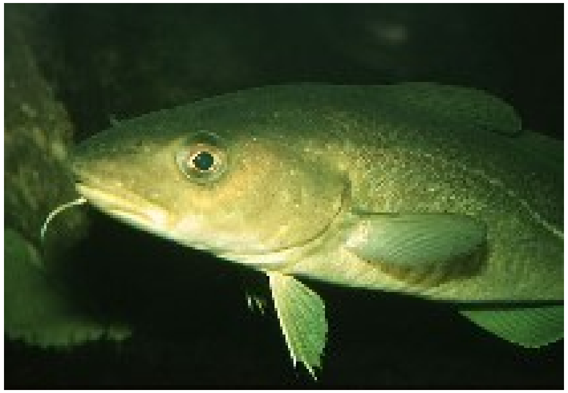
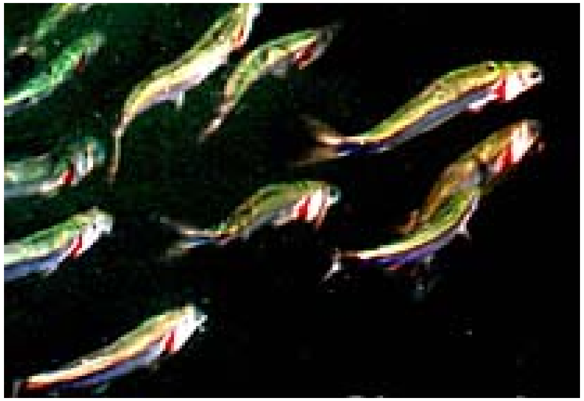
Research Surveys

Why they are crucial?

How can they be better designed?

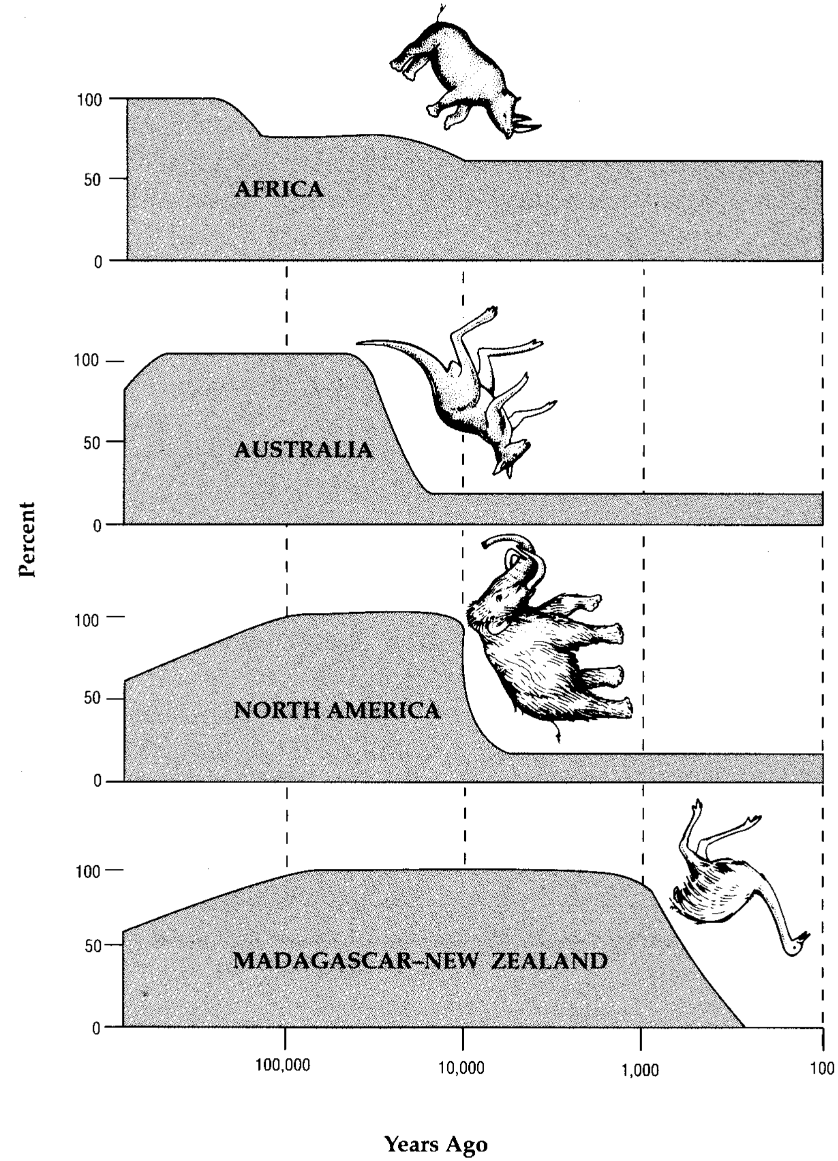
How can they be better utilized?

Ransom A. Myers
Dalhousie University, Halifax, NS, Canada

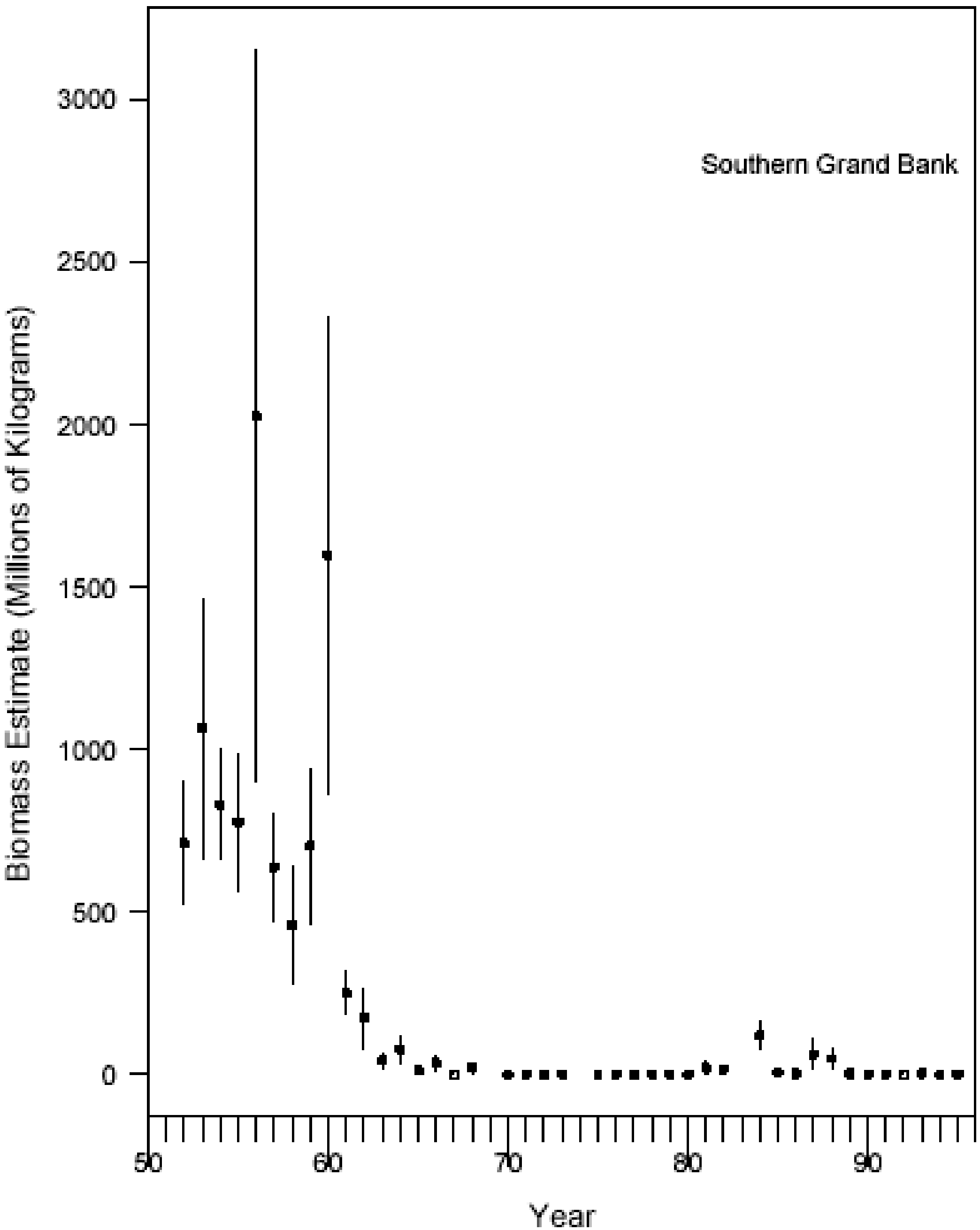
Reason #1 for Having Research Surveys

- Don’t loose the pieces!

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



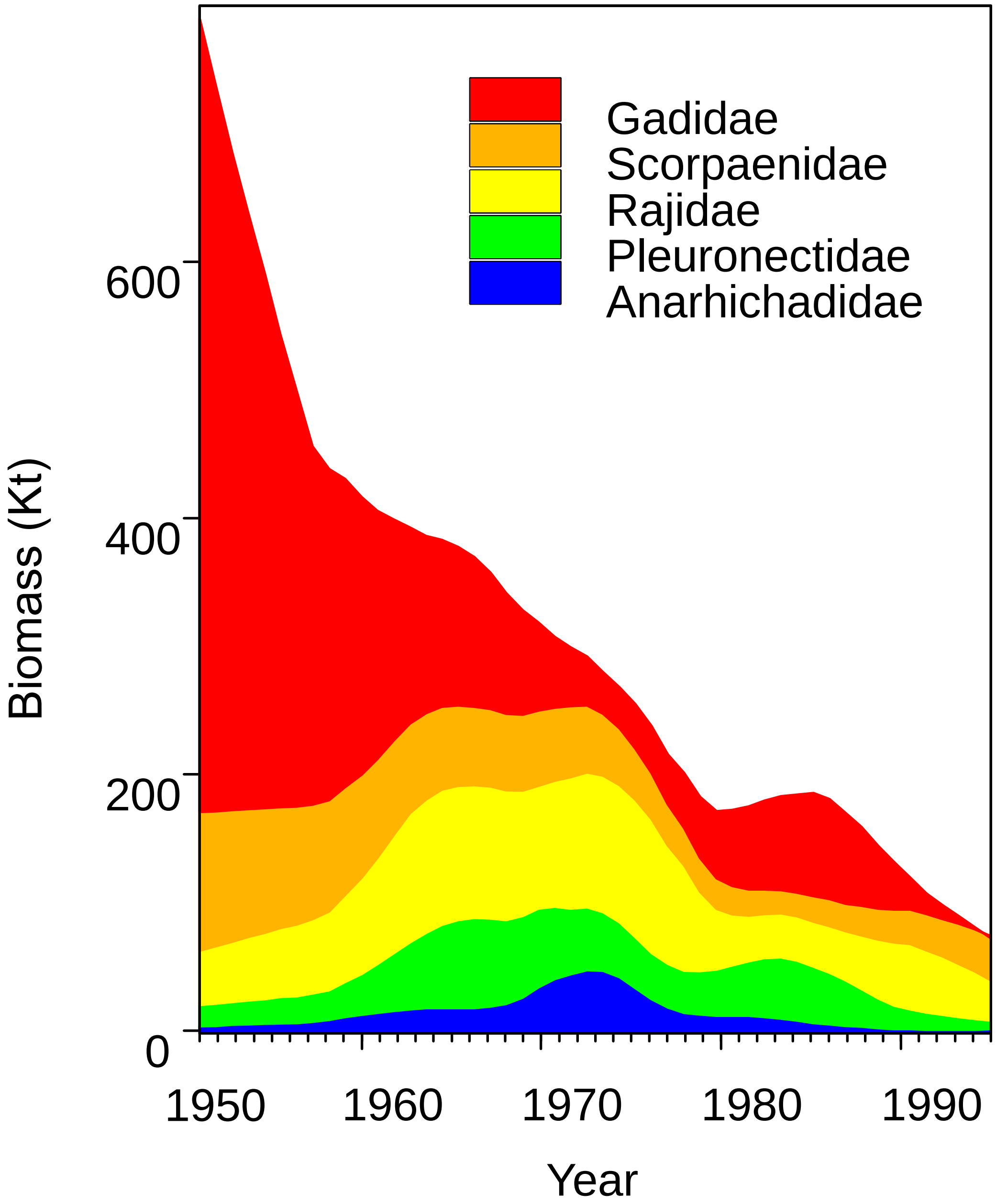
The extinction of large mammals and flightless birds coincided closely with the arrival of humans in North America, Madagascar, and New Zealand, and less decisively earlier in Australia. In Africa, where humans and animals evolved together for millions of years, the damage was less severe.

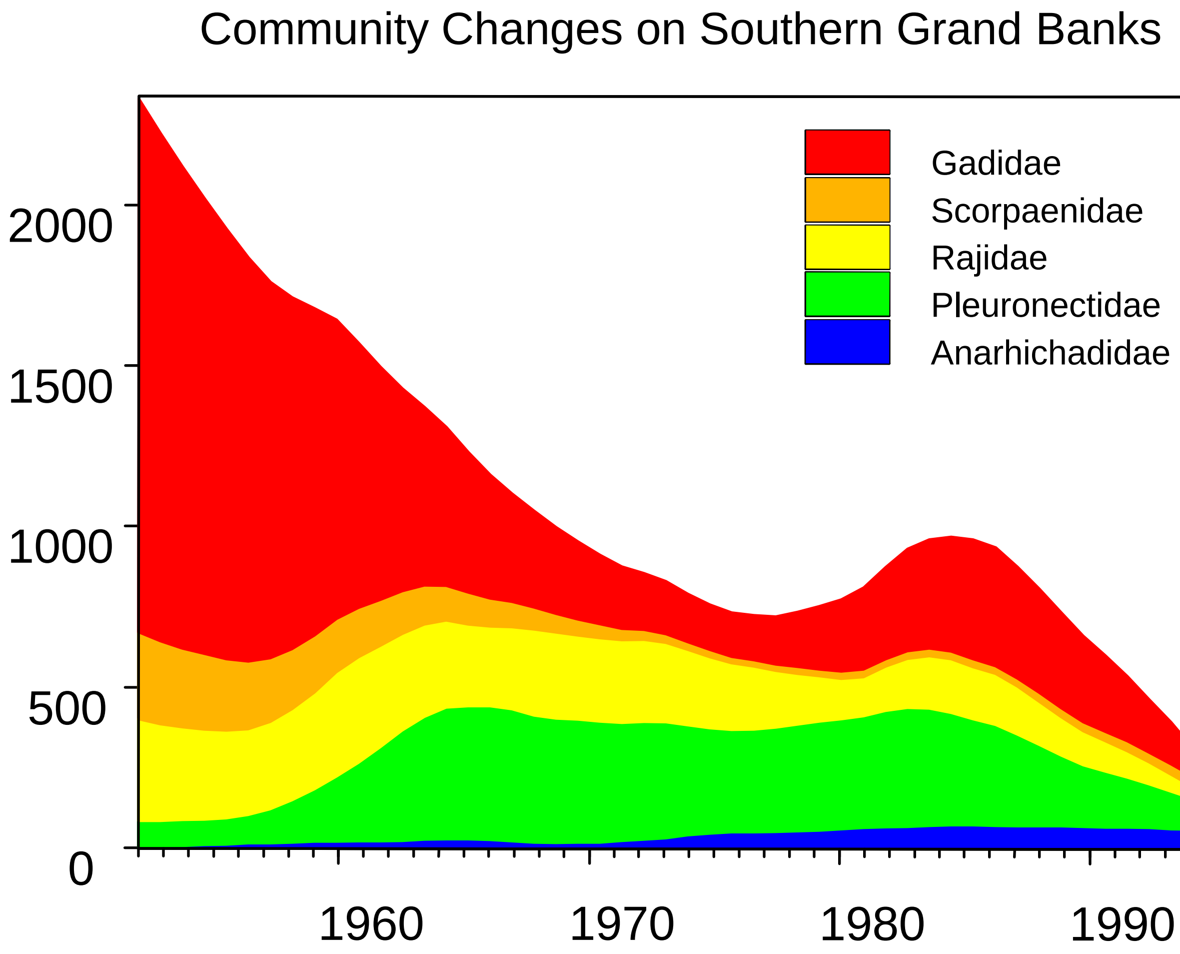


Loss of haddock on the Grand Banks – data from research surveys

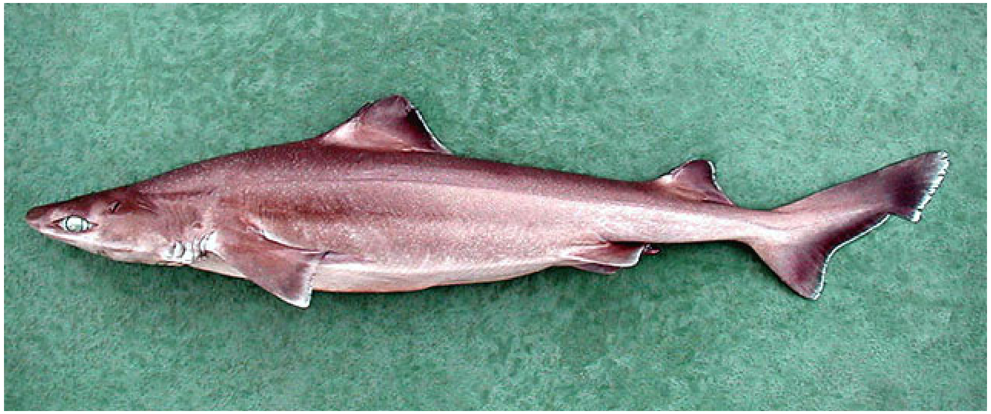
What has changed?

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



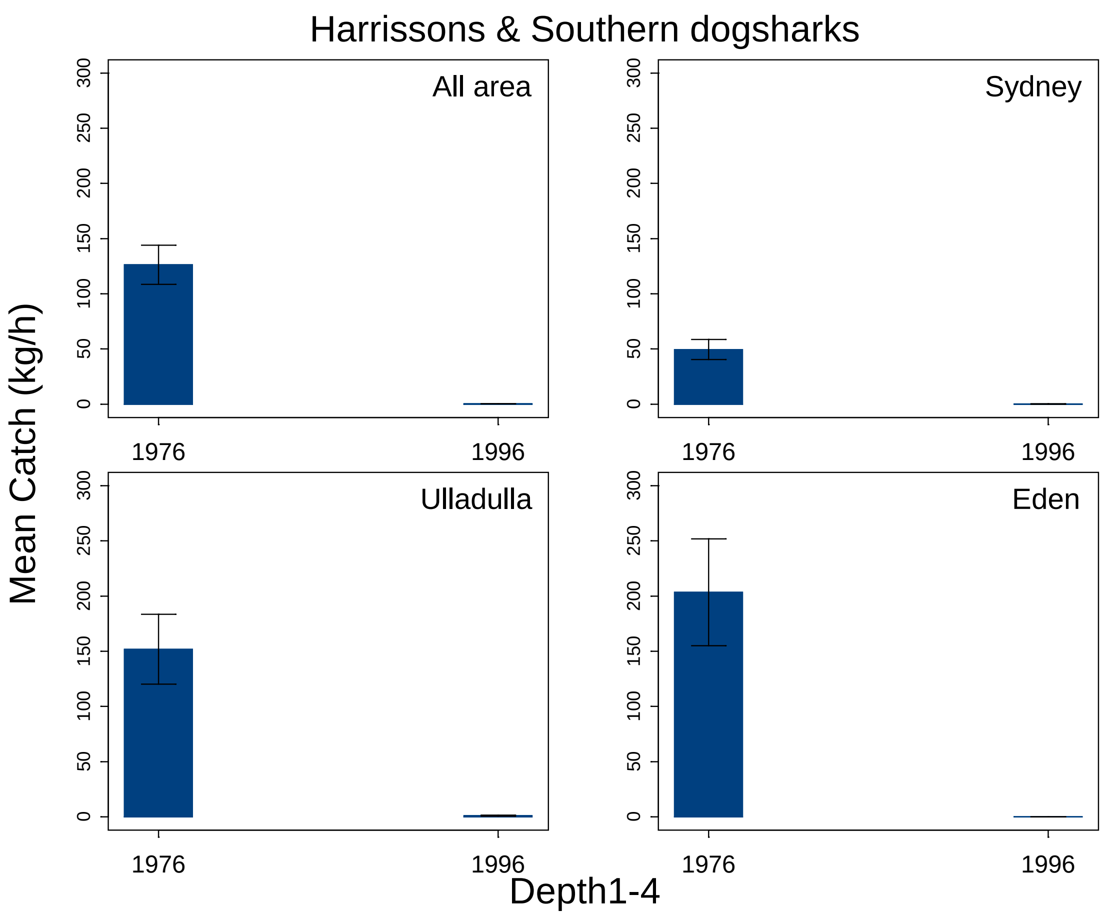


Community Changes on Southern Grand Banks
Gadidae
Scorpaenidae
Rajidae
Pleuronectidae
Anarhichadidae
2000
1500
1000
500
0
1960
1970
1980
1990



Harrissons and Southern dogsharks in 1977 amounted at 18.5% of total biomass in surveys off New South Wales.

30 years later they declined by a factor of about 300.



Graham *et al* 2001 – Mar.Freshwater Res. (52)

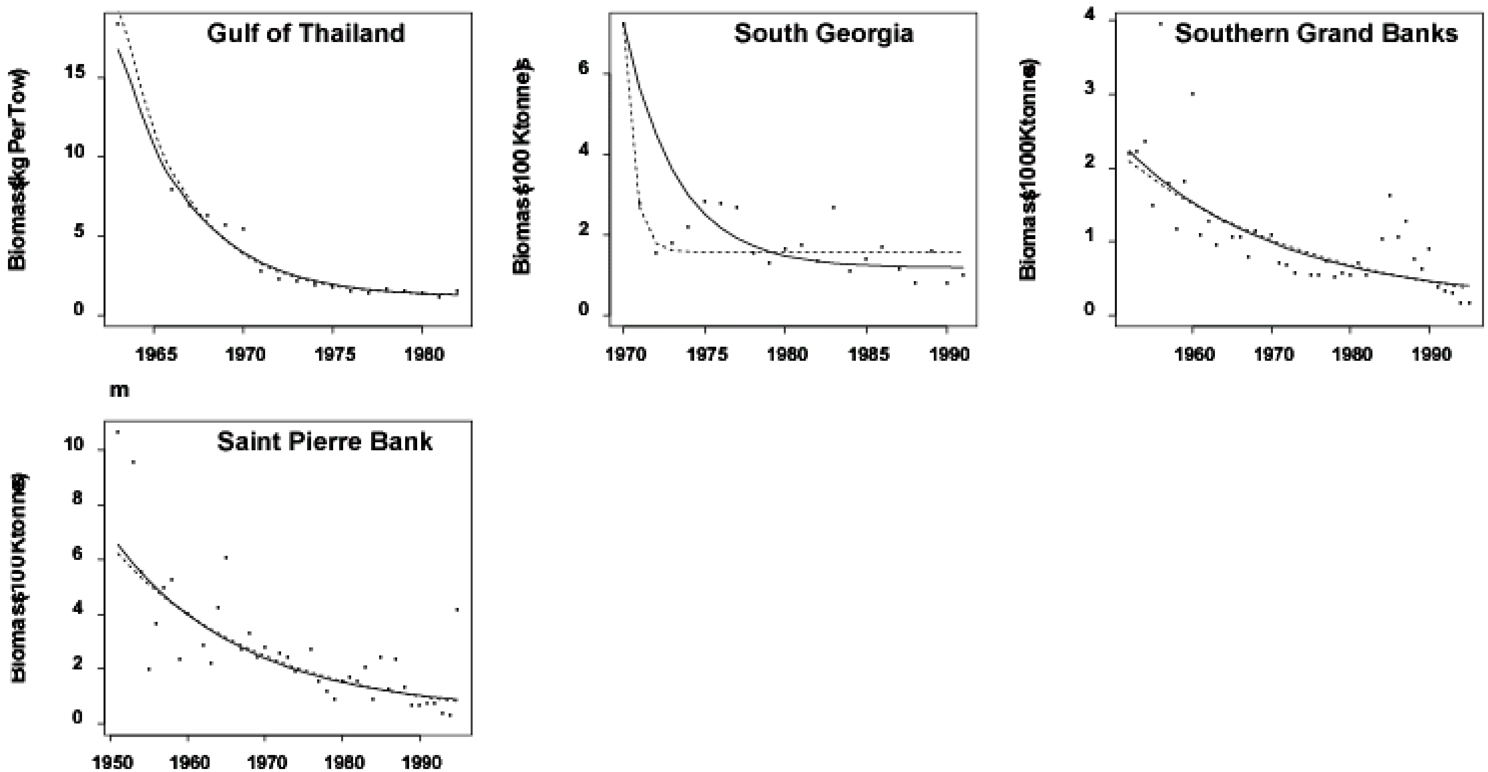
How long does it take to "rescue" an old survey?

- At least 2 years for a very good graduate student.
- Once all scientists and technicians are dead, then there is much greater uncertainty.

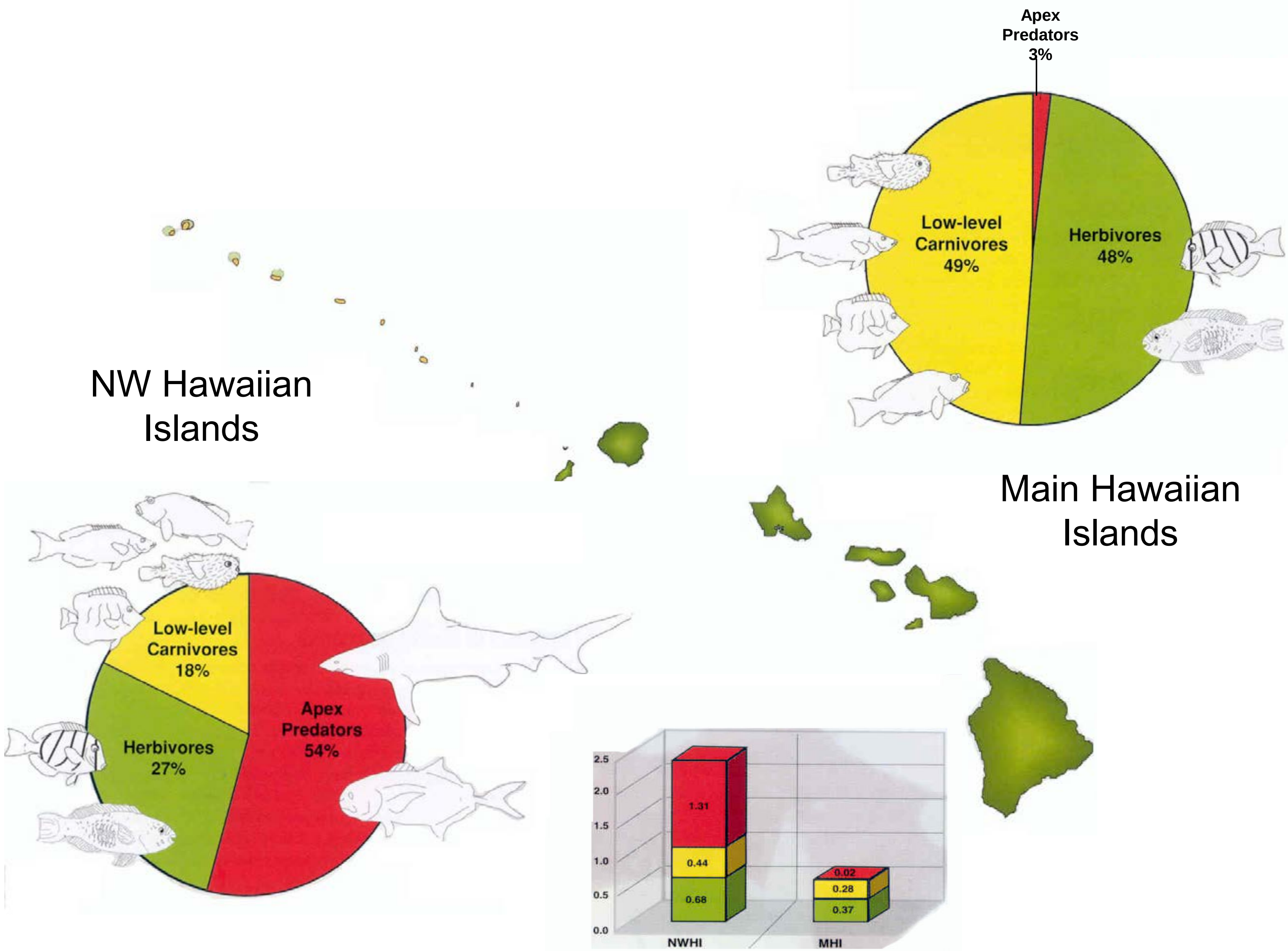
What is the half-life an old survey?

- about 10 years for a government surveys
- about 10 months for a university survey
- about 10 days for a consultant’ survey

Shelf seas



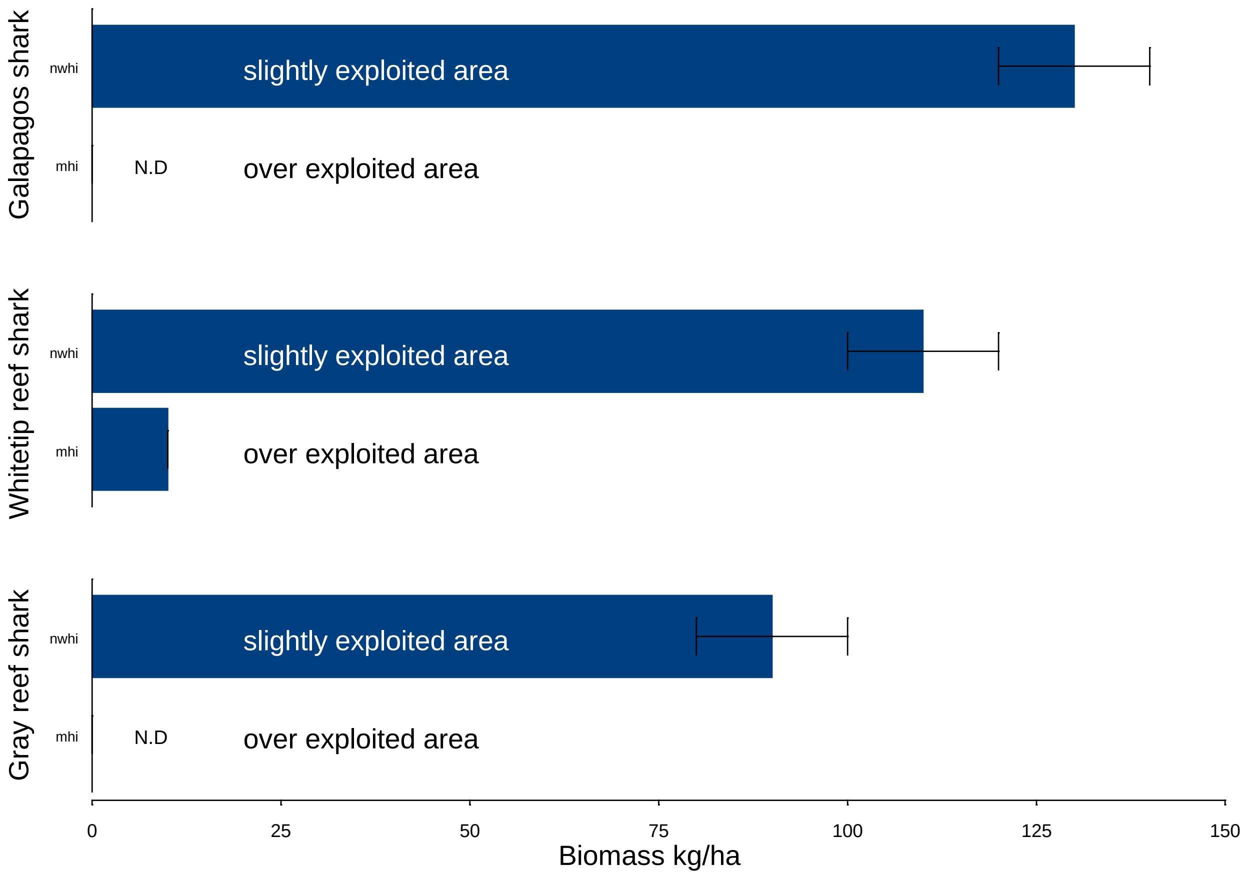
Gulf of Thailand
South Georgia
Southern Grand Banks
Saint Pierre Bank
0
5
10
15
1965
1970
1975
1980
0
2
4
6
1970
1975
1980
1985
1990
0
1
2
3
4
1960
1970
1980
1990
m
0
2
4
6
8
10
1950
1960
1970
1980
1990



Comparative fish biomass (mT/ha)

Loss of Reef Sharks in the Hawaiian Islands

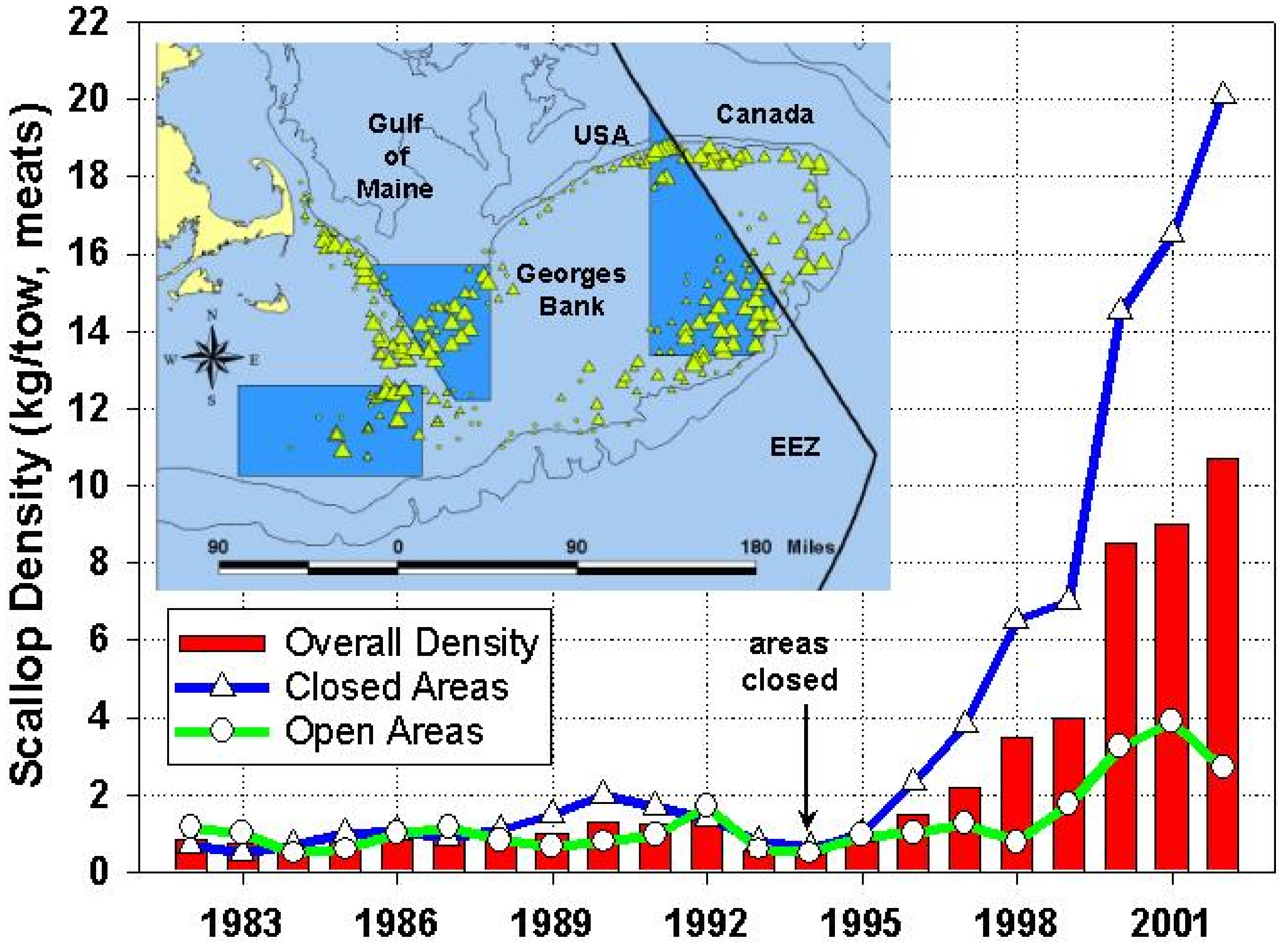
N.W.Hawaiian Islands vs Main Hawaiian Islands



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

Reason #2 for Having Research Surveys

- We don’t know shit without them.

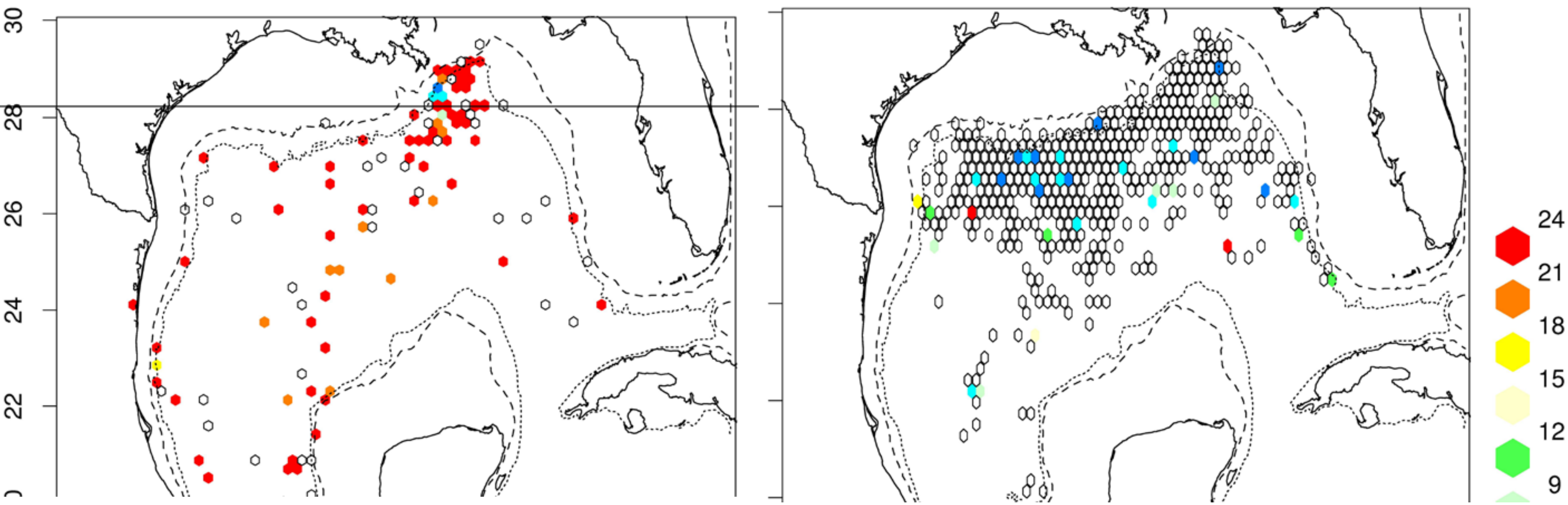


Scallop Density (kg/tow, meats)
22
20
18
16
14
12
10
8
6
4
2
0
1983
1986
1989
1992
1995
1998
2001
Gulf of Maine
USA
Canada
Georges Bank
EEZ
N
S
W
E
90
0
90
180 Miles
Overall Density
Closed Areas
Open Areas
areas closed

Loss of sharks in the Gulf of Mexico

1000 fold decline – no one could tell without surveys

[redacted]



1950's 1990's

Oceanic Whitetip captures per 10,000 hooks

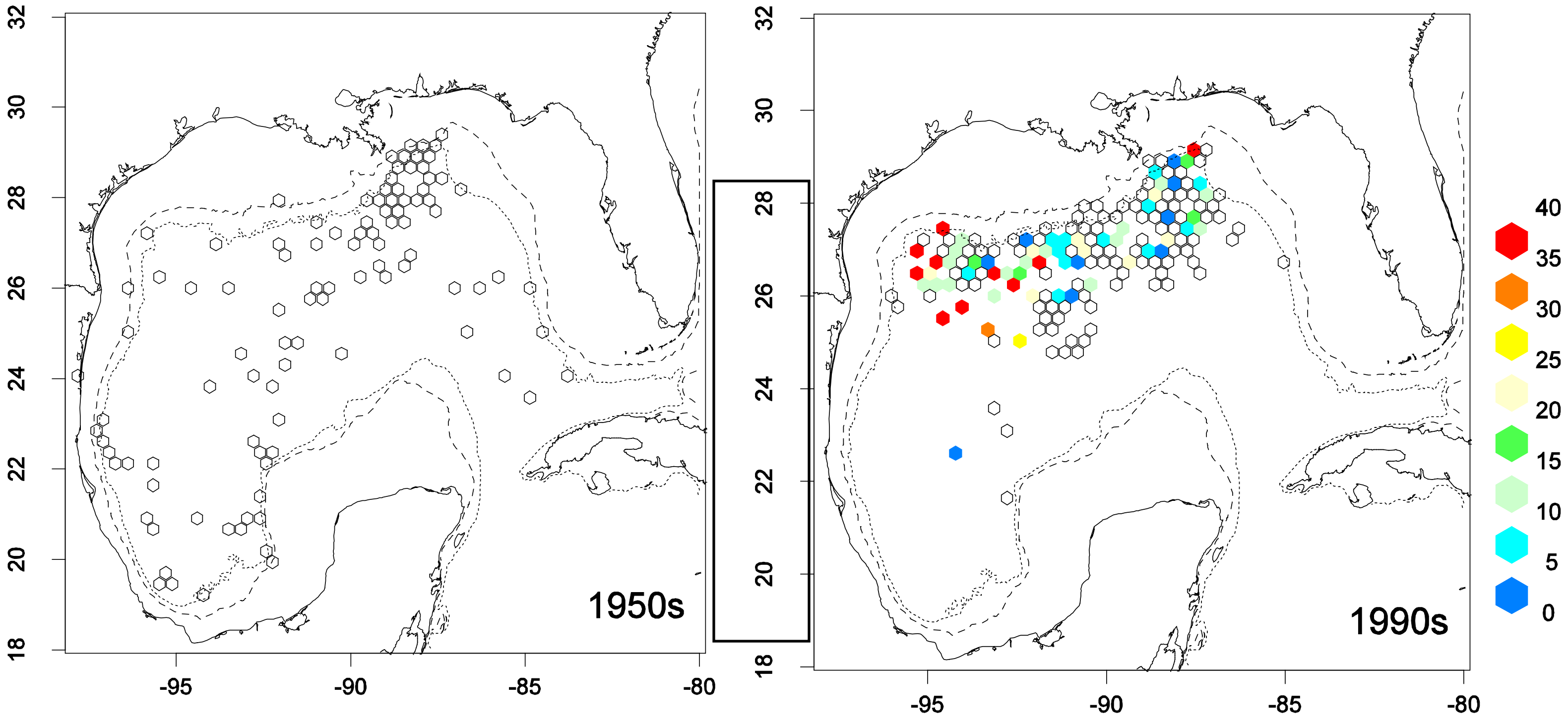
Many thanks to NMFS for data and advice

Did everything decline?

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



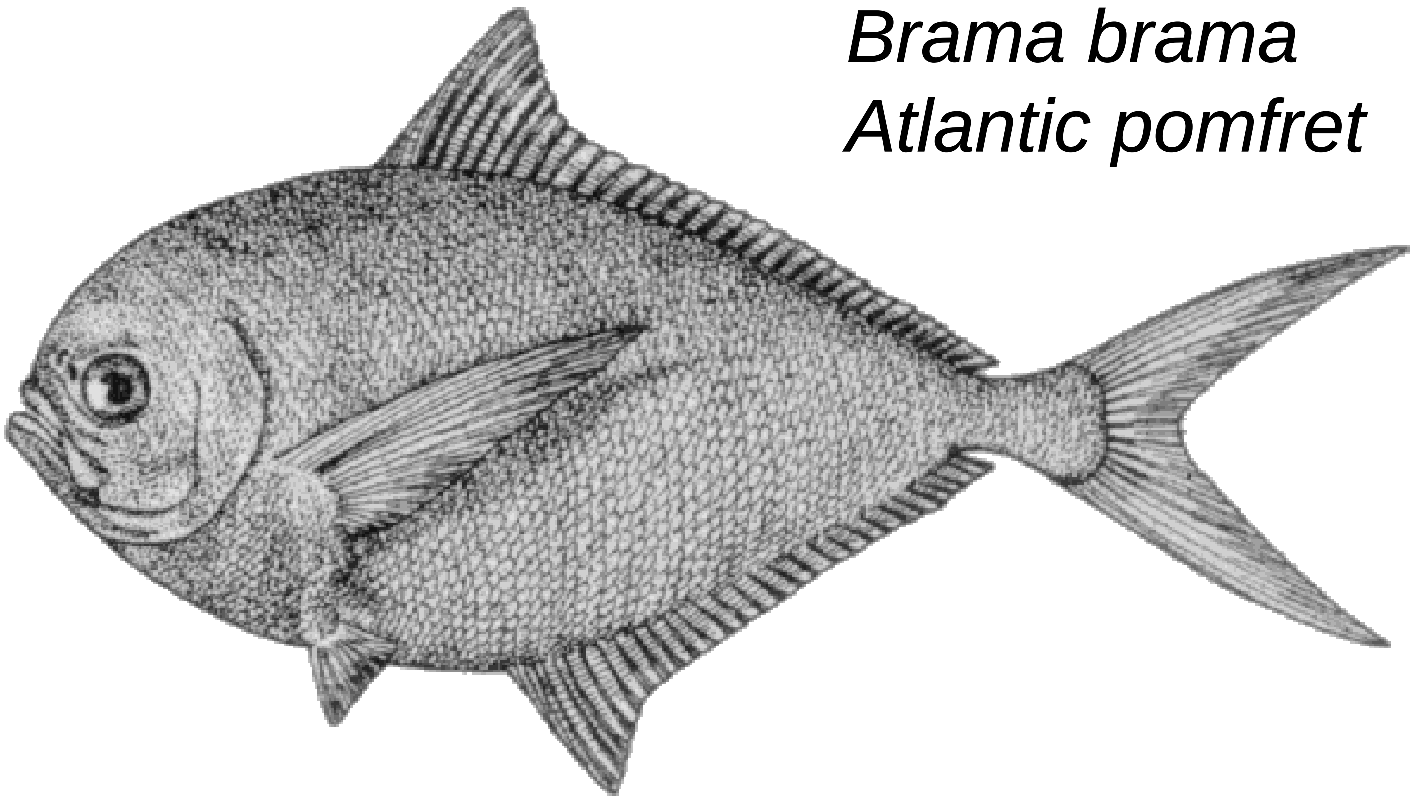
1950's

1990's

Pelagic stingray captures per 10,000 hooks

Many thanks to NMFS for data and advice

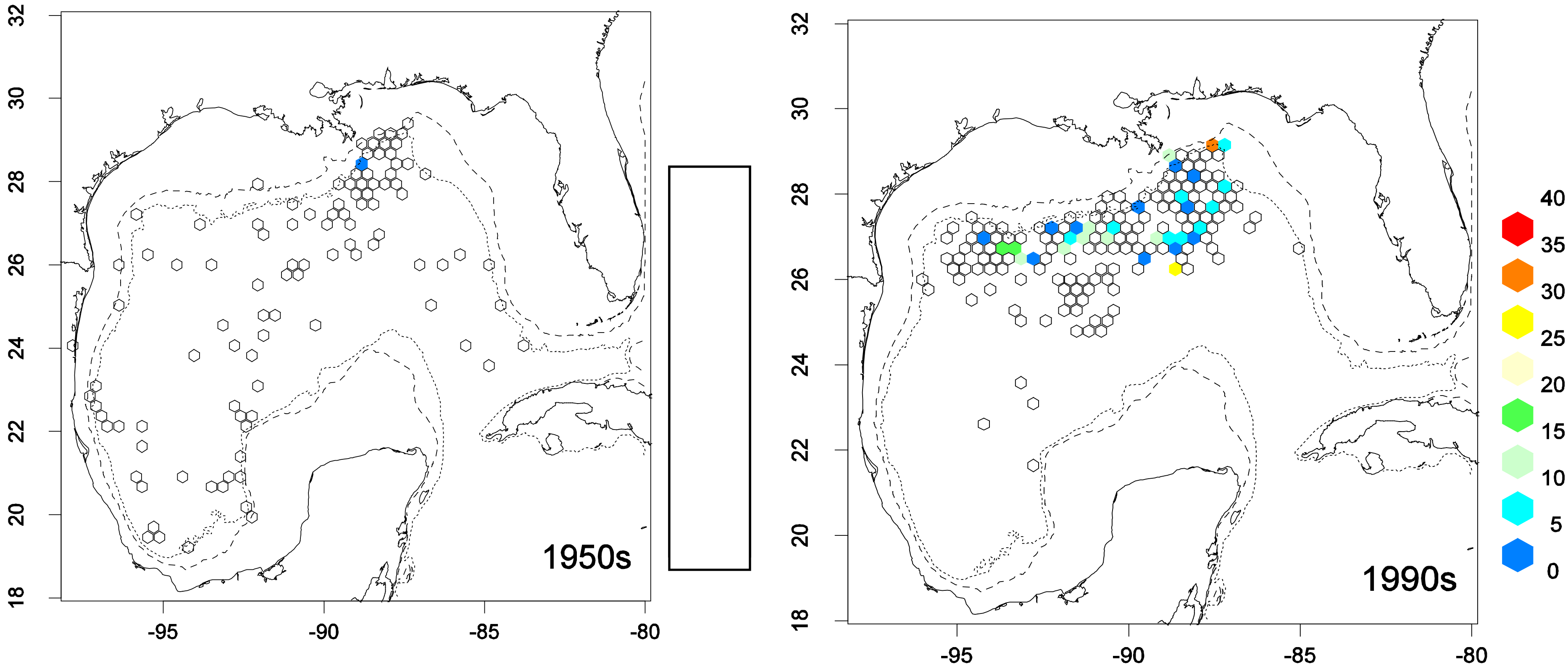
What about prey fish?



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

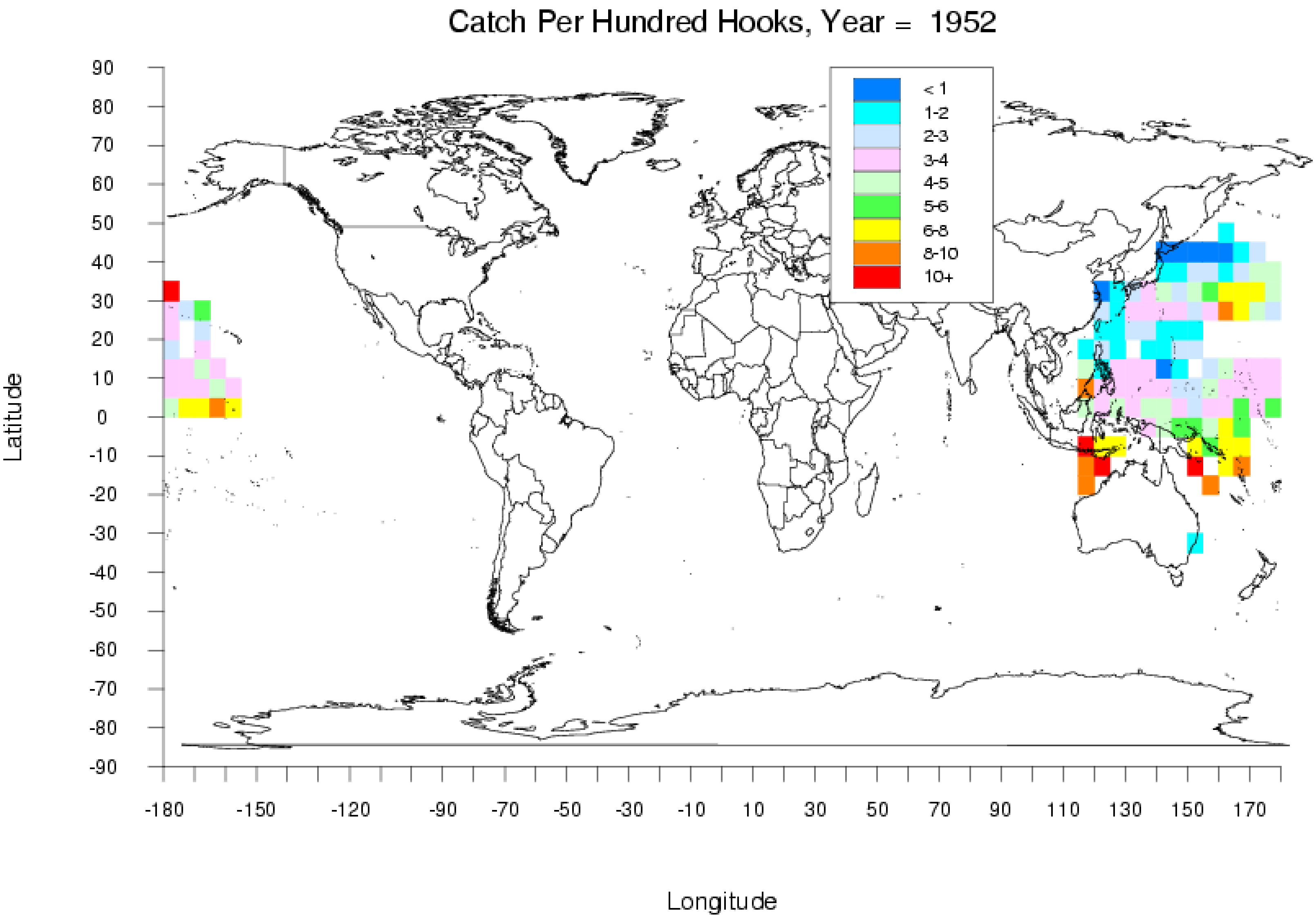
1990's

Pomfret captures per 10,000 hooks

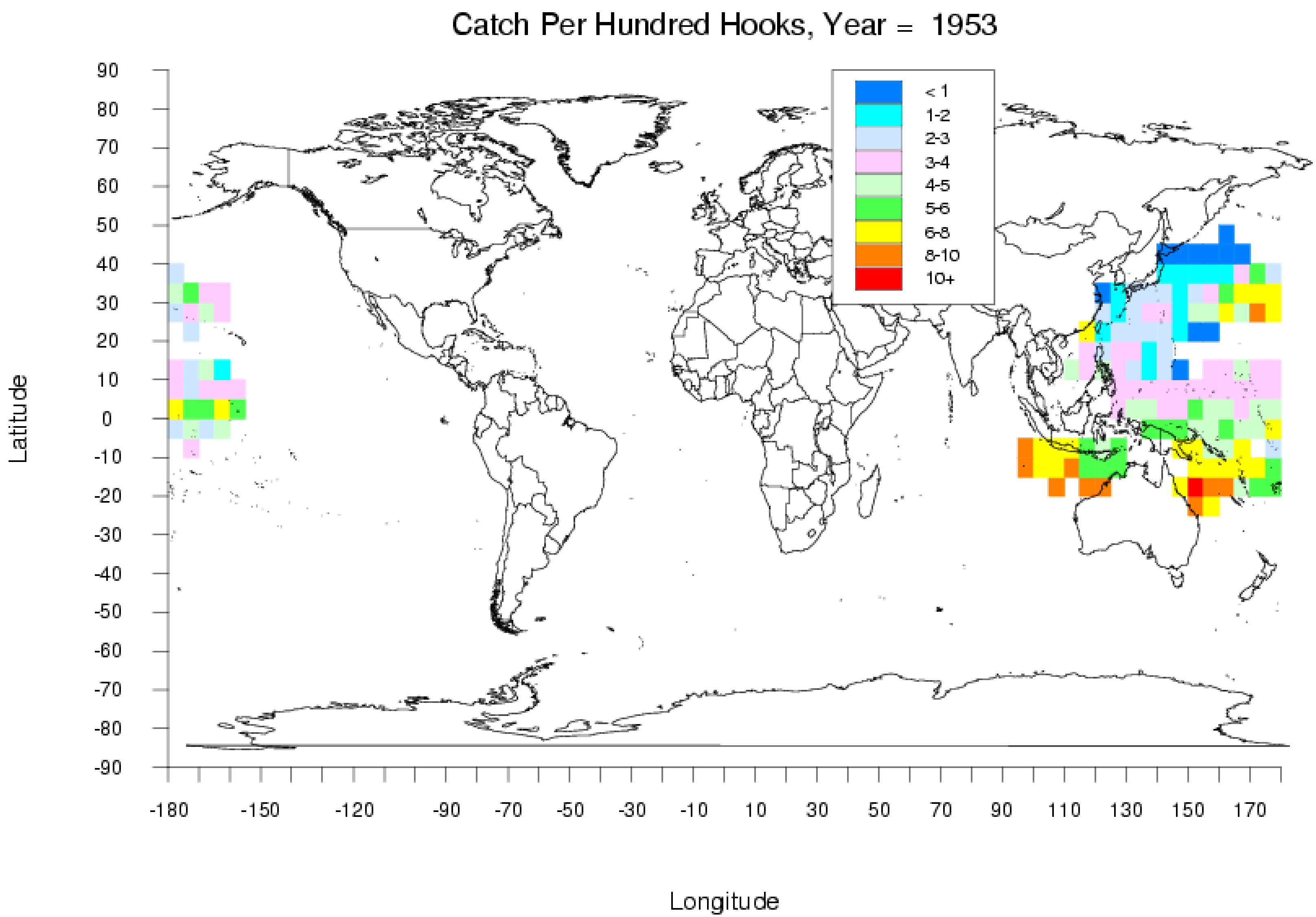
Many thanks to NMFS for data and advice

Reason #3 for having Research Surveys

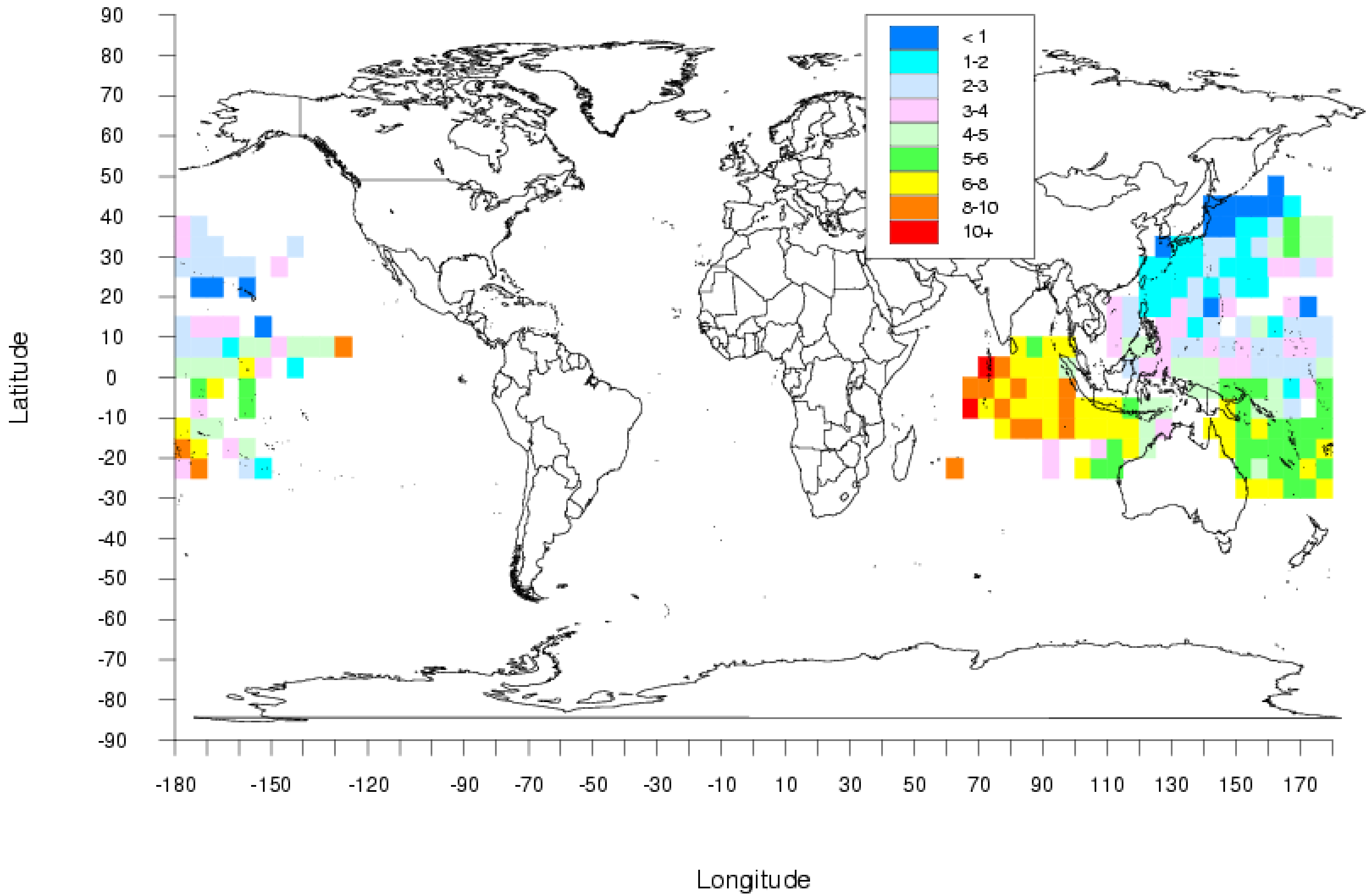
- No matter how obvious a pattern is, someone who is biased (i.e. does agree with me) will disagree.

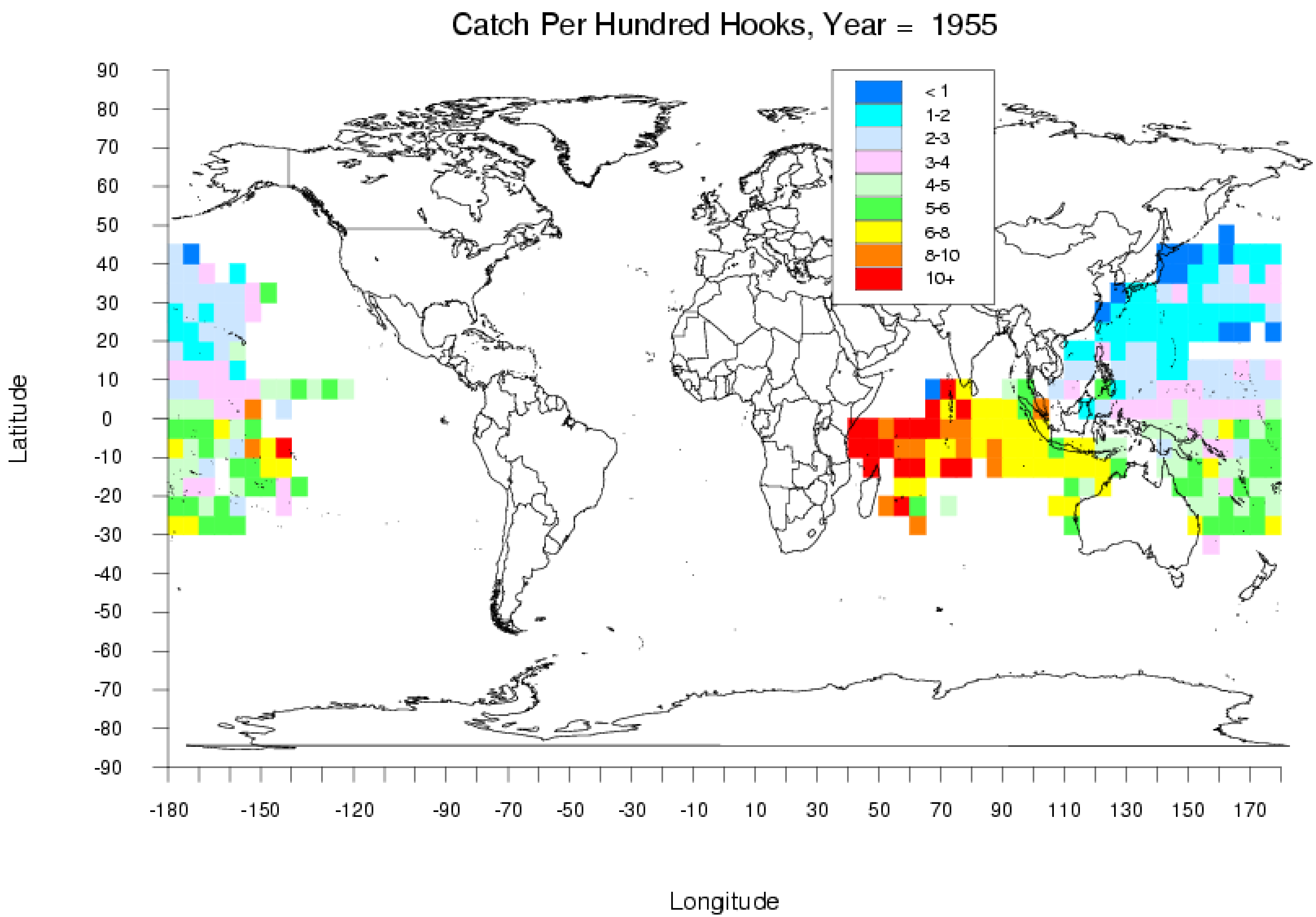


Myers and Worm 2003 *Nature* 423:280-283 download from http://fish.dal.ca

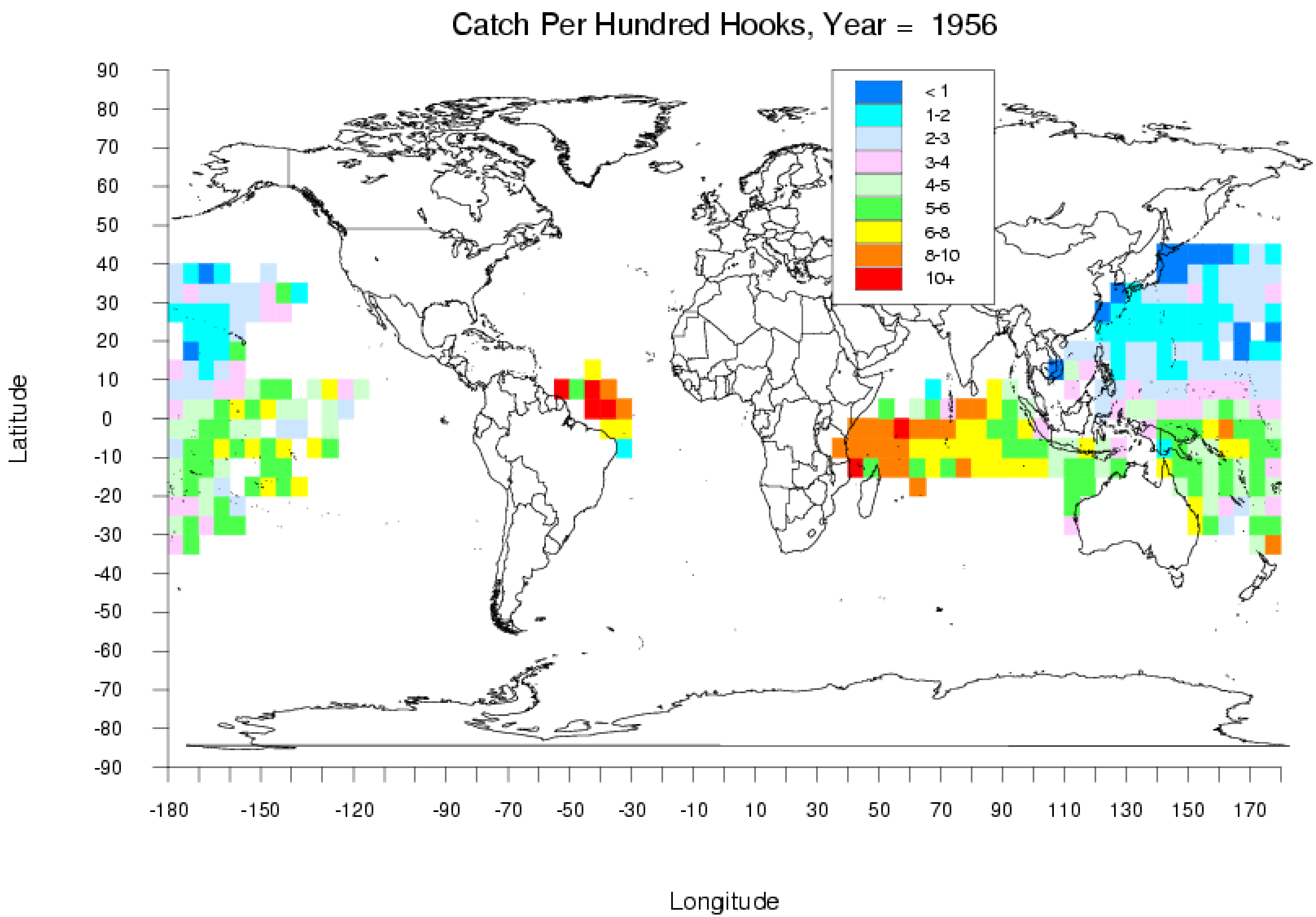

Catch Per Hundred Hooks, Year = 1953
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

Catch Per Hundred Hooks, Year = 1954





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



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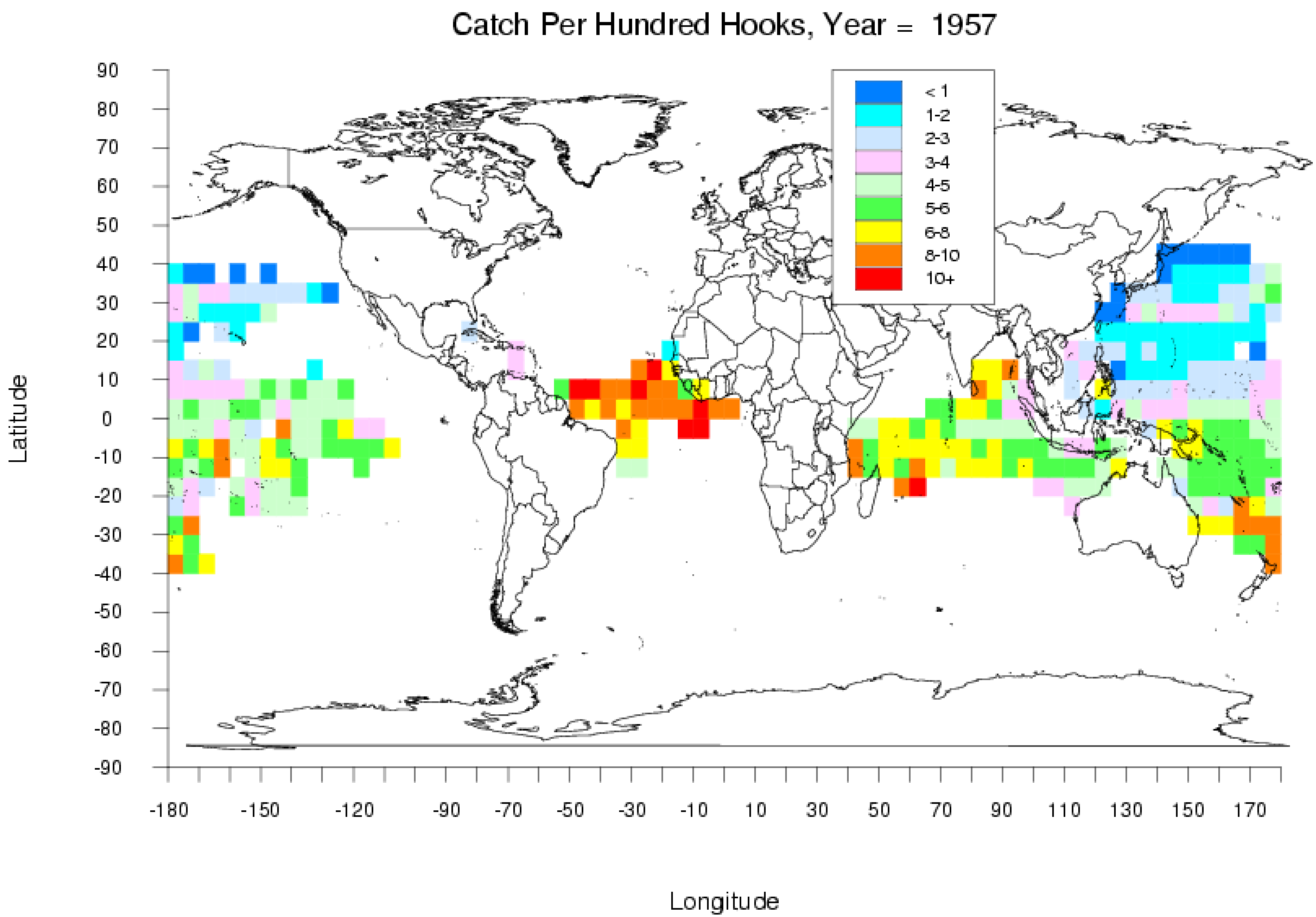
70
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1957
< 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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-10
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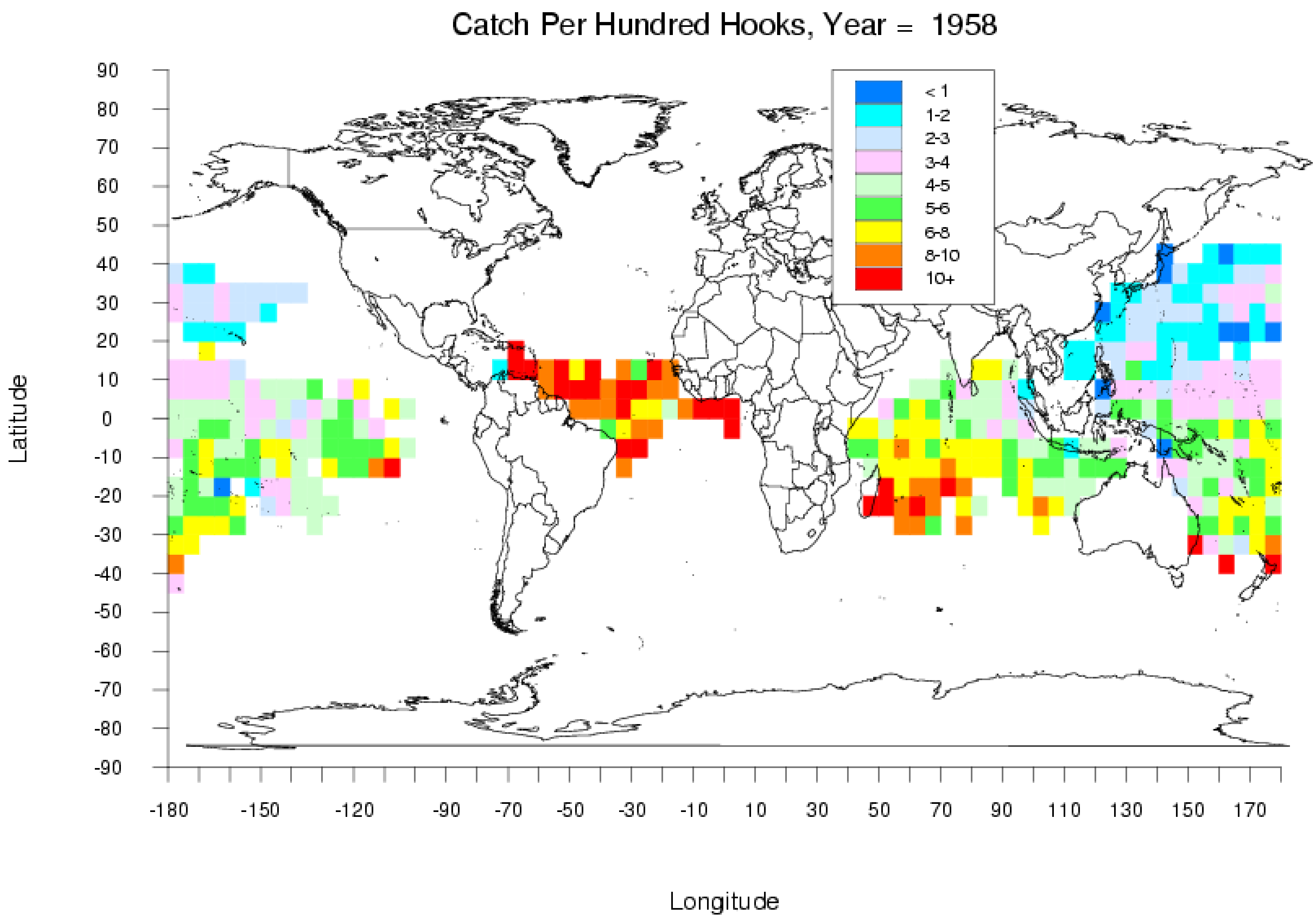
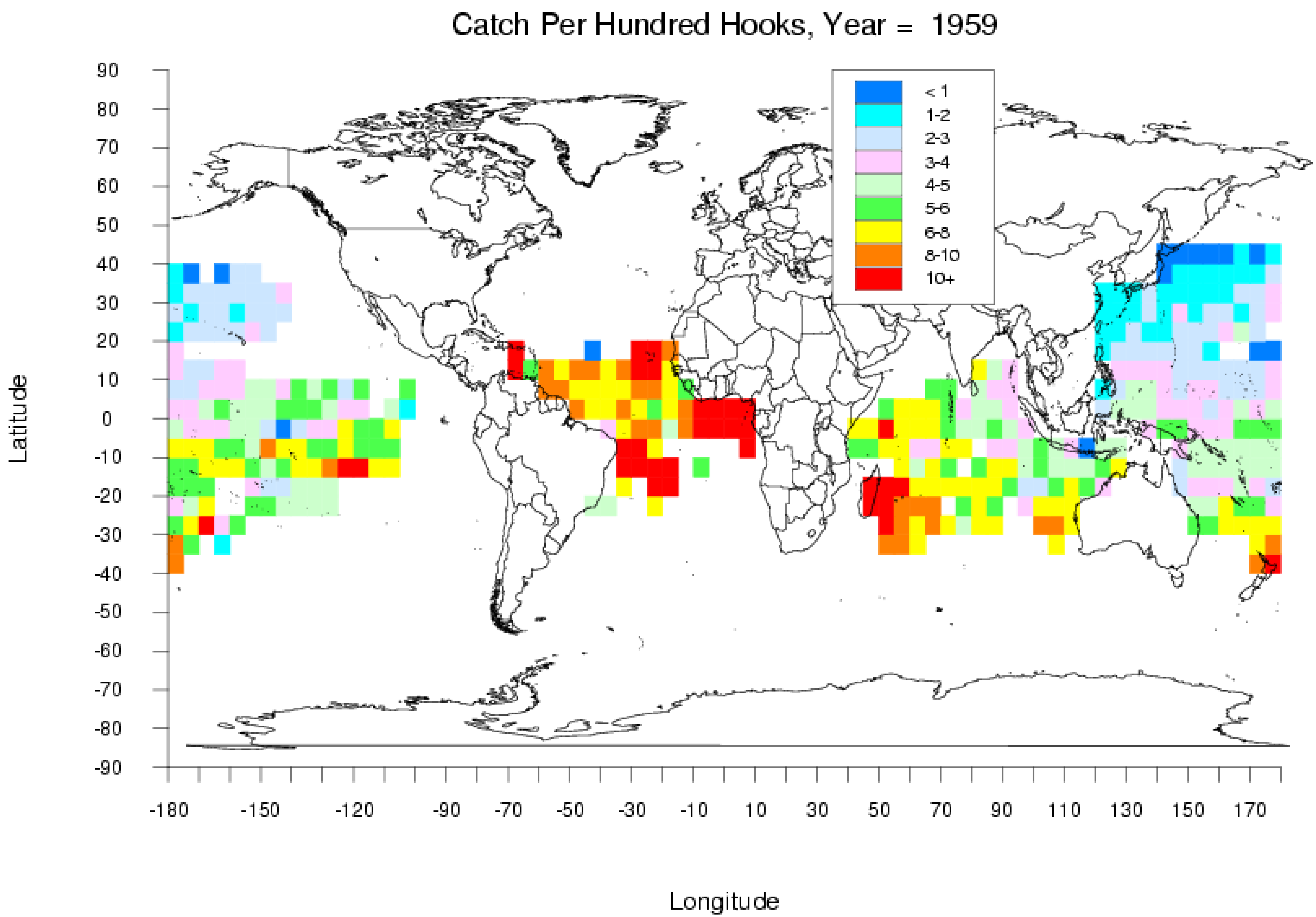
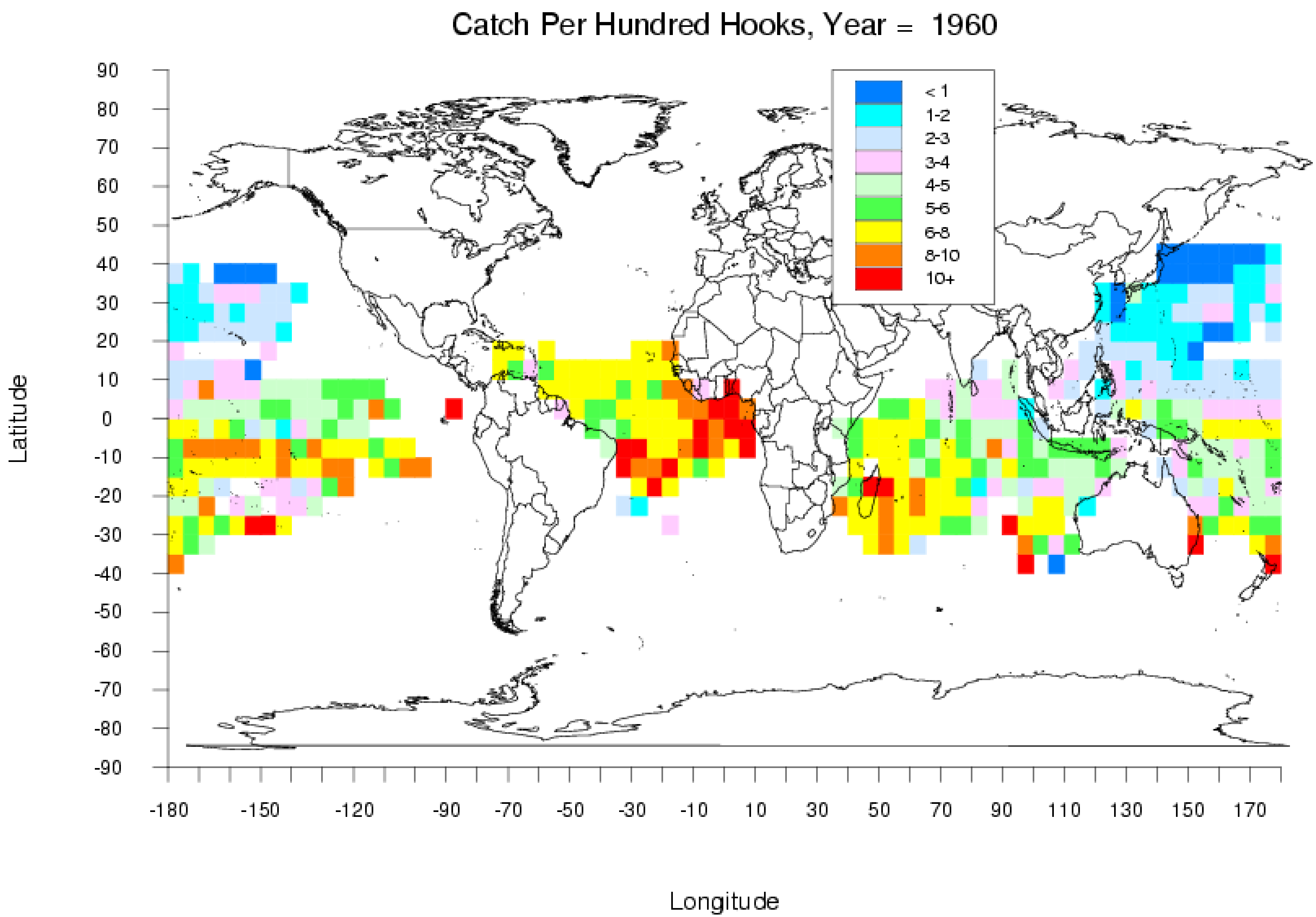
70
90
110
130
150
170



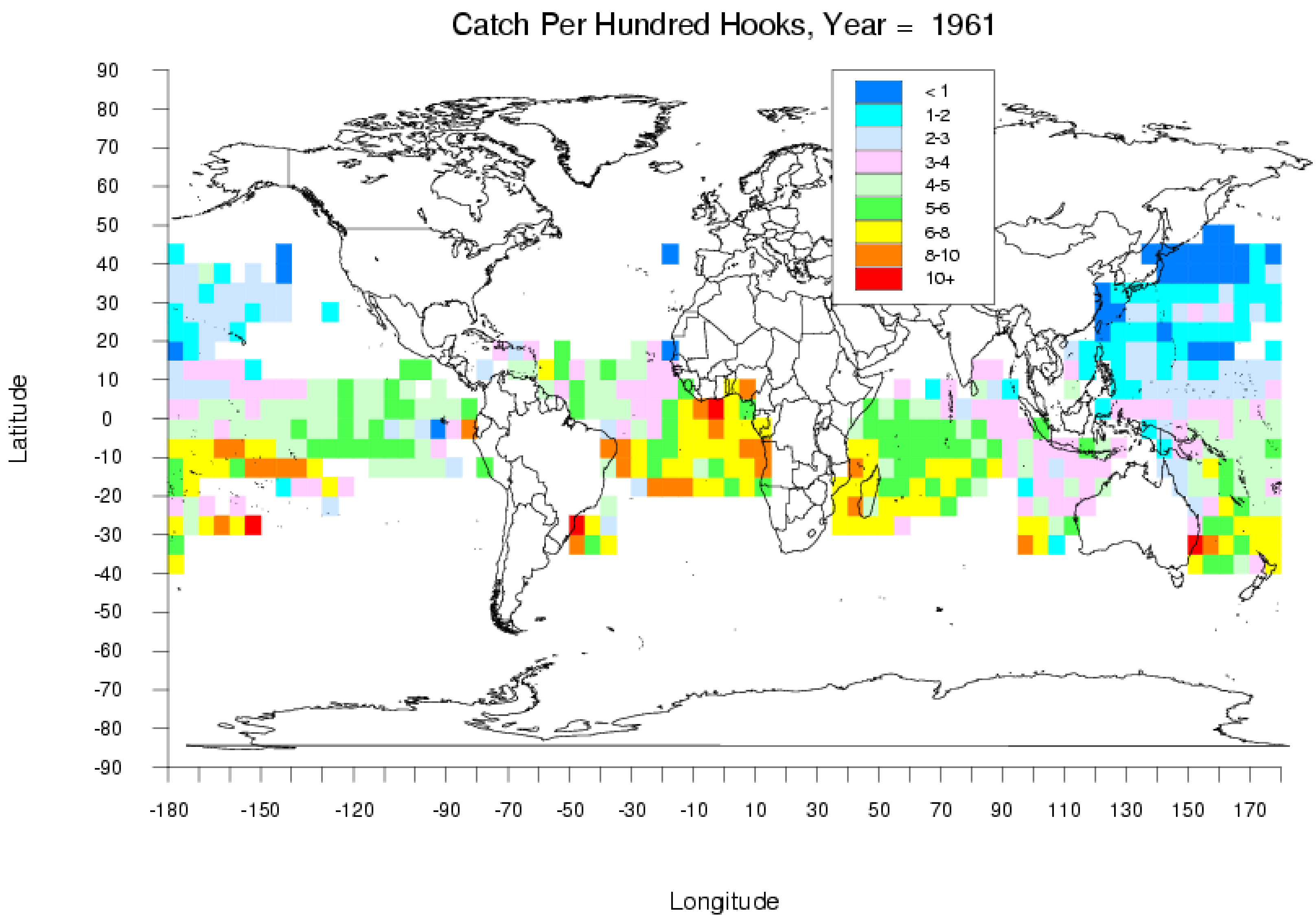
Catch Per Hundred Hooks, Year = 1958
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude



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



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
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170



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
Longitude
-180
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-120
-90
-70
-50
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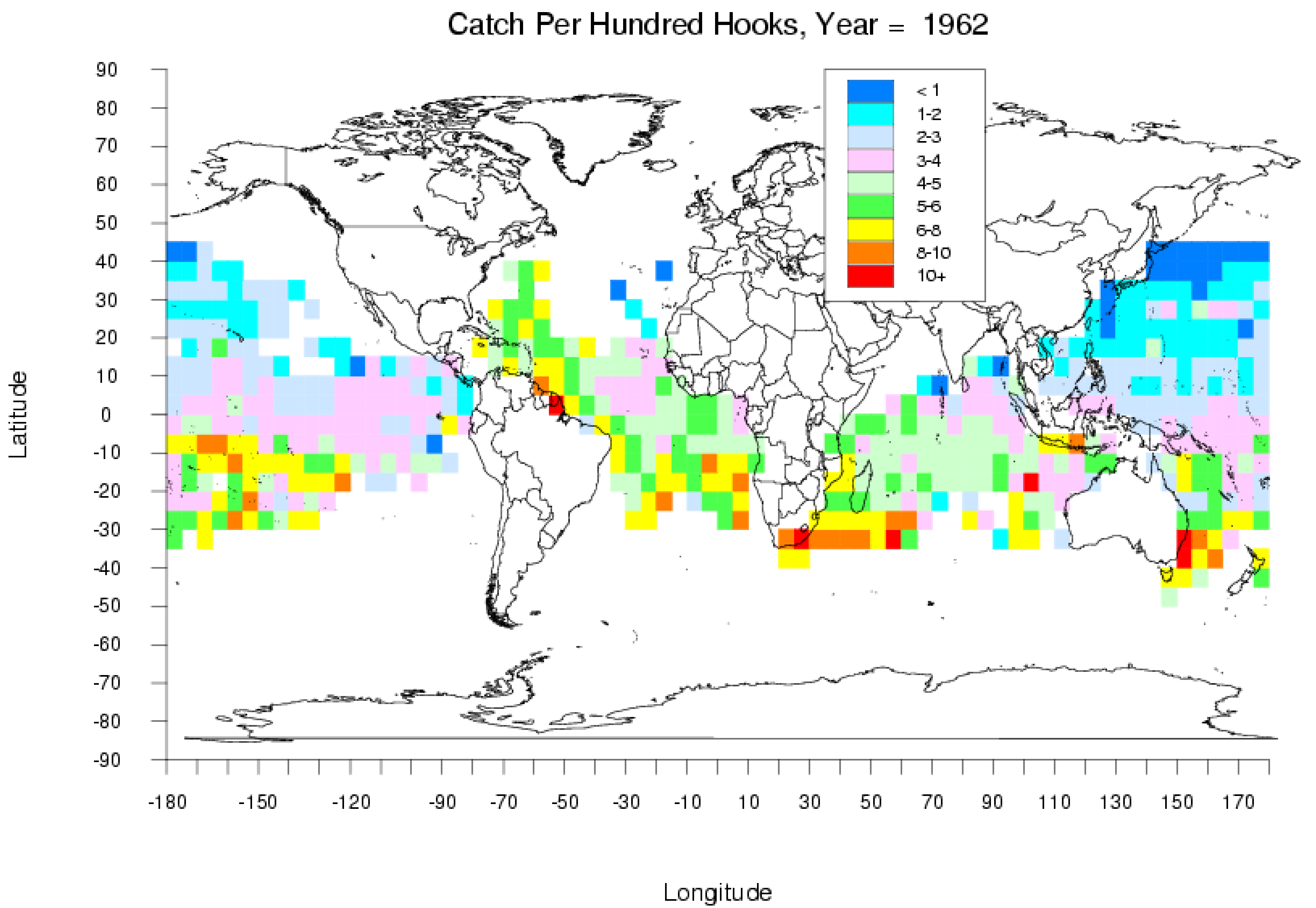
170



Catch Per Hundred Hooks, Year = 1962
< 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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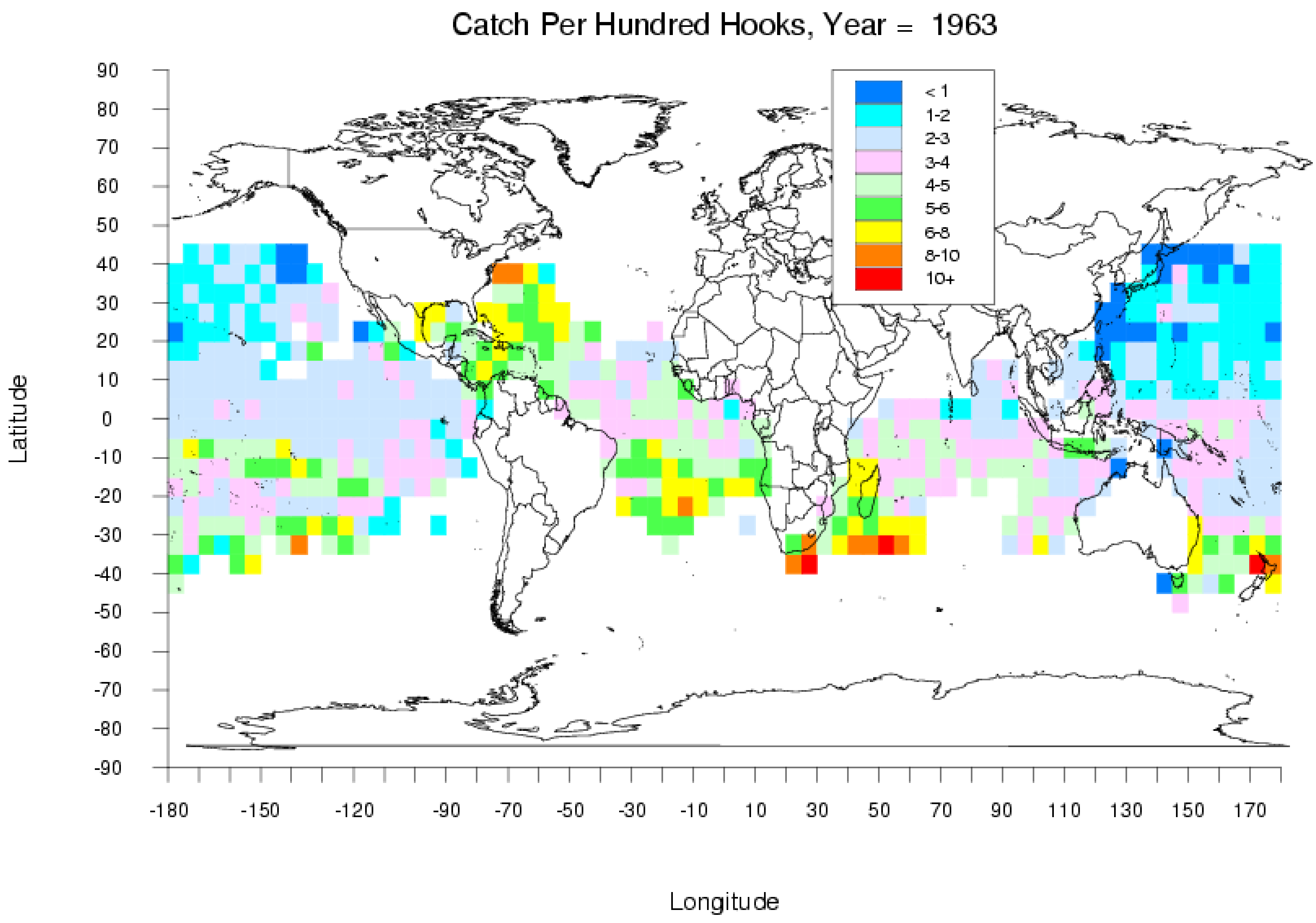

Catch Per Hundred Hooks, Year = 1963
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
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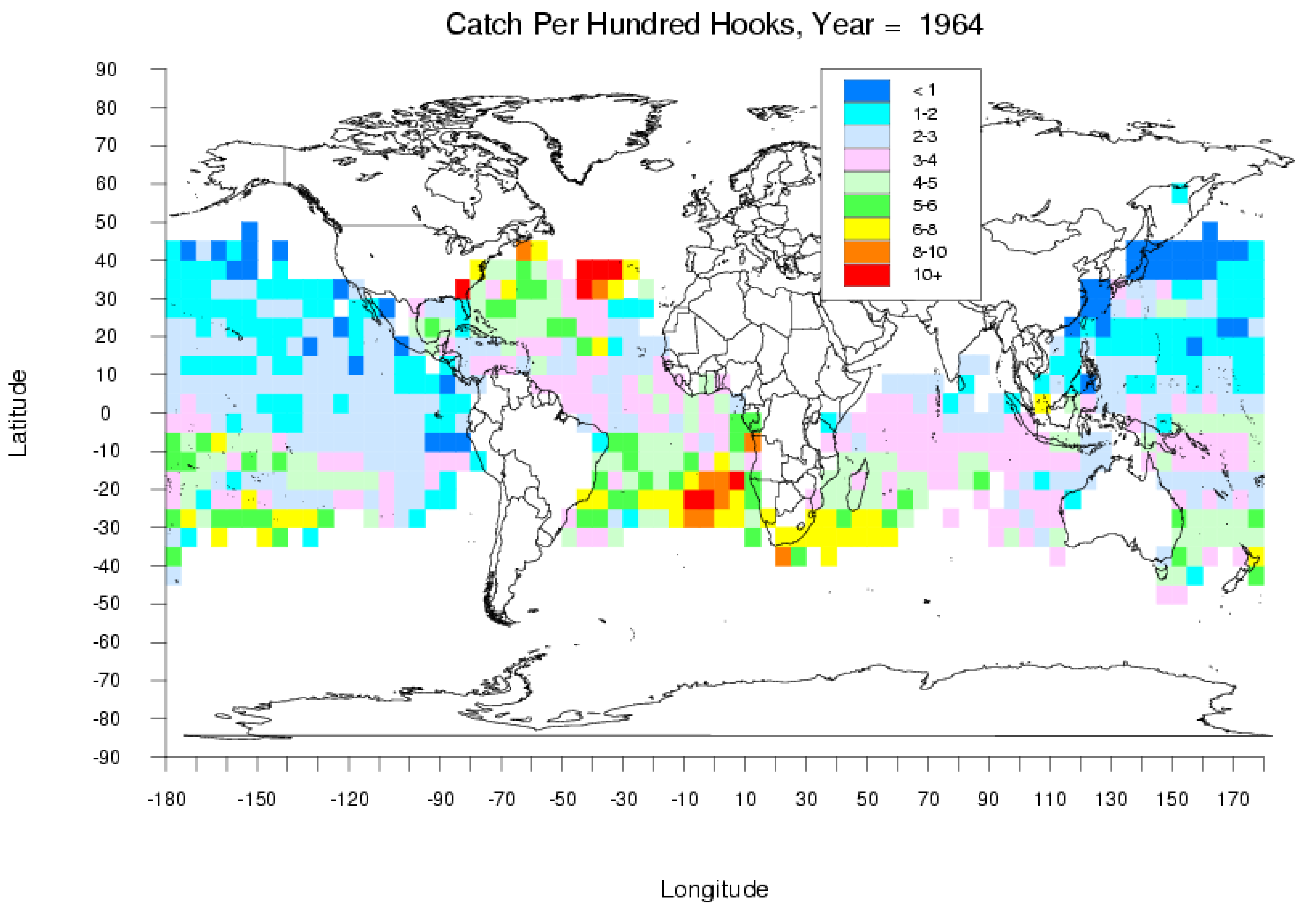
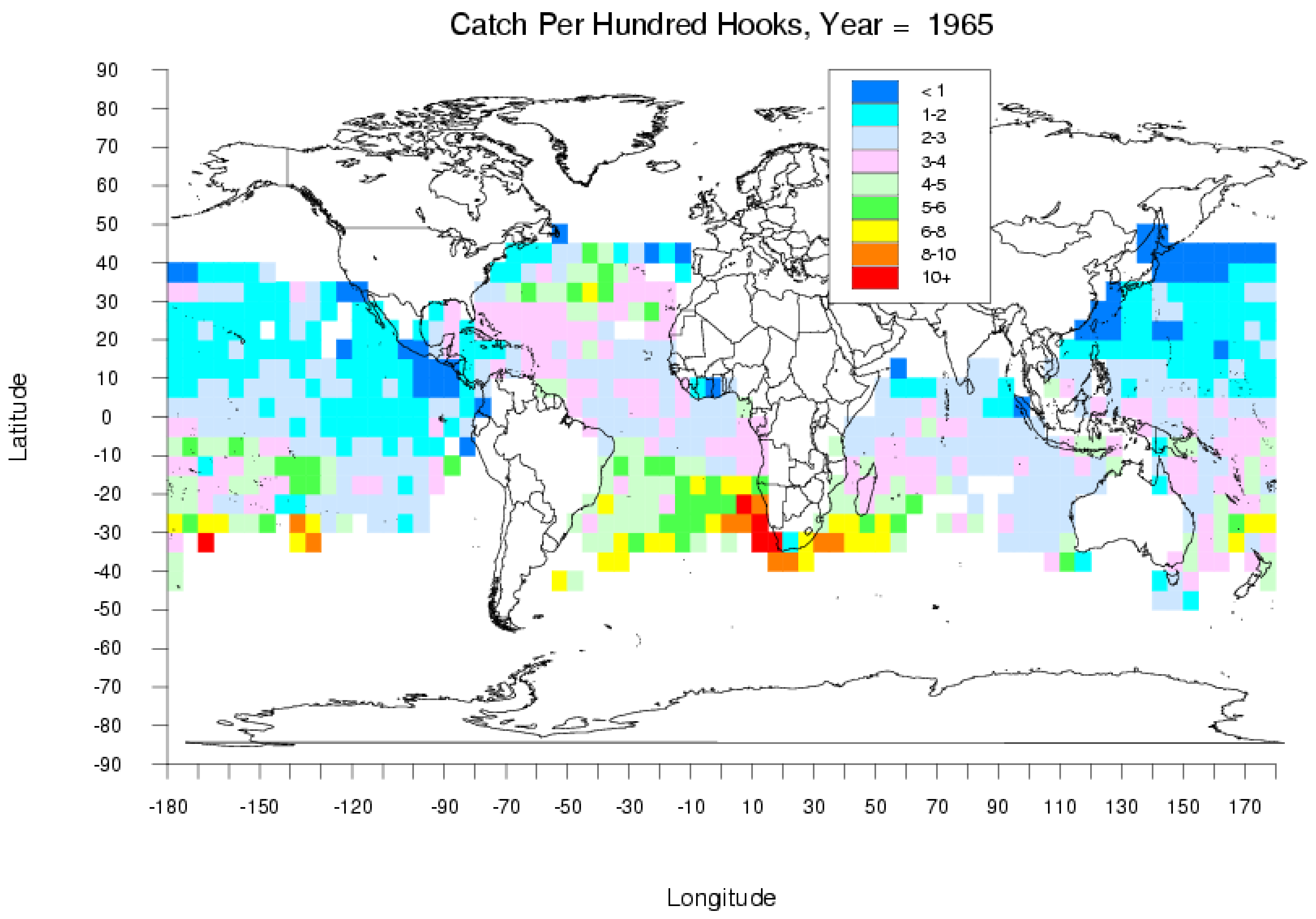
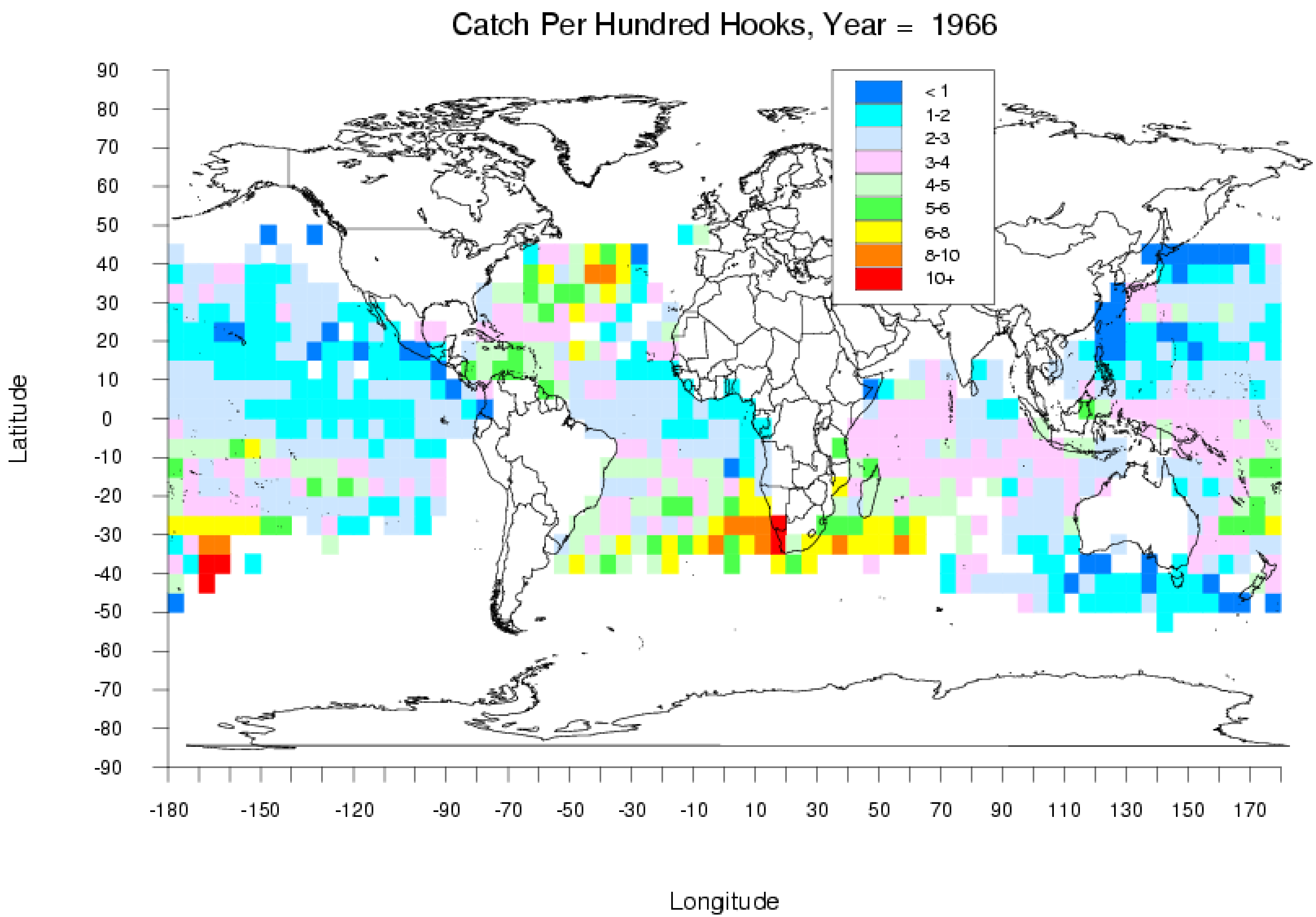
90
110
130
150
170



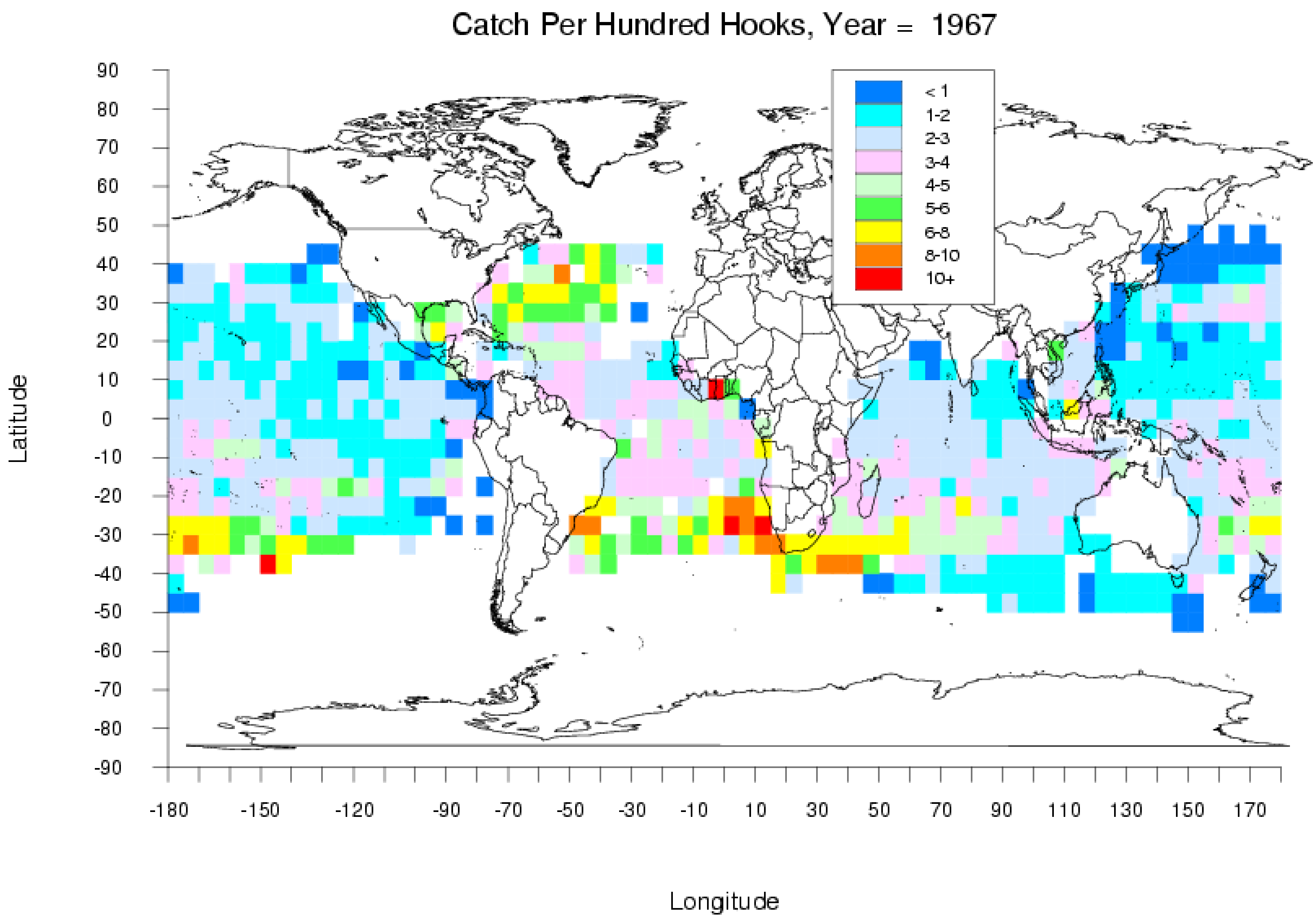
Catch Per Hundred Hooks, Year = 1964
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+



Catch Per Hundred Hooks, Year = 1965
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
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+



Catch Per Hundred Hooks, Year = 1966
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 = 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
-80
-90
-180
-150
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90
110
130
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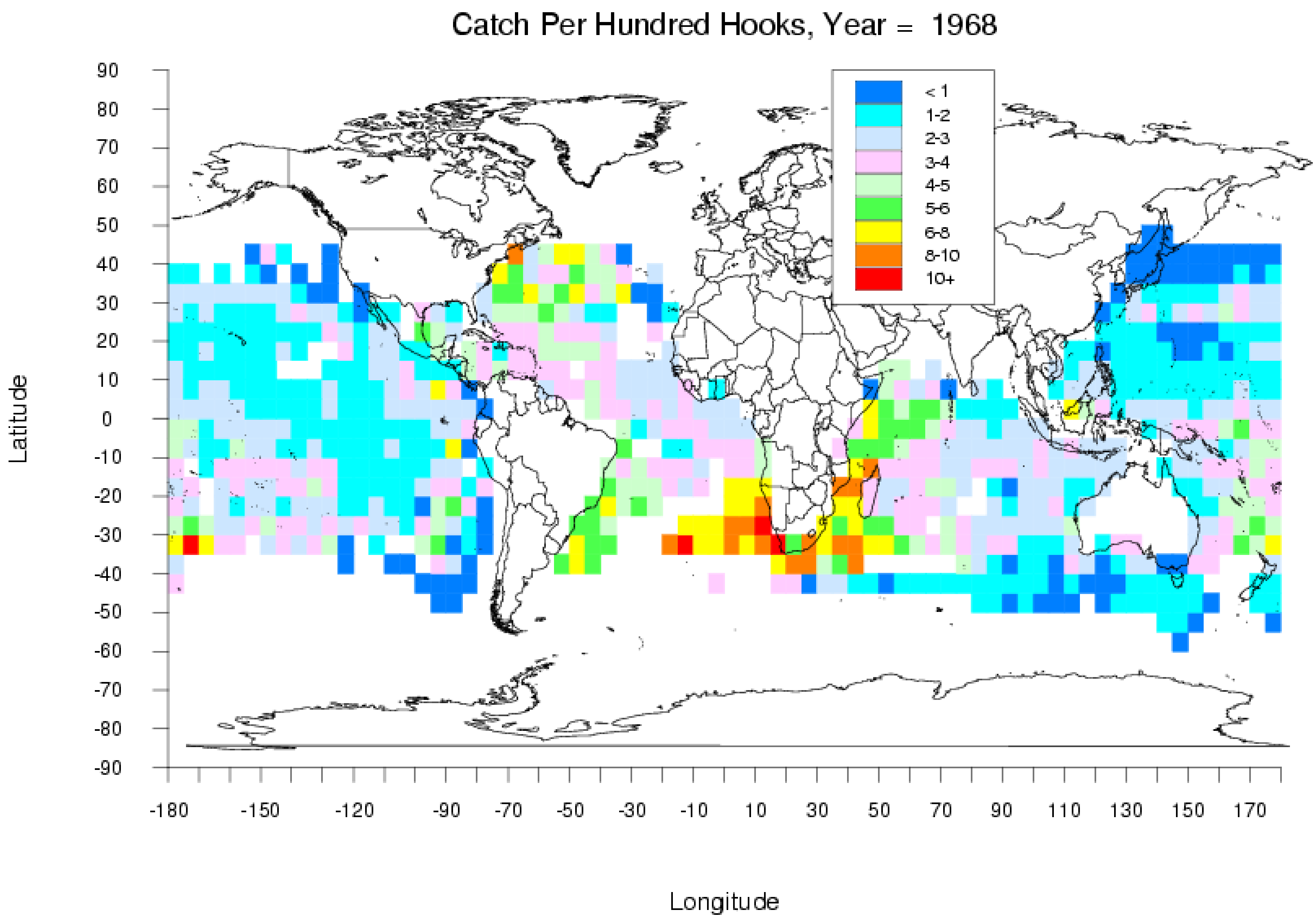
170



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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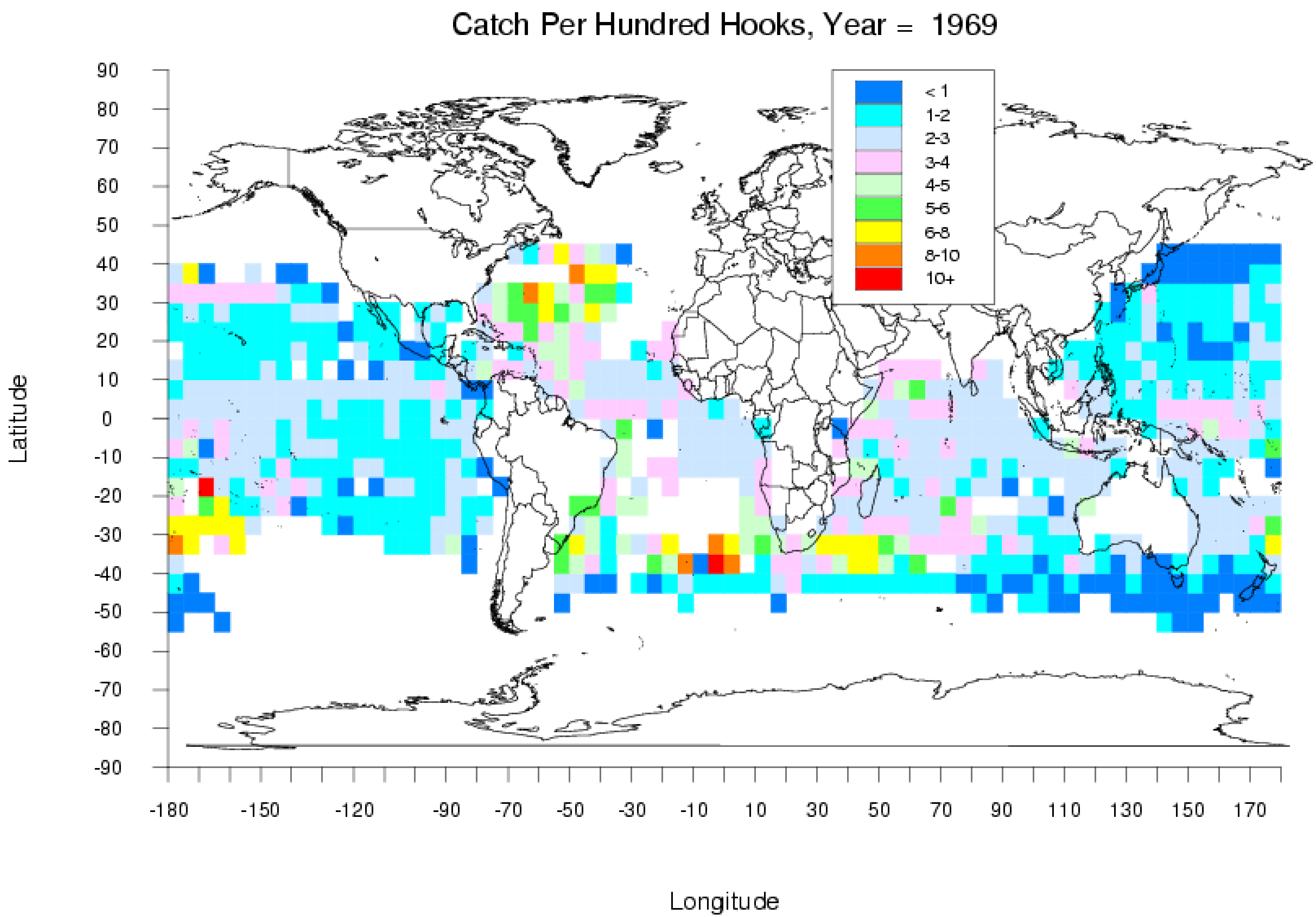
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1969
< 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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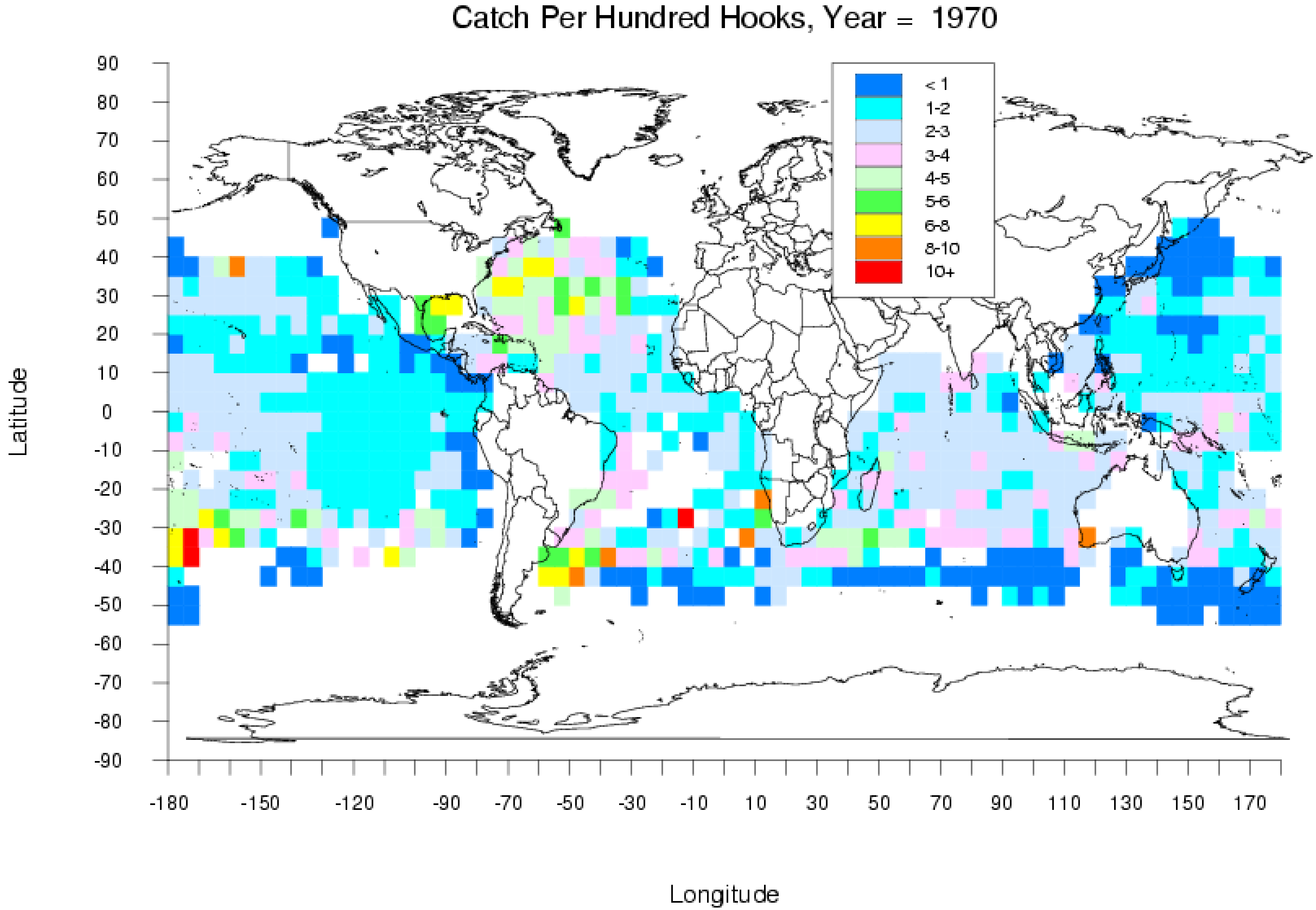
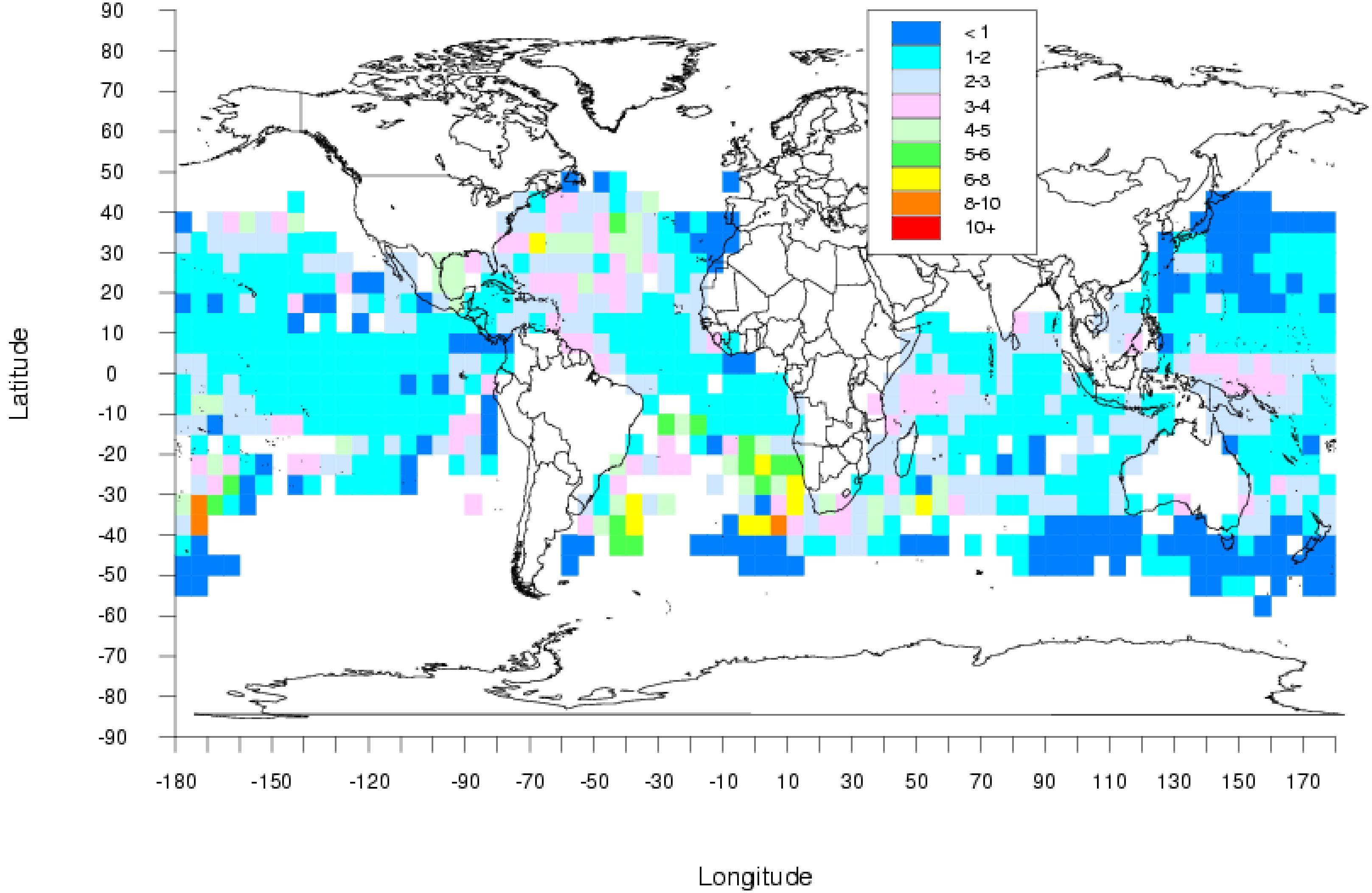
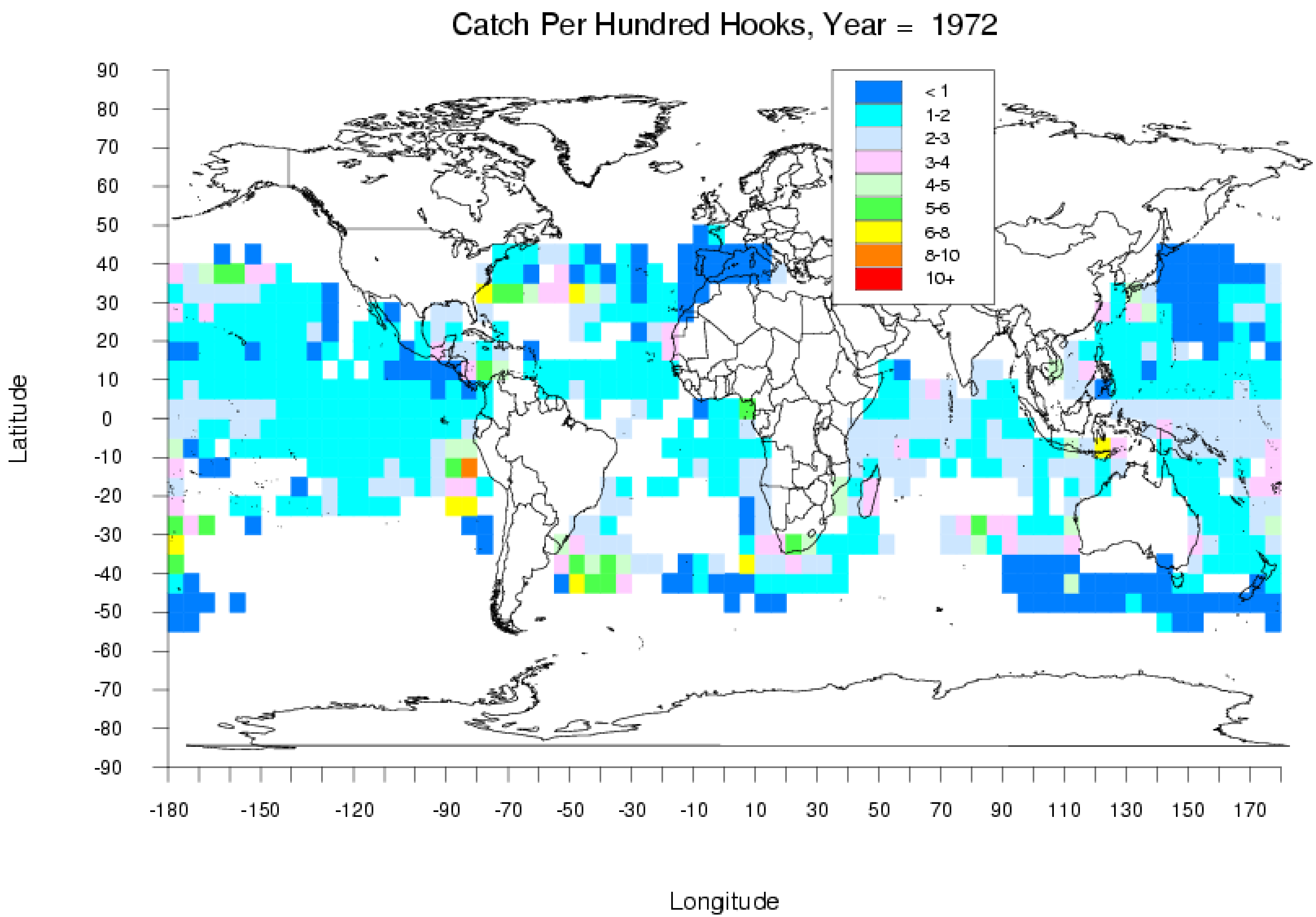
90
110
130
150
170

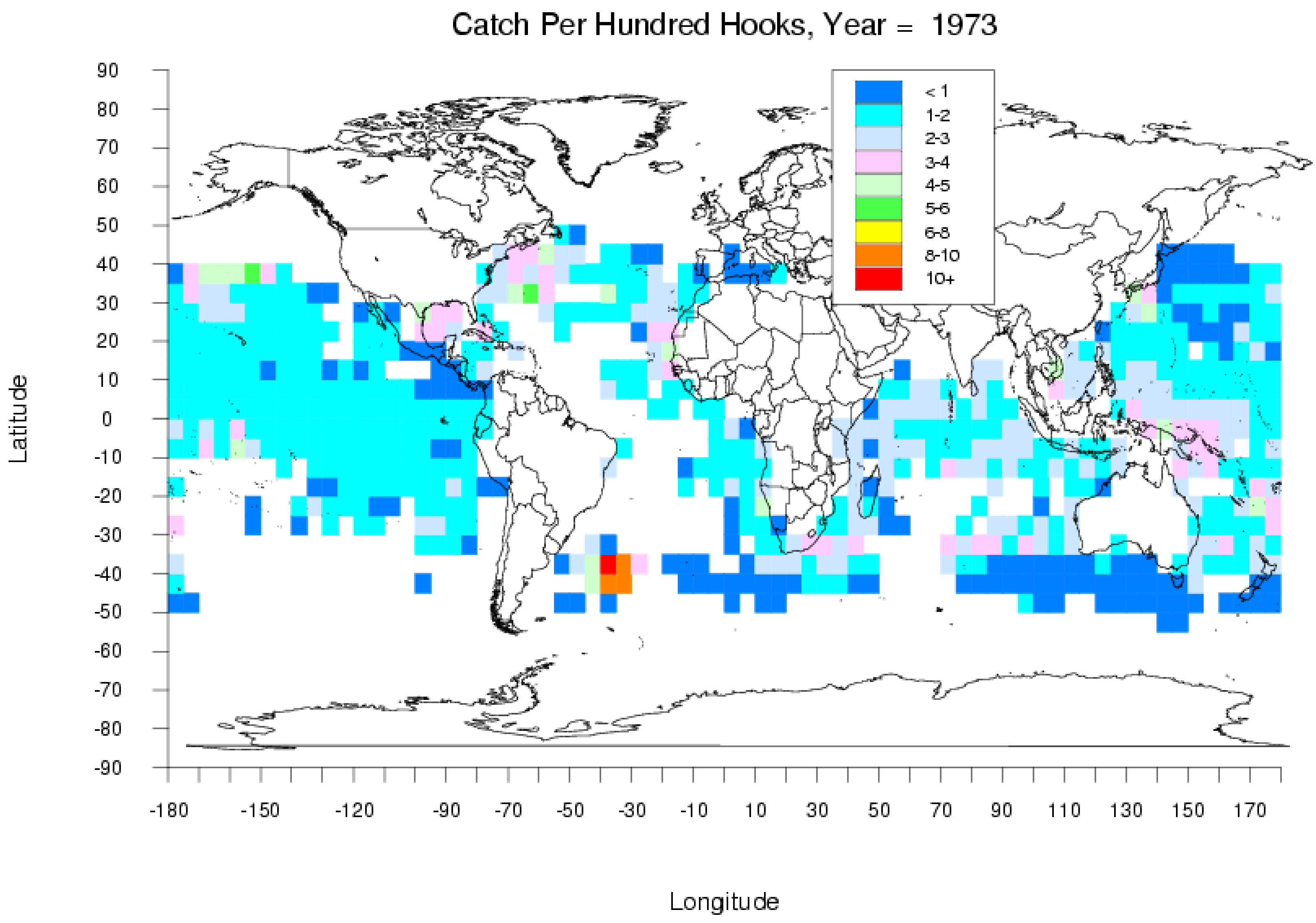

Catch Per Hundred Hooks, Year = 1970
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

Catch Per Hundred Hooks, Year = 1971

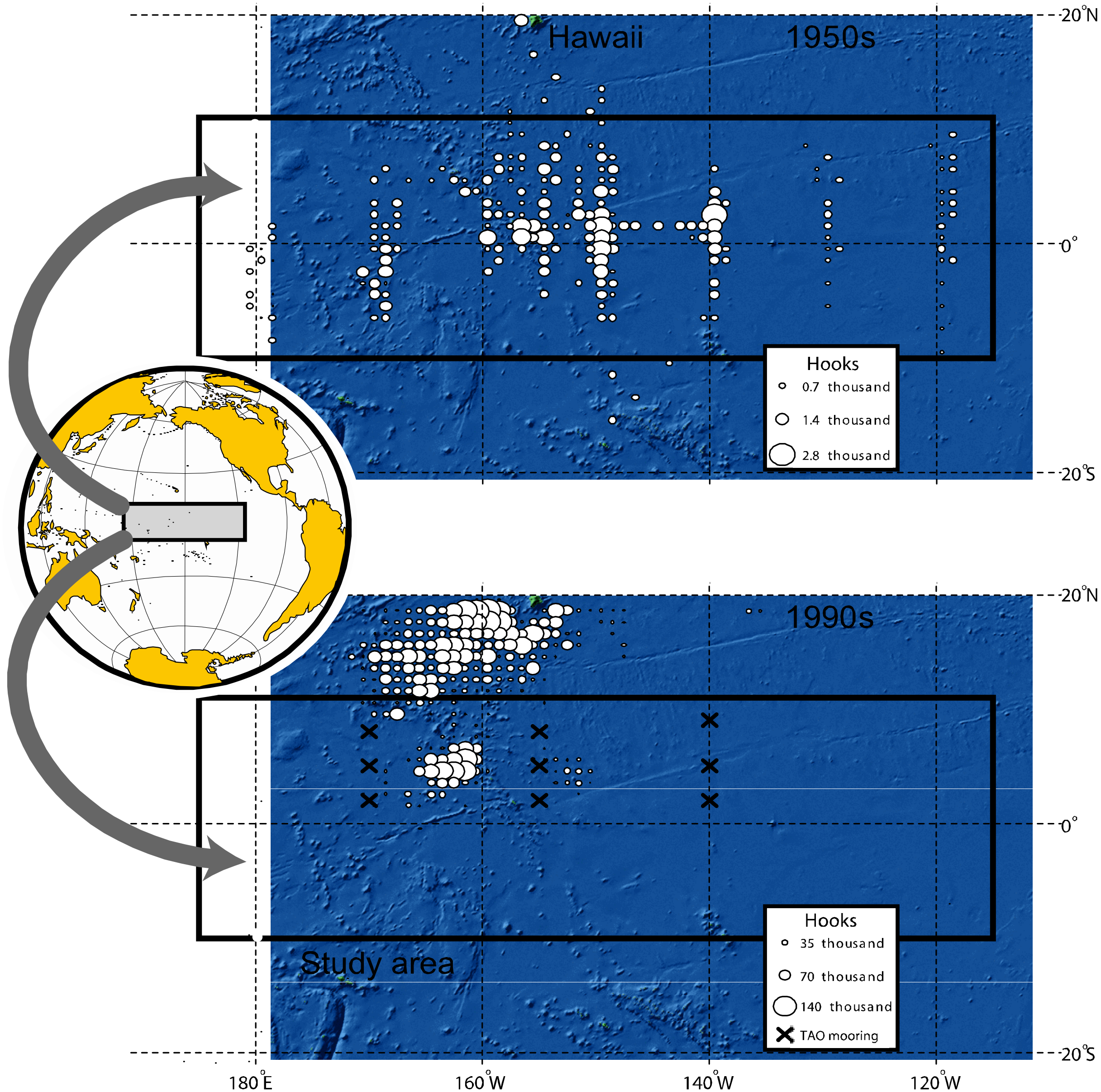




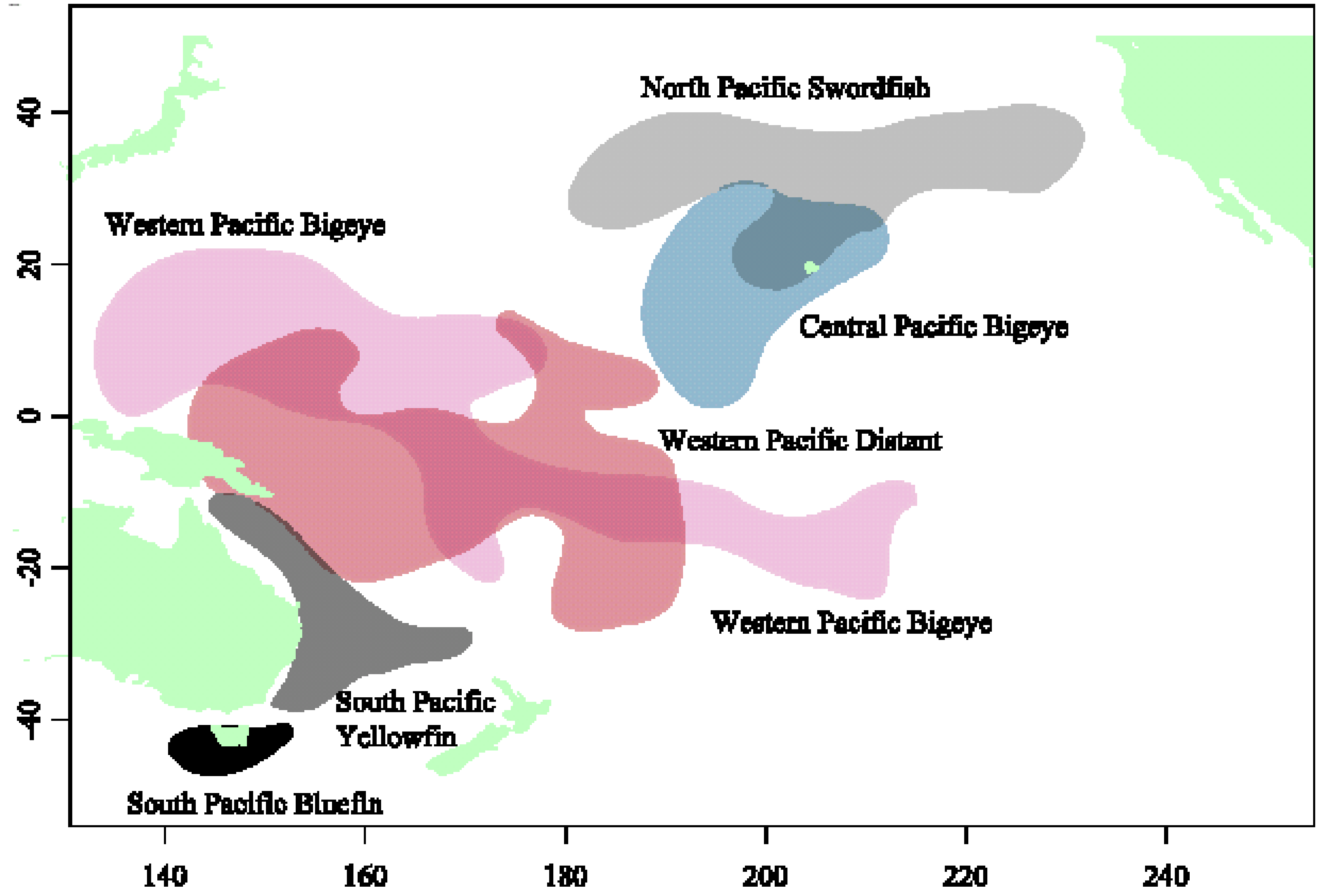
Catch Per Hundred Hooks, Year = 1972
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude

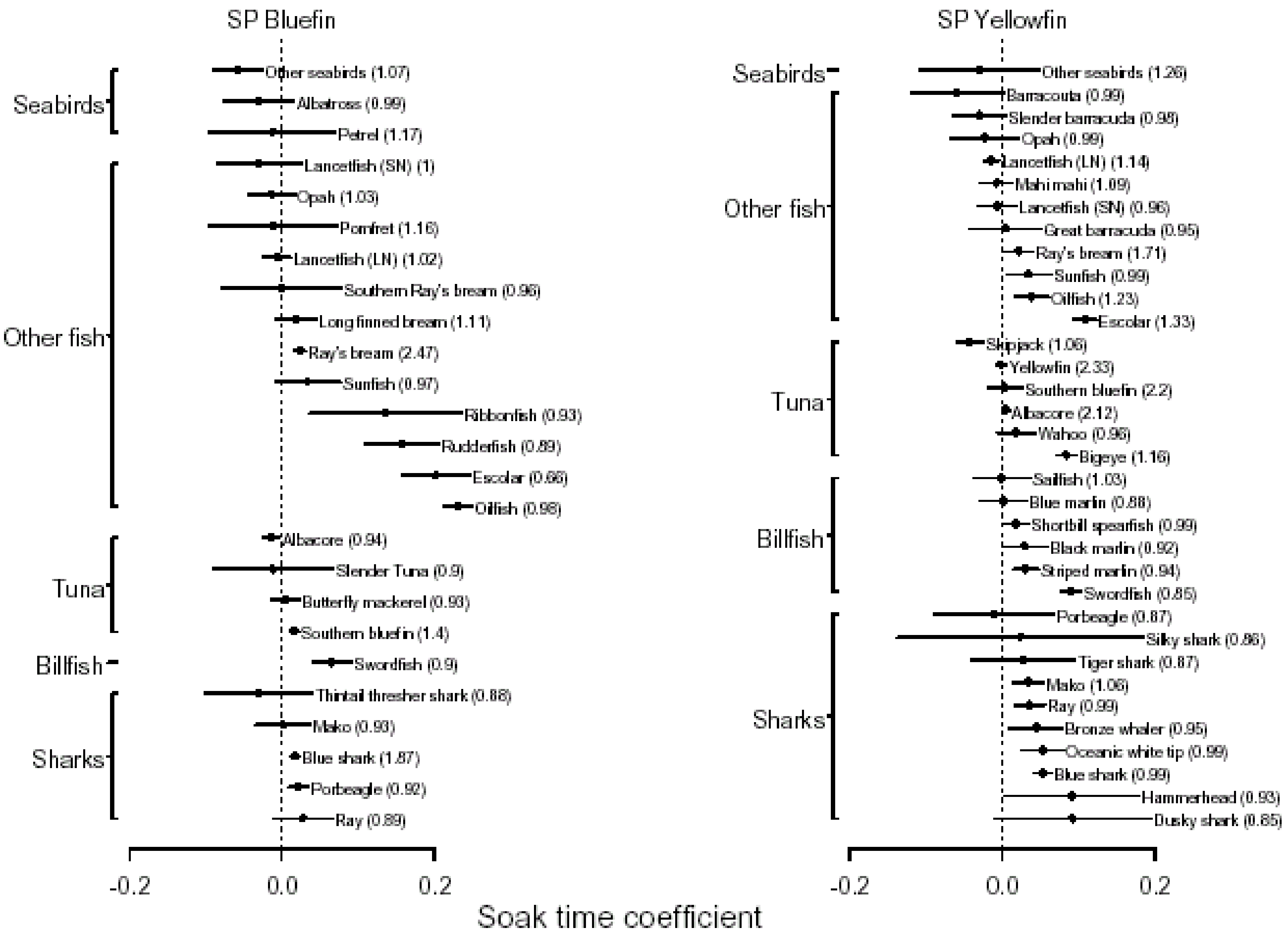


Catch Per Hundred Hooks, Year = 1973
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170

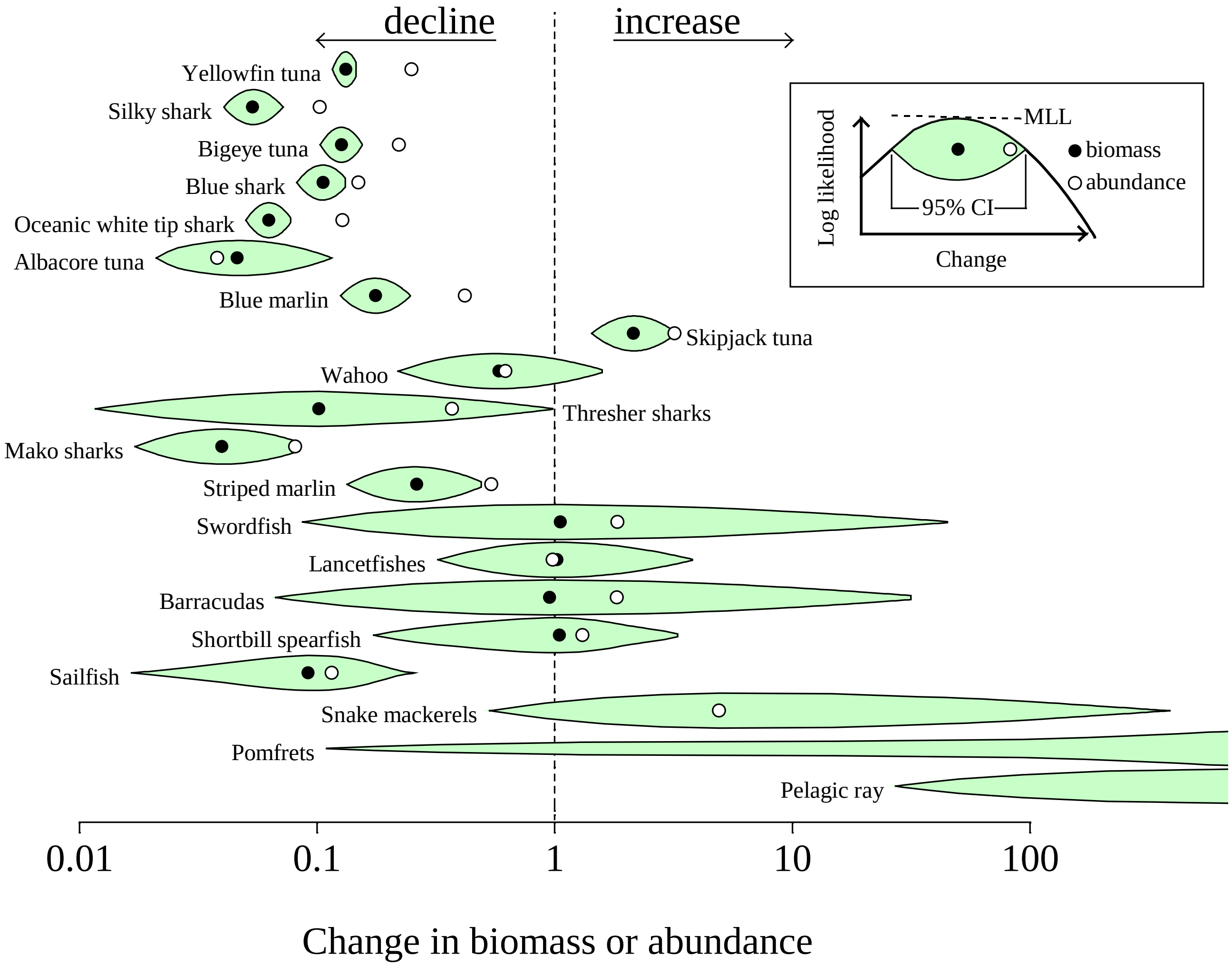


Hawaii
1950s
Hooks
0.7 thousand
1.4 thousand
2.8 thousand
20°N
0°
20°S
1990s
Hooks
35 thousand
70 thousand
140 thousand
TAO mooring
Study area
180°E
160°W
140°W
120°W


North Pacific Swordfish
Western Pacific Bigeye
Central Pacific Bigeye
Western Pacific Distant
Western Pacific Bigeye
South Pacific
Yellowfin
South Pacific Bluefin
40
20
0
-20
-40
140
160
180
200
220
240

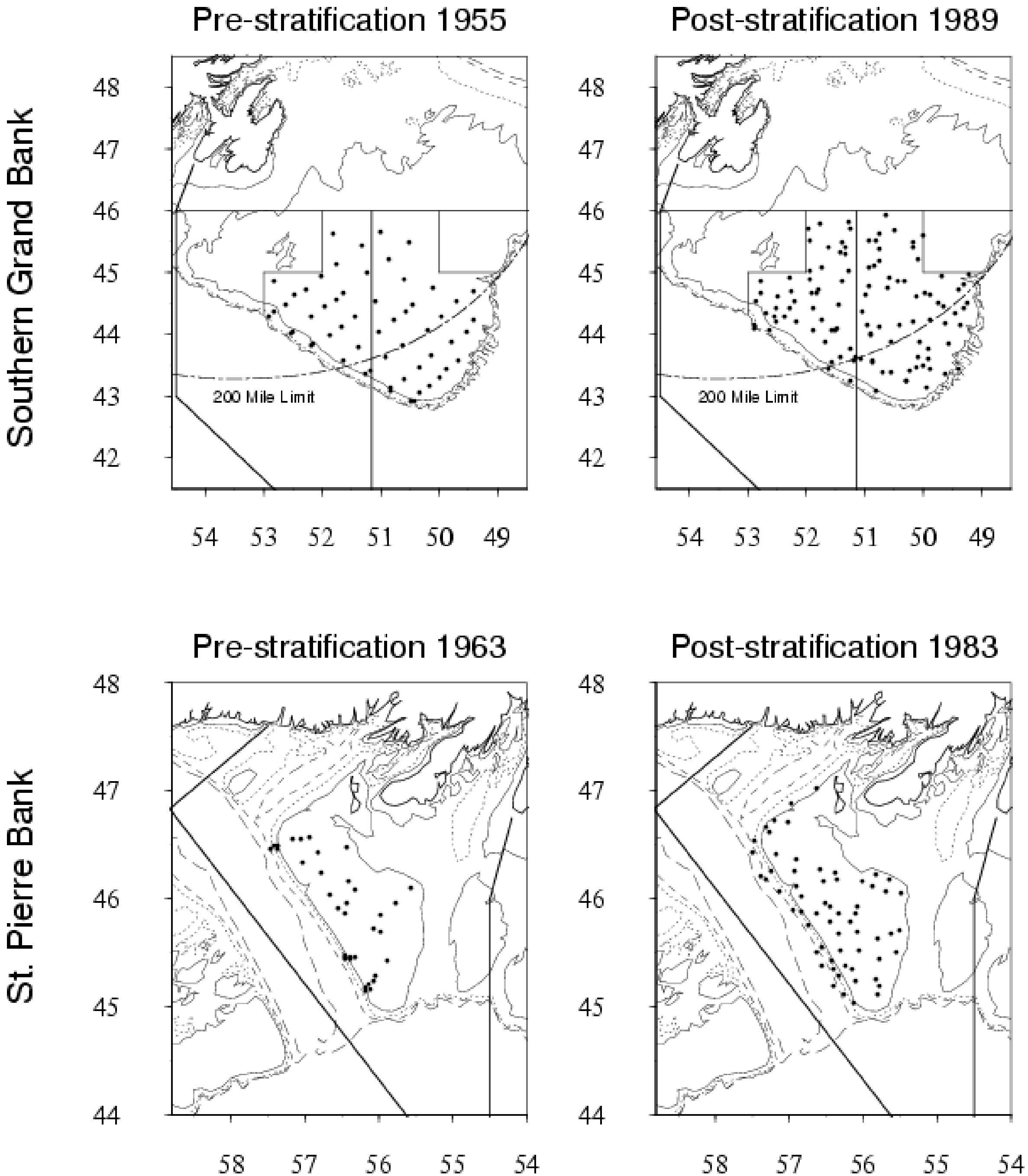


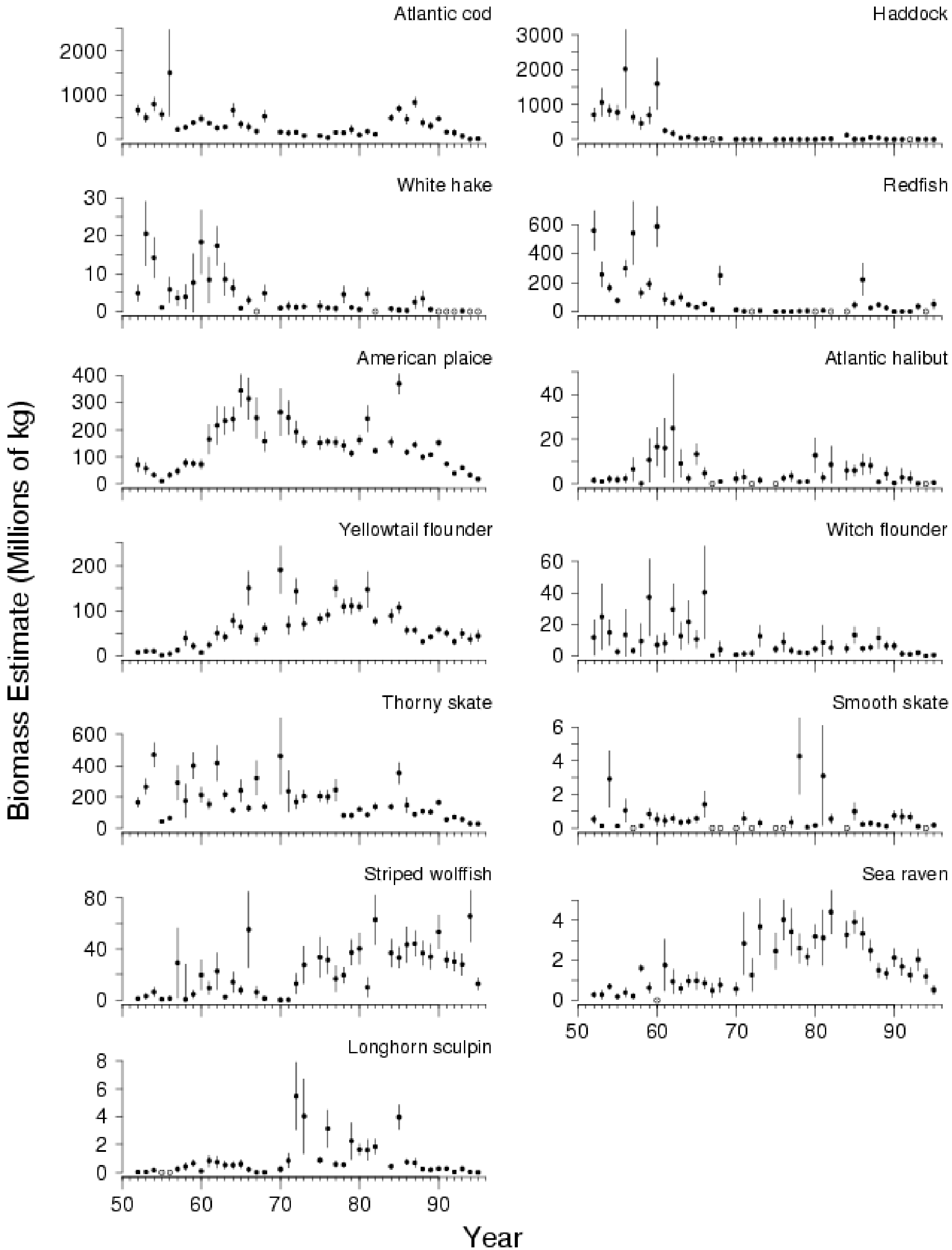
SP Bluefin
Seabirds
Other seabirds (1.07)
Albatross (0.99)
Petrel (1.17)
Other fish
Lancetfish (SN) (1)
Opah (1.03)
Pomfret (1.16)
Lancetfish (LN) (1.02)
Southern Ray's bream (0.96)
Long finned bream (1.11)
Ray's bream (2.47)
Sunfish (0.97)
Ribbonfish (0.93)
Rudderfish (0.89)
Escolar (0.86)
Oilfish (0.98)
Tuna
Albacore (0.94)
Slender Tuna (0.9)
Butterfly mackerel (0.93)
Southern bluefin (1.4)
Billfish
Swordfish (0.9)
Sharks
Thintail thresher shark (0.88)
Mako (0.93)
Blue shark (1.87)
Porbeagle (0.92)
Ray (0.89)
SP Yellowfin
Seabirds
Other seabirds (1.26)
Other fish
Barracouta (0.99)
Slender barracuda (0.98)
Opah (0.99)
Lancetfish (LN) (1.14)
Mahi mahi (1.09)
Lancetfish (SN) (0.96)
Great barracuda (0.95)
Ray's bream (1.71)
Sunfish (0.99)
Oilfish (1.23)
Escolar (1.33)
Tuna
Skipjack (1.06)
Yellowfin (2.33)
Southern bluefin (2.2)
Albacore (2.12)
Wahoo (0.96)
Bigeye (1.16)
Billfish
Sailfish (1.03)
Blue marlin (0.88)
Shortbill spearfish (0.99)
Black marlin (0.92)
Striped marlin (0.94)
Swordfish (0.85)
Sharks
Porbeagle (0.87)
Silky shark (0.86)
Tiger shark (0.87)
Mako (1.06)
Ray (0.99)
Bronze whaler (0.95)
Oceanic white tip (0.99)
Blue shark (0.99)
Hammerhead (0.93)
Dusky shark (0.85)
-0.2
0.0
0.2
-0.2
0.0
0.2
Soak time coefficient


decline
increase
Yellowfin tuna
Silky shark
Bigeye tuna
Blue shark
Oceanic white tip shark
Albacore tuna
Blue marlin
Skipjack tuna
Wahoo
Thresher sharks
Mako sharks
Striped marlin
Swordfish
Lancetfishes
Barracudas
Shortbill spearfish
Sailfish
Snake mackerels
Pomfrets
Pelagic ray
Log likelihood
MLL
biomass
abundance
95% CI
Change
0.01
0.1
1
10
100
Change in biomass or abundance

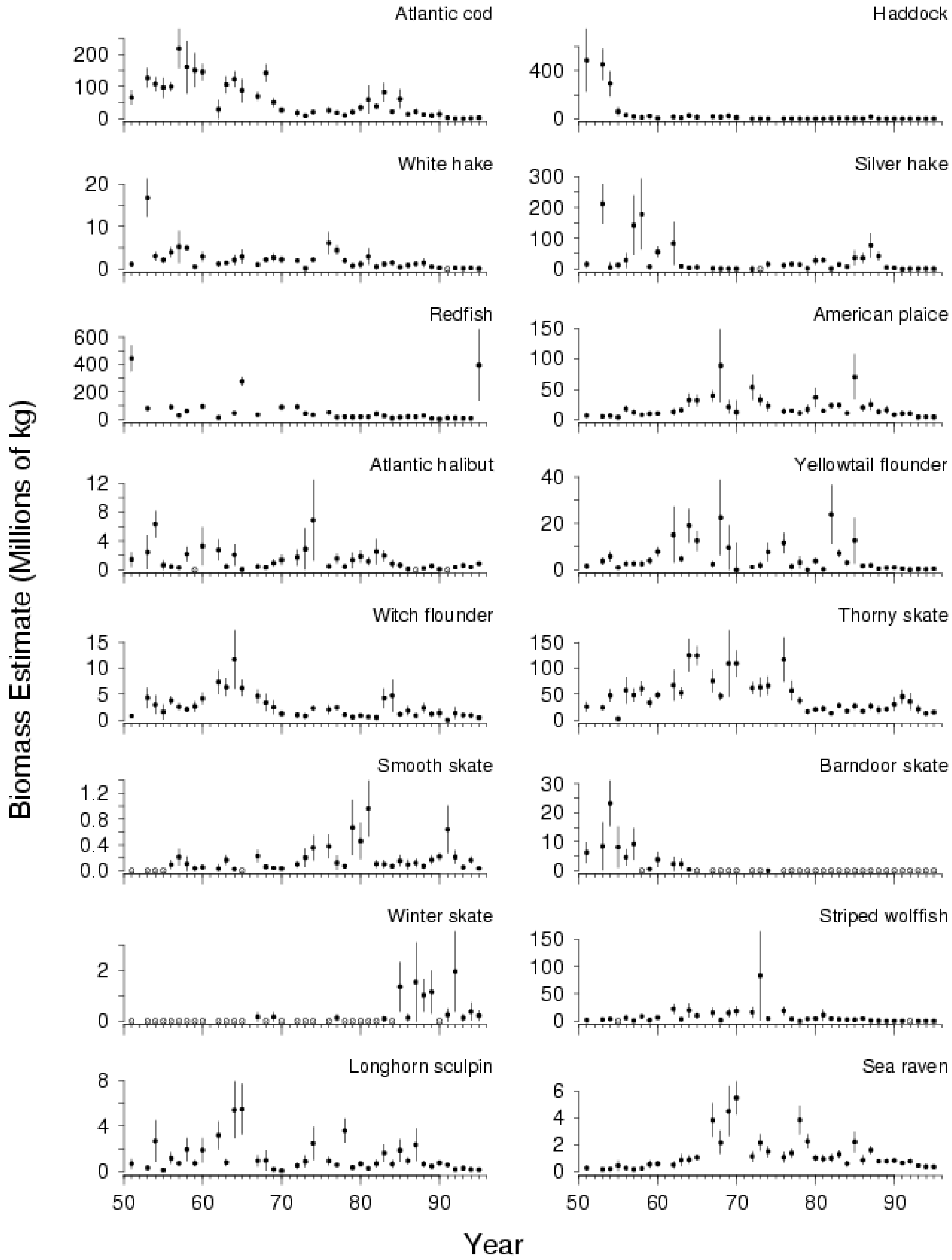
Reason #4 for having Research Surveys

- We can understand biology.

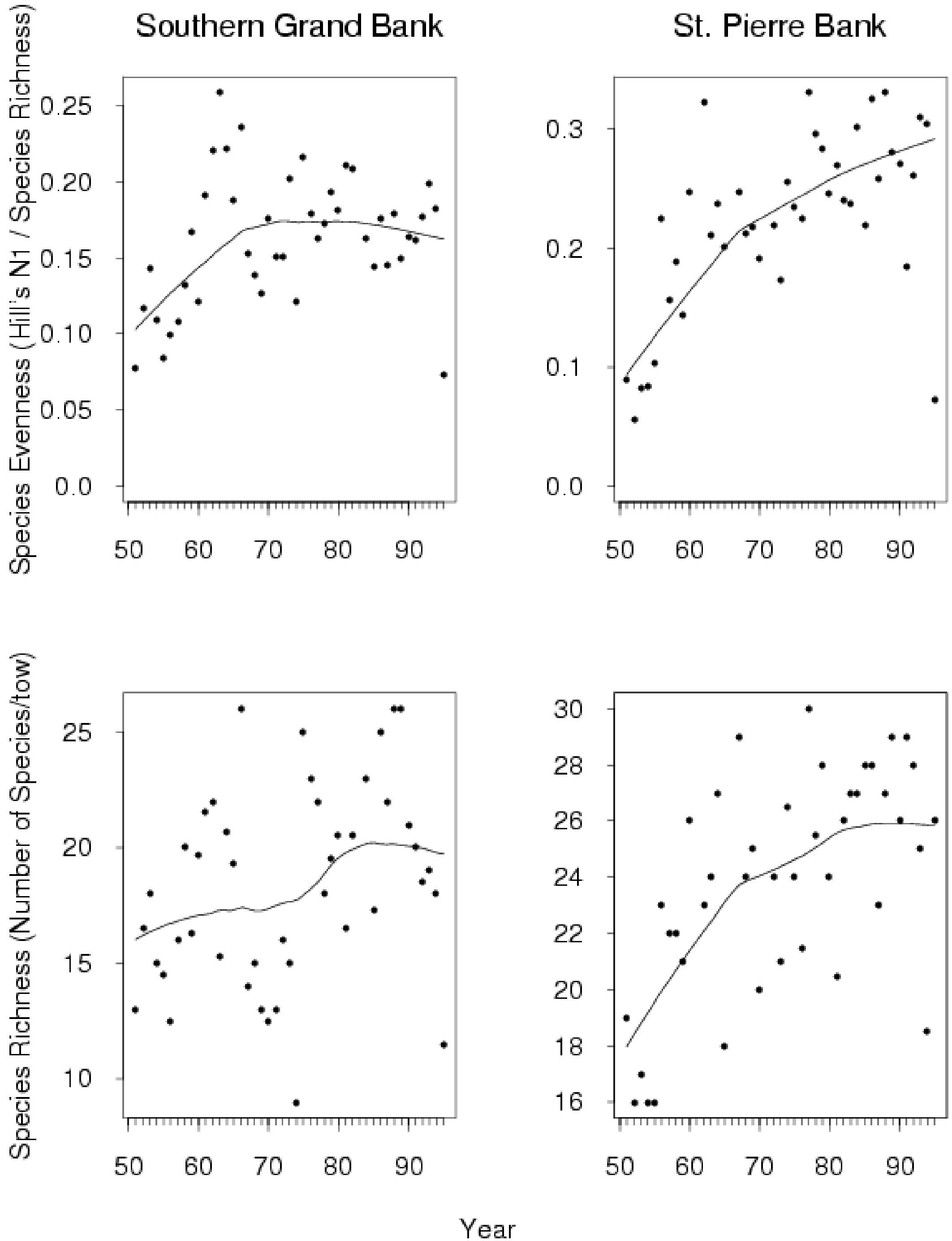

Southern Grand Bank
Pre-stratification 1955
Post-stratification 1989
200 Mile Limit
200 Mile Limit
48
47
46
45
44
43
42
54
53
52
51
50
49
St. Pierre Bank
Pre-stratification 1963
Post-stratification 1983
48
47
46
45
44
58
57
56
55
54

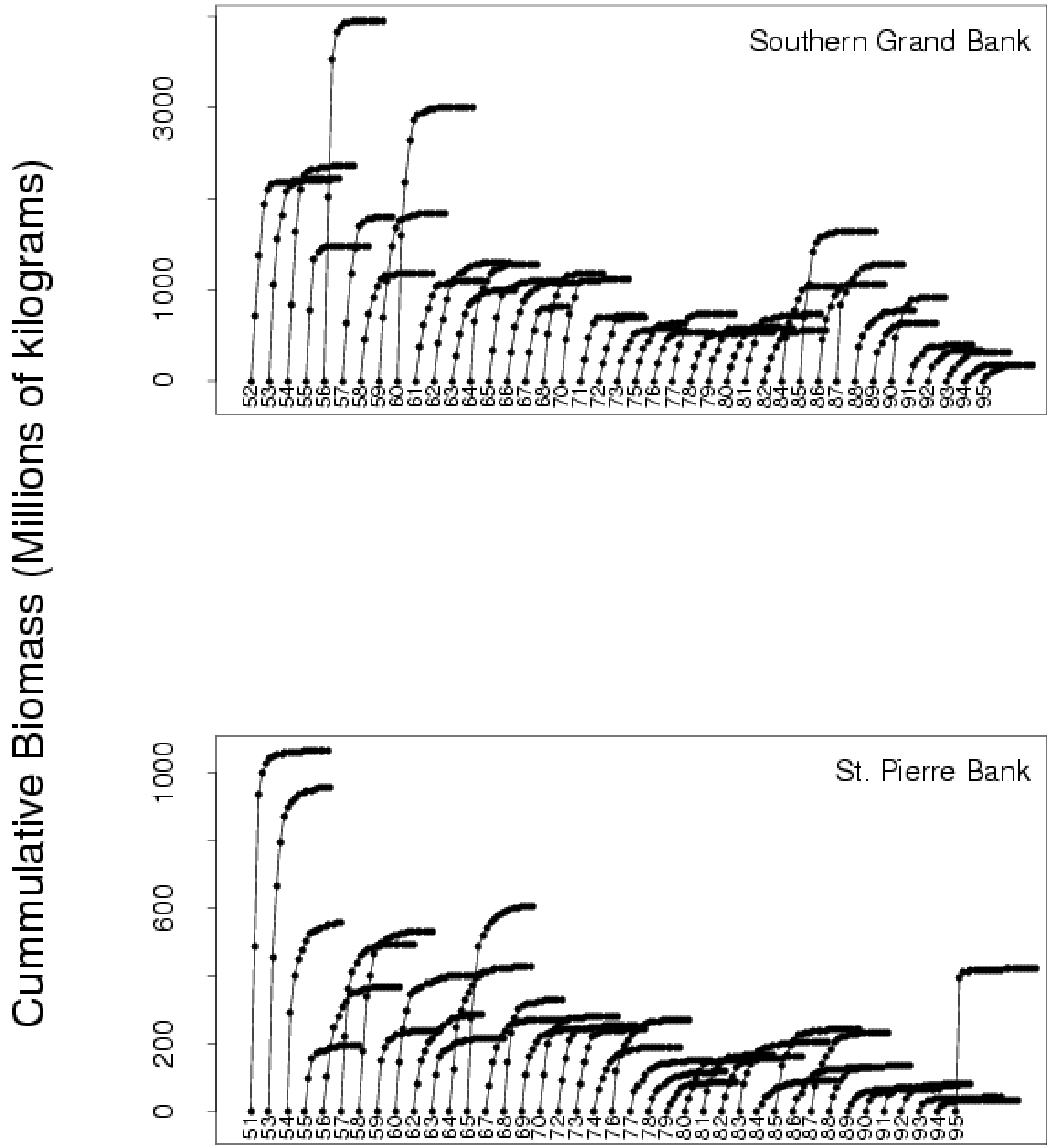


Atlantic cod
Haddock
White hake
Redfish
American plaice
Atlantic halibut
Yellowtail flounder
Witch flounder
Thorny skate
Smooth skate
Striped wolffish
Sea raven
Longhorn sculpin
Biomass Estimate (Millions of kg)
Year

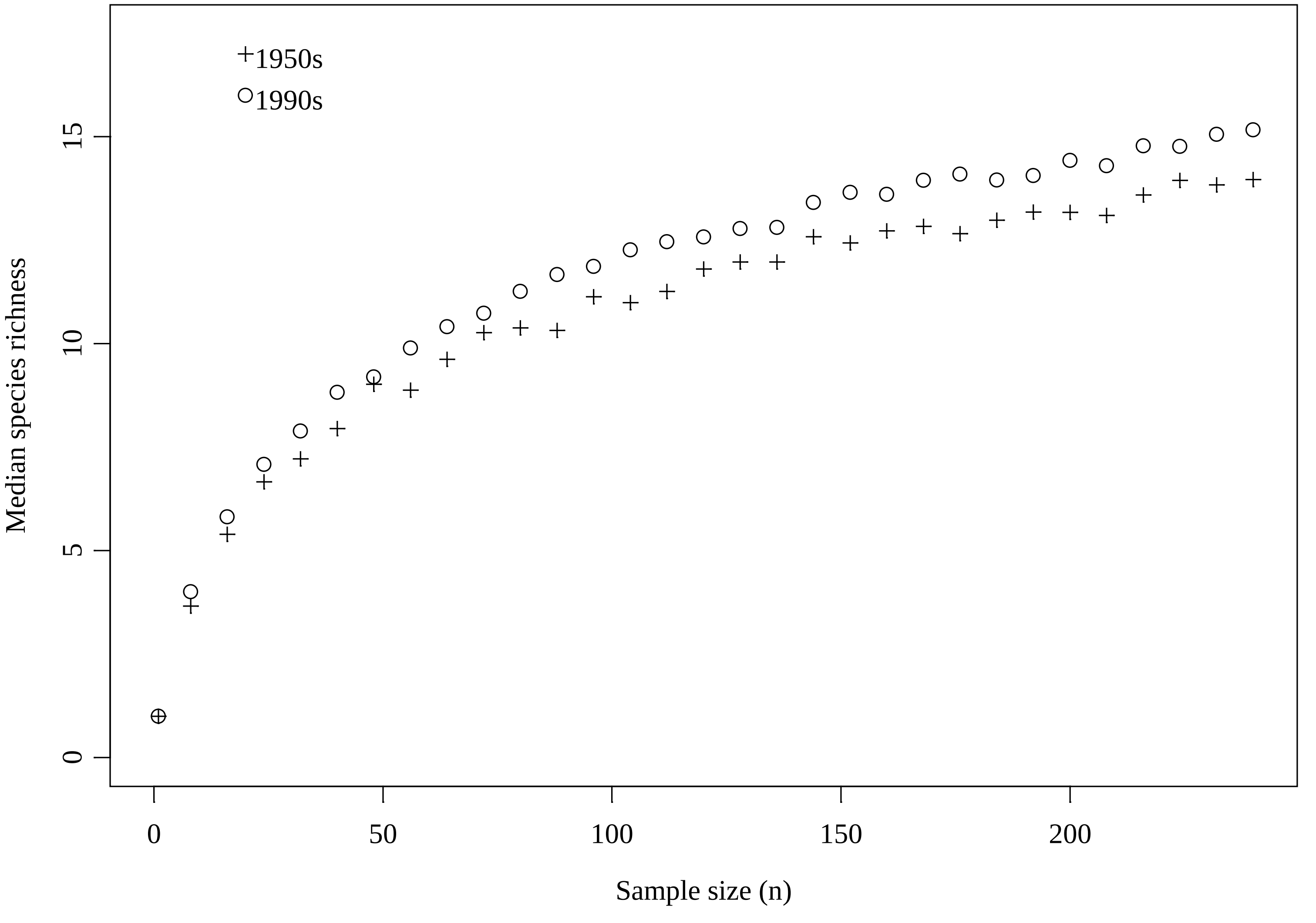


Atlantic cod
Haddock
White hake
Silver hake
Redfish
American plaice
Atlantic halibut
Yellowtail flounder
Witch flounder
Thorny skate
Smooth skate
Barndoor skate
Winter skate
Striped wolffish
Longhorn sculpin
Sea raven
Biomass Estimate (Millions of kg)
Year


Southern Grand Bank
St. Pierre Bank
Species Evenness (Hill's N1 / Species Richness)
Species Richness (Number of Species/tow)
Year



Cummulative Biomass (Millions of kilograms)
Southern Grand Bank
0
1000
3000
St. Pierre Bank
0
200
600
1000



1950s
1990s
Median species richness
0
5
10
15
0
50
100
150
200
Sample size (n)

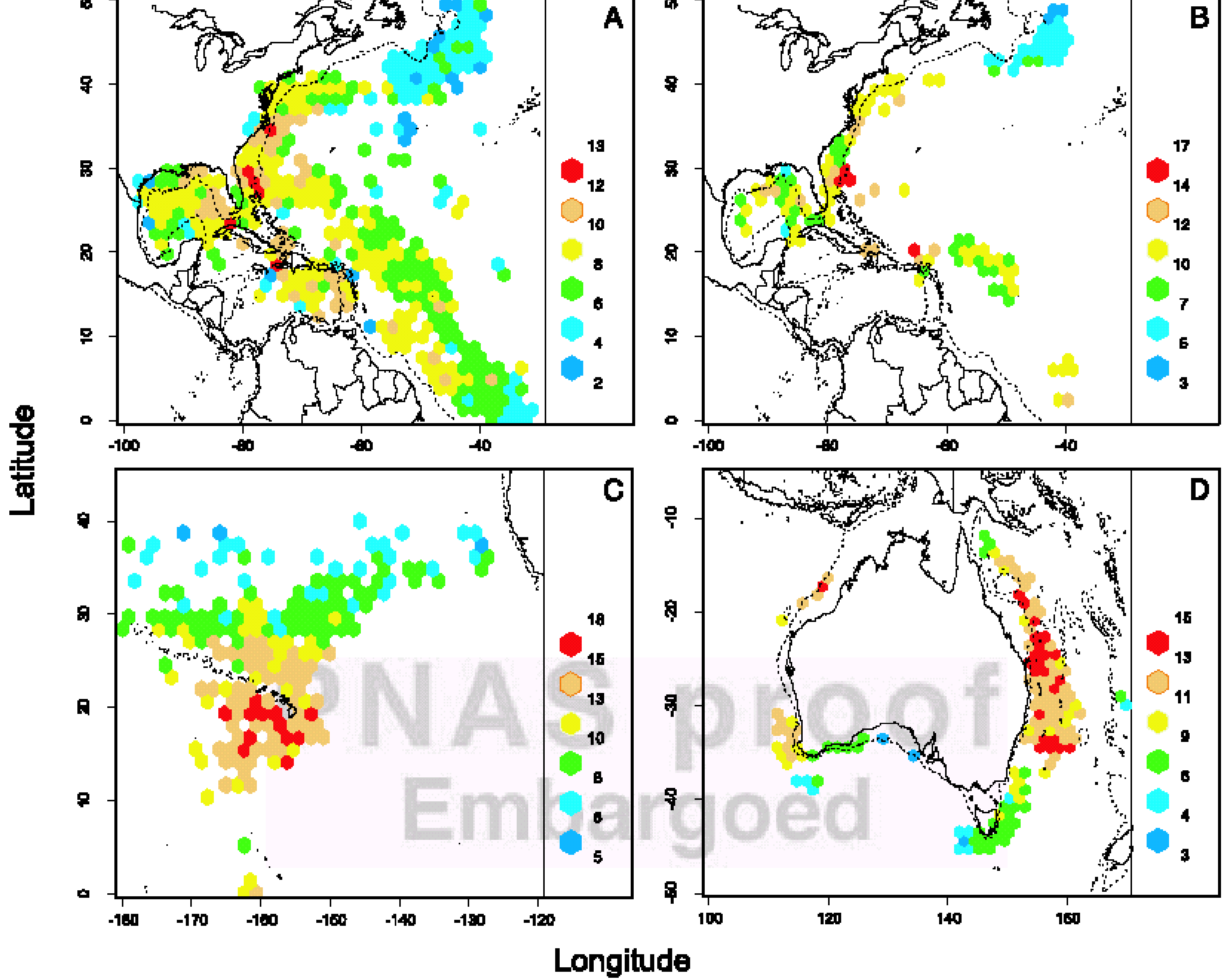
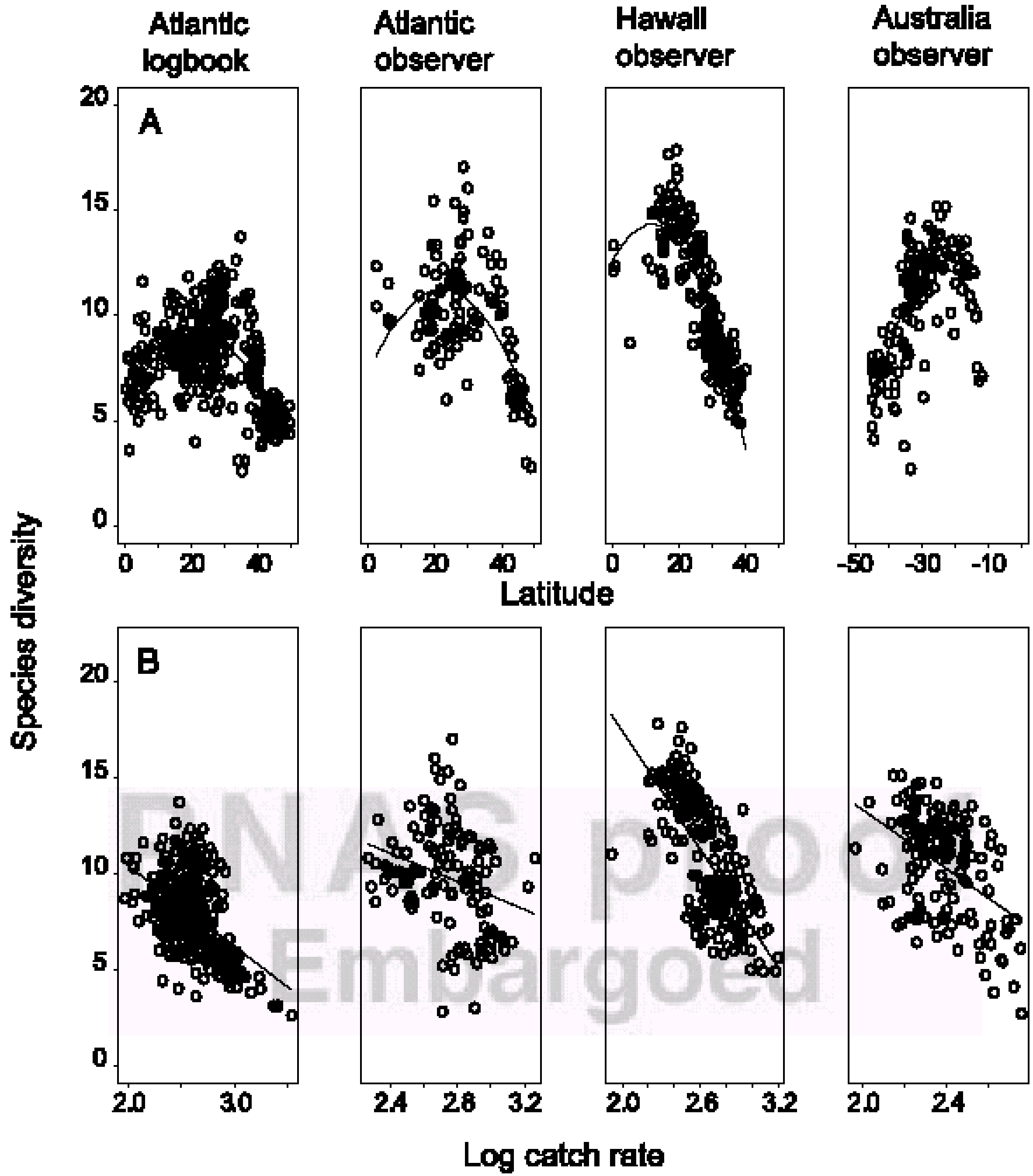


Fig. 2. Predator diversity in the ocean, predicted from the northwest Atlantic long-line logbook (*A*), and observer data (*B*), Hawaiian observer data (*C*), and Australian observer data (*D*). Color codes indicate levels of species diversity calculated by rarefaction and expressed as the expected number of species per 50 individuals. Red cells indicate areas of maximum diversity, or hotspots. The dotted lines represent 1,000-m isobaths, identifying the outer margins of continental slopes.

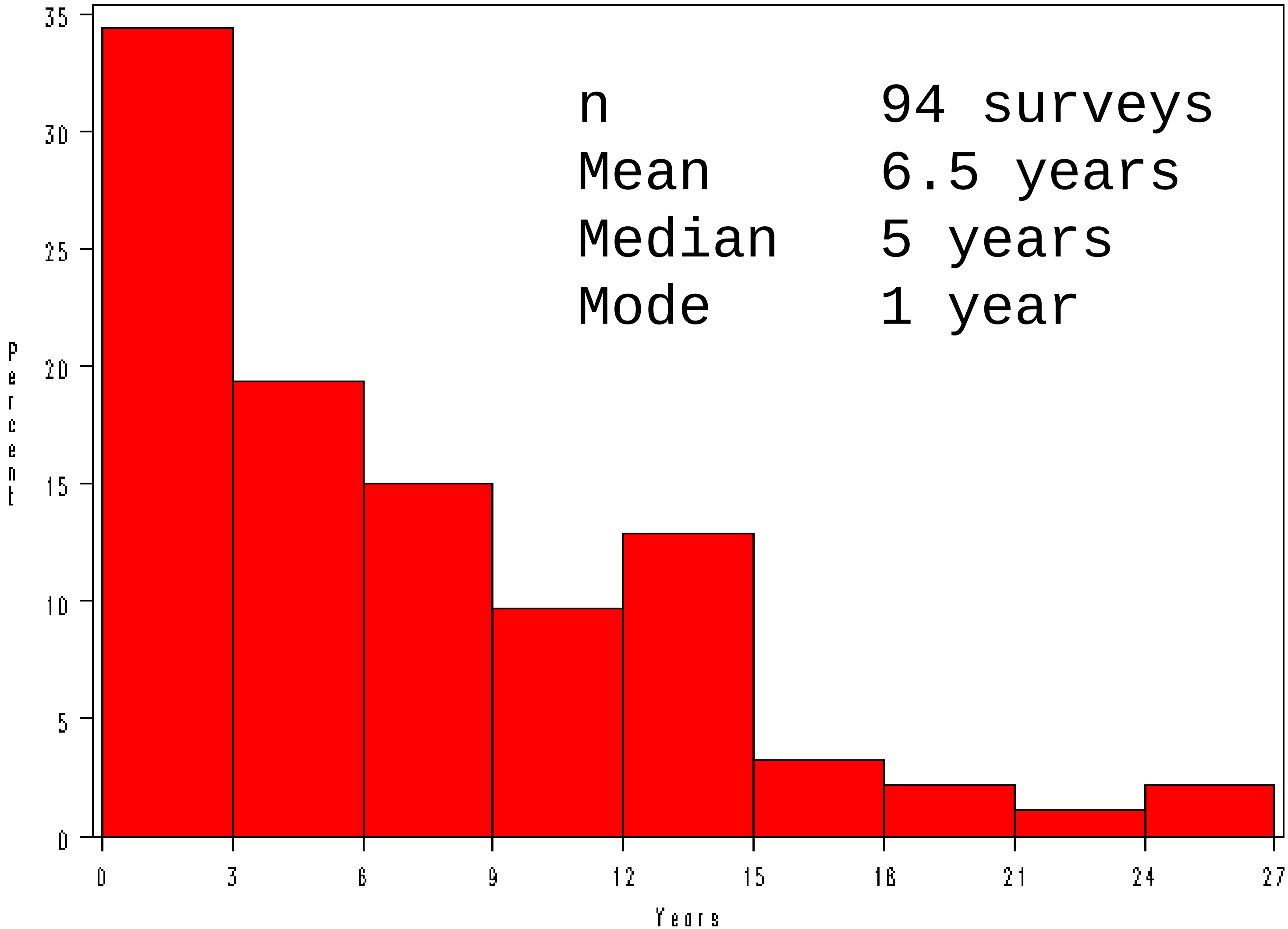


Atlantic logbook
Atlantic observer
Hawaii observer
Australia observer
A
B
Species diversity
Latitude
Log catch rate
0
5
10
15
20
0
20
40
-50
-30
-10
2.0
3.0
2.4
2.8
3.2
2.6

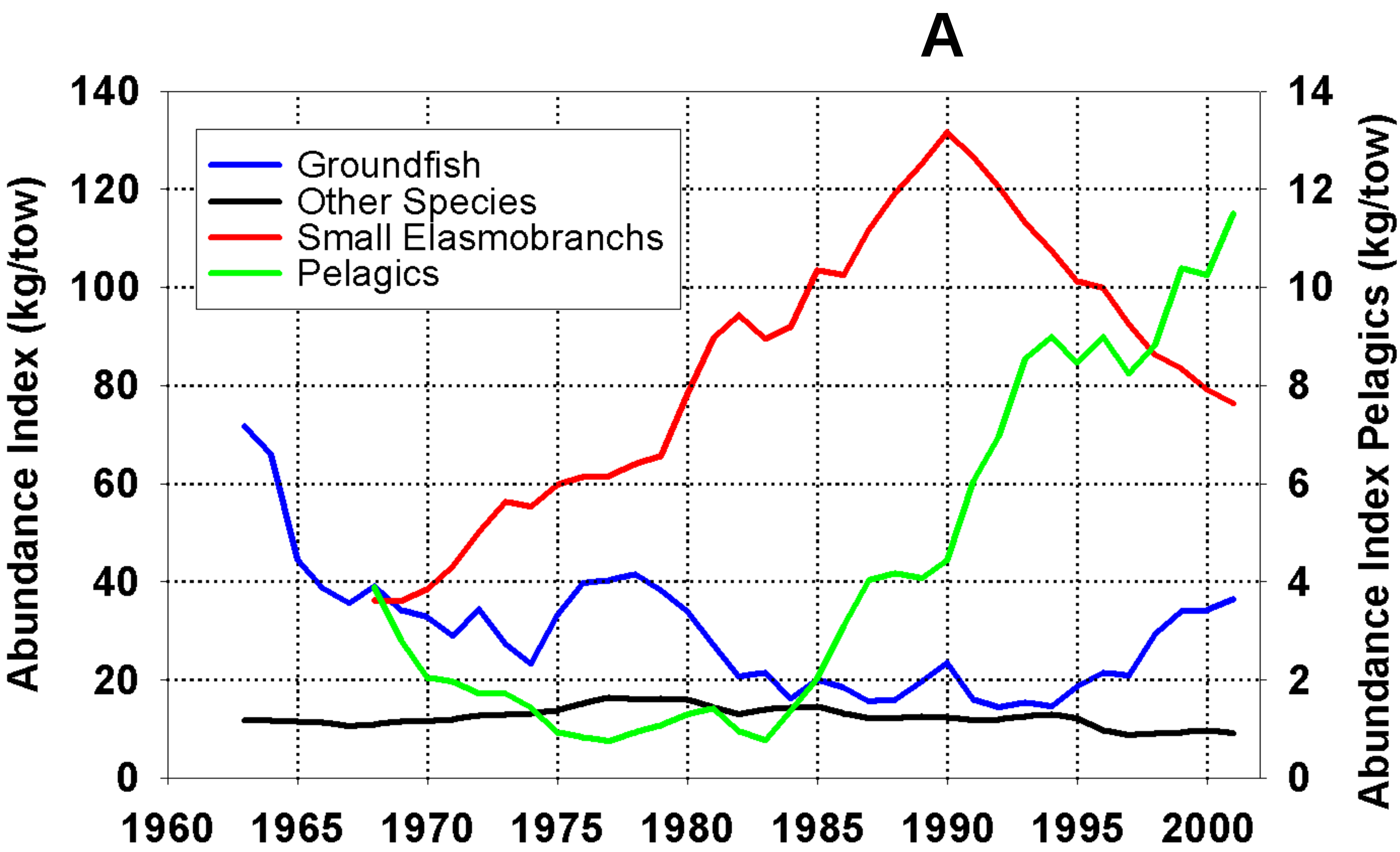
3 Central design criteria

- Don’t change the design or gear.
- Identify and count everything (trash today is gold tomorrow, e.g. snow crabs, hagfish, urchins, Atlantic halibut).
- Keep sample sites constant in space and time.

How long do surveys last before they are “improved”? Not very long.



Histogram of all research surveys in Northwest Atlantic (north of Nova Scotia)



A
Groundfish
Other Species
Small Elasmobranchs
Pelagics
Abundance Index (kg/tow)
Abundance Index Pelagics (kg/tow)
140
120
100
80
60
40
20
0
14
12
10
8
6
4
2
0
1960
1965
1970
1975
1980
1985
1990
1995
2000

Make surveys consistent.

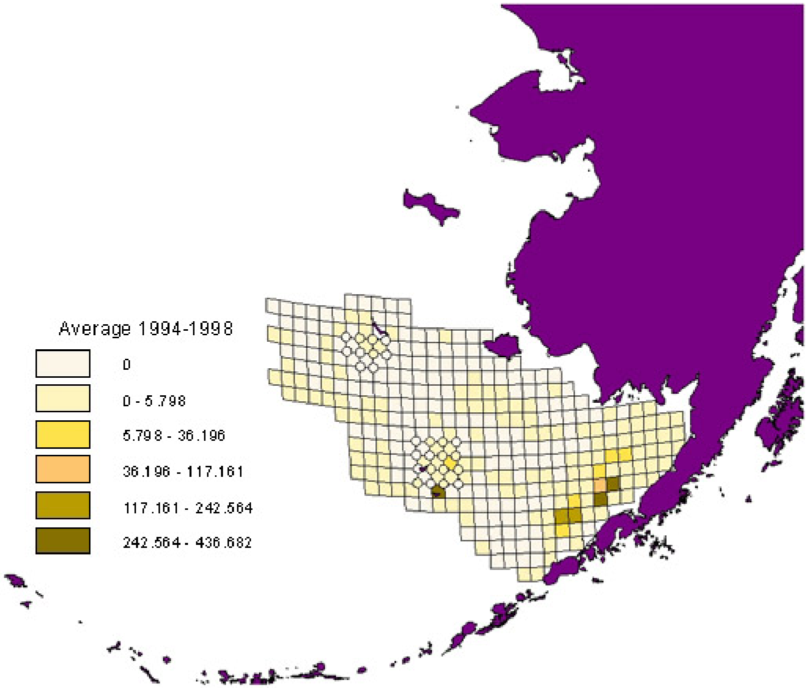
No matter how smart the old guy was, remember that you can modify the protocols to improve the survey. This is always the case for any new person.

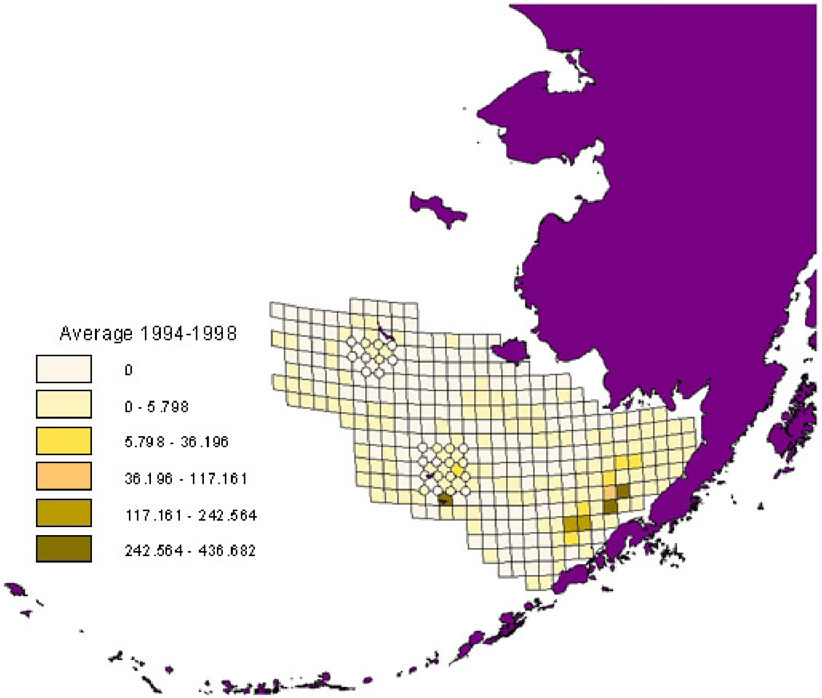
It is not possible to standardize very different survey gear with the amount of time available. For example in the Newfoundland groundfish surveys, in order to estimate the selectivity of cod, other species was done.

How many samples do you need to take to cross compare two different types of trawl gear?

- More than you can because you have to examine all depth, species and size composition –
- Not all size/species are present in the year a comparison is done.

Count Everything (even the jellyfish)





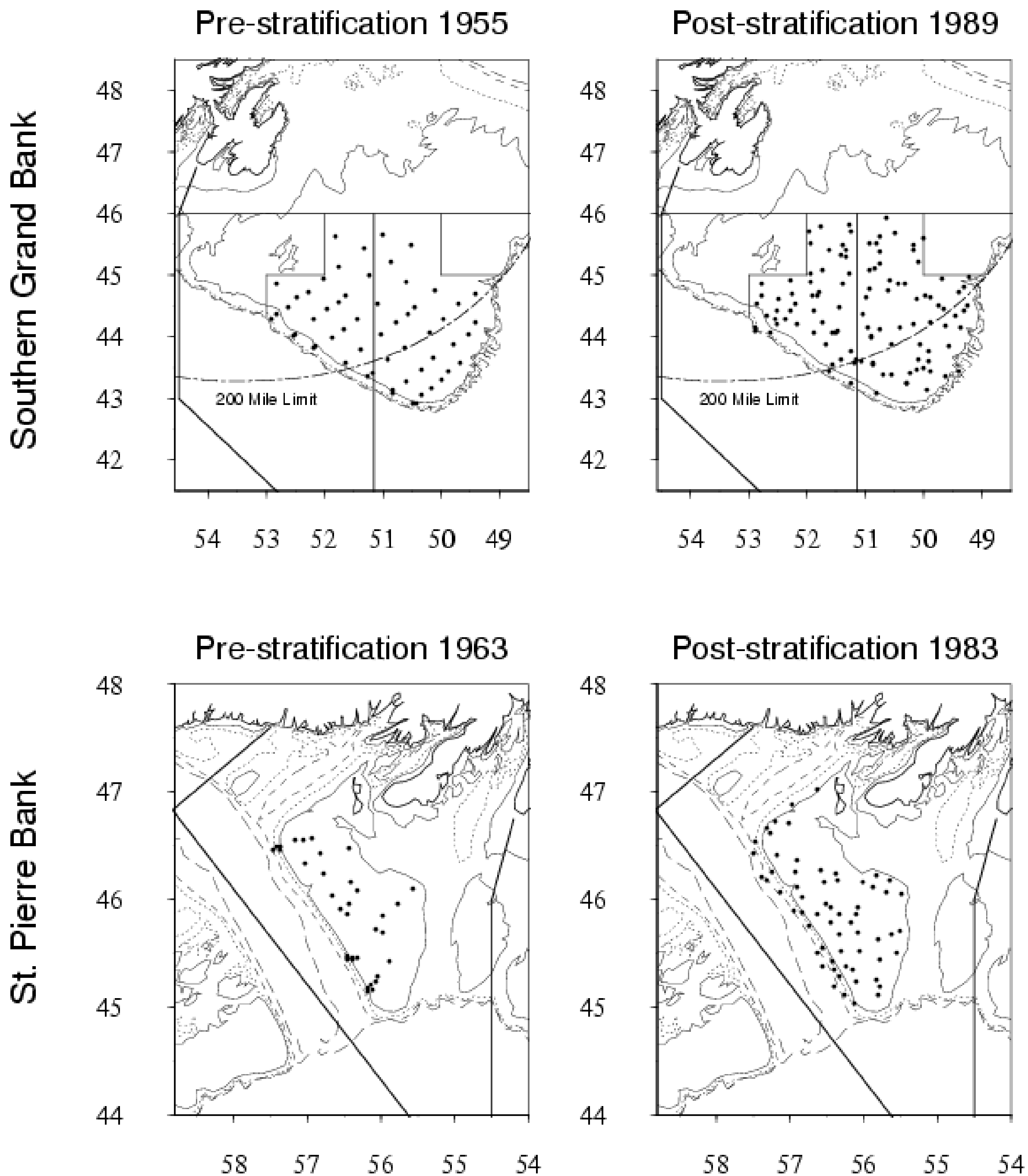
Sponges
Distribution and Abundance Maps (kg/hectare)
(Data derived from standard NMFS groundfish/crab trawl surveys where catches of noncommercial species are also enumerated and weighed.)

In Alaska NMFS even counts the sponges.


5 cm

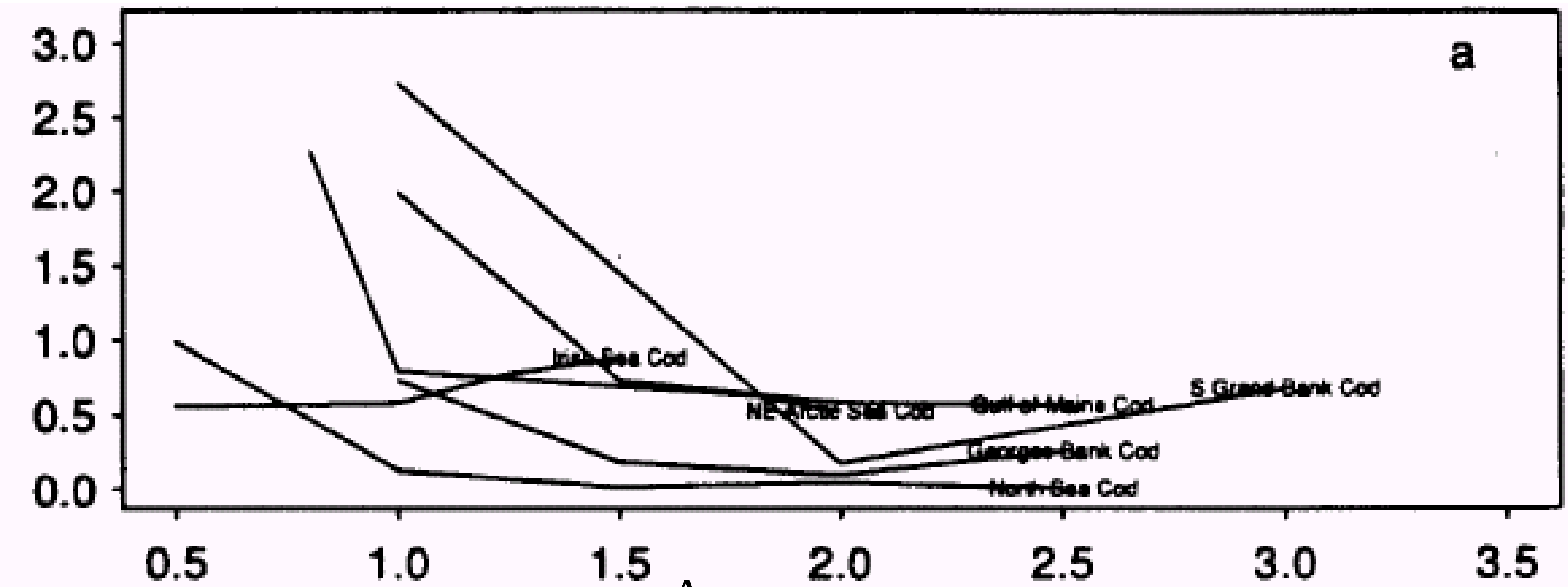
Keep sites constant in space and time.

- Perhaps the most accurate groundfish survey in the world is the English Groundfish fixed station survey with a sampling CV of


Pre-stratification 1955
Post-stratification 1989
Southern Grand Bank
200 Mile Limit
200 Mile Limit
Pre-stratification 1963
Post-stratification 1983
St. Pierre Bank

Fixed station surveys (English North Sea) have much lower estimation error variances for cod

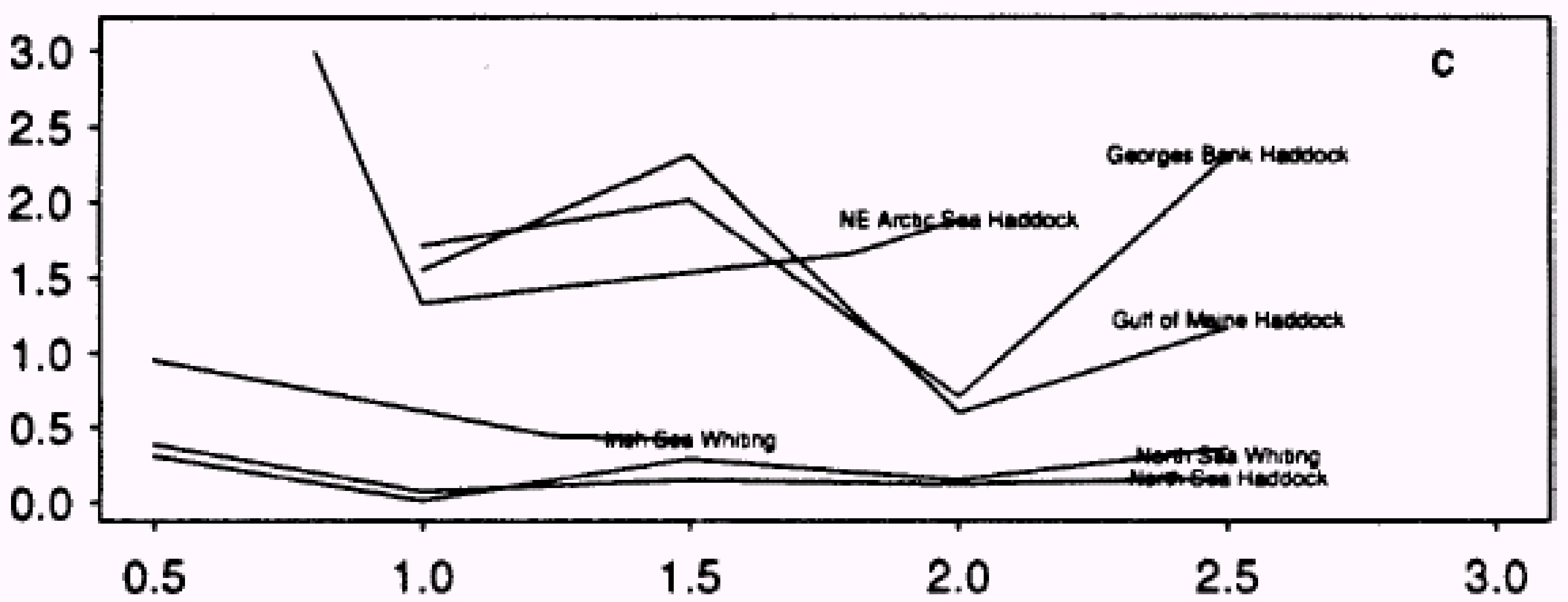
Estimation error variance



Age

Fixed station surveys (English North Sea) have much lower estimation error variances for haddock and whiting

Estimation error variance

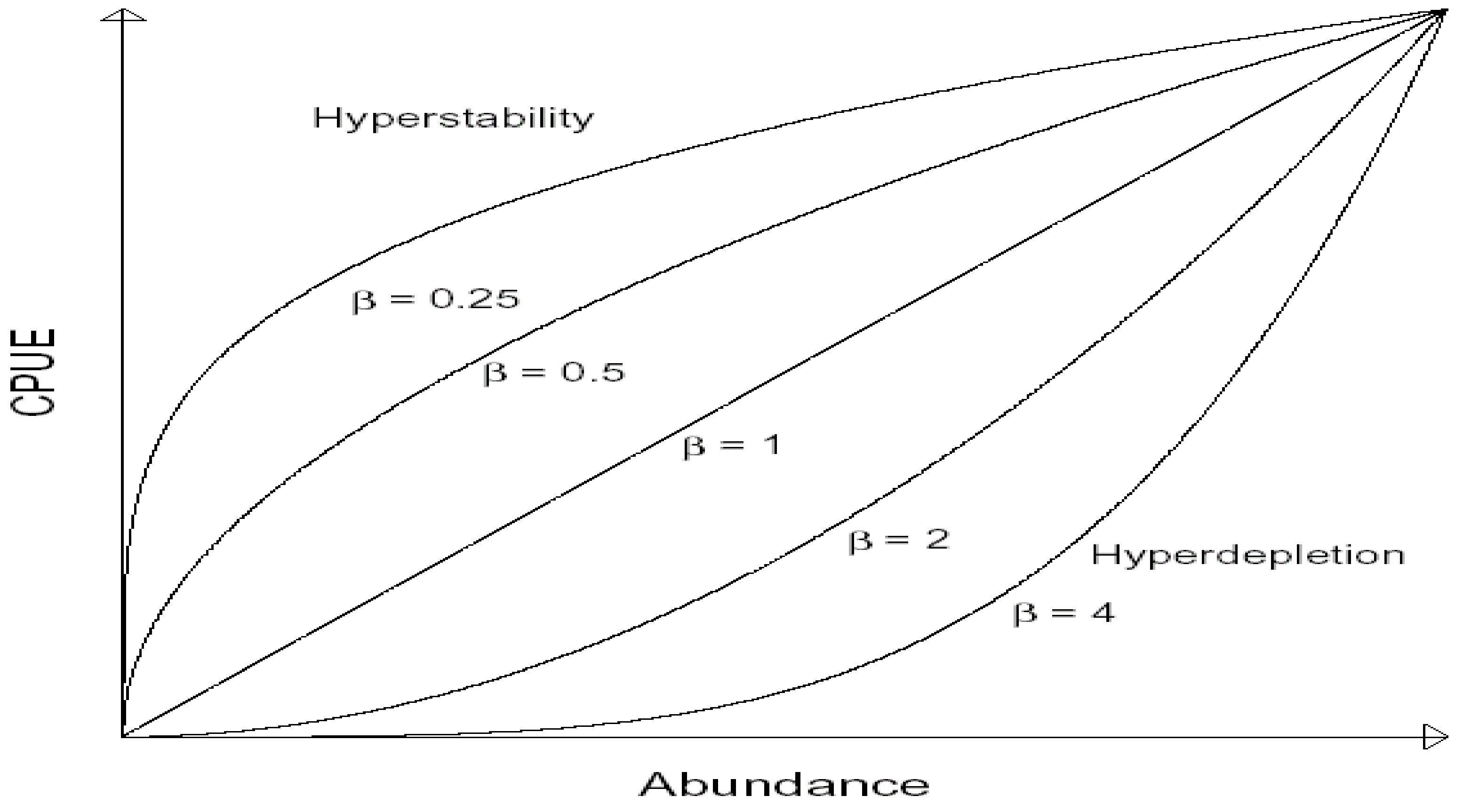


Age

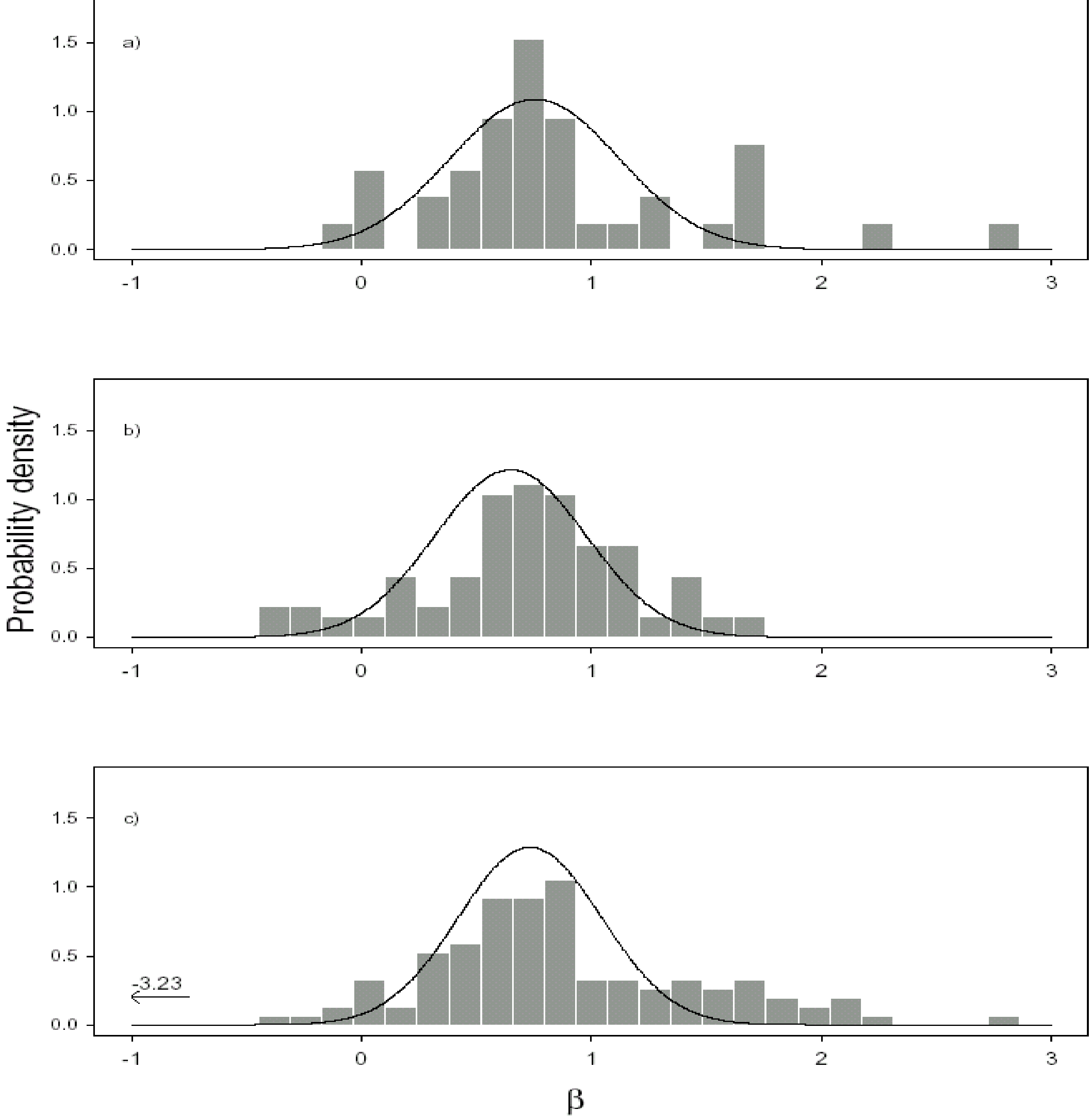
A word about acoustic surveys

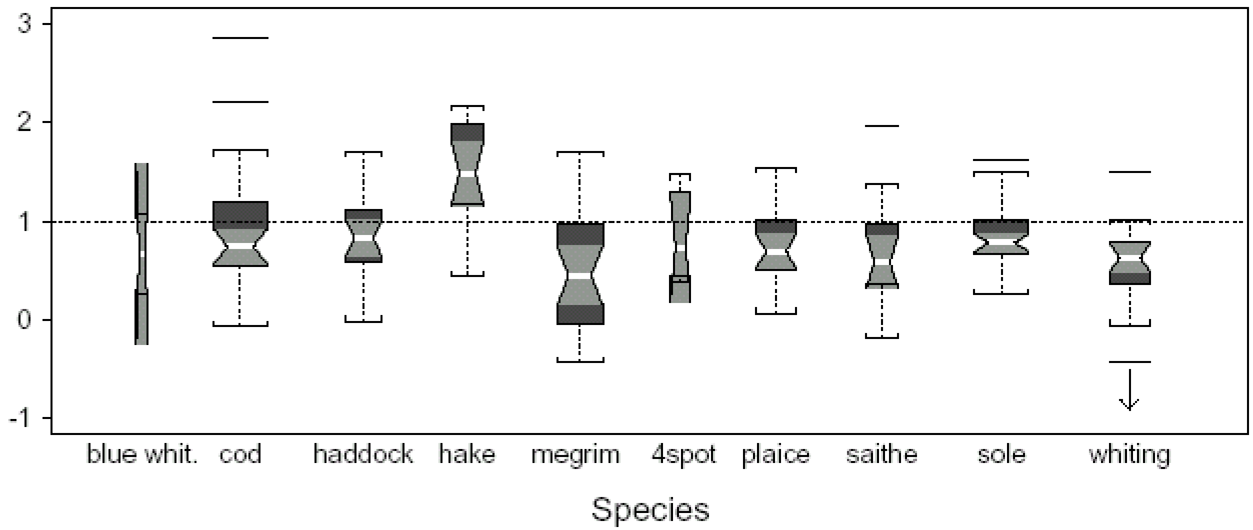
- They show great promise, just as they did 50 years ago.
- Check back in 2053.

Calibrate CPUE

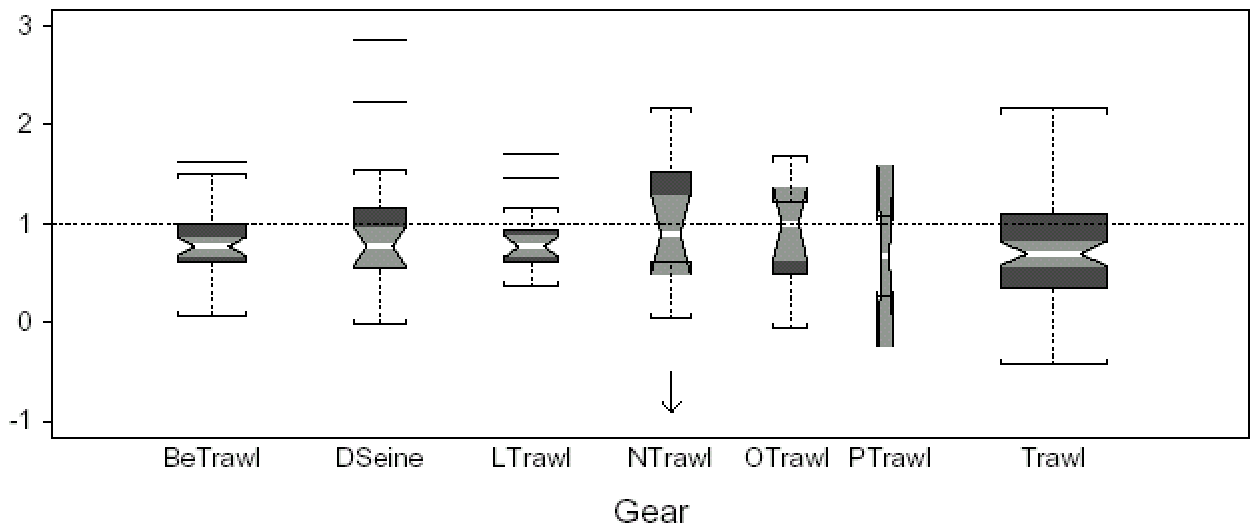


Harley Myers CJFSA 2001 http:fish.dal.ca


a)
b)
c)
Probability density
β
-3.23
1.5
1.0
0.5
0.0
-1
0
1
2
3



3
2
1
0
-1
blue whit.
cod
haddock
hake
megrim
4spot
plaice
saithe
sole
whiting
Species



3
2
1
0
-1
BeTrawl
DSeine
LTrawl
NTrawl
OTrawl
PTrawl
Trawl
Gear

Resolve Fundamental Questions of Population and Community Biology:

- The basic approach:
- Hierarchical model – over species – over populations – over cohorts
- Surveys are vastly underutilized for this – New methods need to be developed.

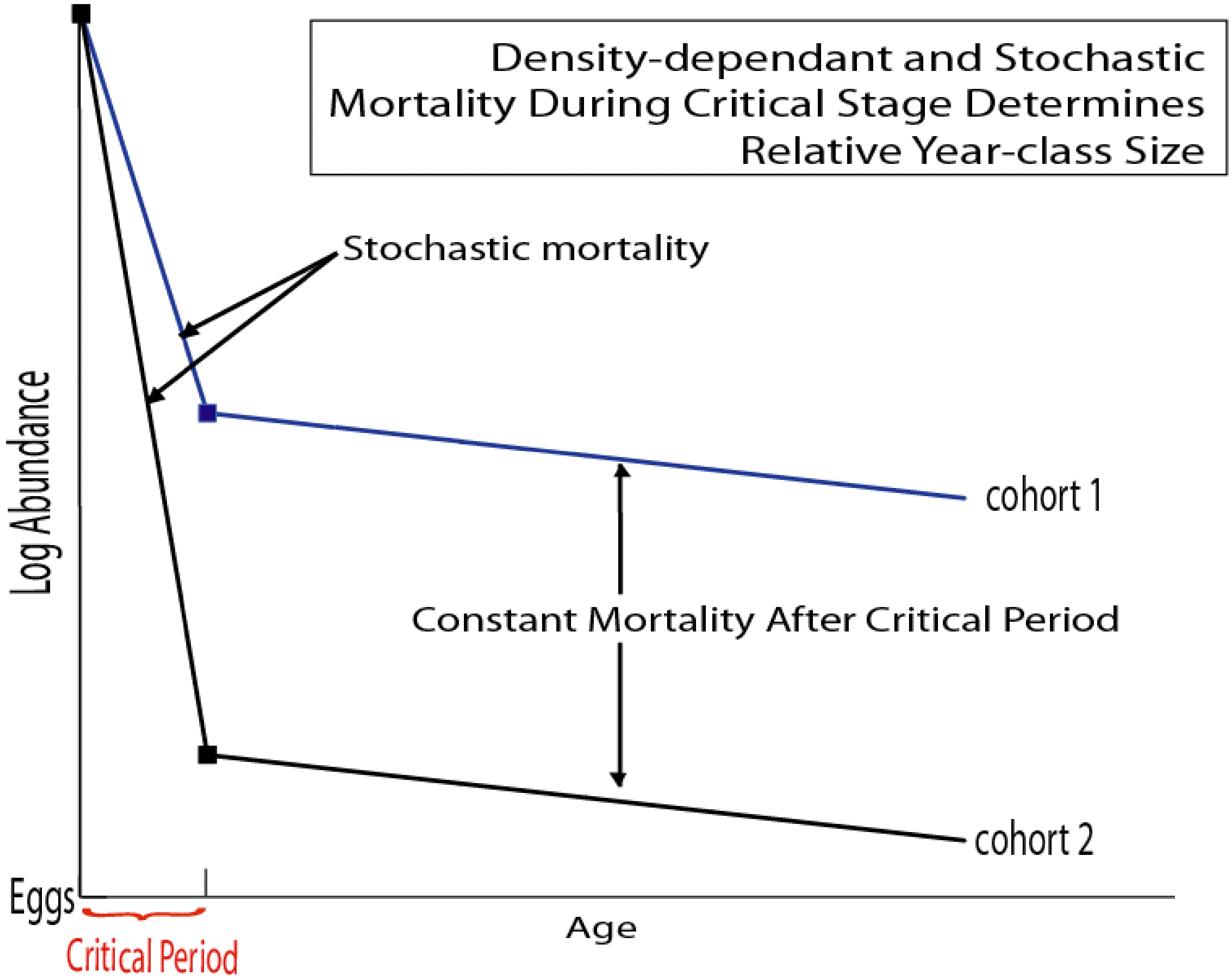
How to use survey data for one cohort:

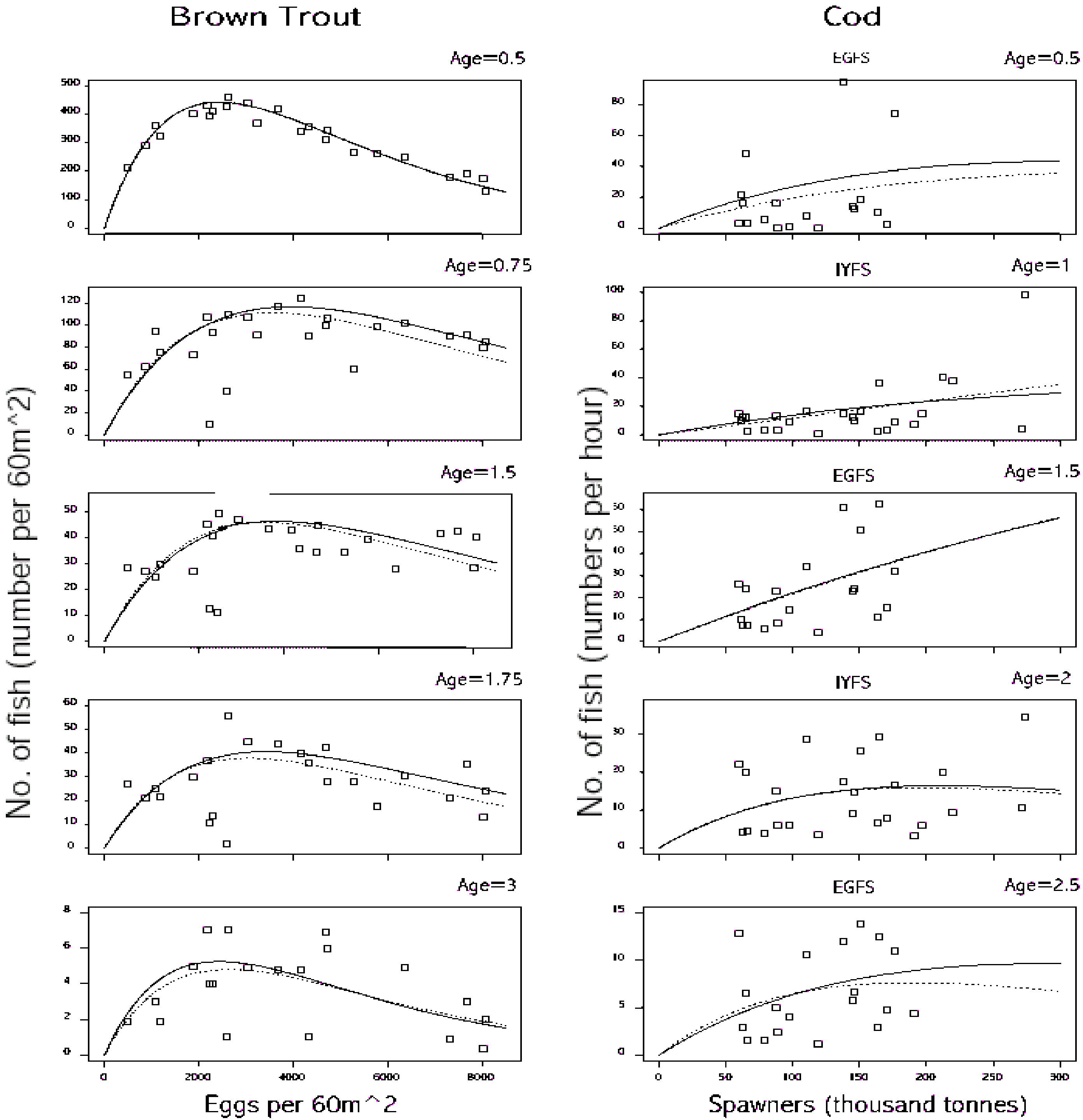
- The basic approach:
- Hierarchical model – over species – over populations – over cohorts
- Result are general results –
- Surveys are vastly underutilized for working out

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.

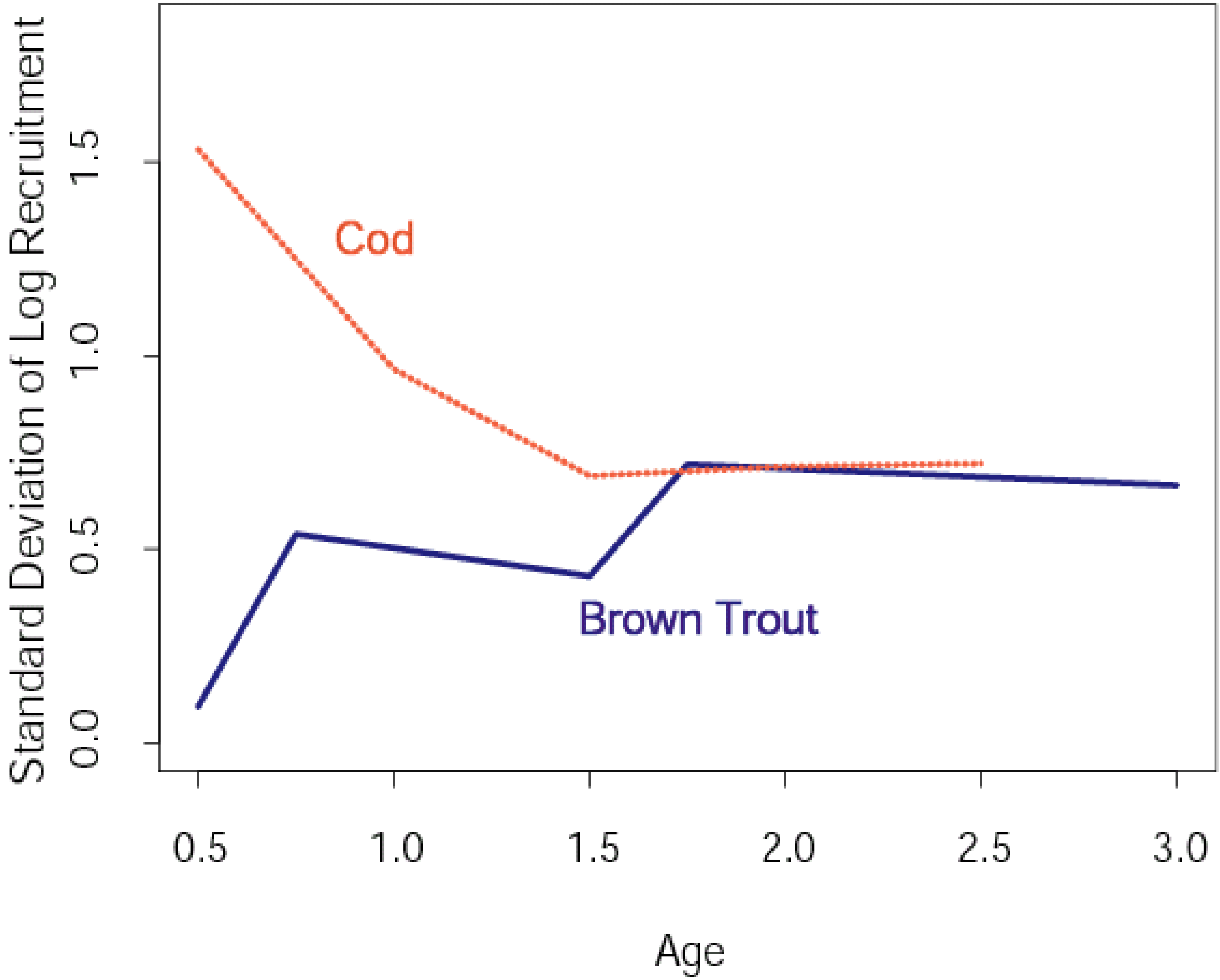
Hjort's Hypothesis: Strong Version



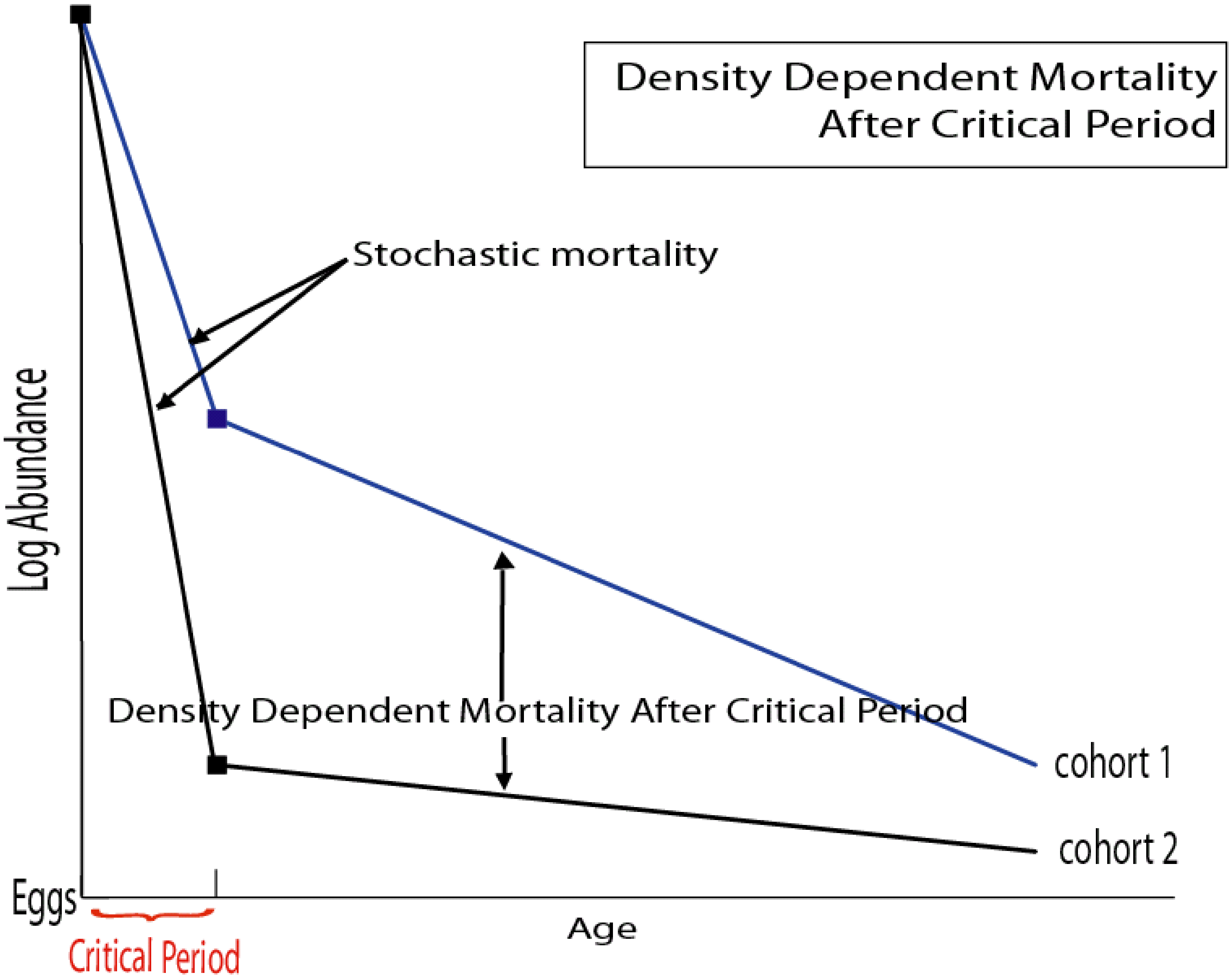


Brown Trout
Cod
Age=0.5
EGFS
Age=0.5
Age=0.75
IYFS
Age=1
Age=1.5
EGFS
Age=1.5
Age=1.75
IYFS
Age=2
Age=3
EGFS
Age=2.5
No. of fish (number per 60m^2)
No. of fish (numbers per hour)
Eggs per 60m^2
Spawners (thousand tonnes)

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



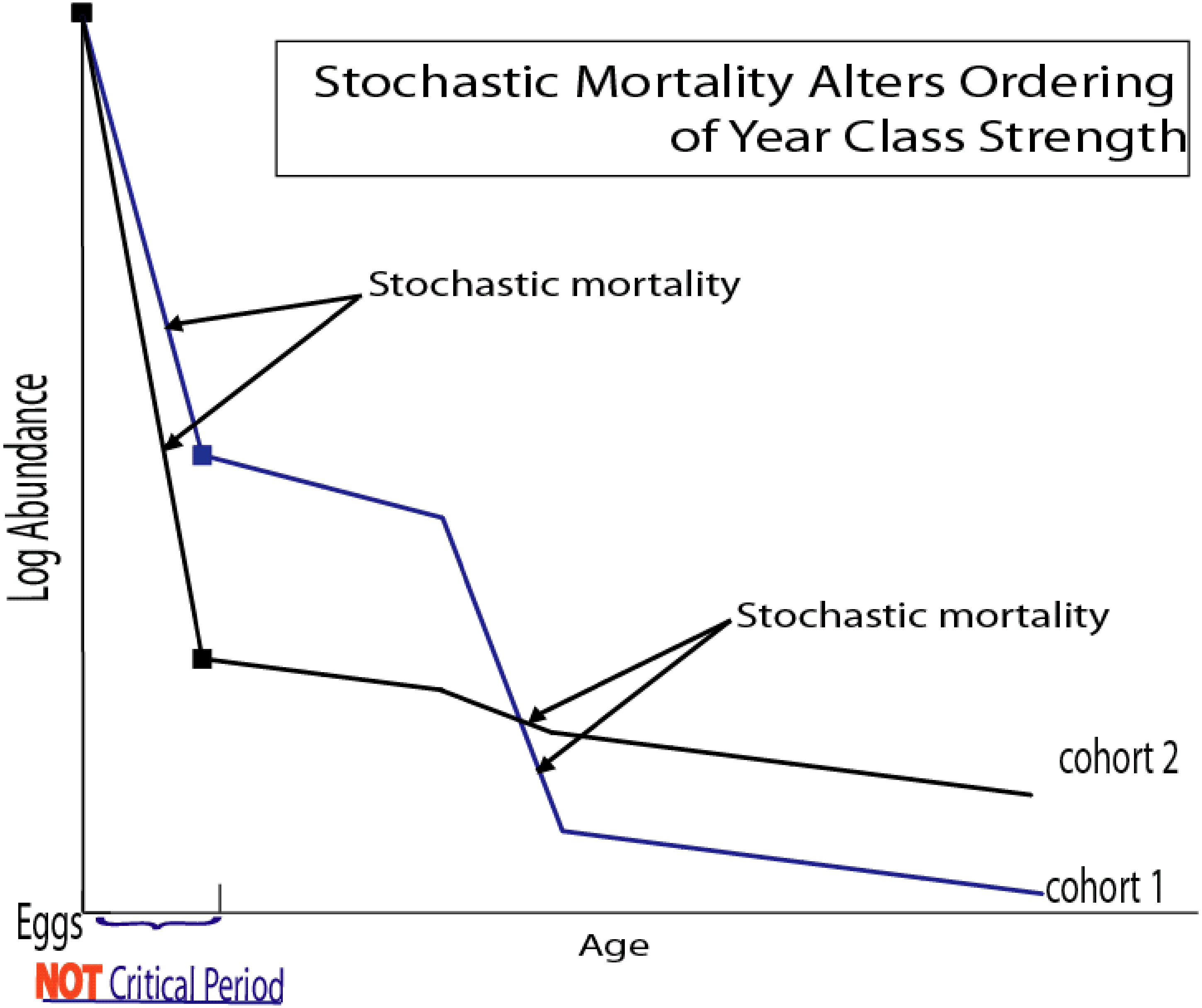
Hjort's Hypothesis: Weak Version



Critical period hypothesis: weak version

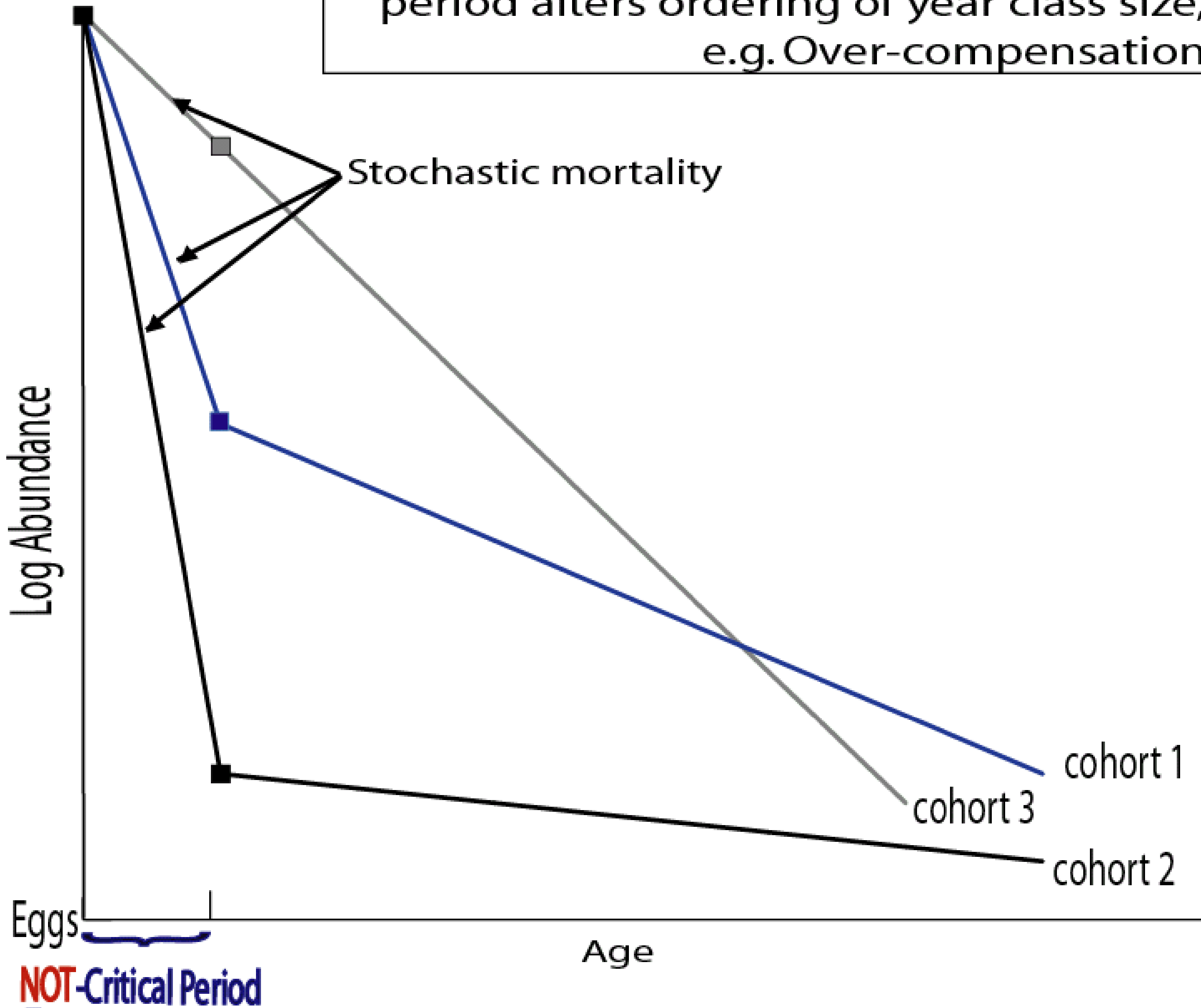
- $Var(mortality_{age<critical}) >> Var(mortality_{age>critical})$ Density-dependent mortality after the critical period does not alter ordering of year-class size.

Hjort's Hypothesis: NOT Stochastic Mortality



Hjort's Hypothesis: NOT

Density Dependent mortality after critical period alters ordering of year class size, e.g. Over-compensation



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.

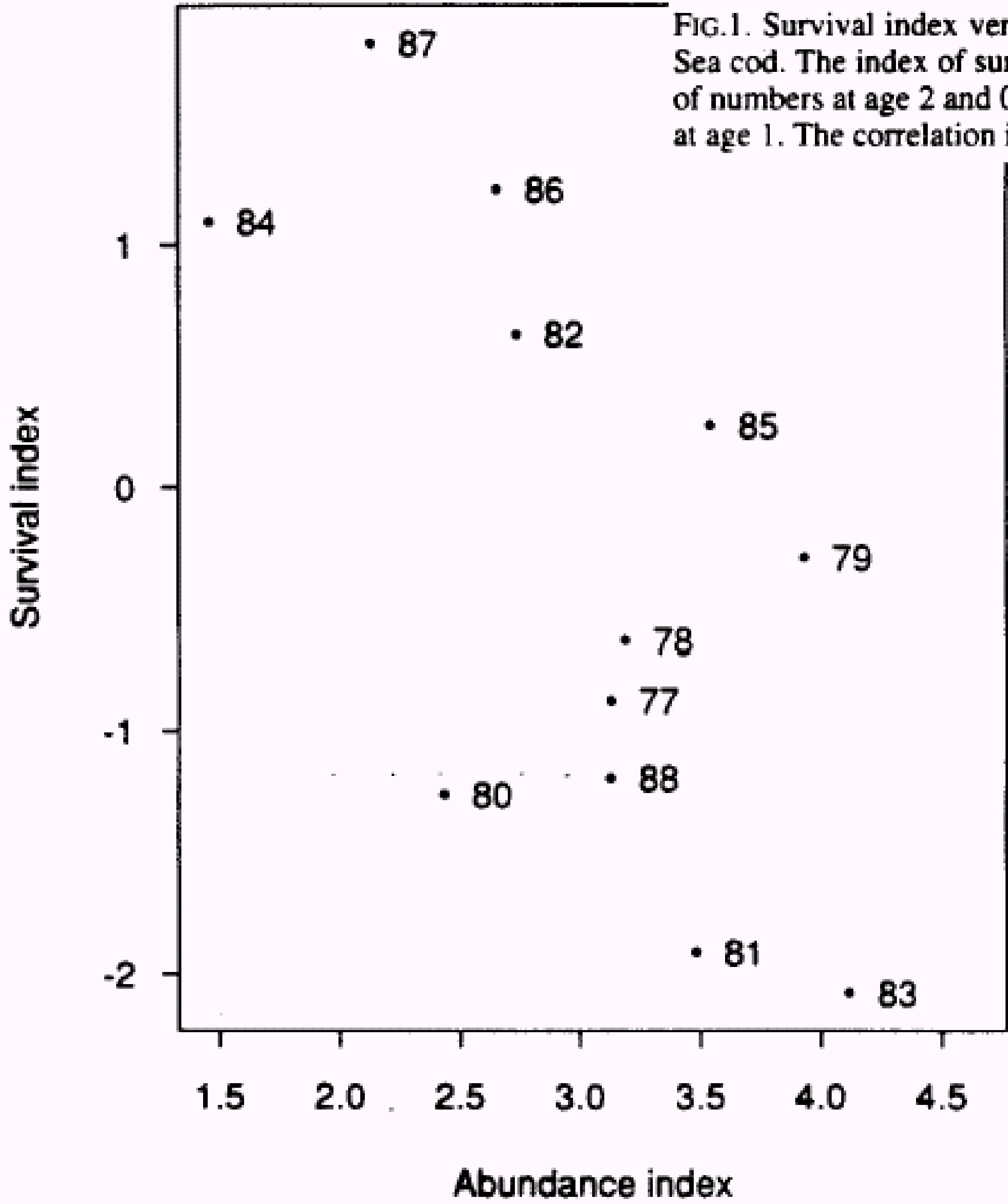


FIG.1. Survival index versus abundance index for the EGFS of North Sea cod. The index of survival is the difference between the log index of numbers at age 2 and 0. The index of abundance is the log numbers at age 1. The correlation is –0.65 (p-value = 0.0054).

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		

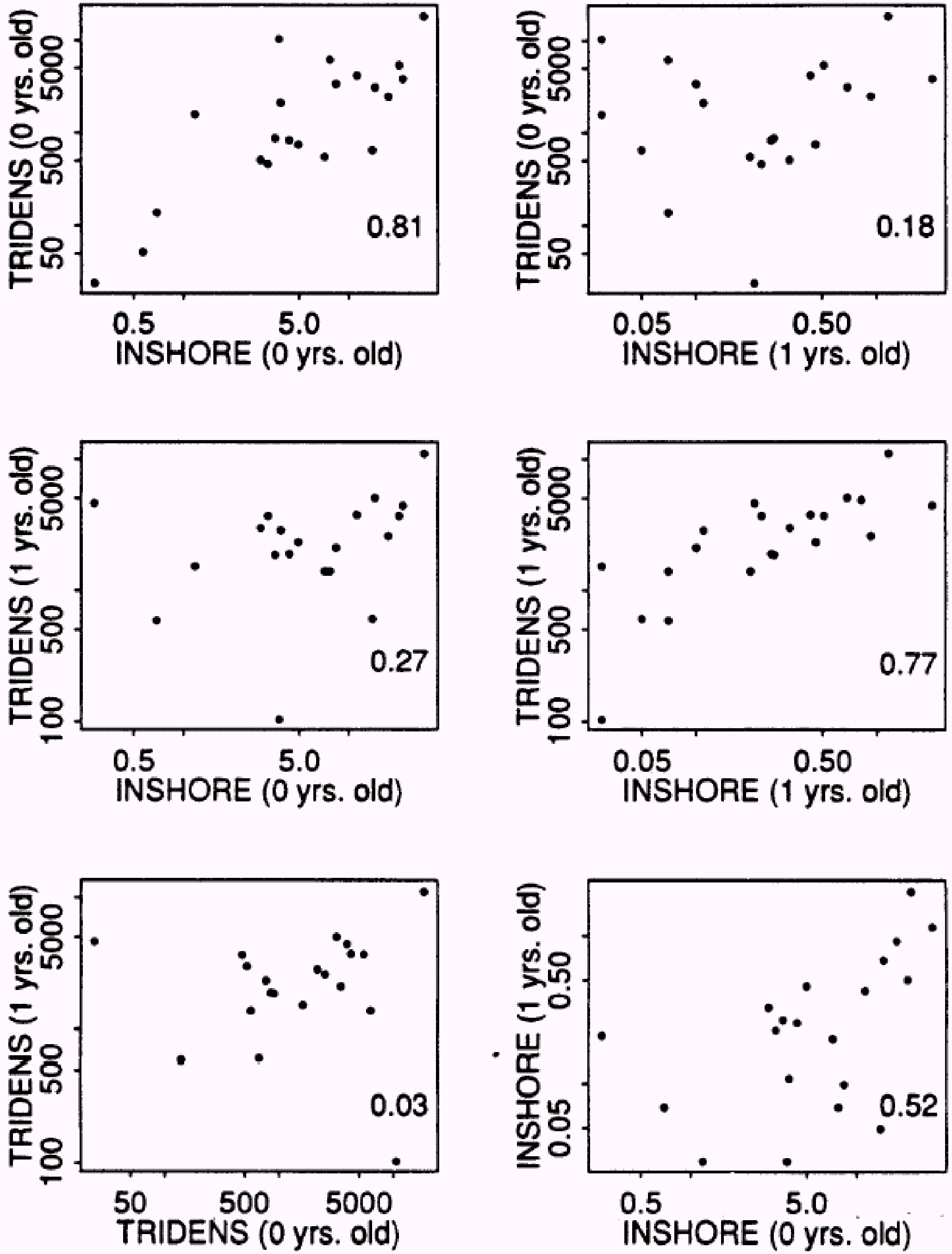
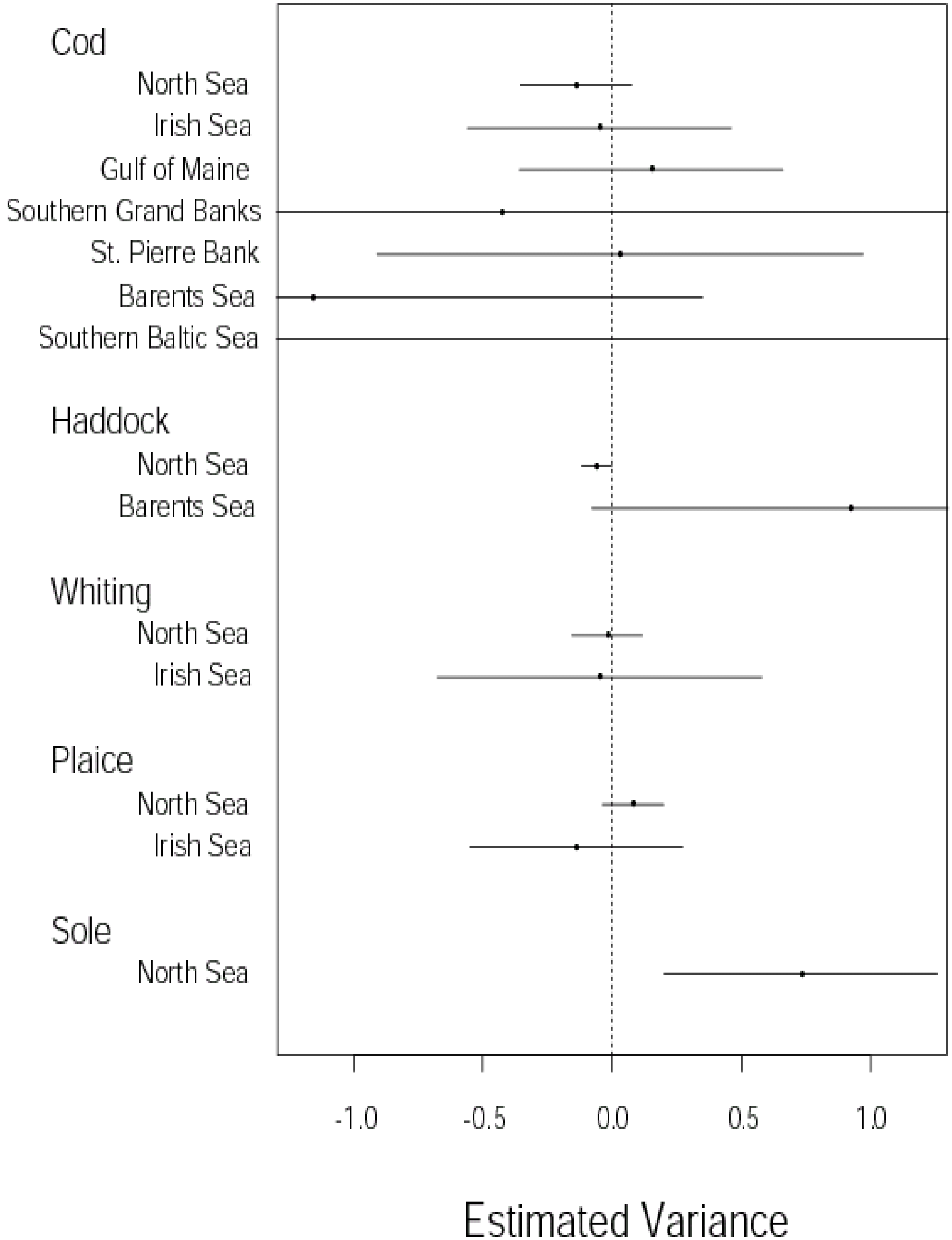


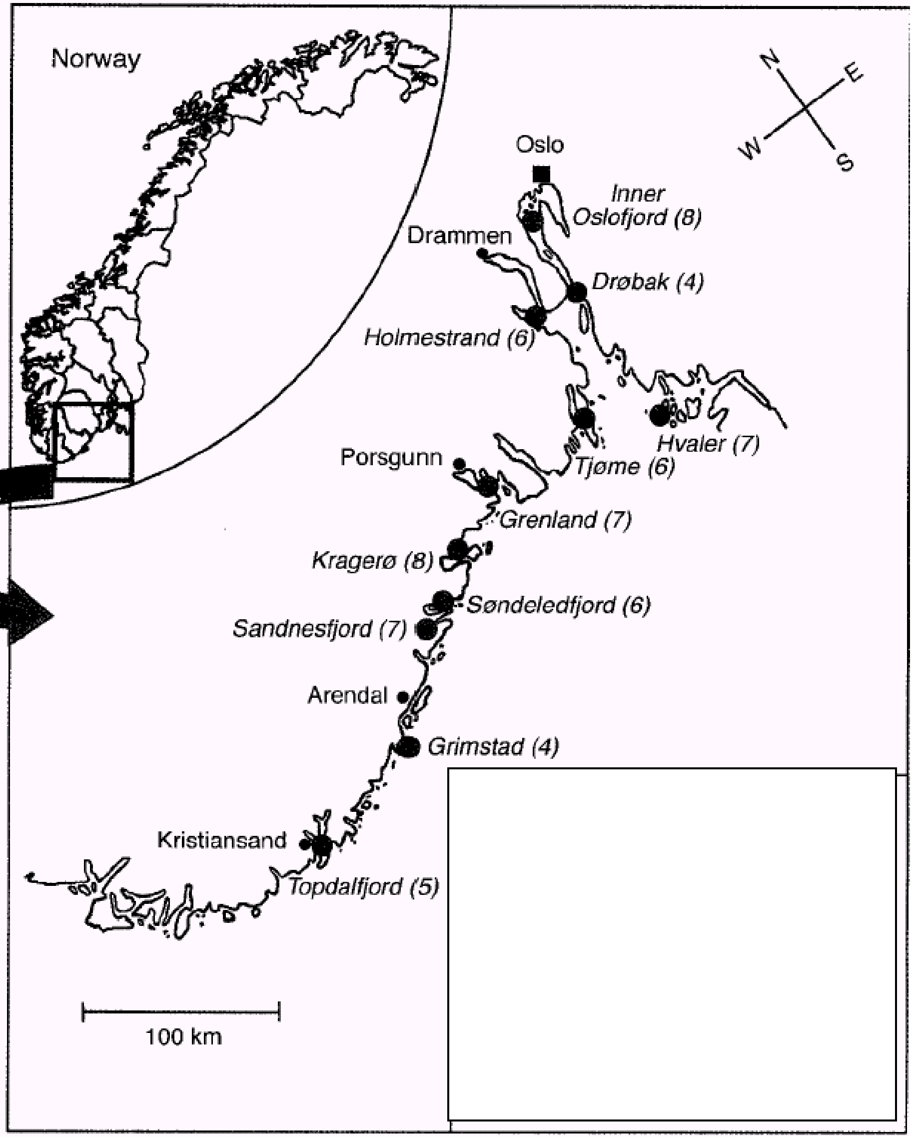
FIG. 1. Pairwise plots of abundance estimates for North Sea sole (Table 1). The estimates are log transformed. The correlation coefficient is presented in the lower right corner.

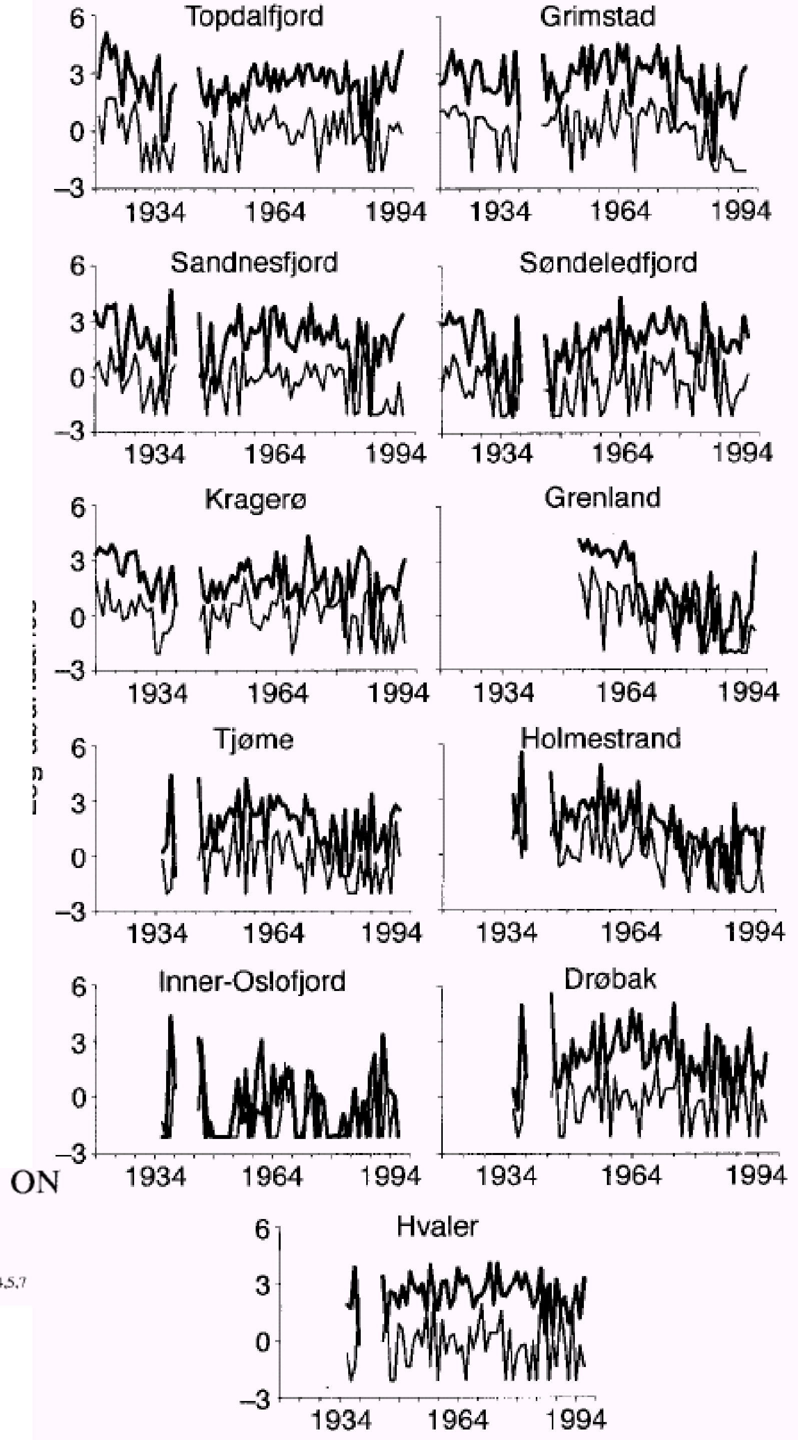
$$
\begin{bmatrix}
\mathrm{VAR}(l_{t,0,1}) & \mathrm{COV}(l_{t,0,1}, l_{t,0,2}) & \mathrm{COV}(l_{t,0,1}, l_{t,1,1}) & \mathrm{COV}(l_{t,0,1}, l_{t,1,2}) \\
 & \mathrm{VAR}(l_{t,0,2}) & \mathrm{COV}(l_{t,0,2}, l_{t,1,1}) & \mathrm{COV}(l_{t,0,2}, l_{t,1,2}) \\
 & & \mathrm{VAR}(l_{t,1,1}) & \mathrm{COV}(l_{t,1,1},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

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

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







EFFECTS OF DENSITY-DEPENDENT AND STOCHASTIC PROCESSES ON THE REGULATION OF COD POPULATIONS

JEAN-MARC FROMENTIN,[1,4] RANSOM A. MYERS,[2] OTTAR N. BJØRNSTAD,[3,4] NILS CHR. STENSETH,[4,5,7]

Ecology, 82(2), 2001, pp. 567–579

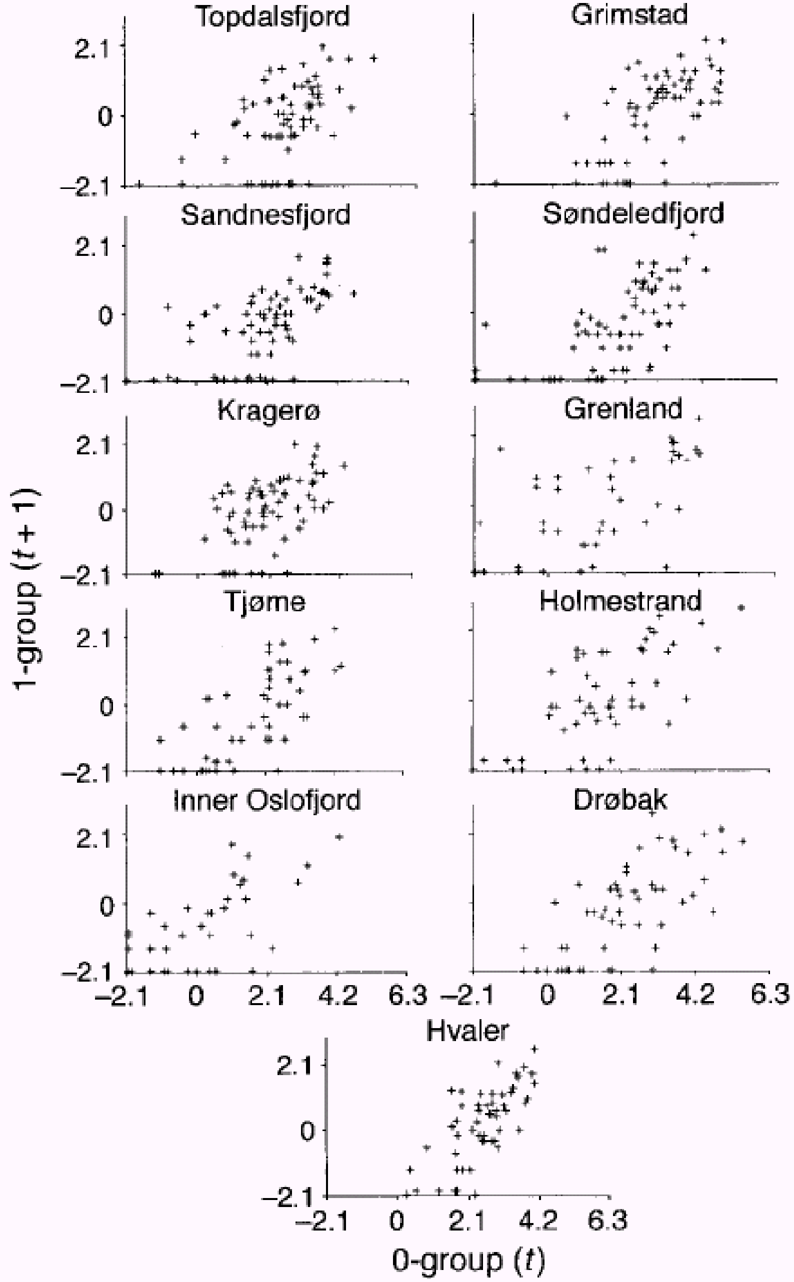


FIG. 4. Relationships between the $\log_e$ 0-group at time t (x-axis) and the $\log_e$ 1-group at time $t + 1$ (y-axis) for each area.

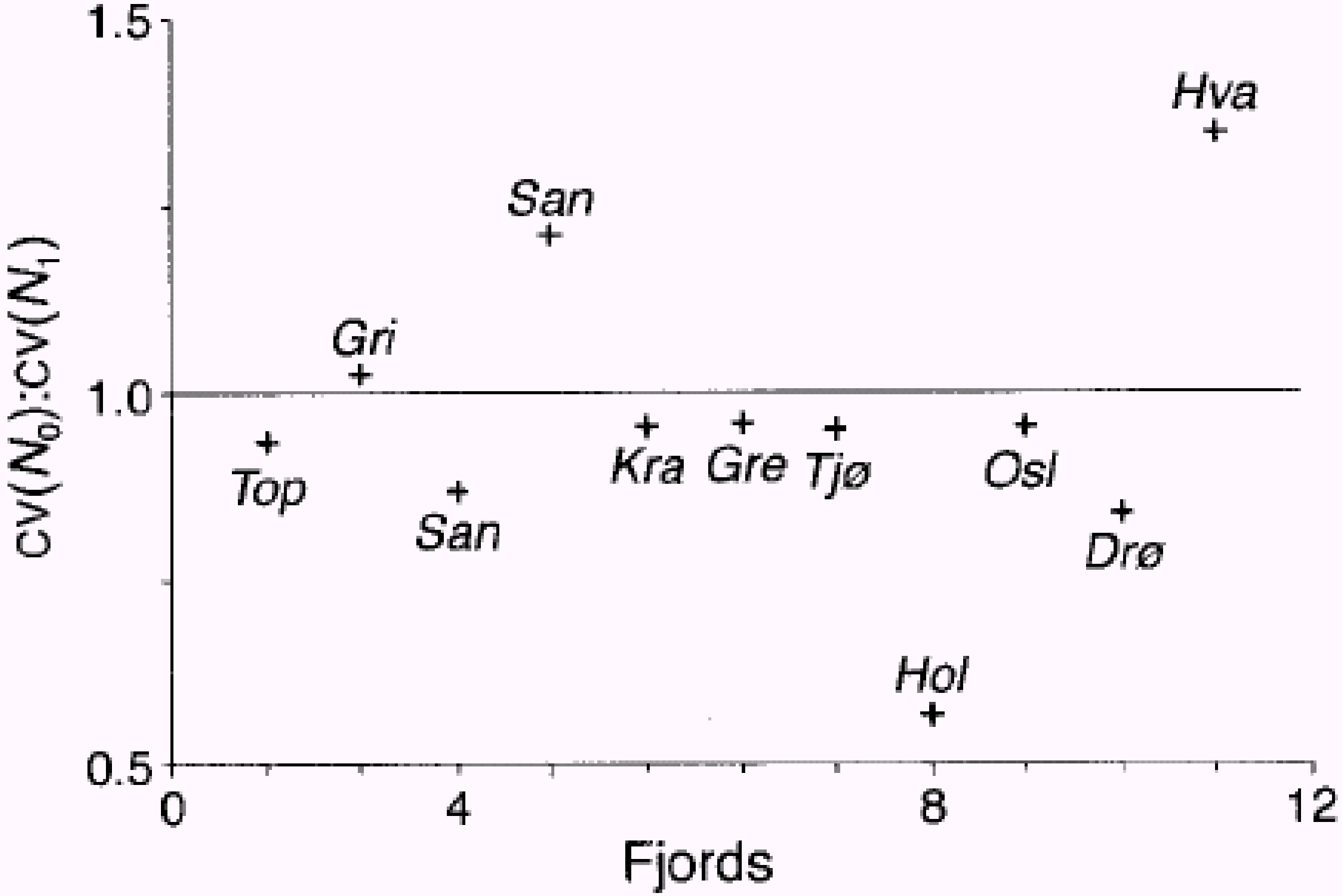
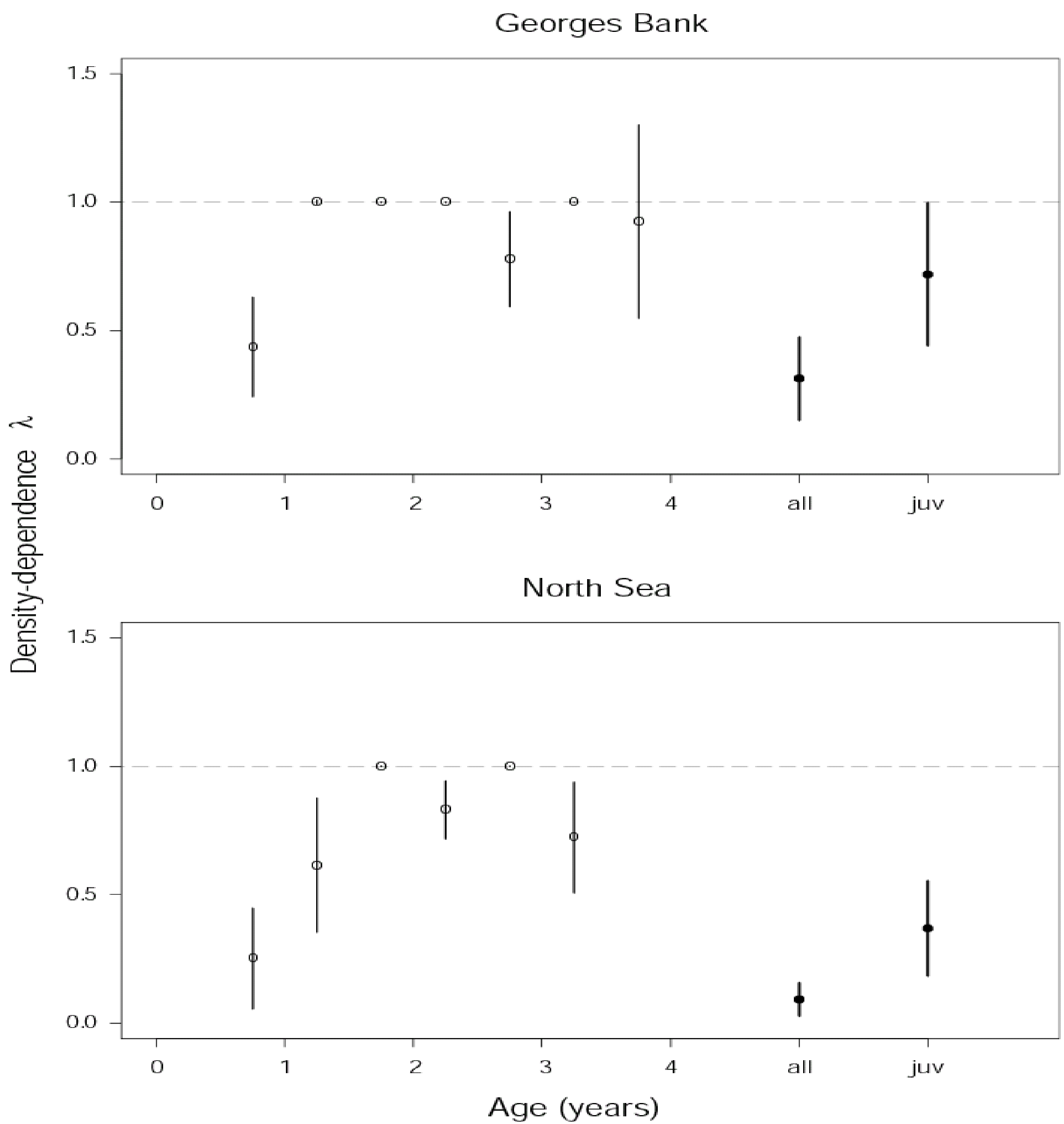


FIG. 5. Values of the ratios of the coefficients of variation of the 1-group, CV(N_1), to those of the 0-group, CV(N_0), for the 11 areas (identified by their first three letters). This ratio indicates whether the relative variability in the 1-group is lower than (ratio <1.0) or greater than (ratio >1.0) the variability in the 0-group.

Models must actually deal with the non-Gaussian nature of the data.

Nonlinear key factor analysis with measurement error.

- Myers and Cadigan analysis limited to one form of density-dependent mortality – mortality proportional to log abundance, other cases VERY hard.
- We have recently developed solutions for nonlinear random effects models with measurement error for the general problem that can estimate ANY nonlinear function and ANY distribution for mortality and estimation errors.
- These methods use simulated maximum likelihood methods to in a random effects nonlinear state space model using auto-differential software.



Georges Bank
North Sea
Density-dependence λ
Age (years)
1.5
1.0
0.5
0.0
0
1
2
3
4
all
juv

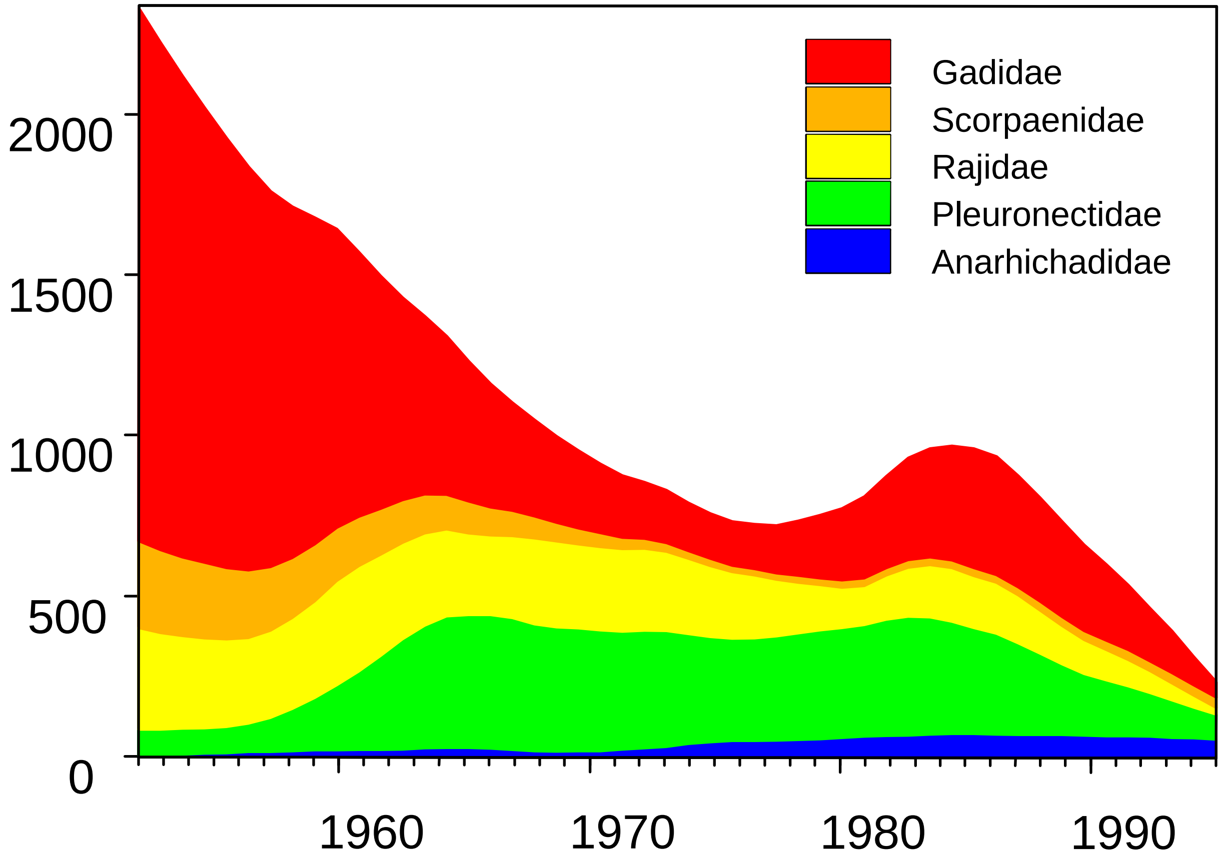
Predictions and Preliminary Results:

- Hjort’s strong hypothesis: never true.
- Hjort’s weak hypothesis: approximately true for gadoids, flatfish, and freshwater percids.
- Hjort is wrong for salmonids
- Small pelagics – At low abundance Hjort’s weak hypothesis true, but not true for high abundance.
- Species interactions more important.

Underutilized Research Surveys

- Multi-species analysis require the analysis of surveys in multiple areas.

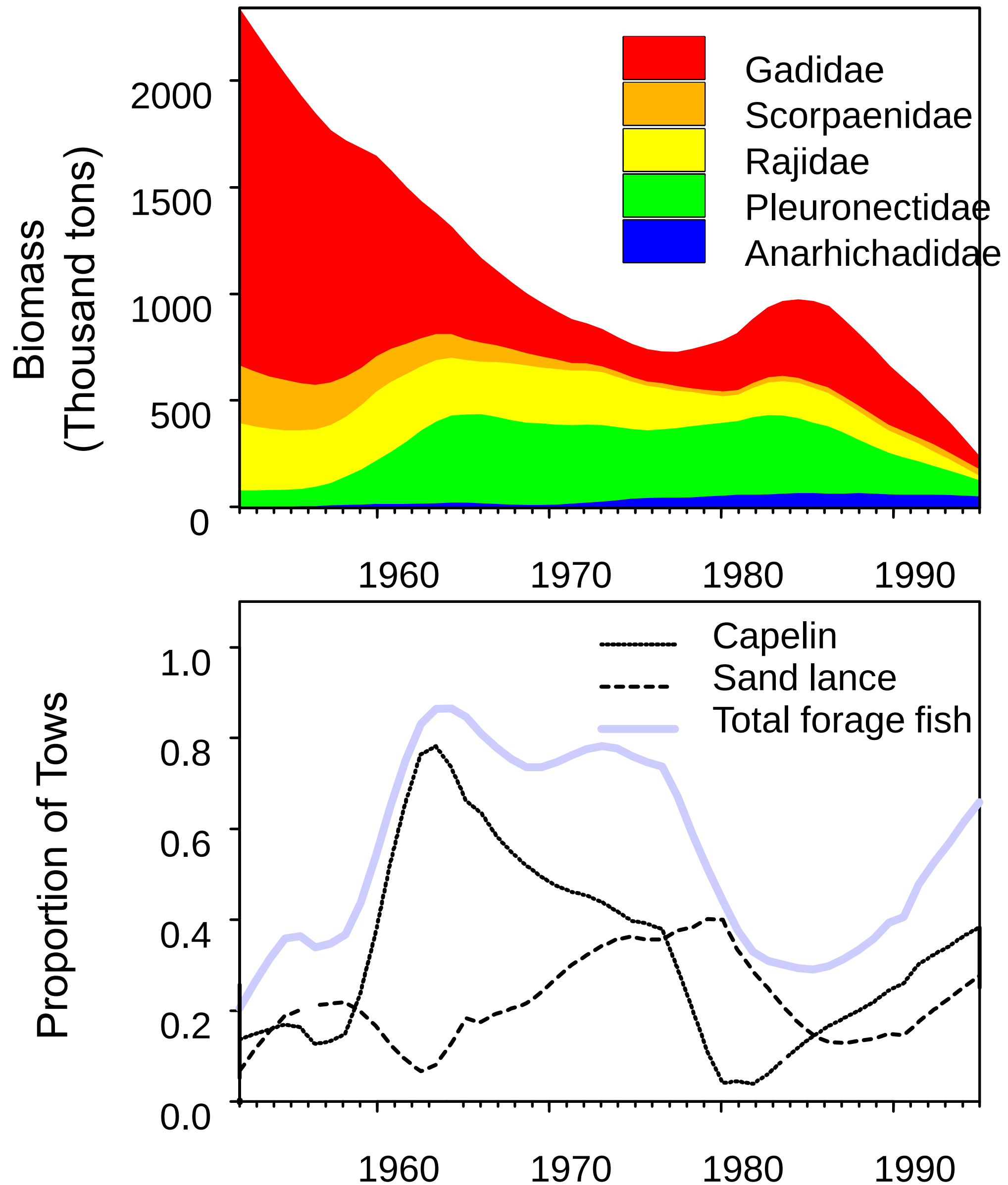
Community Changes on Southern Grand Banks



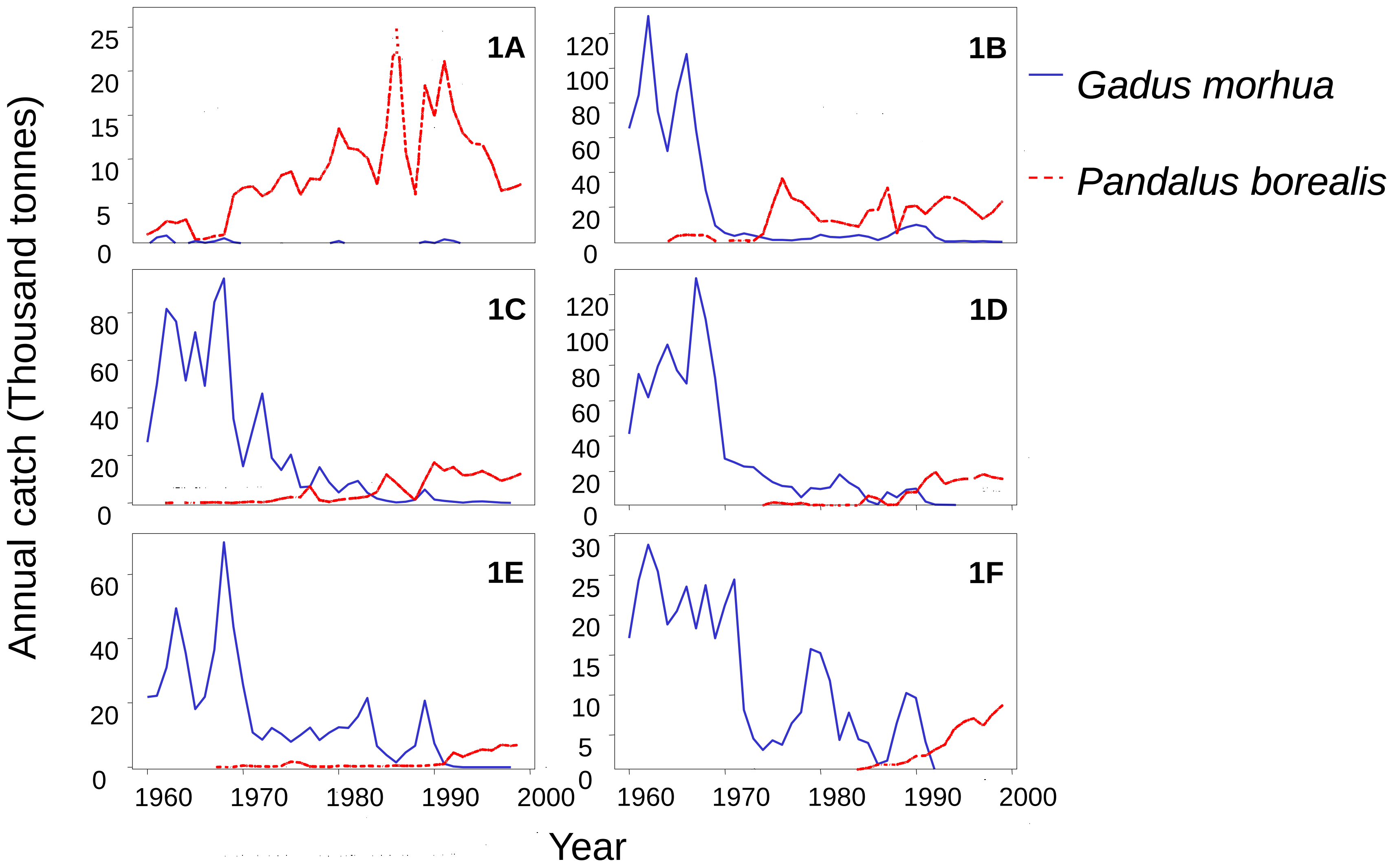
Grand Banks forage fish

- Groundfish and small forage fish biomass are inversely correlated

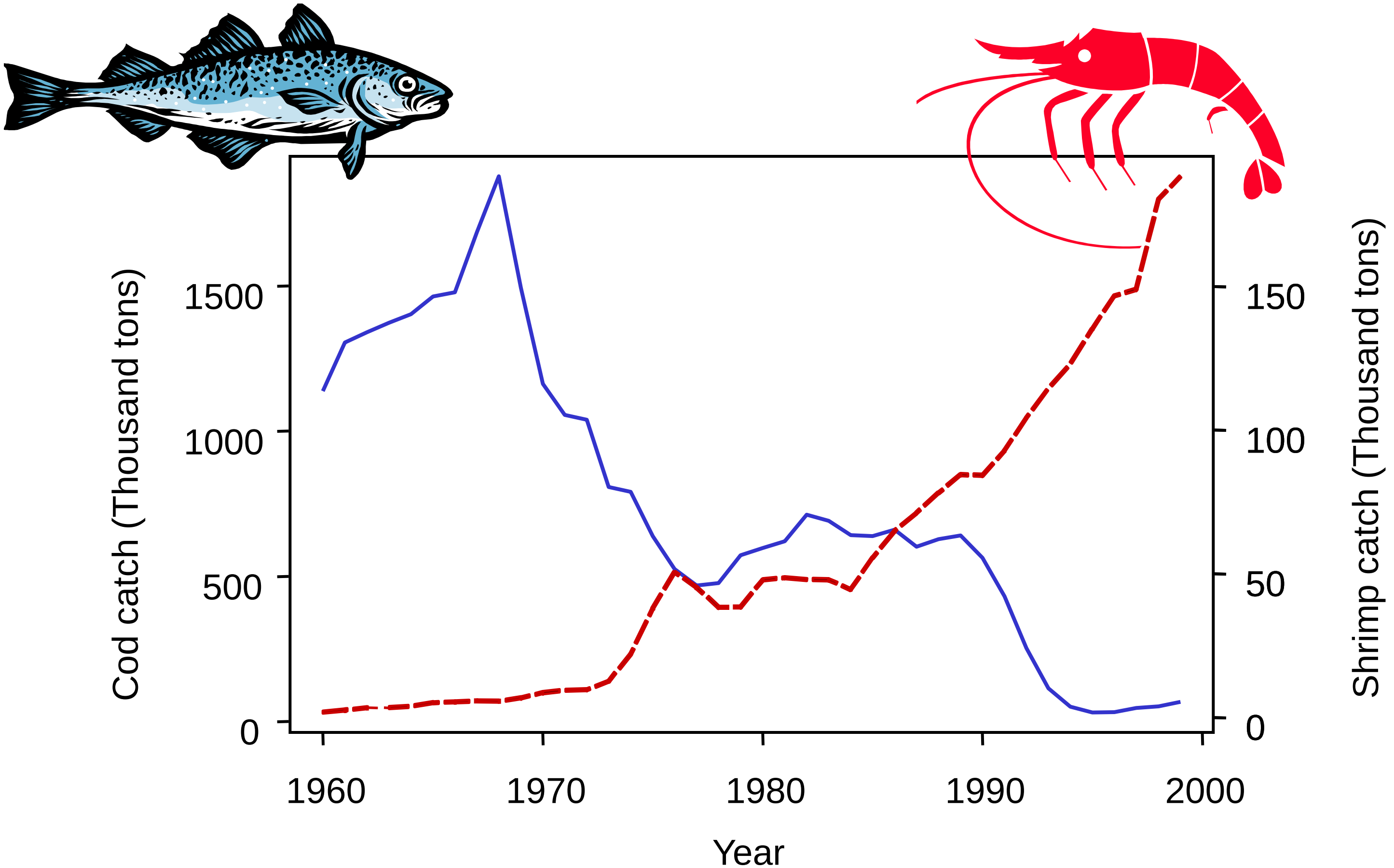
Source: Casey 2000



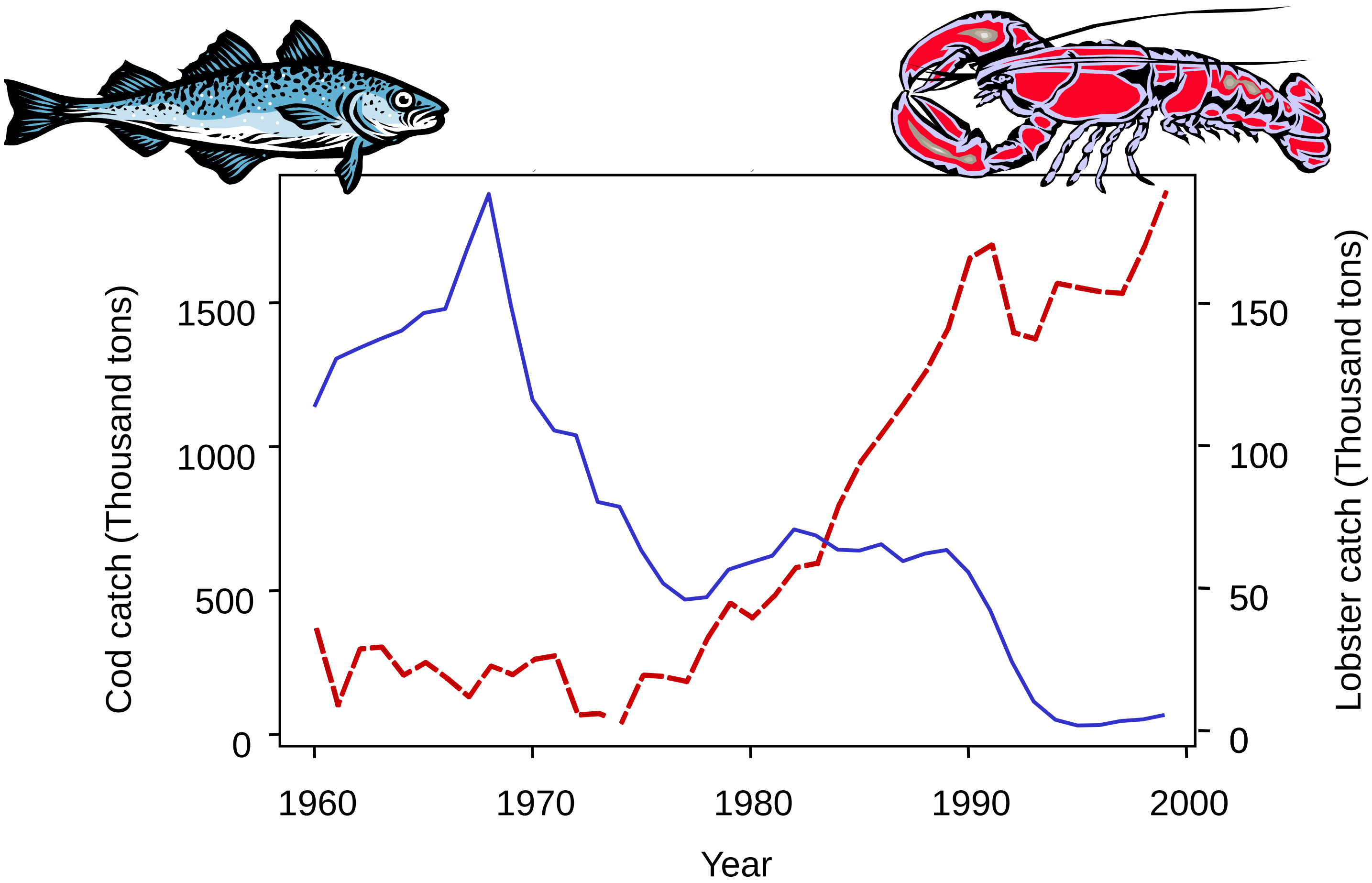
Serial increases in Greenland shrimp



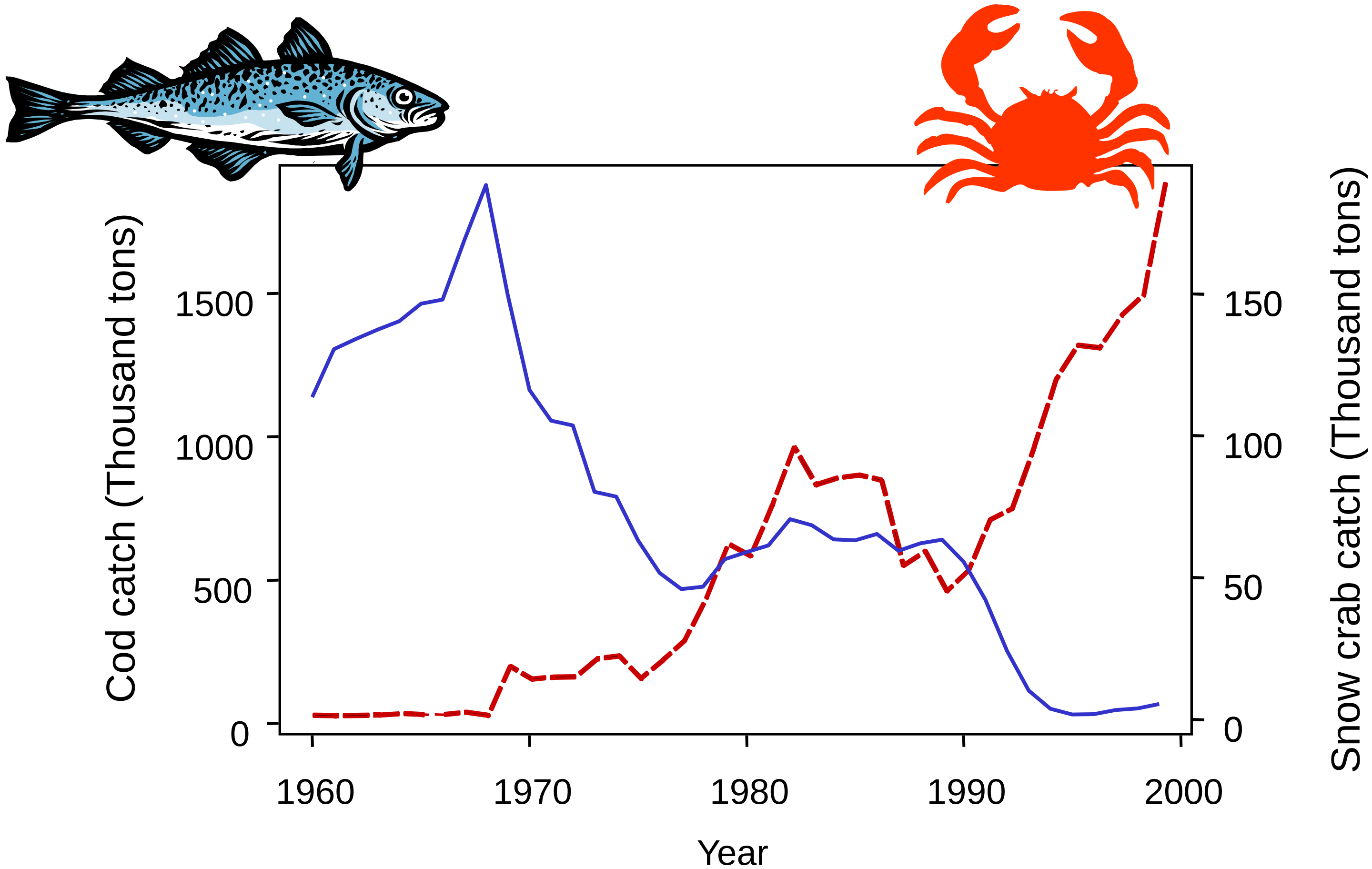
Cod versus shrimp catches in all NAFO areas combined



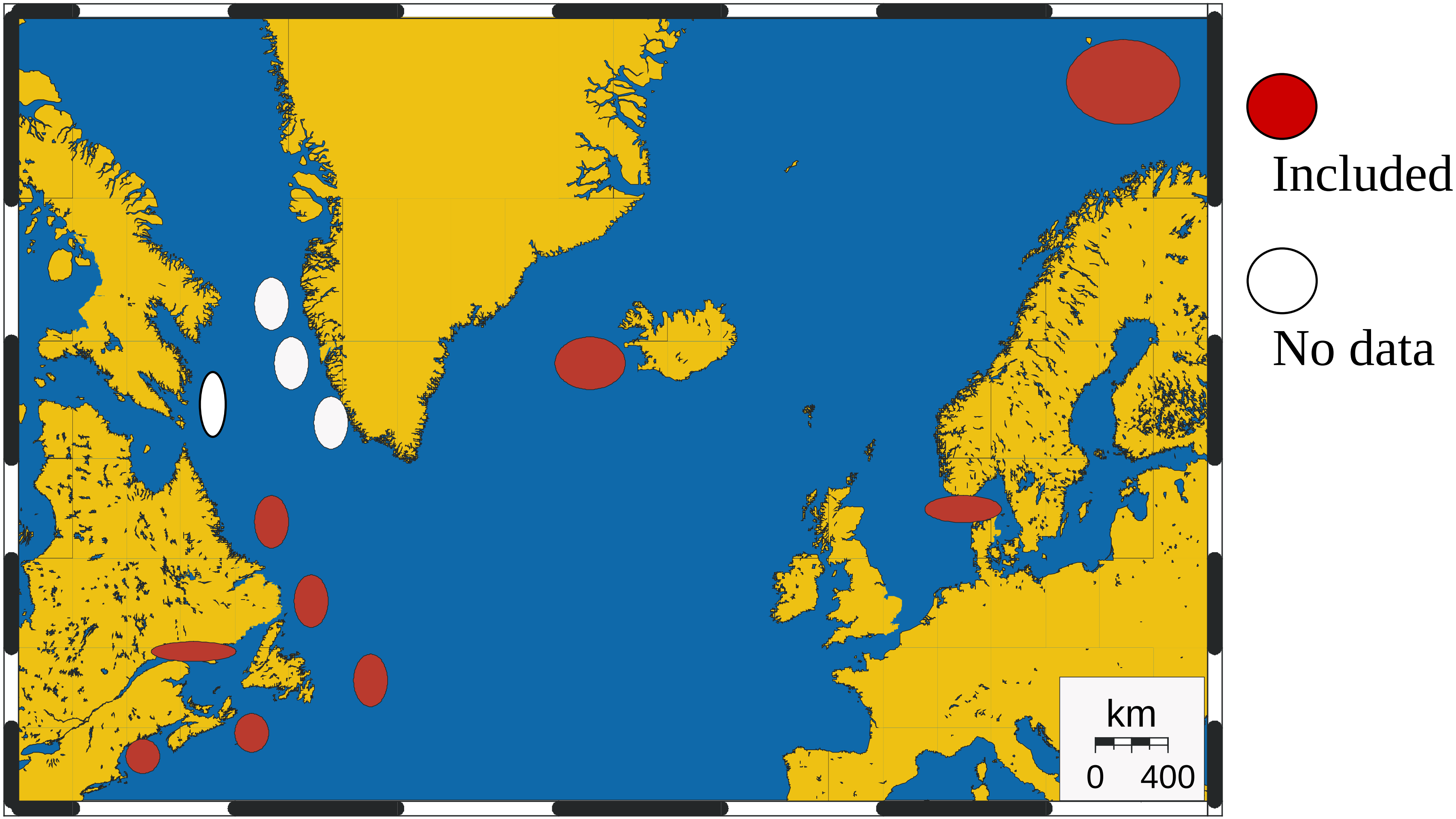
Cod versus lobster catches



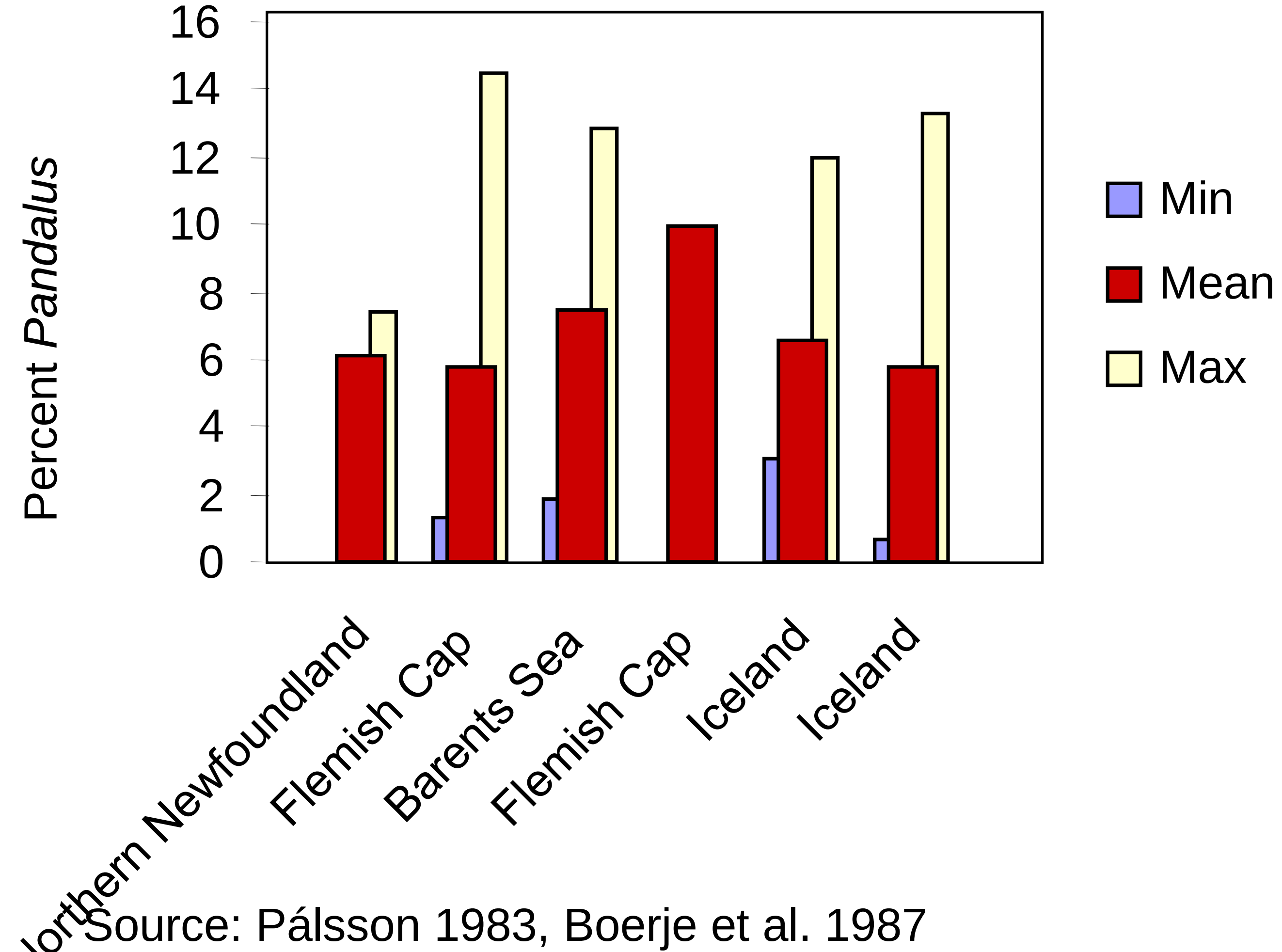
Cod versus crab catches



Major shrimp stocks in the North Atlantic

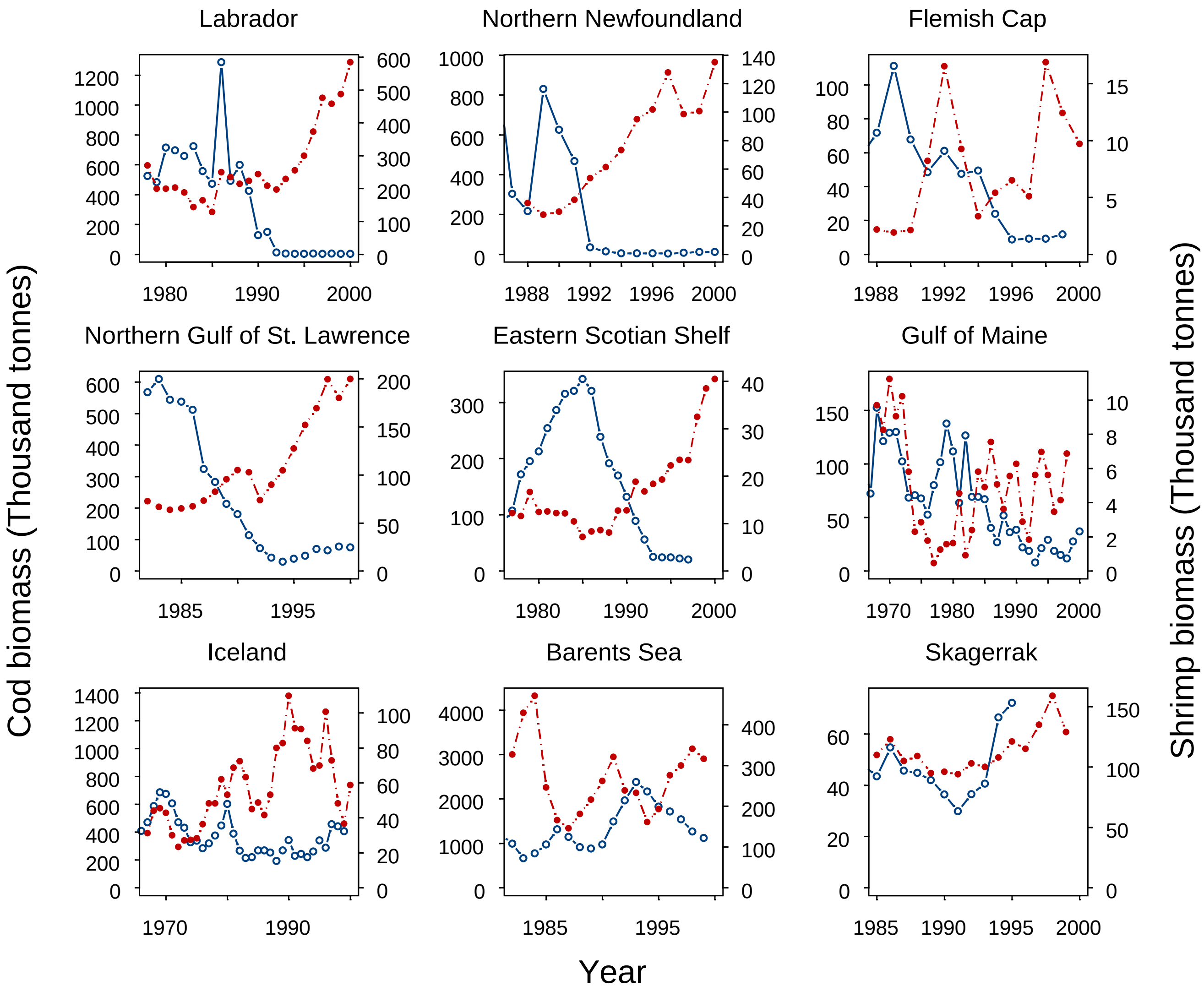


Similar cod diet across regions

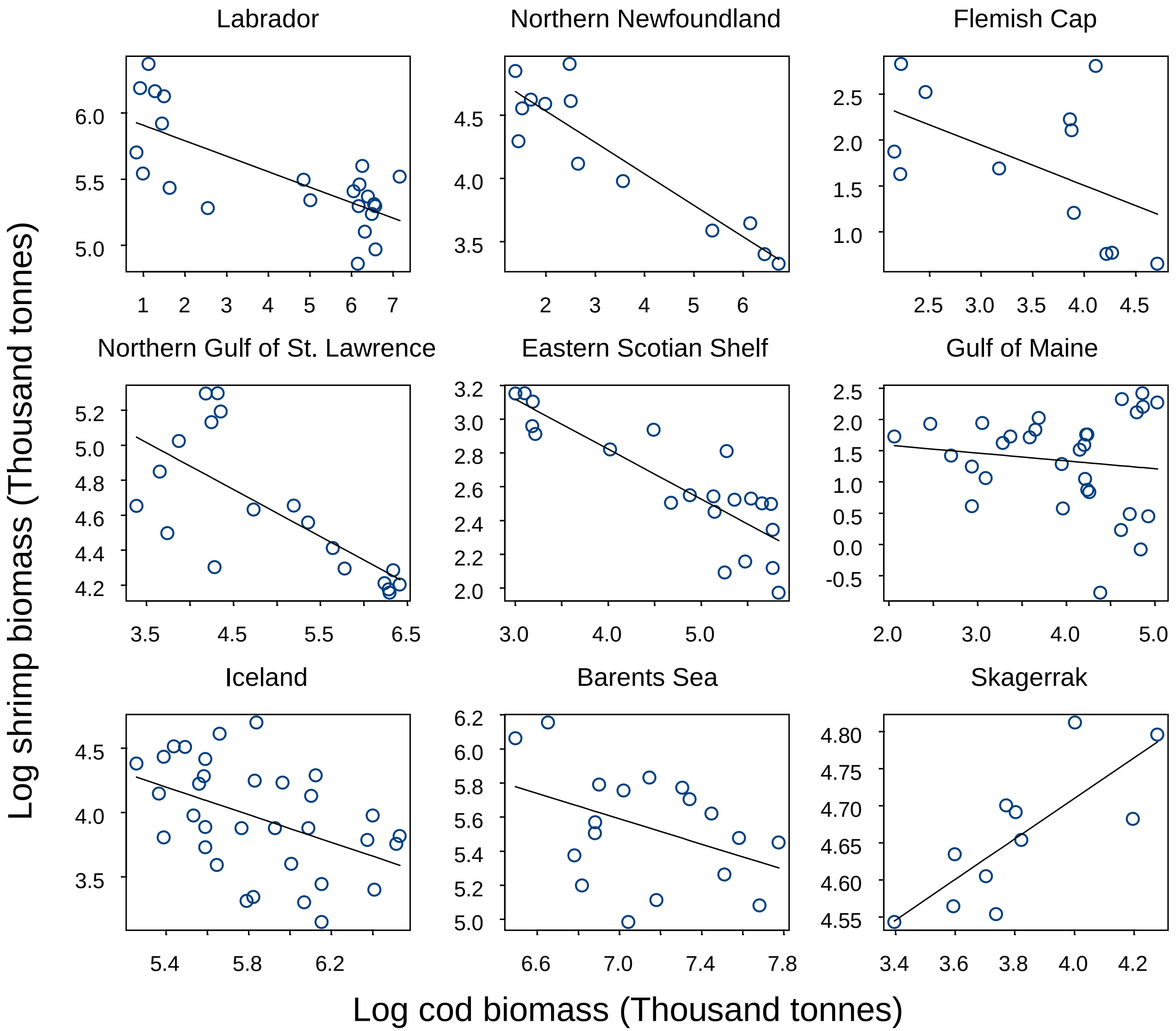


Source: Pálsson 1983, Boerje et al. 1987
Magnússon and Pálsson 1991, Rodríguez-Marín and del Río 1999
Lilly et al. 2000, Berenboim et al. 2000, Torres et al. 2000

Cod and shrimp biomass in the North Atlantic: time series



Cod and shrimp biomass in the North Atlantic: correlations

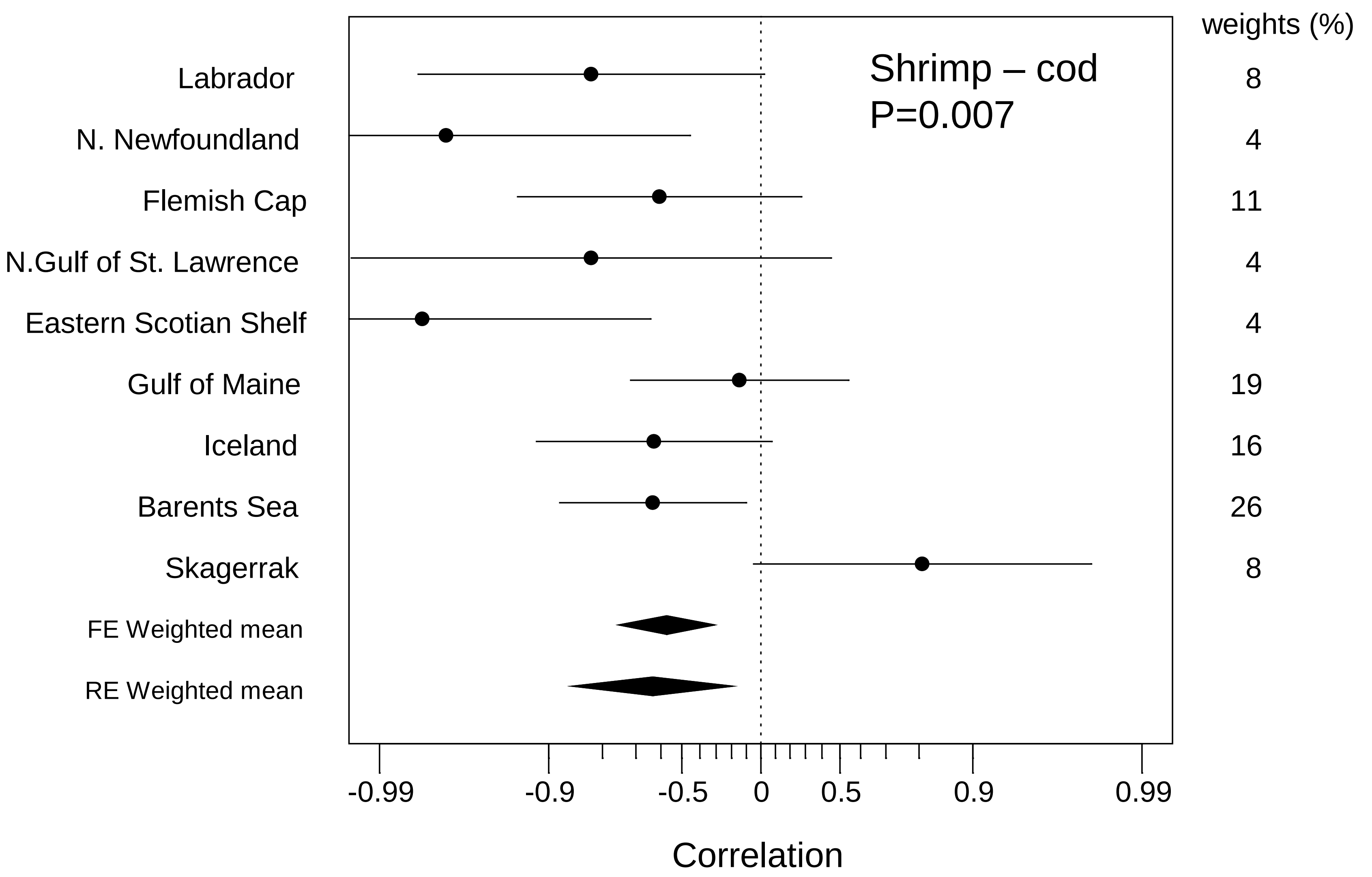


Step 1: Dealing with autocorrelation and measurement error

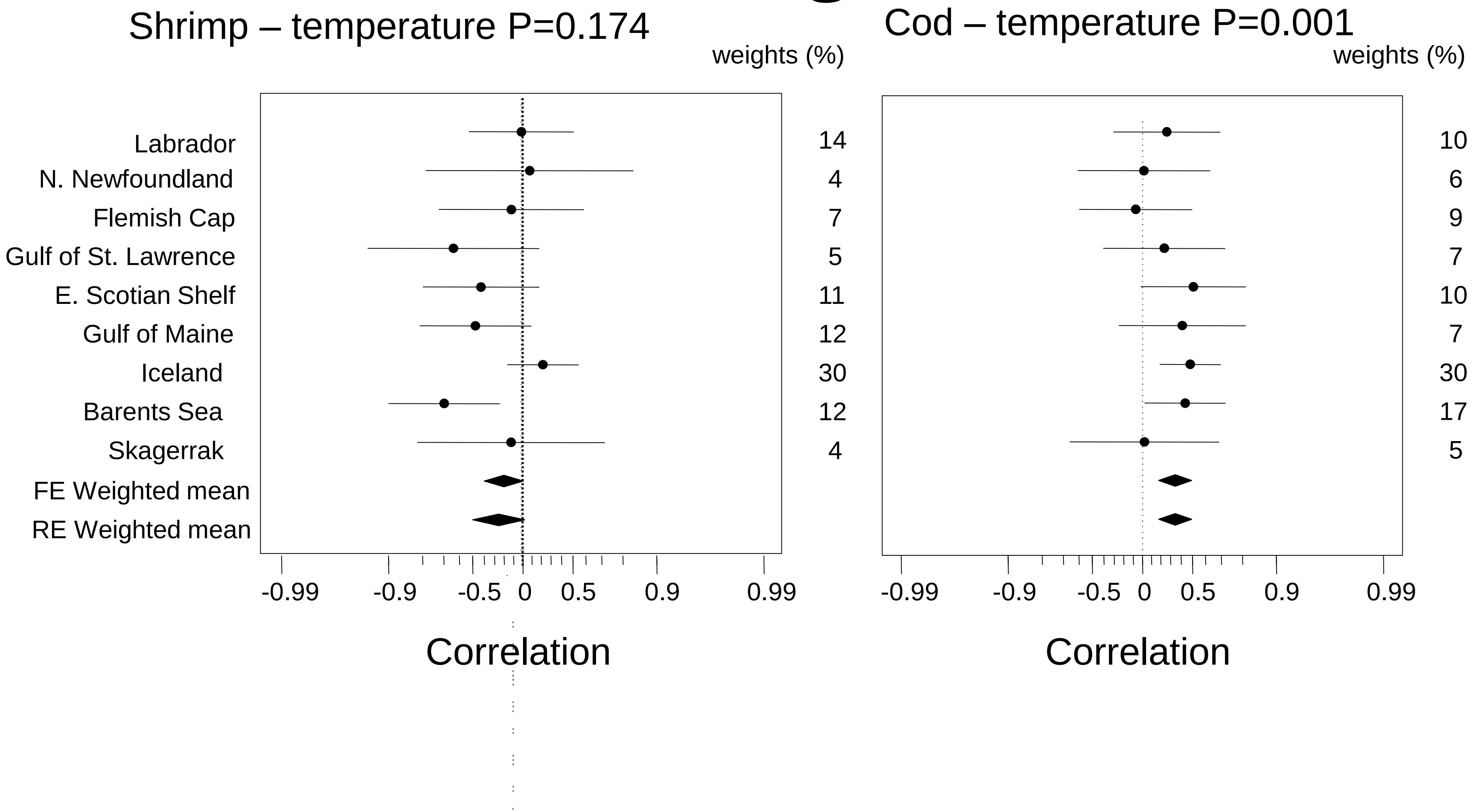
Region	Simple analysis *r*	*N*	*P*	Corrected analysis *r**	*N**	*P**
Labrador	-0.746	23	0.000	-0.827	4.8	0.054
N. Newfoundland	-0.911	13	0.000	-0.976	3.3	0.012
Flemish Cap	-0.526	12	0.073	-0.607	6.3	0.161
N.Gulf of St. Lawrence	-0.708	19	0.000	-0.827	3.4	0.165
Eastern Scotian Shelf	-0.856	21	0.000	-0.982	3.5	0.004
Gulf of Maine	-0.131	31	0.485	-0.147	9.3	0.701
Iceland	-0.459	33	0.006	-0.63	8.2	0.075
Barents Sea	-0.412	18	0.087	-0.635	11.7	0.023
Skagerrak	0.788	11	0.002	0.808	5.0	0.061

Source: Hedges & Olkin 1985, Pyper & Peterman 1998

Step 2: Random-effects meta-analysis

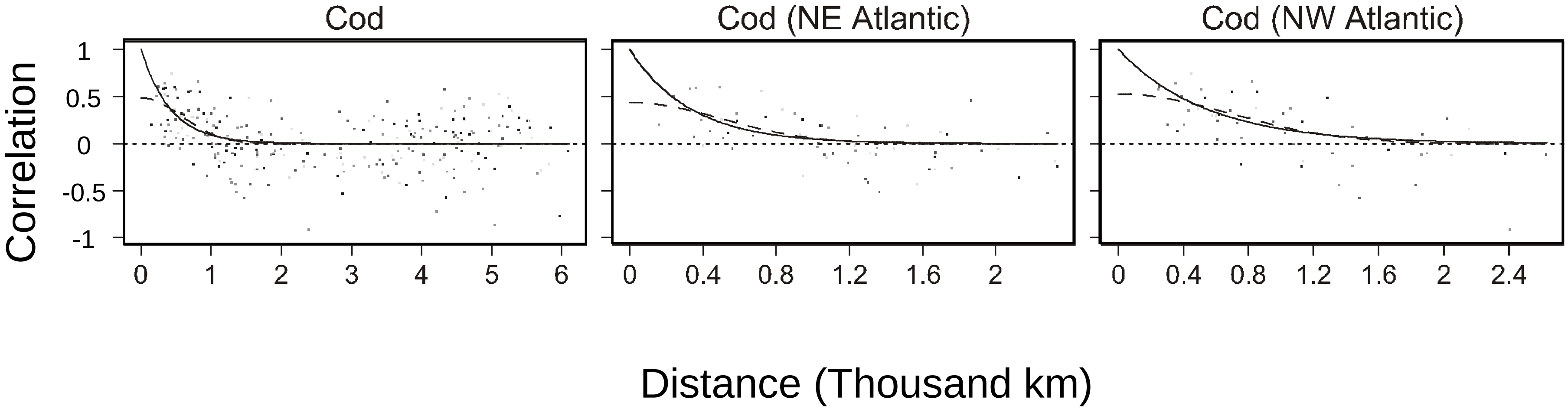


Step 3: Testing environmental forcing



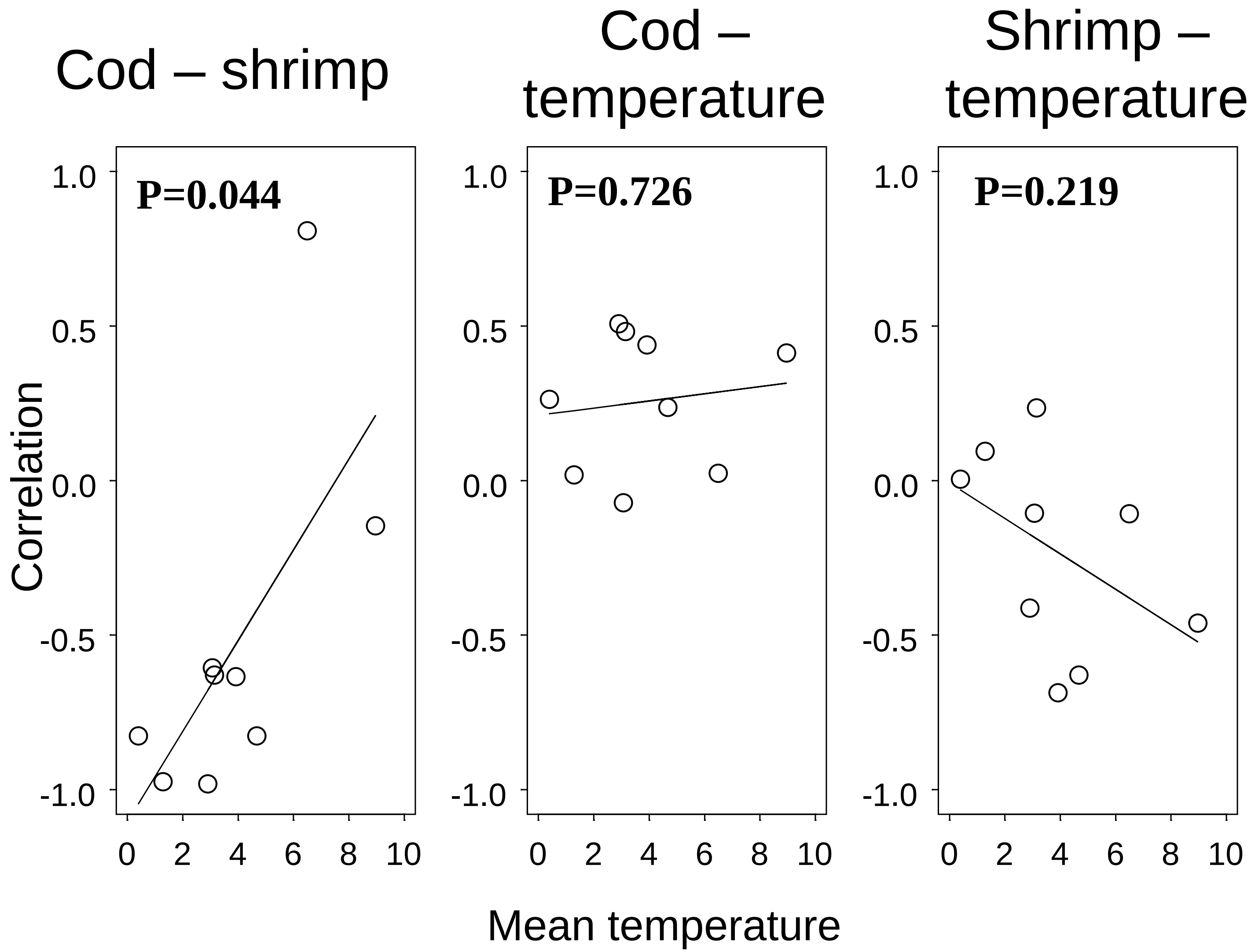
Step 4: Examining spatial correlation

- Cod recruitment is correlated on scales <500 km
- Stocks are not entirely independent
- Sensitivity analysis shows that this does not change results

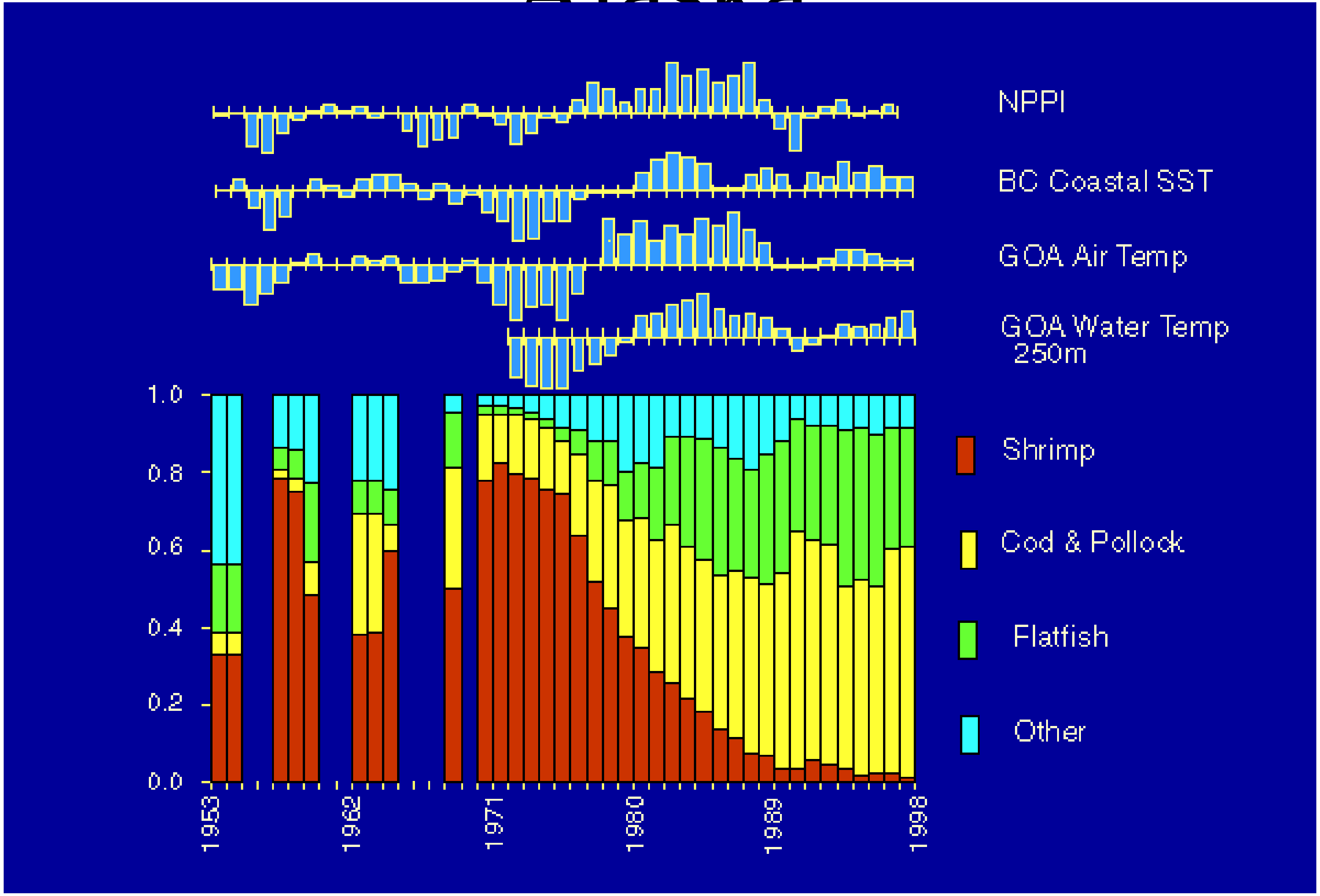


Source: Myers et al. 1997

Step 5: Testing for latitudinal gradients

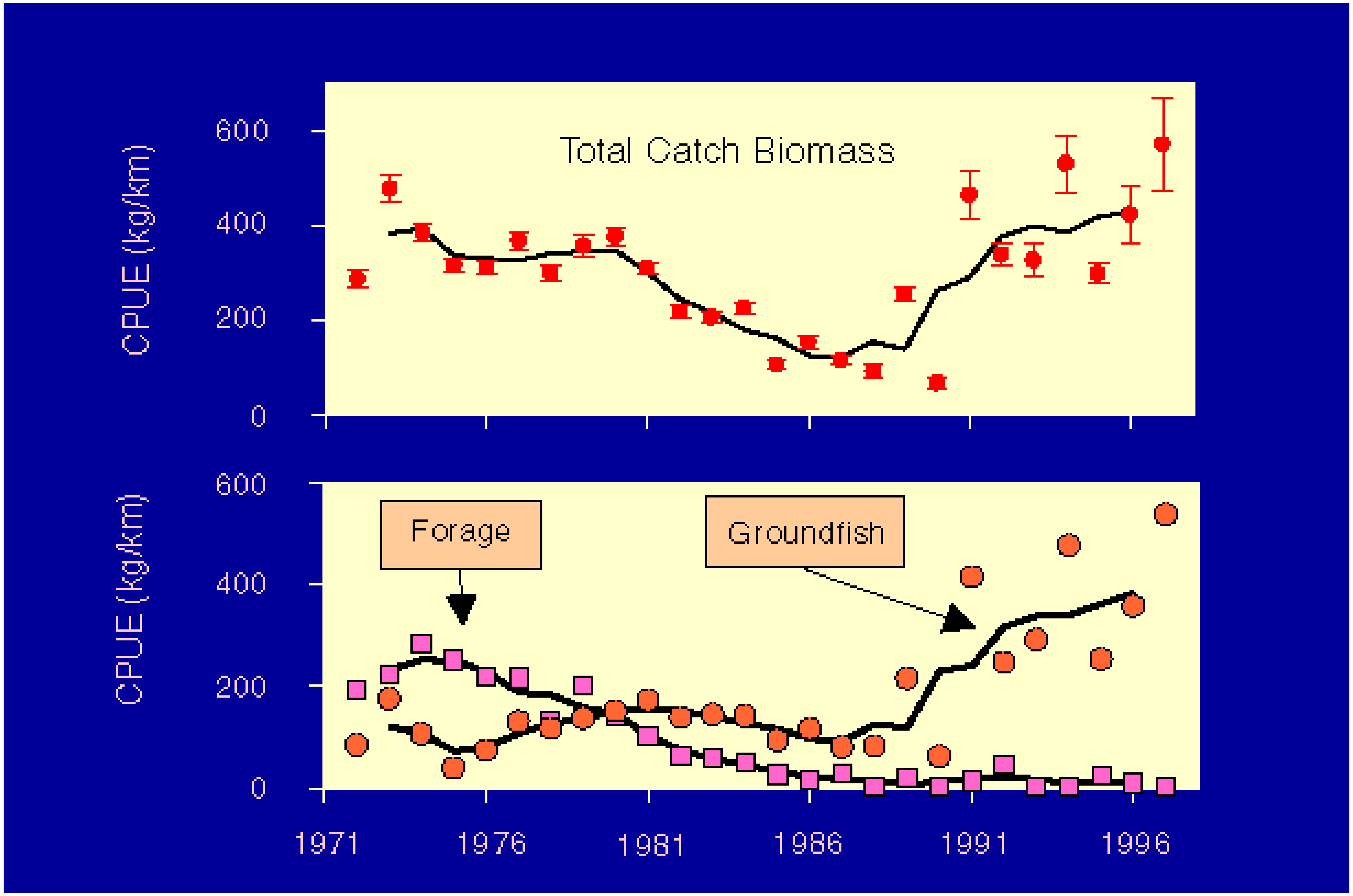


Common patterns? Gulf of Alaska



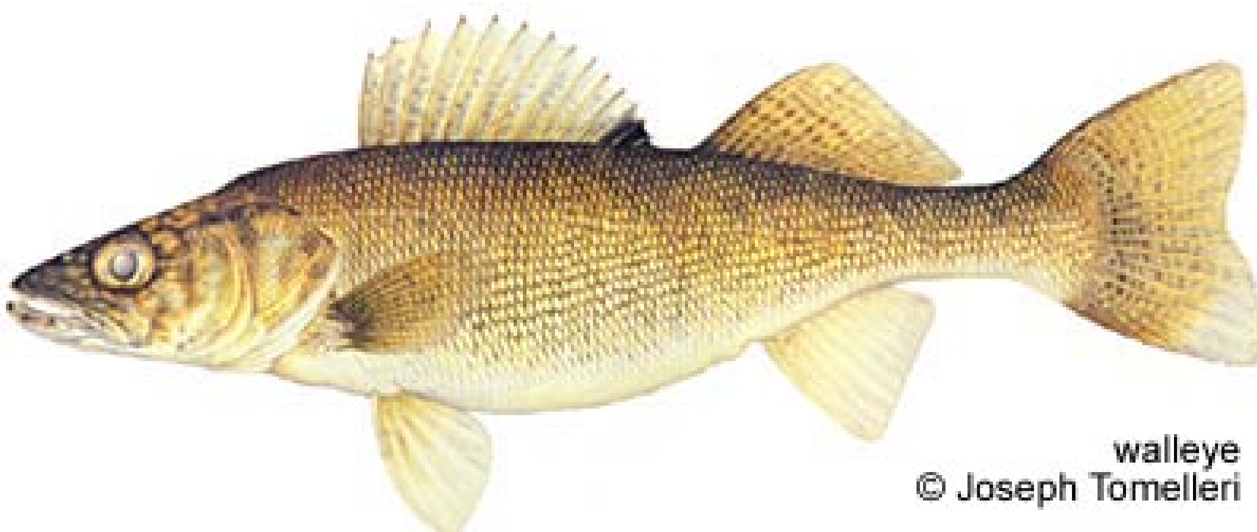
From: Anderson and Piatt 1999

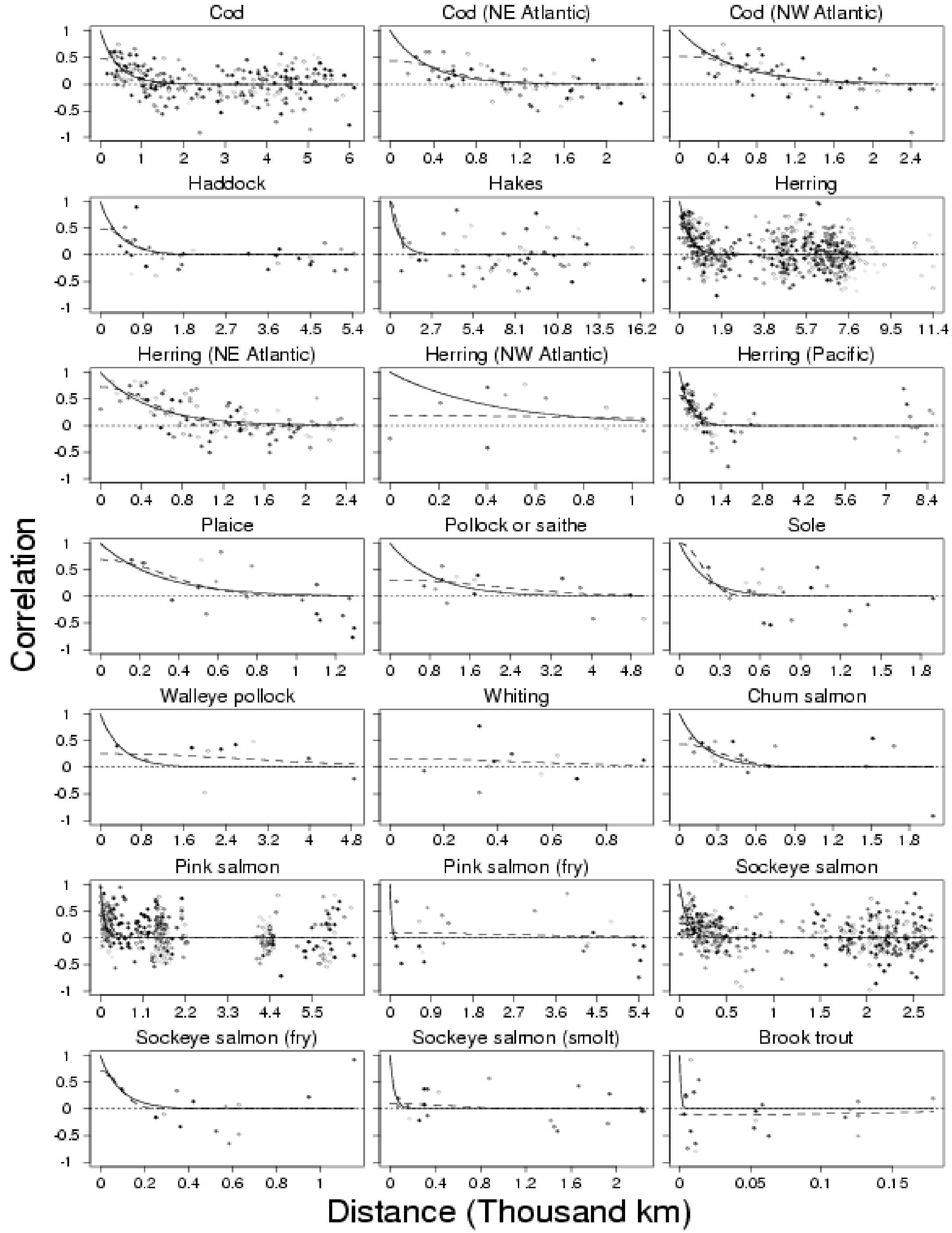
Gulf of Alaska forage fish

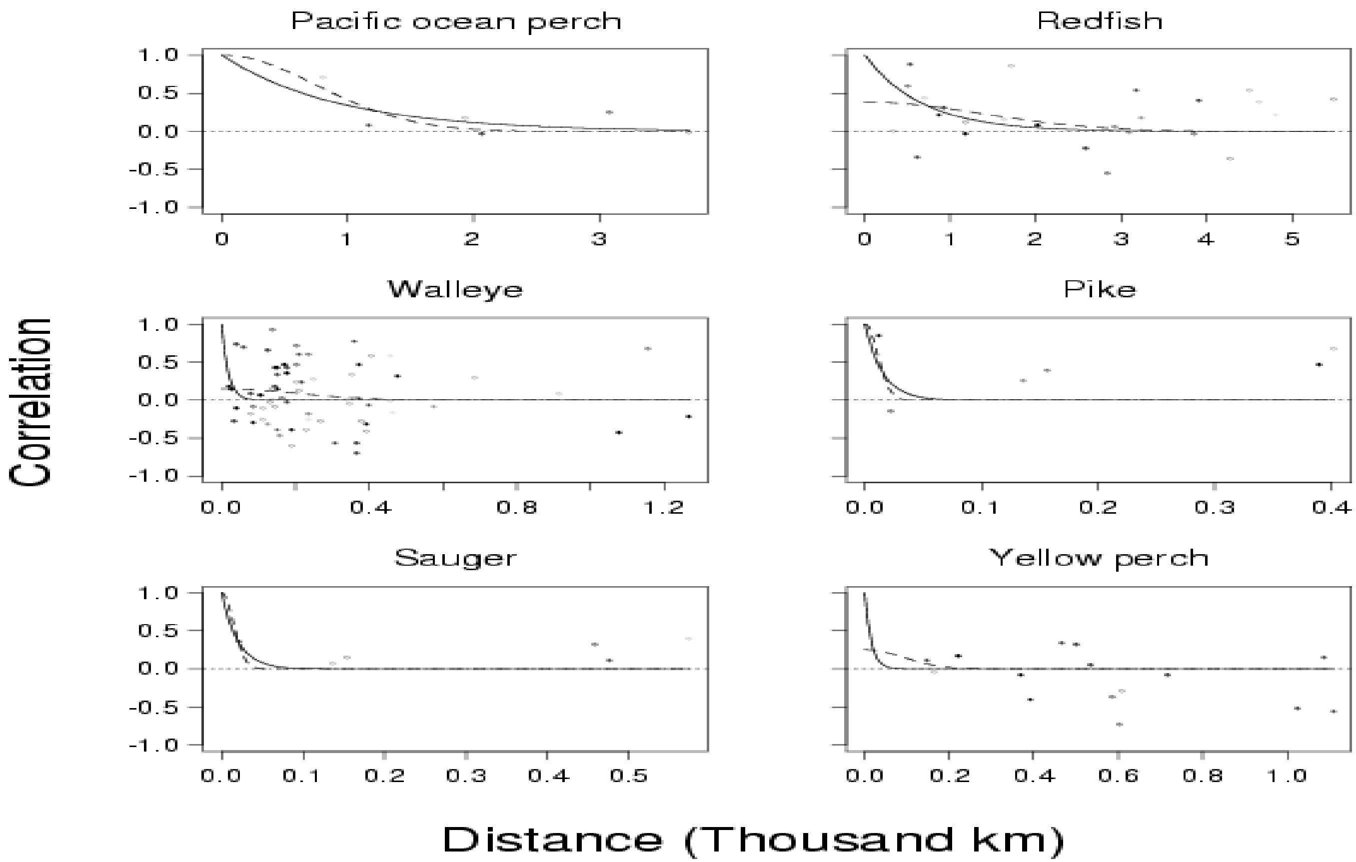


From: Anderson and Piatt 1999

Space – the final frontier

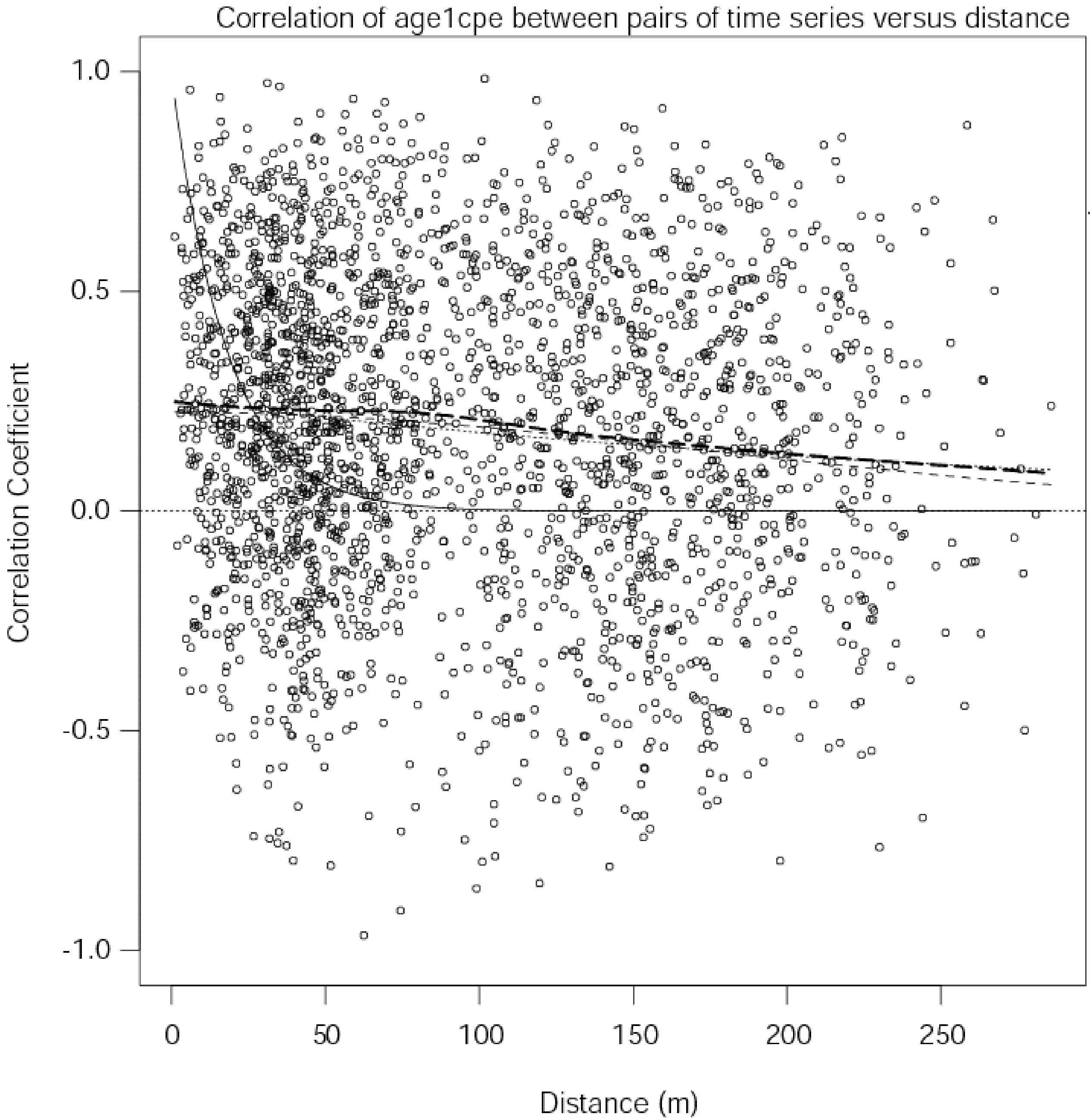


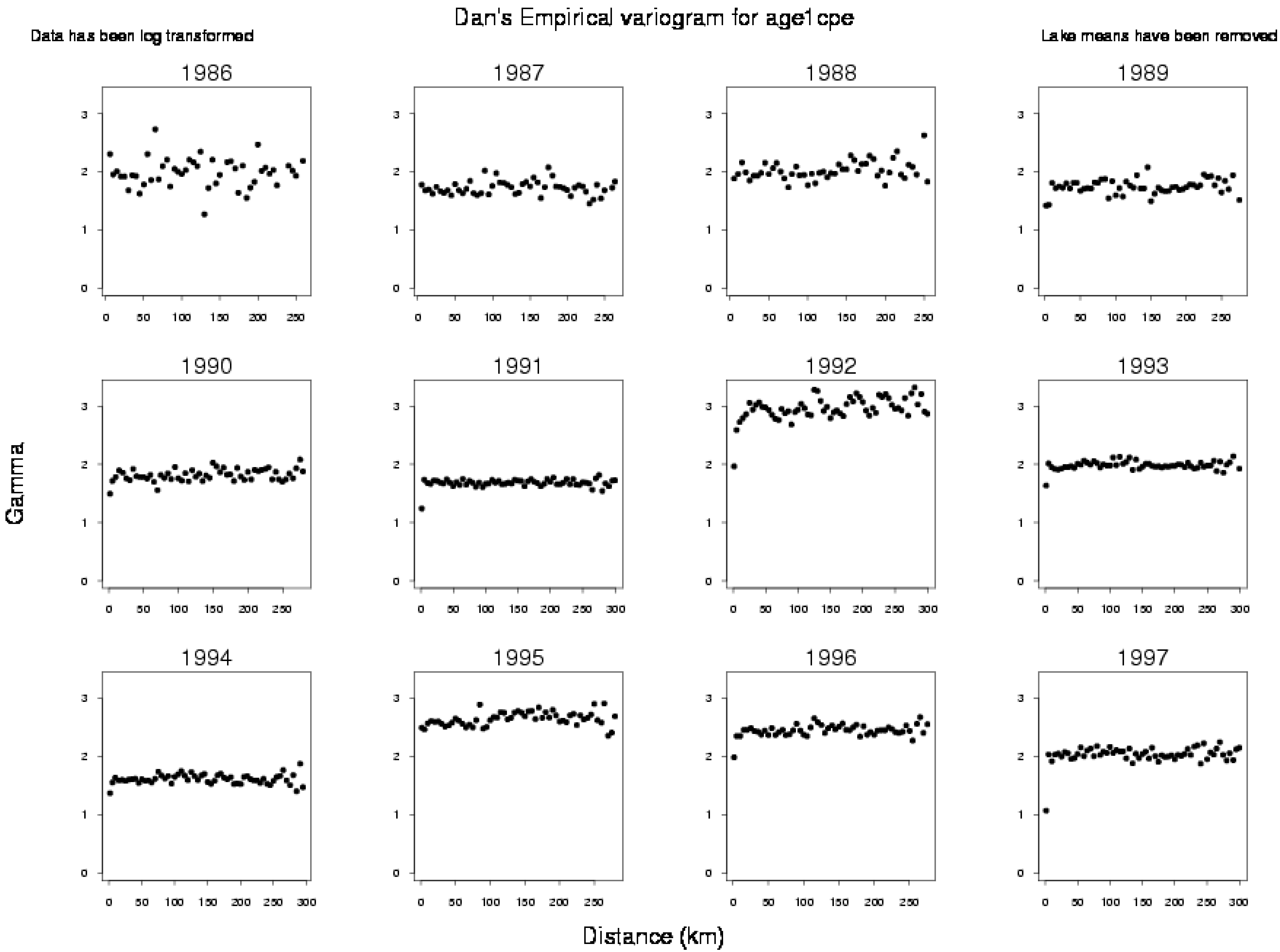

Cod
Cod (NE Atlantic)
Cod (NW Atlantic)
Haddock
Hakes
Herring
Herring (NE Atlantic)
Herring (NW Atlantic)
Herring (Pacific)
Plaice
Pollock or saithe
Sole
Walleye pollock
Whiting
Chum salmon
Pink salmon
Pink salmon (fry)
Sockeye salmon
Sockeye salmon (fry)
Sockeye salmon (smolt)
Brook trout
Correlation
Distance (Thousand km)



Pacific ocean perch
Redfish
Walleye
Pike
Sauger
Yellow perch
Correlation
Distance (Thousand km)

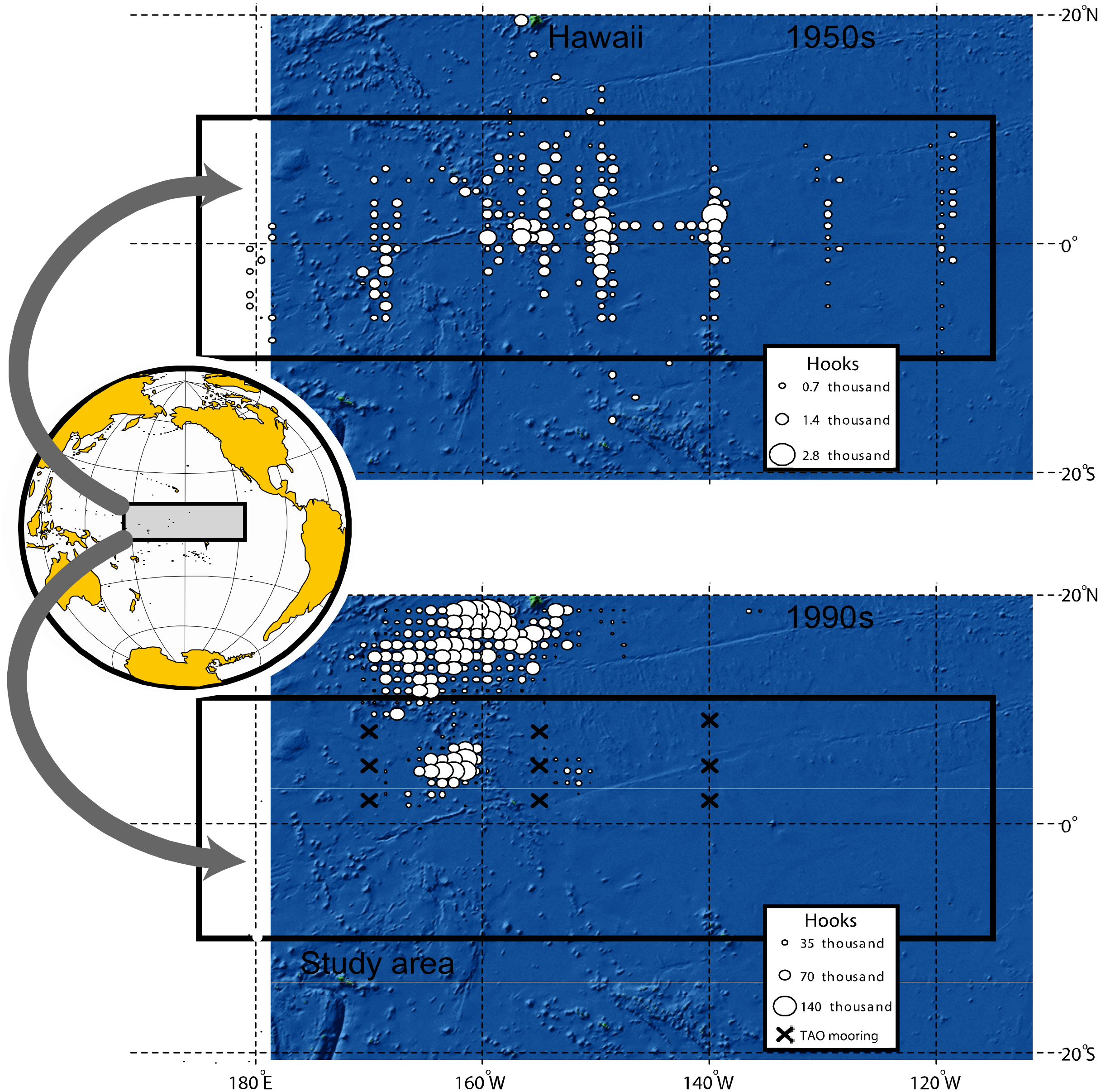
ent


Correlation of age1cpe between pairs of time series versus distance
Correlation Coefficient
1.0
0.5
0.0
-0.5
-1.0
0
50
100
150
200
250
Distance (m)


Dan's Empirical variogram for age1cpe
Data has been log transformed
Lake means have been removed
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
Gamma
Distance (km)

A modest proposal

- Global repeat of the earliest surveys



Hawaii
1950s
Hooks
0.7 thousand
1.4 thousand
2.8 thousand
20°N
0°
20°S
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

The Awards:

- For the longest shelf survey that absolute abundance has been estimated:
- Newfoundland DFO for the Southern Gulf and St. Pierre Bank Groundfish Surveys

The Awards:

- For the longest consistent shelf survey:
- Woods Hole NMFS for the spring Georges Bank/Gulf of Maine surveys

The Awards:

- For the best Coral Ecosystem survey:
- State of Hawaii/NMFS for the Northwest Hawaiian Islands survey

The Awards:

- For the best inland lake survey:
- State of Minn. DNR for their Large Lake Surveys

The Awards:

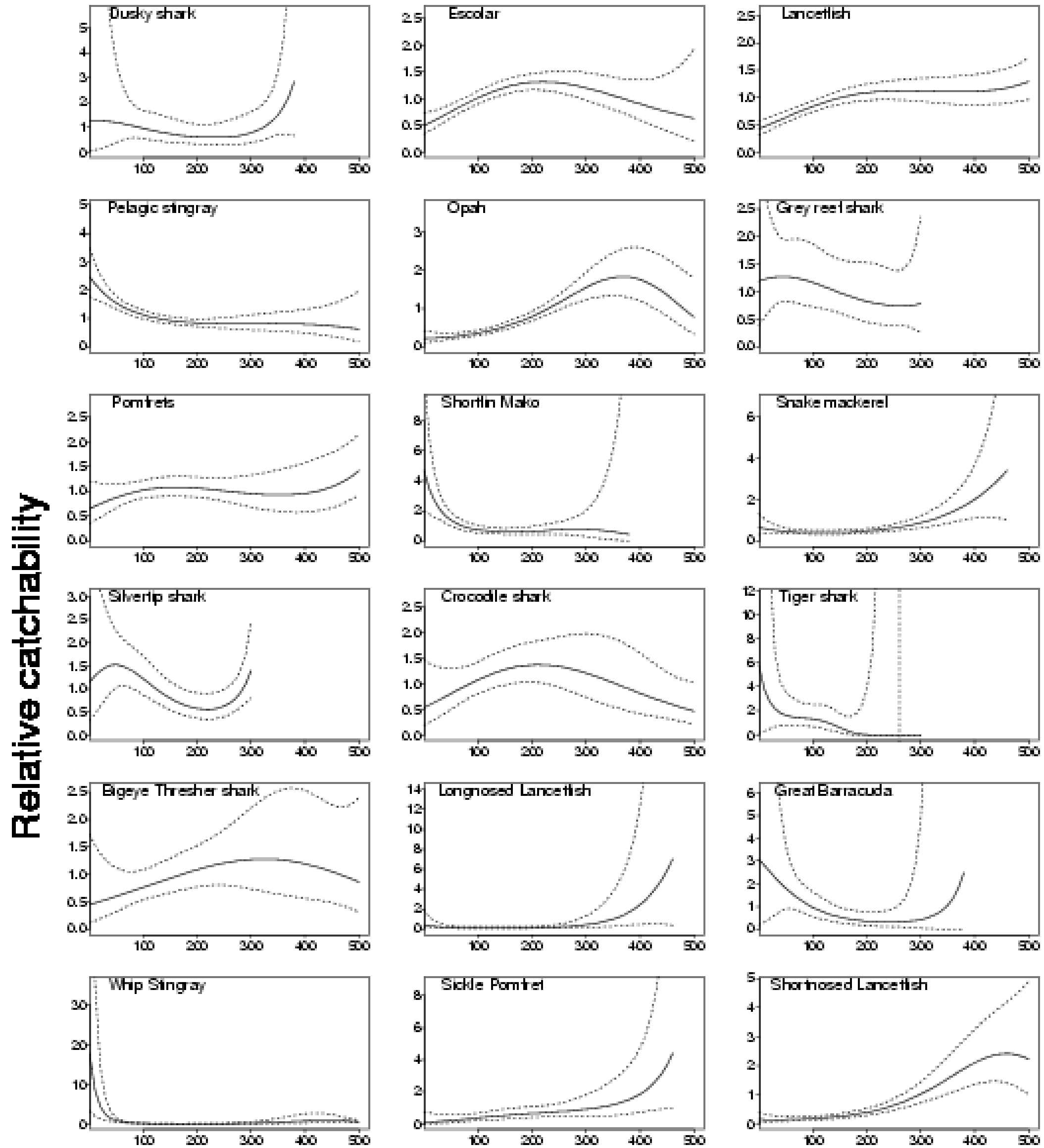
- For the best (and only) surveys of close to virgin open water pelagic systems:
- NMFS Hawaii for the 1950’s Pacific longline survey
- NMFS Pascagoula for 1950’s Gulf of Mexico longline survey

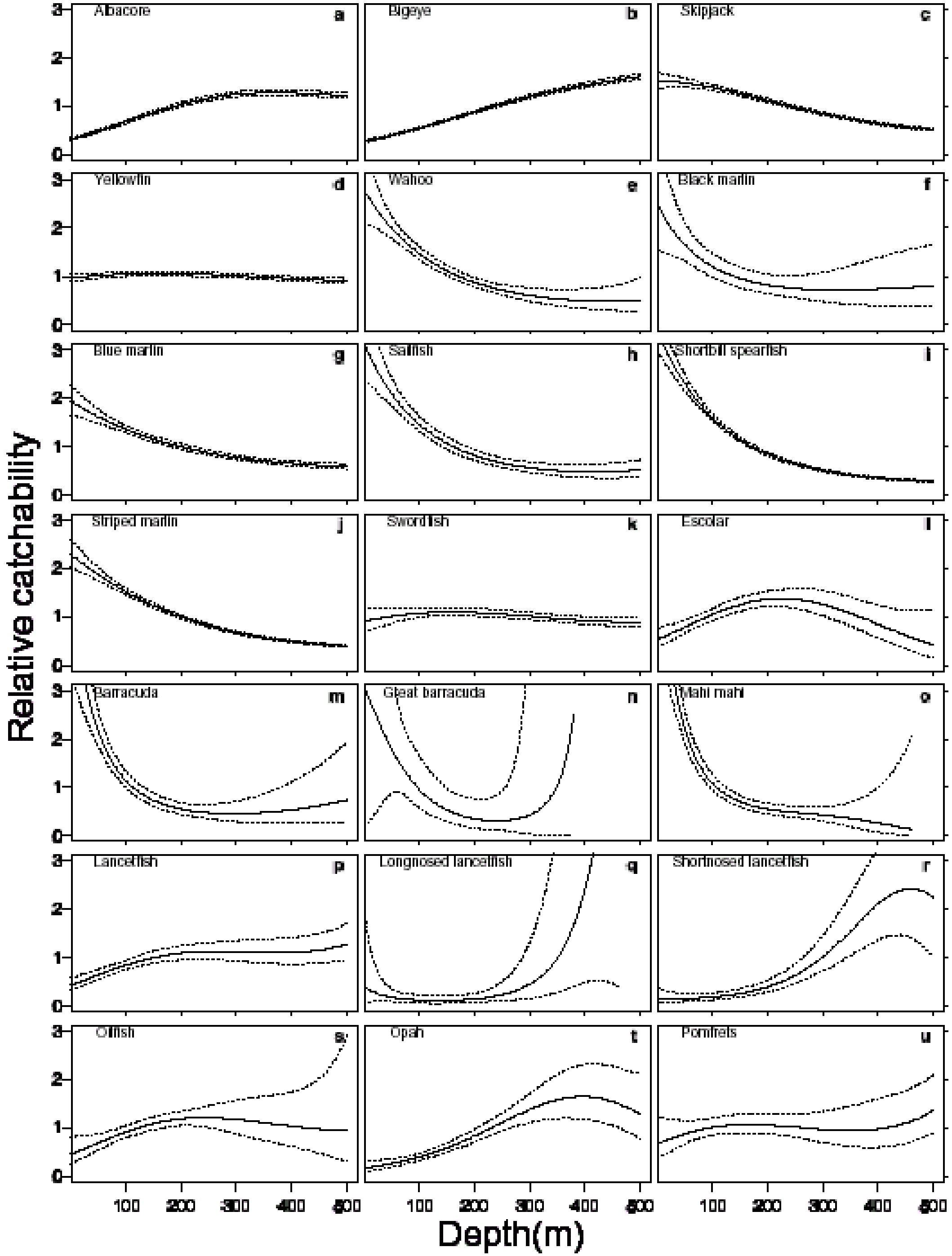
50 years of surveys in the open ocean – it was a very different place

Ransom A. Myers
Peter Ward
Julia Baum
Dalhousie University

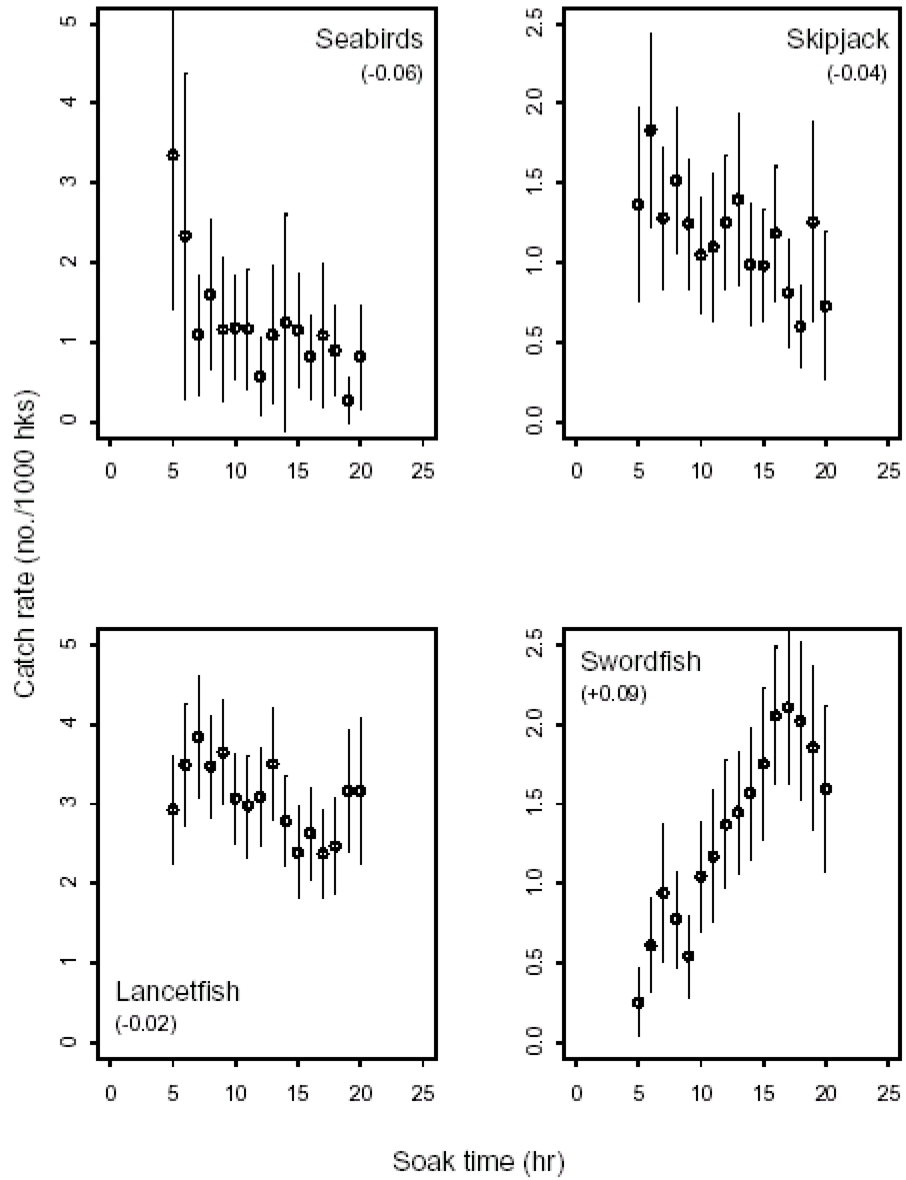
Methods

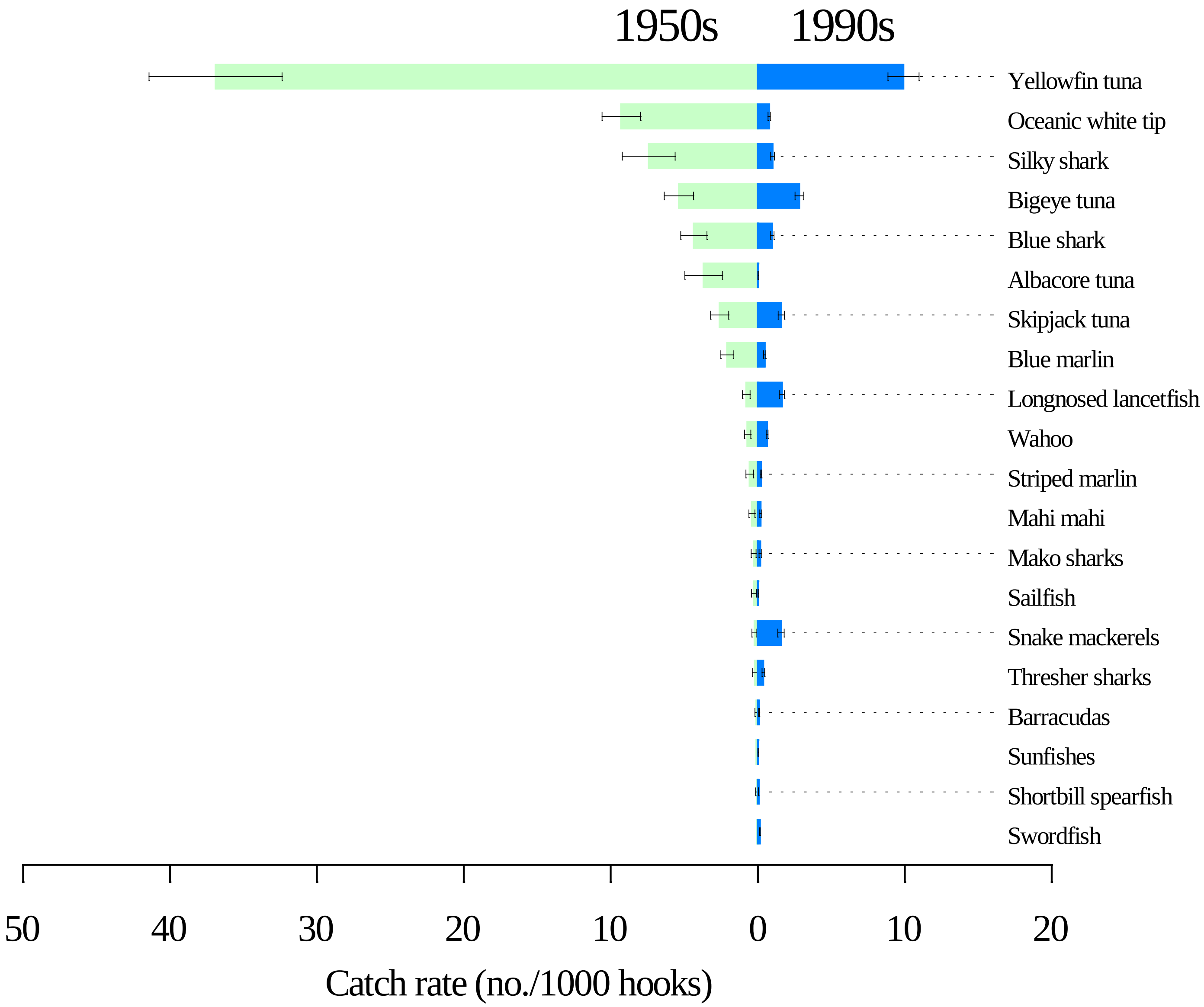
- Collect all survey data in the world
- Develop new methods, using meta-analytic methods, that allow different surveys to be cross calibrated
- Infer the virgin state of the worlds open oceans.

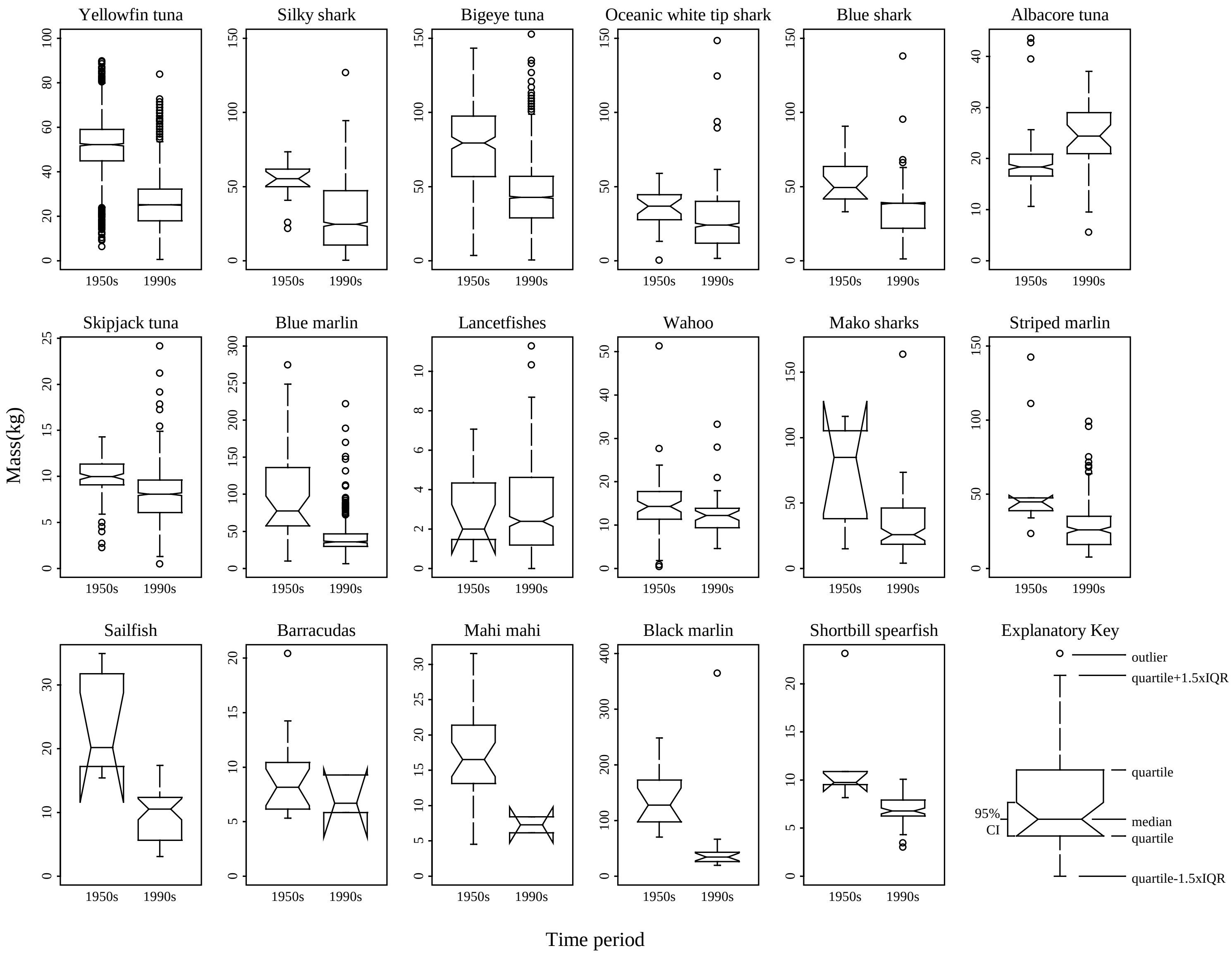

Relative catchability
Dusky shark
Escolar
Lancetfish
Pelagic stingray
Opah
Grey reef shark
Pomfrets
Shortfin Mako
Snake mackerel
Silvertip shark
Crocodile shark
Tiger shark
Bigeye Thresher shark
Longnosed Lancetfish
Great Barracuda
Whip Stingray
Sickle Pomfret
Shortnosed Lancetfish

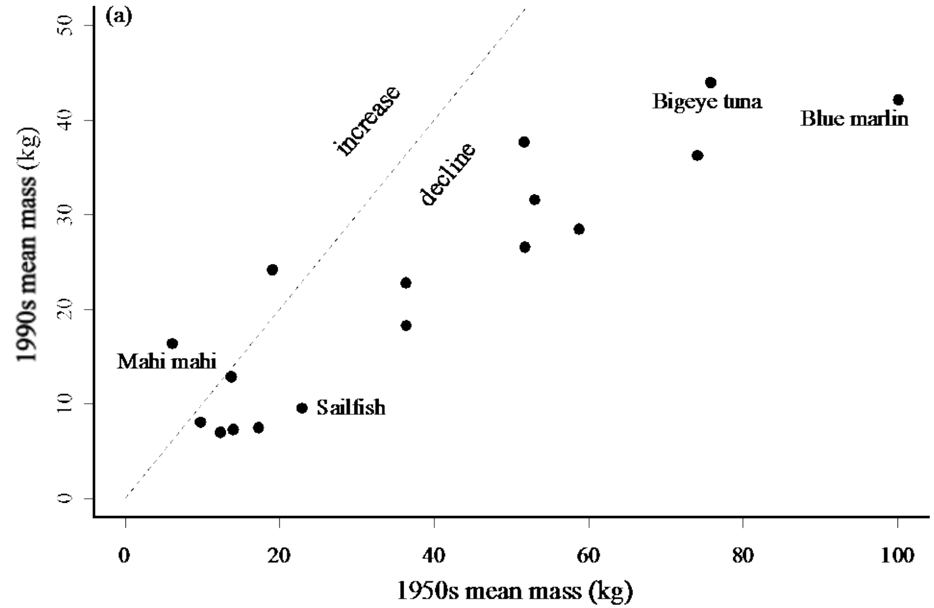


Albacore
a
Bigeye
b
Skipjack
c
Yellowfin
d
Wahoo
e
Black marlin
f
Blue marlin
g
Sailfish
h
Shortbill spearfish
i
Striped marlin
j
Swordfish
k
Escolar
l
Barracuda
m
Great barracuda
n
Mahi mahi
o
Lancetfish
p
Longnosed lancetfish
q
Shortnosed lancetfish
r
Oilfish
s
Opah
t
Pomfrets
u
Relative catchability
0 1 2 3
100 200 300 400 500
Depth(m)

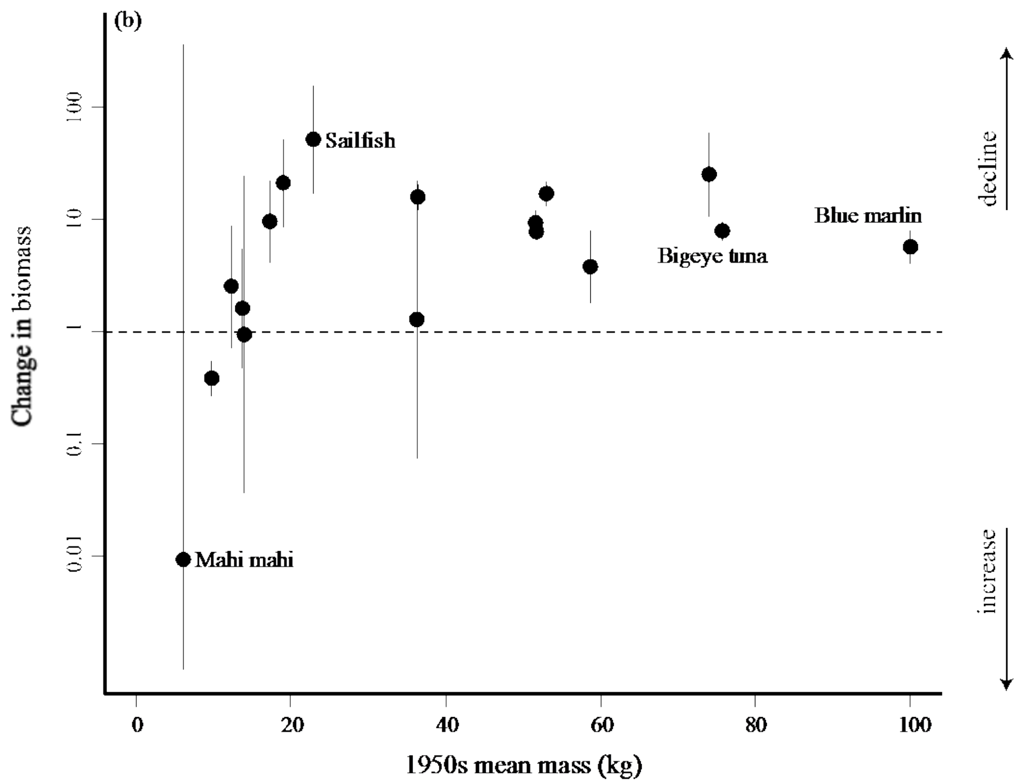

Seabirds
(-0.06)
Skipjack
(-0.04)
Lancetfish
(-0.02)
Swordfish
(+0.09)
Catch rate (no./1000 hks)
Soak time (hr)


1950s
1990s
Yellowfin tuna
Oceanic white tip
Silky shark
Bigeye tuna
Blue shark
Albacore tuna
Skipjack tuna
Blue marlin
Longnosed lancetfish
Wahoo
Striped marlin
Mahi mahi
Mako sharks
Sailfish
Snake mackerels
Thresher sharks
Barracudas
Sunfishes
Shortbill spearfish
Swordfish
50
40
30
20
10
0
10
20
Catch rate (no./1000 hooks)

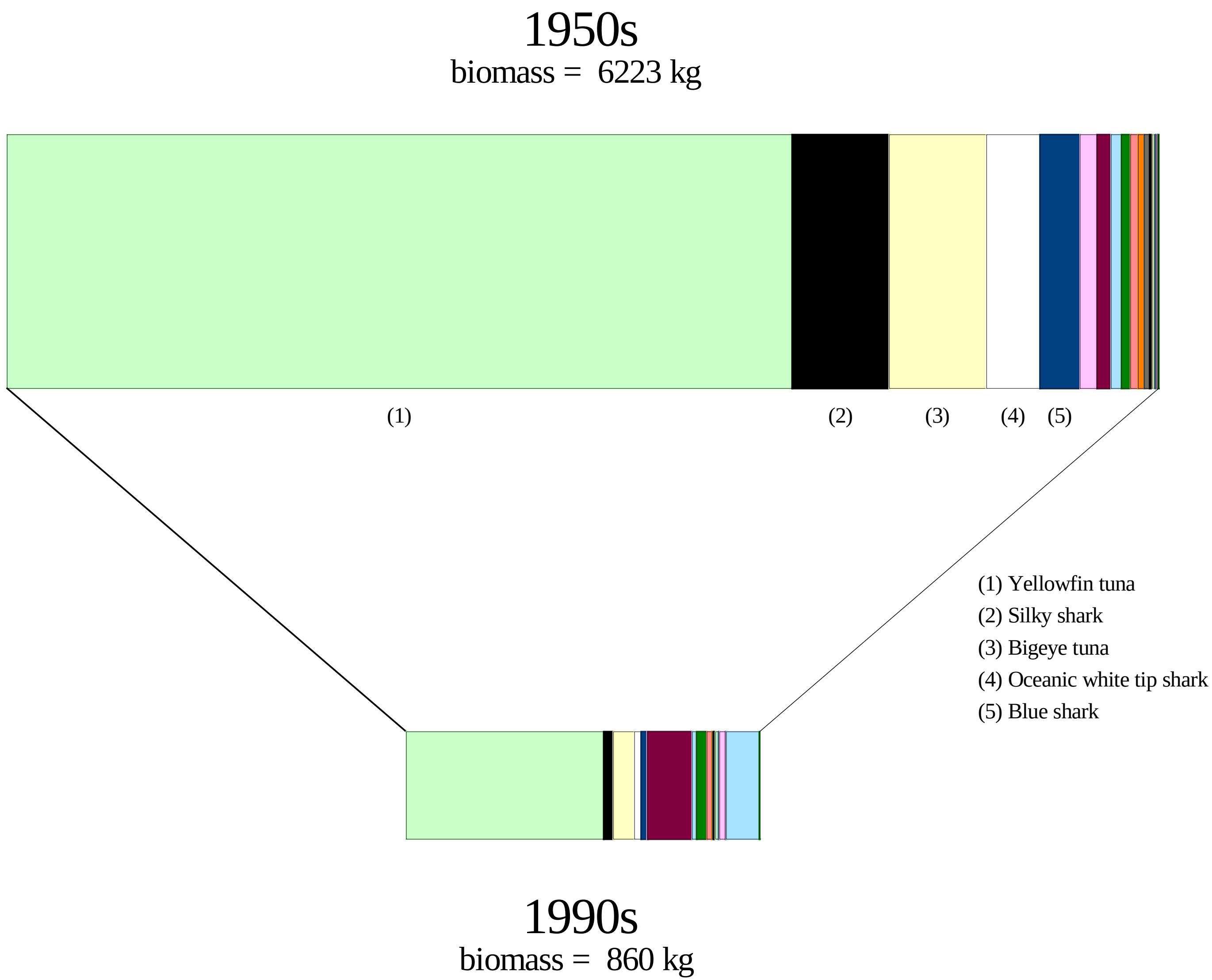

Yellowfin tuna
Silky shark
Bigeye tuna
Oceanic white tip shark
Blue shark
Albacore tuna
Skipjack tuna
Blue marlin
Lancetfishes
Wahoo
Mako sharks
Striped marlin
Sailfish
Barracudas
Mahi mahi
Black marlin
Shortbill spearfish
Explanatory Key
outlier
quartile+1.5xIQR
quartile
95% CI
median
quartile
quartile-1.5xIQR
1950s
1990s
Mass(kg)
Time period



(a)
1990s mean mass (kg)
1950s mean mass (kg)
increase
decline
Bigeye tuna
Blue marlin
Mahi mahi
Sailfish



(b)
Change in biomass
1950s mean mass (kg)
Sailfish
Blue marlin
Bigeye tuna
Mahi mahi
decline
increase


1950s
biomass = 6223 kg
(1)
(2)
(3)
(4)
(5)
(1) Yellowfin tuna
(2) Silky shark
(3) Bigeye tuna
(4) Oceanic white tip shark
(5) Blue shark
1990s
biomass = 860 kg