



Interactions in a multispecies age-structured assessment model for the Gulf of Alaska

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Fisheries Modeling

The application of mathematical models to fish populations is an effort to explain observed data through the mapping of unobservable processes

Predation

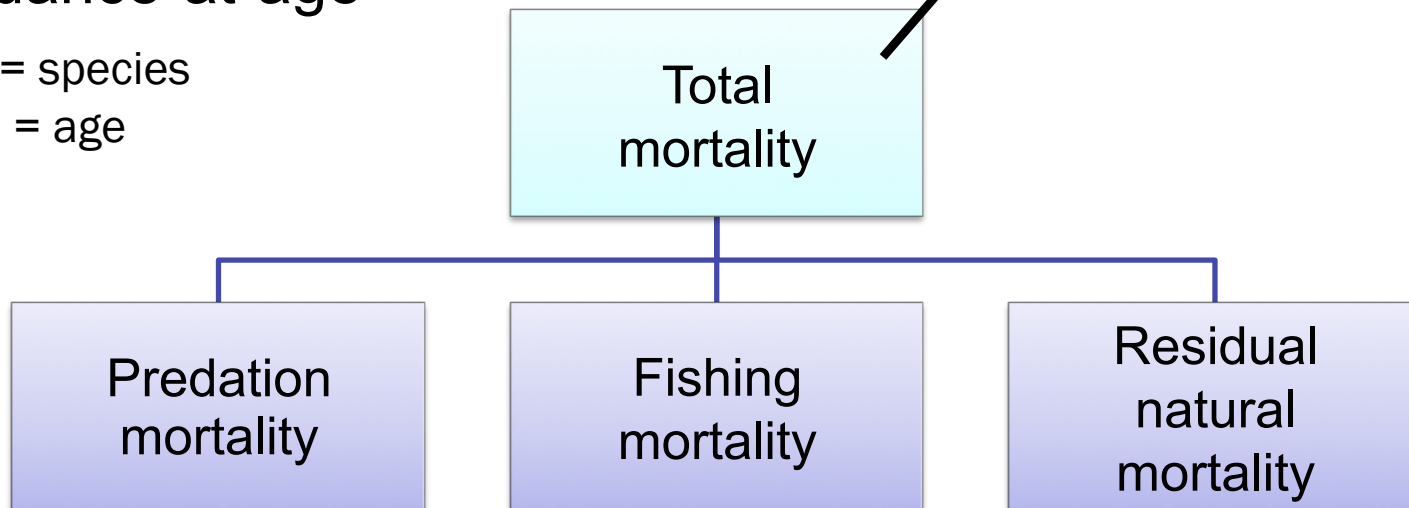


Multispecies Age-Structured Assessment (MSASA)

$$N_{i,a+1,t+1} = N_{i,a,t} e^{-Z_{i,a,t}}$$

Abundance-at-age

i = species
 a = age





Modeling predation

$$\rho_{i,j}$$

Species-
preference

Proportion of annual food of
predator species j , age b that
is of prey species i , age a

$$\exp\left[-\frac{1}{2\sigma_{i,j}^2}\left(\ln\frac{w_{j,b}}{w_{i,a}} - \eta_{i,j}\right)^2\right]$$

Size-
preference

$$B_{i,a,t}$$

Prey
biomass

$$\frac{\phi_{i,a,j,b,t}}{\phi_{j,b,t}}$$

i = prey
 j = predator
 a = prey age
 b = predator age



Modeling predation

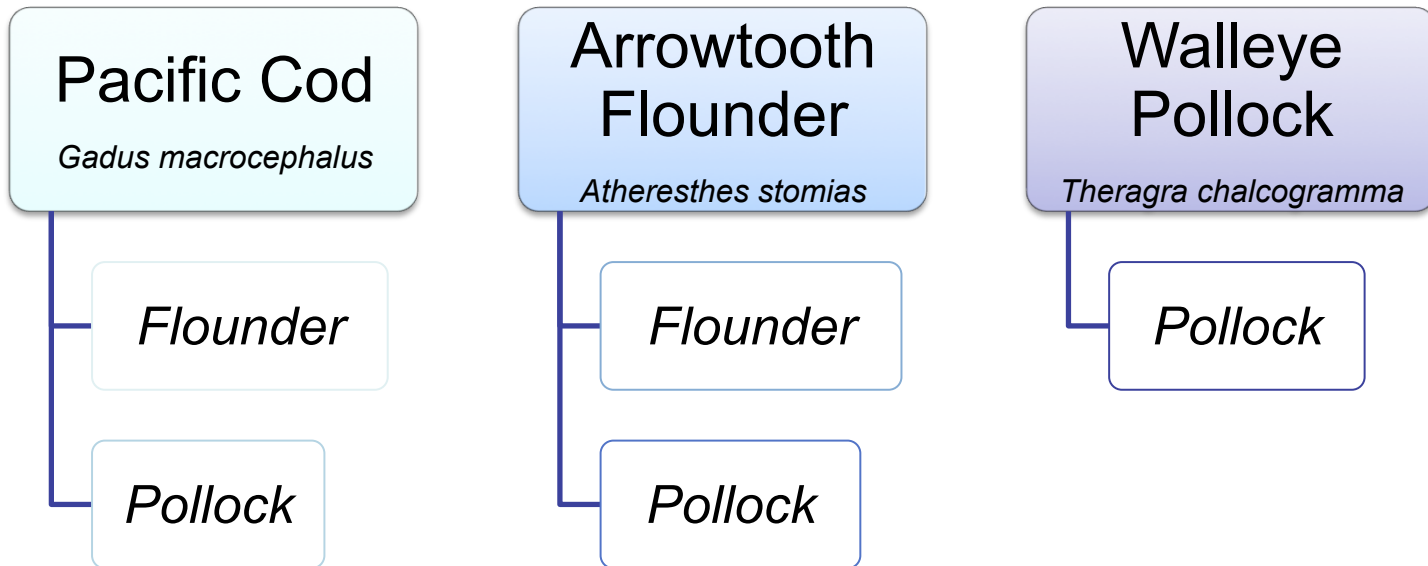
$$P_{i,a,t} = \frac{1}{B_{i,a,t}} \sum_j \sum_b I_{j,b} N_{j,b,t} \frac{\phi_{i,a,j,b,t}}{\phi_{j,b,t}}$$

Prey biomass Annual predator ration Predator abundance Stomach proportions

Predation is estimated as the ratio of biomass consumed relative to the total biomass of prey i,a



Three species with predator-prey links:





Multispecies Age-Structured Assessment

Simplifying assumptions of temporal invariance:

- Length/weight-at-age
 - Gear selectivity
 - Survey catchability (set to 1)
 - Annual predator ingestion rate
(input from bioenergetics work)
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Objective Function Components

Data from the Alaska Fisheries Science Center stock assessments and research programs

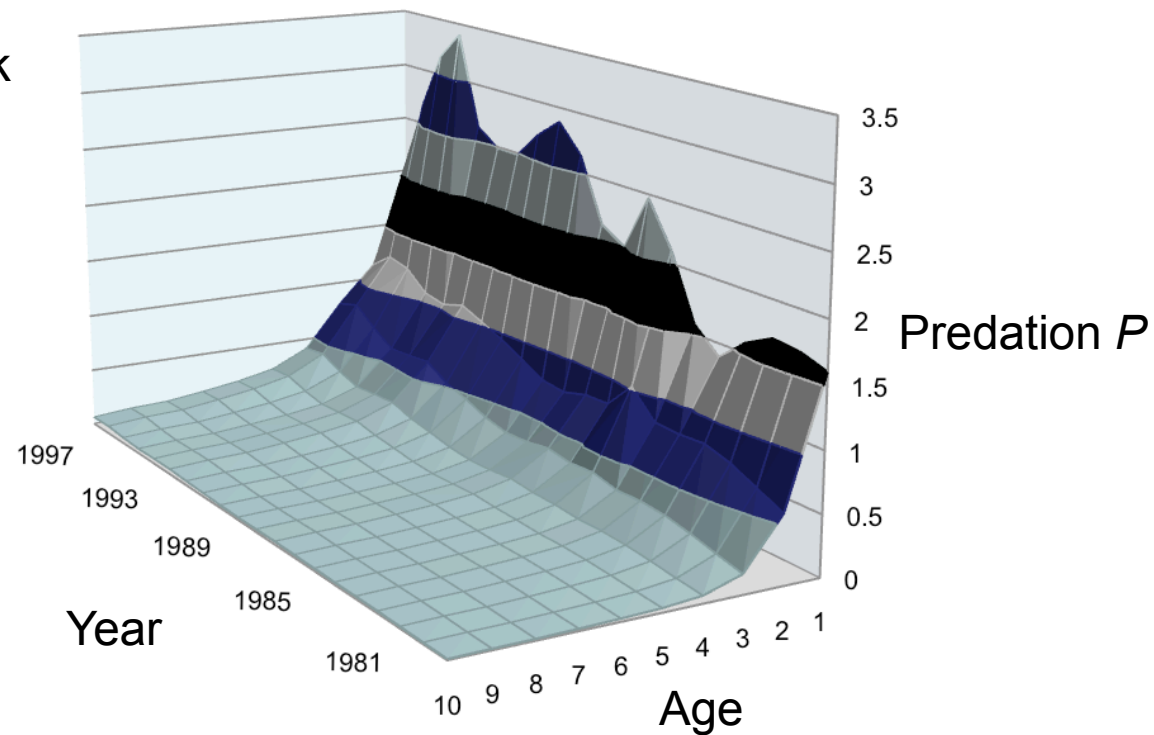
- Catch-at-age (*except flounder*)
 - Survey-at-age
 - Total annual catch
 - Total annual survey biomass
 - Stomach-contents
-



Results

- Model outputs matched AFSC indices of catch and survey; predation reasonable

Predation on pollock





Model expansion

- Add Pacific Halibut (*Hippoglossus stenolepis*)
 - Add Steller Sea Lion (*Eumetopias jubatus*)
 - Input as external predators – abundance not estimated
 - Major predator profile for walleye pollock
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Pacific Halibut

- Drastic changes in growth over time:
use distinct weights-at-age for each year
 - Distinct weights-at-age = distinct annual ingestion
 - Ages 8 – 20+
 - Pollock predator
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Steller Sea Lion

- No estimates of abundance-at-age
 - Aerial survey values distributed following life tables and estimated survival rates
 - Ingestion rates from bioenergetic studies
 - Ages 1 – 13+
 - Males, females, nursing females
 - Pup ingestion needs assimilated into nursing parent
 - Schedules of reproductive maturity used to establish number of nursing females per year
 - Predators of pollock, cod, and flounder
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Sea lion stomach-content matrix

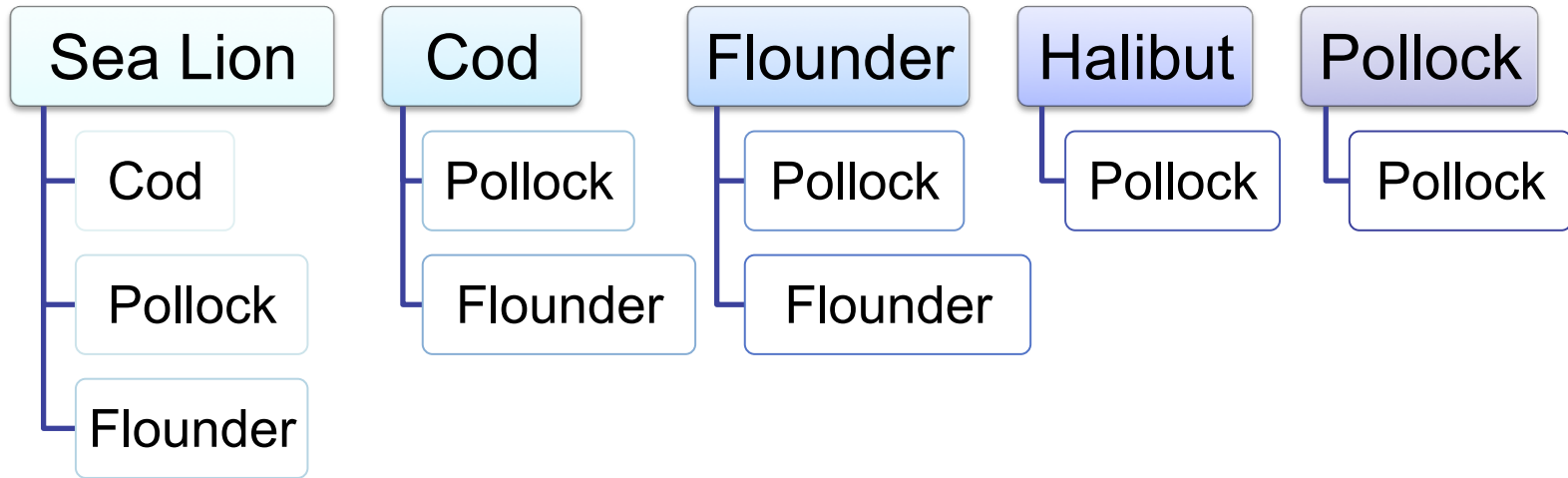
Set minimums:

- Pollock > 0.3 of total stomach weight
- Pacific Cod > 0.2 of total stomach weight
- Flounder > 0.05 of total stomach weight

Objective function assigns penalty for values below these minimums. If greater than these values, no penalty or addition to total OF score.



Expanded Model





Initial Results

Pollock unable to sustain increased predation

- Open residual natural mortality to estimation
- New bounds for size / species-preference parameters

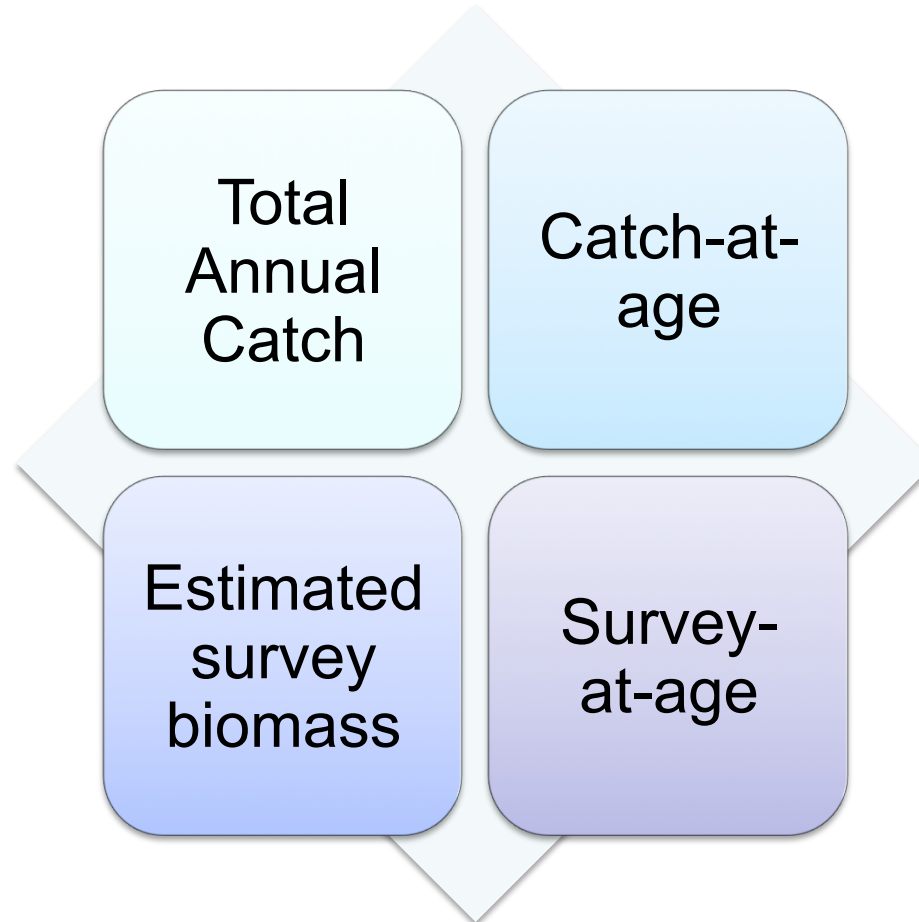
Flounder: 0.247 (bounded)

Cod: 0.362

Pollock: 0.05 (bounded)



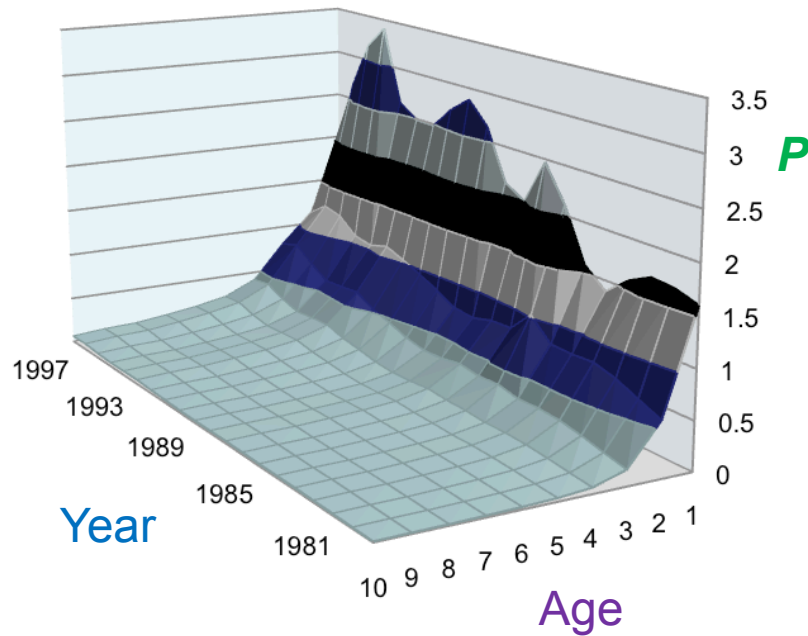
Expanded Model Results



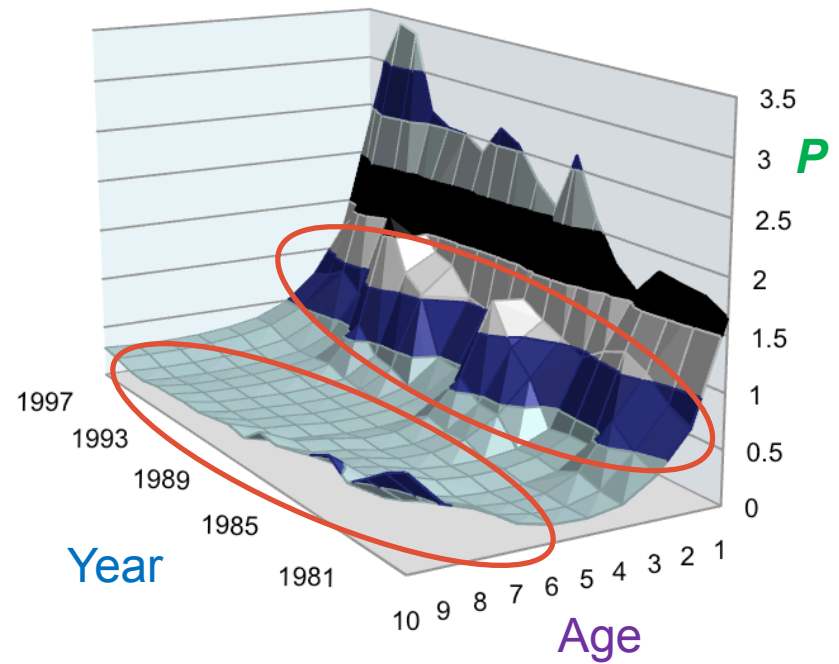


Expanded Model Results

Predation mortality on pollock



Core Model

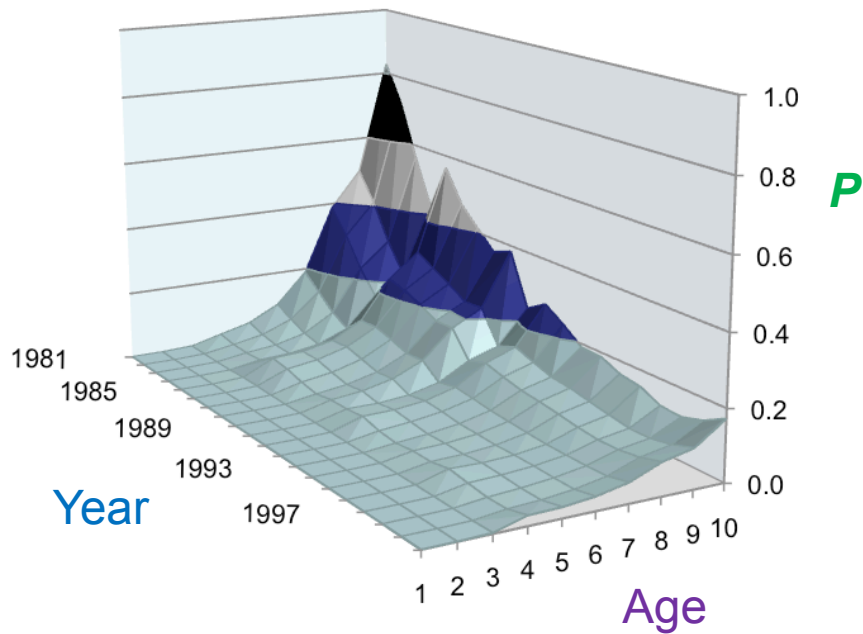


Expanded Model

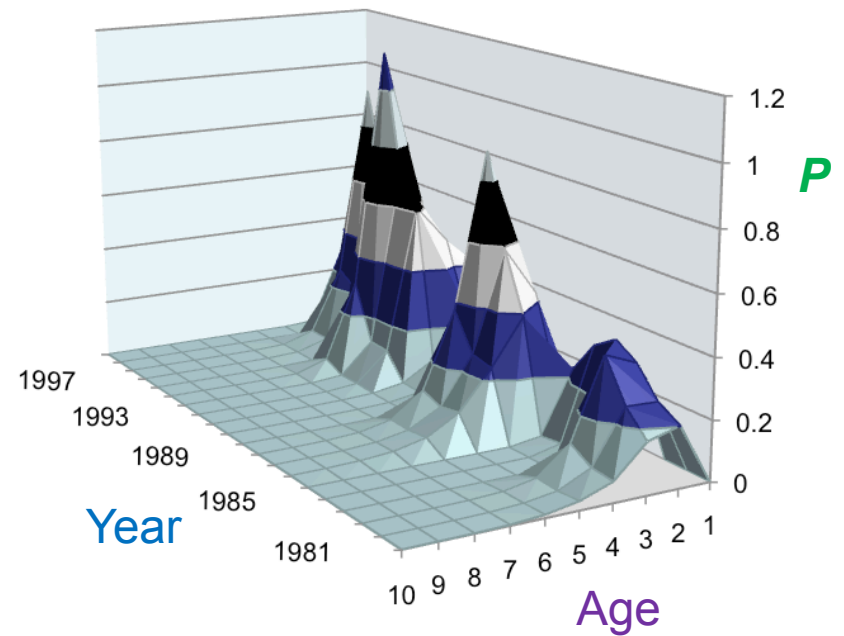


Expanded Model Results

Predation mortality on pollock



Sea Lion

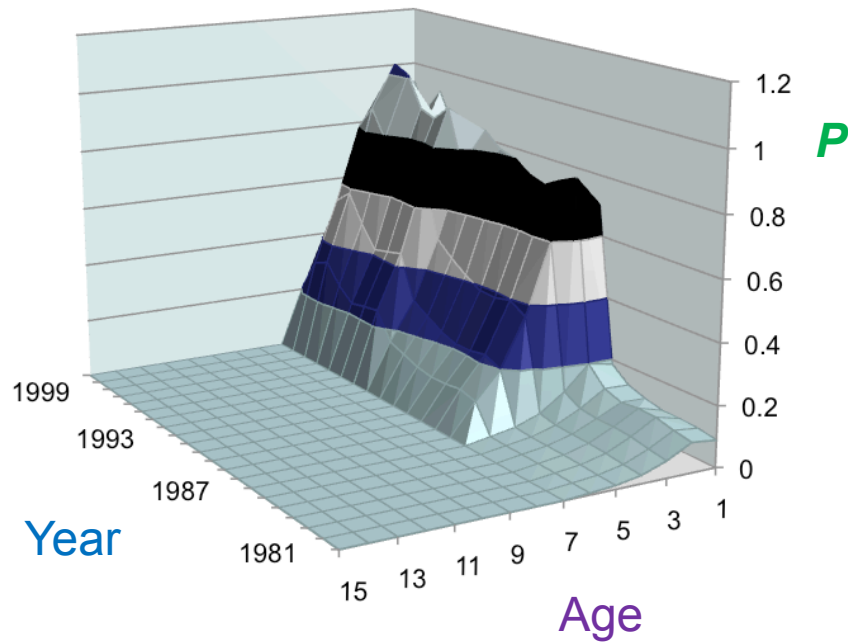


Halibut

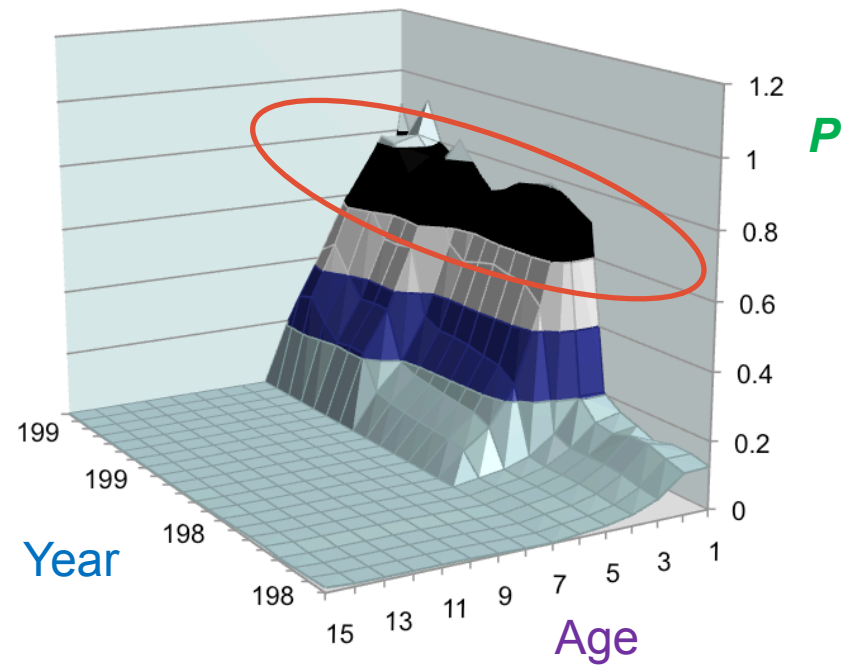


Expanded Model Results

Predation mortality on flounder



Core Model

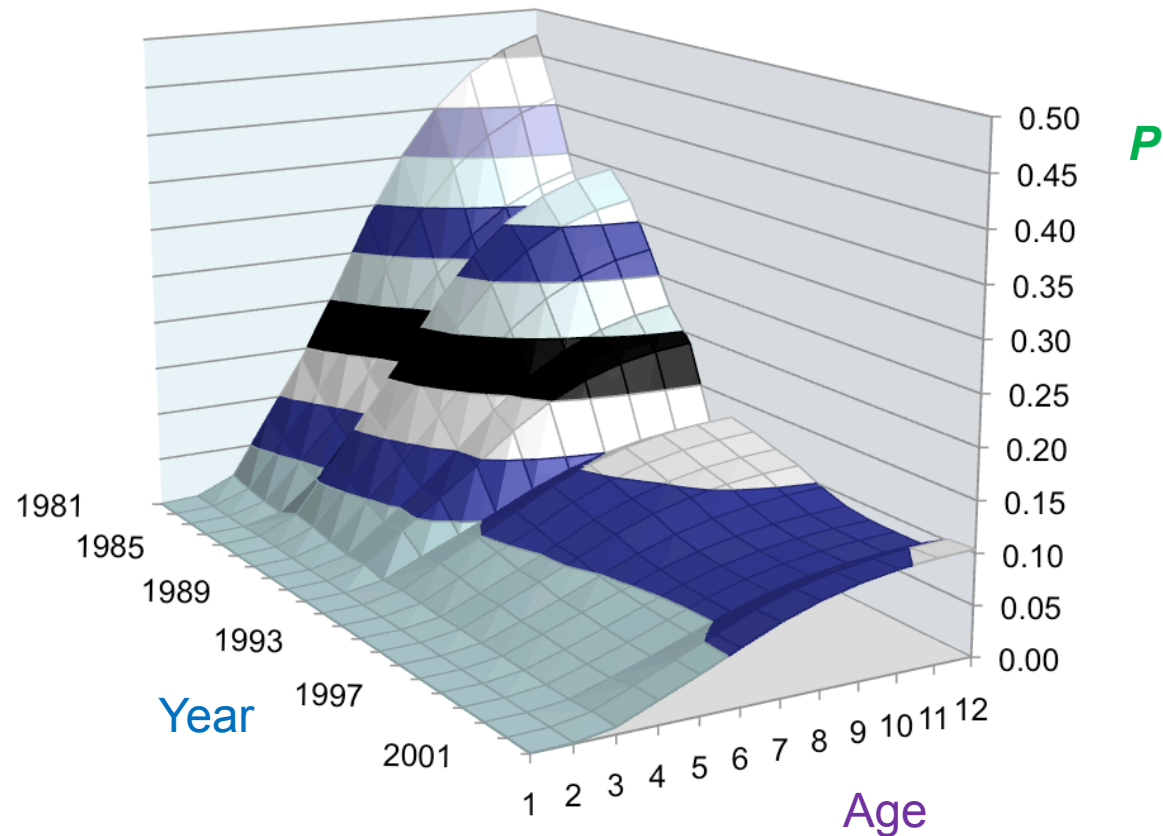


Expanded Model



Expanded Model Results

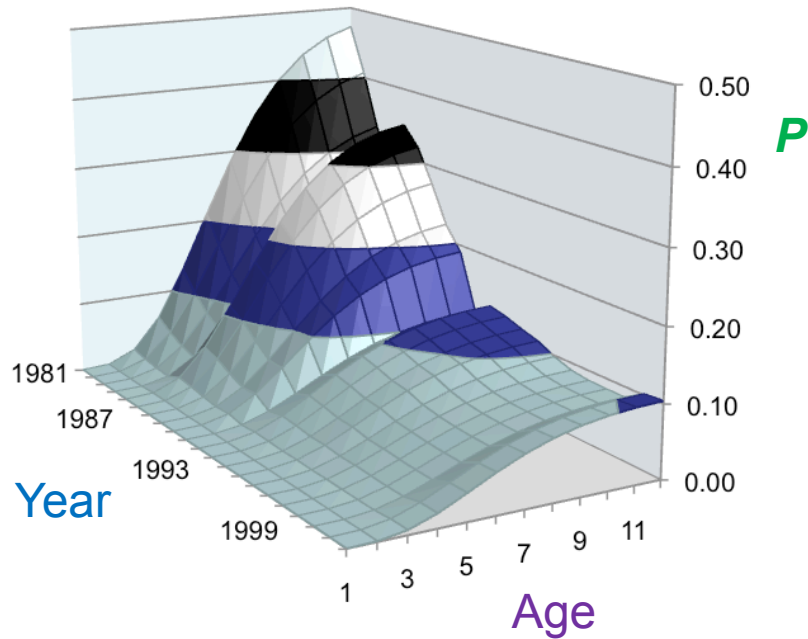
Predation mortality on cod



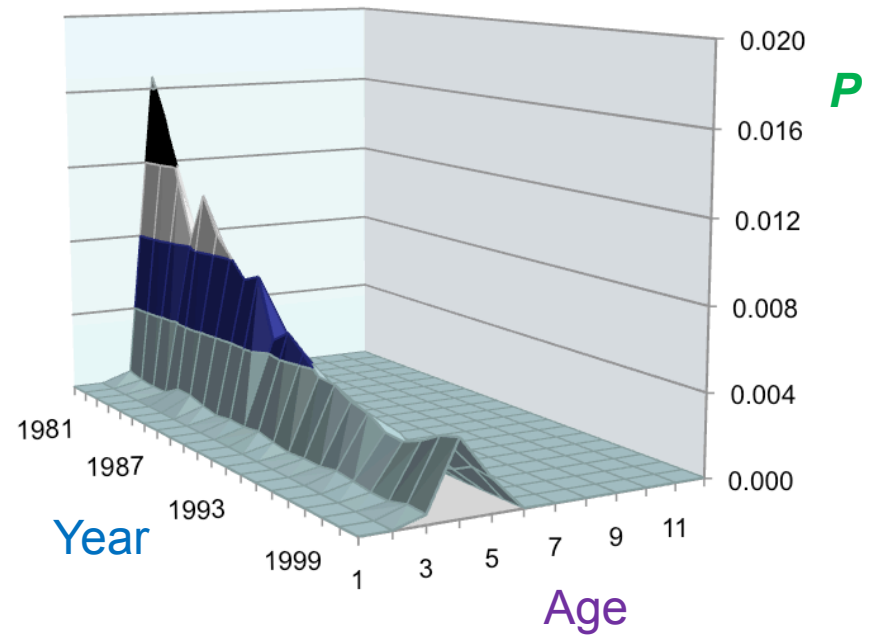


Expanded Model Results

Sea lion predation on cod



Male sea lion

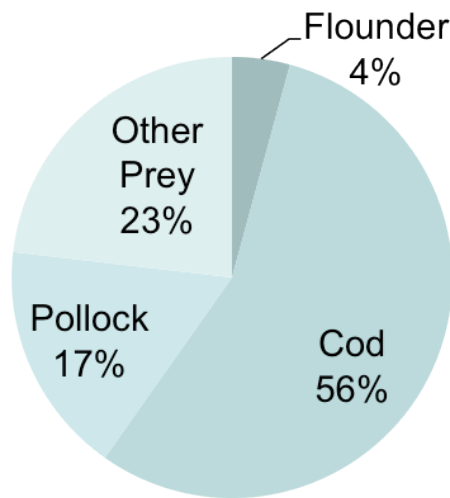


Female sea lion

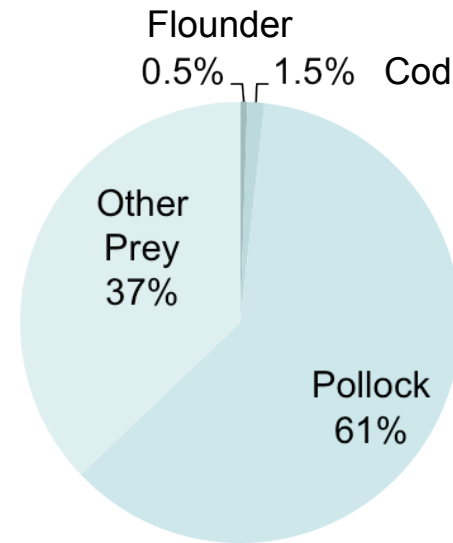


Expanded Model Results

Sea lion predation: stomach contents



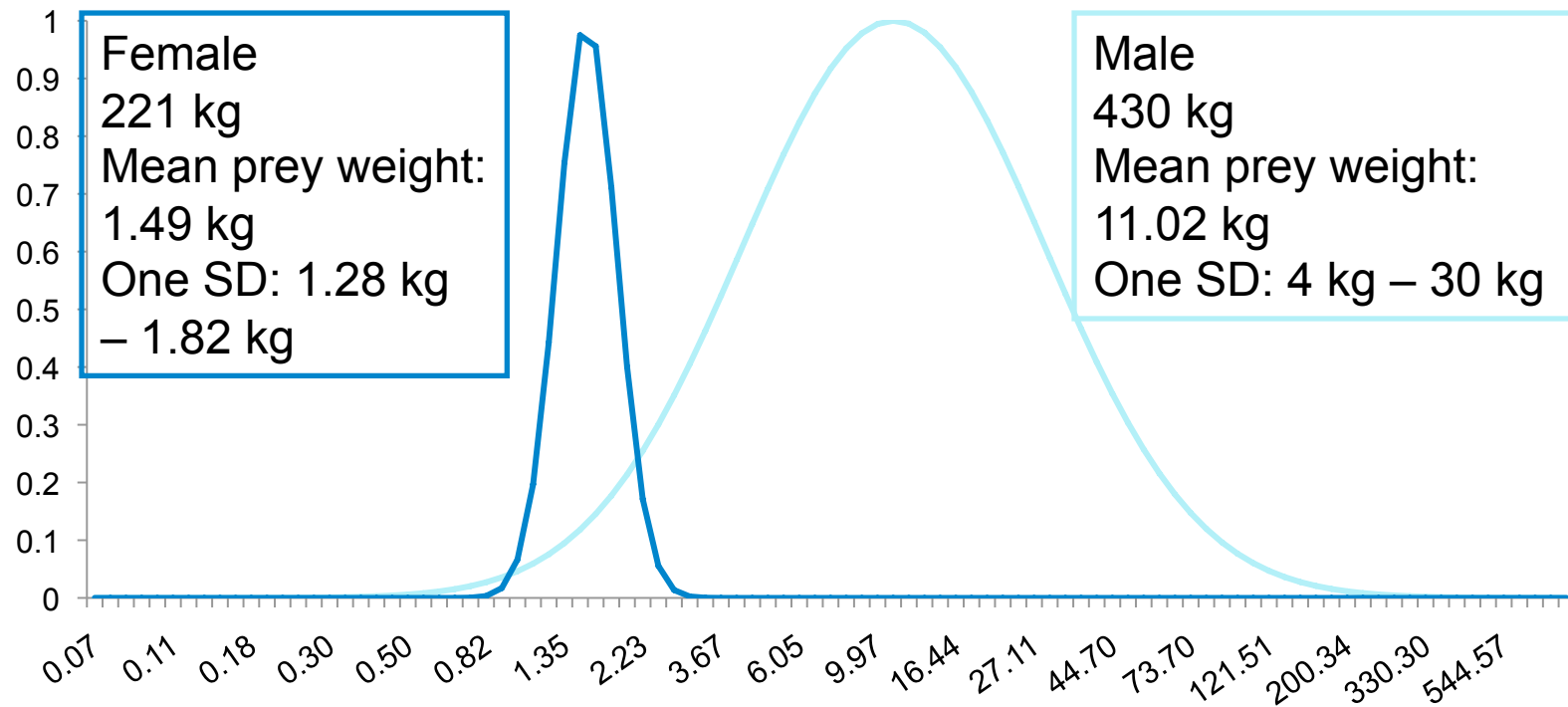
Average male sea lion stomach proportions



Average female sea lion stomach proportions



Age-8 sea lion size-preference

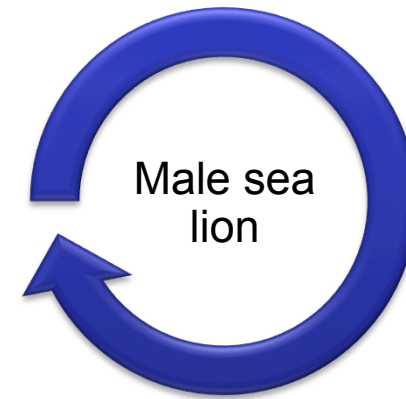
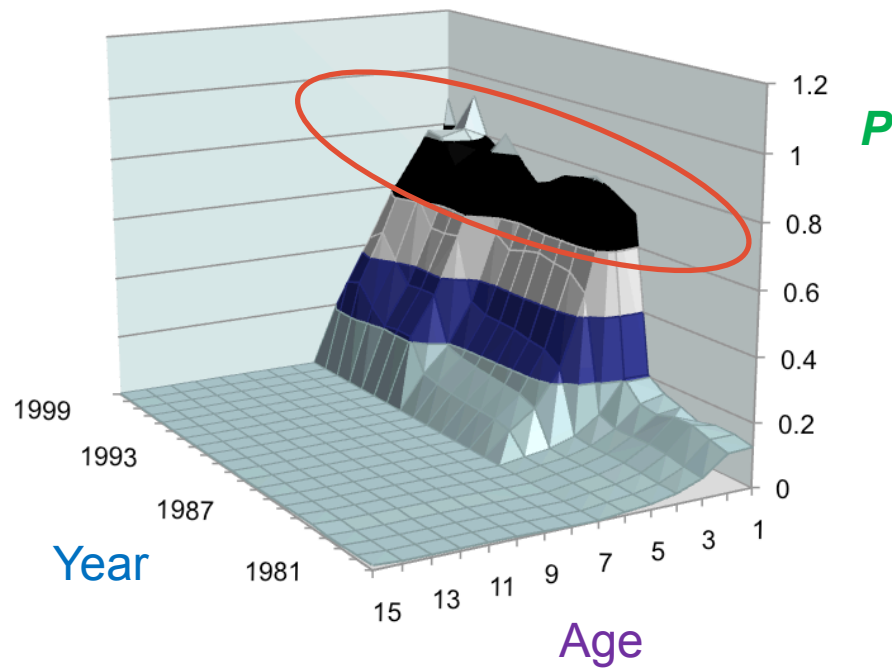


Female			
Pollock Age 8	Pollock Age 9	Pollock Age 10	Cod Age 3

Male					
Cod Age 7	Cod Age 8	Cod Age 9	Cod Age 10	Cod Age 11	Cod Age 12



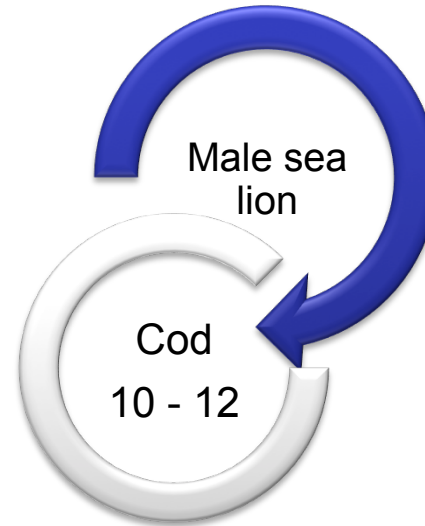
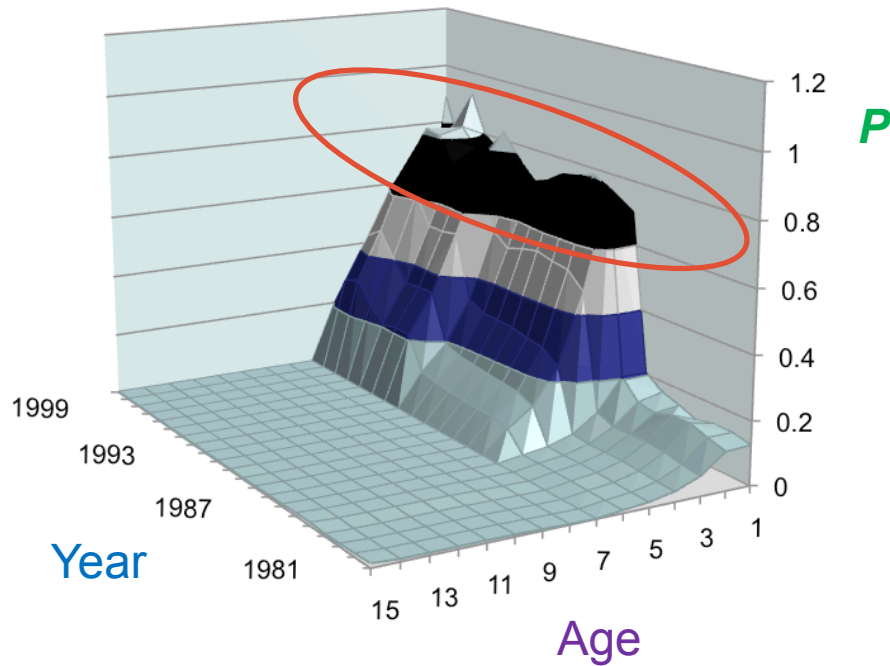
Predation Cascade



Predation mortality on flounder



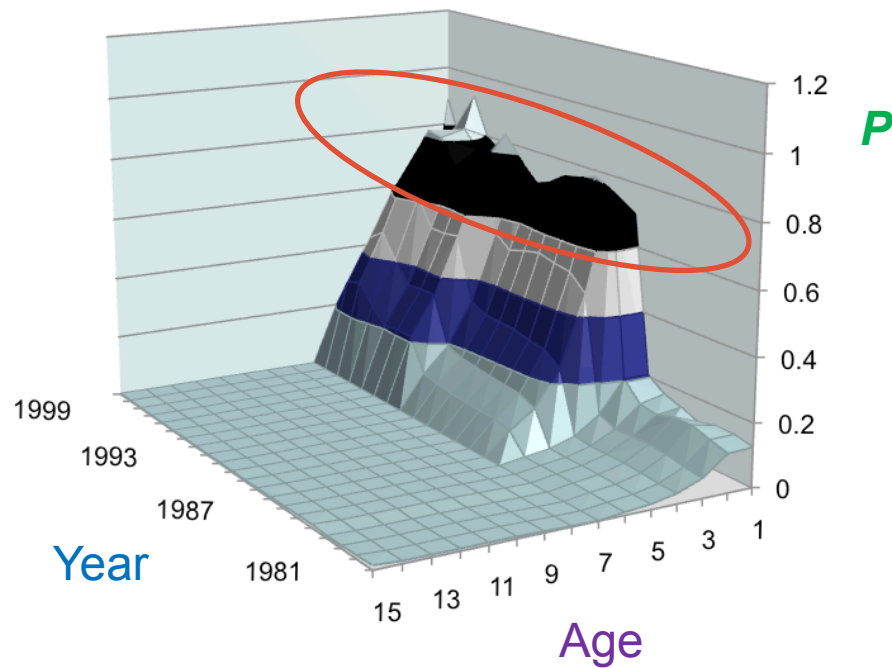
Predation Cascade



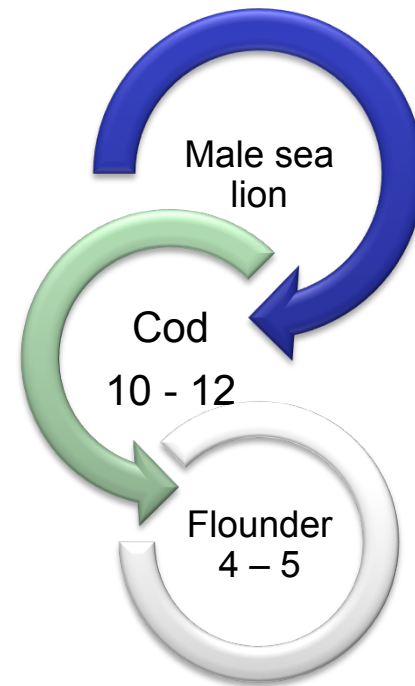
Predation mortality on flounder



Predation Cascade

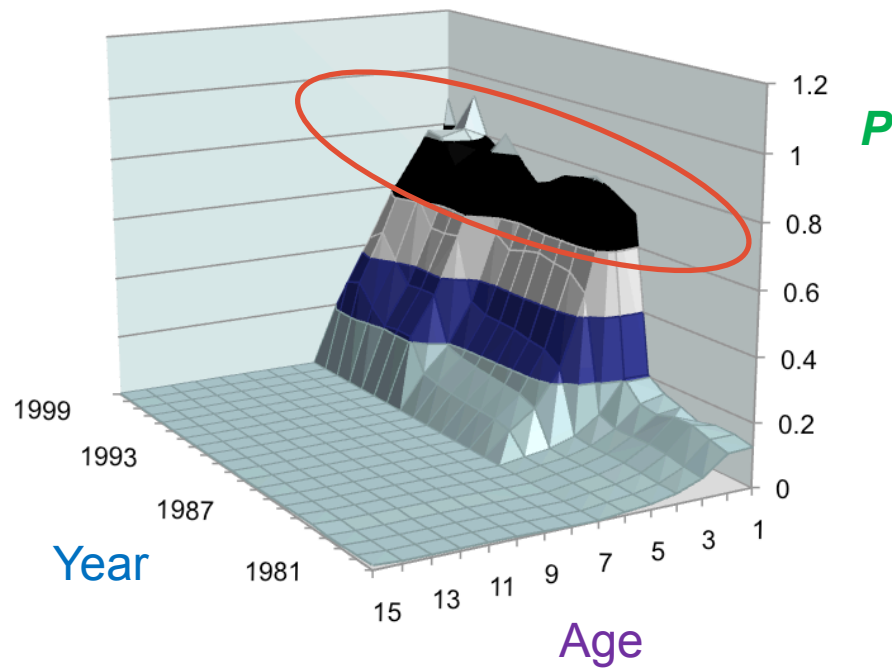


Predation mortality on flounder

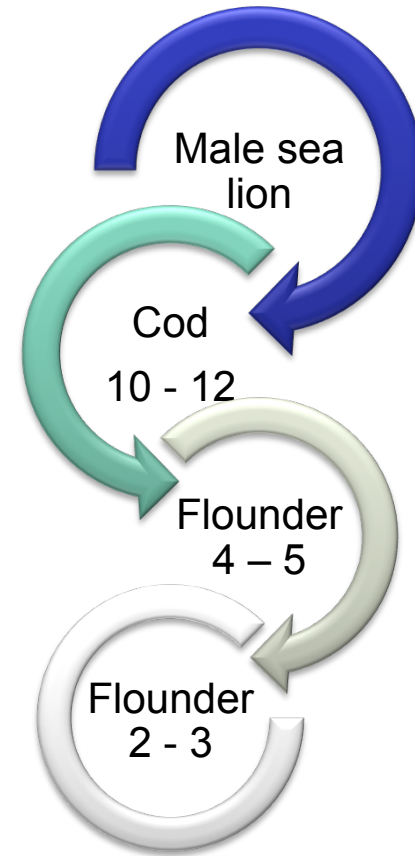




Predation Cascade



Predation mortality on flounder





Conclusions

- Addition of larger predators distributes predation across older prey
 - These older prey are fully recruited into the commercial fisheries
 - Predation dynamics cascade beyond first-order effects
 - Changes to catch levels may significantly affect populations other than the targeted species through predation cascades
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Conclusions - issues

- Model outputs highly sensitive to parameter bounds
- Model outputs highly sensitive to structural assumptions

Metadata to assist in setting these levels



Integration into EBFM stock assessments

- Precision and accuracy assessment through simulations at the ARSC
 - Fisheries simulations to assess the impacts of the commercial fisheries on overall system dynamics
 - Examine management strategies for both commercial fisheries as well as the Endangered Species Act
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