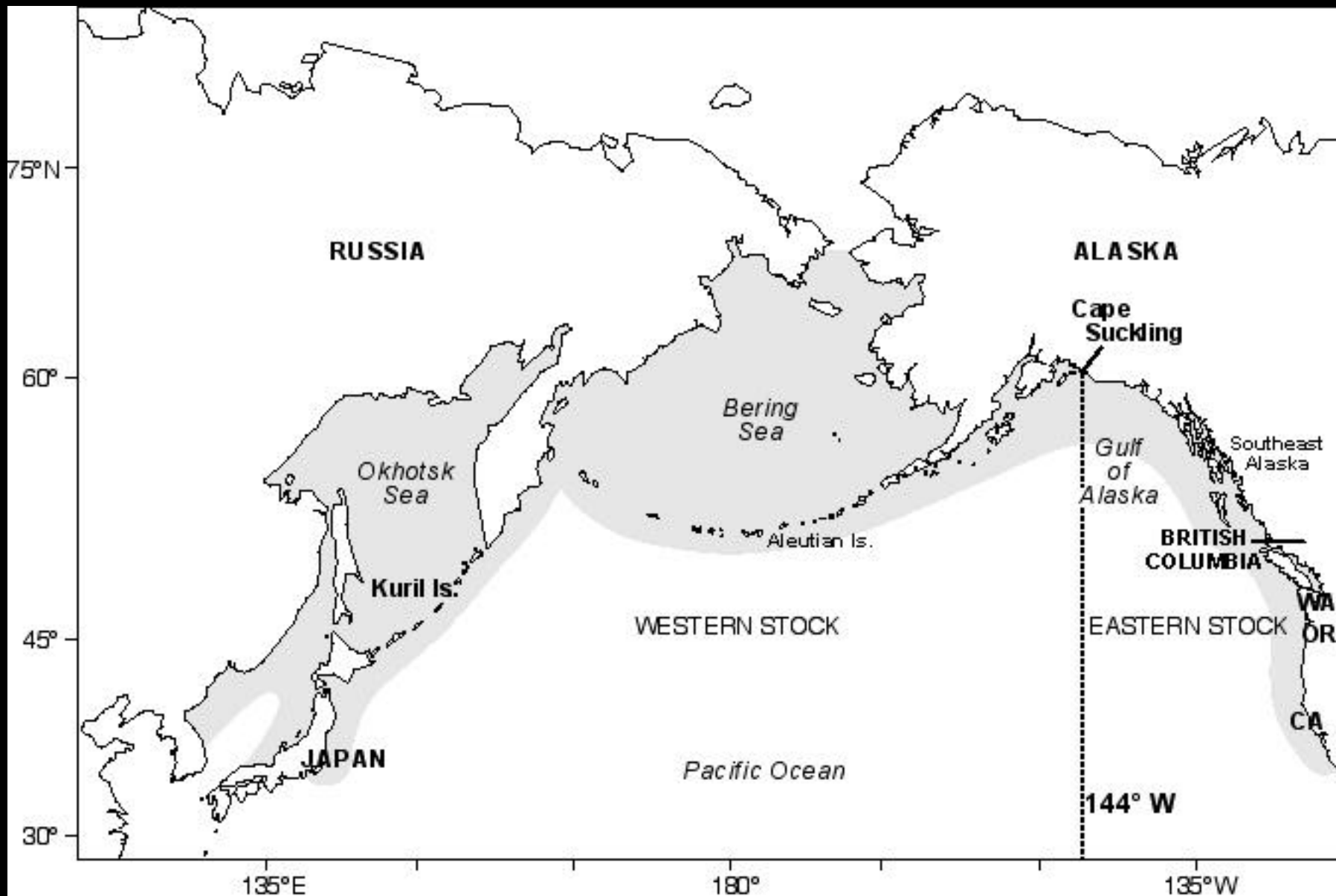


# Detecting effects of management on long-lived species





1969



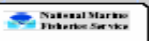
1979



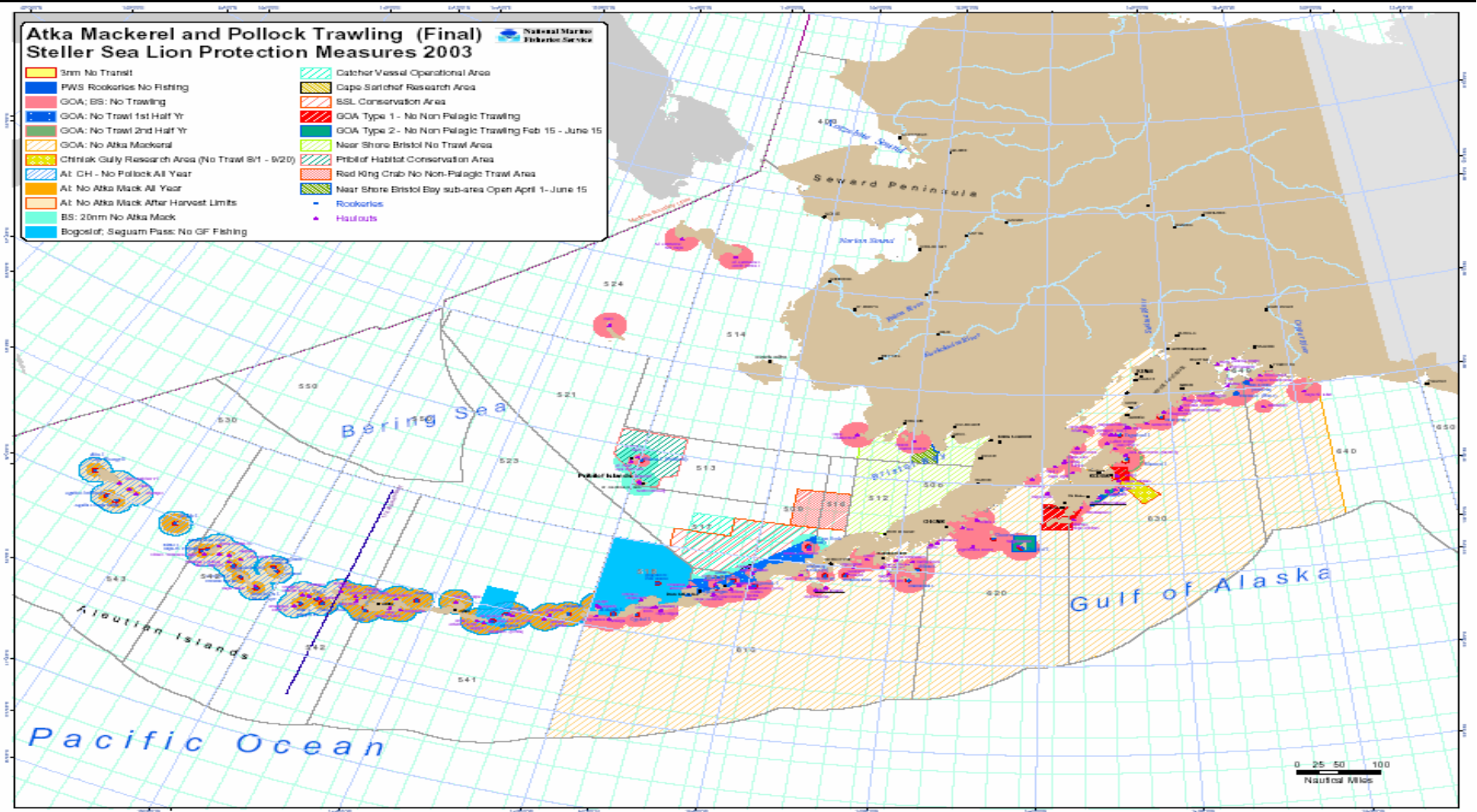
1986

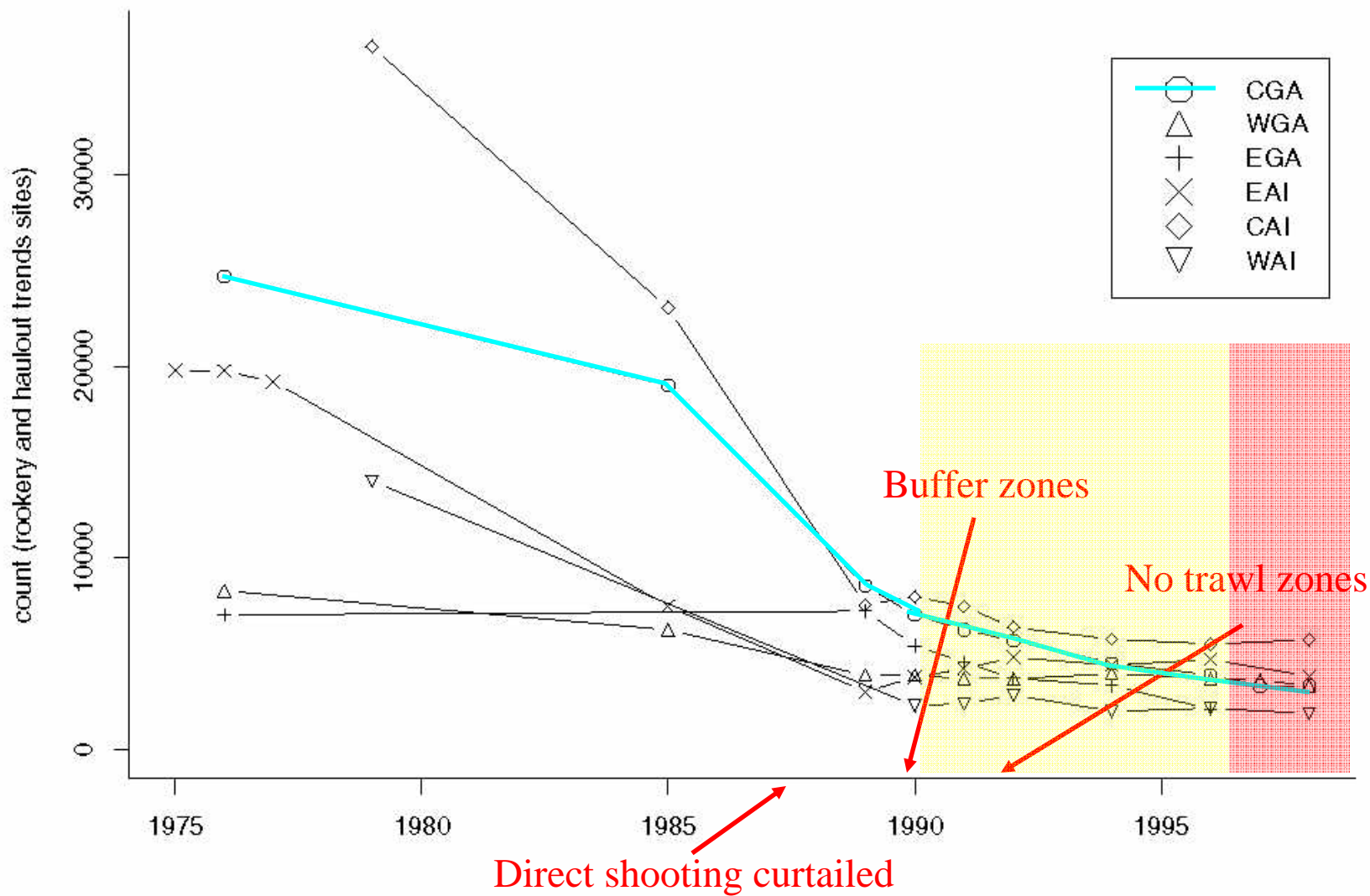


# Atka Mackerel and Pollock Trawling (Final) Steller Sea Lion Protection Measures 2003



- |  |   |
|--|---|
| 3nm No Transit                                     | Catcher Vessel Operational Area                       |
| PWS Rookeries No Fishing                           | Cape Sarichef Research Area                           |
| GOA; BS: No Trawling                               | SSL Conservation Area                                 |
| GOA: No Trawl 1st Half Yr                          | GOA Type 1 - No Non Palagic Trawling                  |
| GOA: No Trawl 2nd Half Yr                          | GOA Type 2 - No Non Palagic Trawling Feb 15 - June 15 |
| GOA: No Atka Mackerel                              | Near Shore Bristol No Trawl Area                      |
| Chirikof Gully Research Area (No Trawl 8/1 - 8/20) | Prble of Habitat Conservation Area                    |
| At CH - No Pollock All Year                        | Red King Crab No Non-Palagic Trawl Area               |
| At No Atka Mackerel All Year                       | Near Shore Bristol Bay sub-area Open April 1- June 15 |
| At No Atka Mackerel After Harvest Limits           | Rookeries   |
| BS: 20nm No Atka Mackerel                          | Haulouts  |
| Bogofot, Seguam Pass: No GF Fishing                |   |





- **Challenge:** The slow response of population size to small survivorship and fecundity improvements prevents rapid detection of the effects of management actions.
- **Solution?** Age-structure shifts?



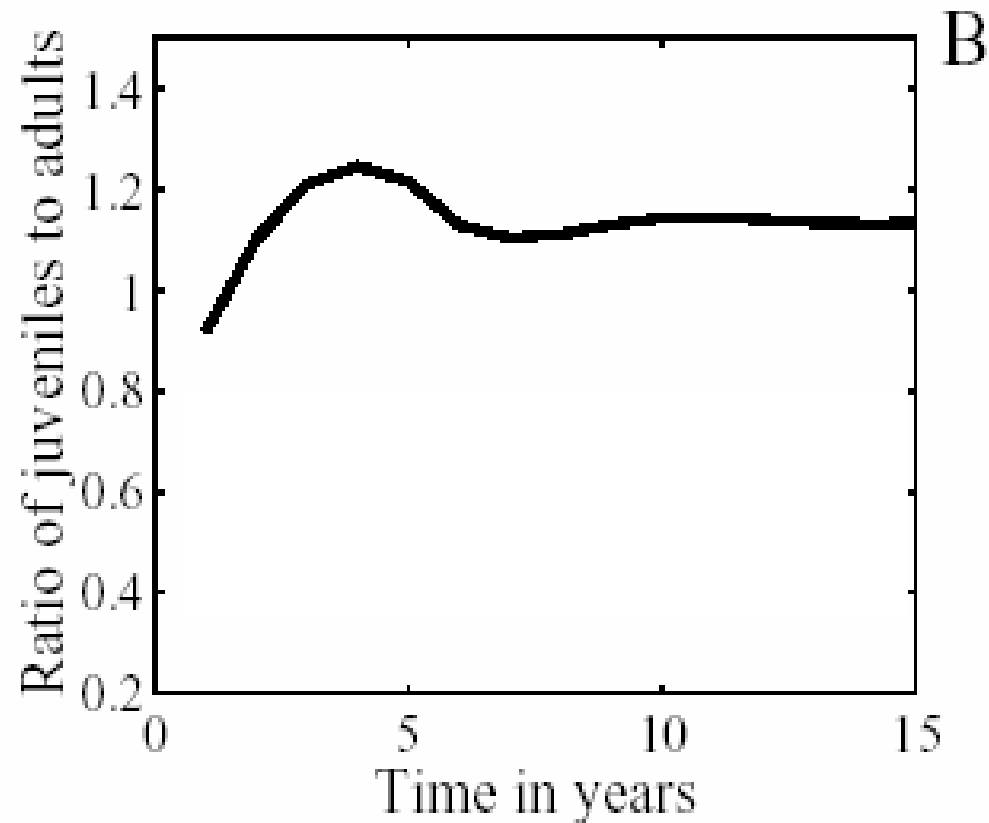
# York matrix model based on tagging data from Marmot Is. '70s

age 0	1	2	3	4	5	6	...	31
0	0	0.0788	0.1669	0.2376	0.2819	0.278 <sup>†</sup>	....	0
0.782	0	0	0	0	0	0	...	0
0	0.782	0	0	0	0	0	...	0
0	0	0.782	0	0	0	0	...	0
0	0	0	0.930	0	0	0	...	0
0	0	0	0	0.909	0	0	...	0
0	0	0	0	0	... <sup>‡</sup>	0	...	0
0	0	0	0	0	0	...	...	0



## Changes in ratios of juveniles to adults after a 20% increase in juvenile survival

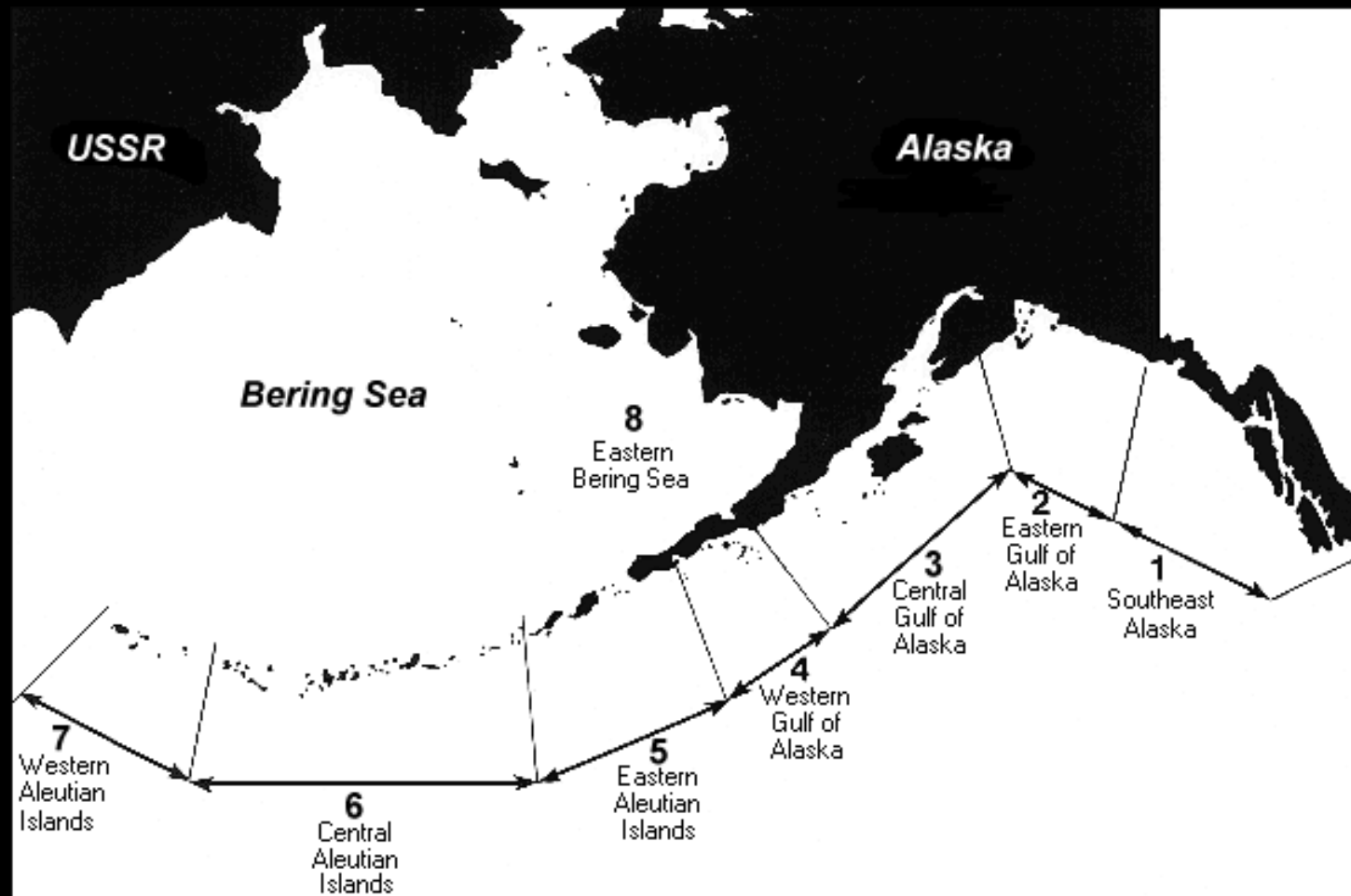
- Most extreme values occur 4-5 yrs following a change
- Ratio stabilizes 10 yrs following the change





# Development of 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

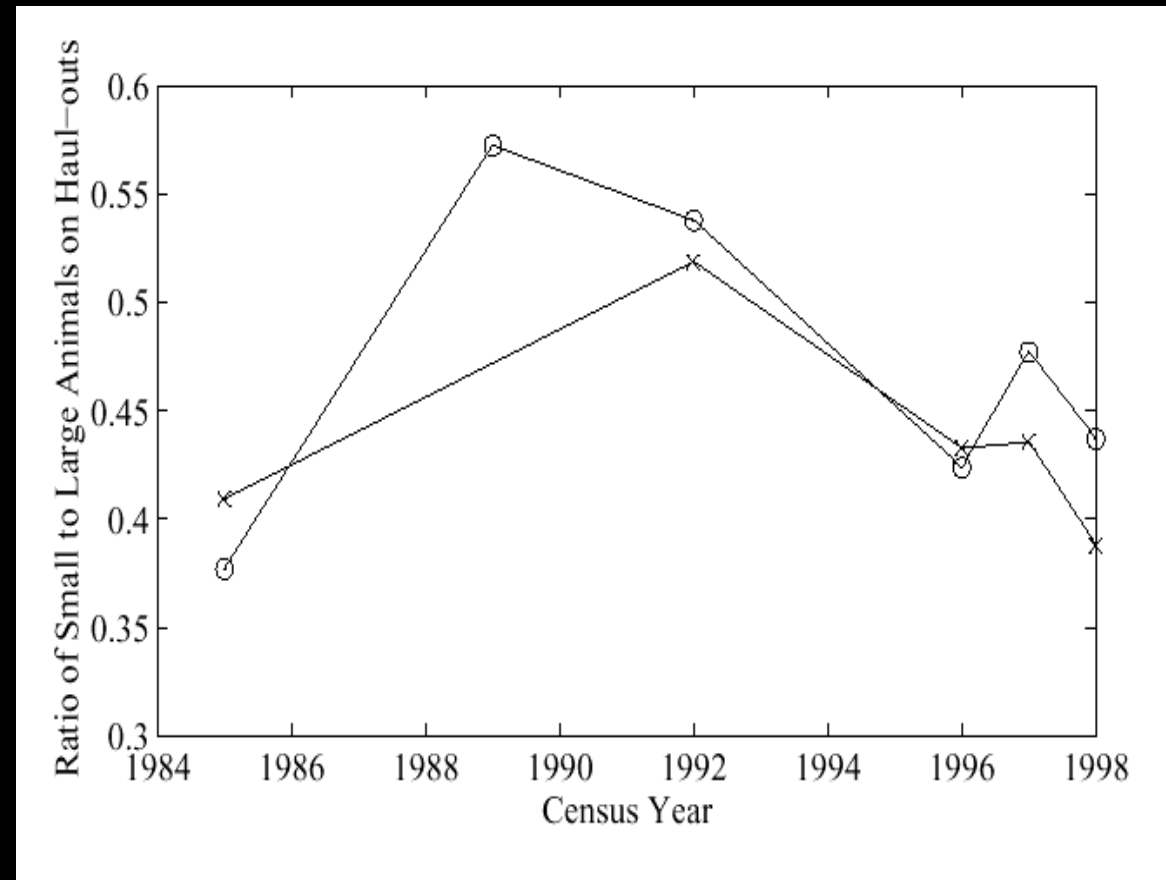


# Results

- 35 Haul-out locations in the Central Gulf of Alaska
- 6 census years:  
1985-1998
- 25,322 individual measurements

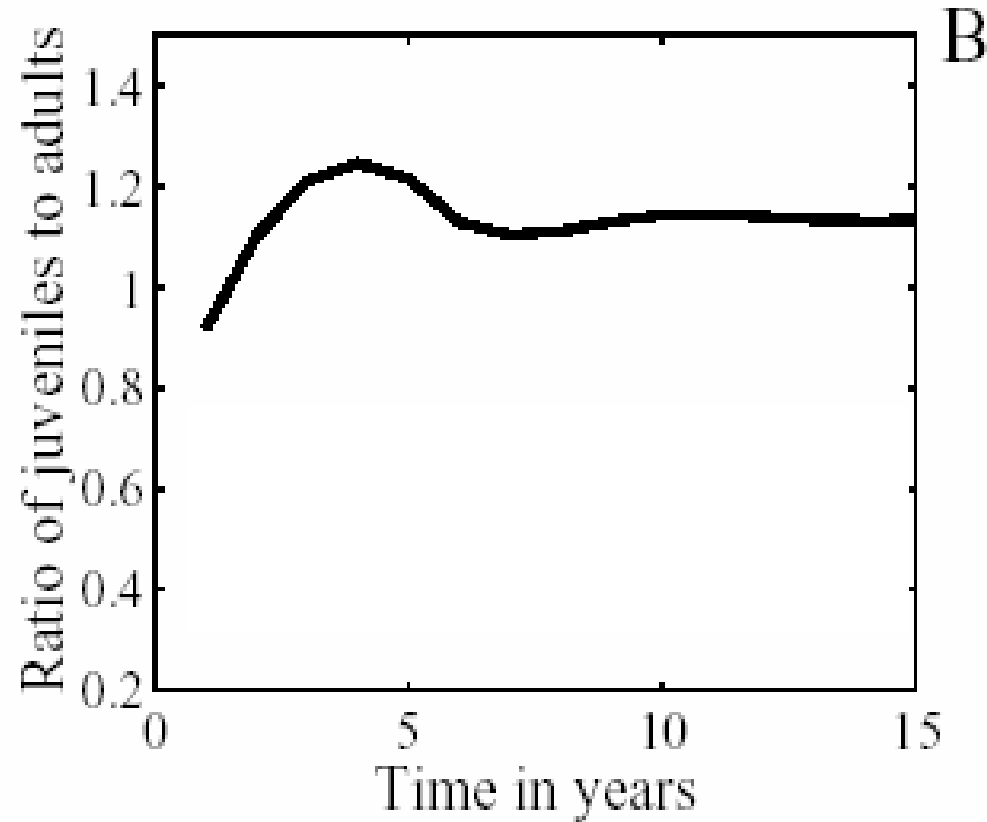
# Historical changes in the ratio of small to large animals

- Between 1985 and 1989, the metric doubles and then declines
- Similar to the transitory spikes predicted after an improvement in juvenile survivorship.

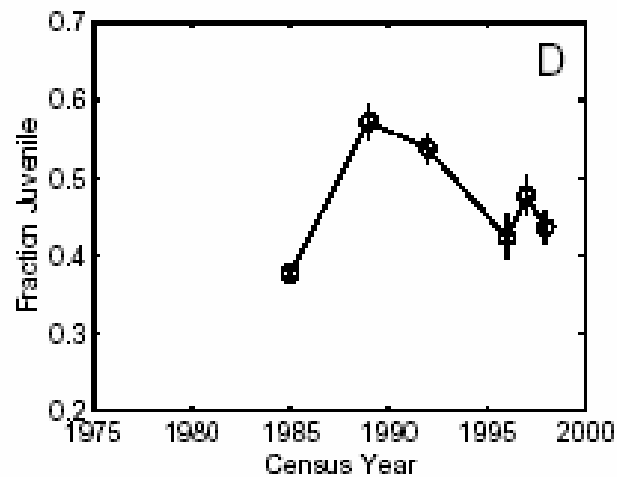
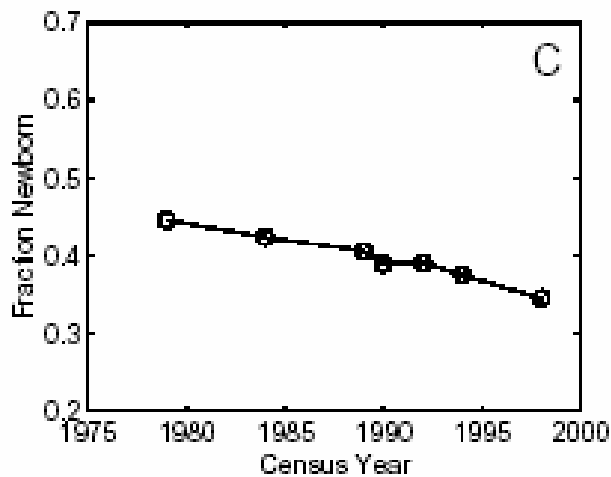
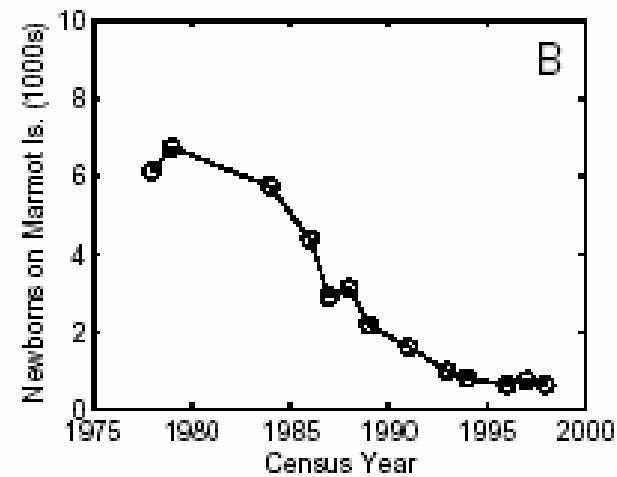
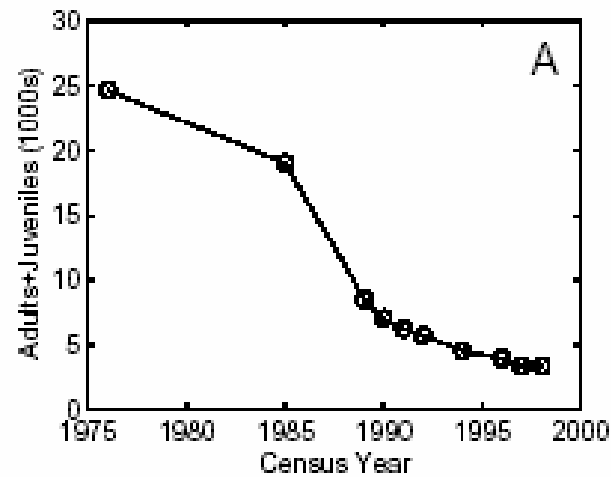




# Changes in ratios of juveniles to adults after a 20% increase in juvenile survival



# Using the matrix model to explore what changes in demographic rates are consistent with the data:



# The model: changing demographic rates in the 1980's and 1990's

For  $t = 1976$  to 1982,

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

For  $t = 1983$  to 1987,

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

For  $t = 1988$  to 1992,

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

For  $t = 1993$  to 1998,

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

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

9 free parameters

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

$$S(\theta) = \frac{1}{2\sigma_{\ln N}^2} \sum_{i=1}^k (\ln(N_i) - \ln(0.524(\hat{J}_i + \hat{A}_i)))^2$$
$$+ \frac{1}{2\sigma_{\ln P}^2} \sum_{i=1}^n (\ln(P_i) - \ln(0.323\hat{P}_i))^2$$
$$+ \frac{1}{2\sigma_J^2} \sum_{i=1}^m ((J/T)_i - (0.8\hat{J}_i / (\hat{J}_i + 0.21\hat{A}_i)))^2$$

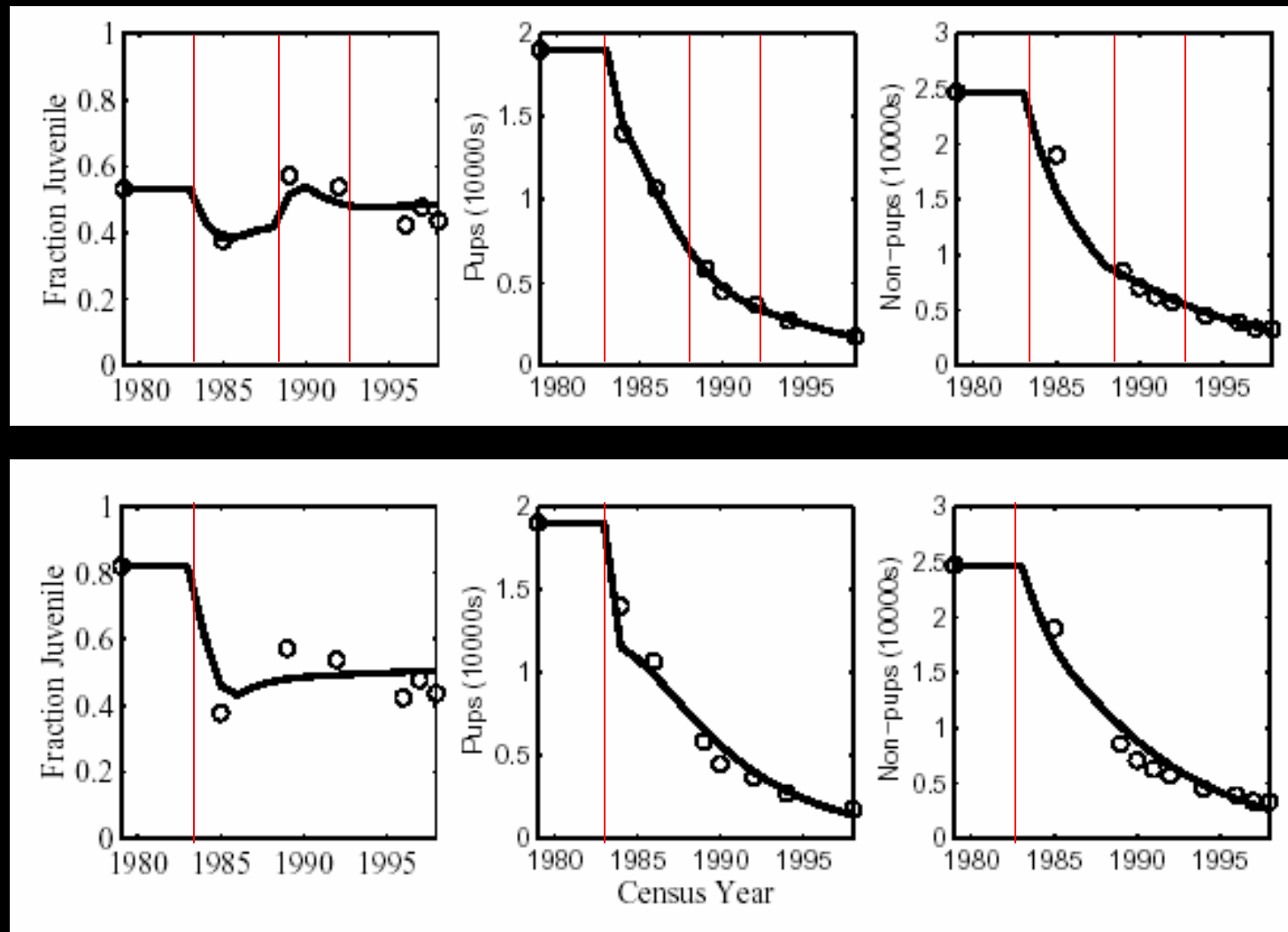
+ a constant

**Model**

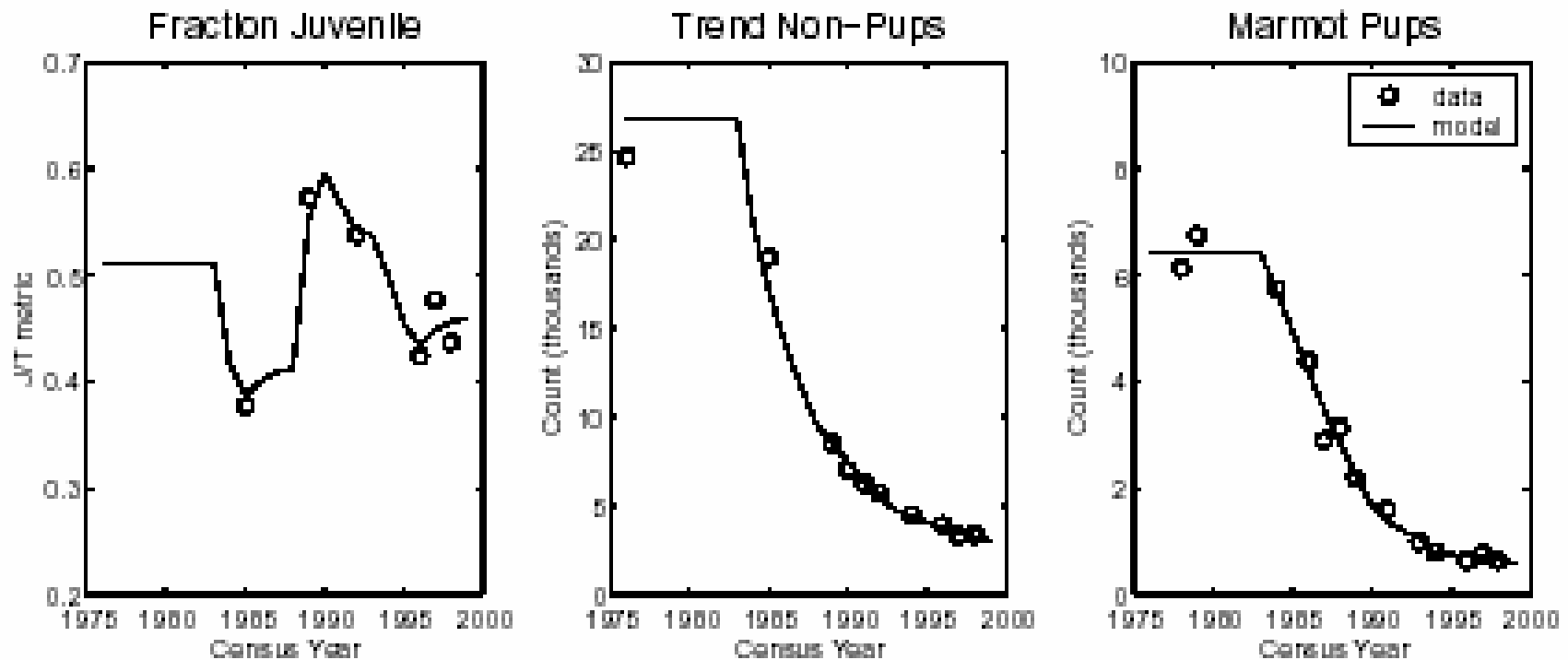
**Data**

**Relationship between the indices and true value**

# One change in demographic rates or multiple?

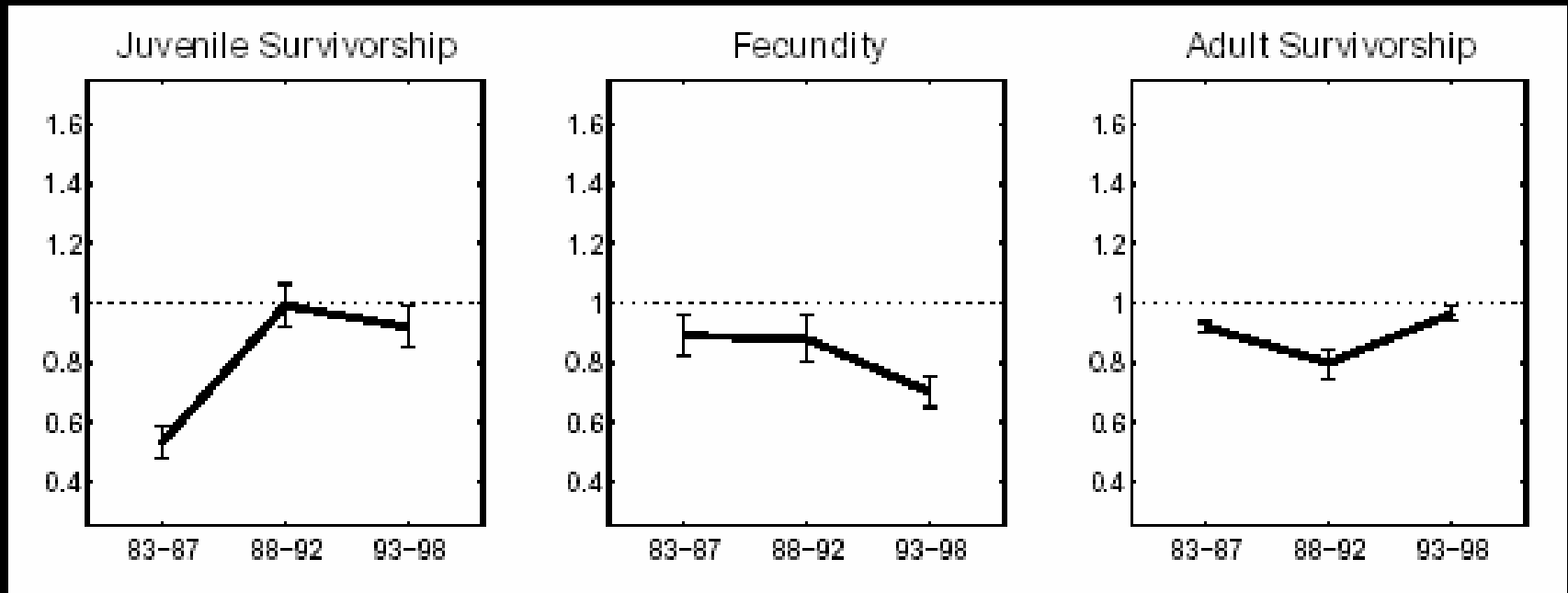


# Maximum likelihood fit of model with 3 temporal changes to data



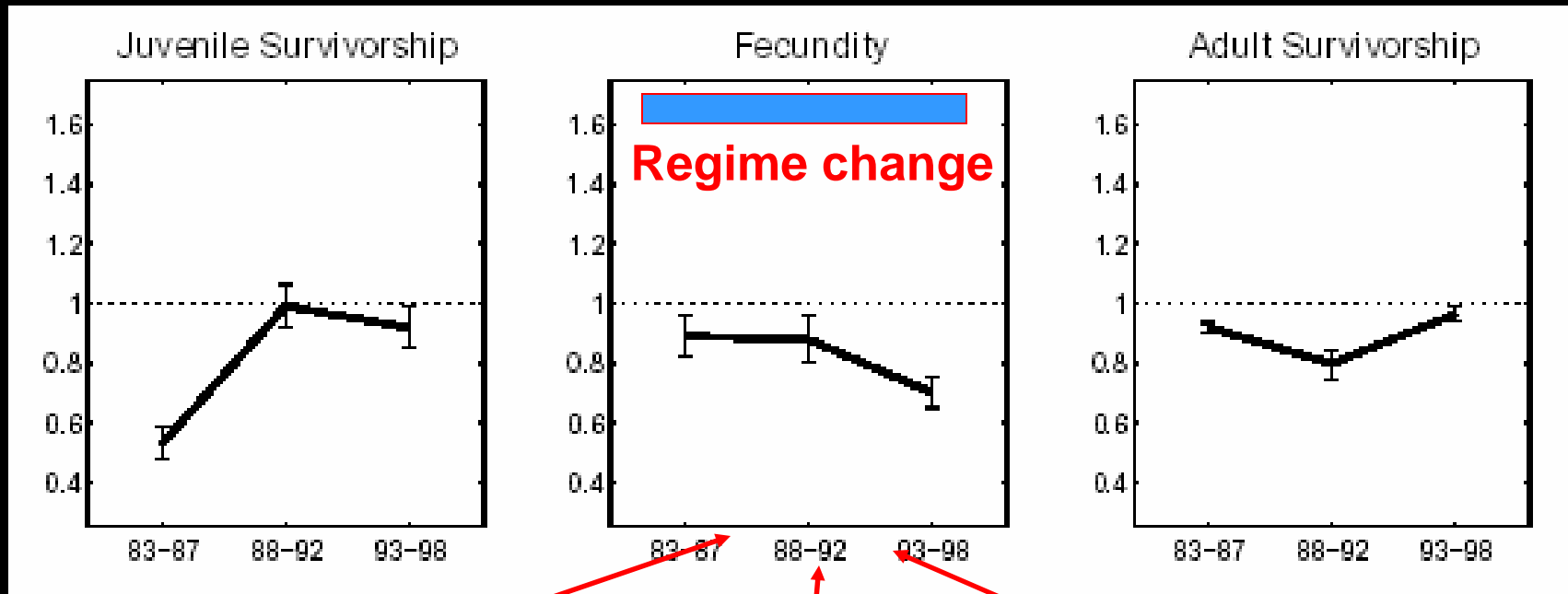
# Maximum likelihood estimates of the changes in demographic parameters

Relative to 1970s levels



# What explains these changes?

Relative to 1970s levels



Shooting of  
Sea lions curtailed

Buffer zones

No trawl zones



# Conclusions

- Early 1980's, juvenile survivorship collapsed leading to a population collapse
- Late 1980's juvenile survivorship recovers
- Fecundity has been gradually eroding since the early 1980s
- Adult survivorship appears to have recovered to near pre-collapse levels

# Age-structure information improves the ability to make inferences about demographic changes

Relative to 1970s levels

