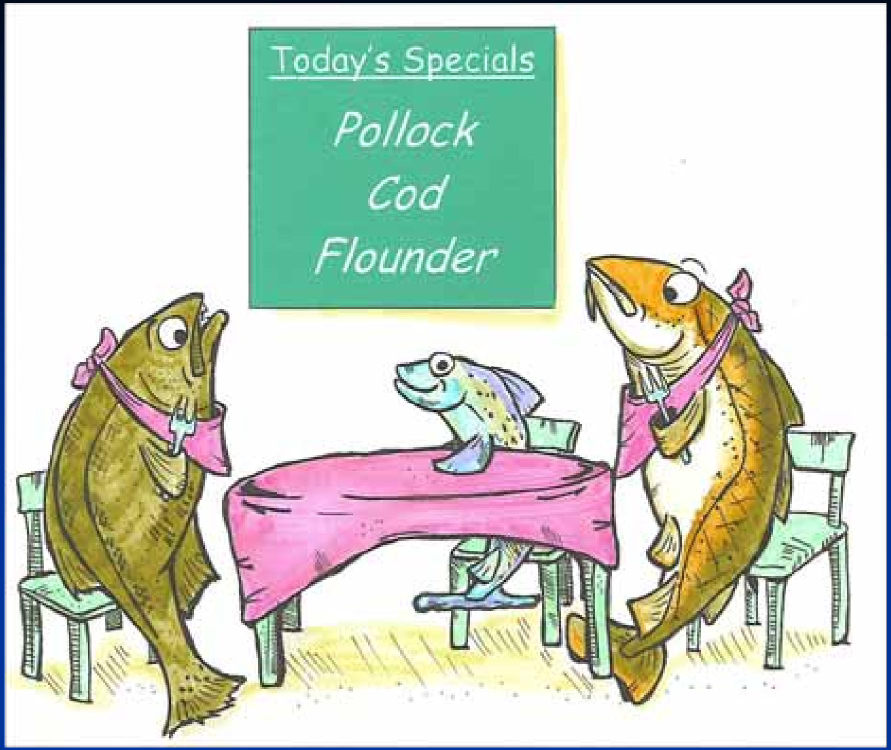

Estimating Predation Mortality with a Three-Species Model in the Gulf of Alaska

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General Approach

Construct a set of simplified single-species models and connect them through predation.

- SSM: Single-species models
  - Designed to match stock assessment output
  - $Z = F + M$
- MSM: Multispecies model
  - Calculates predation from gut data assumed to be measured without error
  - $Z = F + M + P$
- MSASA: Multispecies Age-Structured Assessment
  - Estimates predation from a series of model parameters
  - $Z = F + M + P$

Three species with close predator-prey links

Pacific Cod (*Gadus macrocephalus*)

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Arrowtooth Flounder
(Atheresthes stomias)

Walleye Pollock
(Theragra chalcogramma)

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Work forward from Age 1 cohort

$$N_{i,a+1,t+1} = N_{i,a,t} e^{(-Z)}$$

- No recruitment function: Age 1 is a model parameter.

- **Deconstruct Z into:**
  - **Fishing mortality *F***
  - **Predation mortality *P***
  - **Residual natural mortality *M***

$$N_{i,a+1,t+1} = N_{i,a,t} e^{(-M-F-P_1-P_2....P_n)}$$

The Multispecies Model (MSM) and the Multispecies Age-Structured Assessment (MSASA) are simply extensions of the SSM in which $Z = F + M + P$

Natural Mortality

- SSM: Set to values used in the stock assessments
  - Ages 1 and 2 for prey species set higher to mimic *P*

	SSM
ATF 1	0.45
ATF 2	0.4
ATF 3+	0.24
COD	0.37
PLK 1	0.9
PLK 2	0.8
PLK 3+	0.3

Natural Mortality

- MSM / MSASA: Set all ages to stock assessment values.

	SSM
ATF 1	0.45
ATF 2	0.4
ATF 3+	**0.24**
COD	**0.37**
PLK 1	0.9
PLK 2	0.8
PLK 3+	**0.3**

Modeling predation

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

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

Annual Ingestion

Predator abundance

Total ingestion by predator j * Proportion of the ingested food that is prey i, age a

Σ Total amount of prey i consumed by predator j

$$P_{i,a,t} = \frac{\text{Total amount of prey i consumed by all predators}}{\text{Biomass of prey i}}$$

Predation for the MSM

$$P_{i,a,t} = \frac{1}{N_{i,a,t} W_{i,a}} \sum_{j} \sum_{b} I_{j,b} N_{j,b,t} \frac{\phi_{i,a,j,b,t}}{\phi_{j,b,t}}$$

Proportion of ingested food for predator *j,b* composed of prey *i,a* taken directly from gut studies.

Predation for the MSASA

Estimating stomach contents

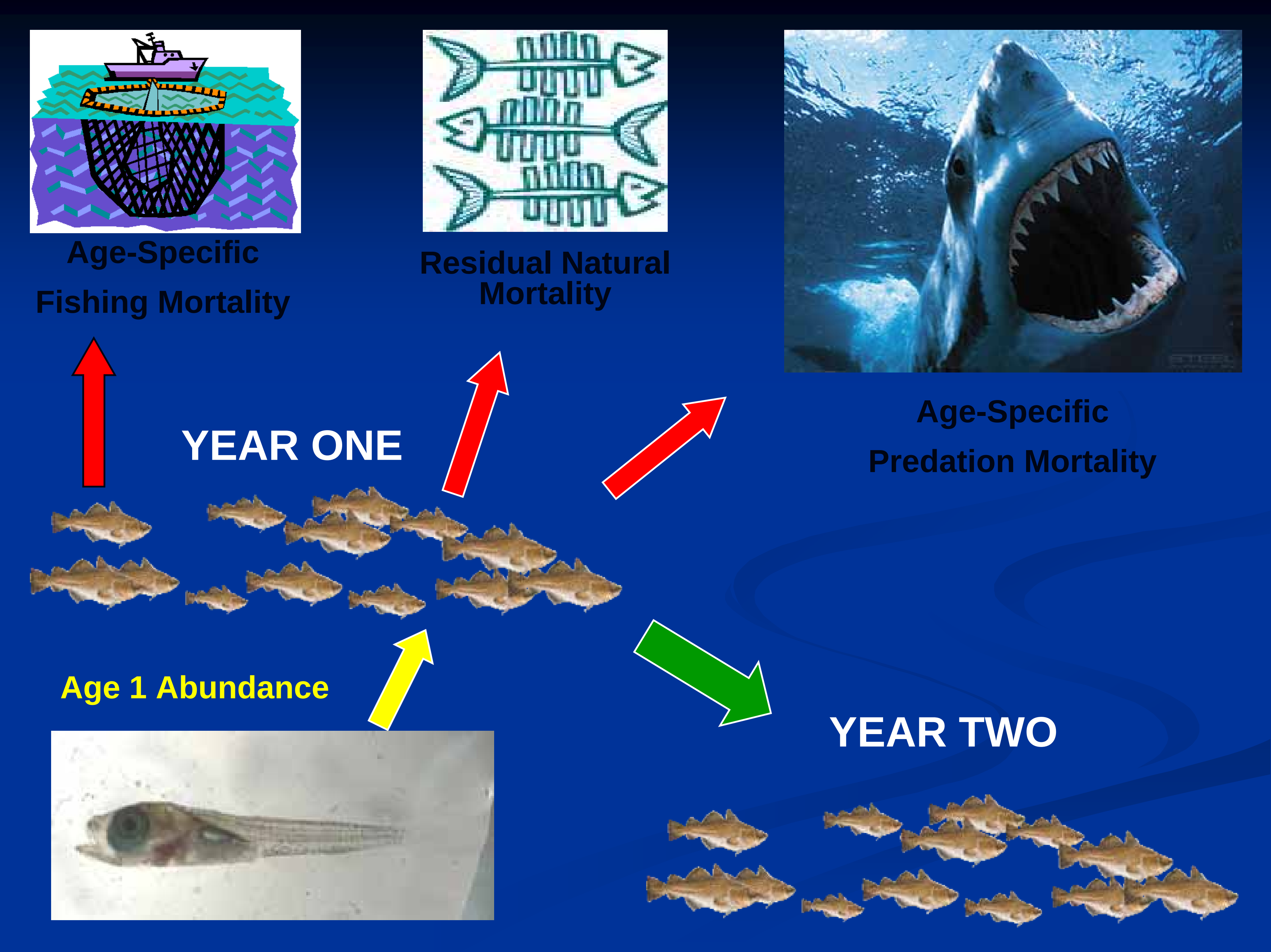
SIZE-PREFERENCE: Defined by the gamma function

SUITABILITY: size-preference * prey vulnerability

- **Scaled to 1 to create a distribution of gut contents for each predator**

AVAILABILITY: suitability * prey biomass

$$\text{Stomach} = \frac{\text{Biomass of prey } \textit{i,a} \text{ available to predator } \textit{j,b}}{\text{Total food available to predator } \textit{j,b}}$$


Age-Specific
Fishing Mortality
Residual Natural
Mortality
Age-Specific
Predation Mortality
YEAR ONE
Age 1 Abundance
YEAR TWO

Likelihood Components

- Catch-at-age
- Survey-at-age
- Total Annual Catch
- Estimated survey biomass

Additional MSASA component:

- Gut data

Results

The SSM is a valid baseline for evaluating predation.

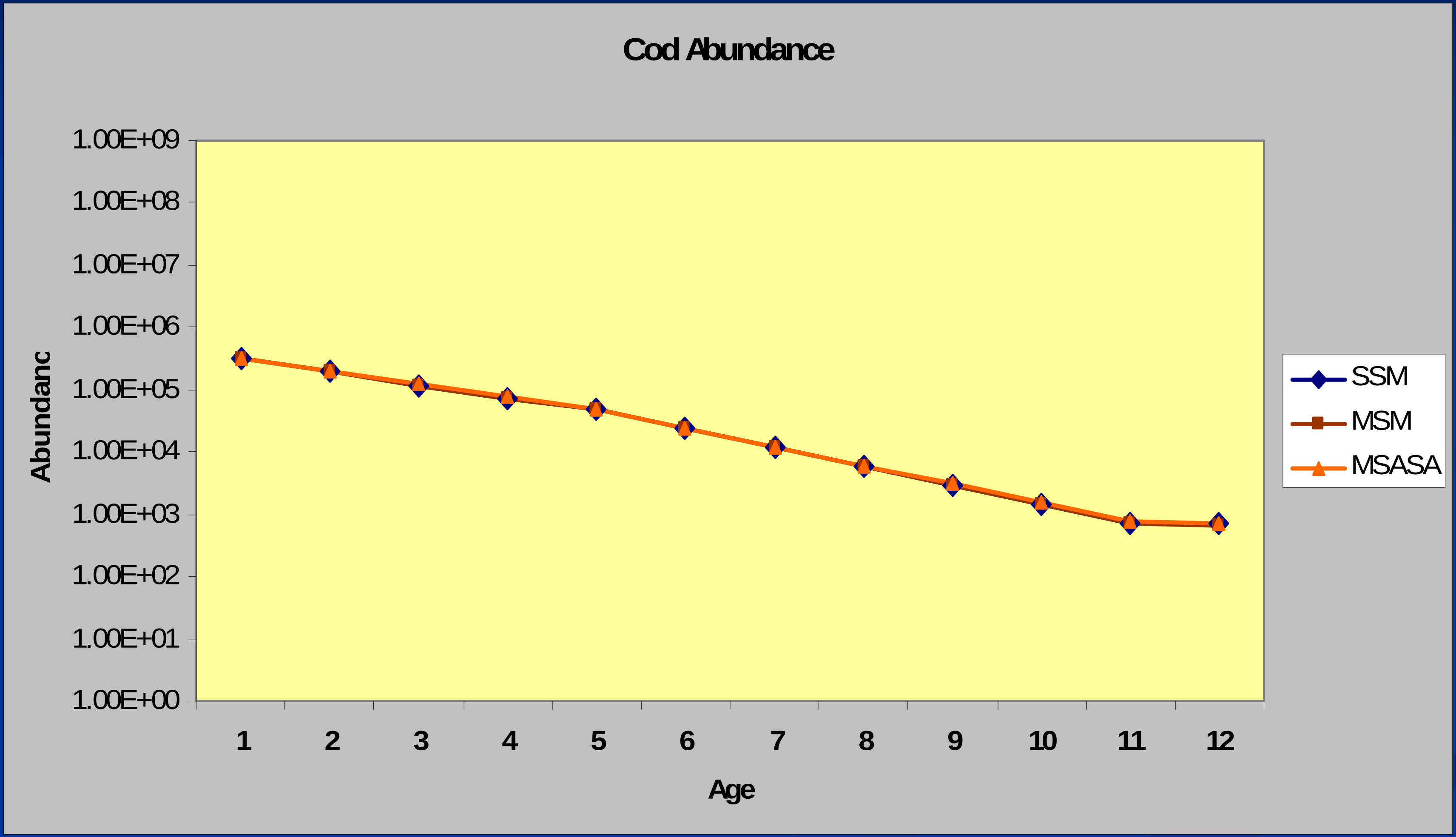
Matches stock assessment ranges for:

- **Catch and Survey data**
- **Values for *F* and *Q***
- **Gear selectivity patterns**
- **Estimates of abundance**

We assume that stock assessment estimates of biomass, abundance, *Q*, *F*, and gear selectivities are essentially correct.

Results

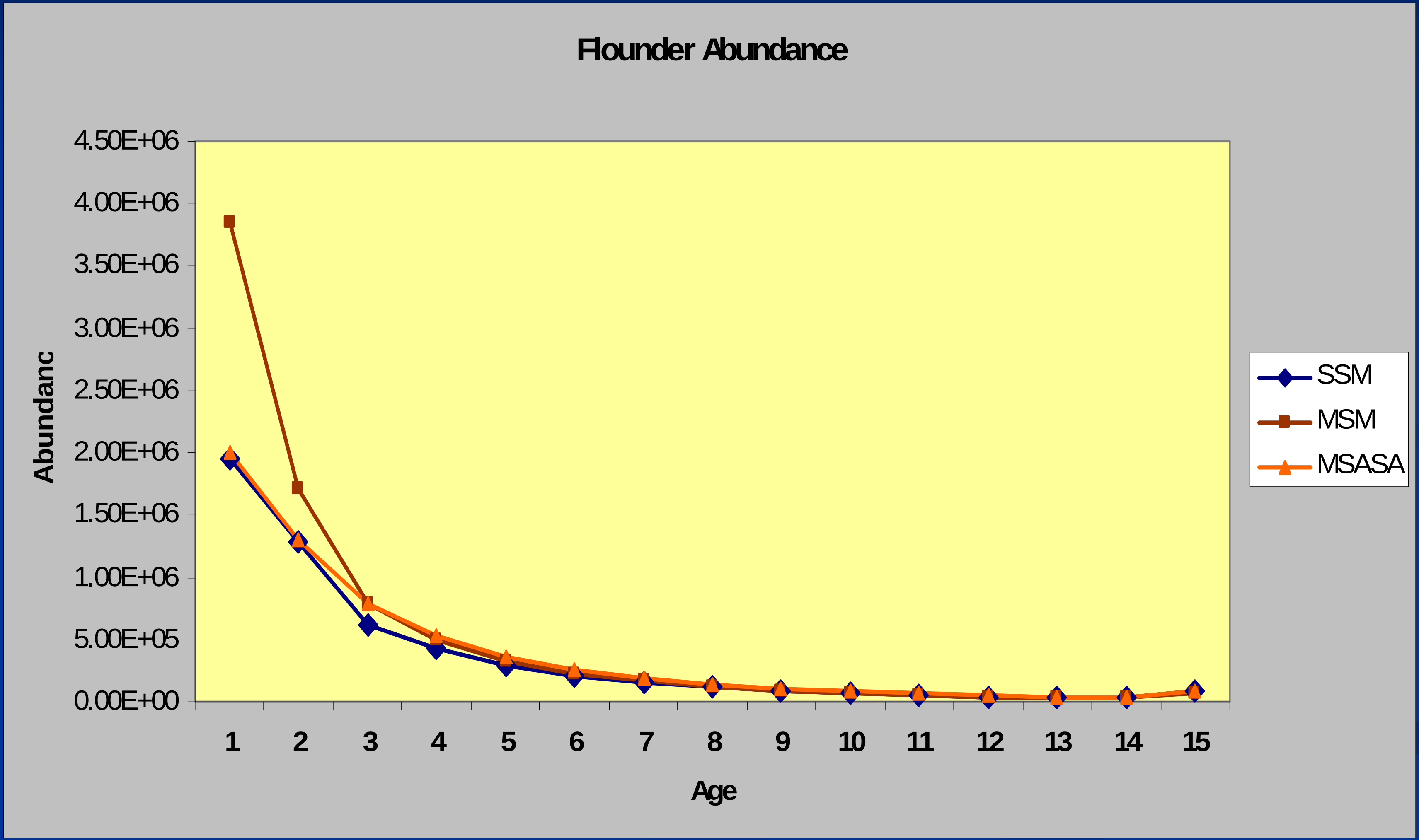
Abundance



No predation = no change in abundance from SSM

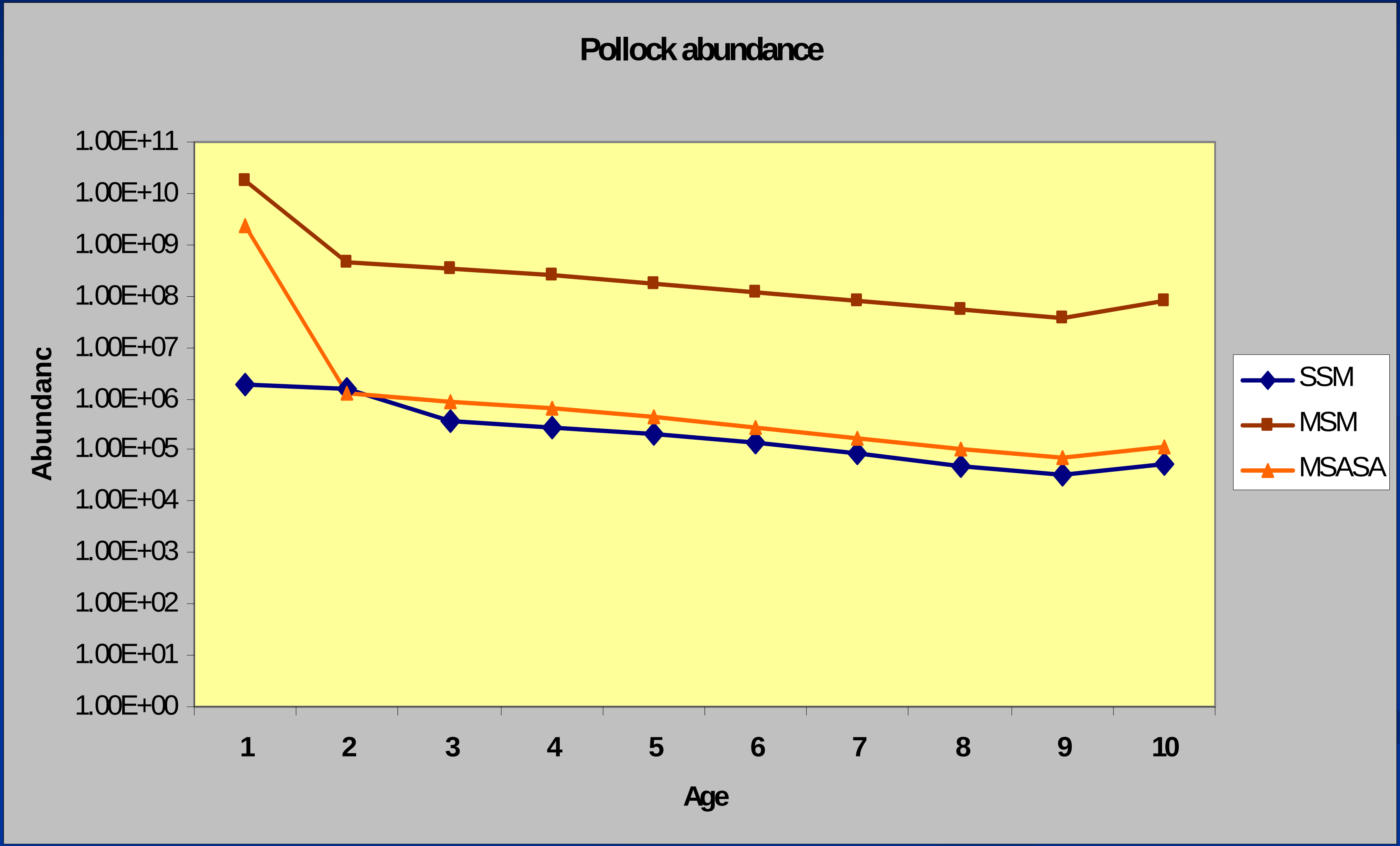
Results

Abundance

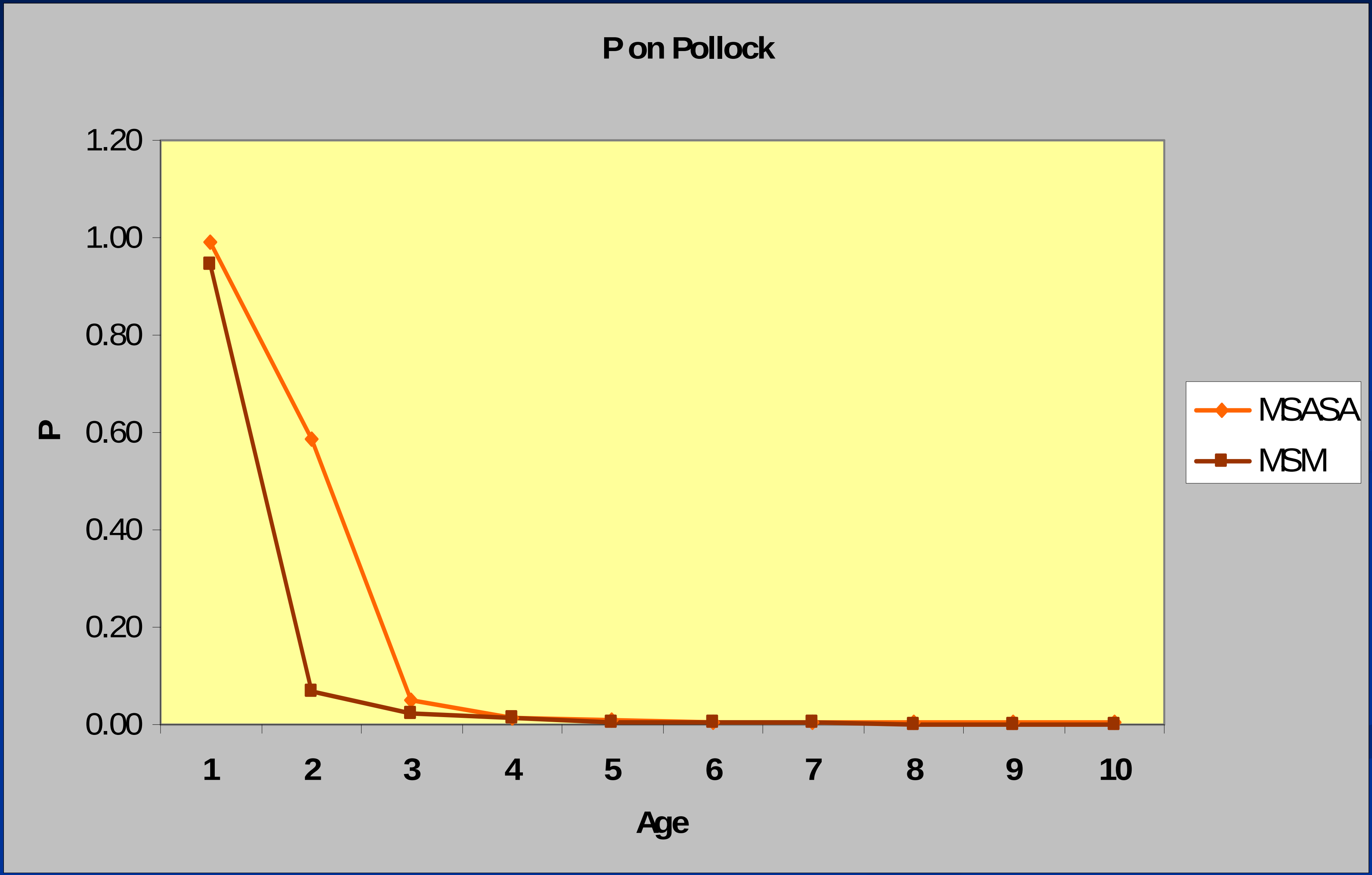


Results

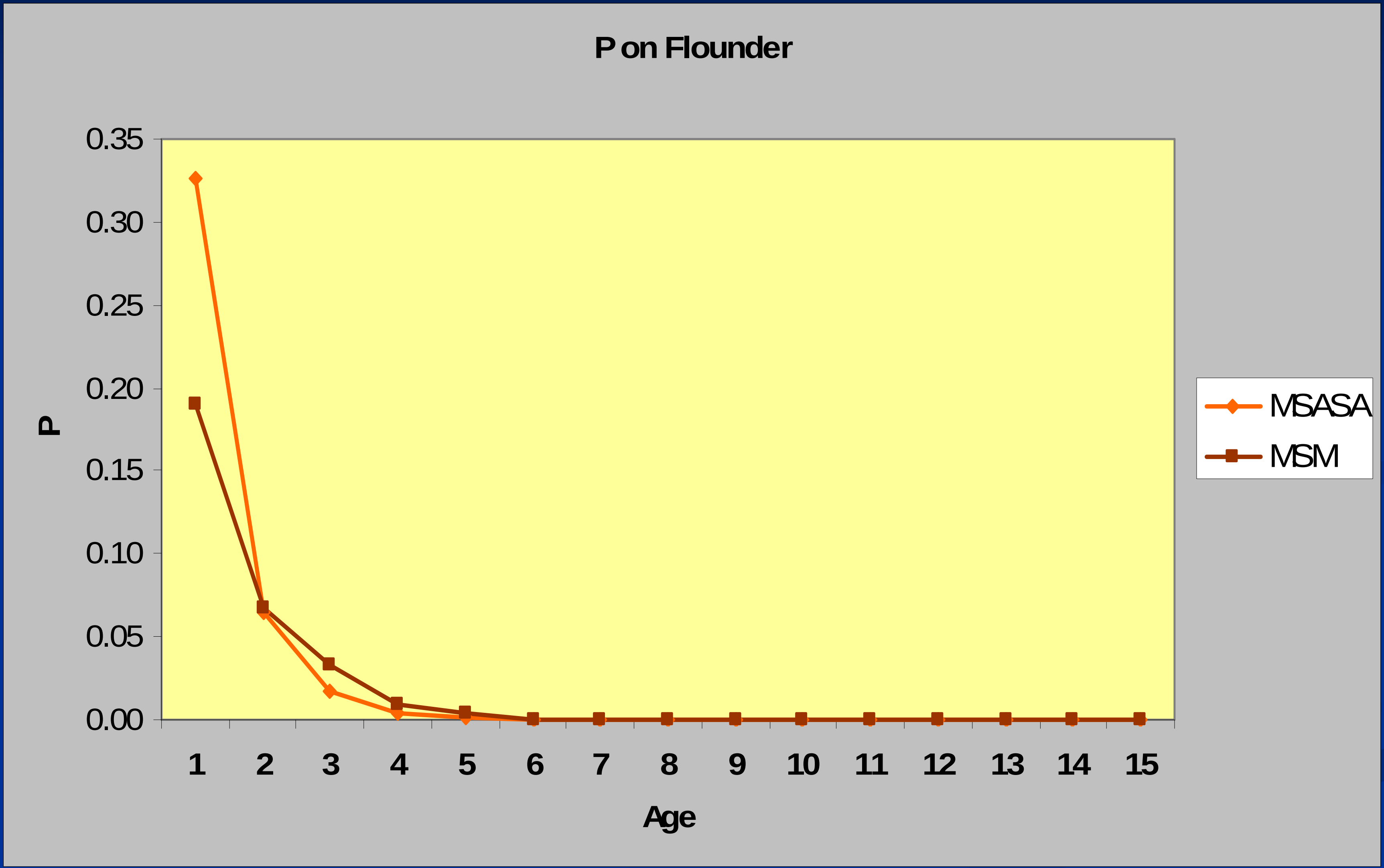
Abundance



Predation Mortality



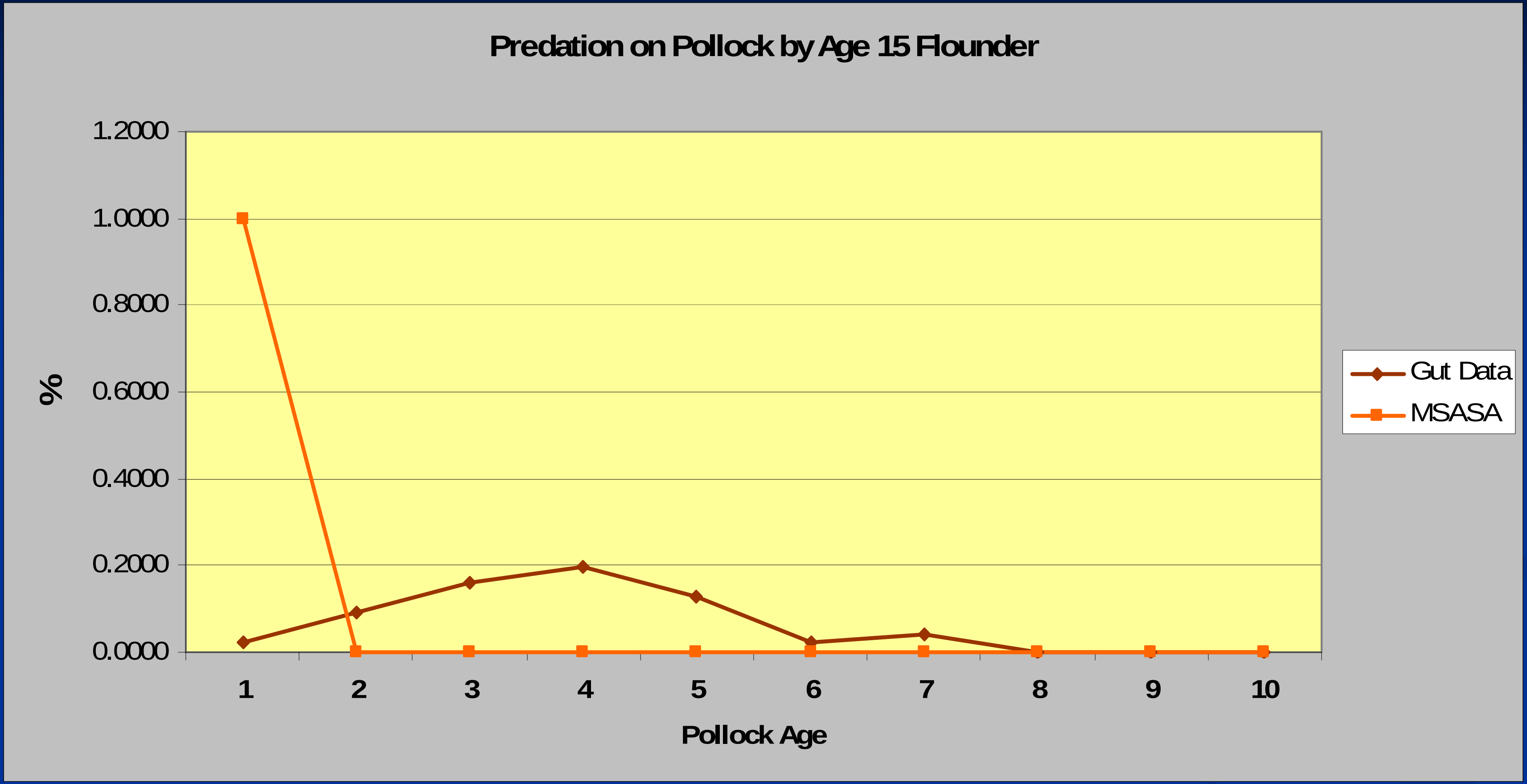
Predation Mortality



Catch and Survey Factors

	SSM	MSM	MSASA
ATF Q	1	1	0.88
PLK Q	0.75	0.0009	0.46
ATF F	N/A	N/A	N/A
PLK F	0.15	0.0002	0.1

Issues: Gut Content



1. **Weak forcing from gut data: too many zeroes**
2. **Large majority of predation on Age 1 Pollock skews model predictions**

Issues: Natural Mortality

Traditional single-species models have included predation under the umbrella of *M*.

By separating *P* from *M*, values for *M* should decrease.

When set as model parameter, *M* increases with the addition of predation. Why?

In Sum

OBSERVED

- Predation mortality is separable from natural mortality
- Predation mortality is estimable
- The MSASA is both computationally workable and biologically sound

REQUIRED

- Improved assessment of gut data and its integration into model function
- Improved understanding of relationship between *M*, *P*, and cohort dynamics

What's going on down there??