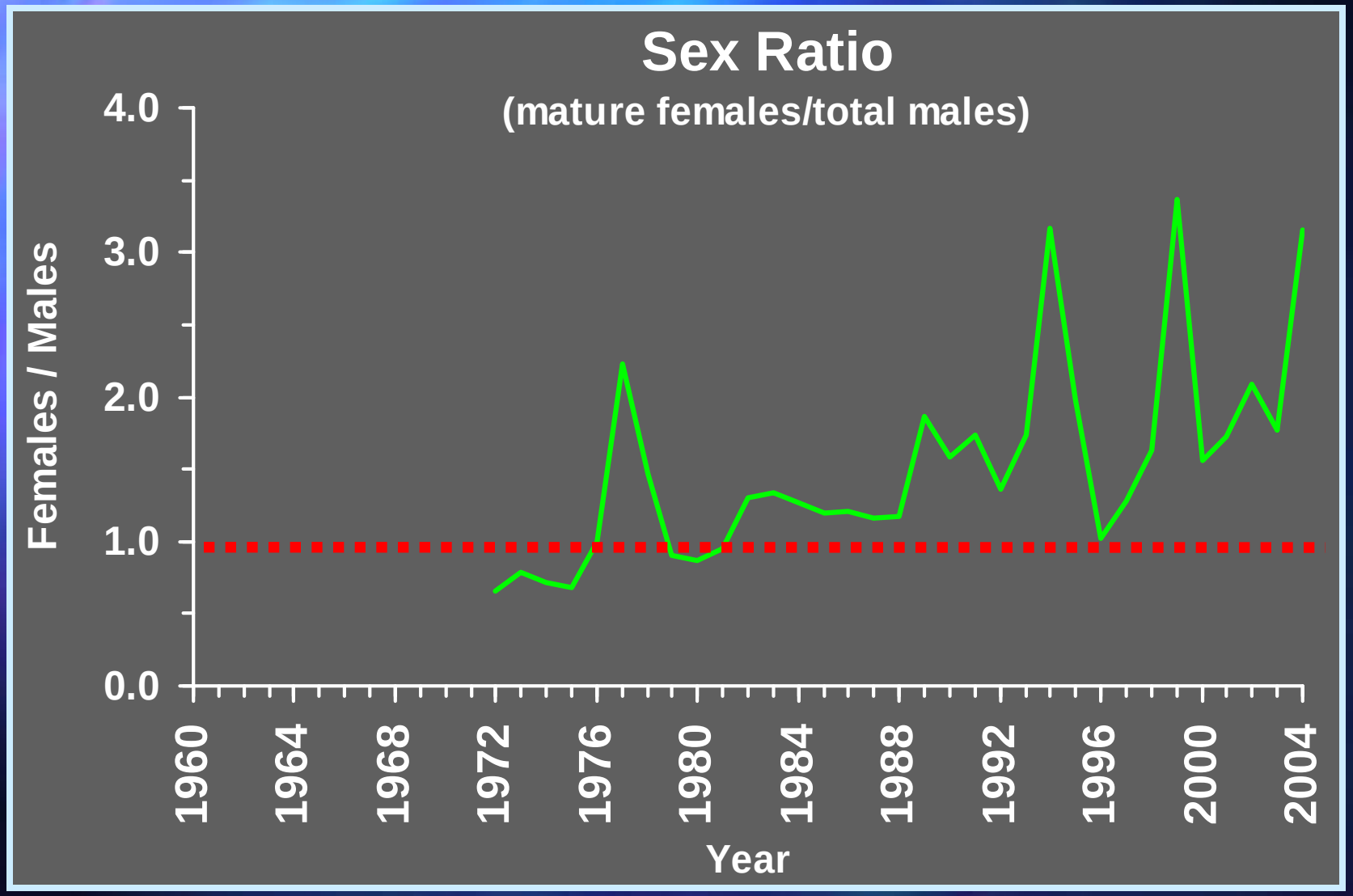


Fishery Effects: Kodiak



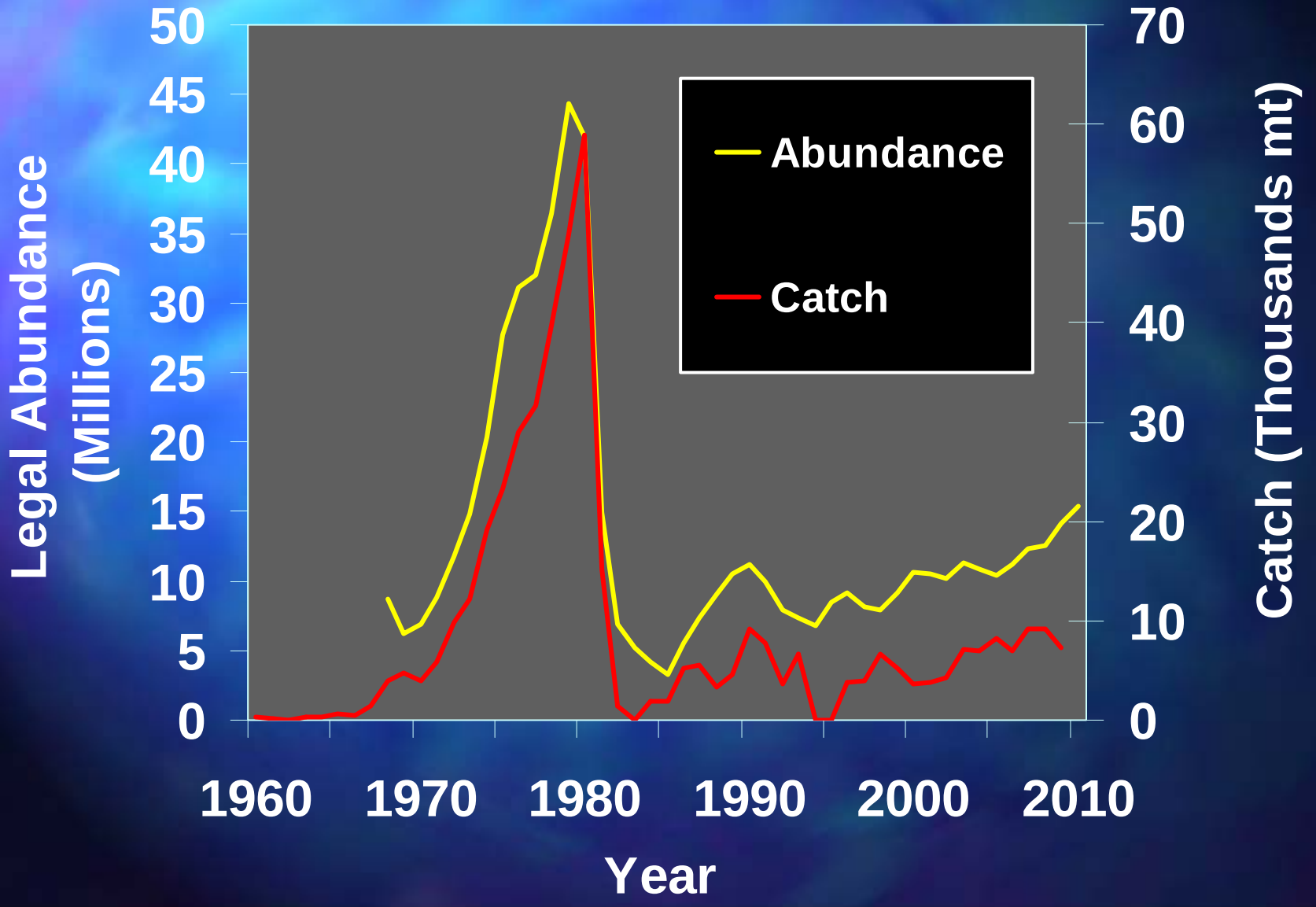
Bechtol and Kruse (2009a)

Fishery Effects: Kodiak

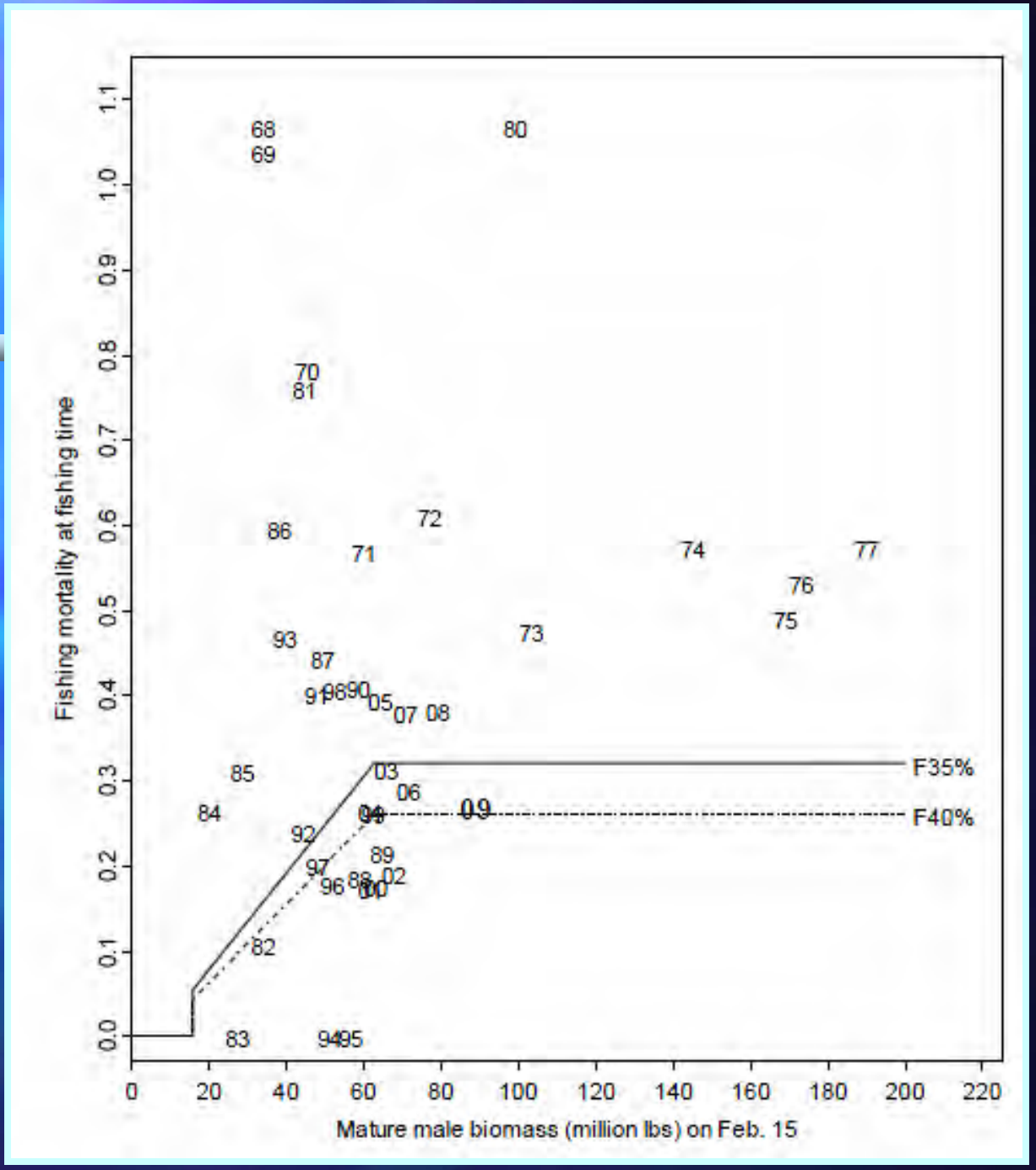


Bechtol and Kruse (2009a)

Abundance & Catch: Bristol Bay

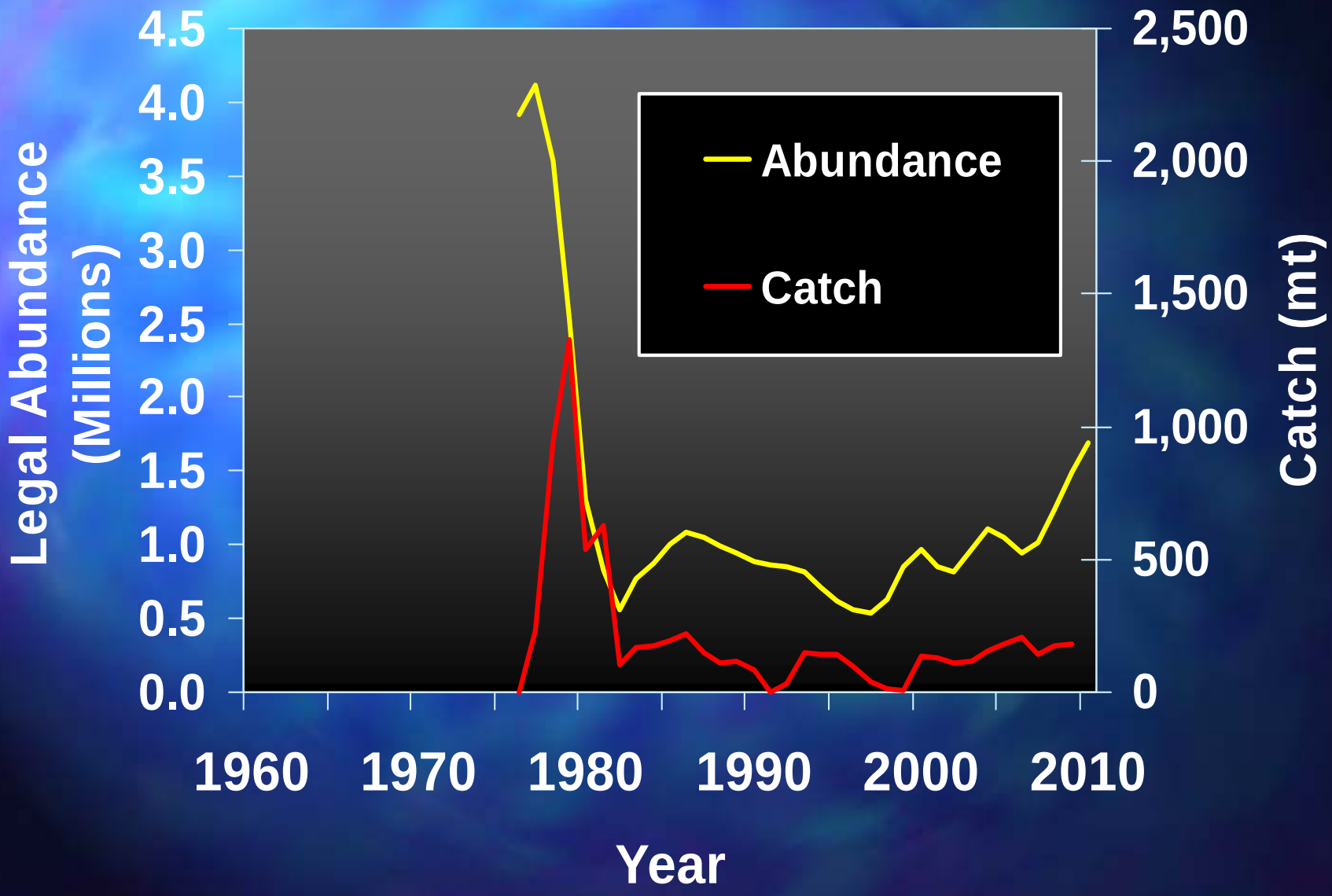


Fishery Effects: Bristol Bay

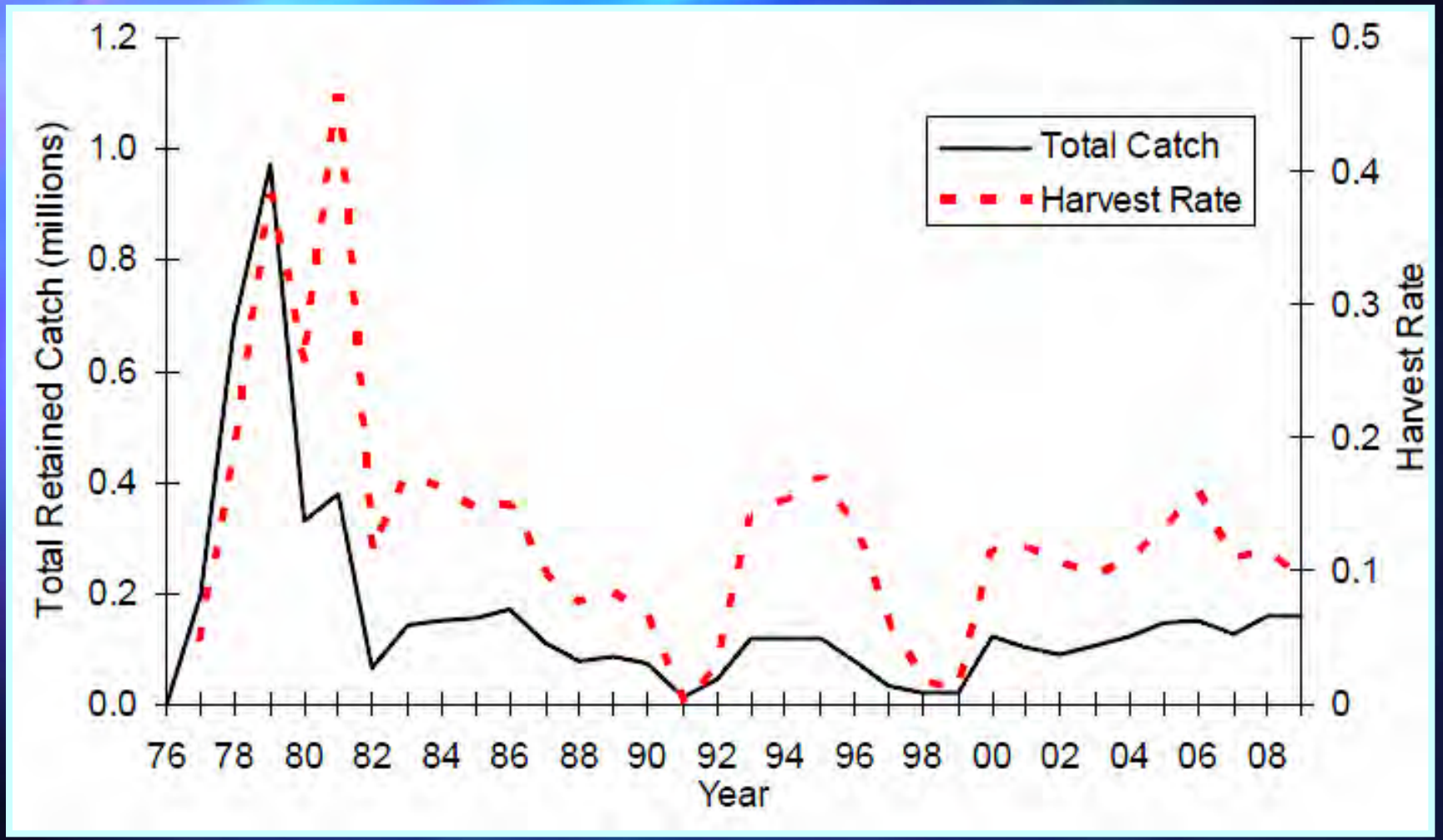


Zheng and Siddeek (2010)

Abundance & Catch: Norton Sound

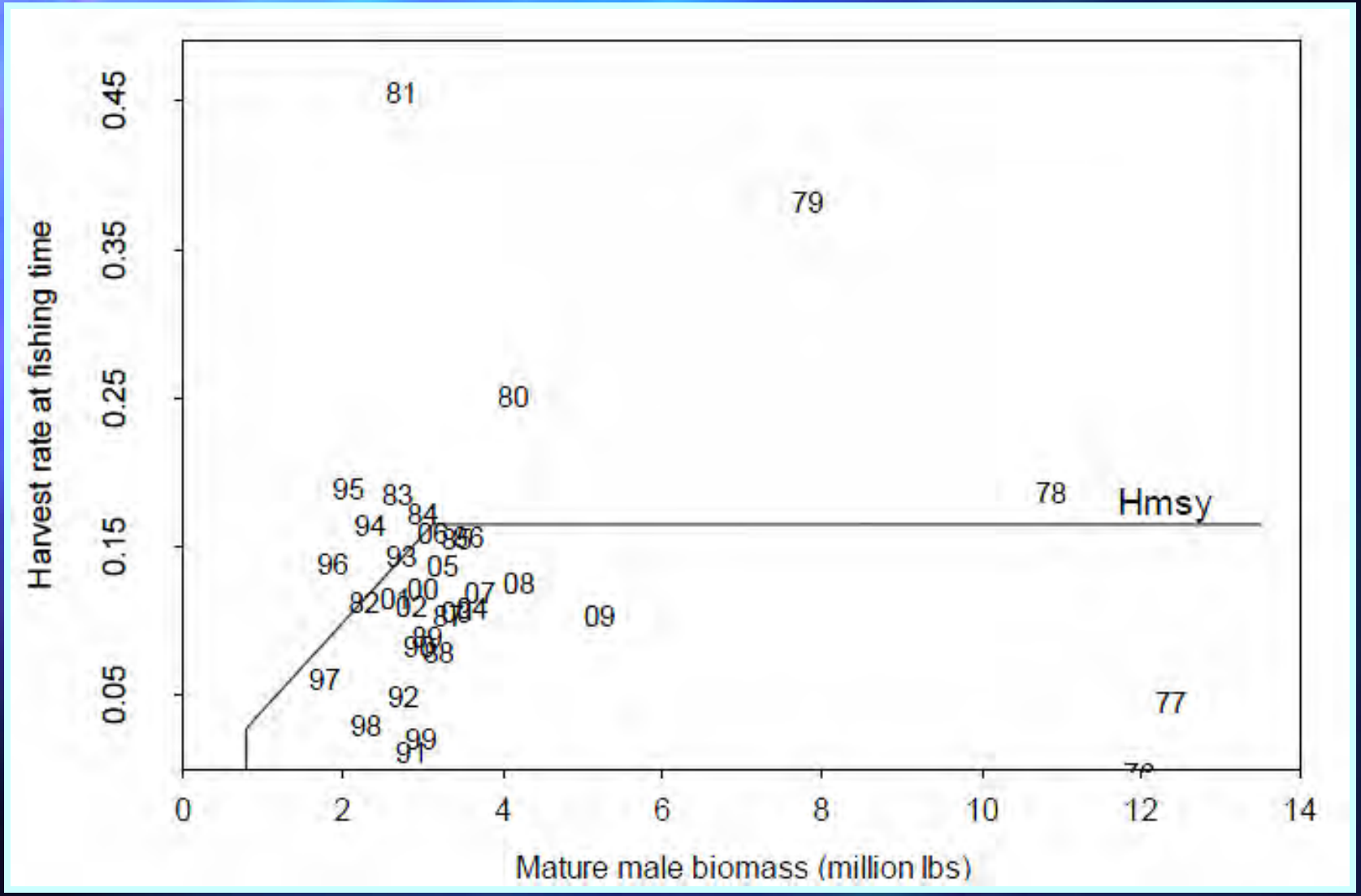


Fishery Effects: Norton Sound



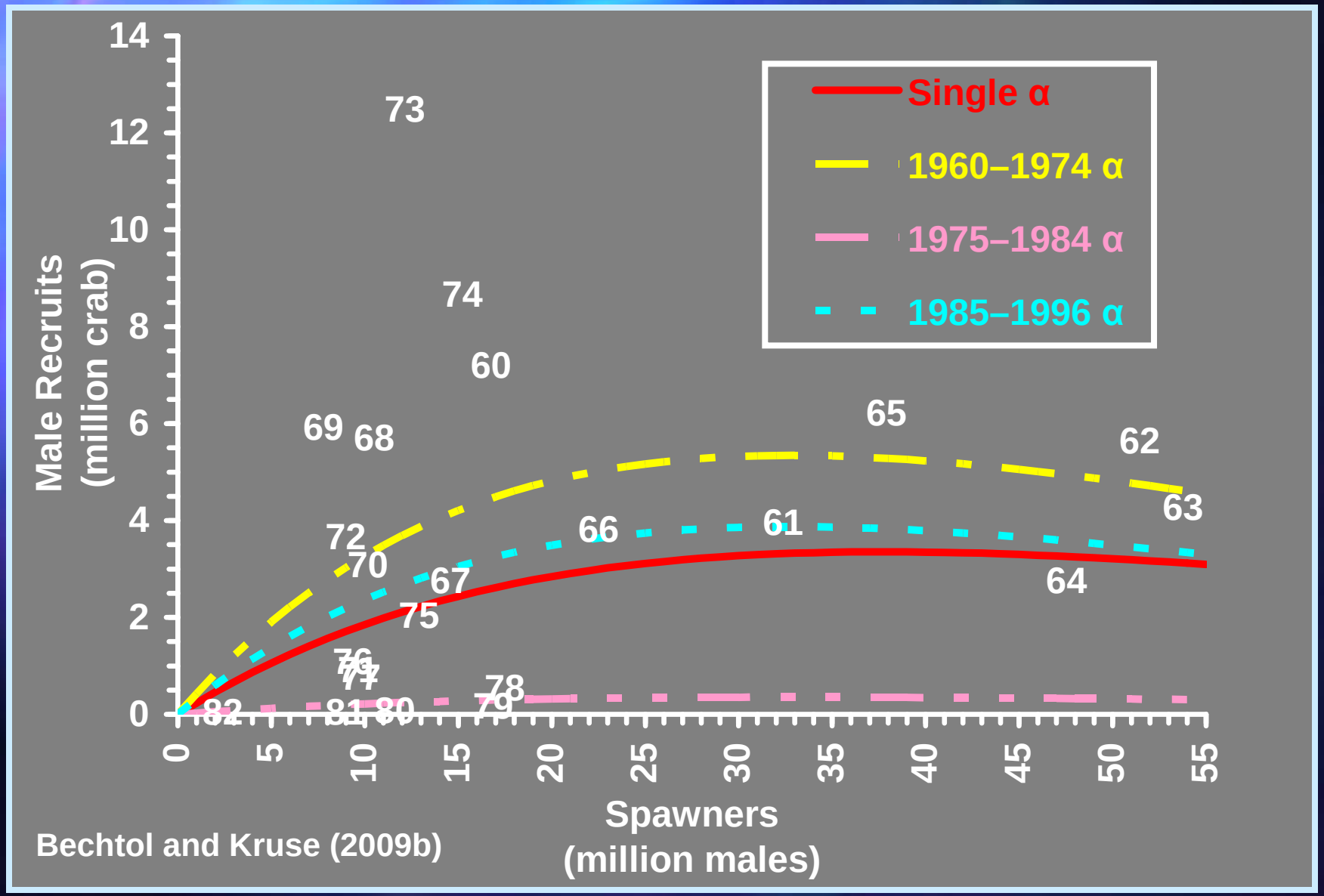
Zheng et al. (2010)

Fishery Effects: Norton Sound

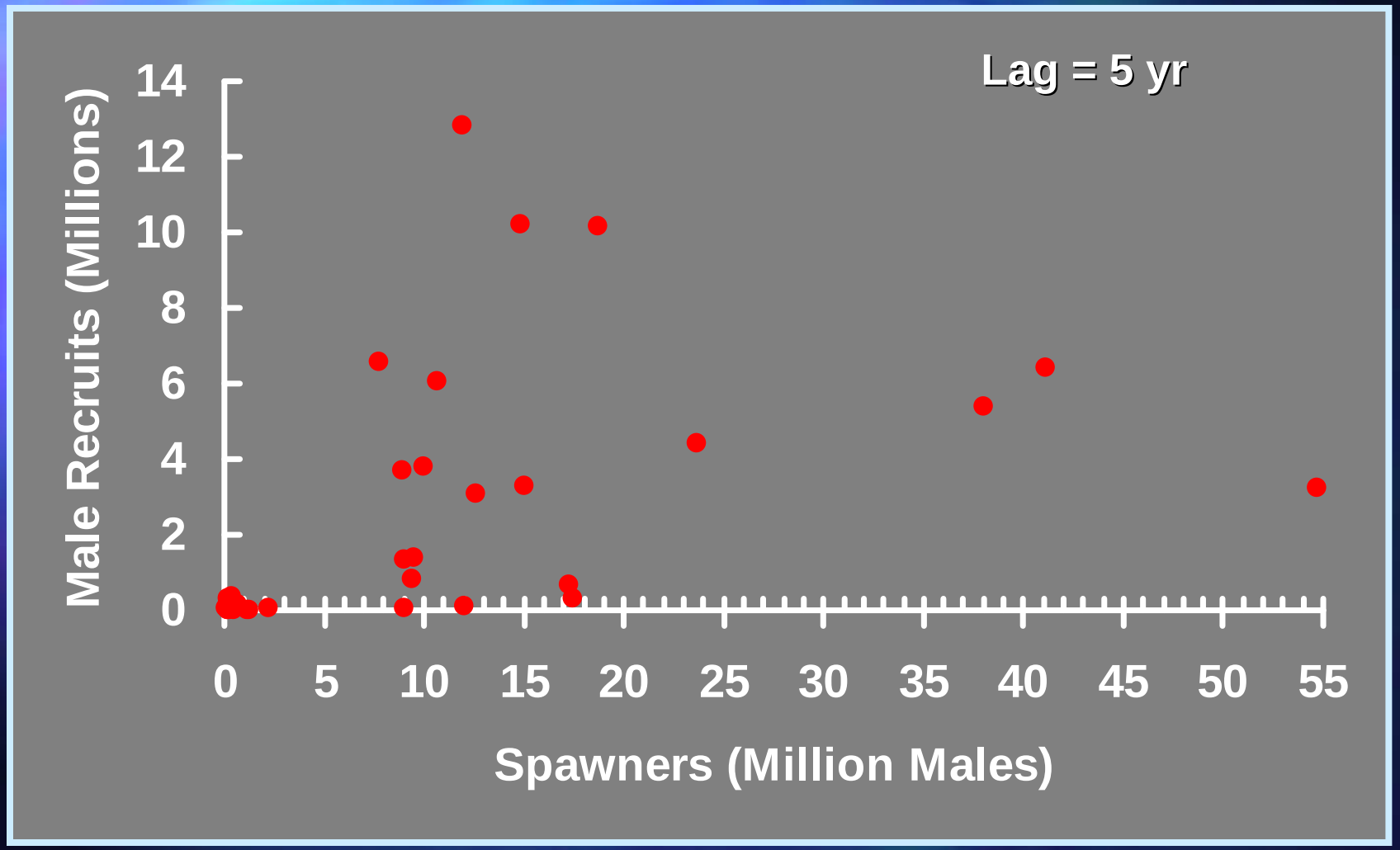


Zheng et al. (2010)

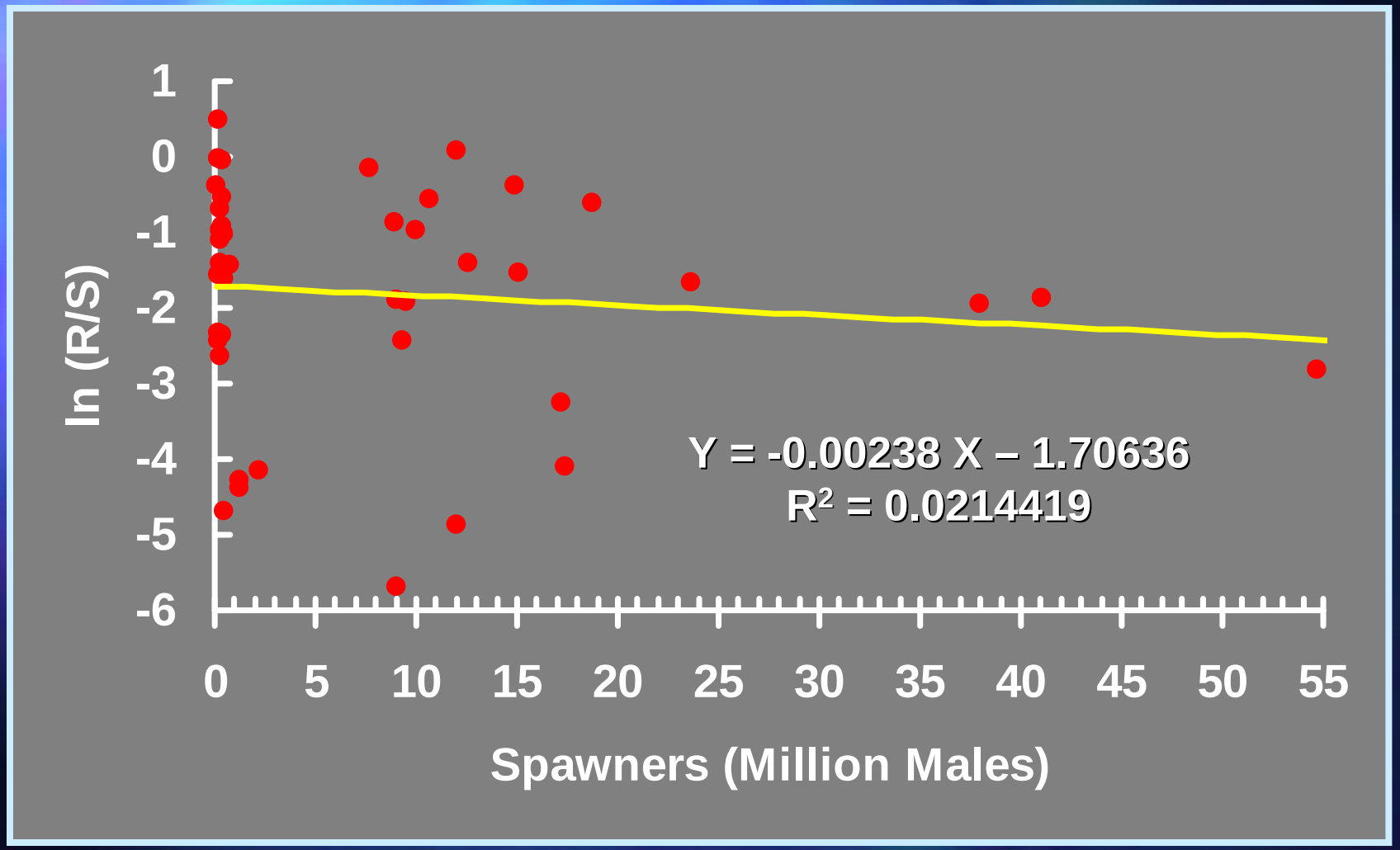
Stock-Recruit Relationship: Kodiak



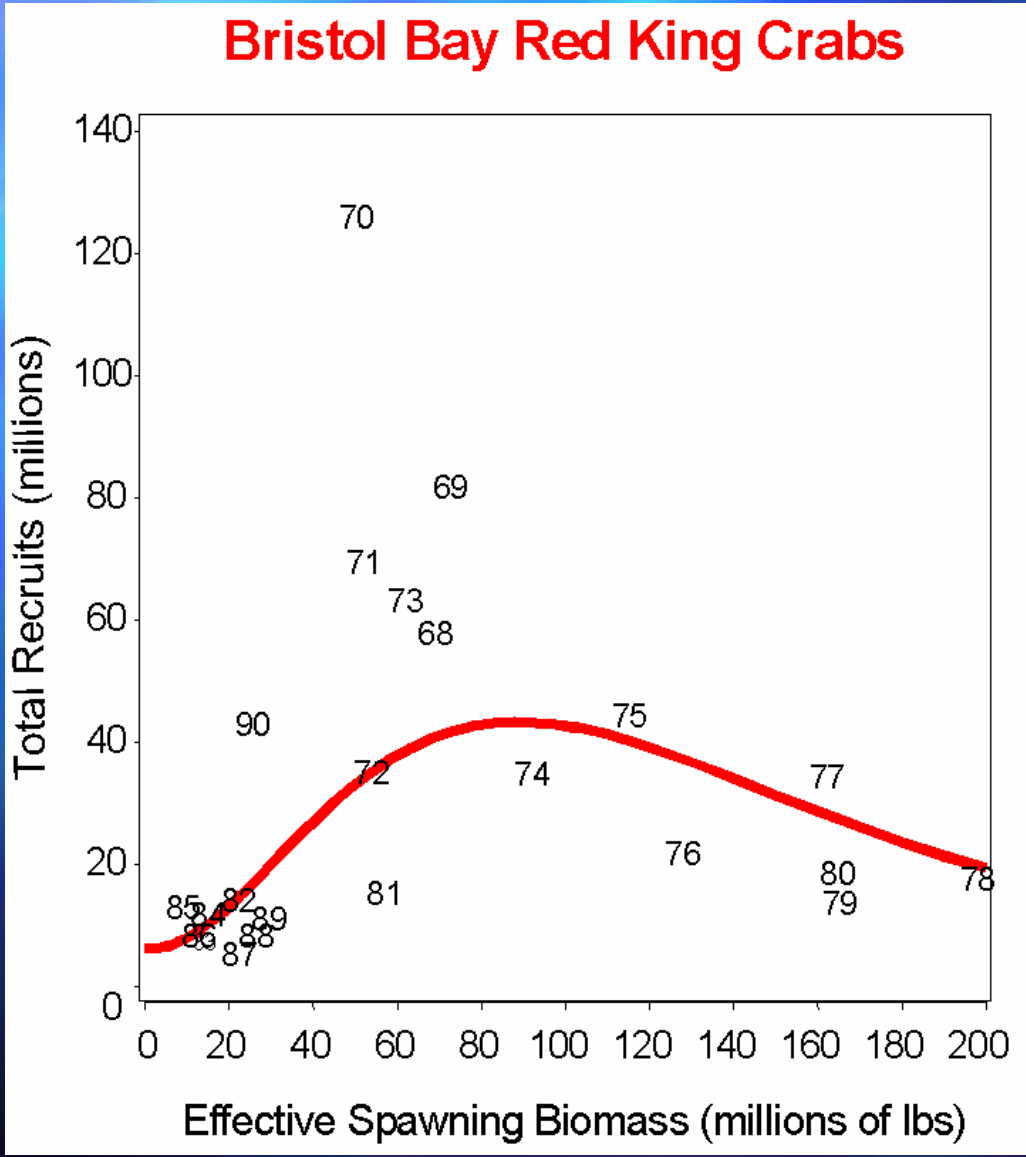
S-R Relationship: Kodiak (thru 2010)



S-R Relationship: Kodiak



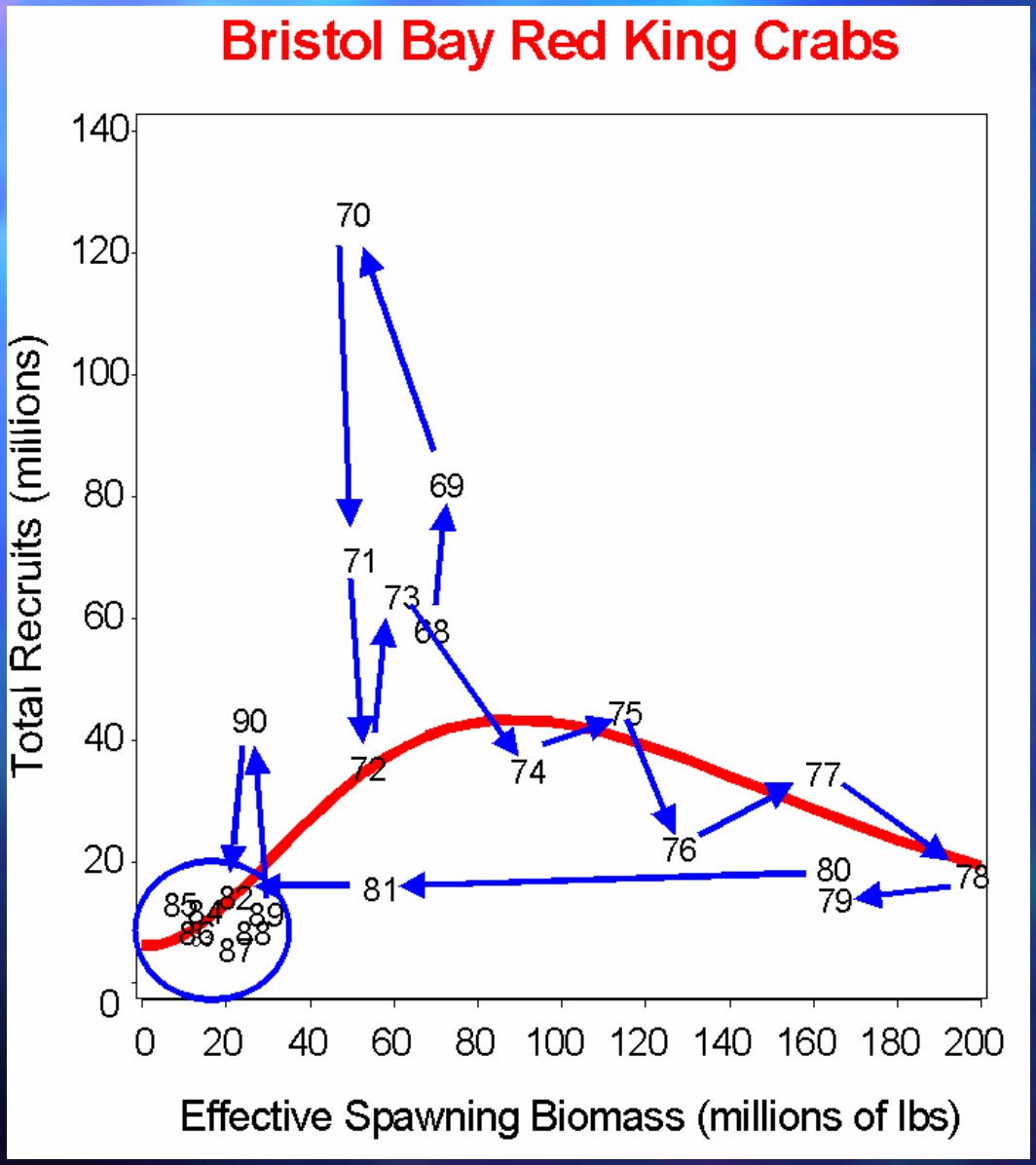
S-R Relationship: Bristol Bay



Zheng et al. (1995)

Zheng and Kruse (2003)

S-R Relationship: Bristol Bay



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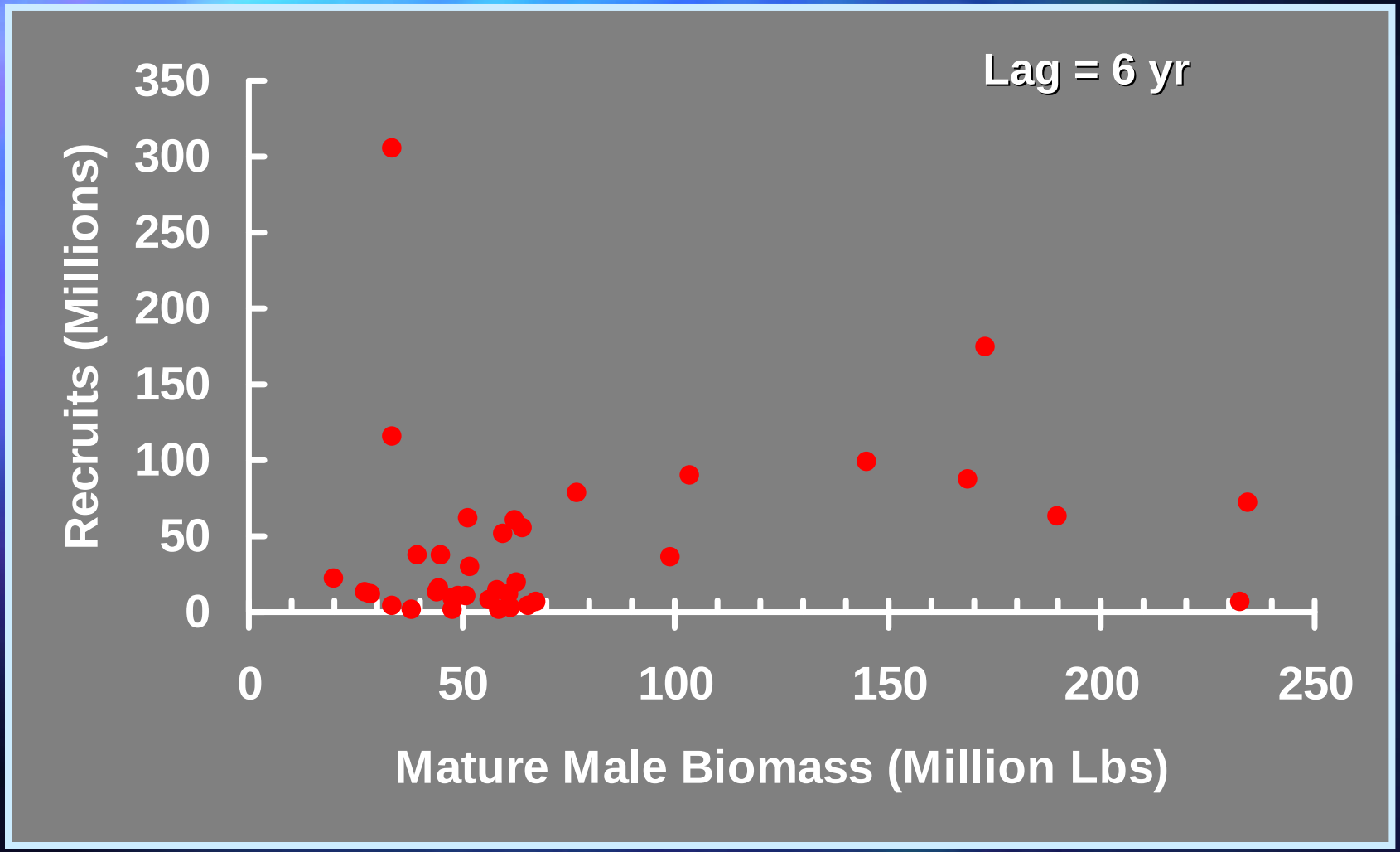

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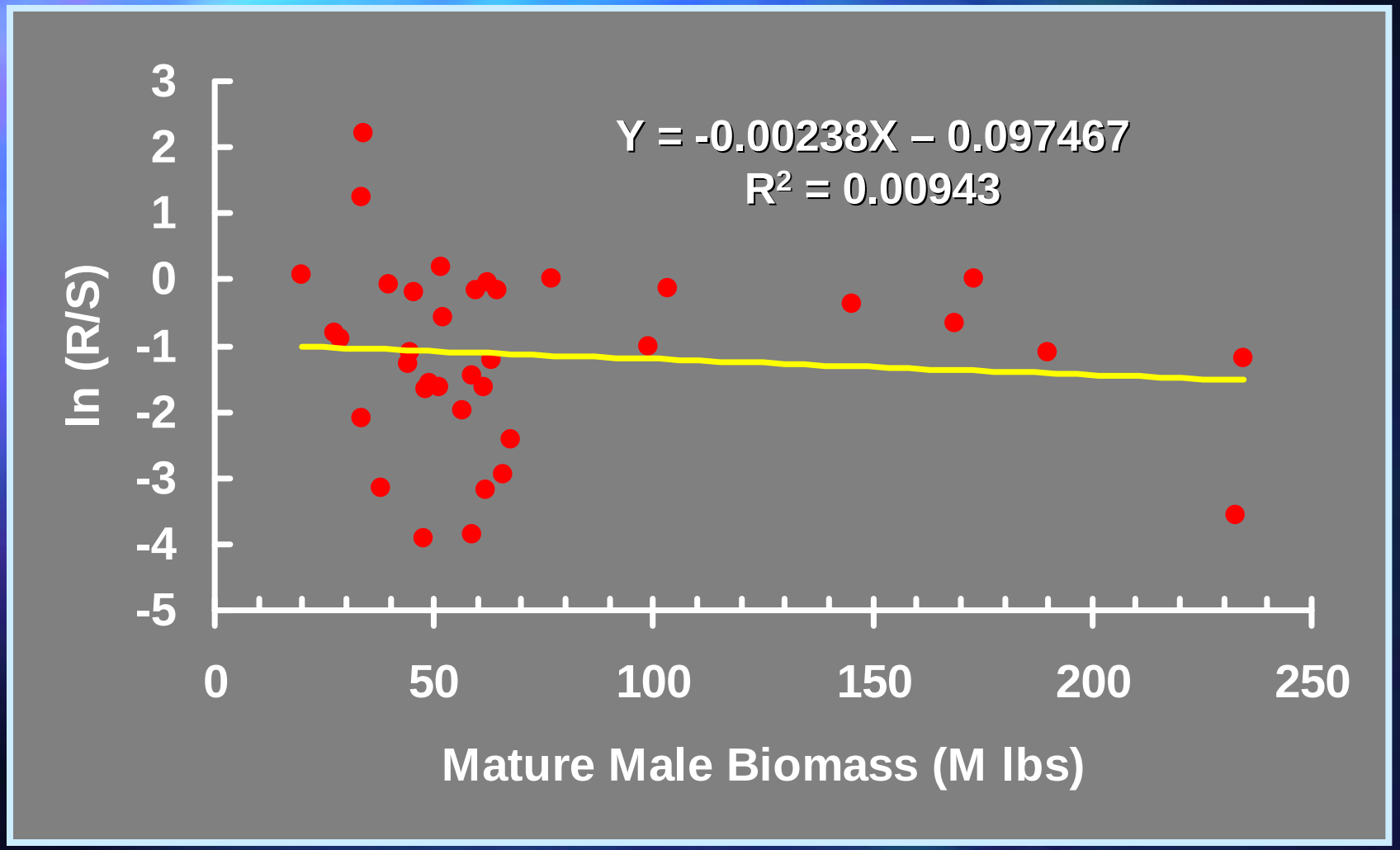
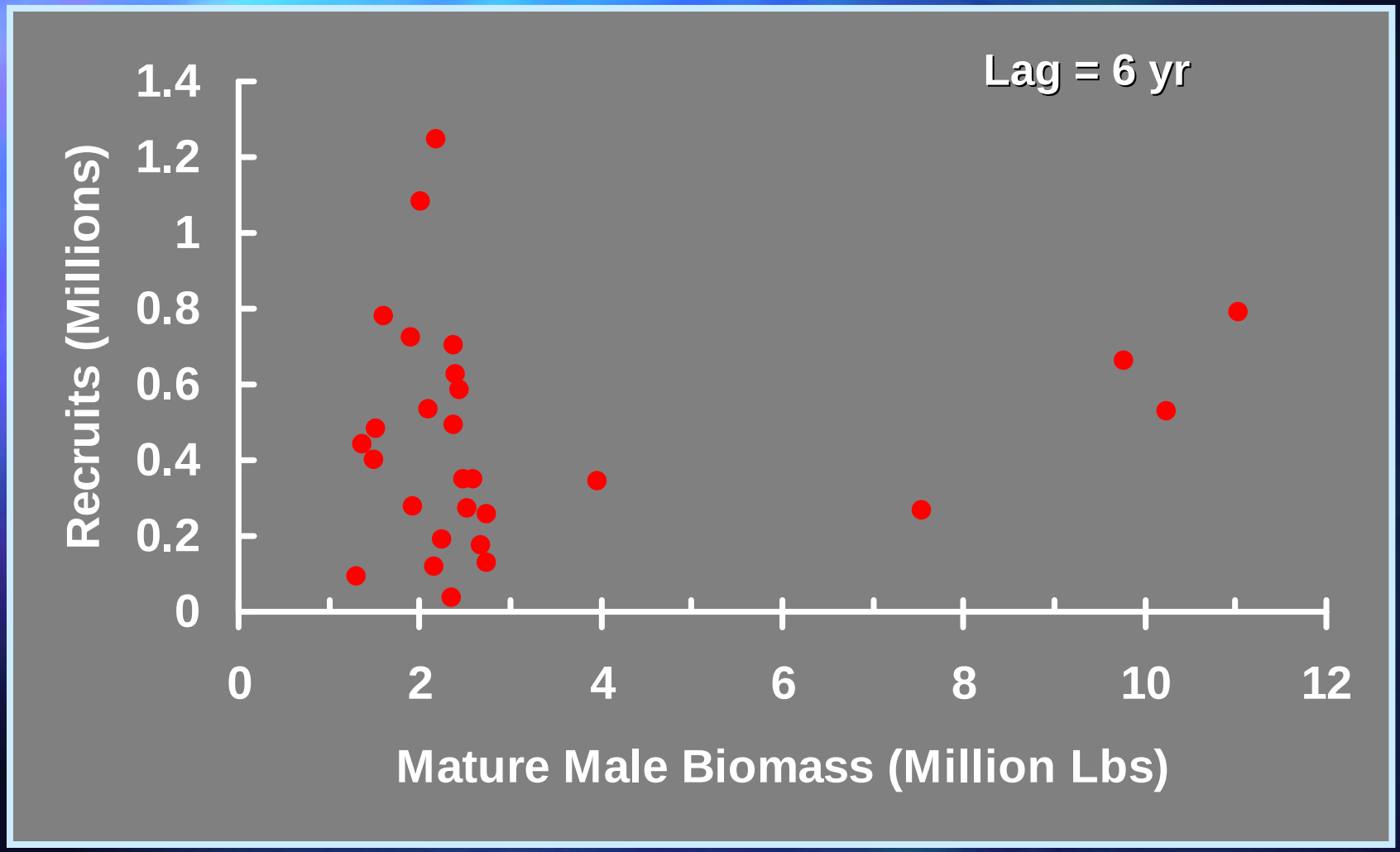
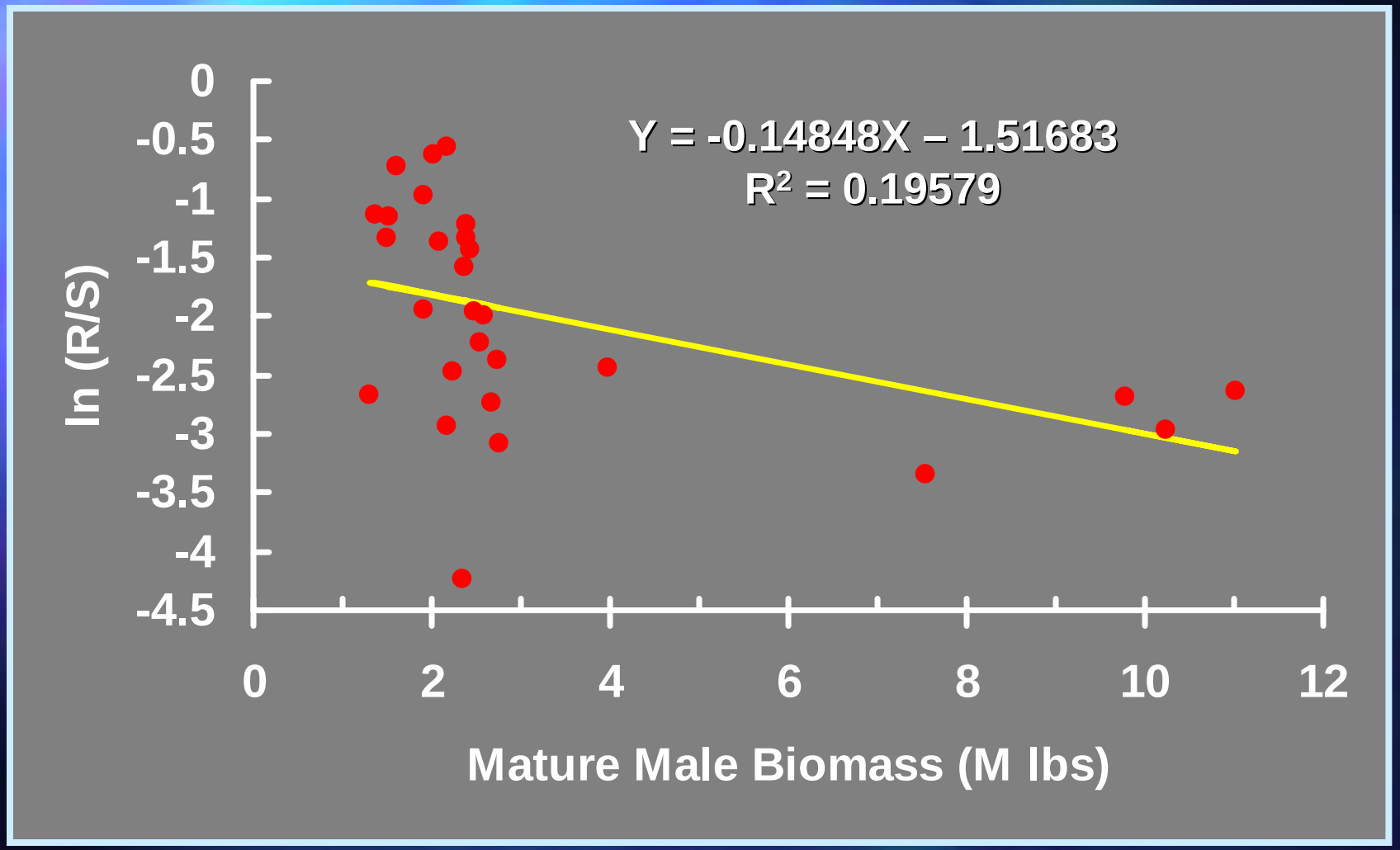


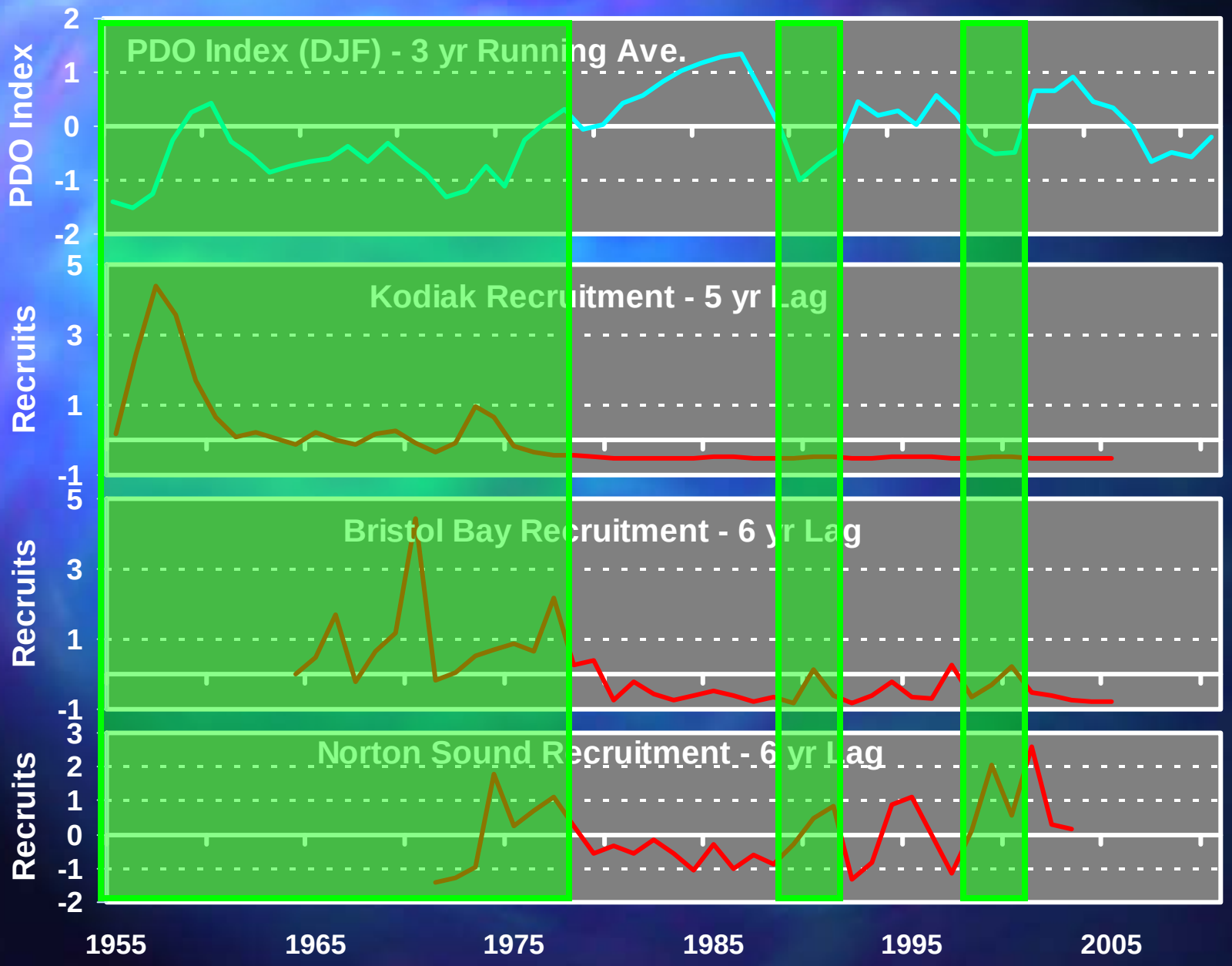
S-R Relationship: Norton Sound



S-R Relationship: Norton Sound



Climate Effects?



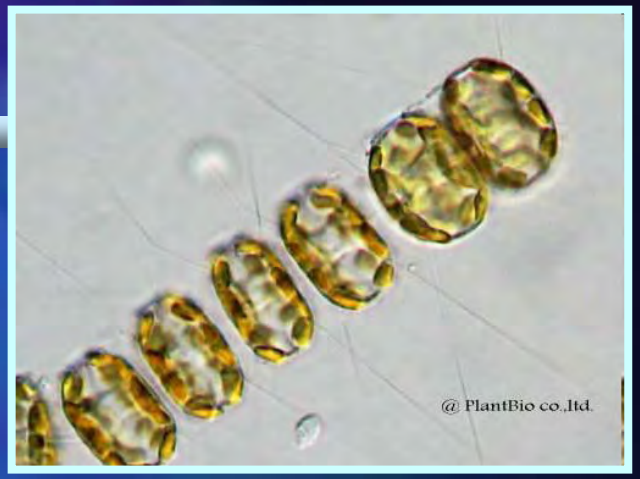
Larval Prey Hypothesis

Prey species and timing are hypothesized to be important to red king crab larvae:

- **Diatoms, such as *Thalassiosira* spp., are important components of the diet of first-feeding larvae. They predominate the spring bloom in years of light winds when the water column is stable. Years of strong wind mixing associated with intensified Aleutian Lows may depress red king crab larval survival and subsequent recruitment.**

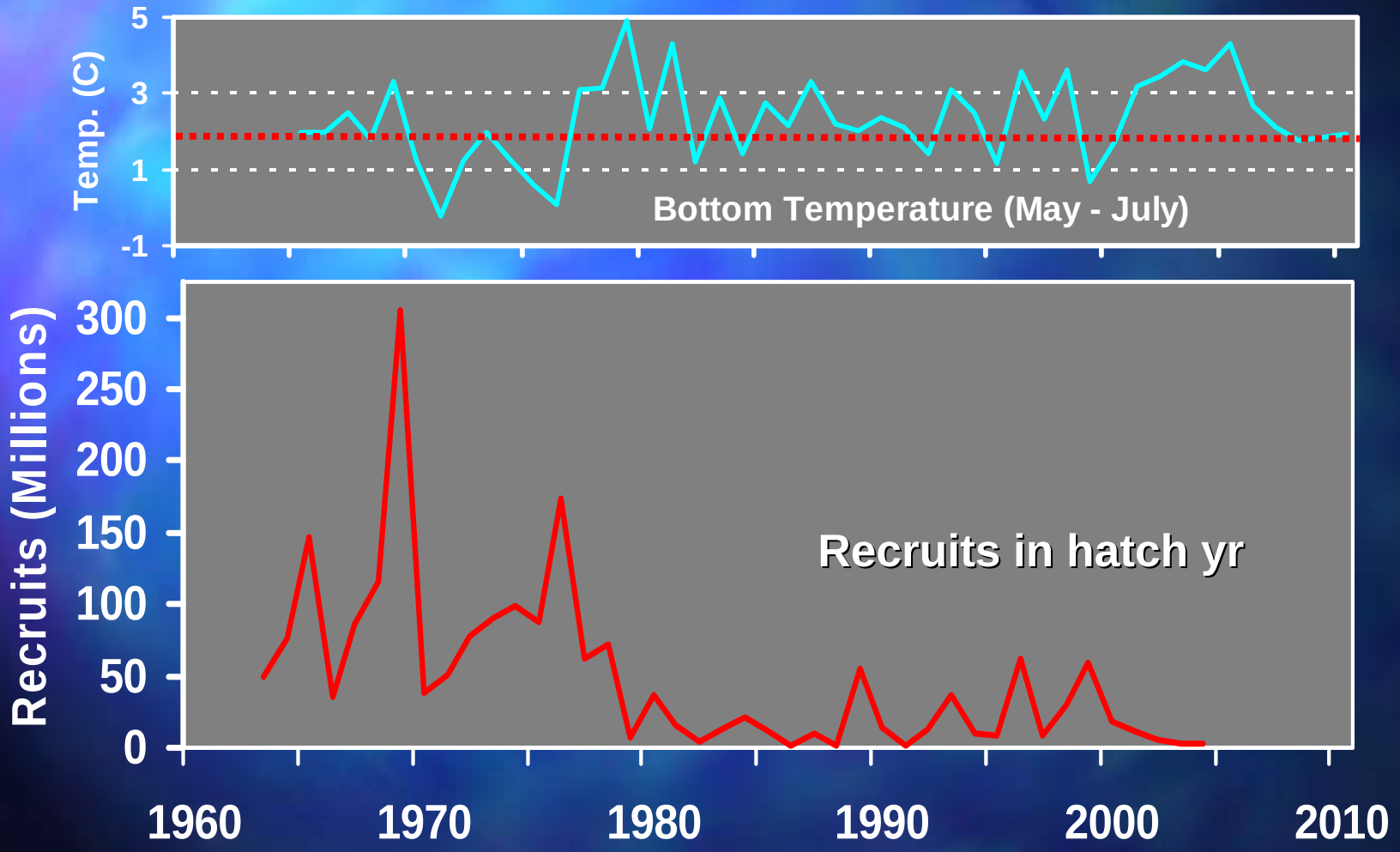
Zheng and Kruse (2000) based on APPRISE findings

The Case for *Thalassiosira*

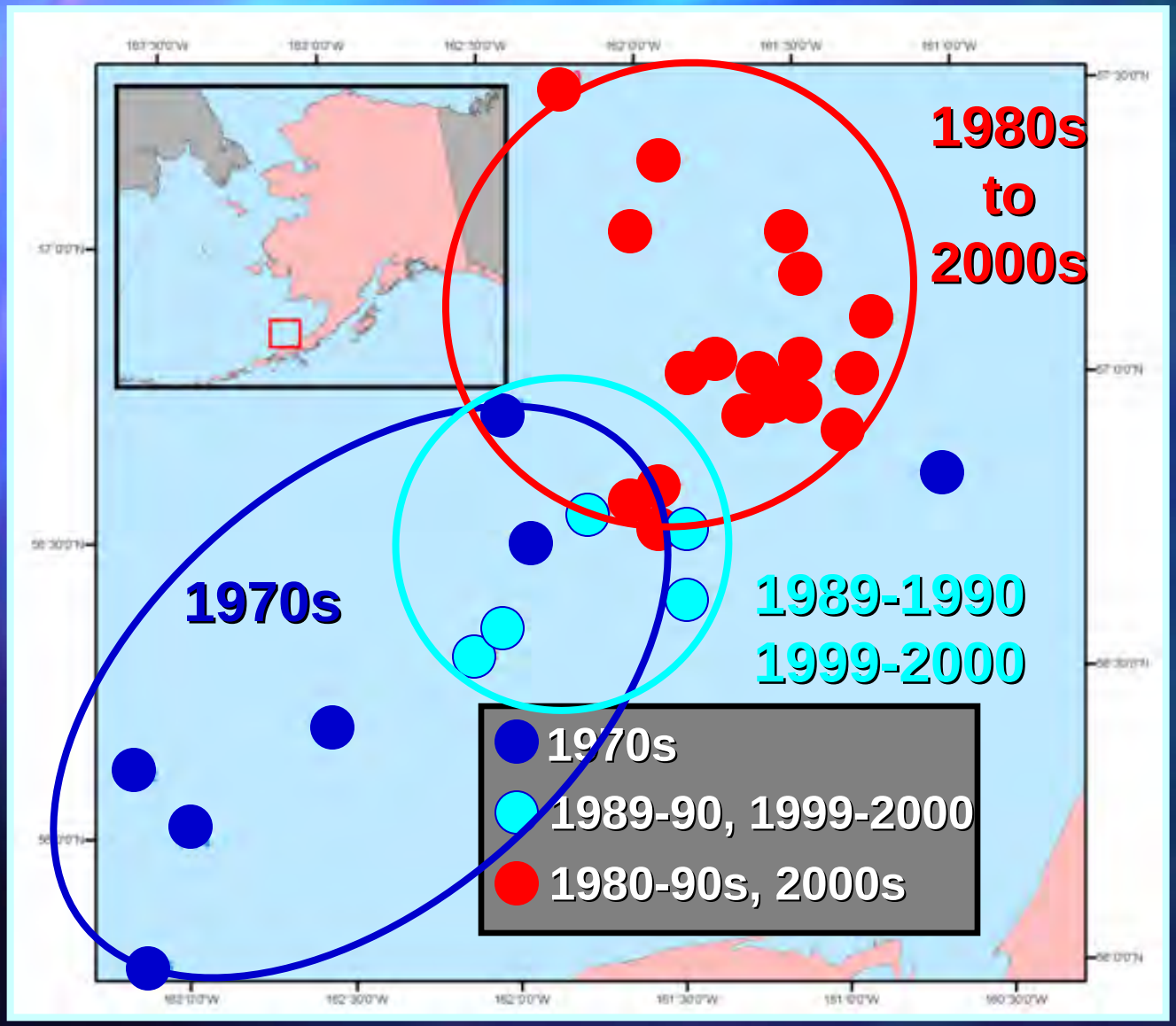


- Prey: copepod nauplii, barnacle nauplii, flagellates, and diatoms
- Larvae must feed within 2-6 d (Paul & Paul 1980)
- Diatoms (e.g., *Thalassiosira* sp.) support survival of first-feeding larvae (Paul et al. 1989); growth rates related to *Thalassiosira* concentration
- Larvae can survive to Z2 on *Thalassiosira* alone (B. Daly, UAF, pers. comm.)
- Highest survival to glaucothoe on *Artemia* nauplii + *Thalassiosira* (Persselin & Daly 2010)

Temperature Effects: Bristol Bay?

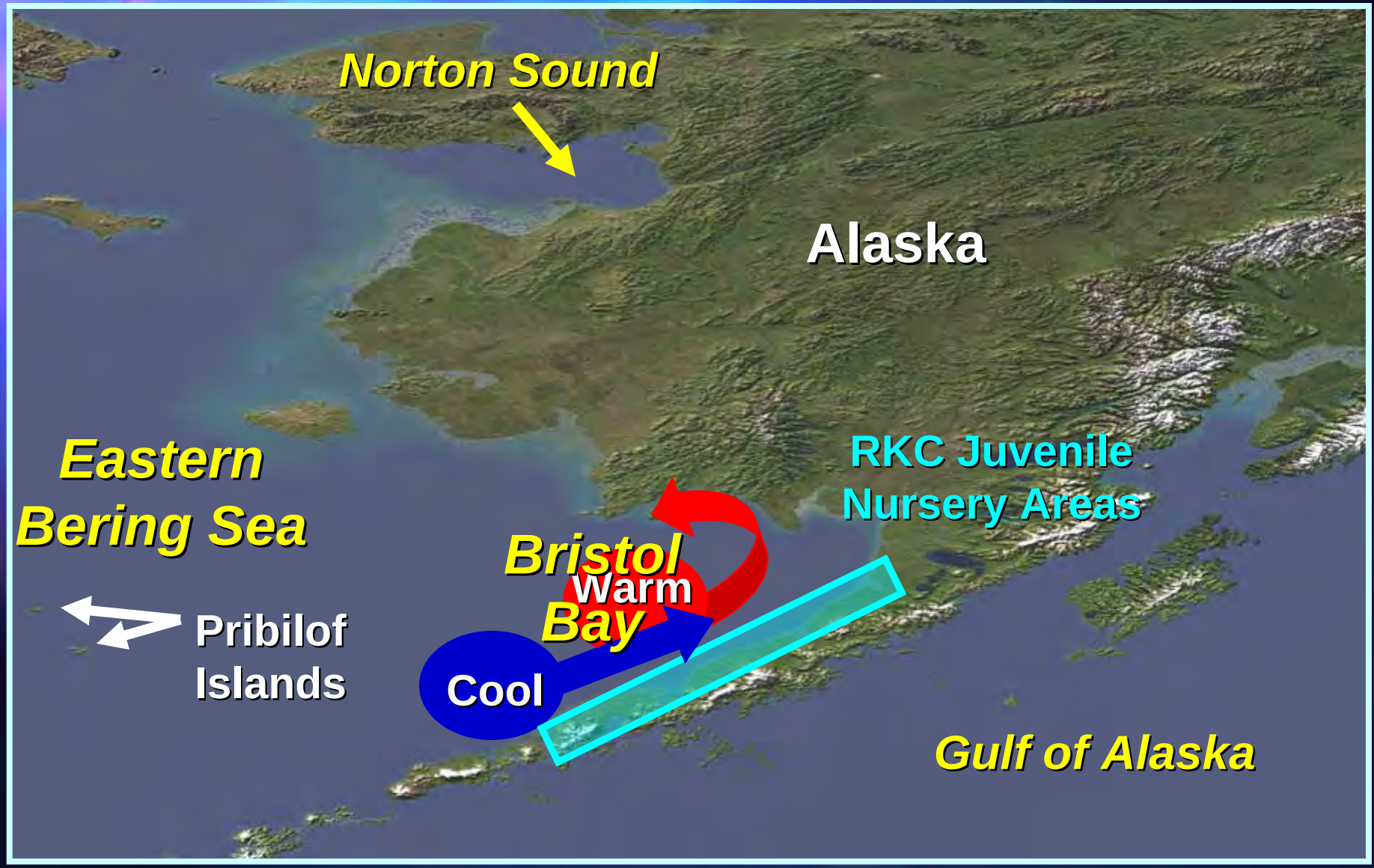


Temperature Affects Crab Distribution

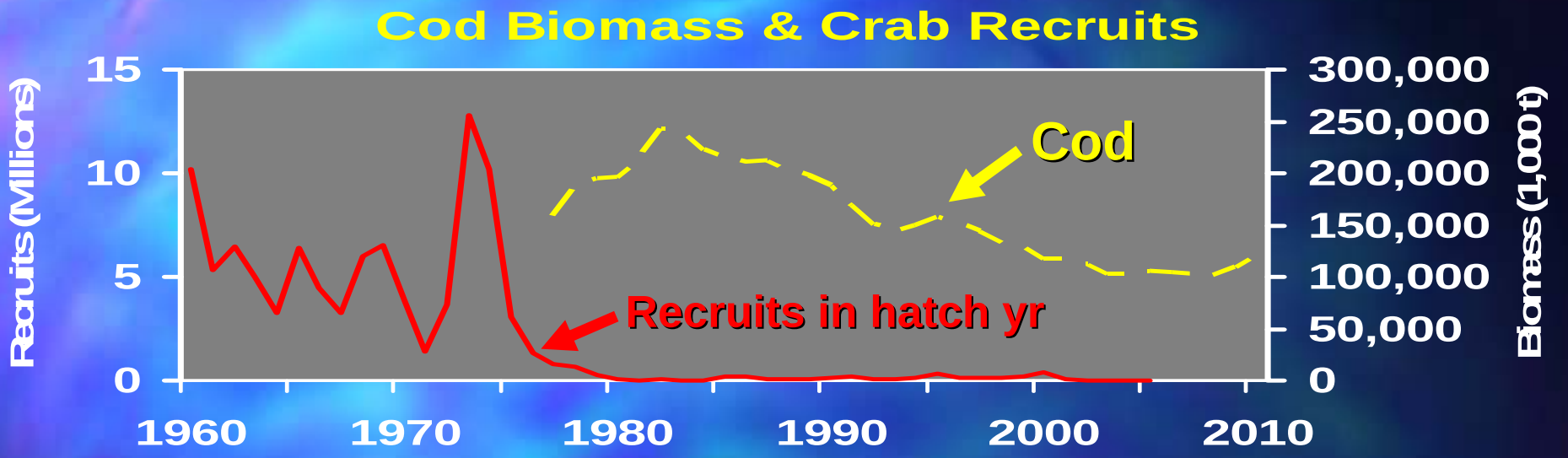


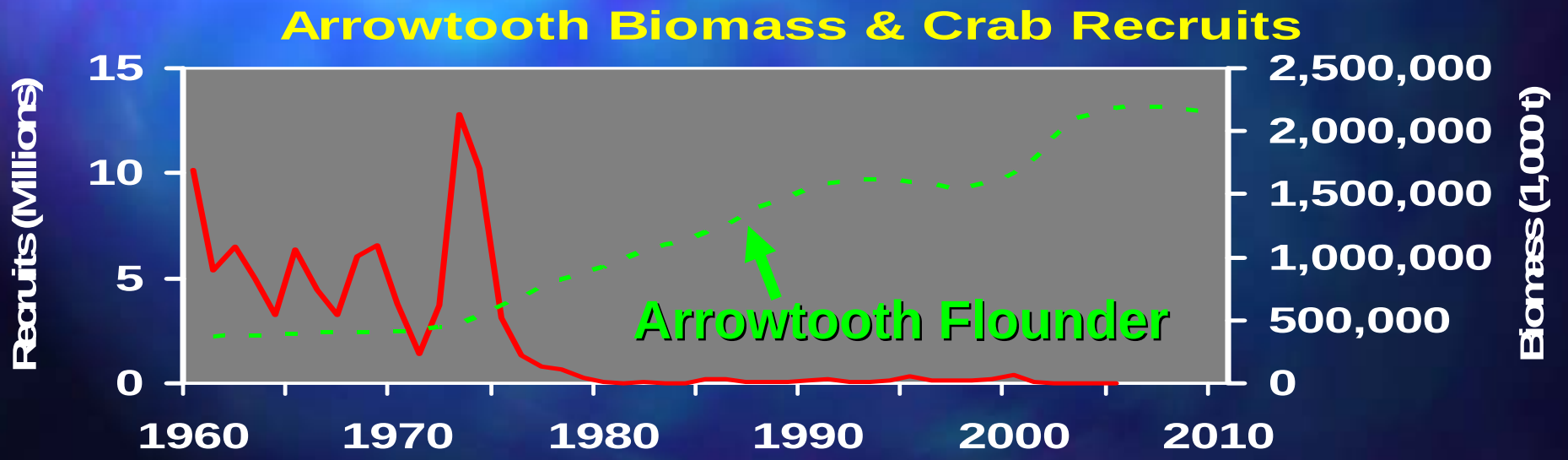
Centers of Distribution of mature female red king crabs in Bristol Bay (after Zheng & Kruse 2006)

Expected Effects on Larval Advection



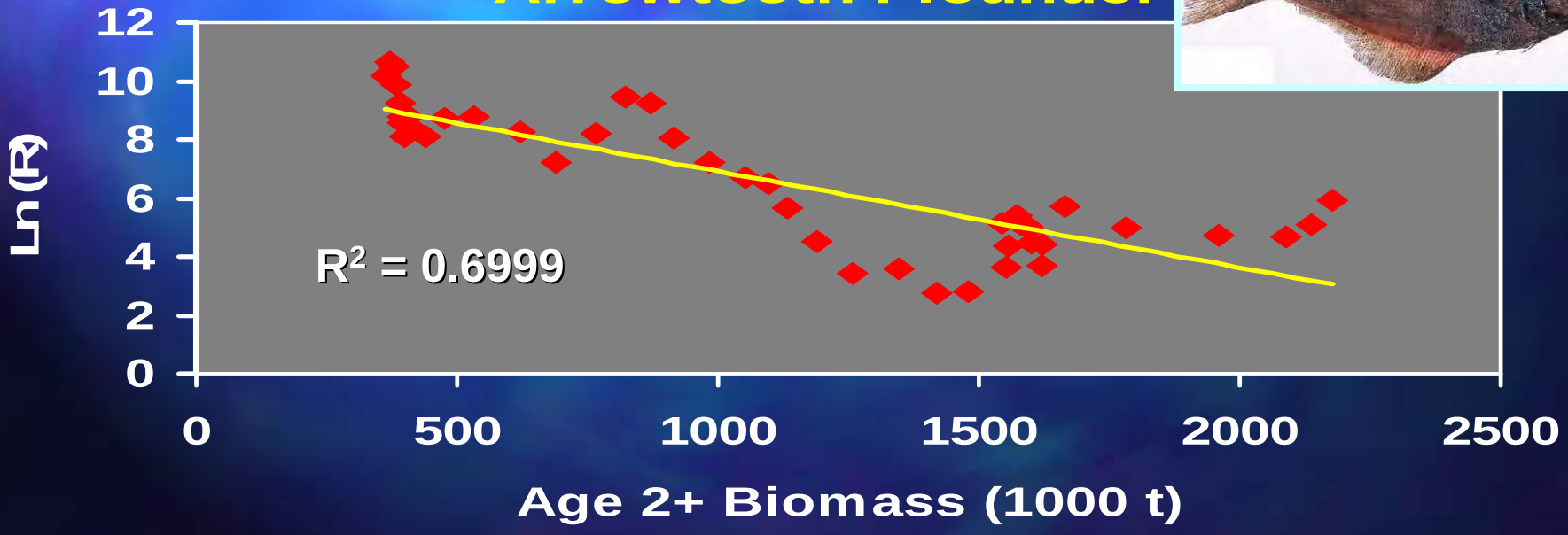
Kodiak Predation Effects?



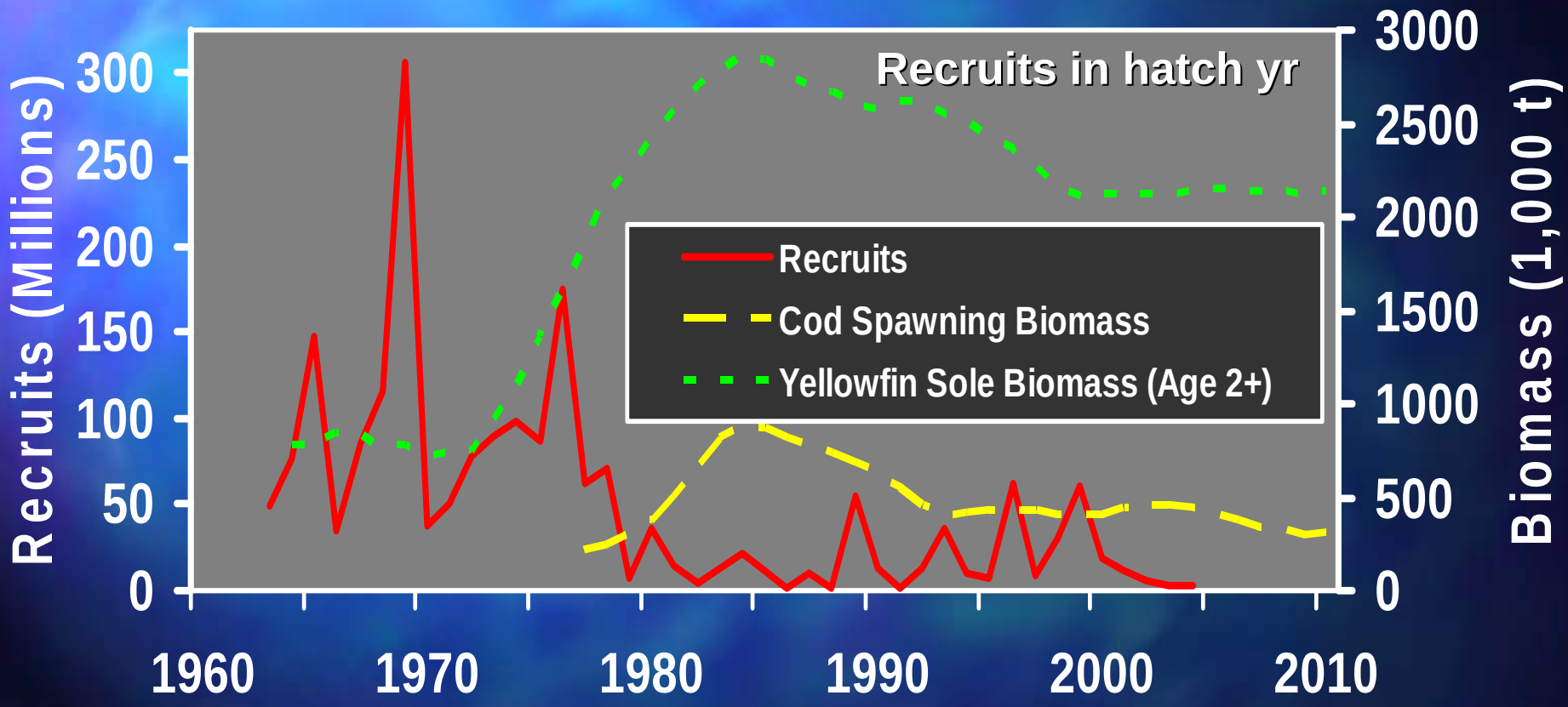


Pacific Cod

Arrowtooth Flounder

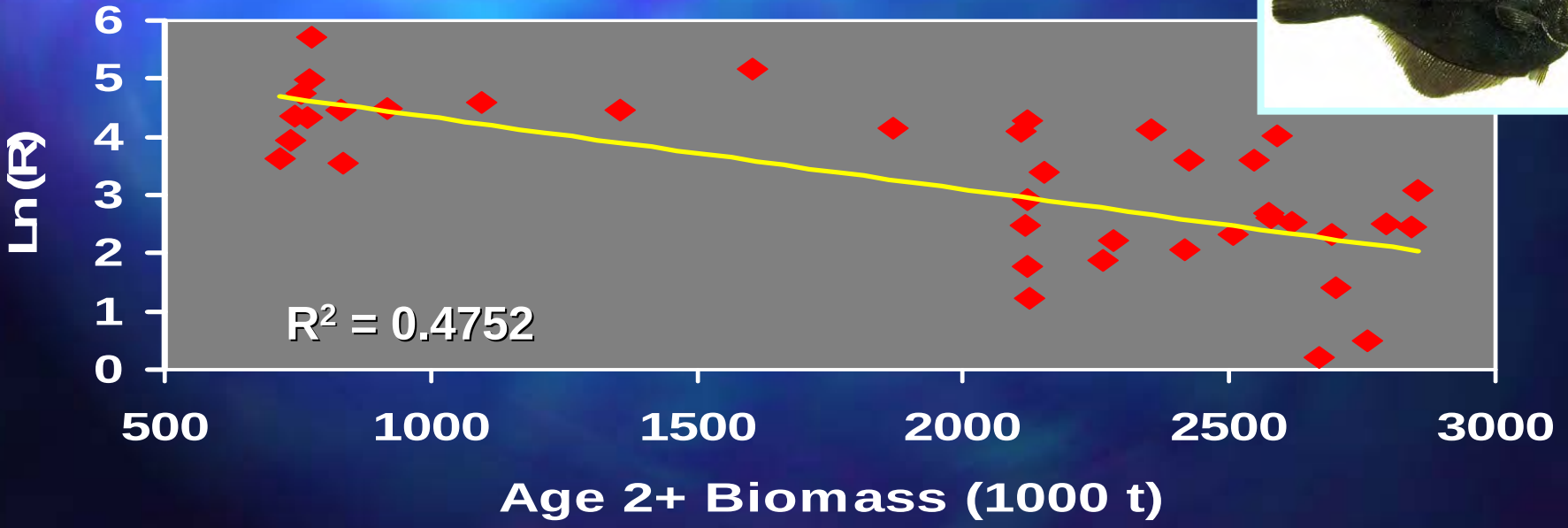


Bristol Bay: Predation Effects?

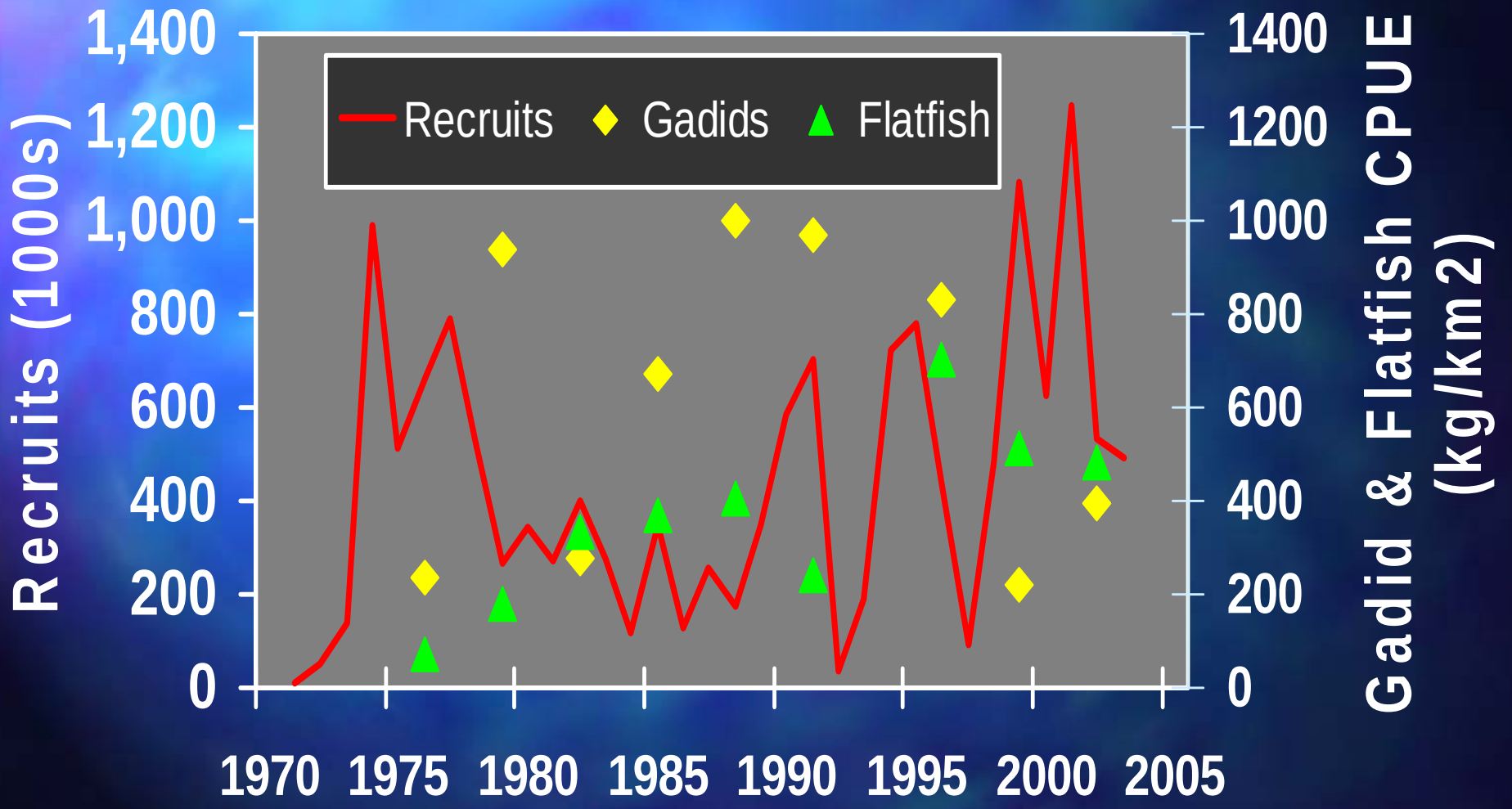


Pacific Cod

Yellowfin Sole



Norton Sound: Predation Effects?



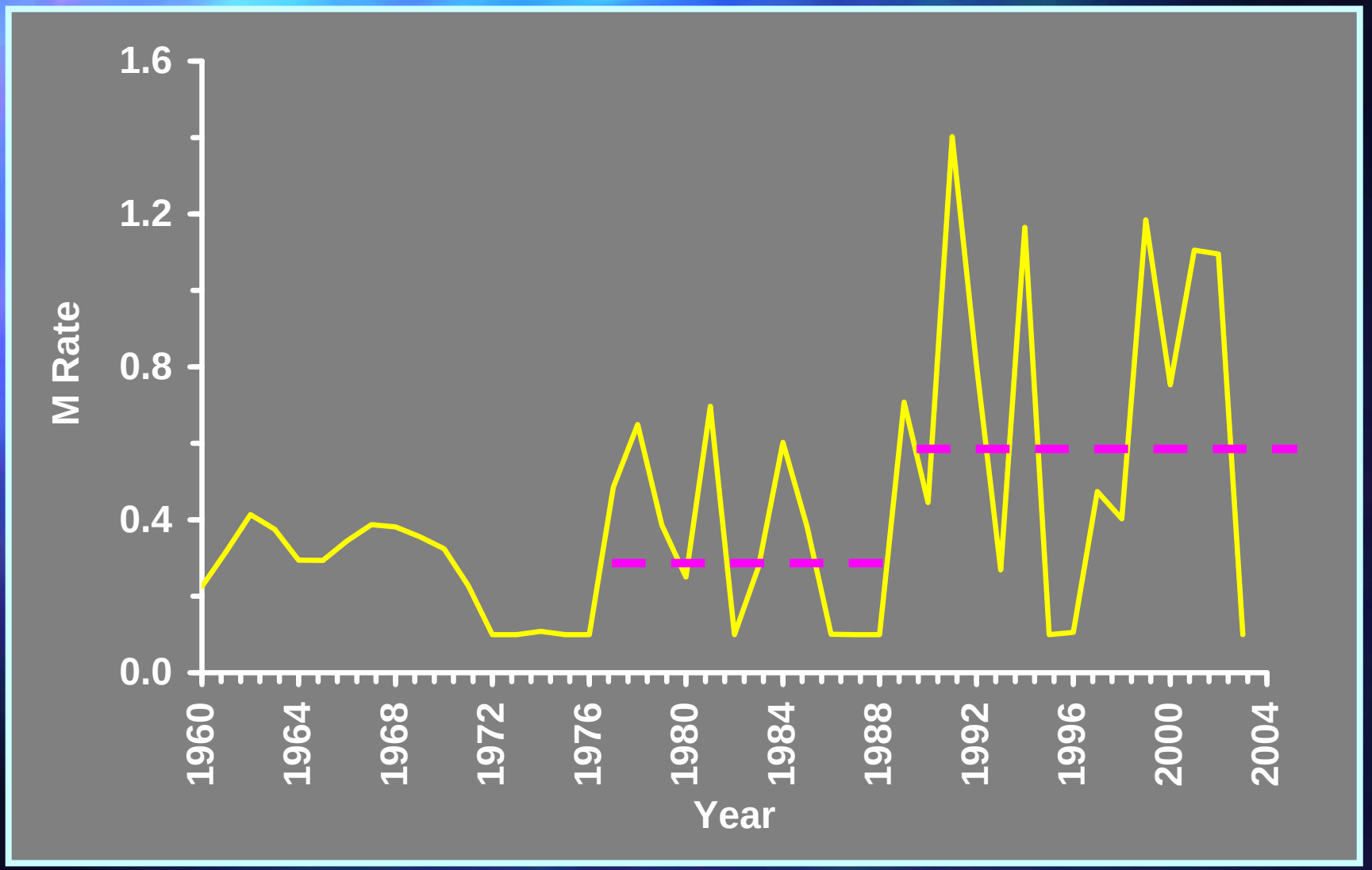
Gadids

Saffron cod, pollock, P. cod

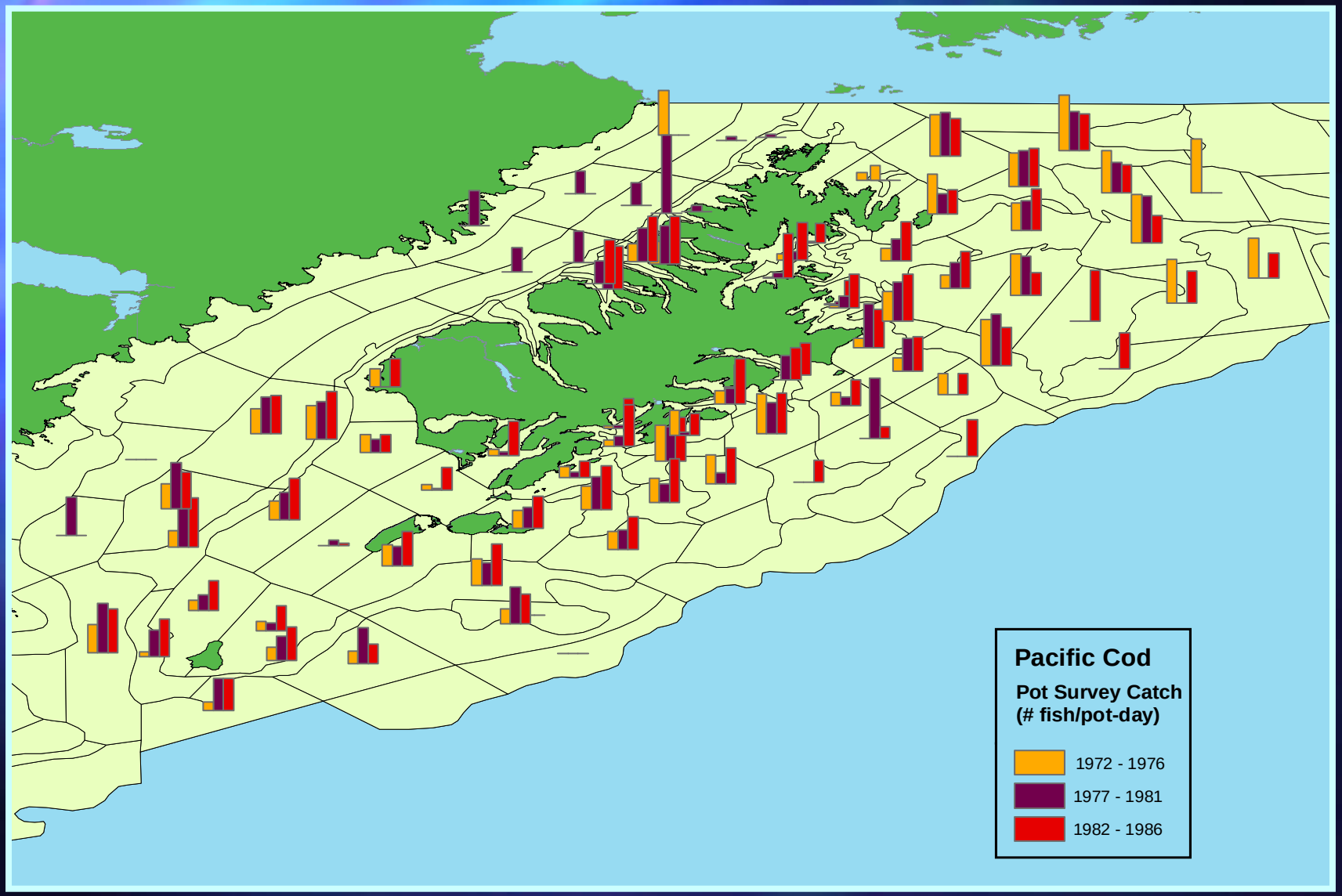
Flatfish

Halibut, starry flounder, yellowfin sole

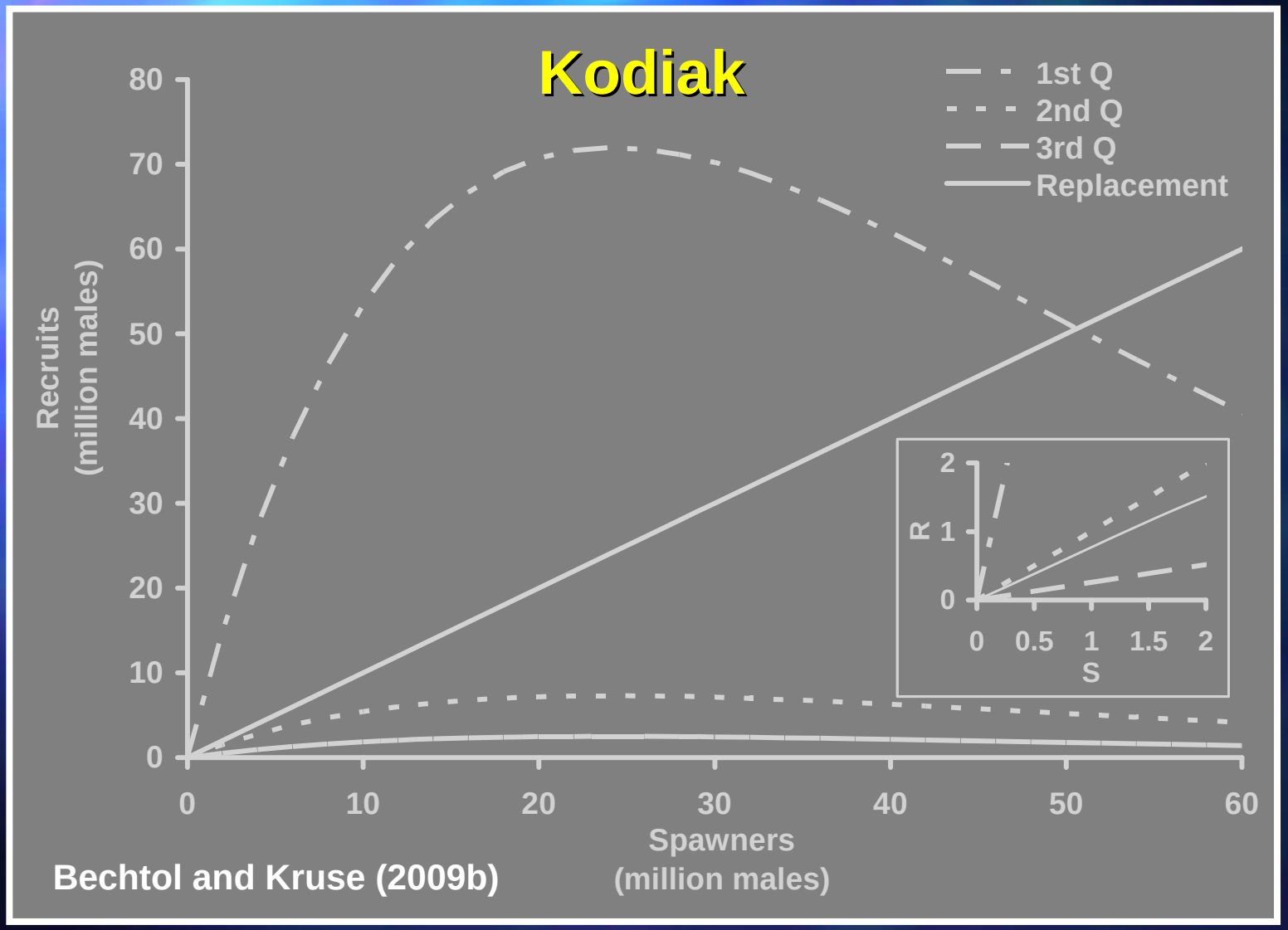
Natural Mortality Prevents Recovery off Kodiak?



Pacific Cod: Spatial Changes off Kodiak



Effect of Predation on S-R Relationship



The Predation Paradox

- Strong crab recruitment across systems in late 1960s when groundfish were low
- Significant negative associations between king crab recruitment and groundfish biomass
- Yet, field studies have found low rates of king crab in stomachs of cod, halibut, flatfish, and sculpins (Gray 1964, Jewett 1978, Jewett & Powell 1979, Clausen 1981, Best & St-Pierre 1988)
- In the eastern Bering Sea, cod are estimated to consume 1.4-4.8% of mature females, except 14.3% in 1989 (Livingston 1989, Livingston et al. 1993)
- Representative studies in juvenile nursery grounds are lacking to draw definitive conclusions

Conclusions

- Contrasts across GOA, EBS, and Norton Sound indicate that fishing played a role in historical declines in red king crabs
- Some commonality of recruitment patterns suggest a role of climate and predation
- Hypotheses:
  - Spring bloom timing and composition
  - Shifts in geographic distribution of mature females relative to nursery grounds
  - Predation of young juveniles
- Next steps: field studies of predation and modeling of other stocks


Questions?