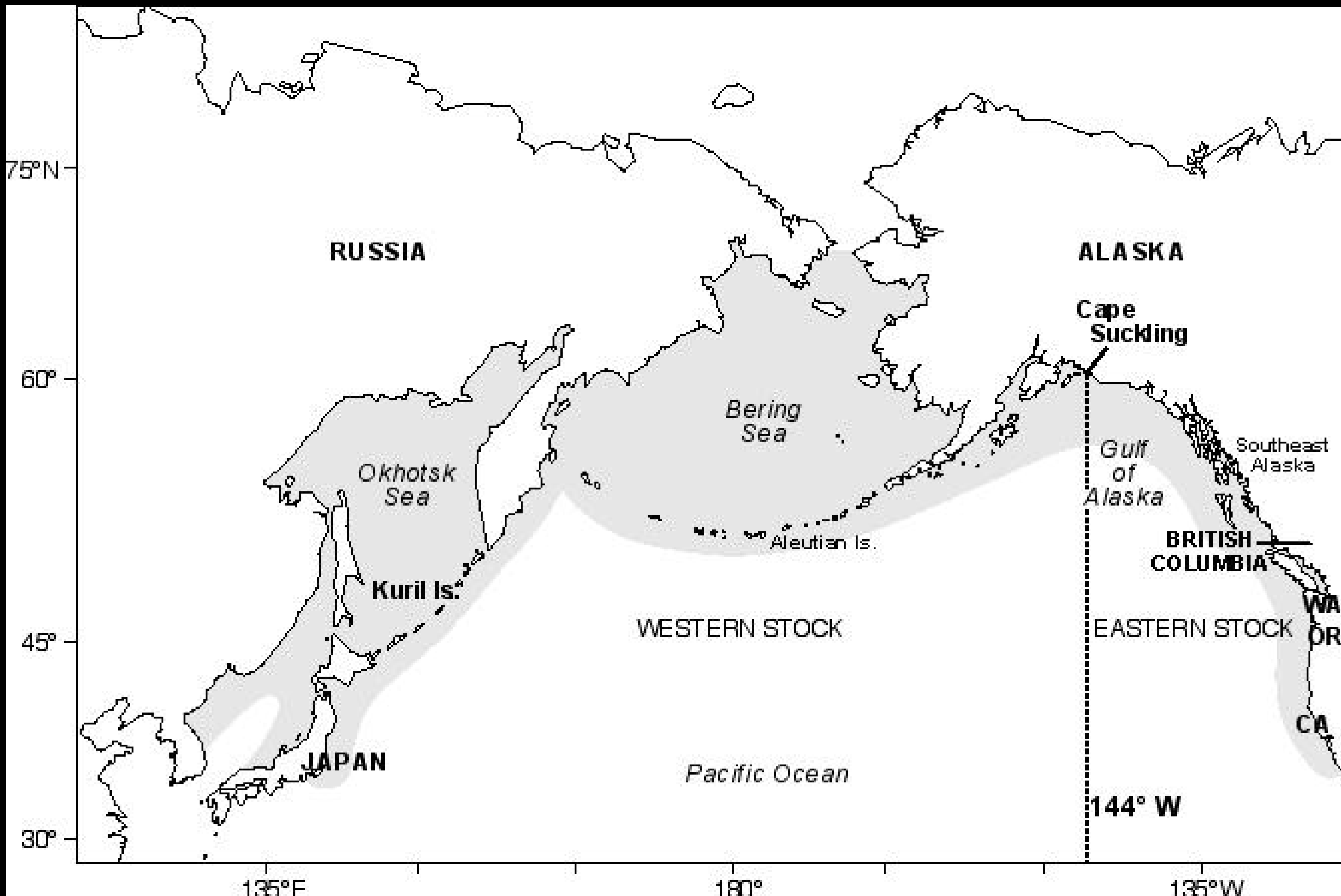
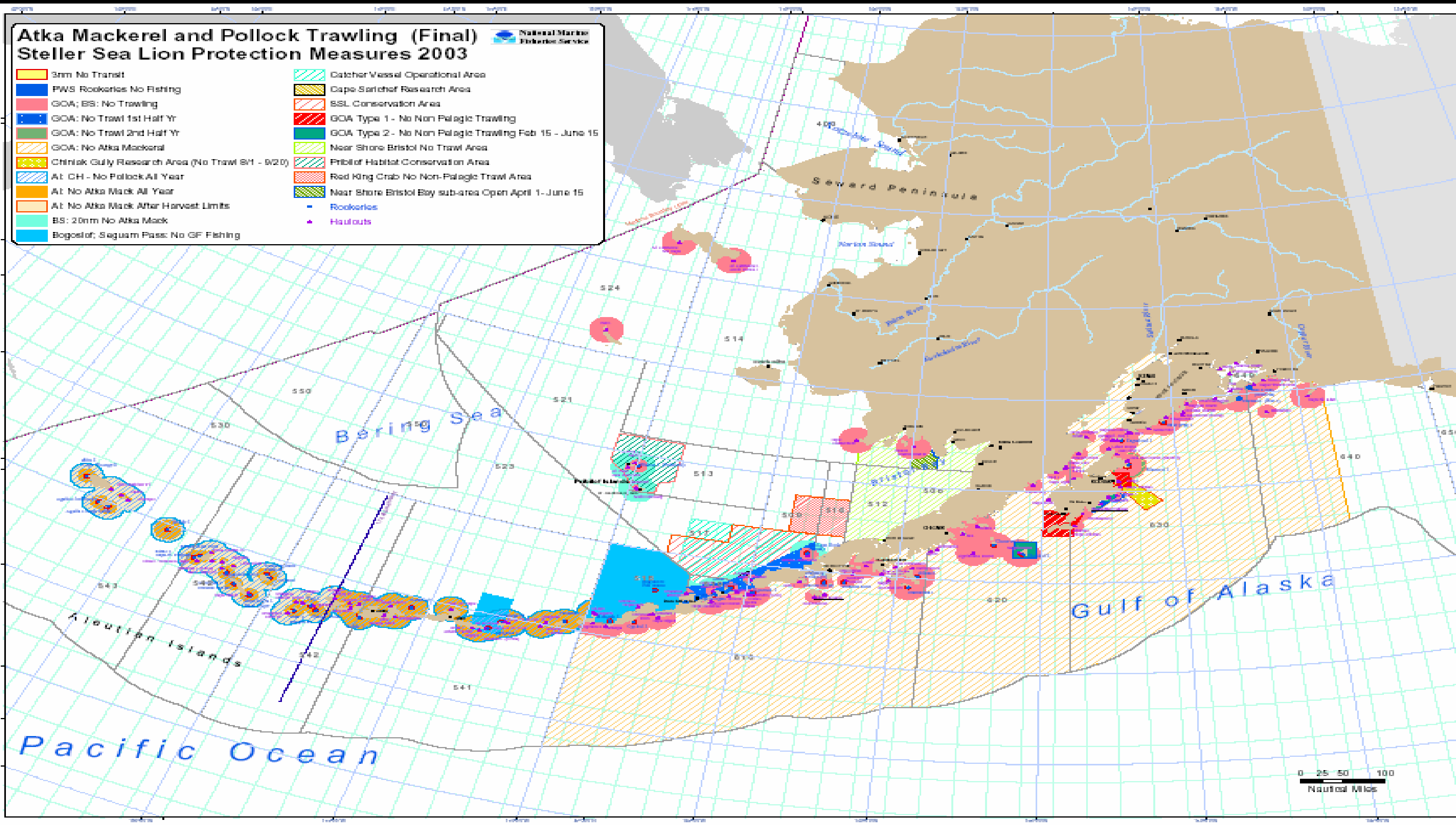
Detecting effects of management on long-lived species


RUSSIA
ALASKA
Cape Suckling
Bering Sea
Okhotsk Sea
Gulf of Alaska
Southeast Alaska
Aleutian Is.
BRITISH COLUMBIA
Kuril Is.
WESTERN STOCK
EASTERN STOCK
WA
OR
CA
JAPAN
Pacific Ocean
144° W
75°N
60°
45°
30°
135°E
180°
135°W

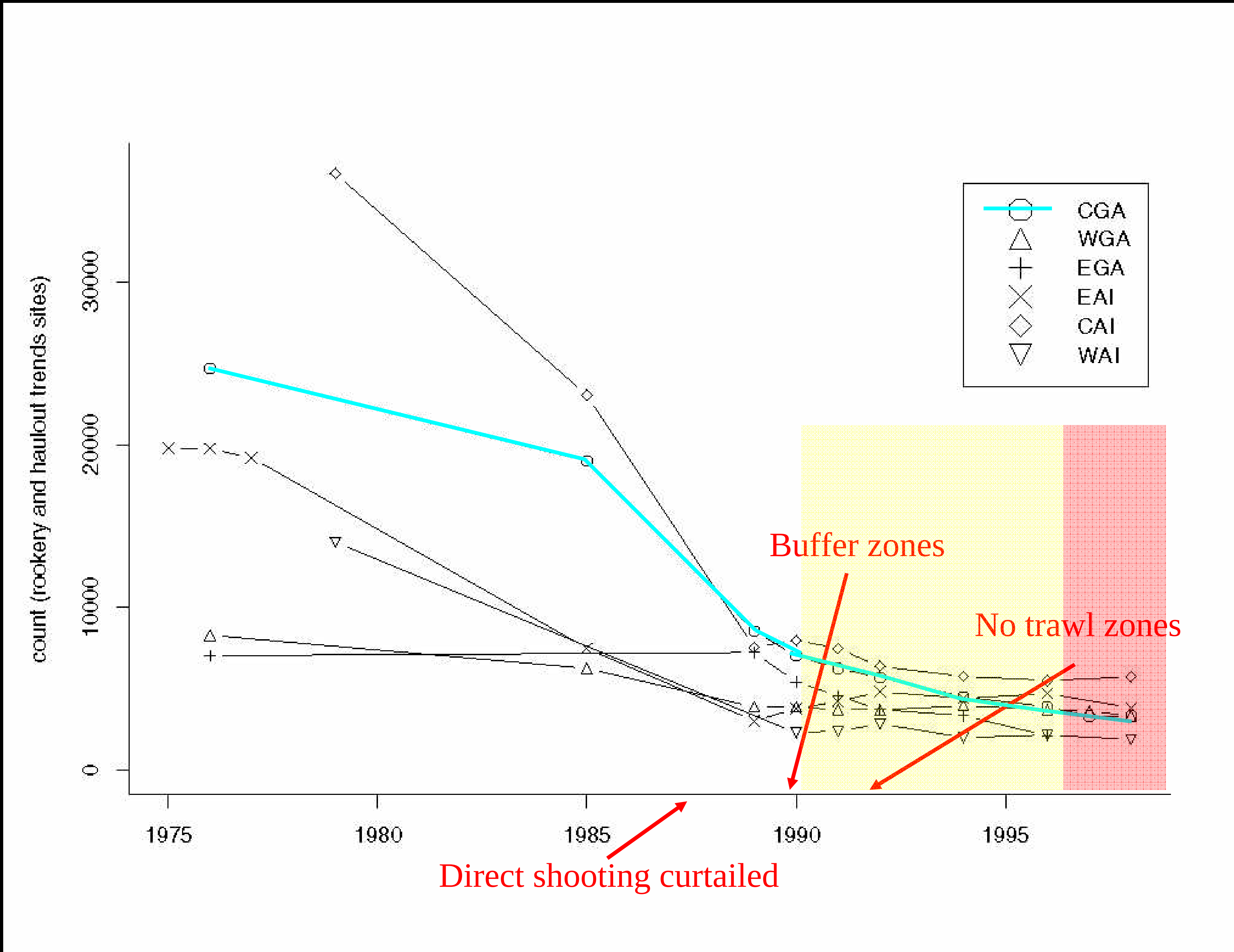
1969

1979

1986



Atka Mackerel and Pollock Trawling (Final)
Steller Sea Lion Protection Measures 2003
National Marine Fisheries Service
3nm No Transit
PWS Rookeries No Fishing
GOA; BS: No Trawling
GOA: No Trawl 1st Half Yr
GOA: No Trawl 2nd Half Yr
GOA: No Atka Mackeral
Chiniak Gully Research Area (No Trawl 8/1 - 9/20)
AI: CH - No Pollock All Year
AI: No Atka Mack All Year
AI: No Atka Mack After Harvest Limits
BS: 20nm No Atka Mack
Bogoslof; Seguam Pass: No GF Fishing
Catcher Vessel Operational Area
Cape Sarichef Research Area
SSL Conservation Area
GOA Type 1 - No Non Pelagic Trawling
GOA Type 2 - No Non Pelagic Trawling Feb 15 - June 15
Near Shore Bristol No Trawl Area
Pribilof Habitat Conservation Area
Red King Crab No Non-Pelagic Trawl Area
Near Shore Bristol Bay sub-area Open April 1-June 15
Rookeries
Haulouts
Seward Peninsula
Bering Sea
Pribilof Islands
Bristol Bay
Gulf of Alaska
Aleutian Islands
Pacific Ocean
0 25 50 100
Nautical Miles



count (rookery and haulout trends sites)
0
10000
20000
30000
1975
1980
1985
1990
1995
CGA
WGA
EGA
EAI
CAI
WAI
Buffer zones
No trawl zones
Direct shooting curtailed

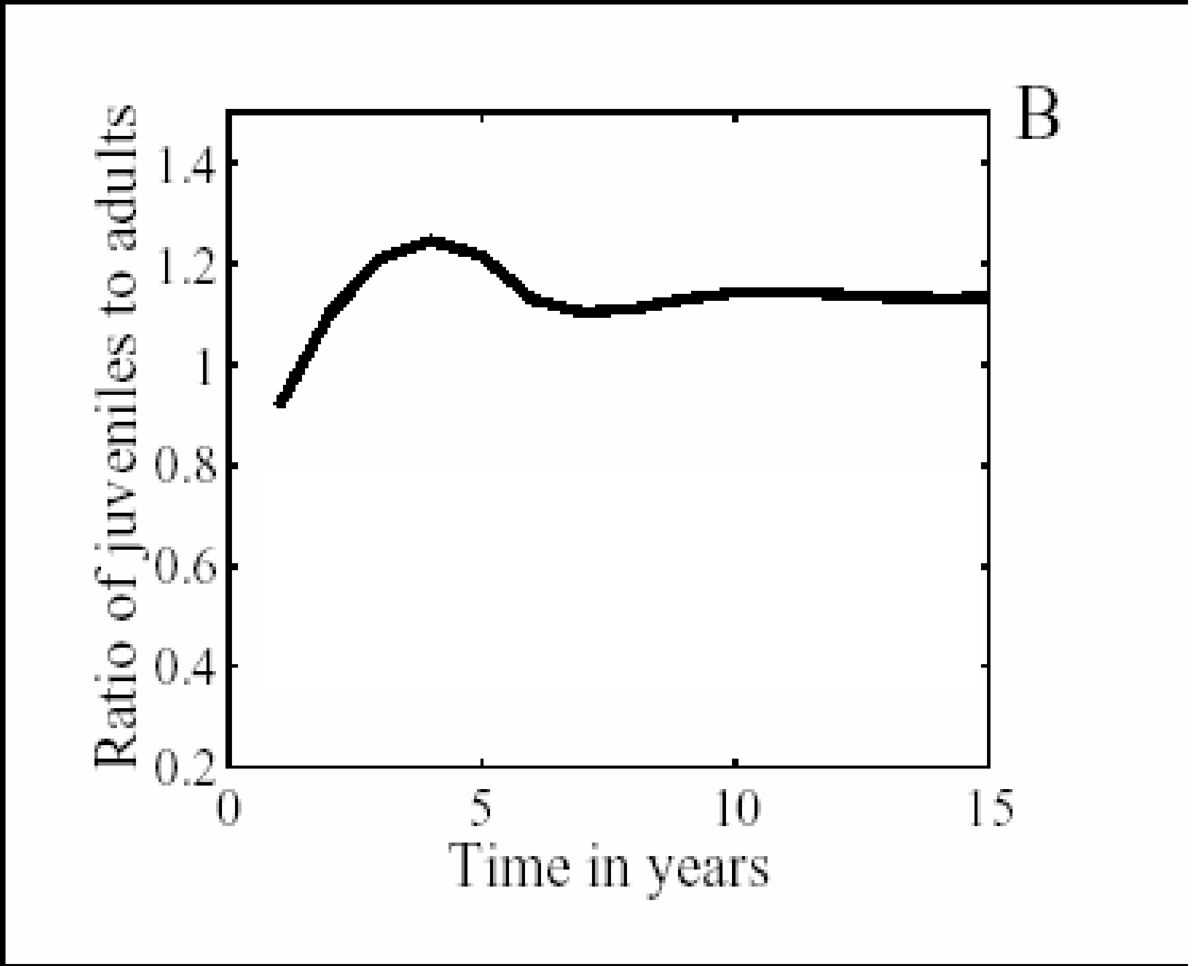
- **Challenge:** The slow response of population size to small survivorship and fecundity improvements prevents rapid detection of the effects of management actions.
- **Solution?** Age-structure shifts?

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†	….	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	…‡	0	…	0
0	0	0	0	0	0	…	…	0

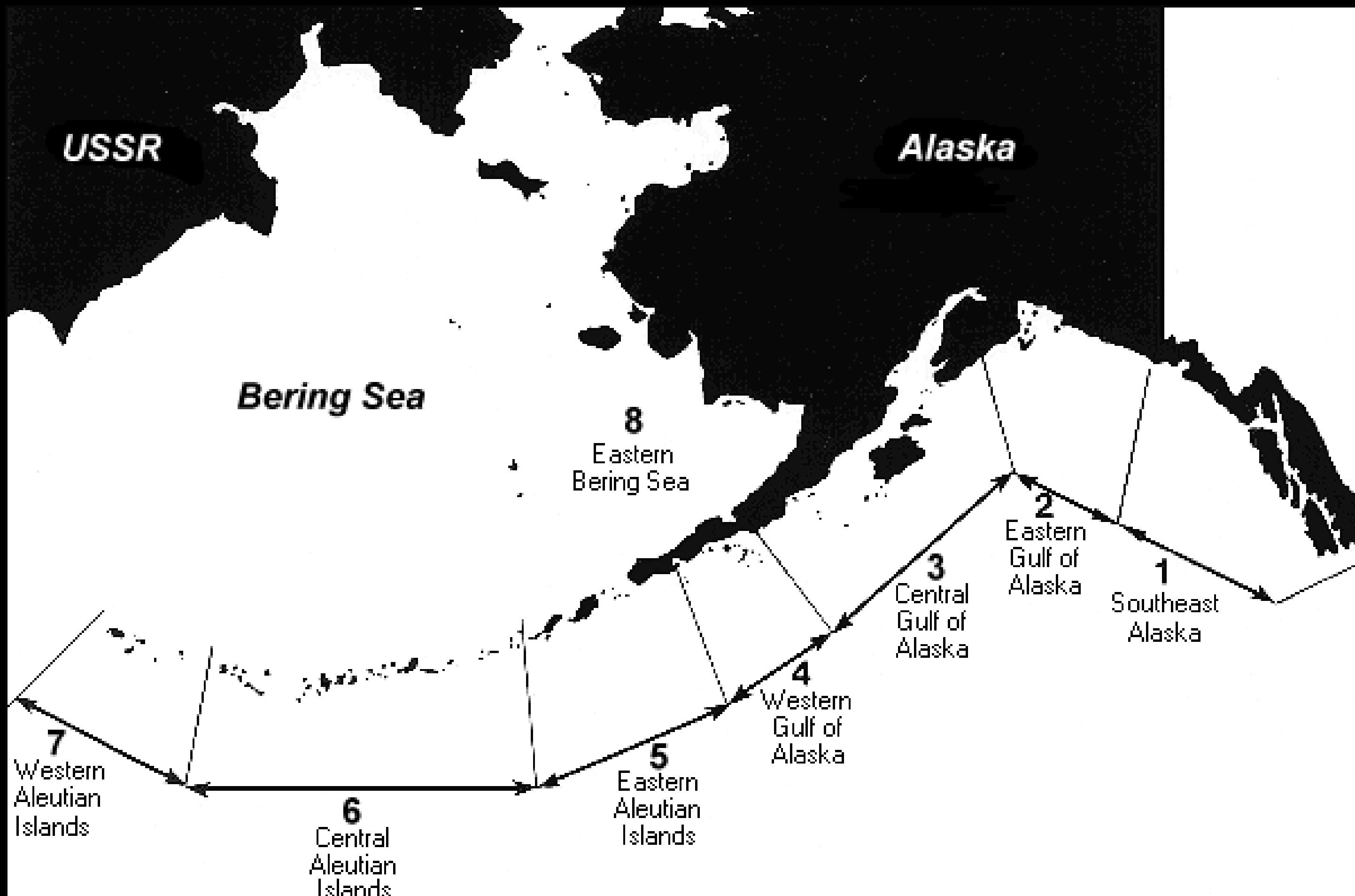
Changes in ratios of juveniles to adults after a 20% increase in juvenile survival

- Most extreme values occur 4-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**


USSR
Alaska
Bering Sea
8
Eastern
Bering Sea
1
Southeast
Alaska
2
Eastern
Gulf of
Alaska
3
Central
Gulf of
Alaska
4
Western
Gulf of
Alaska
5
Eastern
Aleutian
Islands
6
Central
Aleutian
Islands
7
Western
Aleutian
Islands

The data

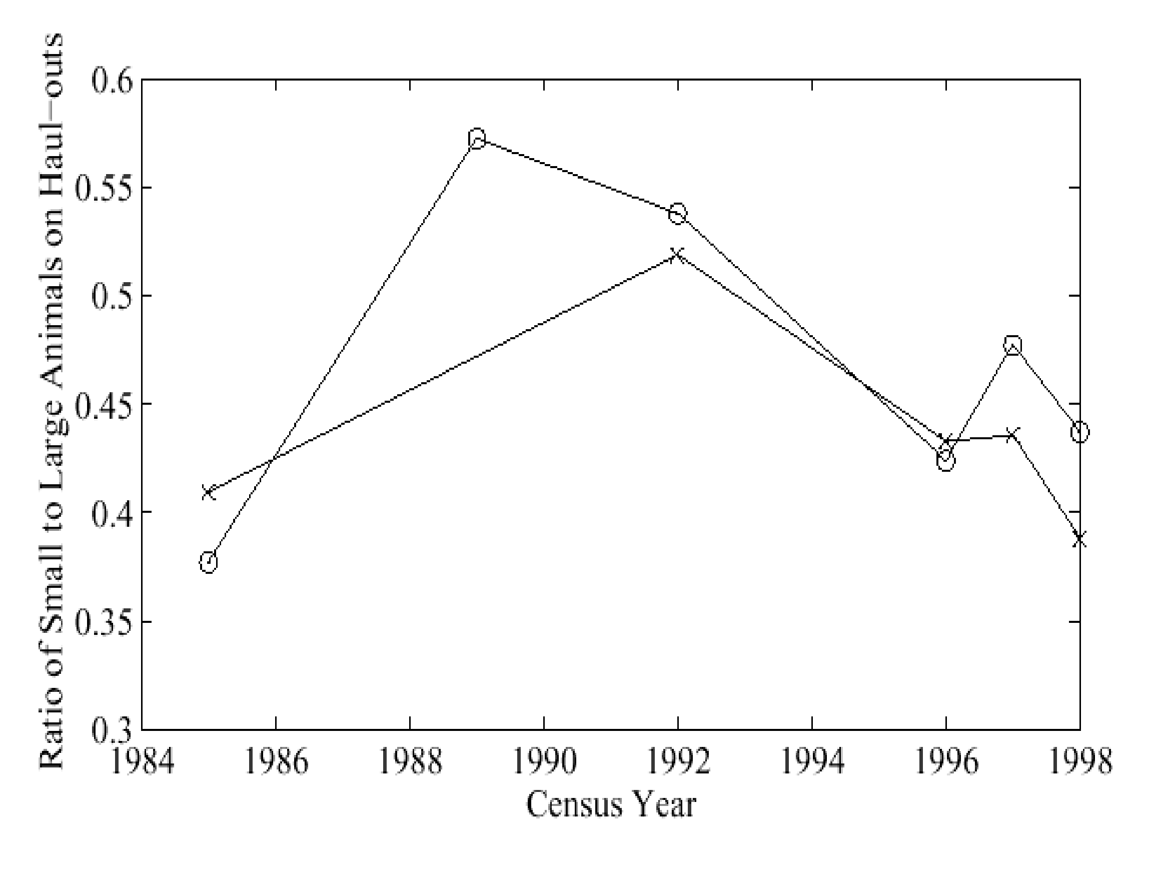
Measurements

Results

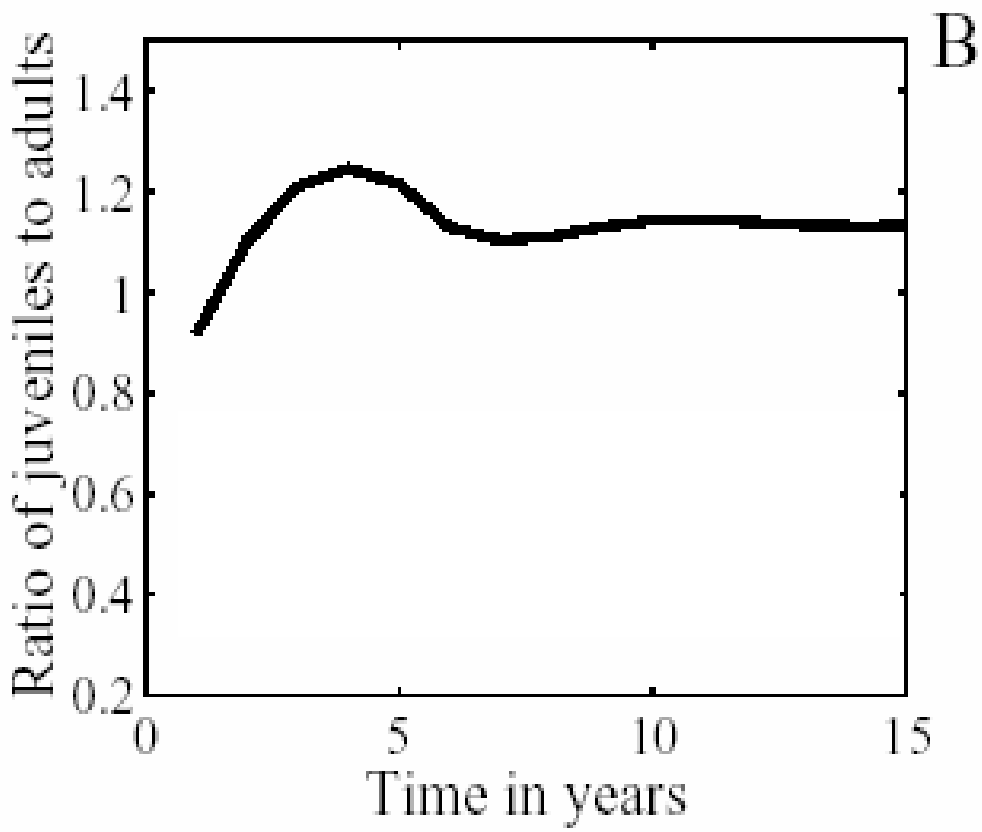
- 35 Haul-out locations in the Central Gulf of Alaska
- 6 census years: 1985-1998
- 25,322 individual measurements

Historical changes in the ratio of small to large animals

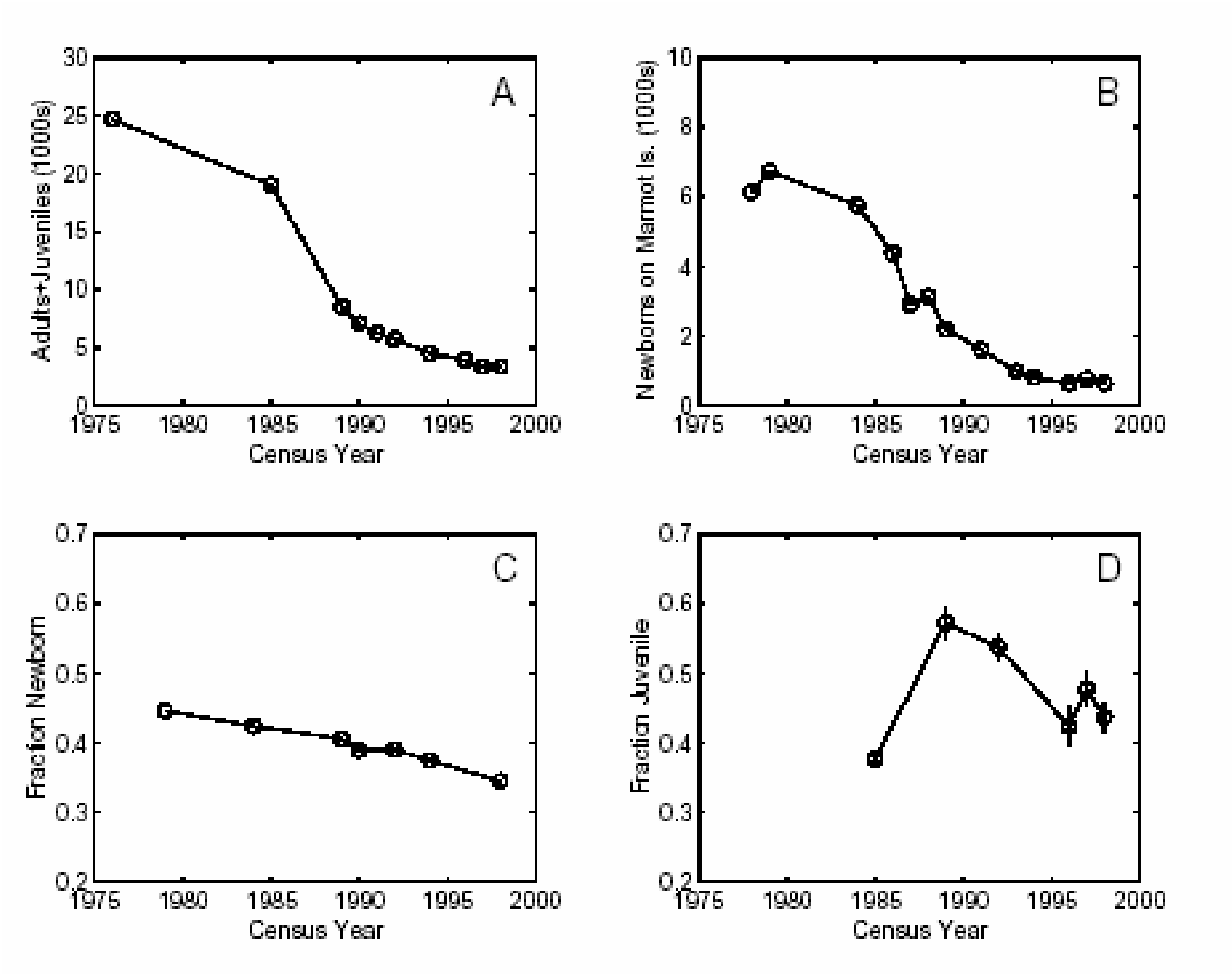
- Between 1985 and 1989, the metric doubles and then declines
- Similar to the transitory spikes predicted after an improvement in juvenile survivorship.



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

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

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

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

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

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

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

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

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

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

9 free parameters

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

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

$$+ \frac{1}{2\sigma^2_{\ln P}} \sum_{i=1}^{n} (\ln(P_i) - \ln(0.323\hat{P}_i))^2$$

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

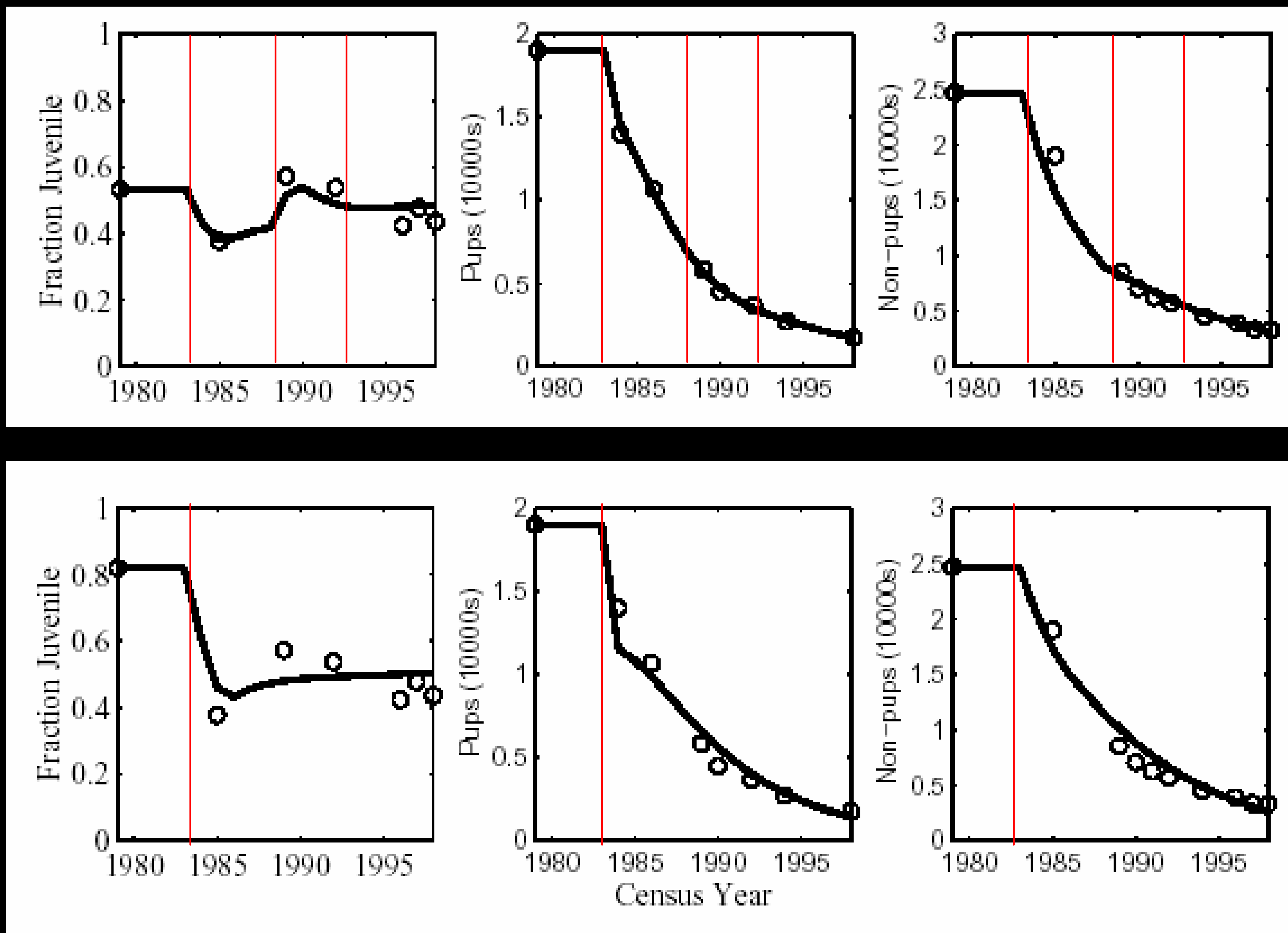
$$+ \text{a constant}$$

Model

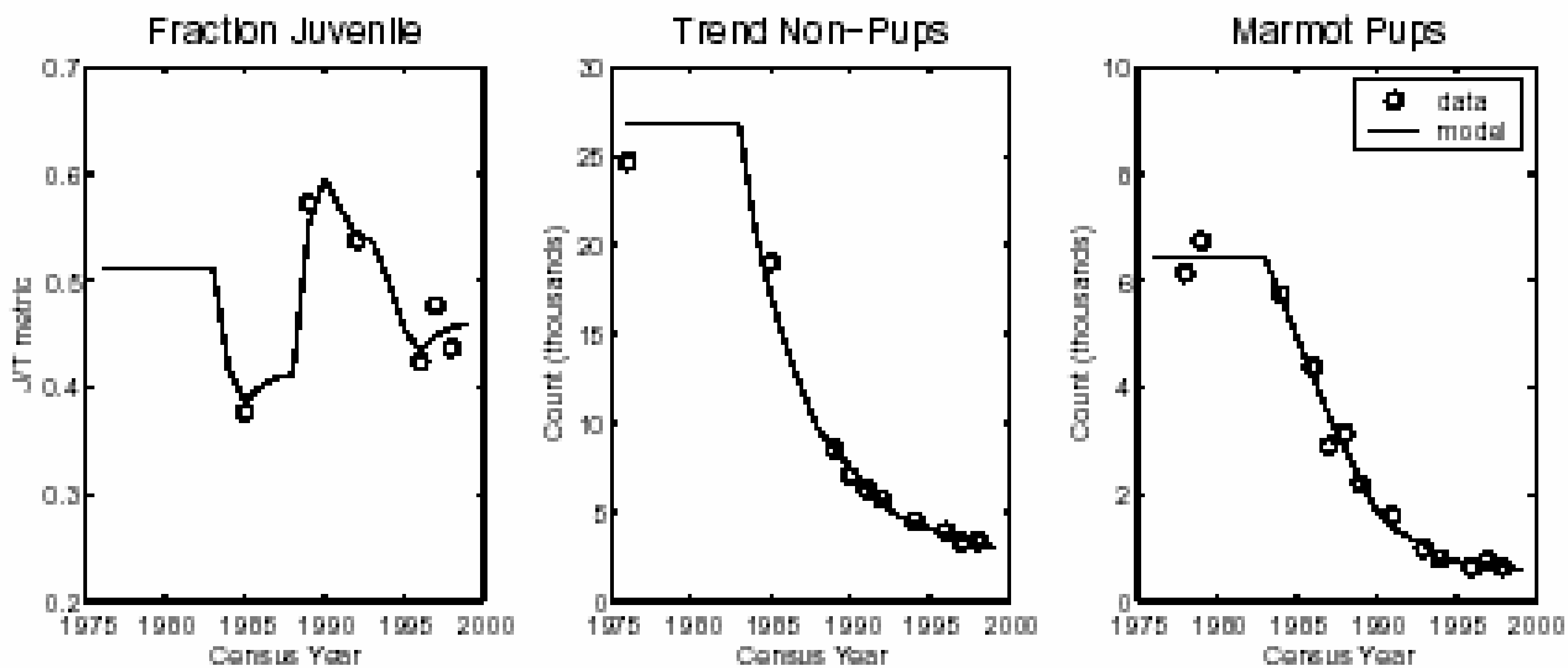
Data

Relationship between the indices and true value

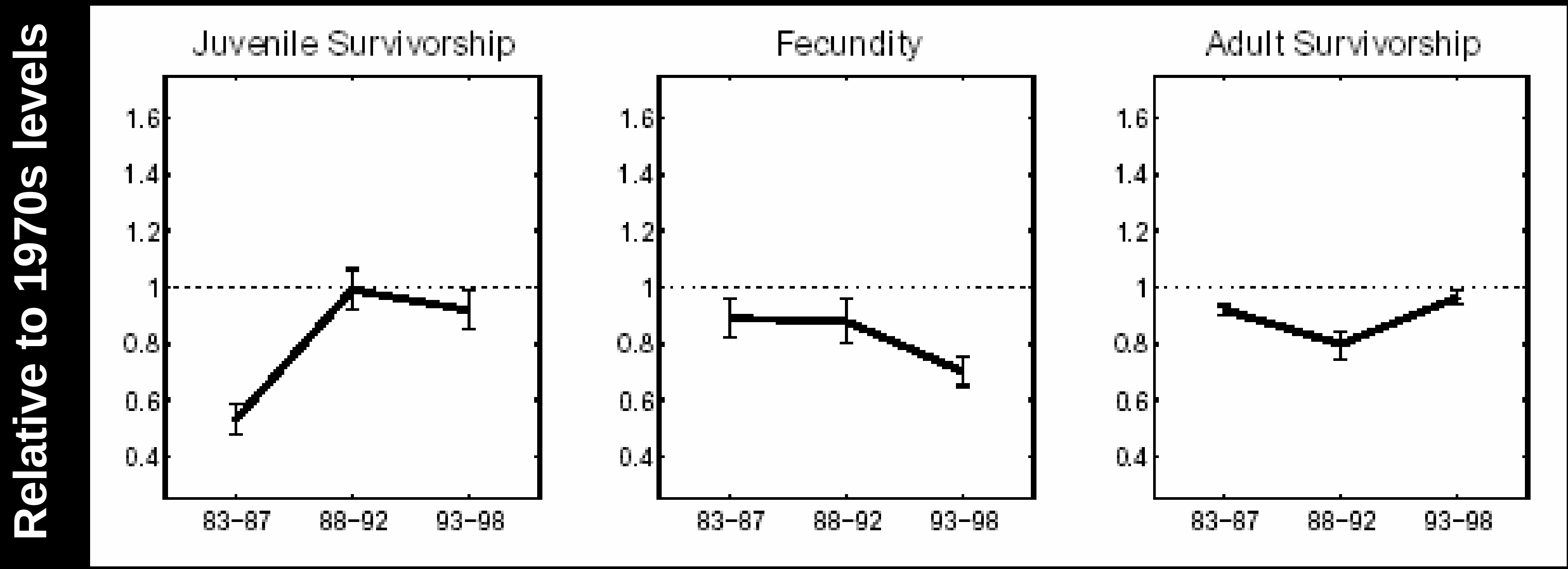
One change in demographic rates or multiple?



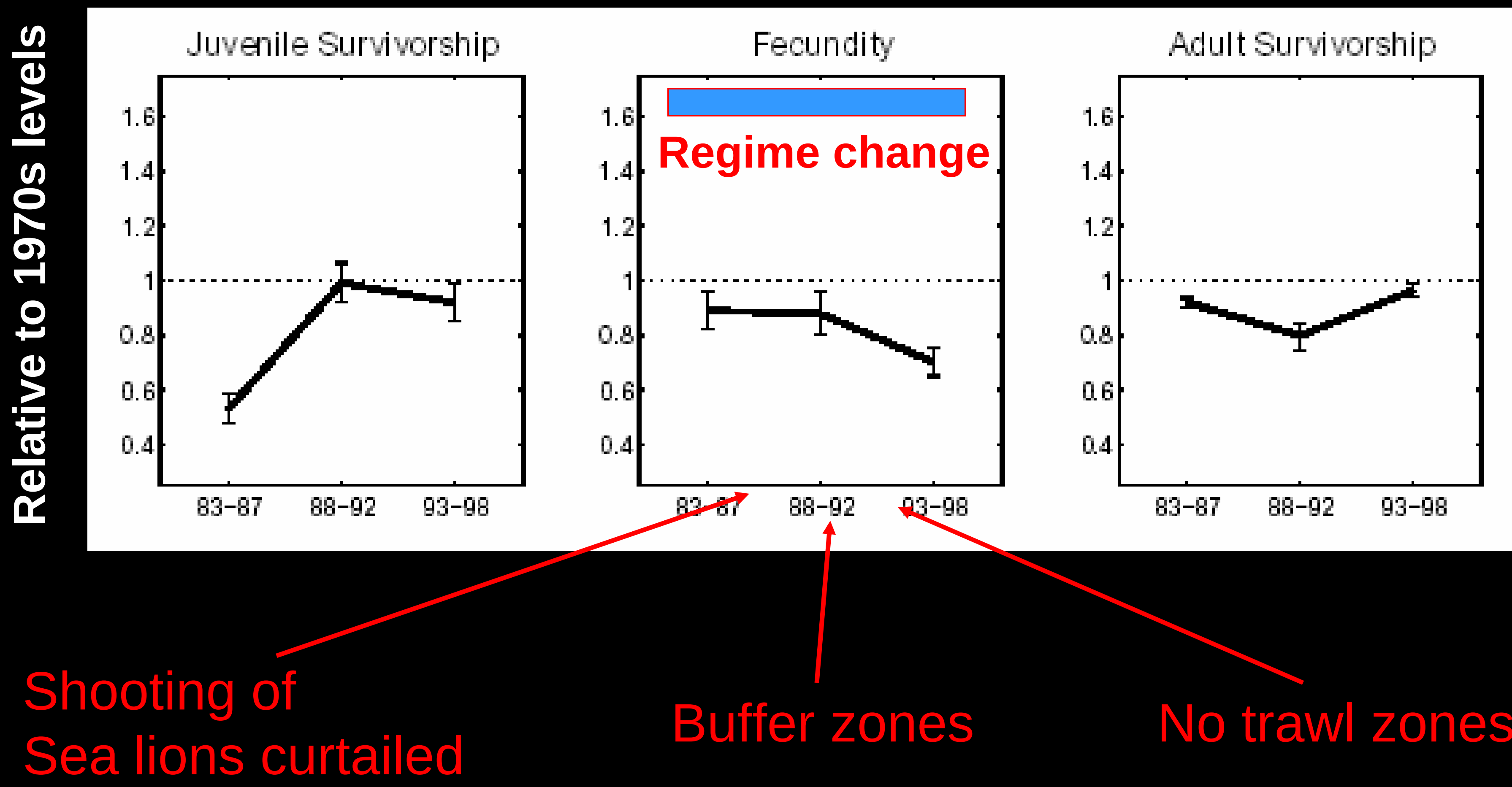
Maximum likelihood fit of model with 3 temporal changes to data



Maximum likelihood estimates of the changes in demographic parameters



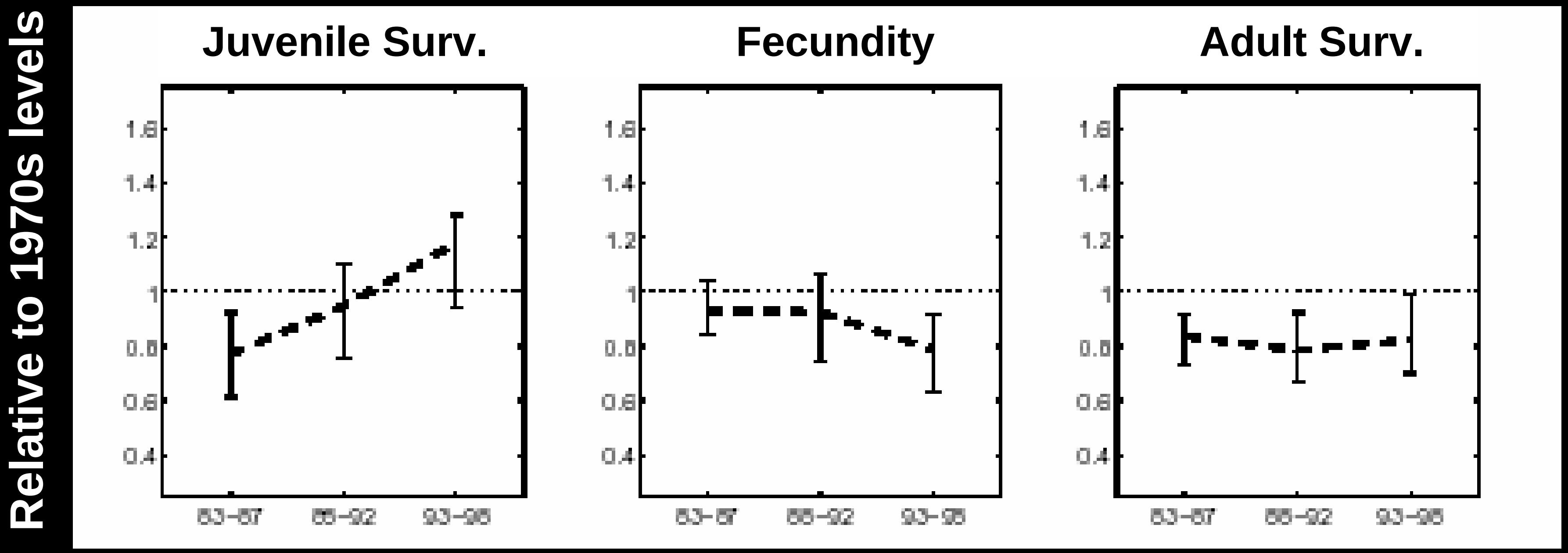
What explains these changes?

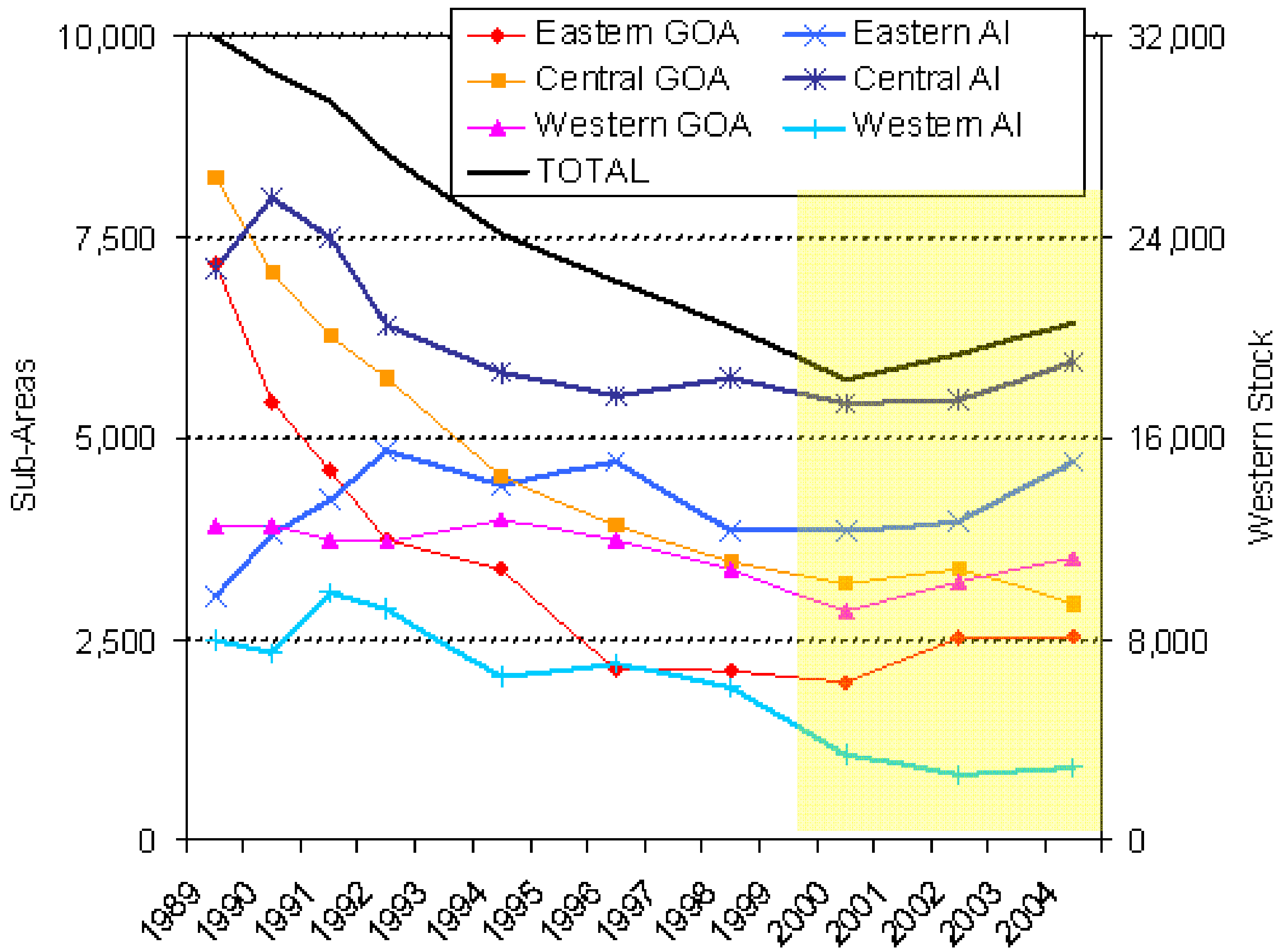


Conclusions

- 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




Eastern GOA
Central GOA
Western GOA
TOTAL
Eastern AI
Central AI
Western AI
10,000
7,500
5,000
2,500
0
Sub-Areas
32,000
24,000
16,000
8,000
0
Western Stock
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004