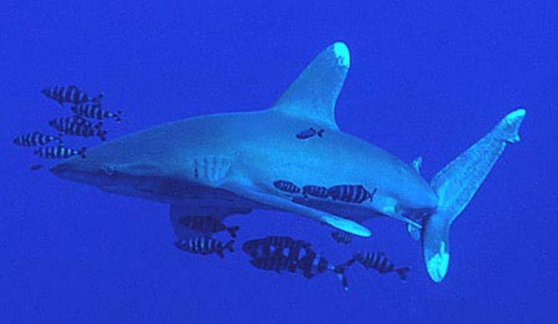
Changes in exploited marine systems – From the open ocean to Hudson River

Ransom A. Myers (RAM)
Dalhousie University

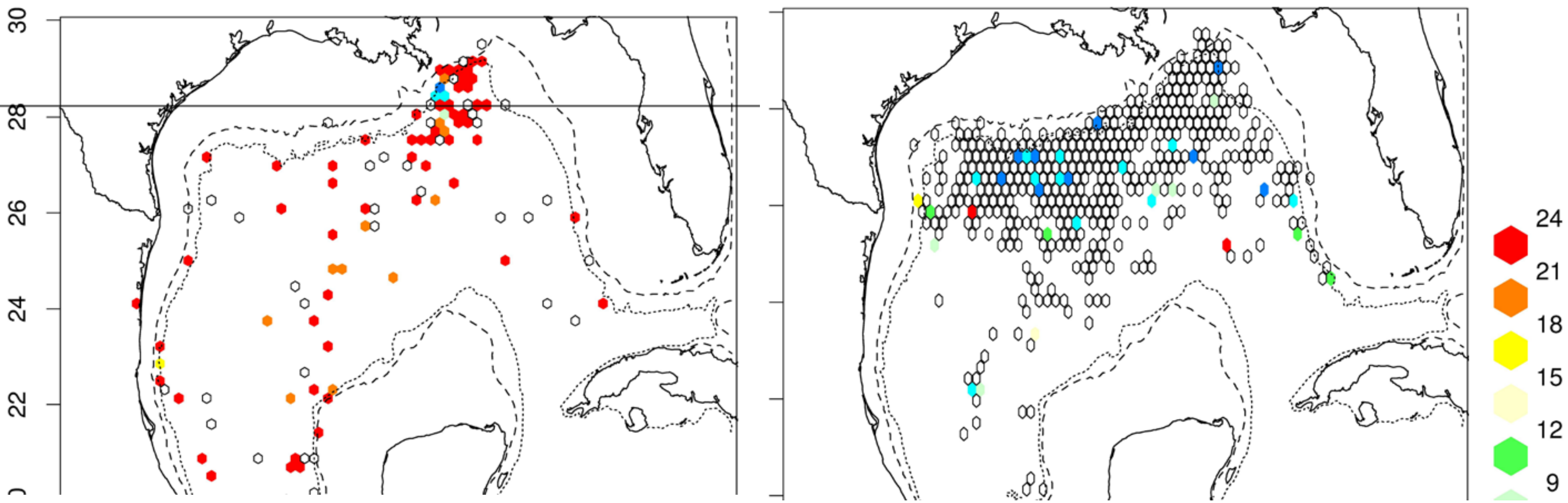
What was the most common large animal (>40 Kg) in the world? (perhaps this one was)



Loss of sharks in the Gulf of Mexico

300 fold decline – no one noticed

[redacted]

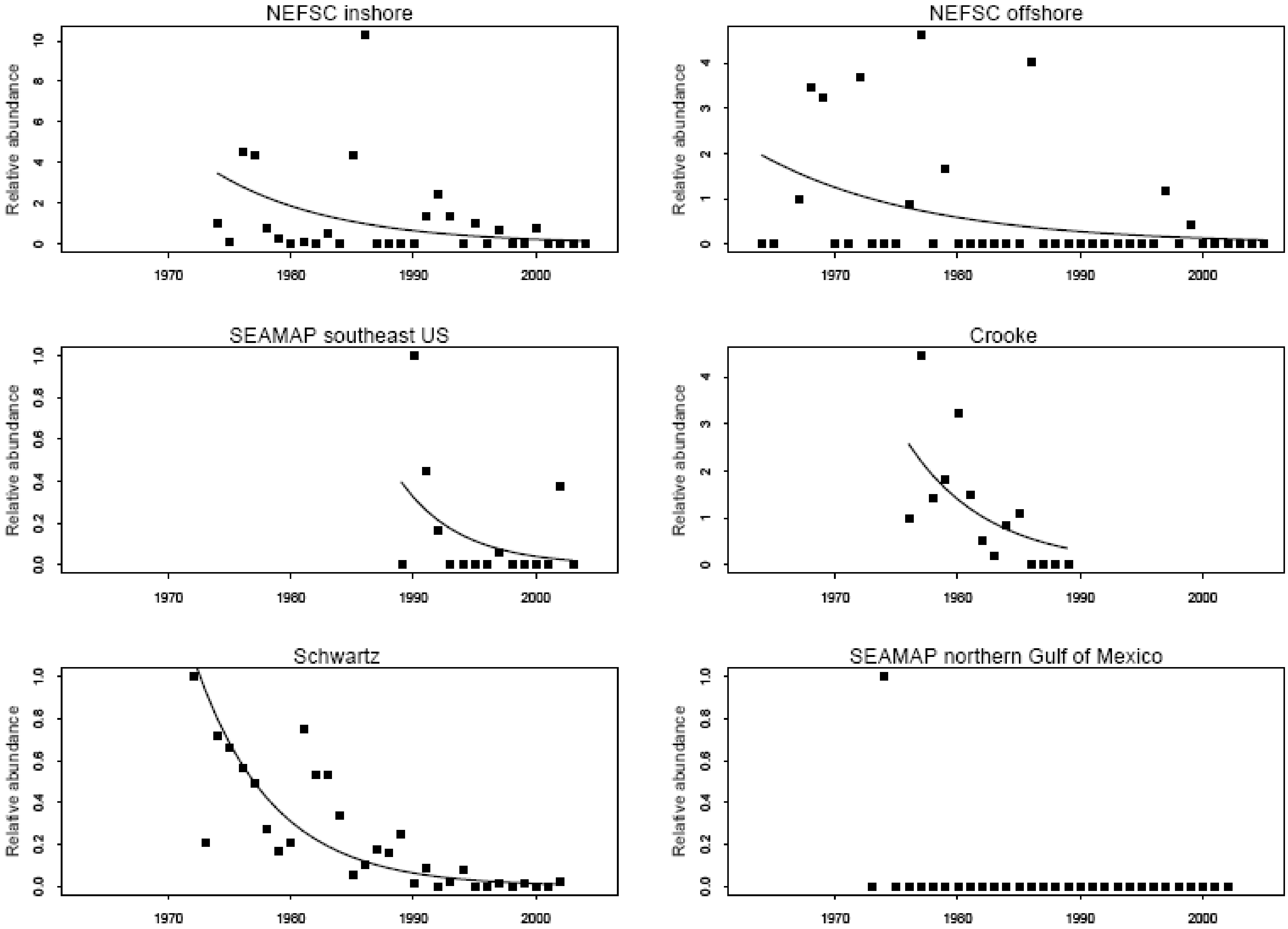


1950's 1990's

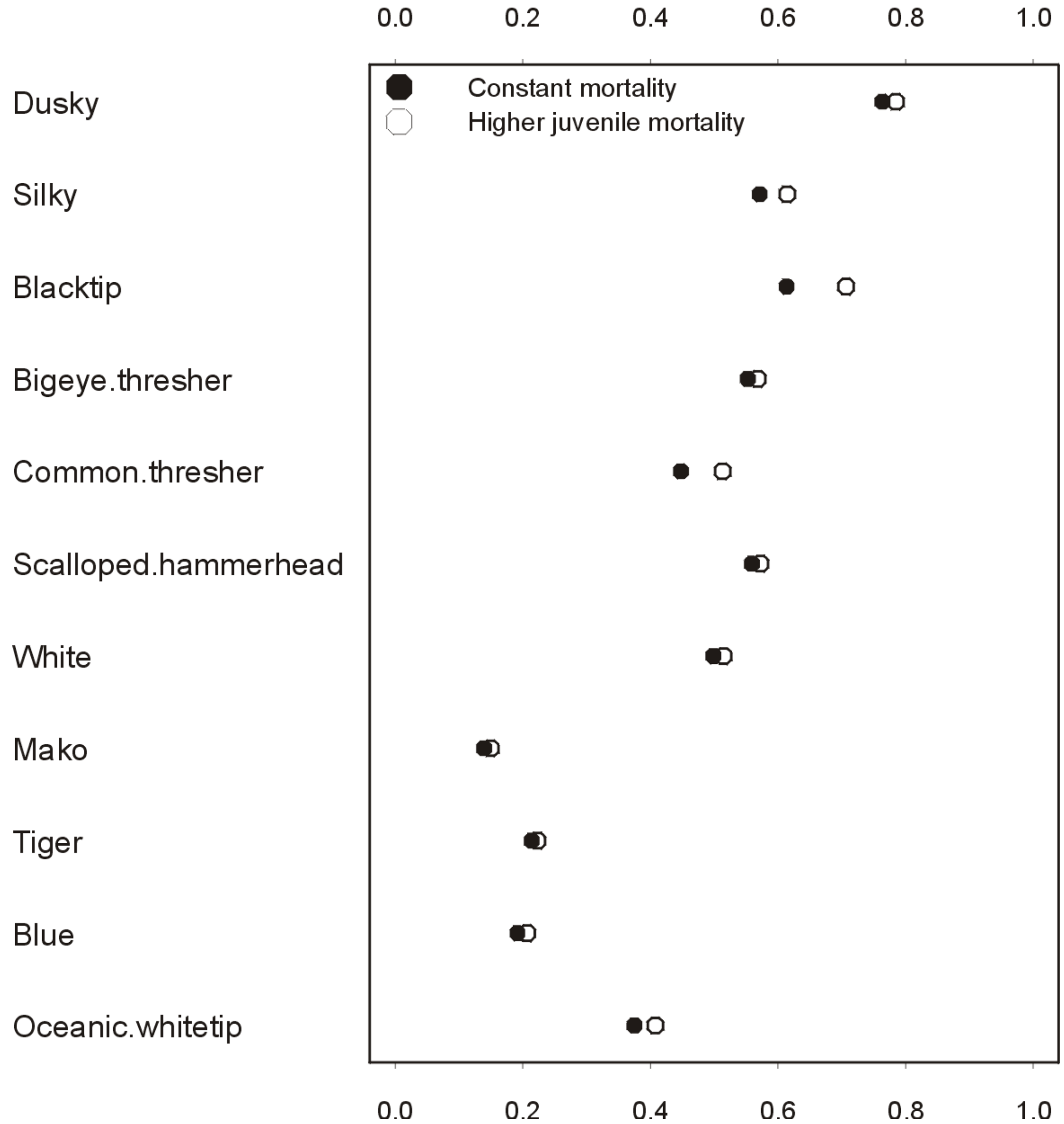
Oceanic Whitetip captures per 10,000 hooks

Baum and Myers, 2004 Ecology Letters

Loss of Dusky Sharks in the Eastern US



Proportional reduction in current fishing mortality needed to ensure survival of shark populations



Myers & Worm, Phil. Trans. Royal Society B 2005

What does this imply:

- It is not possible to think about ecosystems without thinking about history.


788
757
525
650
620
770

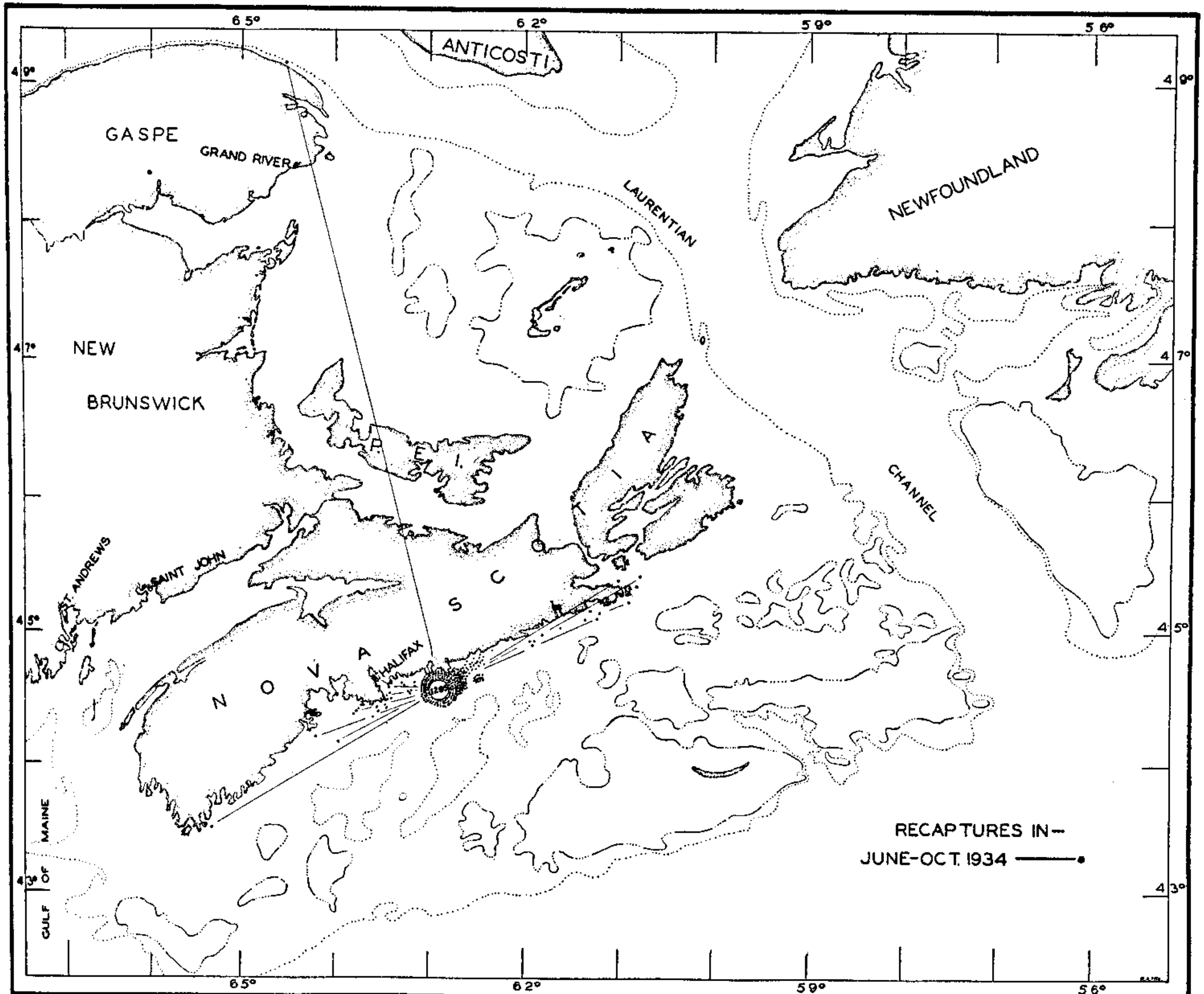


FIG. 21.—Recaptures to October, 1934, of cod tagged in the Jeddore Rock to Egg Island area, N.S., in May, 1934.

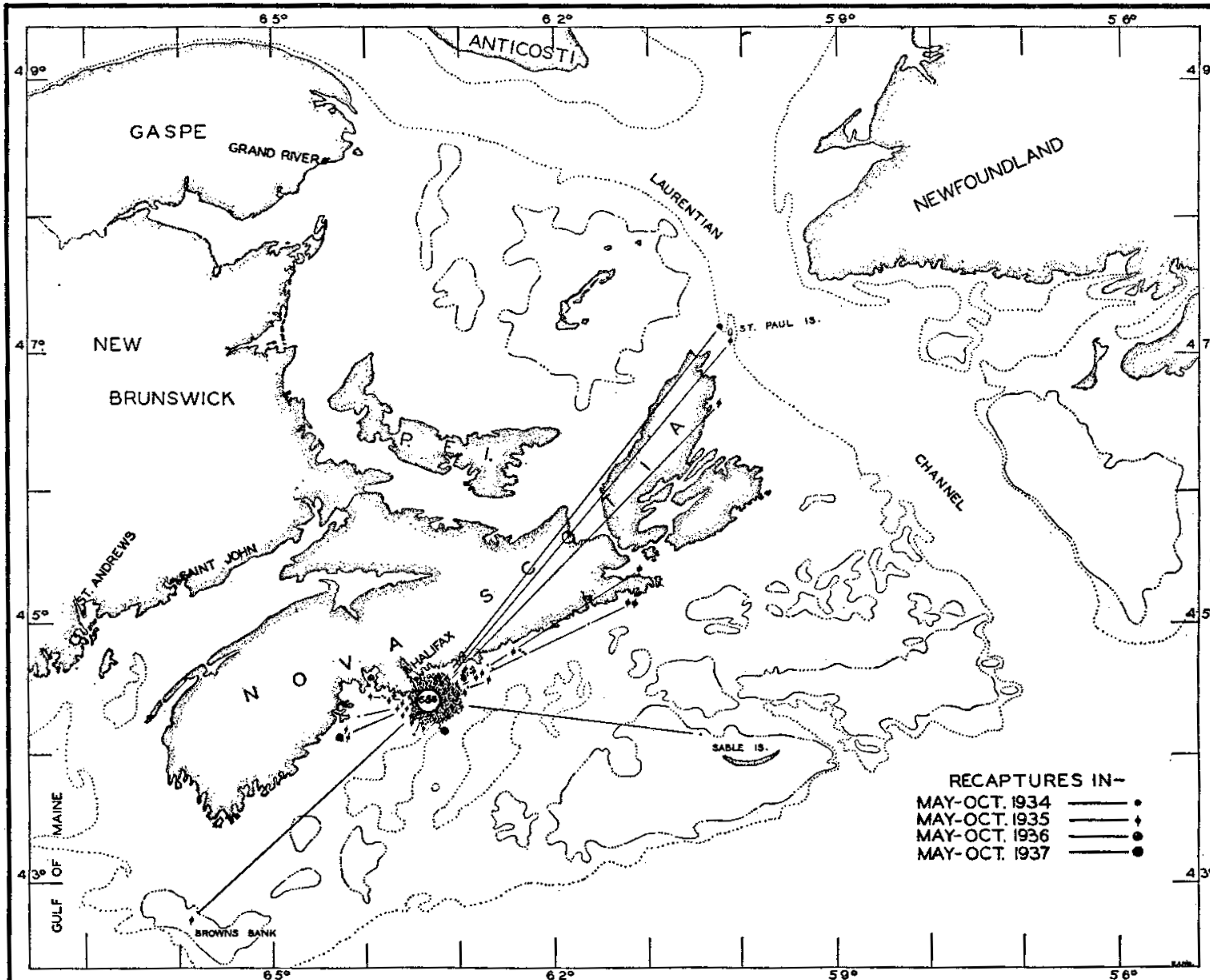


FIG. 18.—Recaptures in May to October, 1934, 1935, 1936 and 1937, of cod tagged near Halifax in June, 1934.

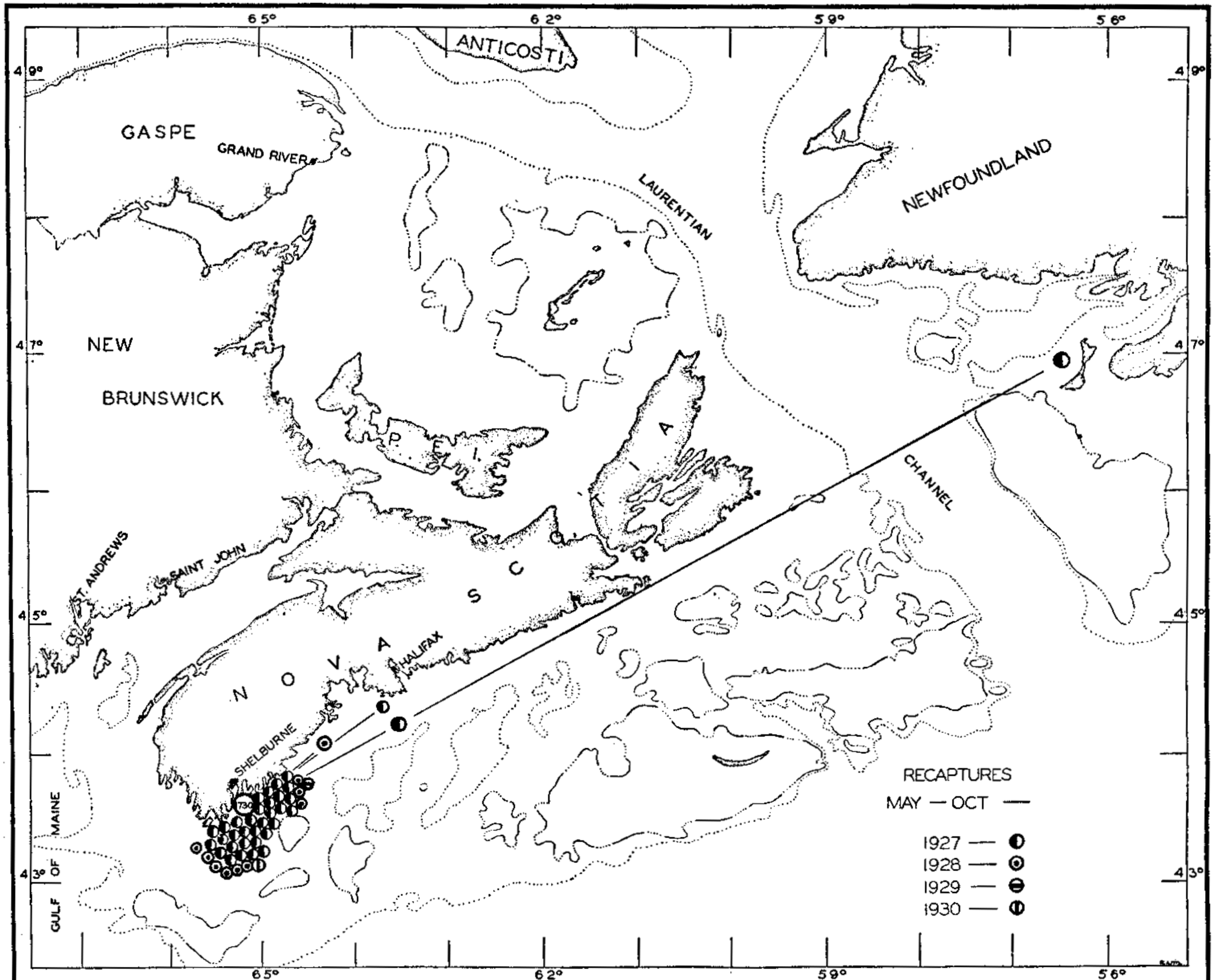


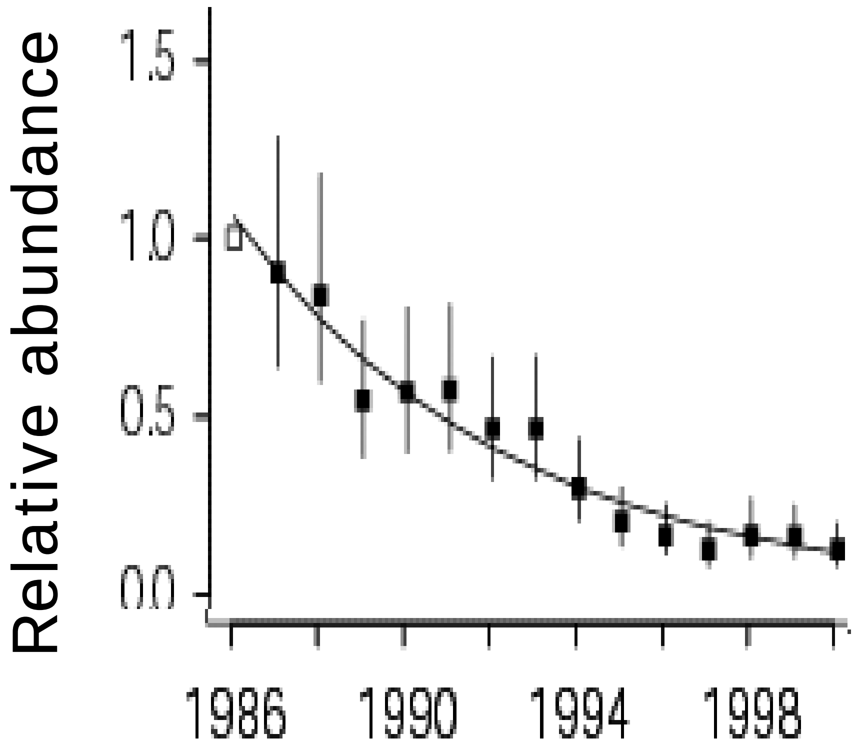
FIG. 15.—Recaptures during "summers" of 1927, 1928, 1929 and 1930 of cod tagged off Shelburne, N.S., during September and the first day of October, 1926.

What does this imply:

- Loss of populations is one of the most important consequences to overfishing.

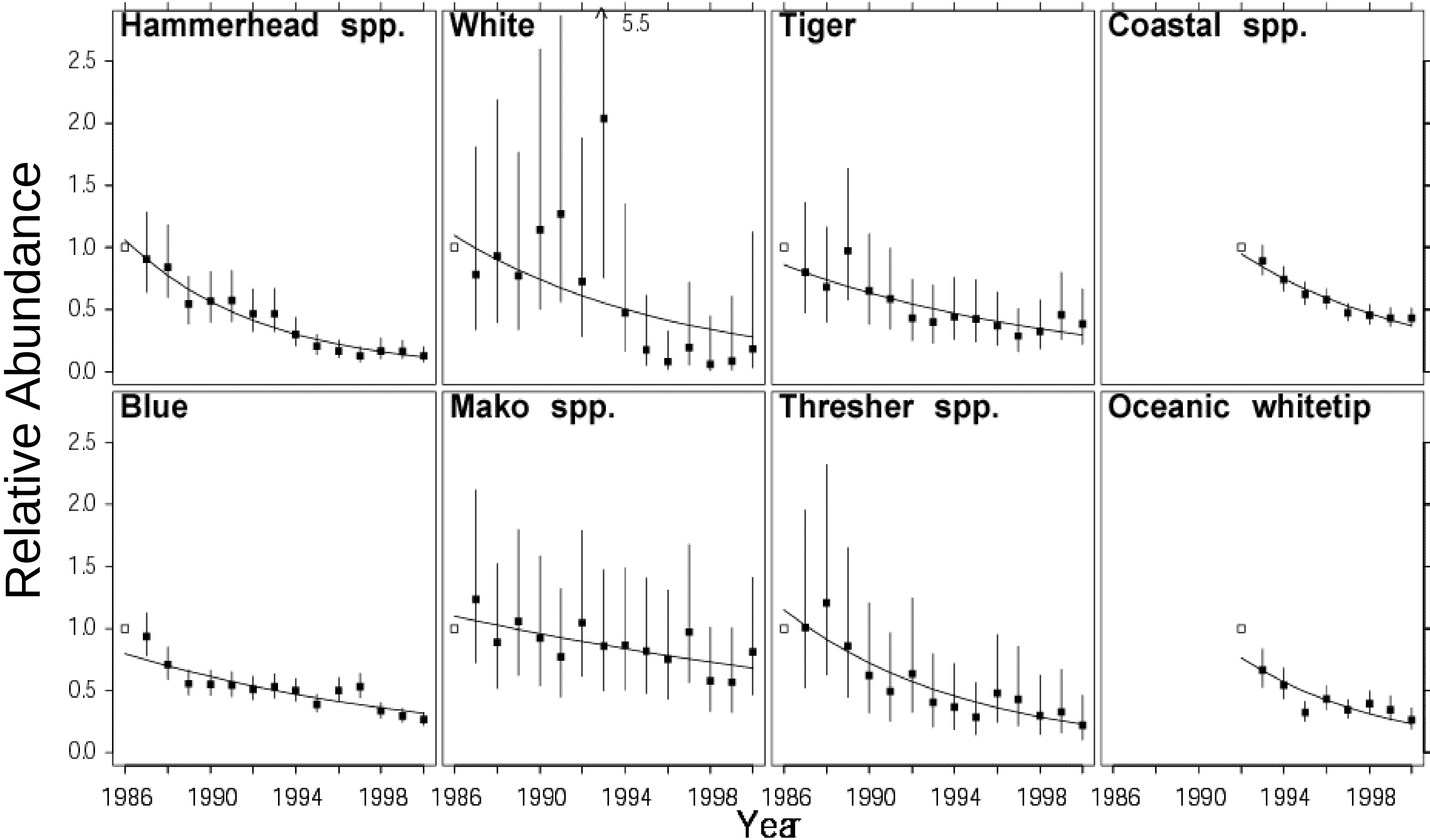
Hammerhead sharks

Sphyrna lewini



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

Results

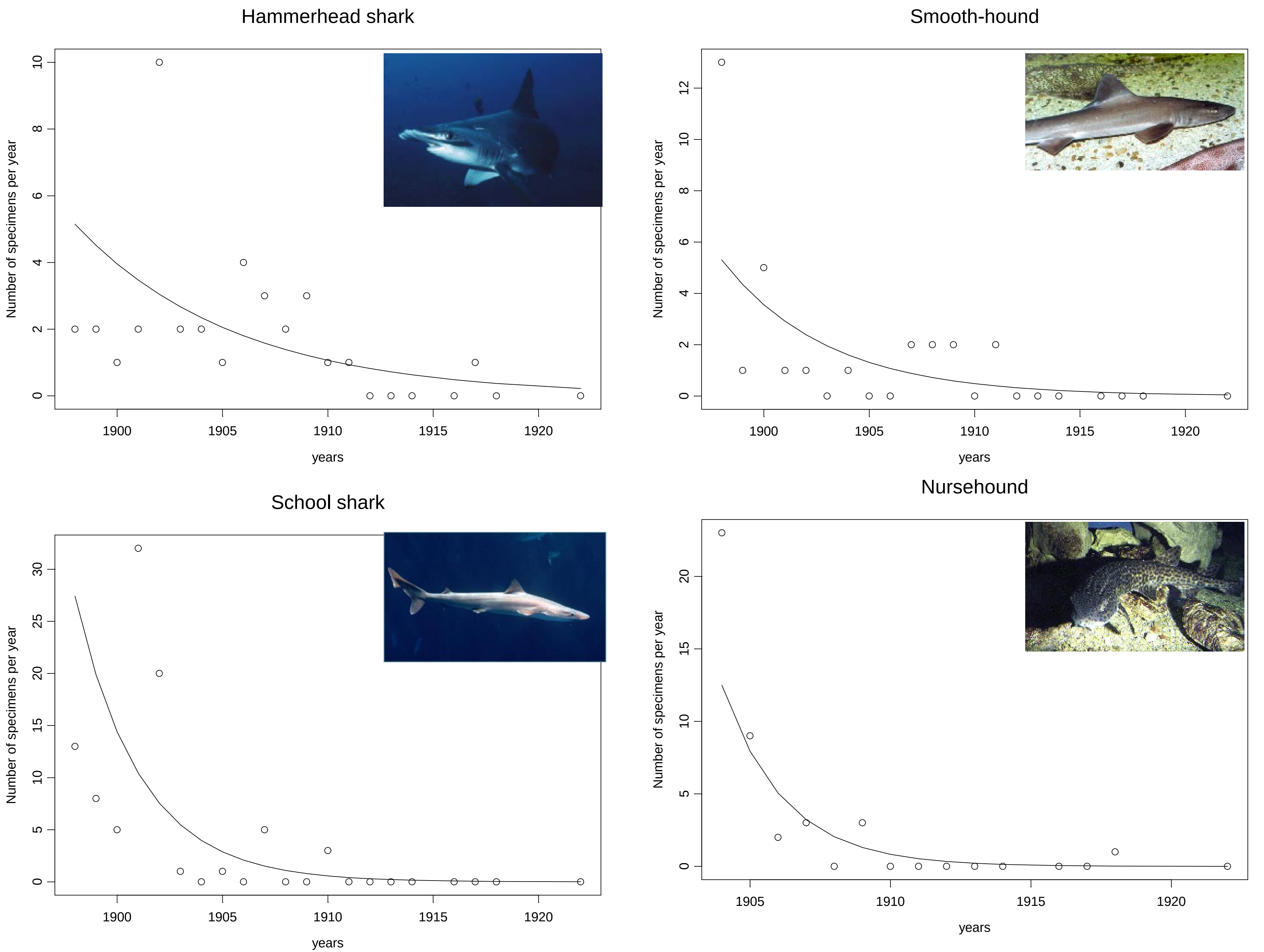


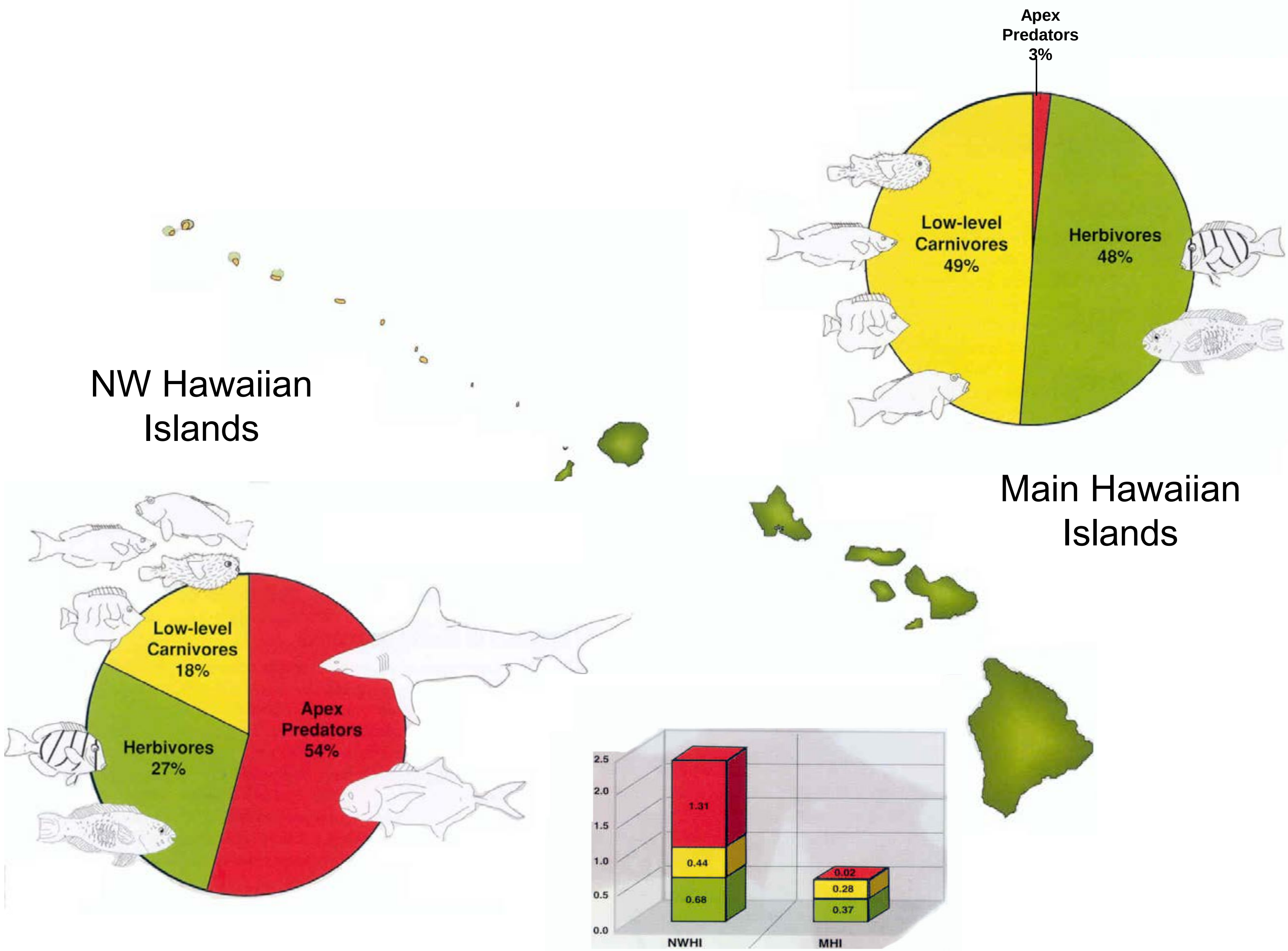
Hammerhead spp.
White
5.5
Tiger
Coastal spp.
Blue
Mako spp.
Thresher spp.
Oceanic whitetip
Relative Abundance
0.0
0.5
1.0
1.5
2.0
2.5
1986
1990
1994
1998
Year

Decline of Mediterranean Sharks

By catch associated with a Tuna Trap
In Tirrenian Sea

"Tonnarella di Baratti"

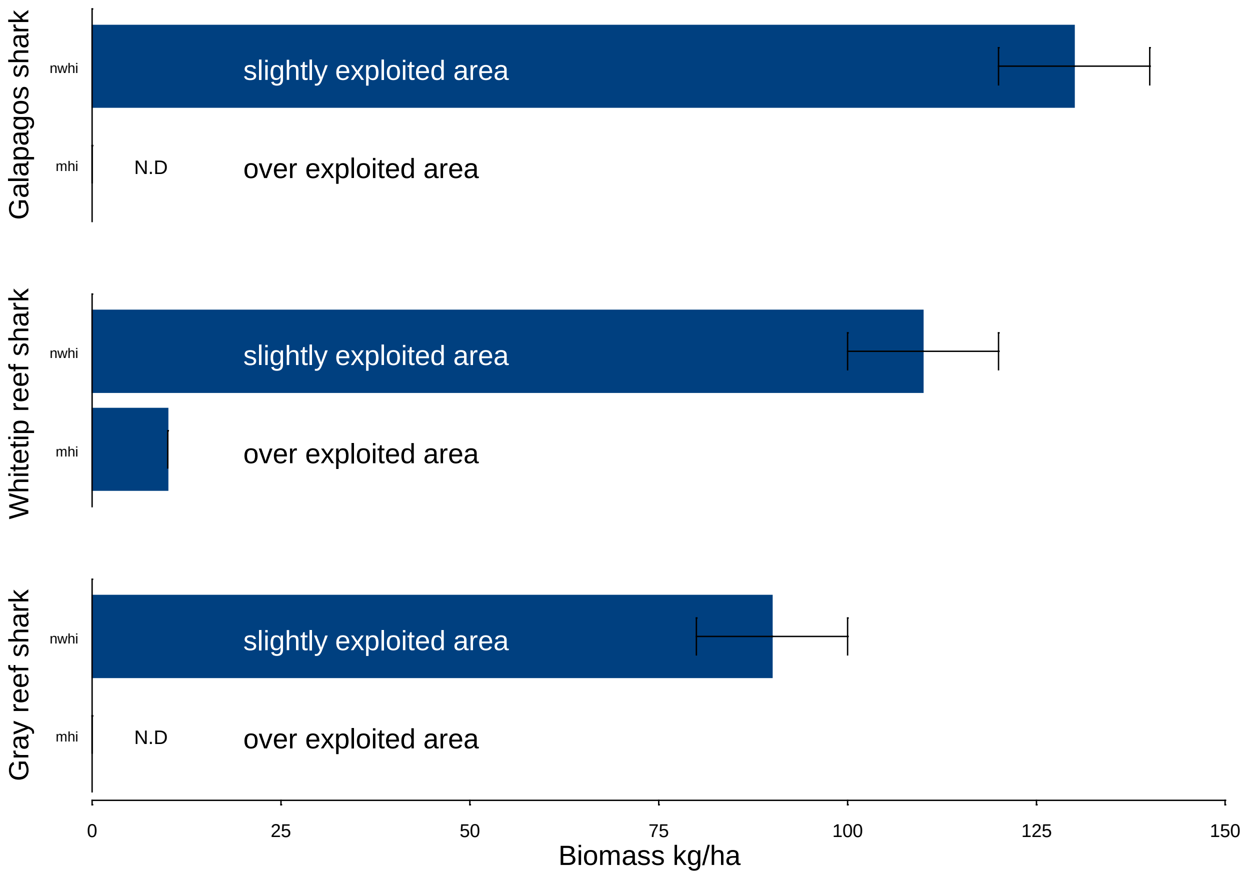

Hammerhead shark
Number of specimens per year
years
Smooth-hound
Number of specimens per year
years
School shark
Number of specimens per year
years
Nursehound
Number of specimens per year
years



Comparative fish biomass (mT/ha)

Loss of Reef Sharks in the Hawaiian Islands

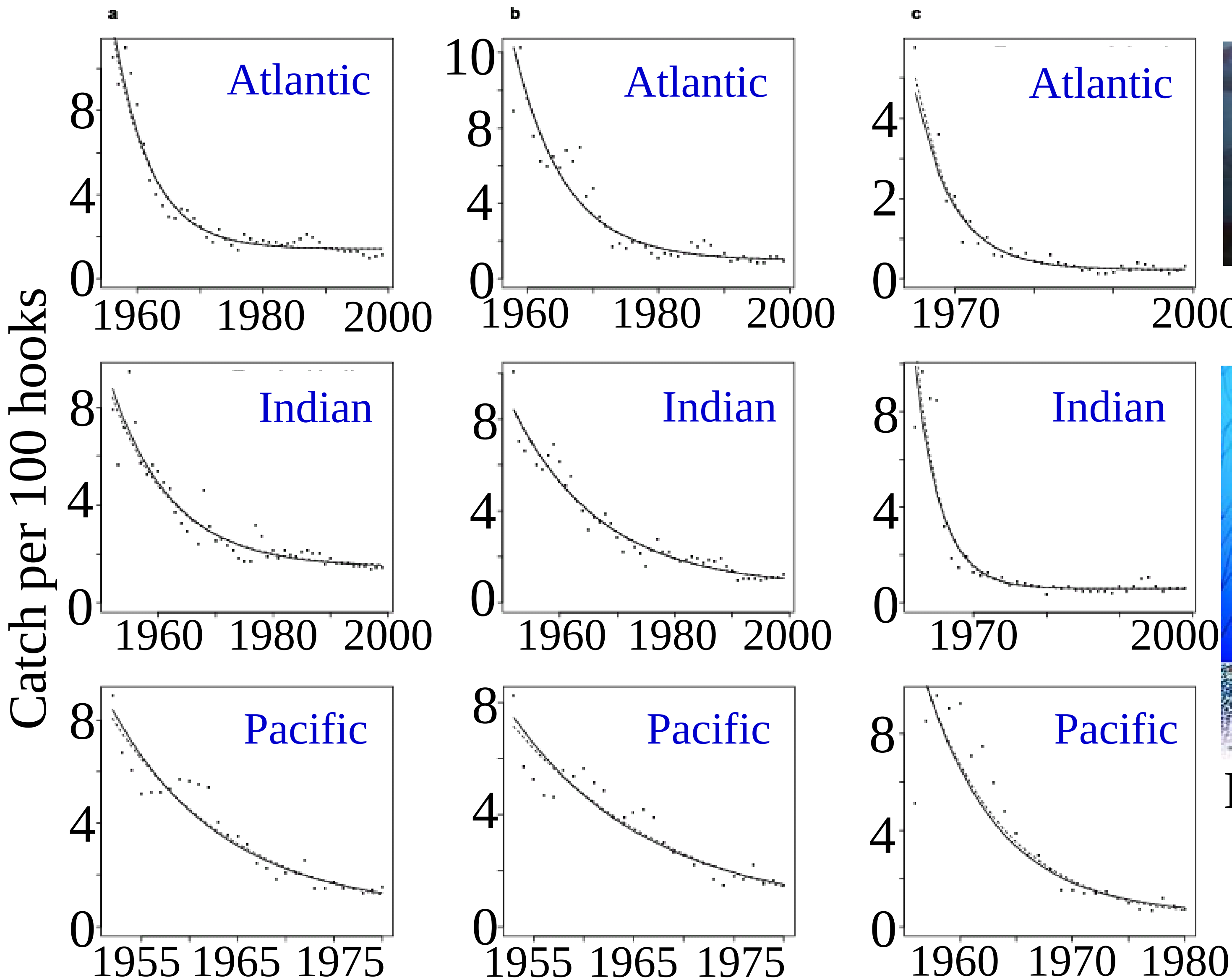
N.W.Hawaiian Islands vs Main Hawaiian Islands



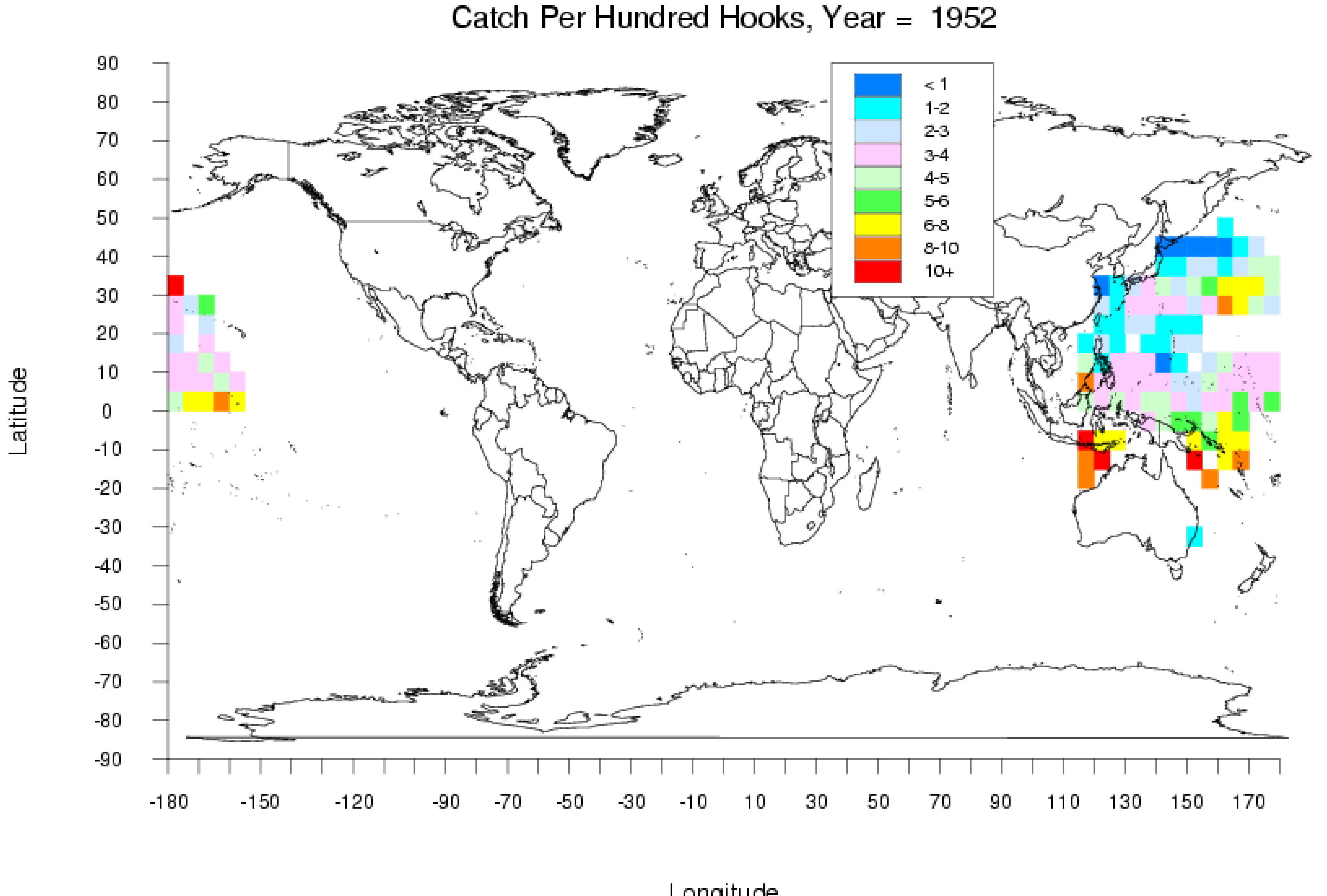
Friedlander A.M. & E.E. DeMartini 2002 - Marine Ecology Progress Series


555
lbs.
LBS.
1135
CABO
BLANCO

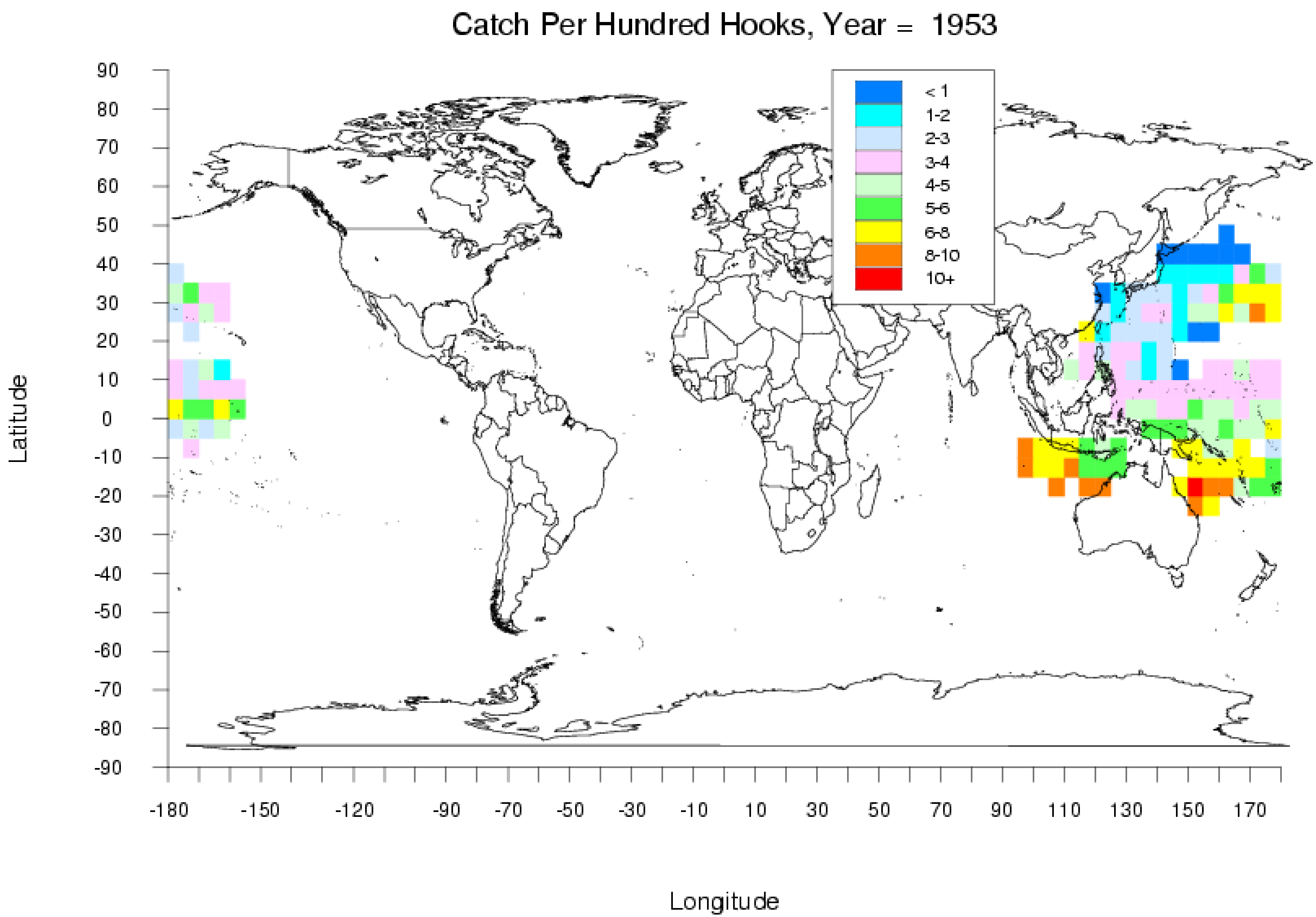
Common patterns of decline

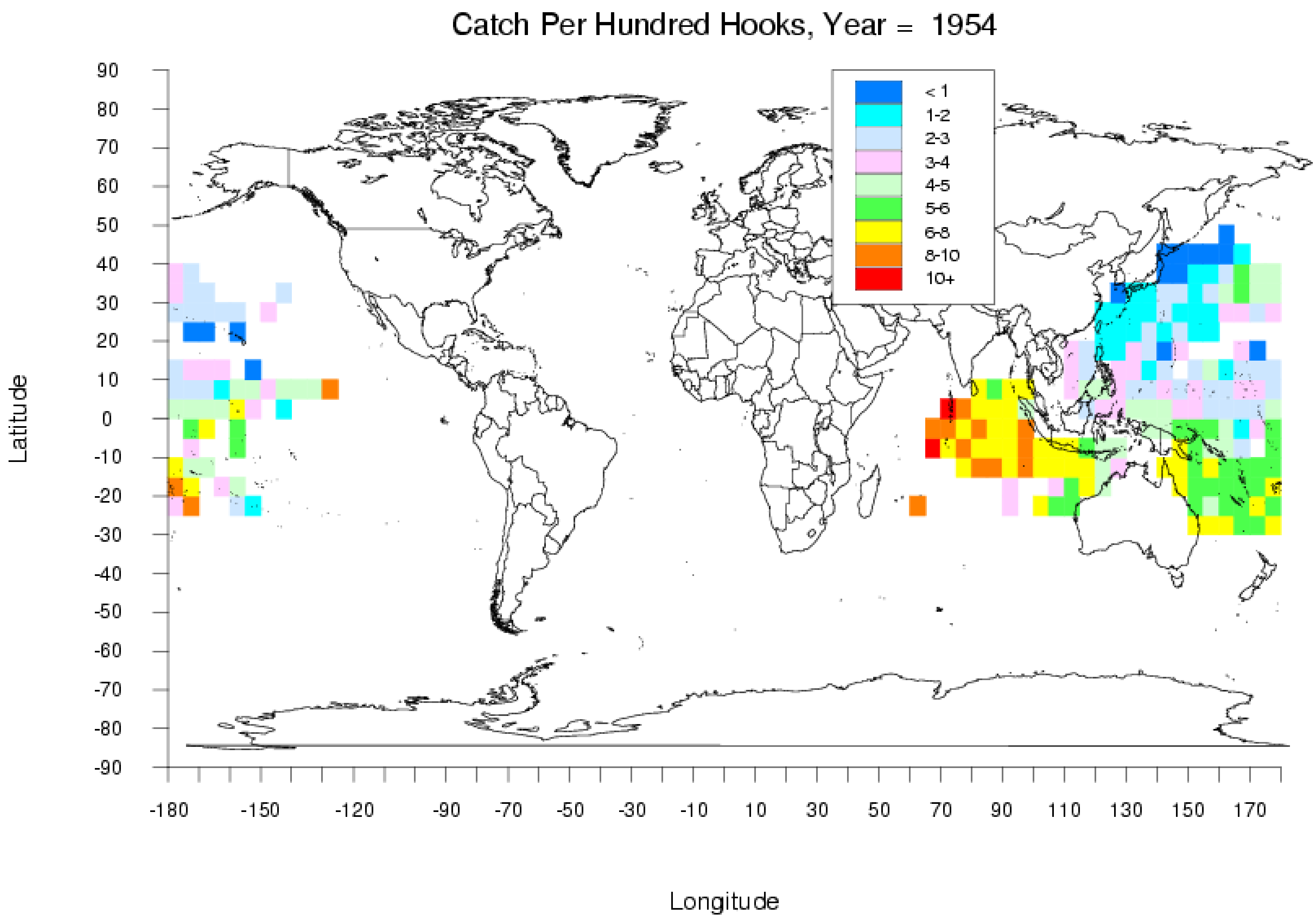


Myers and Worm (2003)



Myers and Worm Nature 2003


Catch Per Hundred Hooks, Year = 1953
< 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 = 1954
< 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
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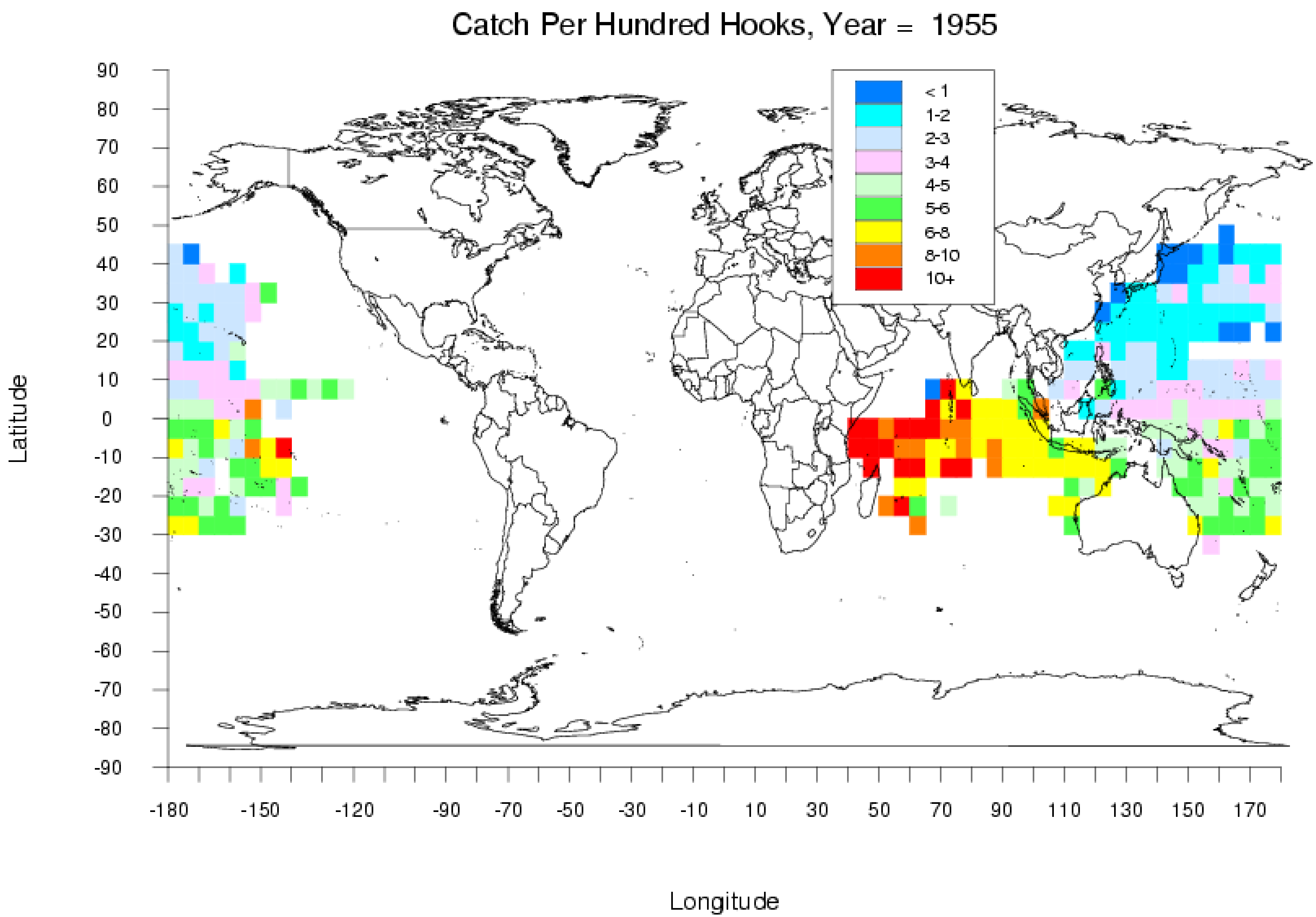
70
90
110
130
150
170



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
Longitude
-180
-150
-120
-90
-70
-50
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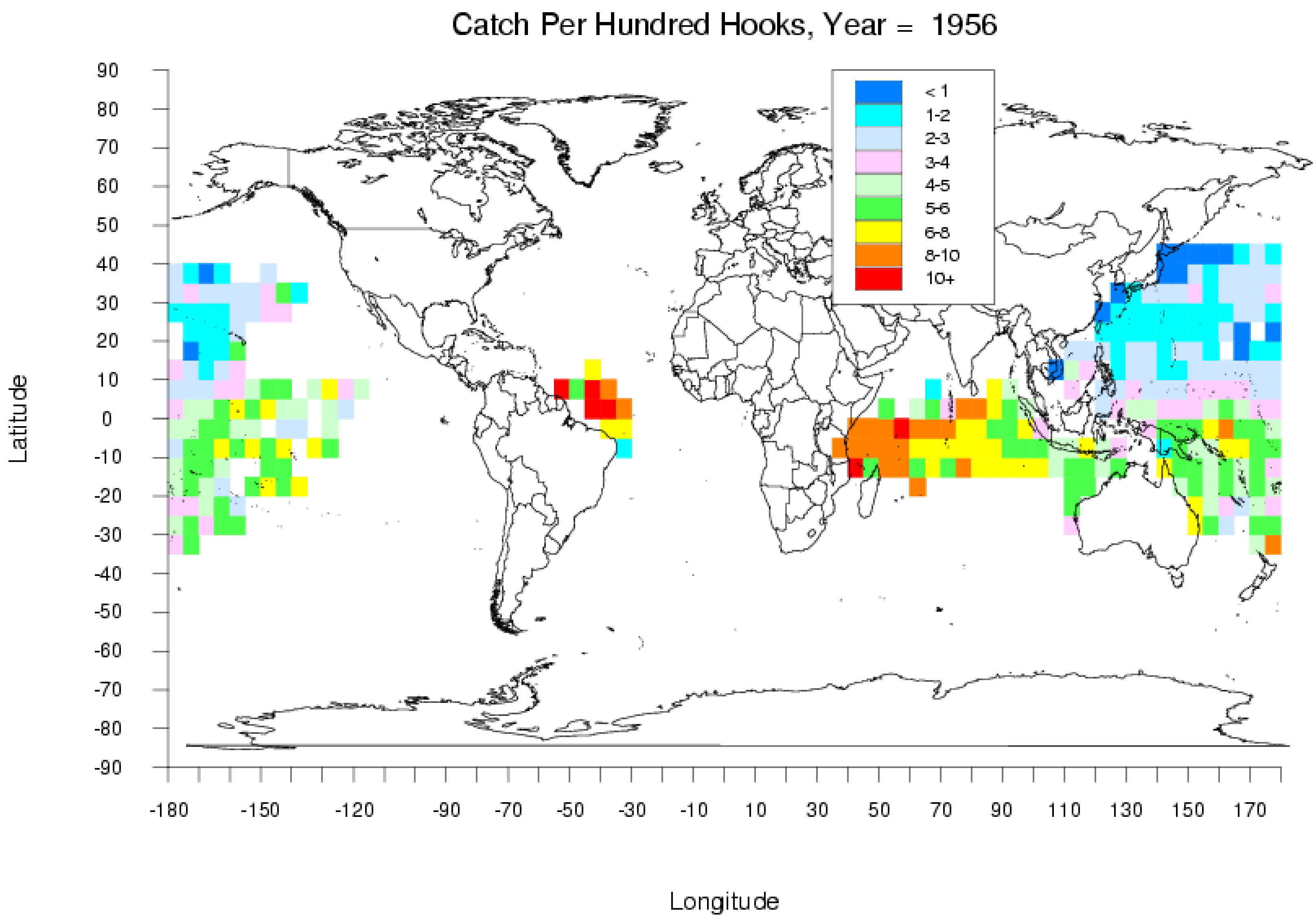
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1956
< 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
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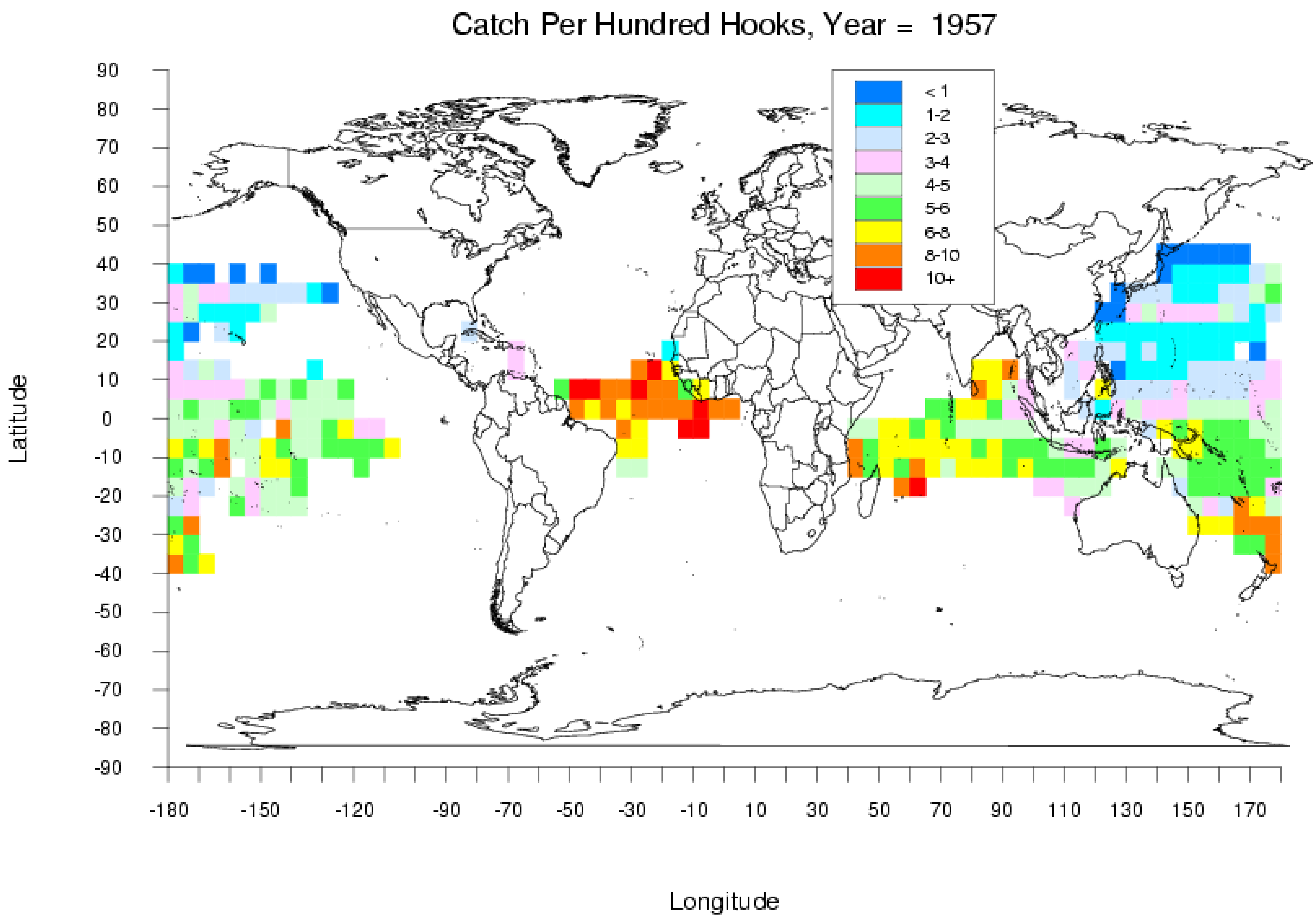
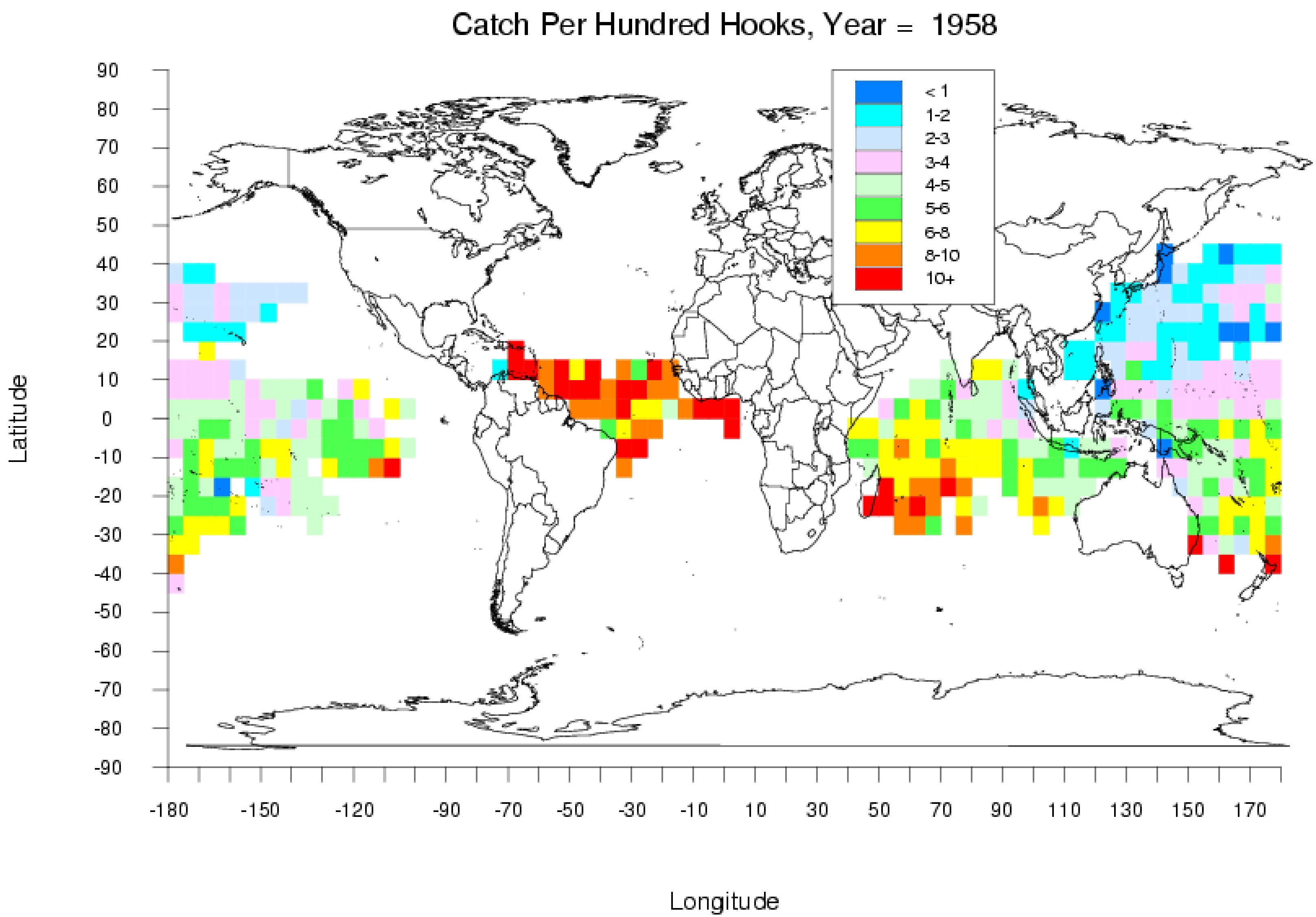
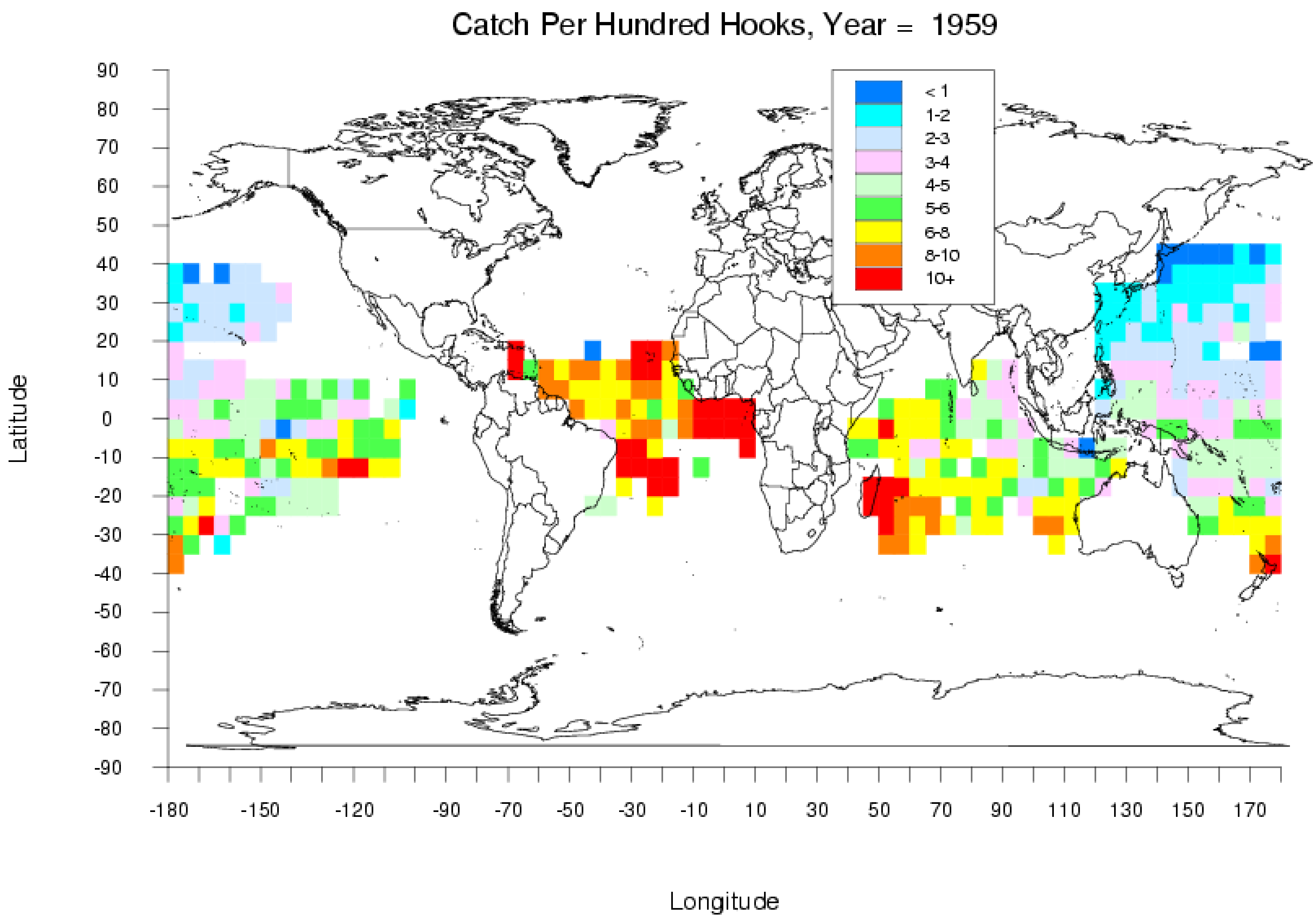
70
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1957
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 = 1958
< 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 = 1959
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
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-70
-50
-30
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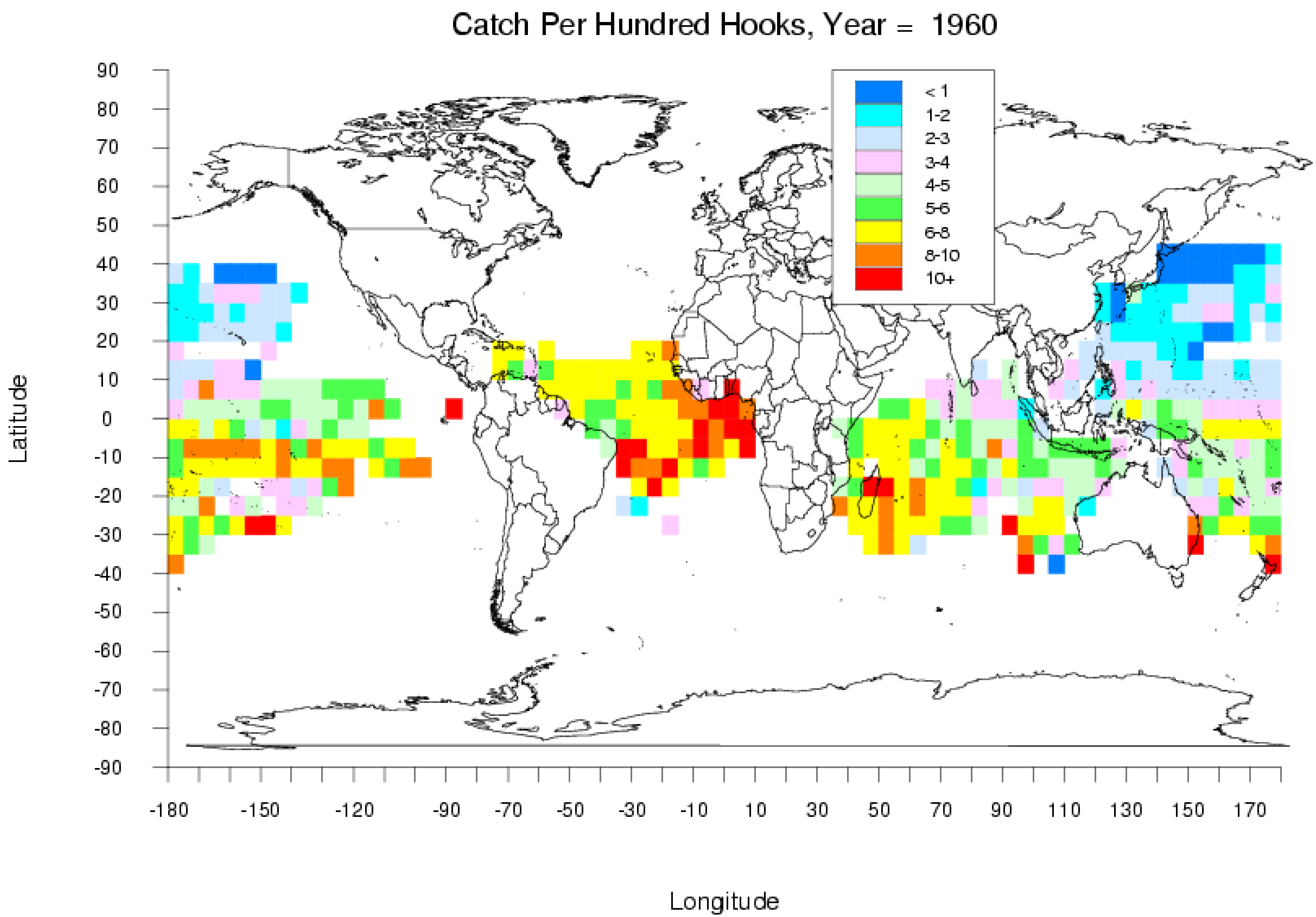
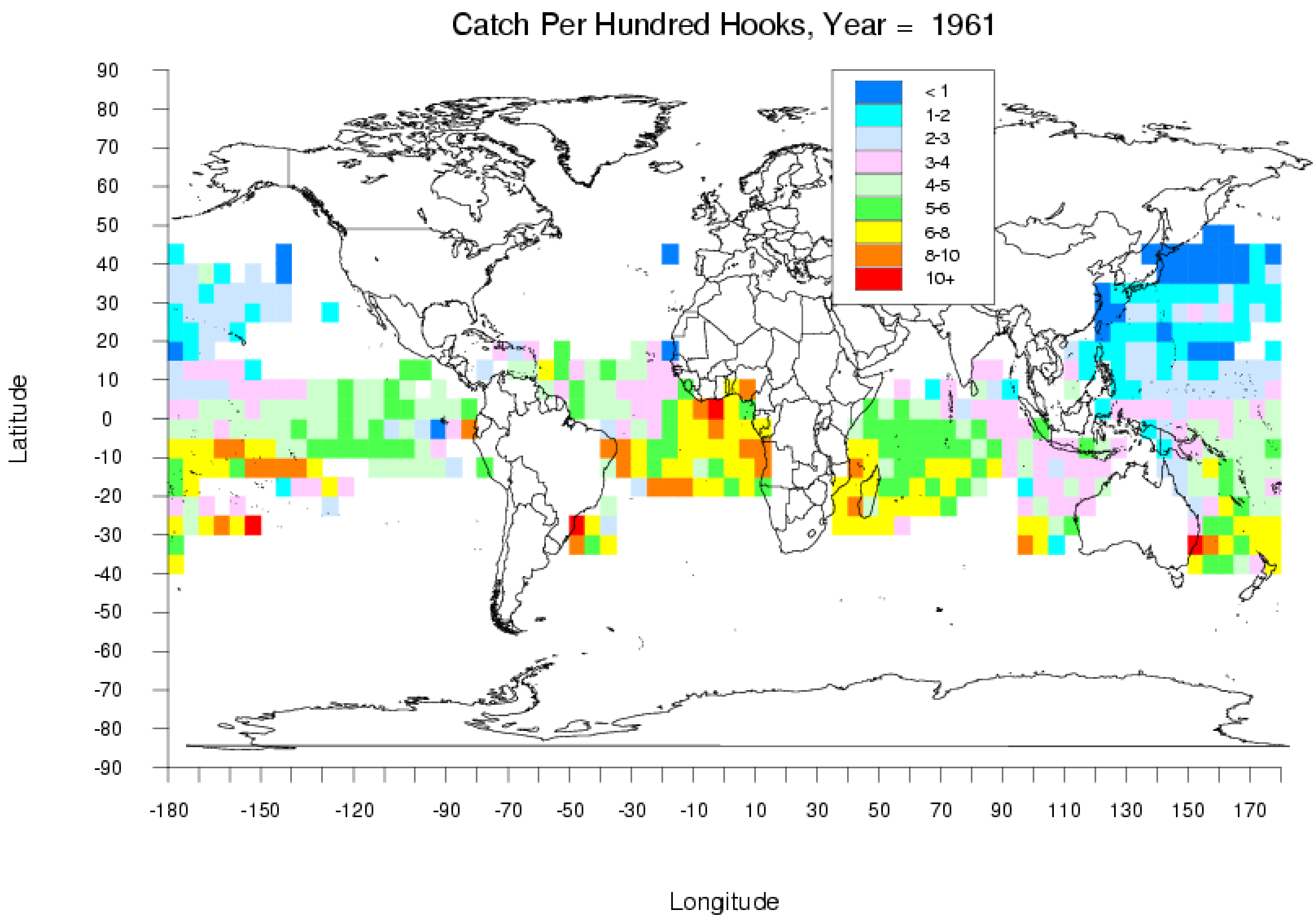
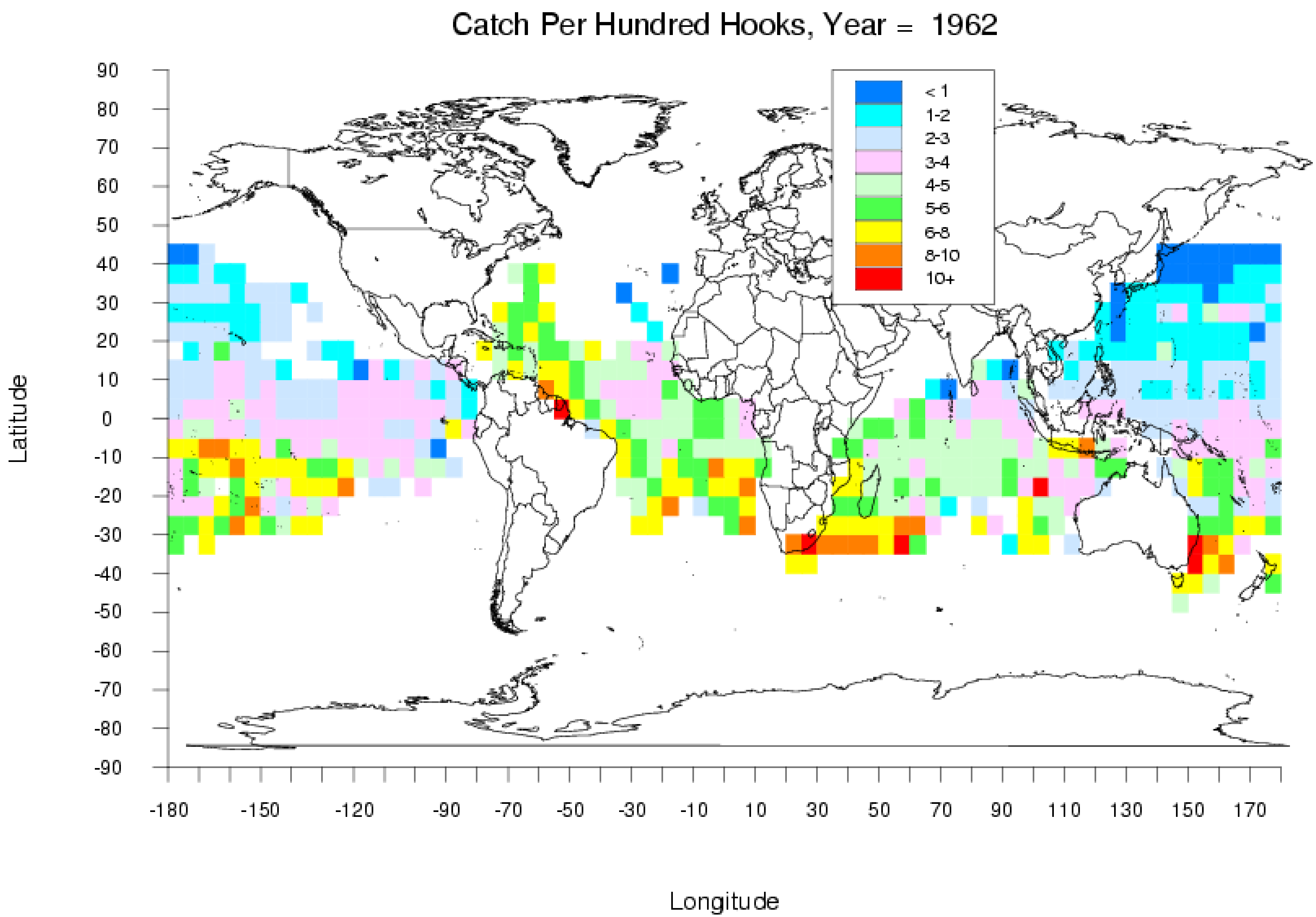
90
110
130
150
170



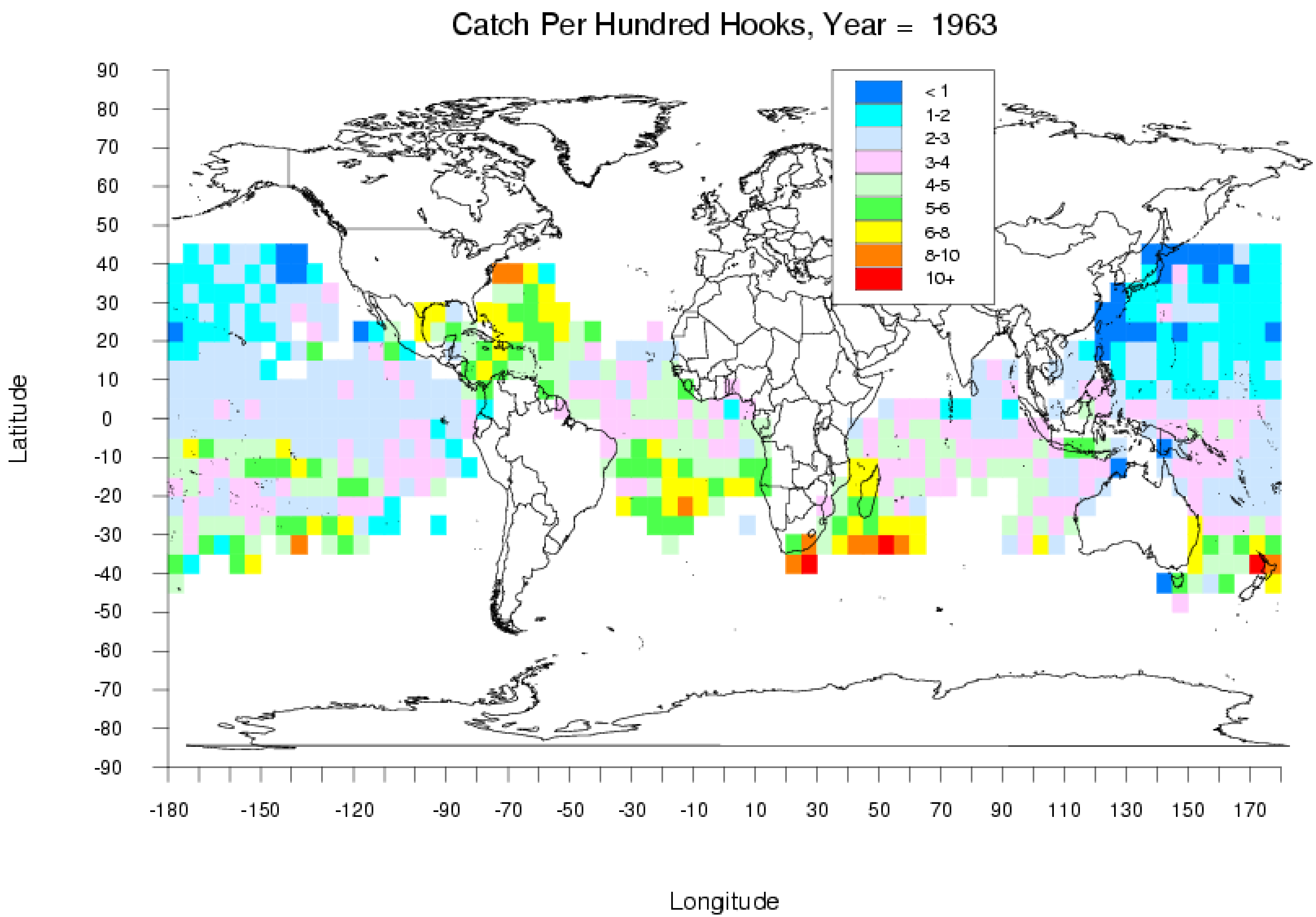
Catch Per Hundred Hooks, Year = 1960
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude



Catch Per Hundred Hooks, Year = 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
< 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 = 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
Longitude
-180
-150
-120
-90
-70
-50
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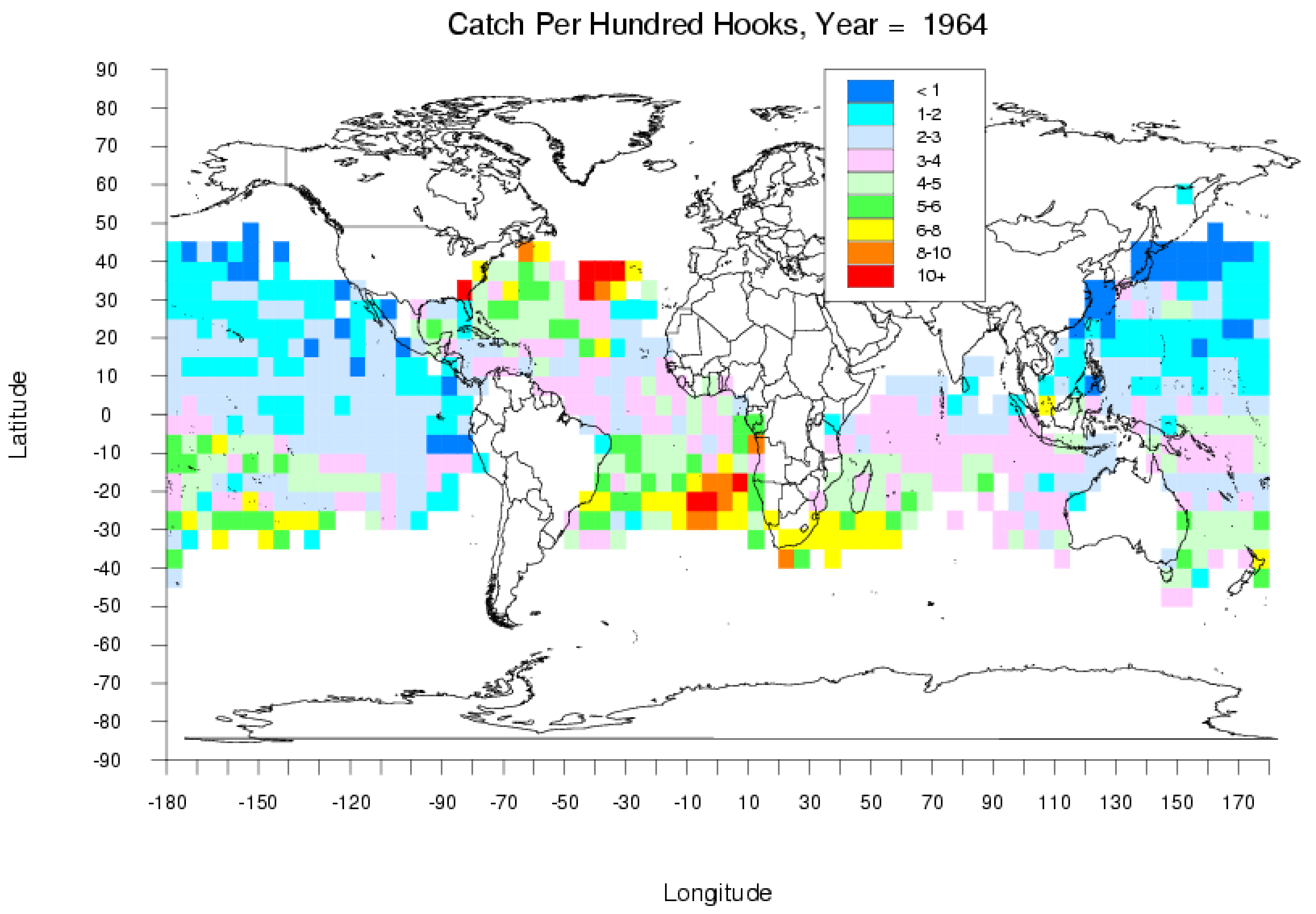
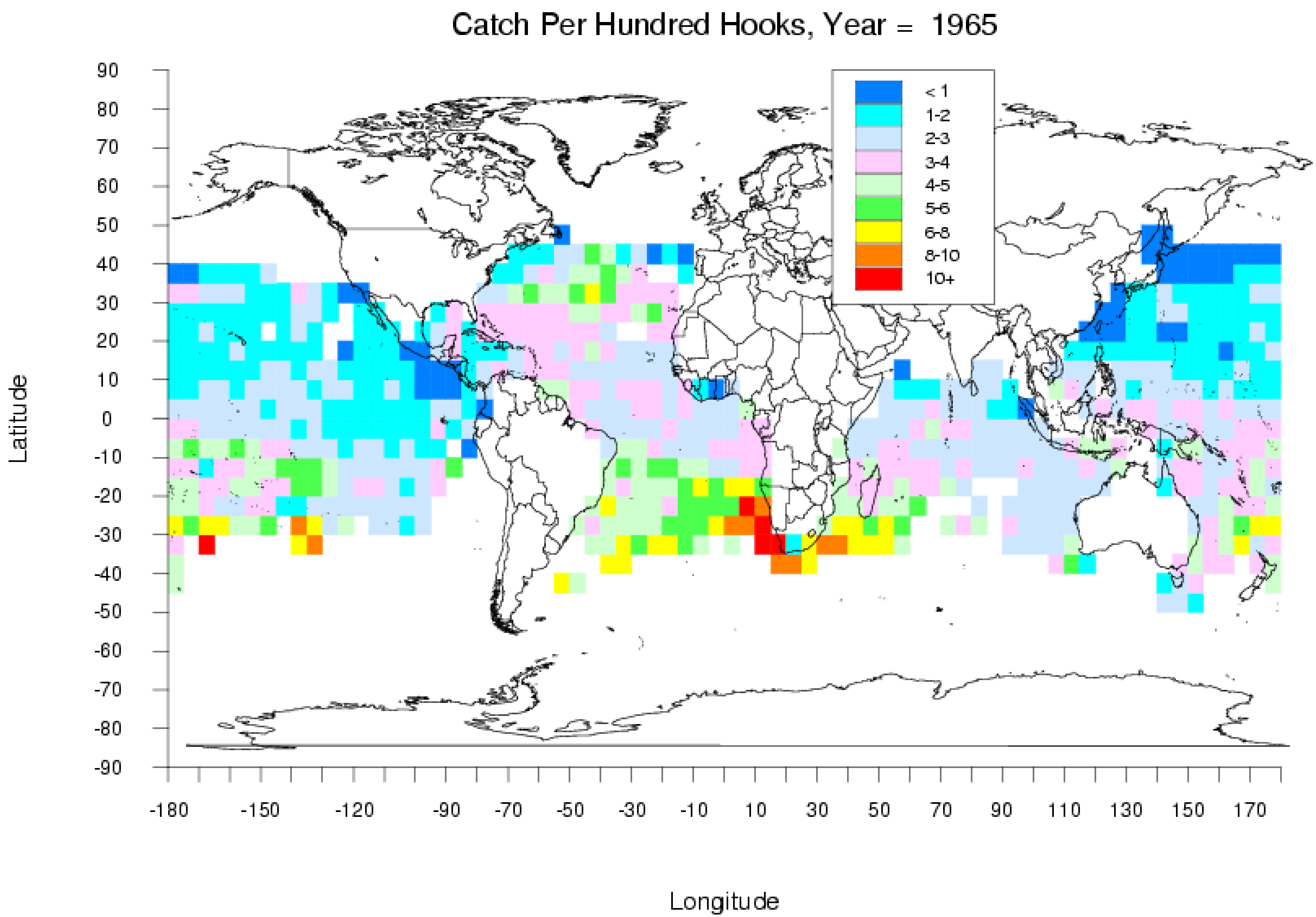
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1964
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
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+


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
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-70
-50
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150
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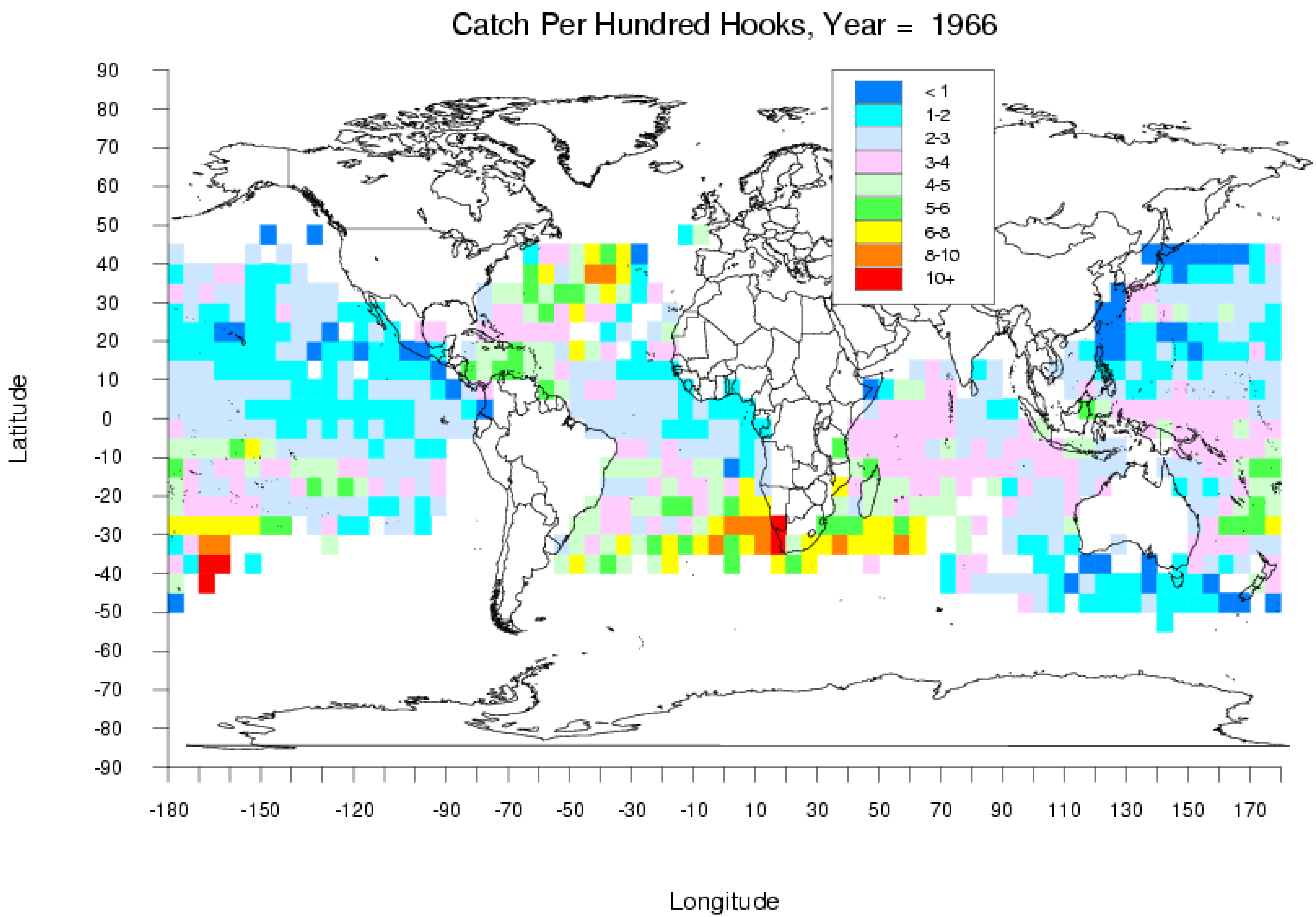
Catch Per Hundred Hooks, Year = 1966
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
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-40
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-60
-70
-80
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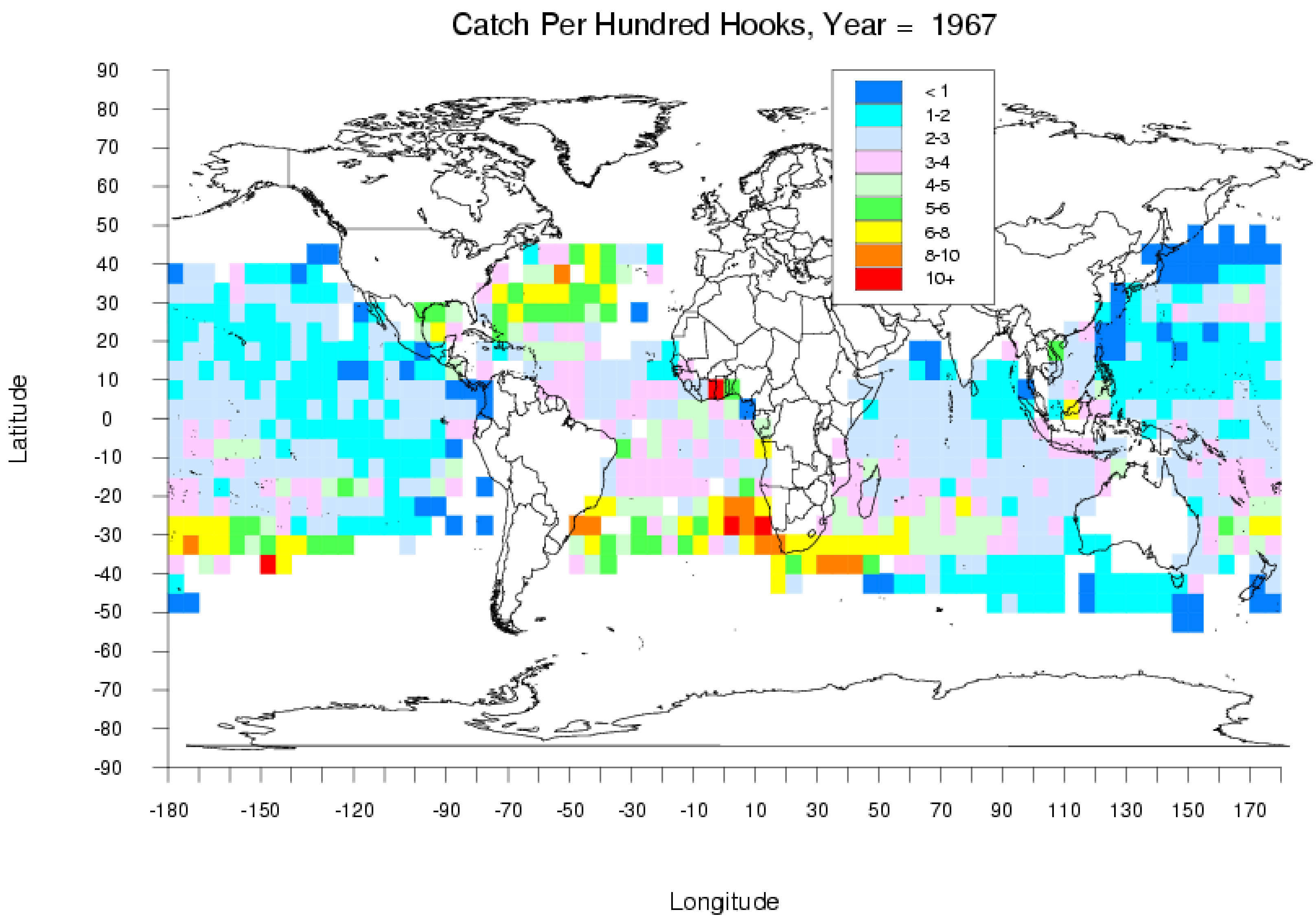
Catch Per Hundred Hooks, Year = 1967
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
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150
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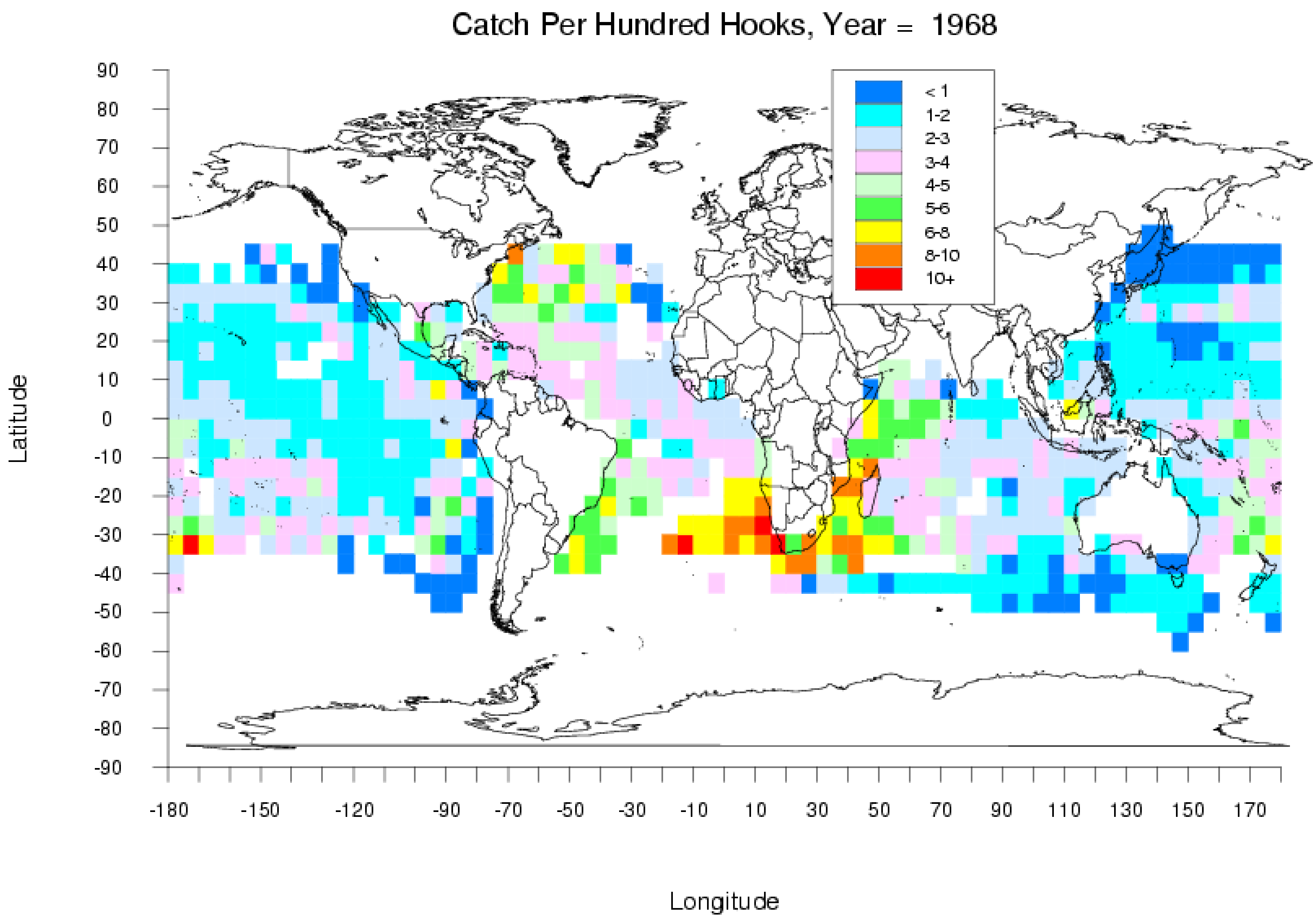
Catch Per Hundred Hooks, Year = 1968
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
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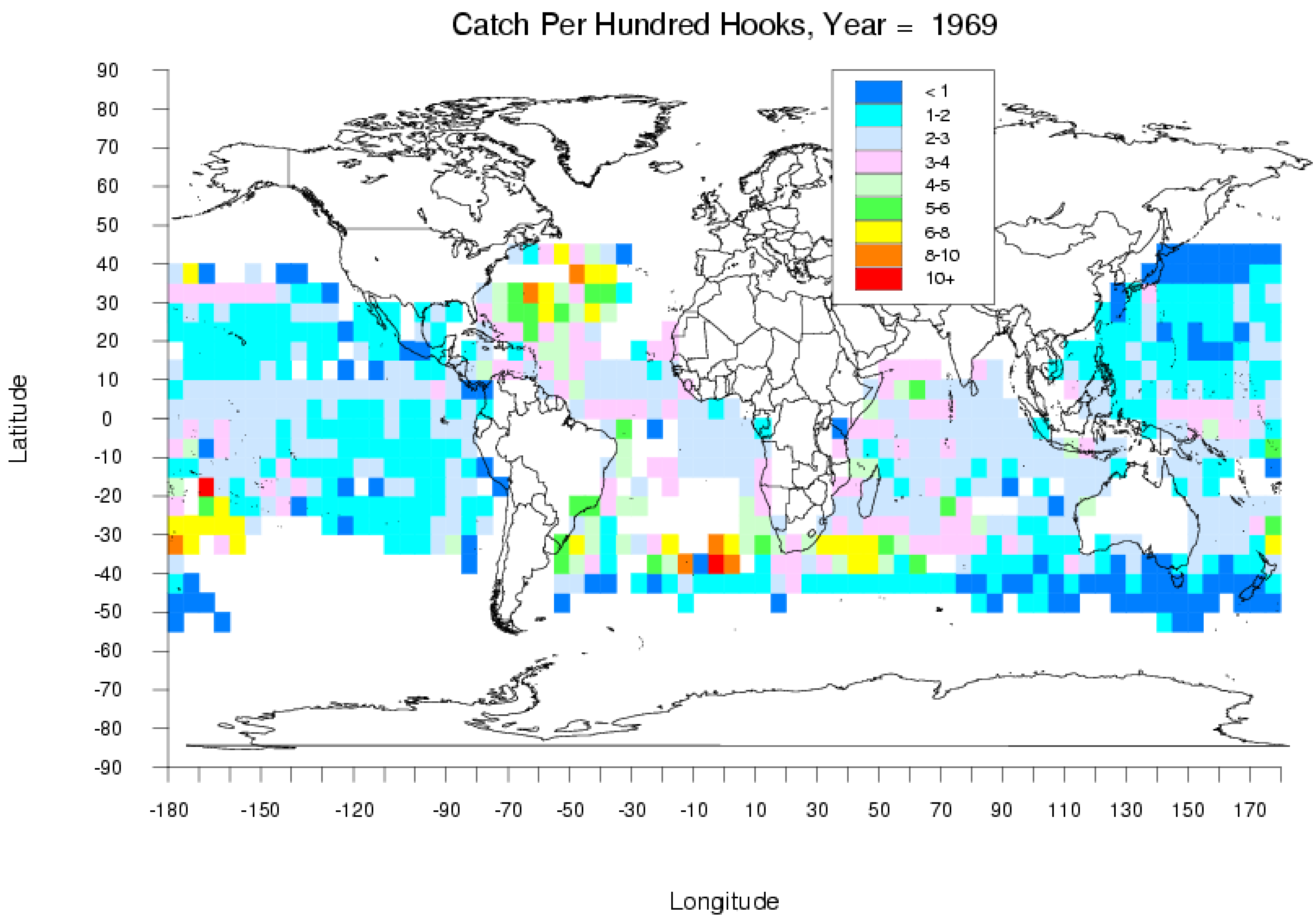
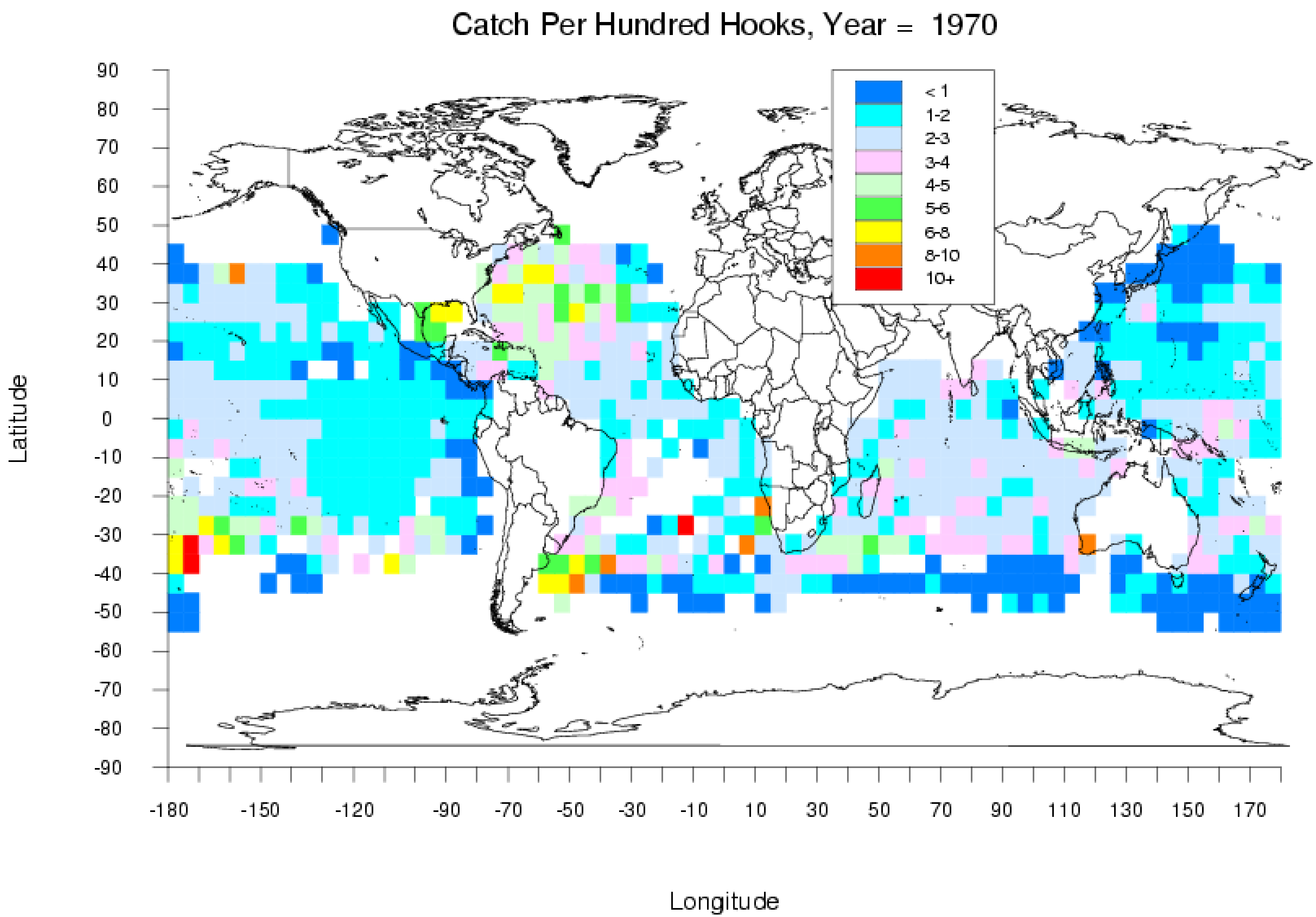
90
110
130
150
170



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
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
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-150
-120
-90
-70
-50
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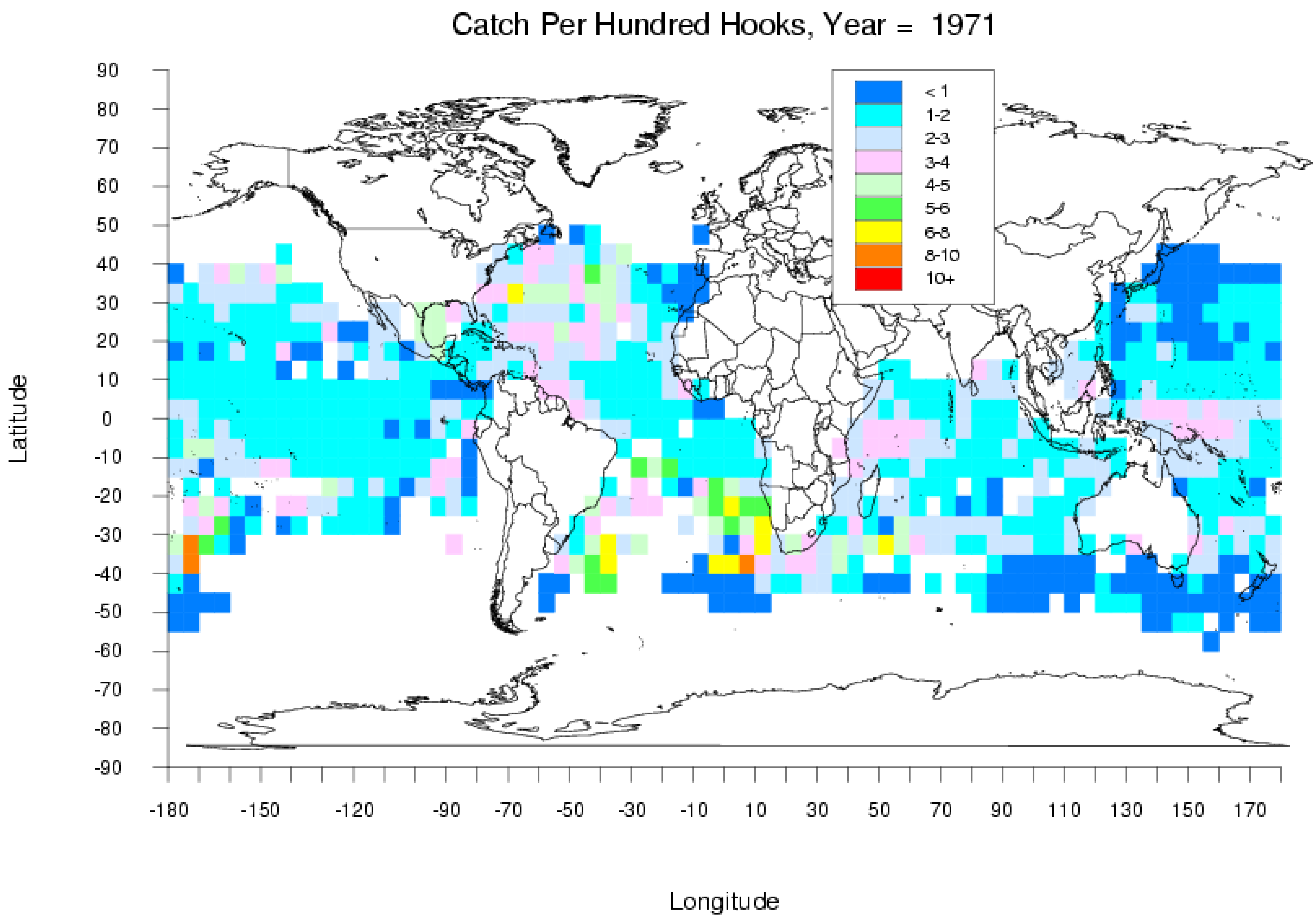
90
110
130
150
170


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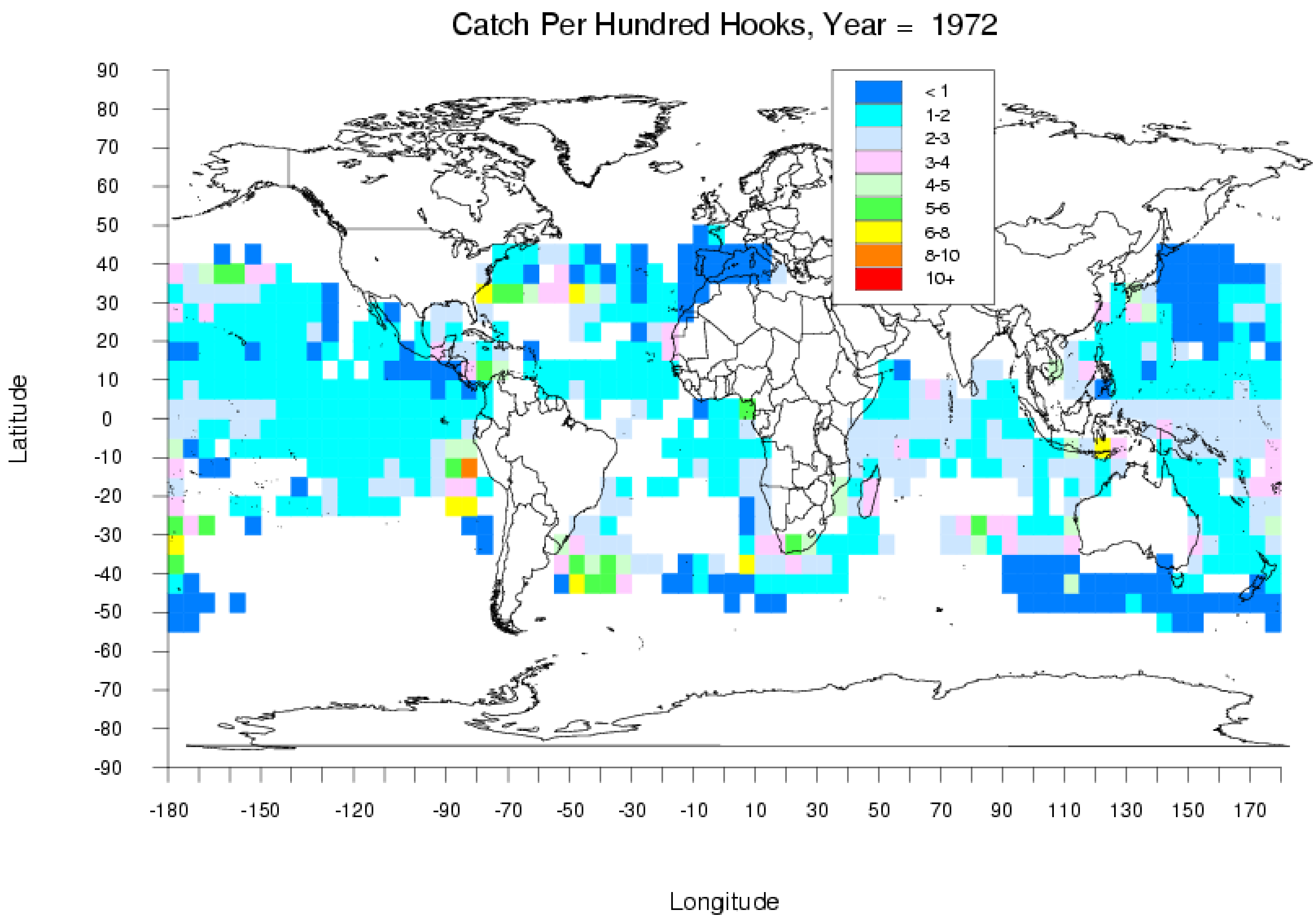
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1972
< 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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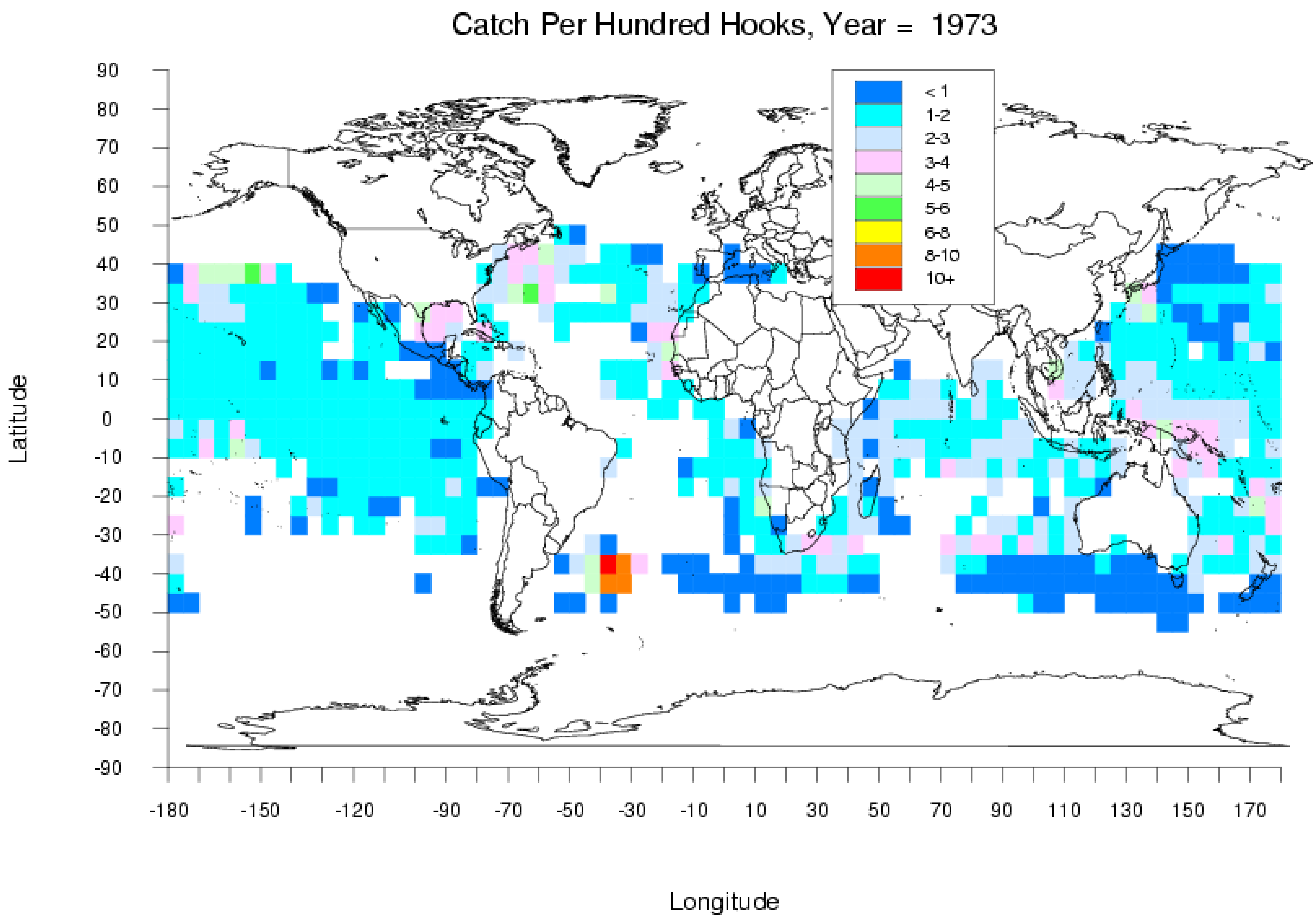
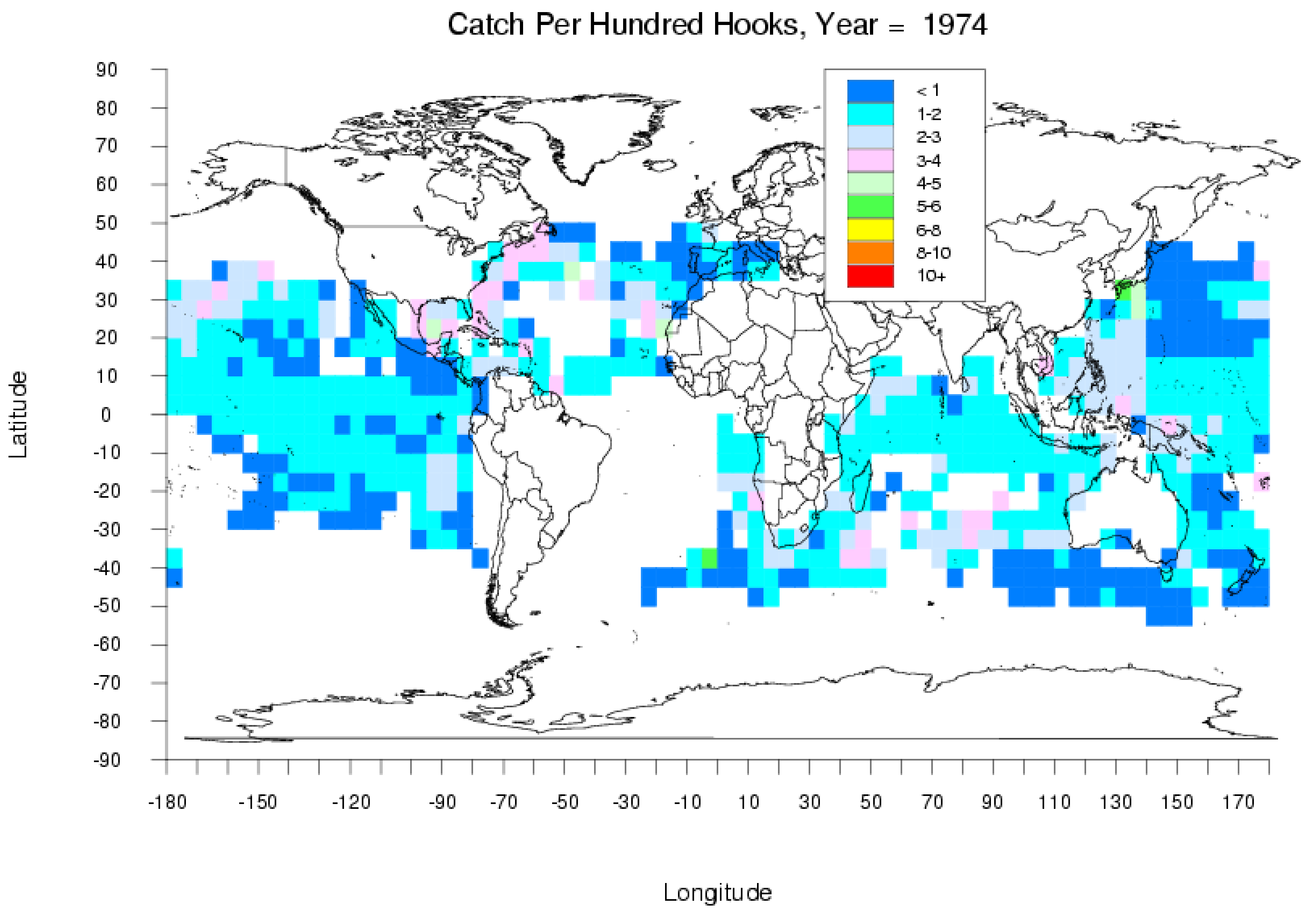
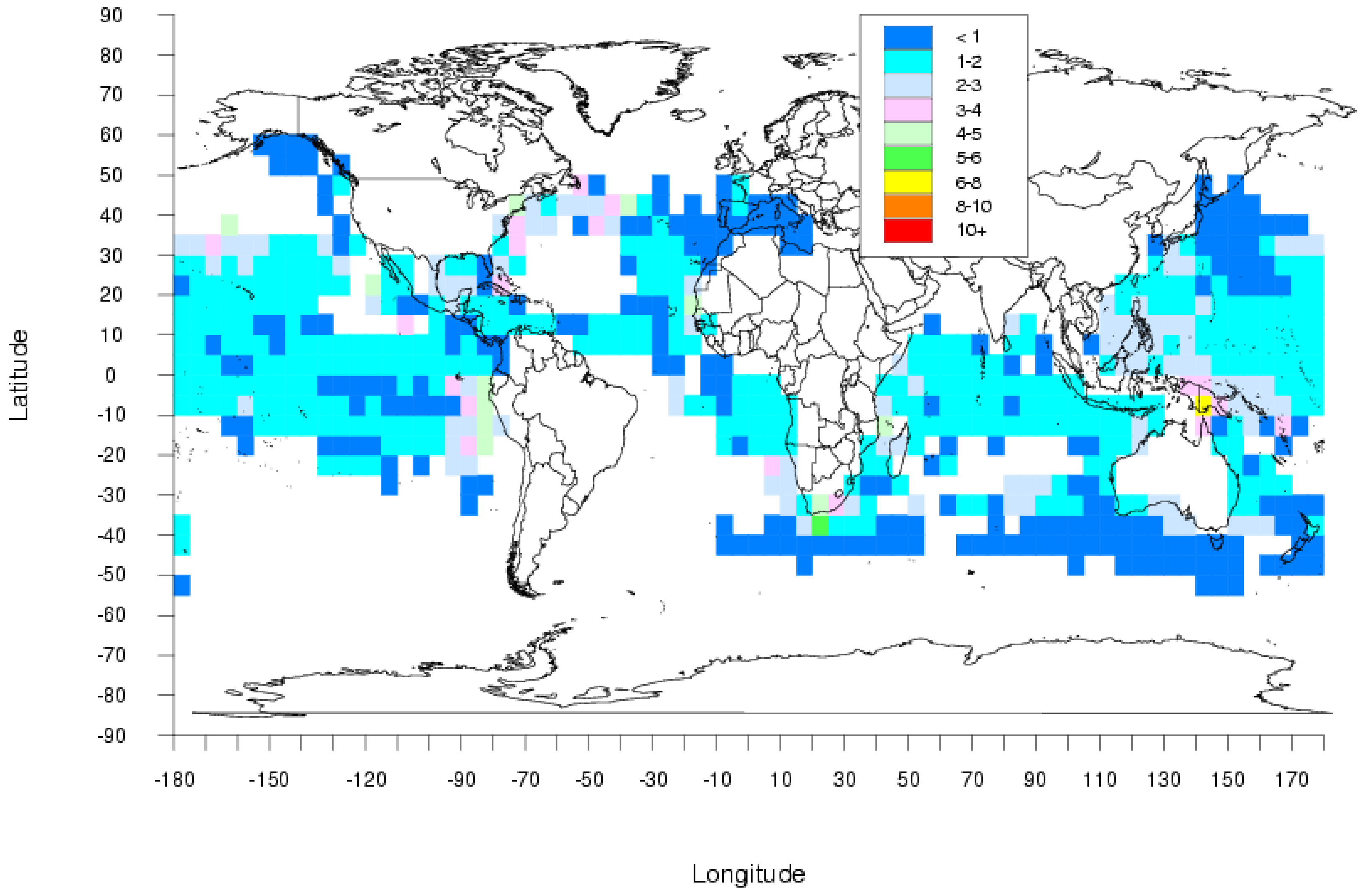
30
50
70
90
110
130
150
170

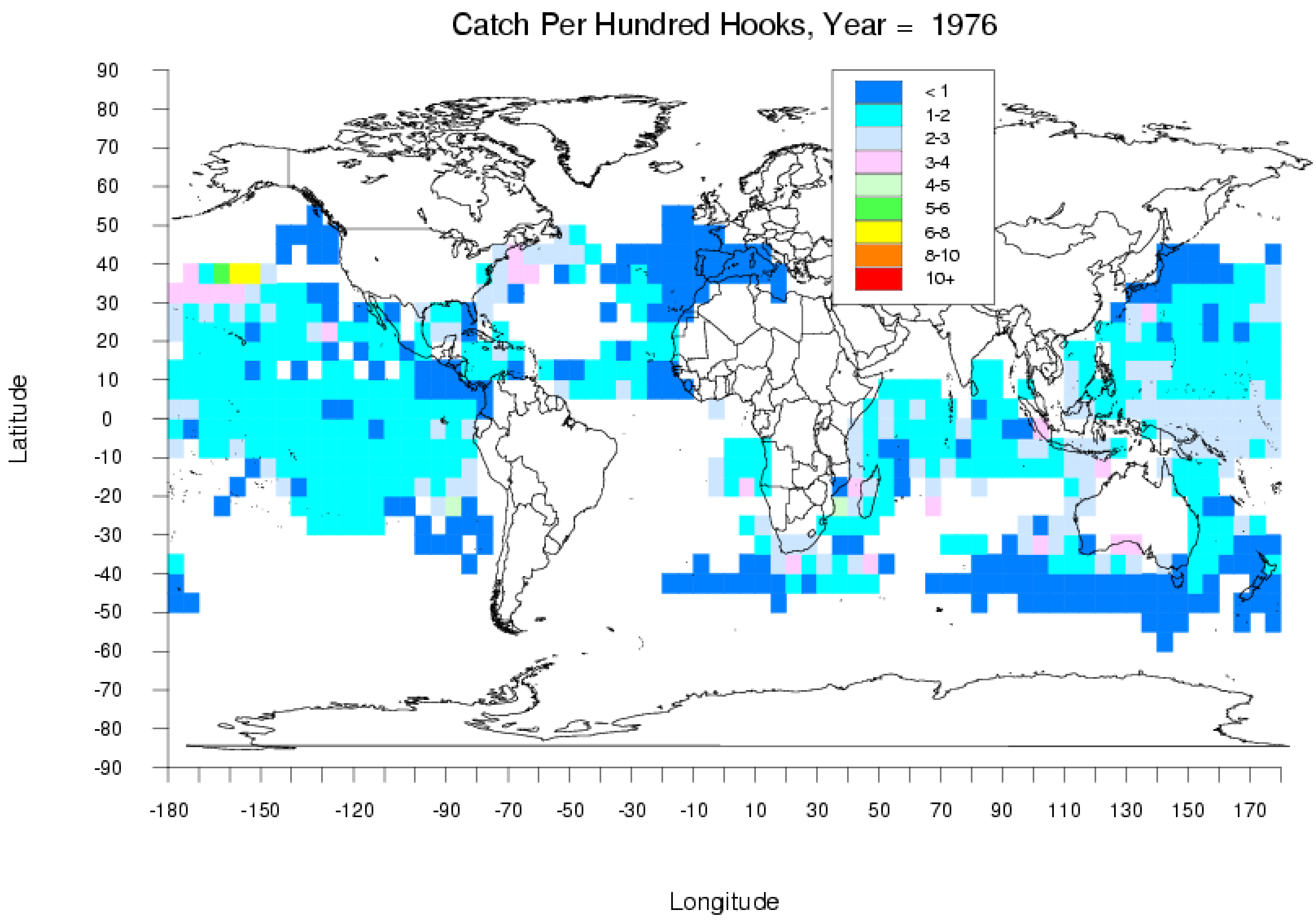


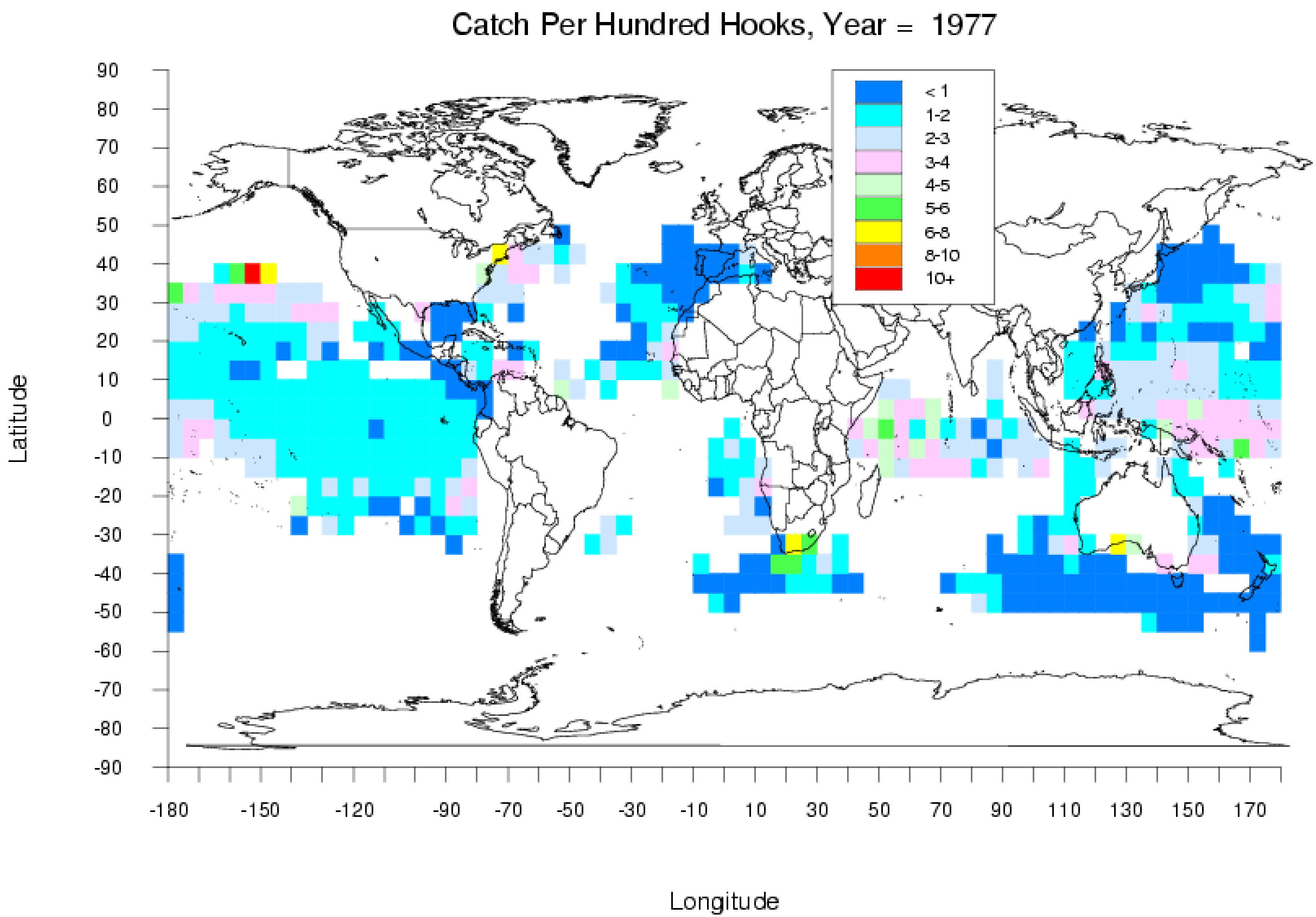
Catch Per Hundred Hooks, Year = 1973
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude


Catch Per Hundred Hooks, Year = 1974
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+

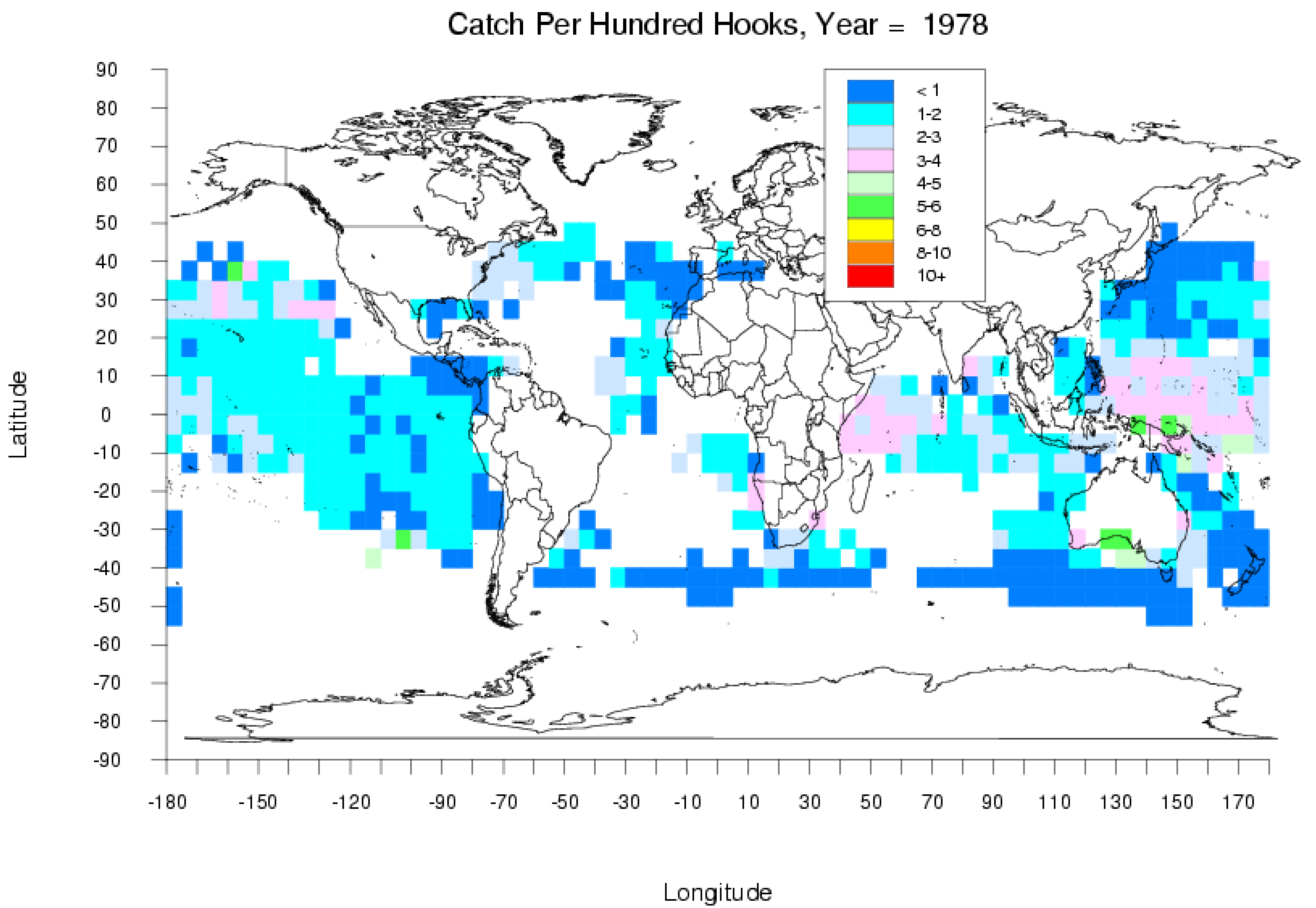
Catch Per Hundred Hooks, Year = 1975

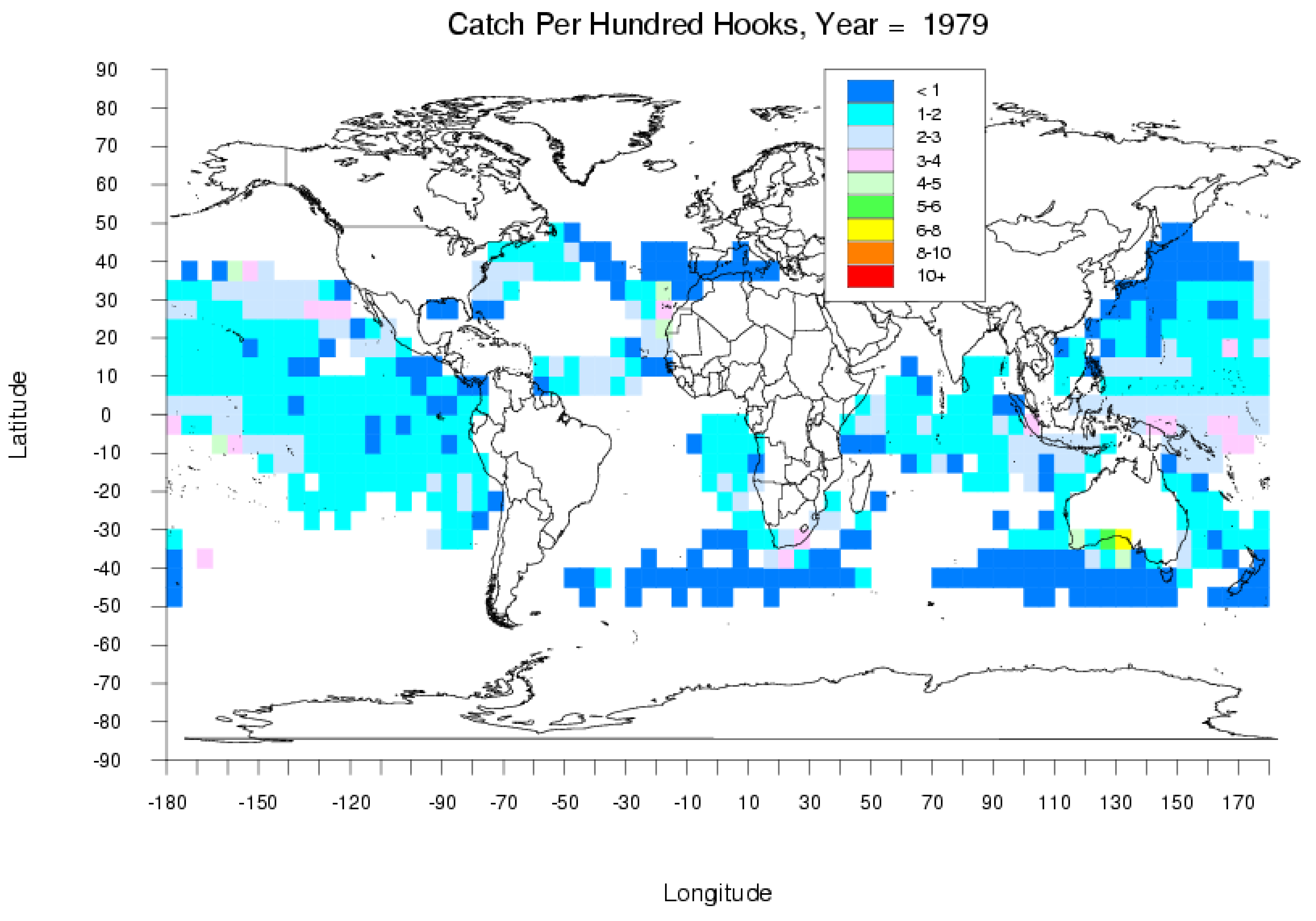


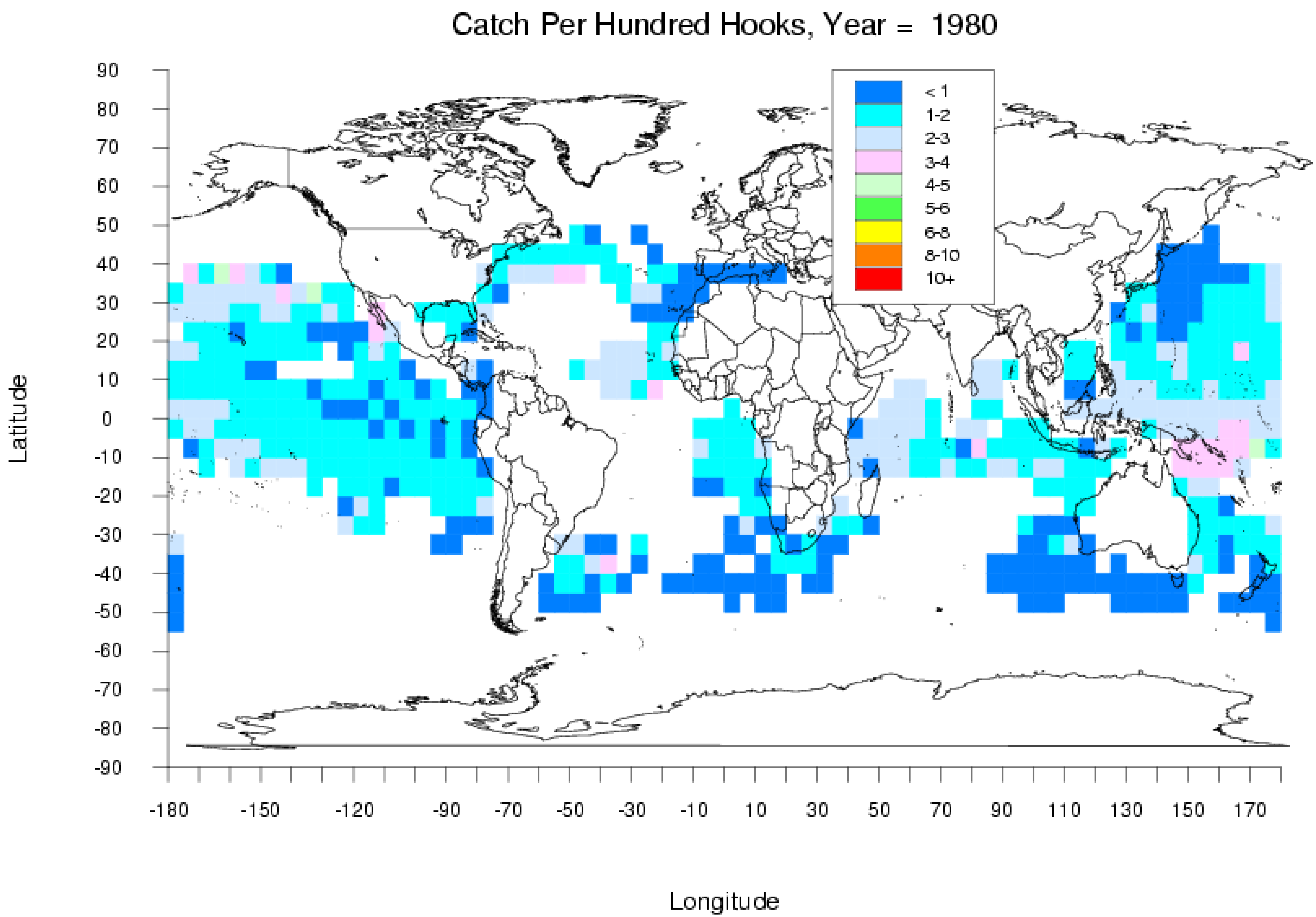

Catch Per Hundred Hooks, Year = 1976
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170



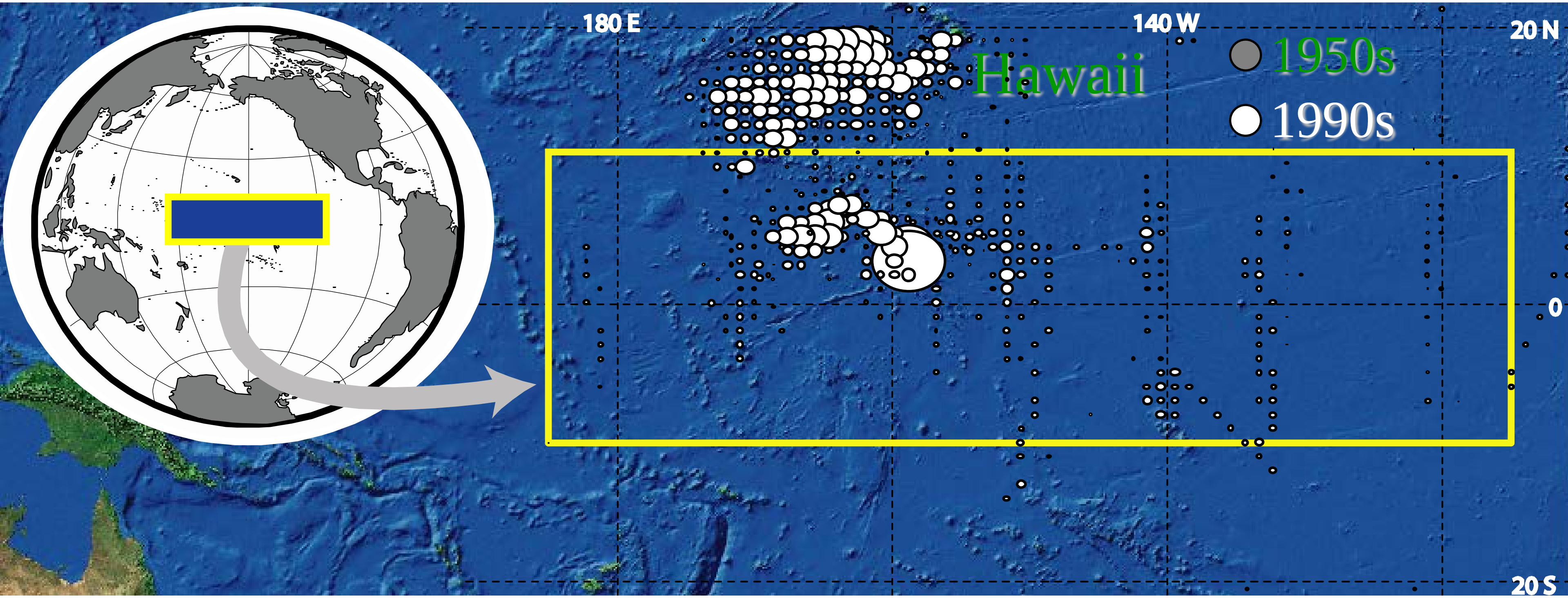
Catch Per Hundred Hooks, Year = 1977
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170


Catch Per Hundred Hooks, Year = 1978
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
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

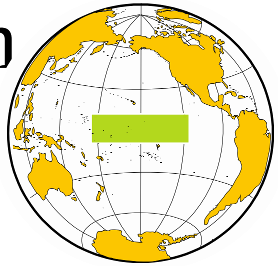

Catch Per Hundred Hooks, Year = 1979
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

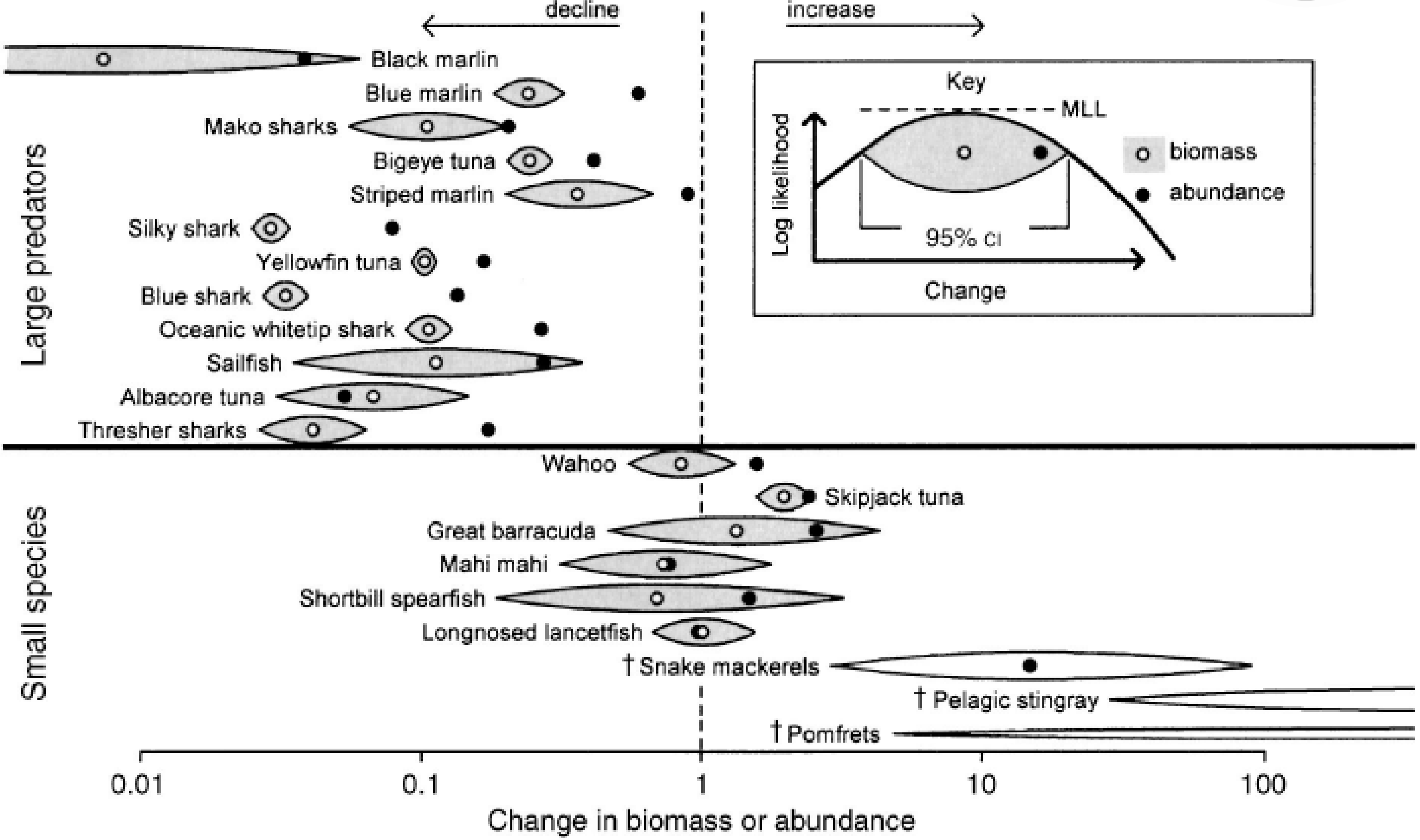

Catch Per Hundred Hooks, Year = 1980
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

Study area



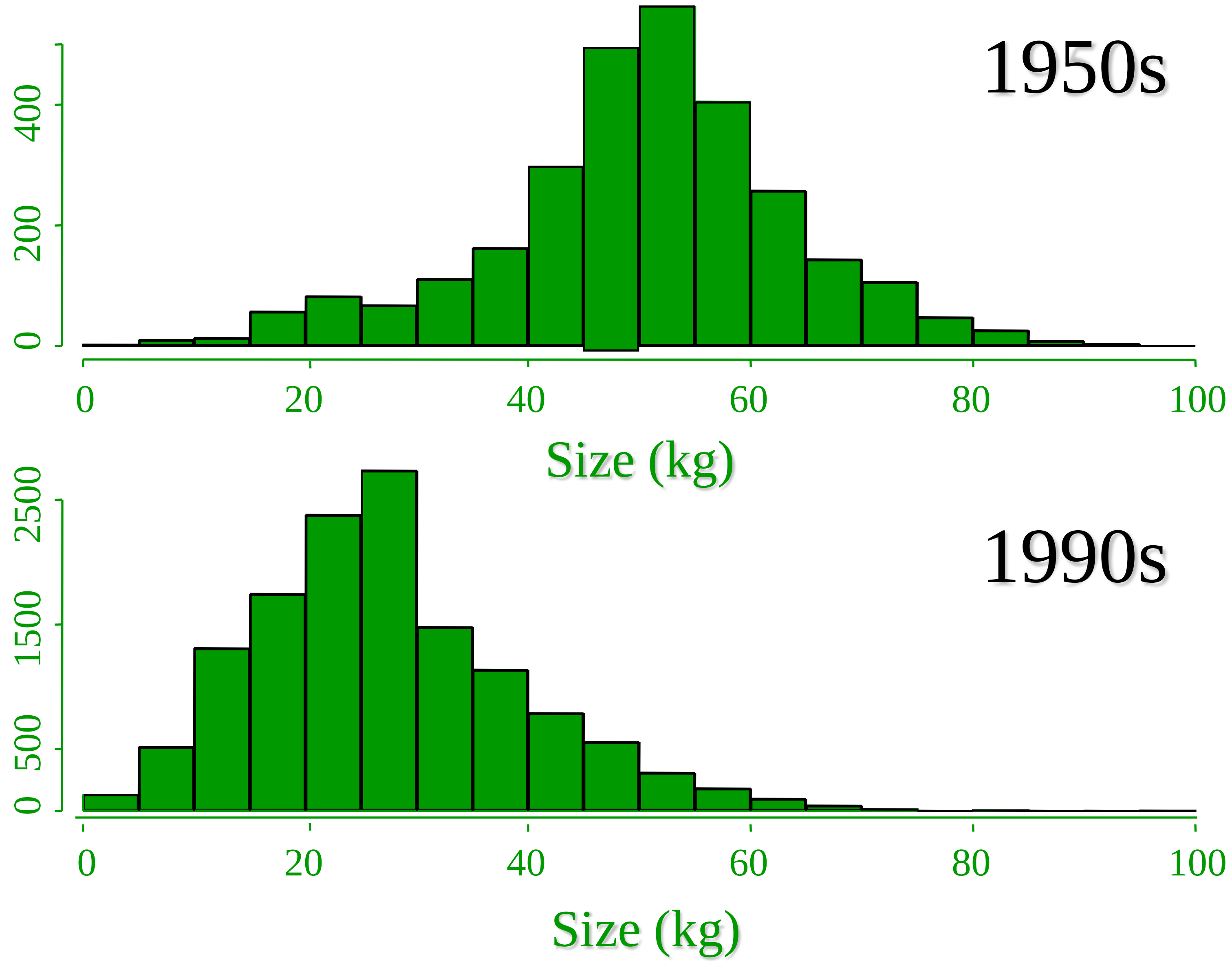
Analysis repeated using independent research data





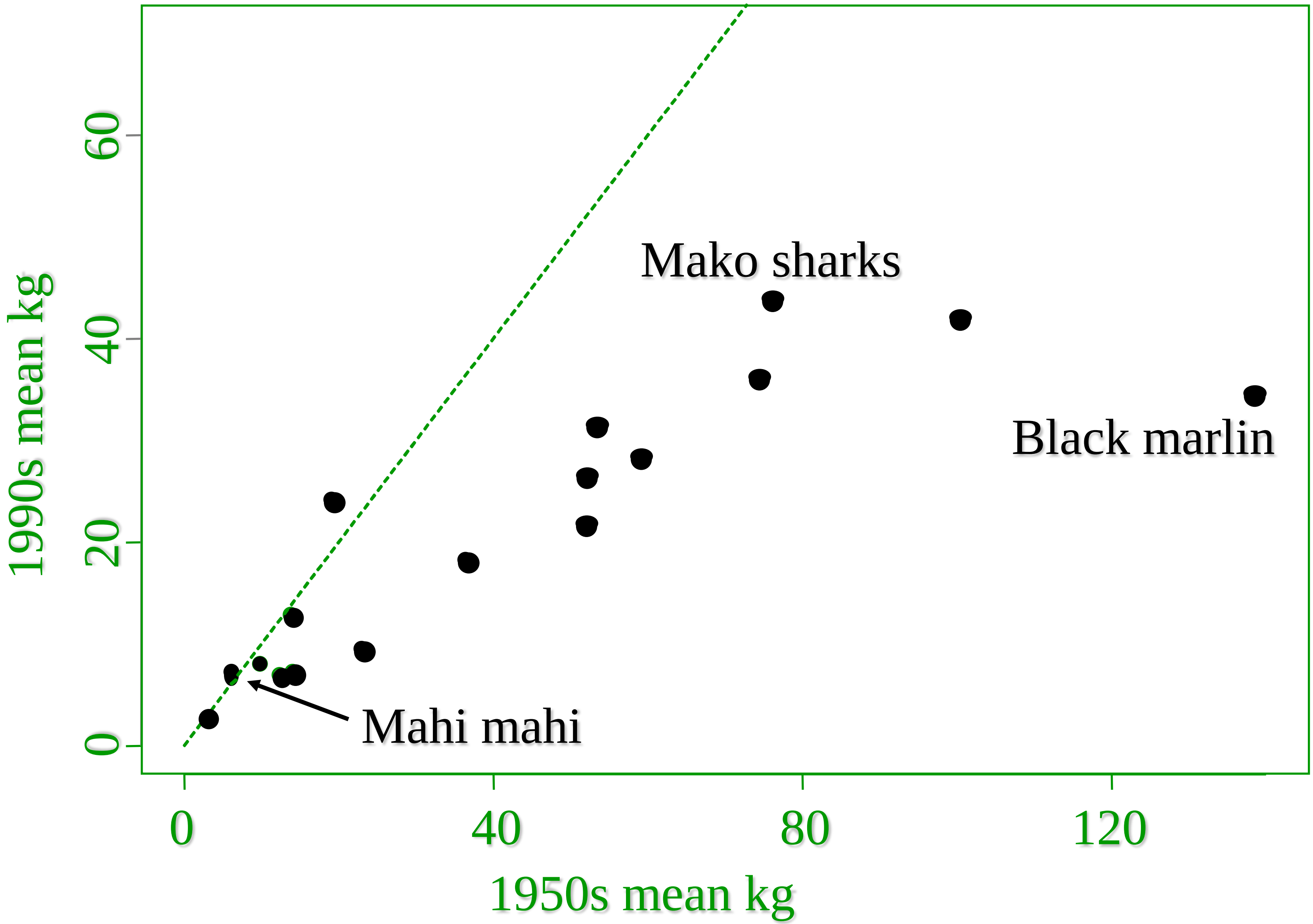
Ward and Myers 2005 Eology

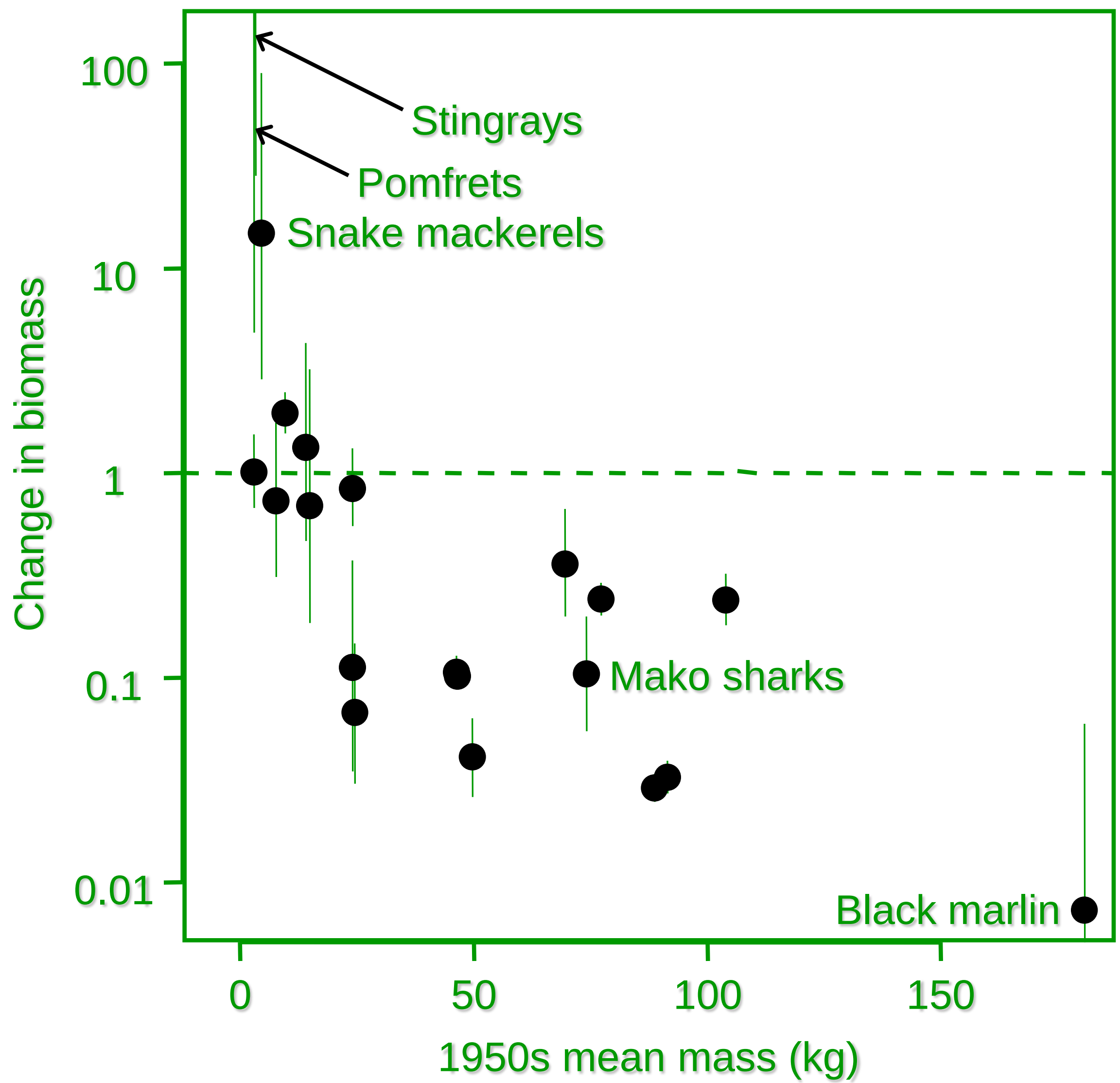
These estimates are conservative: 2 (fish are smaller)



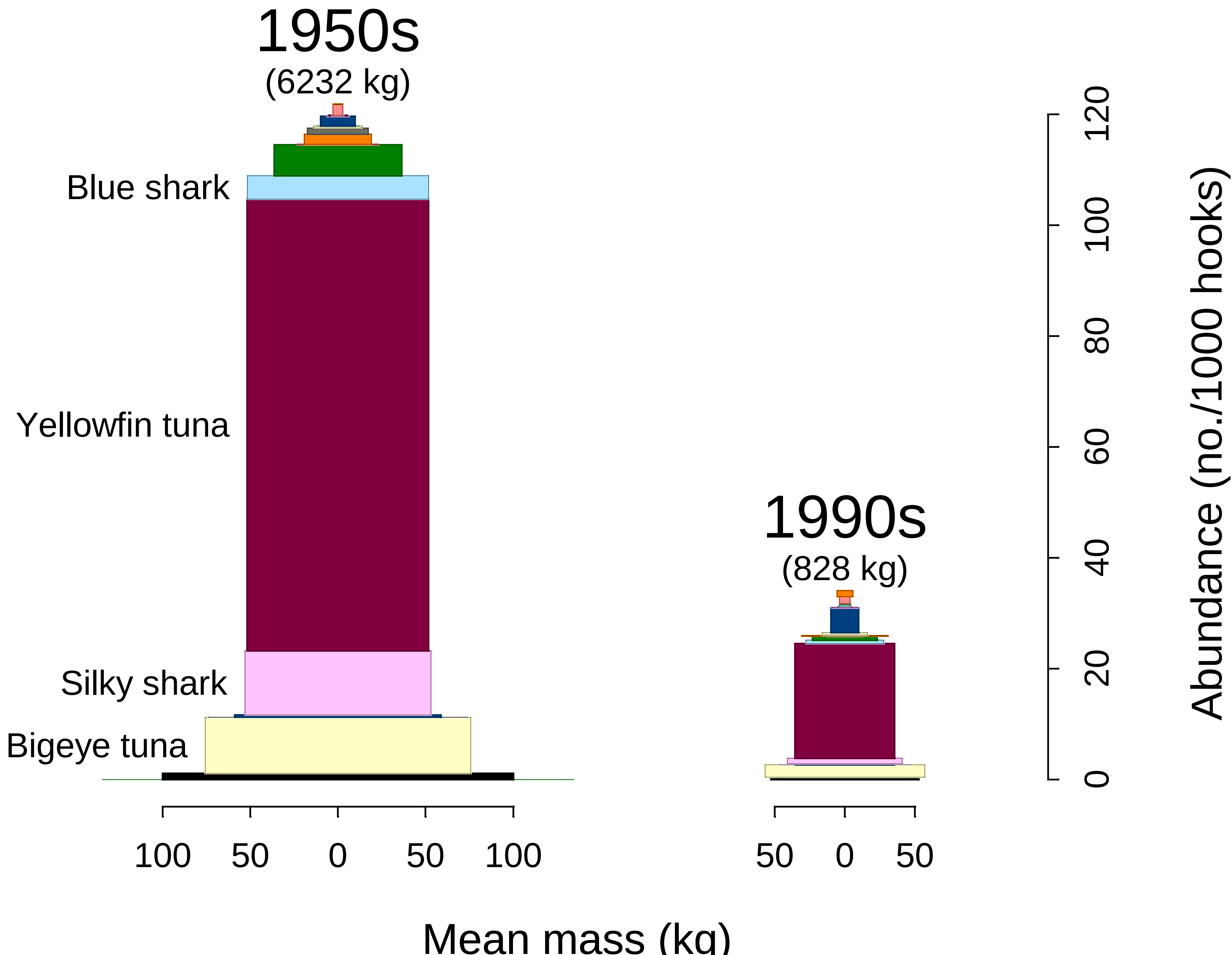
Yellowfin tuna – equitorial Pacific

Change in body size





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

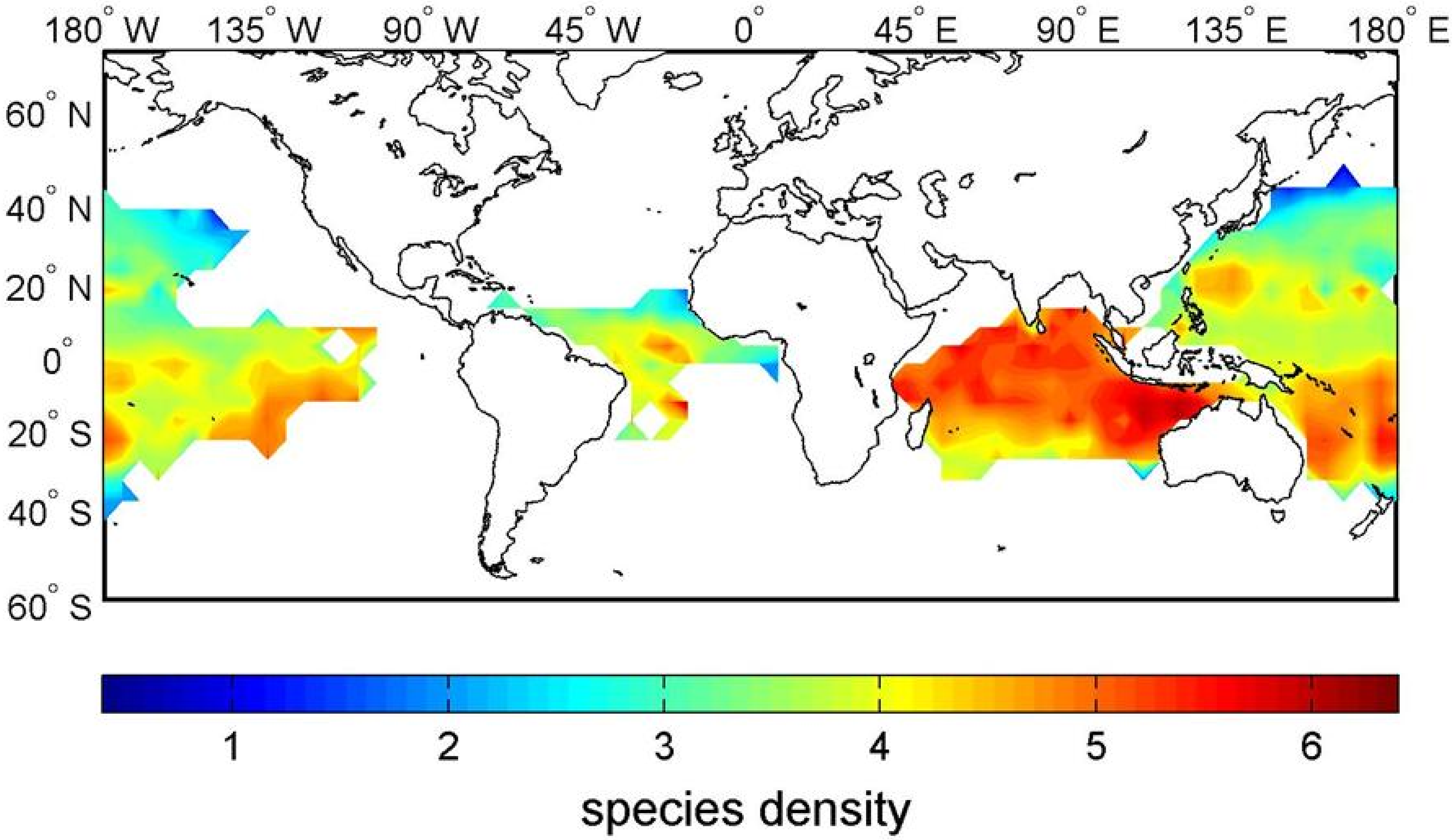

1950s
(6232 kg)
Blue shark
Yellowfin tuna
Silky shark
Bigeye tuna
1990s
(828 kg)
100
50
0
50
100
50
0
50
Mean mass (kg)
0
20
40
60
80
100
120
Abundance (no./1000 hooks)

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

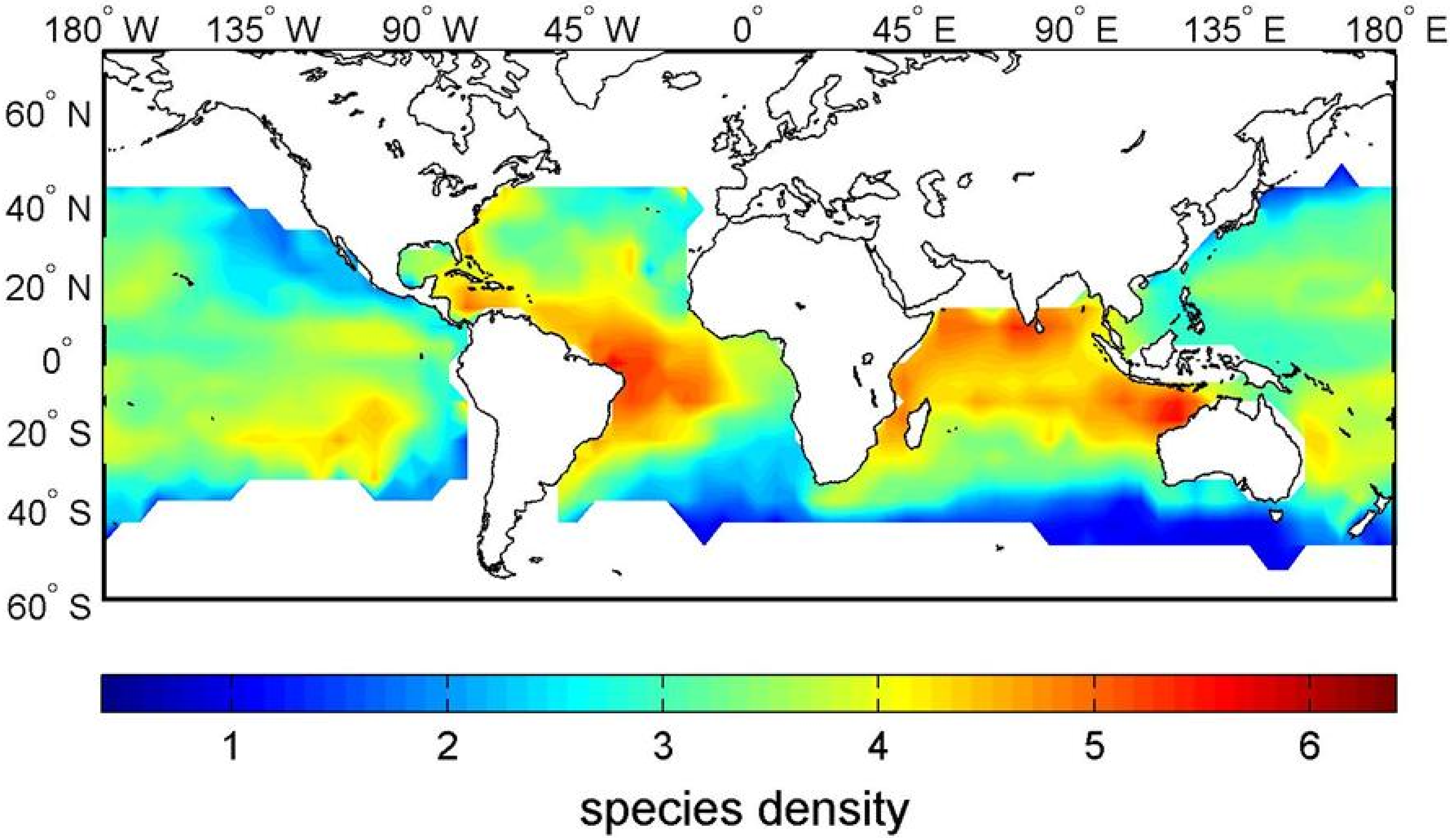
After data from: Worm B, Sandow M, Oschlies A, Lotze HK, Myers RA (2005) Global patterns of predator diversity in the open oceans. **Science** Aug. 2005.

1950s



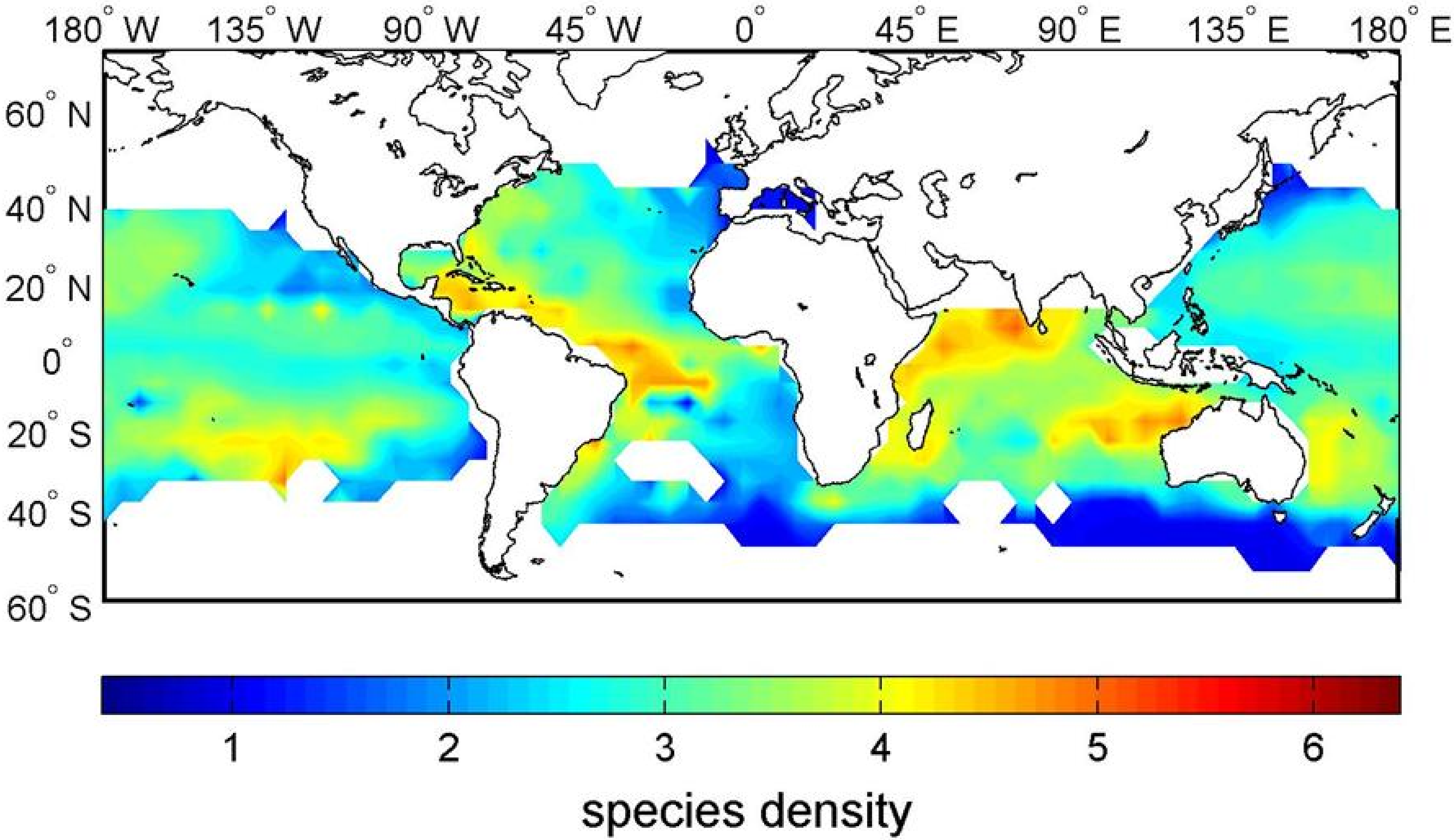
Worm B, Sandow M, Oschlies A, Lotze HK, Myers RA (Science Aug. 2005)

1960s



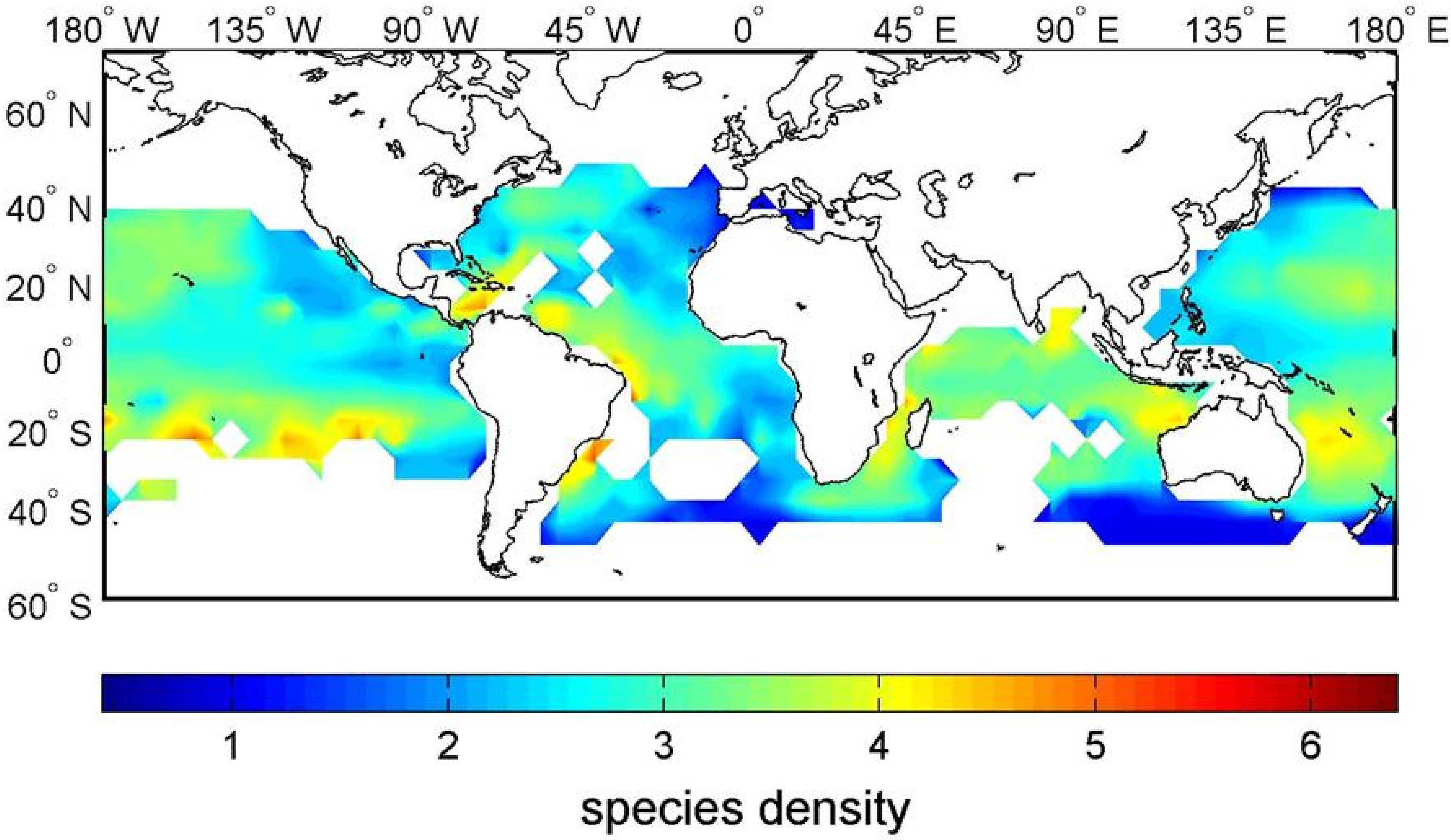
Worm B, Sandow M, Oschlies A, Lotze HK, Myers RA (Science Aug. 2005)

1970s



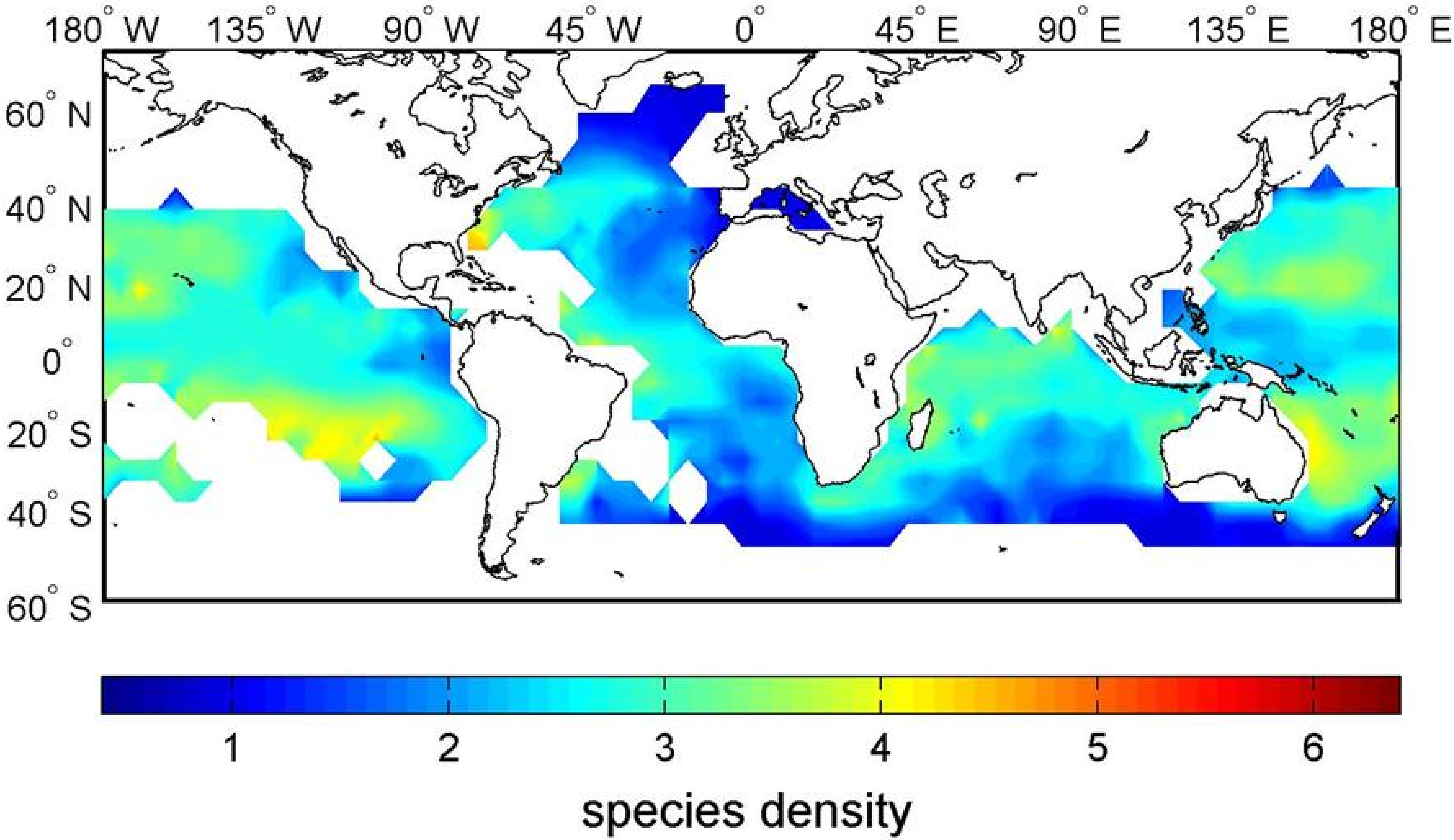
Worm B, Sandow M, Oschlies A, Lotze HK, Myers RA (Science Aug. 2005)

1980s



Worm B, Sandow M, Oschlies A, Lotze HK, Myers RA (Science Aug. 2005)

1990s

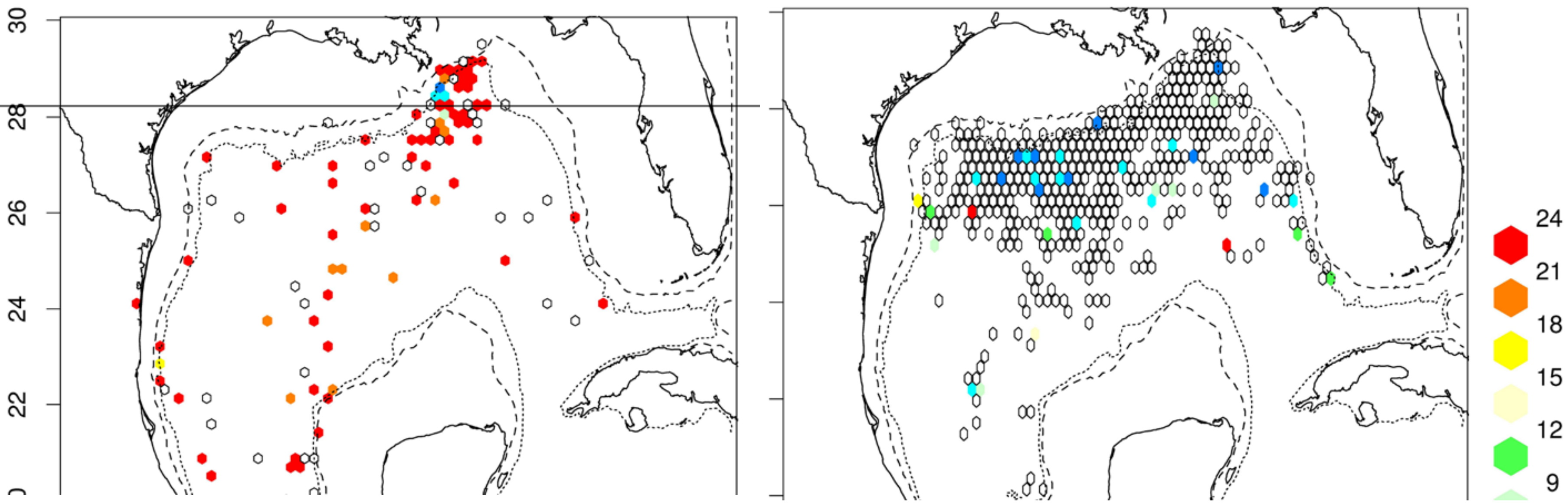


Worm B, Sandow M, Oschlies A, Lotze HK, Myers RA (Science Aug. 2005)

Loss of sharks in the Gulf of Mexico

300 fold decline – no one noticed

[redacted]



1950's　　1990's

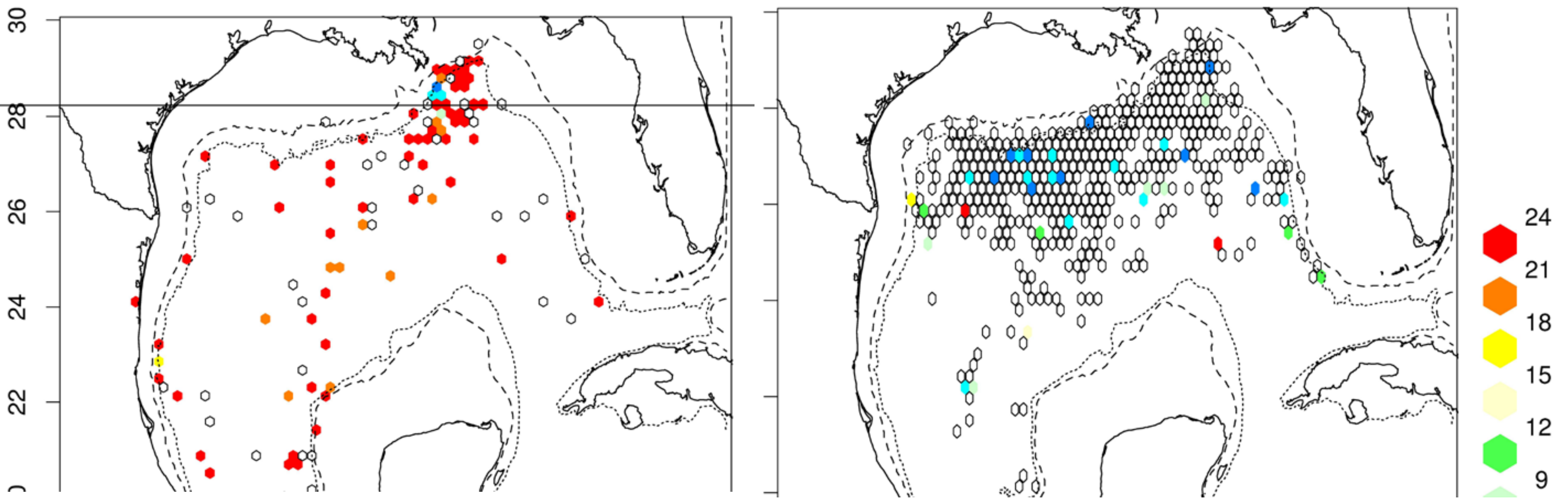
Oceanic Whitetip captures per 10,000 hooks

Many thanks to NMFS for data and advice

Loss of sharks in the Gulf of Mexico

300 fold decline – no one noticed

[redacted]

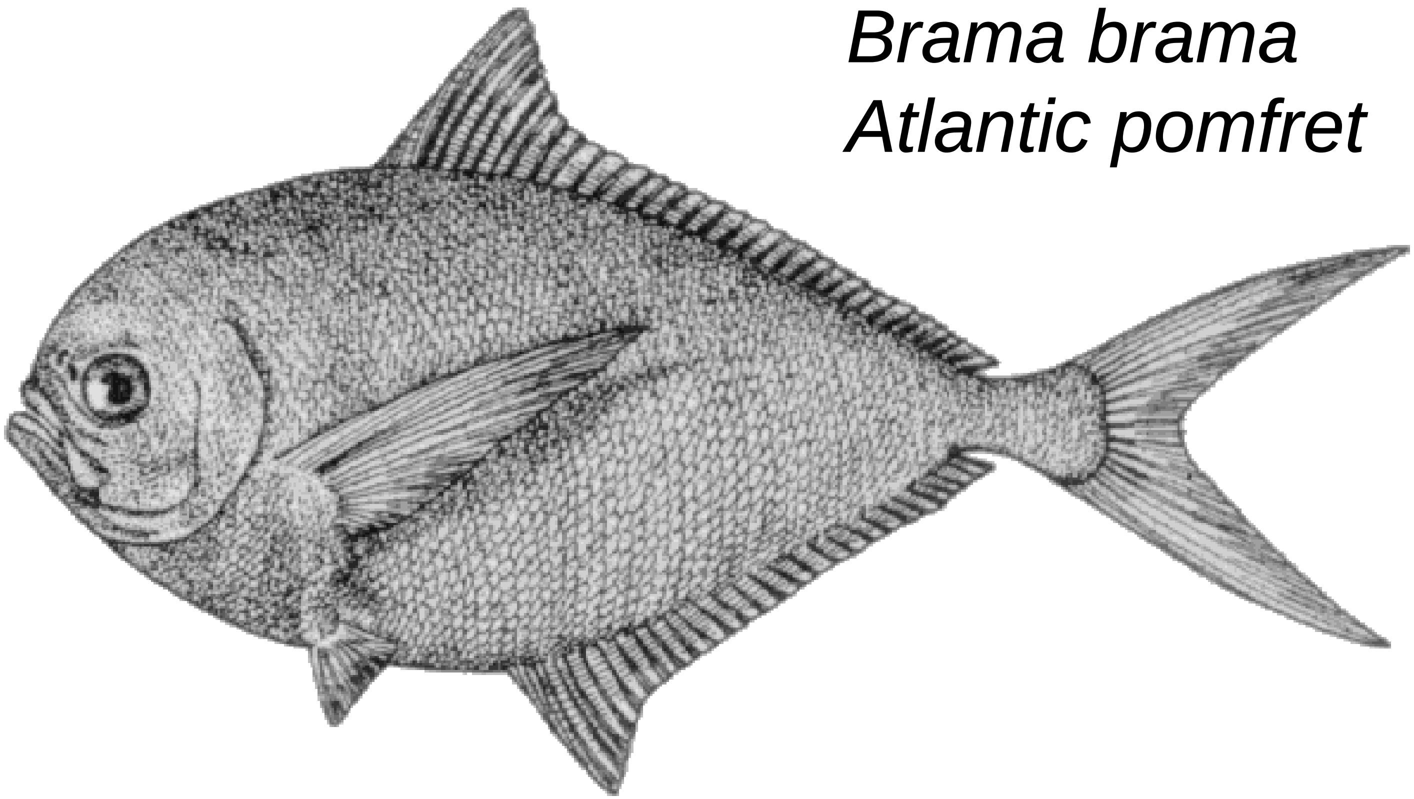


1950's 1990's

Oceanic Whitetip captures per 10,000 hooks

Many thanks to NMFS for data and advice

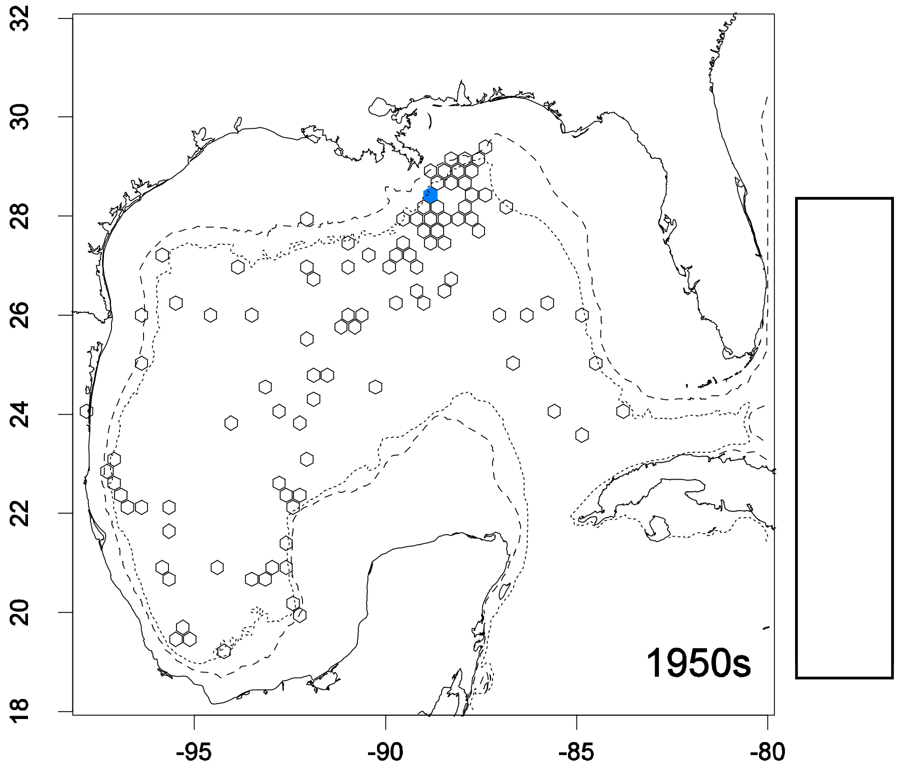
What about prey fish?

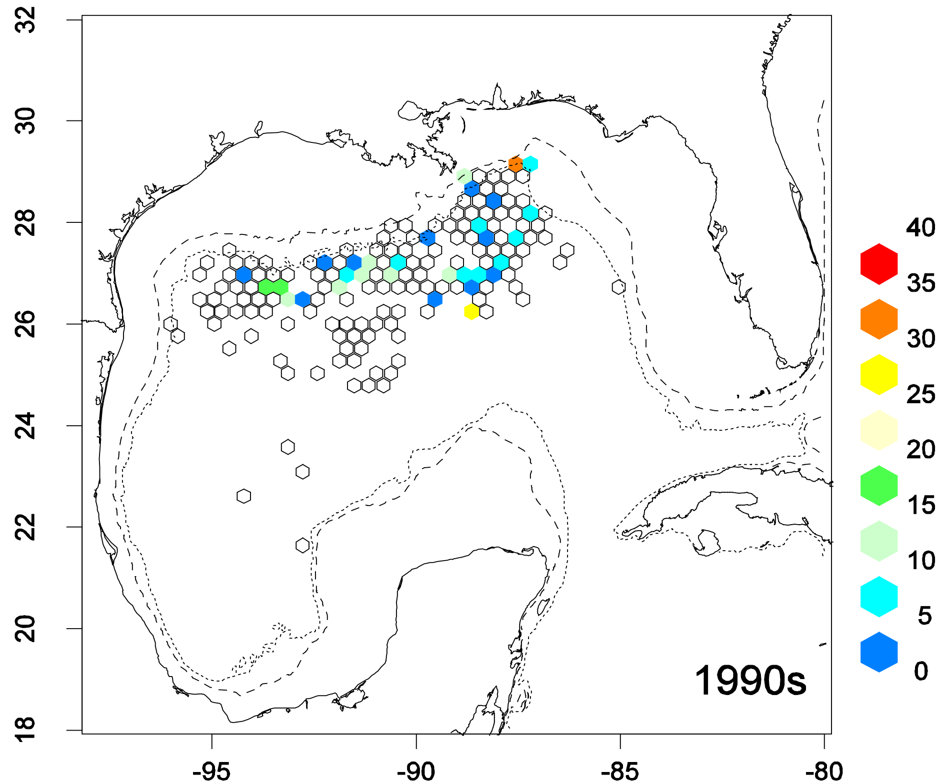


Brama brama
Atlantic pomfret

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

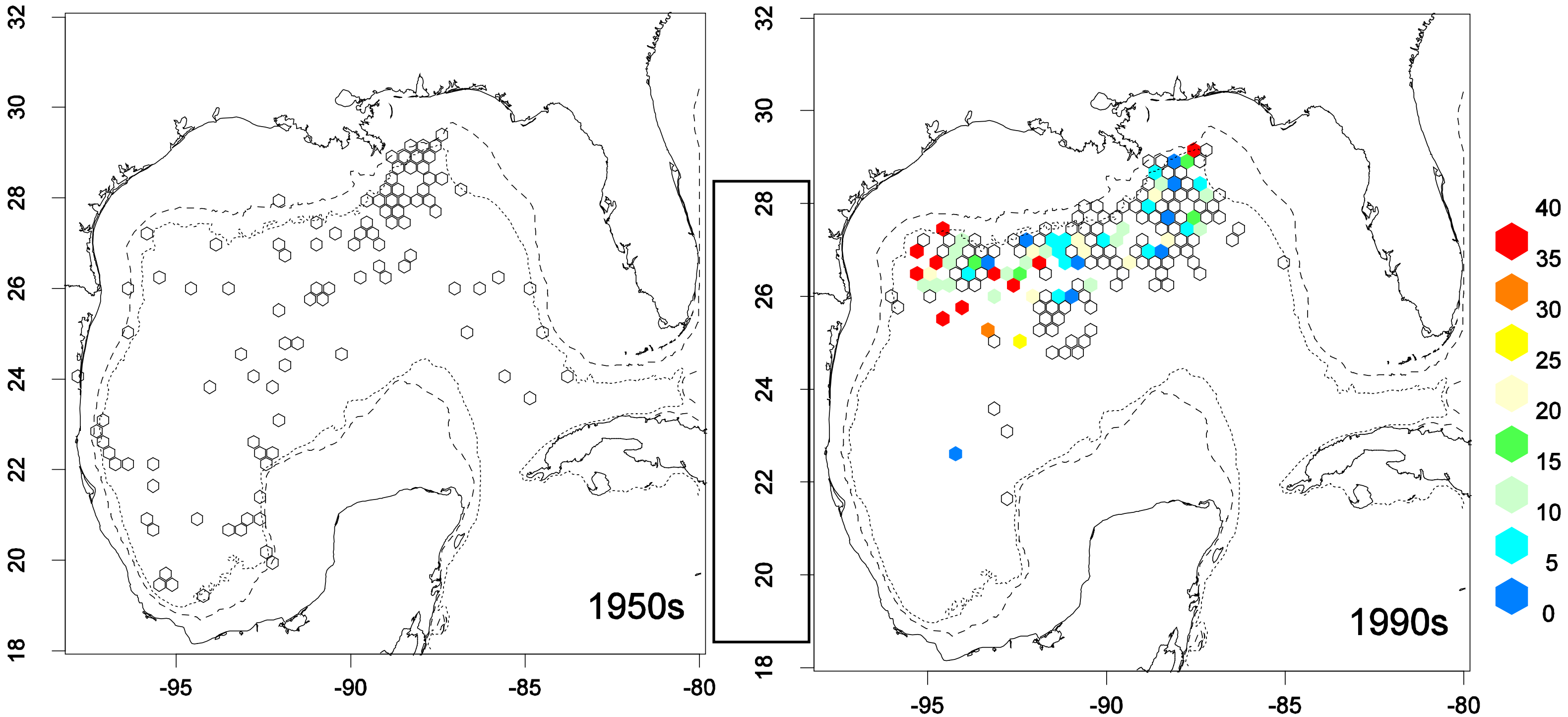
Many thanks to NMFS for data and advice

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



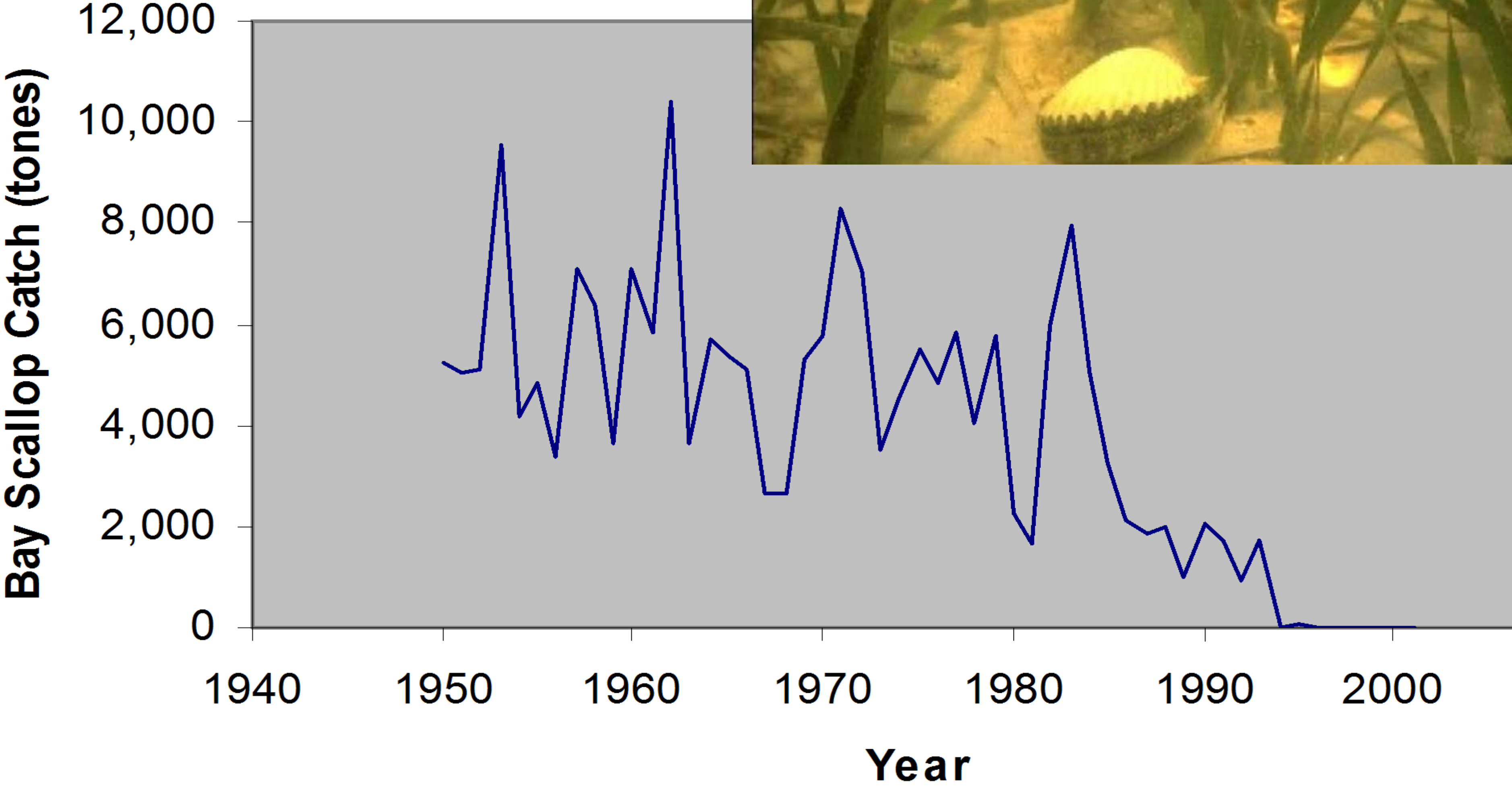
1950's

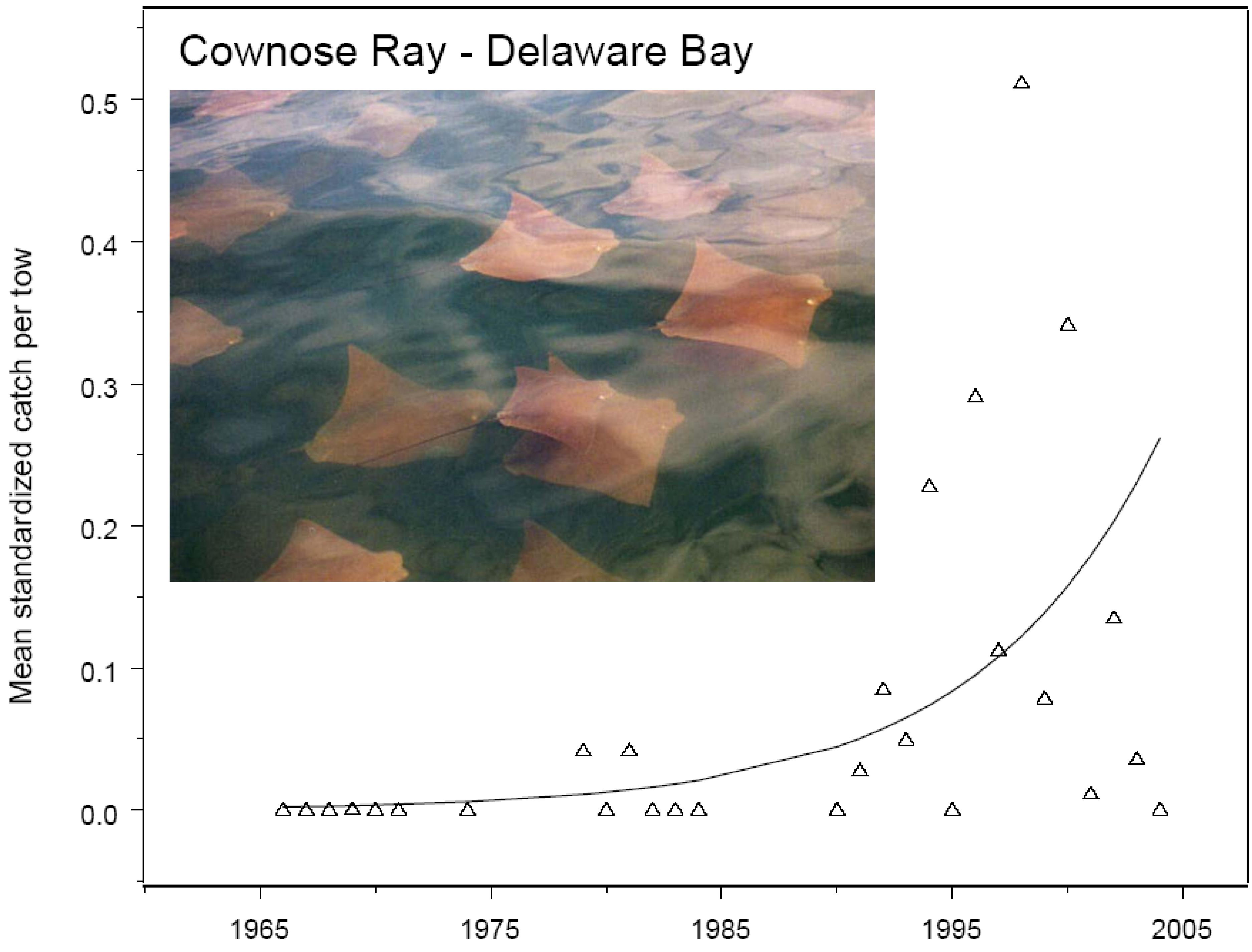
1990's

Pelagic stingray captures per 10,000 hooks

Many thanks to NMFS for data and advice

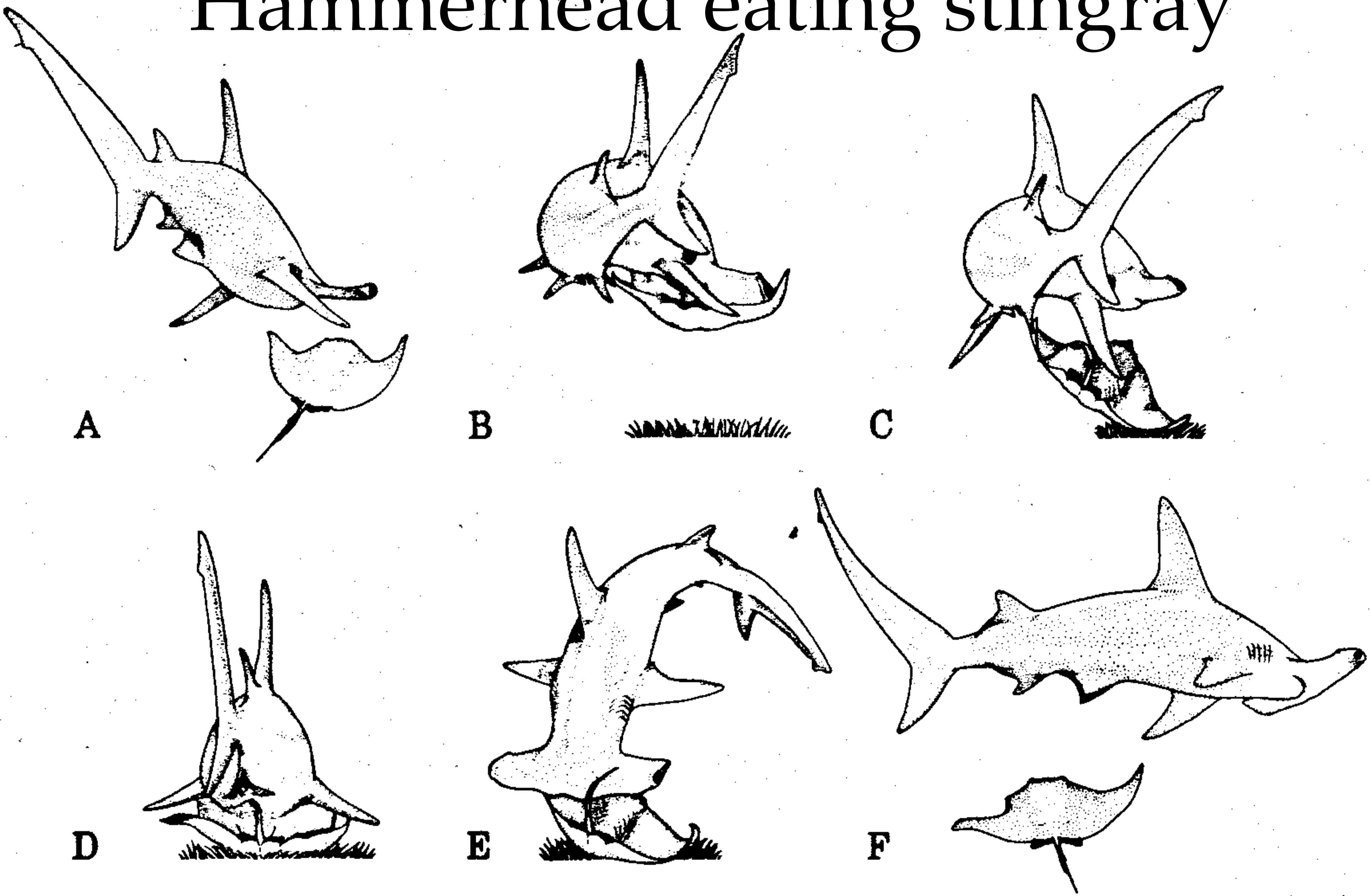
Bay Scallops Northeast US





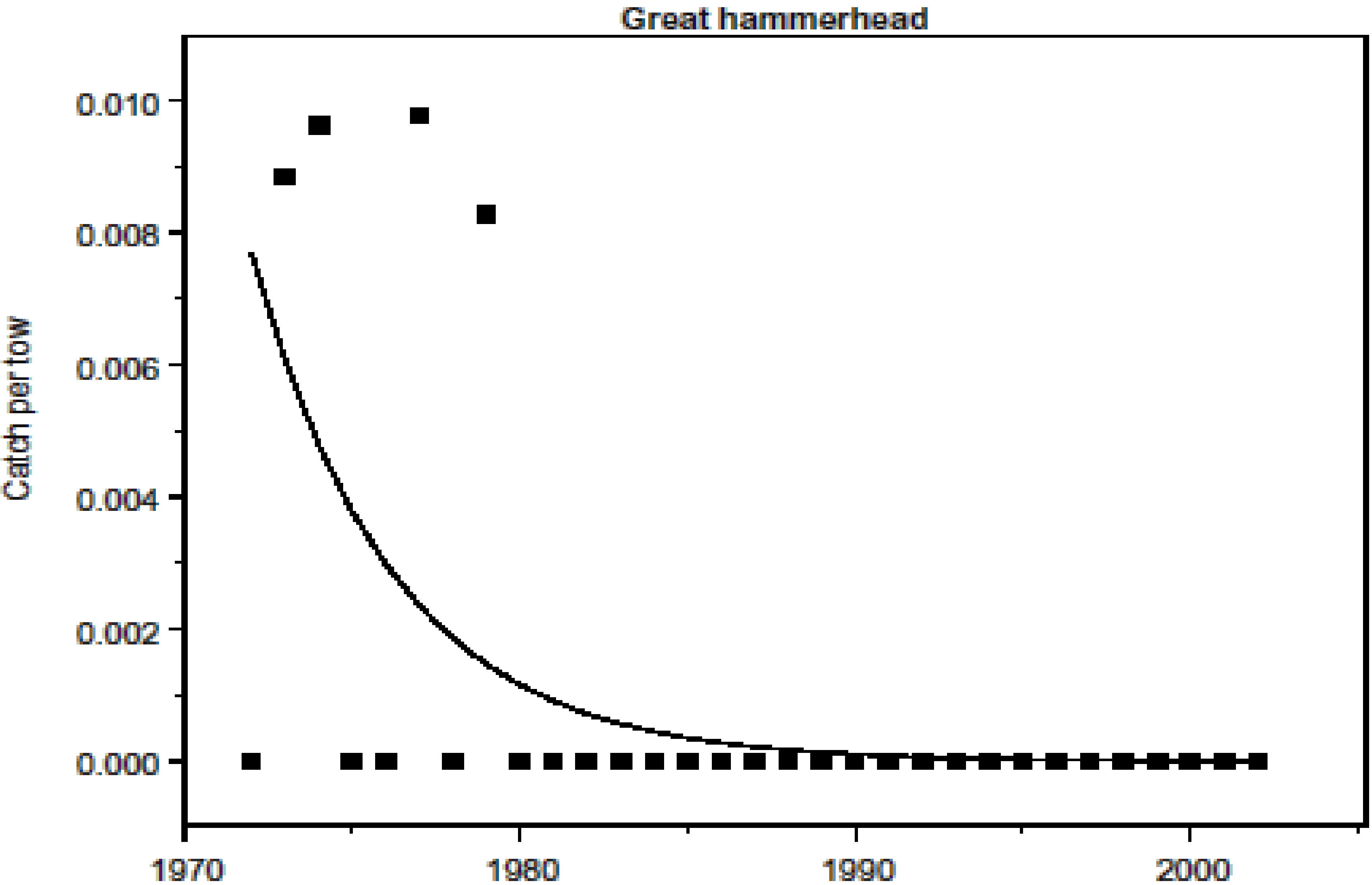
Cowenose Ray - Delaware Bay
Mean standardized catch per tow
0.5
0.4
0.3
0.2
0.1
0.0
1965
1975
1985
1995
2005

Hammerhead eating stingray

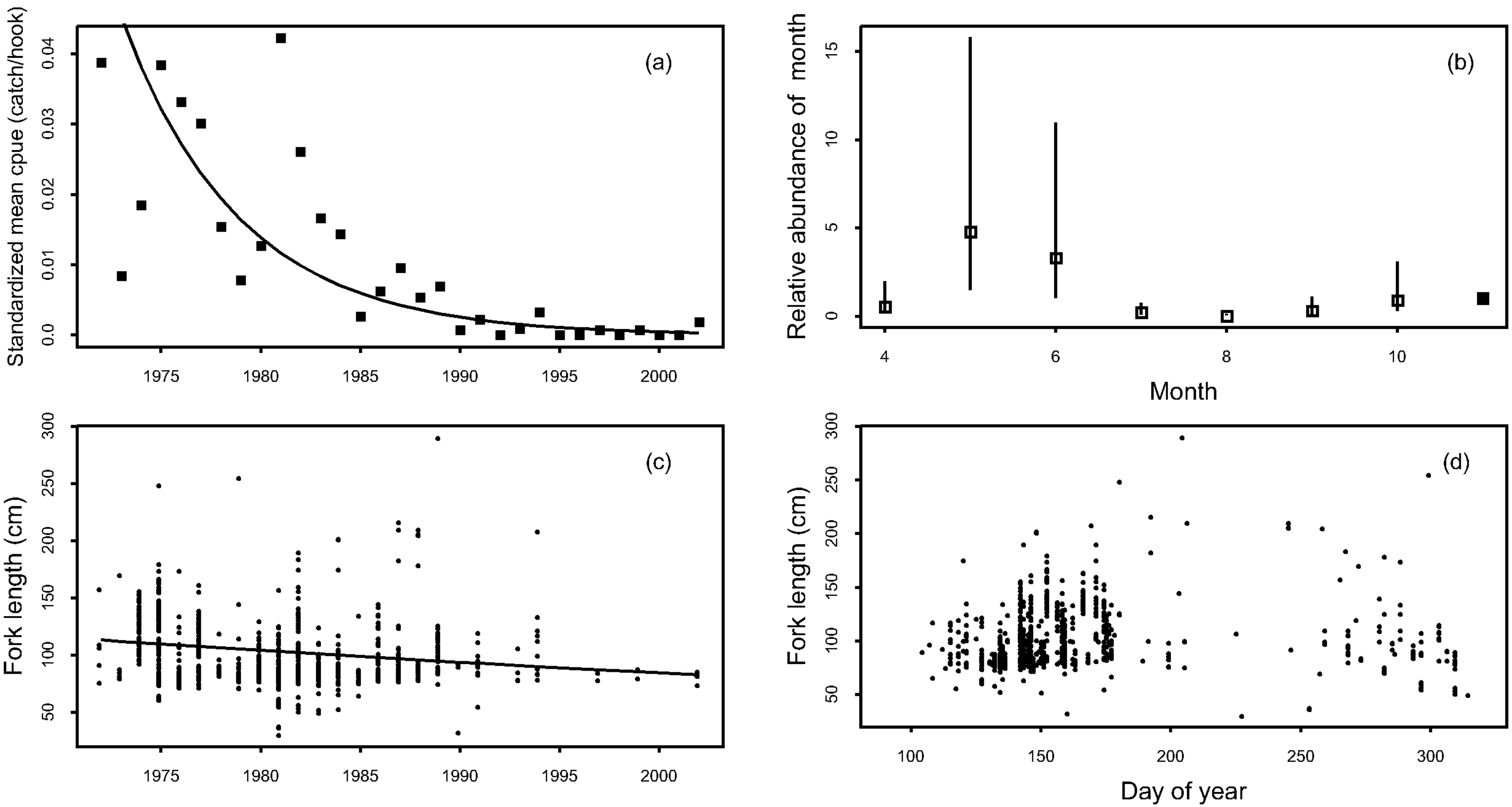


Strong, W.R. Jr; Snelson, F.F. Jr; Gruber, S.H. Copeia 1990, 836-839

Loss of hammerheads from surveys



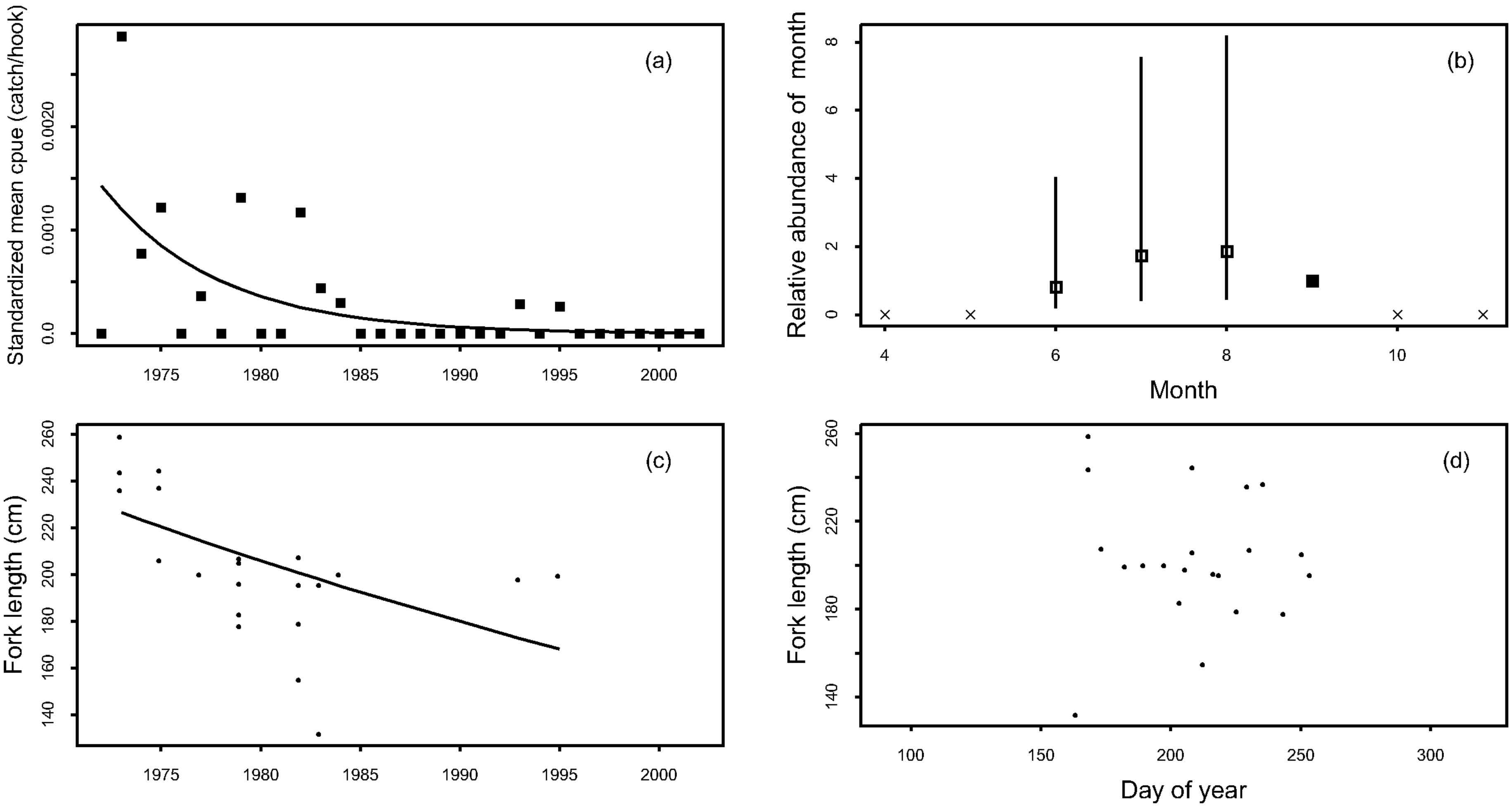
Dusky shark



Generalized linear model results

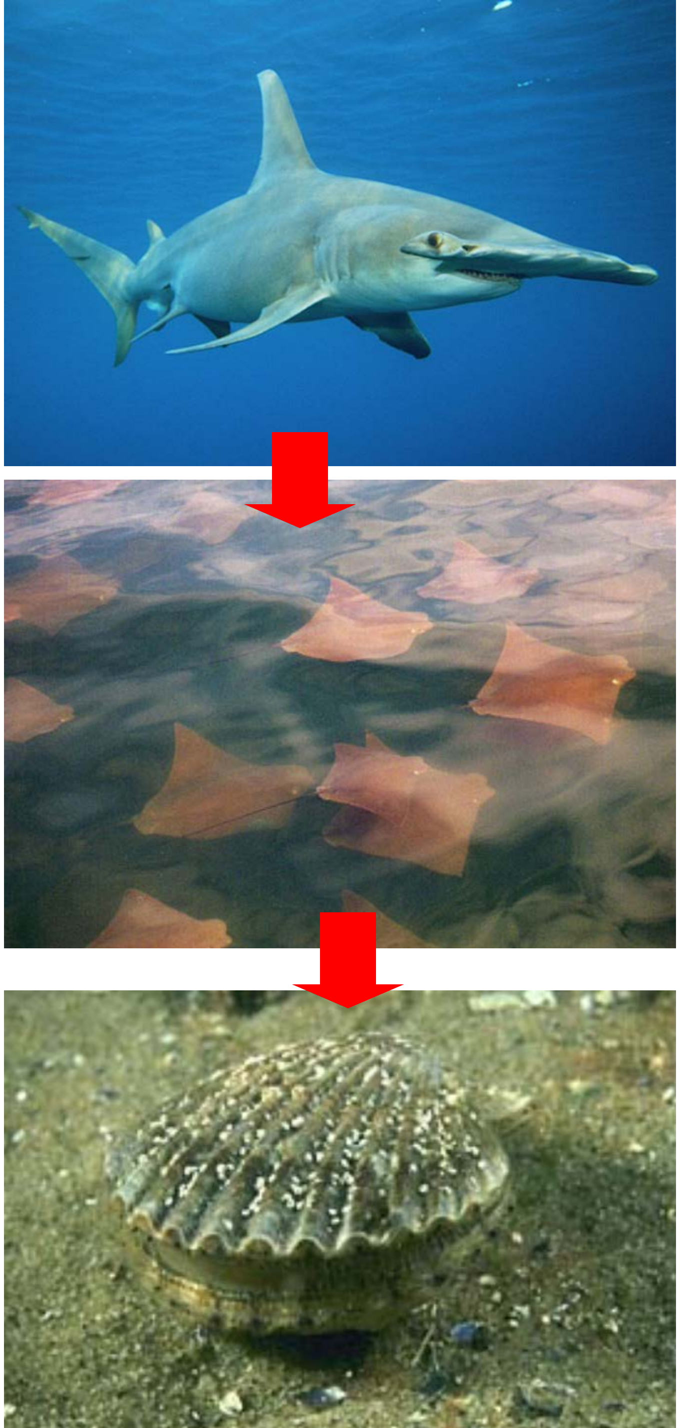
	Estimate	StdErr	p	k/scale
Abundance	-0.169	0.0171	5.67e-23	4.28
Length	-0.0105	1.4e-3	8.85e-14	18.8

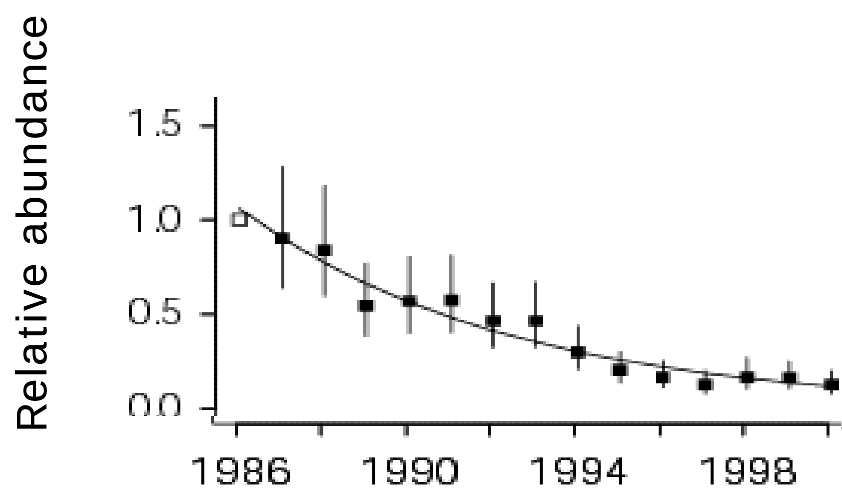
Bull shark

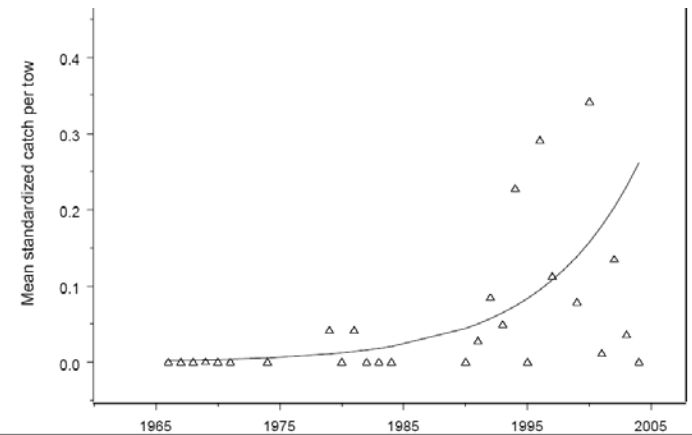


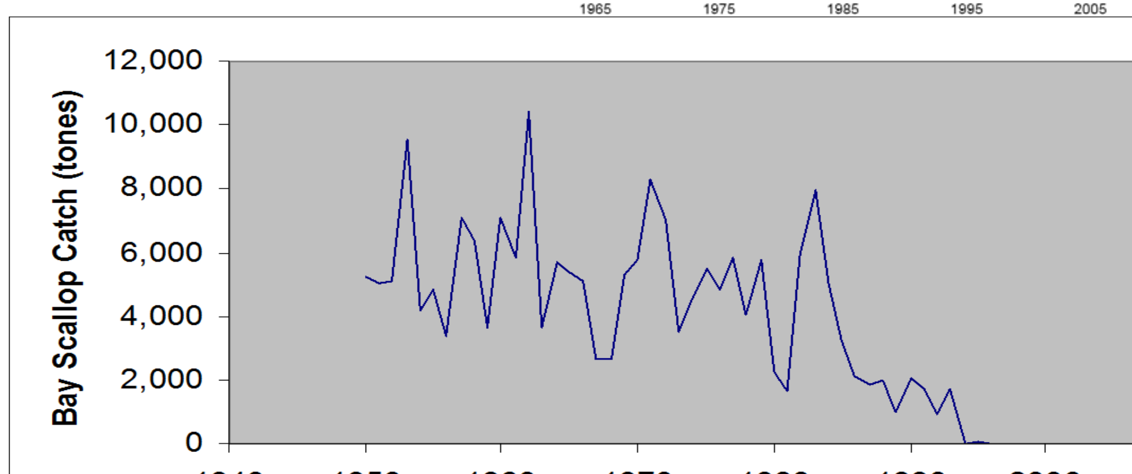
Generalized linear model results

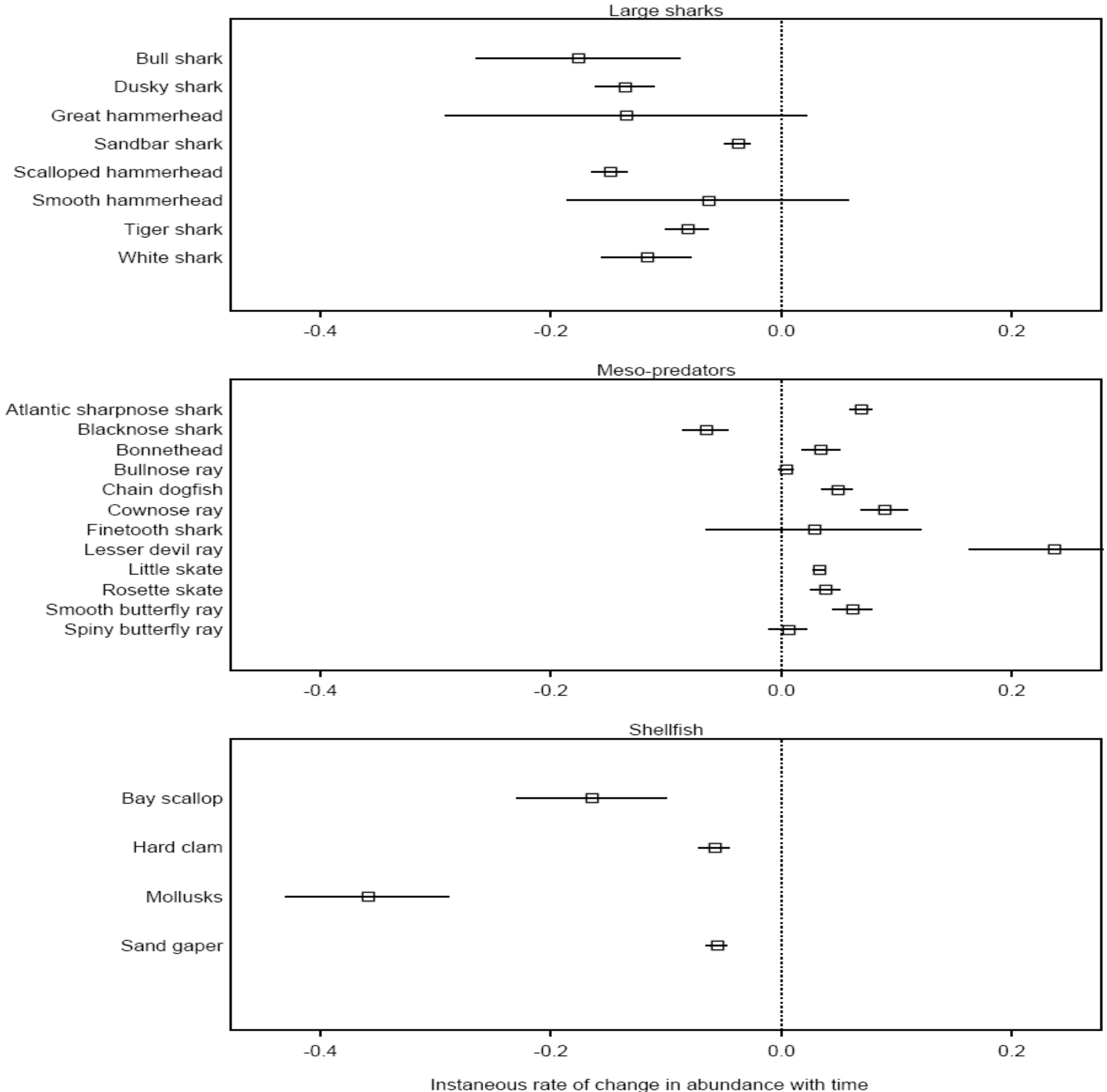
	Estimate	StdErr	p	k/scale
Abundance	-0.172	0.0443	9.99e-5	4.28
Length	-0.0136	5.e-3	6.69e-3	63.2

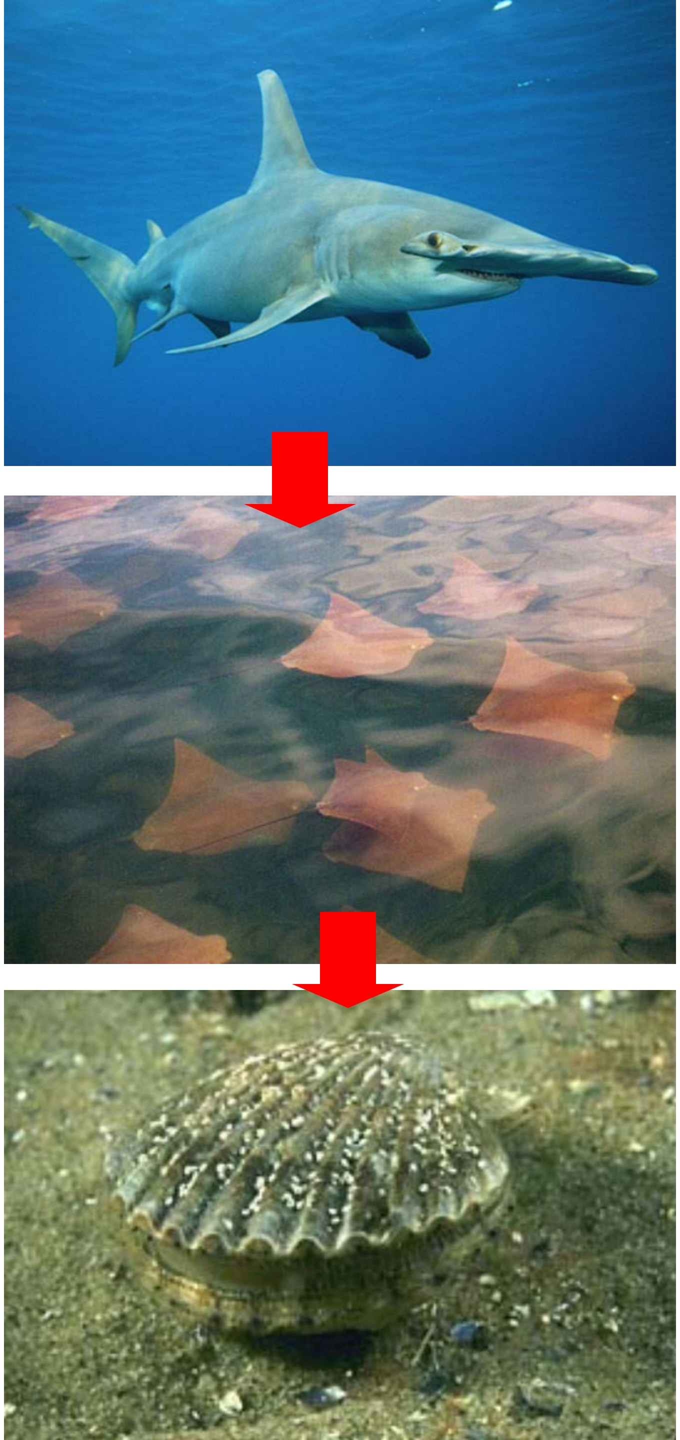



Relative abundance
1.5
1.0
0.5
0.0
1986
1990
1994
1998


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



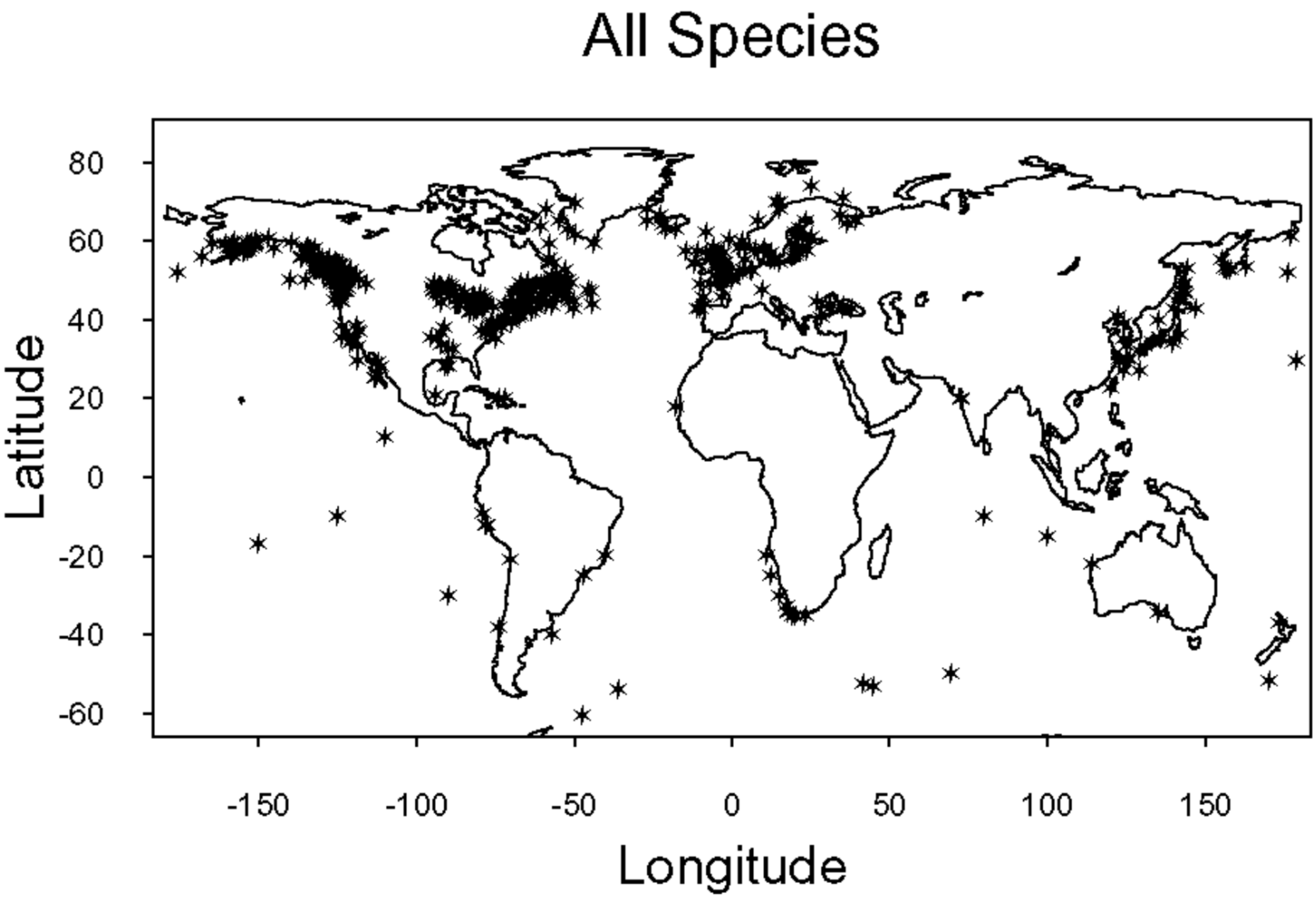
Trophic Cascades: Consequences of the loss of top predators may be greater than we think

Why is estimating density-dependence such a hard thing to do?

- Large estimation error
- Complex nonlinear process
- The issue is primarily one about creation and elimination of variability, it is simply not possible to think about these processes without models

Solutions

- Collect all the data in the world
- Analyze it in the right way


All Species
Latitude
80
60
40
20
0
-20
-40
-60
-150
-100
-50
0
50
100
150
Longitude

General result 1:

- More Egg => More Fish

Three simple questions

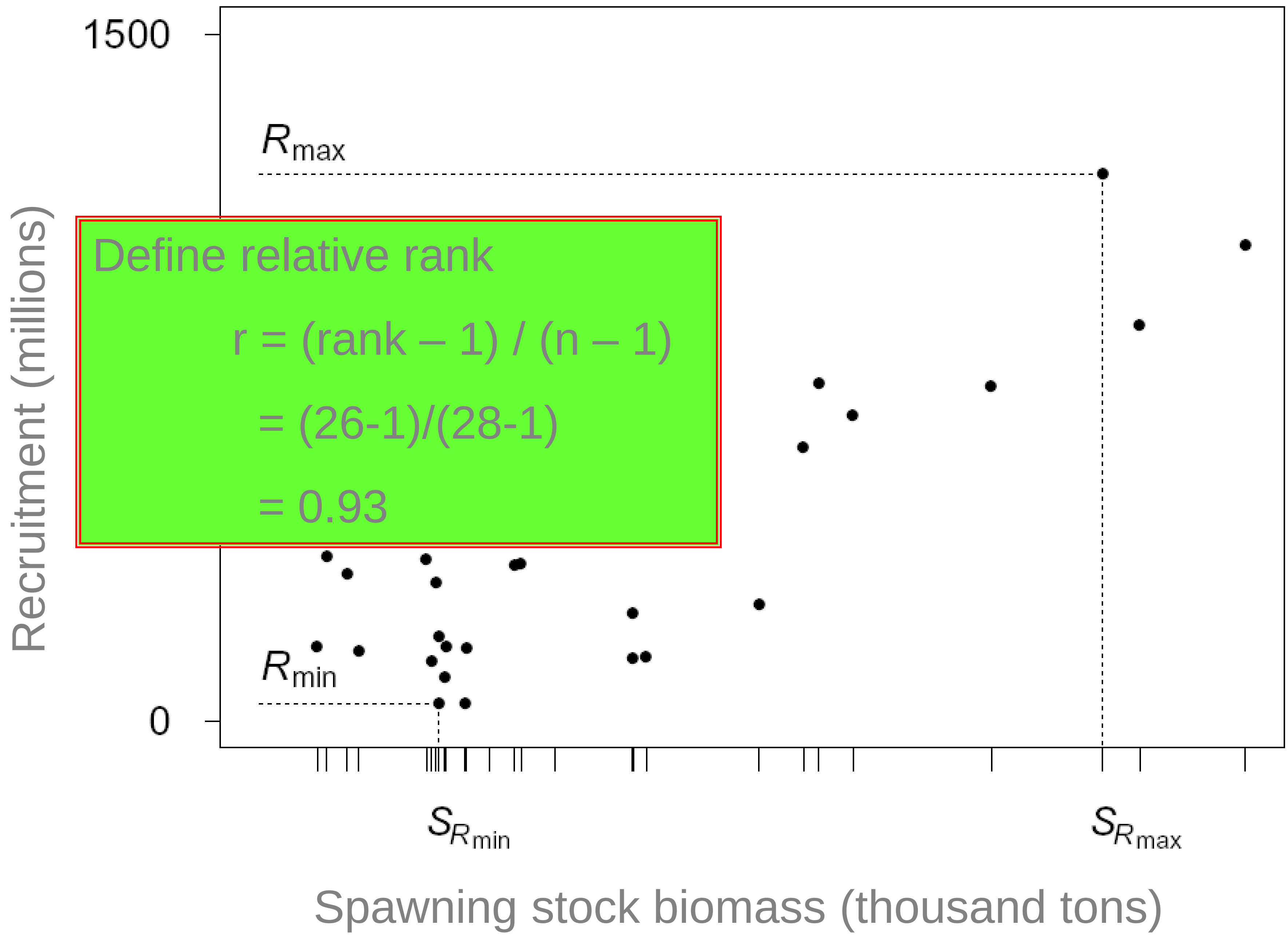
1. Does the largest recruitment occur when the spawner abundance is high?

Three simple questions

1. Does the largest recruitment occur when the spawner abundance is high?
2. Does the smallest recruitment occur when spawner abundance is low?

Three simple questions

1. Does the largest recruitment occur when the spawner abundance is high?
2. Does the smallest recruitment occur when spawner abundance is low?
3. Is the mean recruitment higher if the spawner abundance is above rather than below the median?

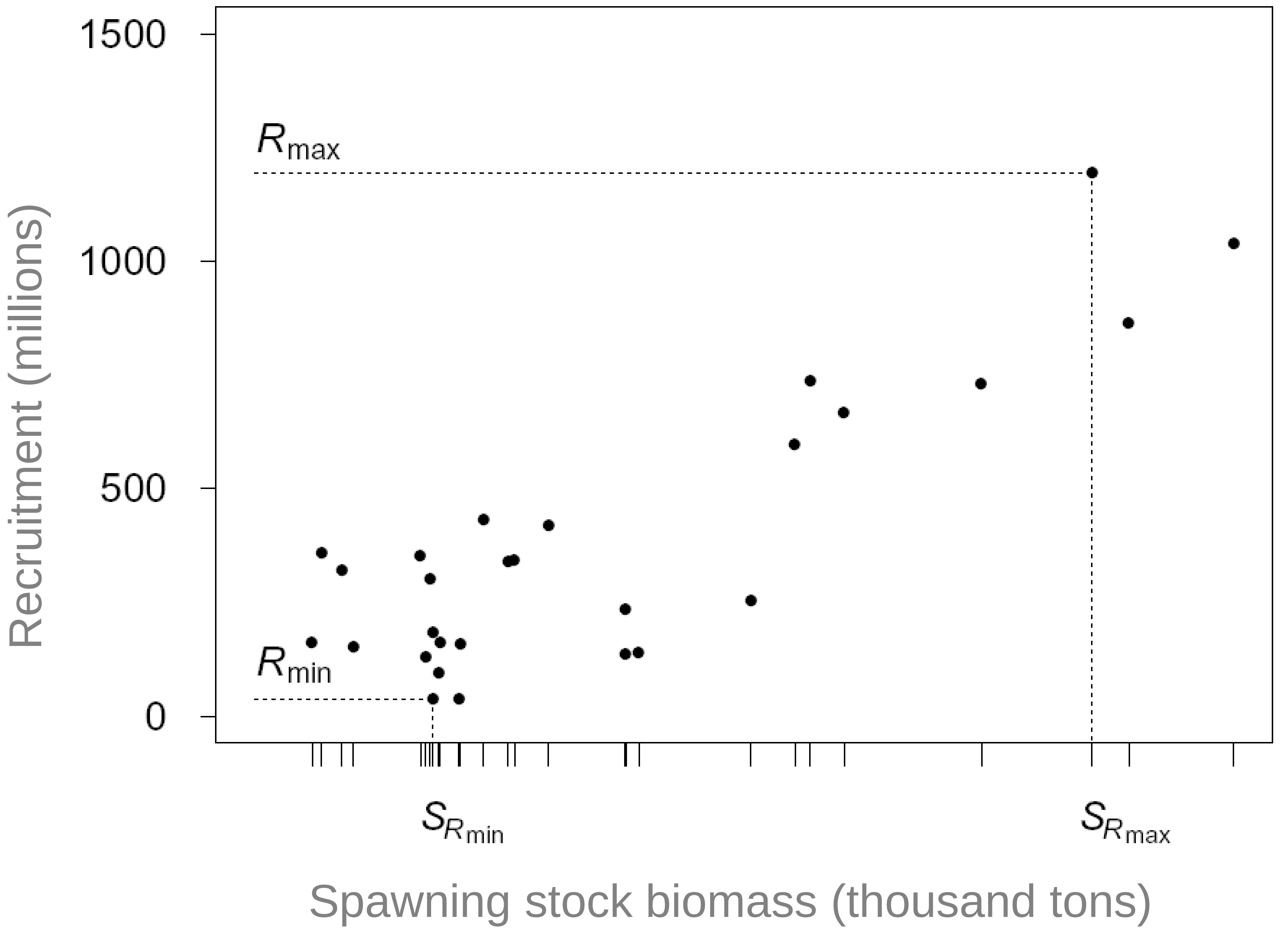


Define relative rank

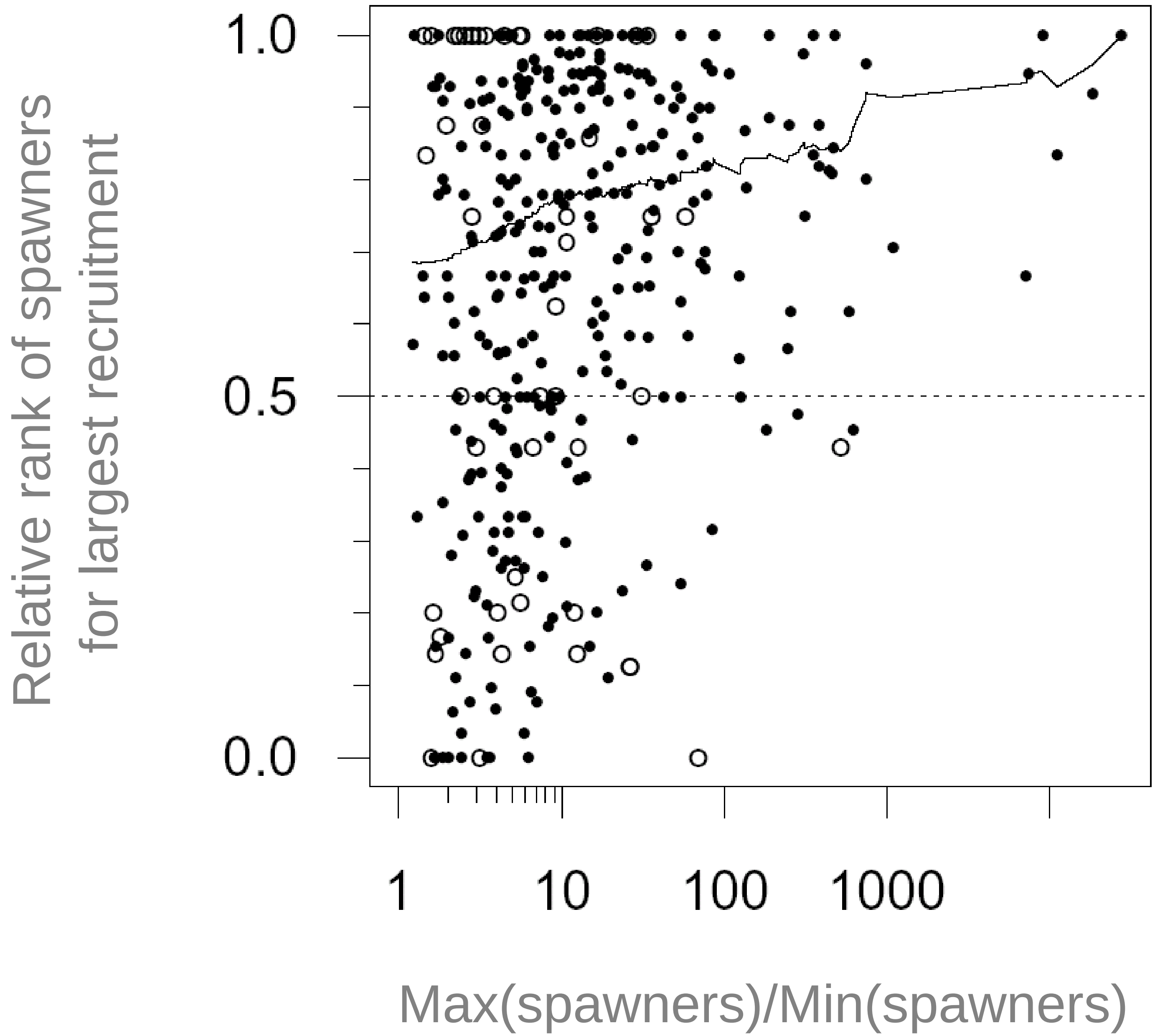
$$r = (\text{rank} - 1) / (n - 1)$$

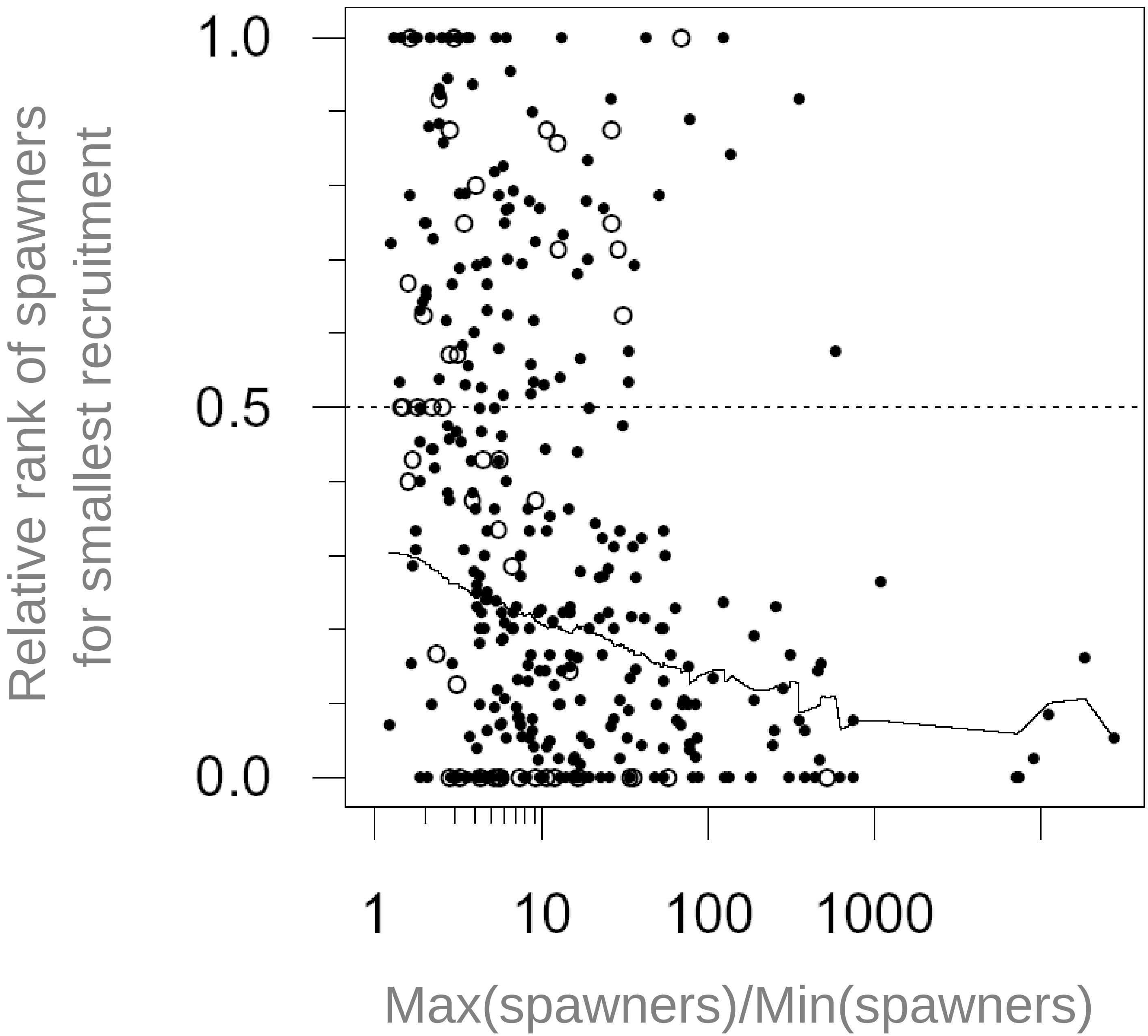
$$= (26-1)/(28-1)$$

$$= 0.93$$

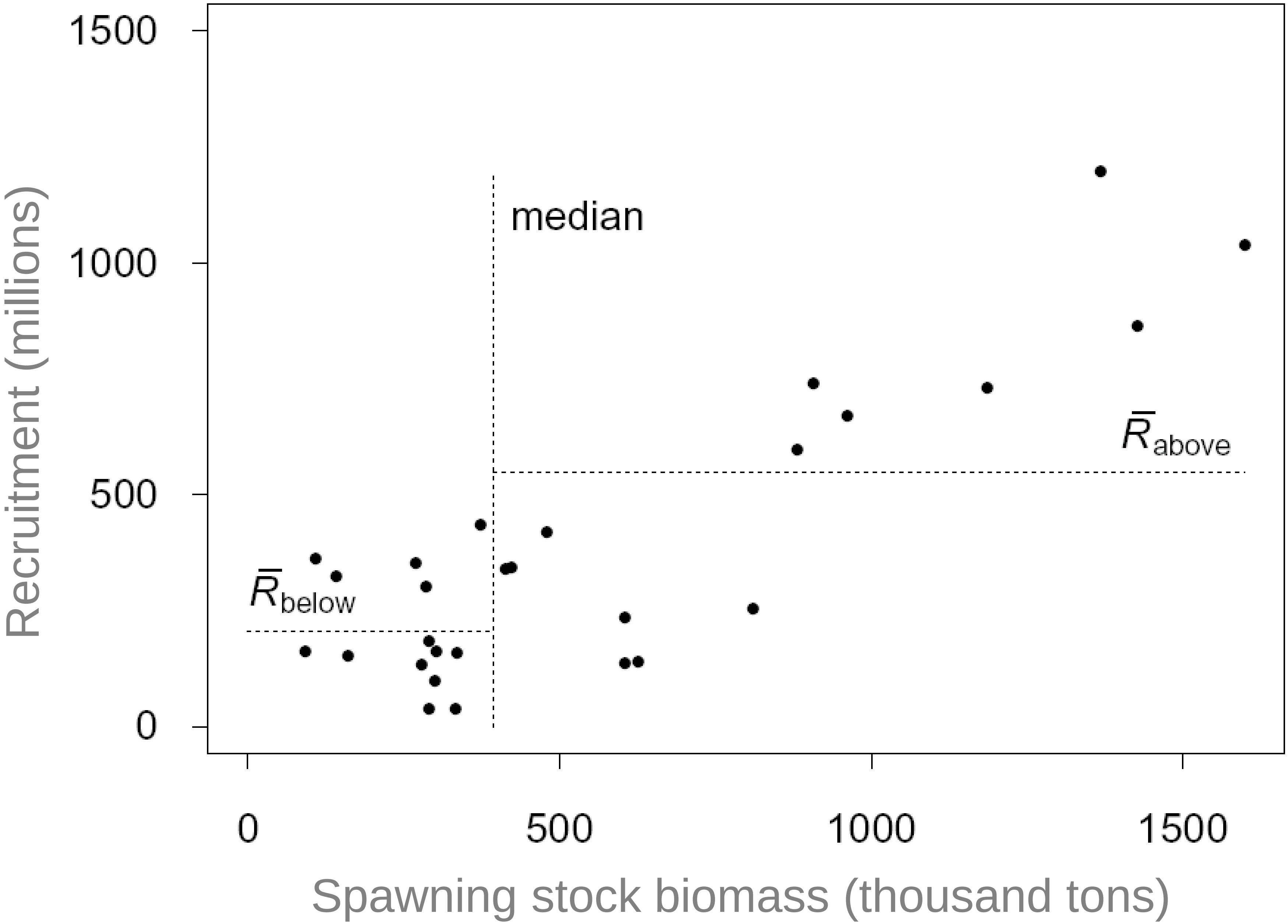


1500
1000
500
0
Recruitment (millions)
R_{max}
R_{min}
$S_{R_{min}}$
$S_{R_{max}}$
Spawning stock biomass (thousand tons)

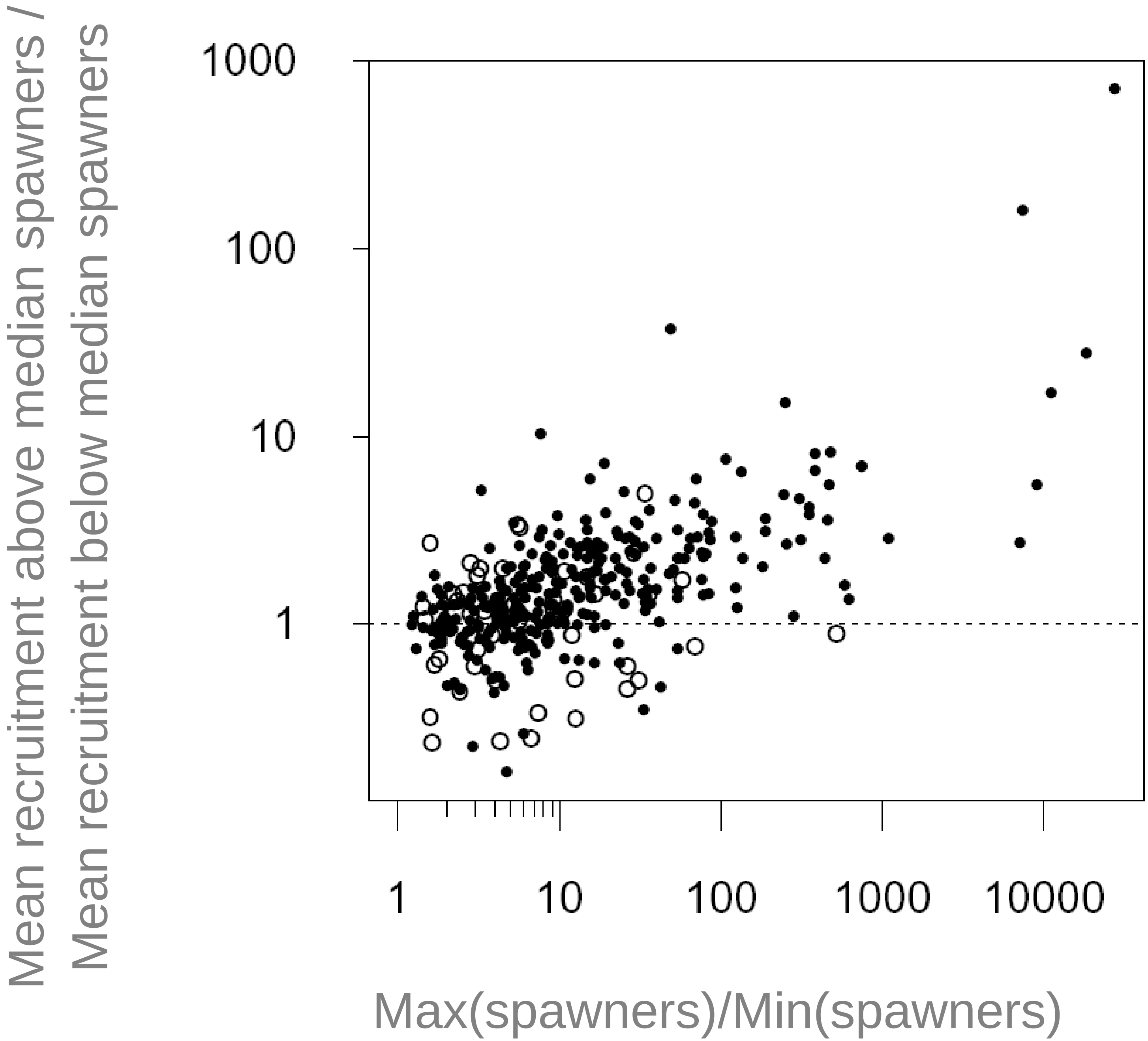

Relative rank of spawners
for largest recruitment
1.0
0.5
0.0
1
10
100
1000
Max(spawners)/Min(spawners)



1.0
0.5
0.0
Relative rank of spawners for smallest recruitment
1
10
100
1000
Max(spawners)/Min(spawners)



1500
1000
500
0
median
$\bar{R}_{\text{above}}$
$\bar{R}_{\text{below}}$
Recruitment (millions)
0
500
1000
1500
Spawning stock biomass (thousand tons)

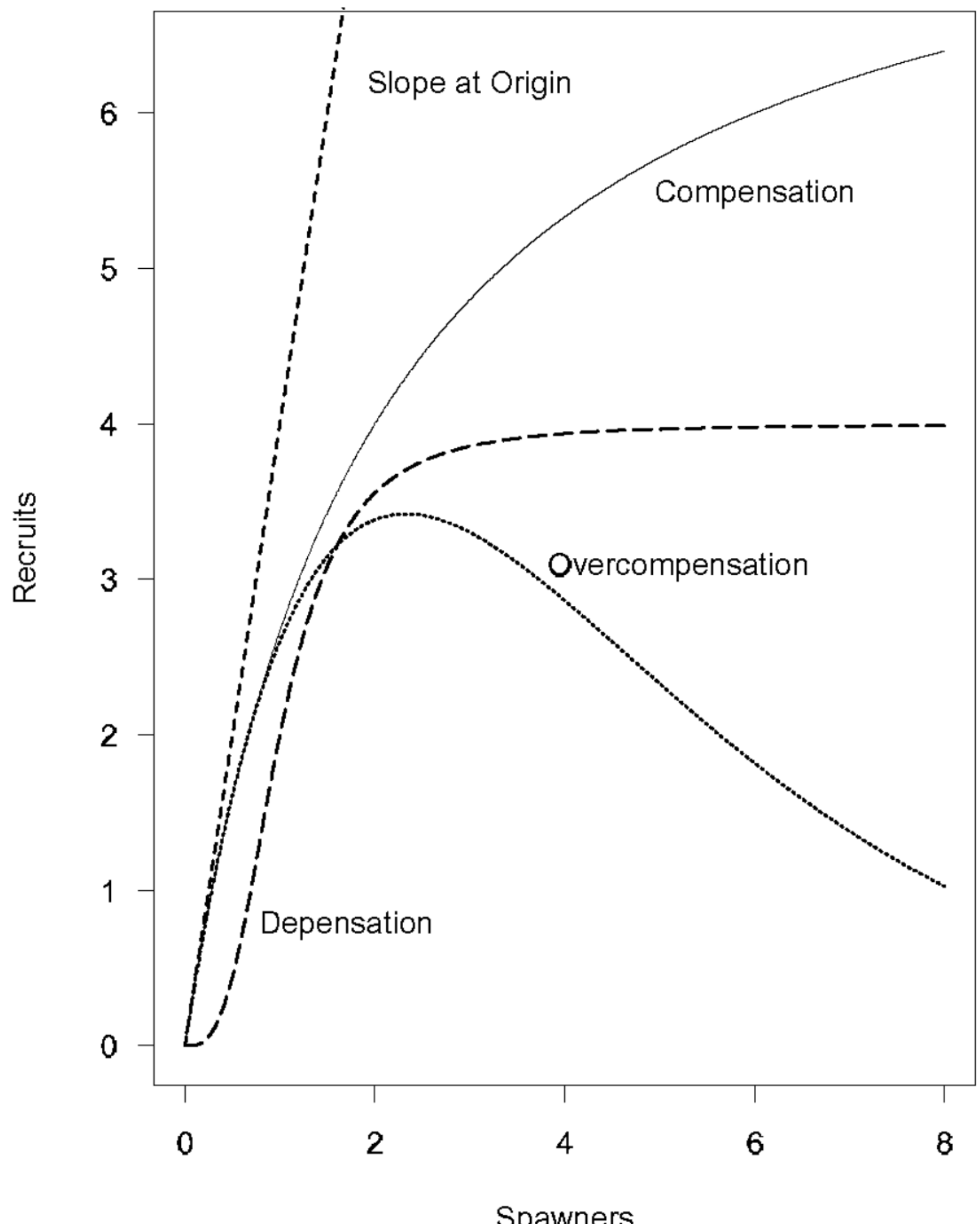

Mean recruitment above median spawners /
Mean recruitment below median spawners
1000
100
10
1
1
10
100
1000
10000
Max(spawners)/Min(spawners)

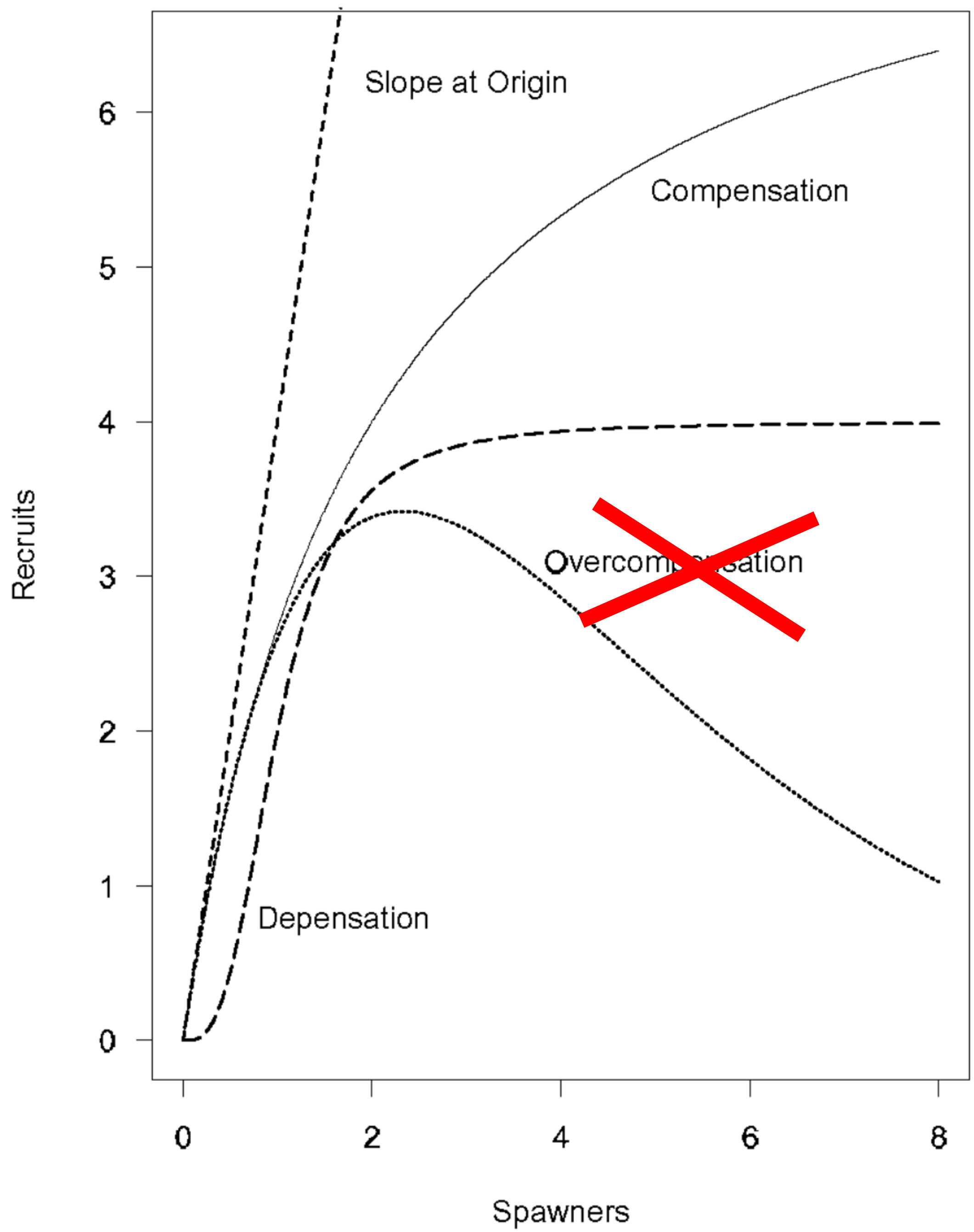
What does this imply 1:

- Compensation is not infinite.

What does this imply 2:

Ricker type recruitment is very rare, at least in the range of spawner abundances usually observed in exploited populations (it is not good for the fish to kill a lot of them).

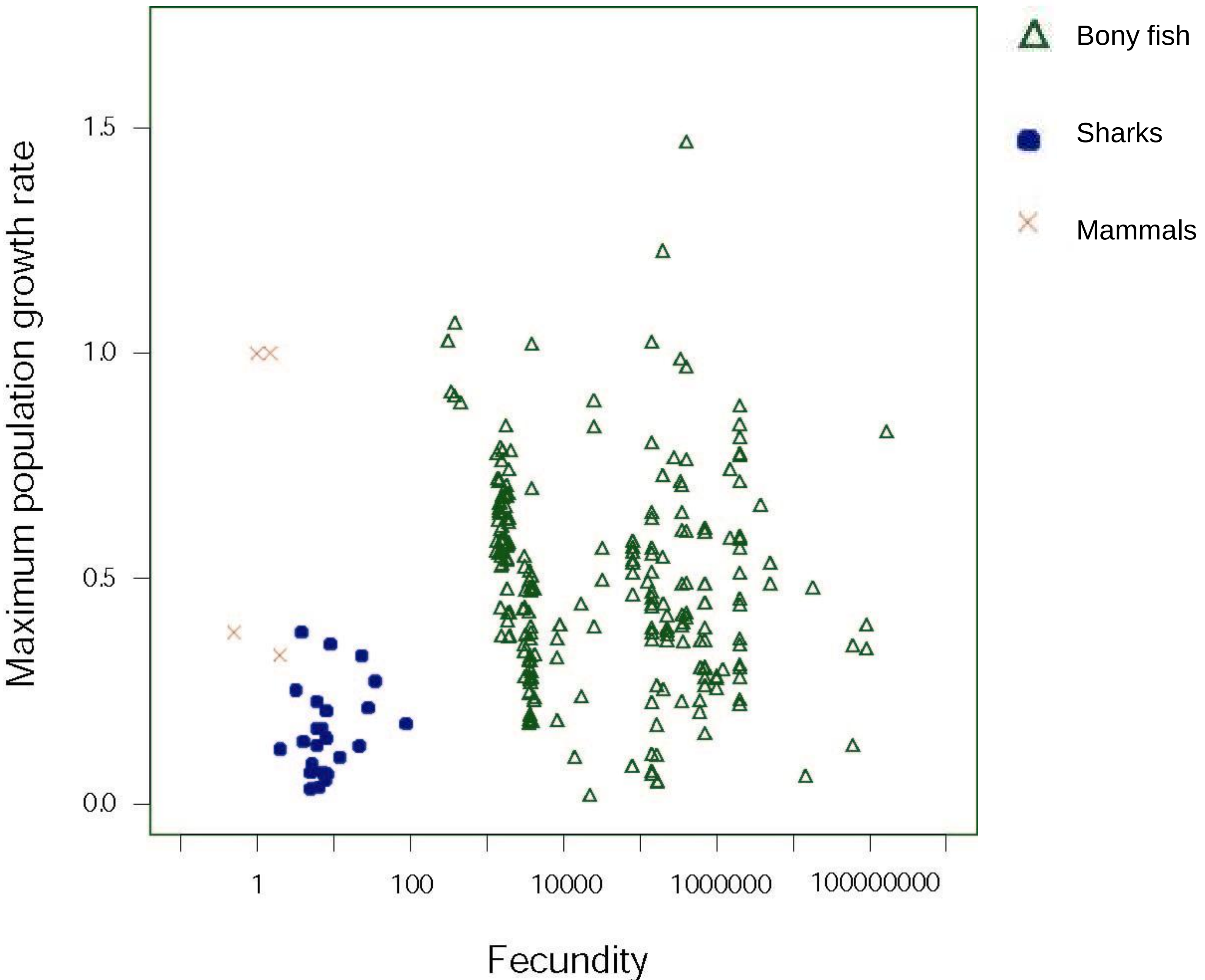

Slope at Origin
Compensation
Overcompensation
Depensation
Recruits
Spawners
0
1
2
3
4
5
6
0
2
4
6
8

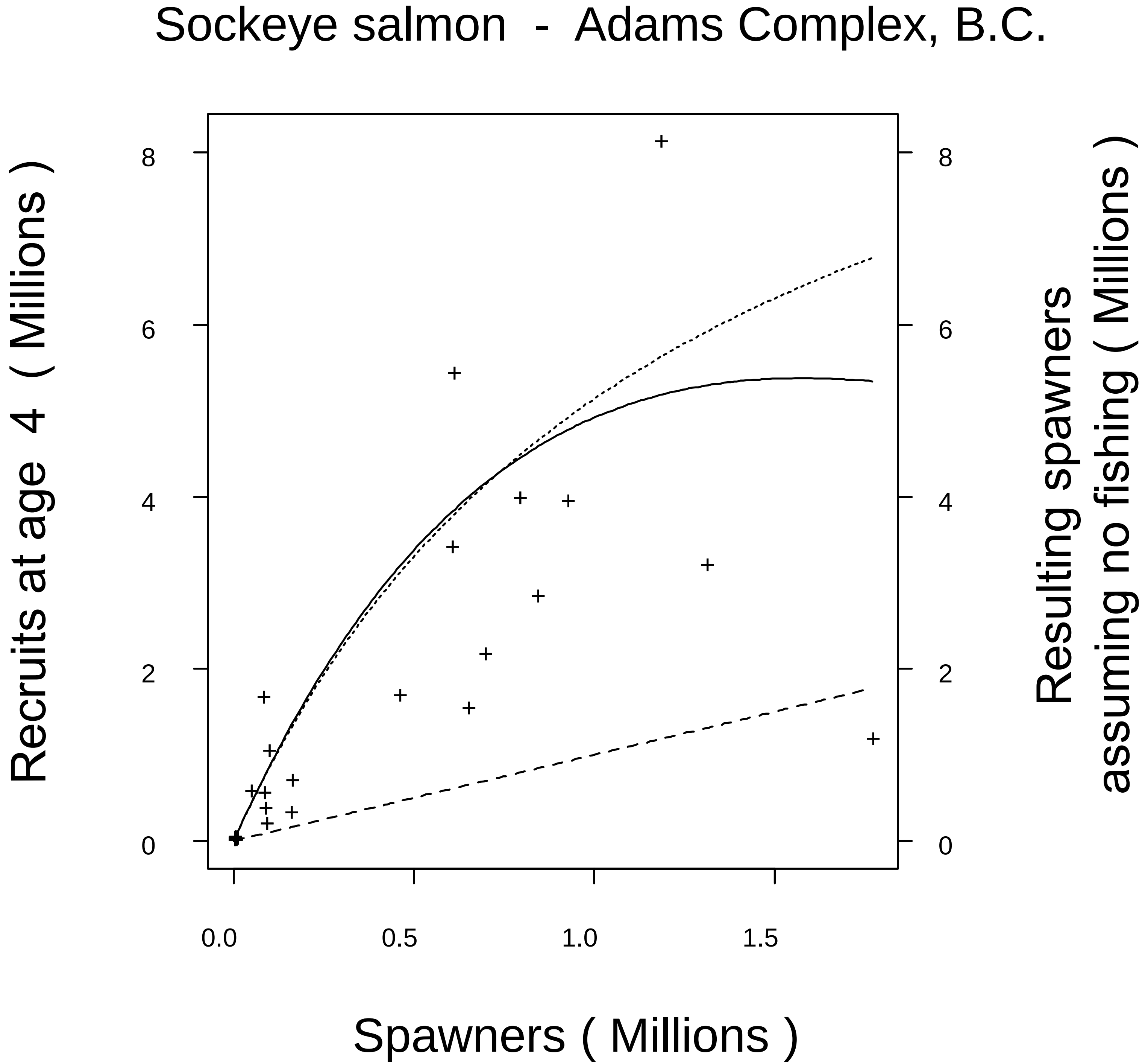

Slope at Origin
Compensation
Overcom sation
Depensation
Recruits
Spawners
0
1
2
3
4
5
6
0
2
4
6
8

General Result 2:

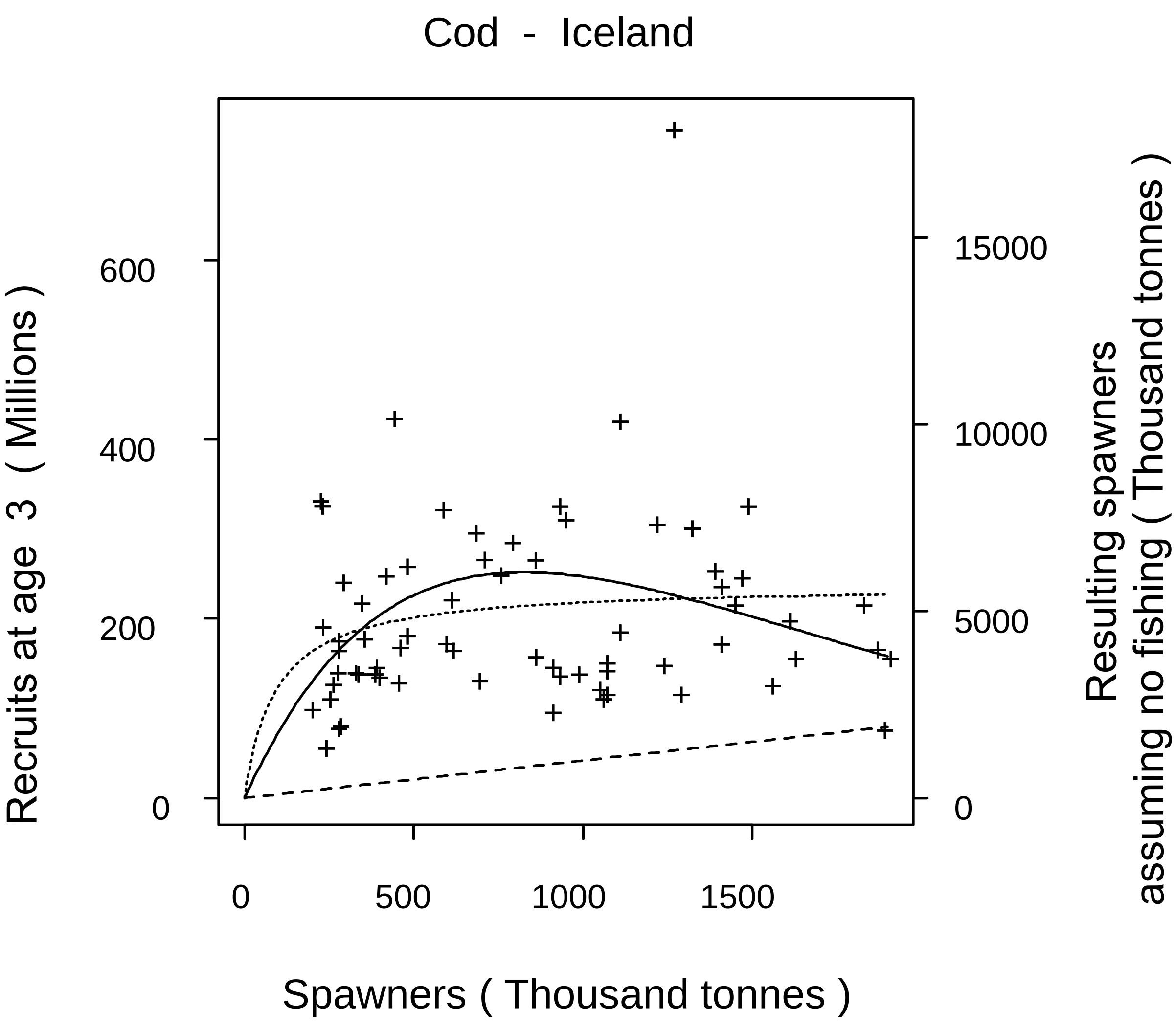
- The level of compensation (the scope for the reduction in density-dependent mortality to allow a population increase) is relative constant among almost all fish species

What is the maximum interest rate (on average) you can obtain by investing in striped bass futures?

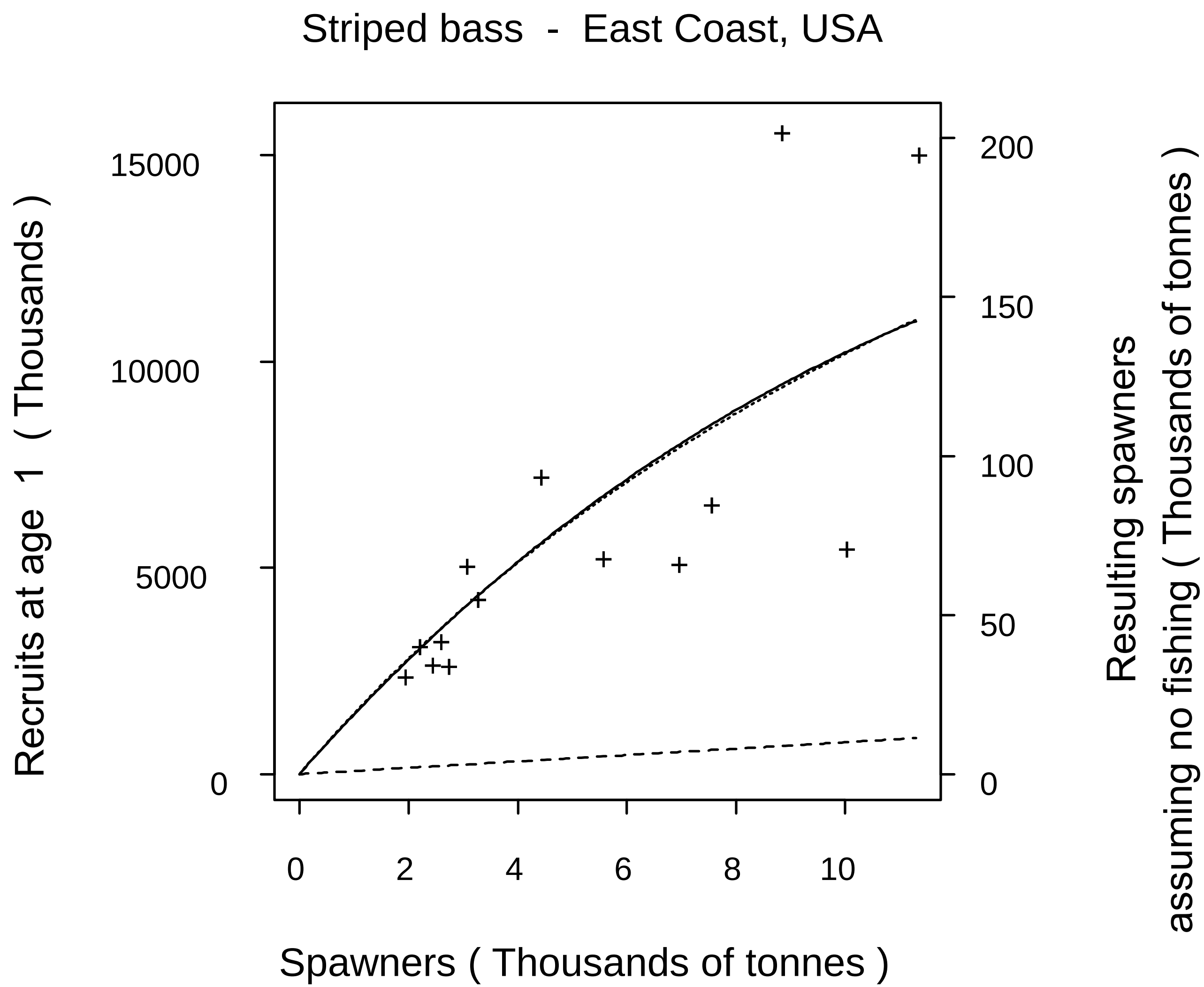


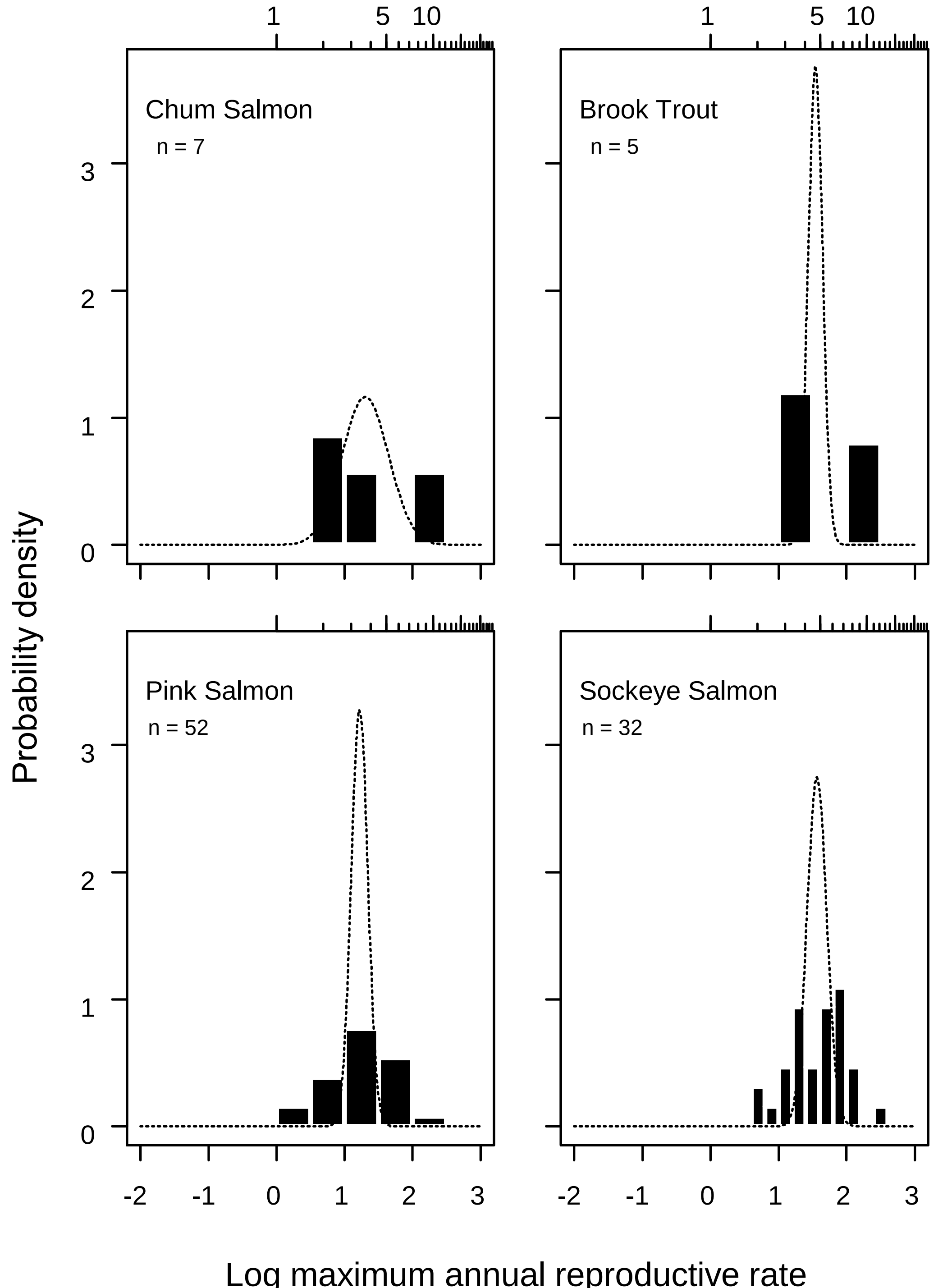


Sockeye salmon - Adams Complex, B.C.
Recruits at age 4 (Millions)
Resulting spawners
assuming no fishing (Millions)
Spawners (Millions)
0
2
4
6
8
0.0
0.5
1.0
1.5

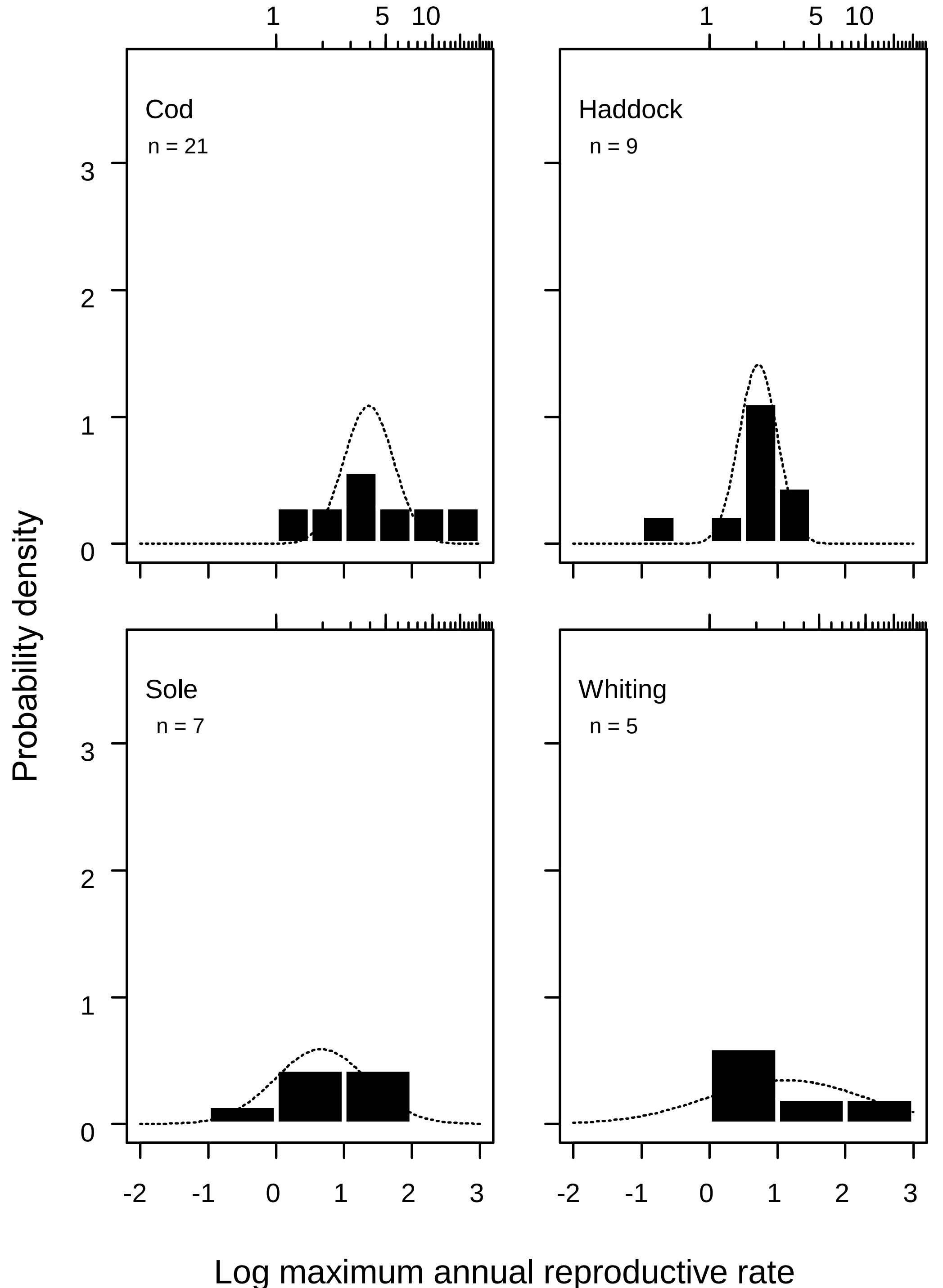


Cod - Iceland
Recruits at age 3 (Millions)
0
200
400
600
0
500
1000
1500
Spawners (Thousand tonnes)
0
5000
10000
15000
Resulting spawners
assuming no fishing (Thousand tonnes)

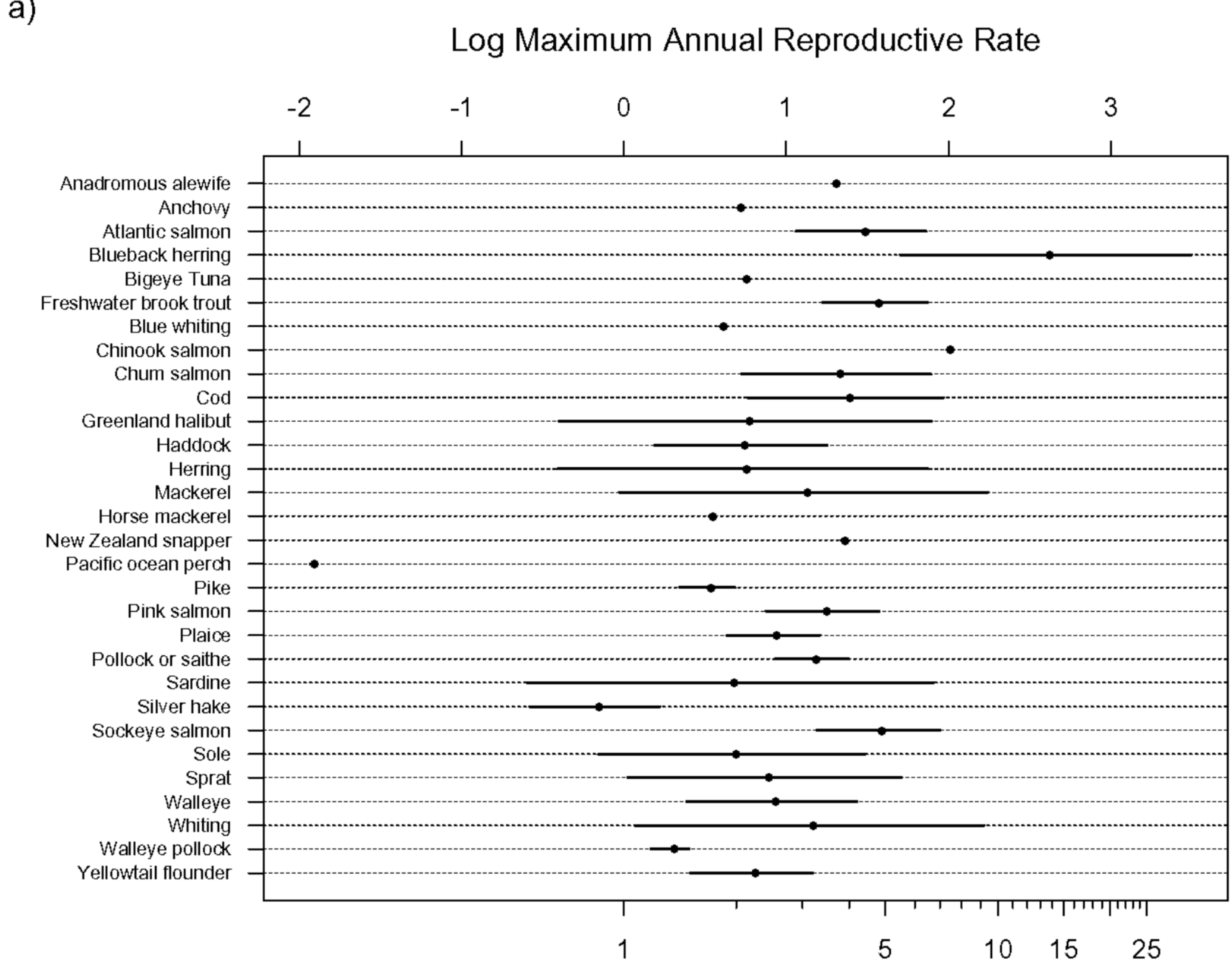

Striped bass - East Coast, USA
Recruits at age 1 (Thousands)
15000
10000
5000
0
0
2
4
6
8
10
Spawners (Thousands of tonnes)
200
150
100
50
0
Resulting spawners
assuming no fishing (Thousands of tonnes)



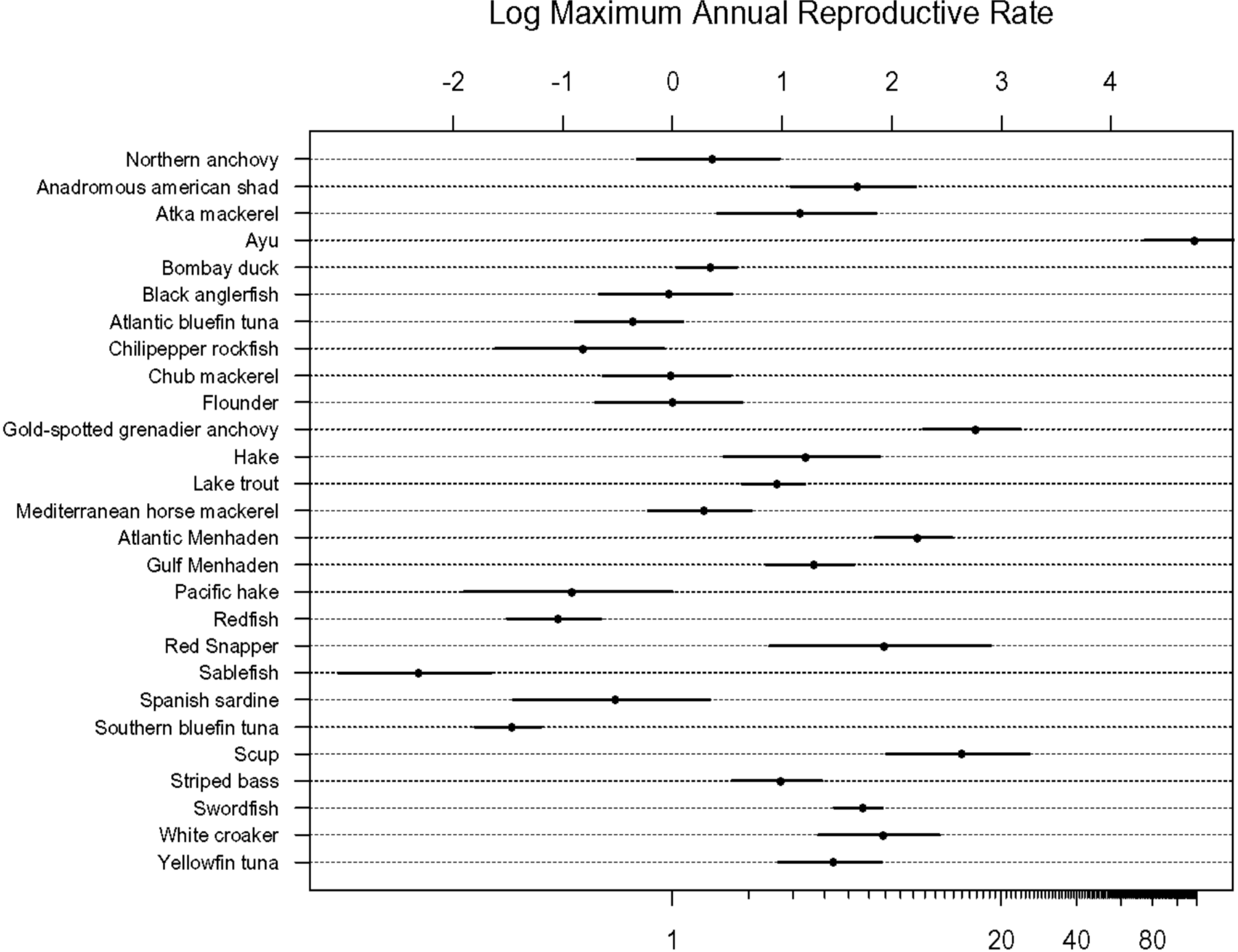
Chum Salmon
n = 7
Brook Trout
n = 5
Pink Salmon
n = 52
Sockeye Salmon
n = 32
1
5
10
0
1
2
3
-2
-1
Probability density
Log maximum annual reproductive rate



Cod
n = 21
Haddock
n = 9
Sole
n = 7
Whiting
n = 5
1
5
10
0
1
2
3
-2
-1
0
1
2
3
Probability density
Log maximum annual reproductive rate

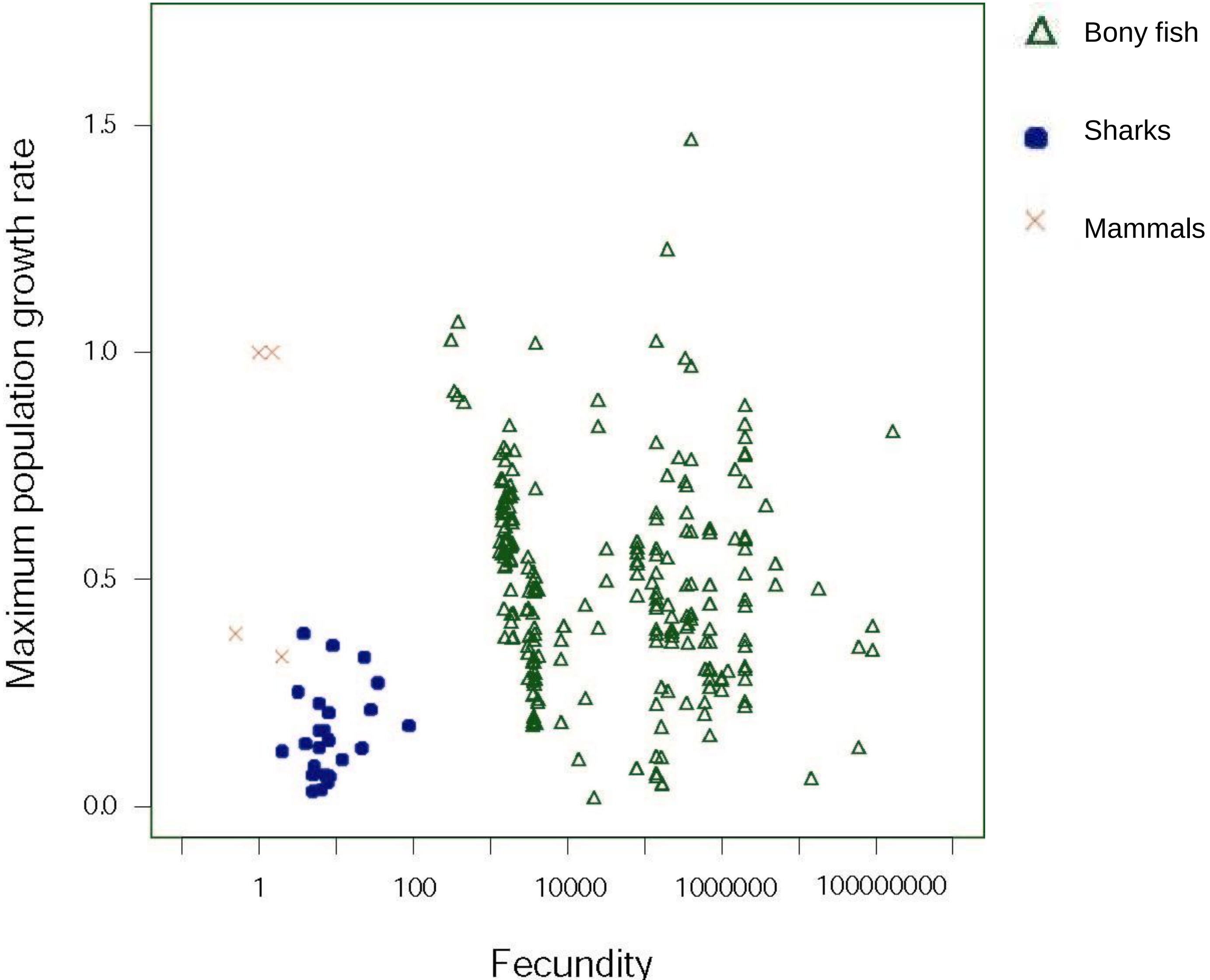


Maximum average rate that spawners can produce replacement spawners per year



Maximum average rate that spawners can produce replacement spawners per year

Are fish different from mammals?



Approach

- Separate data into two parts: one for hypothesis generation, one for hypothesis testing (this keeps me from "cheating").

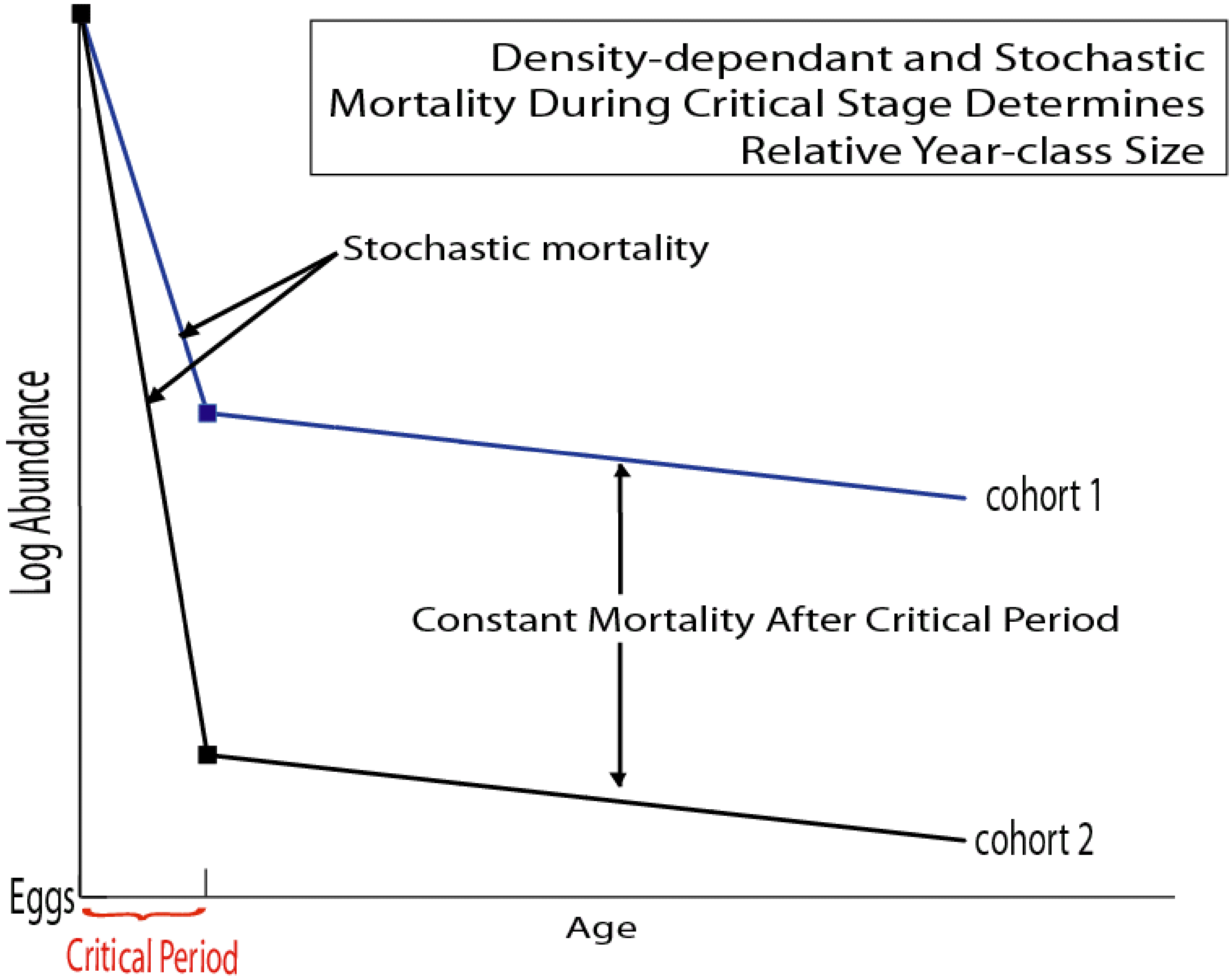
Four Ways to Look at Density-dependent Mortality

- Use Virtual Population Analysis to obtain an estimate of scope of compensation (we just did this)
- Use Linear State Space Models using the Analysis of Covariance Structure
- Use Generalized Linear Mixed Effects Models
- Use Meta-analytic nonlinear, non-Gaussian state space models.

Hjort's (1914) critical period hypothesis

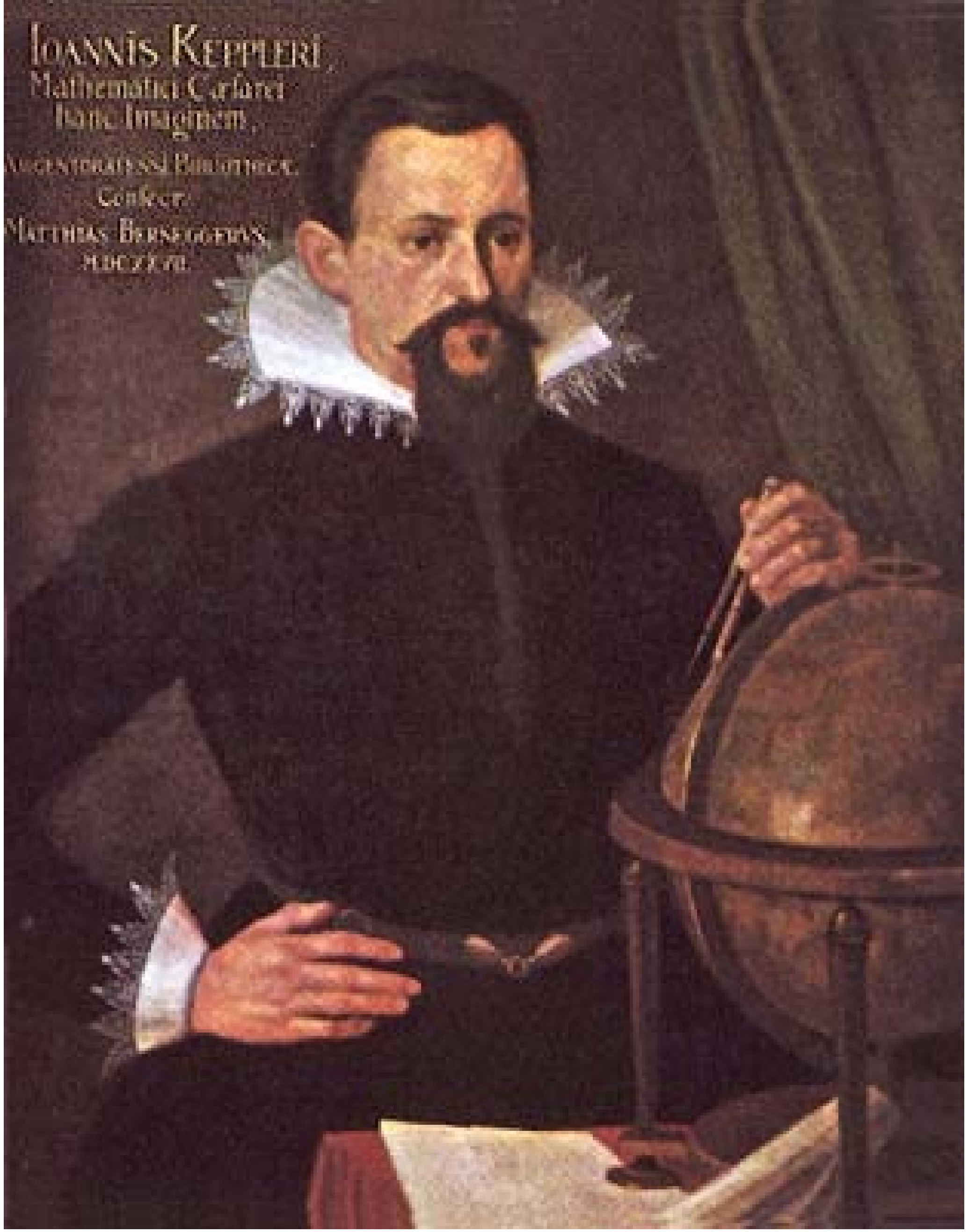
- ‘the numerical value of a year class is apparently stated at a very early age, and continues in approximately the same relation to that of other year classes throughout the life of the individuals”
- This is the fundamental issue in population regulation and ecology of fish.

Hjort's Hypothesis: Strong Version

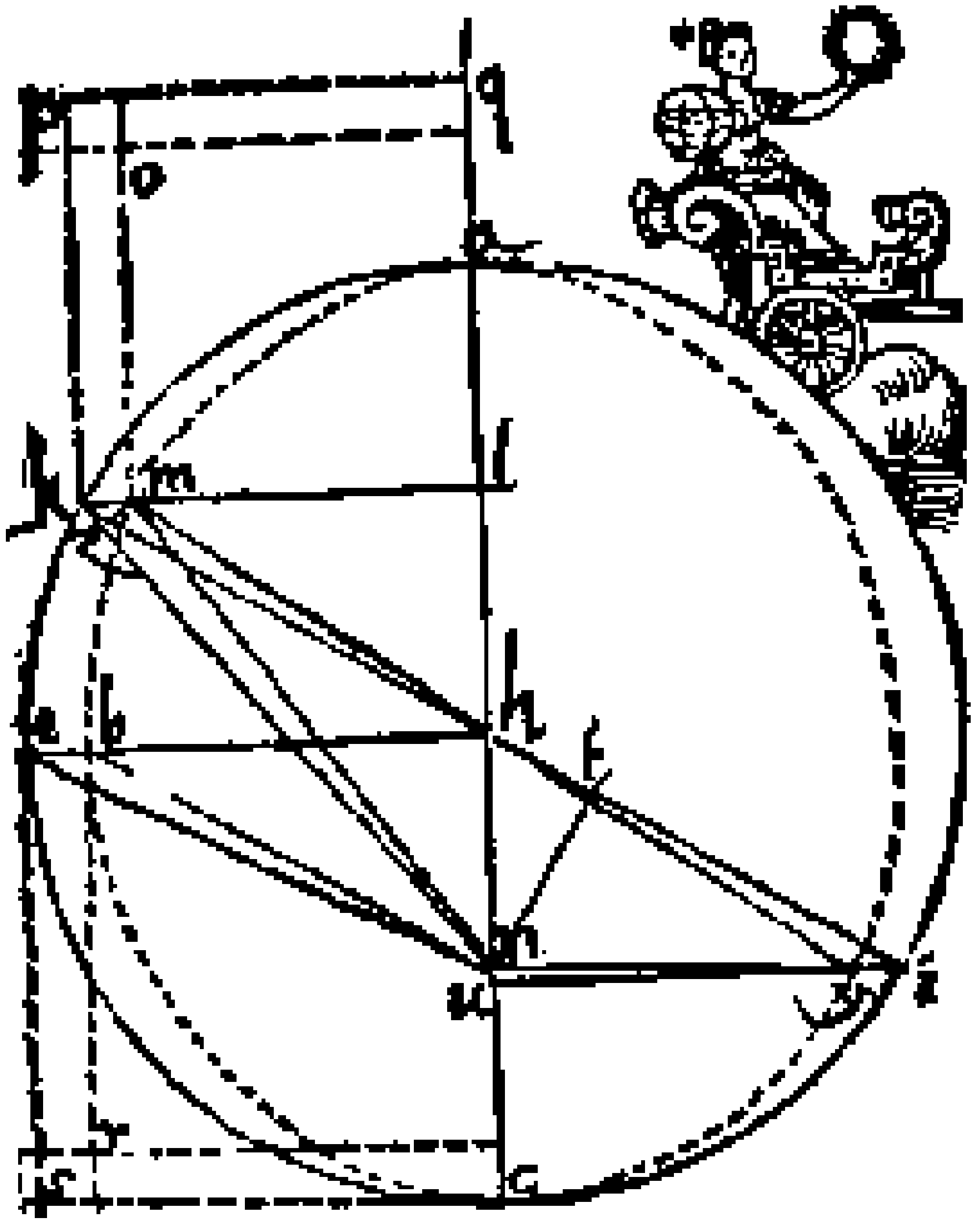


Why we need new methods to analyze marine data

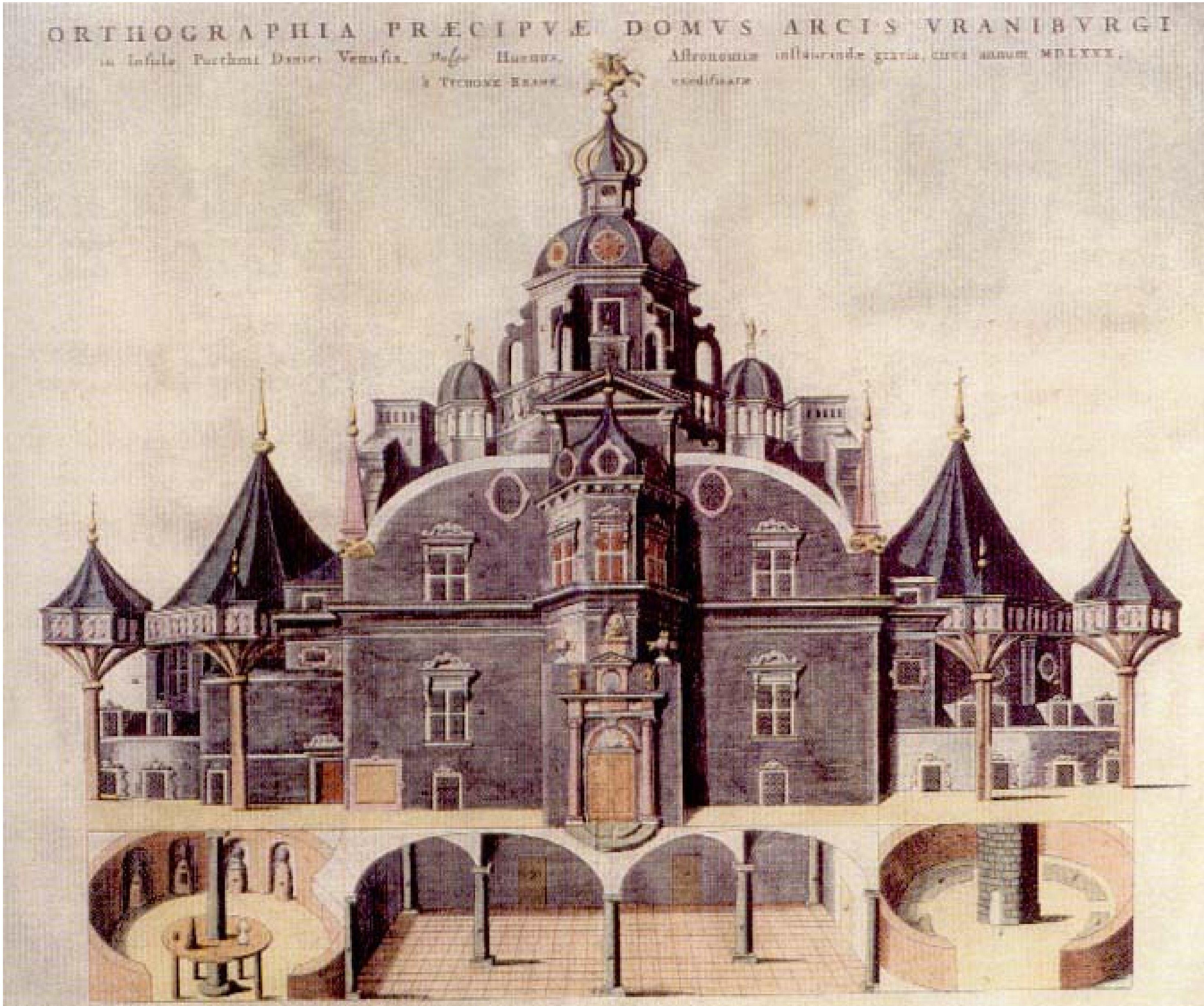
What can we learn from the history of physics.

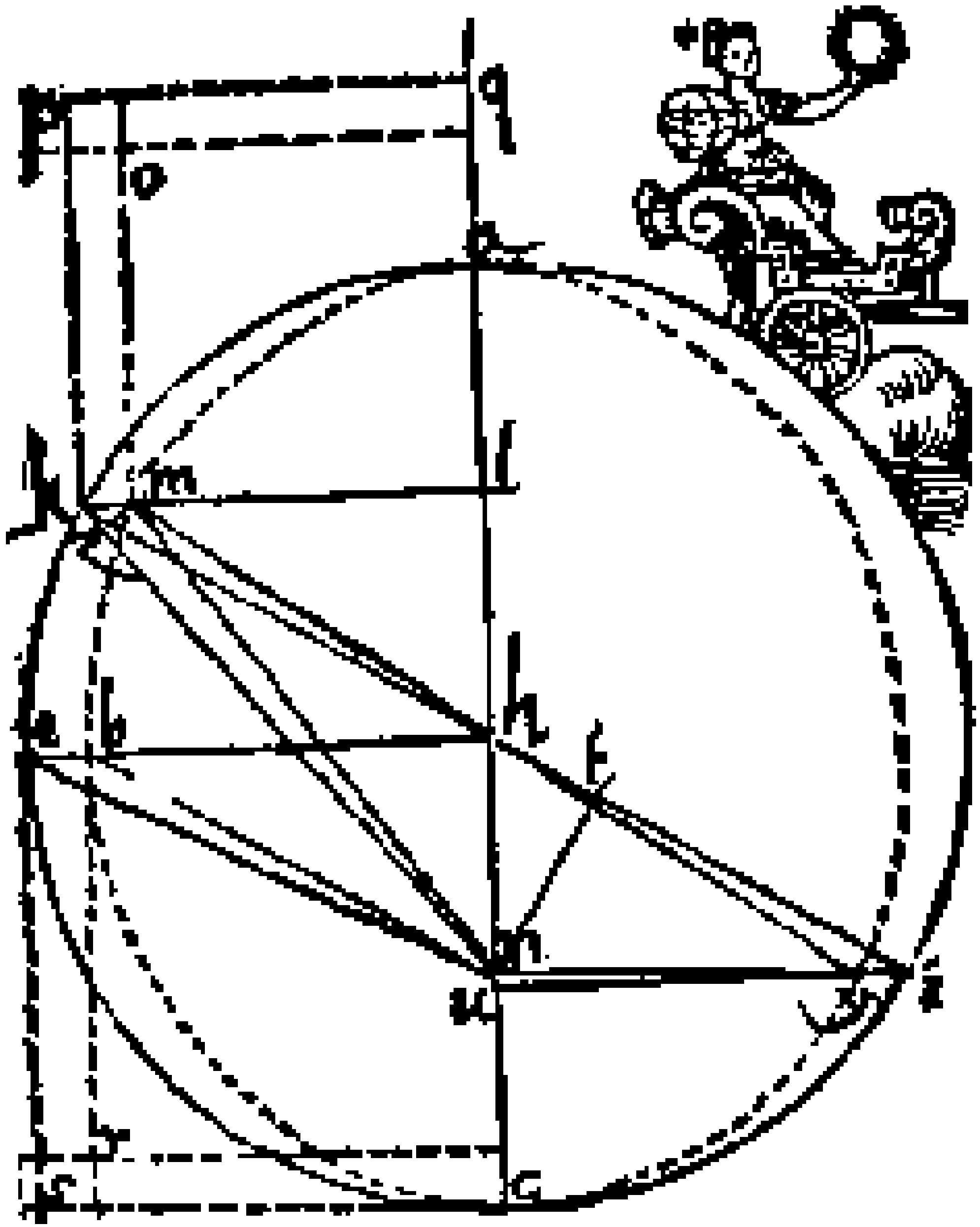


Imperial Mathematician

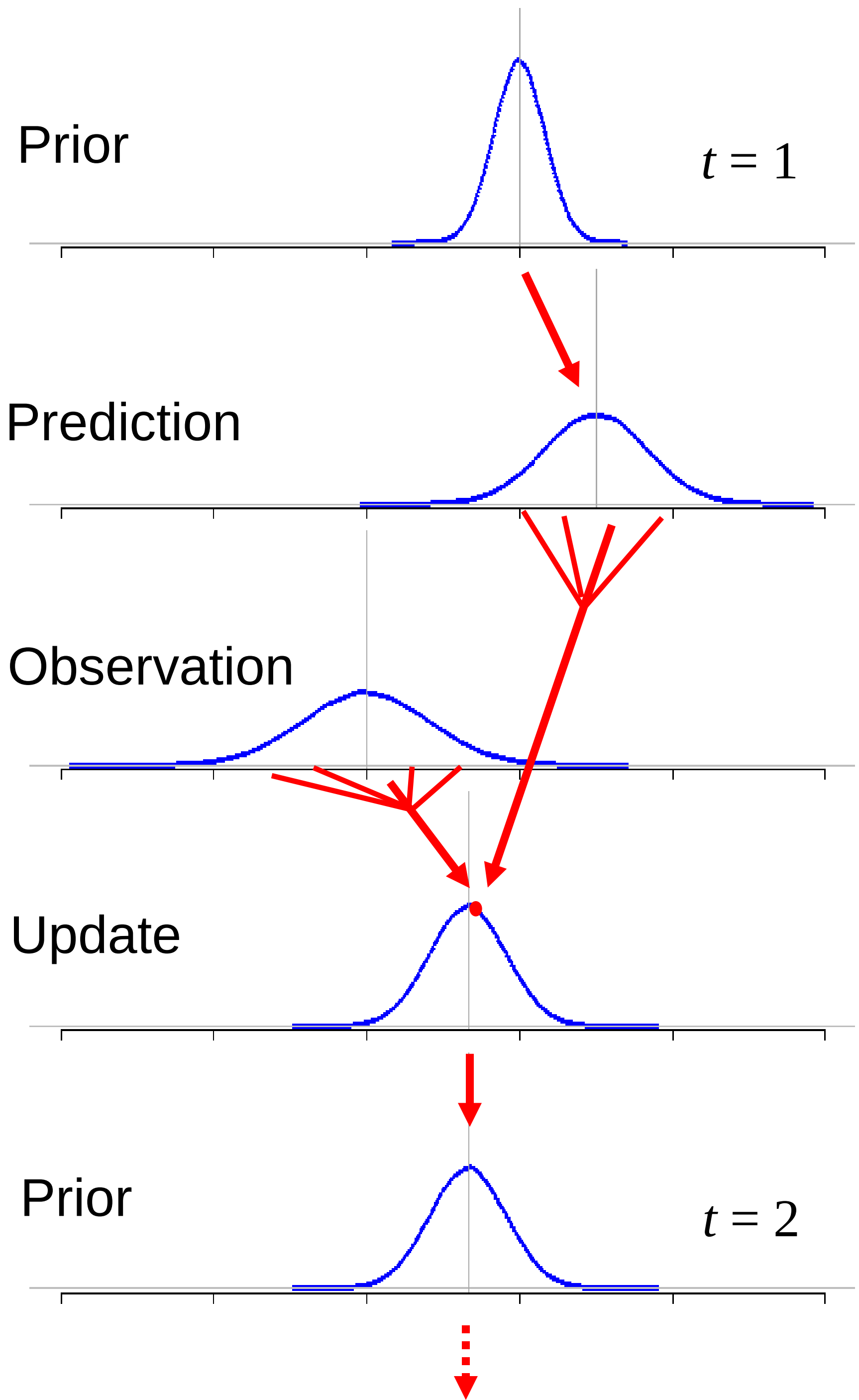


Kepler's elliptical orbit for Mars..


ORTHOGRAPHIA PRÆCIPVÆ DOMVS ARCIS VRANIBVRGI



Kepler's elliptical orbit for Mars..



Previous abundance estimates

Apply dynamics (transition eqn)

Observe a location with error

Integrate over predicted & observed densities (Bayes Rule)

Updated prediction becomes prior for next time step

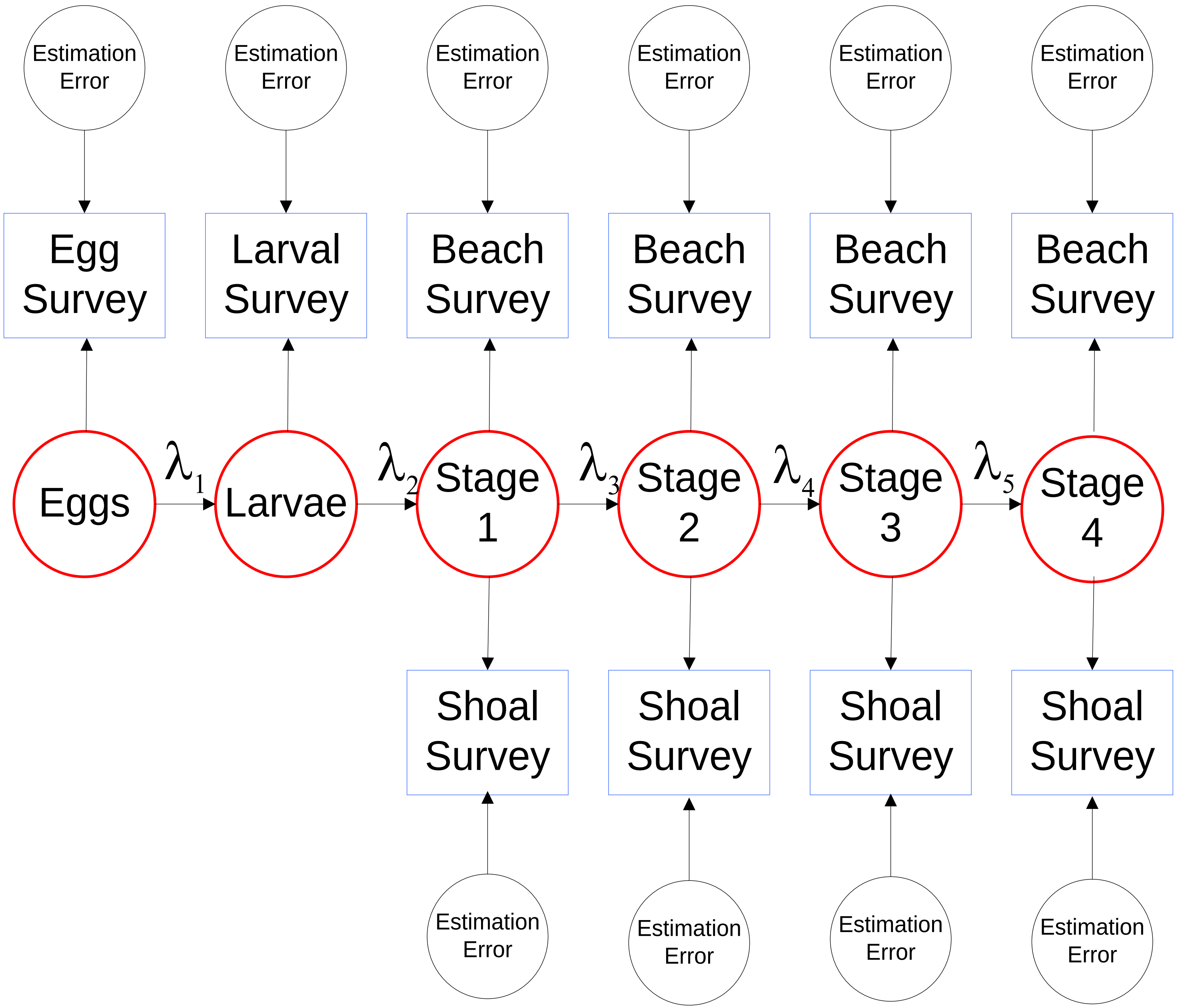
Estimate parameters by Bayesian or Likelihood Analysis

Bayes Rule

$$p(\mathbf{x}_t \mid \mathrm{Y}_t;\gamma) = \frac{p_y(\mathbf{y}_t \mid \mathbf{x}_t)\, p(\mathbf{x}_t \mid \mathrm{Y}_{t-1};\gamma)}{\int p_y(\mathbf{y}_t \mid \mathbf{x}_t)\, p(\mathbf{x}_t \mid \mathrm{Y}_{t-1};\gamma)\, d\mathbf{x}_t}$$

Innovation Likelihood of Observe Population Trajectories

Stage-based data for striped bass from Hudson Estuary:



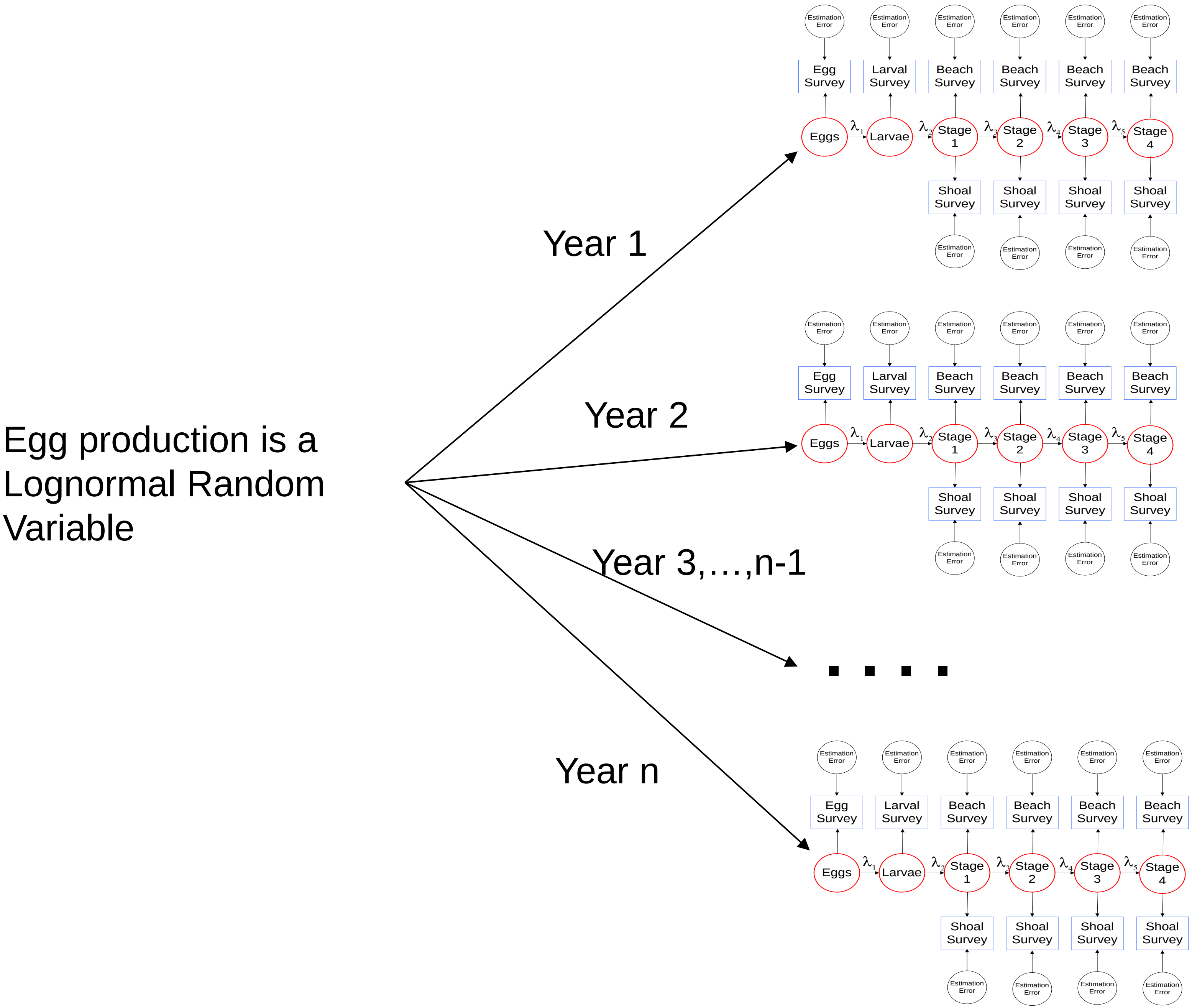

Egg production is a Lognormal Random Variable
Year 1
Year 2
Year 3,…,n-1
Year n
Estimation Error
Egg Survey
Larval Survey
Beach Survey
Eggs
Larvae
Stage 1
Stage 2
Stage 3
Stage 4
λ_1
λ_2
λ_3
λ_4
λ_5
Shoal Survey
. . . .

Table 1. Data for the North Sea cod stock from VPA in millions of fish, IYFS innumbers per hour fished, and EGFS in numbers per hour fished.

Year class	VPA 1-yr-olds	IYFS 1-yr-olds	IYFS 2-yr-olds	EGFS 0-yr-olds	EGFS 1-yr-olds	EGFS 2-yr-olds
1970	847	98.30	34.50			
1971	159	4.10	10.60			
1972	289	38.00	9.50			
1973	232	14.70	6.20			
1974	426	40.30	19.90			
1975	196	7.90	3.20			4.50
1976	726	36.70	29.30		62.70	12.50
1977	426	12.90	9.30	13.90	22.80	5.80
1978	449	9.90	14.80	12.60	24.20	6.70
1979	800	16.90	25.50	18.60	50.80	13.90
1980	271	2.90	6.70	10.20	11.40	2.90
1981	557	9.20	16.60	74.20	32.40	11.00
1982	269	3.90	8.00	2.50	15.40	4.70
1983	534	15.20	17.60	95.10	61.20	11.90
1984	108	0.90	3.60	0.40	4.30	1.20
1985	581	17.00	28.80	8.30	34.40	10.70
1986	257	8.80	6.10	1.20	14.20	4.10
1987	201	3.60	6.30	0.40	8.40	2.50
1988	324	13.10	15.20	16.80	22.80	5.10
1989		3.30		6.0	6.10	
1990				3.90		

1-Compensation

Abundance

Dynamical Equation:

$$N_{t,1} = N_{t,0}\, e^{-m - (1-\lambda)\log N_{t,0} + \varepsilon_t}$$

Cohort Age

Log Abundance

Log Transformation:

$$L_{t,a} = \log N_{t,a}$$

Abundance

Background Mean Mortality Stochastic Mortality

Dynamical Equation for Log Abundance:

$$L_{t,1} = -m + \lambda L_{t,0} + \varepsilon_t$$

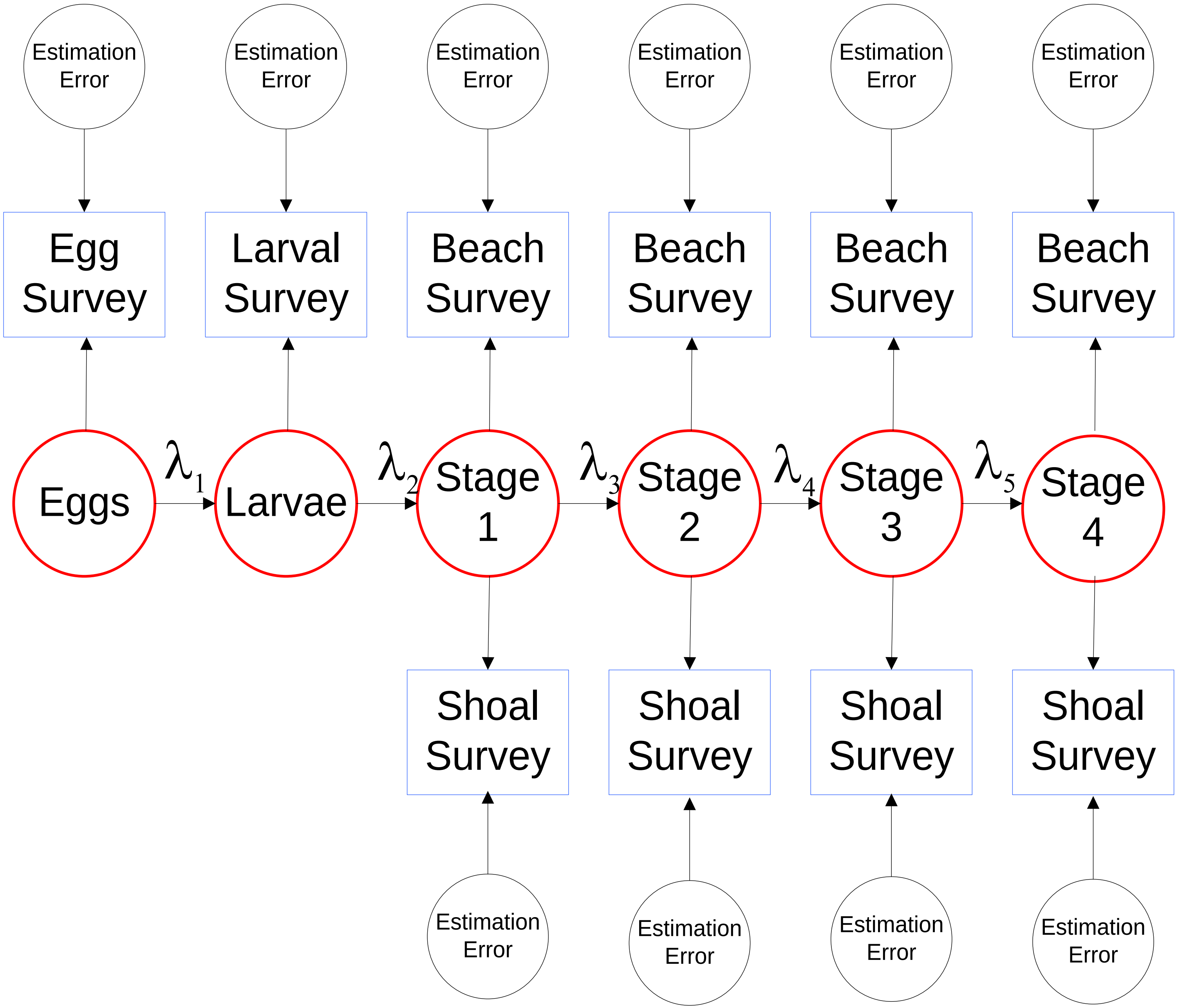
Myers and Cadigan 1993a,b 1993

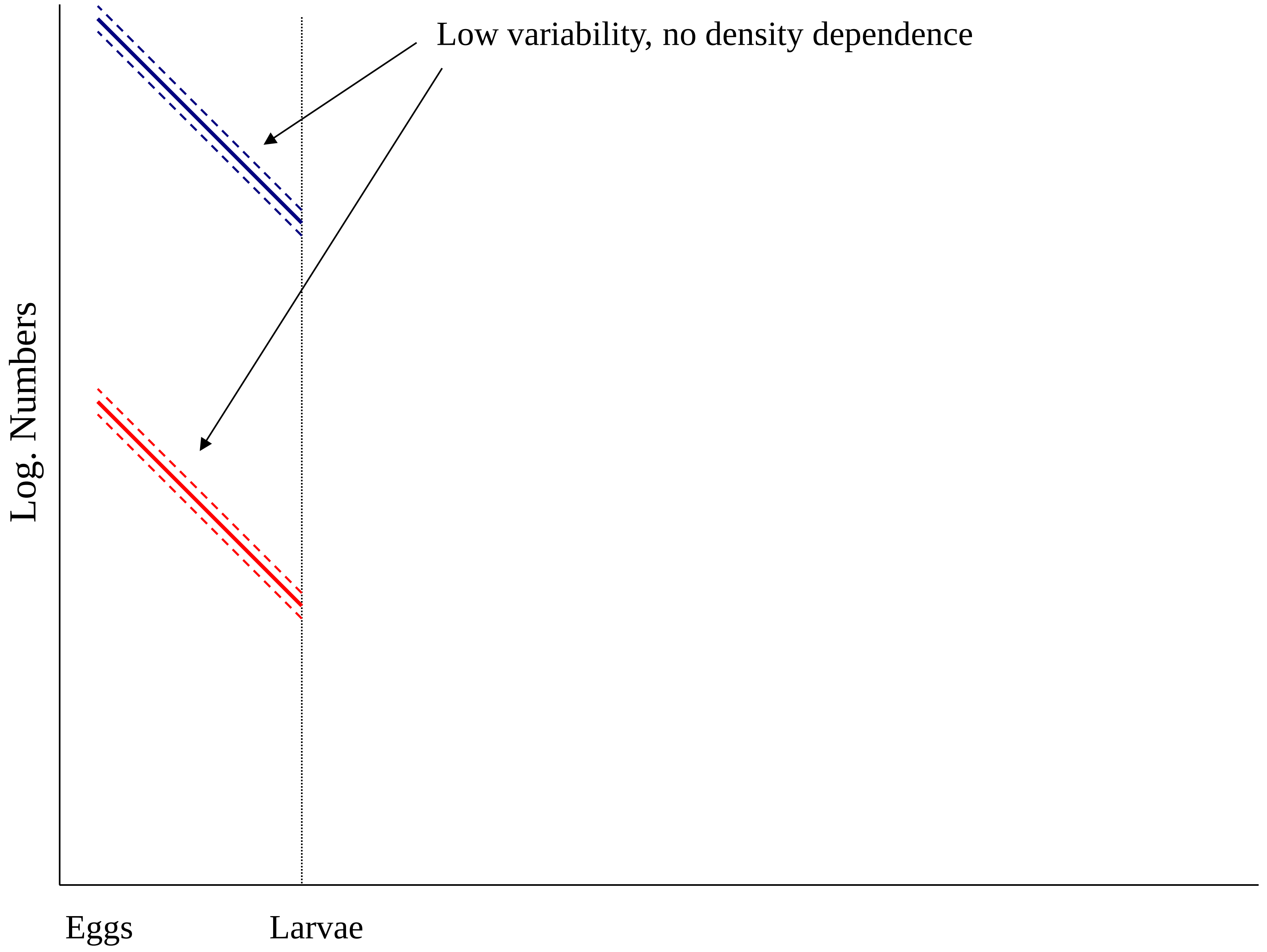
Analysis of Covariance Structures

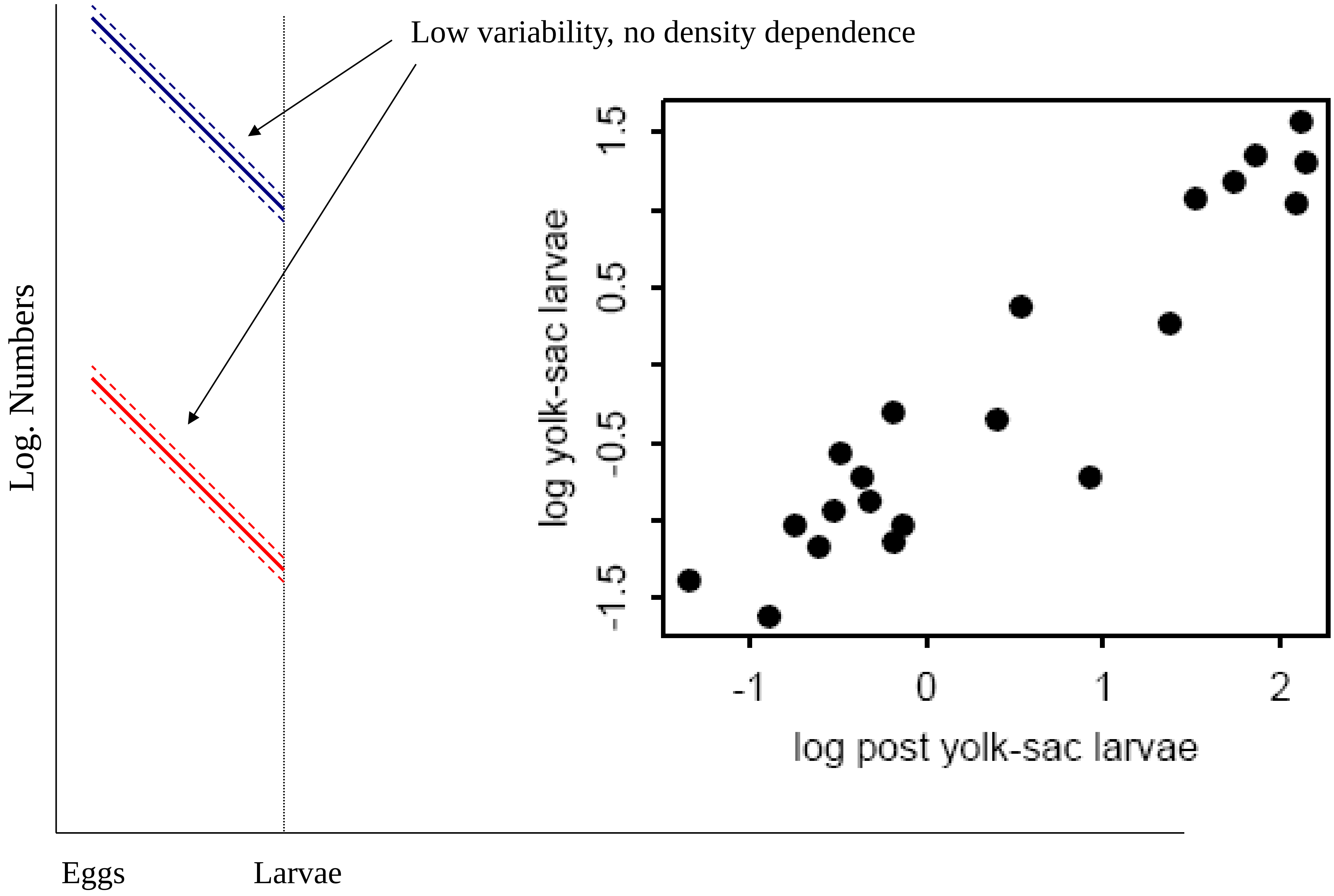
$$\begin{bmatrix} VAR(l_{t,0,1}) & COV(l_{t,0,1}, l_{t,0,2}) & COV(l_{t,0,1}, l_{t,1,1}) & COV(l_{t,0,1}, l_{t,1,2}) \\ & VAR(l_{t,0,2}) & COV(l_{t,0,2}, l_{t,1,1}) & COV(l_{t,0,2}, l_{t,1,2}) \\ & & VAR(l_{t,1,1}) & COV(l_{t,1,1}, l_{t,1,2}) \\ & & & VAR(l_{t,1,2}) \end{bmatrix}$$

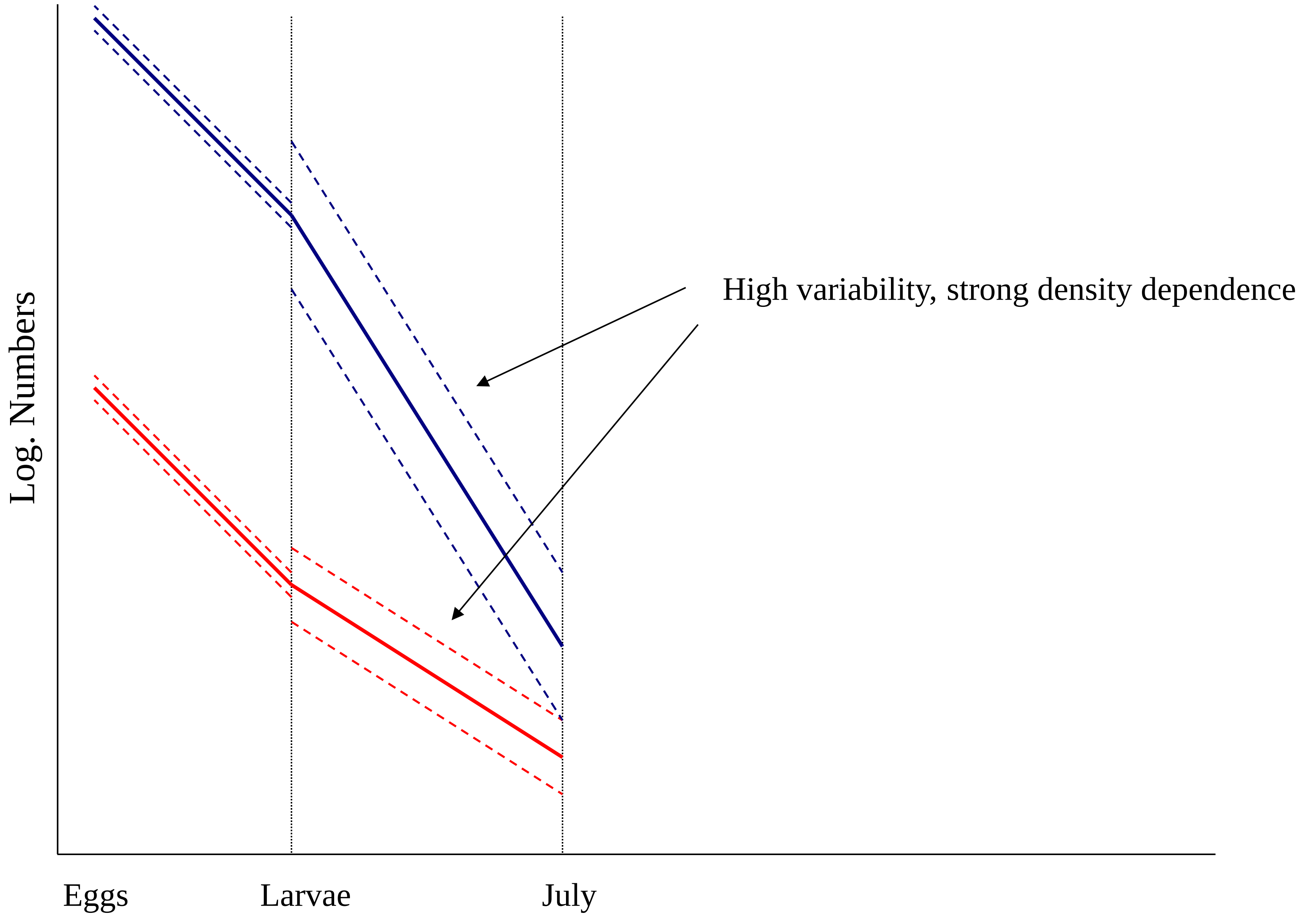
$$= \begin{bmatrix} \phi + \theta_{0,1} & \phi & \lambda\phi & \lambda\phi \\ & \phi + \theta_{0,2} & \lambda\phi & \lambda\phi \\ & & \lambda^2\phi + \psi + \theta_{1,1} & \lambda^2\phi + \psi \\ & & & \lambda^2\phi + \psi + \theta_{1,2} \end{bmatrix}.$$

Myers and Cadigan 1993a,b 1993

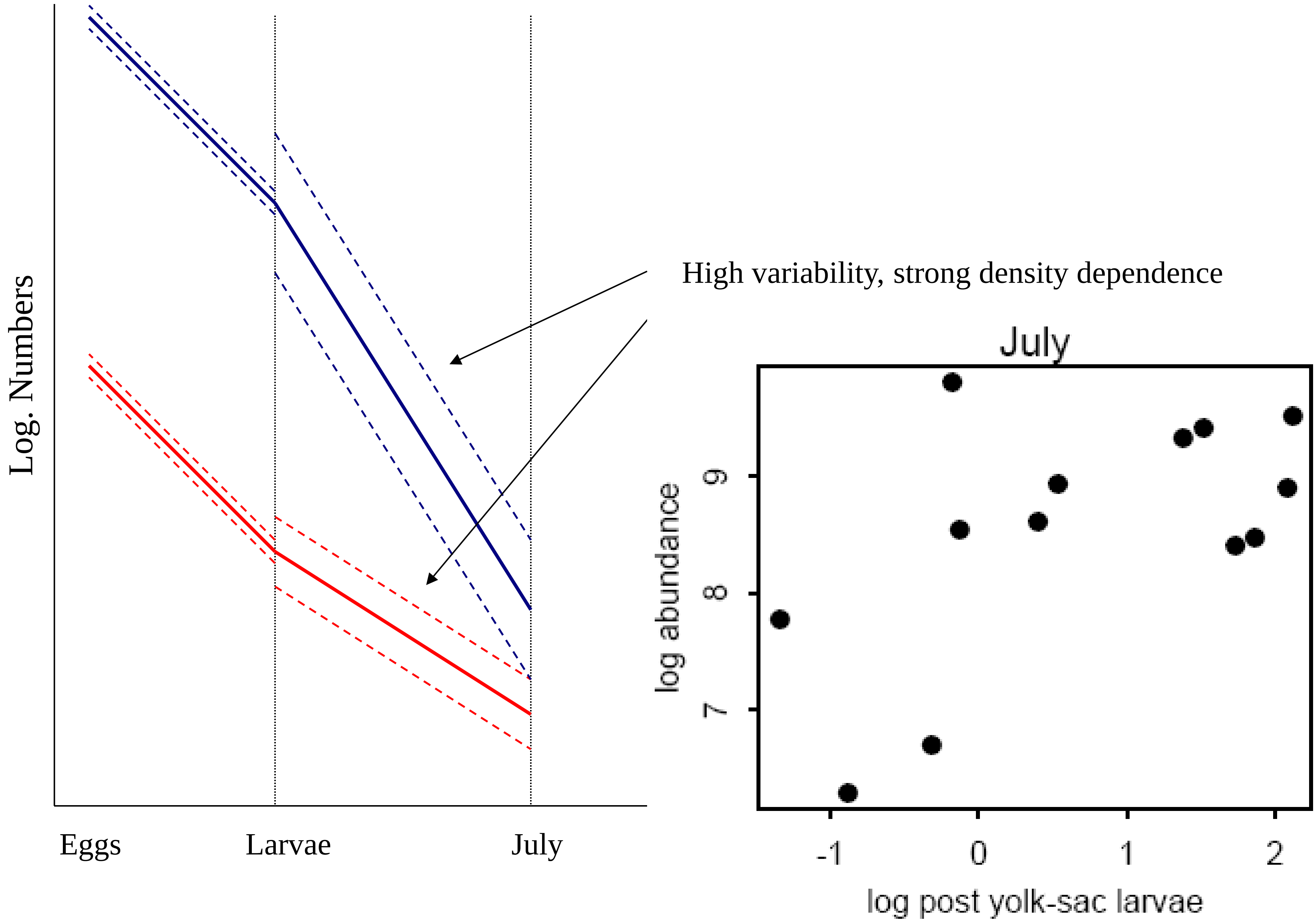

Estimation Error
Estimation Error
Estimation Error
Estimation Error
Estimation Error
Estimation Error
Egg Survey
Larval Survey
Beach Survey
Beach Survey
Beach Survey
Beach Survey
Eggs
λ1
Larvae
λ2
Stage 1
λ3
Stage 2
λ4
Stage 3
λ5
Stage 4
Shoal Survey
Shoal Survey
Shoal Survey
Shoal Survey
Estimation Error
Estimation Error
Estimation Error
Estimation Error


Low variability, no density dependence
Log. Numbers
Eggs
Larvae


Low variability, no density dependence
Log. Numbers
Eggs
Larvae
log yolk-sac larvae
1.5
0.5
-0.5
-1.5
-1
0
1
2
log post yolk-sac larvae



Log. Numbers
High variability, strong density dependence
Eggs
Larvae
July



High variability, strong density dependence
Log. Numbers
Eggs
Larvae
July
July
log abundance
7
8
9
-1
0
1
2
log post yolk-sac larvae

The greatest part of density-dependent mortality occurs around June

- This density dependent mortality is large, and is described by the equation

$$N_{t,1} = N_{t,0}\, e^{-m - (1-\lambda) \log N_{t,0} + \varepsilon_t}$$

Variation in larvae = 1.2

DDM = 0.75 (se.e = 0.2)

Variation in mortality = 0.8

The greatest part of density-dependent mortality occurs around June

- This density dependent mortality is large, and is described by the equation

$$N_{t,1} = N_{t,0}\, e^{-m - (1-\lambda) \log N_{t,0} + \varepsilon_t}$$

Variance in larvae = 1.14

DDM = 0.75 (se = 0.2)

Variance in mortality = 0.67

Variation due to larvae = 1.14*(.25^2) = 0.75

That is, by July a round 10% of the variance in relative abundance is due to egg/larval abundance.

The greatest part of density-dependent mortality occurs around June

- This density dependent mortality is large, and is described by the equation

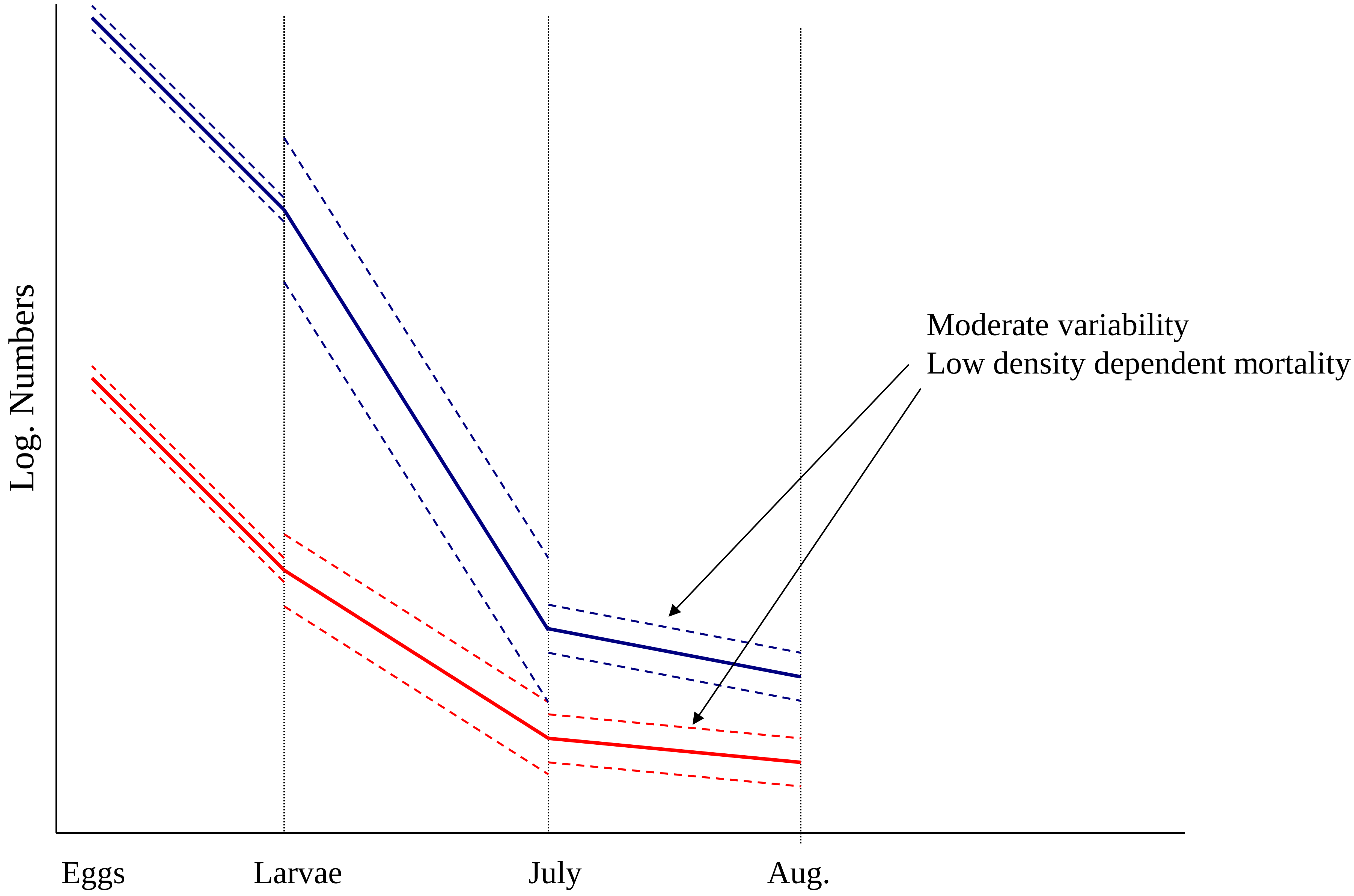
$$N_{t,1} = N_{t,0}\, e^{-m - (1-\lambda) \log N_{t,0} + \varepsilon_t}$$

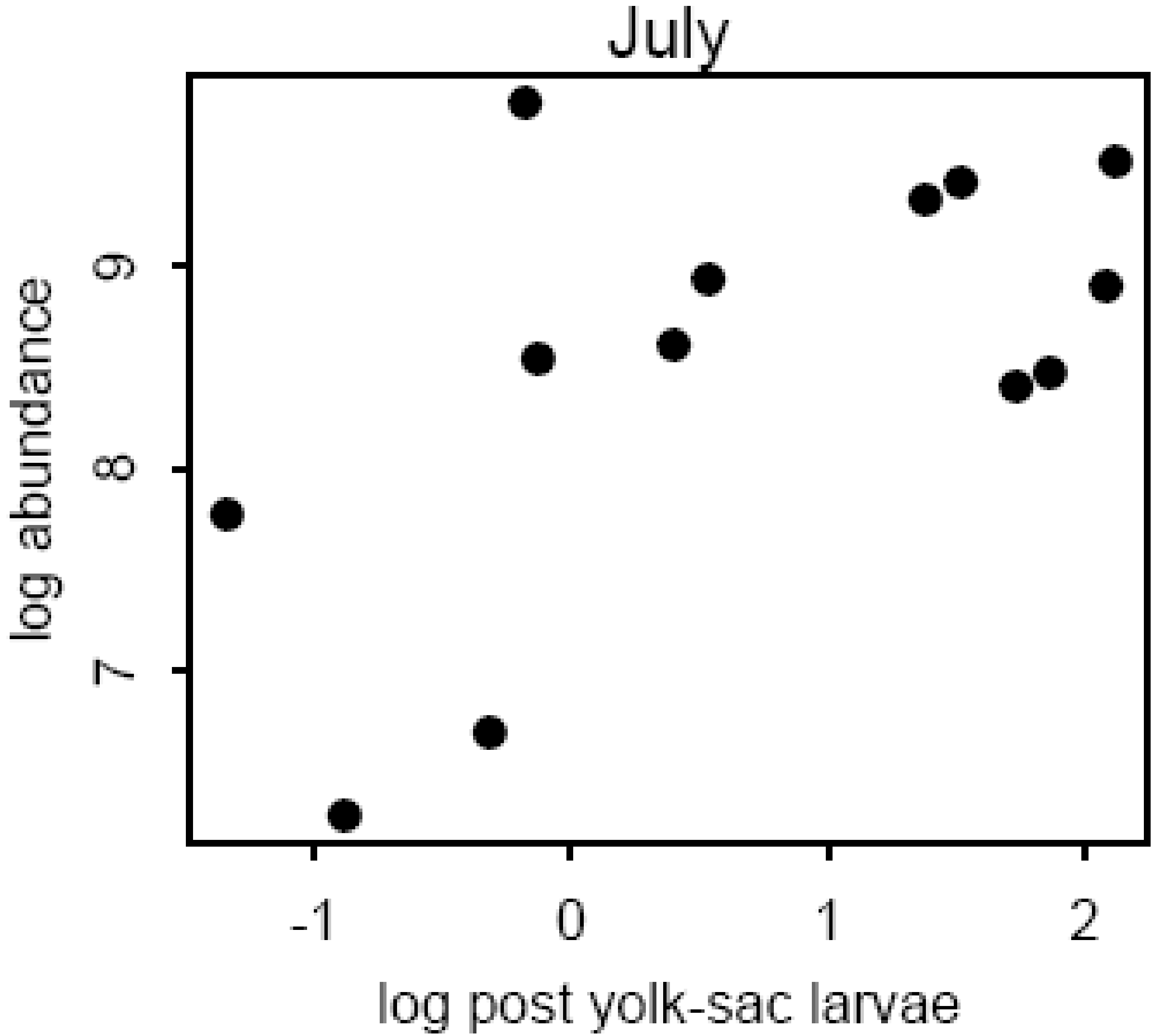
Variance in larvae = 1.14

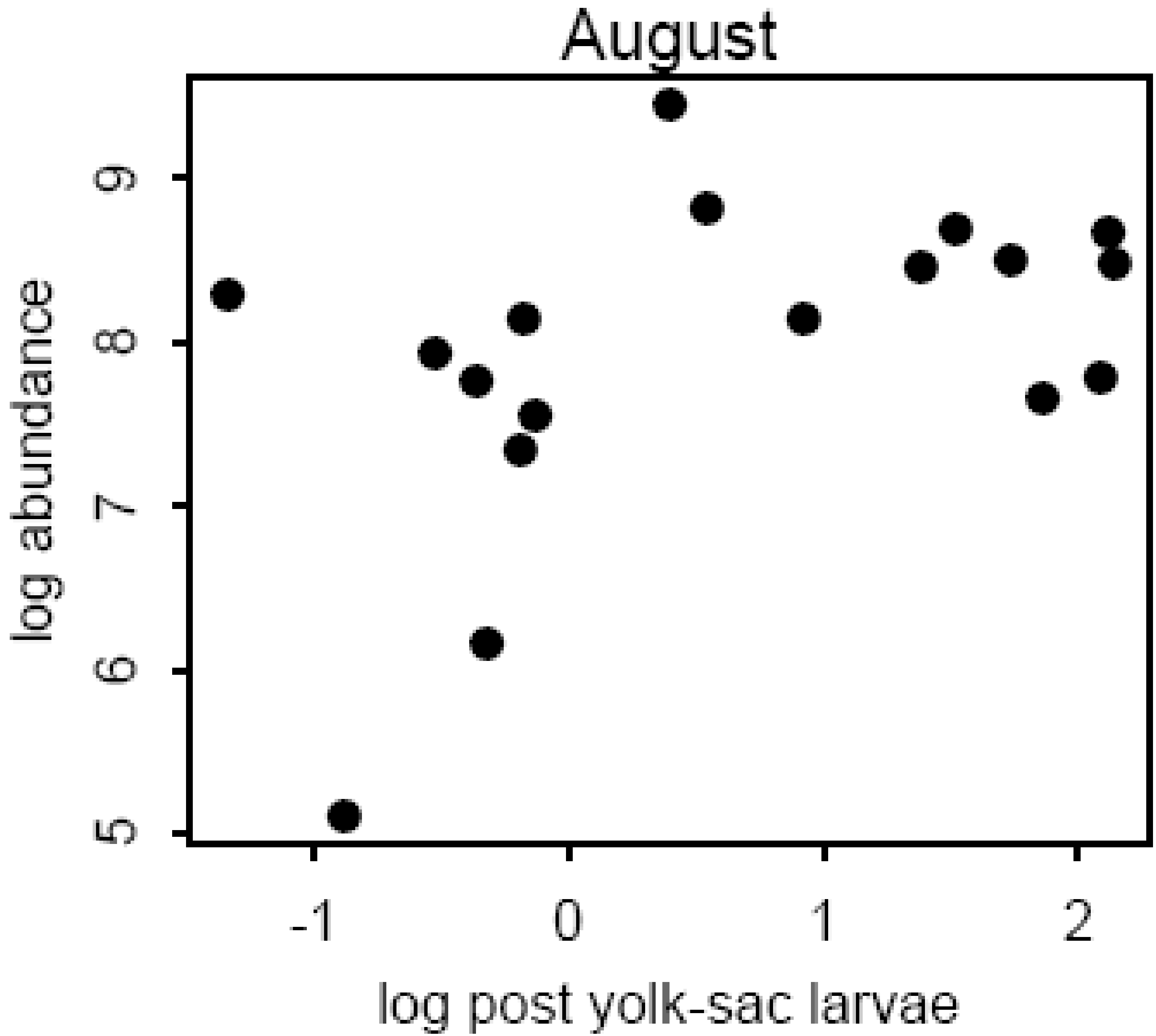
DDM = 0.75 (se = 0.2)

Variance in mortality = 0.67

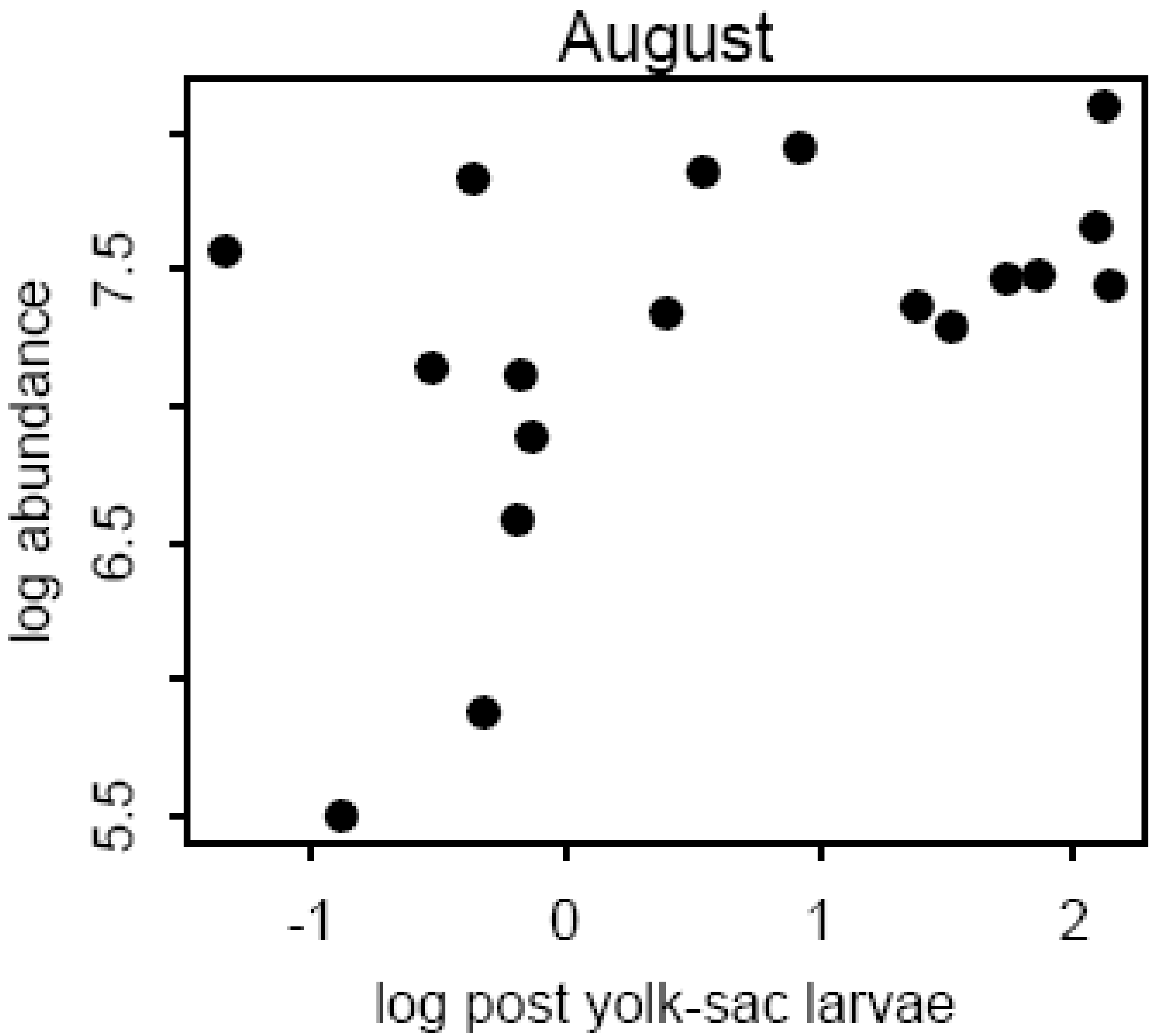
Results confirmed from beach and shoal surveys.


Log. Numbers
Moderate variability
Low density dependent mortality
Eggs
Larvae
July
Aug.

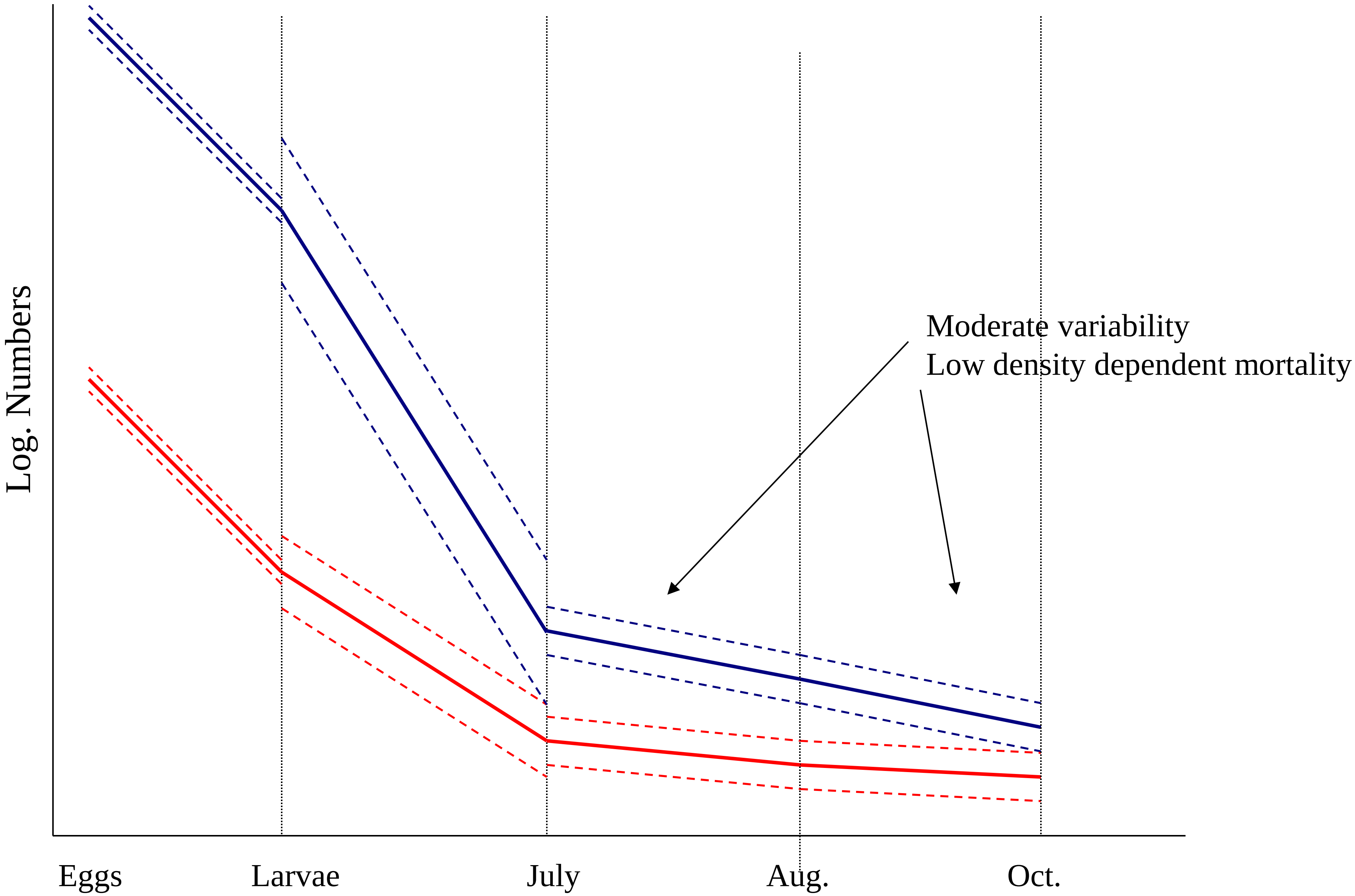

July
log abundance
9
8
7
-1
0
1
2
log post yolk-sac larvae



August
log abundance
9
8
7
6
5
-1
0
1
2
log post yolk-sac larvae



Industry Beach Survey



Log. Numbers
Moderate variability
Low density dependent mortality
Eggs
Larvae
July
Aug.
Oct.

The density dependent mortality after June is weak

- This density dependent mortality is large, and is described by the equation

$$N_{t,1} = N_{t,0}\, e^{-m - (1-\lambda) \log N_{t,0} + \varepsilon_t}$$

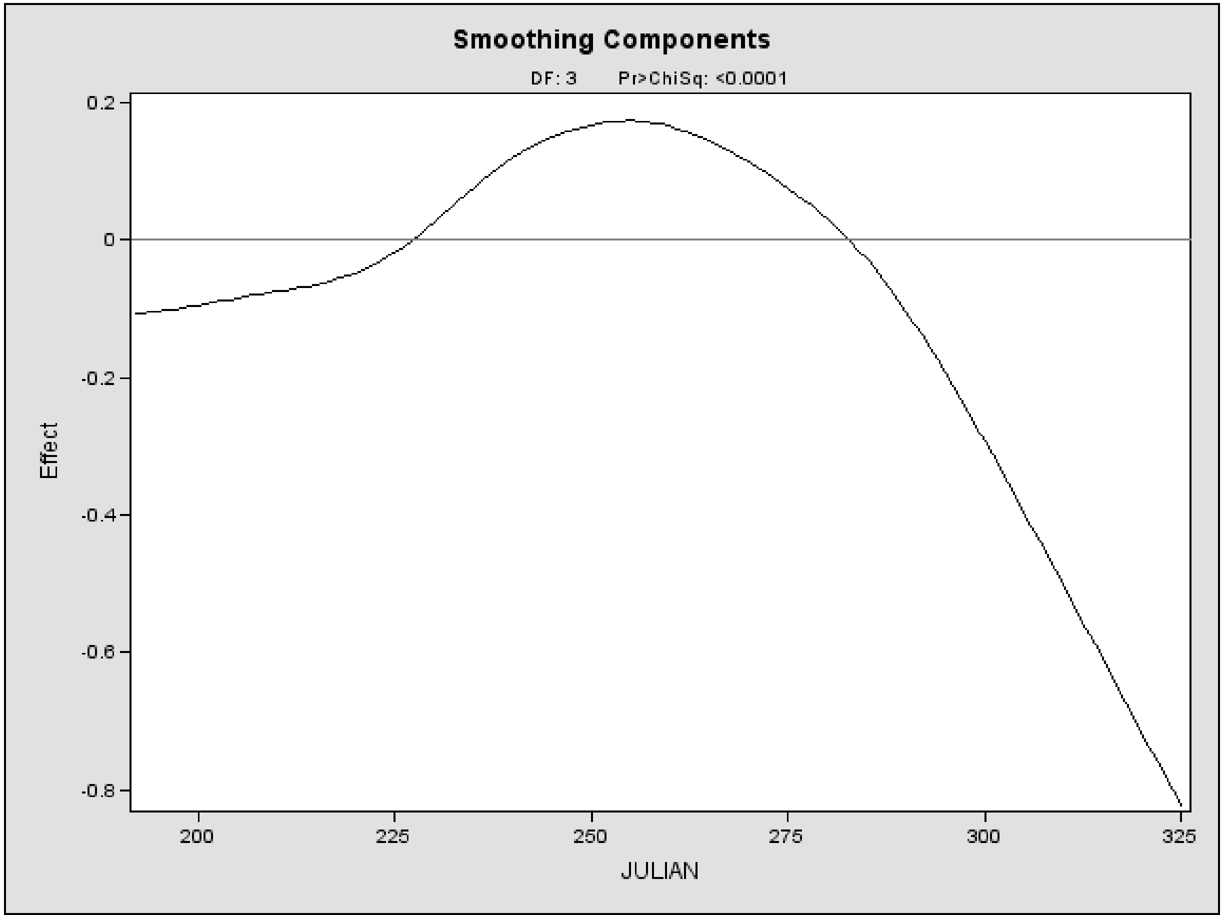
DDM = 0.82
(se = 0.16)

Variance in
mortality = 0.05

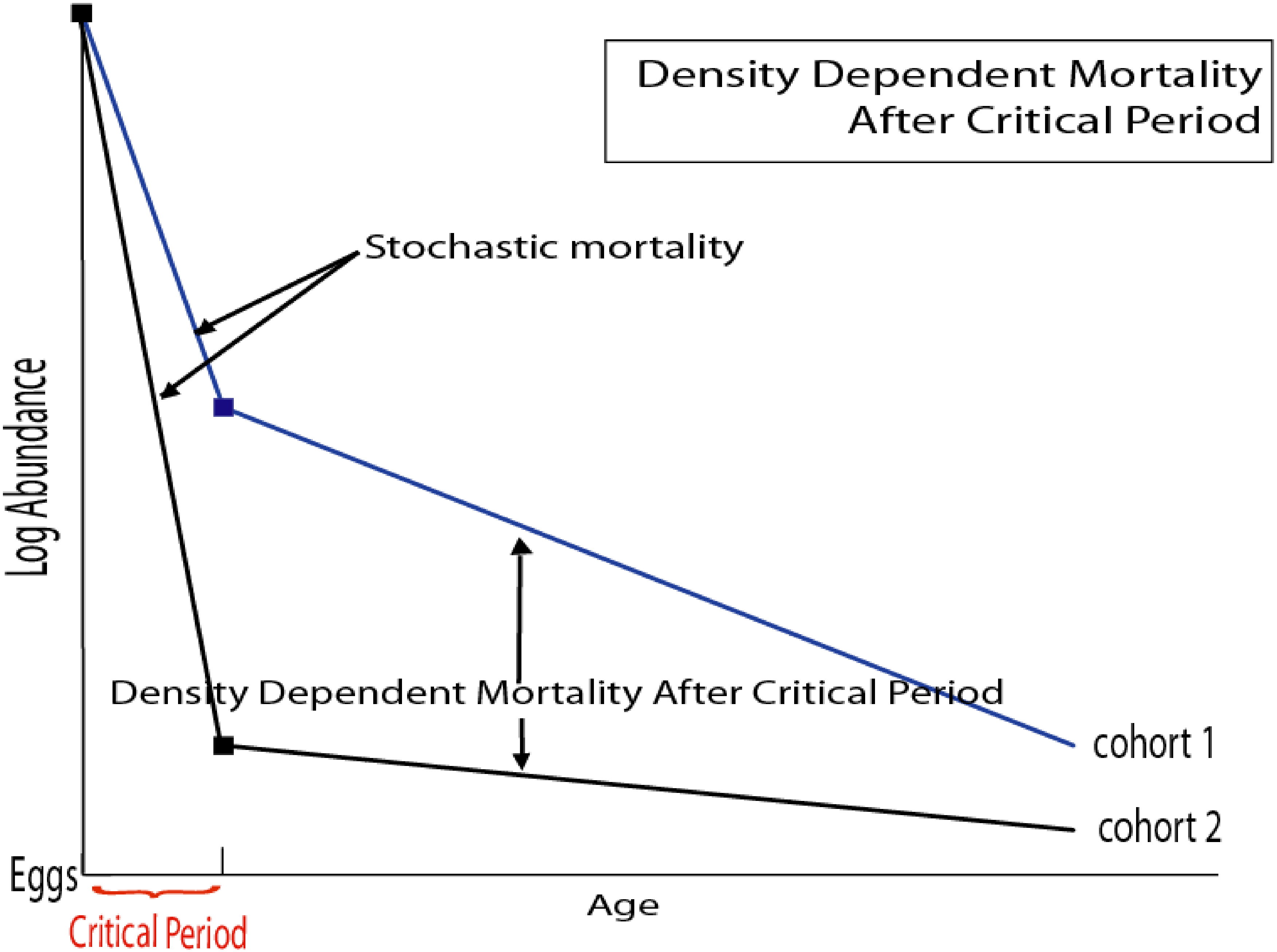
Results confirmed from beach, shoal and DEC surveys, and from alternative methods.

Alternative approach: Generalized linear mixed effects model

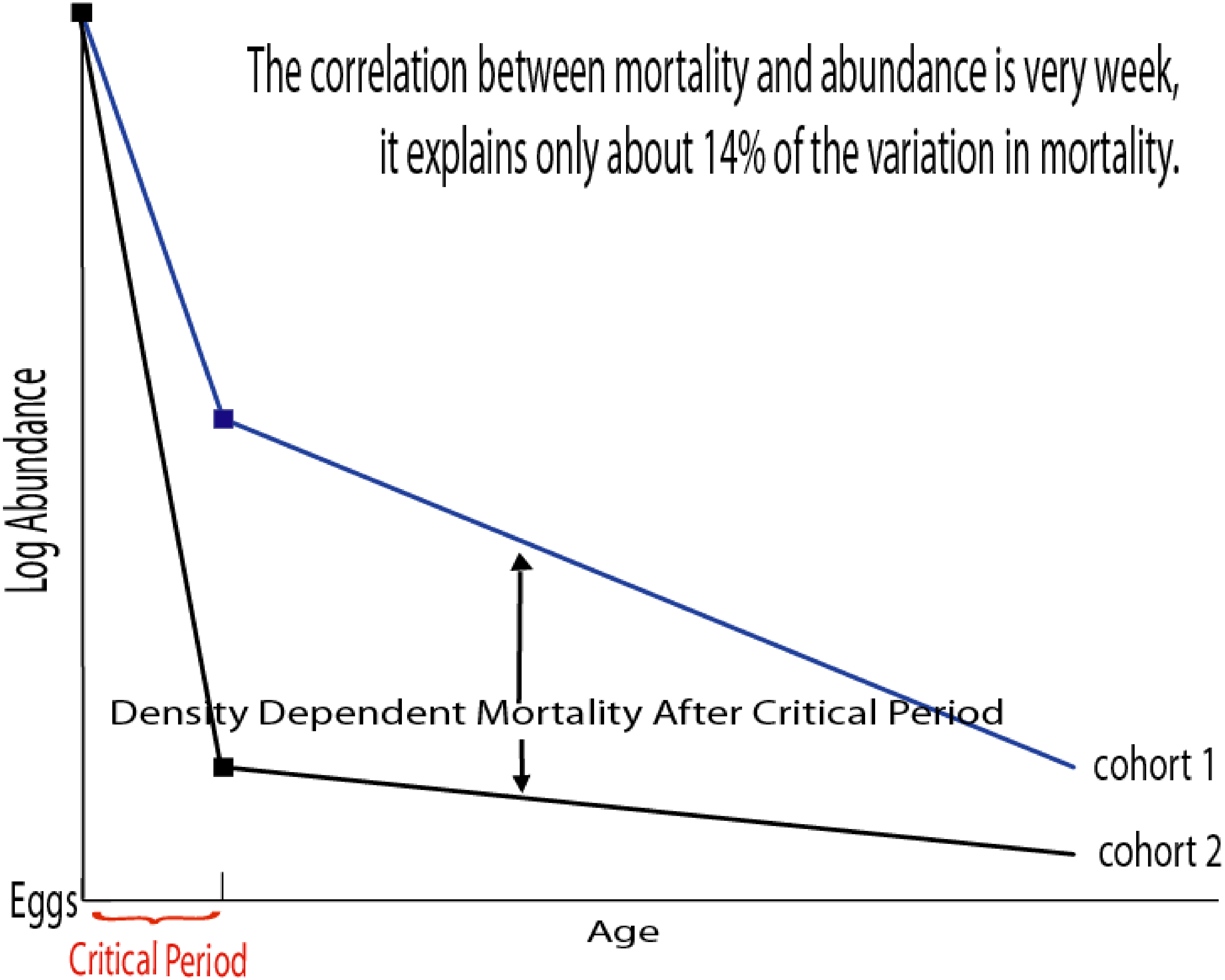
- Model that accounts for year, sample station, variation in catchability through the year



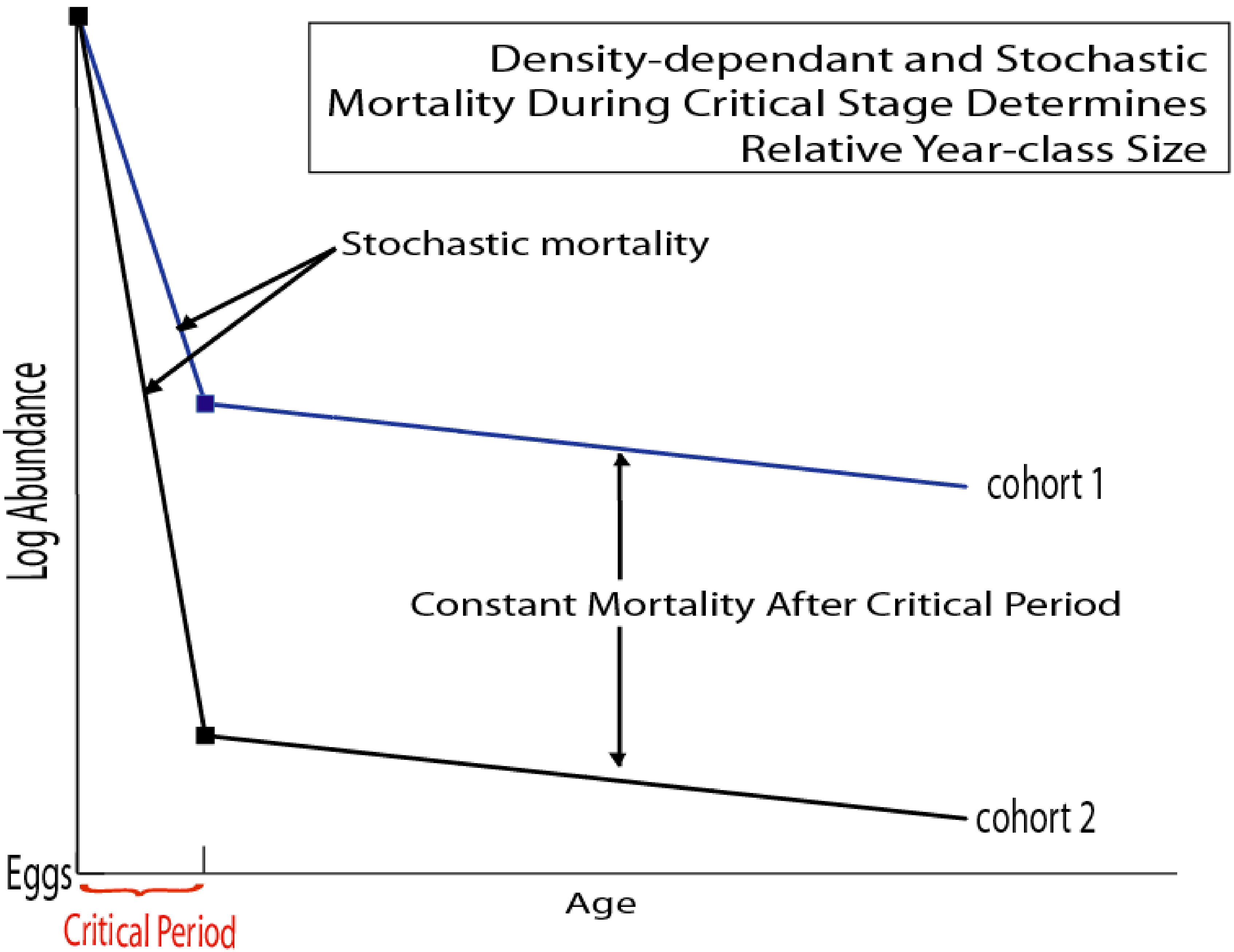
Does density dependenct mortality occur after July?



Does density dependenct mortality occur after July?



After July, this closer to the truth



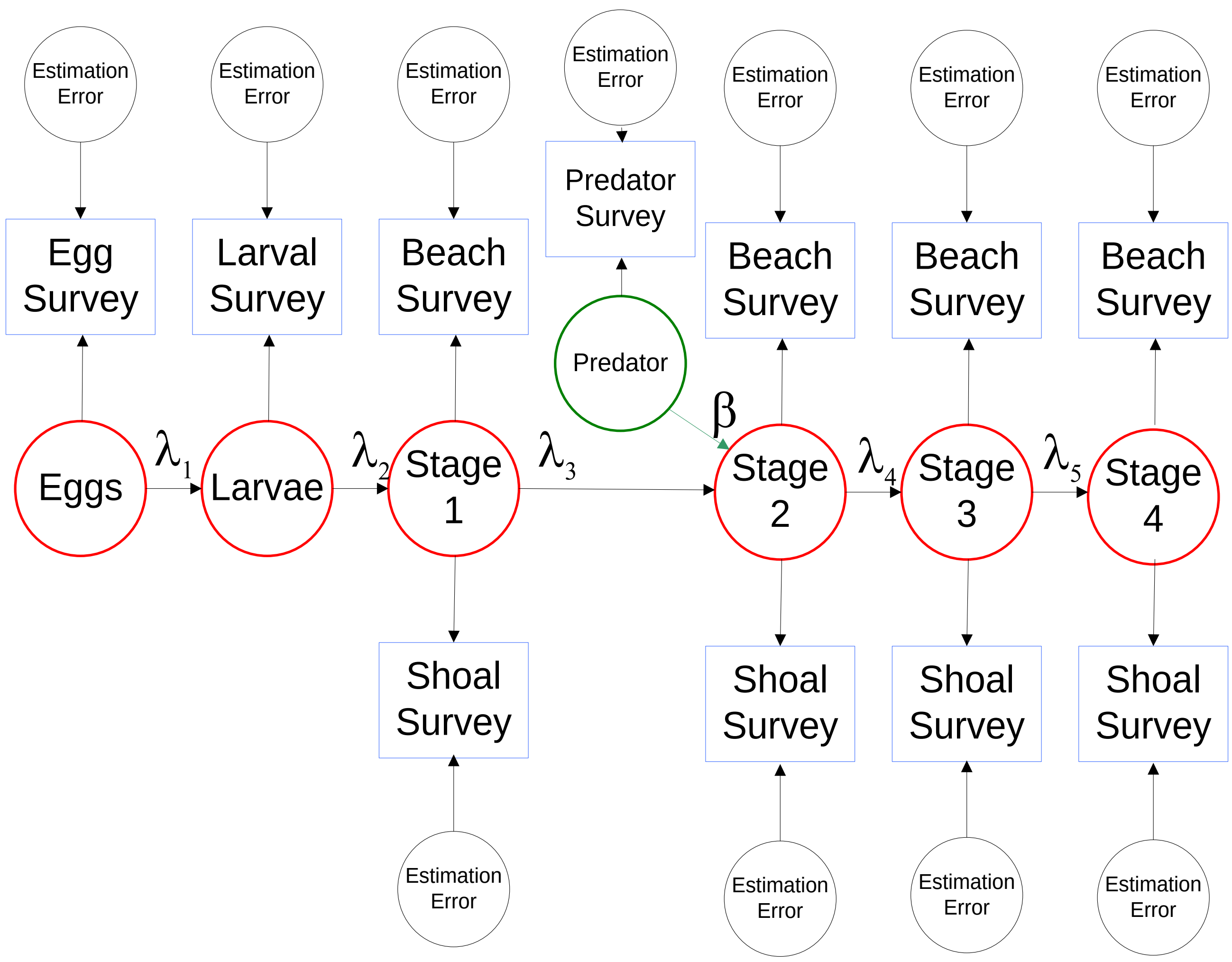
Hjort's (1914) critical period hypothesis

- ‘the numerical value of a year class is apparently stated at a very early age, and continues in approximately the same relation to that of other year classes throughout the life of the individuals”
- June (soon after the larval period) is the critical period for Hudson River Striped bass.

Questions

- How do we include species interactions?
- How do we include more general functional forms (we assumed mortality is proportional to log (numbers).
- How do we include more general error distribution, e.g. discrete distribution.
- How do we include more general random effects distribution?

Extension: Includes species interactions



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

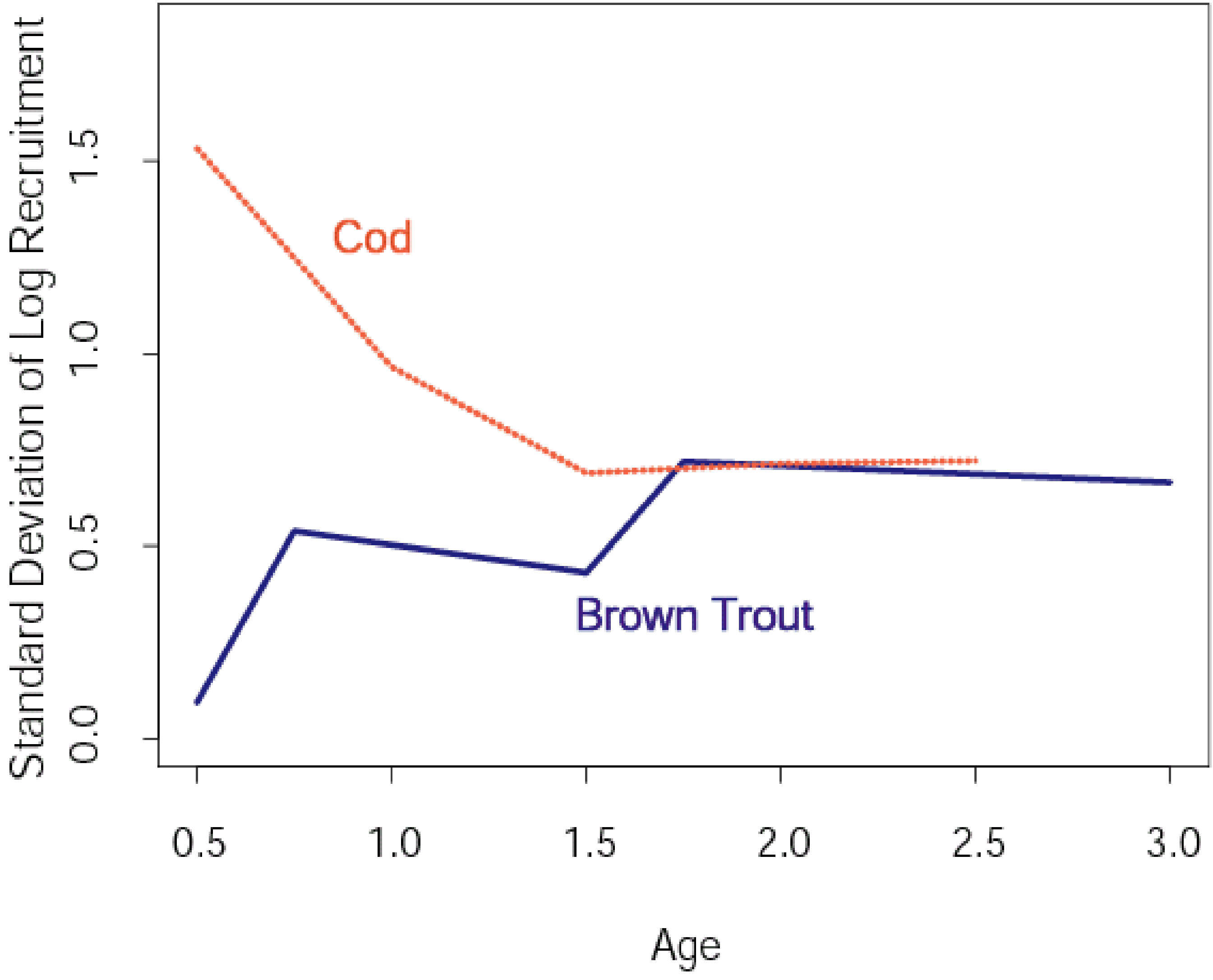
despite massive denial

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

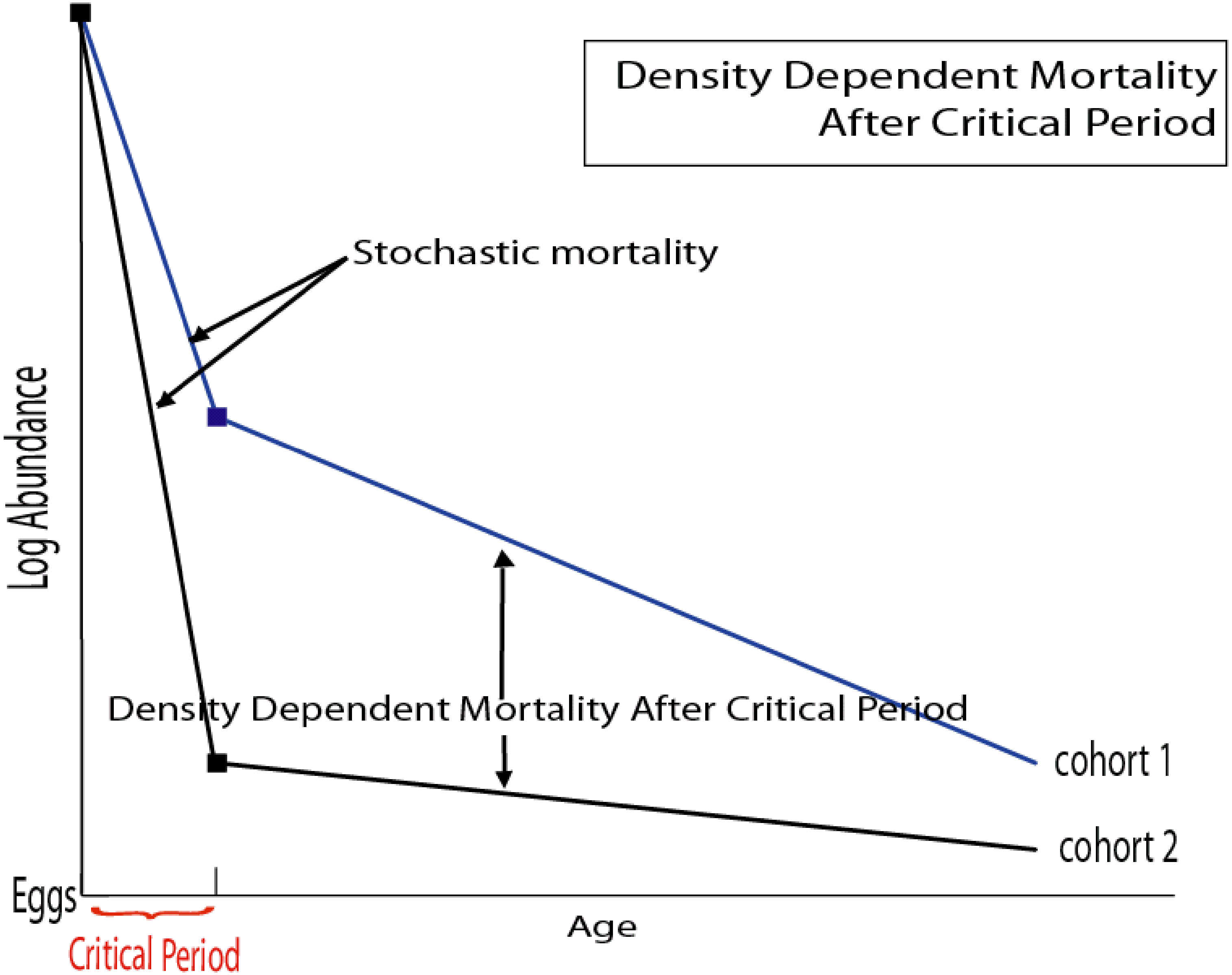
Critical period hypothesis: strong version

- $\text{Var}(\text{mortality}_{\text{age<critical}}) >> \text{Var}(\text{mortality}_{\text{age>critical}})$
- Density dependent mortality ≈ 0 for age > critical age
- We know of no cases where this is even approximately true.

Variability in recruitment increase with age for cod and decreases for trout.



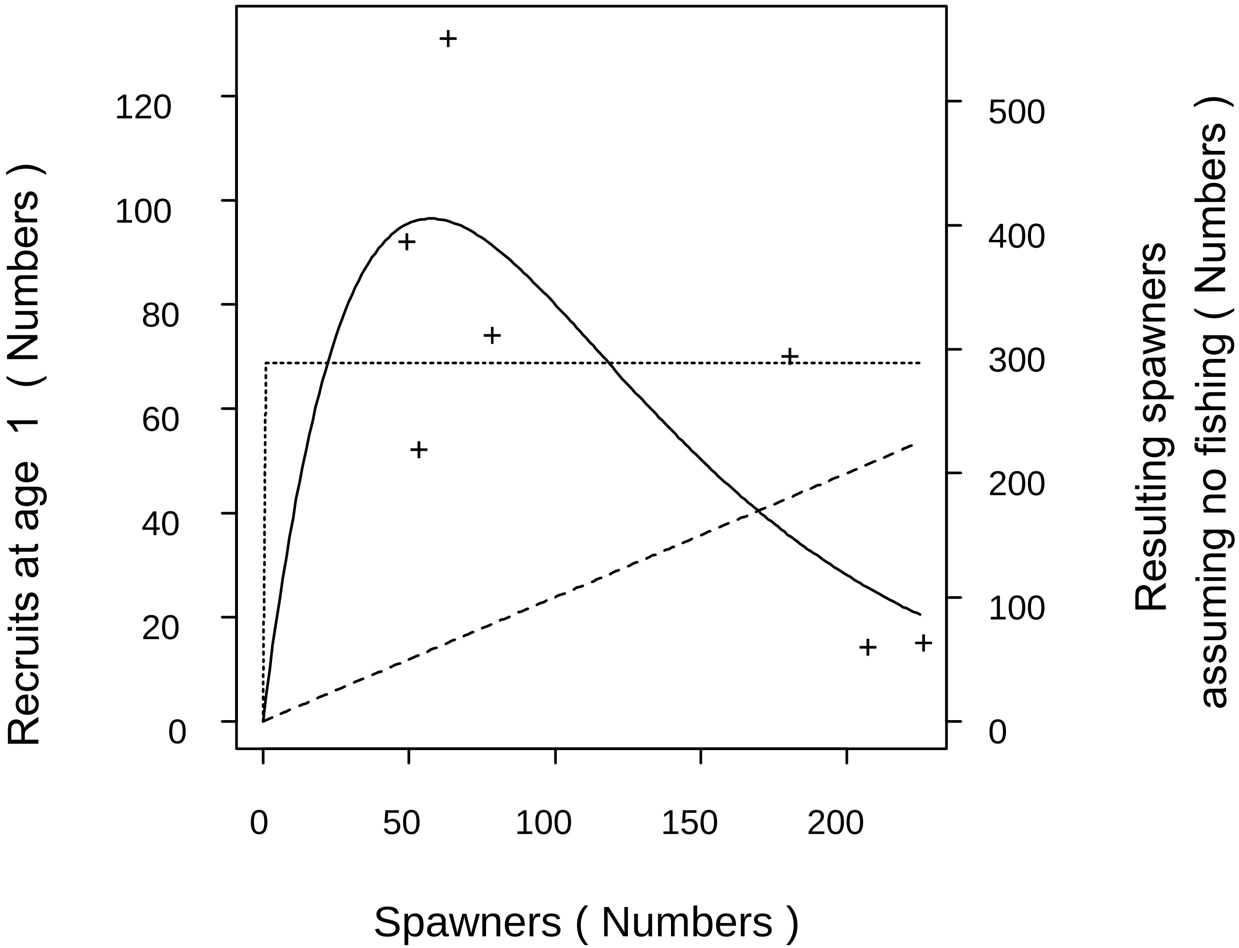
Hjort's Hypothesis: Weak Version



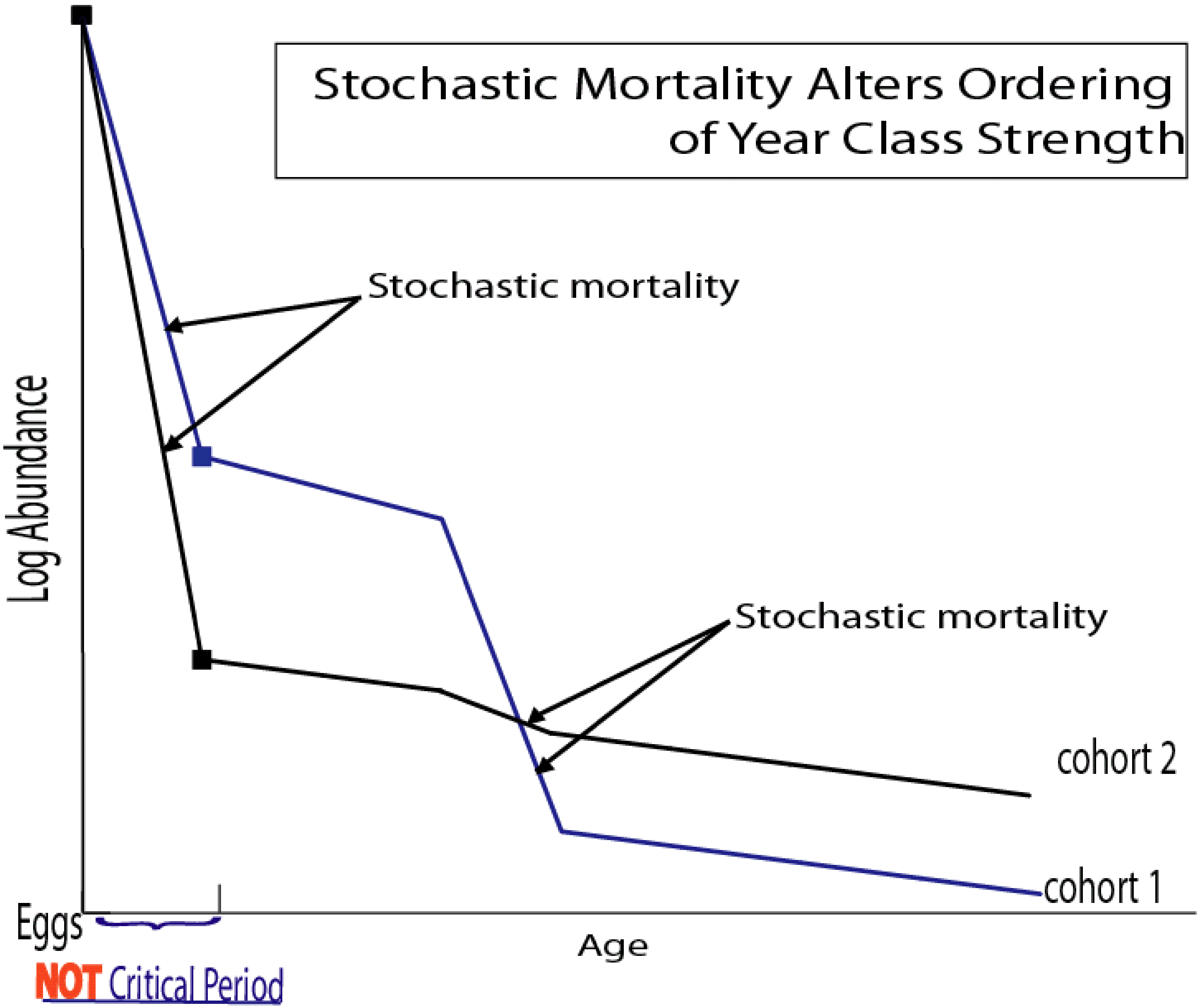
Critical period hypothesis: weak version

- $Var(mortality_{age<critical}) >> Var(mortality_{age>critical})$ Density-dependent mortality after the critical period does not alter ordering of year-class size.

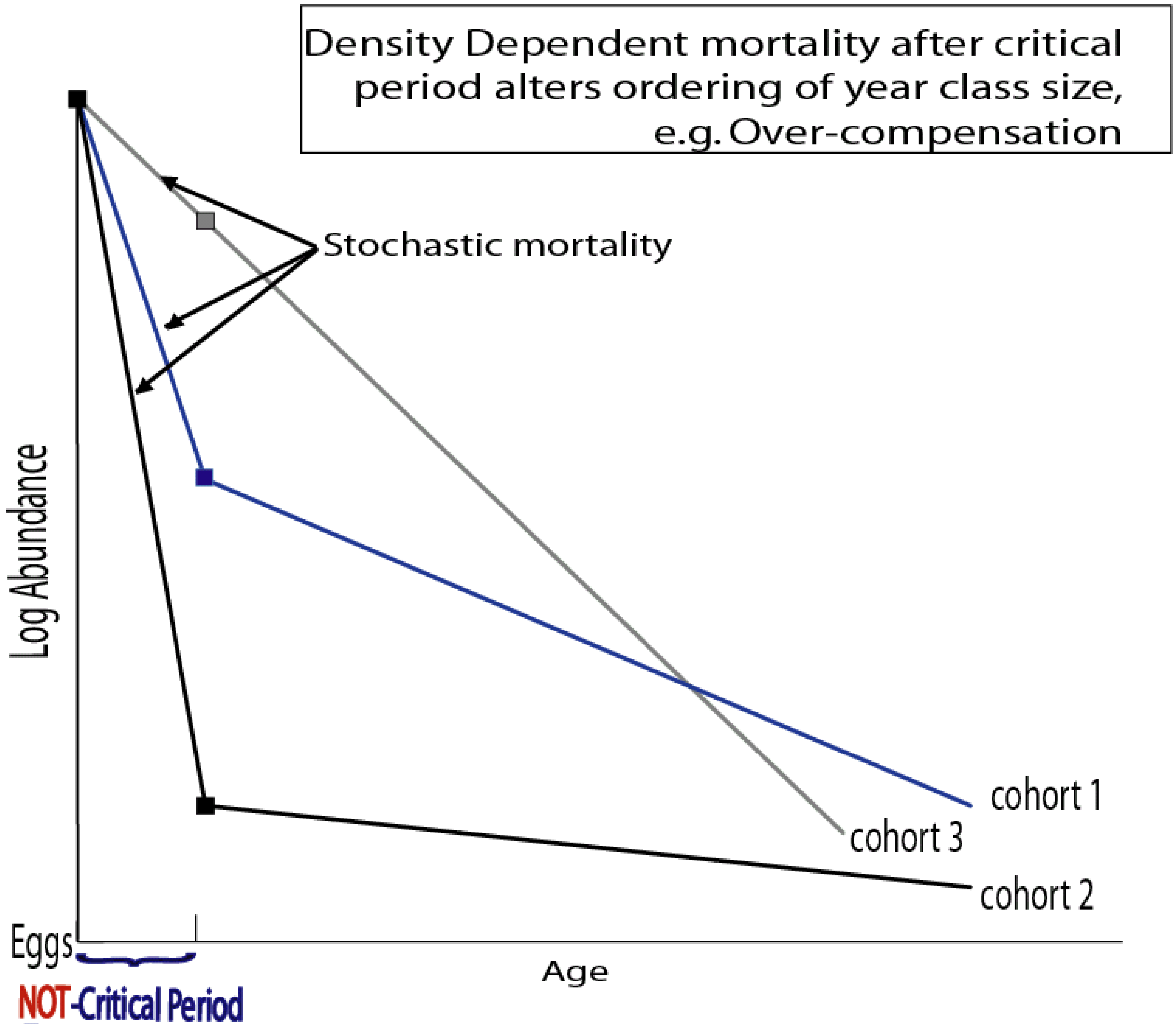
Freshwater brook trout - Hell Diver 3 Lake, Sierra Nevada



Hjort's Hypothesis: NOT Stochastic Mortality



Hjort's Hypothesis: NOT



To test Hjort's hypothesis we need a model which:

- Use research surveys which estimate abundance at different ages of the same cohort.
- Estimate the variance in mortality.
- Estimate density-dependent mortality.

- Treat cohorts as random effects.
- Include measurement error.
- Obtain estimates that can be combined across populations.

The state of the art until now:

- Myers and Cadigan (1993a and b) developed method to estimate density-dependent mortality and the variance in mortality in the presence of measurement error.
- Results could be combined across populations using meta-analysis.
- Can. J. Fish Aquat. Sci. 50: 1576—1590.
- Can. J. Fish Aquat. Sci. 50: 1591 – 1598.

Hudson River – using meta-analytic state space models

- Each cohort is examined multiple times from different surveys.
- Egg, larval, seine, and trawl surveys are included.
- Data is divided into two parts: (1) one part used for model generation and (2) one part used for model testing.

Results for Hudson River – using meta-analytic state space models

- Very strong density-dependent mortality, the functional form of density dependent mortality is identified.
- Strong density-dependent mortality occurs early, i.e. in June.

Next stage

- Modeling species interaction on each life-history stage.
- Modeling density-dependent habitat expansion
- Management implications.

Prime difficulty:

- Estimation of fish abundance is hard, and even the best surveys have large estimation error (you cannot carry out a simple, controlled experiment).
-

Solution to estimation error problems

- Use methods that optimally account for estimation error.
- Use independent data sets (i.e. the beach and shoal surveys).
- Break data into parts: generate hypotheses using one data set, and test with other.
- Use meta-analysis of multiple populations.

Behaviour of Biological Communities

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.

What do we know from previous studies?

- Collect all the data in the world
- Analyze it in the right way.

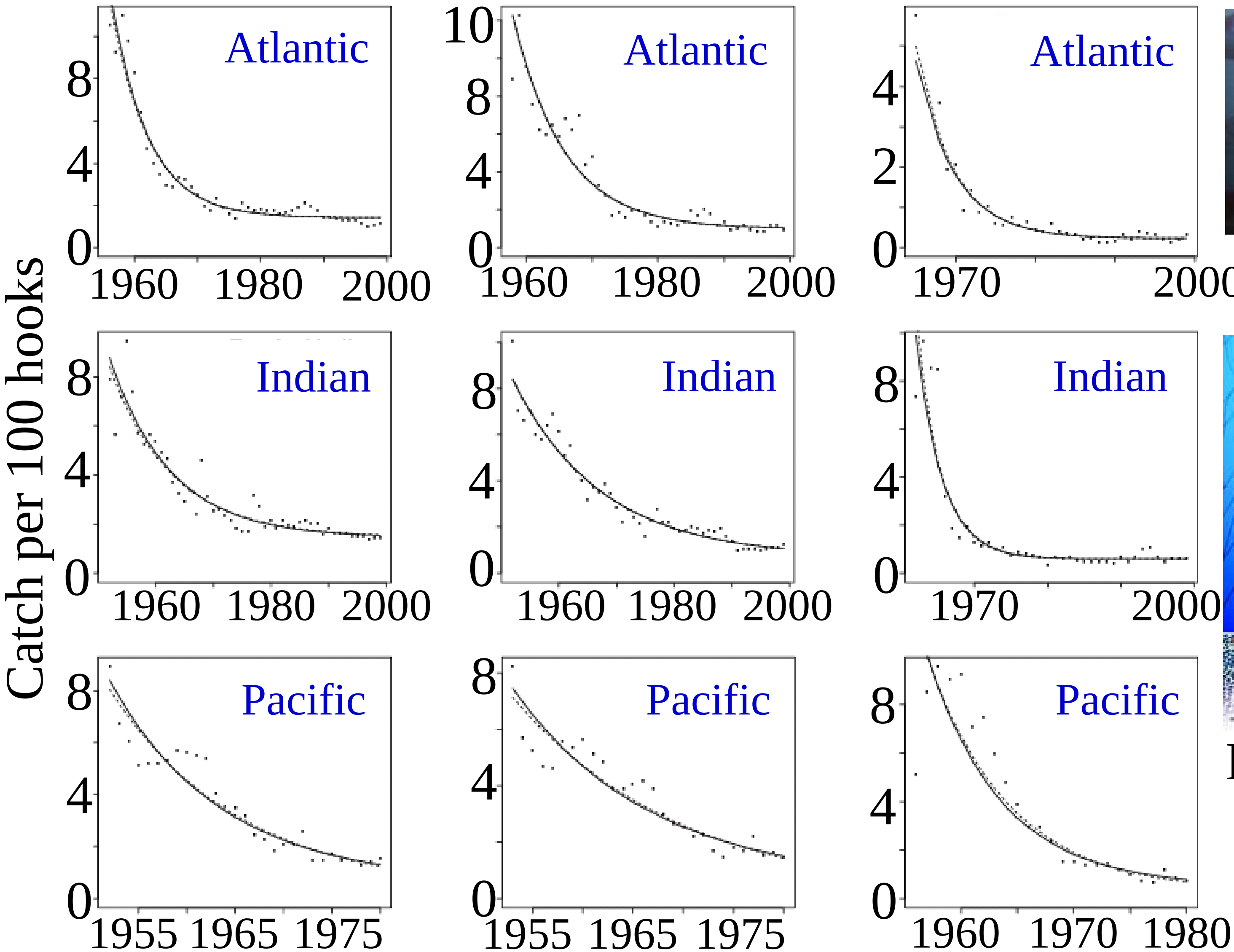
What is consistent with the Hudson River Data, with virtually all other data in the world:

- Higher spawner abundance => higher recruitment
- Strong density dependence, similar levels to all commercial cod and flatfish in the world
- Higher variability in survival at low spawner abundances,
- Lower variability in survival at high spawner abundances

What is unique about Hudson River striped bass?

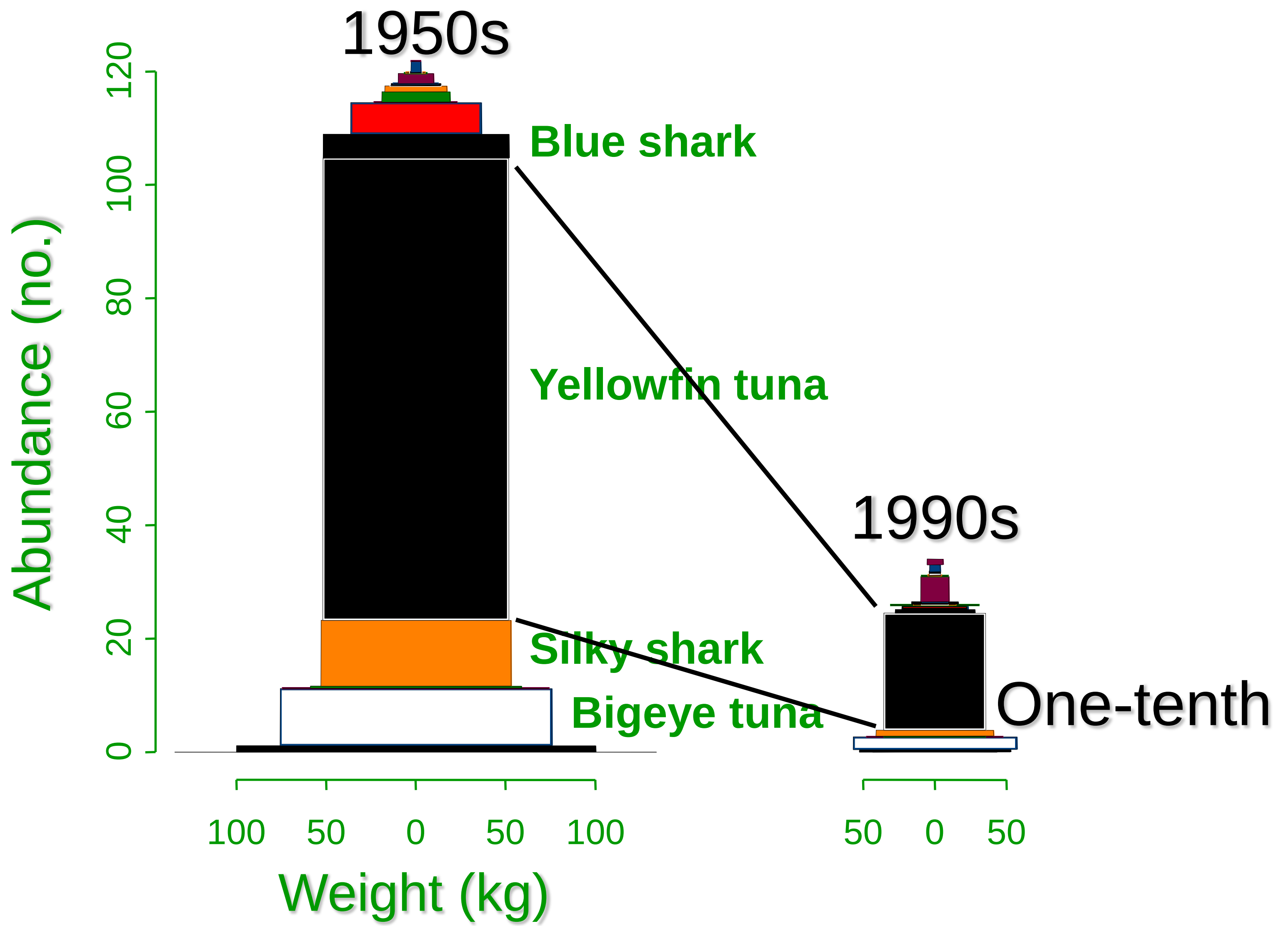
- Density dependent mortality occurs in a very short life-history stage, during first settlement to the beach areas around June. This is also the most important time for variability in survival.

Common patterns of decline

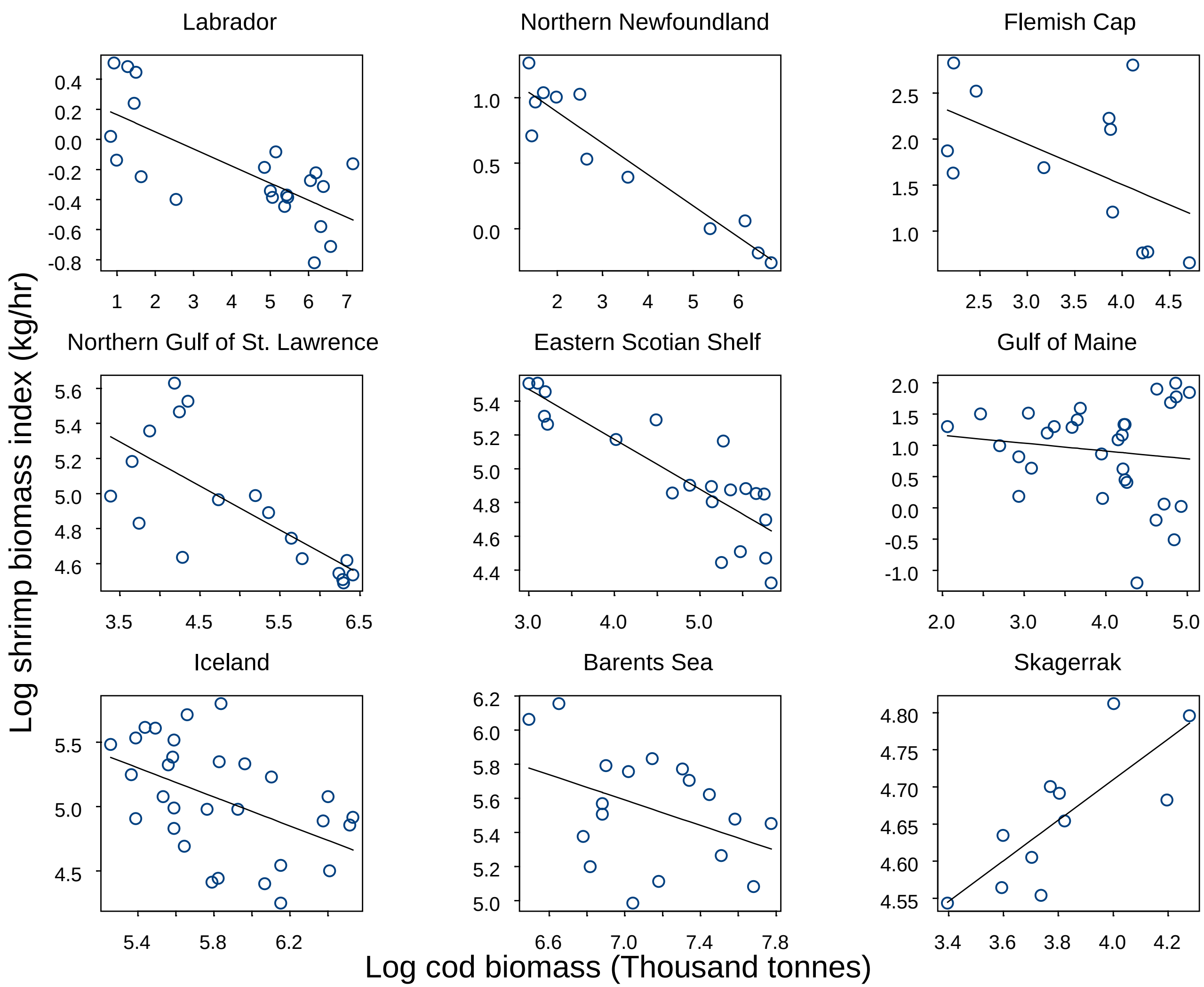


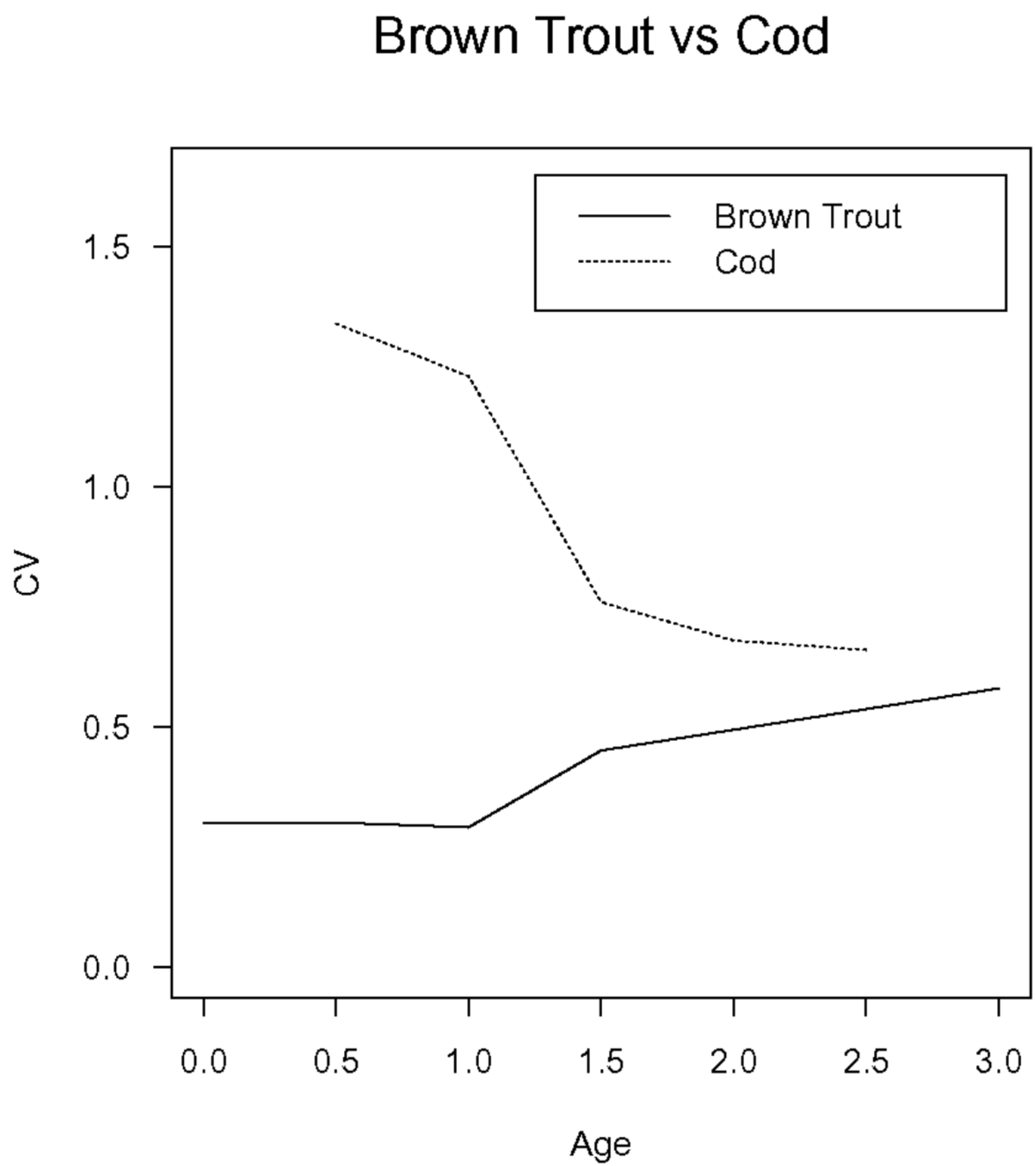
Myers and Worm (2003)

Change in total biomass

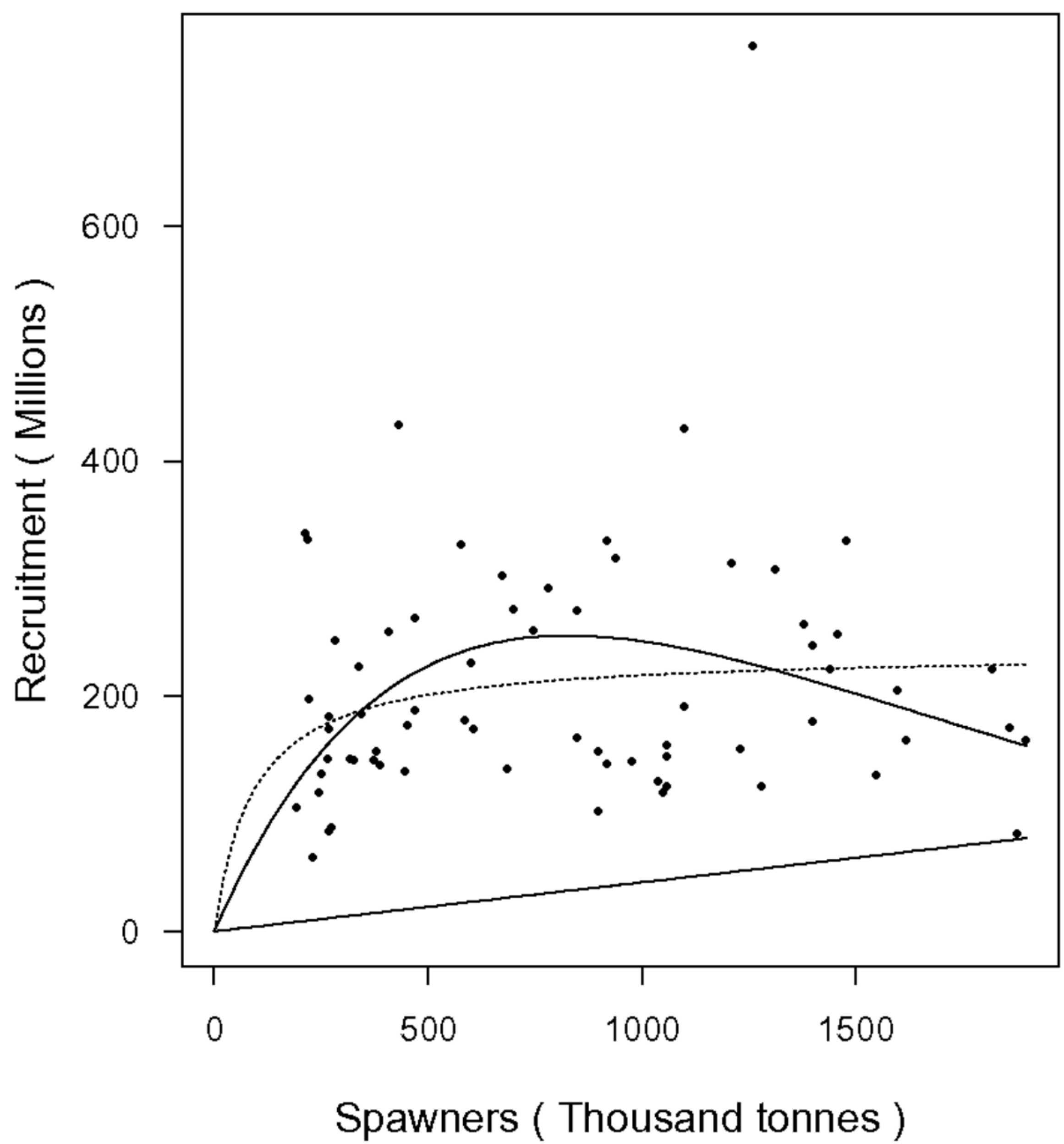


Cod and shrimp biomass in the North Atlantic: correlations

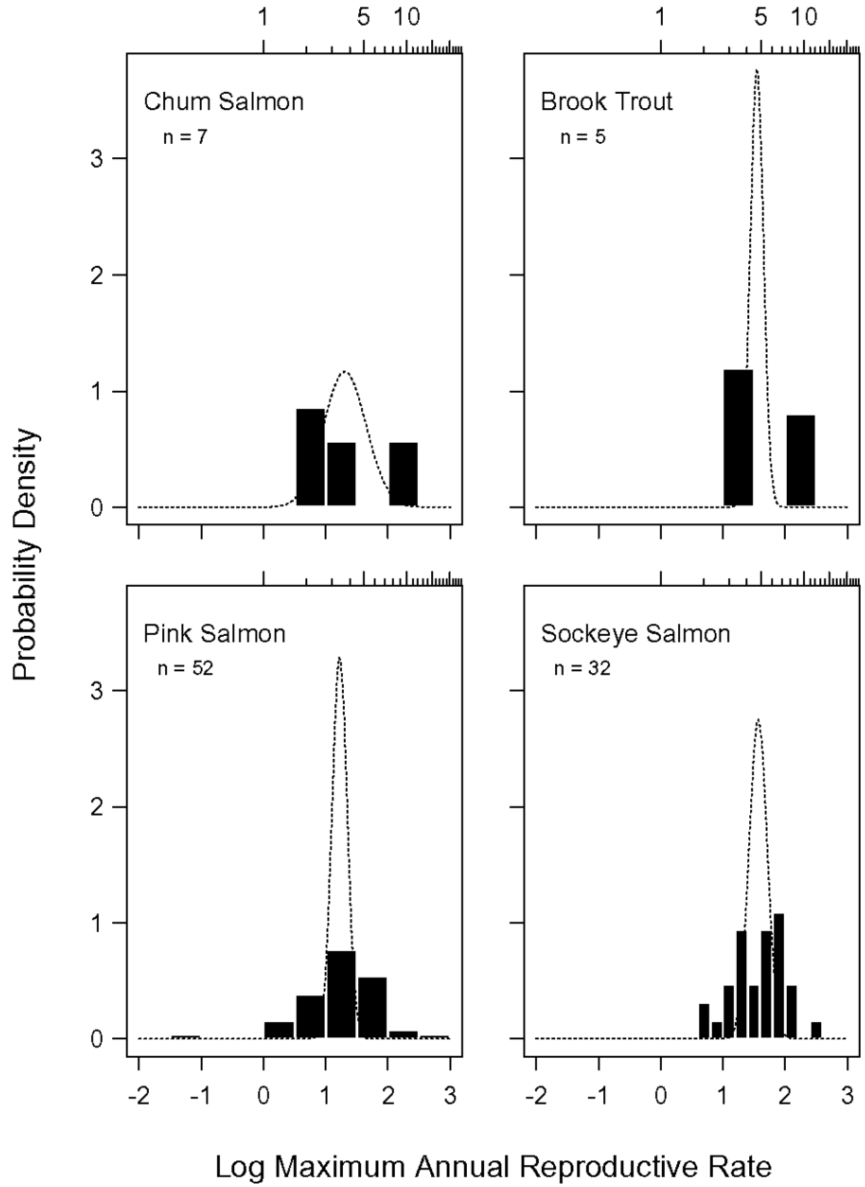




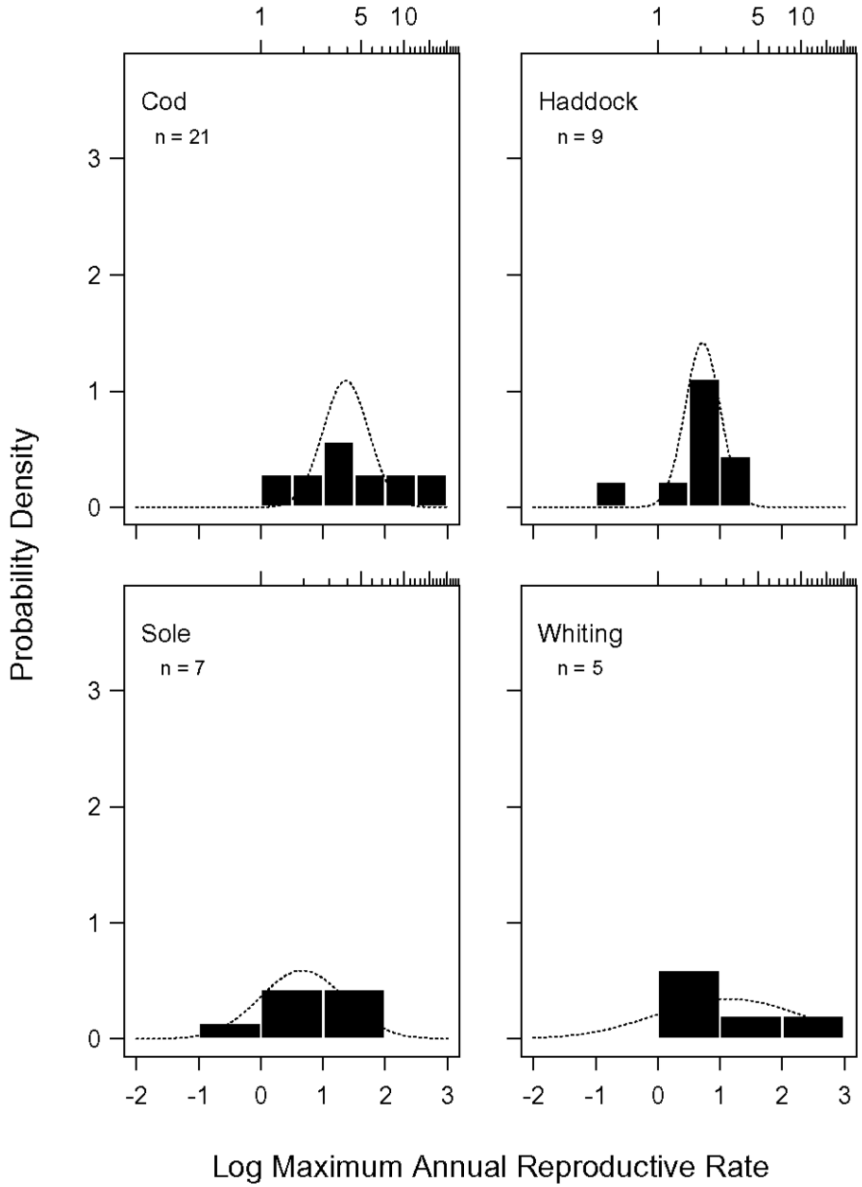
Brown Trout vs Cod
Brown Trout
Cod
CV
Age
0.0
0.5
1.0
1.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0



600
400
200
0
Recruitment (Millions)
0
500
1000
1500
Spawners (Thousand tonnes)



Chum Salmon
n = 7
Brook Trout
n = 5
Pink Salmon
n = 52
Sockeye Salmon
n = 32
1
5
10
0
1
2
3
-2
-1
Probability Density
Log Maximum Annual Reproductive Rate



Cod
n = 21
Haddock
n = 9
Sole
n = 7
Whiting
n = 5
1
5
10
0
1
2
3
-2
-1
Probability Density
Log Maximum Annual Reproductive Rate

Behaviour of Ecological Communities

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

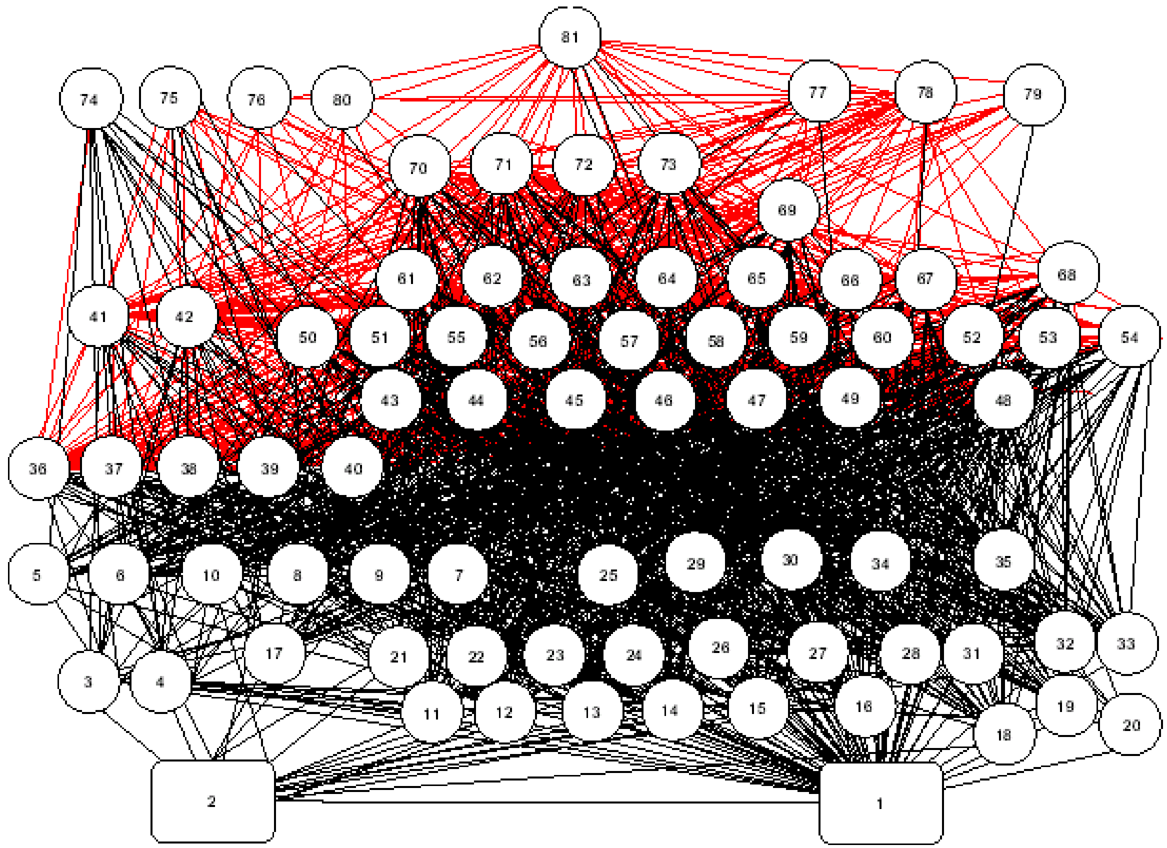


Fig. 1. Species and links of the northwest Atlantic food web. This tangled 'bird's nest' represents interactions at the approximate trophic level of each species, with increasing trophic level towards the top of the web. The left side of the web generally typifies pelagic organisms, and the right to 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 = wolfish, 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

Hjort's critical period hypothesis; When does density-dependent and stochastic mortality occur?

Models, Analysis and Meta-Analysis

Ransom A. Myers
Biology Department, Dalhousie University
Halifax, Canada

Implications for Hudson Esturary

- Where do striped bass fit in the ecosystem in a historical context?
- Was it the top predator? – in the river, perhaps so, but in the ocean no.
- Look at traditional

Ecologist have often looked at the complexity

- Show link diagram
- Say that the complexity exits, but we can understand much more if we look at general principals

Hjort's (1914) critical period hypothesis

- ‘the numerical value of a year class is apparently stated at a very early age, and continues in approximately the same relation to that of other year classes throughout the life of the individuals”
- This is the fundamental issue in population regulation and ecology of fish.

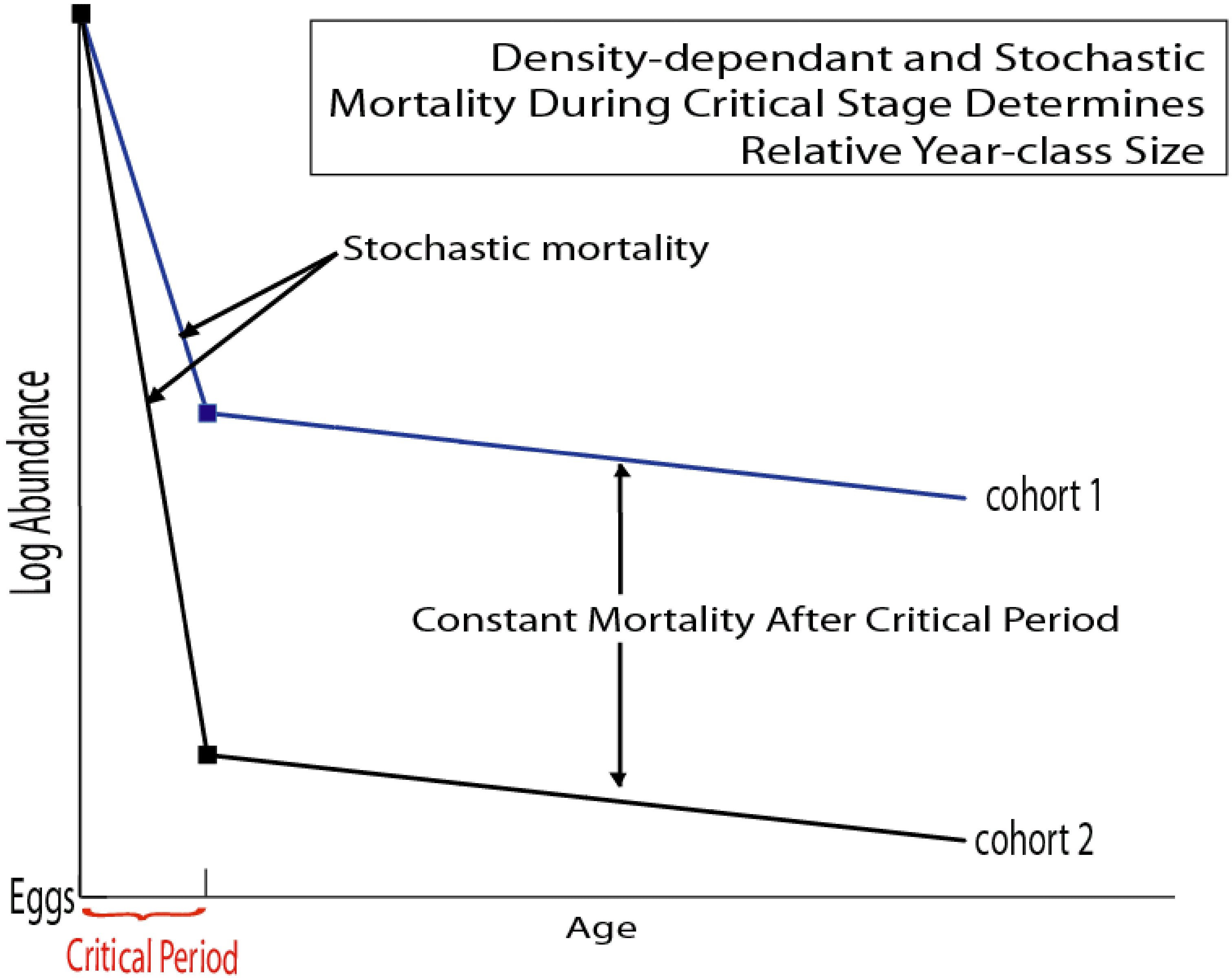
Fundamental Limitation of Statistics

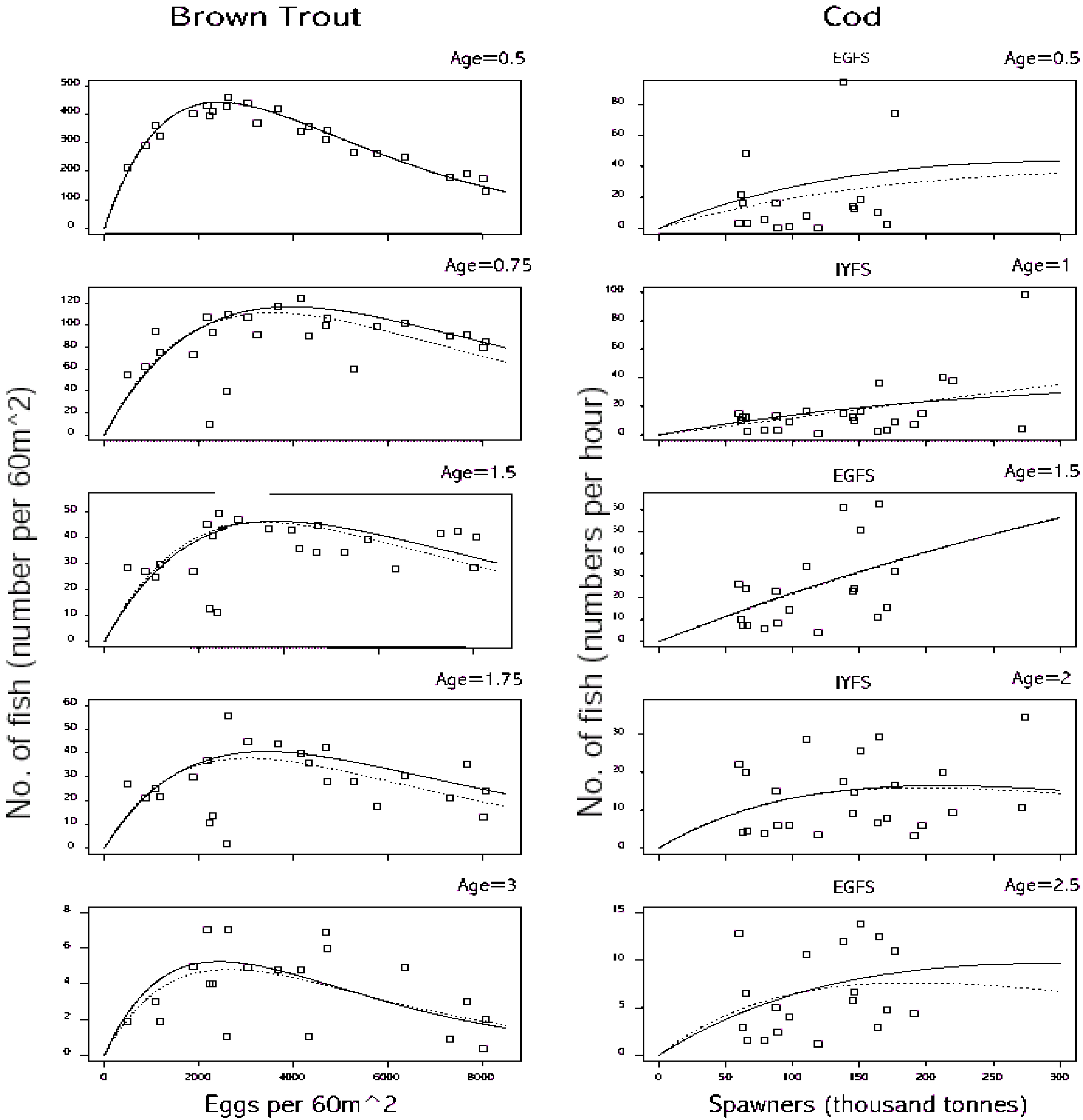
- We only really understand linear models with Gaussian errors.
- We start with these models, and modify them.

Hjort's (1914) critical period hypothesis

- ‘the numerical value of a year class is apparently stated at a very early age, and continues in approximately the same relation to that of other year classes throughout the life of the individuals”
- This is the fundamental issue in population regulation and ecology of fish.

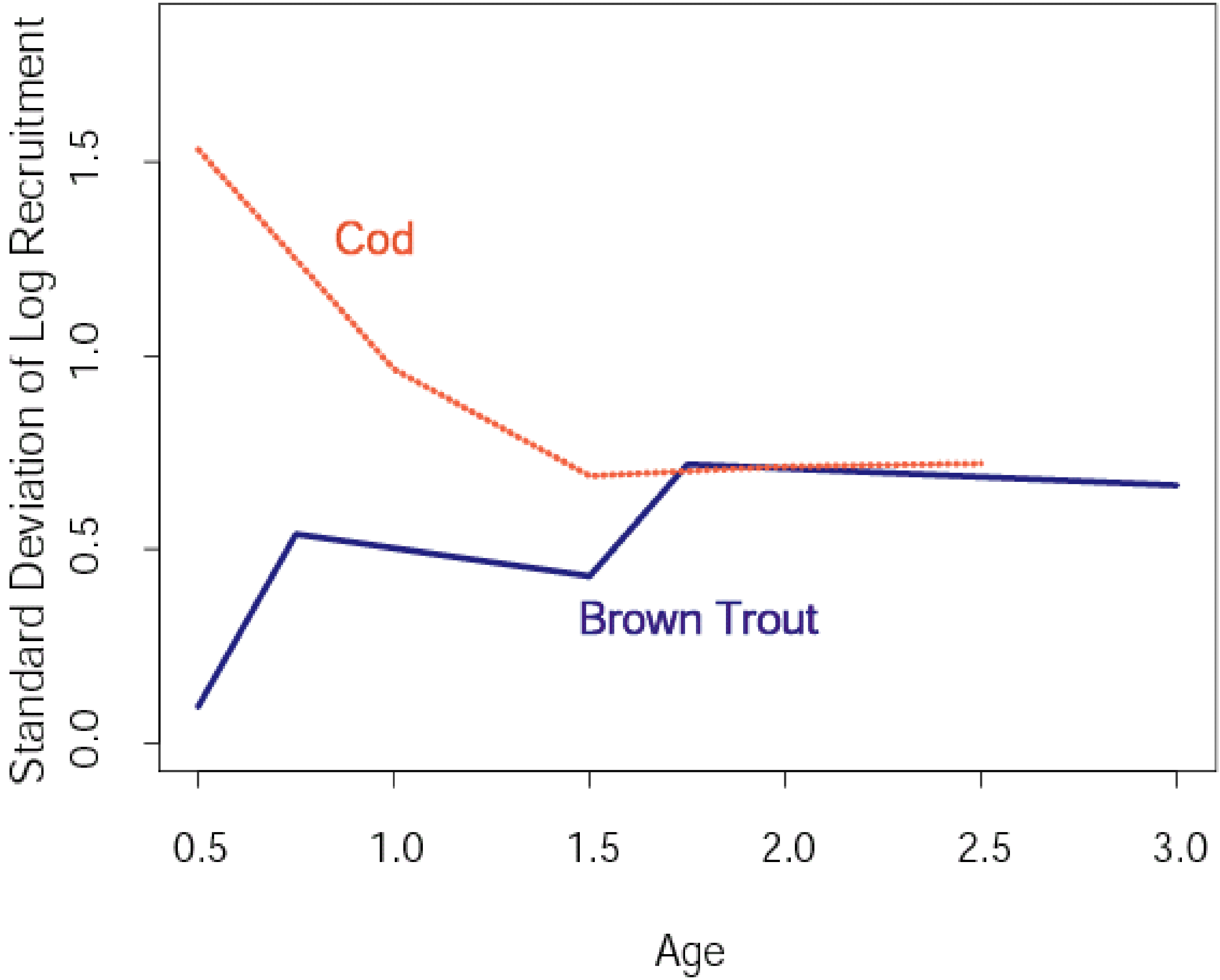
Hjort's Hypothesis: Strong Version



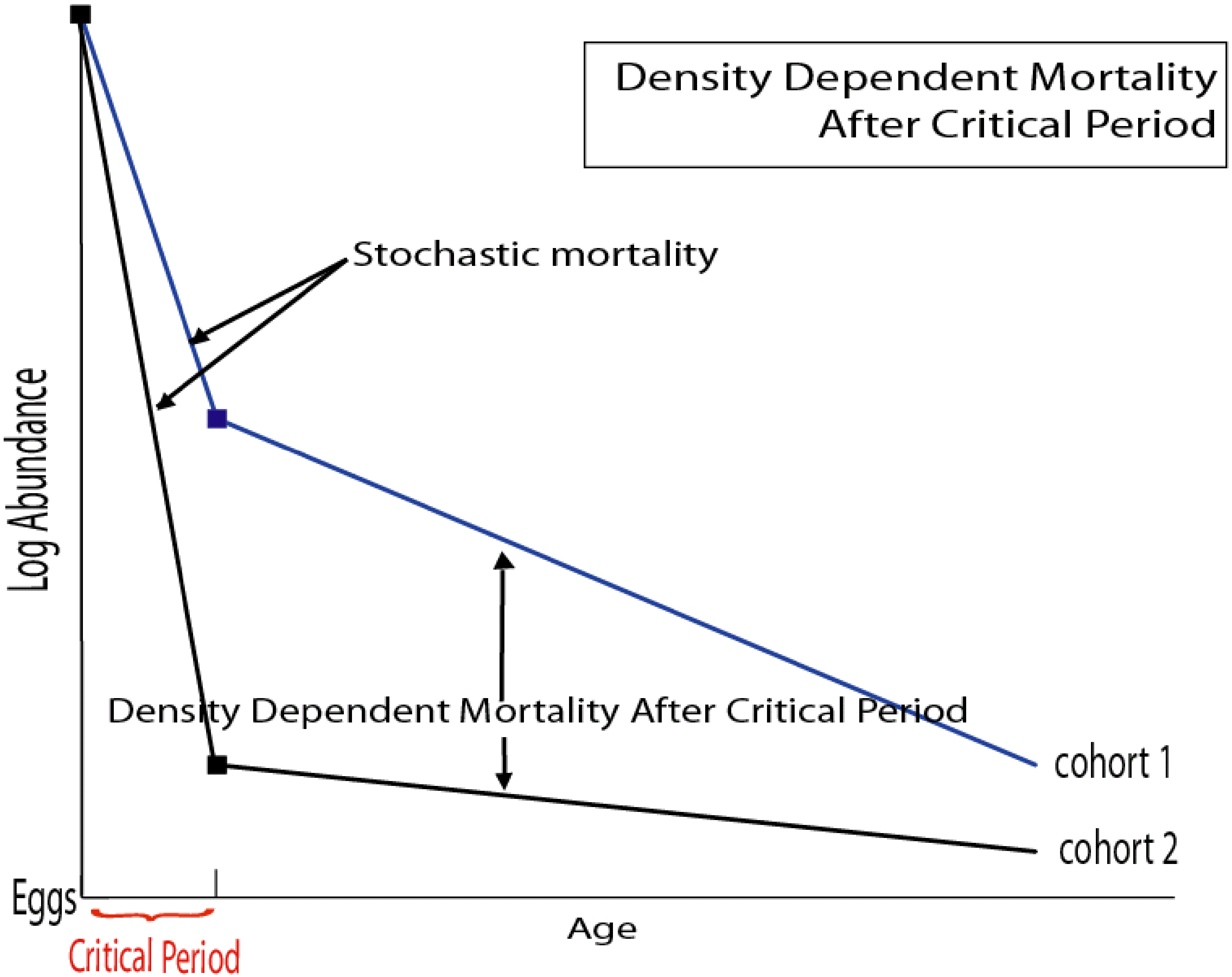


Brown Trout
Cod
Age=0.5
EGFS
Age=0.5
Age=0.75
IYFS
Age=1
Age=1.5
EGFS
Age=1.5
Age=1.75
IYFS
Age=2
Age=3
EGFS
Age=2.5
No. of fish (number per 60m^2)
No. of fish (numbers per hour)
Eggs per 60m^2
Spawners (thousand tonnes)

Variability in recruitment increase with age for cod and decreases for trout.



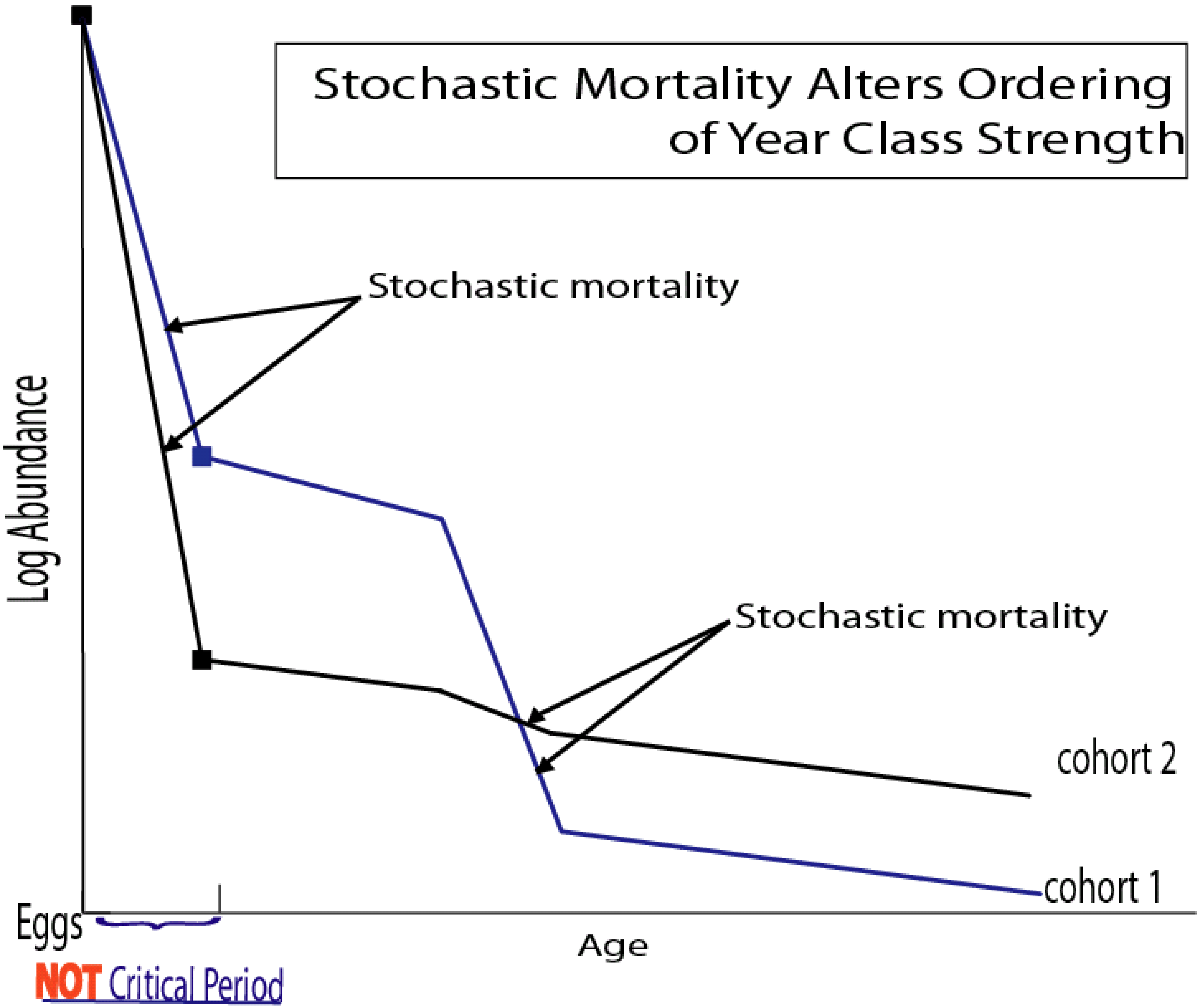
Hjort's Hypothesis: Weak Version



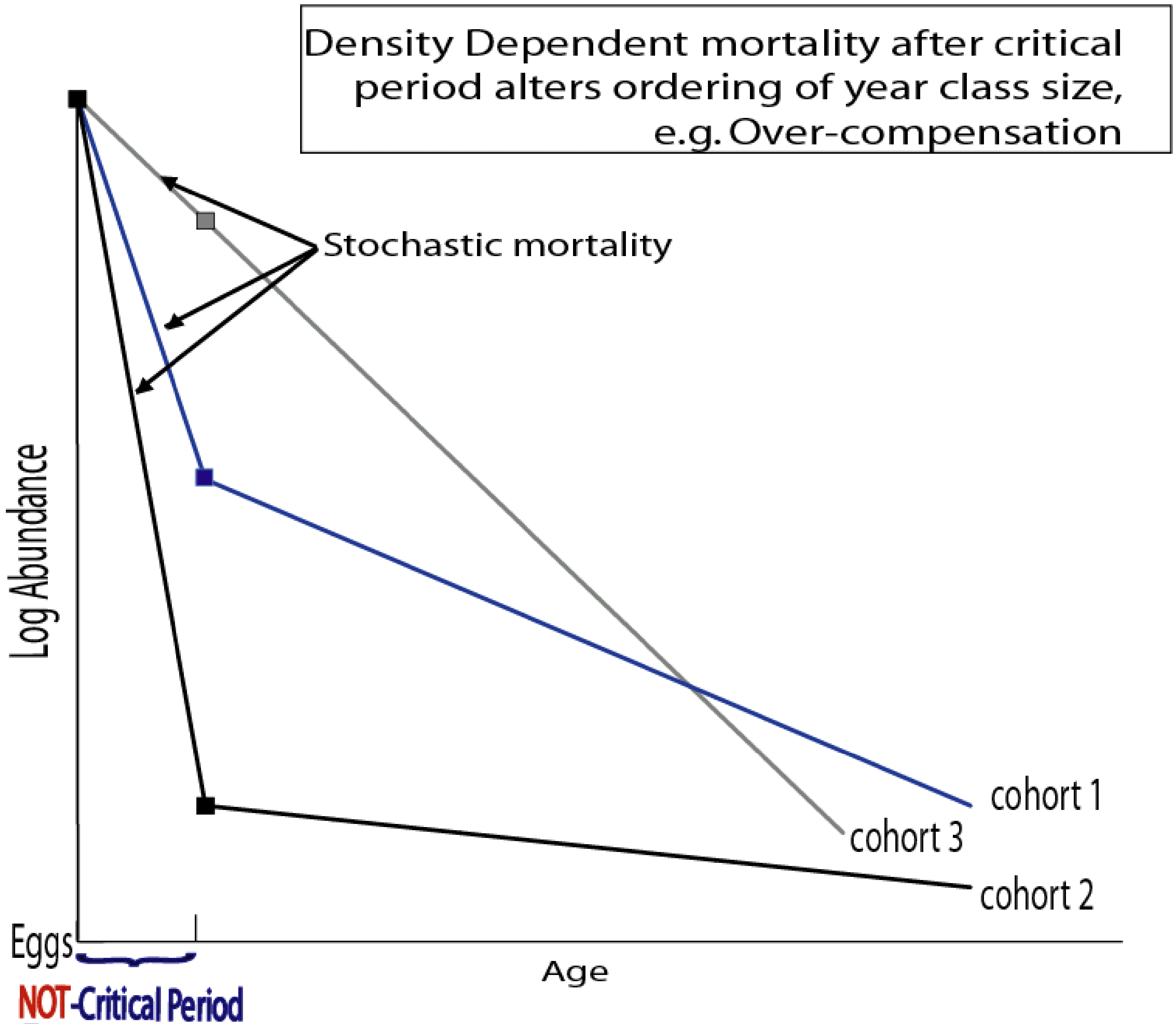
Critical period hypothesis: weak version

- Var(mortality$_{age<critical}$) >>Var(mortality$_{age>critical}$) Density-dependent mortality after the critical period does not alter ordering of year-class size.

Hjort's Hypothesis: NOT Stochastic Mortality



Hjort's Hypothesis: NOT



To test Hjort’s hypothesis we need a model which:

- Use research surveys which estimate abundance at different ages of the same cohort.
- Estimate the variance in mortality.
- Estimate density-dependent mortality.

- Treat cohorts as random effects.
- Include measurement error.
- Obtain estimates that can be combined across populations.

The state of the art until now:

- Myers and Cadigan (1993a and b) developed method to estimate density-dependent mortality and the variance in mortality in the presence of measurement error.
- Results could be combined across populations using meta-analysis.
- Can. J. Fish Aquat. Sci. 50: 1576—1590.
- Can. J. Fish Aquat. Sci. 50: 1591 – 1598.

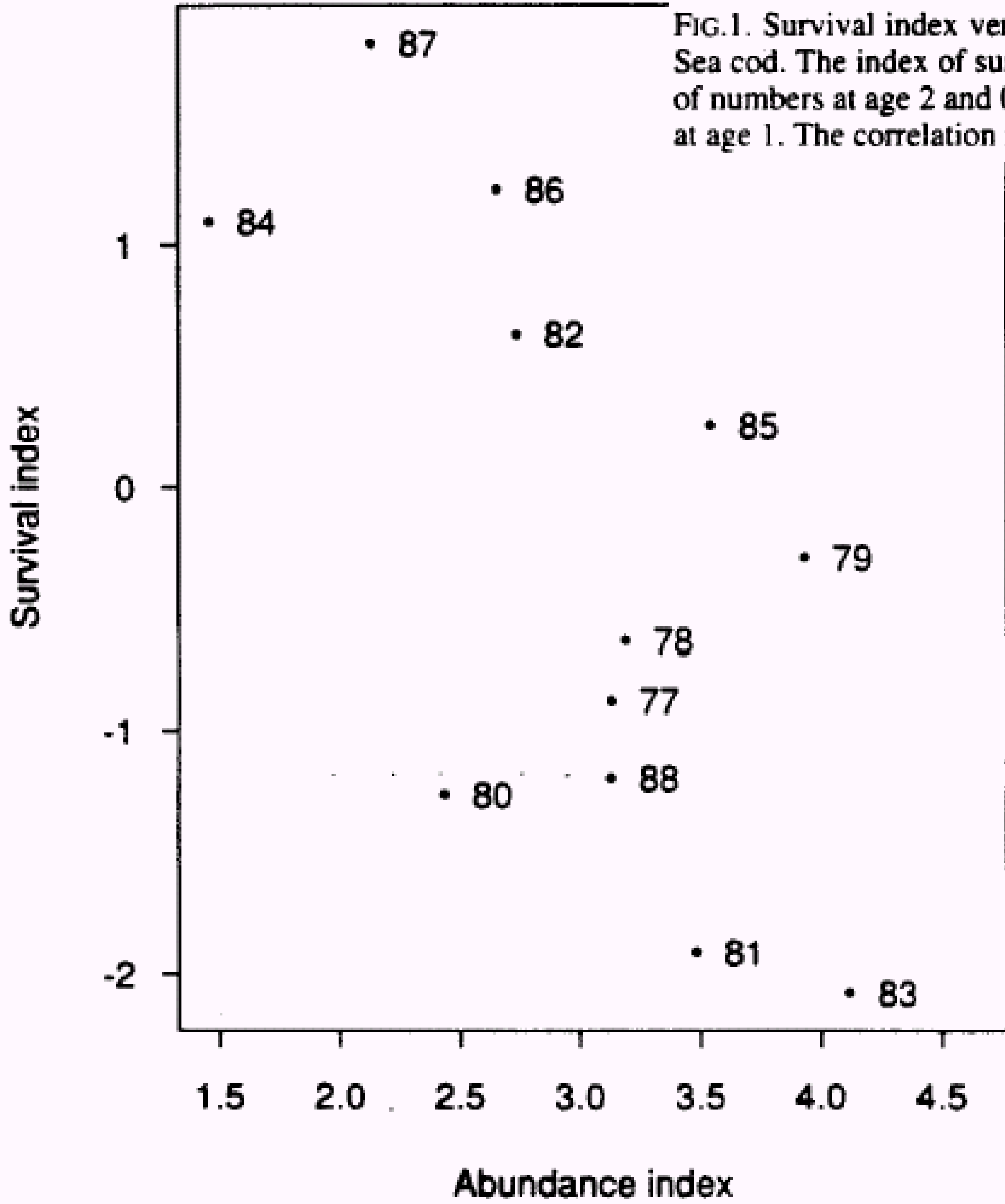


FIG. 1. Survival index versus abundance index for the EGFS of North Sea cod. The index of survival is the difference between the log index of numbers at age 2 and 0. The index of abundance is the log numbers at age 1. The correlation is −0.65 (p-value = 0.0054).

TABLE 1. Data for the North Sea cod stock from VPA in millions of fish, IYFS innumbers per hour fished, and EGFS in numbers per hour fished.

Year class	VPA 1-yr-olds	IYFS 1-yr-olds	IYFS 2-yr-olds	EGFS 0-yr-olds	EGFS 1-yr-olds	EGFS 2-yr-olds
1970	847	98.30	34.50			
1971	159	4.10	10.60			
1972	289	38.00	9.50			
1973	232	14.70	6.20			
1974	426	40.30	19.90			
1975	196	7.90	3.20			4.50
1976	726	36.70	29.30		62.70	12.50
1977	426	12.90	9.30	13.90	22.80	5.80
1978	449	9.90	14.80	12.60	24.20	6.70
1979	800	16.90	25.50	18.60	50.80	13.90
1980	271	2.90	6.70	10.20	11.40	2.90
1981	557	9.20	16.60	74.20	32.40	11.00
1982	269	3.90	8.00	2.50	15.40	4.70
1983	534	15.20	17.60	95.10	61.20	11.90
1984	108	0.90	3.60	0.40	4.30	1.20
1985	581	17.00	28.80	8.30	34.40	10.70
1986	257	8.80	6.10	1.20	14.20	4.10
1987	201	3.60	6.30	0.40	8.40	2.50
1988	324	13.10	15.20	16.80	22.80	5.10
1989		3.30		6.0	6.10	
1990				3.90		

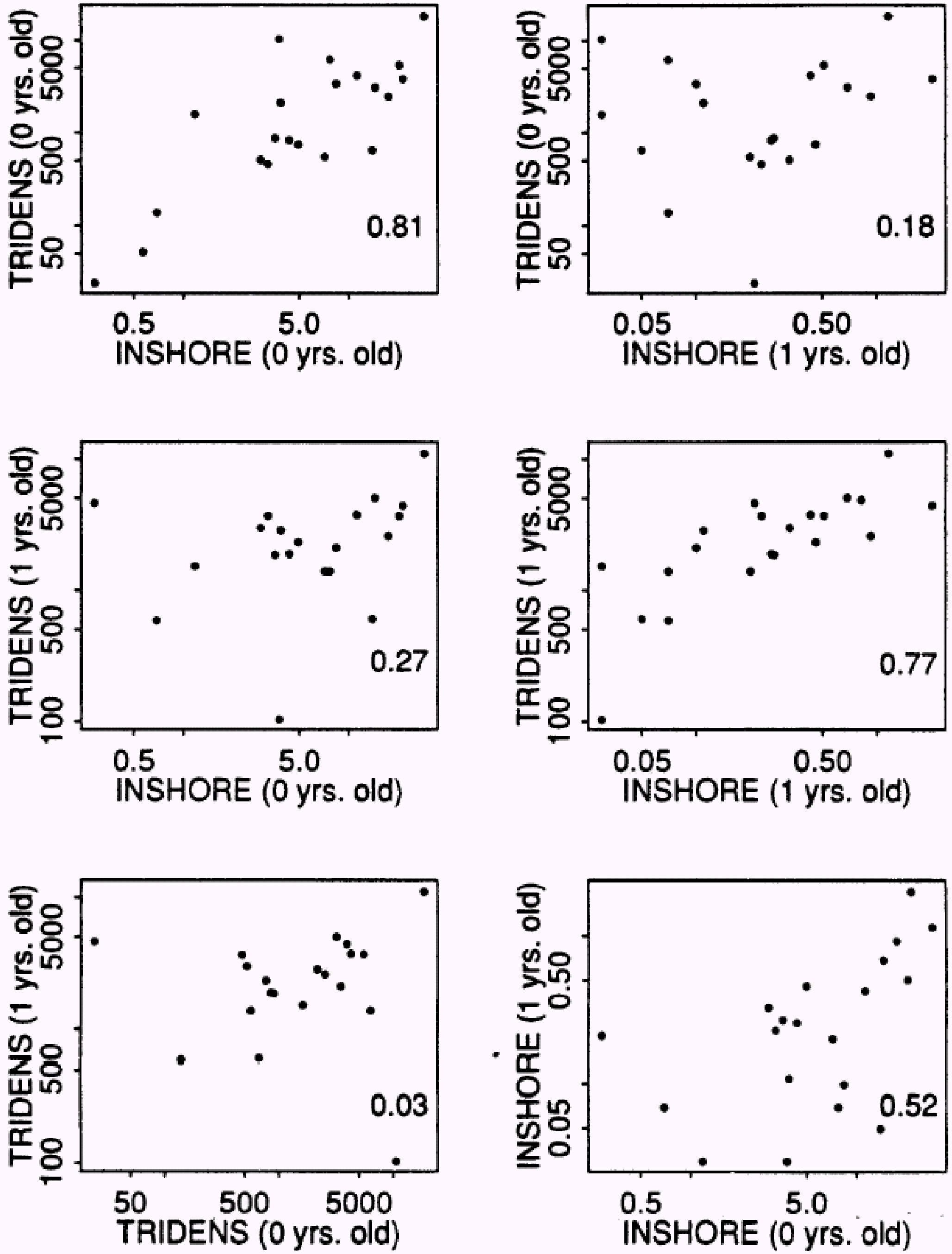
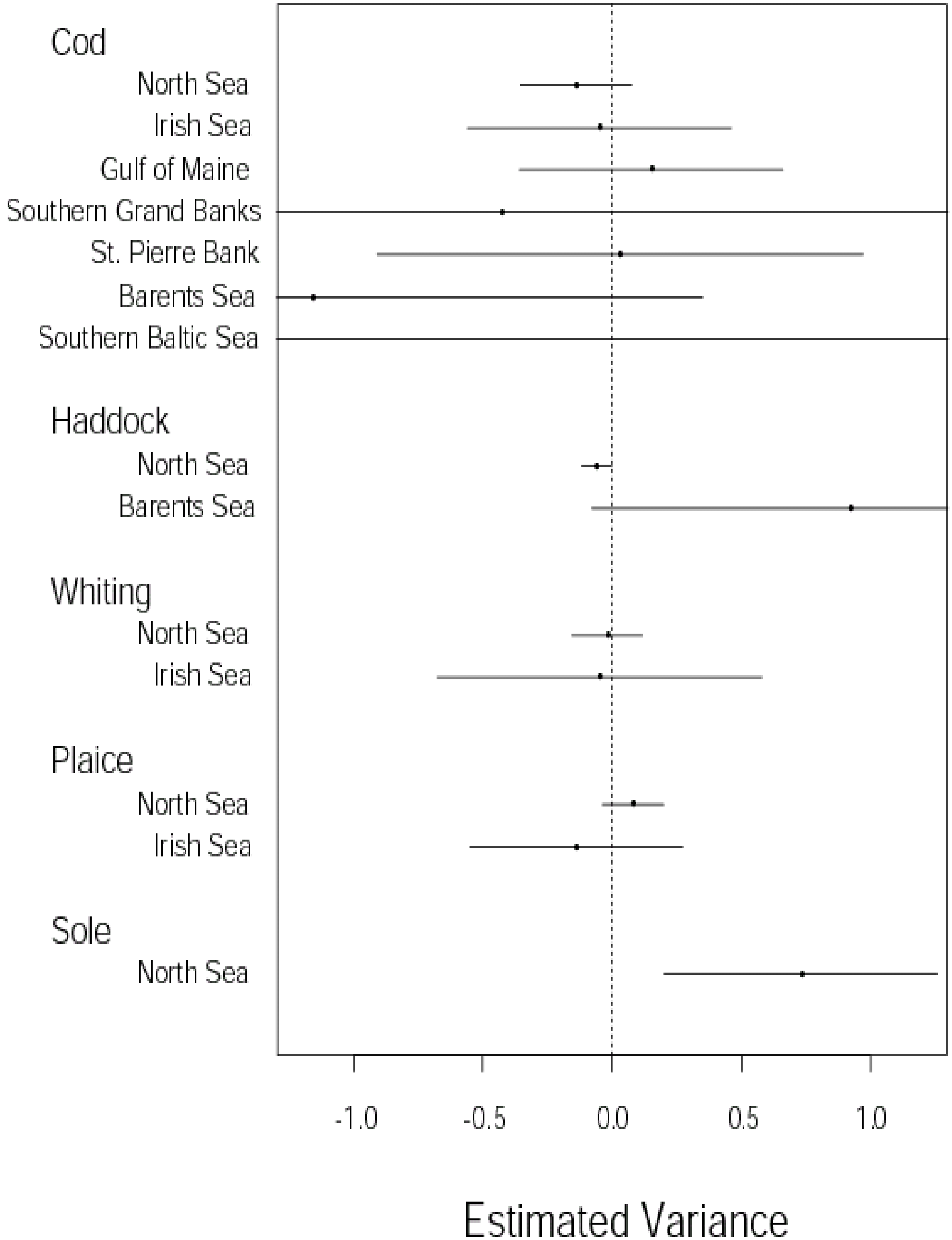


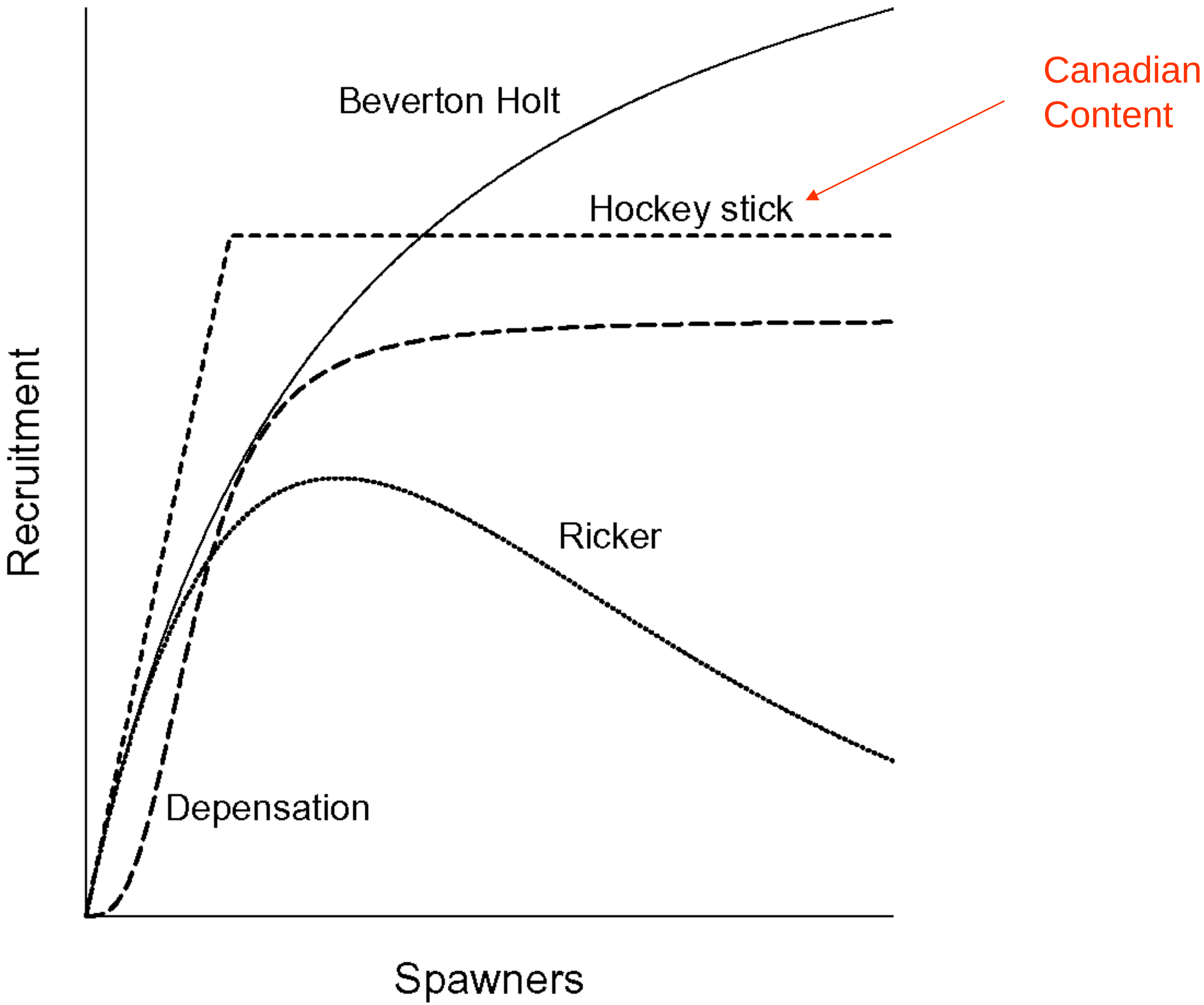
FIG. 1. Pairwise plots of abundance estimates for North Sea sole (Table 1). The estimates are log transformed. The correlation coefficient is presented in the lower right corner.

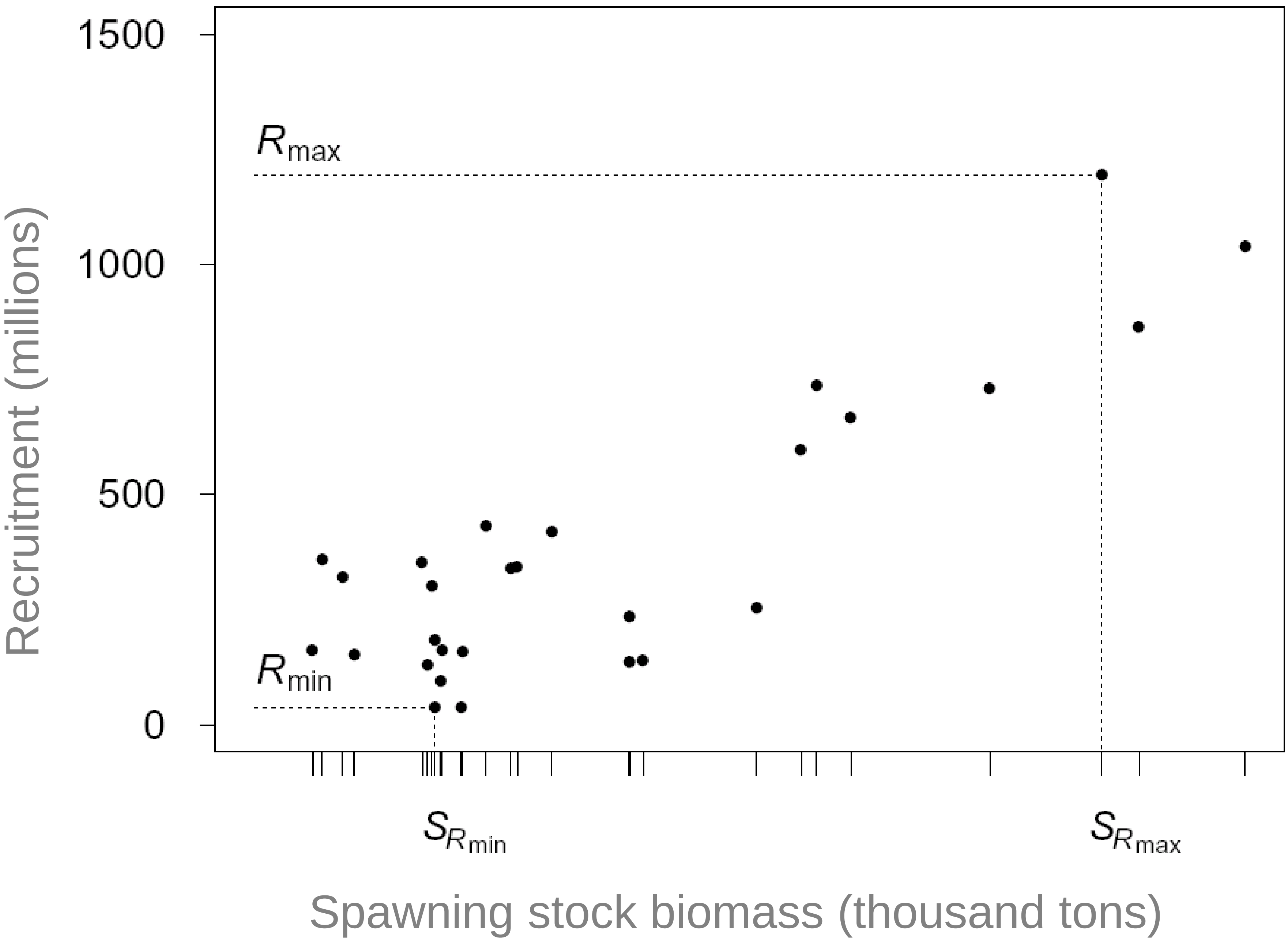
$$
\begin{bmatrix}
\mathrm{VAR}(l_{t,0,1}) & \mathrm{COV}(l_{t,0,1}, l_{t,0,2}) & \mathrm{COV}(l_{t,0,1}, l_{t,1,1}) & \mathrm{COV}(l_{t,0,1}, l_{t,1,2}) \\
 & \mathrm{VAR}(l_{t,0,2}) & \mathrm{COV}(l_{t,0,2}, l_{t,1,1}) & \mathrm{COV}(l_{t,0,2}, l_{t,1,2}) \\
 & & \mathrm{VAR}(l_{t,1,1}) & \mathrm{COV}(l_{t,1,1}, l_{t,1,2}) \\
 & & & \mathrm{VAR}(l_{t,1,2})
\end{bmatrix}
$$

$$
= \begin{bmatrix}
\phi + \theta_{0,1} & \phi & \lambda\phi & \lambda\phi \\
 & \phi + \theta_{0,2} & \lambda\phi & \lambda\phi \\
 & & \lambda^2\phi + \psi + \theta_{1,1} & \lambda^2\phi + \psi \\
 & & & \lambda^2\phi + \psi + \theta_{1,2}
\end{bmatrix}
$$

Variance in mortality after critical period low for gadoids and flatfish.




Canadian
Content
Beverton Holt
Hockey stick
Ricker
Depensation
Recruitment
Spawners



1500
1000
500
0
Recruitment (millions)
R_{max}
R_{min}
$S_{R_{min}}$
$S_{R_{max}}$
Spawning stock biomass (thousand tons)

Summarizing information from more than one population

- Weighted mean of relative ranks

$$\frac{\sum_{i=1}^{k} n_i r_{\max,i}}{\sum_{i=1}^{k} n_i}$$

- If spawner abundance and recruitment were independent, the expected value of $r_{\max,i}$ would be 0.5

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.

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

despite massive denial

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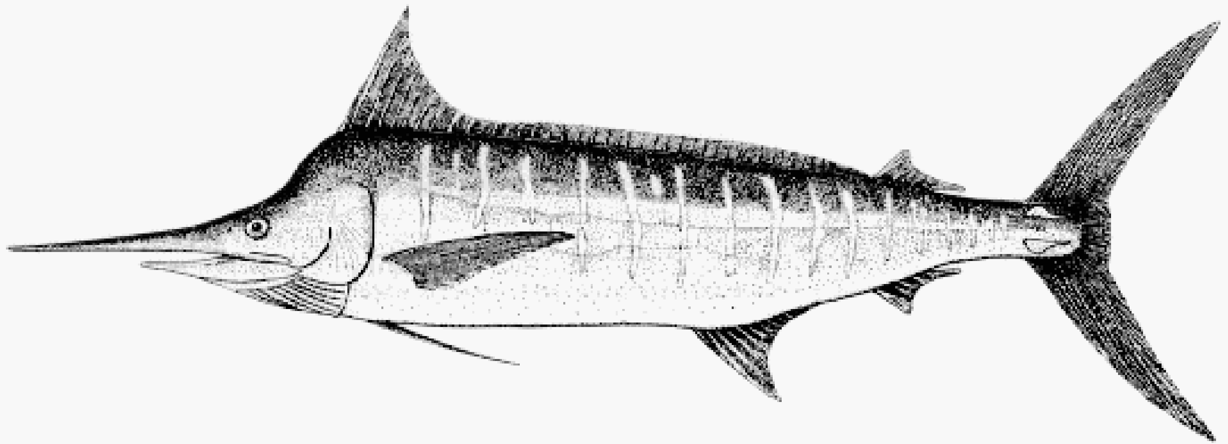
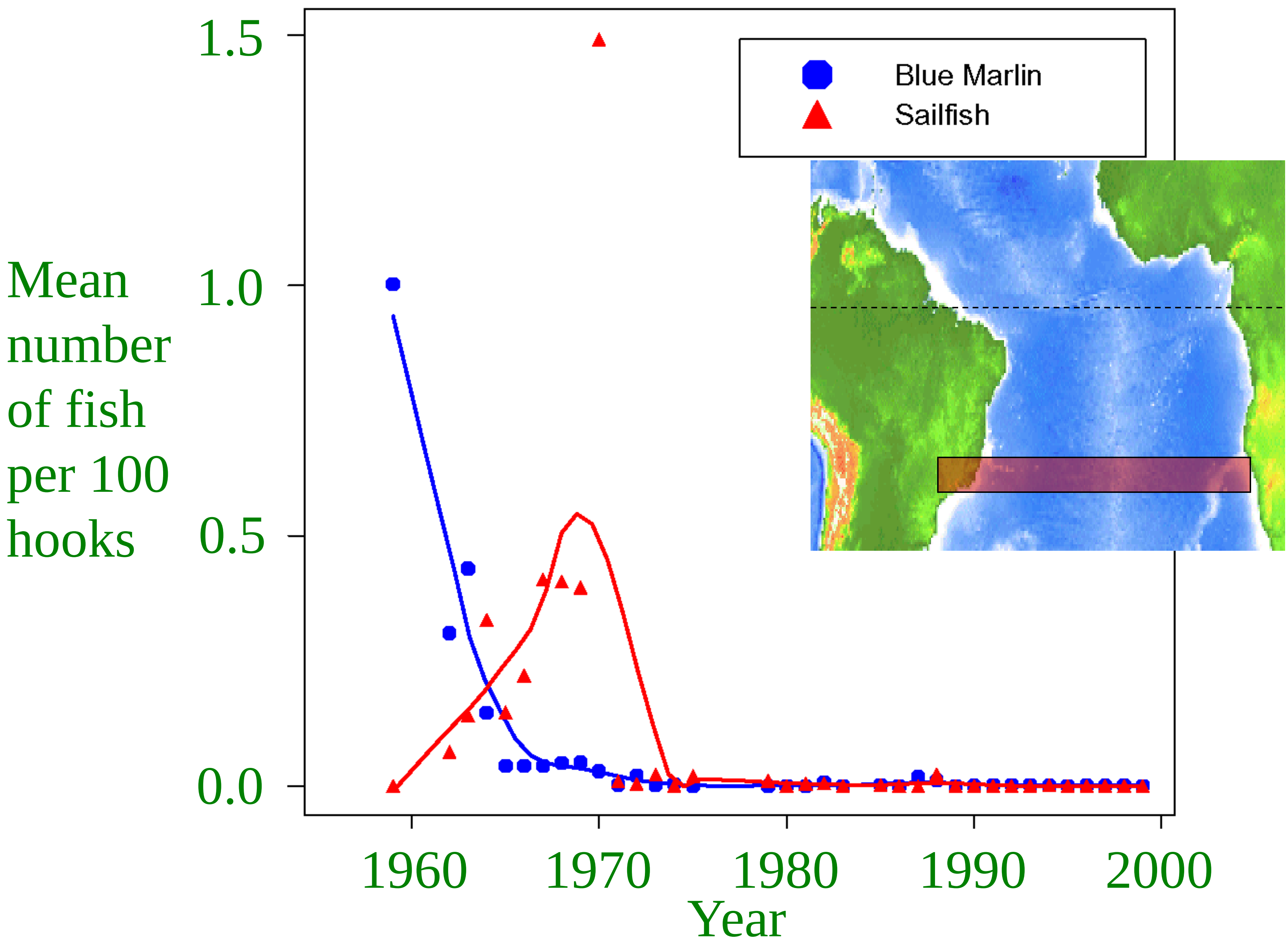
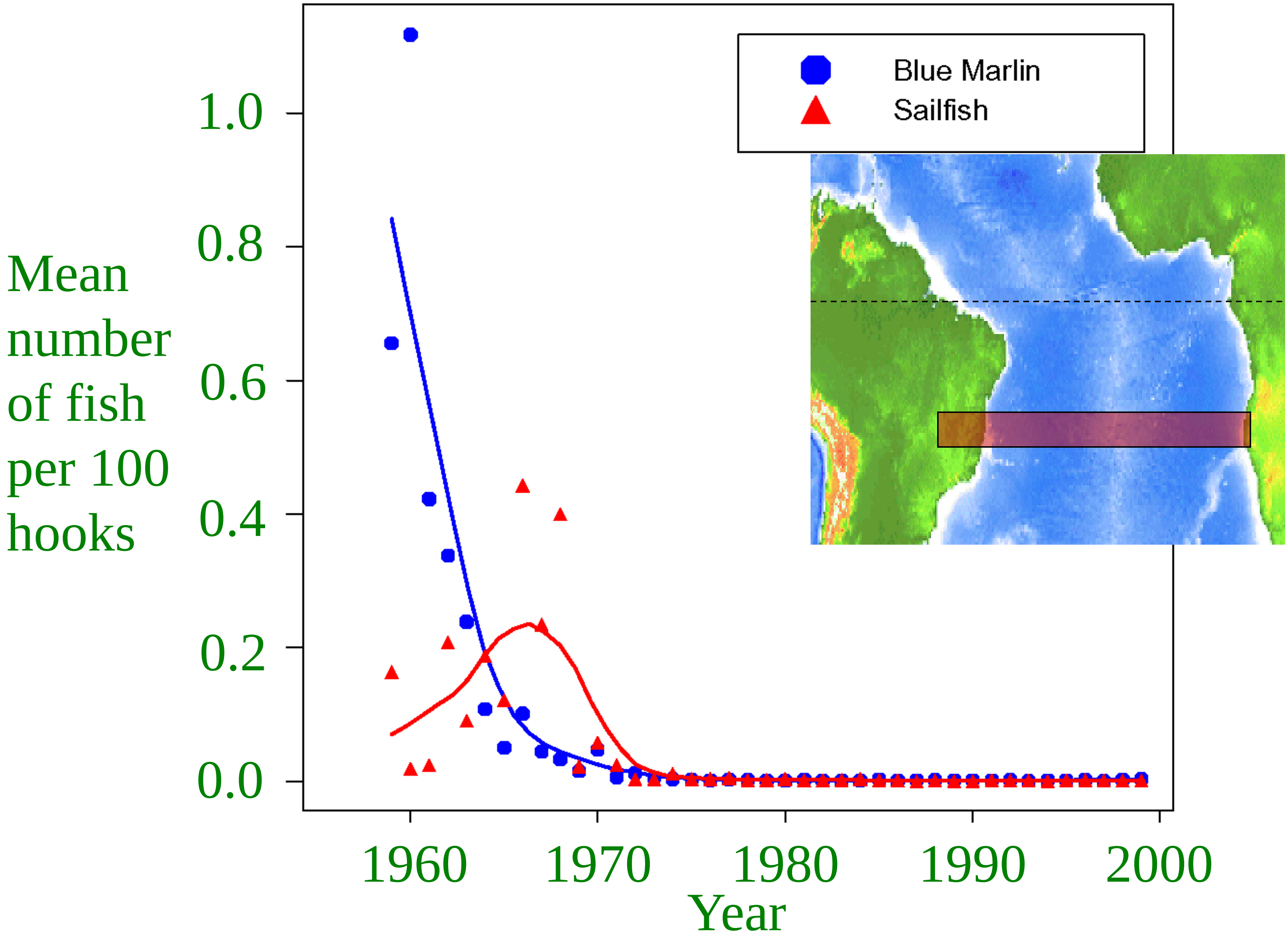


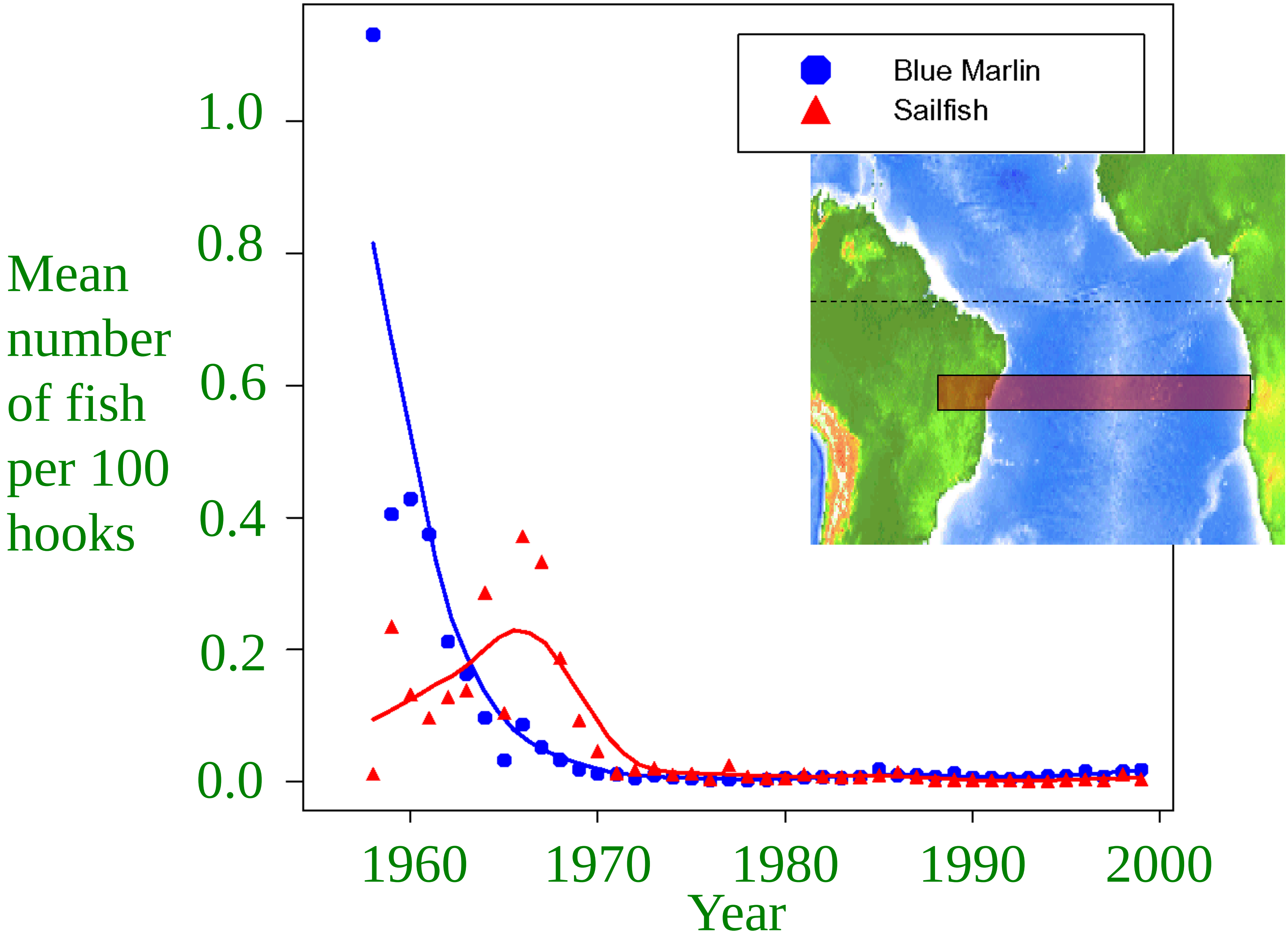
Blue marlin (*Makaira nigricans)*

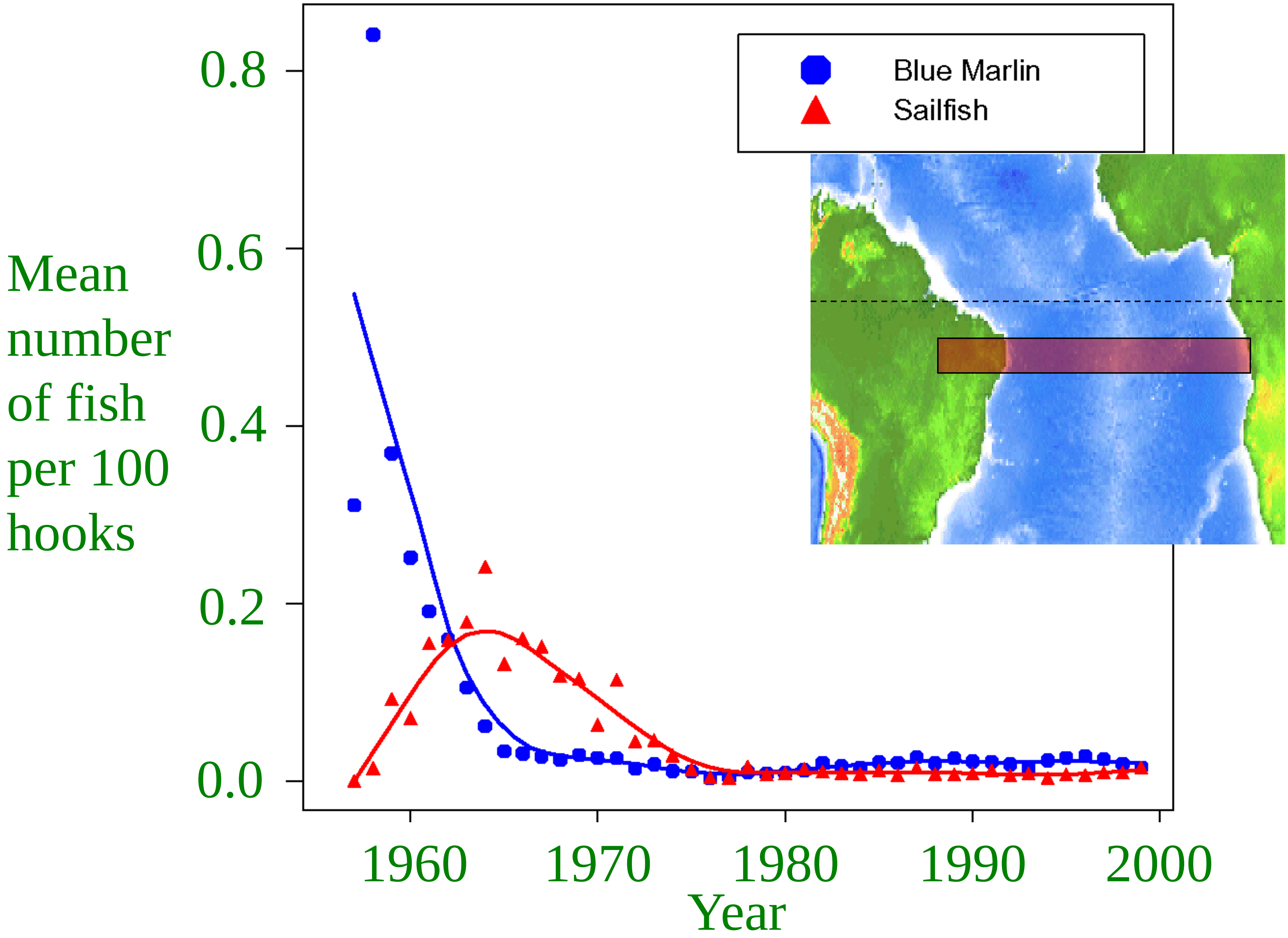
Sailfish (*Istiophorus albicans)*

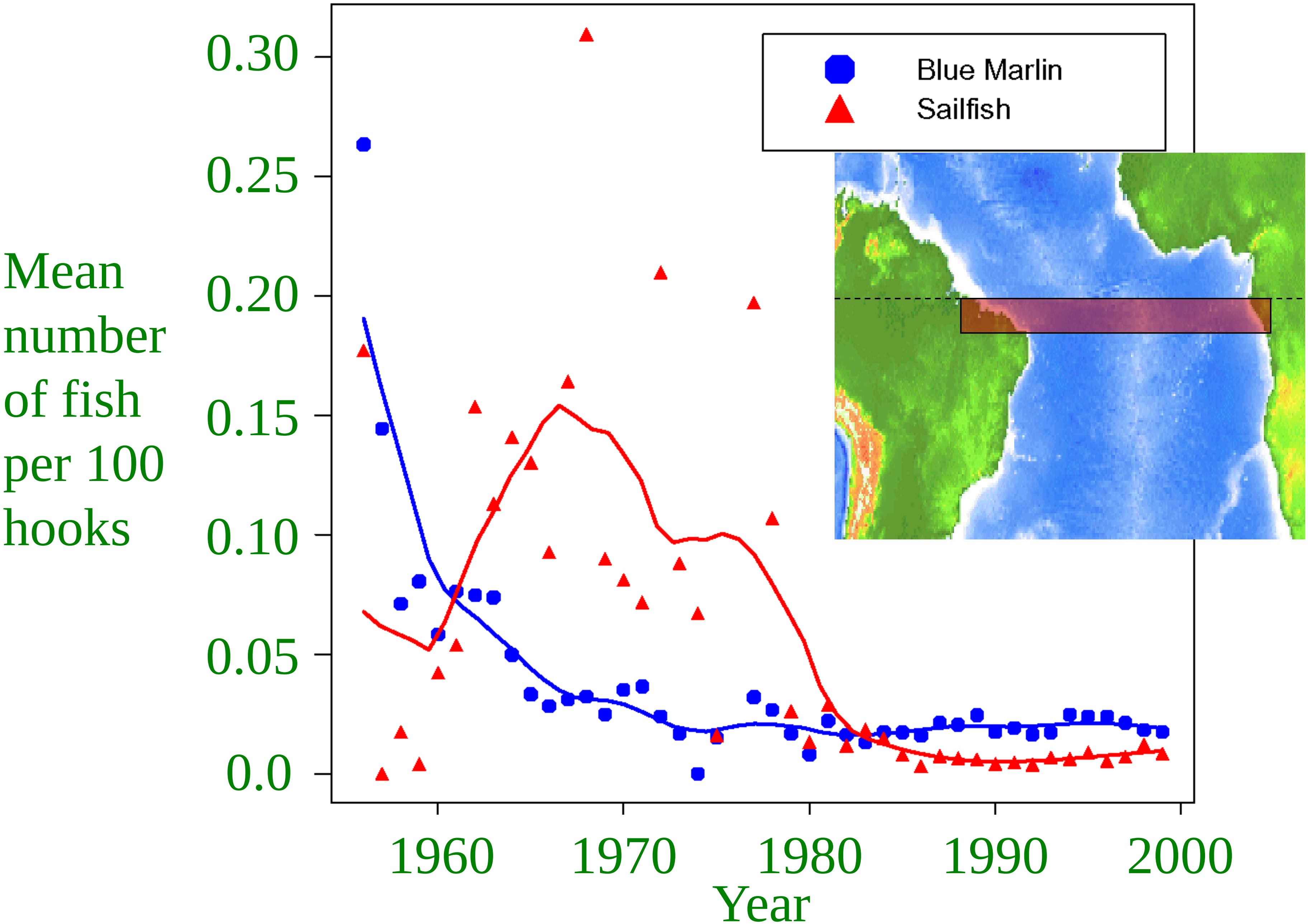

Mean number of fish per 100 hooks
1.5
1.0
0.5
0.0
Blue Marlin
Sailfish
1960
1970
1980
1990
2000
Year



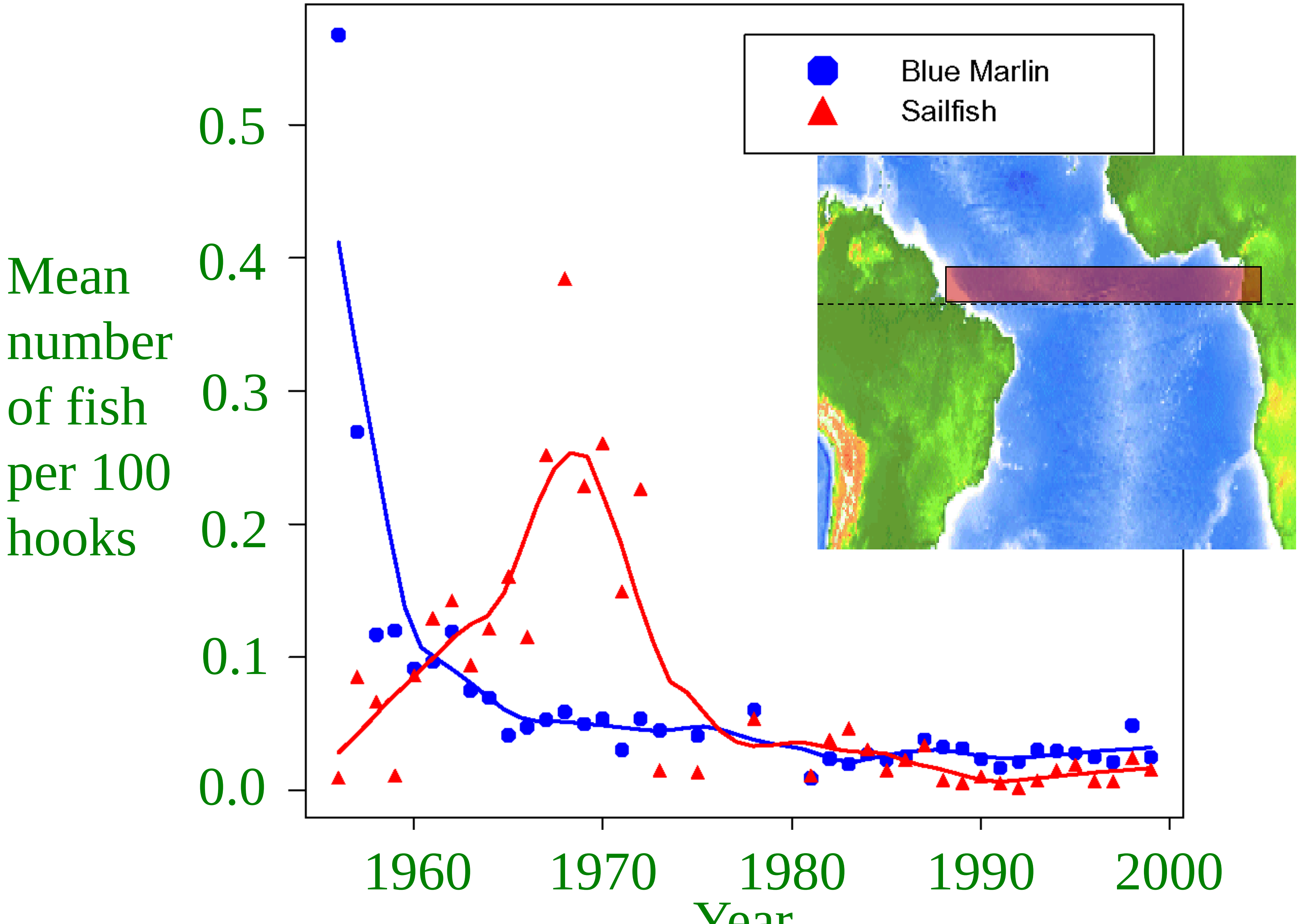
Blue Marlin
Sailfish
Mean number of fish per 100 hooks
1.0
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
Year


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
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

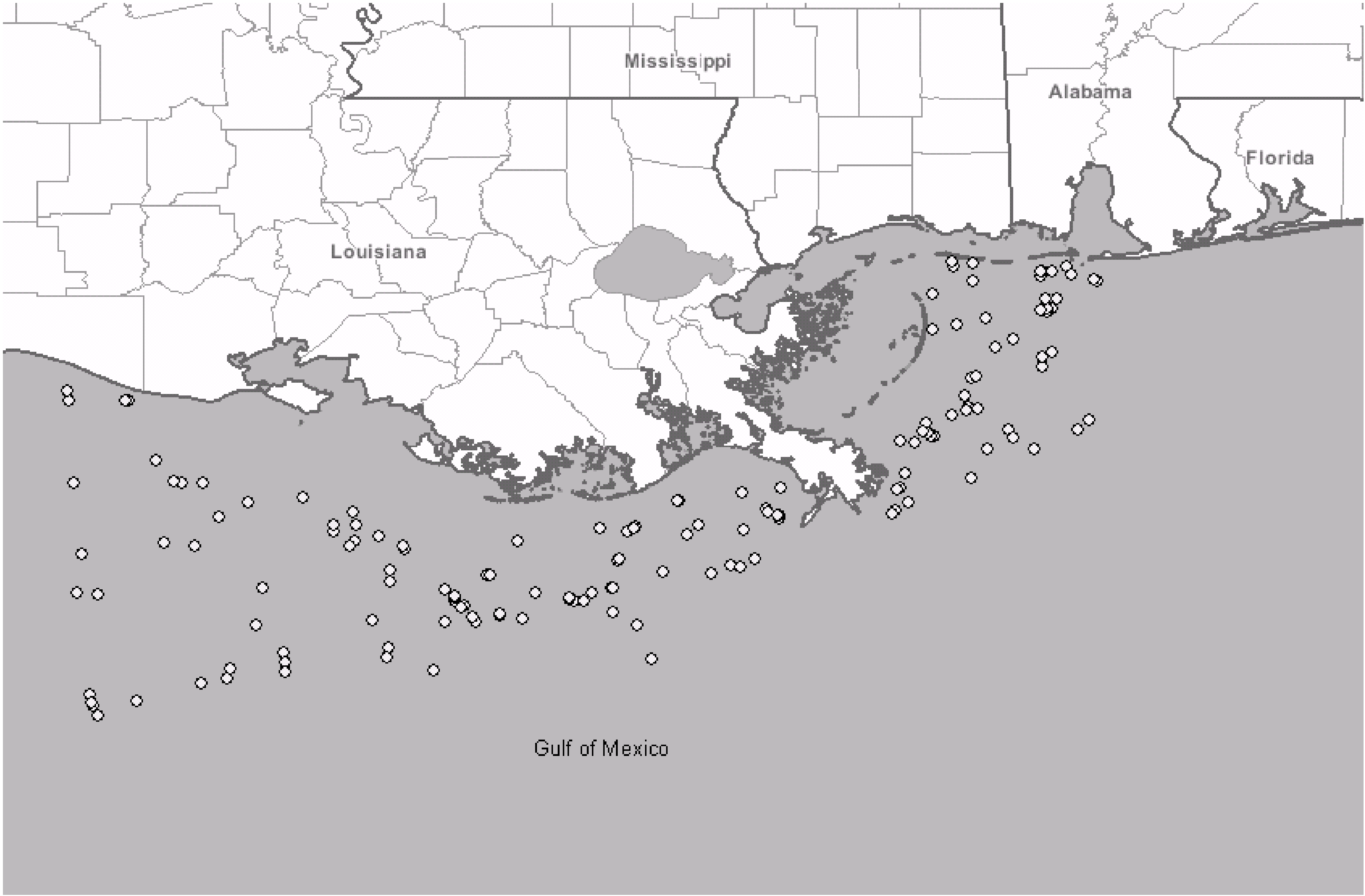


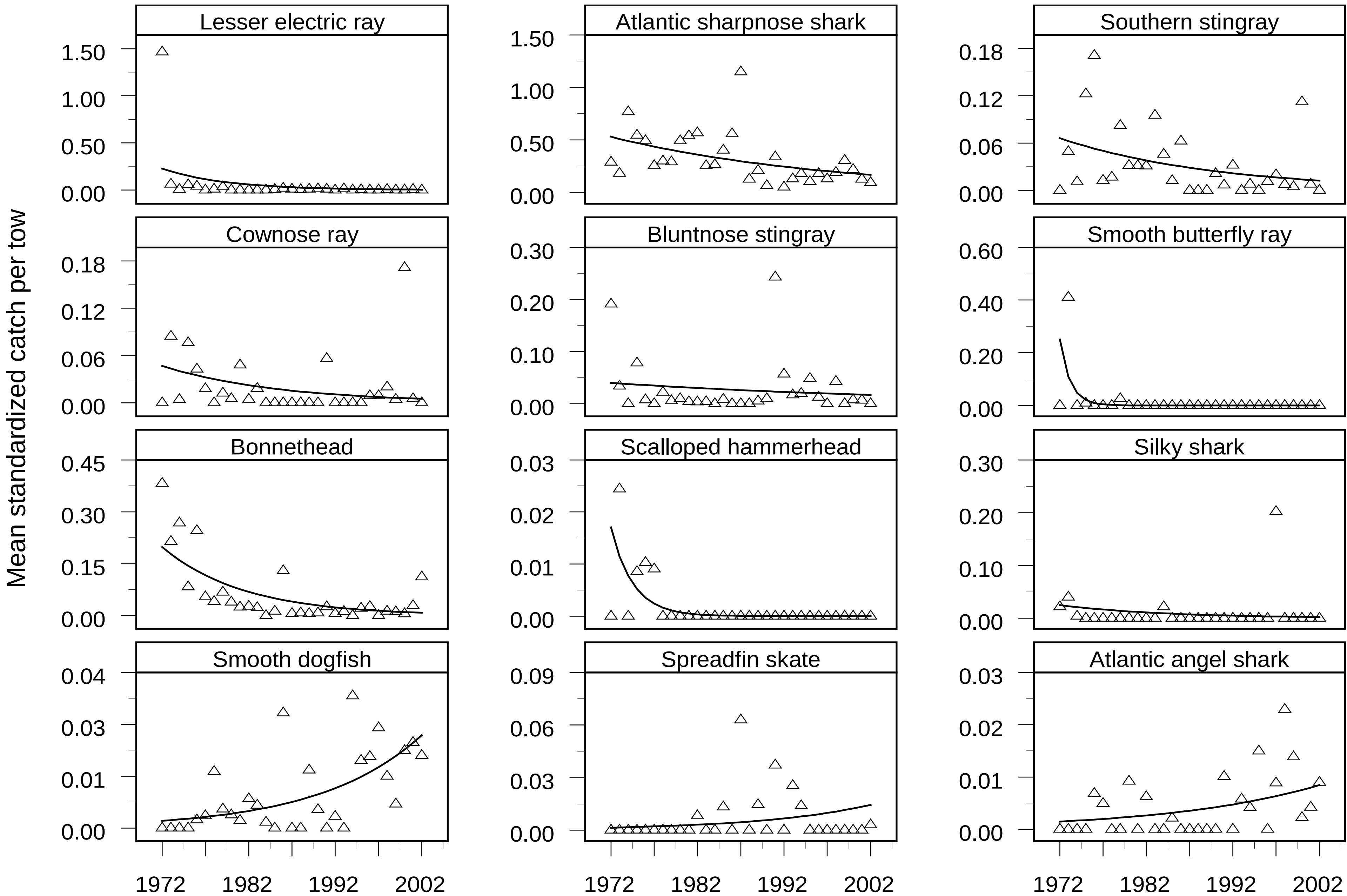
Blue Marlin
Sailfish
Mean number of fish per 100 hooks
0.0
0.1
0.2
0.3
0.4
0.5
1960
1970
1980
1990
2000
Year

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

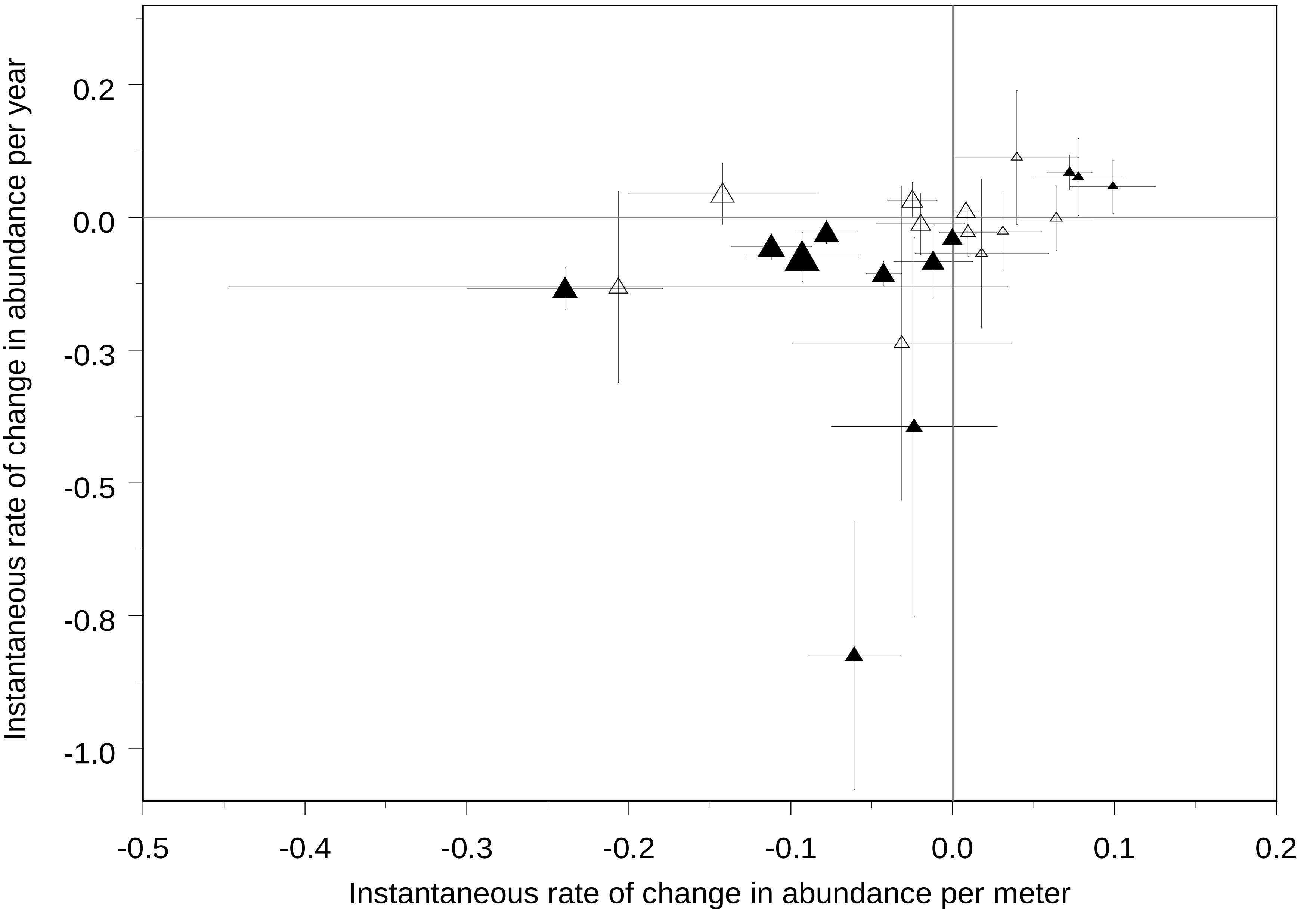
FMAP (Future of Marine Animal Populations)
part of the Sloan Census of Life http://www.fmap.ca
Pew Global Sharks Assessment http://www.globalsharks.ca

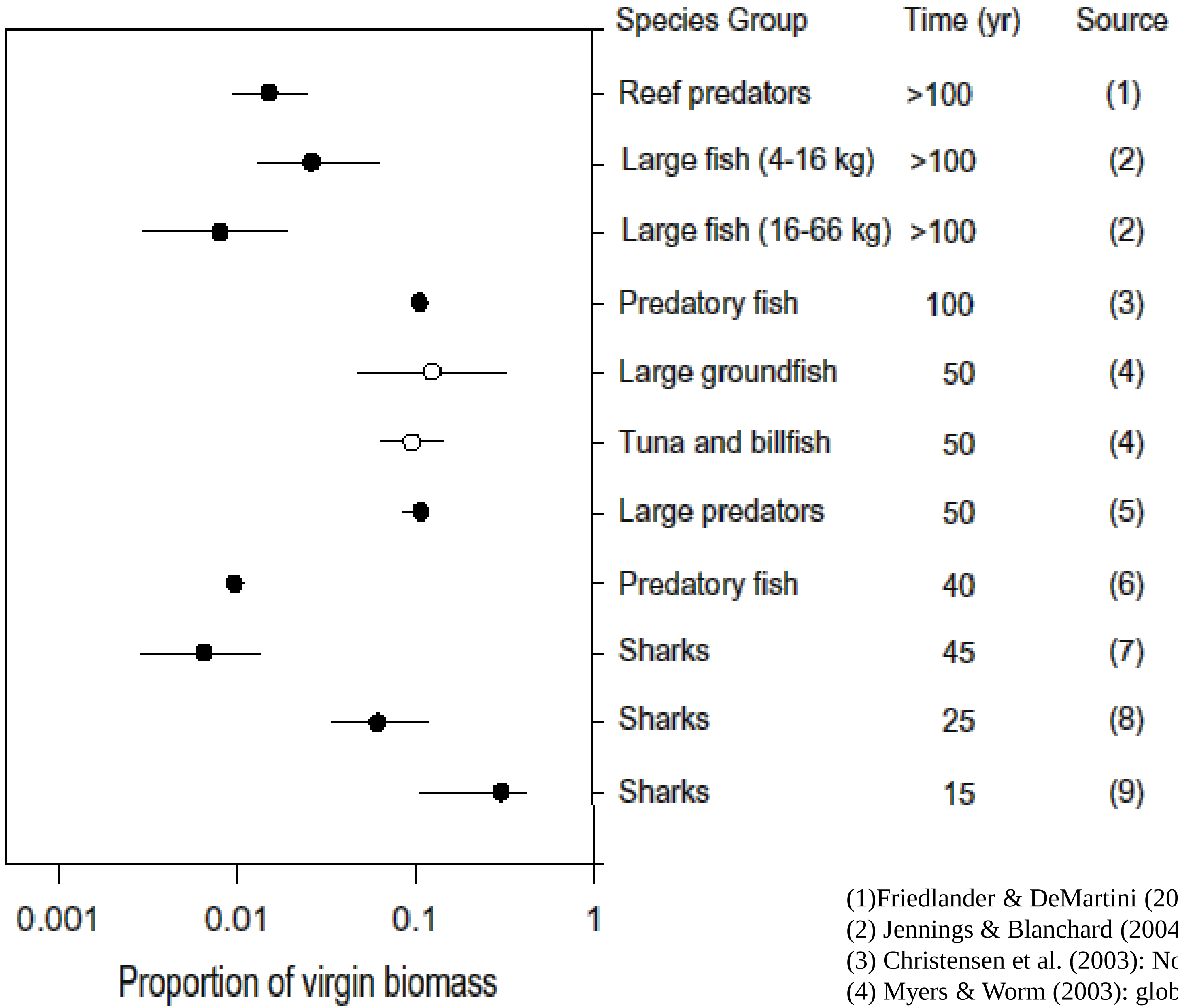
Is shrimp trawling driving sharks and rays extinct?




Mean standardized catch per tow
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
1972
1982
1992
2002

Shallow species are going extinct
Deep species are increasing





(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.

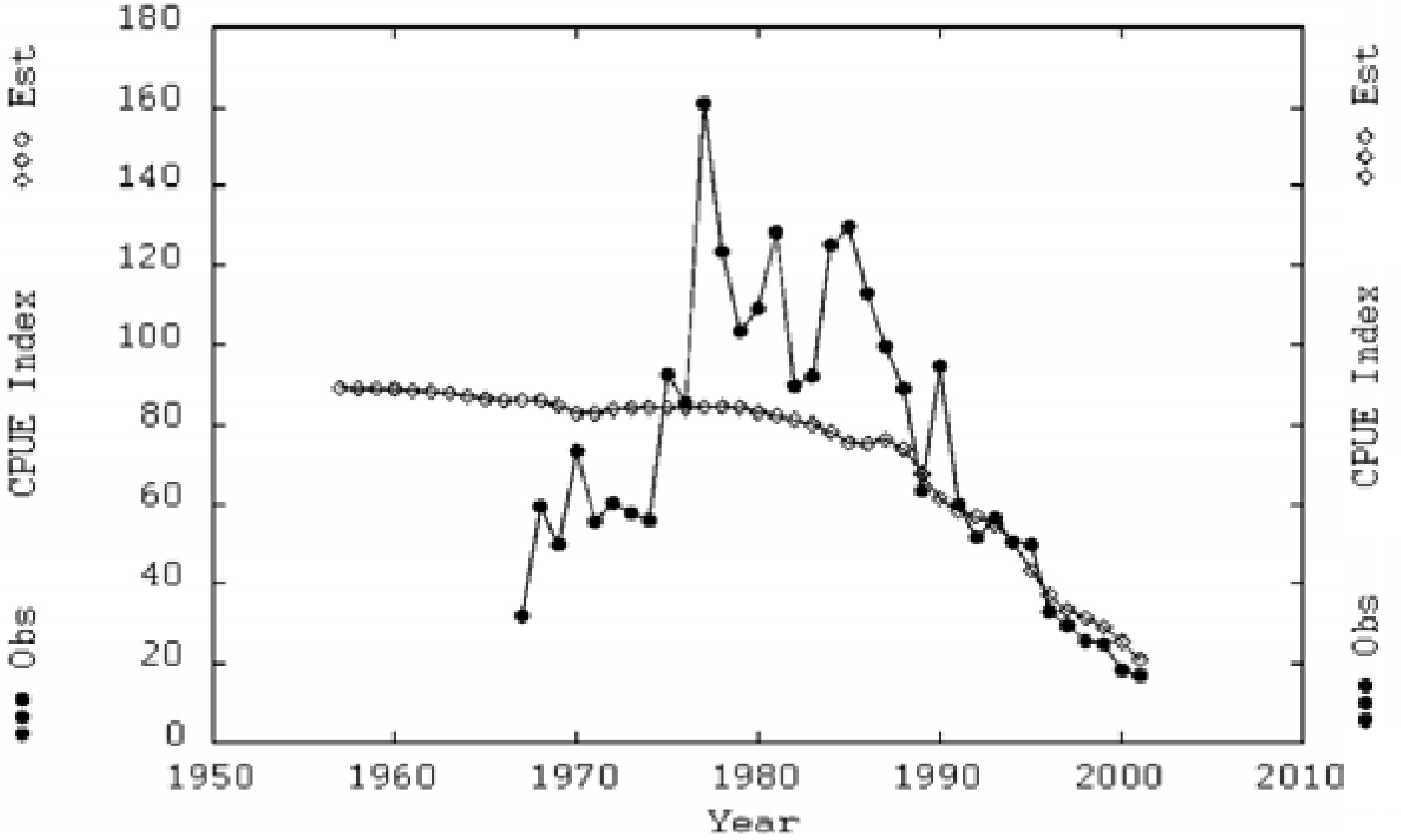
Source: Myers and Worm 2005.
Proc. R. Soc. Lond. B (2005)

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

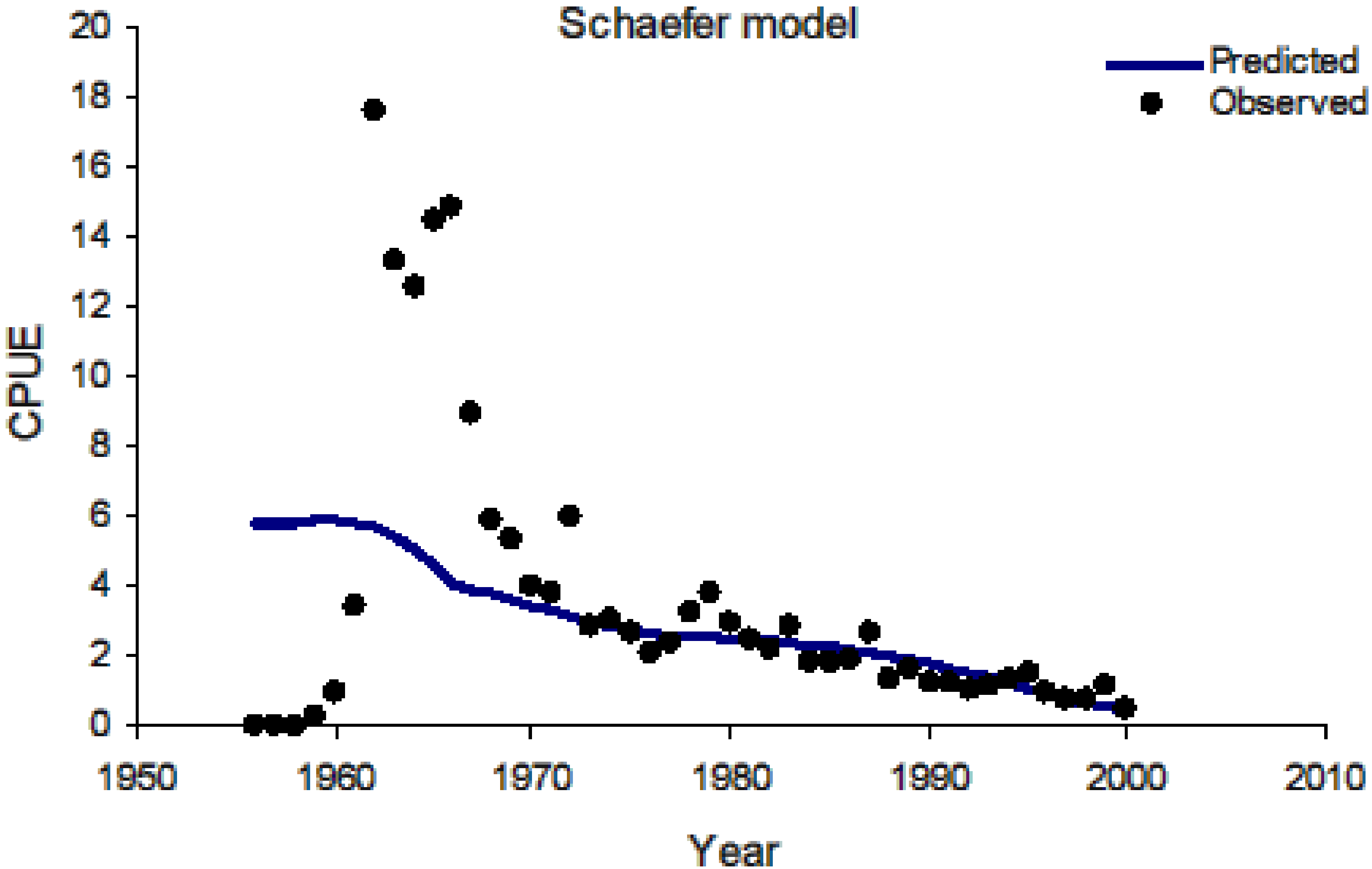
FMAP (Future of Marine Animal Populations)
part of the Sloan Census of Life http://www.fmap.ca
Pew Global Sharks Assessment http://www.globalsharks.ca

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

Sensitivity 4, Japanese index



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.

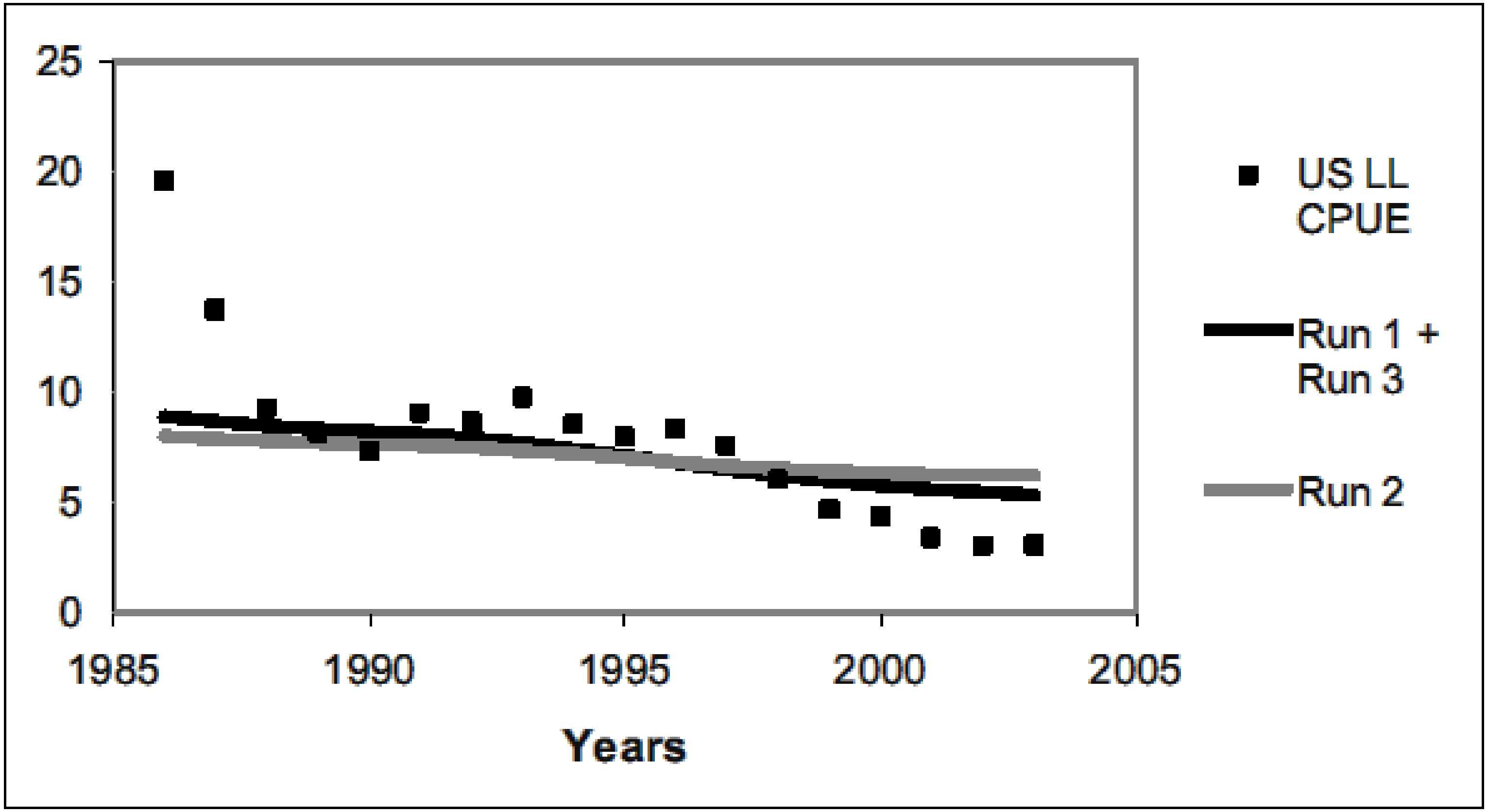
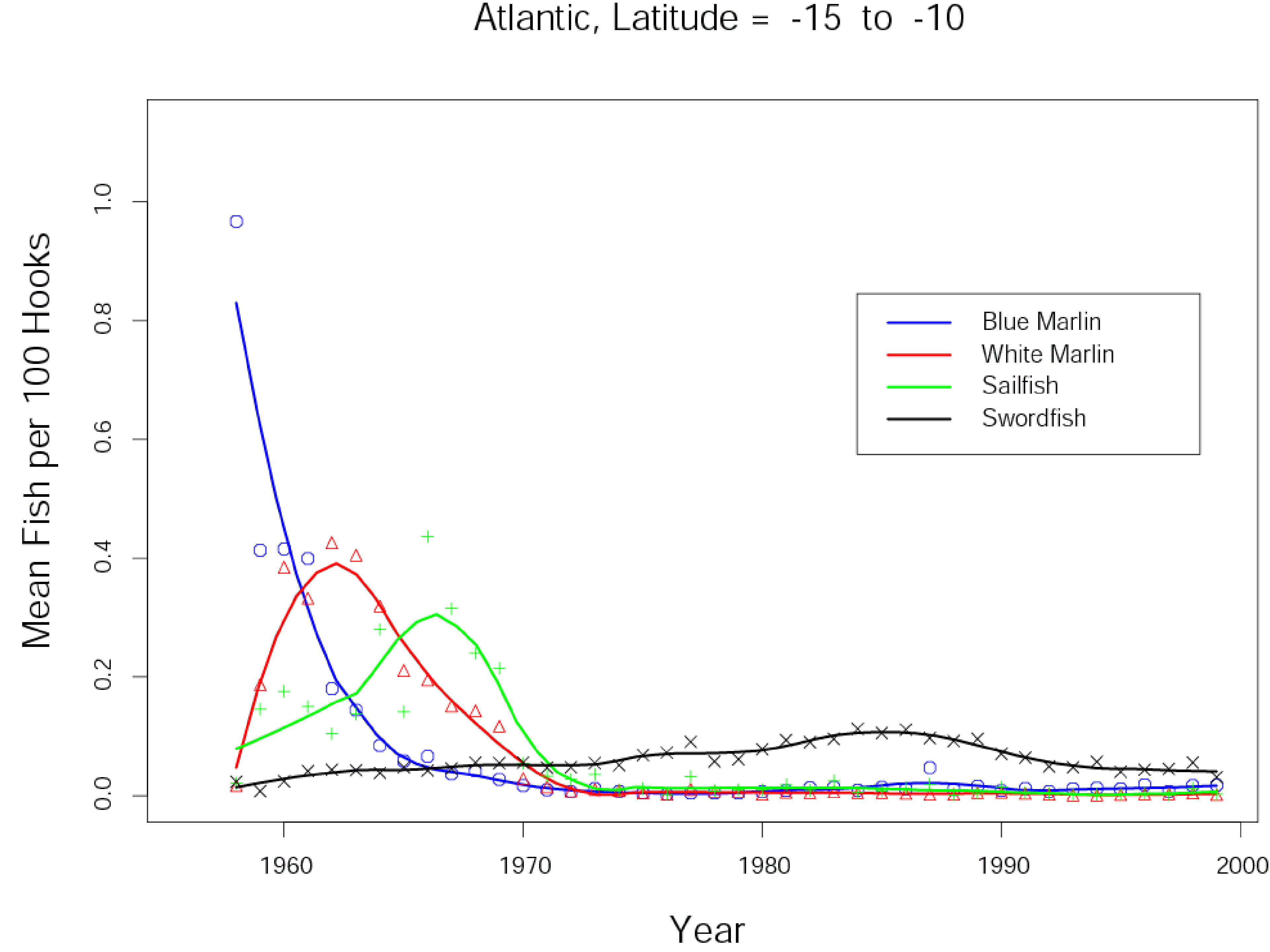
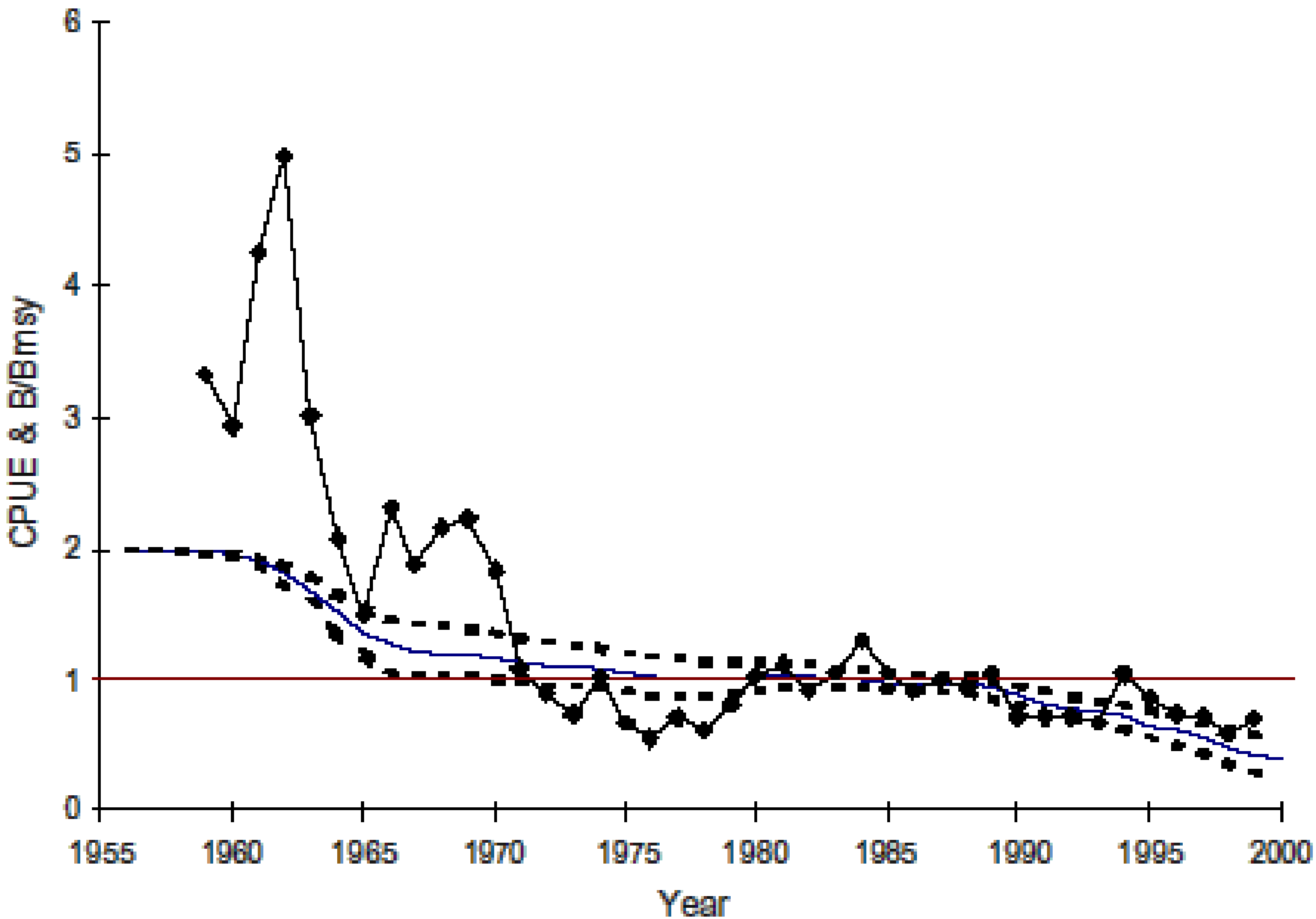


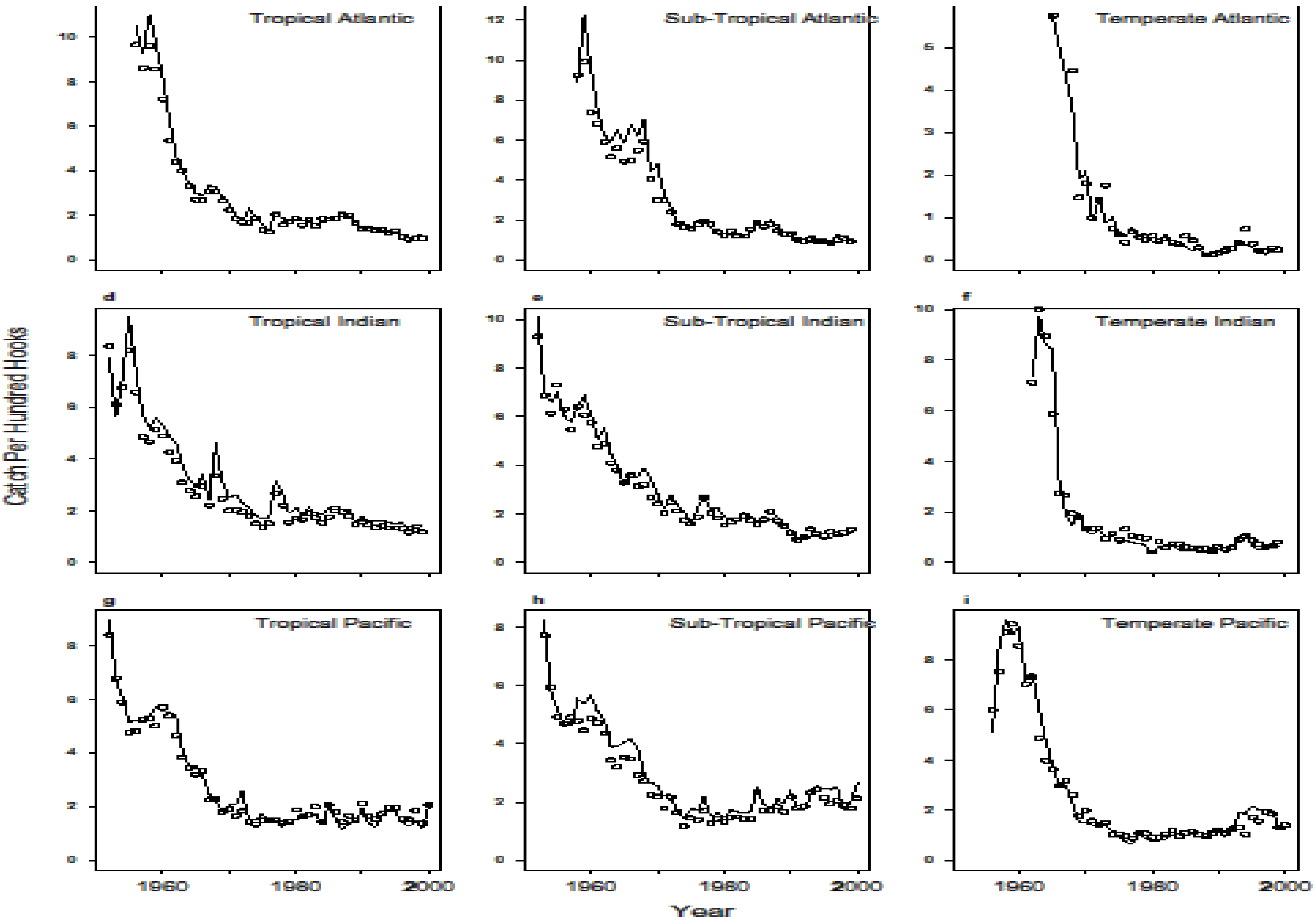
Figure 10 (above). Fit of the model to the North Atlantic blue shark CPUE data for each of the runs considered.


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

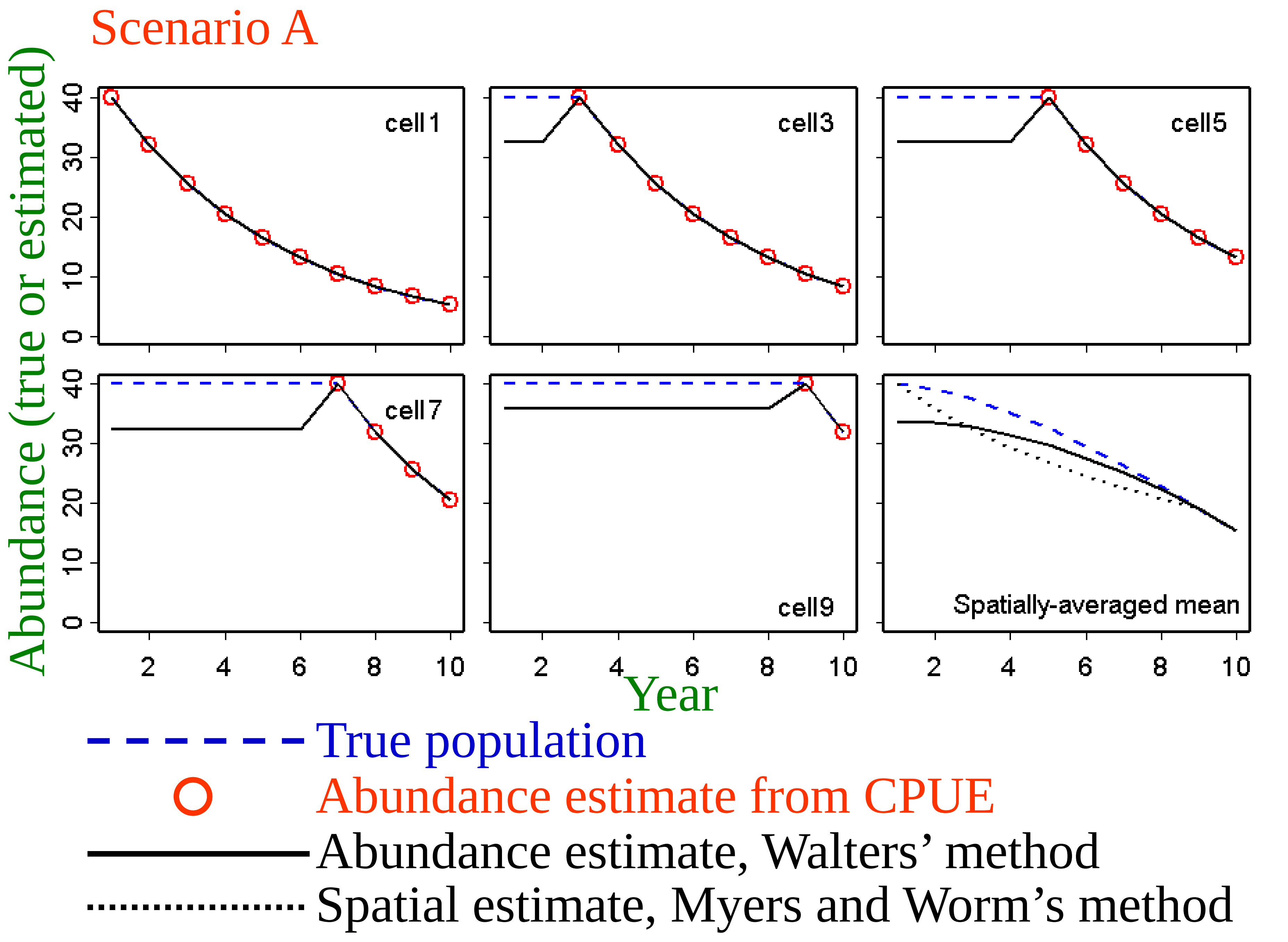
Bluefine tuna (observed diamonds) and modeled – not a very good fit.



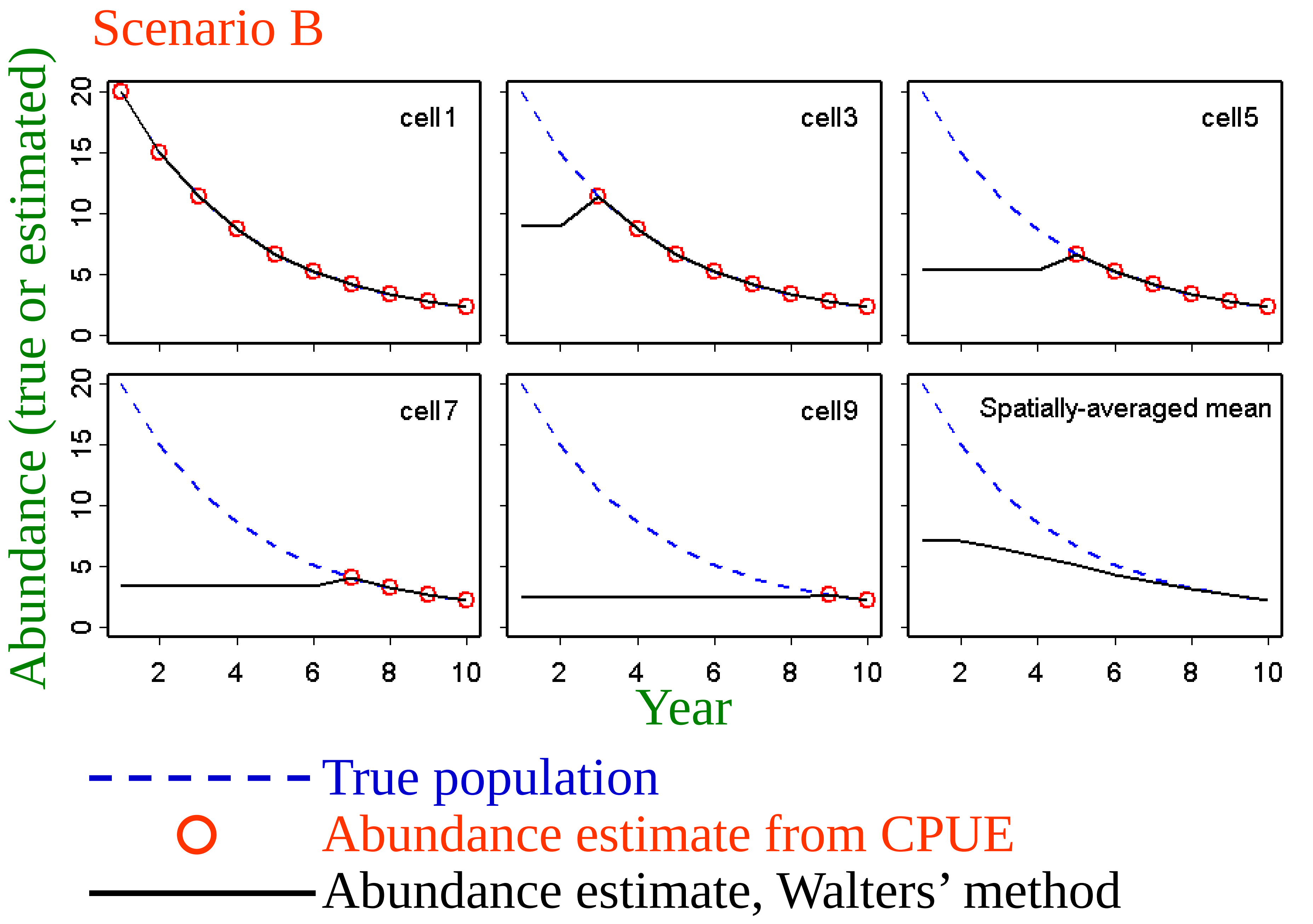
RED HERRING 1: RATIO ESTIMATION



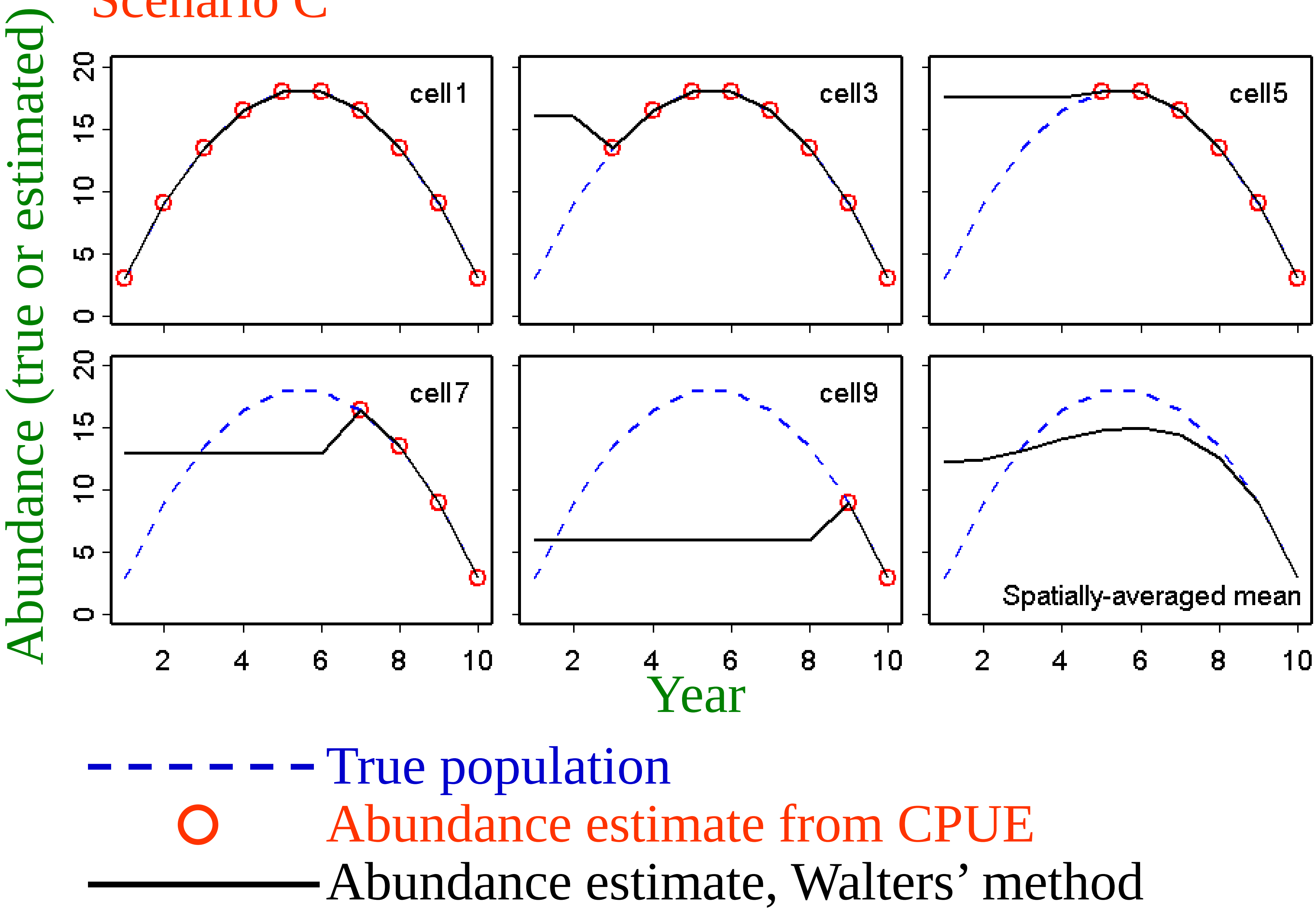
RED HERRING 2: SPATIAL ESTIMATION



Scenario A
Abundance (true or estimated)
cell1
cell3
cell5
cell7
cell9
Spatially-averaged mean
Year
True population
Abundance estimate from CPUE
Abundance estimate, Walters' method
Spatial estimate, Myers and Worm's method


Scenario B
Abundance (true or estimated)
cell 1
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

Scenario C

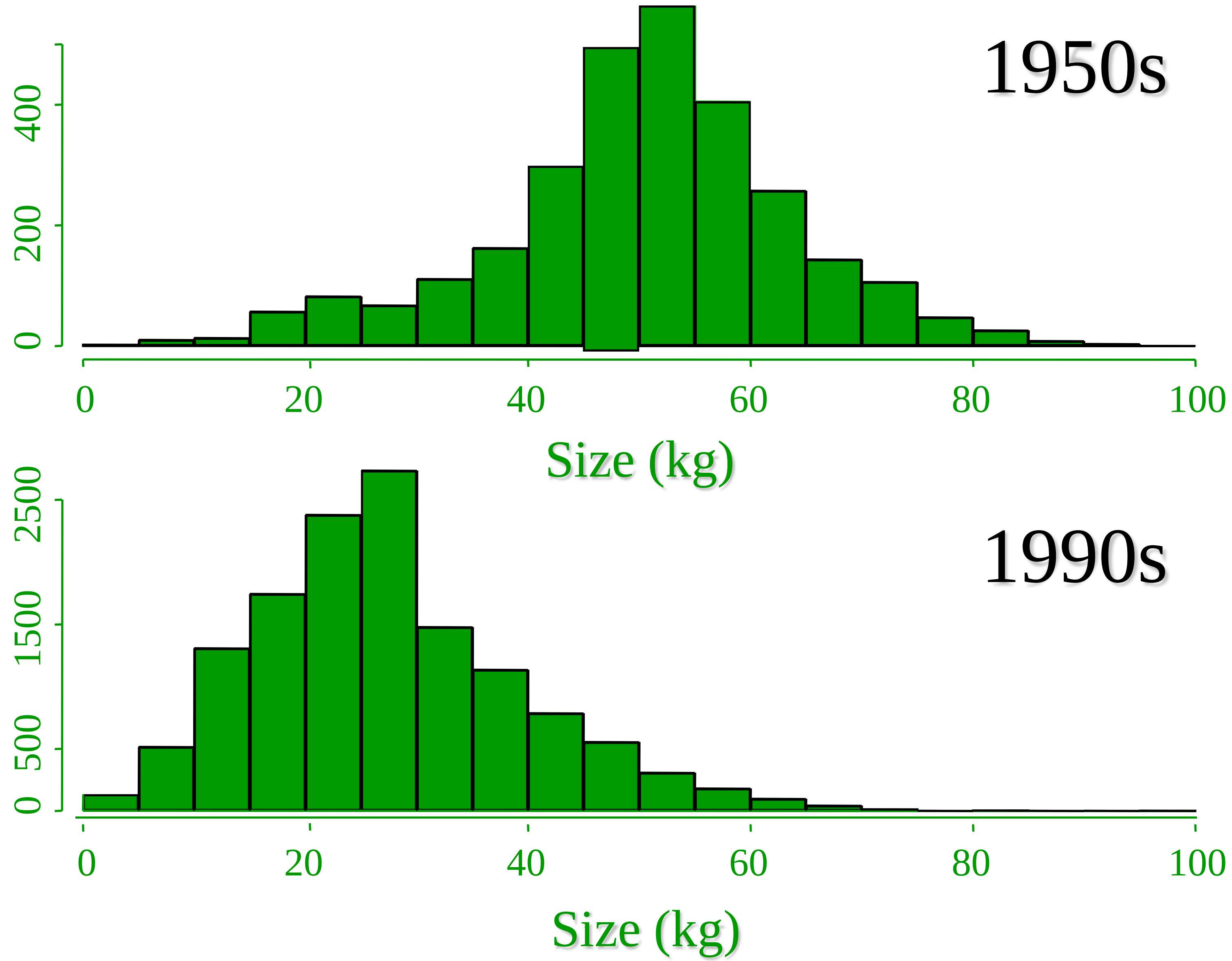


Abundance (true or estimated)
cell 1
cell3
cell5
cell 7
cell9
Spatially-averaged mean
0
5
10
15
20
2
4
6
8
10
Year
True population
Abundance estimate from CPUE
Abundance estimate, Walters' method

These estimates are conservative: 1.

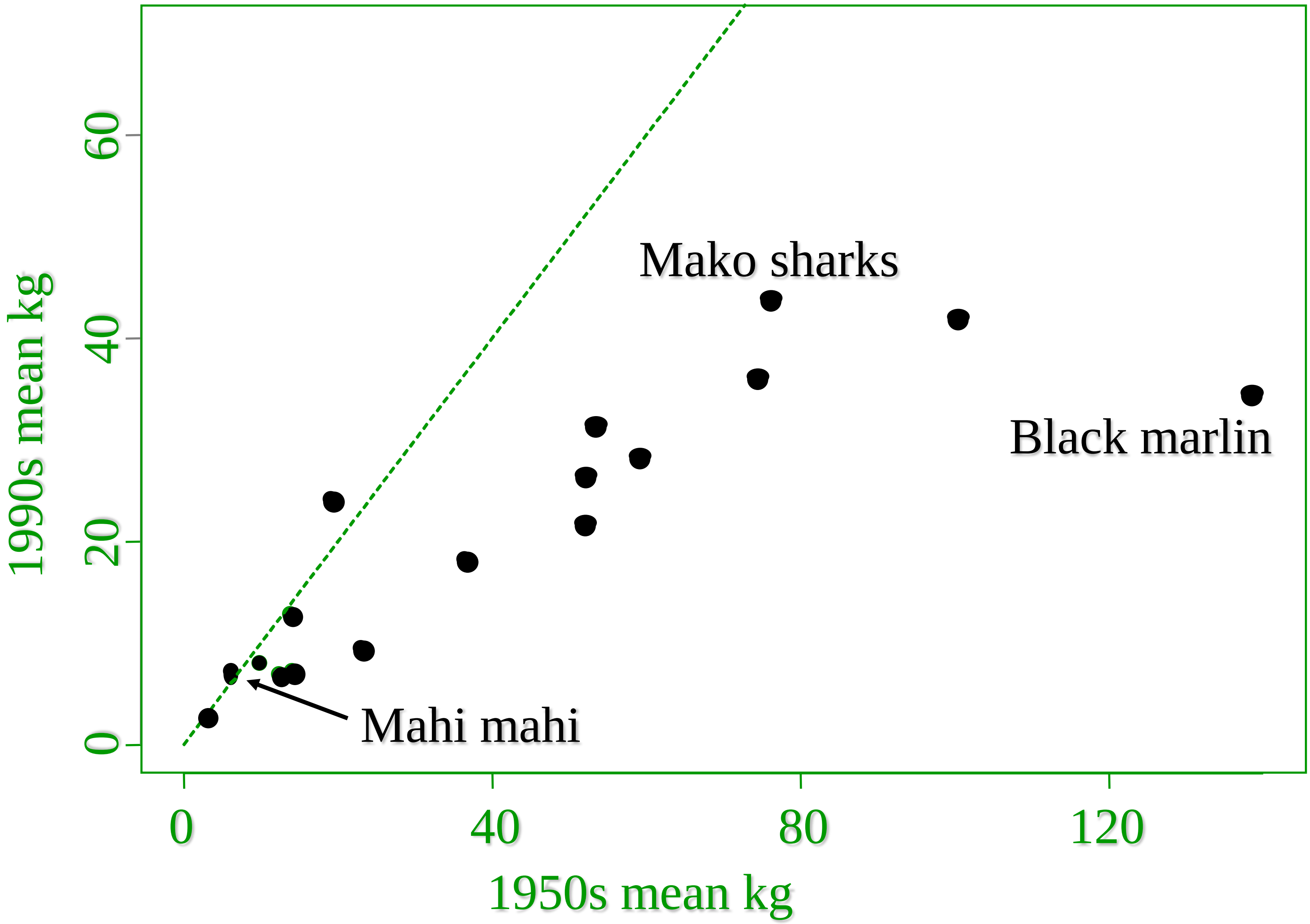
Bits of tuna did not count; ~25-30% of tropical tunas were initially not counted because of shark damage.

These estimates are conservative: 2 (fish are smaller)



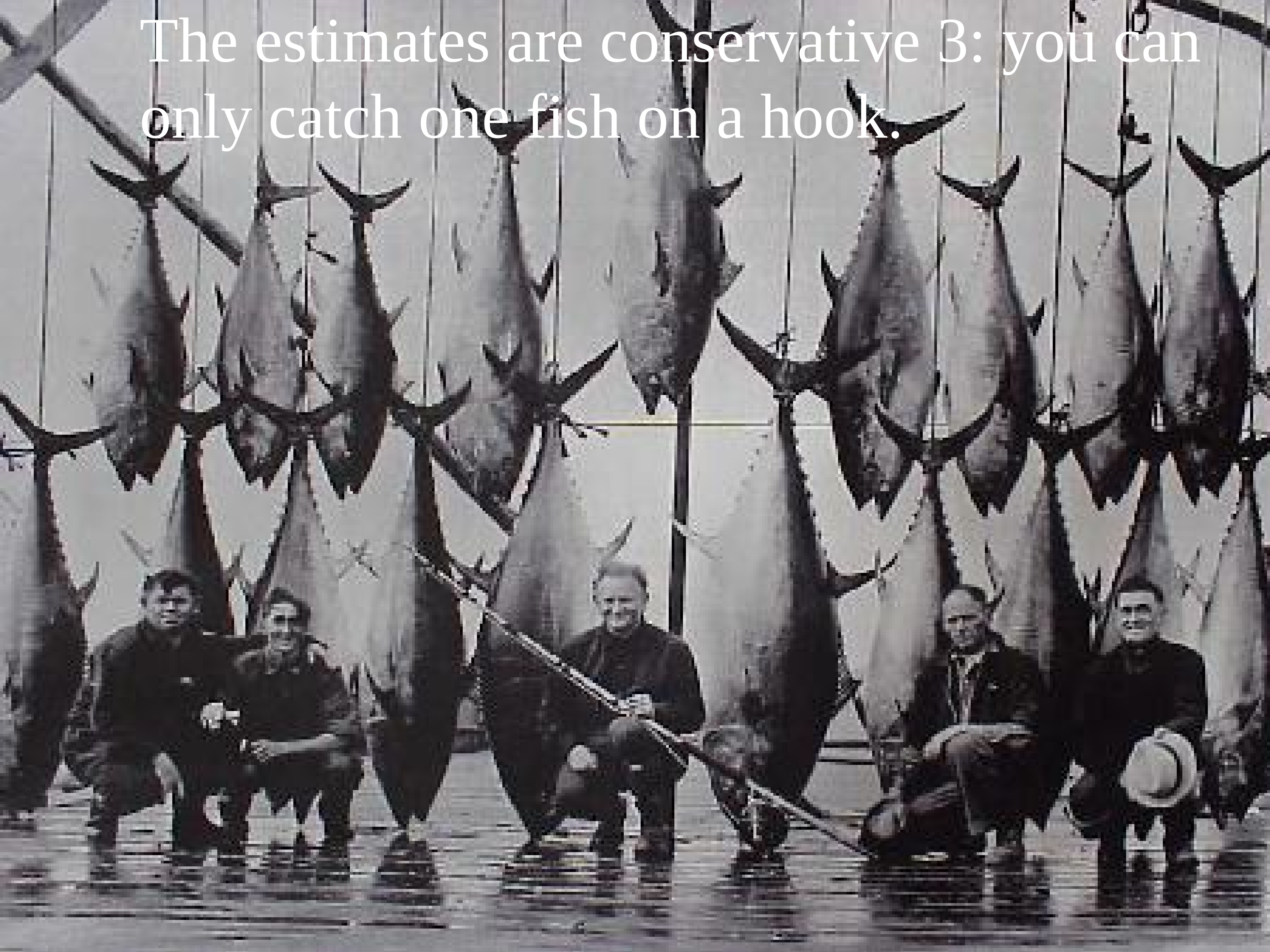
Yellowfin tuna – equitorial Pacific

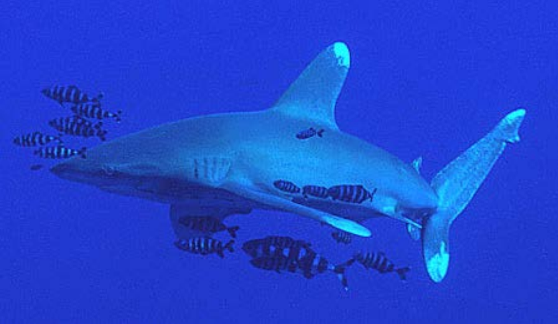
Change in body size




555
lbs.
LBS.
1135
CABO
BLANCO

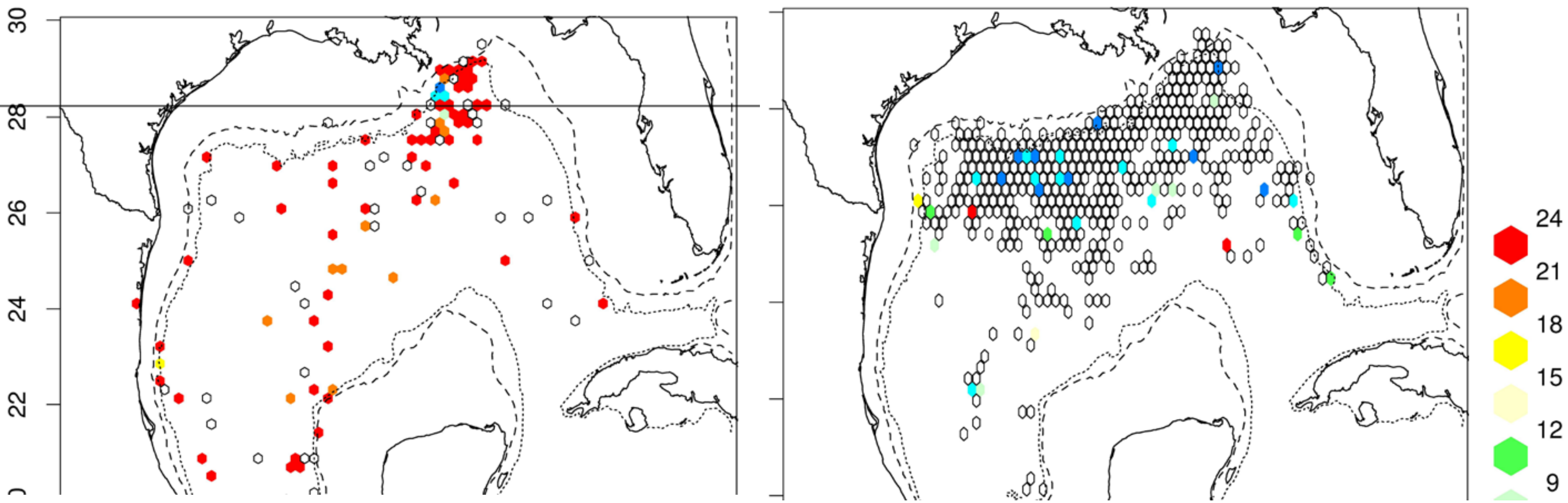
The estimates are conservative 3: you can only catch one fish on a hook.





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

[redacted]



1950’s 1990’s

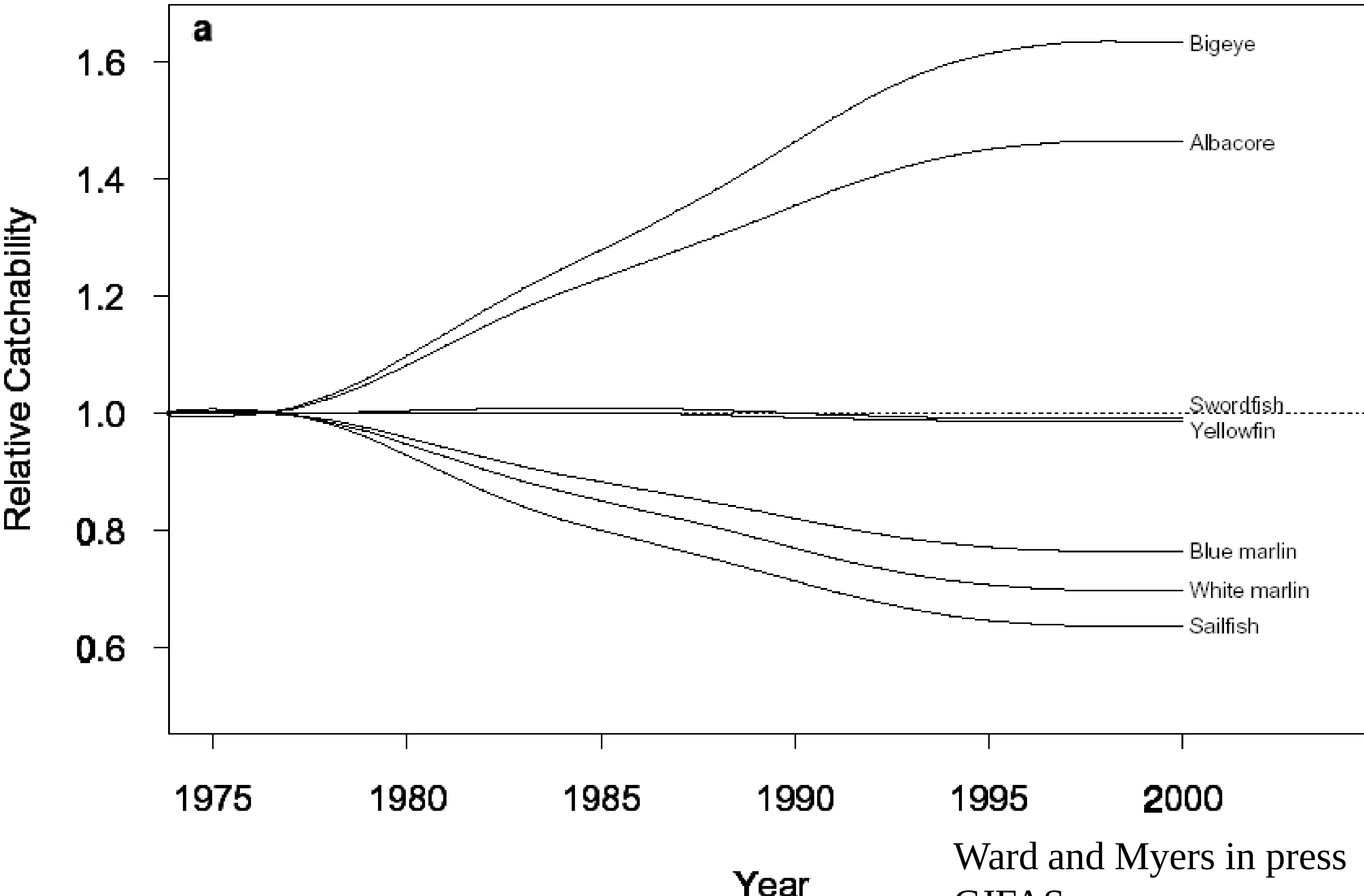
Oceanic Whitetip captures per 10,000 hooks

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.

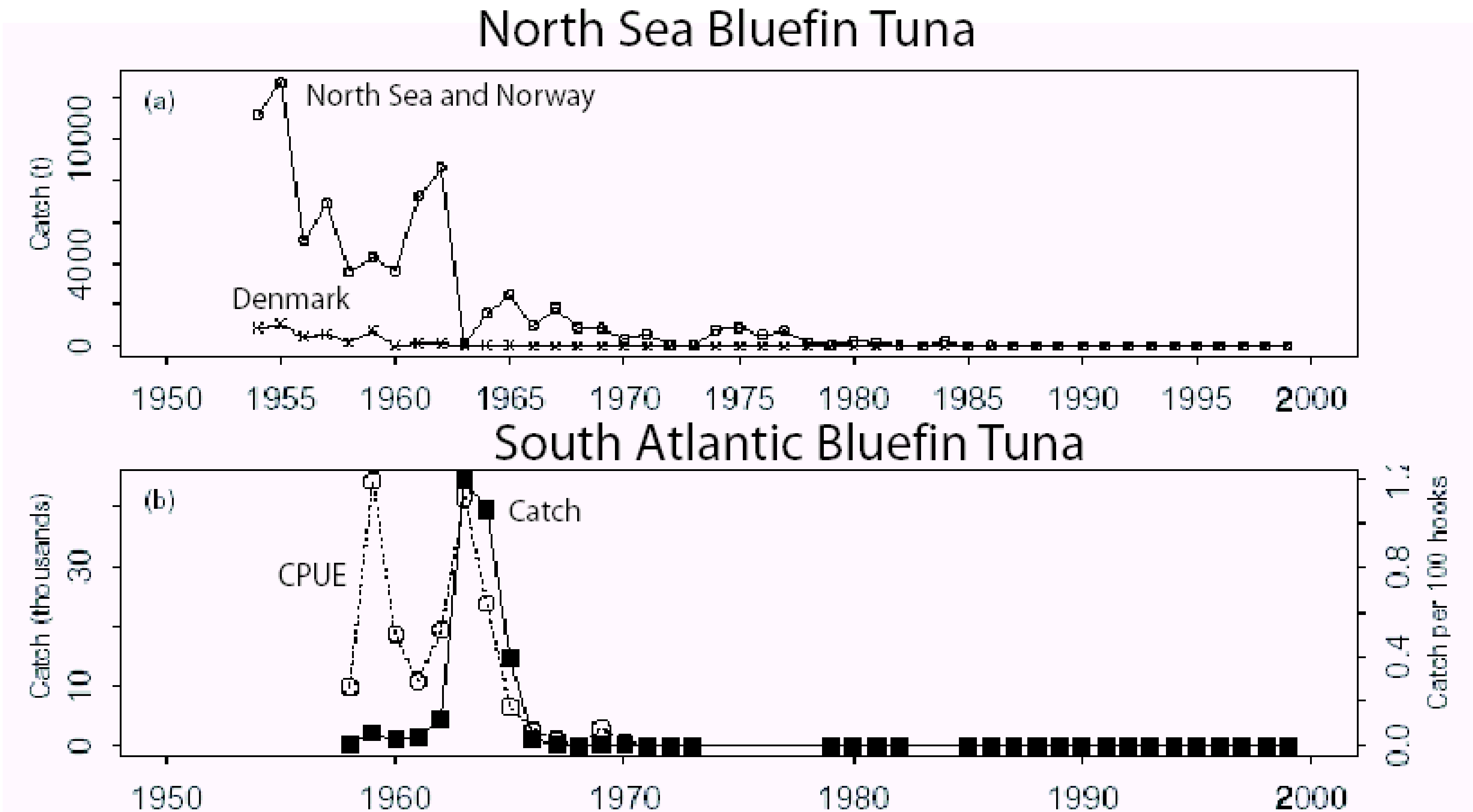


Ward and Myers in press
CJFAS

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

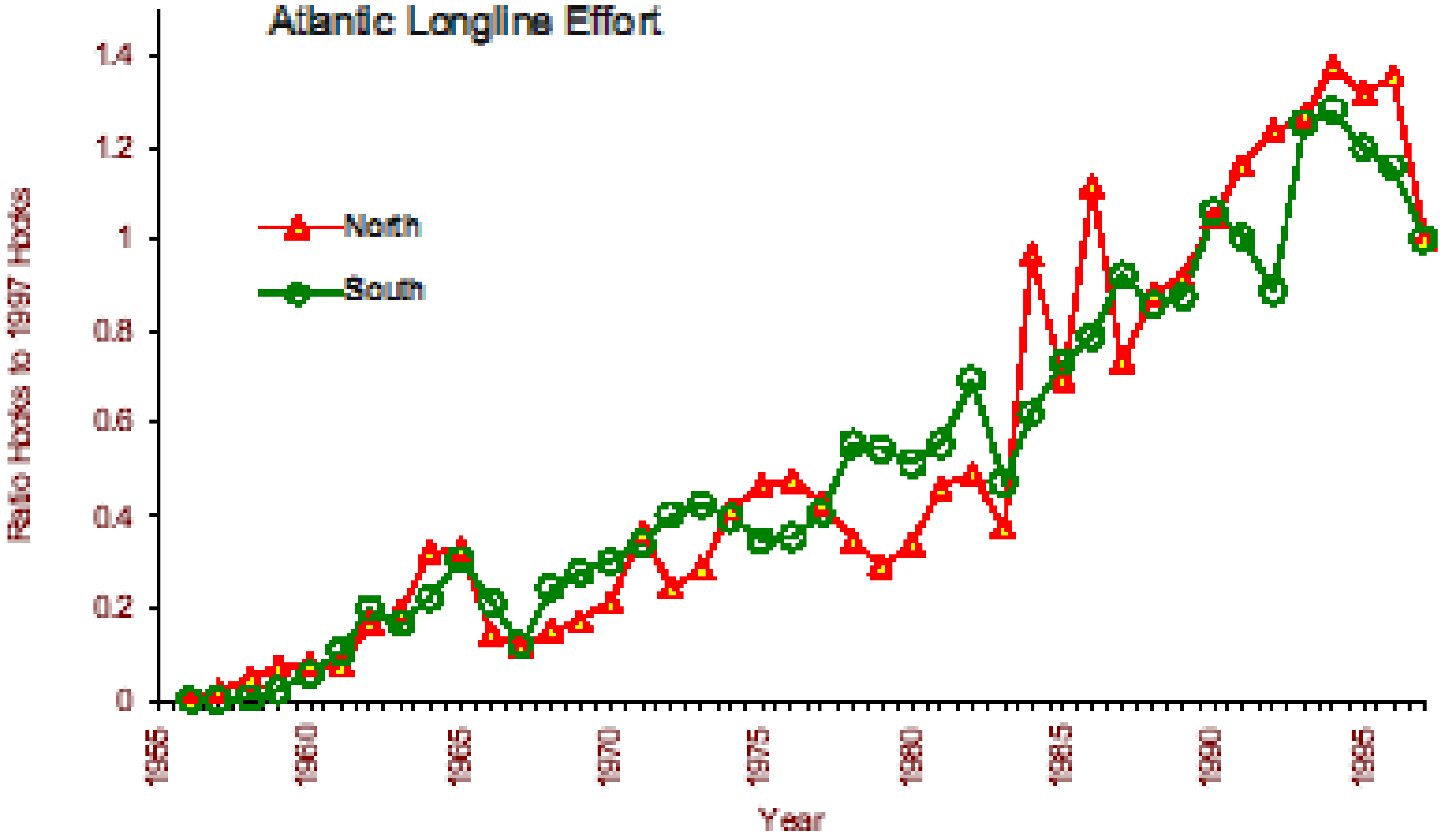


Perceived Contradiction in Initial Rapid Decline in CPUE

- 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

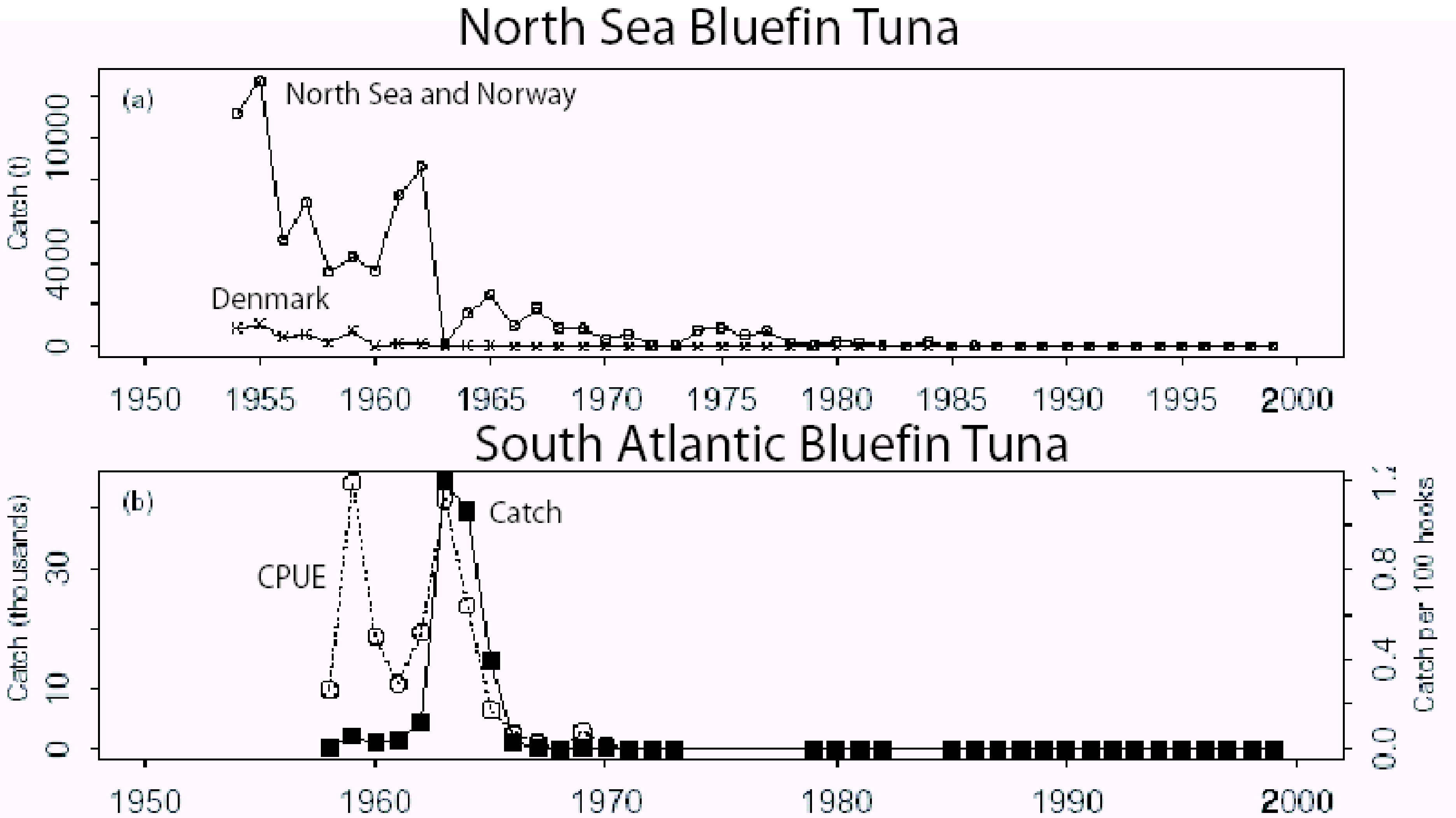
Perceived Contradiction in Initial Rapid Decline in CPUE

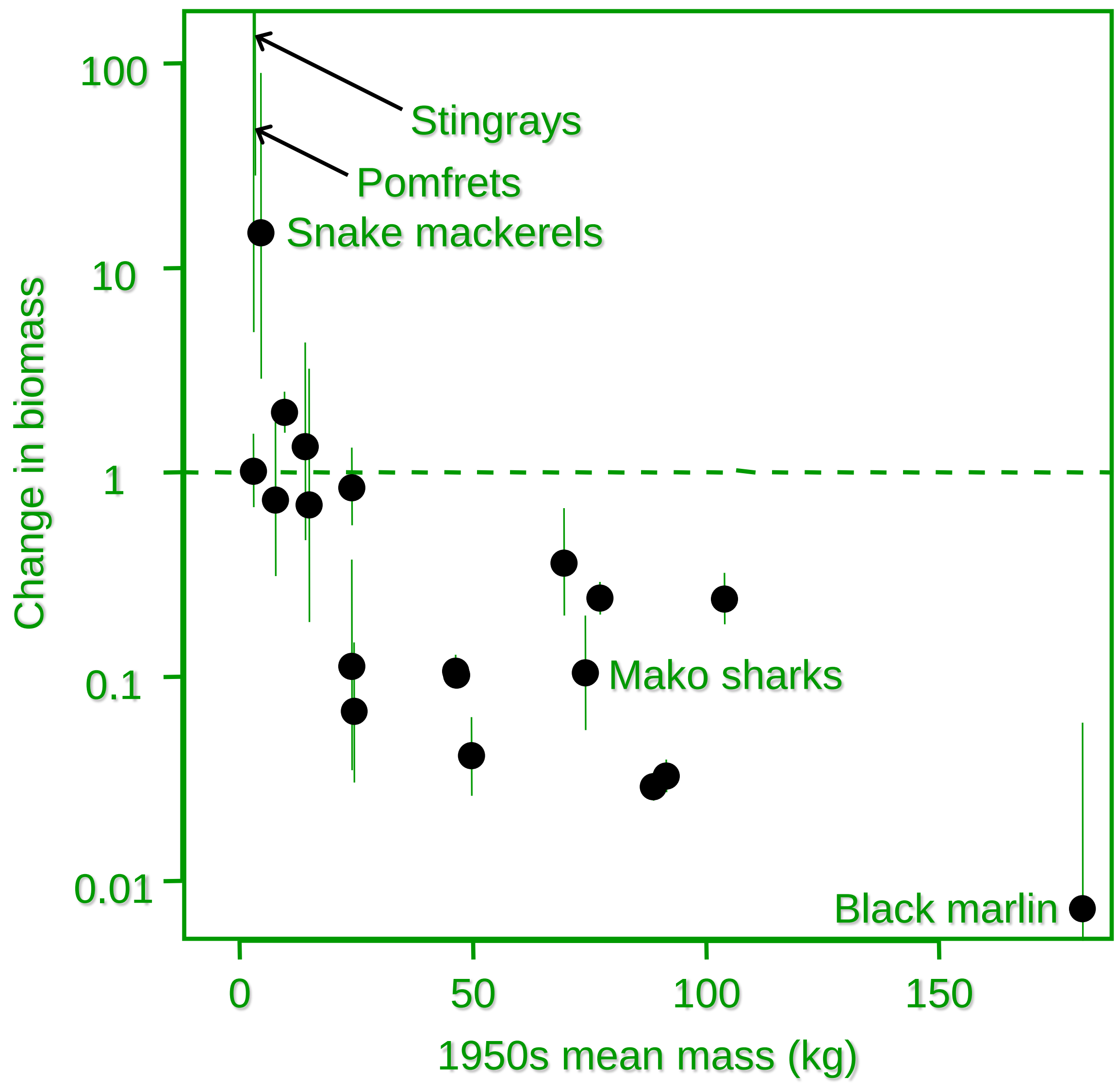
IF catchability is constant

THEN the population dynamics are impossible.

However, catchability decreases with size and size has declined

Loss of Bluefin Tuna Populations in the Atlantic



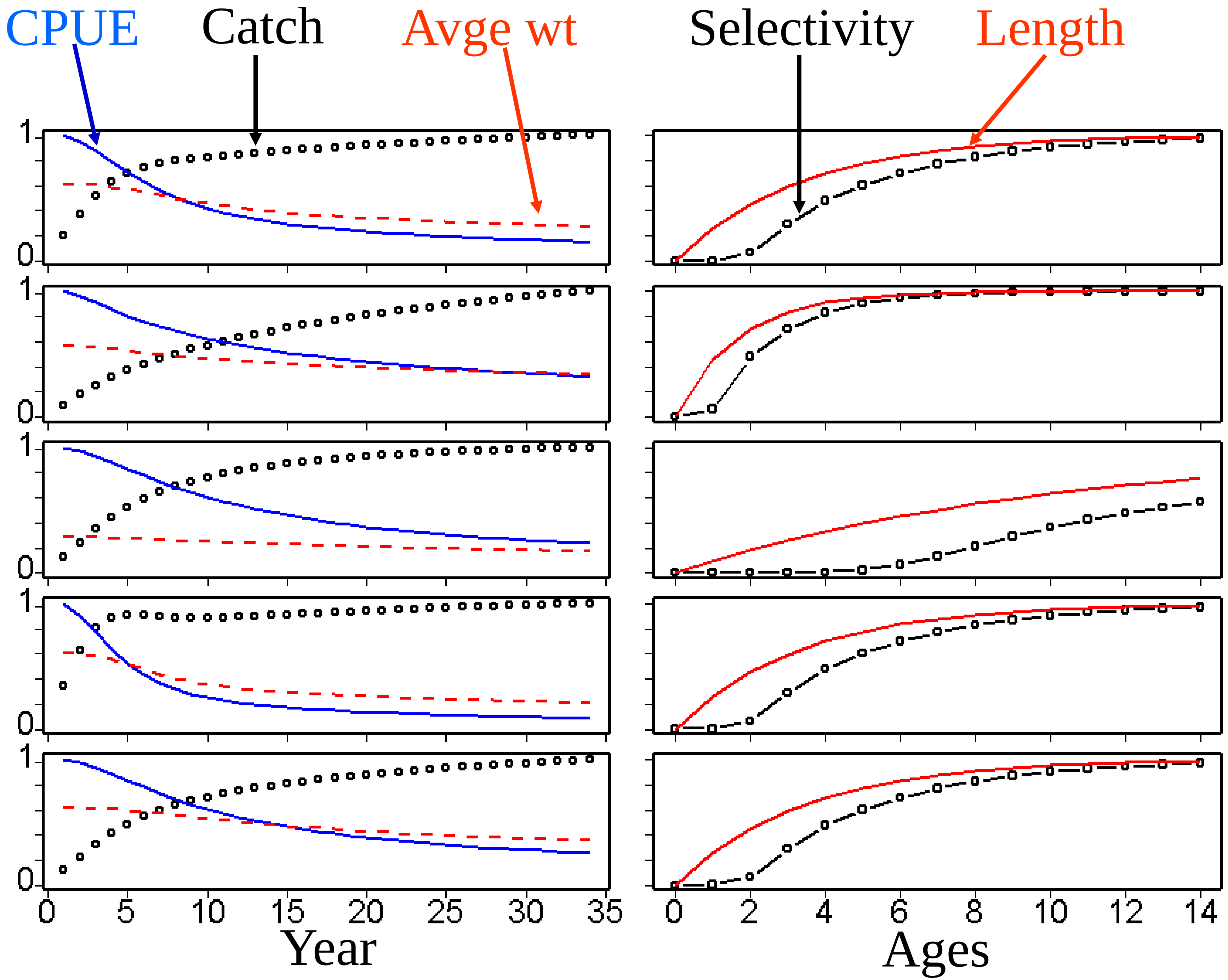


100
10
1
0.1
0.01
Change in biomass
Stingrays
Pomfrets
Snake mackerels
Mako sharks
Black marlin
0
50
100
150
1950s mean mass (kg)

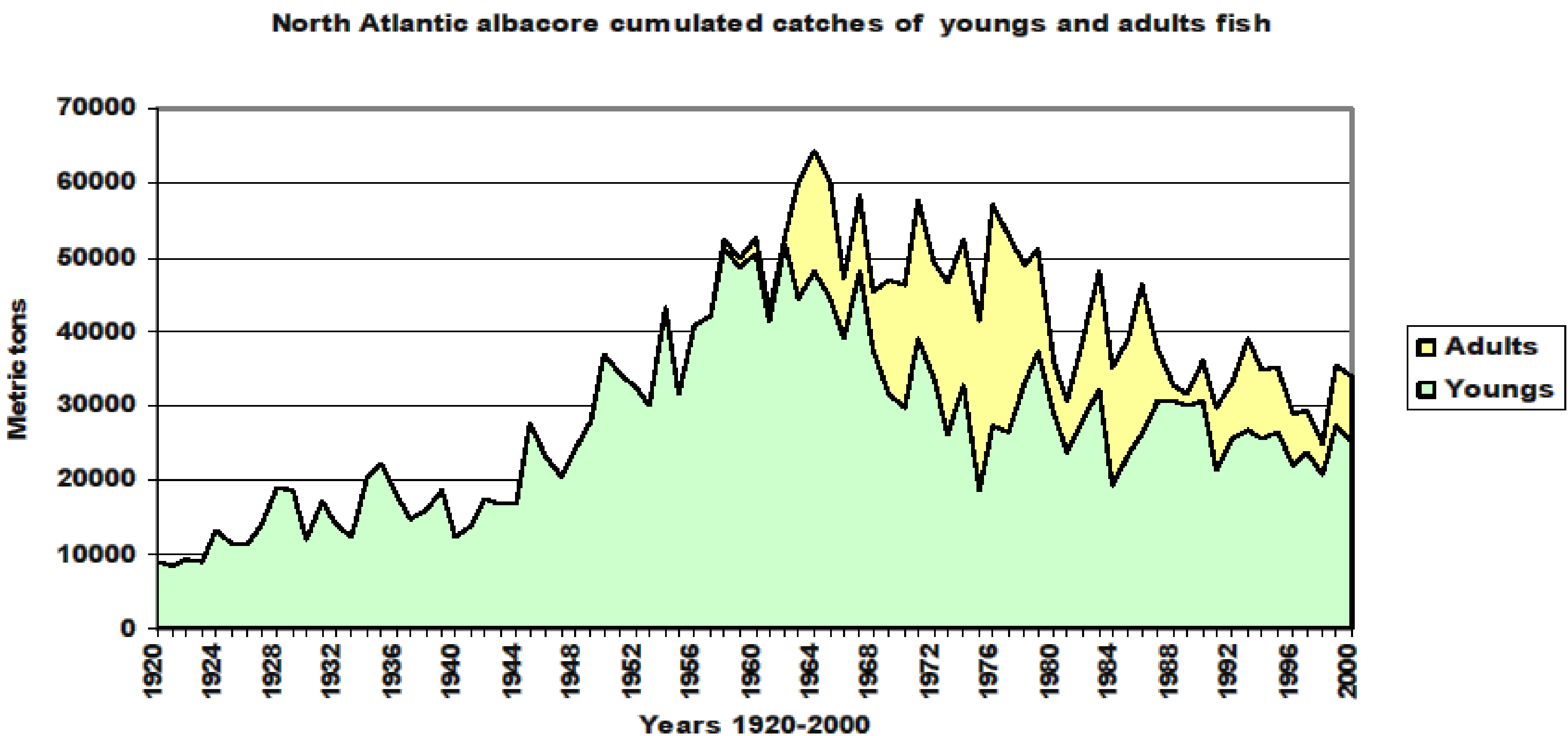

555
lbs.
Cabo Blan
LBS.
1135
CABO
BLANCO

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**

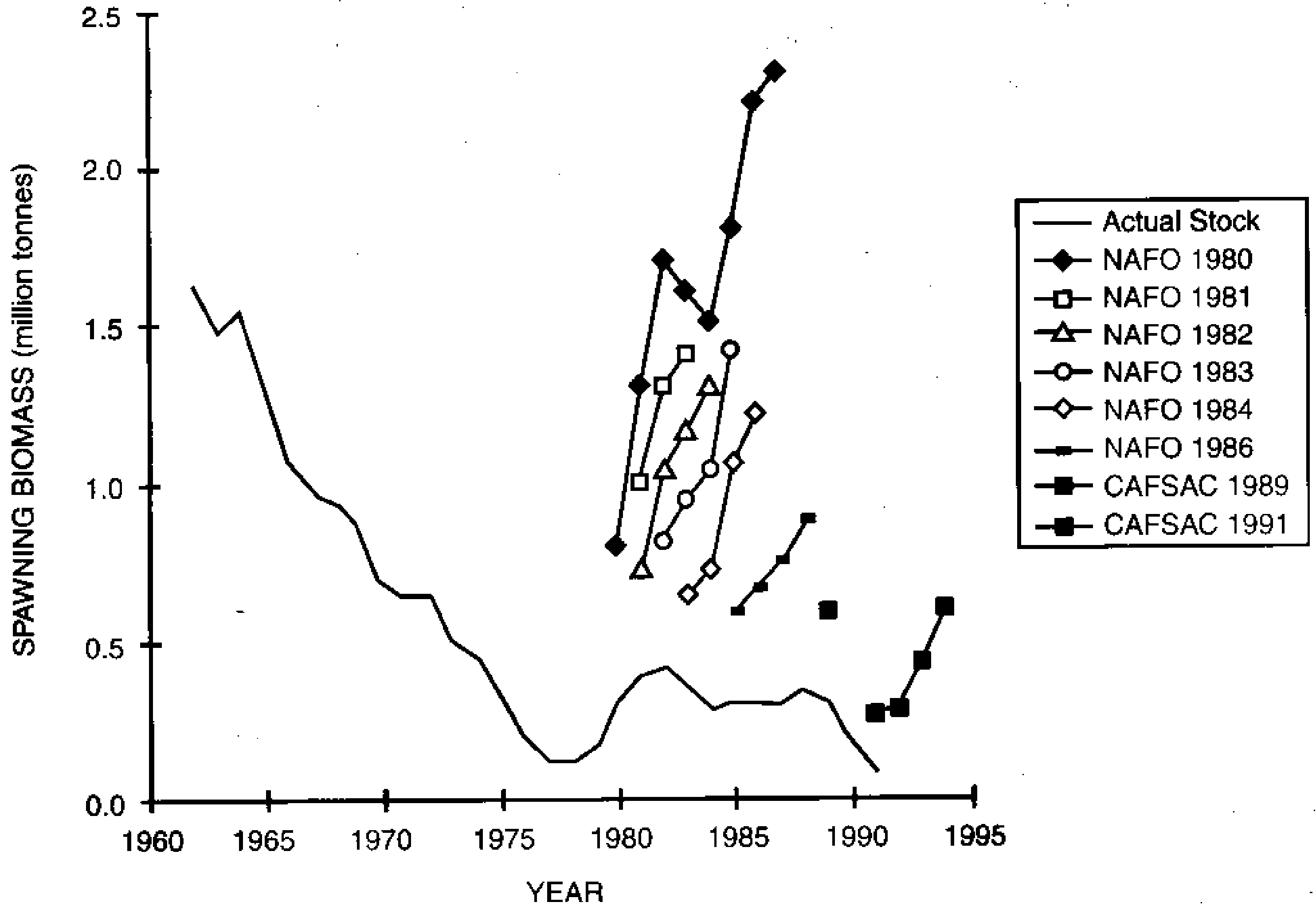


Fig. 3. **Recent reconstruction, using virtual population analysis, of the Newfoundland northern cod** decline, compared with estimates and projections published in various years after Canada took over the fishery under extended jurisdiction. VPA estimates based on data in Baird *et al.* (1992) (see 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.

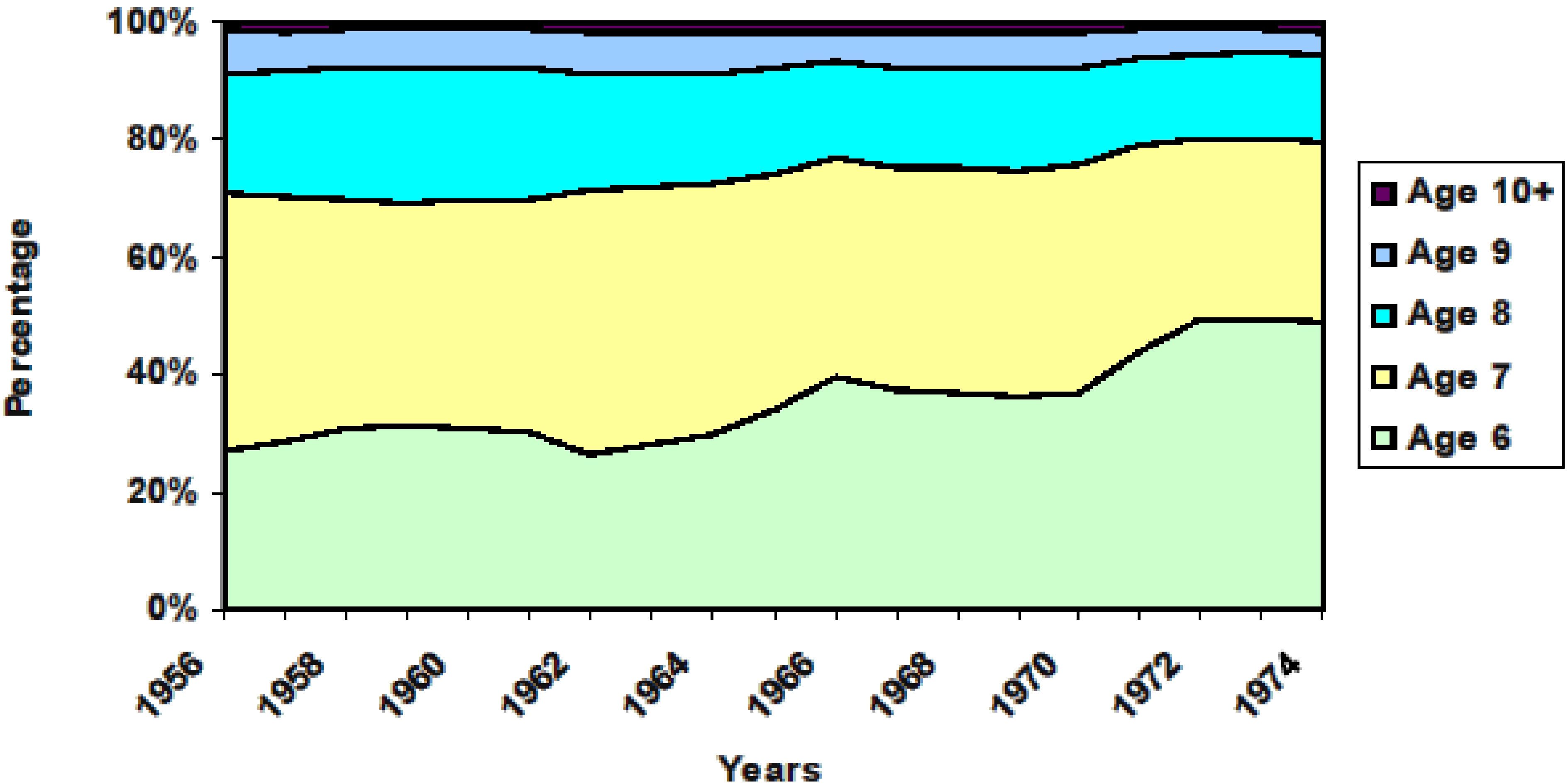
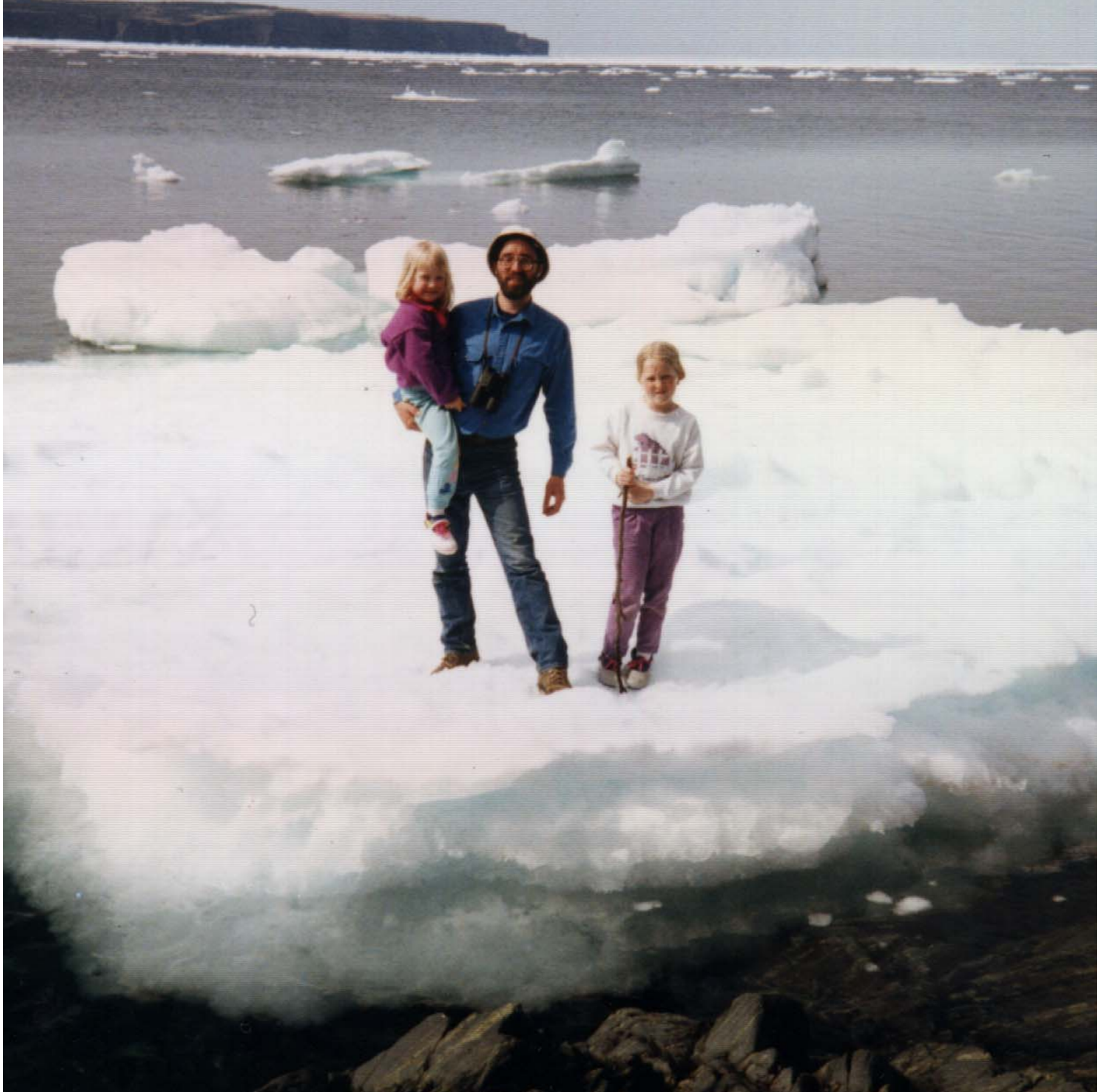


Figure 7 : Evolution of contribution of age classes 6 to 10+ computed by Morita (1977) in longliners albacore catches, 1956-1974.



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 ↑

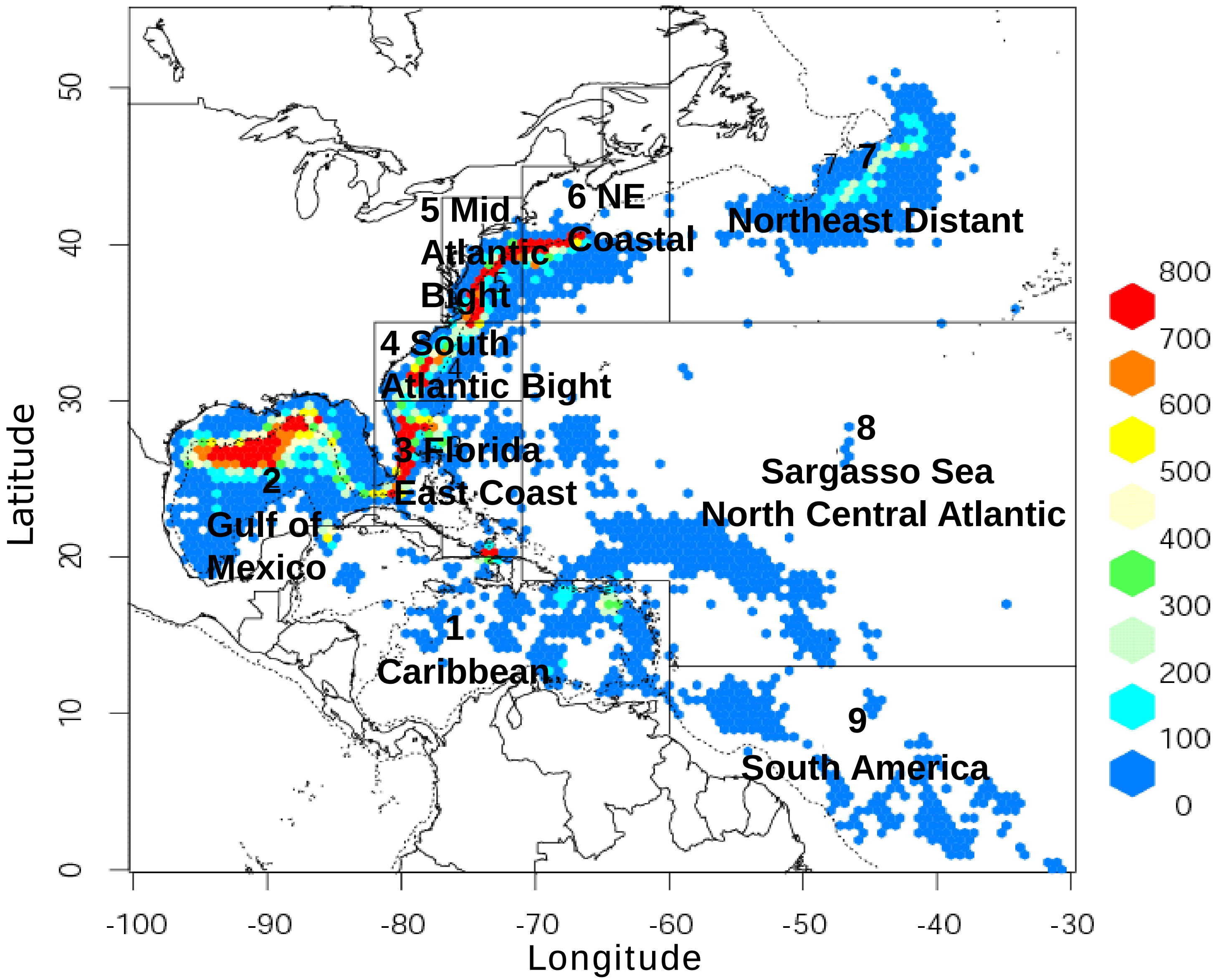
↓

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.

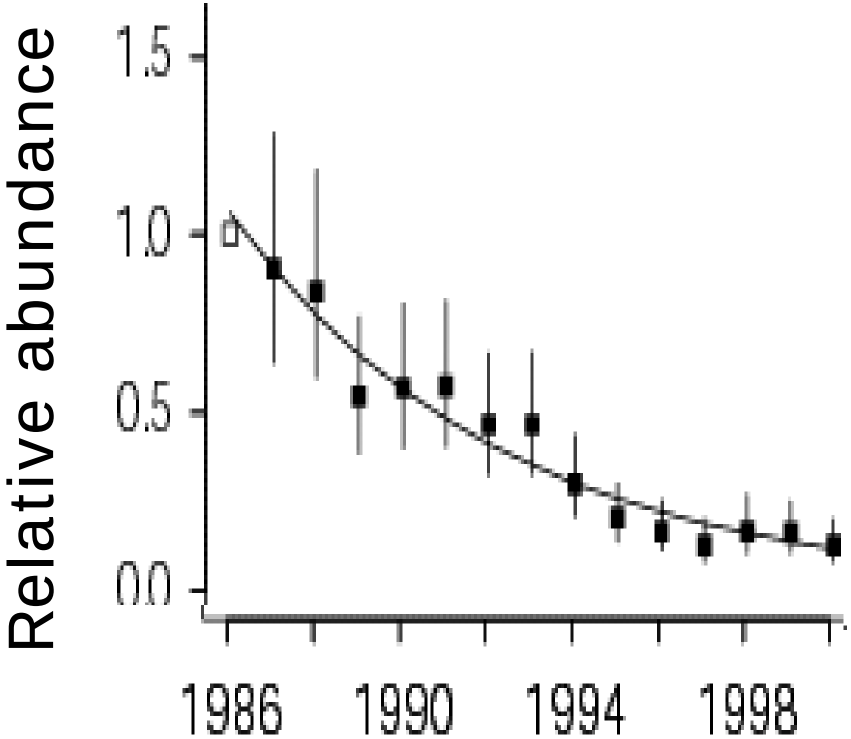
However, it also has great benefits.

To act is to live.

To be suppressed is to die.

Hammerhead sharks

Sphyrna lewini



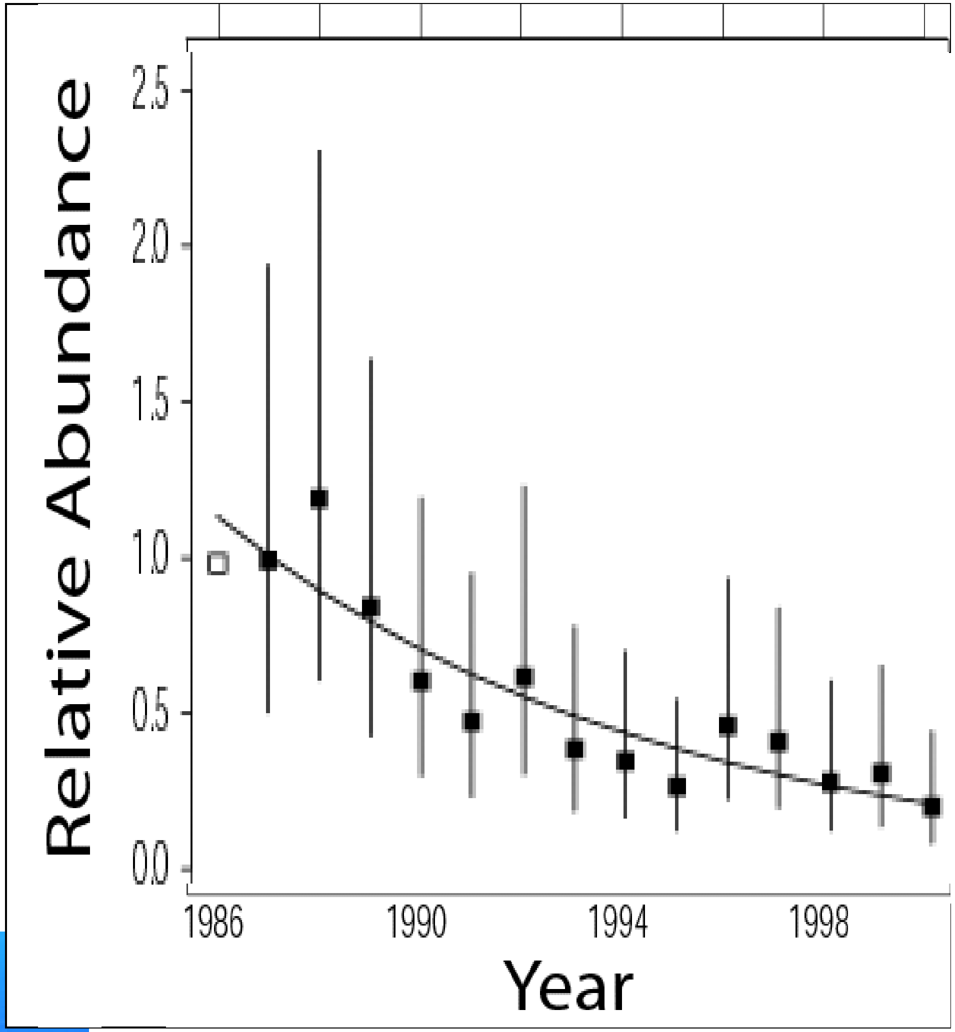
Science. Jan. 2003. J.K. Baum, R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, P.A. Doherty

The rest of the slides are back up.


90% OF EVERY
BIG FISH
SPECIES
WIPED OUT
AKRON BEACON JOURNAL © 03

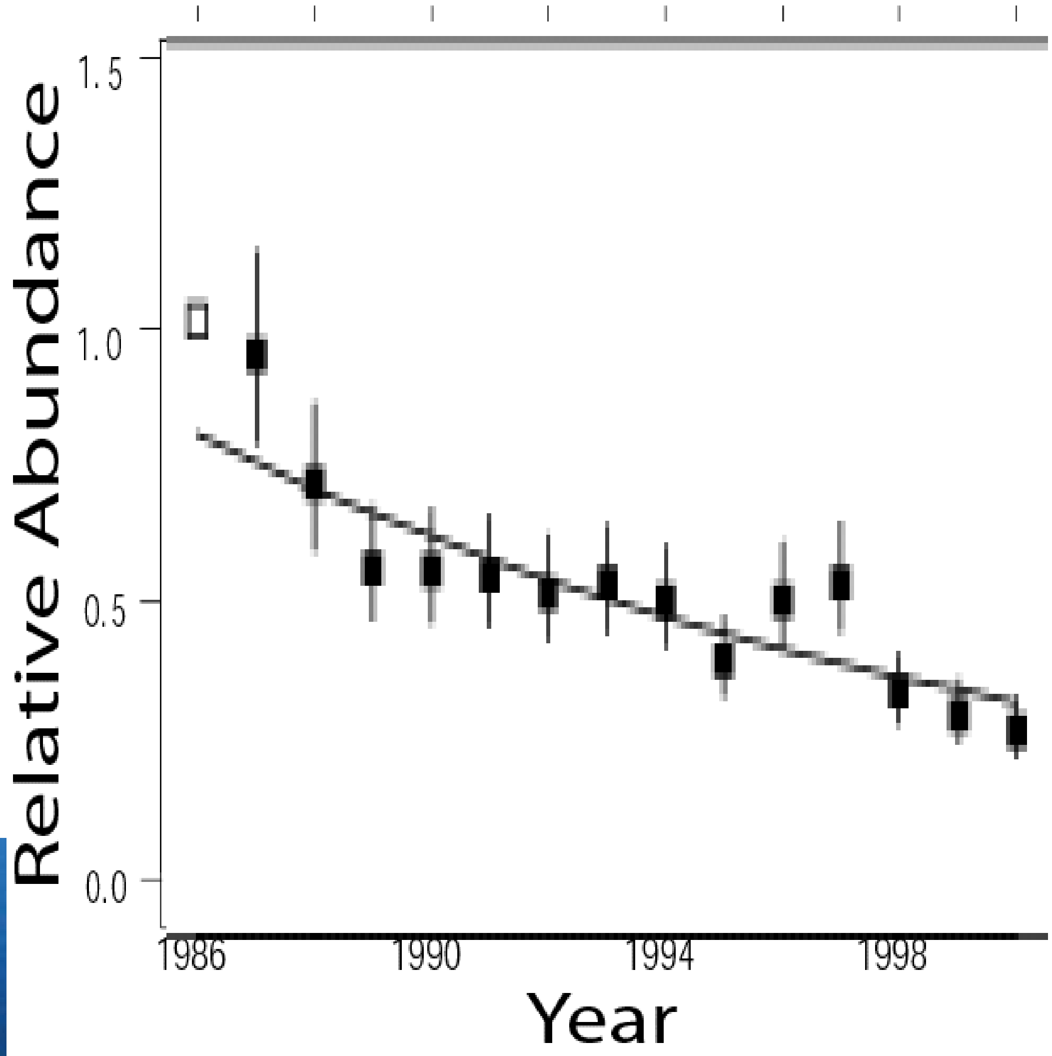
Thresher sharks

Alopias spp.

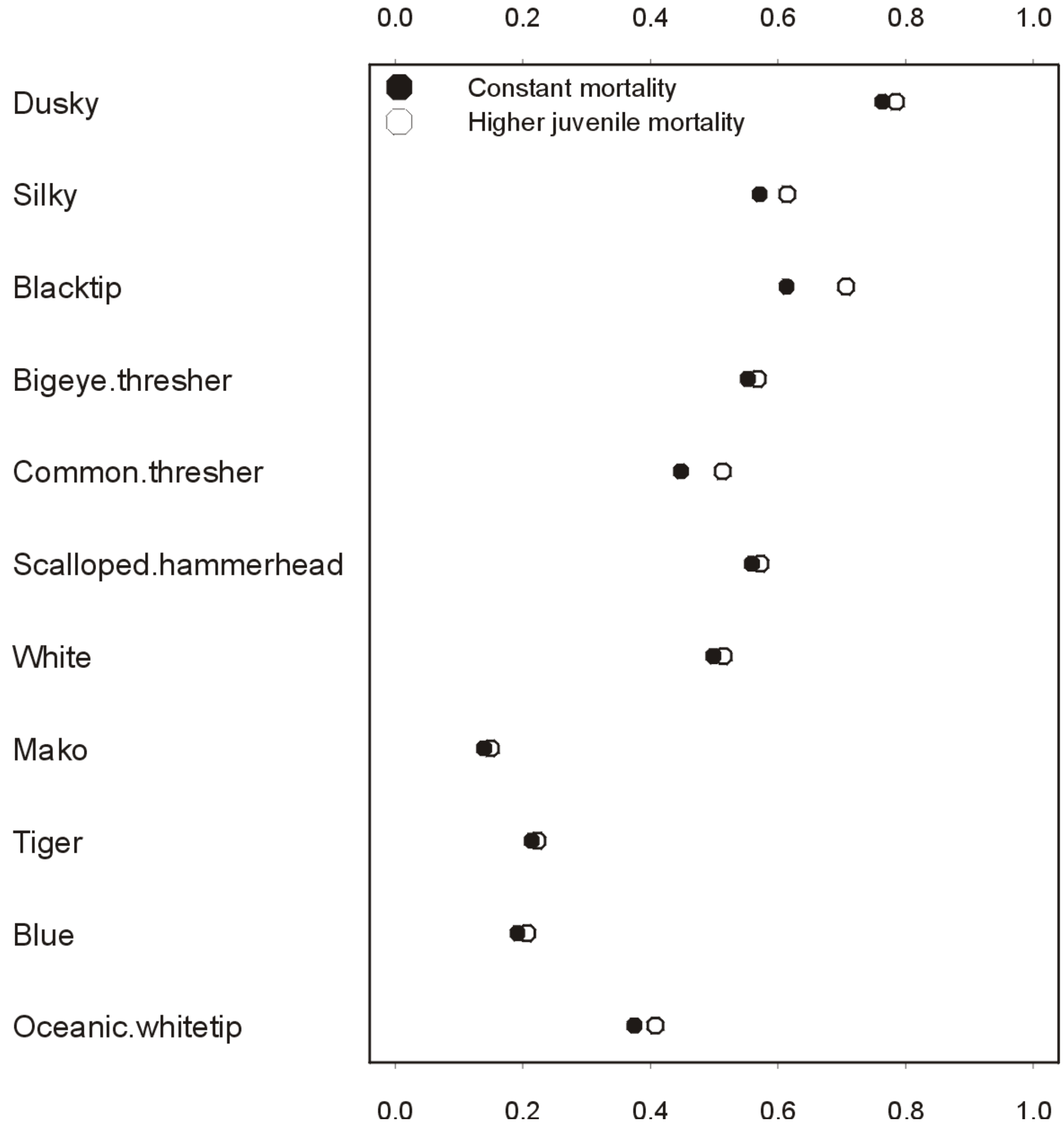


Blue sharks

Prionace glauca

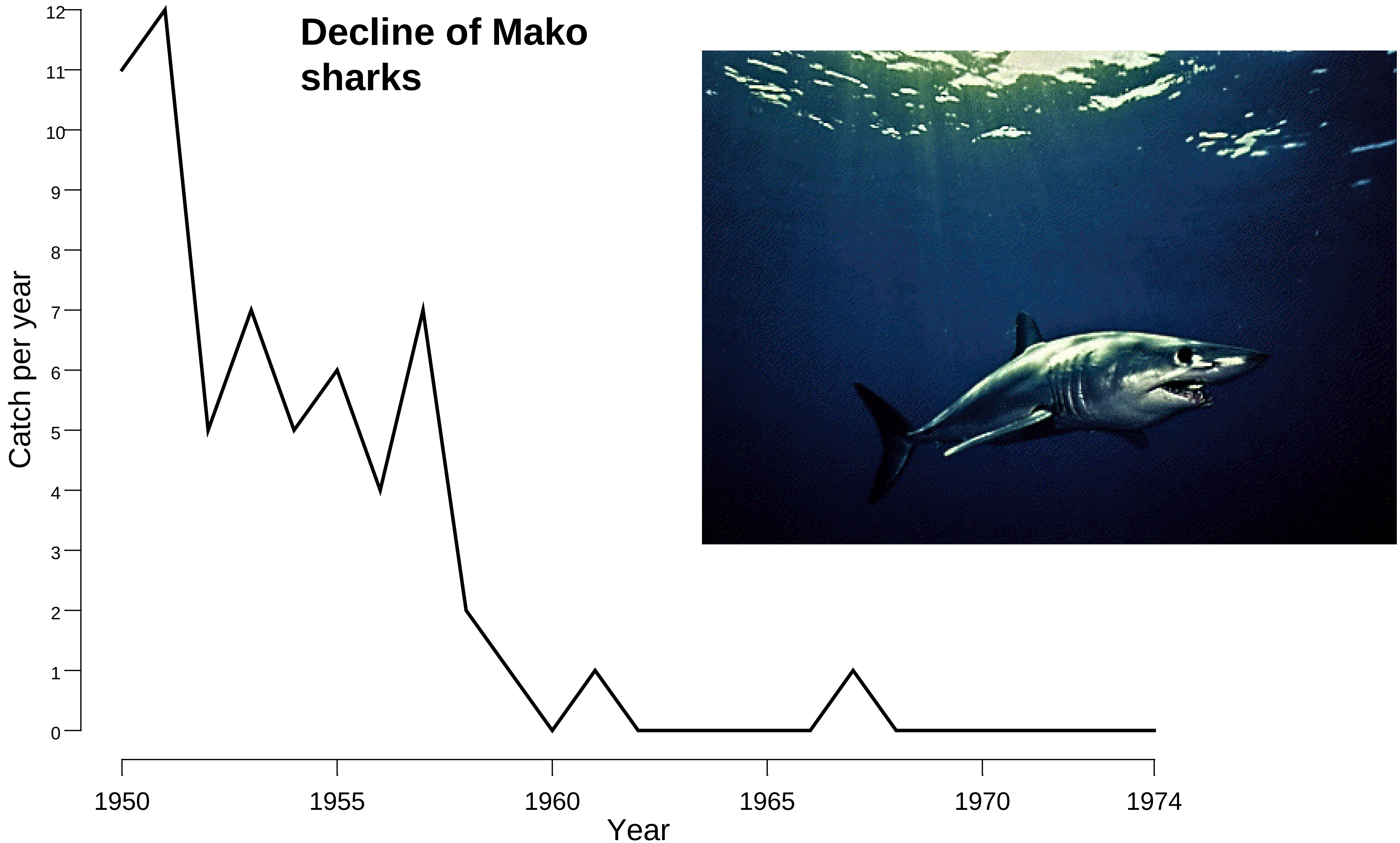


Proportional reduction in current fishing mortality needed to ensure survival of shark populations



Letter from senate

Put in cod



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

These estimates are conservative: 1.

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~25-30% of tropical tunas were initially not counted because of shark damage.

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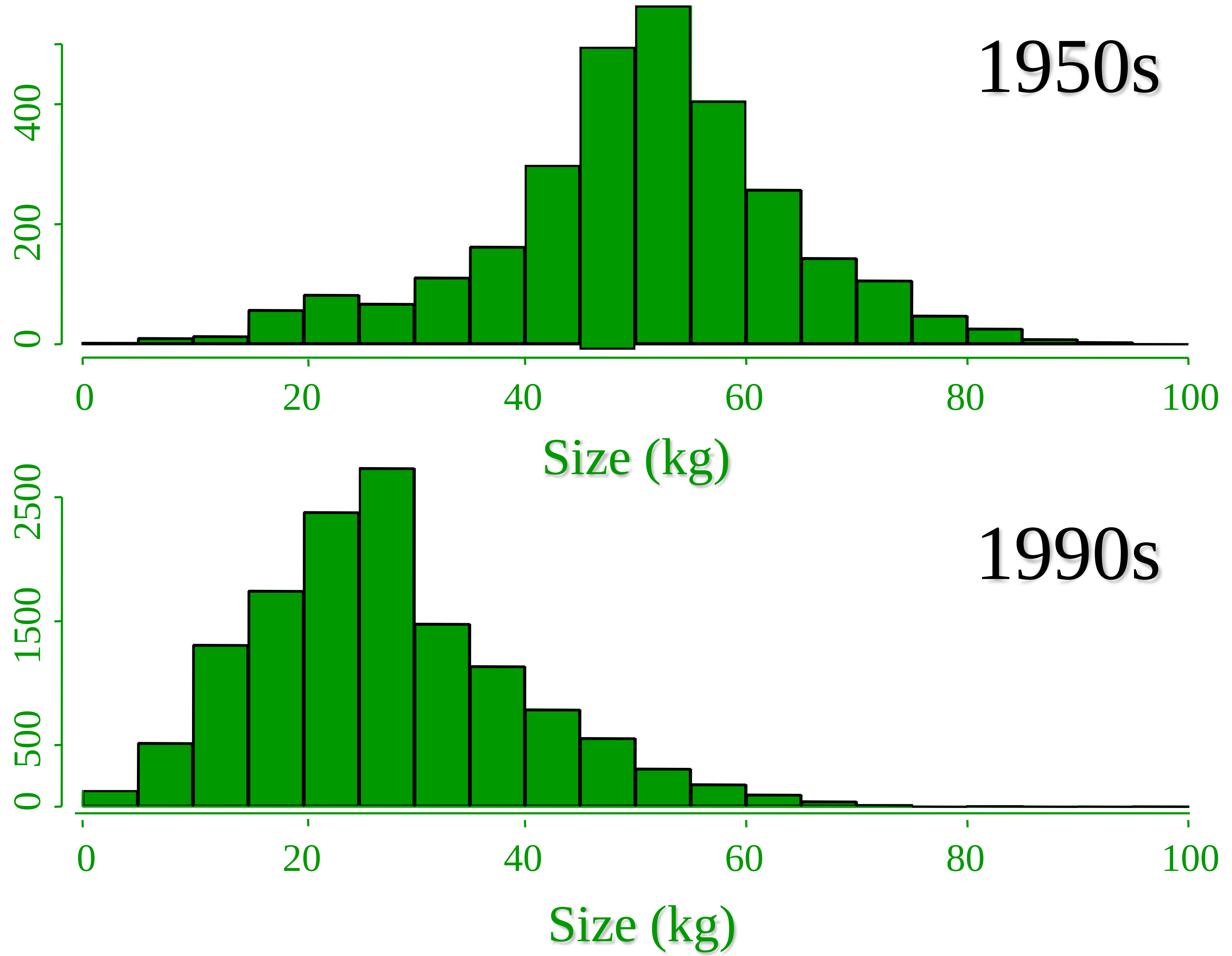
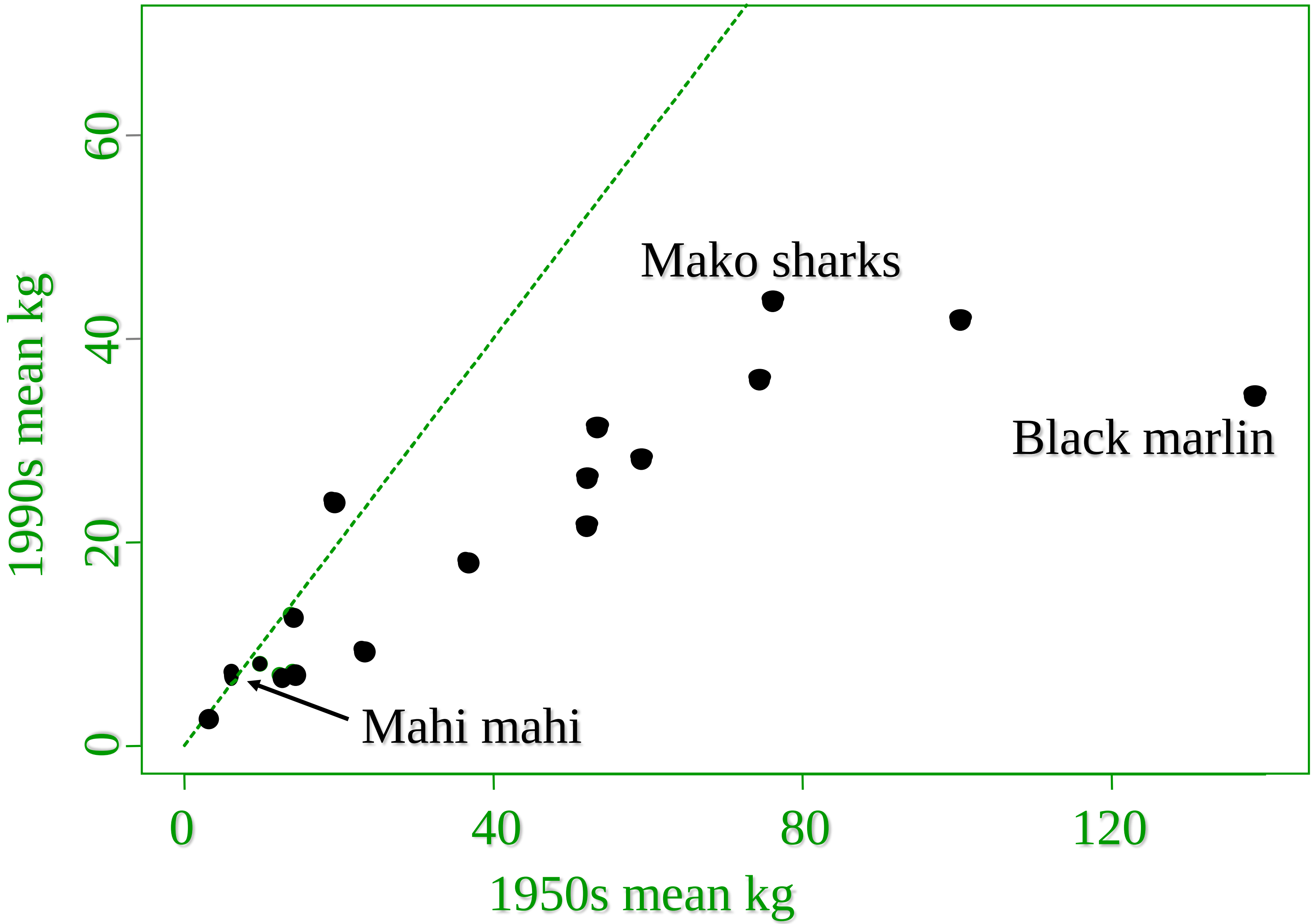


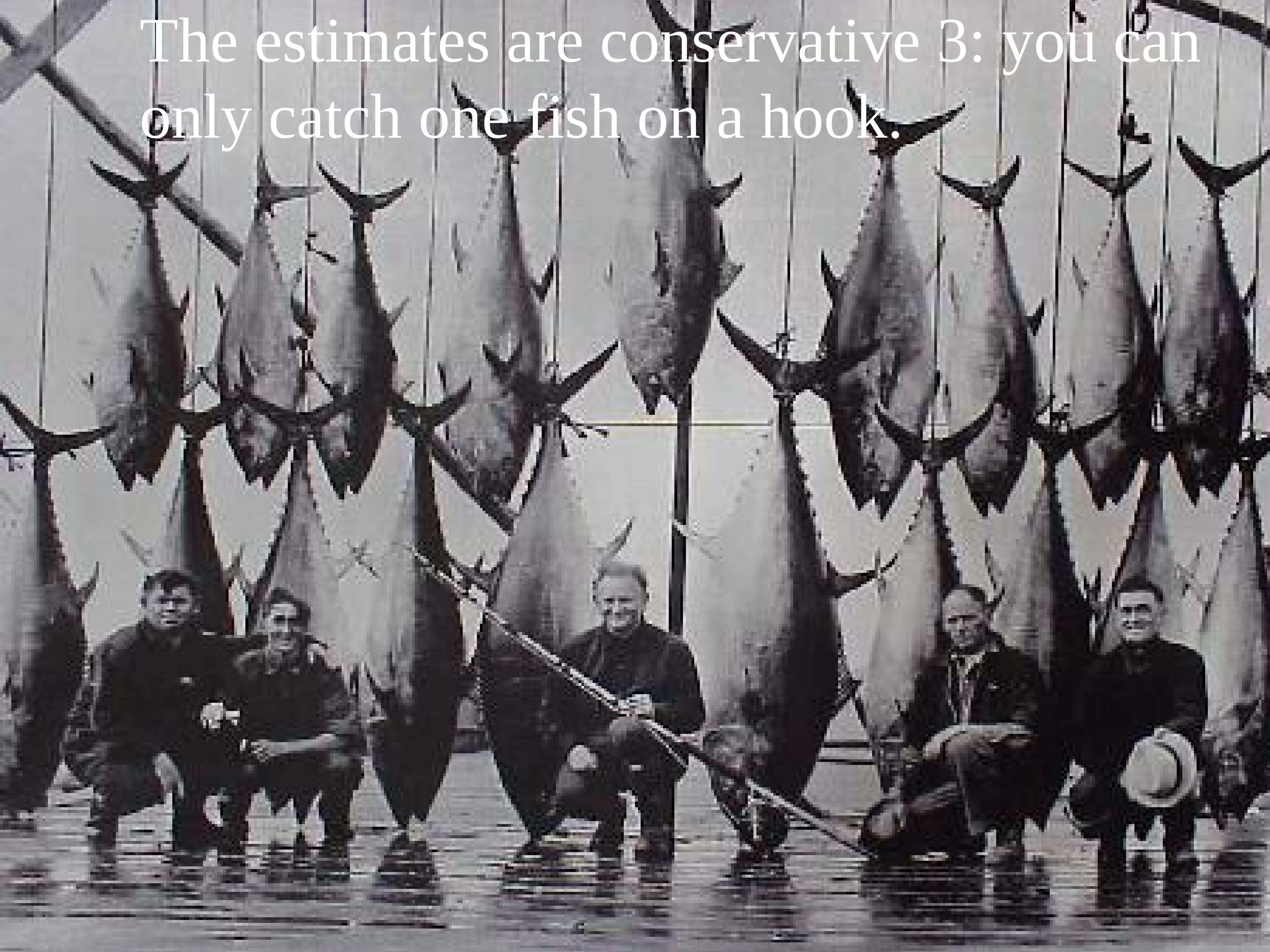
Yellowfin tuna – equitorial Pacific

Change in body size




555
lbs.
Cabo
LBS.
1135
CABO
BLANCO

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



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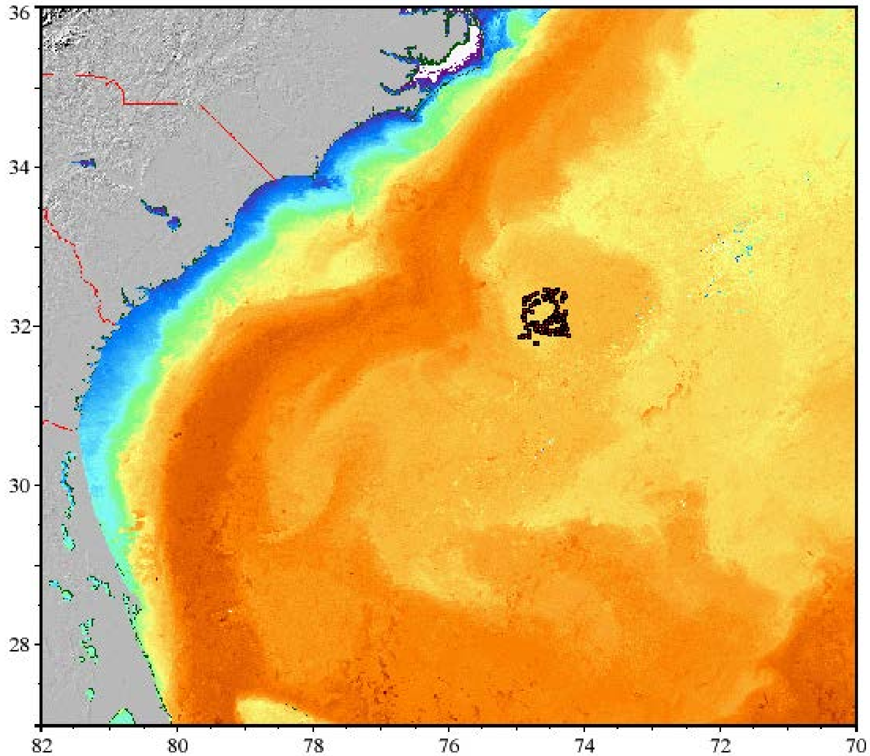
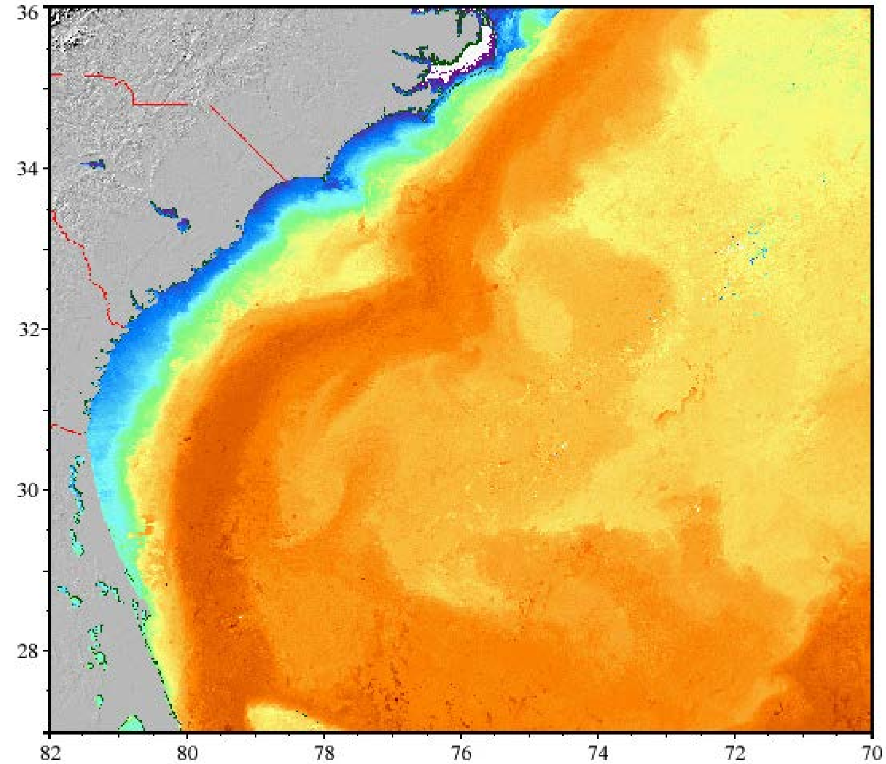
- In 1950 the US harvested ~170,000 tons.
- The 1950 harvest of albacore by Spain was greater than the total recent harvest in the North Atlantic.
- Species that migrate long distances (e.g. southern bluefin tuna, northern bluefin tuna, and albacore) would have reduced by these harvests.

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





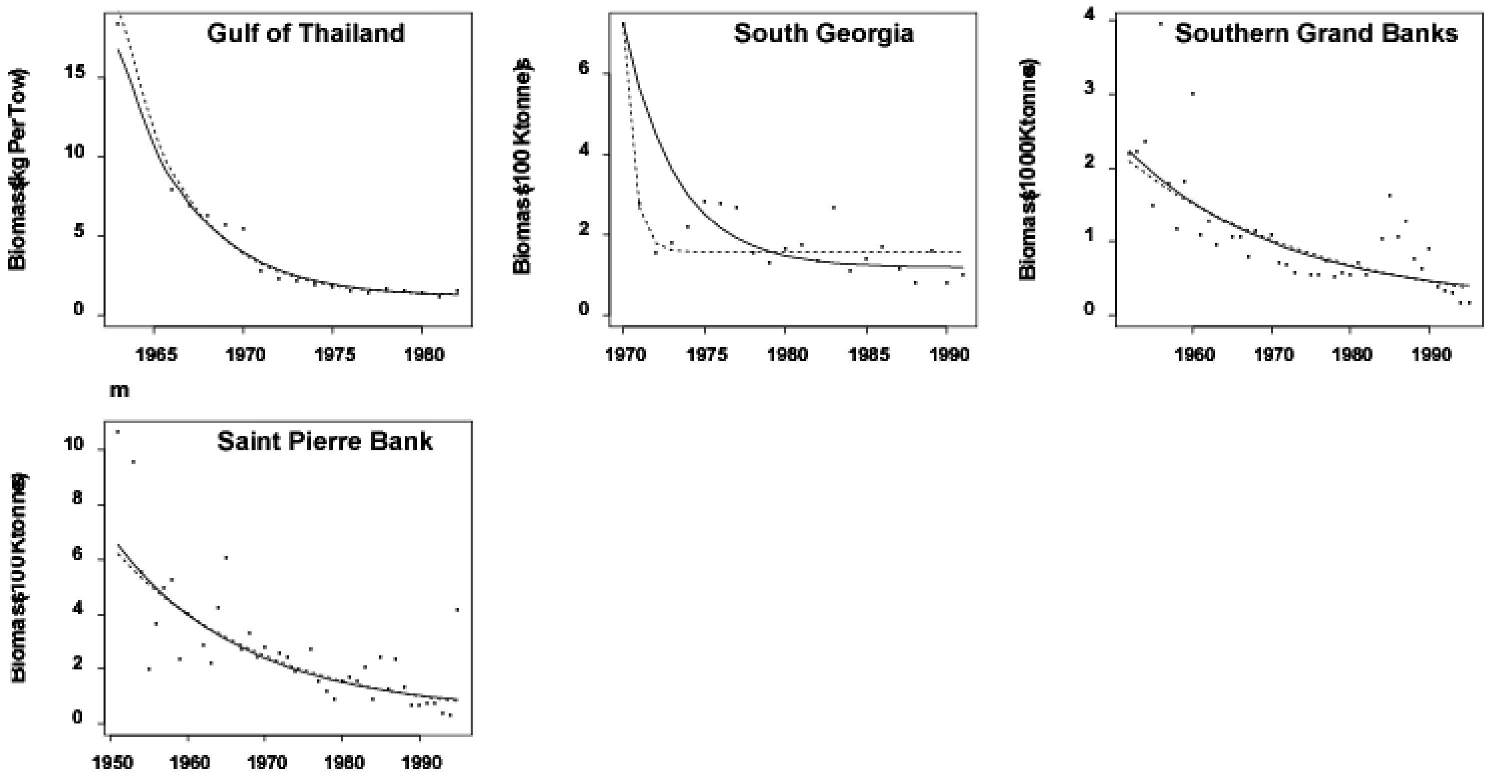
Locations of a leatherback turtle over a two week period tagged by my student Mike James that maintains its position within a cold core ring (somehow).

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.

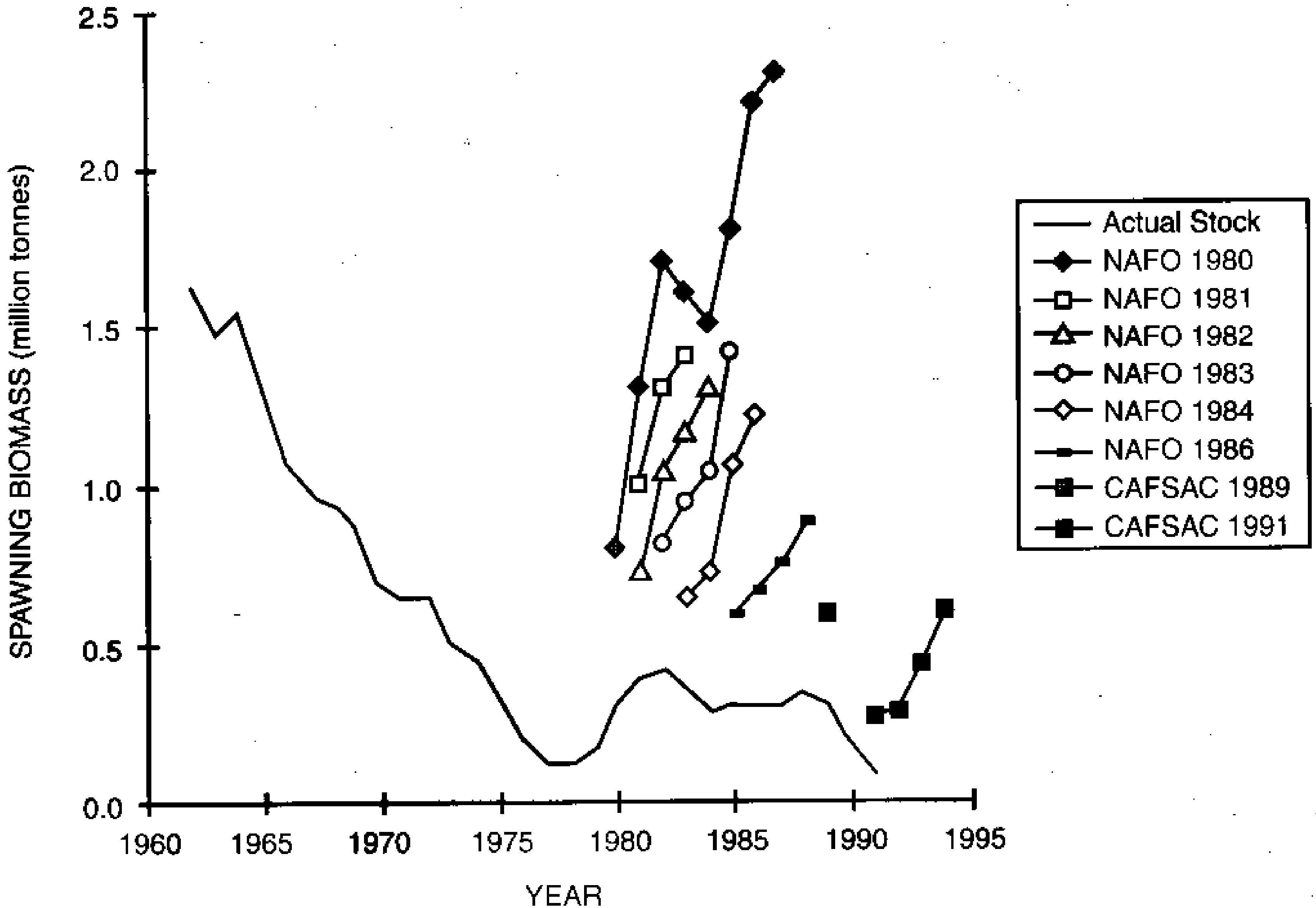
Why is it so important.
What makes them work.

Shelf seas



Gulf of Thailand
Biomass(kg Per Tow)
15
10
5
0
1965
1970
1975
1980
South Georgia
Biomass(100 Ktonnes)
6
4
2
0
1970
1975
1980
1985
1990
Southern Grand Banks
Biomass(1000Ktonnes)
4
3
2
1
0
1960
1970
1980
1990
m
Saint Pierre Bank
Biomass(100Ktonnes)
10
8
6
4
2
0
1950
1960
1970
1980
1990

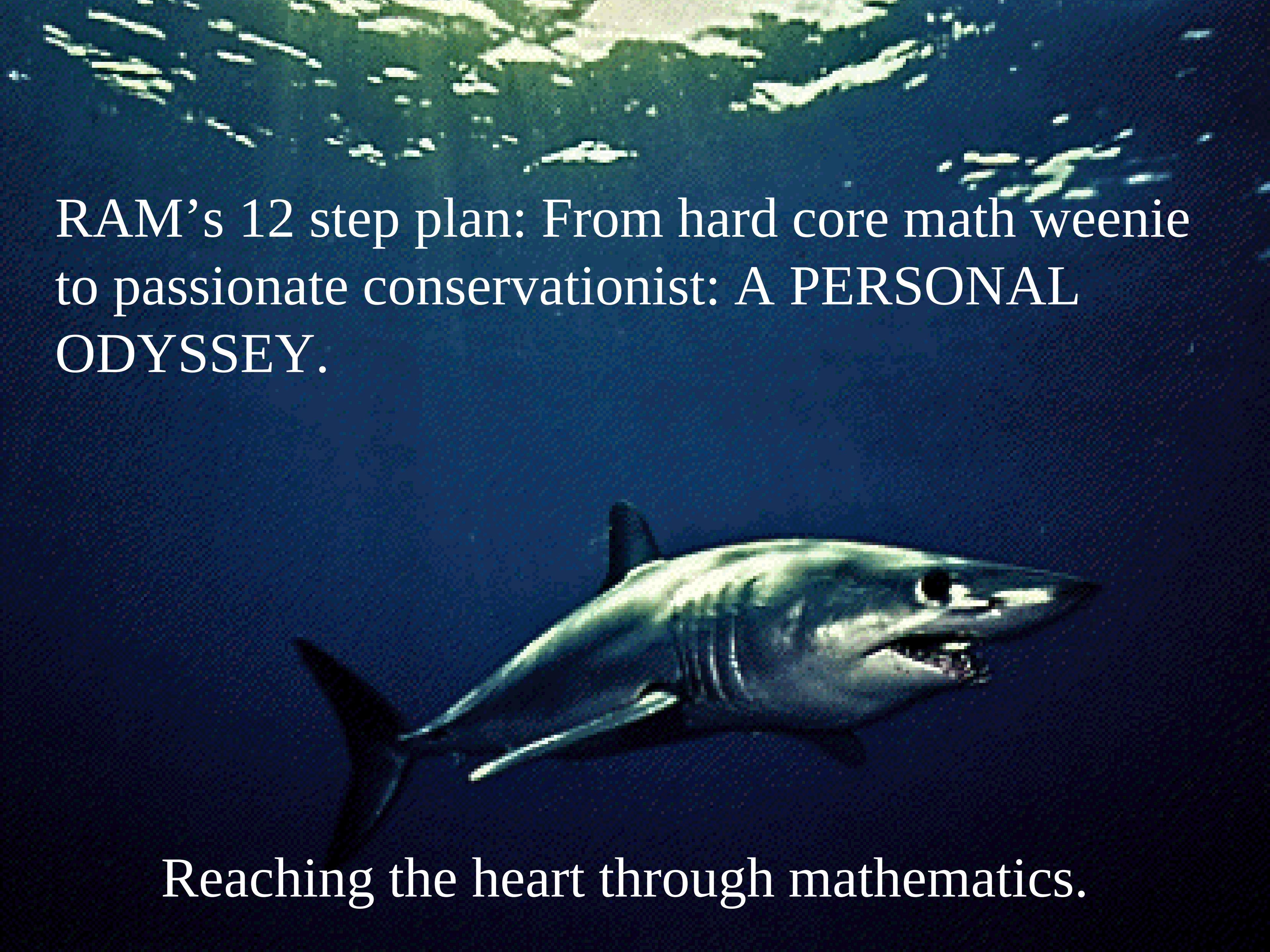
Government science was consistently wrong, and there was no effective voice from universities.



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.

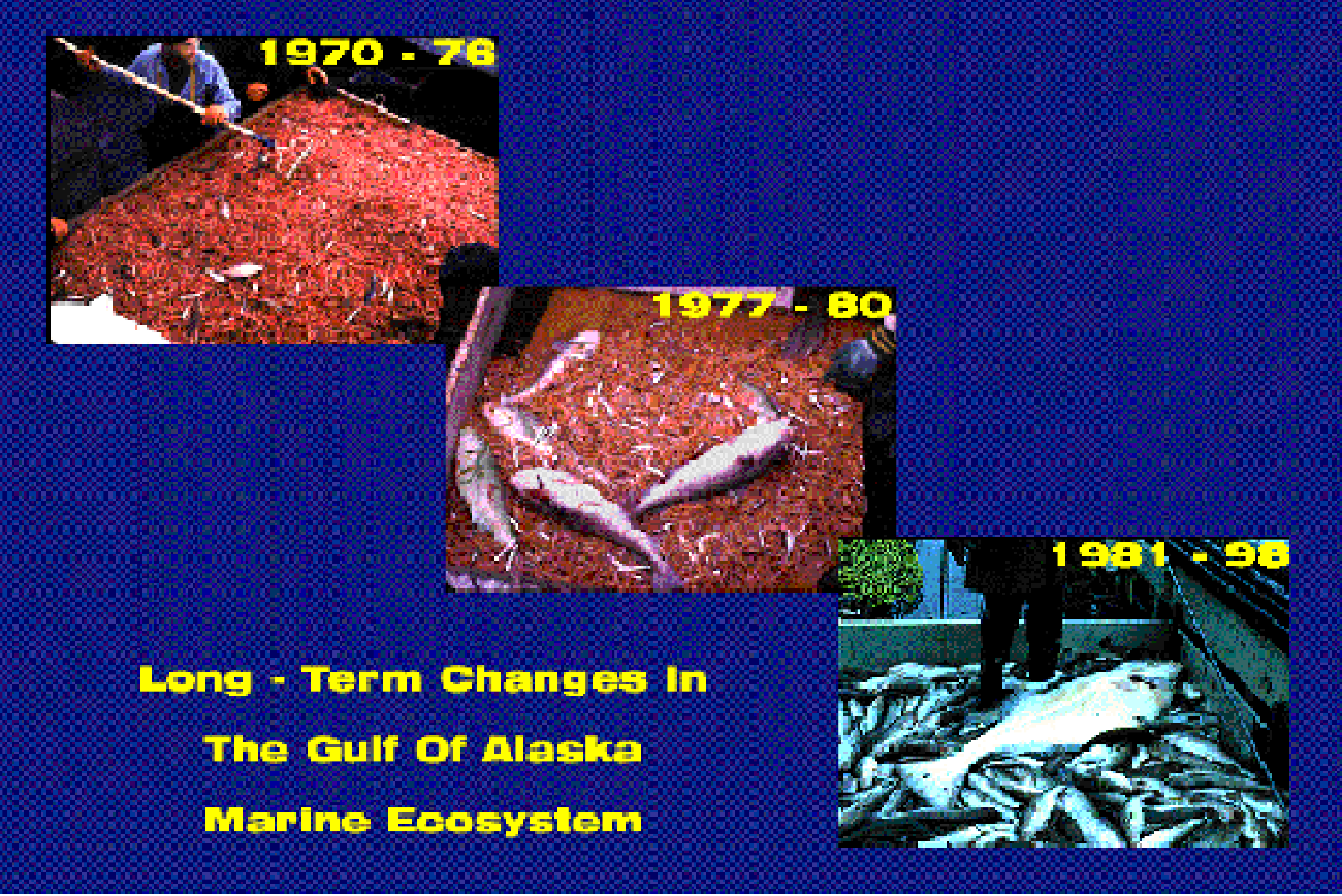
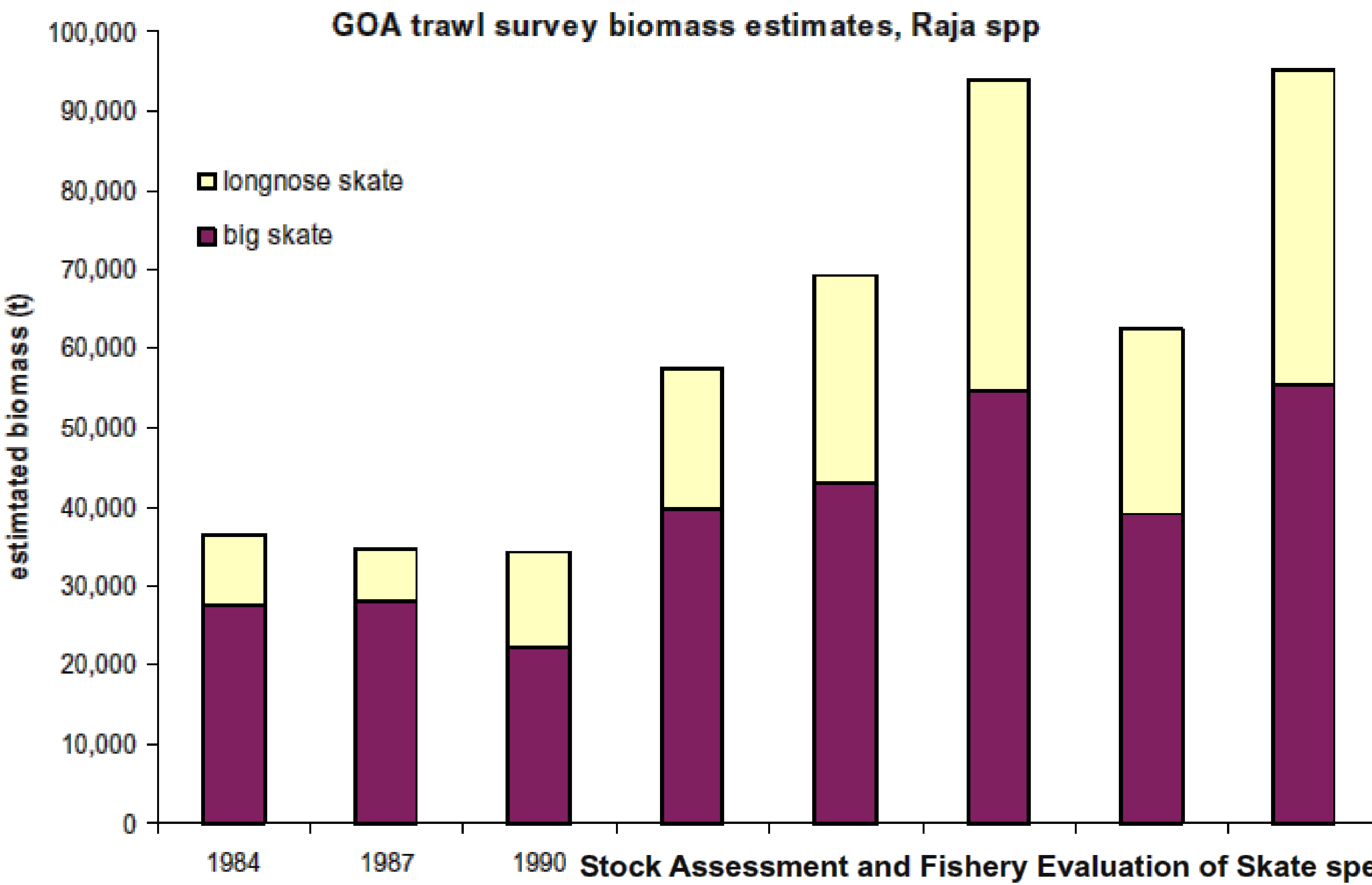


Figure stolen from Paul Anderson

- 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

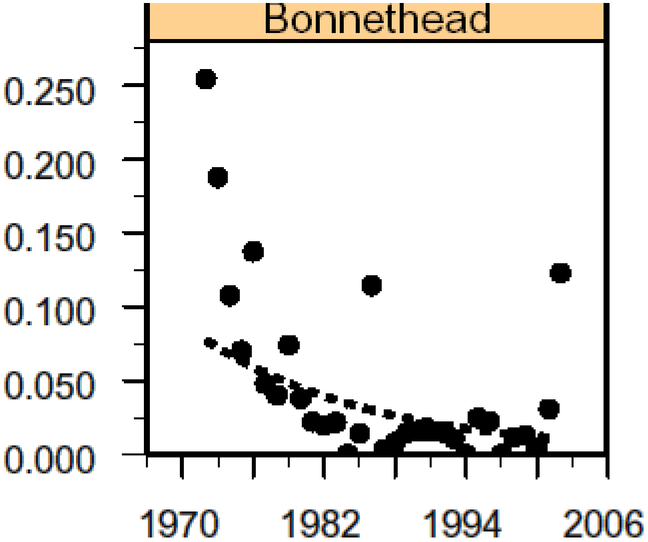
by
Sarah Gaichas[1], Michael Ruccio[2], Duane Stevenson[1], and Rob Swanson[3]

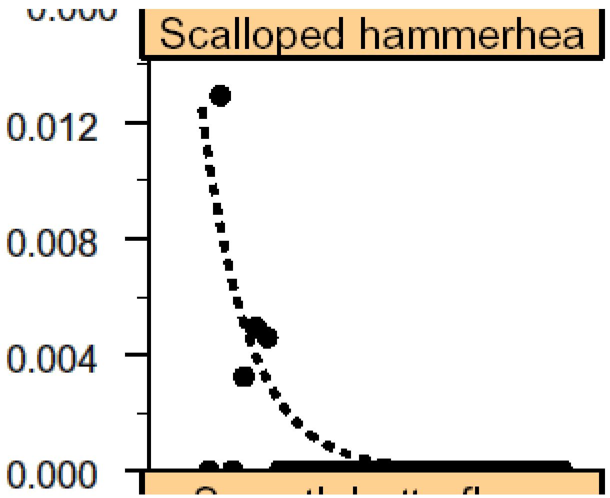
Figure 1. Big skate, *Raja binoculata*, with stock assessment author for scale.

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

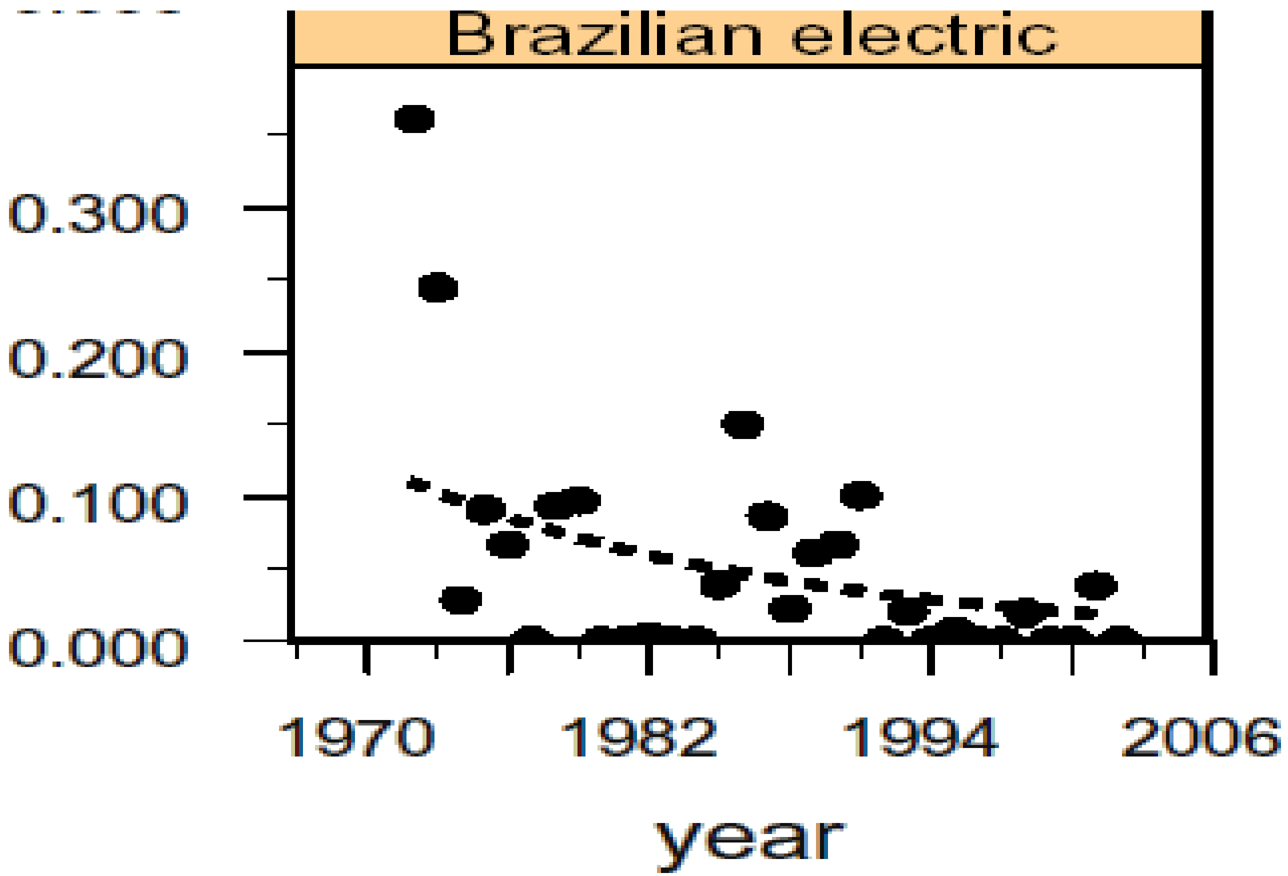
by
Sarah Gaichas[1], Michael Ruccio[2], Duane Stevenson[1], and Rob Swanson[3]

All large sharks declined

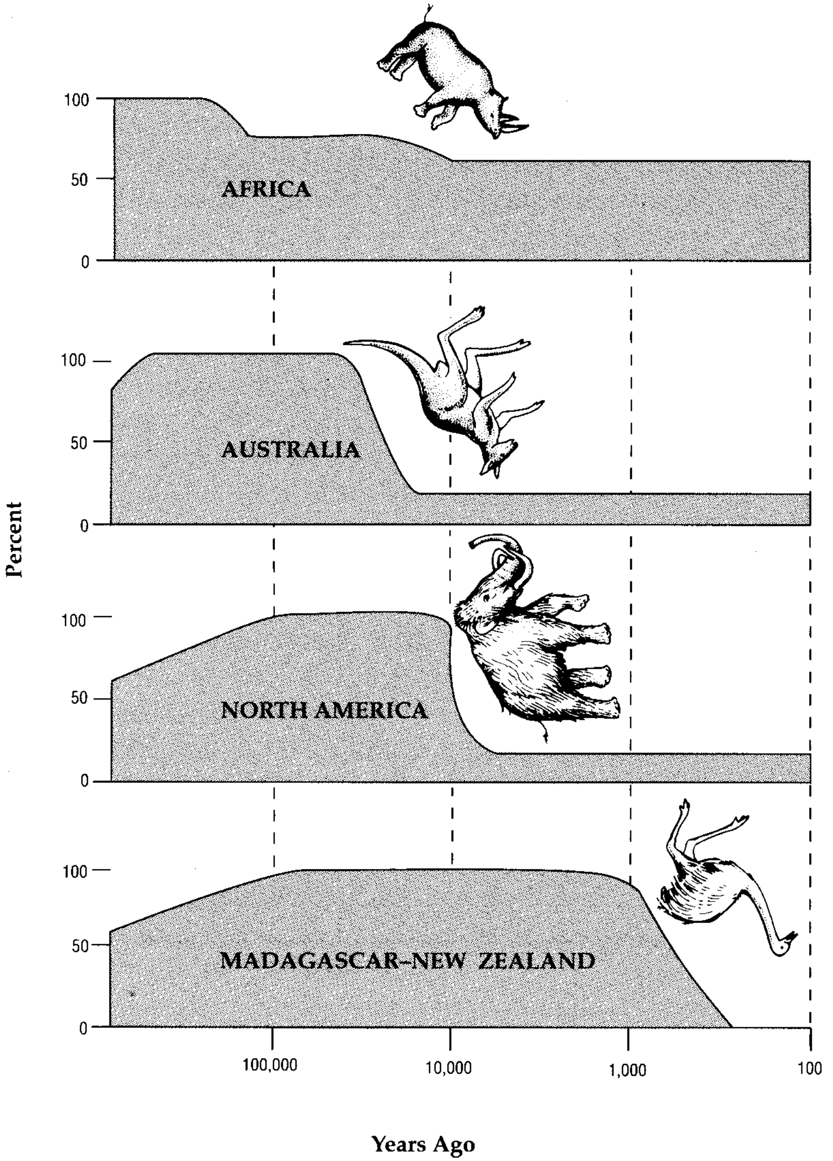




Shallow water species that do not survive discarding: large declines:



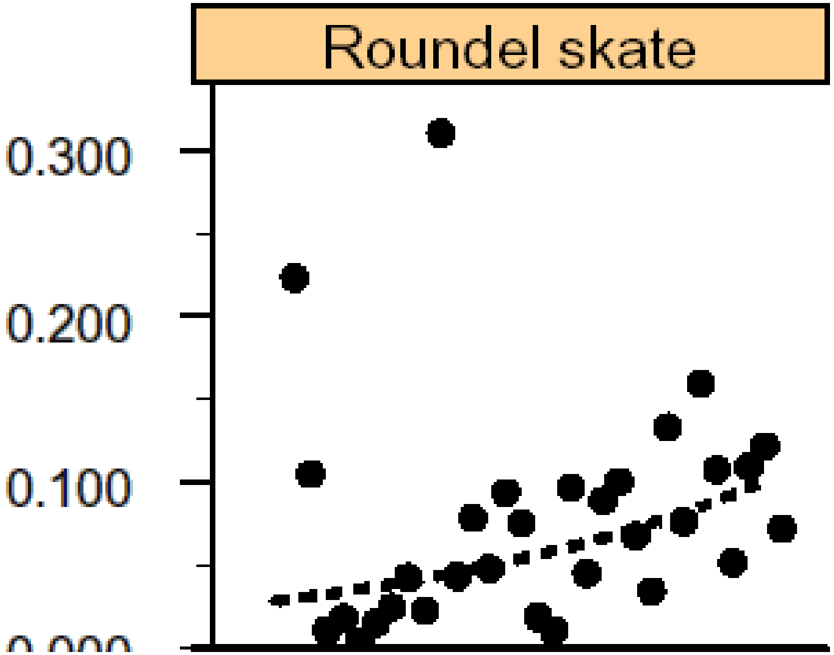
Are the pleistocene extinctions* going to be repeated in the ocean?

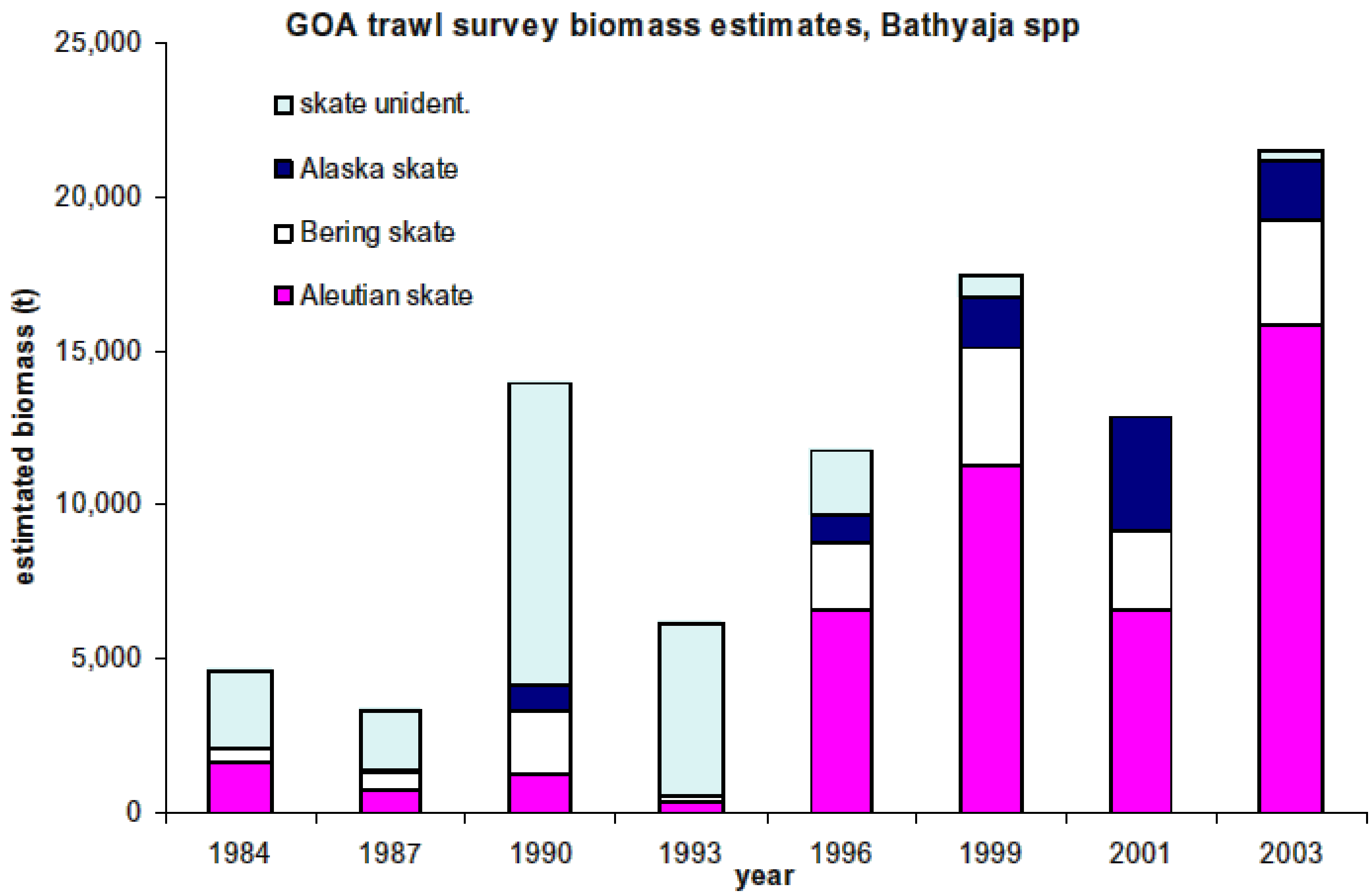


The extinction of large mammals and flightless birds coincided closely with the arrival of humans in North America, Madagascar, and New Zealand, and less decisively earlier in Australia. In Africa, where humans and animals evolved together for millions of years, the damage was less severe.

*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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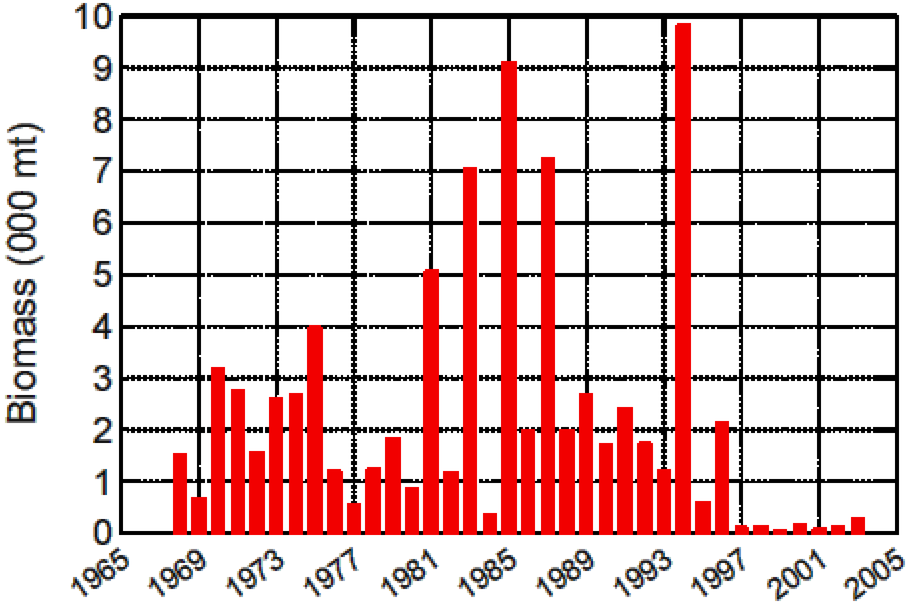
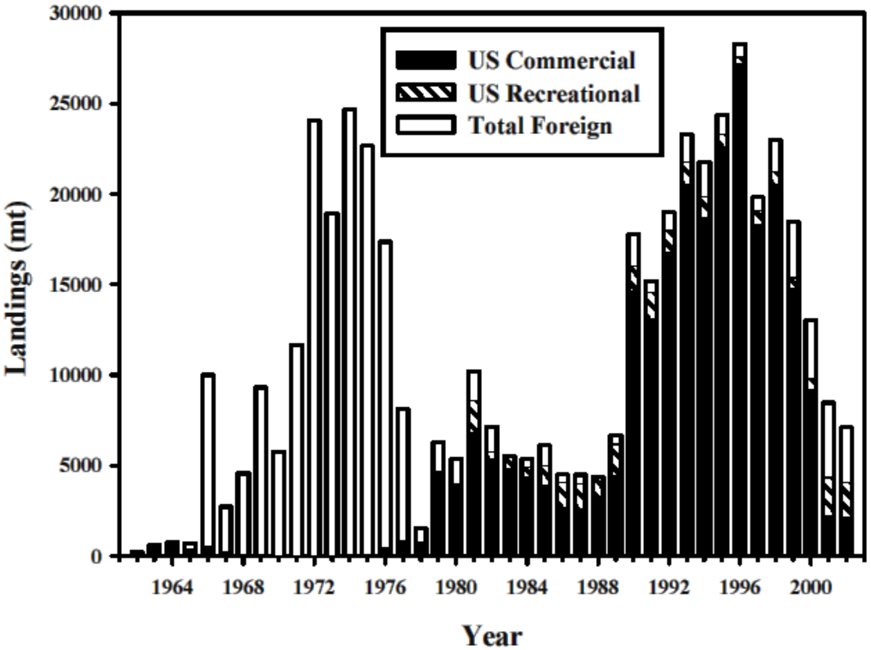
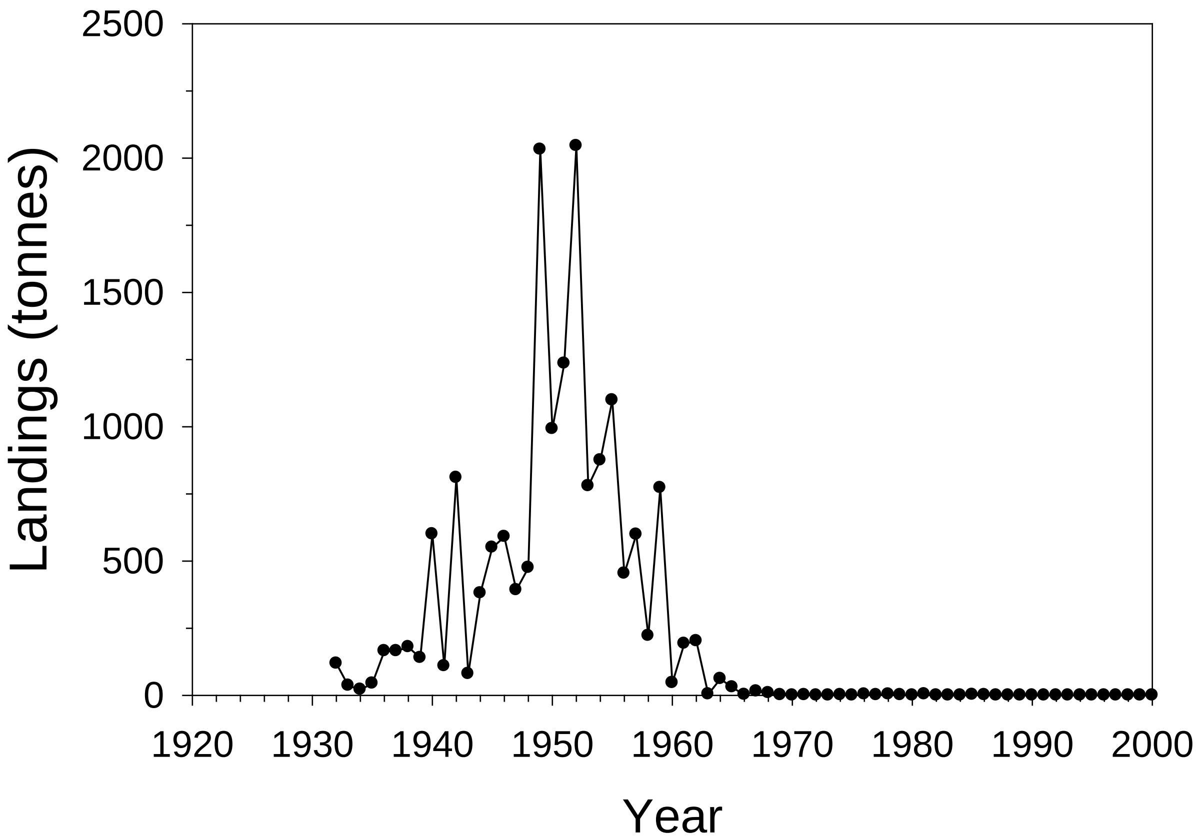
Spiny Dogfish, Northwest Atlantic: Good Science – Ugly Decisions





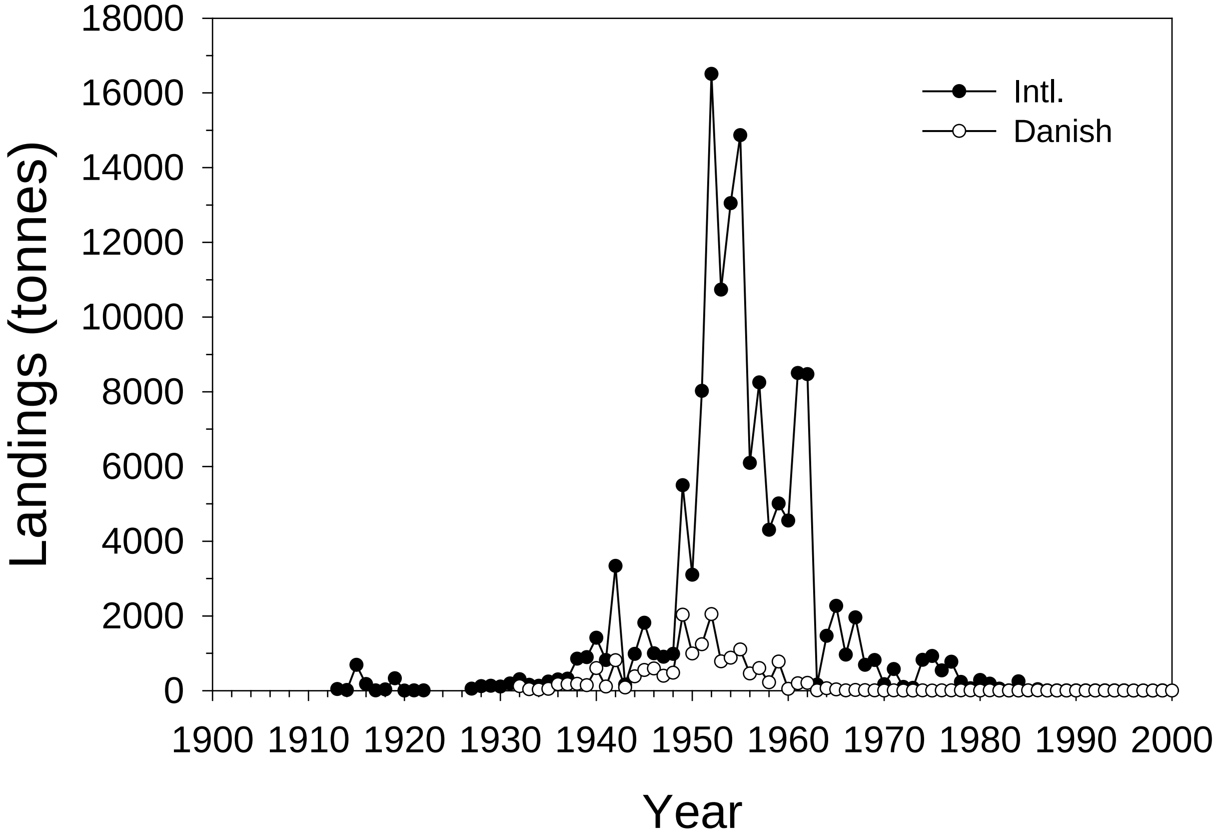
Danish Landings of Bluefin Tuna *Thunnus thynnus*



DIFRES

Data source: DIFRES, ICES, FAO

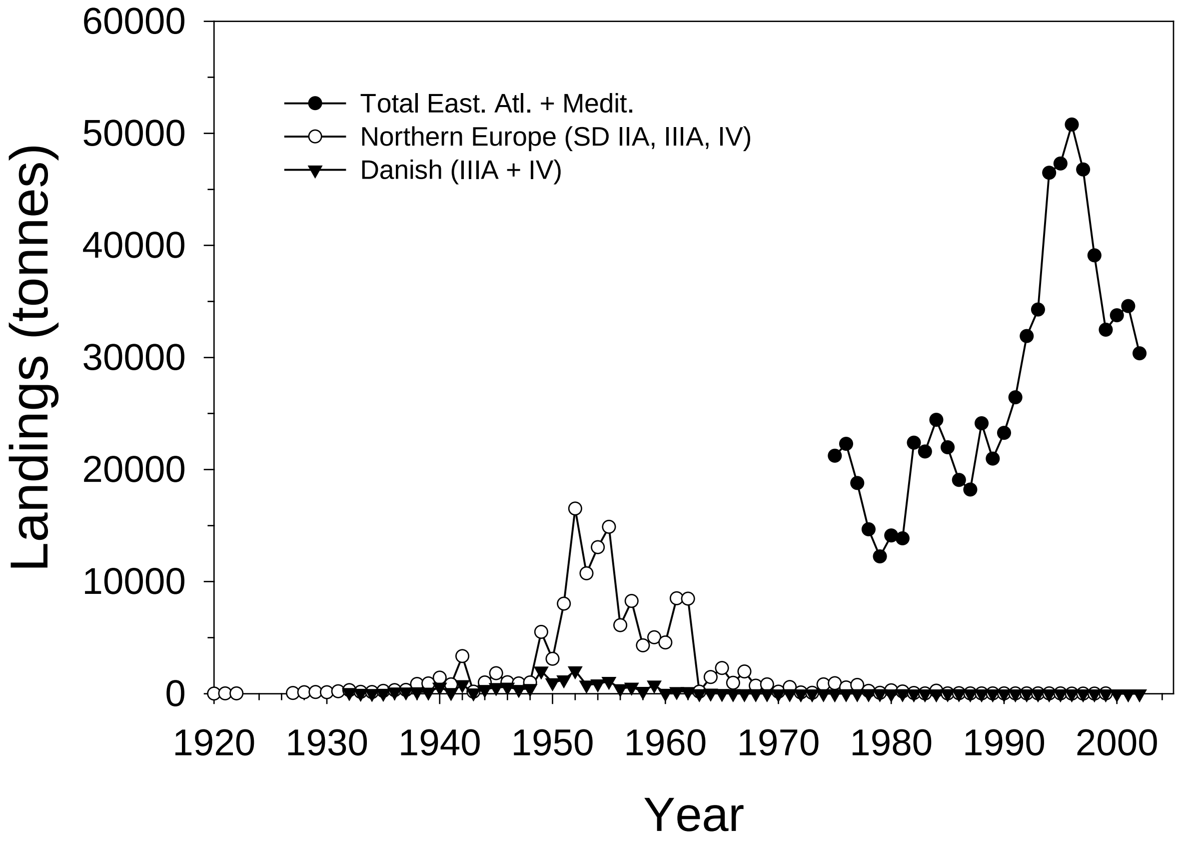
Landings of Bluefin Tuna *Thunnus thynnus* in Northern Europe*



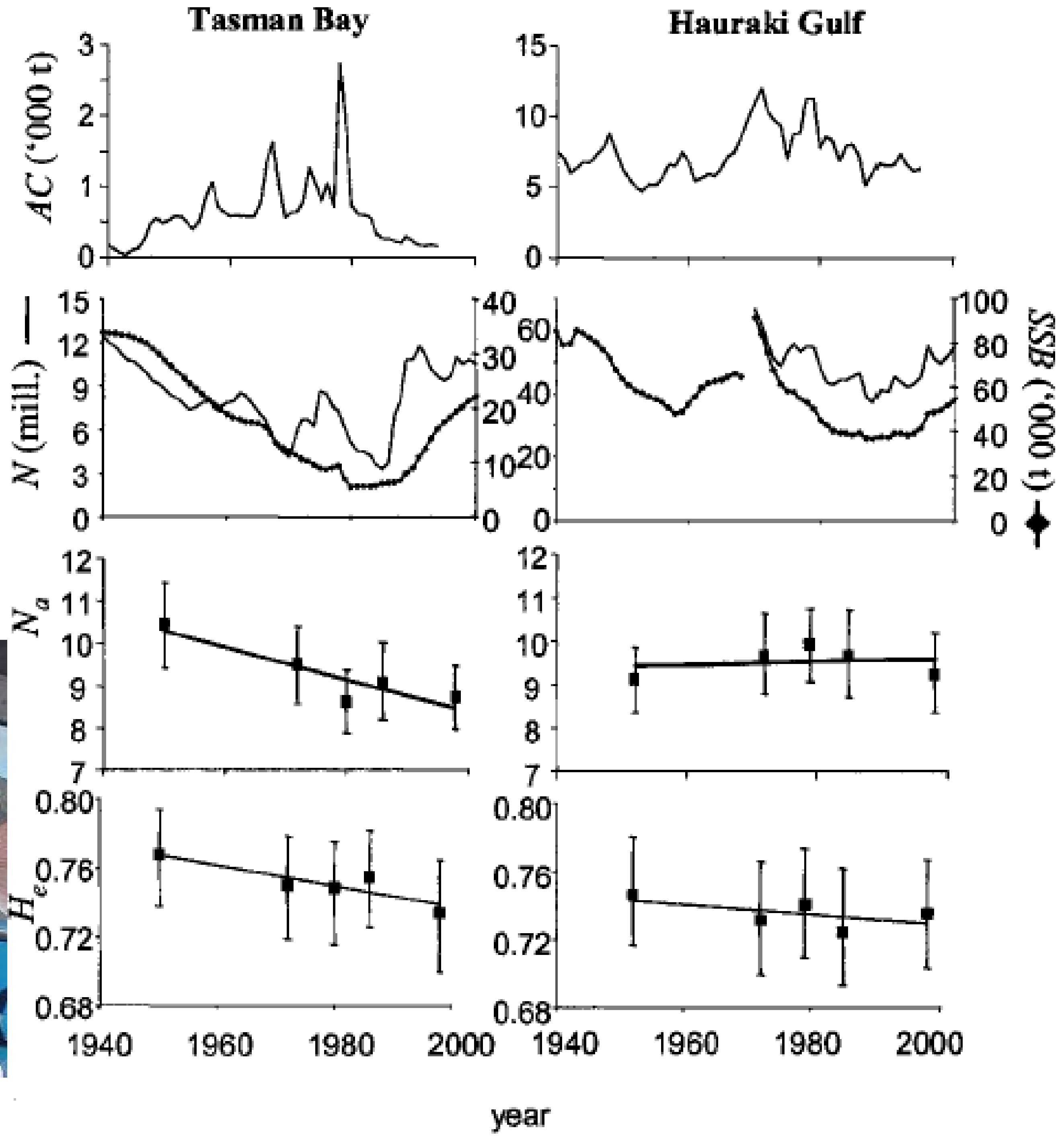
* = Norwegian Sea, North Sea, Skagerrak, Kattegat, Øresund

DIFRES

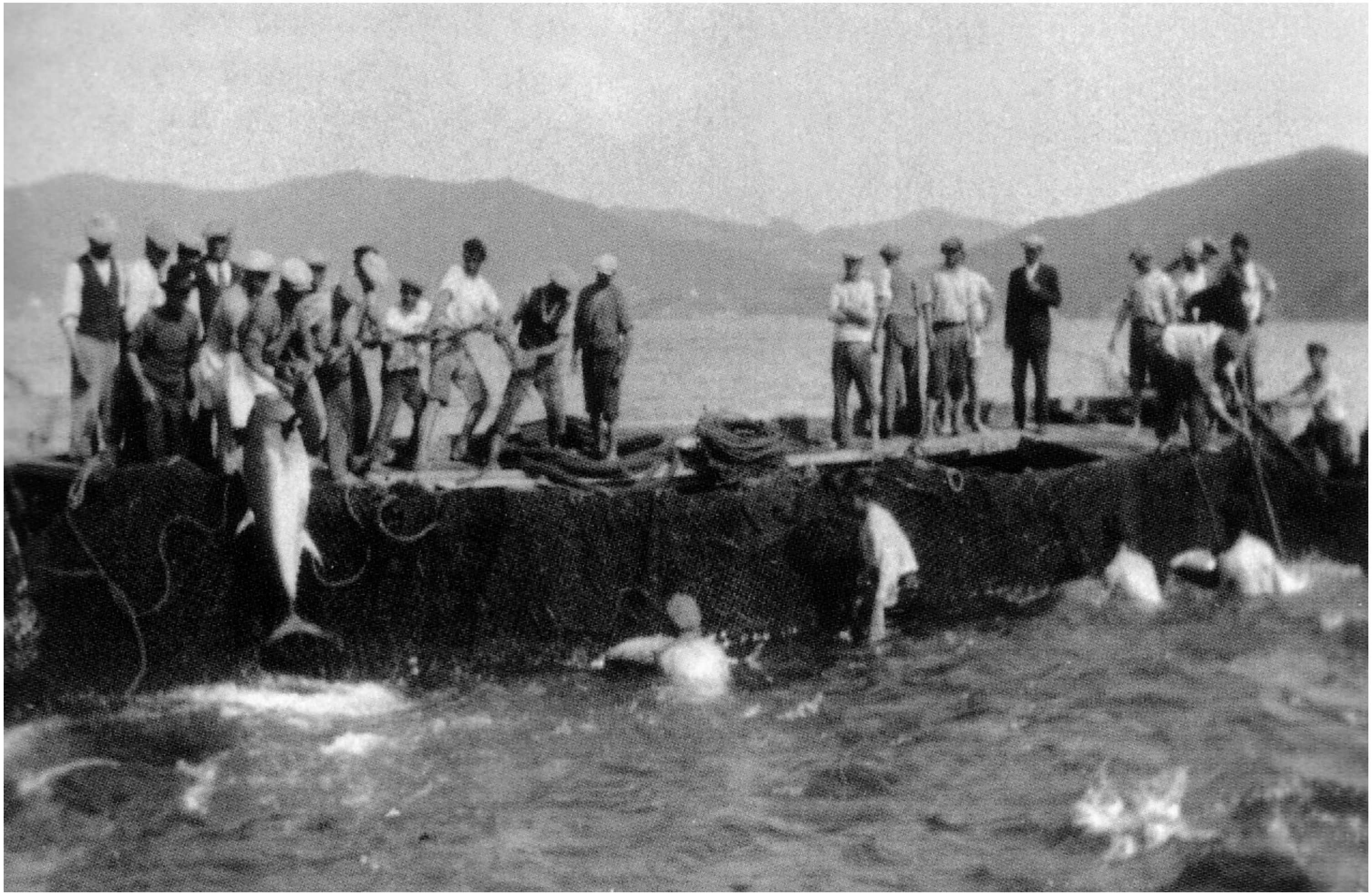
Landings of Bluefin Tuna
Thunnus thynnus in Northeast Atlantic

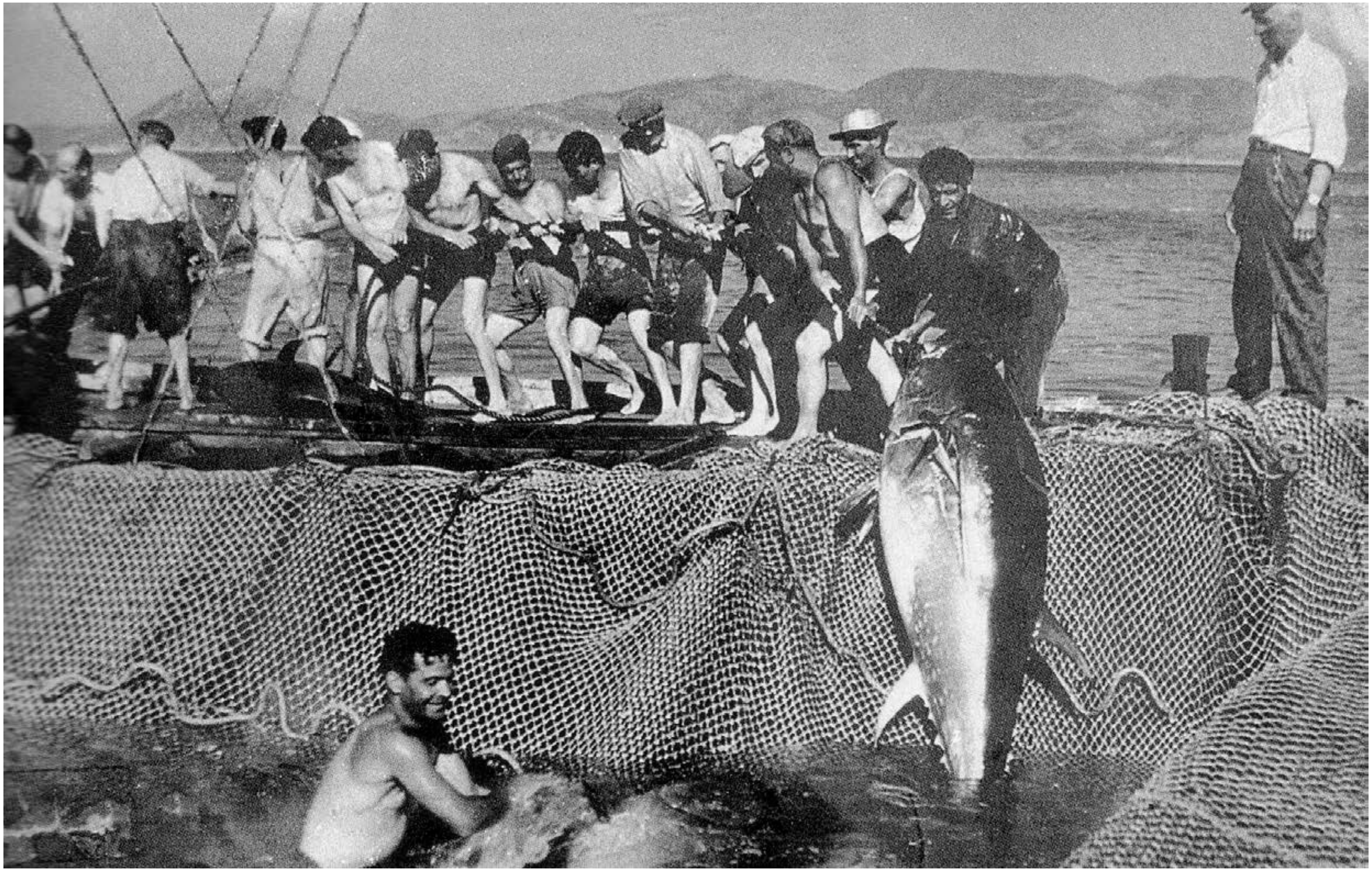


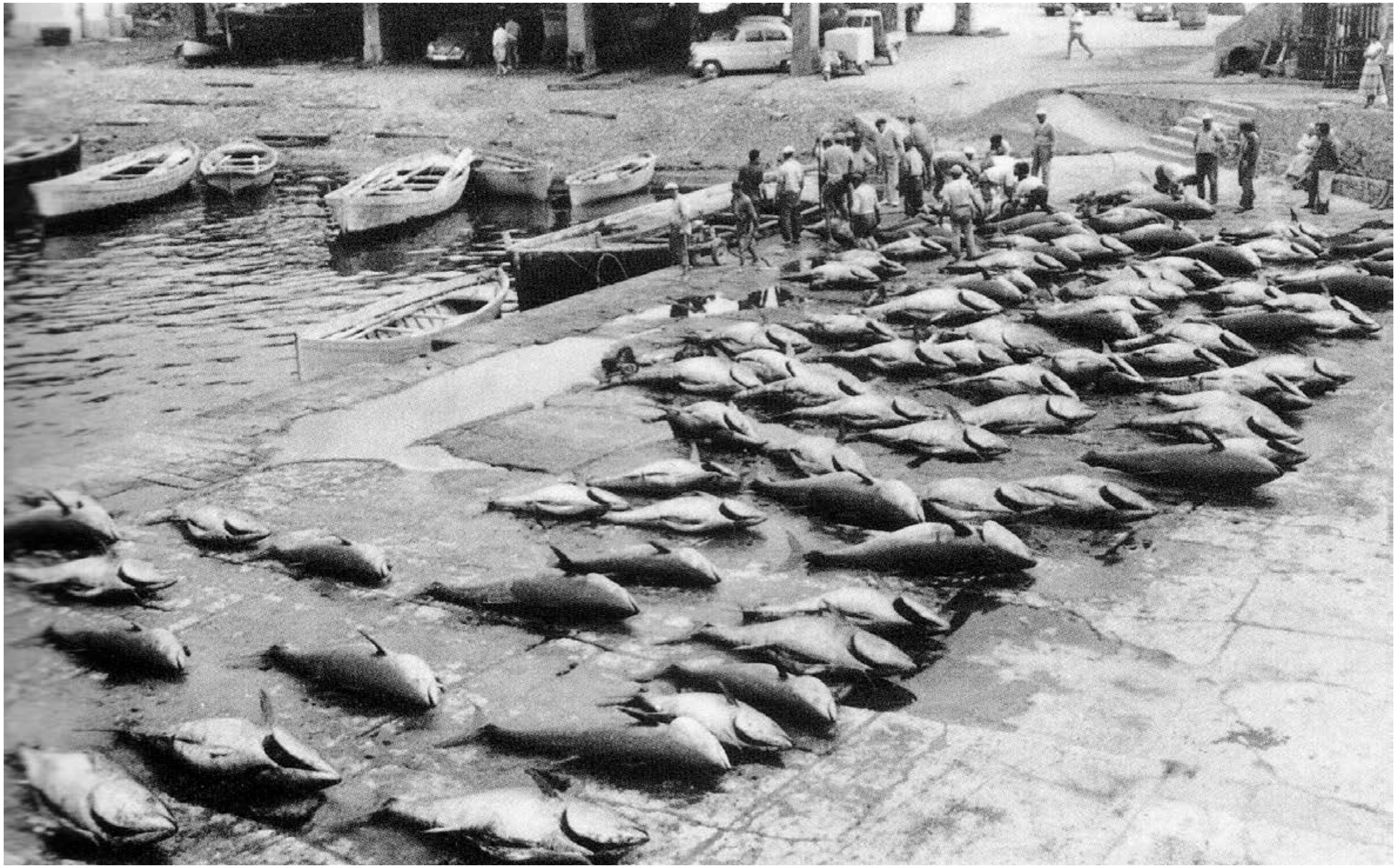
DIFRES



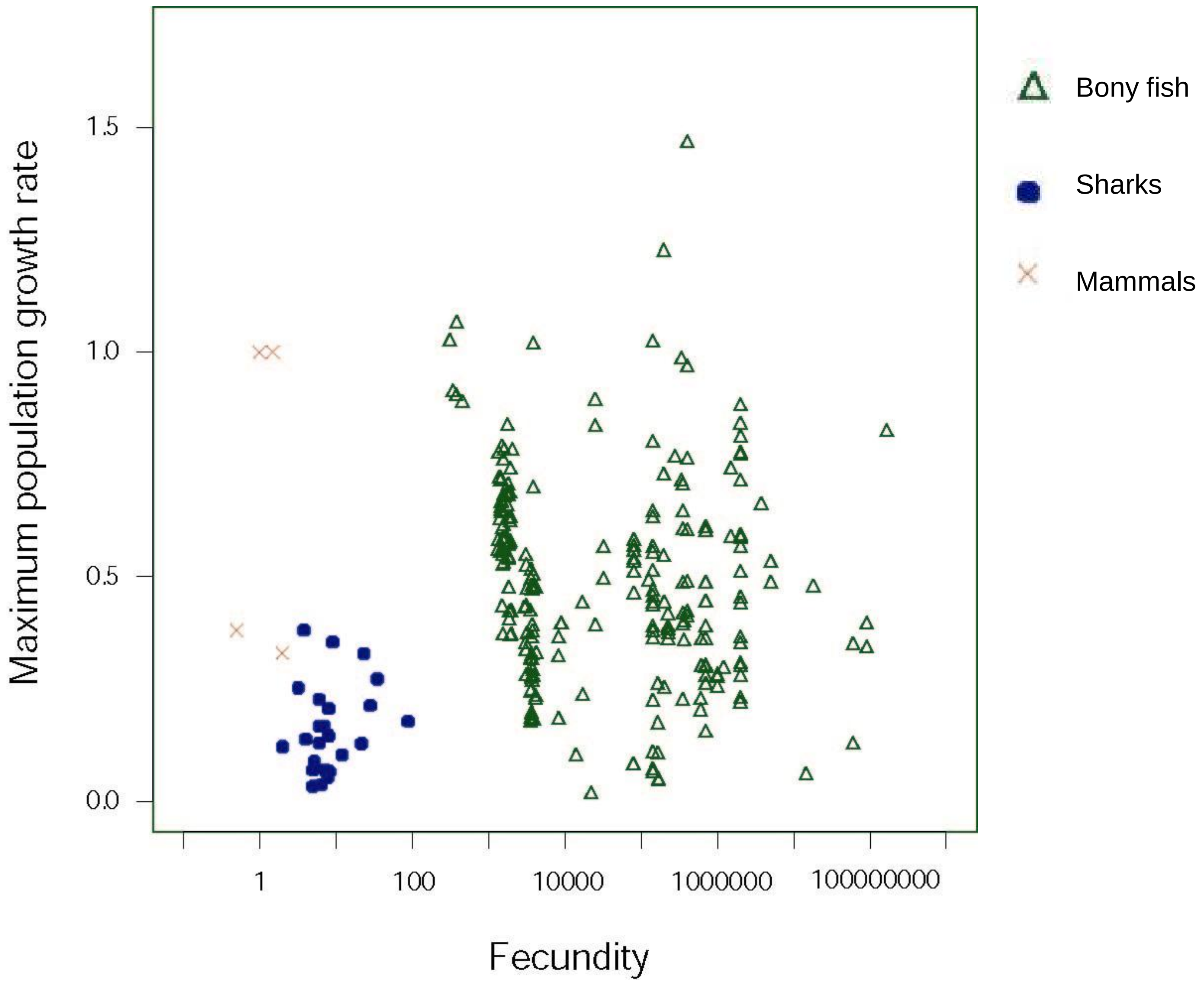
Hauser, et al. PNAS, 2002



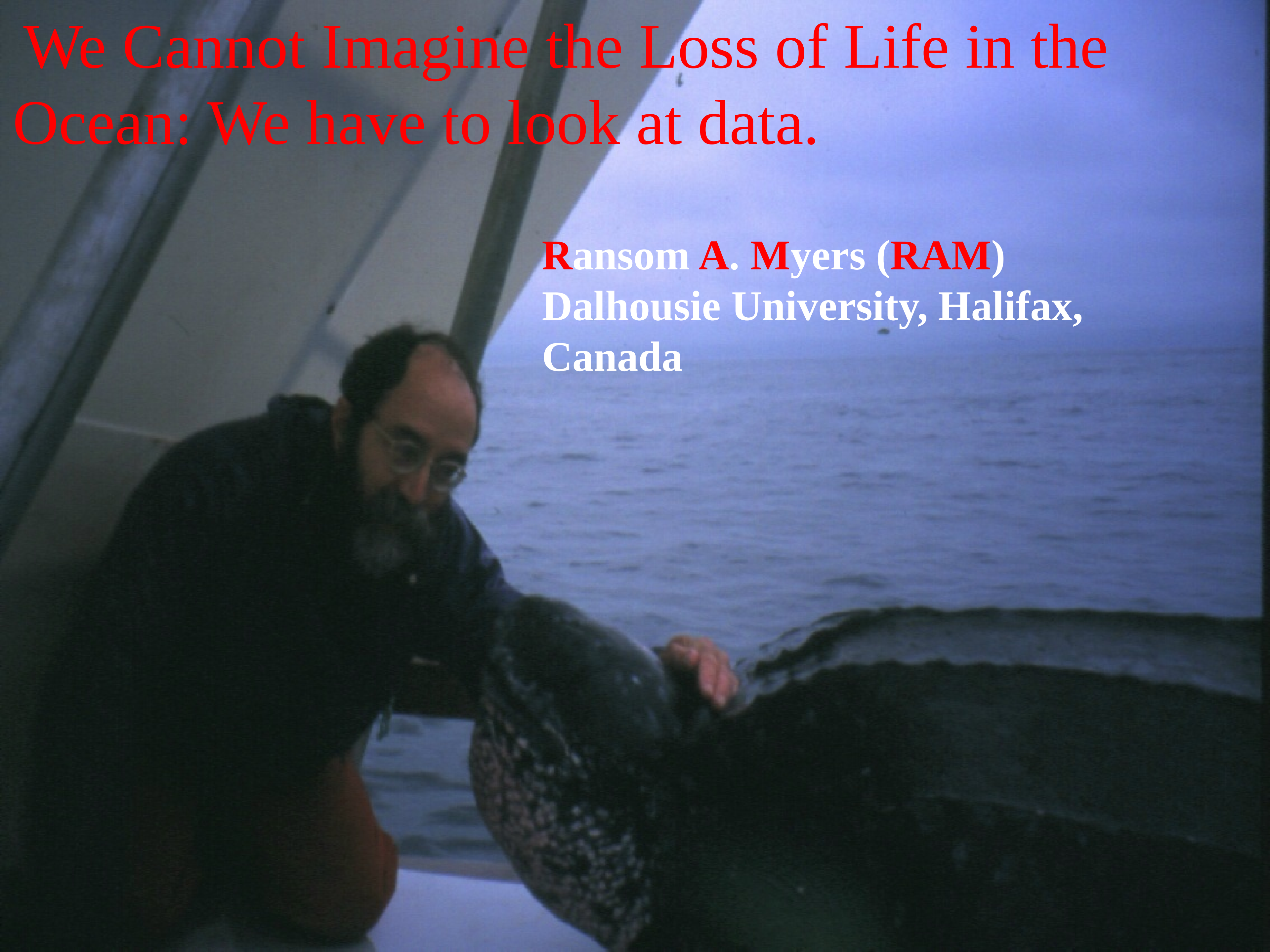




Life history of sharks...

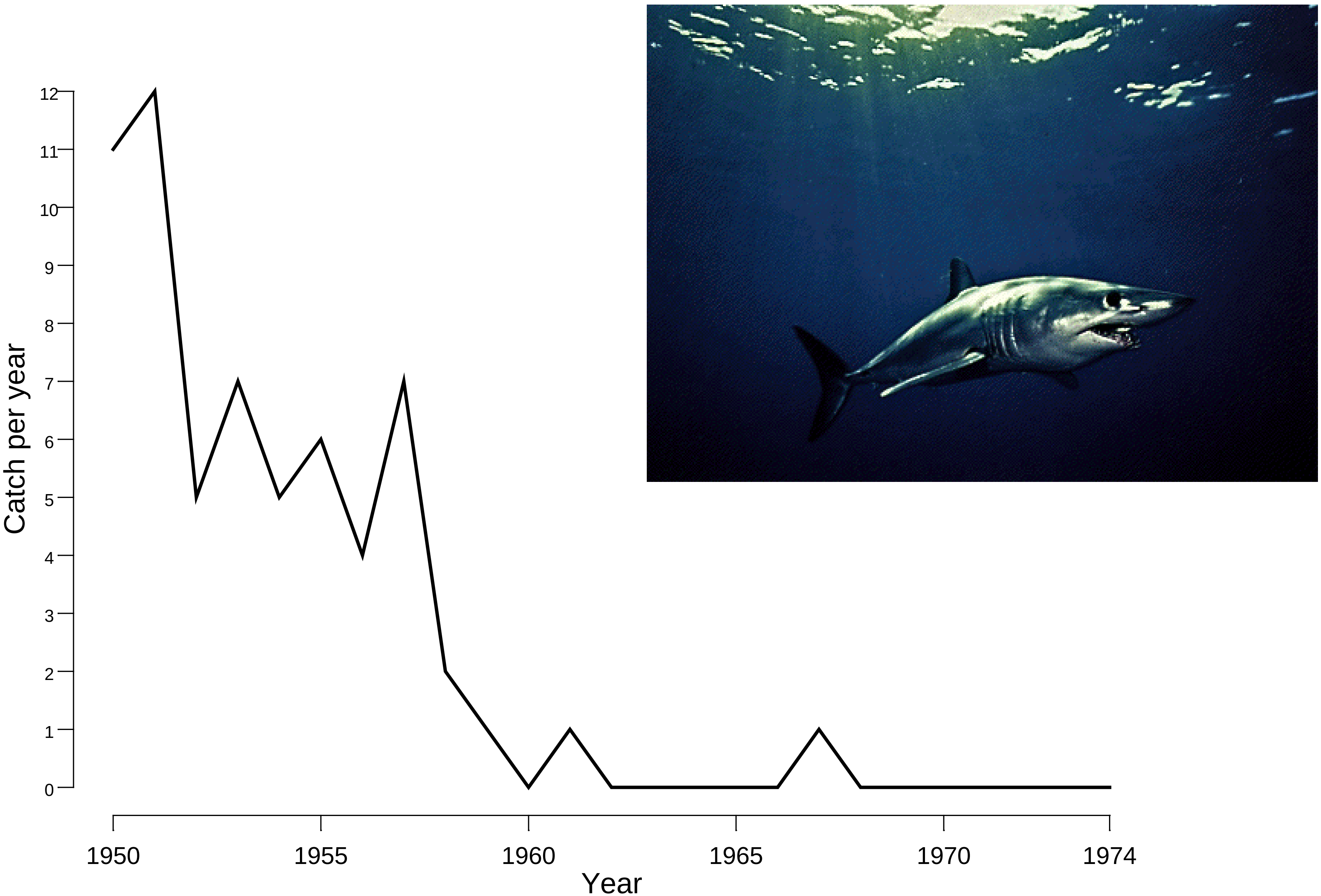


We Cannot Imagine the Loss of Life in the Ocean: We have to look at data.



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

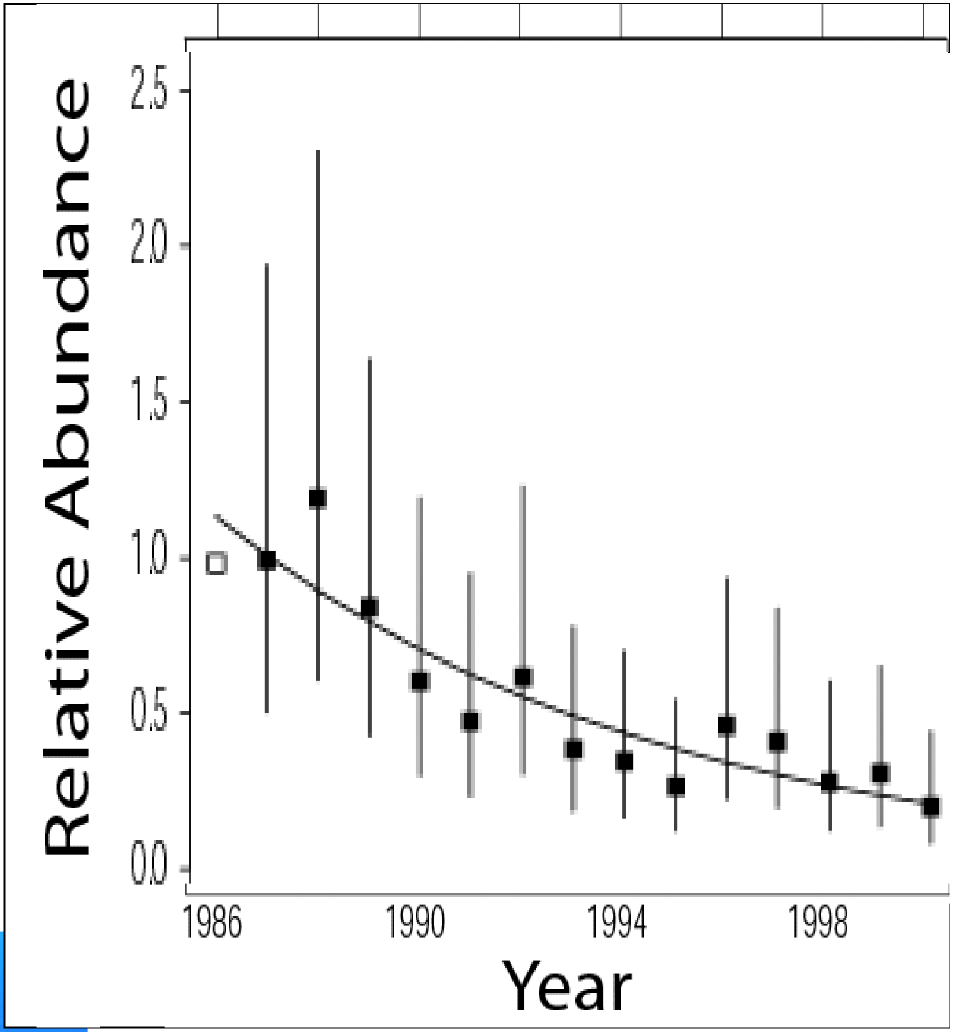
Decline of Mako sharks



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

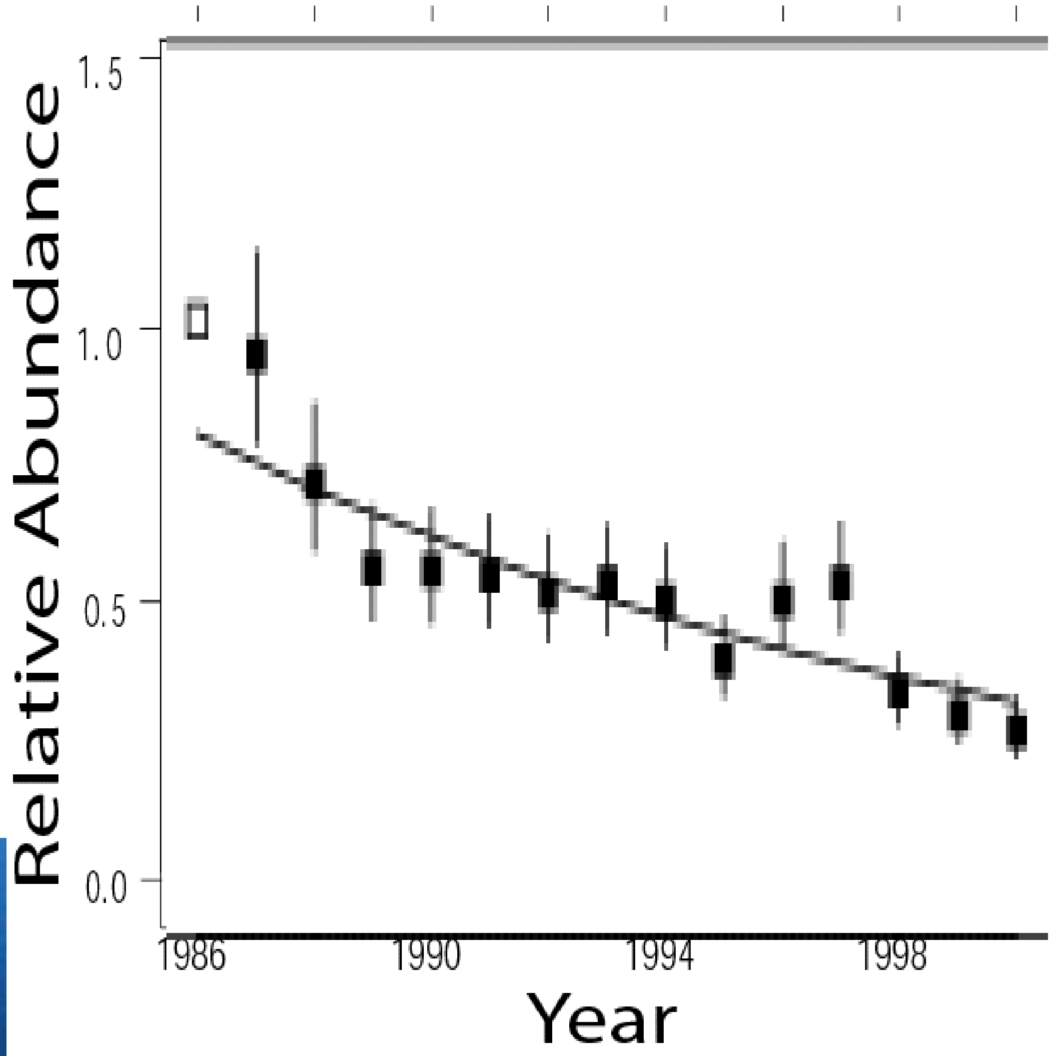
Thresher sharks

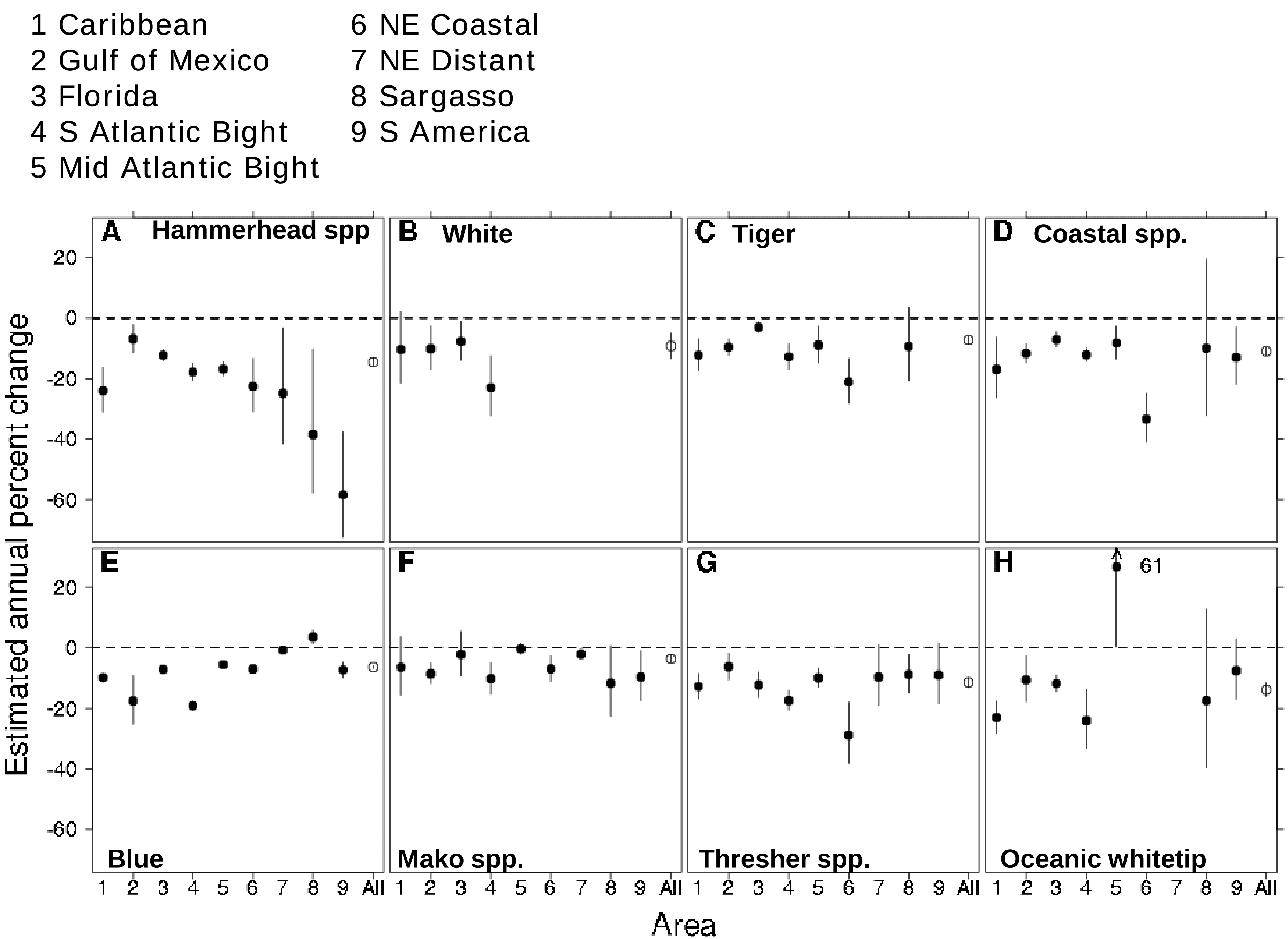
Alopias spp.

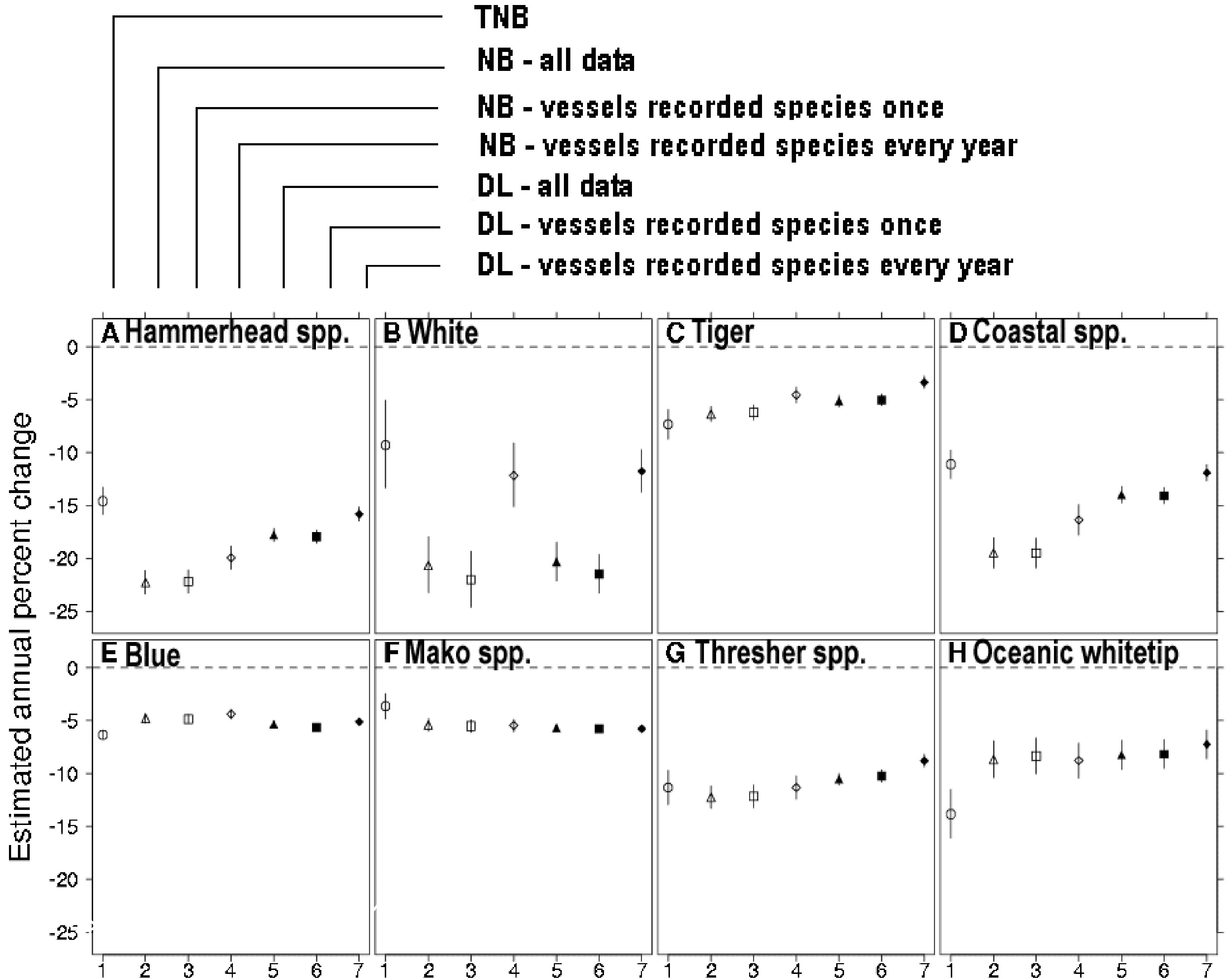


Blue sharks

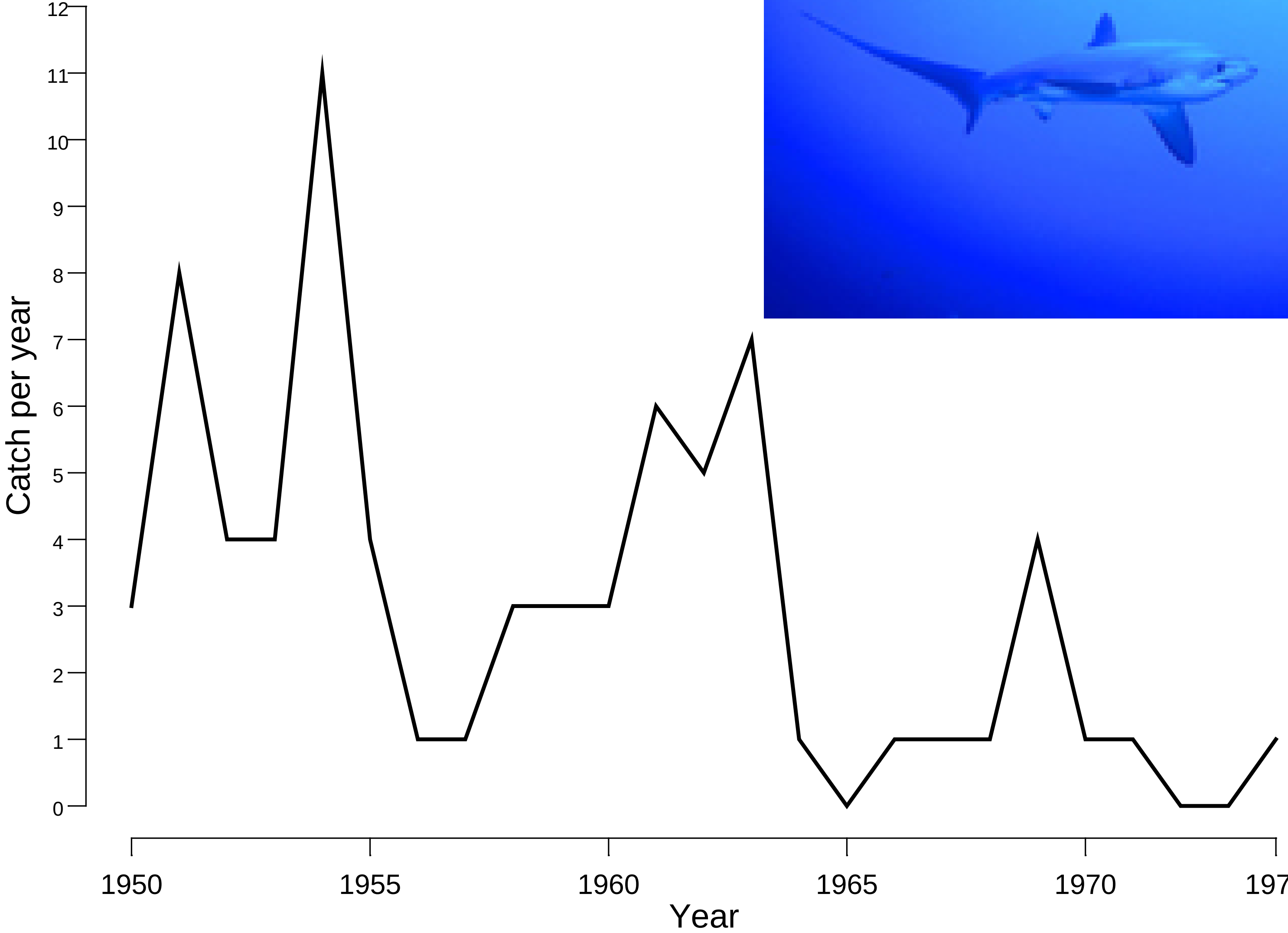
Prionace glauca




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
F
G
H
Blue
Mako spp.
Thresher spp.
Oceanic whitetip
61
Estimated annual percent change
20
0
-20
-40
-60
1 2 3 4 5 6 7 8 9 All
Area

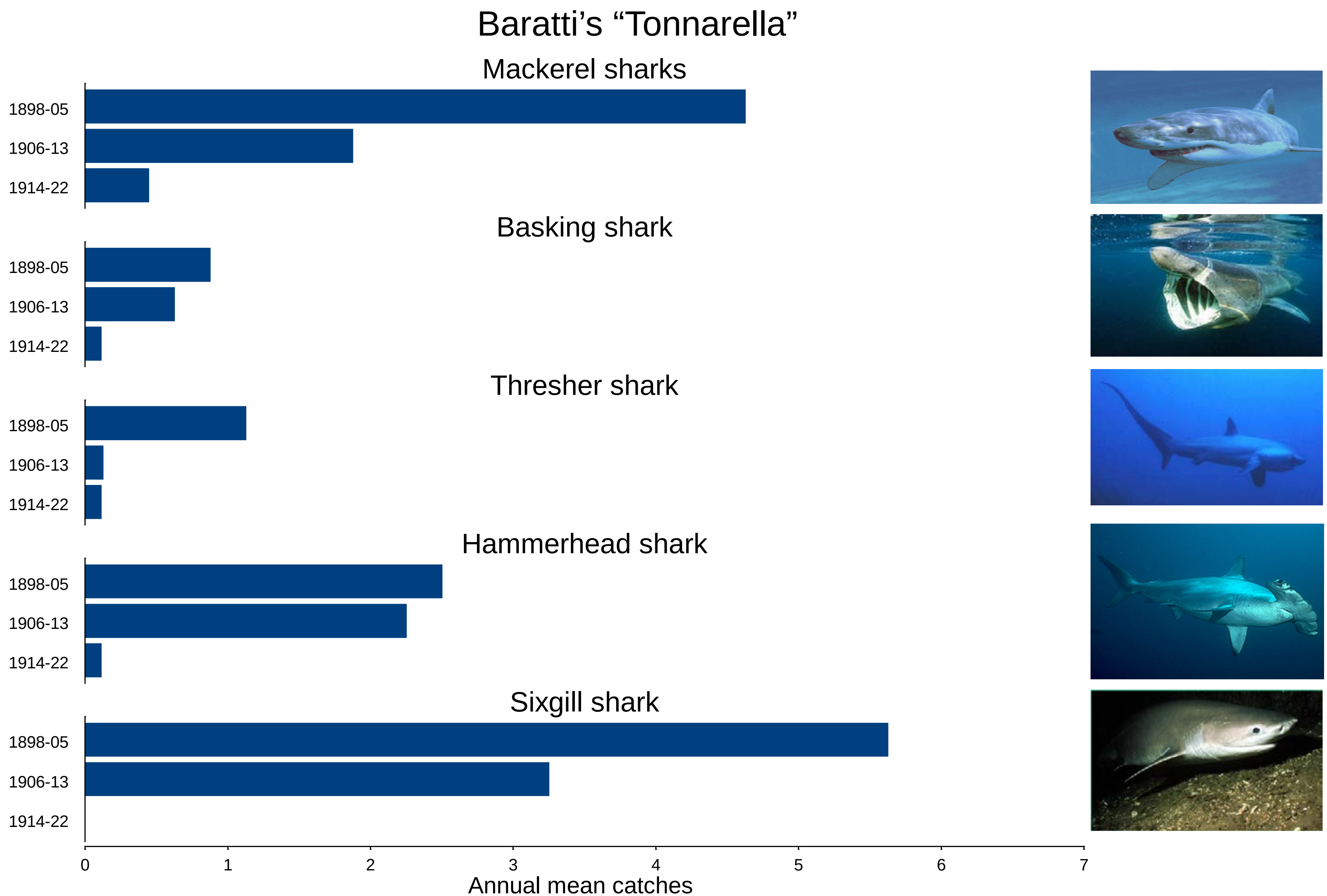

TNB
NB - all data
NB - vessels recorded species once
NB - vessels recorded species every year
DL - all data
DL - vessels recorded species once
DL - vessels recorded species every year
A Hammerhead spp.
B White
C Tiger
D Coastal spp.
E Blue
F Mako spp.
G Thresher spp.
H Oceanic whitetip
Estimated annual 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)

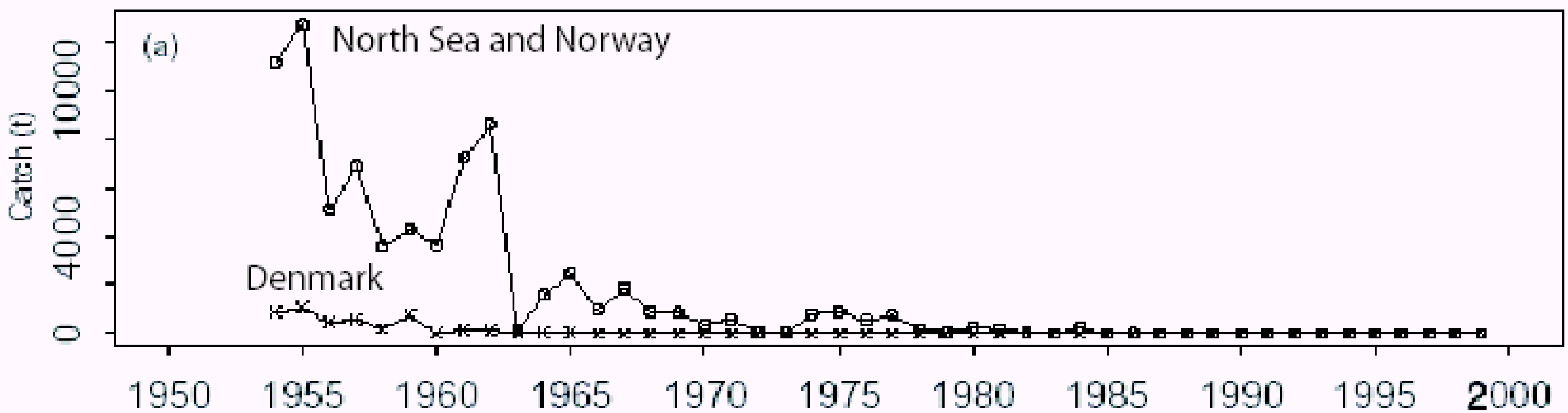
Decline in Large Sharks's Catches by an Italian Tuna Trap



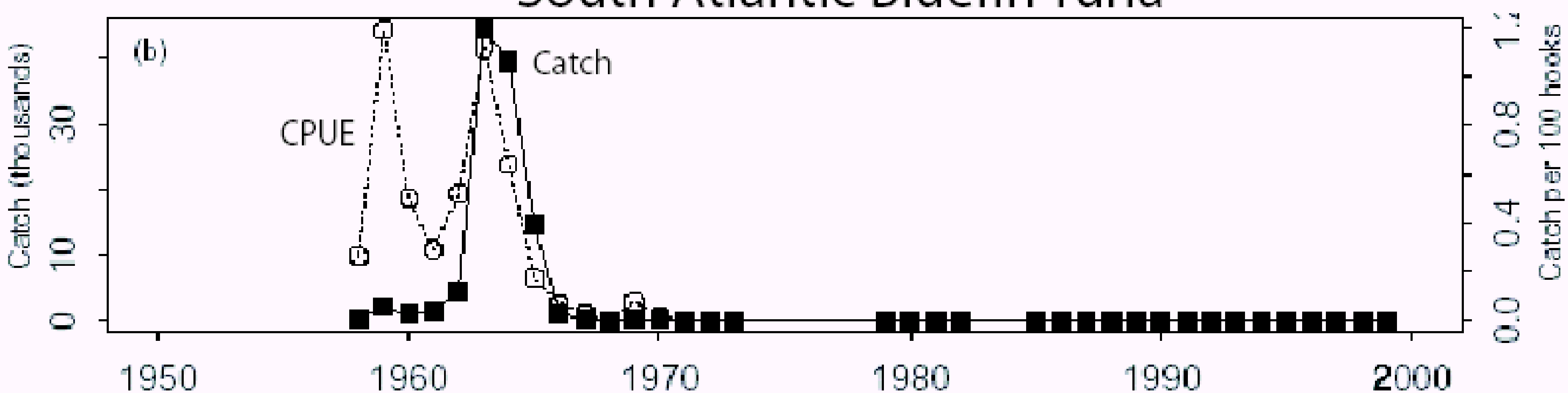
Vacchi M. *et al*. 2000 - 4th-Meeting-of-the-European-Elasmobranch-Association-Proceedings

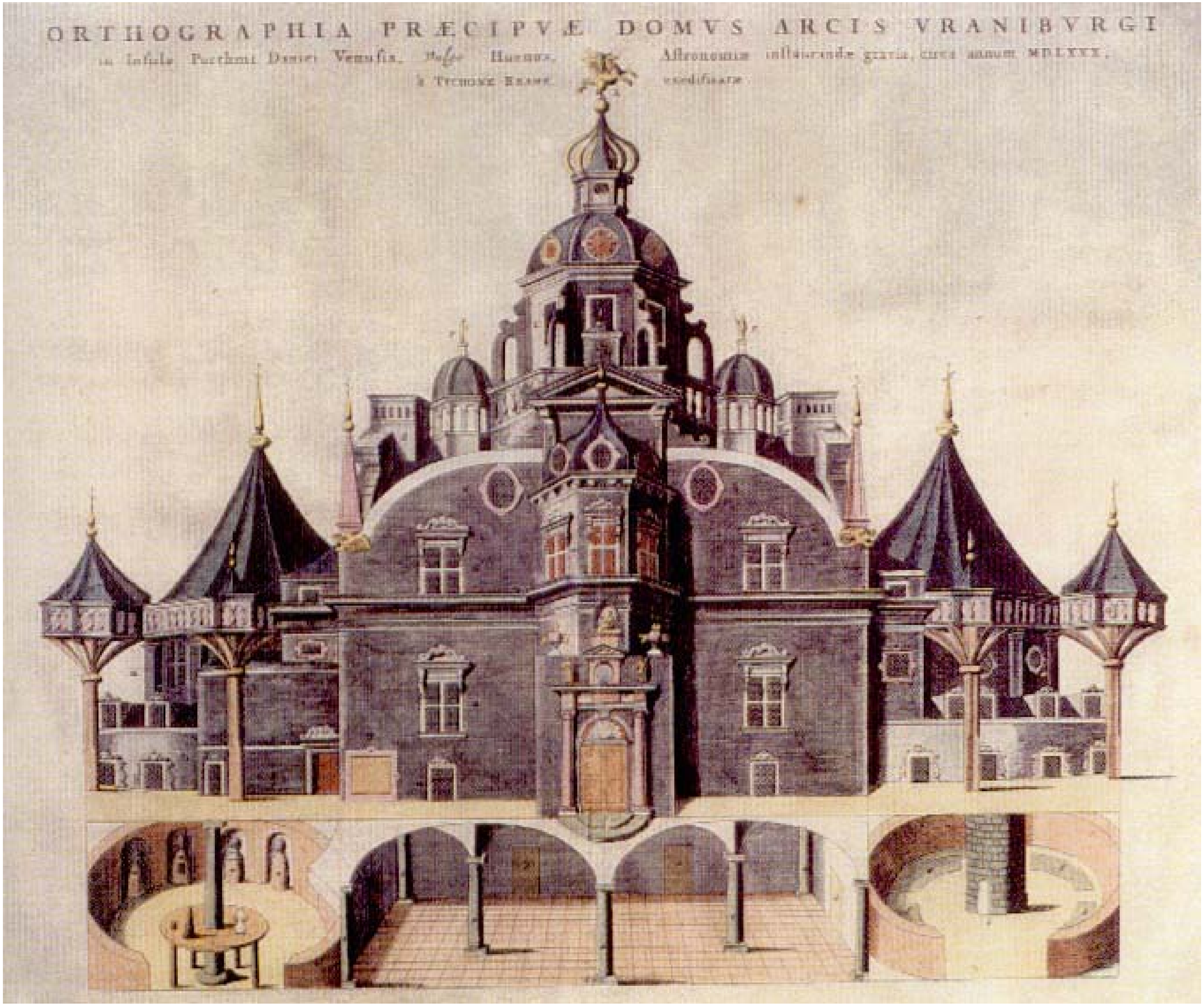
Loss of Bluefin Tuna Populations in the Atlantic

North Sea Bluefin Tuna



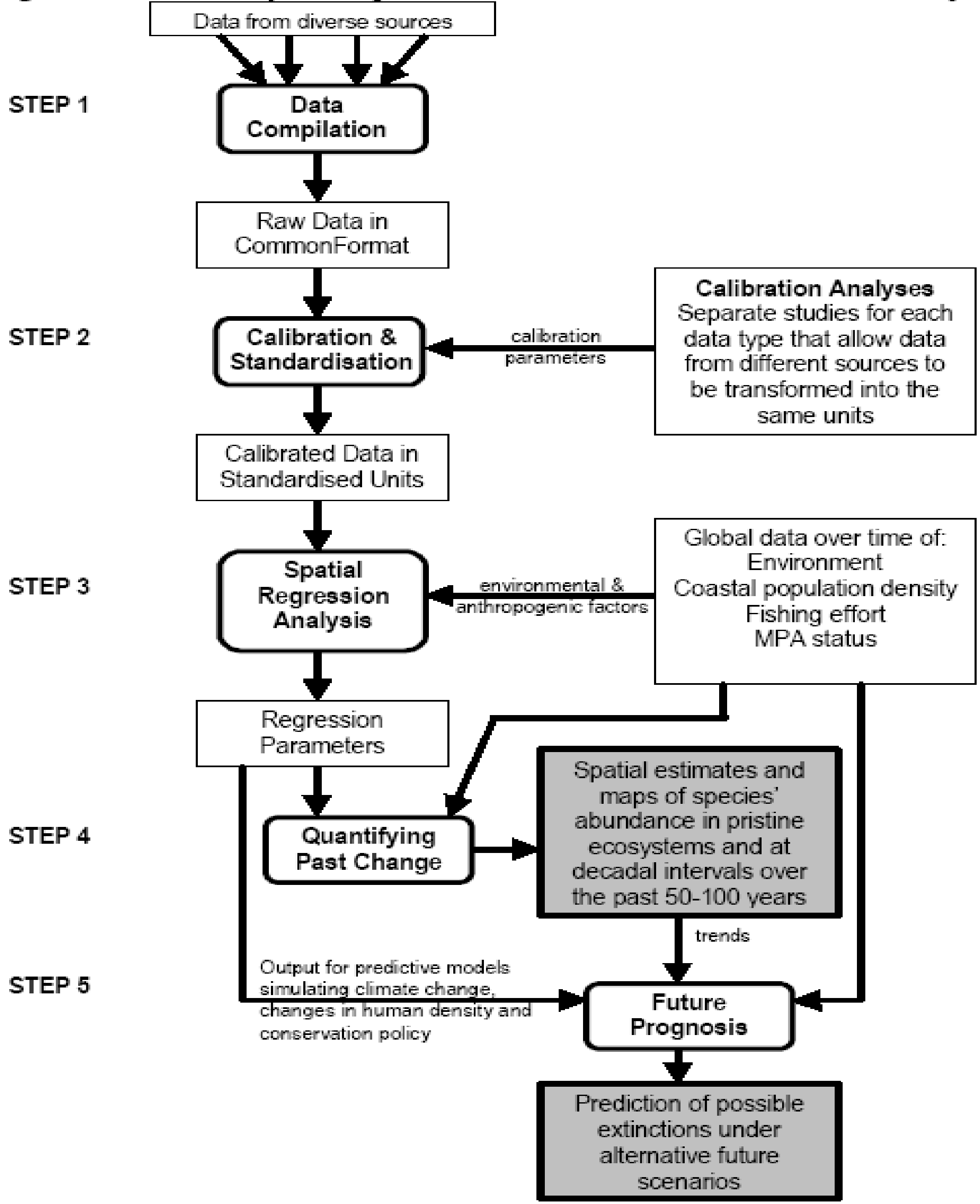
South Atlantic Bluefin Tuna




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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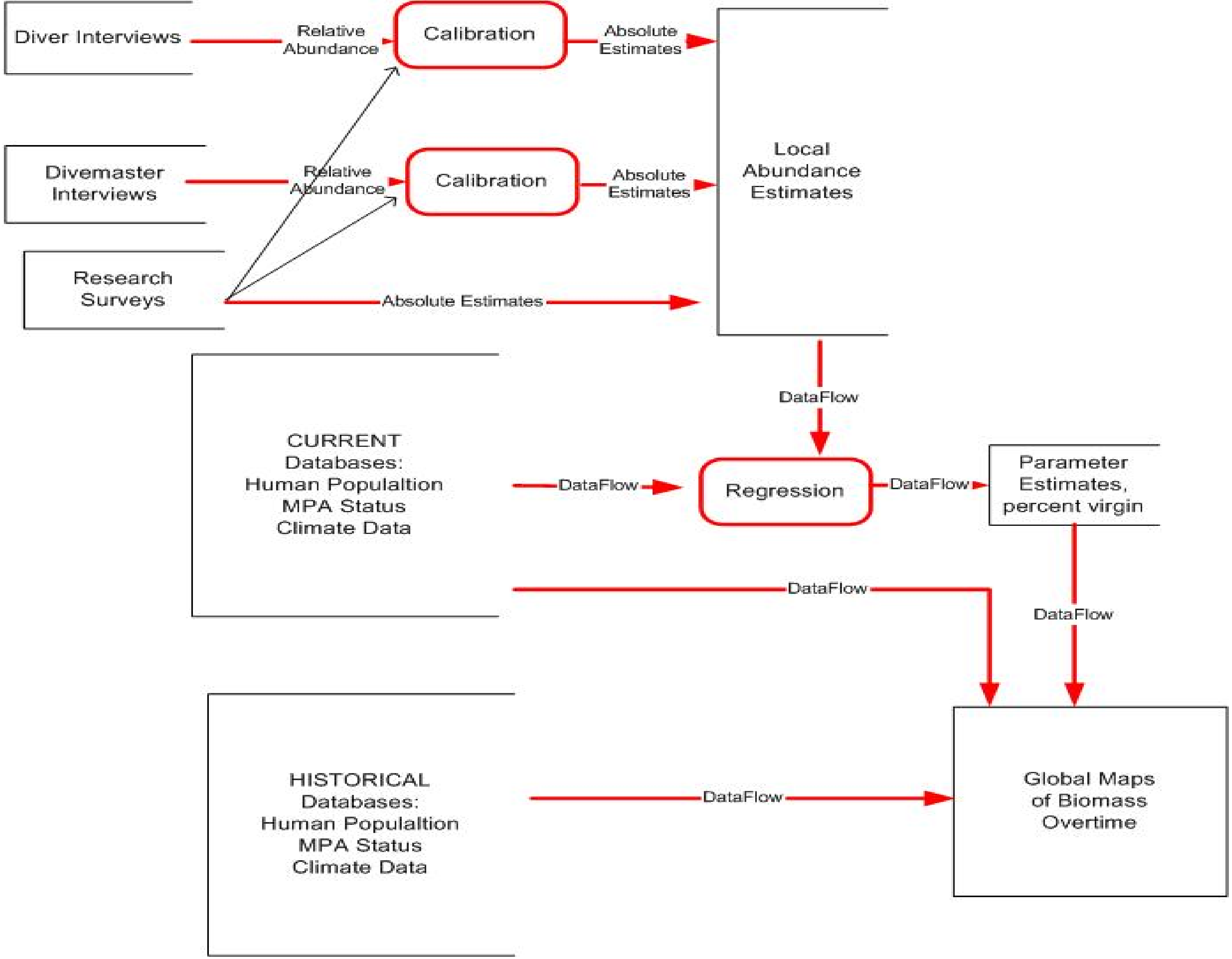
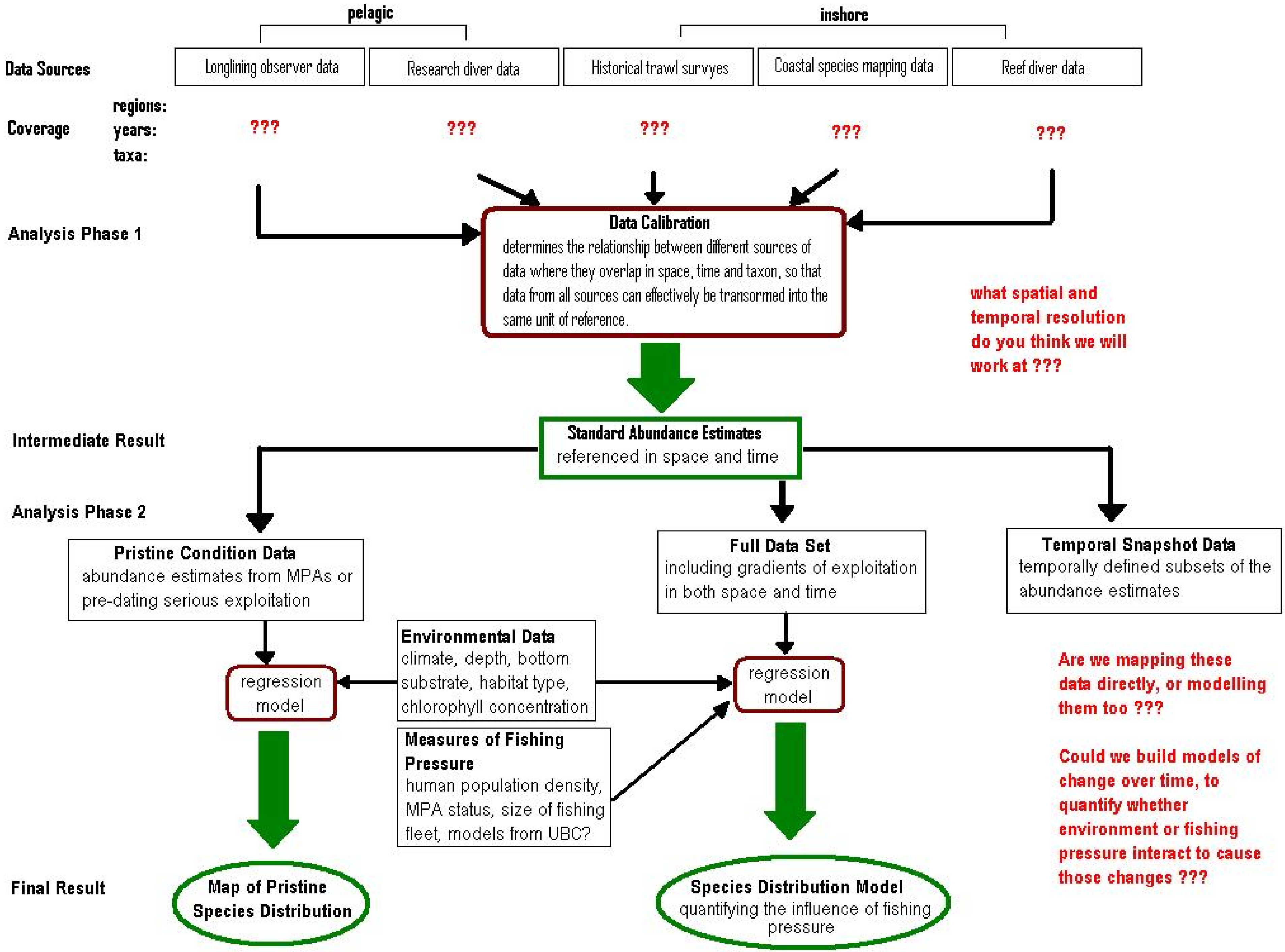


Outline of data flow to produce global maps of abundance for reef species. The goal is produce maps for species that are of interest to divers over time, and estimate the "pristine" abundances and biomass, and t he time trends over time to the present. This will be critical to estimating extinction probability.



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
Measures of Fishing Pressure
human population density, MPA status, size of fishing fleet, models from UBC?
Are we mapping these data directly, or modelling them too ???
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

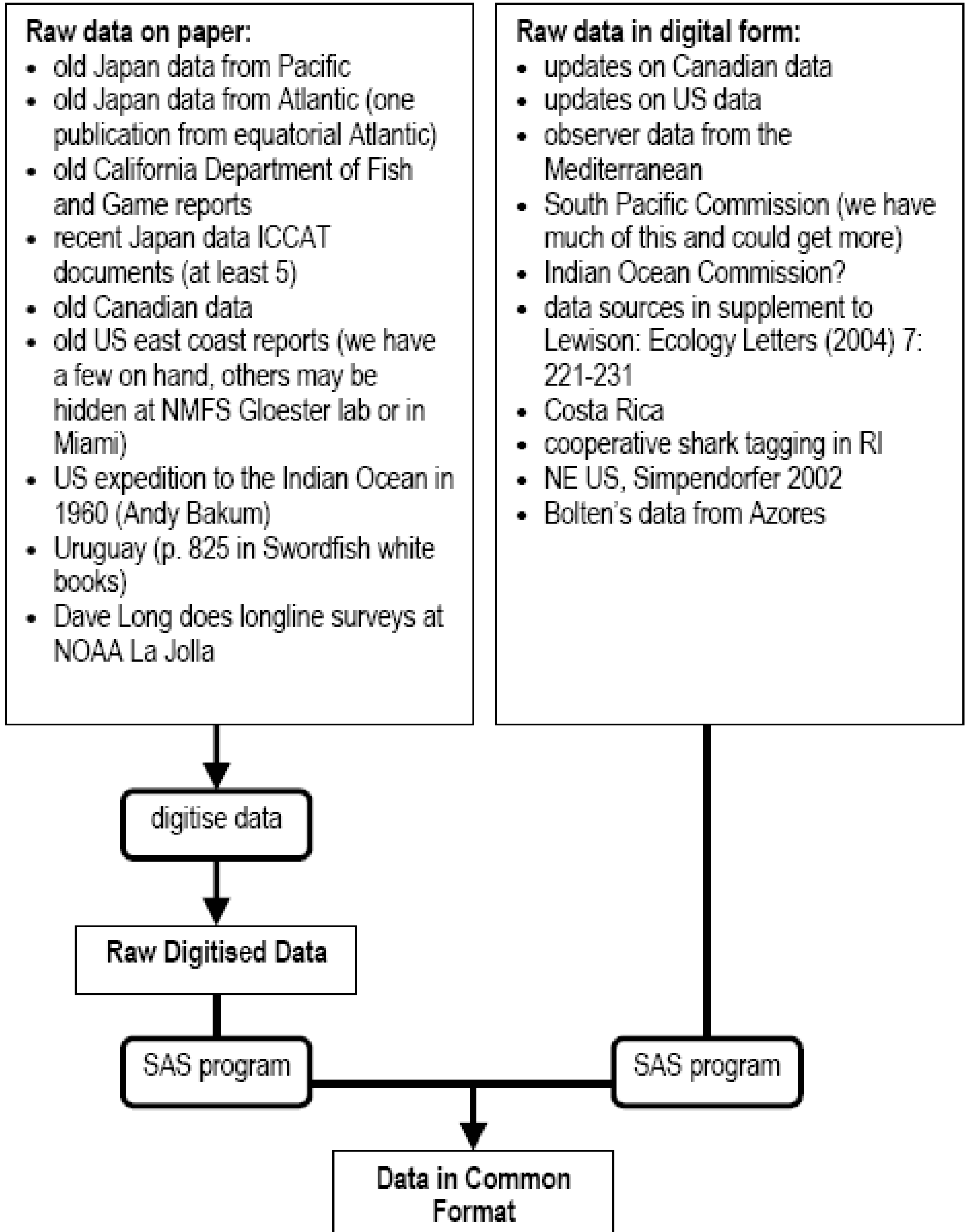
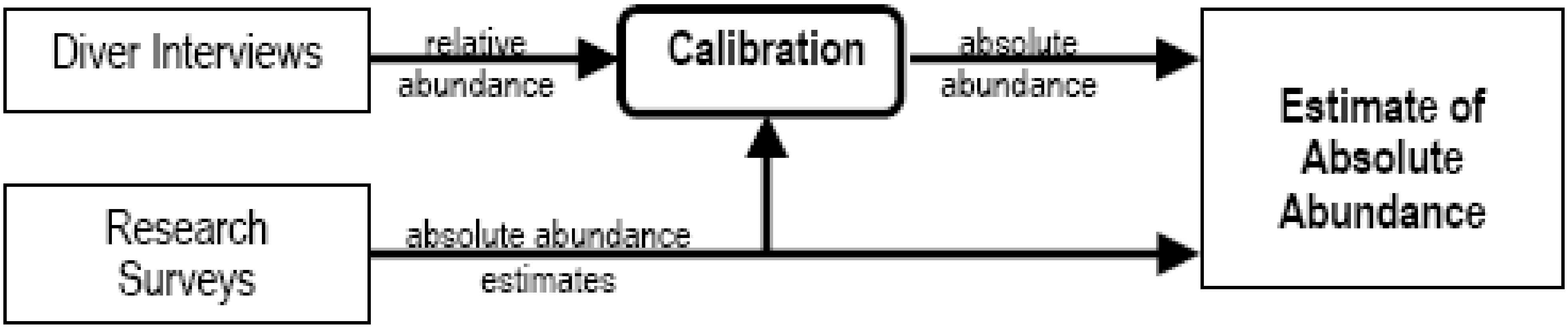

Raw data on paper:
old Japan data from Pacific
old Japan data from Atlantic (one publication from equatorial Atlantic)
old California Department of Fish and Game reports
recent Japan data ICCAT documents (at least 5)
old Canadian data
old US east coast reports (we have a few on hand, others may be hidden 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.



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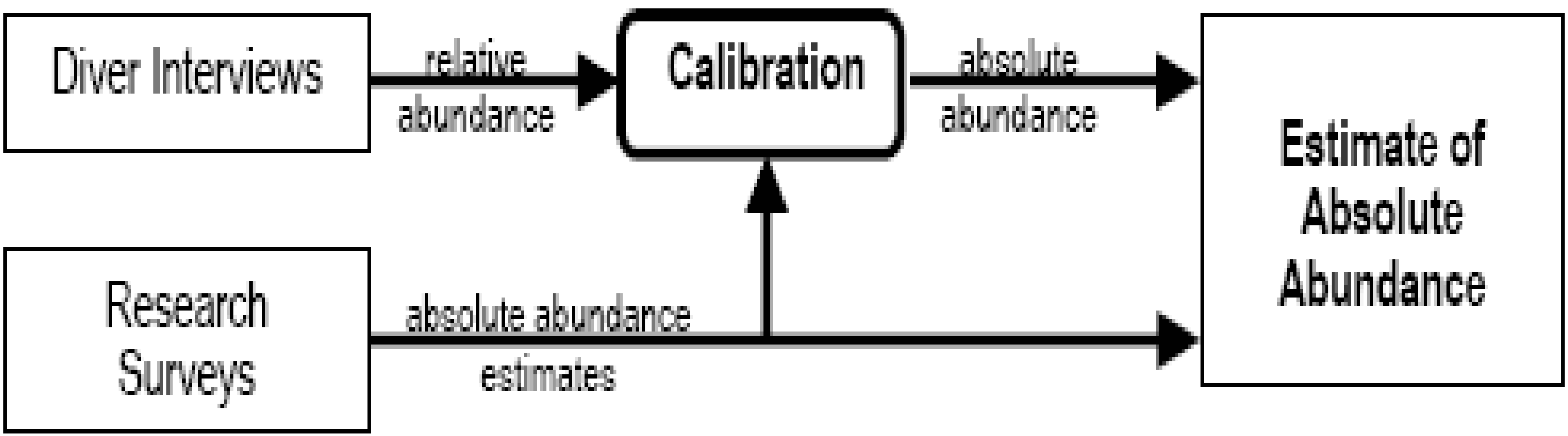
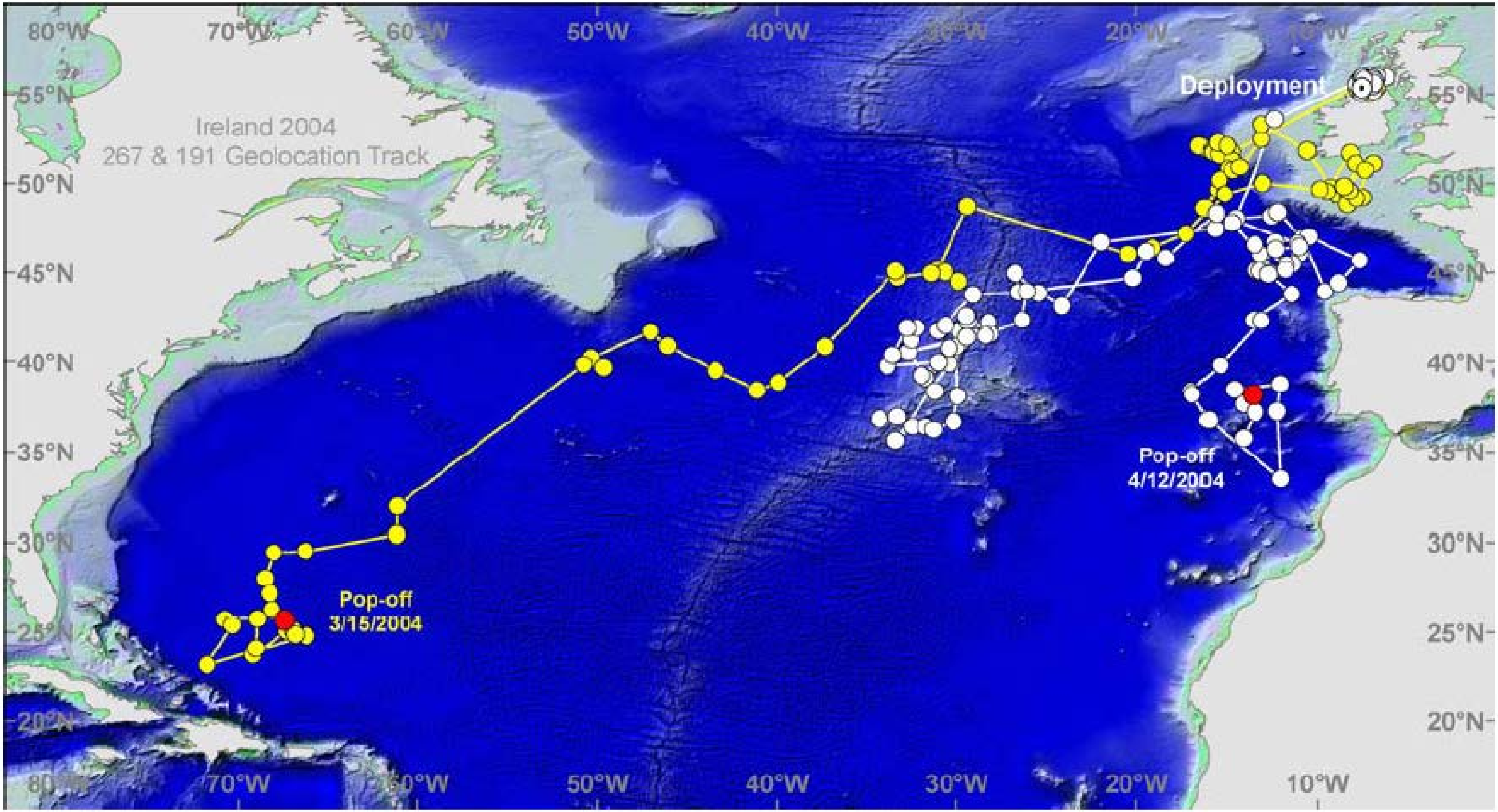
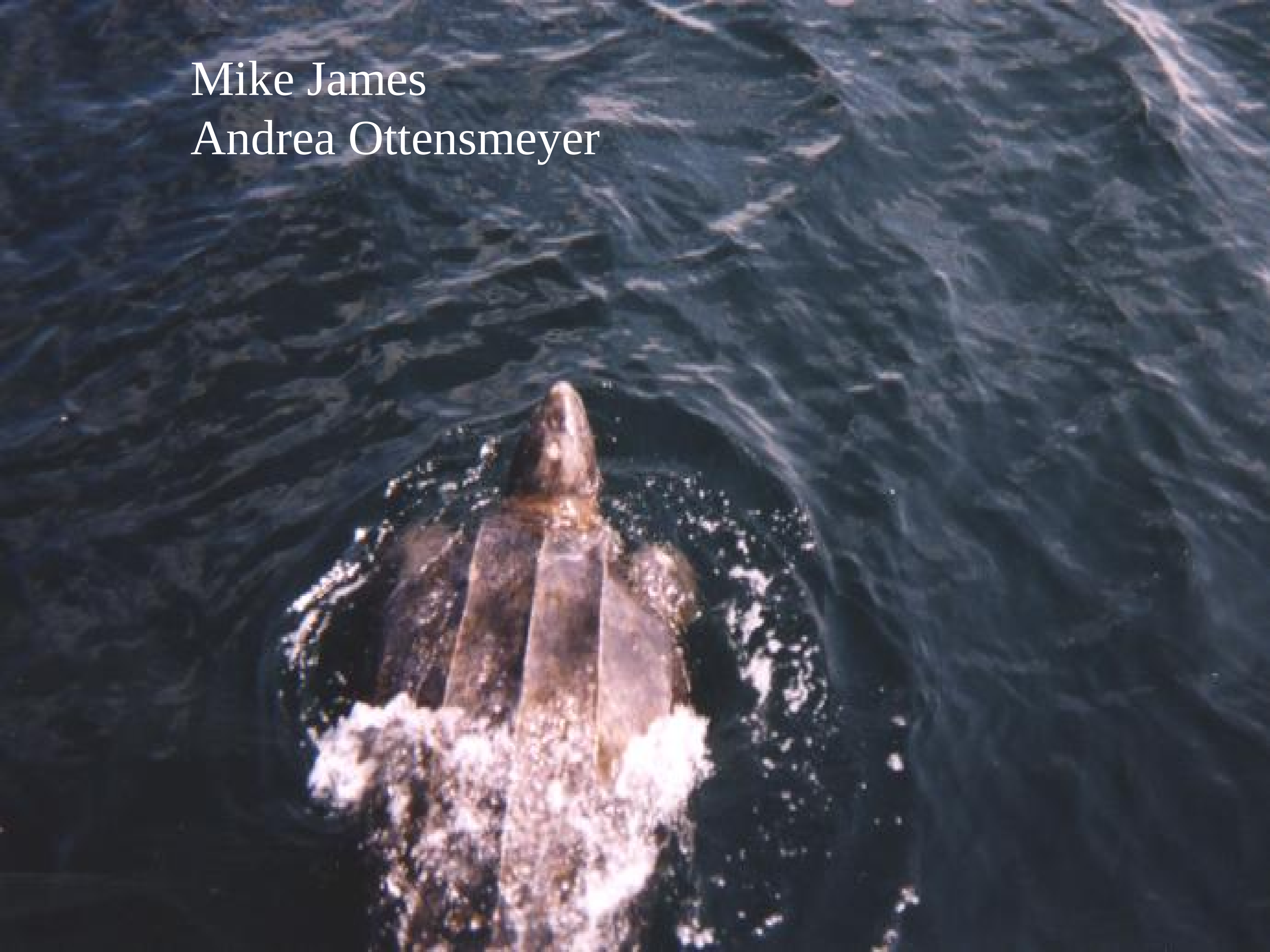




Ireland 2004
267 & 191 Geolocation Track
Deployment
Pop-off
3/15/2004
Pop-off
4/12/2004
80°W
70°W
60°W
50°W
40°W
30°W
20°W
10°W
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N

Photo by Matthew Godfrey


Mike James
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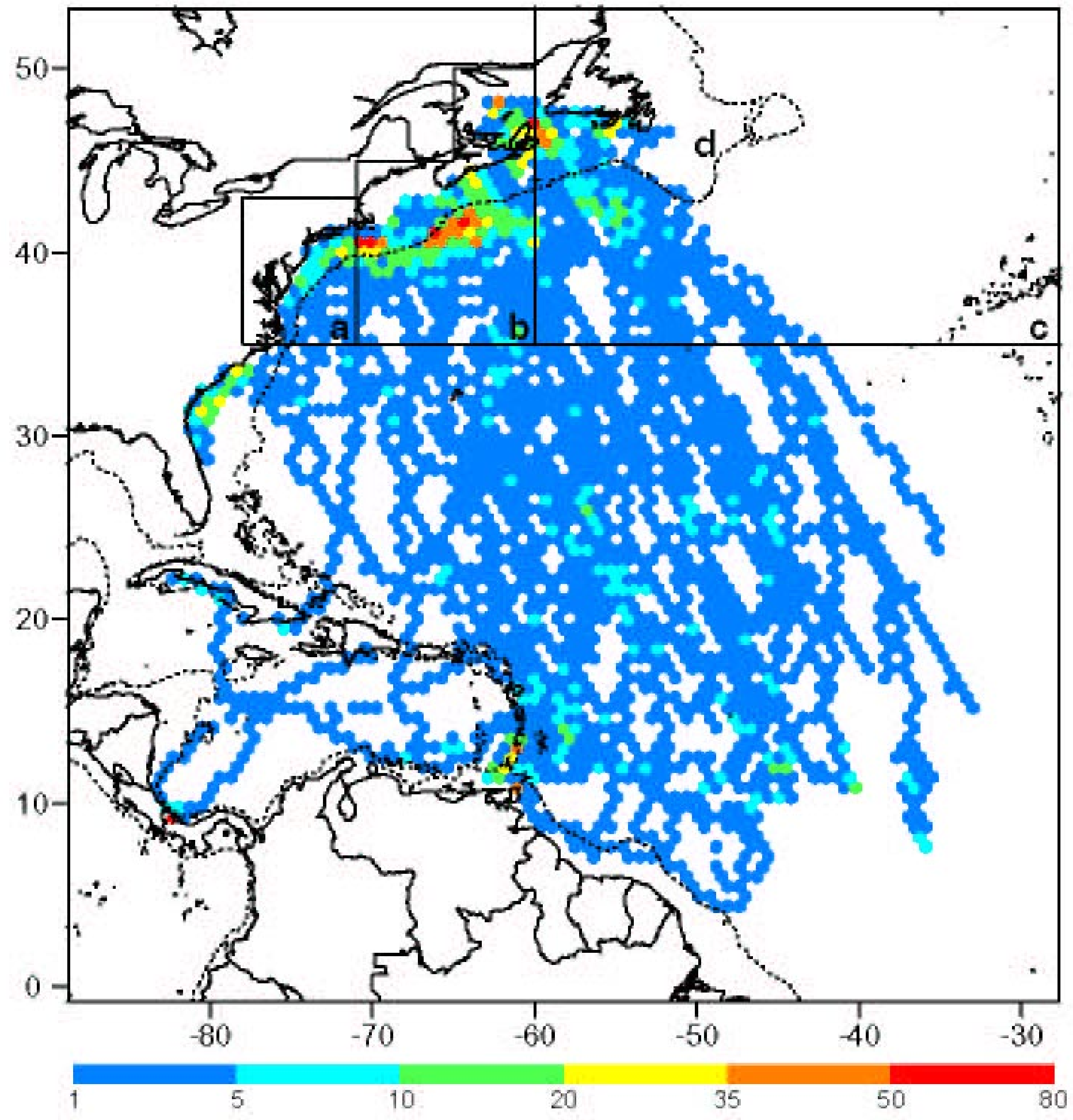
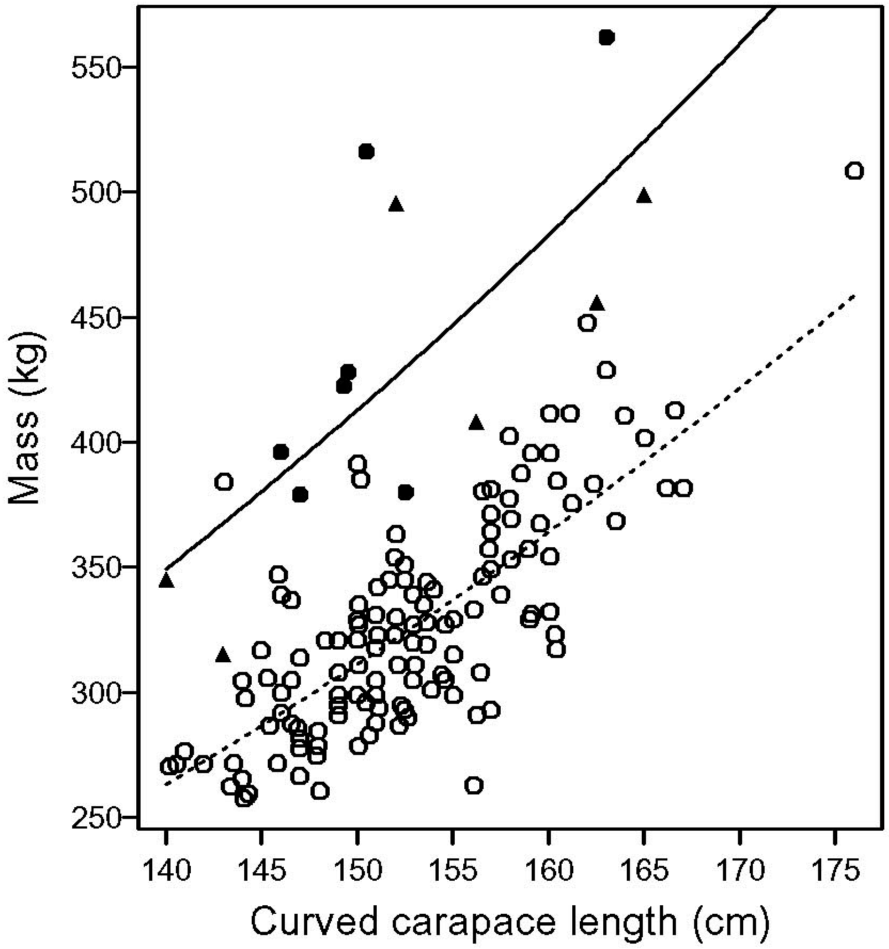
James, Ottensmeyer and Myers
Ecology Letters (2005)



Weights in Canadian waters



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

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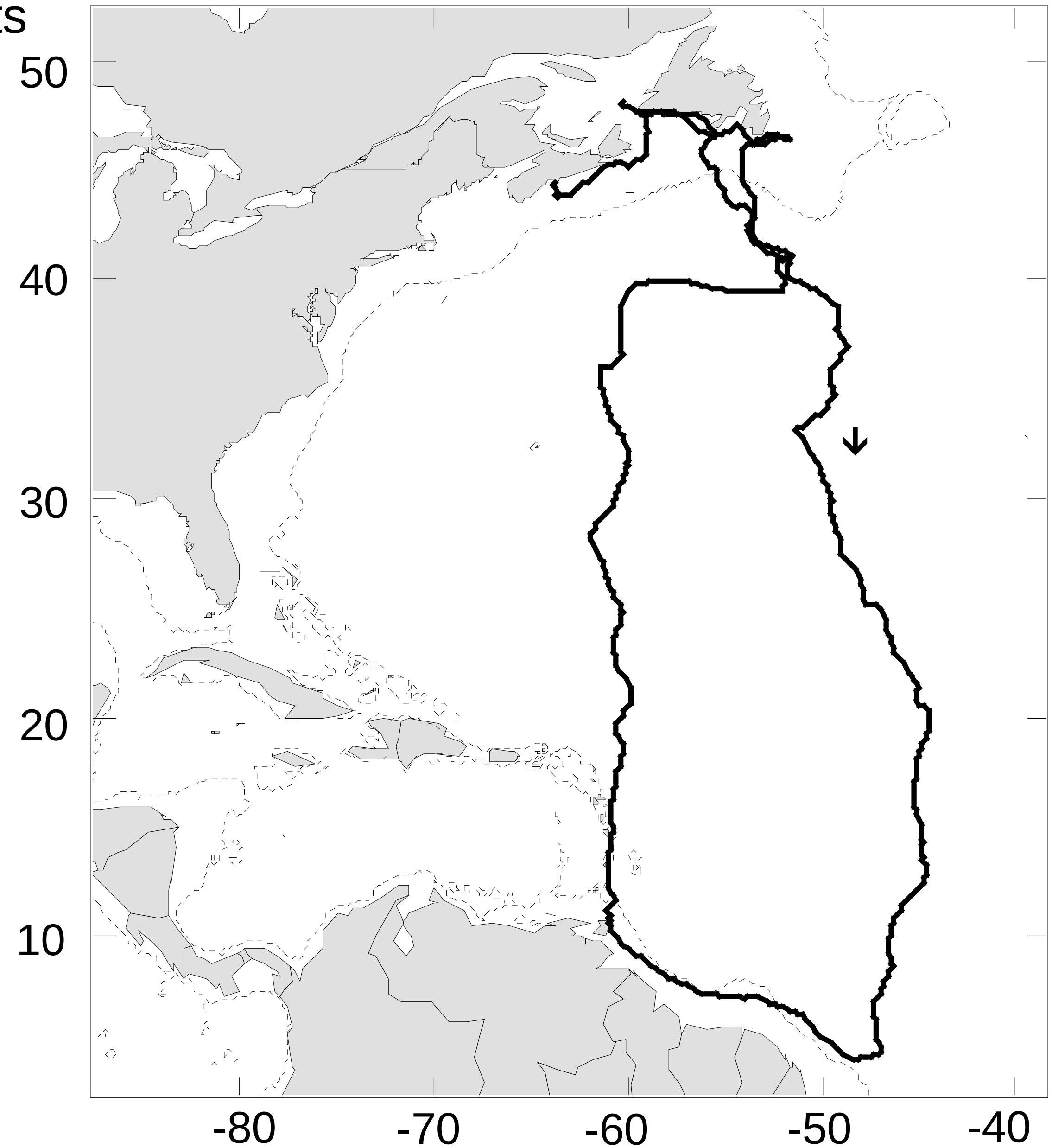
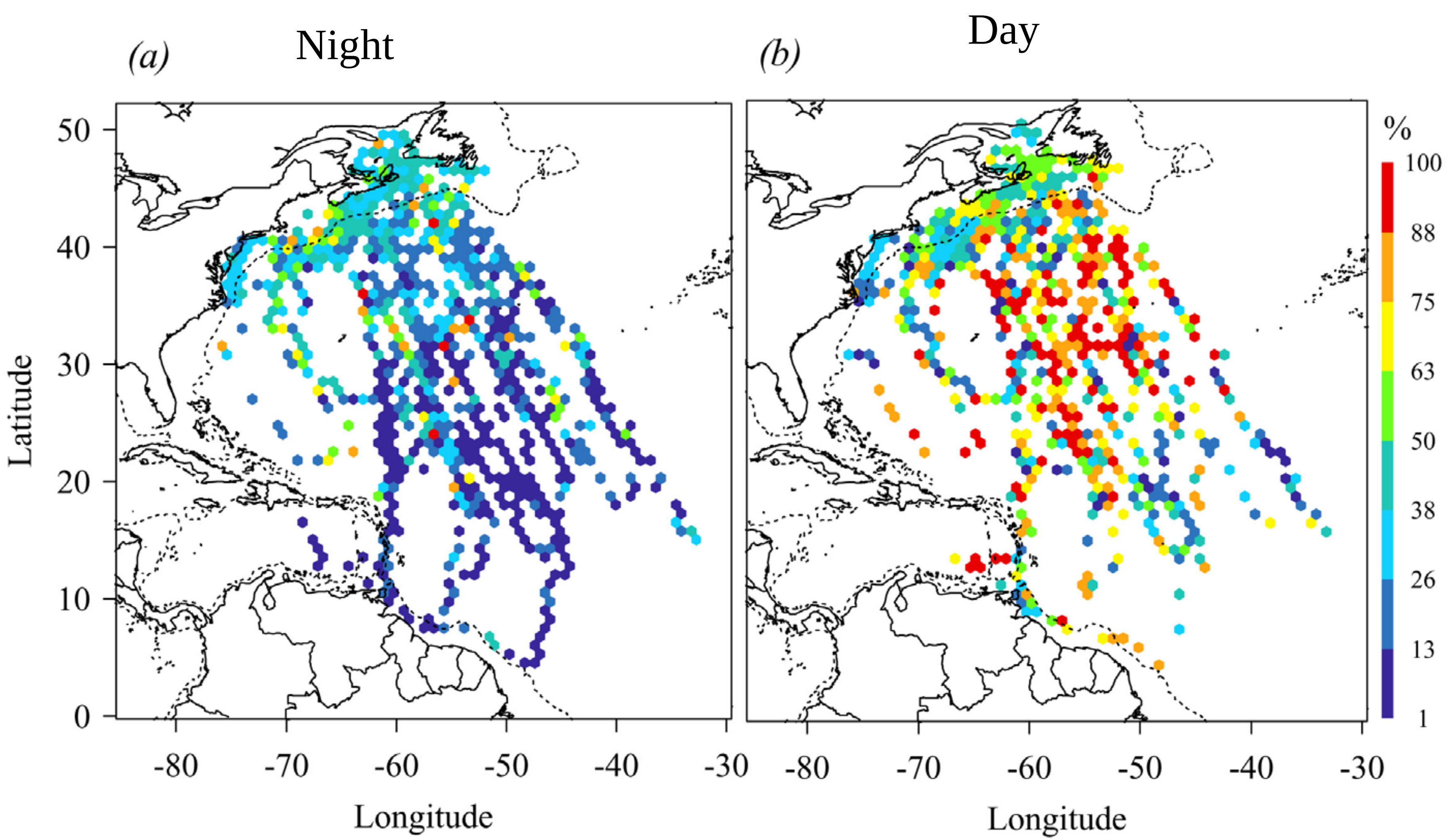


Turtles are close to the surface during the day during migration



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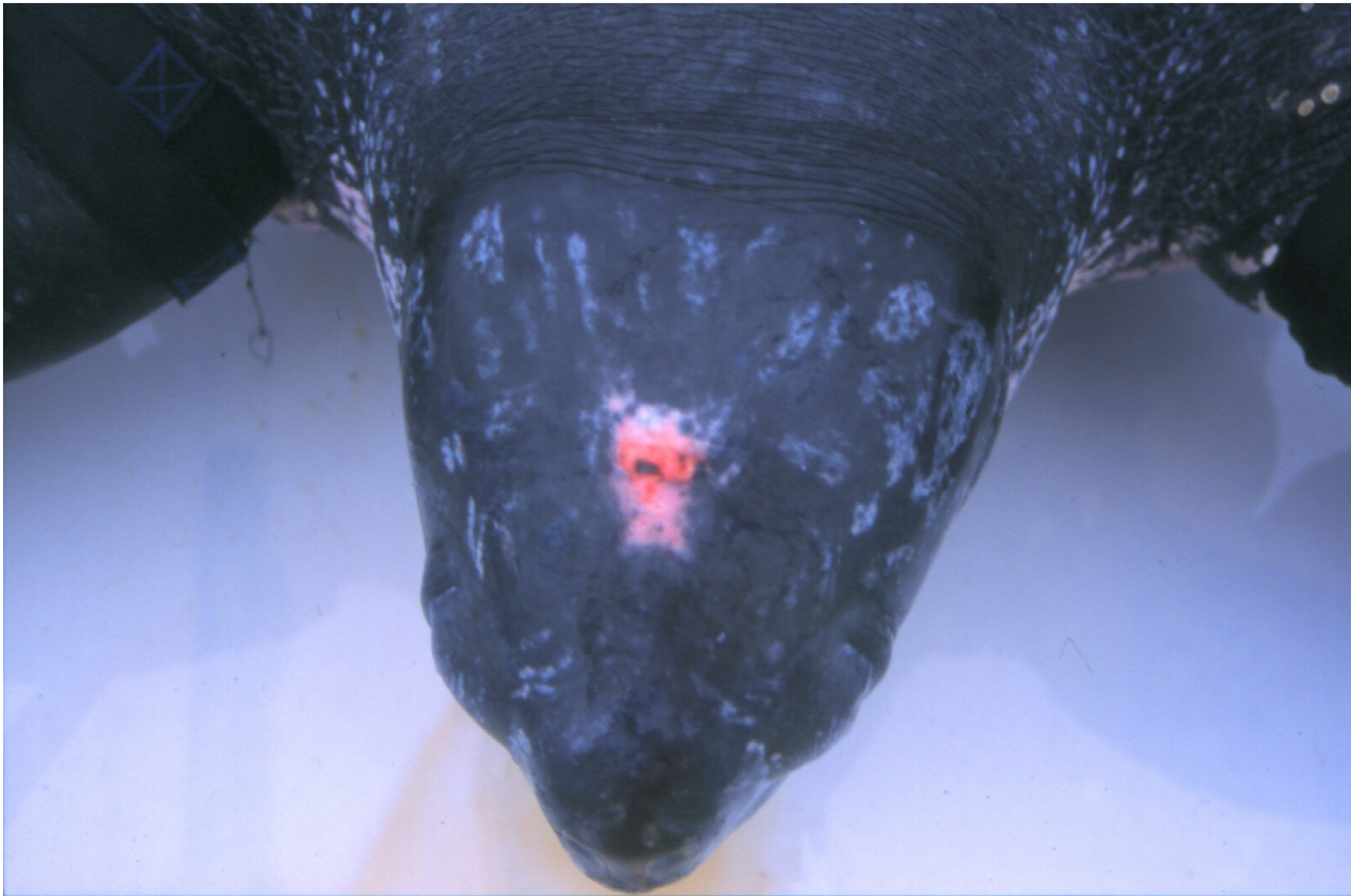
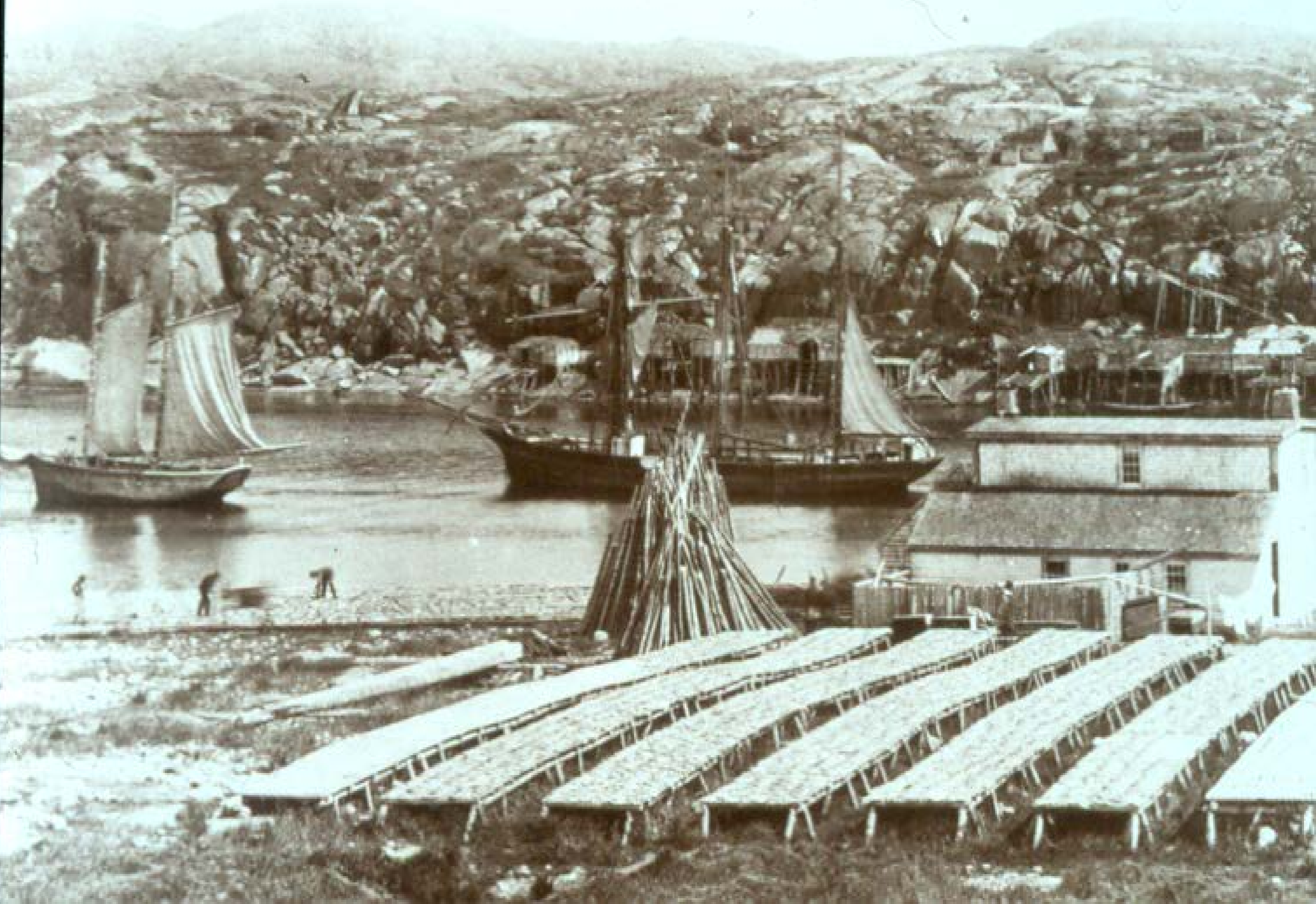
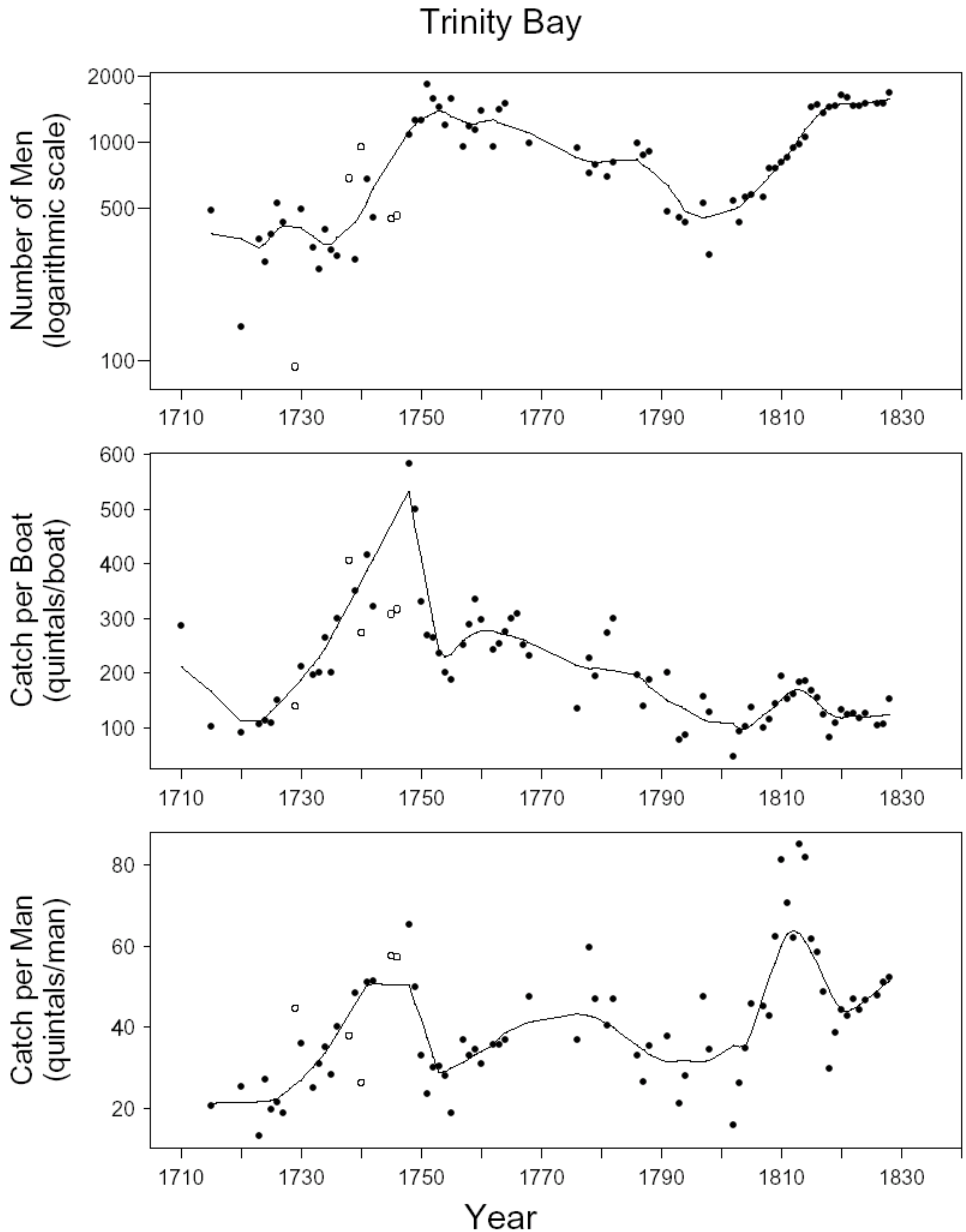
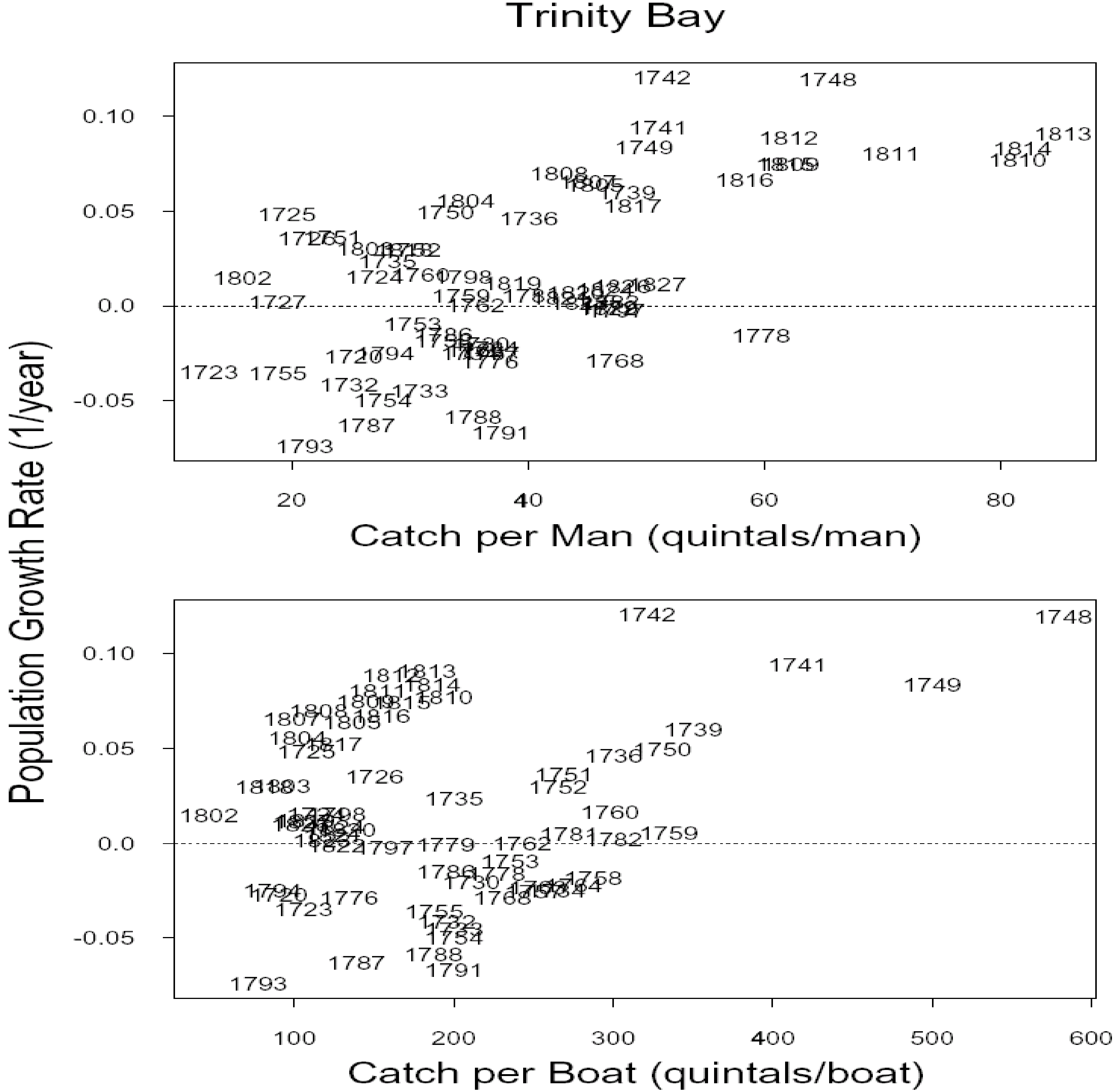


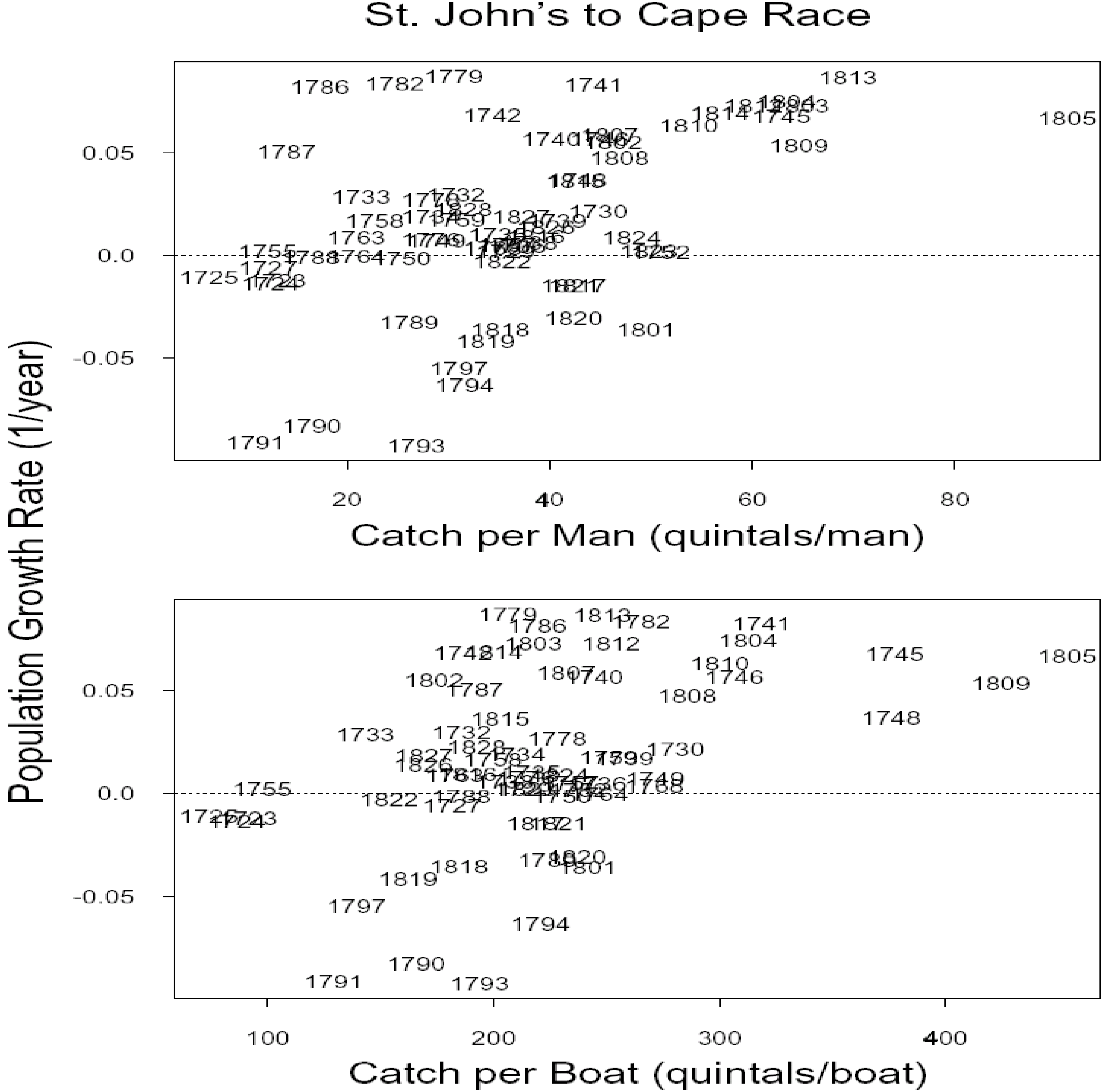
Real Historical Data

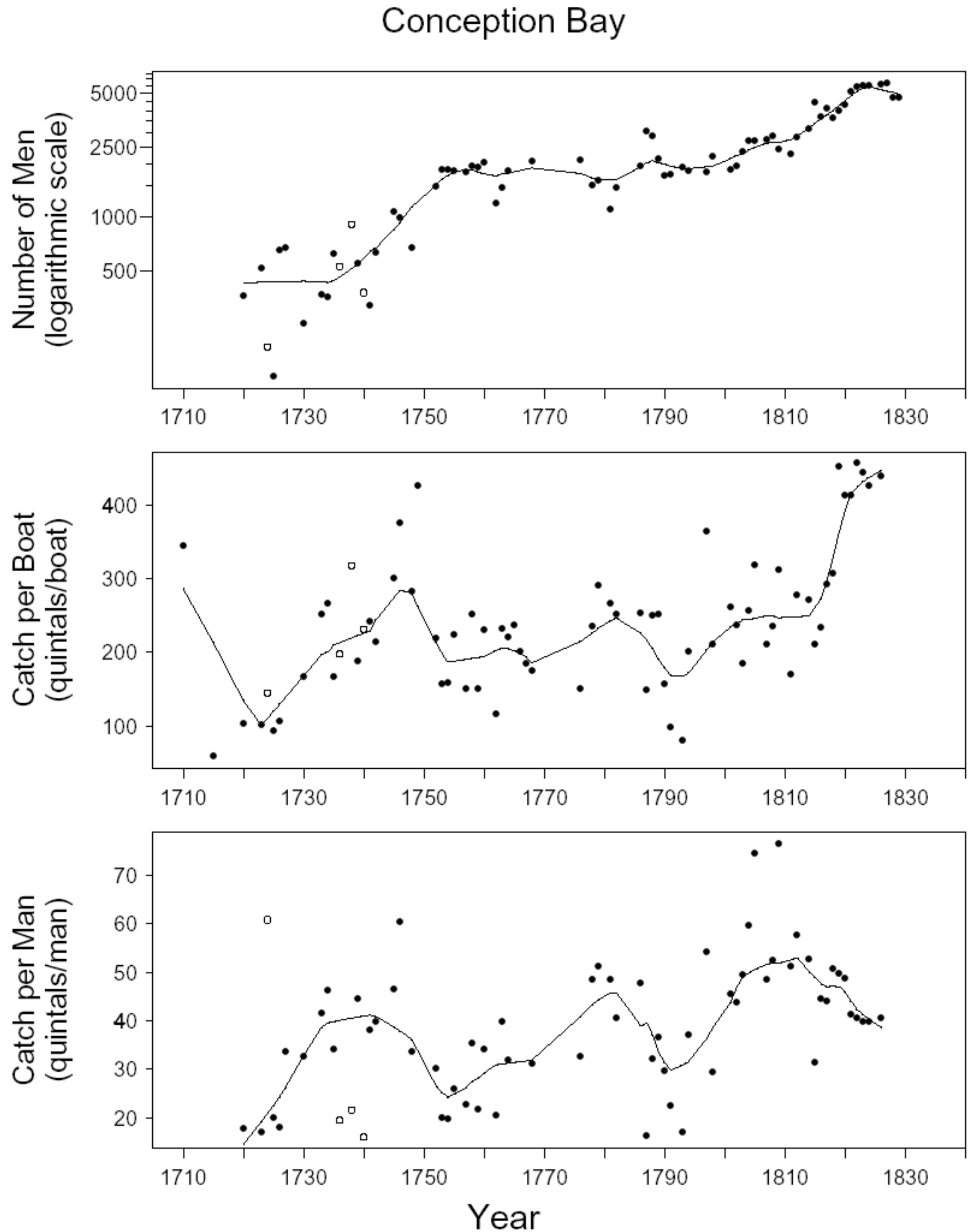


NEW BRITAIN
COUNTRY OF ESKIMAUX
ANTICOSTI
GULF
OF
S.T LAURENCE
NEW
FOUND
LAND
ESKIMAUX
Green Bank
Part of the Great Bank of N. Found Land
S. Peters Bank
Canso Bank
Sable I.
OF NOVA SCOTIA
A New & Accurate Map of the
Islands of
NEWFOUNDLAND, CAPE BRETON,
S.T JOHN and ANTICOSTA;
together with the Neighbouring
Countries of
NOVA SCOTIA, CANADA &c.
Drawn from the most approved Modern
Maps and Charts,
and Regulated by Astron.l Observat.s
By Eman. Bowen
Longitude West from London


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)
100
200
300
400
Catch per Boat (quintals/boat)

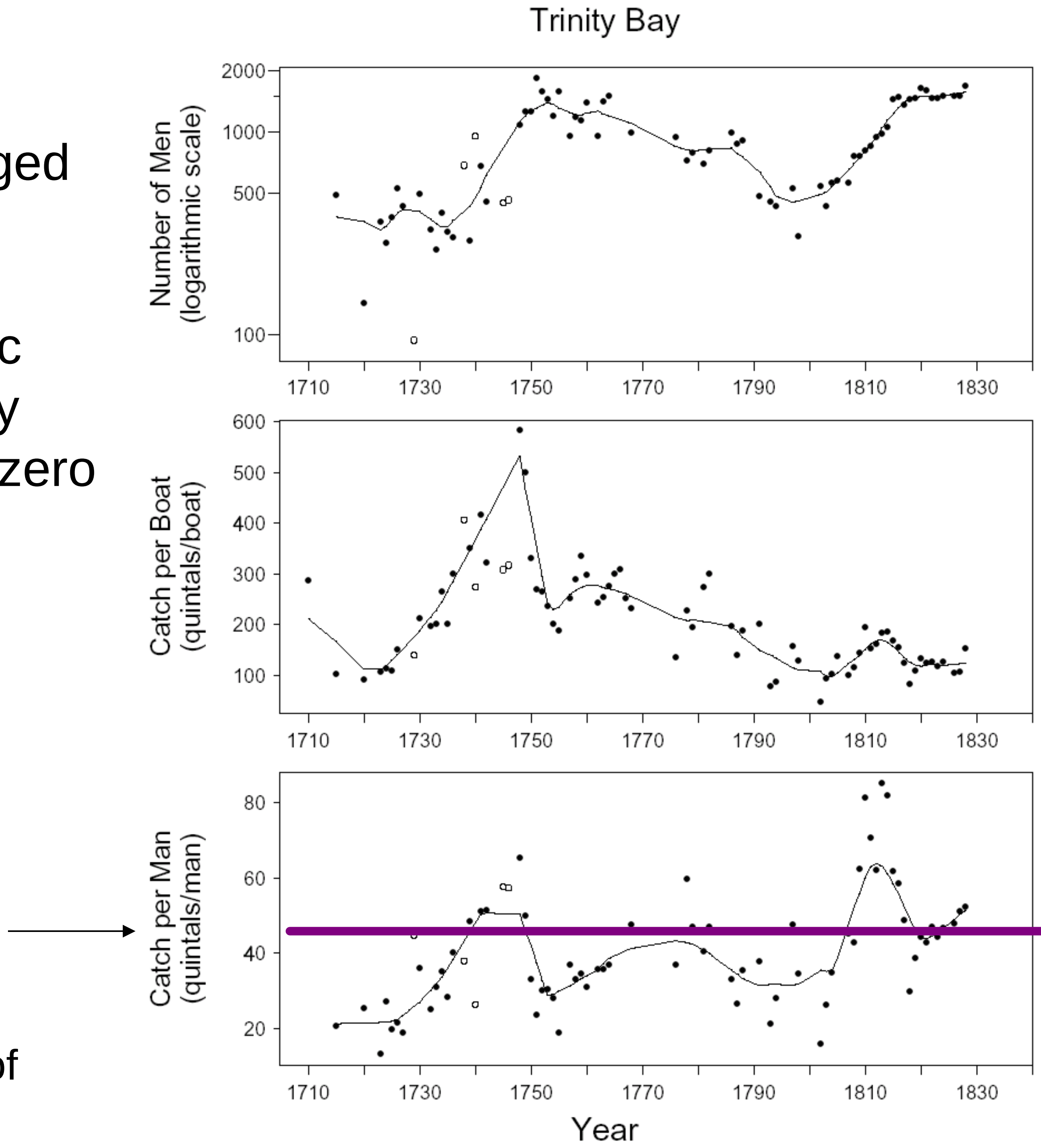


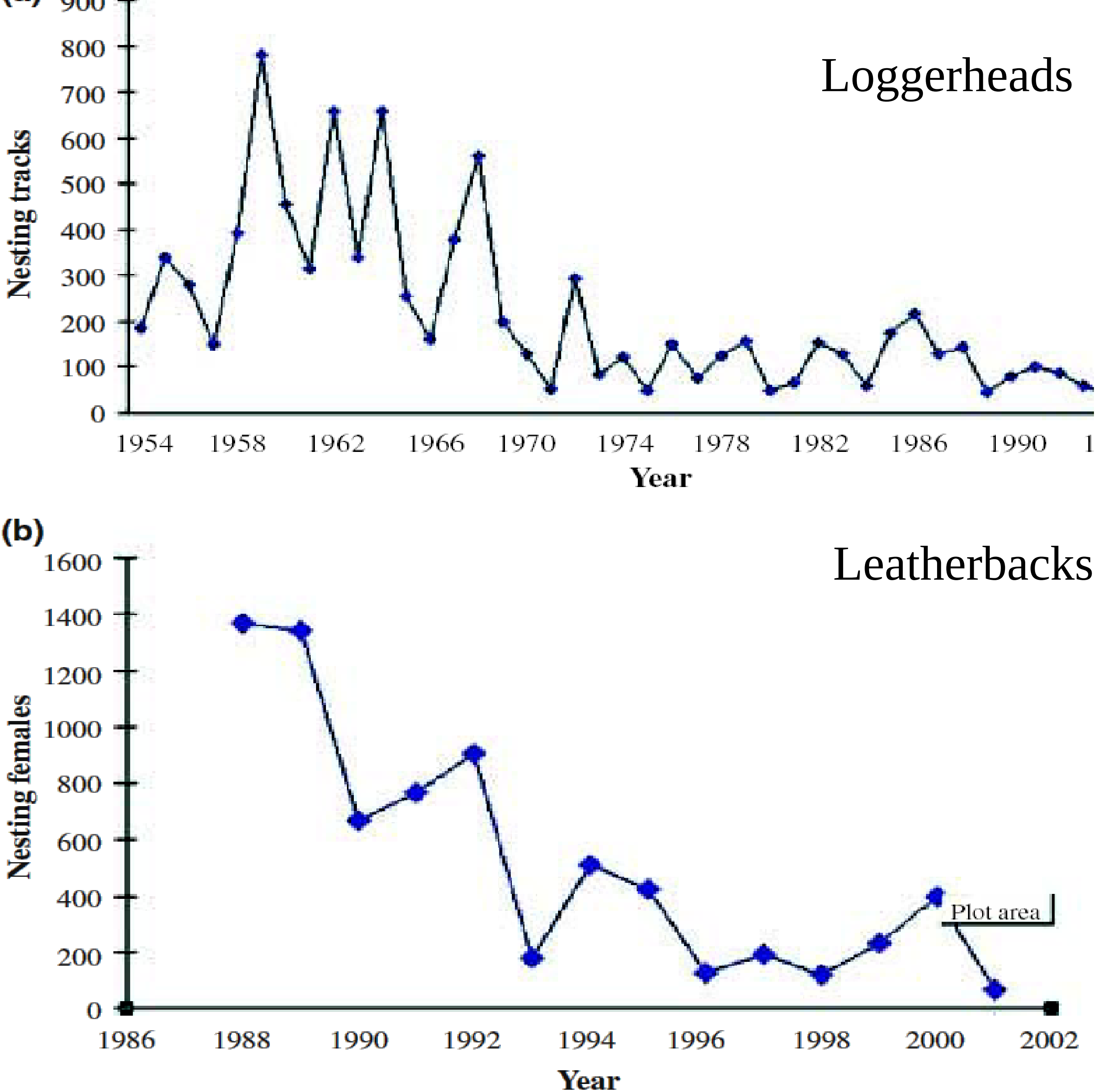
Conception Bay
Number of Men (logarithmic scale)
5000
2500
1000
500
Catch per Boat (quintals/boat)
400
300
200
100
Catch per Man (quintals/man)
70
60
50
40
30
20
1710
1730
1750
1770
1790
1810
1830
Year

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).

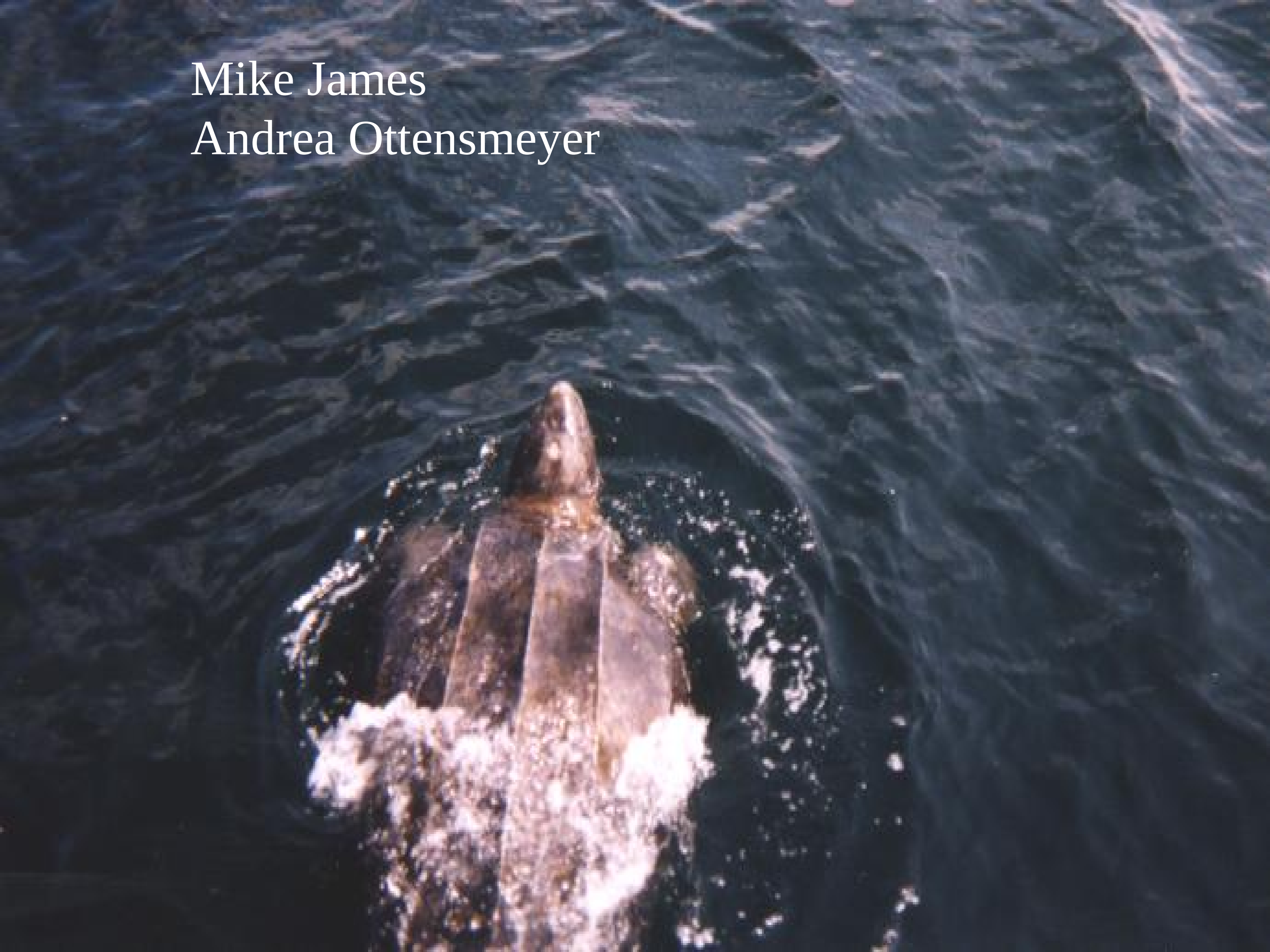




Lewison et al. 2004
Ecology Letters

Photo by Matthew Godfrey

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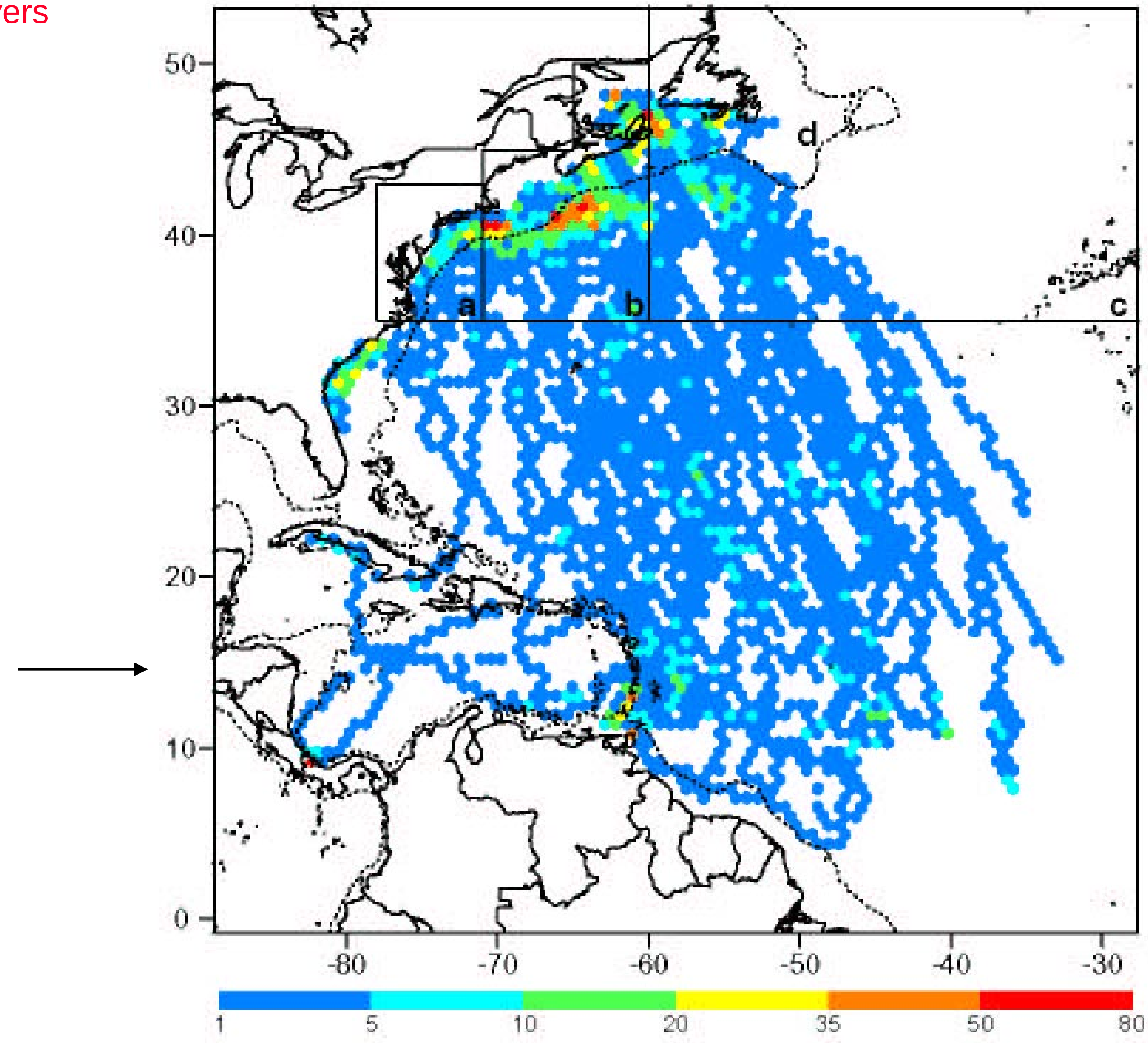

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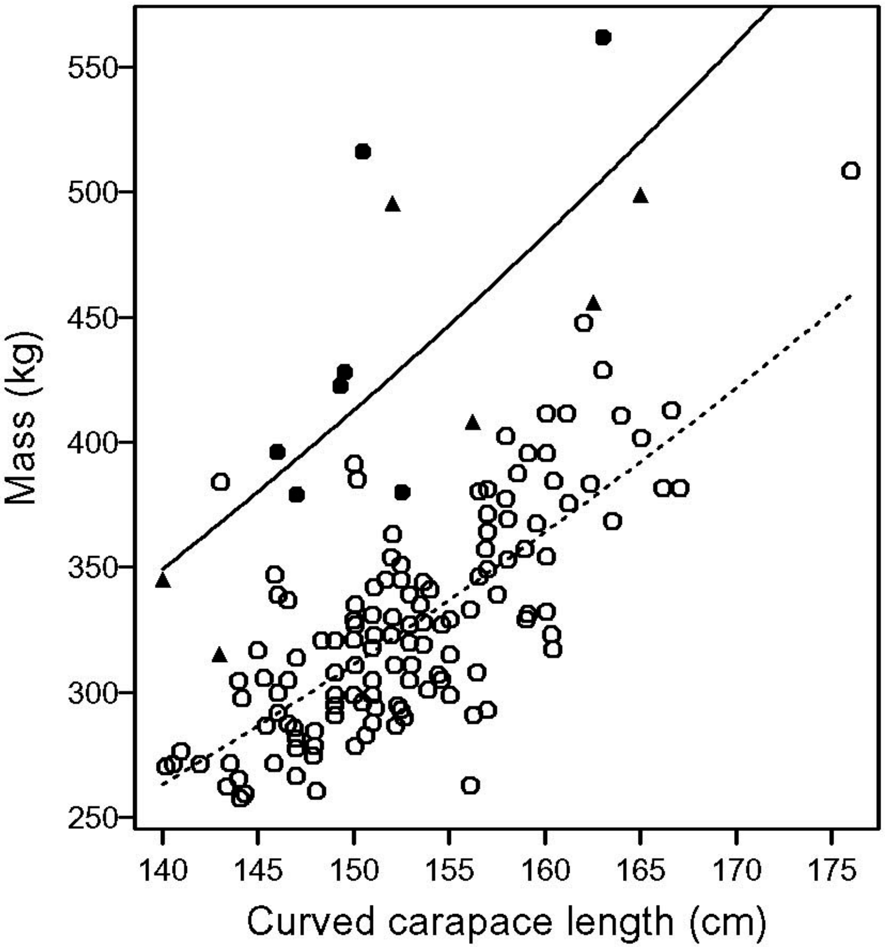

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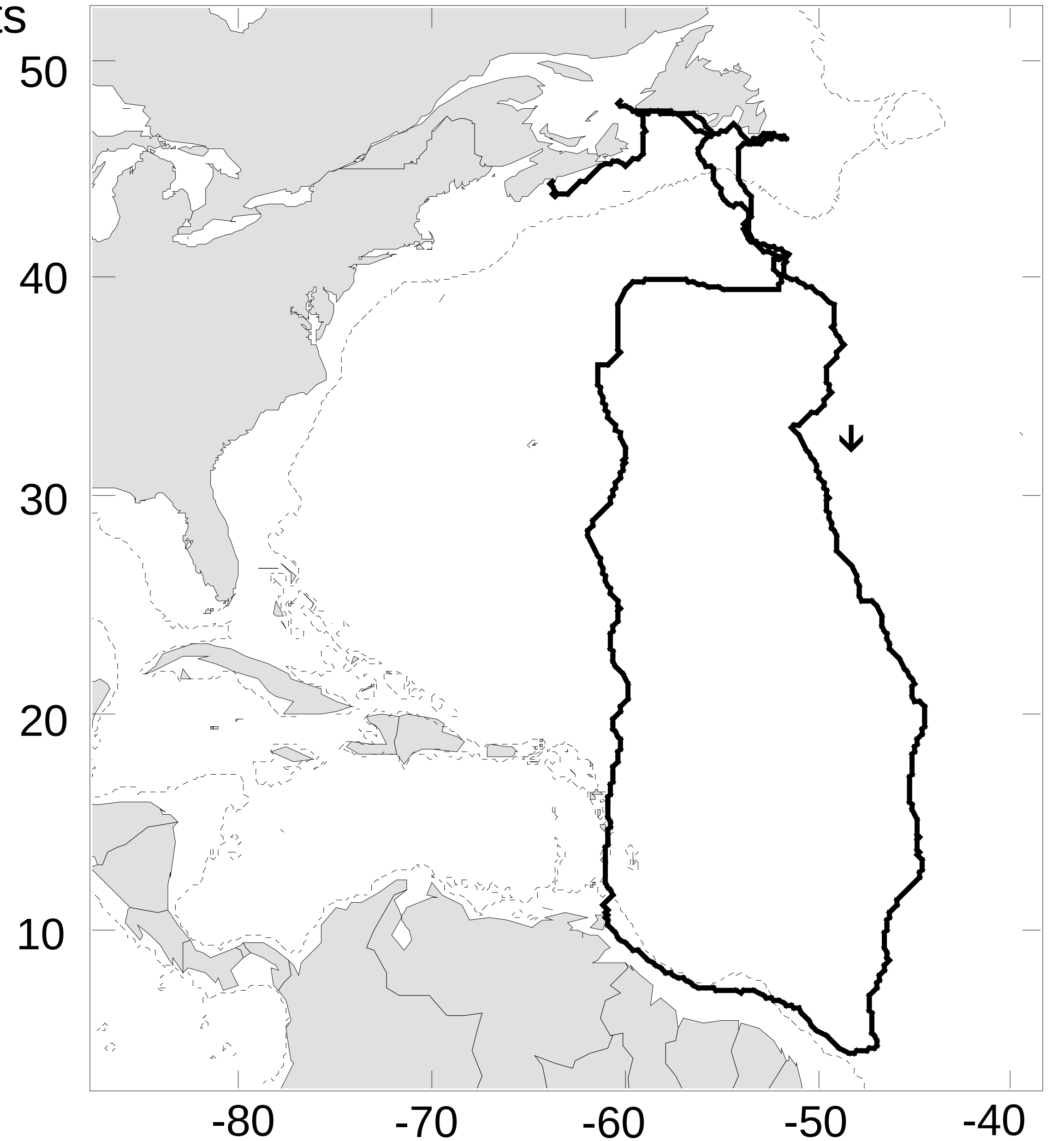

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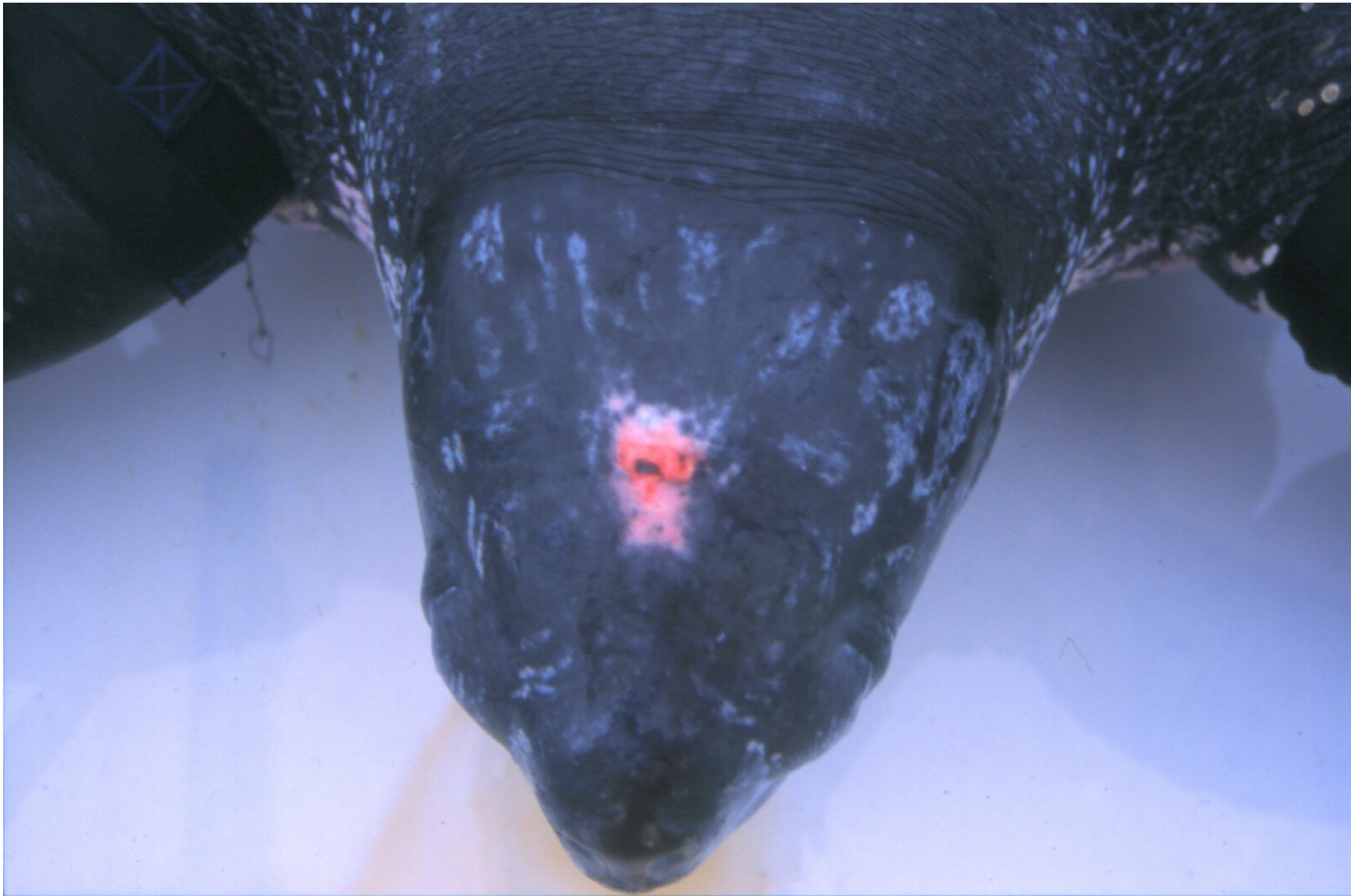

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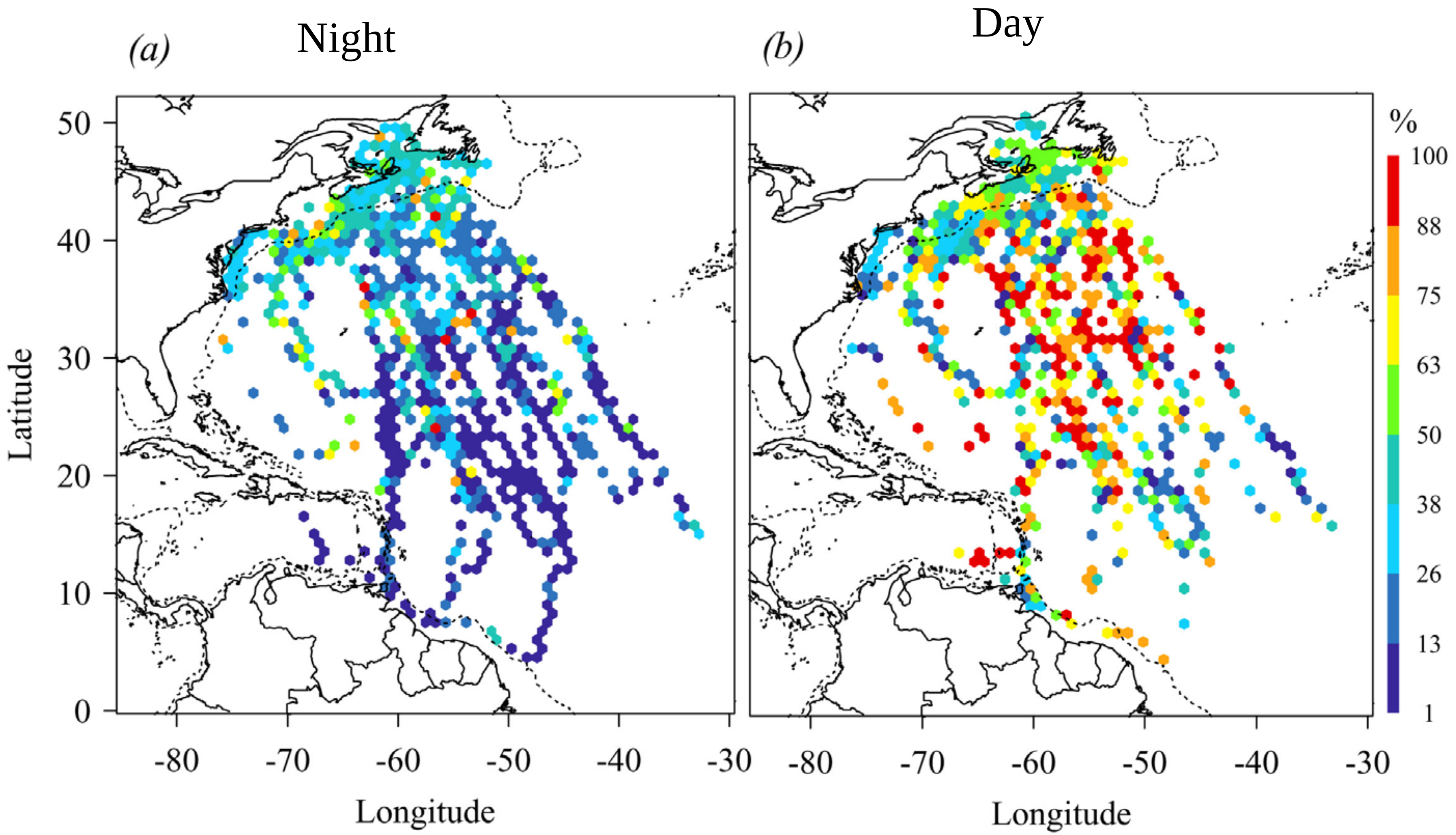
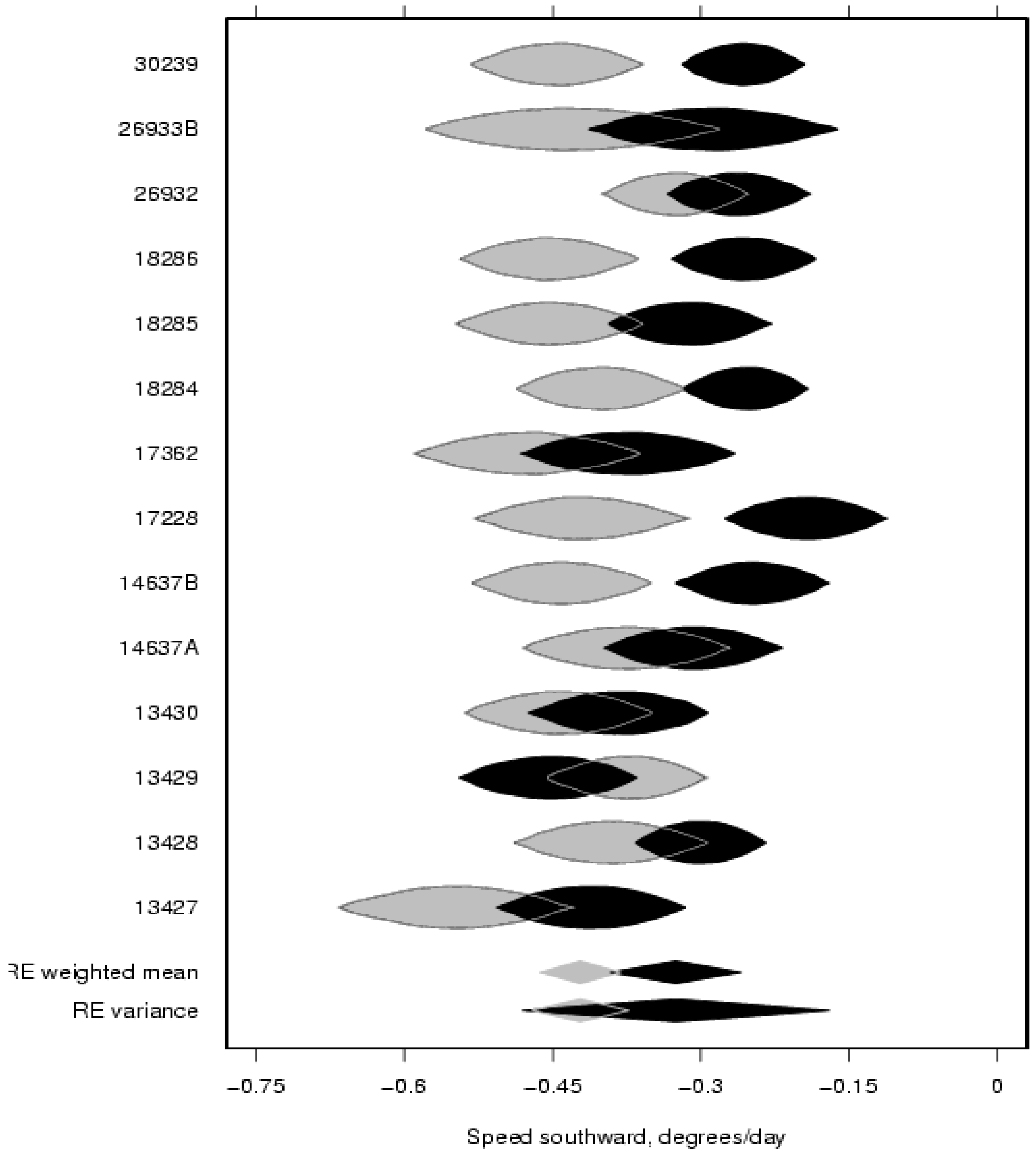


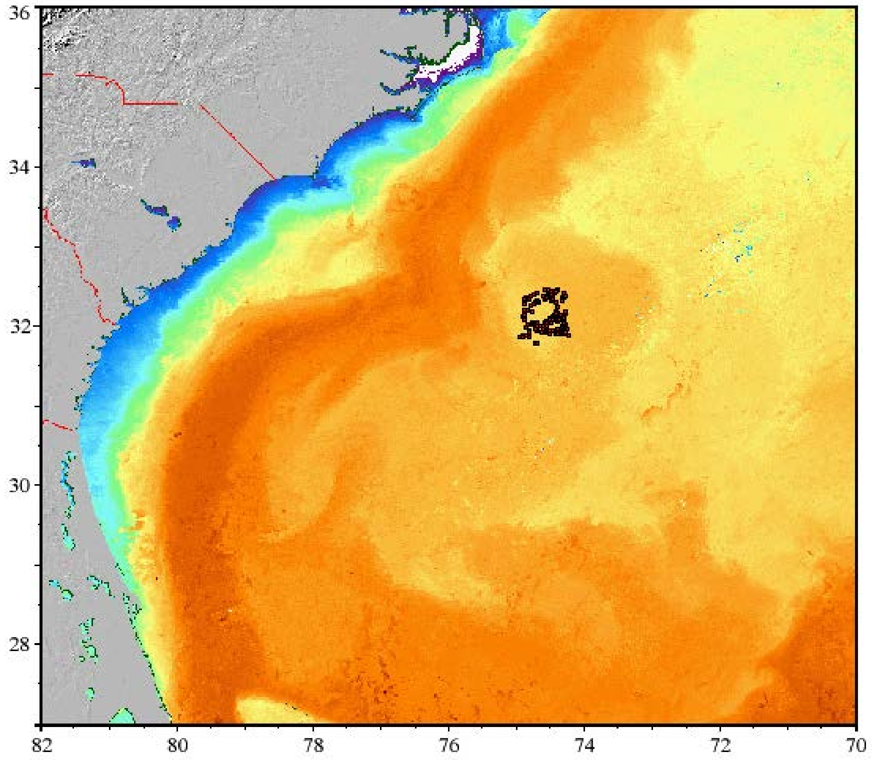
Turtles make more progress south during the day

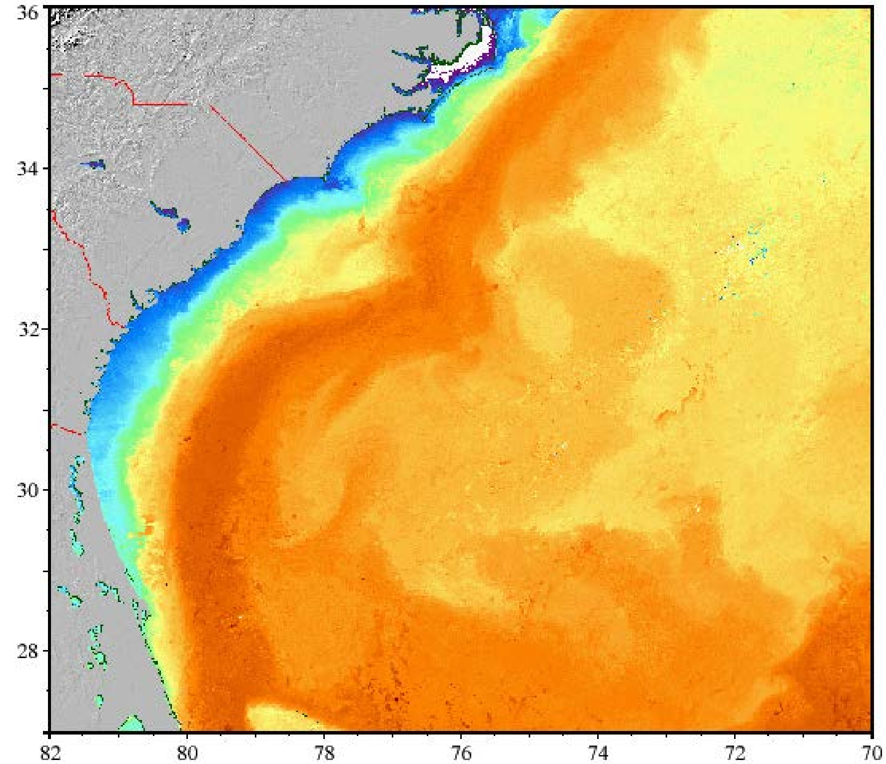


Totally Stupid Reasons for not Believing the Obvious

- 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: 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).

New Materials for Fishing Gear Double Efficiency

Results from paired experiment
M – Monofilament
B – Multifilament (old gear)

Design, every other gangion was monofilament

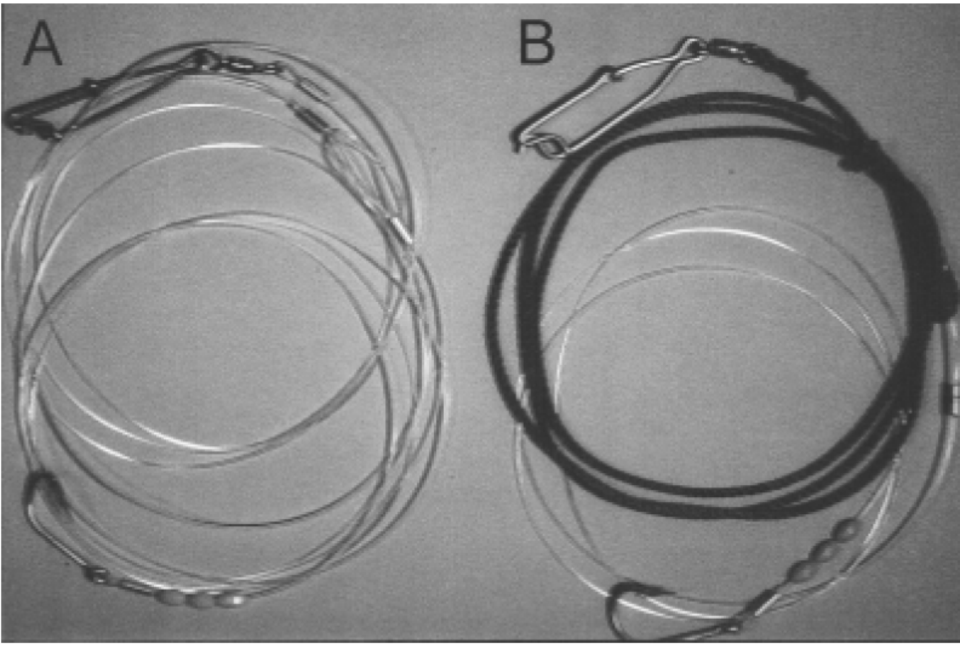
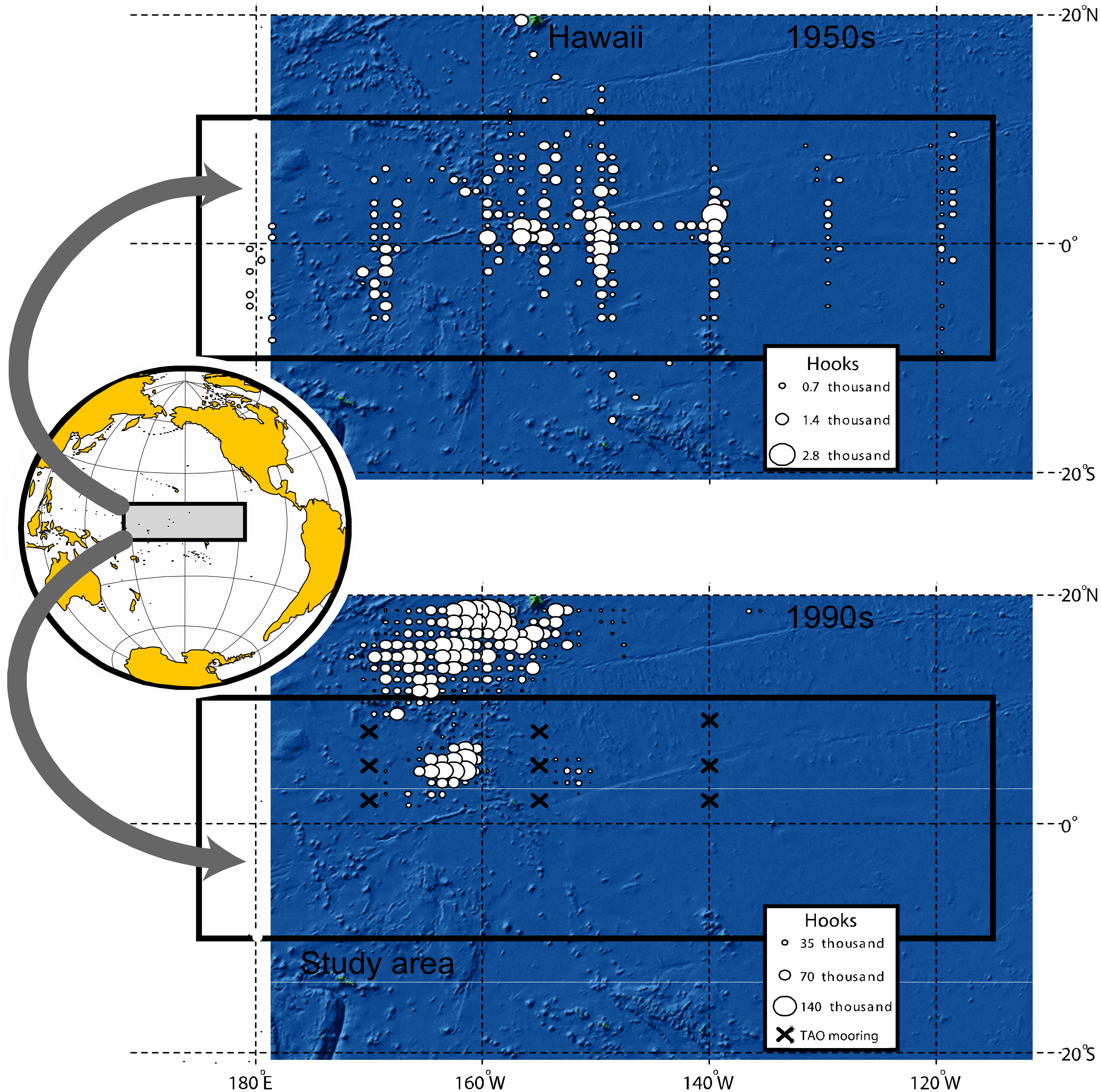
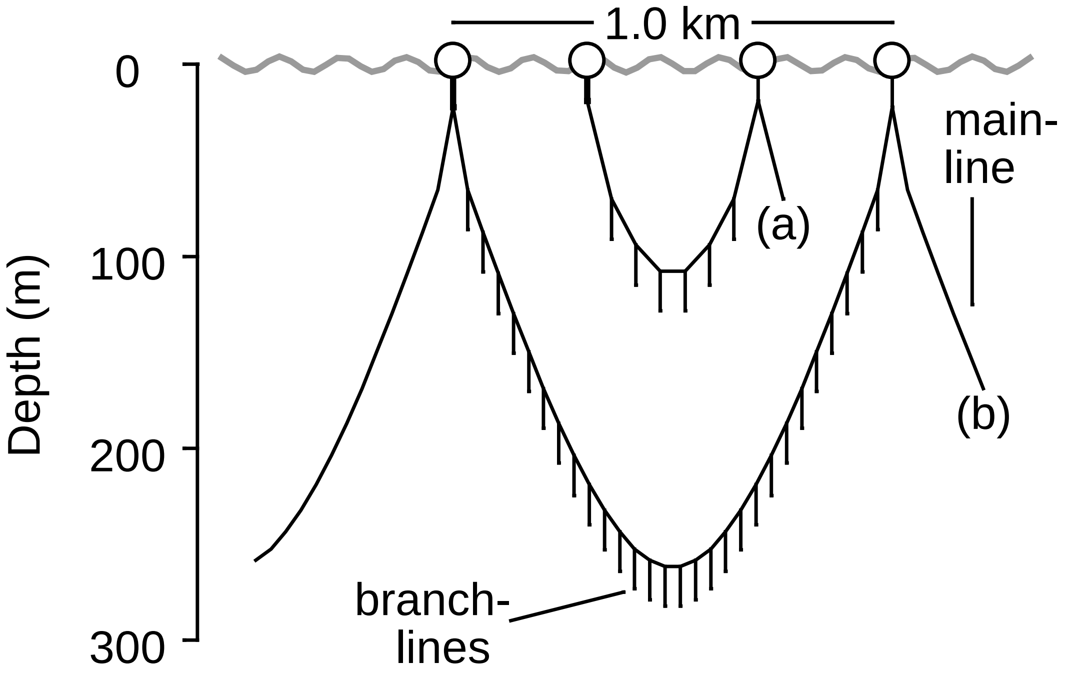


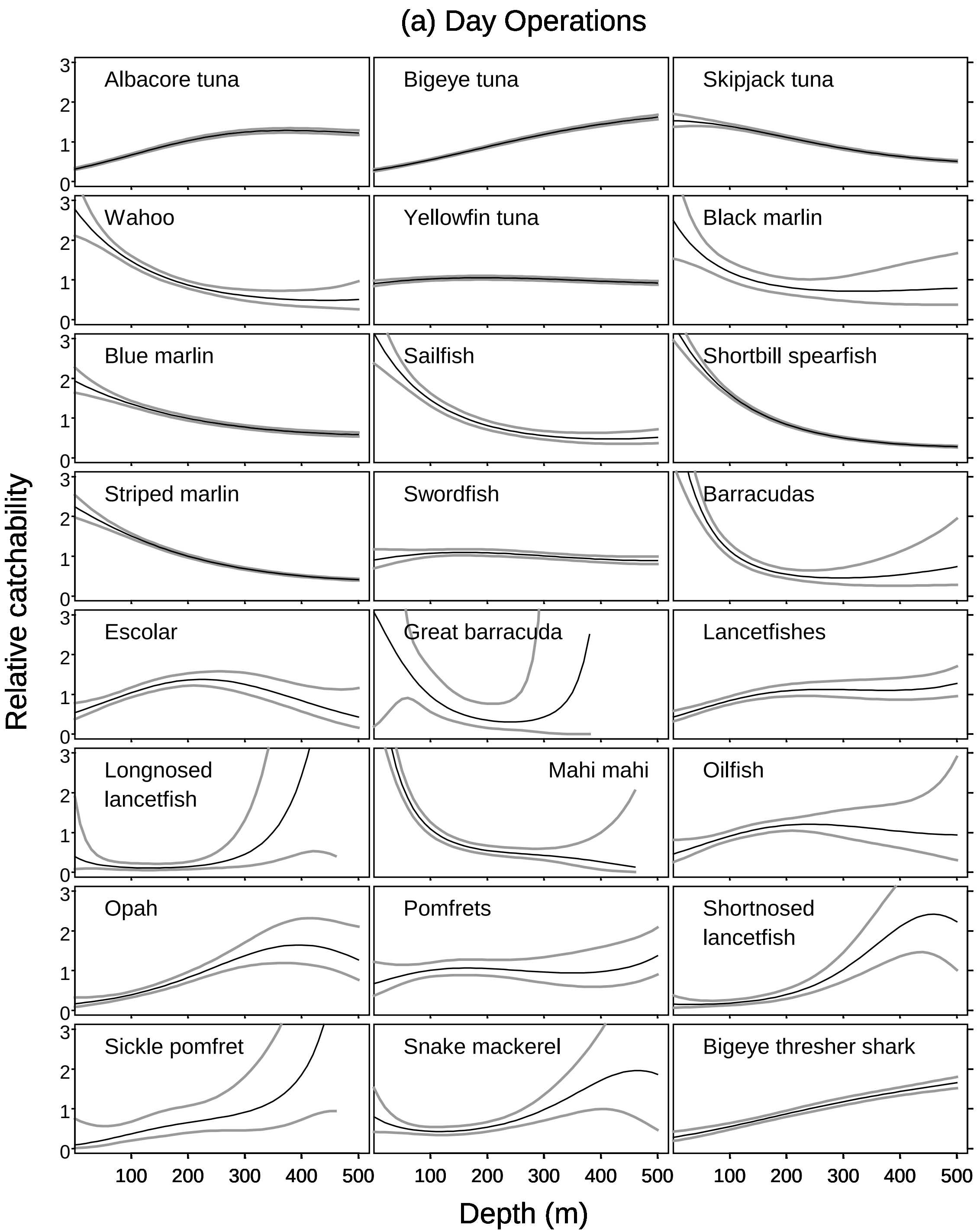
Figure 3
Monofilament nylon (A) and tarred multifilament nylon (B) gangions used for ten pelagic longline sets conducted off Georges Bank from 22 July to 2 August 1999.

Species	Gangion	n
Swordfish	M	260
	B	128
Yellowfin tuna	M	9
	B	1
Mako shark	M	58
	B	39
Blue shark	M	225
	B	116
White marlin	M	47
	B	13
Dolphinfish	M	27
	B	10
Stingray	M	63
	B	31
Loggerhead turtle	M	40
	B	26
Total	M	729
	B	364



Hawaii
1950s
Hooks
0.7 thousand
1.4 thousand
2.8 thousand
1990s
Study area
Hooks
35 thousand
70 thousand
140 thousand
TAO mooring
20°N
0°
20°S
180°E
160°W
140°W
120°W


1.0 km
0
100
200
300
Depth (m)
main-
line
(a)
(b)
branch-
lines



(a) Day Operations
Albacore tuna
Bigeye tuna
Skipjack tuna
Wahoo
Yellowfin tuna
Black marlin
Blue marlin
Sailfish
Shortbill spearfish
Striped marlin
Swordfish
Barracudas
Escolar
Great barracuda
Lancetfishes
Longnosed lancetfish
Mahi mahi
Oilfish
Opah
Pomfrets
Shortnosed lancetfish
Sickle pomfret
Snake mackerel
Bigeye thresher shark
Relative catchability
Depth (m)
0
1
2
3
100
200
300
400
500

Ecosystem changes are consistent with a 10 fold decline in predation

- Key prey species would be predicted to increase by the changes in predation rate

Table 7. The occurrence of bramidae and gempylidae in tuna and billfish stomach contents in other studies.

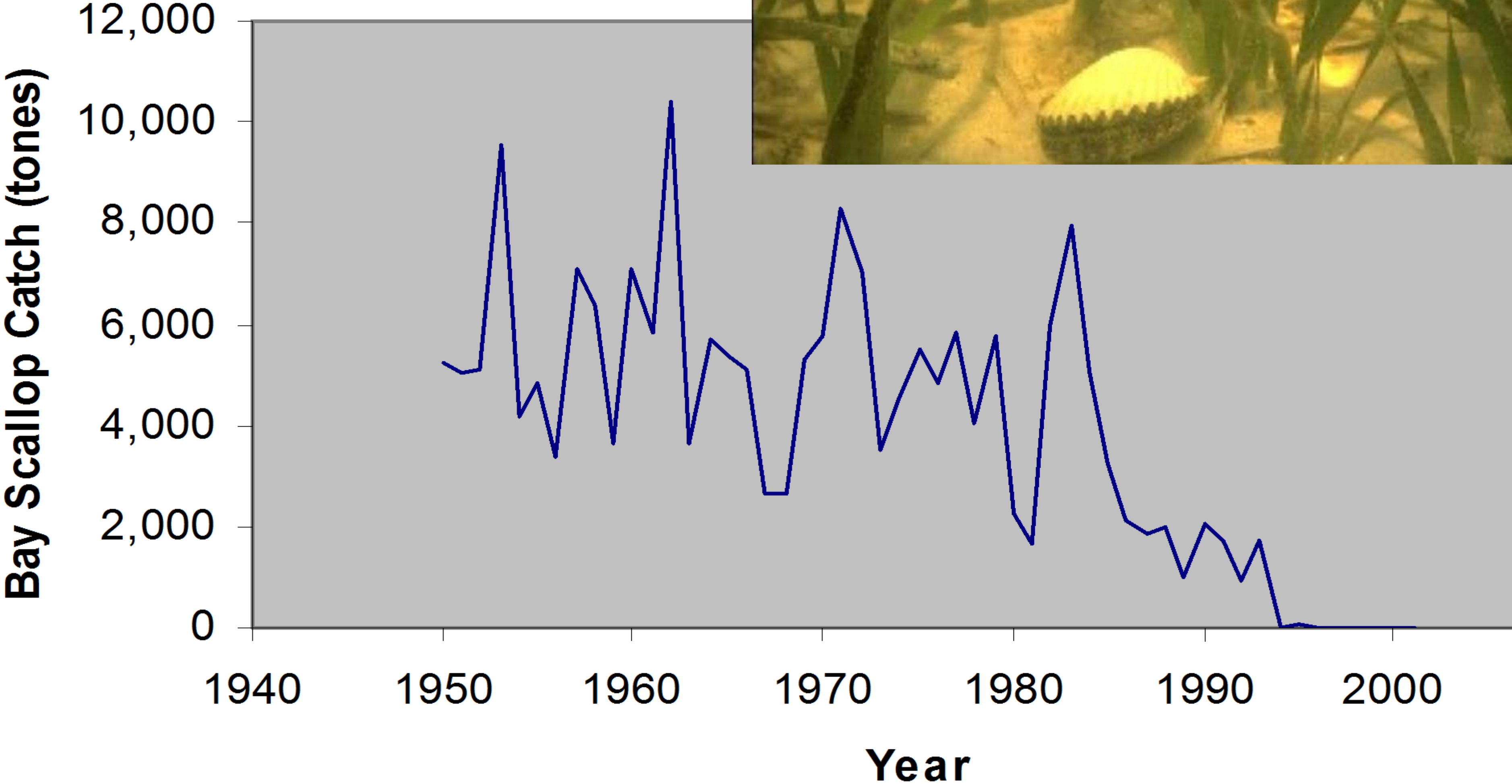
species	Bramidae	Gempylidae	Literature	Region
Bigeye tuna	High	low	Moteki *et al.* (2001)	Pacific
	High	no	Mattews *et al.* (1977)	Atlantic
Yellowfin tuna	High	low	Moteki *et al.* (2001)	Pacific
	High	low	Mattews *et al.* (1977)	Atlantic
Albacore	High	High	Mattews *et al.* (1977)	Atlantic
Sword fish	High	low	Moteki *et al.* (2001)	Pacific

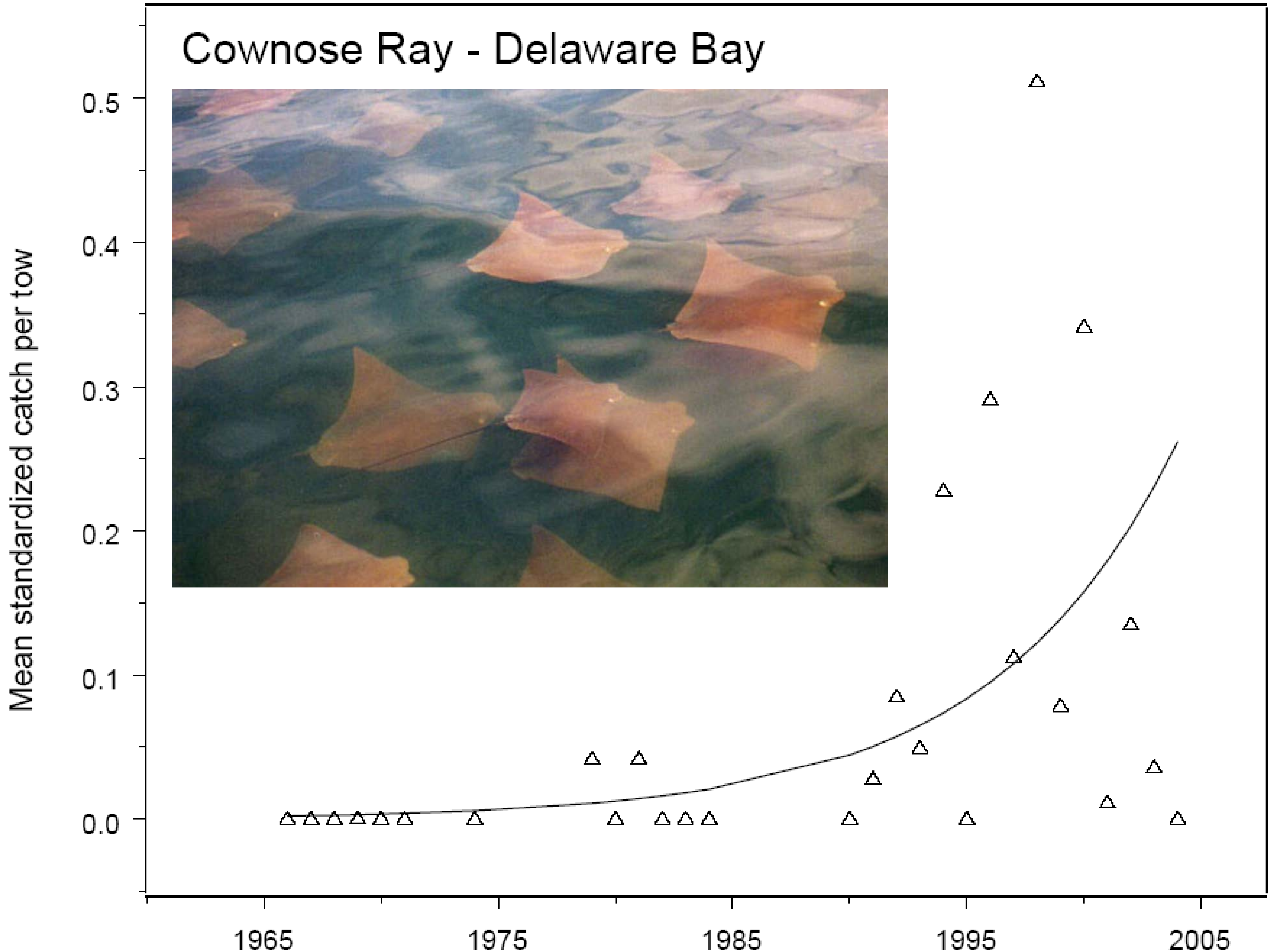
PRELIMINARY STOMACH CONTENTS ANALYSIS OF PELAGIC FISH COLLECTED BY SHOYO-MARU 2002 RESEARCH CRUISE IN THE ATLANTIC OCEAN

Keisuke Satoh[1], Kotaro Yokawa[1], Hirokazu Saito[1], Hiromasa Matsunaga[1], Hiroaki Okamoto[1] and Yuji Uozumi[1]

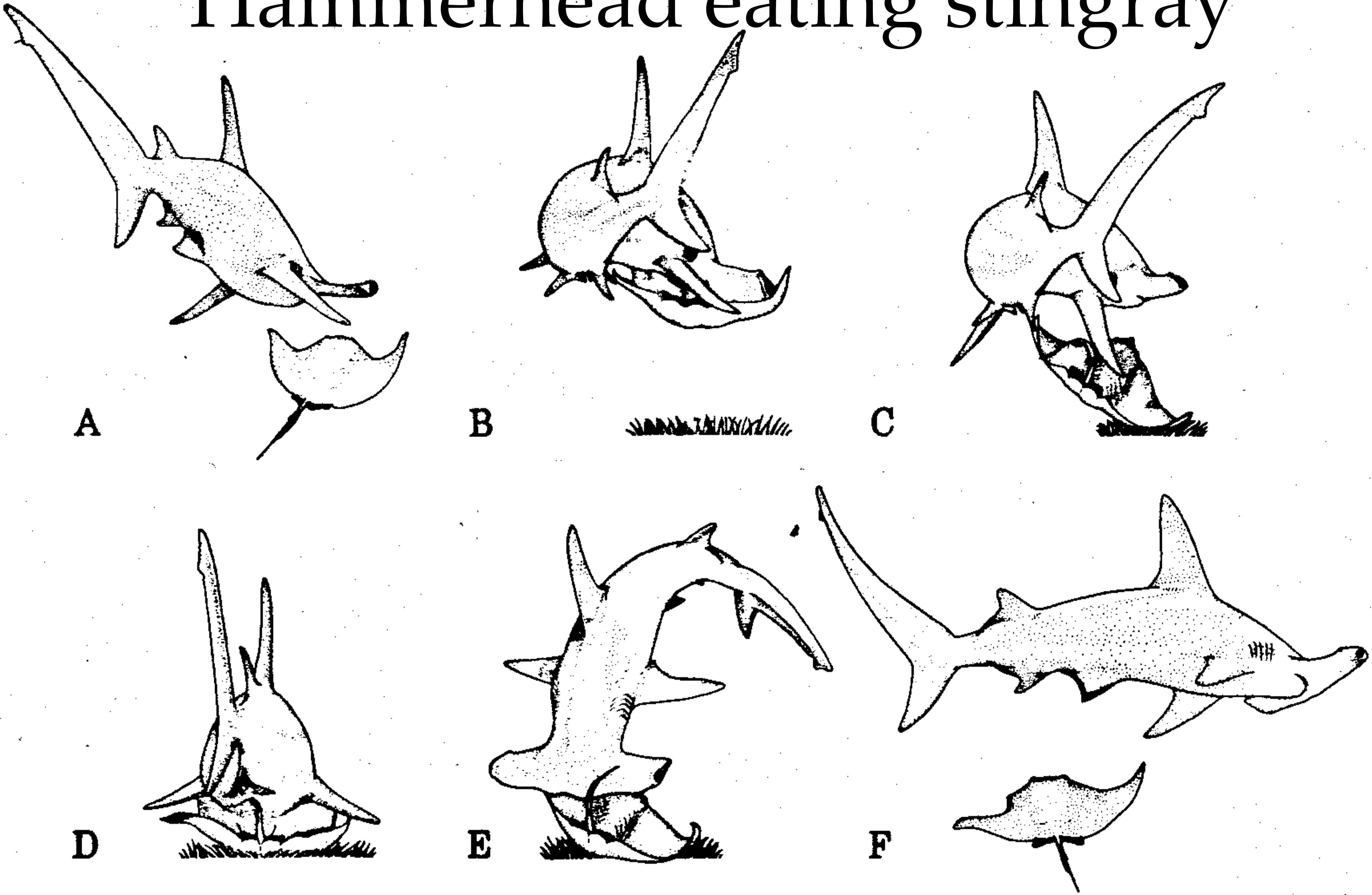
Col. Vol. Sci. Pap. ICCAT, 56(3): 1096-1114 (2004)

Bay Scallops Northeast US



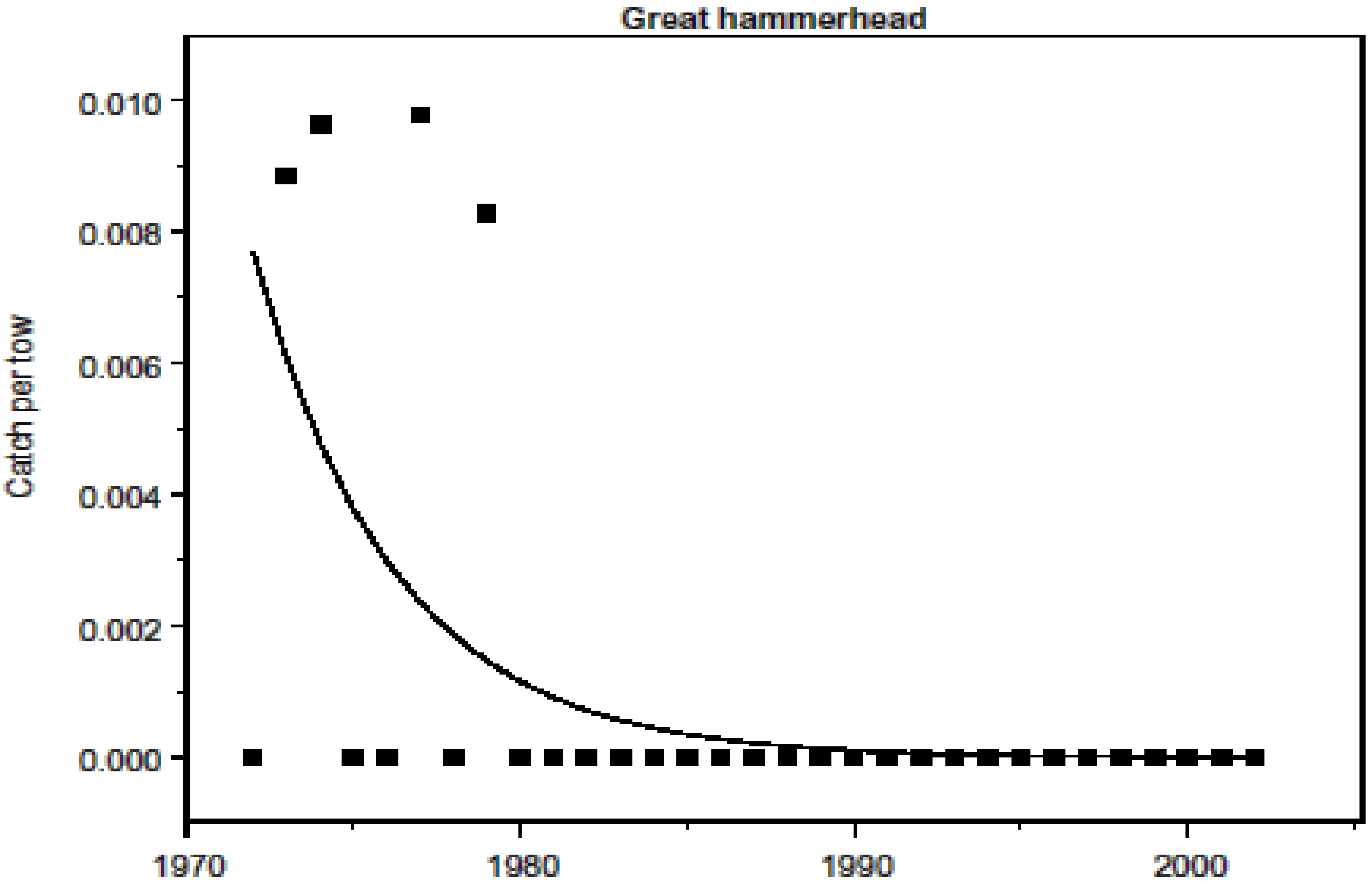

Cownose Ray - Delaware Bay
Mean standardized catch per tow
0.0
0.1
0.2
0.3
0.4
0.5
1965
1975
1985
1995
2005

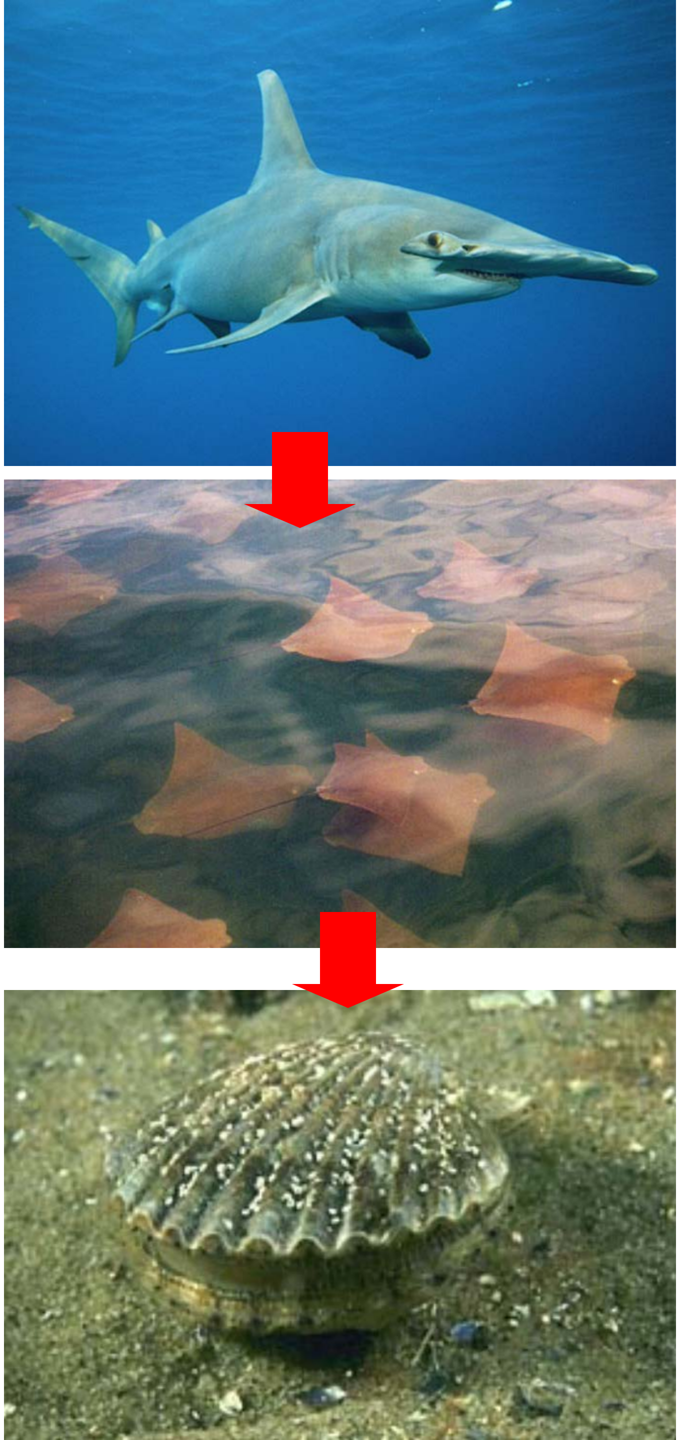
Hammerhead eating stingray

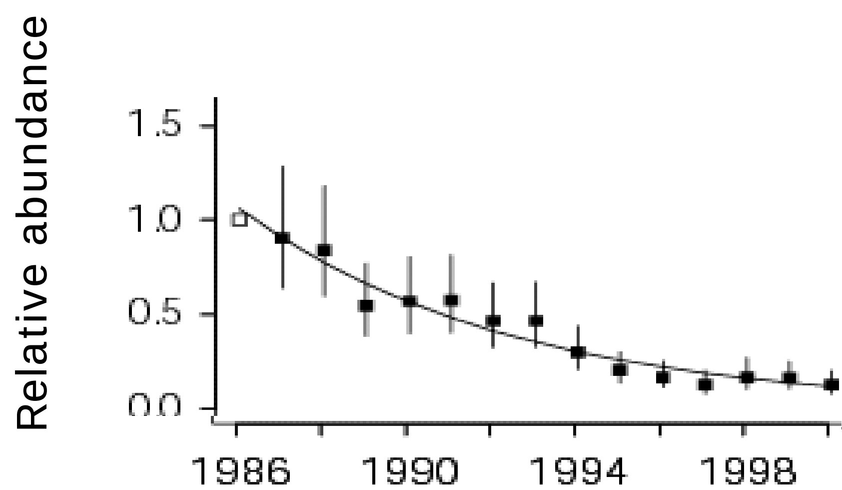


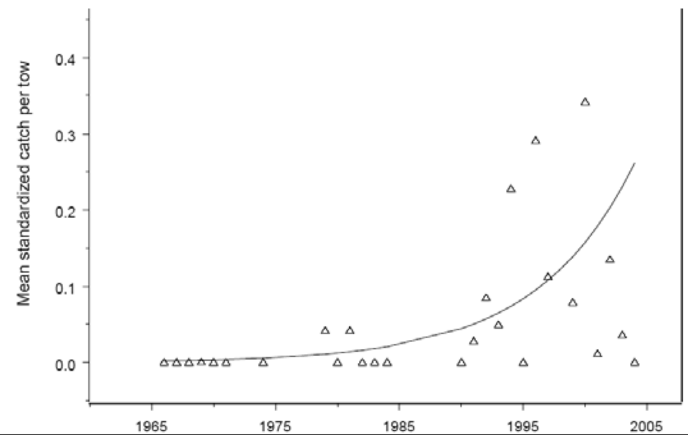
Strong, W.R. Jr; Snelson, F.F. Jr; Gruber, S.H. Copeia 1990, 836-839

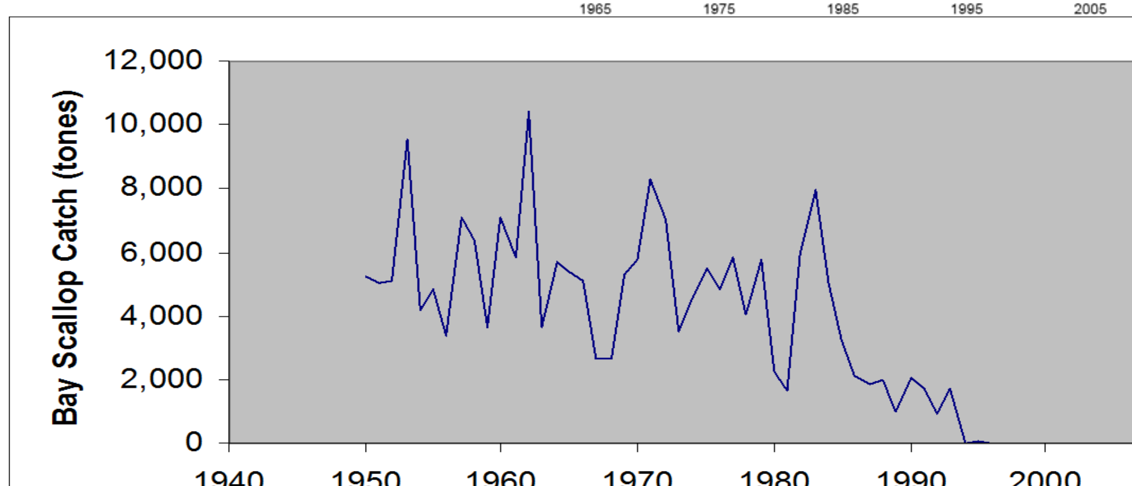
Loss of hammerheads from surveys

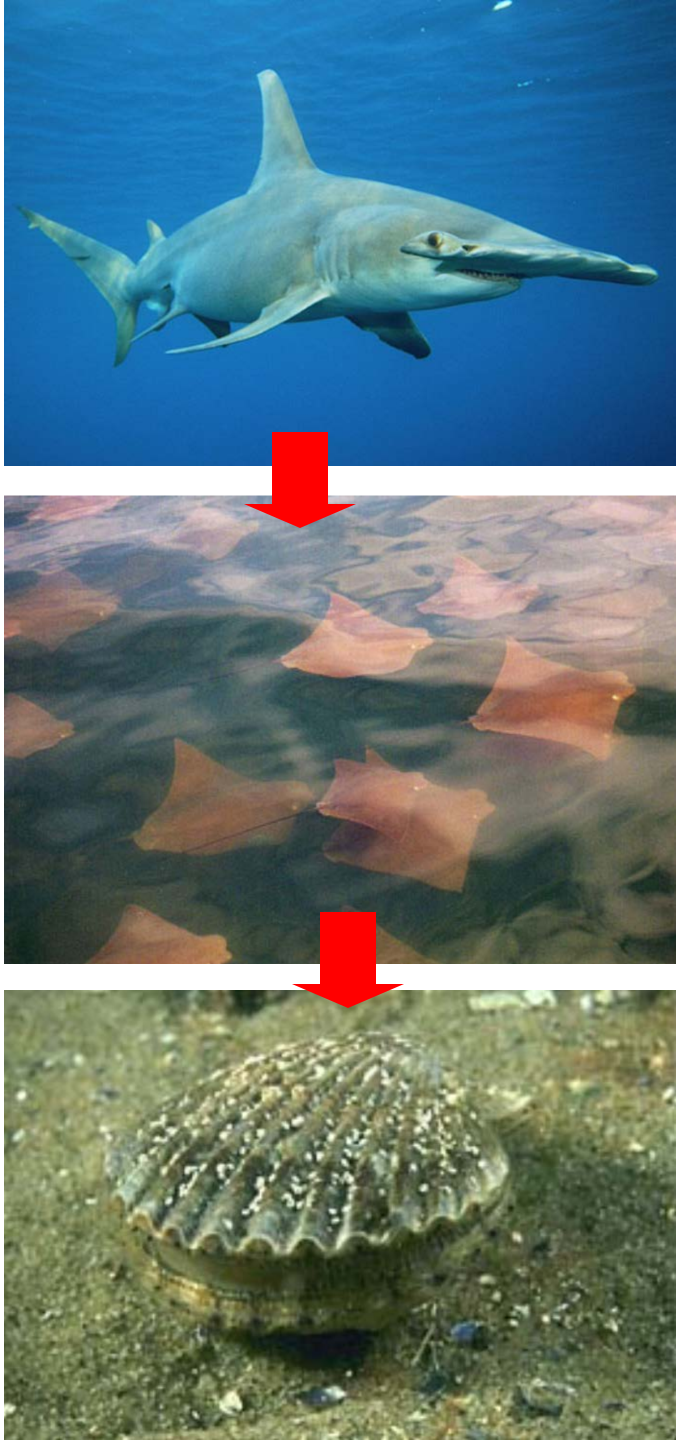





Relative abundance
1.5
1.0
0.5
0.0
1986
1990
1994
1998

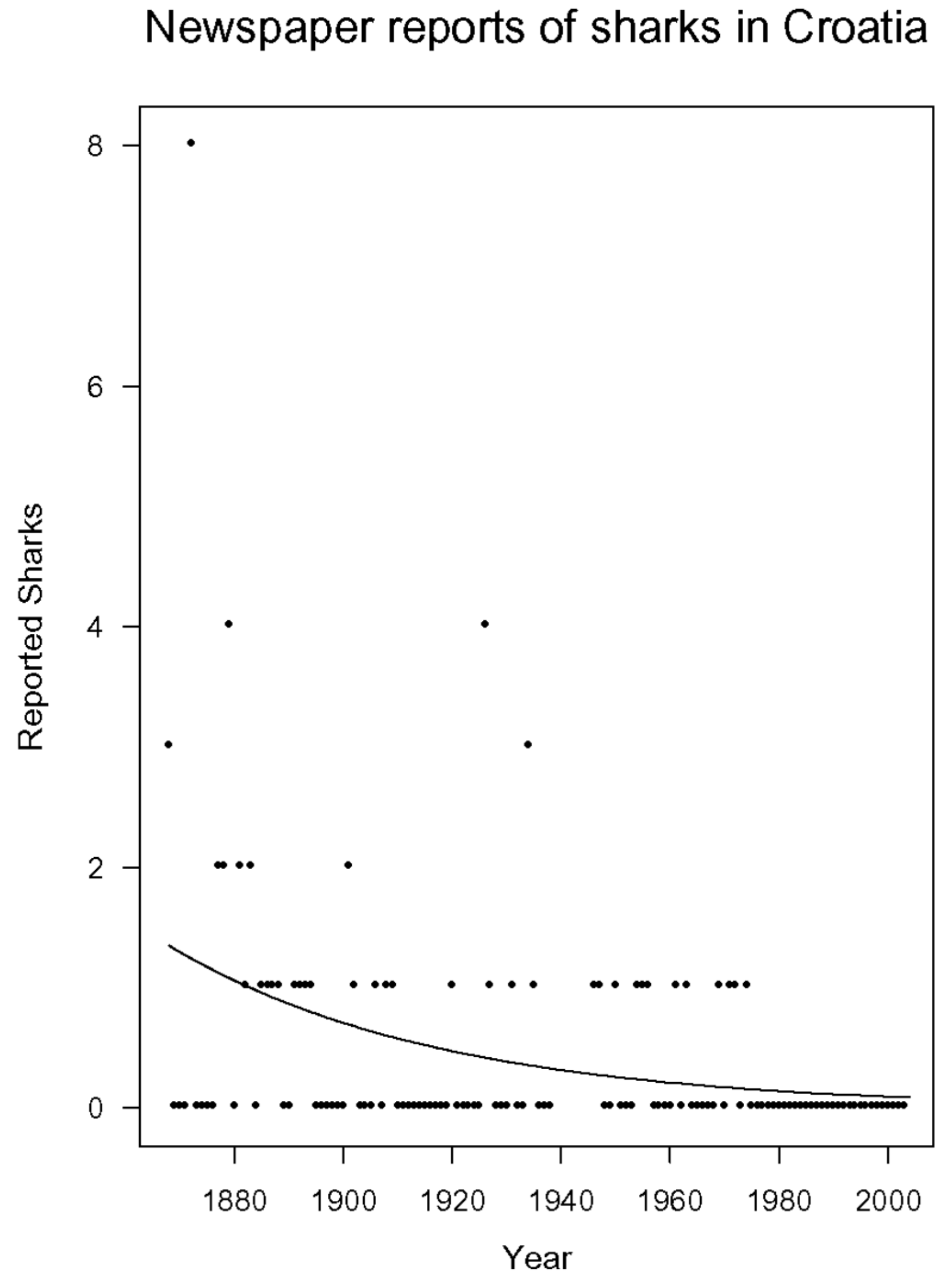

Mean standardized catch per tow
0.4
0.3
0.2
0.1
0.0
1965
1975
1985
1995
2005


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



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

Fitting a simple model to crazy data can yield reliable, and very powerful conclusions



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

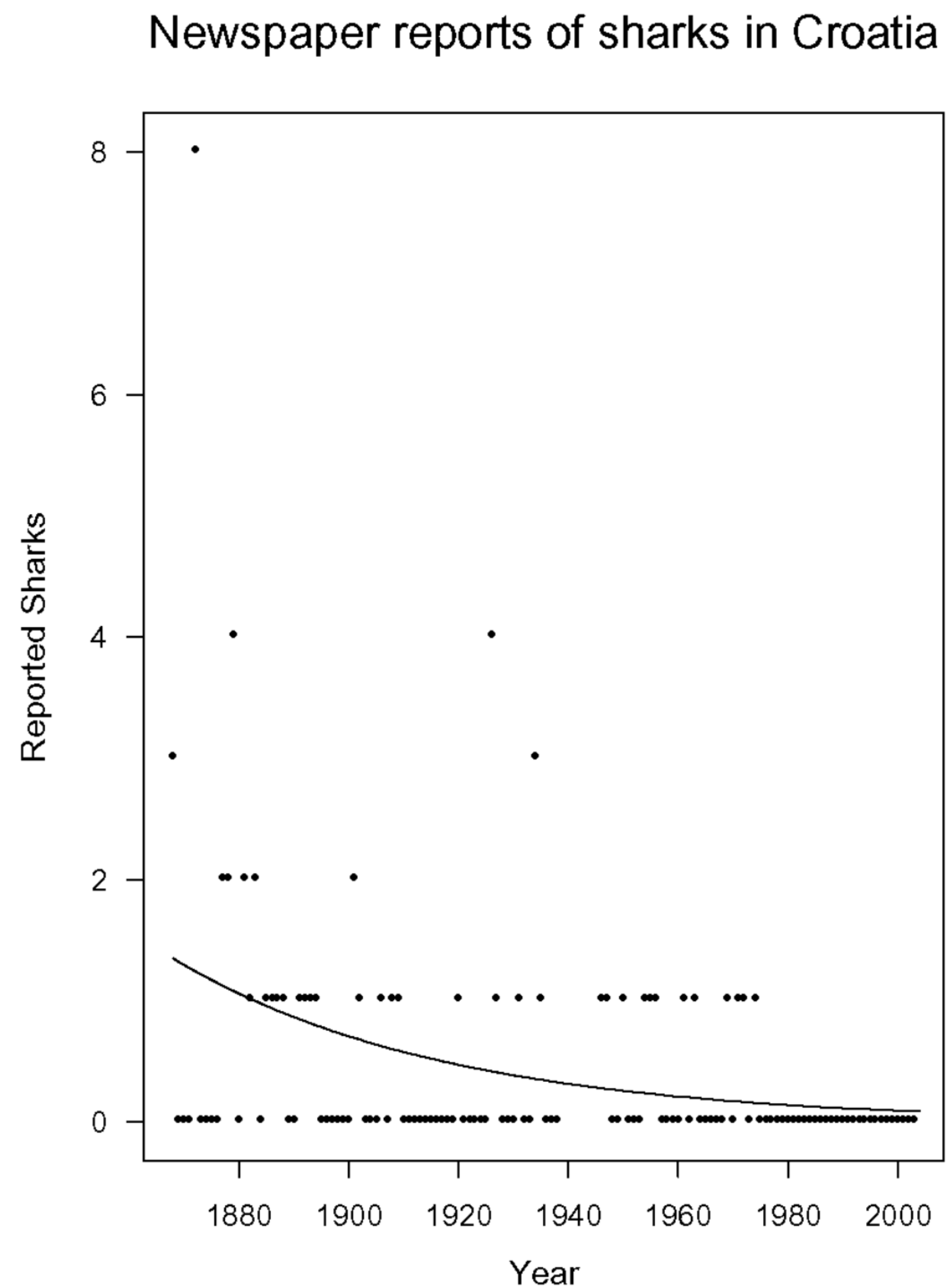
1946 - Pig of 10 kg in stomach

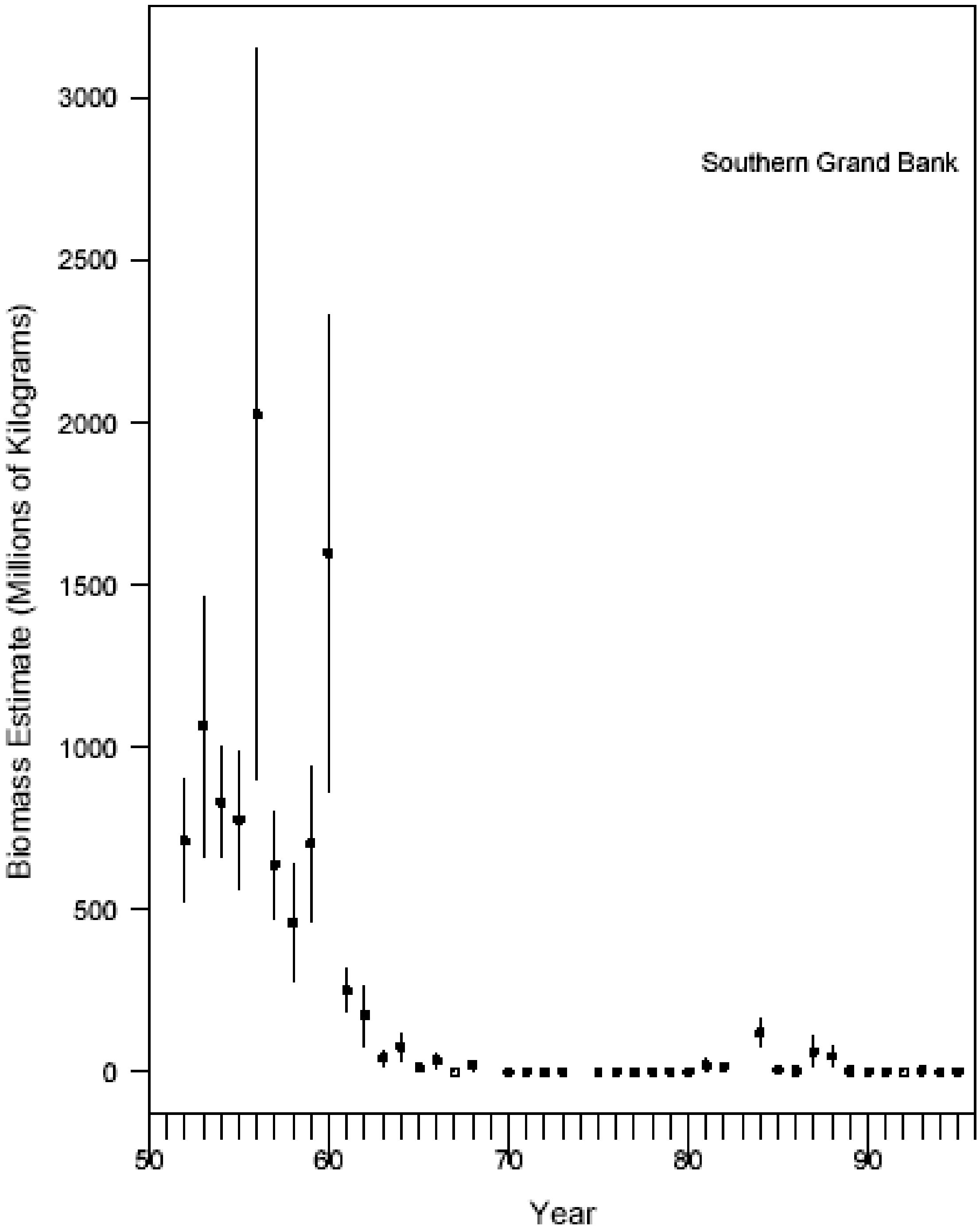
1950 - Encounter during eating a dead calf

1954 - Attack on boat

1975+ -No sightings.

Soldo and Jardas, Periodicum Bologorum, 2002


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



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