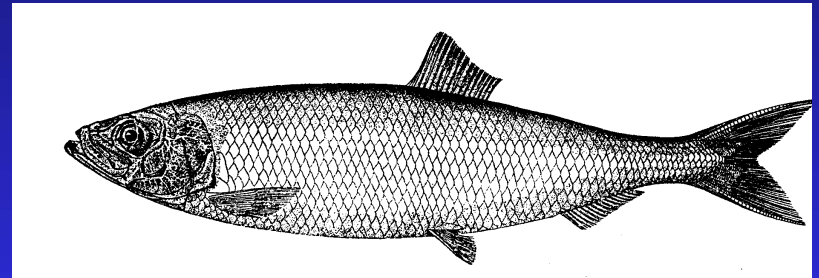


An Ecosystem Approach to the Assessment of the Gulf of Maine- Georges Bank Herring Complex

By

*Bill Overholtz, Jason Link,
and Larry Jacobson*

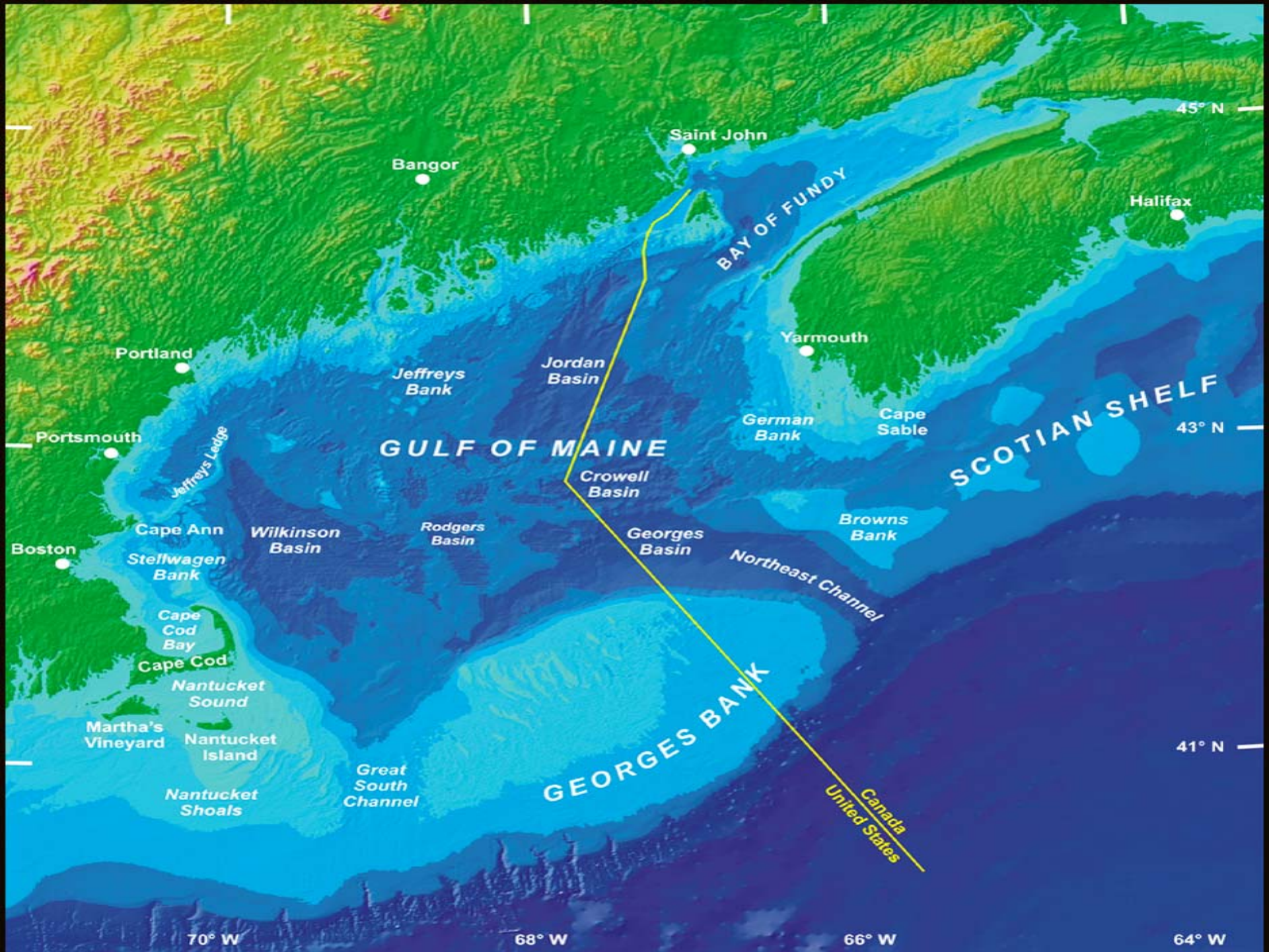


*Northeast Fisheries
Science Center*

Woods Hole, MA 02536

June 3, 2008





Objectives for an Ecosystem Based Assessment for GOM-GB Herring

- *Estimate the Total Consumption of Herring by Predator Groups*
- *Estimate Predation Mortality (M_2) on Herring*
- *Determine the Impact of Predation on Herring Recovery and Dynamics*
- *Quantify the Effect of Predation on Long-Term Yield Potential*

Predator Groups on Atlantic Herring in the GOM Region



Medium
Demersal Fish



Marine
Mammals



Herring



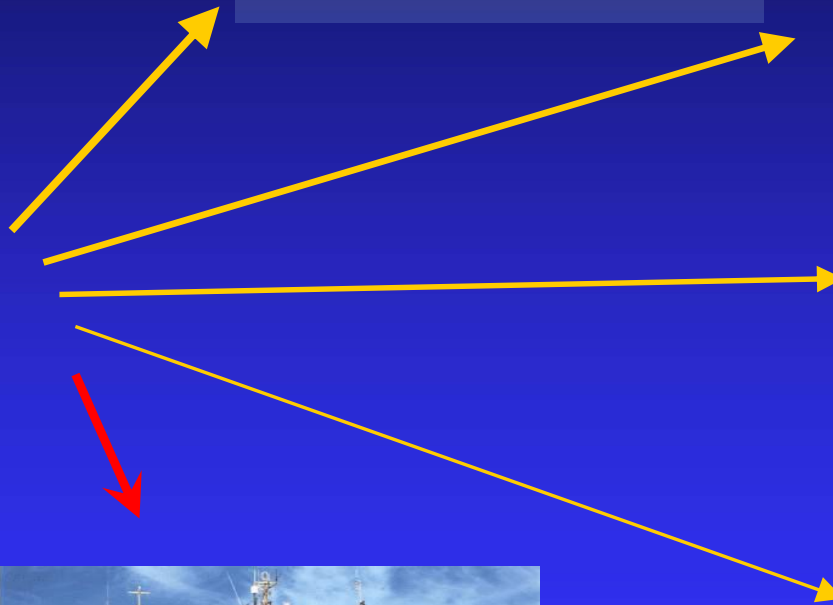
Large Pelagic Fish



Herring Fishery



Seabirds



Medium Demersal Fishes



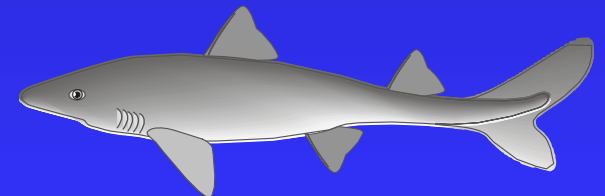
Herring



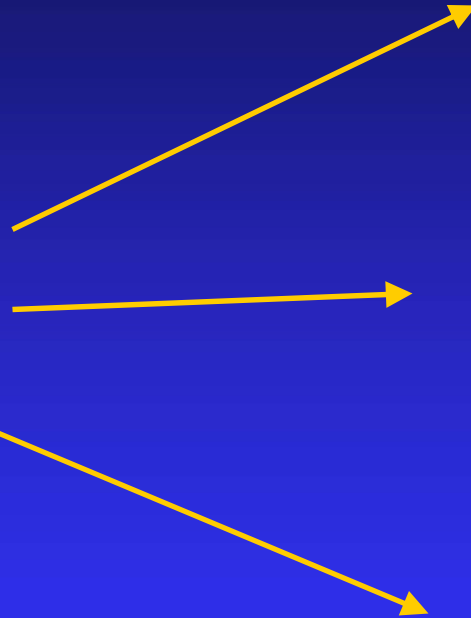
Cod



Silver Hake



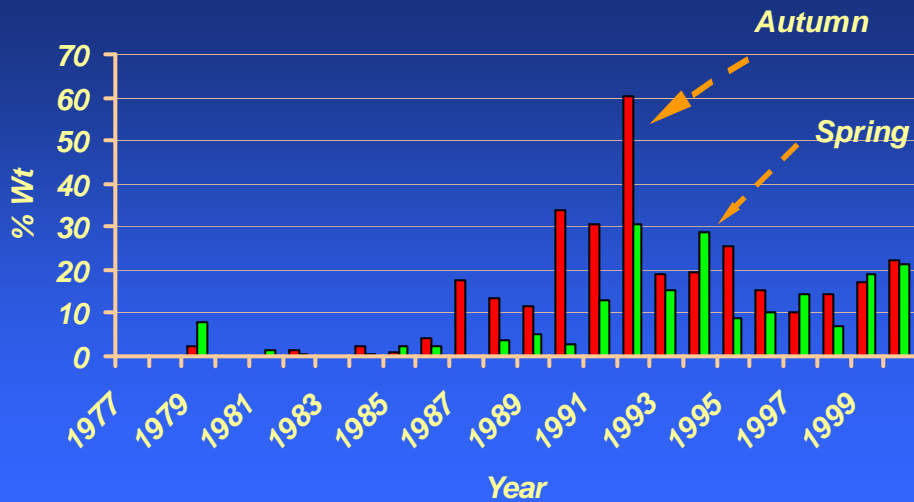
Dogfish



Medium Demersal Fish

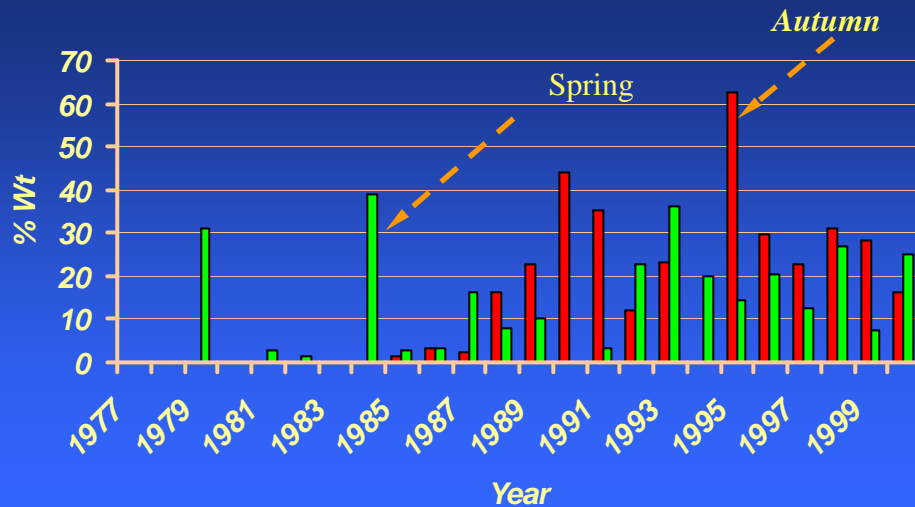
- *Spiny dogfish*
- *Atlantic cod*
- *Silver hake*
- *White hake*
- *Red hake*
- *Pollock*
- *Summer flounder*
- *Winter skate*
- *Thorny skate*
- *Bluefish*
- *Goosefish*
- *Sea raven*

% Herring in Spiny Dogfish Diet



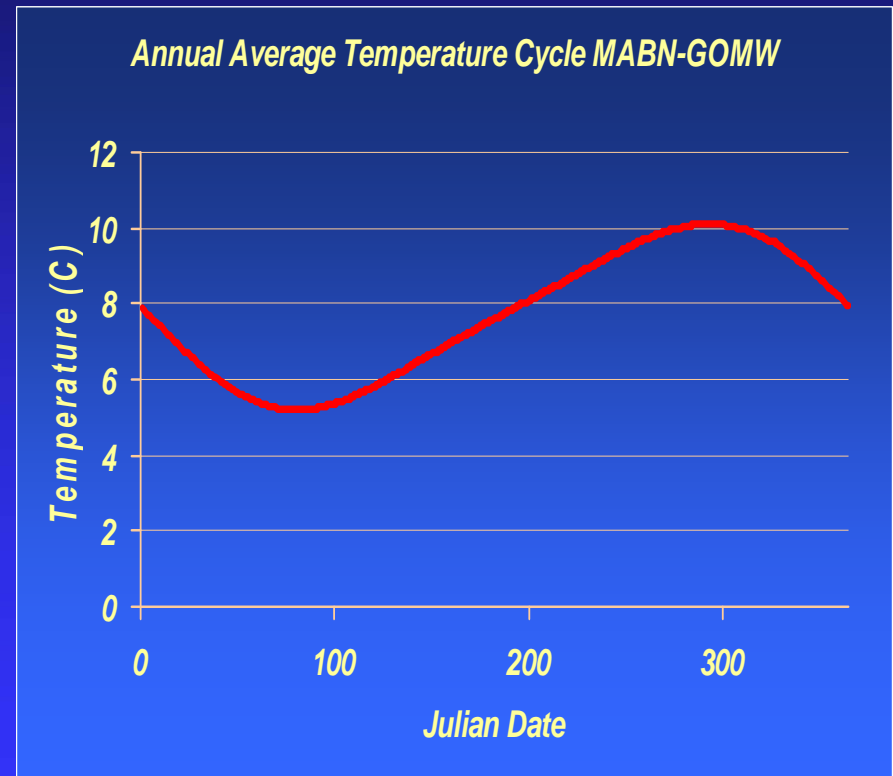
When Herring Began to Recover in the Late 1980s, Predators Increased the % Herring in Their Diet.

% Herring in Silver Hake Diet



Medium Demersal Fish

- $C=24RS$
- R =evacuation rate, S =average stomach contents
- $R=ae^{bT}$
- T =quarterly bottom temperature, a & b are parameters, $a=0.004$ $b=.115$



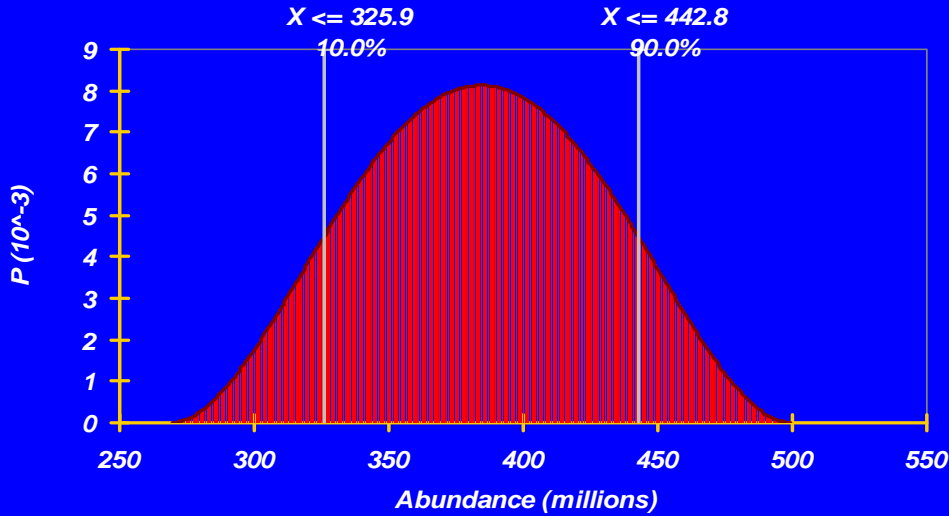
Uncertainty Framework for Consumption Estimates

- *@RISK software (Shelton et al. 1997)*
- *Empirical data or literature values for parameters*
- *Available CV's or 30-50%*
- *Uniform or Pert distributions*
- *Monte Carlo simulation, 5000 draws*
- *Sensitivity analysis and CI envelopes*

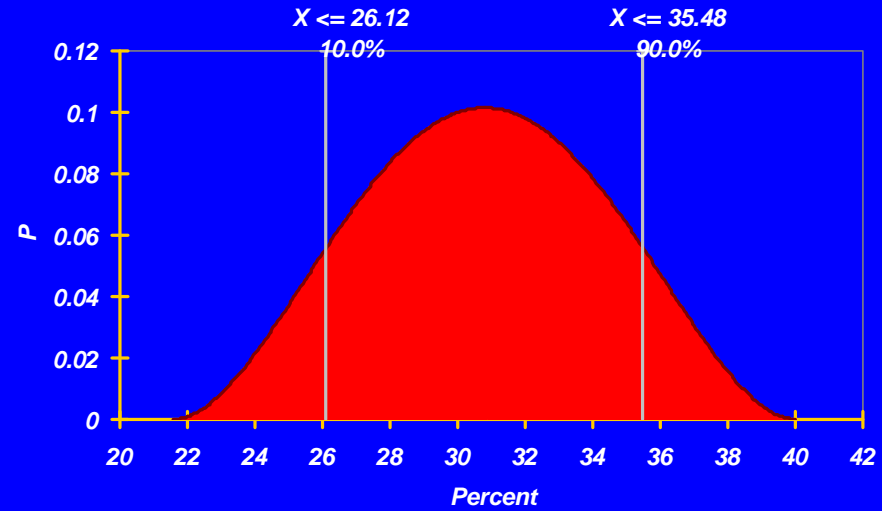
Uncertain Parameters

- *population size of predator*
- *residence time*
- *daily ration*
- *% herring in diet*

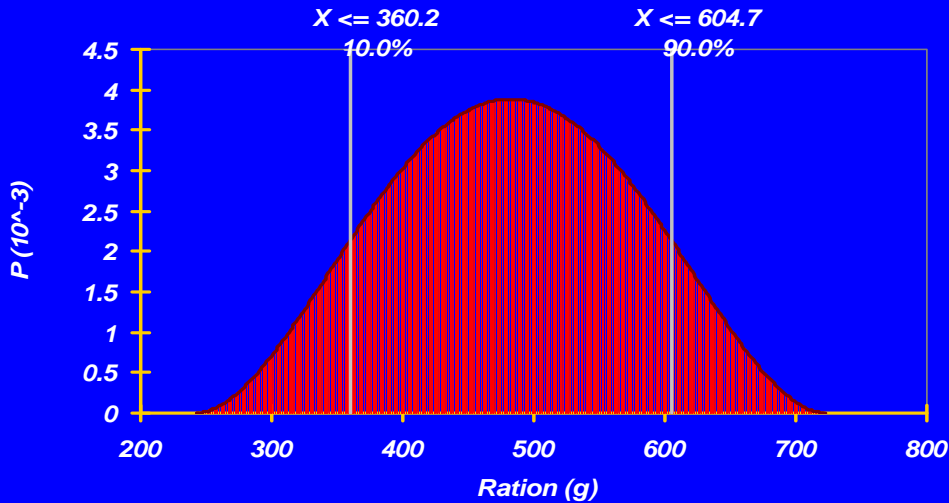
Pert(269.03, 384.33, 499.63) dogfish N



Pert(21.558, 30.798, 40.037) percent herring in diet

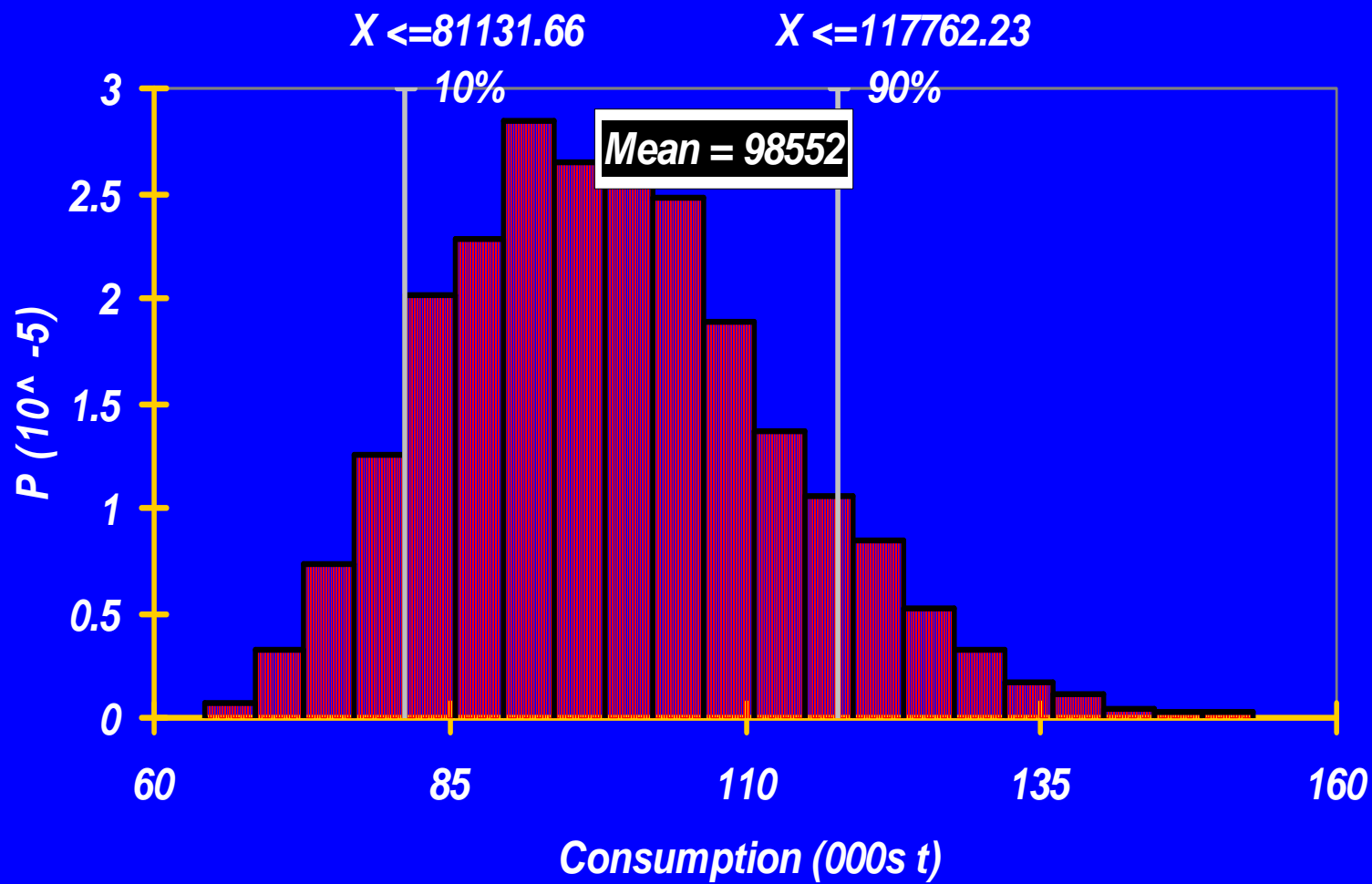


Pert(241.23, 482.46, 723.69) quarterly ration

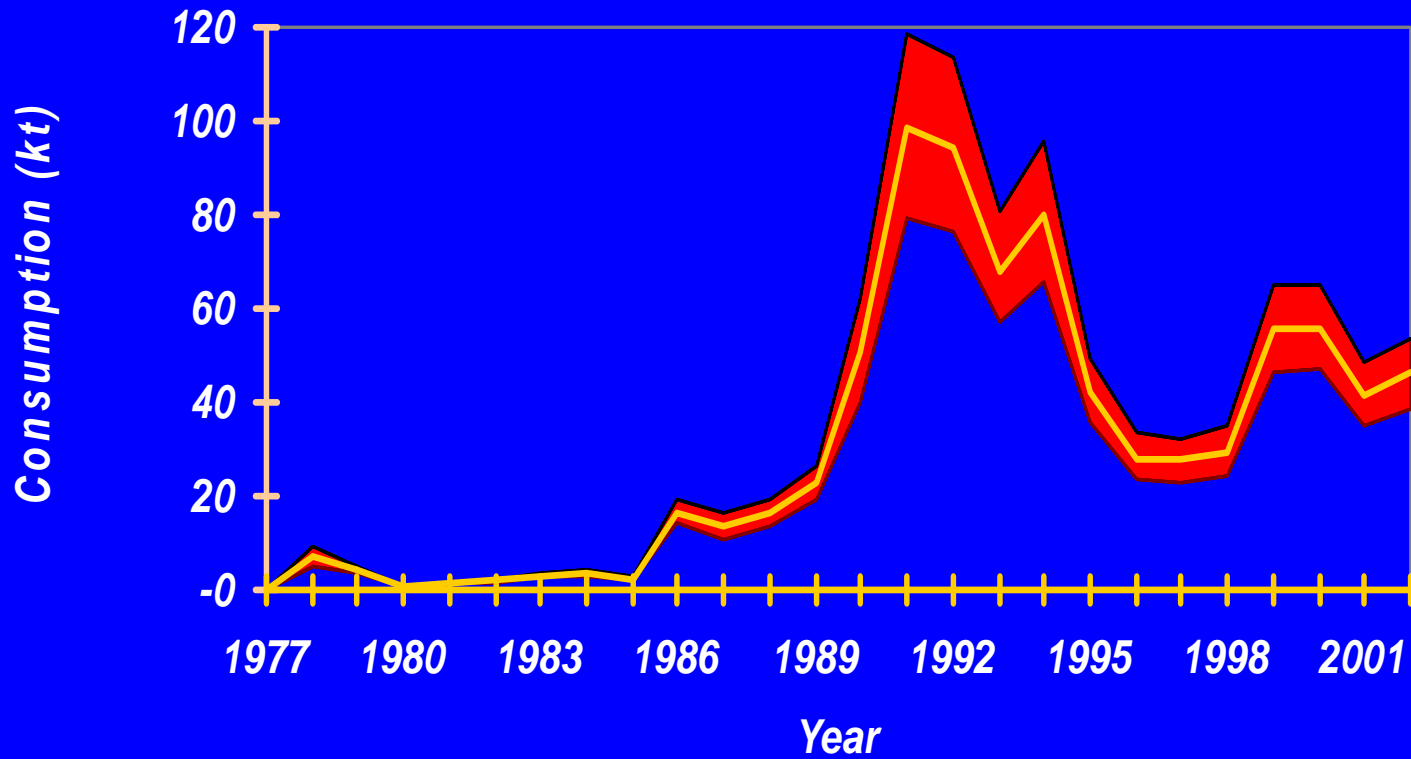


*Input Distributions
for Herring
Consumed by
Dogfish*

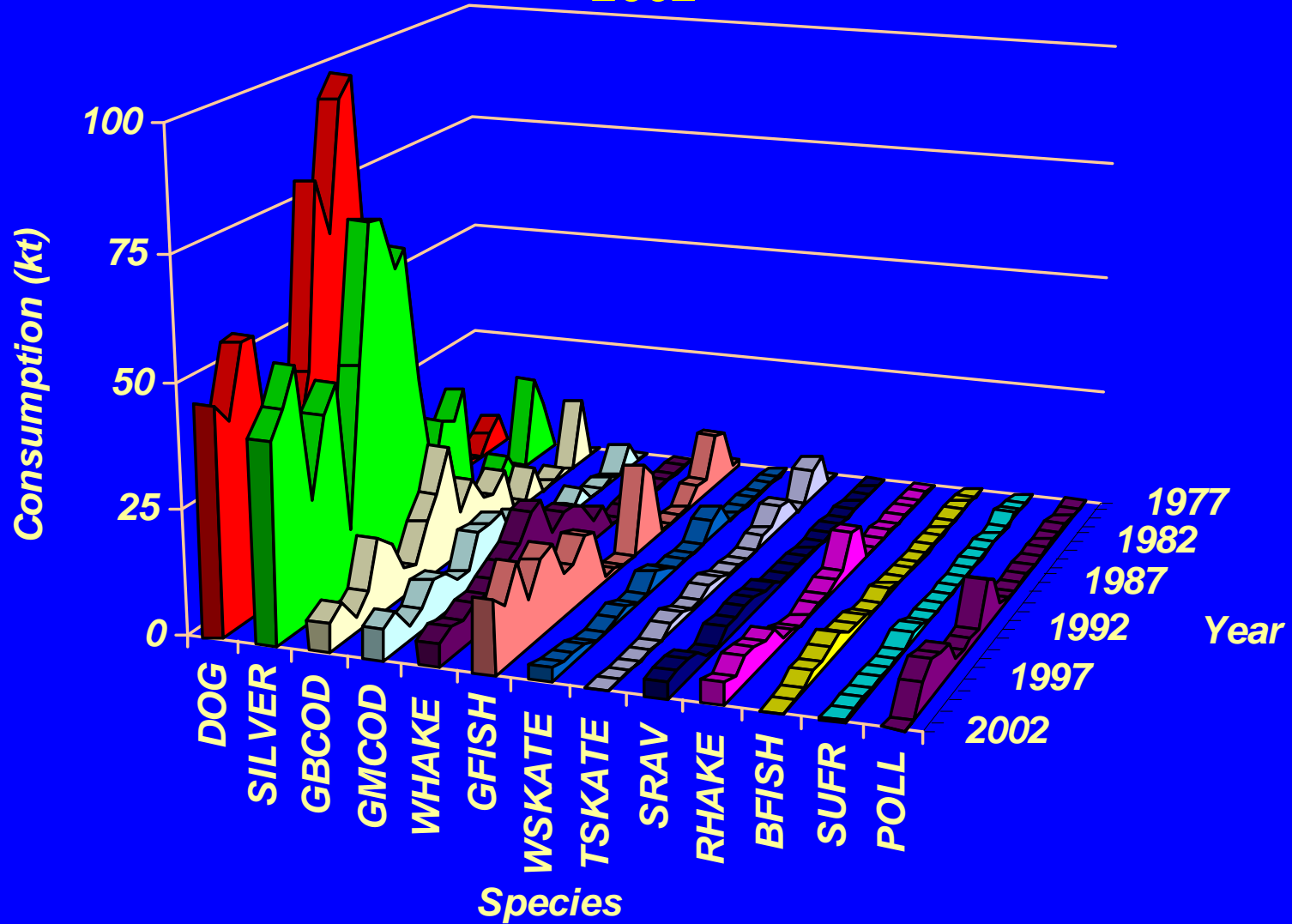
Herring consumed by dogfish in 1991



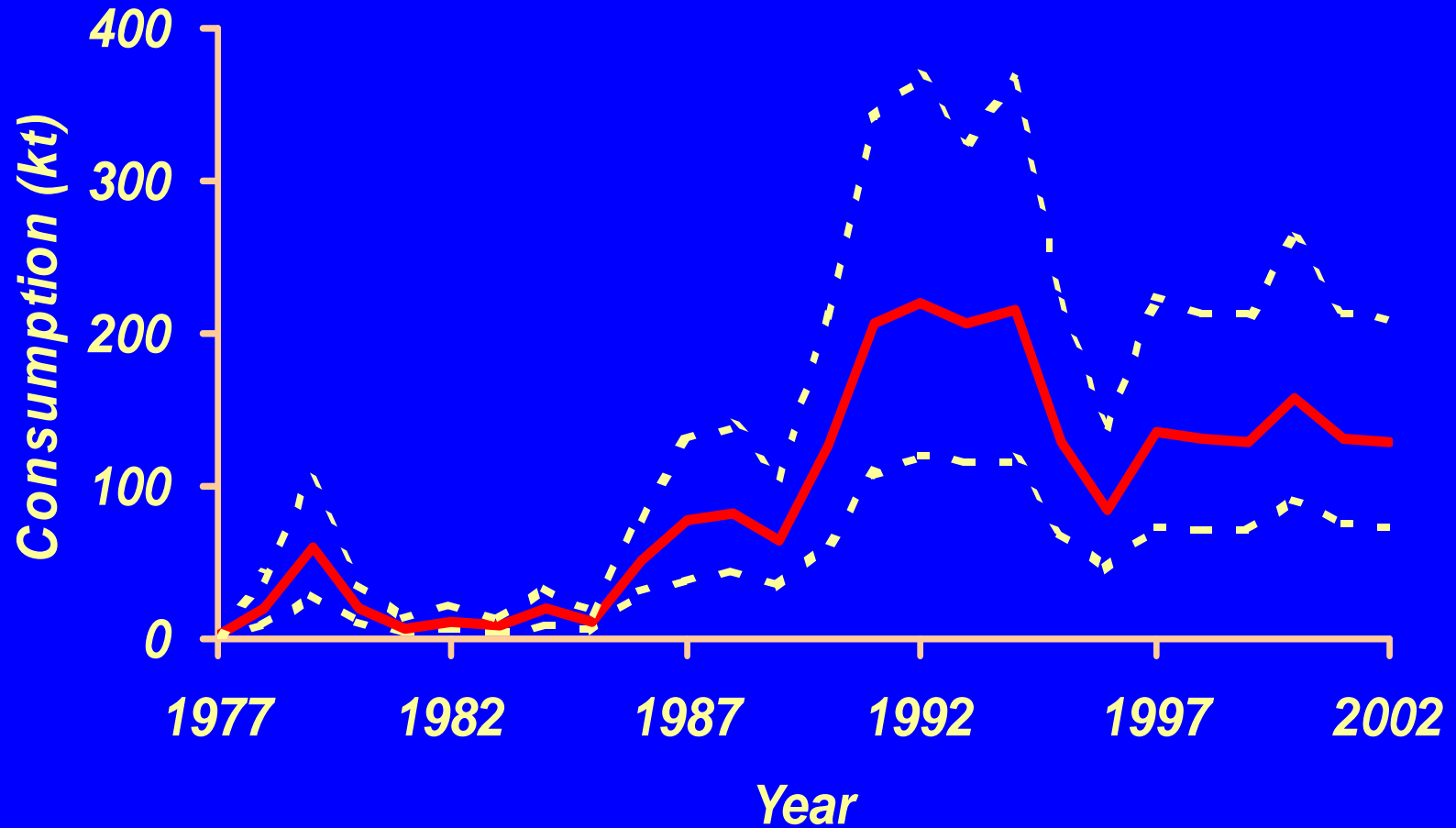
herring consumed by dogfish during 1977-2002



Consumption of Herring by Demersal Fish 1977-2002



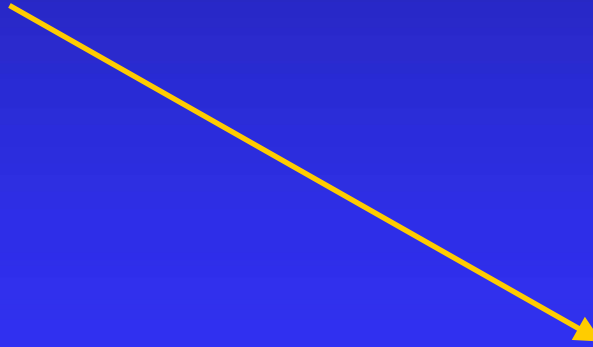
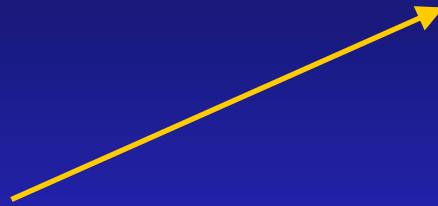
**Total Consumption of Herring (80% CI) by
Demersal Fish 1977-2002**



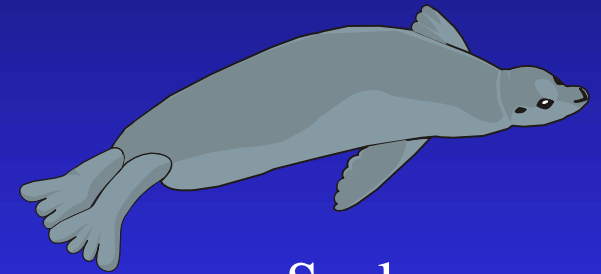
Marine Mammals



Herring



Whales



Seals



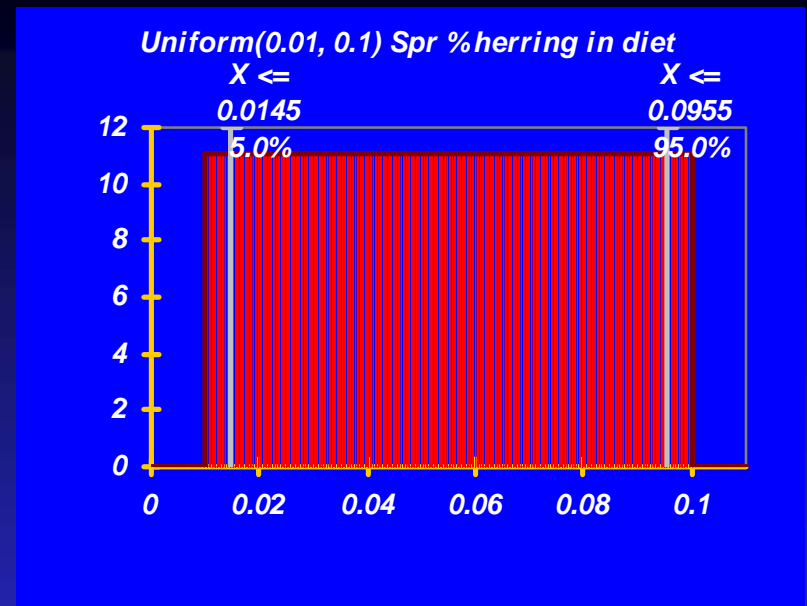
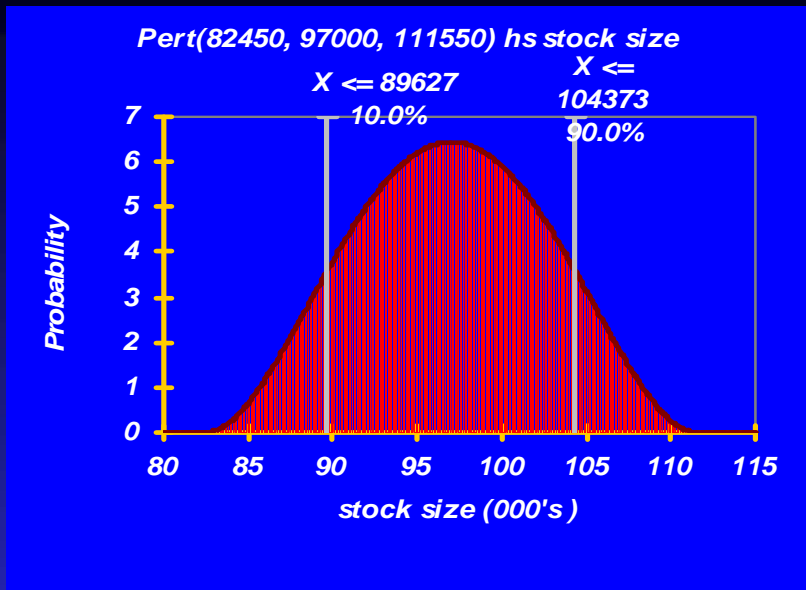
Porpoise & Dolphins

Marine Mammals

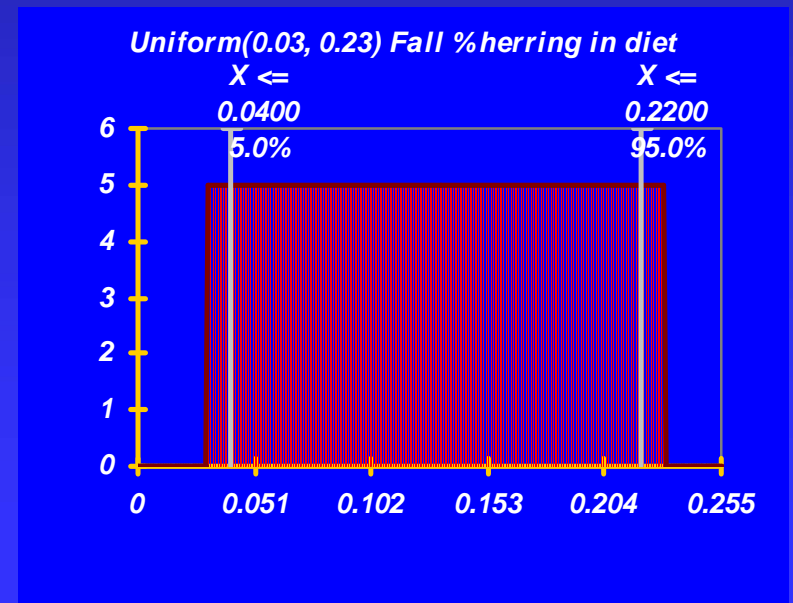
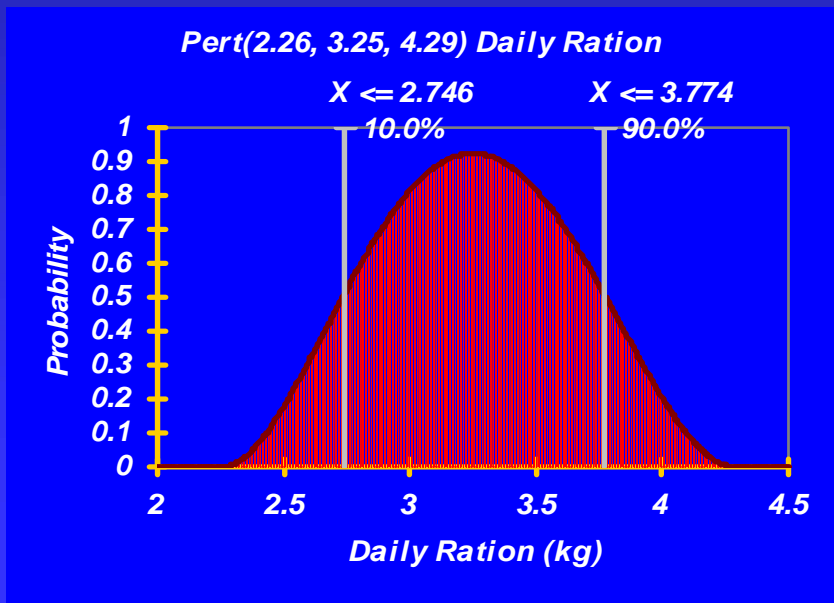
- *Fin whale*
- *Humpback whale*
- *Minke whale*
- *Pilot whale*
- *Harbor porpoise*
- *White-sided dolphin*
- *Harbor seal*
- *Gray seal*

Marine Mammals

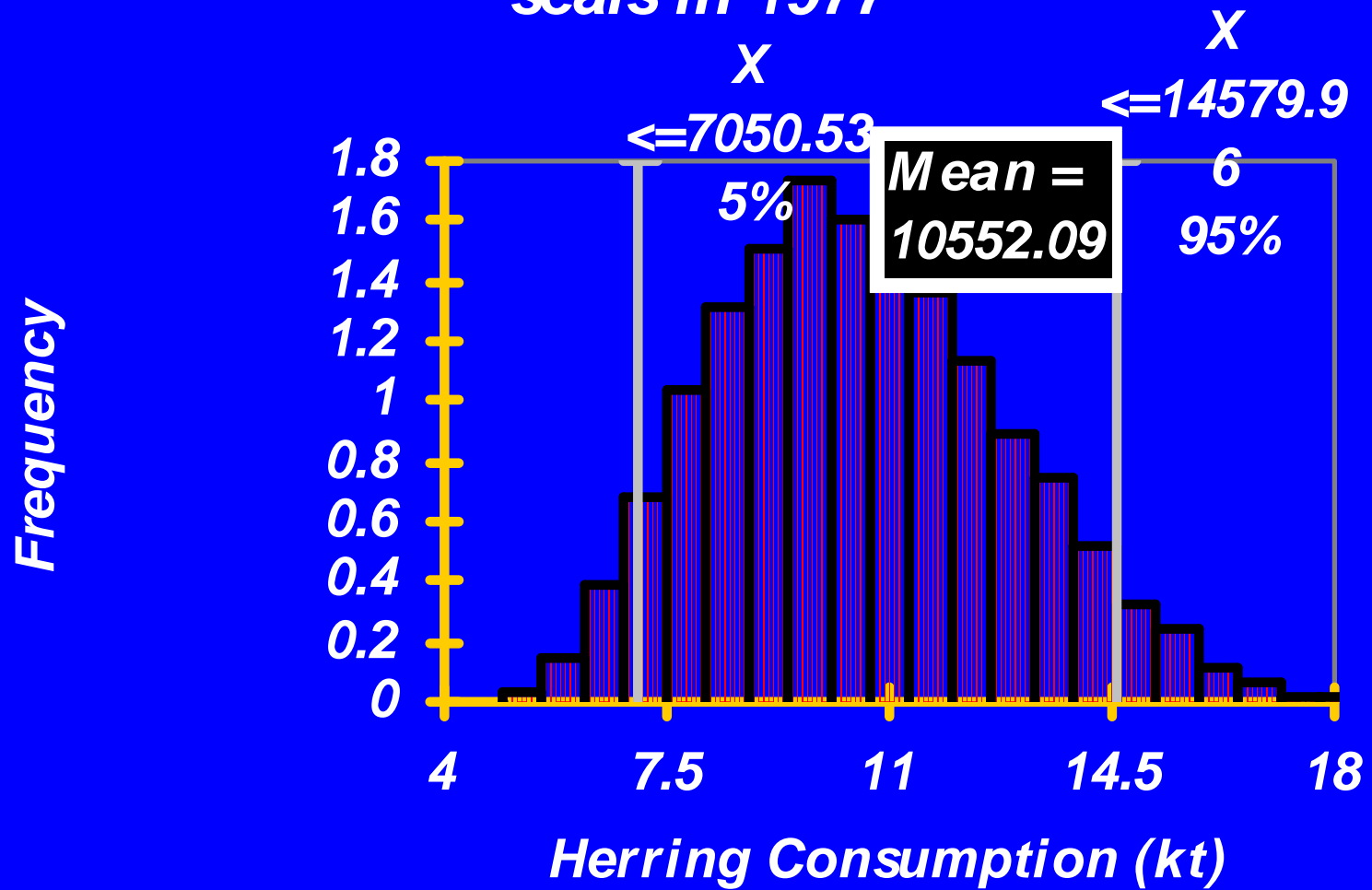
- $C = gM^u$
- *Where M is the body mass (kg) and $g=0.123$ and $u=0.80$*
- *Innes et al. (1987)*
- *Used spline smoother with available empirical information for % herring in diet*



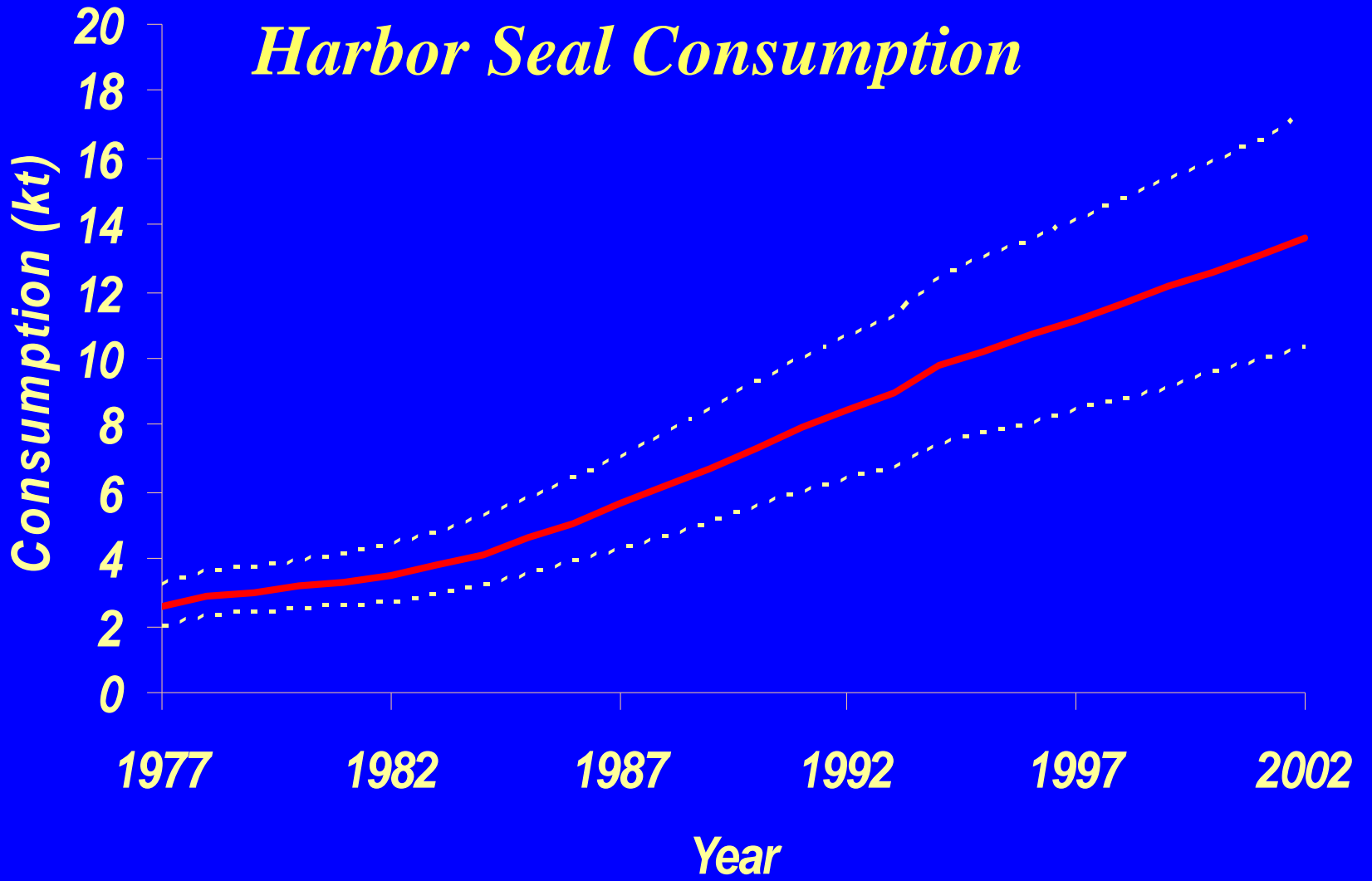
Input Distributions for Herring Consumed by Harbor Seals

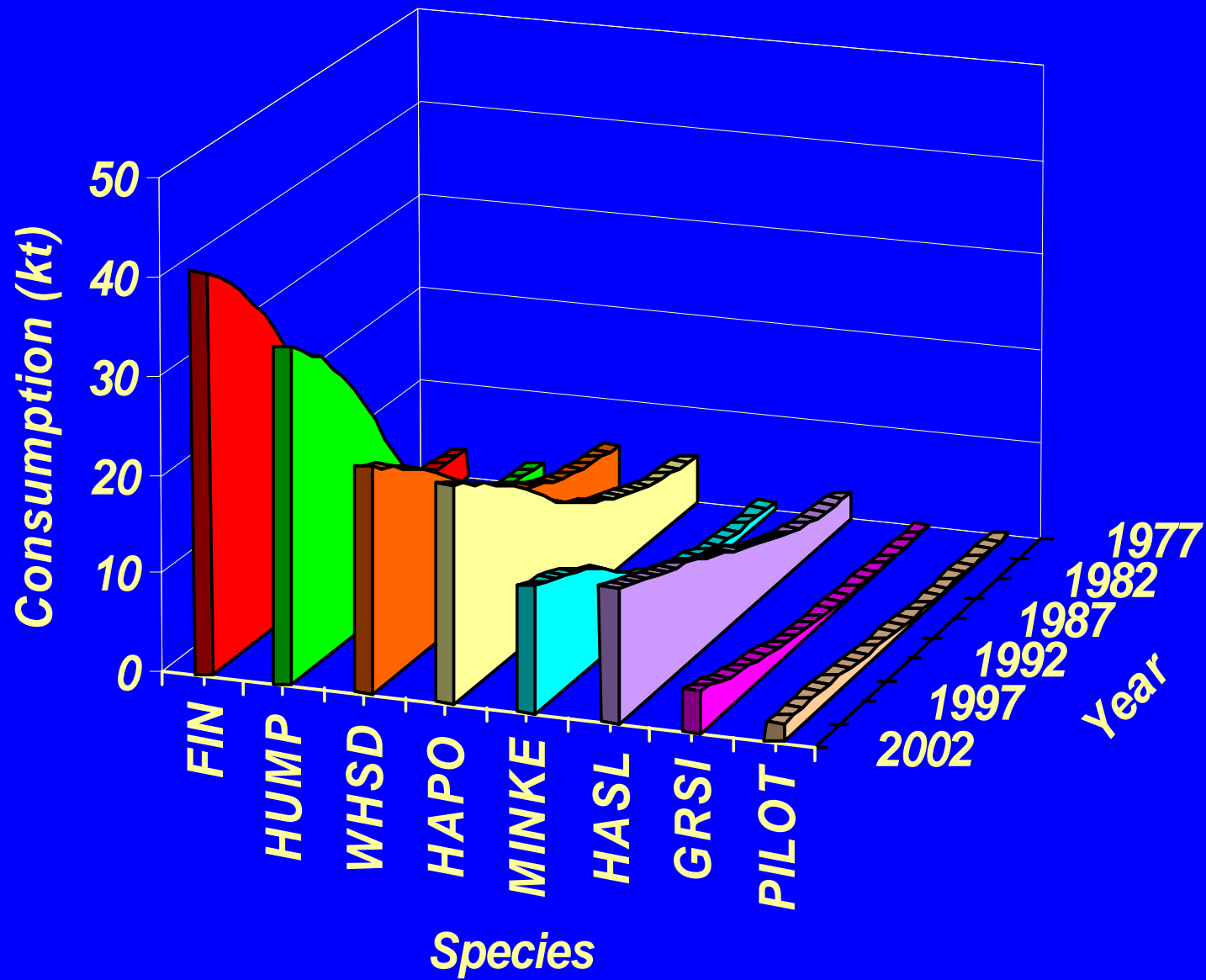


Total herring consumed by harbor seals in 1977

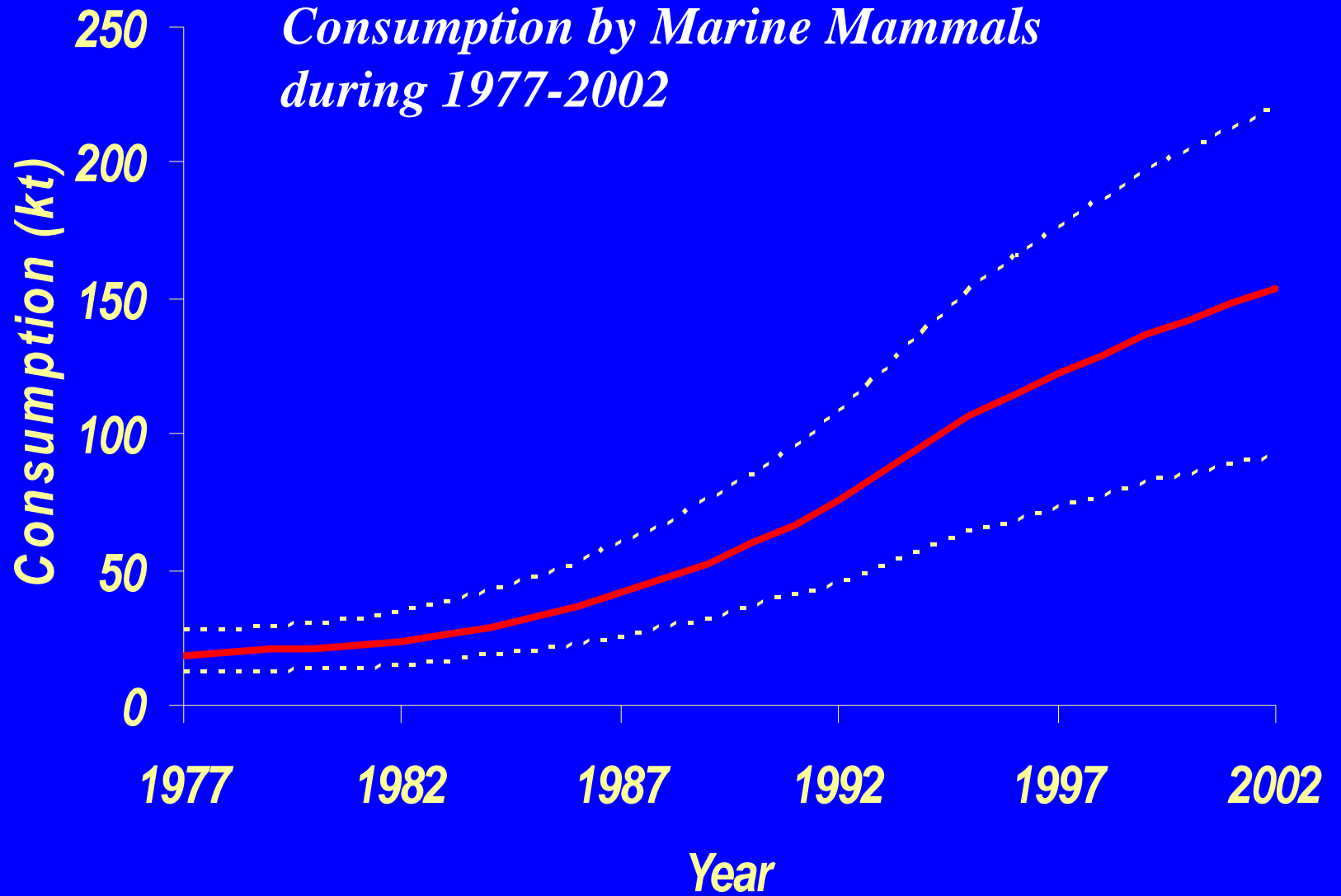


Harbor Seal Consumption





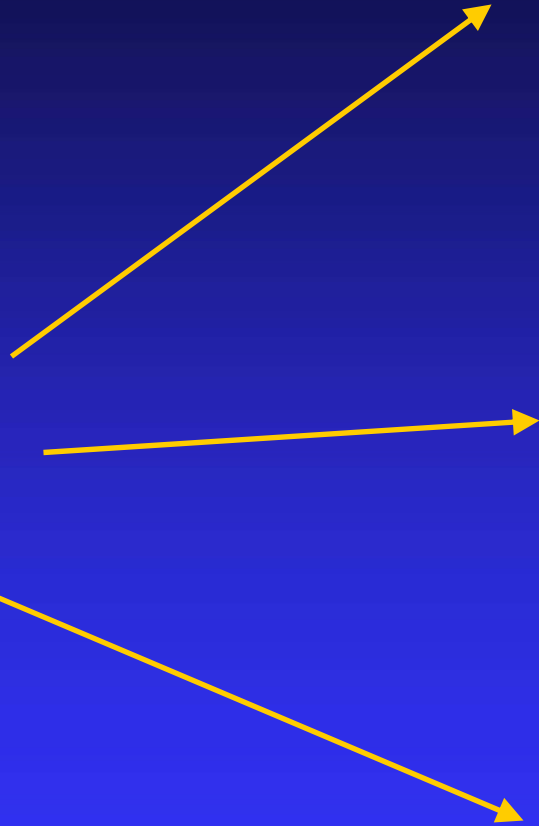
*Consumption by Marine Mammals
during 1977-2002*



Seabirds



Herring



Gannets



Shearwaters

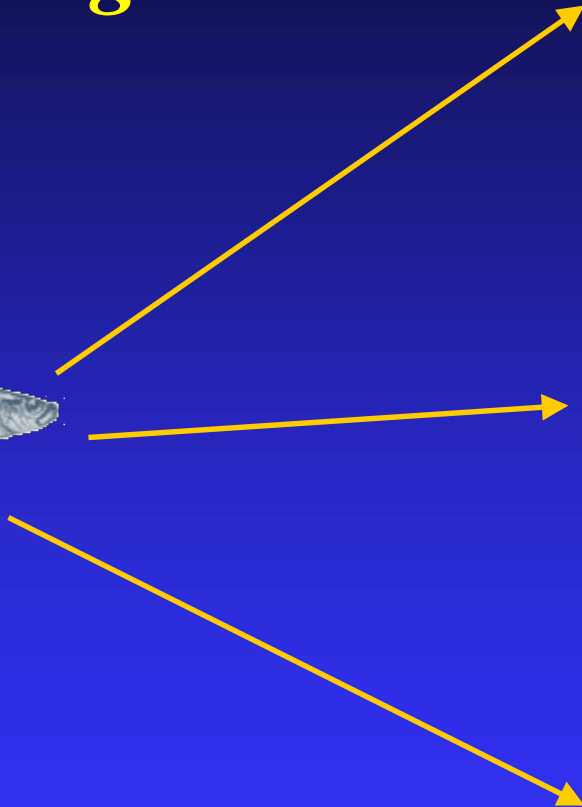


Gulls

Seabirds

- *Northern gannet*
- *Shearwater sp.*
- *Black-legged kittiwake*
- *Black-backed gull*
- *Herring gull*
- *Northern fulmar*

*Large Pelagic
Fish*



Bluefin Tuna

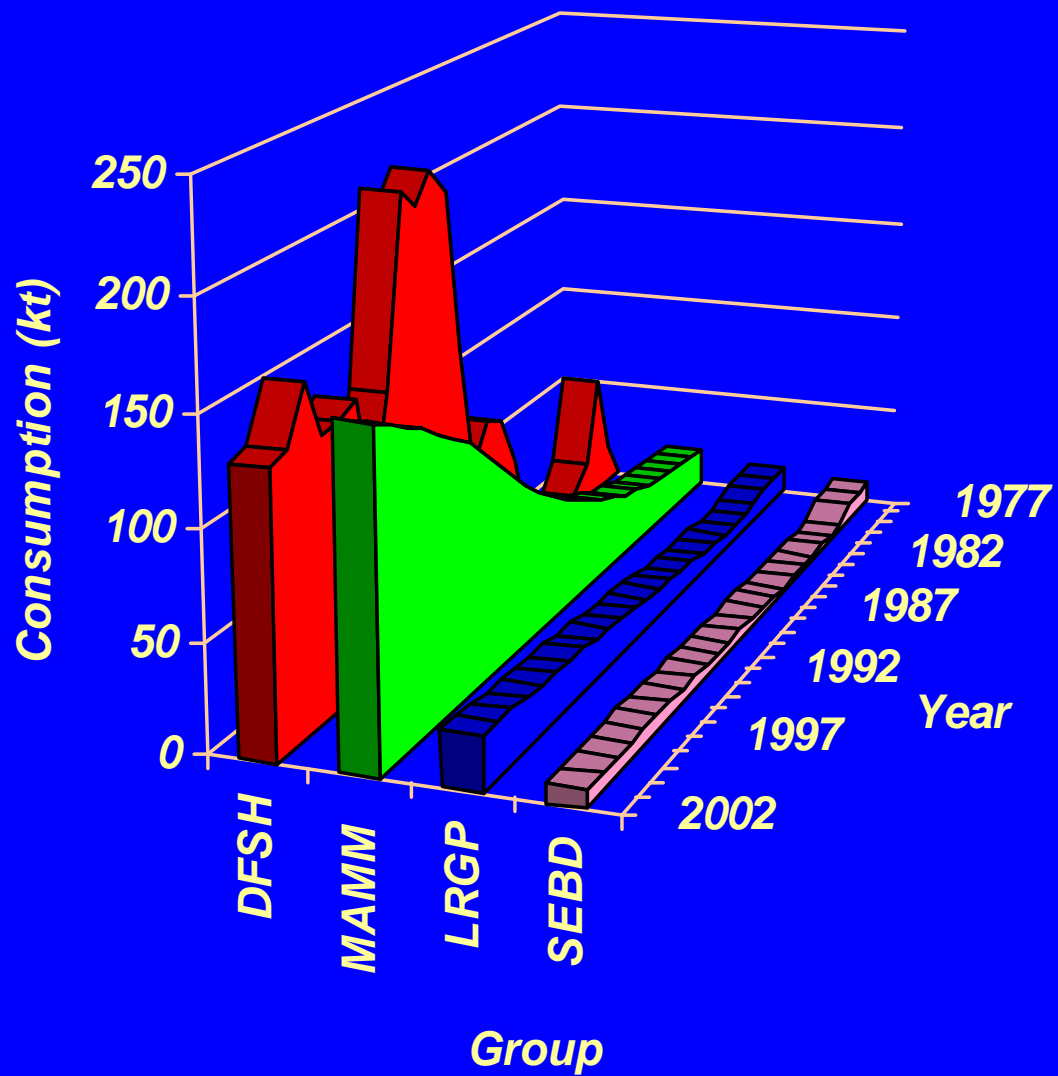


Mako Shark

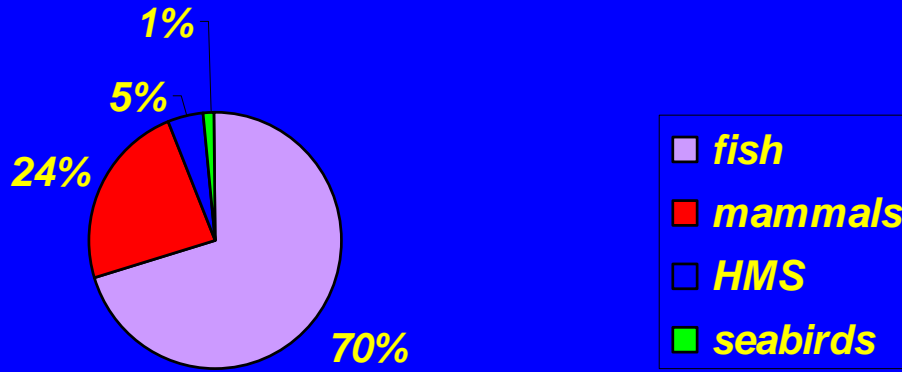


Blue Shark

Consumption of Herring by Predator Group

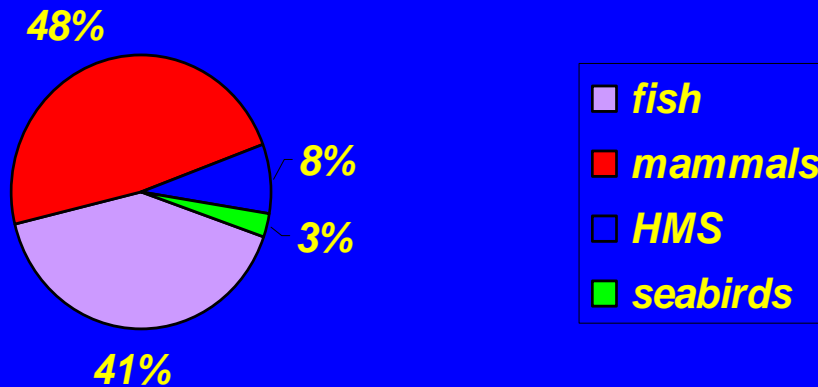


Herring Consumption by Group (1991)



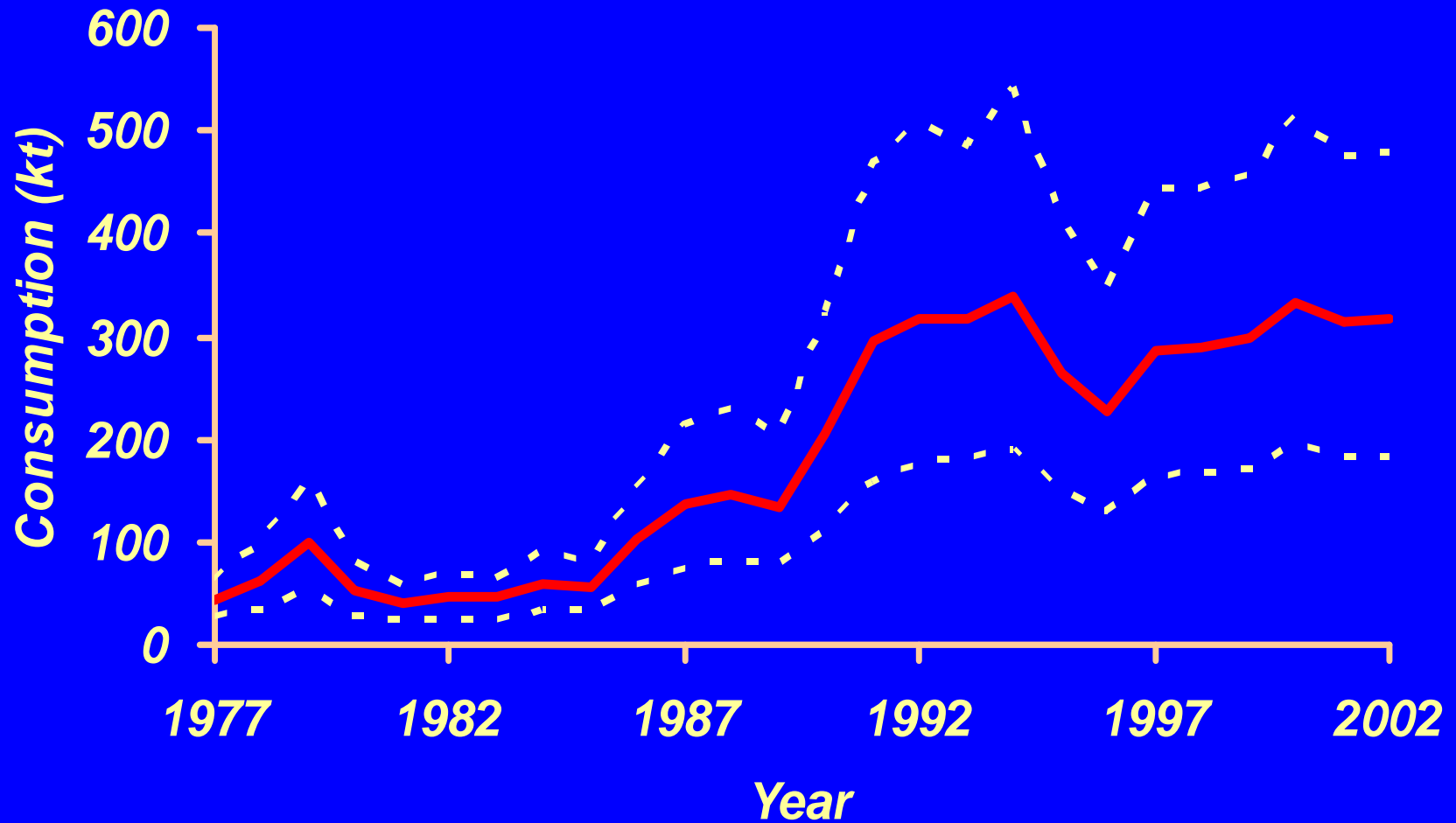
1991- most of the consumption by D-fish

Herring Consumption by Group (2002)



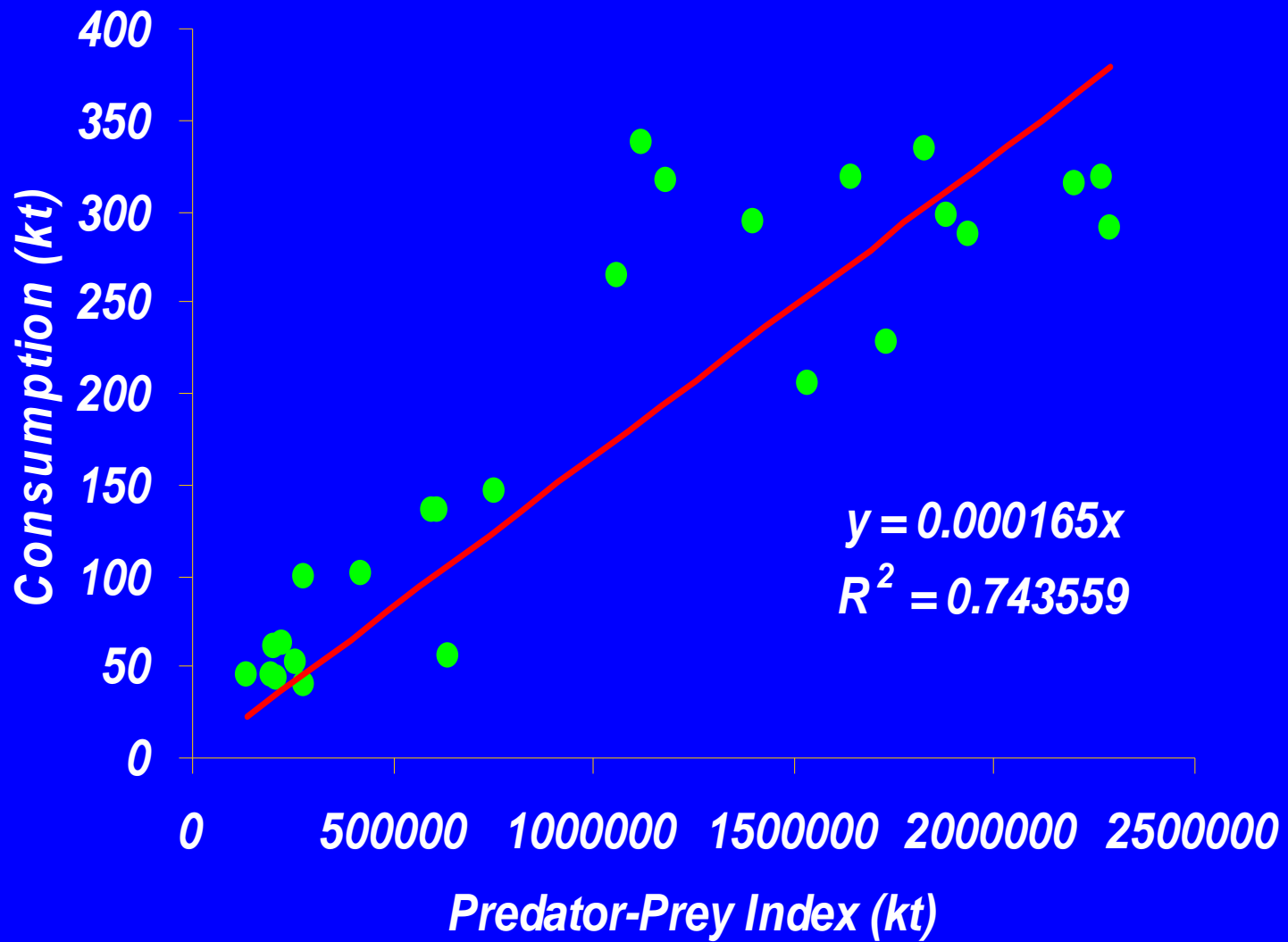
2002-even mix of consumption by mammals and D-fish

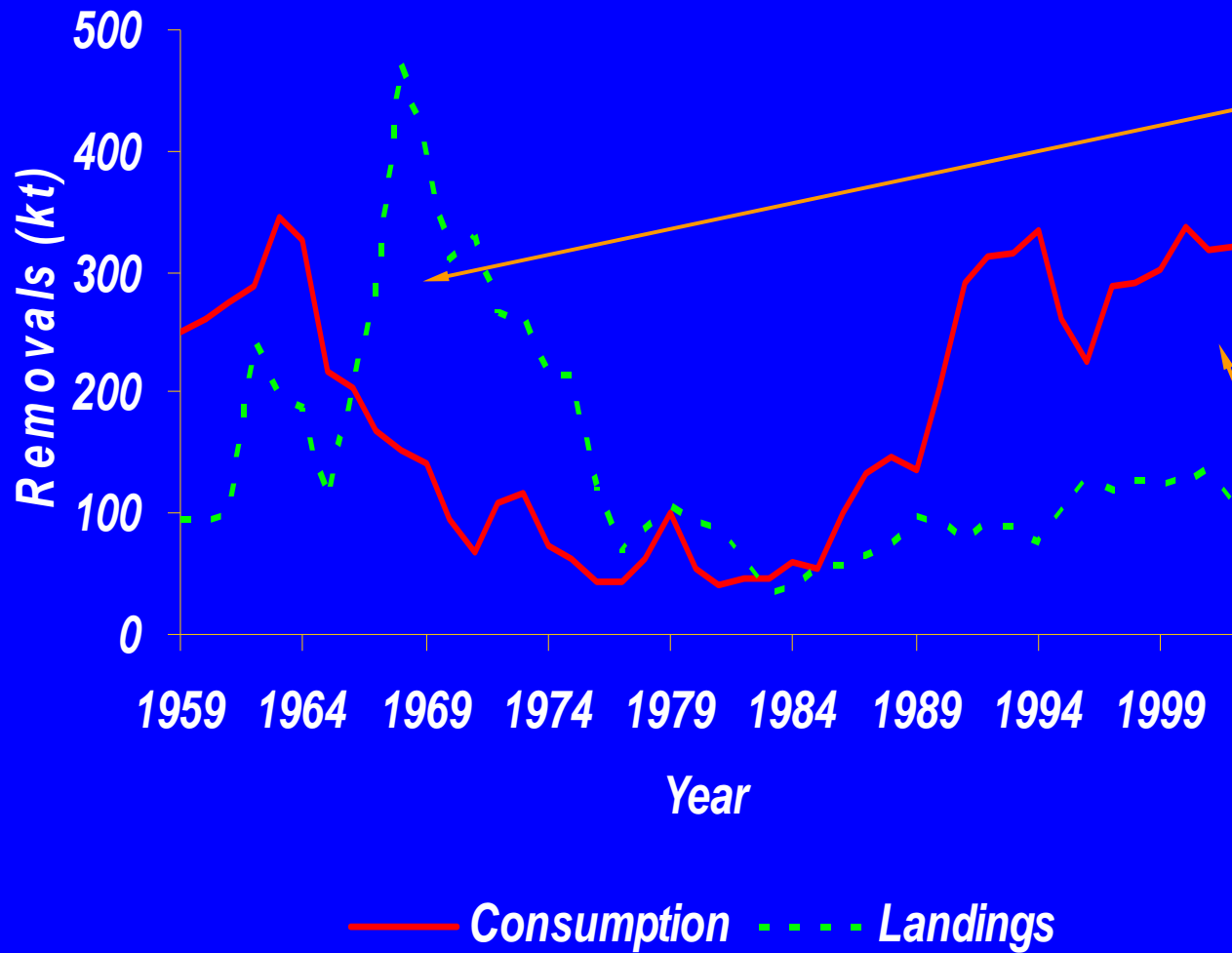
Total Consumption (80% CI) of Herring by Predators 1977-2002



An Ecosystem Assessment of Atlantic Herring

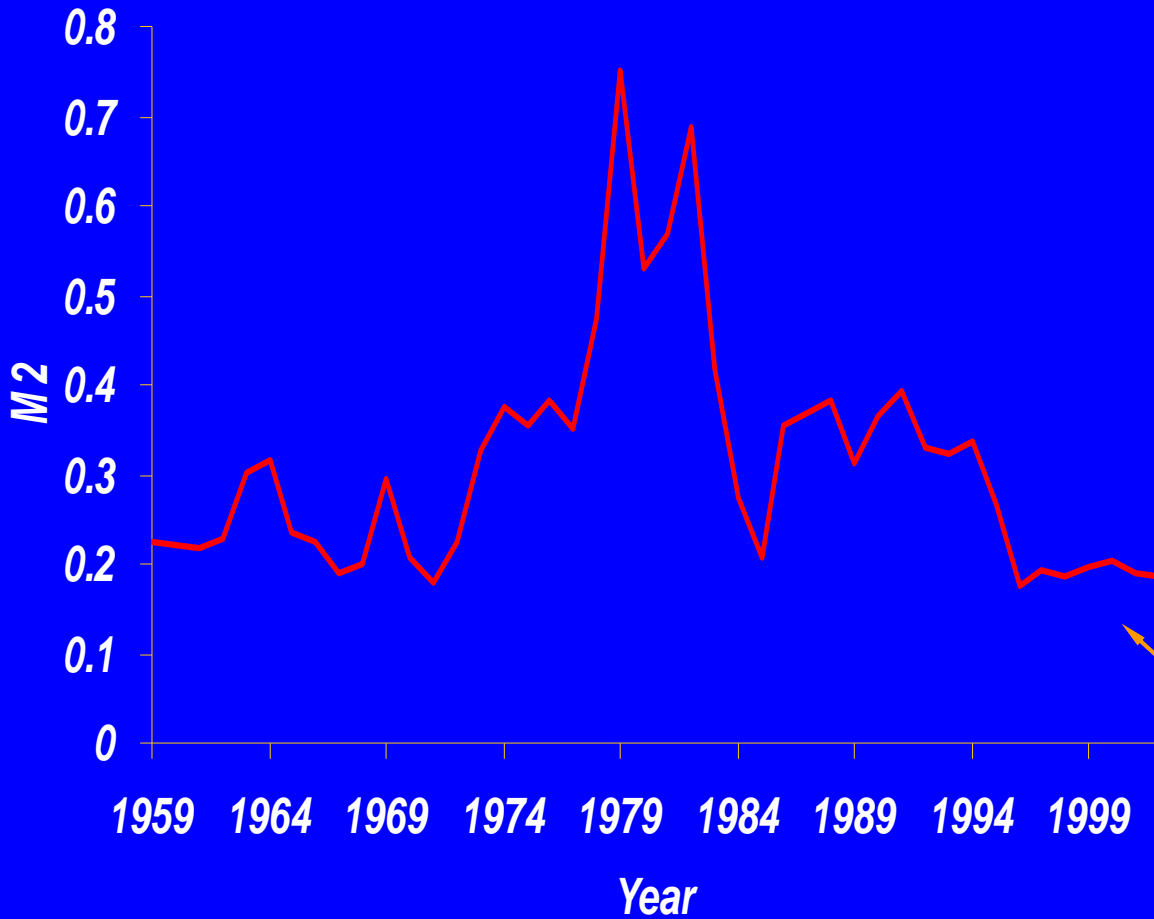
- *Incorporate Predation into Assessment Models ($Z=M1+M2+F$)*
- *Used Delay-Difference Model*
- *Assess Impacts of Predators*
- *Predict Fishery Yield from Predator Mediated System*





Total Removals during the late 1960s early 1970s were very large

More recently predators removed about 3X the fishery!

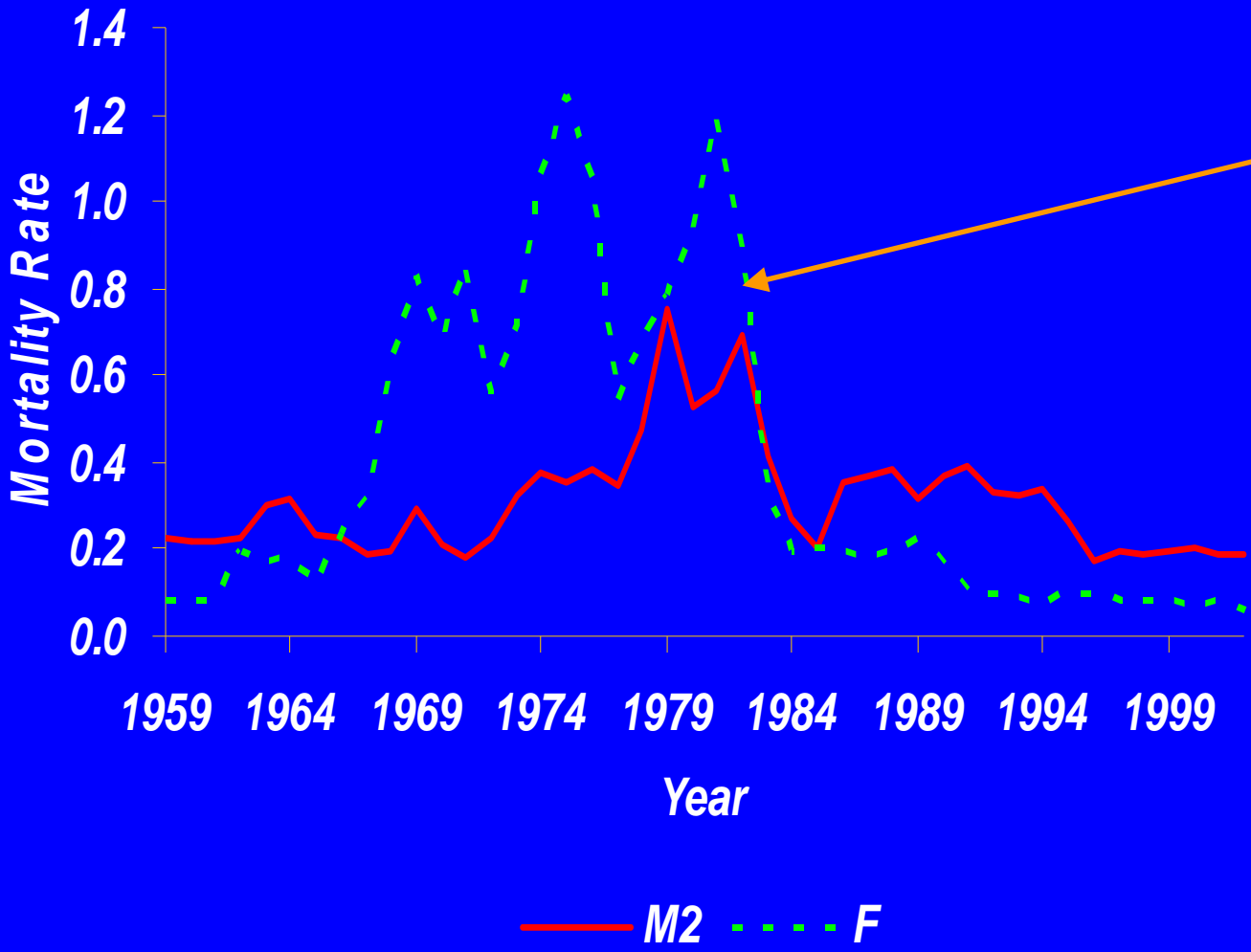


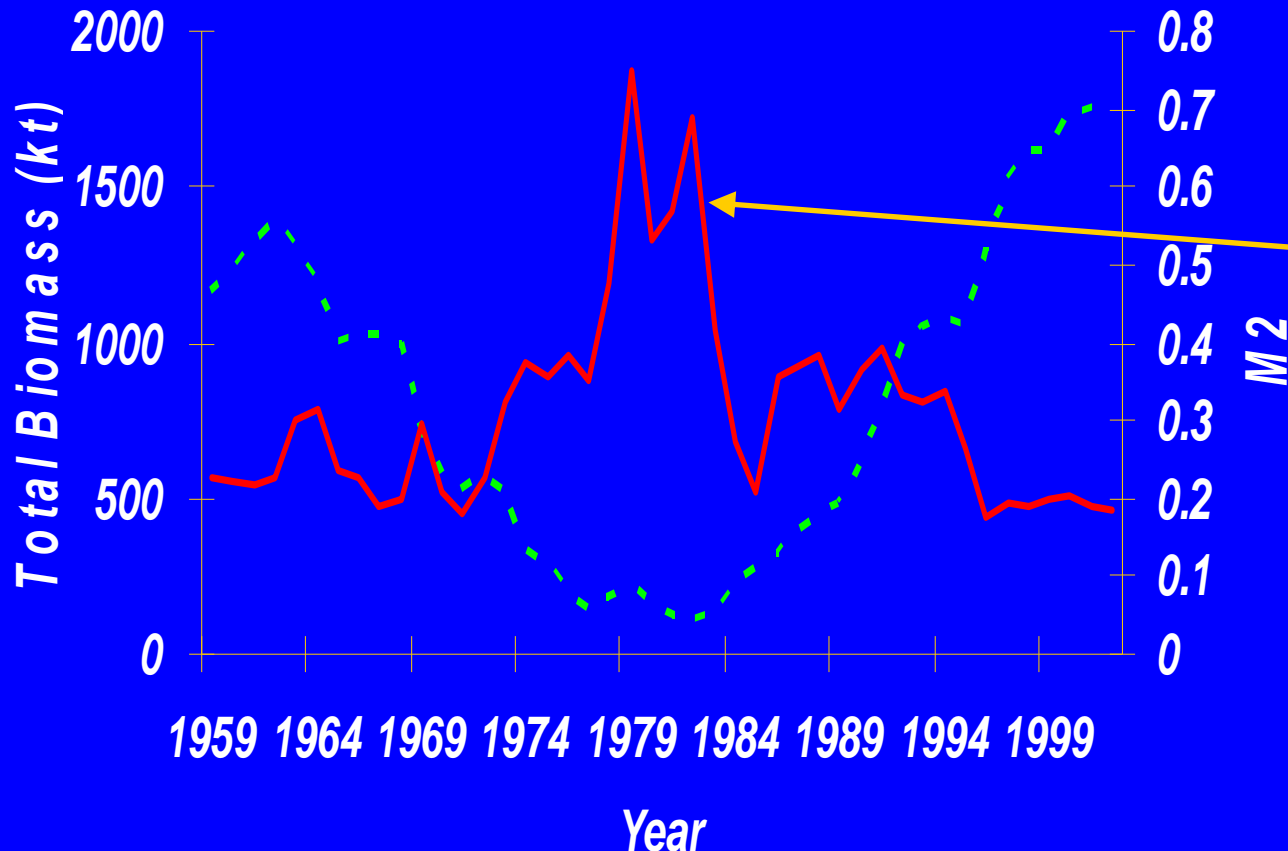
• *M2's are Time Variant*

• *Rates are Prey, Predator, and Fishery Dependent*

Current M2 relatively low < 0.2

Predators and Fishery combined to cause stock decline and slow recovery





- - - TotalBiom
 — M2

M2 was at its highest when herring biomass was the lowest

BRPs & Long-Term Yield

<i>BRP</i>	<i>No Predation</i>	<i>Include Predation</i>
<i>MSY *</i>	<i>222,000</i>	<i>528,000</i>
<i>Bmsy</i>	<i>896,000</i>	<i>1,452,000</i>
<i>Fmsy *</i>	<i>0.25</i>	<i>0.36</i>

Fishery Yield

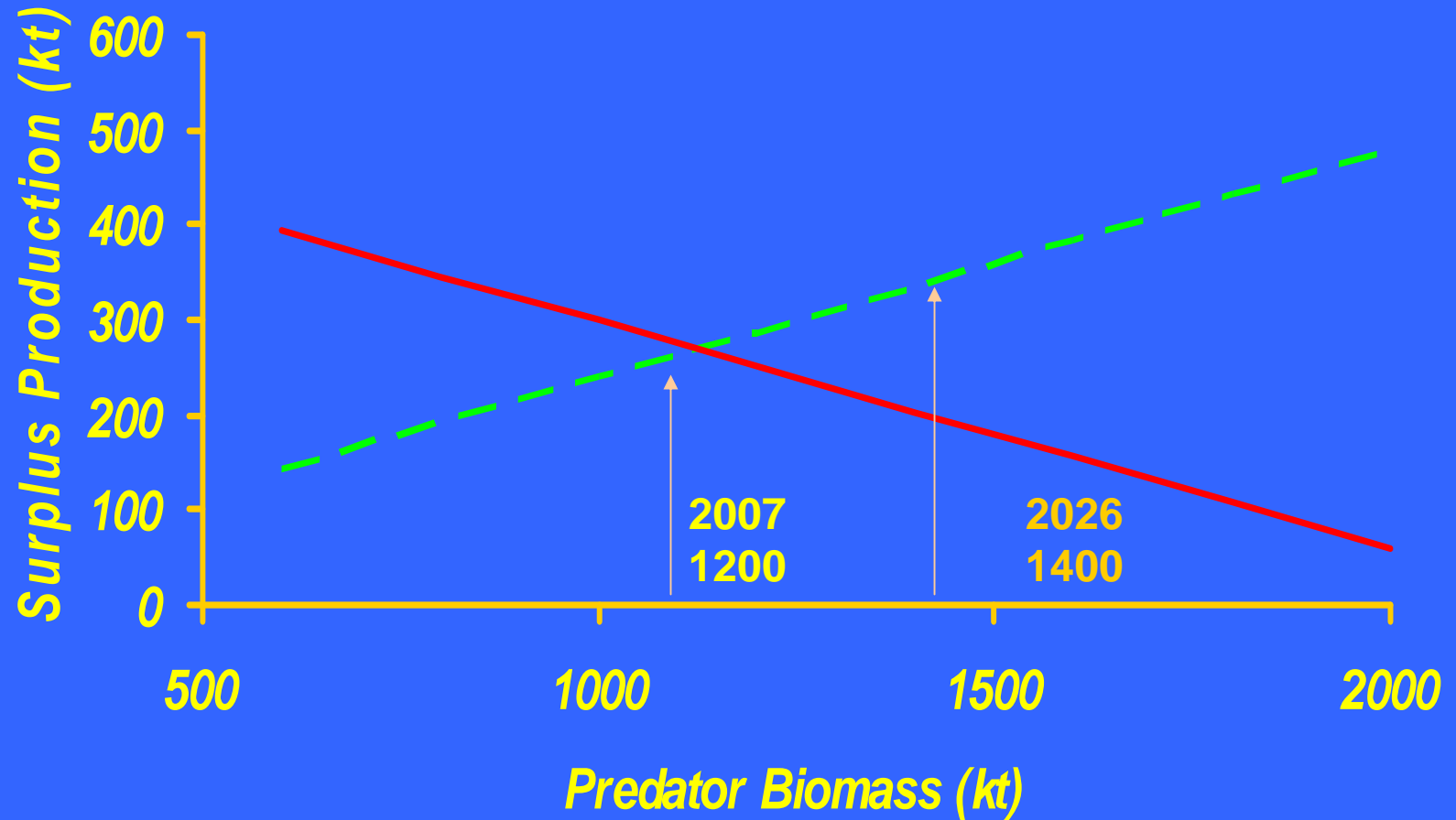
- *Empirical*
- *Predator Allocation:*
- *Recent 275-300 future 350*
- *$528-350=178,000$ mt*
- *Average Proportion:*
- *M2 has averaged 0.25 (85-02)*
- *$.25/.36=.694 * 528 = 362.64$*
- *$528-362.64=165,000$ mt*
- *Analytical*
- *New Fox Model*
- *Overall Biological Surplus = 528,000 mt*
- *SP =156,000-251,000 mt*

<i>predator</i>	<i>SP-predator</i>	<i>SP-fishery</i>
600	144	395
800	192	347
1000	240	299
1200	287	251
1400	335	204
1600	383	156
1800	431	108
2000	479	60

If predators increase, less fishery SP would be available

At Bmsy=1452 kt

Predator vs Fishery Tradeoff



At Bmsy=1452 kt

— — *SP-pred* — — *SP-fishery*

Conclusions

- *Predation impacts are often larger than landings*
- *Enhanced risk of major stock decline at high F 's*
- *Predation mortality (M_2) should be included in stock assessments of prey fish.*
- *SS assessments of prey fish can be optimistic relative to BRPs*
- *If the fishery and predators utilize the same size spectrum of prey, then tradeoffs are probably warranted.*