Detecting effects of management on long-lived species
Direct shooting curtailed

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

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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
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 \( 1982 \),
\[
\hat{N}_{t+1} = Y_{76} \cdot \hat{N}_t
\]

For \( t = 1983 \) to \( 1987 \),
\[
\hat{N}_{t+1} = Y_{83} \cdot \hat{N}_t
\]

For \( t = 1988 \) to \( 1992 \),
\[
\hat{N}_{t+1} = Y_{88} \cdot \hat{N}_t
\]

For \( t = 1993 \) to \( 1998 \),
\[
\hat{N}_{t+1} = Y_{93} \cdot \hat{N}_t
\]

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

9 free parameters
Distance between the model and the data: negative log-likelihood

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

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

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

+ 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

Regime change

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.