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

By

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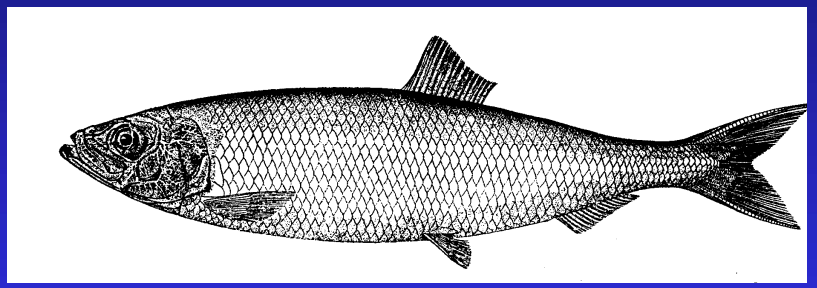

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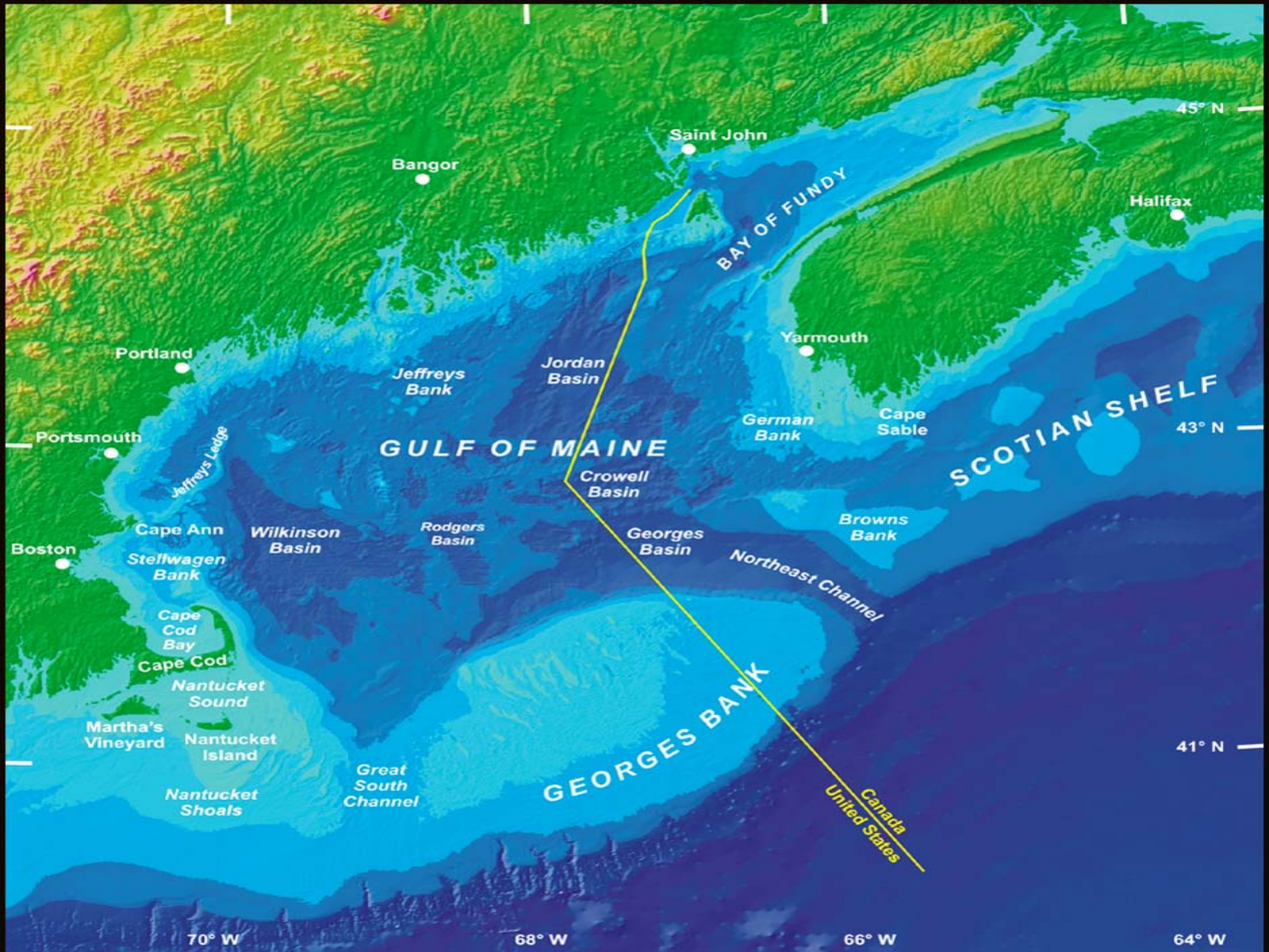

45° N
Saint John
Bangor
BAY OF FUNDY
Halifax
Yarmouth
Portland
Jeffreys Bank
Jordan Basin
German Bank
Cape Sable
SCOTIAN SHELF
43° N
Portsmouth
GULF OF MAINE
Jeffreys Ledge
Crowell Basin
Cape Ann
Wilkinson Basin
Rodgers Basin
Georges Basin
Browns Bank
Boston
Stellwagen Bank
Northeast Channel
Cape Cod Bay
Cape Cod
Nantucket Sound
Martha's Vineyard
Nantucket Island
GEORGES BANK
41° N
Great South Channel
Nantucket Shoals
Canada
United States
70° W
68° W
66° W
64° W

Objectives for an Ecosystem Based Assessment for GOM-GB Herring

- *Estimate the Total Consumption of Herring by Predator Groups*
- *Estimate Predation Mortality (M2) 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

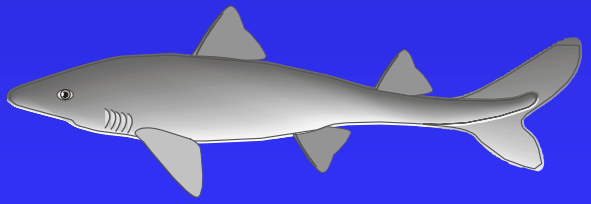
Seabirds

Medium Demersal Fishes

Herring

Cod

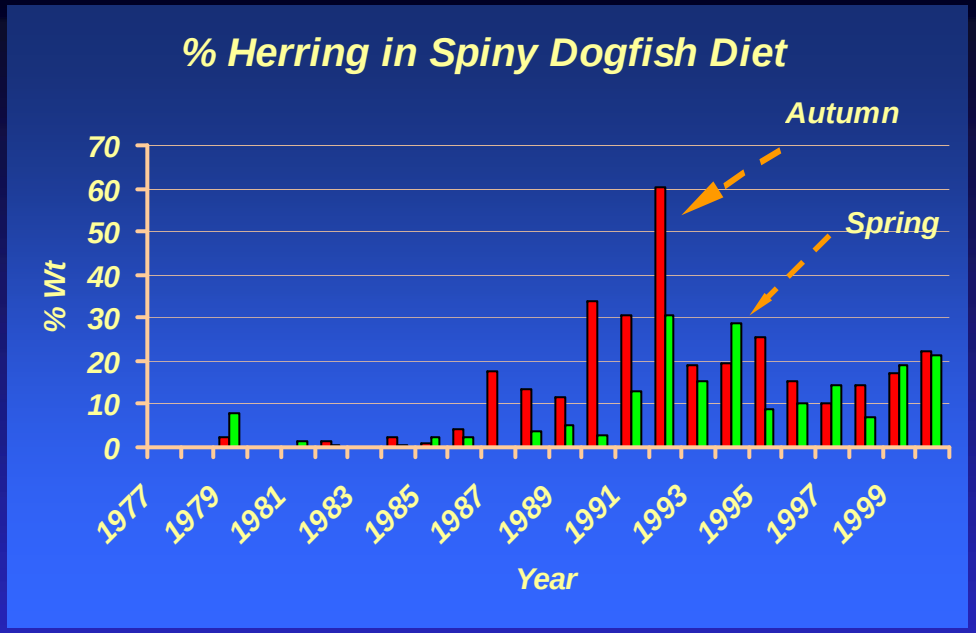
Silver Hake

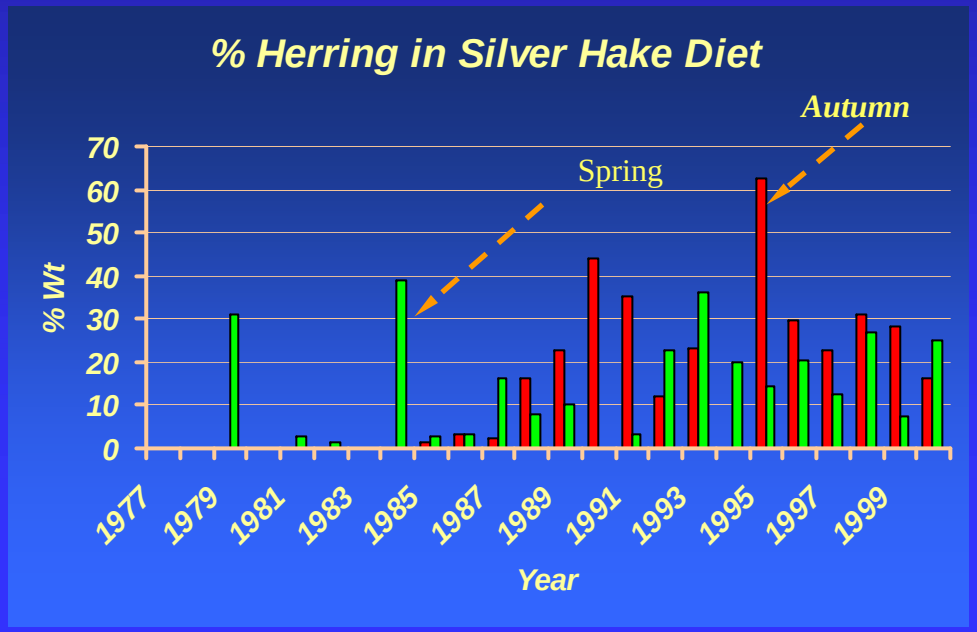


Dogfish

Medium Demersal Fish

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

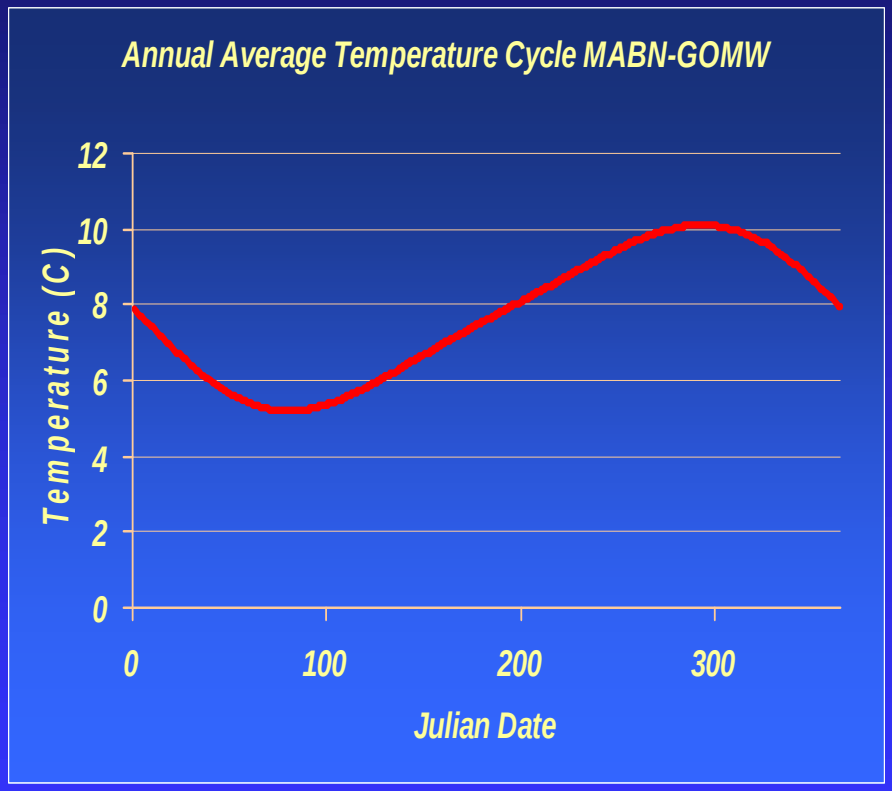




When Herring Began to Recover in the Late 1980s, Predators Increased the % Herring in Their Diet.

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*

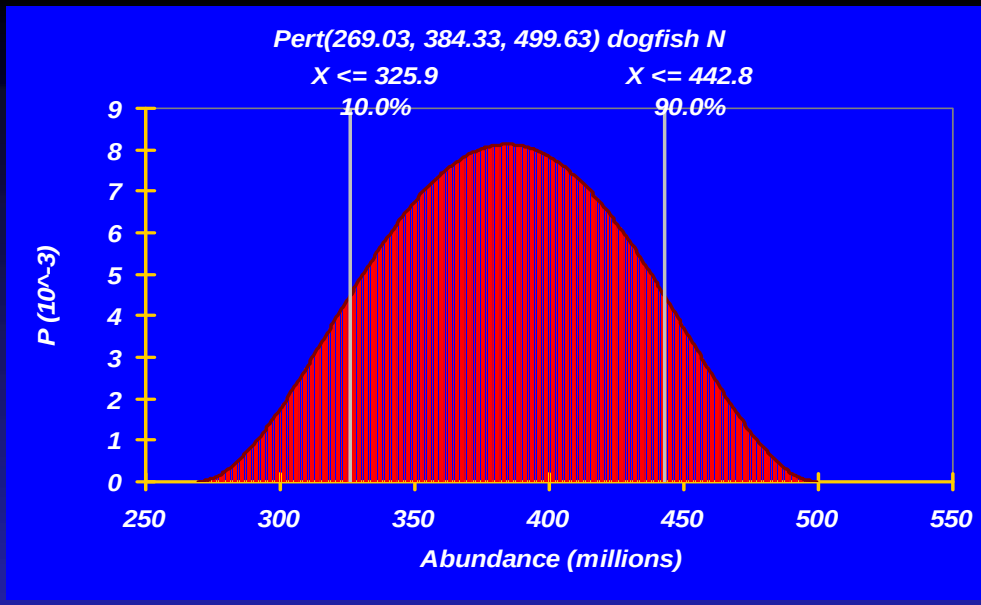


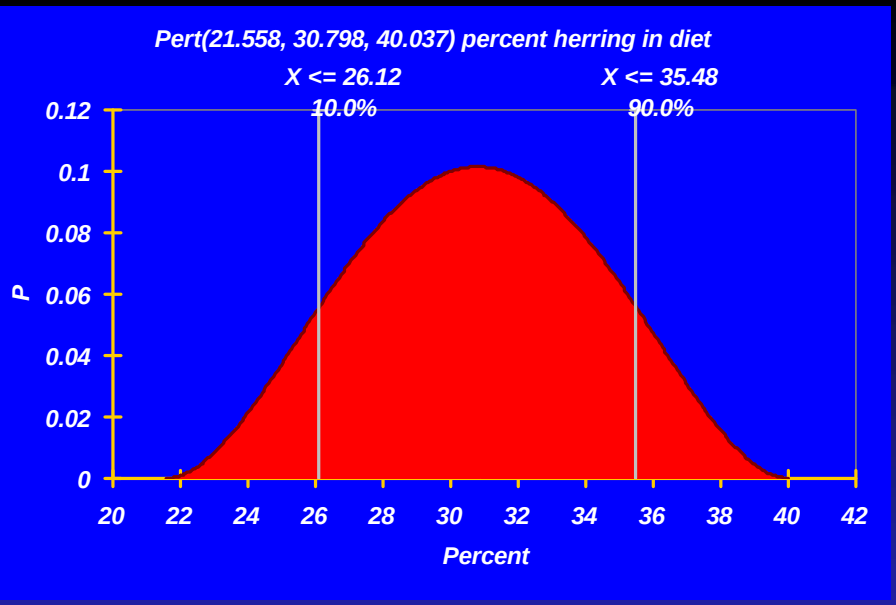
Uncertainty Framework for Consumption Estimates

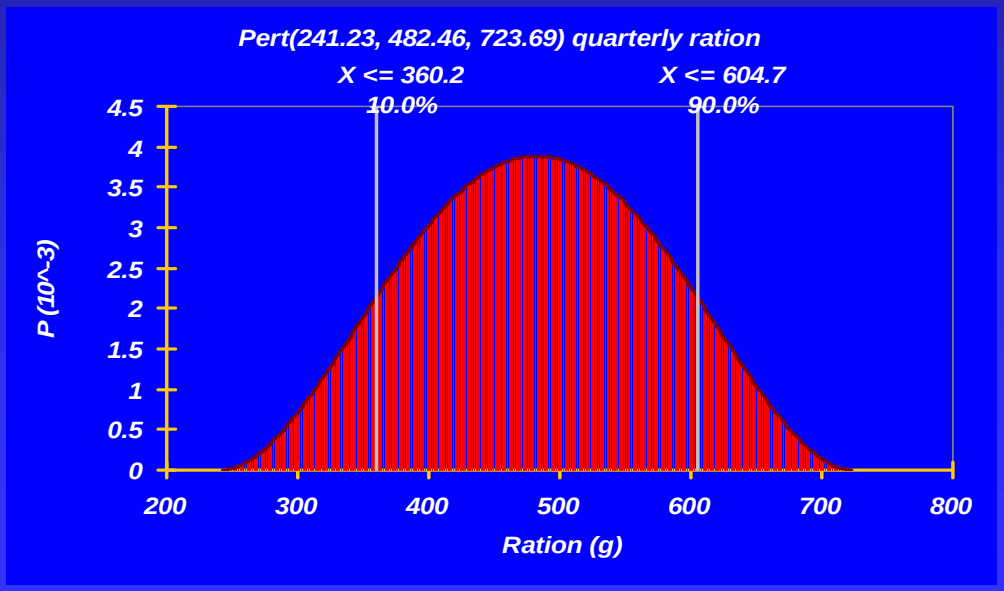
- ***@RISK software (Shelton et al. 1997)***
- ***Empirical data or literature values for parameters***
- ***Available CV's or 30-50%***
- ***Uniform or Pert distributions***
- ***Monte Carlo simulation, 5000 draws***
- ***Sensitivity analysis and CI envelopes***

Uncertain Parameters

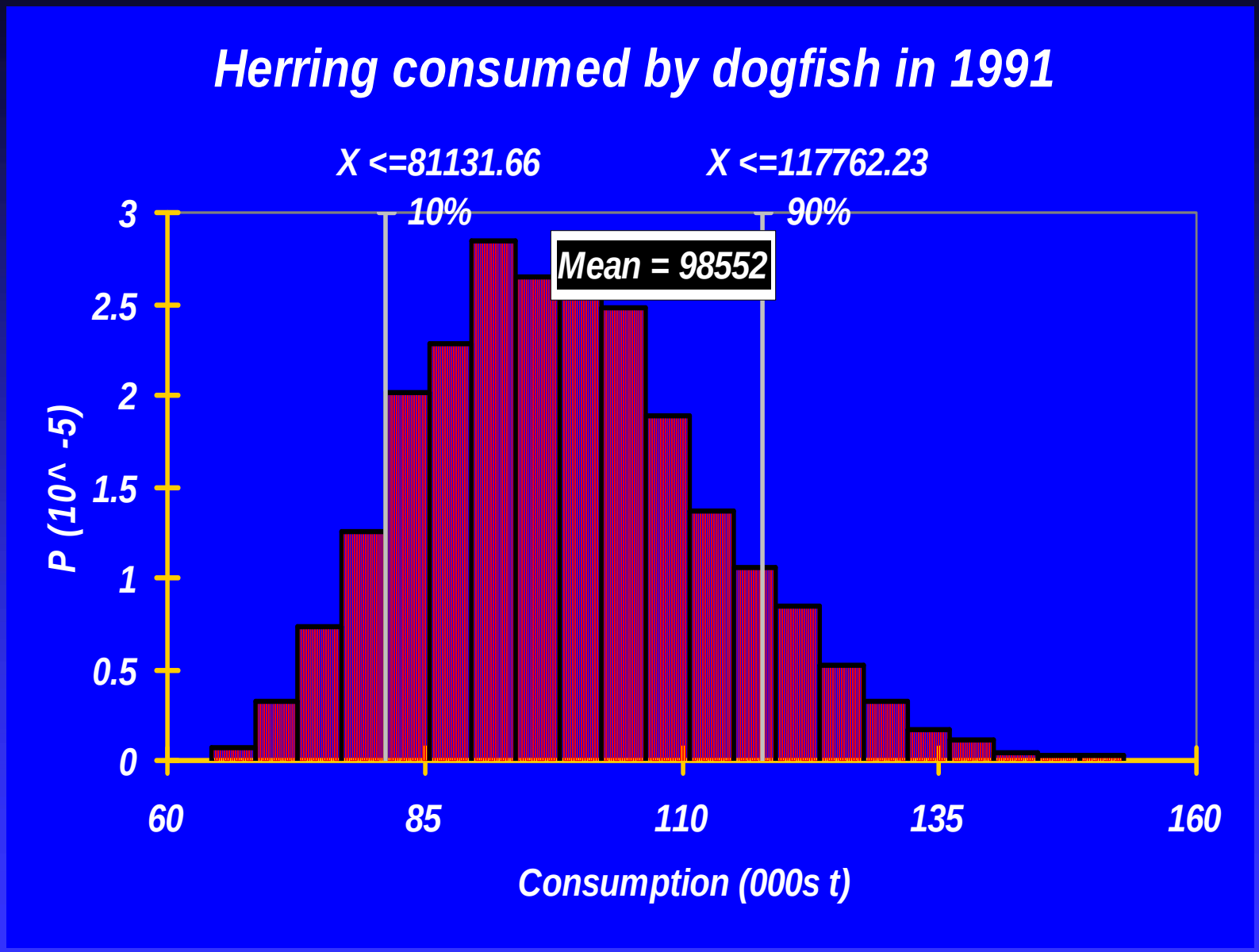
- *population size of predator*
- *residence time*
- *daily ration*
- *% herring in diet*



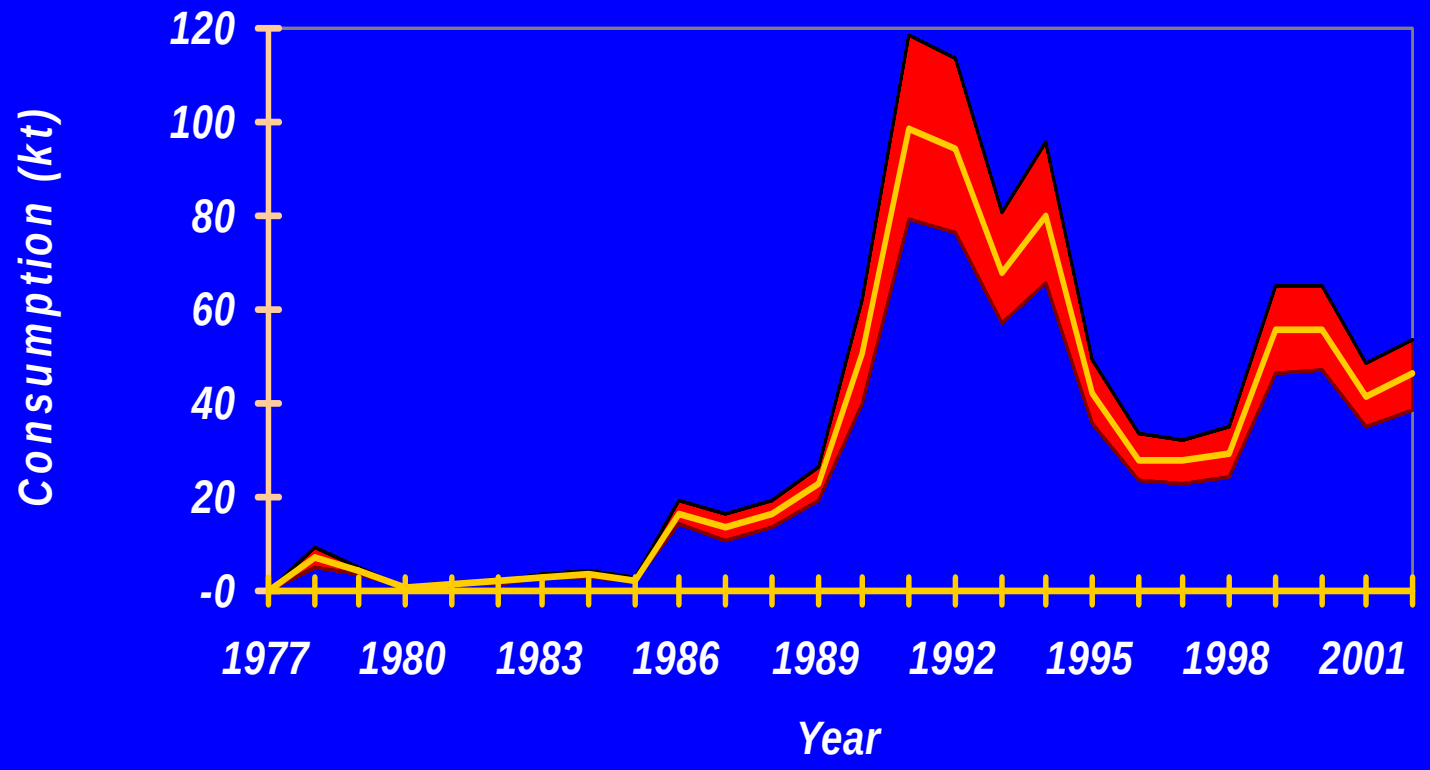




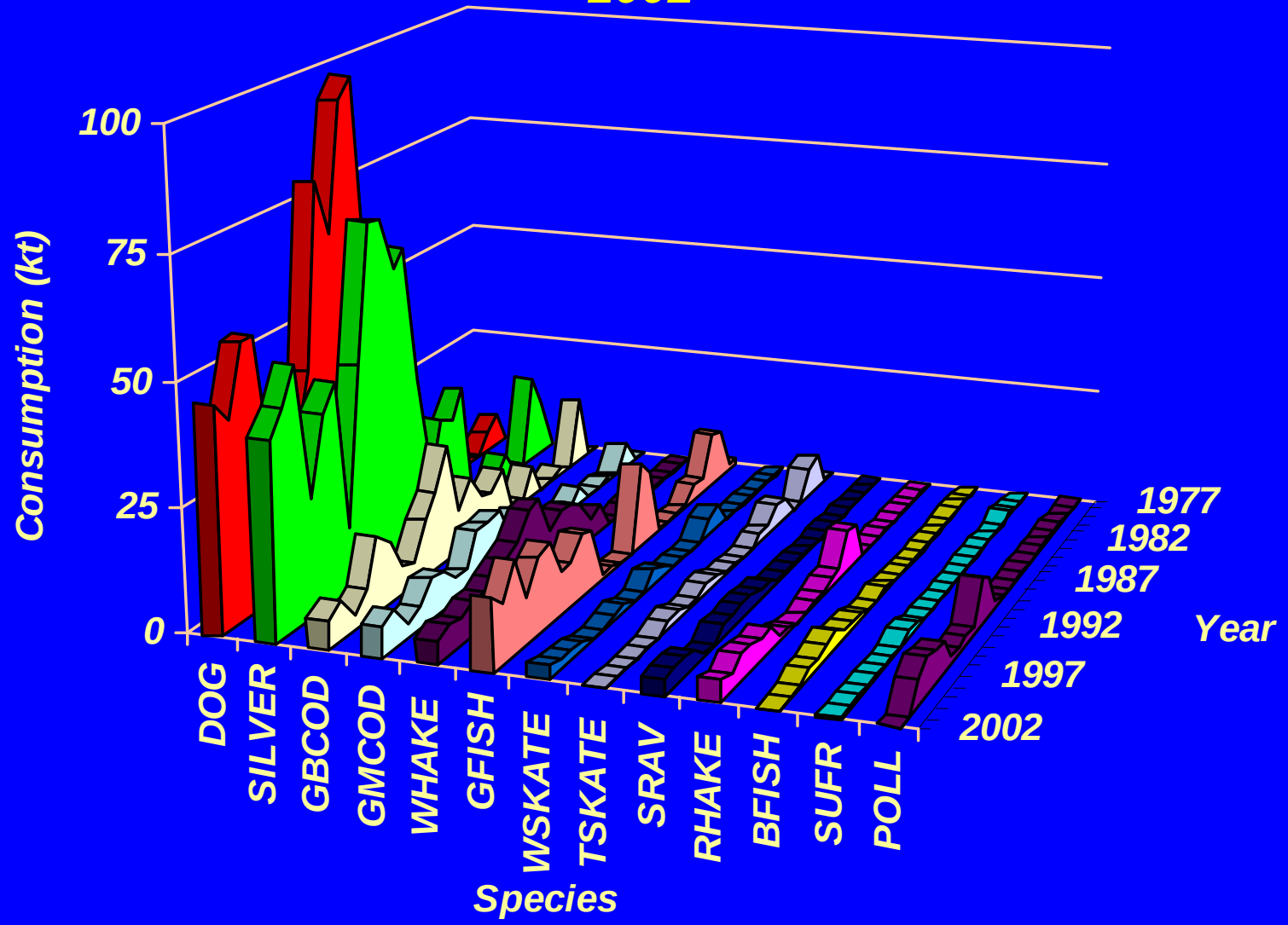
Input Distributions for Herring Consumed by Dogfish

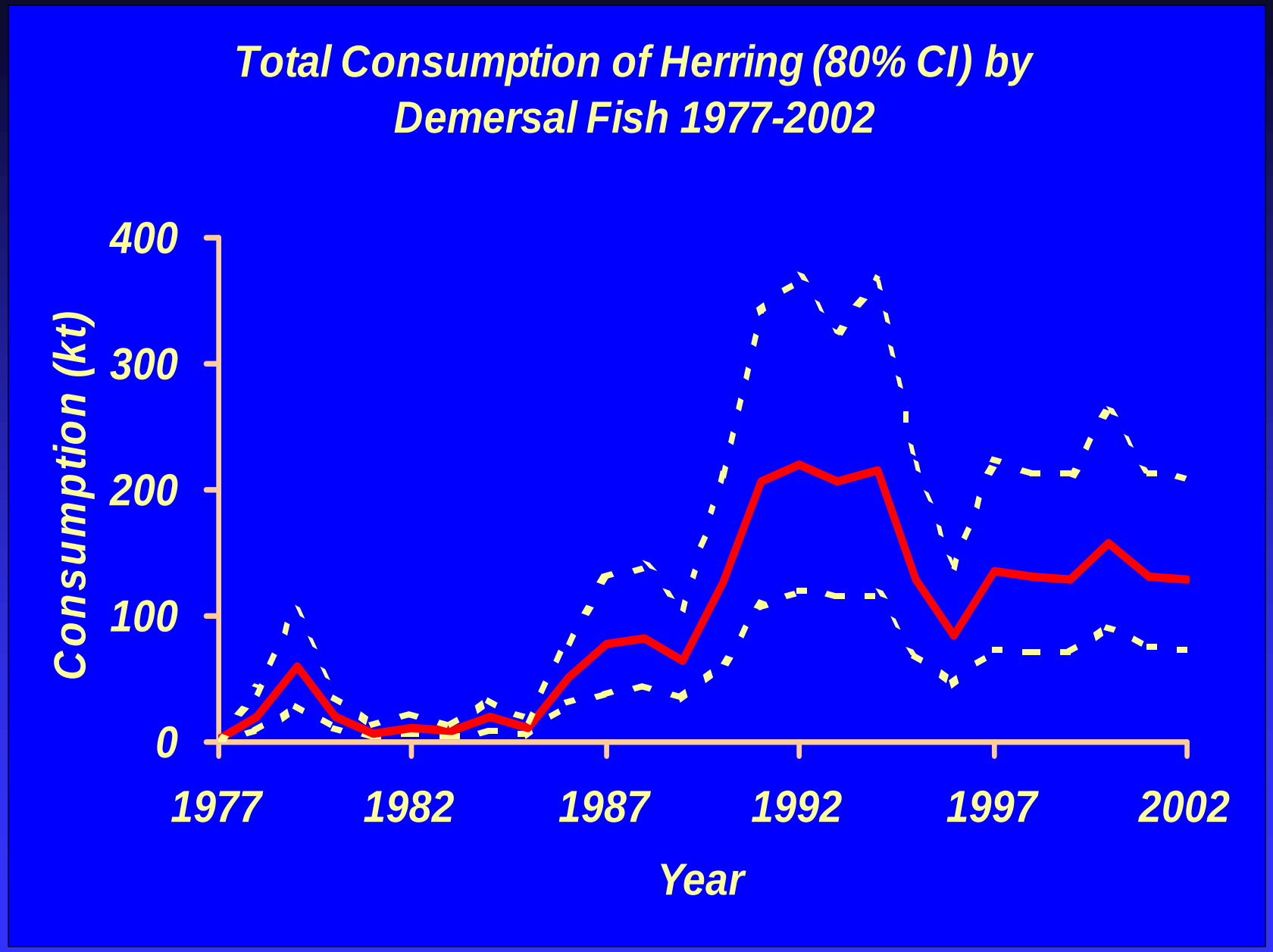

Herring consumed by dogfish in 1991
X <=81131.66
10%
X <=117762.23
90%
Mean = 98552
P (10^ -5)
3
2.5
2
1.5
1
0.5
0
60
85
110
135
160
Consumption (000s t)

herring consumed by dogfish during 1977-2002

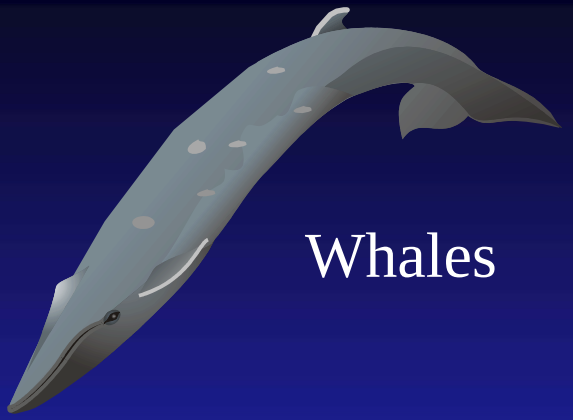


Consumption of Herring by Demersal Fish 1977-2002



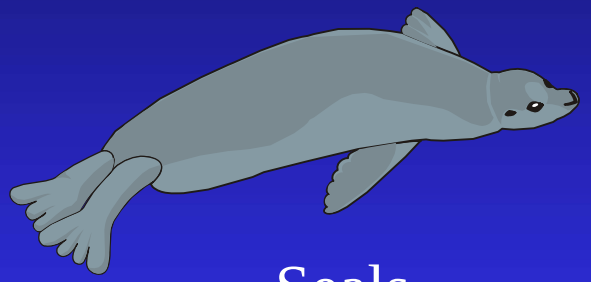

Total Consumption of Herring (80% CI) by Demersal Fish 1977-2002
Consumption (kt)
400
300
200
100
0
1977
1982
1987
1992
1997
2002
Year

Marine Mammals



Whales

Herring



Seals

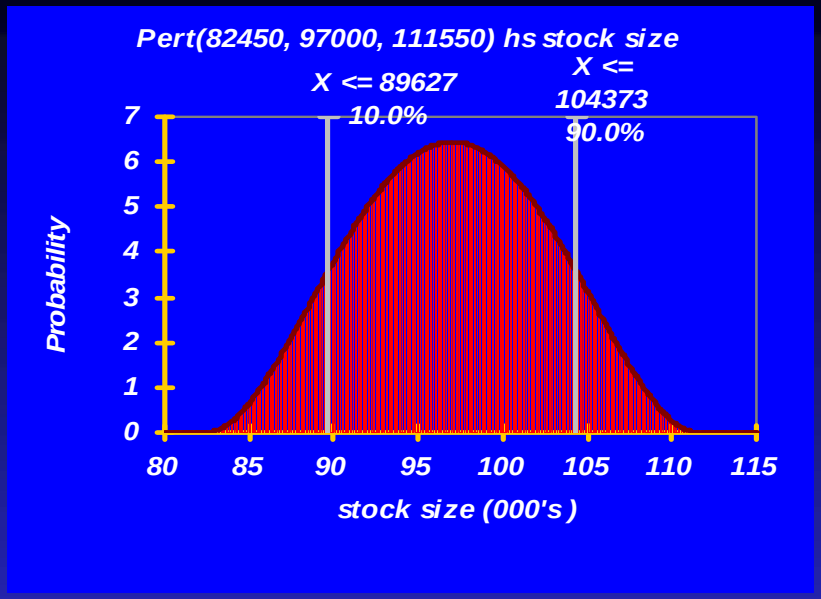
Porpoise & Dolphins

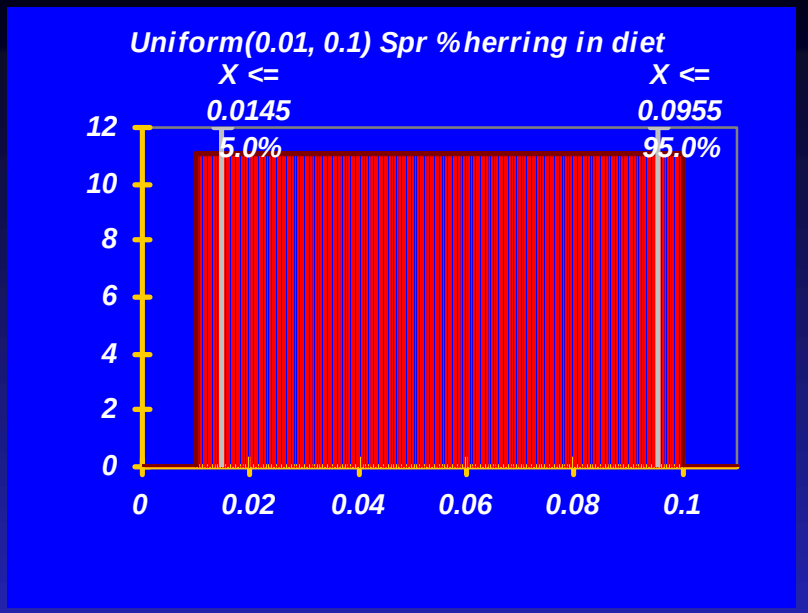
Marine Mammals

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

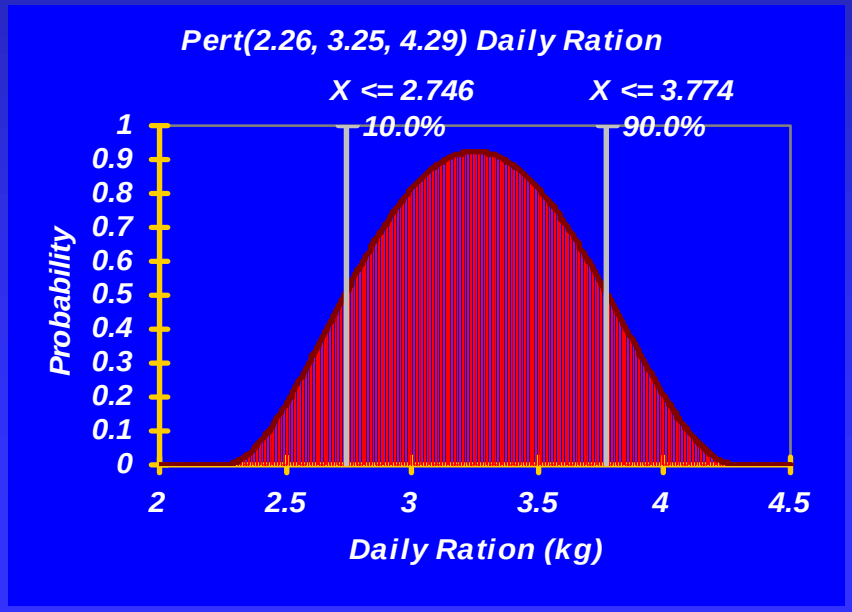
Marine Mammals

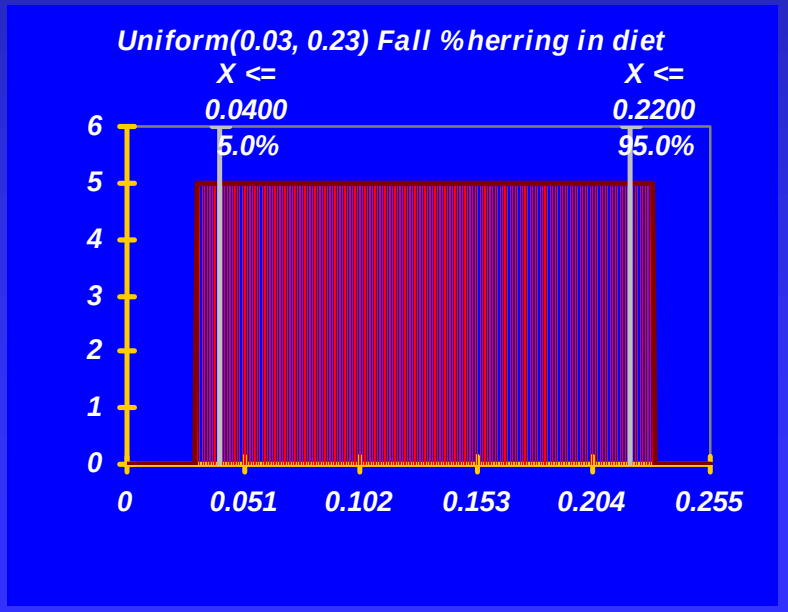
- $C = gM^u$
- *Where M is the body mass (kg) and g=0.123 and u=0.80*
- *Innes et al. (1987)*
- *Used spline smoother with available empirical information for % herring in diet*

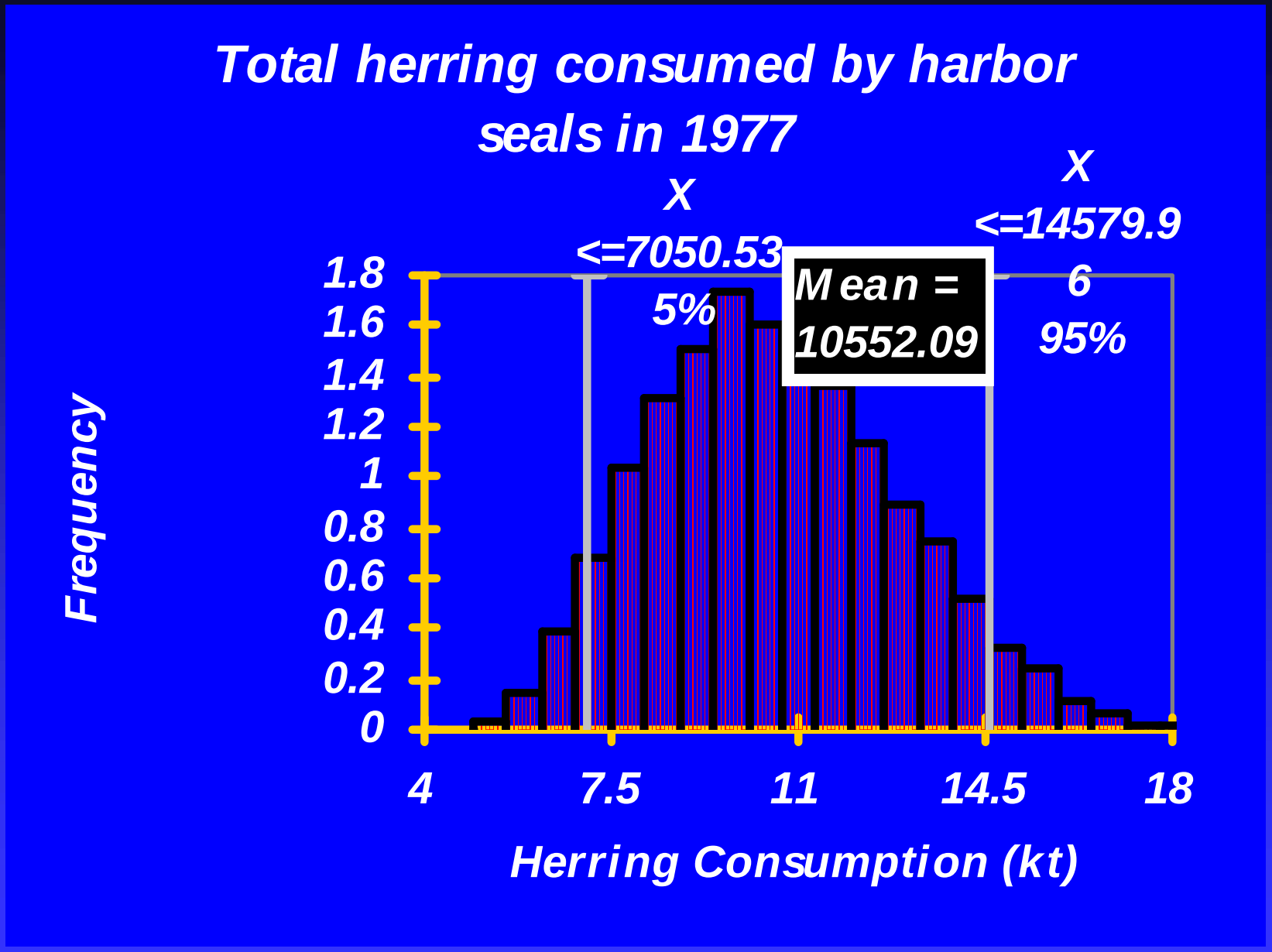


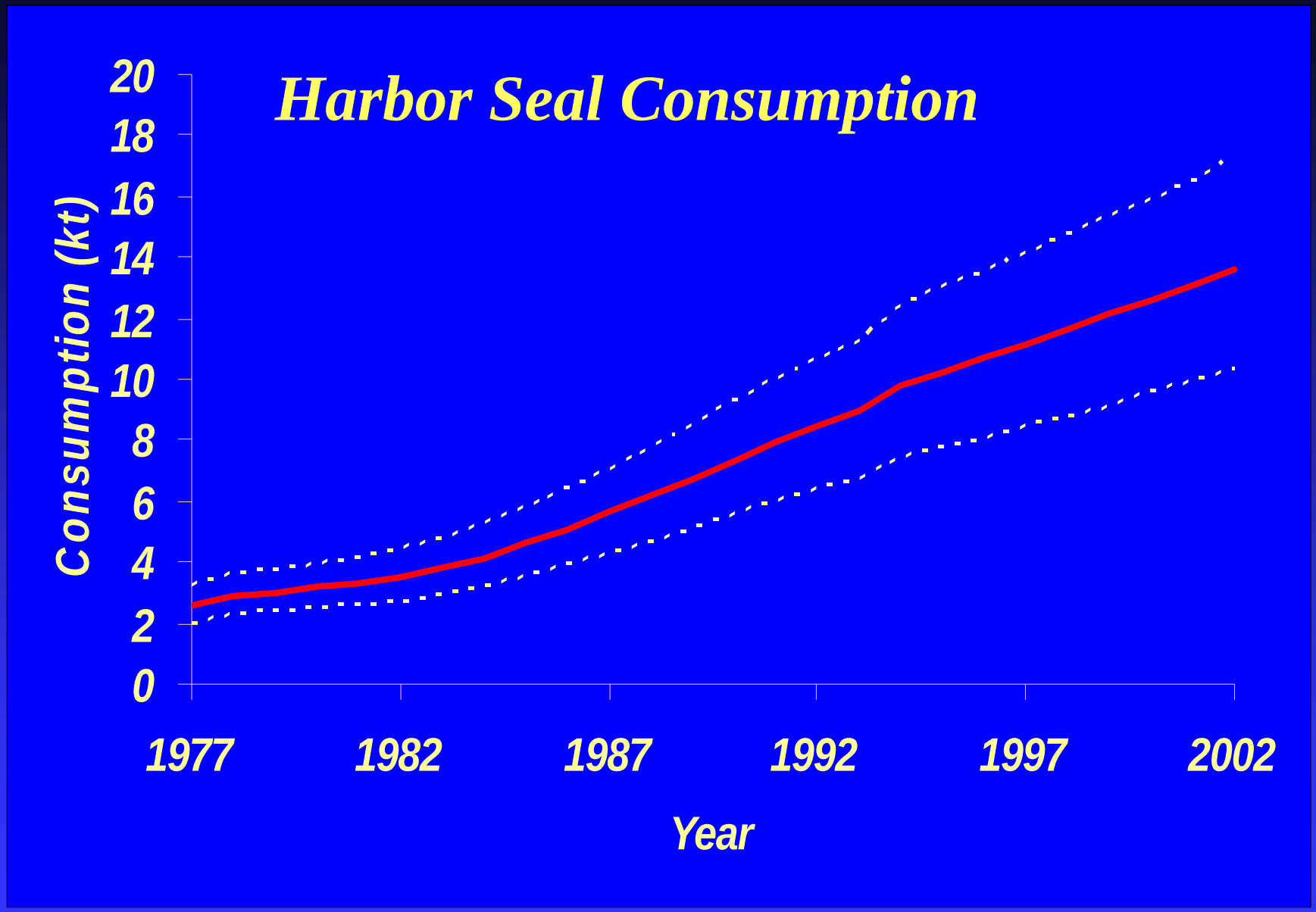


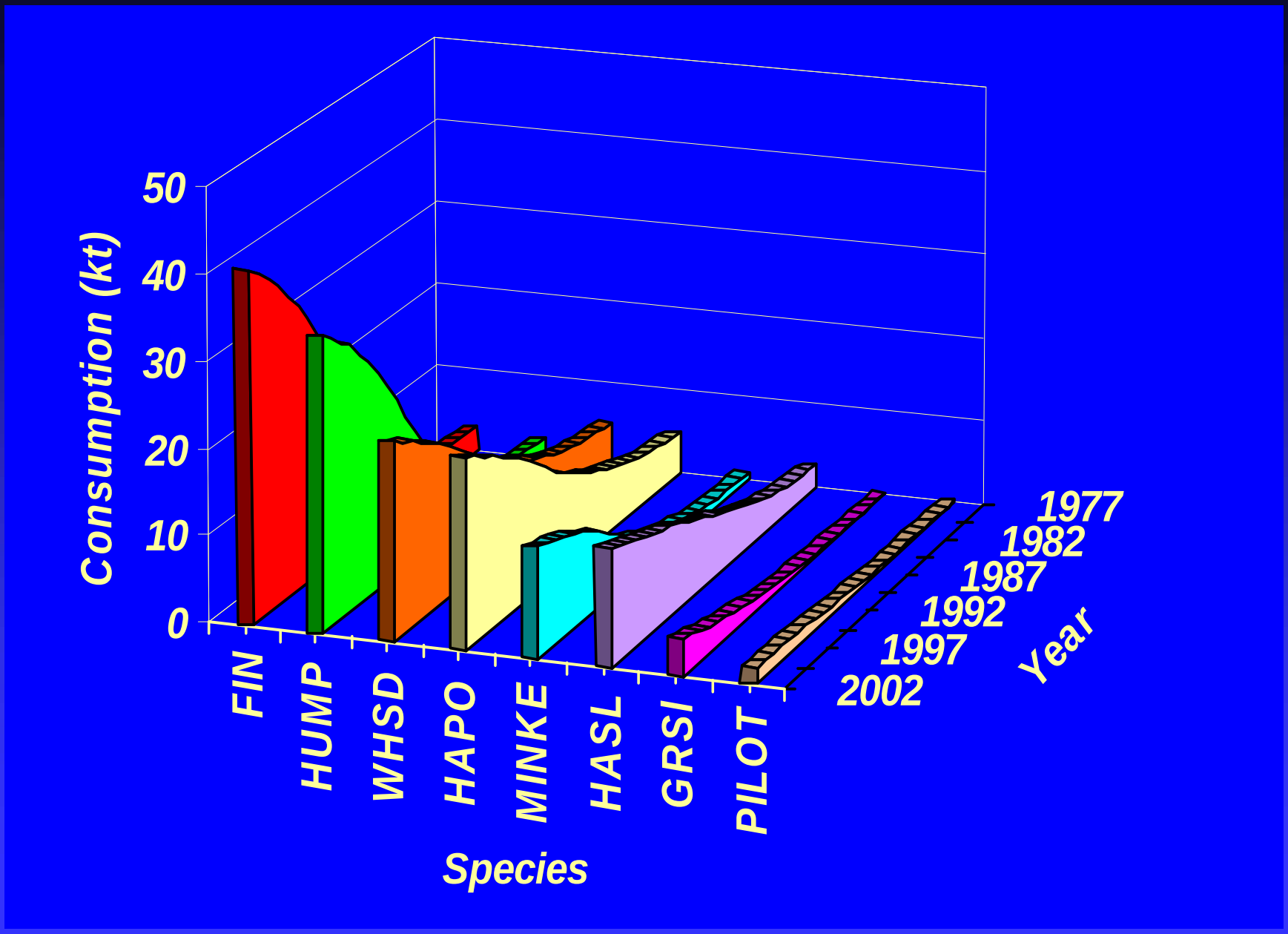
Input Distributions for Herring Consumed by Harbor Seals

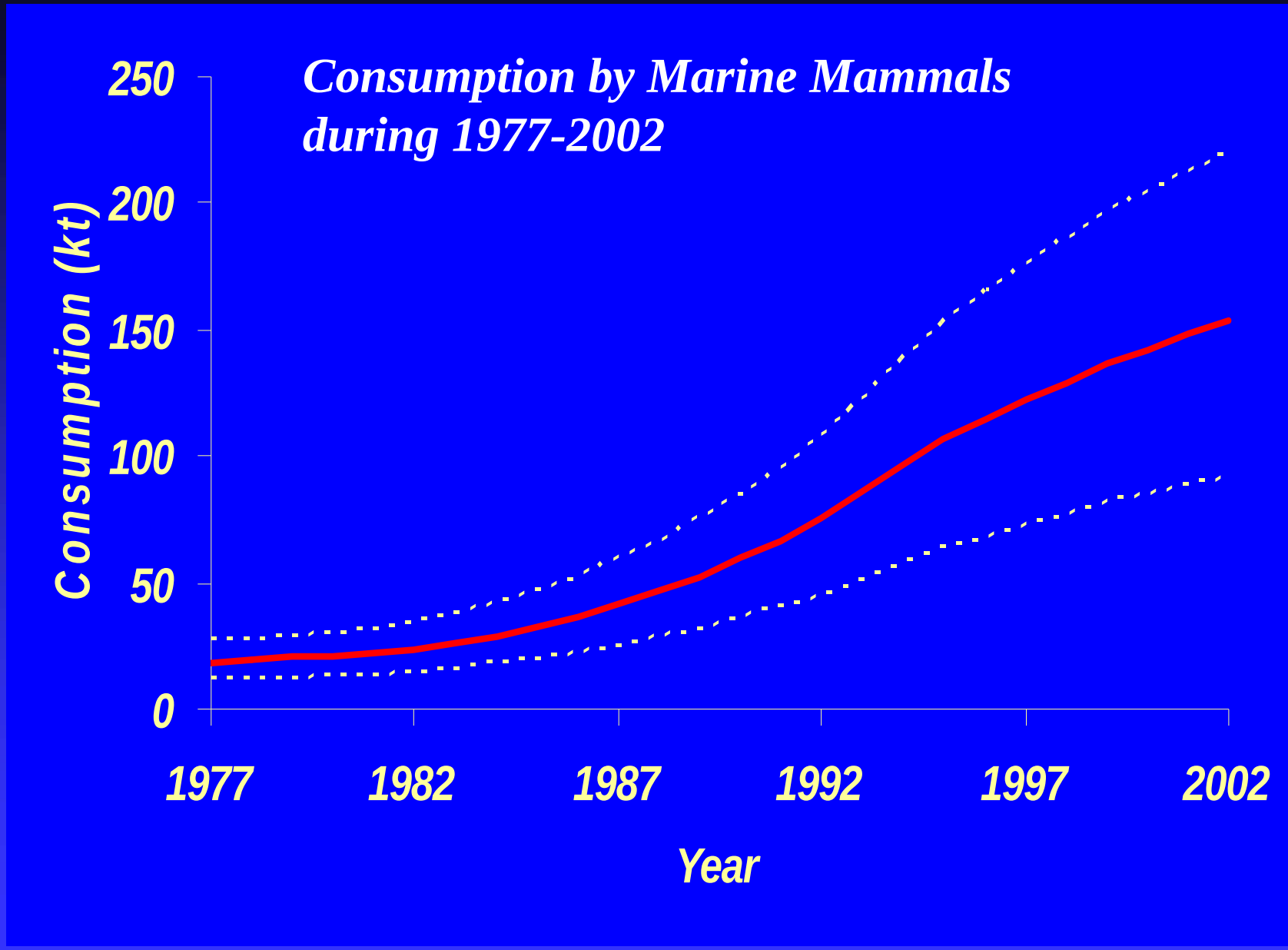





Total herring consumed by harbor seals in 1977
X <=7050.53
5%
X <=14579.96
95%
Mean = 10552.09
Frequency
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
4
7.5
11
14.5
18
Herring Consumption (kt)


Harbor Seal Consumption
Consumption (kt)
20
18
16
14
12
10
8
6
4
2
0
1977
1982
1987
1992
1997
2002
Year


Consumption (kt)
50
40
30
20
10
0
FIN
HUMP
WHSD
HAPO
MINKE
HASL
GRSI
PILOT
Species
1977
1982
1987
1992
1997
2002
Year


Consumption by Marine Mammals during 1977-2002
250
200
150
100
50
0
Consumption (kt)
1977
1982
1987
1992
1997
2002
Year

Seabirds

Herring

Gannets

Shearwaters

Gulls

Seabirds

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

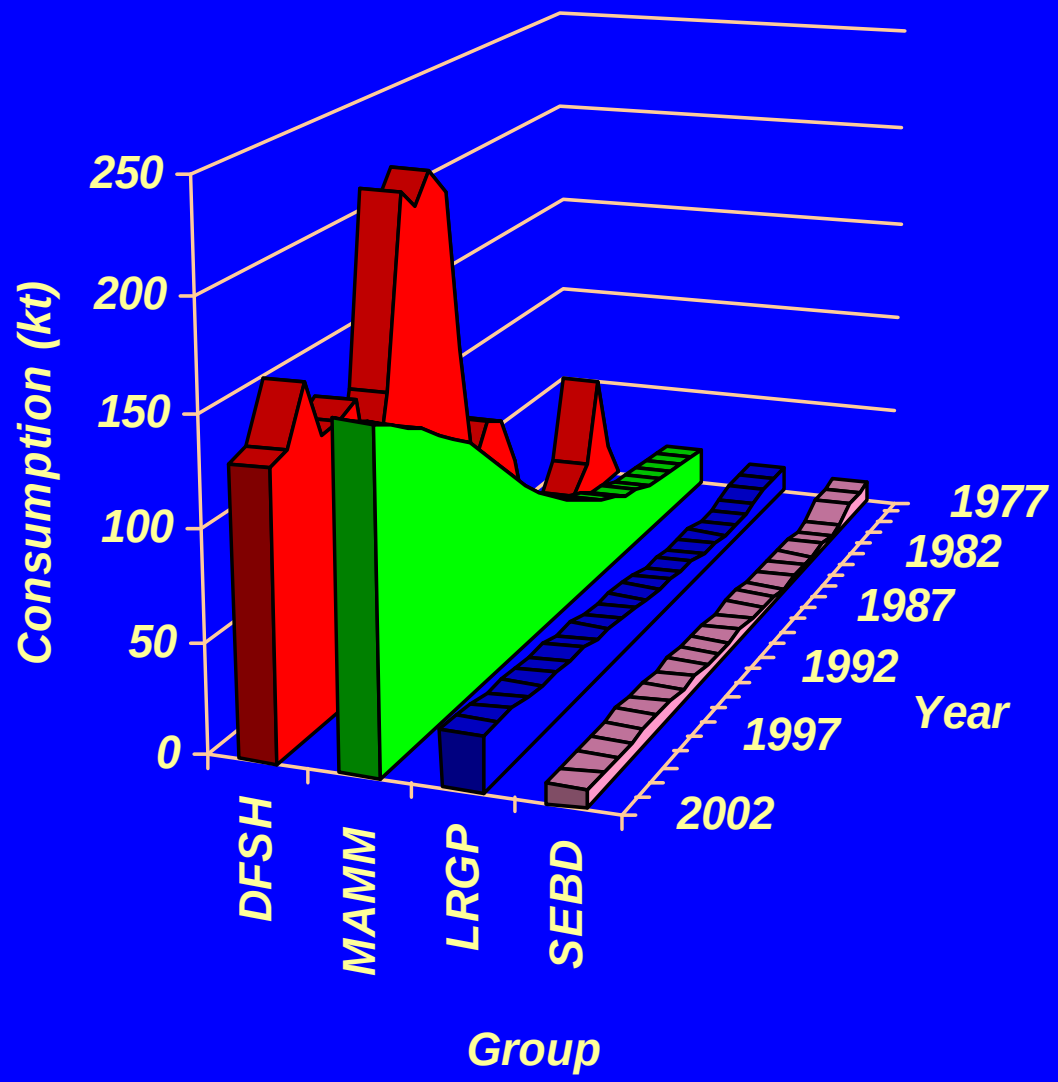
Large Pelagic Fish

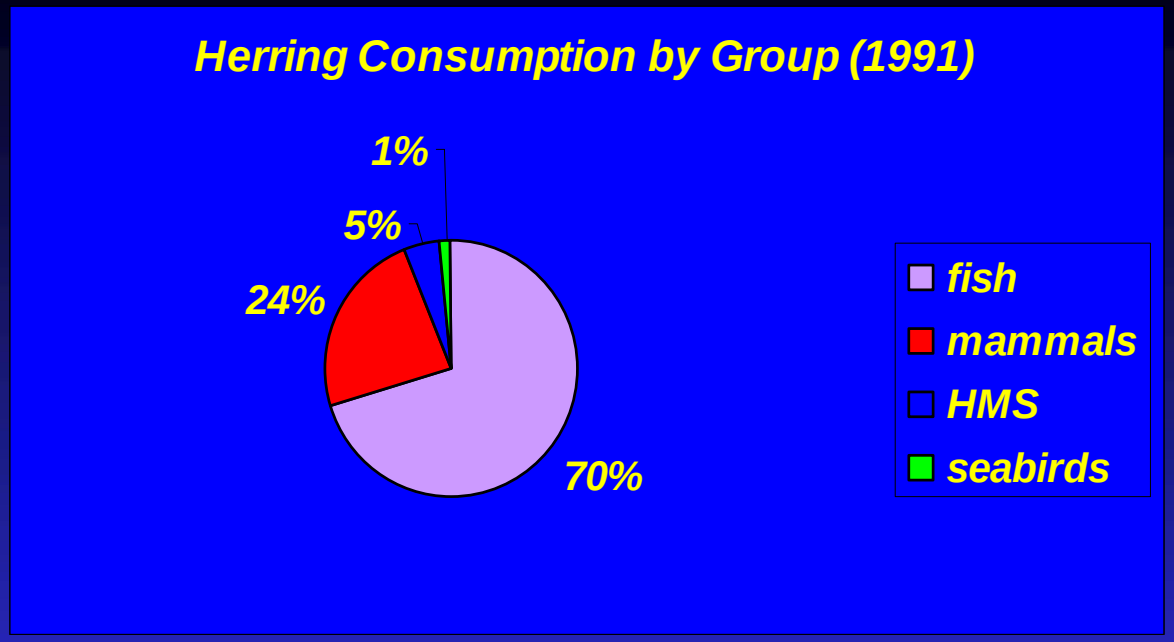
Bluefin Tuna

Mako Shark

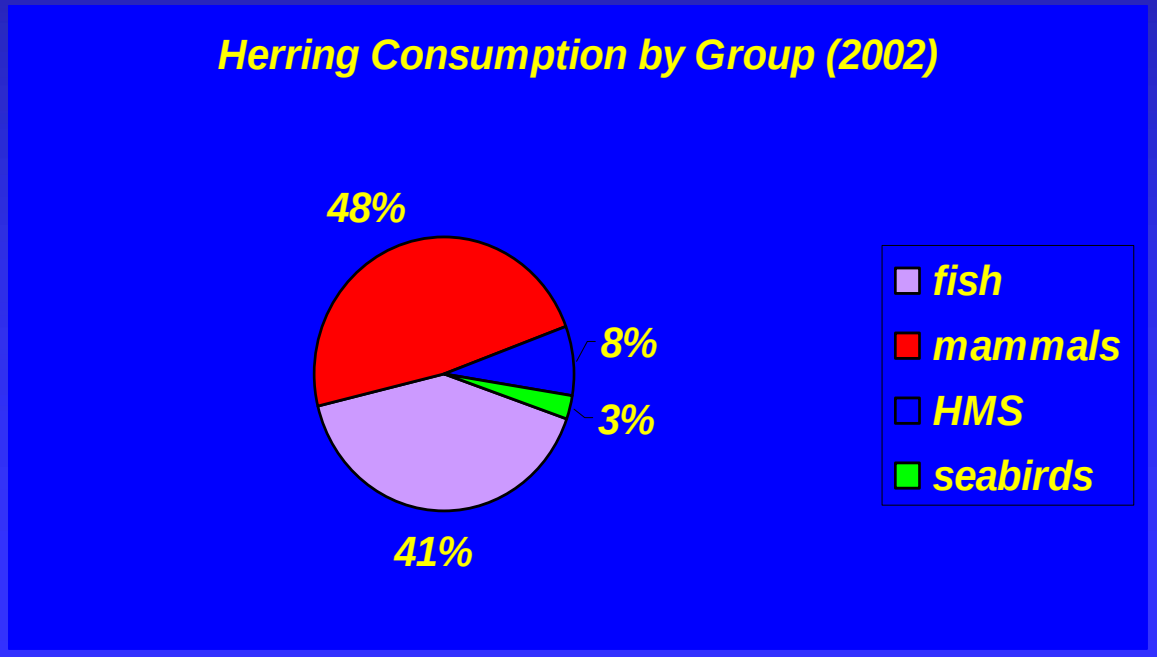
Blue Shark

Consumption of Herring by Predator Group

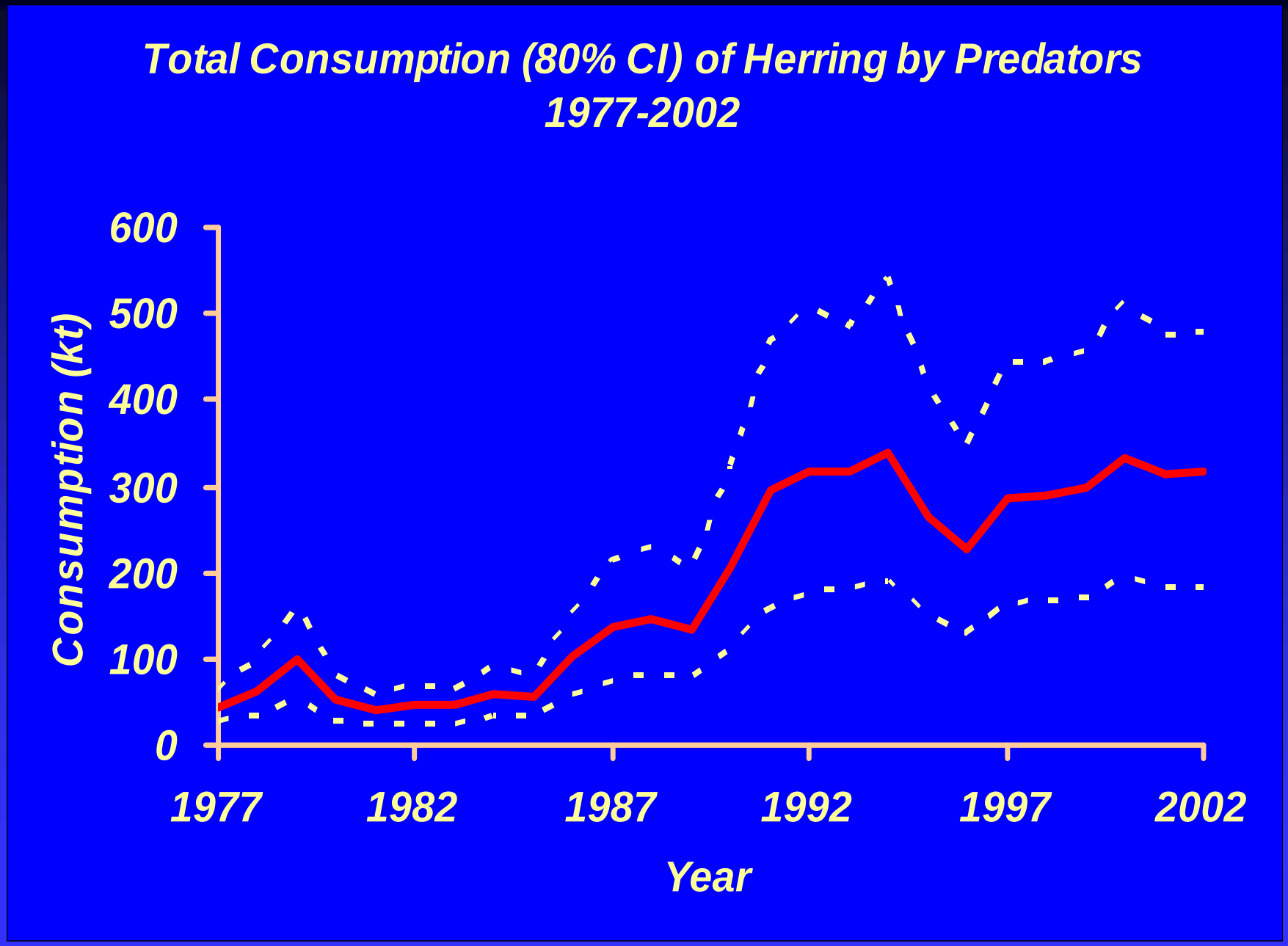




1991- most of the consumption by D-fish

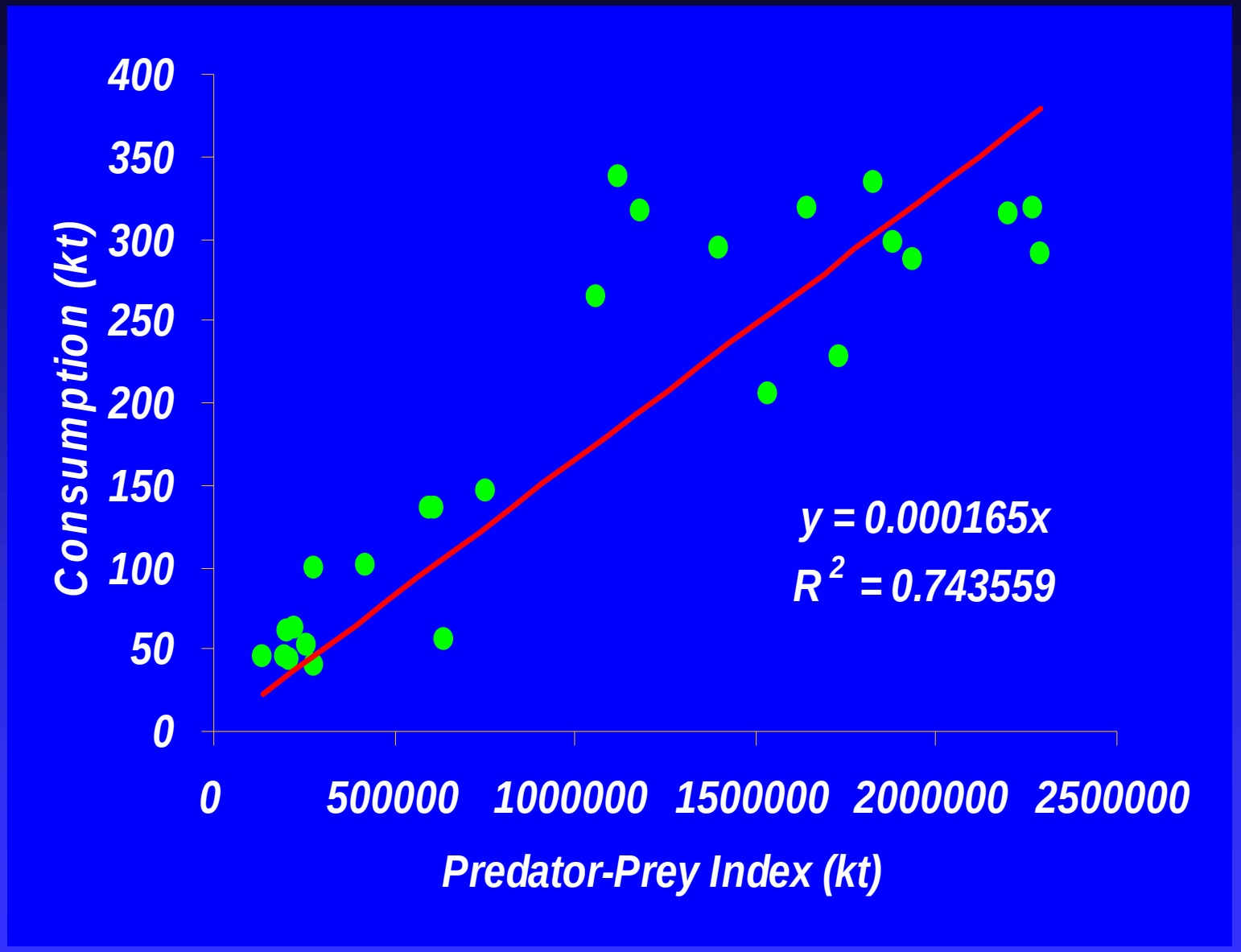


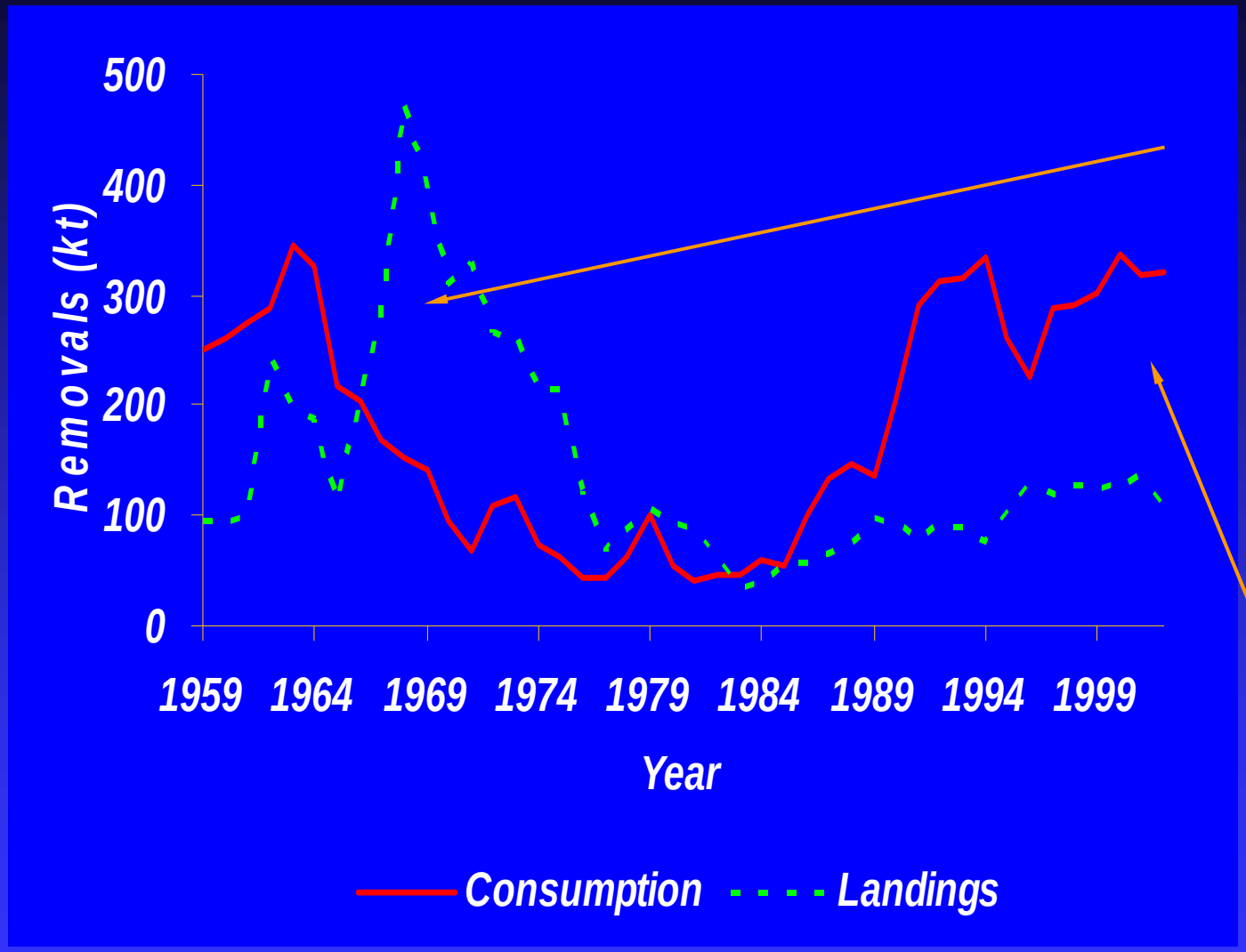
2002-even mix of consumption by mammals and D-fish


Total Consumption (80% CI) of Herring by Predators
1977-2002
Consumption (kt)
600
500
400
300
200
100
0
1977
1982
1987
1992
1997
2002
Year

An Ecosystem Assessment of Atlantic Herring

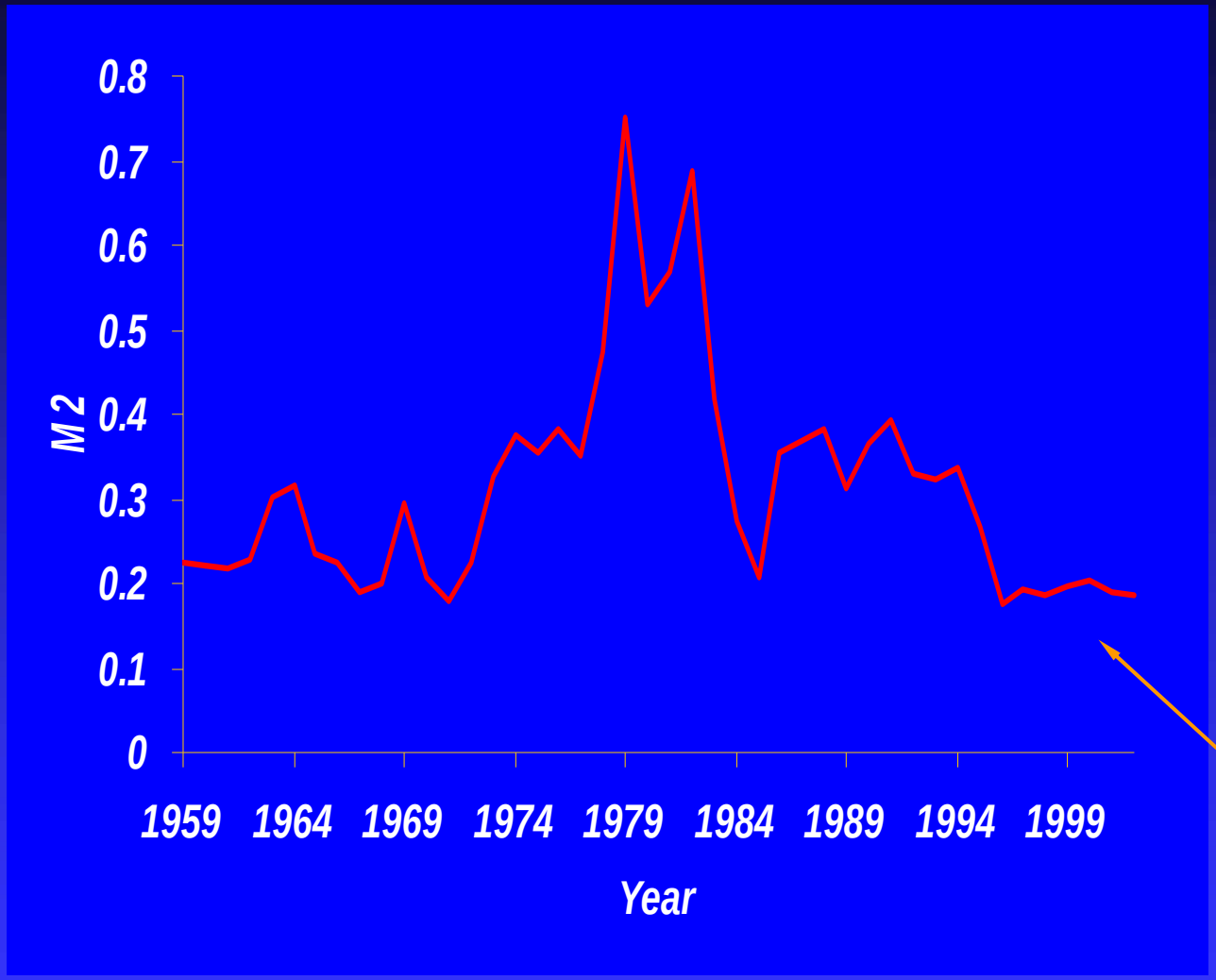
- *Incorporate Predation into Assessment Models (Z=M1+M2+F)*
- *Used Delay-Difference Model*
- *Assess Impacts of Predators*
- *Predict Fishery Yield from Predator Mediated System*


400
350
300
250
200
150
100
50
0
Consumption (kt)
0
500000
1000000
1500000
2000000
2500000
Predator-Prey Index (kt)
y = 0.000165x
R 2 = 0.743559



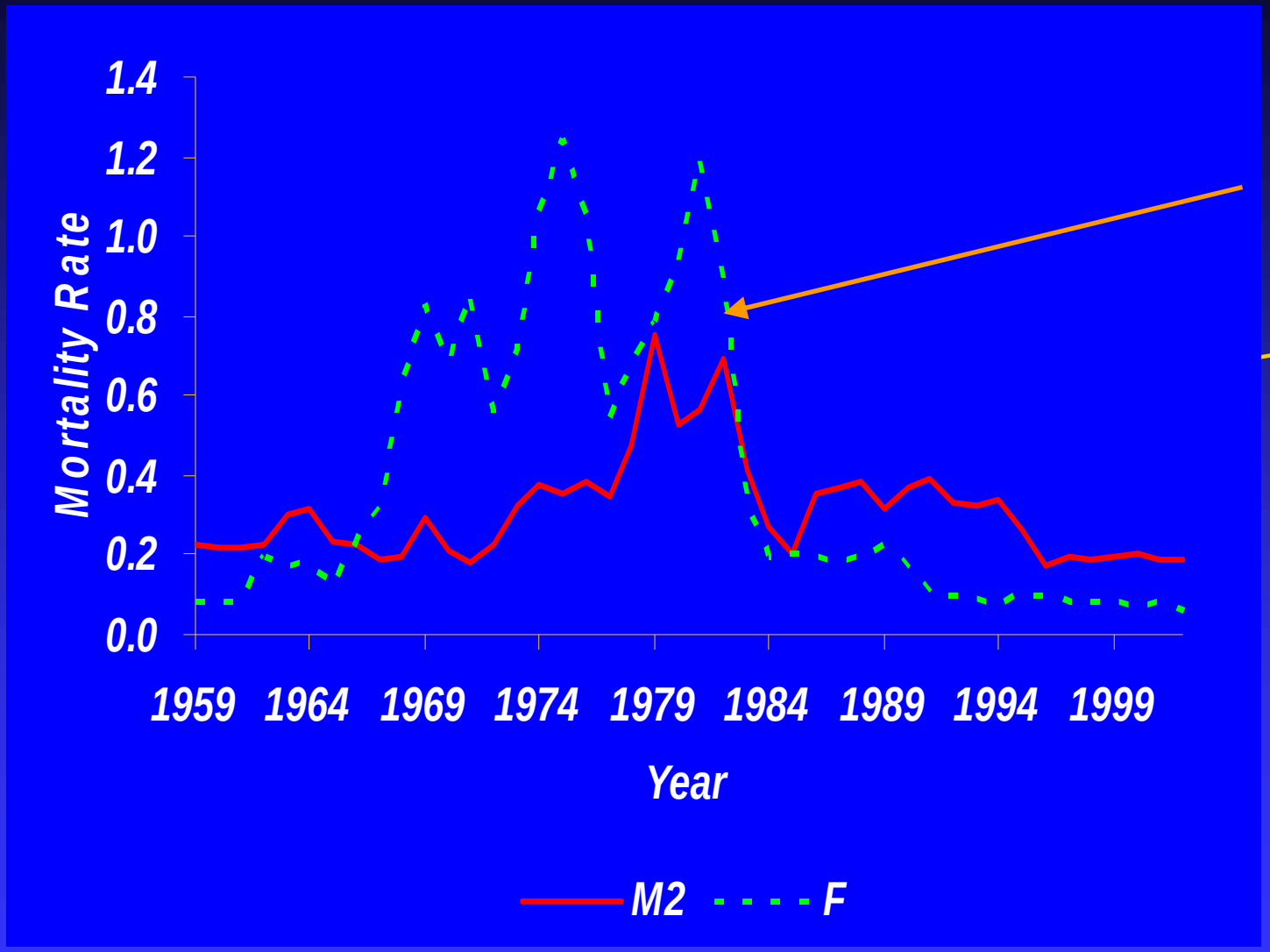
Total Removals during the late 1960s early 1970s were very large

More recently predators removed about 3X the fishery!

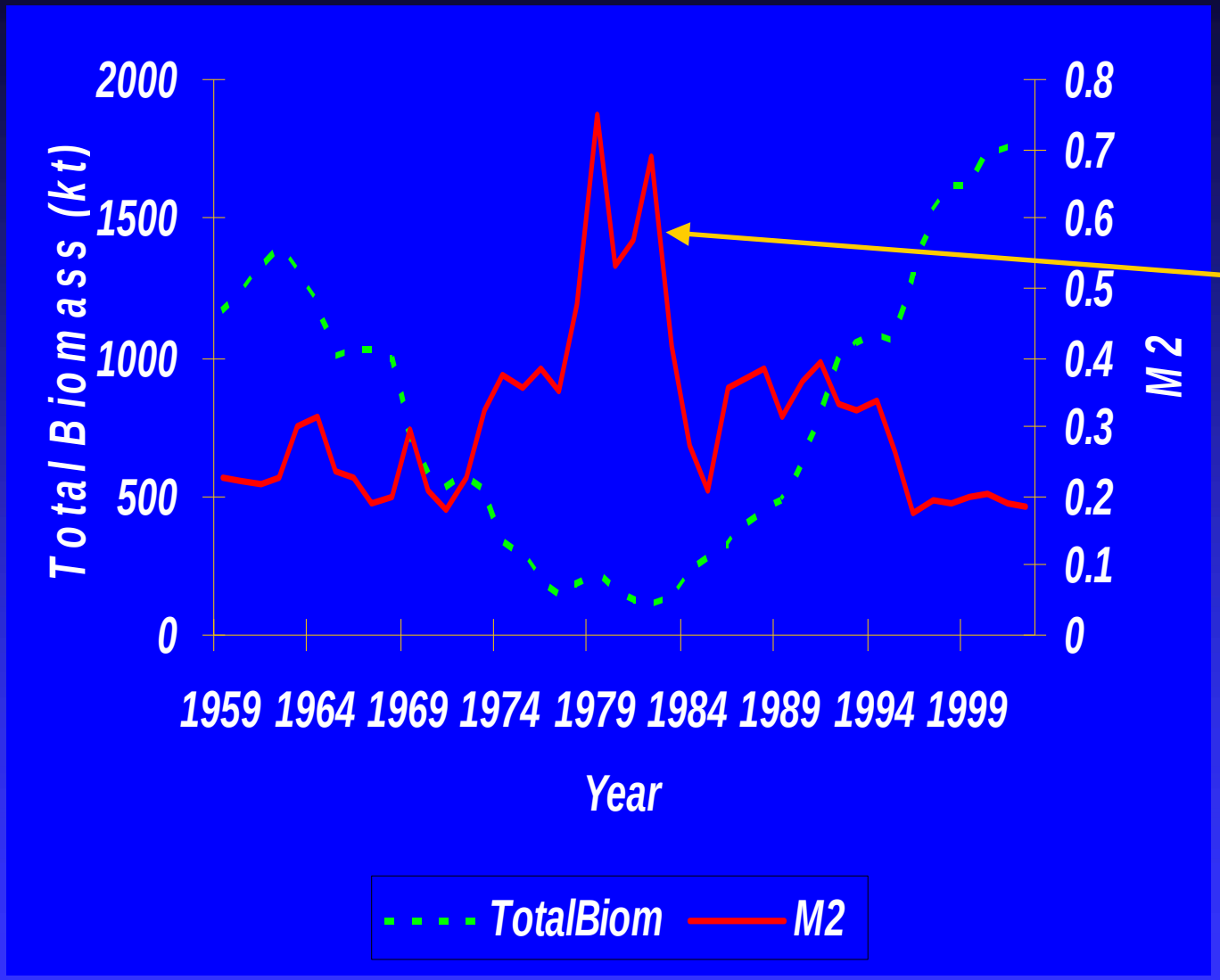


- *M2's are Time Variant*
- *Rates are Prey, Predator, and Fishery Dependent*

Current M2 relatively low < 0.2



Predators and Fishery combined to cause stock decline and slow recovery



M2 was at its highest when herring biomass was the lowest

BRPs &Long-Term Yield

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

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***

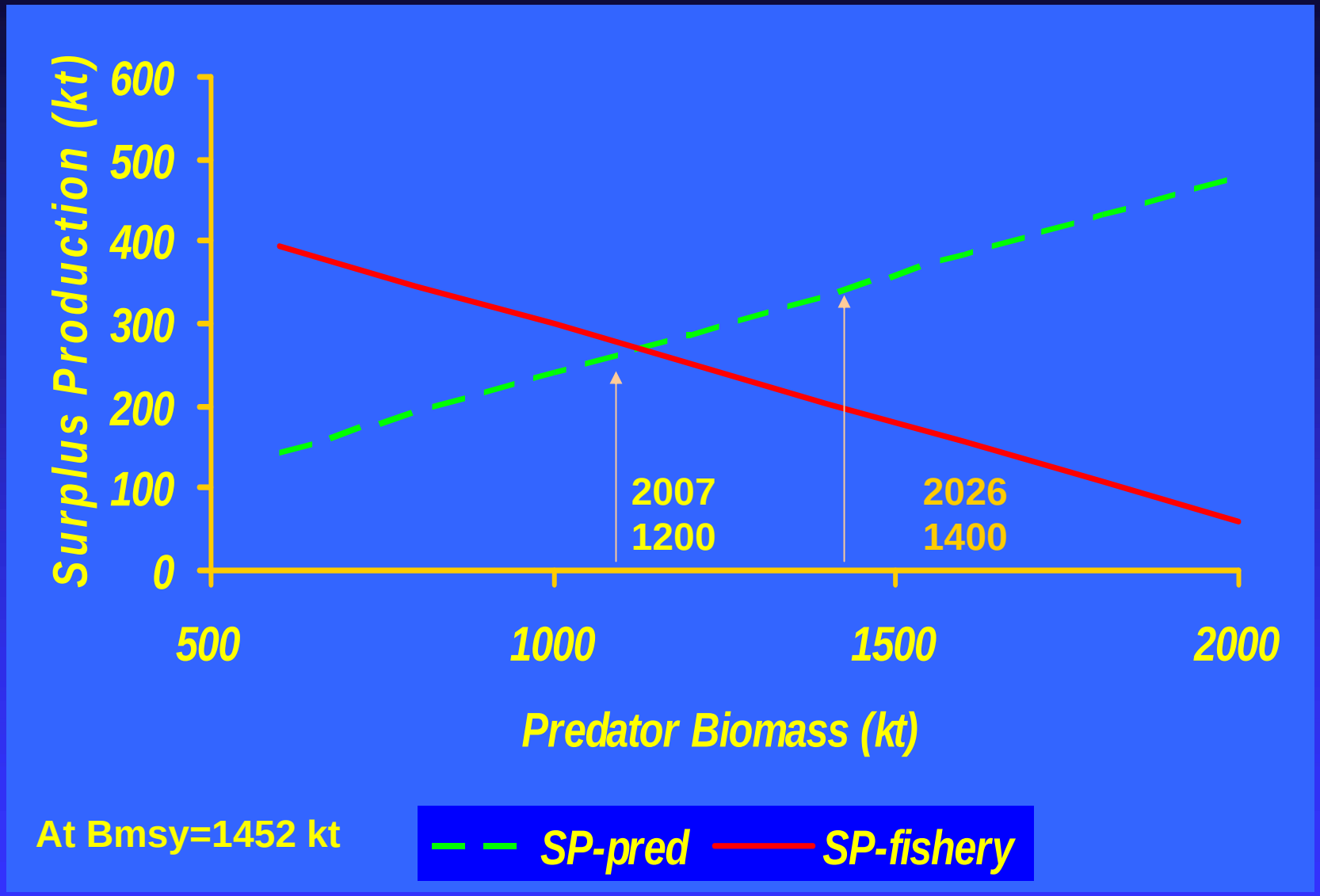
- ***Analytical***
- ***New Fox Model***
- ***Overall Biological Surplus = 528,000 mt***
- ***SP =156,000-251,000 mt***

predator	SP-predator	SP-fishery
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

Conclusions

- *Predation impacts are often larger than landings*
- *Enhanced risk of major stock decline at high F's*
- *Predation mortality (M2) 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.*