Evidence of declining fecundity in the Central Gulf of Alaska

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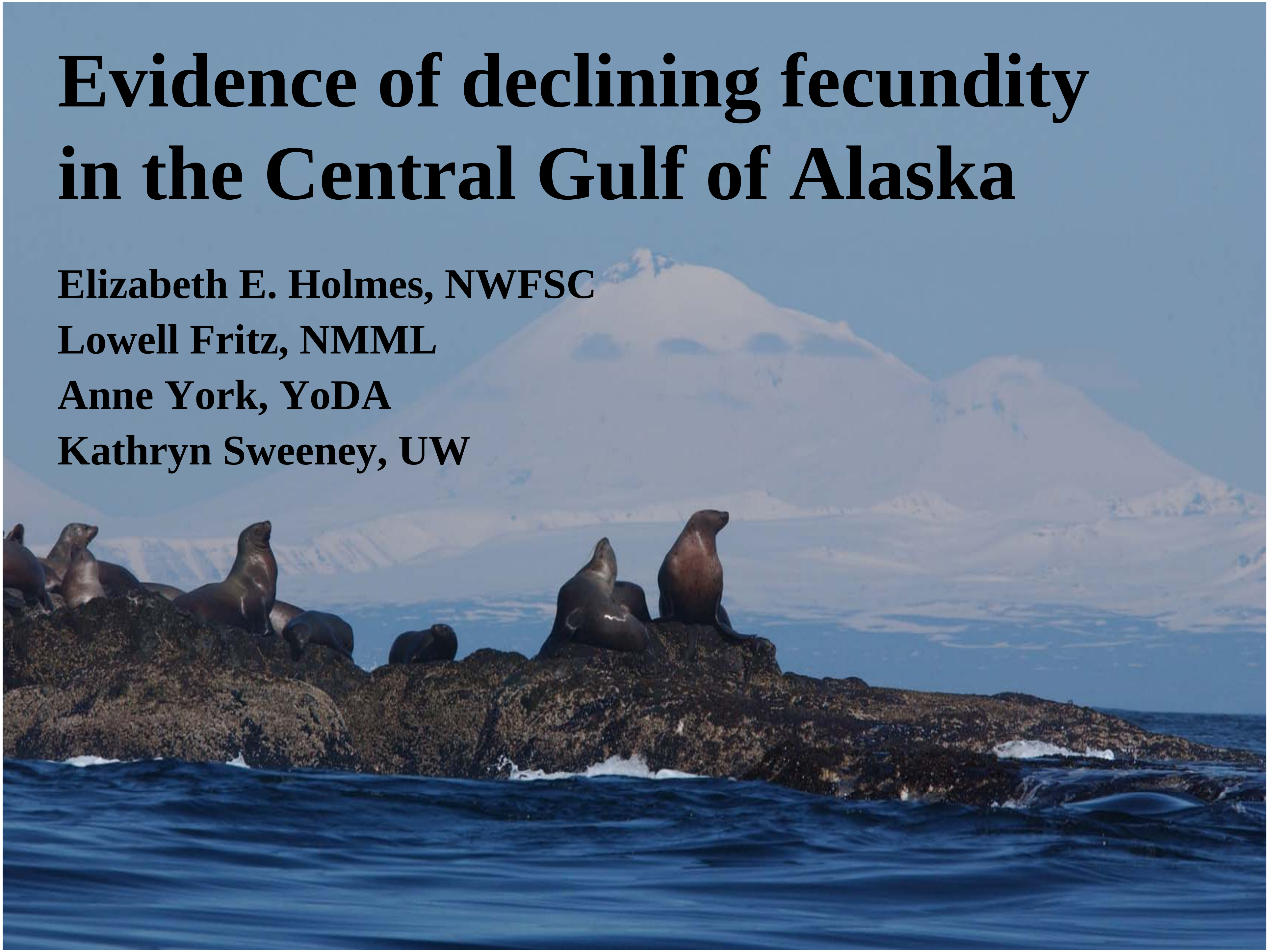


The basic idea

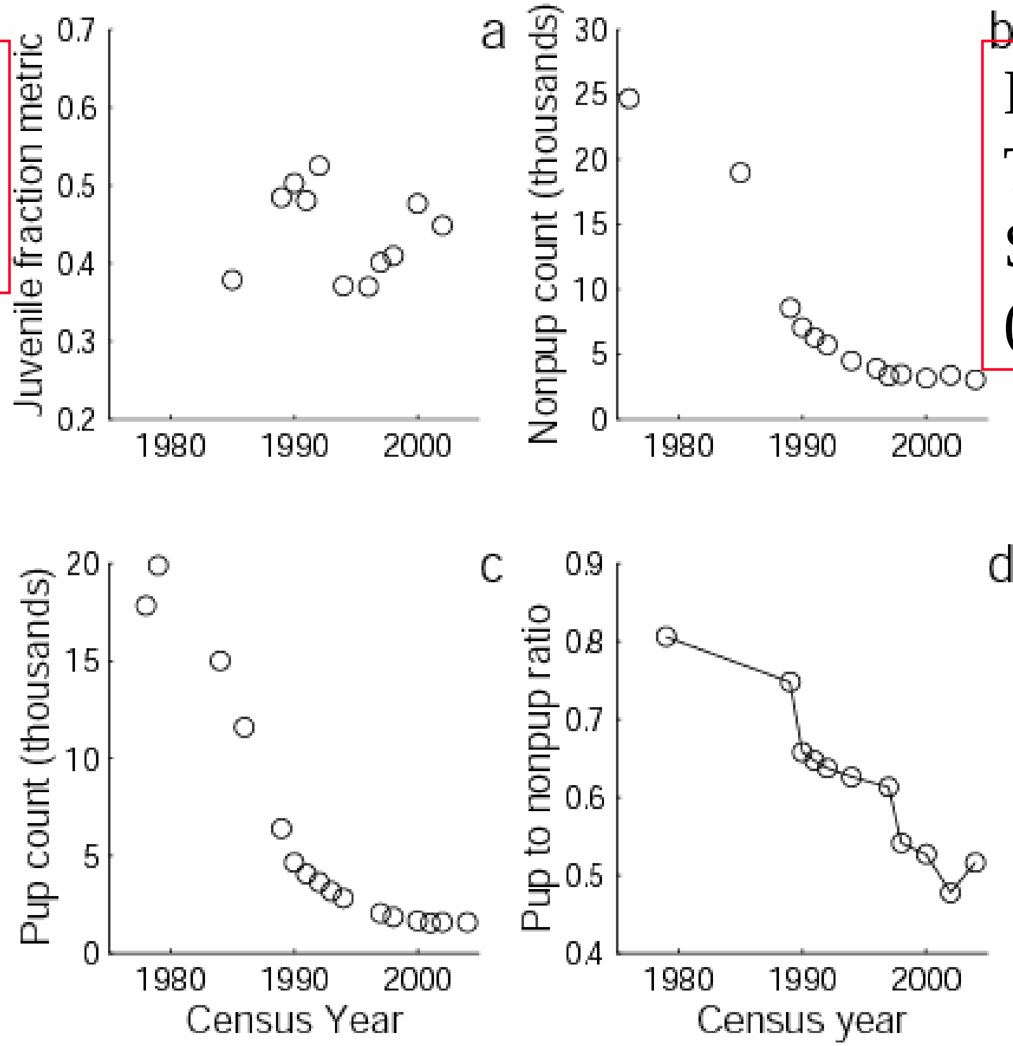
- Develop models for the population based on data and knowledge about SSL life-history.
- Fit to time series data 1976 to 2004: pup, non-pup, and juvenile fraction
- Estimate maximum likelihood fits juvenile survivorship, adult survivorship and fecundity in different time periods
- Statistically quantify the fits

Data are derived mainly from the aerial survey data

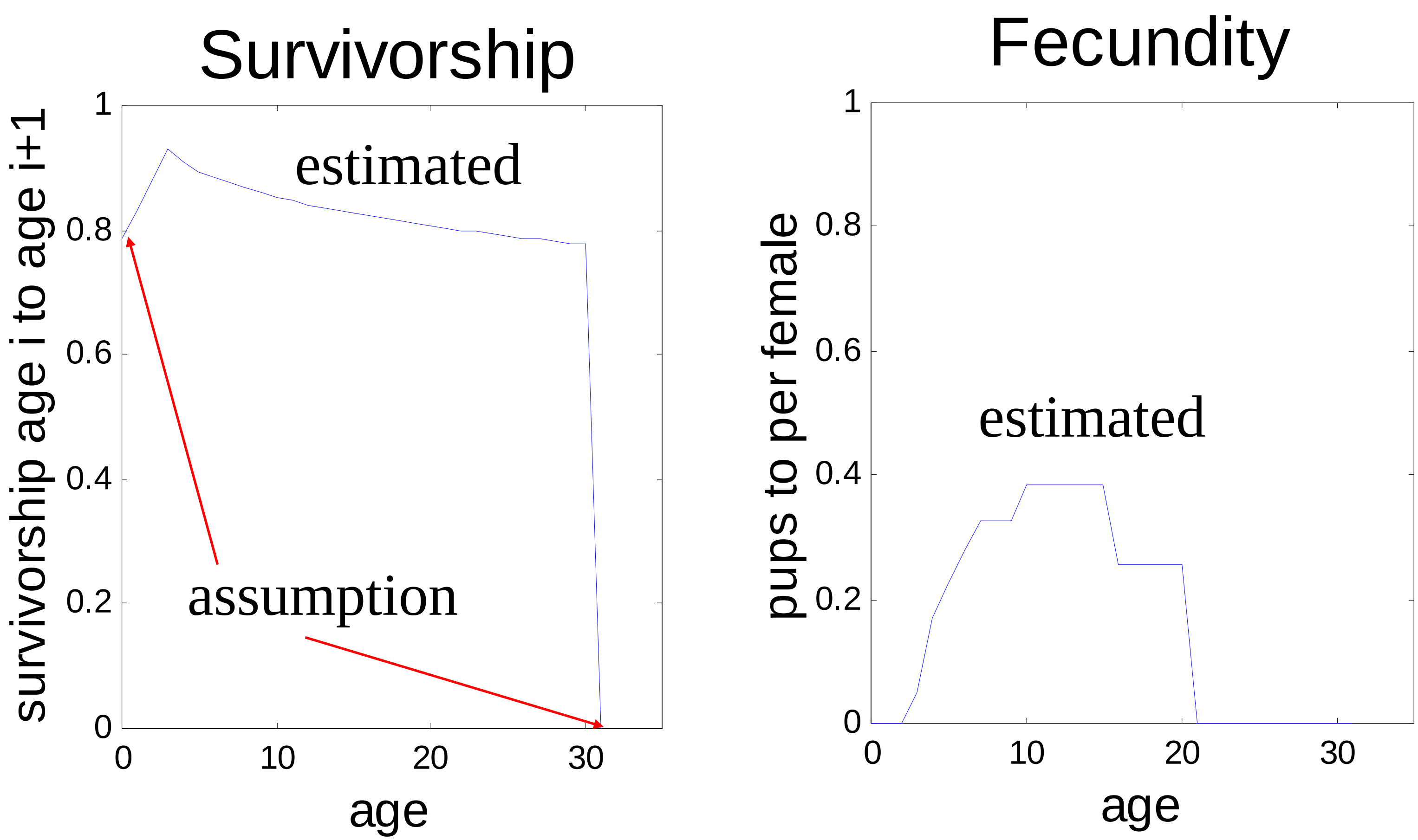
AN AGE-STRUCTURE METRIC

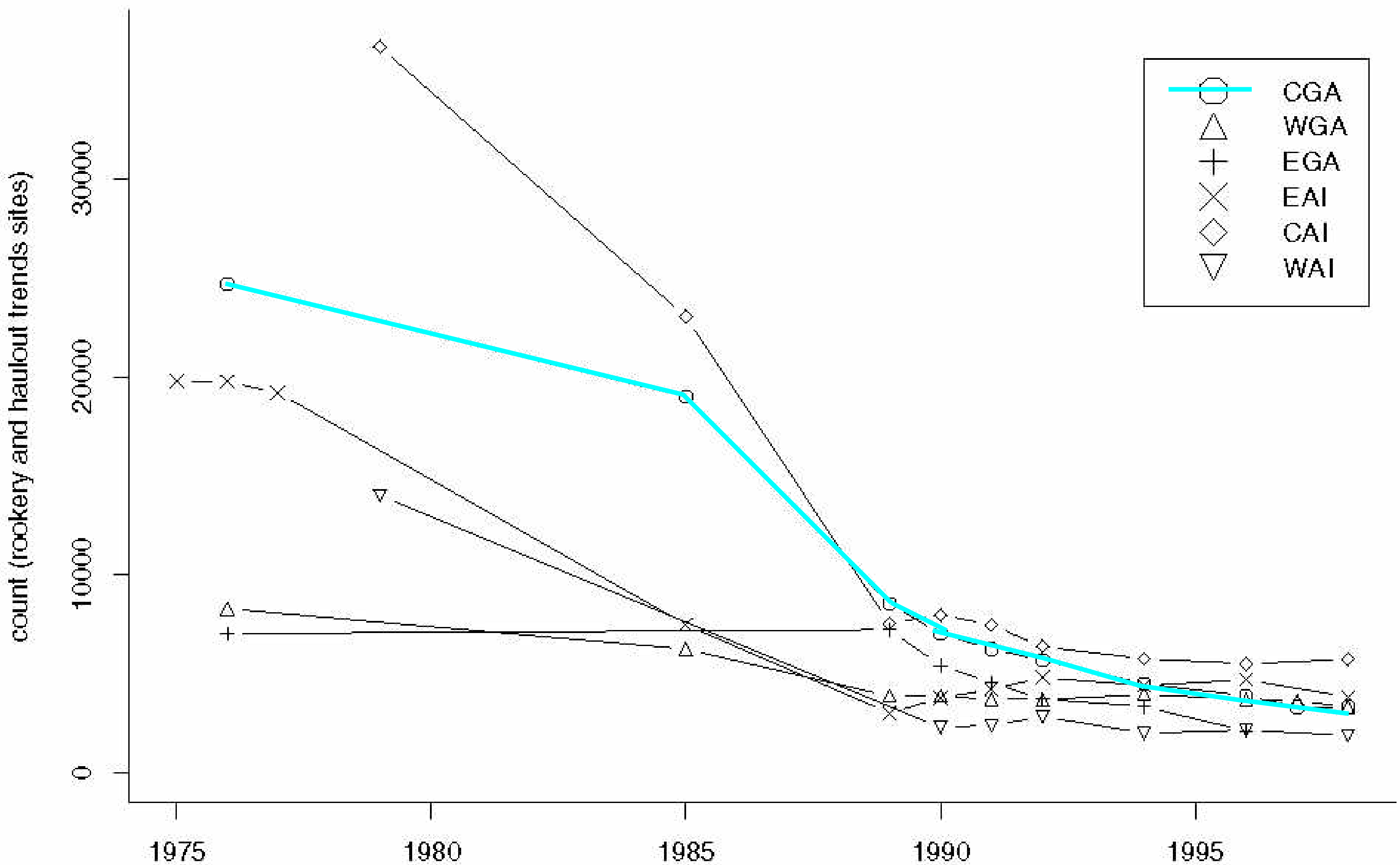
NON-PUPS on TREND SITES (Br SEASON)

TOTAL CGA PUP COUNT



Basic life history can be estimated from 1970s age and pregnancy data from Marmot Is.



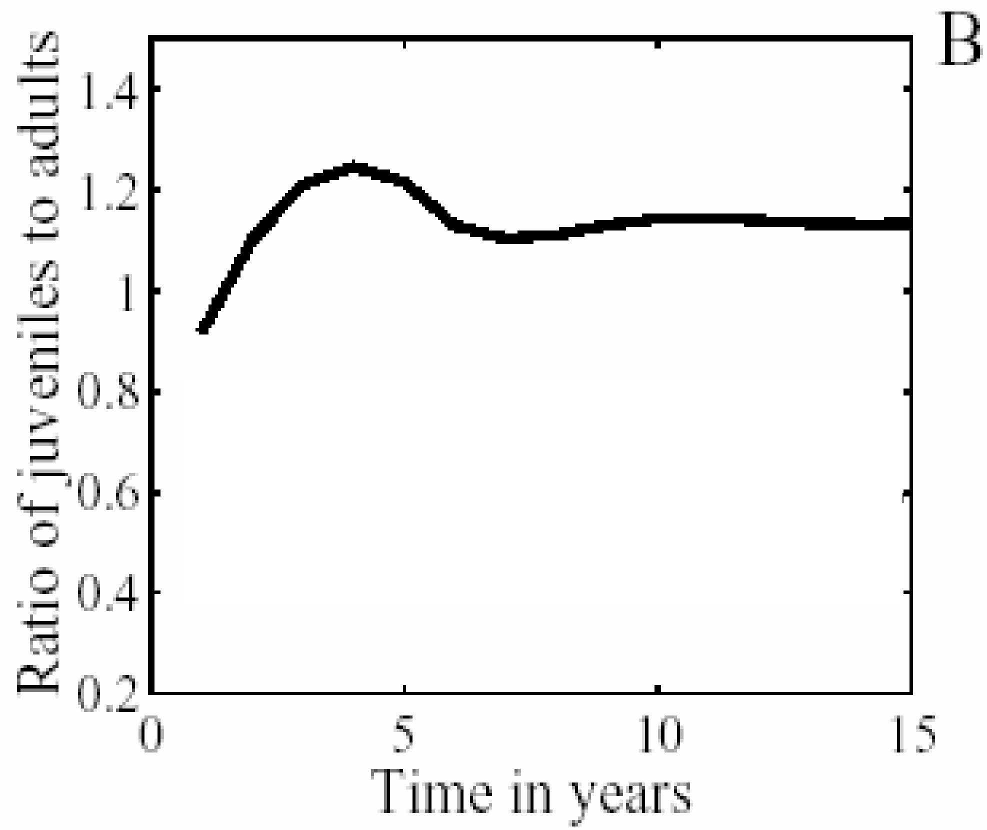


count (rookery and haulout trends sites)
0
10000
20000
30000
1975
1980
1985
1990
1995
CGA
WGA
EGA
EAI
CAI
WAI

Fitting models to total population trends alone does not rapidly detect change

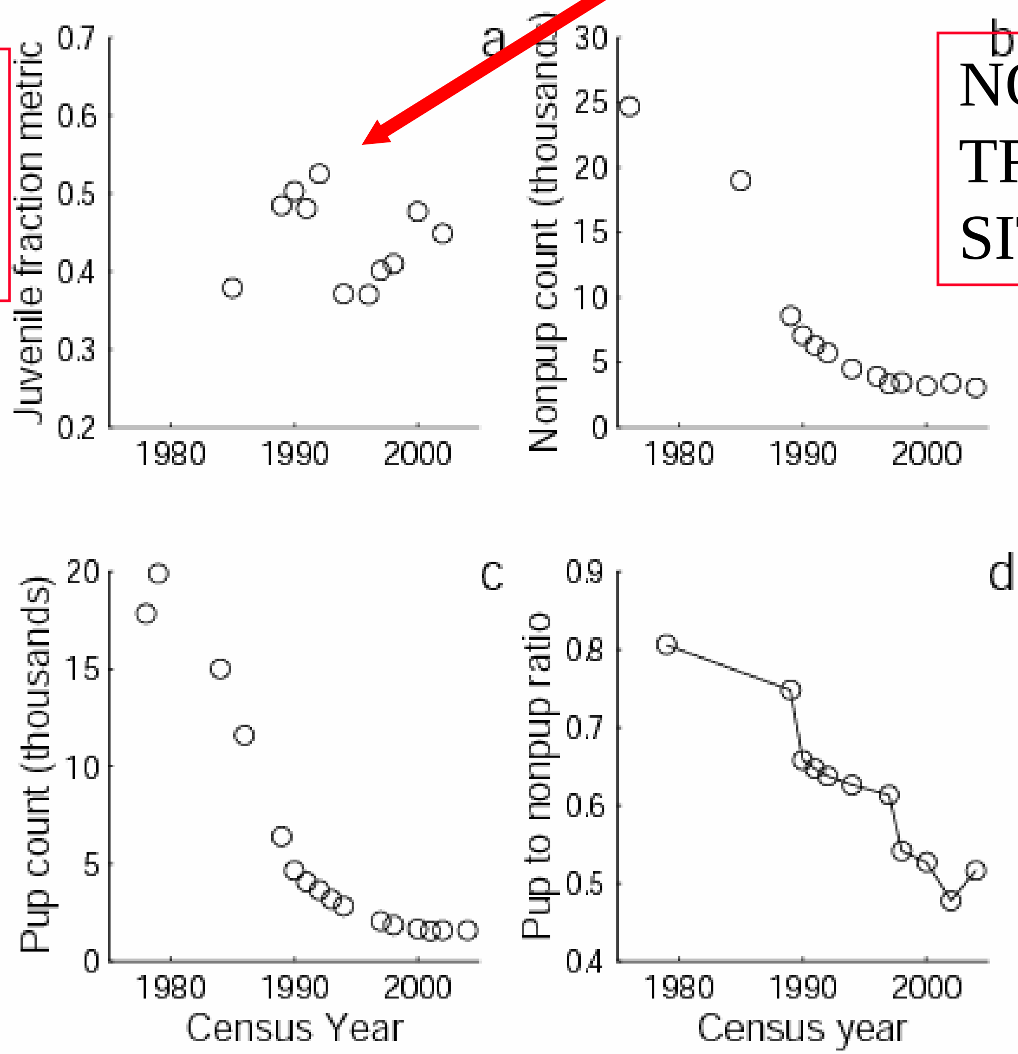
Changes in age-structure is more sensitive to perturbations

- Perturbation was a 20% increase in juvenile survivorship
- Most extreme values occur 4-yrs following a change
- Ratio stabilizes 10 yrs following the change



Changes in juvenile fraction allow us to see perturbations quickly

AN AGE-STRUCTURE METRIC



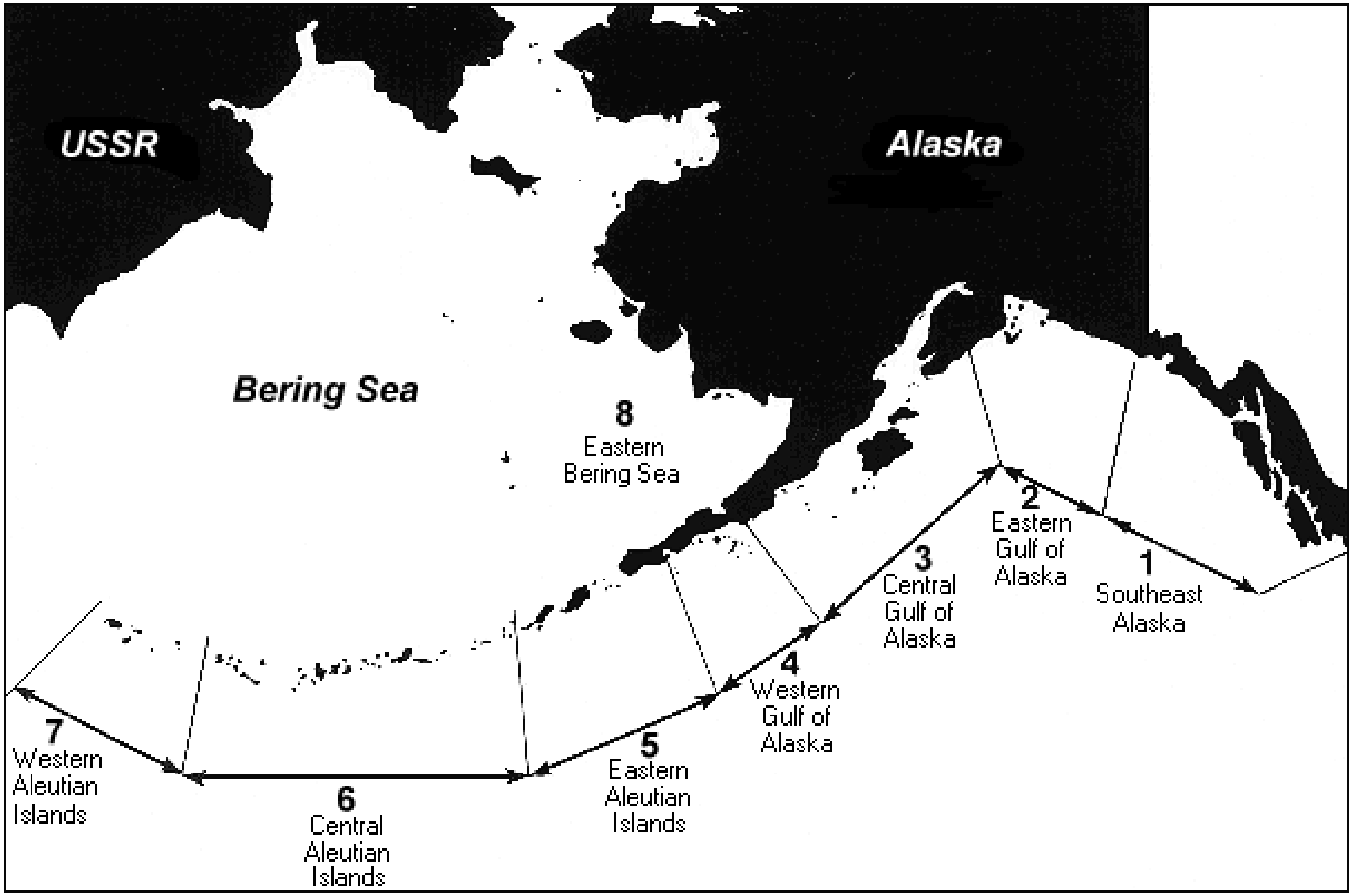
NON-PUPS on TREND SITES

TOTAL CGA PUP COUNT

We used this approach to estimate demographic perturbations in the CGOA

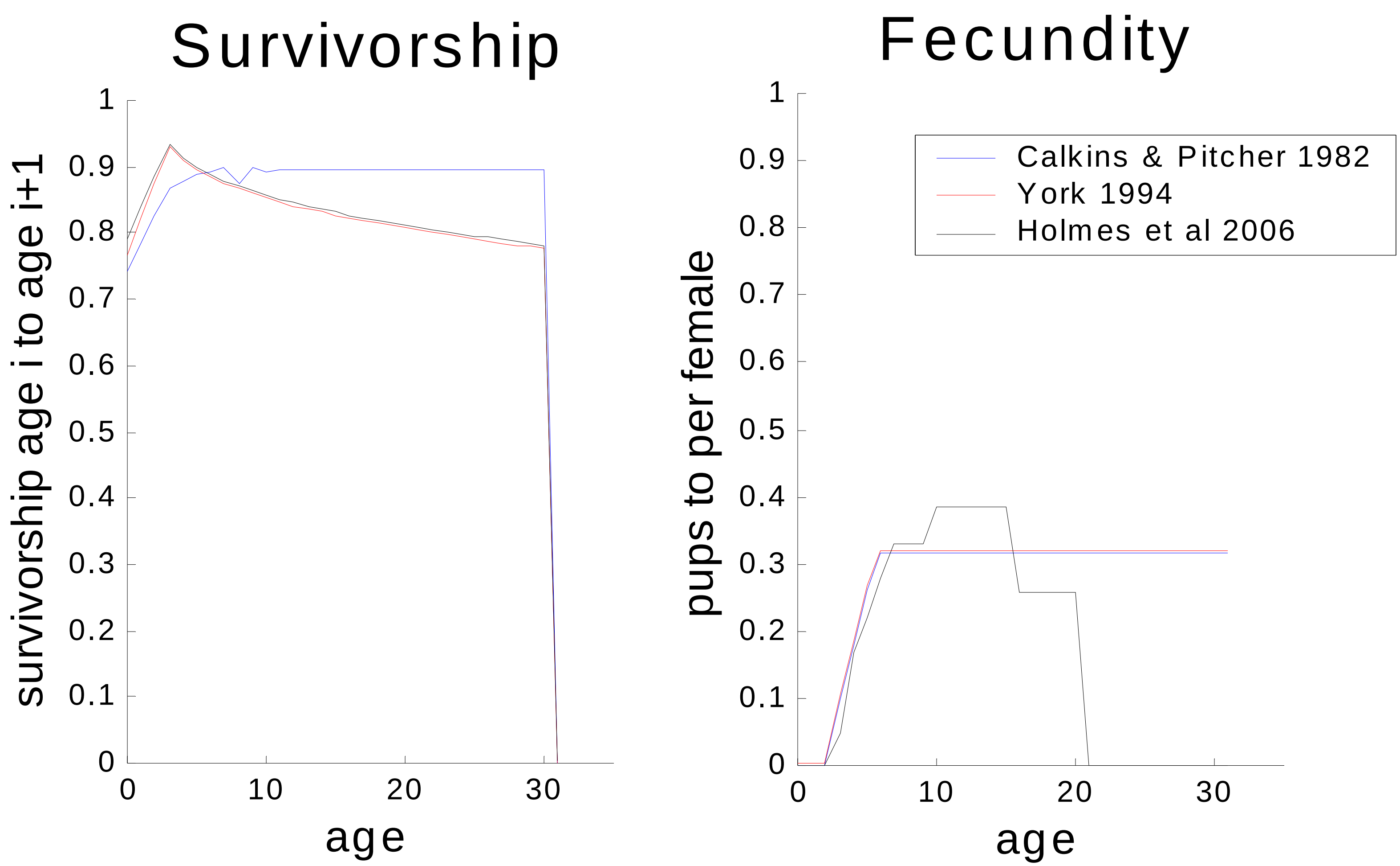
- Can you explain the data with only one early 1980s perturbation?
- How have demographic parameters been changing 1980-2004?
- What demographic parameter change is most consistent with the recent non-pup increases?

We focused on the CGOA



Is the analysis sensitive to the model?

We compared 3 life-history models, all based on the 1970s Marmot Island data



We allowed demographic rates to change through the 1980's and 1990's

$$\text{For } t = 1976 \text{ to } 1982,$$

$$\vec{N}_{t+1} = \mathbf{Y}_{76} \cdot \vec{N}_t$$

$$\text{For } t = 1983 \text{ to } 1987,$$

$$\vec{N}_{t+1} = \mathbf{Y}_{83} \cdot \vec{N}_t$$

$$\text{For } t = 1988 \text{ to } 1992,$$

$$\vec{N}_{t+1} = \mathbf{Y}_{88} \cdot \vec{N}_t$$

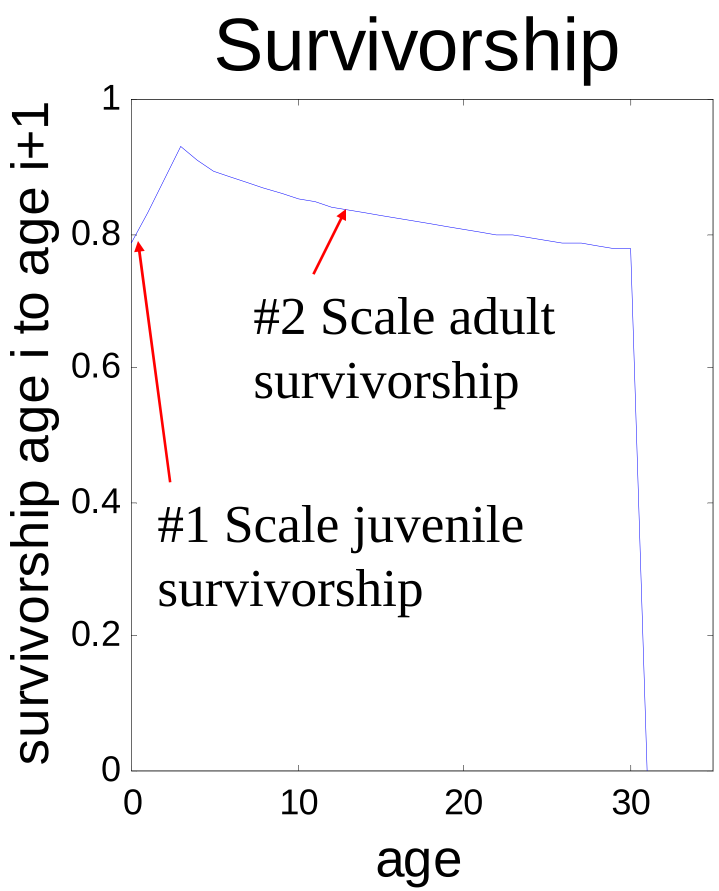
$$\text{For } t = 1993 \text{ to } 1998,$$

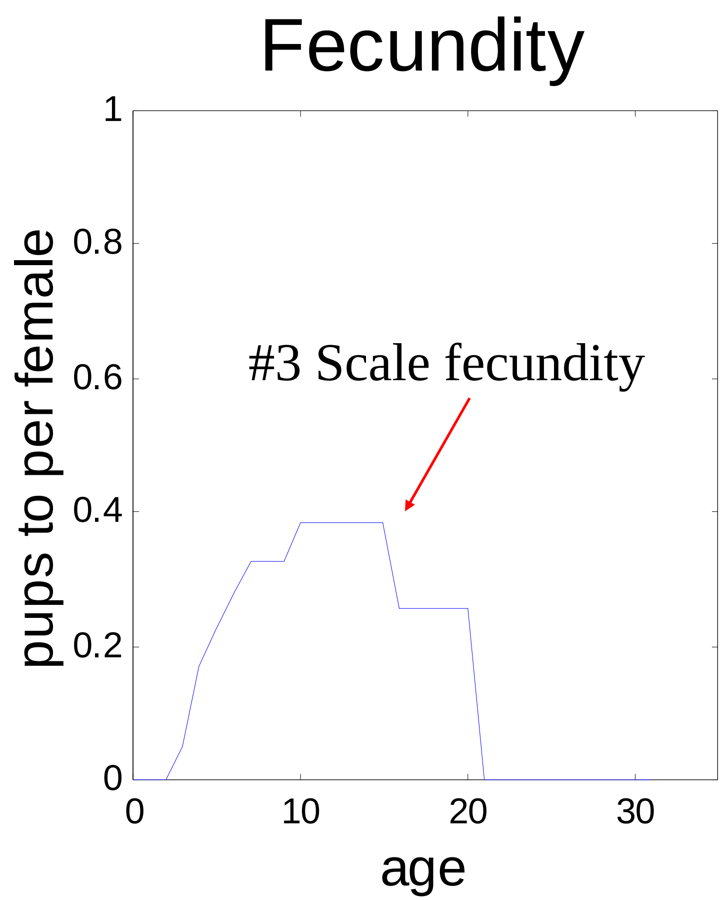
$$\vec{N}_{t+1} = \mathbf{Y}_{93} \cdot \vec{N}_t$$

Matrices with period specific juvenile surv., fecundity, adult surv.

14-17 free parameters

Three scaling parameters





14-17 free parameters

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Matrices with period specific juvenile surv., fecundity, adult surv.

14-17 free parameters

Distance between the model and the data: negative log-likelihood

$$S(\theta)=\frac{1}{2\sigma_{\ln N}^{2}}\sum_{i=1}^{k}(\ln(N_i)-\ln(0.524(\hat{J}_i+\hat{A}_i)))^2$$

$$+\frac{1}{2\sigma_{\ln P}^{2}}\sum_{i=1}^{n}(\ln(P_i)-\ln(0.95\hat{P}_i))^2$$

$$+\frac{1}{2\sigma_{J}^{2}}\sum_{i=1}^{m}((J/T)_i-(0.8\hat{J}_i/(\hat{J}_i+0.21\hat{A}_i))^2$$

$$+\text{a constant}$$

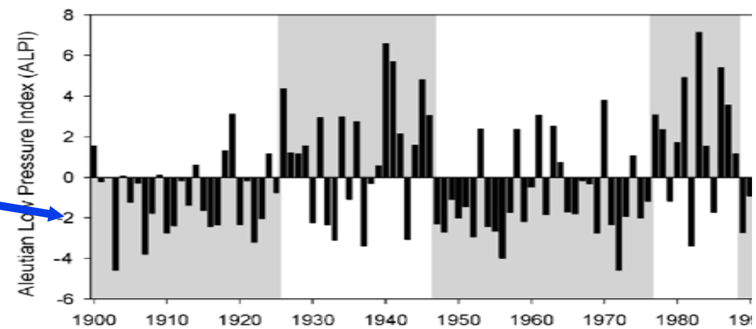
Model

Data

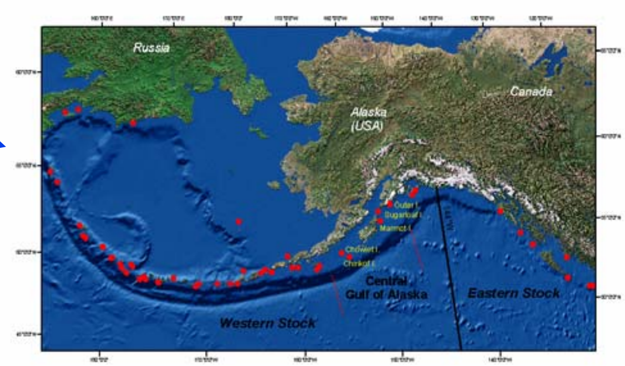
Relationship between the indices and true value

We had to construct plausible time periods for when demographic rates changed. We did this 2 different ways.

- Oceanographic



- Analysis of rookery trends (York 1994)



- ~~Known management actions~~
- ~~Treat each year as a possible change point~~

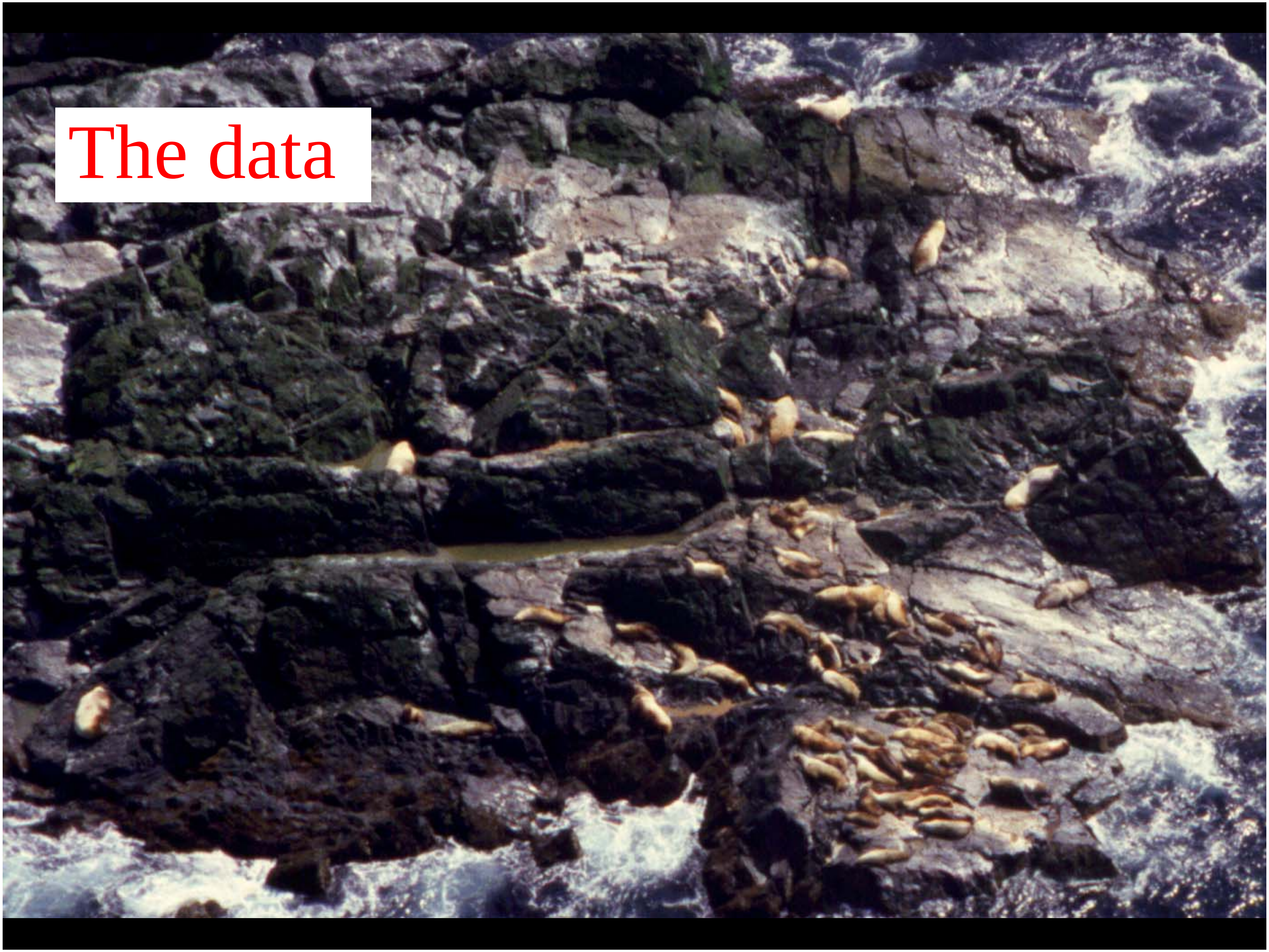
Methodology overview

- Location
- Life-history models
- Temporal changes
- Fitting models
- Historical age-structure proxy

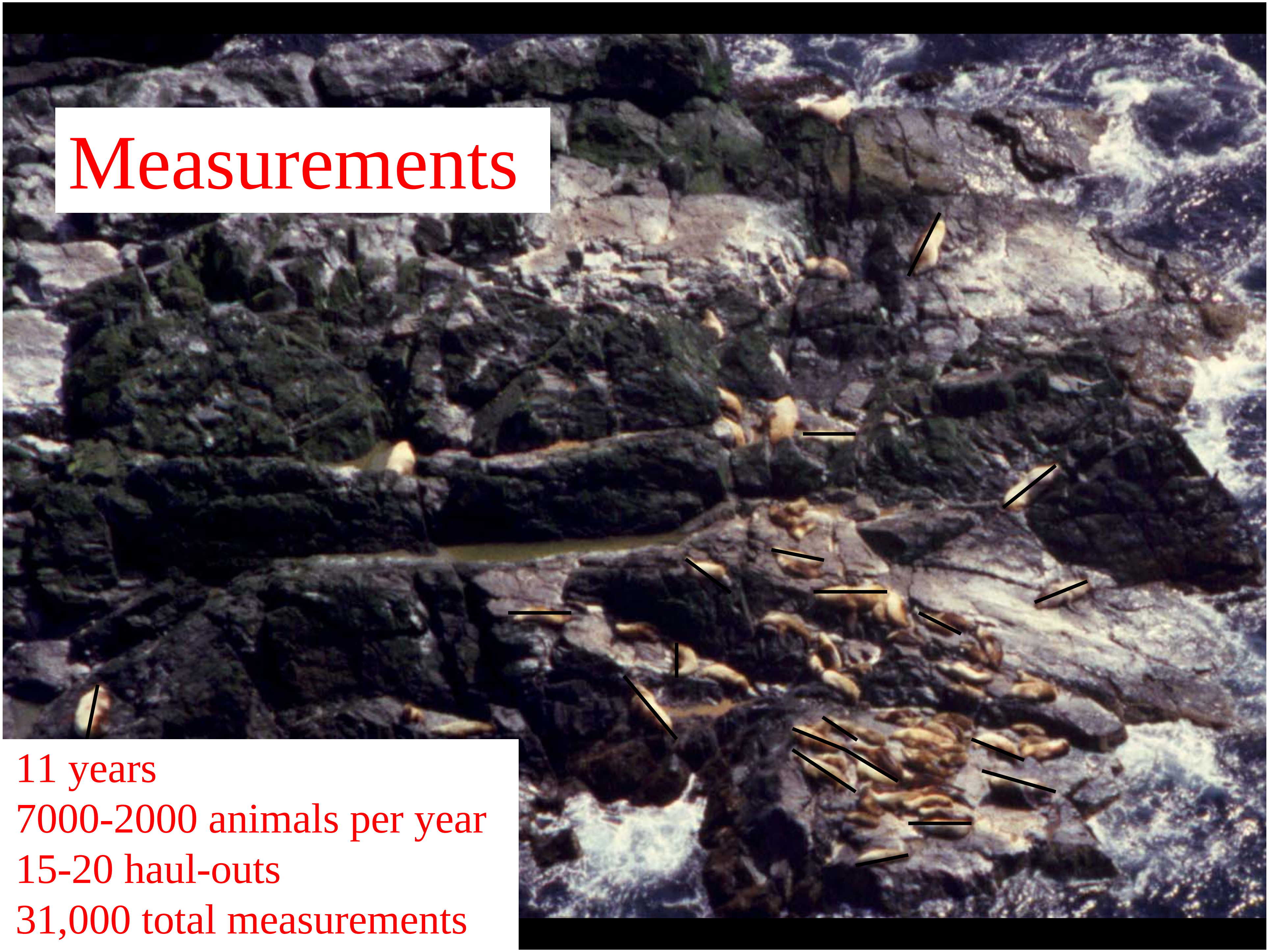
We had to develop a practical proxy for age-structure

- Use models to explore what are sensitive proxies
  - Ratio of pups to non-pups
  - Ratio of rookery to haul-out non-pups
  - Ratio of juveniles to adults
- Develop a practical way to measure the proxy: the ratio of small to large individuals
- Test it

The data



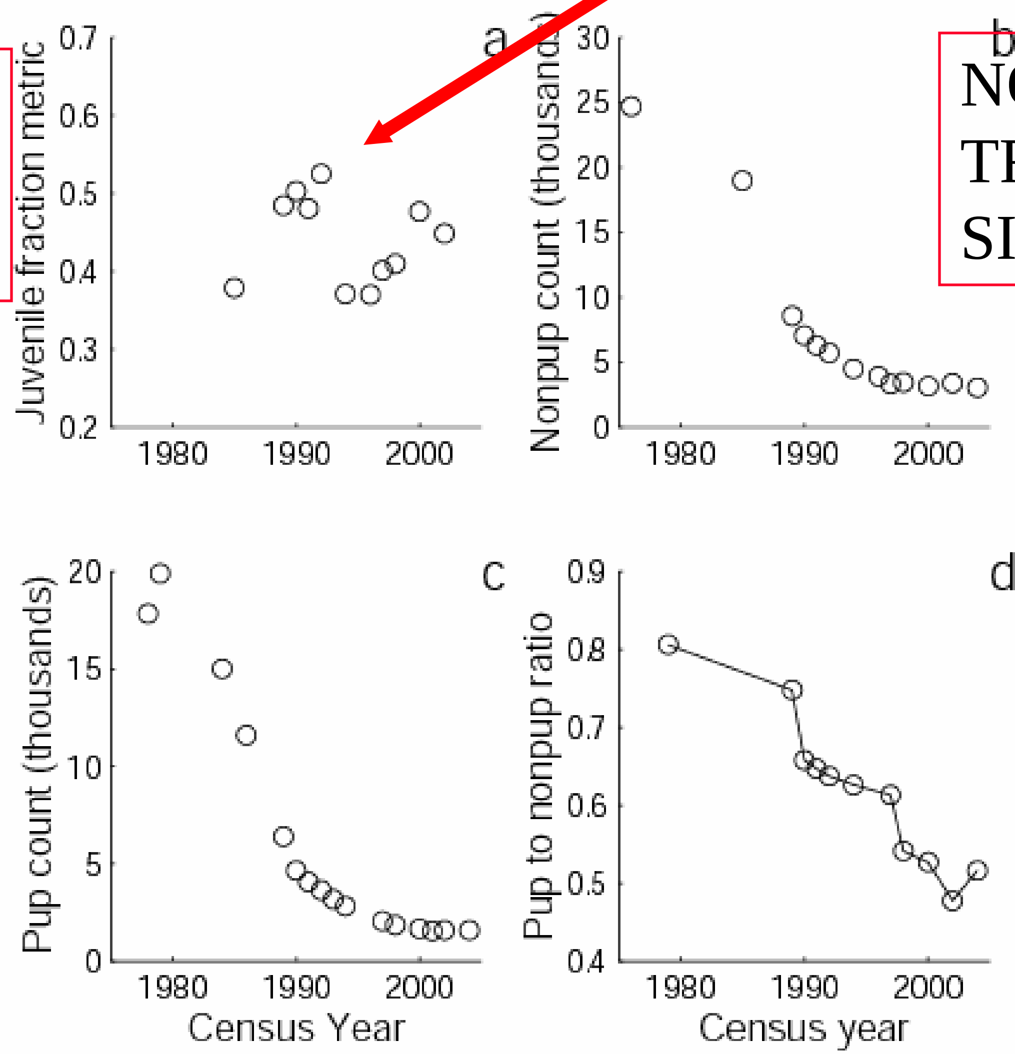
Measurements



11 years
7000-2000 animals per year
15-20 haul-outs
31,000 total measurements

Juvenile fraction has been changing

AN AGE-STRUCTURE METRIC



NON-PUPS on TREND SITES

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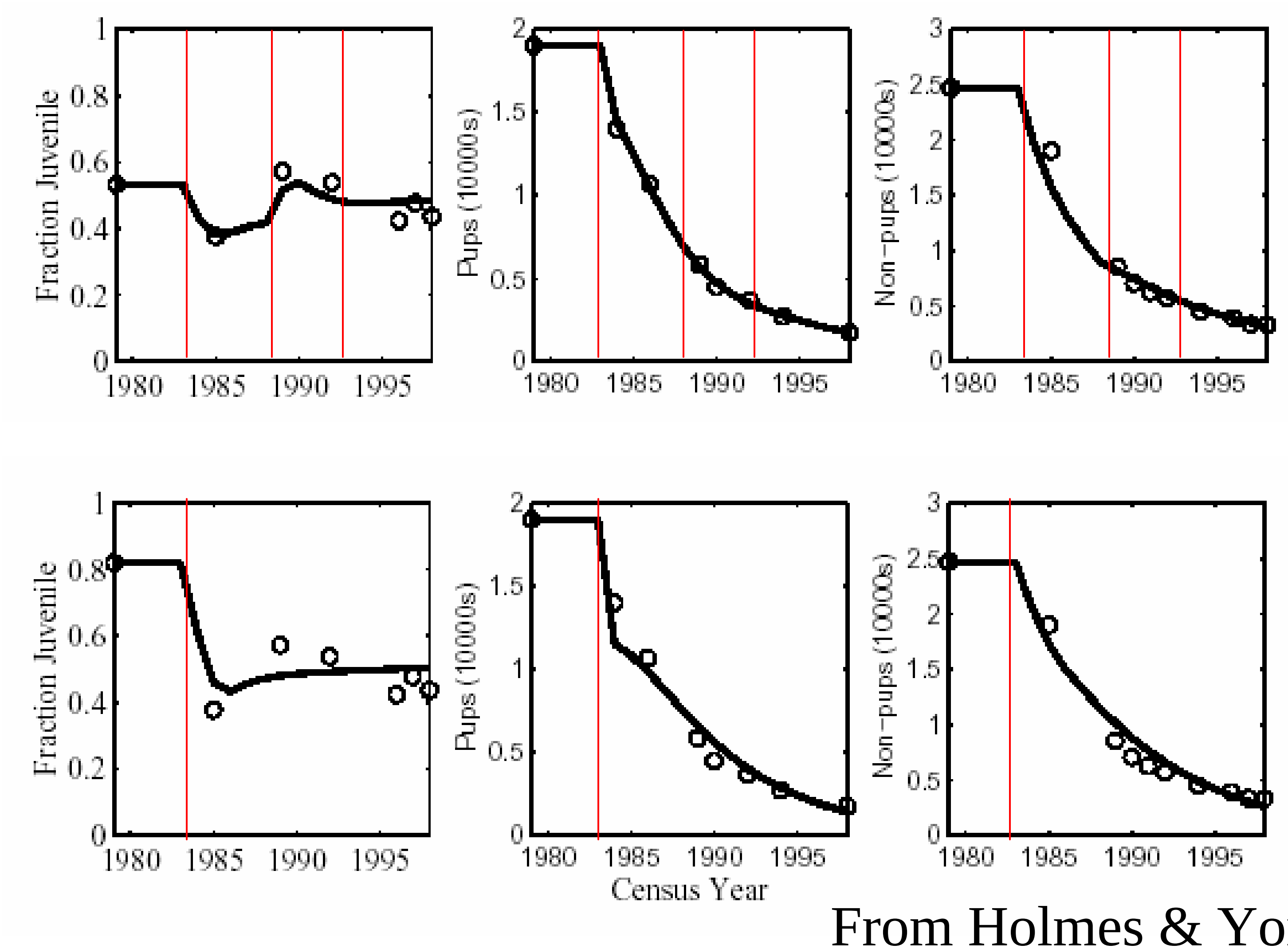
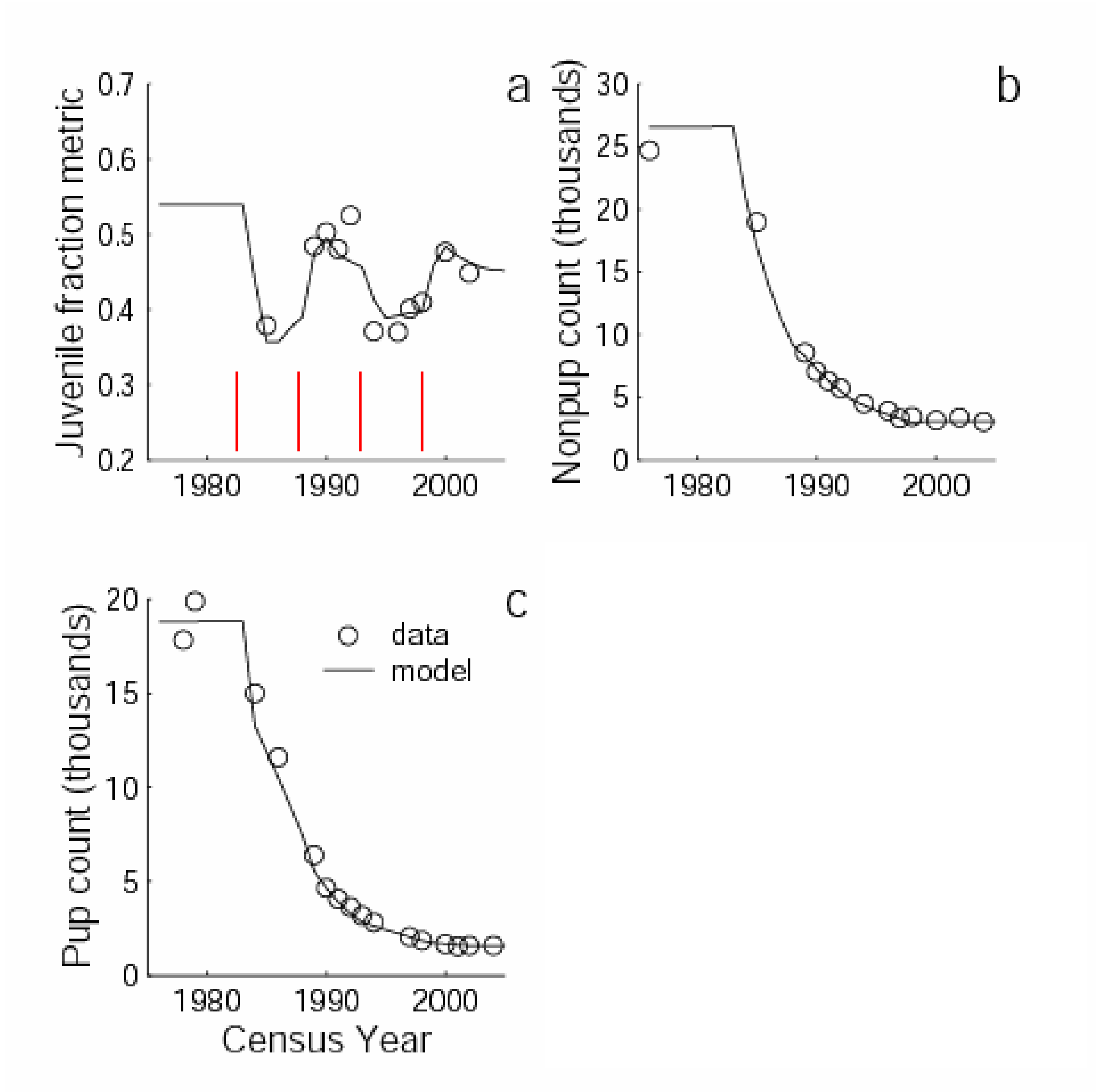
One change in demographic rates or multiple?

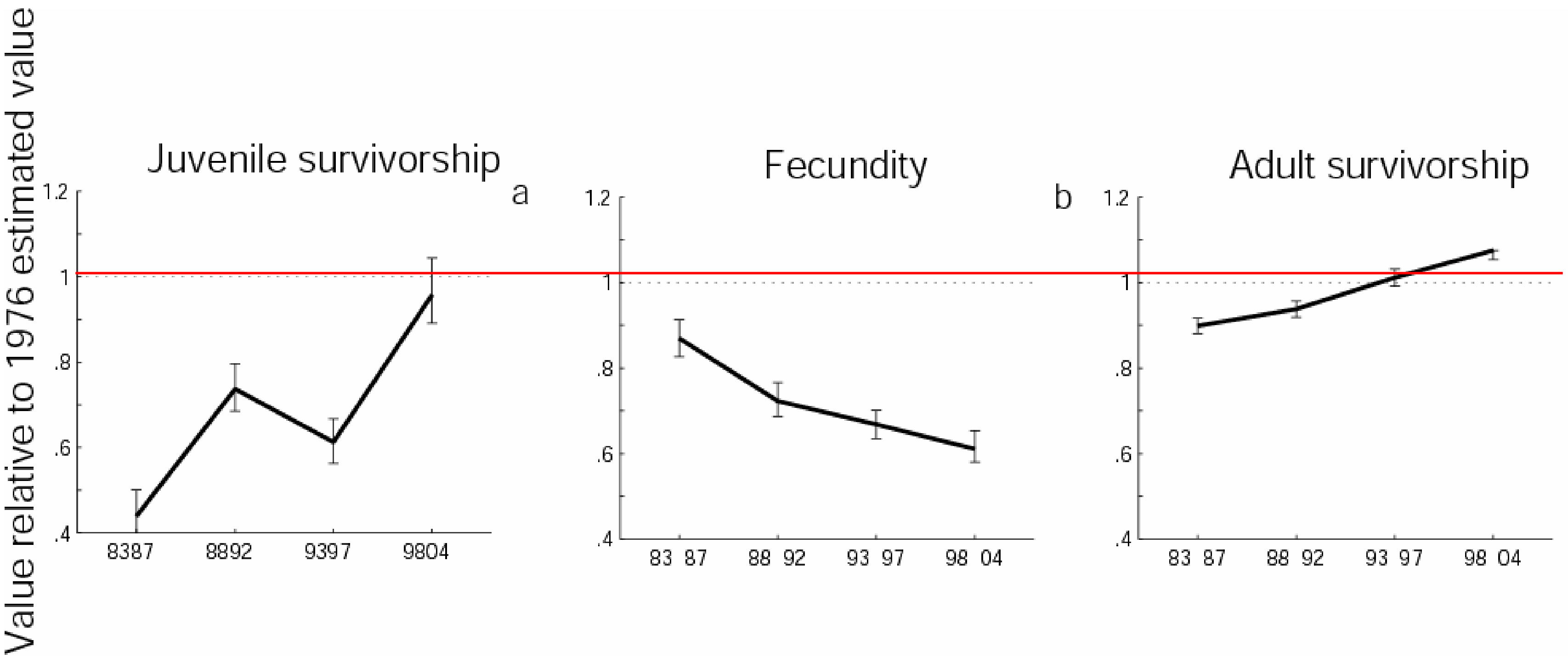


From Holmes & York 2003

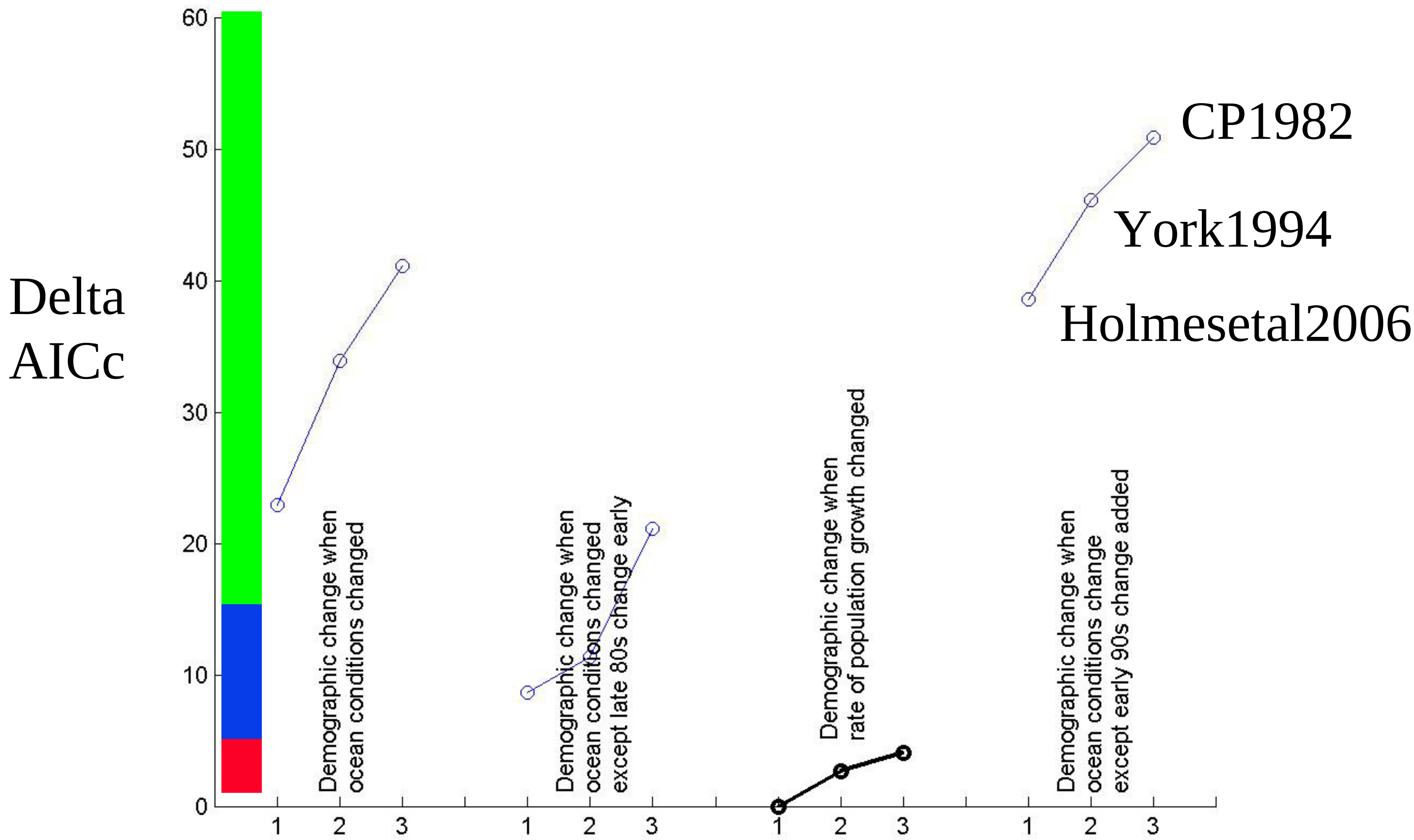
Data are best fit by 4 demographic changes



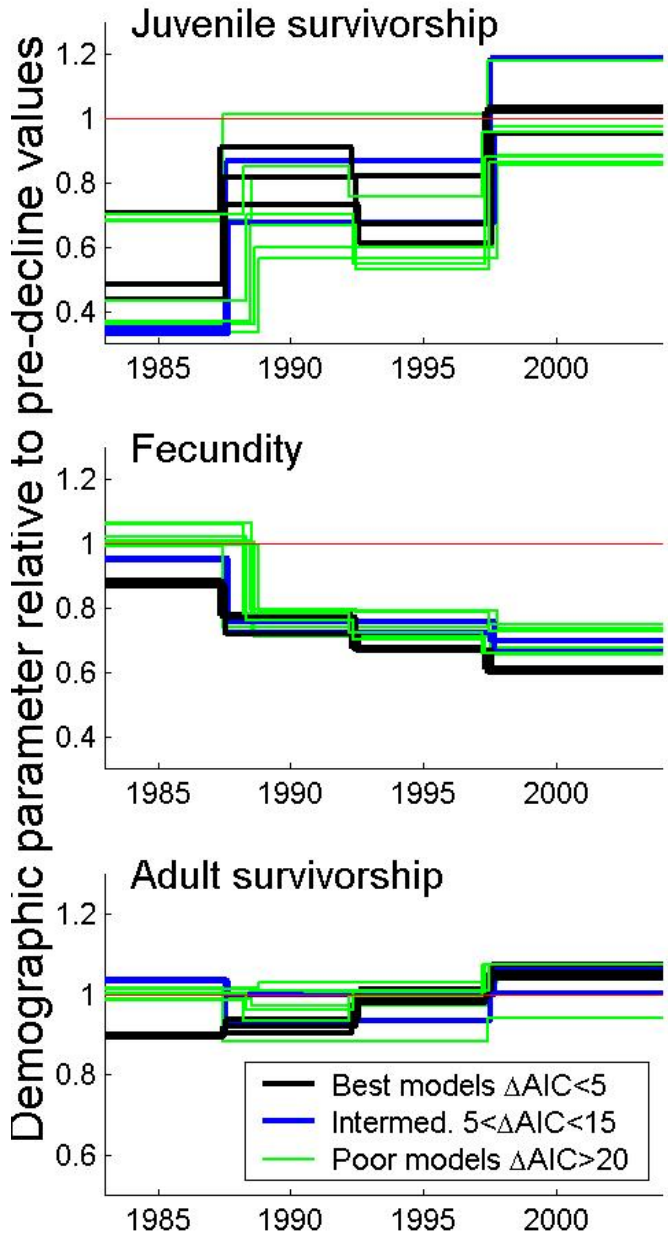
Fit of model indicates rising survivorship and declining fecundity



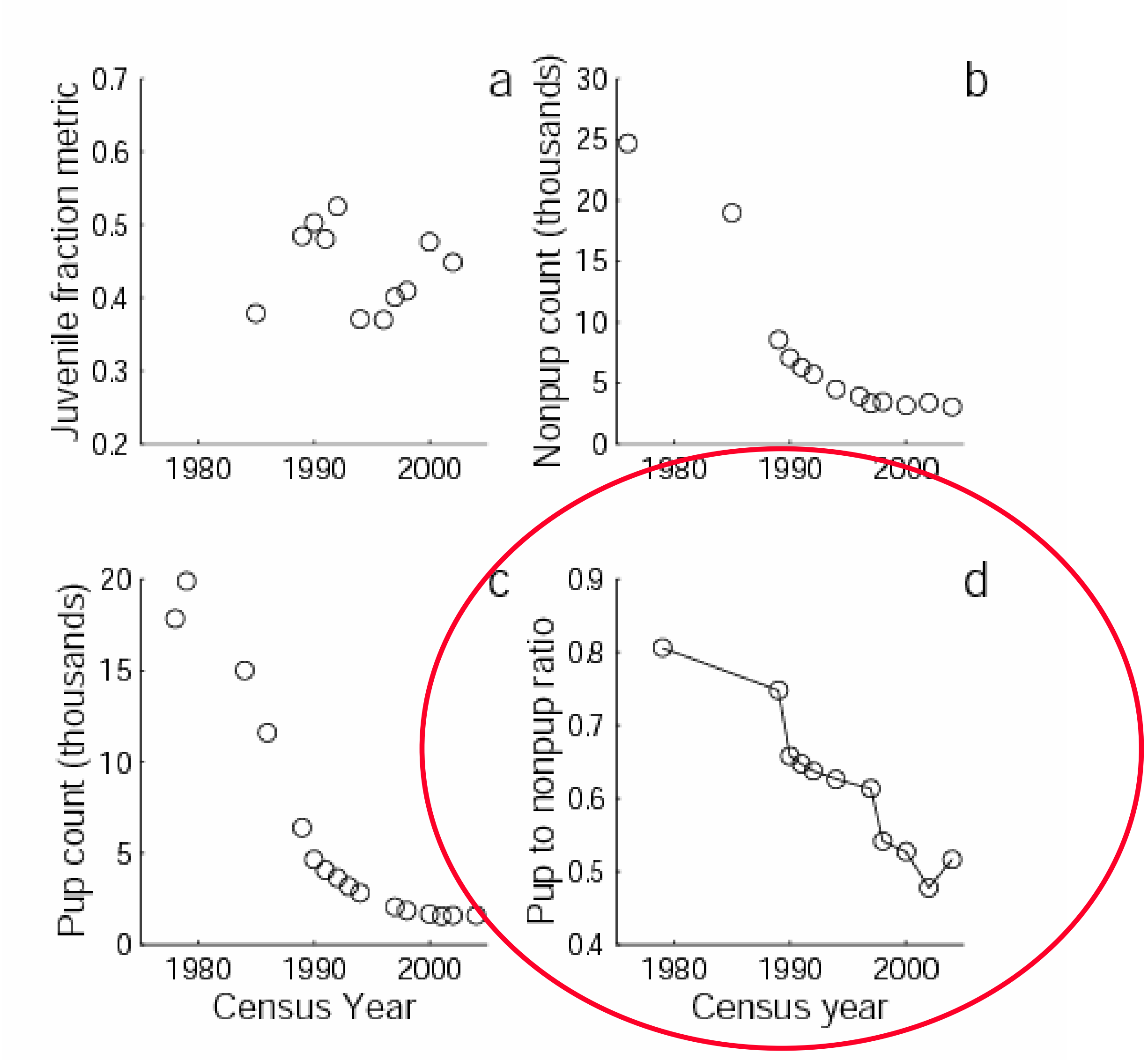
The different models vary in their ability to fit the data

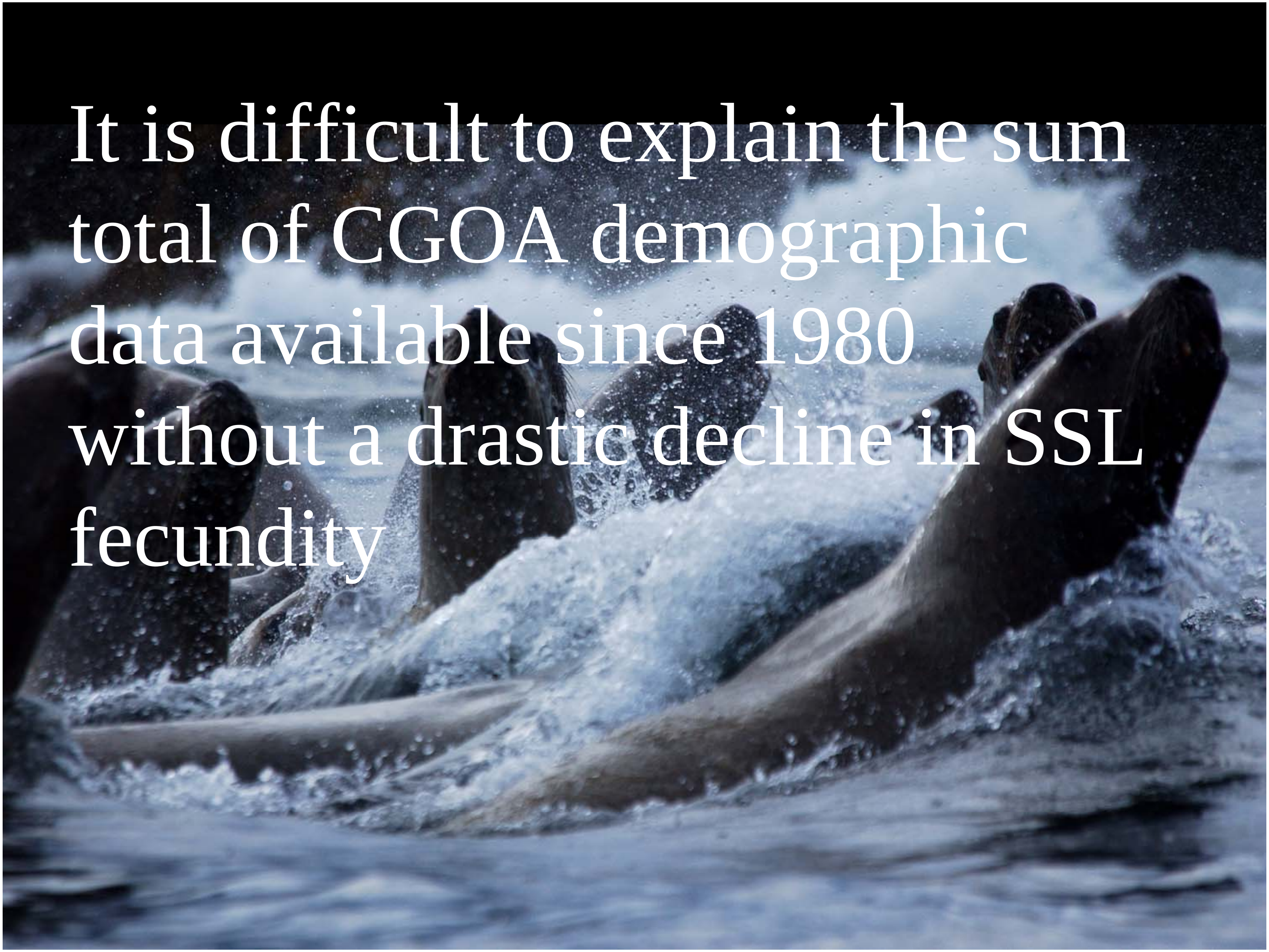


Models agree on declining fecundity and rising juvenile survivorship



Agreement among models is driven by declining pup-to-non-pup ratios




It is difficult to explain the sum total of CGOA demographic data available since 1980 without a drastic decline in SSL fecundity