Fisheries Indicators from Fishery Dependent and Independent Data Streams

RARGOM Theme Session
Wells National Estuarine Reserve
November 15, 2006

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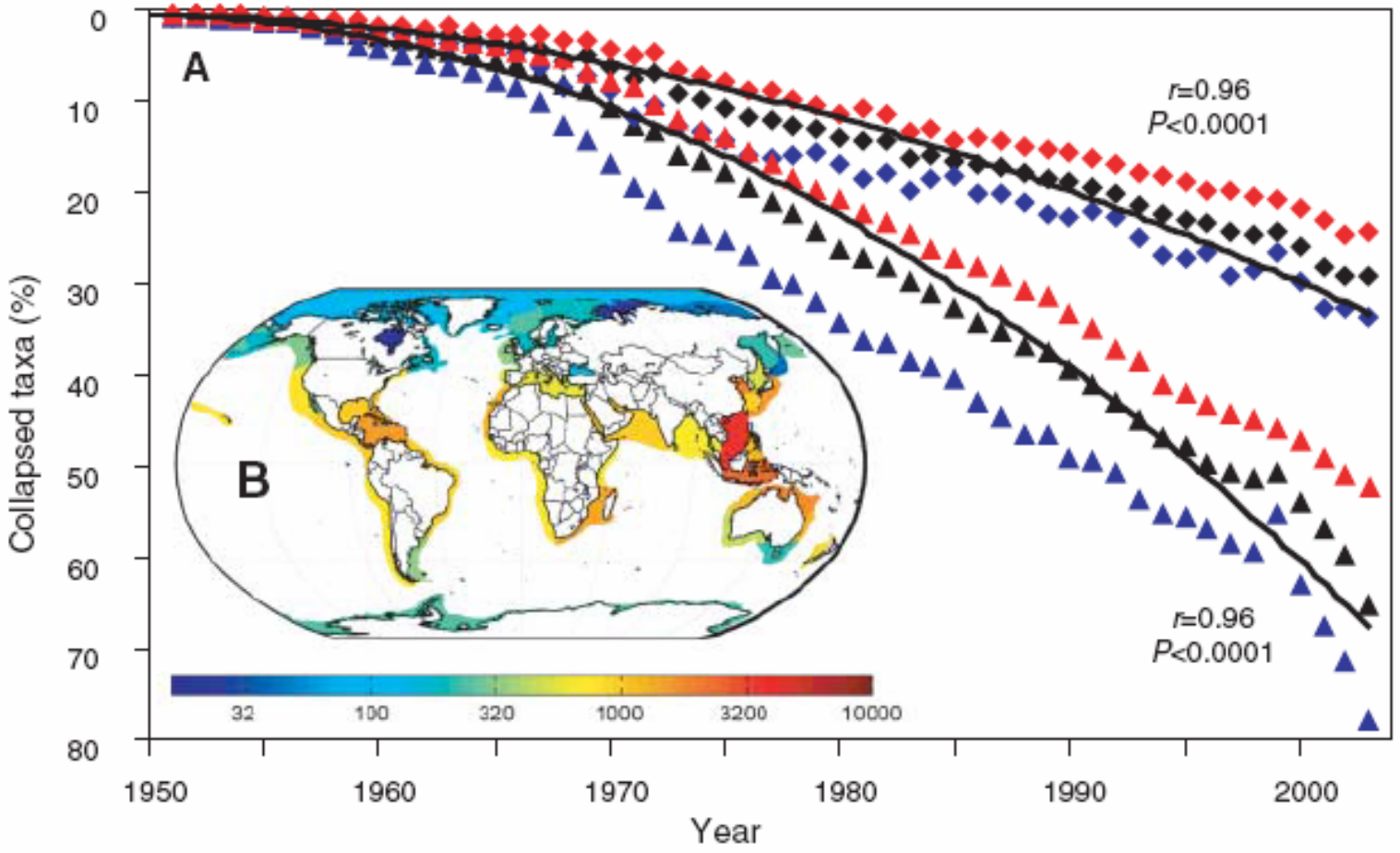


Fig. 3. Global loss of species from LMEs. (**A**) Trajectories of collapsed fish and invertebrate taxa over the past 50 years (diamonds, collapses by year; triangles, cumulative collapses). Data are shown for all (black), species-poor (<500 species, blue), and species-rich (>500 species, red) LMEs. Regression lines

Worm et al. 2006 Science

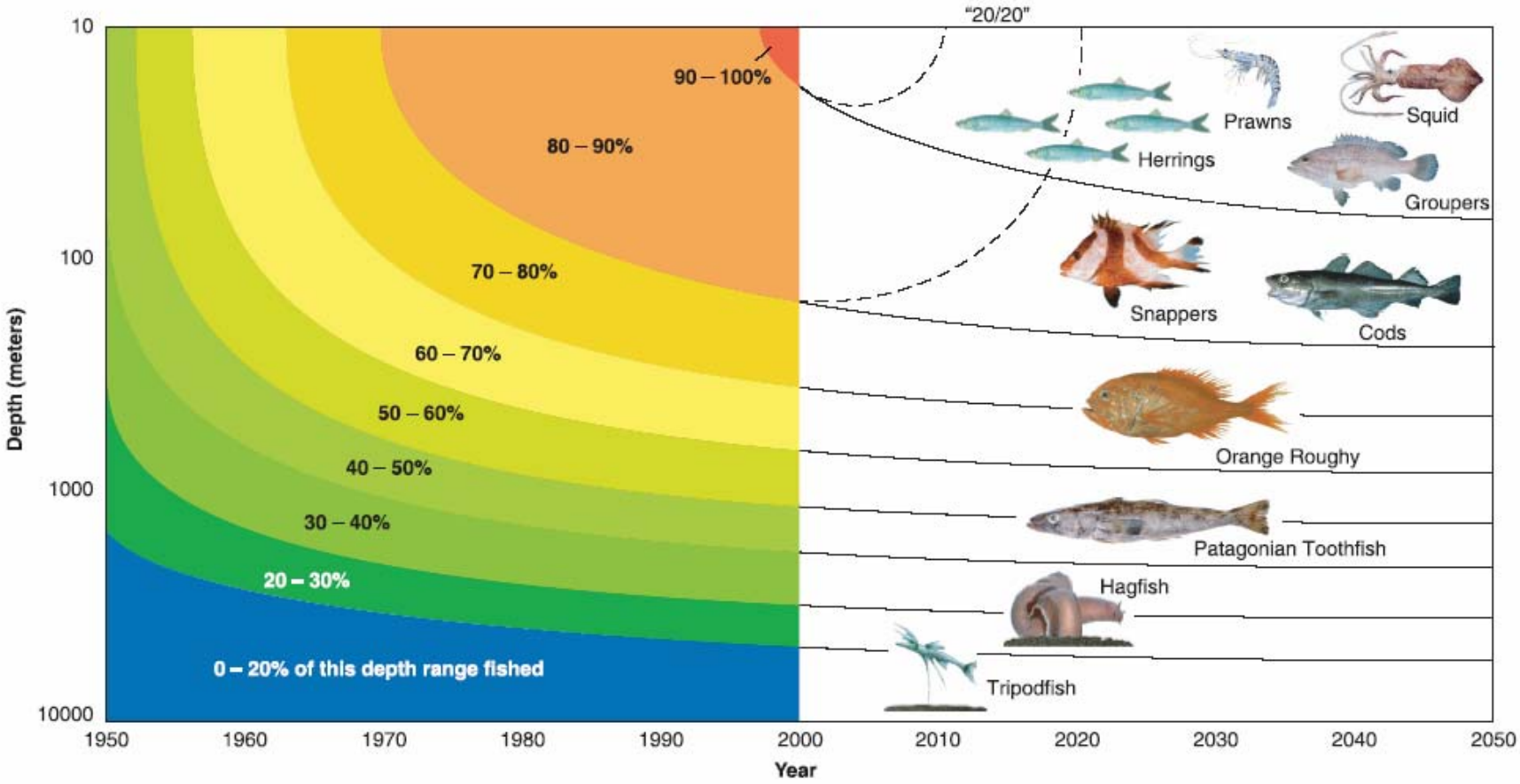
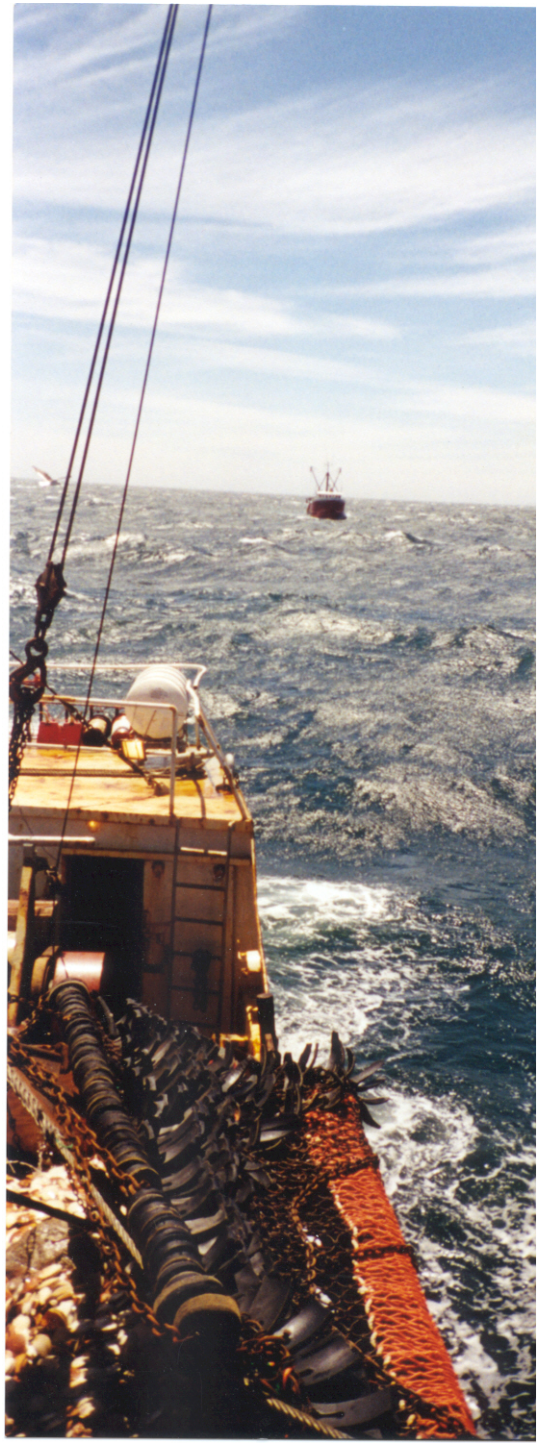


Fig. 1. Fraction of the sea bottom and adjacent waters contributing to the world fisheries from 1950 to 2000 (*30*) and projected to 2050 by depth (logarithmic scale). Note the strong reversal of trends required for 20% of the waters down to 100-m depth to be protected from fishing by 2020.

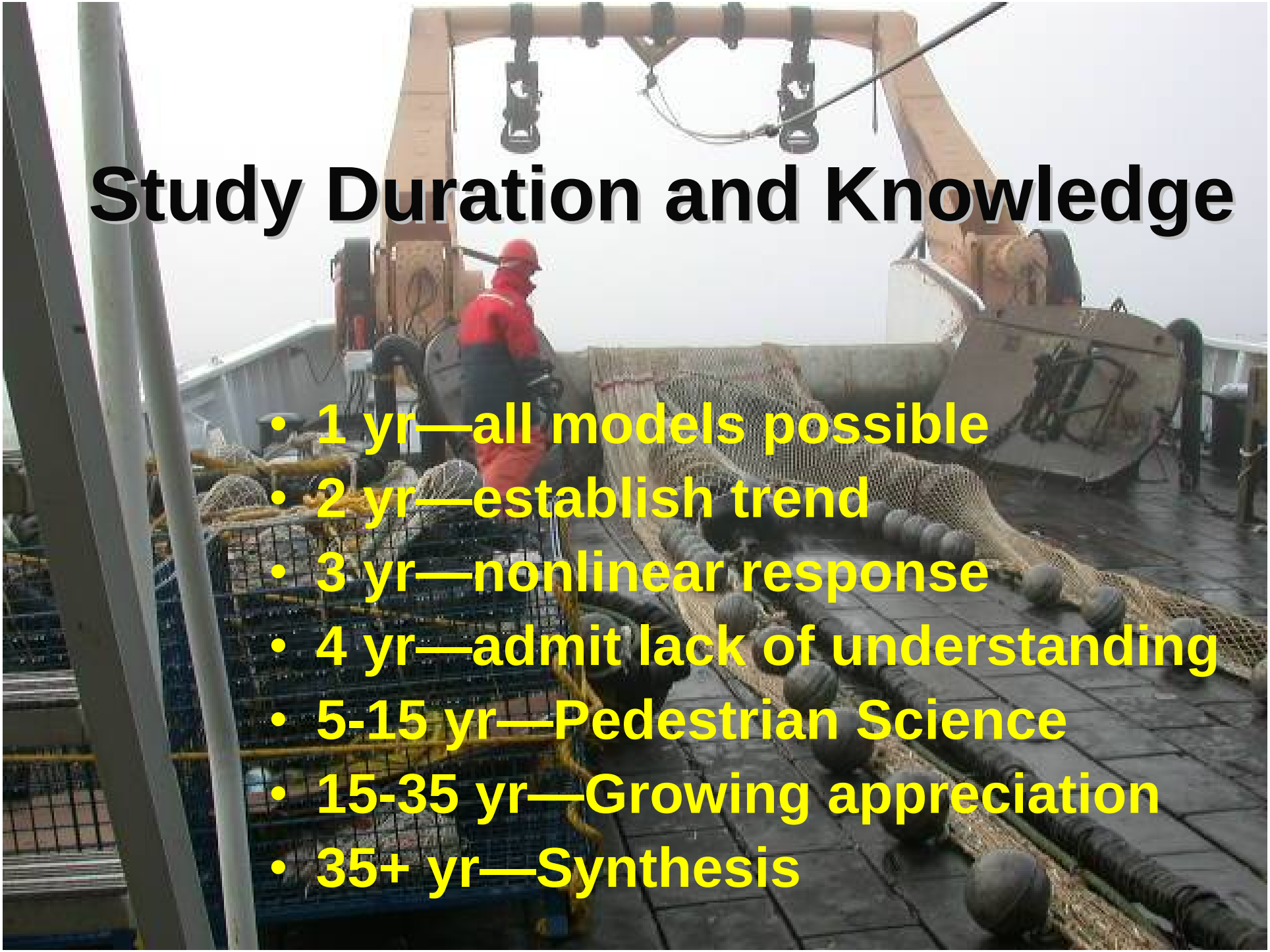
The Future for Fisheries

Daniel Pauly[1]* Jackie Alder,[1] Elena Bennett,[2] Villy Christensen,[1] Peter Tyedmers,[3] Reg Watson[1]



Fisheries Indicators—All gear are selective

- Fisheries Independent Measures
  - Surveys
    - Design based
    - Inference about unobserved
  - Attributes of sampled fish
- Fisheries Dependent Measures
  - Commercial Landings
  - Effort
  - Spatial distribution
  - Discards
- Importance of spatial pattern
  - Scallops, haddock, lobster



Study Duration and Knowledge

- 1 yr—all models possible
- 2 yr—establish trend
- 3 yr—nonlinear response
- 4 yr—admit lack of understanding
- 5-15 yr—Pedestrian Science
- 15-35 yr—Growing appreciation
- 35+ yr—Synthesis

Original Basis of NEFSC Research Vessel Surveys

- "To monitor fluctuations in structure and size of fish populations to provide a measure of the effects of fishing that is independent of commercial fishery statistics."
- "To assess the production potential of Atlantic coastal waters"
- "To determine environmental factors controlling fish distribution and abundance"
- "To provide basic ecological data on fishes (e.g., growth rates and food) necessary to understand interrelationships between fish and their environment"

Grosslein 1969

"A dredging ship may be compared with an air-ship towing a dredge over Copenhagen, catching a policeman in one street and a perambulator in another; and from these it draws conclusions as to the whole population of the town."

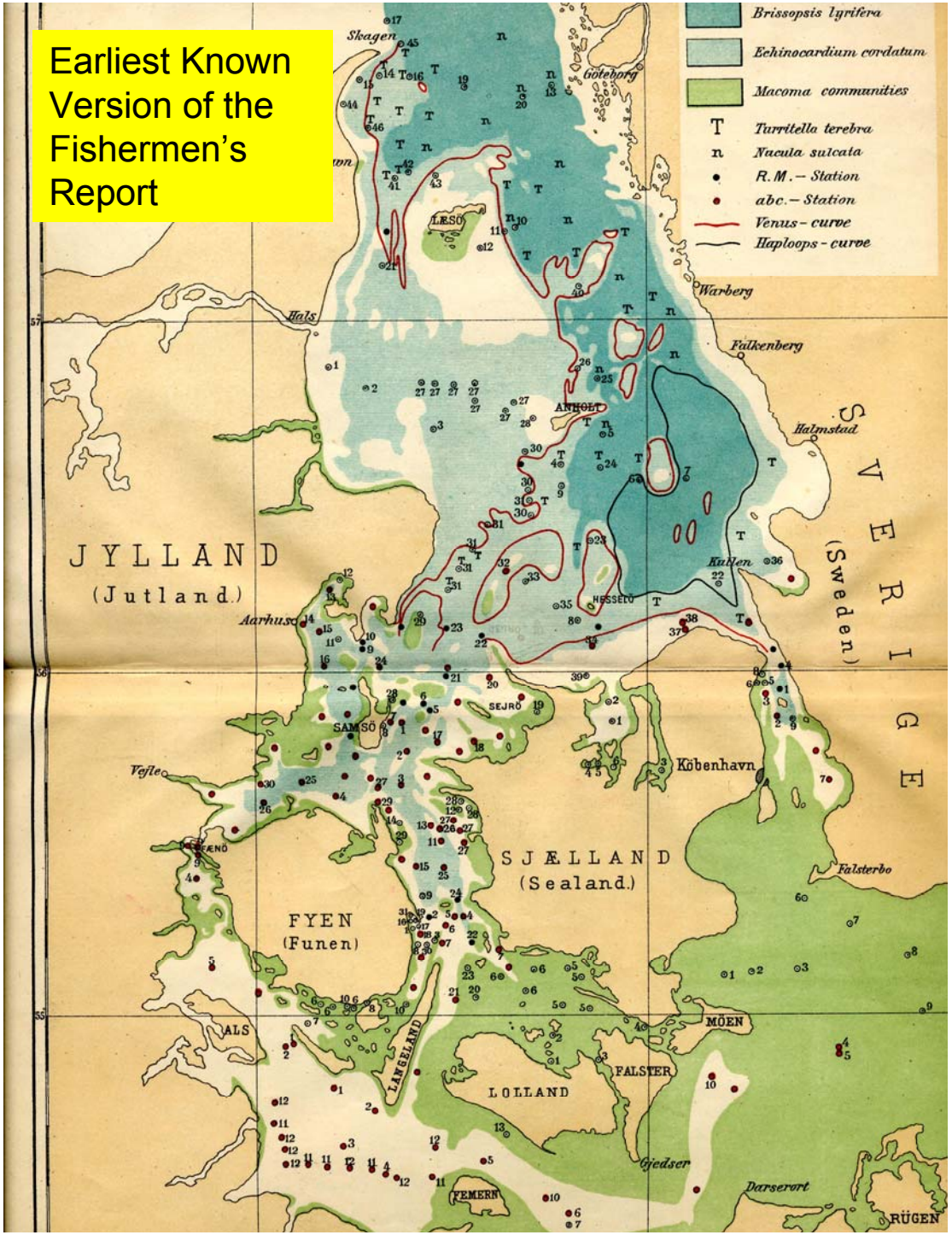
Peterson, C.G.J. 1913. Report of the Danish Biological Station 21. (44 pp.)

The Albatross IV Streams their net at sunset

Scientific Surveys have Met Unanticipated Demands

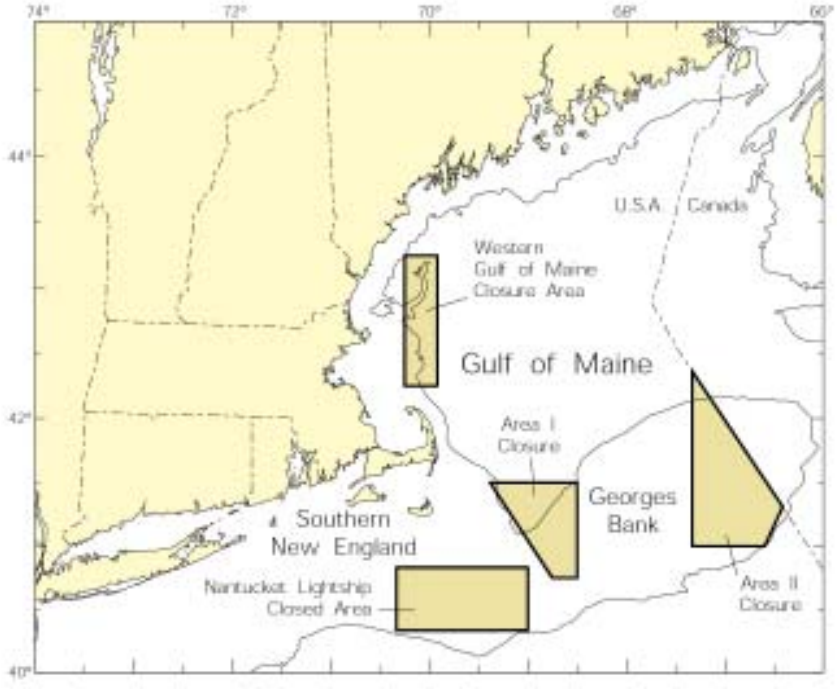
- Advances in population estimation methods.
- Allocation of resources among jurisdictions
- Management demands
  - Season and area closures
  - Effects of gear changes
- Ecosystem monitoring
- Habitat identification

Peterson, C.D.J. 1918. The Sea Bottom and its Production of Fish-Food. Rep. Danish Biological Station. 25.
Activities from 1883-1917

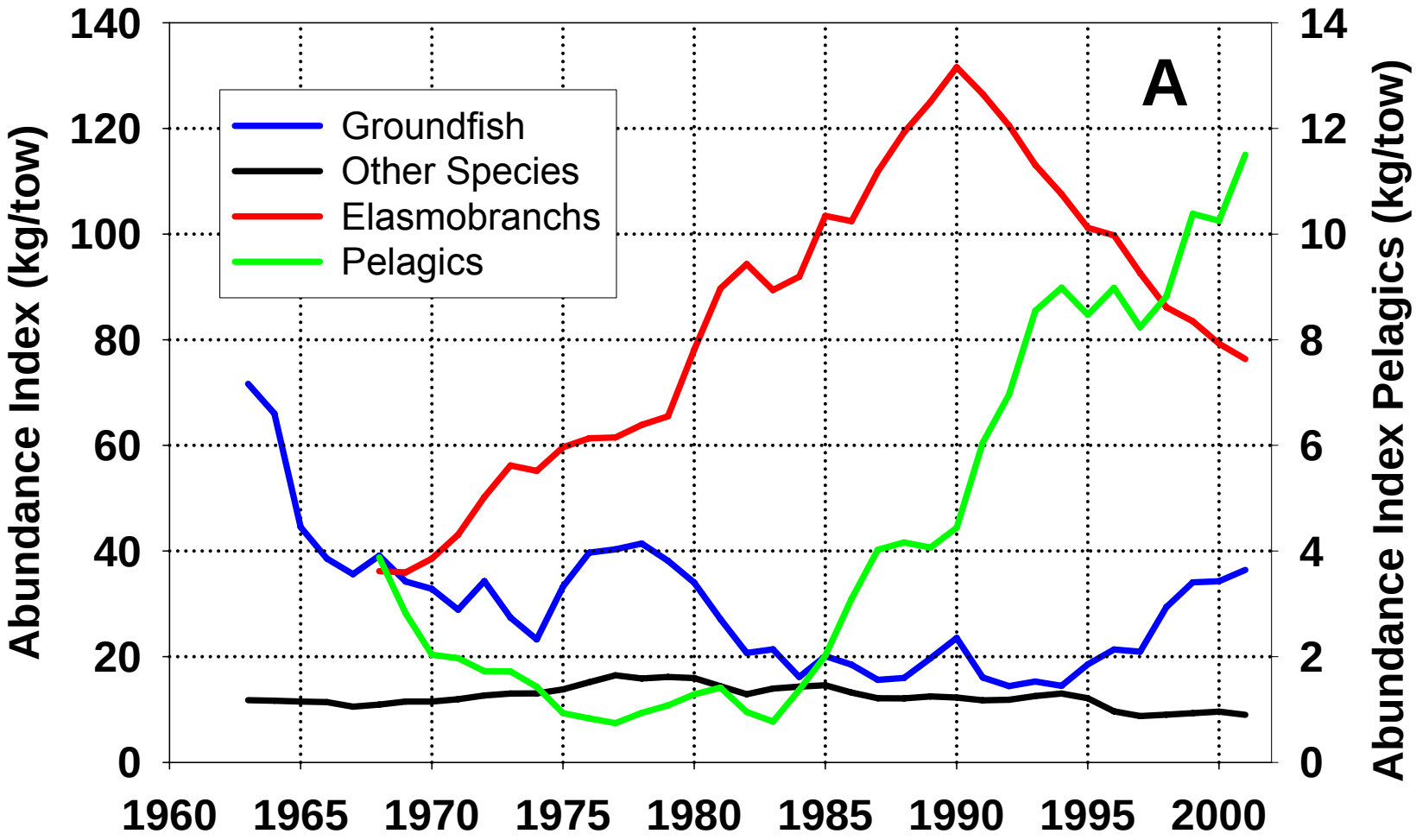


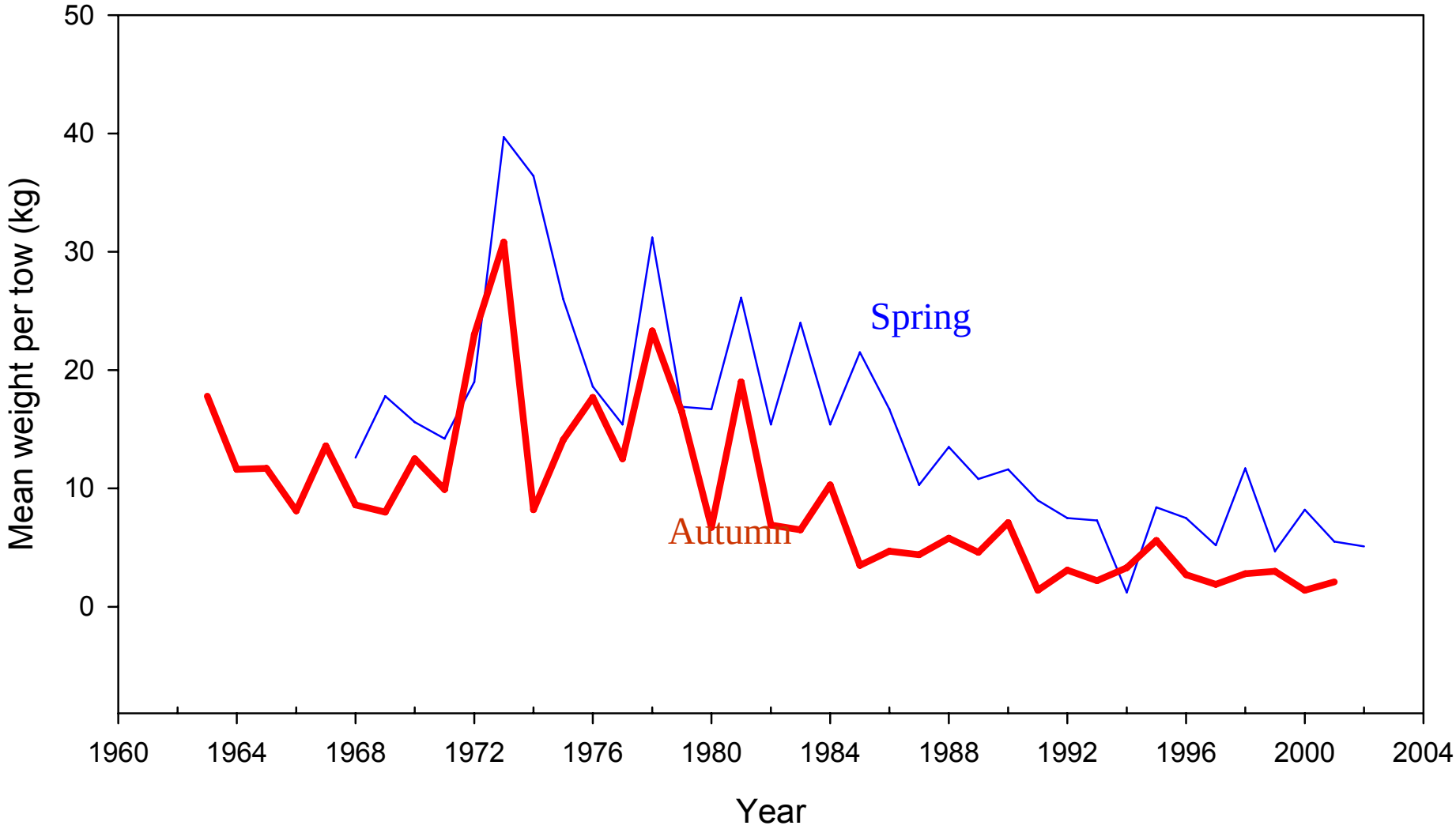
Large Scale Experiments

- Foreign Fleets
- EEZ and Increase in Domestic Fleet
- Closed Areas

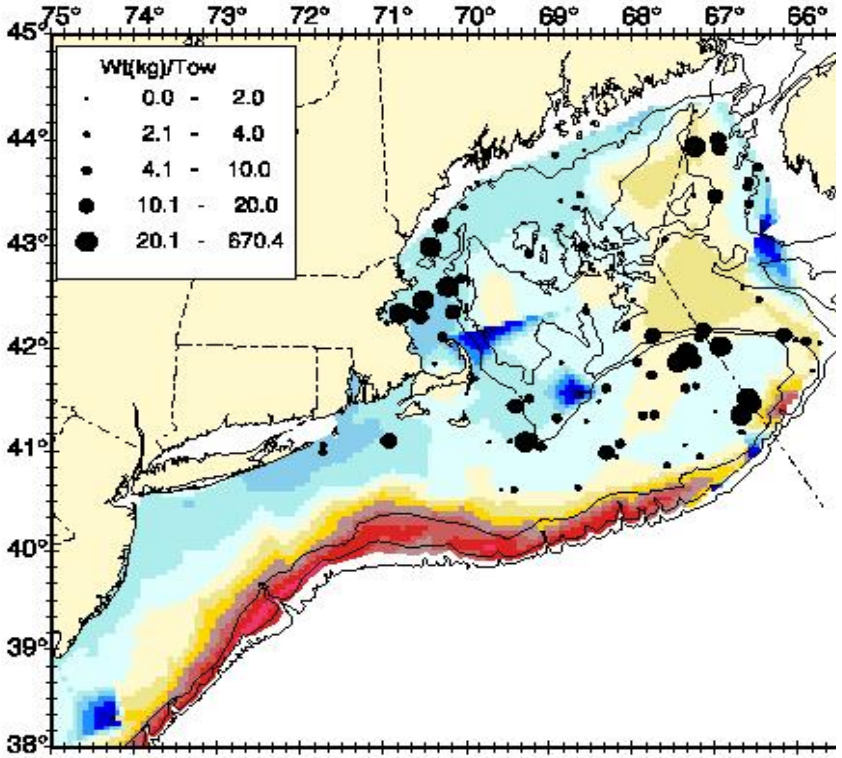


Large Scale Changes in Species Assemblages

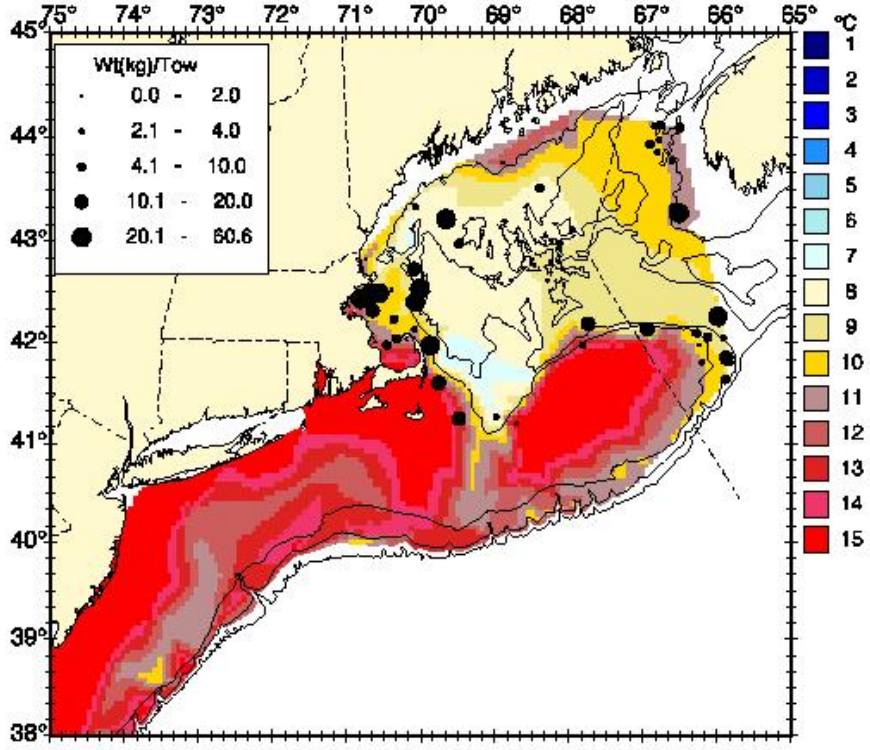




Stratified mean weight per tow (kg) for Georges Bank cod



Distribution of Atlantic cod in the NEFSC Spring Bottom Trawl Survey for 2000 in relation to bottom temperatures.



Distribution of Atlantic cod in the NEFSC Autumn Bottom Trawl Survey for 2000 in relation to bottom temperatures.

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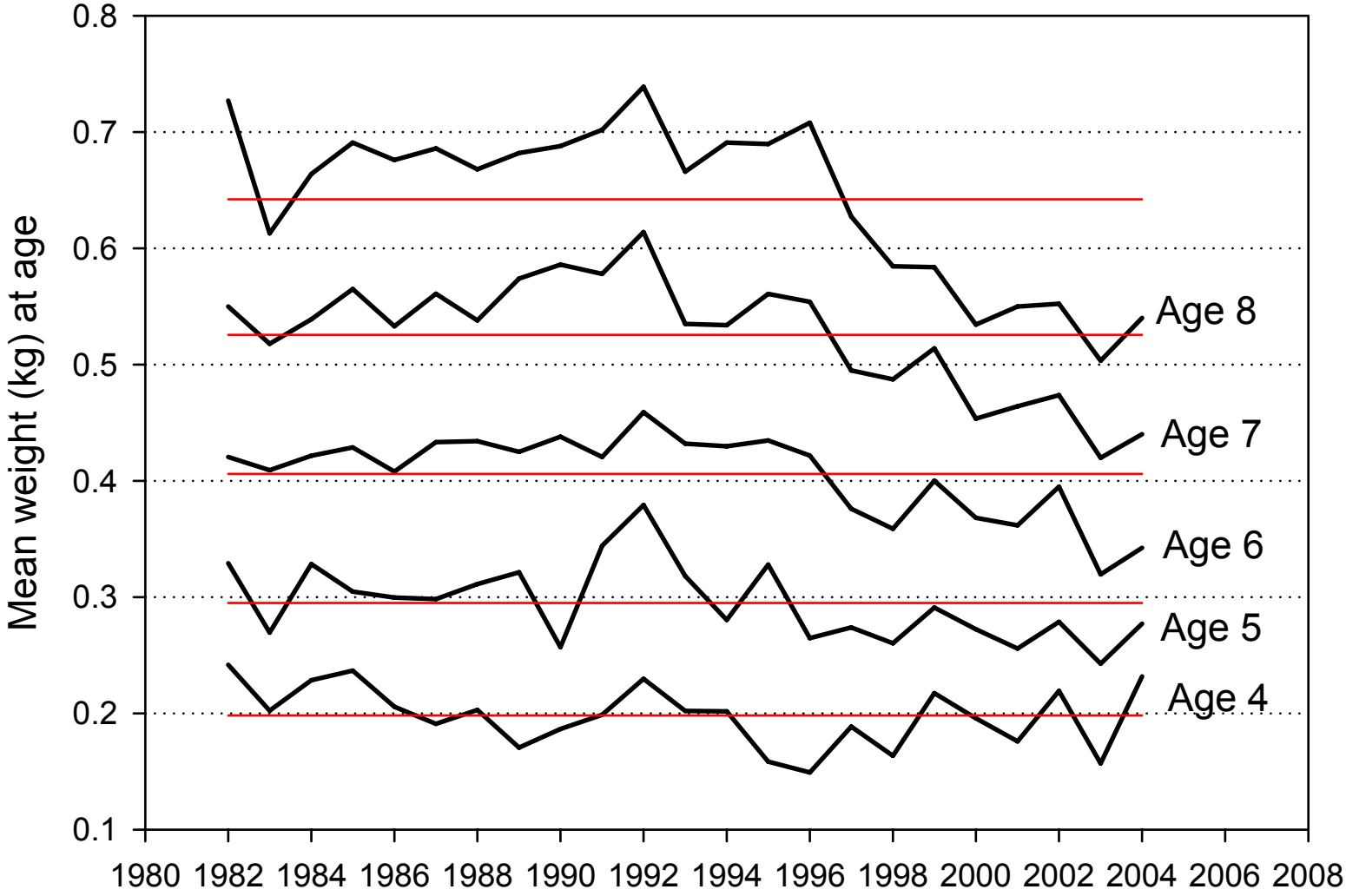
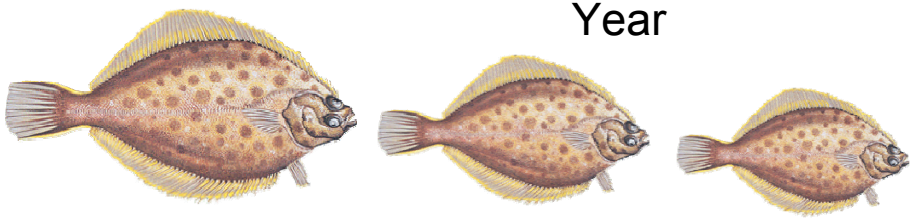
Northeast Fisheries Science Center
Woods Hole, MA

NOAA Fisheries
Northeast Fisheries Science Center
Woods Hole, MA

Distribution of species with temperature overlay: spring 2000 (left) vs fall 2000 (right)

Witch flounder mean weights at age in the catch





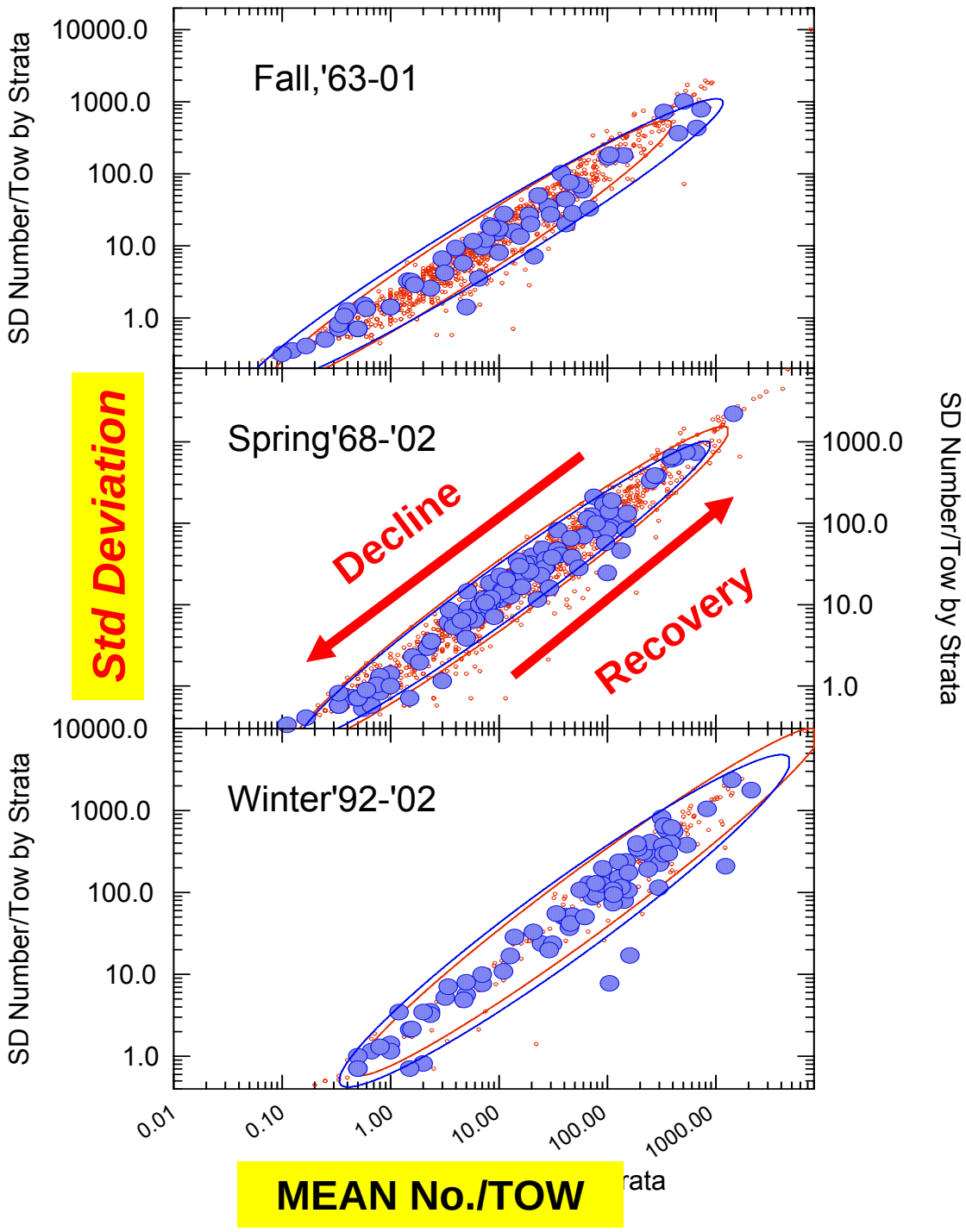
Yellowtail fl.show similar decline

Fishing as a major intervention in marine ecosystems: amenable to manipulation, and vulnerable to lack of understanding

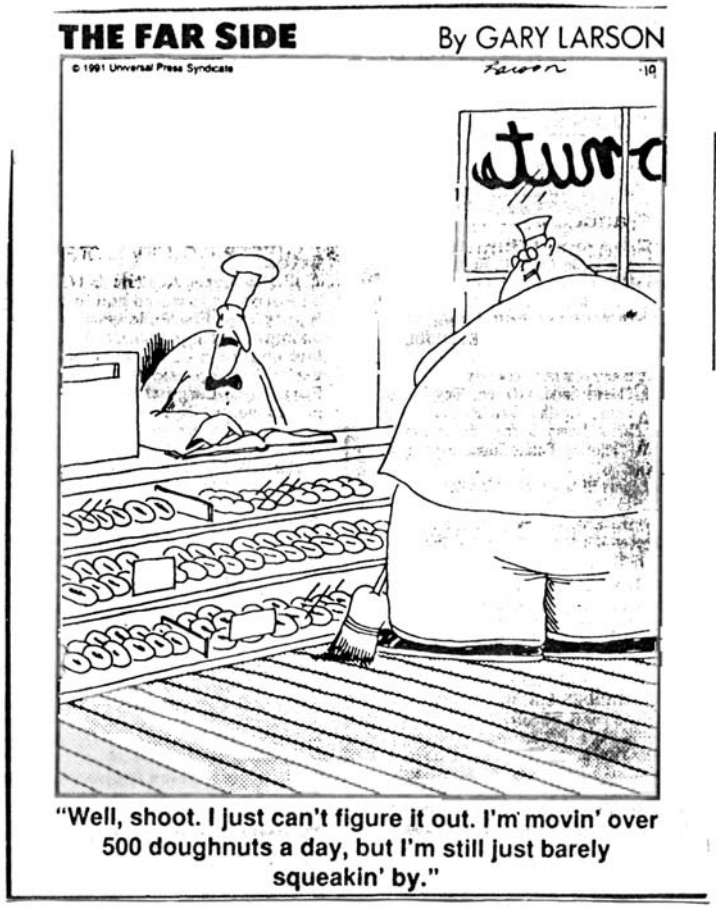
- Magnitude of intervention alters perception of system—a change in the signal to noise ratio.
- Is the change real or random?
- Acceptance sampling considerations
  - Type I error: Falsely concluding that system has changed
  - Type II error: Failing to detect true change
- Interpretation of data is ALWAYS determined by some type of model which assigns importance to observations. Examples:
  - Measures of central tendency and dispersion
  - Moving average, control chart, etc.
  - Smooth
  - Process-oriented model
  - A priori measure of credibility
- Generally desire confirmation from multiple sources: Landings, Discards, Surveys, etc.

Detection of Change becomes more difficult as stocks rebuild

Standard deviation of catch in numbers vs. mean catch (#/tow) for Spiny Dogfish in NEFSC fall, spring and winter trawl surveys. Each dot represents a stratum. Small open dots represent data from 1999 and earlier, large solid circles represent data from 2000-02. Confidence ellipses (95%) are drawn for pre and post warp offset treatment period.



- Fisheries Dependent Data
- Surveys establish trend; fisheries establish scale.
- 1. Surveys establish rates of change in relative indices.
- 2. Fisheries represent a large fraction of the total biomass production.
- Assessment models combine1 and 2.



Well, shoot. I just can't figure it out. I'm movin' over 500 doughnuts a day, but I'm still just barely squeakin; by.

Figure B8. Trends in spawning stock biomass (line) and recruitment (bars) for Georges Bank haddock from 1931-2004.

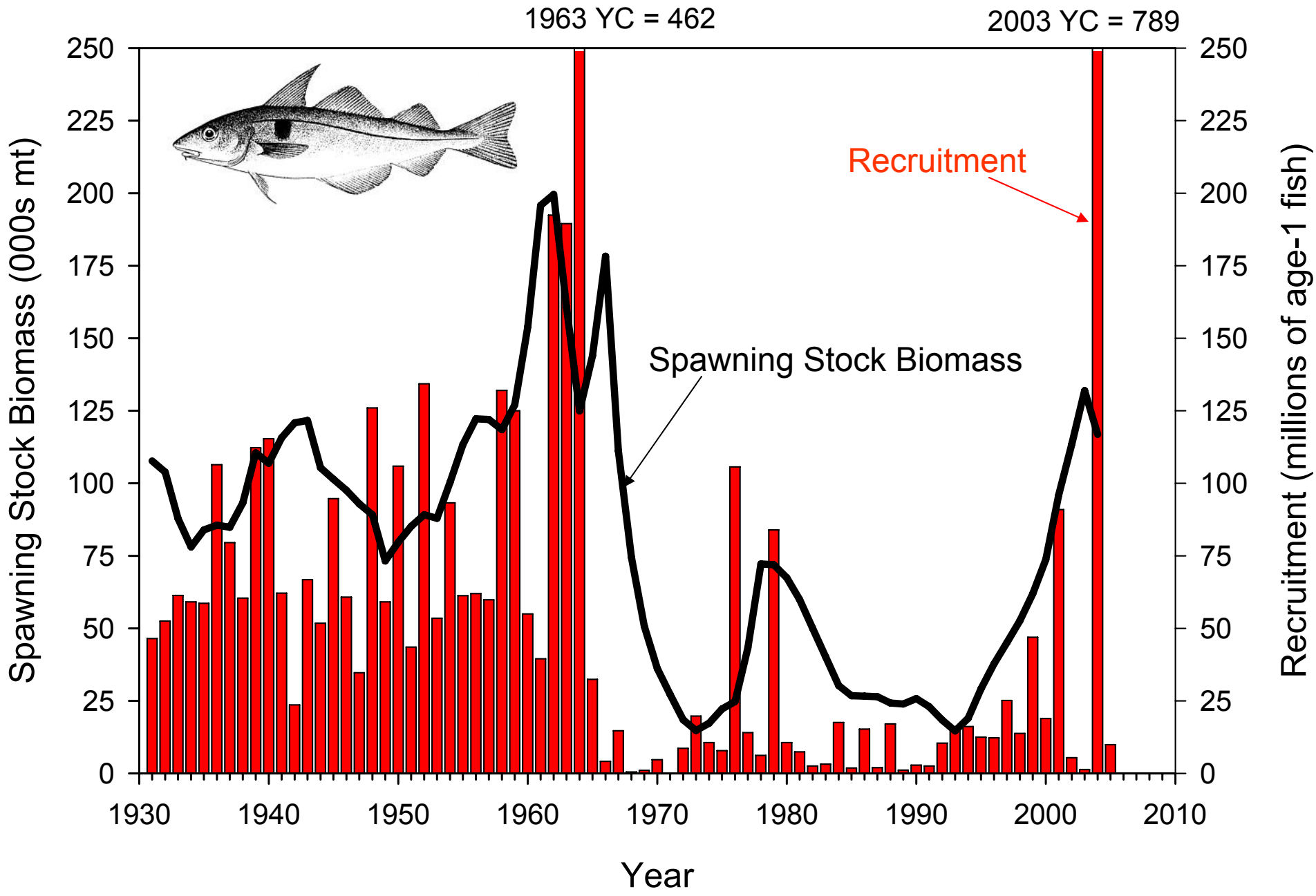
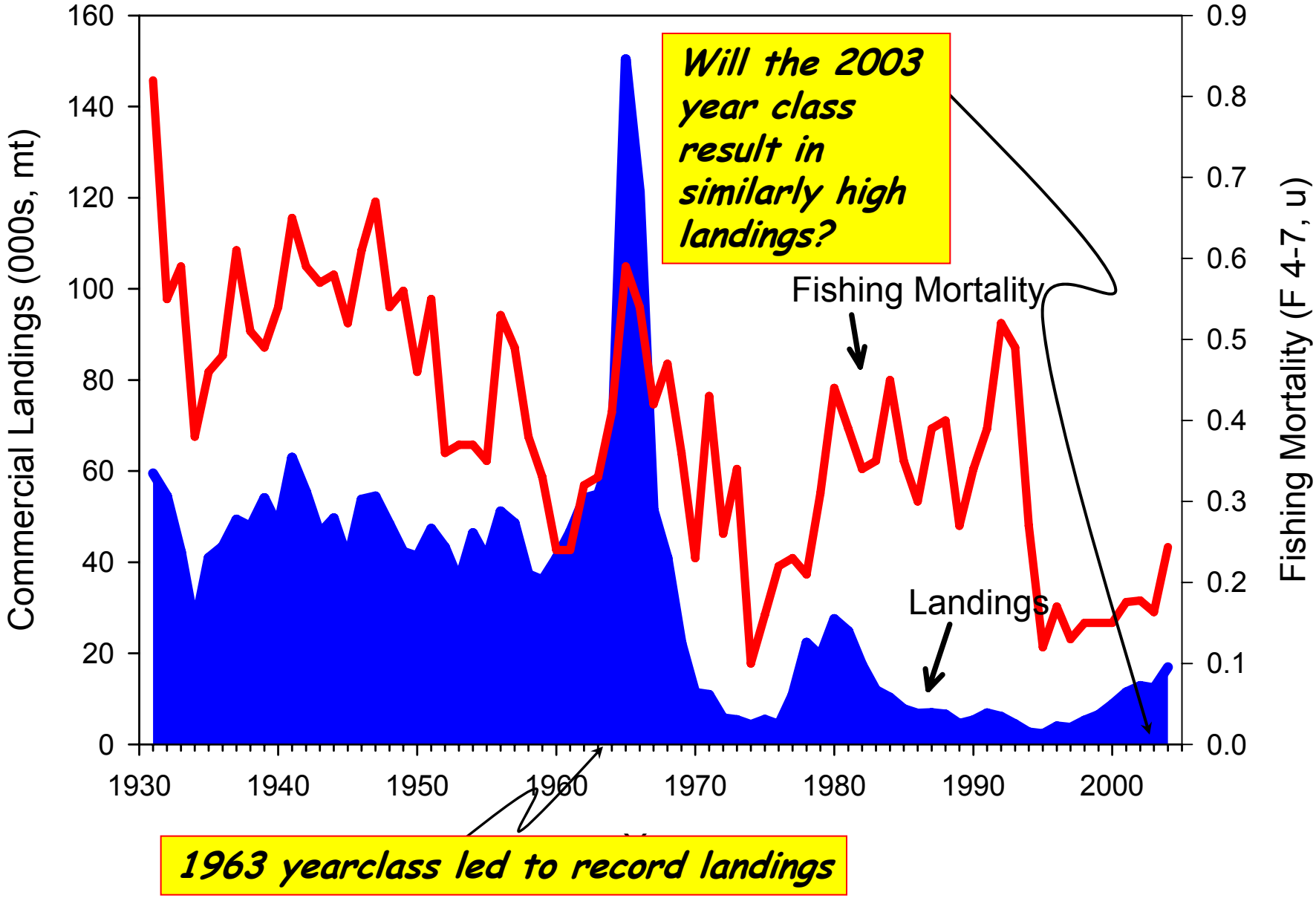
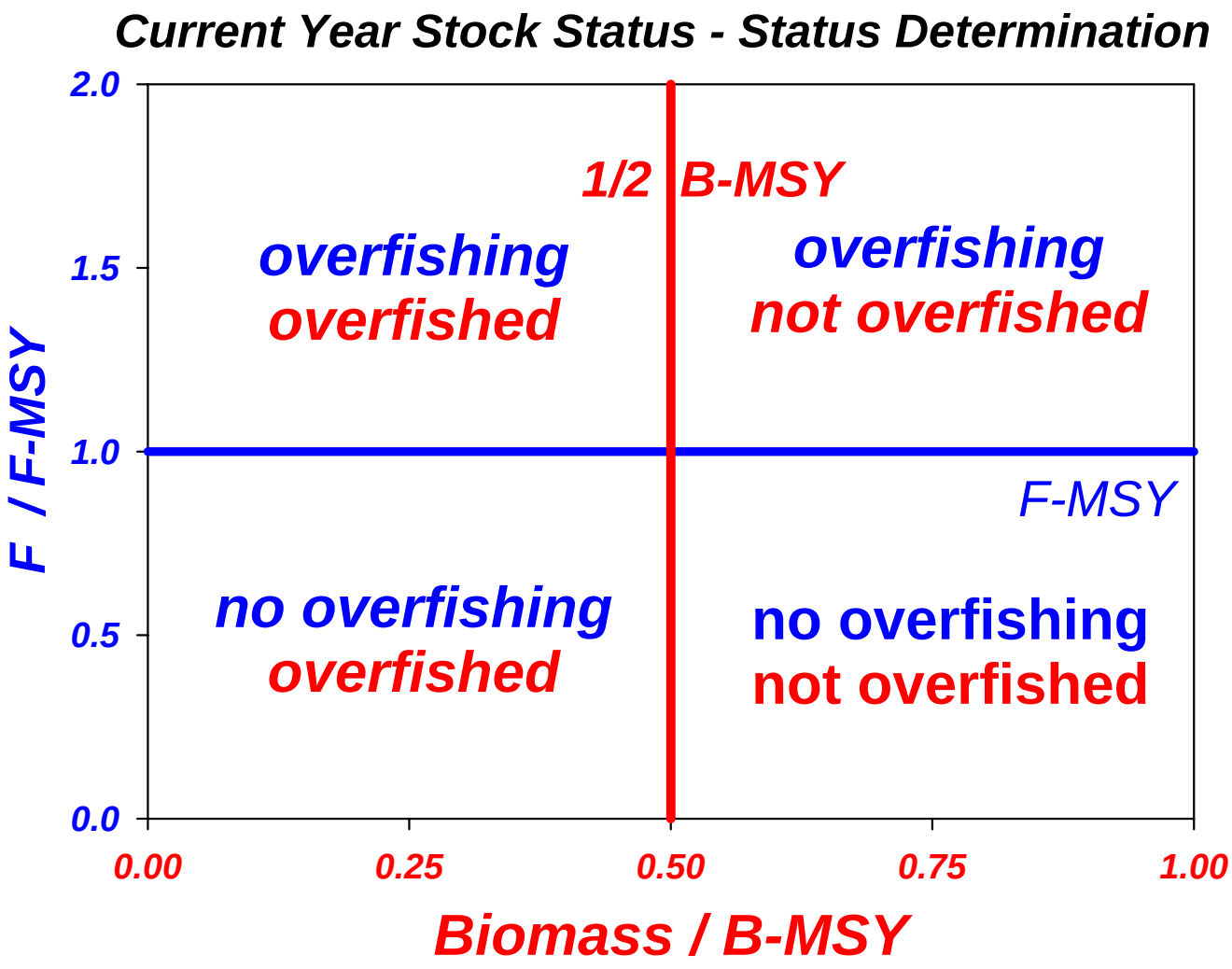


Figure B9. Trends in commercial landings (thousand mt, live weight) and fishing mortality (unweighted mean, ages 4-7) for Georges Bank haddock from 1931-2004.



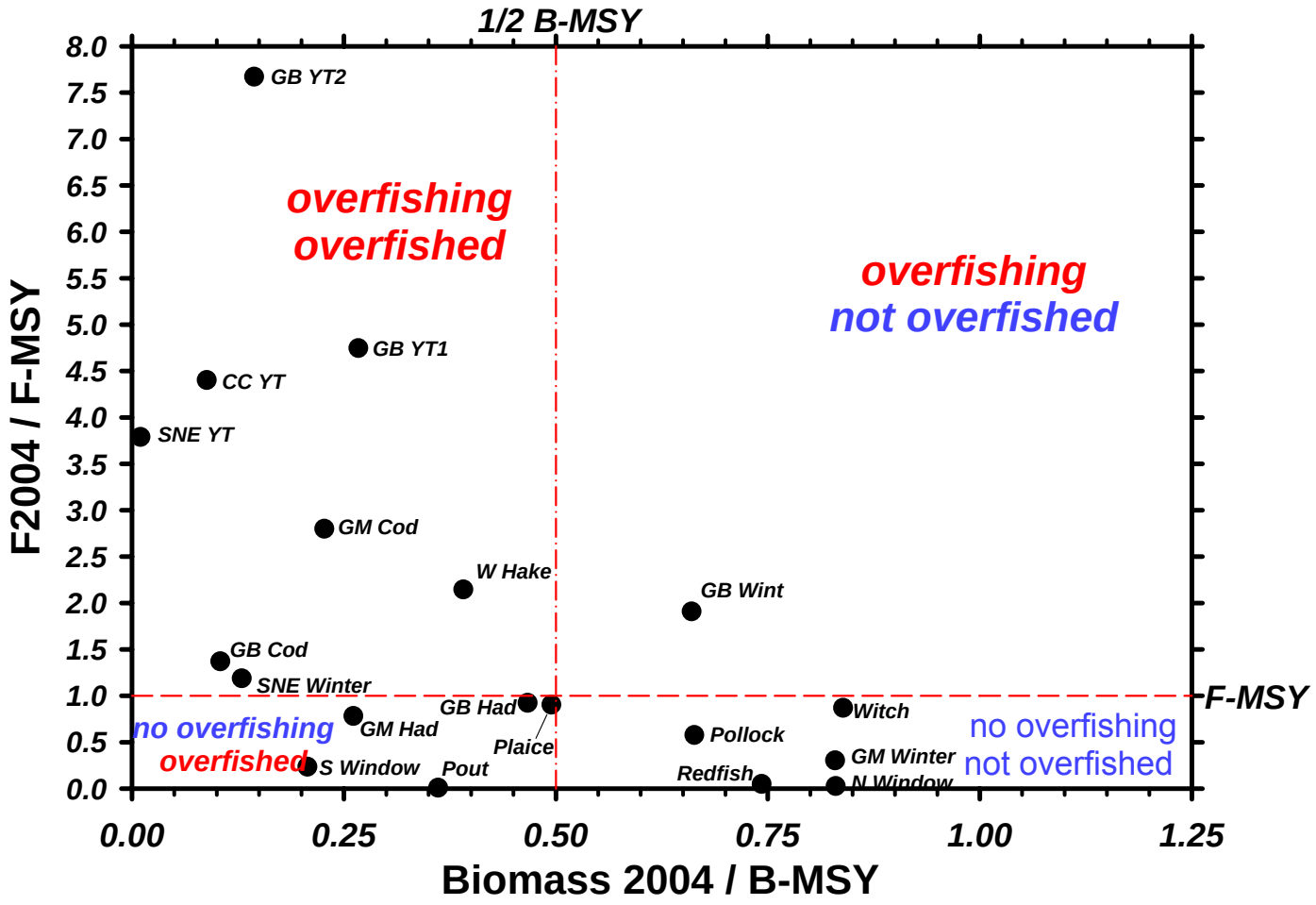


Status determination is based on a comparison of current estimates of fishing mortality and spawning stock biomass with their respective biological reference points. The comparison is based on the ratio of the current value to the reference value. There are 4 possible categories based on overfishing and overfished status.

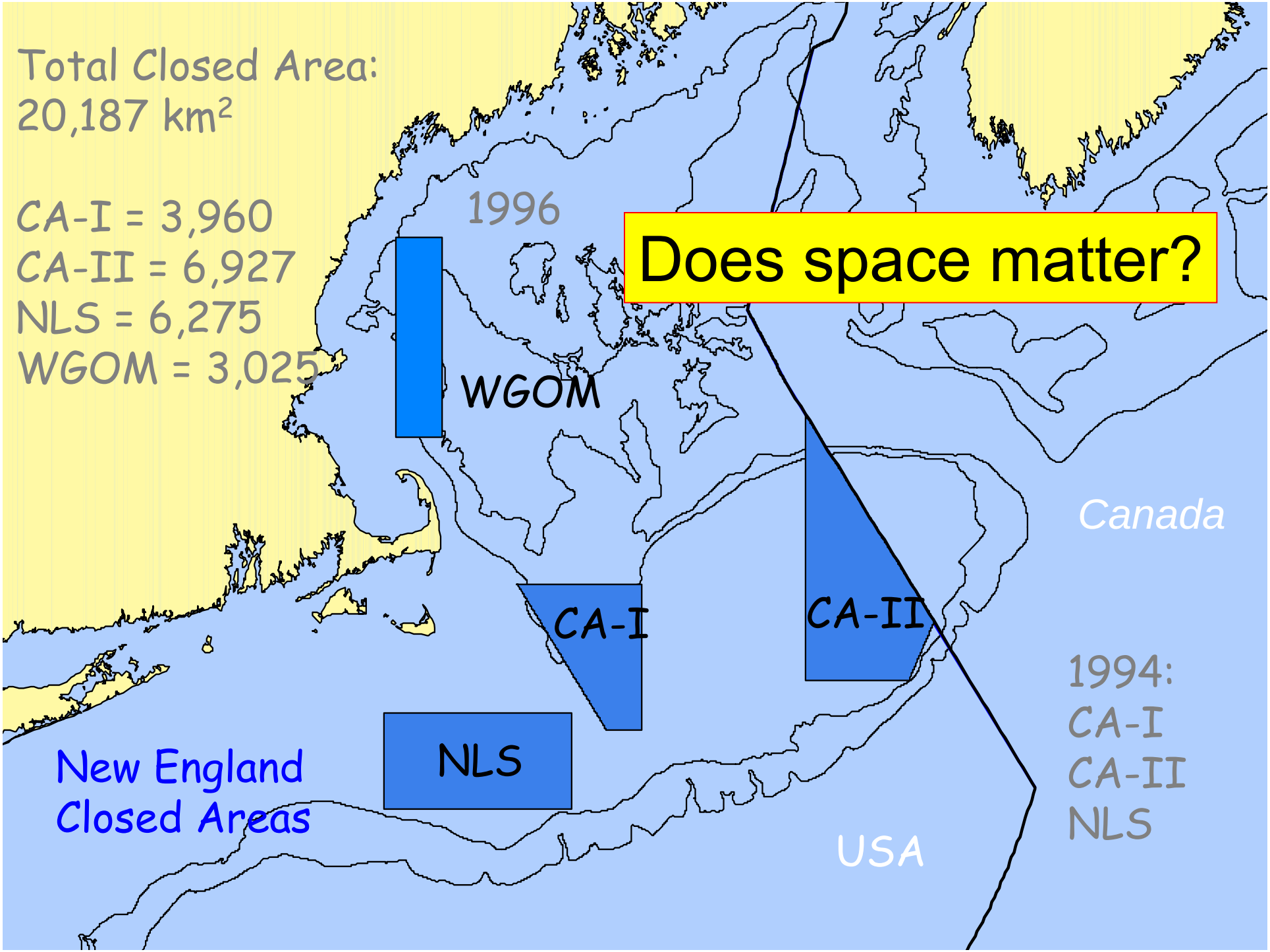
The following figure shows the results of these comparisons for the 2004 calendar year.

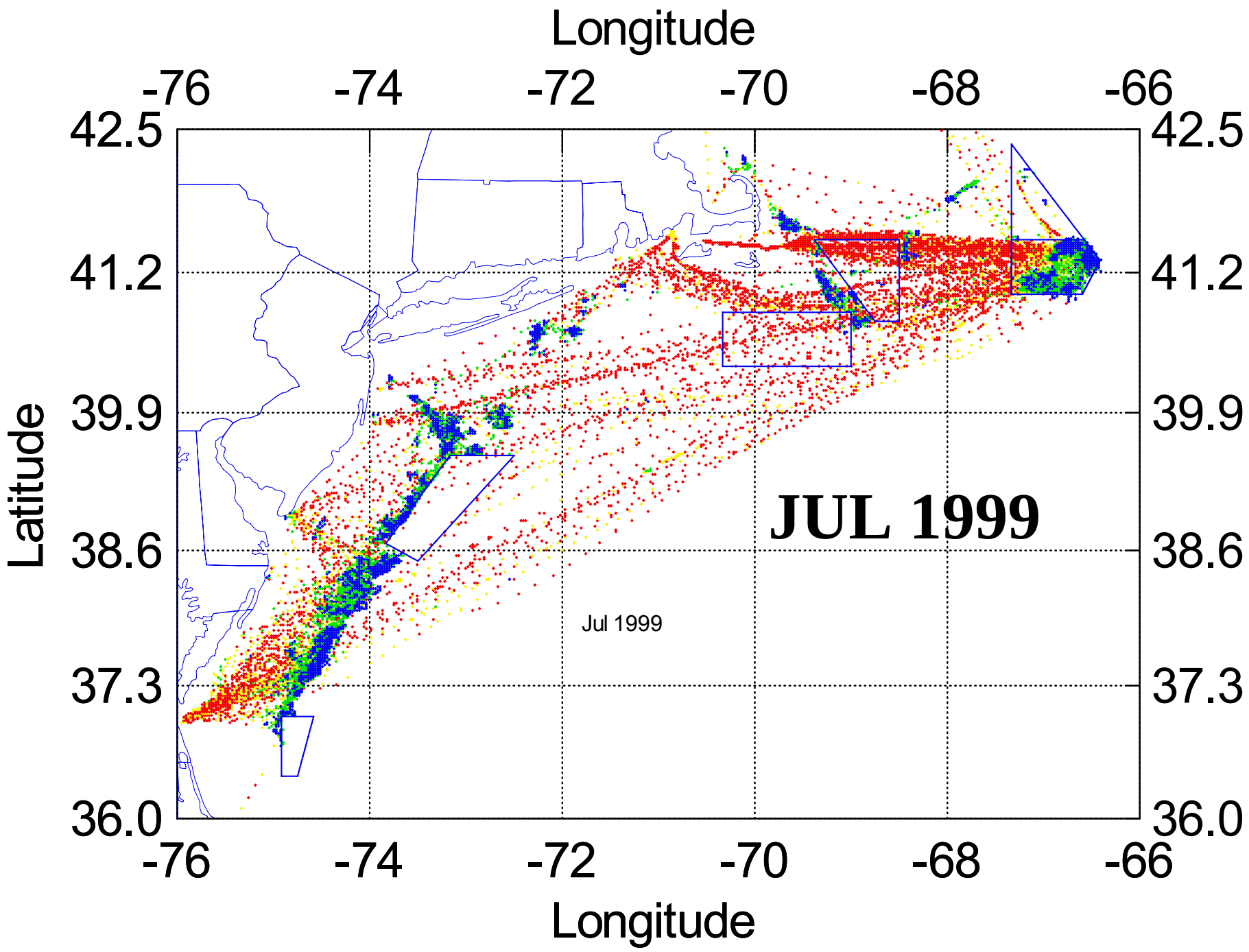
Results of 2005 Groundfish Assessment Review Meeting: Comparisons with Reference Points

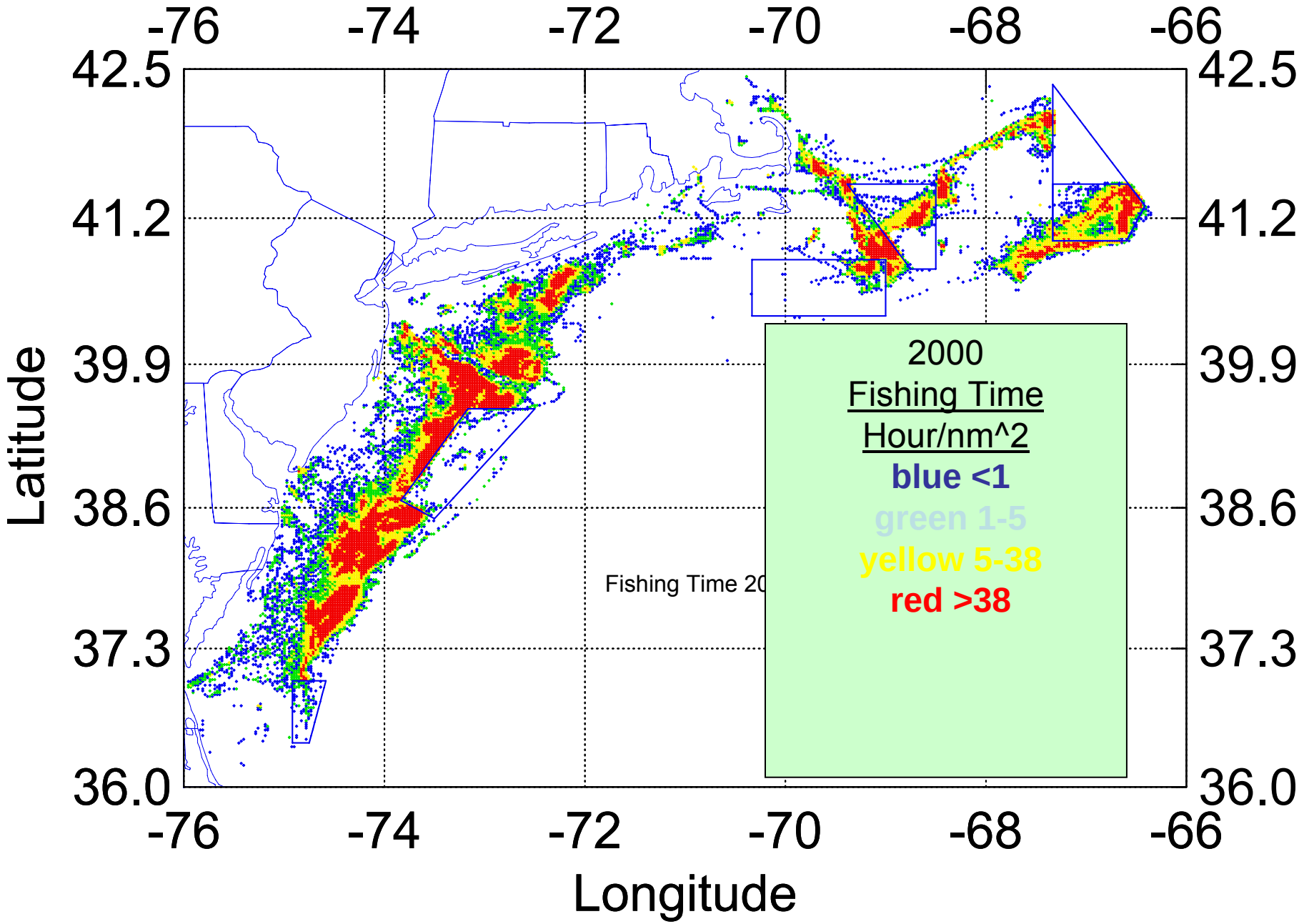
Groundfish Stock Status - 2004

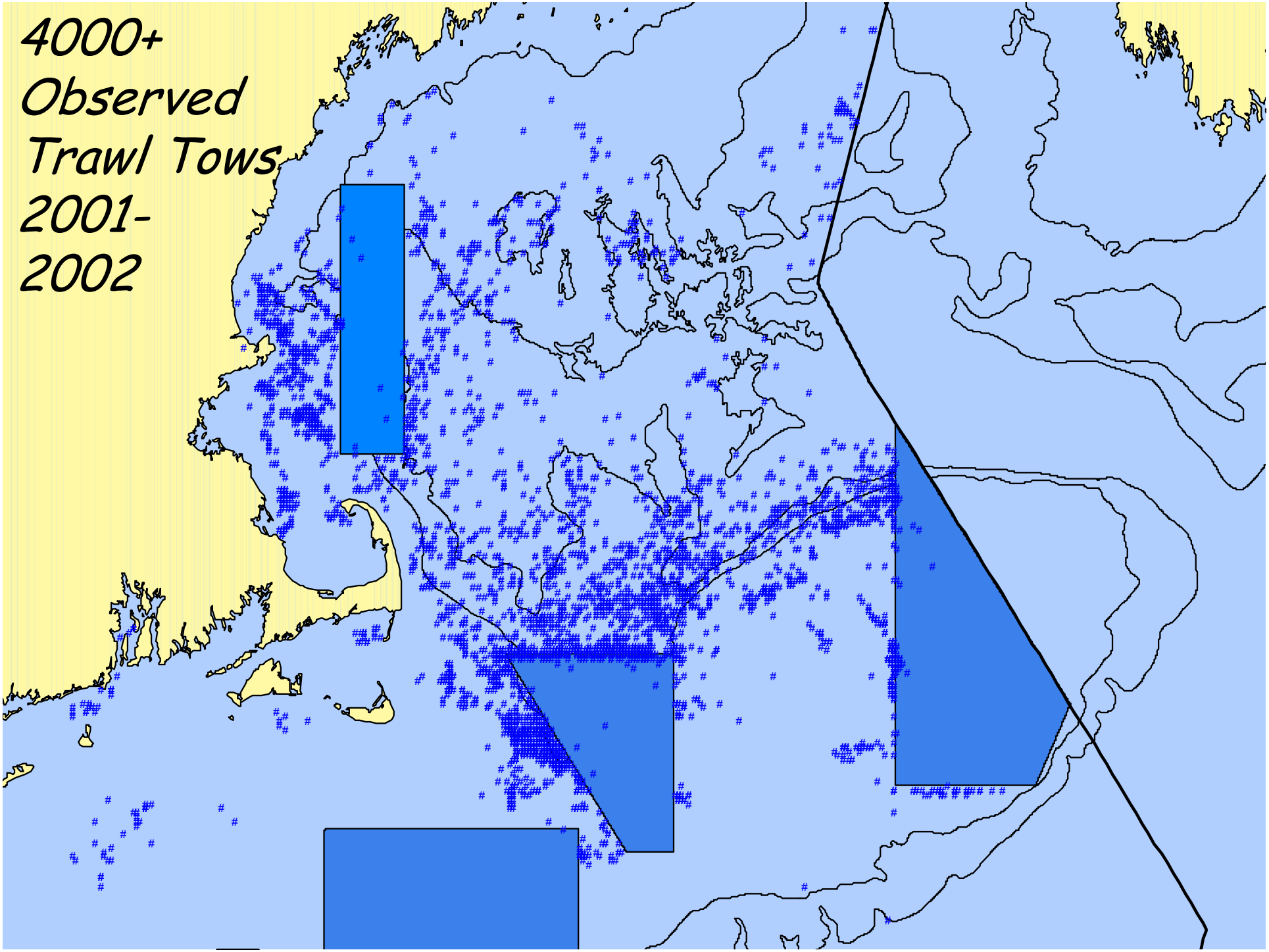


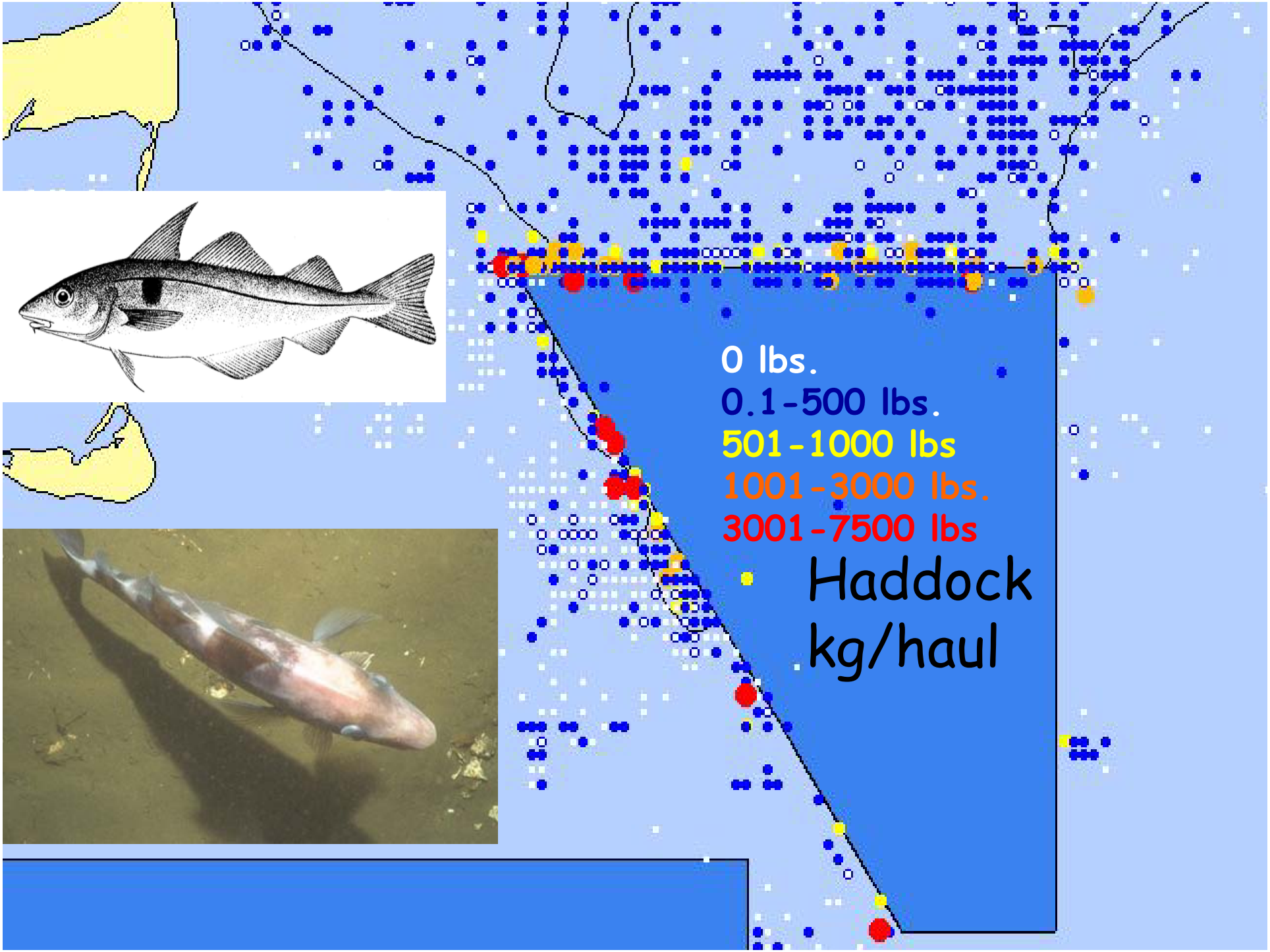
Species Key	
Abbreviation	Stock/Species
GBYT1	Georges Bank Yellowtail Fl. "Base Model"
GBYT2	Georges Bank Yellowtail Fl. "Major Change Model"
CCYT	Cape Cod/Gulf of Maine Yellowtail Fl.
SNEYT	S. New England/Mid Atlantic Yellowtail Fl
GM Cod	Gulf of Maine Cod
W Hake	White Hake
GG Cod	Georges Bank Cod
SNE Winter	S. New England Winter
GM Had	Gulf of Maine Haddock
GB Had	Georges Bank Haddock
Plaice	American Plaice
S Window	Southern Windowpane Fl.
Pout	Ocean Pout
GB Wint	Georges Bank Winter Flounder
Witch	Witch Flounder
Pollock	Pollock
GM Winter	Gulf of Maine Winter Flounder
Redfish	Acadian Redfish
N Window	Northern Windowpane Fl.


Total Closed Area:
20,187 km²
CA-I = 3,960
CA-II = 6,927
NLS = 6,275
WGOM = 3,025
1996
Does space matter?
WGOM
CA-I
CA-II
NLS
Canada
USA
New England
Closed Areas
1994:
CA-I
CA-II
NLS

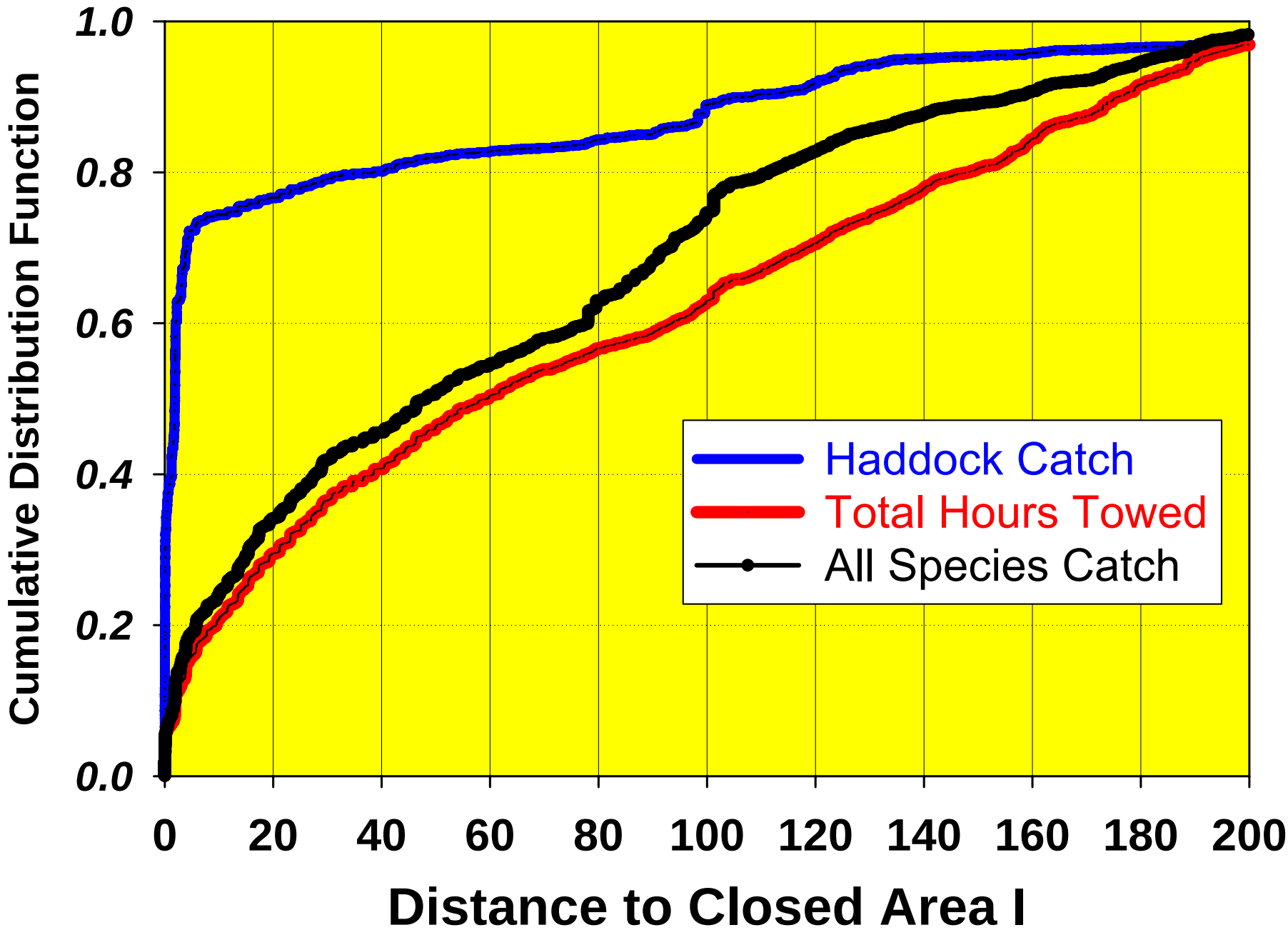

Longitude
-76
-74
-72
-70
-68
-66
42.5
41.2
39.9
38.6
37.3
36.0
Latitude
JUL 1999
Jul 1999
Longitude


-76
-74
-72
-70
-68
-66
42.5
41.2
39.9
38.6
37.3
36.0
Latitude
Longitude
2000
Fishing Time
Hour/nm^2
blue <1
green 1-5
yellow 5-38
red >38
Fishing Time 20


4000+
Observed
Trawl Tows
2001-
2002


0 lbs.
0.1-500 lbs.
501-1000 lbs
1001-3000 lbs.
3001-7500 lbs
Haddock
kg/haul

How Much Catch & Effort is Proximate to CA-I?



Jensen's Inequality

- Function of the mean is less than or equal to the mean of the function
- Relevance—fishermen focus on highest concentrations of fish that can be found, subject to cost constraints and regulations
- Gradients
  - Space –closure areas
  - Target of age classes
  - School effects
- Mixture of populations
  - Open area with refuge
  - Closed area with leakage
  - Try to describe with an average population

Jensen's Inequality: Application to a spatial fishery

$$G(\bar{x}) \leq \int G(x)\, pdf\,(x)\, dx$$

where

$$\bar{x} = \int x\ pdf\,(x)\, dx$$

Suppose x is the average relative density at some location y and G(x) is the amount of fishing effort expended to catch x at location y. Total landings are proportional to the product of fishing effort and local concentration so that the total yield is

$$Landings_1 = \alpha \int x\, G(x)\, pdf\,(x)\, dx$$

Where α is a proportionality constant that scales the relative density x to true population size.

Jensen's Inequality: Application to a spatial fishery

If we incorrectly assume that landings have been extracted from a population whose relative size is defined by xbar,

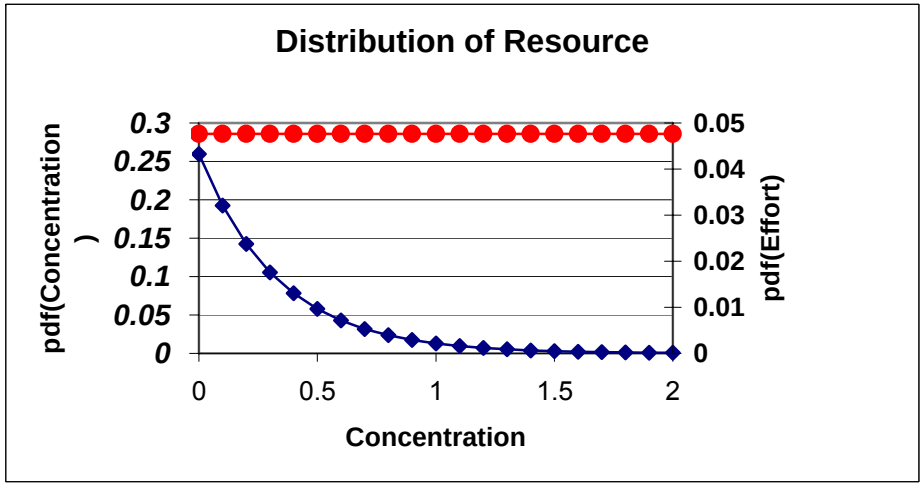
$$Landings_2 = \alpha' \, \bar{x} \, G(\bar{x})$$

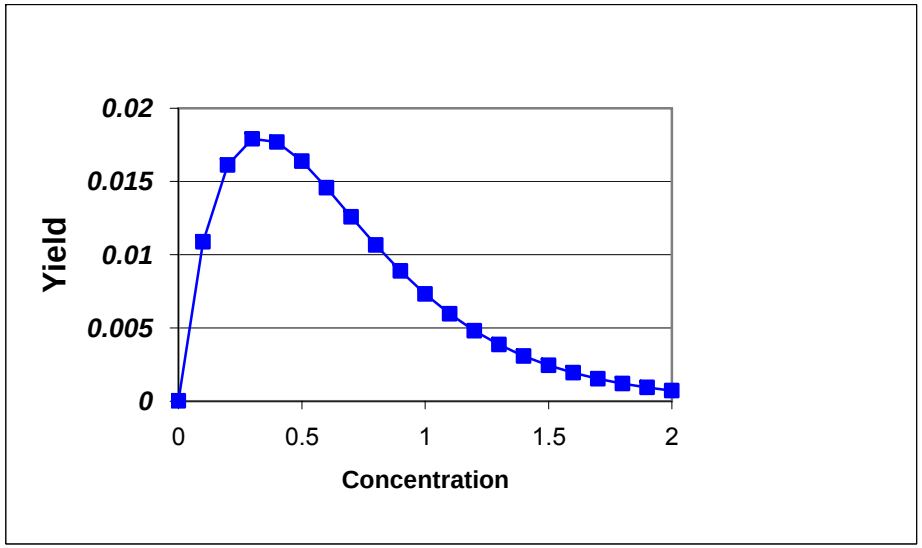
Since landings and relative density are an observed quantities, then Landings1=Landings2. This means that α'>α to compensate for the fact that

$$G(\bar{x}) \leq \int G(x) \, pdf(x) \, dx$$

Therefore a non-spatial treatment of average density *COULD* lead to an overestimate of the population size.

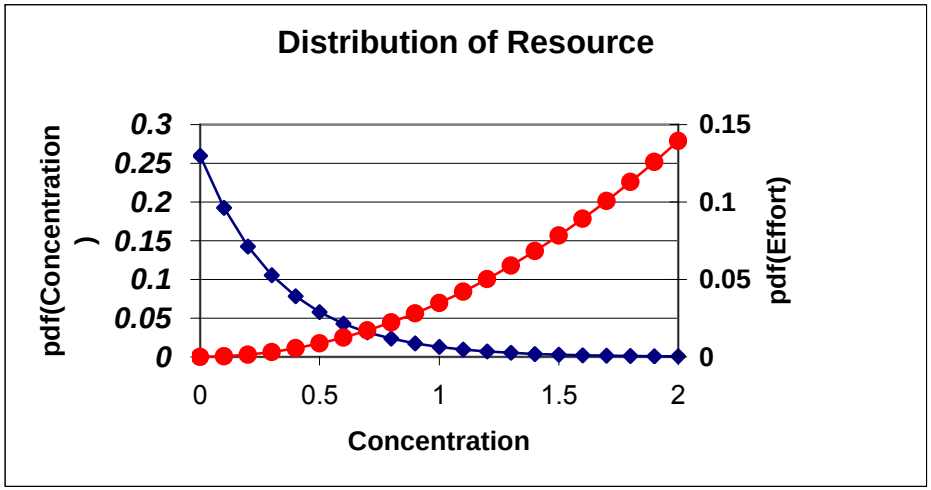
Uniform Distribution of Effort

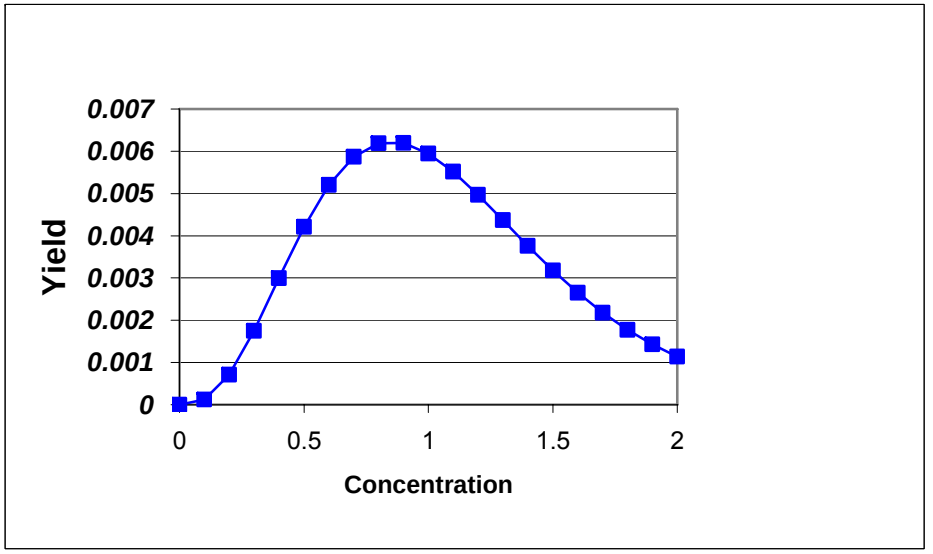




Yield| Ho: Spatial Dist. =
Yield| Ho: Uniform Dist. ***1.00***

Spatial Distribution of Effort

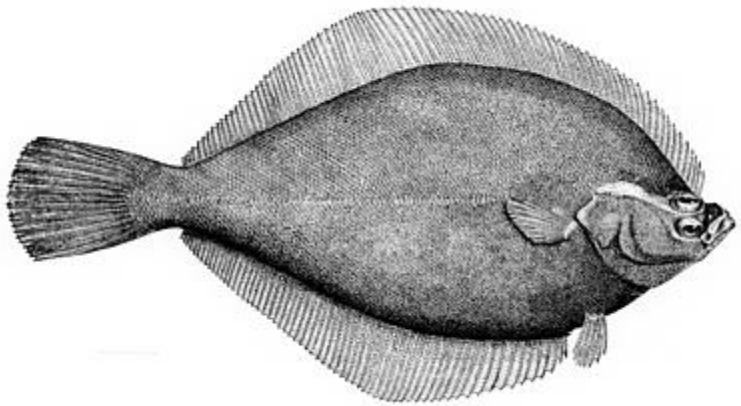


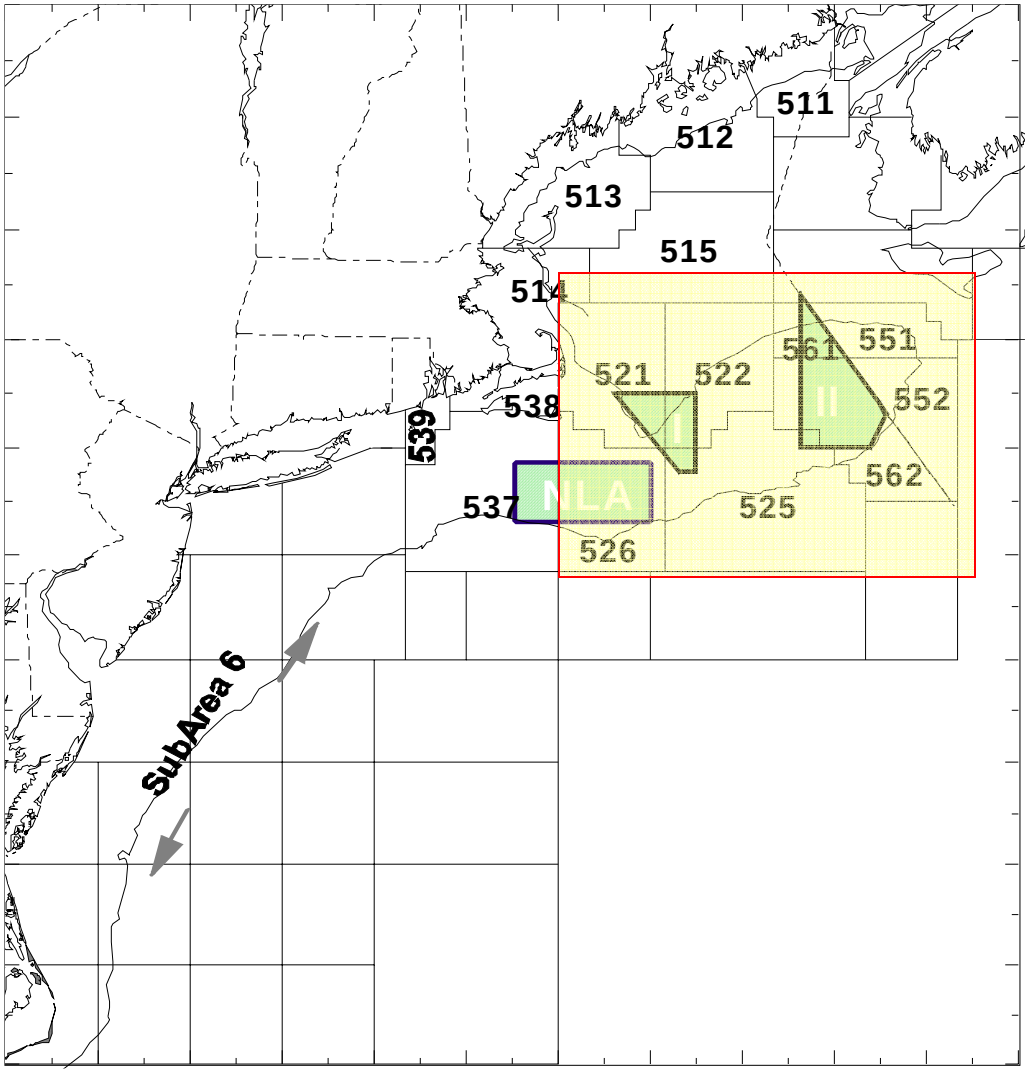


Yield| Ho: Spatial Dist. =
Yield| Ho: Uniform Dist. ***3.76***

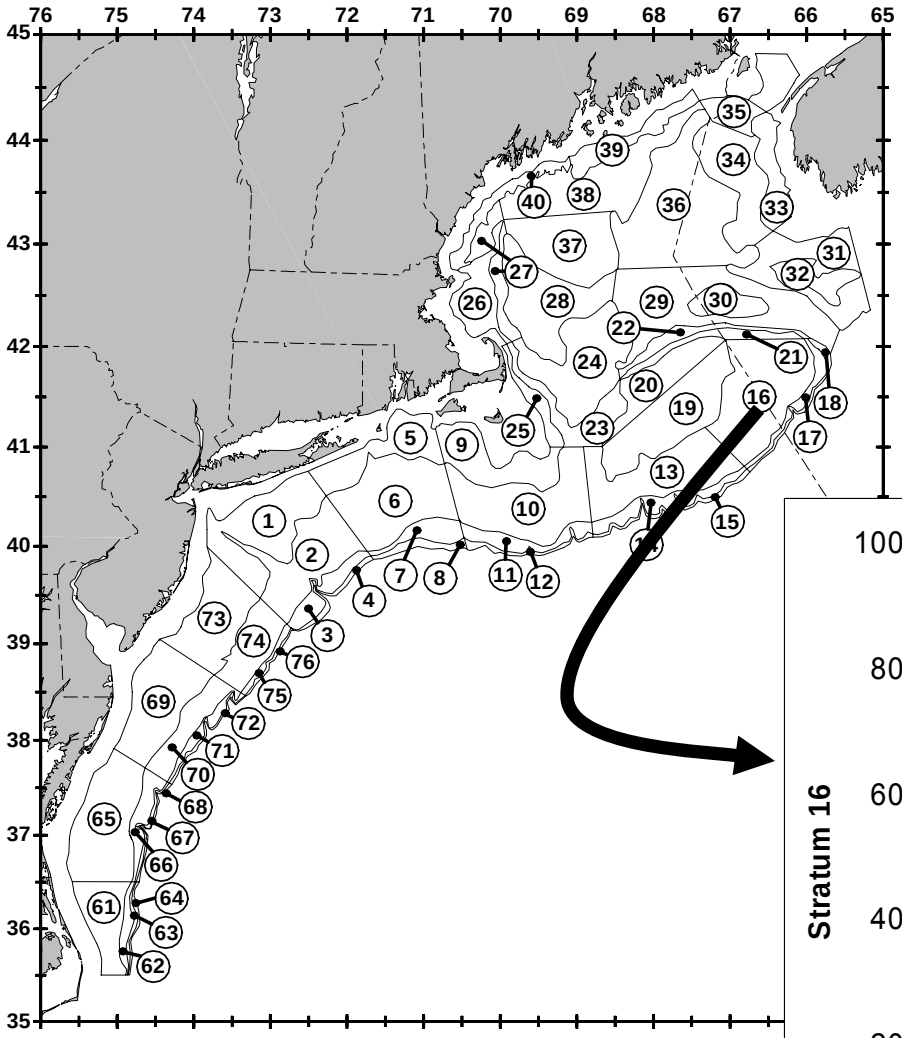
Georges Bank Yellowtail Flounder

- Areas 522, 525, 561, 562, 551, 552



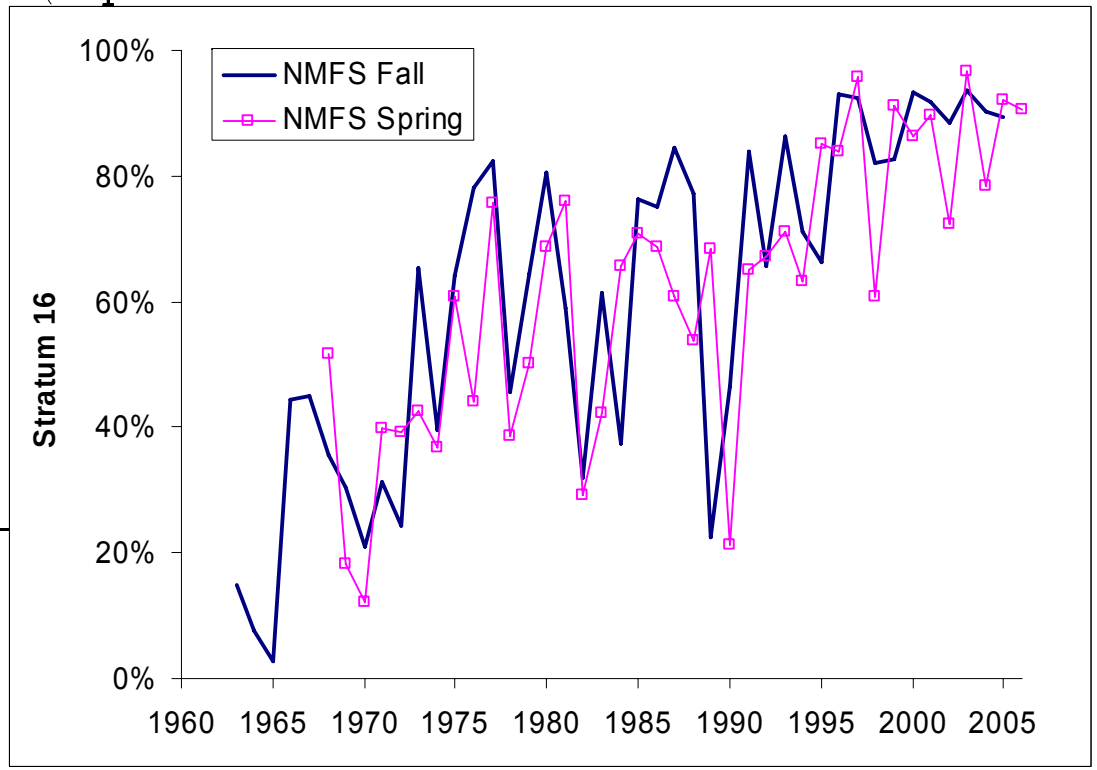


NEFSC offshore bottom trawl survey strata

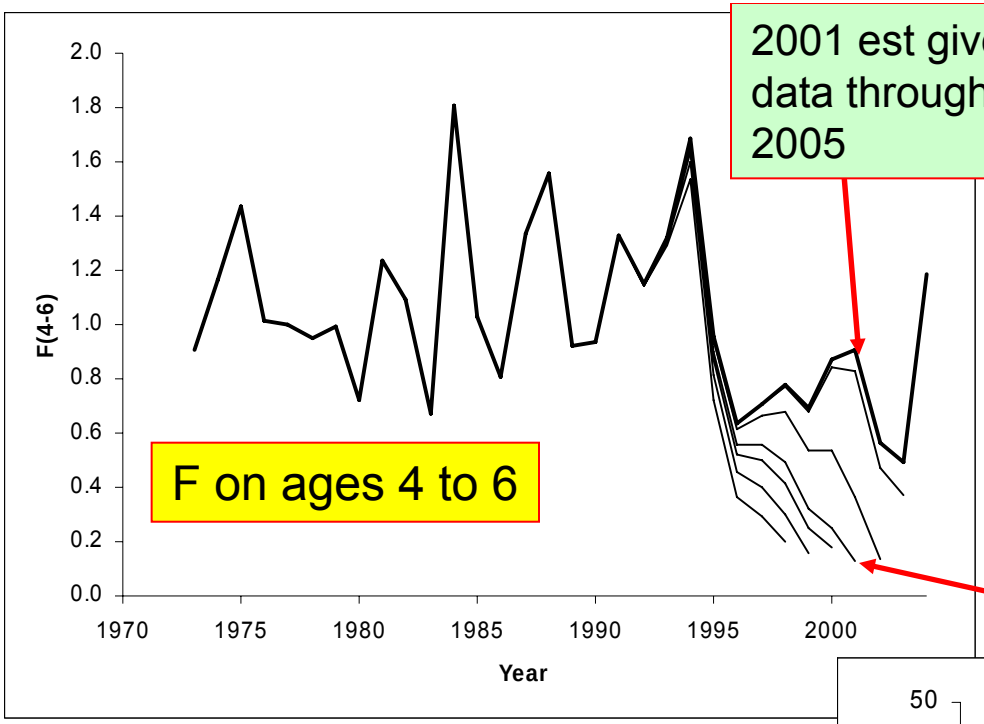


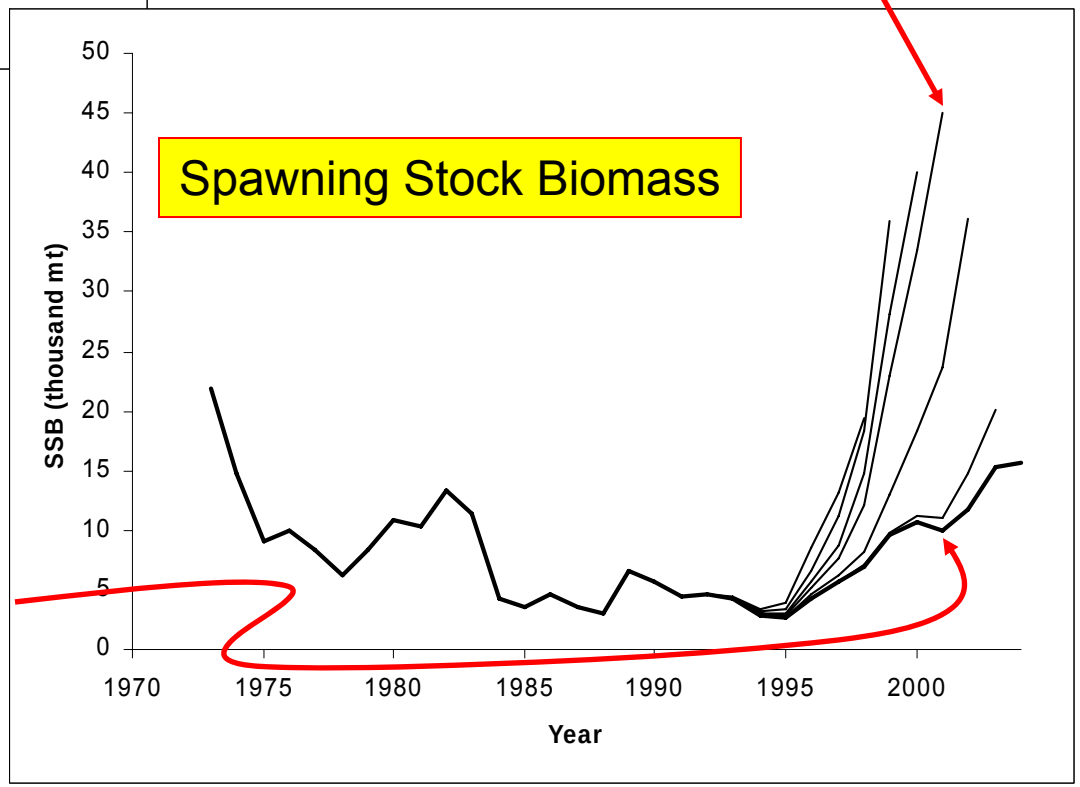
Spatial Concentration of Population Density

Increases in Georges Bank Yellowtail Flounder have been dominated by increases in stratum 16, an area largely closed to fishing since 1994.



GB Yellowtail Retrospective (Base Model)

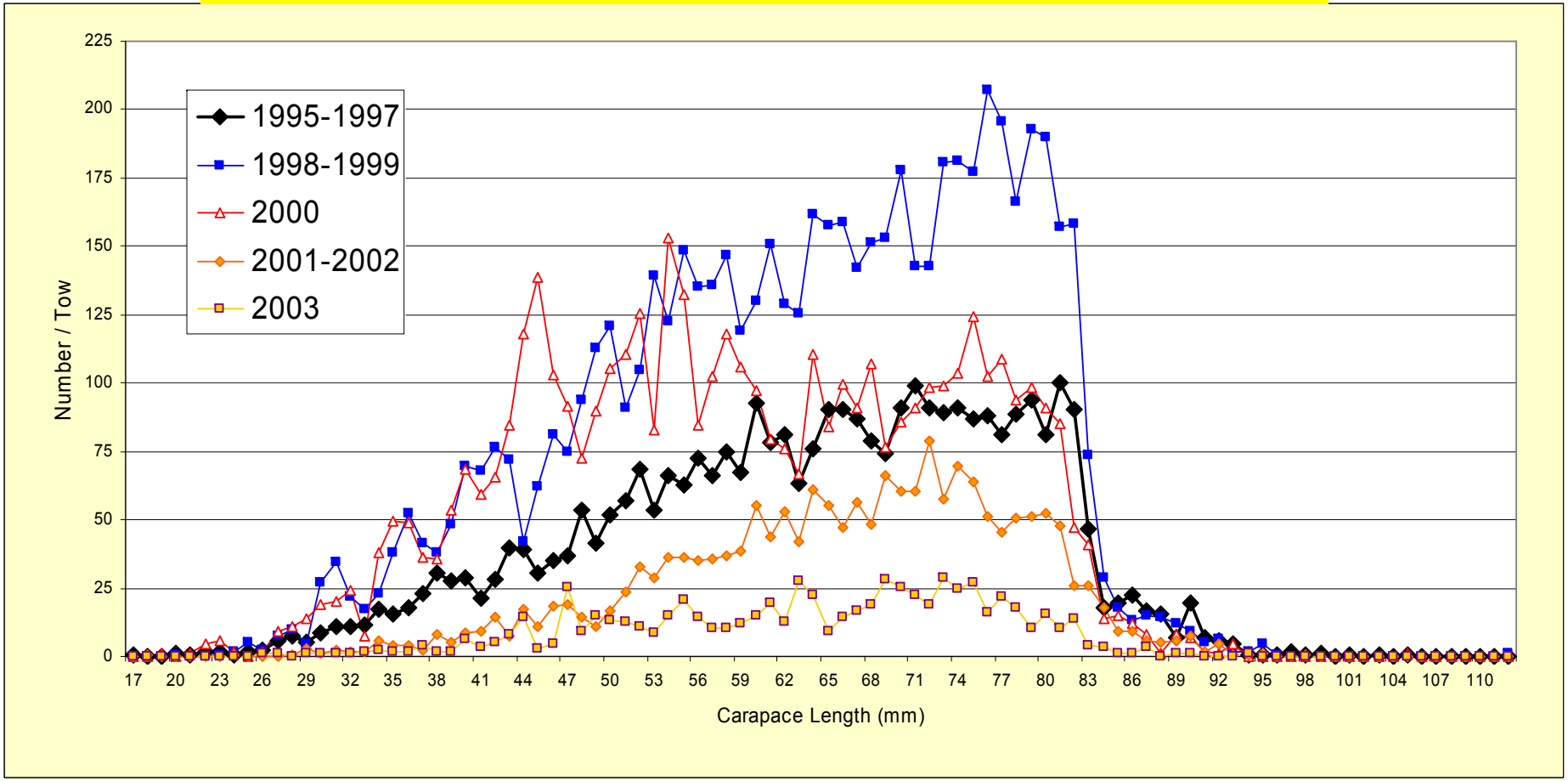




2001 est given data through 2005

Can you guess the legal size limit?

FEMALE LOBSTER LENGTH FREQUENCIES
FROM CT DEP LIST SPRING SURVEY CATCHES 1995-2003



“According to industry sources, the lobster resource in New York has been actively managed since early in the century. As a result of this effort and the strong conservation ethic that has developed among commercial lobsterman over the past decade, the resource continues to be relatively stable and healthy as the total catch has increased”.

By Ken Gall, New York Sea Grant

New York's Seafood Council Newsletter

Spring 1994 Vol. 1, No. 3

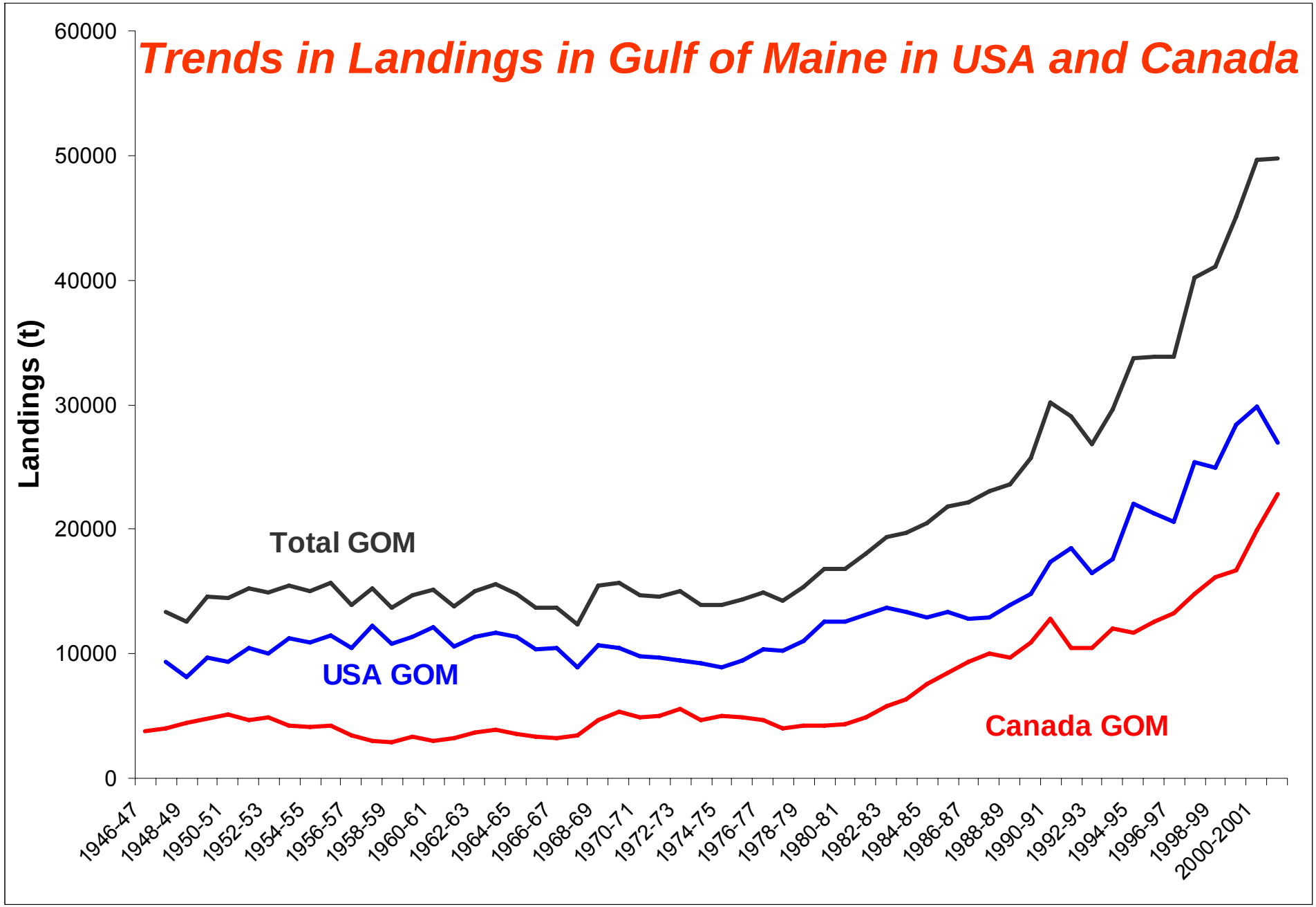
Updated August 1999

Last month, Representative Forbes asked the House Appropriations Committeee, of which he is a member, for $30 million for scientific research and economic aid to the 900 Long Island families who earn their living from lobstering.

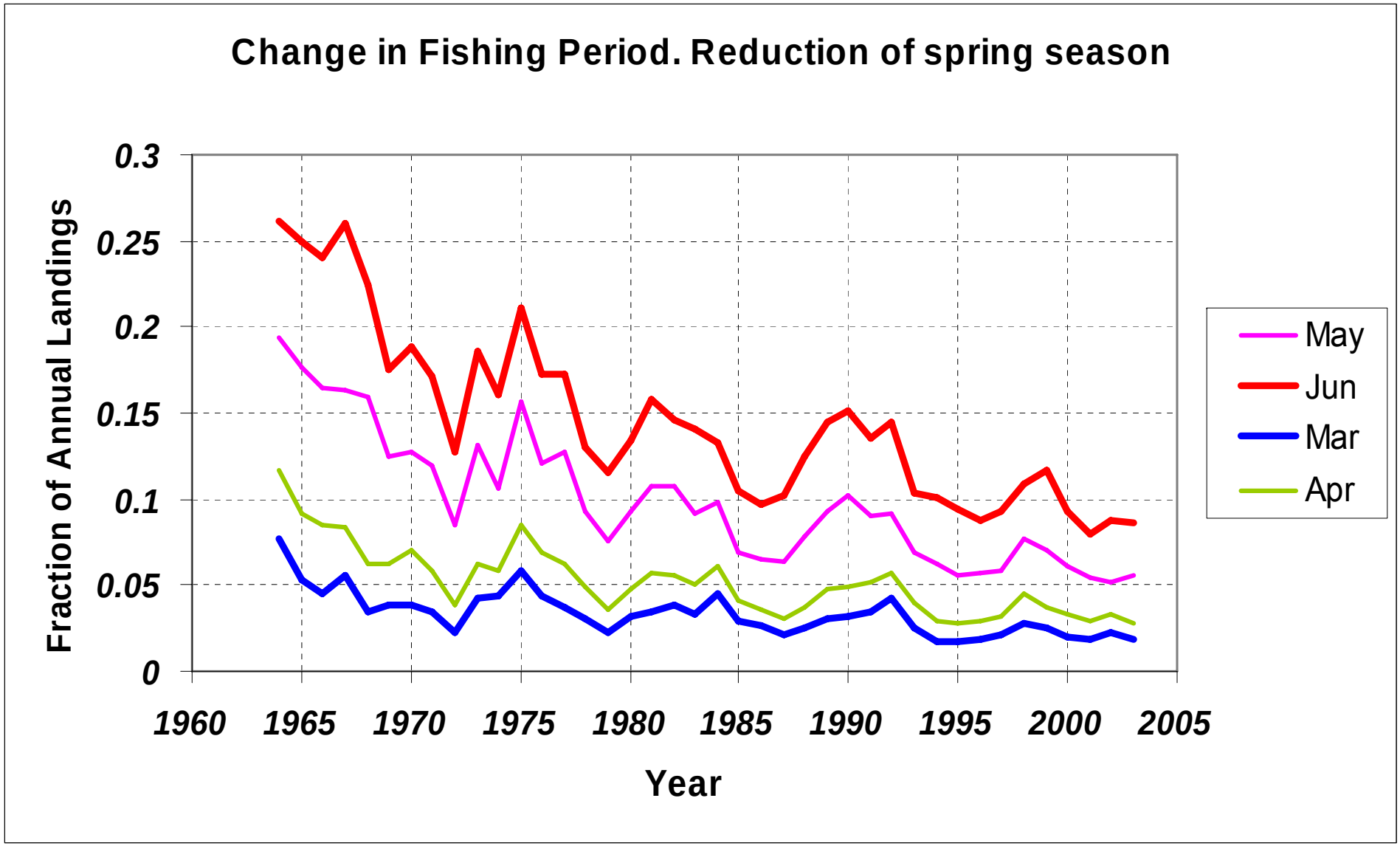
The response was an $8 million allocation for research into the cause of the devastating die-off of lobsters in western Long Island Sound and the epidemic of shell rot in lobsters in the eastern Sound.

Mr. Forbes is still waiting to hear about his request for $19 million to compensate New York and Connecticut lobstermen for lost income and $2 million that would go to help find new jobs for anyone affected by the collapse of the lobster industry.

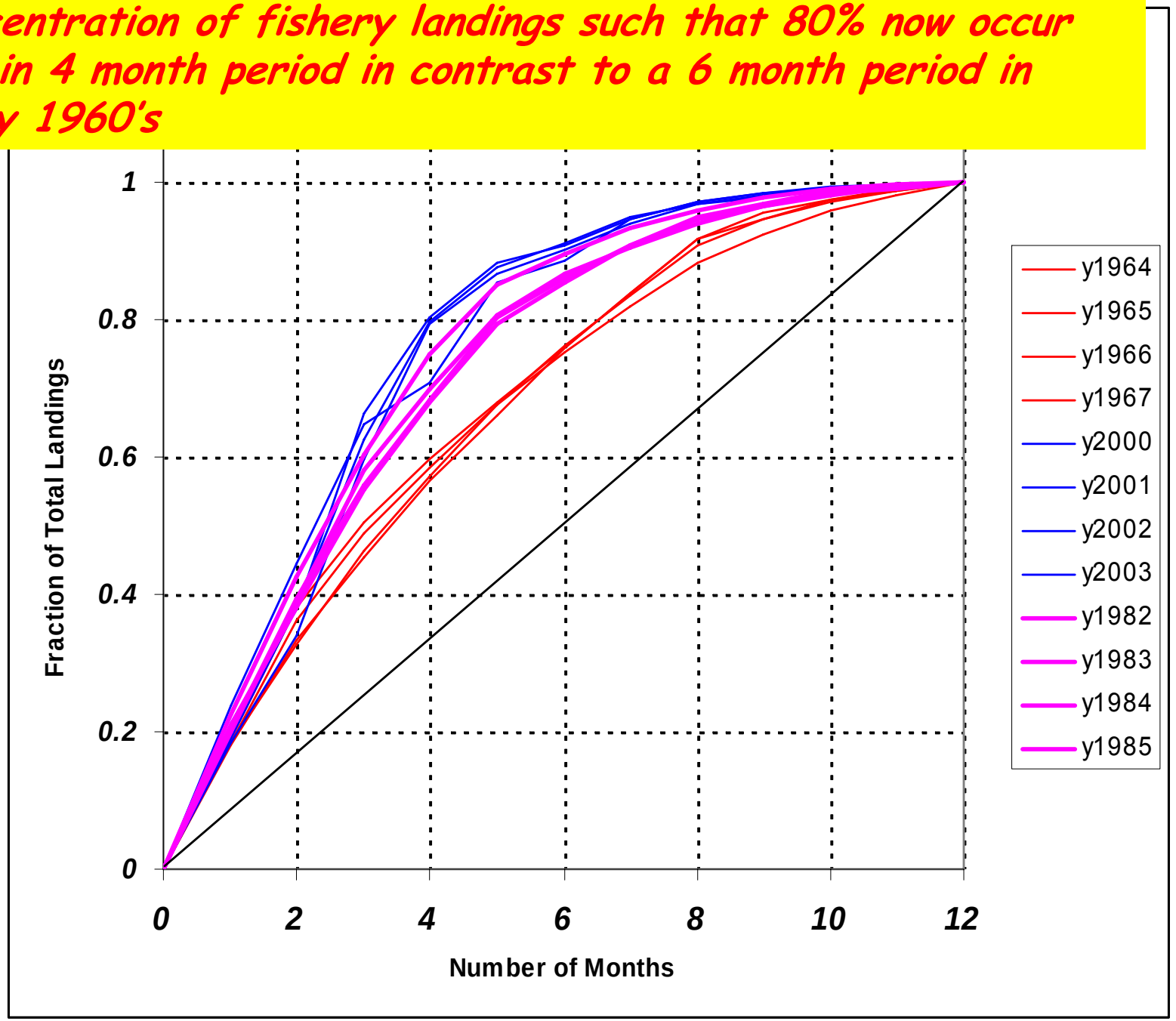
Issue Date: Southampton Press 04/13/2000


Trends in Landings in Gulf of Maine in USA and Canada
Landings (t)
60000
50000
40000
30000
20000
10000
0
Total GOM
USA GOM
Canada GOM
1946-47
1948-49
1950-51
1952-53
1954-55
1956-57
1958-59
1960-61
1962-63
1964-65
1966-67
1968-69
1970-71
1972-73
1974-75
1976-77
1978-79
1980-81
1982-83
1984-85
1986-87
1988-89
1990-91
1992-93
1994-95
1996-97
1998-99
2000-2001

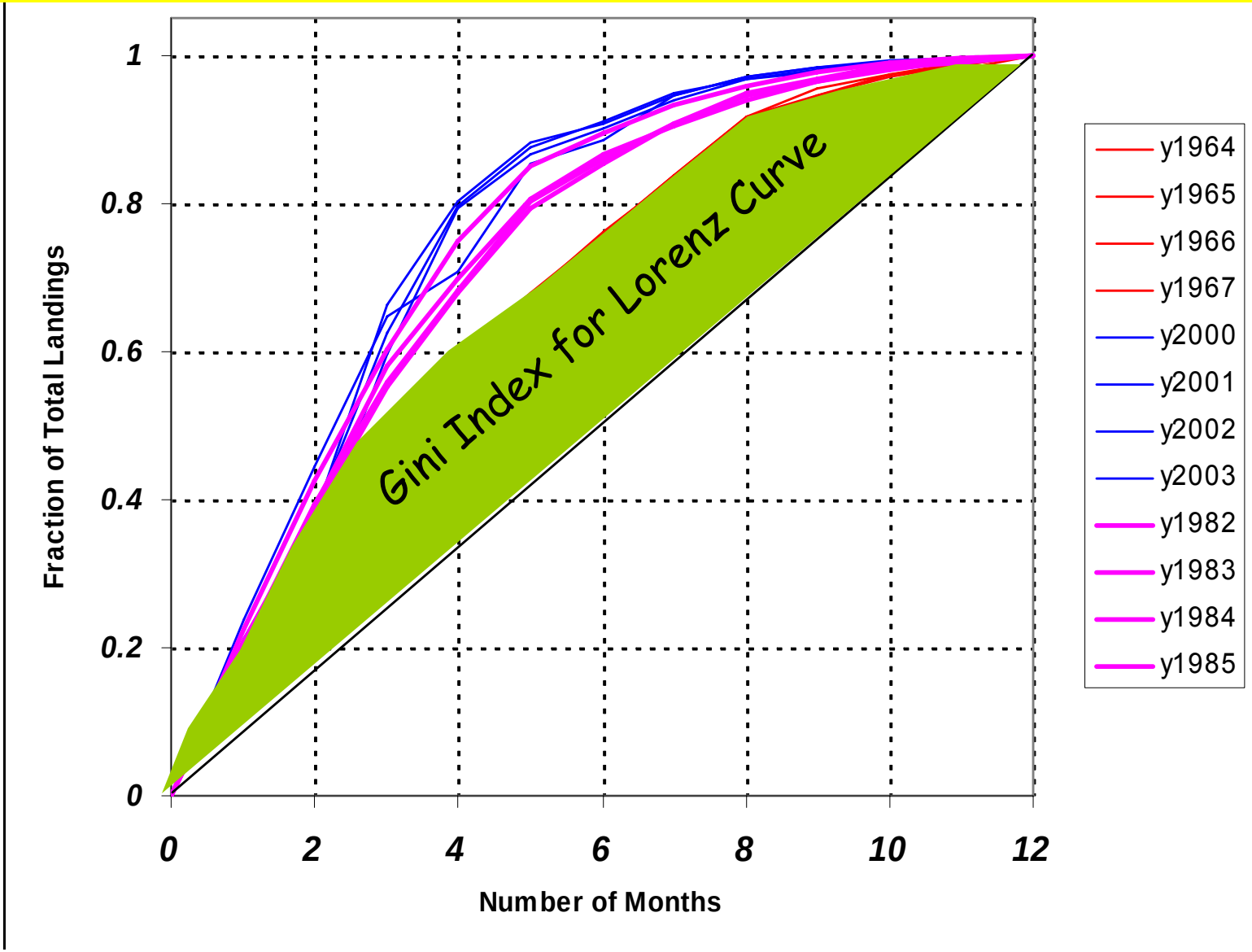
Intense Fishery following the molt has decreased the fraction of landings taken between January and June

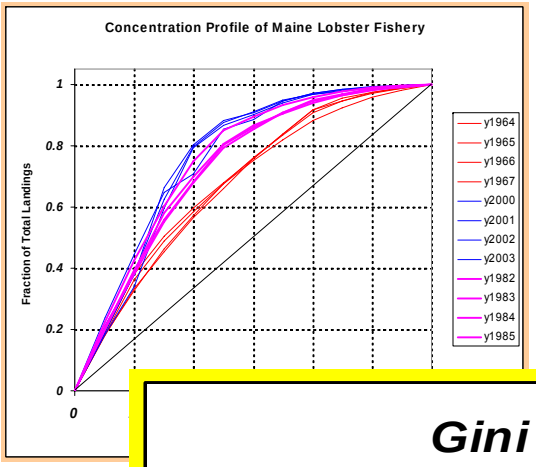


Intense fishing after molt has resulted in a increasing concentration of fishery landings such that 80% now occur within 4 month period in contrast to a 6 month period in early 1960's

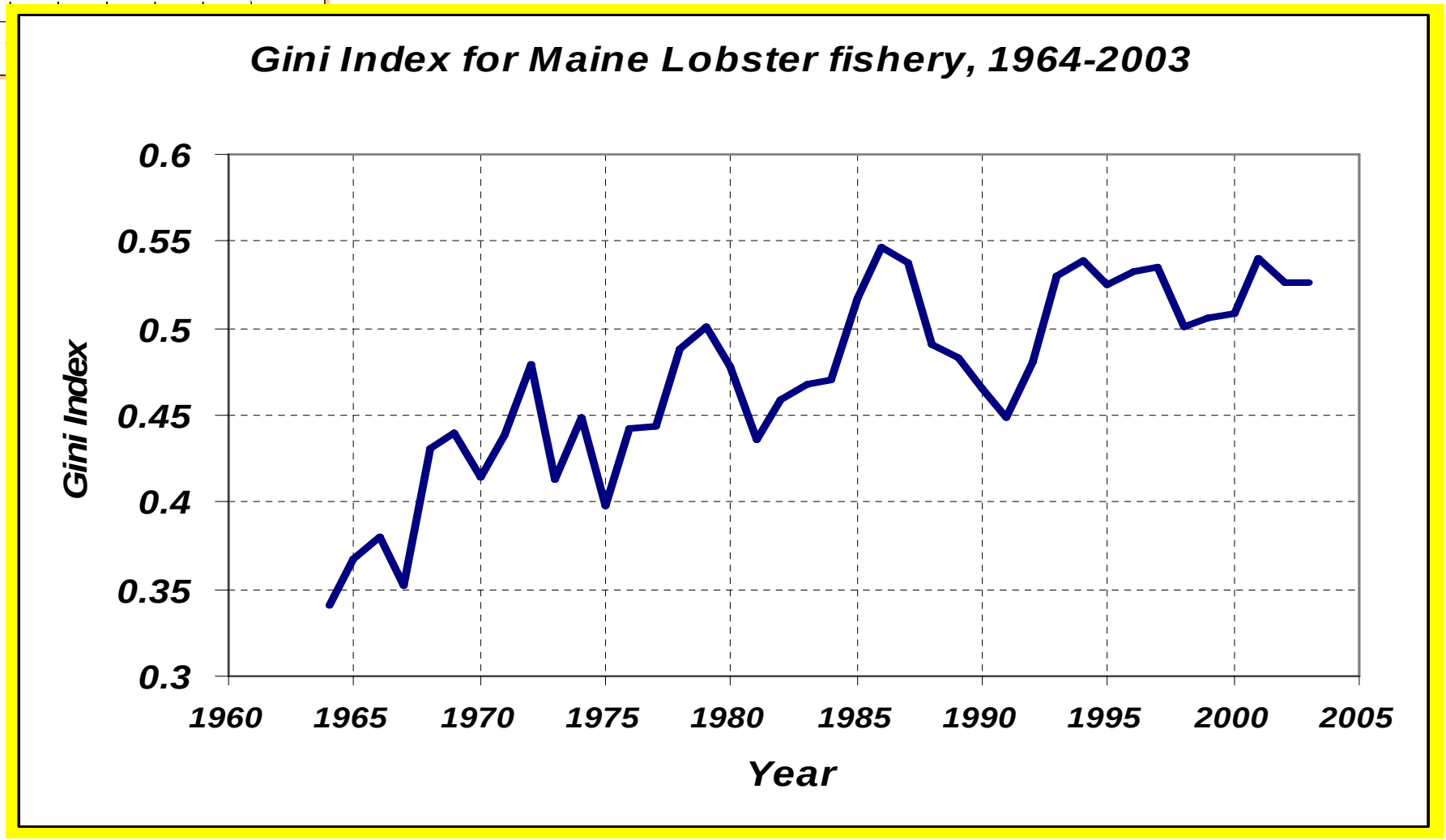


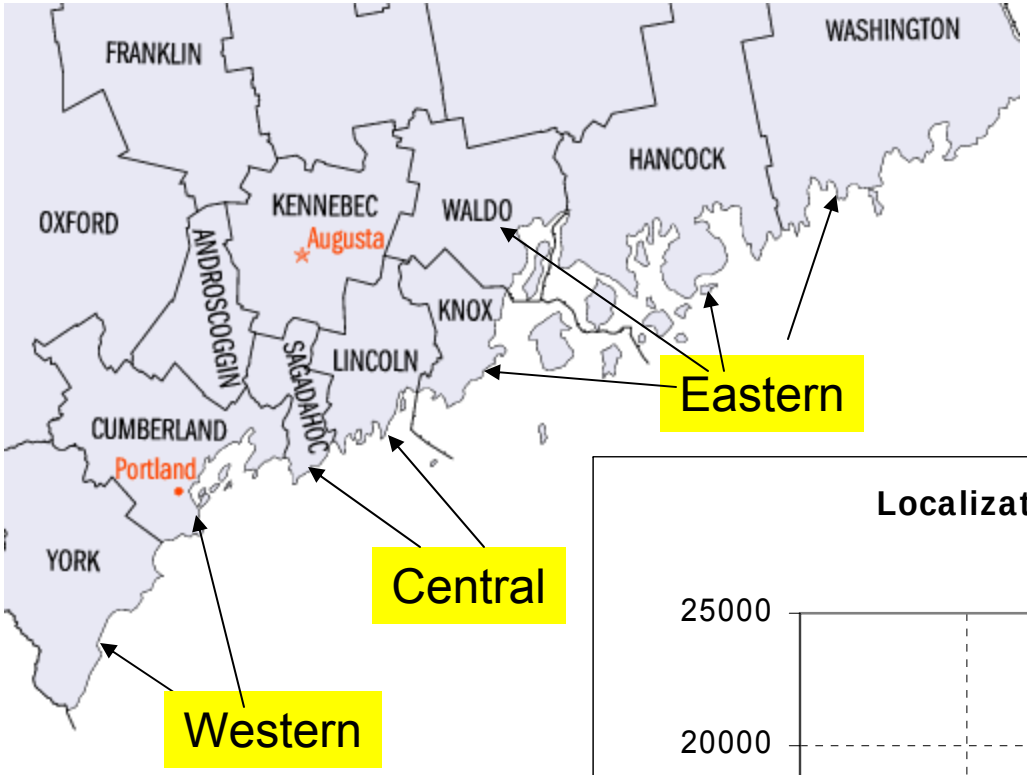
Intense fishing after molt has resulted in a increasing concentration of fishery landings such that 80% now occur within 4 month period in contrast to a 6 month period in early 1960's

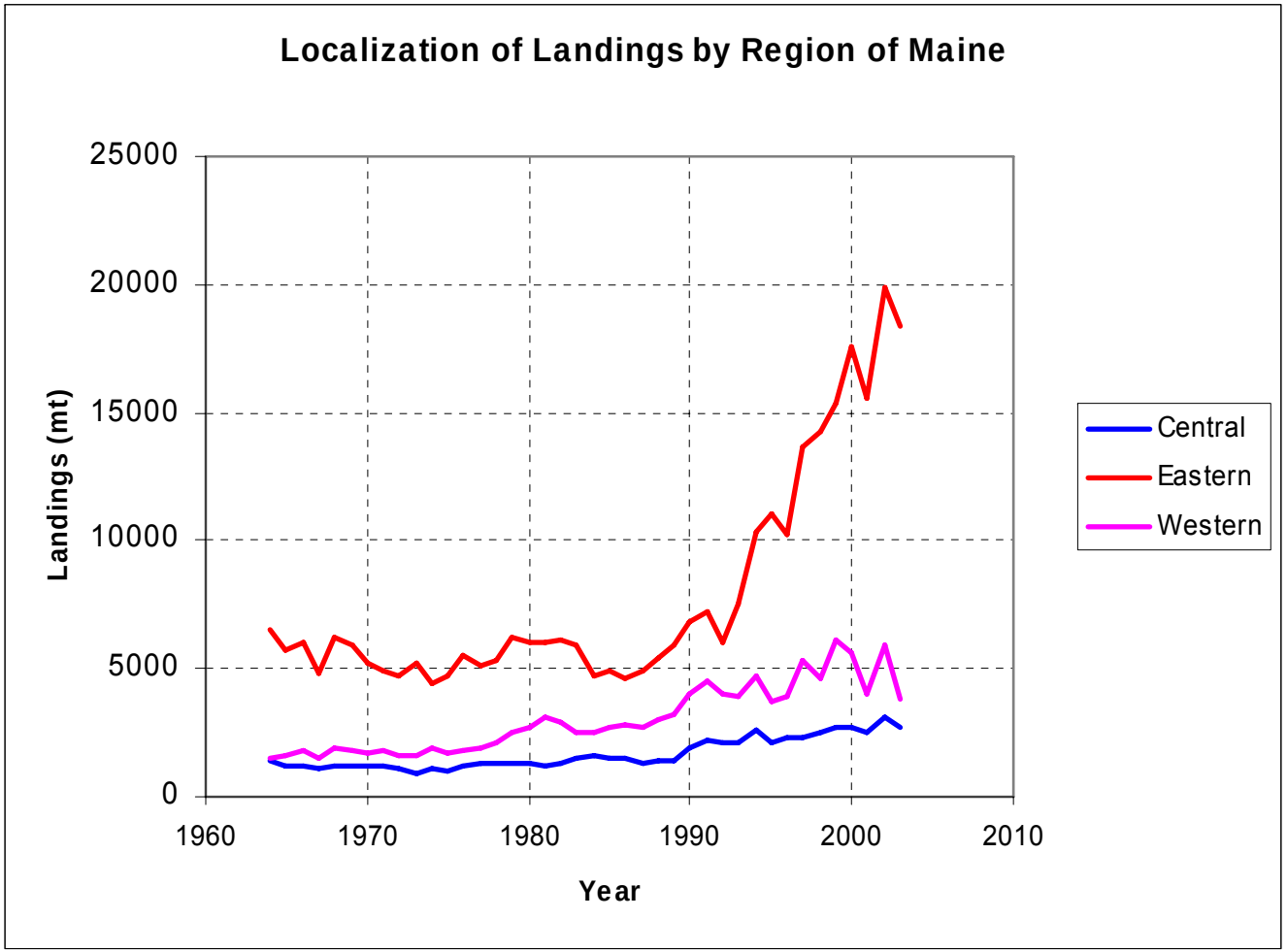




Concentration Profile Trends for Maine Lobster Fishery. Gini Index has increased by nearly 50% since 60's




FRANKLIN
WASHINGTON
HANCOCK
OXFORD
KENNEBEC
Augusta
WALDO
ANDROSCOGGIN
KNOX
LINCOLN
SAGADAHOC
CUMBERLAND
Portland
YORK
Eastern
Central
Western


Localization of Landings by Region of Maine
Landings (mt)
25000
20000
15000
10000
5000
0
1960
1970
1980
1990
2000
2010
Year
Central
Eastern
Western

Assessing Fishing Intensity— Some observable signals

- Seasonal changes in % berried
- % V-Notched
  - New (within season)
  - Old (previous season)
- Fraction of culls in landings
- % Soft shelled, morts in pens
- Fertilized females in landings
- Size composition
- Sex ratio by size class

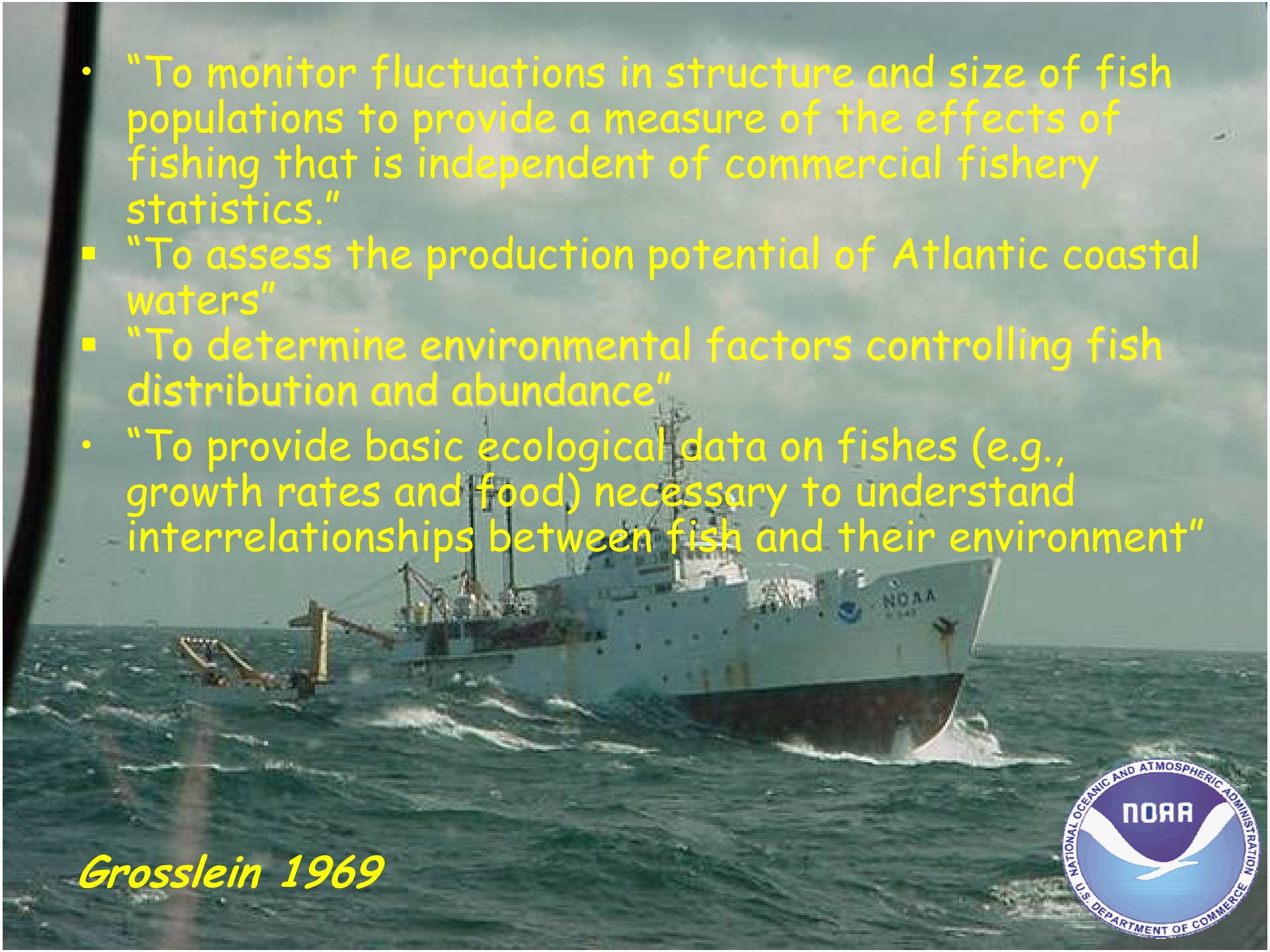
Conclusions

- Survey data, combined with fisheries landings and discards, allows for status determination.
- Attributes of individuals can be important measures of ecosystem processes.
- Fishing vessels as high intensity sampling platforms—synoptic vs intensity
- Effects of concentration of fishing effort in space and time is not fully understood.
- New information on fine-scale spatial and temporal information on harvest patterns will revolutionize understanding of marine fisheries.

END

"An investigator who gives serious attention to the numerous types of systematic error which may enter into his procedures for sampling fish populations may at times tend to forget that even his best efforts will not make the result anything better than a good *sample*, subject to sampling error."

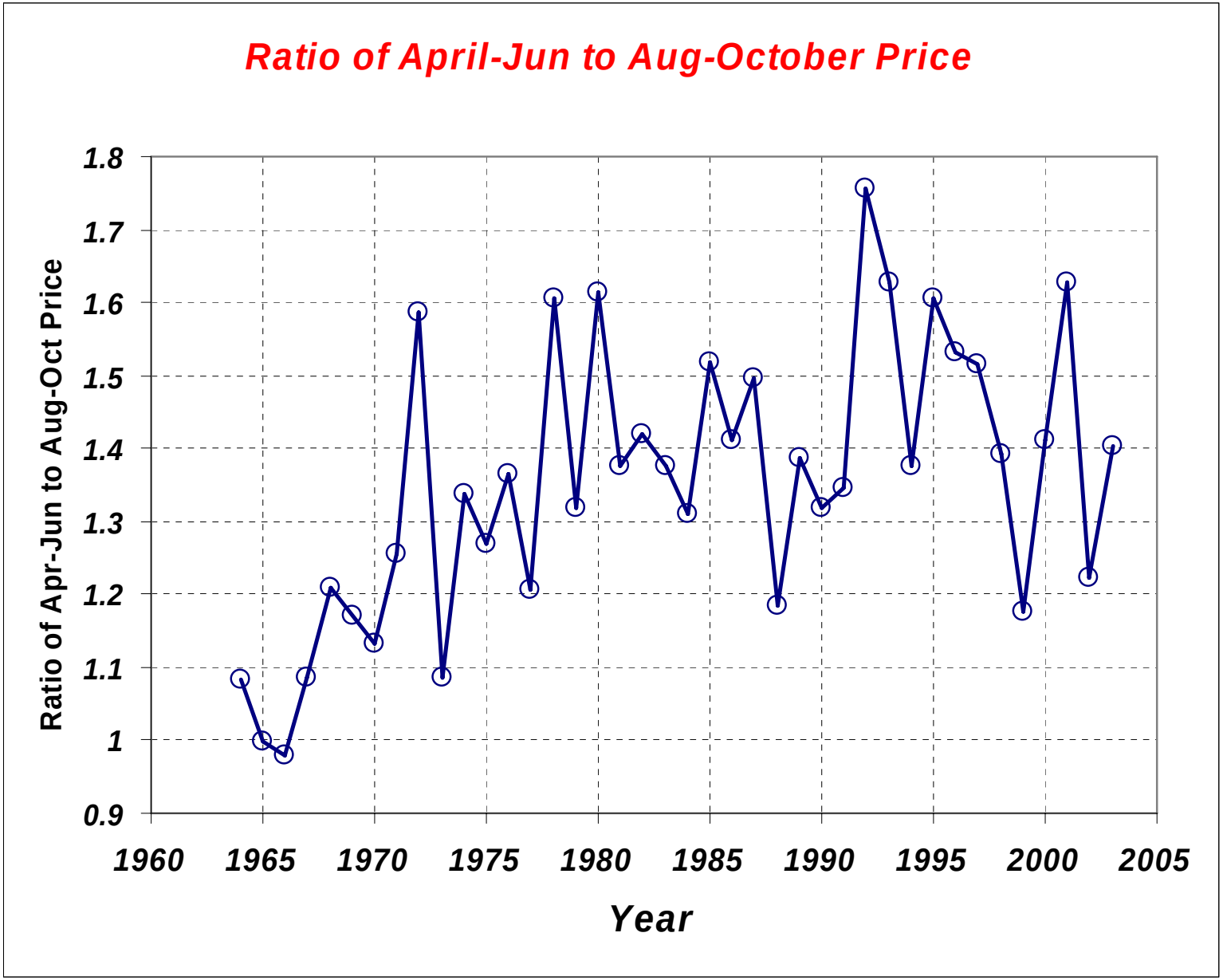
Ricker, W. E. (1945). Some applications of statistical methods to fishery problems. Biometrics Bulletin 1, 73-79.



- "To monitor fluctuations in structure and size of fish populations to provide a measure of the effects of fishing that is independent of commercial fishery statistics."
- "To assess the production potential of Atlantic coastal waters"
- "To determine environmental factors controlling fish distribution and abundance"
- "To provide basic ecological data on fishes (e.g., growth rates and food) necessary to understand interrelationships between fish and their environment"

Grosslein 1969

Hard shell lobsters have typically received about 40% GREATER price than those taken after the molt.



Fishery Dependent Data

Commercial Fisheries

- **Dealers**
  - **Landings and Economic data**

- **Fishermen**
  - **Interviews (1964-1994)**
  - **Mandatory Reporting (1994-present)**
    - **Area fished ; Location**
    - **Species Caught**
    - **Effort**

- **Biological Samples**
  - **Length frequencies**
  - **Age structures**

Recreational Fisheries

- **Intercept**
- **Phone survey**

NAFO Statistical Areas

based on historical fishing grounds

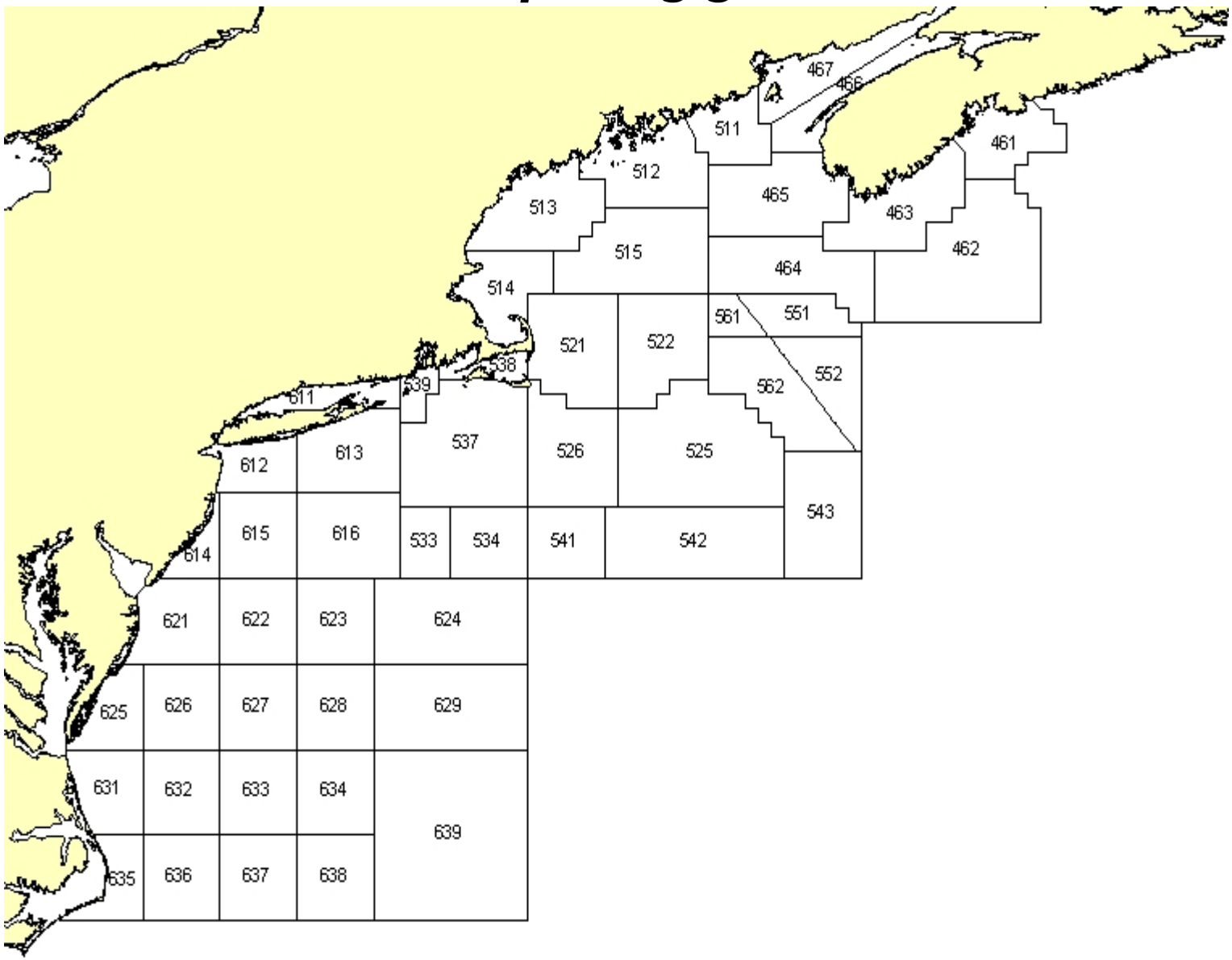
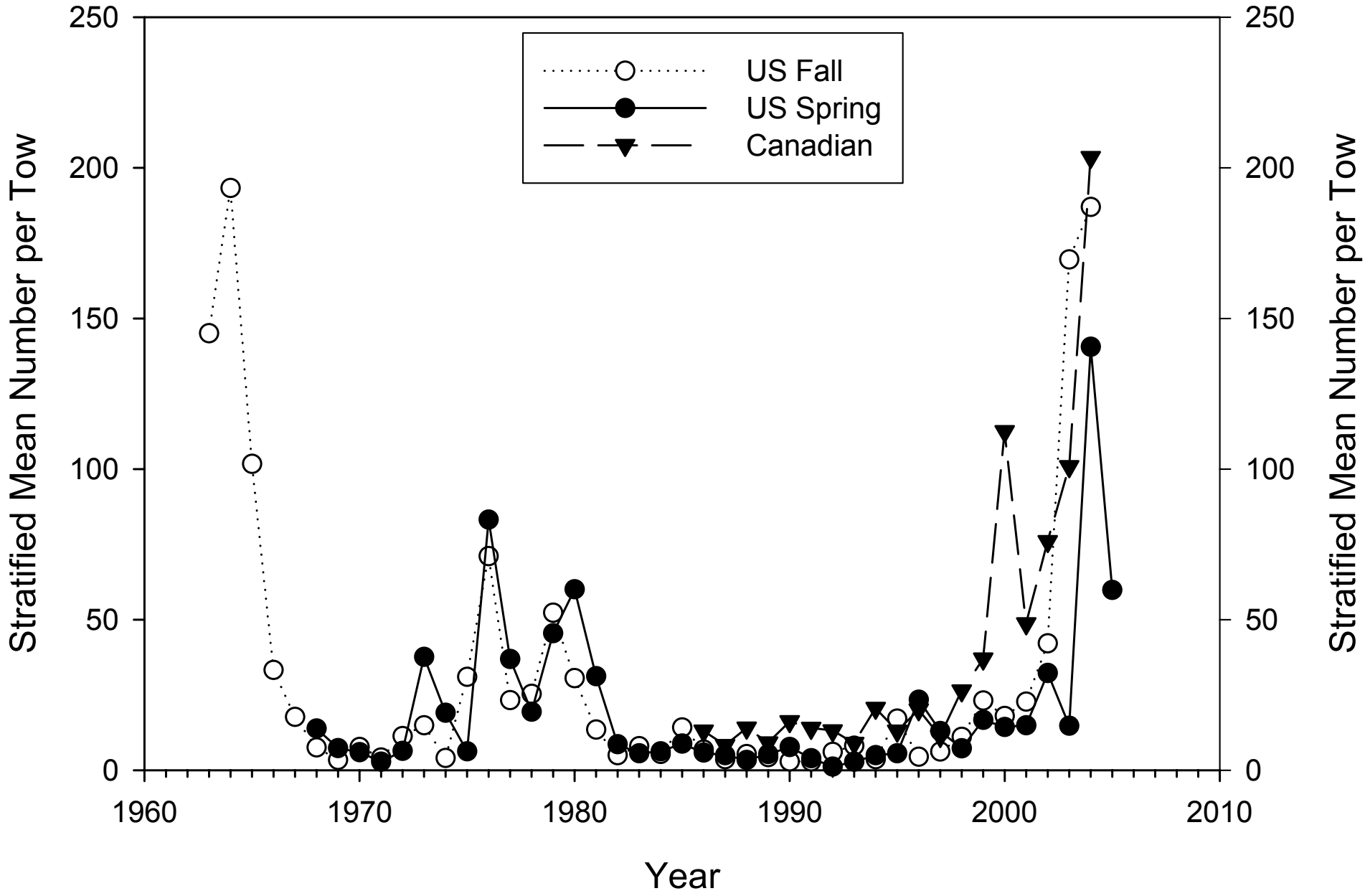
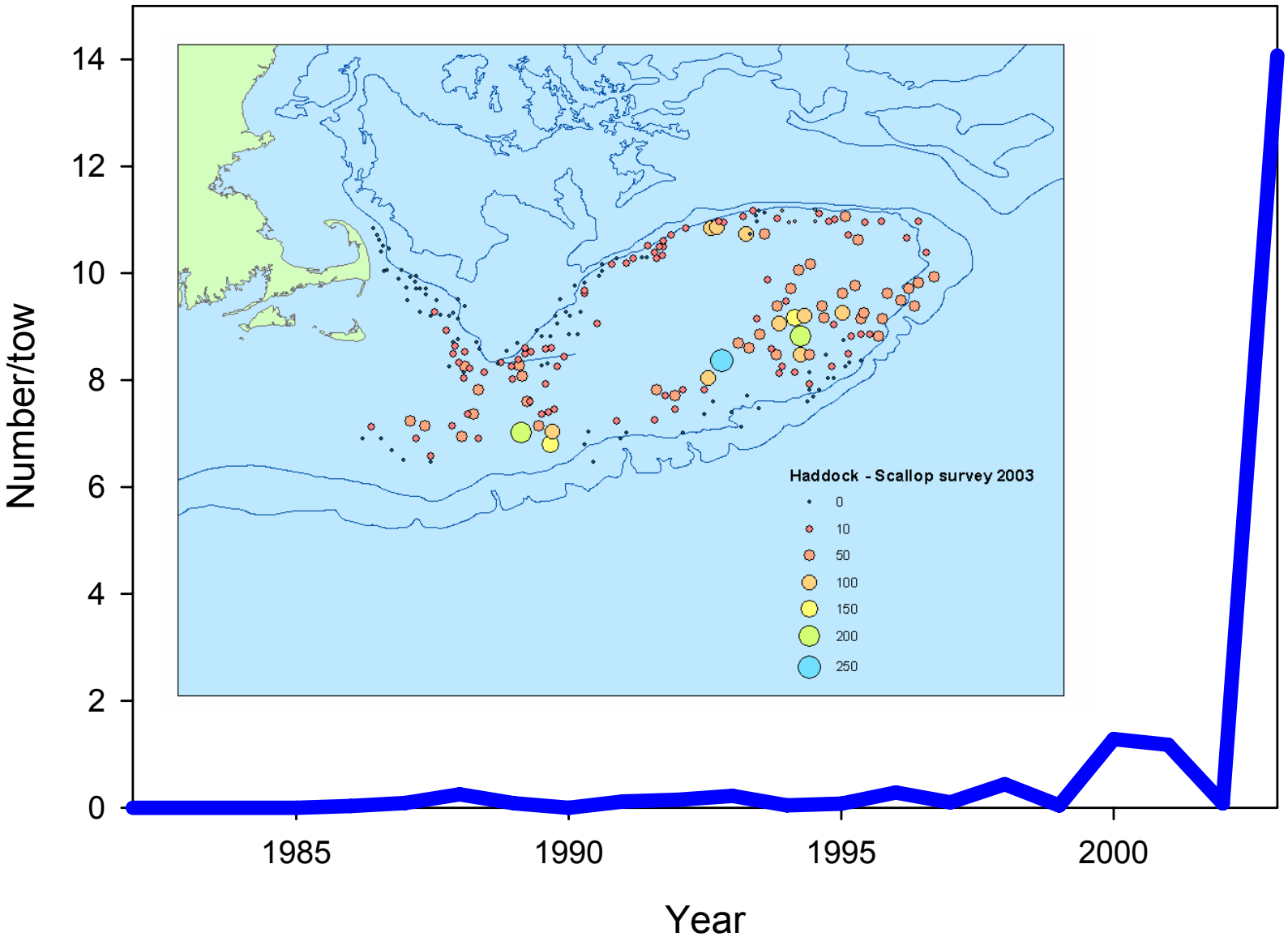
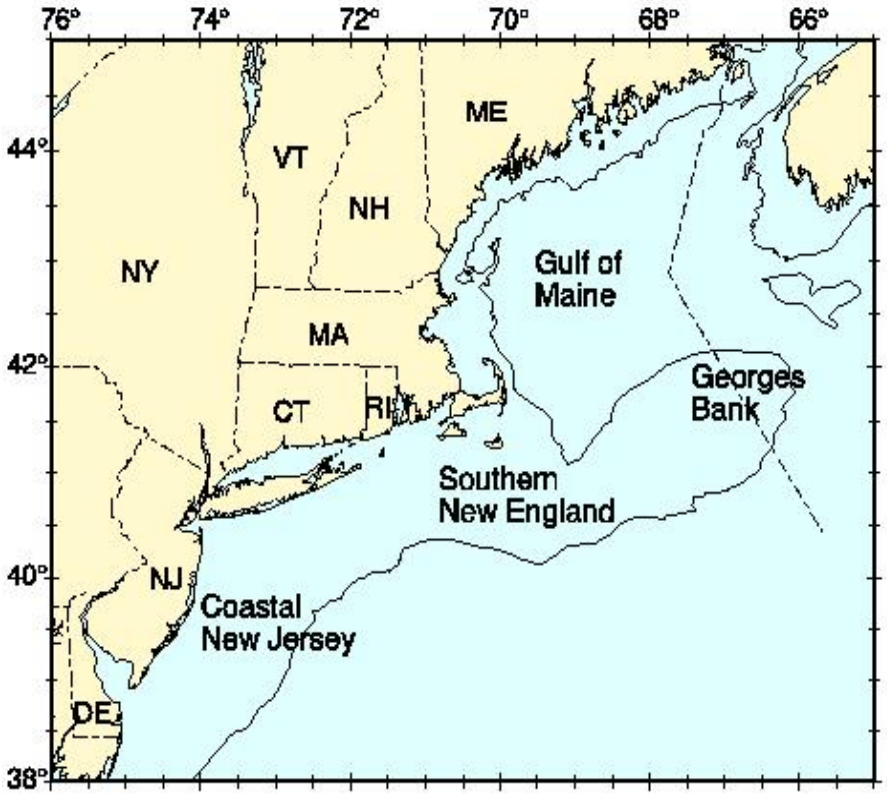


Figure B3. Georges Bank haddock research survey indices, 1963-2005.

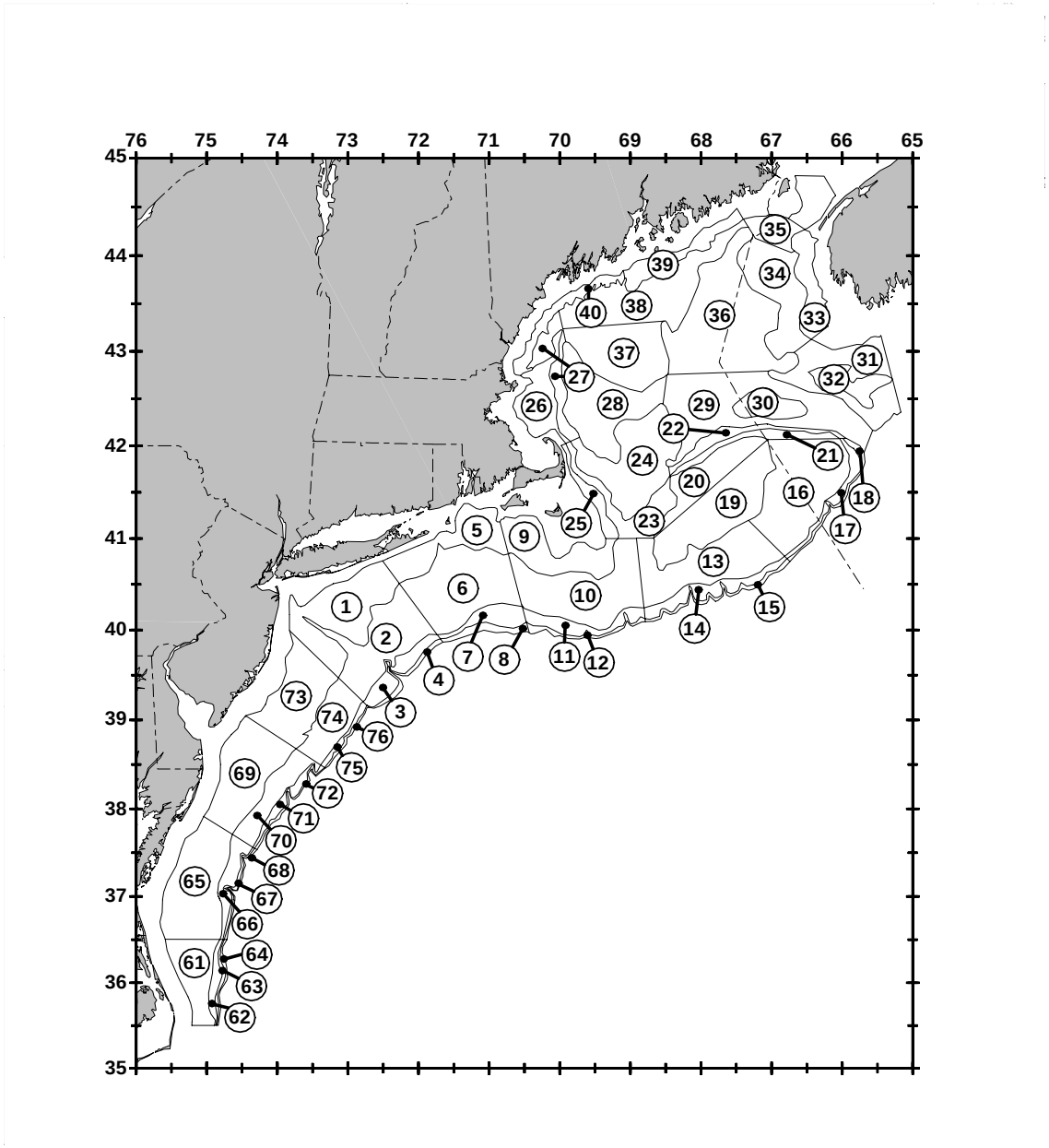


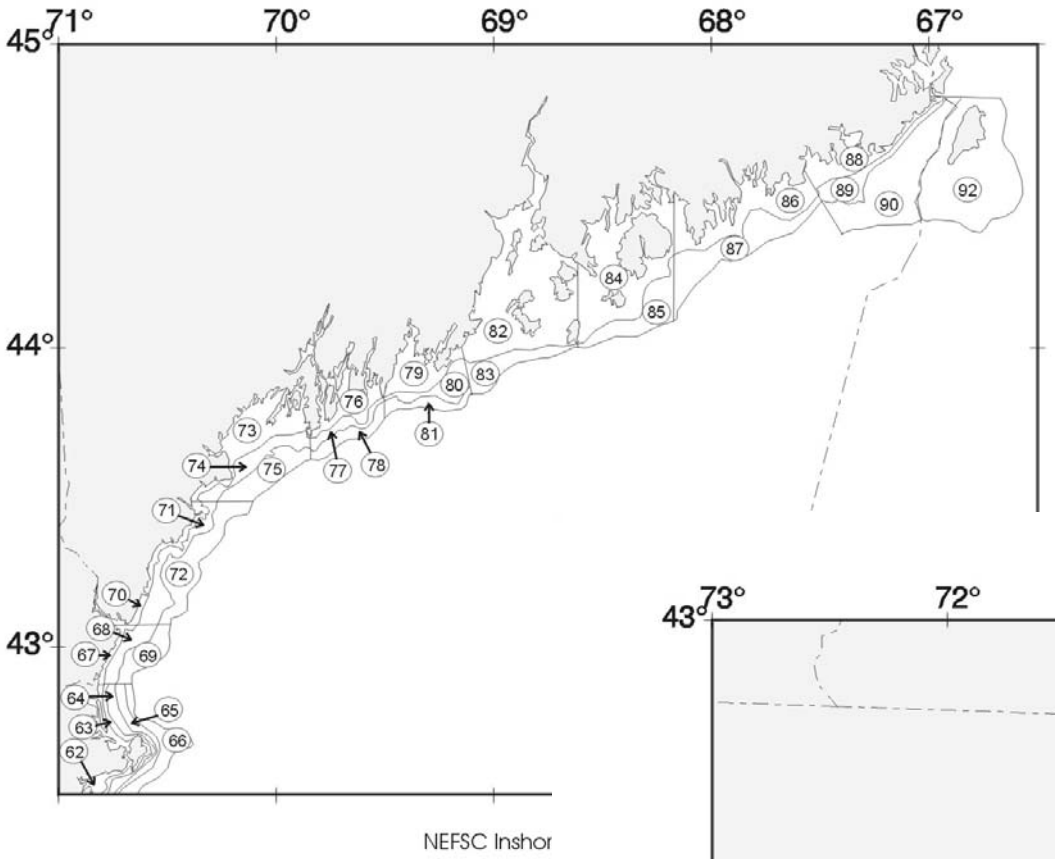
Juvenile Haddock in Scallop Dredge Survey Tows
Summer, 2003



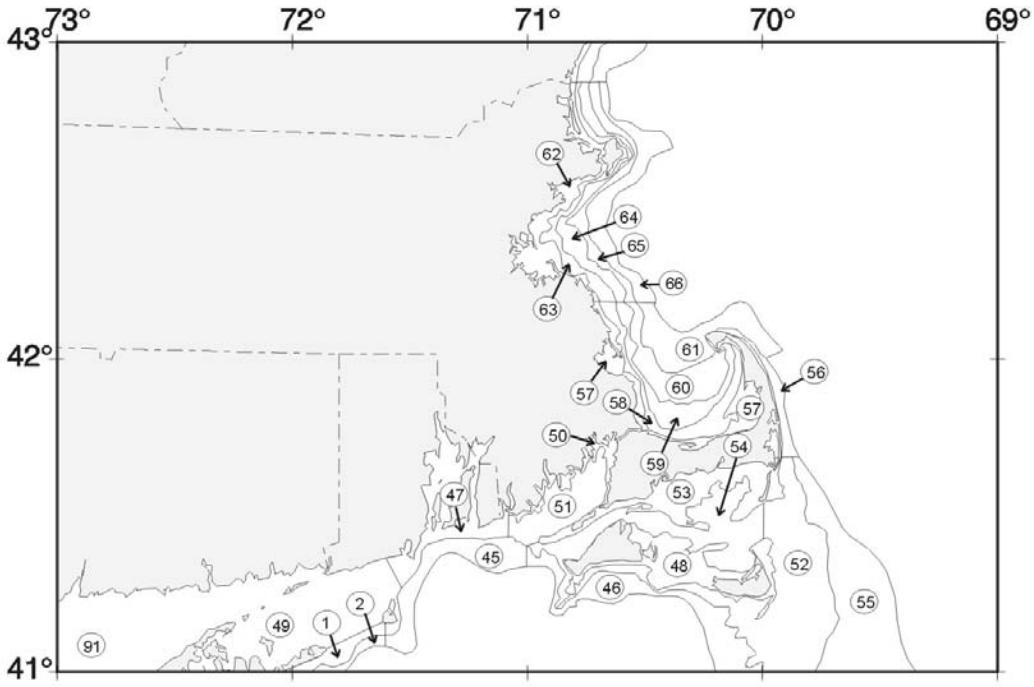

76°
74°
72°
70°
68°
66°
44°
42°
40°
38°
ME
VT
NH
NY
Gulf of
Maine
MA
CT
RI
Georges
Bank
Southern
New England
NJ
Coastal
New Jersey
DE

NEFSC offshore bottom trawl survey strata



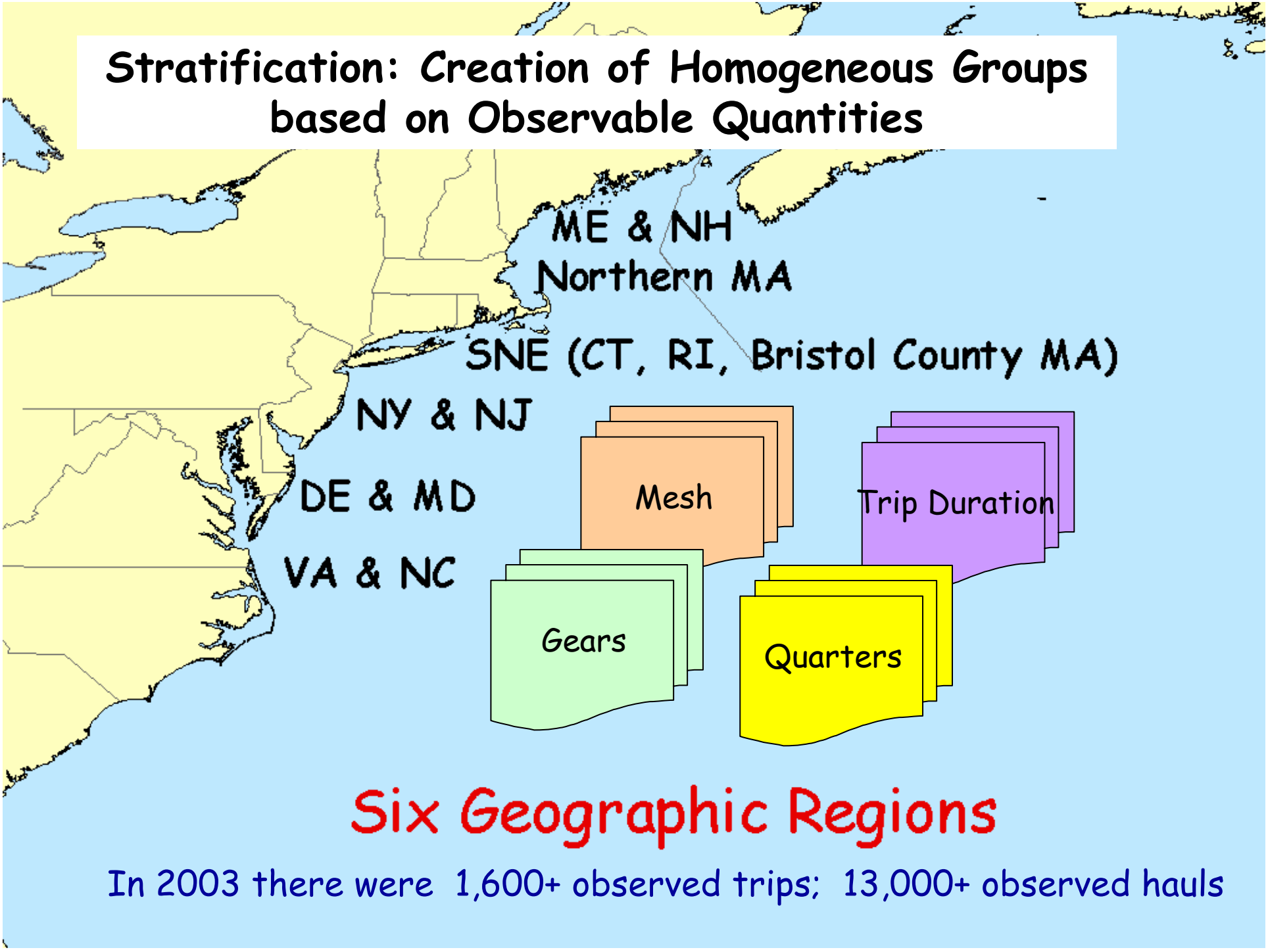


Northern extension of NEFSC inshore bottom trawl survey strata



NEFSC Inshore Bottom Trawl Survey Strata - Cape Cod & Southern New England Areas

Stratification: Creation of Homogeneous Groups based on Observable Quantities



Six Geographic Regions

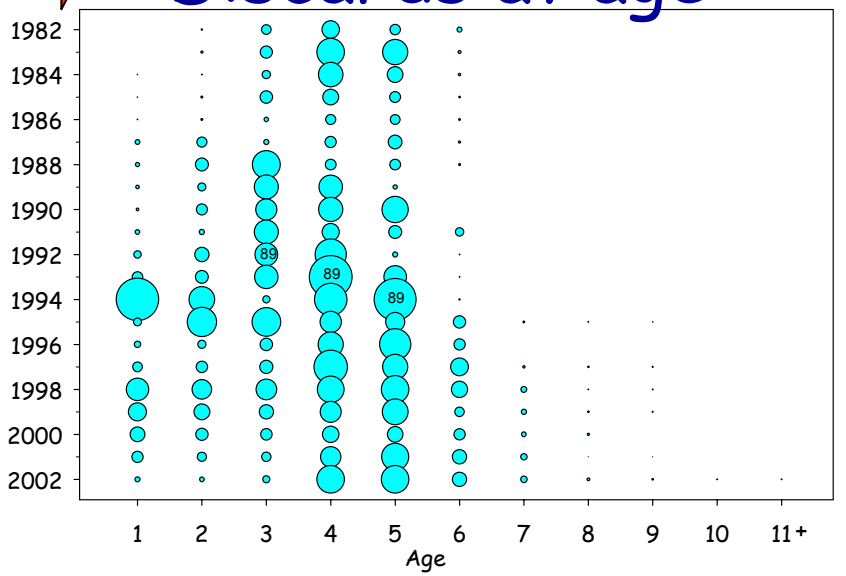
In 2003 there were 1,600+ observed trips; 13,000+ observed hauls

Discard Estimation for Stock Assessments

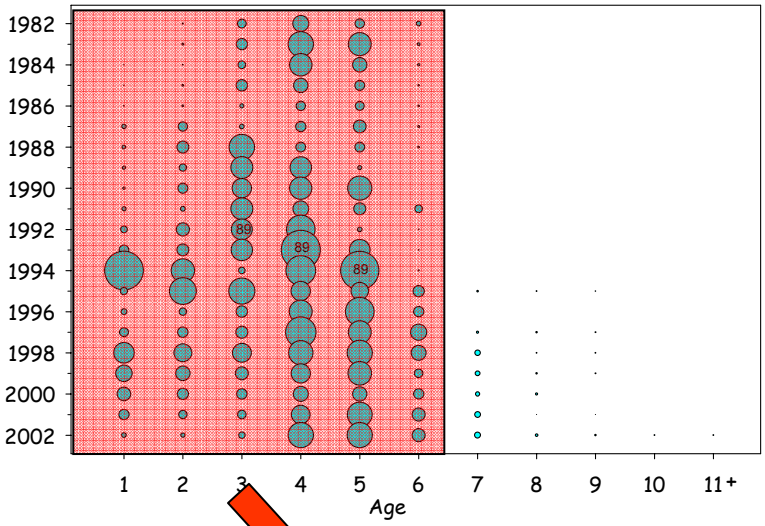
Discard length frequency data
Age and length information

Total Discarded lbs

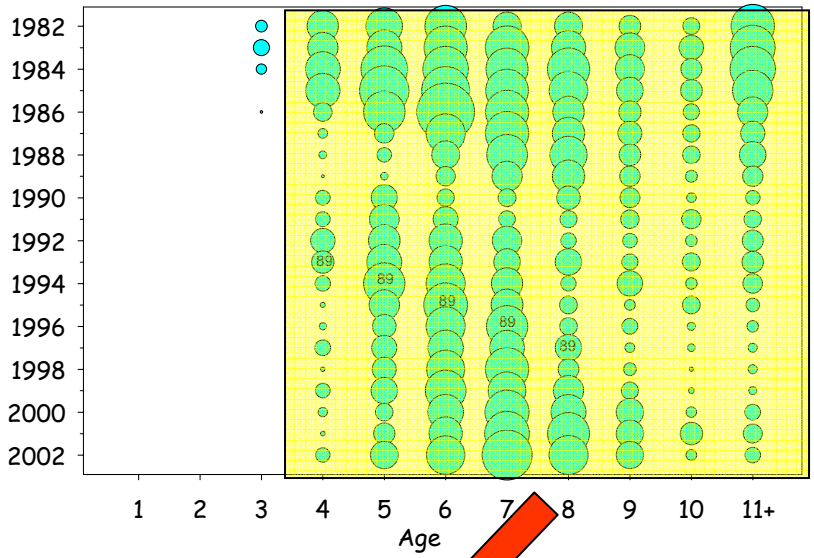
Discards at age



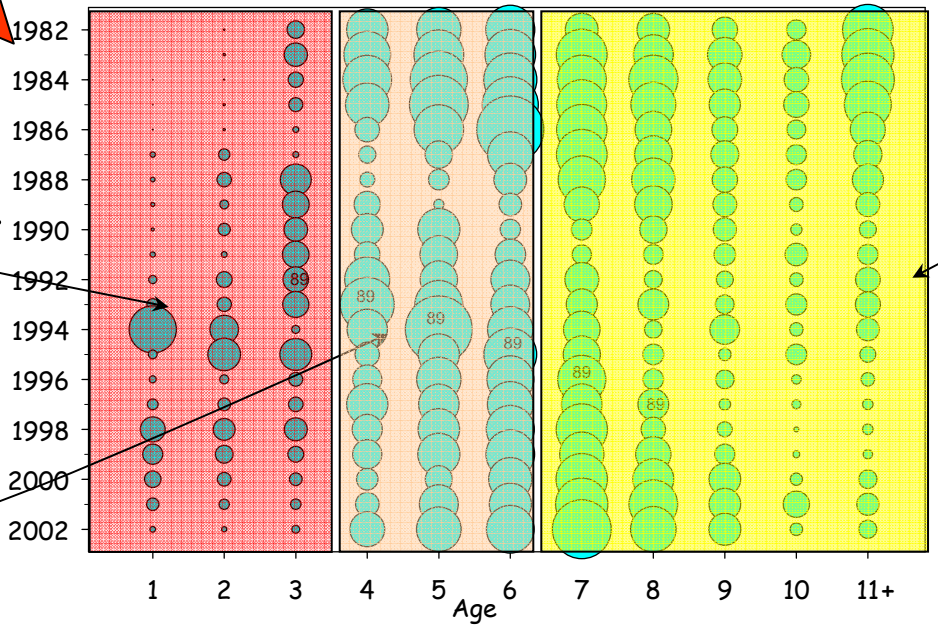
Discards at age



Landings at age



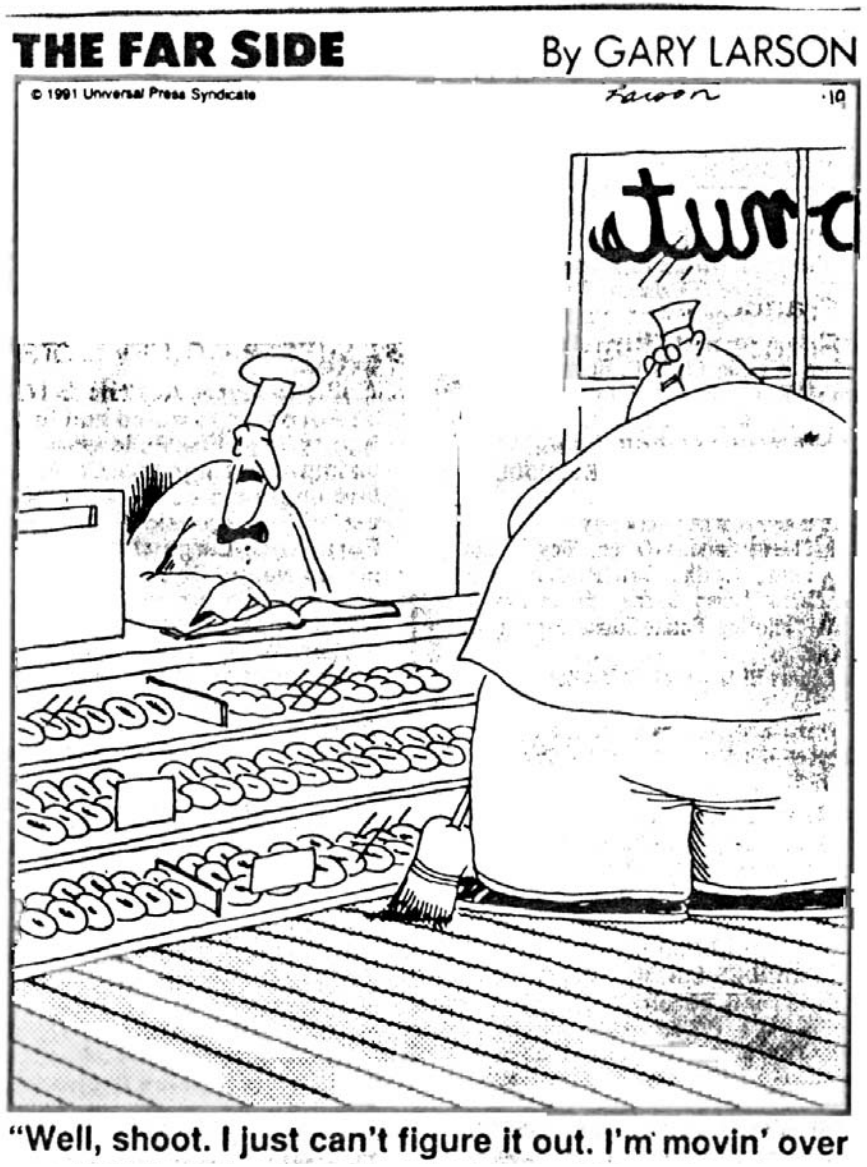
Catch at age



Primarily Discards

Landings Only

Landings + Discard



Well, shoot. I just can't figure it out. I'm movin' over 500 doughnuts a day, but I'm still just barely squeakin; by.

Discards represent unacceptable economic loss.

Accurate and precise estimates of discard could lead to better use of marine resources.

Sound ecosystem management.

"life does not stand still while specialists put their minds in order"

Michael Graham, 1950. Address to United Nations

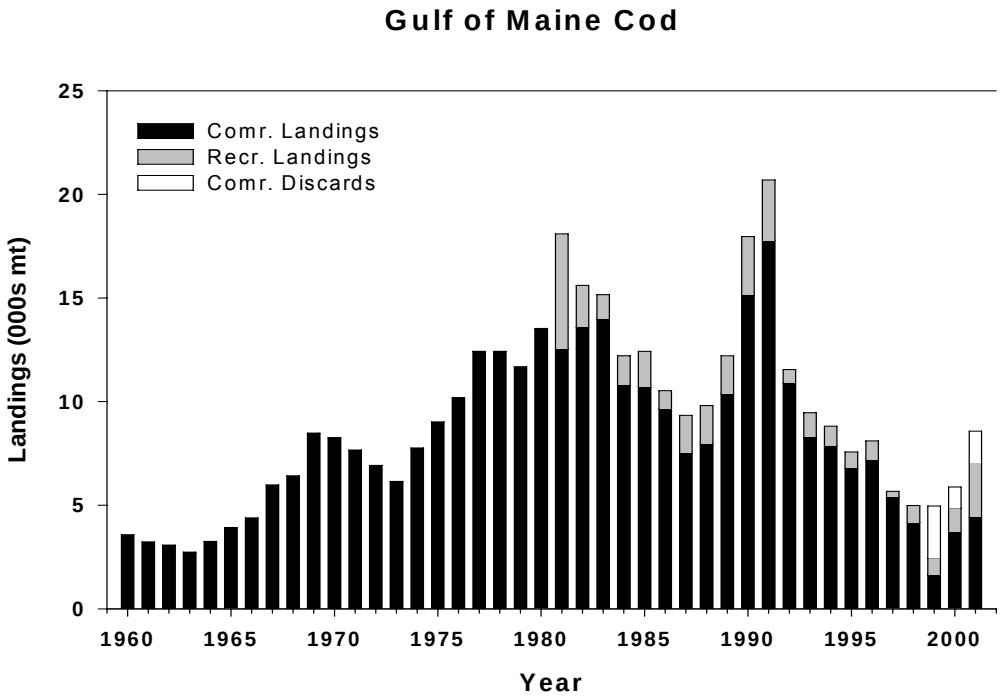
Stratified random surveys

- Stratified by depth and area
- Stations allocated by area
- Station protocol established:
  duration of tow
  configuration of gear
  monitoring of gear
  qualitative assessment of each station

Albatross IV

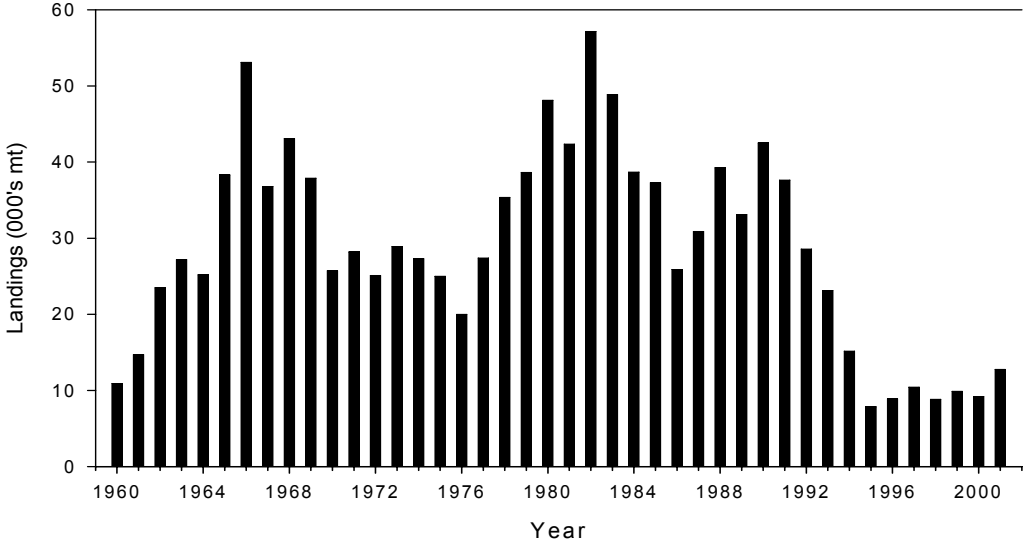
Delaware II

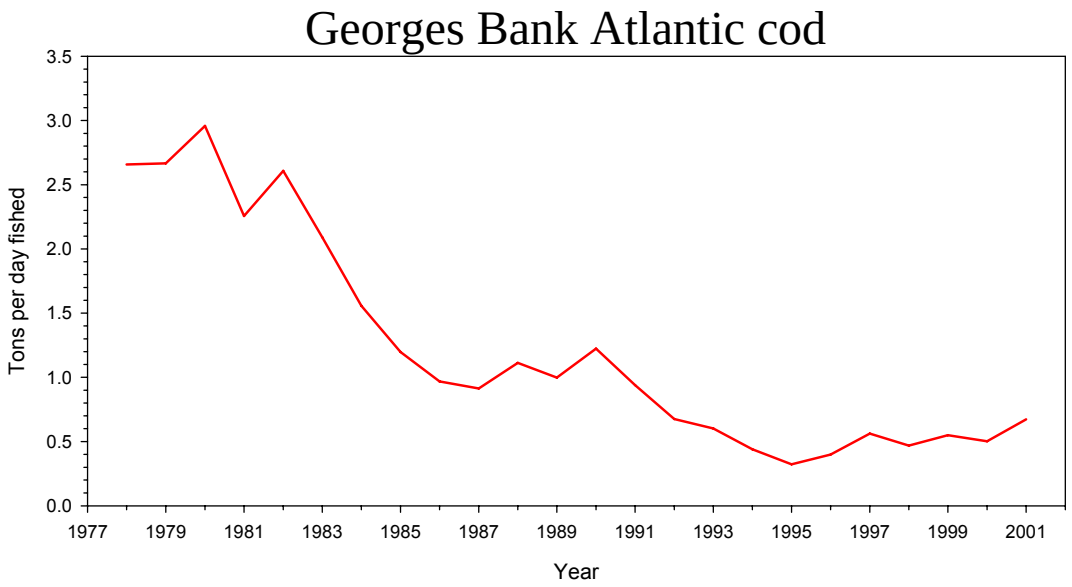
Albatross IV



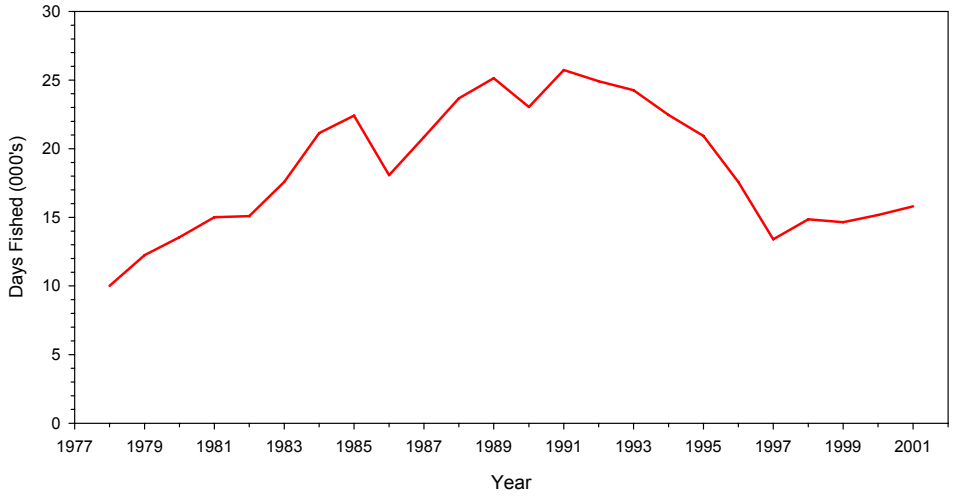
Landings by area ; stock

Georges Bank Cod





LPUE time series



Effort time series

Fishery Independent Data

NEFSC Research Surveys

Stratified random bottom trawl survey

- Spring (1968- present)
- Autumn (1963- present)
- Winter (1992- present)

Stratified random shellfish survey

- Scallop (1975-present)
- Clam (1965-present)

Hydroacoustic surveys

Herring and mackerel (1997-present)

Ecosytem Monitoring Surveys (1996-present)

Marine Mammal surveys (1989-present)

Routine Sampling

Biological Sampling:

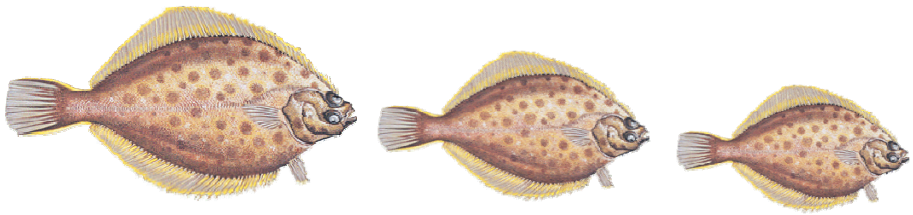
- ✓ Weight of catch
- ✓ Length frequency
- ✓ Age structure
- ✓ Food habits
- ✓ Sex and Maturity

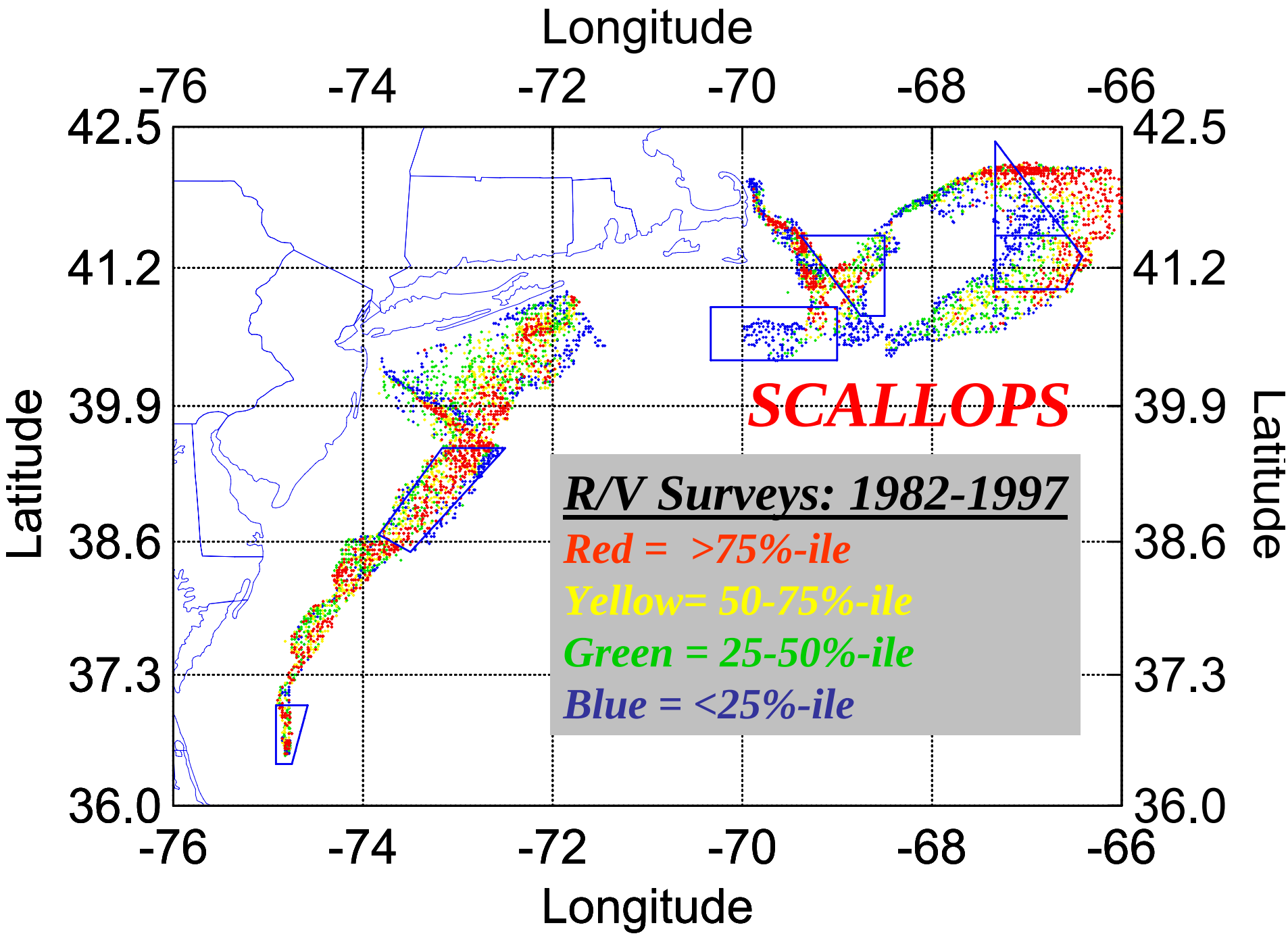
Physical sampling: CTD

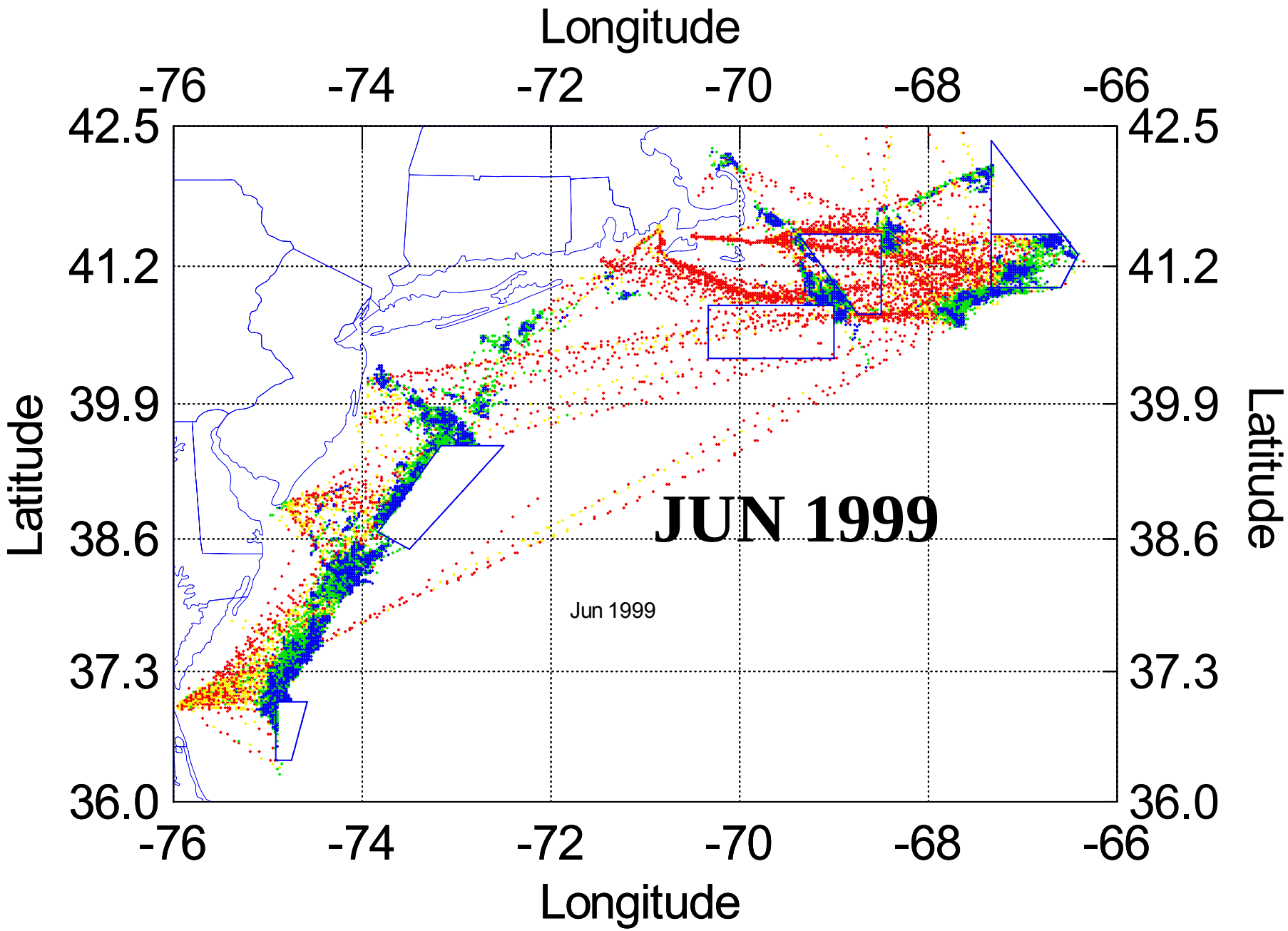
- ✓ Temperature
- ✓ Salinity
- ✓ Depth

Changes in Average Weight at Age

- Reductions in average weight at age are evident for a number of stocks
  - Georges Bank Cod and Haddock
  - Gulf of Maine Winter flounder, Plaice, and Witch flounder
- Appear for stocks at both high and low abundance levels
- Causal mechanisms unknown but could include
  - Environmental change
  - Density dependence
  - Earlier maturation/genetic selection
  - All of the above and more
- **Implications if patterns persist**
  - ***Lower yields***
  - ***Slower rebuilding***
  - ***Possible changes in rebuilding targets when re-evaluated in 2008***




Longitude
-76
-74
-72
-70
-68
-66
42.5
41.2
39.9
38.6
37.3
36.0
Latitude
SCALLOPS
R/V Surveys: 1982-1997
Red = >75%-ile
Yellow= 50-75%-ile
Green = 25-50%-ile
Blue = <25%-ile


Longitude
-76
-74
-72
-70
-68
-66
42.5
41.2
39.9
38.6
37.3
36.0
Latitude
JUN 1999
Jun 1999