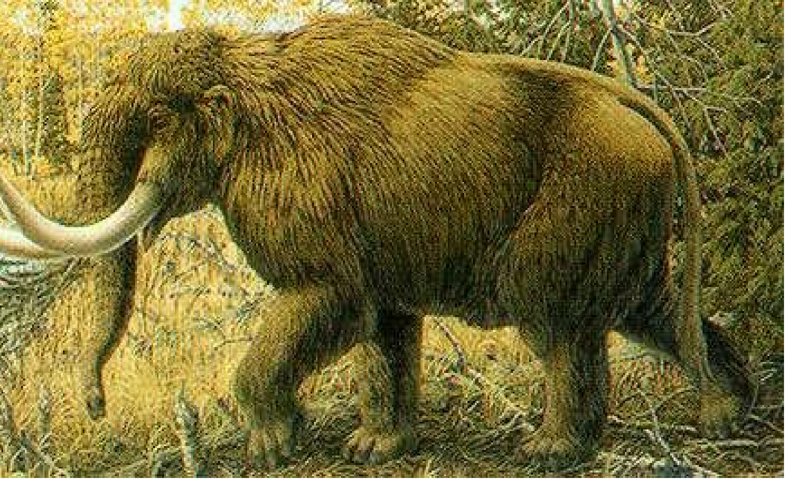
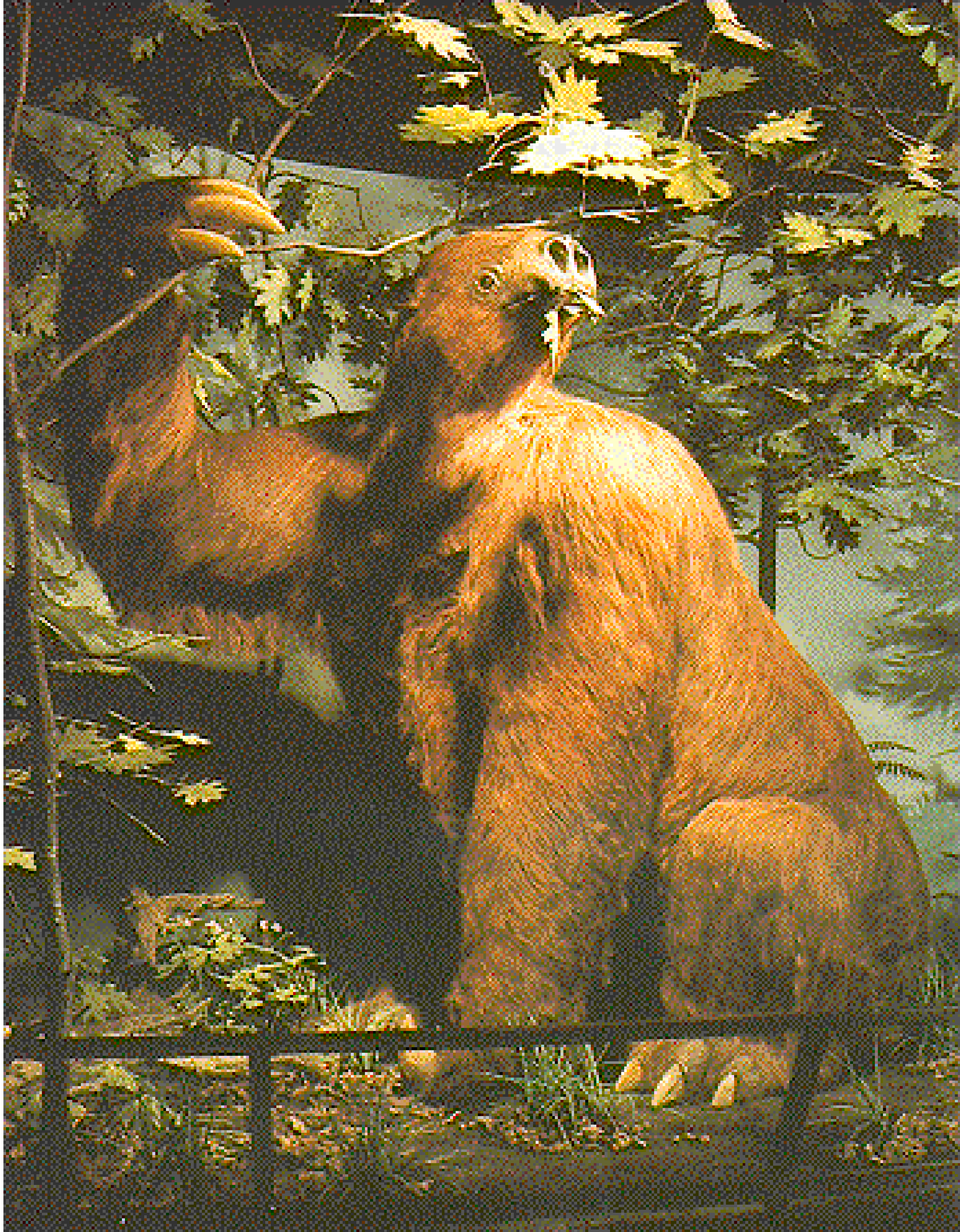
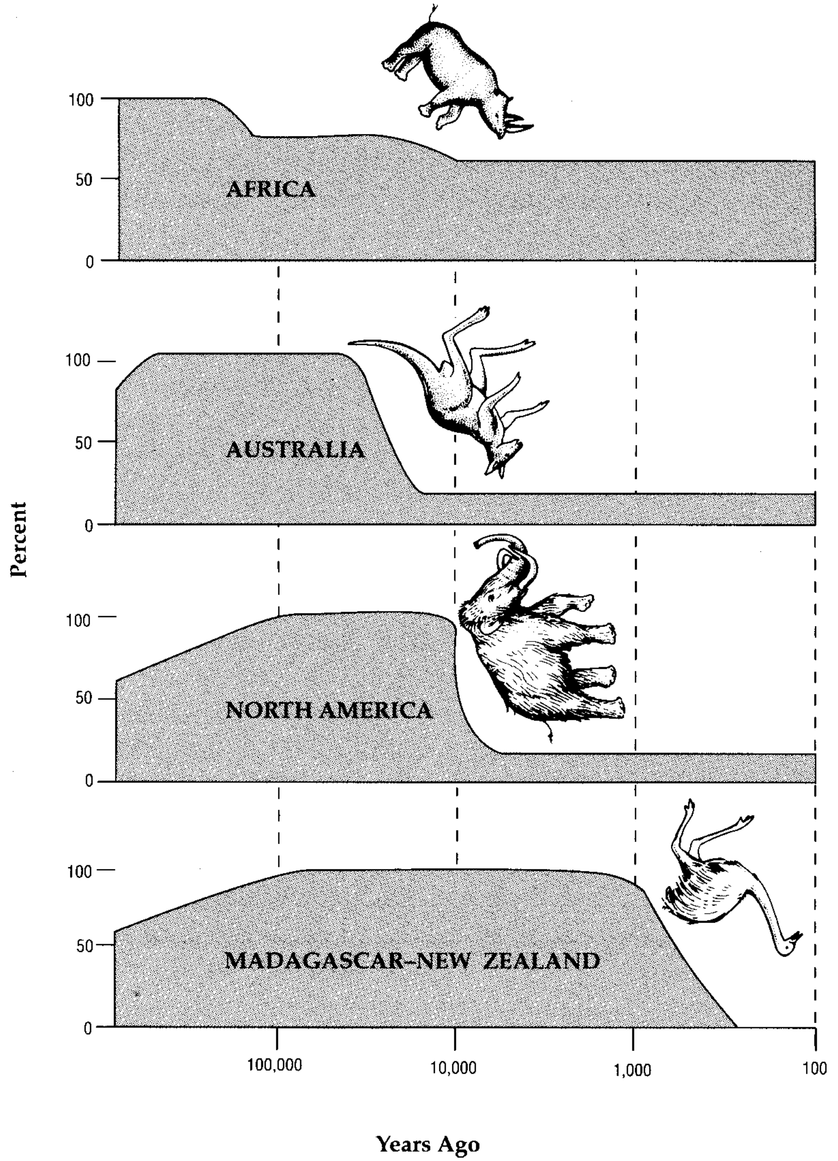




Are the Pleistocene extinctions* going to be repeated in the ocean?



The extinction of large mammals and flightless birds coincided closely with the arrival of humans in North America, Madagascar, and New Zealand, and less decisively earlier in Australia. In Africa, where humans and animals evolved together for millions of years, the damage was less severe.

*Present North American biota has lost almost all large species –
We have no mammoths, mastodons, giant ground sloths, giant beavers, and 65 other species that weighted more than 100 kilograms.

The Global Loss of Large Marine Predators

Ransom A. Myers (RAM)
Dalhousie University, Canada

Pew Global Sharks Assessment

http://www.globalsharks.ca

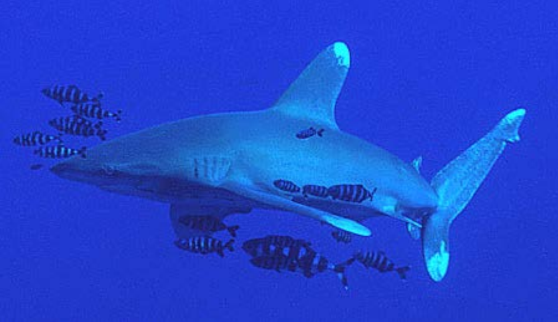
FMAP (Future of Marine Animal Populations)

http://www.fmap.ca

Lenfest Extinction Project

NSERC

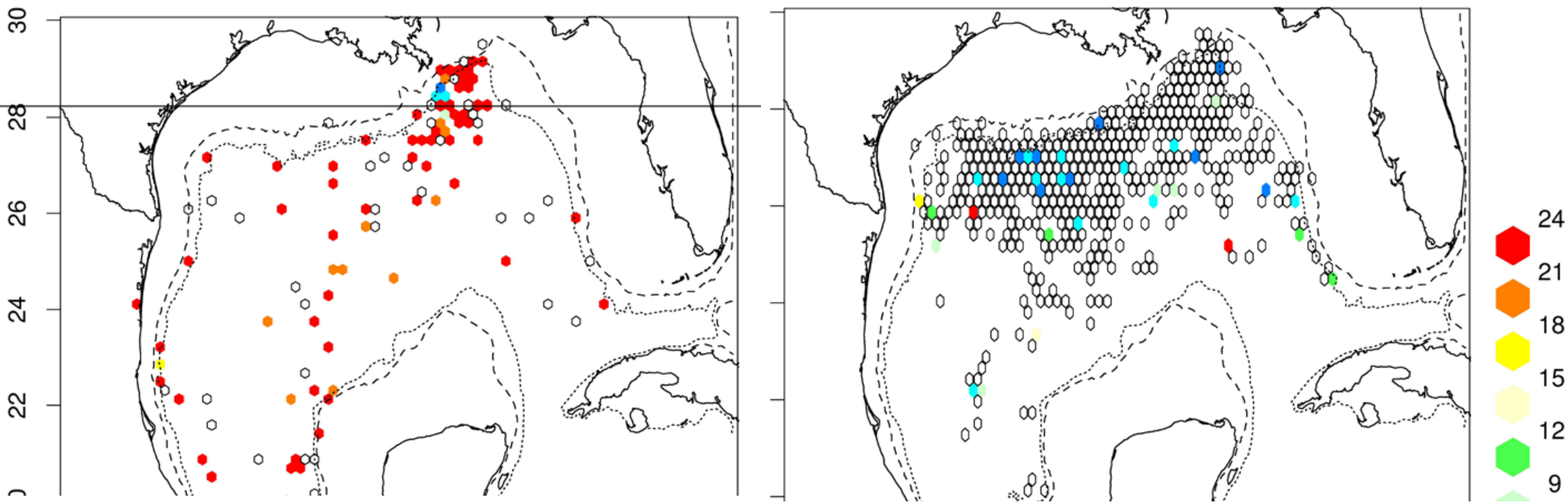
What was the most common large animal (>40 Kg) in the world? (perhaps this one was)



Loss of sharks in the Gulf of Mexico

300 fold decline – no one noticed

[redacted]



1950's 1990's

Oceanic Whitetip captures per 10,000 hooks

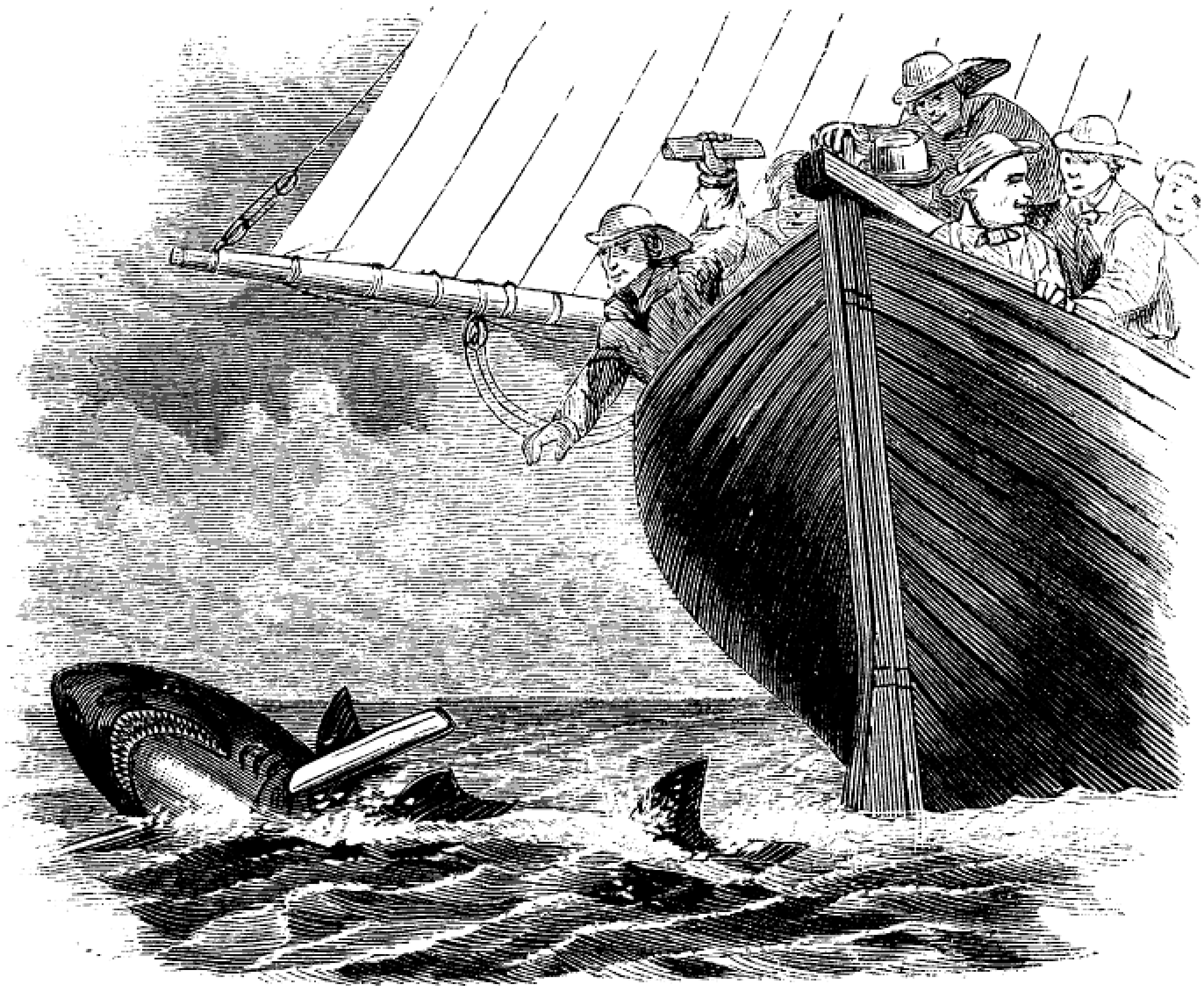
Baum and Myers, 2004 Ecology Letters

Circumstantial evidence of oceanic whitetip sharks being common in the Gulf of Mexico

788
757
525
650
620
770

tience as some line got fouled in the rapid hauling, or an obstreperous fellow in the depths below made off with the best part of a valuable line. To an unsophisticated observer our crew,

Fish, like women, are a very uncertain institution, and their tastes are equally unaccountable. When you least expect it, off they sail and leave you in the lurch when the prize is almost within your grasp; at least such has proved my sailor's experience with them. Thus it was that, while we were merrily hauling up the denizens of Whale Deep, the supply suddenly gave out—either our bait had cloyed on their palates, or, what is quite as likely, they began to smell a submarine rat, and regarded the sudden upward movement of their companions with well-grounded suspicion. As if by simultaneous agreement they suddenly ceased to bite, and after wooing them in vain for a couple of days, we resolved to weigh and head for the northward.



GAFFING A SHARK.

Where I live in Nova Scotia

- There are no shad in shad bay.
- There are no halibut in halibut cove.
- The walrus are gone that were once abundant.
- The beluga whales are gone in the Bay of Fundy.
- Swordfish have been eliminated along the coast.
- The sharks that were once abundant are largely gone.
- Atlantic salmon are extinct in many of the rivers.

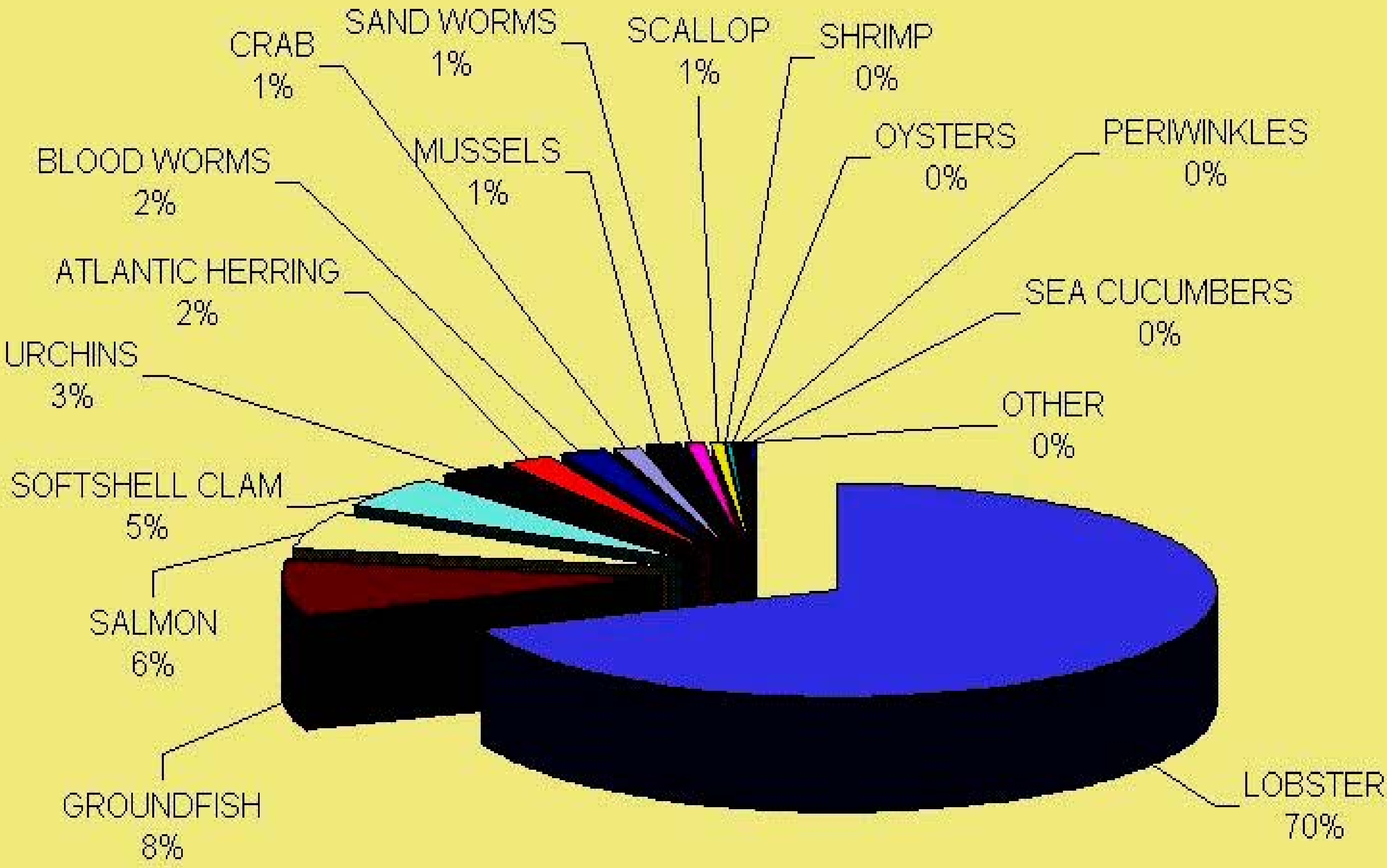

Right whale with lobster bouys- Sept. 2004

Same right whale – April 2005???


Only lobster traps as far as the eye can see…..

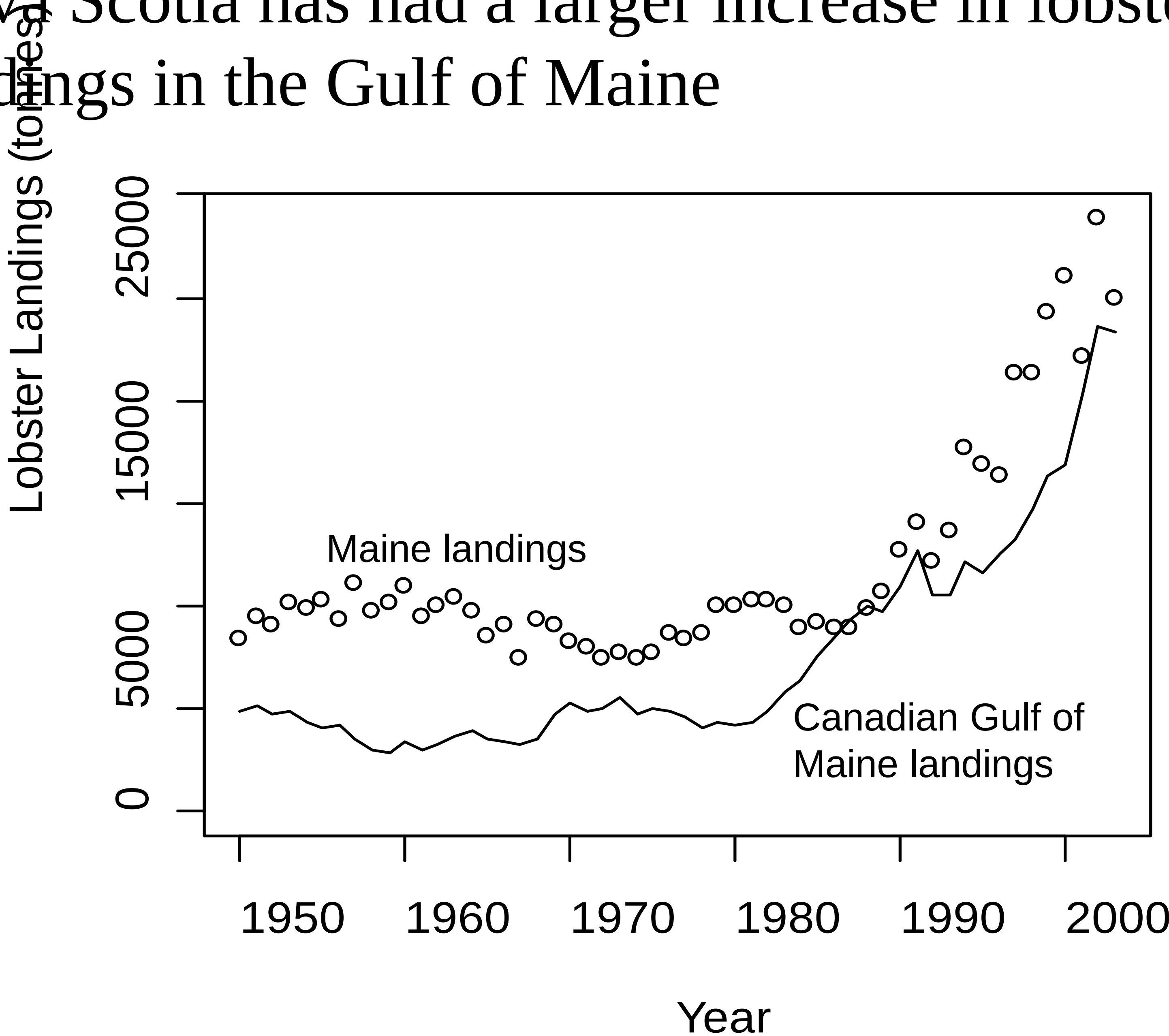
Preliminary 2002 Maine Landings By Value

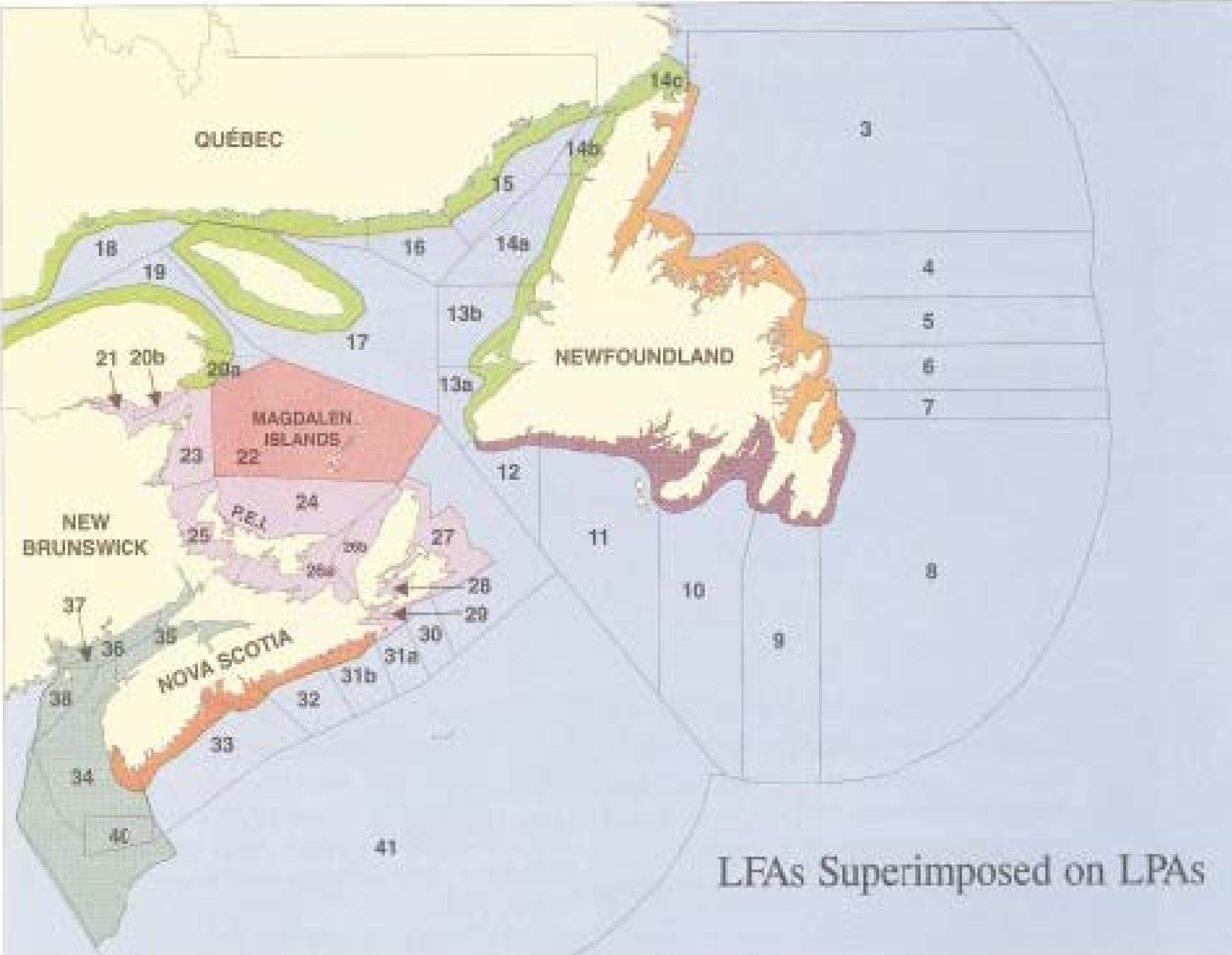
Total Value: $299,198,465 as of 5/20/03



Data compiled collectively by the Maine Department of Marine Resources and the National Marine Fisheries Serv

Nova Scotia has had a larger increase in lobster landings in the Gulf of Maine



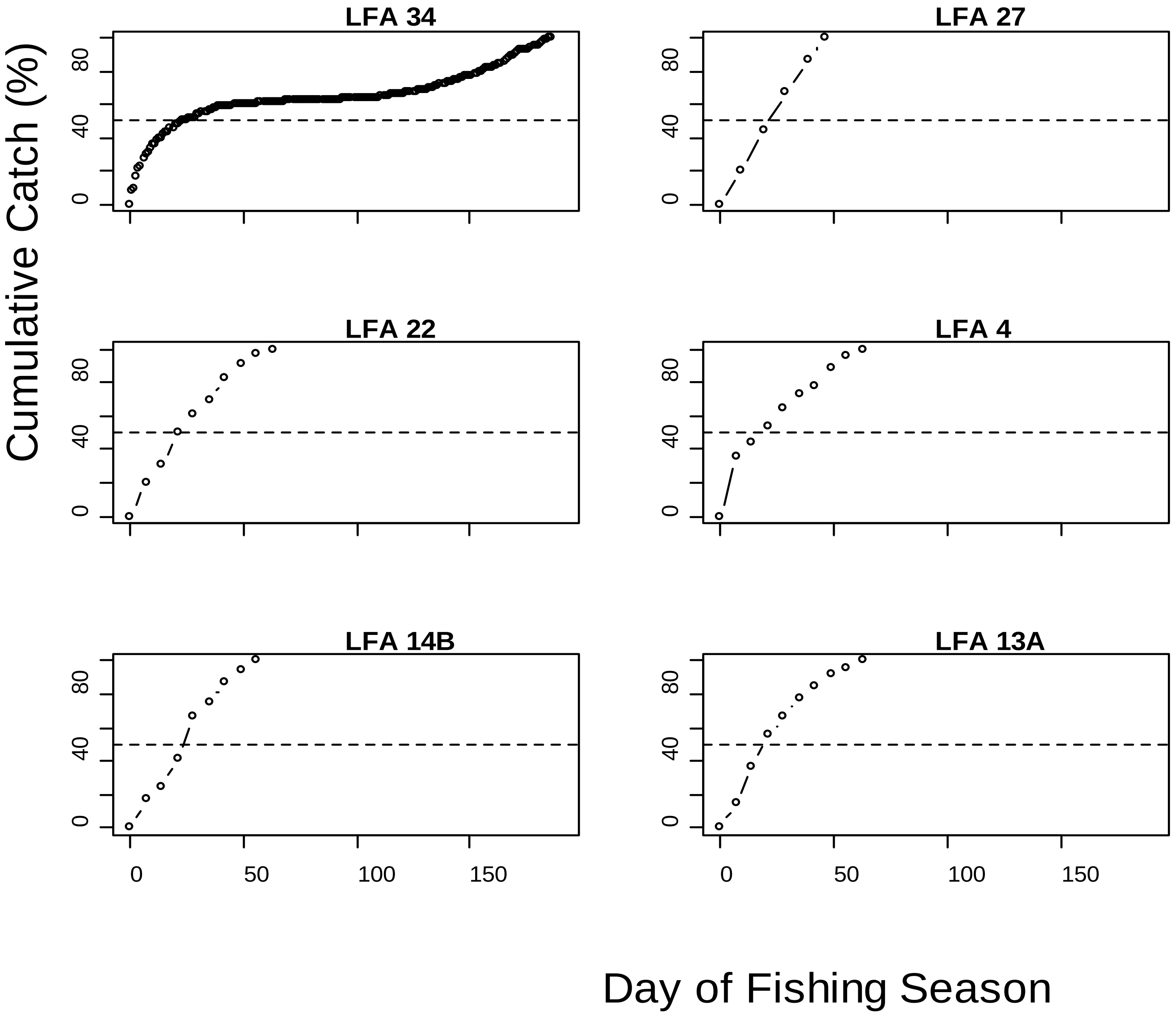


LFAs Superimposed on LPAs

Comparison in 2003

	Maine	LFA 34 (S.W.NS)	Maine/LFA34
Landings tonnes	24935	19000	1.31
Fisheres	6812	986 (licenses)	
Traps	3,189,471	369750 (fall) 394400 (spr)	8.62 (fall number)
Season-days	365	185	1.97
Overcapacity of Maine compared to LFS 34			~13

50% of the catch is obtained in less than 30 days for all regions in Canada

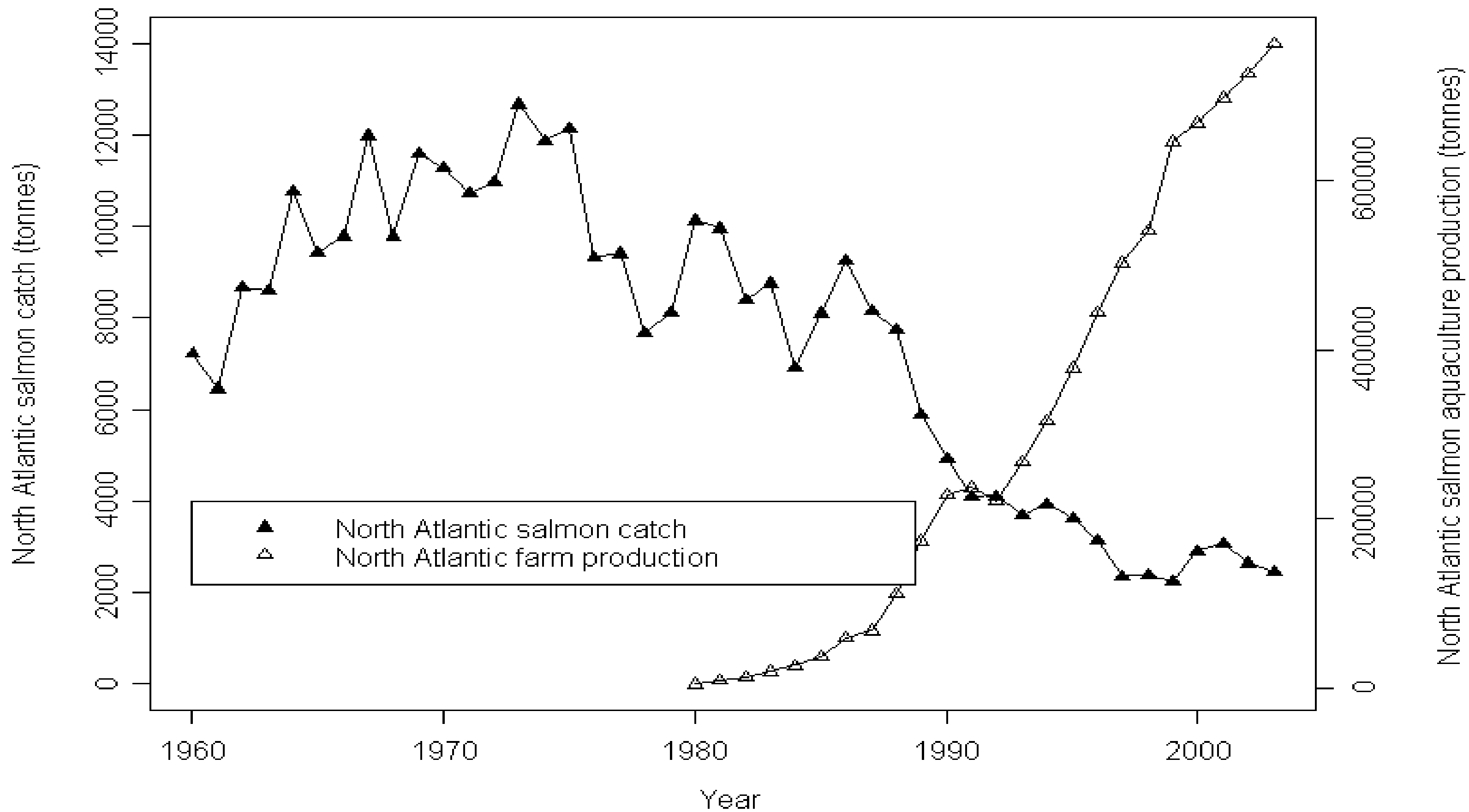


But these estimates vastly overestimate the number of traps needed.

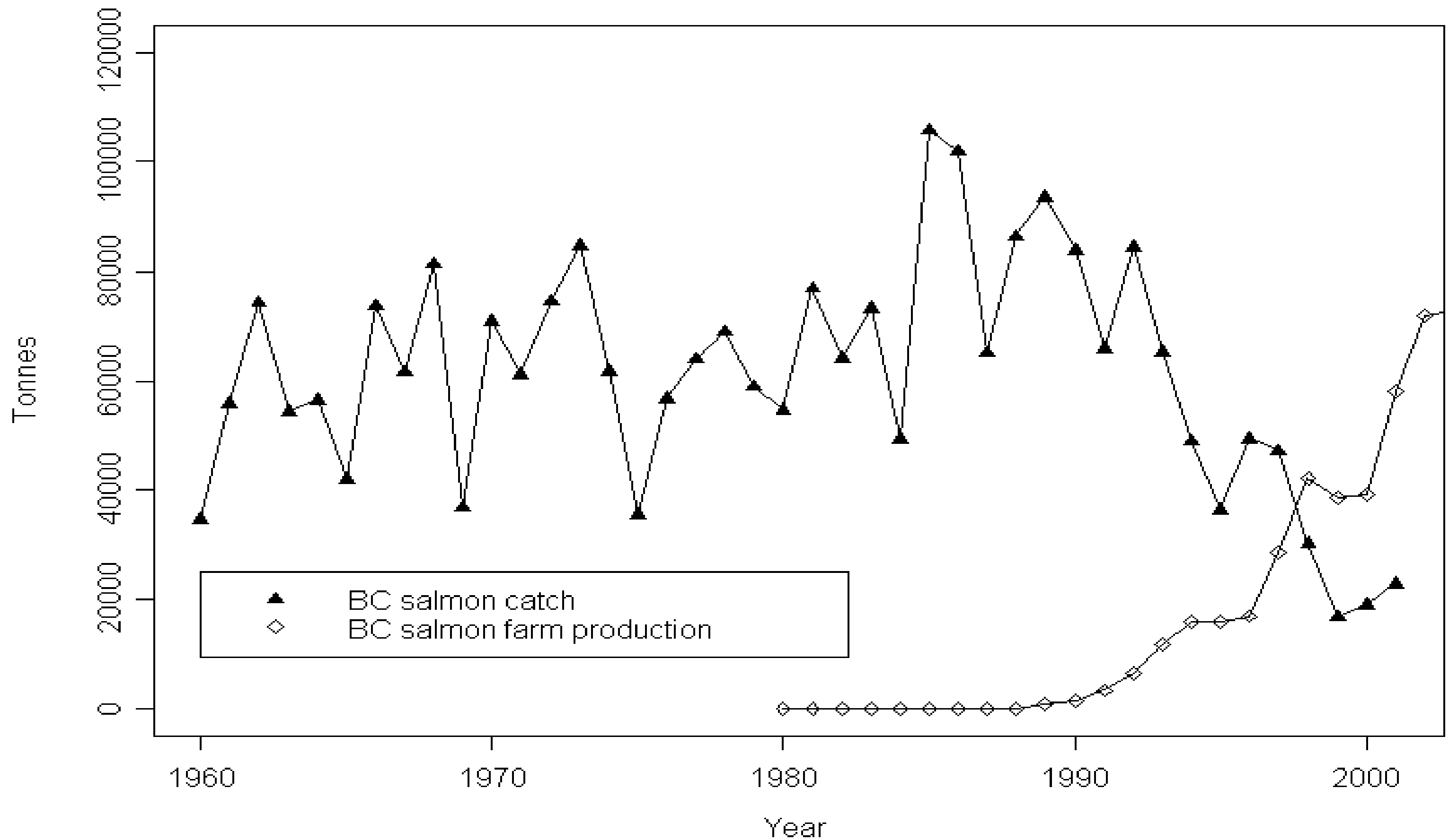
- There is universal agreement among scientist that the fishing mortality is much too high for lobster, typically F is around 0.8.
- In Canada, the seasons range from 2 to 6 months, and the fishing mortality is as high as they are in Maine.
- In Canada, 50% of the catch is obtained in less than 30 days for all regions.
- This implies that the fishing season could be reduced to one month, and still a high fishing mortality could be obtained (around F = 0.4). This fishing mortality is probably still above what is optimal.
- This implies that the amount of effort in Maine is around 75 times too high.

What is the impact of aquaculture on the survival of wild salmon?

(note all the actual work on this was done by Jen Ford)

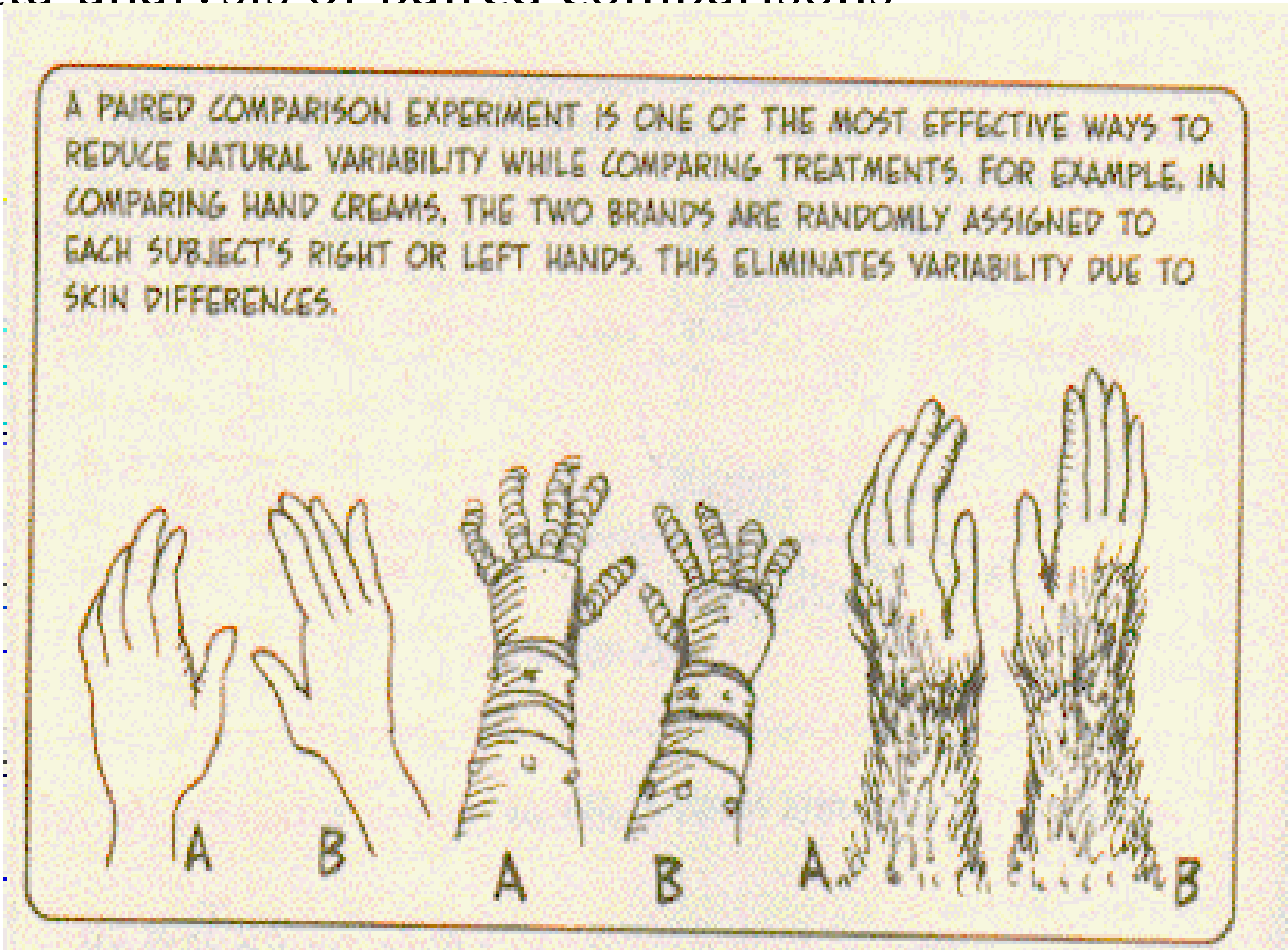


North Atlantic salmon catch (tonnes)
0
2000
4000
6000
8000
10000
12000
14000
North Atlantic salmon aquaculture production (tonnes)
0
200000
400000
600000
1960
1970
1980
1990
2000
Year
North Atlantic salmon catch
North Atlantic farm production

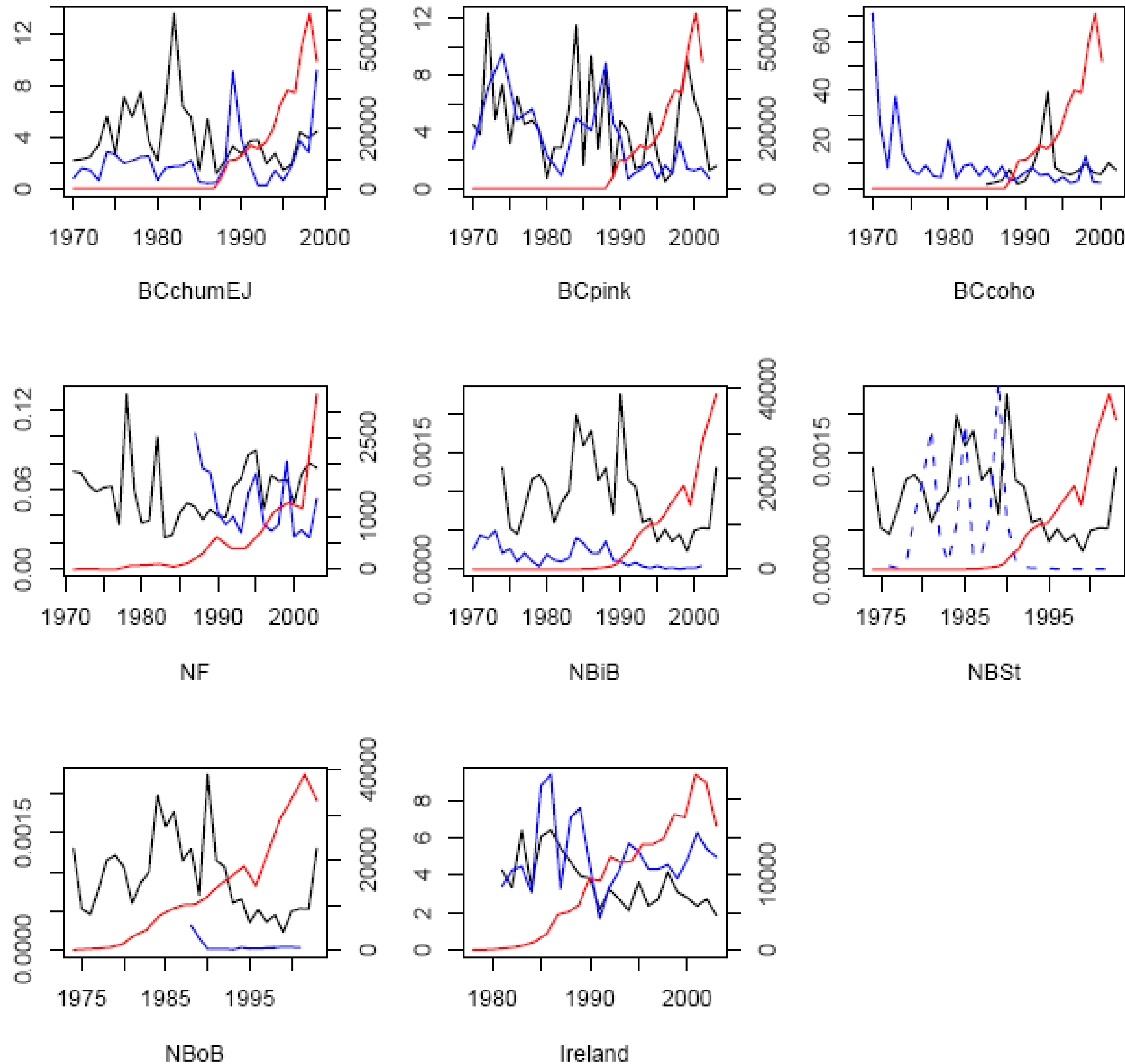


Tonnes
0
20000
40000
60000
80000
100000
120000
1960
1970
1980
1990
2000
Year
BC salmon catch
BC salmon farm production

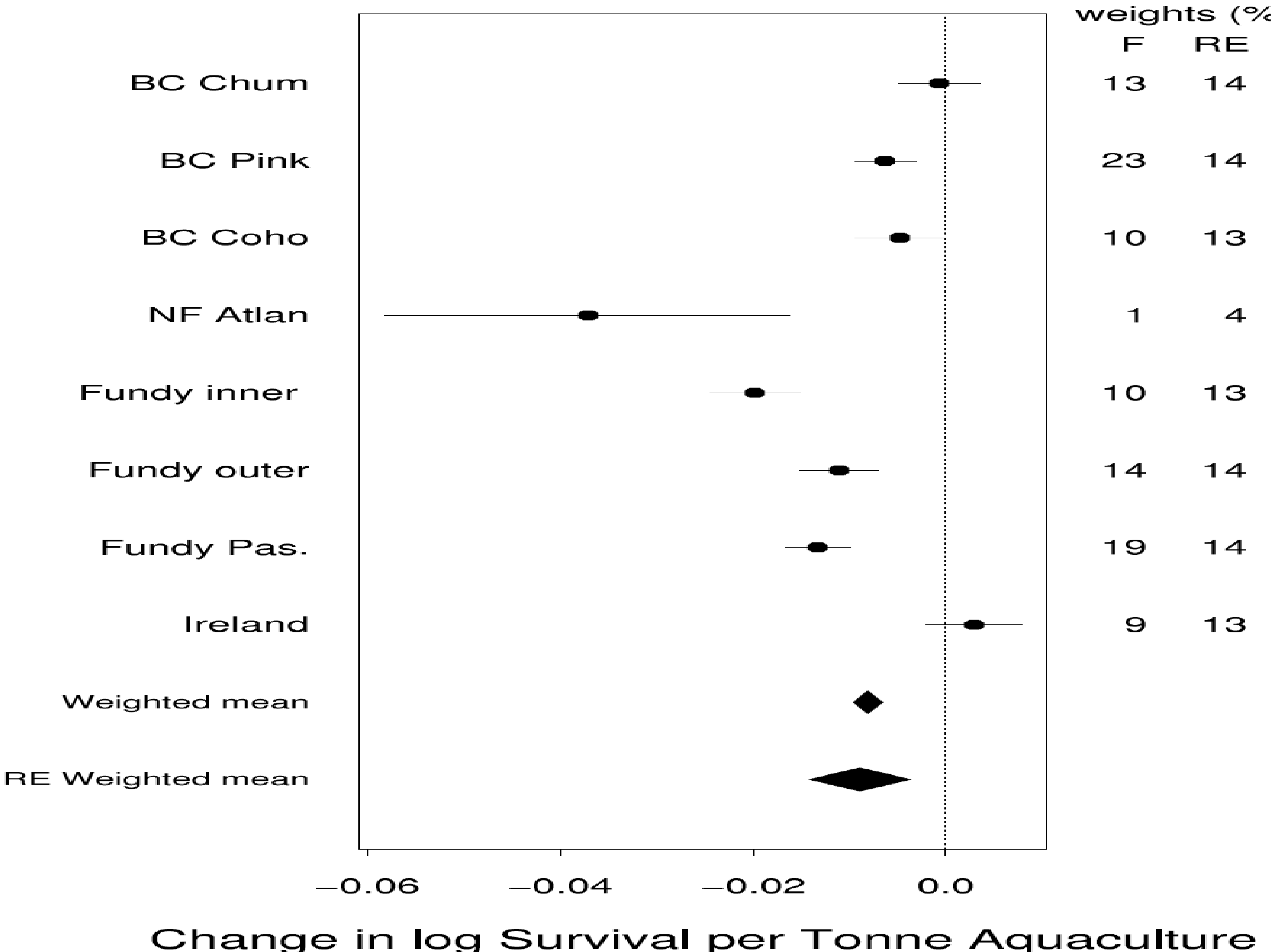
Meta-analysis of paired comparisons

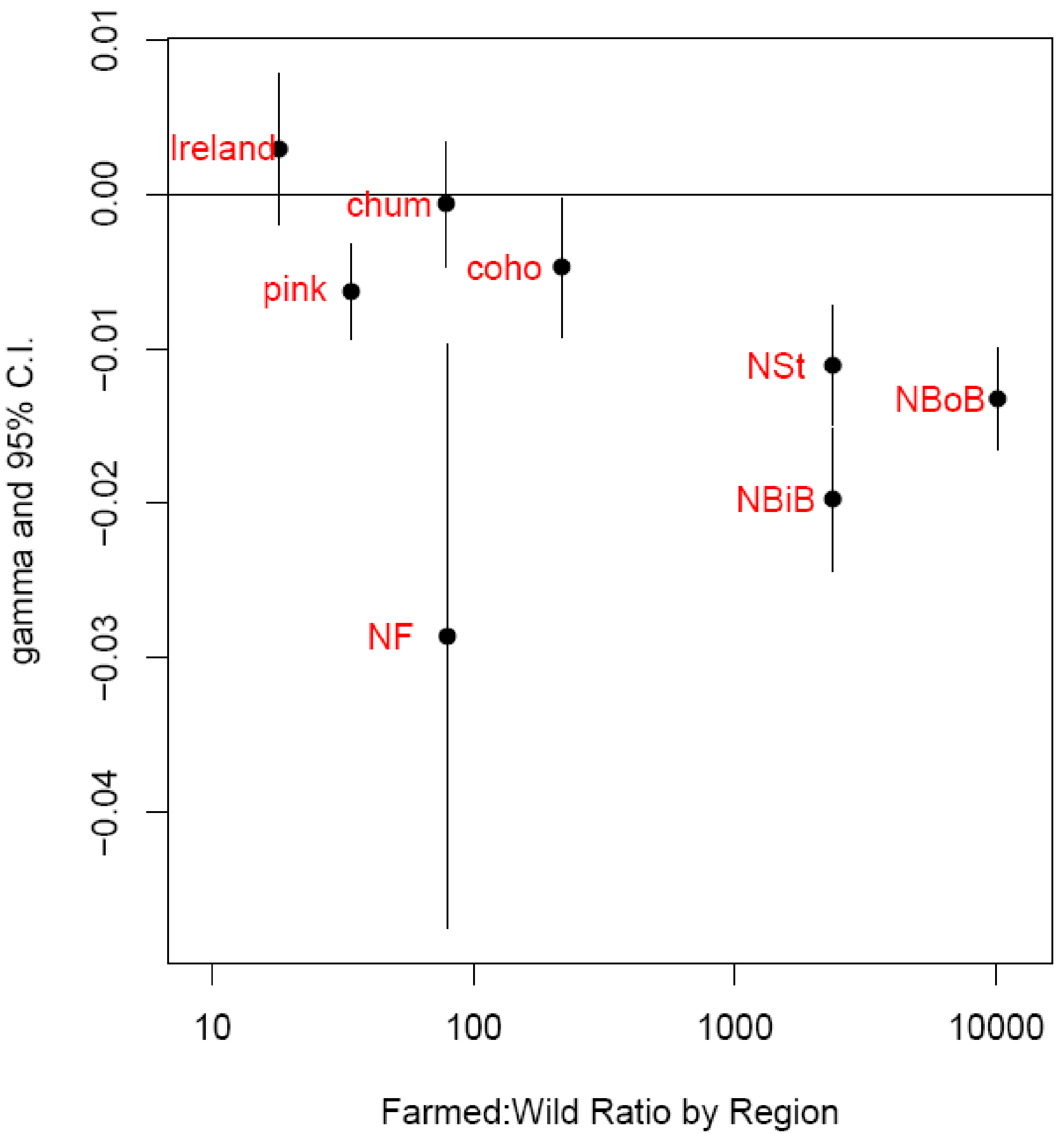


Source: Cartoon Guide to Statistics, Larry Gonick & Woolcott Smith



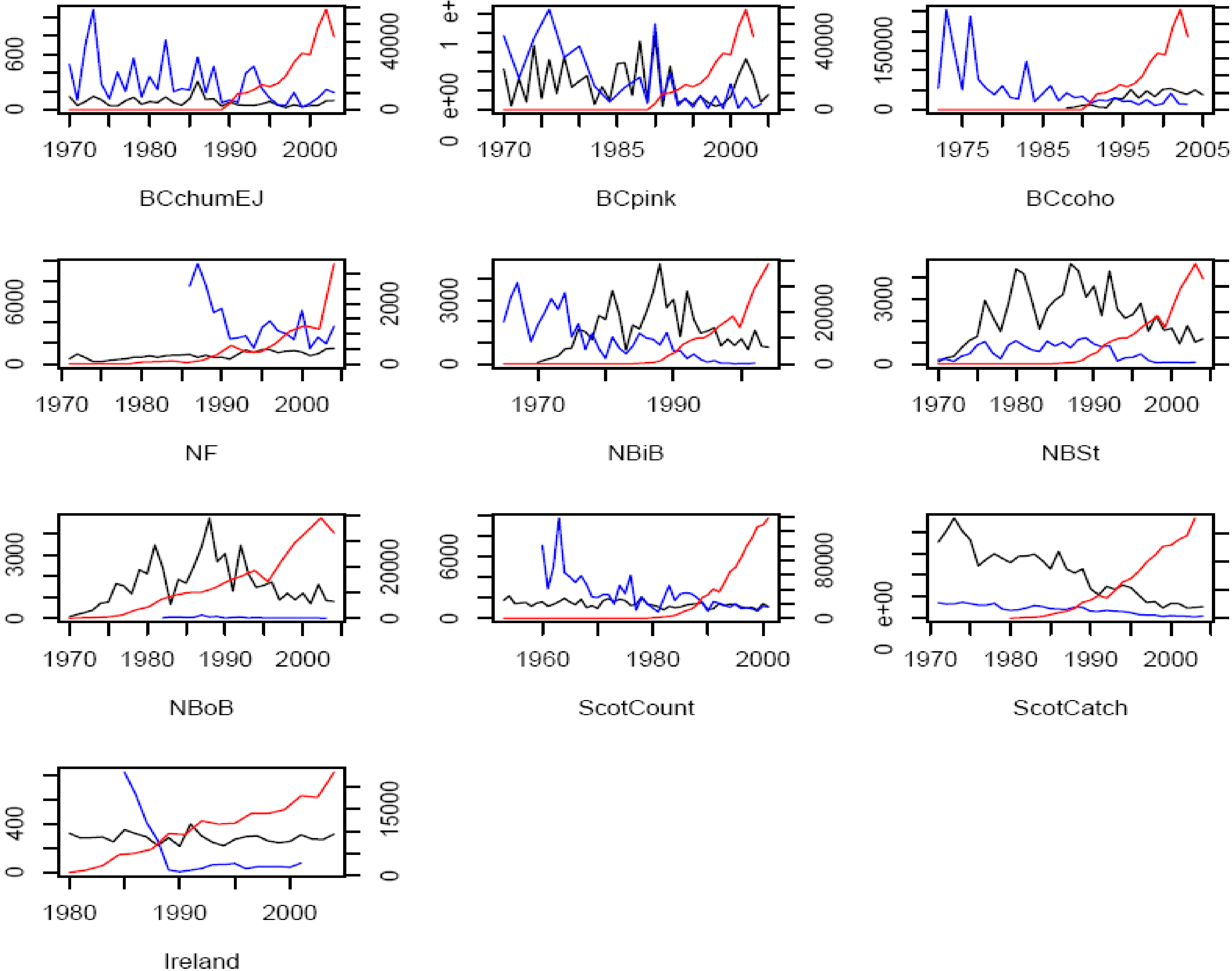
Predicted Survivals (left axis), Exposed in Blue, Farmed Production in Red (right axis)


weights (%
F
RE
BC Chum
13
14
BC Pink
23
14
BC Coho
10
13
NF Atlan
1
4
Fundy inner
10
13
Fundy outer
14
14
Fundy Pas.
19
14
Ireland
9
13
Weighted mean
RE Weighted mean
−0.06
−0.04
−0.02
0.0
Change in log Survival per Tonne Aquaculture

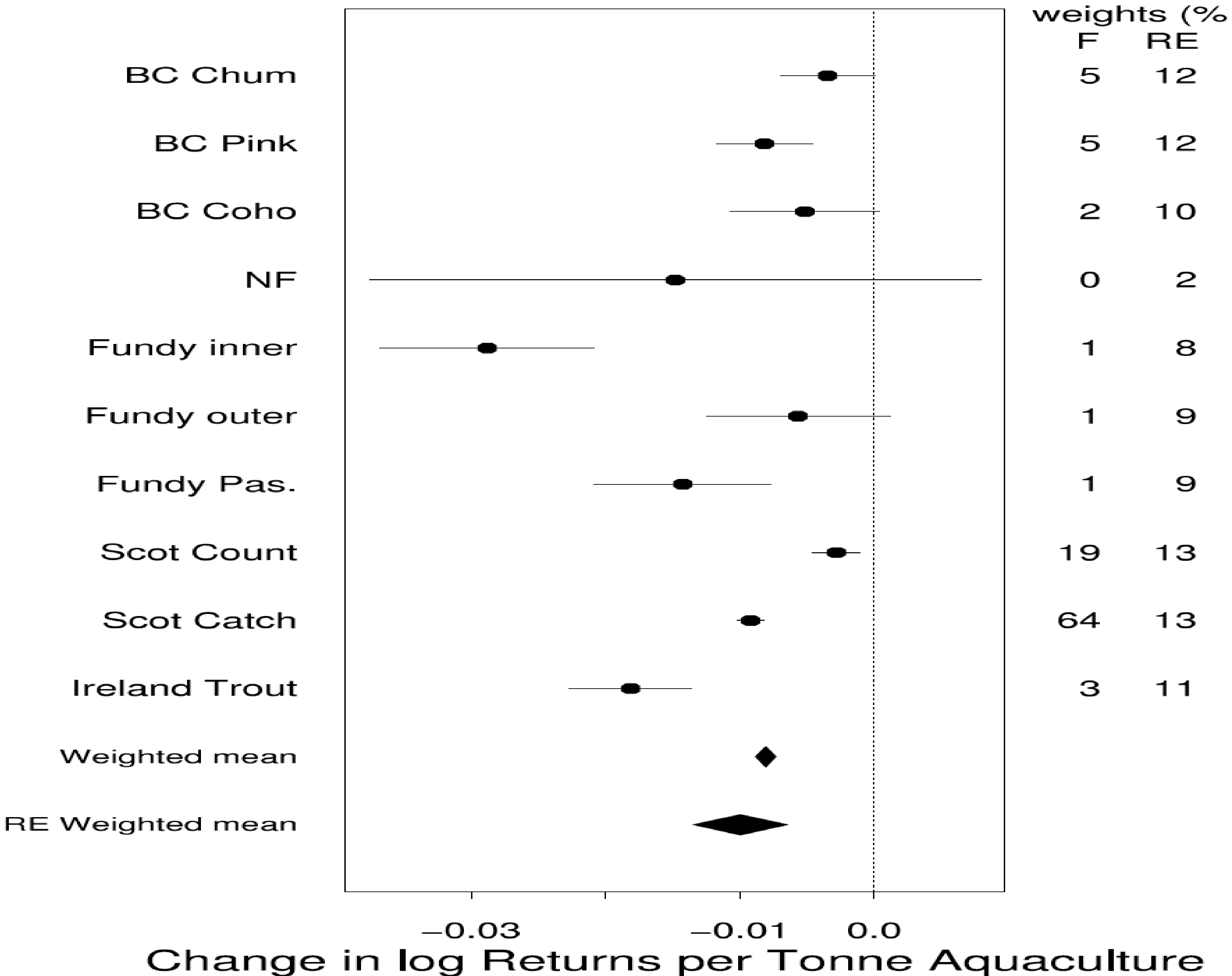


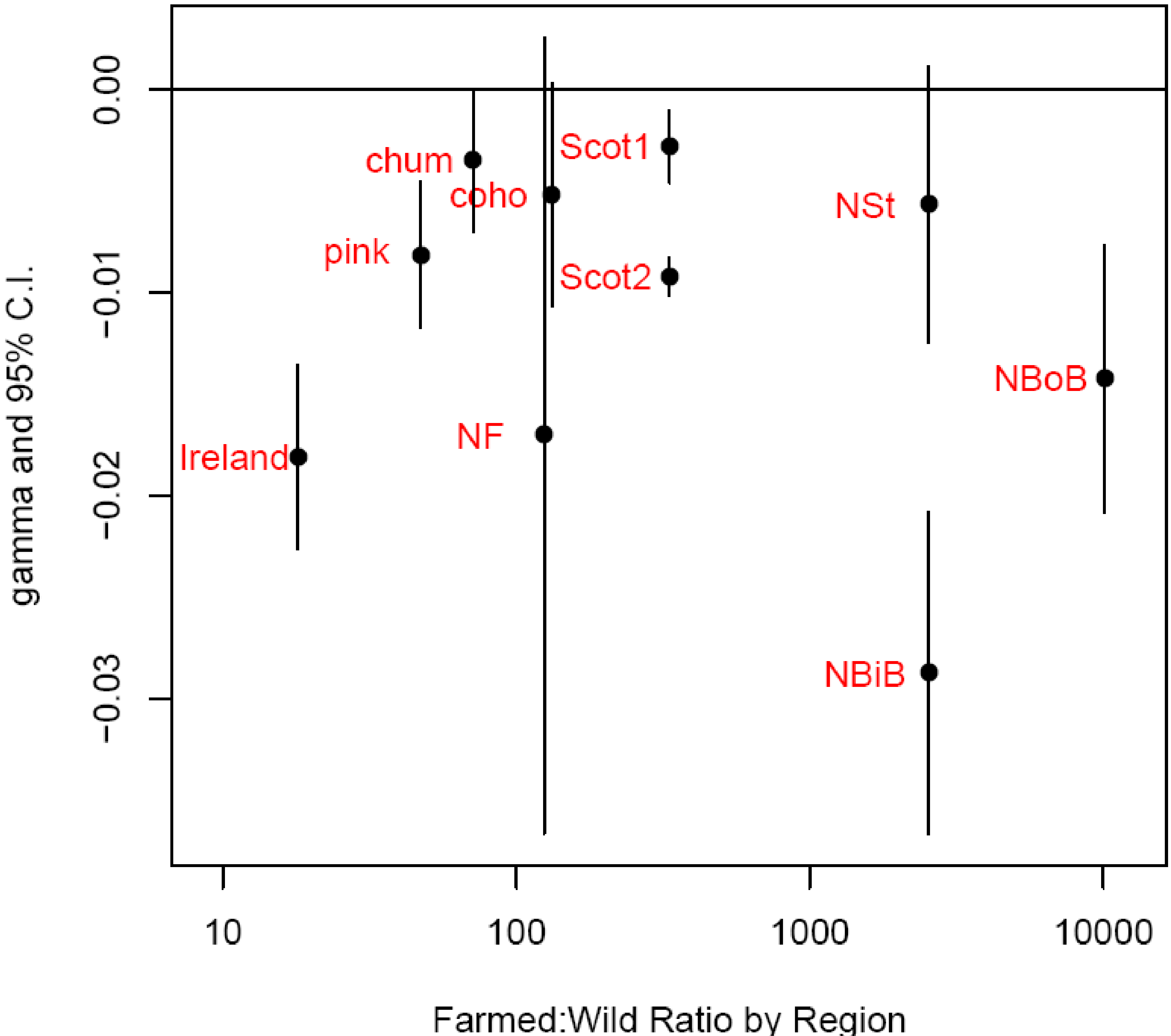
0.01
0.00
−0.01
−0.02
−0.03
−0.04
gamma and 95% C.I.
Ireland
chum
pink
coho
NSt
NBoB
NBiB
NF
10
100
1000
10000
Farmed:Wild Ratio by Region

Always repeat all analyses with independent data



Predicted Returns (left axis), Exposed in Blue, Farmed Production in Red (right axis)

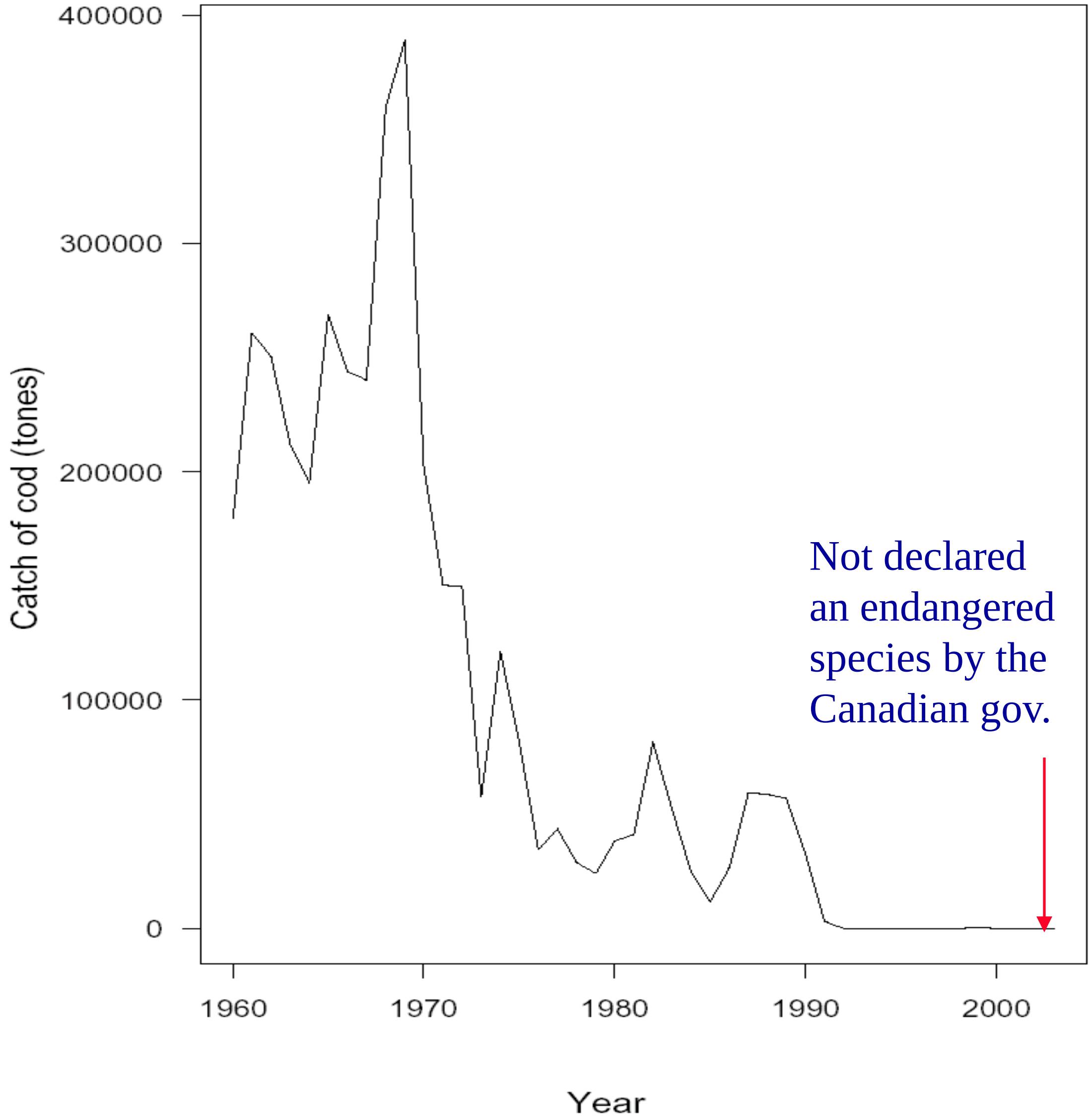

weights (%
F RE
BC Chum 5 12
BC Pink 5 12
BC Coho 2 10
NF 0 2
Fundy inner 1 8
Fundy outer 1 9
Fundy Pas. 1 9
Scot Count 19 13
Scot Catch 64 13
Ireland Trout 3 11
Weighted mean
RE Weighted mean
−0.03
−0.01
0.0
Change in log Returns per Tonne Aquaculture



gamma and 95% C.I.
0.00
-0.01
-0.02
-0.03
chum
coho
pink
Scot1
Scot2
NSt
NBoB
NF
Ireland
NBiB
10
100
1000
10000
Farmed:Wild Ratio by Region



Collapse of cod: cost ~ Can$5,000,000,000.00



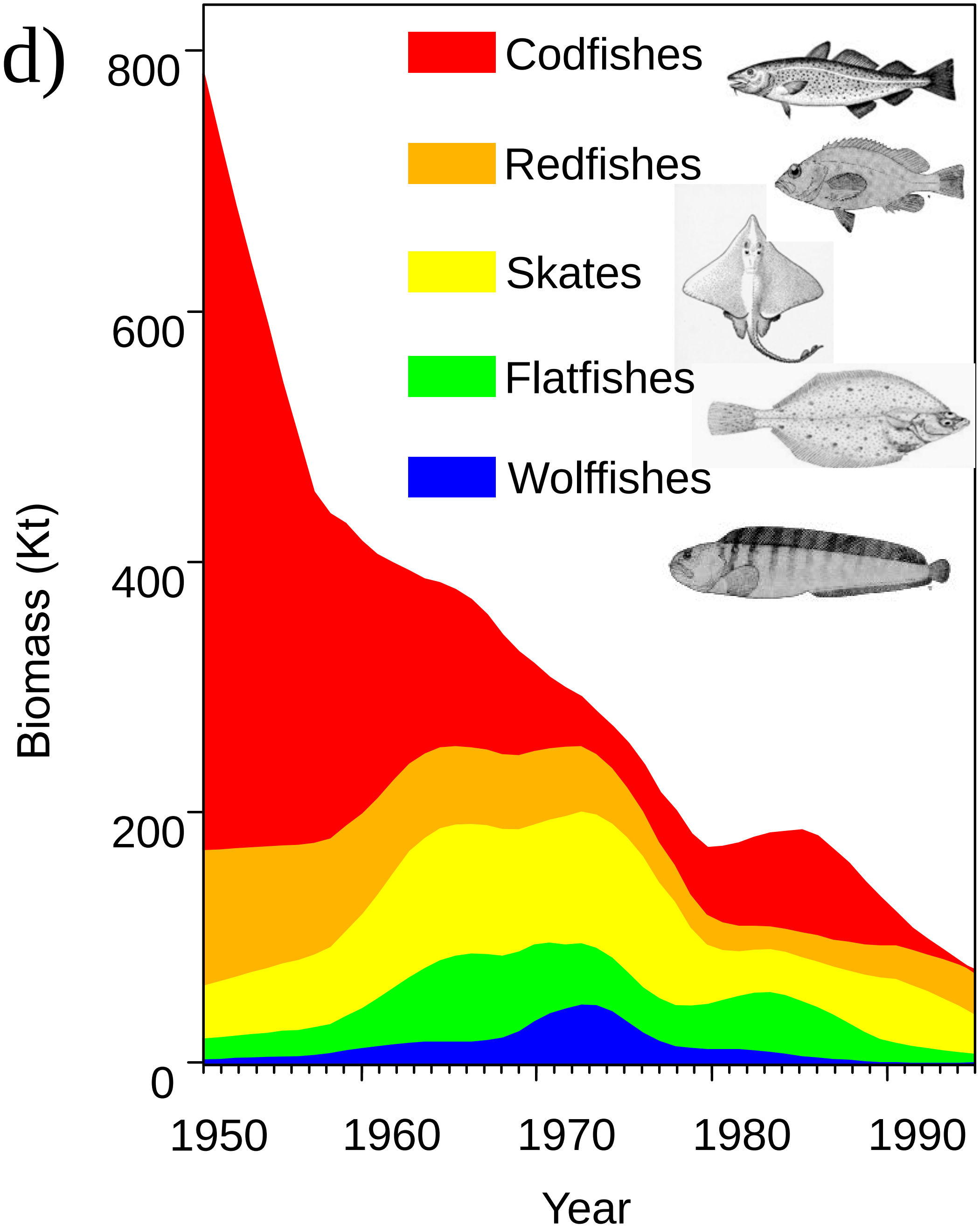
Newfoundland cod

The loss of an industry that employed 40,000 people, and had sustained a culture for 400 years.

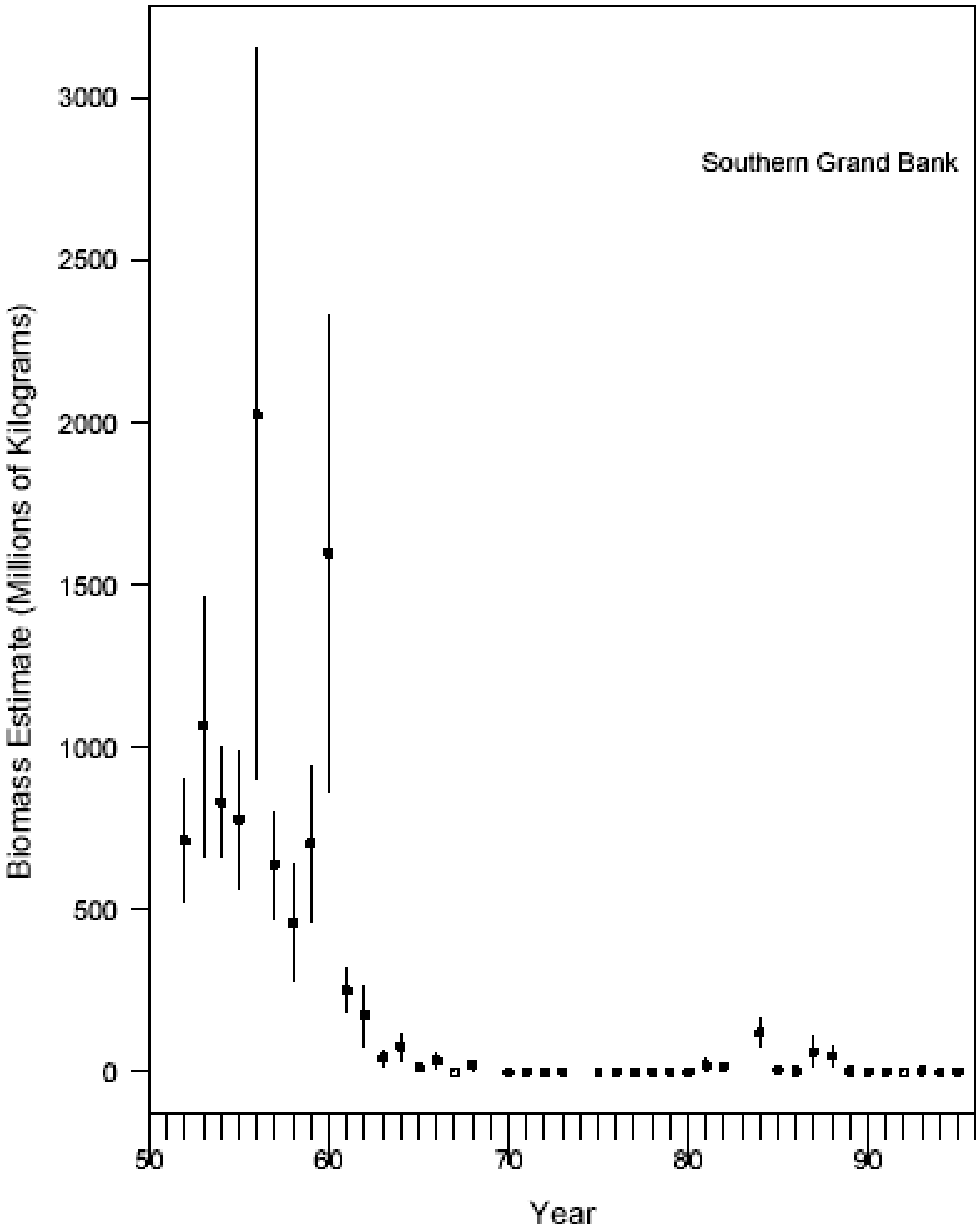
Cod in Newfoundland declared NOT endangered in 2003.

St. Pierre Bank
(south of Newfoundland)

- 90% decline in numbers
- Approx. 50% decline in size
- Large changes in species composition

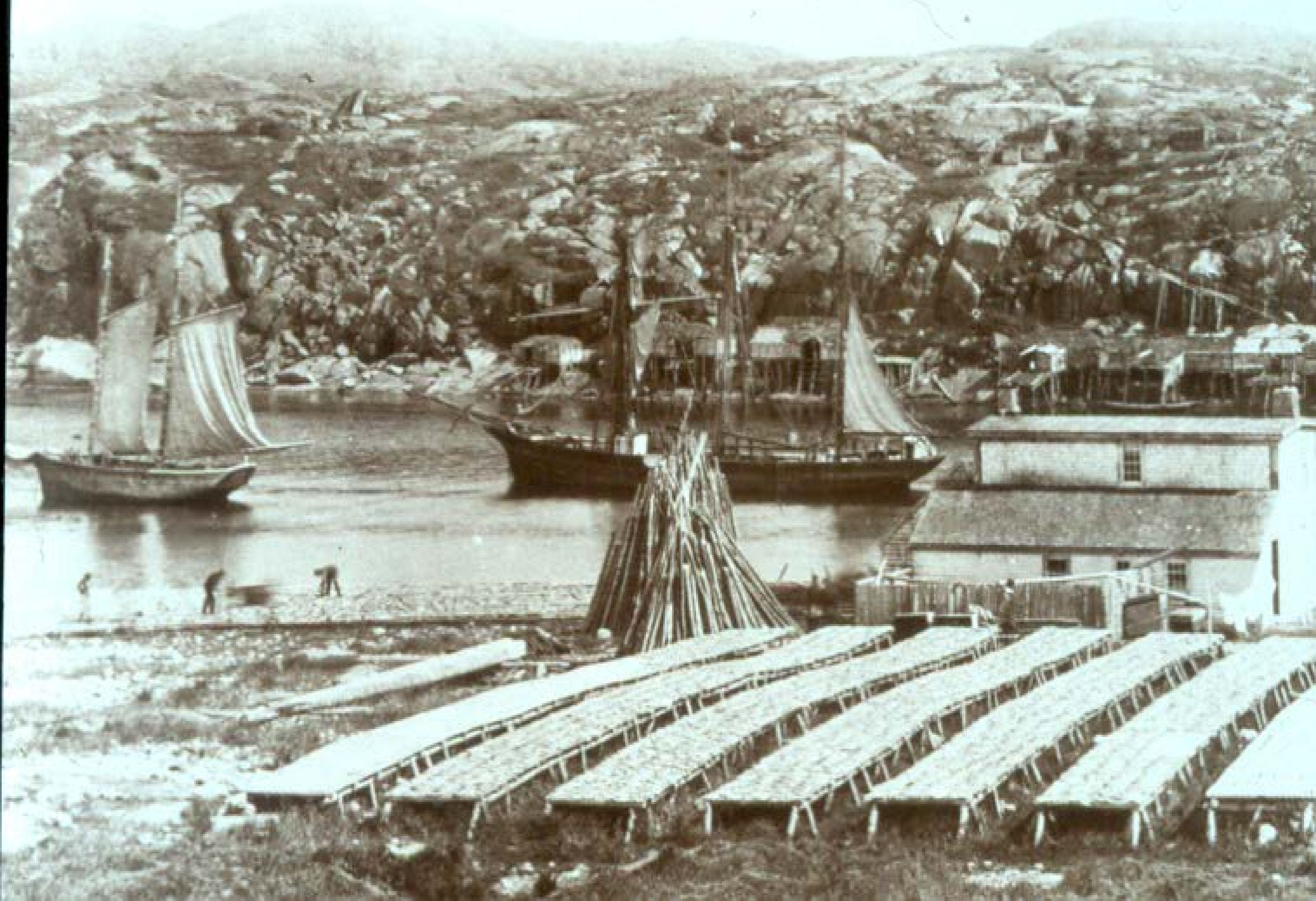


Myers and Worm 2003 Nature



Loss of haddock on the Grand Banks – data from research surveys

The Loss of Cod History



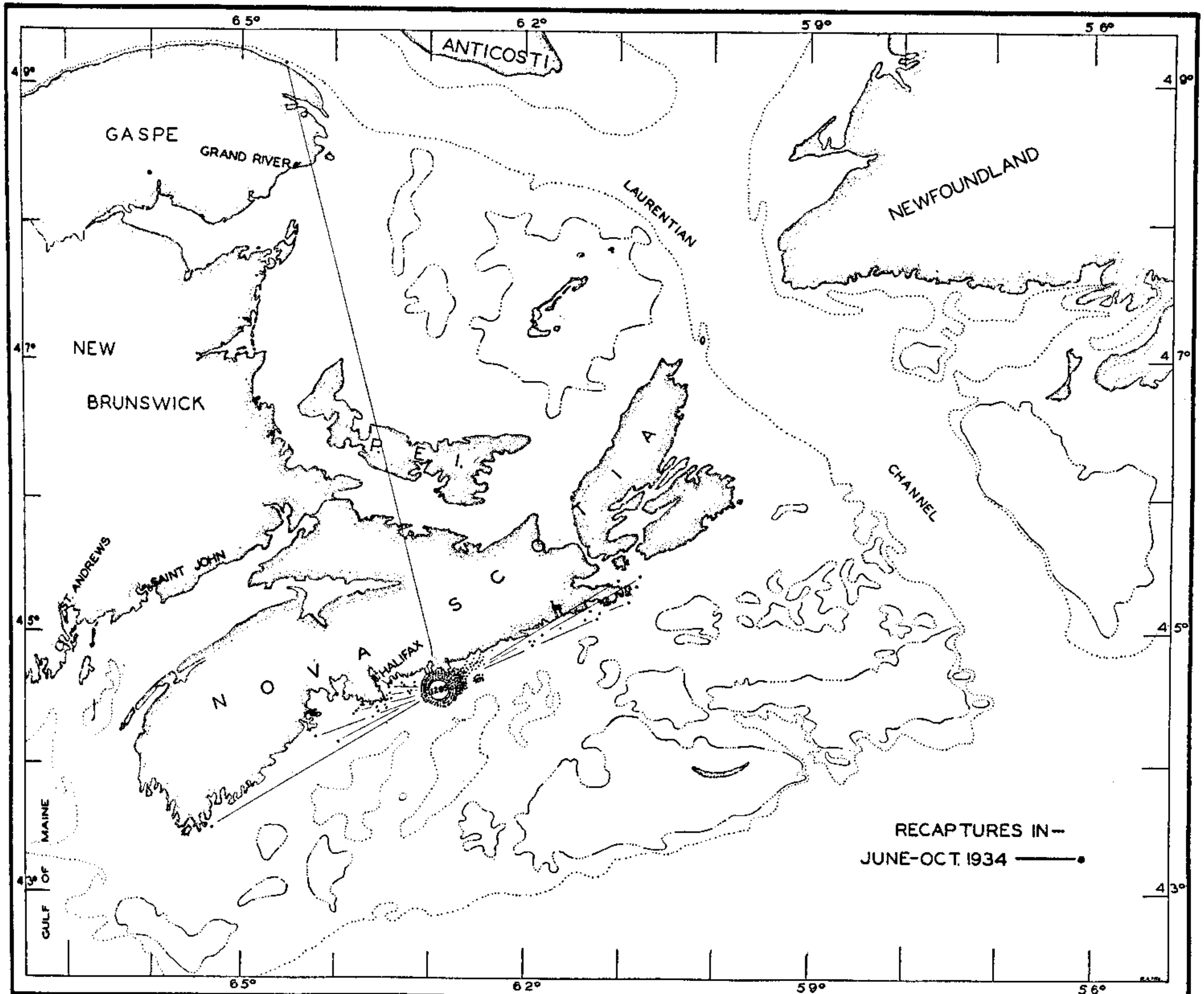


FIG. 21.—Recaptures to October, 1934, of cod tagged in the Jeddore Rock to Egg Island area, N.S., in May, 1934.

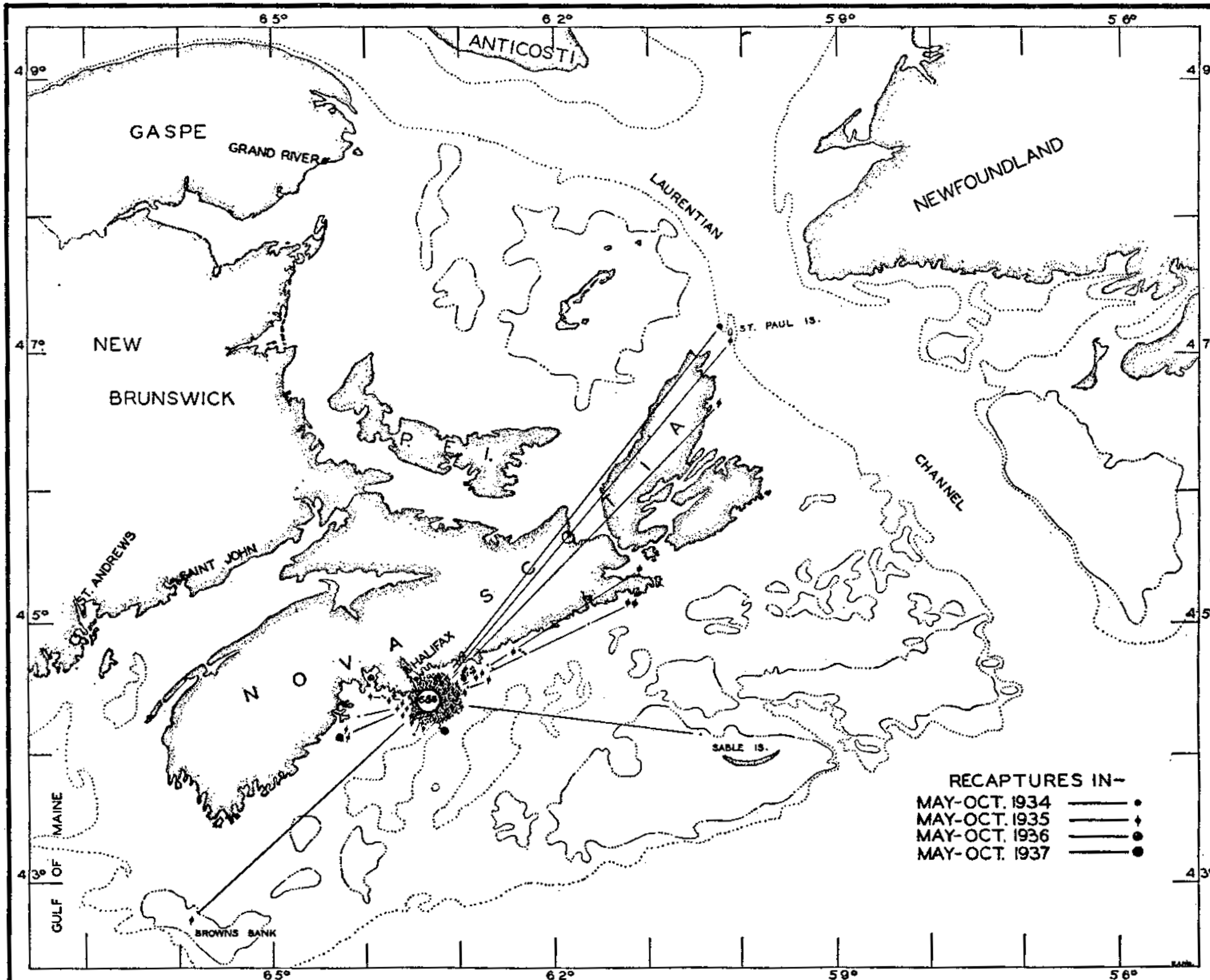


FIG. 18.—Recaptures in May to October, 1934, 1935, 1936 and 1937, of cod tagged near Halifax in June, 1934.

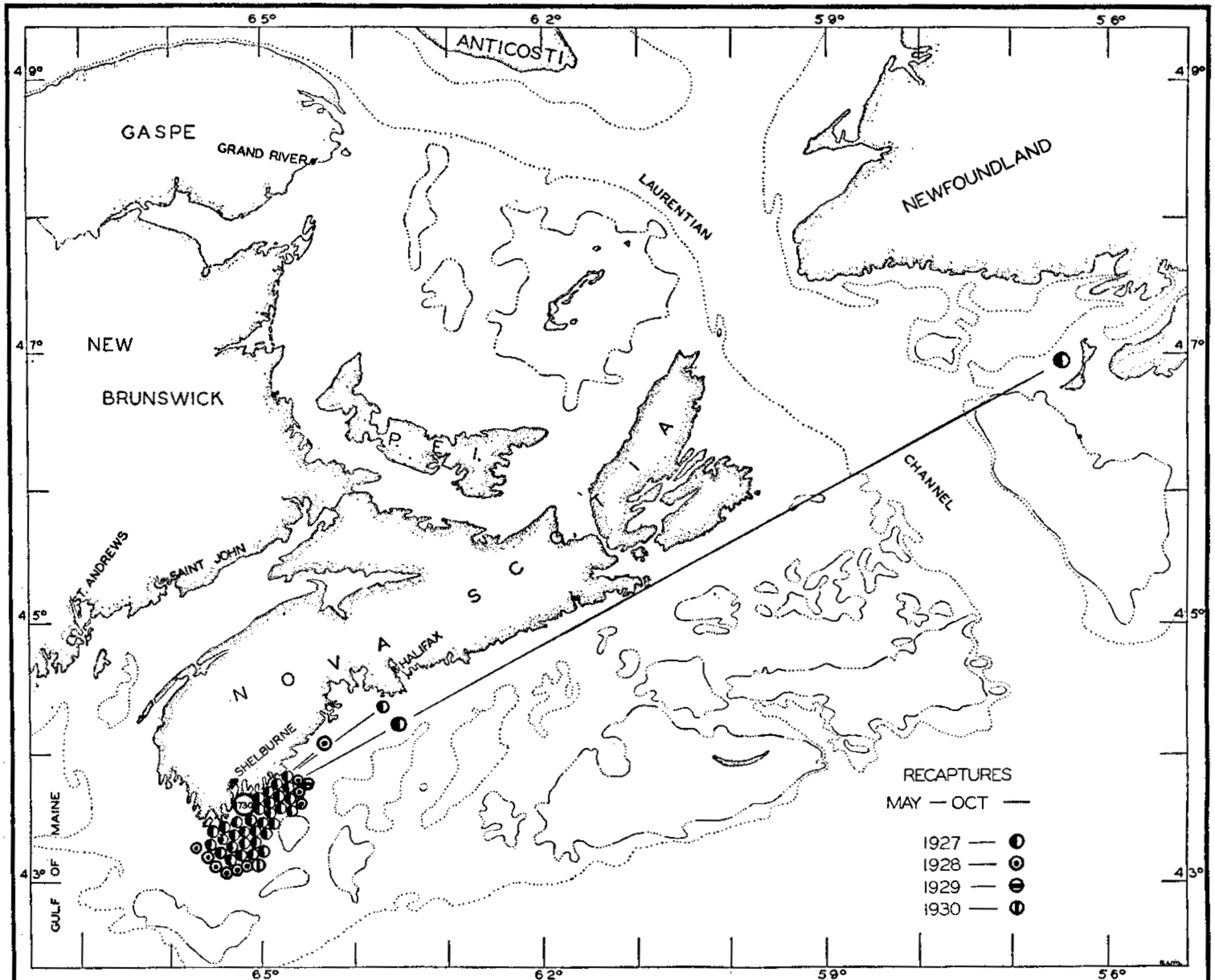
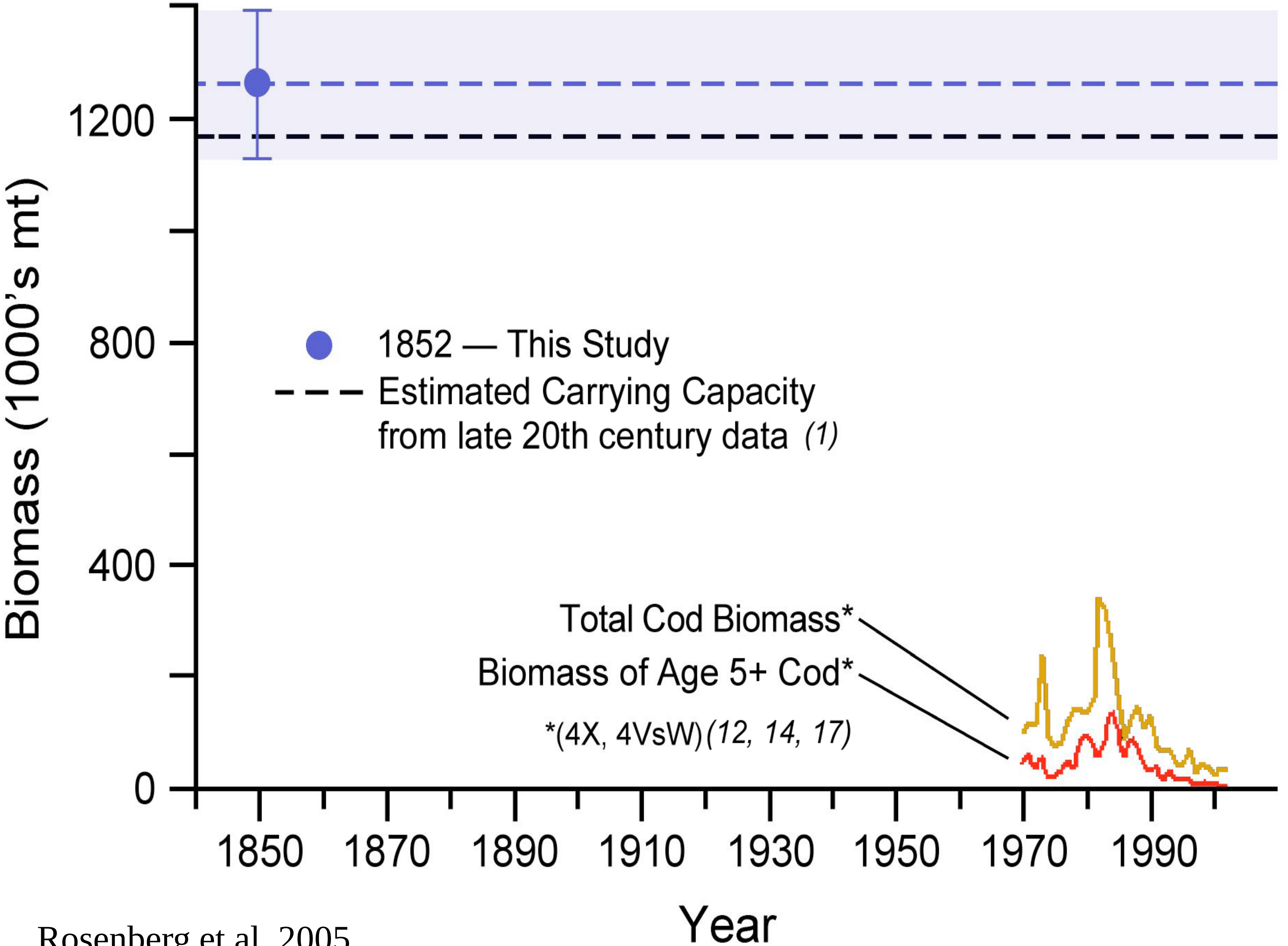
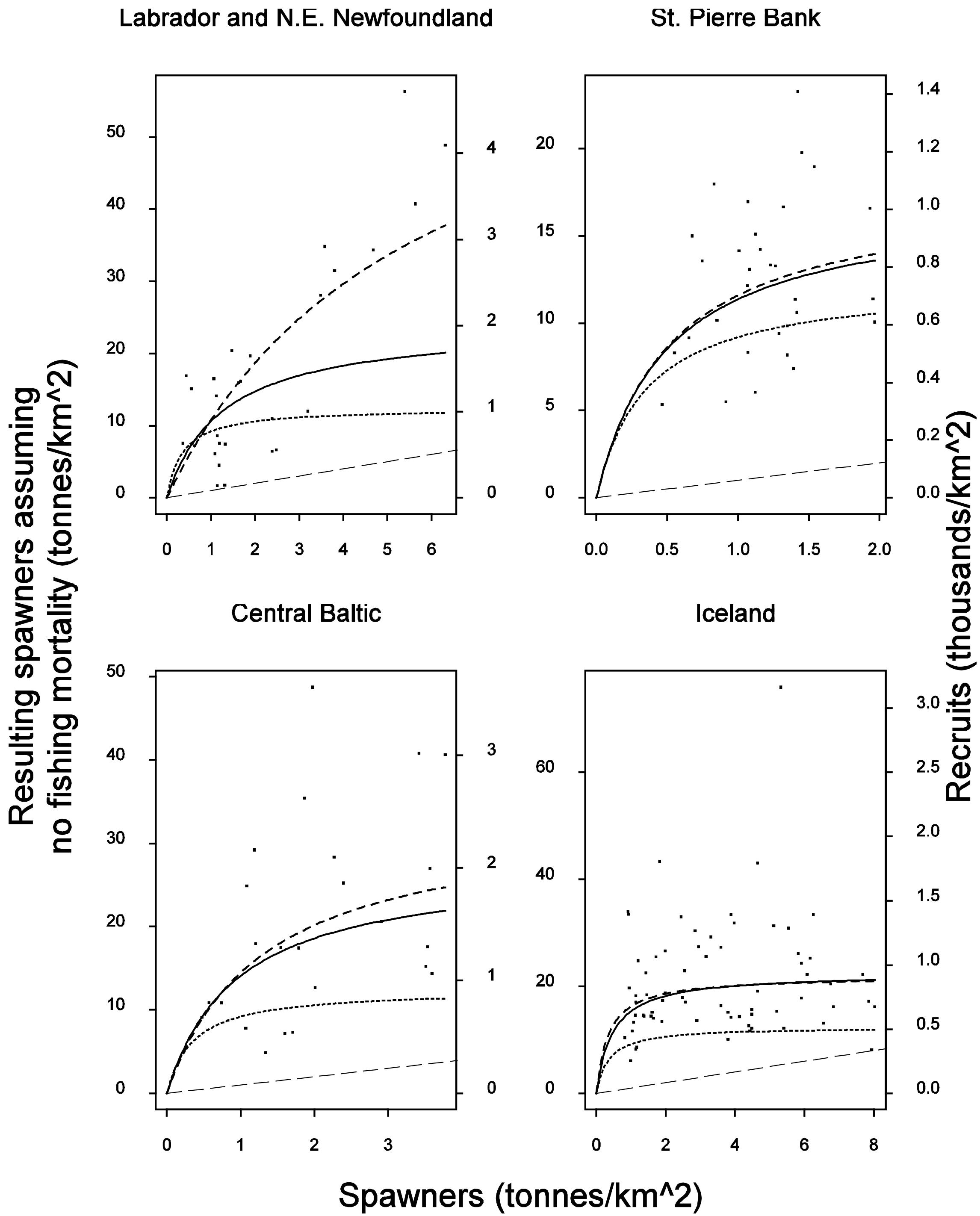


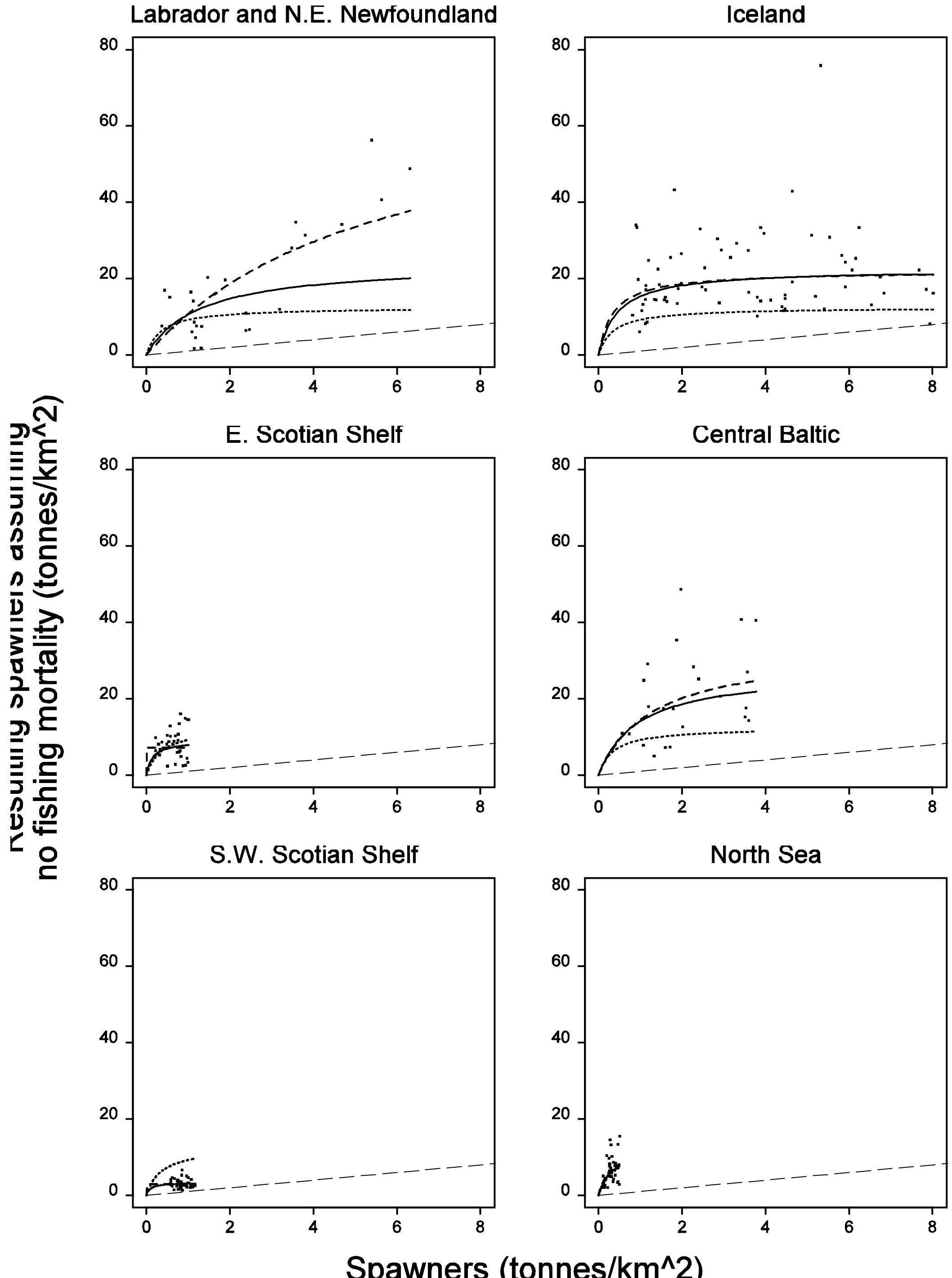
FIG. 15.—Recaptures during "summers" of 1927, 1928, 1929 and 1930 of cod tagged off Shelburne, N.S., during September and the first day of October, 1926.



Rosenberg et al. 2005

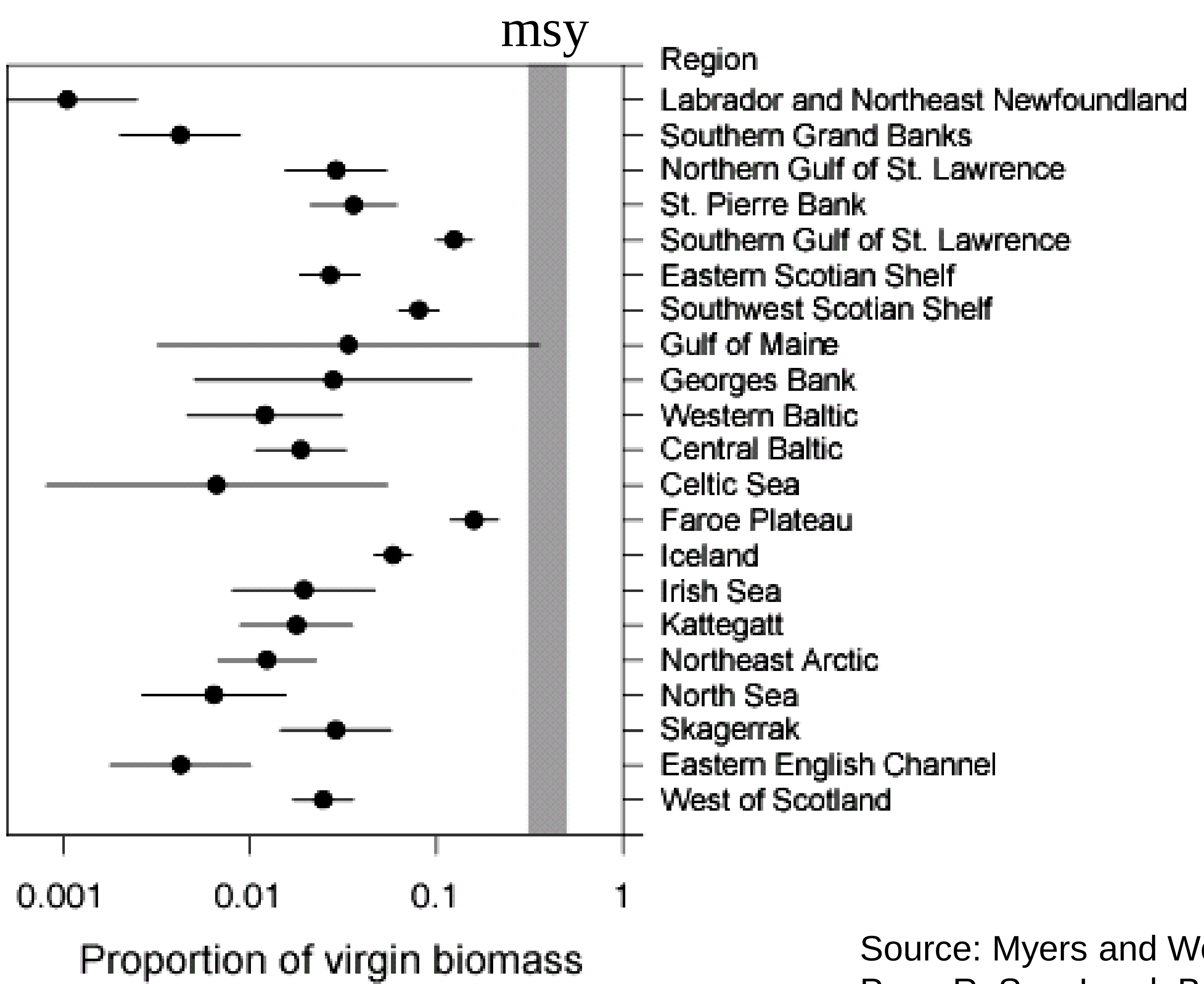


Labrador and N.E. Newfoundland
St. Pierre Bank
Central Baltic
Iceland
Resulting spawners assuming
no fishing mortality (tonnes/km^2)
Recruits (thousands/km^2)
Spawners (tonnes/km^2)

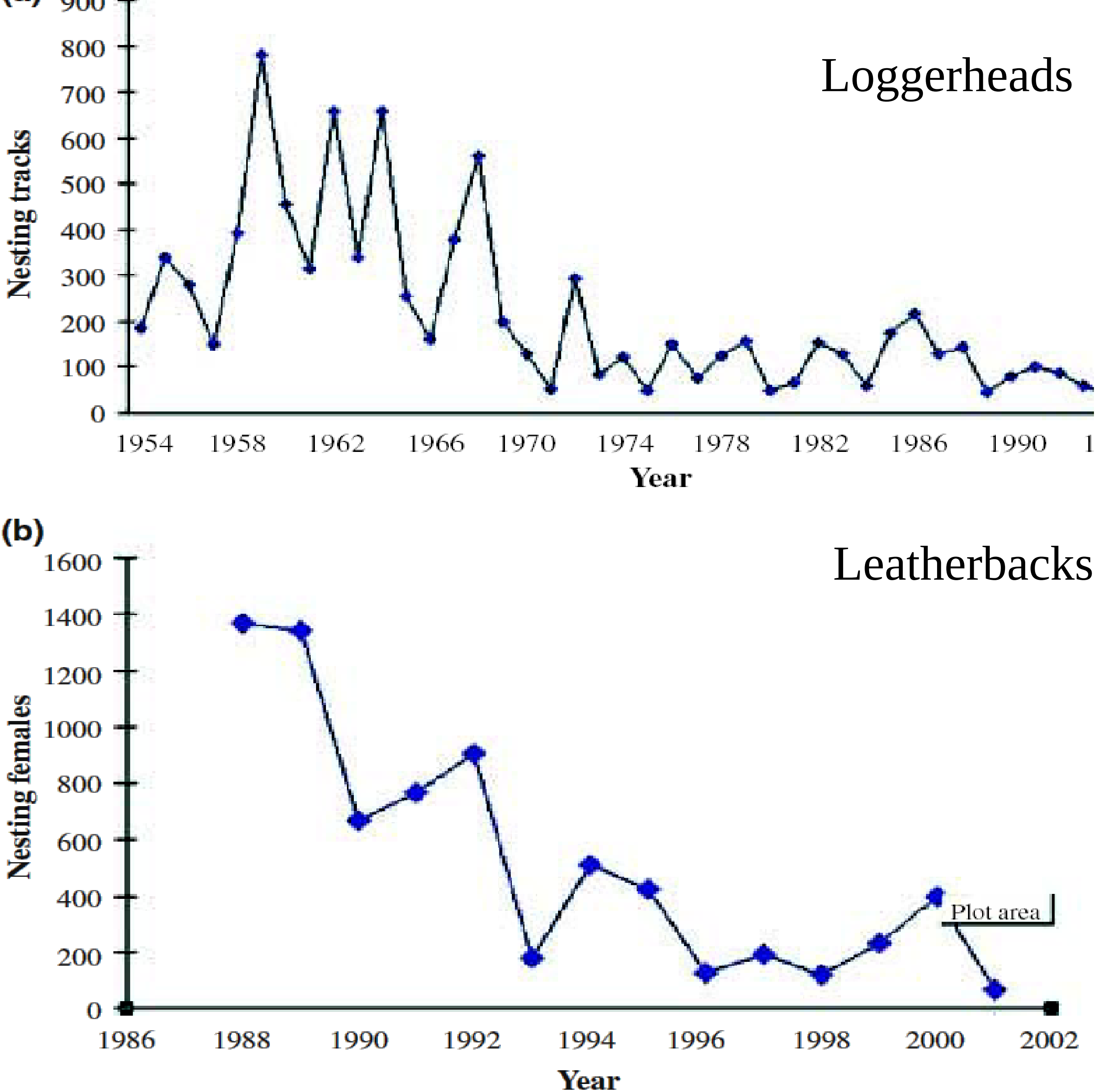


Labrador and N.E. Newfoundland
Iceland
E. Scotian Shelf
Central Baltic
S.W. Scotian Shelf
North Sea
0
20
40
60
80
0
2
4
6
8
no fishing mortality (tonnes/km^2)
Spawners (tonnes/km^2)

There is much less than 10% of cod left -



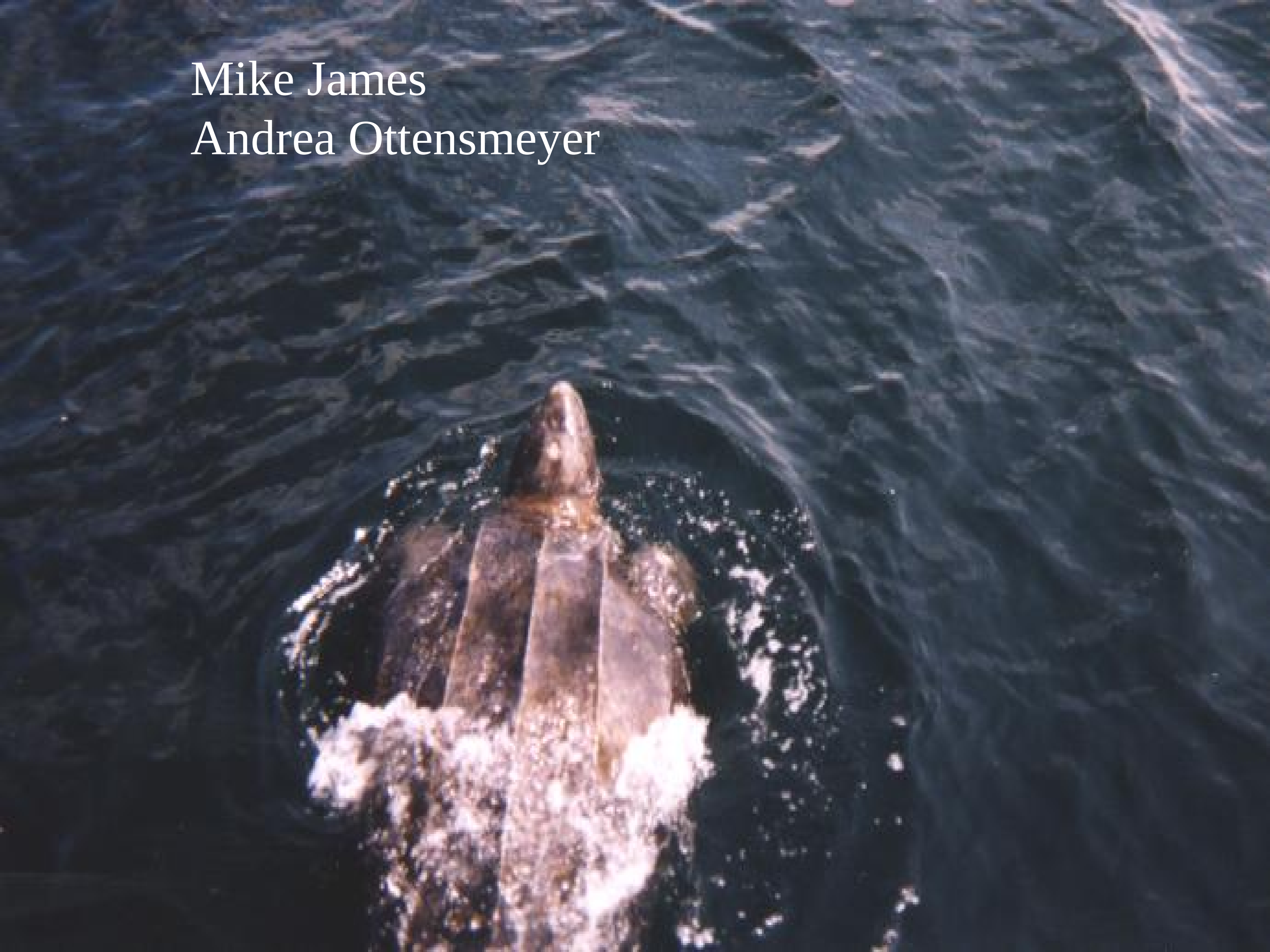
Source: Myers and Worm 2005. Proc. R. Soc. Lond. B

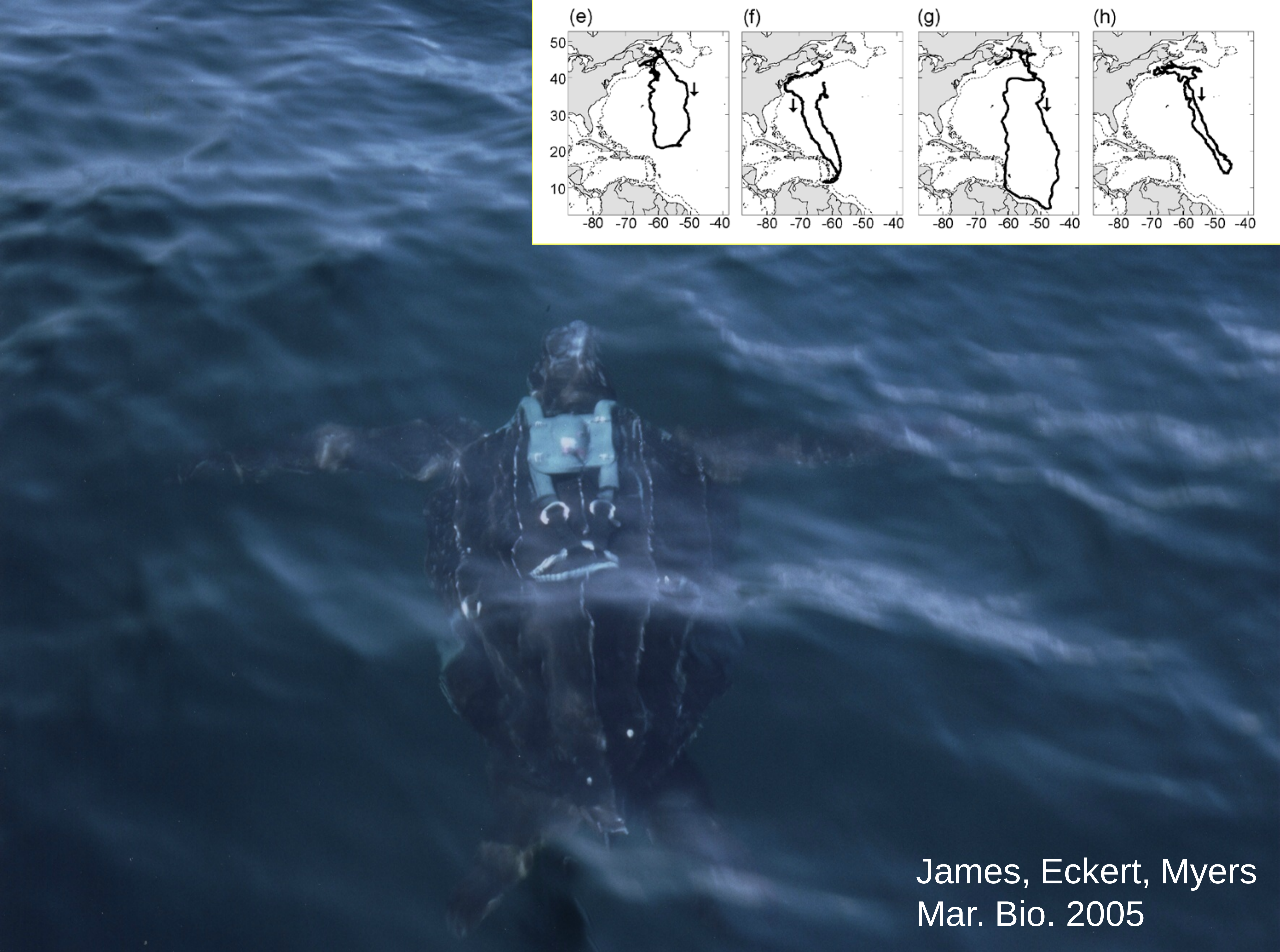


Lewison et al. 2004
Ecology Letters

Photo by Matthew Godfrey

Swordfishing fleet at anchor, Neils Harbour, Cape Breton. 13.


Mike James
Andrea Ottensmeyer

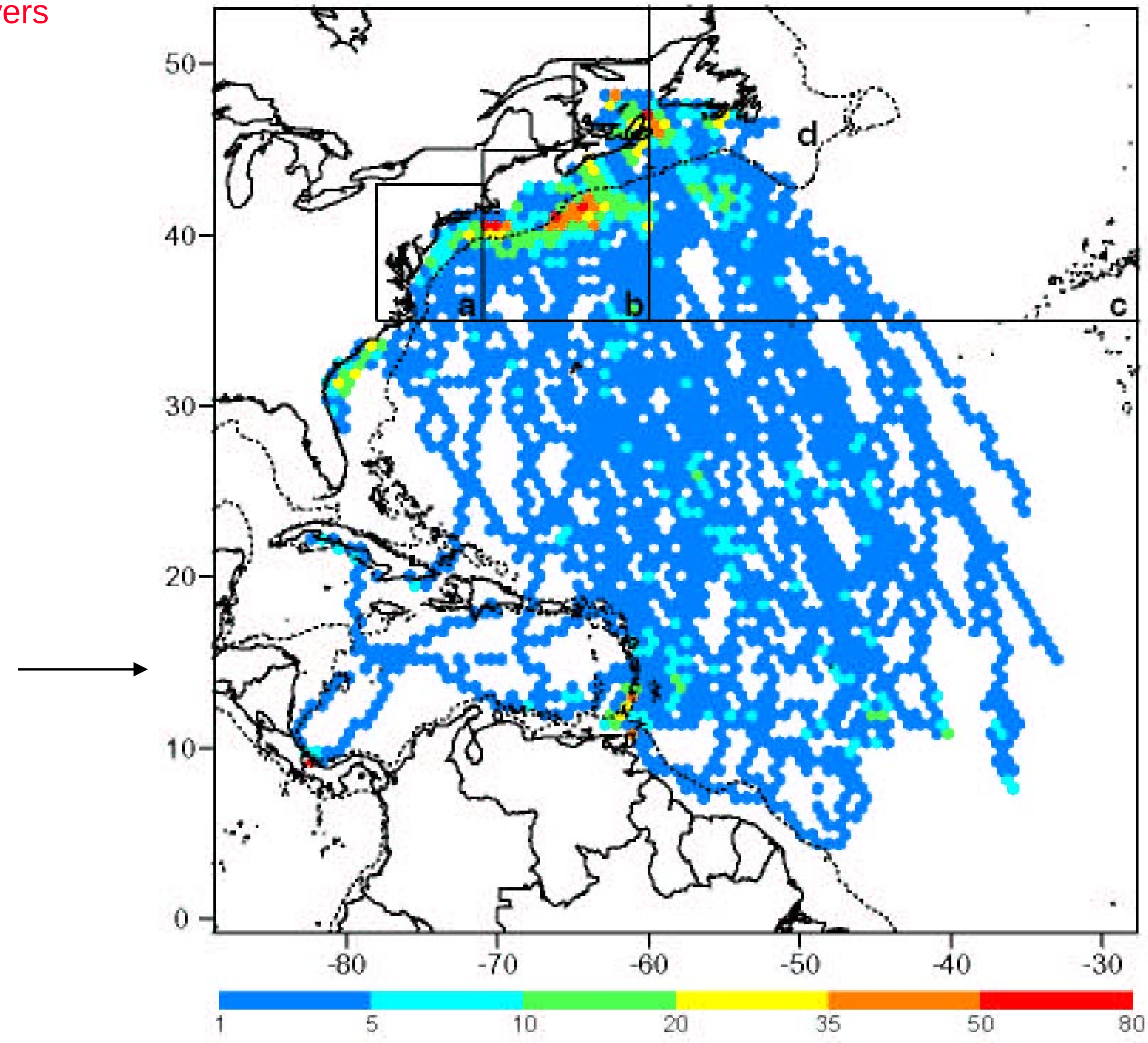


James, Eckert, Myers
Mar. Bio. 2005

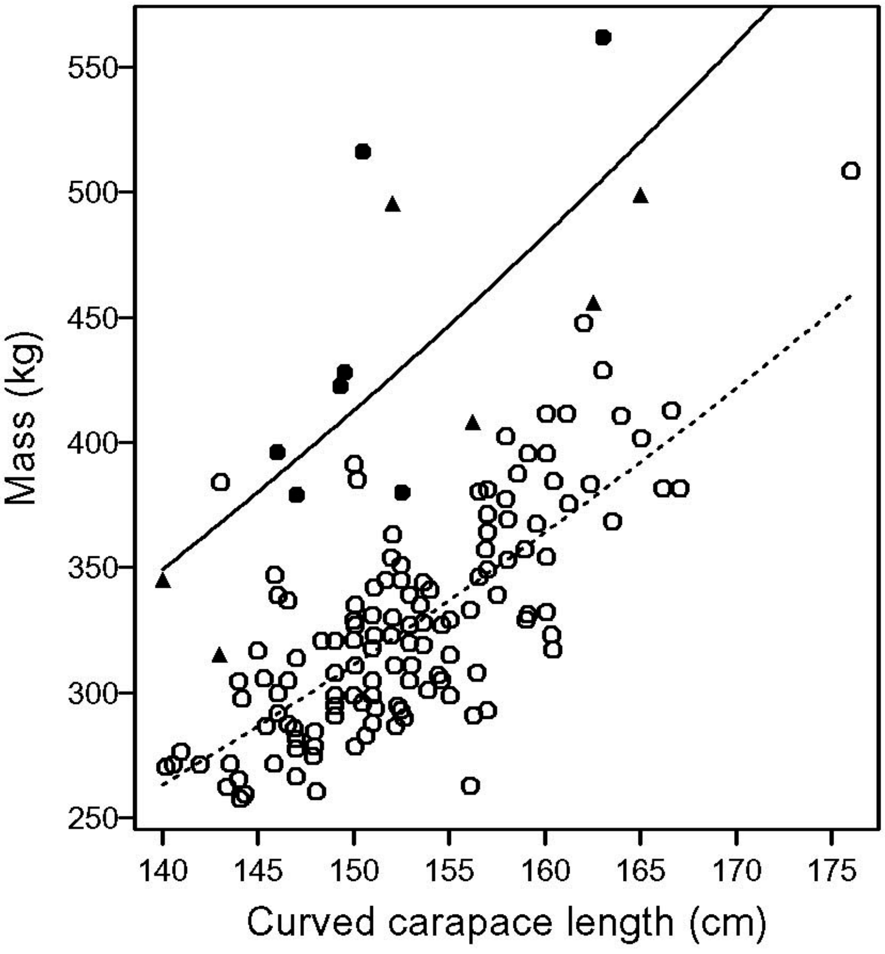
Three commercial fishing vessels are retrofitted seasonally for turtle research

Identification of high-use areas and threats to leatherback sea turtles in northern waters

James, Ottensmeyer and Myers
Ecology Letters (2005)



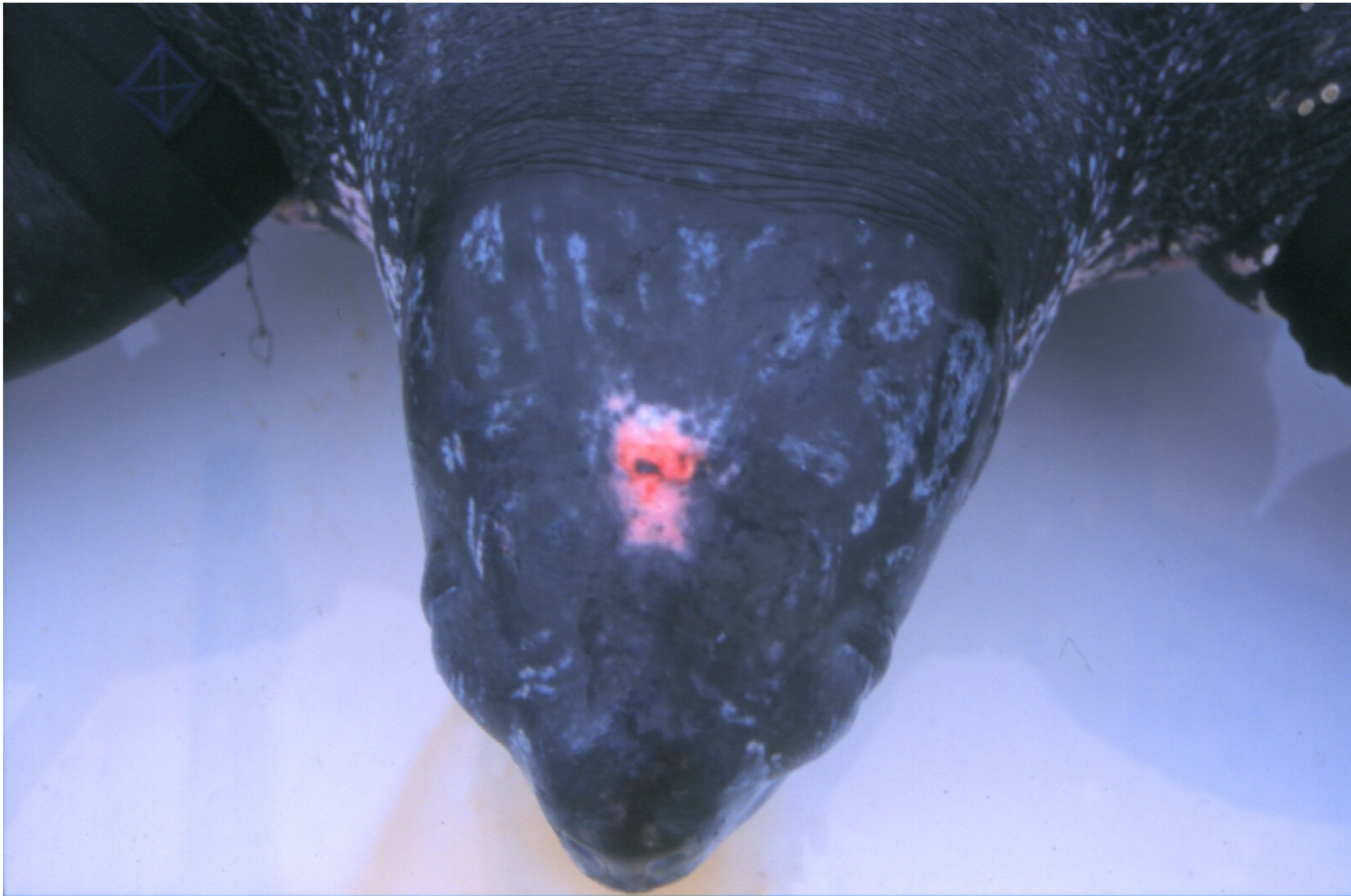
Weights in Canadian waters



Turtles are
33% heavier in Canadian coastal areas versus on the nesting beach

Nesting female morphometrics: St. Croix, U.S.V.I.
Boulon et al. 1996. Chelonian Conserv, Biol. 2:141-147.
Lines fit by constant slope analysis of covariance after log transformation.

Leatherback turtles are unique in that they expose their pineal spot to sunlight.

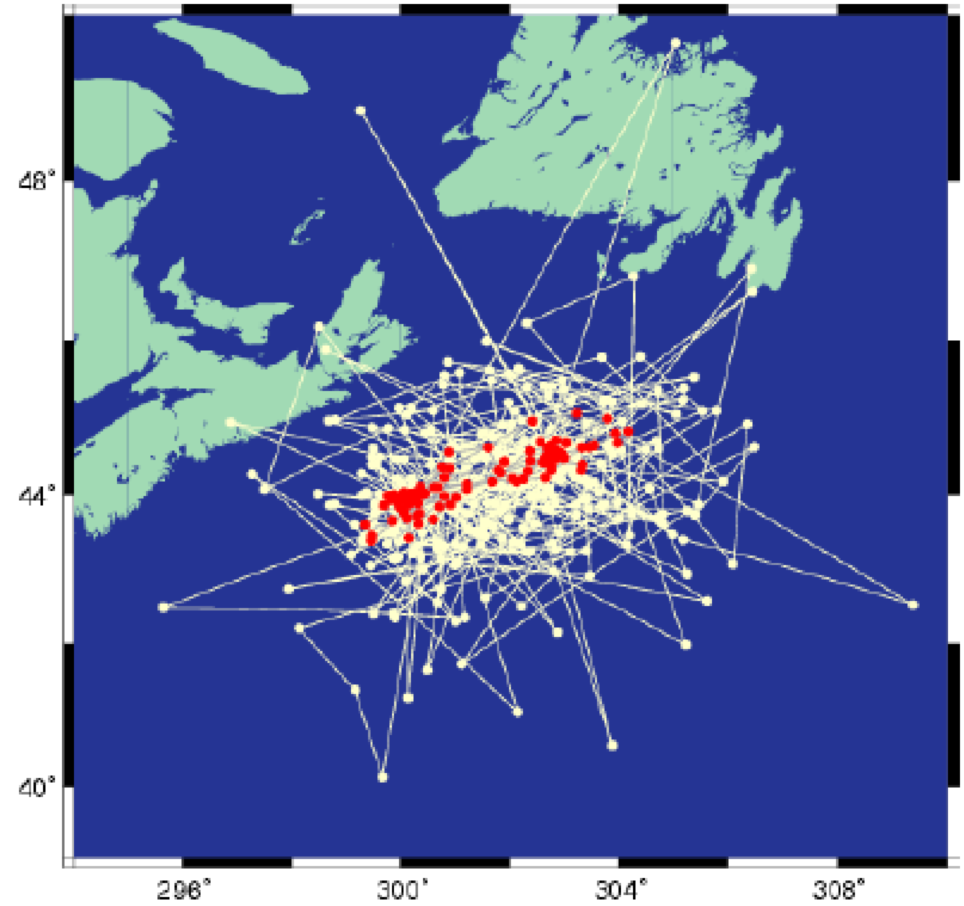


Argos Satellite Telemetry Data

Getting more out of the data

Goals of State-Space analysis

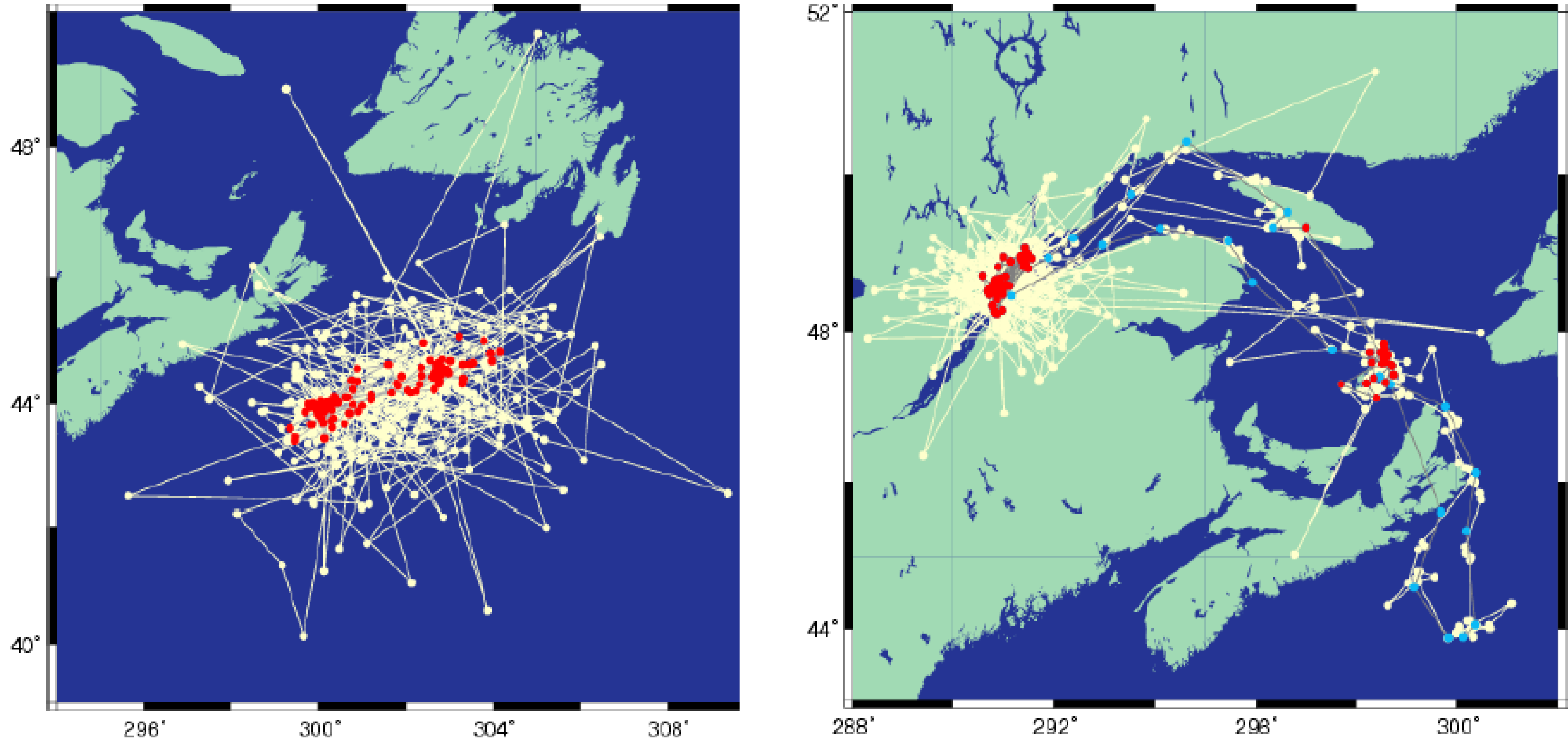
- Infer true locations from noisy data
- Account for error w/out loss of information
- Infer behaviour, test hypotheses



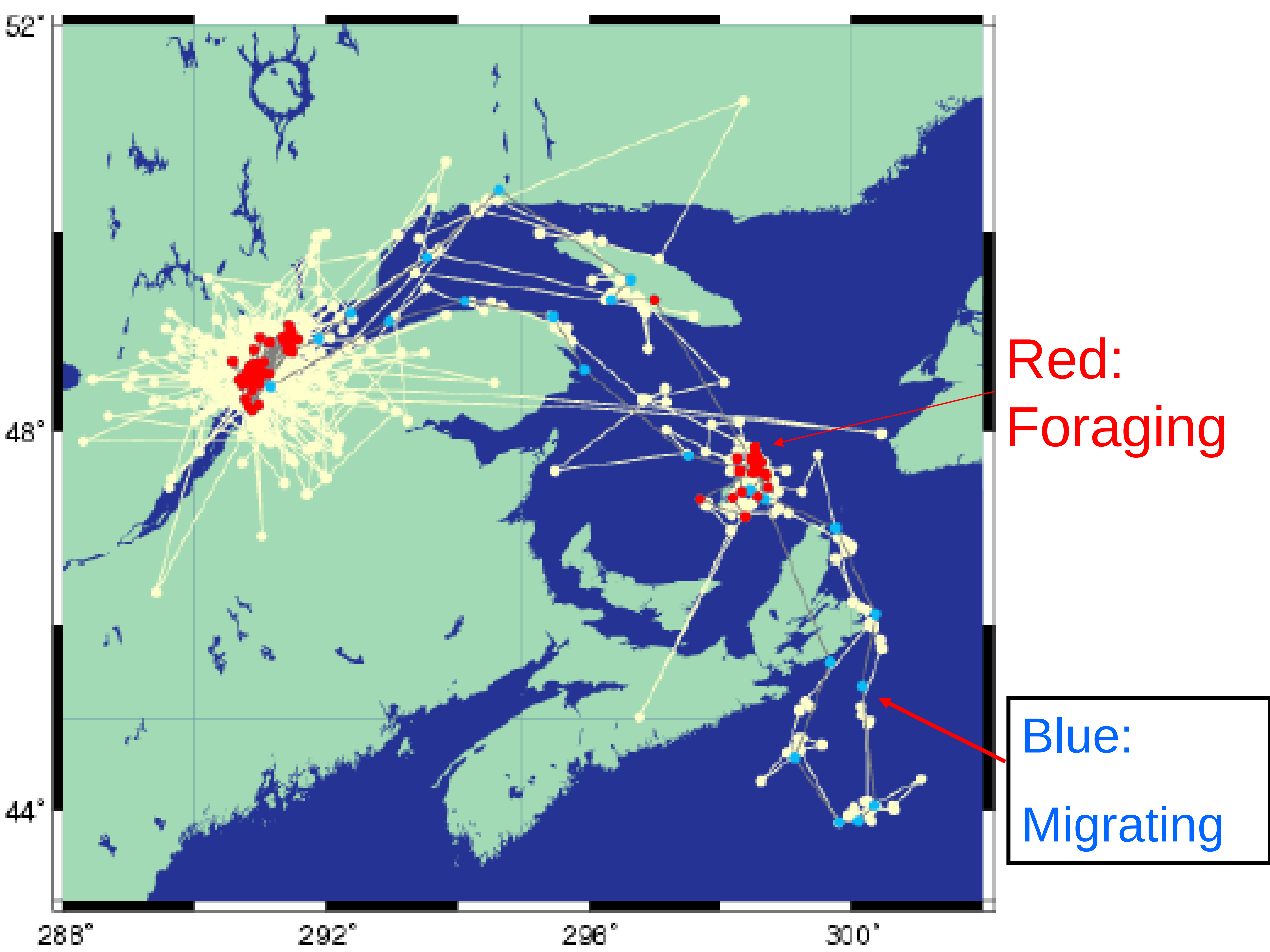
Jonsen, Flemming and Myers (2005) Ecology 86: 2874-2880

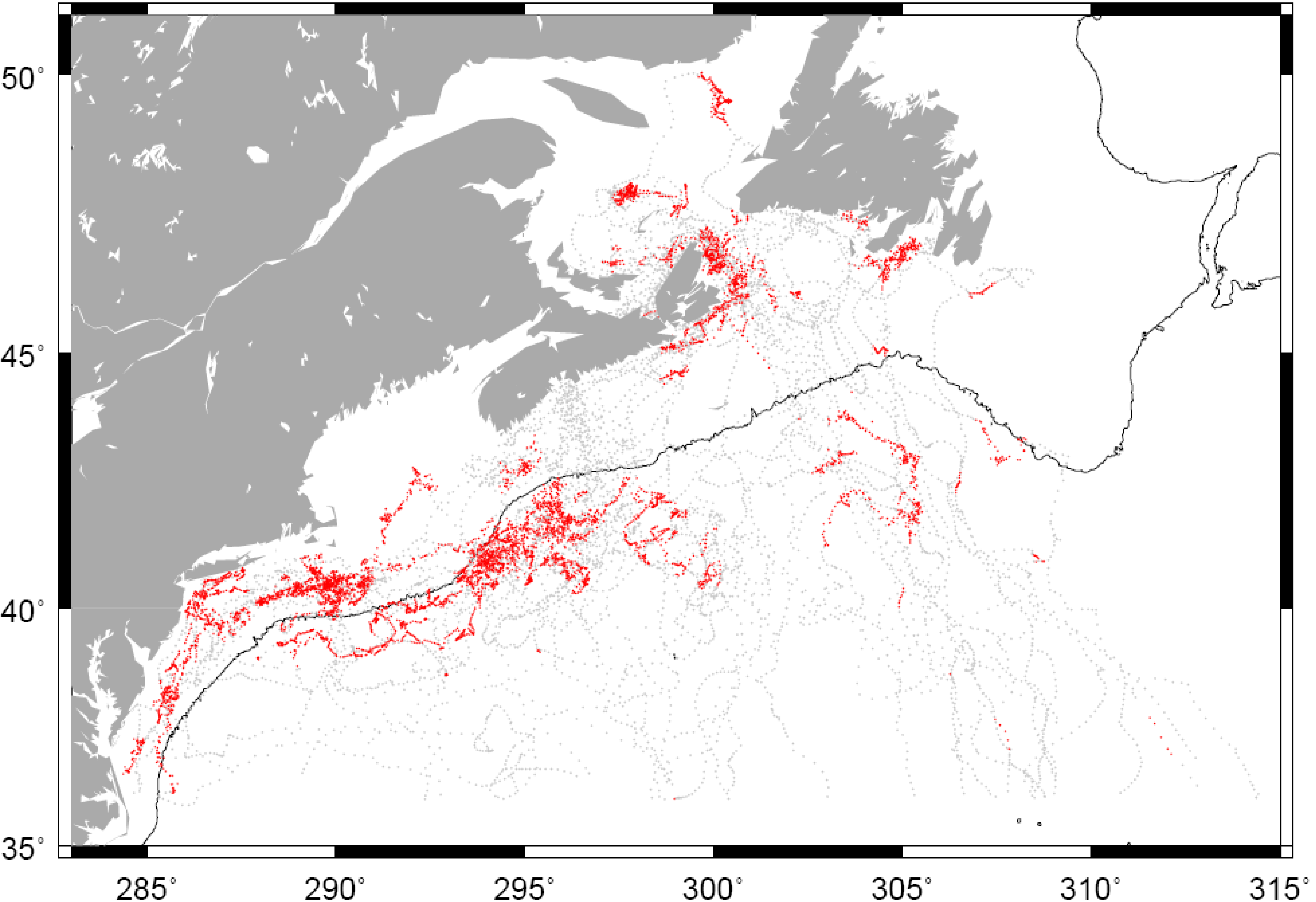
Data Filtering & State Estimation

Jonsen et al. 2005. Ecology 86:2874-2880

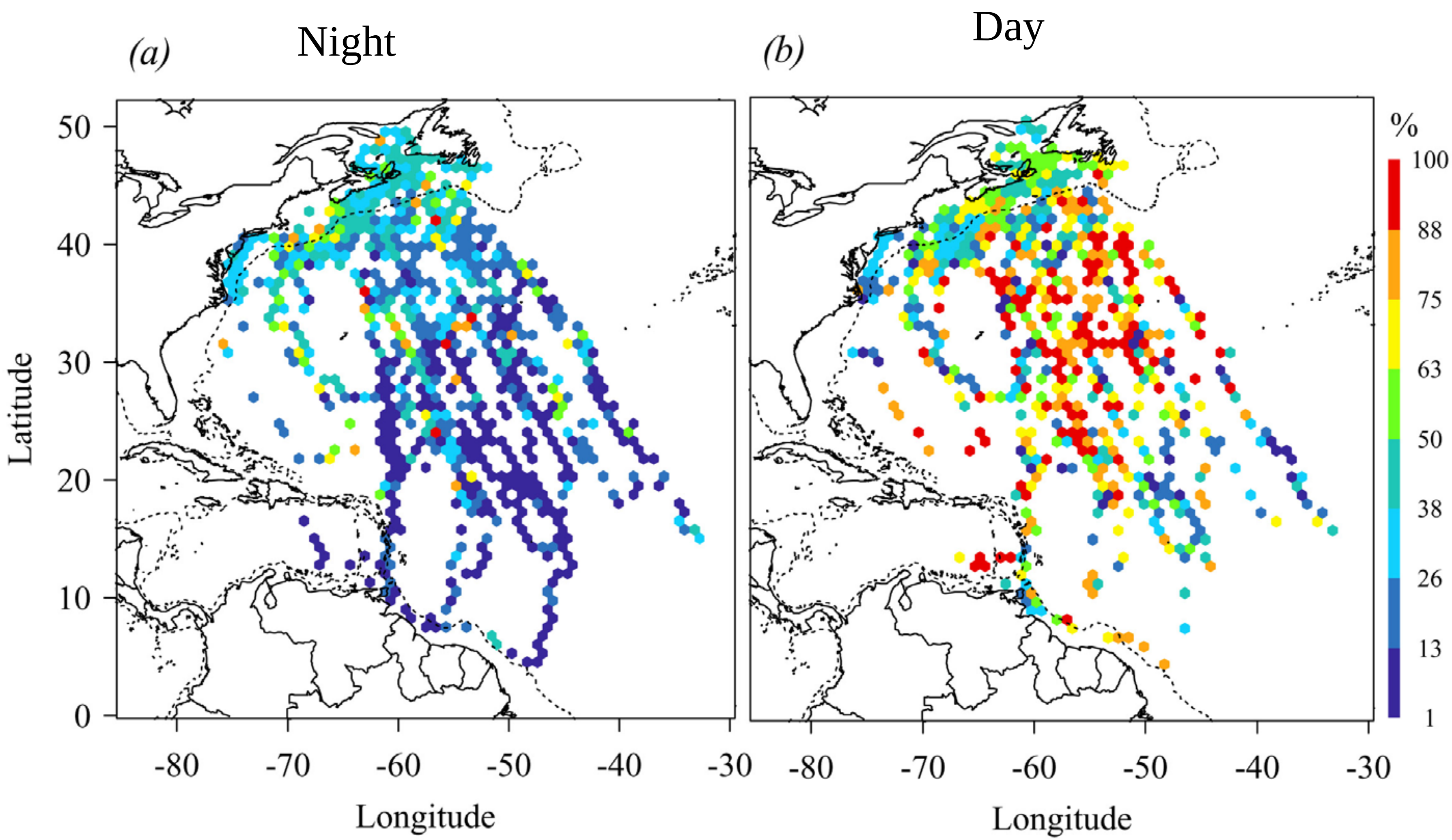


Jonsen, Flemming and Myers (2005) Ecology 86: 2874-2880


52°
48°
44°
288°
292°
296°
300°
Red: Foraging
Blue: Migrating

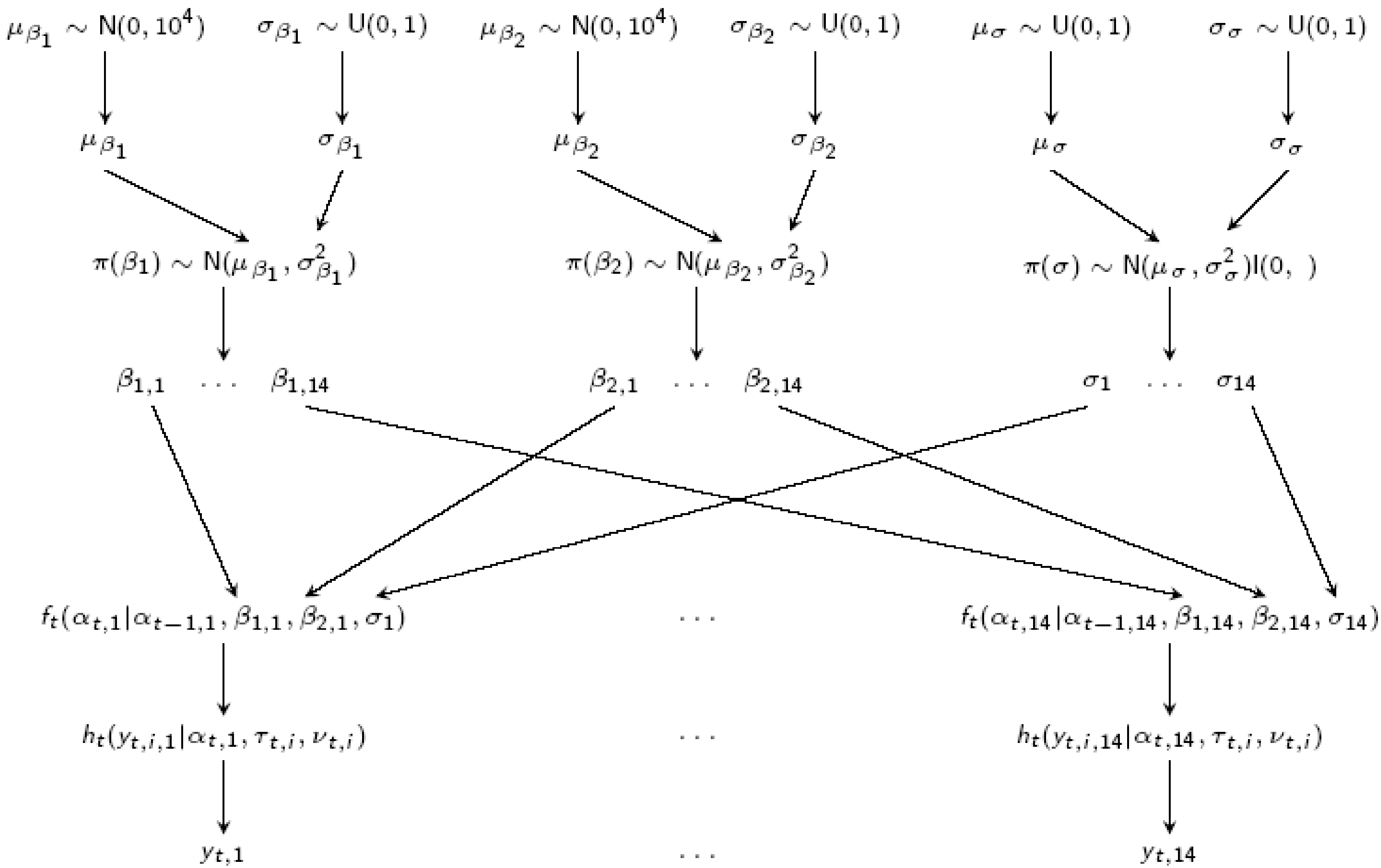

50°
45°
40°
35°
285°
290°
295°
300°
305°
310°
315°

Turtles are close to the surface during the day during migration

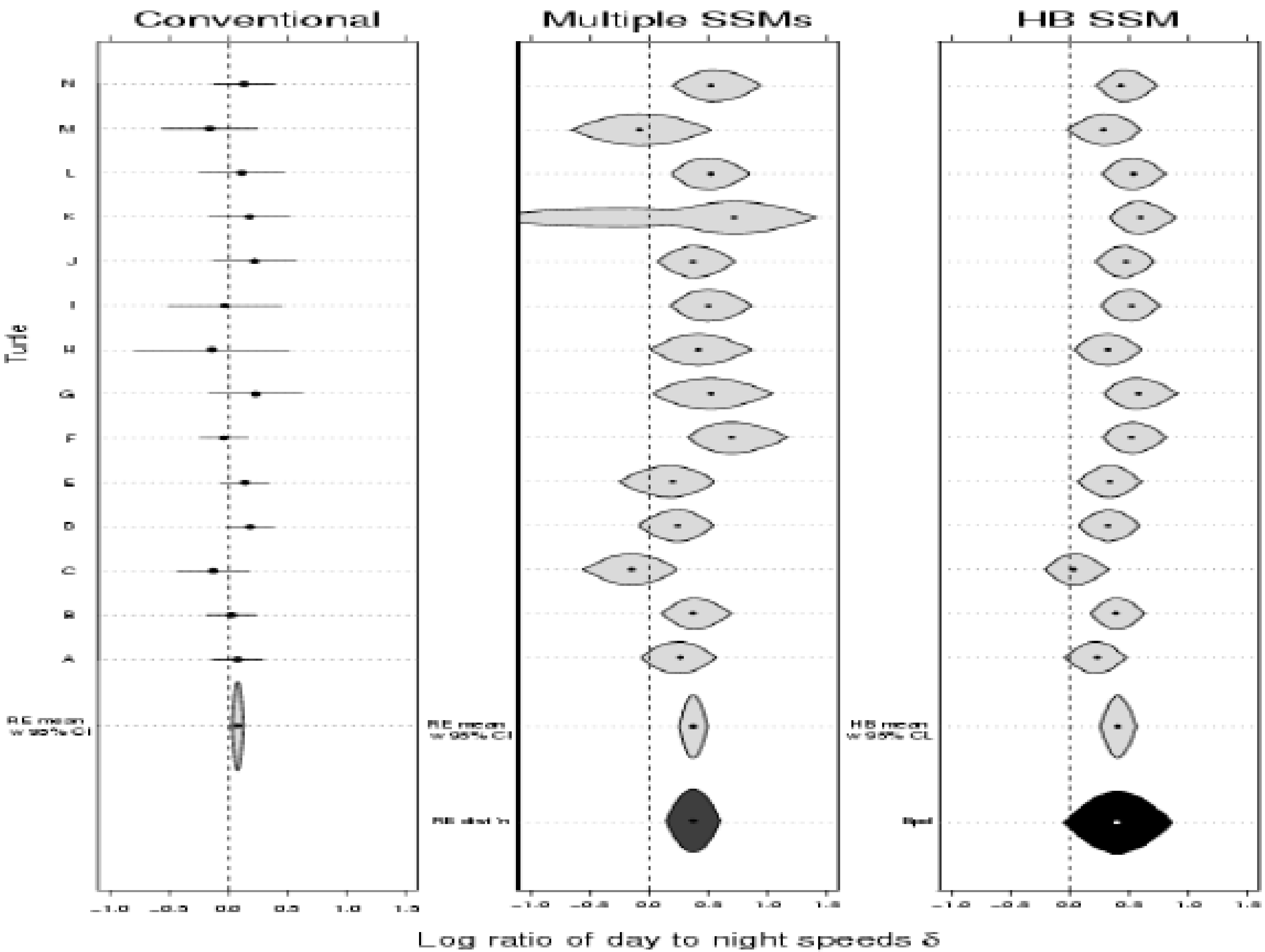


James Otensmvers. Mvers in press Can. J. Zoo.

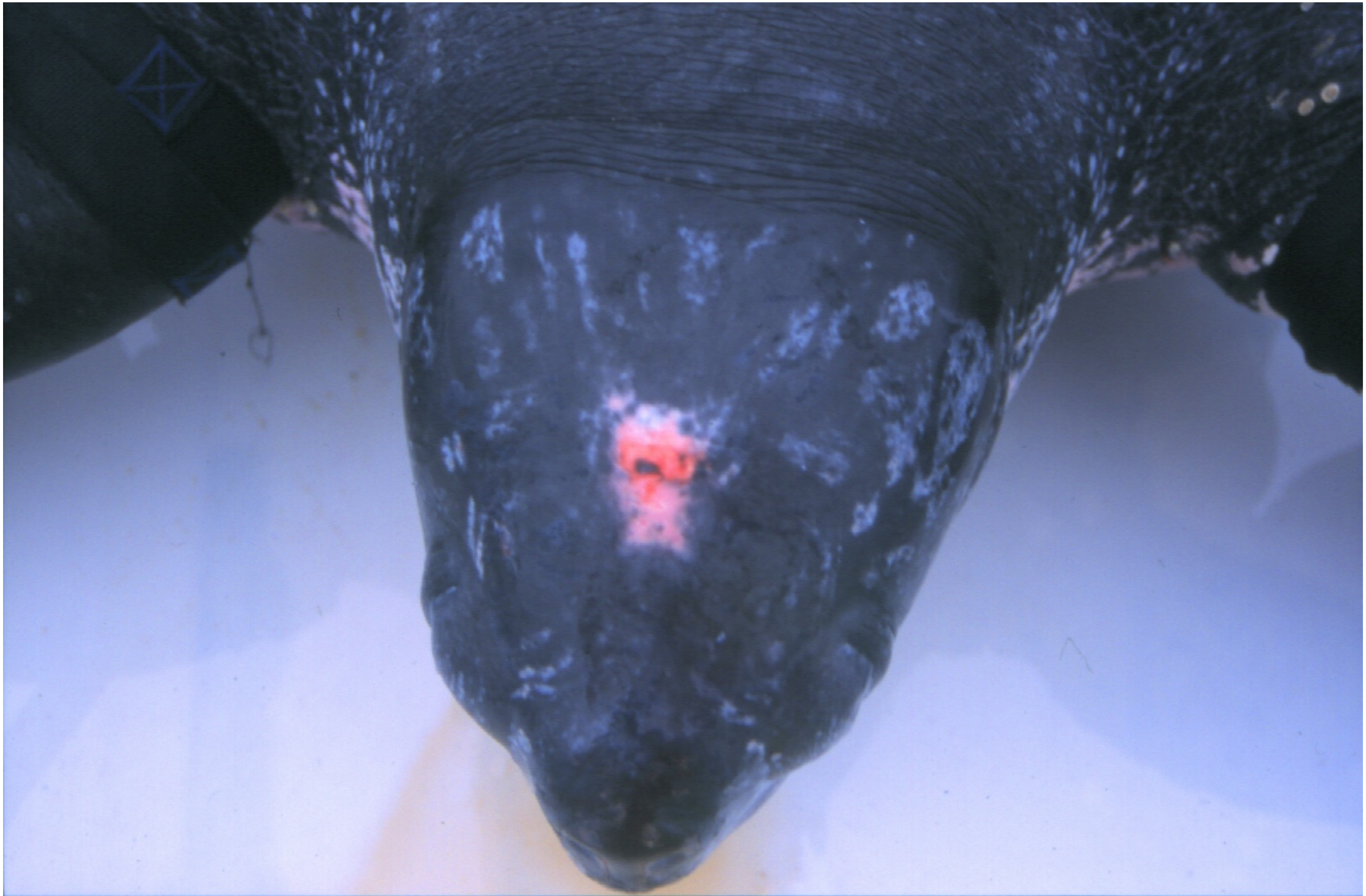
HB SSM


$\mu_{\beta_1} \sim N(0, 10^4)$
$\sigma_{\beta_1} \sim U(0, 1)$
$\mu_{\beta_2} \sim N(0, 10^4)$
$\sigma_{\beta_2} \sim U(0, 1)$
$\mu_{\sigma} \sim U(0, 1)$
$\sigma_{\sigma} \sim U(0, 1)$
μ_{β_1}
σ_{β_1}
μ_{β_2}
σ_{β_2}
μ_{σ}
σ_{σ}
$\pi(\beta_1) \sim N(\mu_{\beta_1}, \sigma^2_{\beta_1})$
$\pi(\beta_2) \sim N(\mu_{\beta_2}, \sigma^2_{\beta_2})$
$\pi(\sigma) \sim N(\mu_{\sigma}, \sigma^2_{\sigma})I(0, \ )$
$\beta_{1,1} \cdots \beta_{1,14}$
$\beta_{2,1} \cdots \beta_{2,14}$
$\sigma_1 \cdots \sigma_{14}$
$f_t(\alpha_{t,1} | \alpha_{t-1,1}, \beta_{1,1}, \beta_{2,1}, \sigma_1)$
$\cdots$
$f_t(\alpha_{t,14} | \alpha_{t-1,14}, \beta_{1,14}, \beta_{2,14}, \sigma_{14})$
$h_t(y_{t,i,1} | \alpha_{t,1}, \tau_{t,i}, \nu_{t,i})$
$\cdots$
$h_t(y_{t,i,14} | \alpha_{t,14}, \tau_{t,i}, \nu_{t,i})$
$y_{t,1}$
$\cdots$
$y_{t,14}$

Conventional Approaches Do Not Work

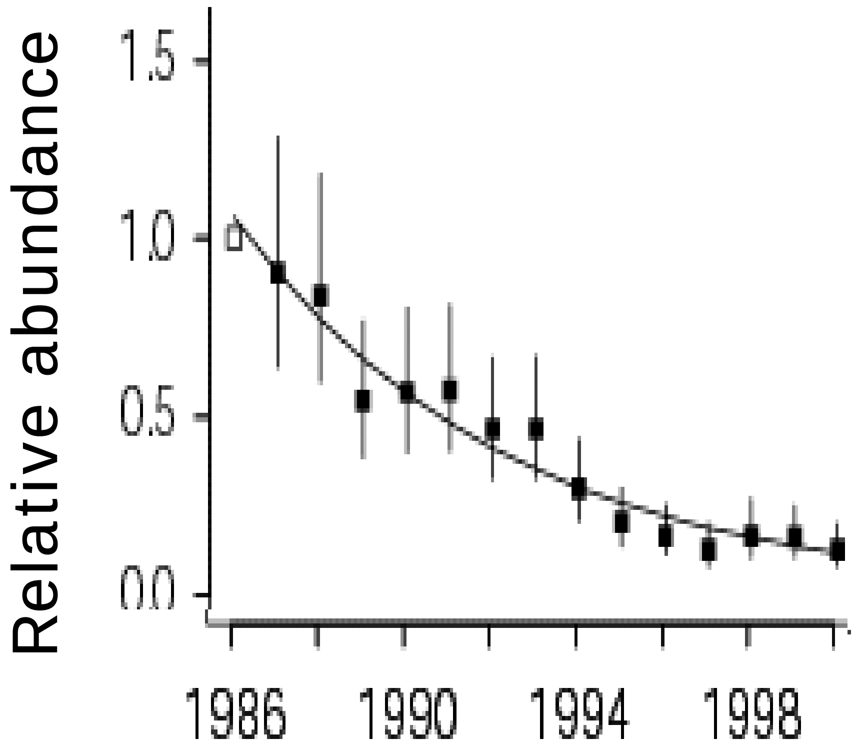


Results are consistent with the hypothesis that the pineal spot improves navigation.



Hammerhead sharks

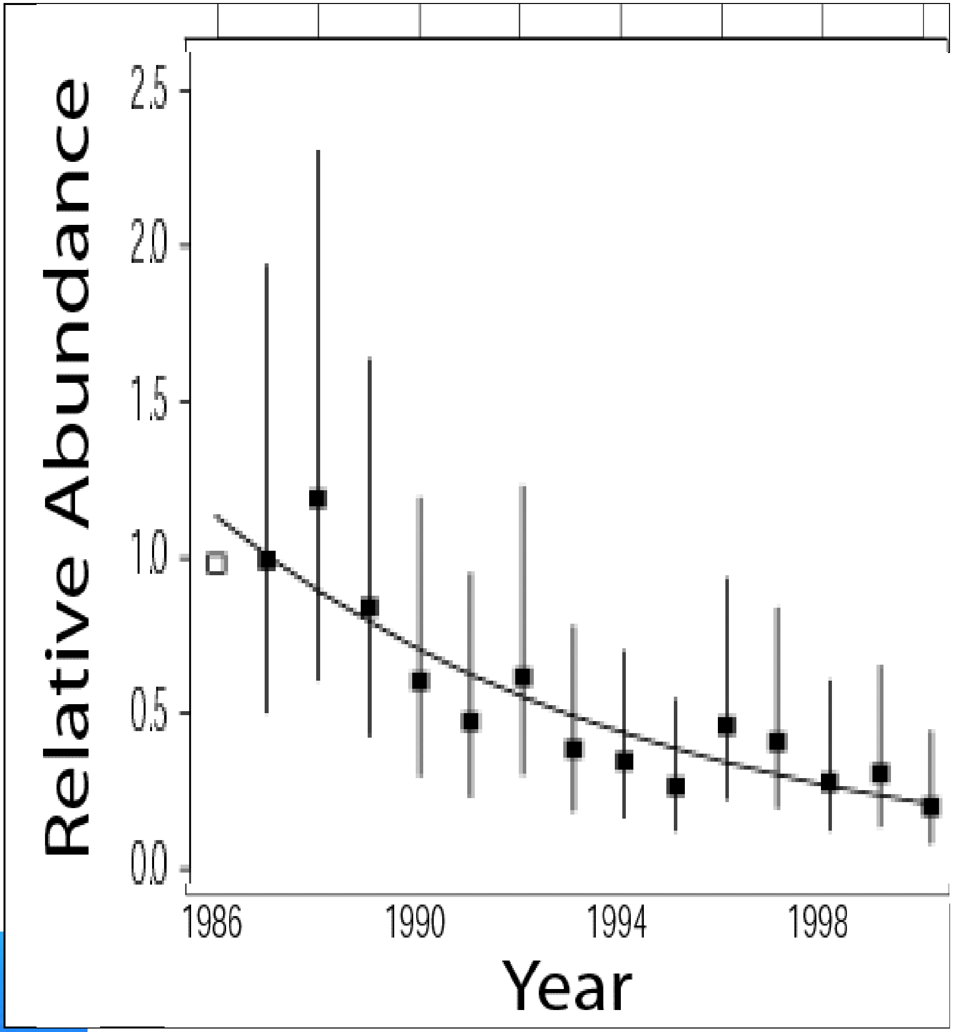
Sphyrna lewini



Science. Jan. 2003. J.K. Baum, R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, P.A. Doherty

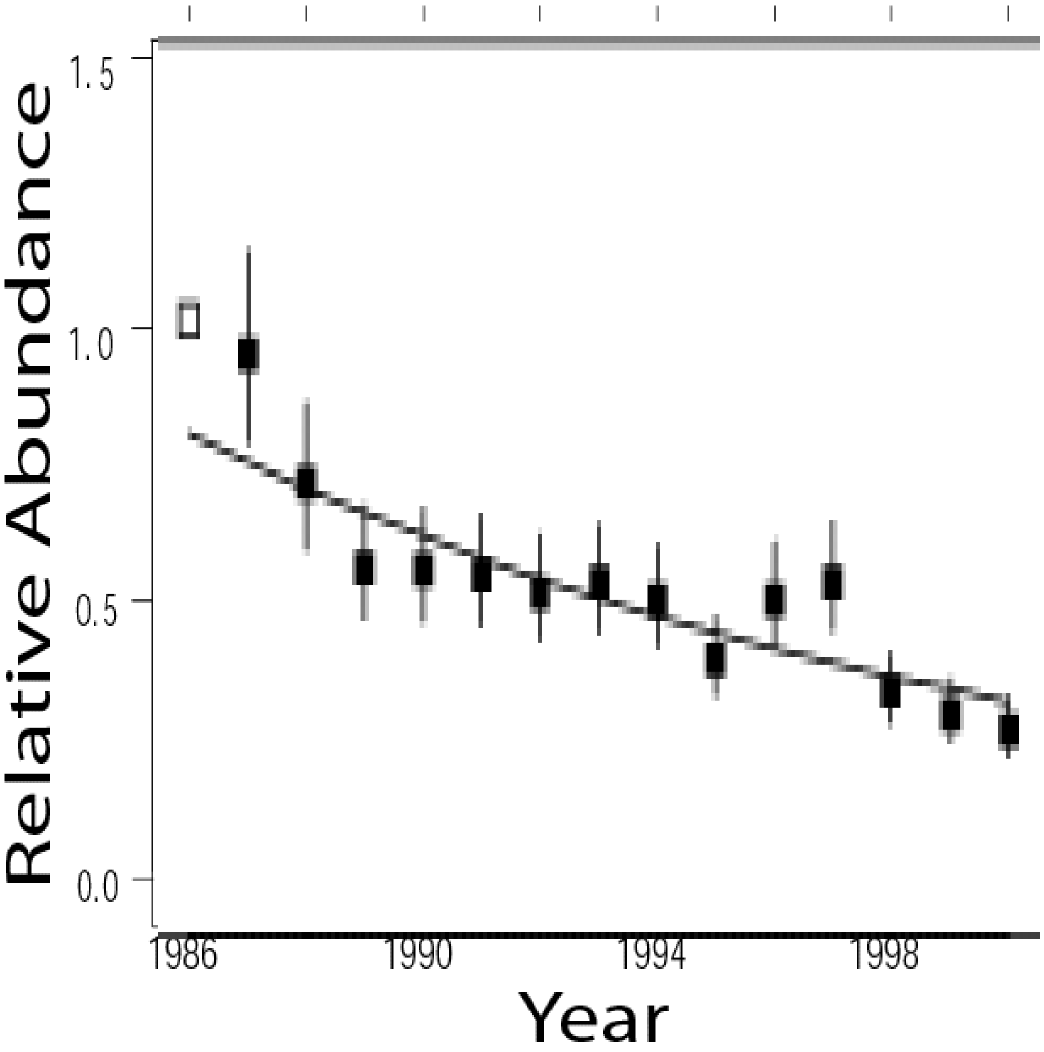
Thresher sharks

Alopias spp.



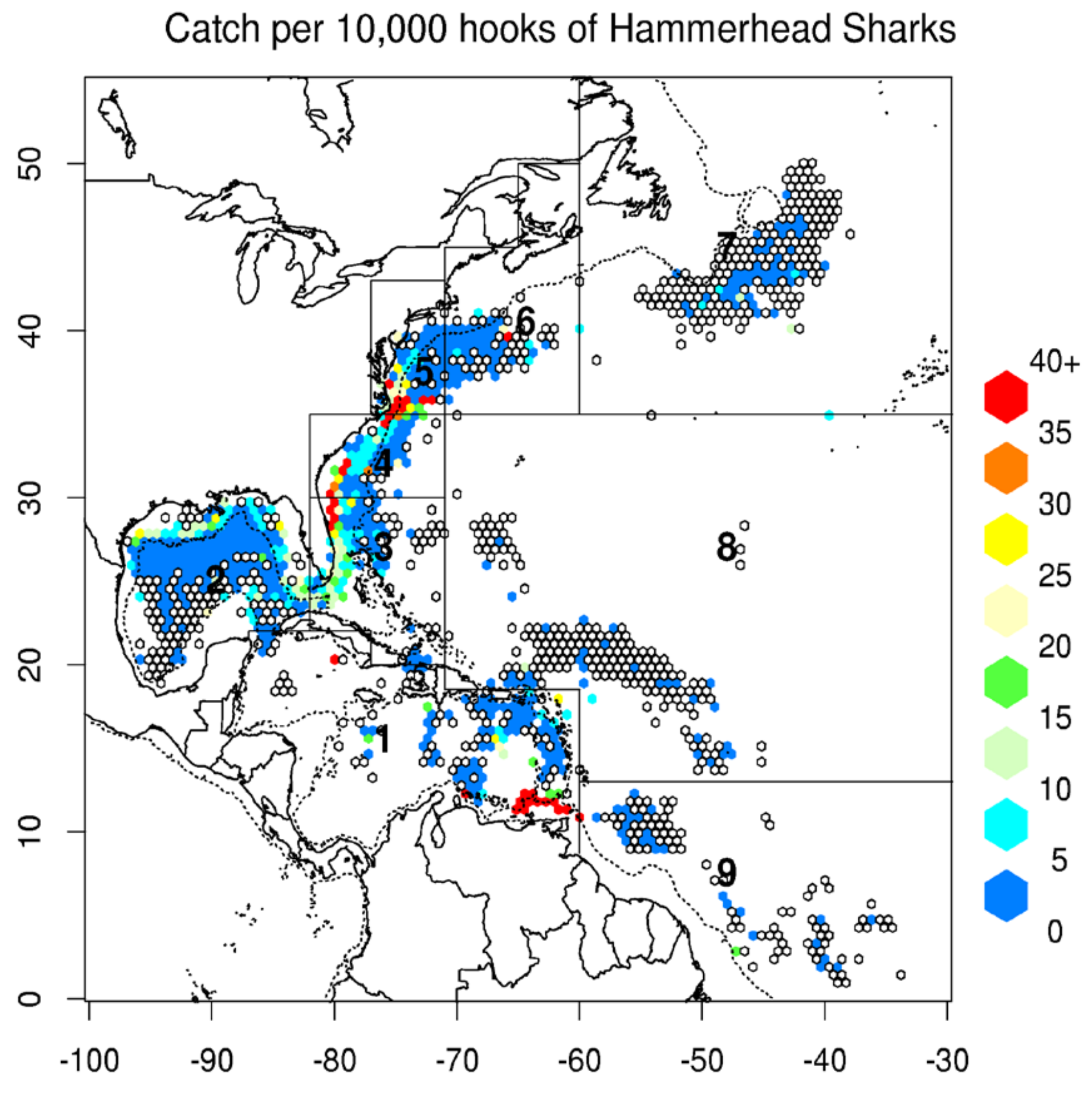
Blue sharks

Prionace glauca

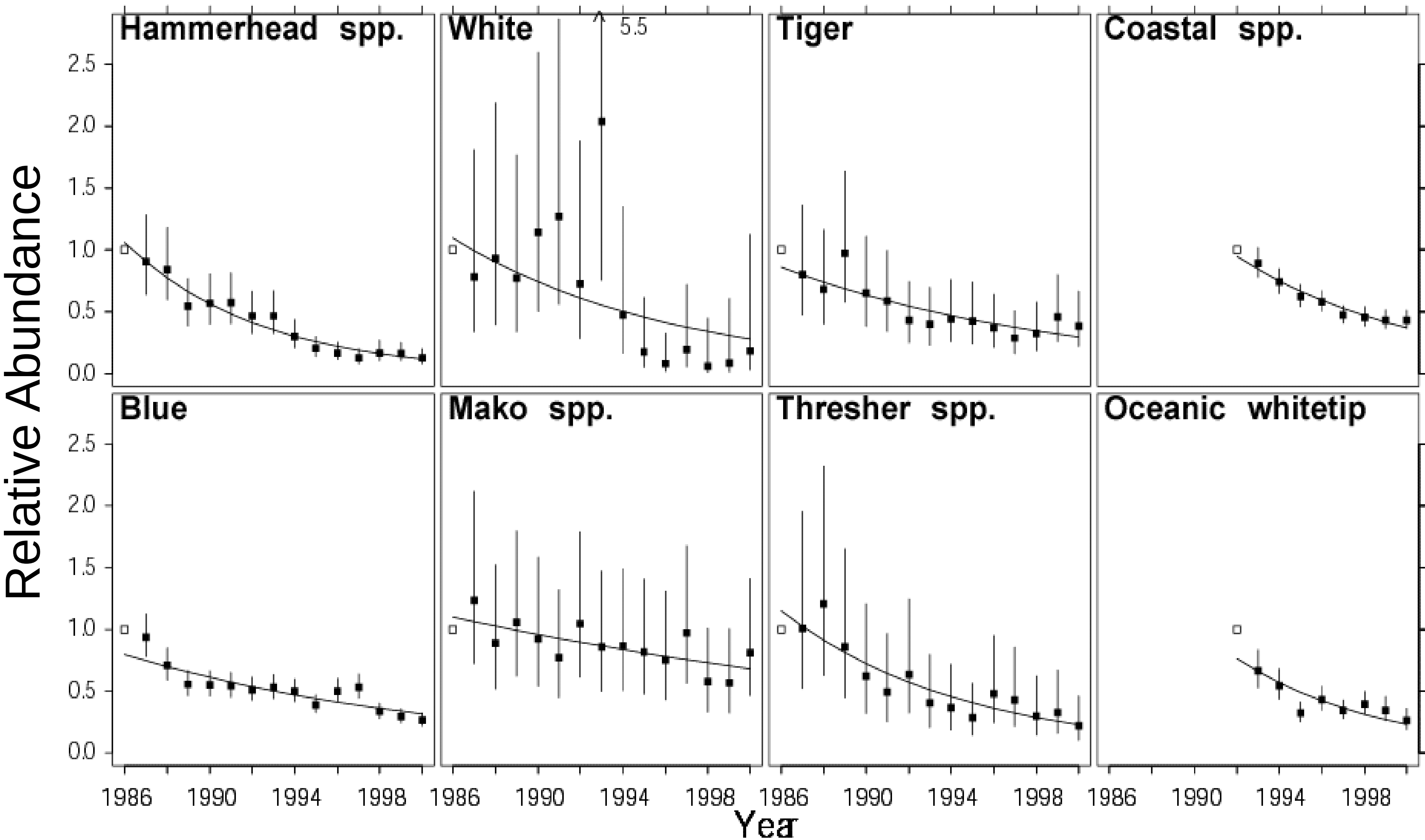


Hammerhead sharks

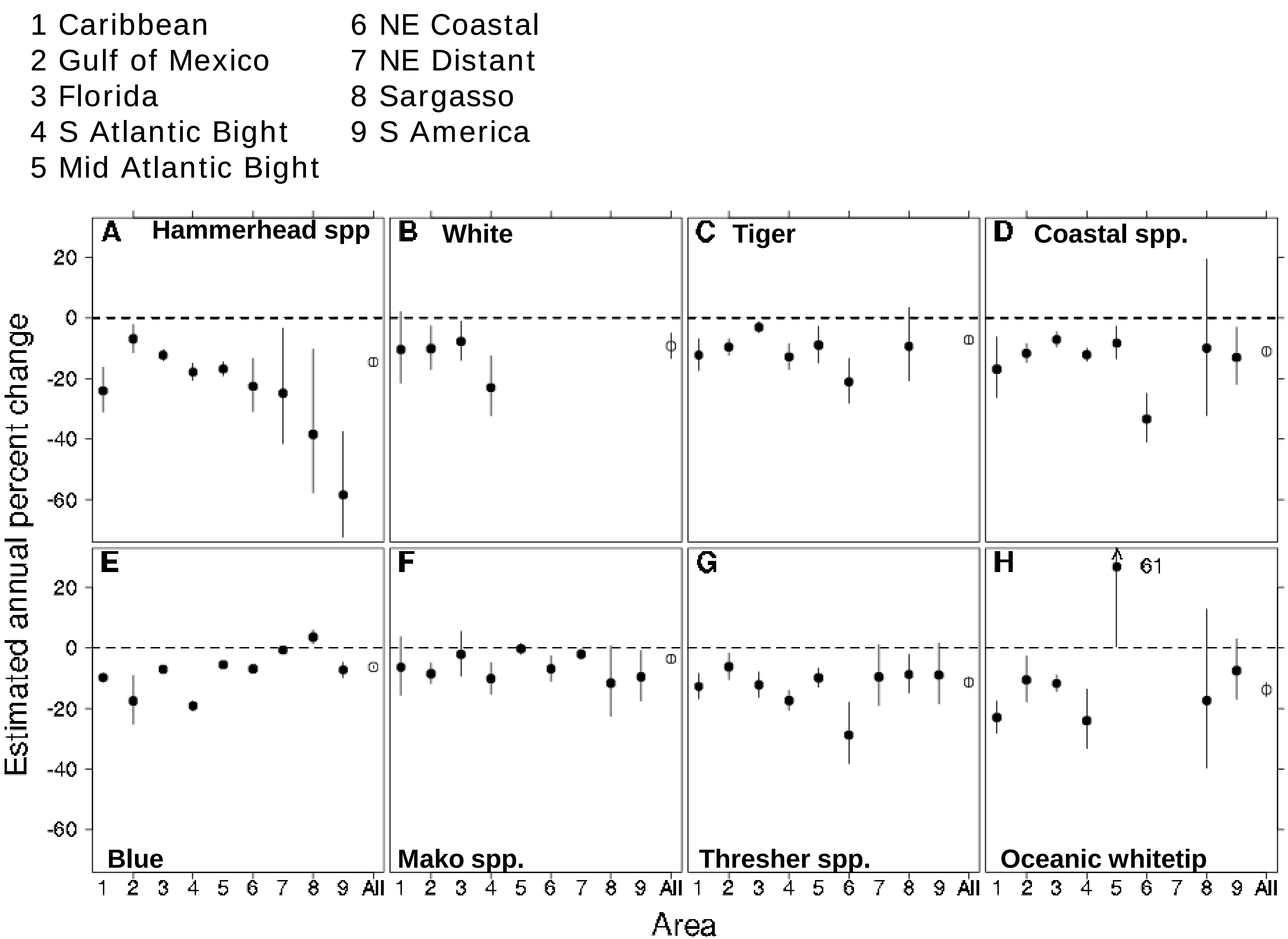
Sphyrna spp.



Results



Hammerhead spp.
White
5.5
Tiger
Coastal spp.
Blue
Mako spp.
Thresher spp.
Oceanic whitetip
Relative Abundance
Year
0.0
0.5
1.0
1.5
2.0
2.5
1986
1990
1994
1998



1 Caribbean
2 Gulf of Mexico
3 Florida
4 S Atlantic Bight
5 Mid Atlantic Bight
6 NE Coastal
7 NE Distant
8 Sargasso
9 S America
A Hammerhead spp
B White
C Tiger
D Coastal spp.
E Blue
F Mako spp.
G Thresher spp.
H Oceanic whitetip
61
Estimated annual percent change
Area
20
0
-20
-40
-60
1 2 3 4 5 6 7 8 9 All

Data Analysis

- Assume catch follows negative binomial distribution
- Analyse positives only → zero-truncated distribution

$$f(y_T) = \frac{\frac{\Gamma(y+\theta)}{\Gamma(y)}^{y_T} \left(\frac{\mu}{\theta+\mu}\right)^{y_T} \left(\frac{\theta}{\theta+\mu}\right)^{\theta}}{1-\left(\frac{\theta}{\theta+\mu}\right)^{\theta}}$$

Robustness Analyses

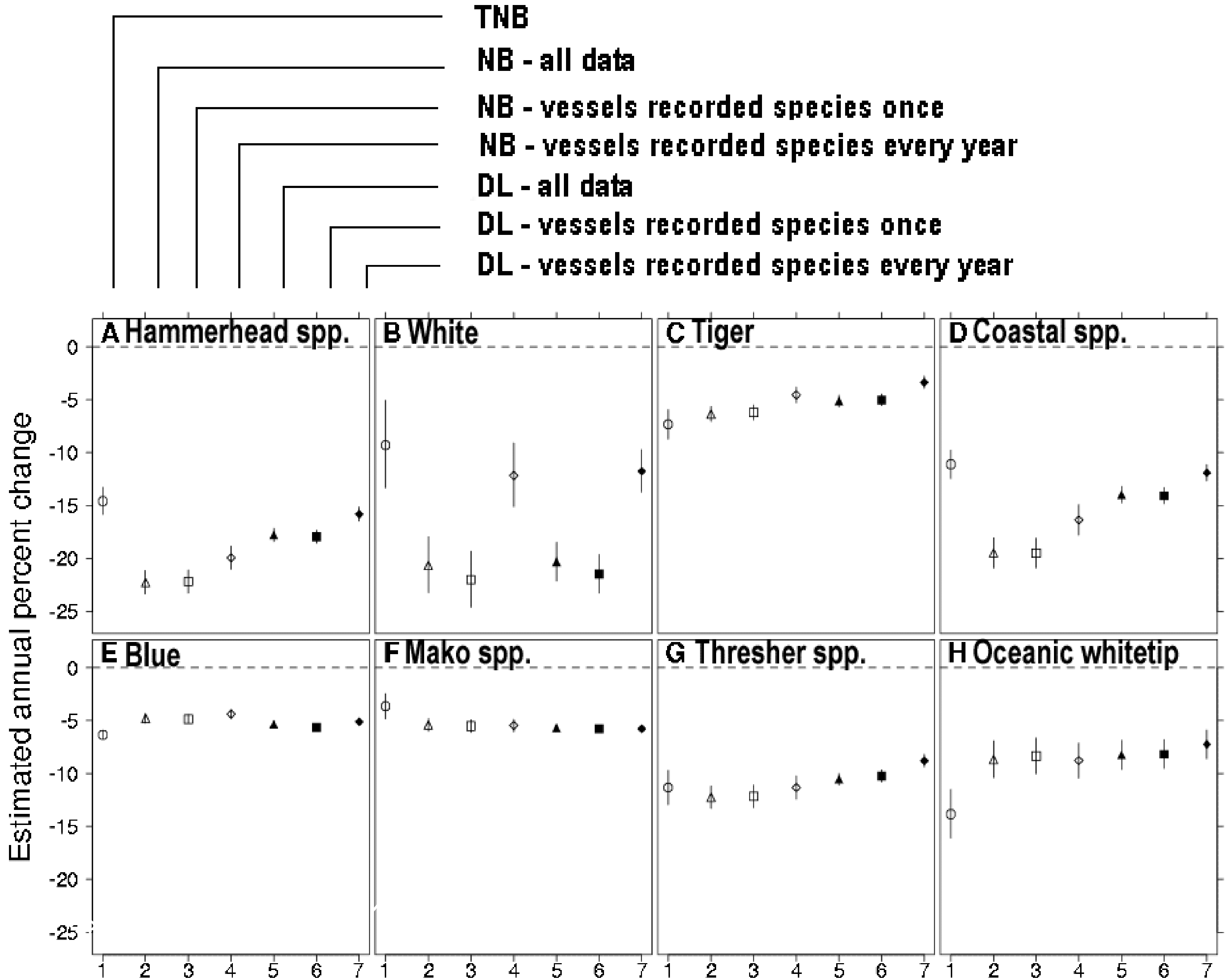
Assume reporting rate has stayed constant for:

- full dataset
- for a subset of vessels: recorded species at least once
  recorded species at least once in a given year

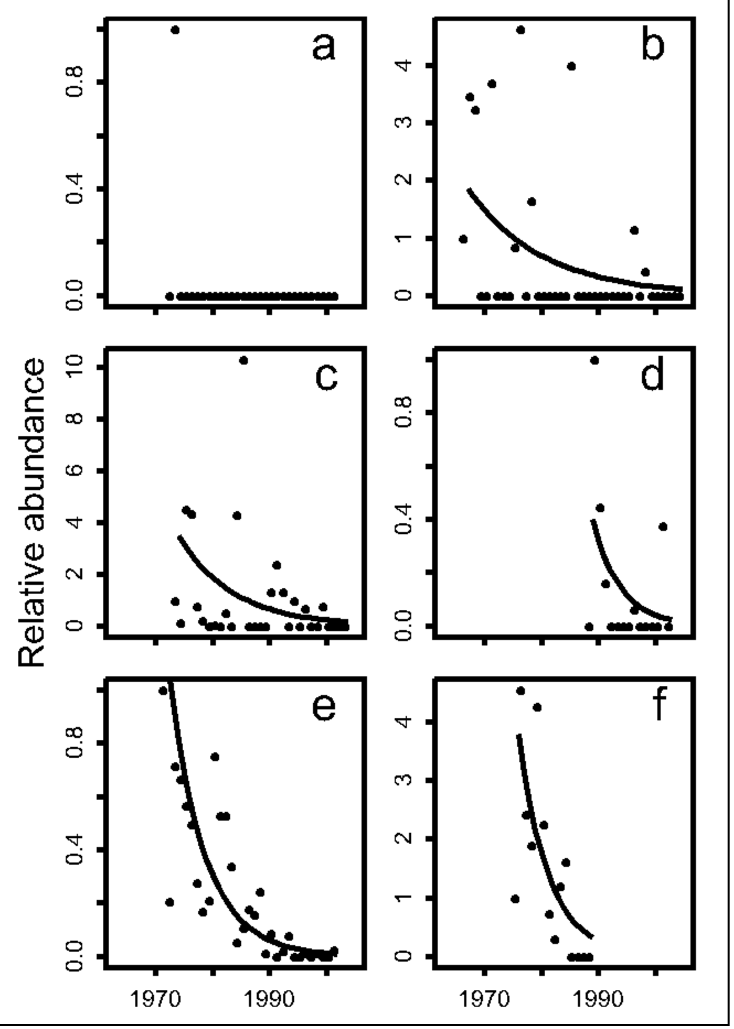
Negative binomial models

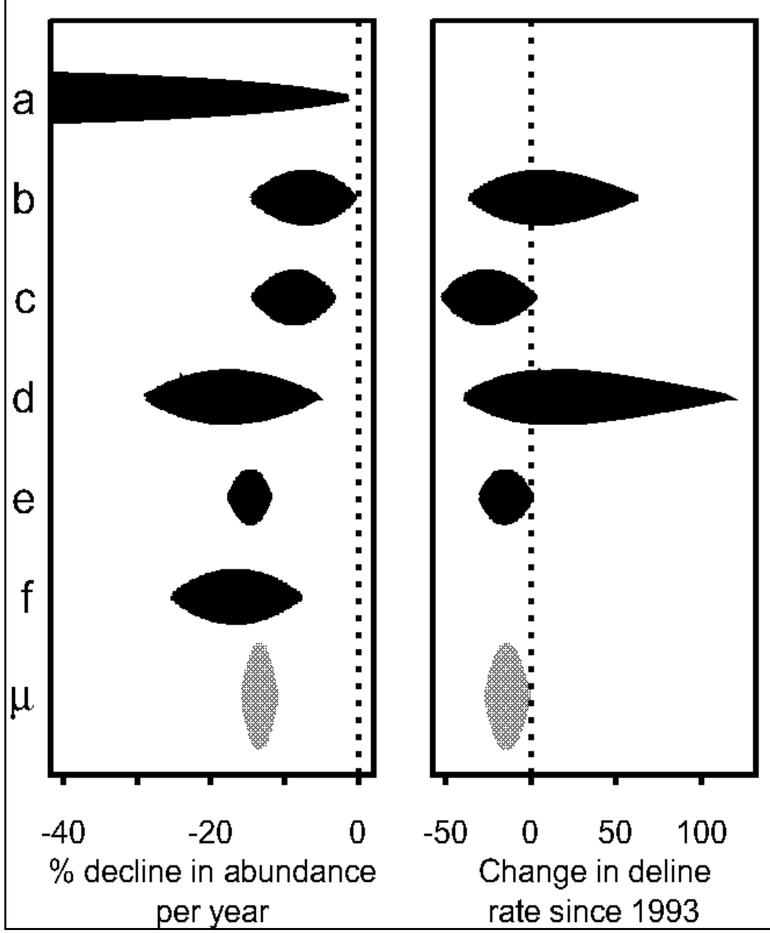
Delta-lognormal models

- proportion of positives modelled separately from positives
- standardized CPUE is the product of the two


TNB
NB - all data
NB - vessels recorded species once
NB - vessels recorded species every year
DL - all data
DL - vessels recorded species once
DL - vessels recorded species every year
A Hammerhead spp.
B White
C Tiger
D Coastal spp.
E Blue
F Mako spp.
G Thresher spp.
H Oceanic whitetip
Estimated annual percent change
0
-5
-10
-15
-20
-25
1
2
3
4
5
6
7


Shark fins for sale in Malaysia
Photo by Sebastian Troeng





a. Northern Gulf of Mexico bottom shrimp trawl survey

b. NMFS offshore bottom trawl survey

c. NMFS inshore bottom trawl survey

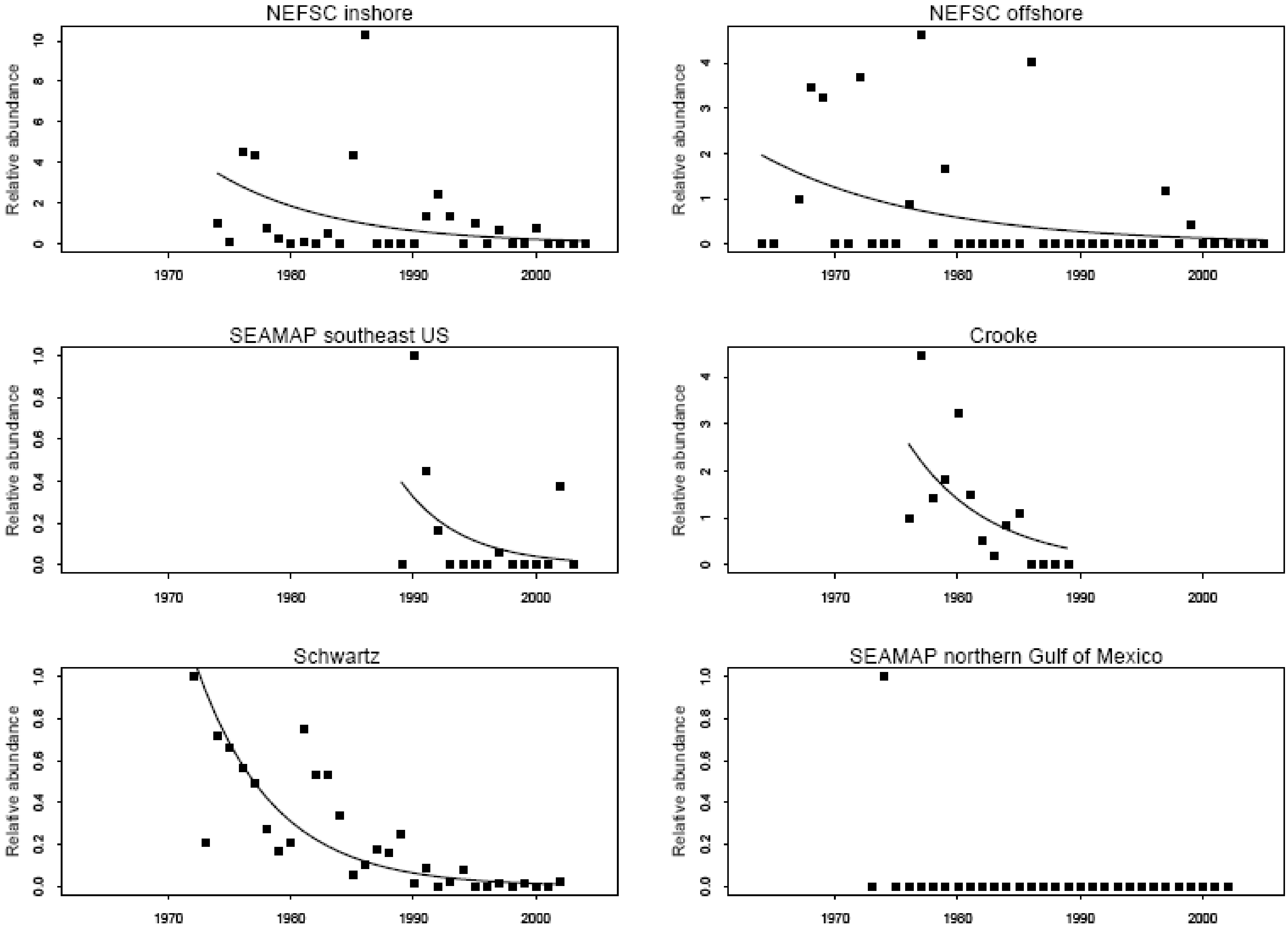
d. Southeast U.S. SEAMAP bottom shrimp trawl survey

e. North Carolina Institute of Marine Sciences longline survey

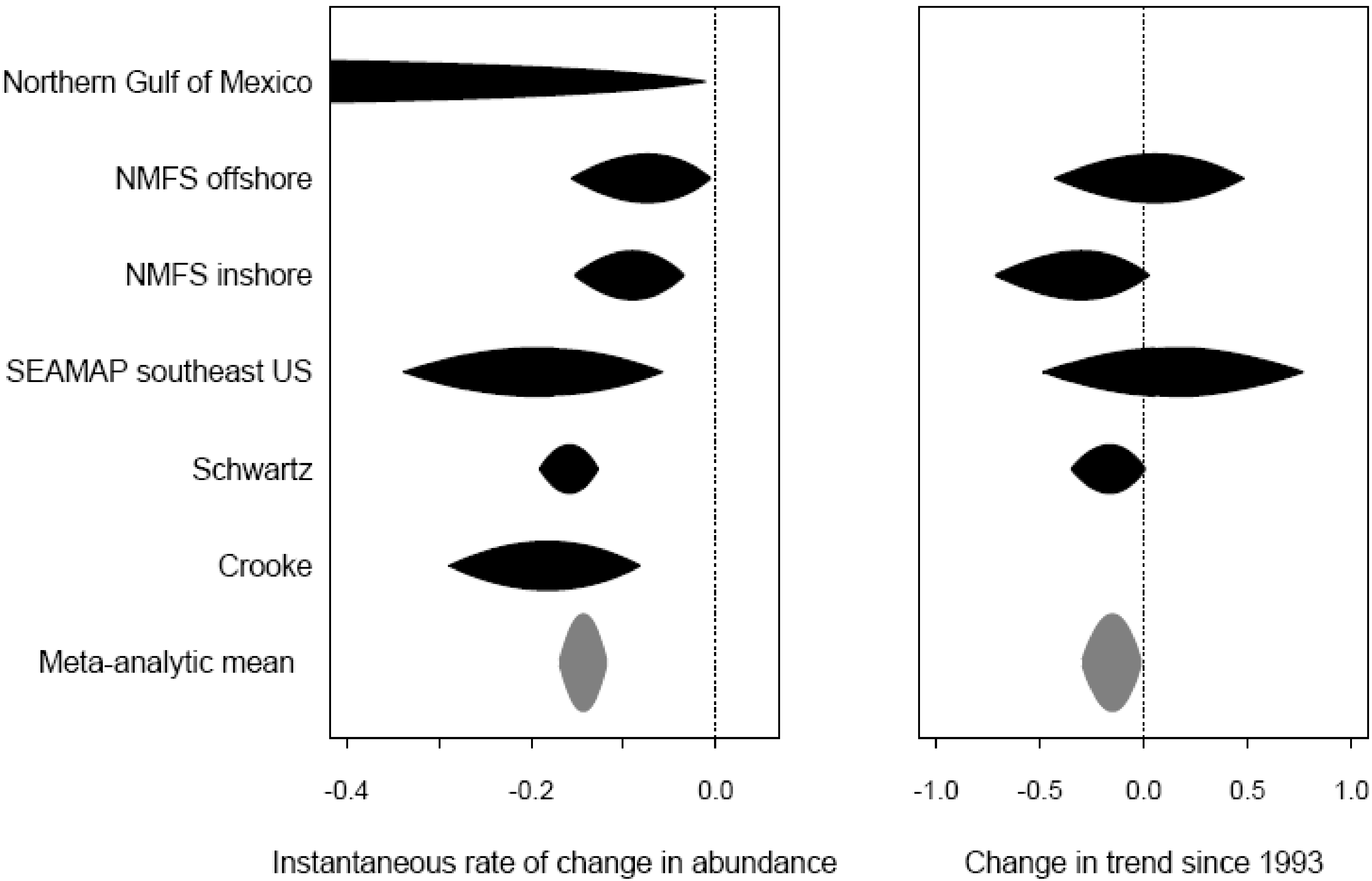
f. Crooke commericial longline data

μ. Meta-analytic mean

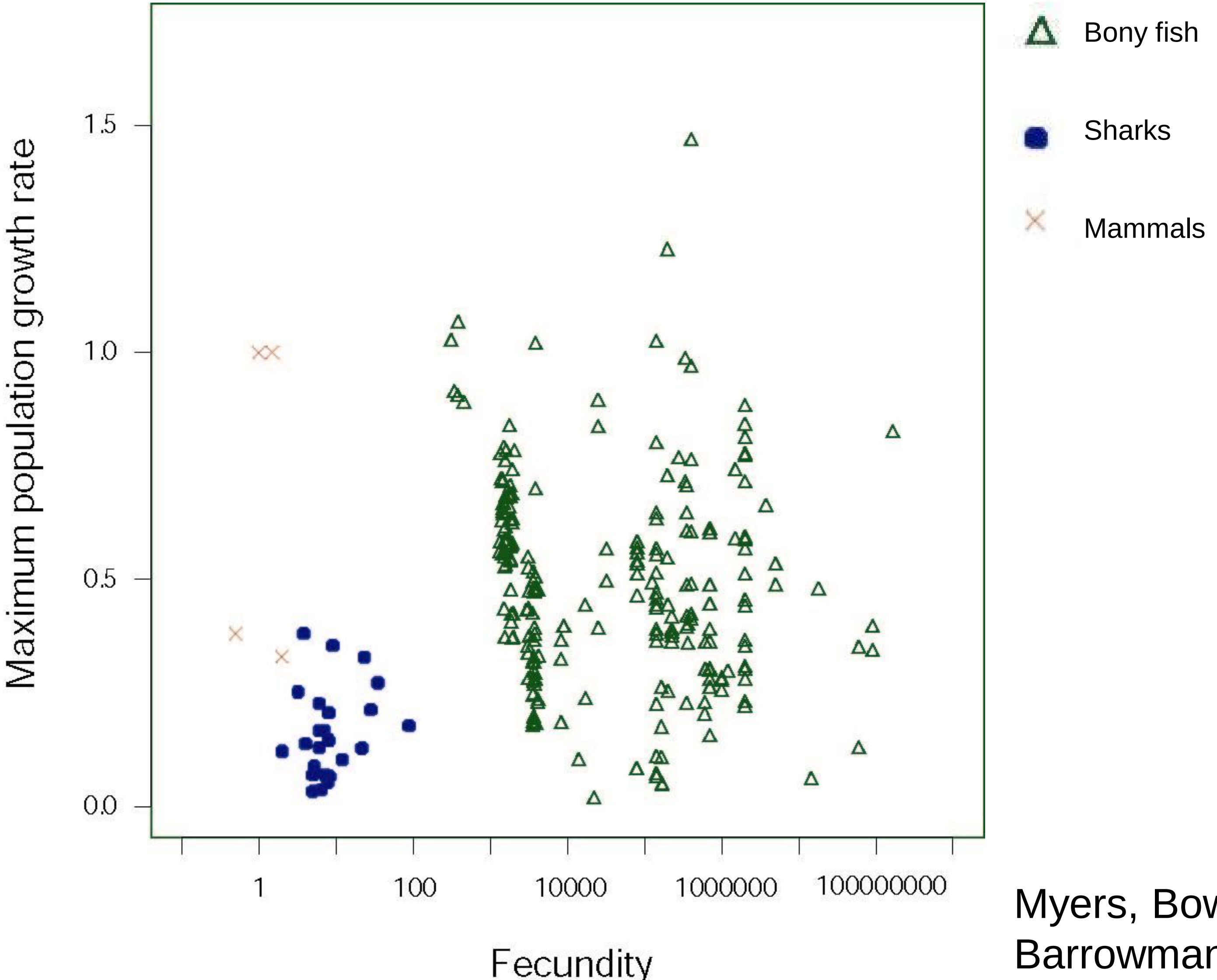
Loss of Dusky Sharks in the Eastern US



Consequences of "protection" since 1993: Rate of decline has increased:

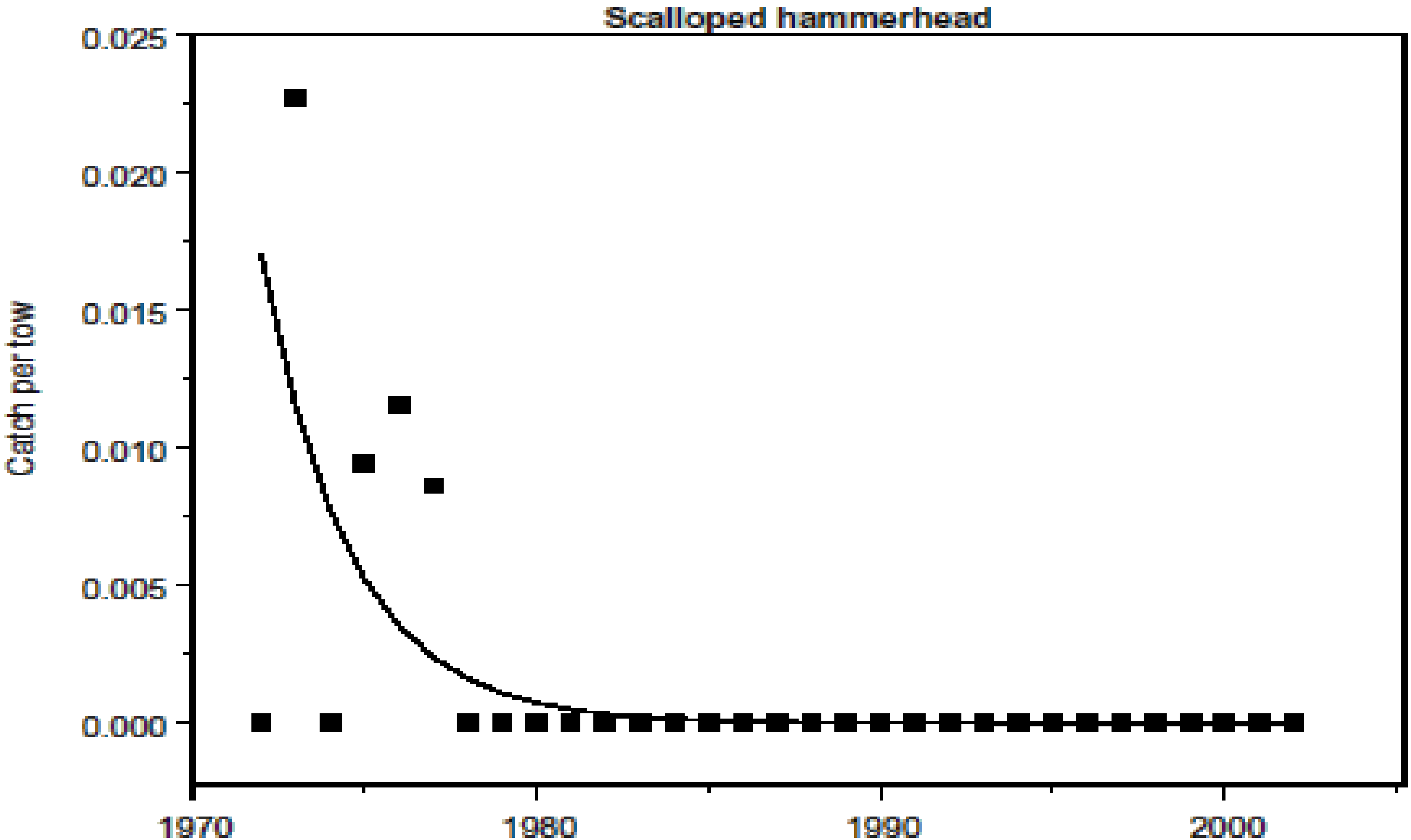


Are fish different from mammals?



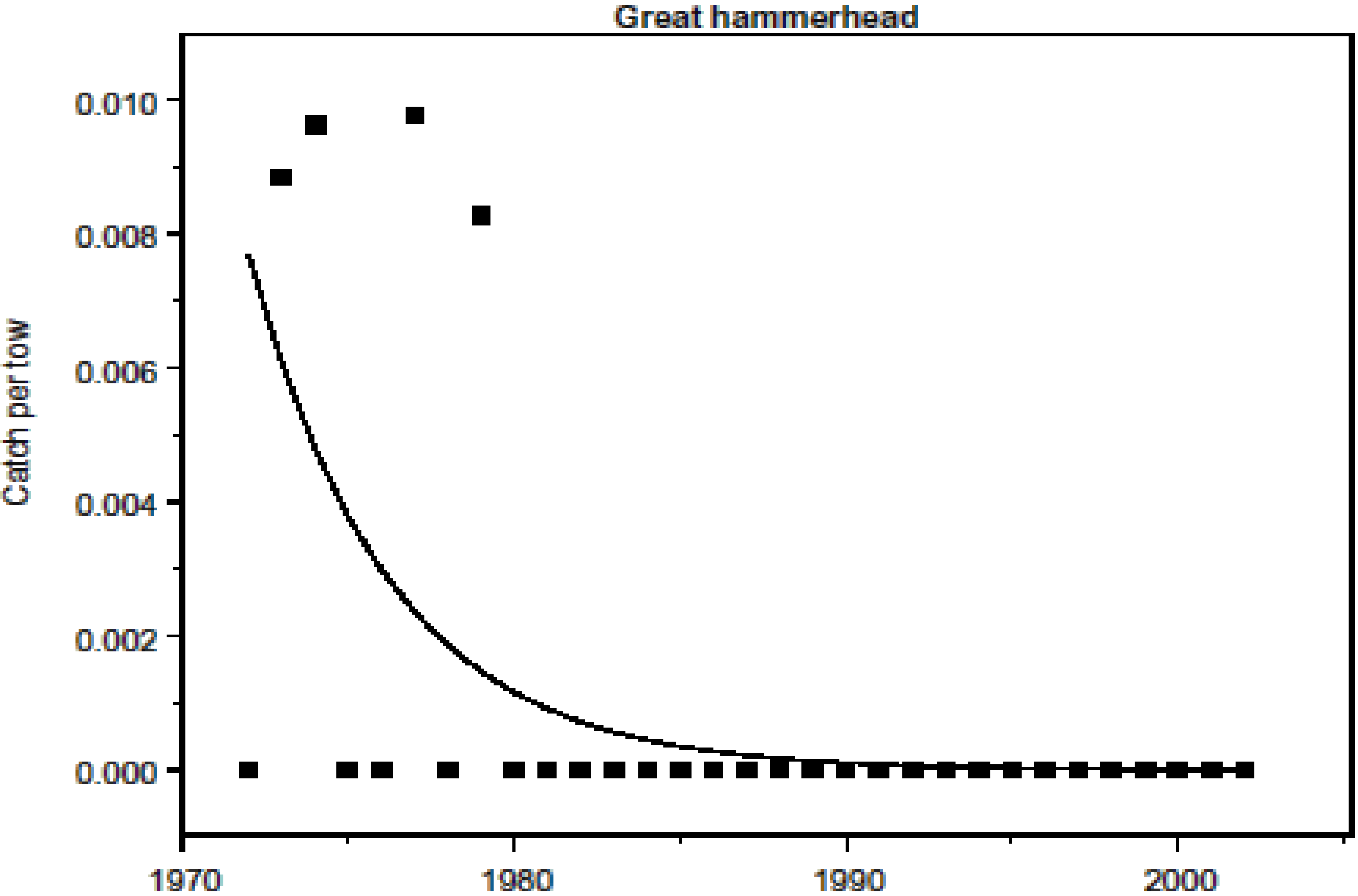
Myers, Bowen, Barrowman 1999

Same results for trawl surveys in Gulf of Mexico

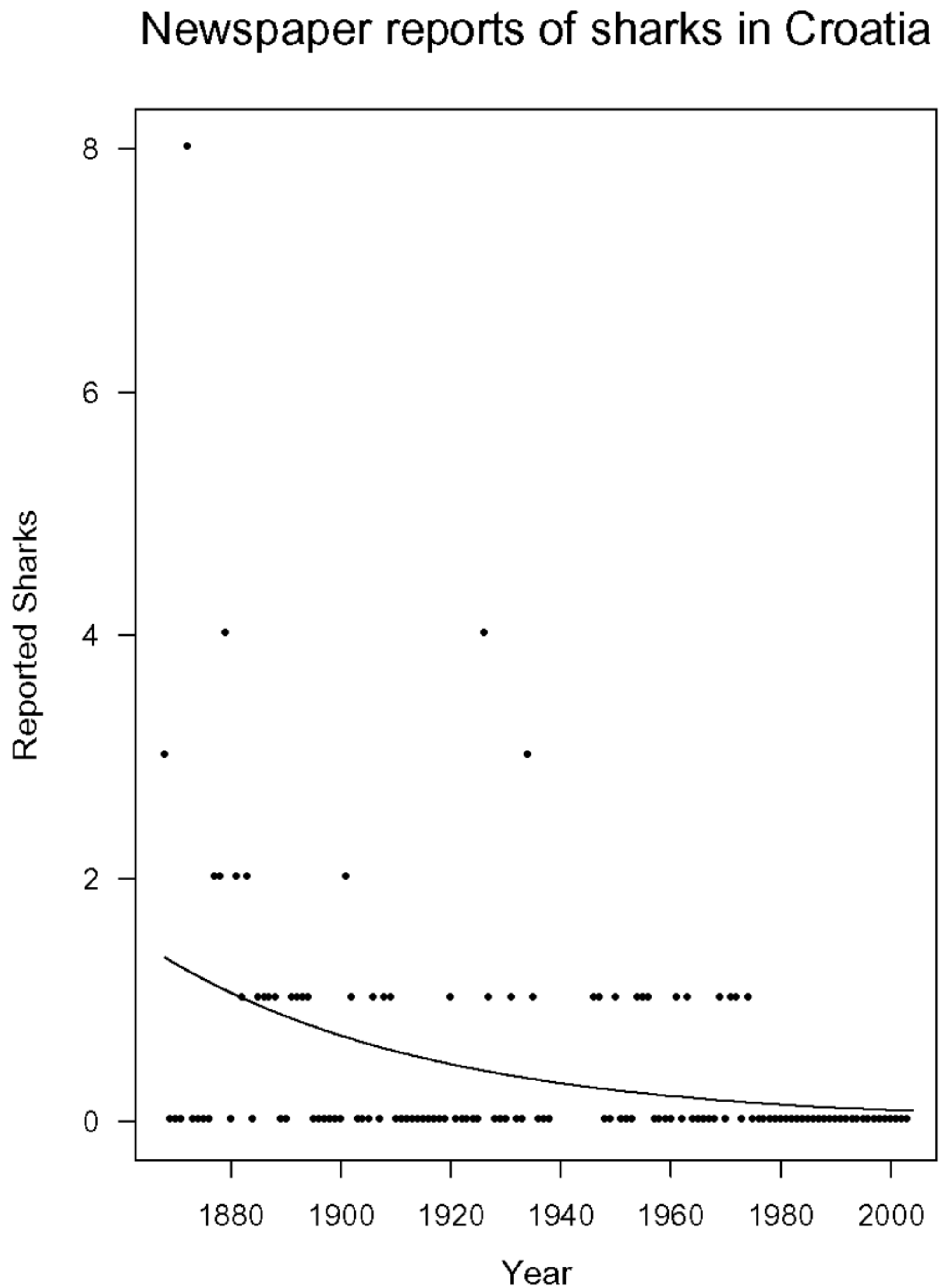


Shepherd and Myers Ecology Letters 2005

Same results for trawl surveys in Gulf of Mexico



Shepherd and Myers Ecology Letters 2005



Newspaper reports of sharks in Croatia
Reported Sharks
8
6
4
2
0
1880
1900
1920
1940
1960
1980
2000
Year

With training, “experts” can ignore the most obvious of data:

1872 - Man's head and leg and dolphin in stomach

1872 – 8 Great White Sharks reported caught

1888 - Woman's body and lamb in stomach

1894 - Preserved at Zagreb Nat. Hist. Mus.

1926 - Woman's shoes, laundry in stomach

1946 - Pig of 10 kg in stomach

1950 - Encounter during eating a dead calf

1954 - Attack on boat

1975+ -No sightings.

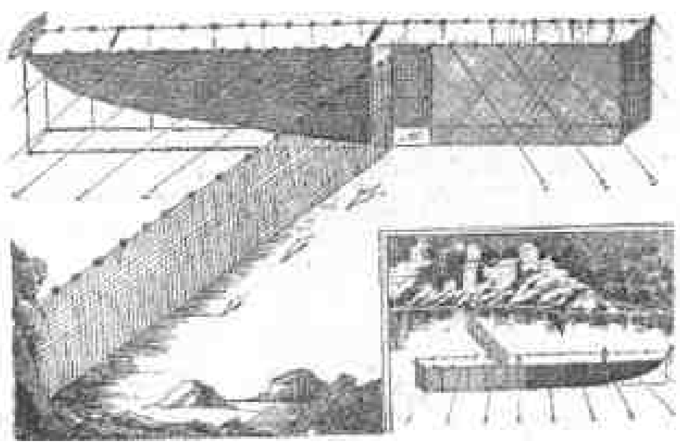
Soldo and Jardas, Periodicum Bologorum, 2002

Decline of Mediterranean Sharks

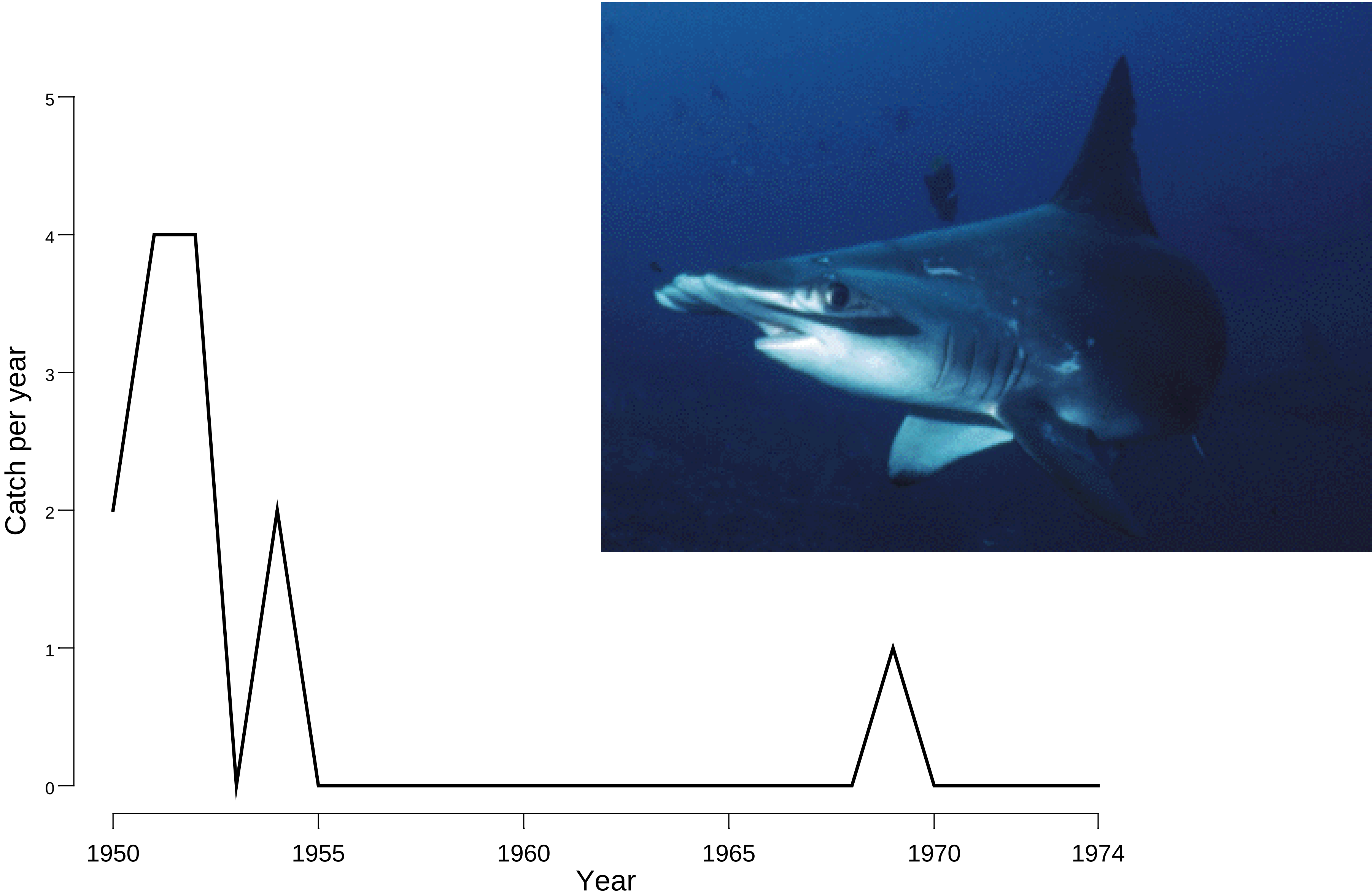
By catch associated with a Tuna Trap

In Ligurian Sea

“Tonnara di Camogli”



Decline of Hammarhead sharks

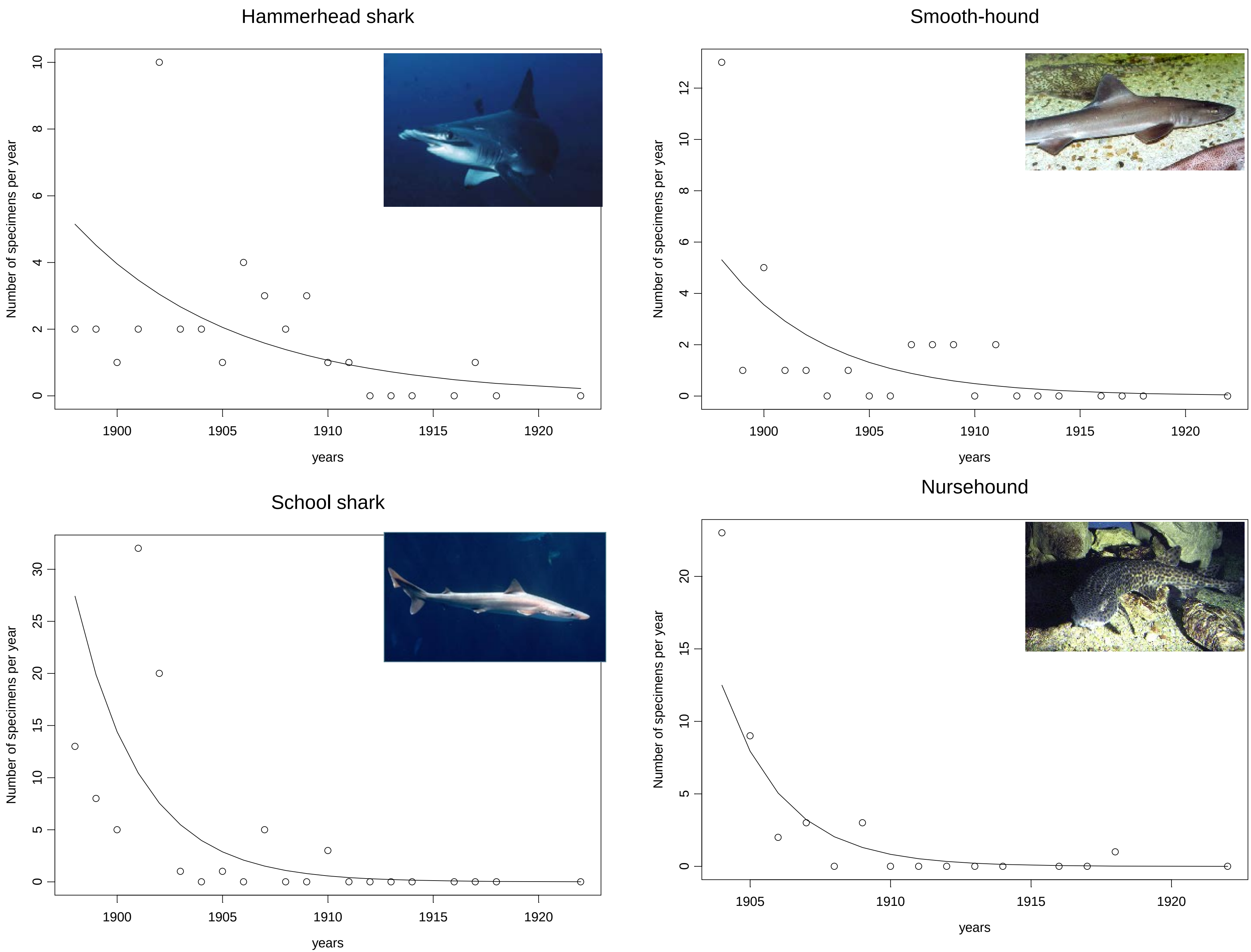


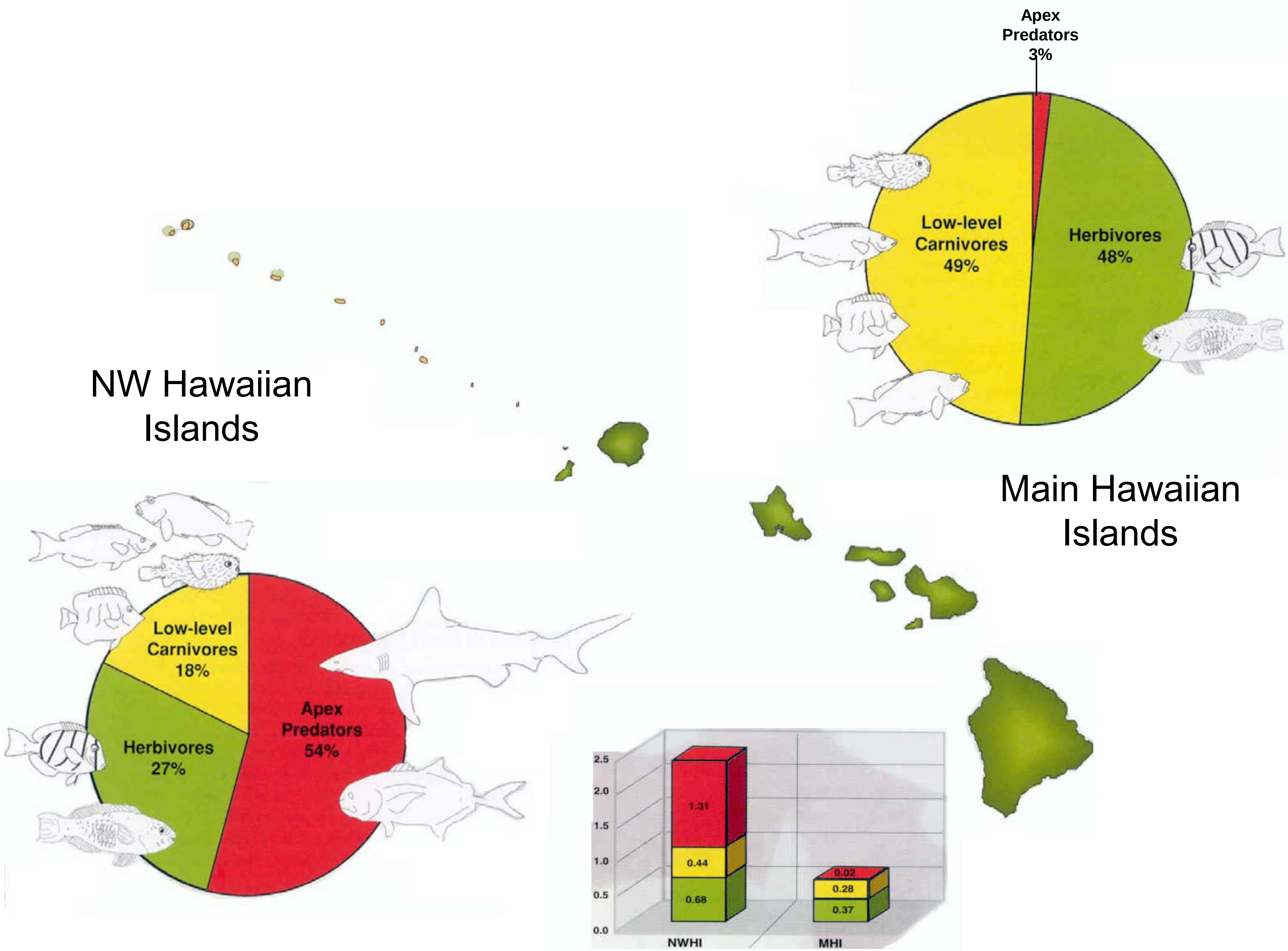
Boero F. & A. Carli 1979 – Boll. Mus. Ist. Biol. Univ. Genoa (47)

Decline of Mediterranean Sharks

By catch associated with a Tuna Trap
In Tirrenian Sea

"Tonnarella di Baratti"

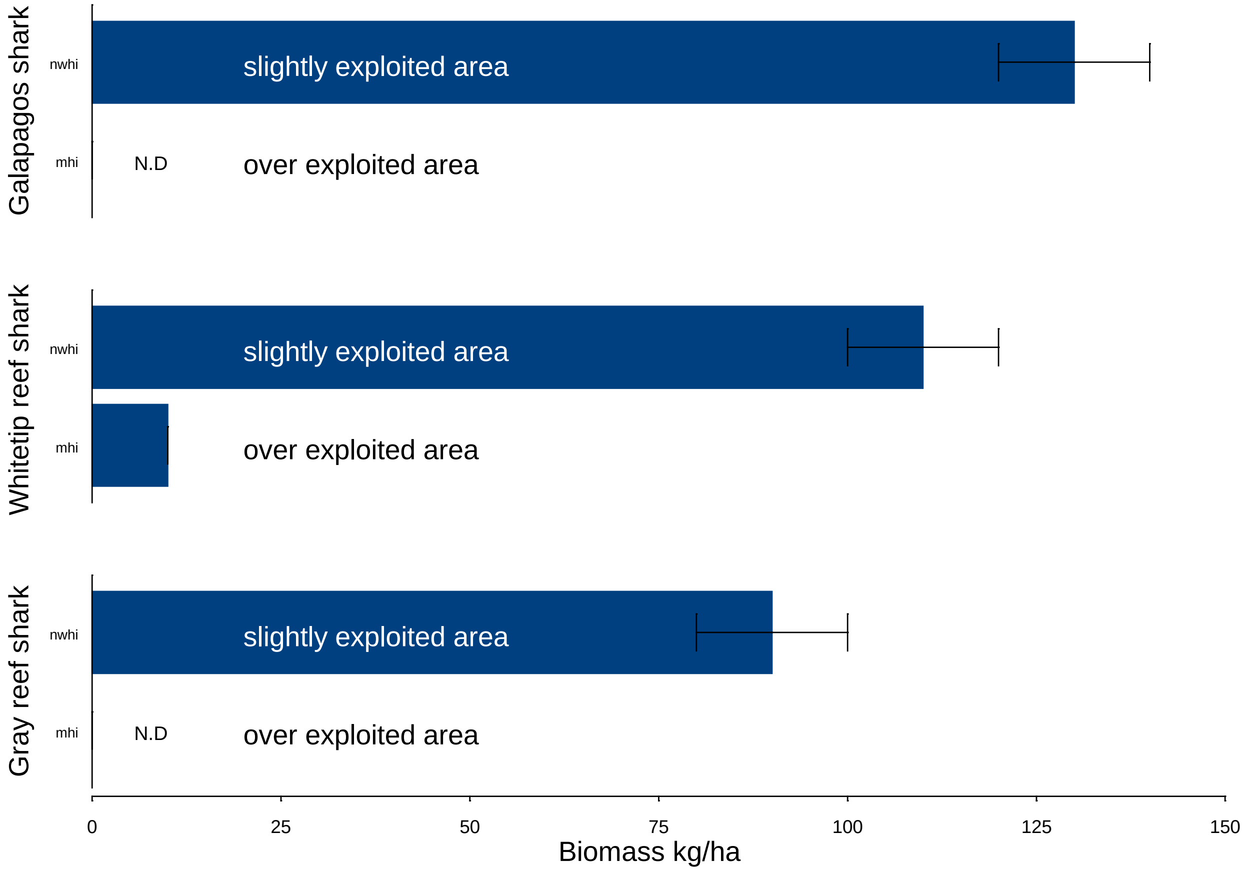

Hammerhead shark
Smooth-hound
School shark
Nursehound
Number of specimens per year
years
1900
1905
1910
1915
1920
0
2
4
6
8
10
12
5
15
20
25
30



Comparative fish biomass (mT/ha)

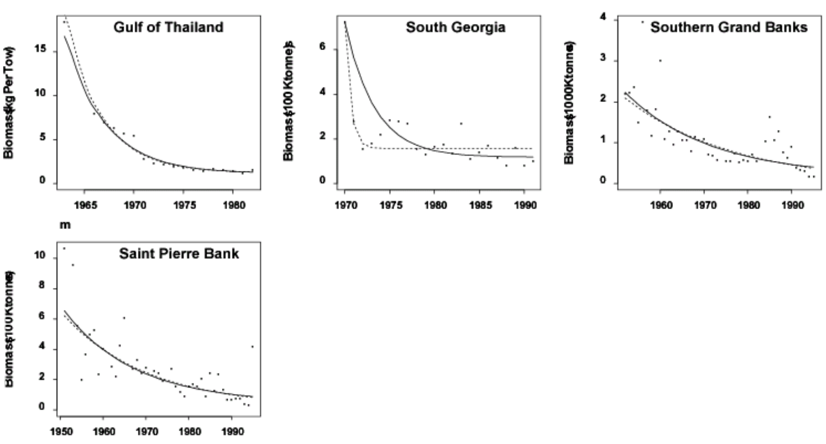
Loss of Reef Sharks in the Hawaiian Islands

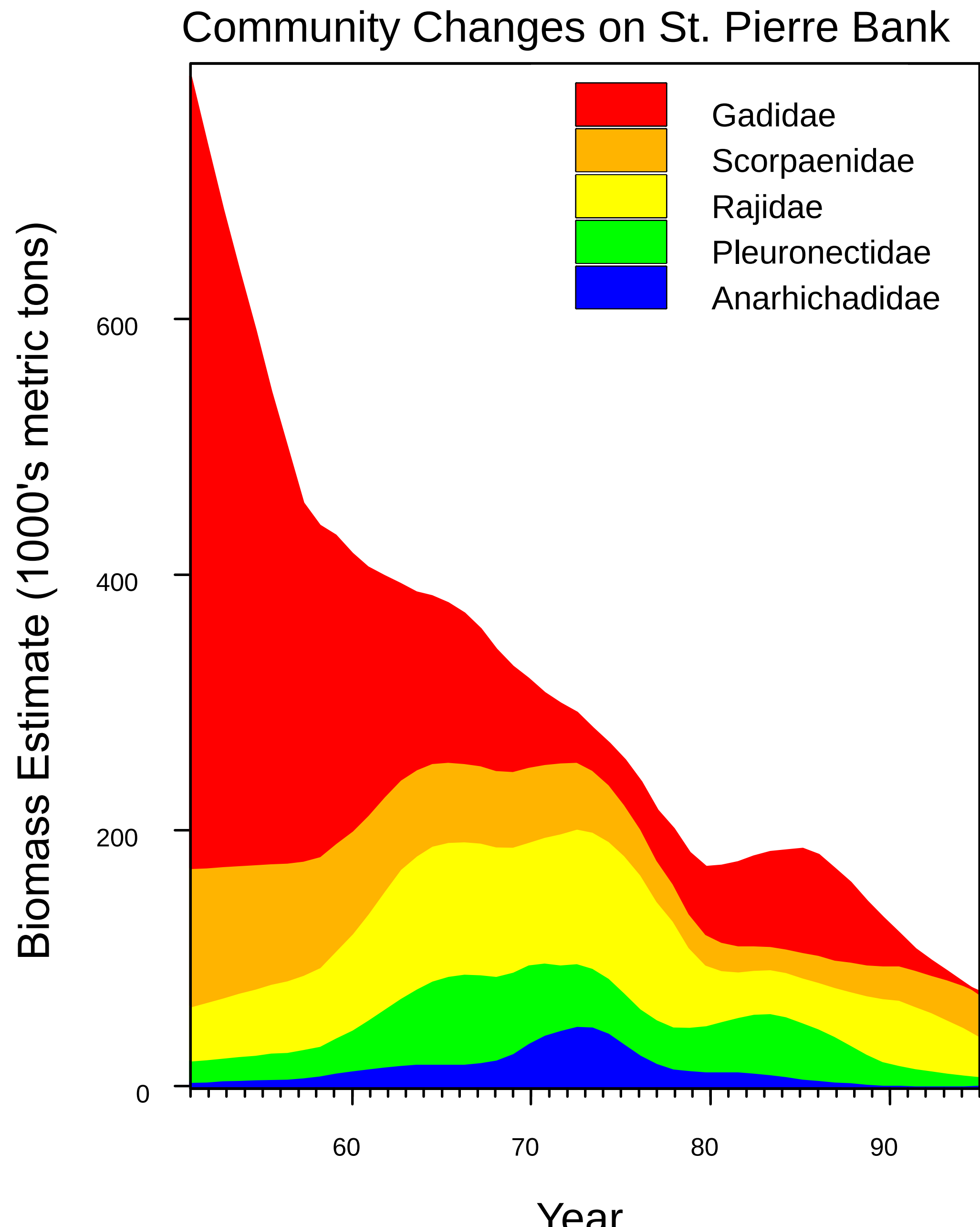
N.W.Hawaiian Islands vs Main Hawaiian Islands



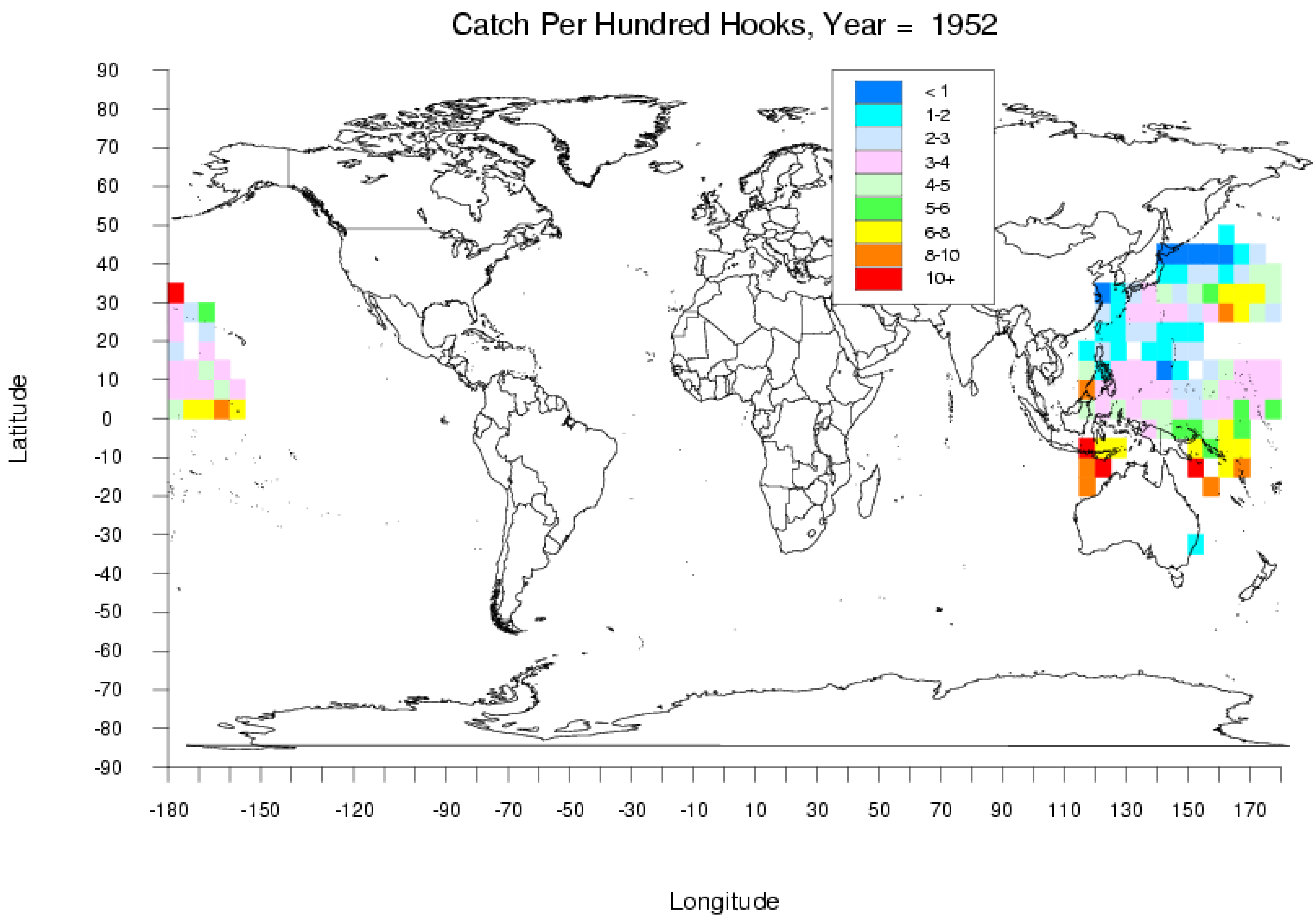
Friedlander A.M. & E.E. DeMartini 2002 - Marine Ecology Progress Series

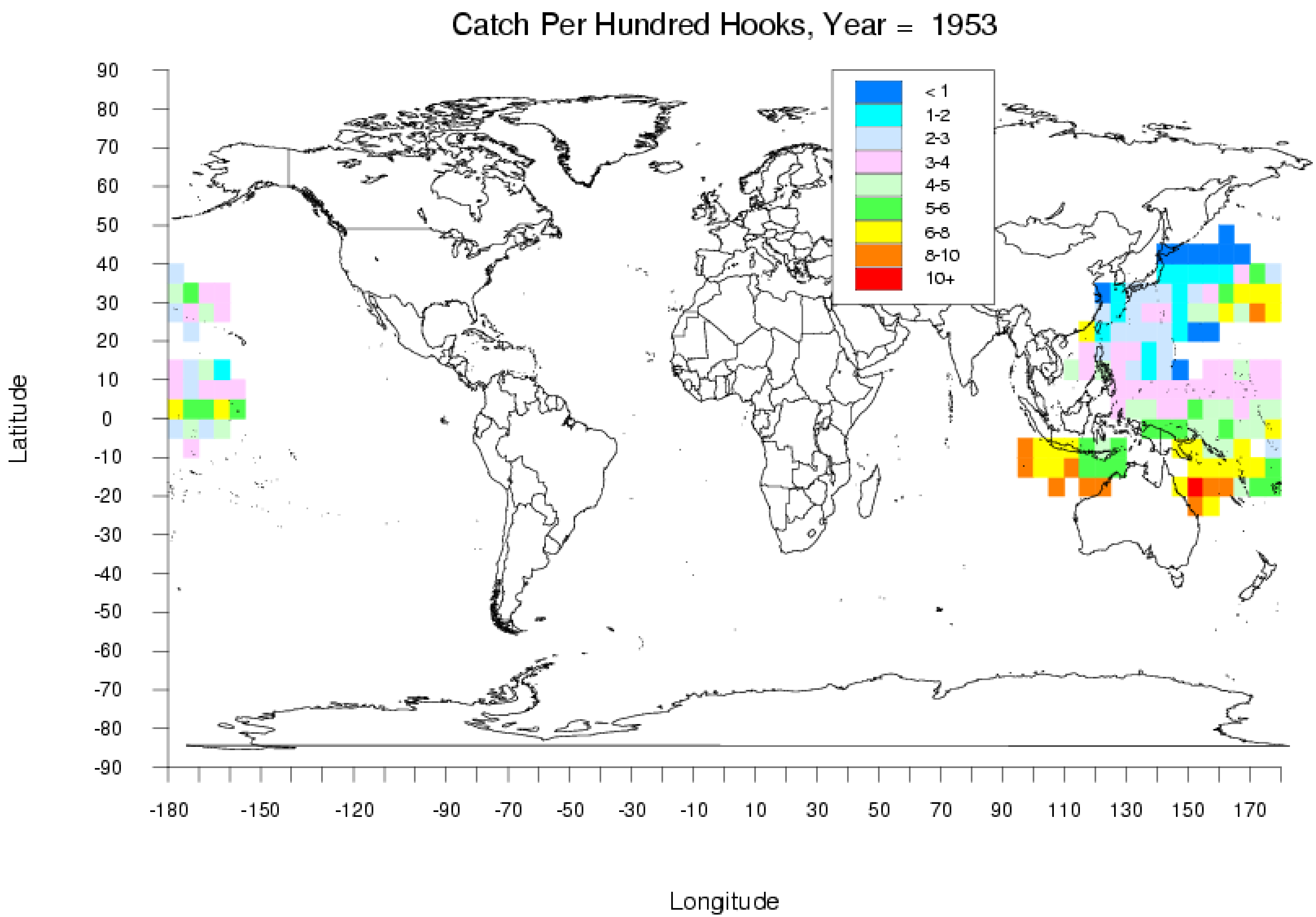

15 May 2003
International weekly journal of science
nature
www.nature.com/nature
Net losses
Industrialized fishing hits fish stocks
Financial markets
You can't buck the physics
Jupiter's moons
Headed for a hundred
Functional genomics
The power of comparison
naturejobs Heidelberg — Europe's molecular biology capital

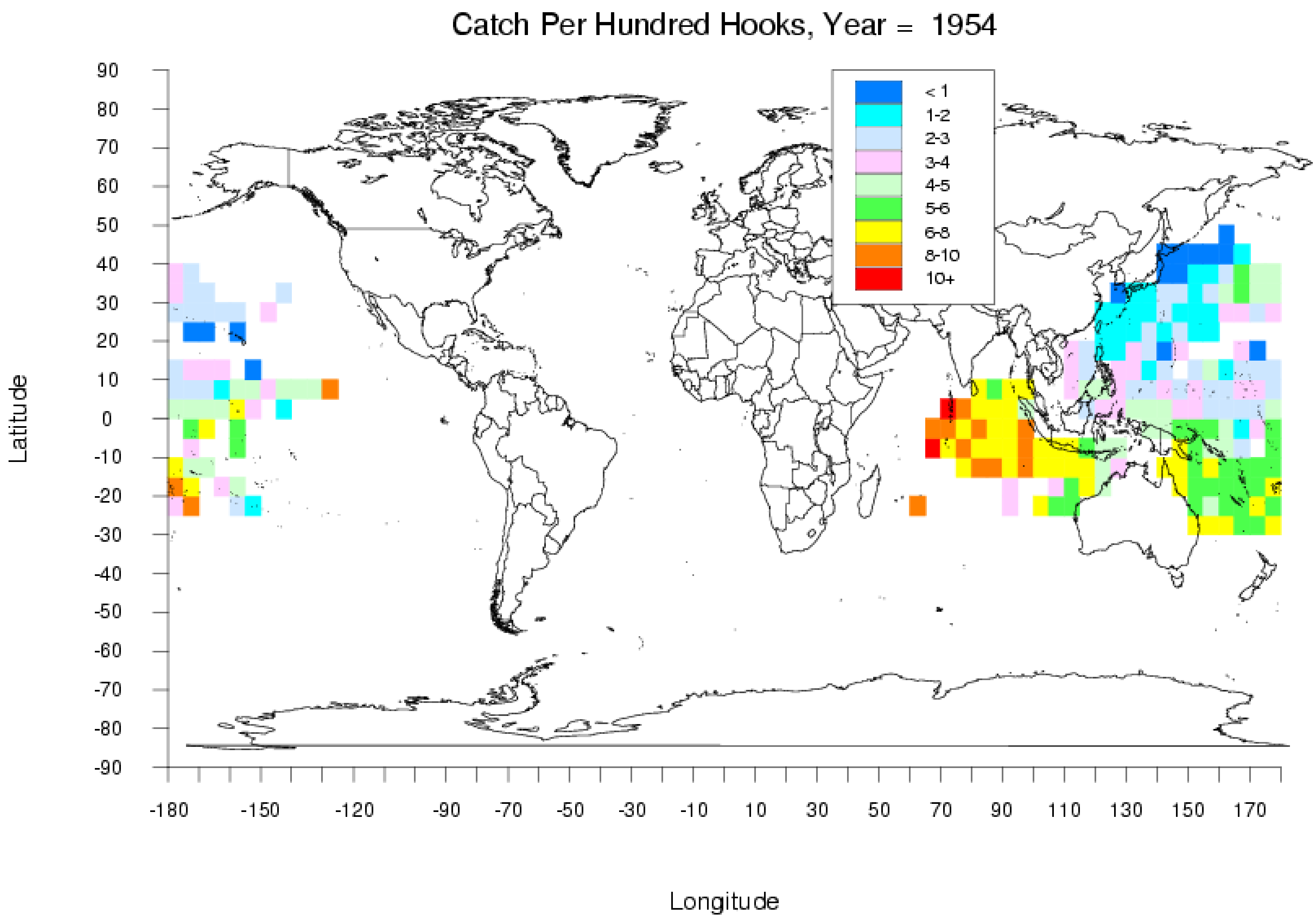

Gulf of Thailand
Biomass(kg Per Tow)
South Georgia
Biomass(100 Ktonnes)
Southern Grand Banks
Biomass(1000Ktonnes)
Saint Pierre Bank
Biomass(100Ktonnes)


Community Changes on St. Pierre Bank
Gadidae
Scorpaenidae
Rajidae
Pleuronectidae
Anarhichadidae
Biomass Estimate (1000's metric tons)
0
200
400
600
60
70
80
90
Year

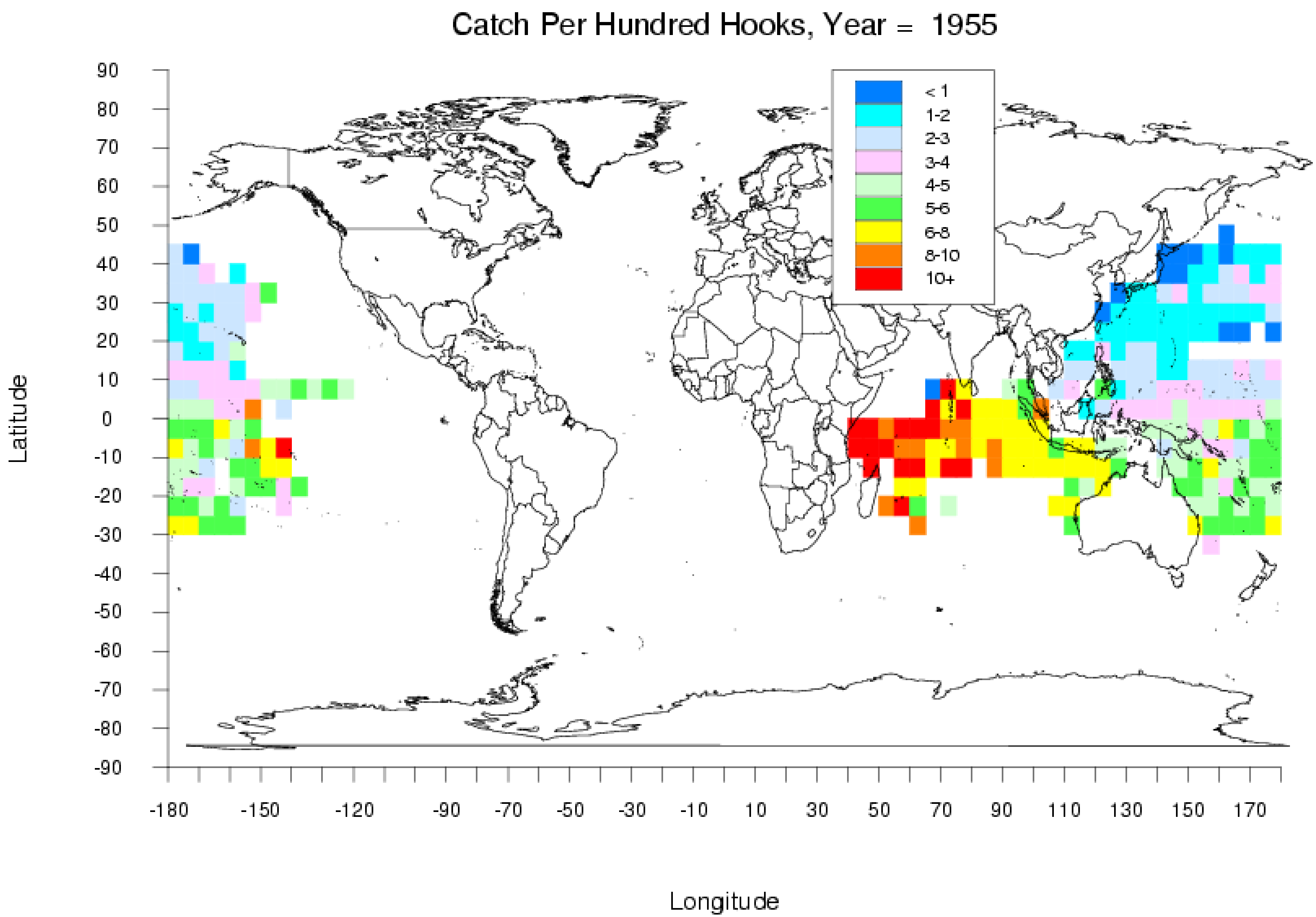

555
lbs.
LBS.
1135
CABO
BLANCO


Catch Per Hundred Hooks, Year = 1952
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

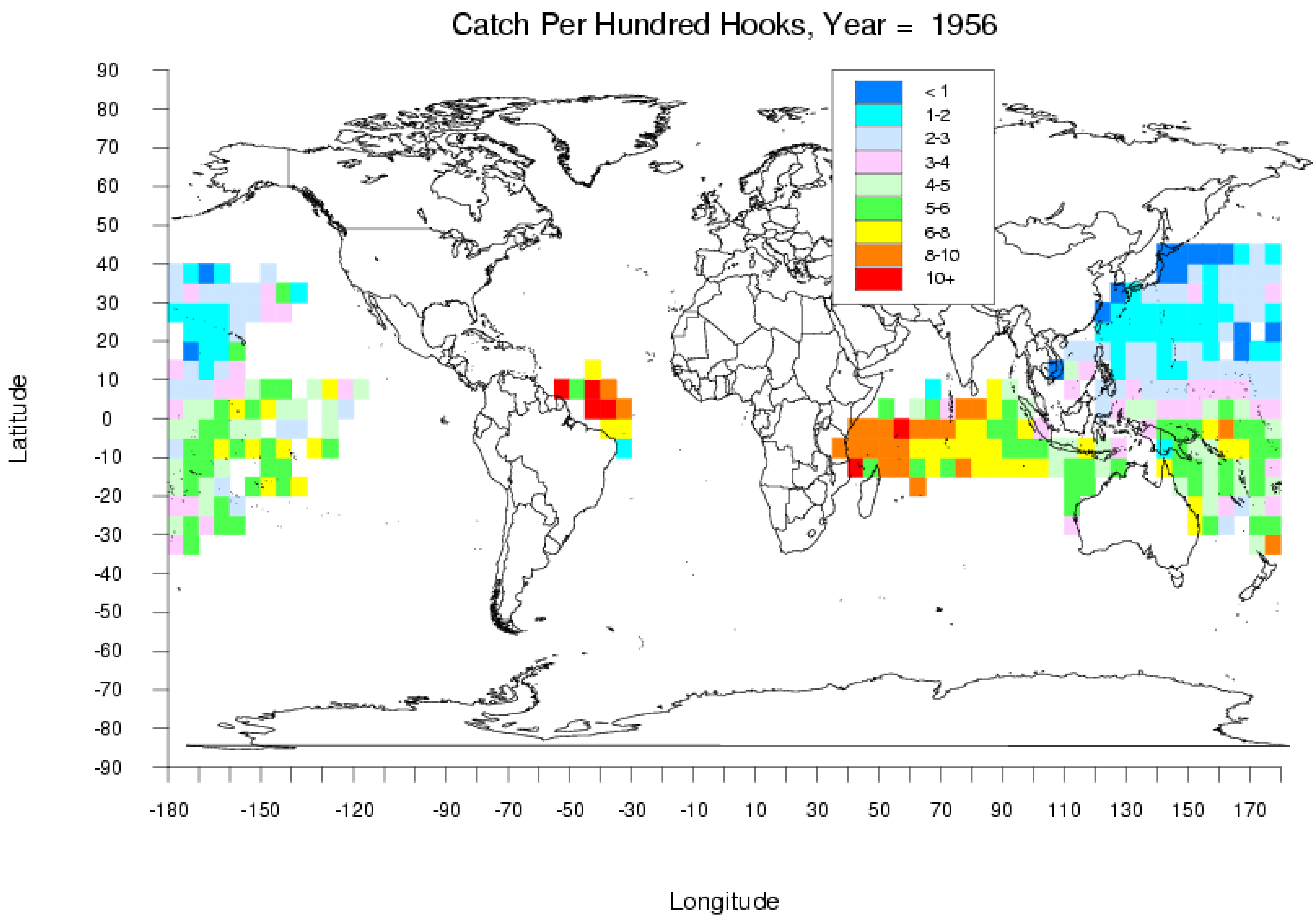

Catch Per Hundred Hooks, Year = 1953
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170



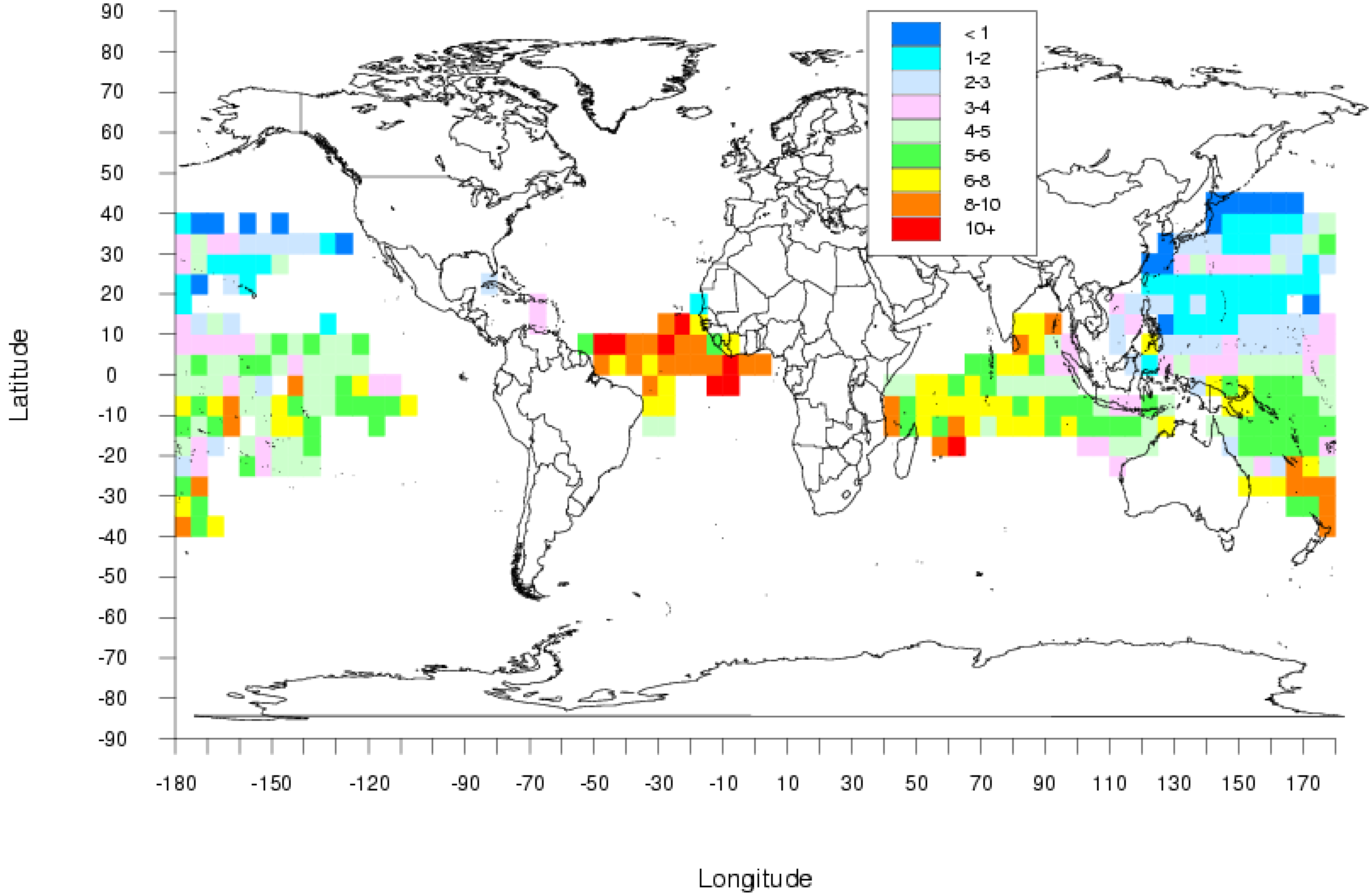
Catch Per Hundred Hooks, Year = 1954
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

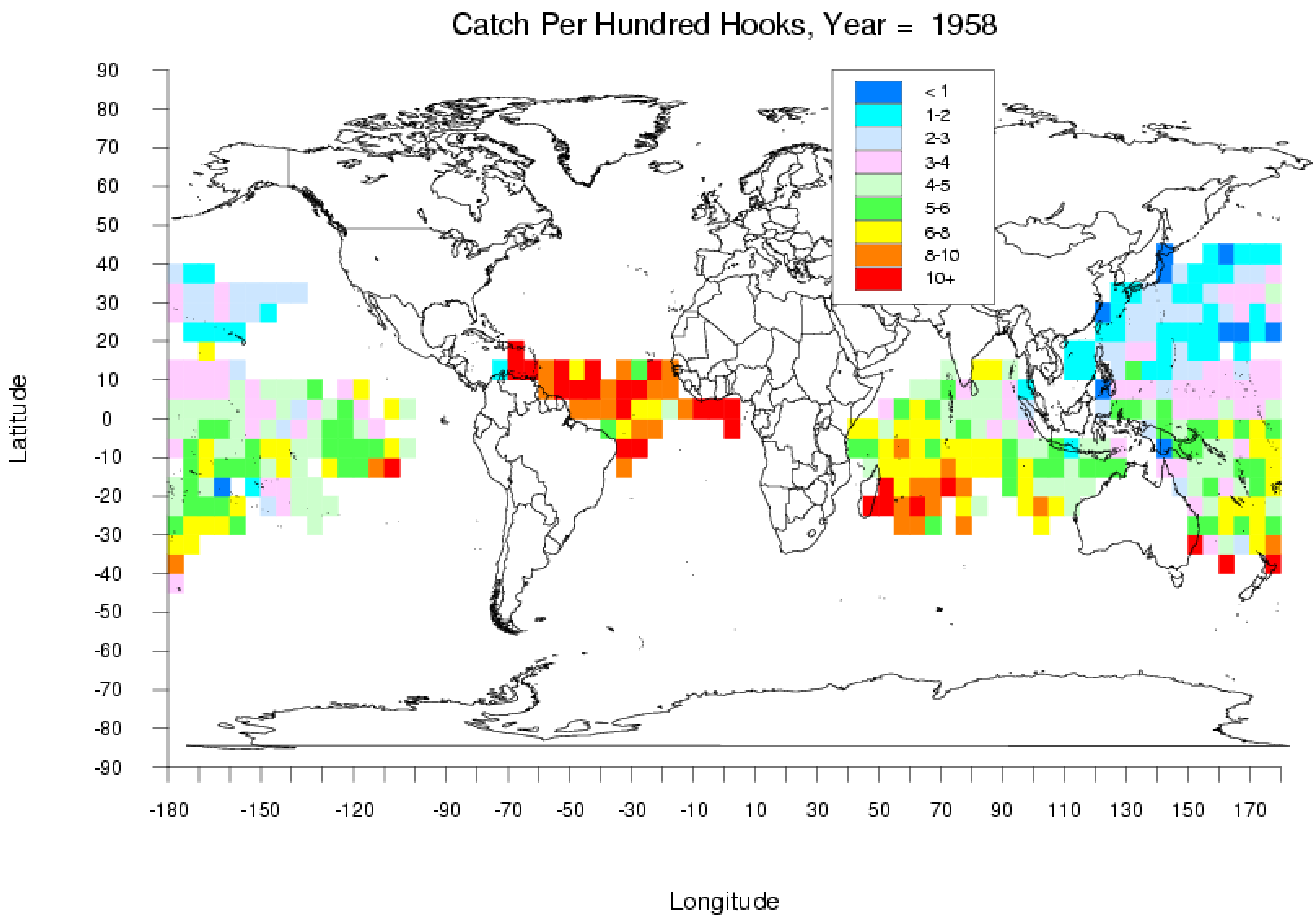


Catch Per Hundred Hooks, Year = 1955
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude

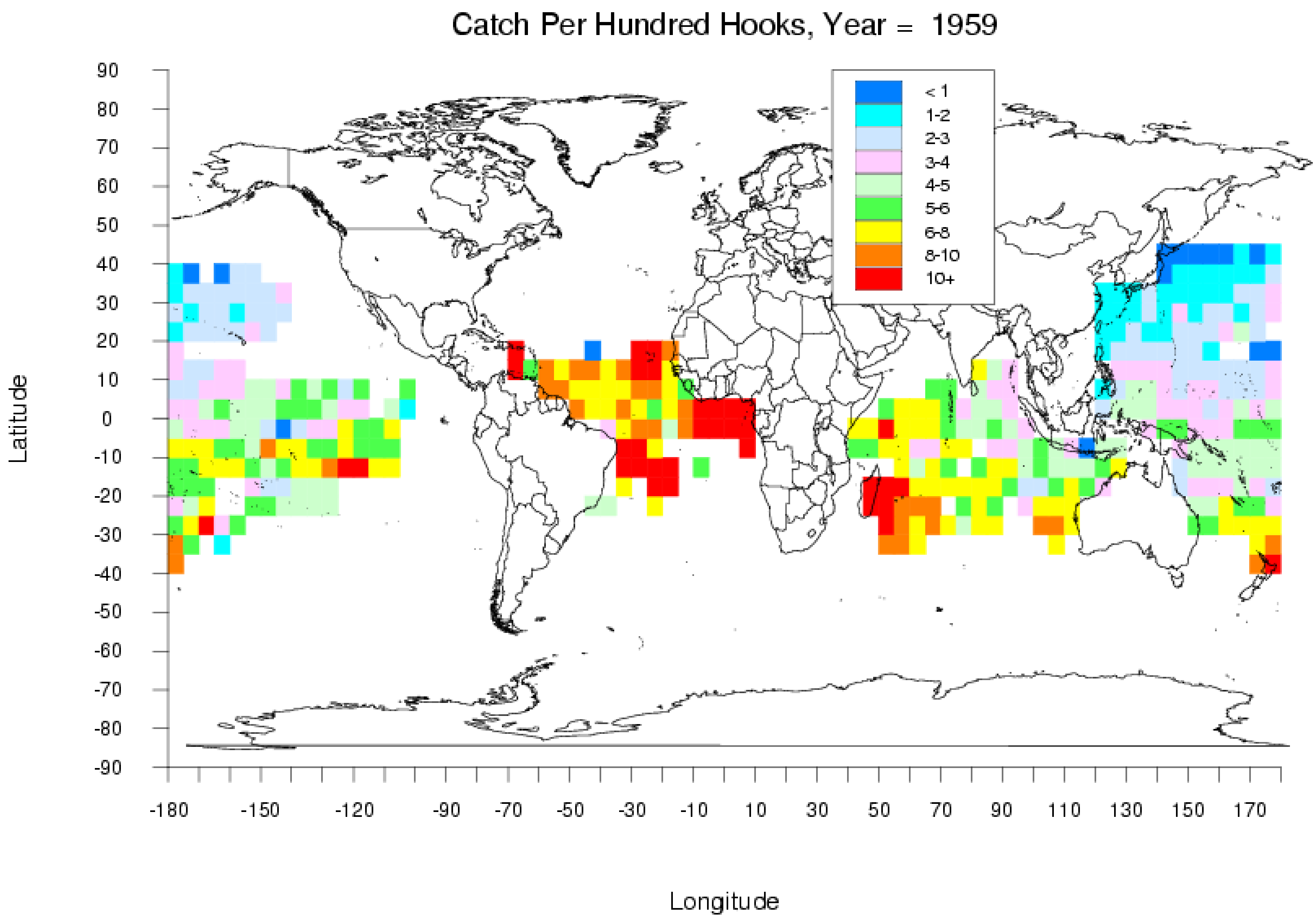

Catch Per Hundred Hooks, Year = 1956
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude

Catch Per Hundred Hooks, Year = 1957

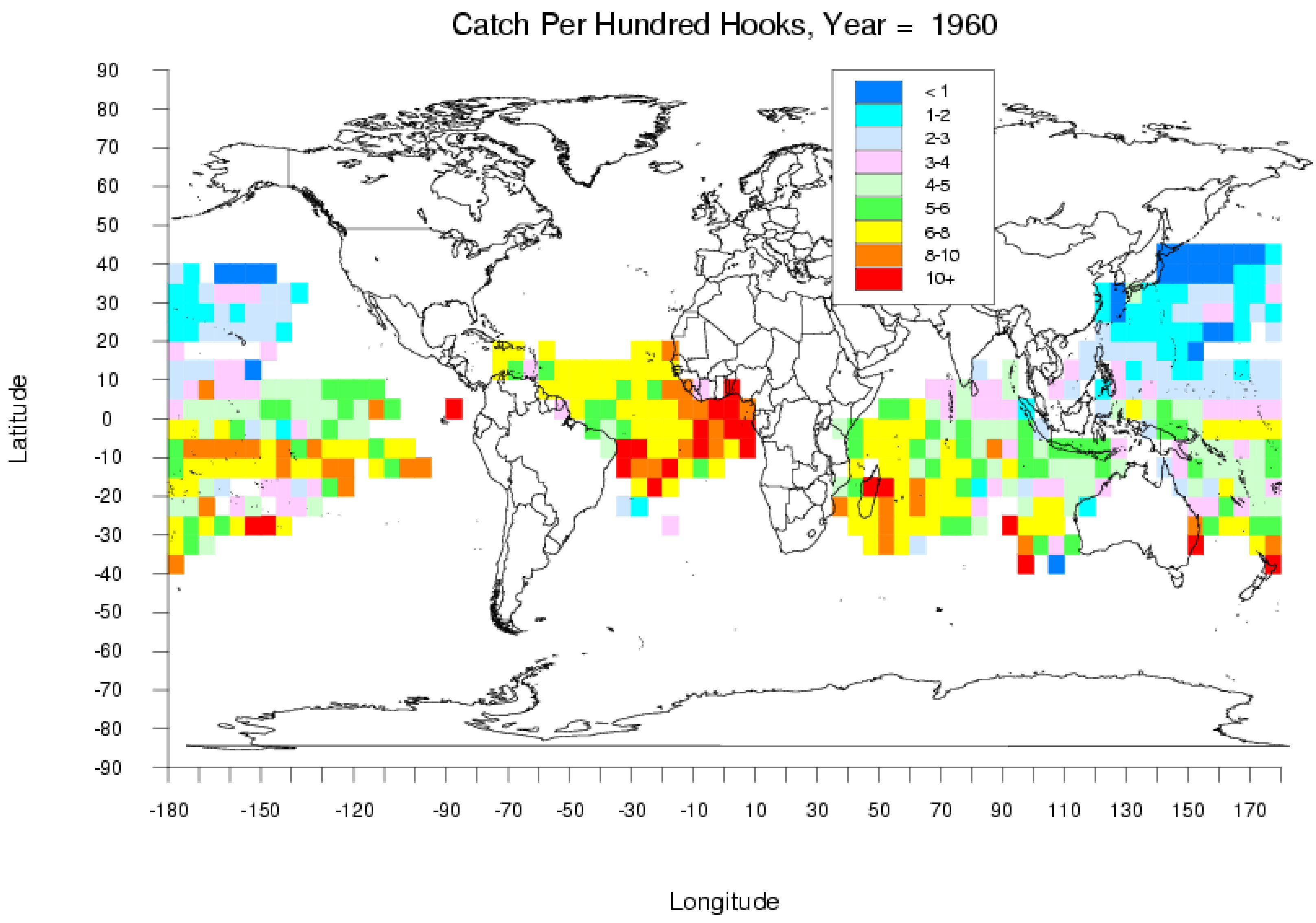




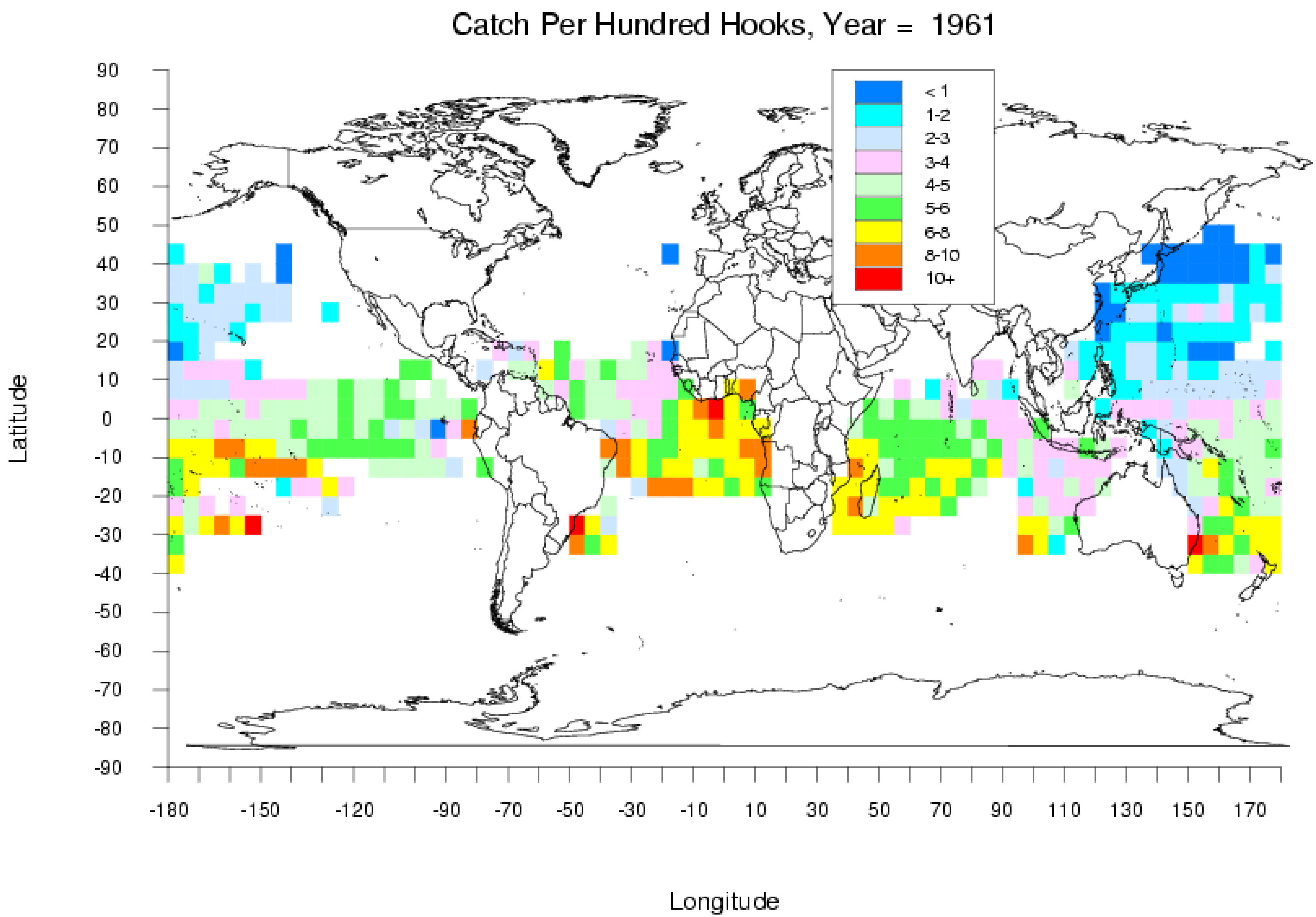
Catch Per Hundred Hooks, Year = 1958
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude



Catch Per Hundred Hooks, Year = 1959
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

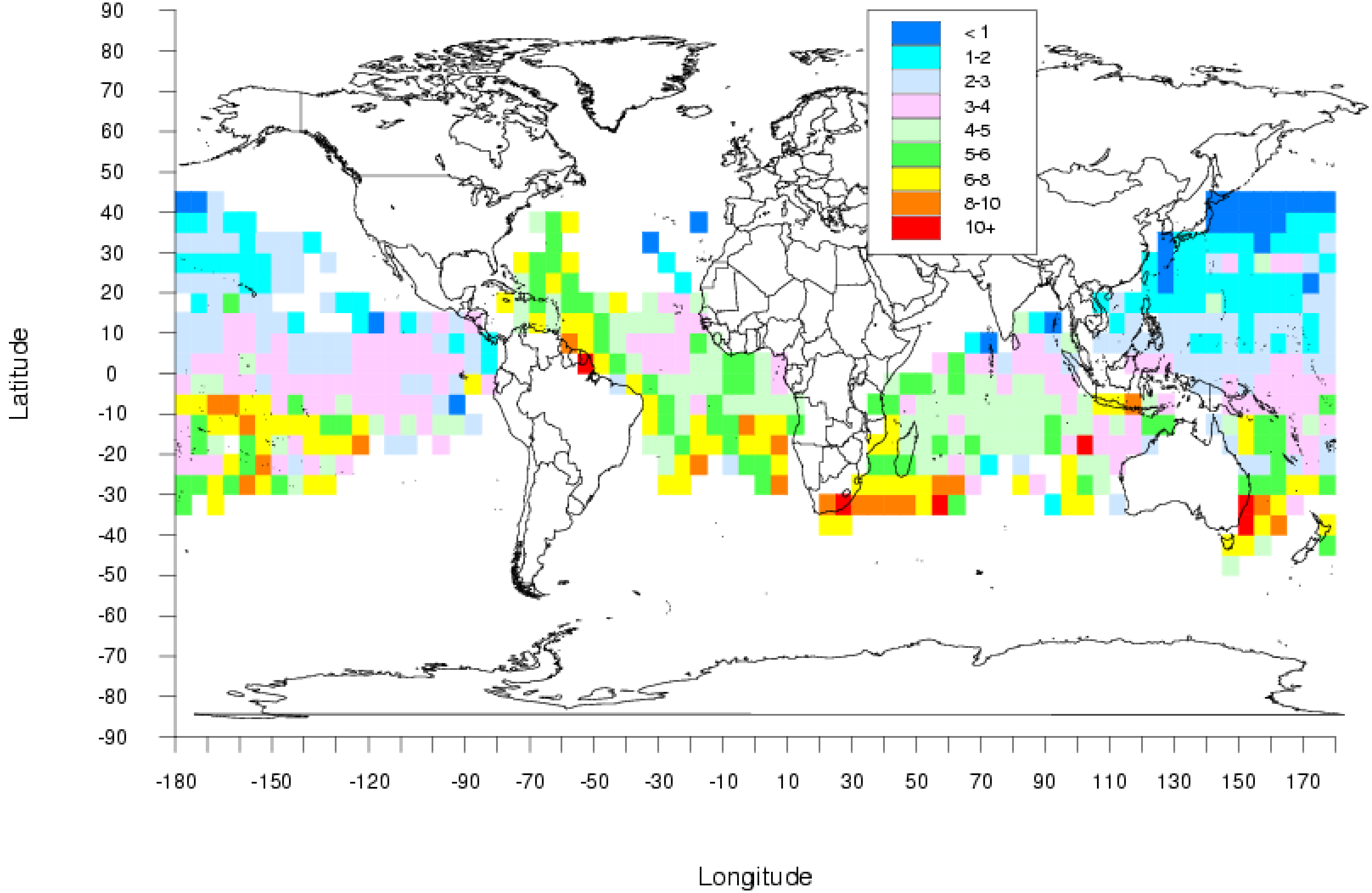


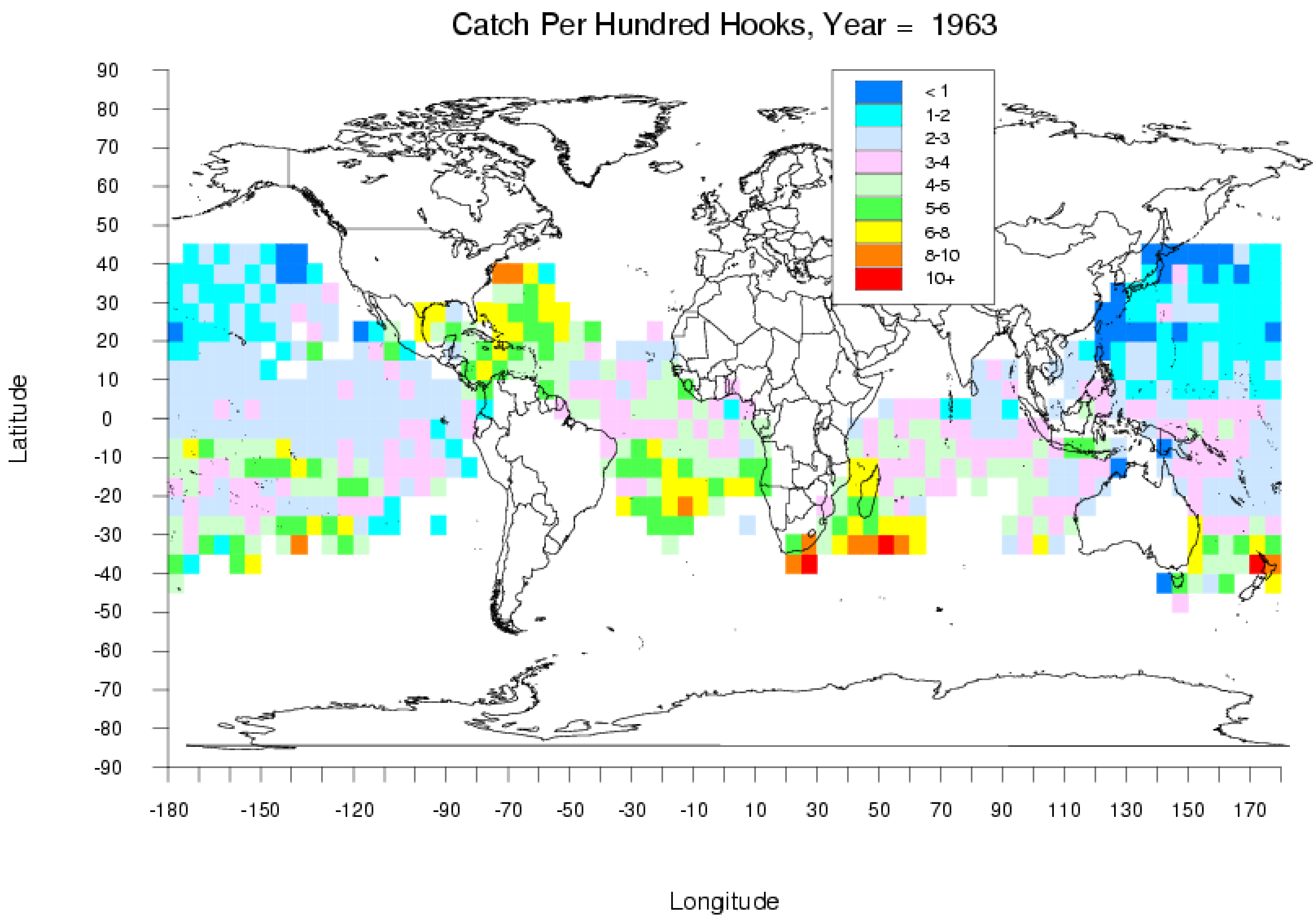
Catch Per Hundred Hooks, Year = 1960
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+



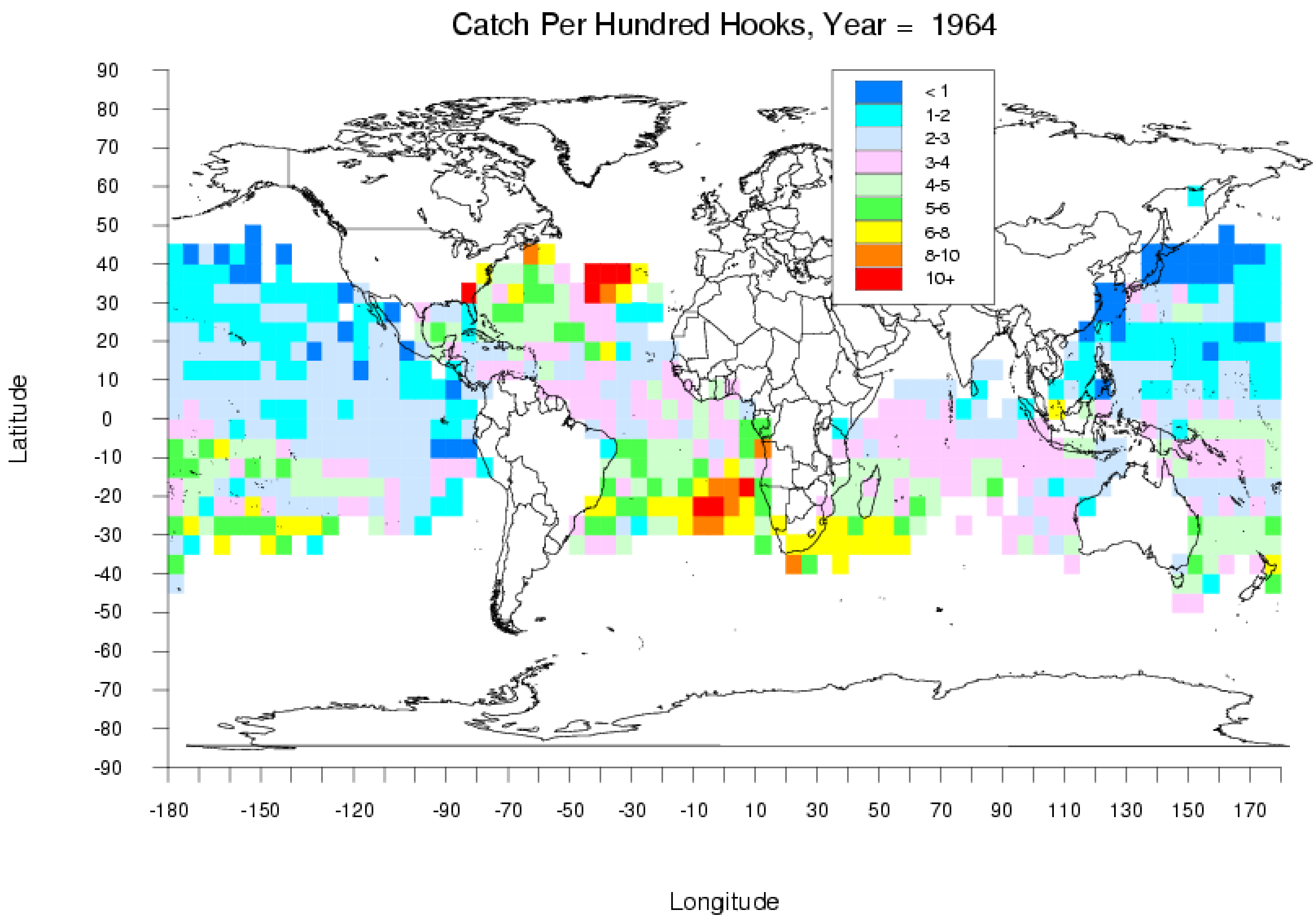
Catch Per Hundred Hooks, Year = 1961
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude

Catch Per Hundred Hooks, Year = 1962

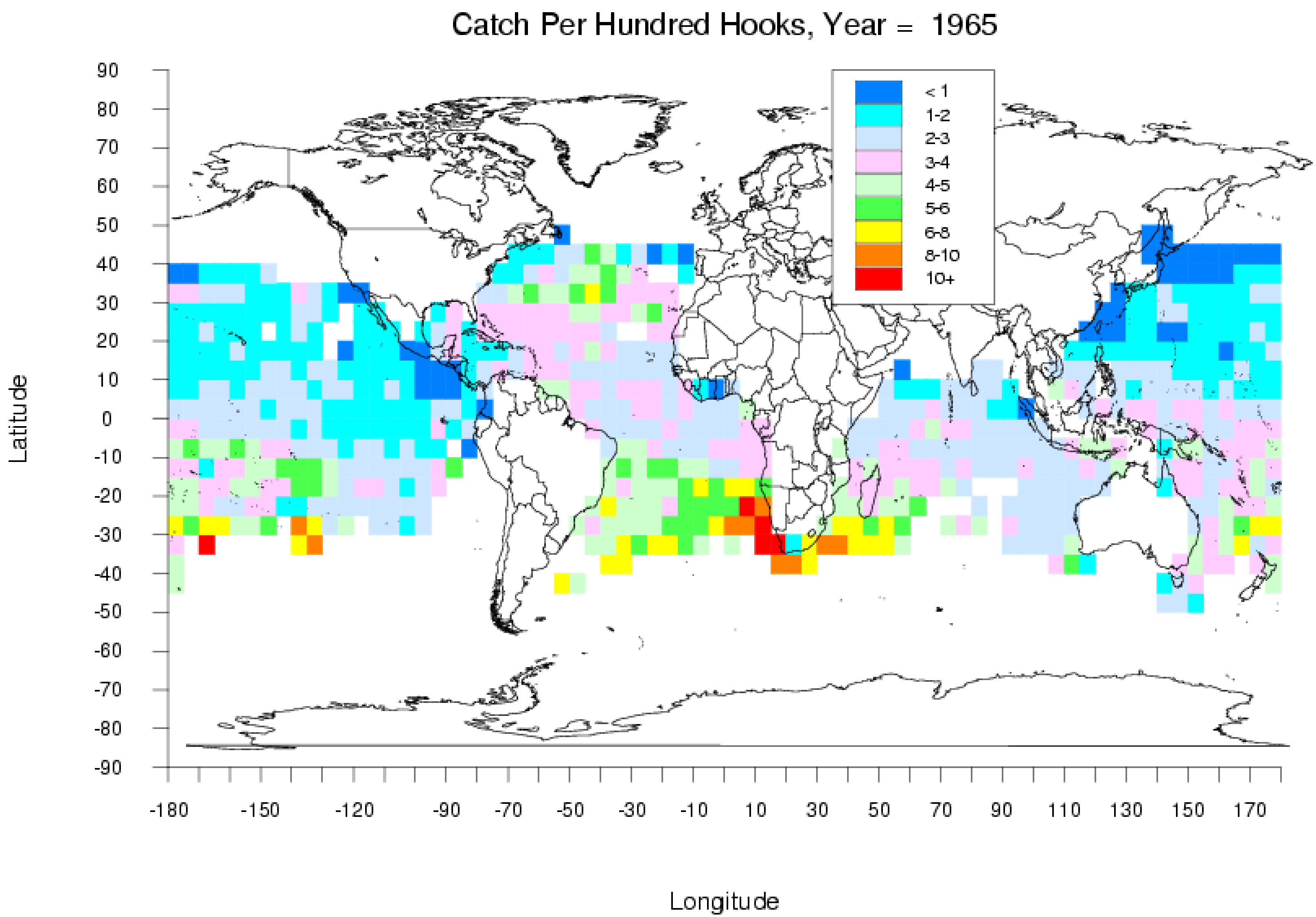




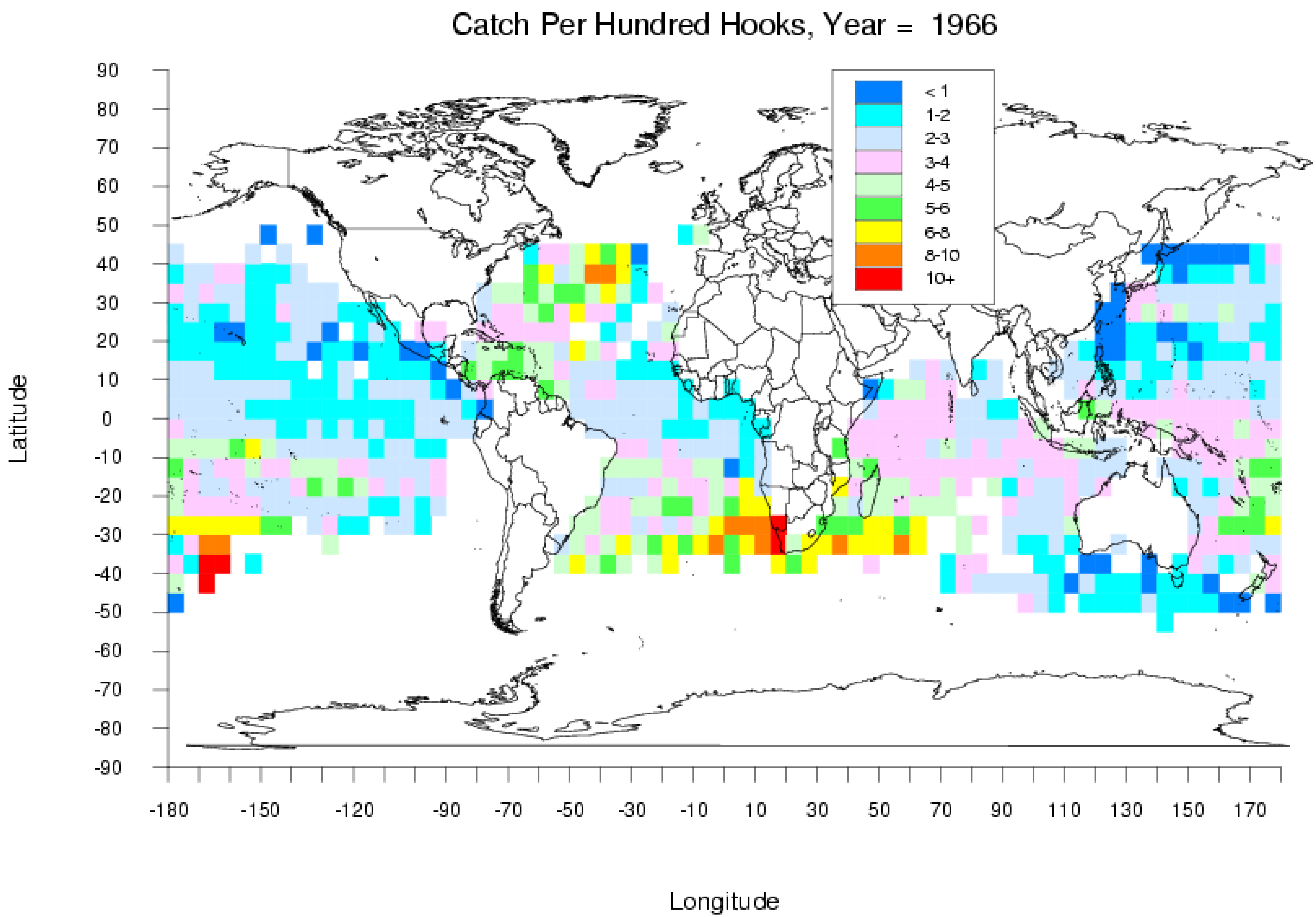
Catch Per Hundred Hooks, Year = 1963
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude



Catch Per Hundred Hooks, Year = 1964
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude

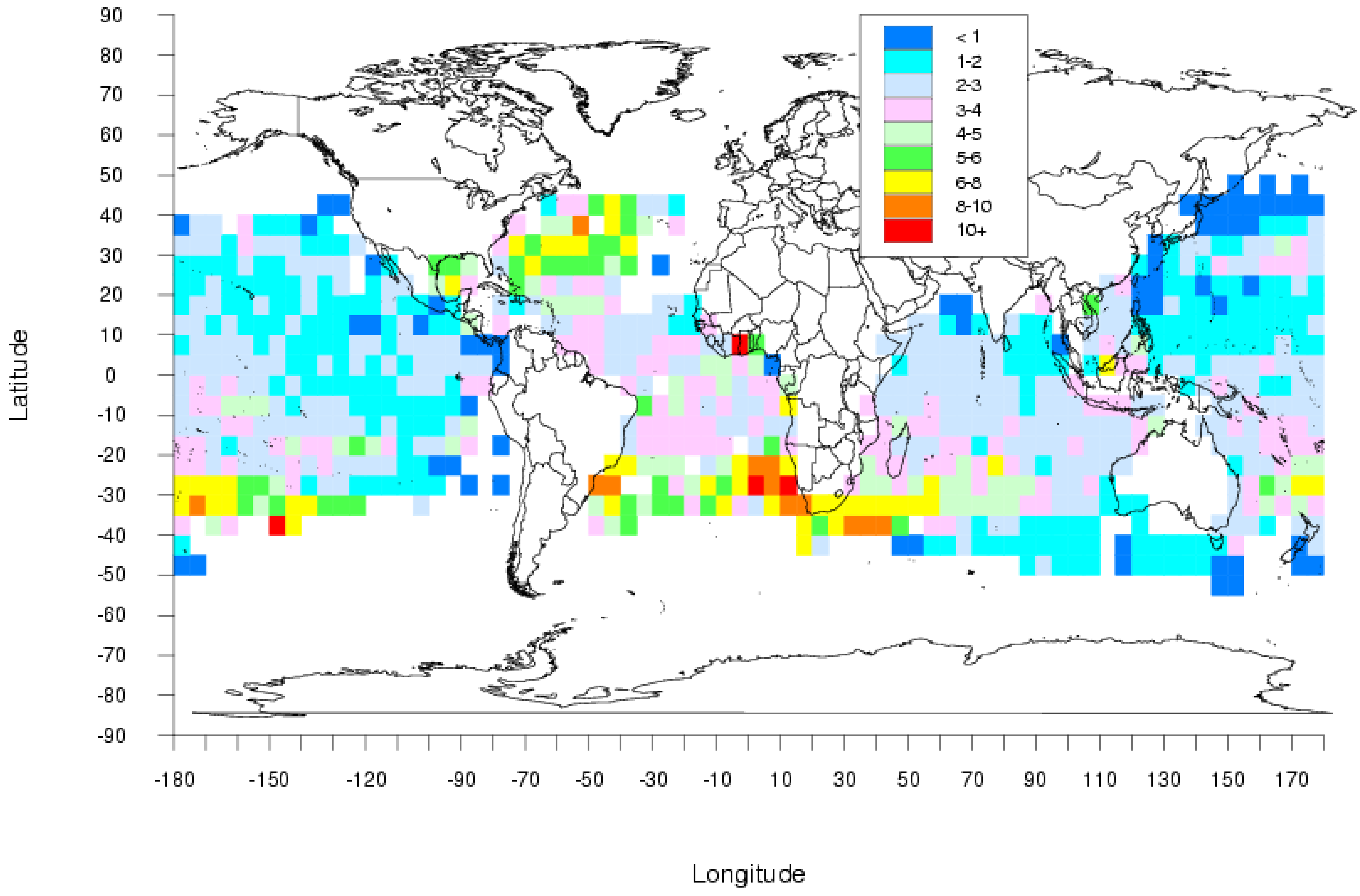


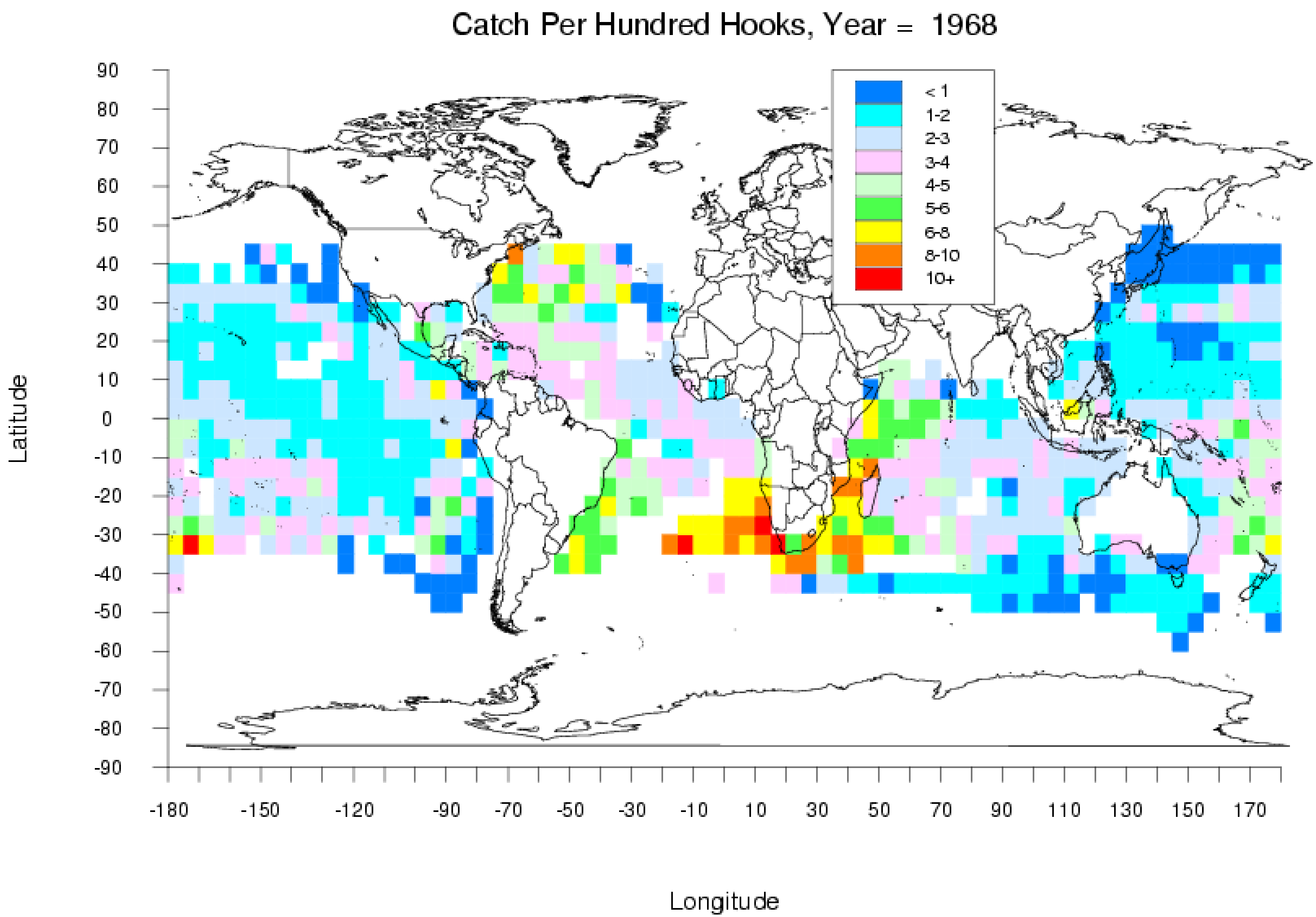
Catch Per Hundred Hooks, Year = 1965
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170



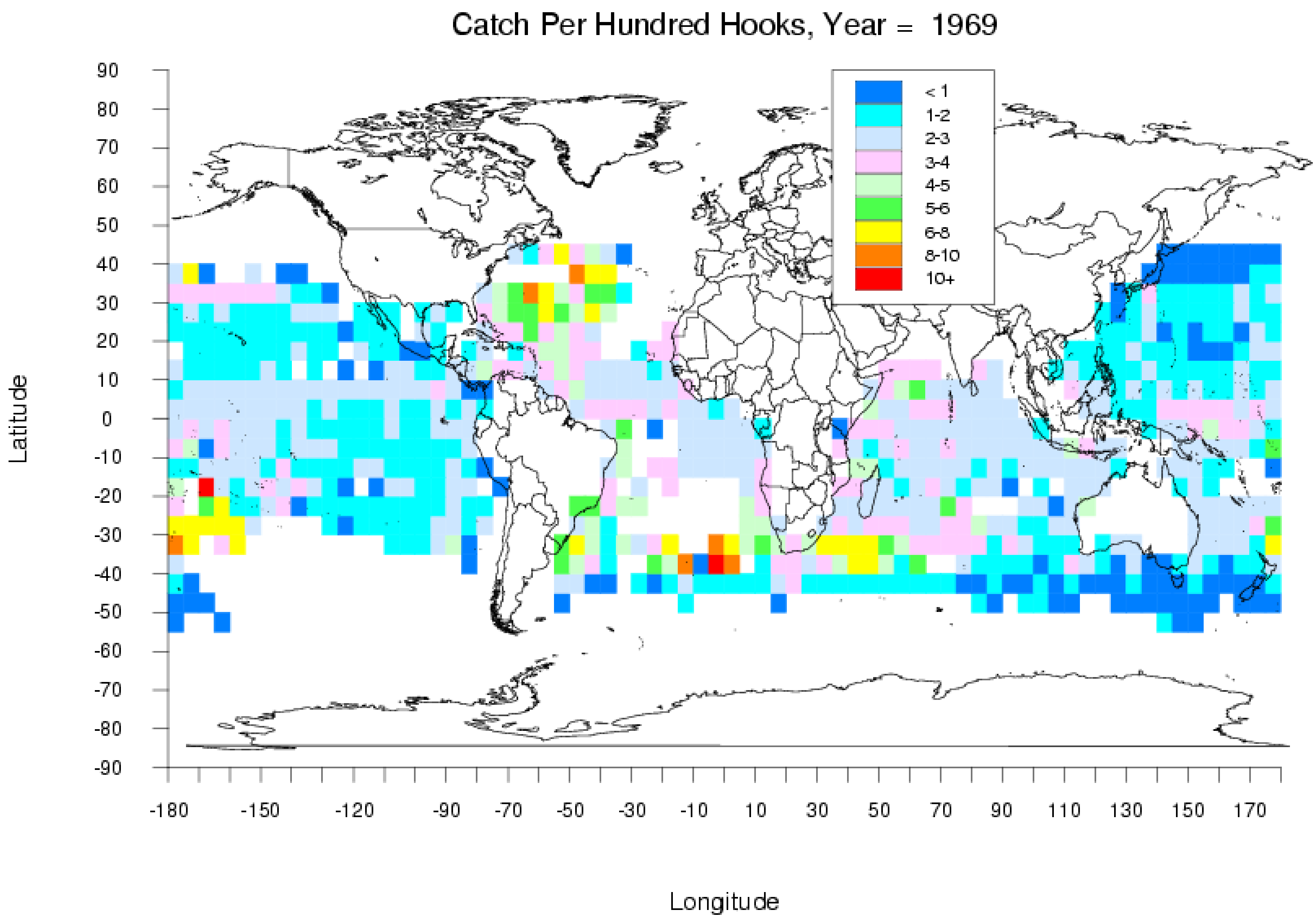
Catch Per Hundred Hooks, Year = 1966
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

Catch Per Hundred Hooks, Year = 1967

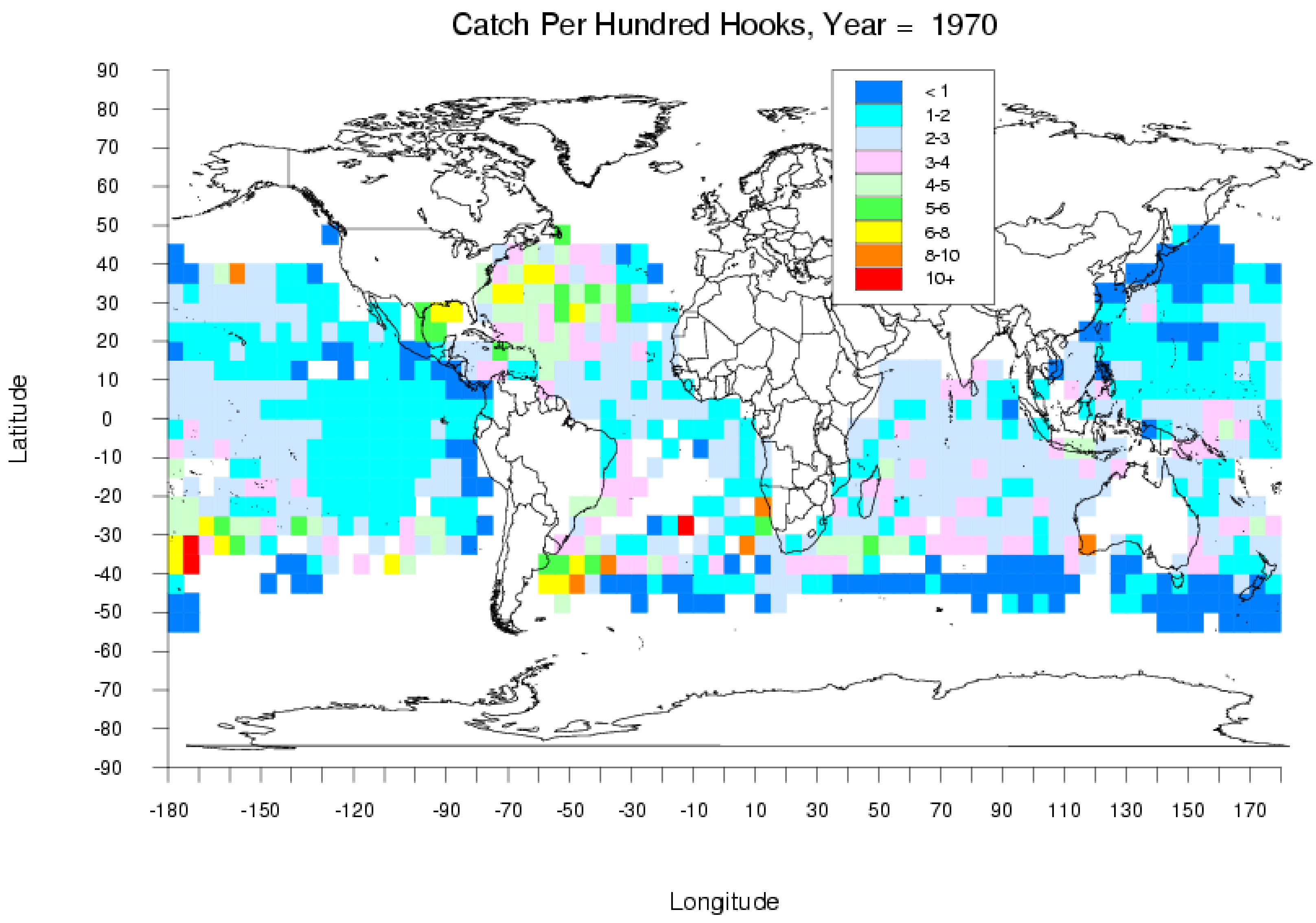




Catch Per Hundred Hooks, Year = 1968
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1969
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+



Catch Per Hundred Hooks, Year = 1970
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
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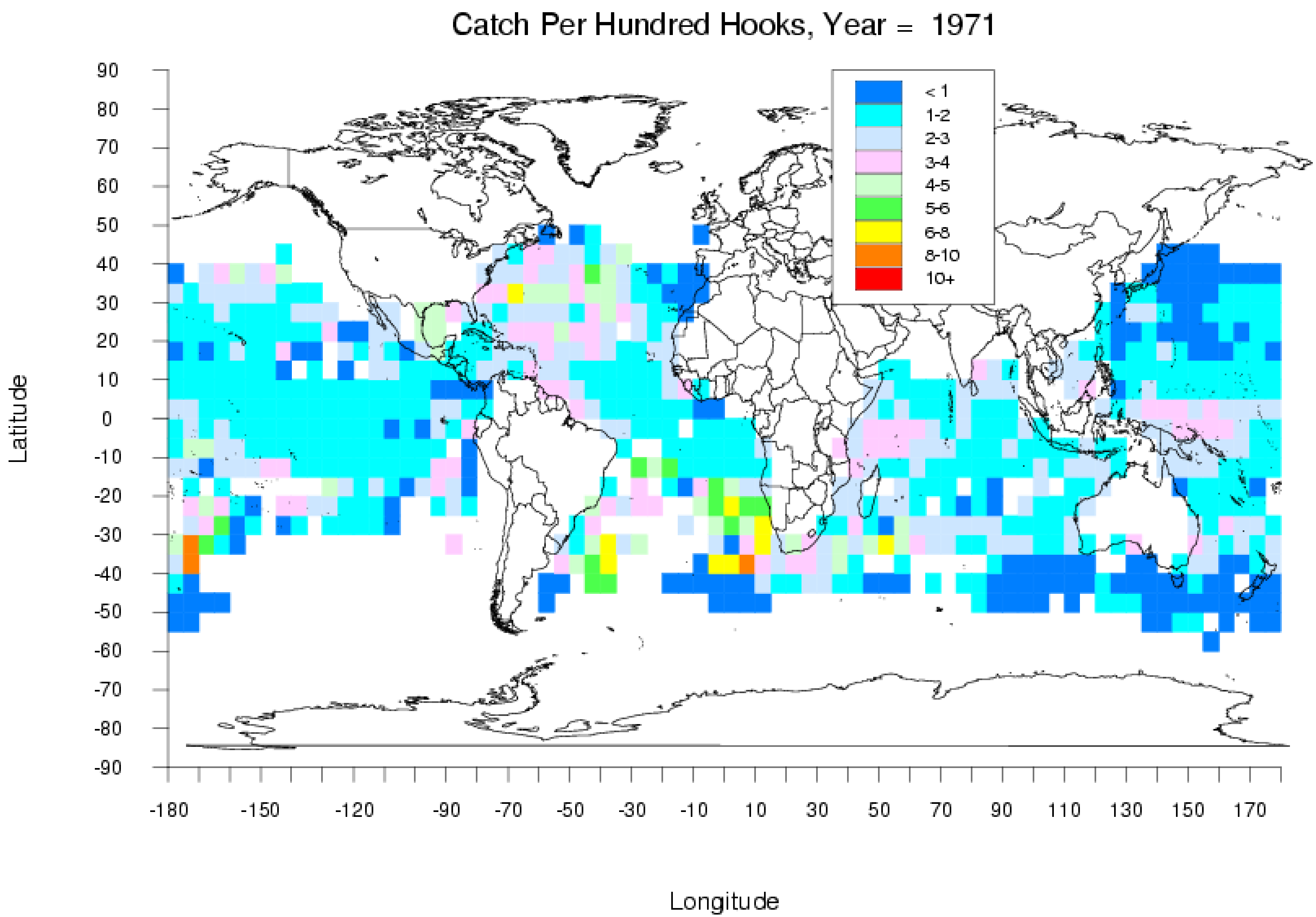
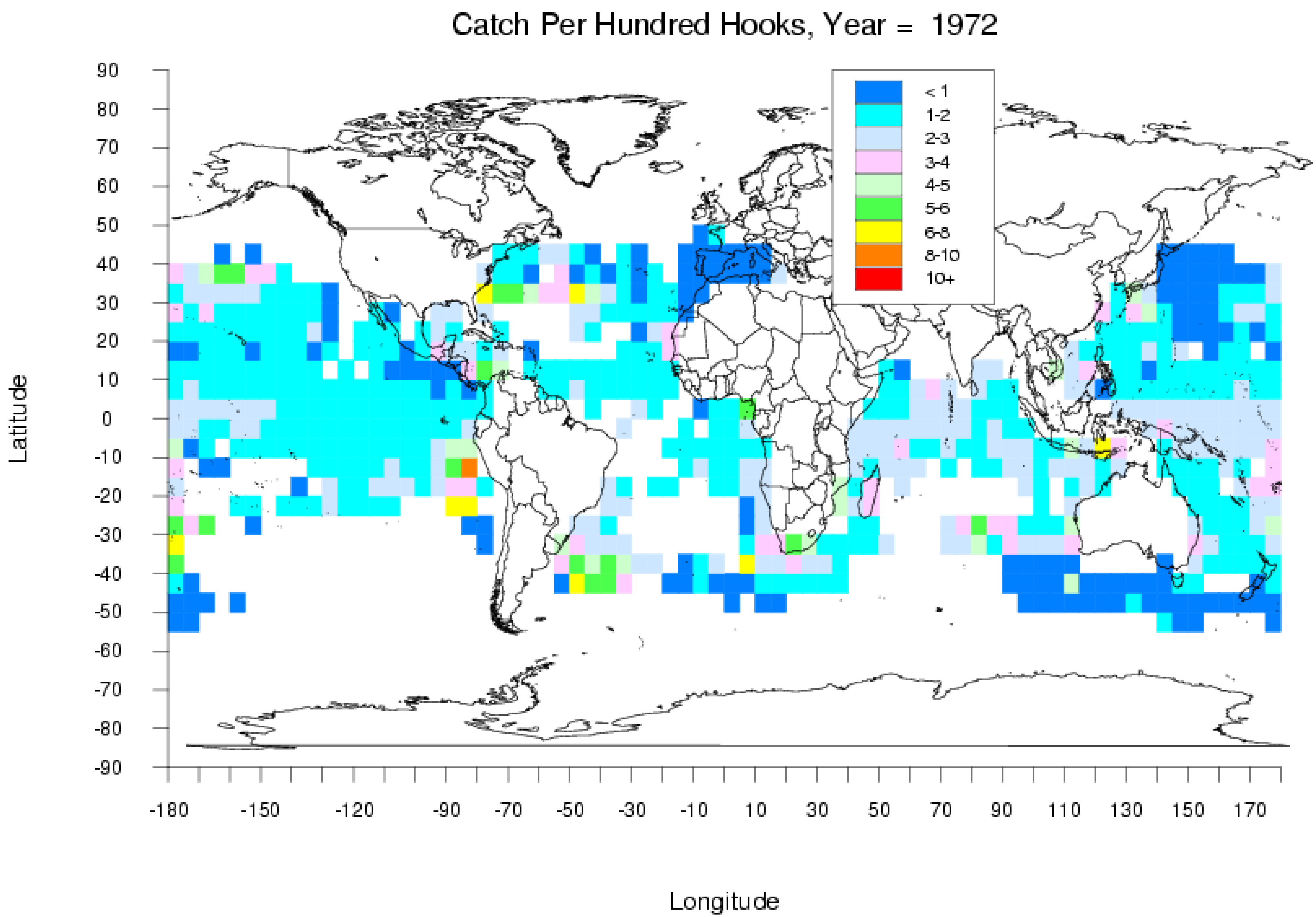
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1971
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170


Catch Per Hundred Hooks, Year = 1972
Latitude
Longitude
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
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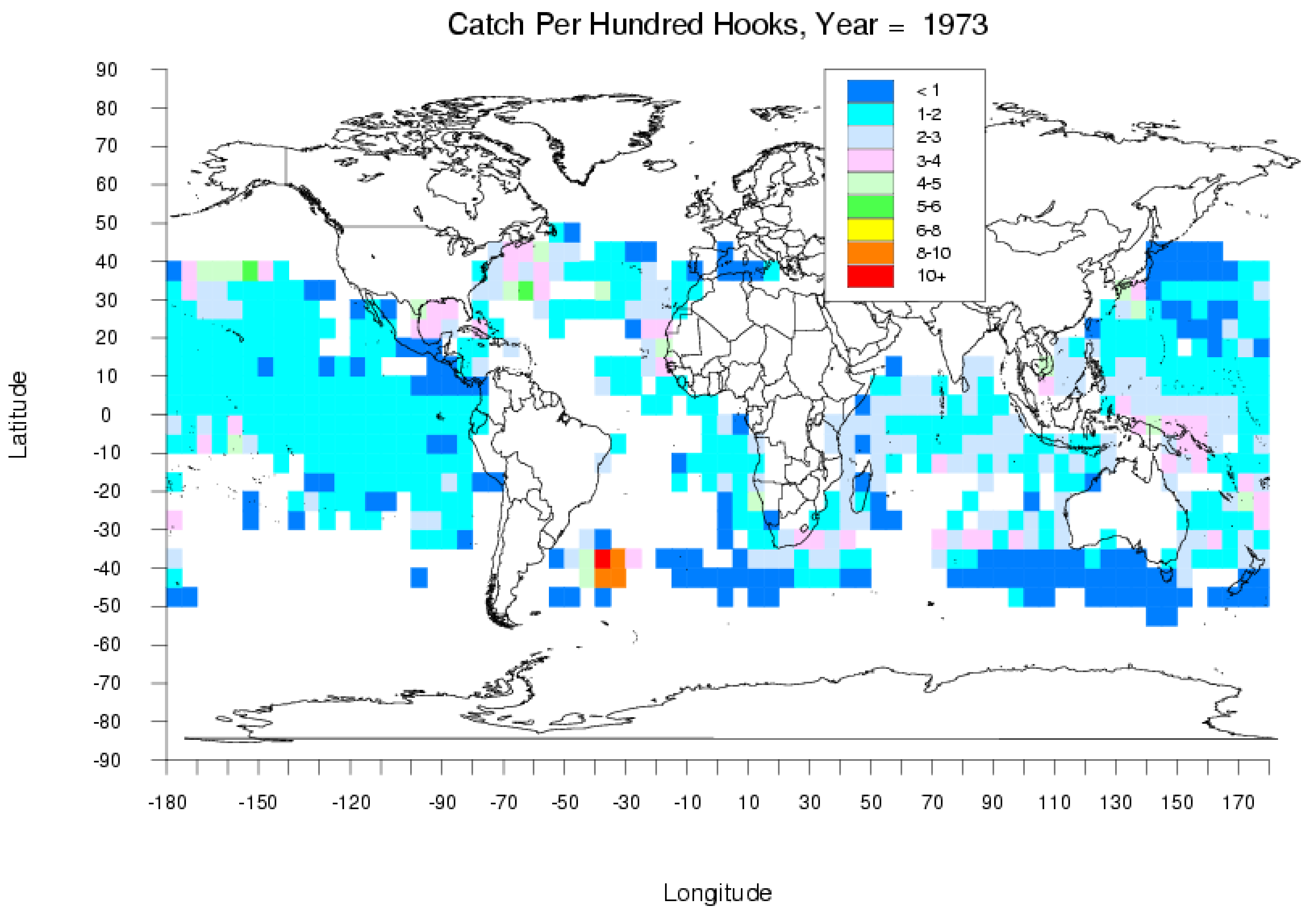
70
90
110
130
150
170


Catch Per Hundred Hooks, Year = 1973
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
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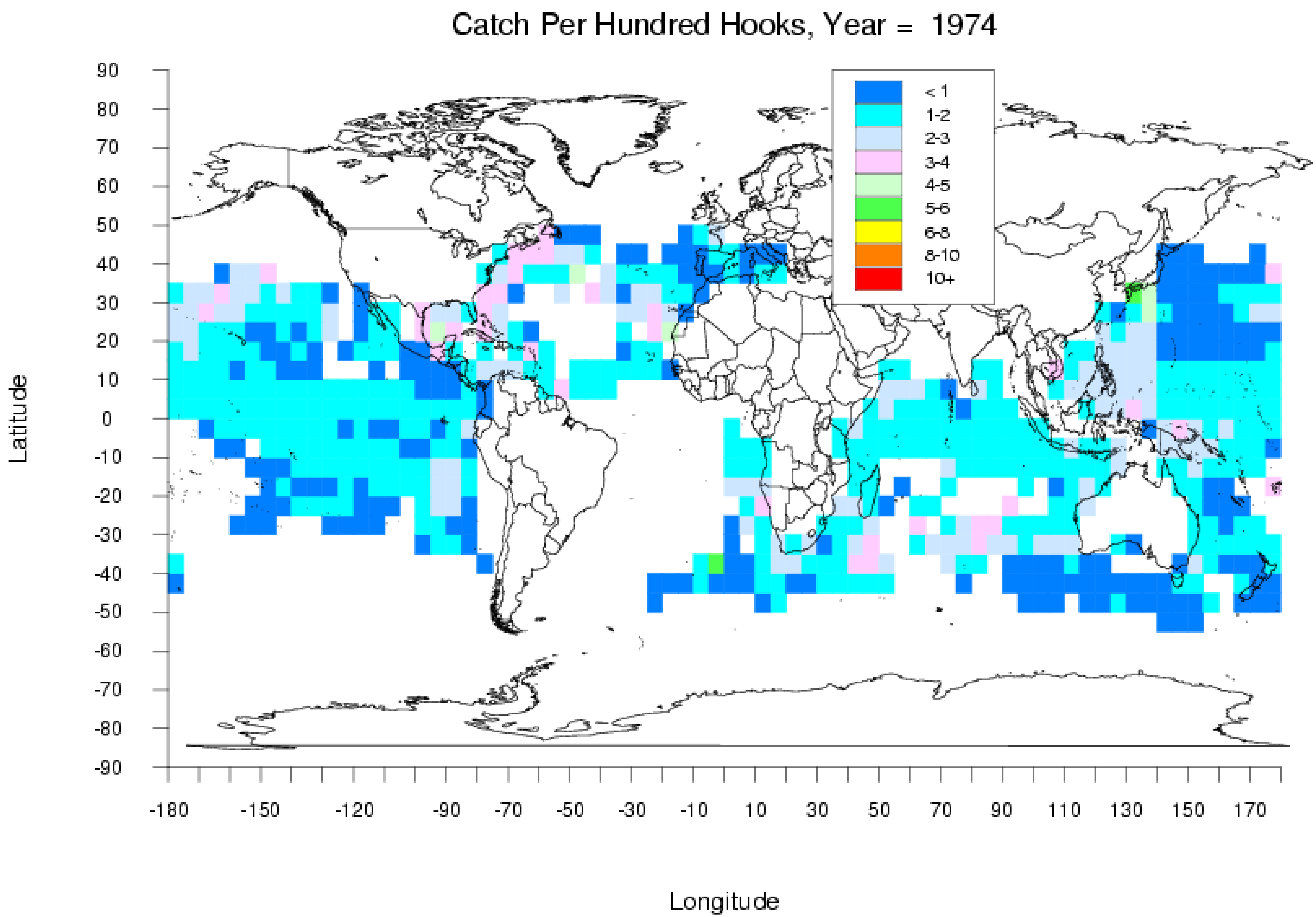
150
170


Catch Per Hundred Hooks, Year = 1974
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
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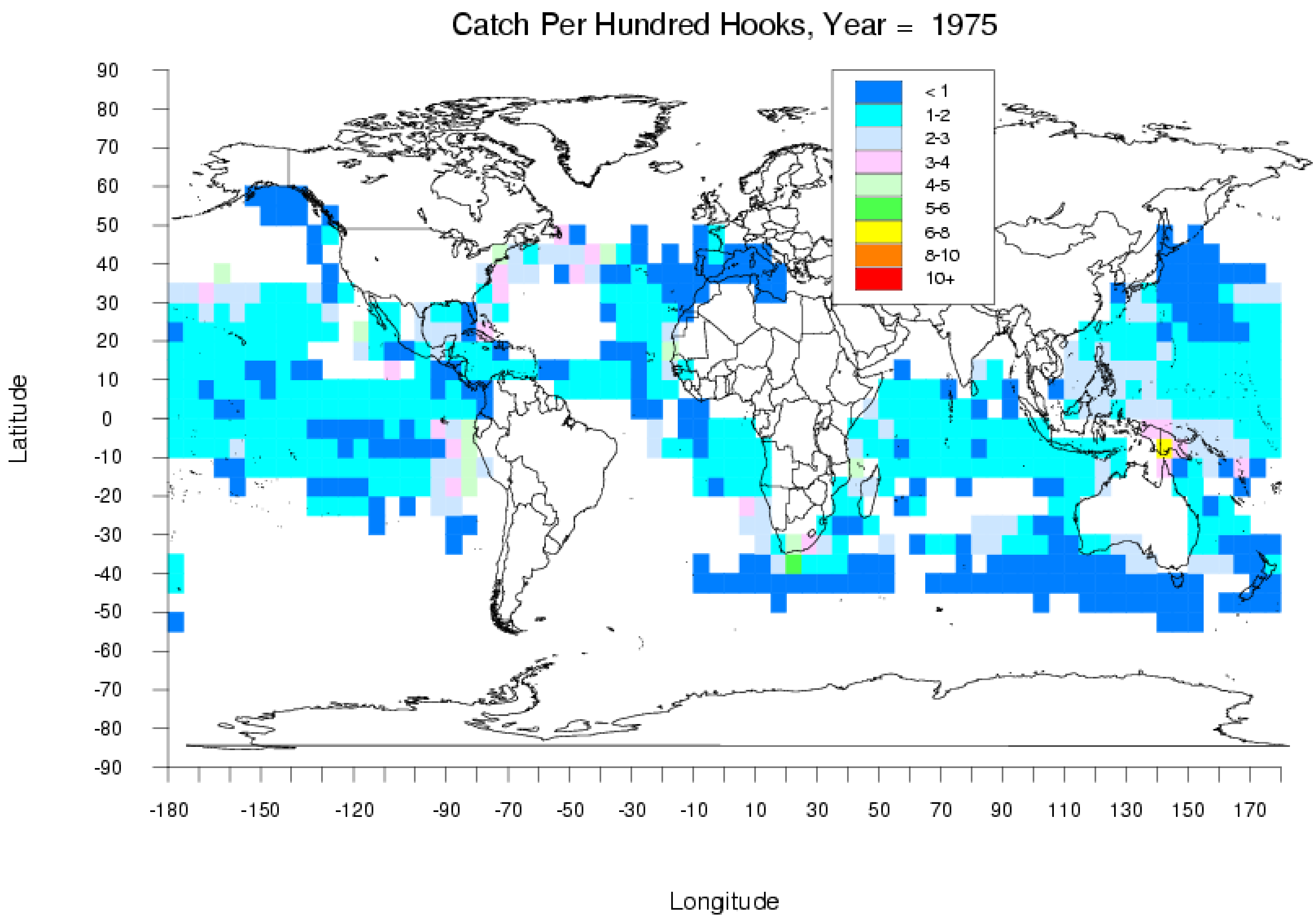
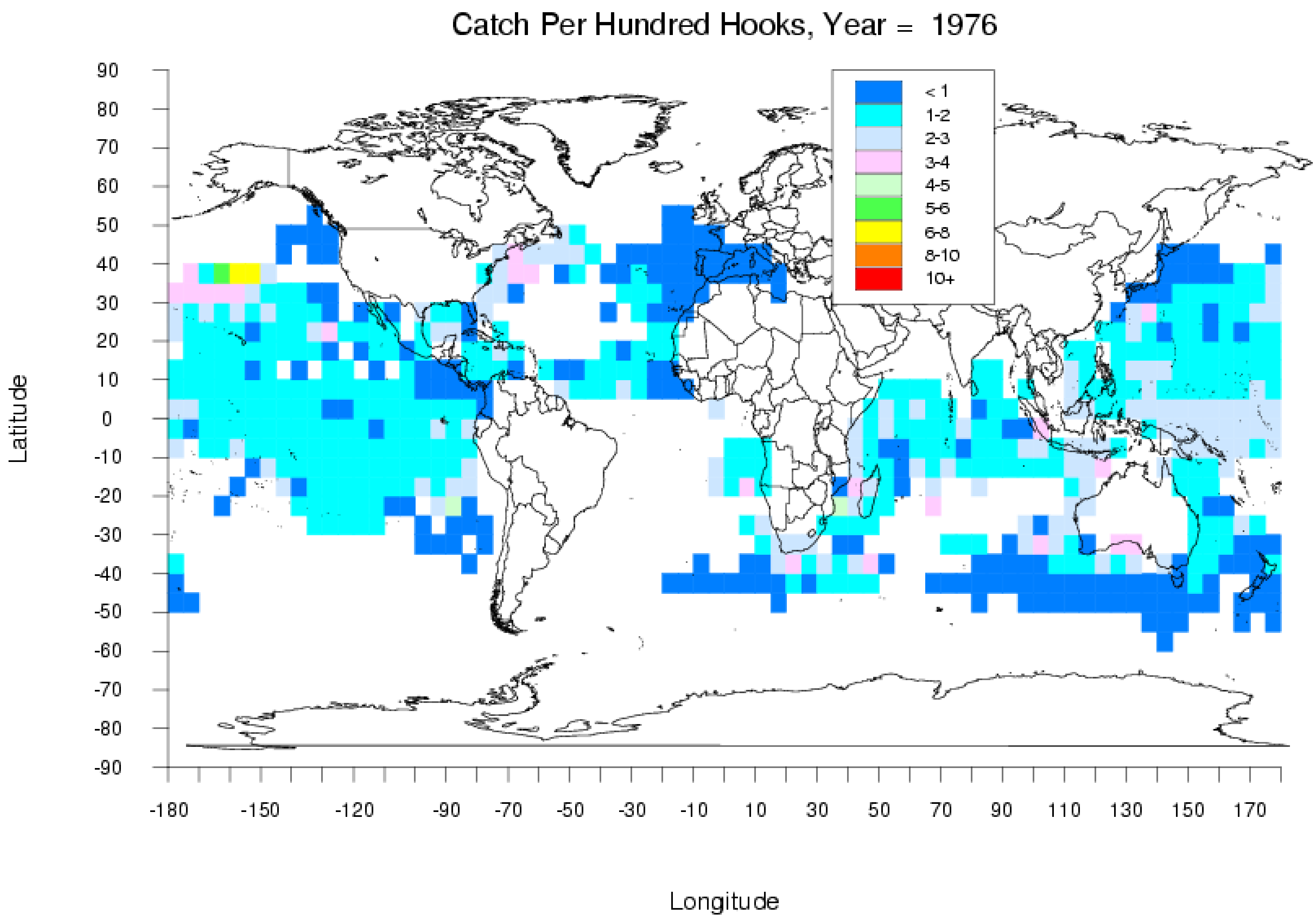
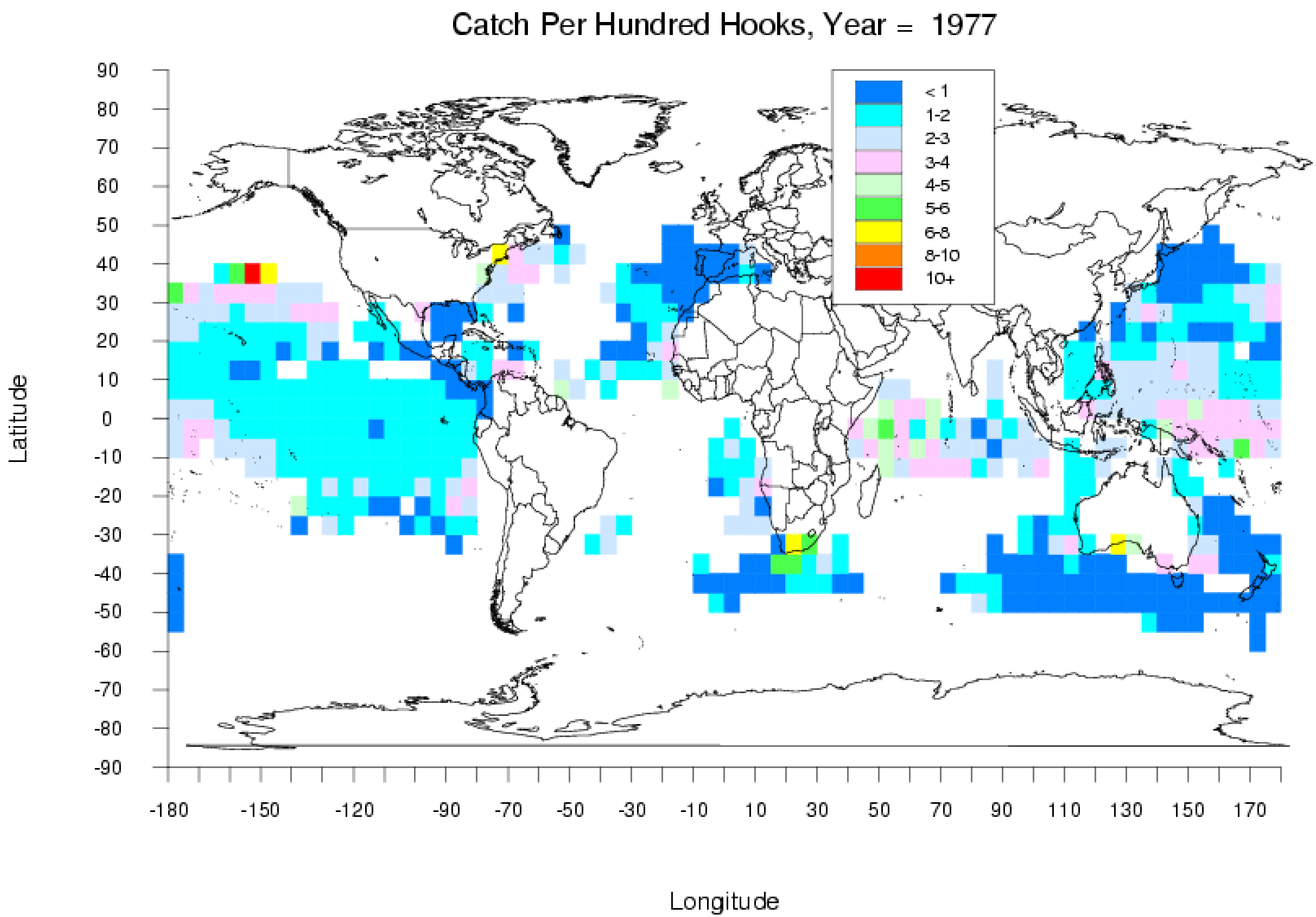
90
110
130
150
170

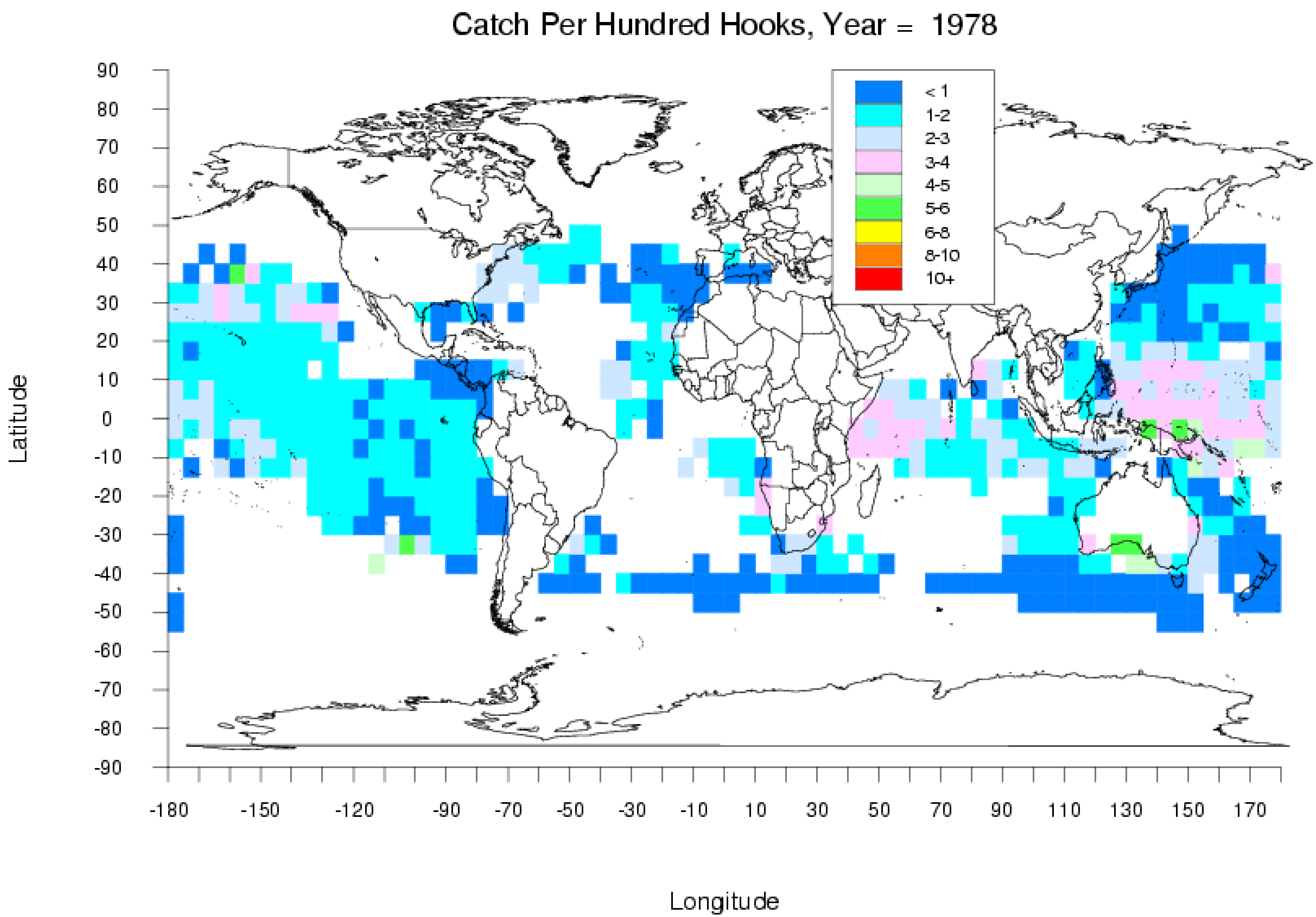


Catch Per Hundred Hooks, Year = 1975
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+

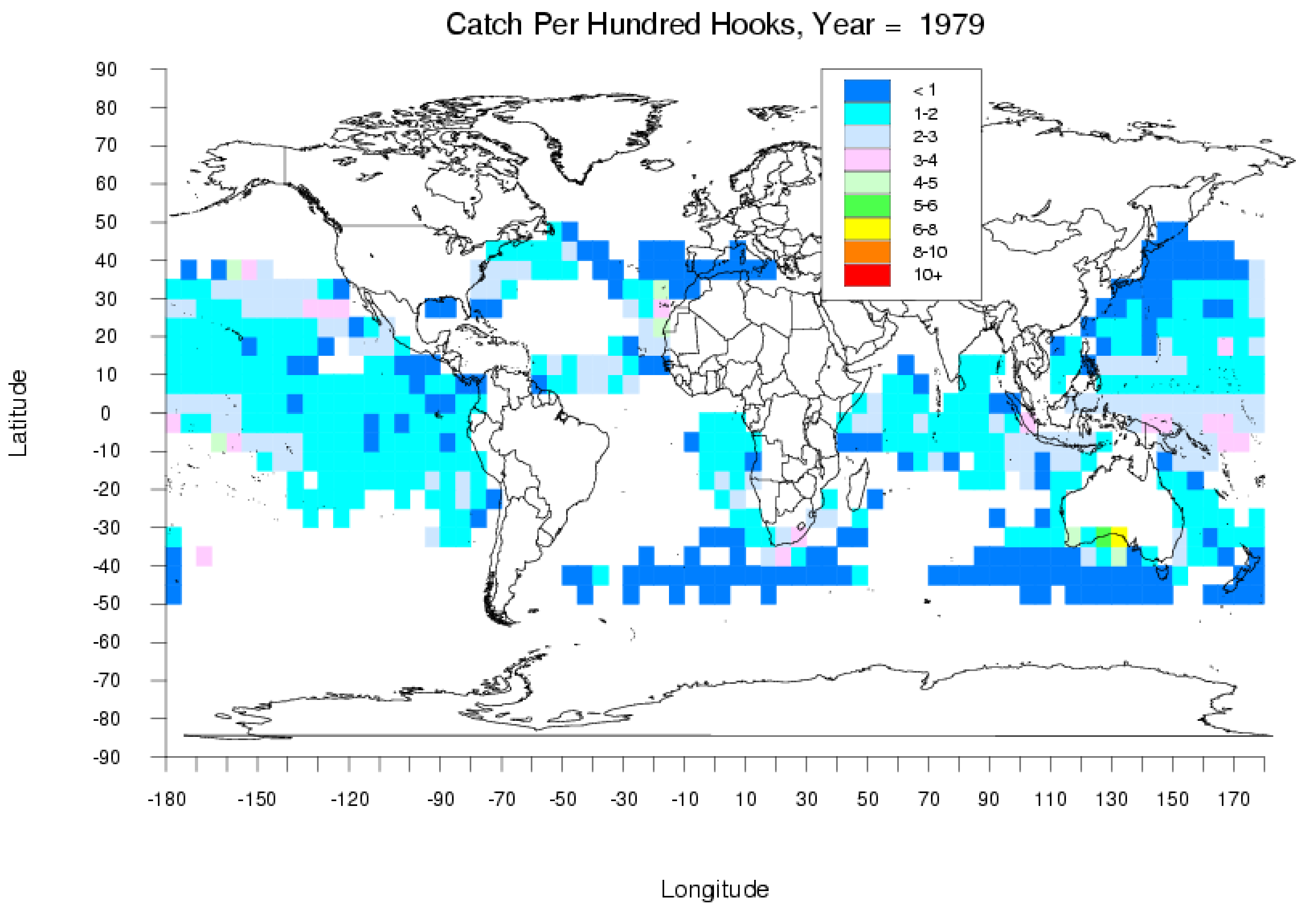


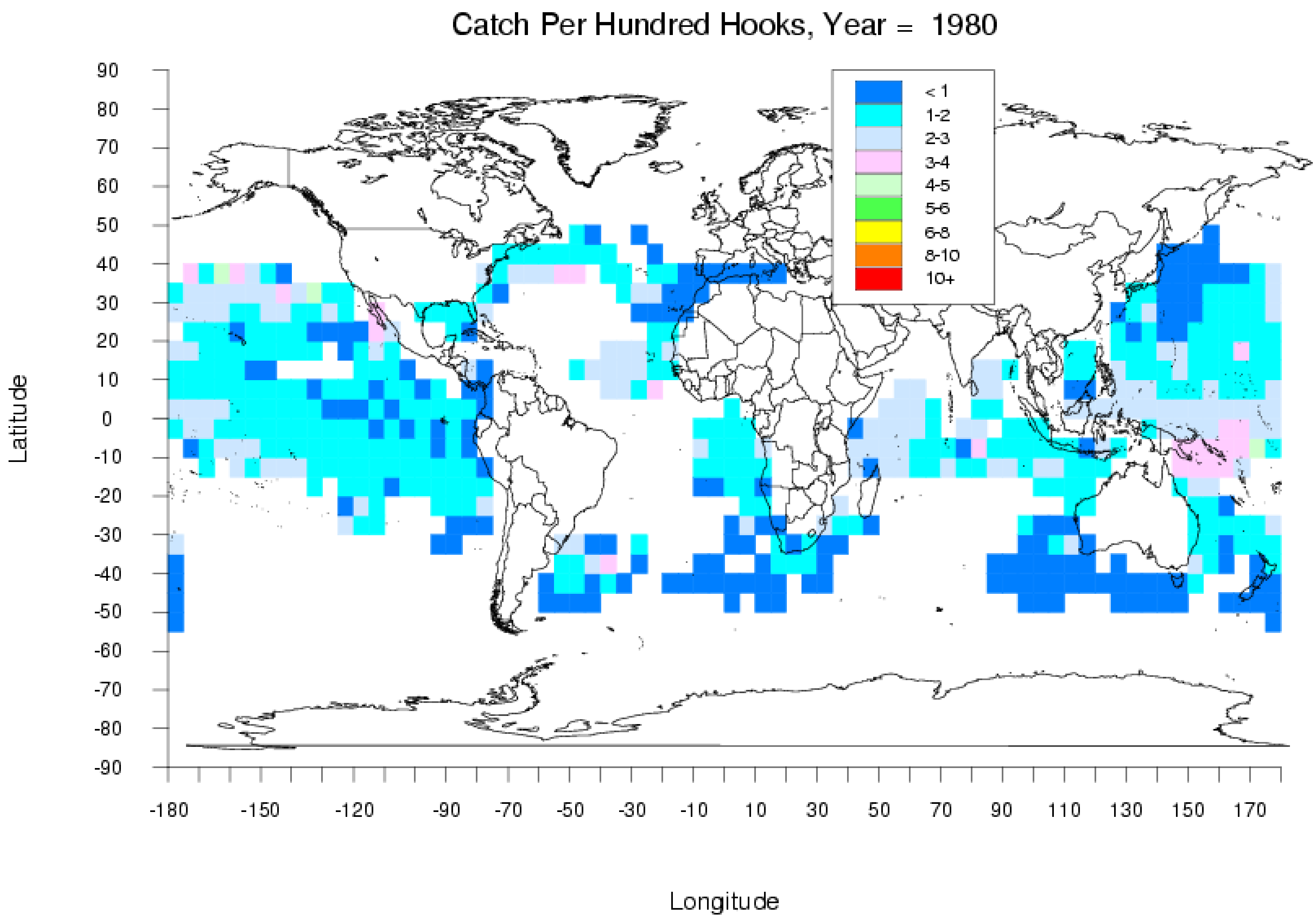
Catch Per Hundred Hooks, Year = 1976
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude


Catch Per Hundred Hooks, Year = 1977
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170



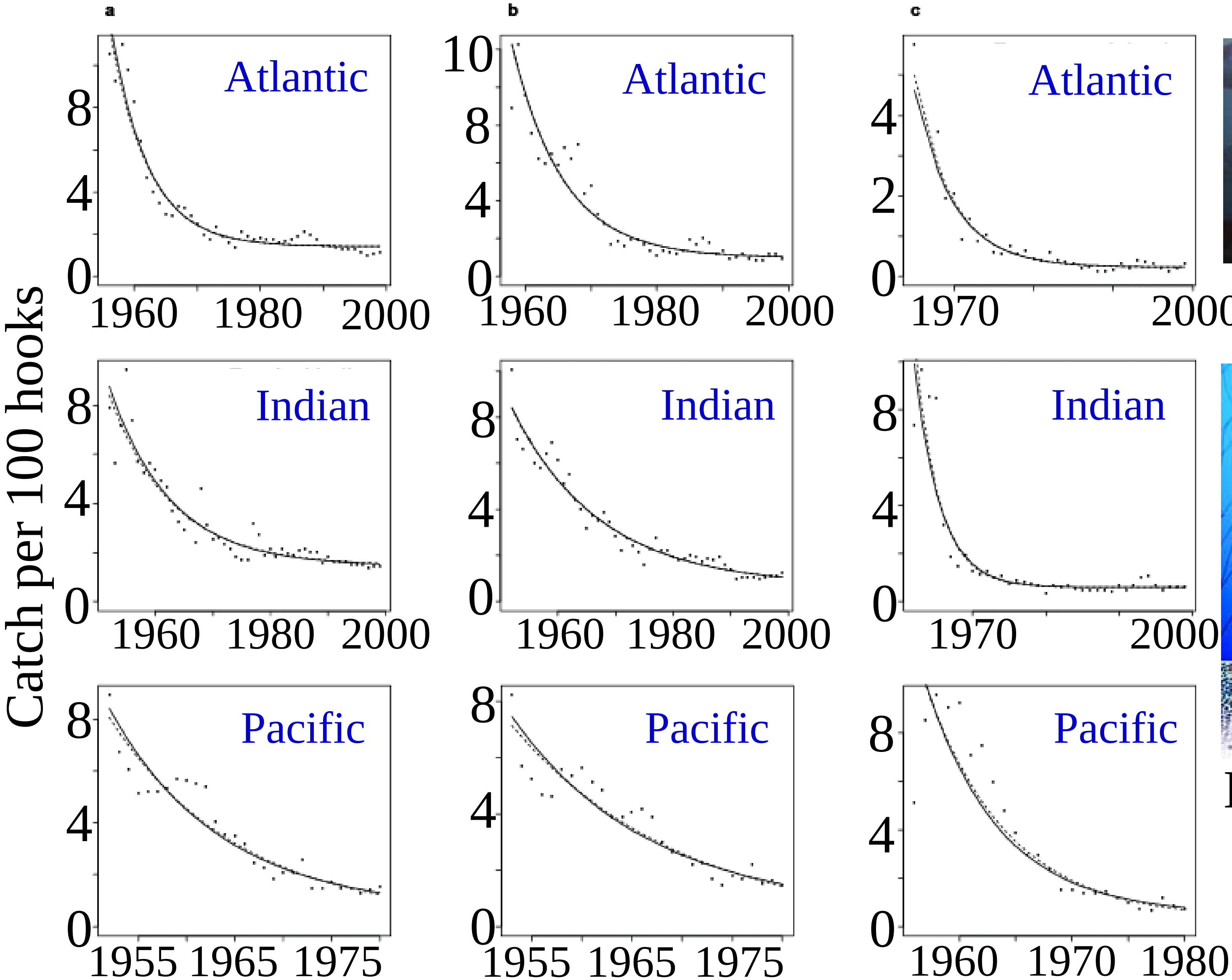
Catch Per Hundred Hooks, Year = 1978
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Latitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude


Catch Per Hundred Hooks, Year = 1979
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

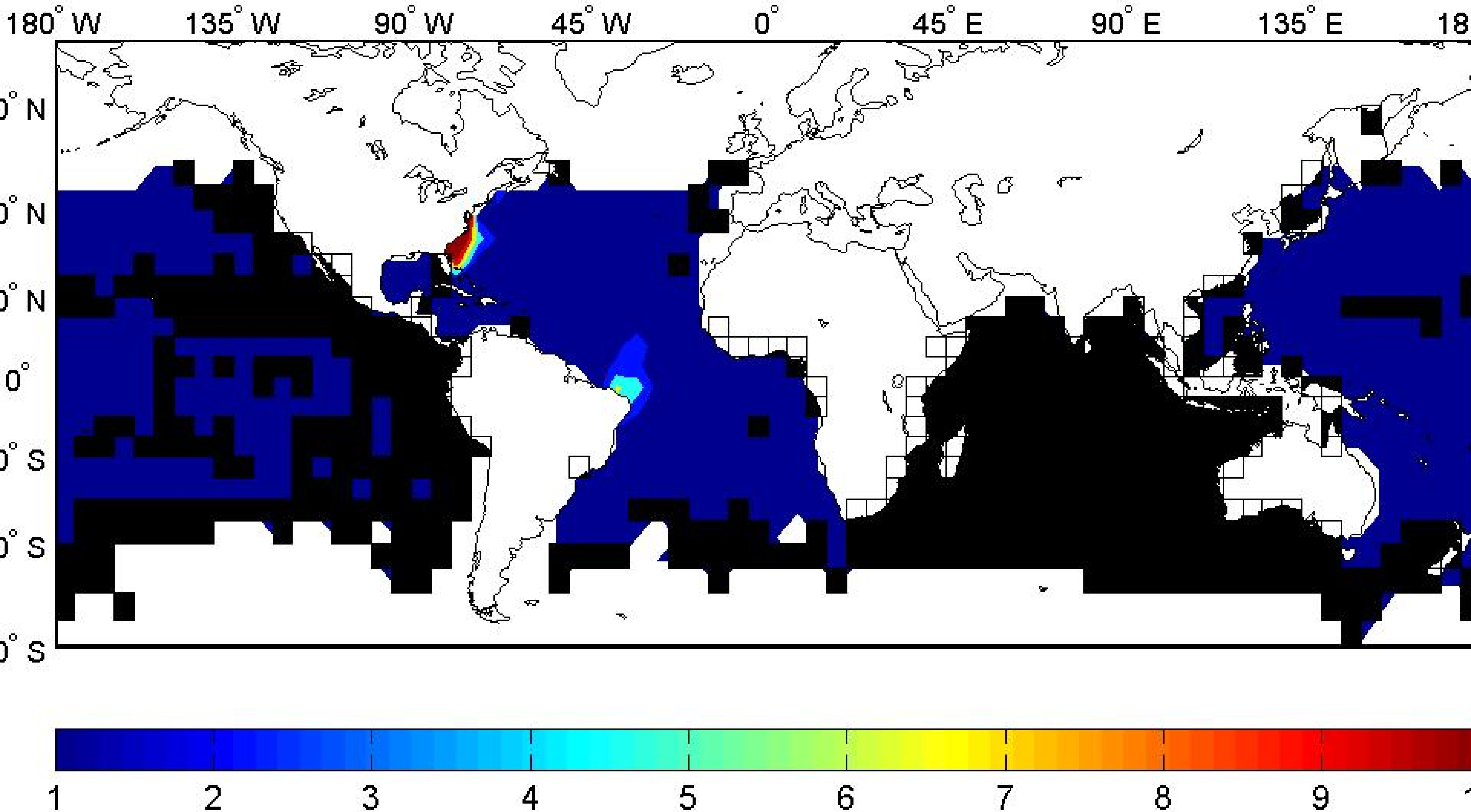


Catch Per Hundred Hooks, Year = 1980
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Latitude
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude

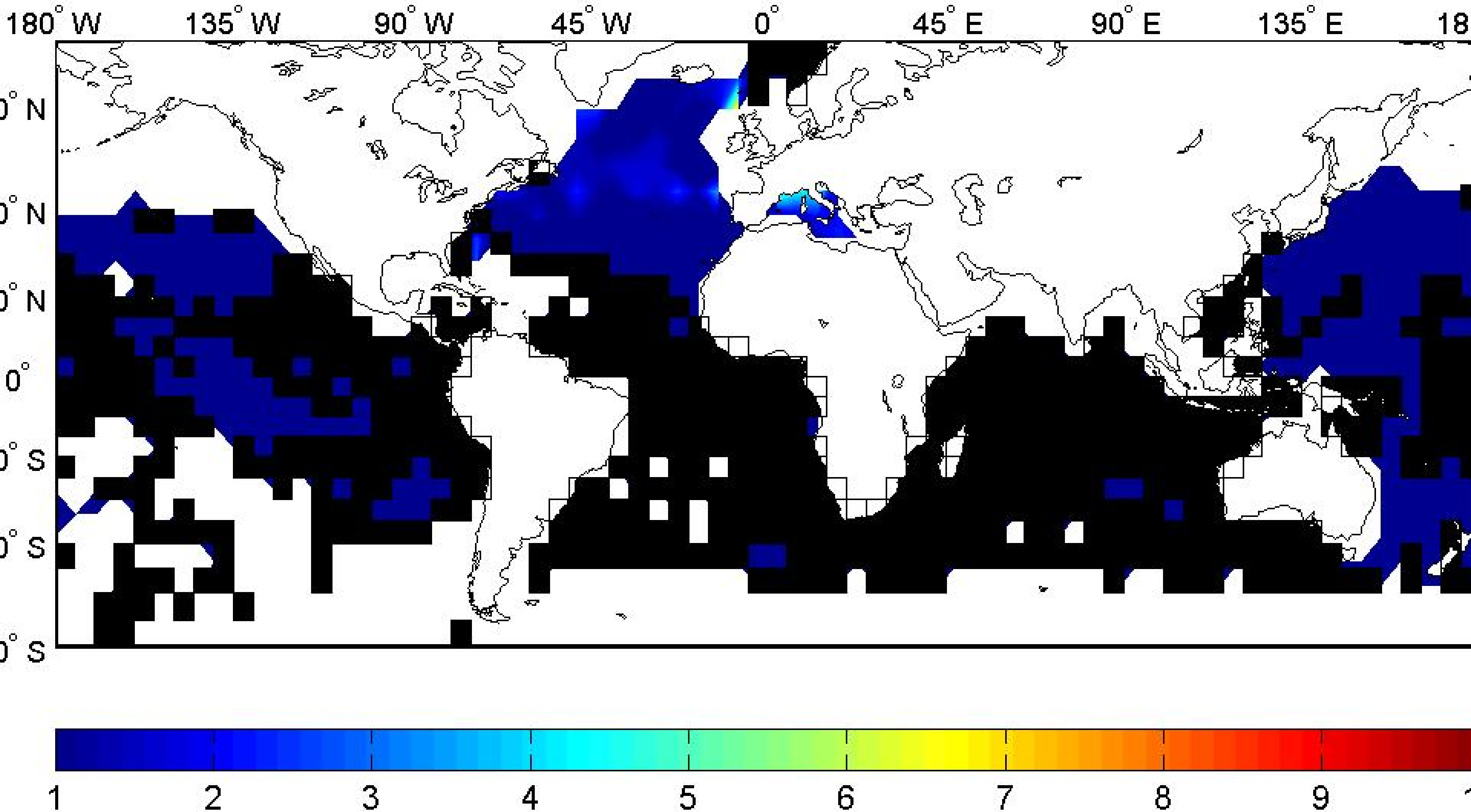
Common patterns of decline



Myers and Worm (2003)



Bluefin Tuna / 1000 hooks 1960

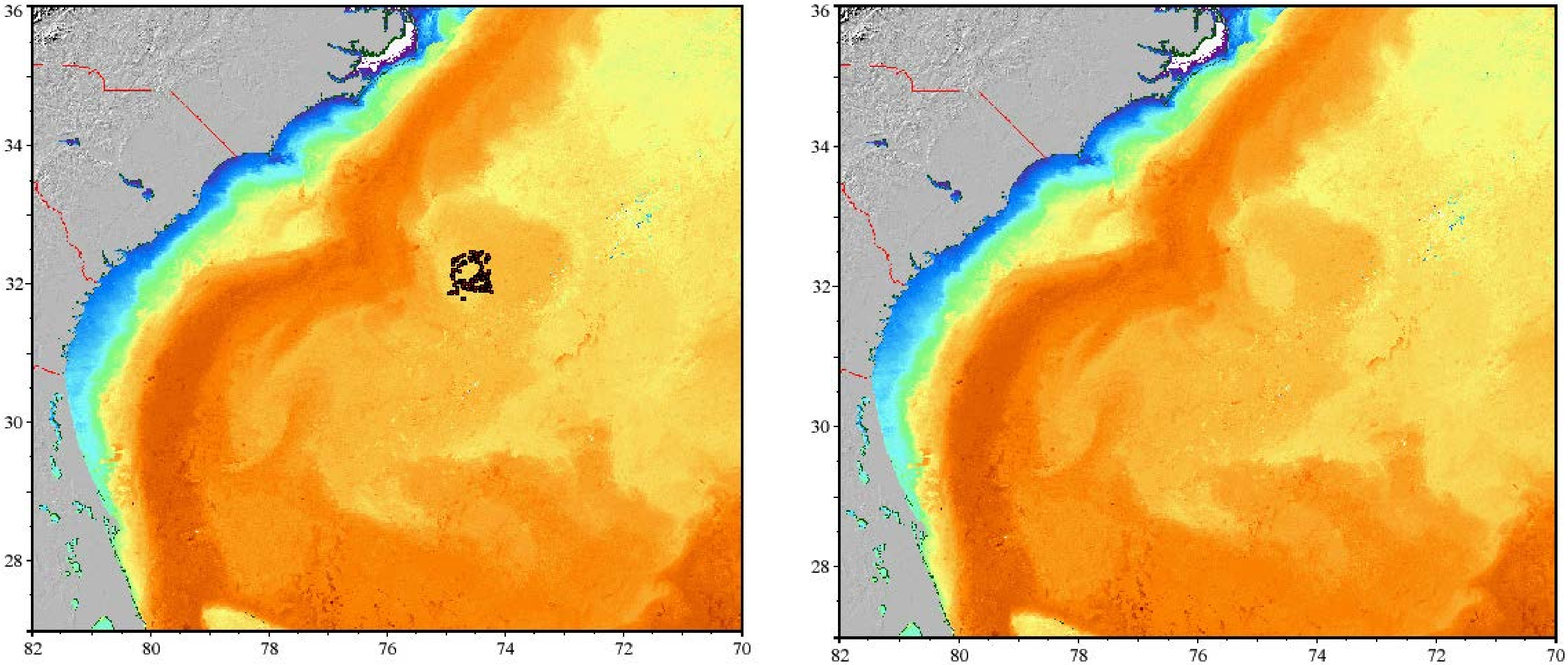


Bluefin Tuna / 1000 hooks 1990

Totally Stupid Reasons for not Believing the Obvious

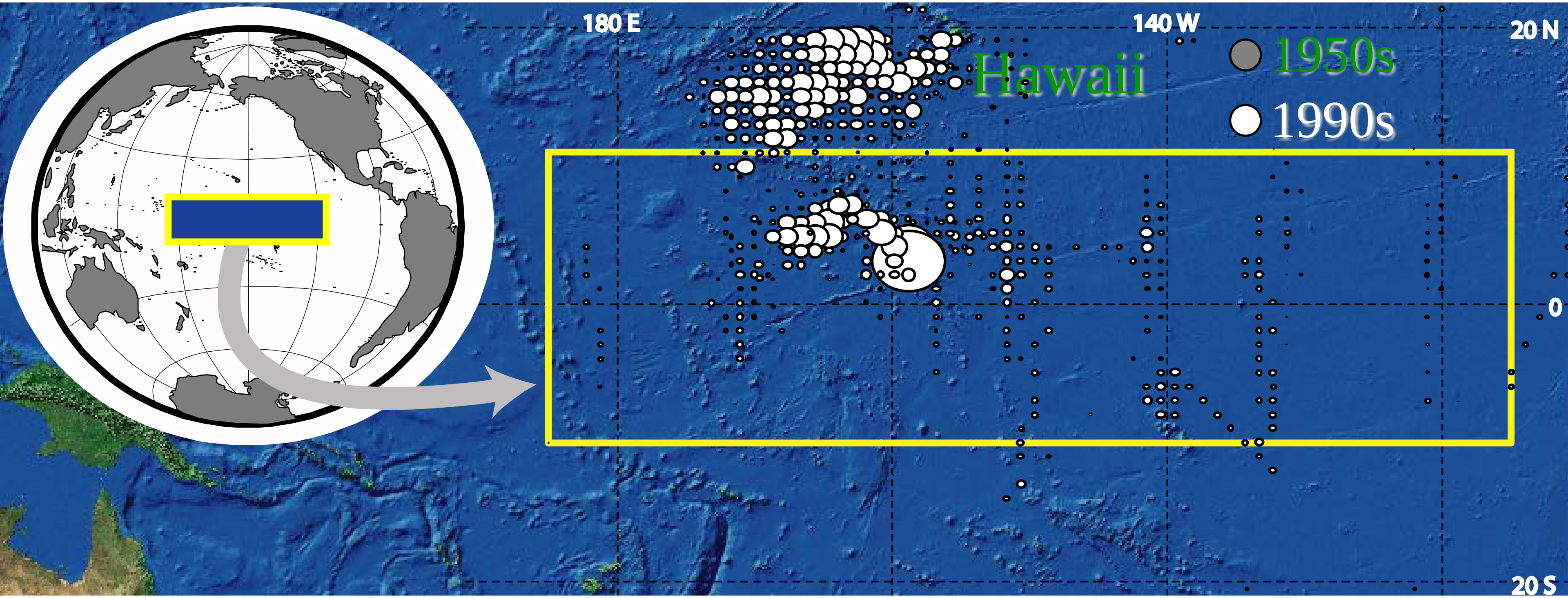
- You ignore research surveys.
- Removing Large Predators Couldn’t Possibly Affect Survival of Other Fish.
- Fishing Couldn’t Possibly Affect the Size of Tuna.
- Fishermen are so stupid they cannot use satellite data to find tuna.
- Fishermen are so stupid that they don’t improve their gear.

These estimates are conservative: Fishermen are smarter (GPS, satellite information, **ACDP** (Acoustic Current Doppler Profiler)).

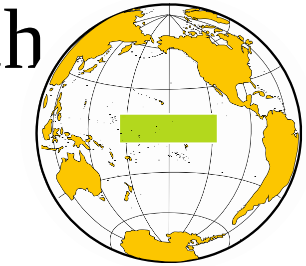


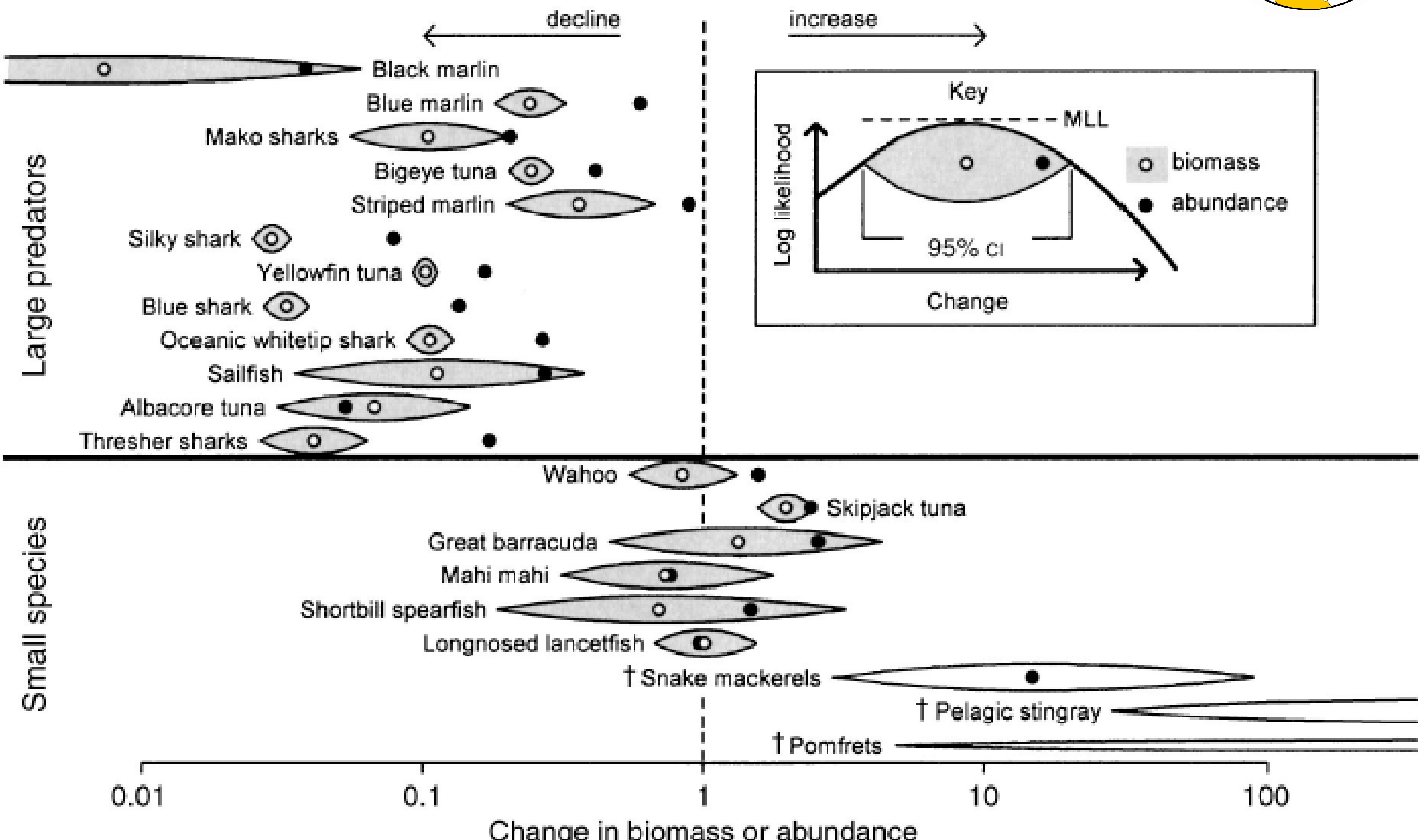
Locations of a leatherback turtle over a two week period tagged by my student Mike James that maintains its position within a cold core ring (somehow).

Study area



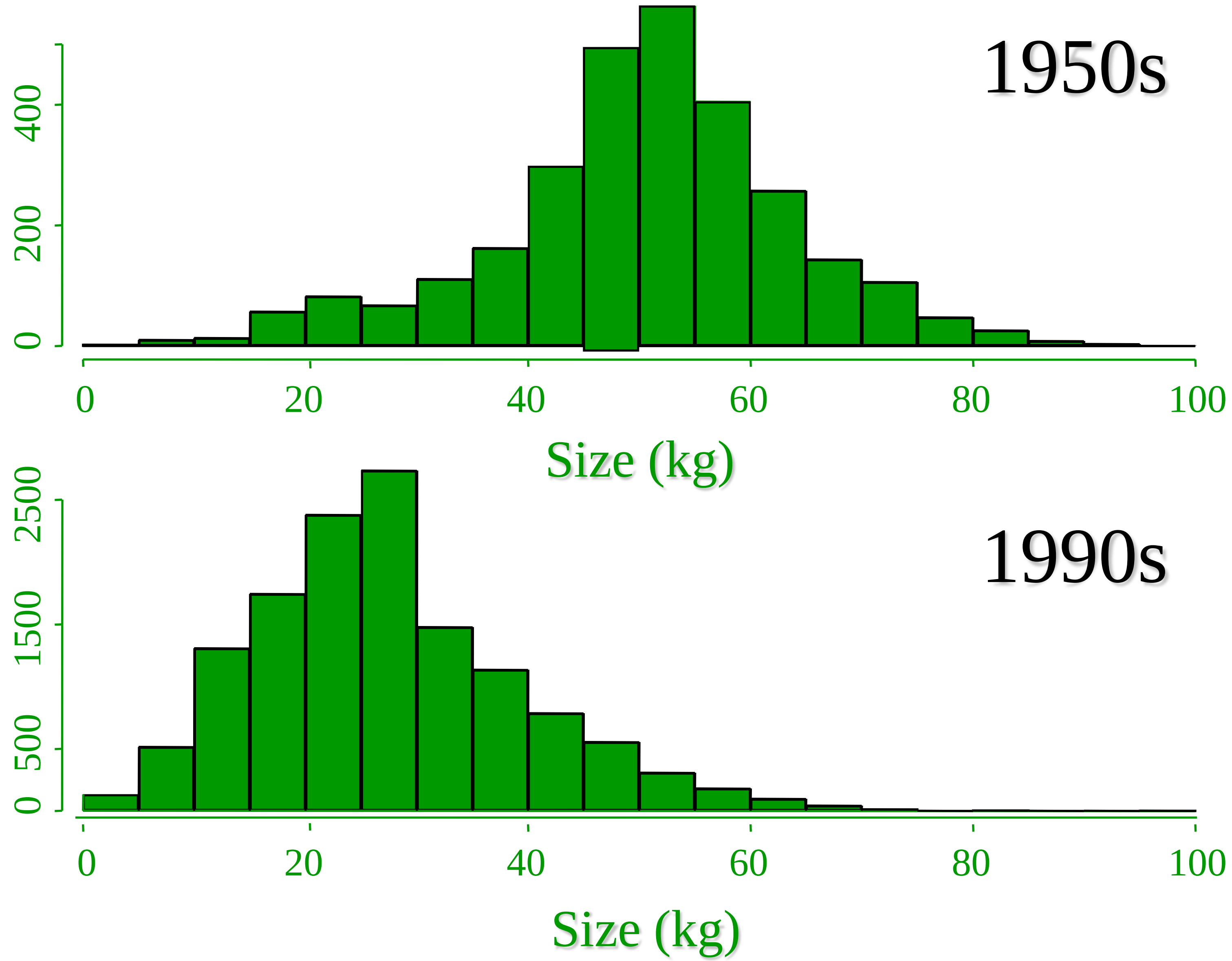
Analysis repeated using independent research data





Ward and Myers 2005 Ecology

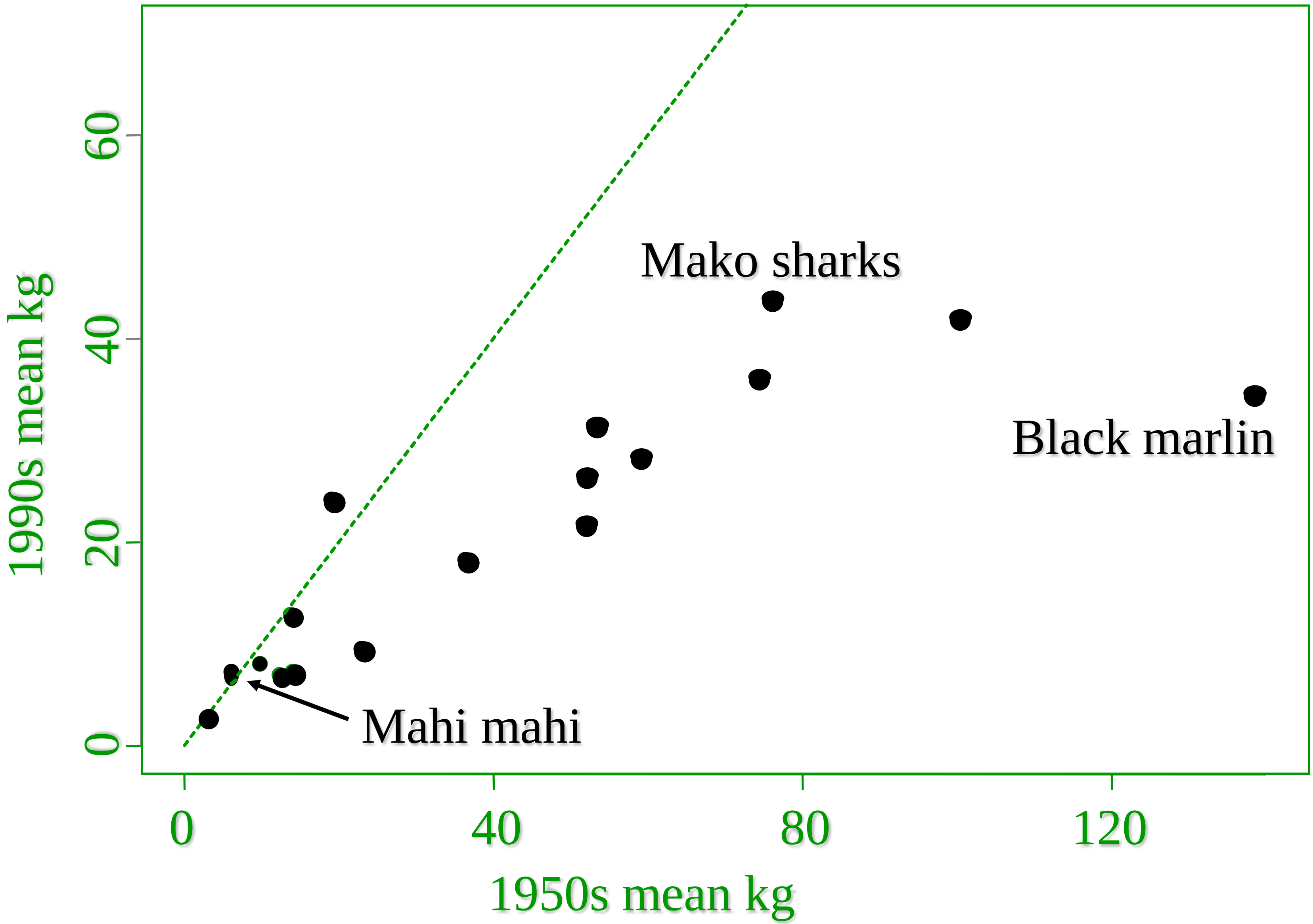
These estimates are conservative: 2 (fish are smaller)



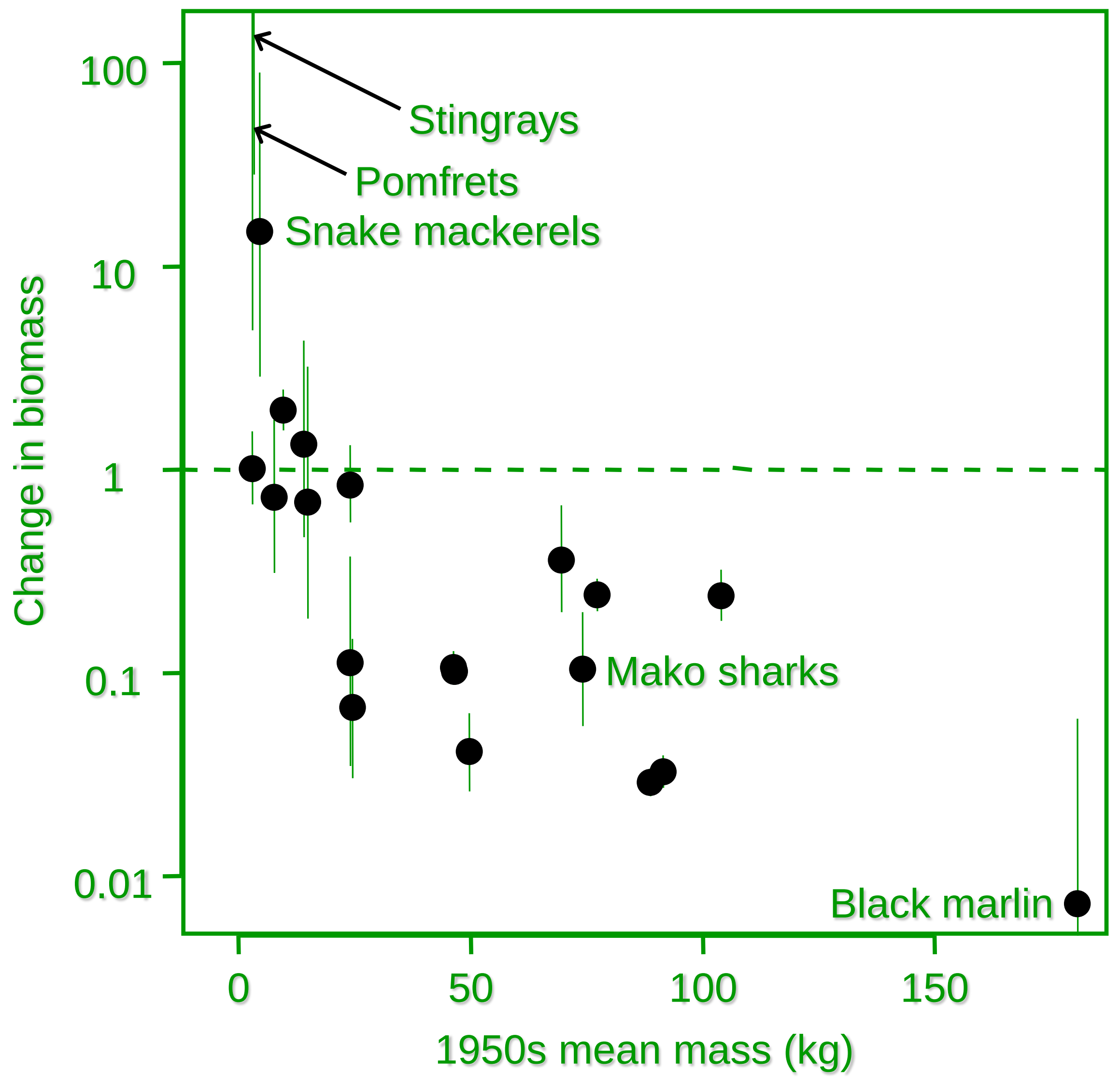
Yellowfin tuna – equitorial Pacific

Ward and Myers 2005 Ecology

Change in body size



Ward and Myers 2005 Ecology

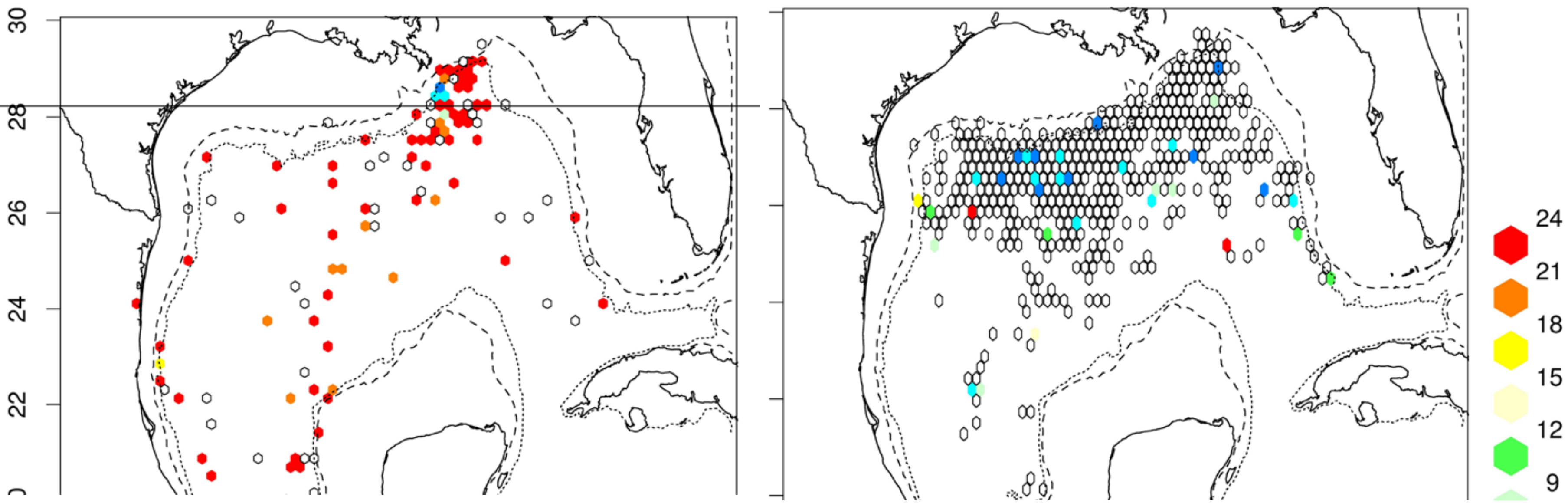


Ward and Myers 2005 Ecology

Loss of sharks in the Gulf of Mexico

300 fold decline – no one noticed

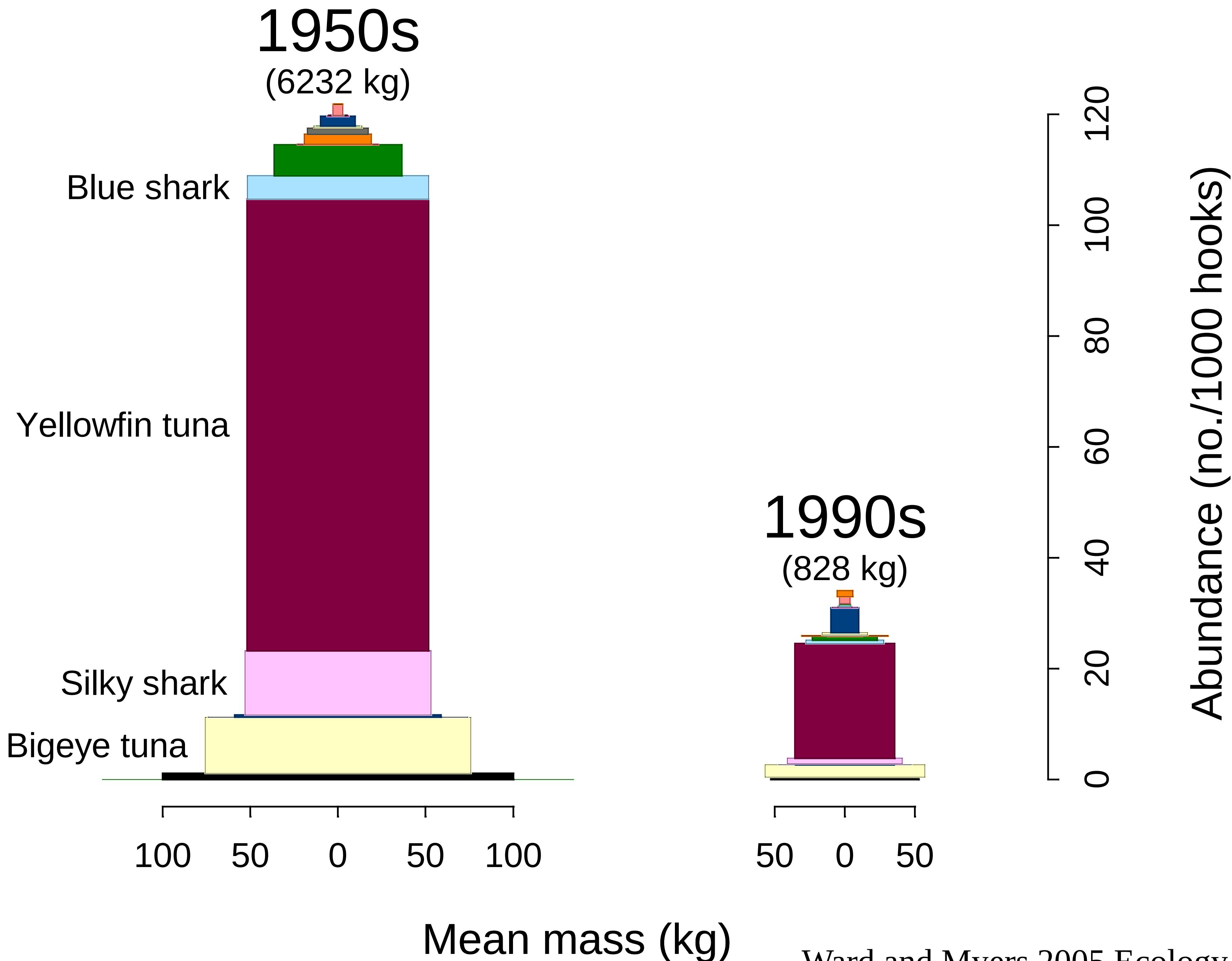
[redacted]



1950's 1990's

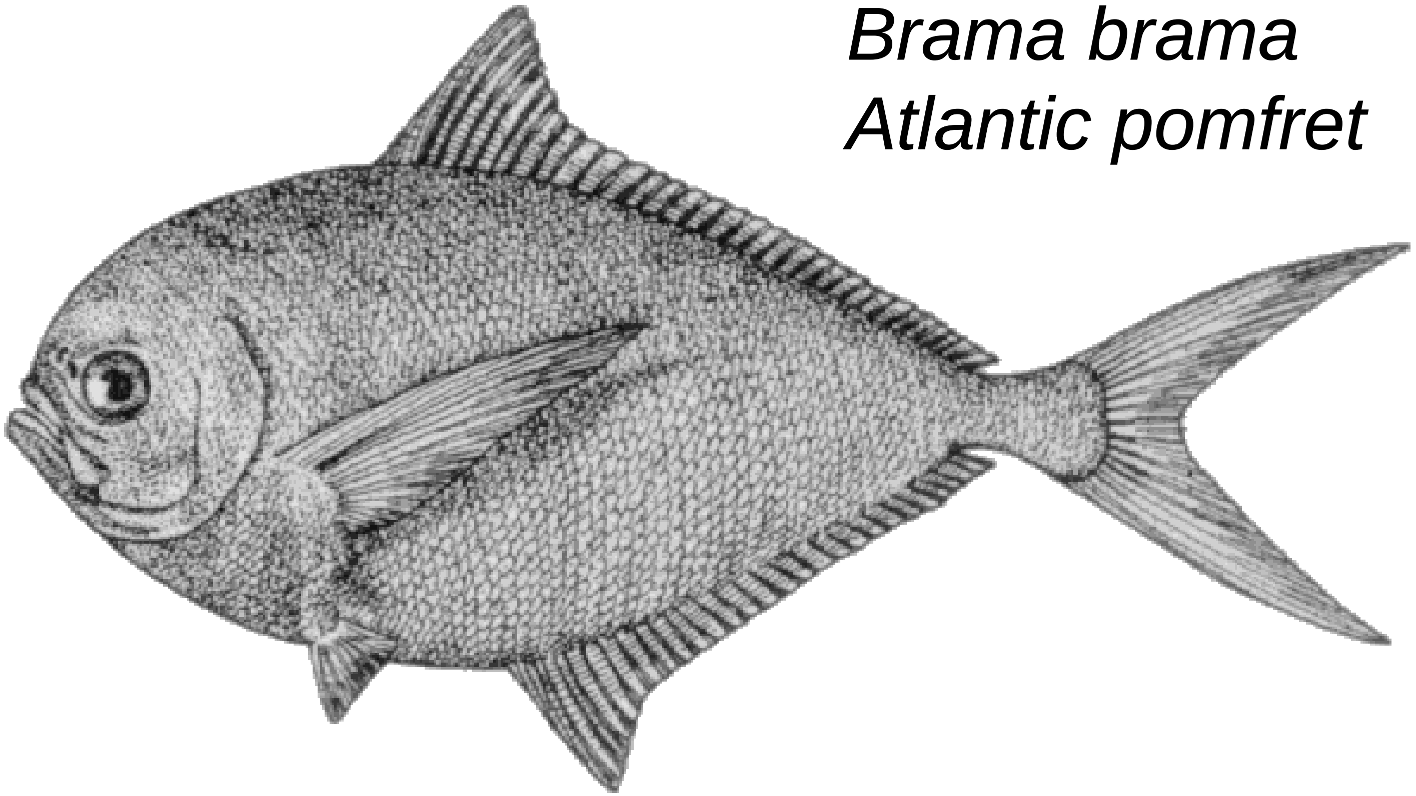
Oceanic Whitetip captures per 10,000 hooks

Many thanks to NMFS for data and advice



Ward and Myers 2005 Ecology

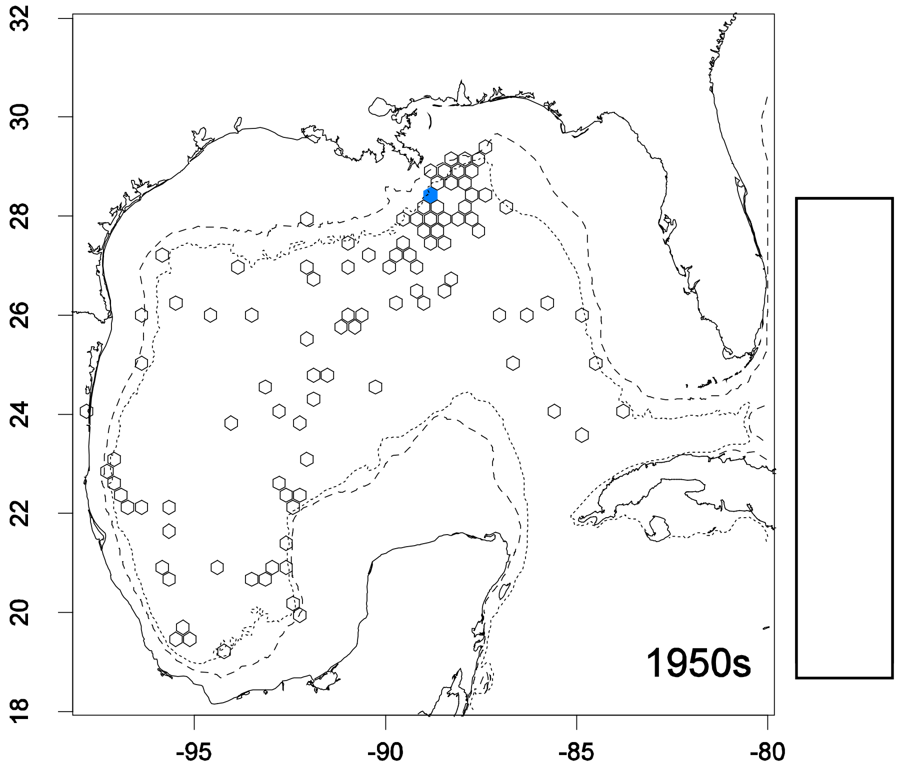
What about prey fish?

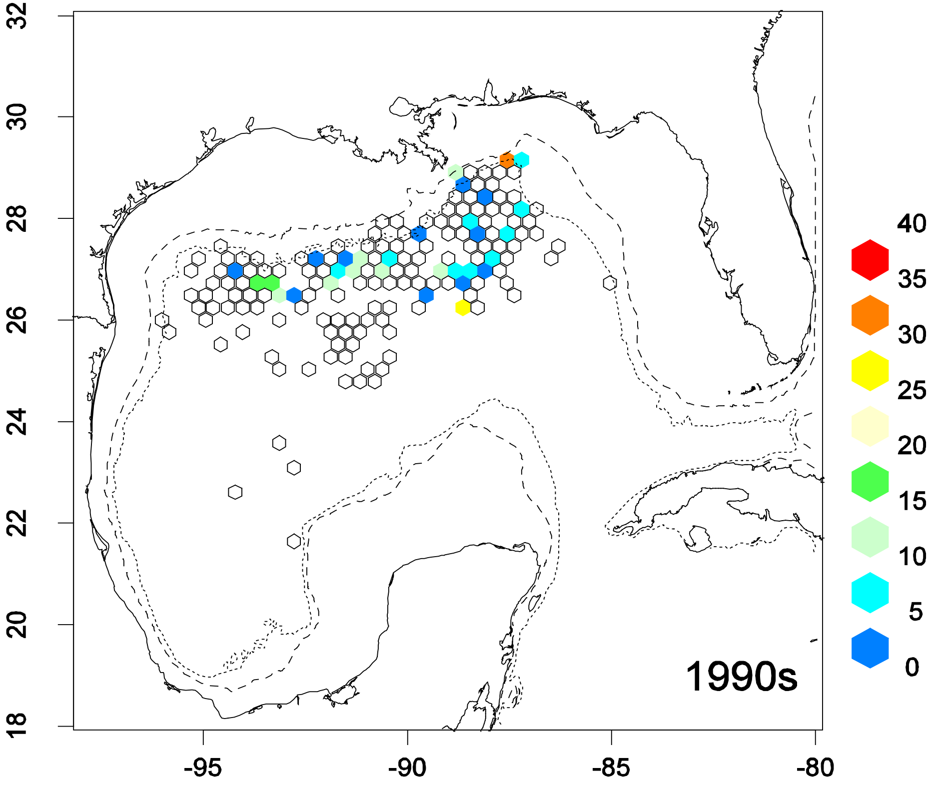


Brama brama
Atlantic pomfret

Illustration taken from the book "Encyclopedia of Canadian Fishes" by Brian W. Coad with Henry Waszczuk and Italo Labignan, 1995,

Explosion of Pomfrets in the Gulf of Mexico
~1000 fold increase – no one noticed



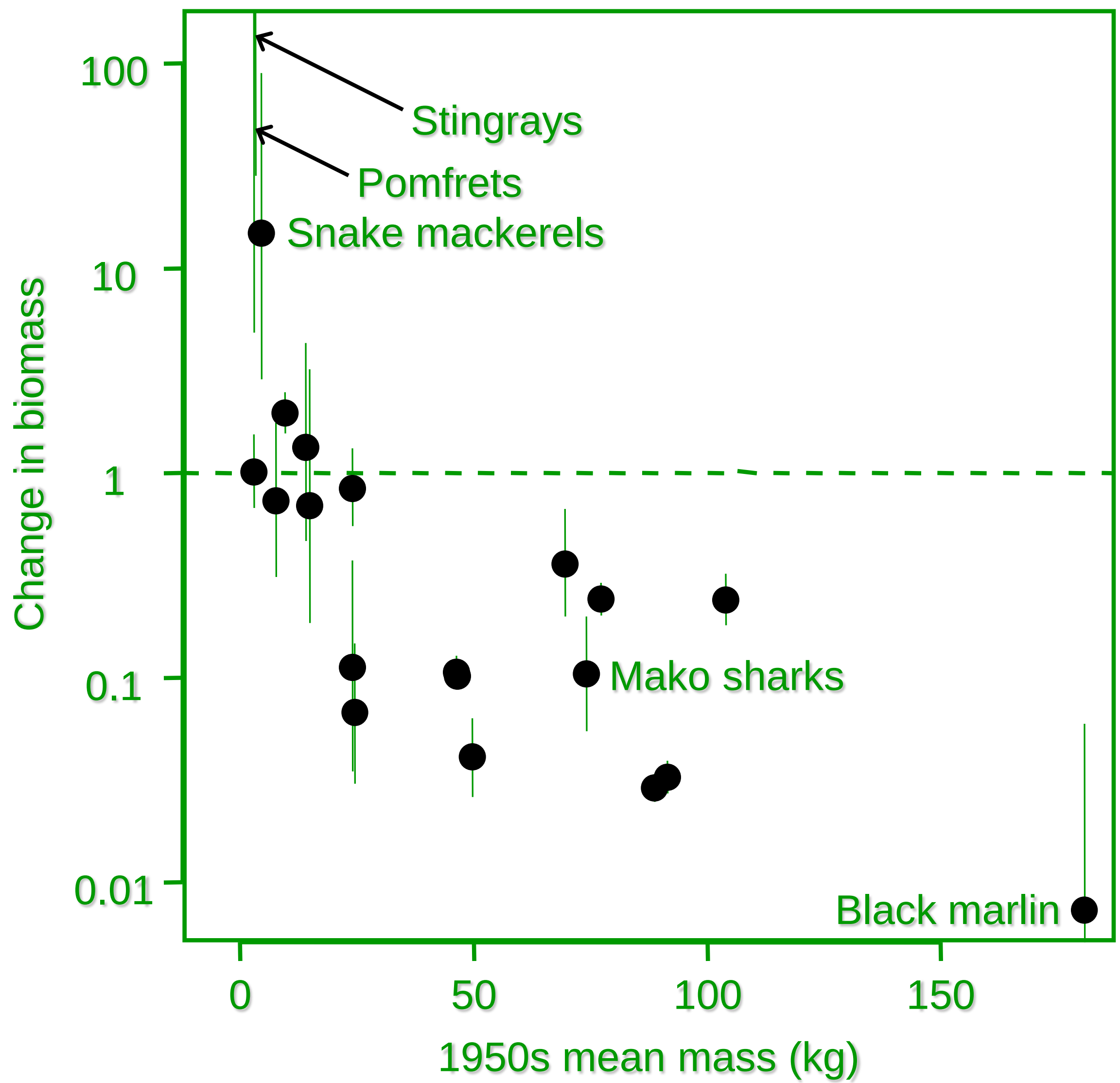


1950's

1990's

Pomfret captures per 10,000 hooks

Many thanks to NMFS for data and advice



Stingrays
Pomfrets
Snake mackerels
Mako sharks
Black marlin
100
10
1
0.1
0.01
Change in biomass
0
50
100
150
1950s mean mass (kg)

Global changes in species diversity

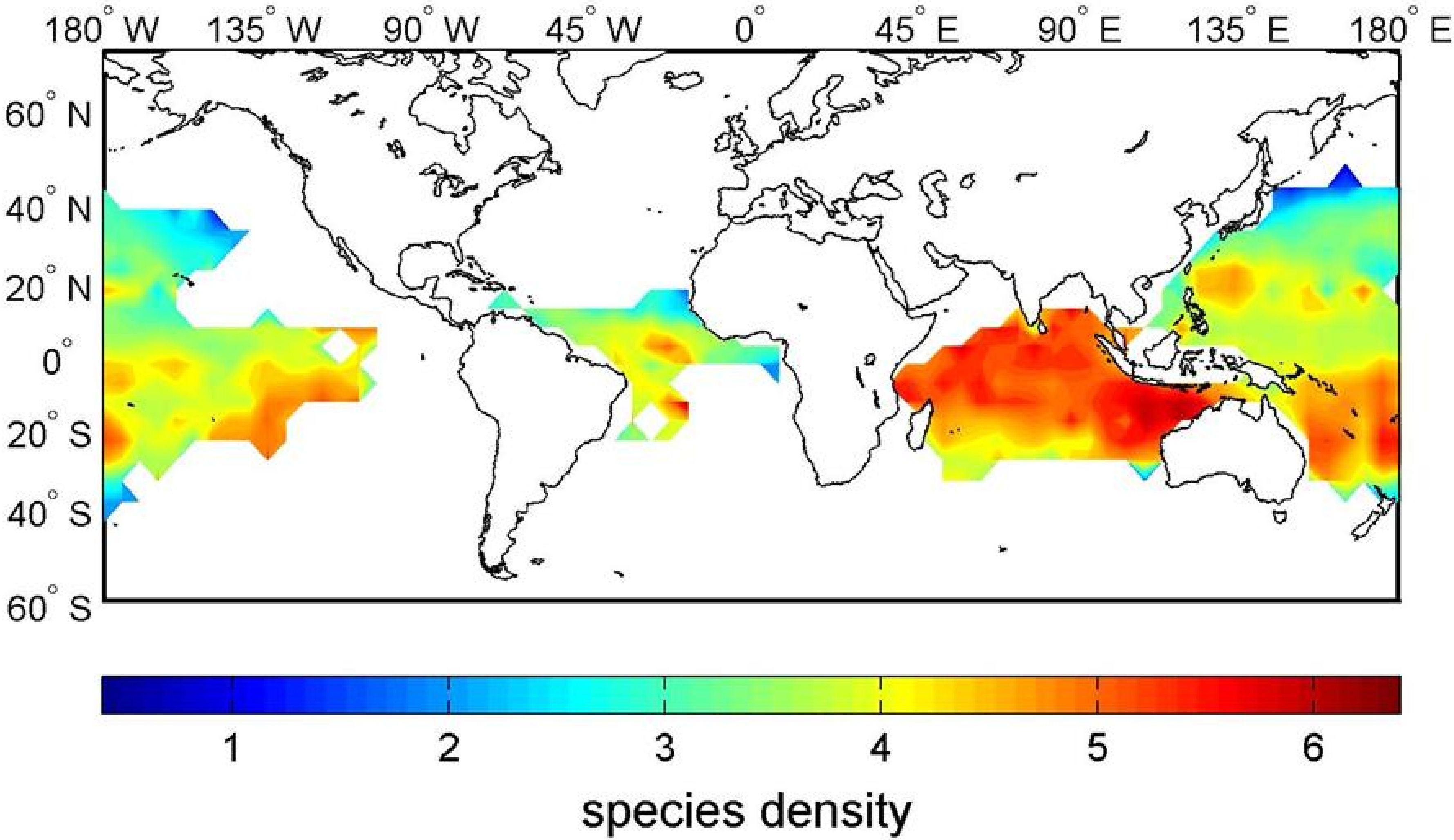
joint work with Boris Worm
Dalhousie University

Loss of species density per decade

- Displayed is the number of tuna and billfish species that are found on a standard longline with 1000 hooks
- The time series runs from 1952-1999
- It shows how large hotspots are disappearing over time and how few concentrations of diversity remain today

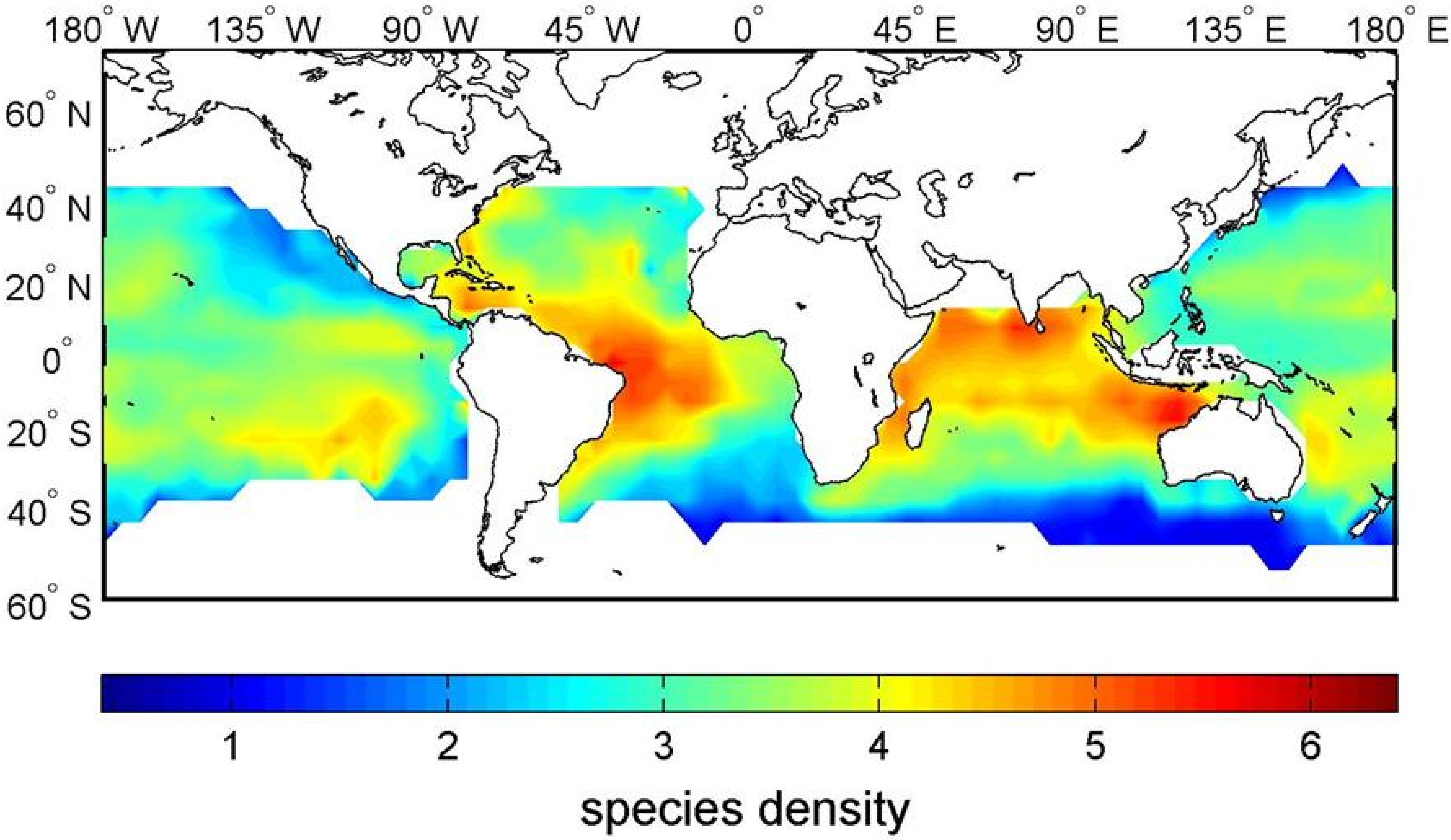
After data from: Worm B, Sandow M, Oschlies A, Lotze HK, Myers RA (2005) Global patterns of predator diversity in the open oceans. **Science** Aug. 2005.

1950s



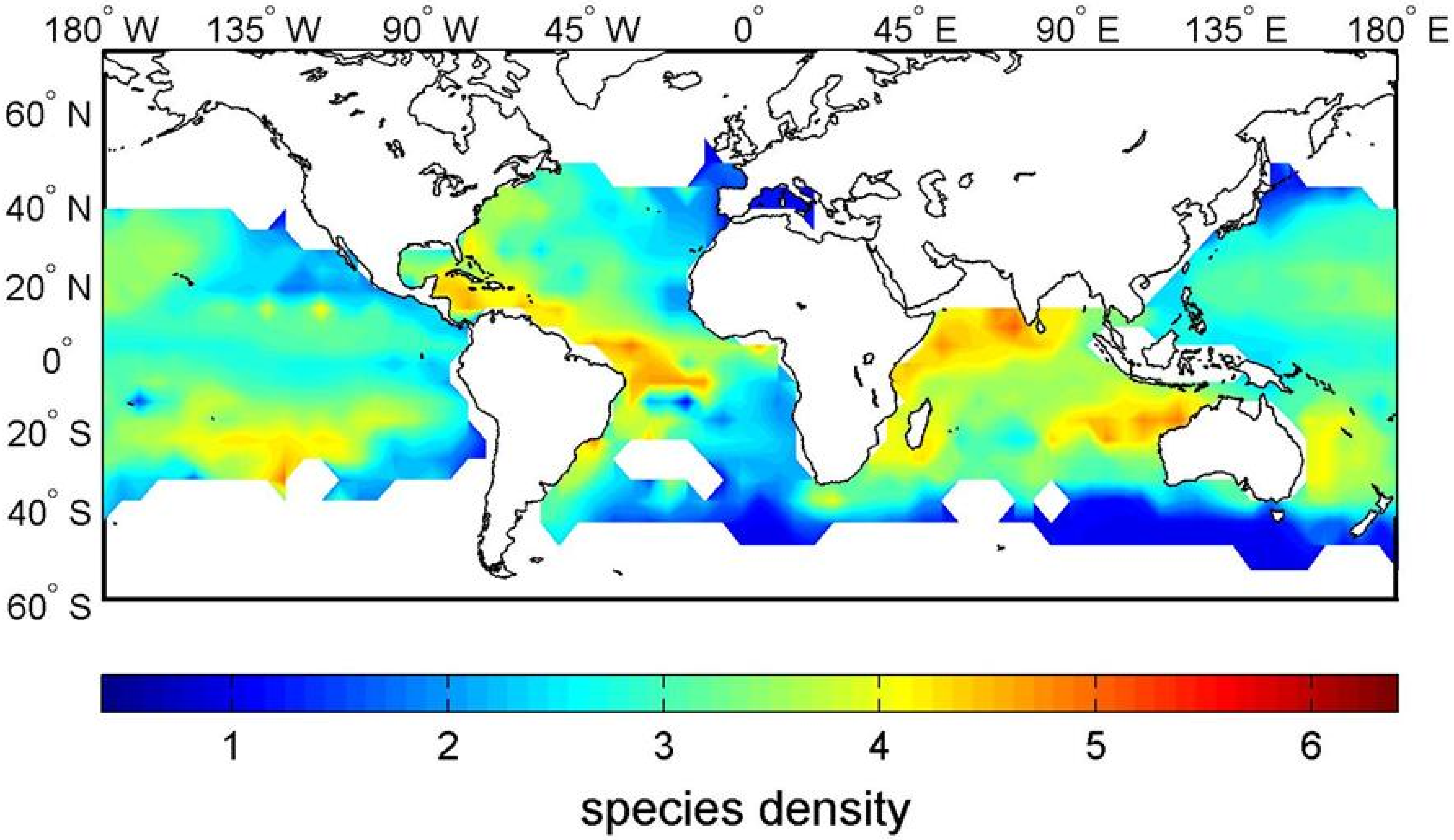
Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

1960s



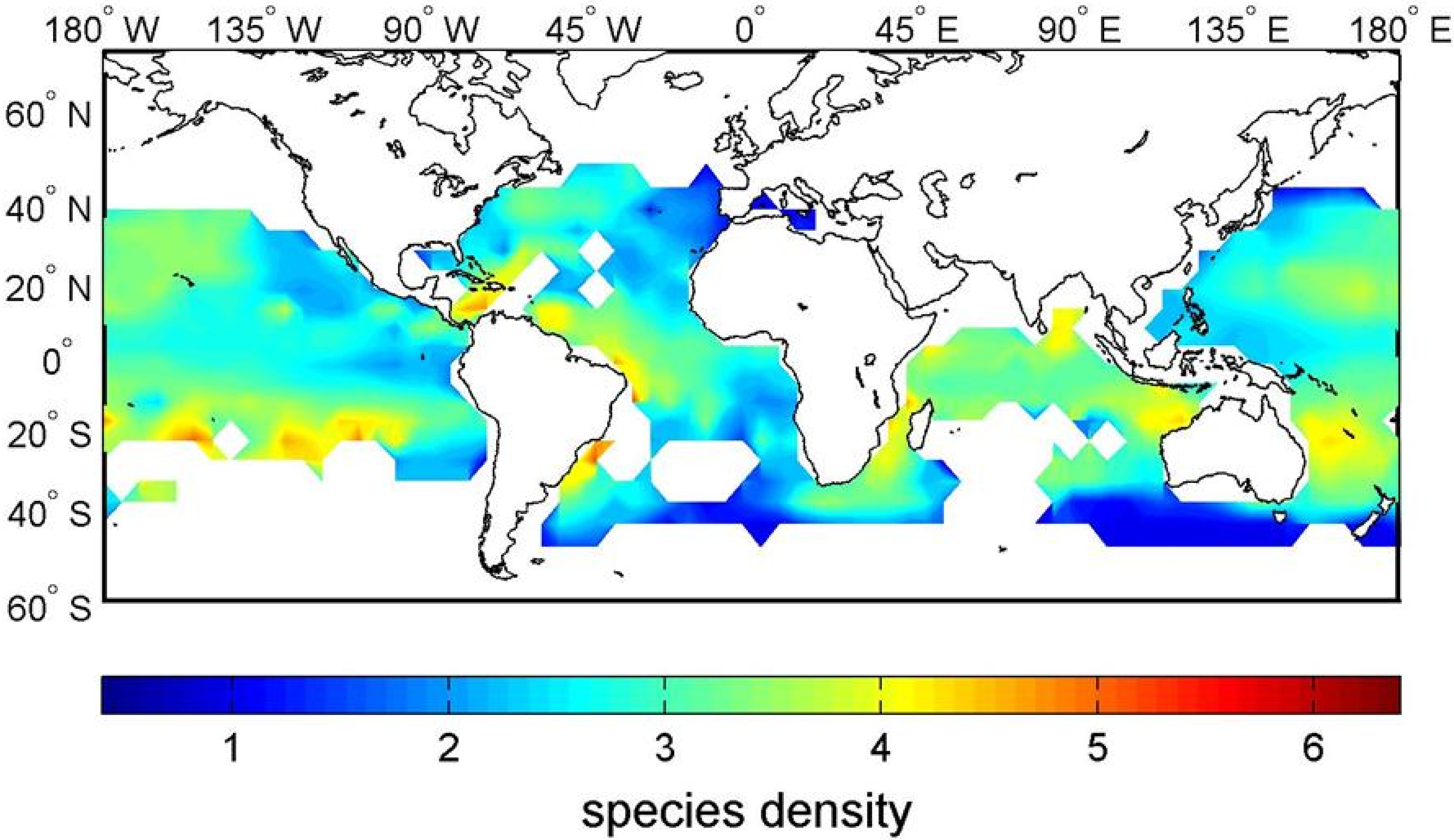
Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-136

1970s



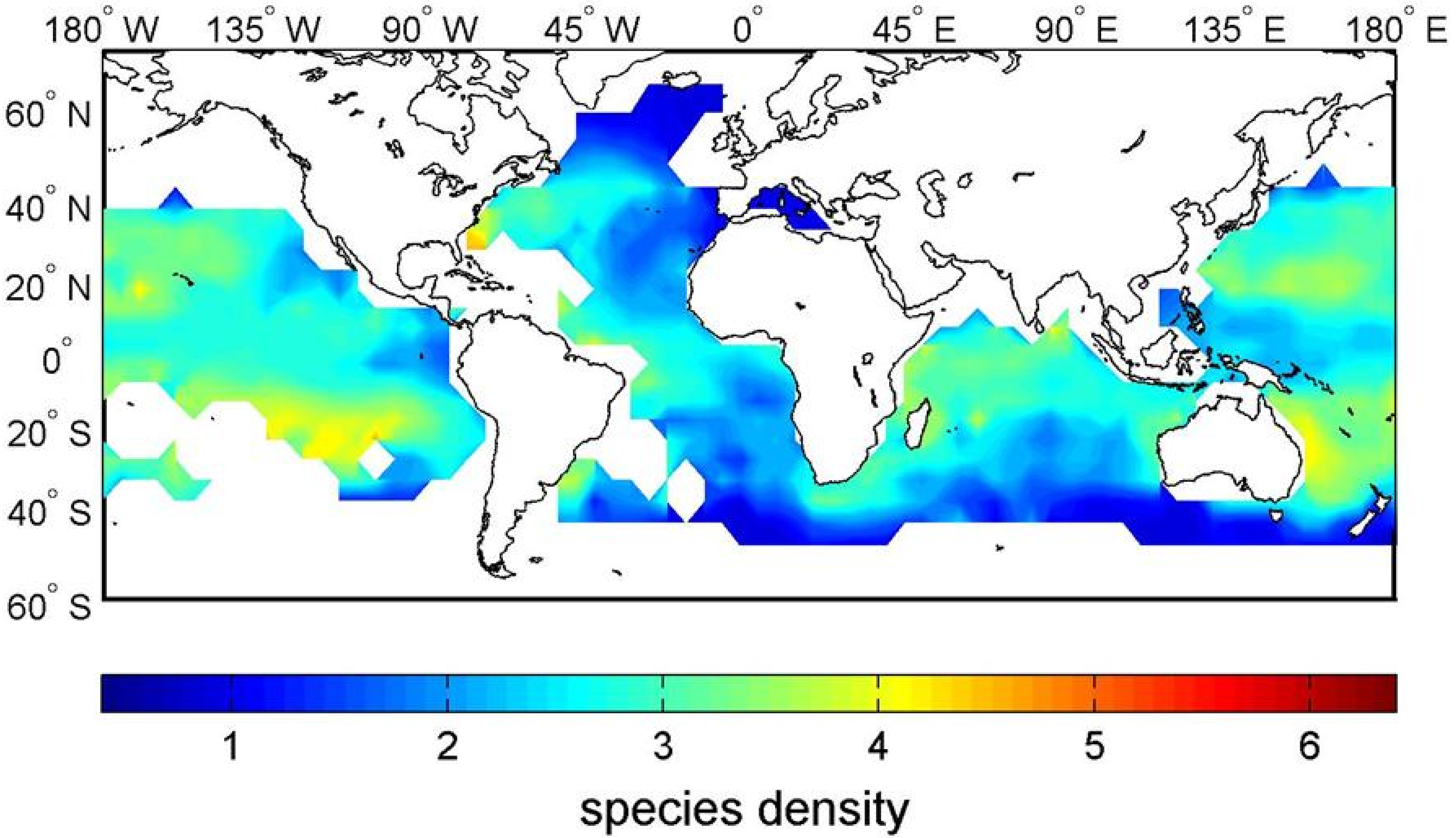
Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-136

1980s



Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-13

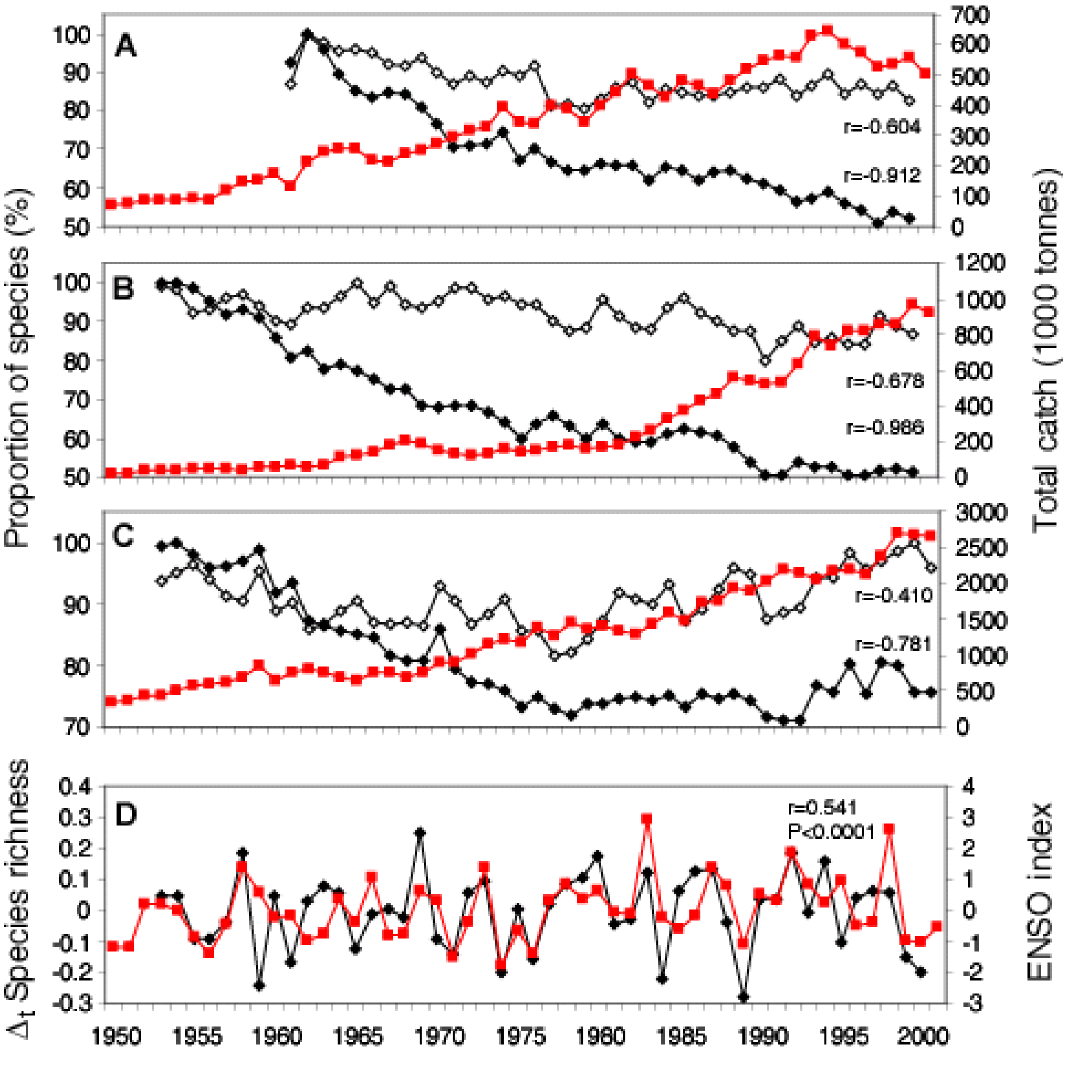
1990s



Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-136

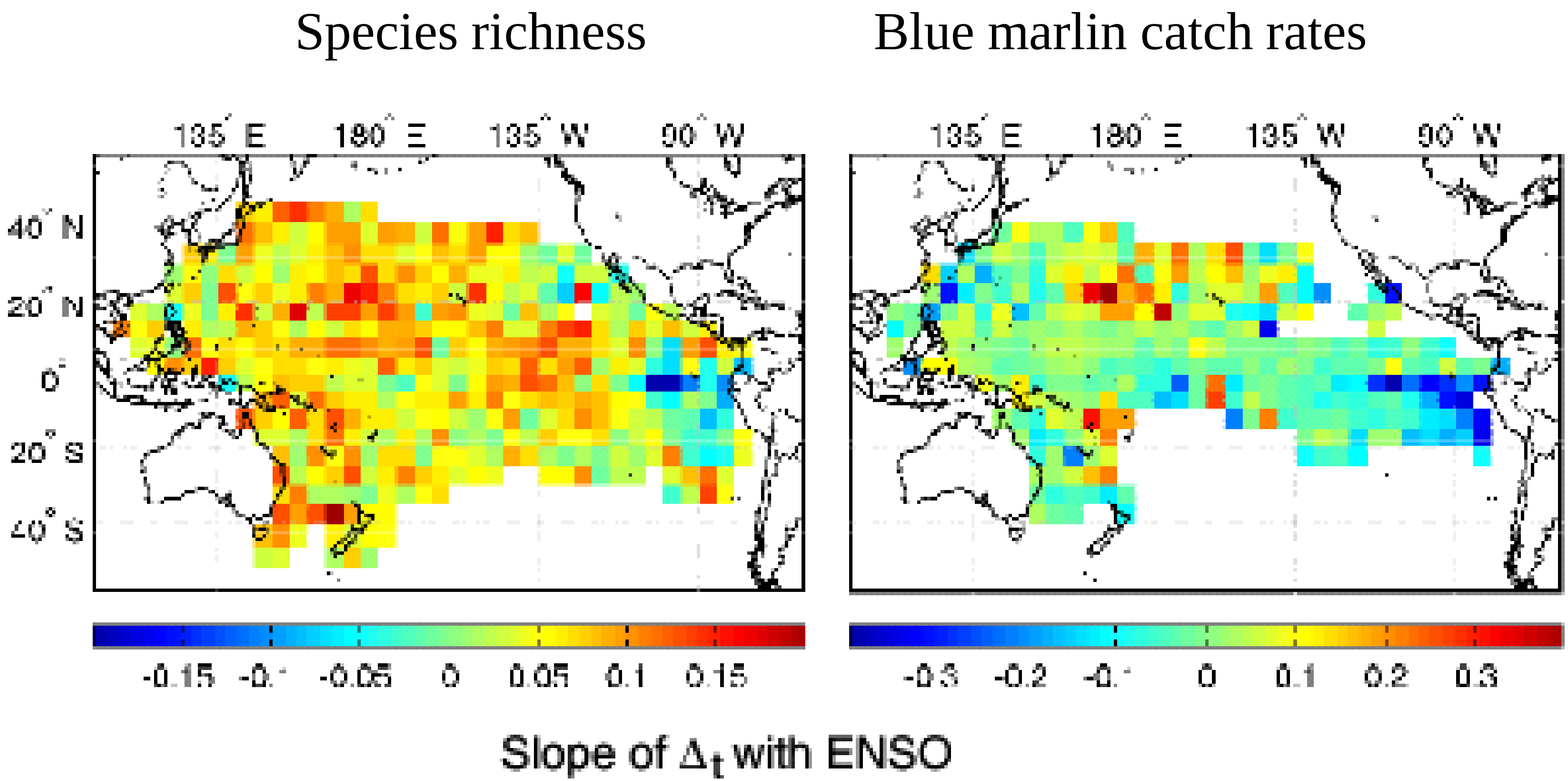
Global decline in ocean predator diversity

- Increasing catches
- Decreasing diversity
- Long-term decline linked to fishing
- Yearly variability linked to climatic changes



Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

ENSO affects diversity across entire Pacific

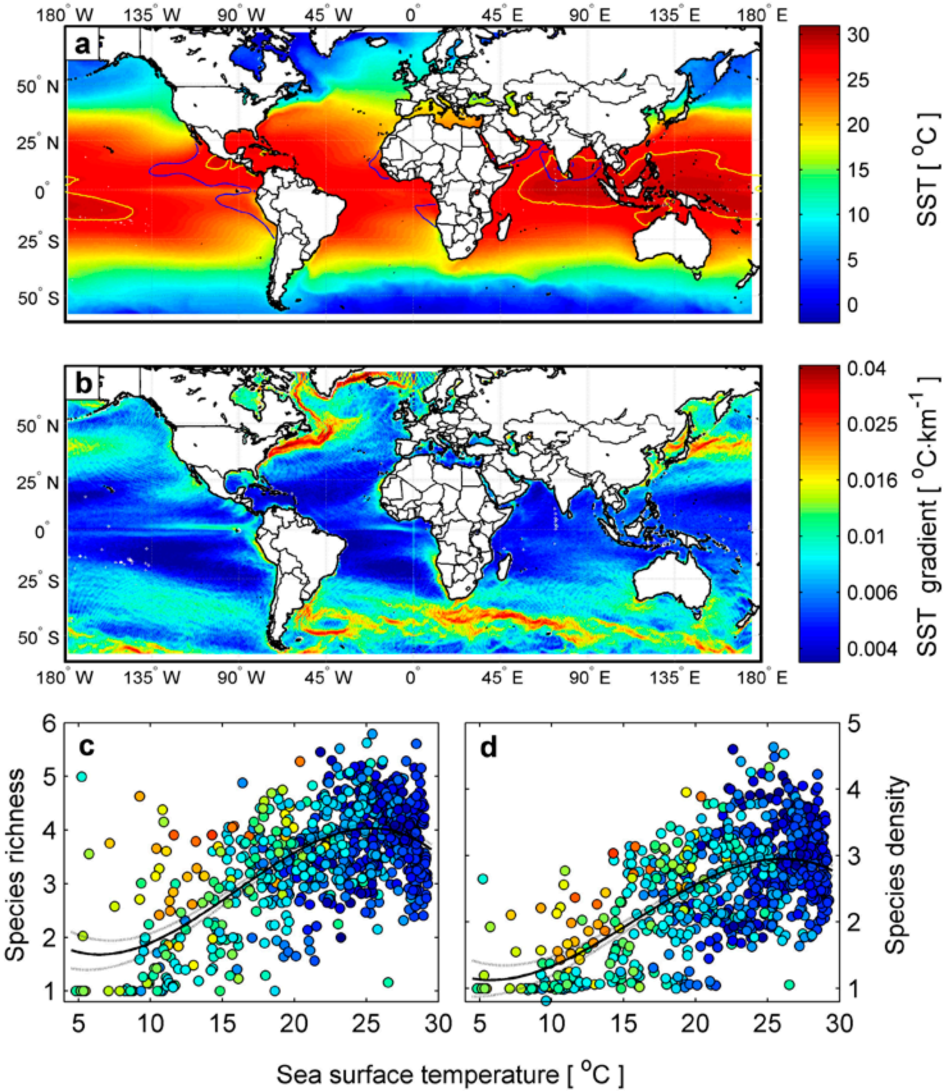


Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

Understand oceanographic drivers of diversity

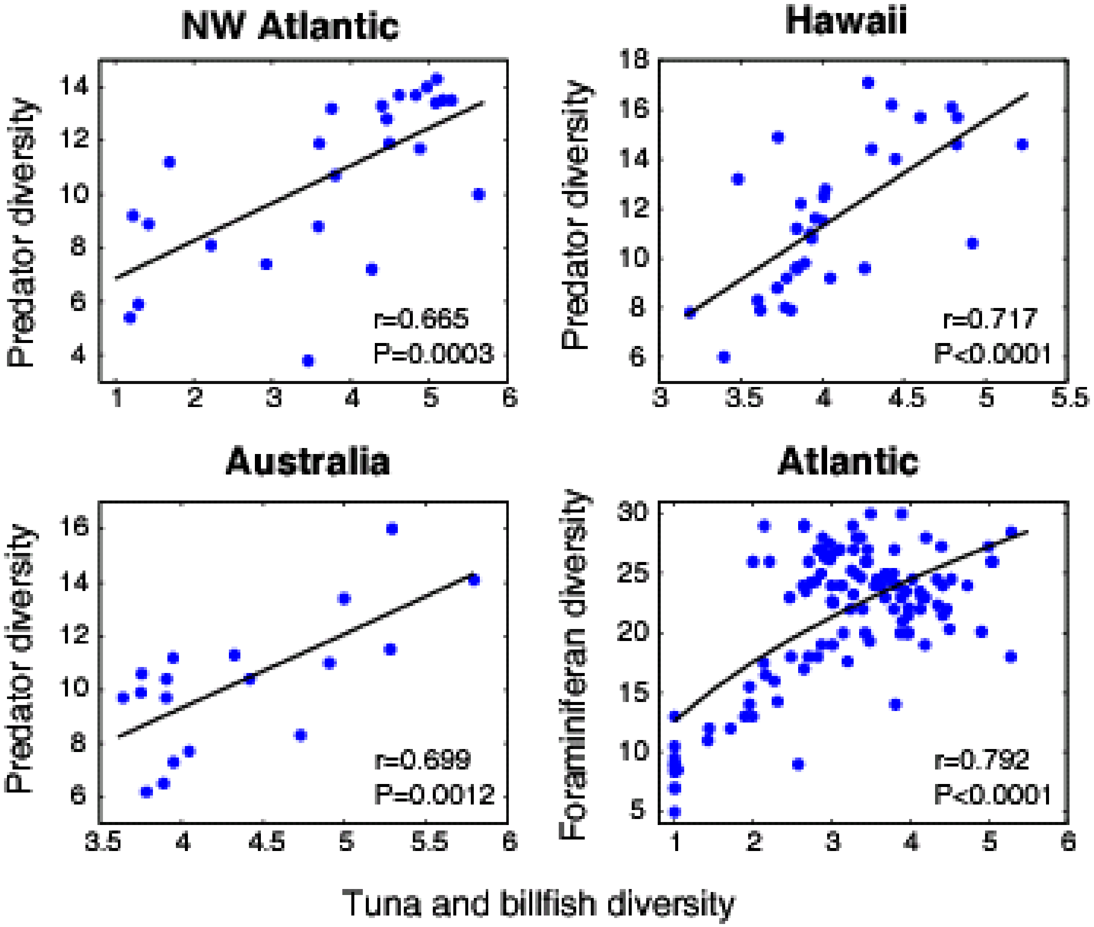
Patterns of diversity were explained by

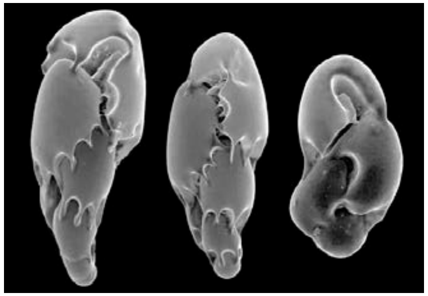
- Mean temperature
- Fronts and eddies
- Oxygen



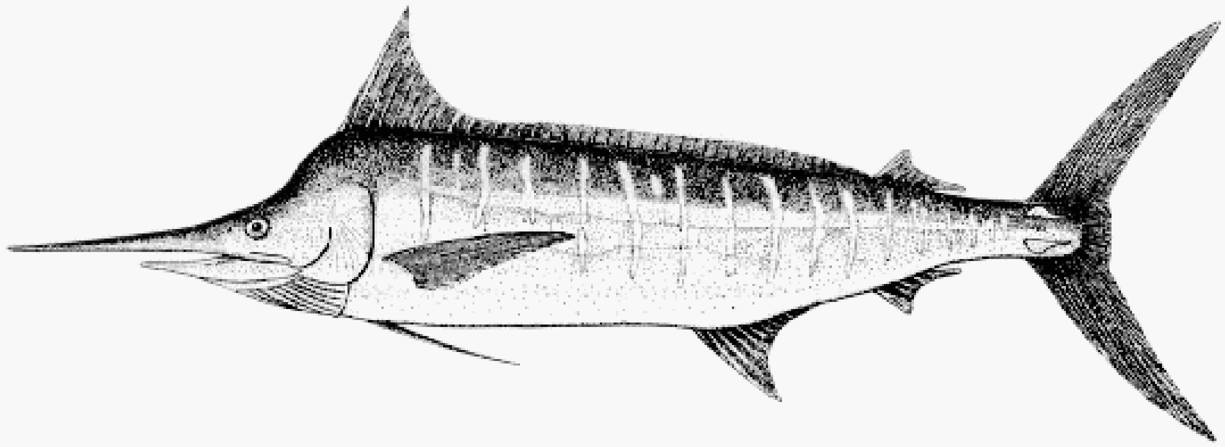
Source: Worm et al. 2005. Science 309:1365-1369

Validate hotspots across species groups



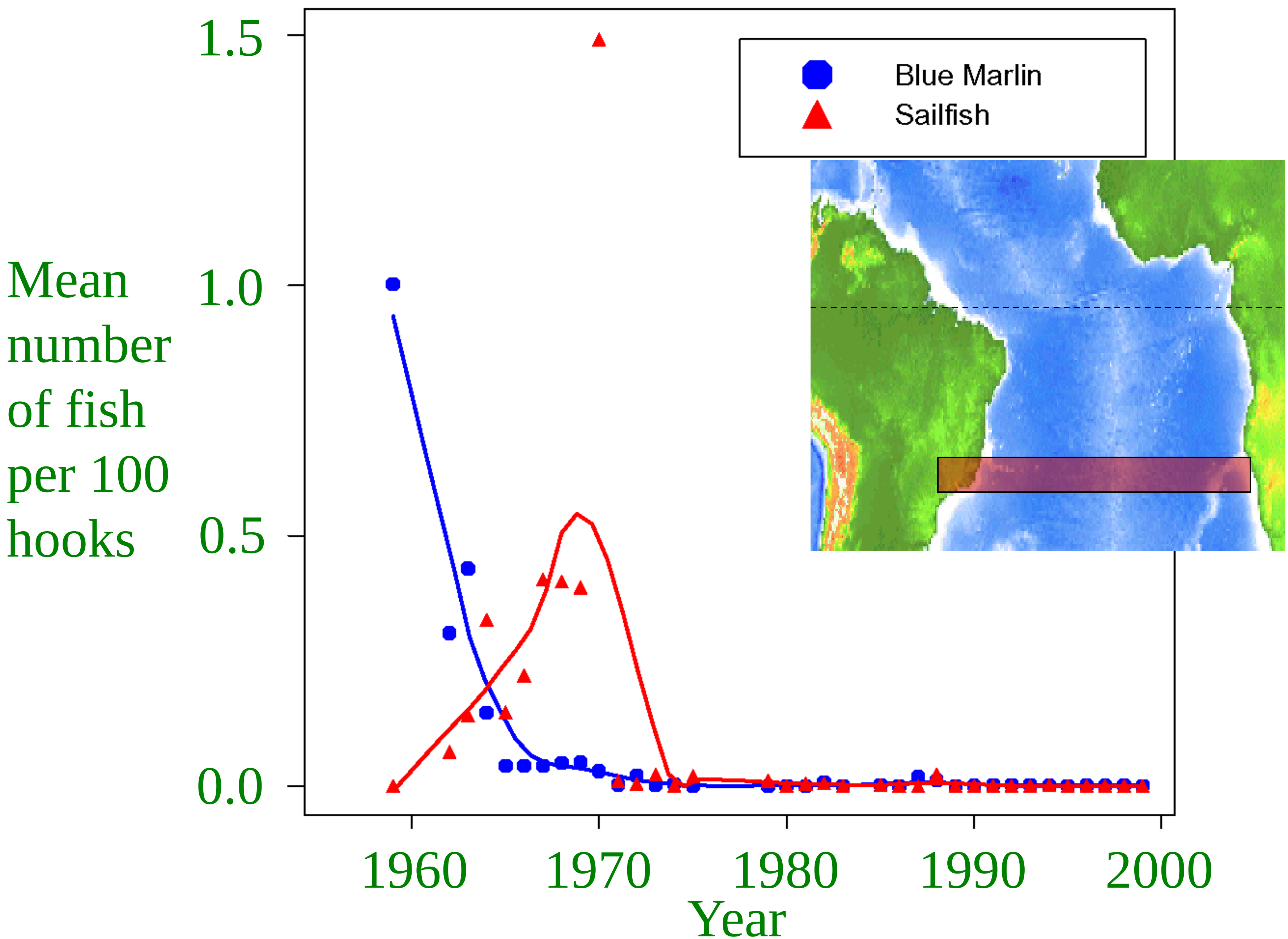


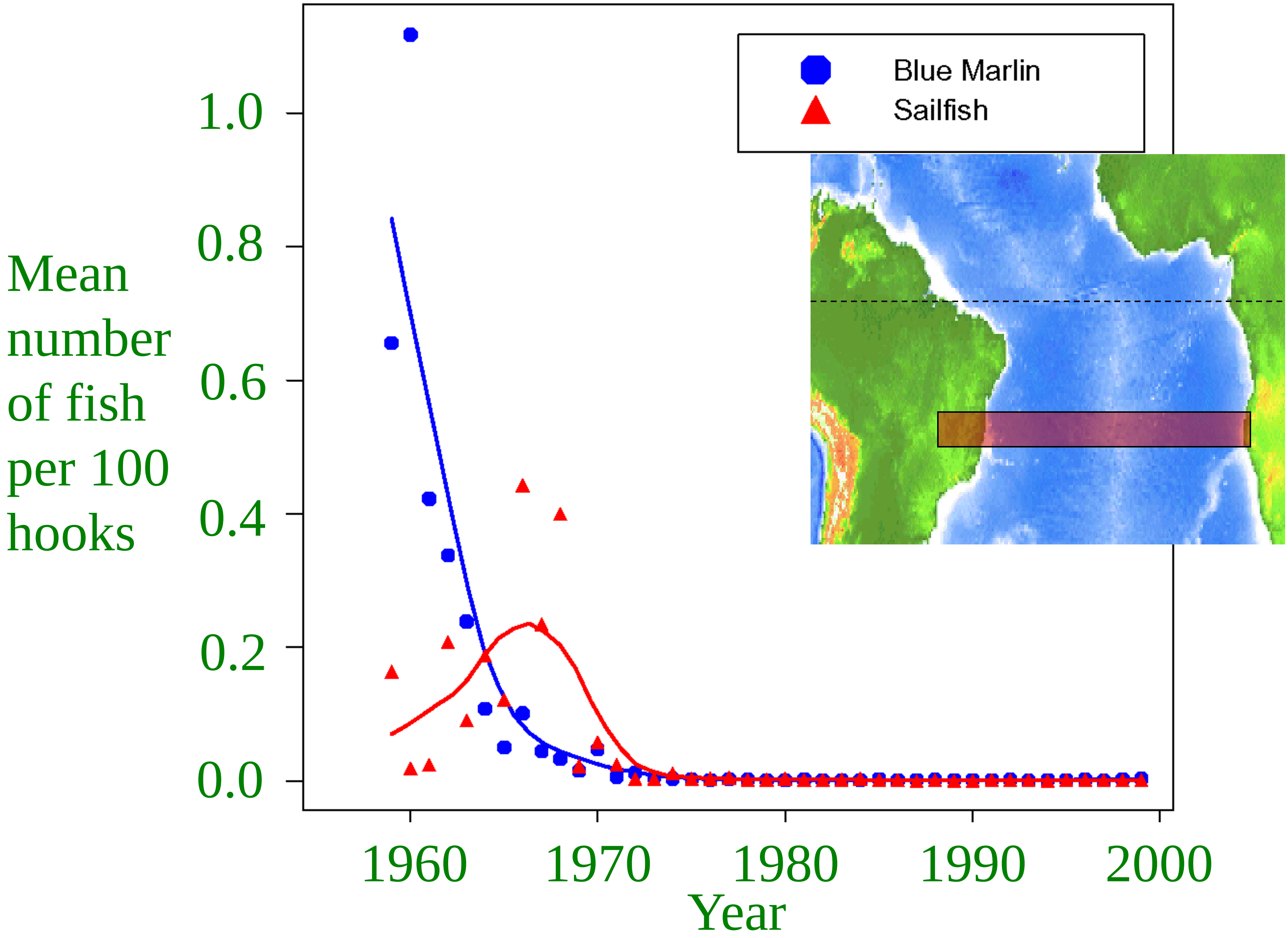
Source: Worm et al. 2005.
Science: 309:1365-1369

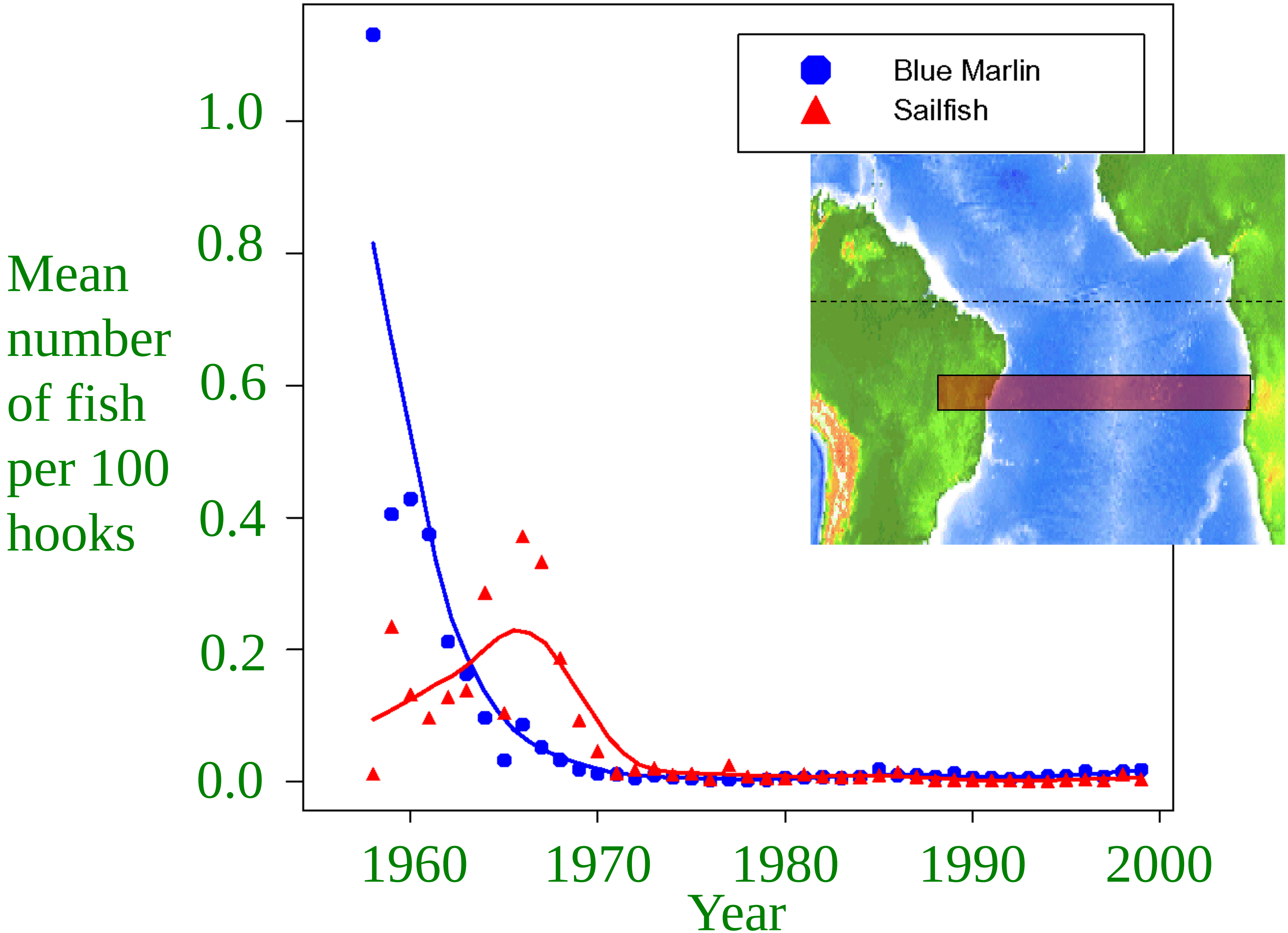


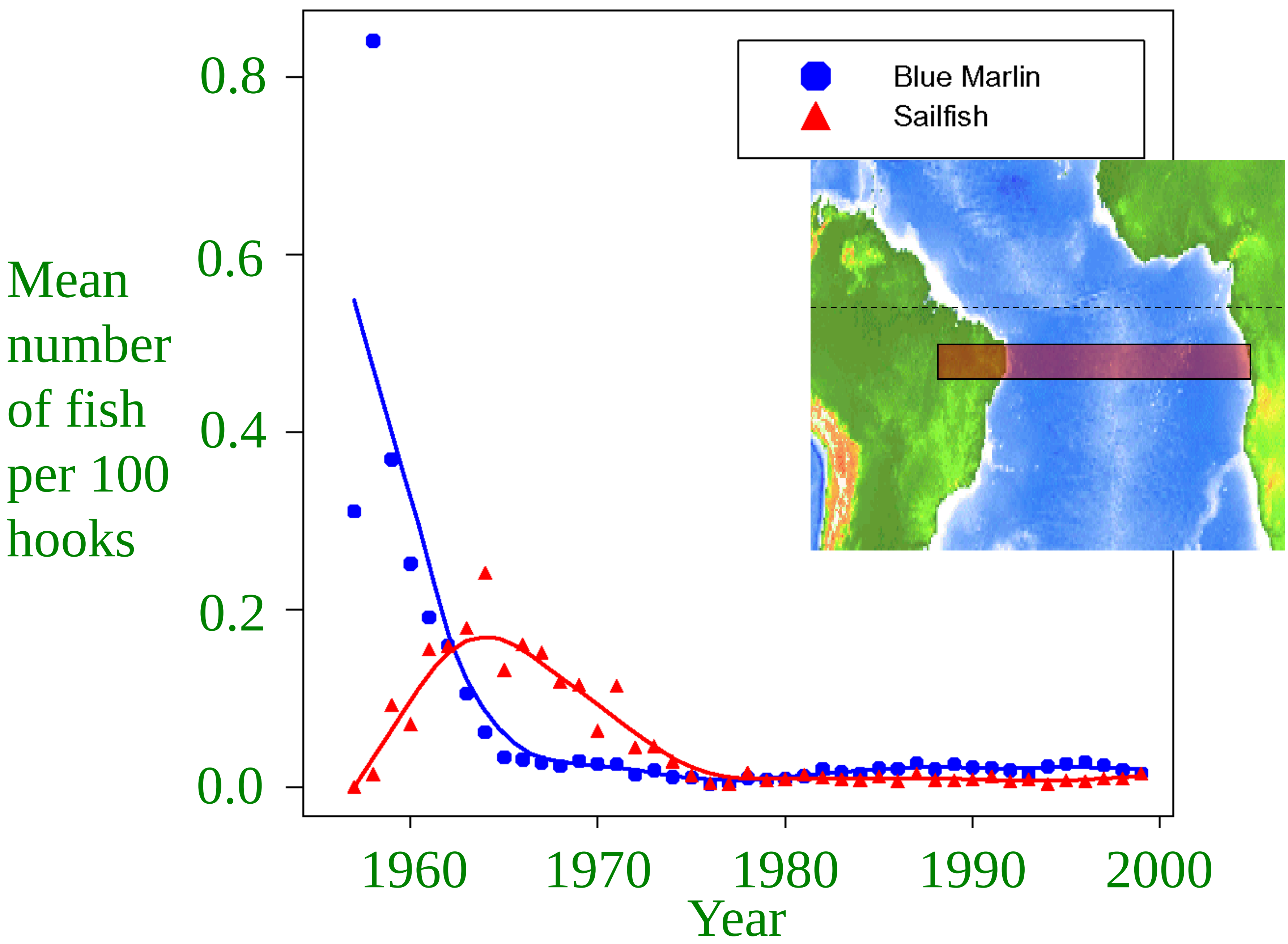
Blue marlin (*Makaira nigricans*)

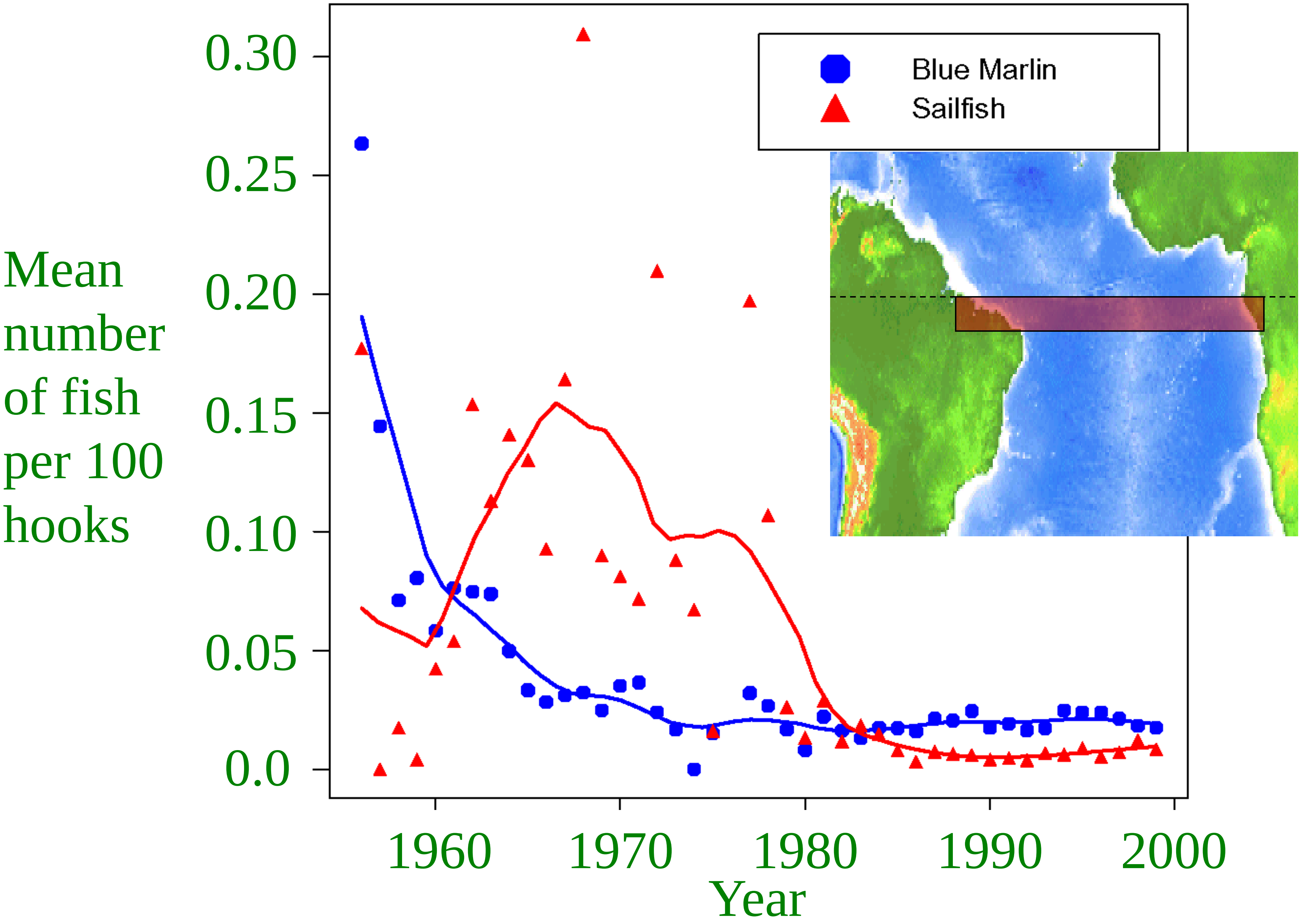
Sailfish (*Istiophorus albicans*)


Mean number of fish per 100 hooks
1.5
1.0
0.5
0.0
Blue Marlin
Sailfish
1960
1970
1980
1990
2000
Year

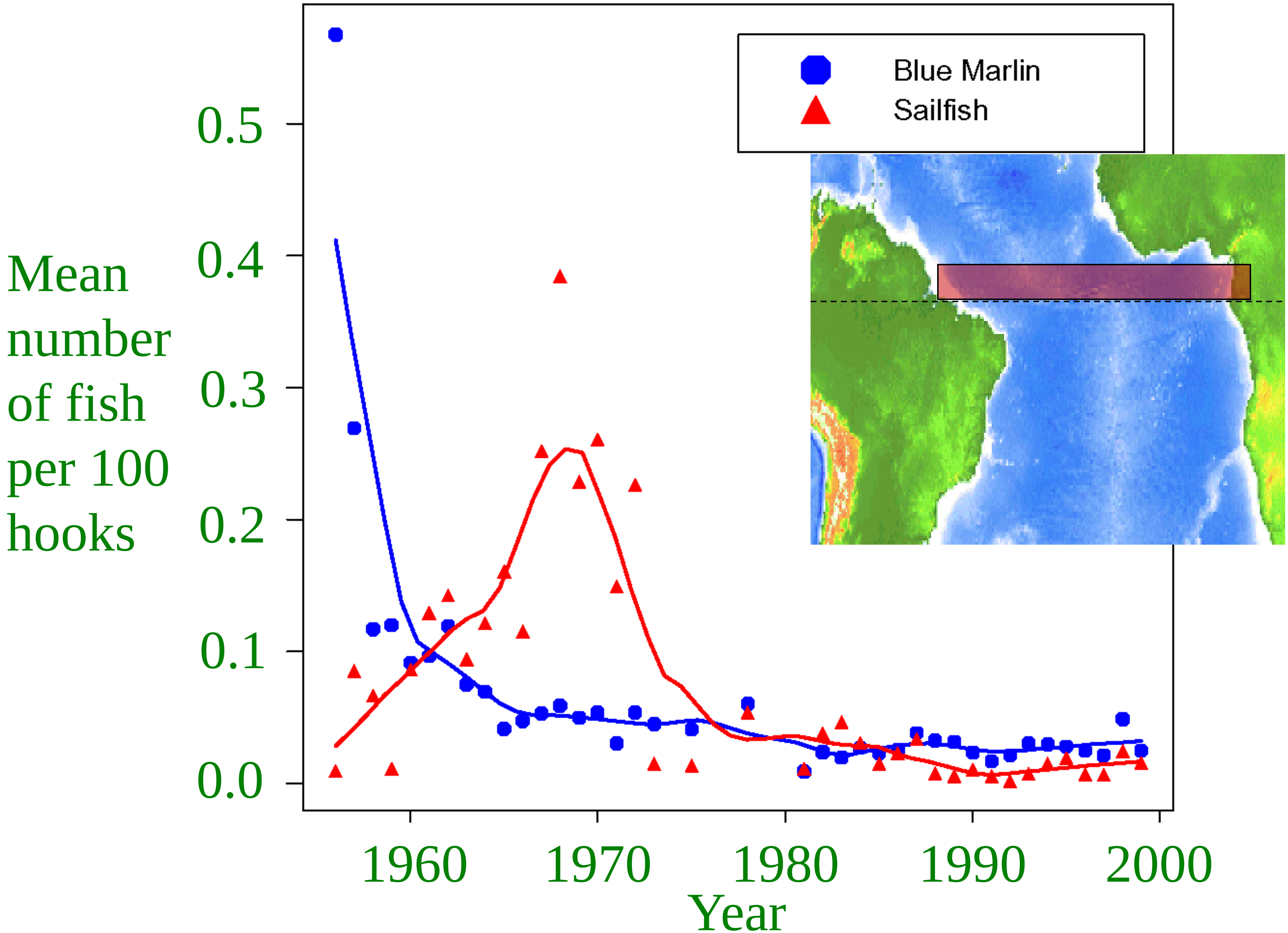

Blue Marlin
Sailfish
Mean number of fish per 100 hooks
1.0
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
Year


Blue Marlin
Sailfish
Mean number of fish per 100 hooks
1.0
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
Year

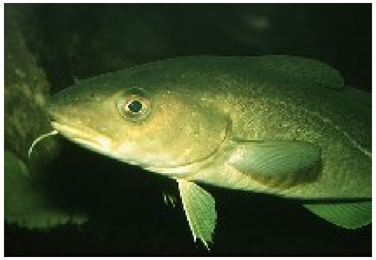

Mean number of fish per 100 hooks
0.8
0.6
0.4
0.2
0.0
Blue Marlin
Sailfish
1960
1970
1980
1990
2000
Year

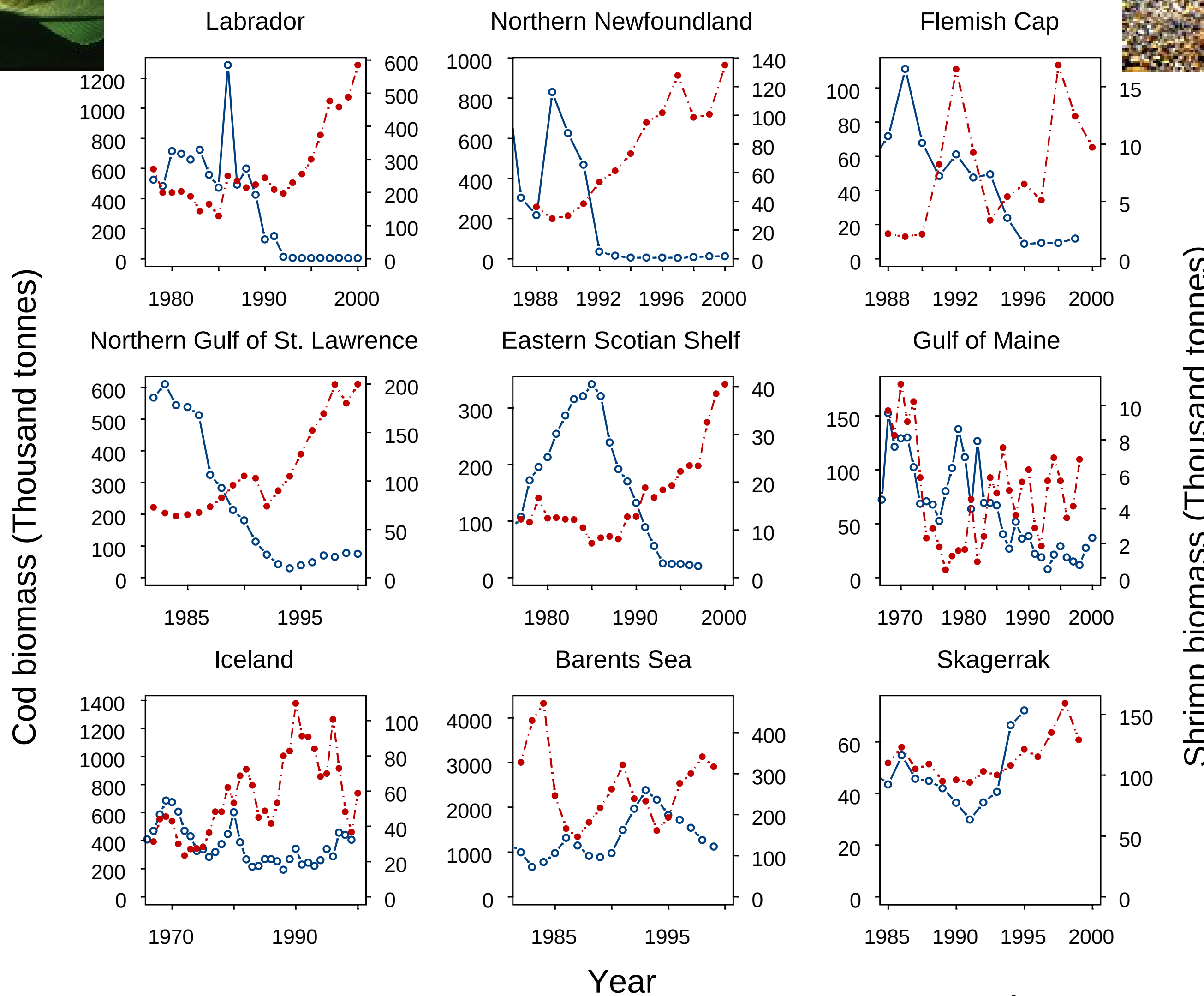


Mean number of fish per 100 hooks
0.30
0.25
0.20
0.15
0.10
0.05
0.0
Blue Marlin
Sailfish
1960
1970
1980
1990
2000
Year


Blue Marlin
Sailfish
Mean number of fish per 100 hooks
0.0
0.1
0.2
0.3
0.4
0.5
1960
1970
1980
1990
2000
Year

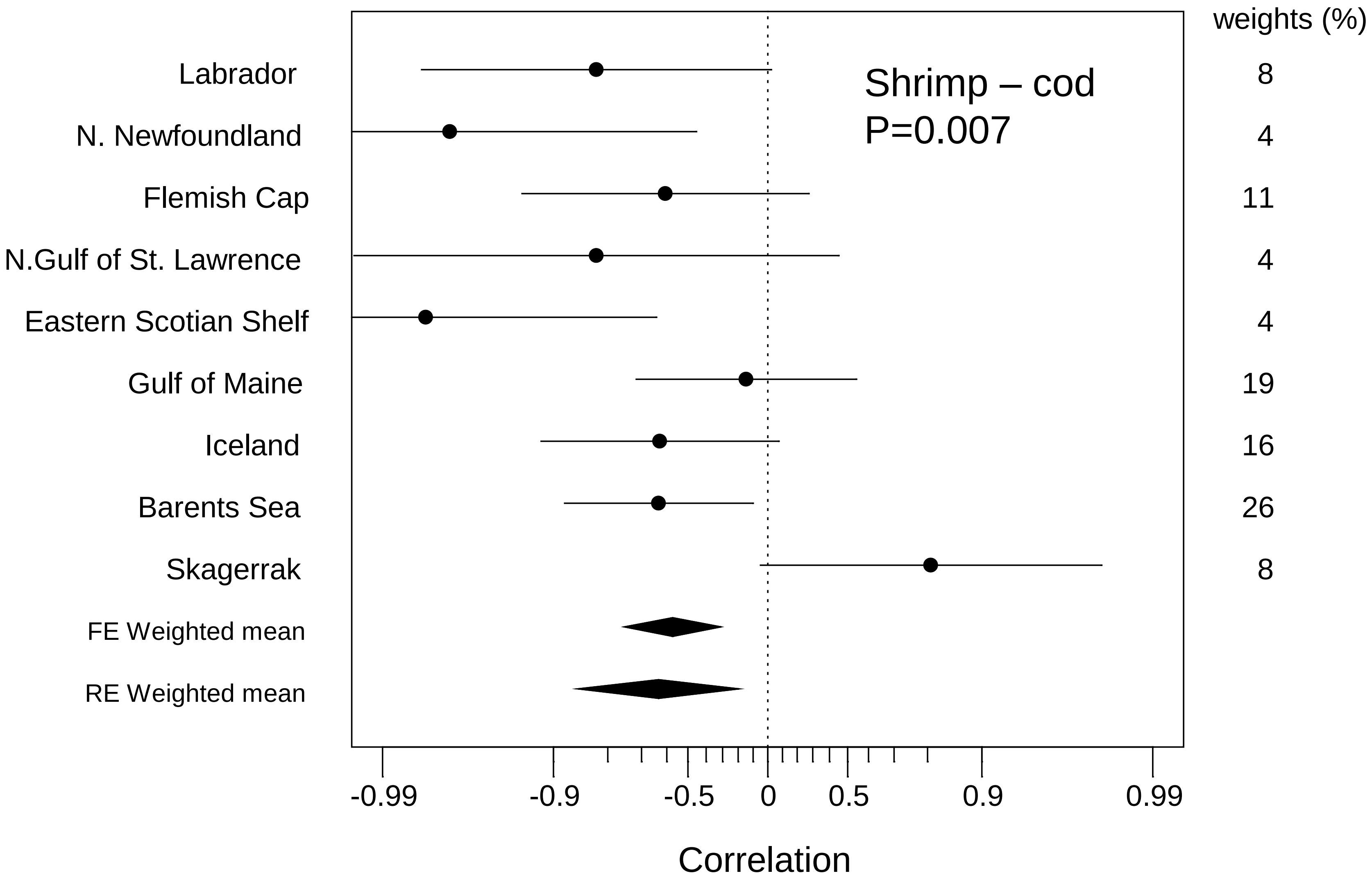
Cod and shrimp biomass in the North Atlantic: time series



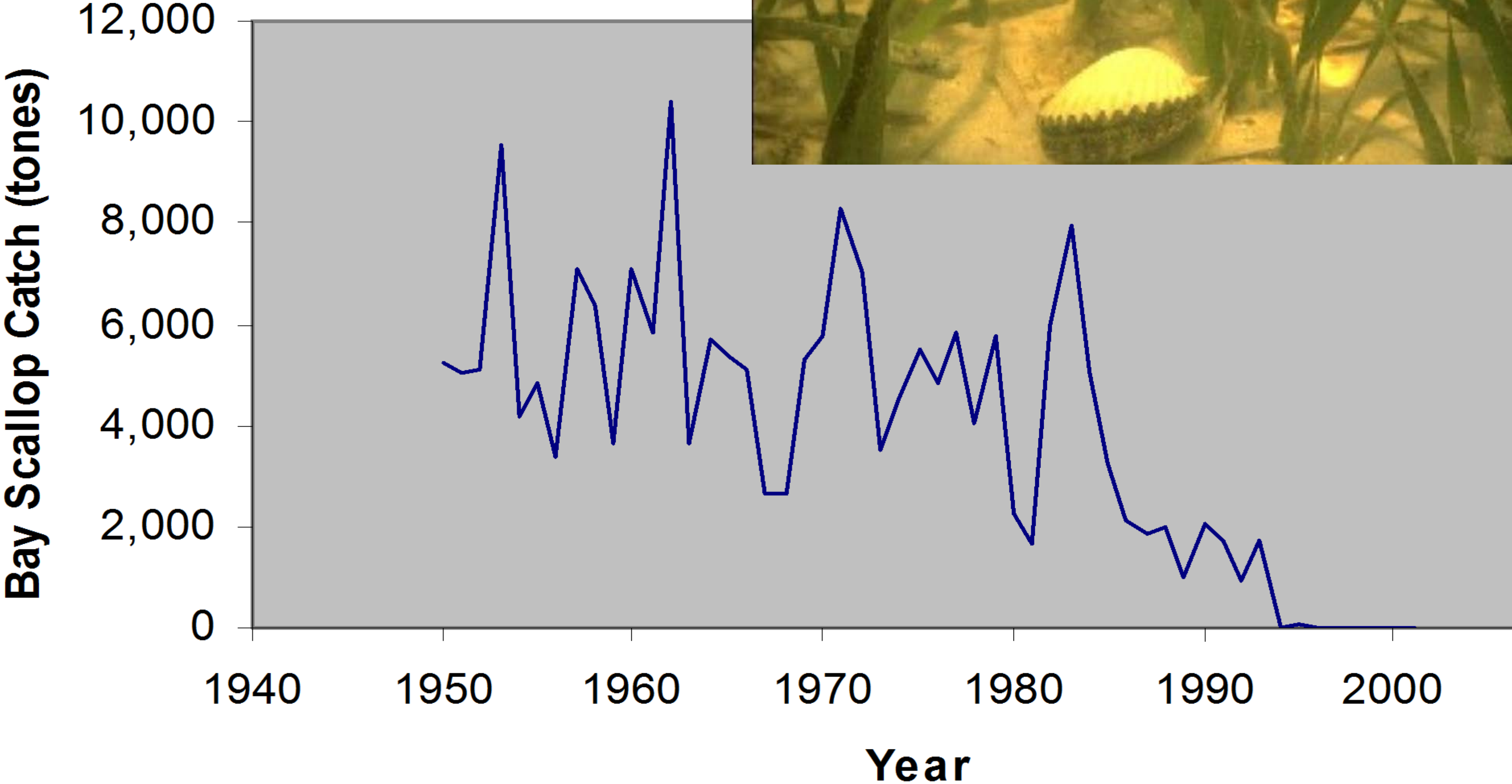


Worm and Myers, Ecology 2003

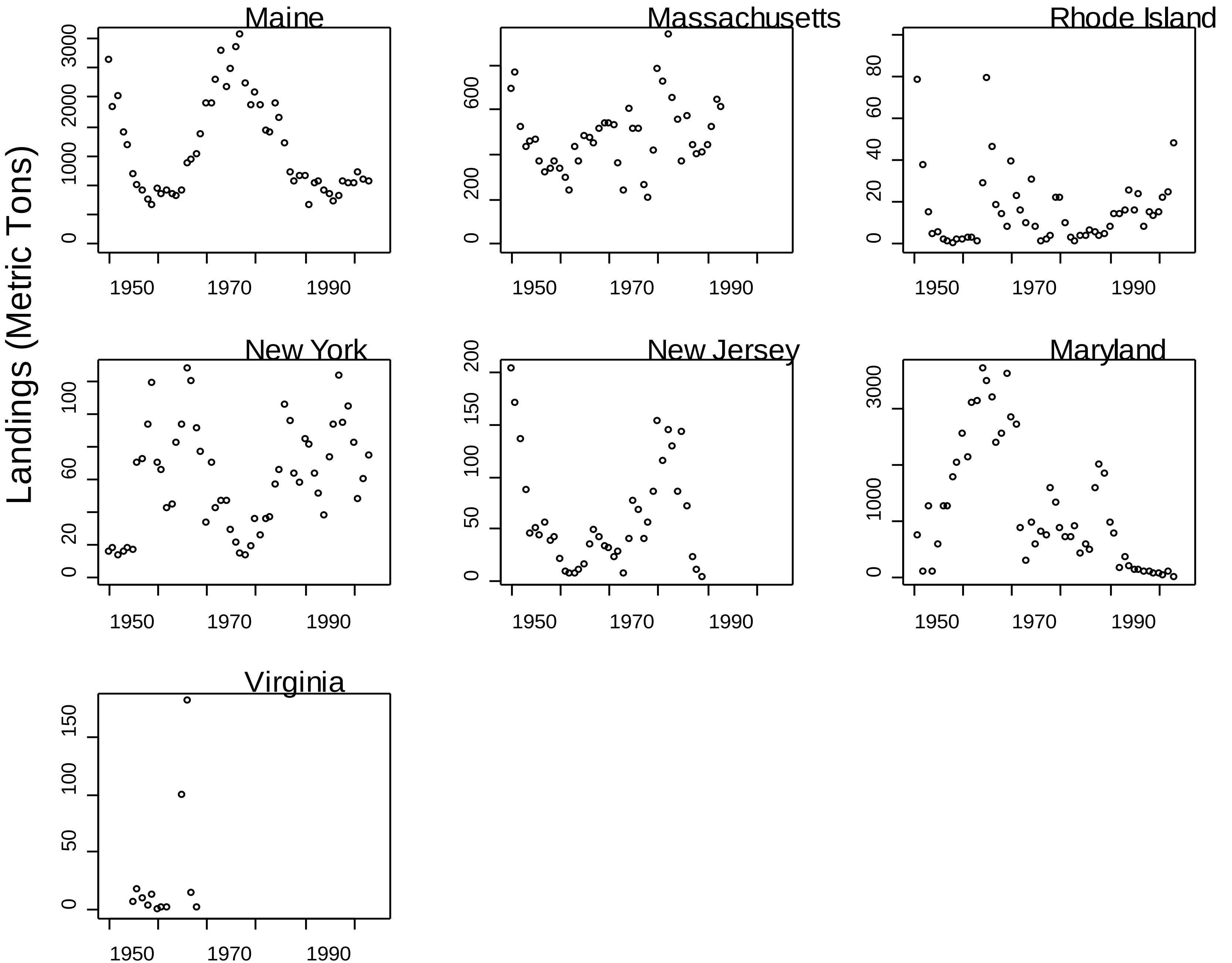
Random-effects meta-analysis

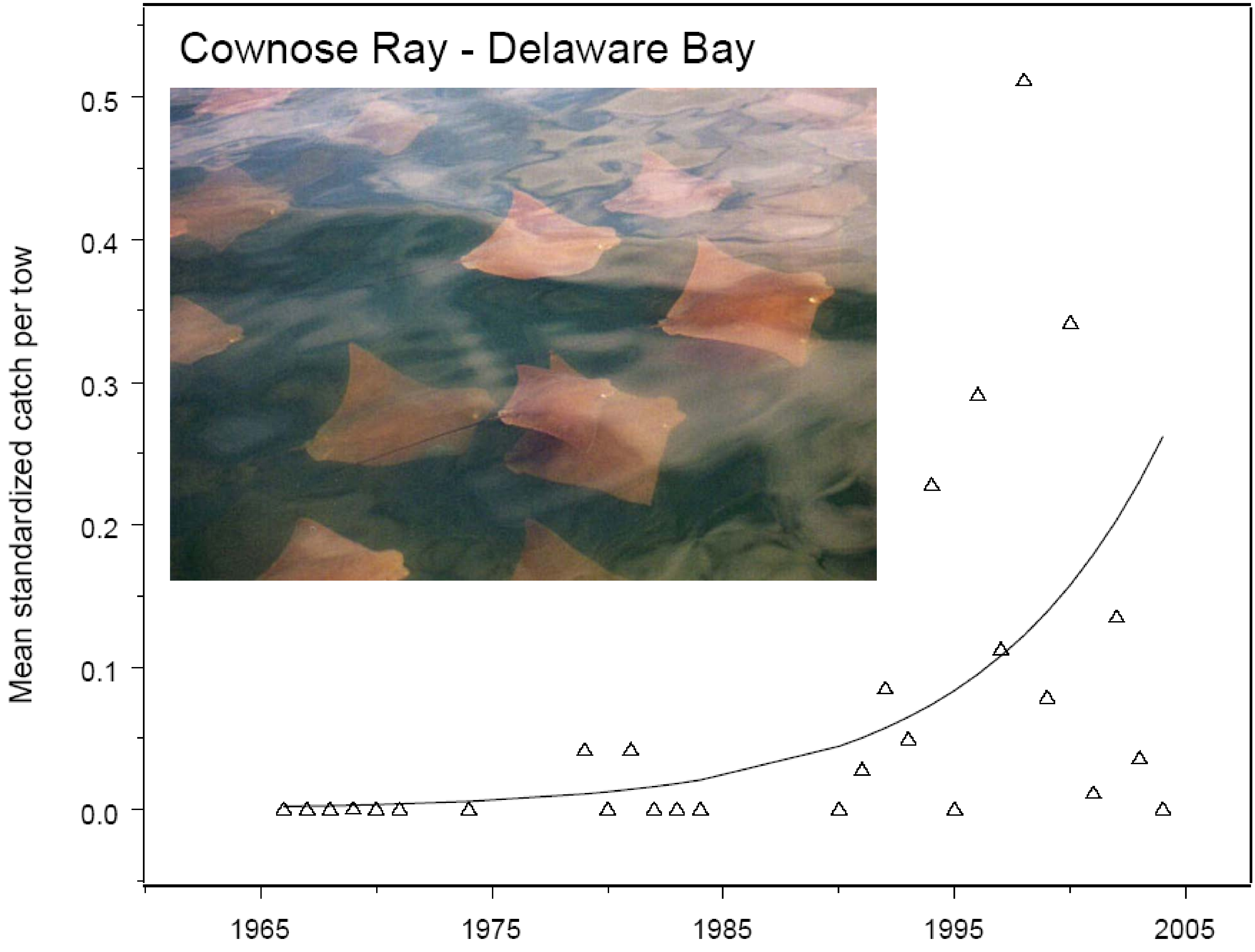


USA Bay Scallops Landings

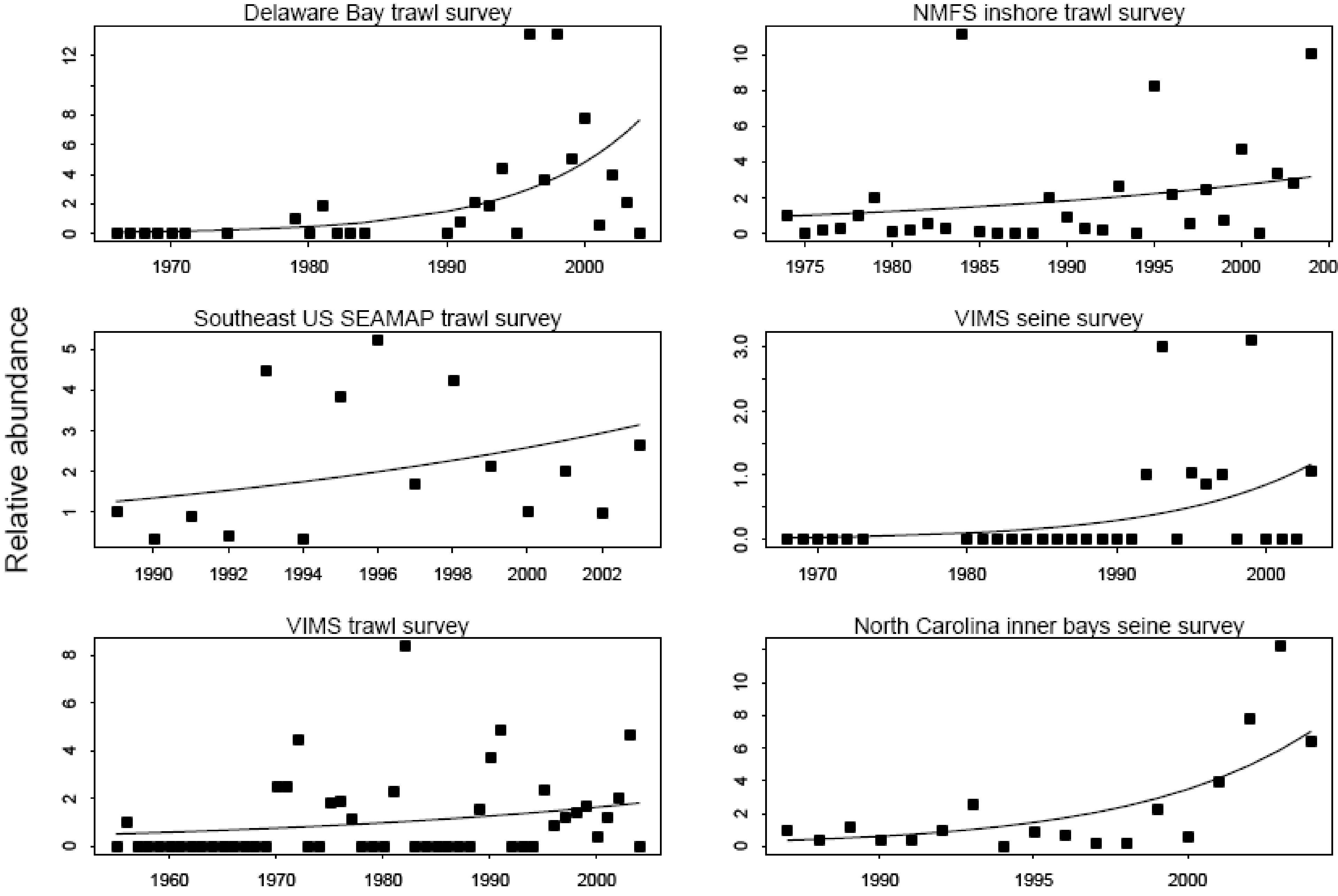


Loss of softshell clams south of Long Island

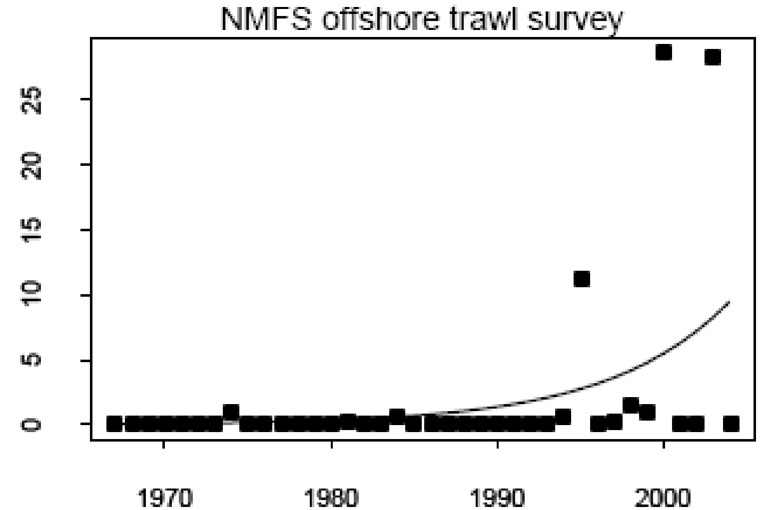



Cowncose Ray - Delaware Bay
Mean standardized catch per tow
0.5
0.4
0.3
0.2
0.1
0.0
1965
1975
1985
1995
2005

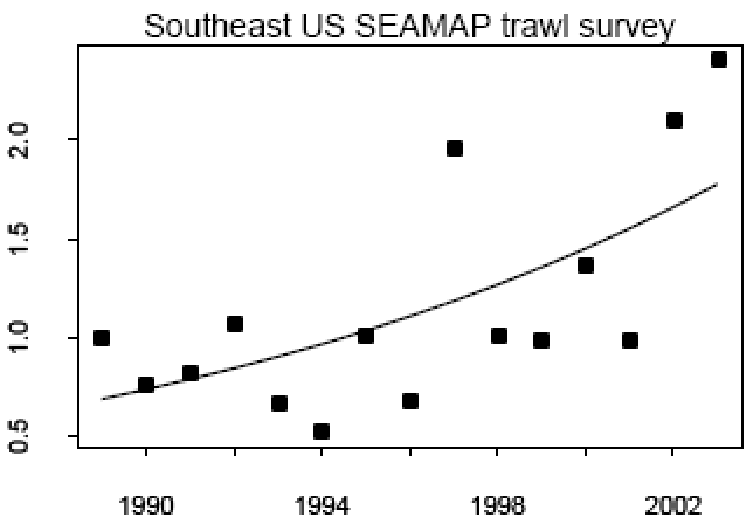
Meta-analysis of cownose ray trends

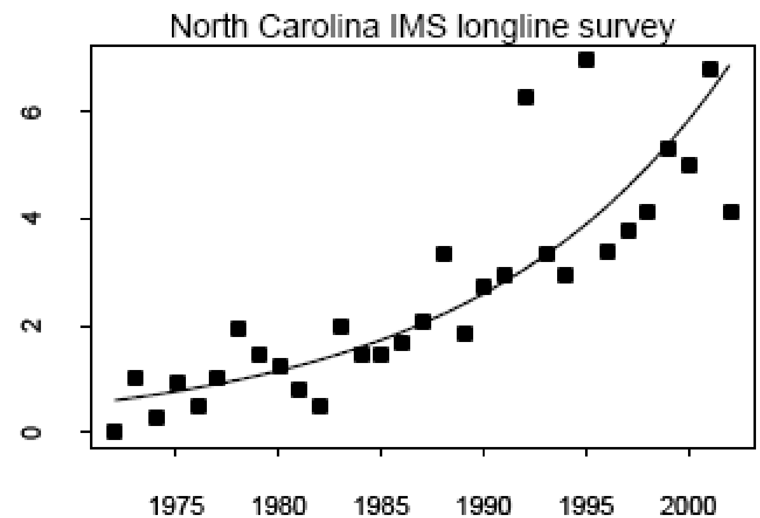


Increase in small sharks: Sharpnose shark

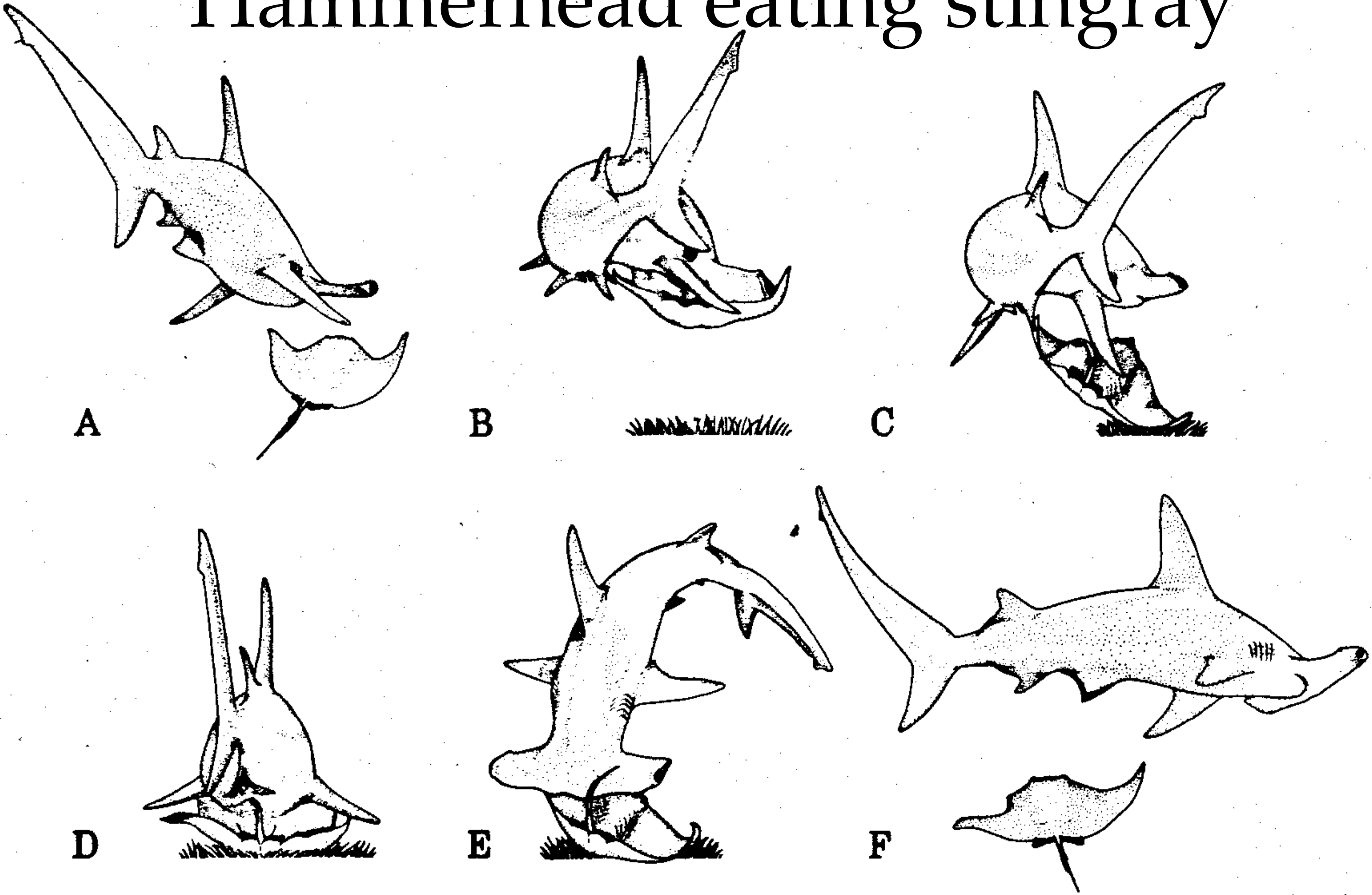


Relative abundance





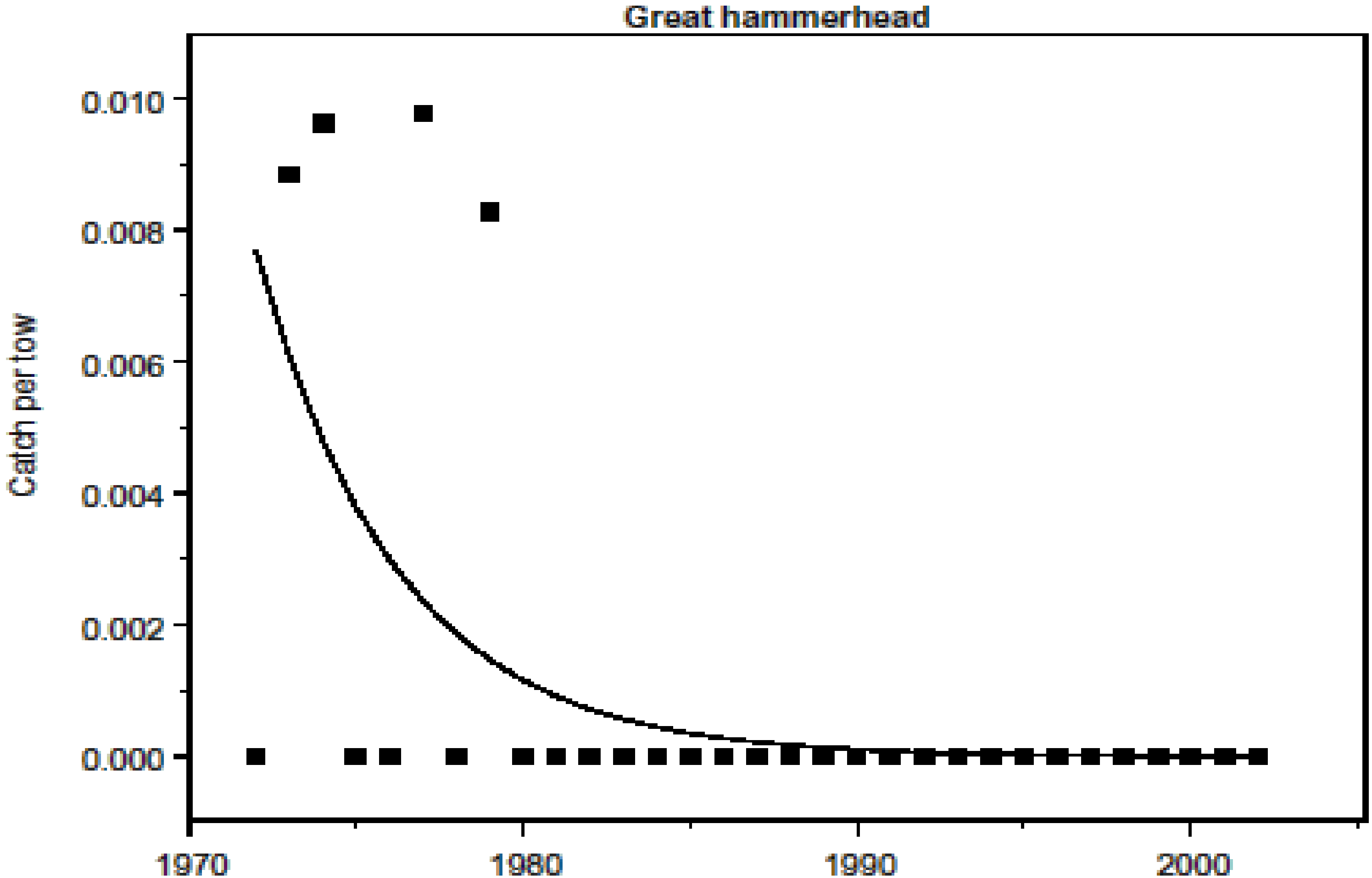
Hammerhead eating stingray



Strong, W.R. Jr; Snelson, F.F. Jr; Gruber, S.H. Copeia 1990, 836-839

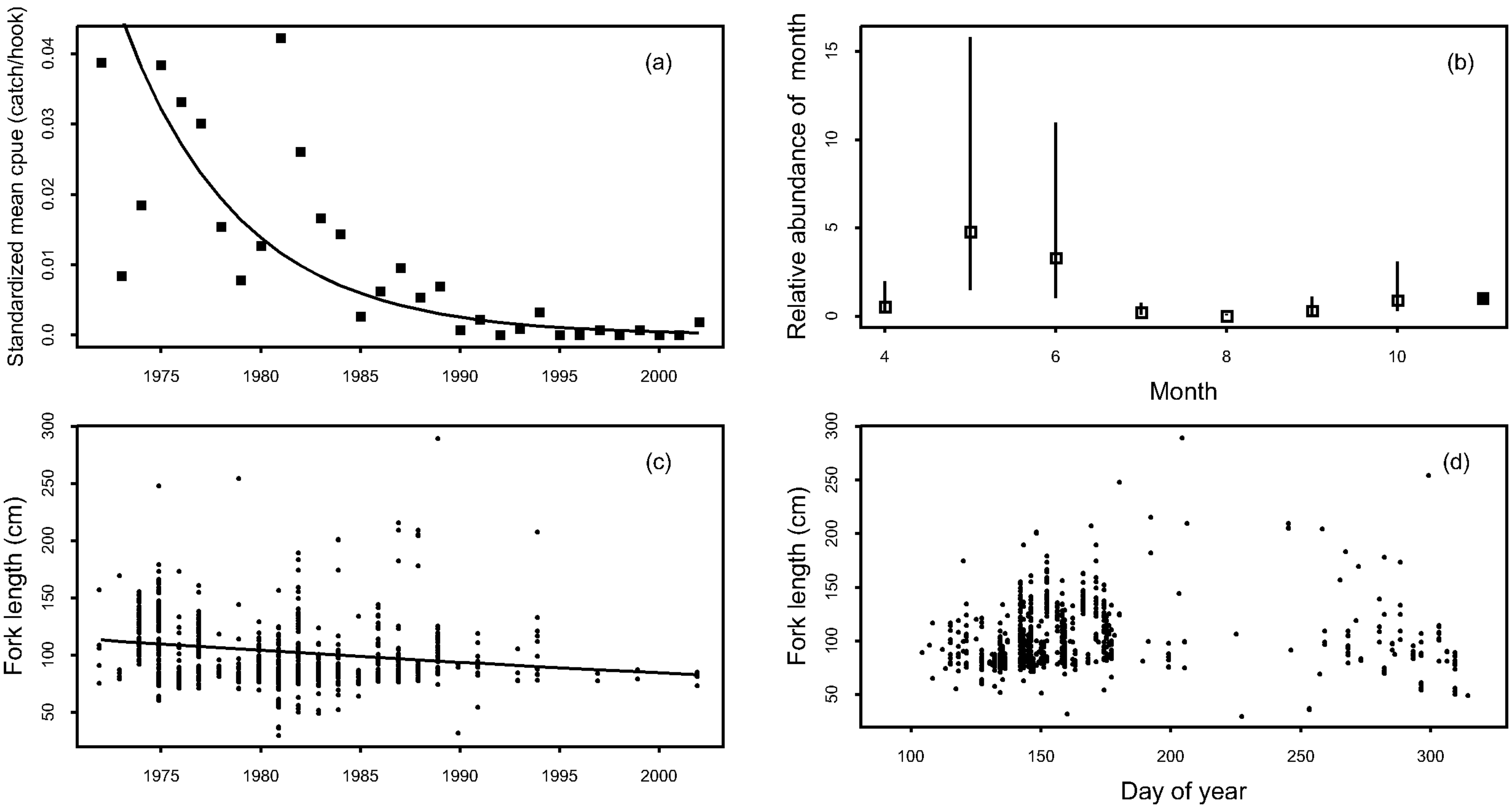

GREAT HAMMERHEAD SHARK PREDATION UPON
SPOTTED EAGLE RAY
Photo by Demian Chapman
D. D. Chapman and S. H. Gruber, 2002 Bull. of Mar. Sci. 70: 947–952

Loss of hammerheads from surveys



Shepherd and Myers, 2005, Ecology Letters

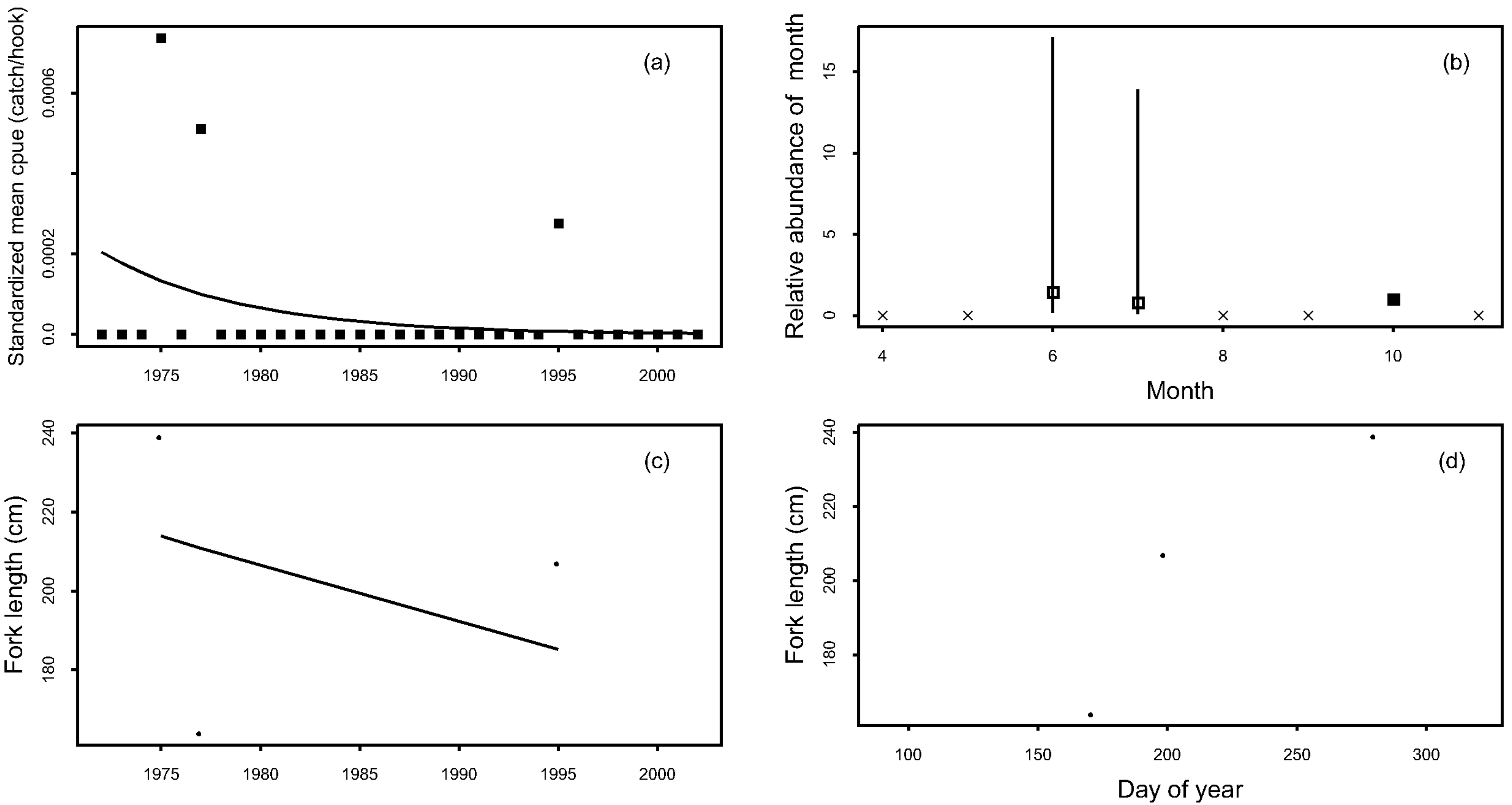
Dusky shark



Generalized linear model results

	Estimate	StdErr	p	k/scale
Abundance	-0.169	0.0171	5.67e-23	4.28
Length	-0.0105	1.4e-3	8.85e-14	18.8

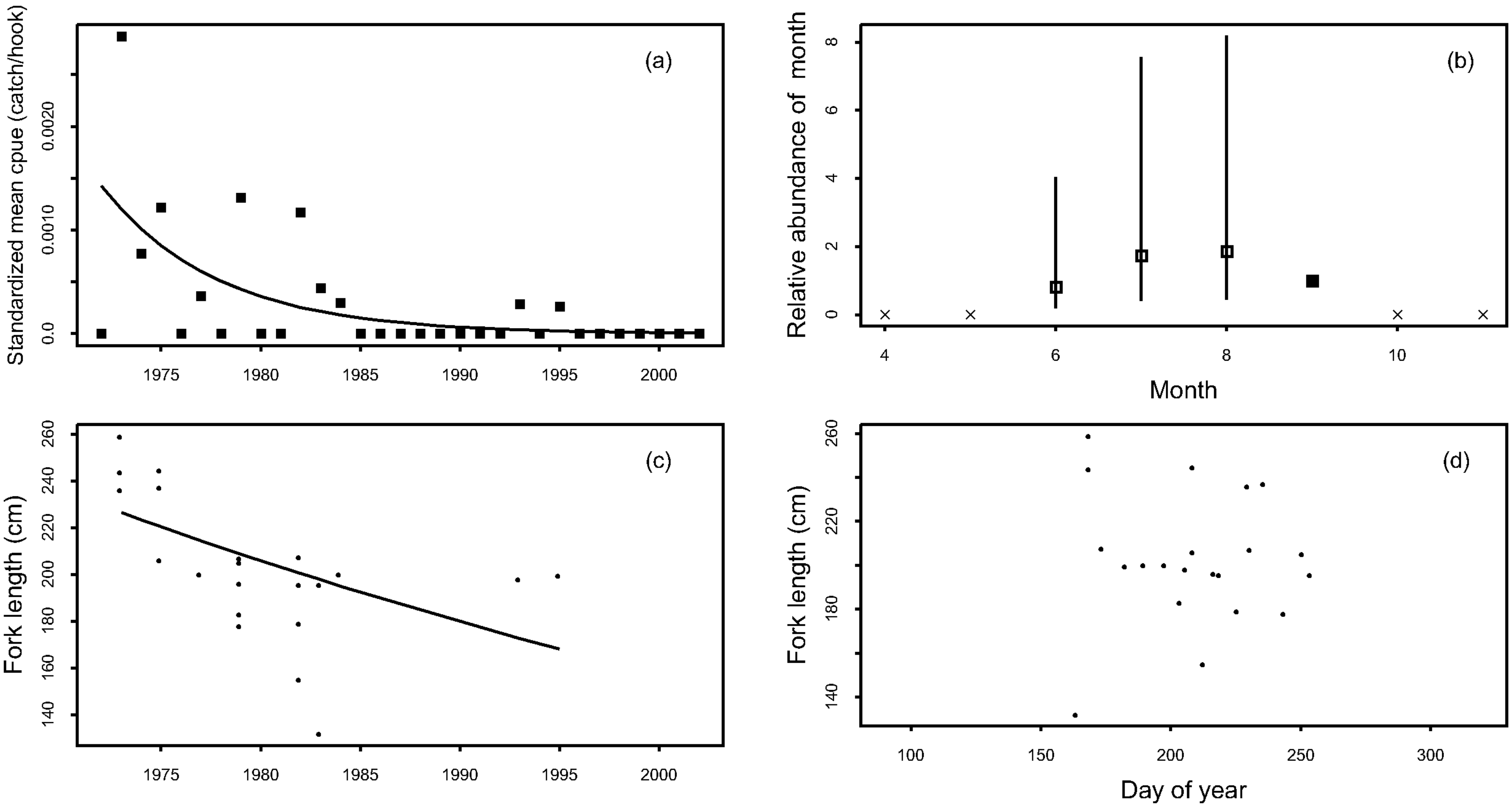
Great hammerhead



Generalized linear model results

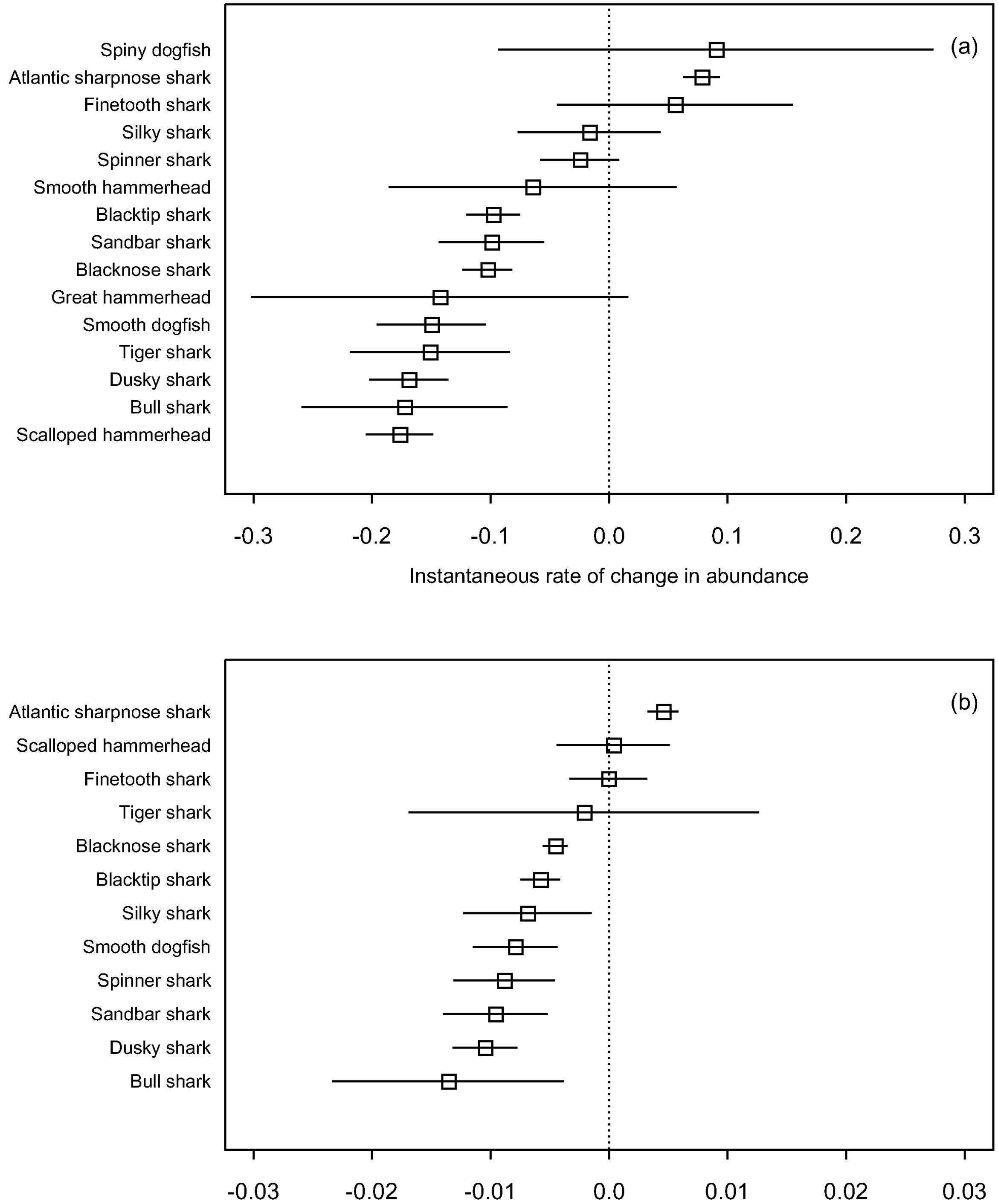
	Estimate	StdErr	p	k/scale
Abundance	-0.143	0.0812	0.079	1.96
Length	-7.19e-3	0.0707	0.919	1

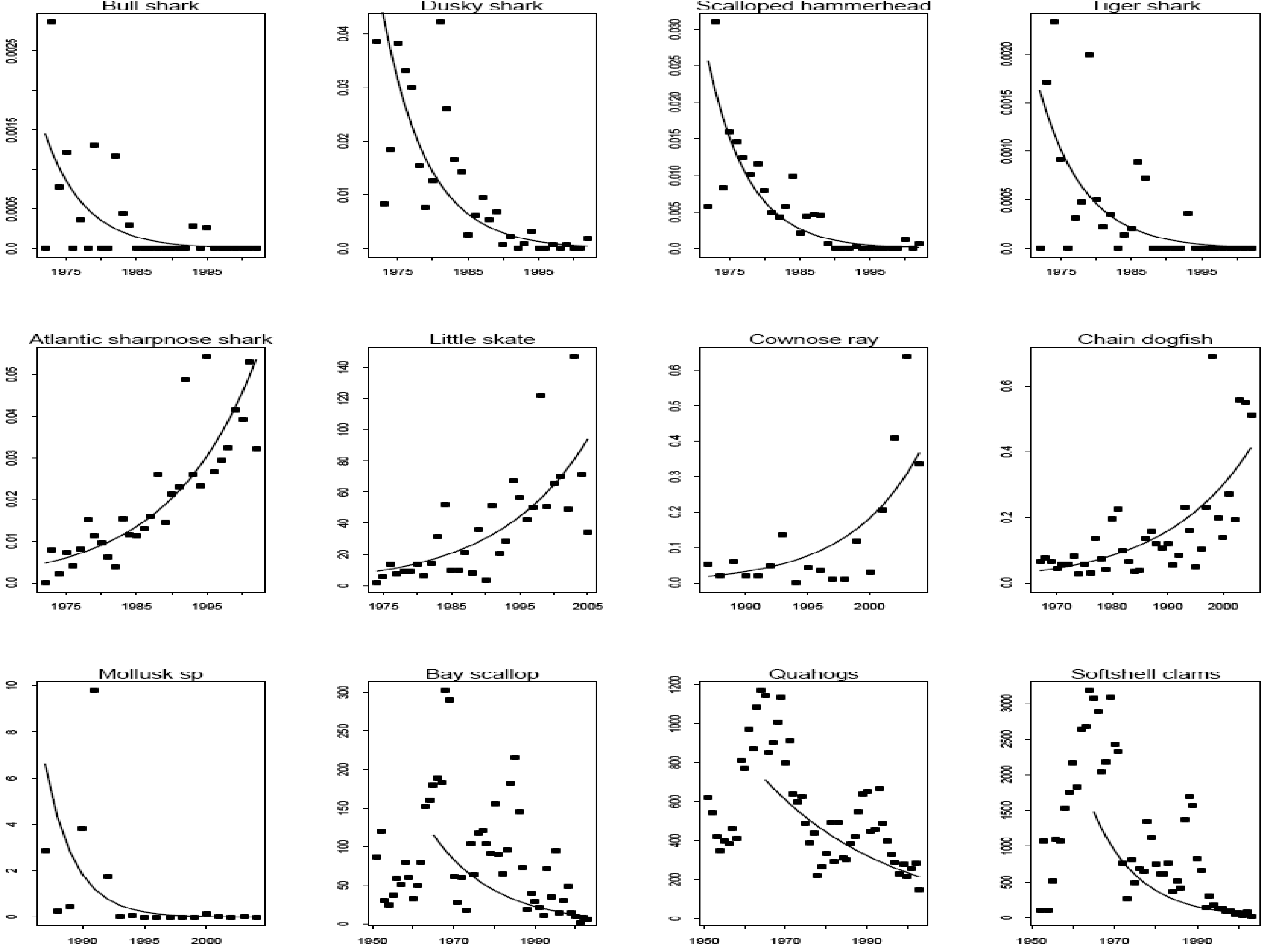
Bull shark



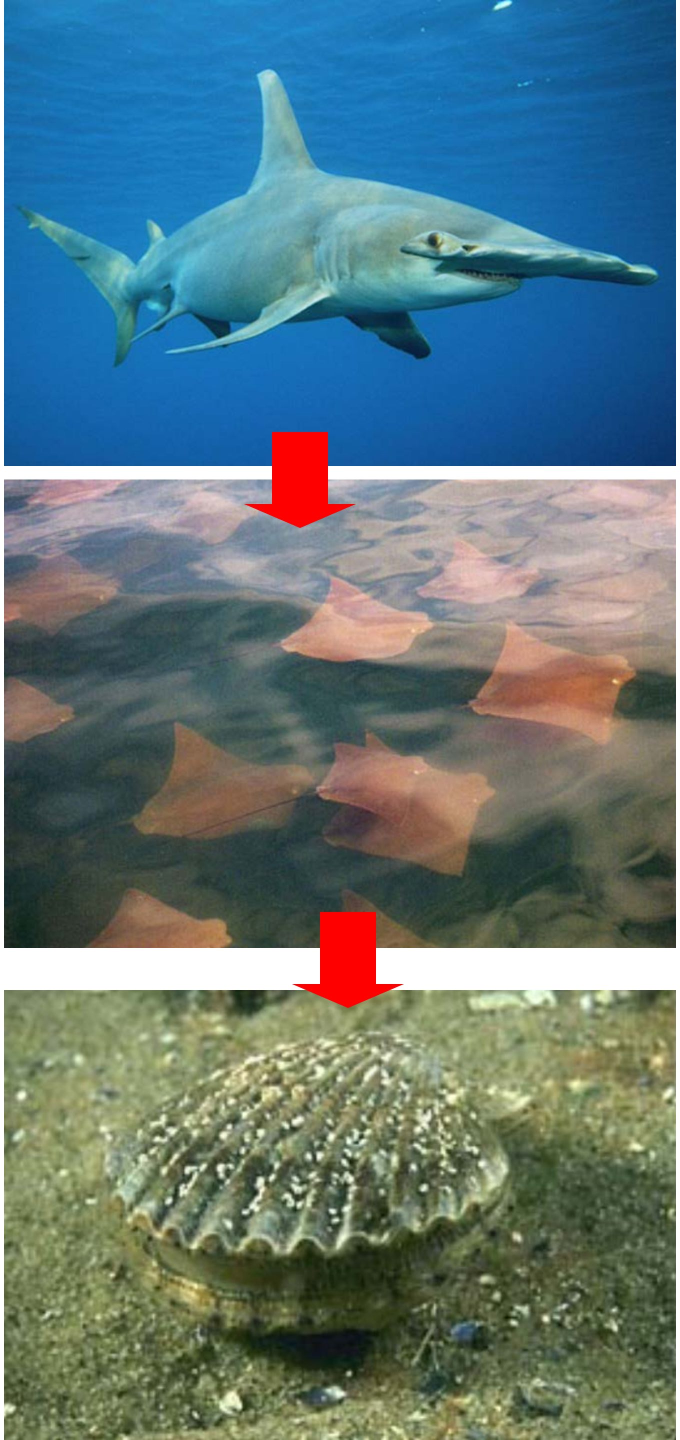
Generalized linear model results

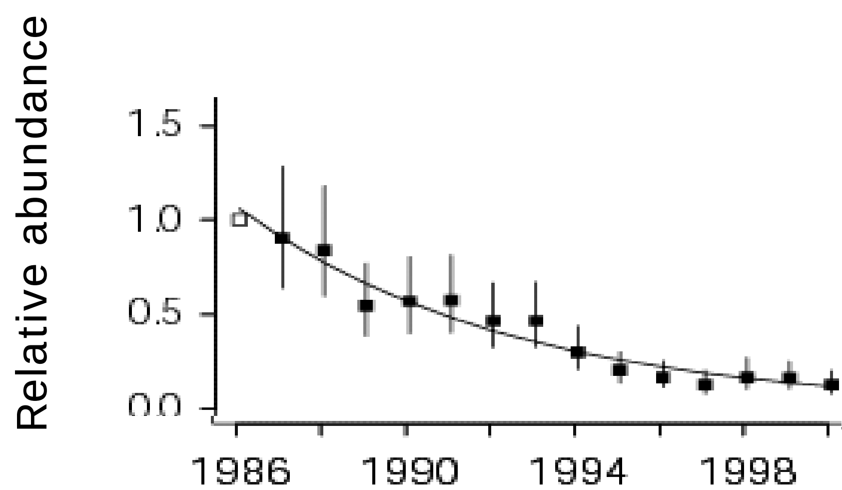
	Estimate	StdErr	p	k/scale
Abundance	-0.172	0.0443	9.99e-5	4.28
Length	-0.0136	5.e-3	6.69e-3	63.2

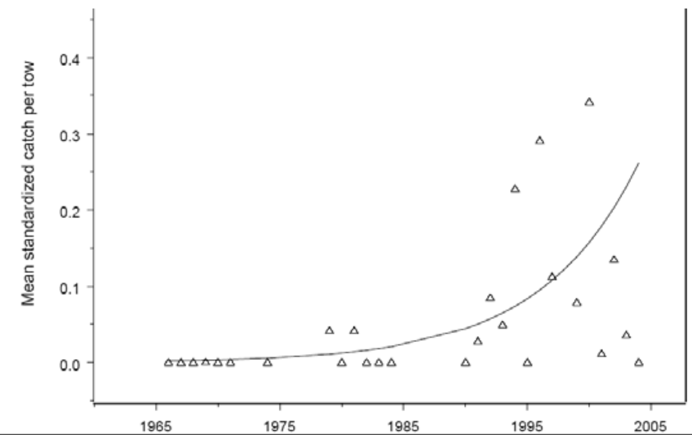

Spiny dogfish
Atlantic sharpnose shark
Finetooth shark
Silky shark
Spinner shark
Smooth hammerhead
Blacktip shark
Sandbar shark
Blacknose shark
Great hammerhead
Smooth dogfish
Tiger shark
Dusky shark
Bull shark
Scalloped hammerhead
(a)
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
Instantaneous rate of change in abundance
Atlantic sharpnose shark
Scalloped hammerhead
Finetooth shark
Tiger shark
Blacknose shark
Blacktip shark
Silky shark
Smooth dogfish
Spinner shark
Sandbar shark
Dusky shark
Bull shark
(b)
-0.03
-0.02
-0.01
0.0
0.01
0.02
0.03

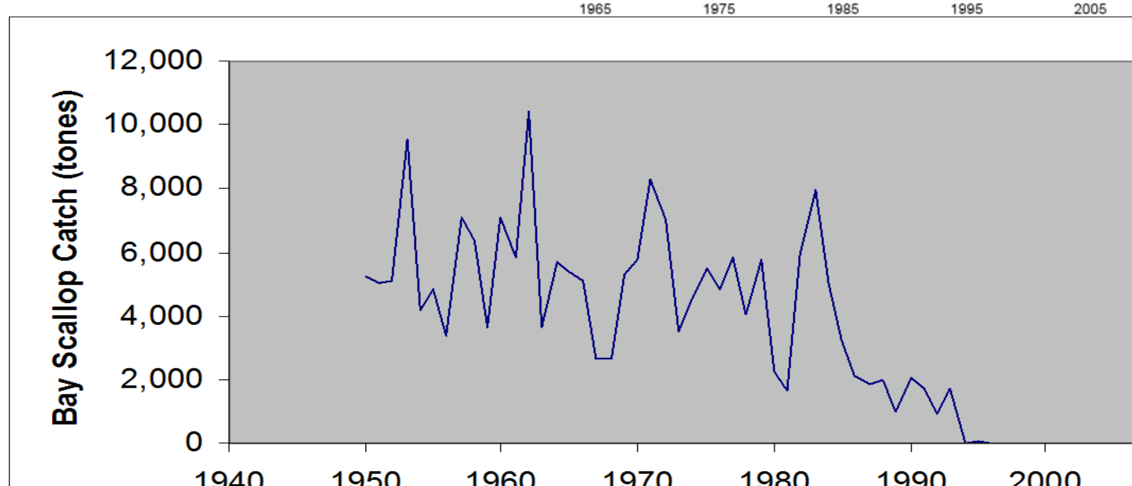


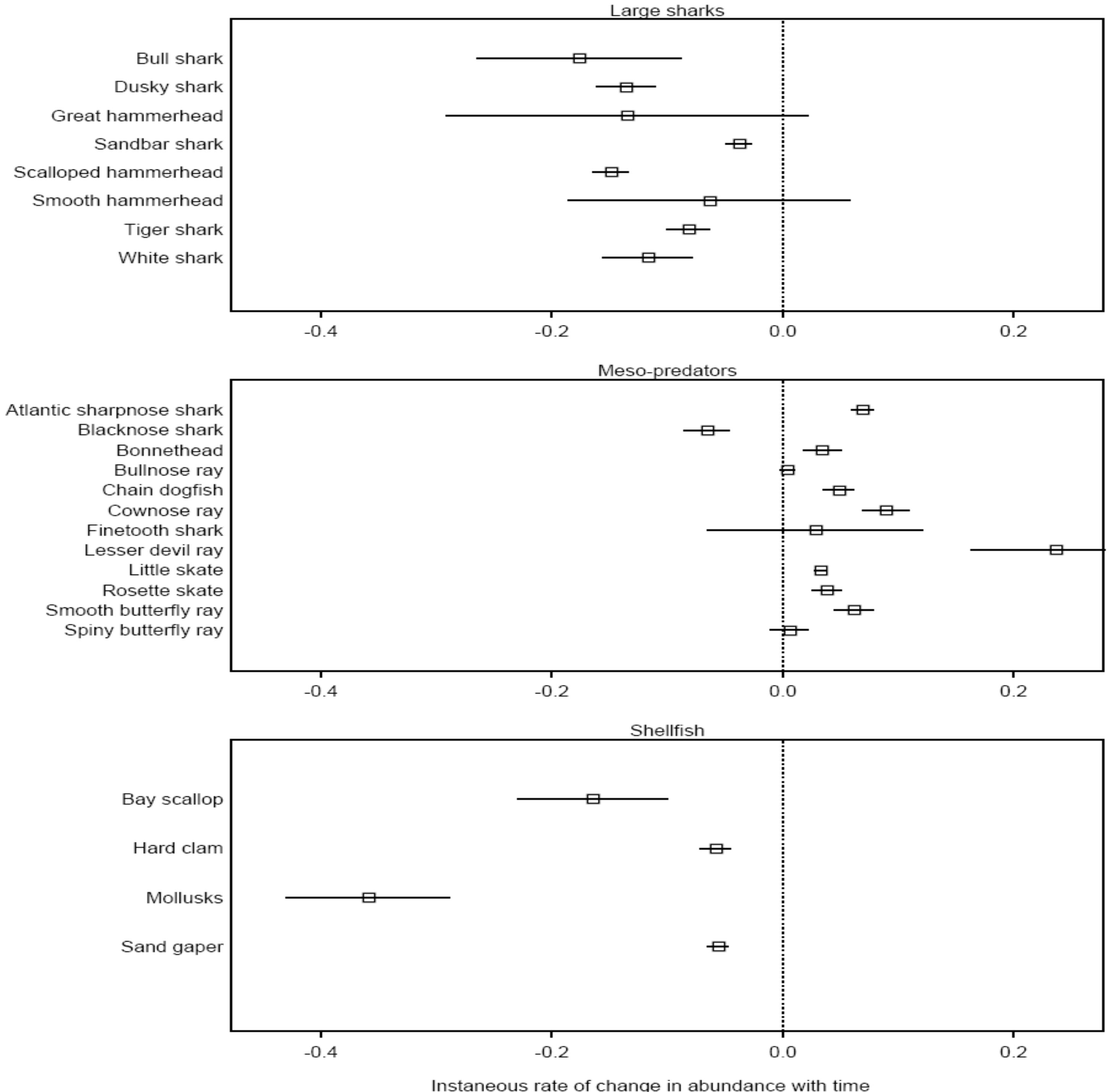
Bull shark
0.0
0.0005
0.0015
0.0025
1975
1985
1995
Dusky shark
0.0
0.01
0.02
0.03
0.04
1975
1985
1995
Scalloped hammerhead
0.0
0.005
0.010
0.015
0.020
0.025
0.030
1975
1985
1995
Tiger shark
0.0
0.0005
0.0010
0.0015
0.0020
1975
1985
1995
Atlantic sharpnose shark
0.0
0.01
0.02
0.03
0.04
0.05
1975
1985
1995
Little skate
0
20
40
60
80
100
120
140
1975
1985
1995
2005
Cownose ray
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1990
1995
2000
Chain dogfish
0.0
0.2
0.4
0.6
1970
1980
1990
2000
Mollusk sp
0
2
4
6
8
10
1990
1995
2000
Bay scallop
0
50
100
150
200
250
300
1950
1970
1990
Quahogs
0
200
400
600
800
1000
1200
1950
1970
1990
Softshell clams
0
500
1000
1500
2000
2500
3000
1950
1970
1990




Relative abundance
1.5
1.0
0.5
0.0
1986
1990
1994
1998

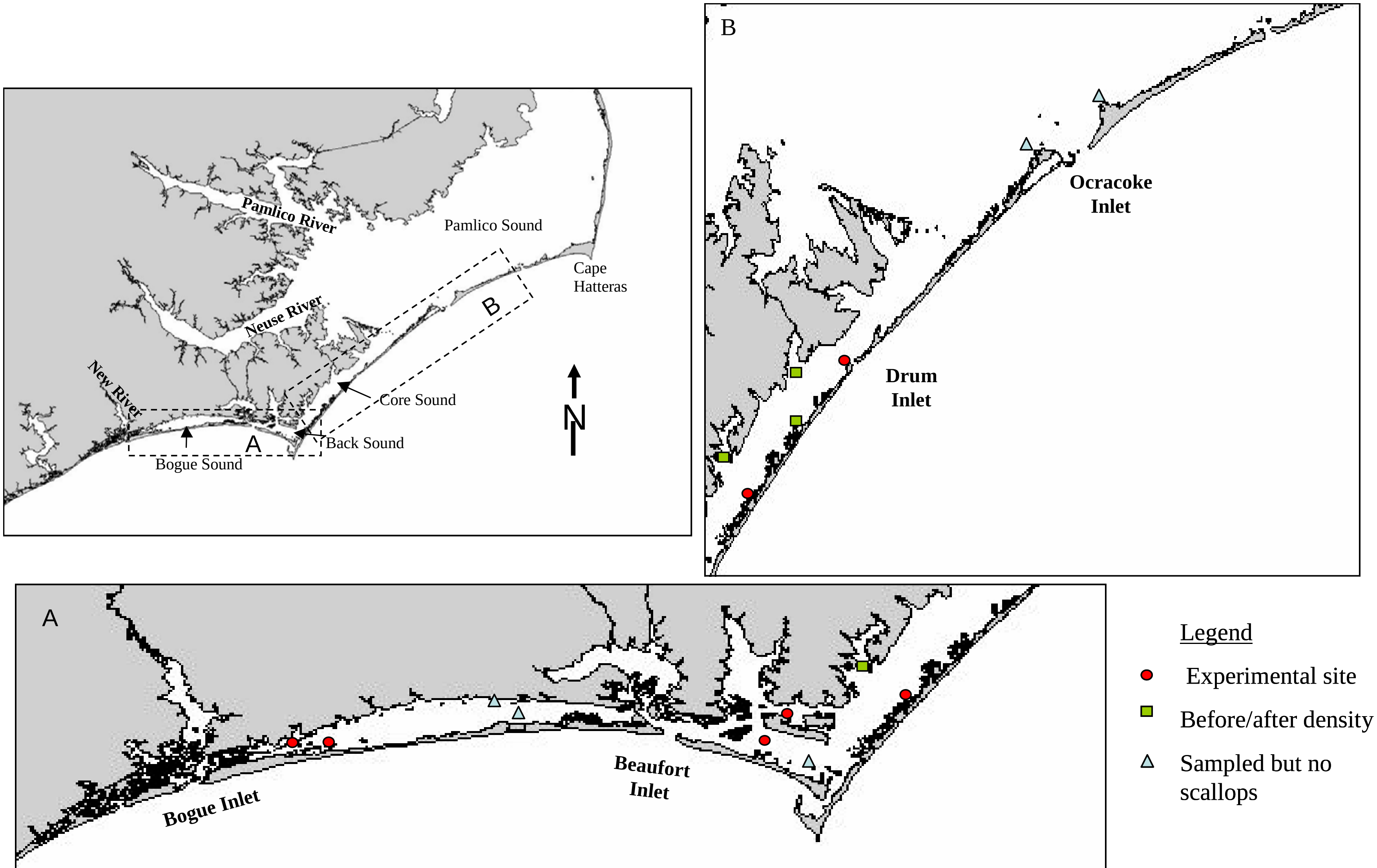

Mean standardized catch per tow
0.4
0.3
0.2
0.1
0.0
1965
1975
1985
1995
2005


Bay Scallop Catch (tones)
12,000
10,000
8,000
6,000
4,000
2,000
0
1940
1950
1960
1970
1980
1990
2000

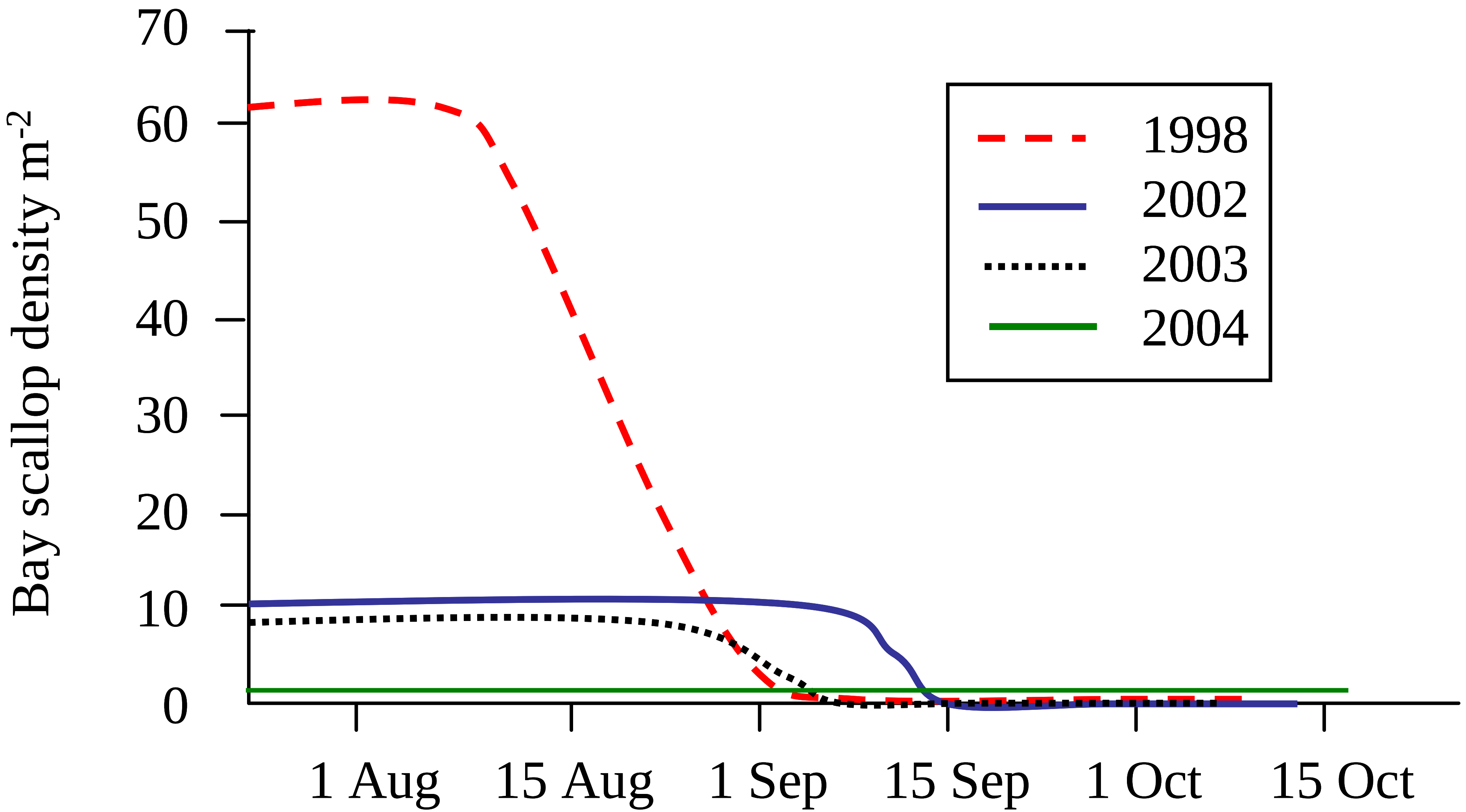


Large sharks
Bull shark
Dusky shark
Great hammerhead
Sandbar shark
Scalloped hammerhead
Smooth hammerhead
Tiger shark
White shark
-0.4
-0.2
0.0
0.2
Meso-predators
Atlantic sharpnose shark
Blacknose shark
Bonnethead
Bullnose ray
Chain dogfish
Cownose ray
Finetooth shark
Lesser devil ray
Little skate
Rosette skate
Smooth butterfly ray
Spiny butterfly ray
-0.4
-0.2
0.0
0.2
Shellfish
Bay scallop
Hard clam
Mollusks
Sand gaper
-0.4
-0.2
0.0
0.2
Instaneous rate of change in abundance with time

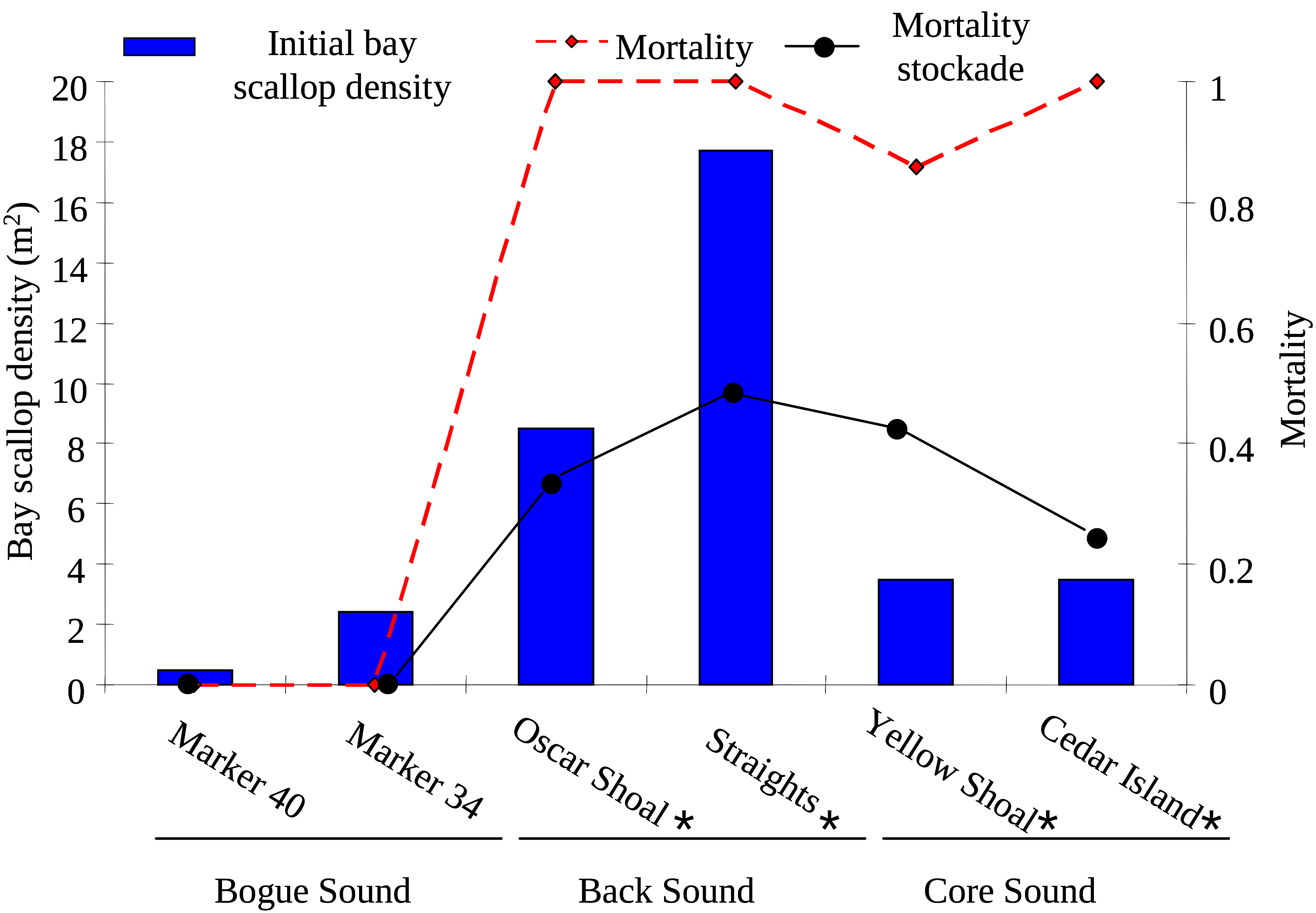
Experimental Results of Pete Peterson and Sean Powers in North Carolina



Loss of Bay Scallops with Cownose Ray Fall Migration



Excluding cownose rays allow the survival of bay scallops.



Excluding cownose rays allow the survival of bay scallops.

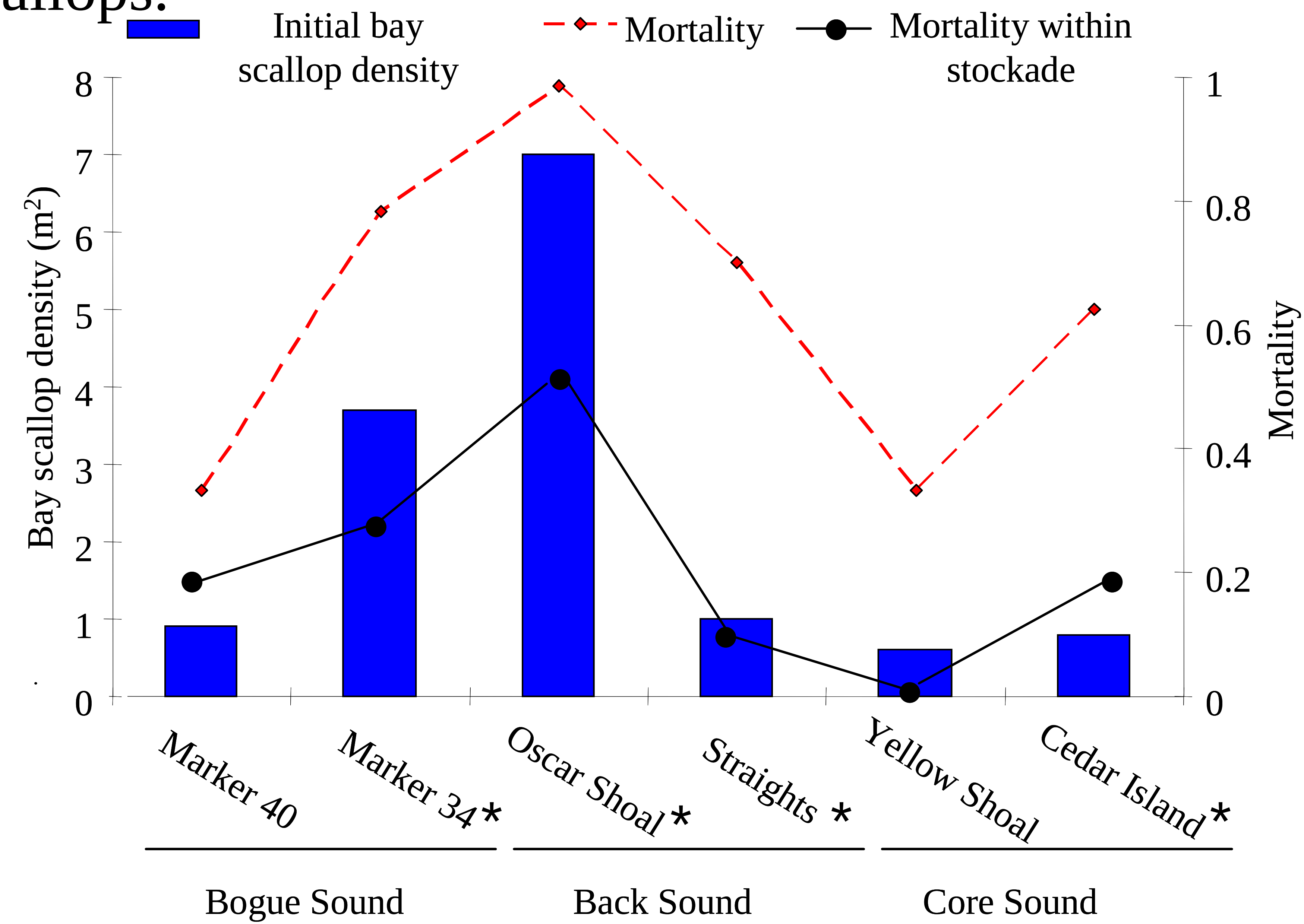
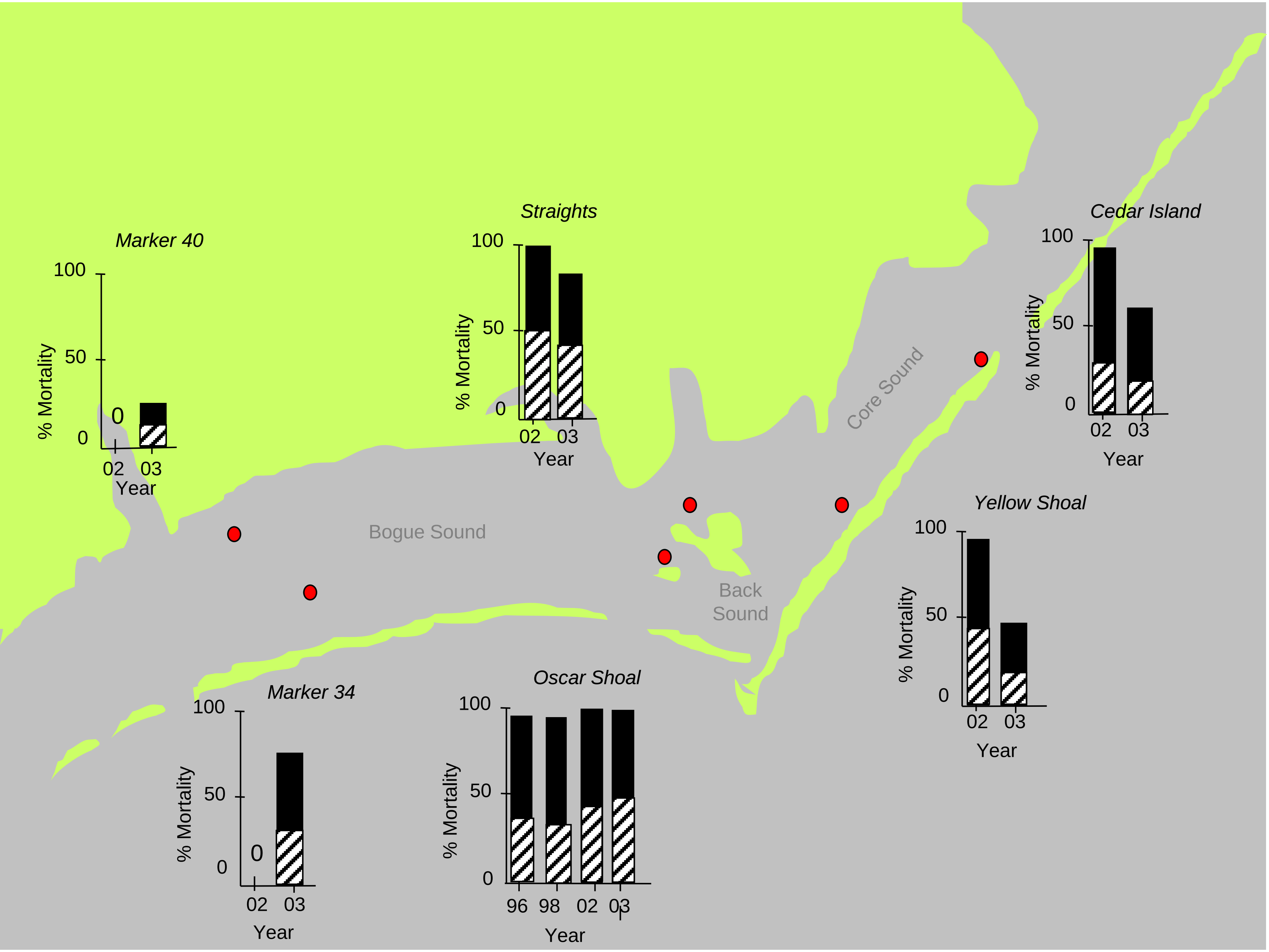
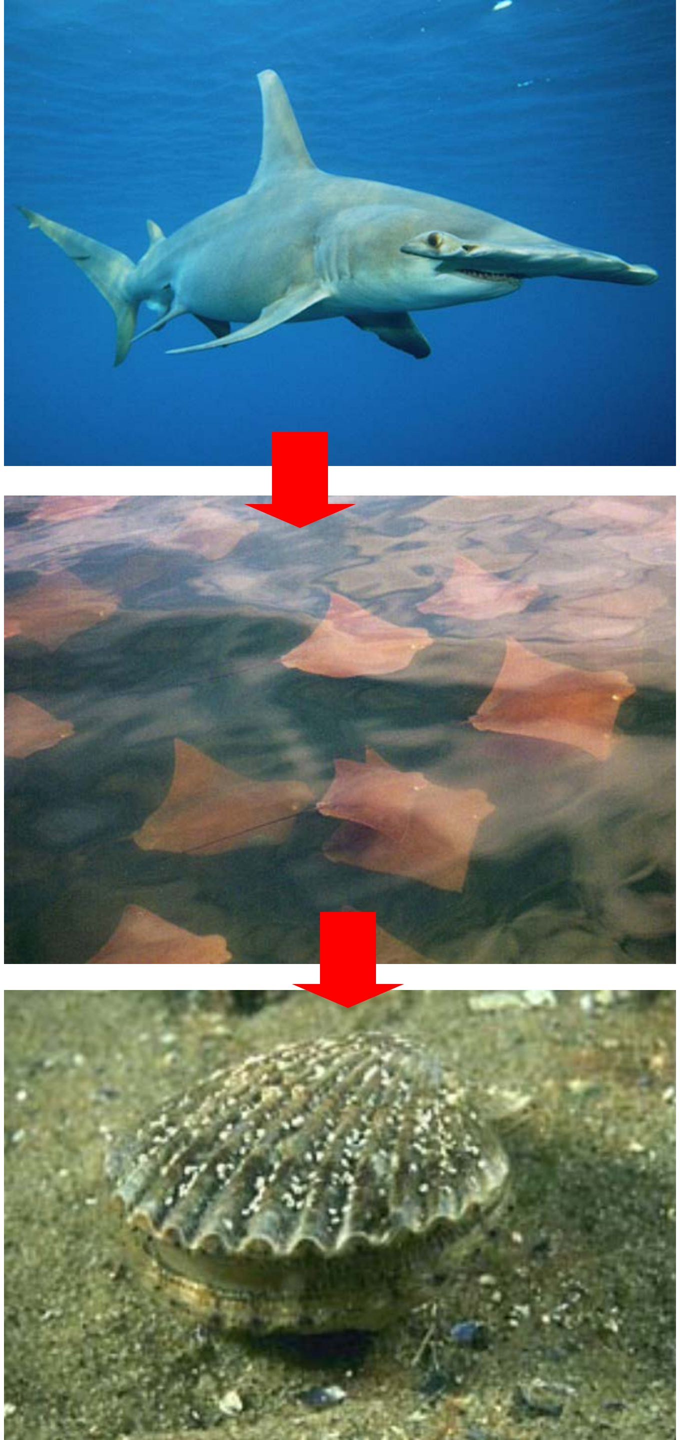


Fig 1. Total and stockade mortality





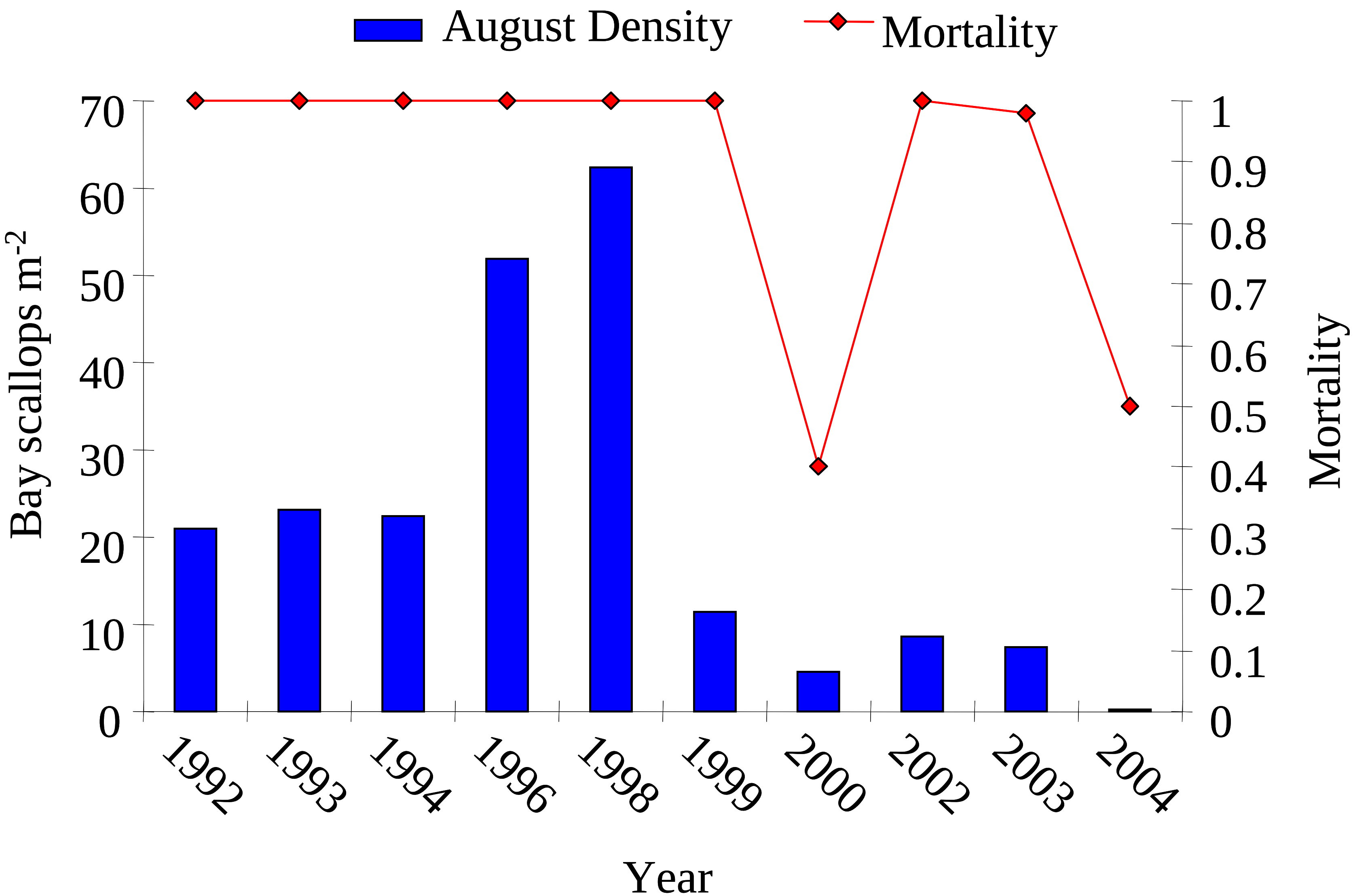
Trophic Cascades: Consequences of the loss of top predators may be greater than we think

The First Collective Act of Humanity was to save the great whales –

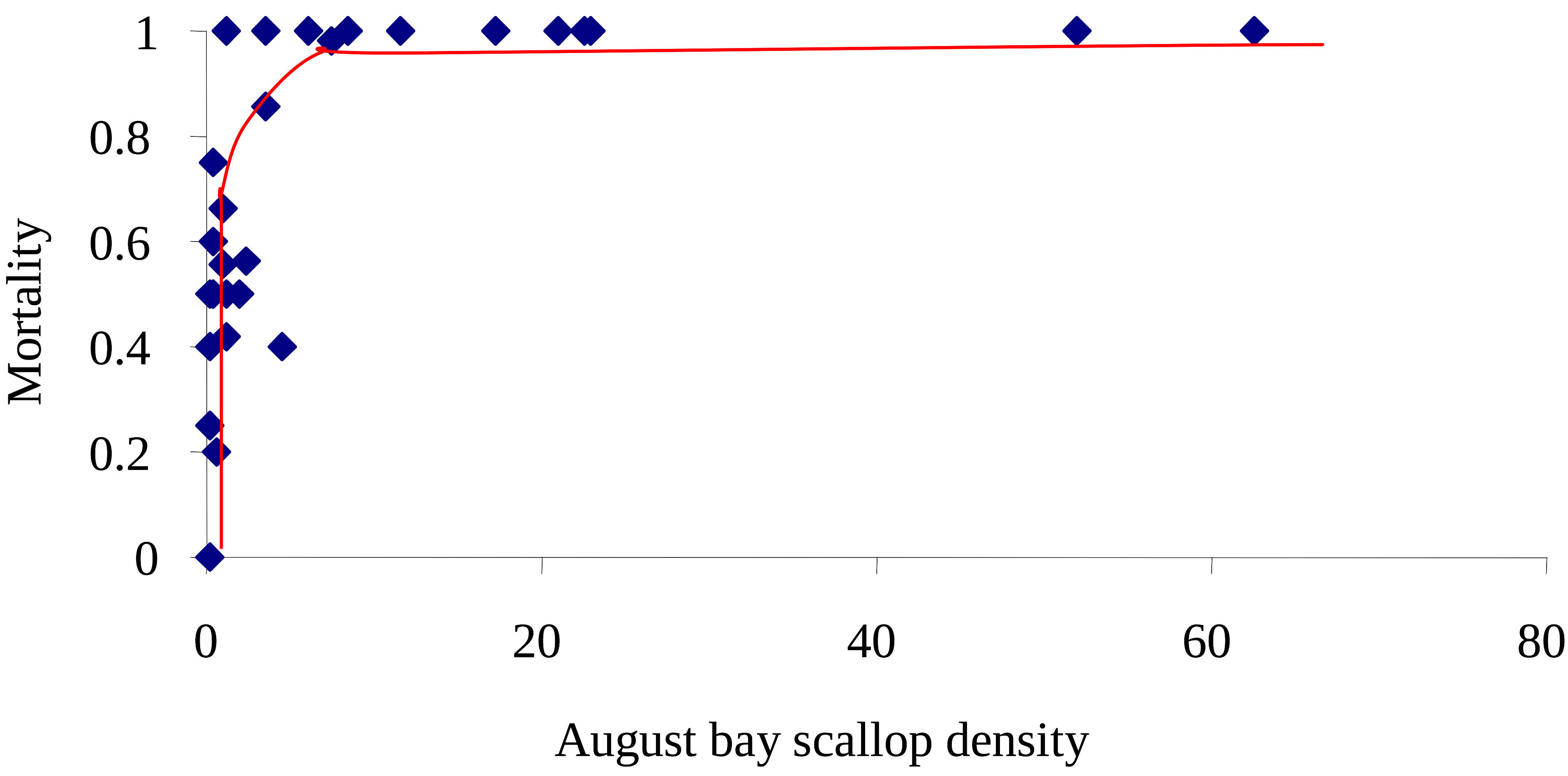
despite massive denial

– we can do
the same for the remaining virgin areas of the oceans and for the great sharks.

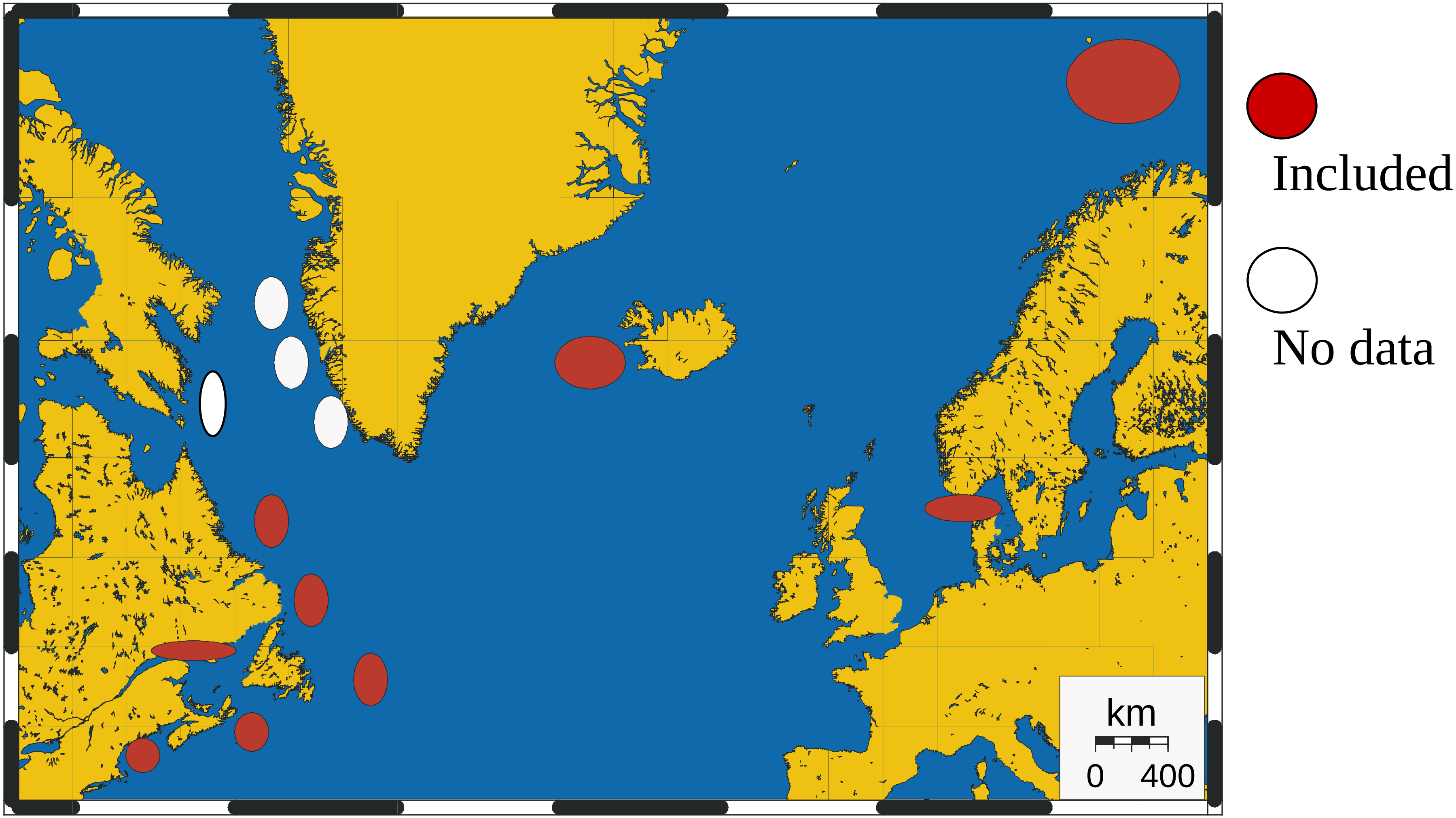
Mortality of almost 100% during fall migration of cownose rays



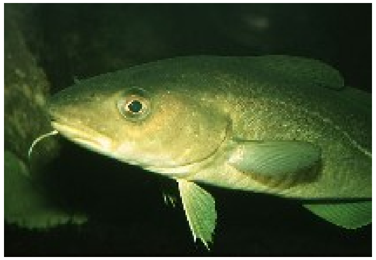
Mortality of almost 100% during fall migration of cownose rays

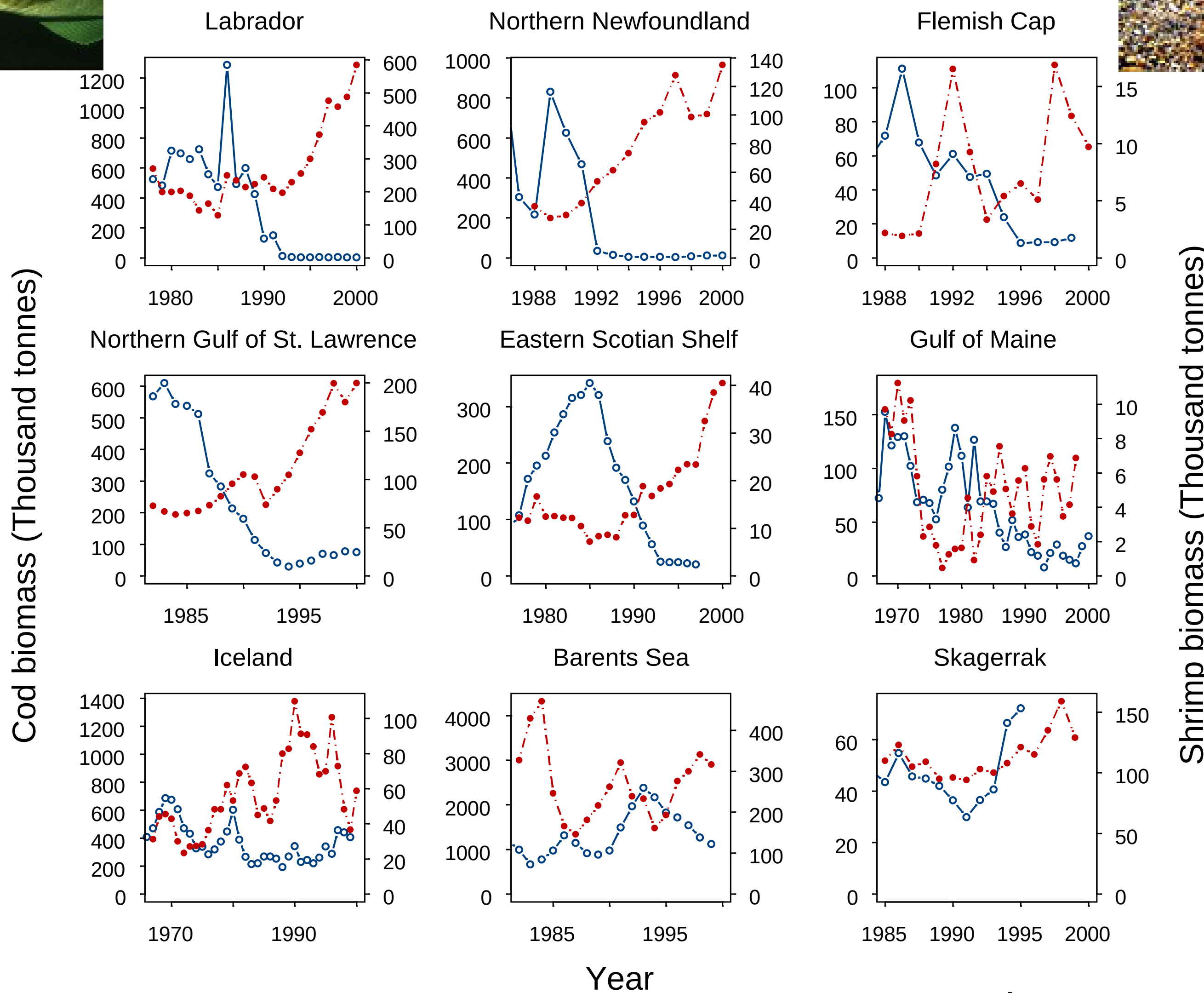


Major shrimp stocks in the North Atlantic



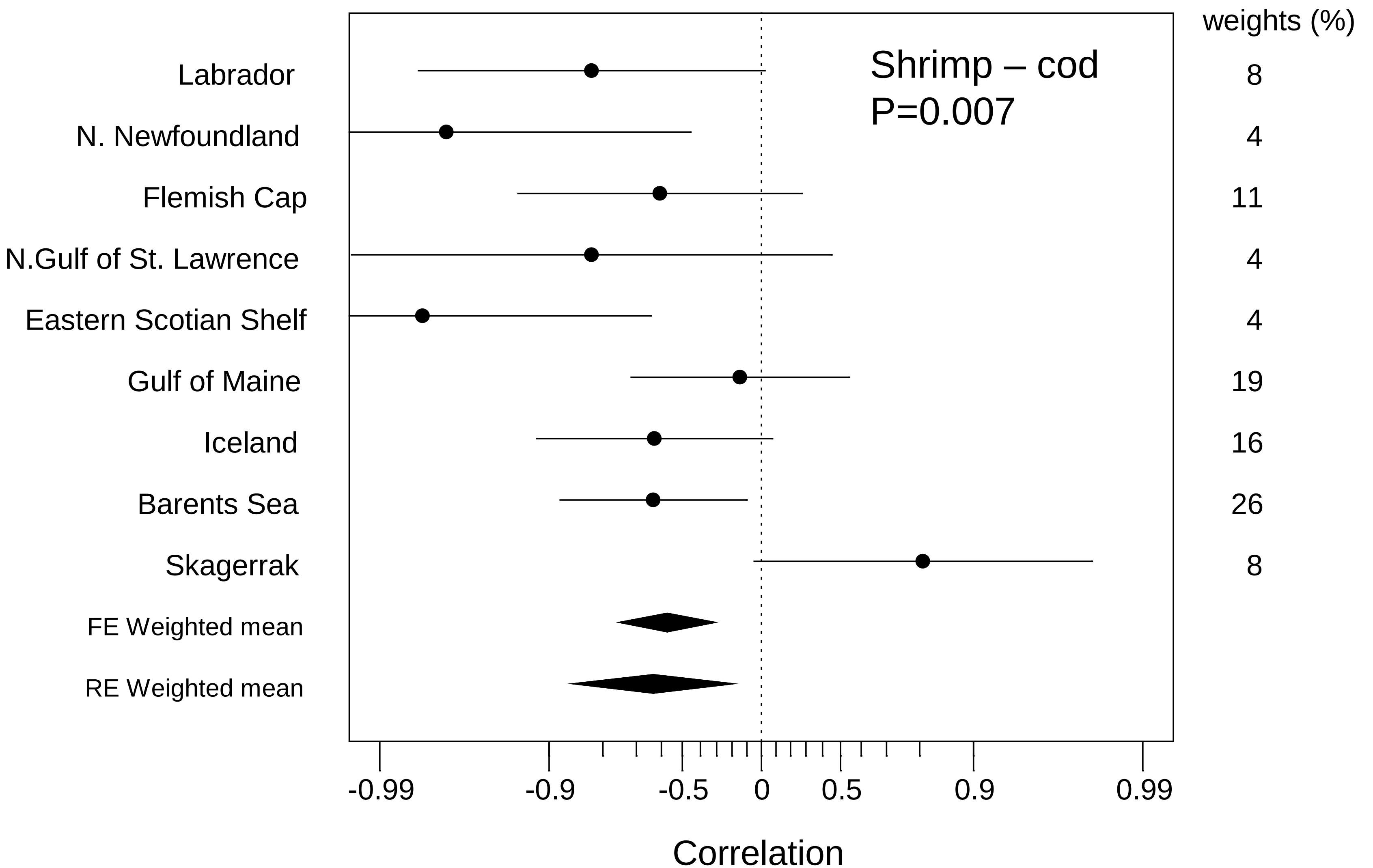
Cod and shrimp biomass in the North Atlantic: time series

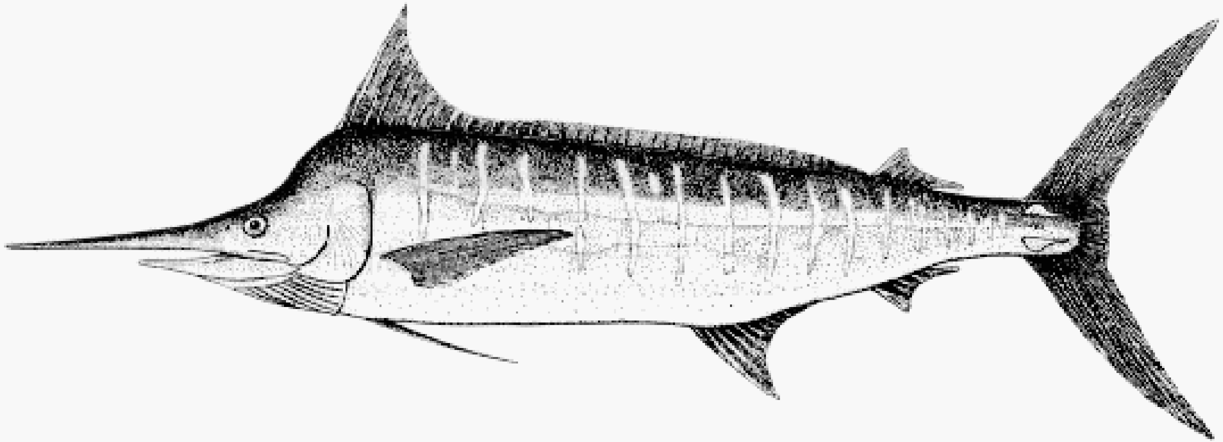




Worm and Myers, Ecology 2003

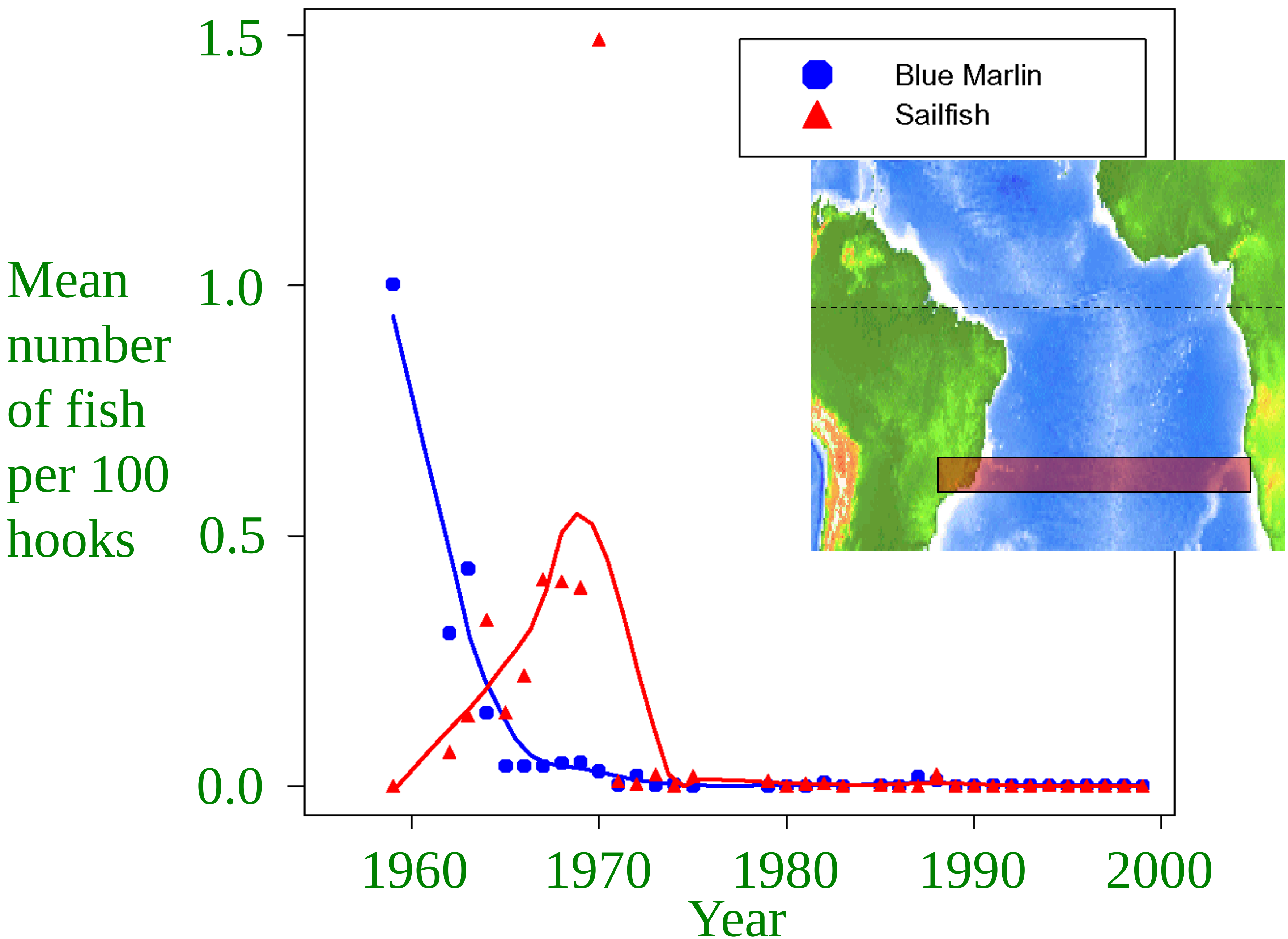
Step 2: Random-effects meta-analysis

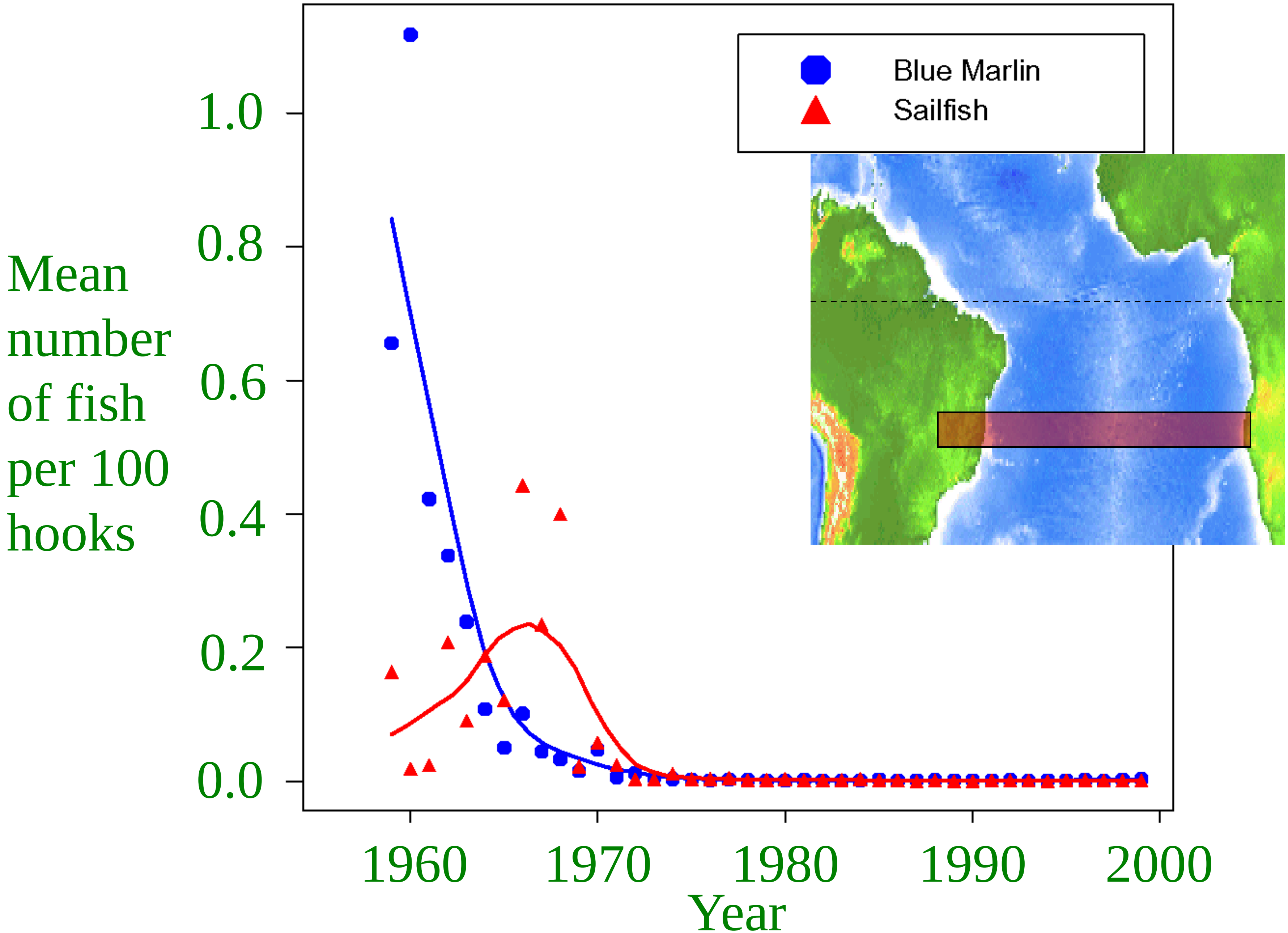


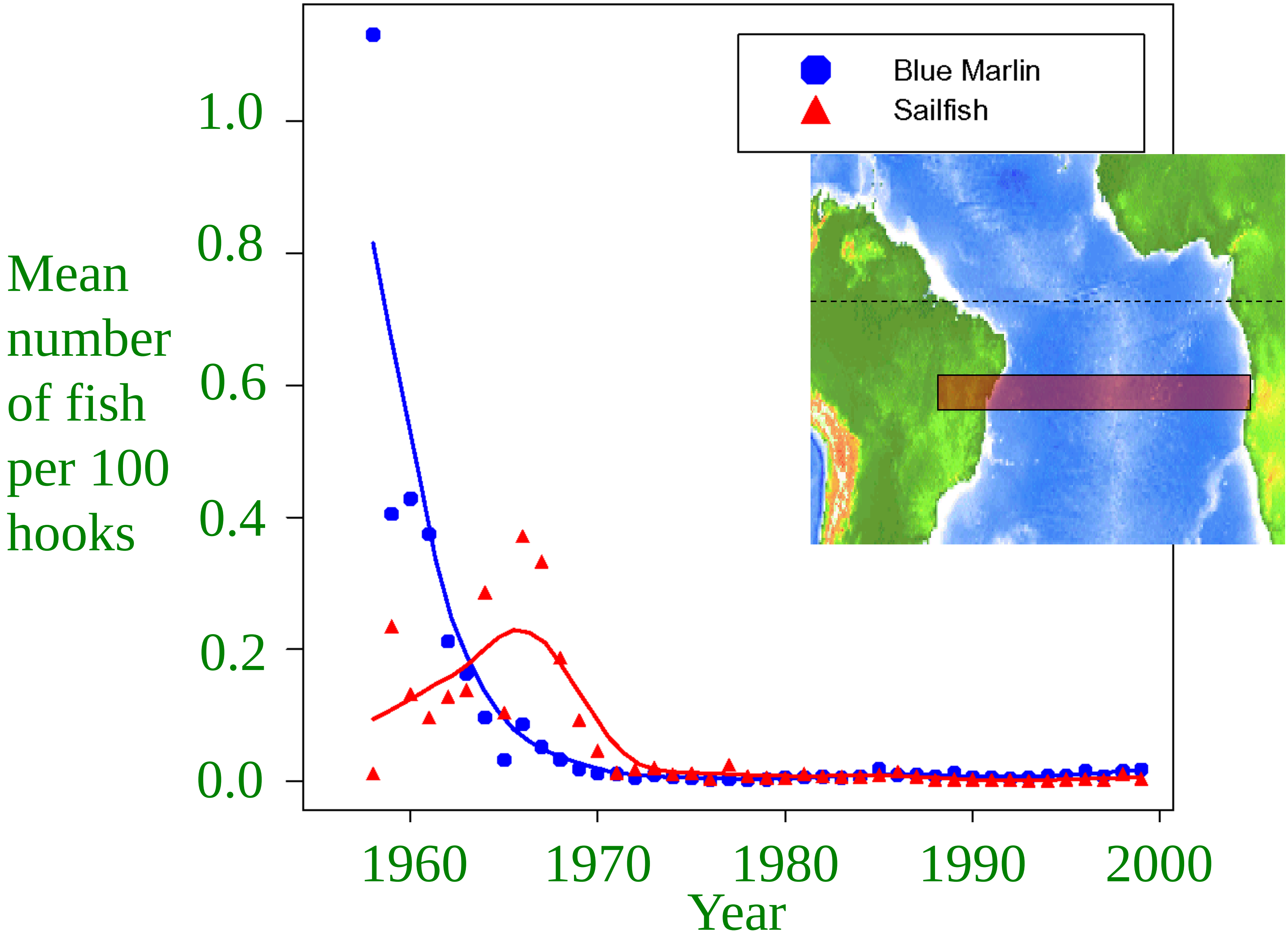


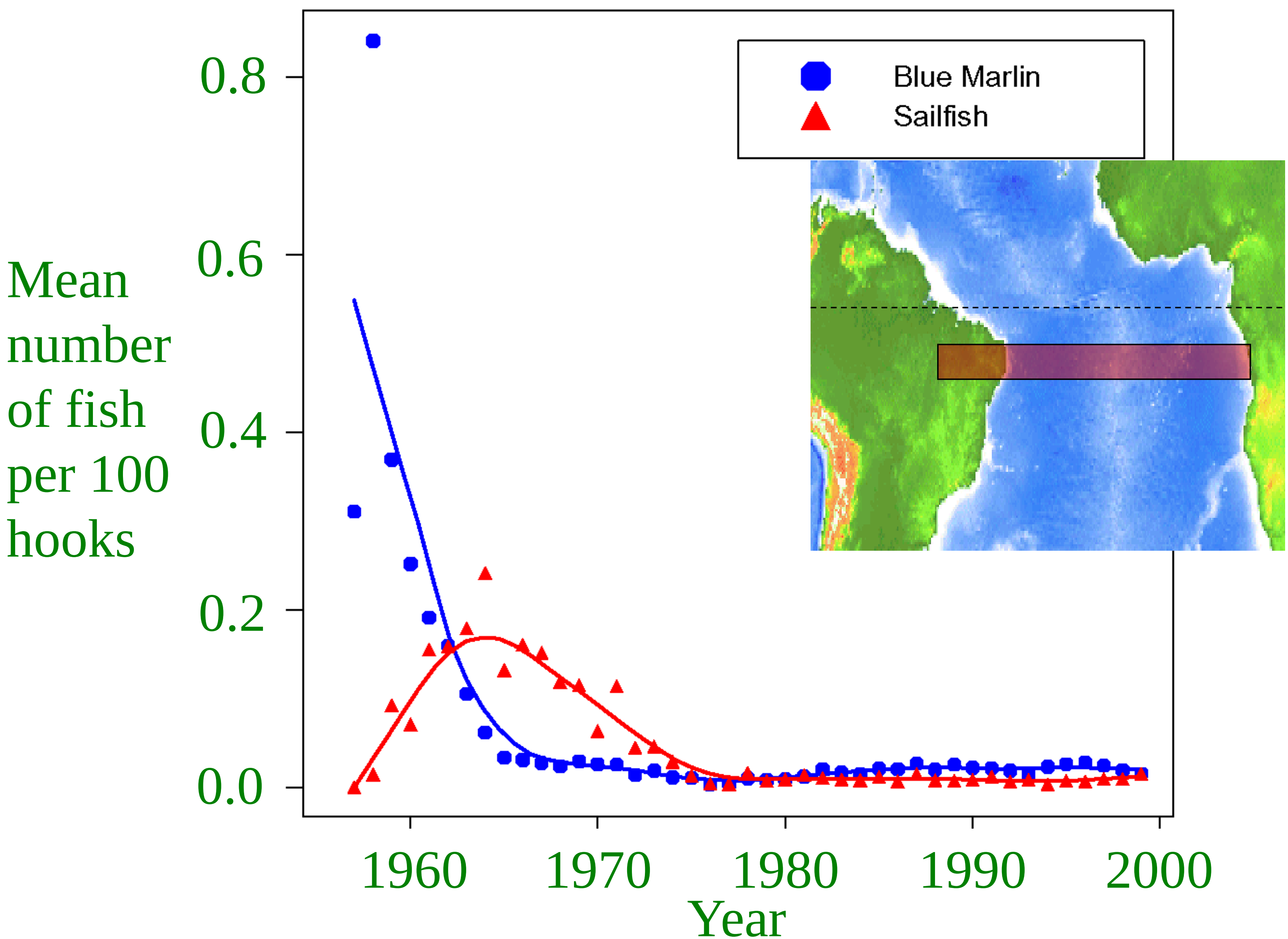
Blue marlin (*Makaira nigricans)*

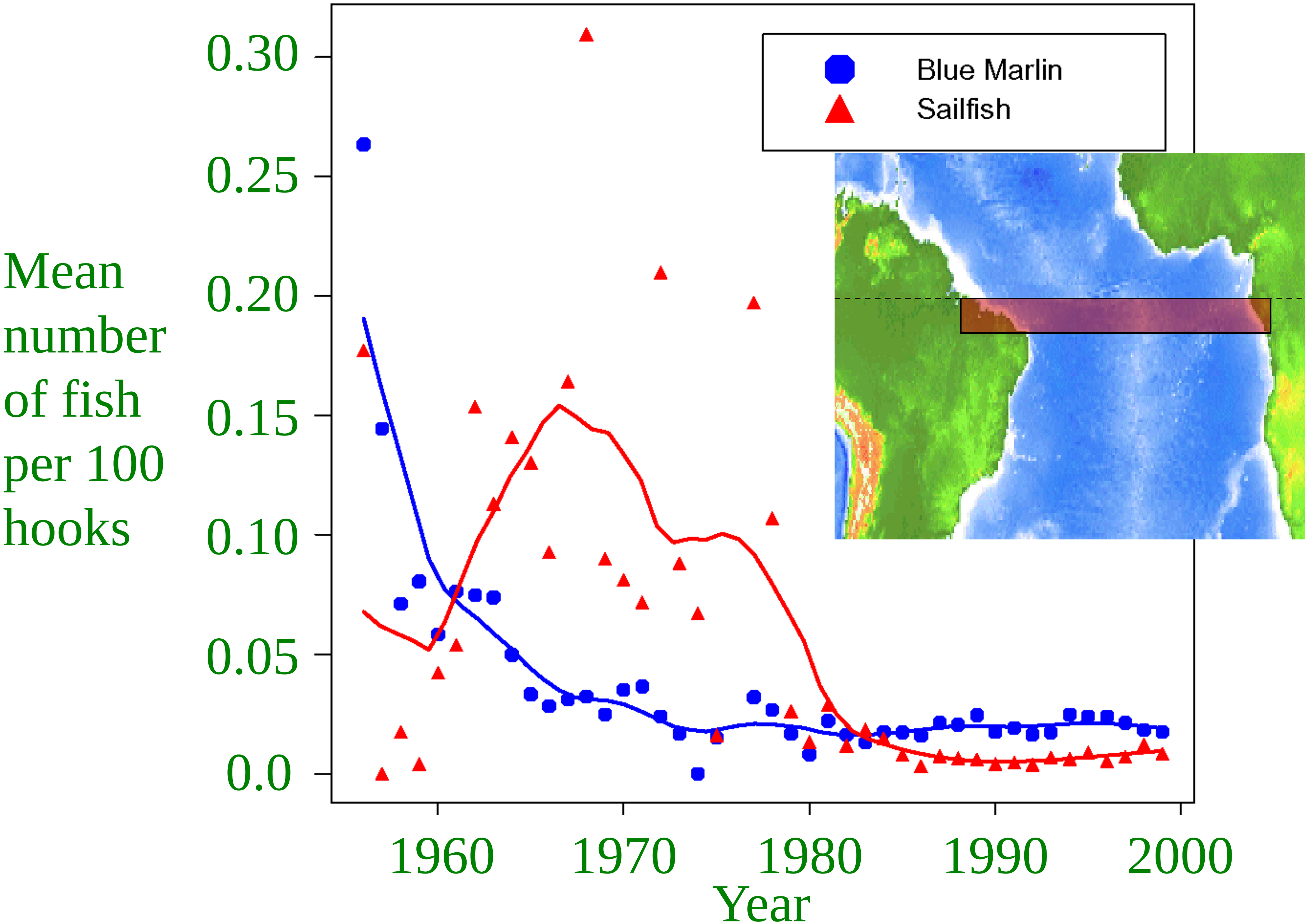
Sailfish (*Istiophorus albicans)*

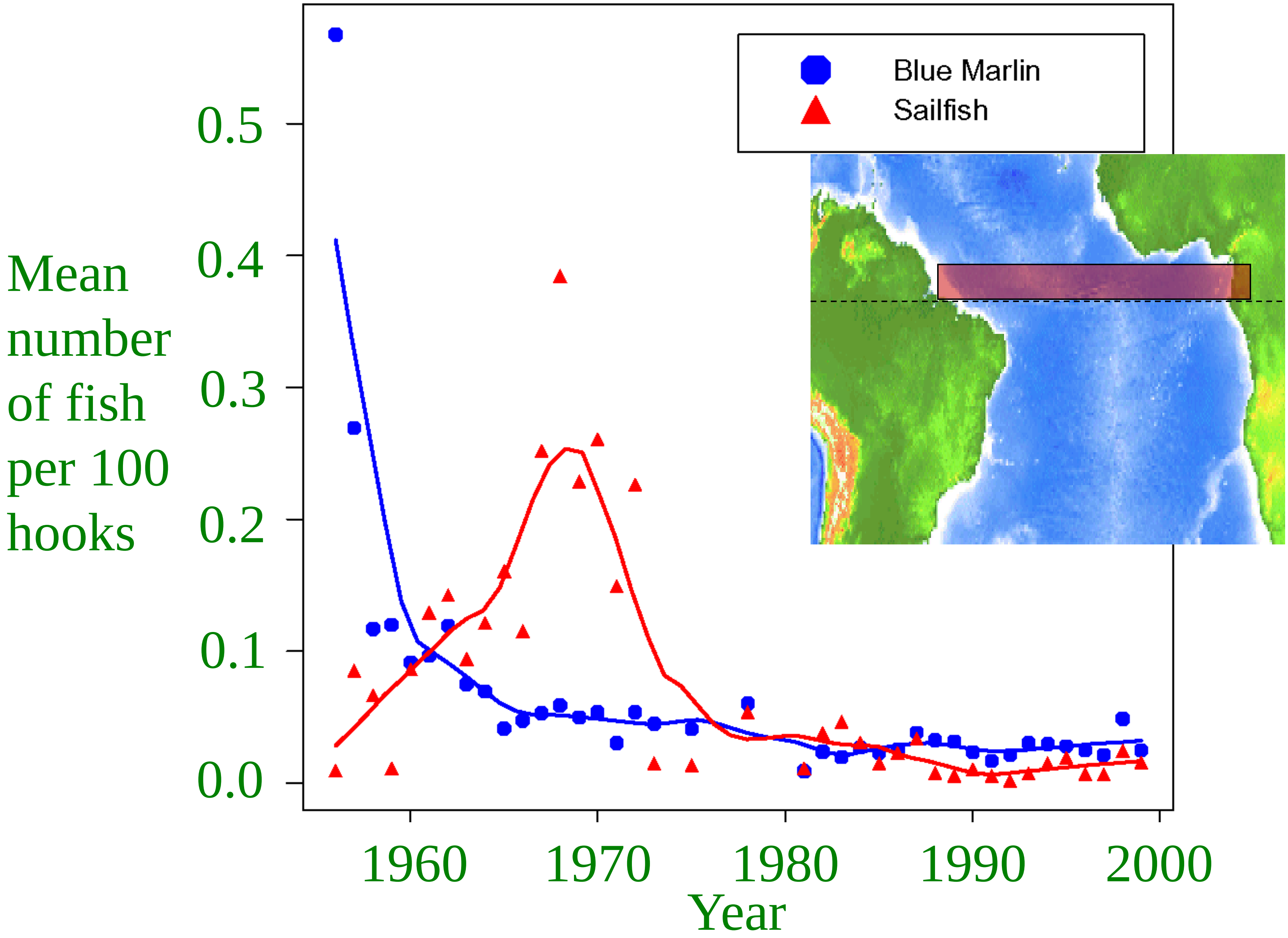

Blue Marlin
Sailfish
Mean number of fish per 100 hooks
1.5
1.0
0.5
0.0
1960
1970
1980
1990
2000
Year


Blue Marlin
Sailfish
Mean number of fish per 100 hooks
1.0
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
Year


Blue Marlin
Sailfish
Mean number of fish per 100 hooks
1.0
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
Year

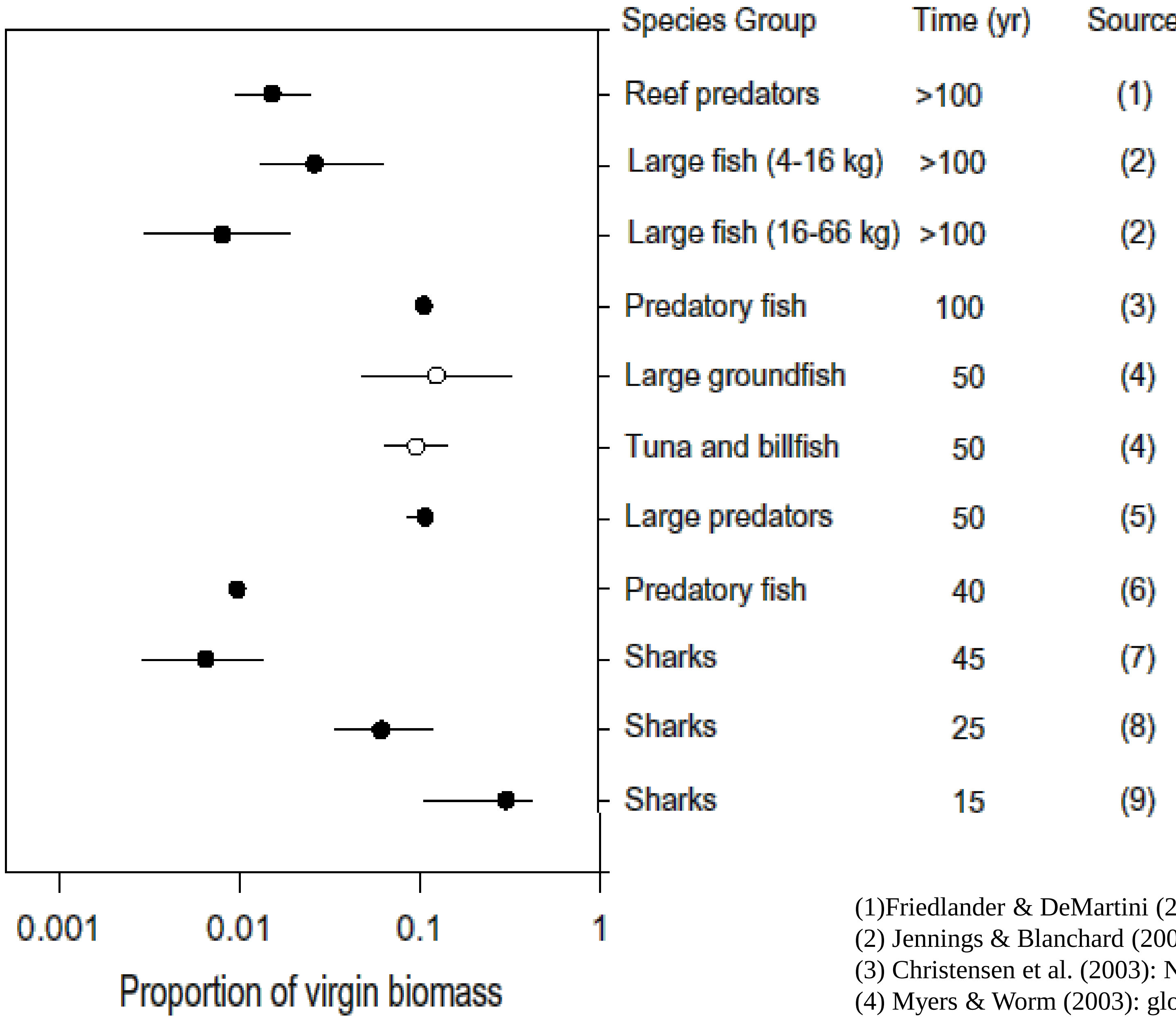

Mean
number
of fish
per 100
hooks
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
Year
Blue Marlin
Sailfish


Mean number of fish per 100 hooks
0.30
0.25
0.20
0.15
0.10
0.05
0.0
1960
1970
1980
1990
2000
Year
Blue Marlin
Sailfish


Blue Marlin
Sailfish
0.5
0.4
0.3
0.2
0.1
0.0
Mean number of fish per 100 hooks
1960
1970
1980
1990
2000
Year

Not only have large predators declined by at least a fact
10, but mesopredators have often increased by at least a
factor of 10.

FMAP (Future of Marine Animal Populations)
part of the Sloan Census of Life http://www.fmap.ca
Pew Global Sharks Assessment http://www.globalsharks.ca



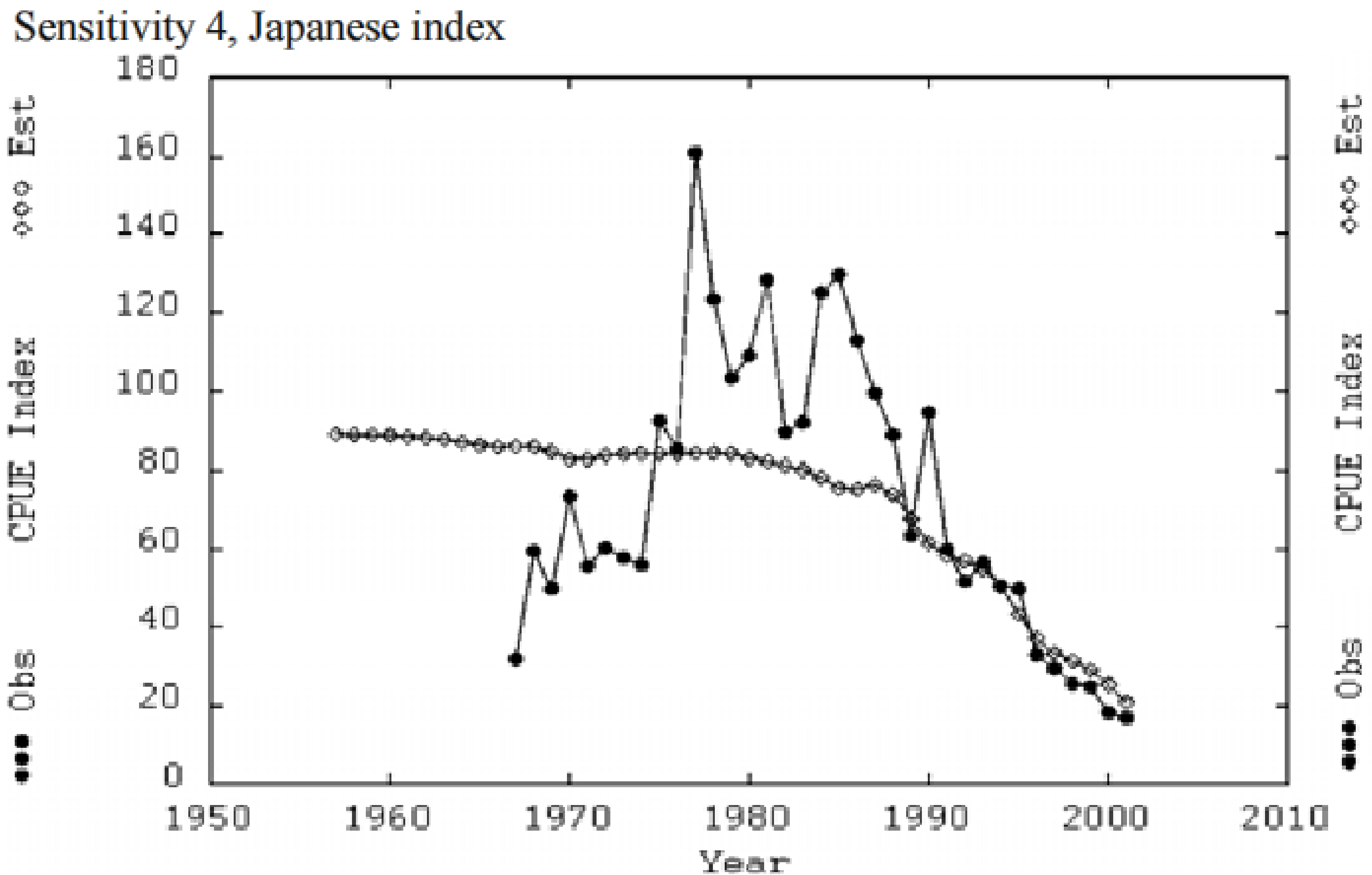
(1)Friedlander & DeMartini (2002): Hawaiian reefs;
(2) Jennings & Blanchard (2004): North Sea;
(3) Christensen et al. (2003): North Atlantic;
(4) Myers & Worm (2003): global;
(5) Ward & Myers (2003): North Pacific;
(6) Tang et al. (2003): Bohai Sea;
(7) Baum & Myers (2004): Gulf of Mexico;
(8) Vacchi et al. (2000): Mediterranean Sea;
(9) Baum et al. (2003): Northwest Atlantic.

Source: Myers and Worm 2005.
Proc. R. Soc. Lond. B (2005)

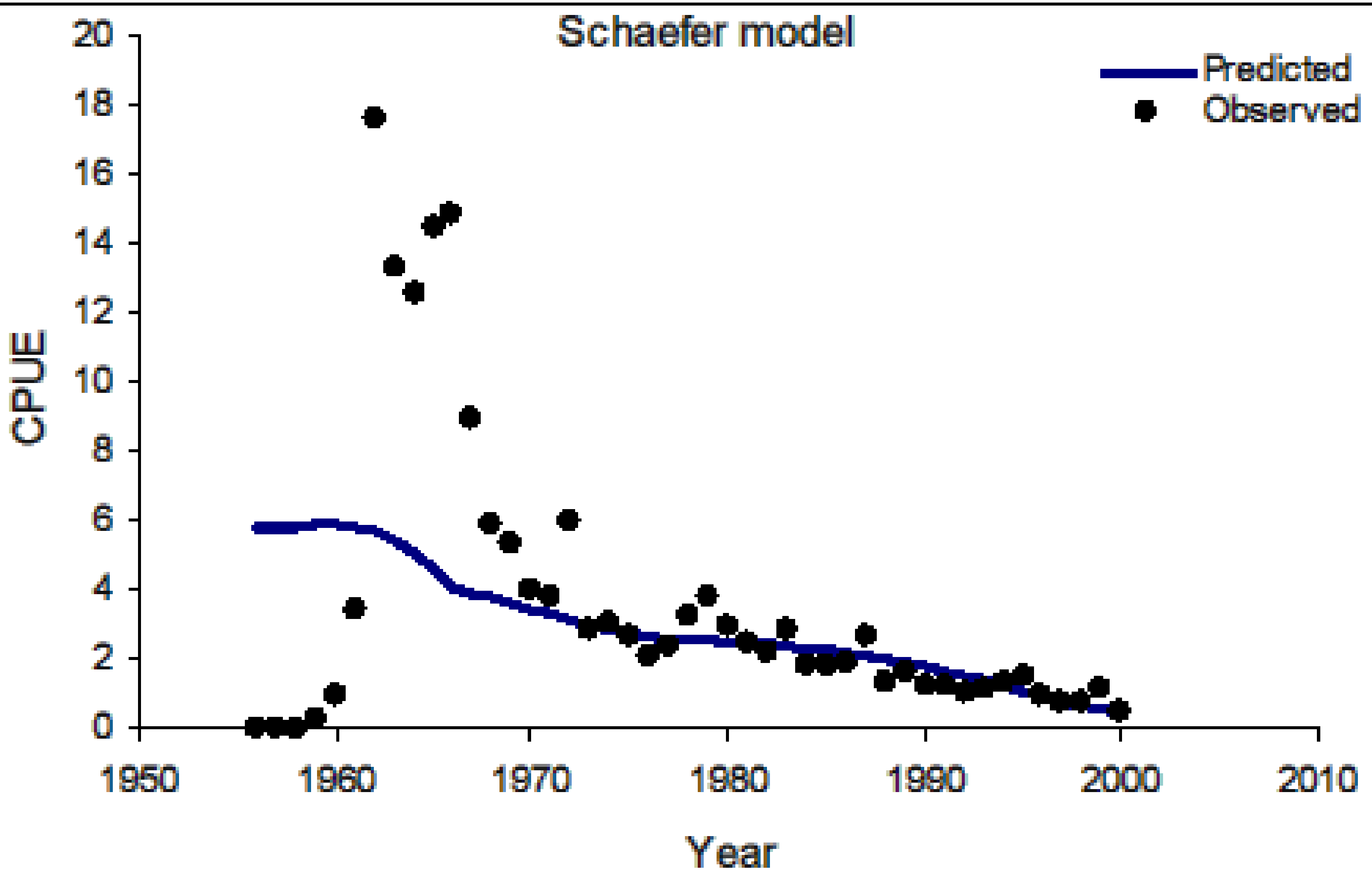
Not only have large predators declined by at least a fact
10, but mesopredators have often increased by at least a
factor of 10.

FMAP (Future of Marine Animal Populations)
part of the Sloan Census of Life http://www.fmap.ca
Pew Global Sharks Assessment http://www.globalsharks.ca

Single species models are not even remotely consistent with the data, e.g. Swordfish from the South Atlantic



White Marlin: Atlantic, single species models do not work
Very well.



ICCAT shark assessments in the Atlantic don't even remotely fit reliable data: Similar pattern for US government research surveys.

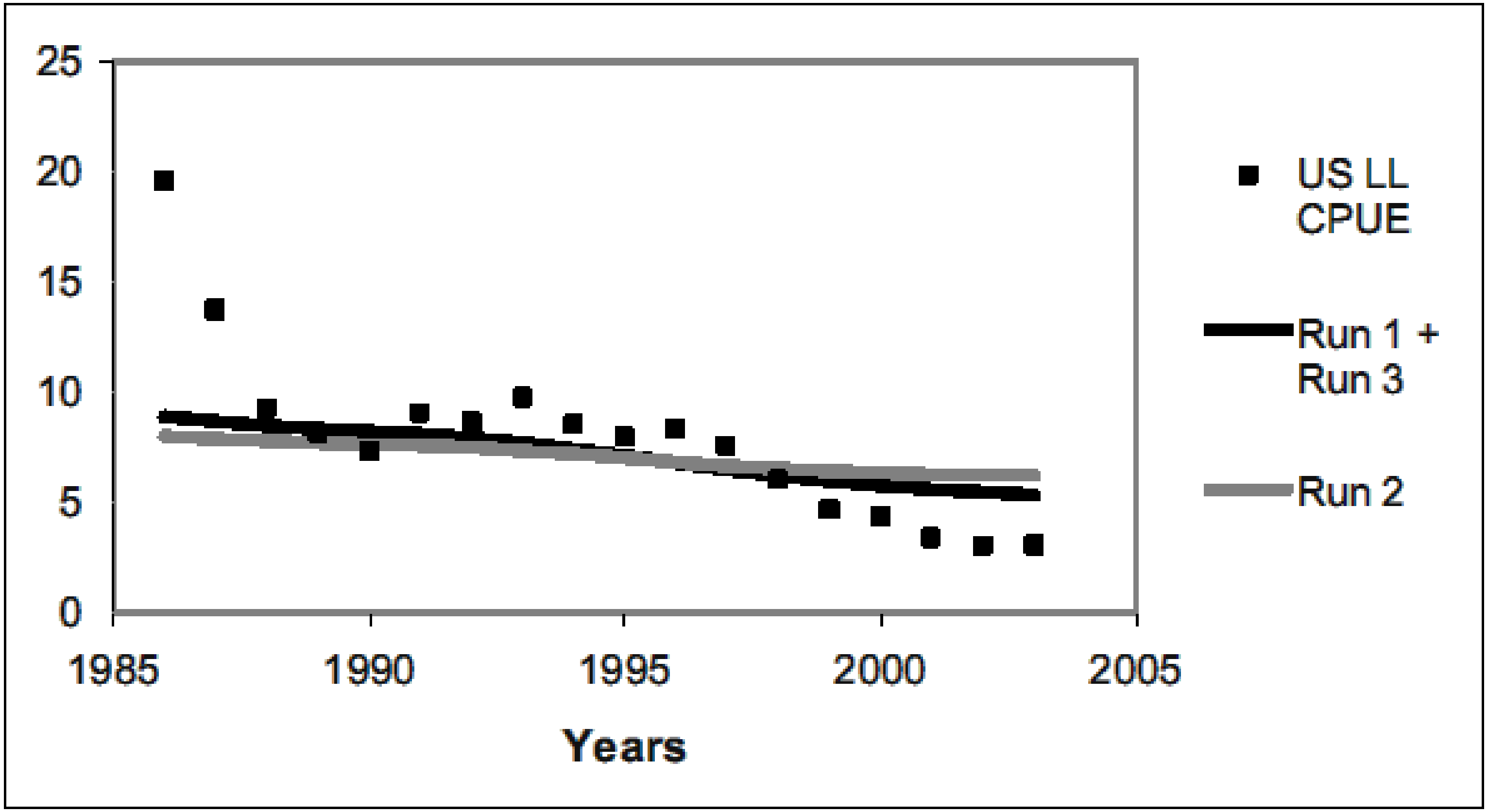
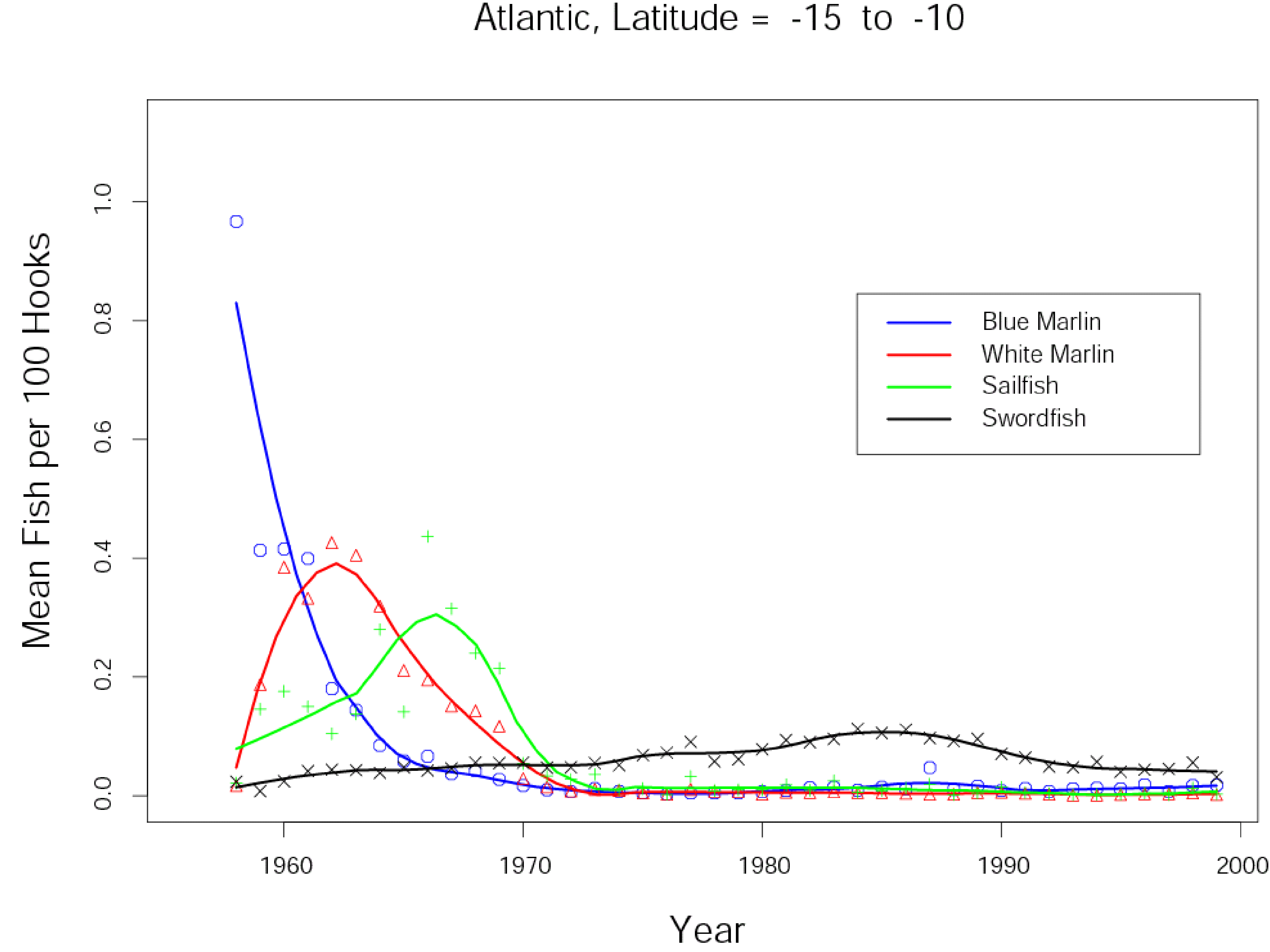
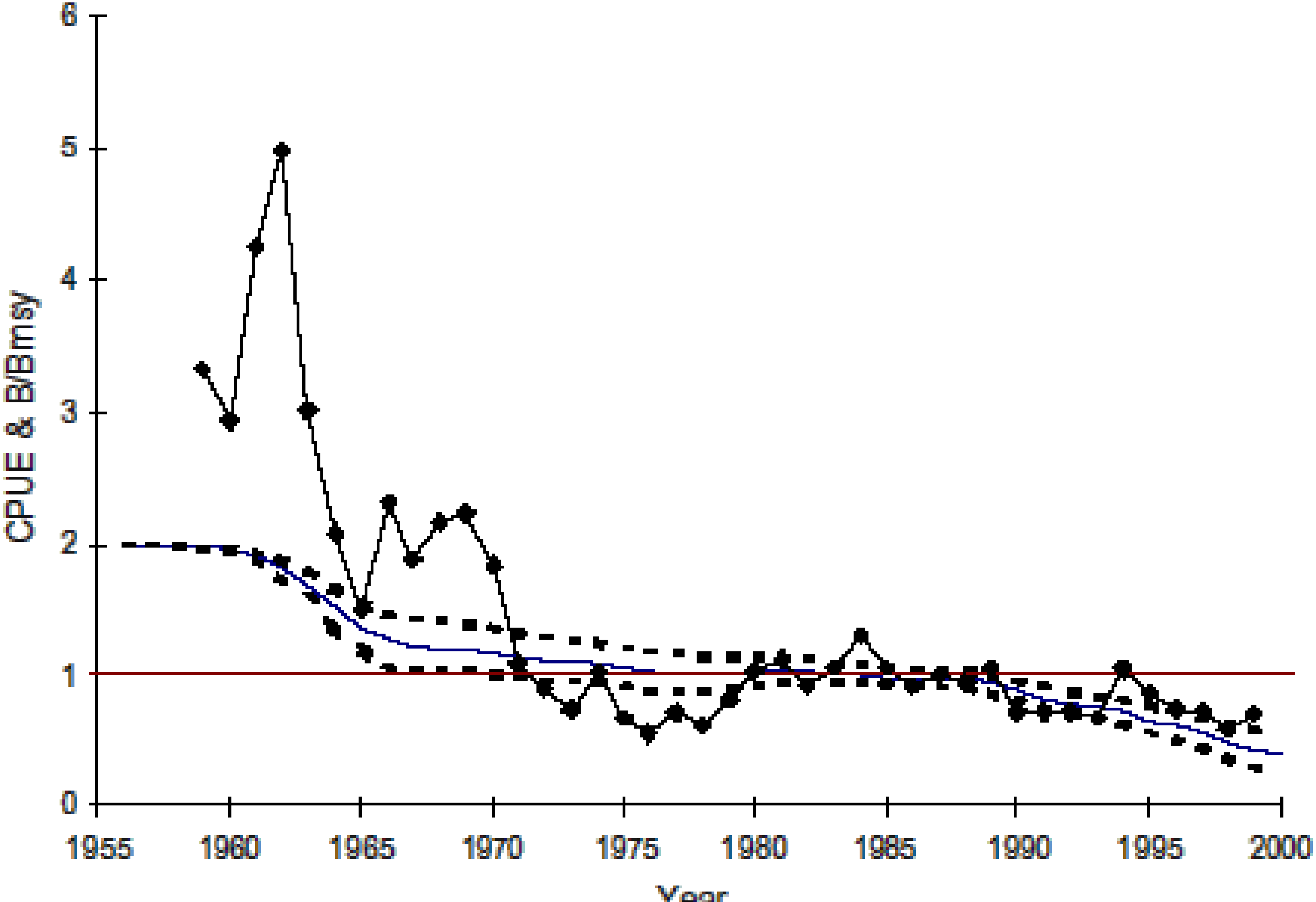


Figure 10 (above). Fit of the model to the North Atlantic blue shark CPUE data for each of the runs considered.

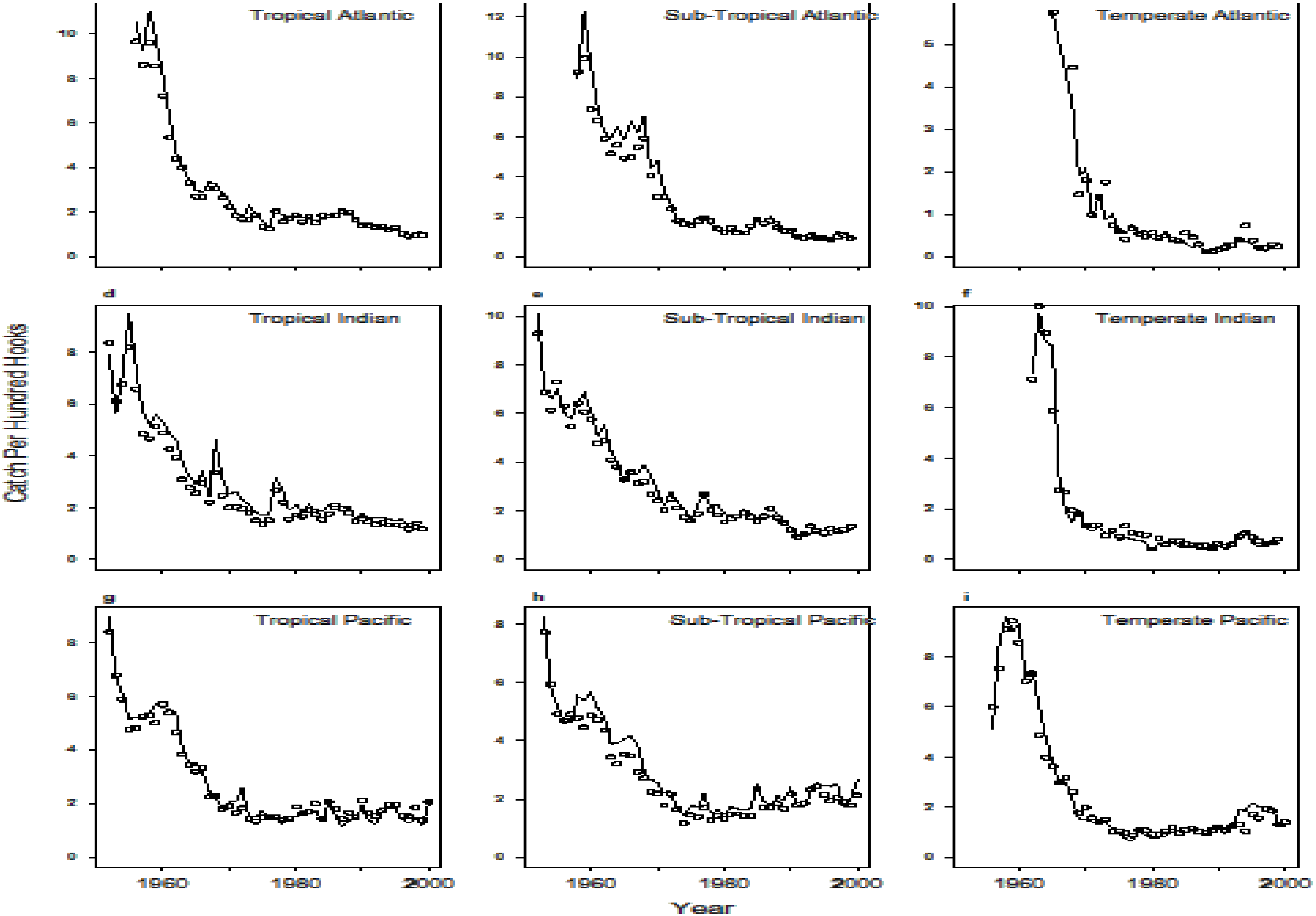


Atlantic, Latitude = -15 to -10
Mean Fish per 100 Hooks
Year
Blue Marlin
White Marlin
Sailfish
Swordfish
0.0
0.2
0.4
0.6
0.8
1.0
1960
1970
1980
1990
2000

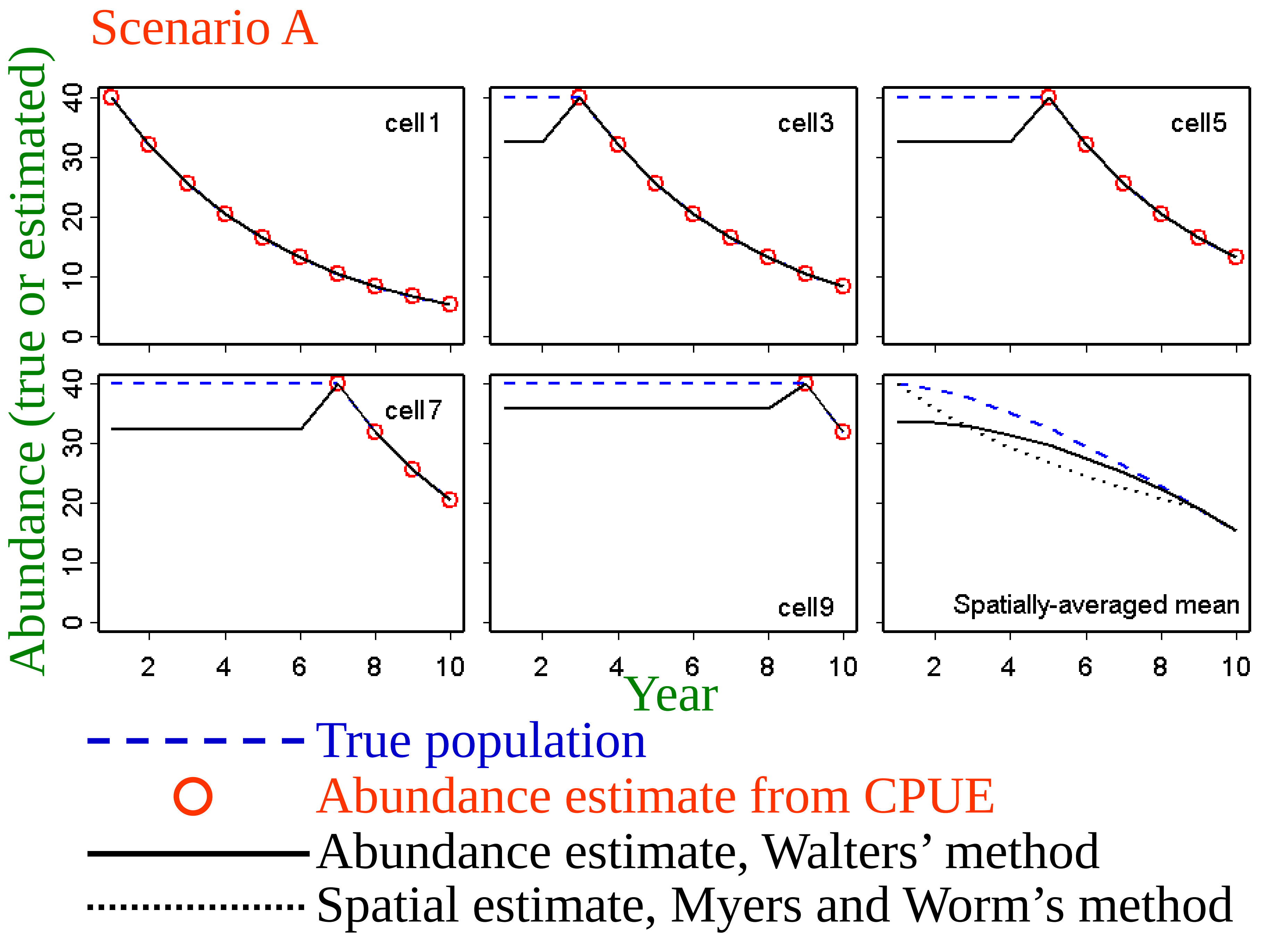
Bluefine tuna (observed diamonds) and modeled – not a very good fit.



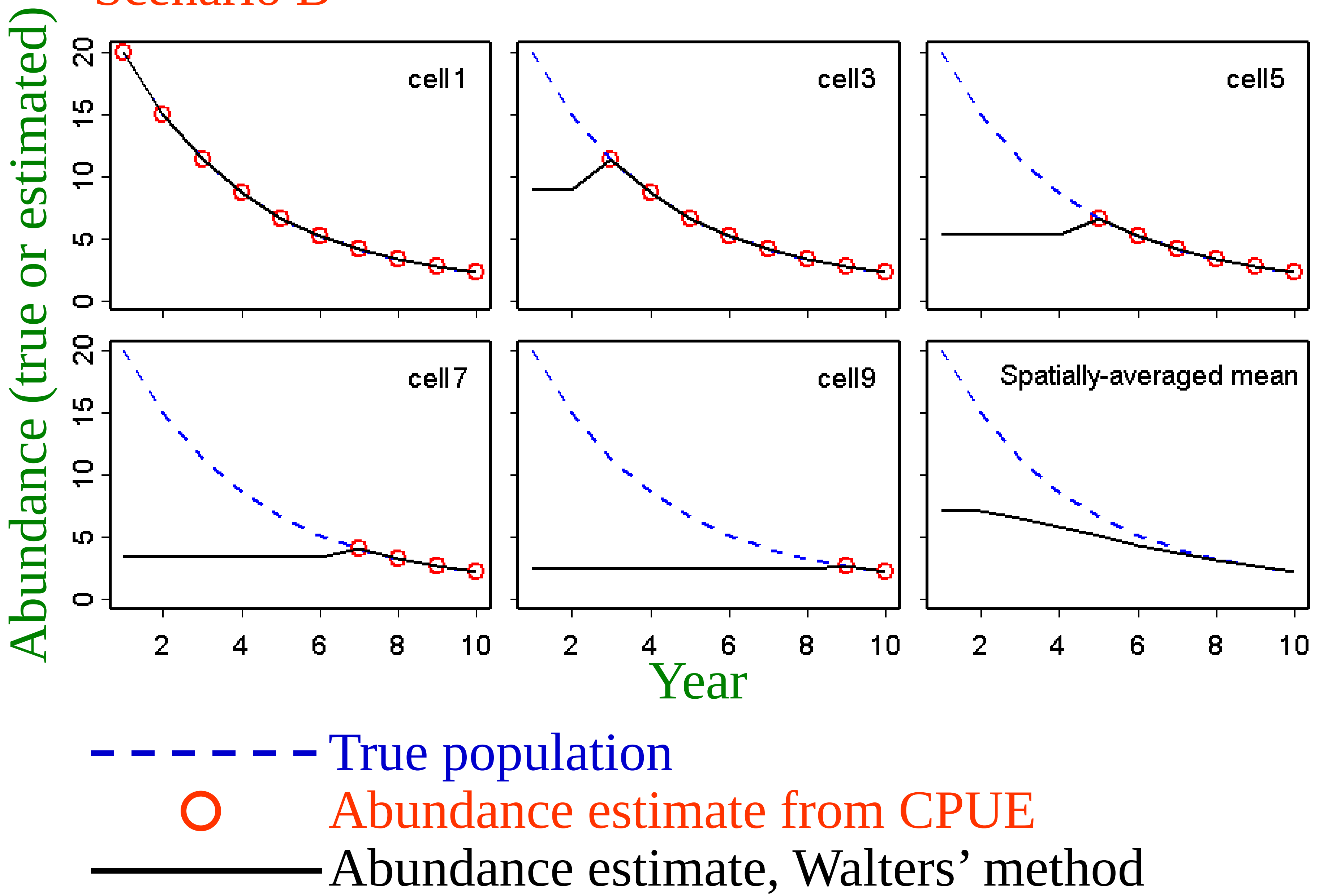
RED HERRING 1: RATIO ESTIMATION



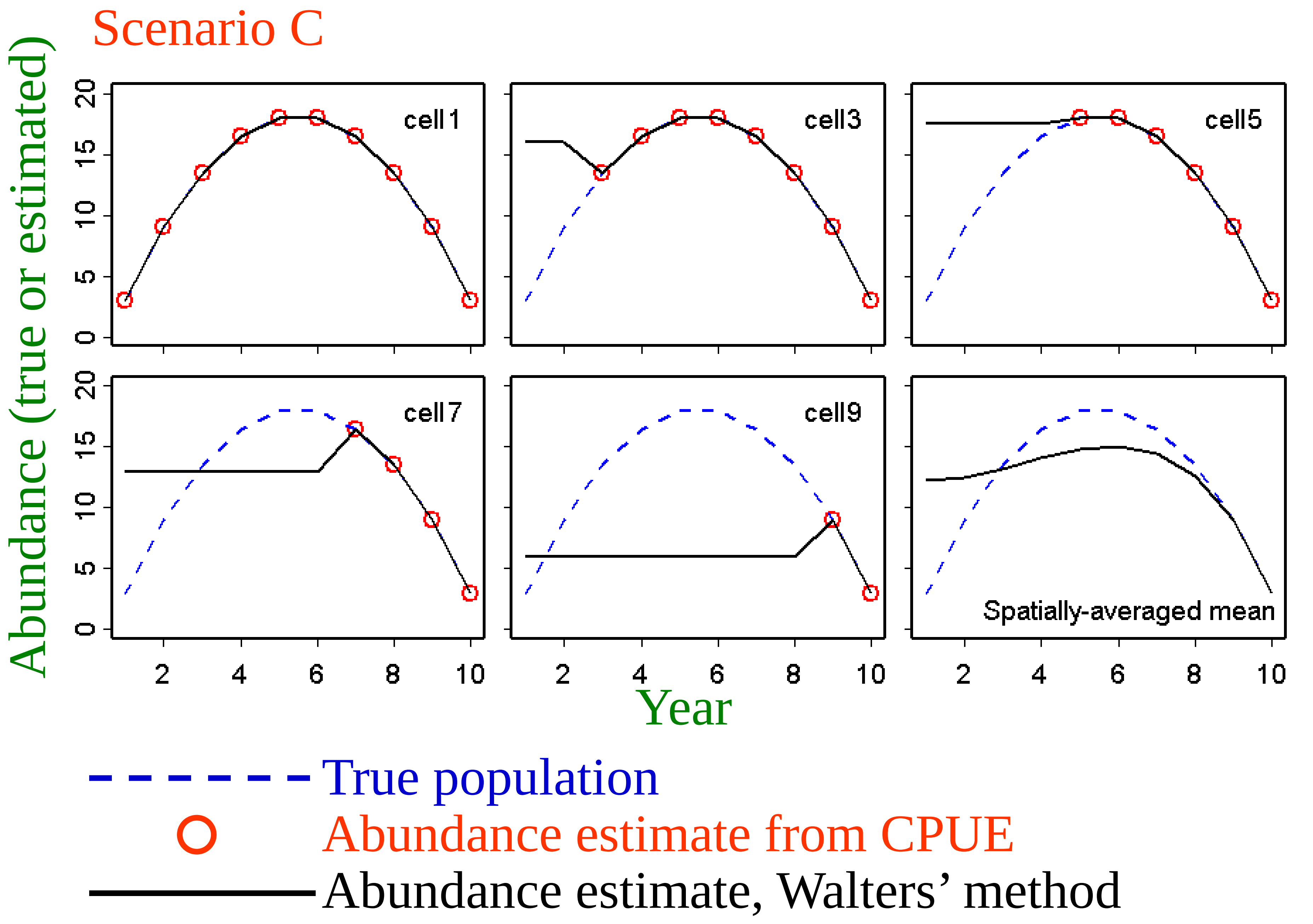
RED HERRING 2: SPATIAL ESTIMATION


Scenario A
Abundance (true or estimated)
Year
cell1
cell3
cell5
cell7
cell9
Spatially-averaged mean
0
10
20
30
40
2
4
6
8
10
True population
Abundance estimate from CPUE
Abundance estimate, Walters' method
Spatial estimate, Myers and Worm's method

Scenario B



Abundance (true or estimated)
Year
cell 1
cell3
cell5
cell7
cell9
Spatially-averaged mean
0
5
10
15
20
2
4
6
8
10
True population
Abundance estimate from CPUE
Abundance estimate, Walters' method

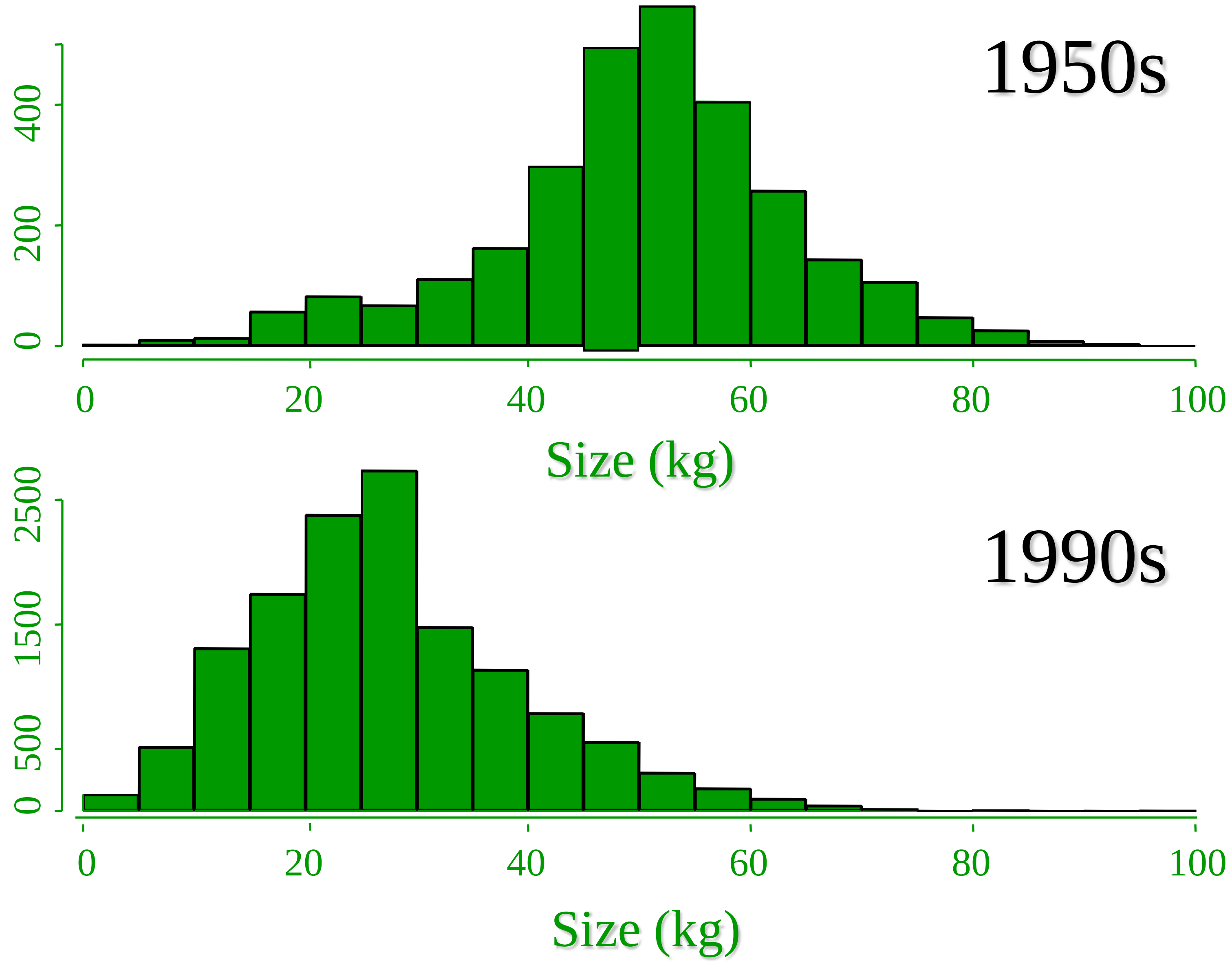


Scenario C
Abundance (true or estimated)
cell1
cell3
cell5
cell7
cell9
Spatially-averaged mean
0
5
10
15
20
2
4
6
8
10
Year
True population
Abundance estimate from CPUE
Abundance estimate, Walters' method

These estimates are conservative: 1.

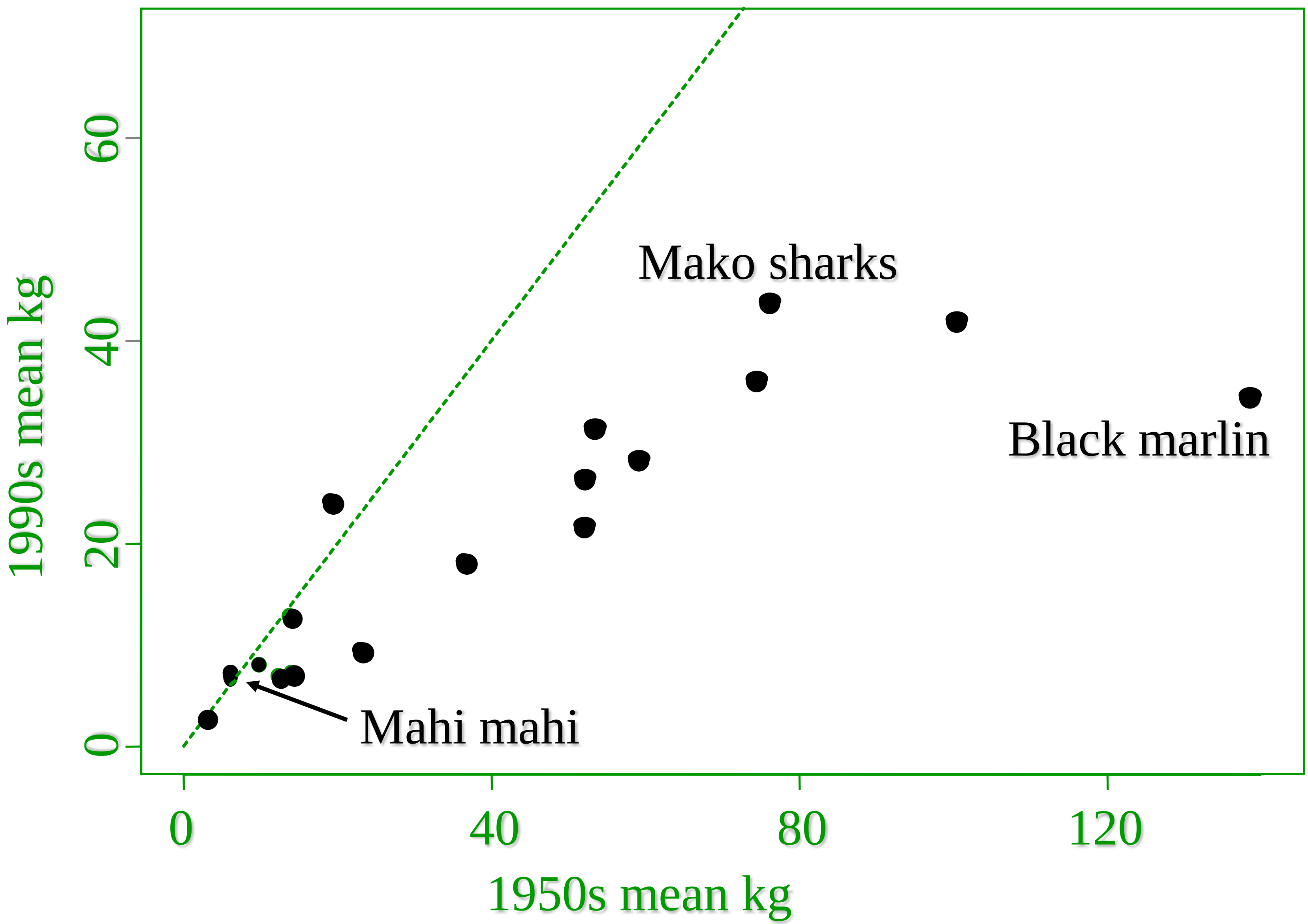
Bits of tuna did not count; ~25-30% of tropical tunas were initially not counted because of shark damage.

These estimates are conservative: 2 (fish are smaller)



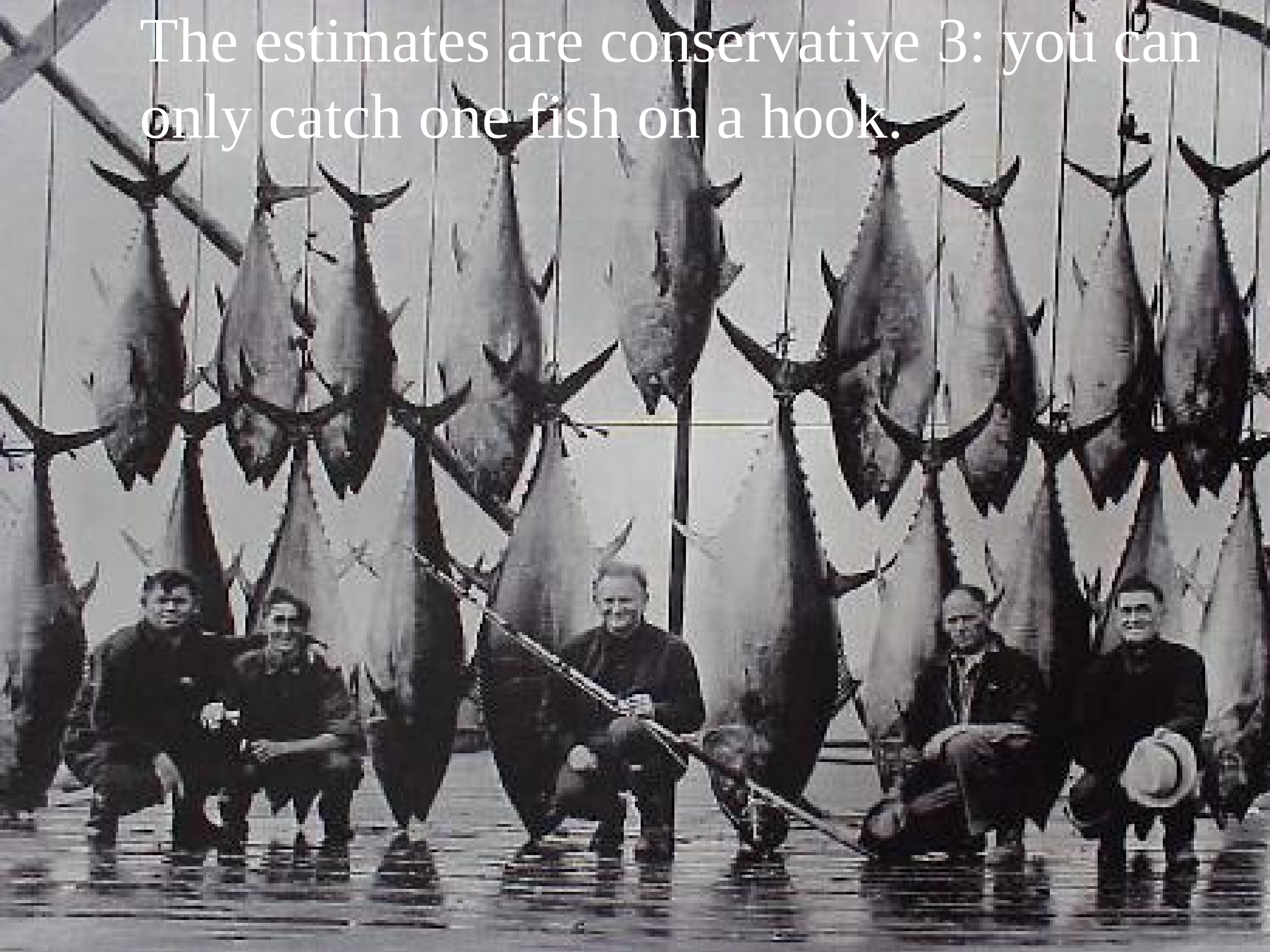
Yellowfin tuna – equitorial Pacific

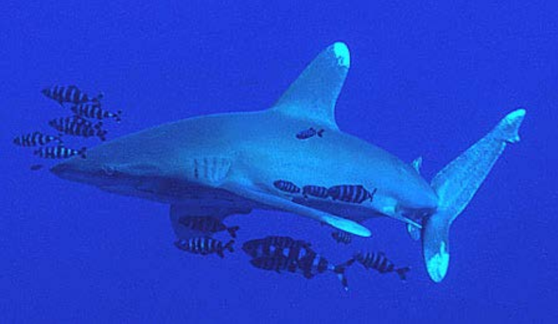
Change in body size




555
lbs.
Cabo Bla
LBS.
1135
CABO
BLANCO

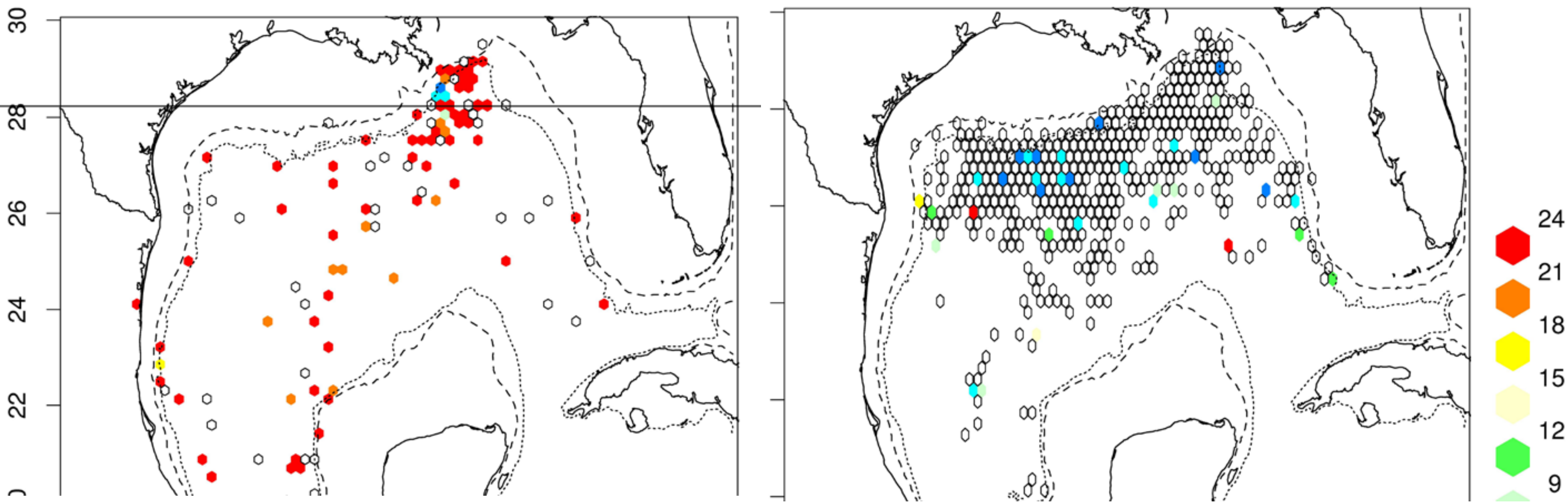
The estimates are conservative 3: you can only catch one fish on a hook.





These estimates are conservative 4: The sharks probably declined more.

[redacted]



1950's 1990's

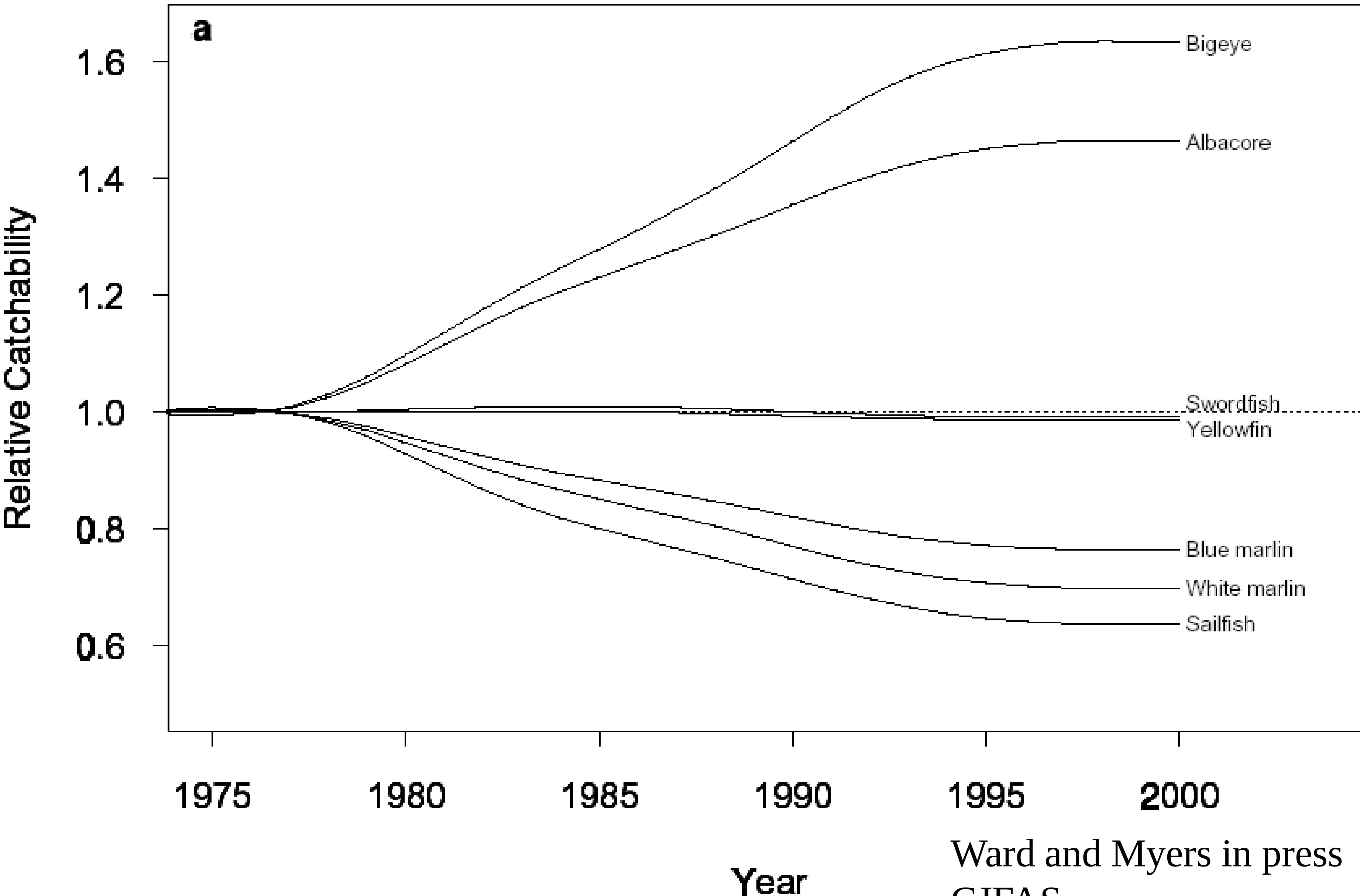
Oceanic Whitetip captures per 10,000 hooks

Baum and Myers, submitted to Ecology Letters

These estimates are conservative 5: The oceans were not virgin.

- Japan harvested ~1,000,000 tons of tuna and marlin in the 5 years before WWII.
- In 1950 the US harvested ~170,000 tons.
- The 1950 harvest of albacore by Spain was greater than the total recent harvest in the North Atlantic.
- Species that migrate long distances (e.g. southern bluefin tuna, northern bluefin tuna, and albacore) would have reduced by these harvests.

These estimates are conservative 7:
changes in depth increases overall efficiency.

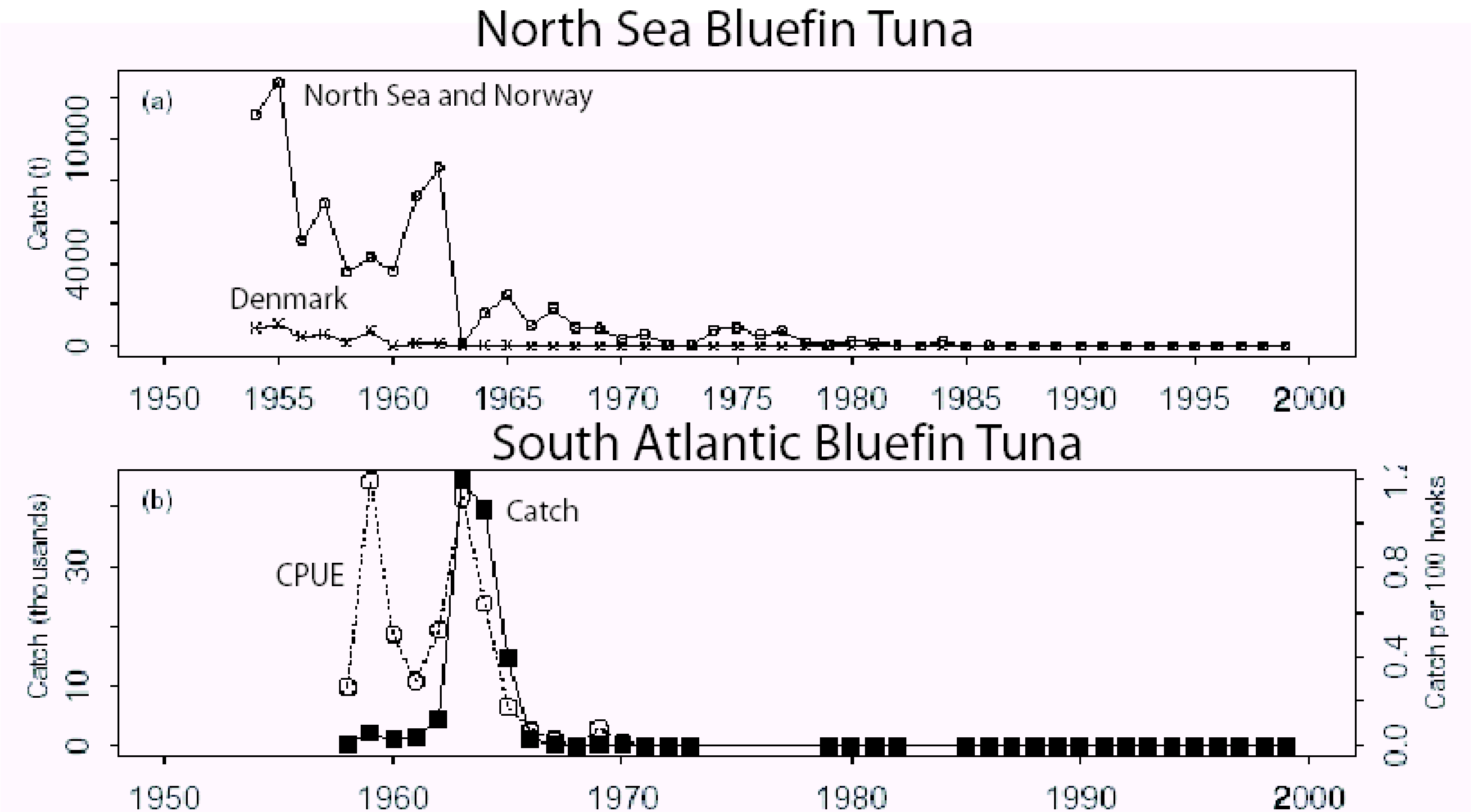


Ward and Myers in press
CJFAS

Declines confirmed by independent data:

- The initial high catch rates were seen in early research surveys by Japan and US.
- Declines seen in harpoon fisheries for swordfish and tuna.
- Most tuna traps in the Mediterranean have largely been abandoned, Italy there is a decline from 100 to 3 tuna traps.
- Complete loss of species in some areas.

Loss of Bluefin Tuna Populations in the Atlantic

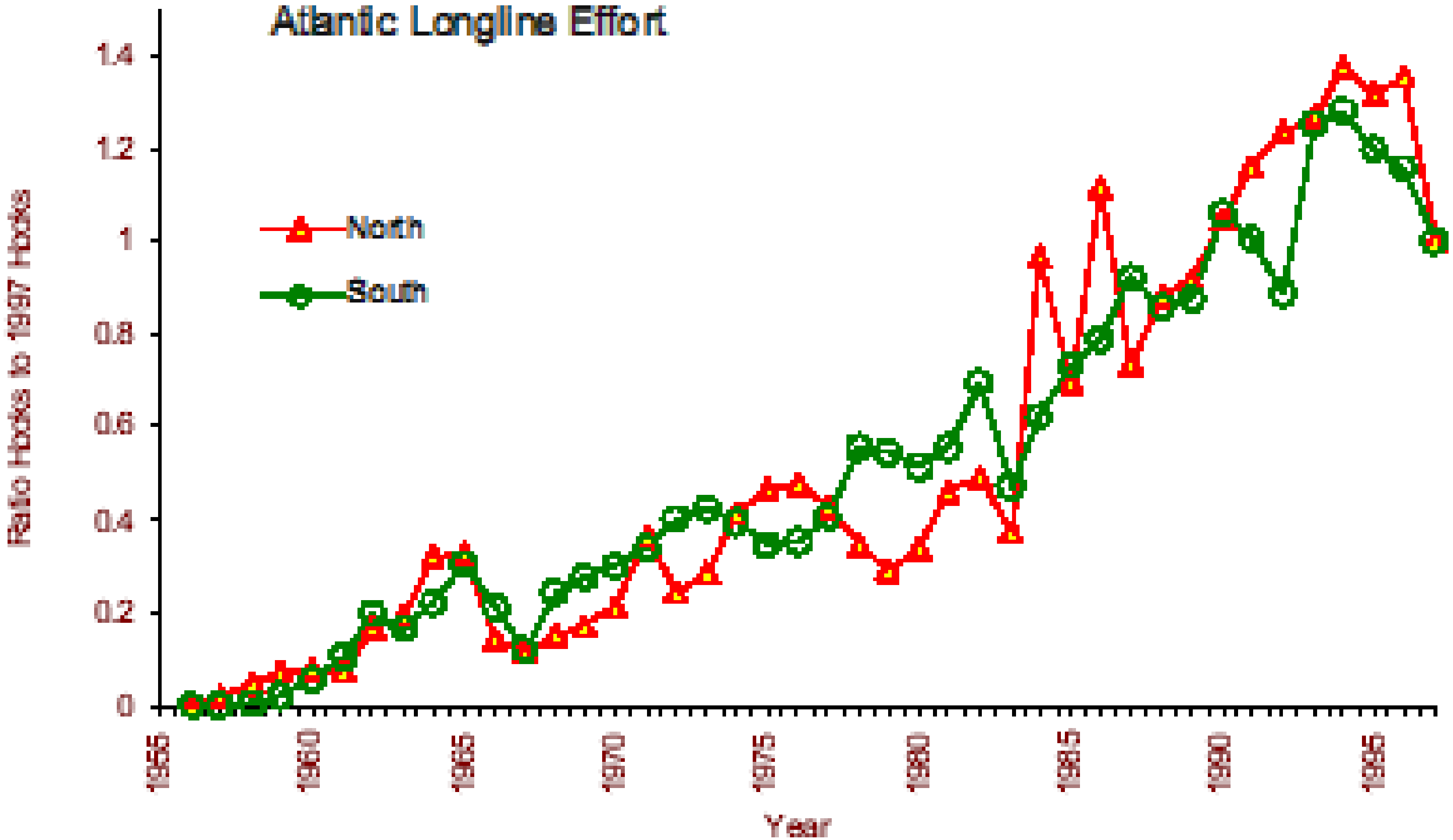


Perceived Contradiction in Initial Rapid Decline in CPUE

- 1. Large declines occurred when effort was relatively small

Perceived Contradiction in Initial Rapid Decline in CPUE

2. Present effort is much higher.



Perceived Contradiction in Initial Rapid Decline in CPUE

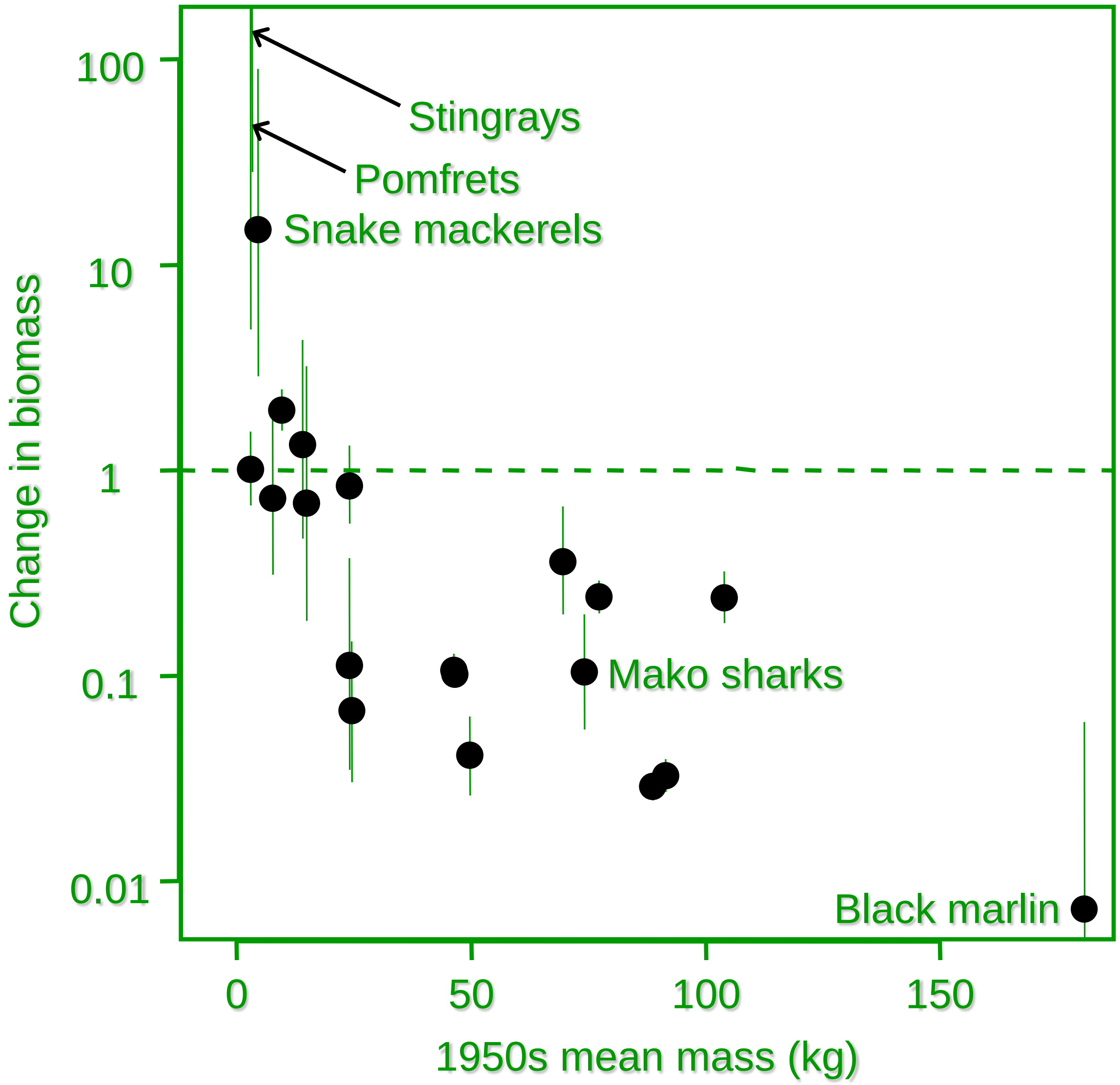
3. Present fishing mortality due to longlines is around 0.6

Perceived Contradiction in Initial Rapid Decline in CPUE

IF catchability is constant

THEN the population dynamics are impossible.

However, catchability decreases with size and size has declined

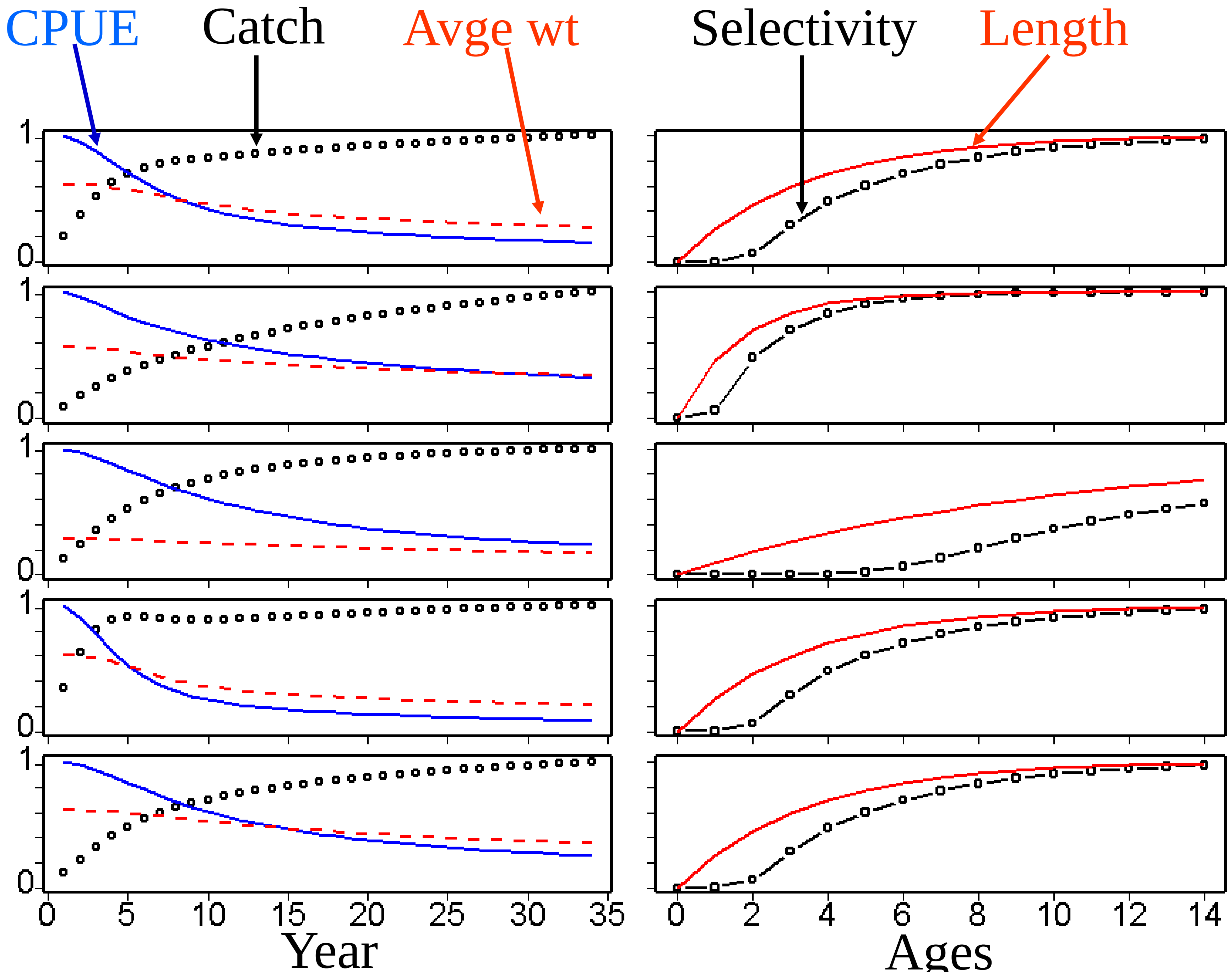


Change in biomass
100
10
1
0.1
0.01
0
50
100
150
1950s mean mass (kg)
Stingrays
Pomfrets
Snake mackerels
Mako sharks
Black marlin

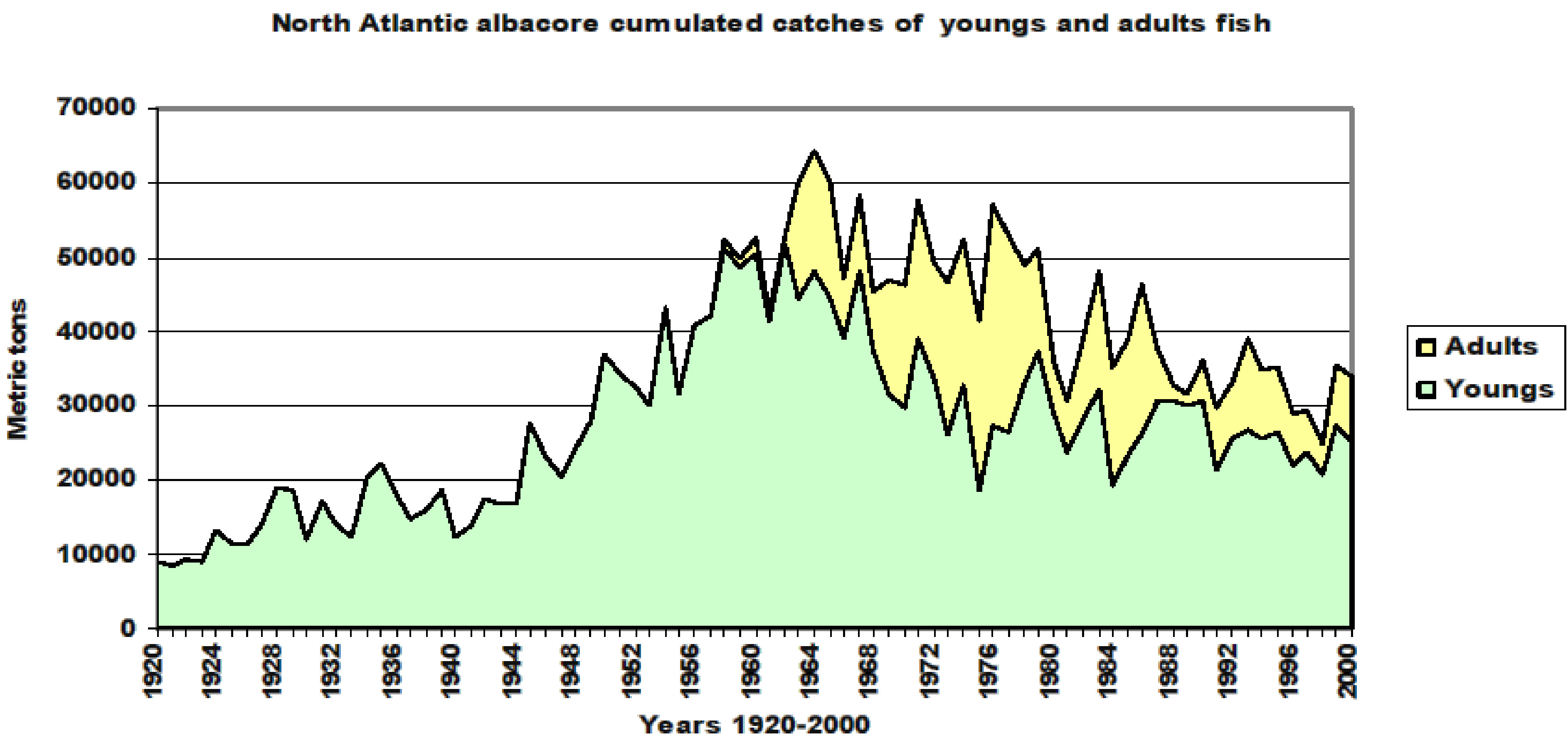

555
lbs.
LBS.
1135
CABO
BLANCO

A Toy Model

- Recruitment constant
- Longline effort increases linearly over 35 years
- Catchability is proportional to the product of: (a) a cumulative normal and (b) food intake (respiration is proportional to the 2/3's power of mass)
- Present fishing mortality is around 0.6.



CPUE
Catch
Avge wt
Selectivity
Length
1
0
0
5
10
15
20
25
30
35
Year
0
2
4
6
8
10
12
14
Ages


North Atlantic albacore cumulated catches of youngs and adults fish
Metric tons
70000
60000
50000
40000
30000
20000
10000
0
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
Years 1920-2000
Adults
Youngs

Conclusion

- Immediate action needed to protect some sharks, leatherbacks, loggerheads, and some tuna (Atlantic northern bluefin)
- Productivity (juvenile survival) has increased with exploitation.
- Rapid declines in CPUE reflect real declines in large fish
- Reduced effort is needed to achieve greater economic yield

Acknowledgements

- Boris Worm, Peter Ward, Leah Gerber, Julia Baum, Dan Kehler, Francesco Ferretti
- Pew Charitable Trusts
- Sloan Foundation – Census of Marine Life, Future of Marine Animal Populations (FMAP)
- NSERC
- Pelagic Fisheries Research Program
- German Research Council
- Killam Foundation
- Numerous colleagues who shared data

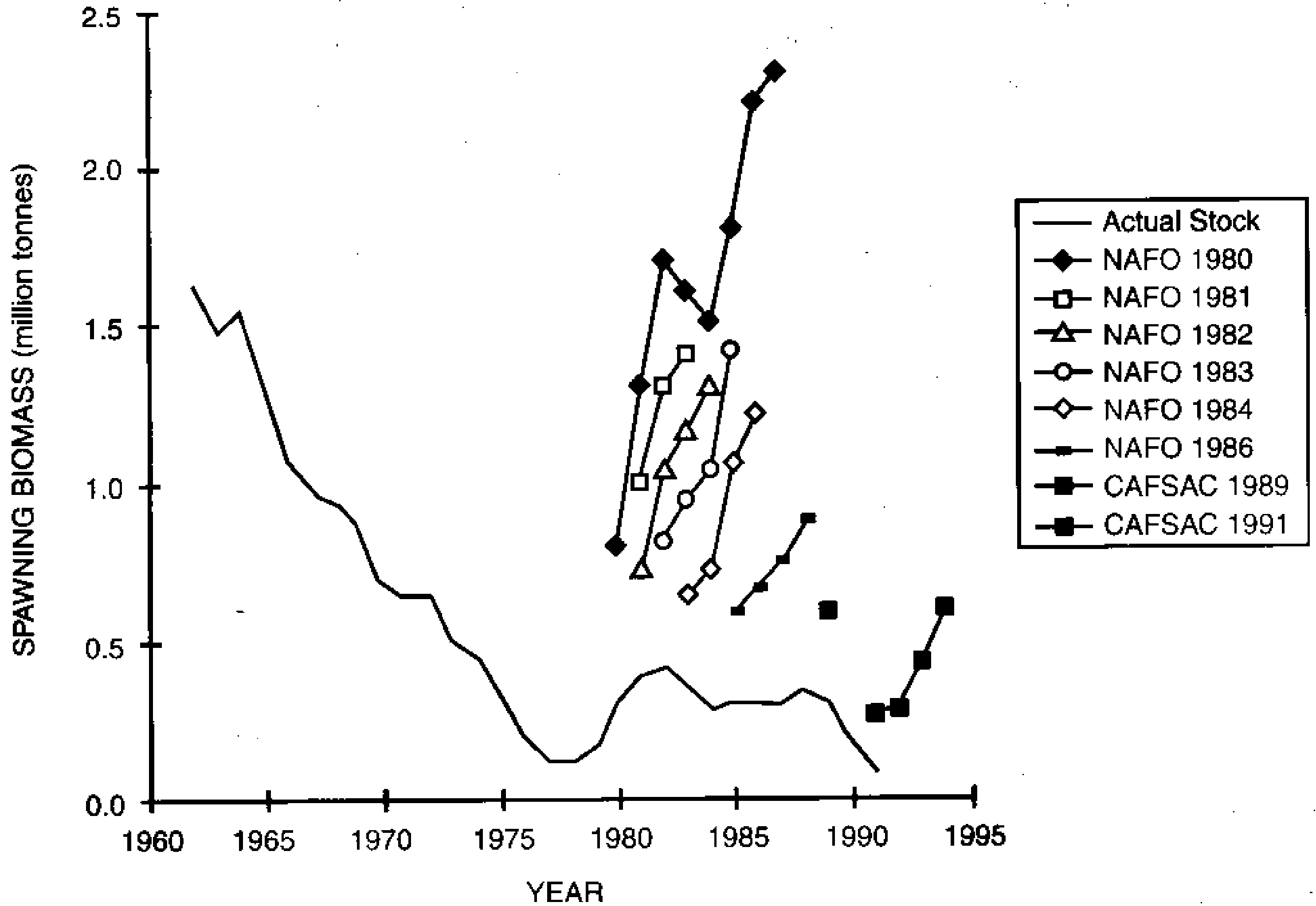


Fig. 3. **Recent reconstruction, using virtual population analysis, of the Newfoundland northern cod** decline, compared with estimates and projections published in various years after Canada took over the fishery under extended jurisdiction. VPA estimates based on data in Baird *et al.* (1992) (see also Hutchings and Myers, 1994). NAFO estimates from annual reports for years indicated of North Atlantic Fisheries Organization Scientific Council Reports, Dartmouth, NS. CAFSAC estimates from Canadian Atlantic Fisheries Scientific Advisory Committee Advisory Documents 89/1 and 91/1.

Rapid decline in older albacore.

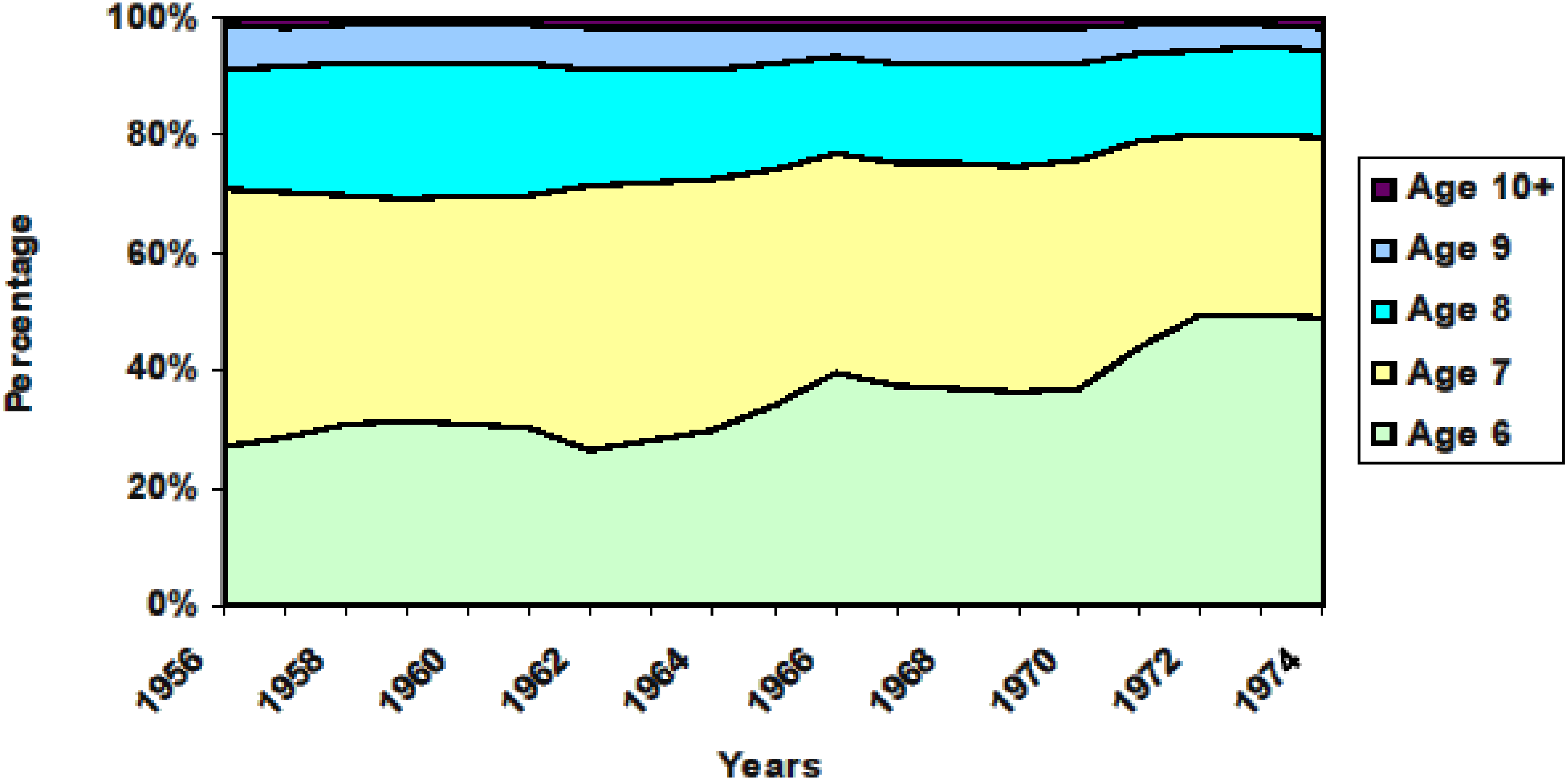
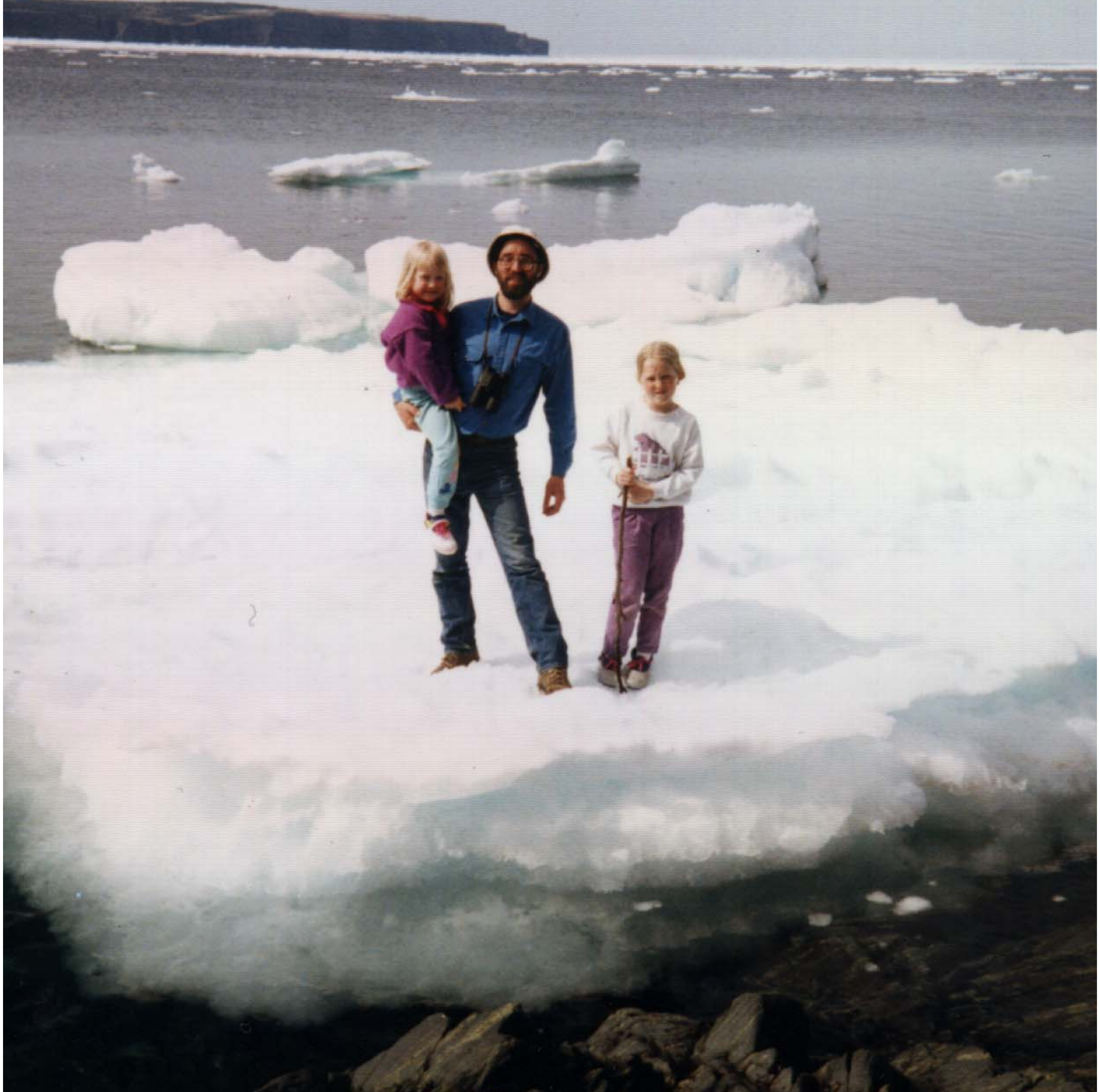


Figure 7 : Evolution of contribution of age classes 6 to 10+ computed by Morita (1977) in longliners albacore catches, 1956-1974.



Marine ecosystem robustness and the collaps
marine fisheries

Ransom A. Myers (RAM)
Dalhousie University, Halifax, Canada

One hypothesis:

Fishing mortality ↑

↓

Predation on sailfish juveniles ↓

↓

Survivorship of sailfish juveniles ↑

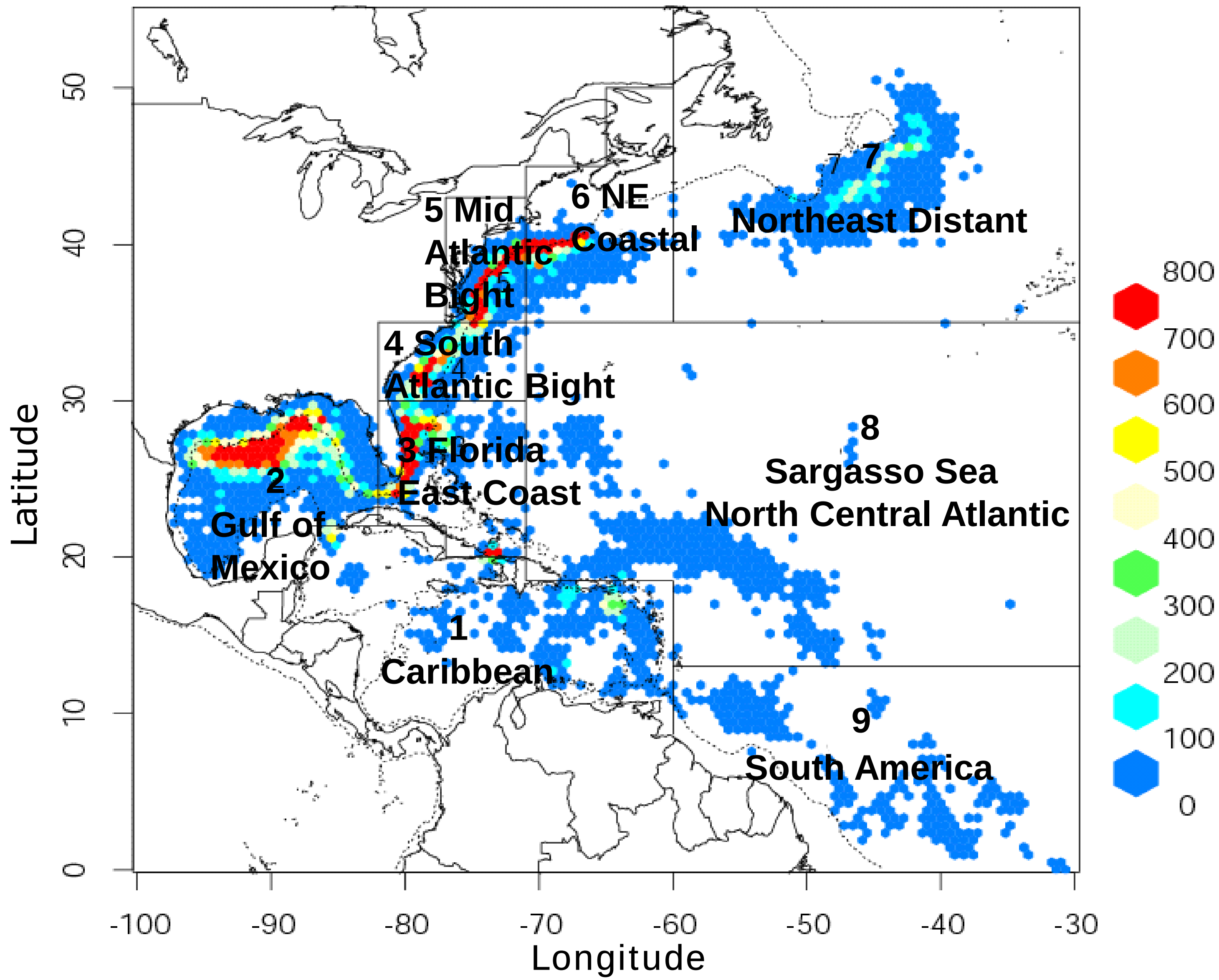
↓

Sailfish population ↑

Collapse and Conservation of Shark Populations in the Northwest Atlantic

Science. Jan. 2003. J.K. Baum, R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, P.A. Doherty

U.S. Atlantic pelagic longline sets 1986-2000



Political action is costly for any scientist.

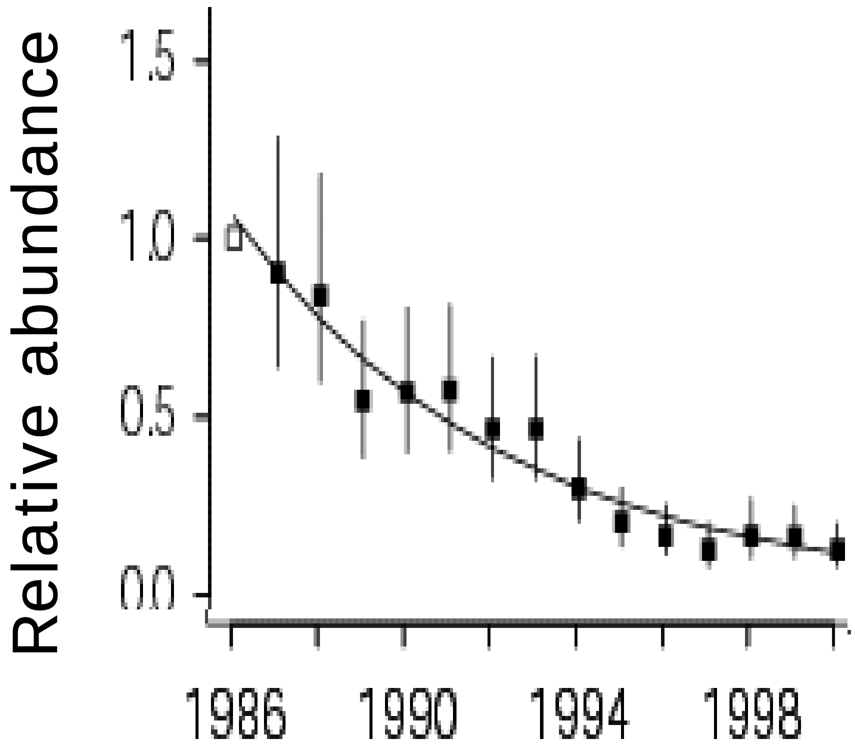
However, it also has great benefits.

To act is to live.

To be suppressed is to die.

Hammerhead sharks

Sphyrna lewini



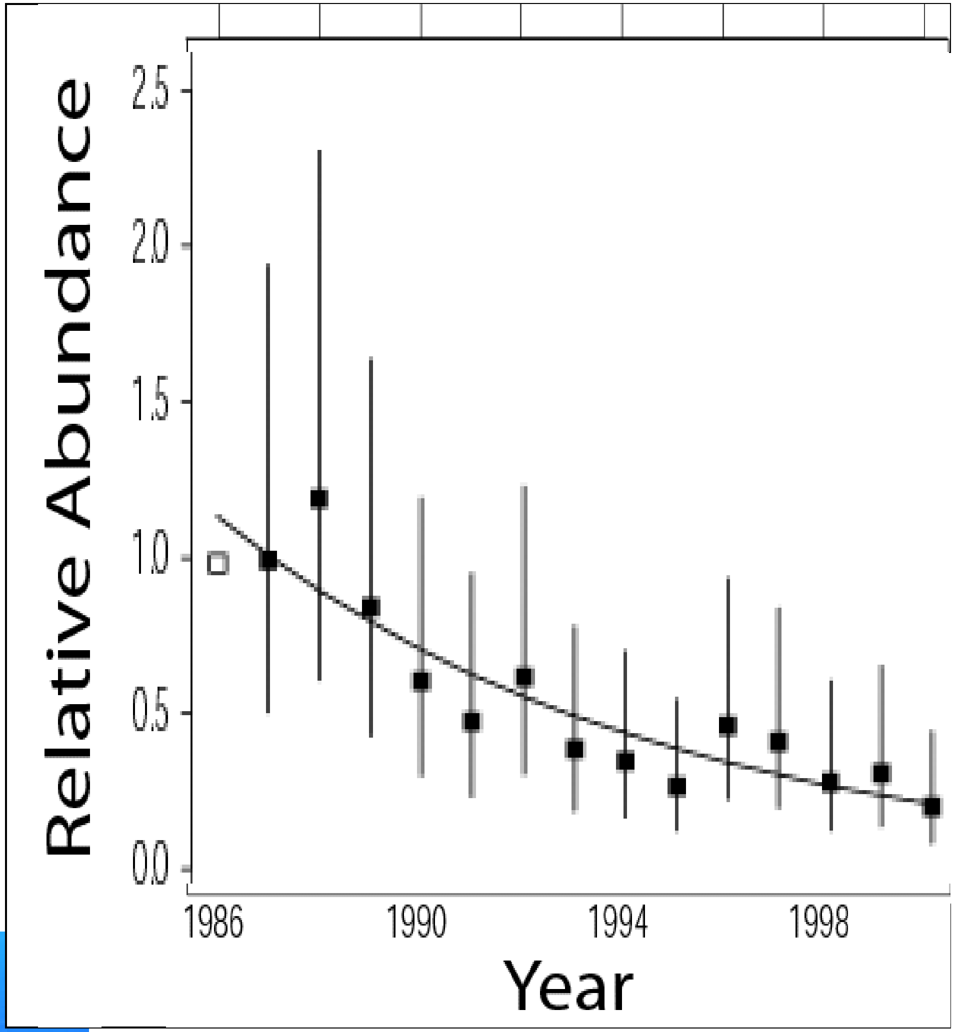
Science. Jan. 2003. J.K. Baum, R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, P.A. Doherty

The rest of the slides are back up.


90% OF EVERY BIG FISH SPECIES WIPED OUT

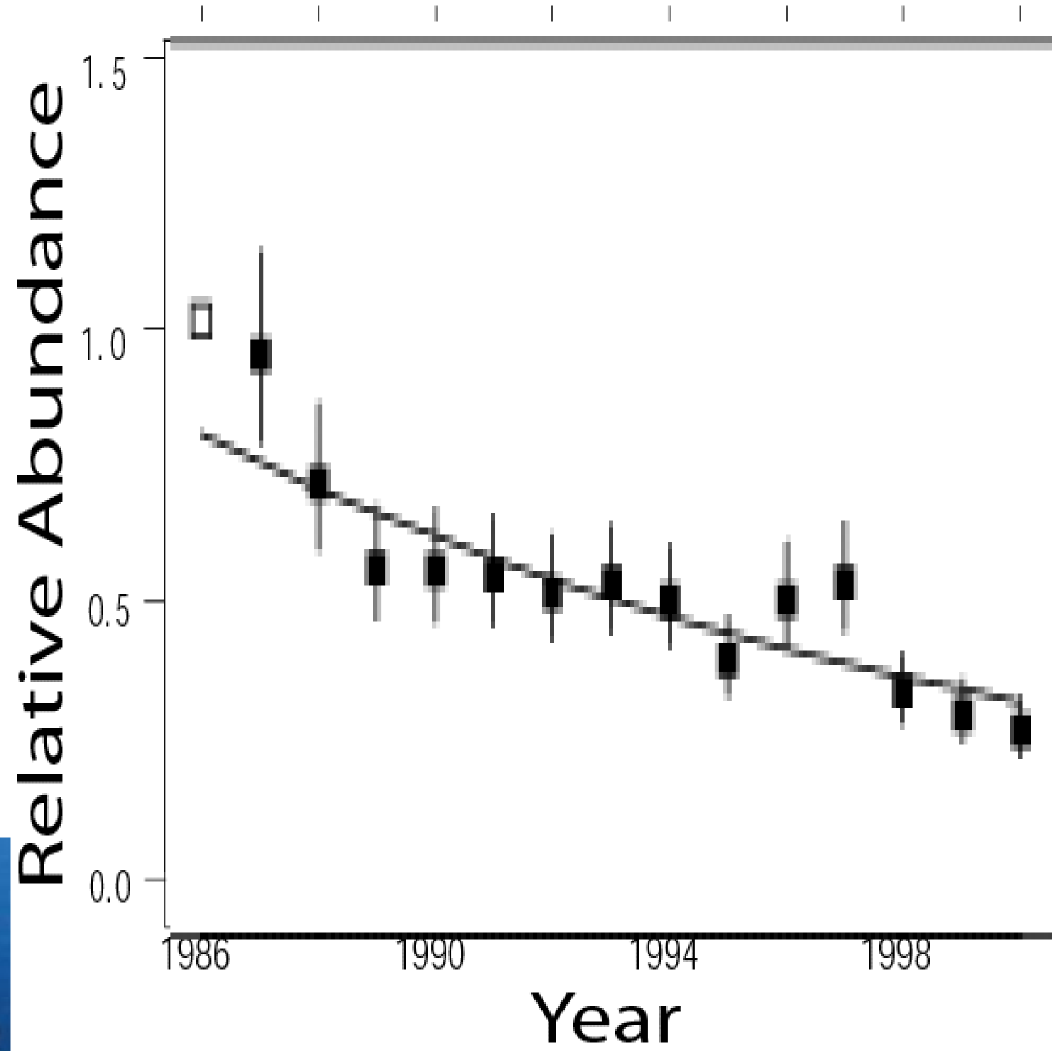
Thresher sharks

Alopias spp.



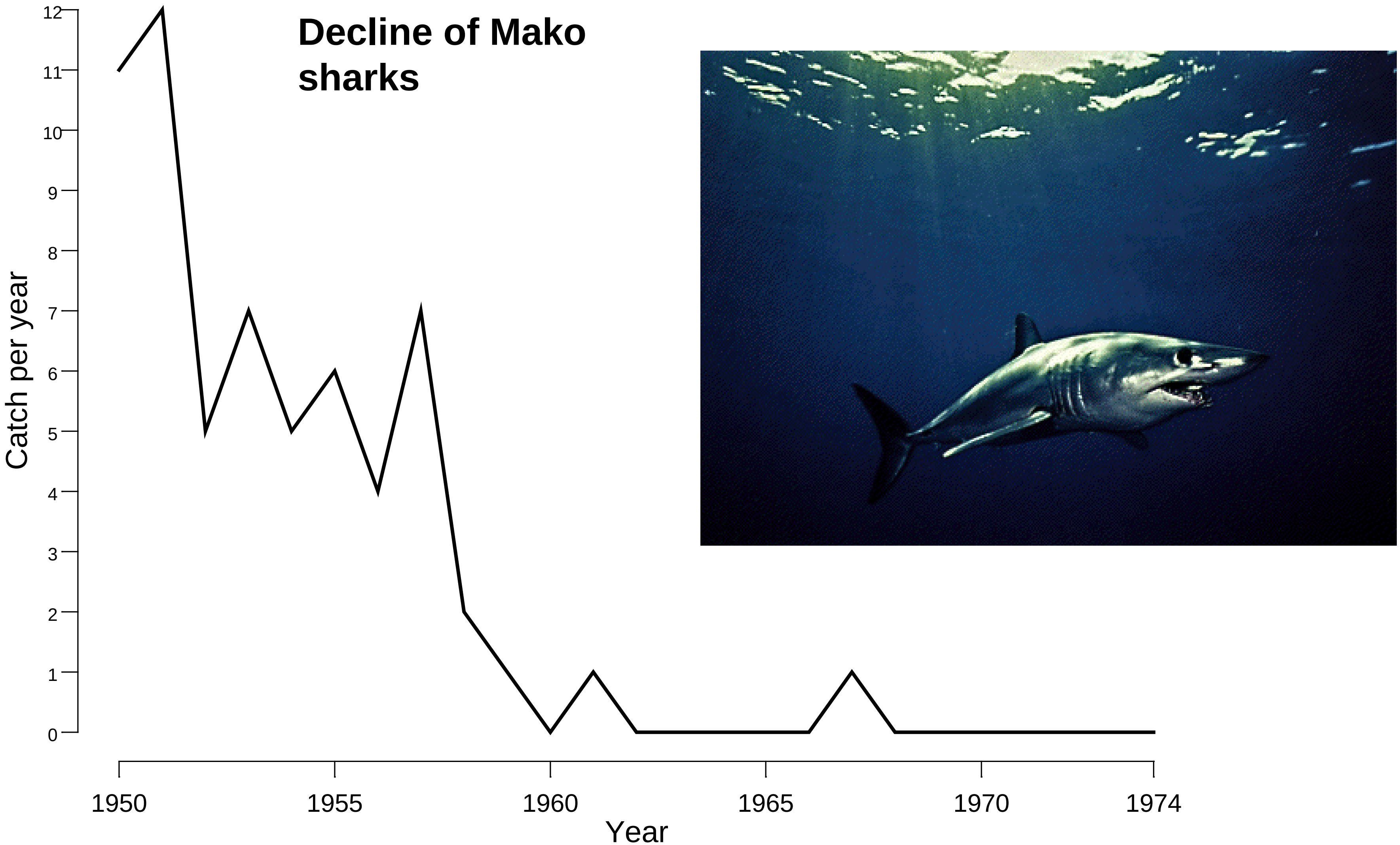
Blue sharks

Prionace glauca



Letter from senate

Put in cod



Boero F. & A. Carli 1979 – Boll. Mus. Ist. Biol. Univ. Genoa (47)

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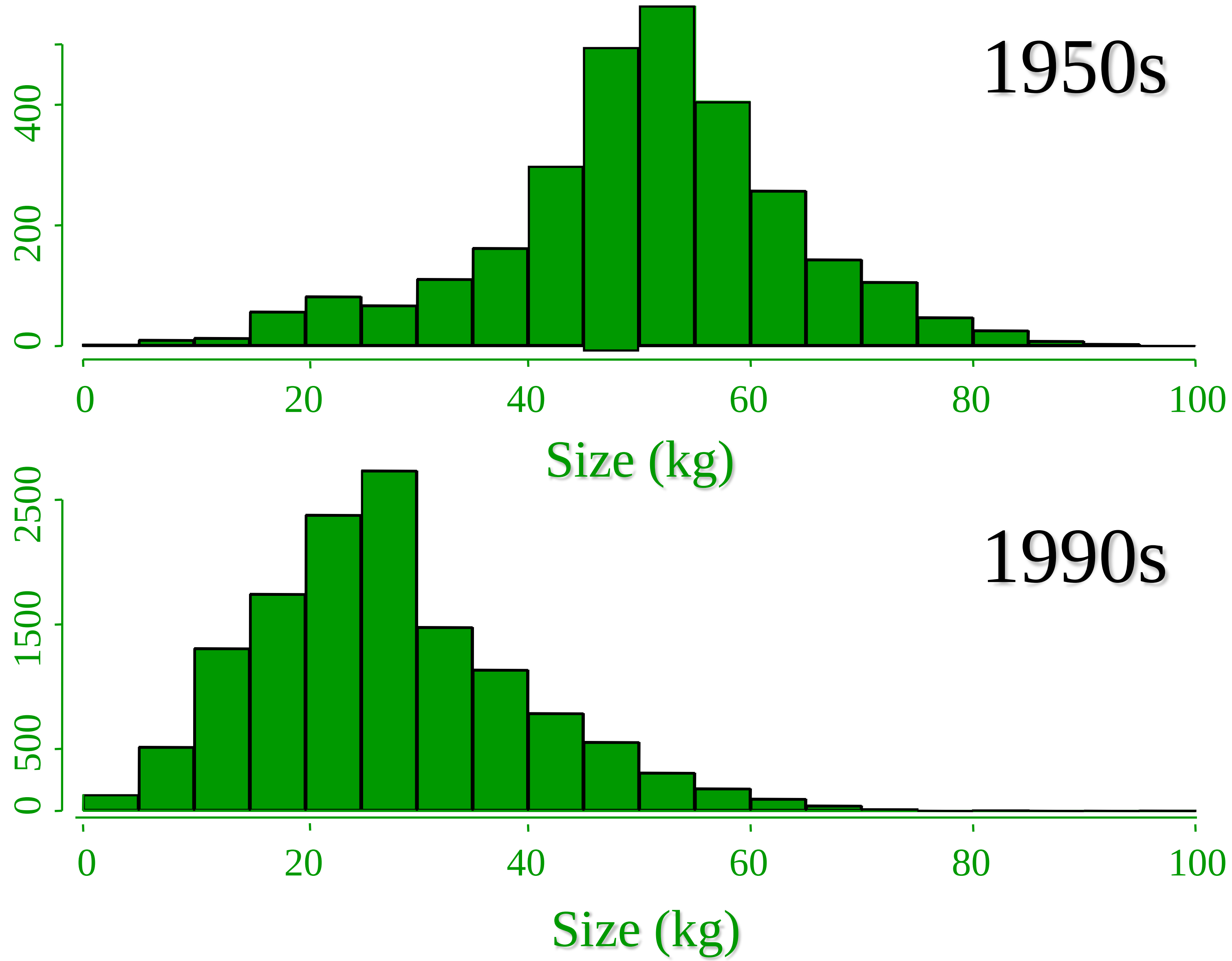
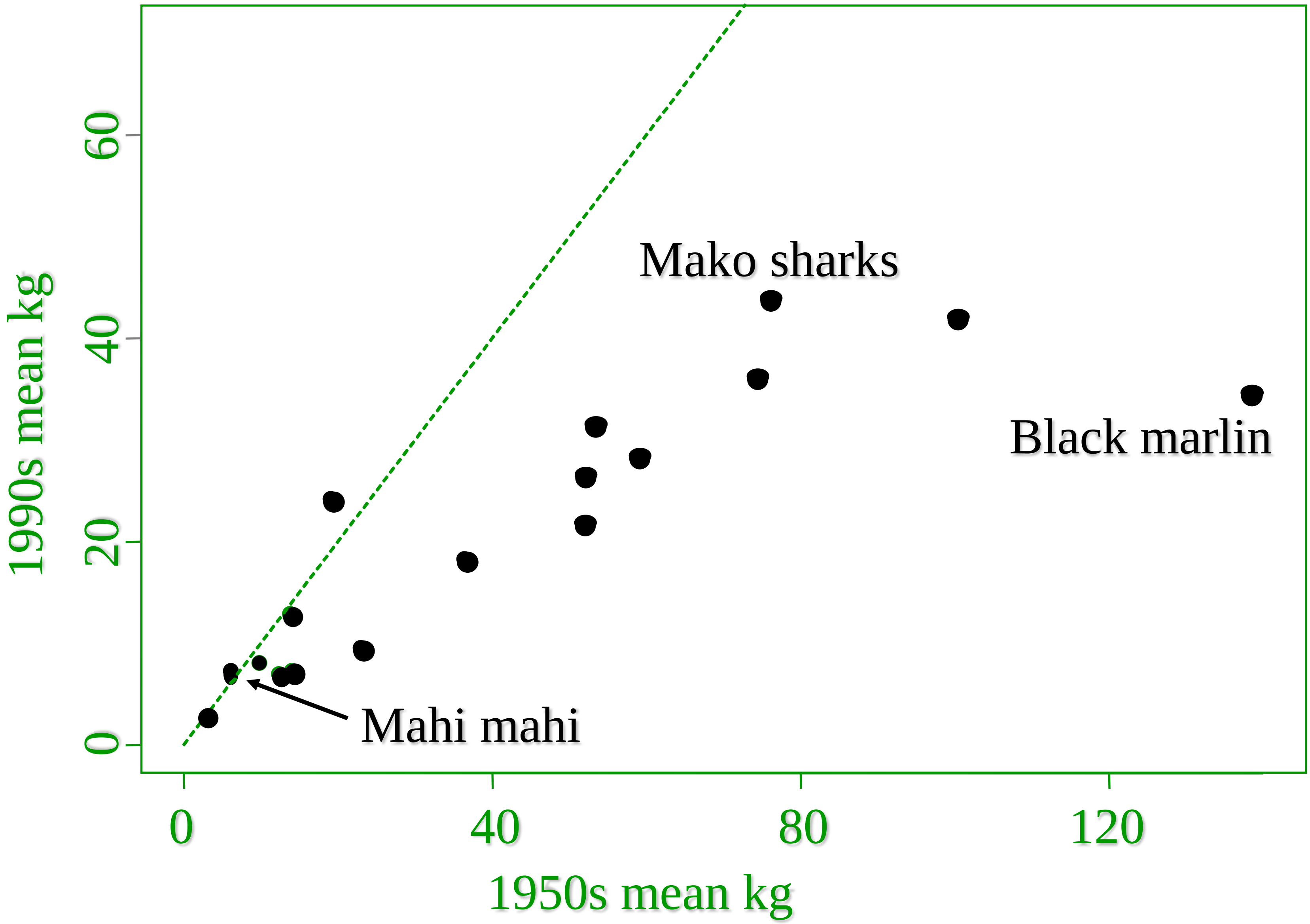
These estimates are conservative: 2 (fish are smaller)



Yellowfin tuna – equitorial Pacific

Change in body size




555
lbs.
LBS.
1135
CABO
BLANCO

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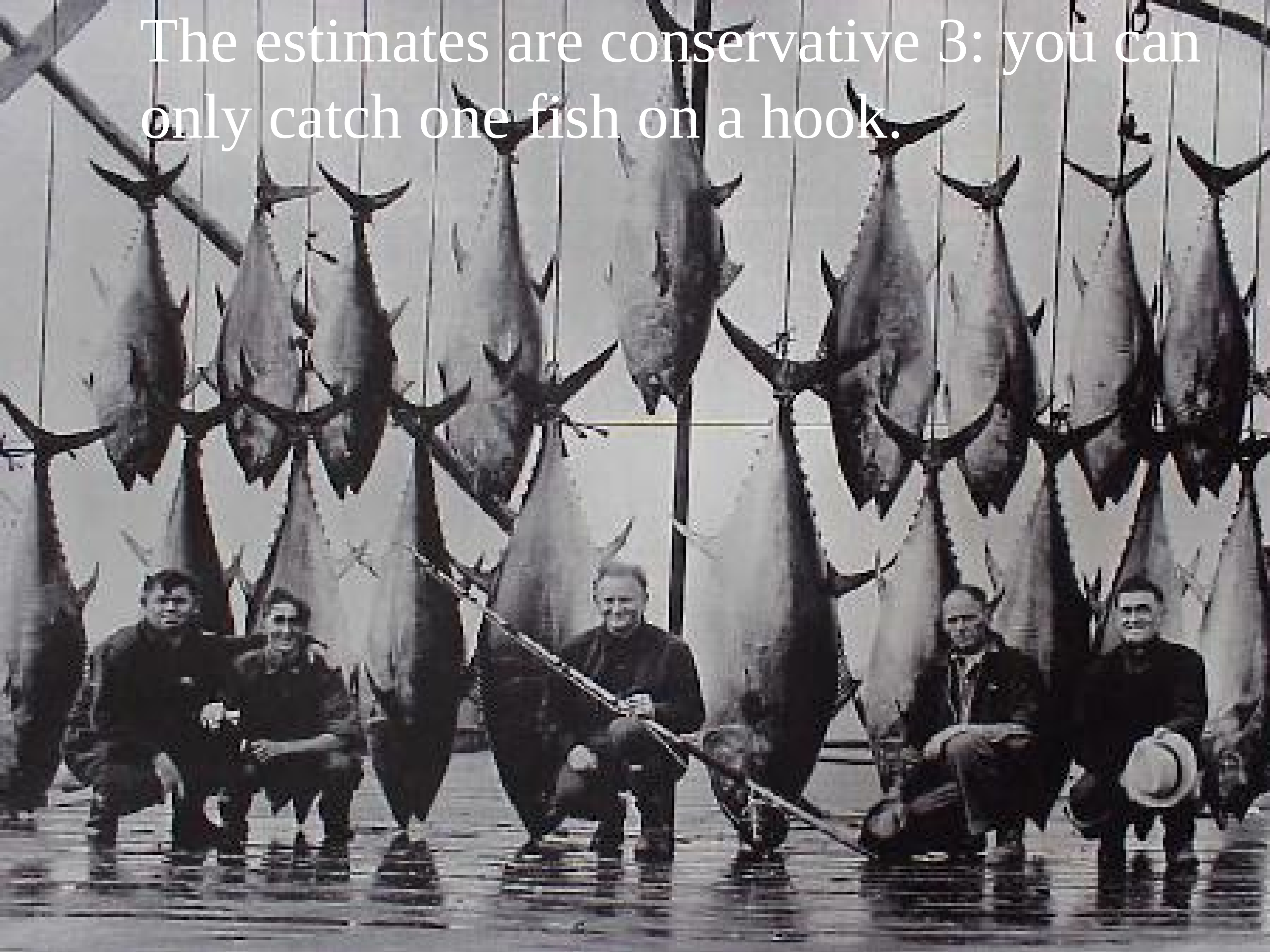

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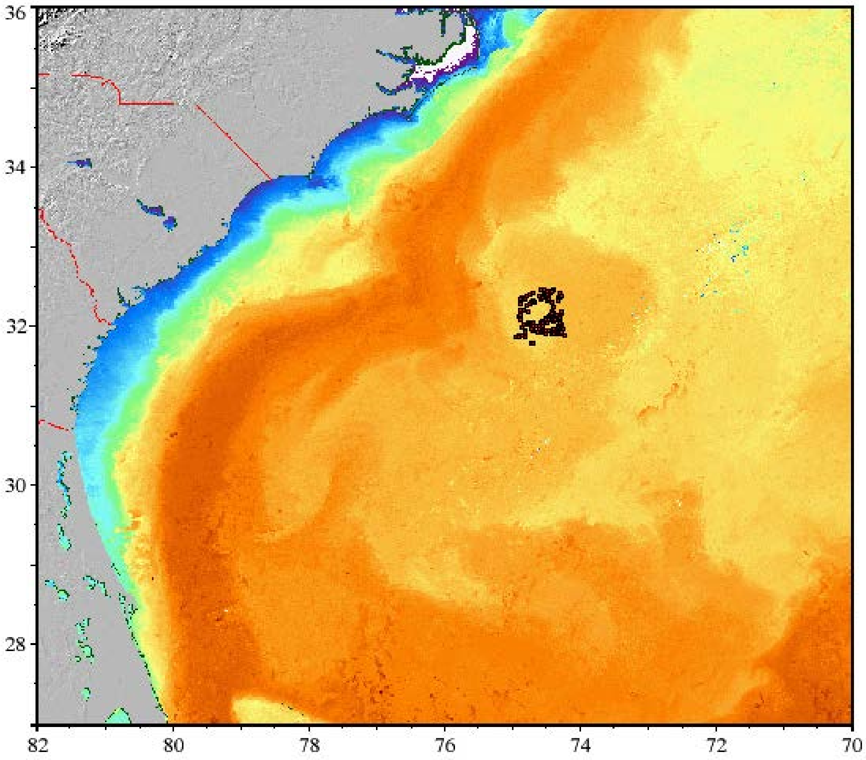
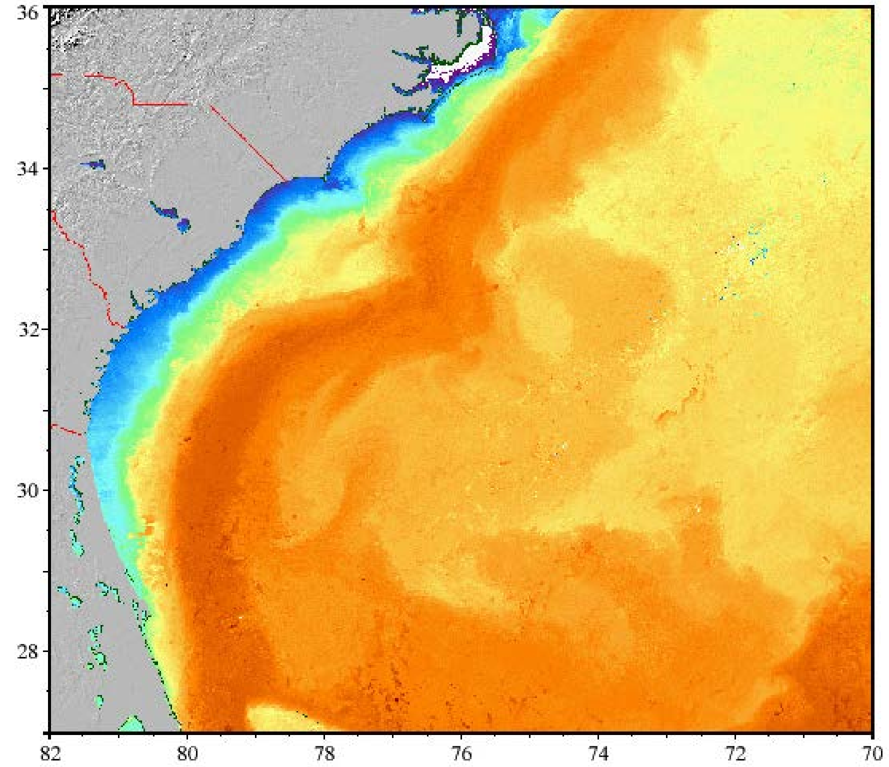
- Japan harvested ~1,000,000 tons of tuna and marlin in the 5 years before WWII.
- In 1950 the US harvested ~170,000 tons.
- The 1950 harvest of albacore by Spain was greater than the total recent harvest in the North Atlantic.
- Species that migrate long distances (e.g. southern bluefin tuna, northern bluefin tuna, and albacore) would have reduced by these harvests.

These estimates are conservative: 6 Fishermen are smarter (gps, satellite information, **ACDP** (Acoustic Current Doppler Profiler)).





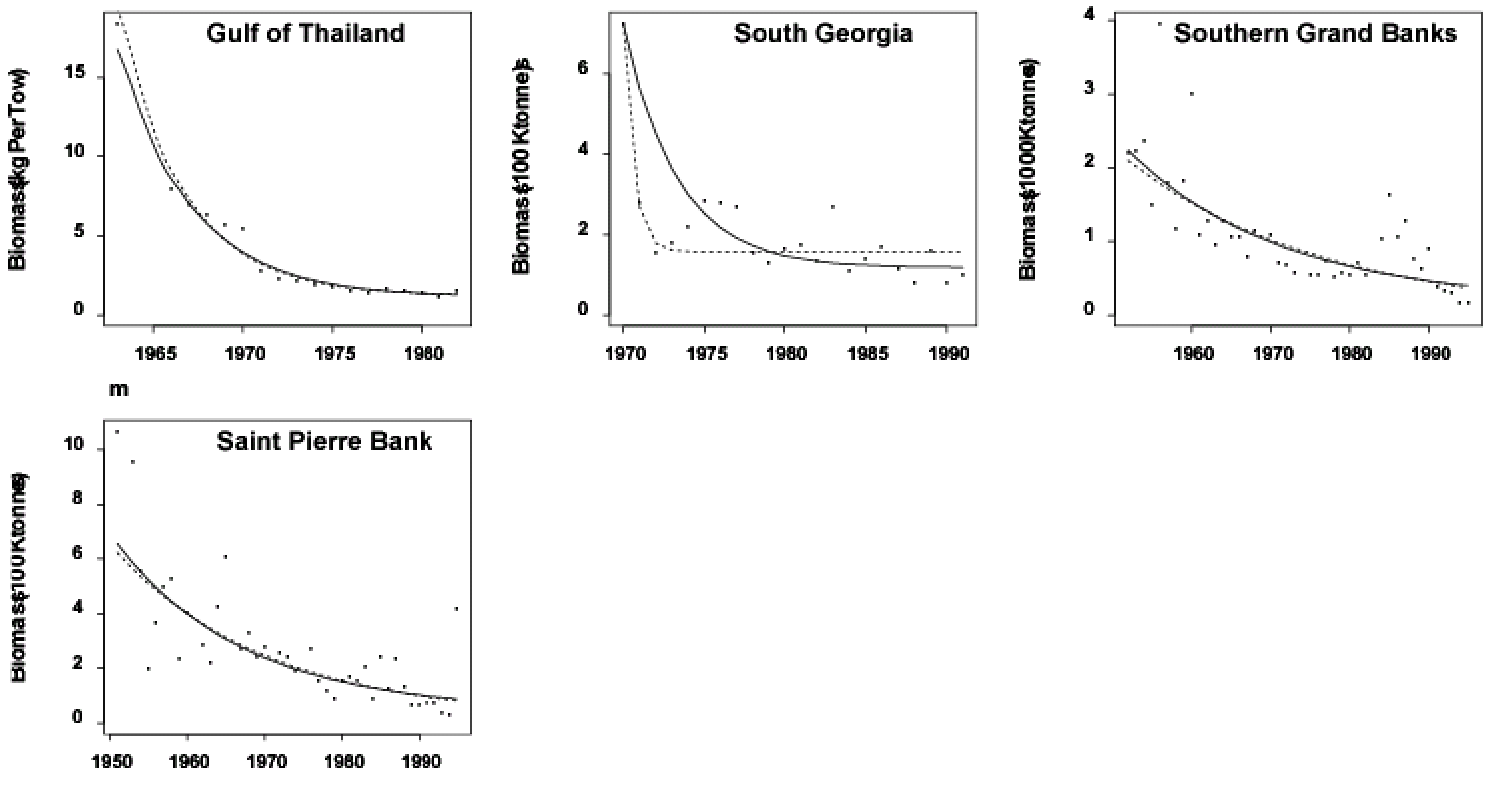
Locations of a leatherback turtle over a two week period tagged by my student Mike James that maintains its position within a cold core ring (somehow).

However, fish may be a lot smarter too (the stupid ones were caught).

Step 8: You need emotional support. Support from colleagues and family is essential. You cannot do it (for long) by yourself.

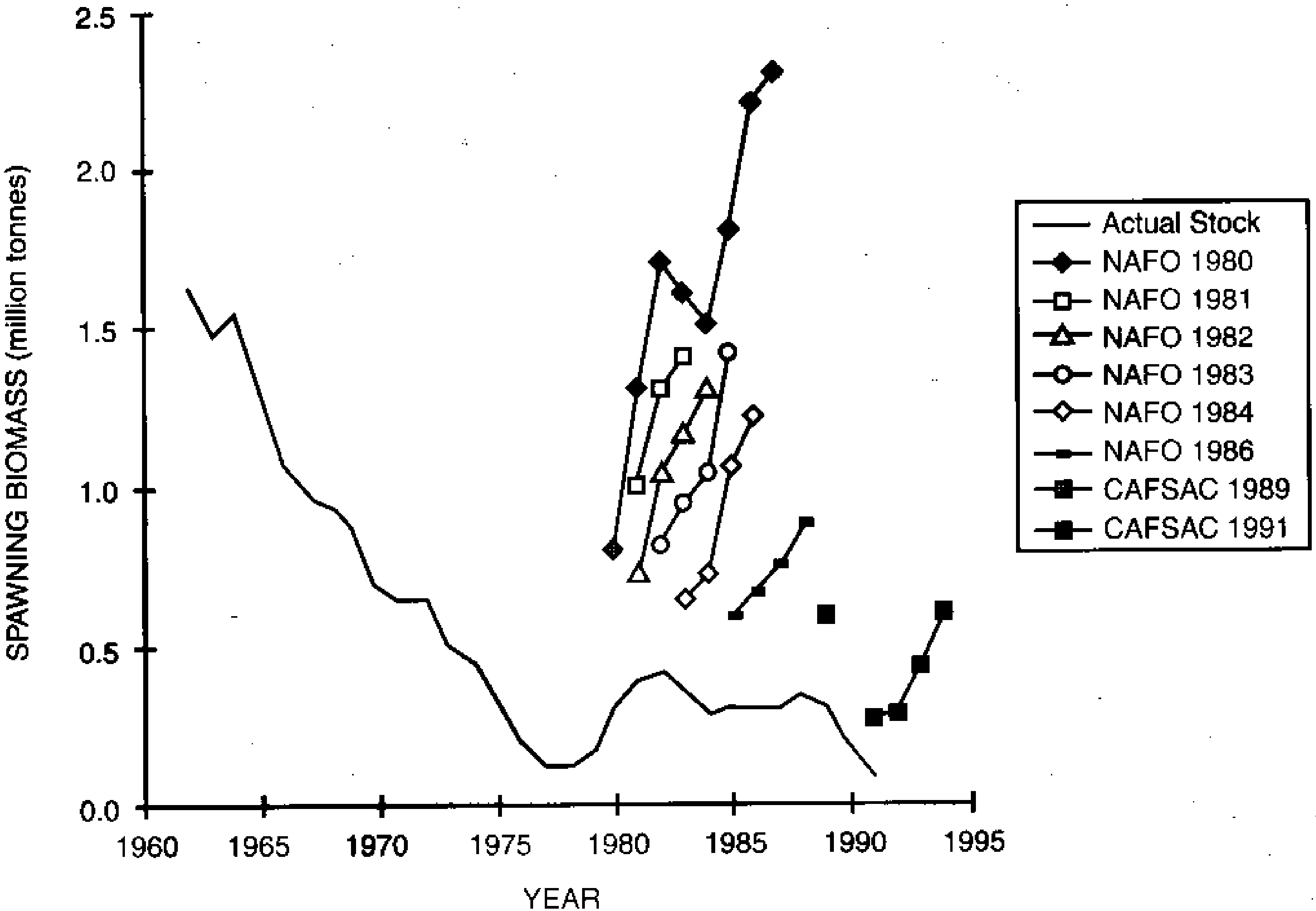
Why is it so important.
What makes them work.

Shelf seas



Gulf of Thailand
South Georgia
Southern Grand Banks
Saint Pierre Bank
15
10
5
0
1965
1970
1975
1980
6
4
2
0
1970
1975
1980
1985
1990
4
3
2
1
0
1960
1970
1980
1990
m
10
8
6
4
2
0
1950
1960
1970
1980
1990

Government science was consistently wrong, and there was no effective voice from universities.



Lessons I Learned from the Cod Disaster:

- Government constrained scientists may consistently ignore what the data tells them.
- Independence is key.
- Multiple, independent analyses are crucial; or else you will be dismissed.
- Speak clearly and honestly to the press, the politicians must know that someone is watching.
- Be proactive, once an animal is ecologically extinct it is too late.


15 May 2003
International weekly journal of science
nature
www.nature.com/nature
Net losses
Industrialized fishing hits fish stocks
Financial markets
You can't buck the physics
Jupiter's moons
Headed for a hundred
Functional genomics
The power of comparison

RAM’s 12 step plan: From hard core math weenie to passionate conservationist: A PERSONAL ODYSSEY.

Reaching the heart through mathematics.

Final point: keep fighting, keep hoping!

This happened last week: Oceanic Whitetip declared critically endangered by ICUN

- Last year is was “species of least concern”.
- This change was not because we published one paper in Science, but papers based upon 3 independent datasets (plus 2 math/stats technical papers).
- Skeptics remain – more analyses are in prep from scuba surveys of jellyfish (one notices large sharks while diving in the clear open ocean.

Conclusion: The Factor of 10 Hypothesis

- Scientific investigations of marine fish stocks almost always begin after the fact.
- Here we compile data from which the size of the community of large predatory fishes can be estimated.
- New fisheries tend to deplete the biomass of large predators by at least a factor of 10 .
- These declines happen very rapidly, usually in a decade or less.

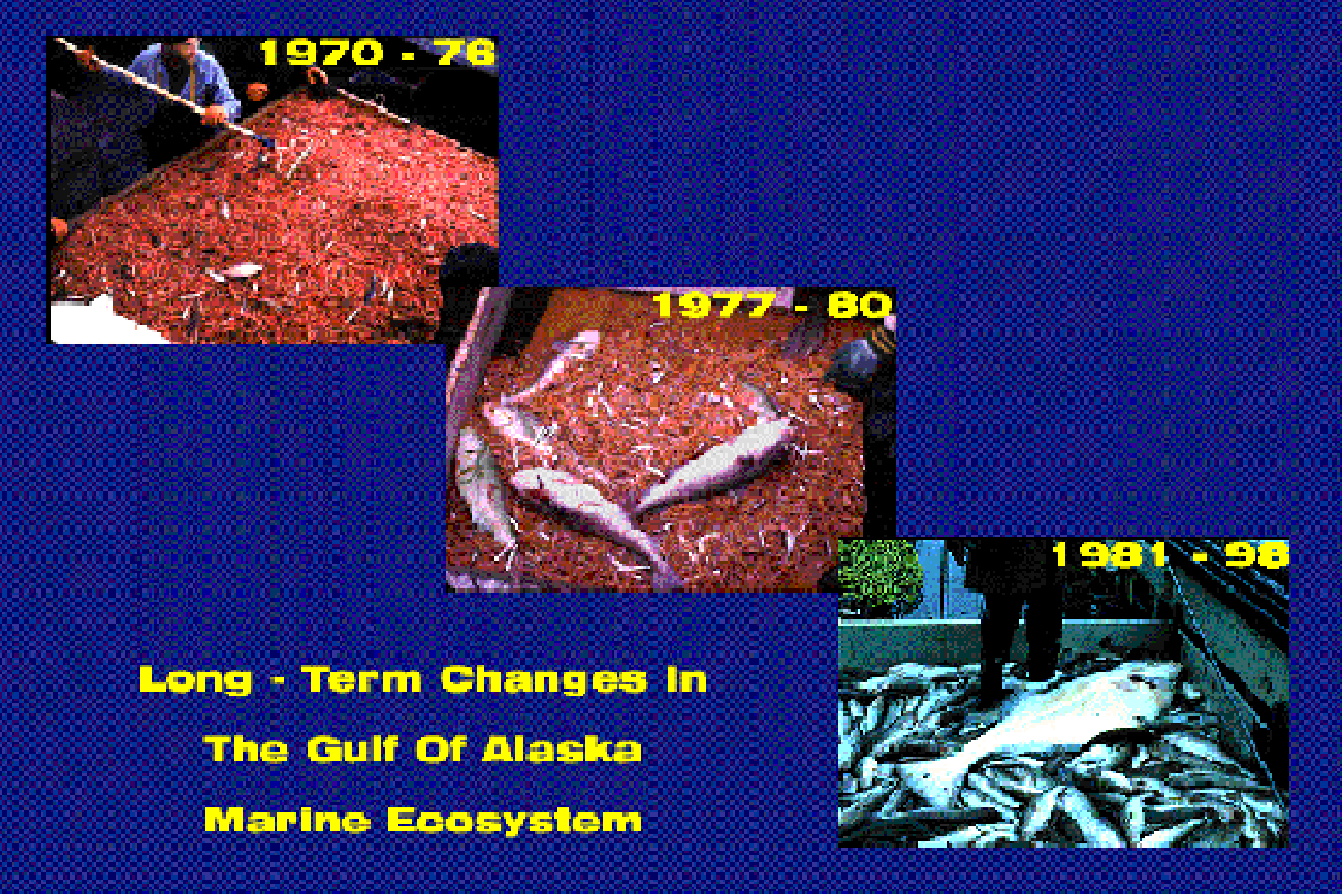
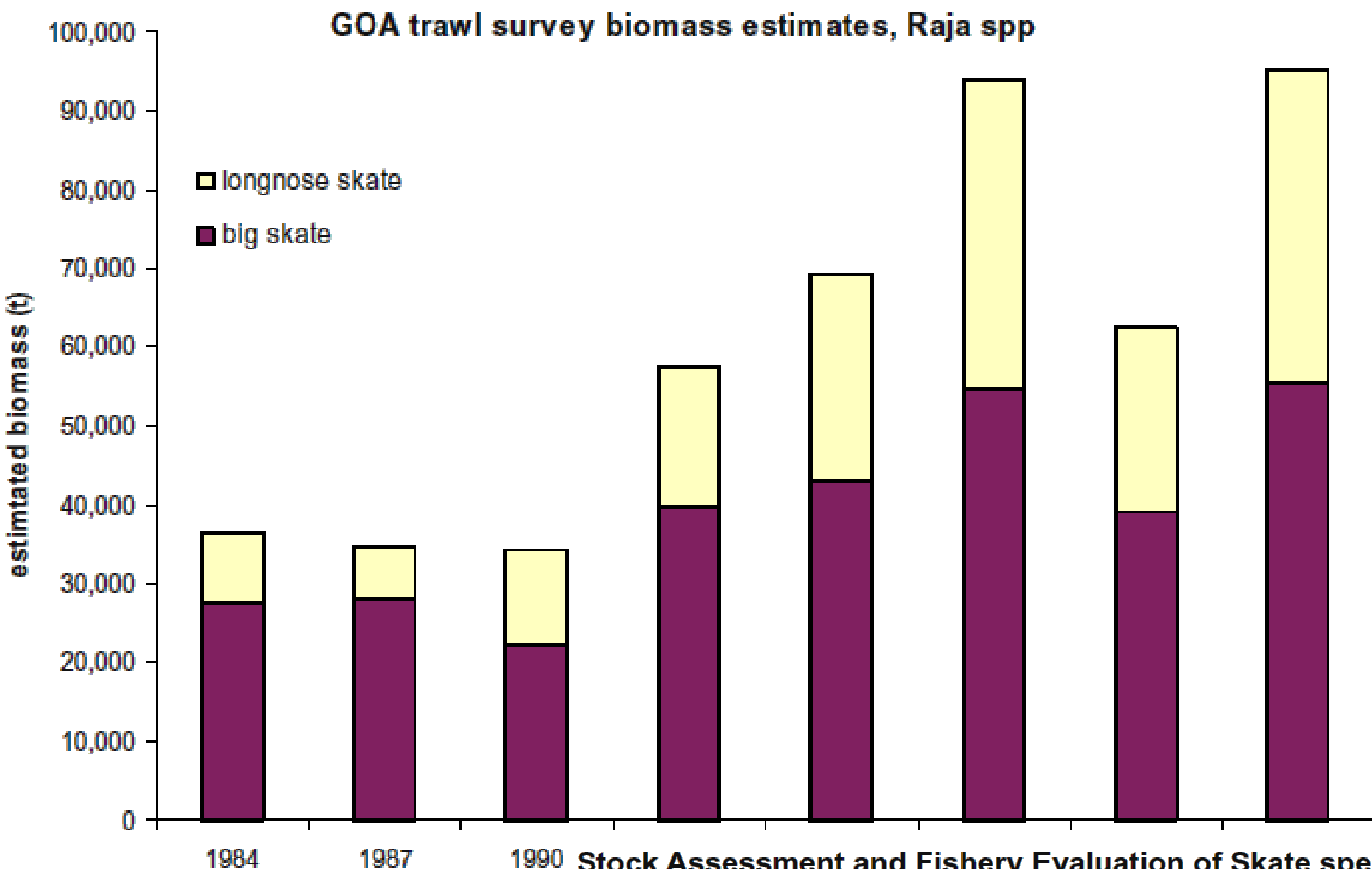


Figure stolen from Paul Anderson

- The Good -
- Ban directed fisheries on sharks.
- Control fishing on skates.
- Keep a watch on bycatch.

- The Alaska Board of Fisheries prohibited all directed fisheries for sharks in 1998. In Southeast the bycatch rate for sharks and skates taken during other longline fisheries is 35% of the target species.



Stock Assessment and Fishery Evaluation of Skate species (*Rajidae*) in the Gulf of Alaska

by

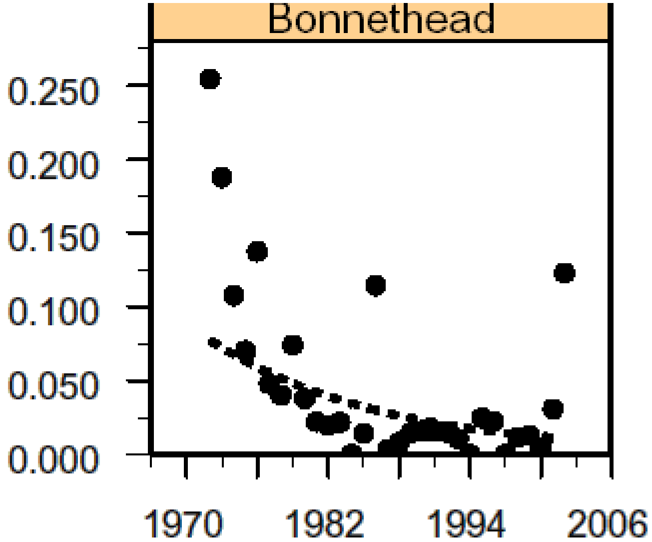
Sarah Gaichas[1], Michael Ruccio[2], Duane Stevenson[1], and Rob Swanson[3]

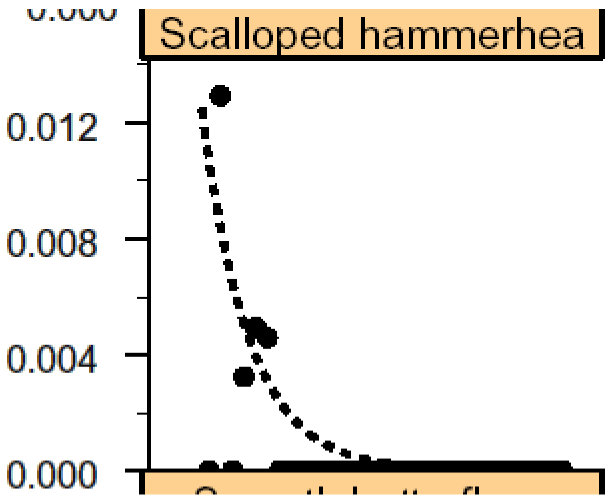
Figure 1. Big skate, *Raja binoculata*, with stock assessment author for scale.

Stock Assessment and Fishery Evaluation of Skate species (*Rajidae*) in the Gulf of Alaska

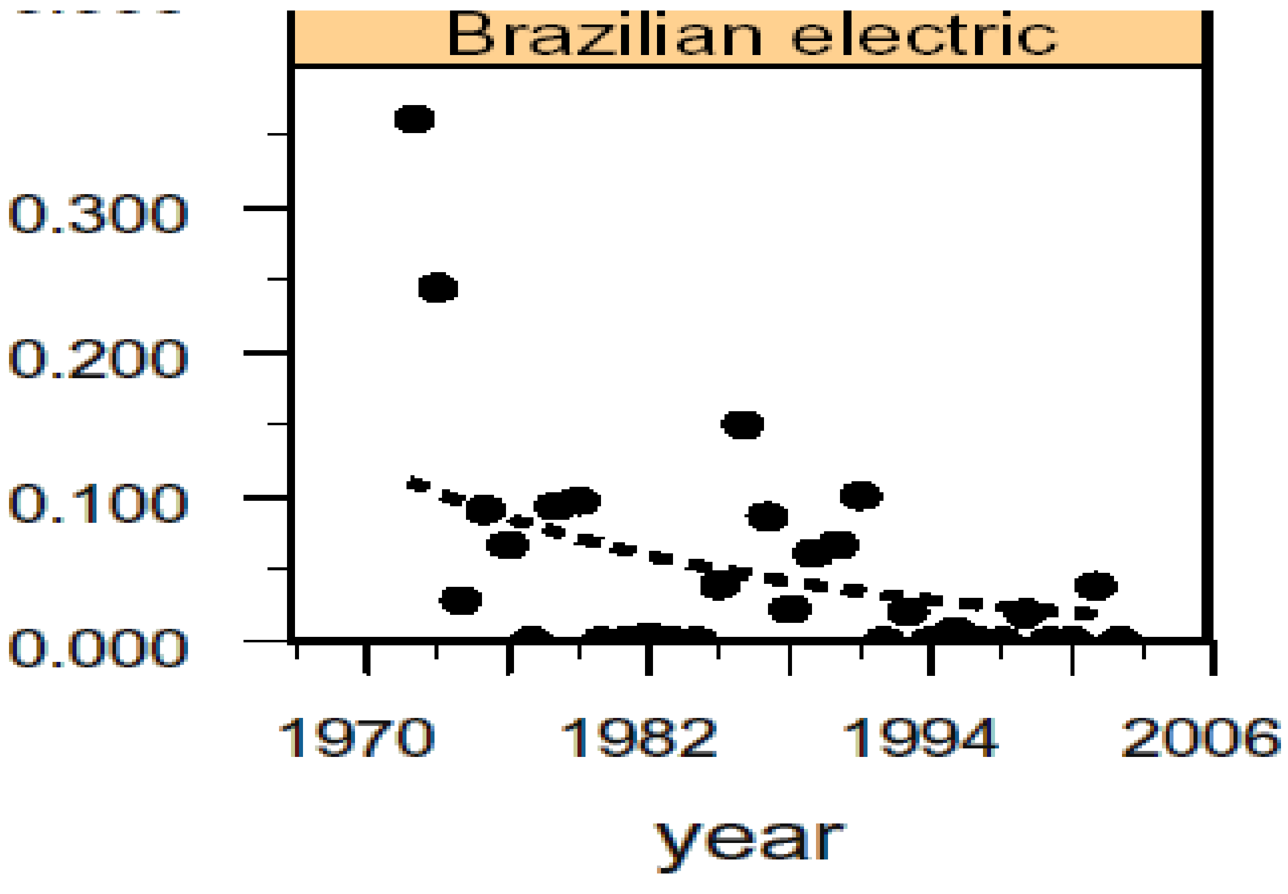
by
Sarah Gaichas[1], Michael Ruccio[2], Duane Stevenson[1], and Rob Swanson[3]

All large sharks declined





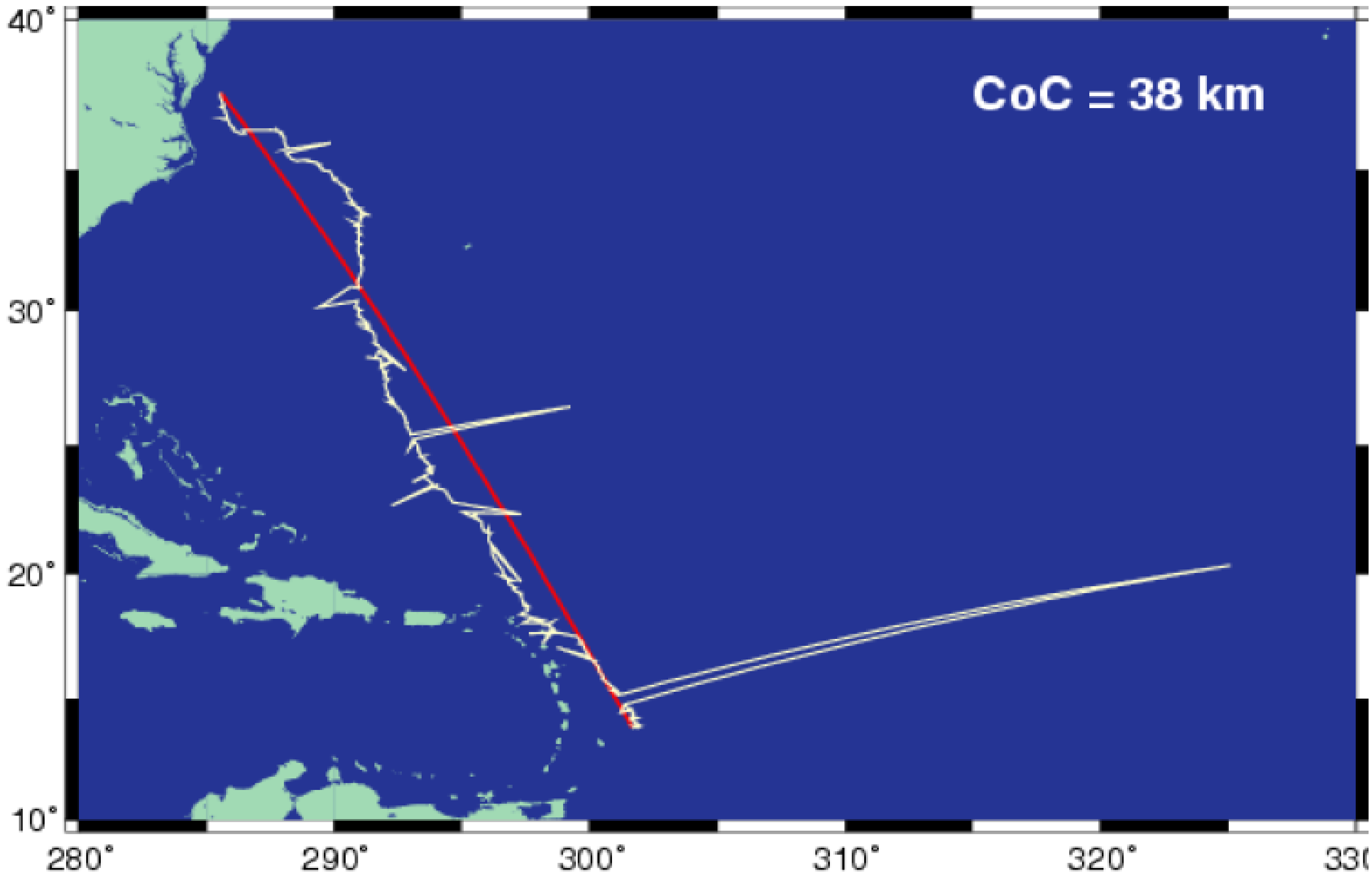
Shallow water species that do not survive discarding: large declines:



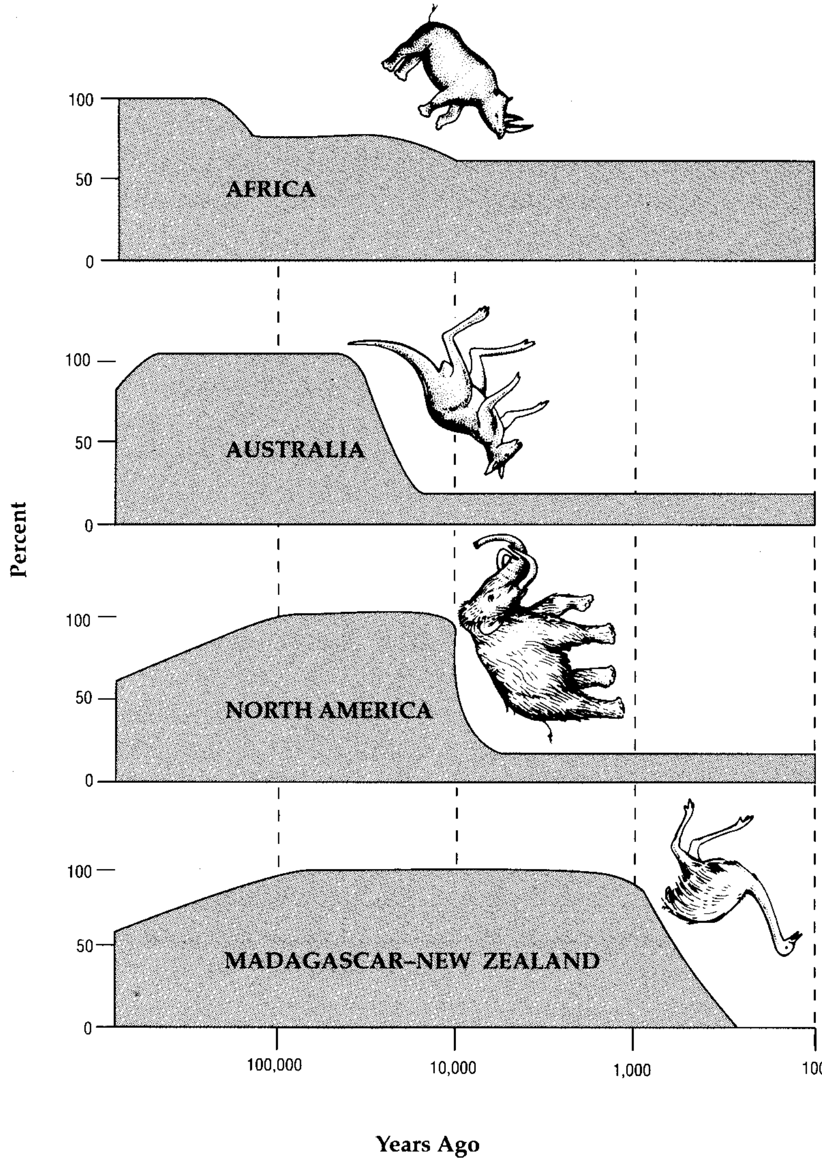
State-space models allow you to think about things, that it is very difficult to think about otherwise

Navigation: Estimating the "Circle of Confusion"

Flemming et al. in press. Environmetrics



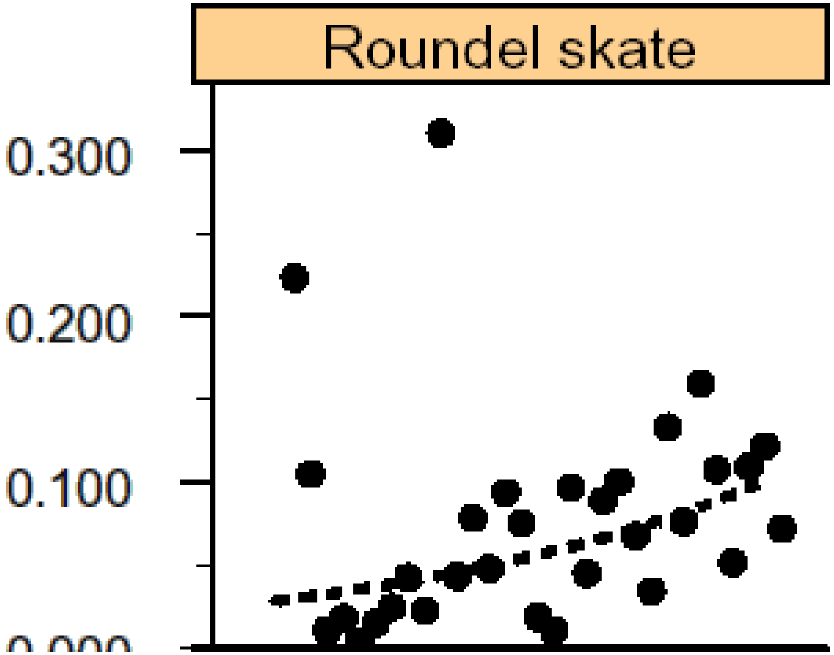
Are the pleistocene extinctions* going to be repeated in the ocean?

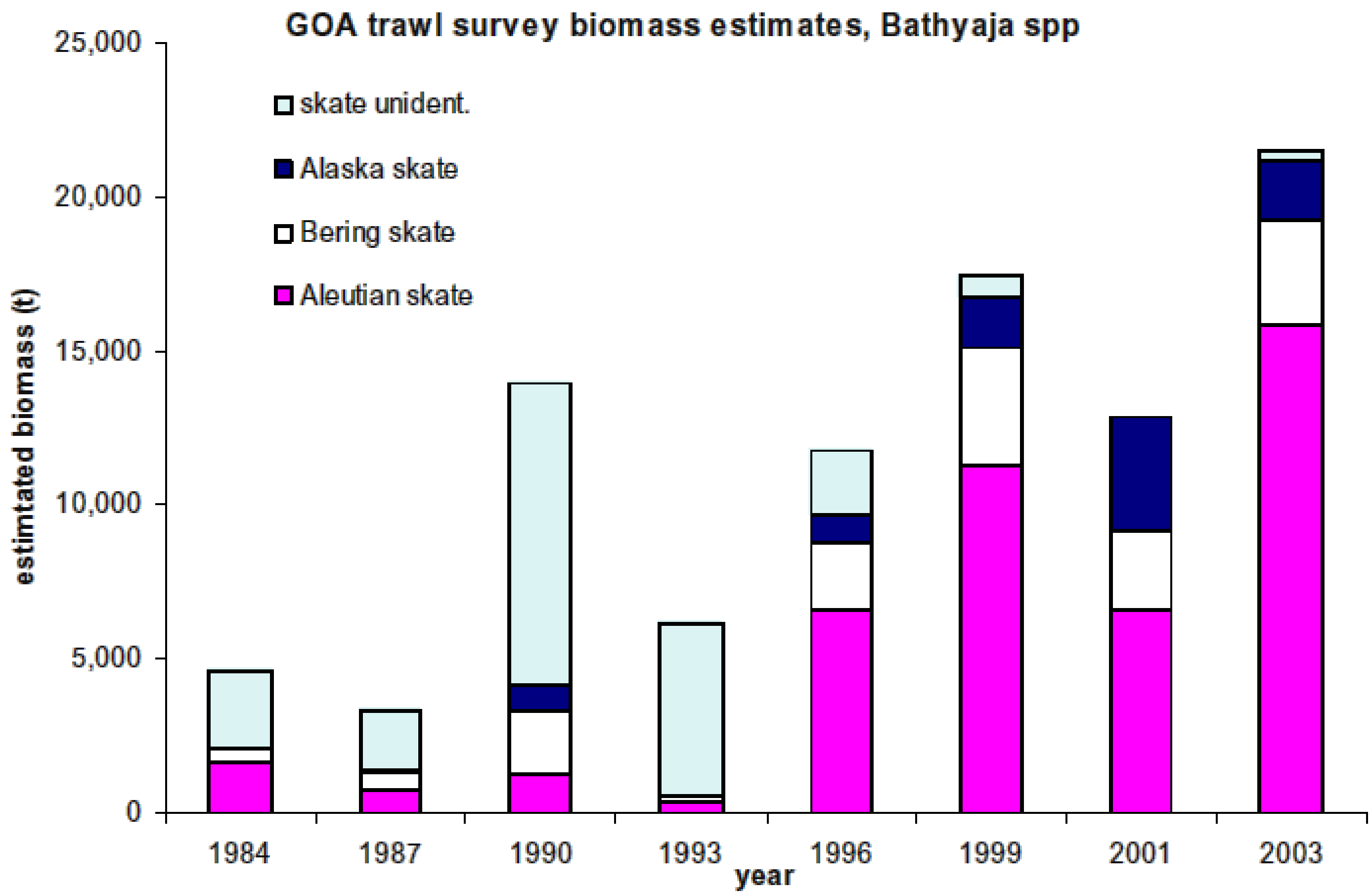


The extinction of large mammals and flightless birds coincided closely with the arrival of humans in North America, Madagascar, and New Zealand, and less decisively earlier in Australia. In Africa, where humans and animals evolved together for millions of years, the damage was less severe.

*Present North American biota has lost almost all large species –
We have no mammoths, mastodons, giant ground sloths, giant beavers, and 65 other species that weighted more than 100 kilograms.

Deeper skate species that survive discarding increased





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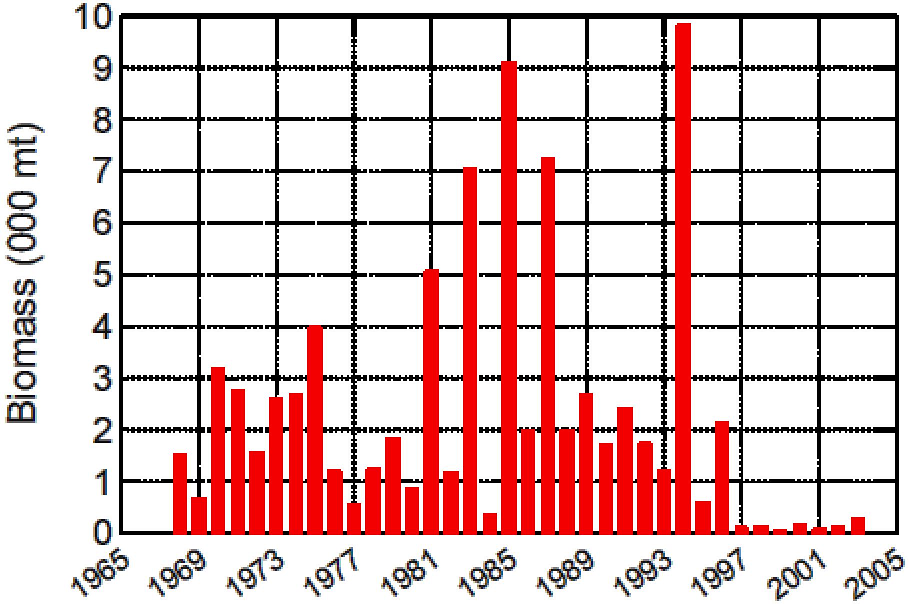
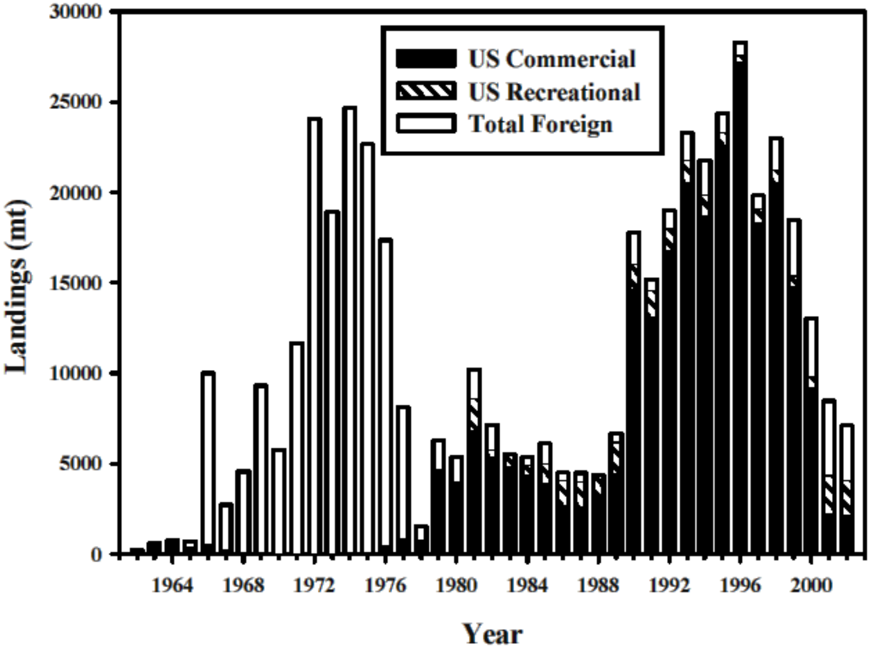
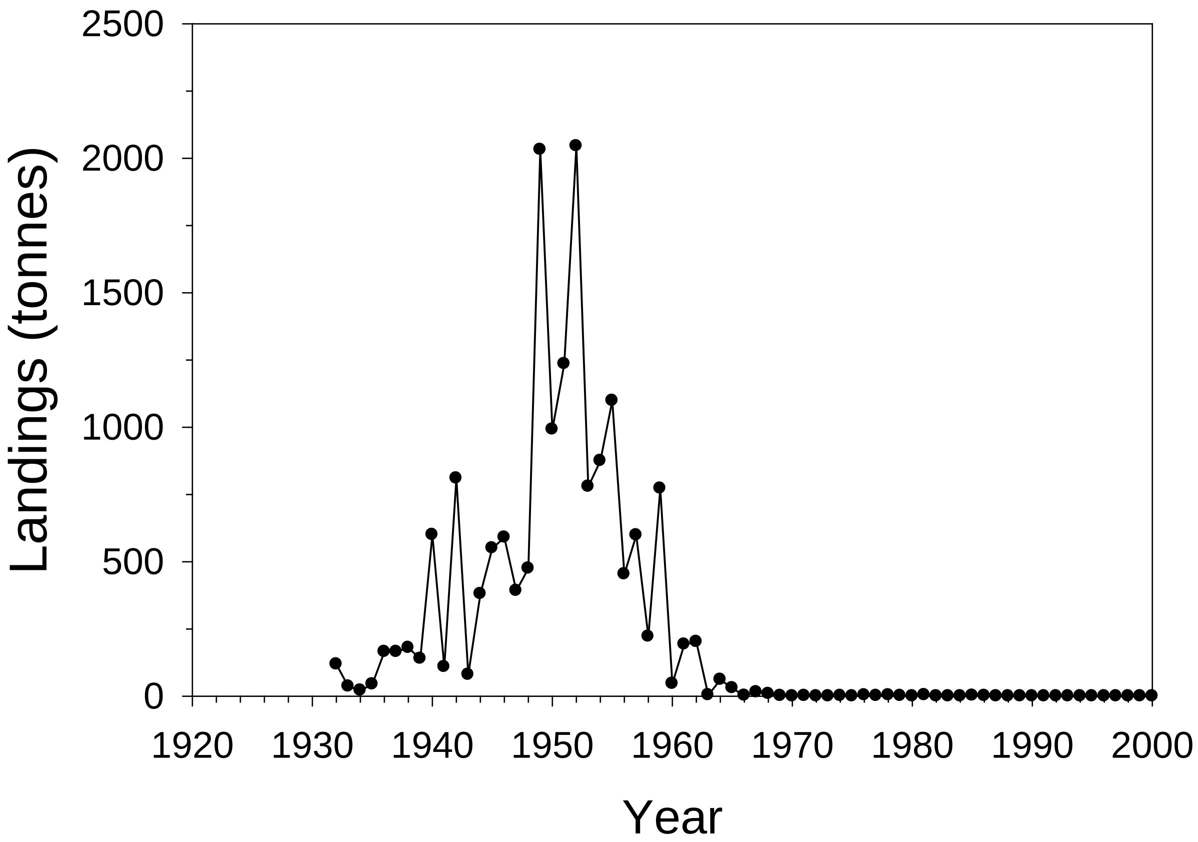
Spiny Dogfish, Northwest Atlantic: Good Science – Ugly Decisions





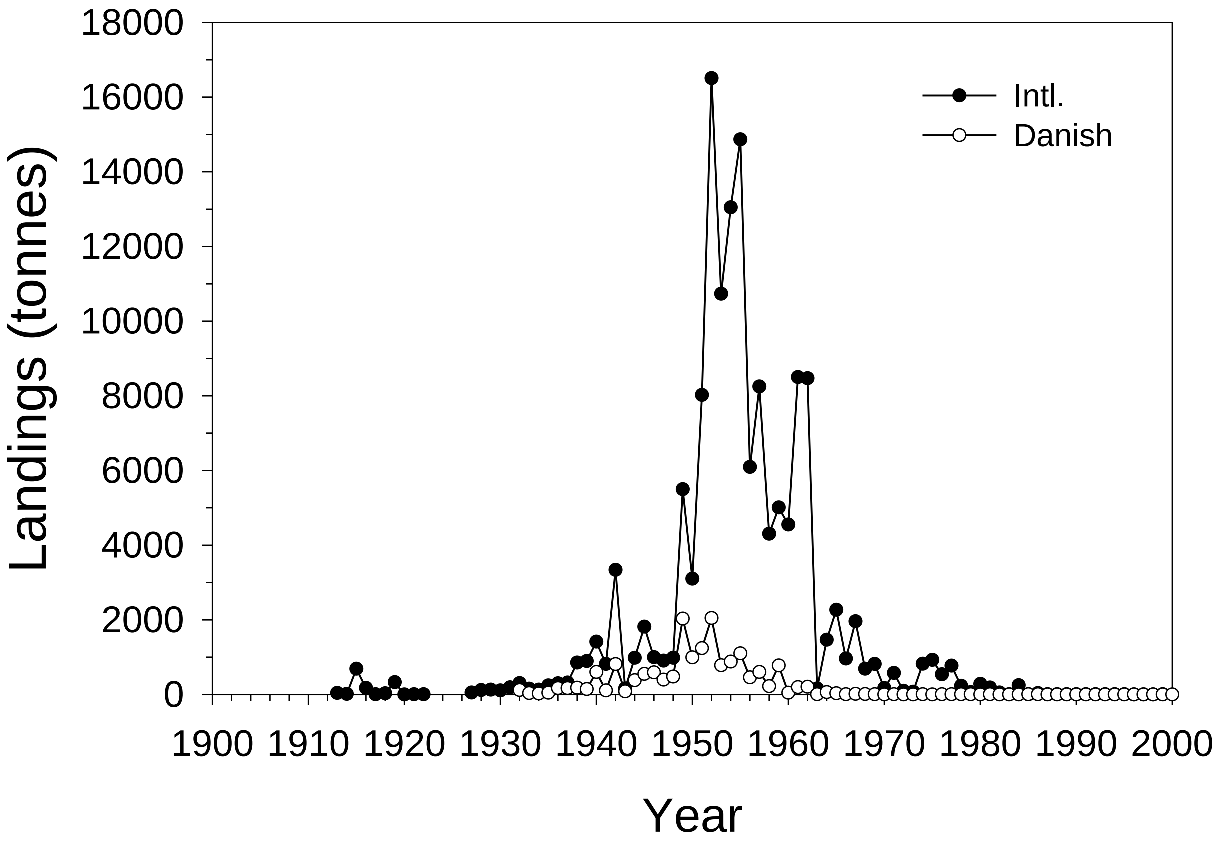
Danish Landings of Bluefin Tuna *Thunnus thynnus*



Data source: DIFRES, ICES, FAO

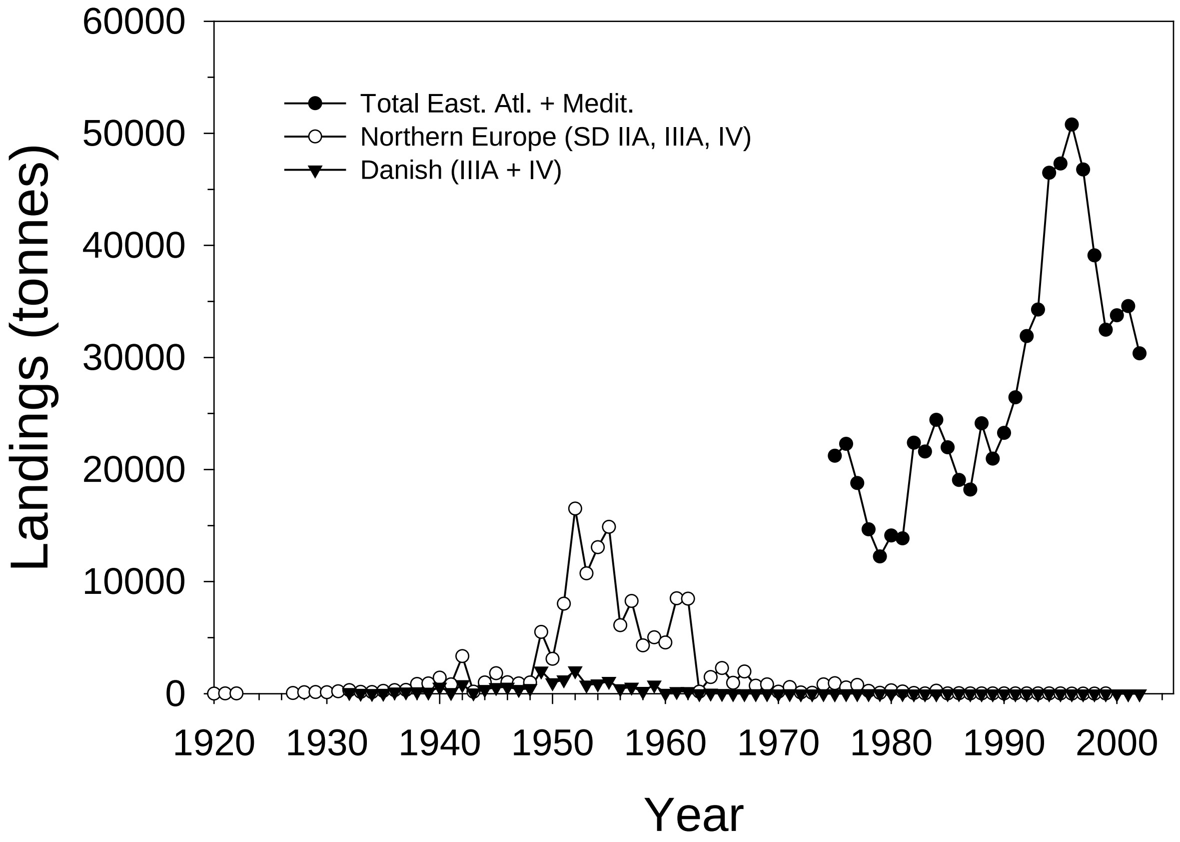
DIFRES

Landings of Bluefin Tuna *Thunnus thynnus* in Northern Europe*

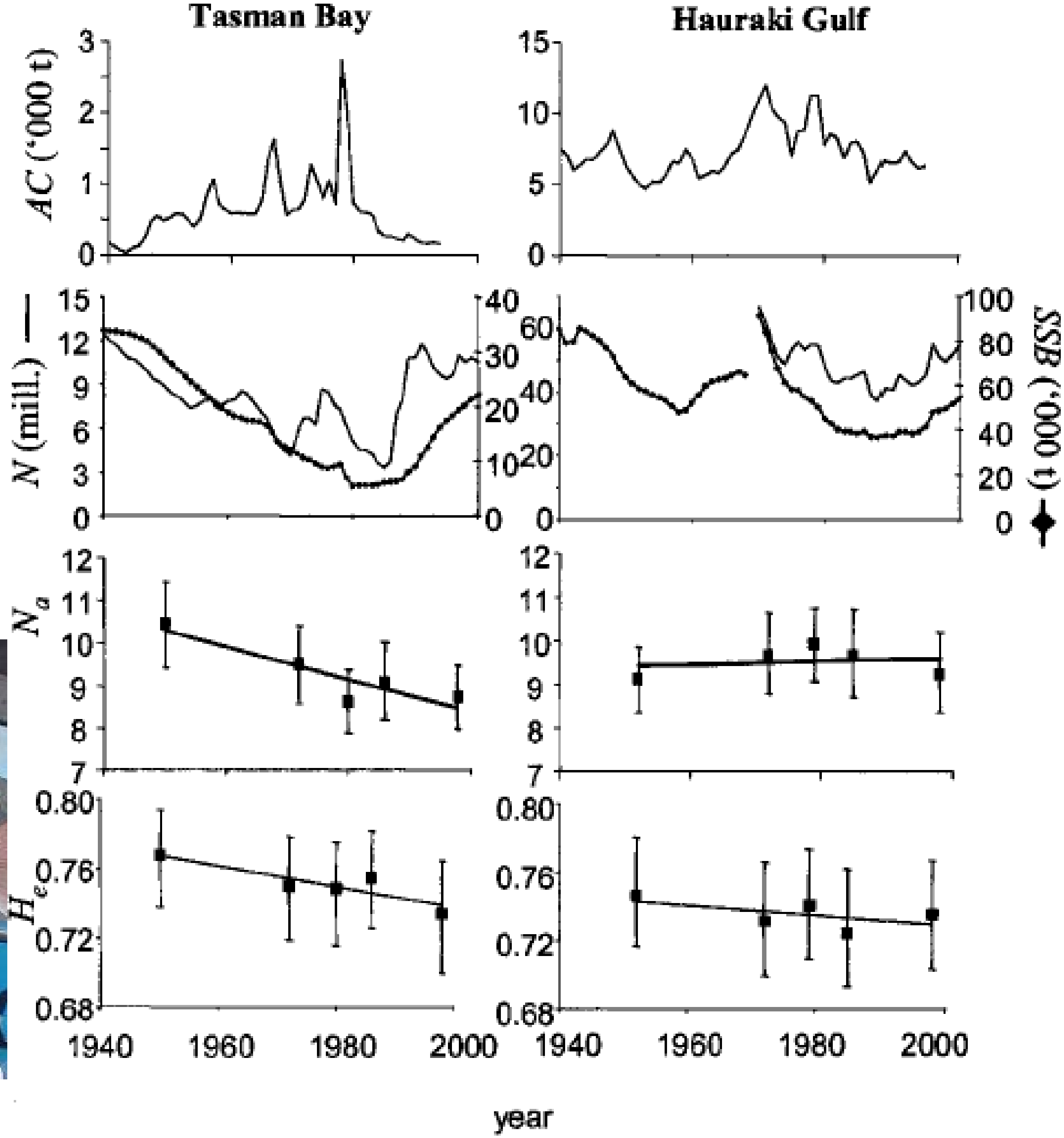


* = Norwegian Sea, North Sea, Skagerrak, Kattegat, Øresund

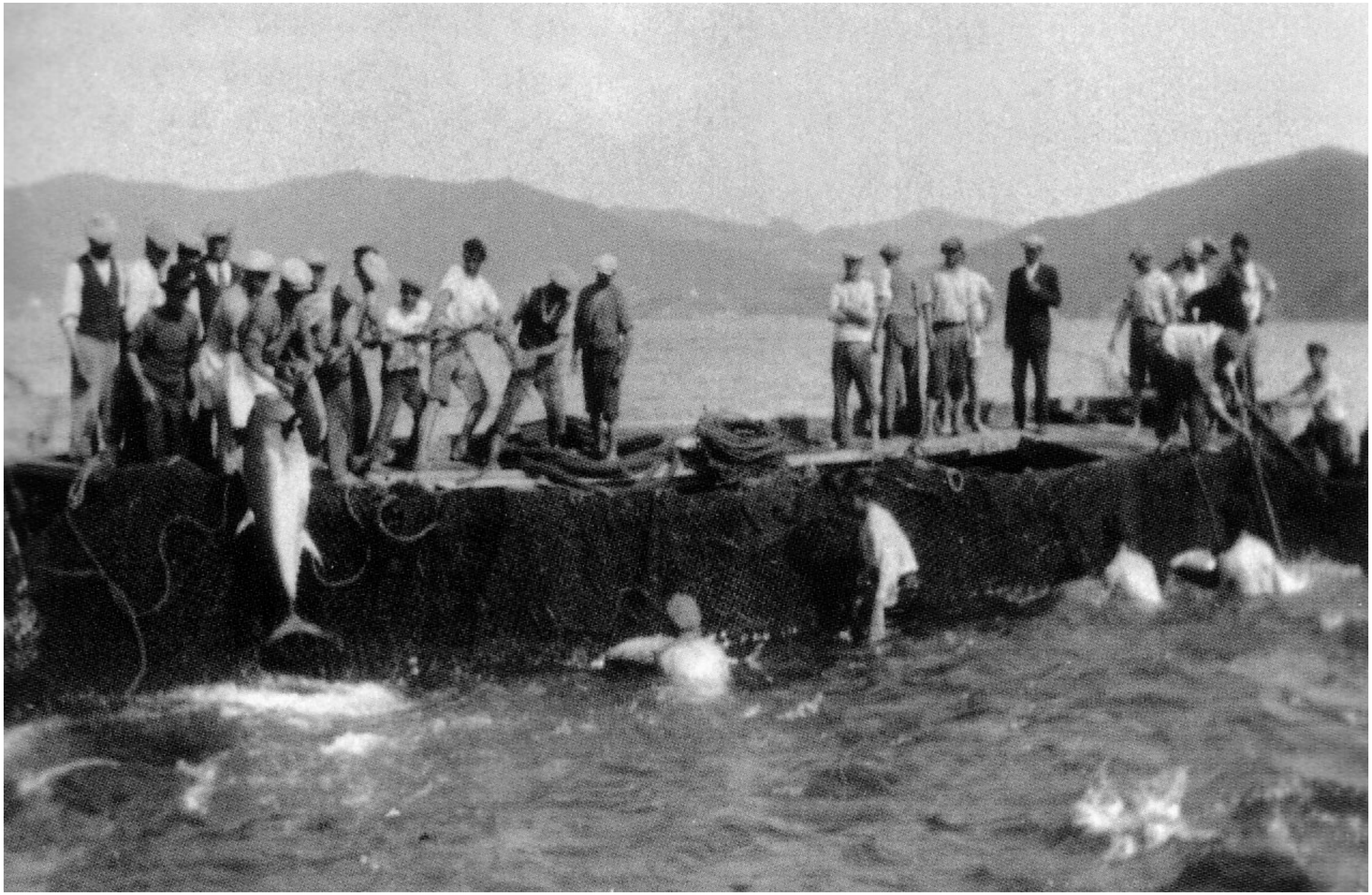
Landings of Bluefin Tuna
Thunnus thynnus in Northeast Atlantic

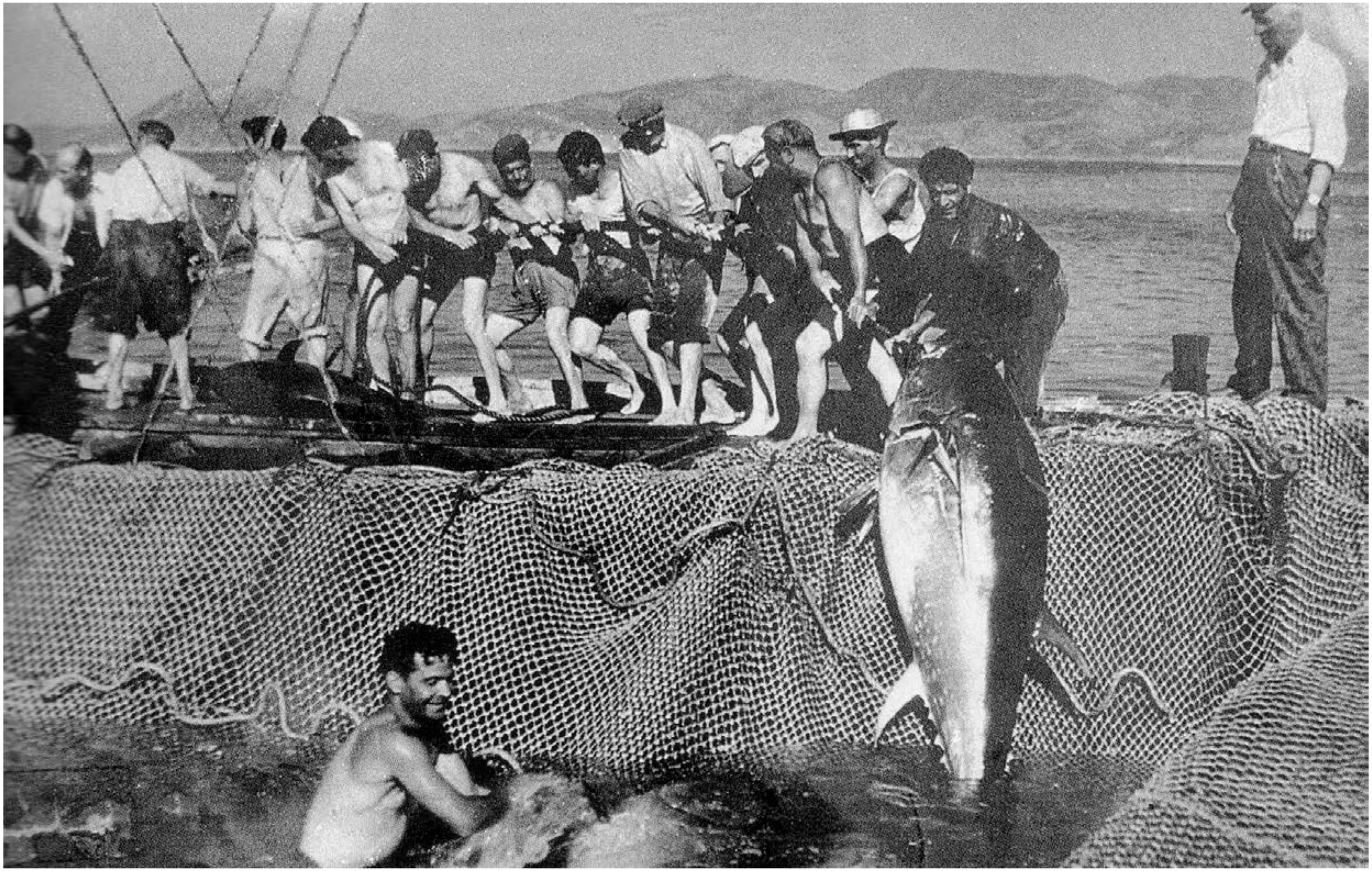


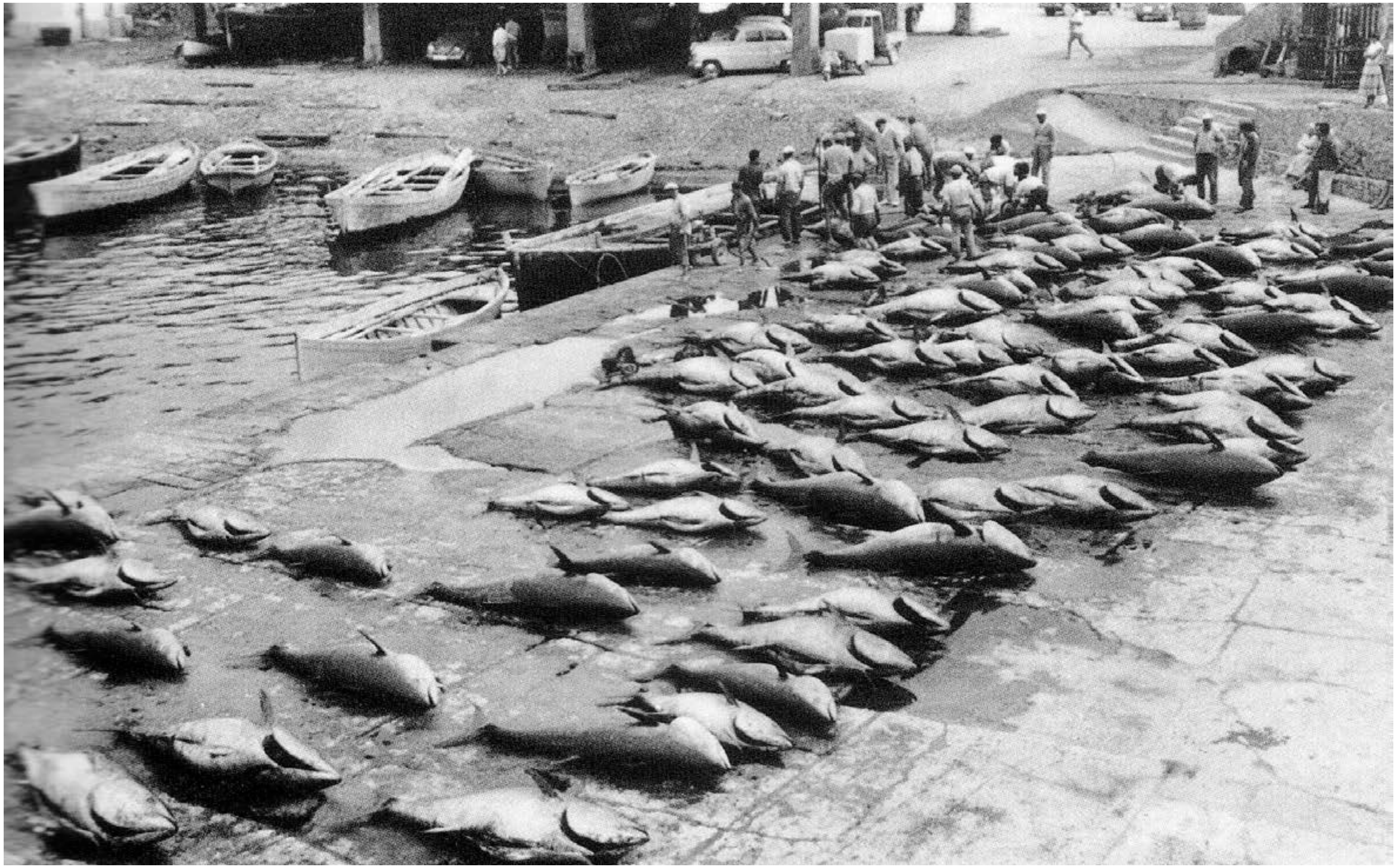
DIFRES



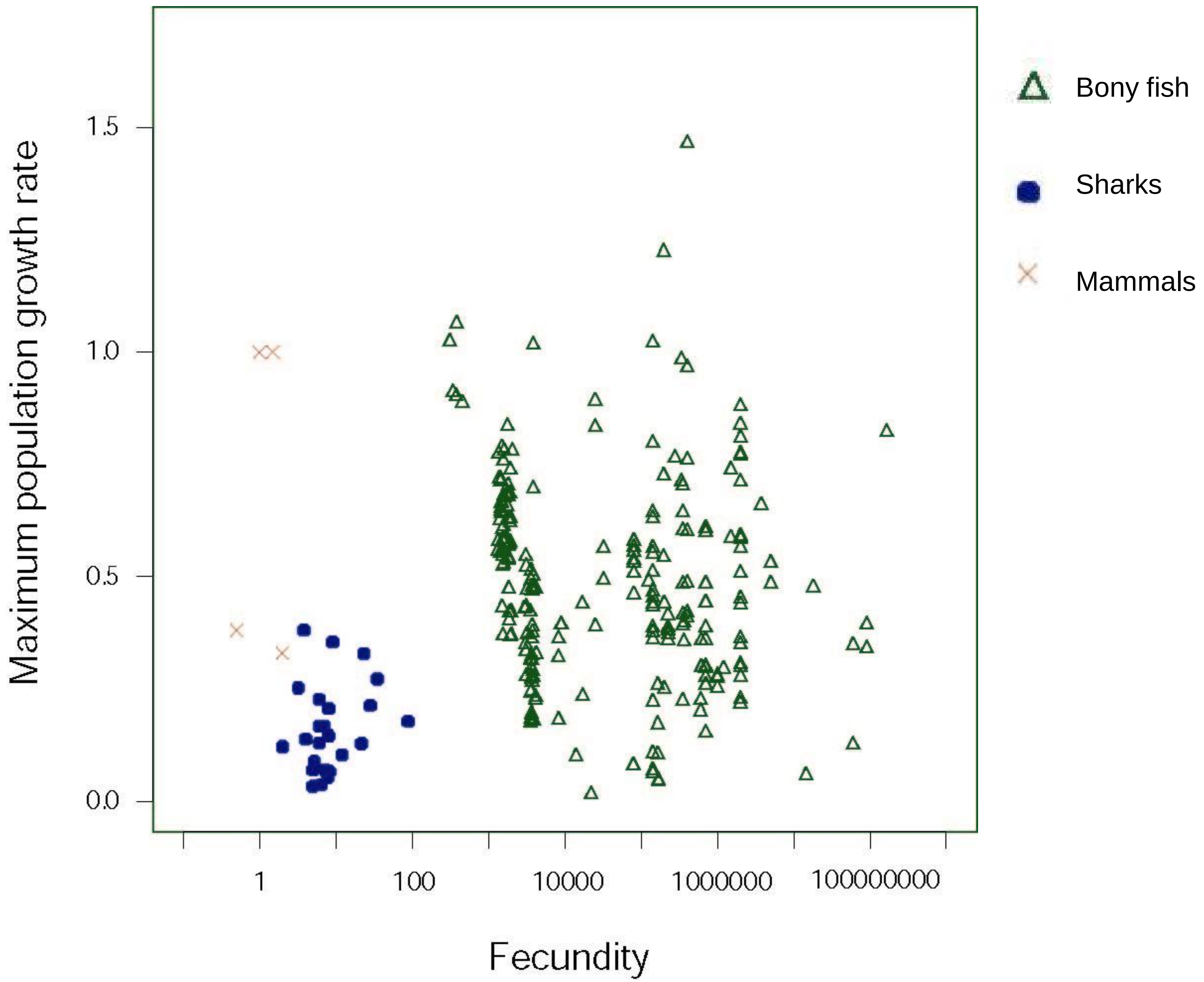
Hauser, et al. PNAS, 2002





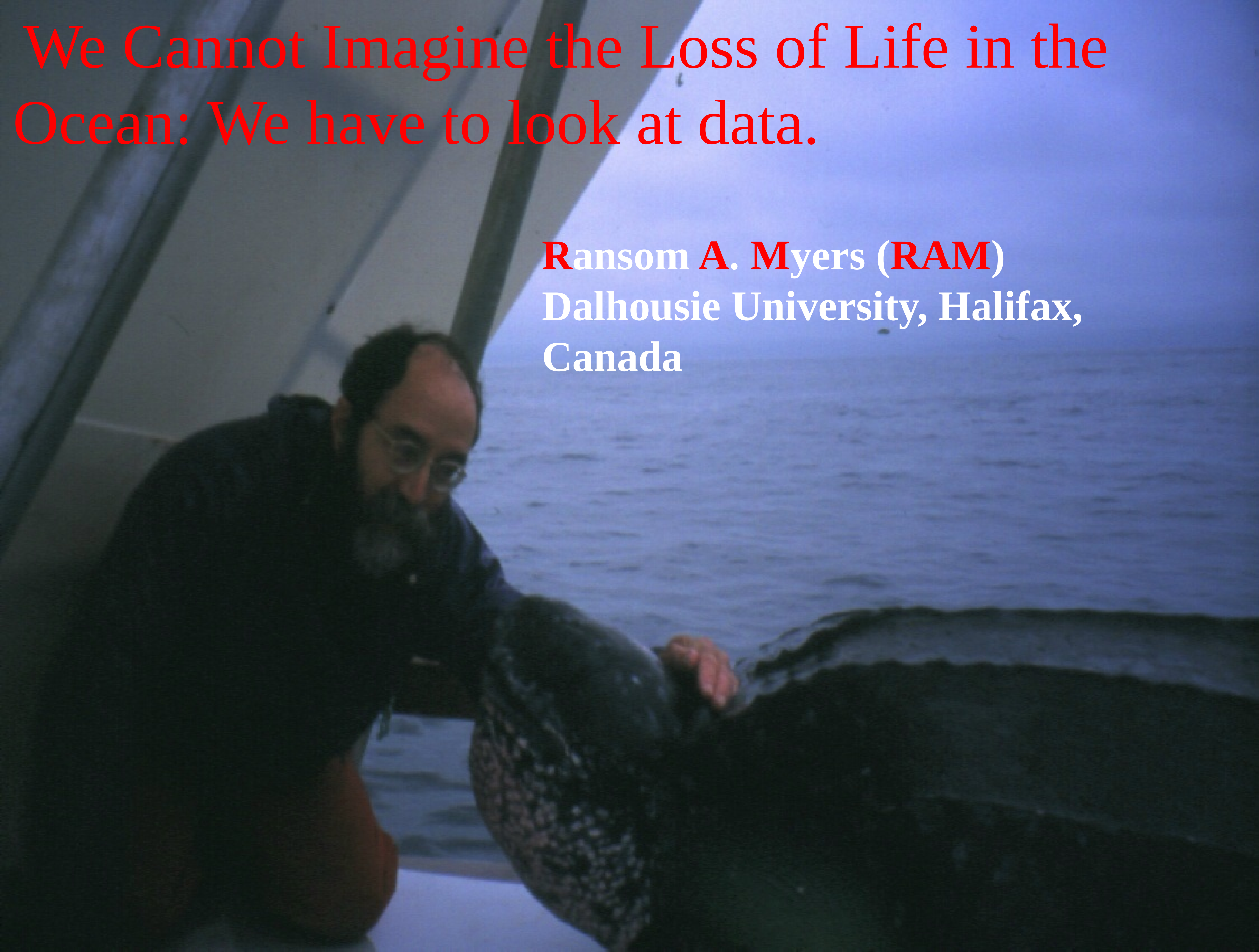


Life history of sharks…

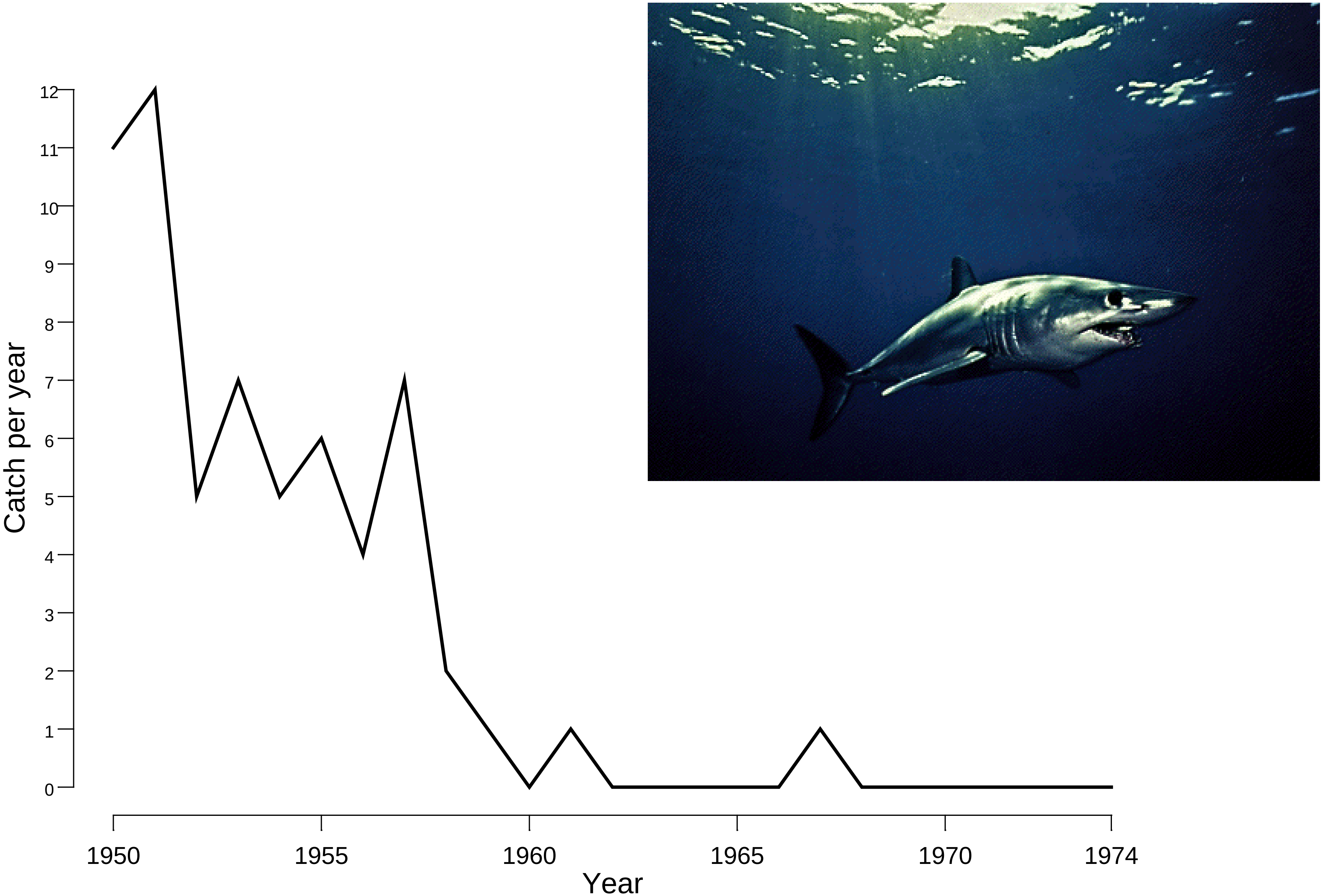


We Cannot Imagine the Loss of Life in the Ocean: We have to look at data.

Ransom A. Myers (RAM)
Dalhousie University, Halifax, Canada

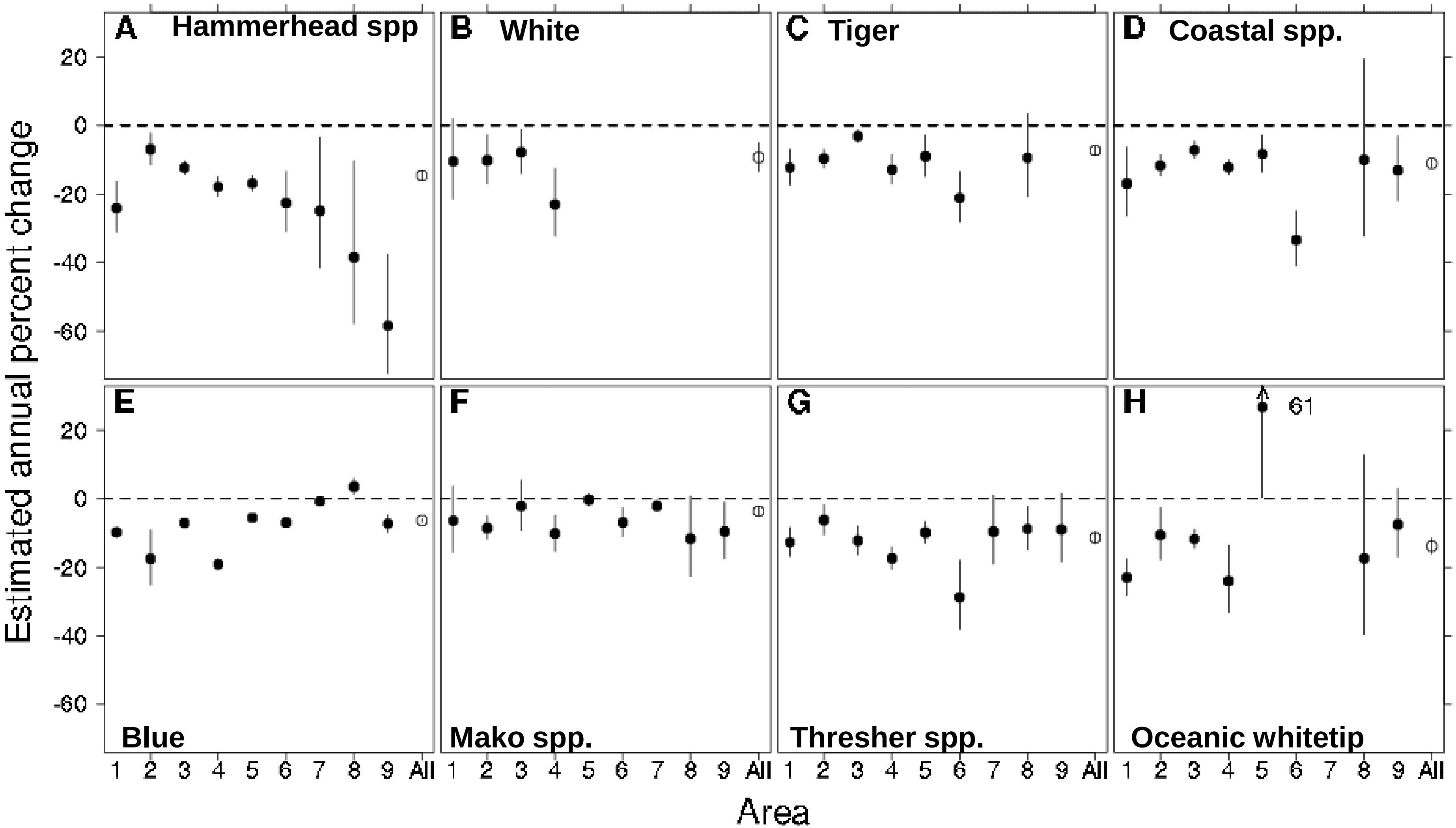


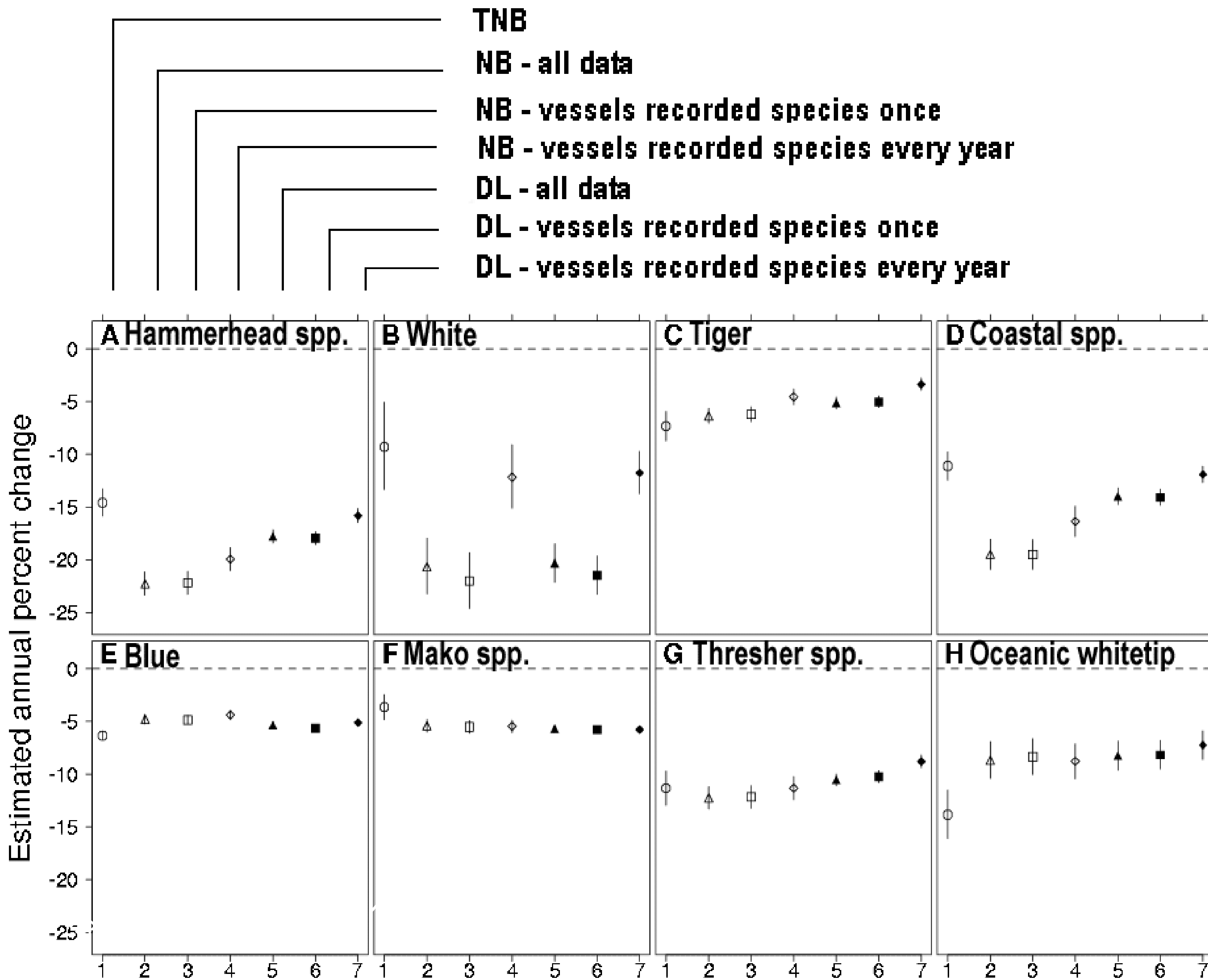
Decline of Mako sharks



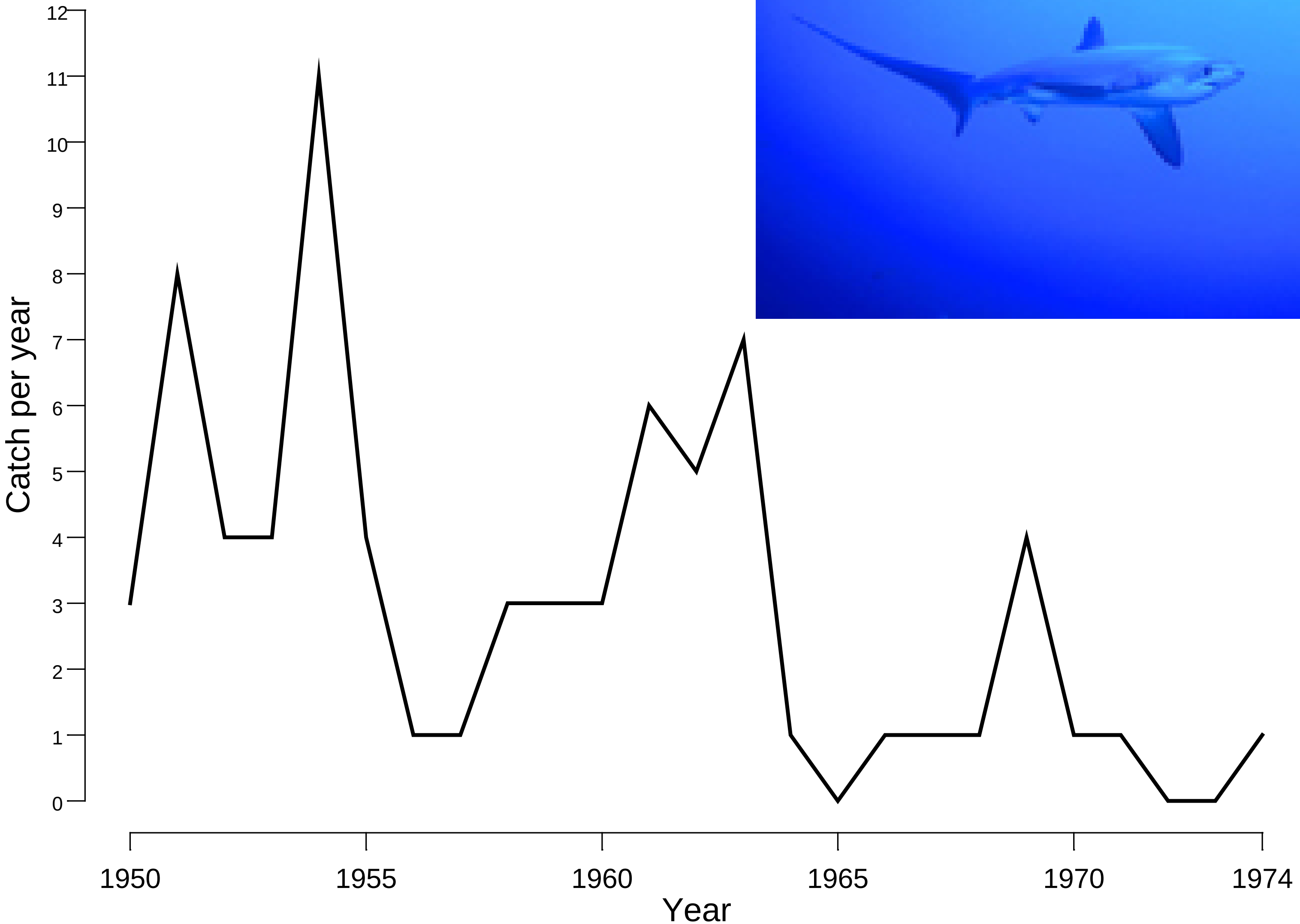
Boero F. & A. Carli 1979 – Boll. Mus. Ist. Biol. Univ. Genoa (47)

1 Caribbean
2 Gulf of Mexico
3 Florida
4 S Atlantic Bight
5 Mid Atlantic Bight
6 NE Coastal
7 NE Distant
8 Sargasso
9 S America




TNB
NB - all data
NB - vessels recorded species once
NB - vessels recorded species every year
DL - all data
DL - vessels recorded species once
DL - vessels recorded species every year
A Hammerhead spp.
B White
C Tiger
D Coastal spp.
E Blue
F Mako spp.
G Thresher spp.
H Oceanic whitetip
Estimated annual percent change
0
-5
-10
-15
-20
-25
1
2
3
4
5
6
7

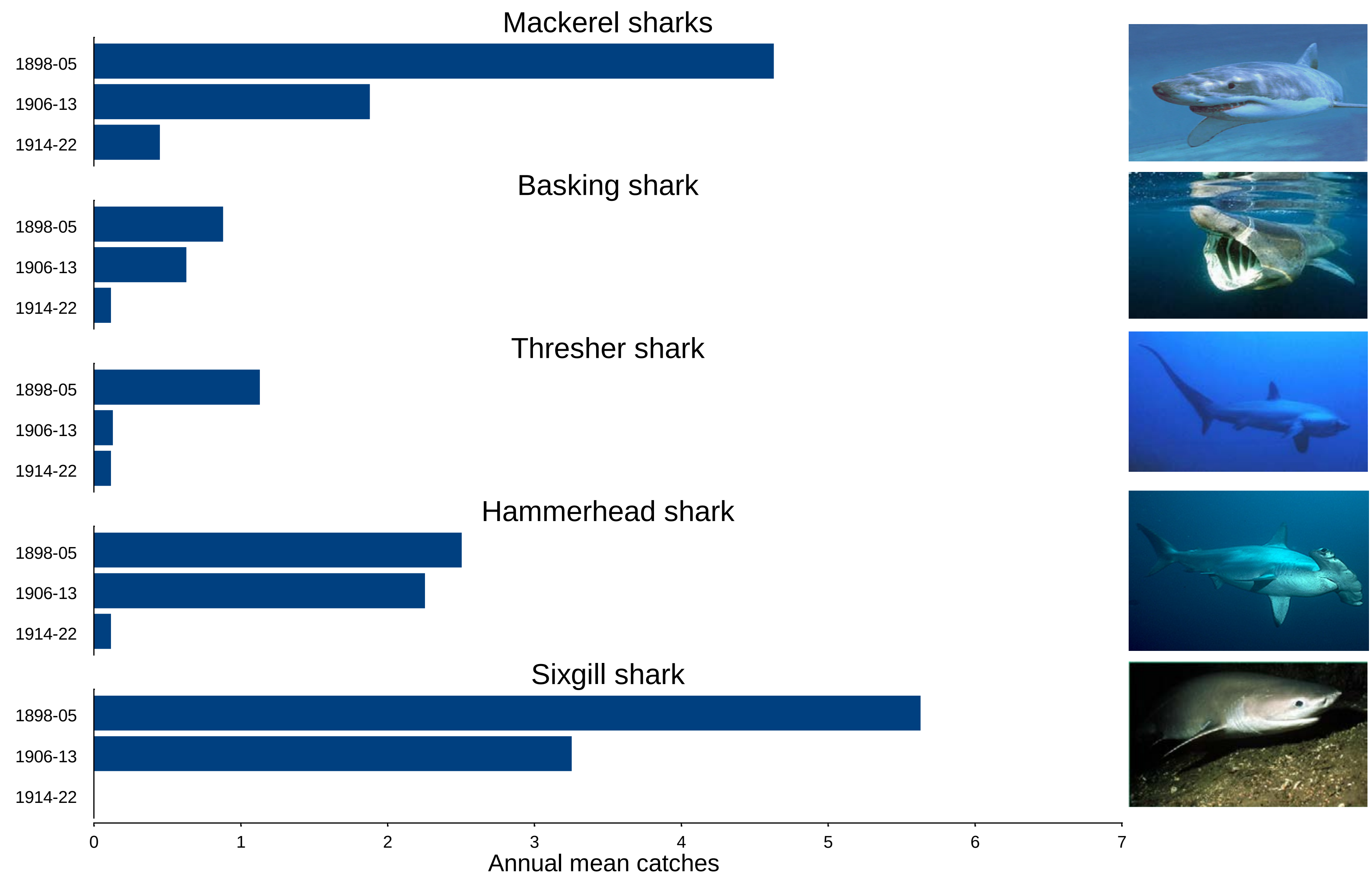
Decline of Thresher sharks



Boero F. & A. Carli 1979 – Boll. Mus. Ist. Biol. Univ. Genoa (47)

Decline in Large Sharks's Catches by an Italian Tuna Trap

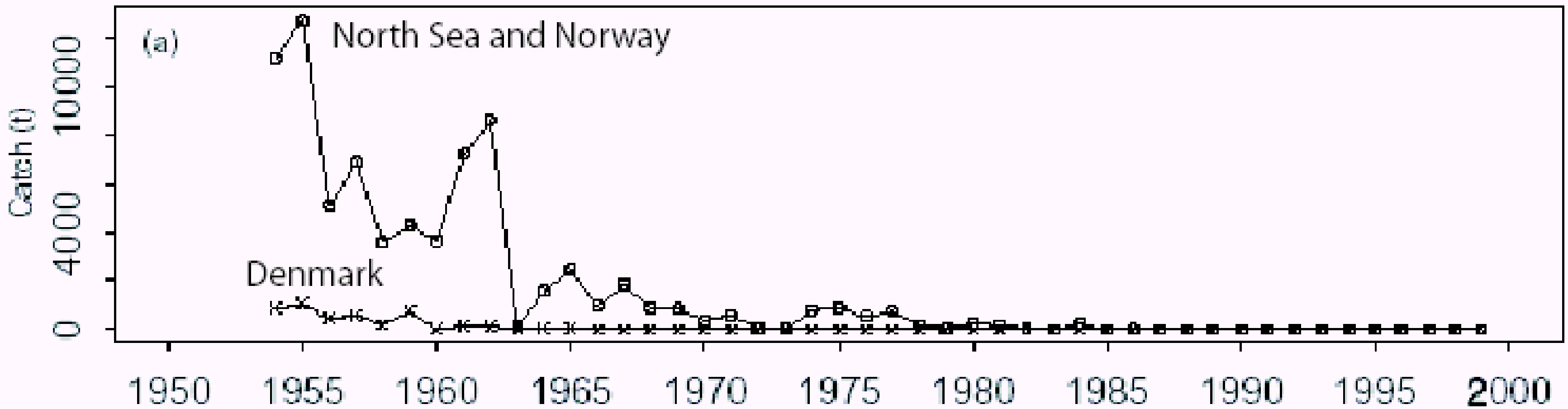
Baratti's "Tonnarella"



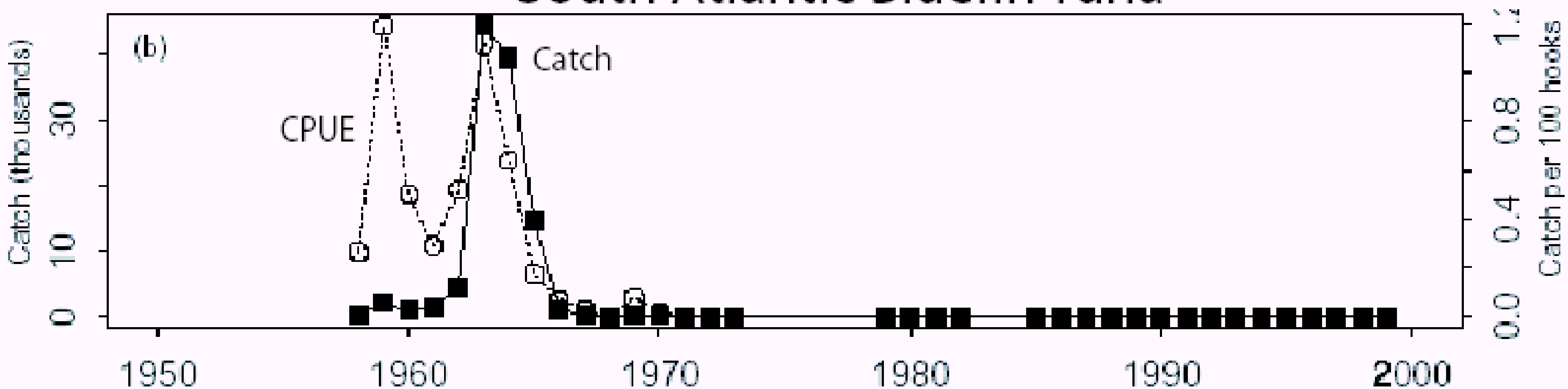
Vacchi M. *et al*. 2000 - 4th-Meeting-of-the-European-Elasmobranch-Association-Proceedings

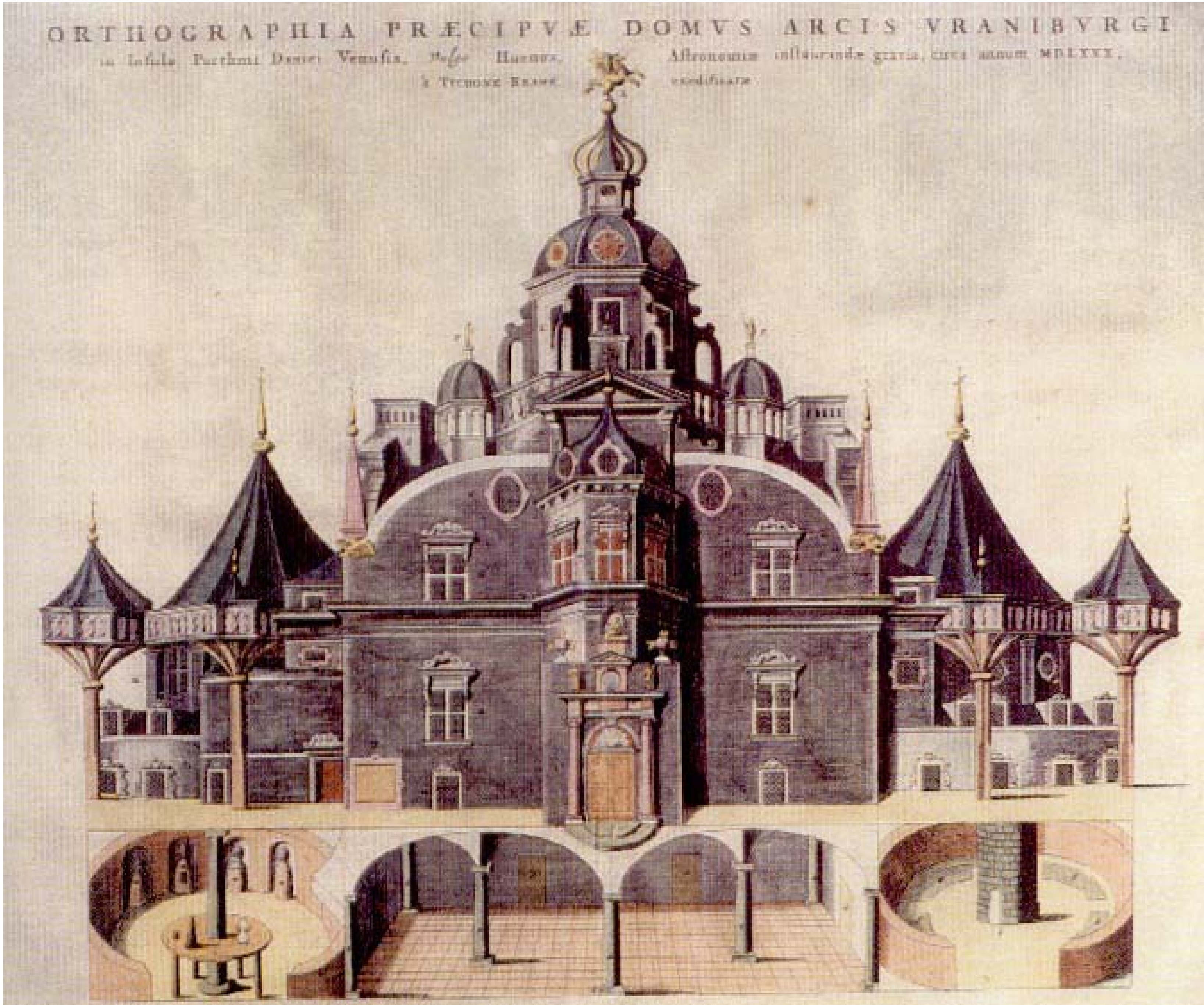
Loss of Bluefin Tuna Populations in the Atlantic

North Sea Bluefin Tuna



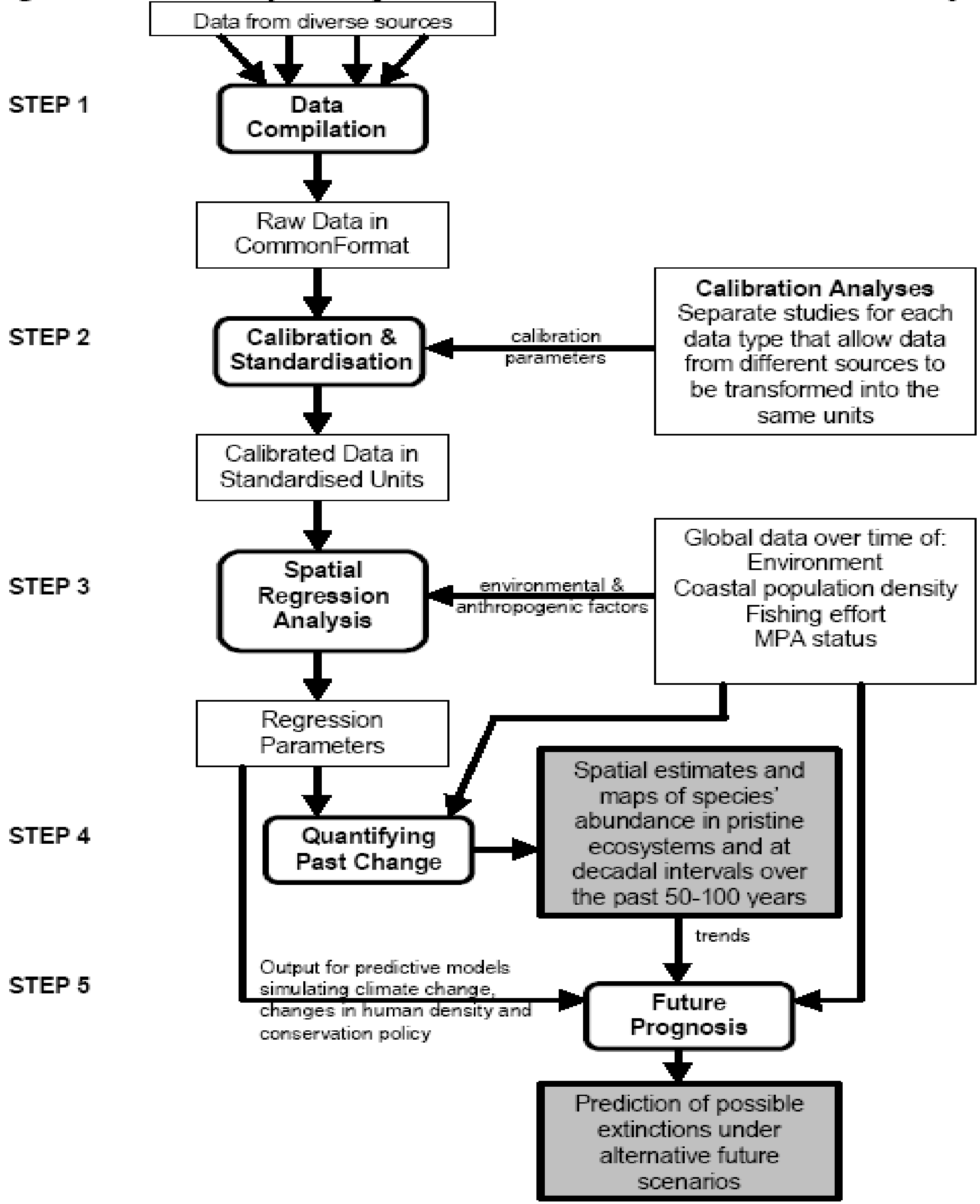
South Atlantic Bluefin Tuna



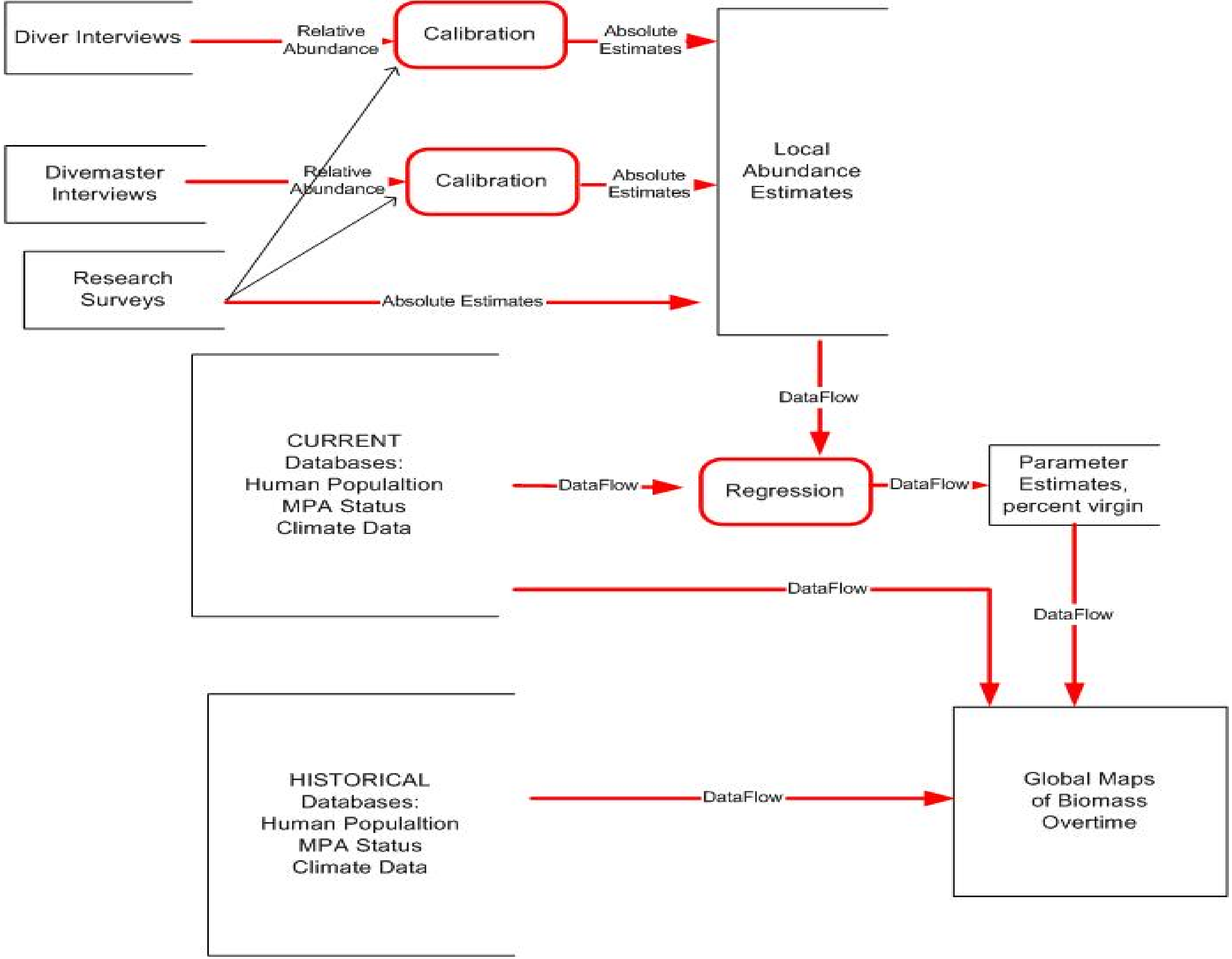

ORTHOGRAPHIA PRÆCIPVÆ DOMVS ARCIS VRANIBVRGI

Strategy:

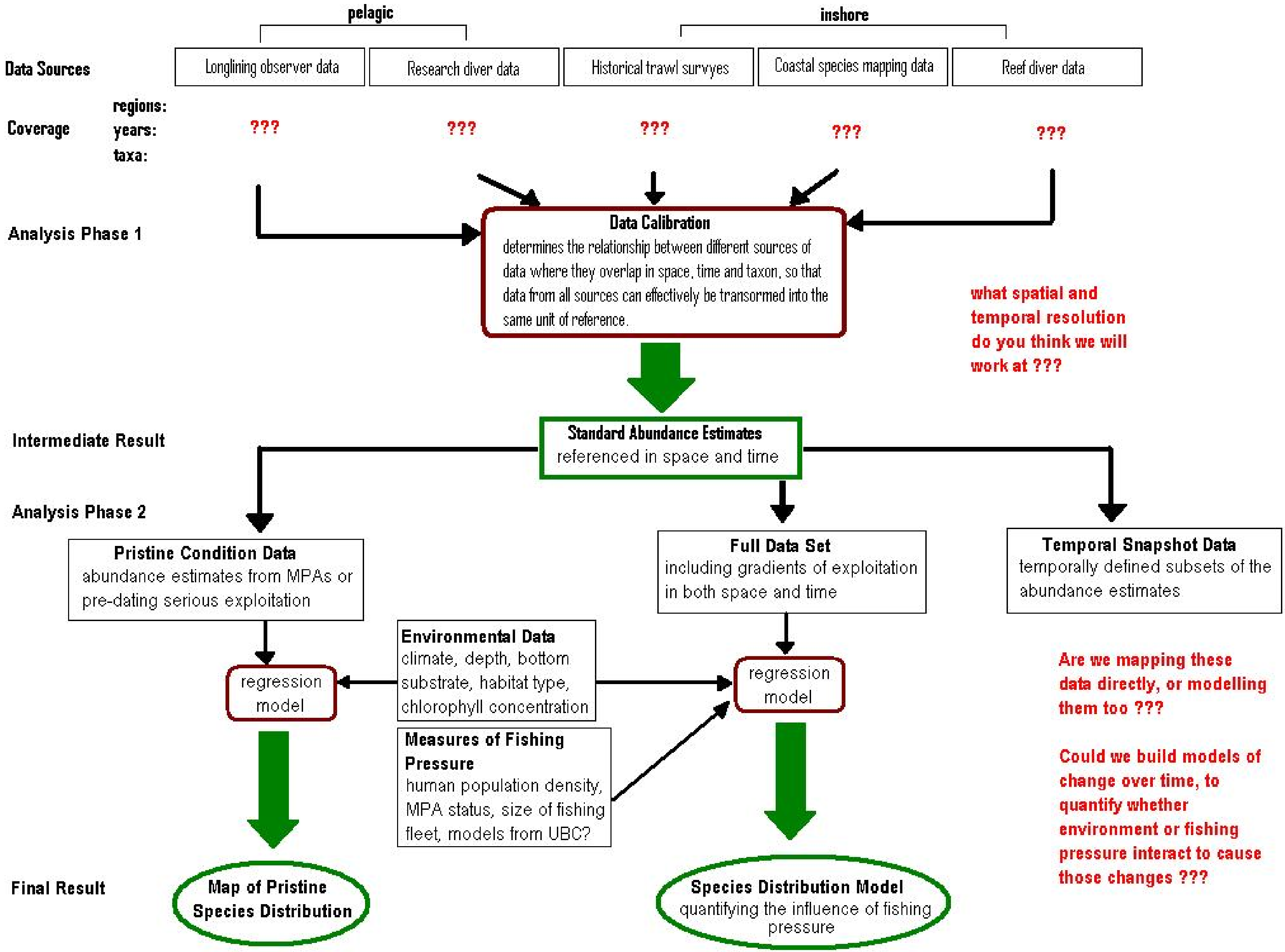
- Formulate the most important problem in terms of a critical model where in terms of a few parameters that can be well estimated.
- Compile all data in the world on the issue
- Analyze it the right way


Data from diverse sources
STEP 1
Data Compilation
Raw Data in CommonFormat
STEP 2
Calibration & Standardisation
calibration parameters
Calibration Analyses
Separate studies for each data type that allow data from different sources to be transformed into the same units
Calibrated Data in Standardised Units
STEP 3
Spatial Regression Analysis
environmental & anthropogenic factors
Global data over time of:
Environment
Coastal population density
Fishing effort
MPA status
Regression Parameters
STEP 4
Quantifying Past Change
Spatial estimates and maps of species' abundance in pristine ecosystems and at decadal intervals over the past 50-100 years
trends
STEP 5
Output for predictive models simulating climate change, changes in human density and conservation policy
Future Prognosis
Prediction of possible extinctions under alternative future scenarios


copyright 2003 Dr.Chris Harvey-Clark all rights reserved



Outline of data flow to produce global maps of abundance for reef species. The goal is produce maps for species that are of interest to divers over time, and estimate the "pristine" abundances and biomass, and t he time trends over time to the present. This will be critical to estimating extinction probability.


pelagic
inshore
Data Sources
Longlining observer data
Research diver data
Historical trawl survyes
Coastal species mapping data
Reef diver data
Coverage
regions:
years:
taxa:
???
???
???
???
???
Analysis Phase 1
Data Calibration
determines the relationship between different sources of data where they overlap in space, time and taxon, so that data from all sources can effectively be transormed into the same unit of reference.
what spatial and temporal resolution do you think we will work at ???
Intermediate Result
Standard Abundance Estimates
referenced in space and time
Analysis Phase 2
Pristine Condition Data
abundance estimates from MPAs or pre-dating serious exploitation
Full Data Set
including gradients of exploitation in both space and time
Temporal Snapshot Data
temporally defined subsets of the abundance estimates
Environmental Data
climate, depth, bottom substrate, habitat type, chlorophyll concentration
regression model
regression model
Are we mapping these data directly, or modelling them too ???
Measures of Fishing Pressure
human population density, MPA status, size of fishing fleet, models from UBC?
Could we build models of change over time, to quantify whether environment or fishing pressure interact to cause those changes ???
Final Result
Map of Pristine Species Distribution
Species Distribution Model
quantifying the influence of fishing pressure

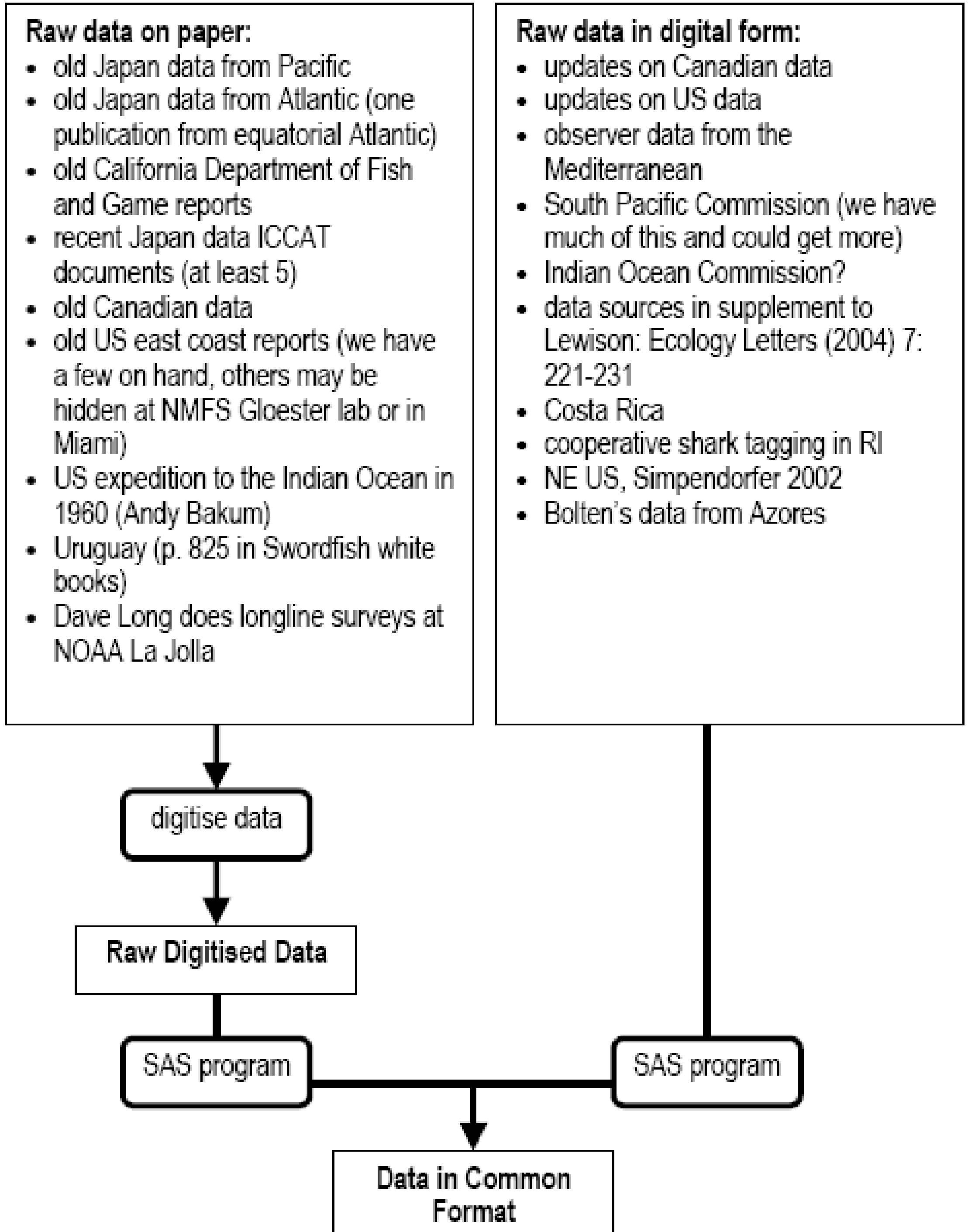

Raw data on paper:
• old Japan data from Pacific
• old Japan data from Atlantic (one publication from equatorial Atlantic)
• old California Department of Fish and Game reports
• recent Japan data ICCAT documents (at least 5)
• old Canadian data
• old US east coast reports (we have a few on hand, others may be hidden at NMFS Gloester lab or in Miami)
• US expedition to the Indian Ocean in 1960 (Andy Bakum)
• Uruguay (p. 825 in Swordfish white books)
• Dave Long does longline surveys at NOAA La Jolla
Raw data in digital form:
• updates on Canadian data
• updates on US data
• observer data from the Mediterranean
• South Pacific Commission (we have much of this and could get more)
• Indian Ocean Commission?
• data sources in supplement to Lewison: Ecology Letters (2004) 7: 221-231
• Costa Rica
• cooperative shark tagging in RI
• NE US, Simpendorfer 2002
• Bolten's data from Azores
digitise data
Raw Digitised Data
SAS program
SAS program
Data in Common Format

Figure 3. Calibration of data gathered from professional and amateur divers.

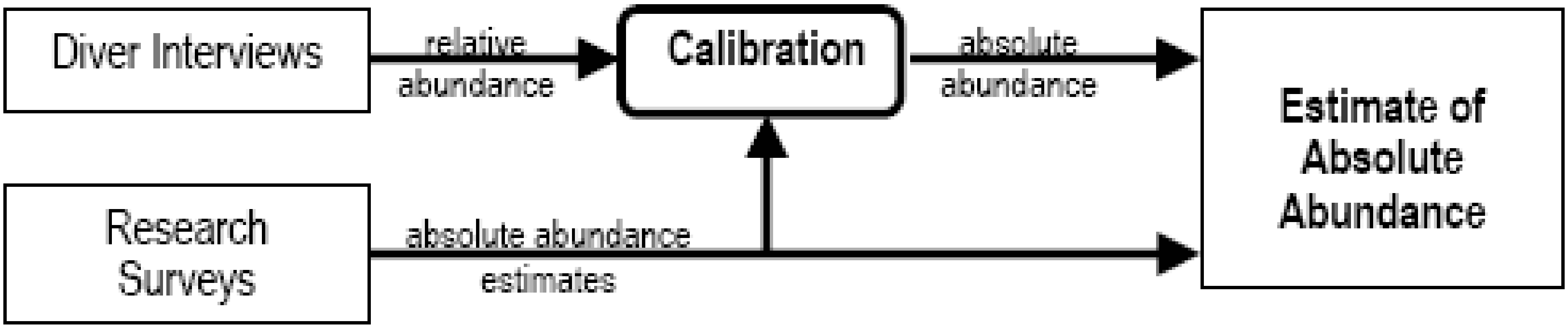
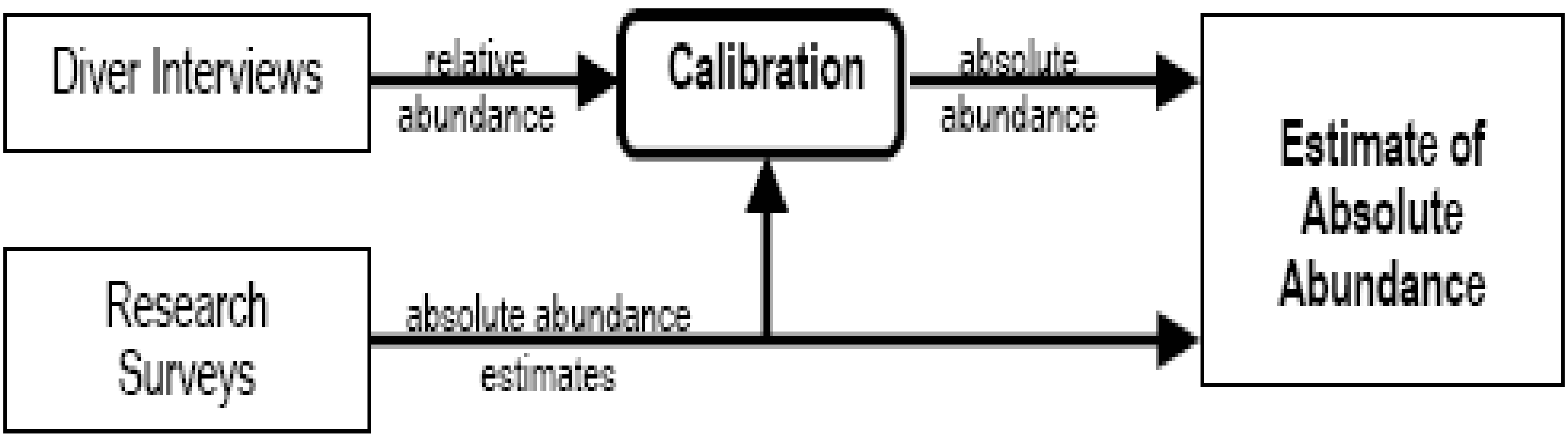


Figure 3. Calibration of data gathered from professional and amateur divers.

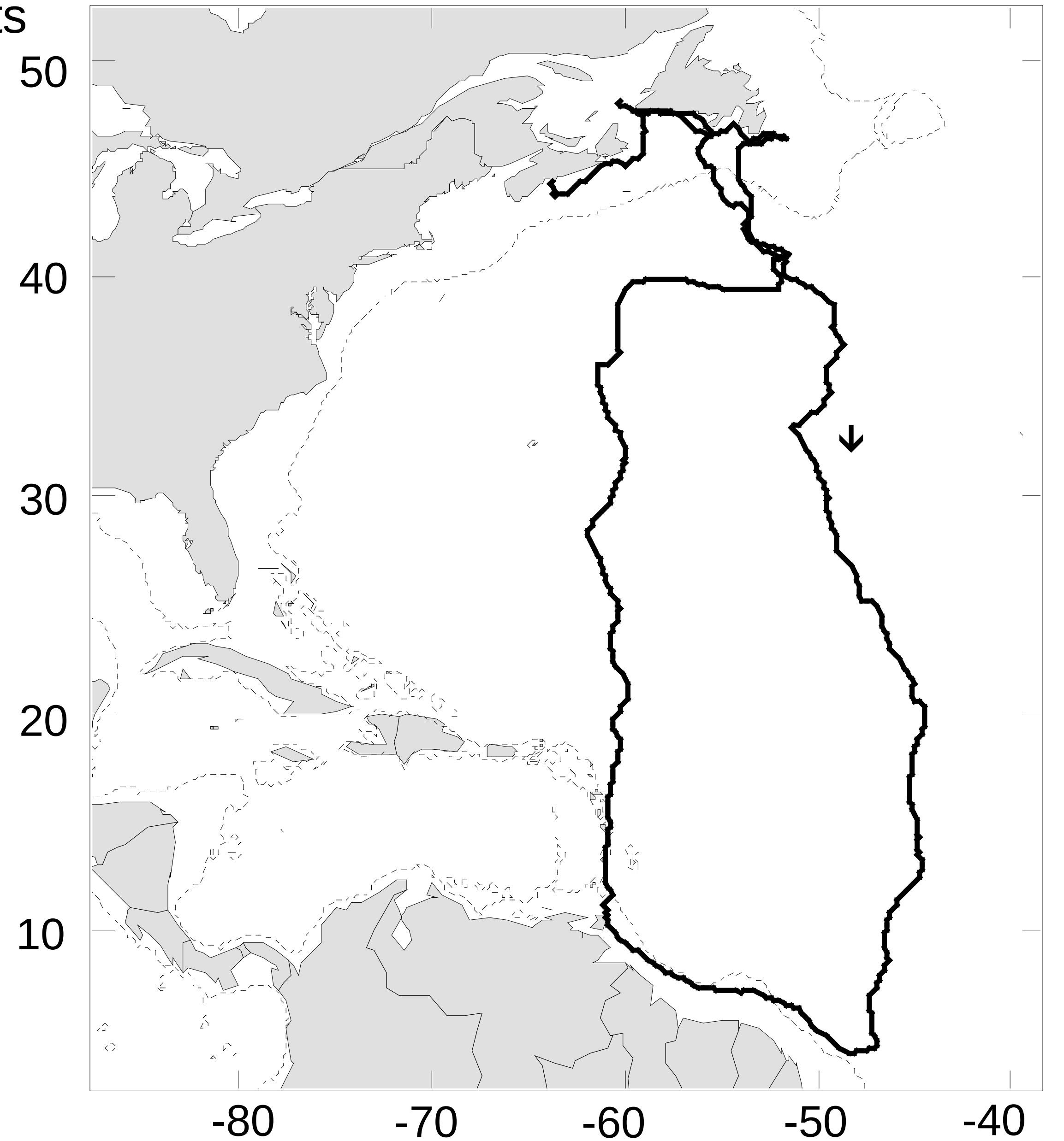


Male leatherback movements

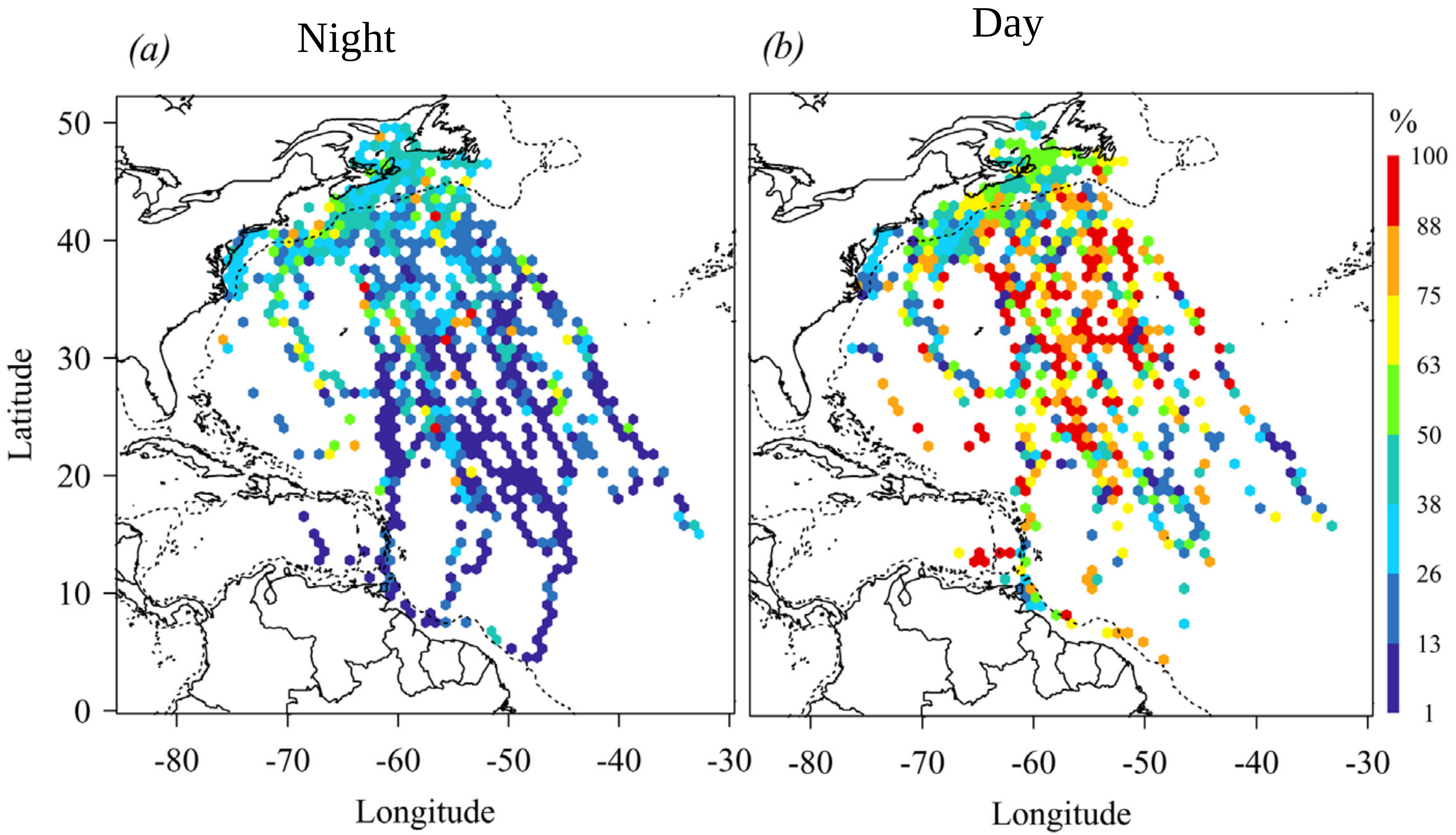
- not previously described

- annual migratory cycle that includes movement between temperate foraging areas and tropical breeding areas

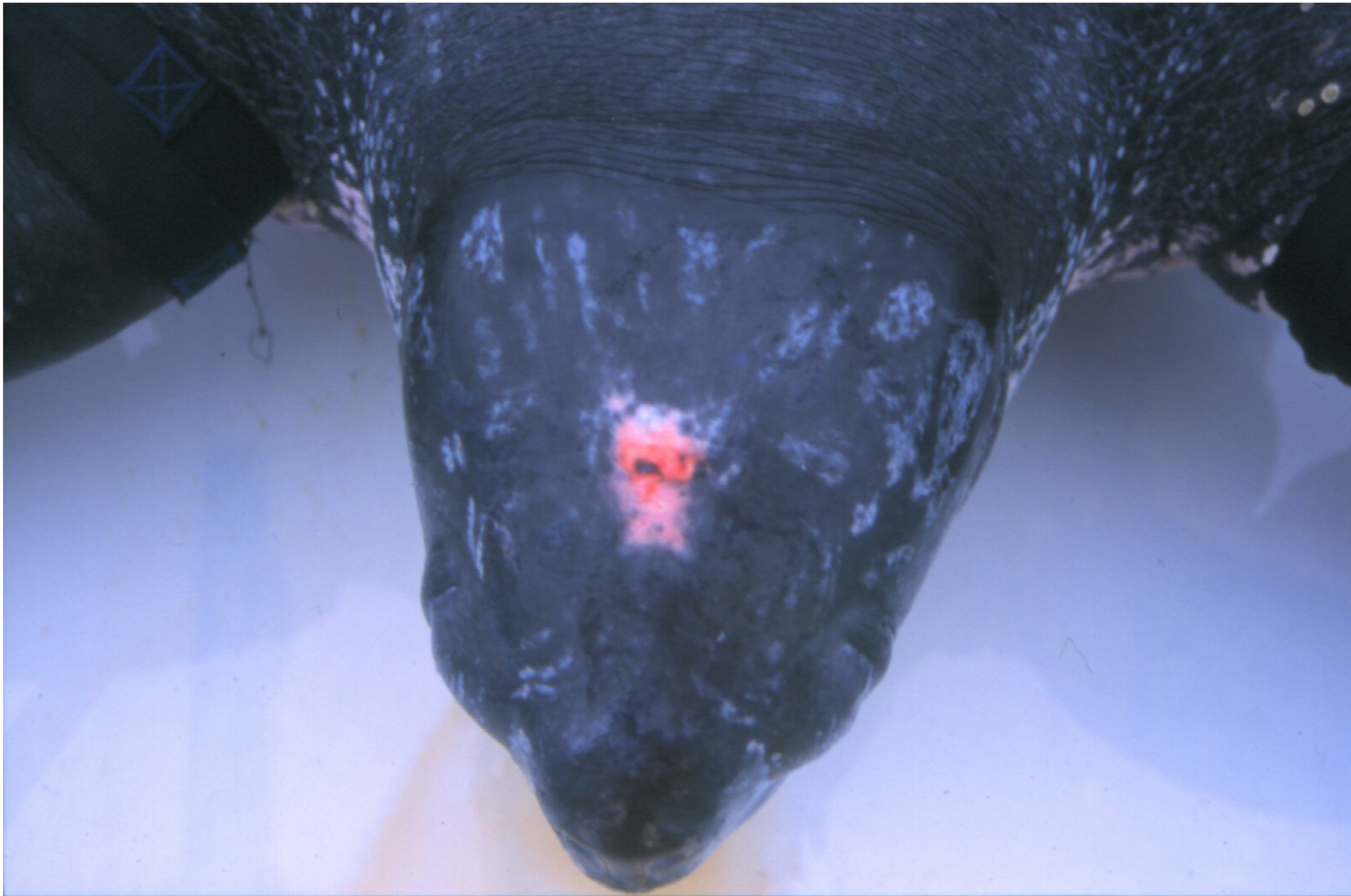
James, Eckert and Myers
Marine Biology (*in press*)

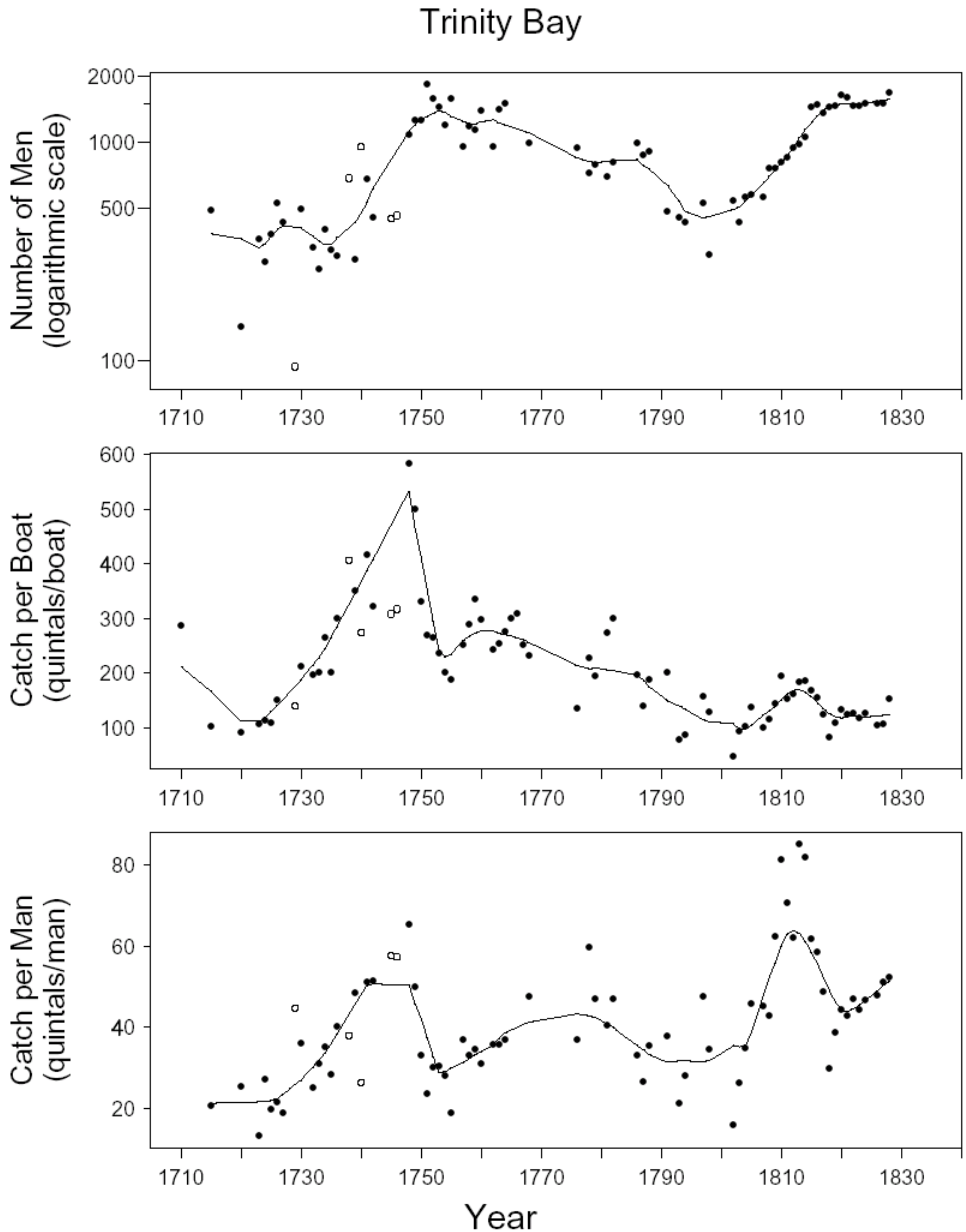


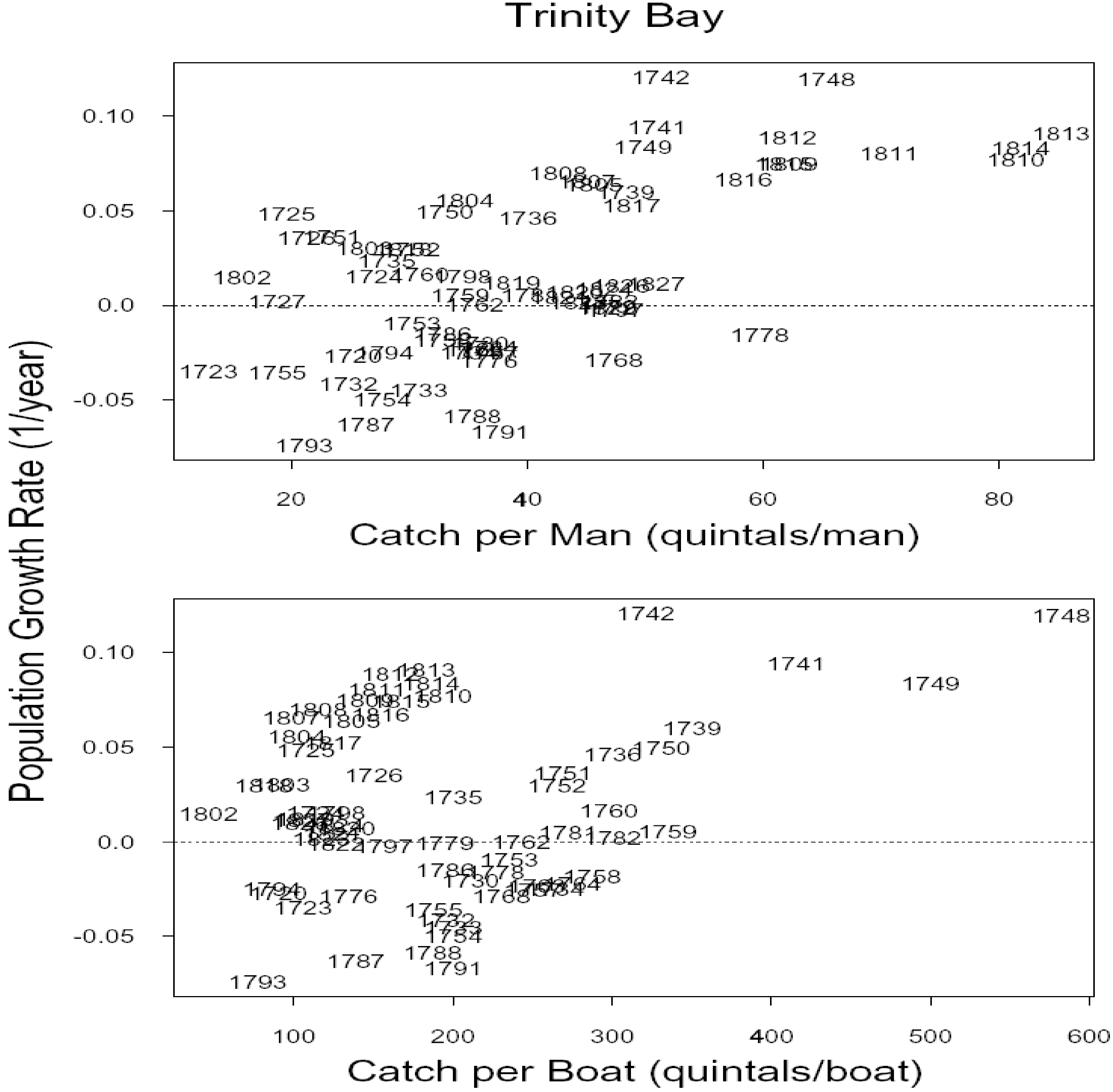
Turtles are close to the surface during the day during migration

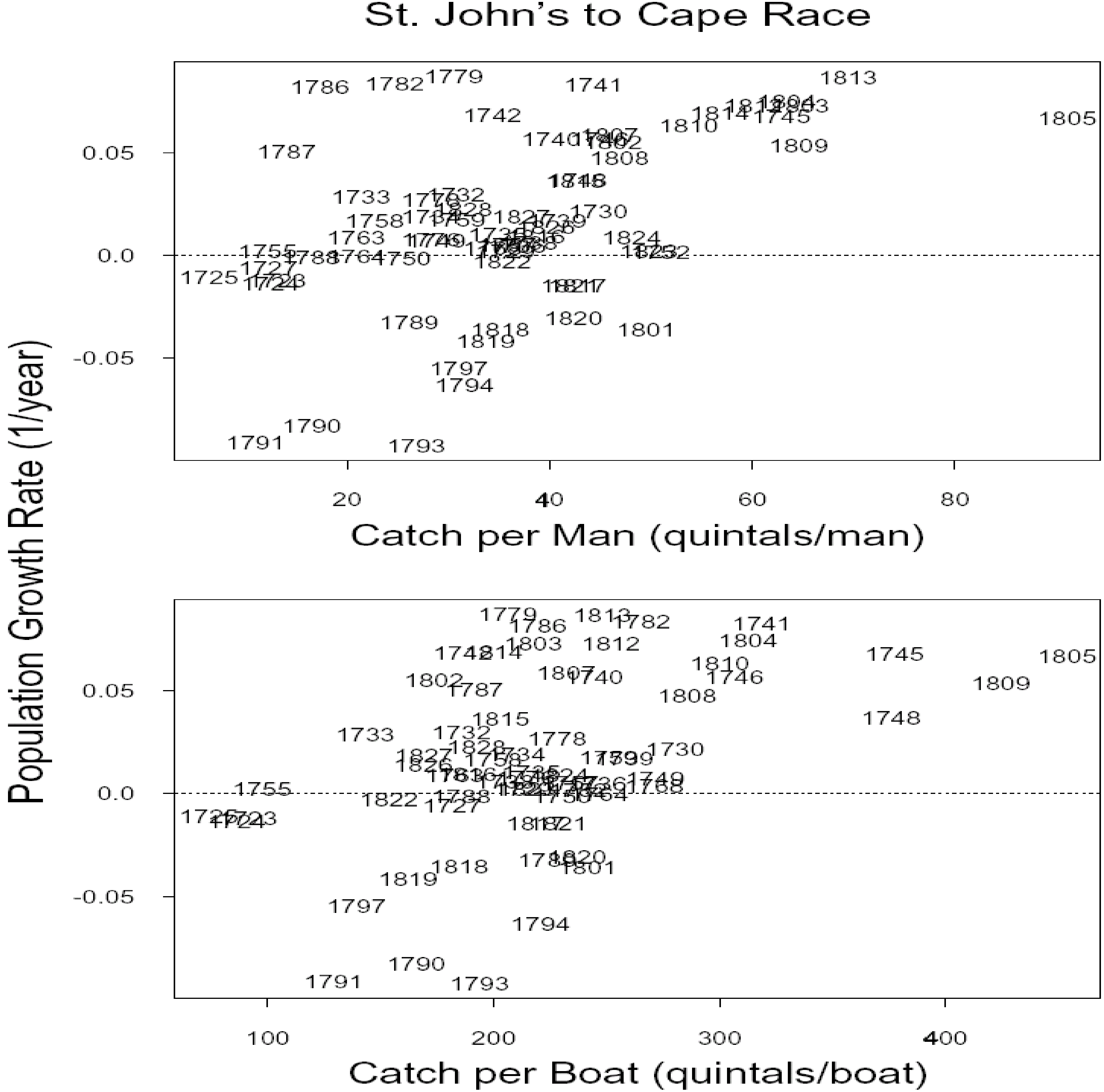


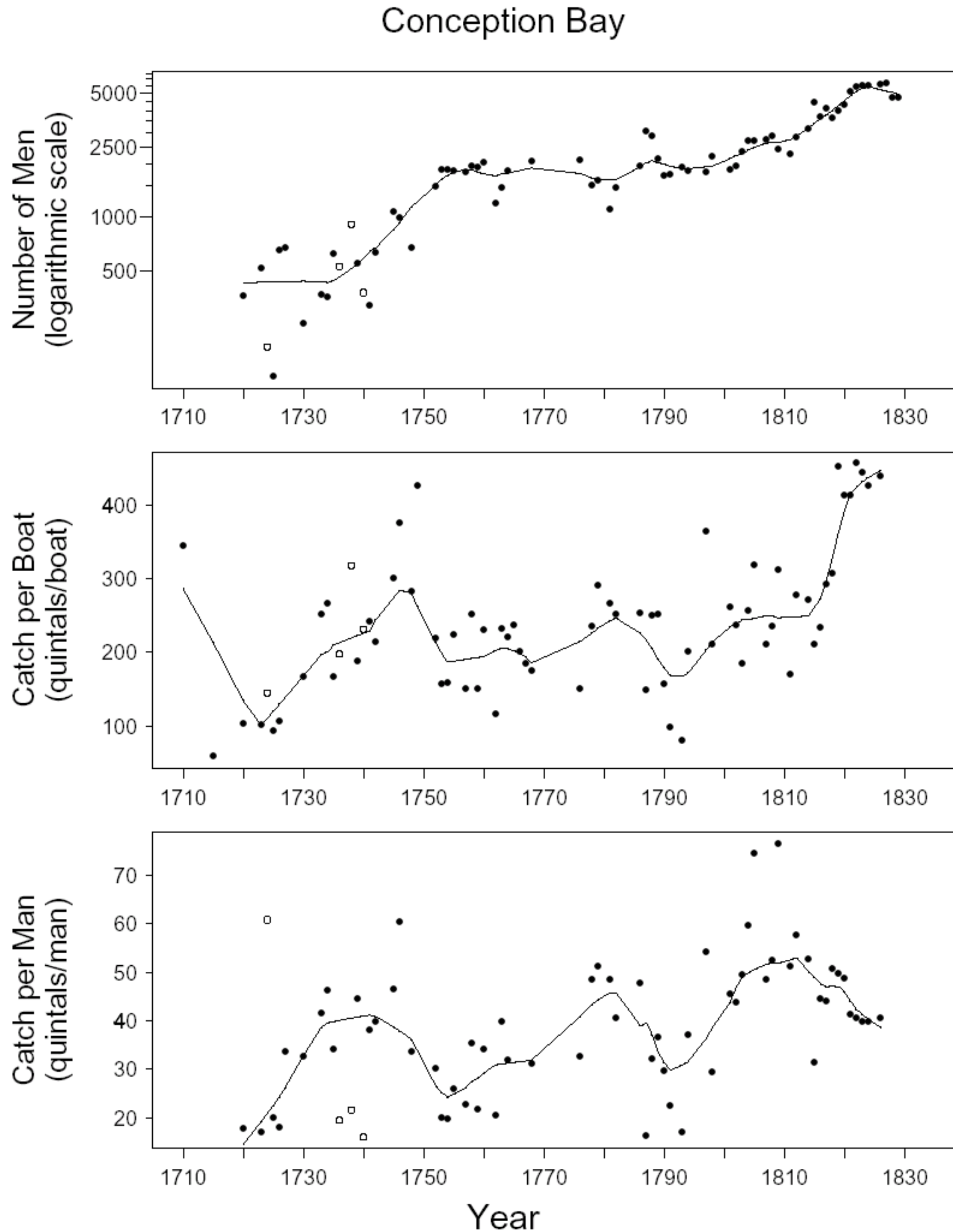
Leatherback turtles are unique in that they expose their pineal spot to sunlight.




Trinity Bay
Number of Men (logarithmic scale)
2000
1000
500
100
Catch per Boat (quintals/boat)
600
500
400
300
200
100
Catch per Man (quintals/man)
80
60
40
20
1710
1730
1750
1770
1790
1810
1830
Year

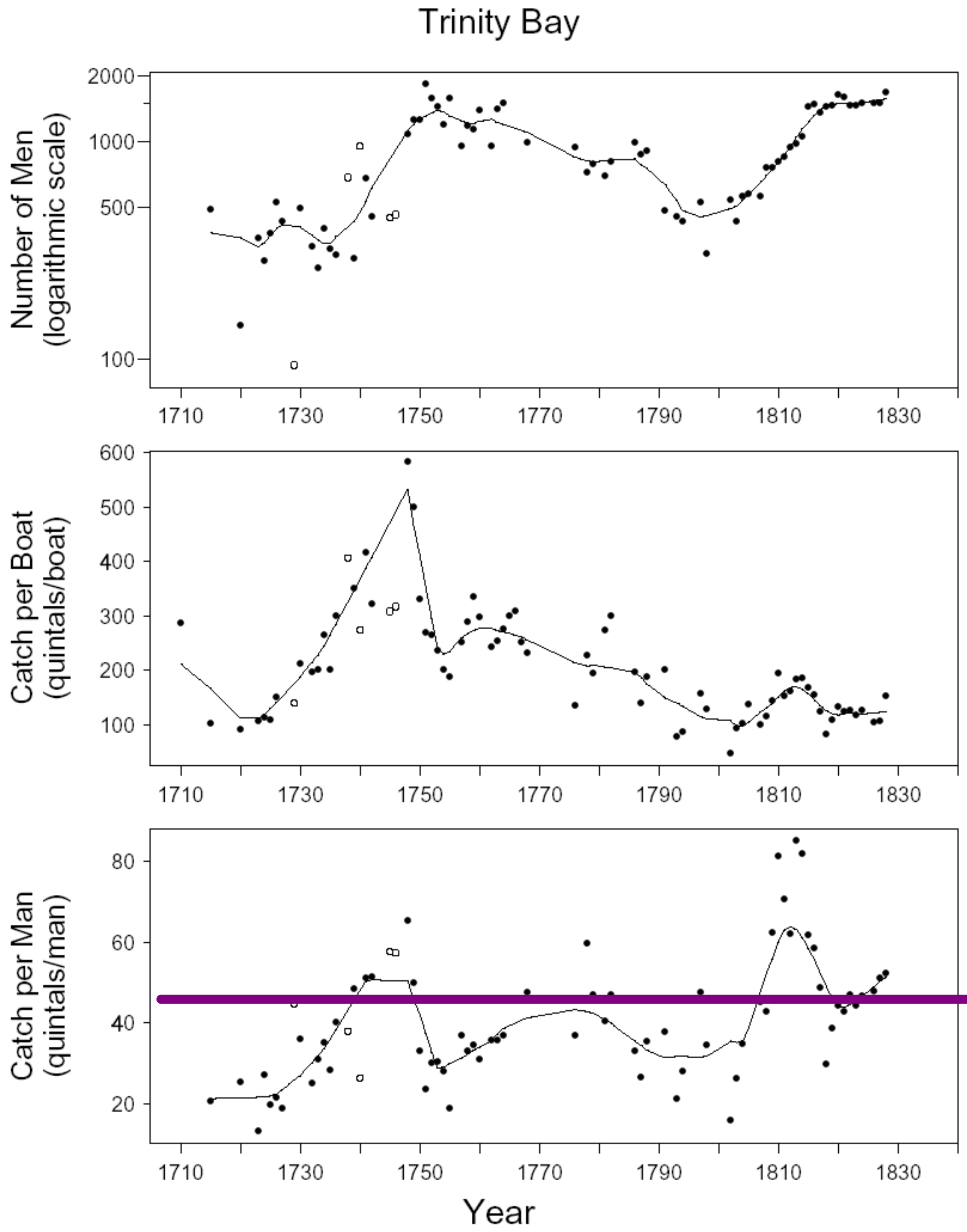

Trinity Bay
Population Growth Rate (1/year)
0.10
0.05
0.0
-0.05
20
40
60
80
Catch per Man (quintals/man)
100
200
300
400
500
600
Catch per Boat (quintals/boat)


St. John's to Cape Race
Population Growth Rate (1/year)
0.05
0.0
-0.05
20
40
60
80
Catch per Man (quintals/man)
0.05
0.0
-0.05
100
200
300
400
Catch per Boat (quintals/boat)


Conception Bay
Number of Men (logarithmic scale)
5000
2500
1000
500
Catch per Boat (quintals/boat)
400
300
200
100
Catch per Man (quintals/man)
70
60
50
40
30
20
1710
1730
1750
1770
1790
1810
1830
Year

The efficiency of the Newfoundland cod fishery had not changed in 4 centuries.

The only bioeconomic equilibrium of a highly subsidized fishery is zero fish.



Catch rates in the 1980's per person (20,000 fishers who caught ~200,000 metric tonnes of cod).


788
757
525
650
620
770

Marine data
Communities are
Claimed to be
Very compex:
Link, MEPS. 2002.

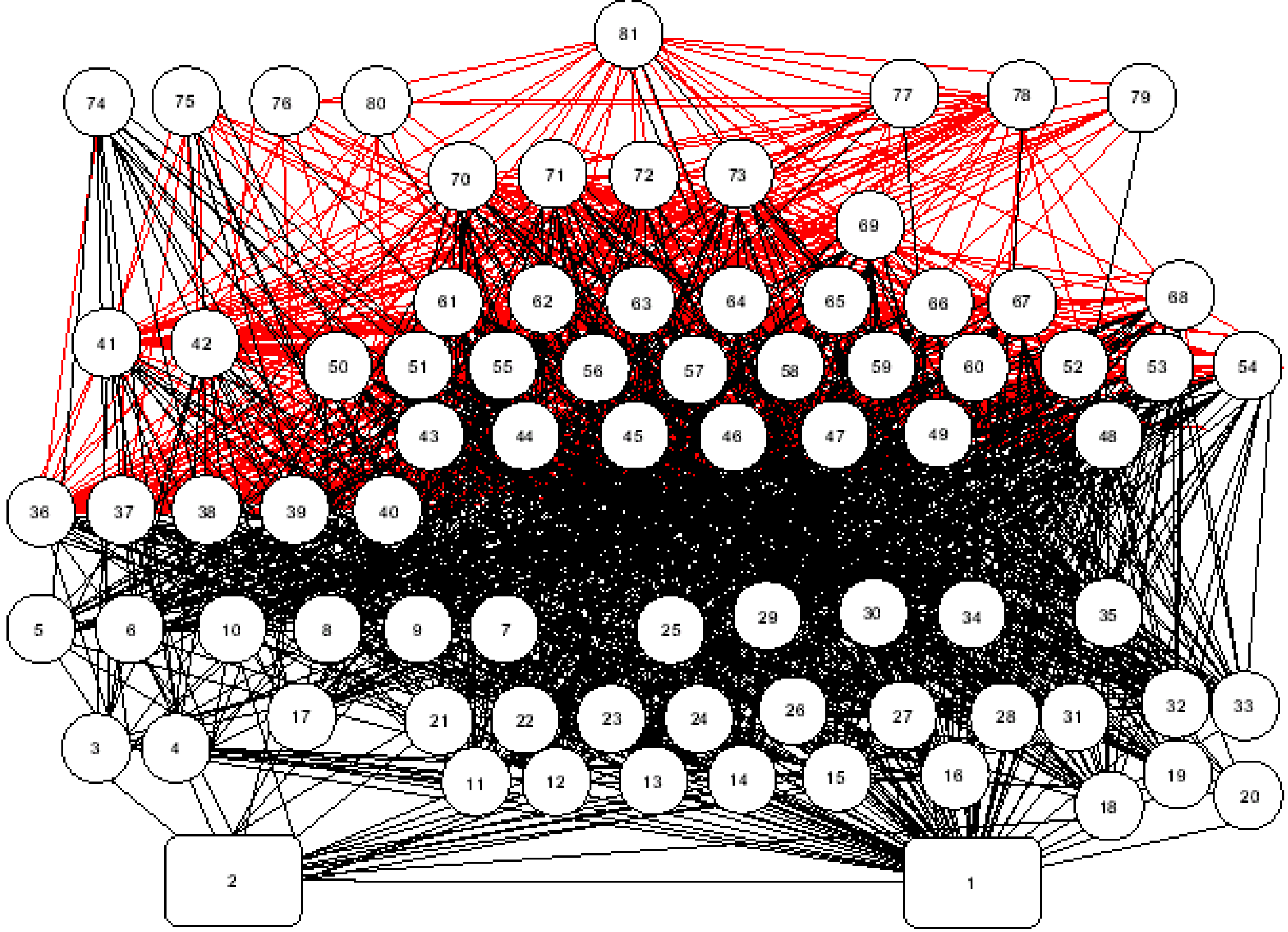


Fig. 1. Species and links of the northwest Atlantic food web. This tangled 'bird's nest' represents interactions at the approximate trophic level of each species, with increasing trophic level towards the top of the web. The left side of the web generally typifies pelagic organisms, and the right to middle represents more benthic/demersally oriented organisms. Red lines indicate predation on fish. 1 = detritus, 2 = phytoplankton, 3 = *Calanus* sp., 4 = other copepods, 5 = ctenophores, 6 = chaetognatha (i.e. arrow worms), 7 = jellyfish, 8 = euphasiids, 9 = *Crangon* sp., 10 = mysids, 11 = pandalids, 12 = other decapods, 13 = gammarids, 14 = hyperiids, 15 = caprellids, 16 = isopods, 17 = pteropods, 18 = cumaceans, 19 = mantis shrimps, 20 = tunicates, 21 = porifera, 22 = cancer crabs, 23 = other crabs, 24 = lobster, 25 = hydroids, 26 = corals and anemones, 27 = polychaetes, 28 = other worms, 29 = starfish, 30 = brittle stars, 31 = sea cucumbers, 32 = scallops, 33 = clams and mussels, 34 = snails, 35 = urchins, 36 = sand lance, 37 = Atlantic herring, 38 = alewife, 39 = Atlantic mackerel, 40 = butterfish, 41 = loligo, 42 = illex, 43 = pollock, 44 = silver hake, 45 = spotted hake, 46 = white hake, 47 = red hake, 48 = Atlantic cod, 49 = haddock, 50 = sea raven, 51 = longhorn sculpin, 52 = little skate, 53 = winter skate, 54 = thorny skate, 55 = ocean pout, 56 = cusk, 57 = wolffish, 58 = cunner, 59 = sea robins, 60 = redfish, 61 = yellowtail flounder, 62 = windowpane flounder, 63 = summer flounder, 64 = witch flounder, 65 = four-spot flounder, 66 = winter flounder, 67 = American plaice, 68 = American halibut, 69 = smooth dogfish, 70 = spiny dogfish, 71 = goosefish, 72 = weakfish, 73 = bluefish, 74 = baleen whales, 75 = toothed whales and porpoises, 76 = seals, 77 = migratory scombrids, 78 = migratory sharks, 79 = migratory billfish, 80 = birds, 81 = humans

Changes in the Bohai Sea

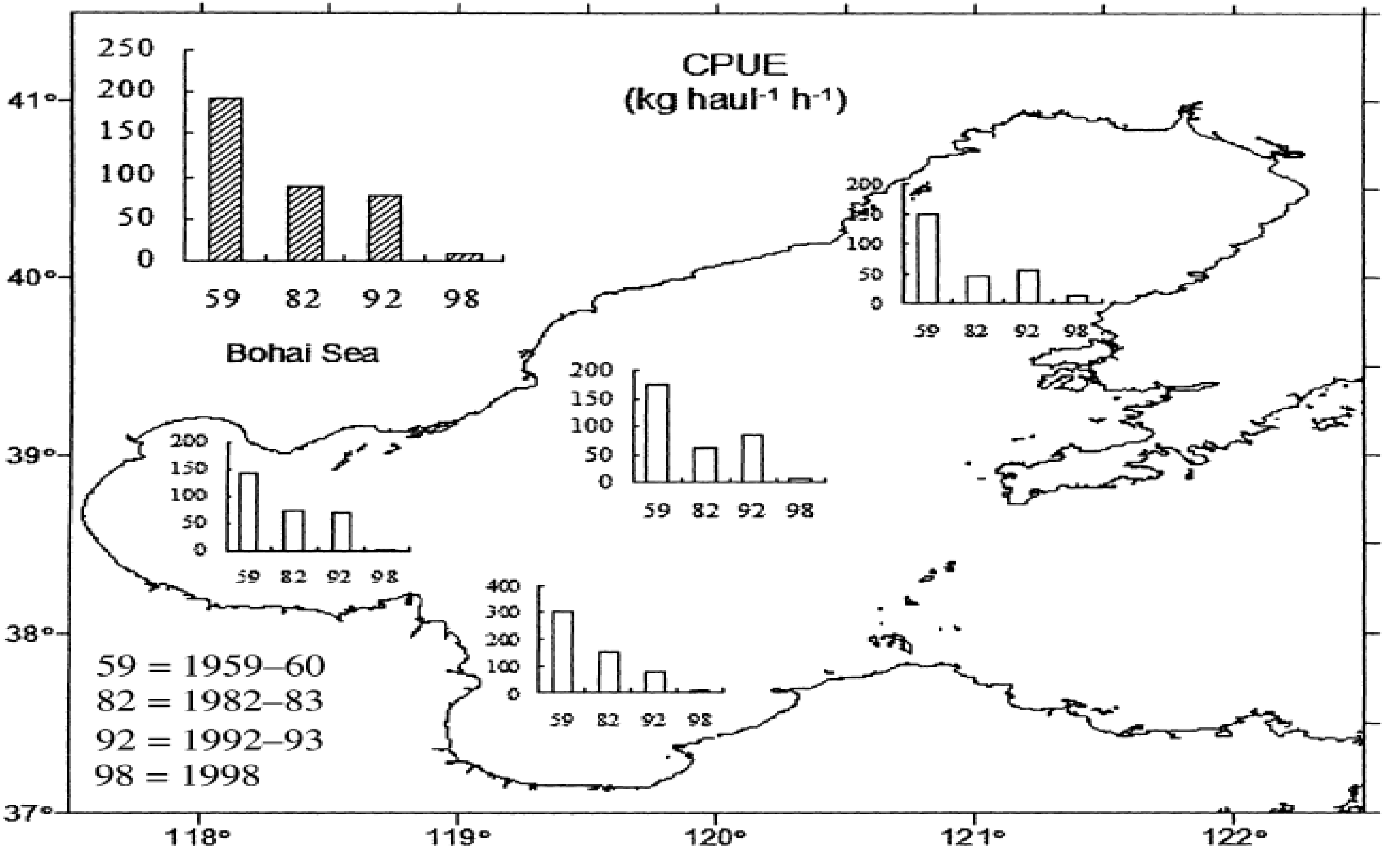
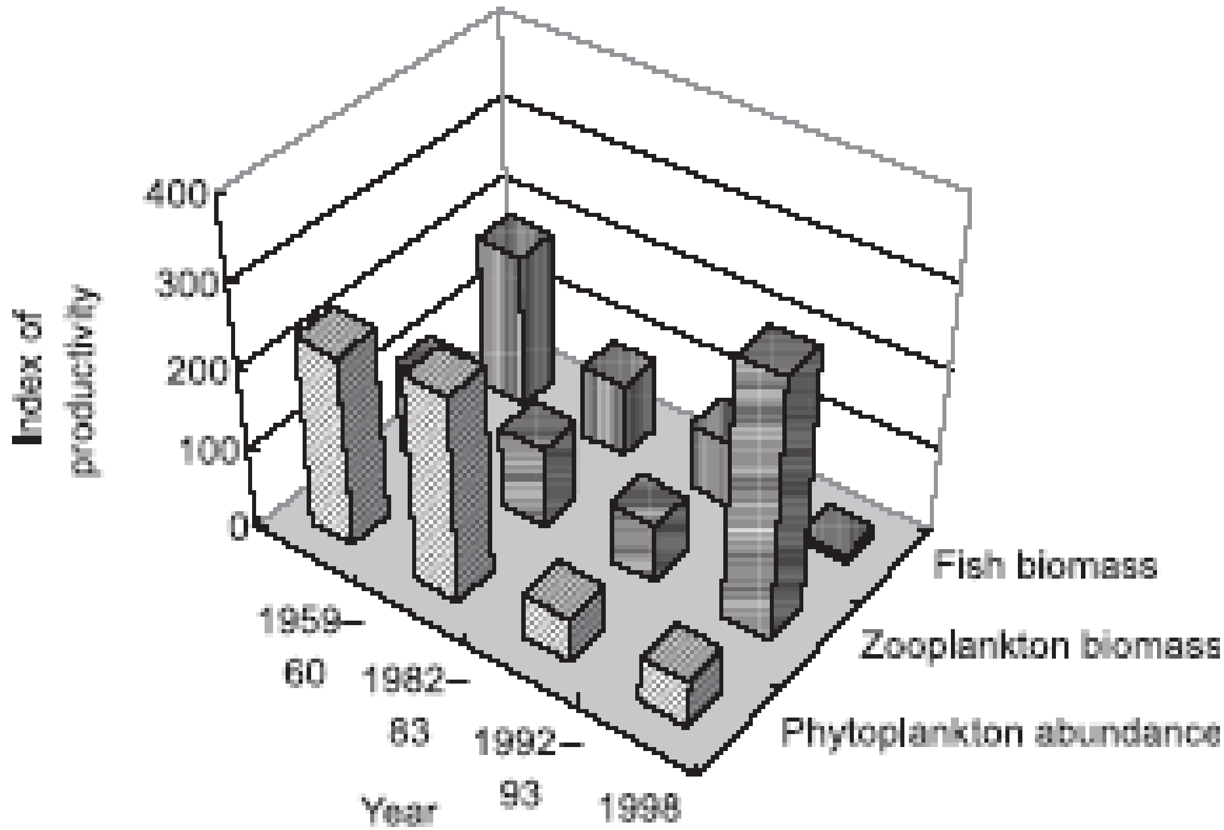


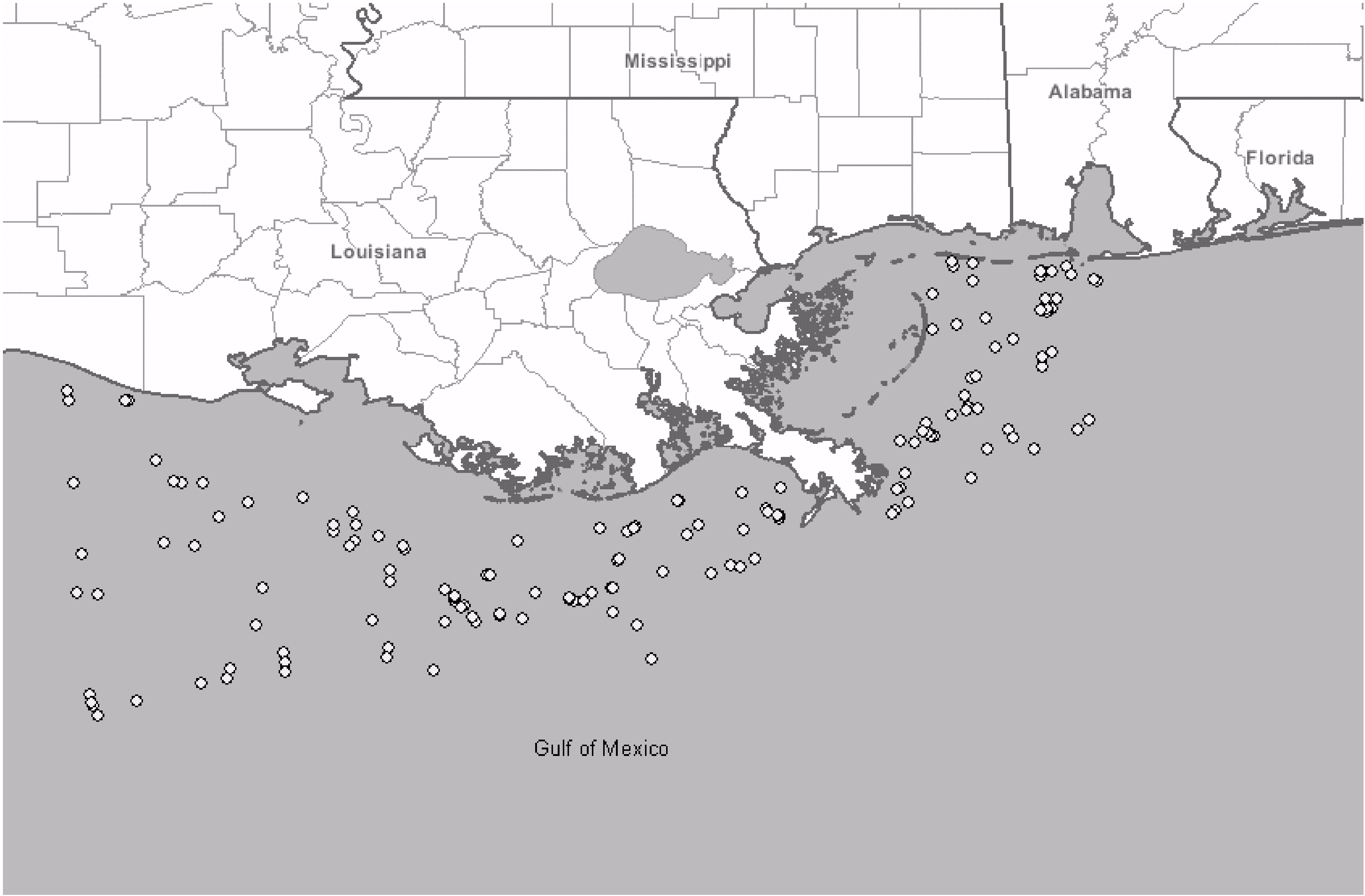
Figure 10. Decadal-scale variations of ecosystem productivity at different trophic levels in the Bohai Sea (phytoplankton abundance, $\times 10^4$ cell m^{-3}, zooplankton biomass, mg m^{-3}, fish biomass, kg $haul^{-1}$ h^{-1}).

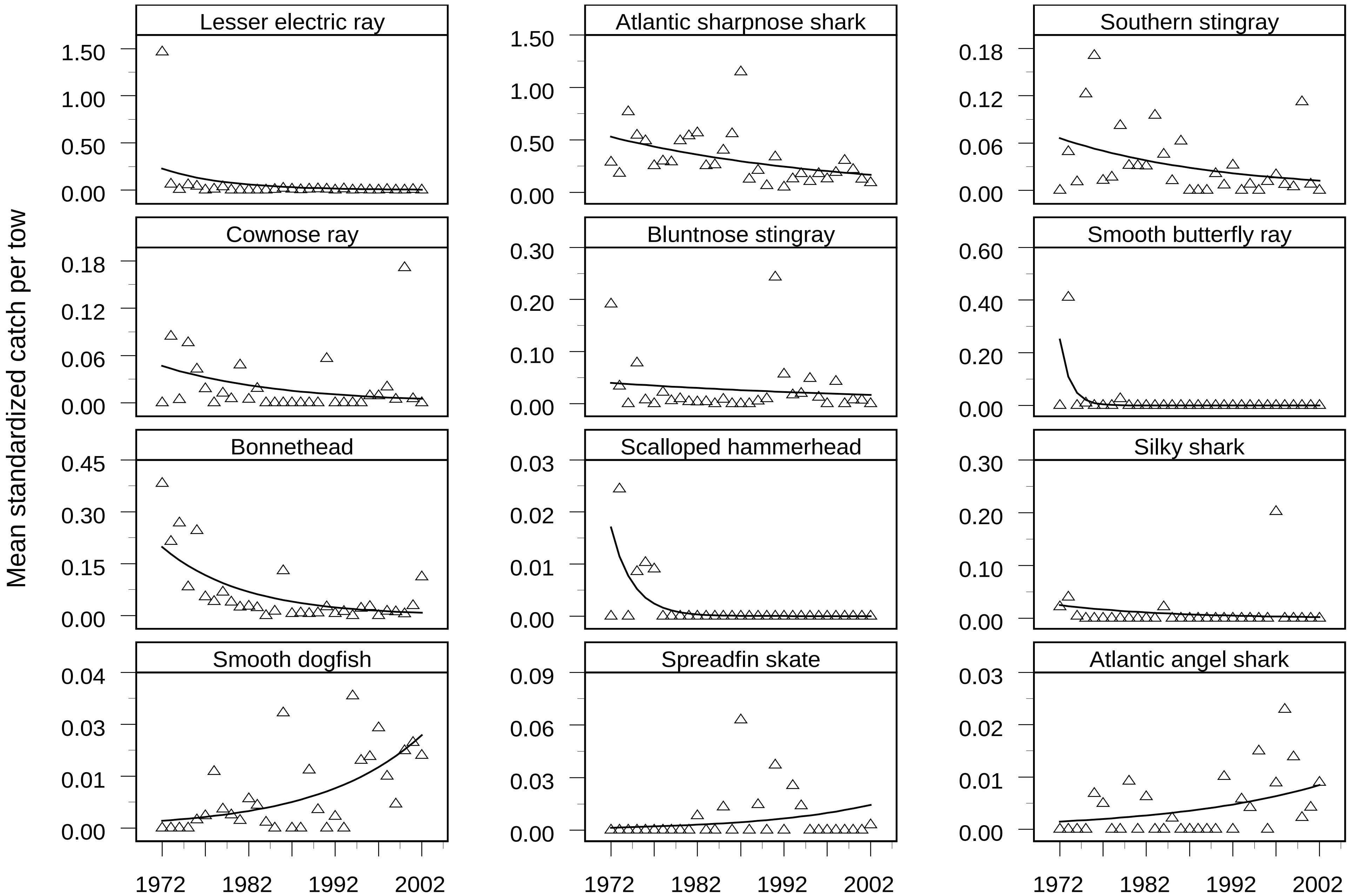


QISHENG TANG,* XIANSHI JIN, JUN WANG, ZHIMENG ZHUANG, YI CUI AND TIANXIANG MENG

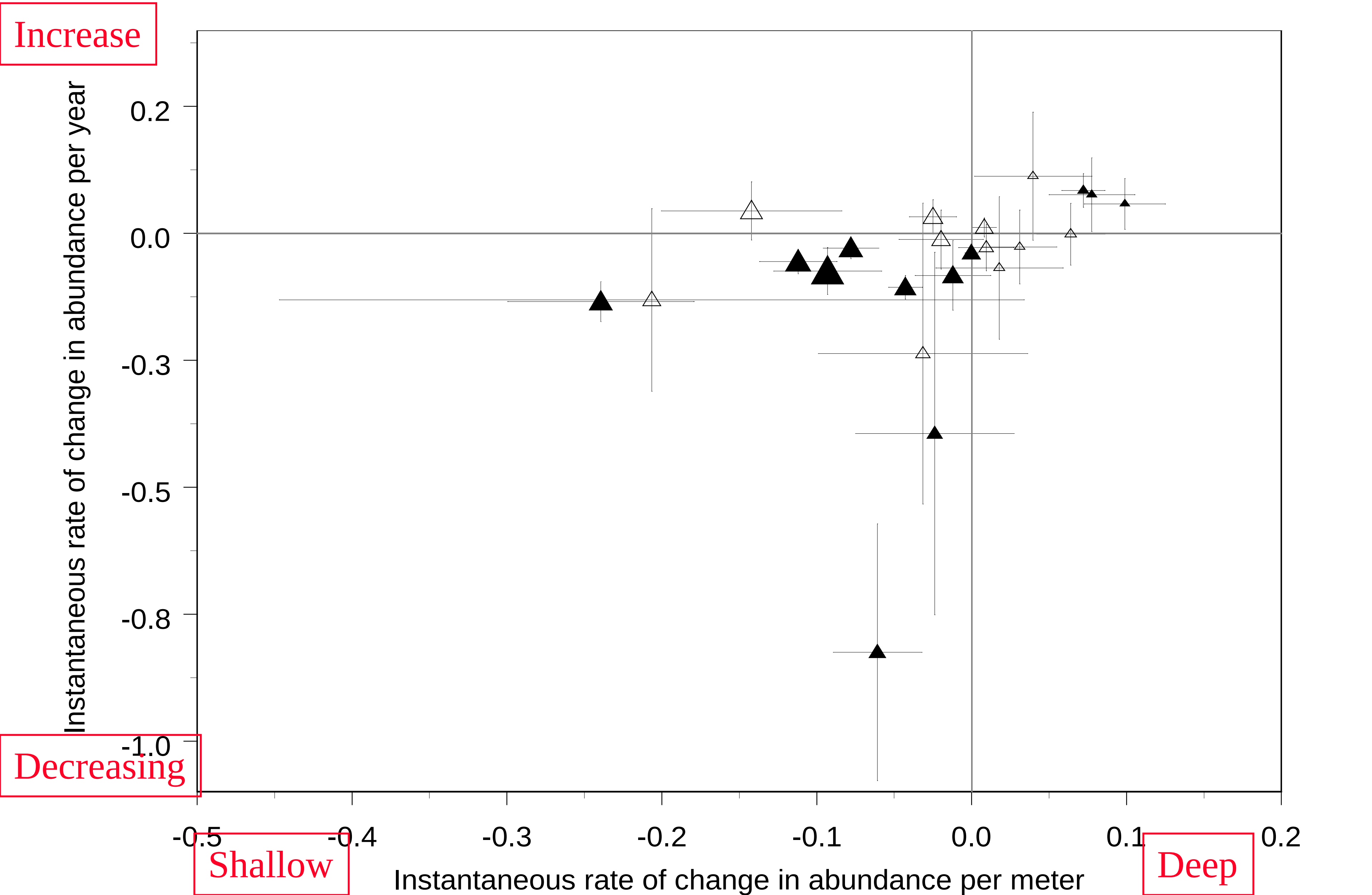
Yellow Sea Fisheries Research Institute, CAFS, 106 Nanjing Road, Qingdao 266071, China

Is shrimp trawling driving sharks and rays extinct?

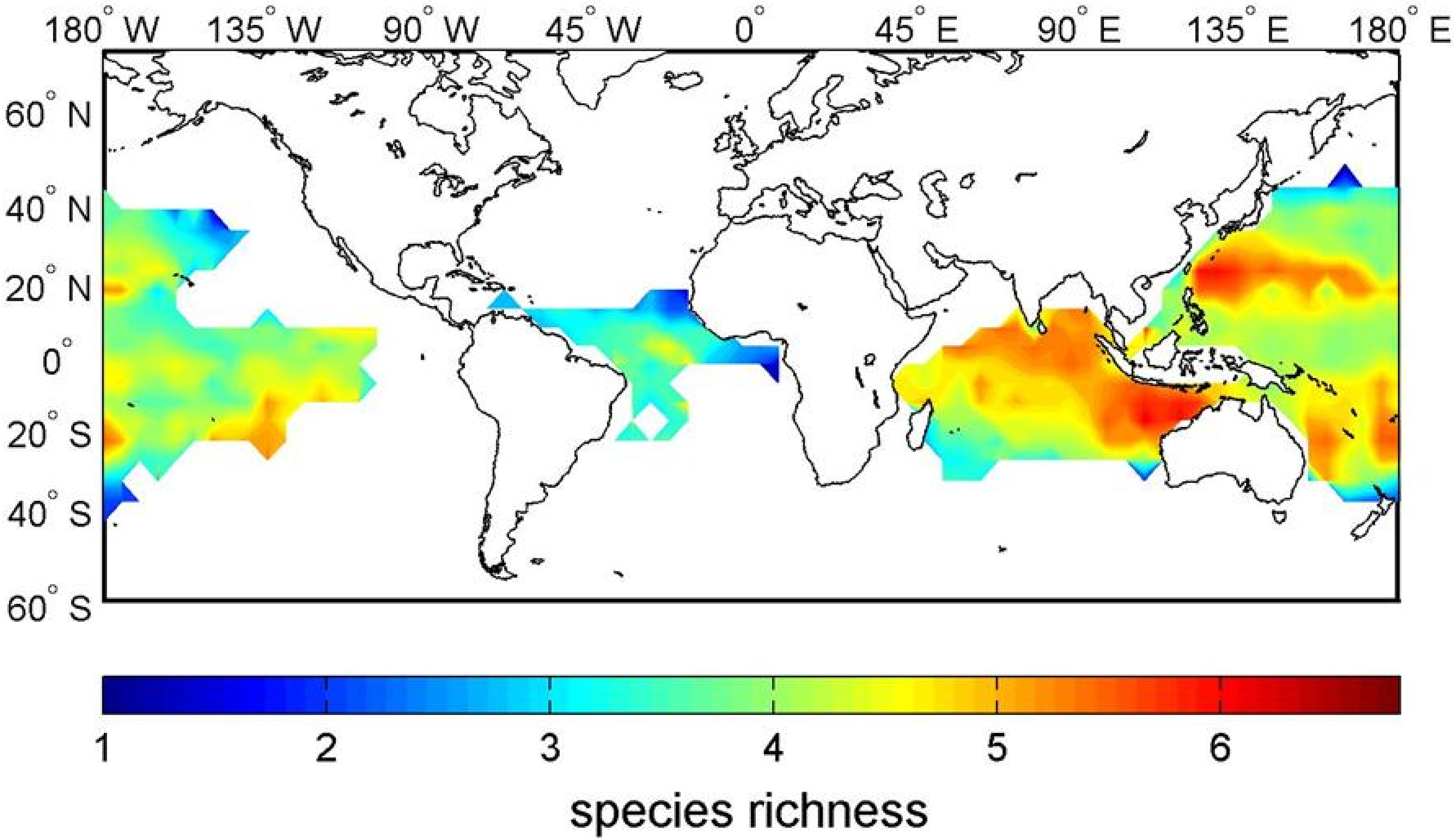



Lesser electric ray
Atlantic sharpnose shark
Southern stingray
Cownose ray
Bluntnose stingray
Smooth butterfly ray
Bonnethead
Scalloped hammerhead
Silky shark
Smooth dogfish
Spreadfin skate
Atlantic angel shark
Mean standardized catch per tow
1972
1982
1992
2002

Shallow species are going extinct
Deep species are increasing

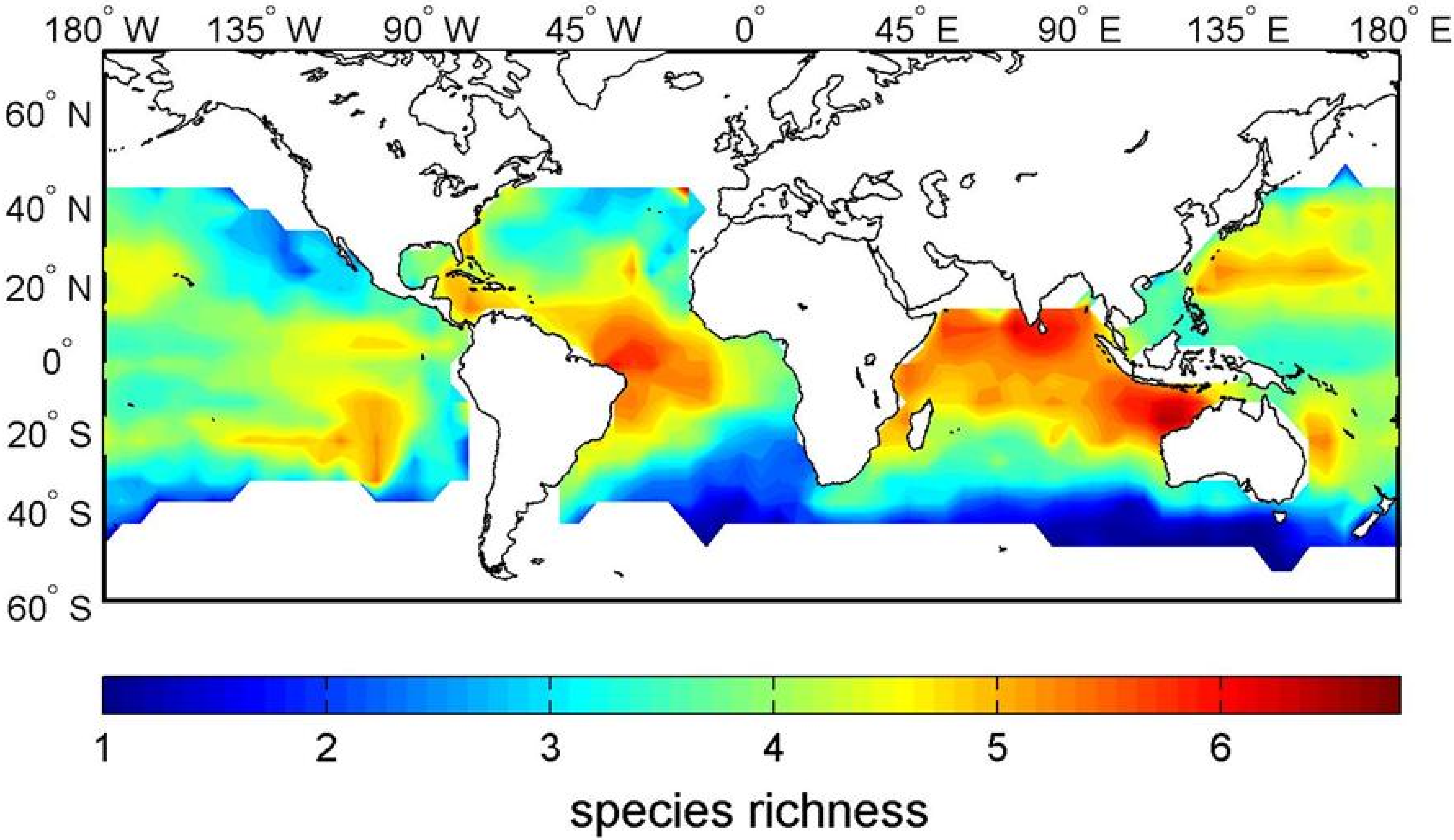


1950s



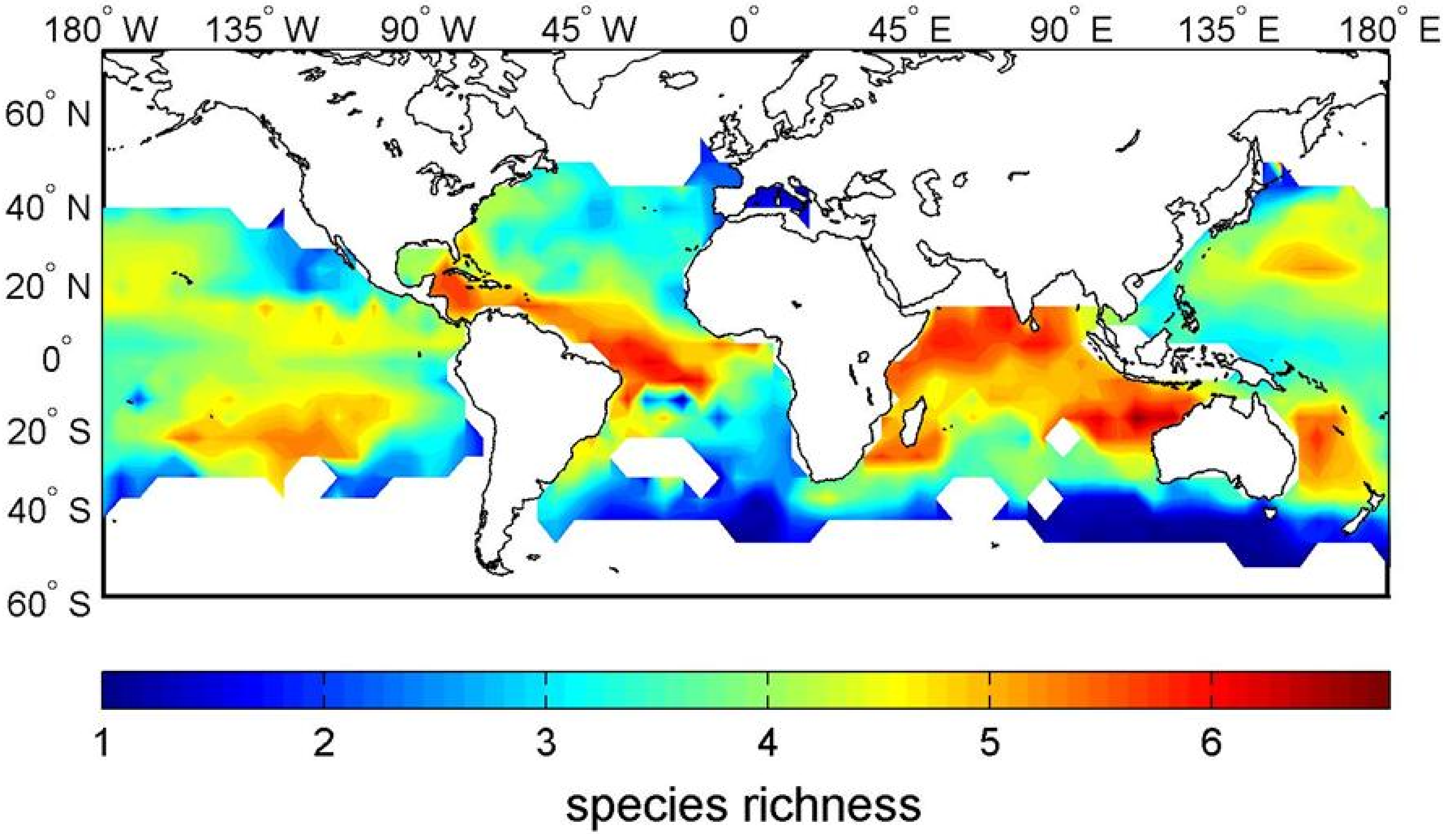
Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

1960s



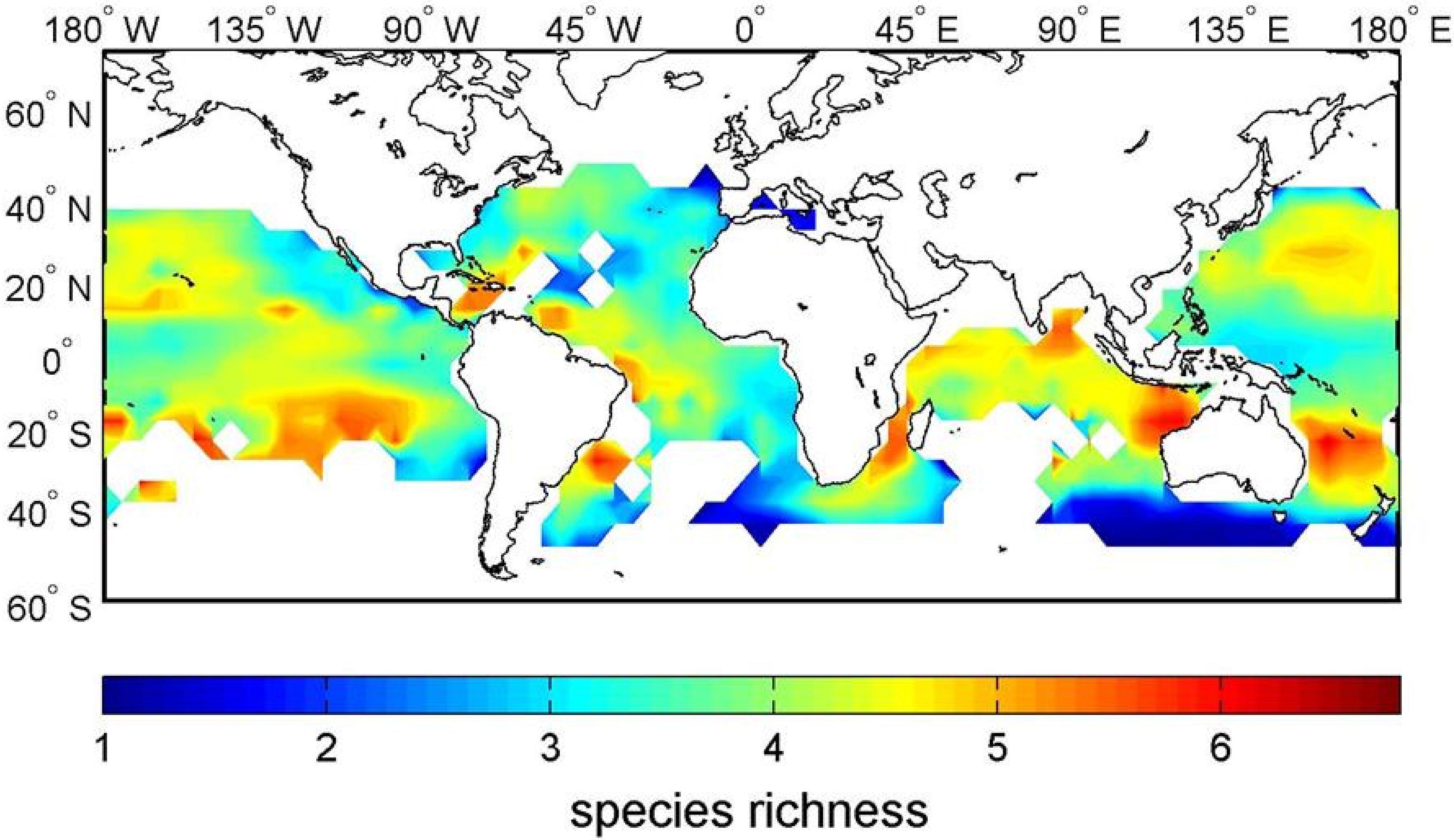
Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

1970s



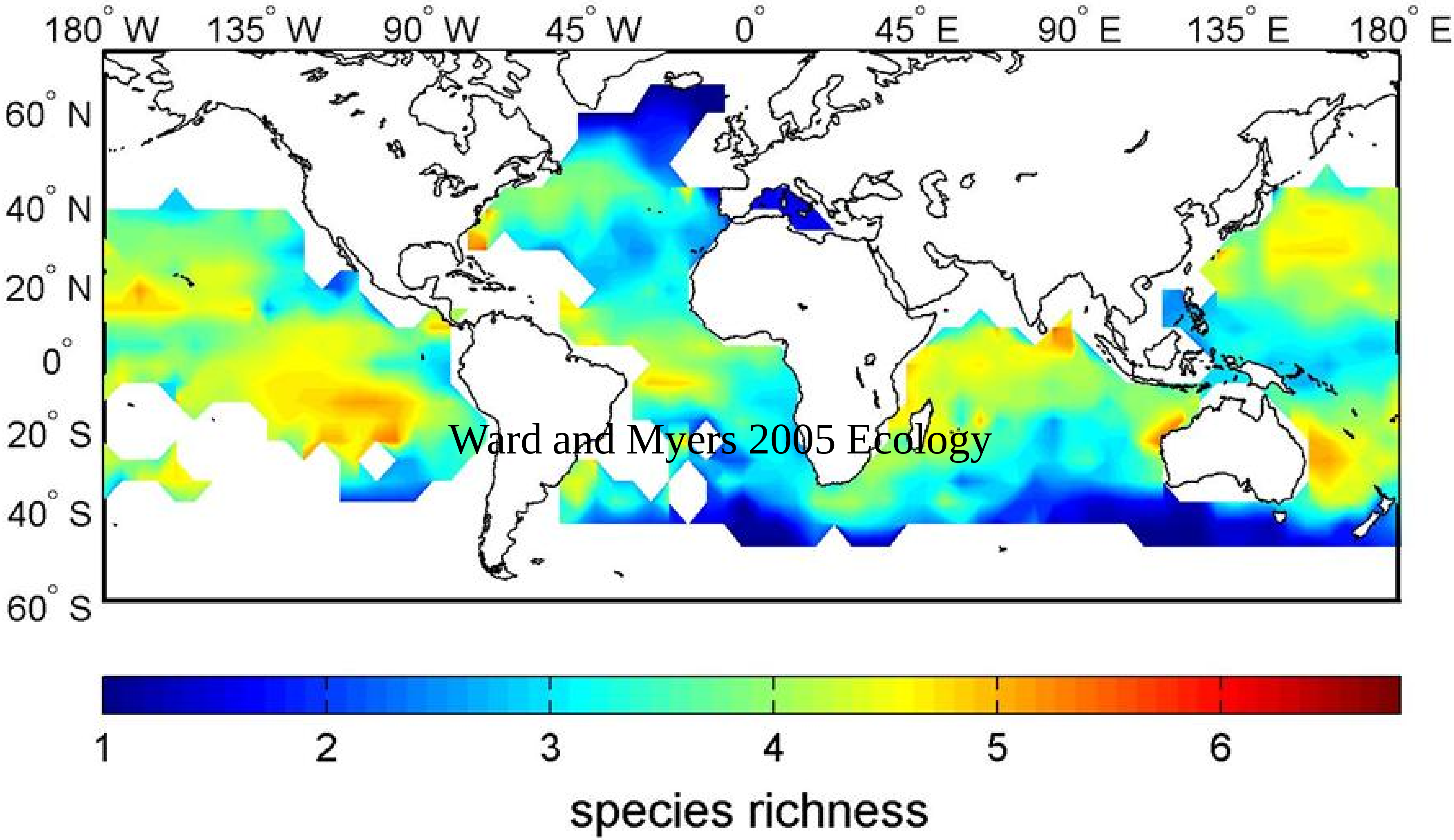
Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

1980s



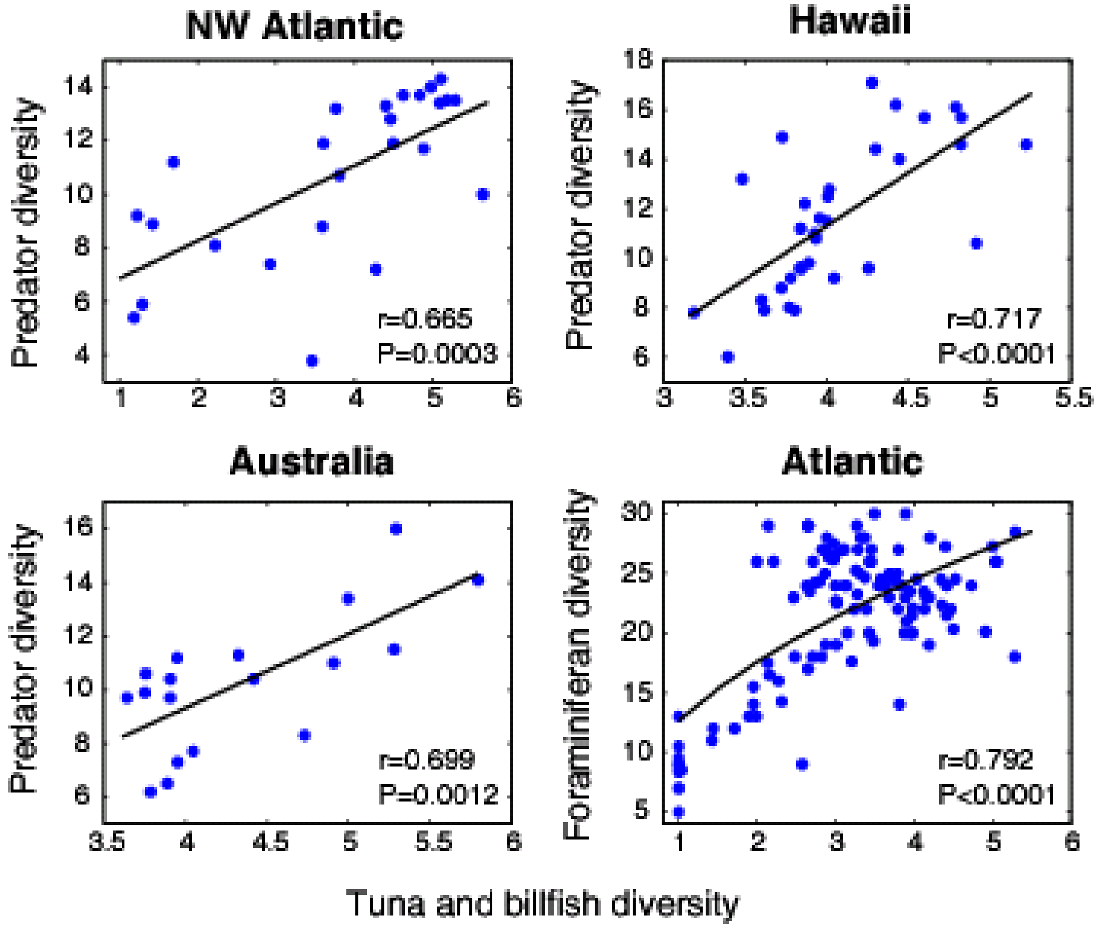
Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

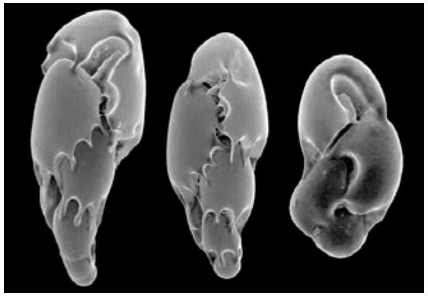
1990s



Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

Validate hotspots across species groups



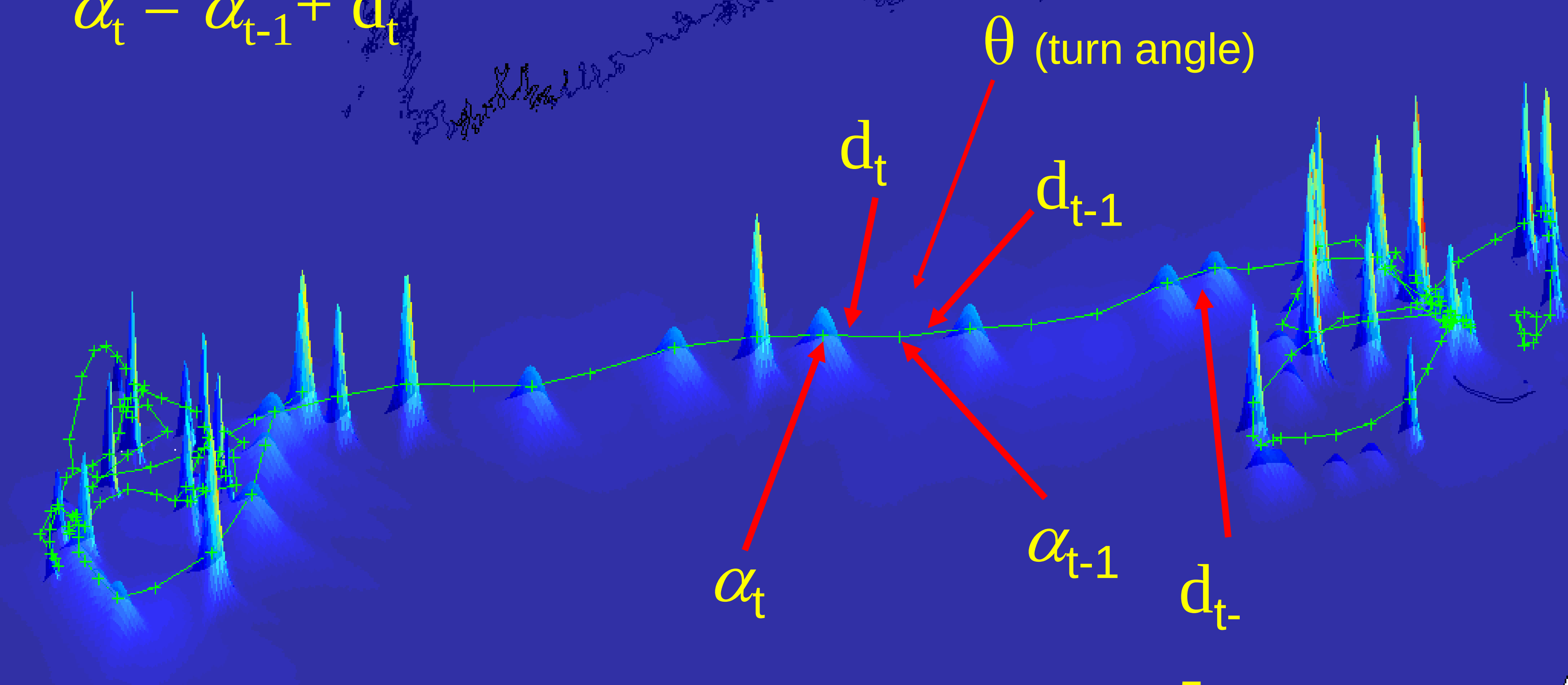


Source: Worm et al. 2005. Science: 309:1365-1369

3-State Movement Equation

$$d_t = \gamma_s T(\theta_s) d_{t-1} + \delta_s T(\theta_{t-5}) d_{t-5} + N_2(0,\Sigma)_s$$

$$\alpha_t = \alpha_{t-1} + d_t$$



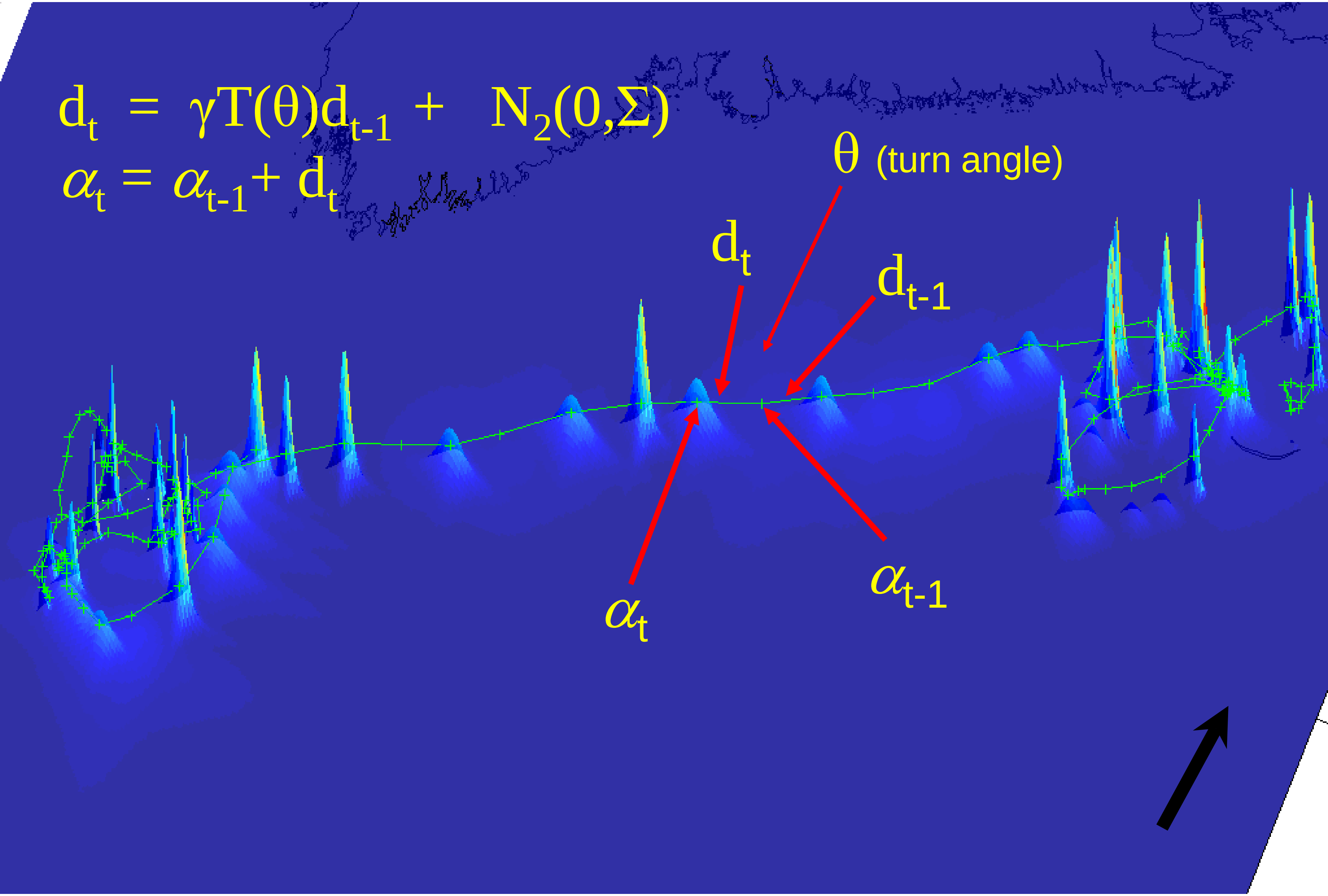
s = behavioural state (1 = migrating; 2 = foraging; 3 = search)

γ, θ, & Σ are now 3 element vectors, 1 element for each state

Movement (Transition) Equation

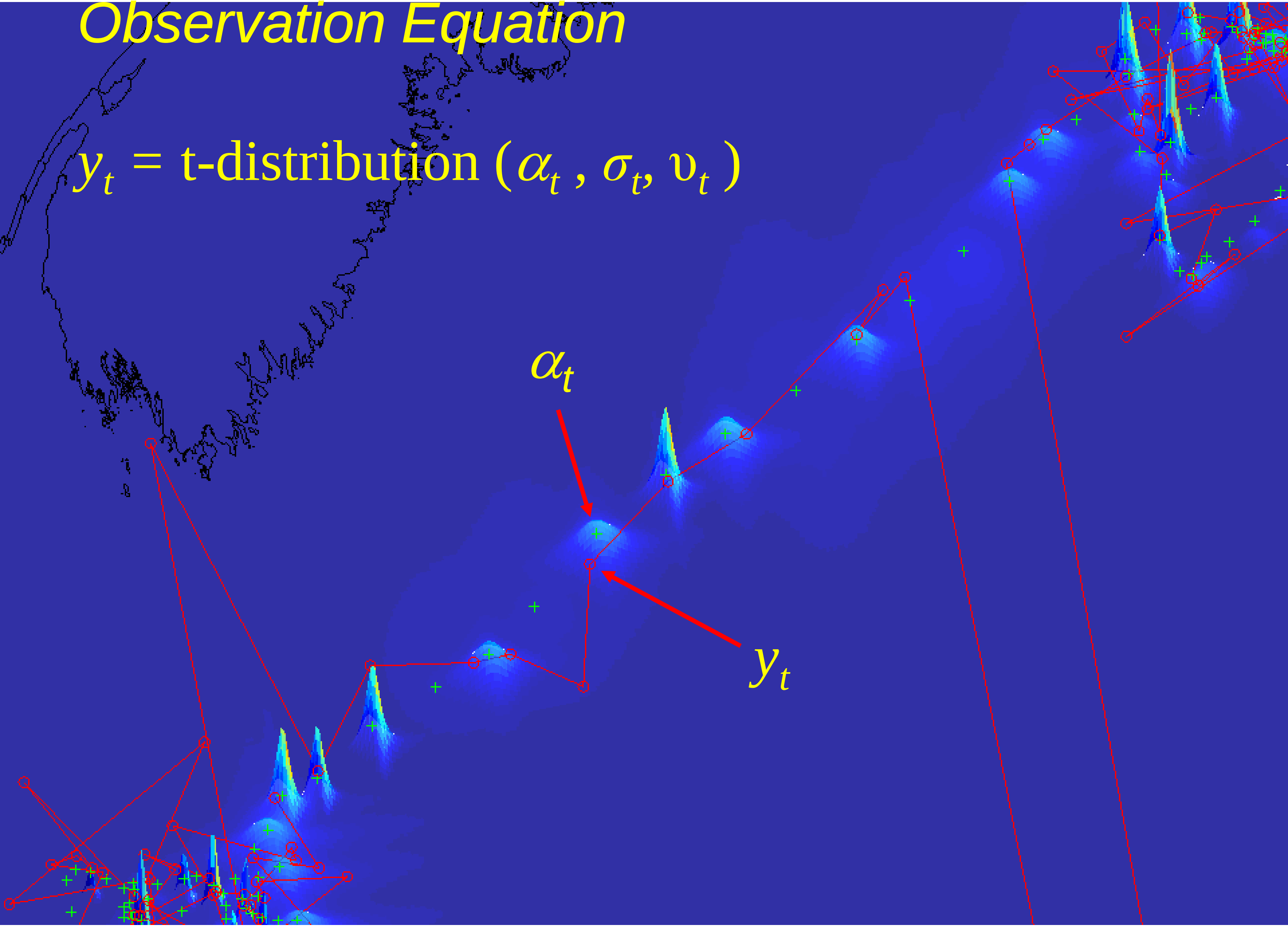
$$d_t = \gamma T(\theta) d_{t-1} + N_2(0,\Sigma)$$

$$\alpha_t = \alpha_{t-1} + d_t$$



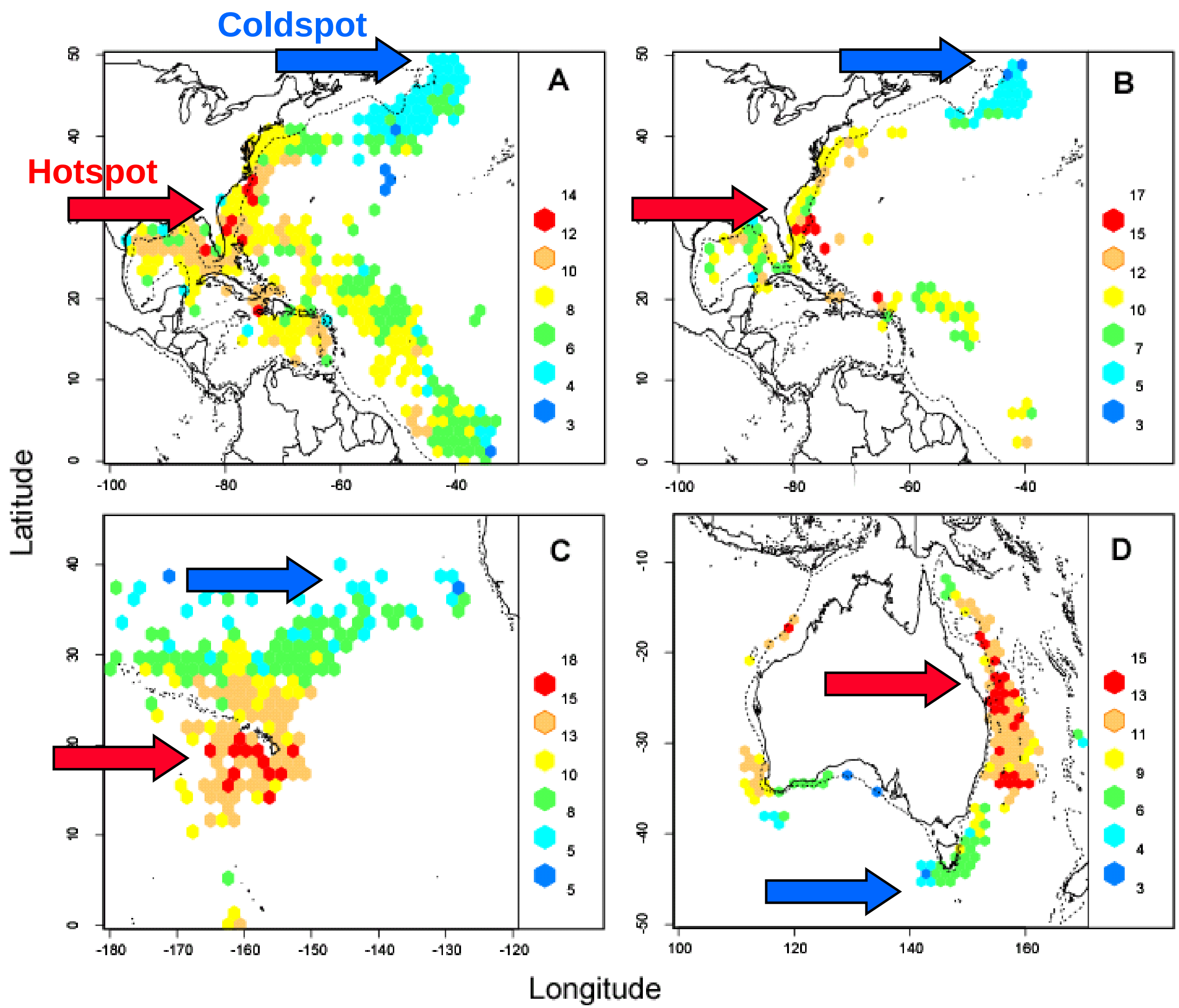
Observation Equation

$$y_t = \text{t-distribution}\,(\alpha_t\ ,\ \sigma_t,\ \upsilon_t\ )$$



Protect diversity hotspots in national waters

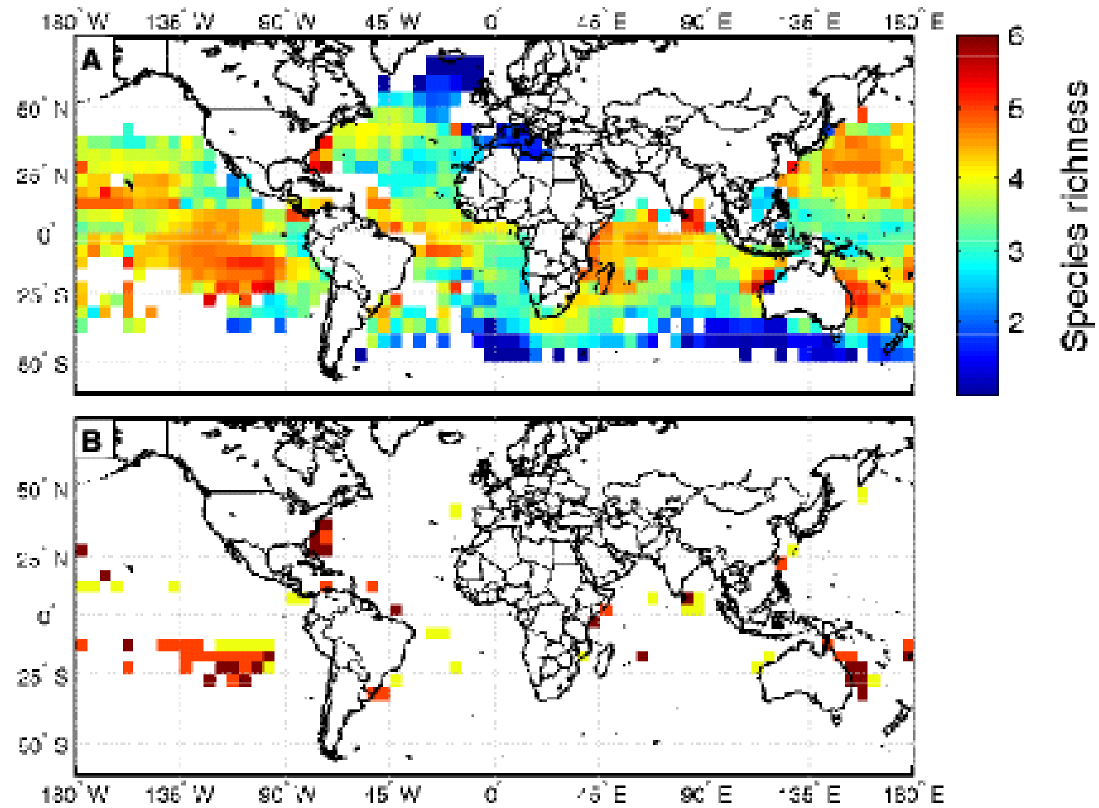
- Special places where many species aggregate
- Key habitats
- Food supply



Source: Worm et al. 2003. PNAS 100:9884-9888

Use remaining hotspots for global conservation

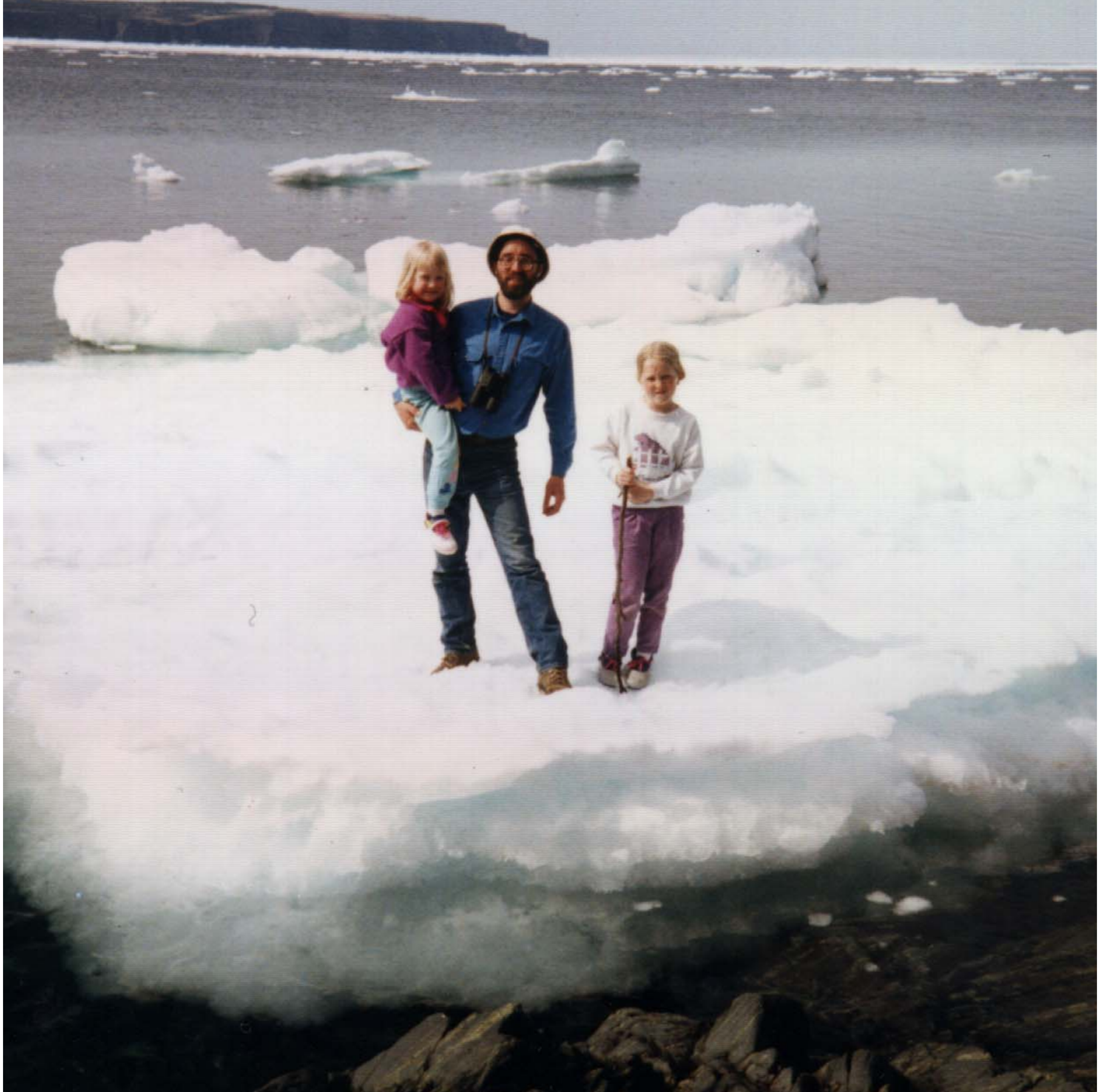
- Consistent patterns of species richness and density
- Five major hotspots:
  - U.S. east coast
  - Hawaiian chain
  - Southeast Pacific
  - Australian east coast
  - Sri Lanka



Source: Worm et al. 2005. Science 309:1365-1369

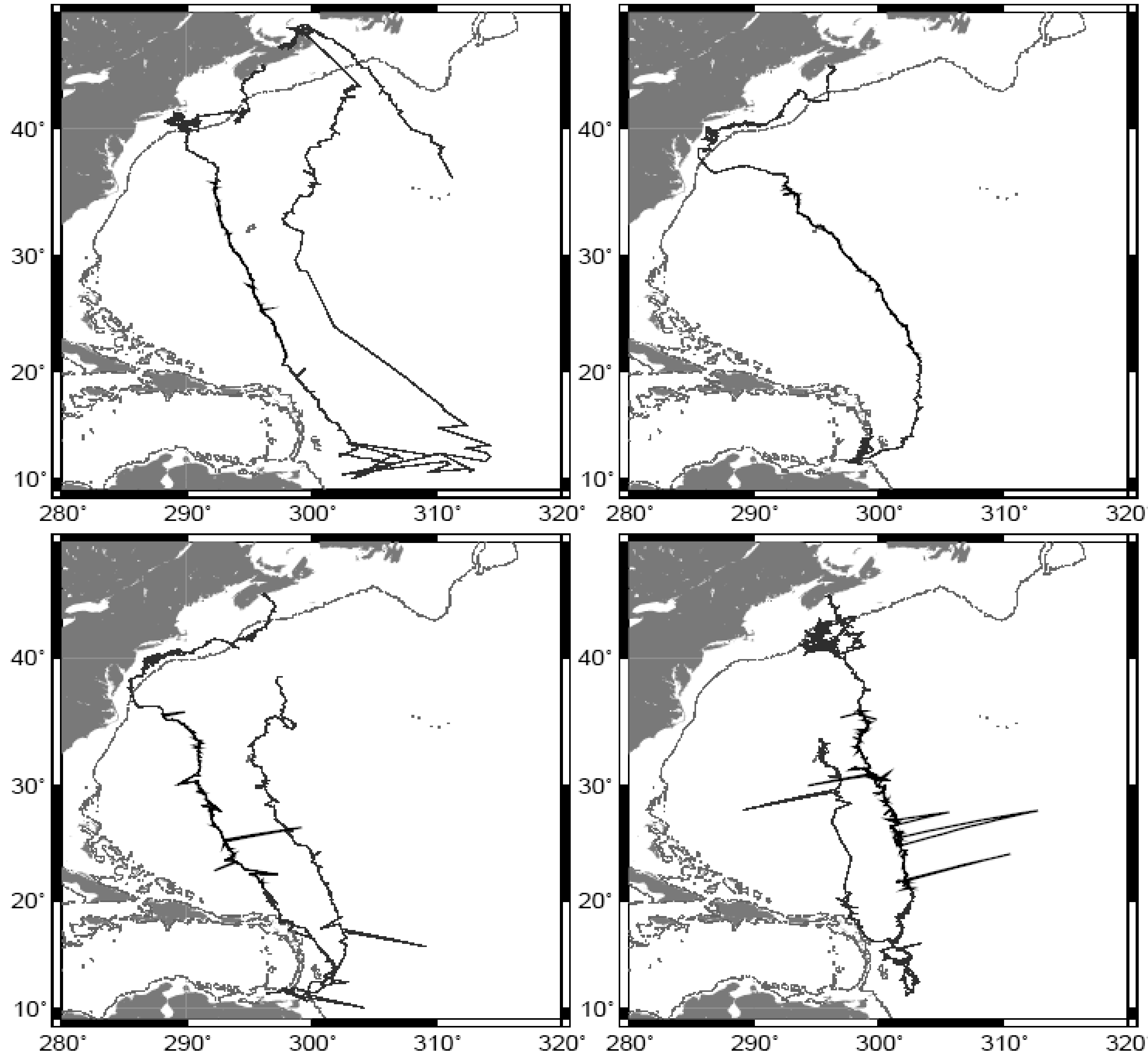
Questions?

- What are the fundamental changes in a community that occur after the apex predators are removed?
- Have lower trophic levels responded?
- How can we carry our a meta-analysis in different communities that may not be independent?

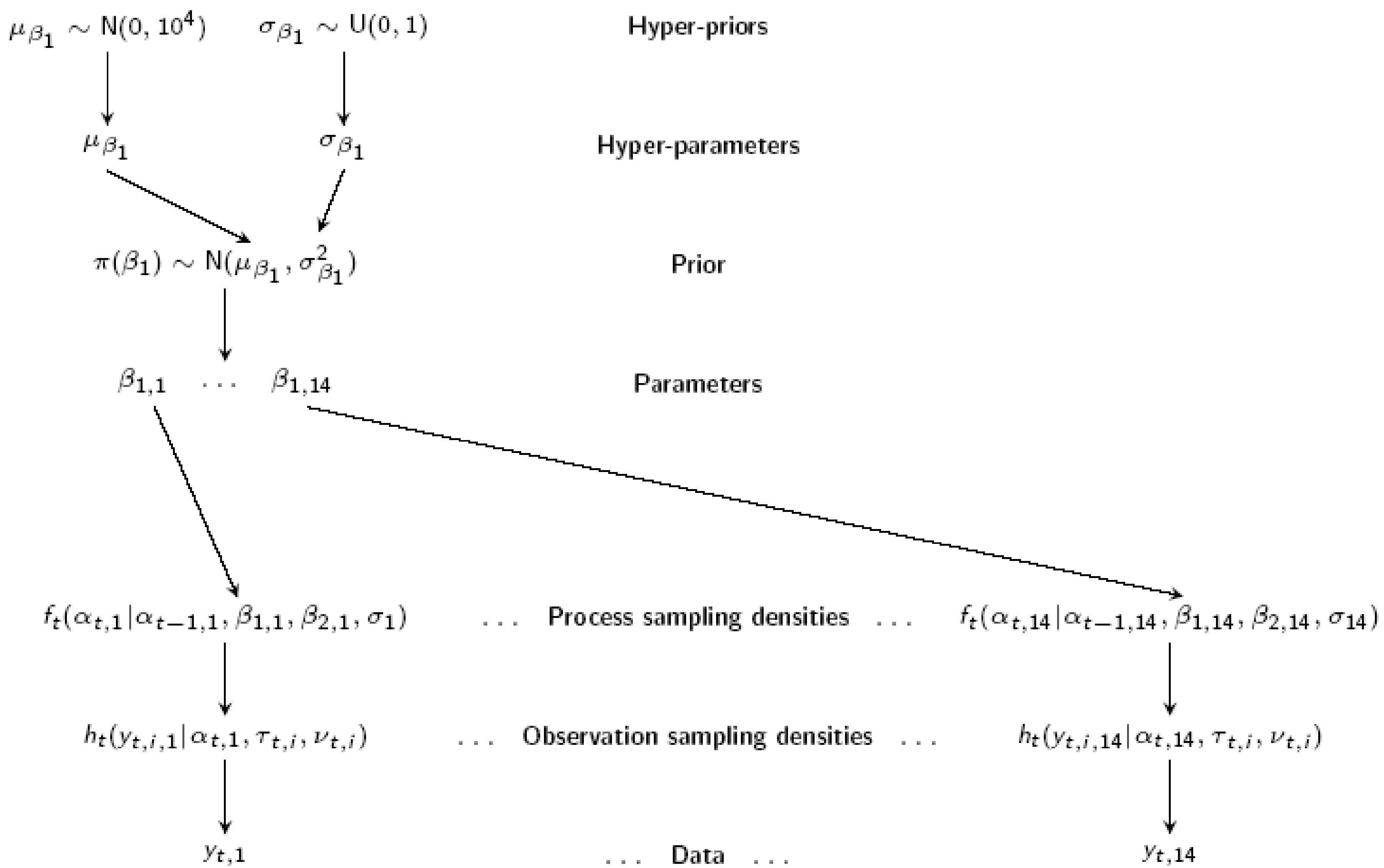


"Take all of these scientists if they feel constrained working within government and make them free," he said. "Scientists are as capable of being prima donnas and as petulant and pompous as anybody else."

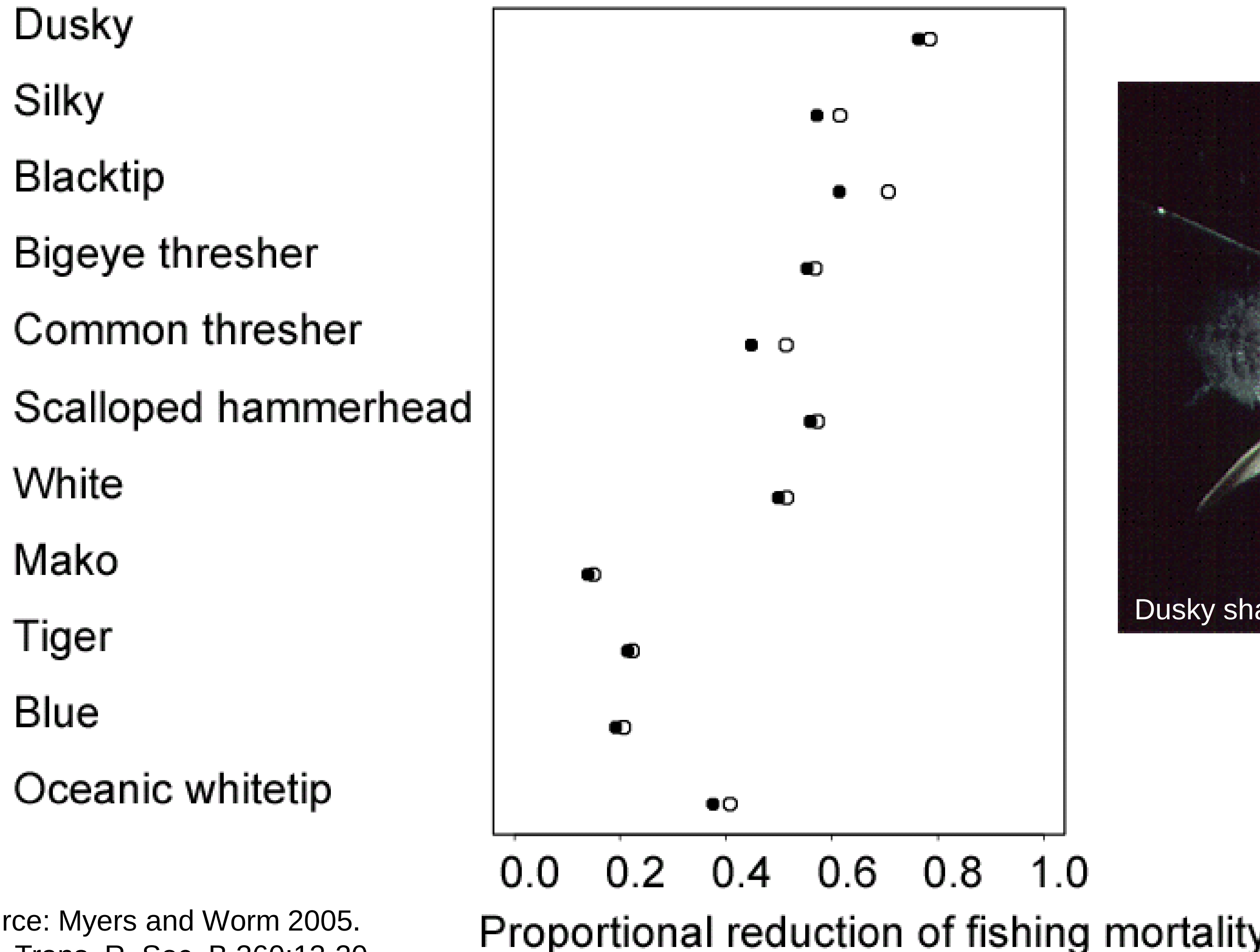
Former fisheries minister Brian Tobin. Globe and Mail Aug. 23, 1997.


40°
30°
20°
10°
280°
290°
300°
310°
320°

Hierarchical Bayes State-Space Model (HB SSM)



Reduce fishing mortality for sensitive species for survival of the species




Dusky shark. Source: NMFS

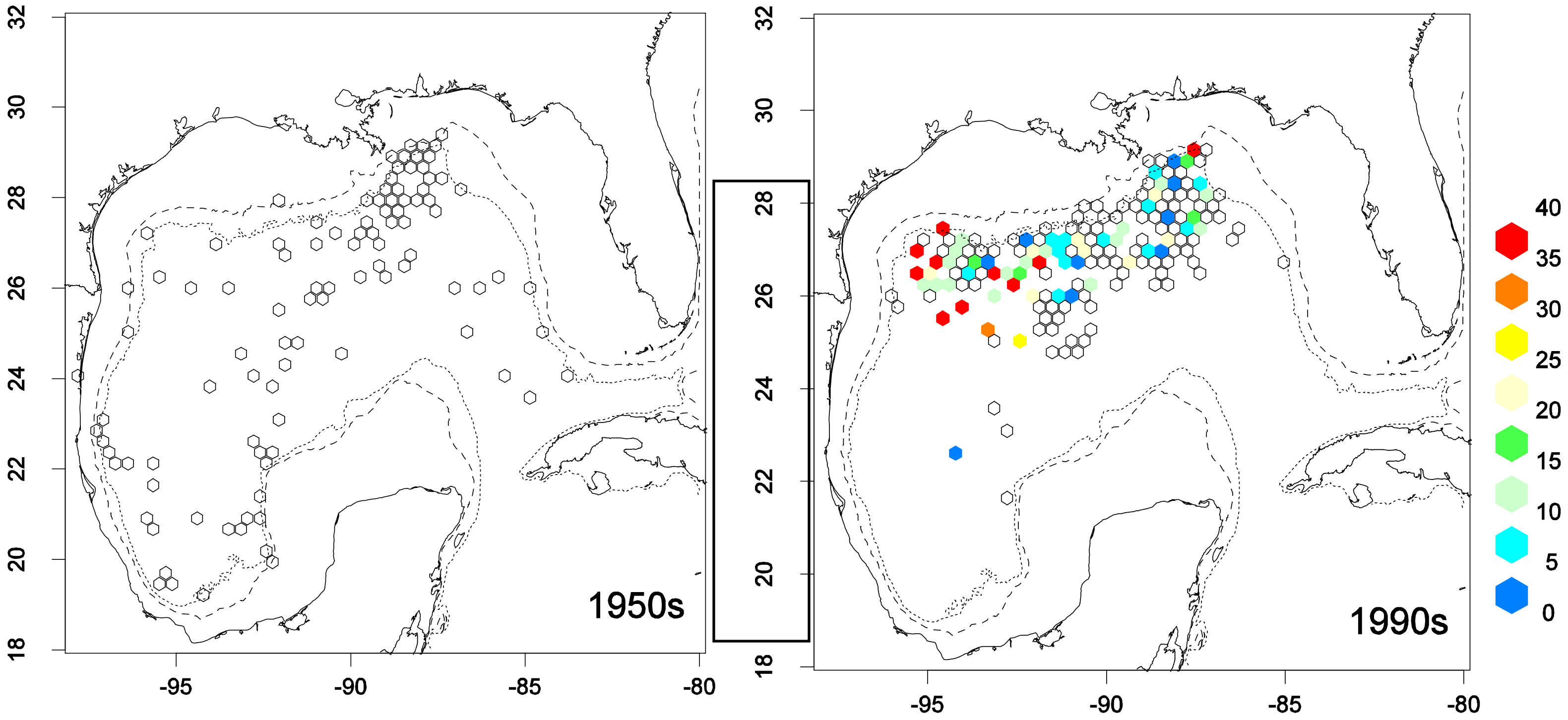
Source: Myers and Worm 2005.
Phil. Trans. R. Soc. B 360:13-20

The Rise of the Marine Mesopredators

Pelagic Sting Ray
Pteroplatytrygon violacea

Photos from Phillip Colla, photography

Explosion of Pelagic Stingrays in the Gulf of Mexico ~1000 fold increase – no one noticed



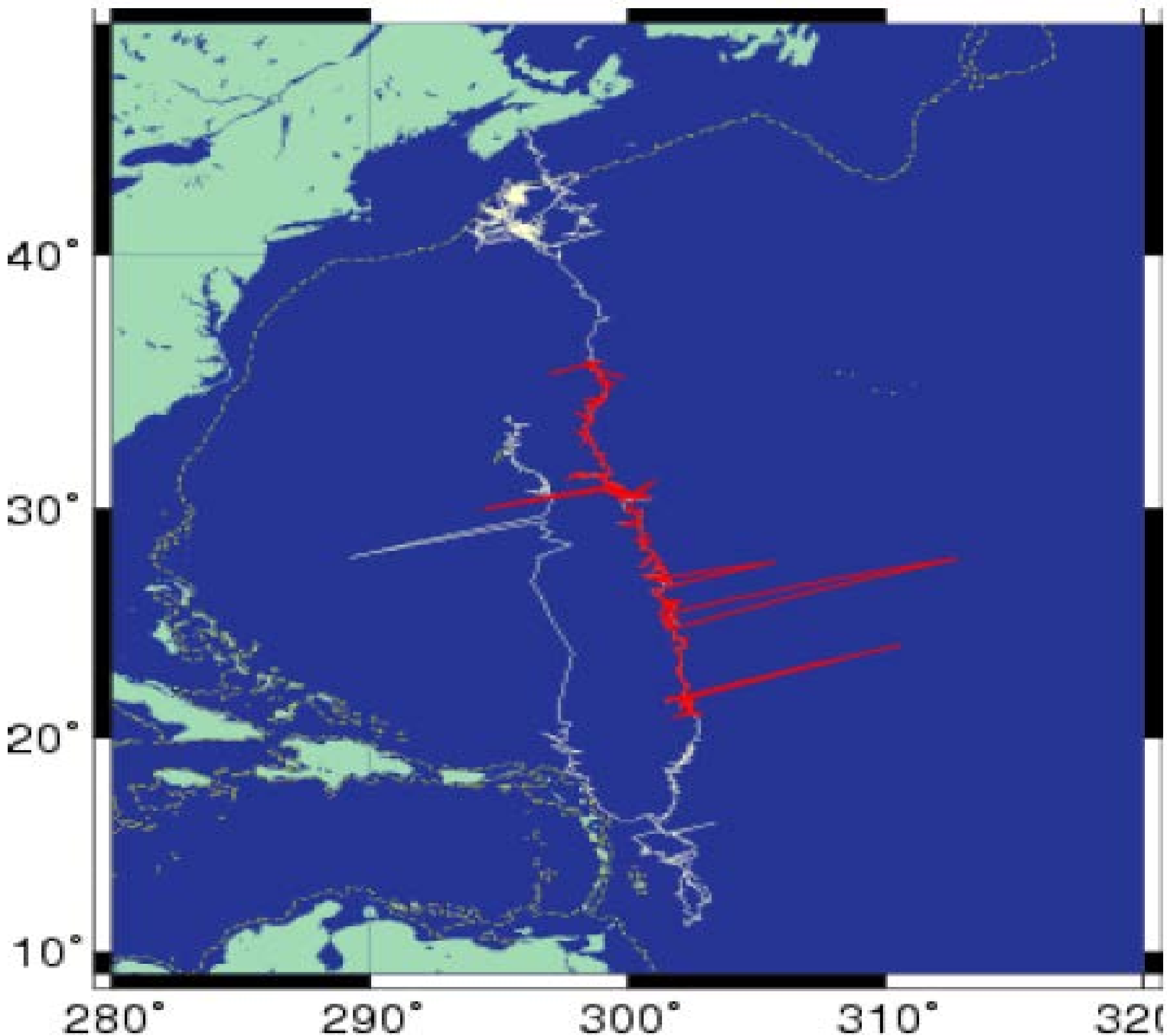
1950's

1990's

Pelagic stingray captures per 10,000 hooks

Many thanks to NMFS for data and advice

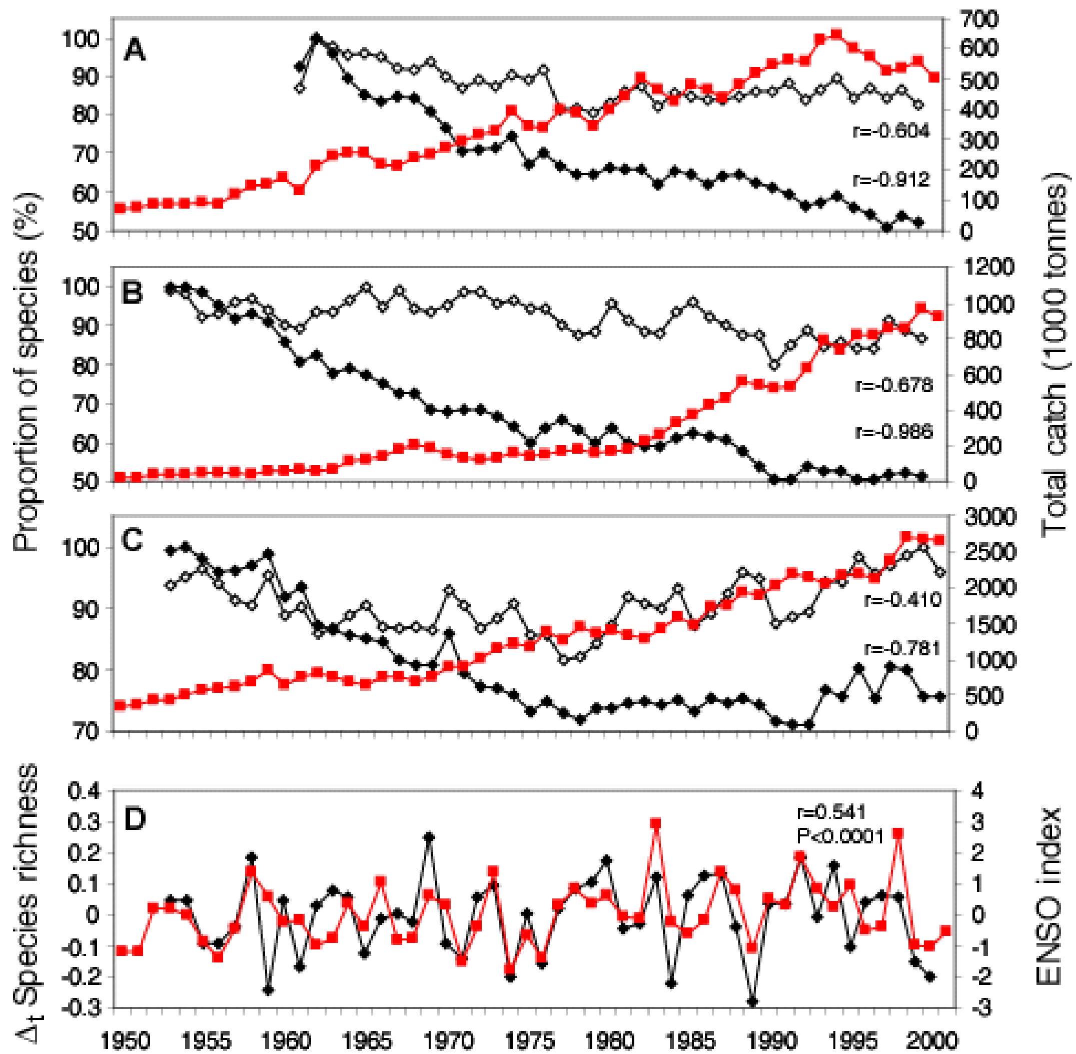
Examining Diel Migration Behaviour in Leatherbacks



Jonsen, James Myers. in press (almost). Journal of Animal Ecology

Global decline in ocean predator diversity

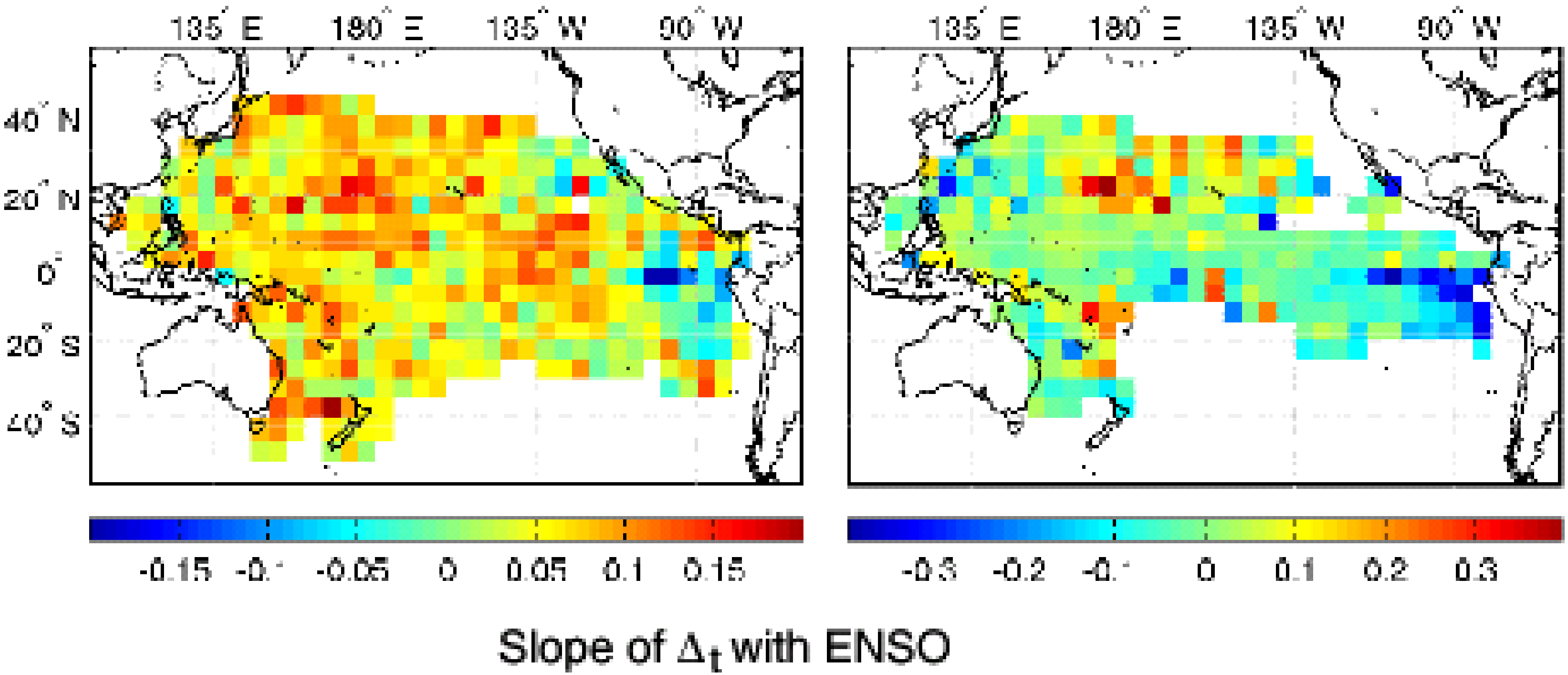
- Increasing catches
- Decreasing diversity
- Long-term decline linked to fishing
- Yearly variability linked to climatic changes



Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

ENSO affects diversity across entire Pacific

Species richness | Blue marlin catch rates

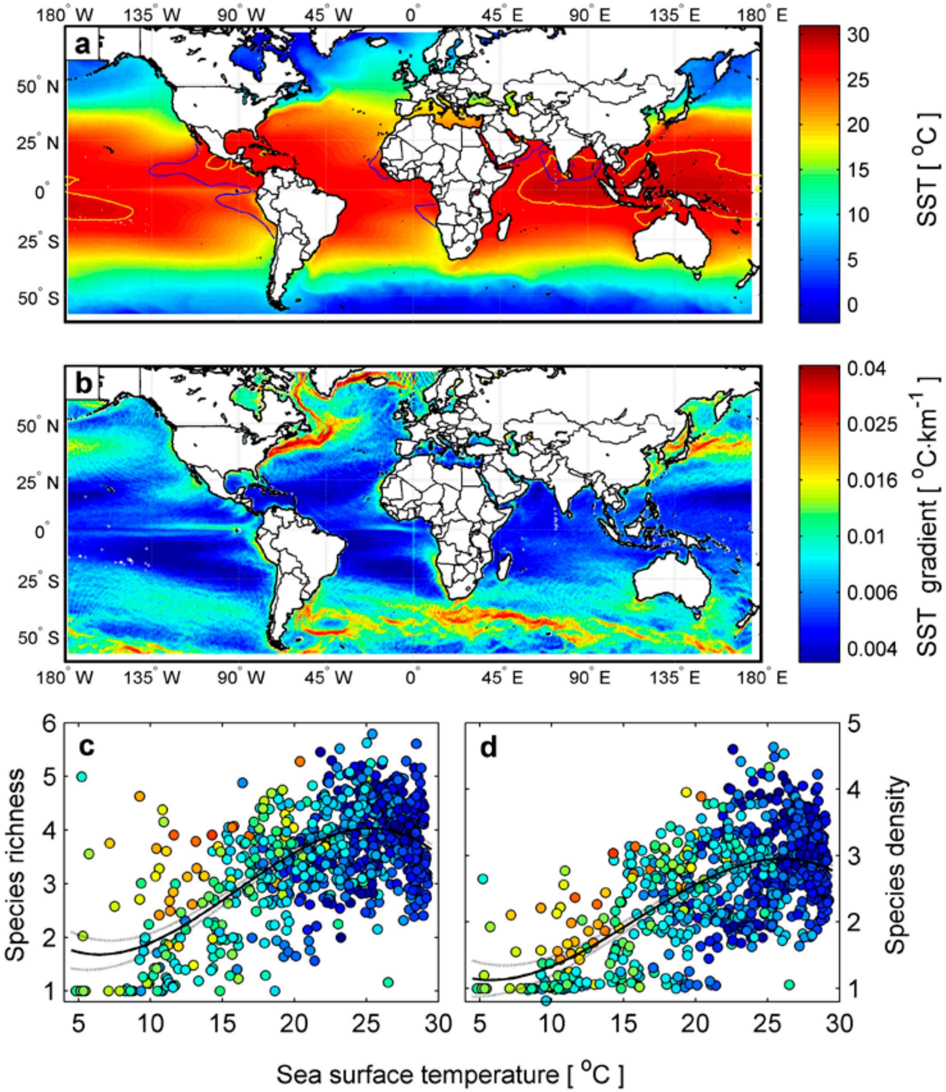


Source: Worm, Sandow, Oschlies, Lotze, Myers 2005. Science 309:1365-1369

Understand oceanographic drivers of diversity

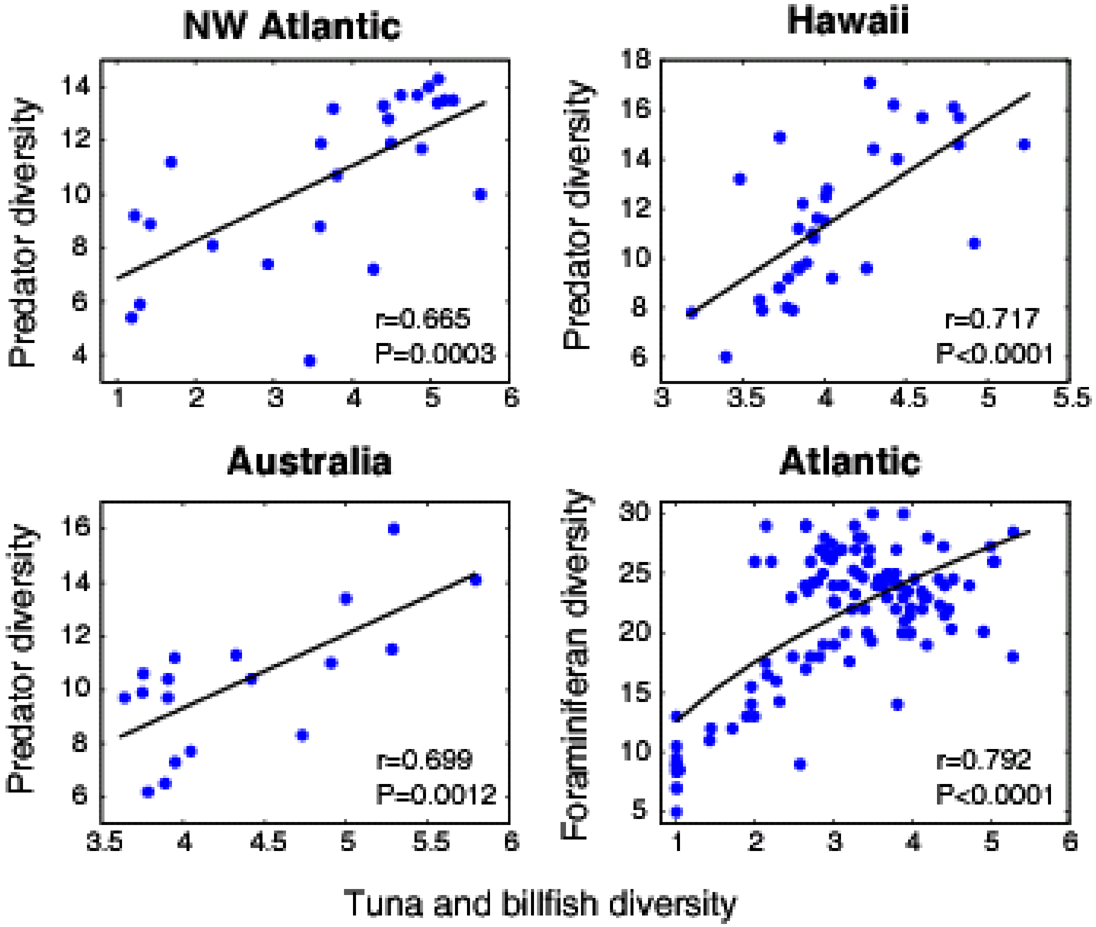
Patterns of diversity were explained by

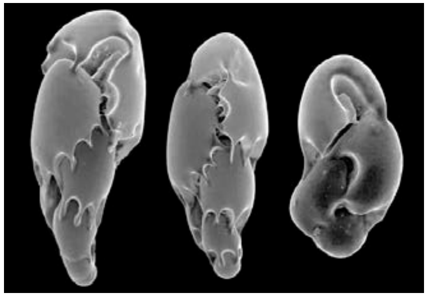
- Mean temperature
- Fronts and eddies
- Oxygen



Source: Worm et al. 2005. Science 309:1365-1369

Validate hotspots across species groups





Source: Worm et al. 2005.
Science: 309:1365-1369

There is always a rapid loss of fitness in the wild with hatcheries; after a few generations hatchery salmon may be useless for recovery.