Robust Estimation of Dynamic Models with Irregularly Spaced Data:

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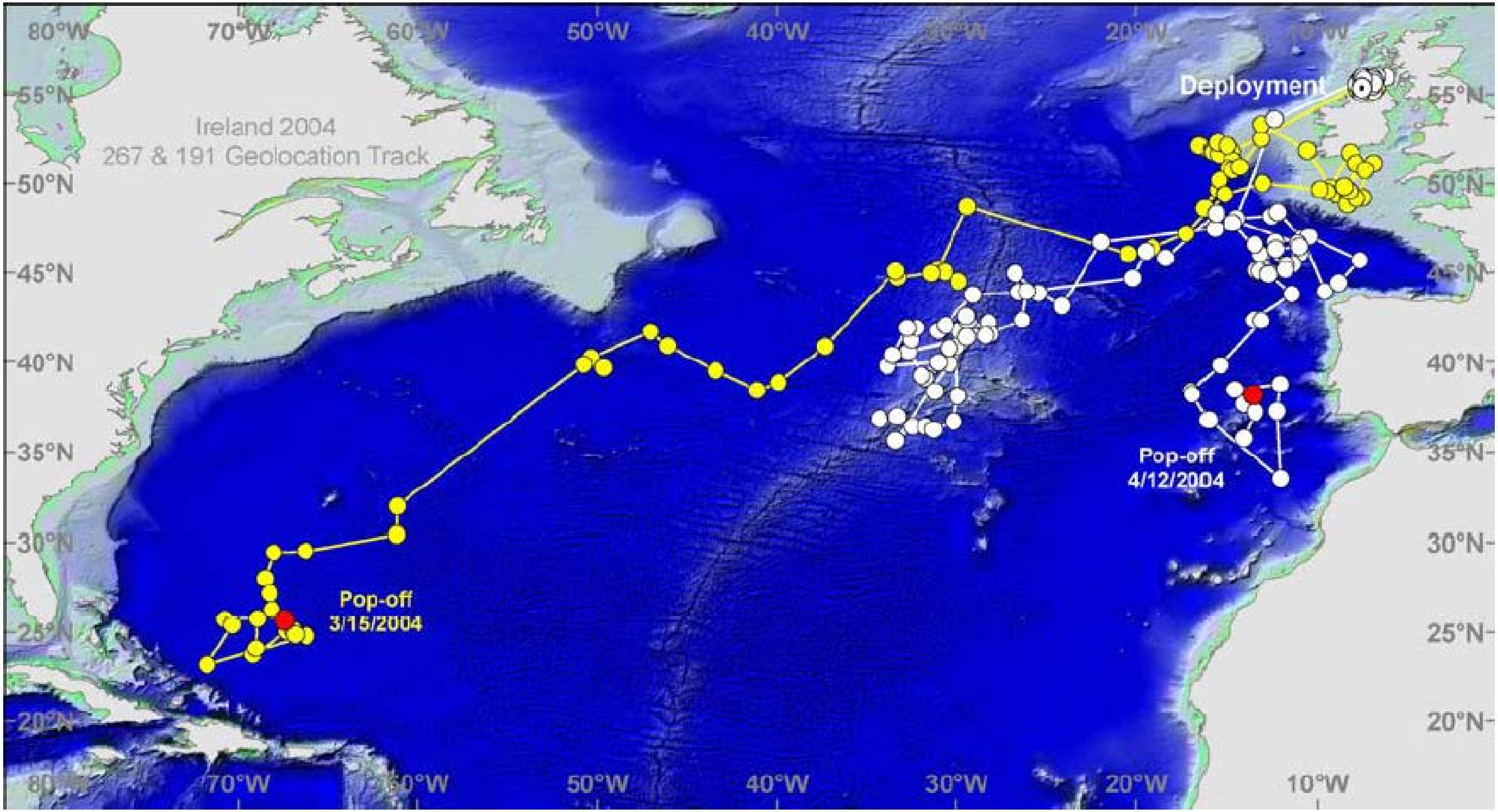
State-Space Models for
Movement
Foraging Behavior
Irregularly Spaced Environmental Data
Community Dynamics

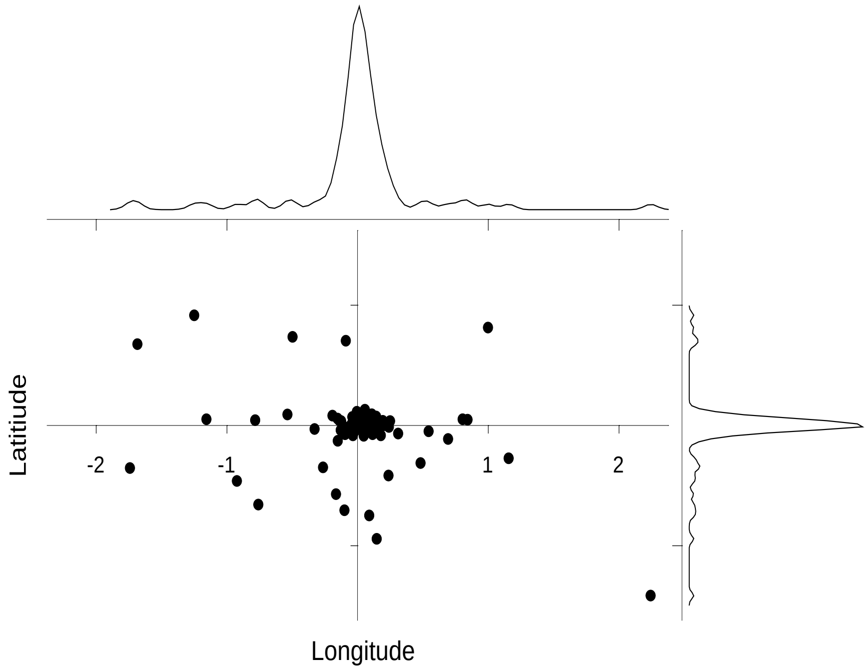
Limitations of Traditional Methods for Time-Series data:

ASSUMPTION: Data Must be Regularly Spaced with No Missing Values
REALITY :MOST Movement DATA HAS MISSING VALUES

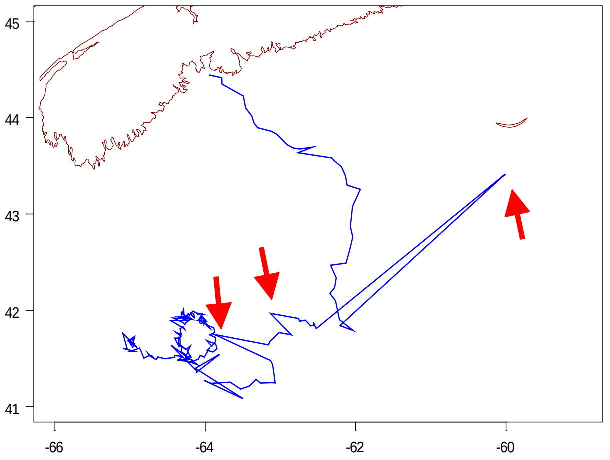


ASSUMPTION: ERRORS ARE GAUSSIAN
REALITY :ERRORS HAVE LONG TAILS

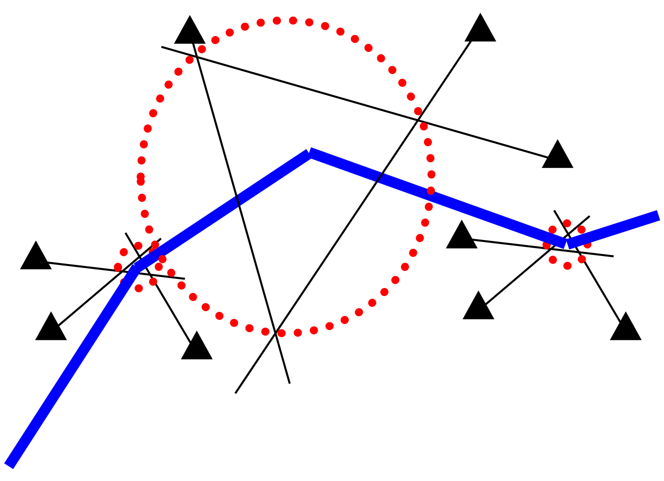
- Estimation error
  - Data observed with error
  - Errors can be non-Gaussian



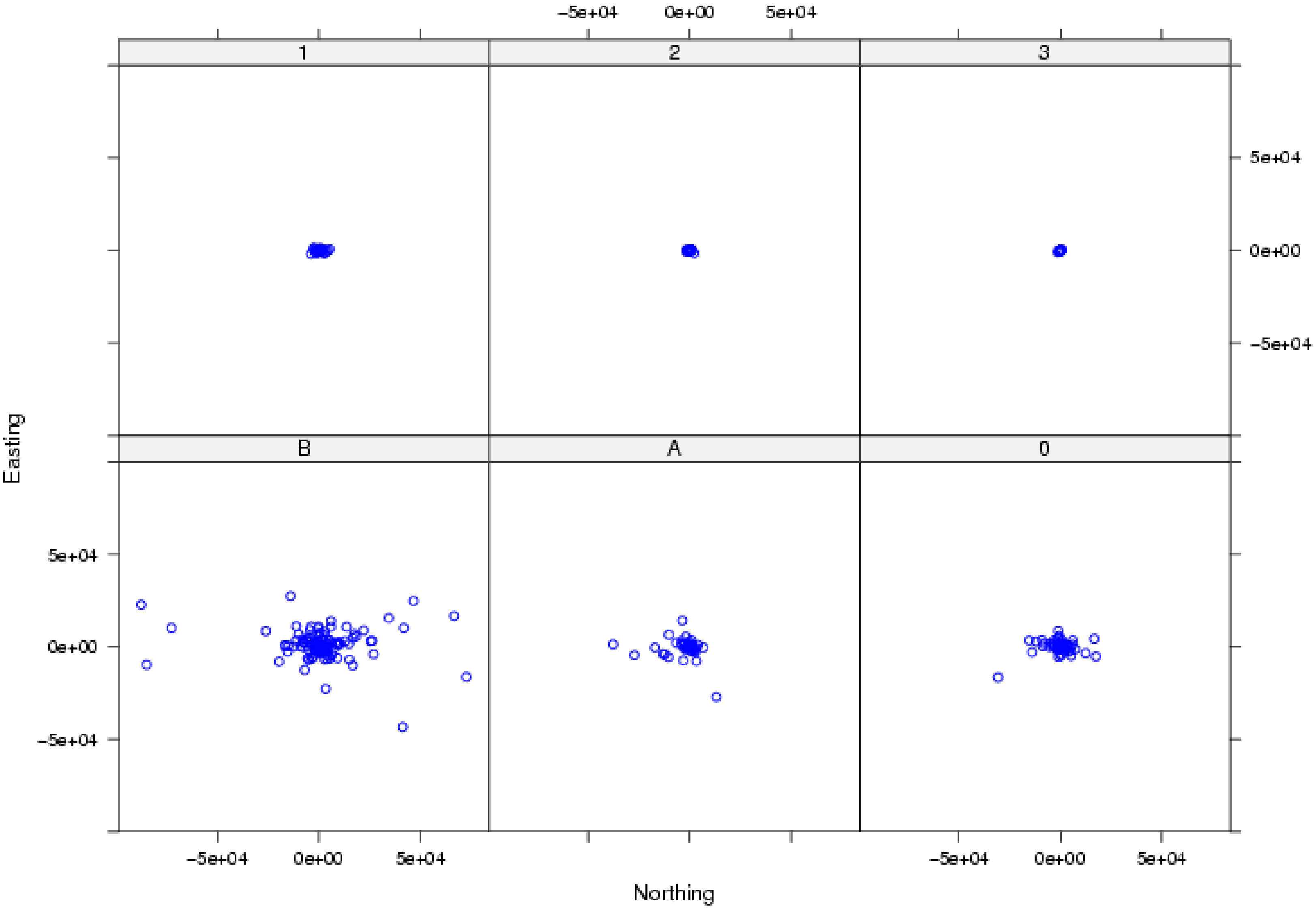
Satellite telemetry



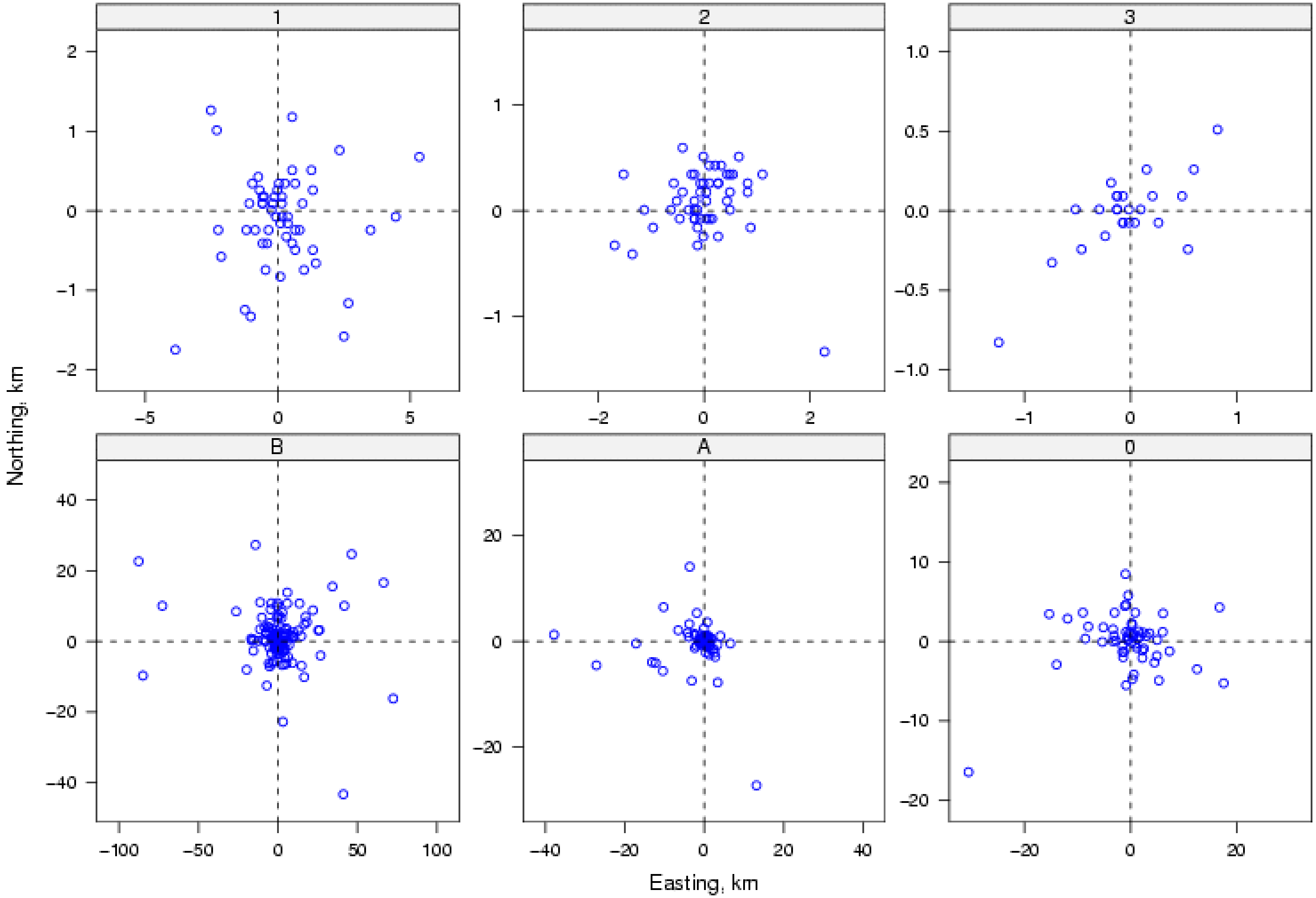
Radio telemetry



Argos location errors

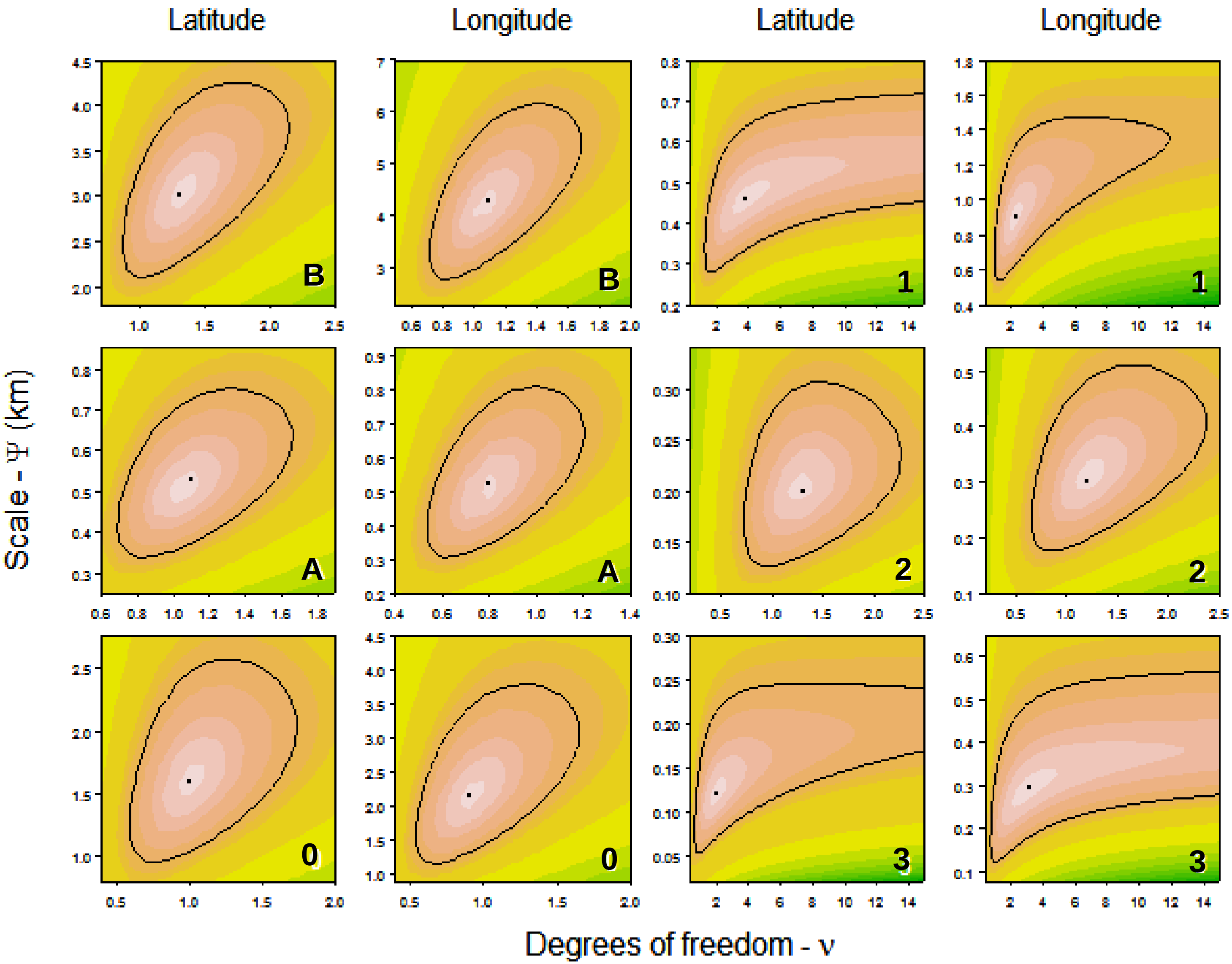


Argos location errors

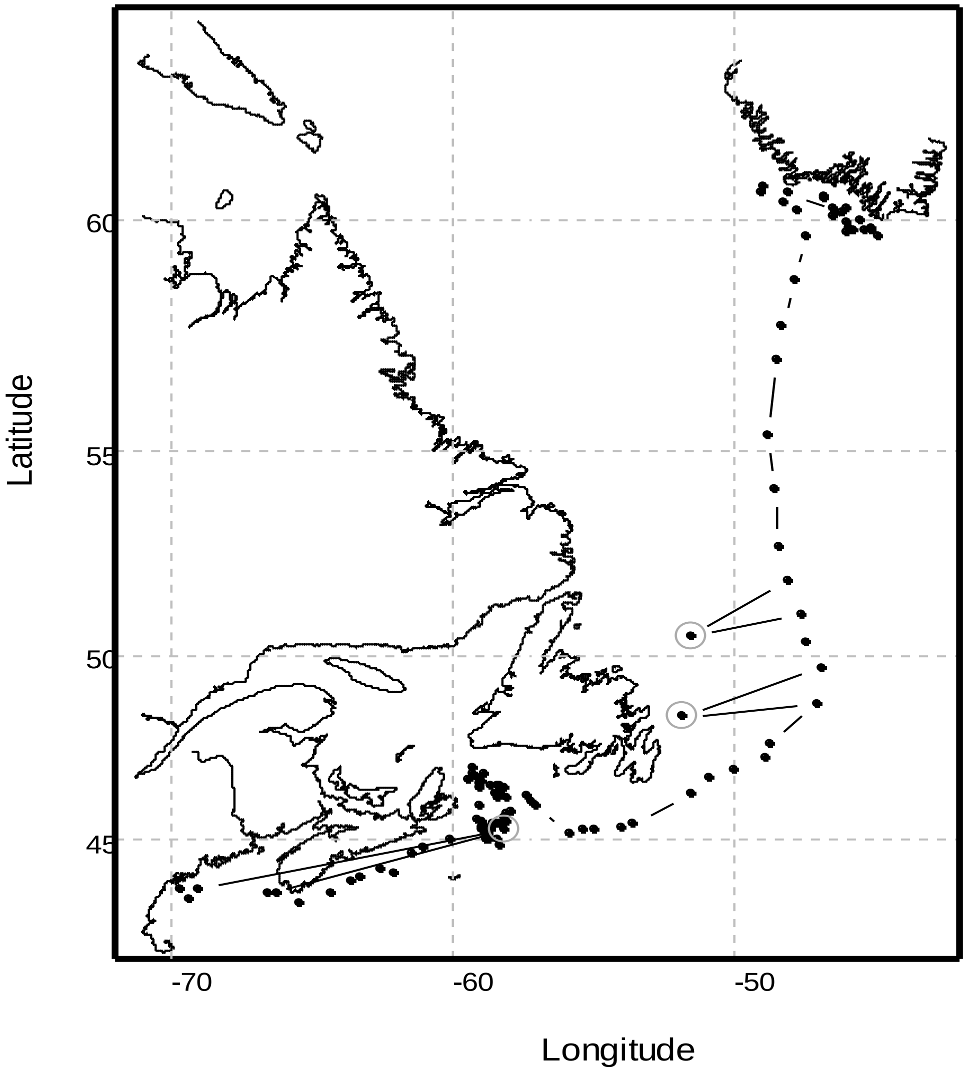


3 locations more than 100 km away removed

Likelihood Contours for t-distribution parameters

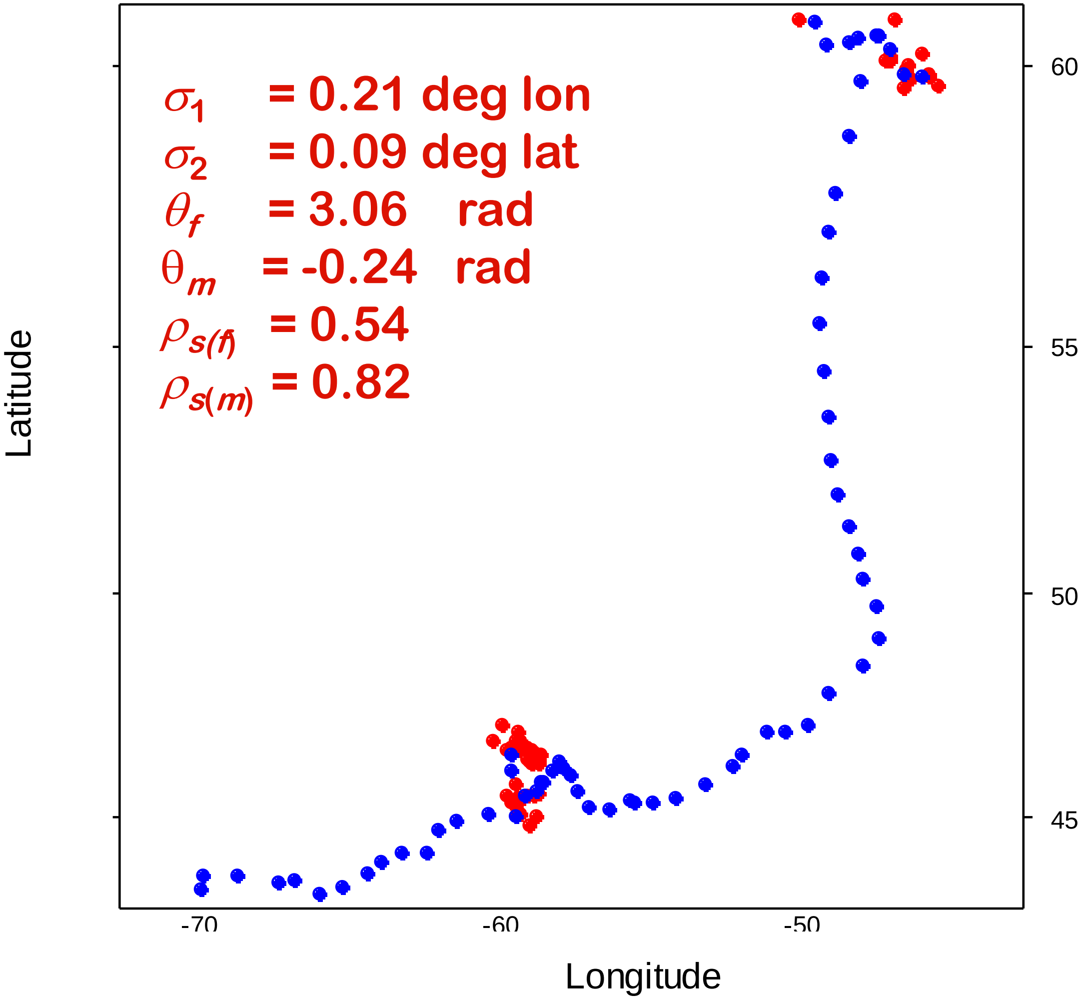


ASSUPTION: BEHAVIOUR IS STATIONARY
REALITY : BEHAVIOUR CHANGES WITH TIME



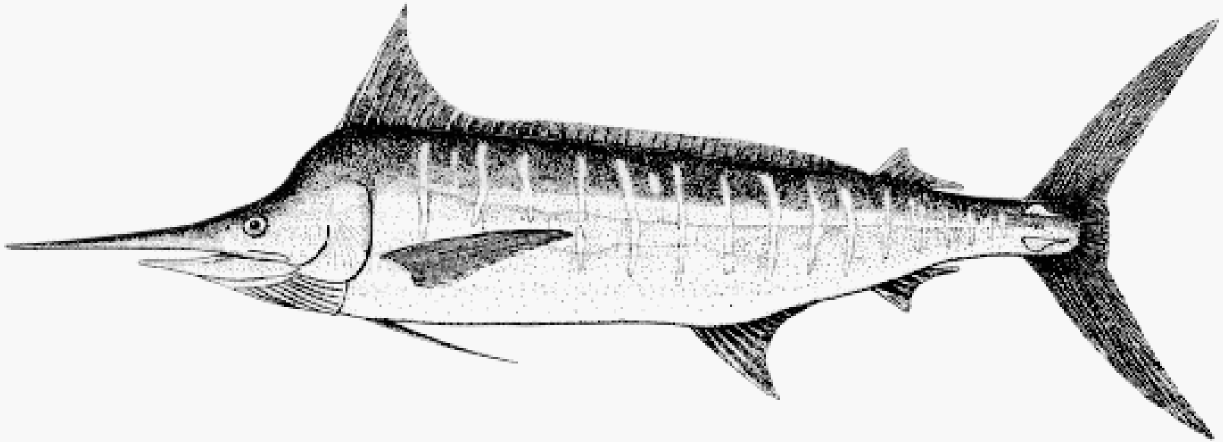
A Switching SSM

Switching model, estimates switches b/w 2 behavioural modes



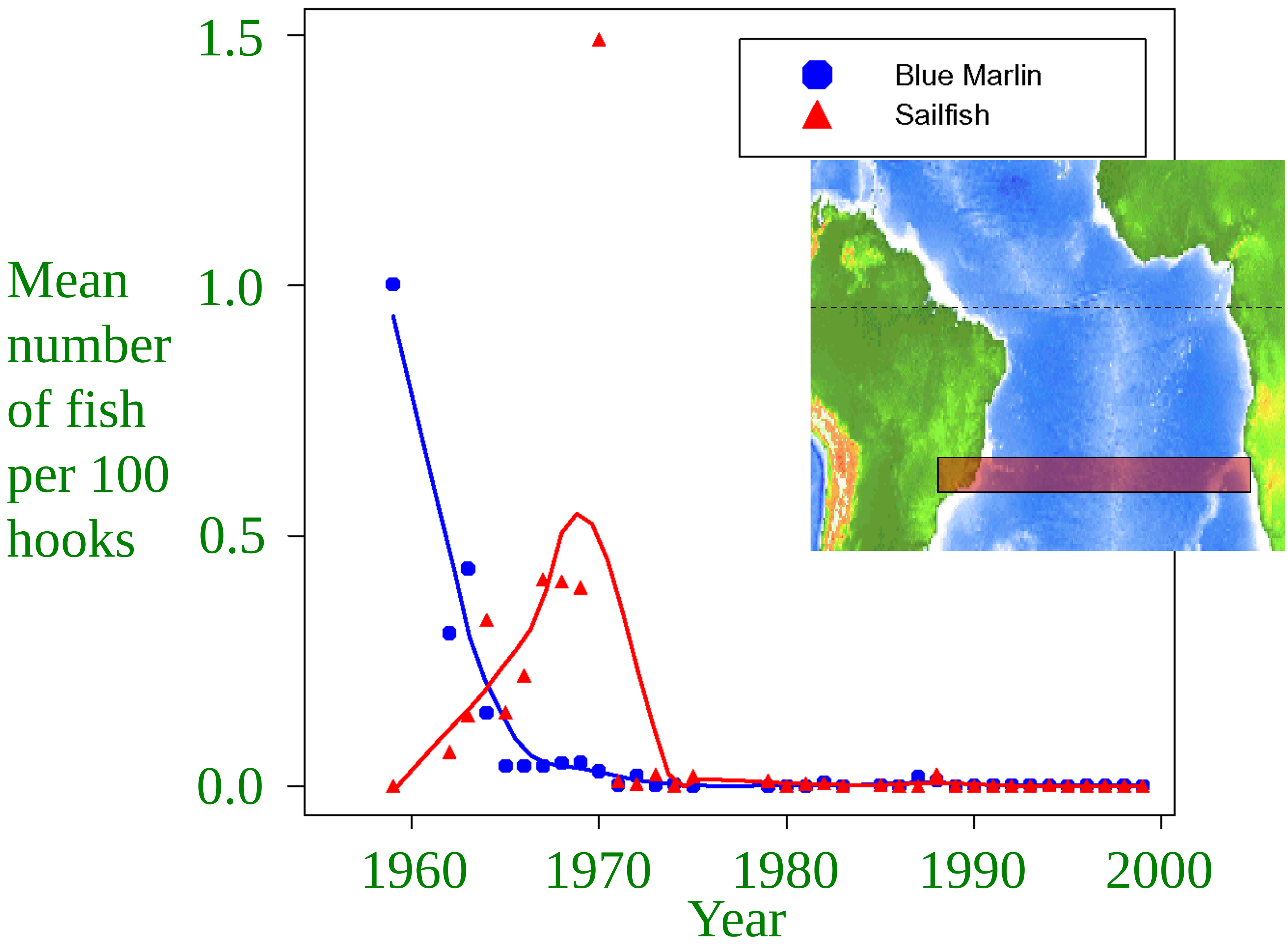
ASSUMPTION: THE WORLD IS LINEAR

REALITY : NONLINEARITY

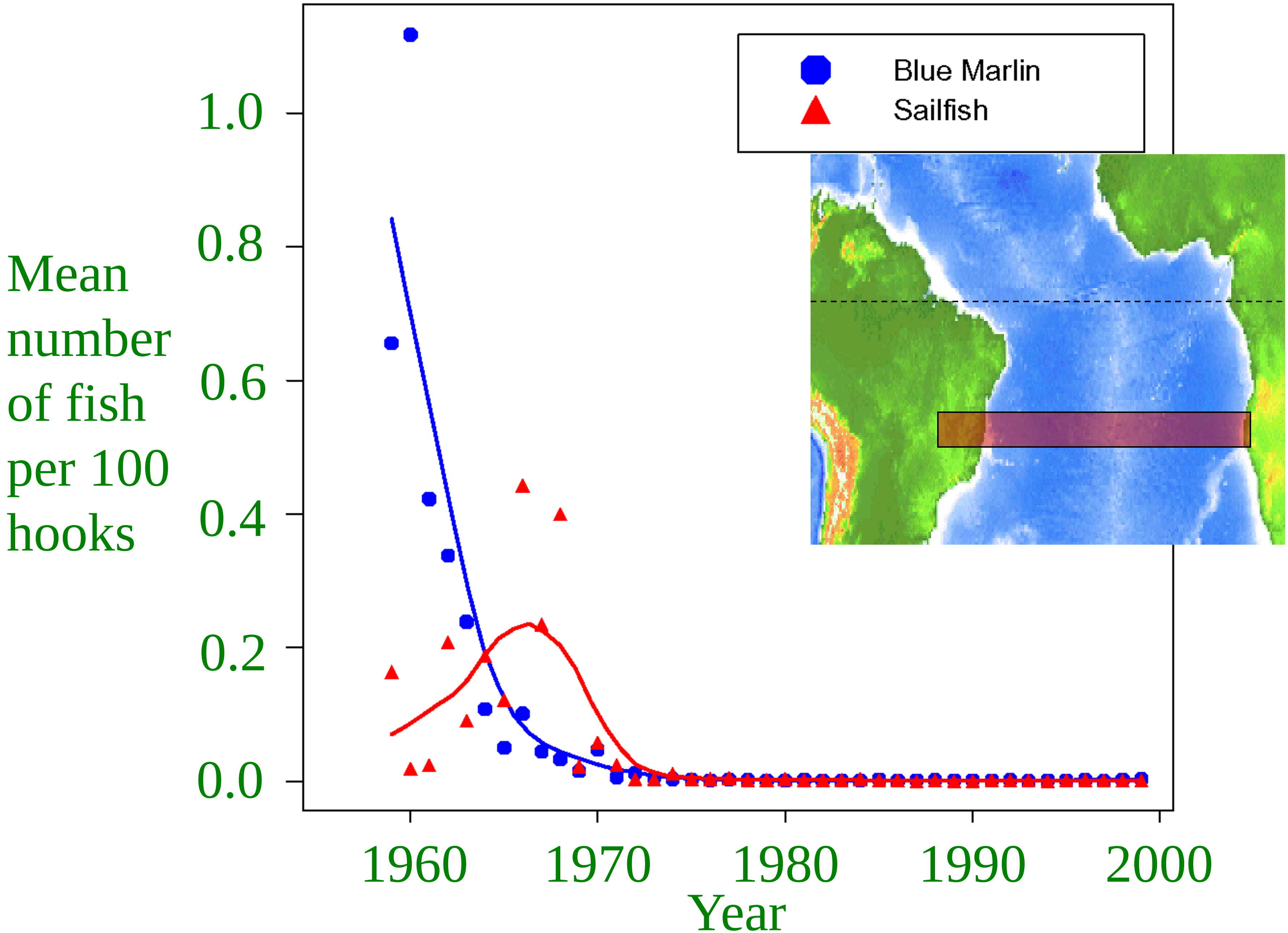


Blue marlin (*Makaira nigricans)*

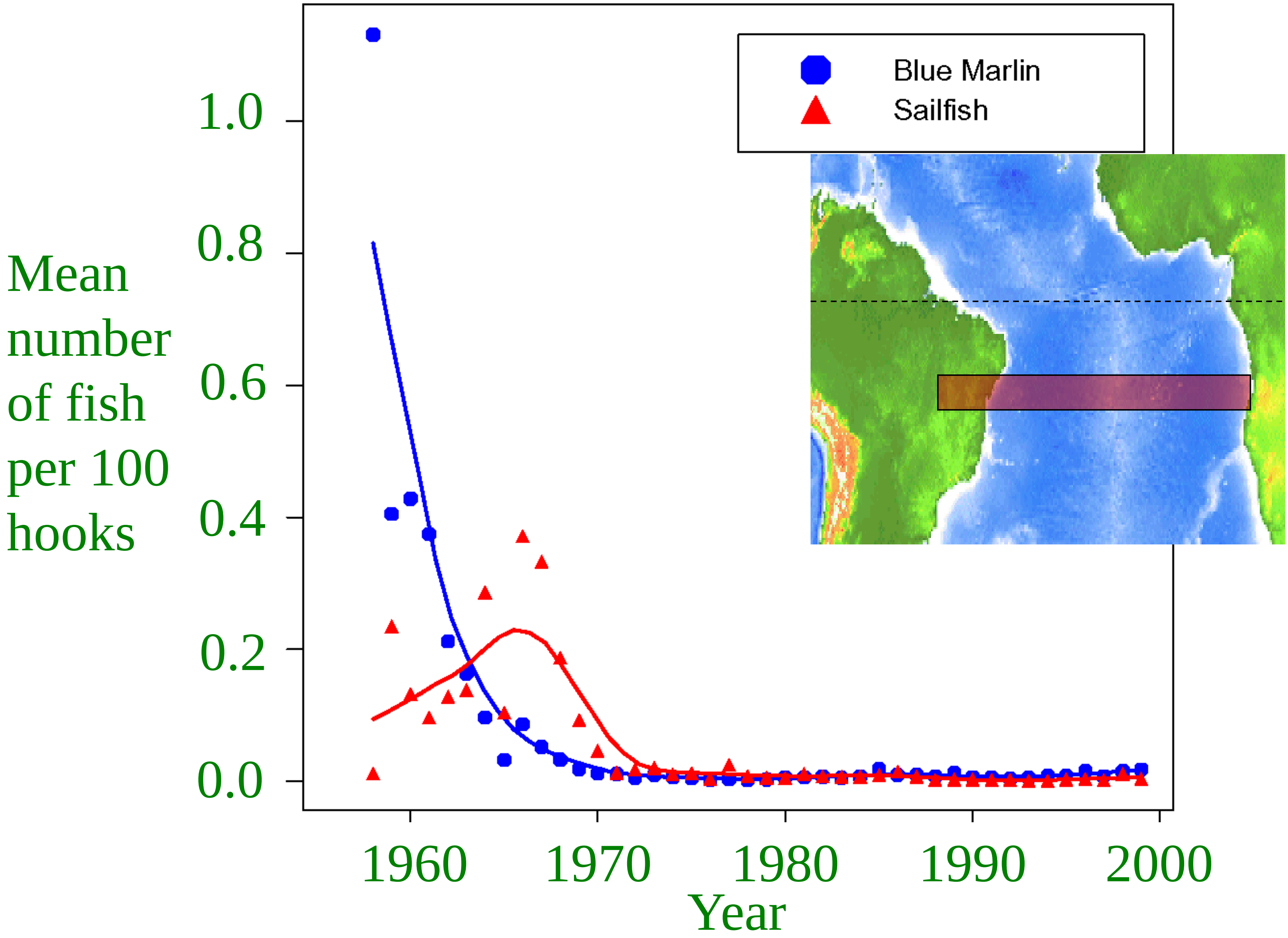
Sailfish (*Istiophorus albicans)*

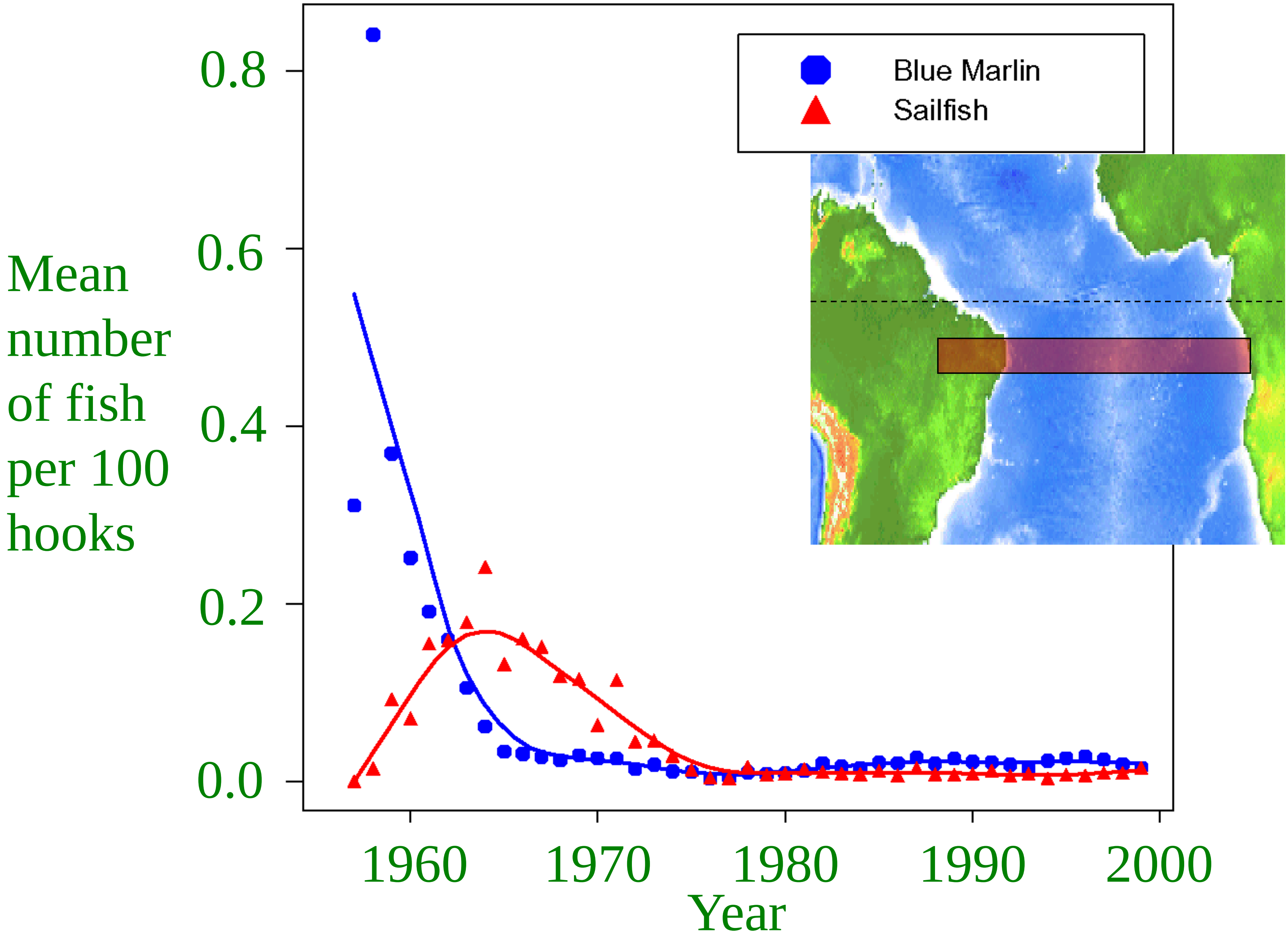


Blue Marlin
Sailfish
Mean number of fish per 100 hooks
1.5
1.0
0.5
0.0
1960
1970
1980
1990
2000
Year

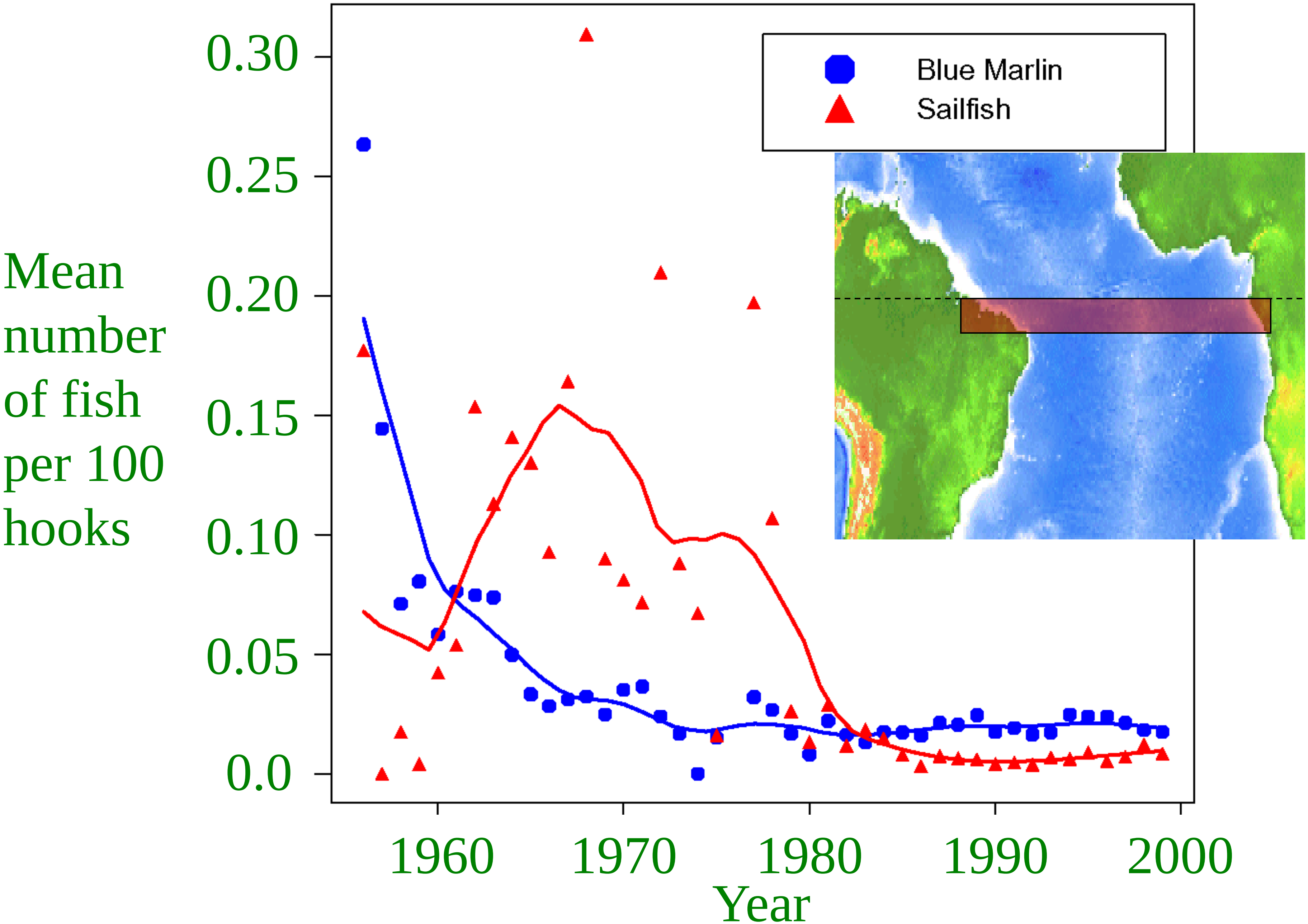


Mean number of fish per 100 hooks
1.0
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
Year
Blue Marlin
Sailfish

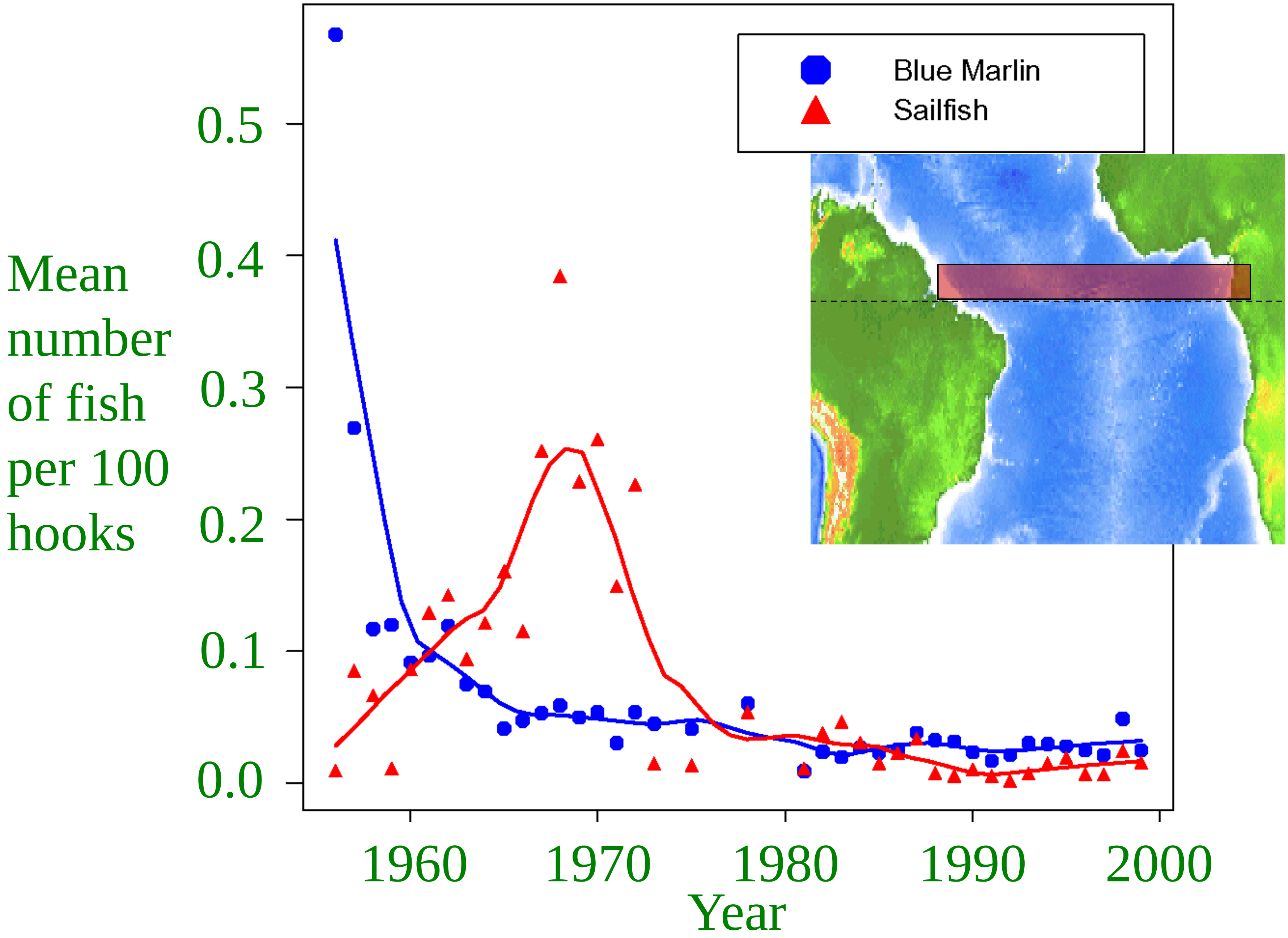

Mean number of fish per 100 hooks
1.0
0.8
0.6
0.4
0.2
0.0
Blue Marlin
Sailfish
1960
1970
1980
1990
2000
Year



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



Mean number of fish per 100 hooks
0.30
0.25
0.20
0.15
0.10
0.05
0.0
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

Can we explain such widespread patterns (seen across the world's largest ecosystem) using a single equation?

One hypothesis:

Fishing mortality ↑

↓

Predation on sailfish juveniles ↓

↓

Survivorship of sailfish juveniles ↑

↓

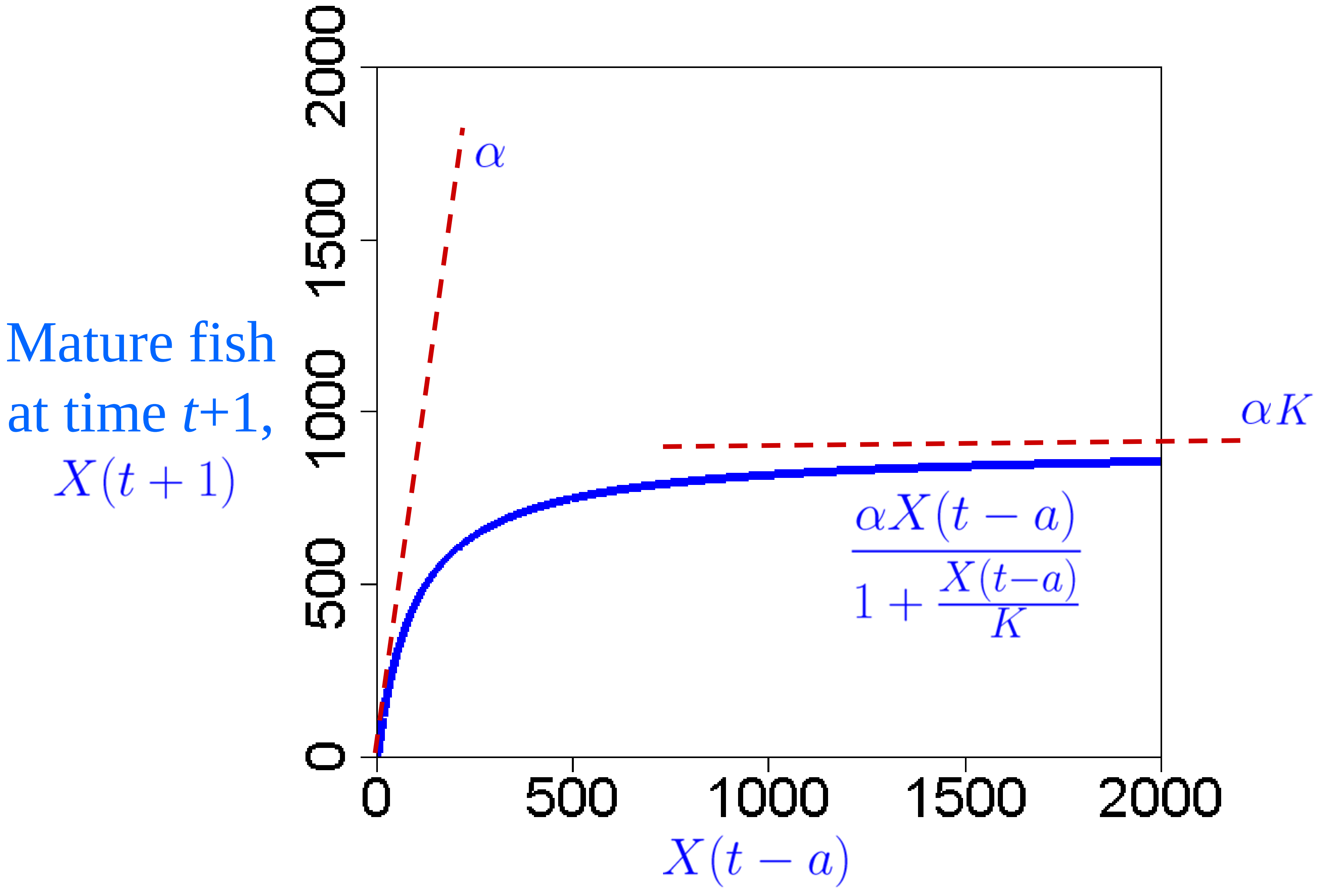
Sailfish population ↑

$X(t)$ – number of mature fish at the start of year t

If fish spawn once then die (e.g. salmon)

$$X(t+1) = \frac{\alpha X(t-a)}{1 + \frac{X(t-a)}{K}}$$

a – age at maturity (fish spawn the year after they reach age a)



Mature fish
at time t+1,
$X(t+1)$
2000
1500
1000
500
0
α
αK
$\frac{\alpha X(t-a)}{1+\frac{X(t-a)}{K}}$
0
500
1000
1500
2000
$X(t-a)$

Now assume proportion p of adults survive from

year to year and continue to spawn:

$$X(t+1) = pX(t) + \frac{\alpha X(t-a)}{1+\frac{X(t-a)}{K}}$$

Now introduce fishing:

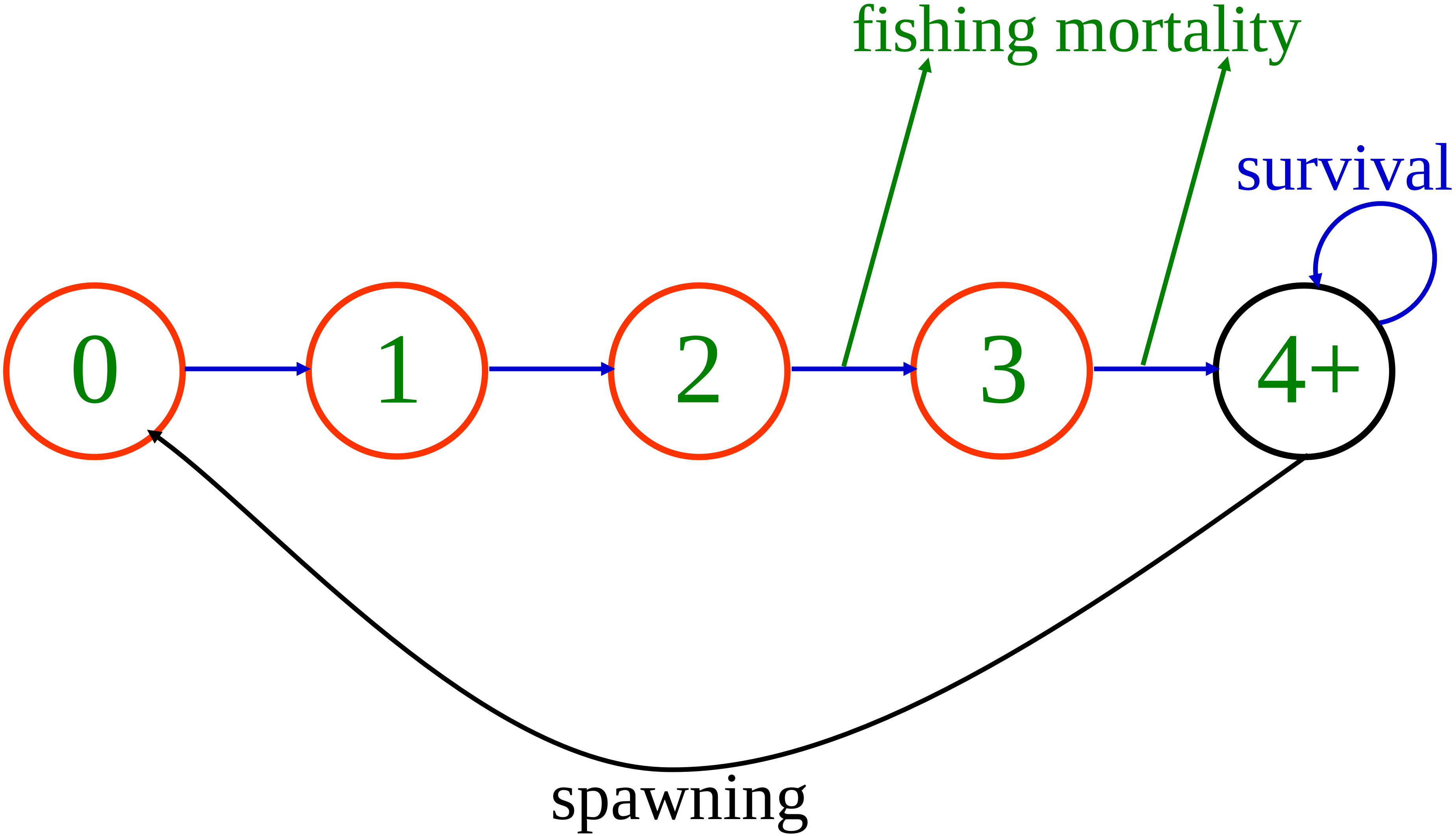
$$X(t+1) = e^{-qF} pX(t) + e^{-cqF} \frac{\alpha X(t-a)}{1+\frac{X(t-a)}{K}}$$

proportions that survive fishing effort F

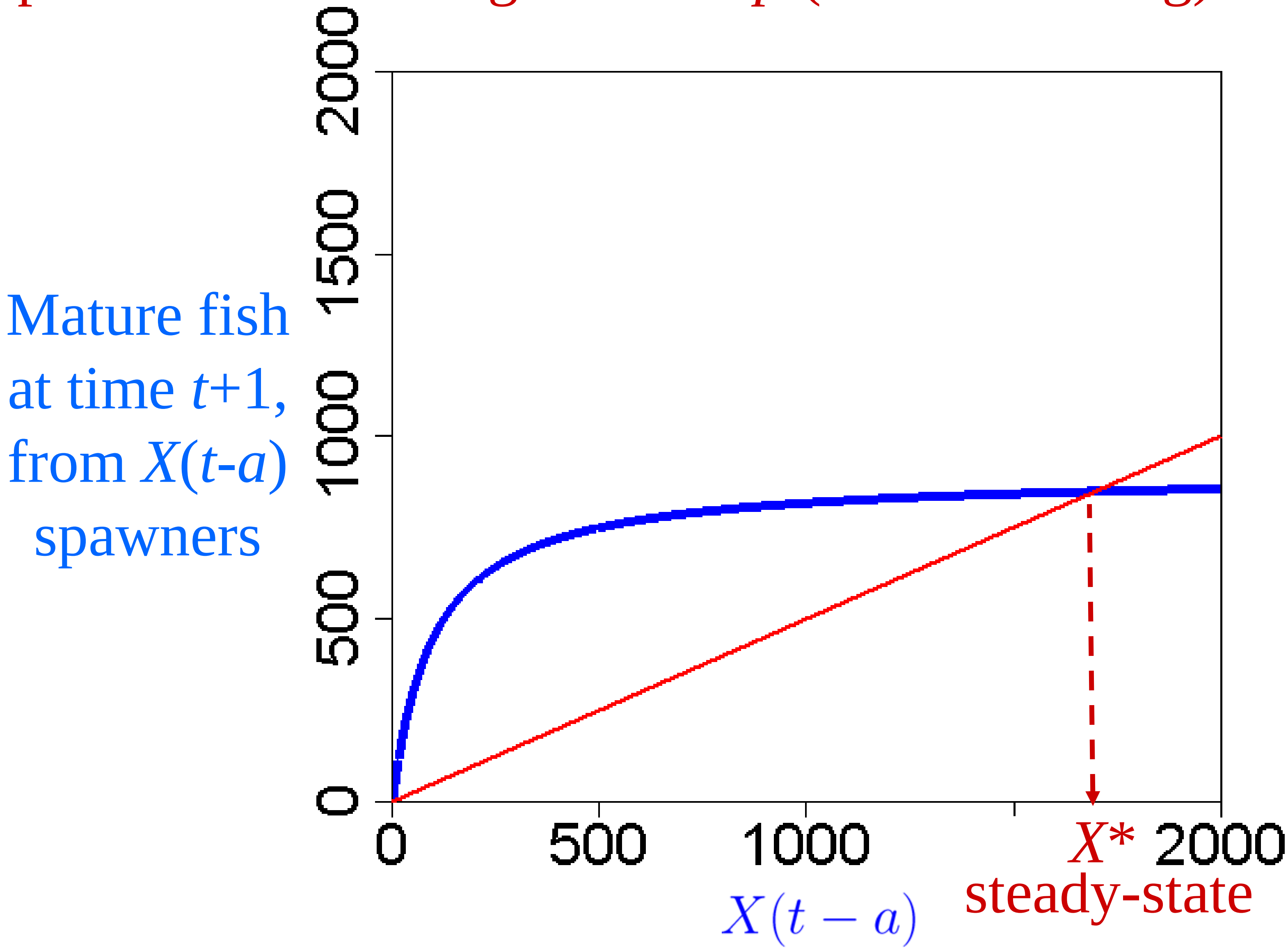
q – species-specific susceptibility to fishing

c – number of years fished before reaching maturity

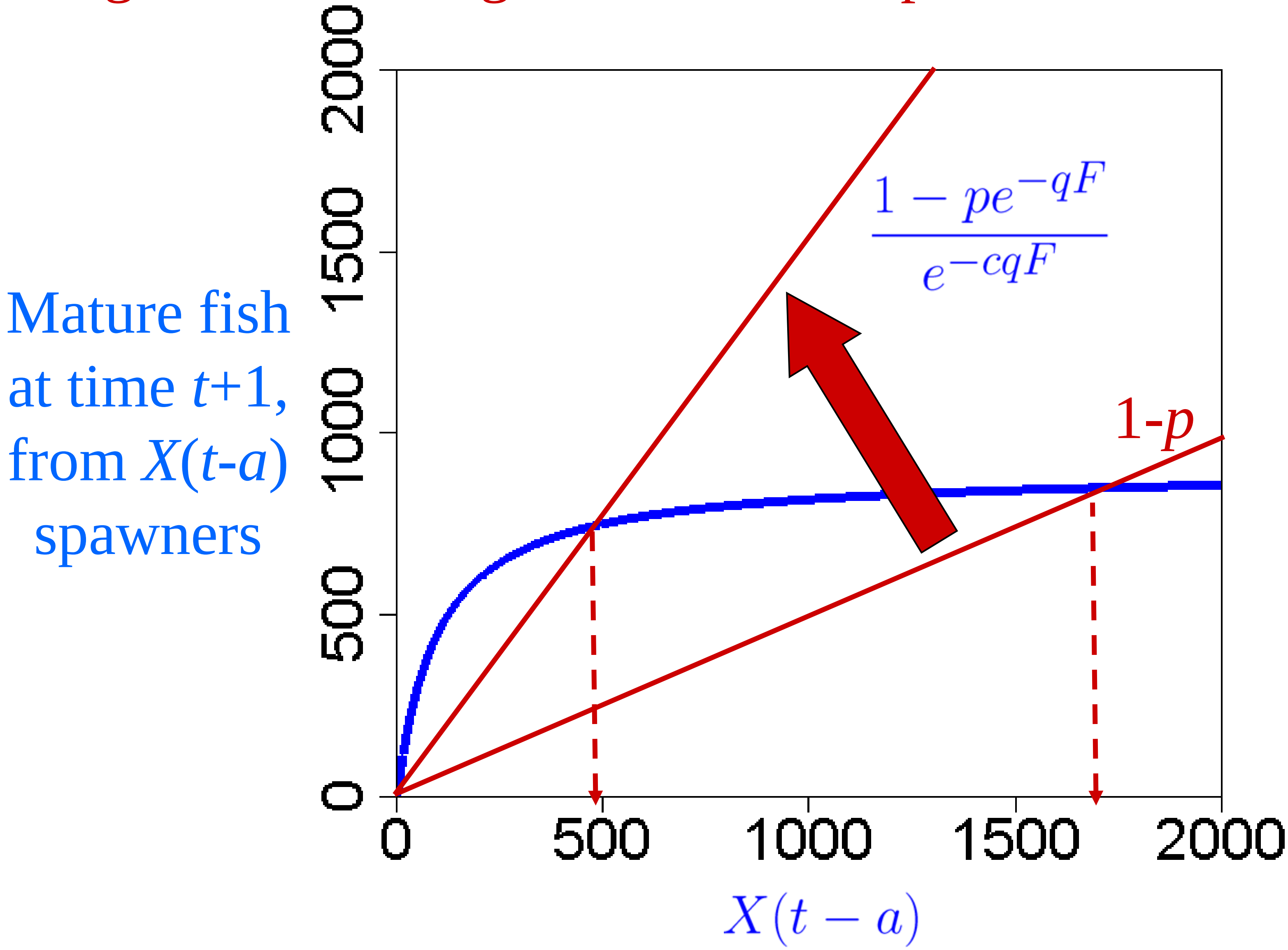
Life cycle (blue marlin):



Replacement line has gradient 1-*p* (with no fishing)

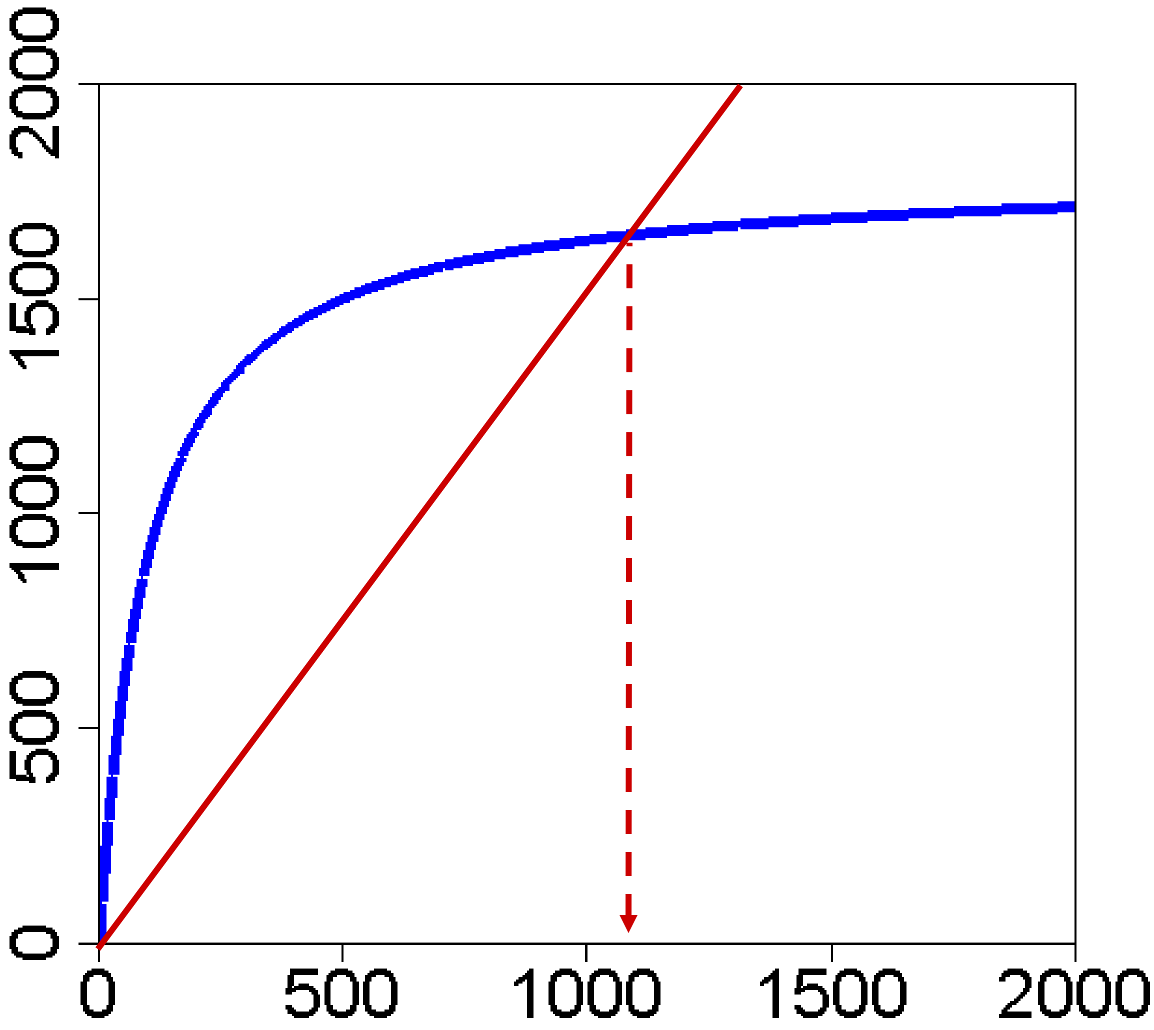


Fishing increases the gradient of the replacement line…



…and increased survivorship gives higher α, raising SR curve.

Mature fish
at time *t*+1,
$X(t+1)$



$X(t-a)$

Now assume proportion p of adults survive from

year to year and continue to spawn:

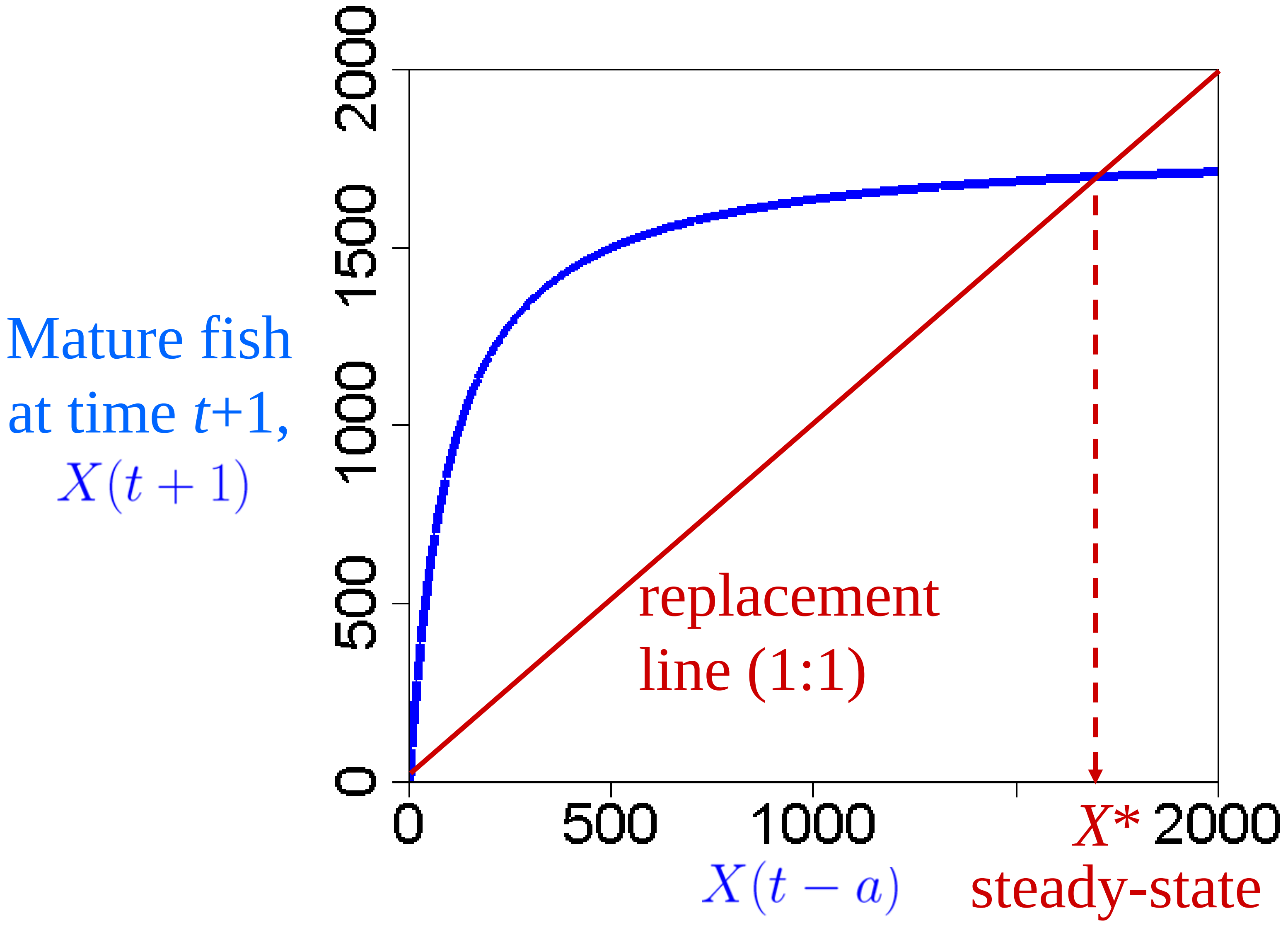
$$X(t+1) = pX(t) + \frac{\alpha X(t-a)}{1 + \frac{X(t-a)}{K}}$$

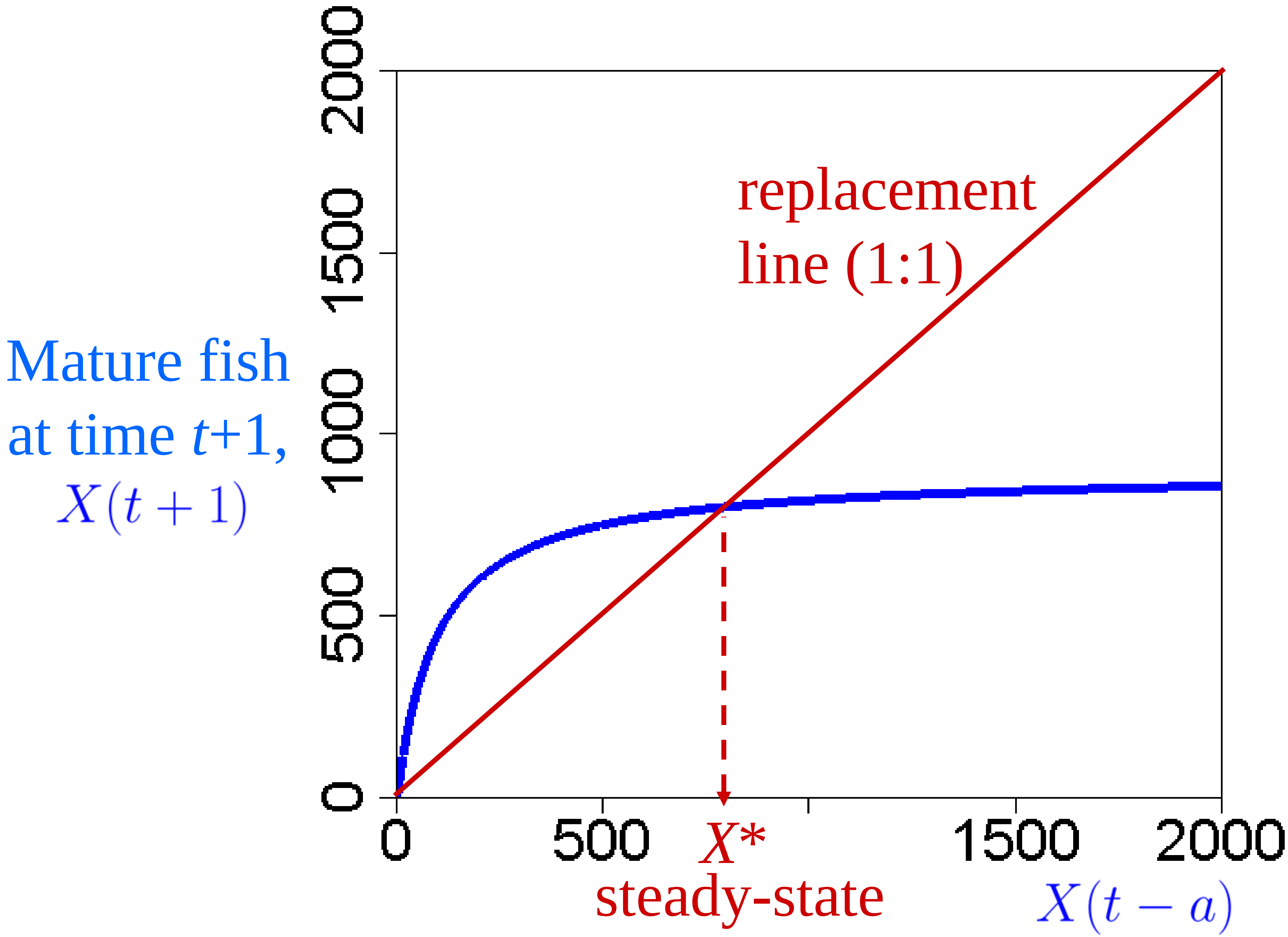
Total future individuals from $X(t-a)$ is

$$\begin{aligned} &\text{average number of times each fish will spawn} \times \frac{\alpha X(t-a)}{1 + \frac{X(t-a)}{K}} \\ &= \sum_{j=0}^{\infty} p^j \times \frac{\alpha X(t-a)}{1 + \frac{X(t-a)}{K}} \\ &= \frac{1}{1-p} \times \frac{\alpha X(t-a)}{1 + \frac{X(t-a)}{K}} \end{aligned}$$

Now assume proportion p of adults survive from year to year and continue to spawn:

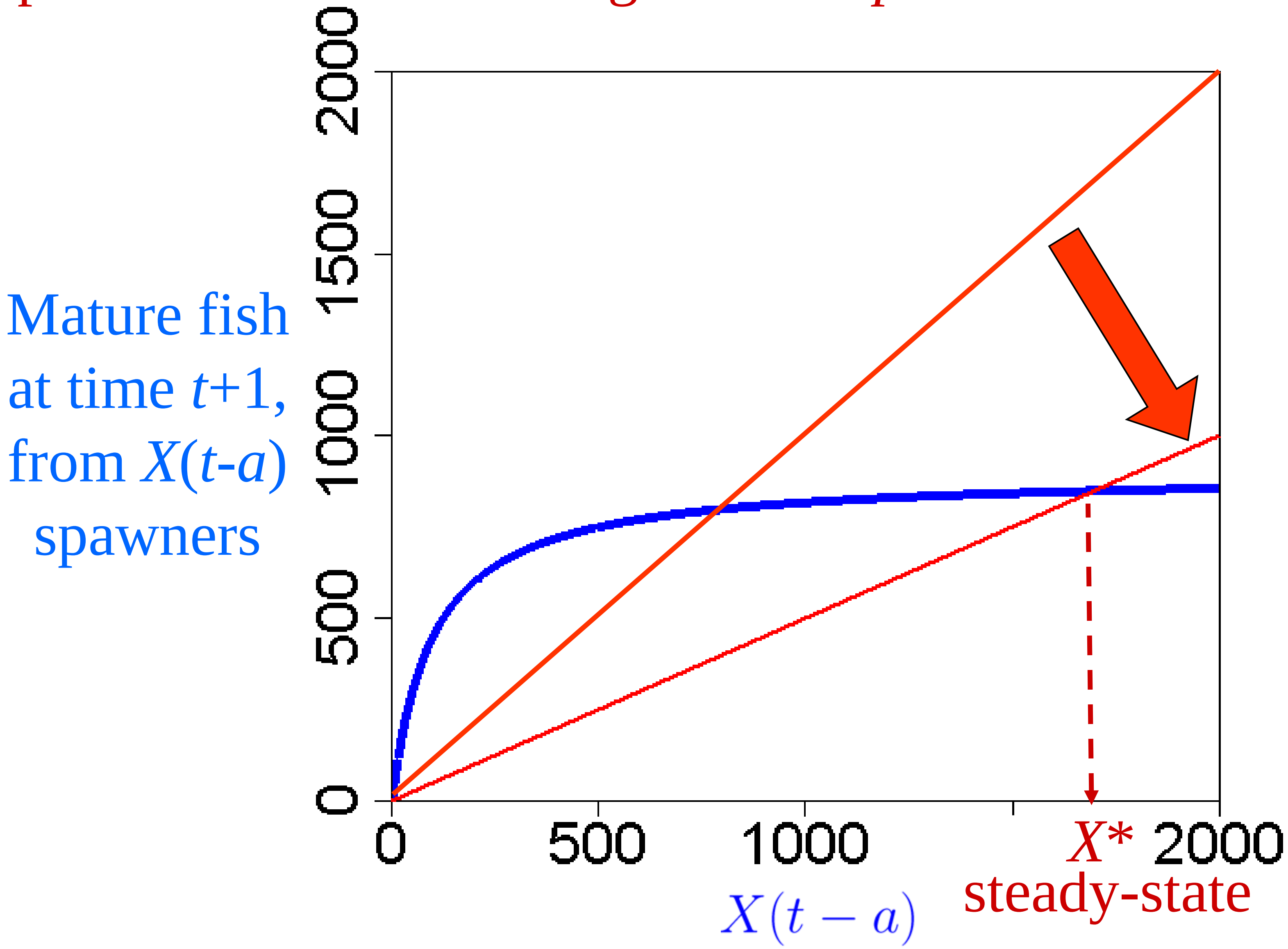
$$X(t+1) = pX(t) + \frac{\alpha X(t-a)}{1 + \frac{X(t-a)}{K}}$$


Mature fish
at time t+1,
$X(t+1)$
0
500
1000
1500
2000
replacement
line (1:1)
0
500
1000
X^* 2000
$X(t-a)$
steady-state



Mature fish
at time t+1,
$X(t+1)$
2000
1500
1000
500
0
replacement
line (1:1)
0
500
1500
2000
X^*
steady-state
$X(t-a)$

Replacement line now has gradient 1-*p* = 0.5



proportions that survive fishing effort F

Now introduce fishing:

$$X(t+1) = e^{-qF} pX(t) + e^{-cqF} \frac{\alpha X(t-a)}{1 + \frac{X(t-a)}{K}}$$

proportions that survive fishing effort F

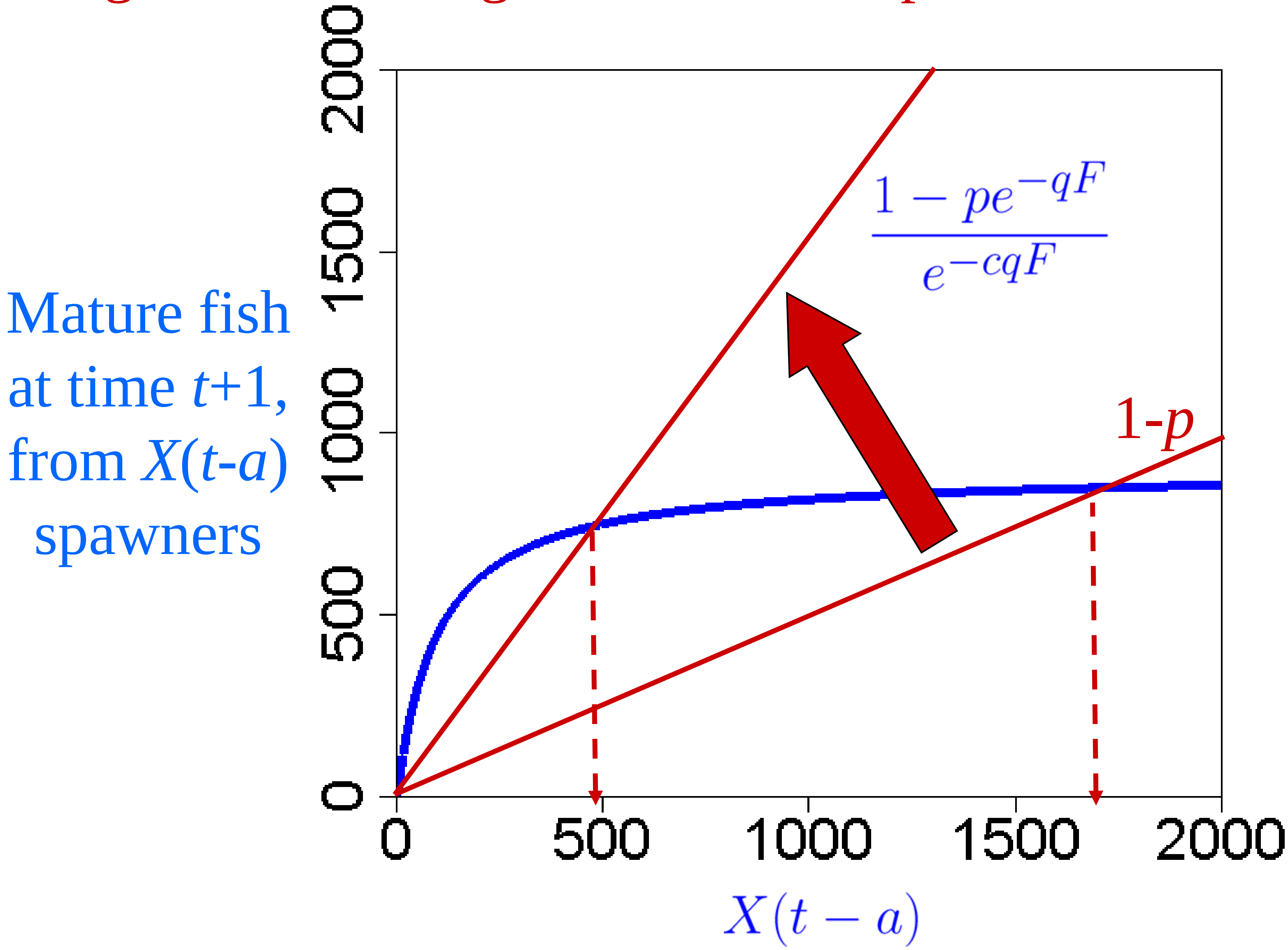
Now introduce fishing:

$$X(t+1) = e^{-qF} p X(t) + e^{-cqF} \frac{\alpha X(t-a)}{1 + \frac{X(t-a)}{K}}$$

q – species-specific susceptibility to fishing

c – number of years fished before reaching maturity

Fishing increases the gradient of the replacement line



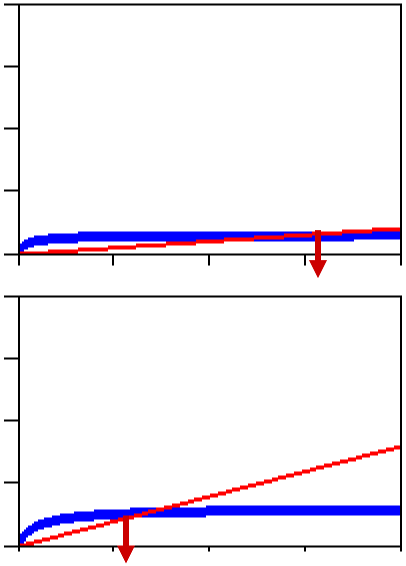
Fishing effort, F = 0

Max. recruits

per spawner, α = 3

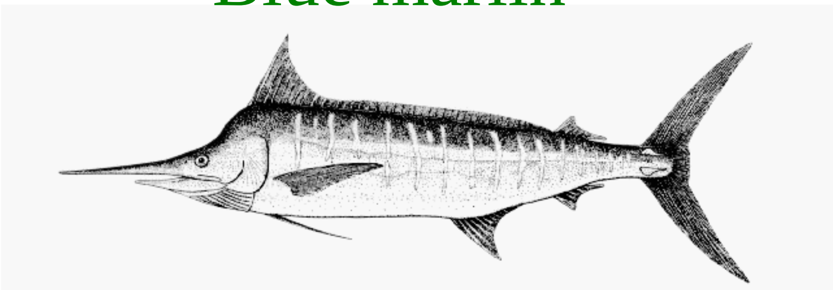
Mature fish

at time *t*+1



$X(t-a)$

Blue marlin



Sailfish

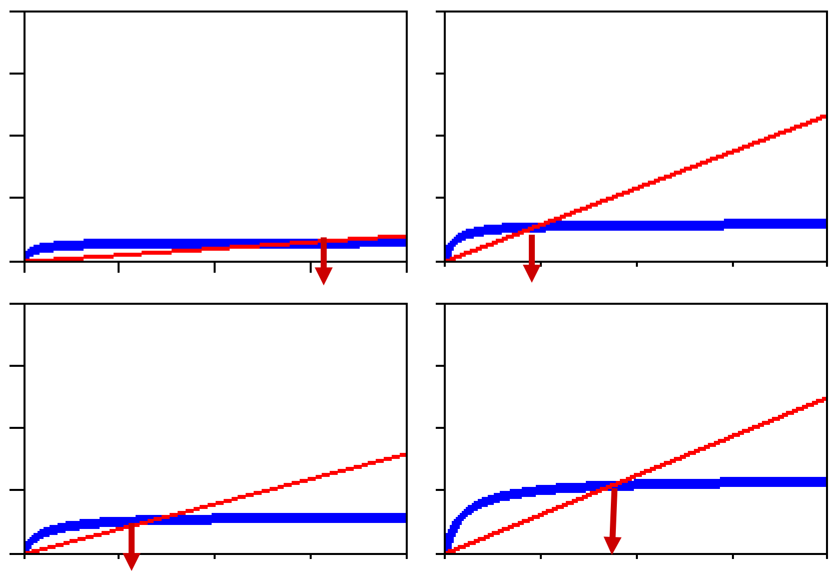
Replacement curve steeper

as shorter lived species

Fishing effort, F = 0 0.2

Max. recruits per spawner, α = 3 6

Mature fish at time t+1



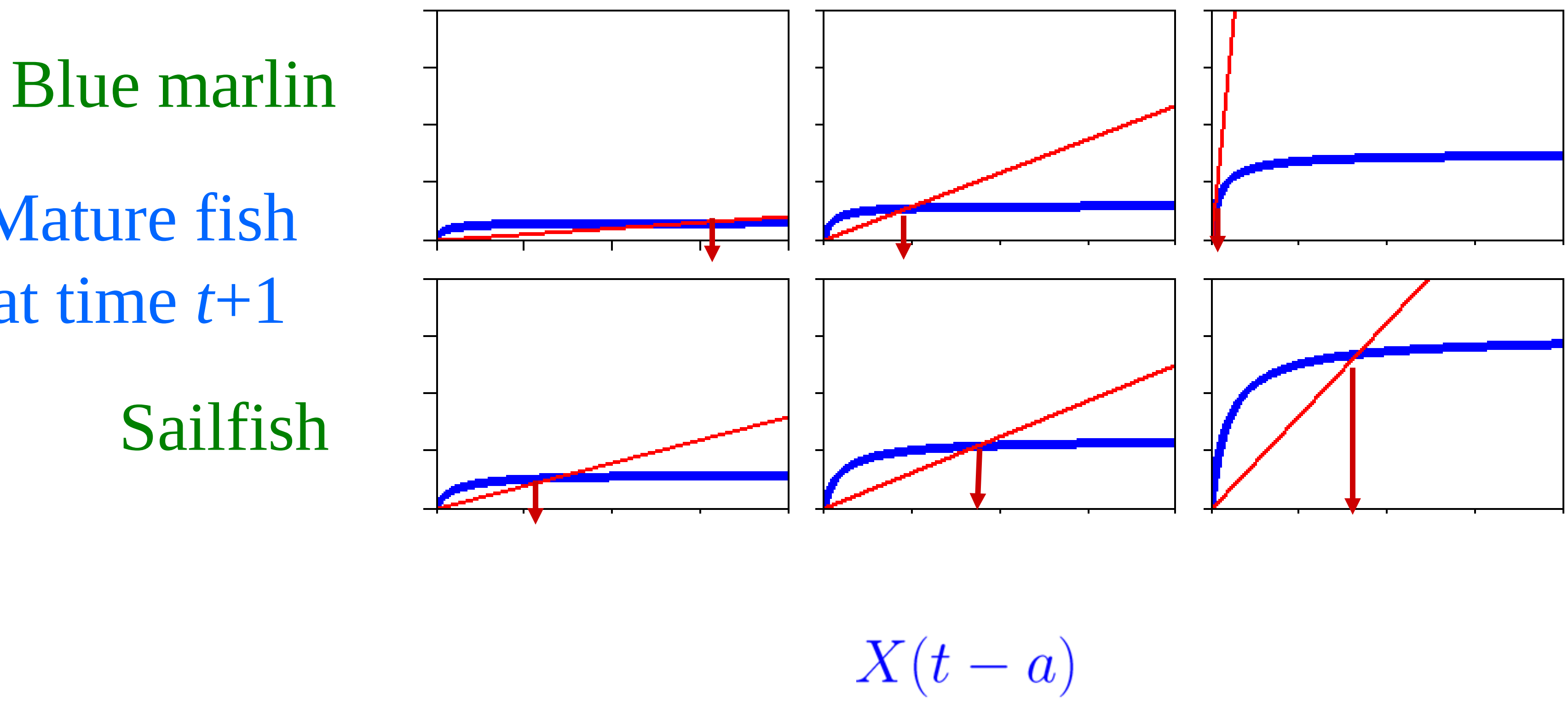
Blue marlin

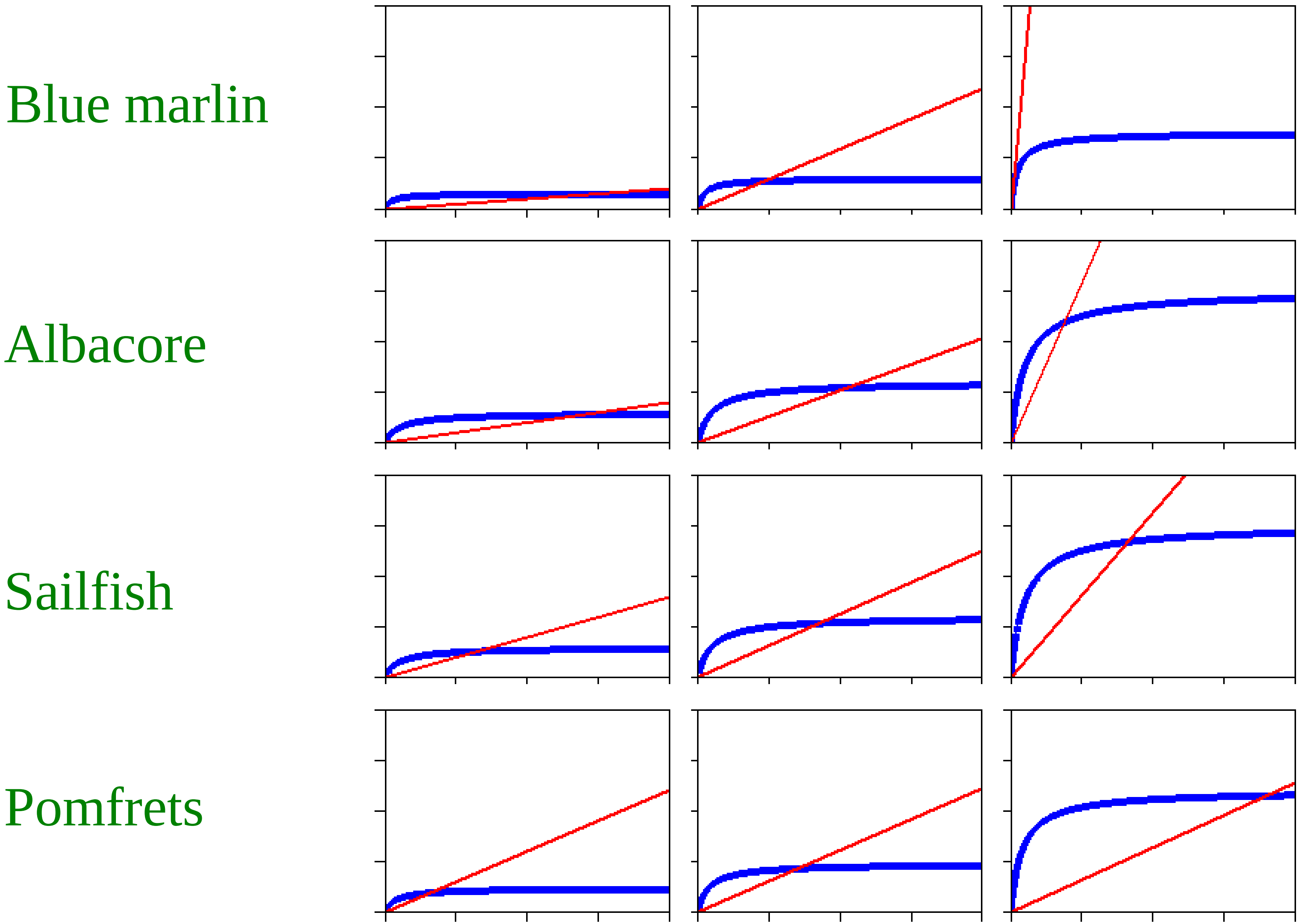
Sailfish

$$X(t-a)$$

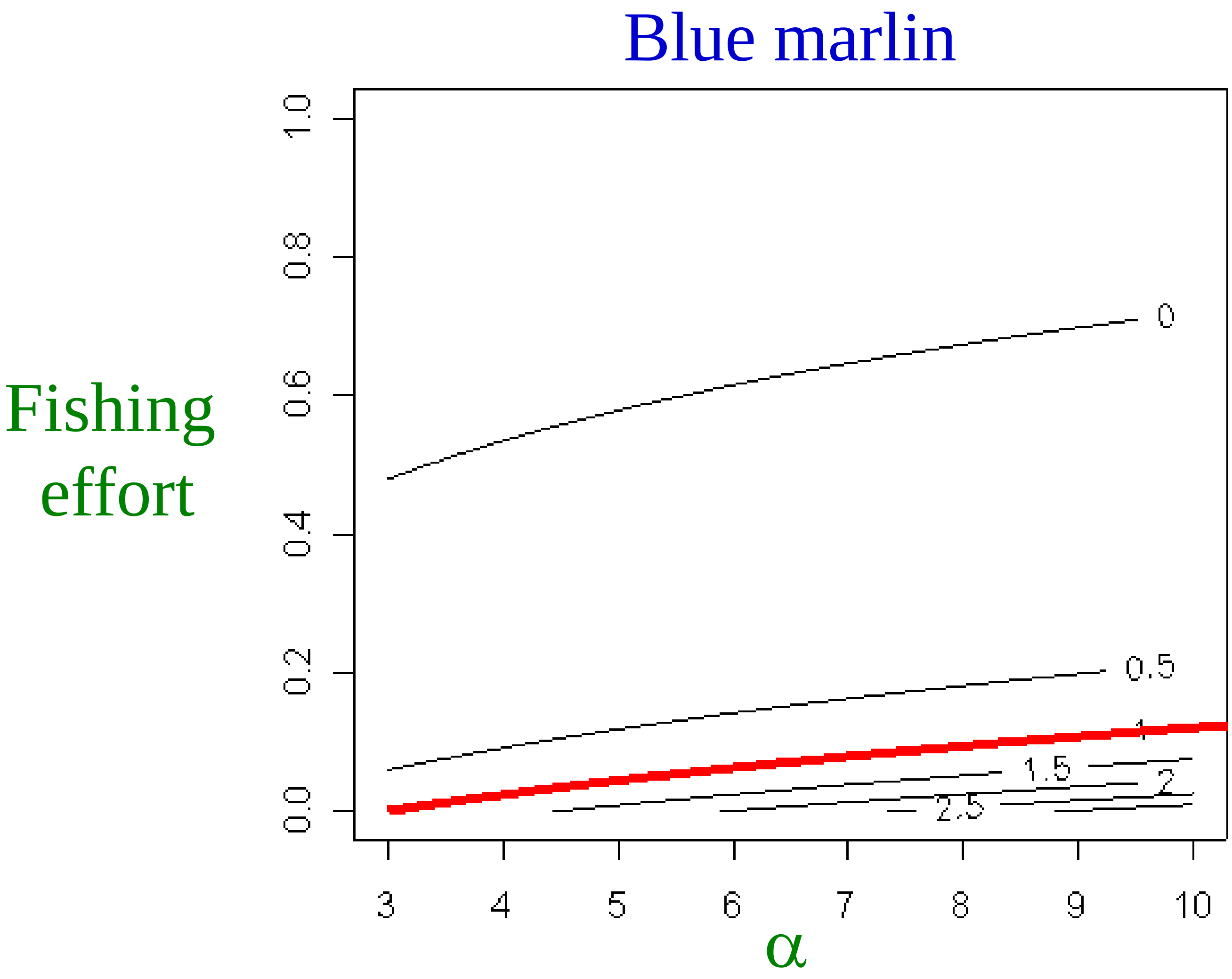
Fishing effort, F = 0 0.2 0.8

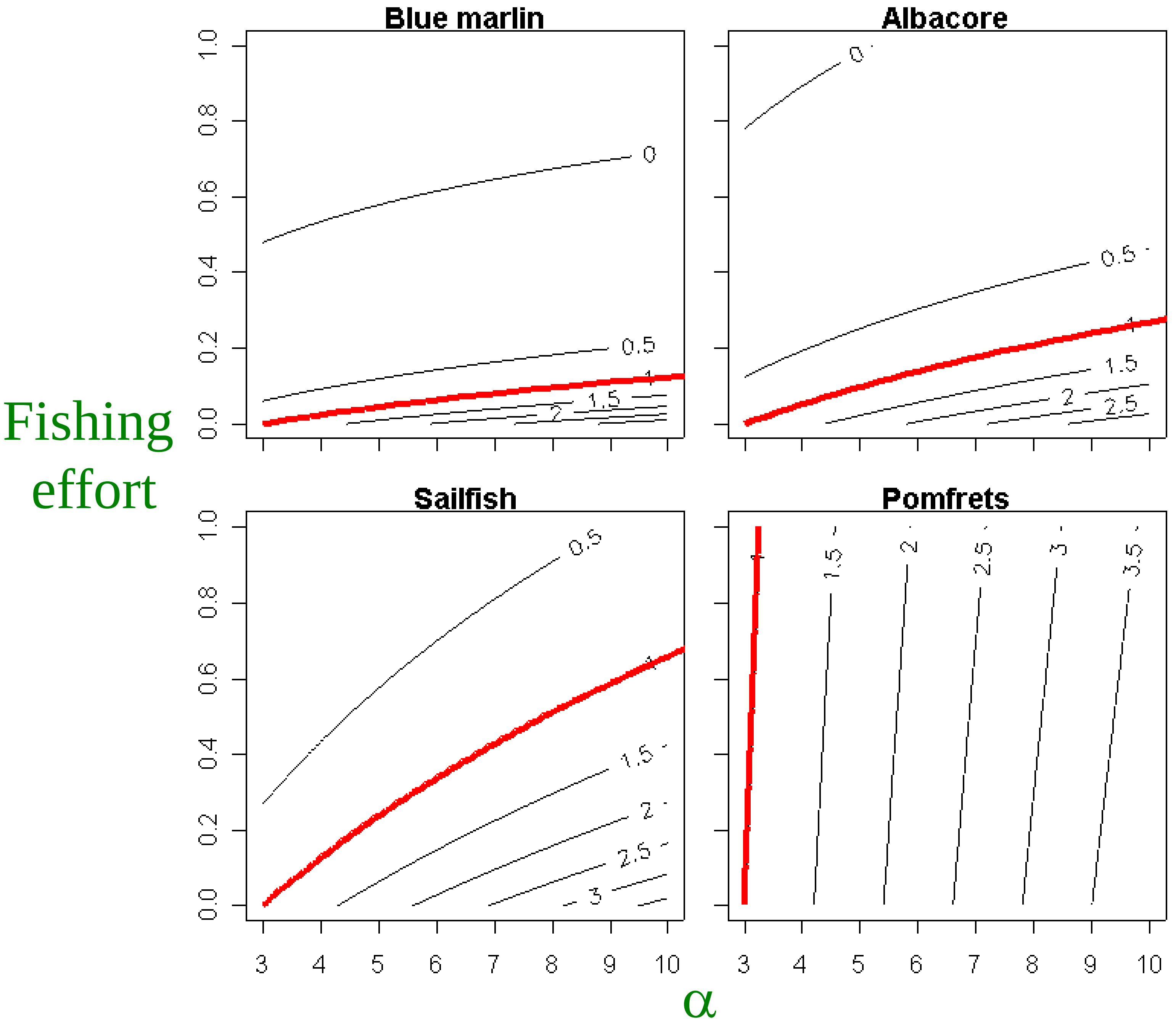
Max. recruits per spawner, α = 3 6 15




Blue marlin
Albacore
Sailfish
Pomfrets

Plot contours of the ratio *R* of the steady state with fishing to the unfished steady state:





Blue marlin
Albacore
Sailfish
Pomfrets
Fishing effort
α
0.0
0.2
0.4
0.6
0.8
1.0
3
4
5
6
7
8
9
10
0
0.5
1
1.5
2
2.5
3
3.5

State-Space models (SSMs)

- Time series models
- Infer unobservable (true) states from data observed with error
- Separate process noise from estimation error
- Extremely flexible framework
  - Accommodates many model structures

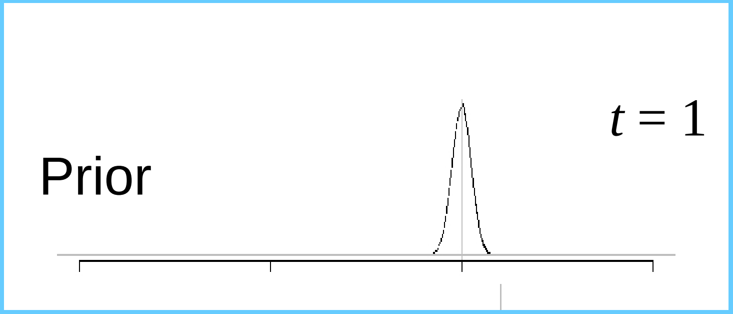
SSMs in more detail

- Measurement eqn.
  - Relates 'true' locations to observed via error function

$$y_t = h_t(\alpha_t, \varepsilon_t)$$

- Transition eqn.
  - Describes movement process

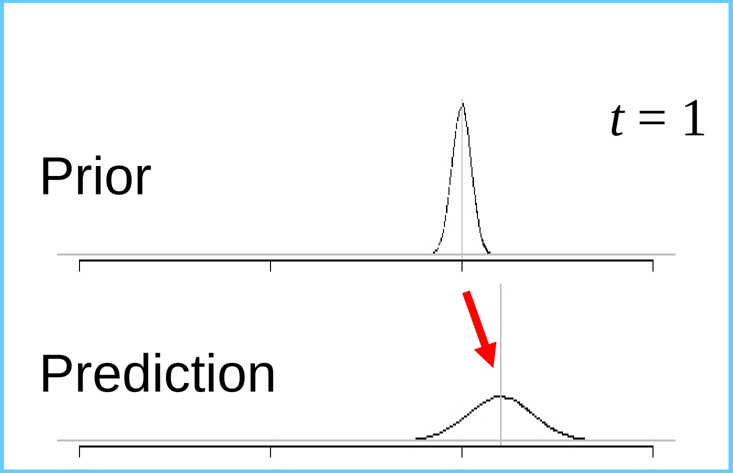
$$\alpha_t = f_t(\alpha_{t-1}, \eta_t; \gamma)$$



$$p(\alpha_1 \mid \alpha_0)$$

1st location = release point

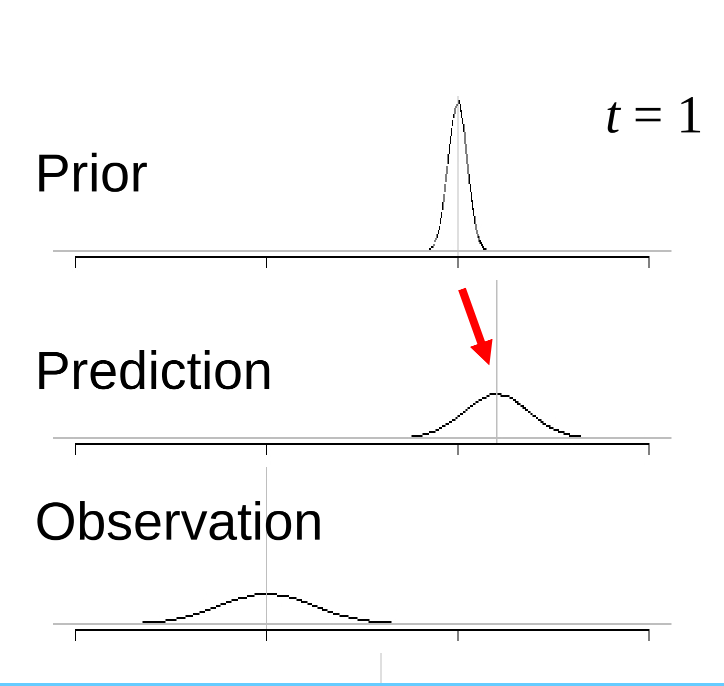
eg release location estimated with GPS



Apply dynamics (transition eqn)

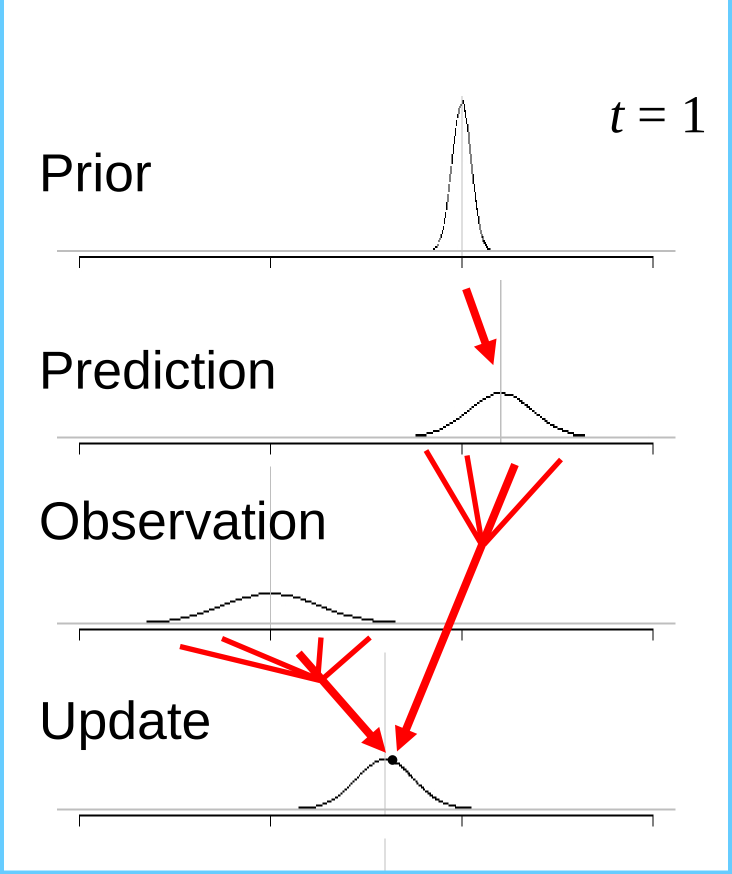
$$p(\alpha_t \mid Y_{t-1};\gamma) =$$

$$\int p_\alpha(\alpha_t \mid \alpha_{t-1};\gamma)\, p(\alpha_{t-1} \mid Y_{t-1};\gamma)\, d\alpha_{t-1}$$



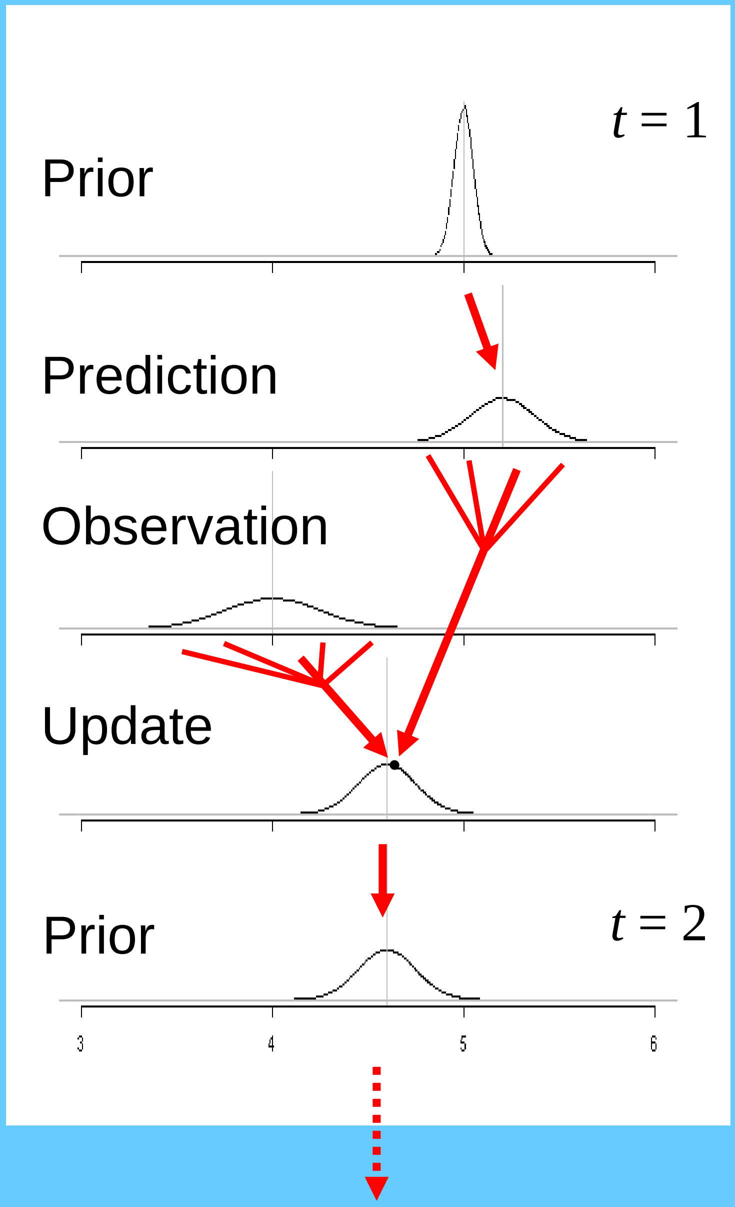
Observe a location with error; σ

$$p_y(y_t \mid \alpha_t) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}[(y_t - \mu)/\sigma]^2}$$



Integrate over predicted & observed densities:
Bayes Rule

$$p(\alpha_t \mid Y_t;\gamma) = \frac{p_y(y_t \mid \alpha_t)\, p(\alpha_t \mid Y_{t-1};\gamma)}{\int p_y(y_t \mid \alpha_t)\, p(\alpha_t \mid Y_{t-1};\gamma)\, d\alpha_t}$$



Updated prediction becomes prior for next time step

$$p(\alpha_{t-1} \mid Y_{t\text{-}1}; \gamma)$$

Estimate biology (γ)

- Innovation for likelihood function
- Allows estimation of γ
- Denominator of Bayes Rule

$$L(\gamma;\mathrm{Y}_T) = p(\mathrm{Y}_T;\gamma) = \prod_{t=1}^{T} p(y_t \mid \mathrm{Y}_{t-1};\gamma) =$$

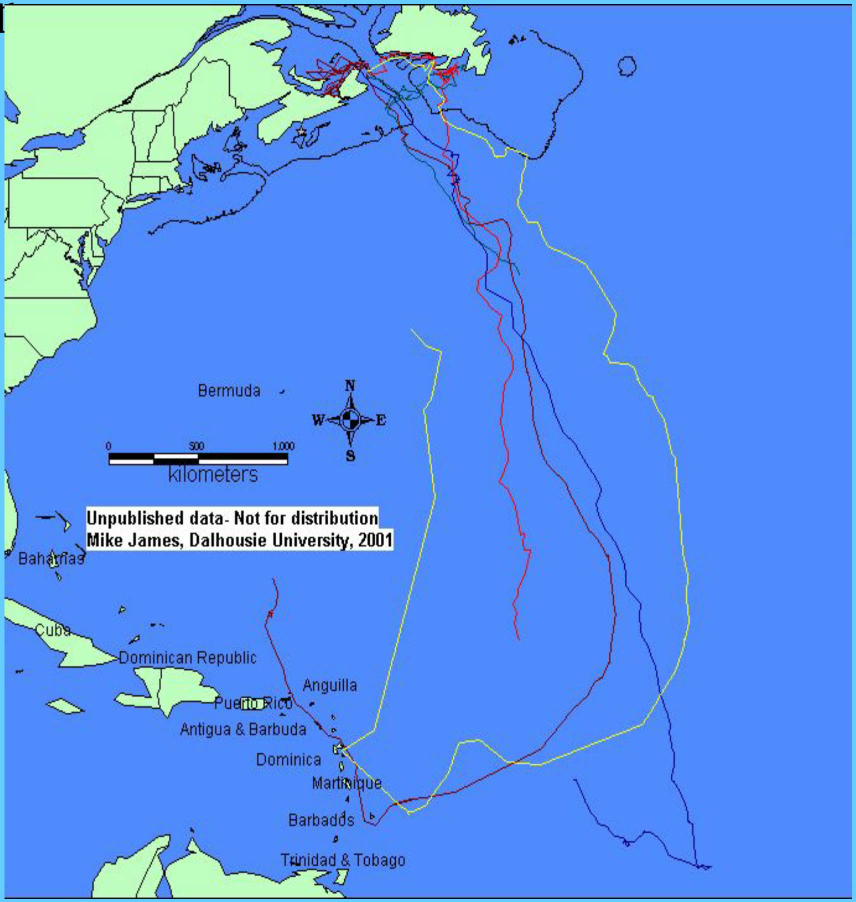
$$\prod_{t=1}^{T} \int p_{\mathrm{y}}(y_t \mid \alpha_t)\, p(\alpha_t \mid \mathrm{Y}_{t-1};\gamma)\, d\alpha_t$$

Meta-analysis is required

- Information combined over multiple pathways

- Biological parameters, γ, random variables

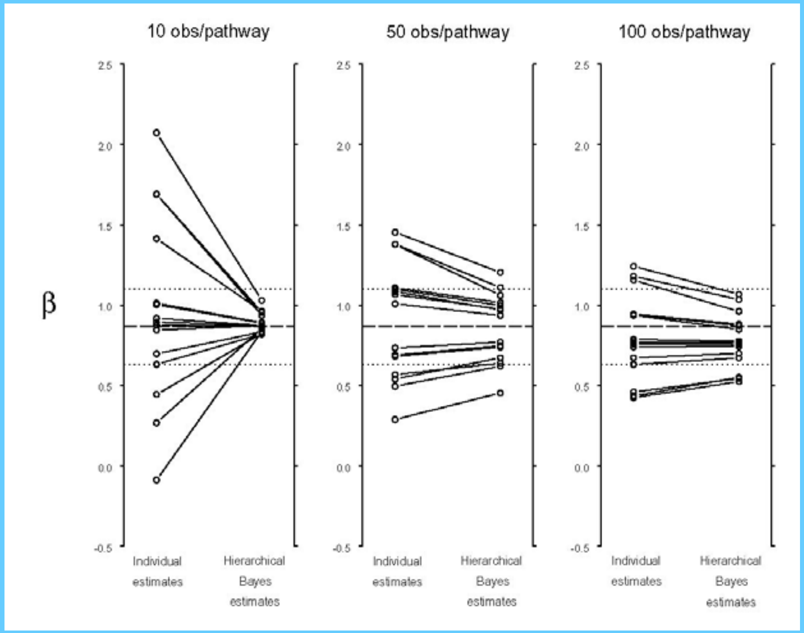
$$\gamma_i \sim N(\mu, \sigma^2)$$

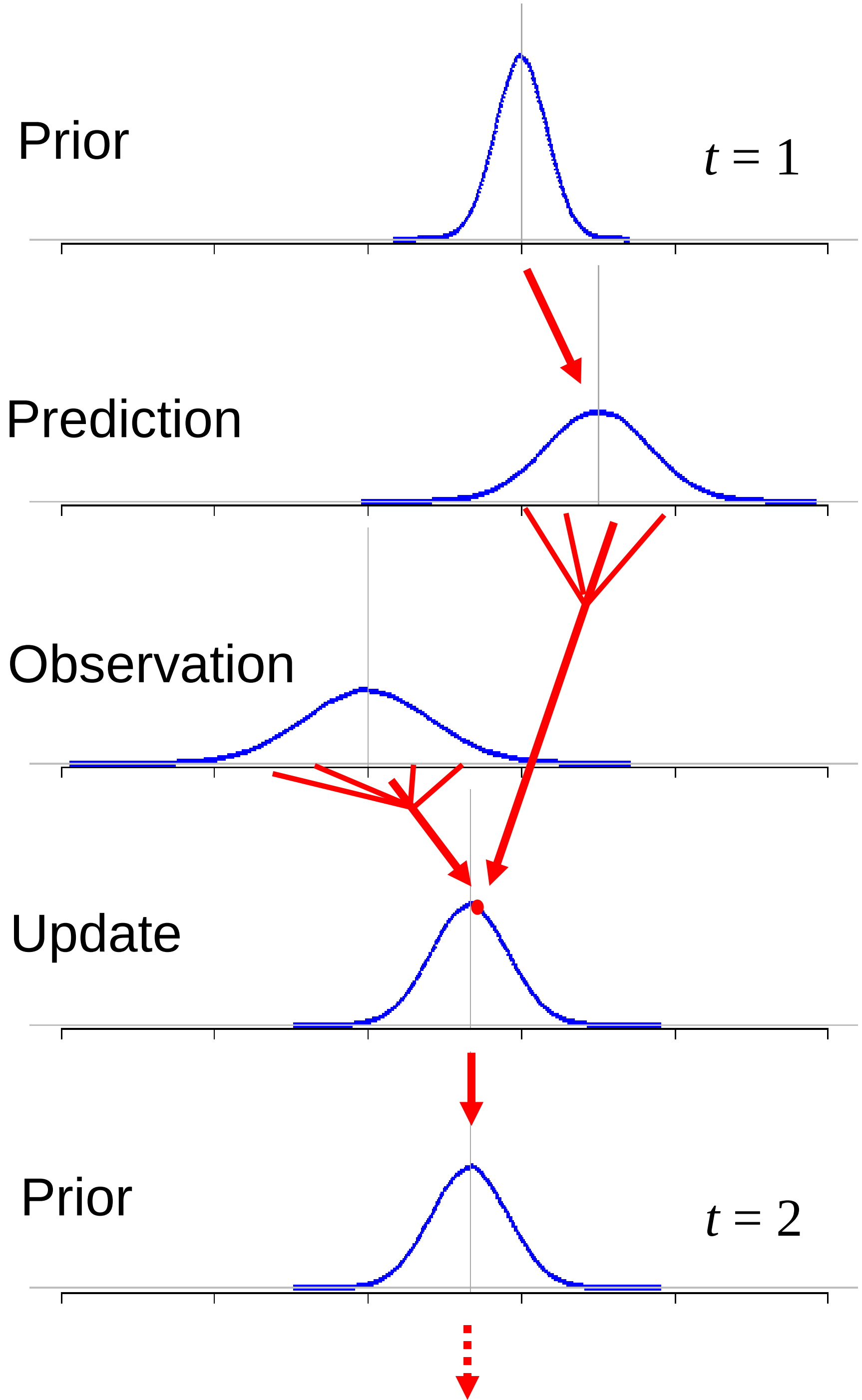


Meta-analysis is required

- Optimal parameter estimation for data-poor paths

- Individual variation inferred





1st location = release point

eg. release location estimated with GPS

Apply dynamics (transition eqn)

Observe a location with error

Integrate over predicted & observed densities (Bayes Rule)

Updated prediction becomes prior for next time step

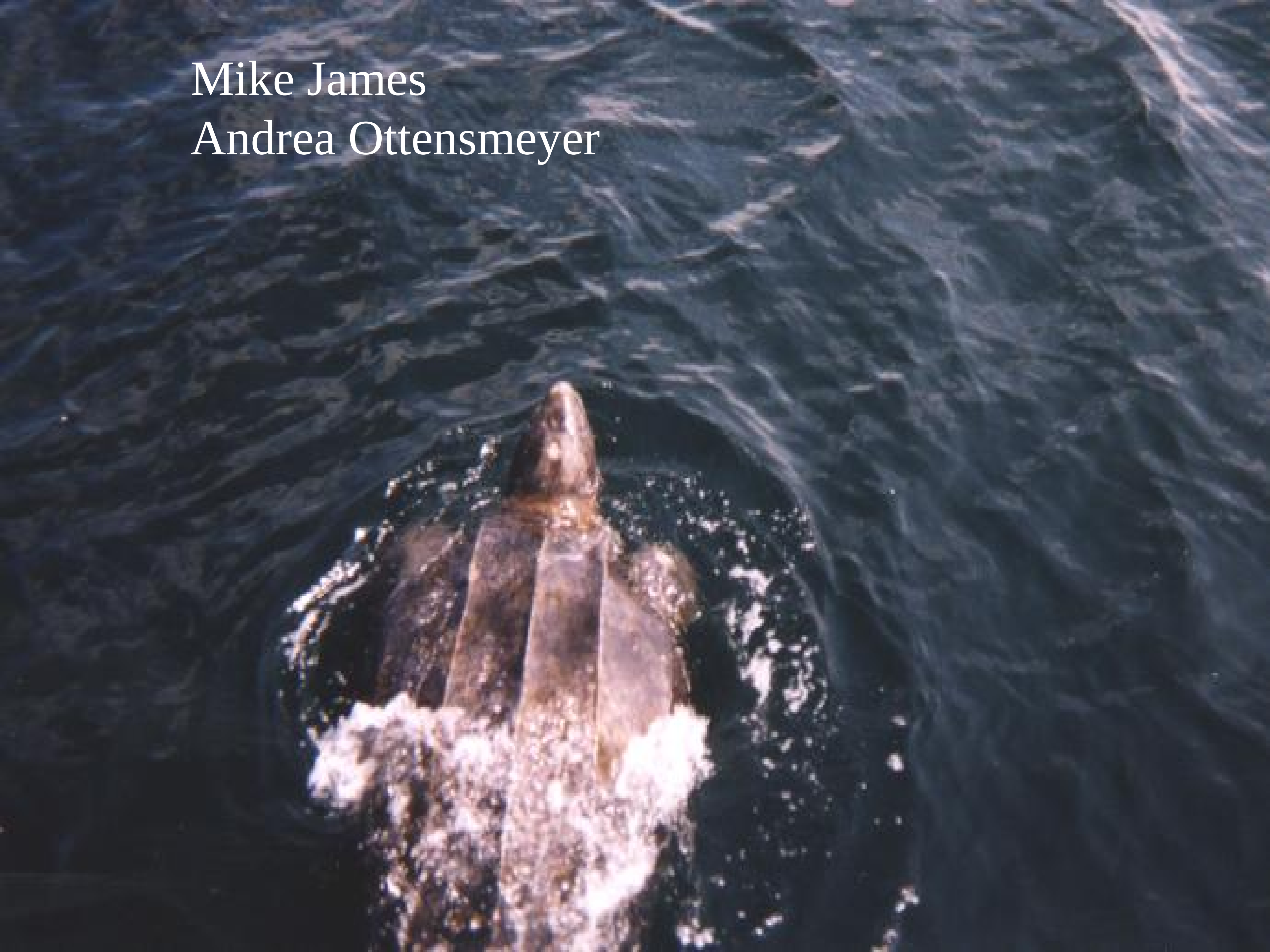
Software

WinBUGS: Bayesian Analysis Using Gibbs Sampling

Bayes Rule

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

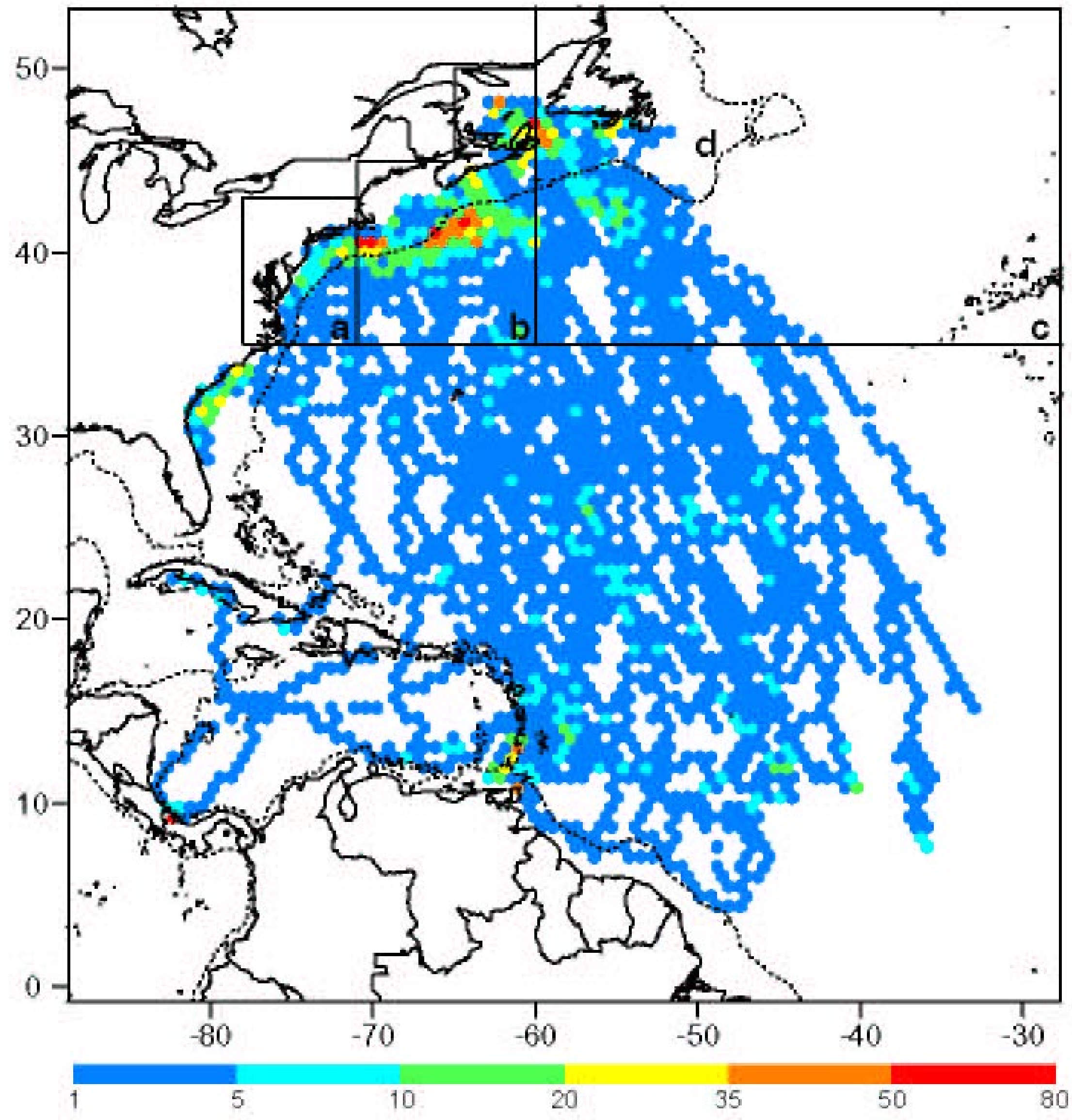
http://www.mrc-bsu.cam.ac.uk/bugs/


Mike James
Andrea Ottensmeyer

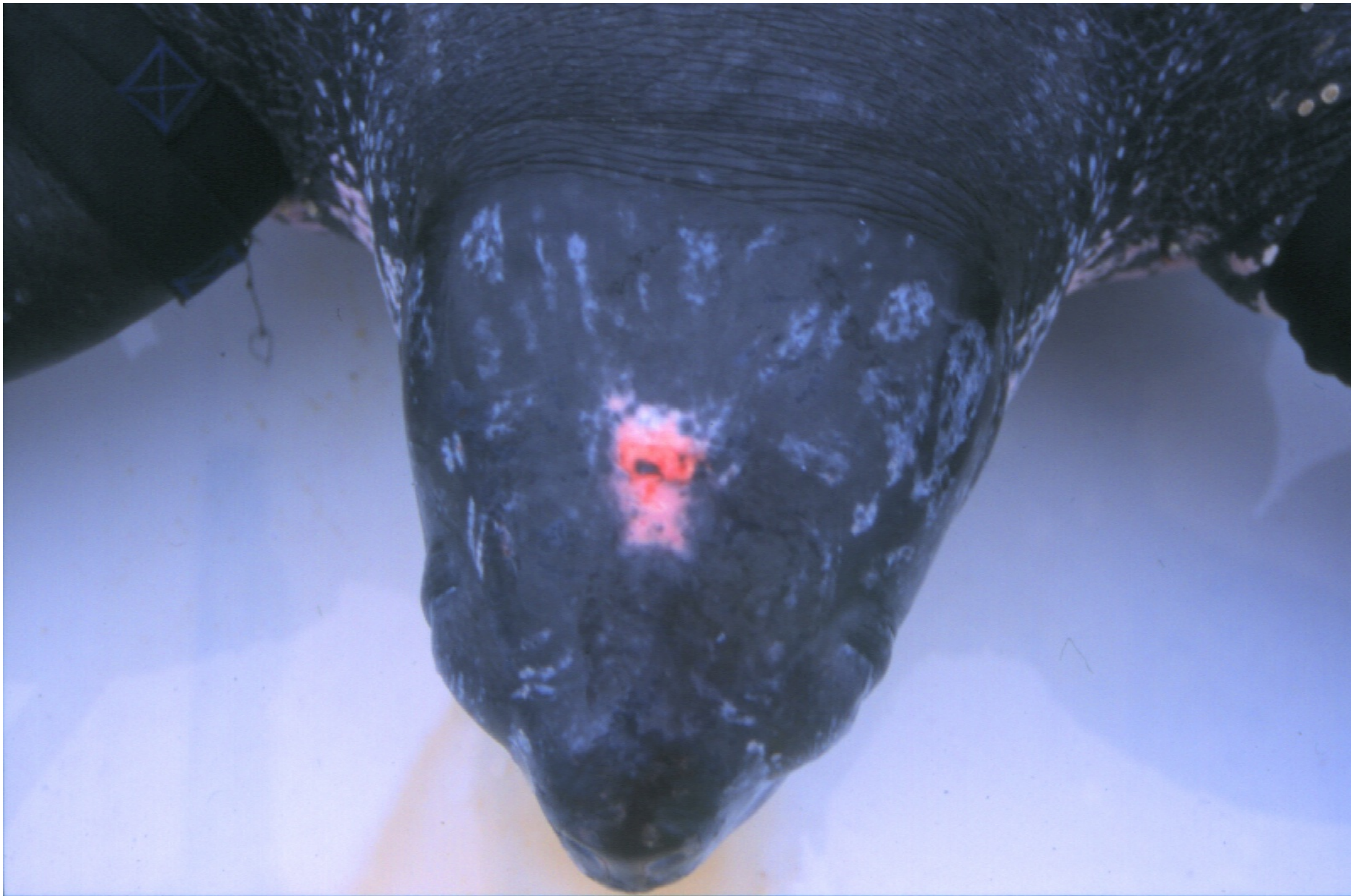
Identification of high-use areas and threats to leatherback sea turtles in northern waters

James, Ottensmeyer and Myers
Ecology Letters (2005)

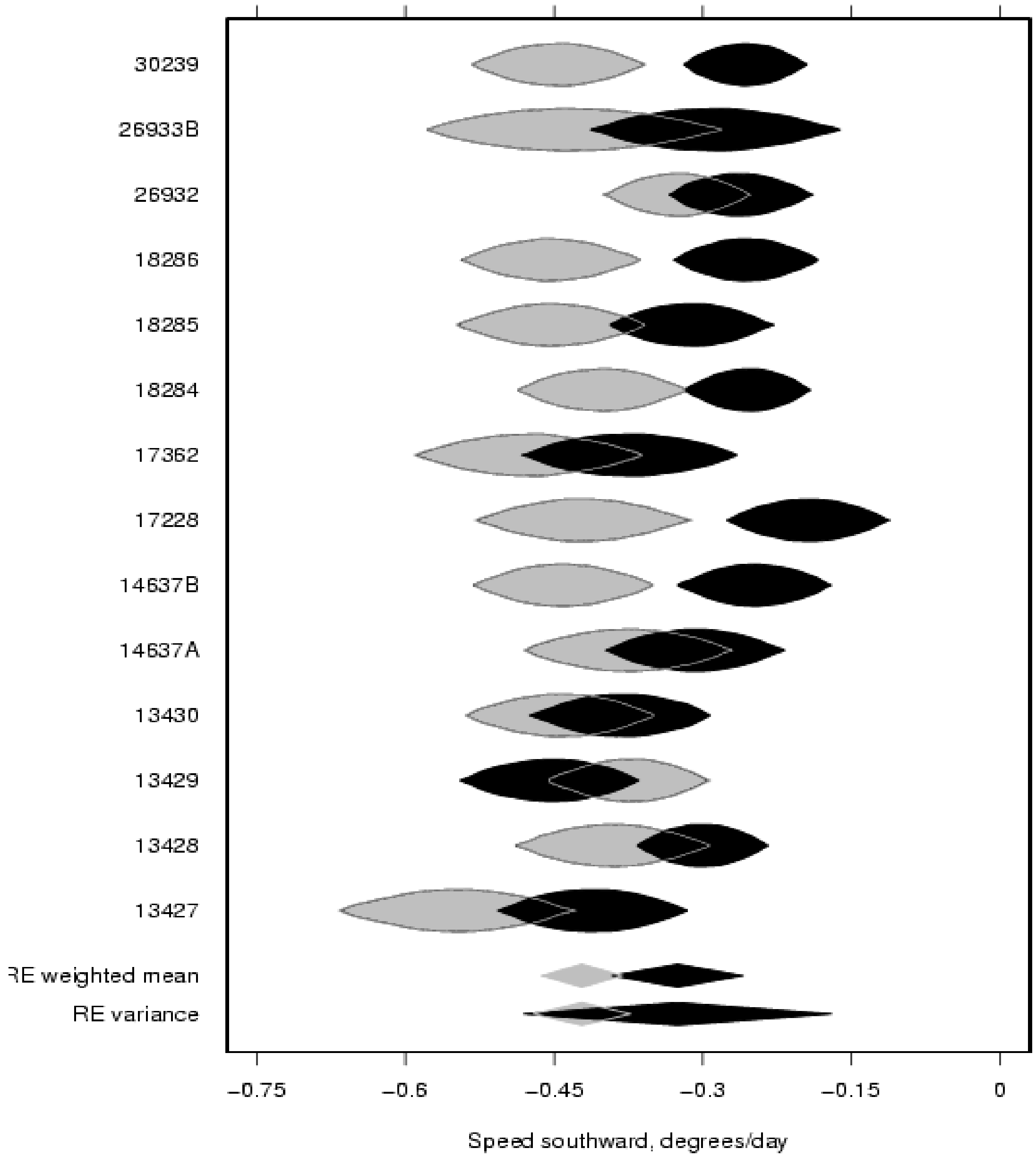
What you can do if you take Stats 2050



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



Turtles make more progress south during the day



Robust Estimation

- Does it make sense to have an error distribution with infinite variance?
- The estimated t-distributions sometimes have degrees of freedom less than 2, i.e. infinite variance.


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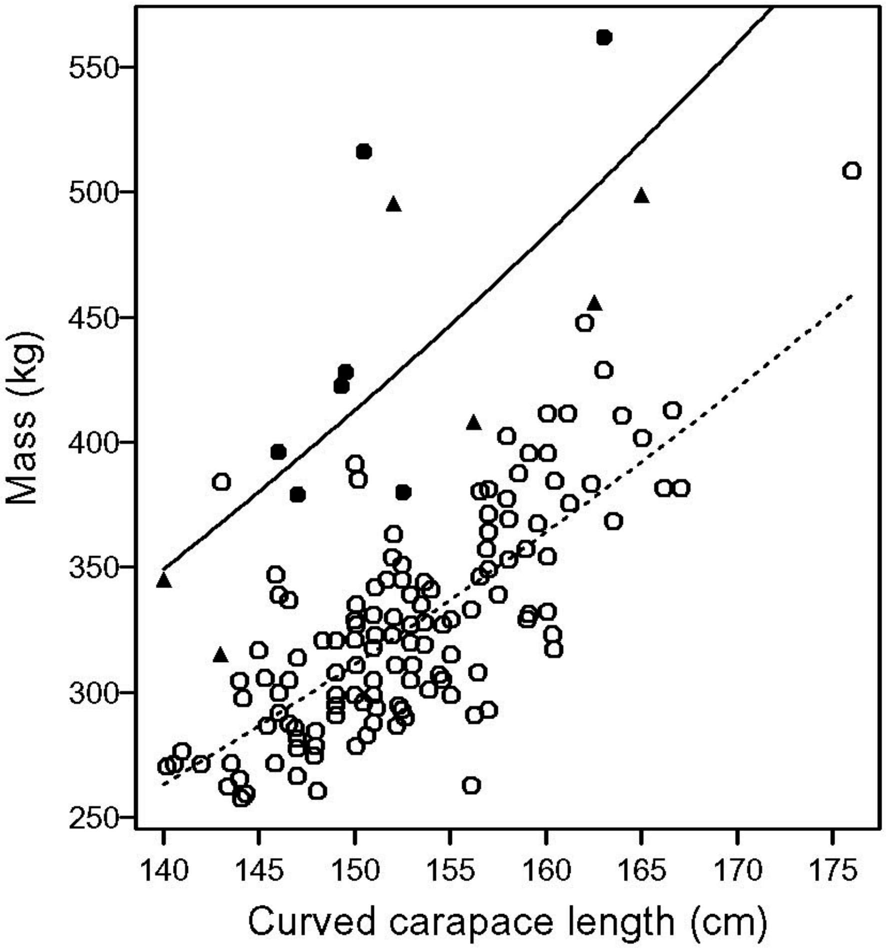
Photo by Matthew Godfrey

Weights in Canadian waters



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

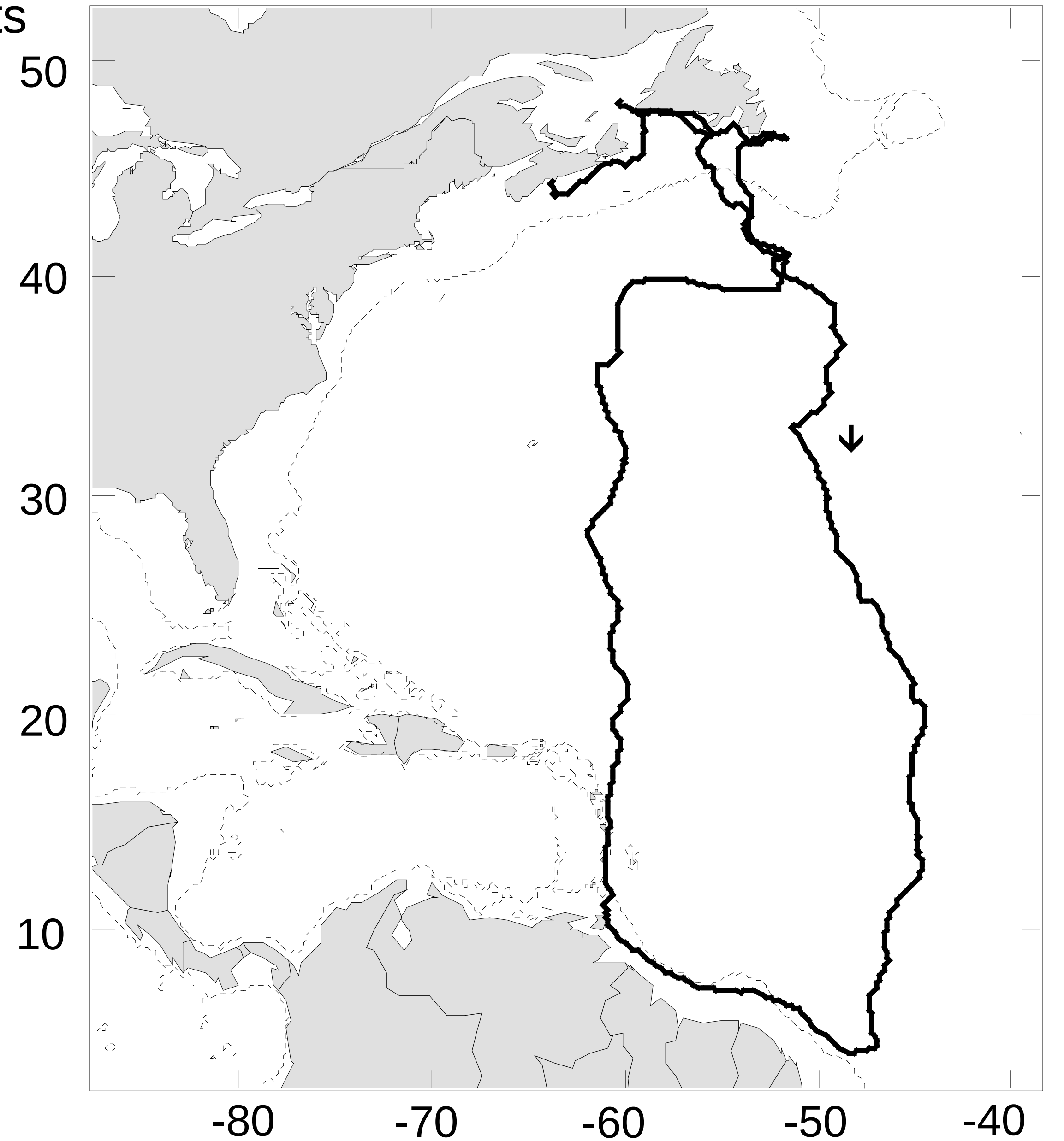
Nesting female morphometrics: St. Croix, U.S.V.I.
Boulon et al. 1996. Chelonian Conserv, Biol. 2:141-147.
Lines fit by constant slope analysis of covariance after log transformation.

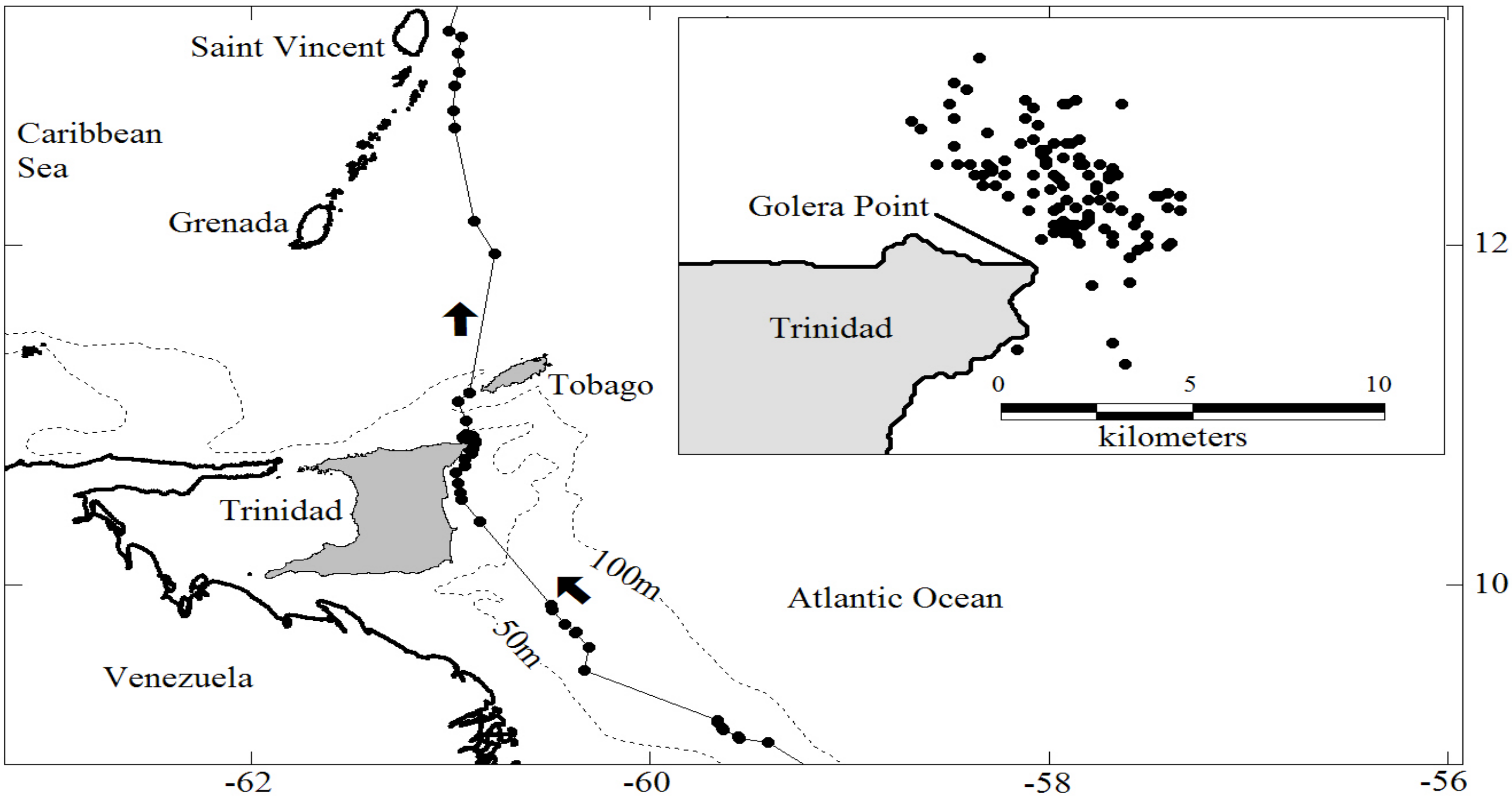
Male leatherback movements

- not previously described

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

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





Male residency in nearshore waters off large nesting colonies

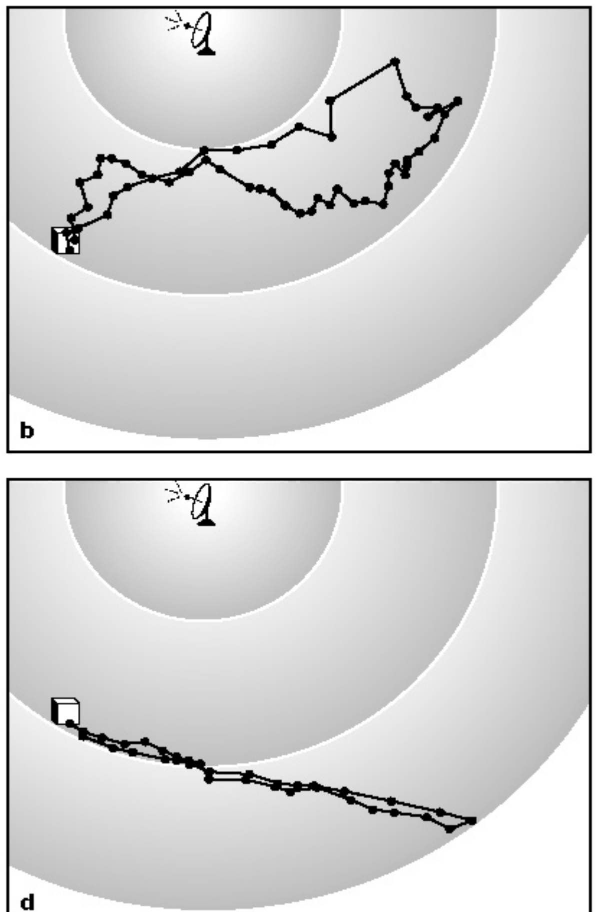
- Location and timing of mating activity not previously known
- long-term tracking (e.g. 20 months +) reveals fidelity for breeding areas

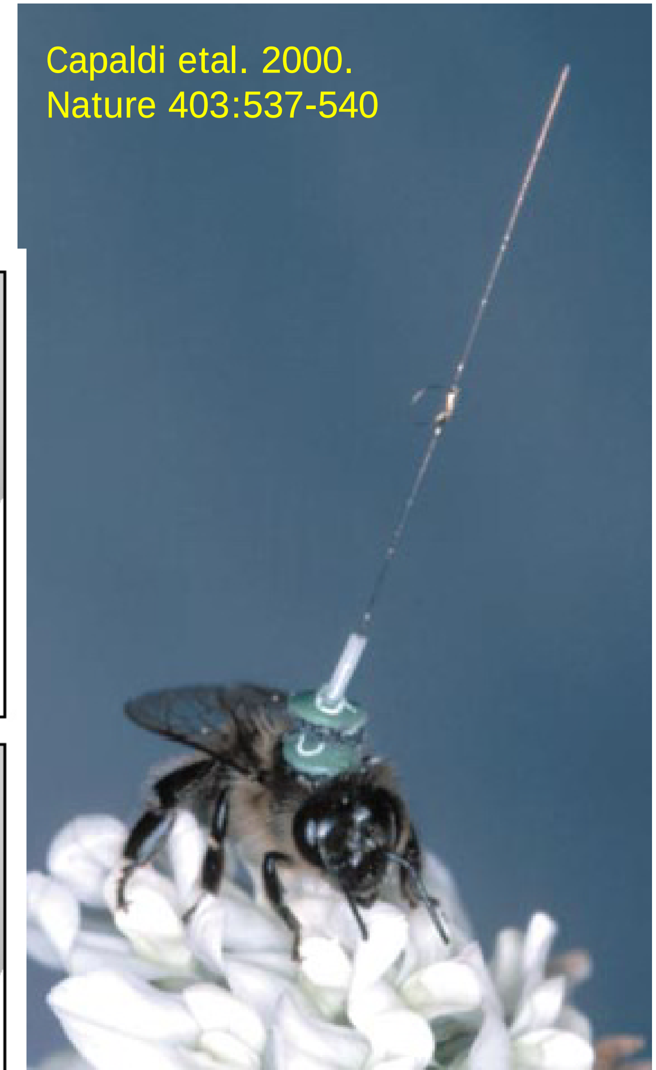
Meta-analytic State Space Movement Models

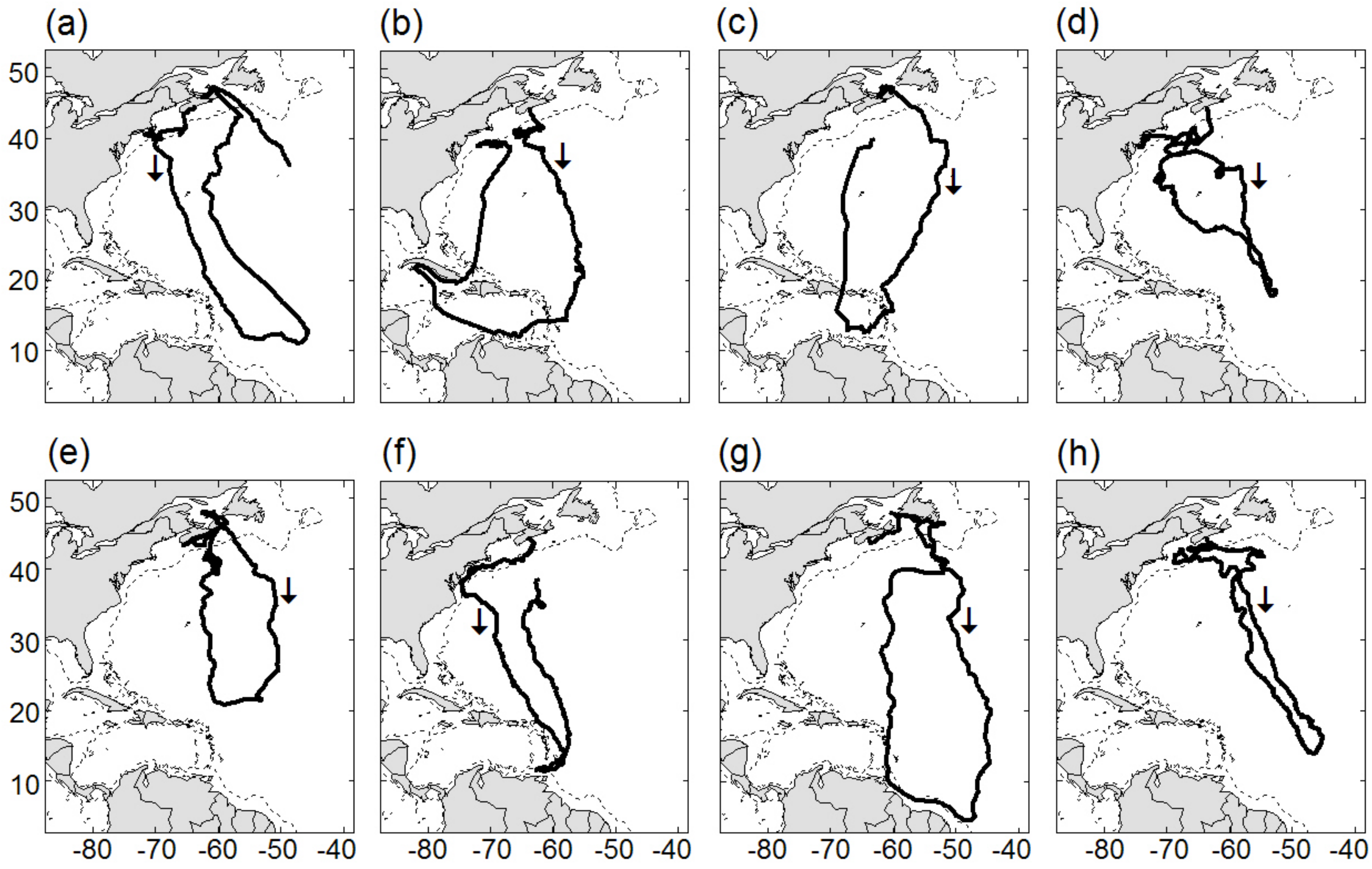
Ian Jonsen

Joanna Mills

Greg Breed

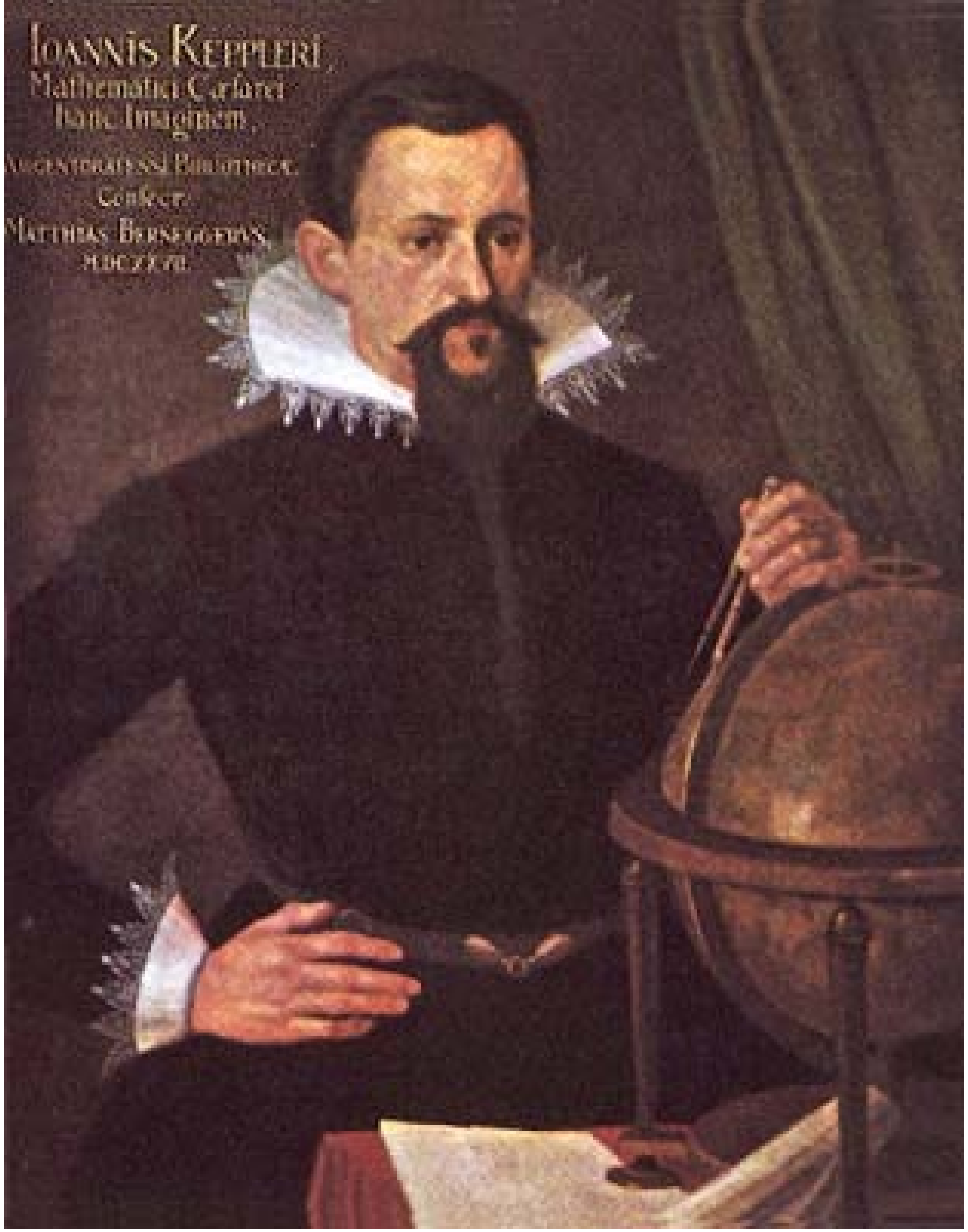




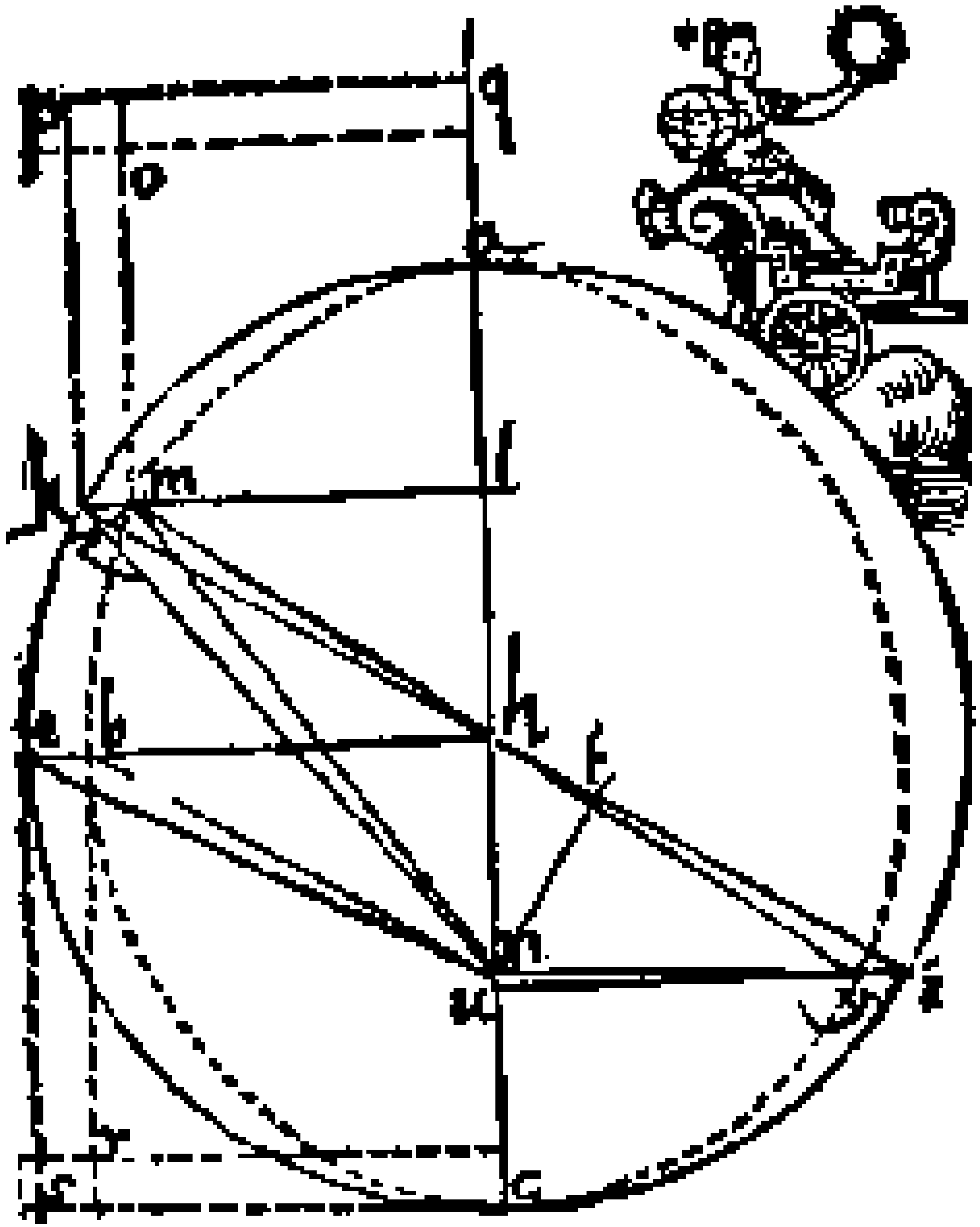


- First documented return migrations to foraging areas
- return migrations to Canada/Northeastern U.S. are annual
- similar migratory cycle for sub-adults and females in their internesting years
- modified cycle for mature males and nesting females (nearshore phase in tropical waters)

Why studying trajectories is an important thing to do.

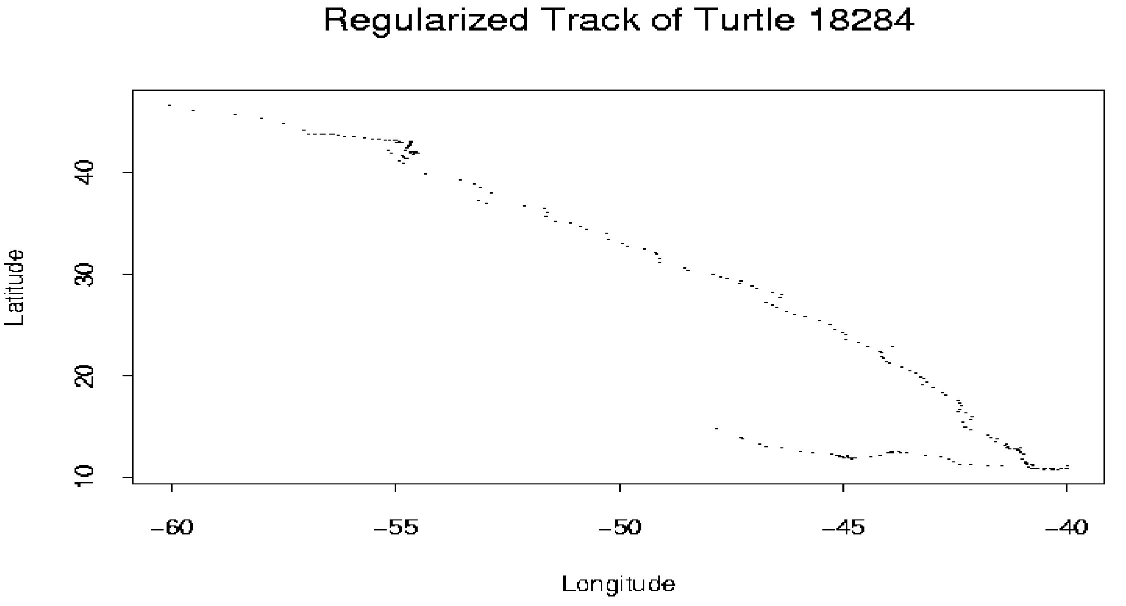


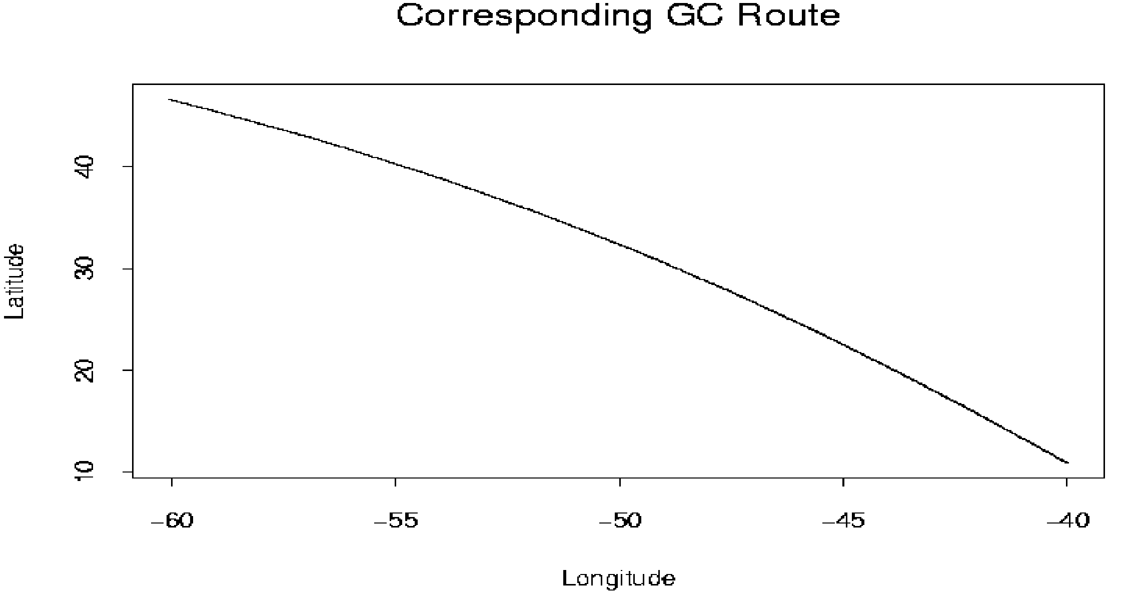
Imperial Mathematician



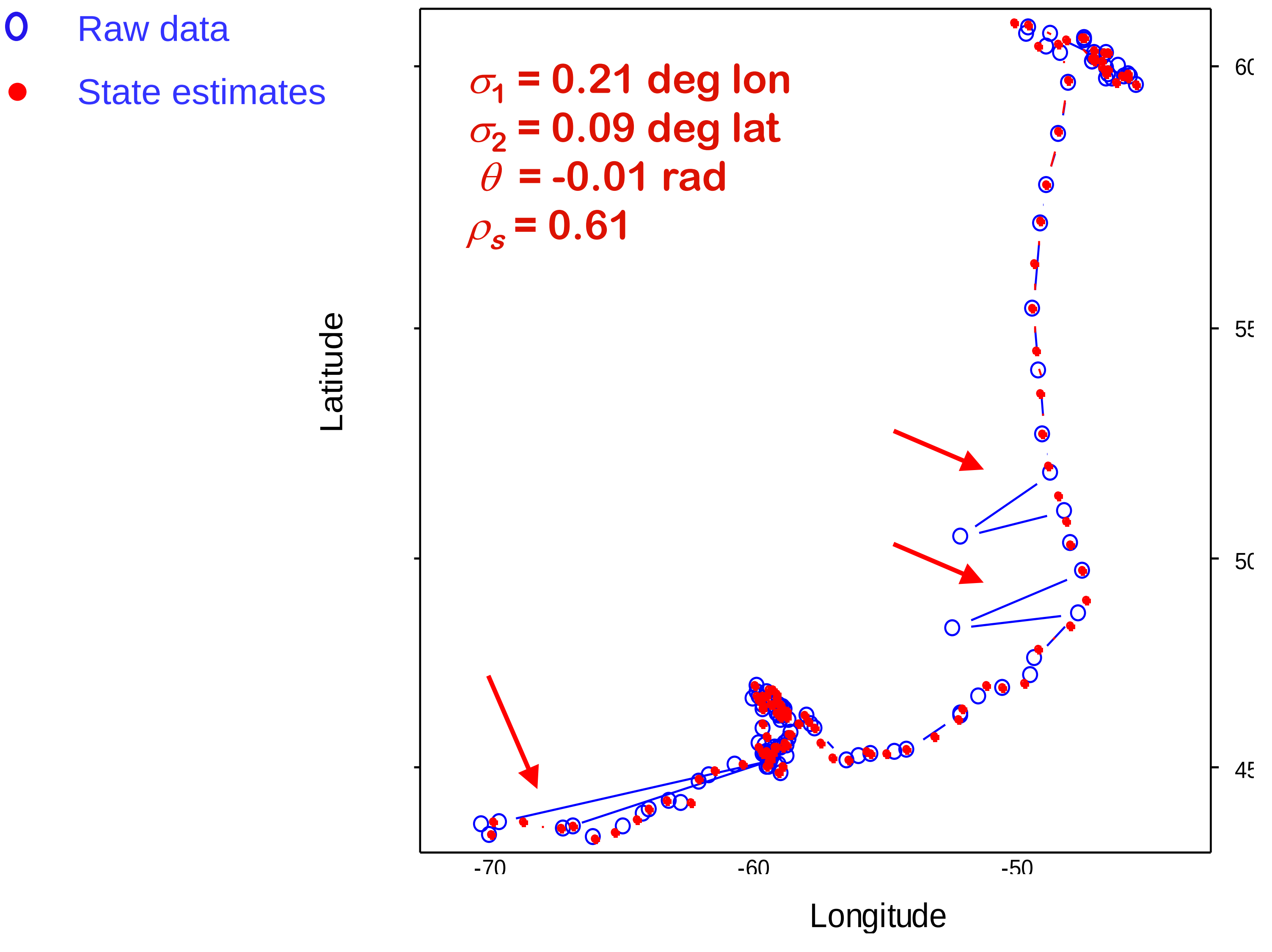
Kepler's elliptical orbit for Mars..

Do animals follow Great Circle Routes for long distance migration?

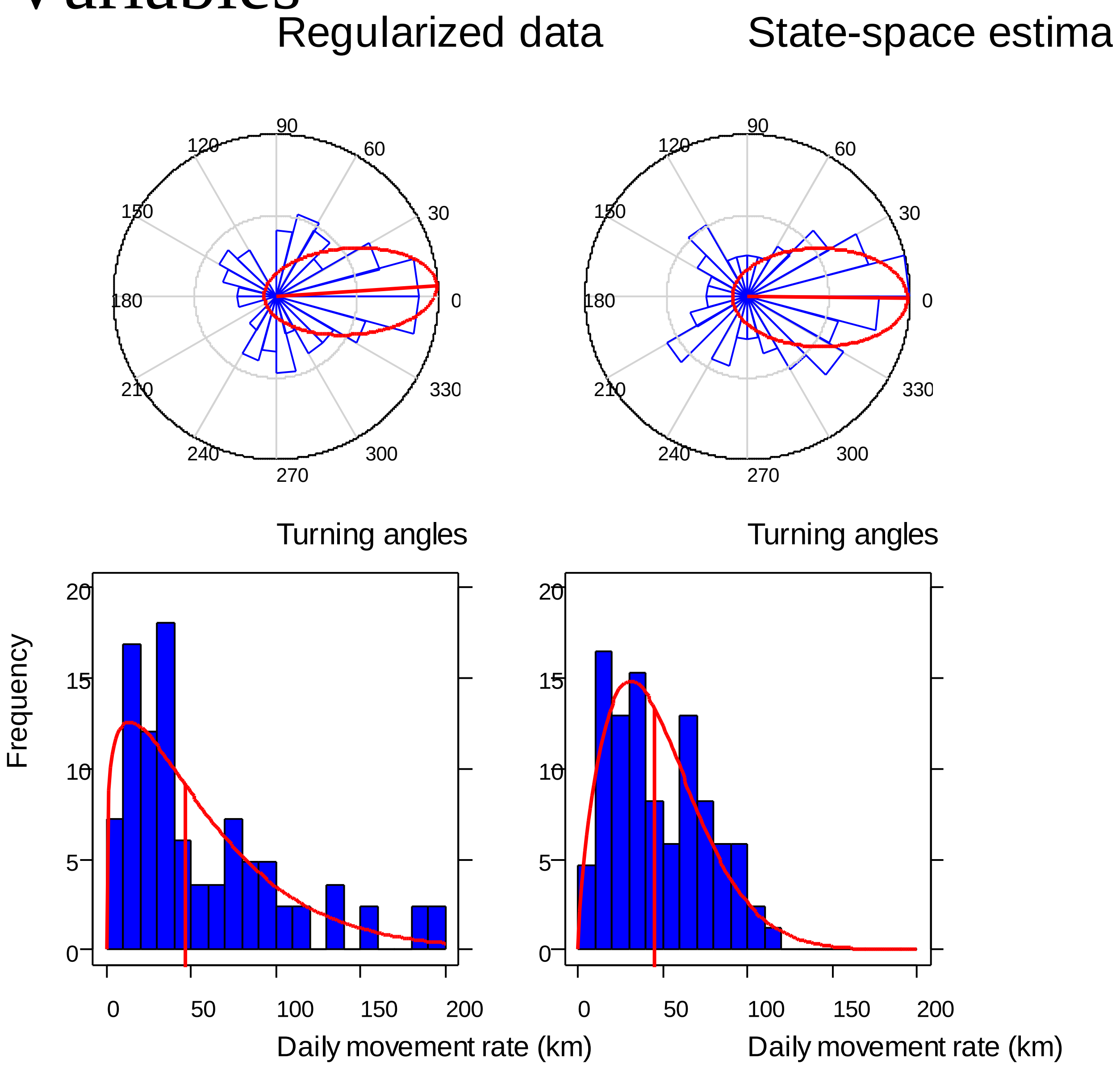




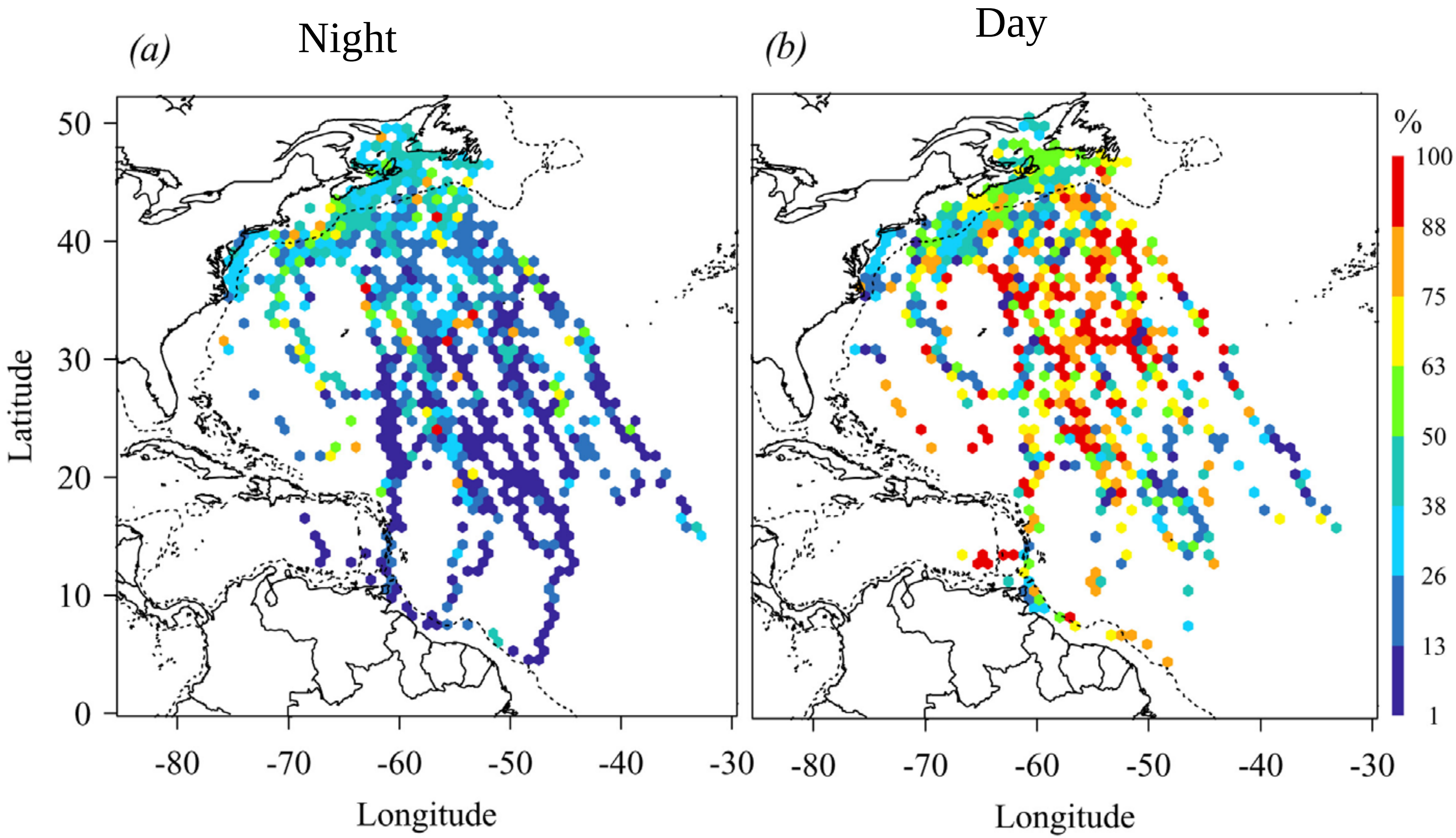
Filtered Data



Derived Variables

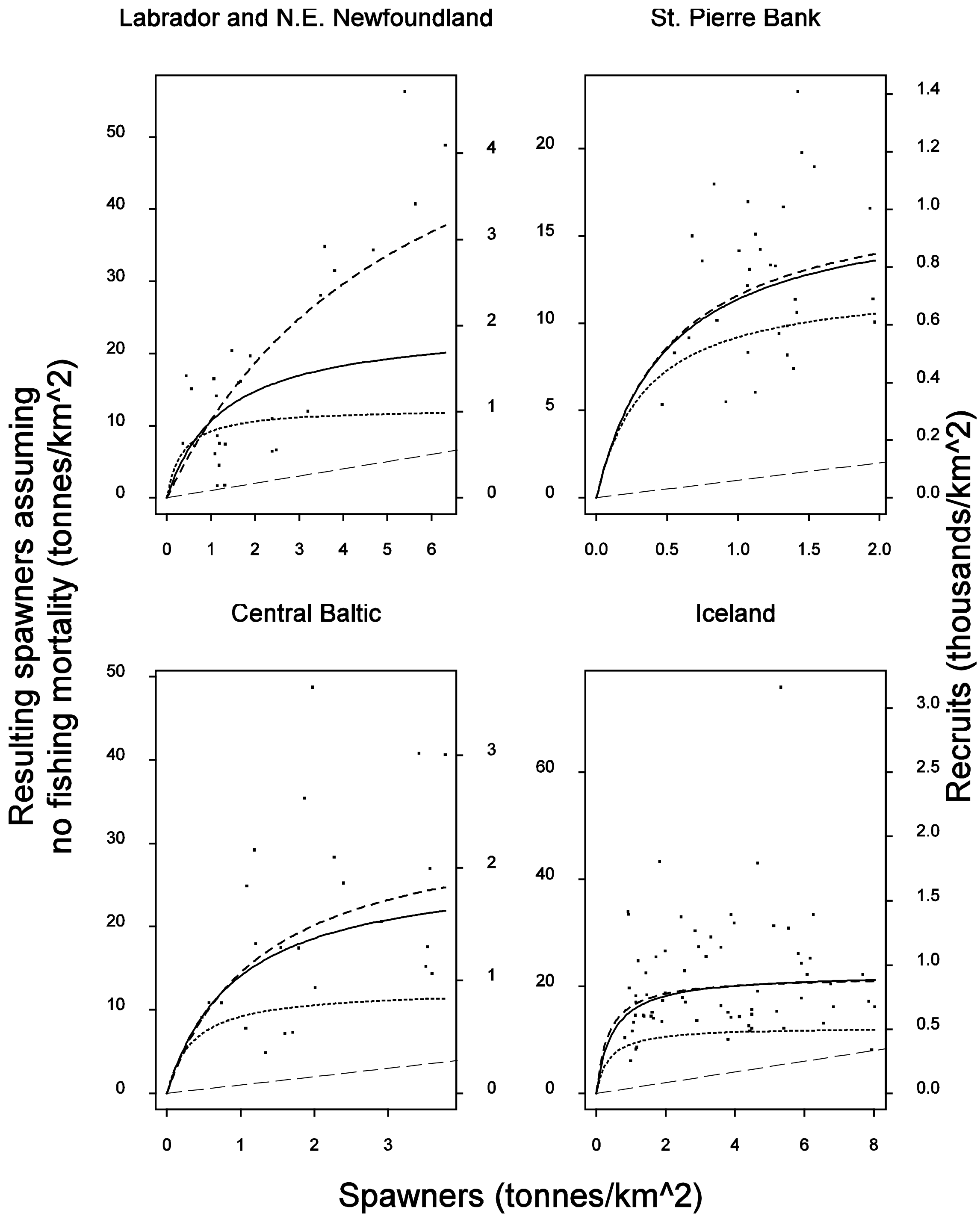


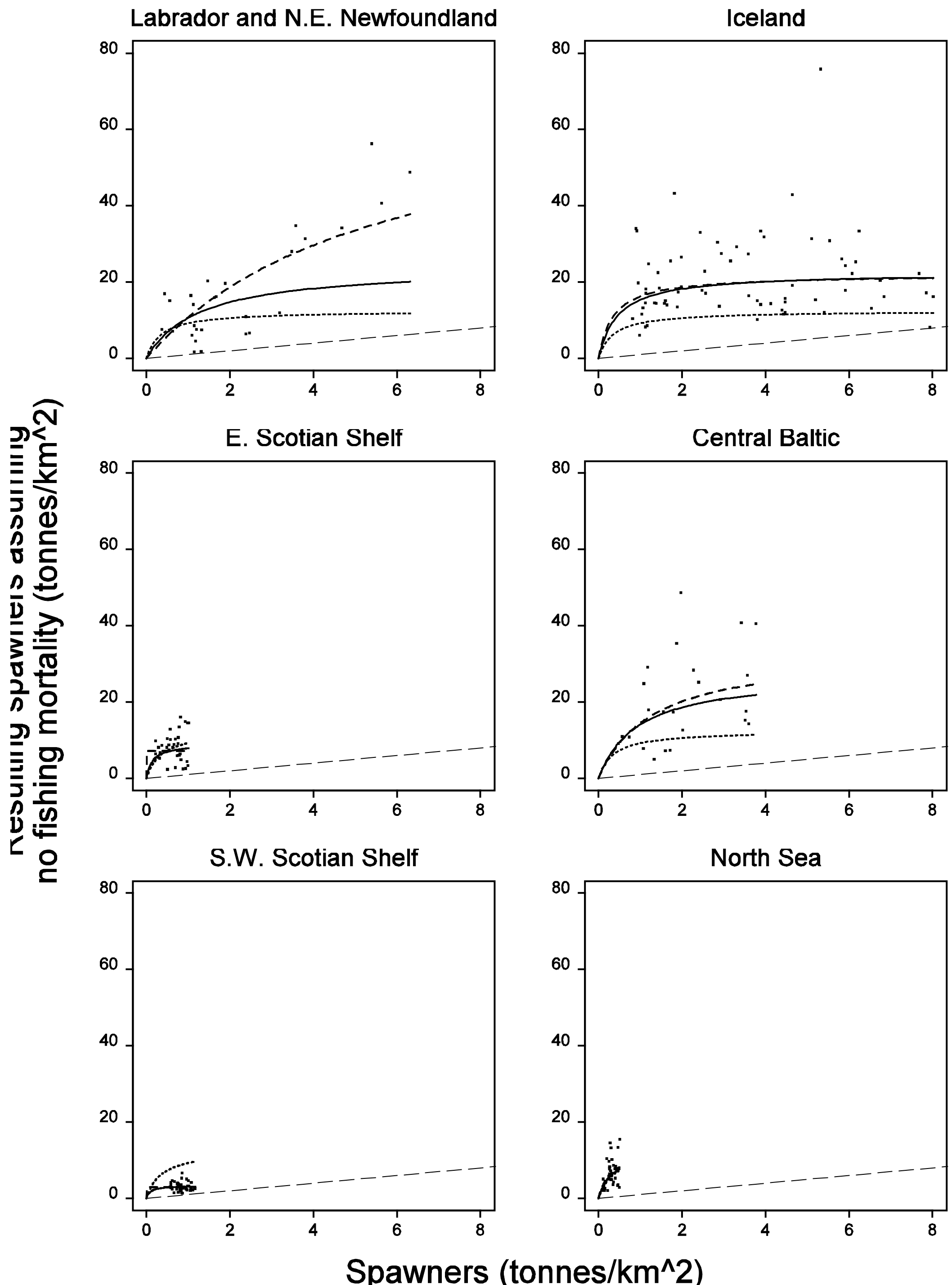
Turtles are close to the surface during the day during migration



Meta-analysis of everything

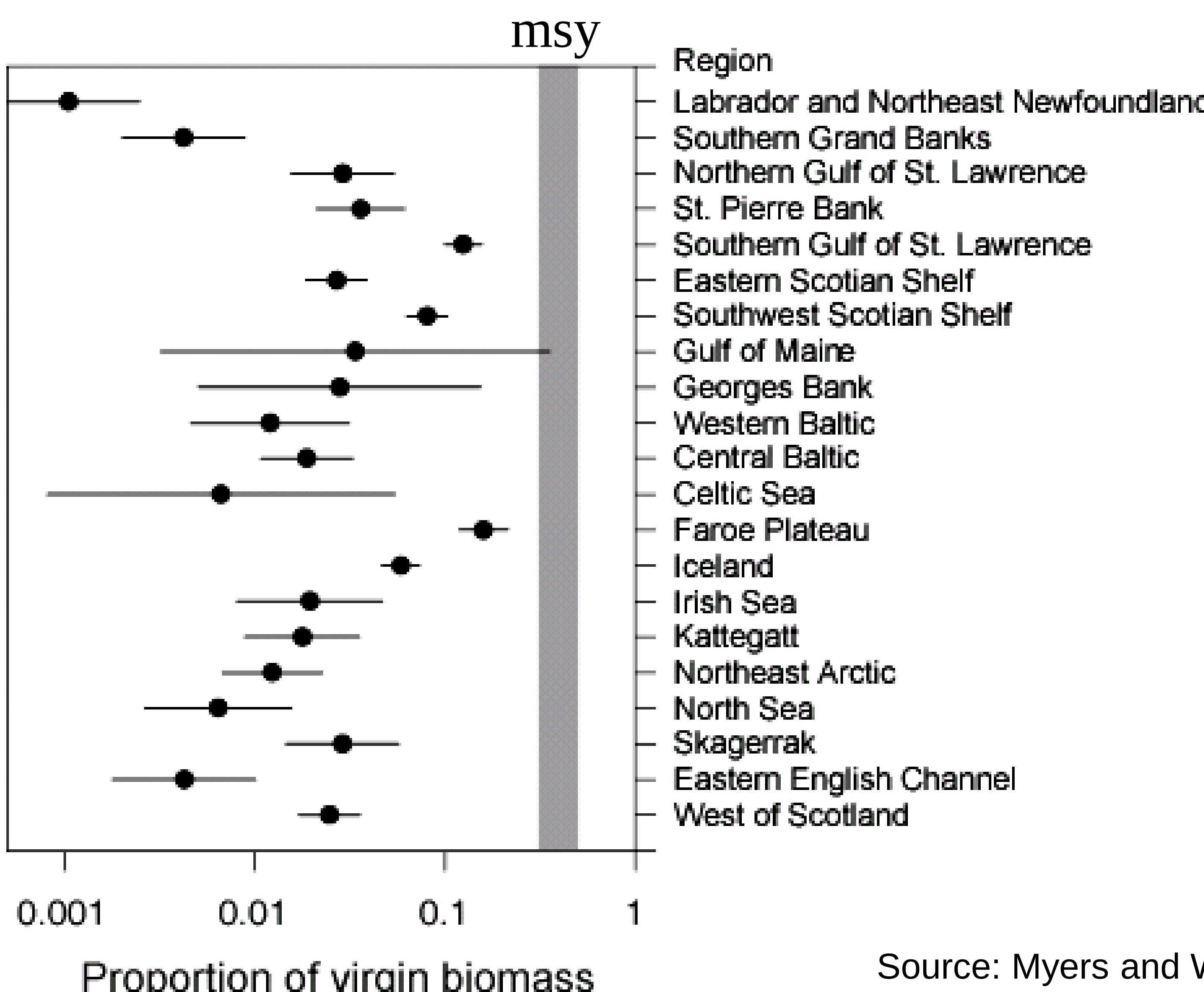
- Dan Ricard – Meta-analysis of diffusion from MPA’s
- Scott Sherrill-Mix – Meta-analysis of fisher’s behaviour when populations change
- Andy Edwards and Coilin Minto – Meta-analysis of species interactions
- Julia Baum – Carrying capacity and recovery


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

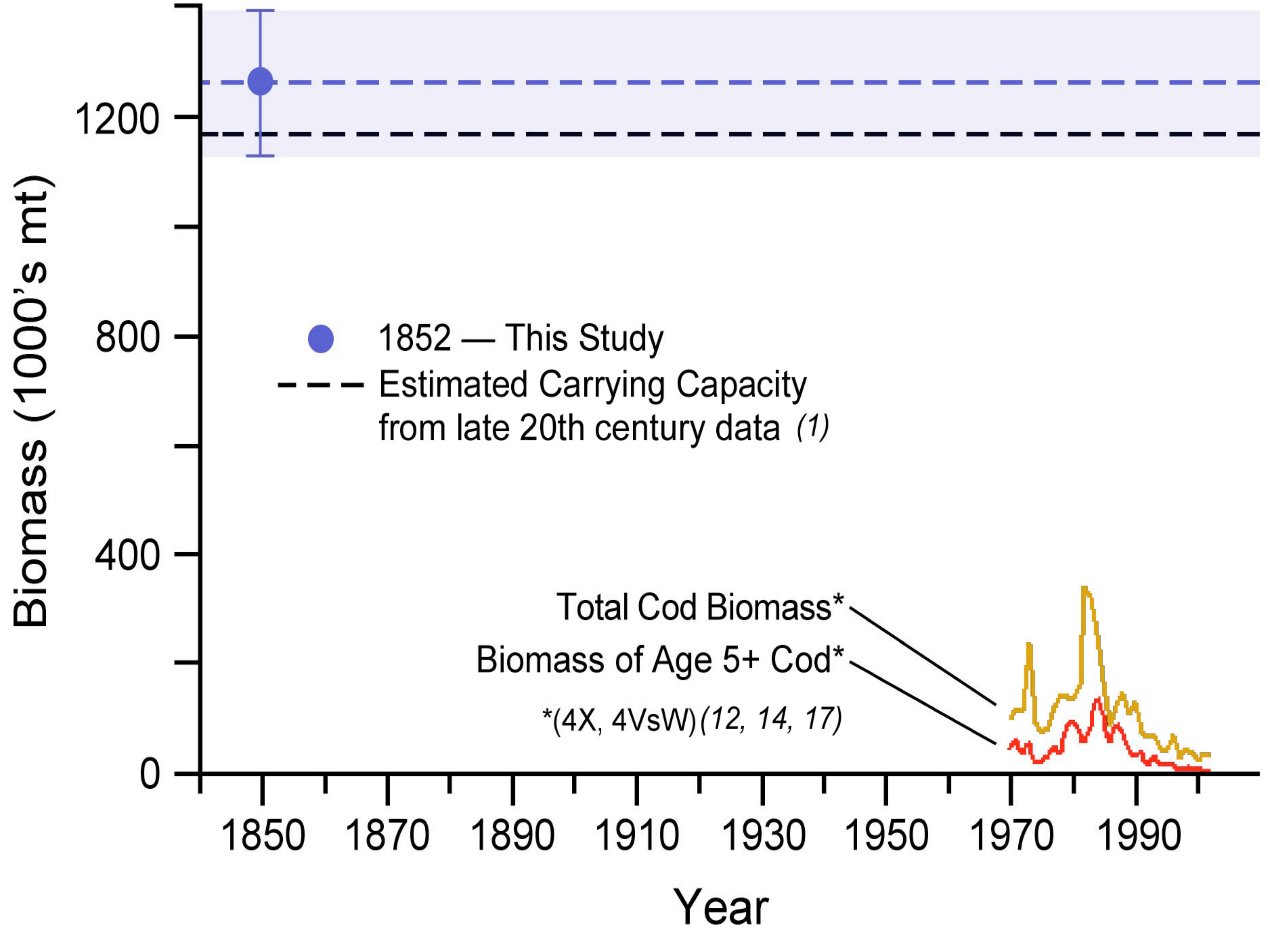


Labrador and N.E. Newfoundland
Iceland
E. Scotian Shelf
Central Baltic
S.W. Scotian Shelf
North Sea
Resulting spawners assuming no fishing mortality (tonnes/km^2)
Spawners (tonnes/km^2)

There is much less than 10% of cod left -



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

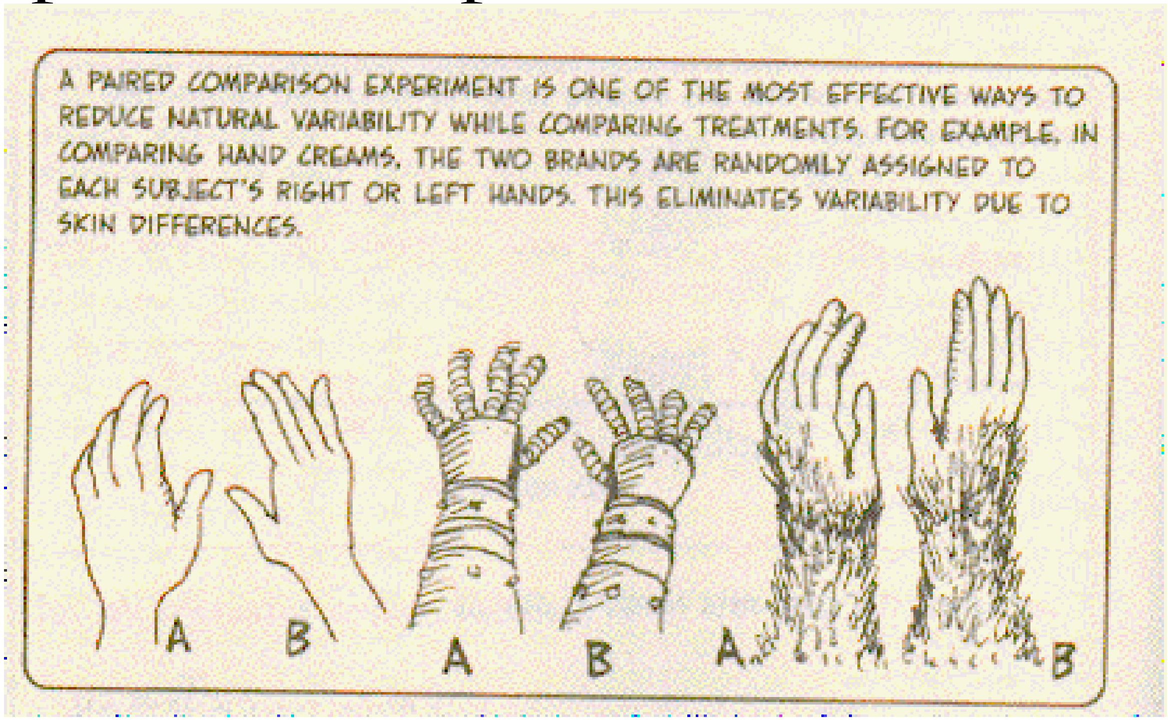


Biomass (1000's mt)
1200
800
400
0
1852 — This Study
Estimated Carrying Capacity
from late 20th century data (1)
Total Cod Biomass*
Biomass of Age 5+ Cod*
*(4X, 4VsW) (12, 14, 17)
1850
1870
1890
1910
1930
1950
1970
1990
Year

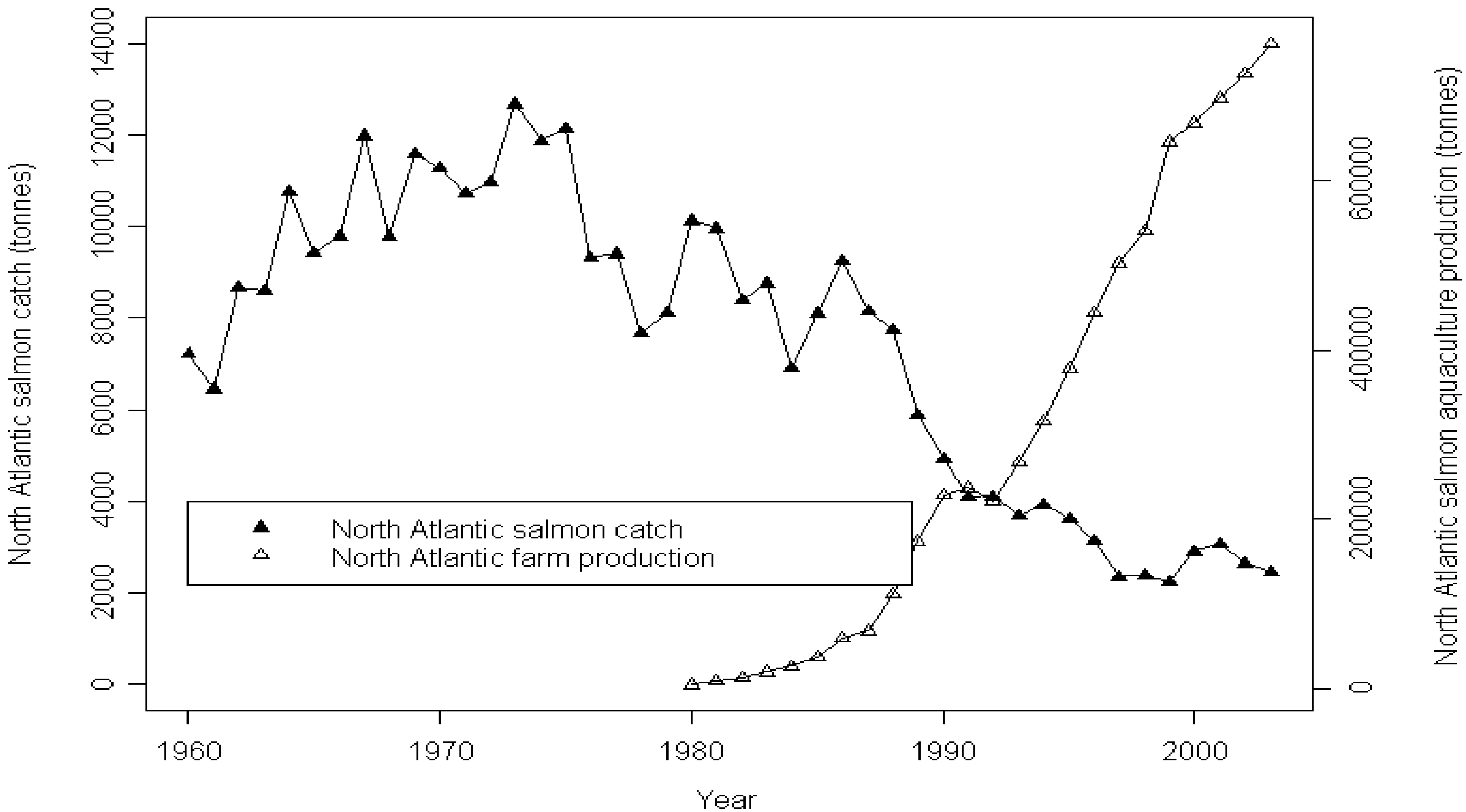
Can wild salmonid populations survive salmon aquaculture?

Jennifer Ford

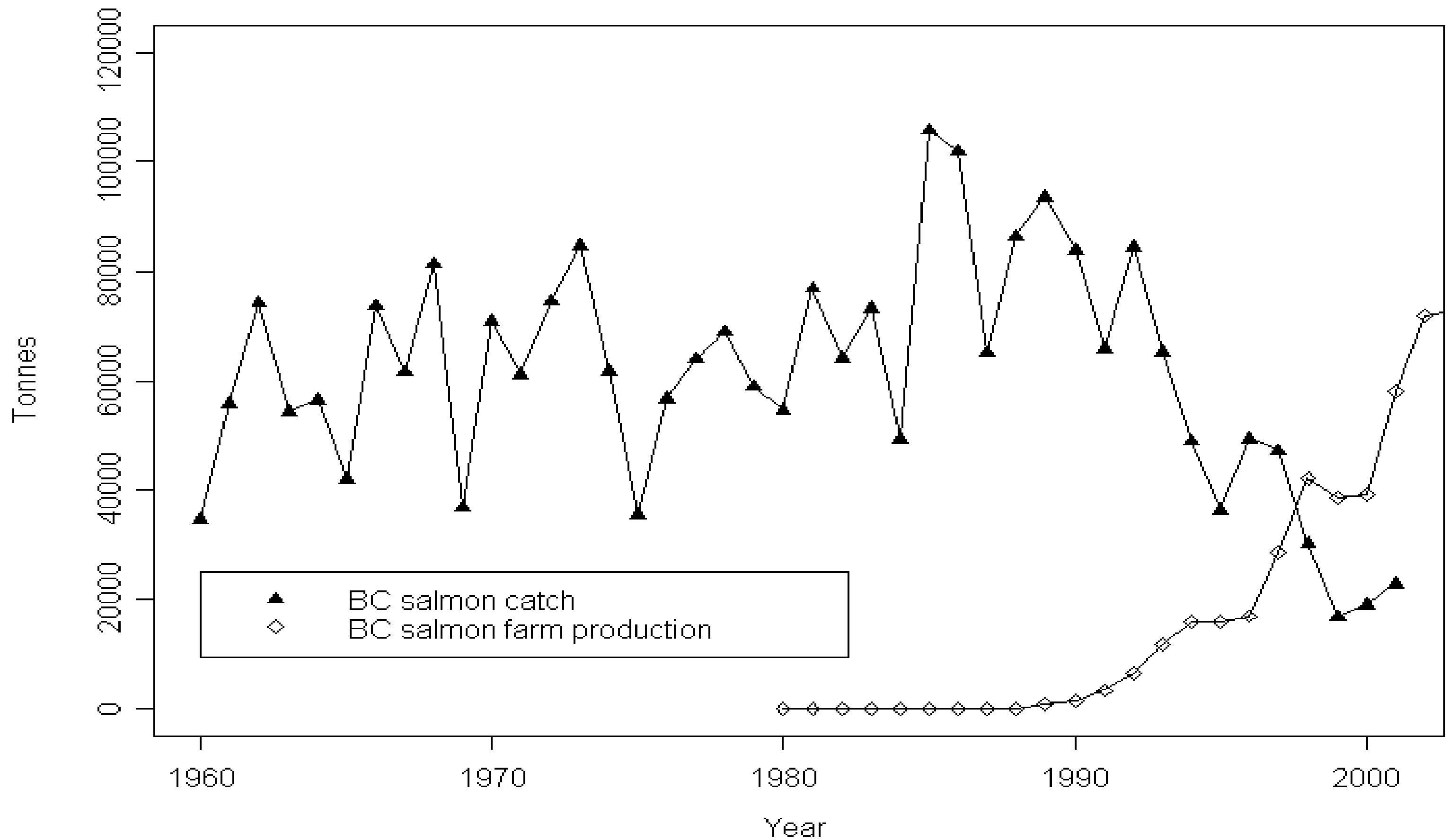
Use paired comparisons.



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



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



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

ECOLOGY

Hatcheries and Endangered Salmon

Ransom A. Myers,[1] Simon A. Levin,[2] Russell Lande,[3] Frances C. James,[4] William W. Murdoch,[5] Robert T. Paine[6]

The role of hatcheries in restoring threatened and endangered populations of salmon to sustainable levels is one of the most controversial issues in applied ecology (*1*). The central issue has been whether such hatcheries can work, or whether, instead, they may actually harm wild populations (*2*, *3*). A new and overriding issue, however, has arisen because of a recent judicial decision.

On 10 September 2001, U.S. District Court Judge Michael Hogan revoked the listing, by the National Marine Fisheries Service (NMFS), of all Oregon coast coho salmon under the Endangered Species Act (*4*). He ruled that, if hatchery fish were included in the same distinct population segment as the wild fish with which they are genetically associated, then they must be listed together. This approach could have devastating consequences: Wild salmon could decline or go extinct while only hatchery fish persist. Petitions are now pending to delist 15 other evolutionarily significant units (ESUs) (*5*).

An ESU is defined as a genetically distinct segment of a species, with an evolutionary history and future largely separate from other ESUs (*6*). For taxonomic purposes, one could use genetic similarity to classify hatchery fish as part of the ESU from which they were derived. However, for assessing ESU extinction risk and/or potential listing under the Endangered Species Act, including hatchery fish in an ESU confounds risk of extinction in the wild with ease of captive propagation and ignores important biological differences between wild and hatchery fish.

We define "hatchery fish" as fish fertilized and/or grown artificially in a production or conservation hatchery. Inevitably, hatchery brood stock show domestication effects, genetic adaptations to hatchery environments that are generally maladaptive in the wild. Hatchery fish usually have poor survival in the wild and altered morphology, migration, and feeding behavior (*7*). On release, hatchery fish, which are typically larger, compete with wild fish (*1*). Their high local abundance may mask habitat degradation, enhance predator populations, and allow fishery exploitation to increase, with concomitant mortality of wild fish (*1*, *8*). The absence of imprinting to the natal stream leads to greater straying rates, and that spreads genes not adapted locally (*1*). Also, hybrids have poor viability, which may take two generations to be detected (*9*).

Interagency draft criteria (*10*) describe hatchery fish most appropriate for inclusion in an ESU as those founded within two generations or those that had regular infusions of fish from the wild population. However, fish grown in hatcheries for even two generations may not assist population recovery; their rate of survival in the wild is much lower than that of wild fish (*11*). Regularly infusing hatchery stocks with natural fish may also be a drain on the natural system. Hence, even these hatchery fish should not be included in an ESU, even if they are indistinguishable at the quasi-neutral molecular genetic loci typically used to identify an ESU.

Much evidence exists that hatcheries cannot maintain wild salmon populations indefinitely (*7*). In the inner Bay of Fundy in Eastern Canada, hatchery supplementation of Atlantic salmon occurred for more than a century (*12*). Despite the longevity of this program, it failed to maintain viable natural populations. Hatcheries effectively disguised long-term problems, which probably contributed to the near extirpation of native Atlantic salmon. Moreover, as recommended by the World Conservation Union (IUCN), long-term reliance on artificial propagation is imprudent, because of the impossibility of its maintenance in perpetuity (*13*).

Although their effectiveness has not been shown (*14*), conservation hatcheries may play a role in future salmon recovery. However, to avoid the dysgenic effects of domestication, even conservation hatcheries should be strictly temporary and should not prevent protection of wild populations under the Endangered Species Act.

To address one of the subsidiary lawsuits, NMFS has pledged to complete a review of eight ESUs by 31 March 2004. NMFS should continue to pursue its current recovery goal of establishing self-sustaining, naturally spawning populations. The danger of including hatchery fish as part of any ESU is that it opens the legal door to the possibility of maintaining a stock solely through hatcheries. However, hatcheries generally reduce current fitness and inhibit future adaptation of natural populations. Hence, the legal definition of an ESU must be unambiguous and must reinforce what is known biologically. Hatchery fish should not be included as part of an ESU.

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References and Notes

1. National Research Council, *Upstream: Salmon and Society in the Pacific Northwest* (National Academy Press, Washington, DC, 1996).
2. R. Hilborn, J. Winton, *Can. J. Fish. Aquat. Sci.* **50**, 2043 (1993).
3. R. S. Waples, *Fisheries* **24**, 12 (February 1999).
4. *Alsea Valley Alliance* v. *Evans*, 161 F. Supp. 2d 1154 (D. Or. 2001).
5. R. Lent, *Fed. Regist.* **67**, 6215 (2002)
6. R. S. Waples, *Mar. Fish. Rev.* **53**, 11 (3: 1991).
7. S. Einum, I. A. Fleming, *Nordic J. Freshw. Res.* **75**, 56 (2001).
8. J. Lichatowich, *Salmon Without Rivers* (Island Press, Washington, DC, 1999).
9. P. McGinnity *et al.*, *Proc. R. Soc. London Ser. B* **270**, 2443 (2003).
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11. R. Reisenbichler, G. Brown, in "Assessing Extinctions Risk for West Coast Salmon," A. D. MacCall, T. C. Wainwright, Eds. (NOAA Tech. Memo. NMFS-NWFSC-556, U.S. Department of Commerce, Washington, DC, 2003), pp. 147–154.
12. A. J. F. Gibson, J. Bryan, P. G. Amiro, *Can. Data Rep. Fish. Aquat. Sci.* (no. 1123), 2003.
13. IUCN, 2002, www.iucn.org/themes/ssc/pubs/policy/exsituen.htm.
14. F. Allendorf, R. S. Waples, in *Conservation Genetics: Case Histories from Nature*, J. C. Avise, J. L. Hamrick, Eds. (Chapman & Hall, New York, 1996), pp. 238–280.
15. We thank R. S. Waples for explaining aspects of the problem and C. A. Ottensmeyer for assistance.

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POLICY FORUM

ECOLOGY

Hatcheries and Endangered Salmon

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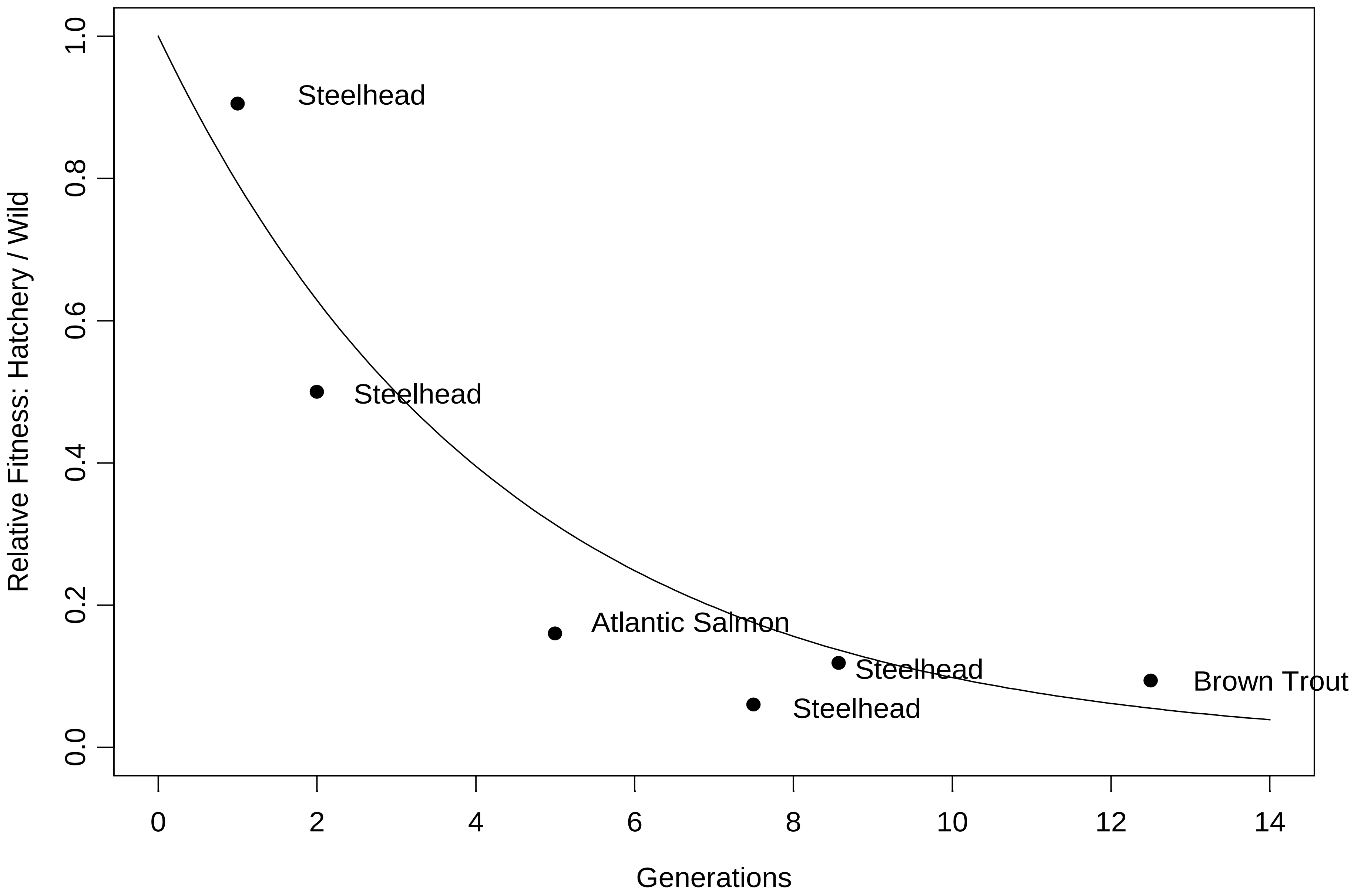
There is always a rapid loss of fitness in the wild with hatcheries; after a few generations hatchery salmon may be useless for recovery.



Sharks

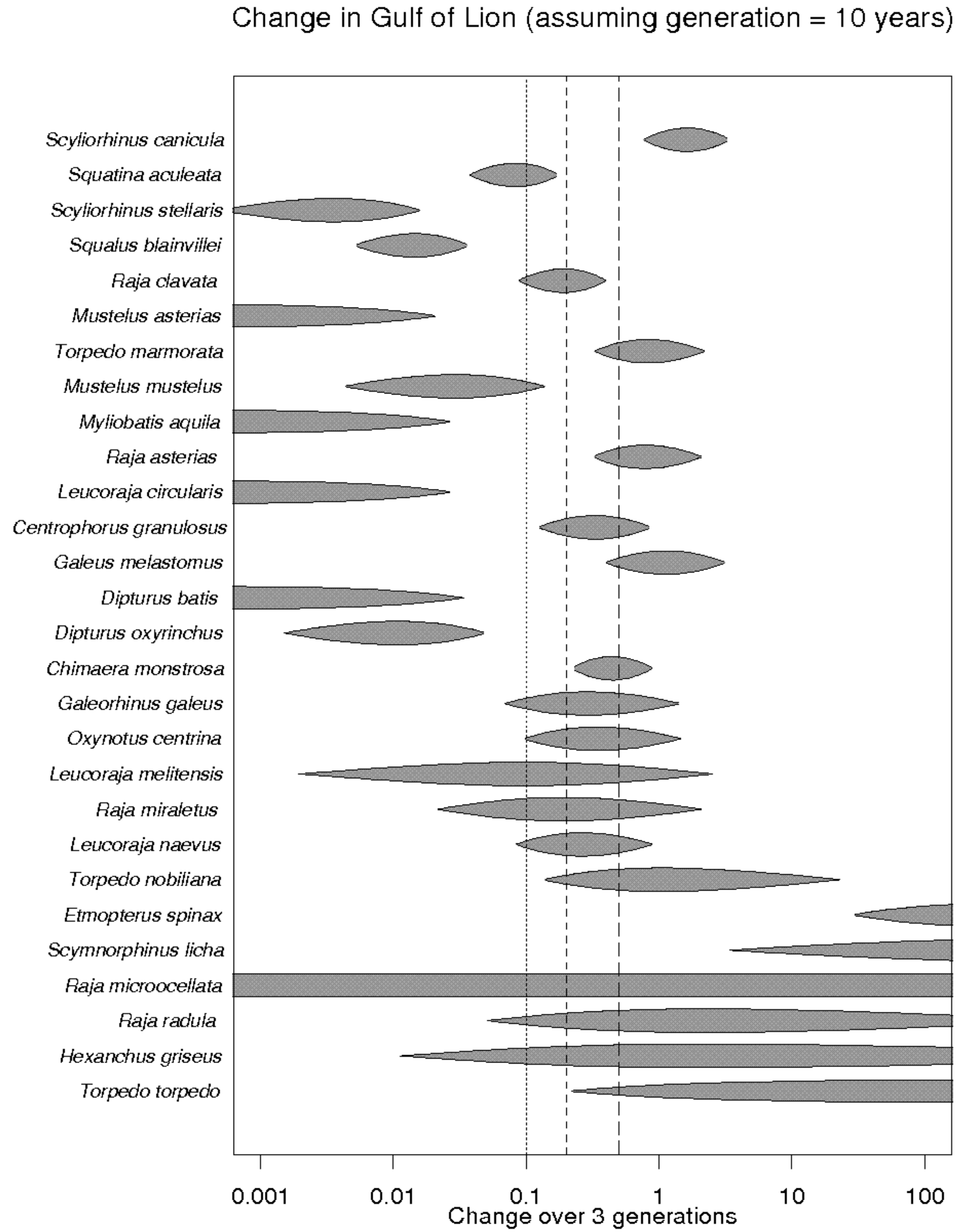
- Christine Ward-Page – Reef sharks
- Luis Lucifora and Travis Shepherd – world
- Anna Massa –Argentina
- Mike Stokesbury – Greenland shark
- Peter Ward – Central Pacific
- Julia Baum – Gulf of Mexico
- Gretchen Fitzgerald – Pelagic species
- Veronica Garcia – deepwater species

How do we Estimate of Trends Using Crazy Data:

There are few guidelines for students dealing with real data

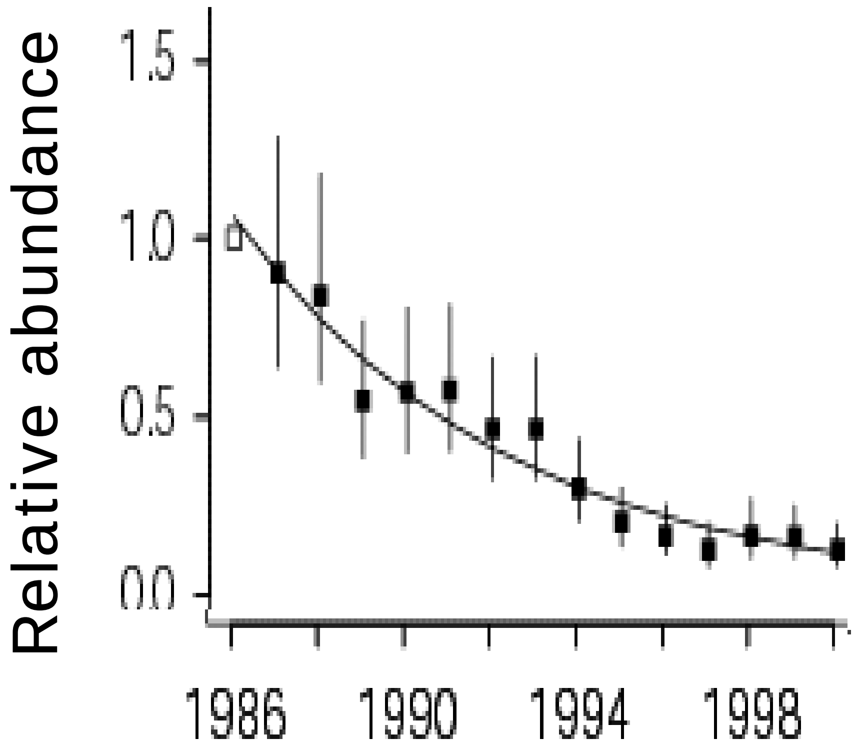
- Joanna Flemming
- Dan Kehler
- Eva Cantonni
- Leah Gerber
- Wade Blanchard

Analysis of old survey data from the Gulf of Lion (where we only have partial data, i.e. the number of positive counts) show that 12 species of sharks and rays meet the IUCN criterion for endangered.



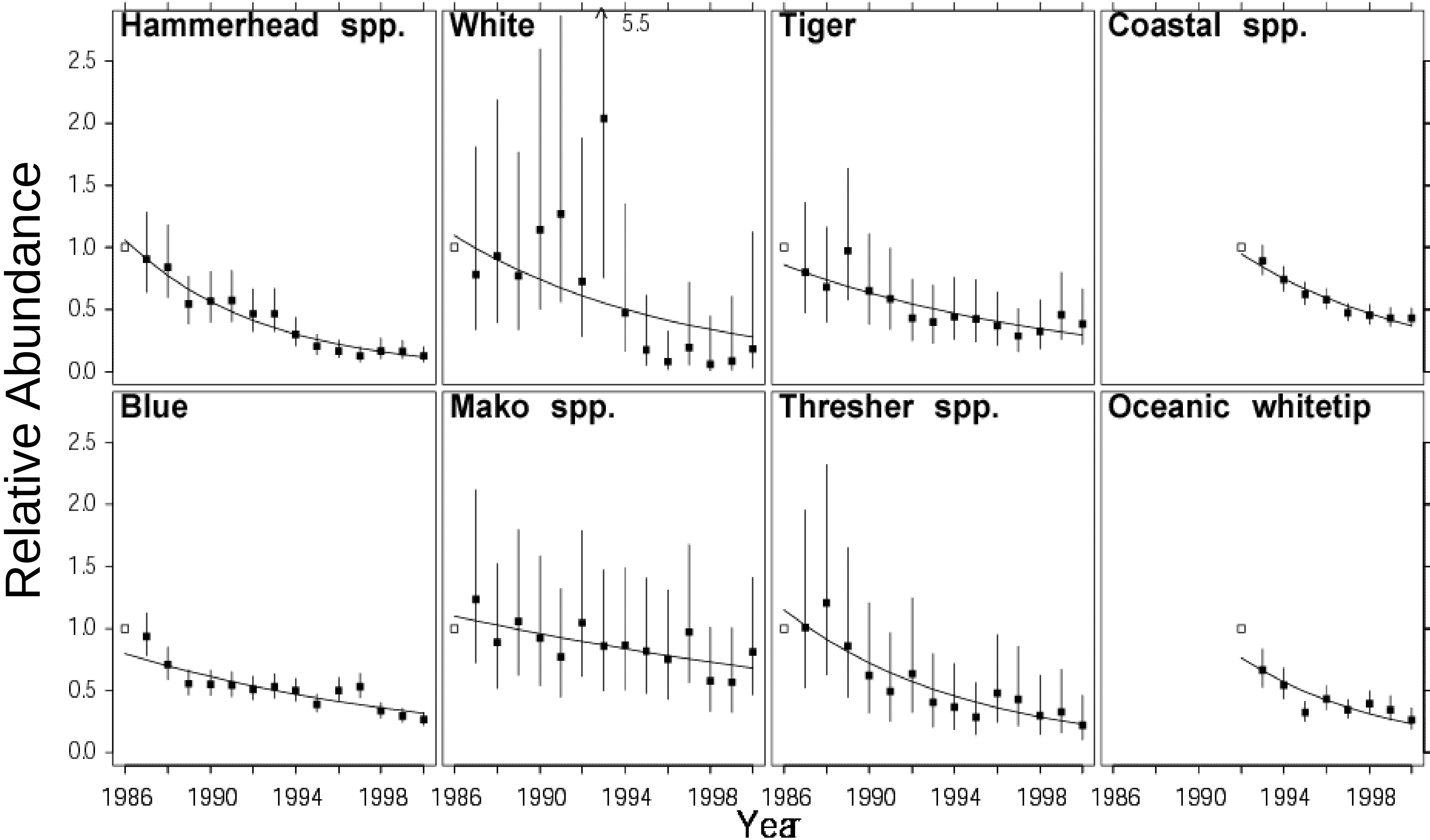
Hammerhead sharks

Sphyrna lewini



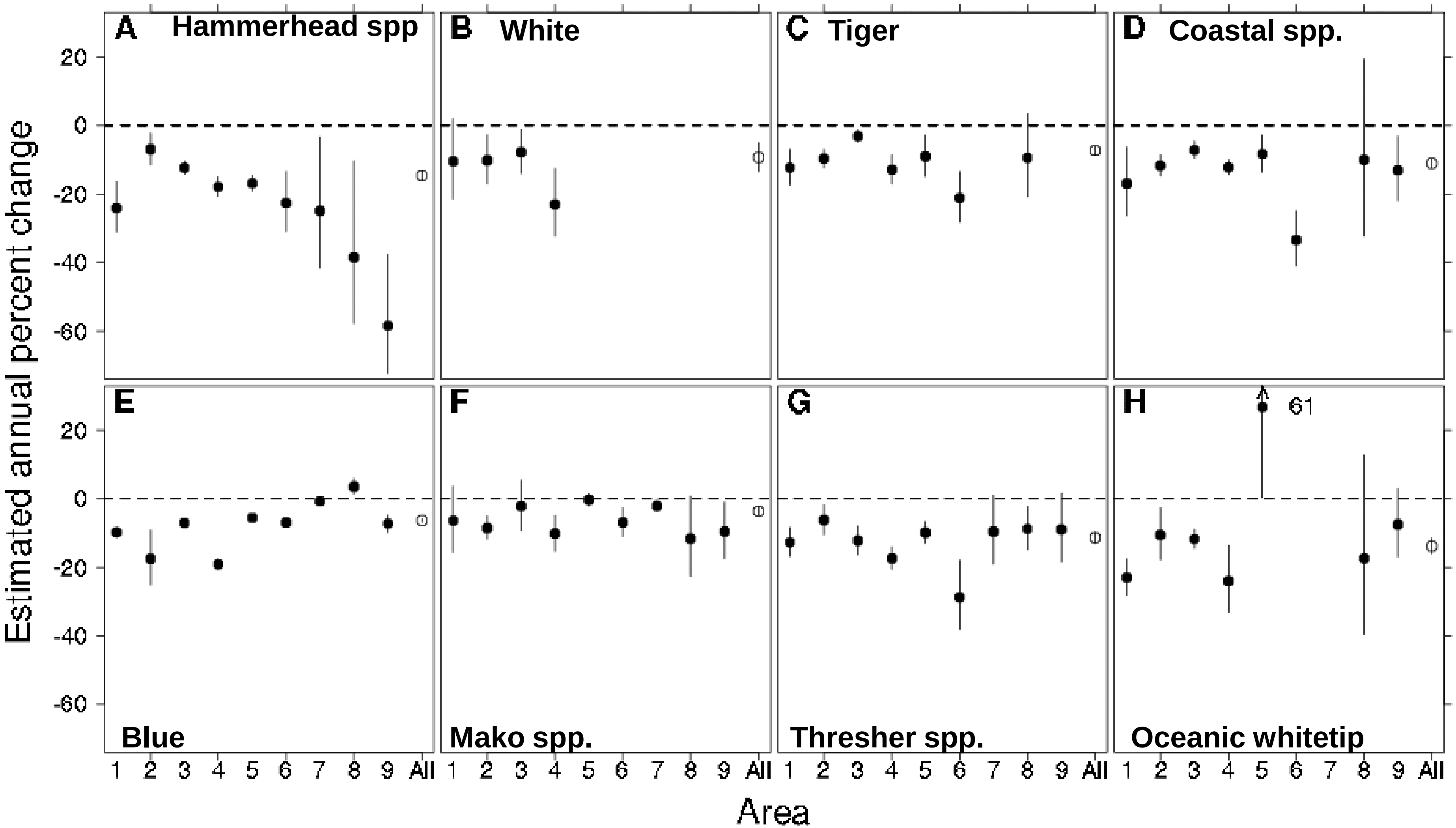
Science. Jan. 2003. J.K. Baum, R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, P.A. Doherty

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

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



Data Analysis

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

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

Robustness Analyses

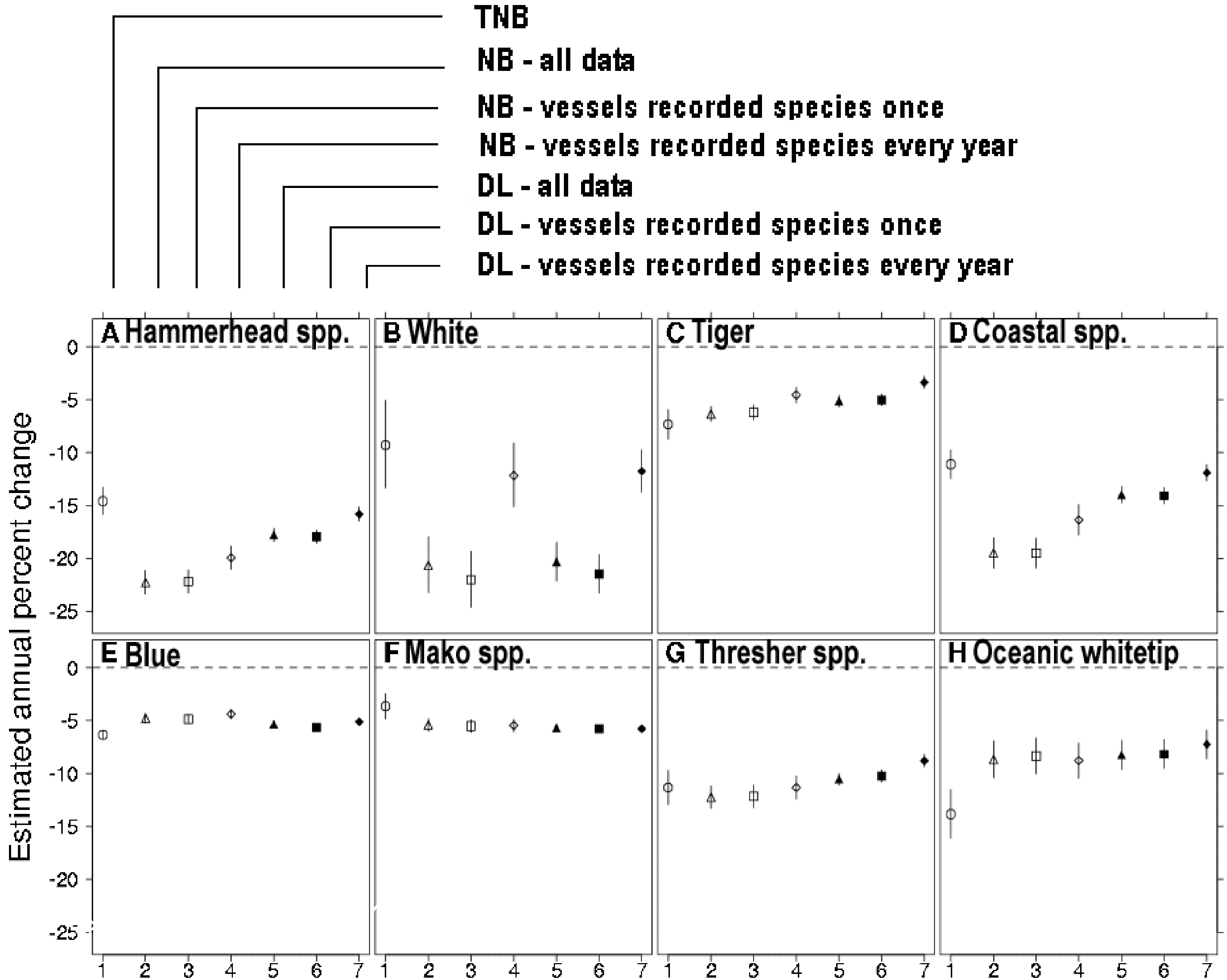
Assume reporting rate has stayed constant for:

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

Negative binomial models

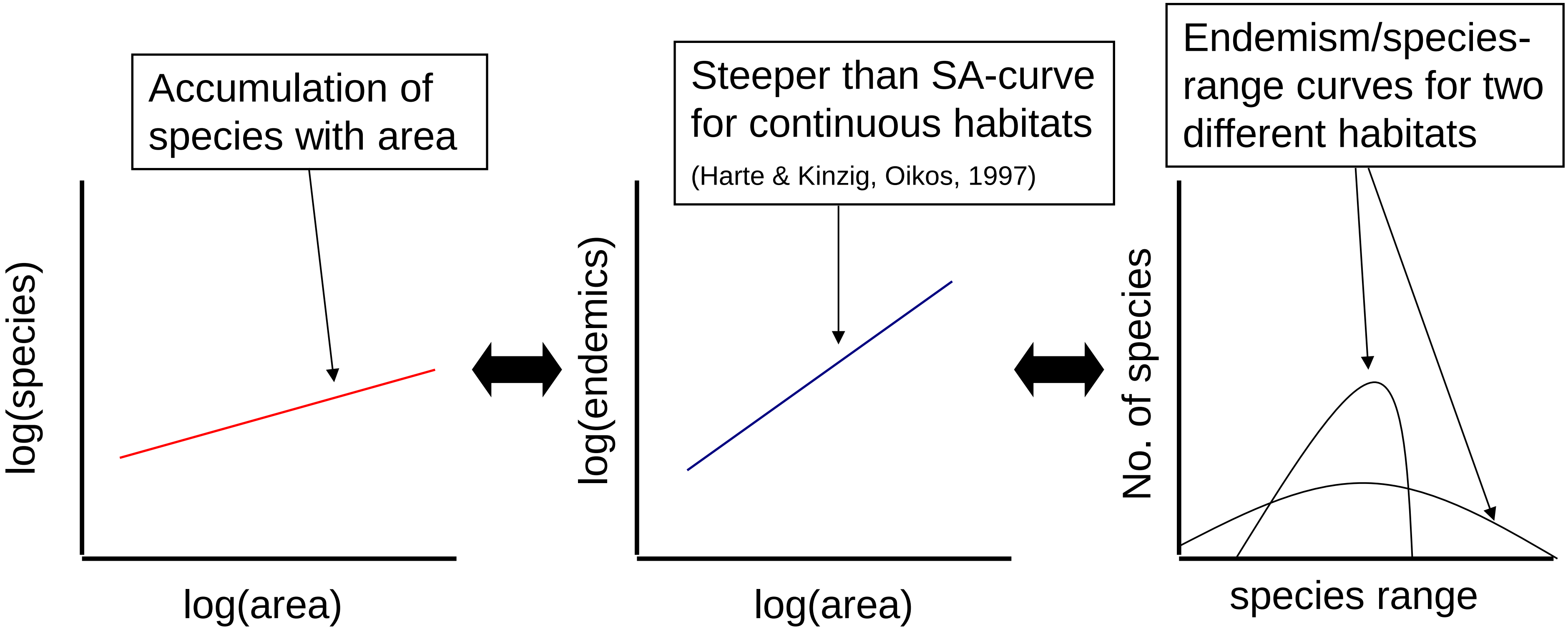
Delta-lognormal models

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



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

Area, species range, and endemism

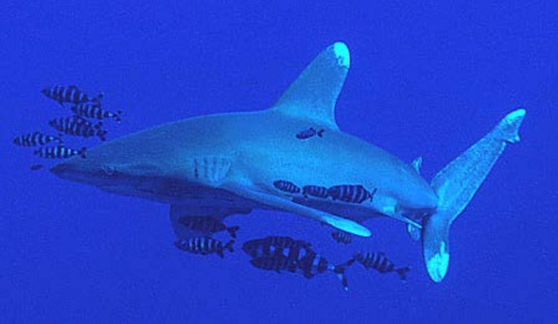


Endemism is explicitly defined by spatial scale. Is there a way to link all these diagrams, and can we create a unifying theoretical model?

Can we compare the patterns of endemism between habitats and assess their differential vulnerability?

Susanna Fuller - Deep water sponge conservation

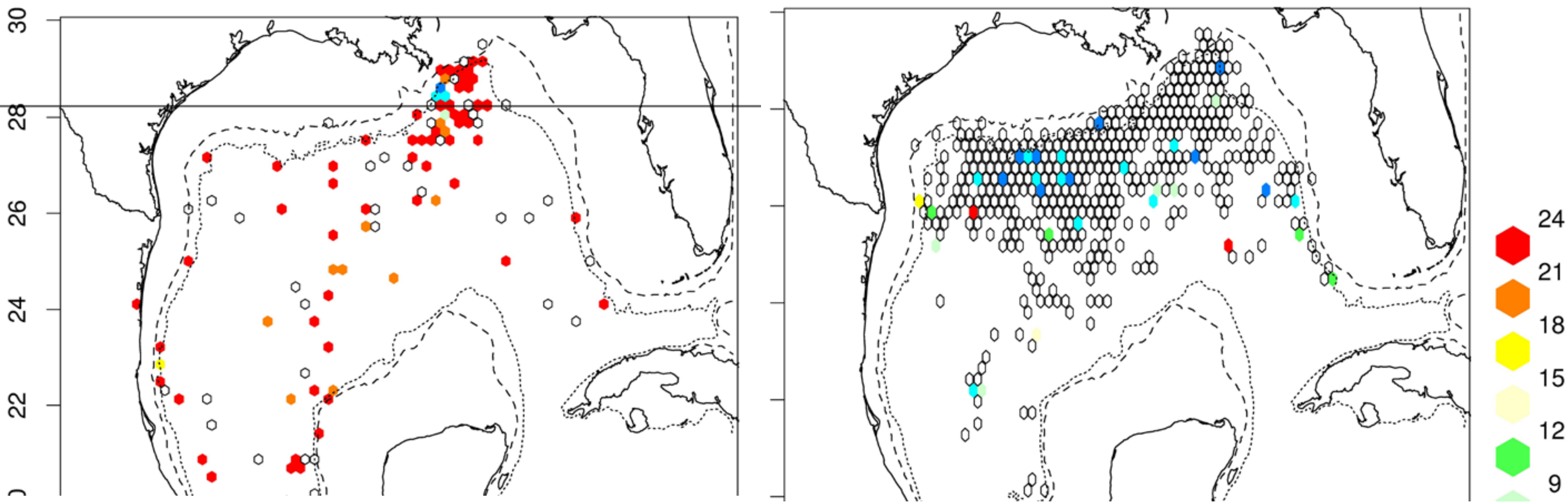
What was the most common large animal (>50 Kg) in the world? (perhaps this one was)



Loss of sharks in the Gulf of Mexico

300 fold decline – no one noticed

[redacted]



1950's

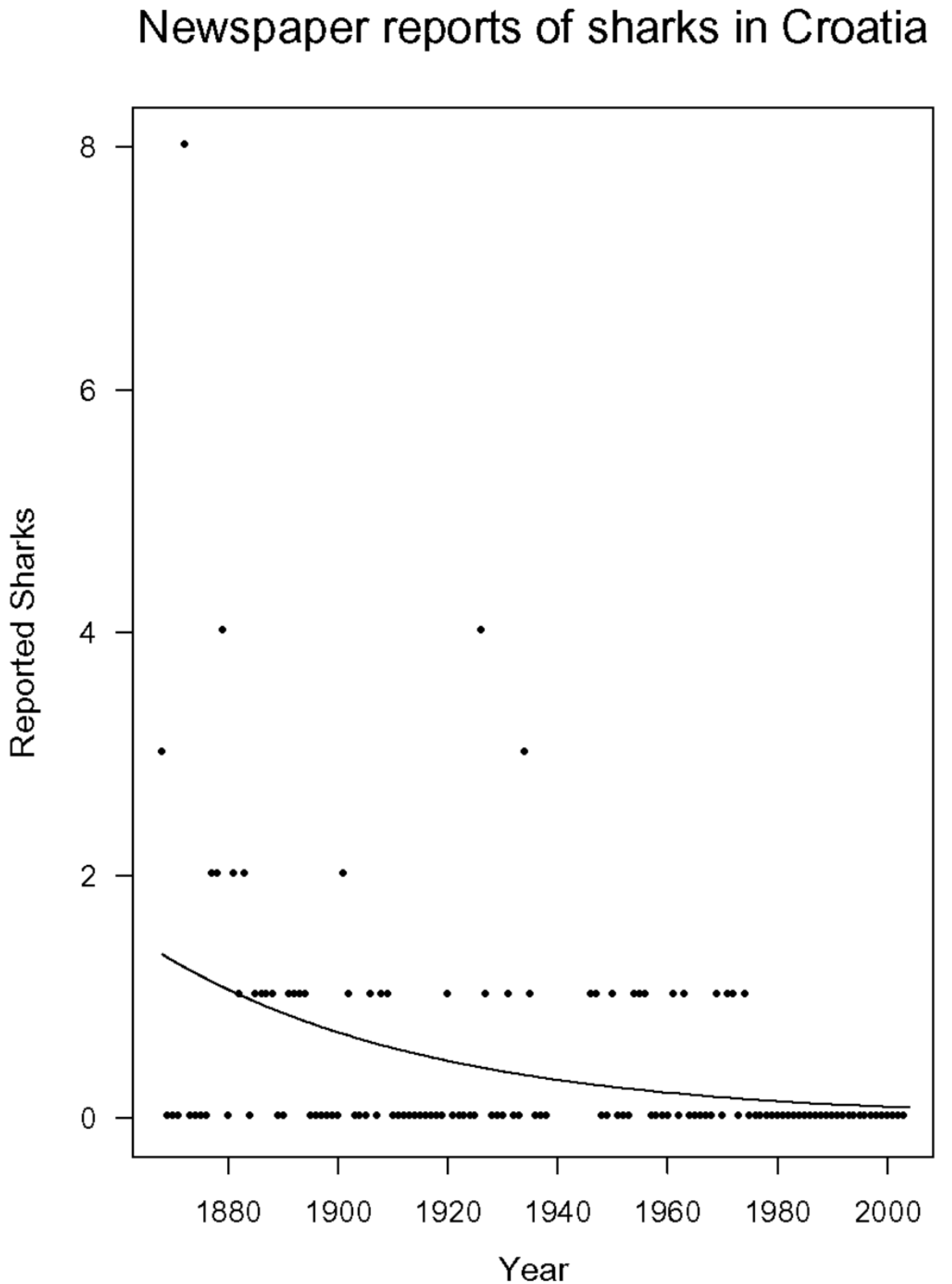
1990's

Oceanic Whitetip captures per 10,000 hooks

Baum and Myers, 2004 Ecology Letters

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

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

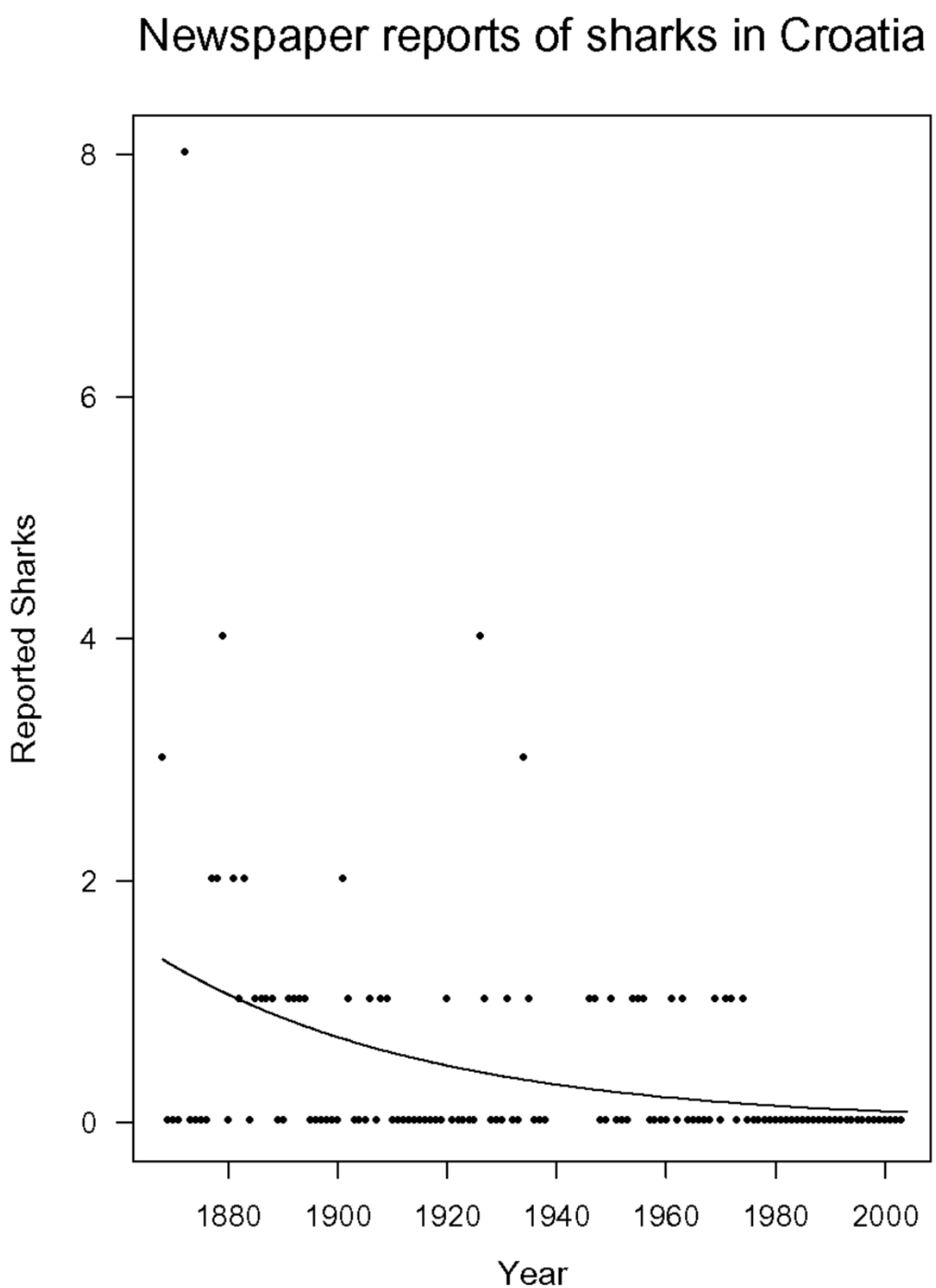
1946 - Pig of 10 kg in stomach

1950 - Encounter during eating a dead calf

1954 - Attack on boat

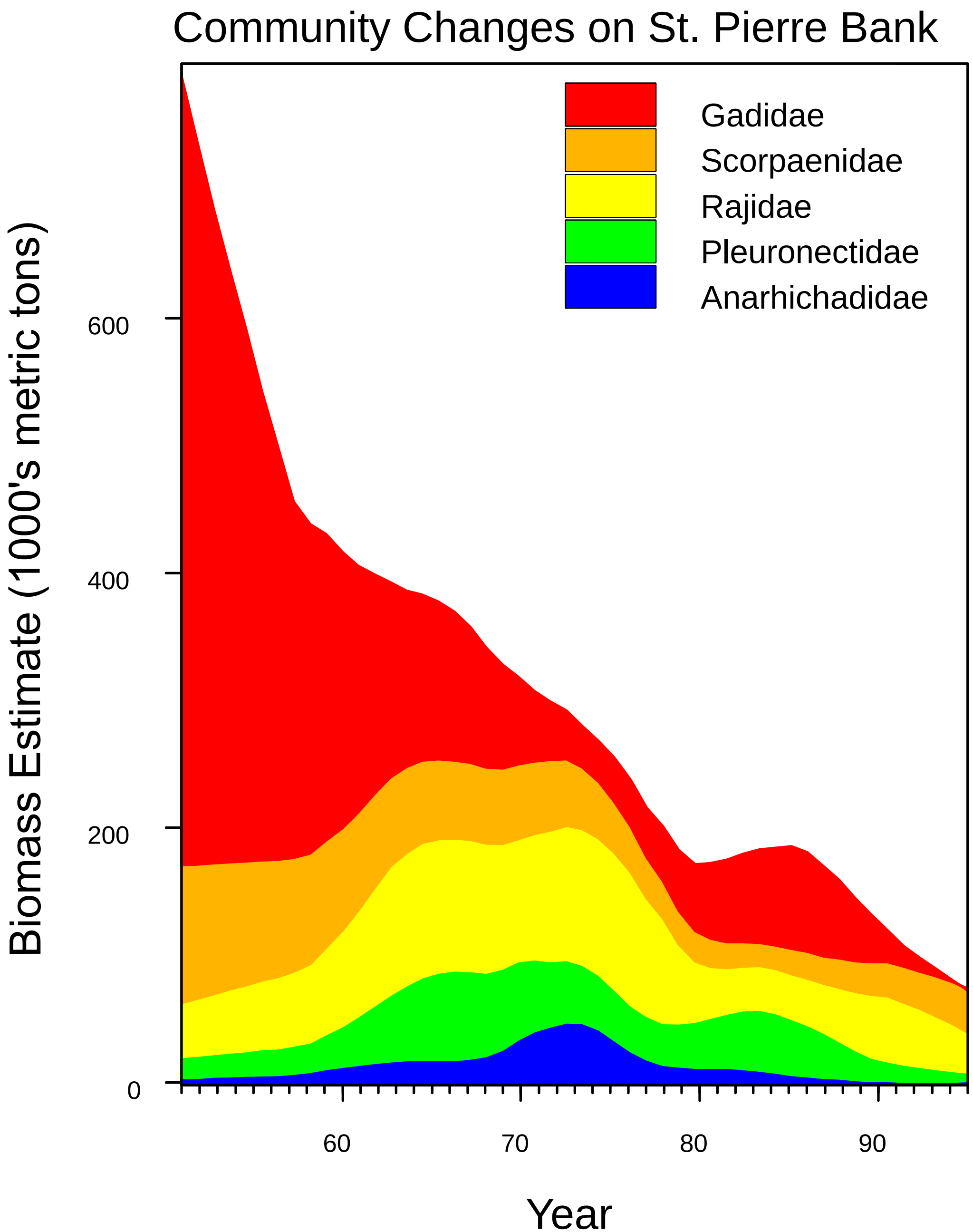
1975+ -No sightings.

Soldo and Jardas, Periodicum Bologorum, 2002

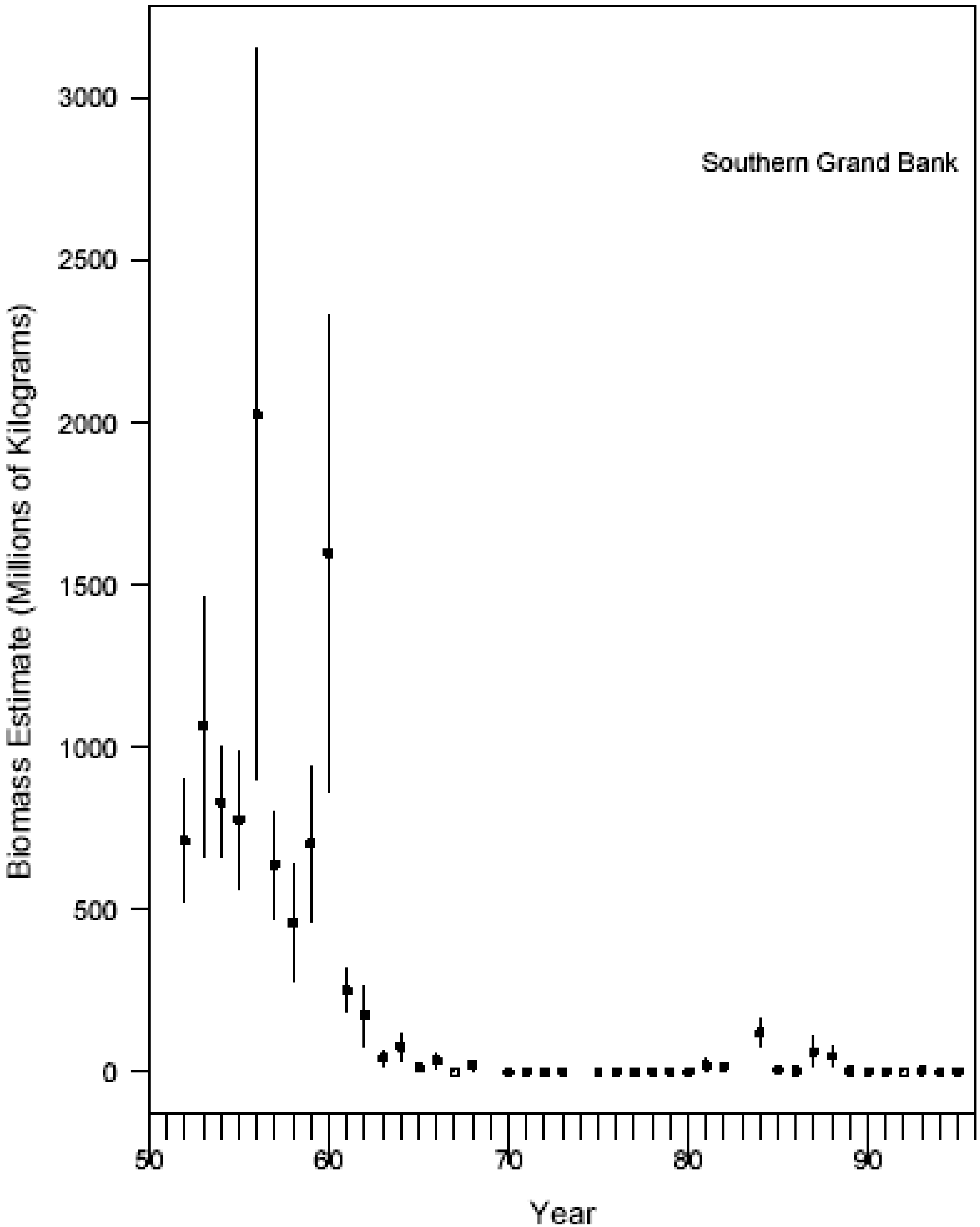


Newspaper reports of sharks in Croatia
Reported Sharks
Year
0
2
4
6
8
1880
1900
1920
1940
1960
1980
2000


788
757
525
650
620
770



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



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

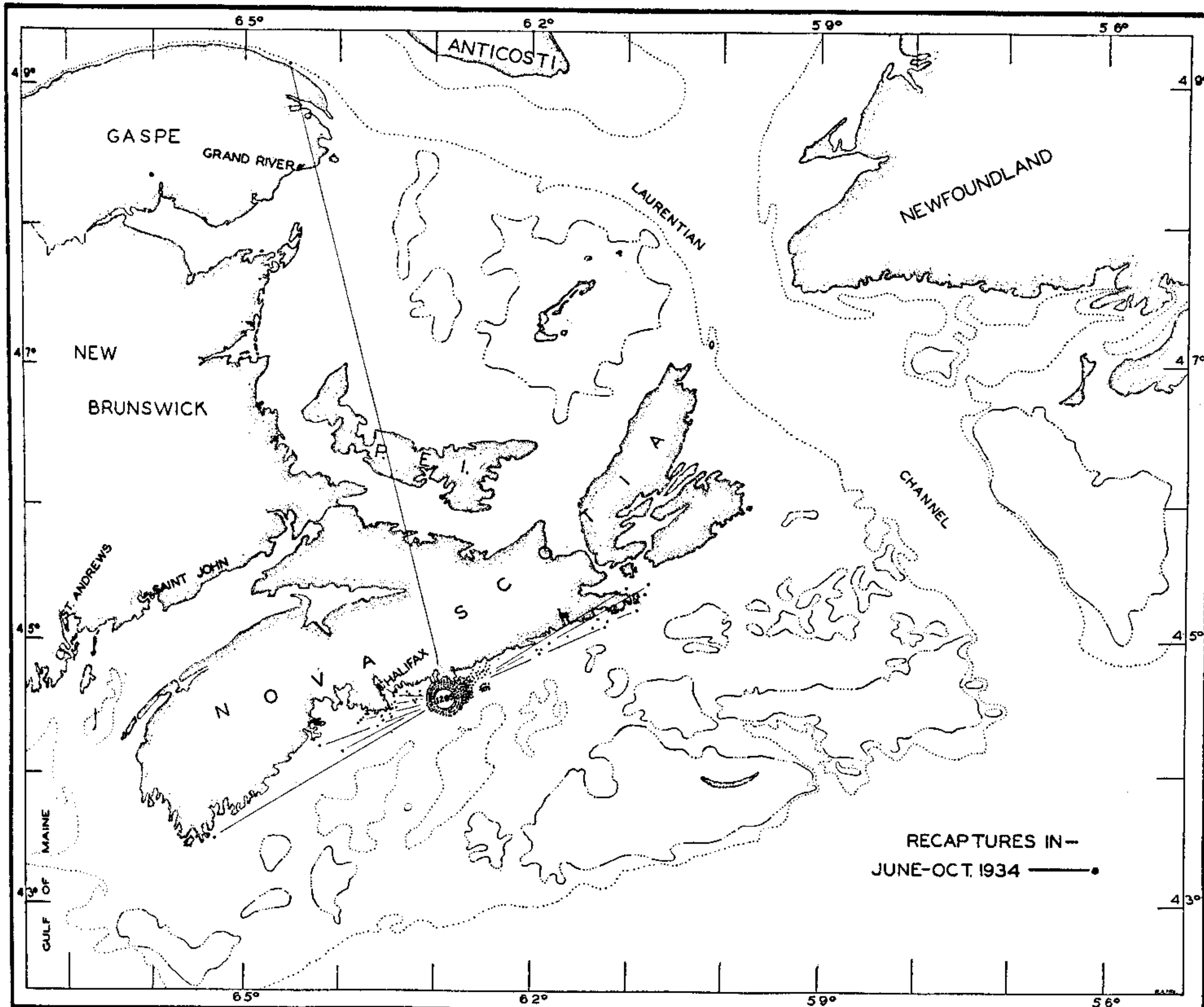


FIG. 21.—Recaptures to October, 1934, of cod tagged in the Jeddore Rock to Egg Island area, N.S., in May, 1934.

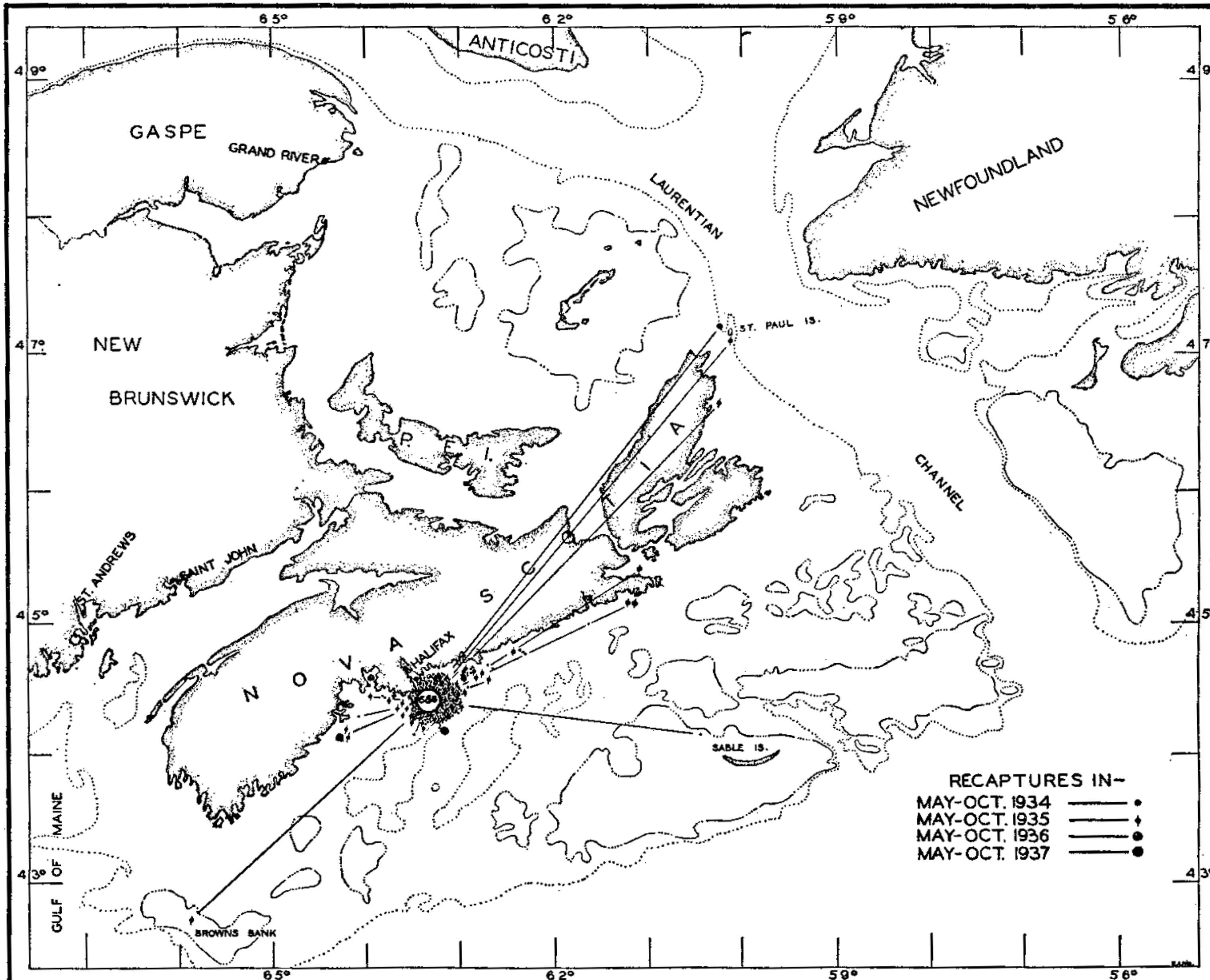


FIG. 18.—Recaptures in May to October, 1934, 1935, 1936 and 1937, of cod tagged near Halifax in June, 1934.

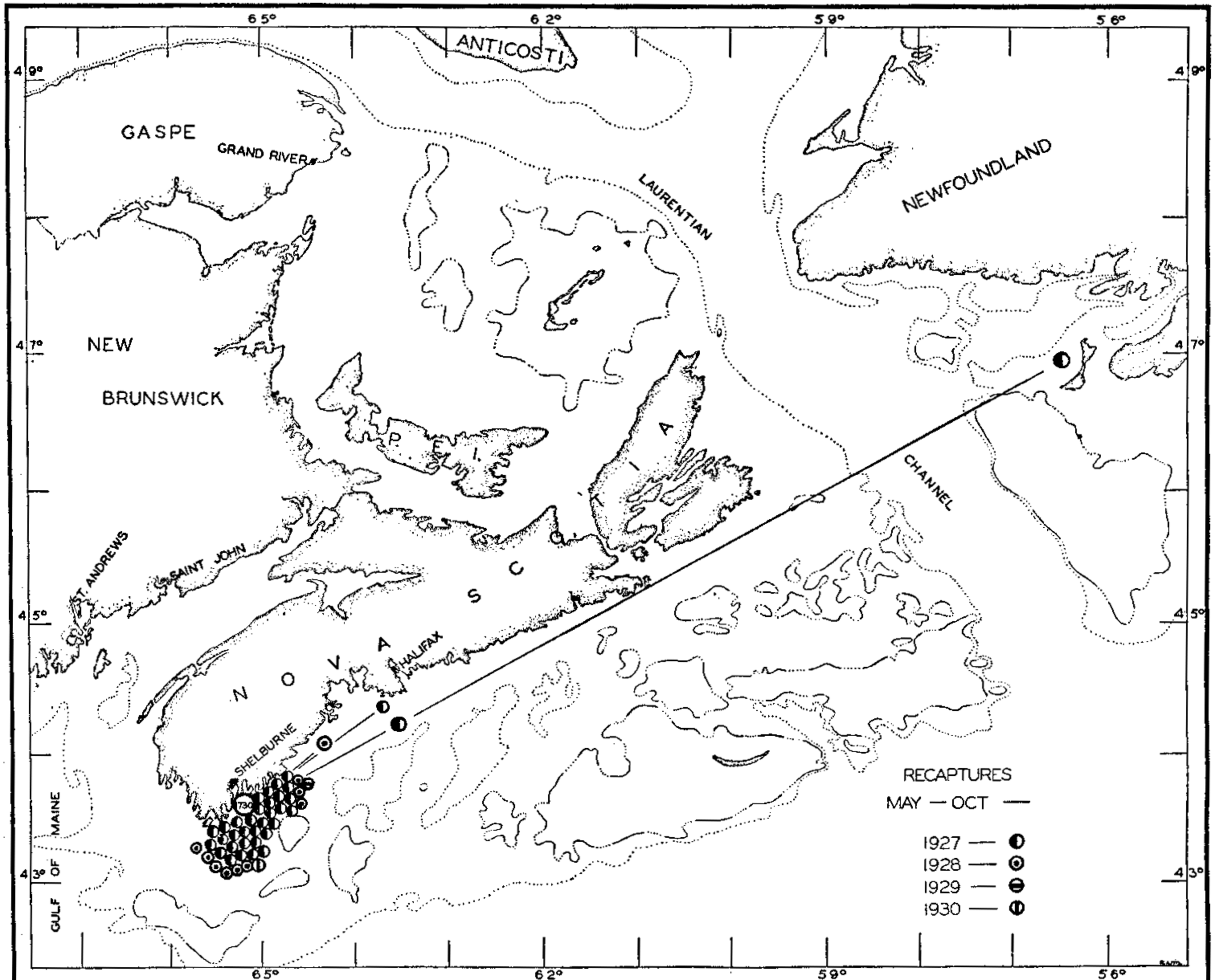
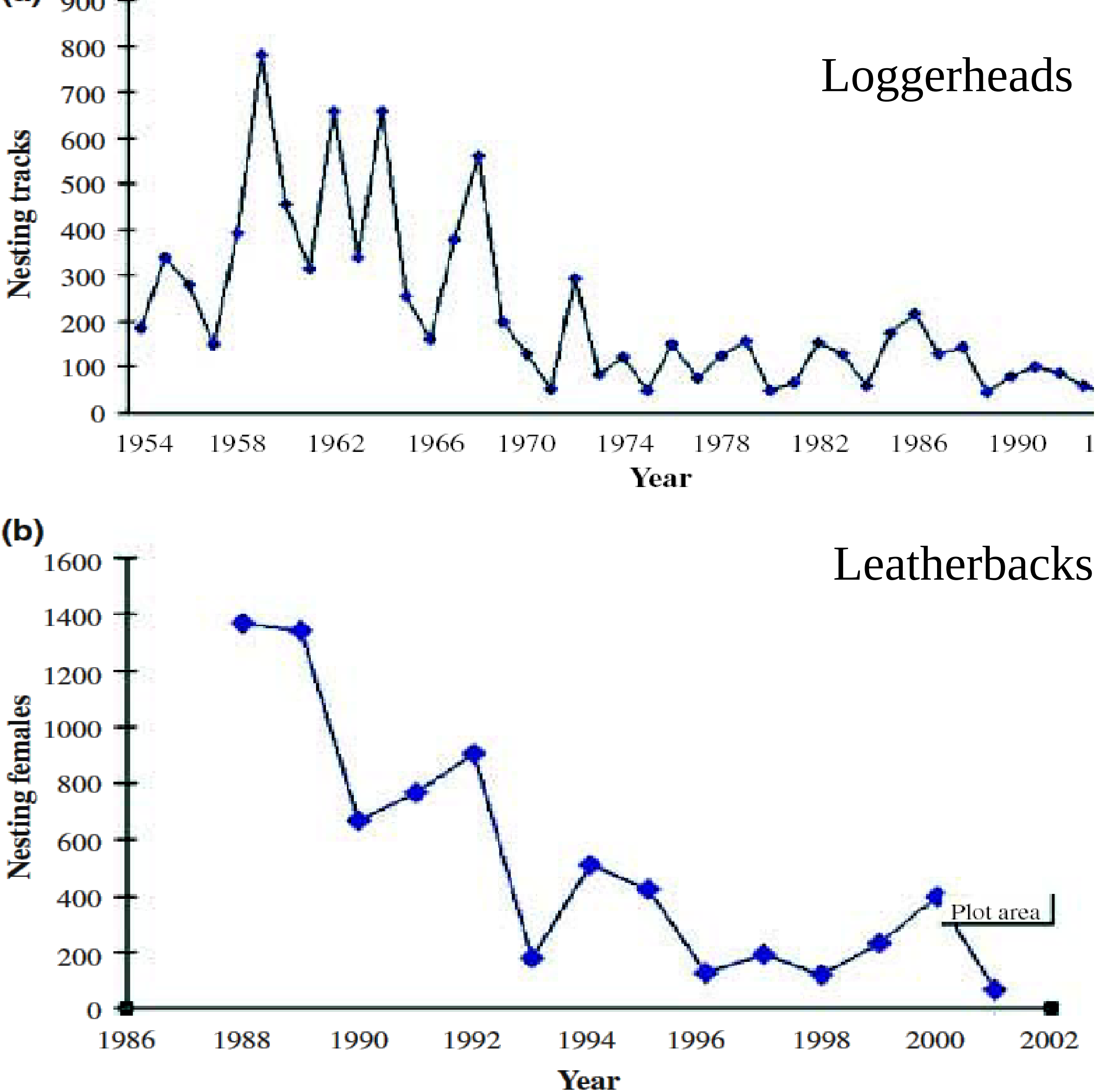


FIG. 15.—Recaptures during "summers" of 1927, 1928, 1929 and 1930 of cod tagged off Shelburne, N.S., during September and the first day of October, 1926.

Hippocratic Oath:
Modified for Fisheries Biologist by RAM:

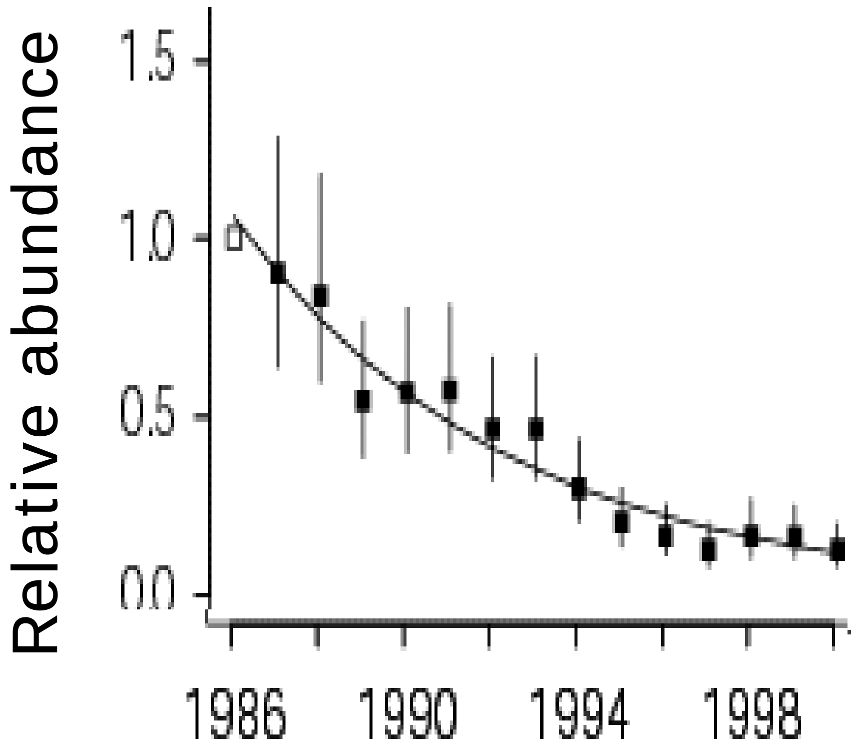
- **"First, don’t drive any population or species extinct”.**



Lewison et al. 2004
Ecology Letters

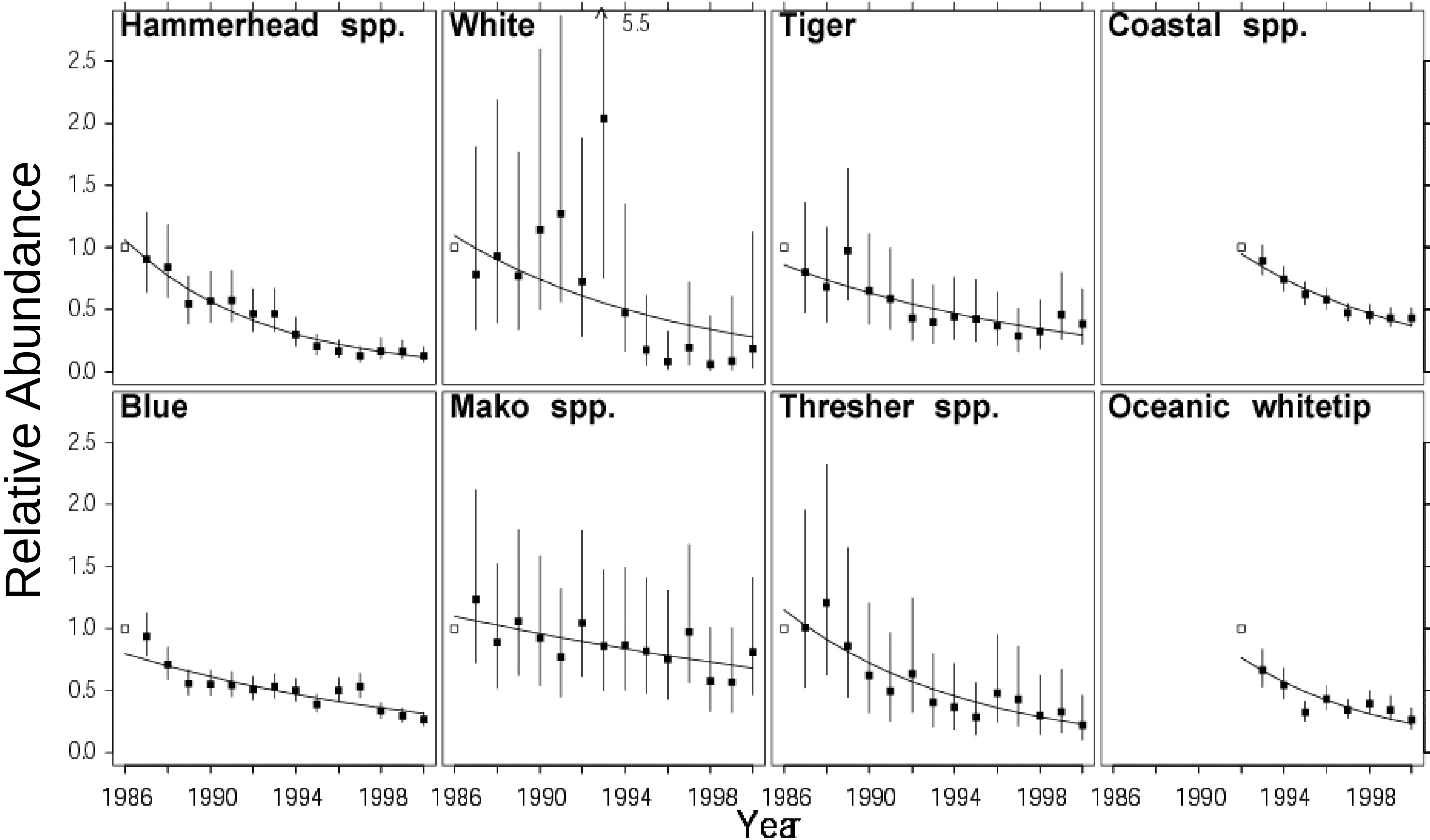
Hammerhead sharks

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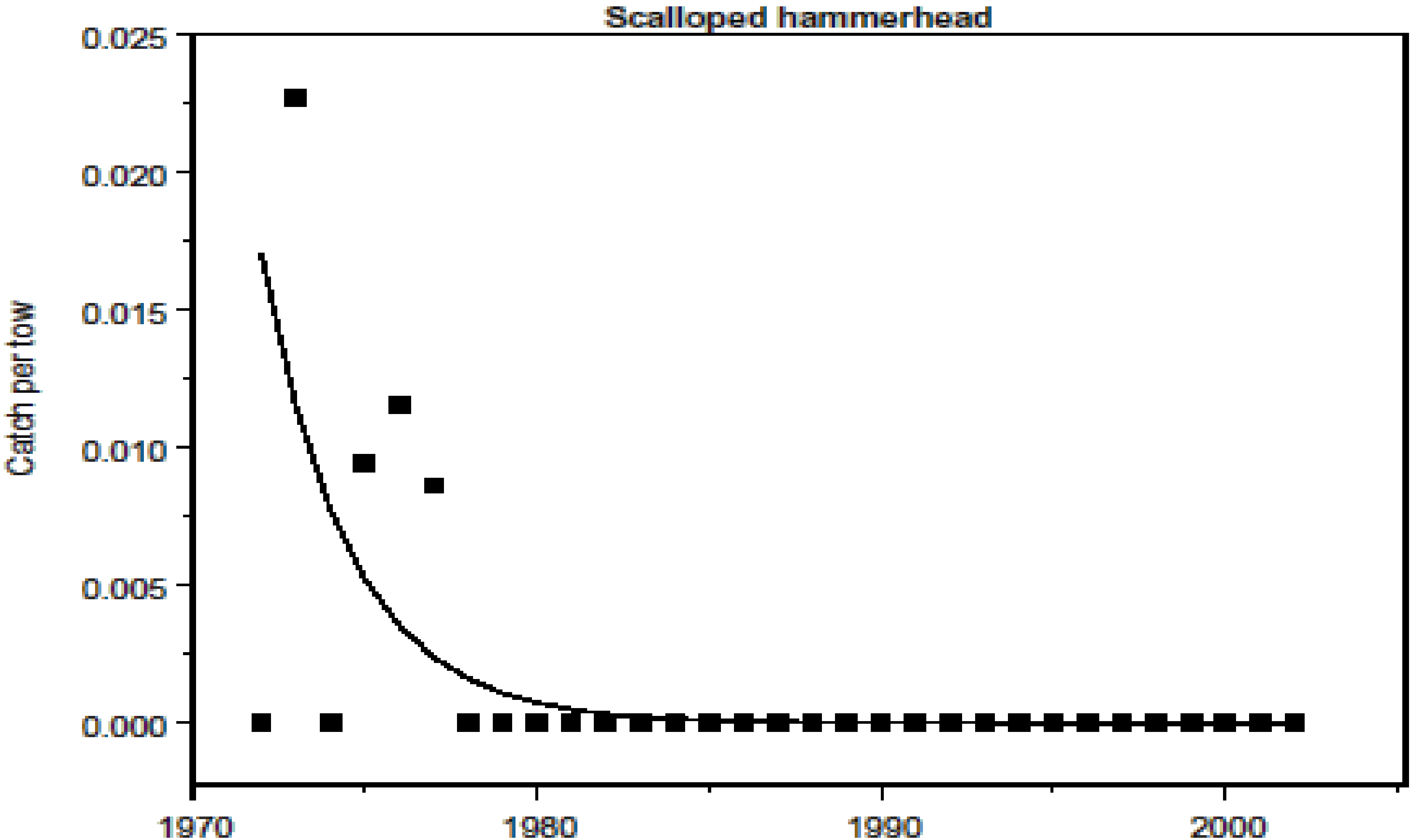
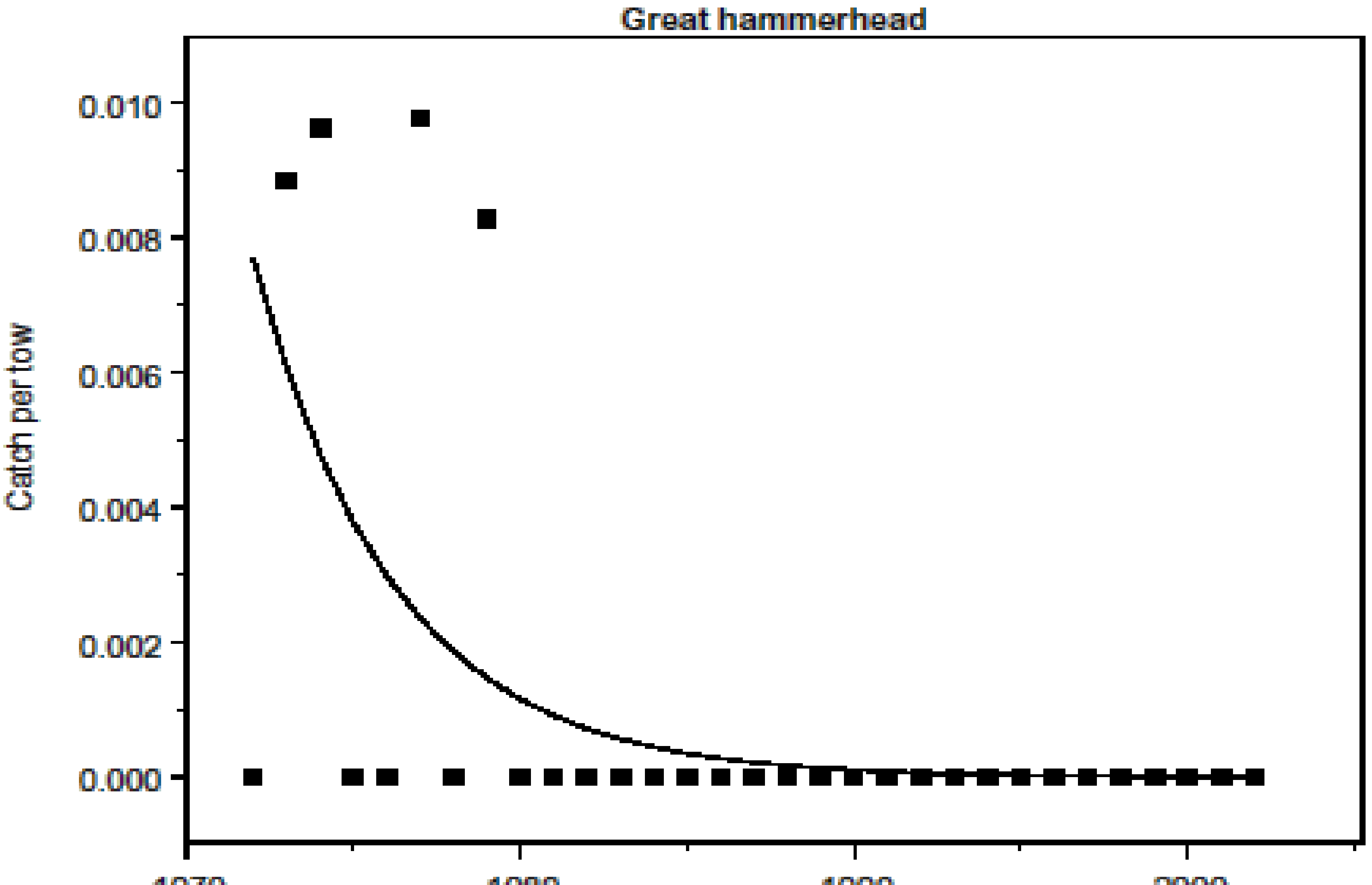
Coastal spp.
Blue
Mako spp.
Thresher spp.
Oceanic whitetip
Relative Abundance
0.0
0.5
1.0
1.5
2.0
2.5
1986
1990
1994
1998
Year

Same results for trawl surveys in Gulf of Mexico



Same results for trawl surveys in Gulf of Mexico

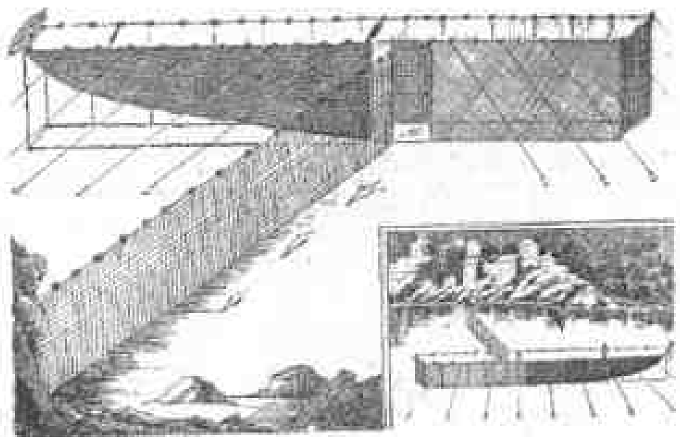


Decline of Mediterranean Sharks

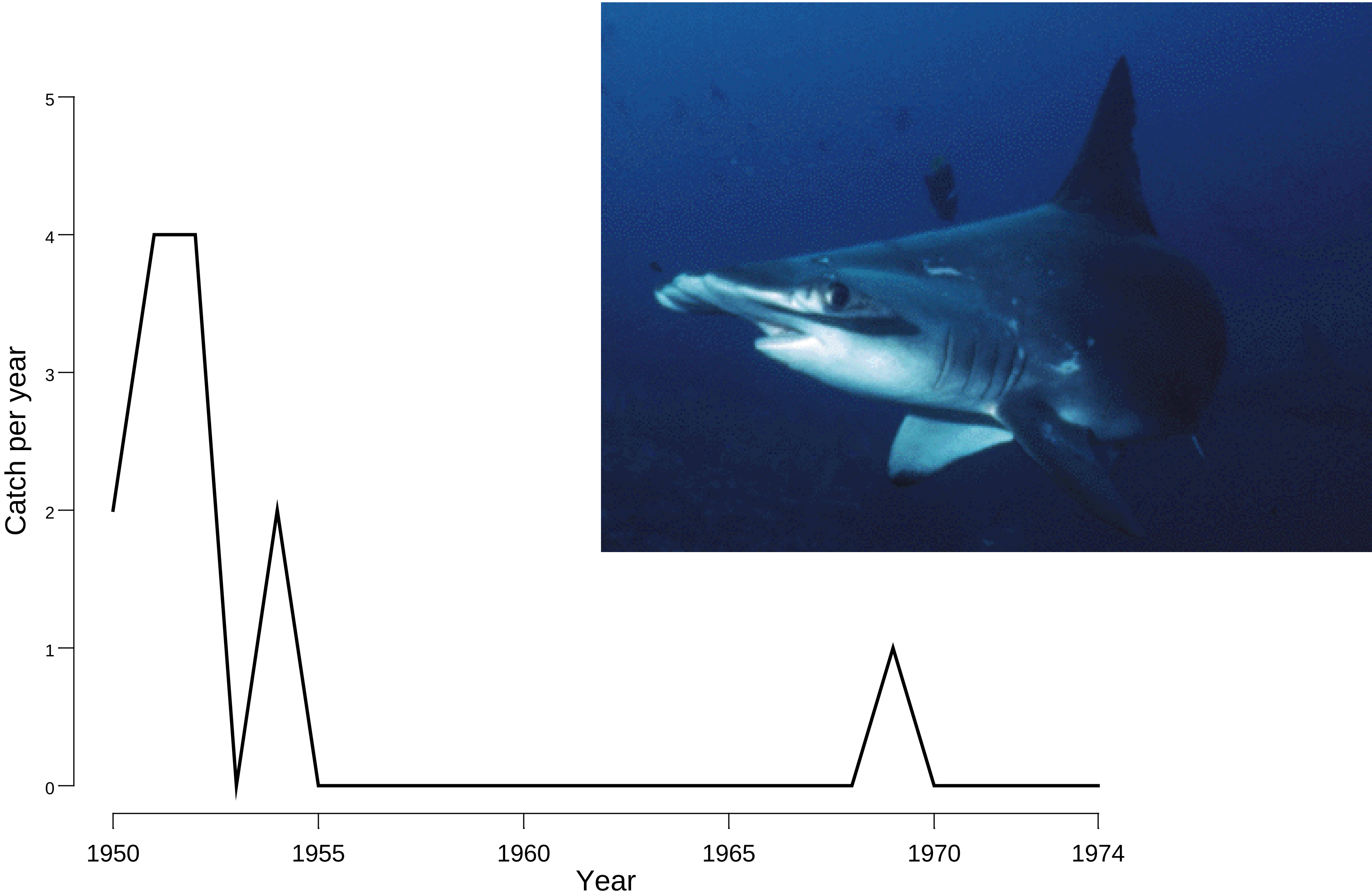
By catch associated with a Tuna Trap

In Ligurian Sea

“Tonnara di Camogli”



Decline of Hammarhead sharks

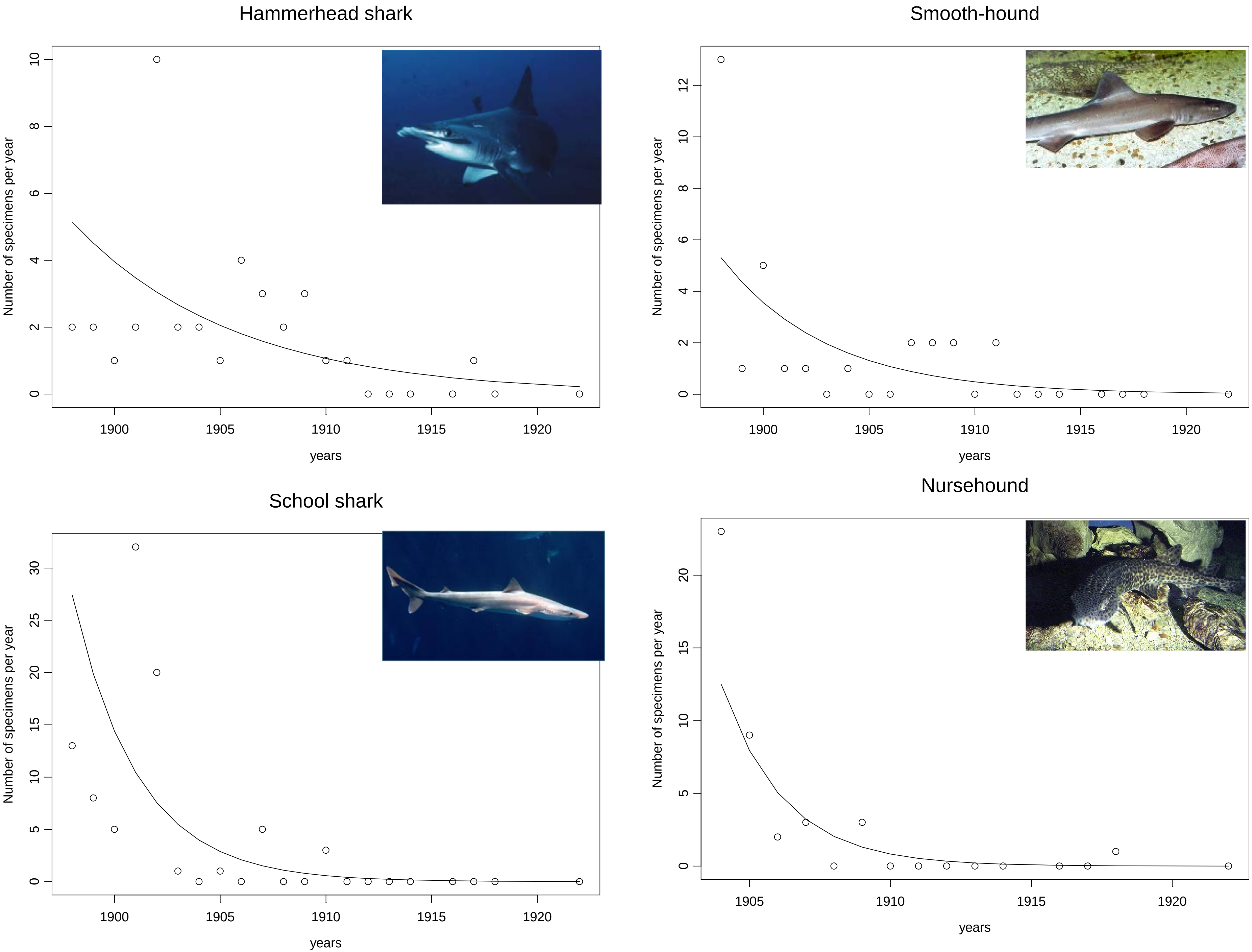


Boero F. & A. Carli 1979 – Boll. Mus. Ist. Biol. Univ. Genoa (47)

Decline of Mediterranean Sharks

By catch associated with a Tuna Trap
In Tirrenian Sea

“Tonnarella di Baratti”

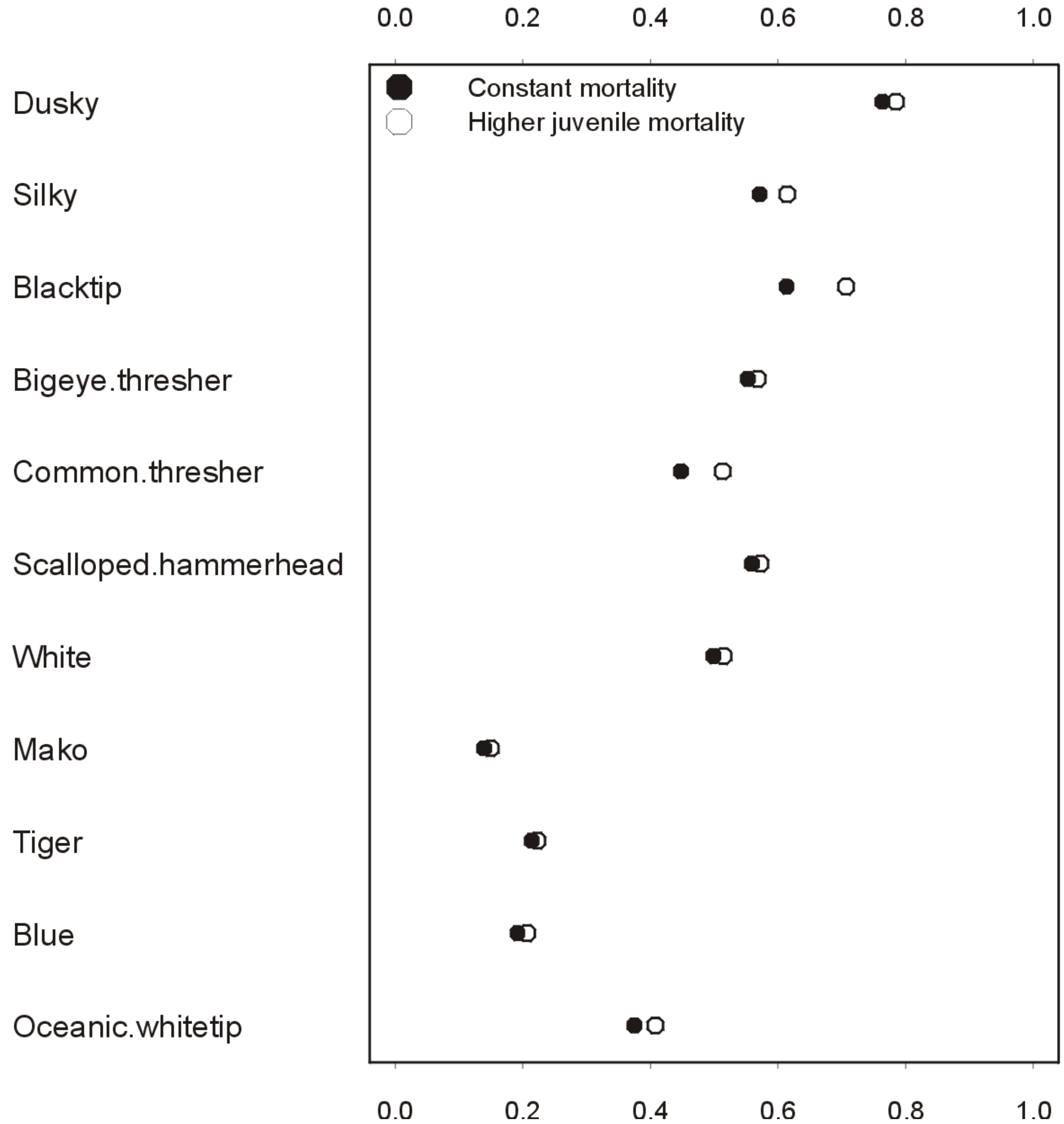


Hammerhead shark
Number of specimens per year
0
2
4
6
8
10
1900
1905
1910
1915
1920
years
Smooth-hound
Number of specimens per year
0
2
4
6
8
10
12
1900
1905
1910
1915
1920
years
School shark
Number of specimens per year
0
5
10
15
20
25
30
1900
1905
1910
1915
1920
years
Nursehound
Number of specimens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

There are at least 2 scalloped hammerhead sharks in the Northwest Atlantic

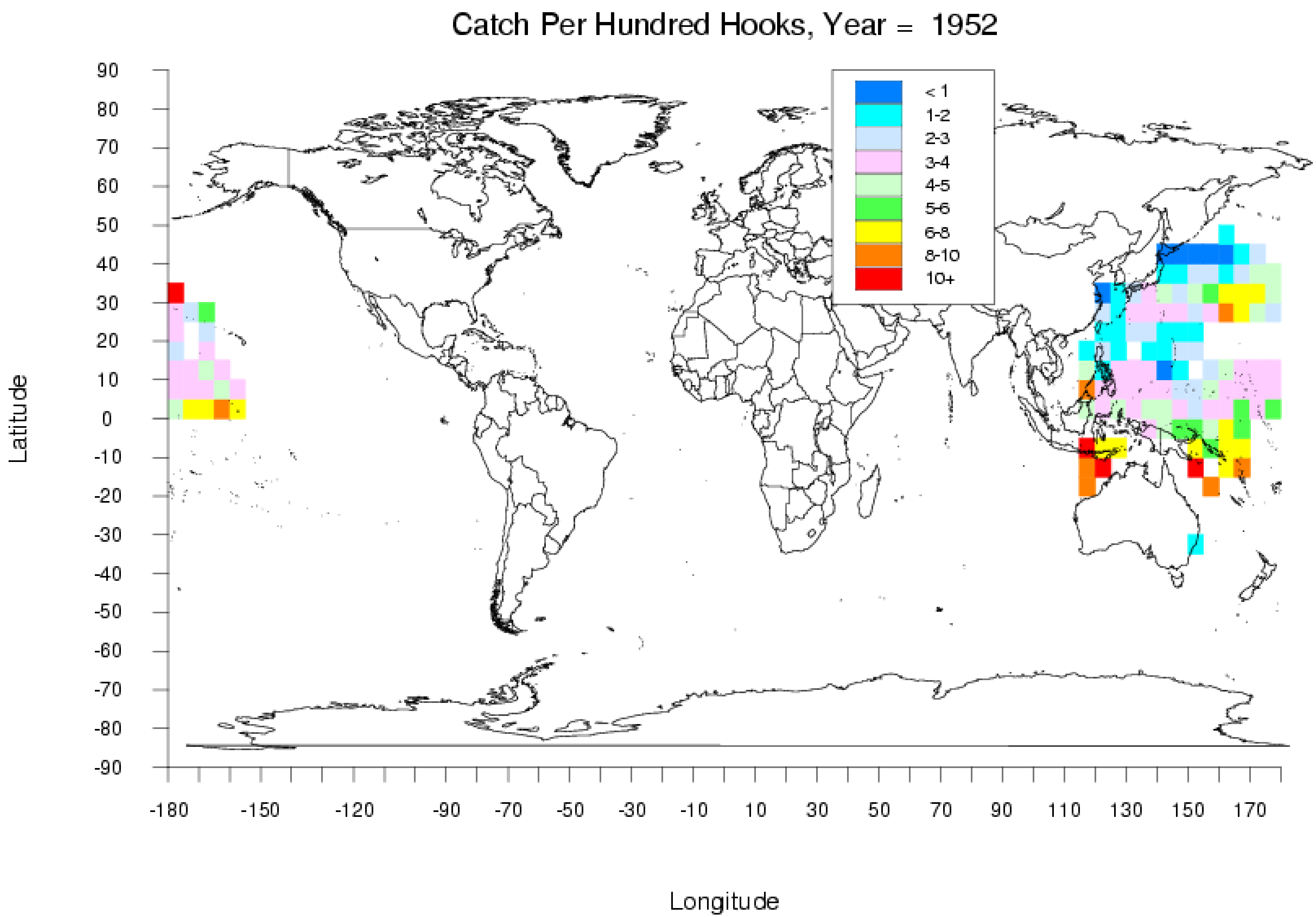
Stoner, D. S., J. M. Grady, W. B. Driggers, K. A. Priede and J. M. Quattro. Molecular Evidence for a Cryptic Species of Hammerhead Shark (Genus *Sphyrna*). *Marine Biology* (submitted).

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

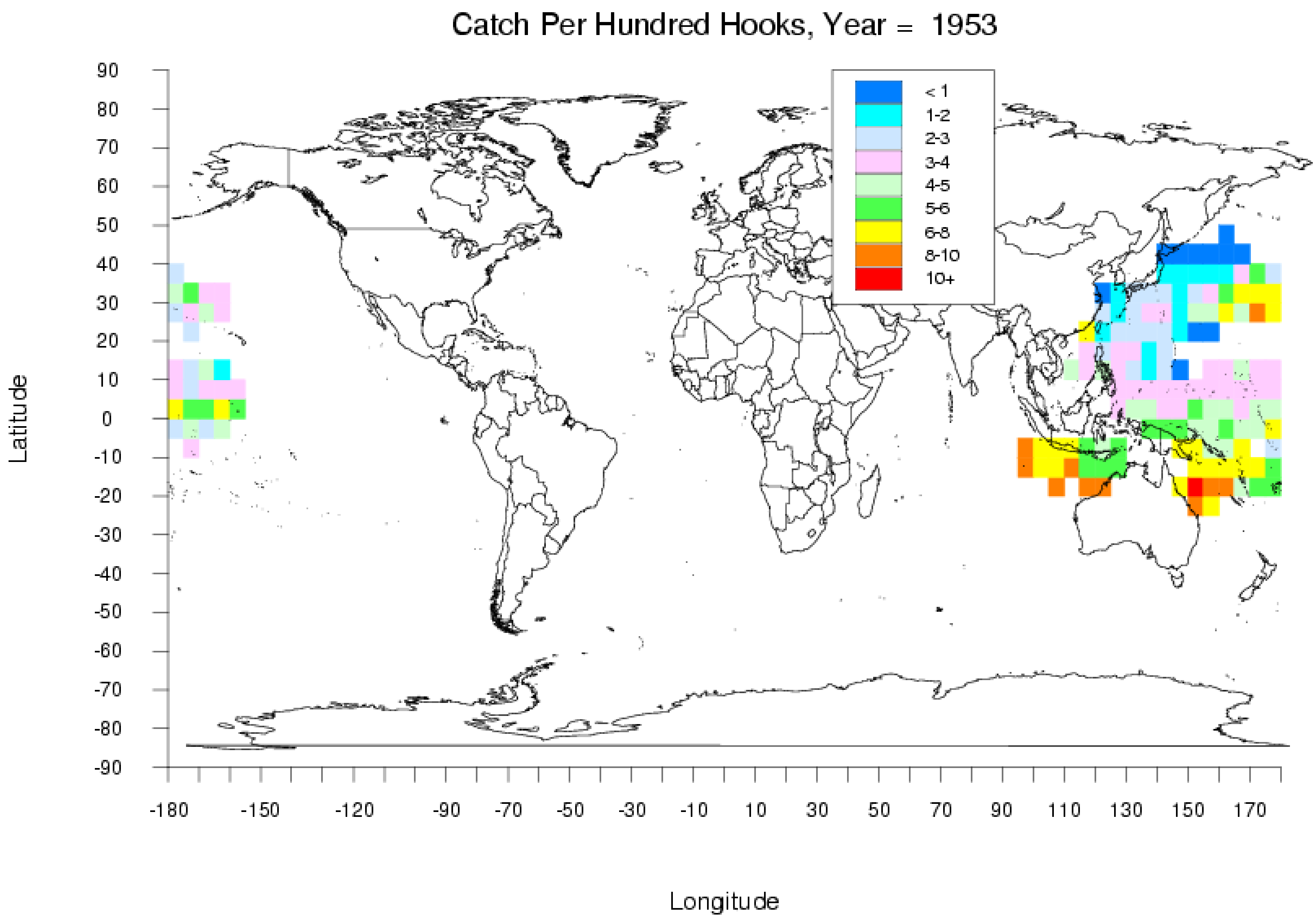


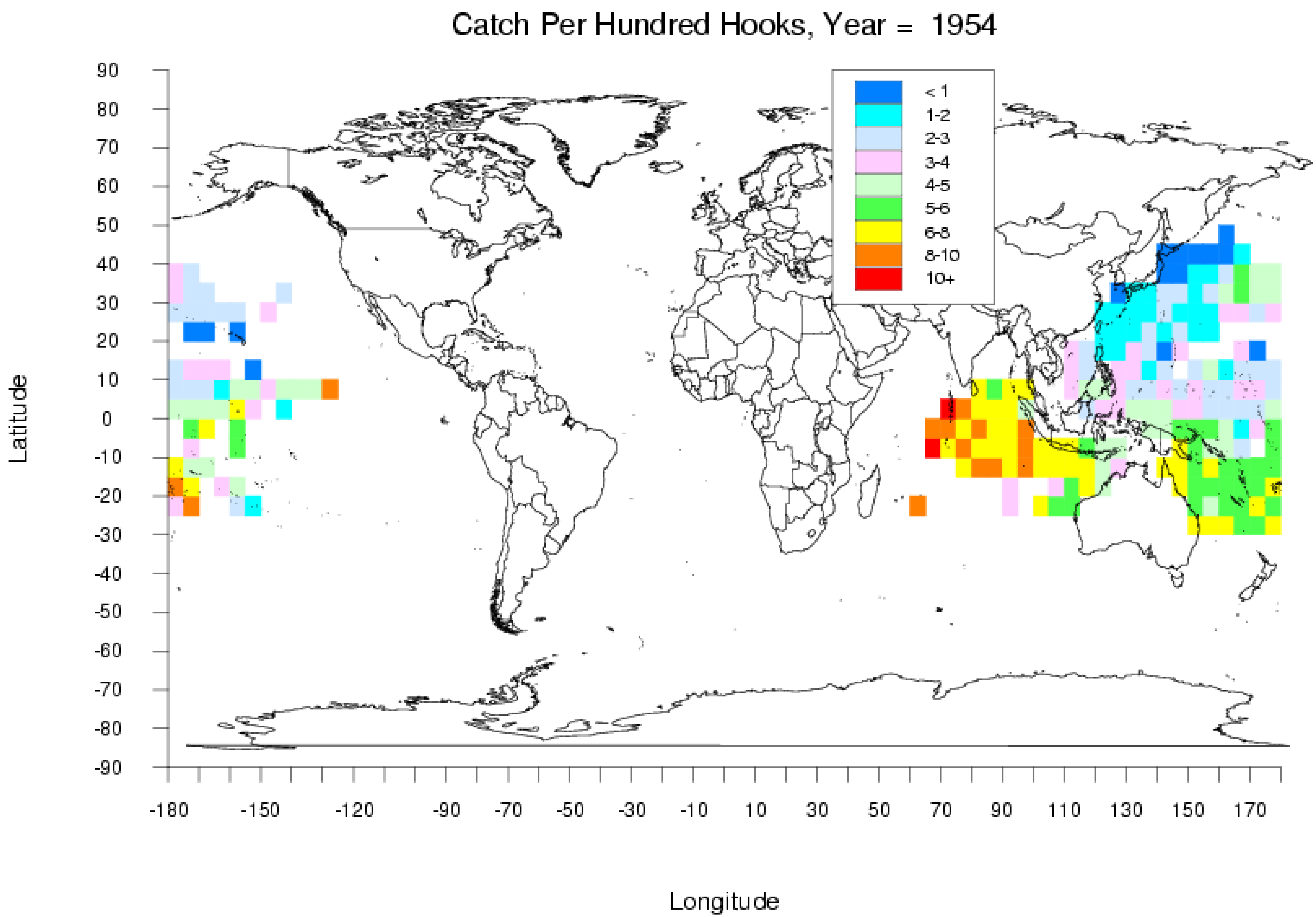
Myers & Worm, PRSB 2005

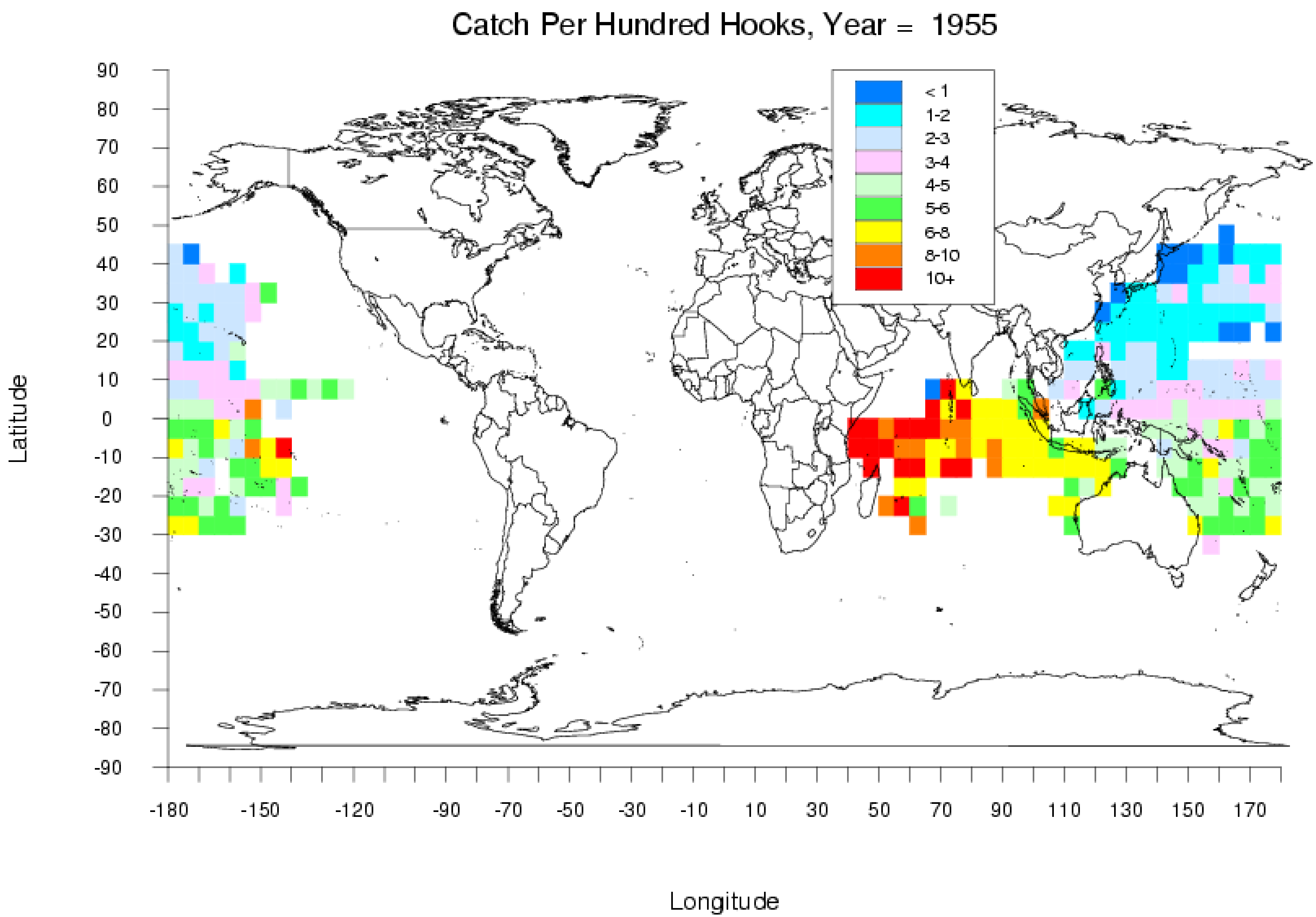

555
lbs.
LBS.
1135
CABO
BLANCO



Catch Per Hundred Hooks, Year = 1952
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
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 = 1953
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 = 1954
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude


Catch Per Hundred Hooks, Year = 1955
< 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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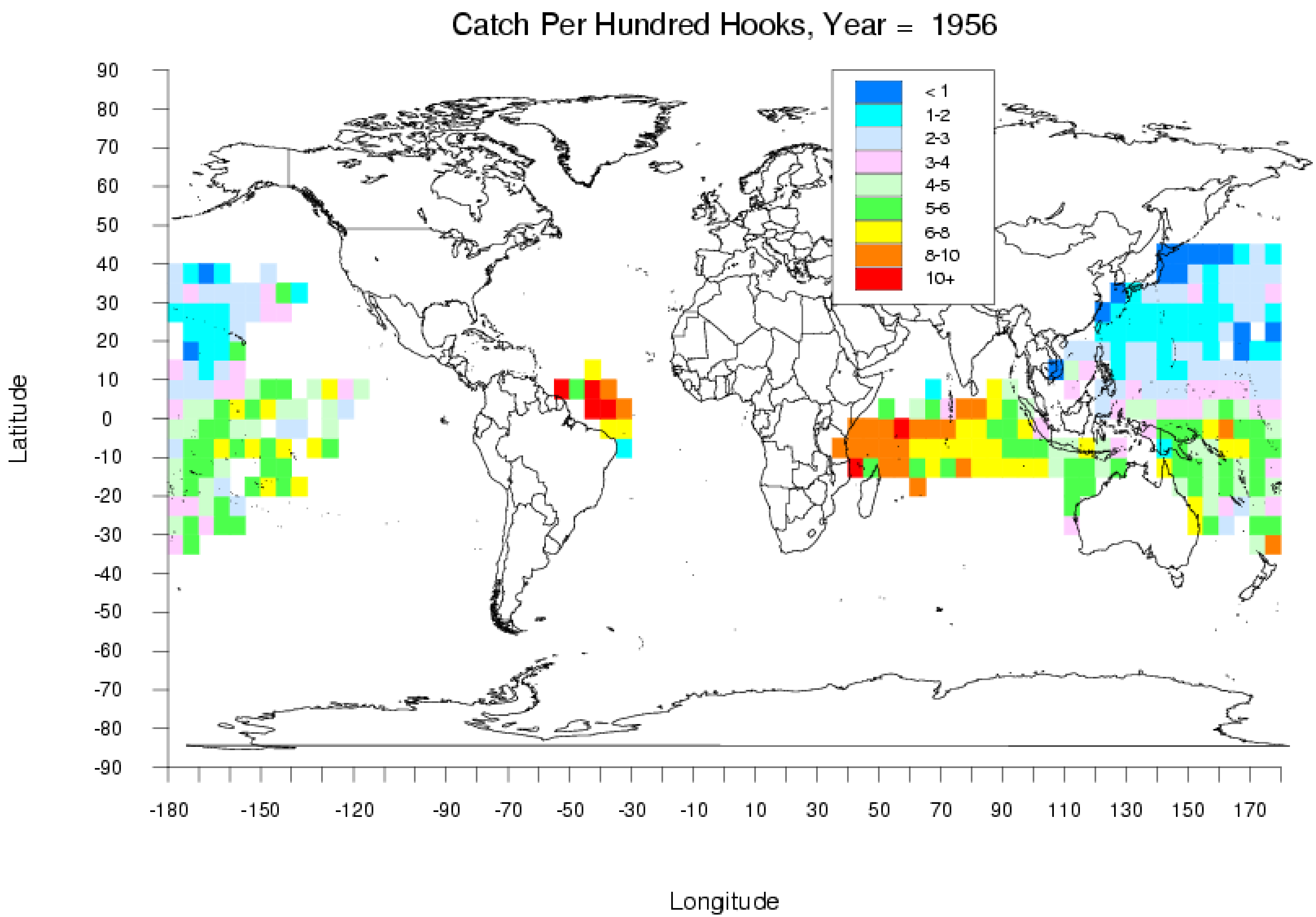
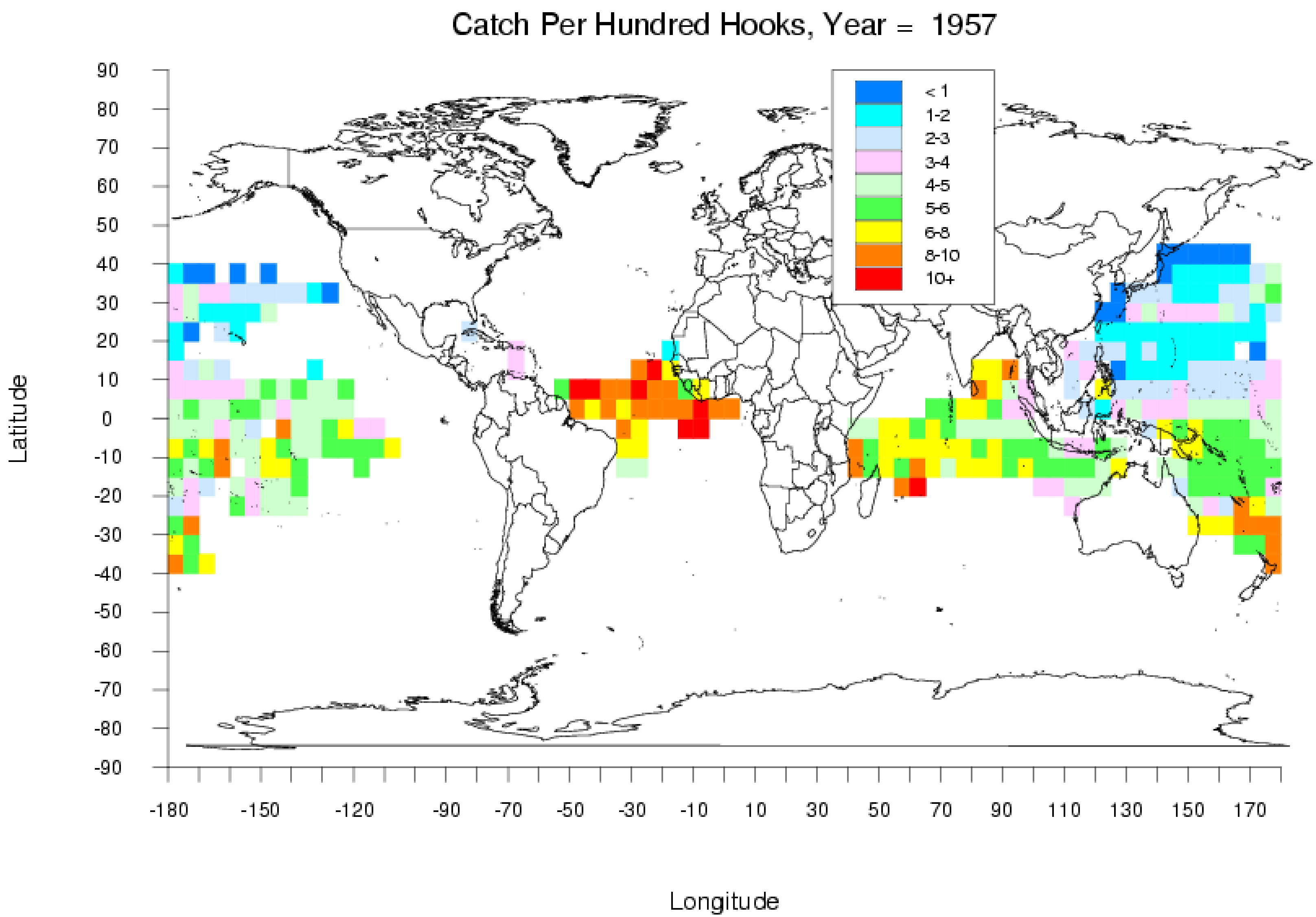
90
110
130
150
170



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



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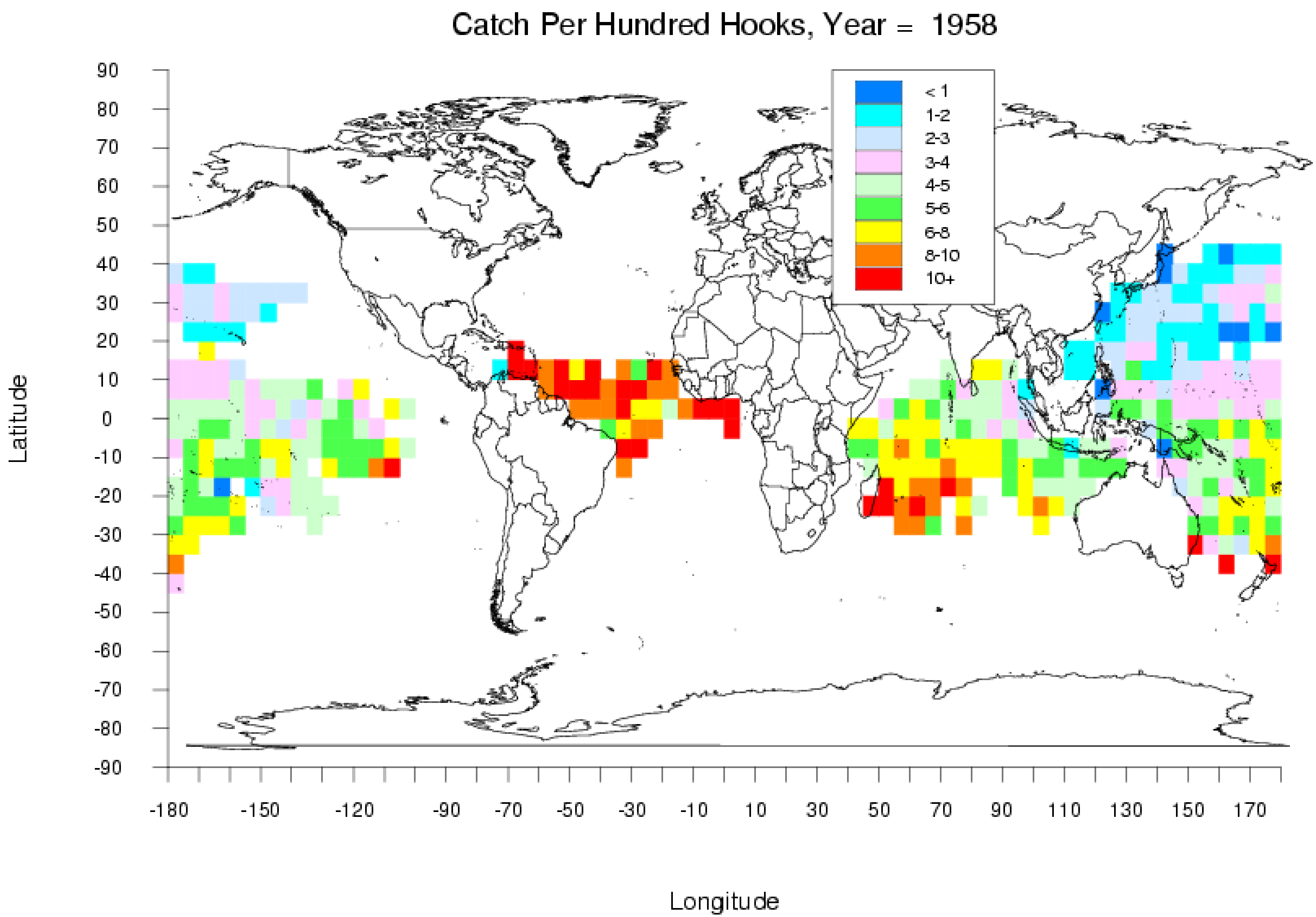
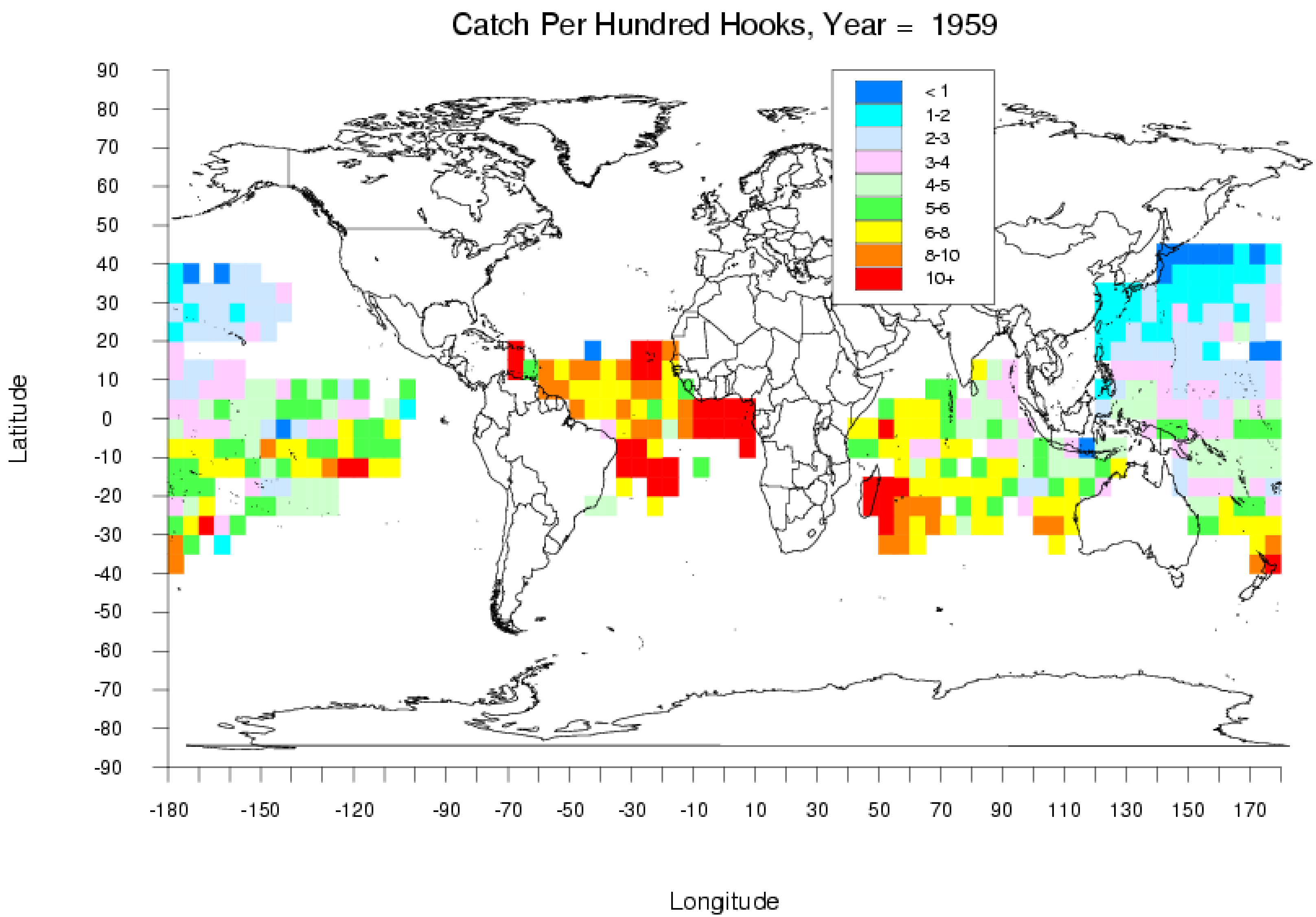
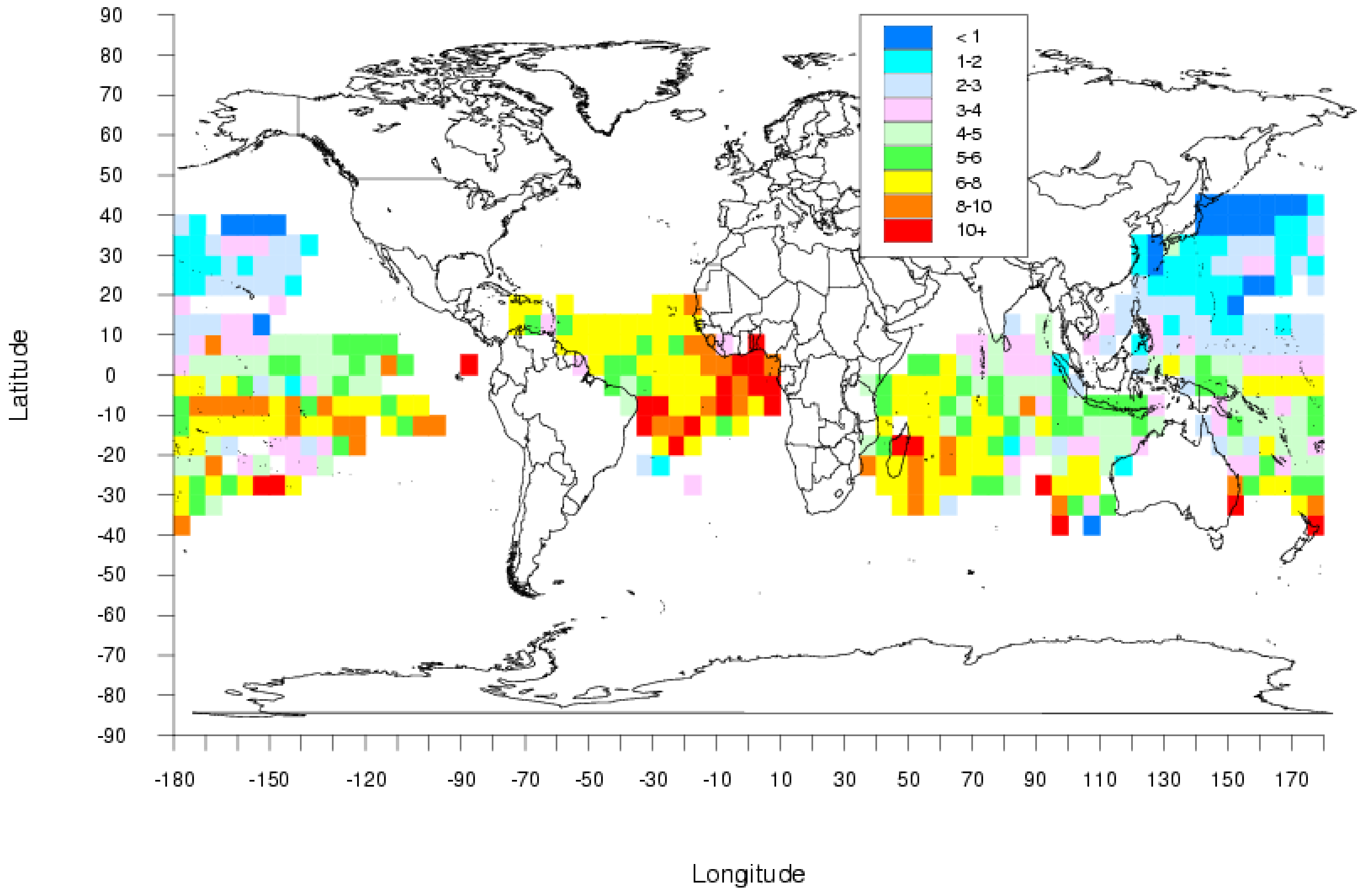
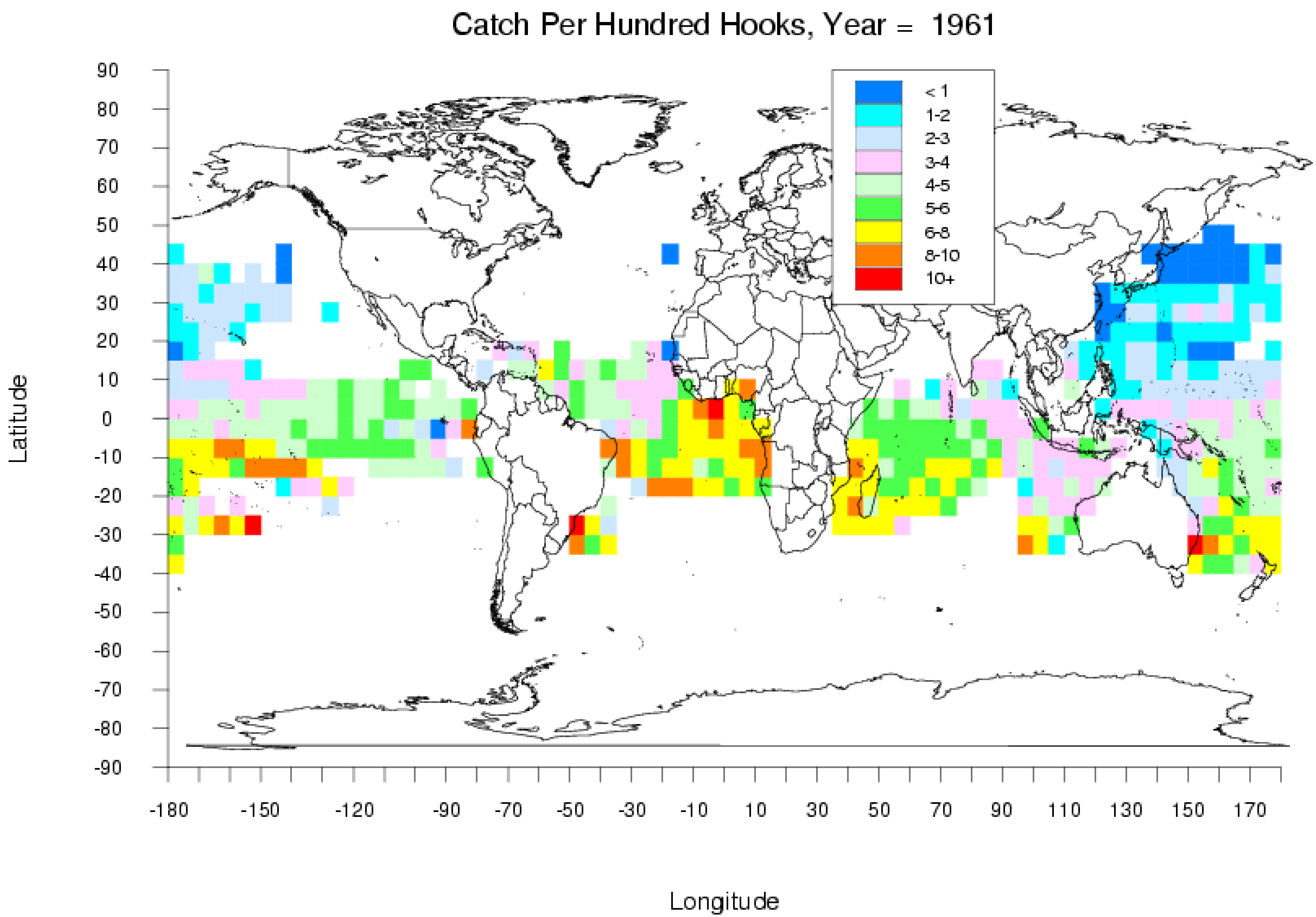
30
50
70
90
110
130
150
170

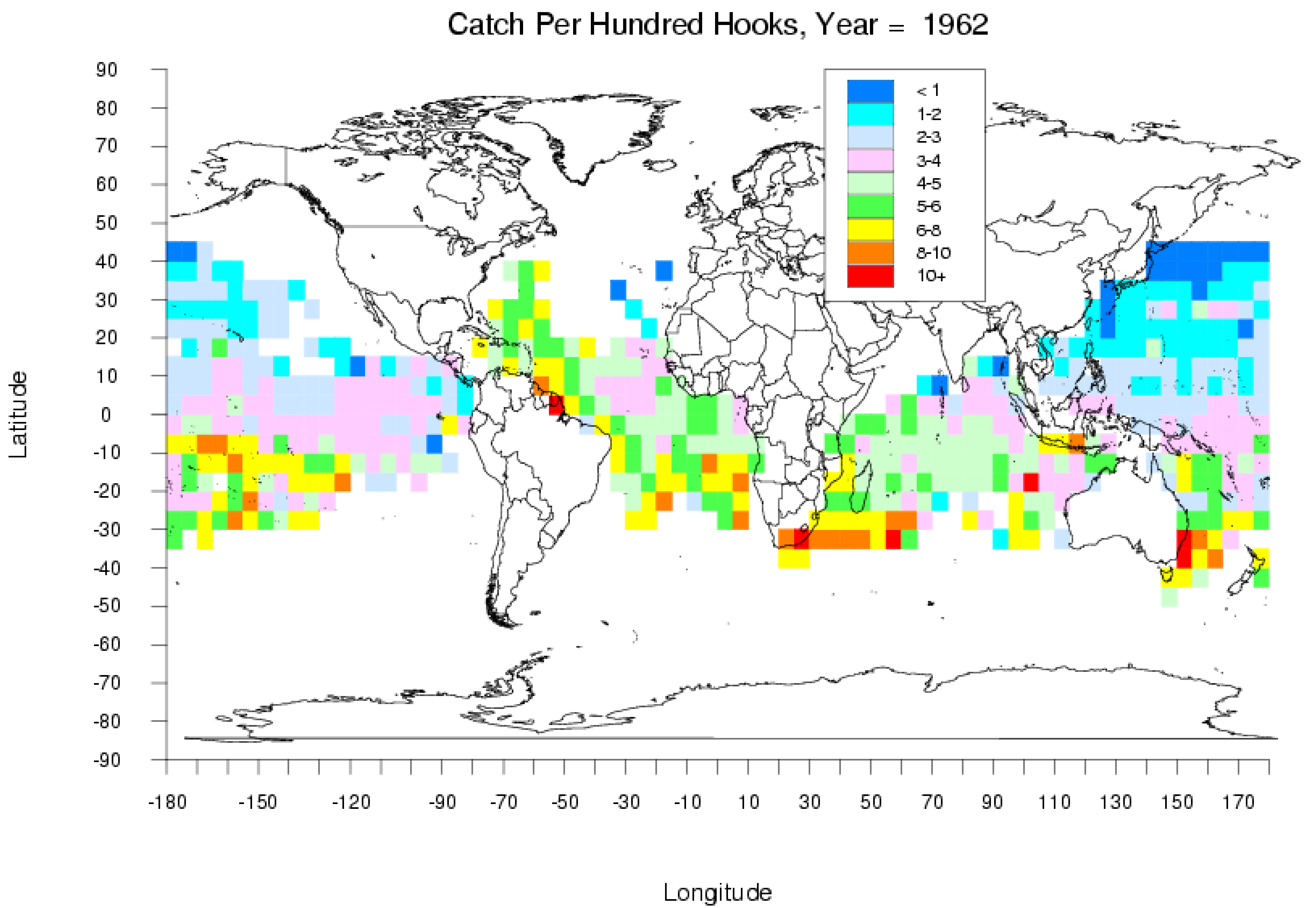

Catch Per Hundred Hooks, Year = 1958
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Latitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude


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

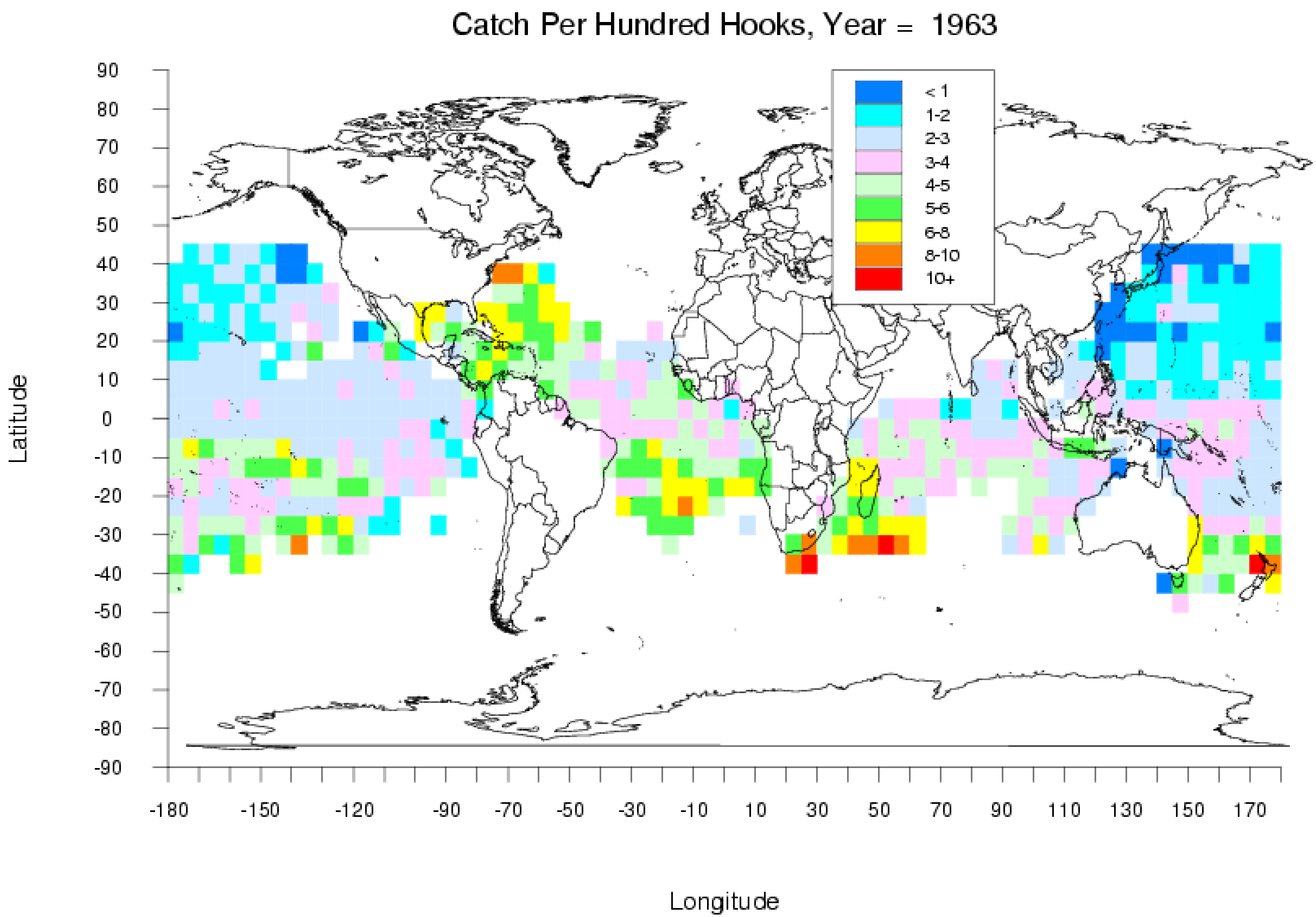
Catch Per Hundred Hooks, Year = 1960



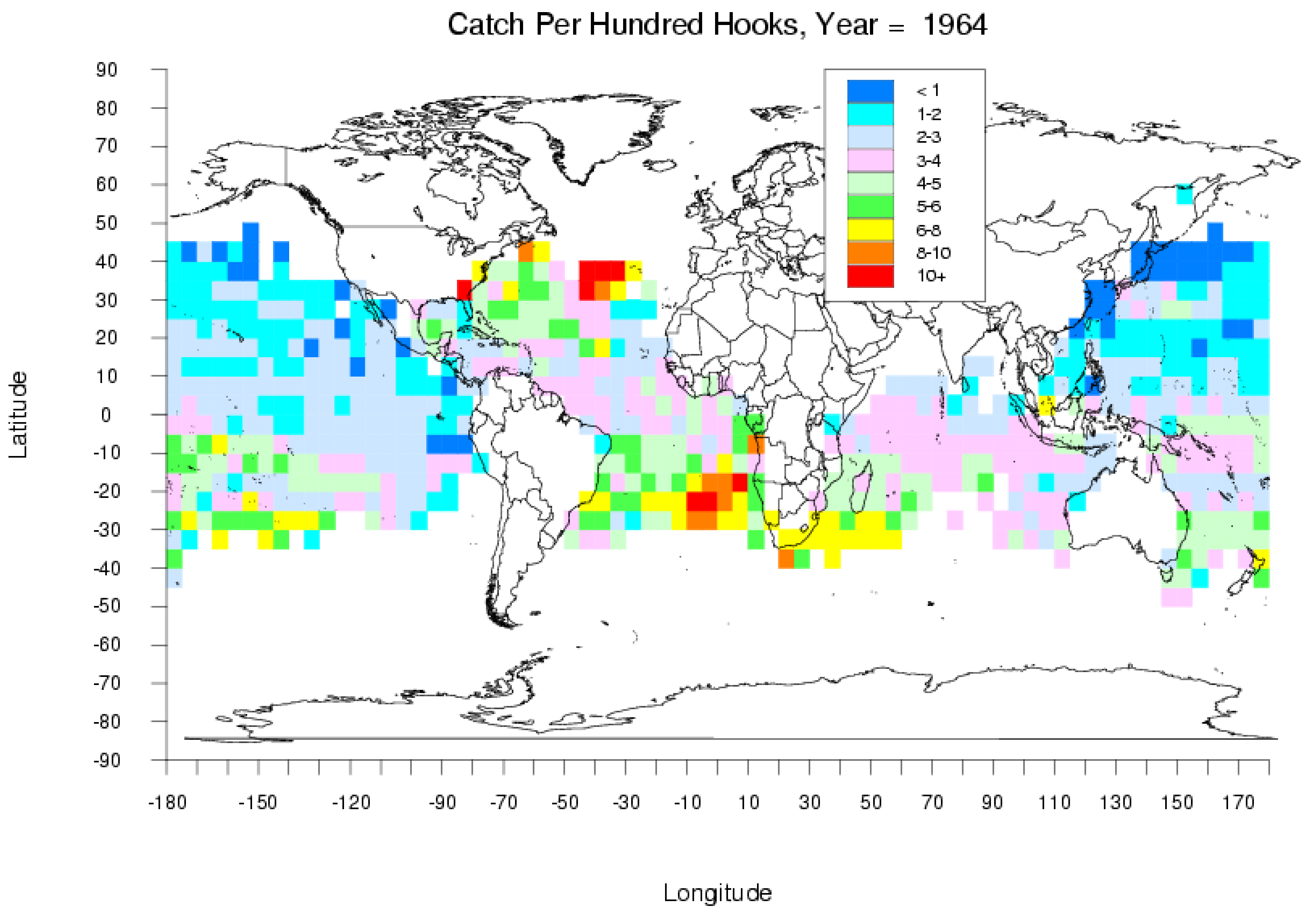

Catch Per Hundred Hooks, Year = 1961
Latitude
Longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+



Catch Per Hundred Hooks, Year = 1962
< 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 = 1963
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude



Catch Per Hundred Hooks, Year = 1964
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
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
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30
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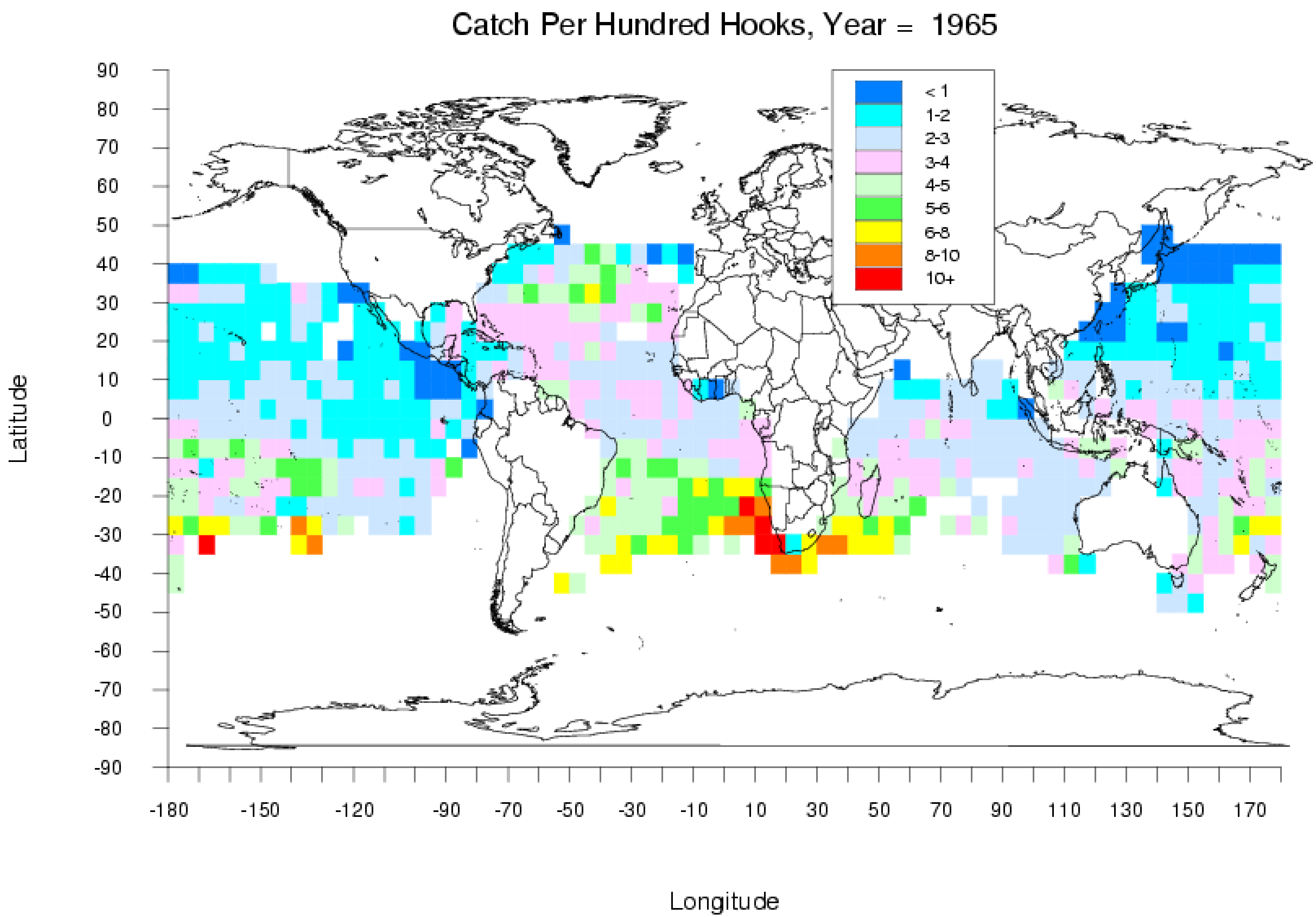
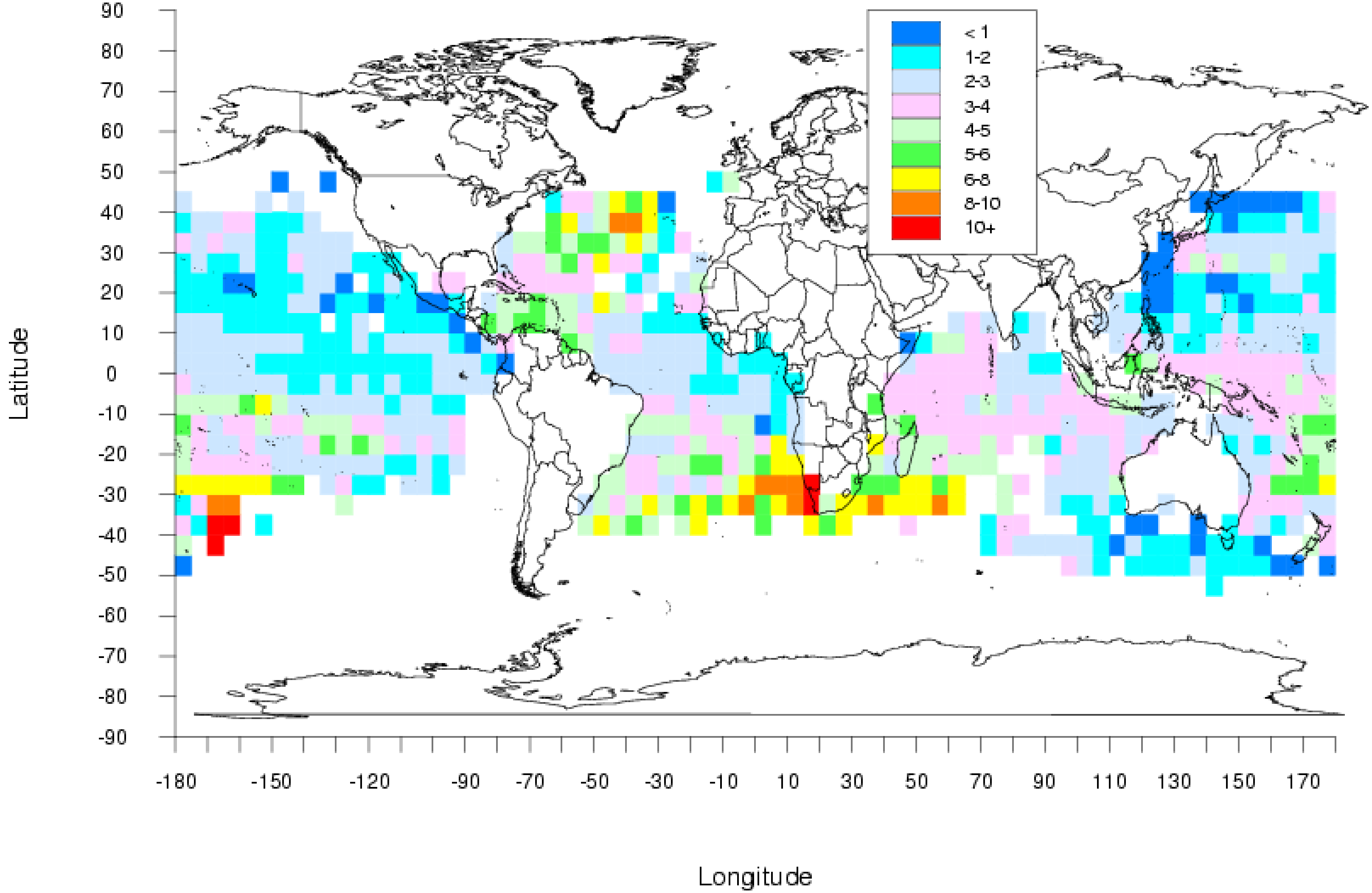
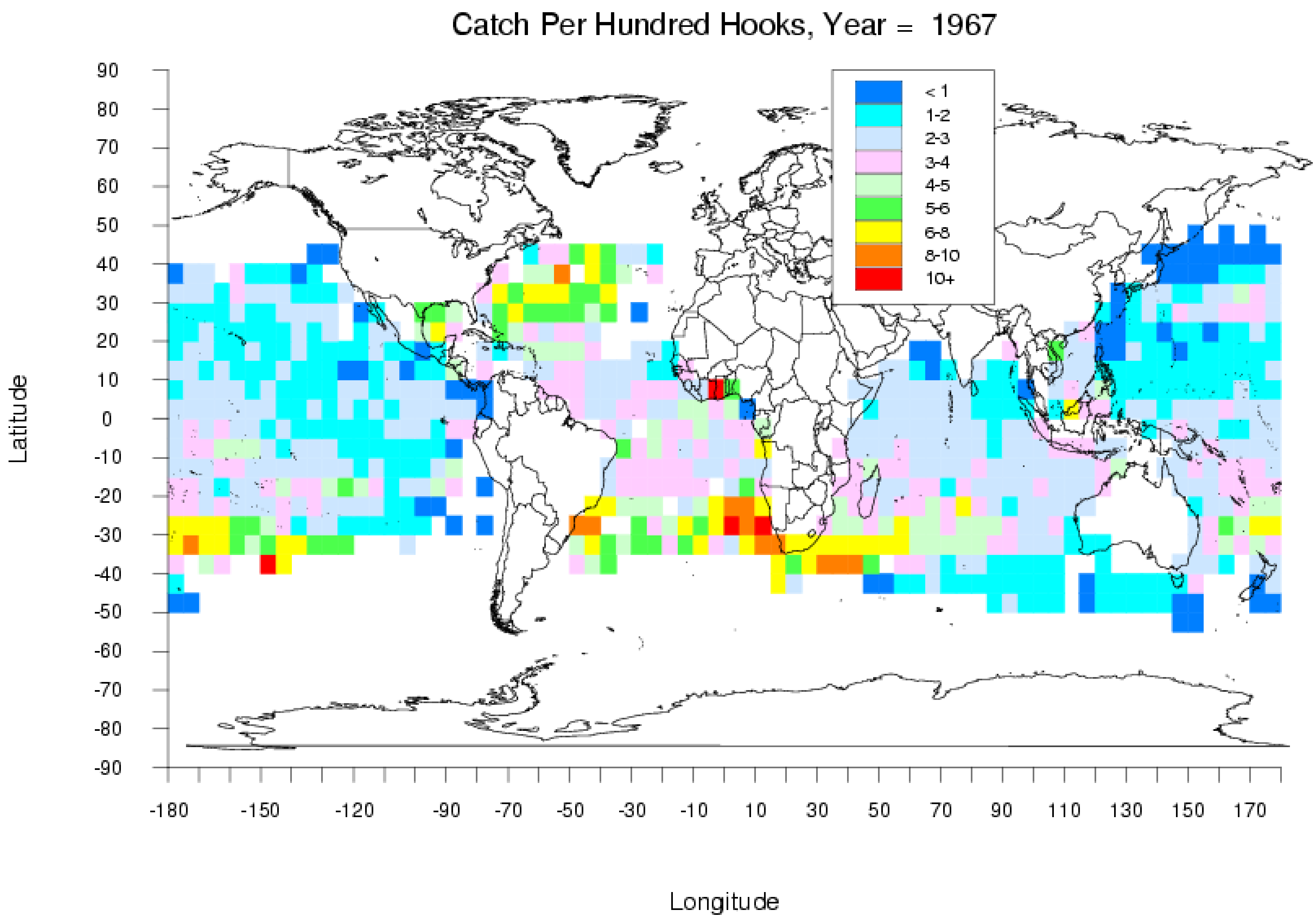
70
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1965
< 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 = 1966





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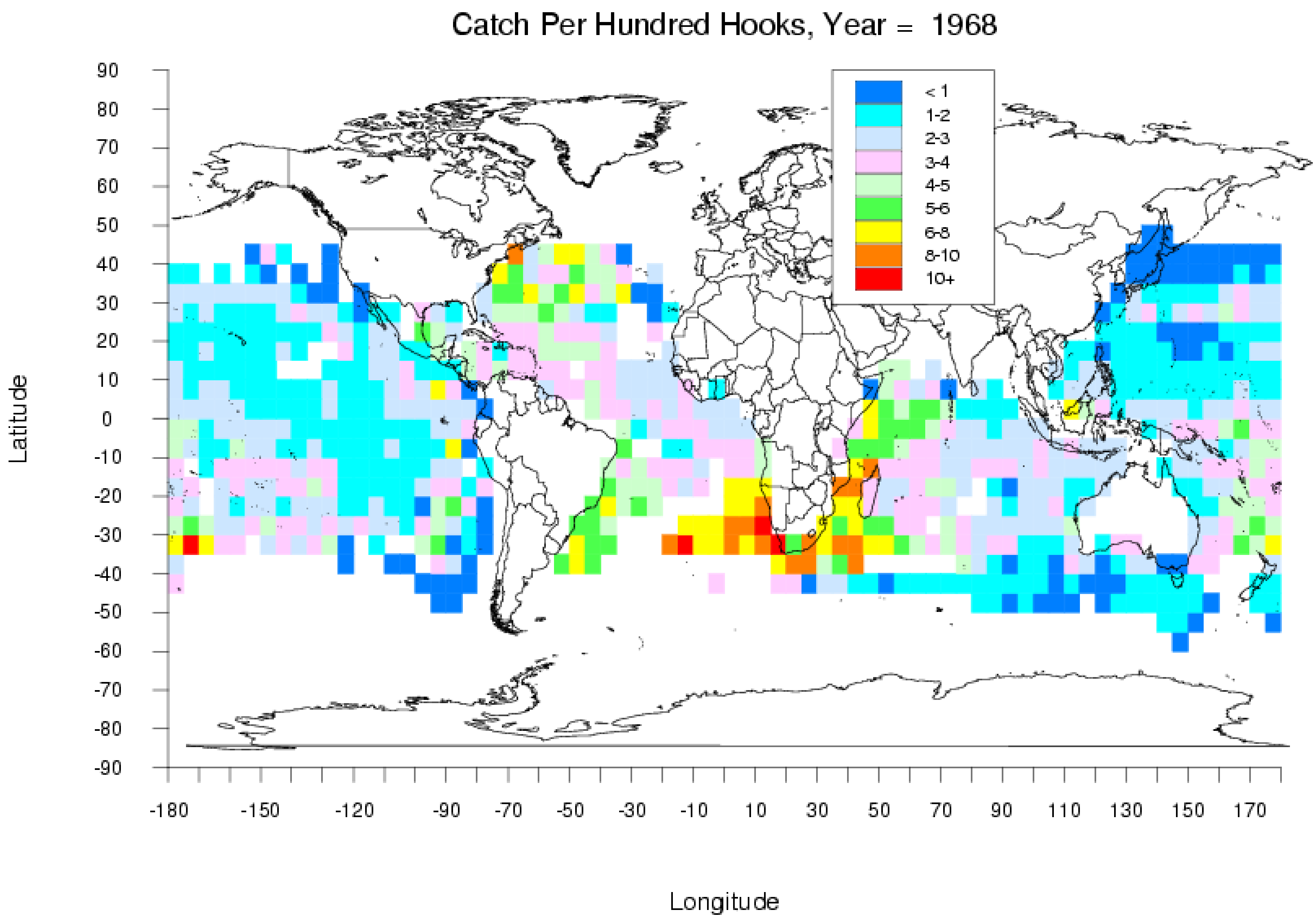
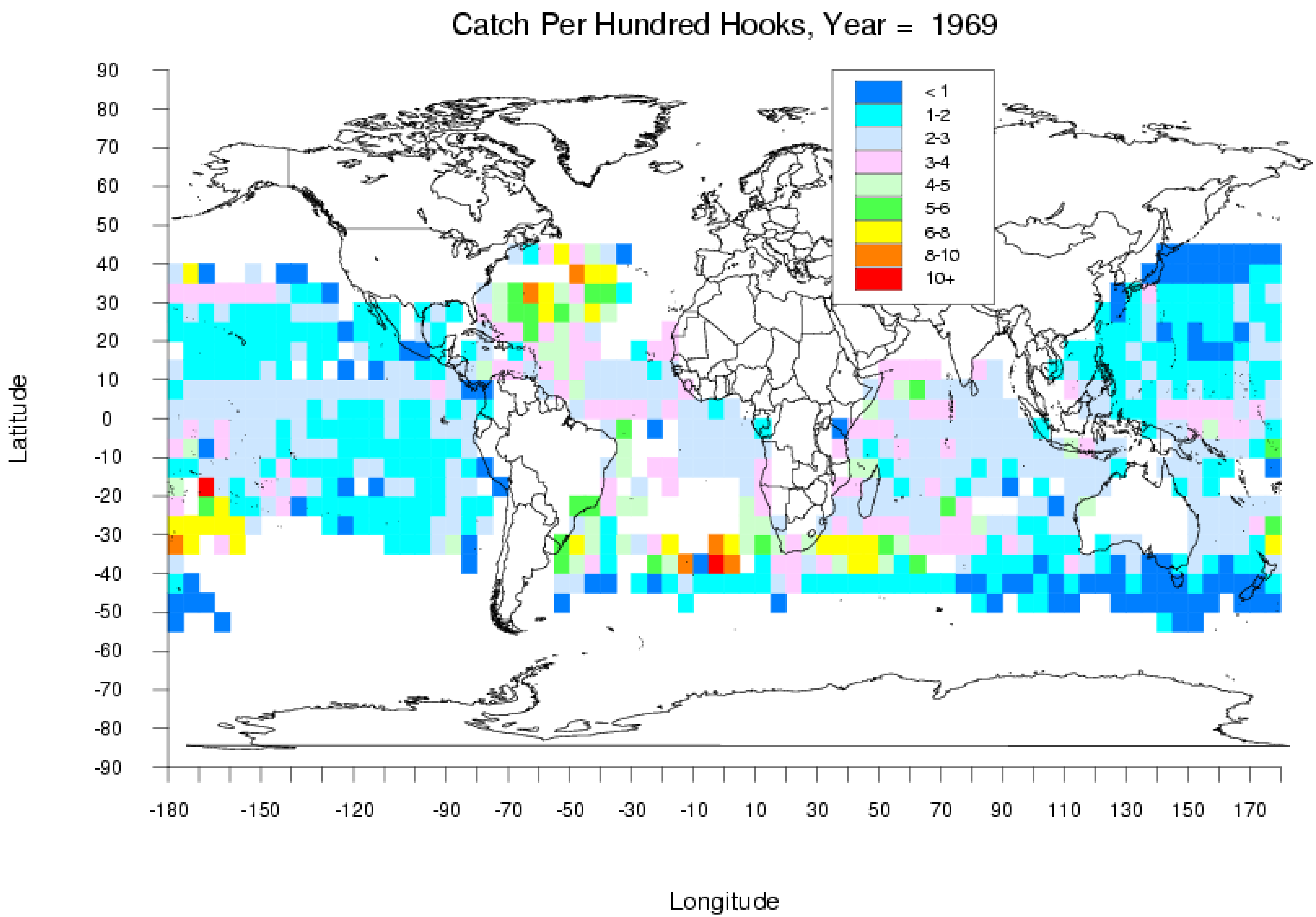
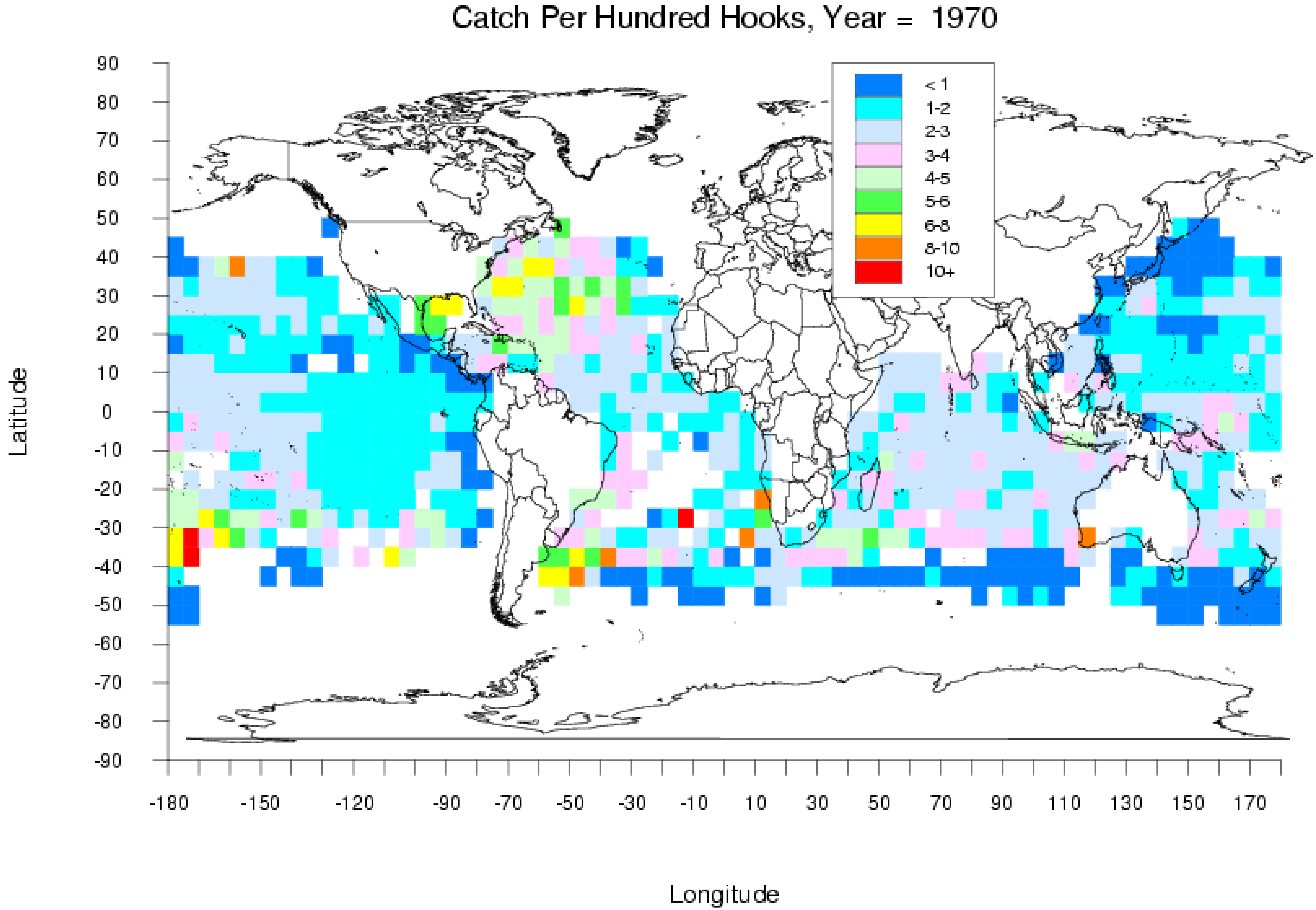
90
110
130
150
170



Catch Per Hundred Hooks, Year = 1968
< 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 = 1969
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
< 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 = 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
-180
-150
-120
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-70
-50
-30
-10
10
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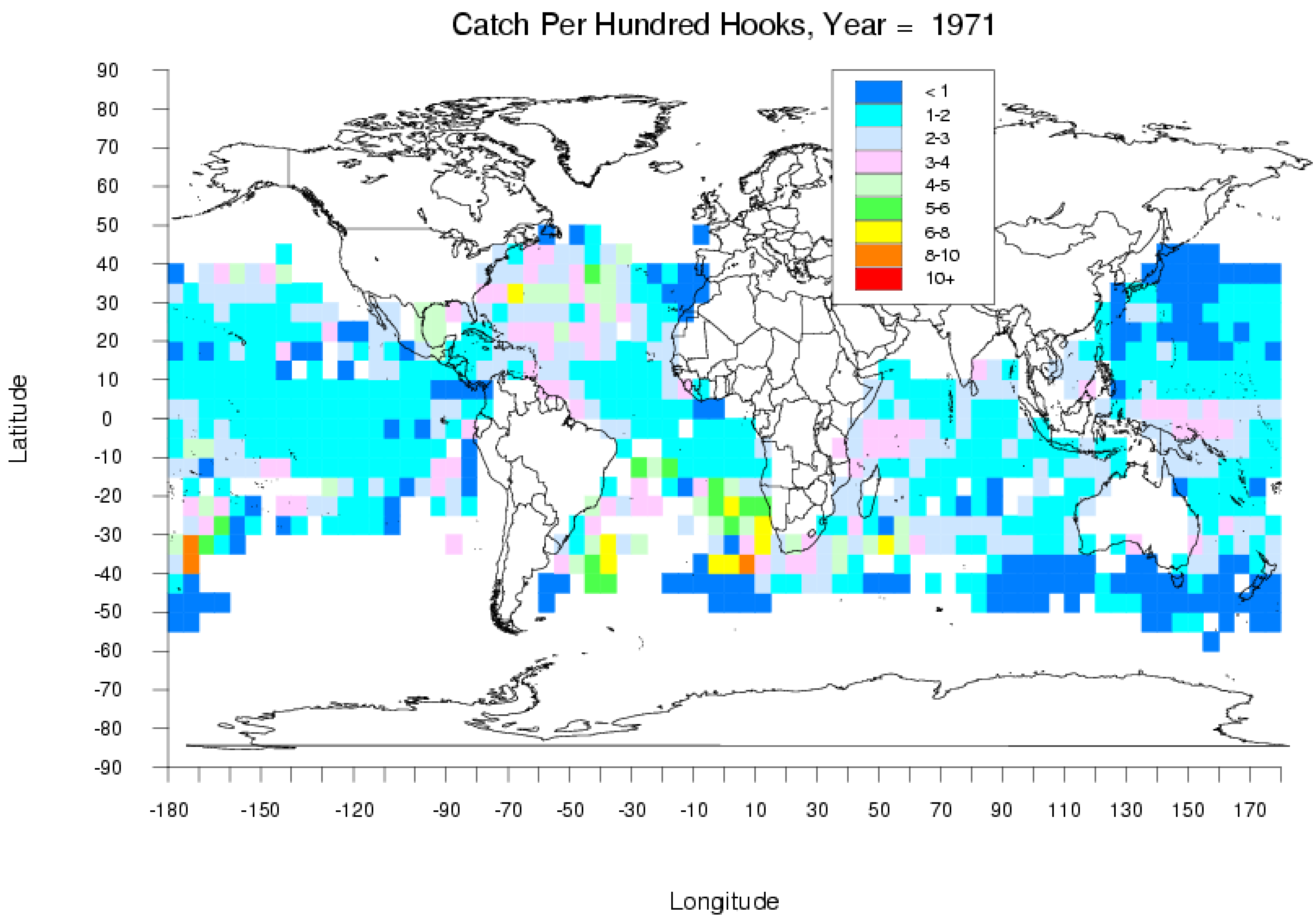
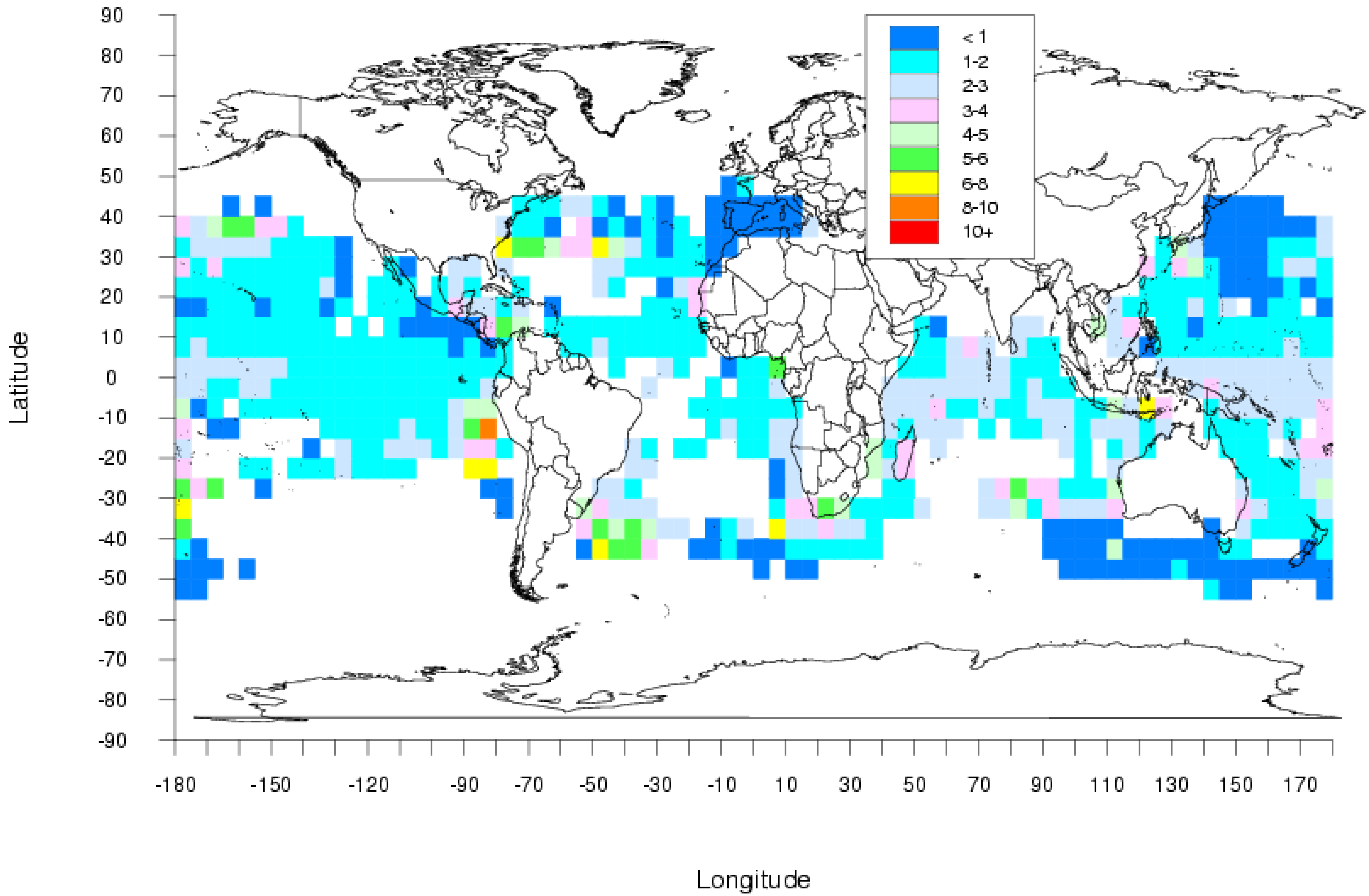
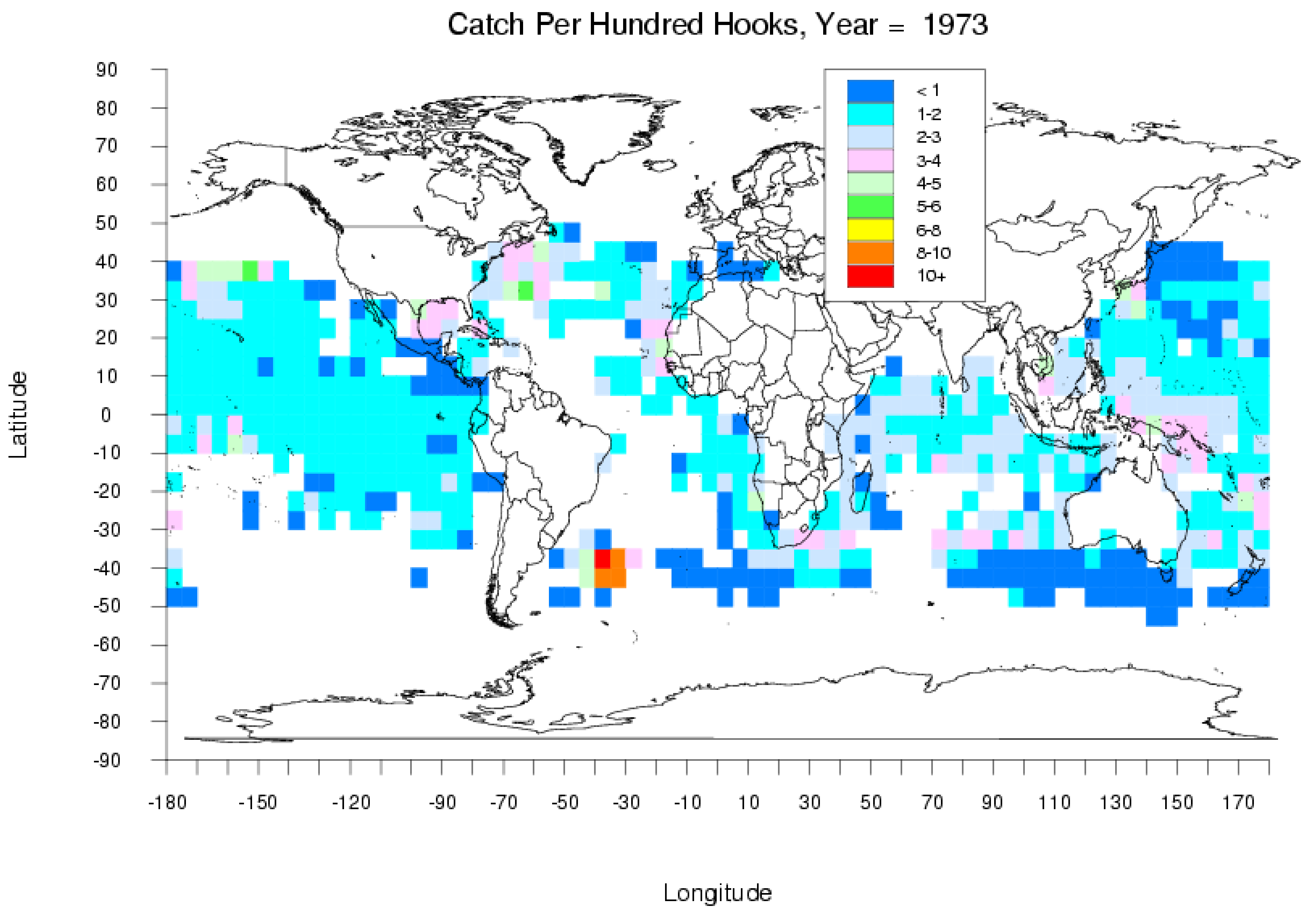
50
70
90
110
130
150
170
Longitude



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

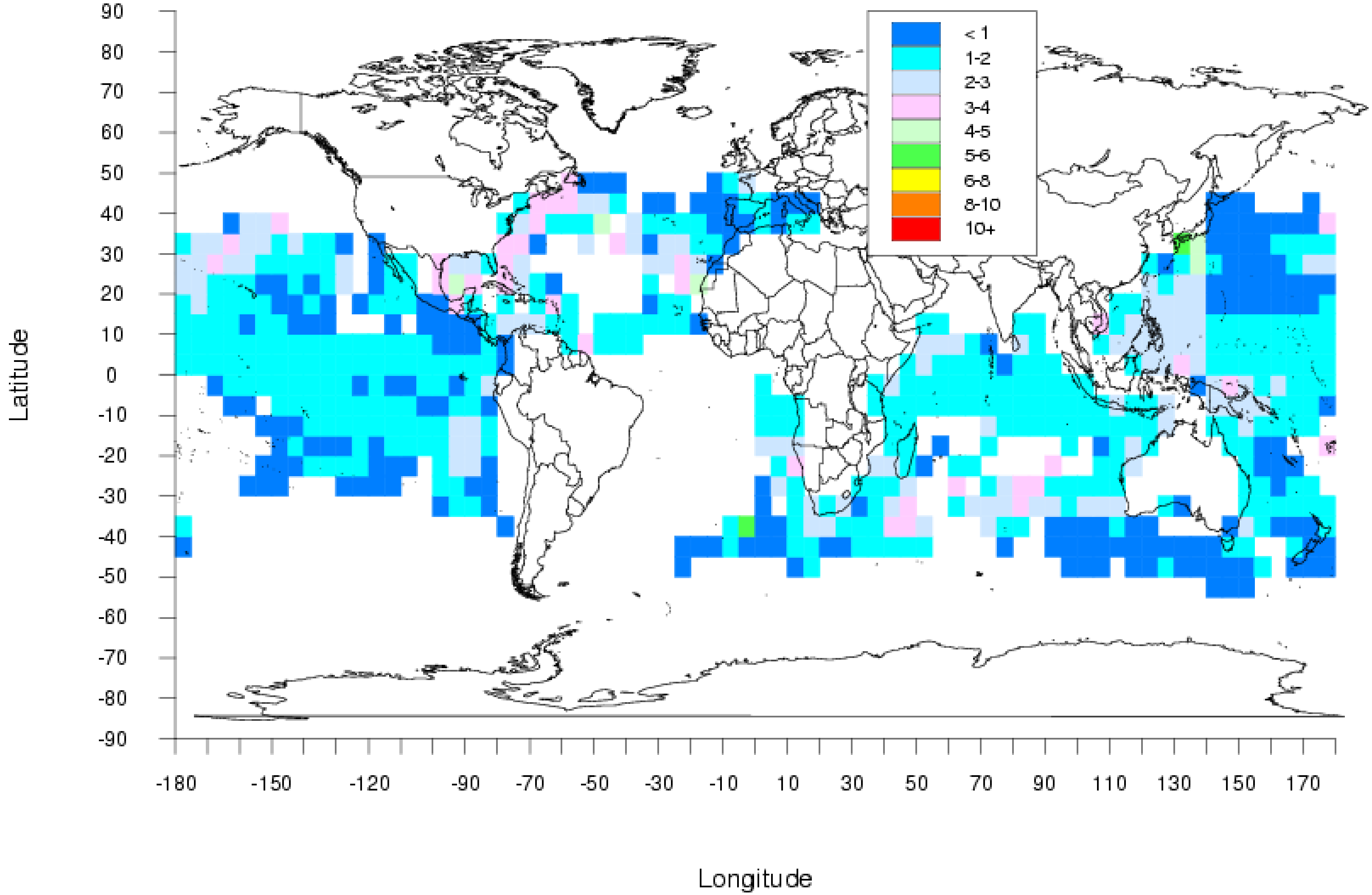
Catch Per Hundred Hooks, Year = 1972

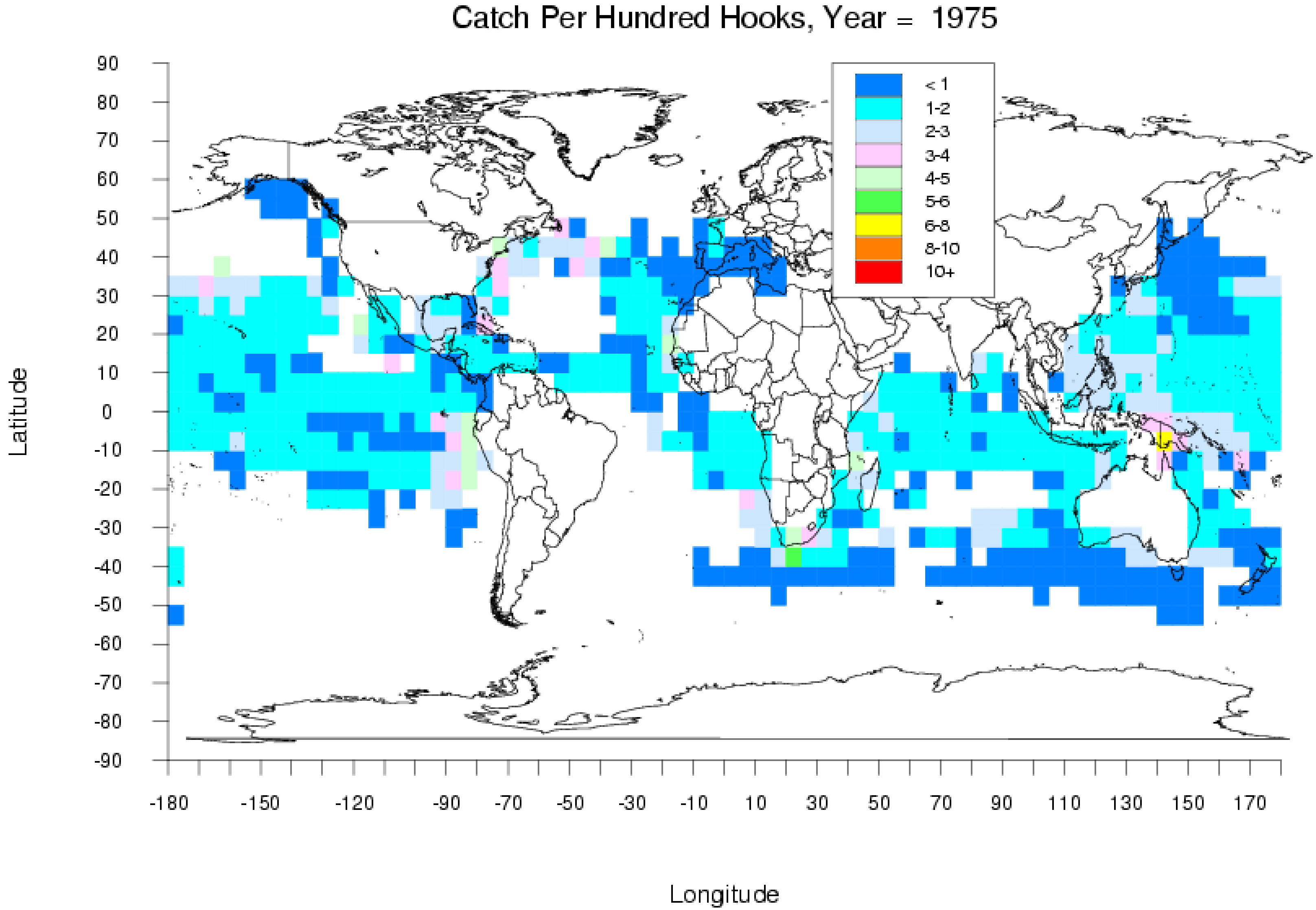




Catch Per Hundred Hooks, Year = 1973
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude

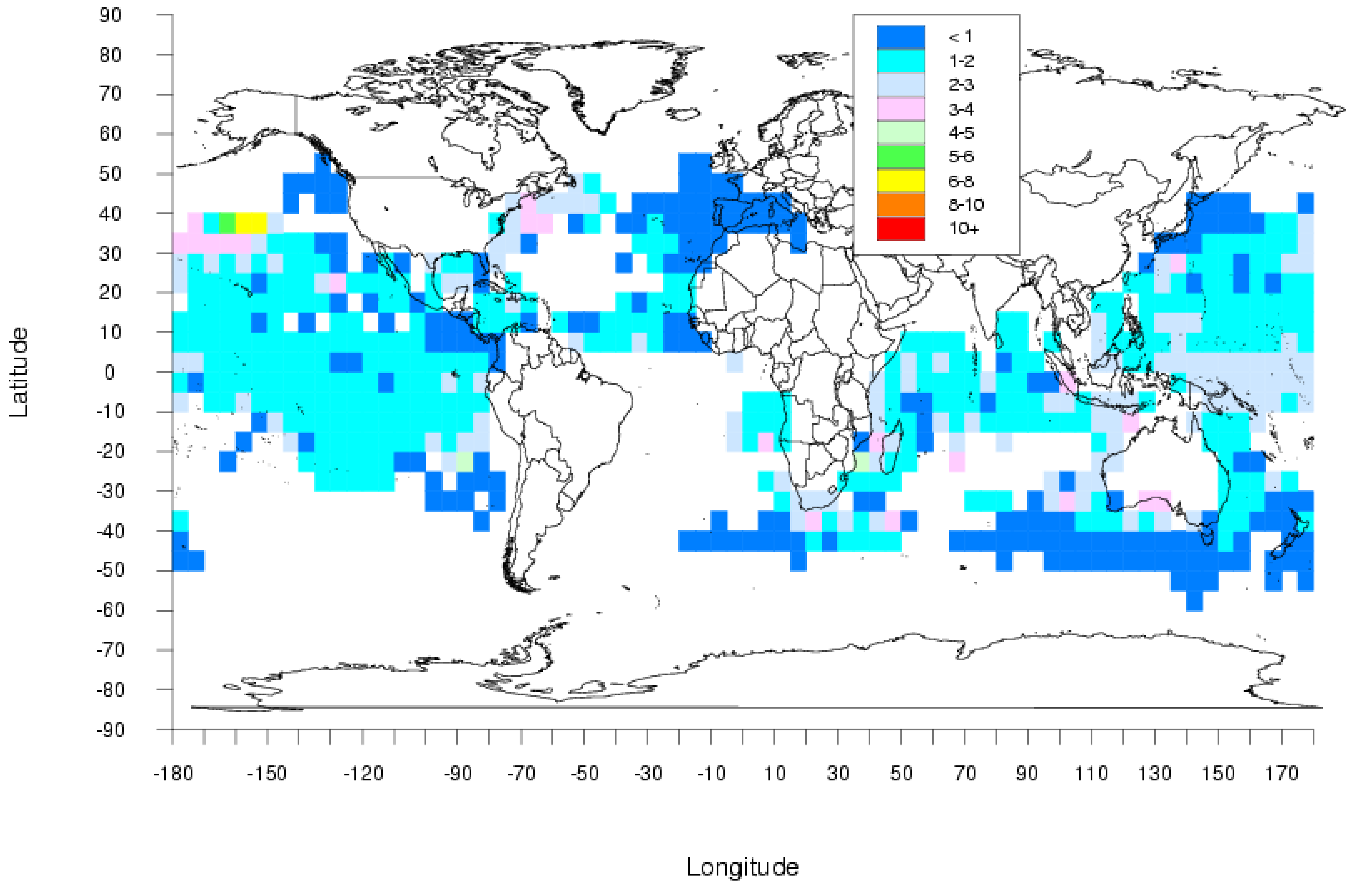
Catch Per Hundred Hooks, Year = 1974

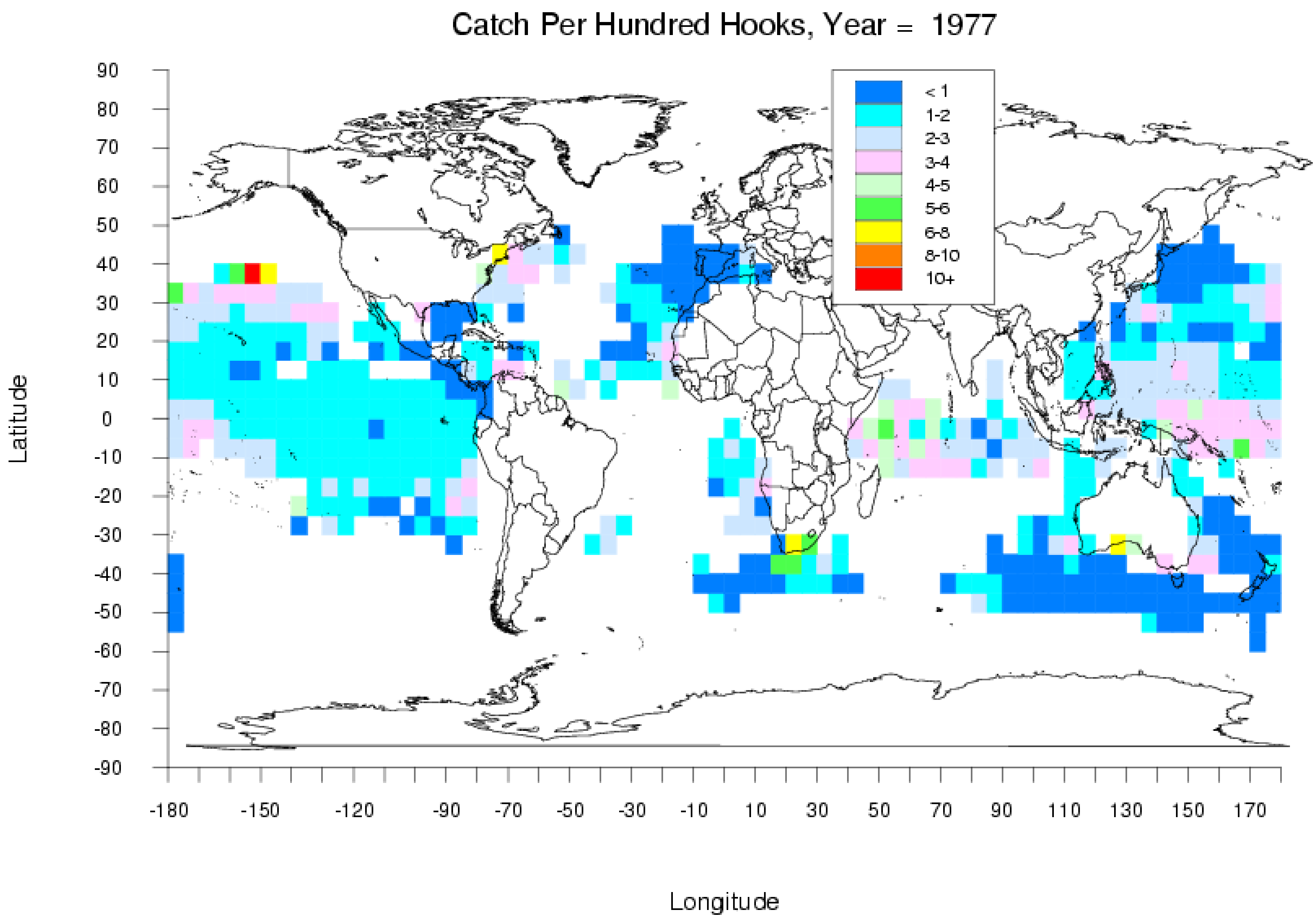


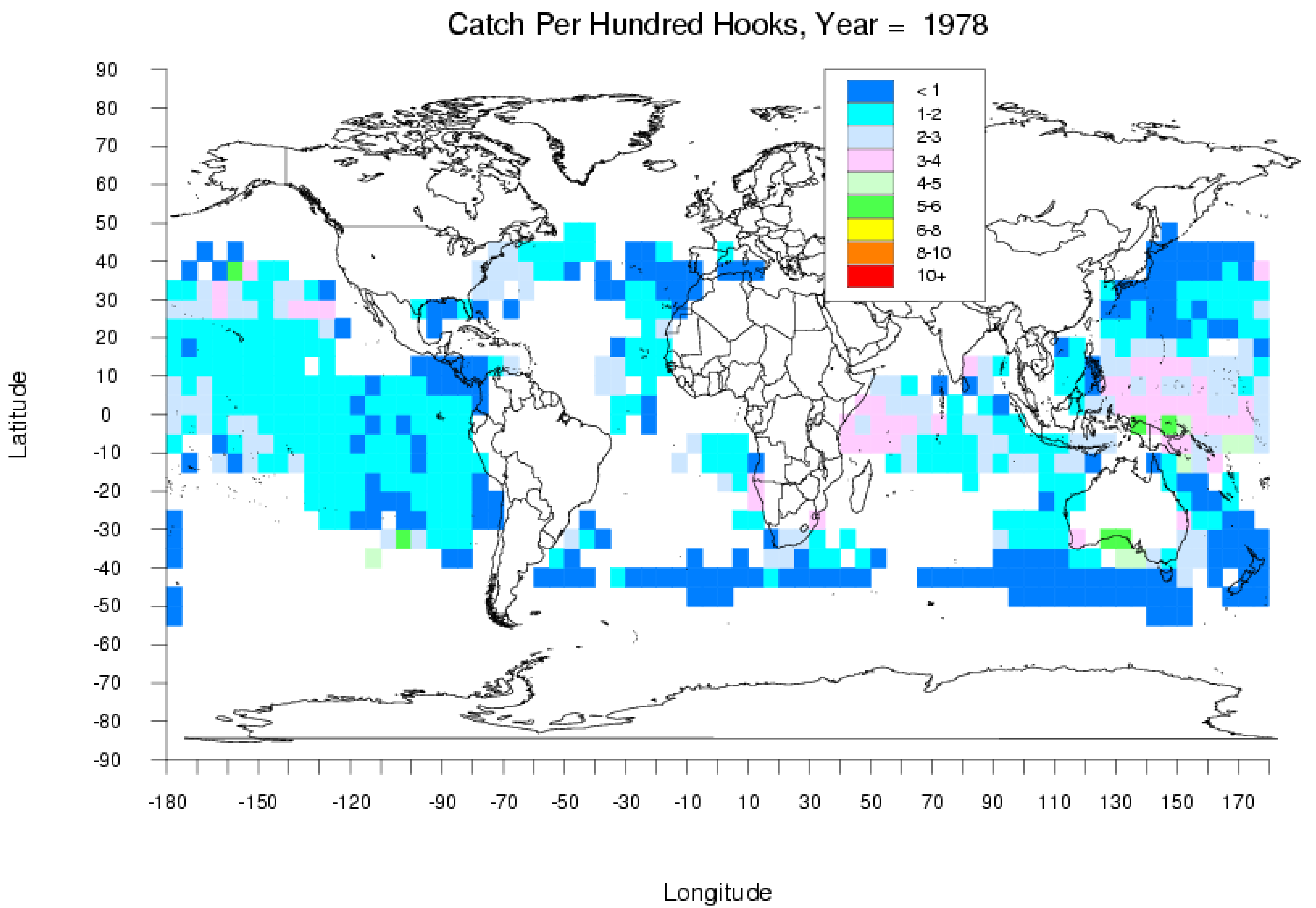


Catch Per Hundred Hooks, Year = 1975
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170
Longitude

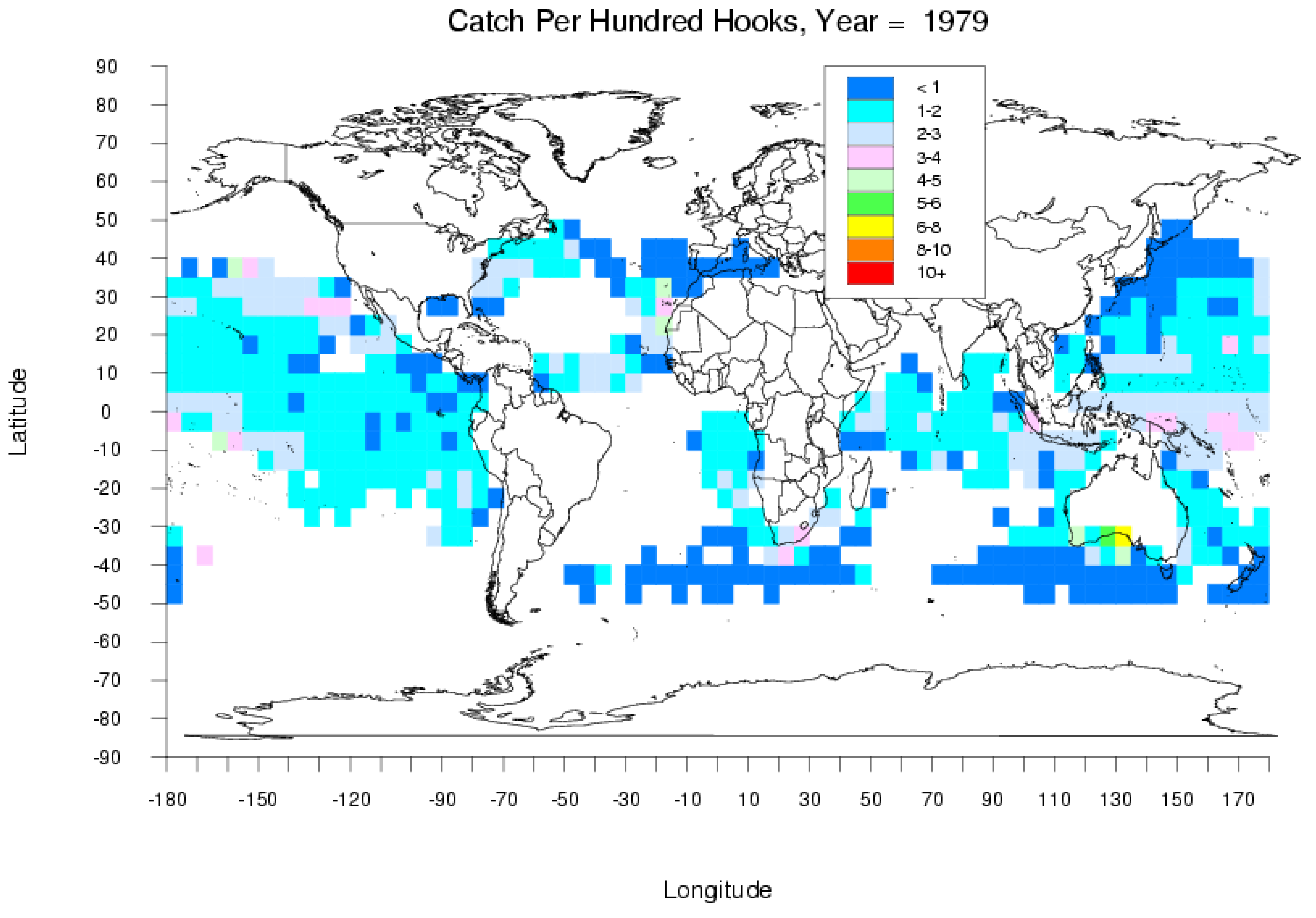
Catch Per Hundred Hooks, Year = 1976




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

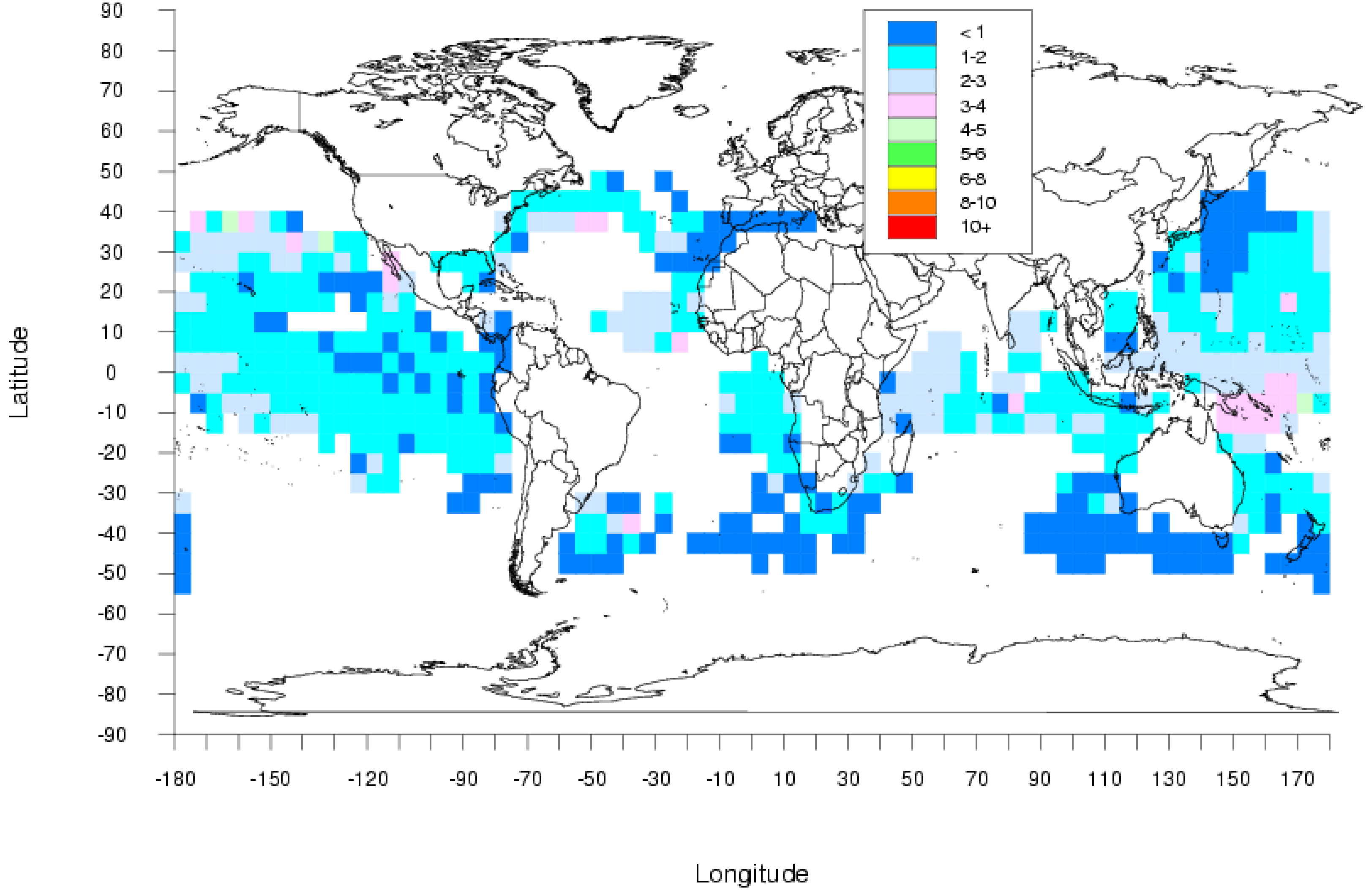


Catch Per Hundred Hooks, Year = 1978
< 1
1-2
2-3
3-4
4-5
5-6
6-8
8-10
10+
Latitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Longitude
-180
-150
-120
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
170



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

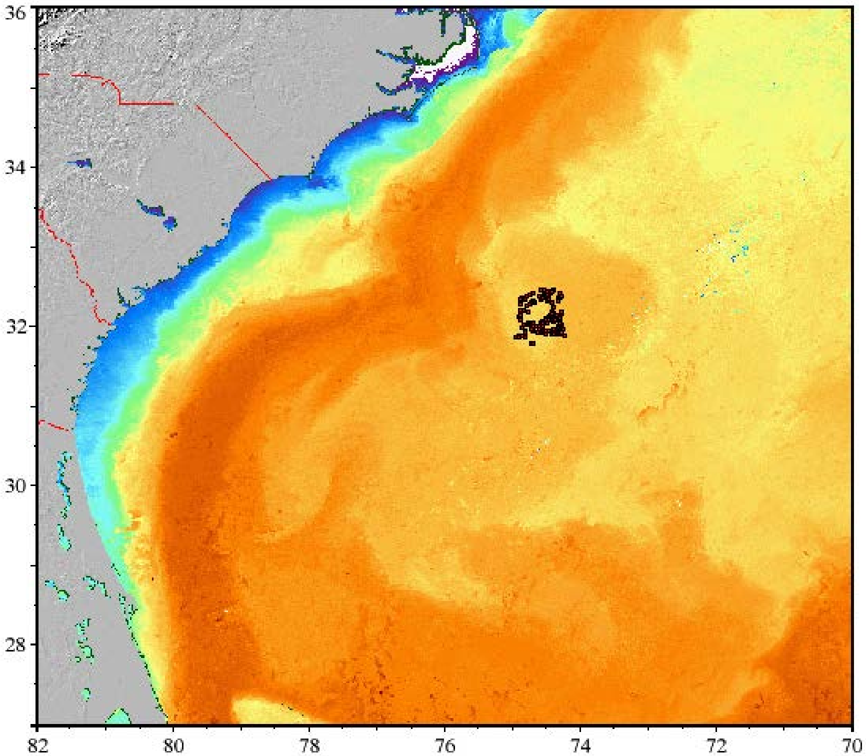
Catch Per Hundred Hooks, Year = 1980

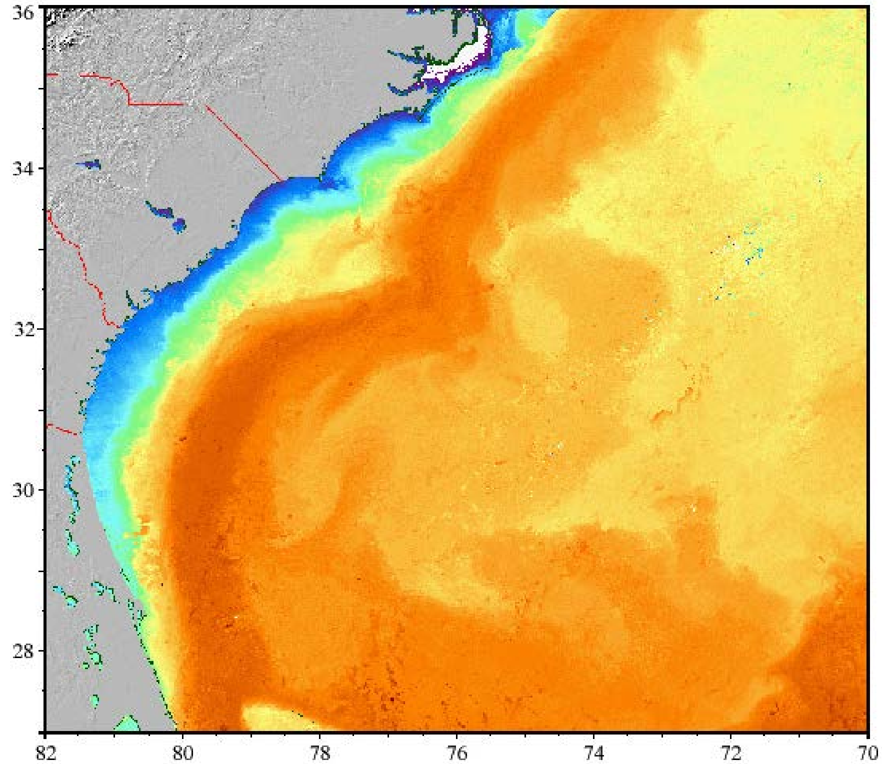


Totally Stupid Reasons for not Believing the Obvious

- 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

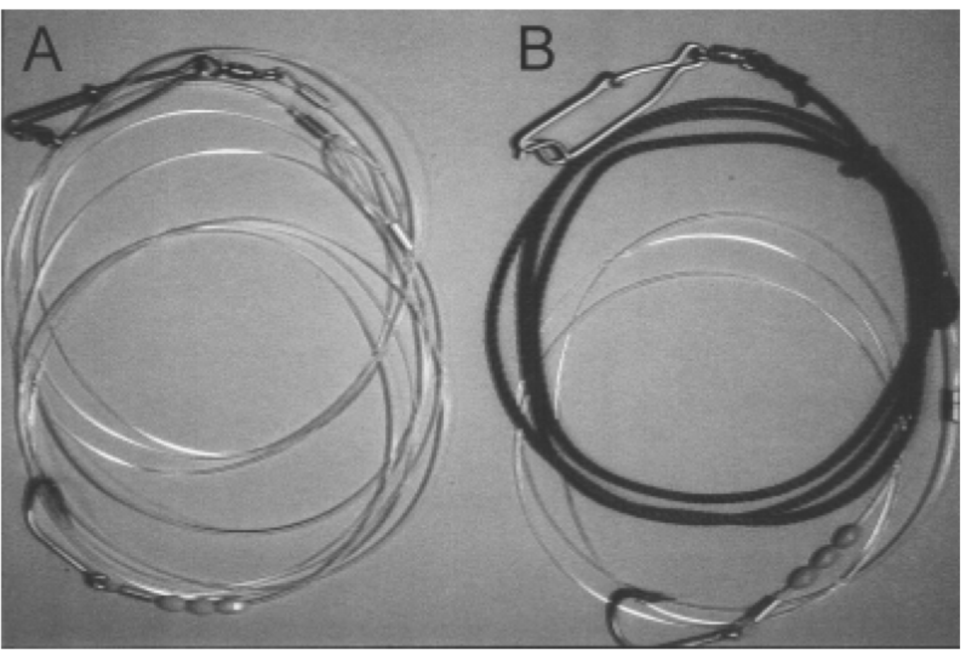
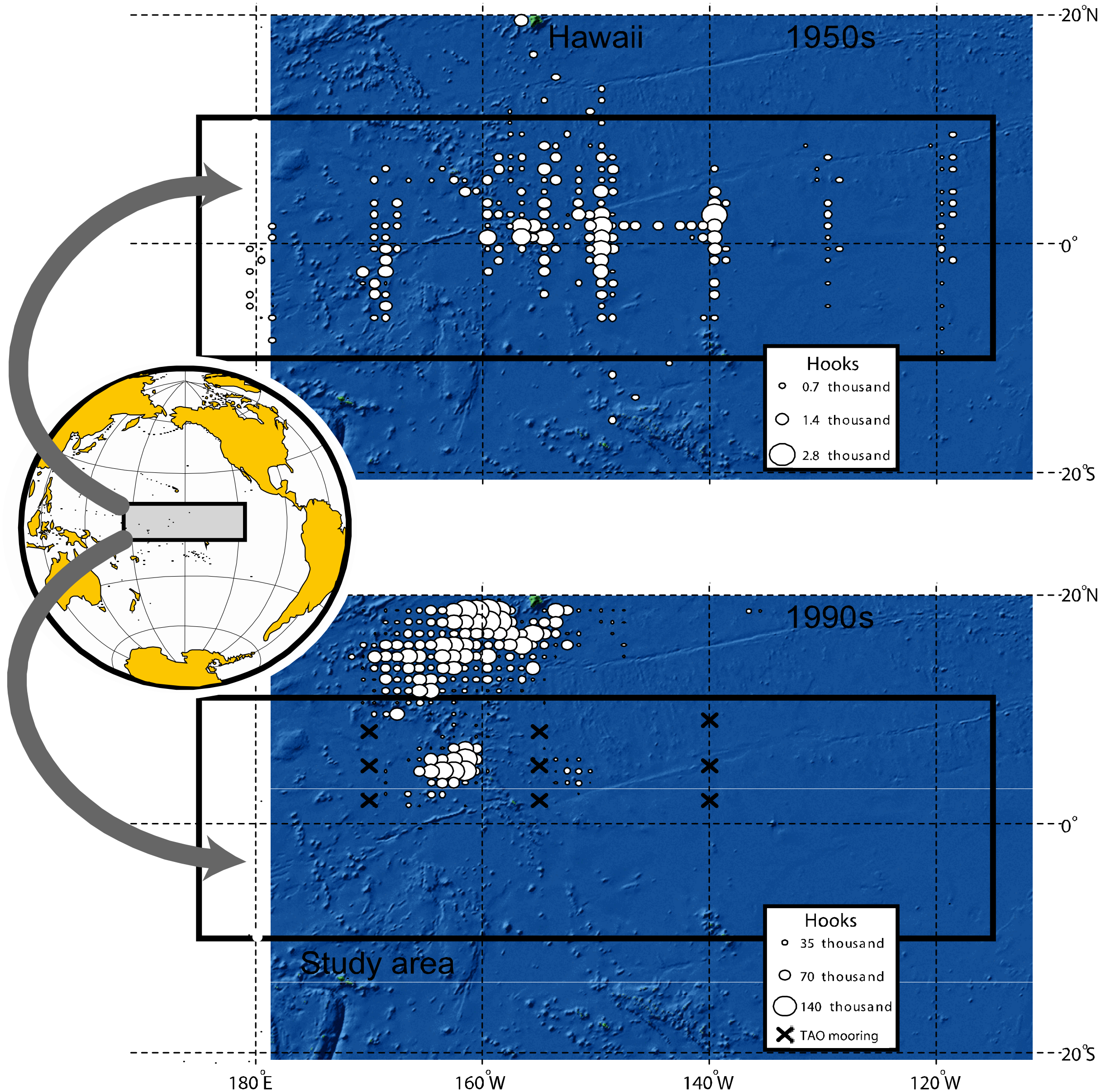
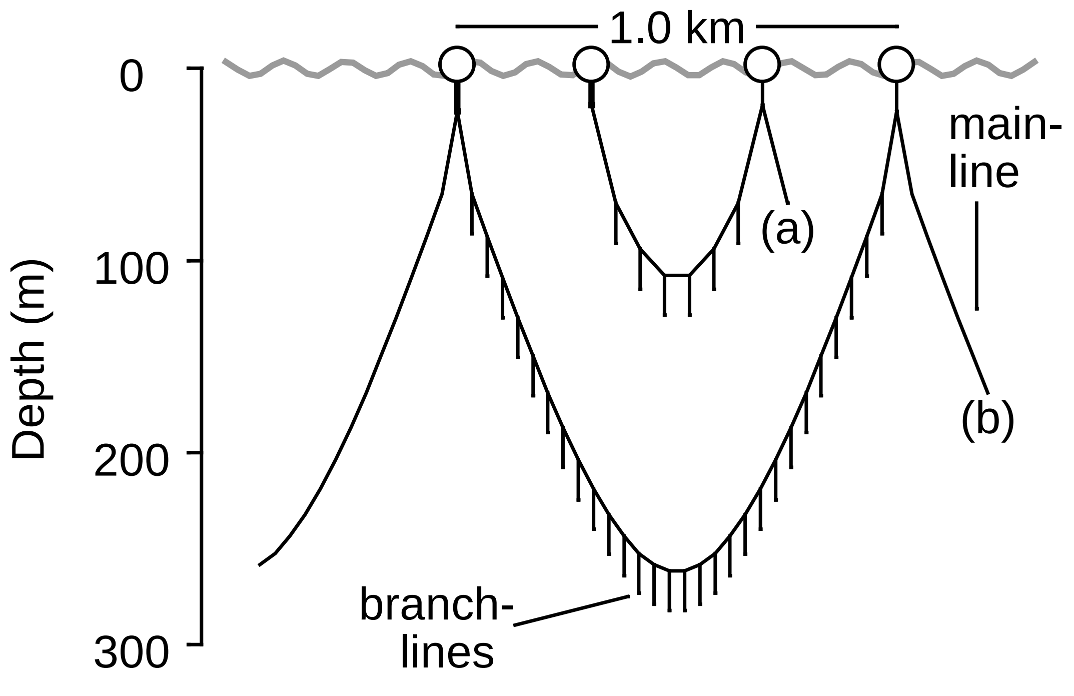


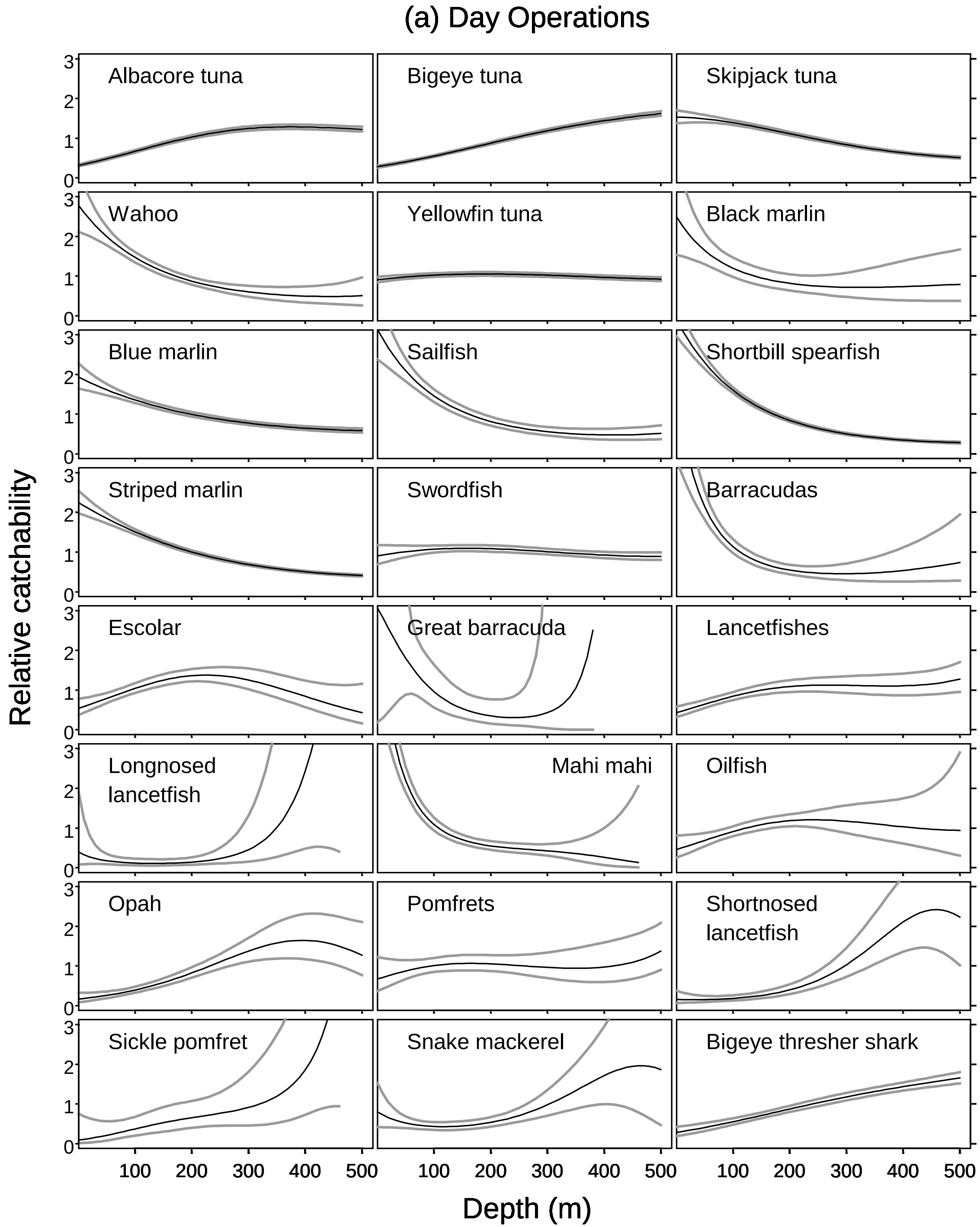
Figure 3
Monofilament nylon (A) and tarred multifilament nylon (B) gangions used for ten pelagic longline sets conducted off Georges Bank from 22 July to 2 August 1999.

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



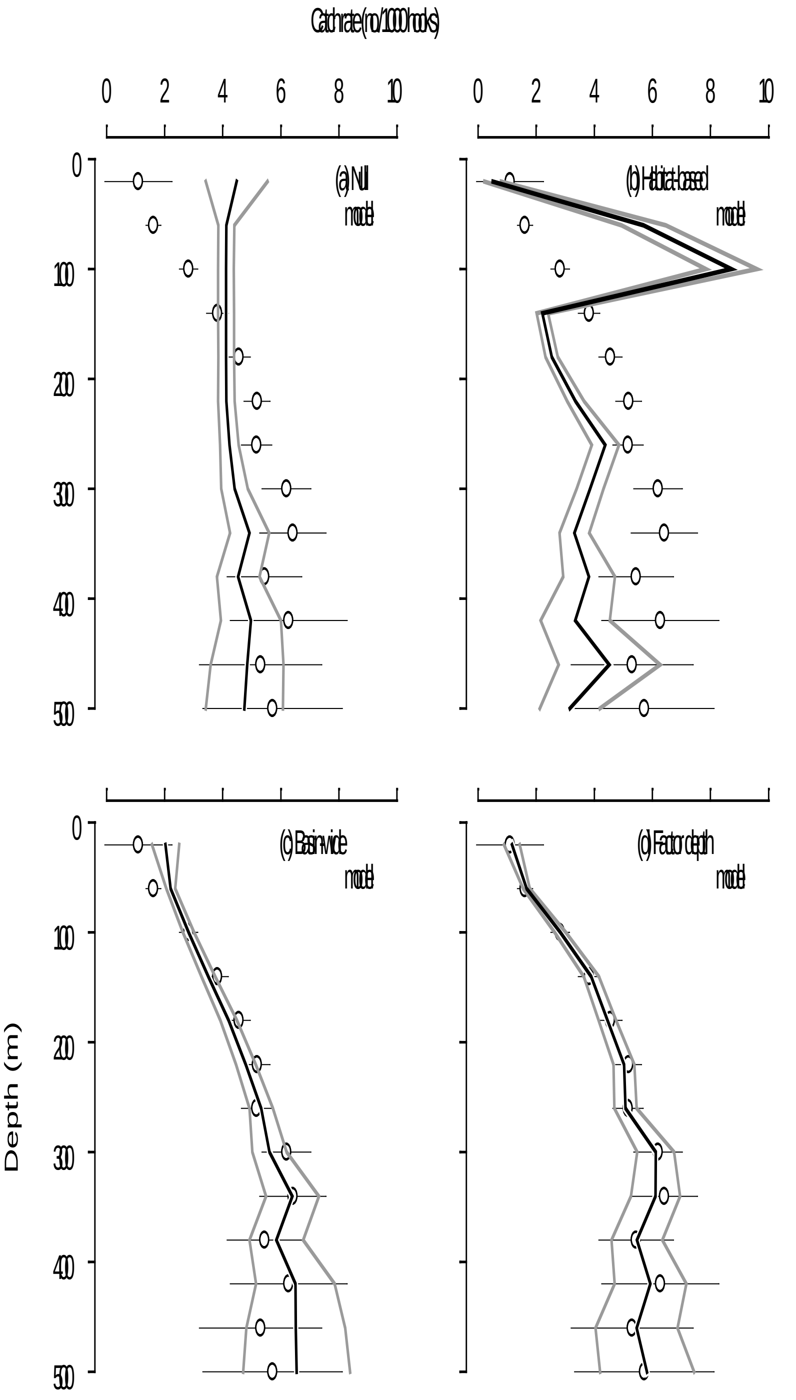
Hawaii
1950s
Hooks
0.7 thousand
1.4 thousand
2.8 thousand
20°N
0°
20°S
1990s
Hooks
35 thousand
70 thousand
140 thousand
TAO mooring
Study area
180°E
160°W
140°W
120°W


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



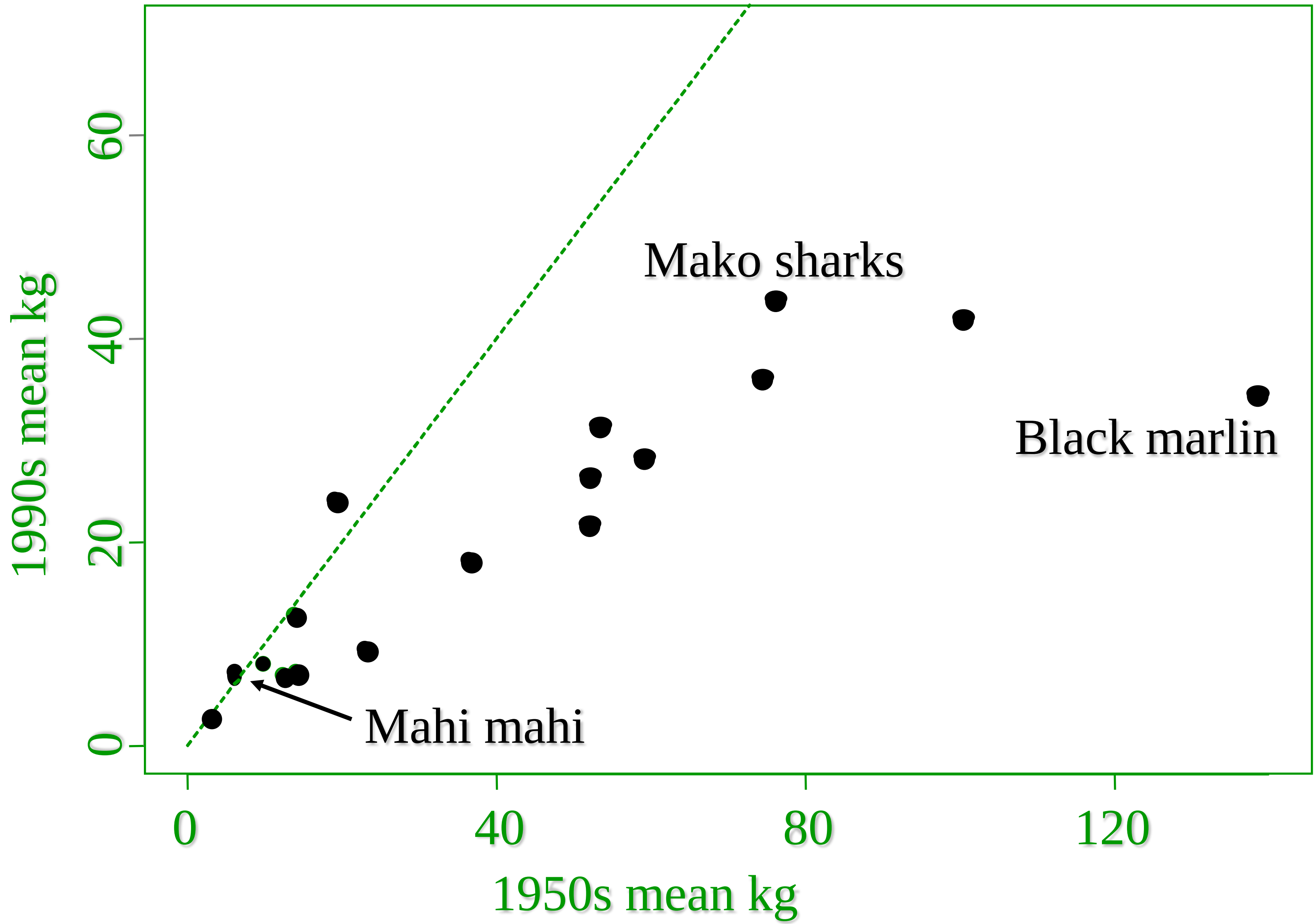
(a) Day Operations
Albacore tuna
Bigeye tuna
Skipjack tuna
Wahoo
Yellowfin tuna
Black marlin
Blue marlin
Sailfish
Shortbill spearfish
Striped marlin
Swordfish
Barracudas
Escolar
Great barracuda
Lancetfishes
Longnosed lancetfish
Mahi mahi
Oilfish
Opah
Pomfrets
Shortnosed lancetfish
Sickle pomfret
Snake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

(This approach shows that non-statistical “habitat models” do not appear to work: results for bigeye tuna)

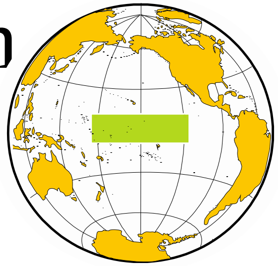


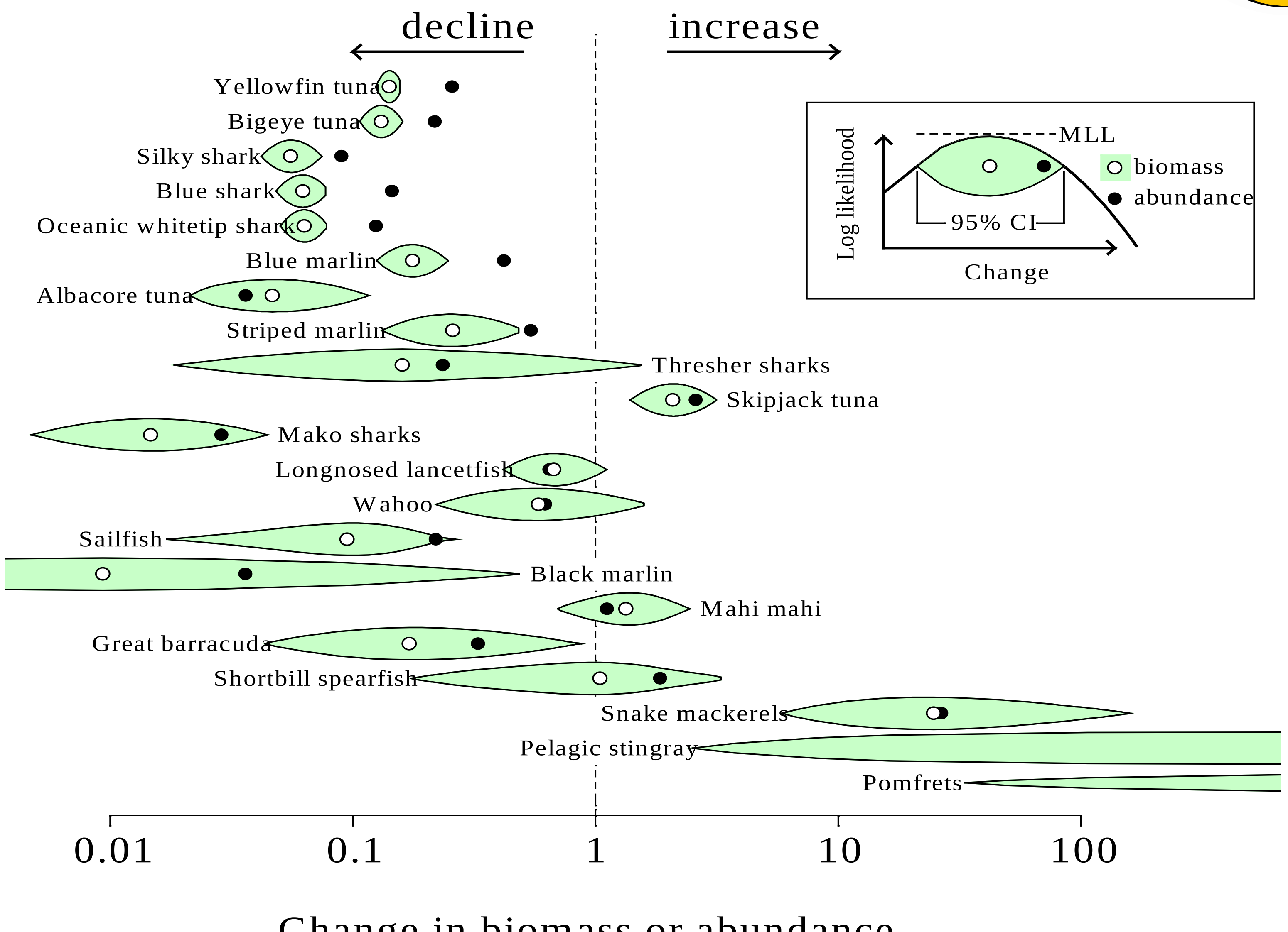
Ward and Myers in press Fisheries Oceanography

Change in body size

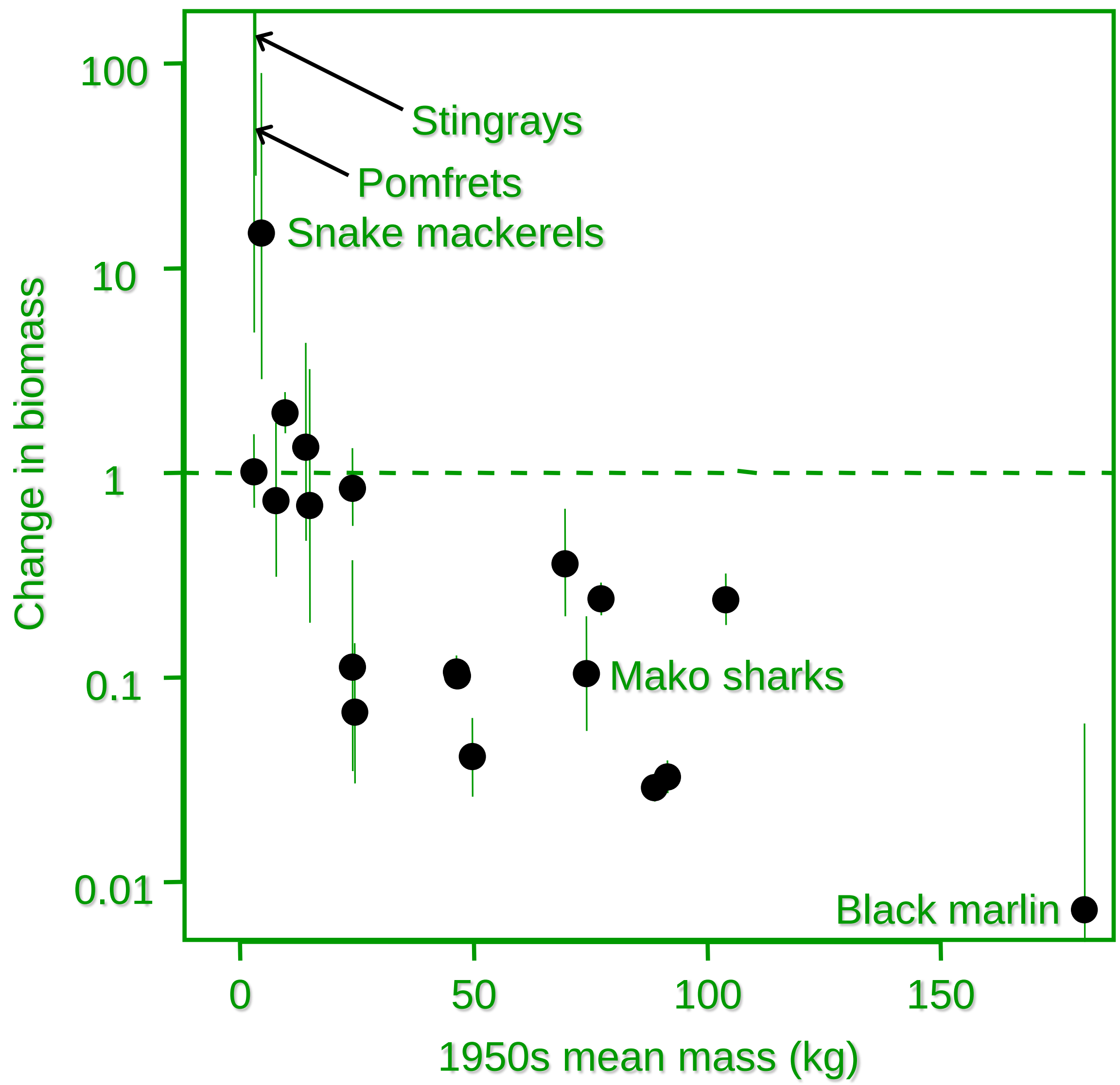


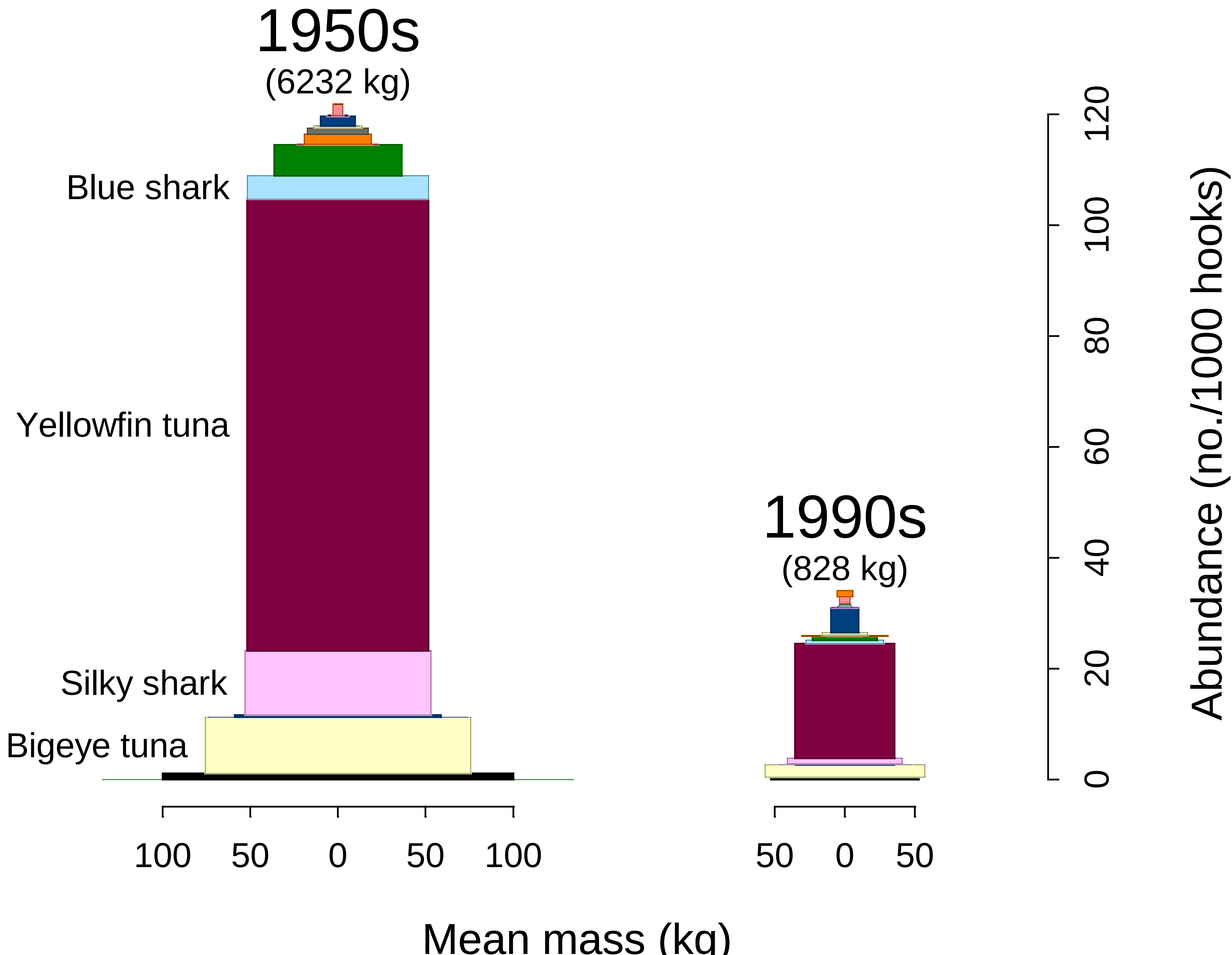
Analysis repeated using independent research data





Ward and Myers 2005 Eology


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)

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

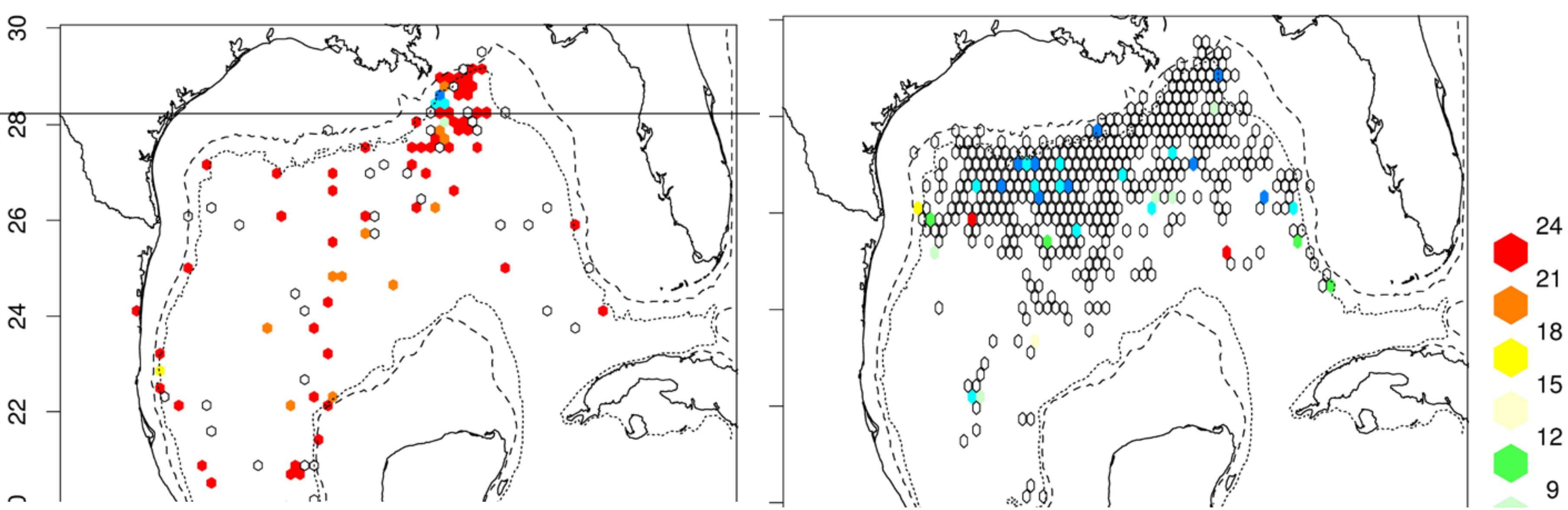
Keisuke Satoh[1], Kotaro Yokawa[1], Hirokazu Saito[1], Hiromasa Matsunaga[1], Hiroaki Okamoto[1] and Yuji Uozumi[1]

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

Loss of sharks in the Gulf of Mexico

300 fold decline – no one noticed

[redacted]

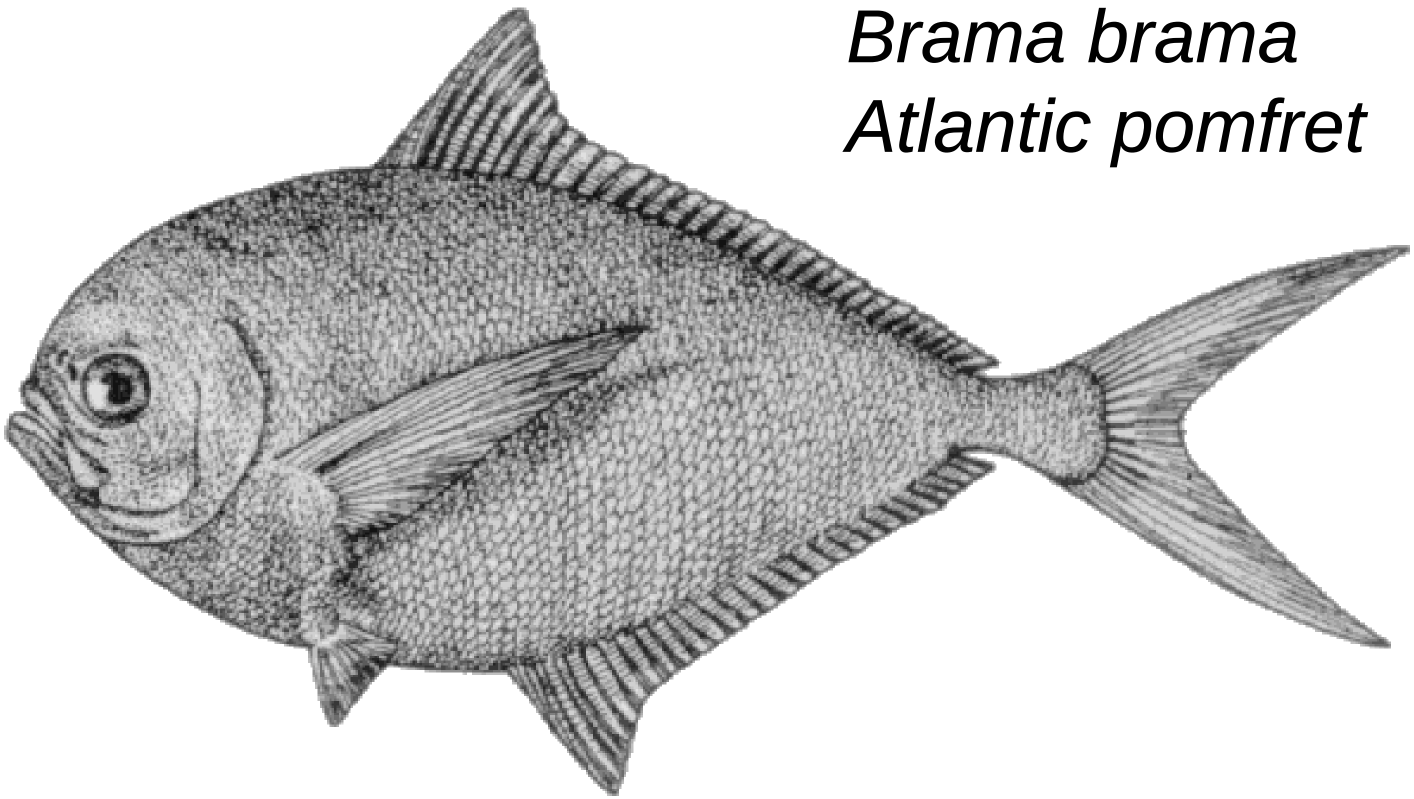


1950's 1990's

Oceanic Whitetip captures per 10,000 hooks

Many thanks to NMFS for data and advice

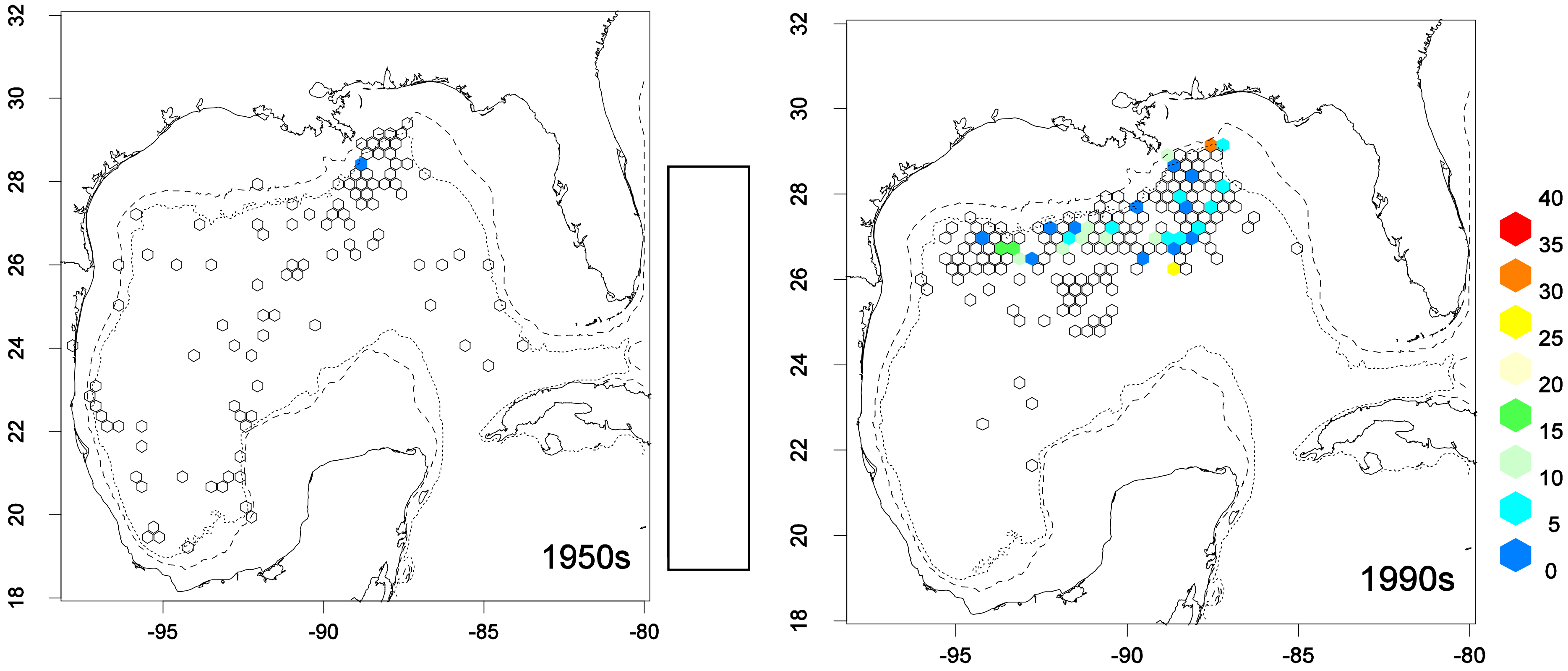
What about prey fish?



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

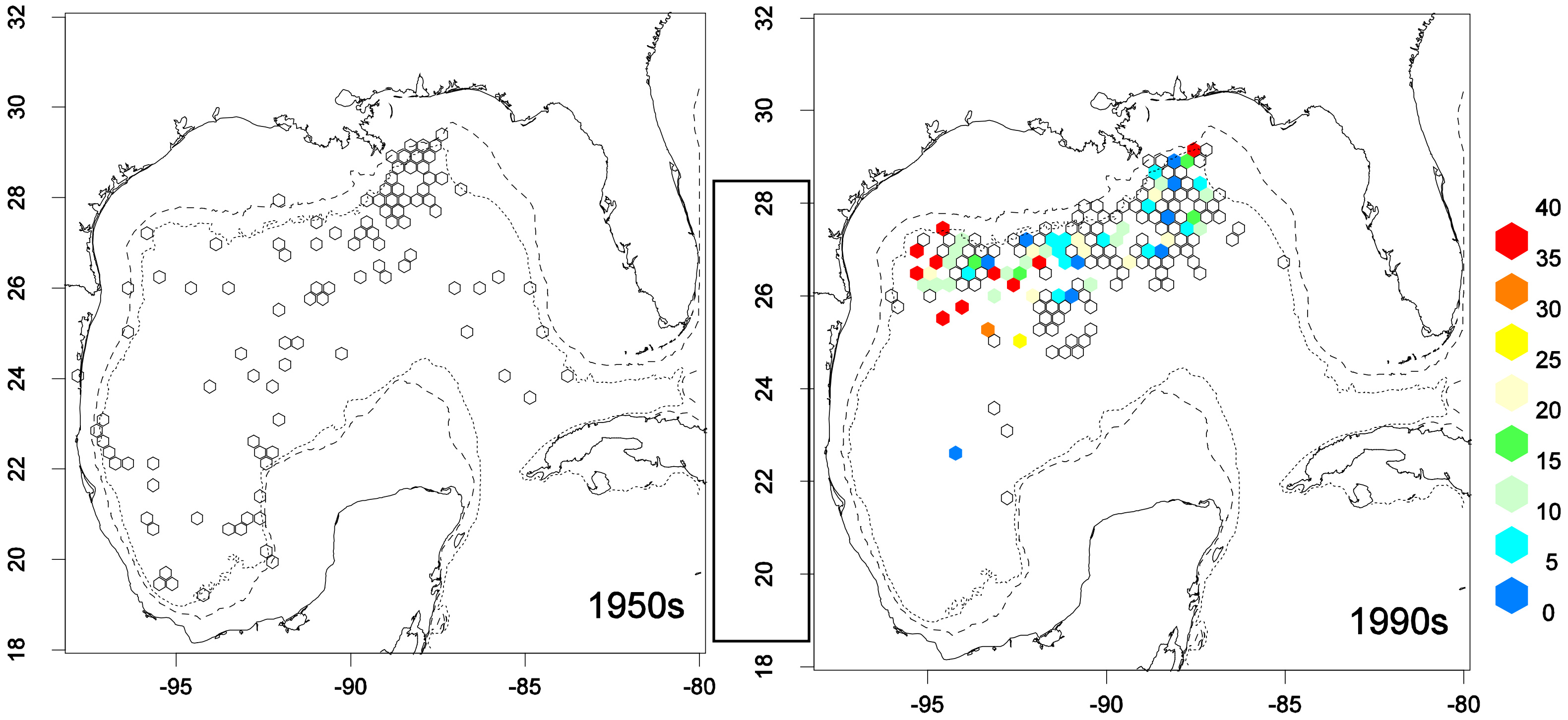
Many thanks to NMFS for data and advice

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

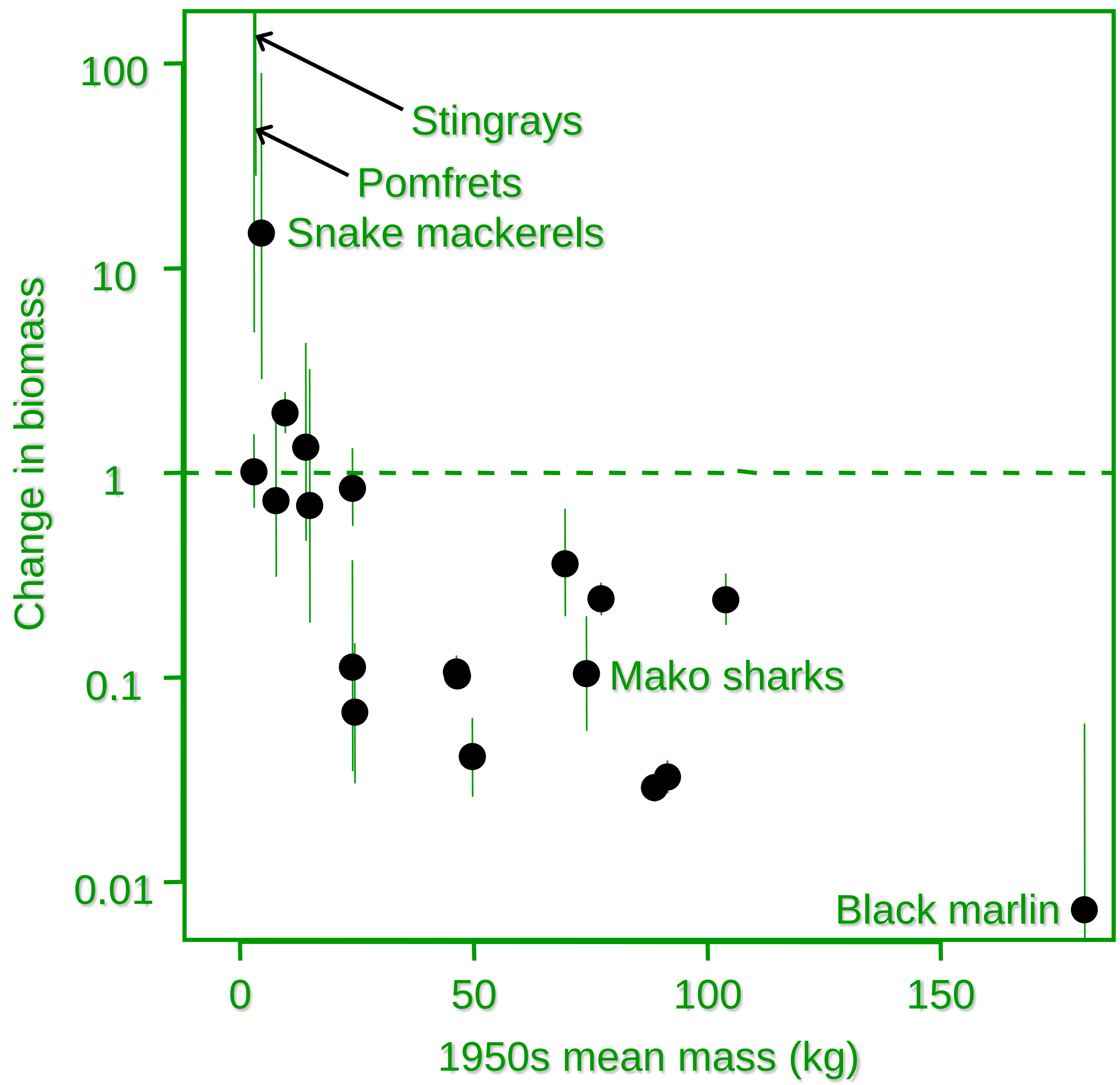


1950's

1990's

Pelagic stingray captures per 10,000 hooks

Many thanks to NMFS for data and advice



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)

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

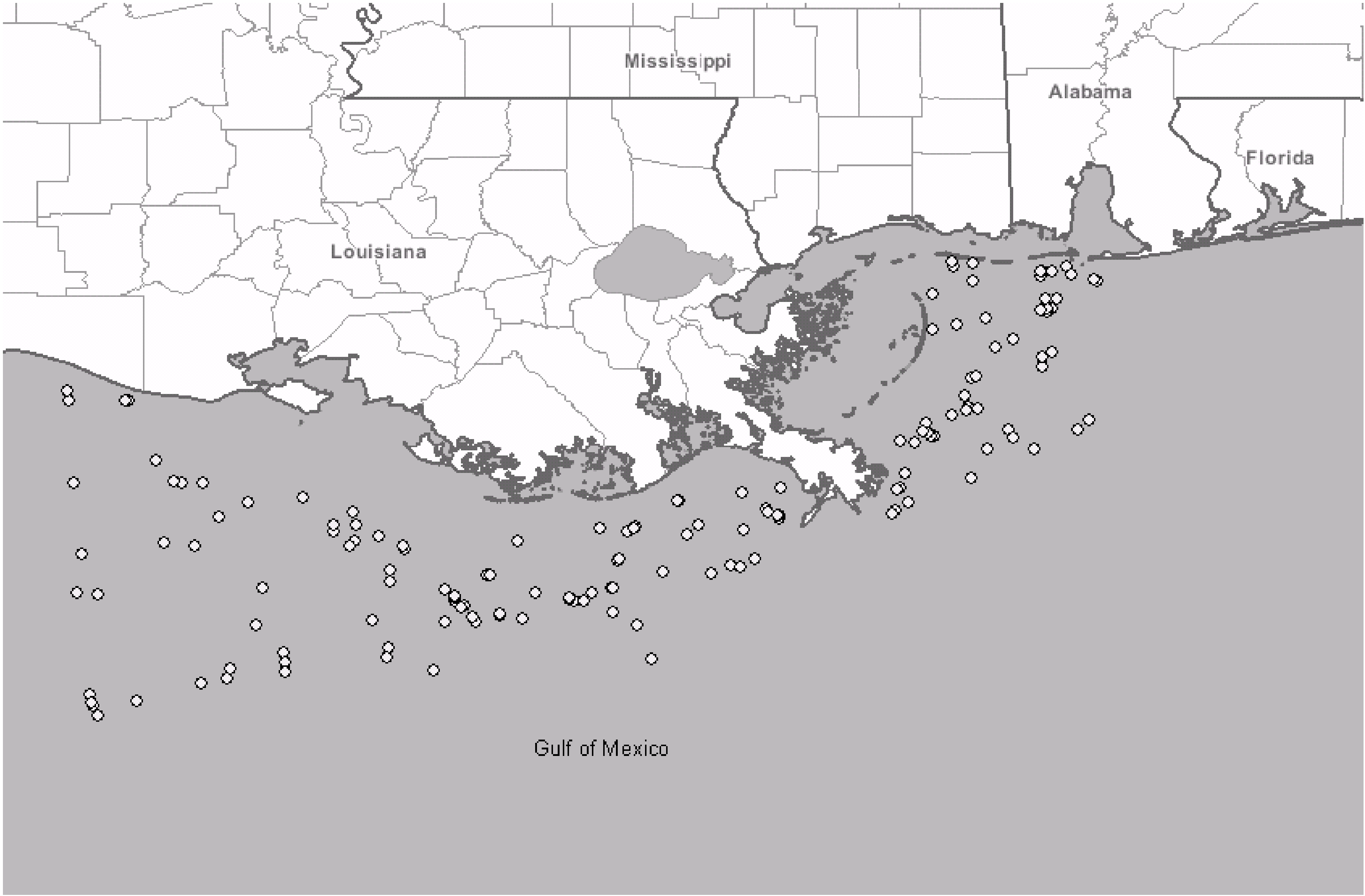
FMAP (Future of Marine Animal Populations)
part of the Sloan Census of Life http://www.fmap.ca
Pew Global Sharks Assessment http://www.globalsharks.ca

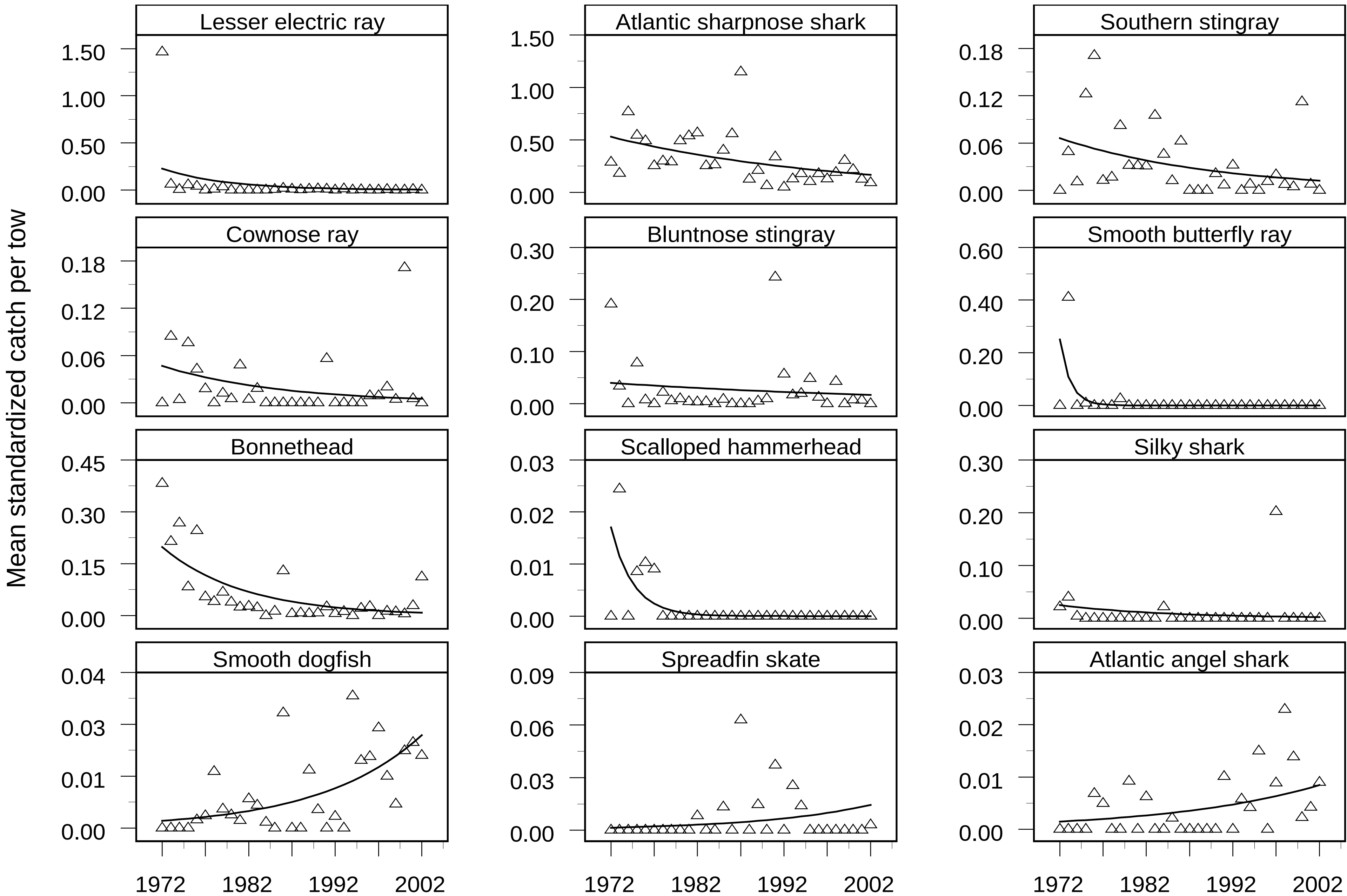
The First Collective Act of Humanity was to save the great whales –

despite massive denial

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

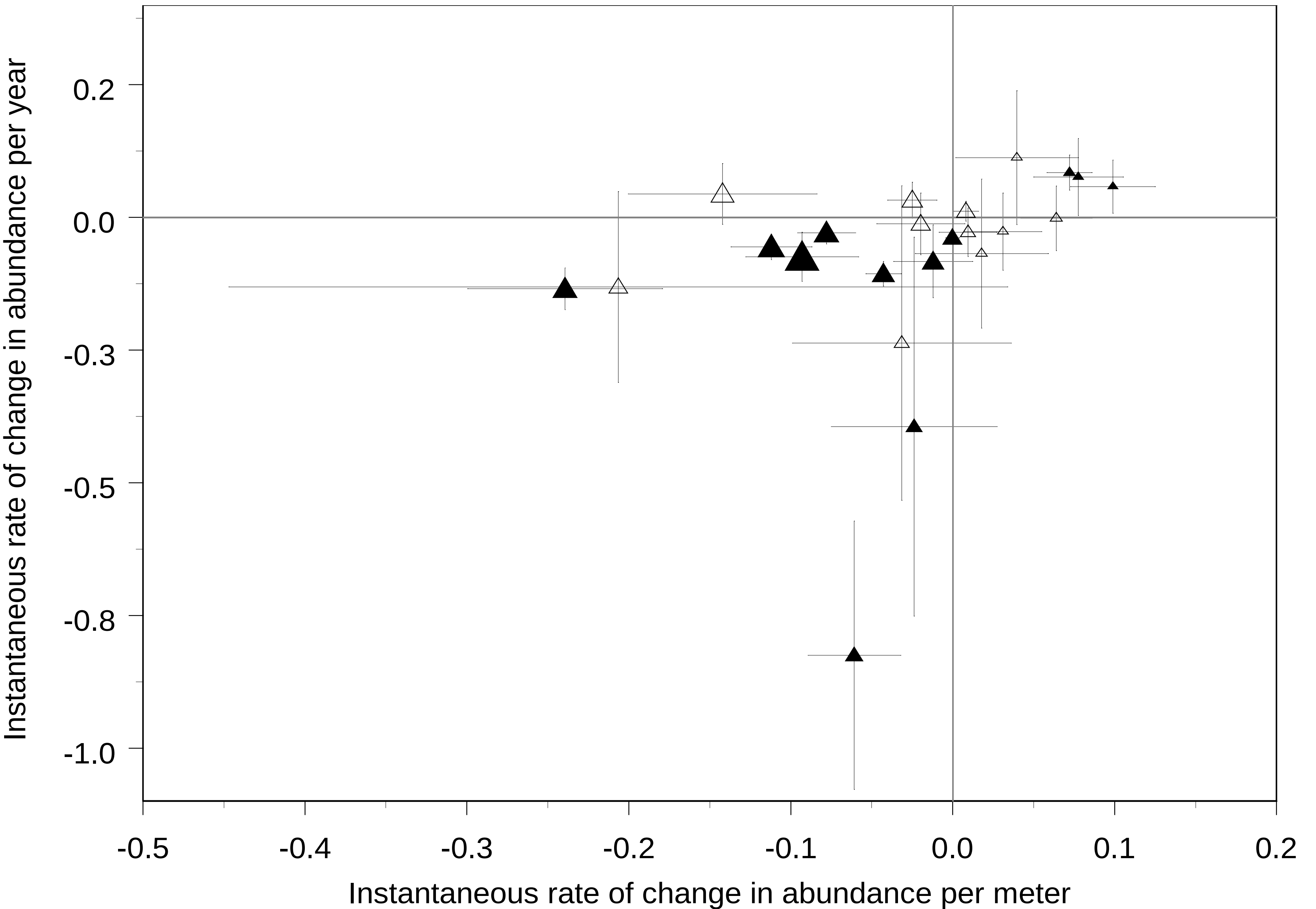
Is shrimp trawling driving sharks and rays extinct?

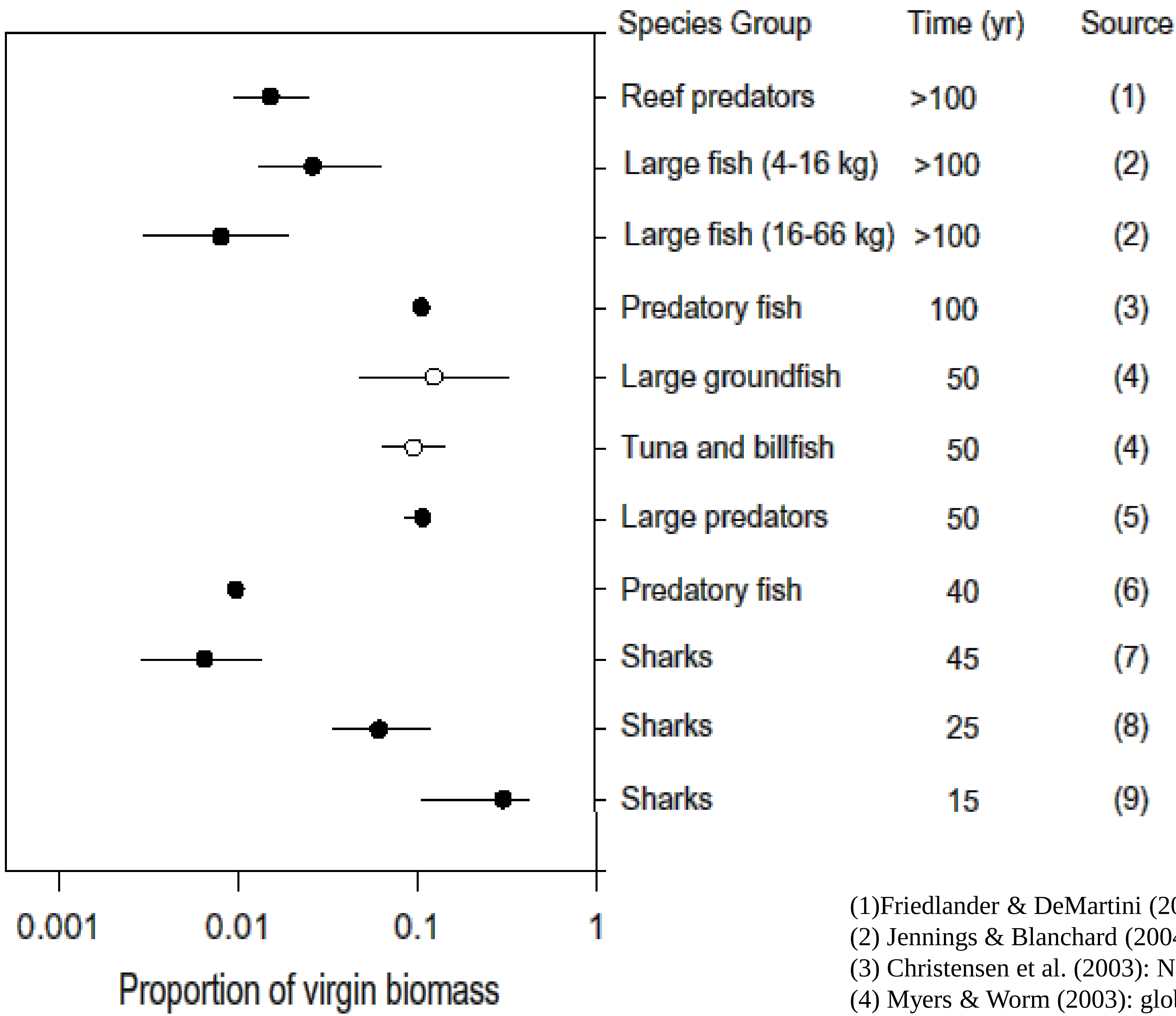




Mean standardized catch per tow
Lesser electric ray
Atlantic sharpnose shark
Southern stingray
Cownose ray
Bluntnose stingray
Smooth butterfly ray
Bonnethead
Scalloped hammerhead
Silky shark
Smooth dogfish
Spreadfin skate
Atlantic angel shark
1972
1982
1992
2002

Shallow species are going extinct
Deep species are increasing





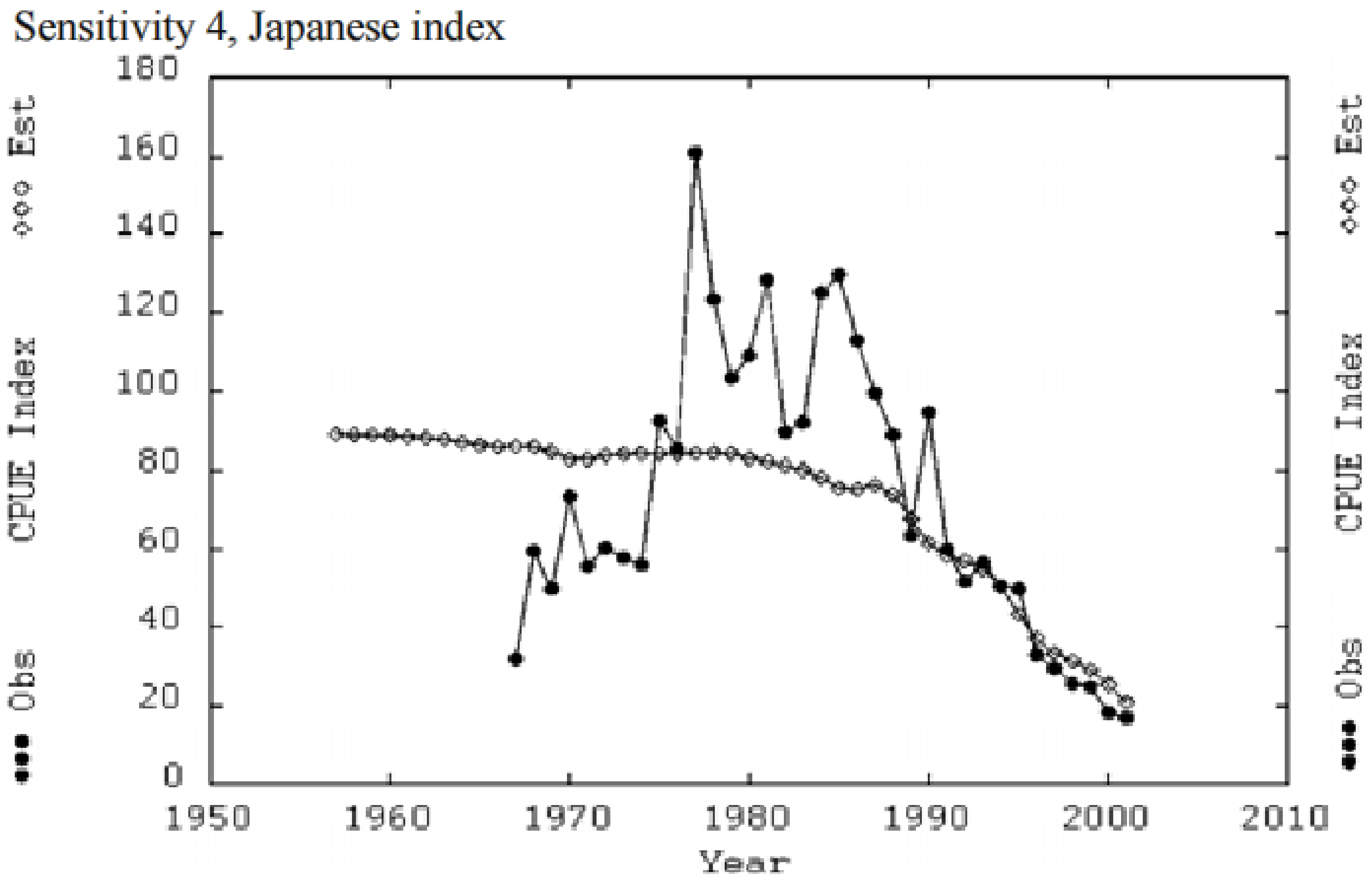
(1)Friedlander & DeMartini (2002): Hawaiian reefs;
(2) Jennings & Blanchard (2004): North Sea;
(3) Christensen et al. (2003): North Atlantic;
(4) Myers & Worm (2003): global;
(5) Ward & Myers (2003): North Pacific;
(6) Tang et al. (2003): Bohai Sea;
(7) Baum & Myers (2004): Gulf of Mexico;
(8) Vacchi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

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

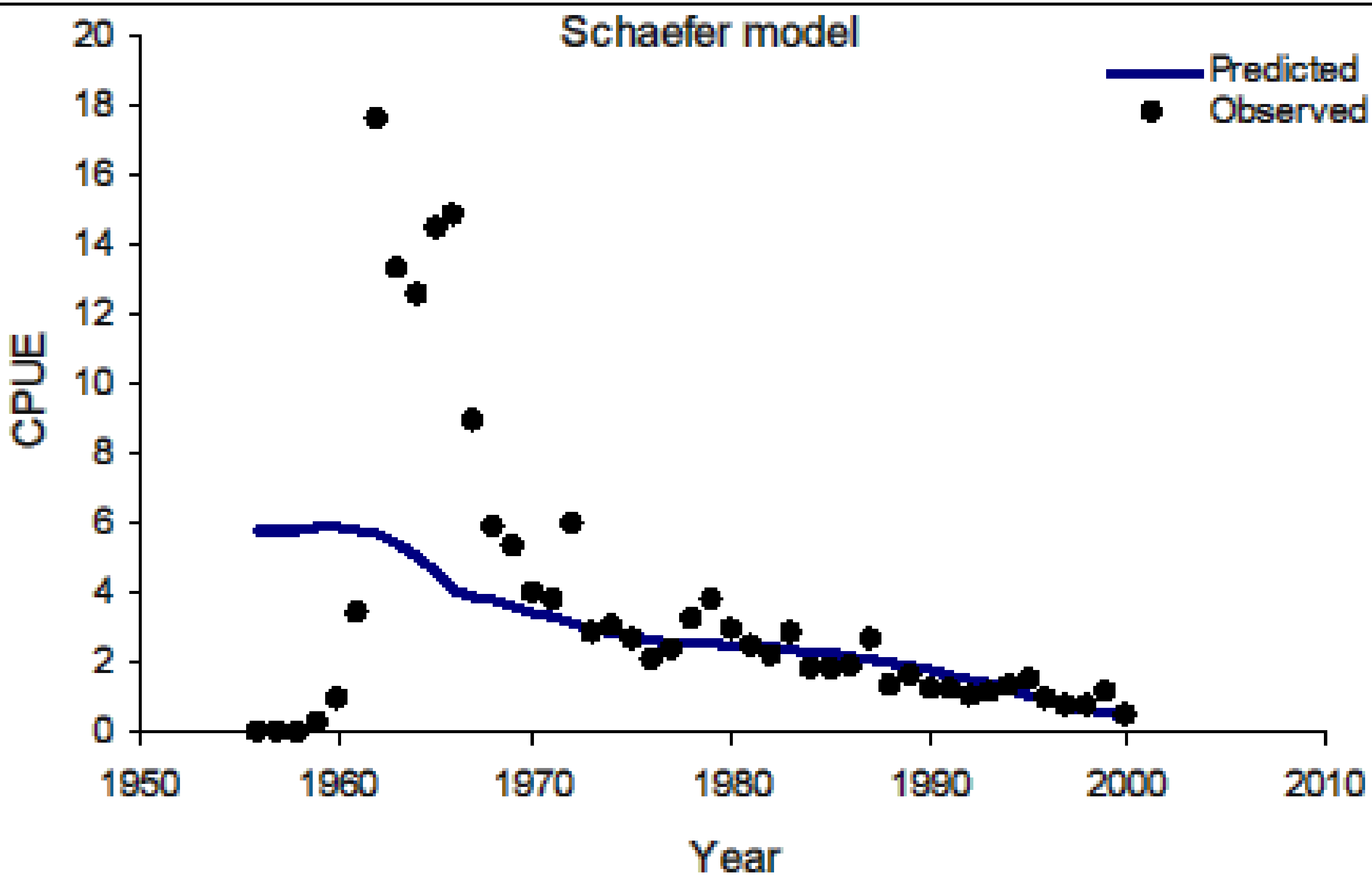
Not only have large predators declined by at least a fact 10, but mesopredators have often increased by at least a factor of 10.

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



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.

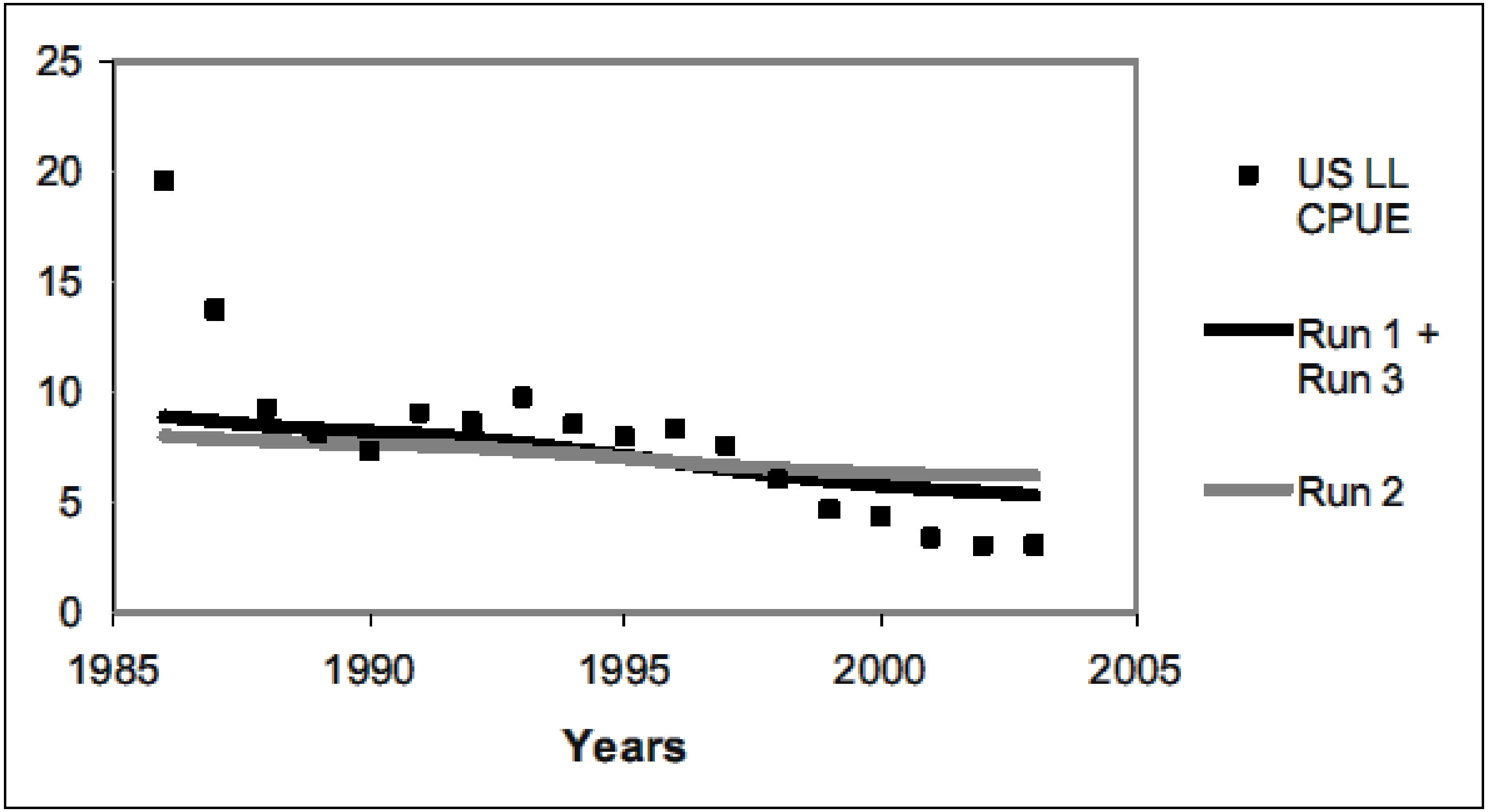
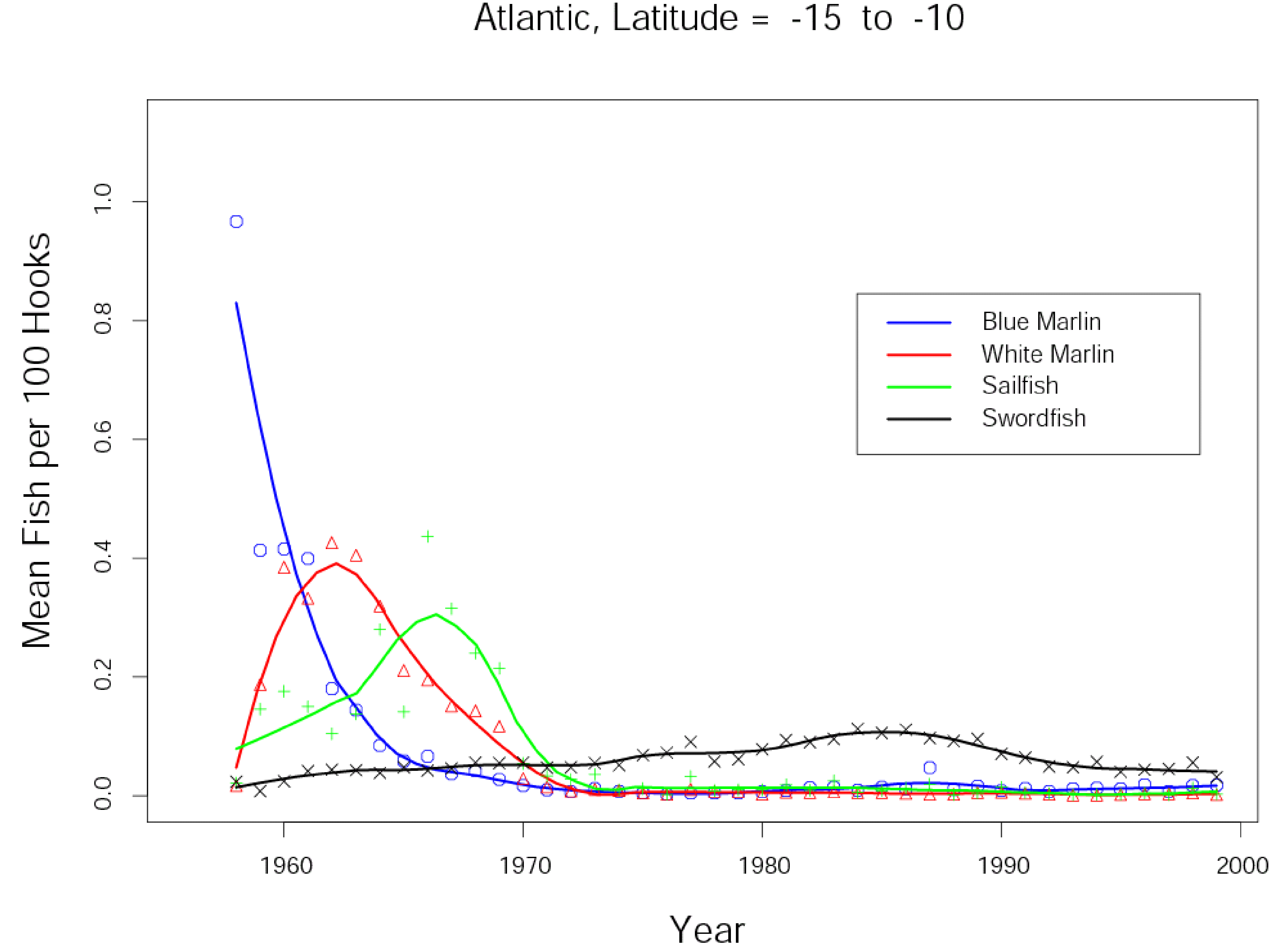
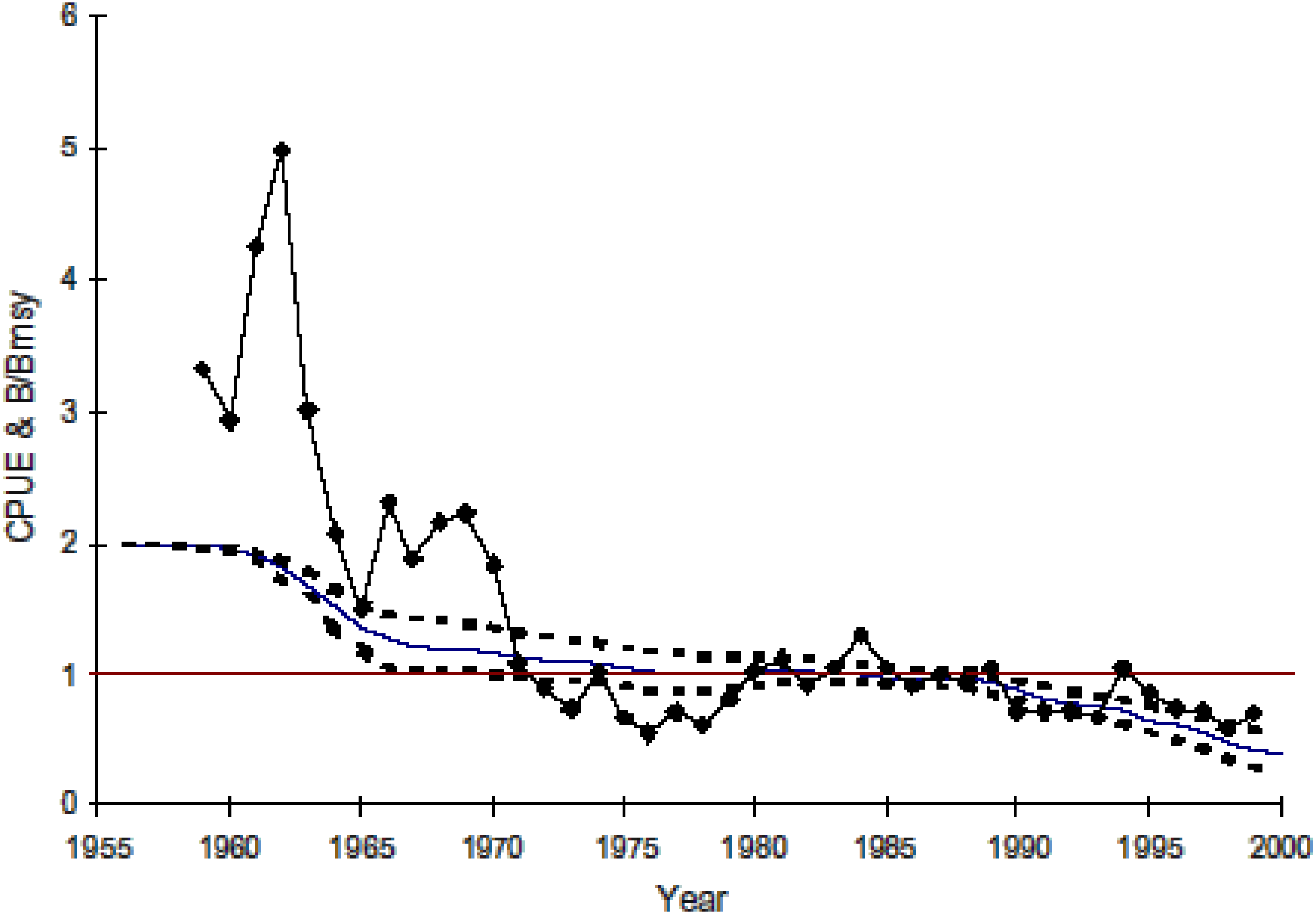


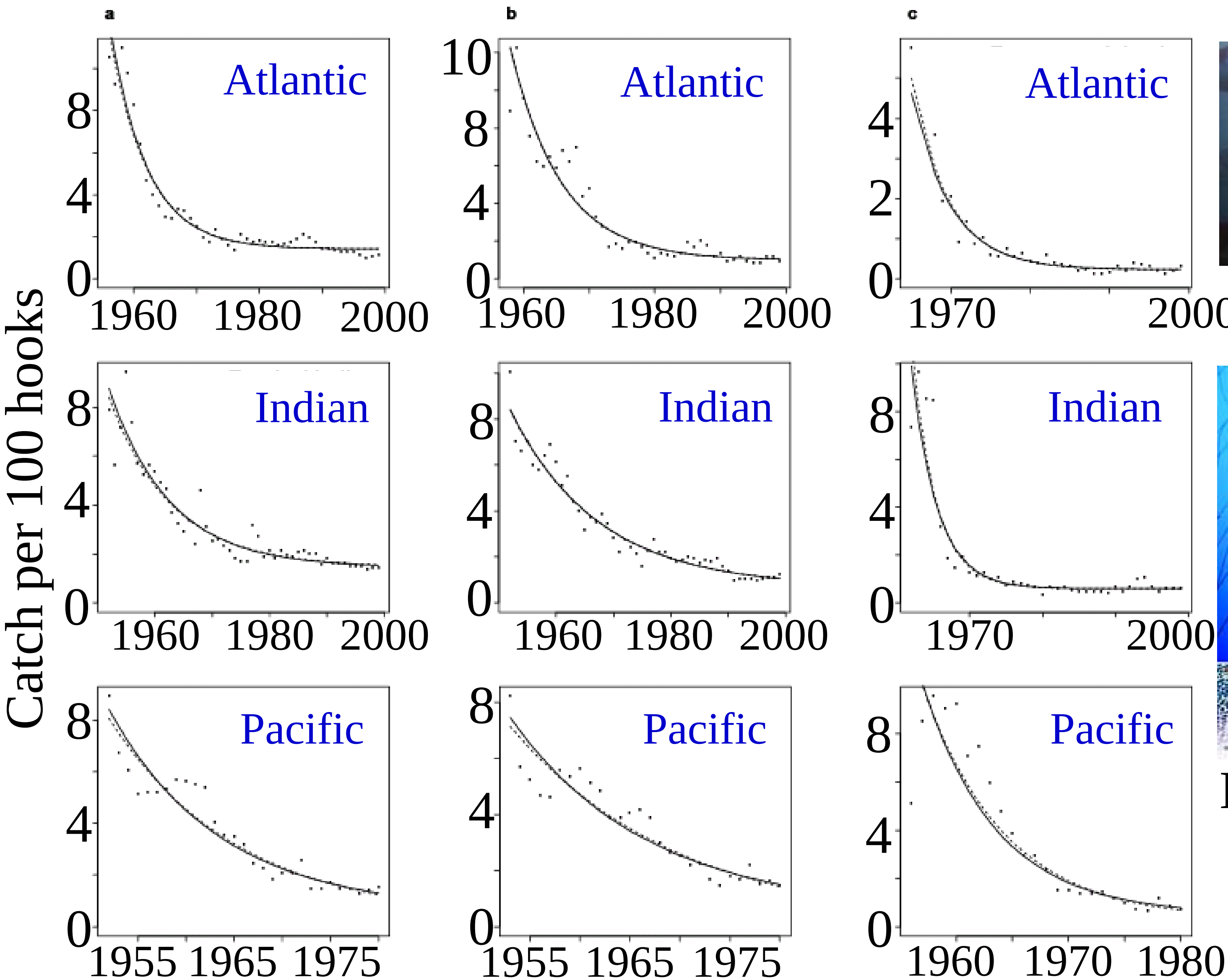
Figure 10 (above). Fit of the model to the North Atlantic blue shark CPUE data for each of the runs considered.


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.

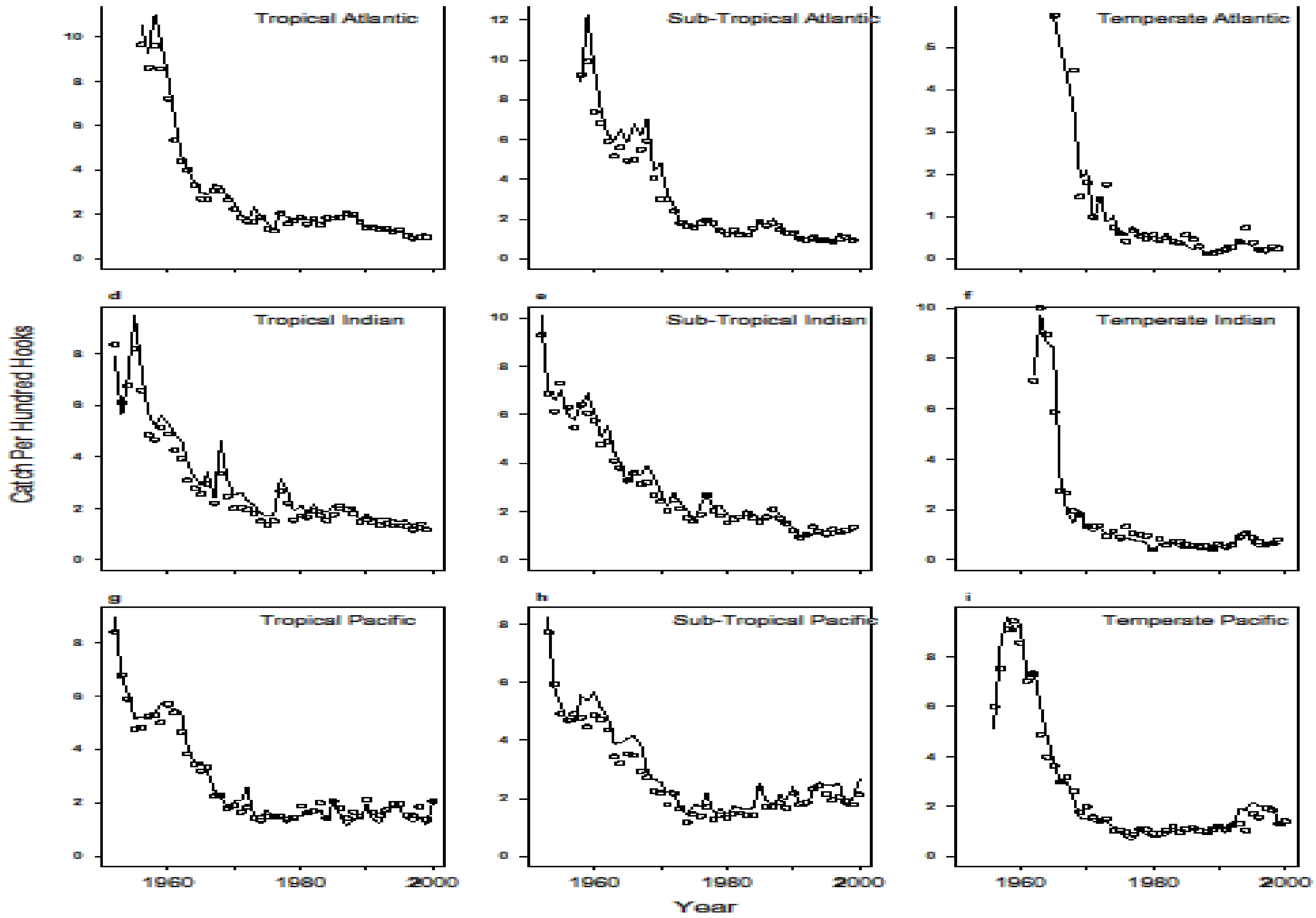


Common patterns of decline

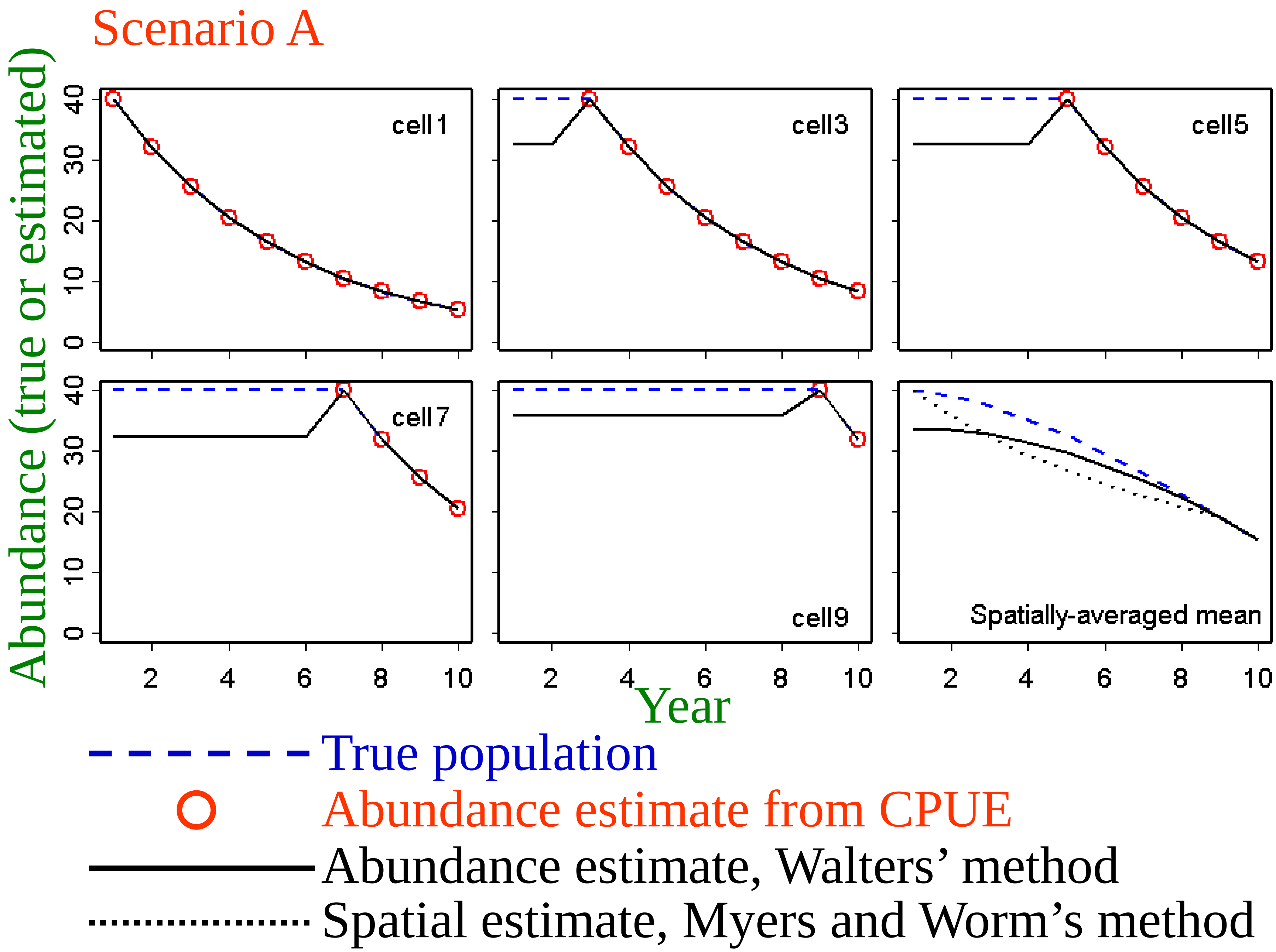


Myers and Worm (2003)

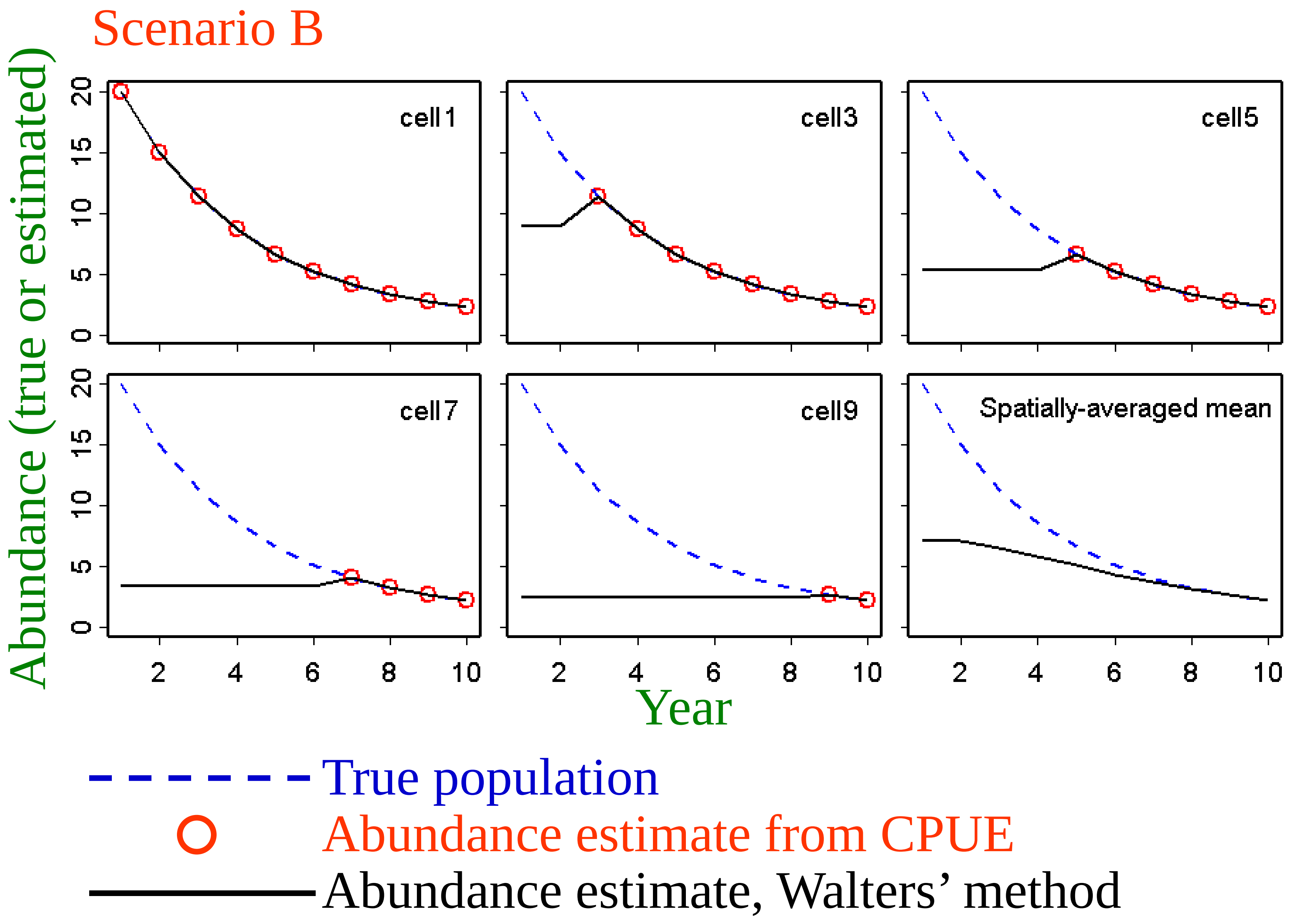
RED HERRING 1: RATIO ESTIMATION



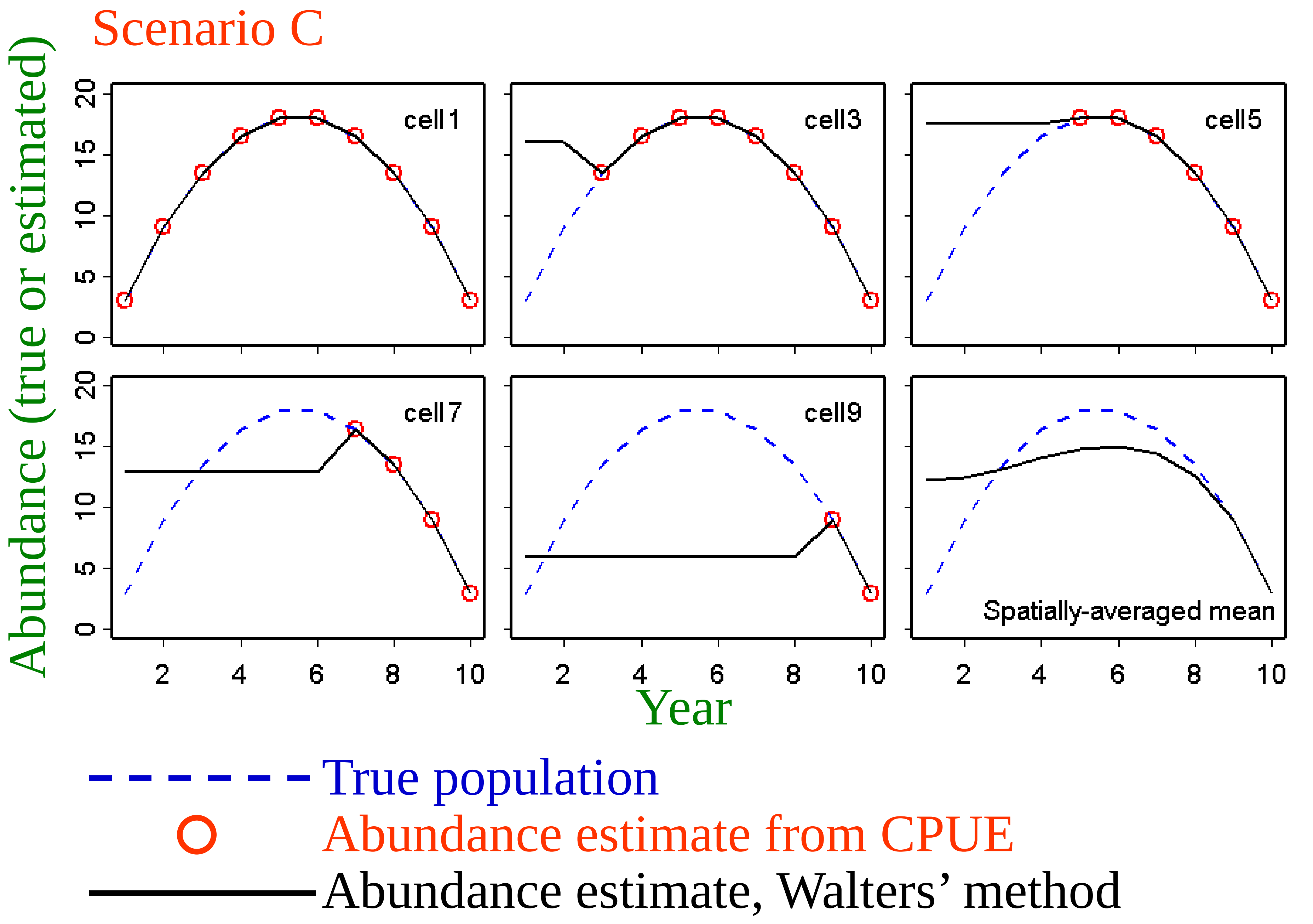
RED HERRING 2: SPATIAL ESTIMATION



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



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

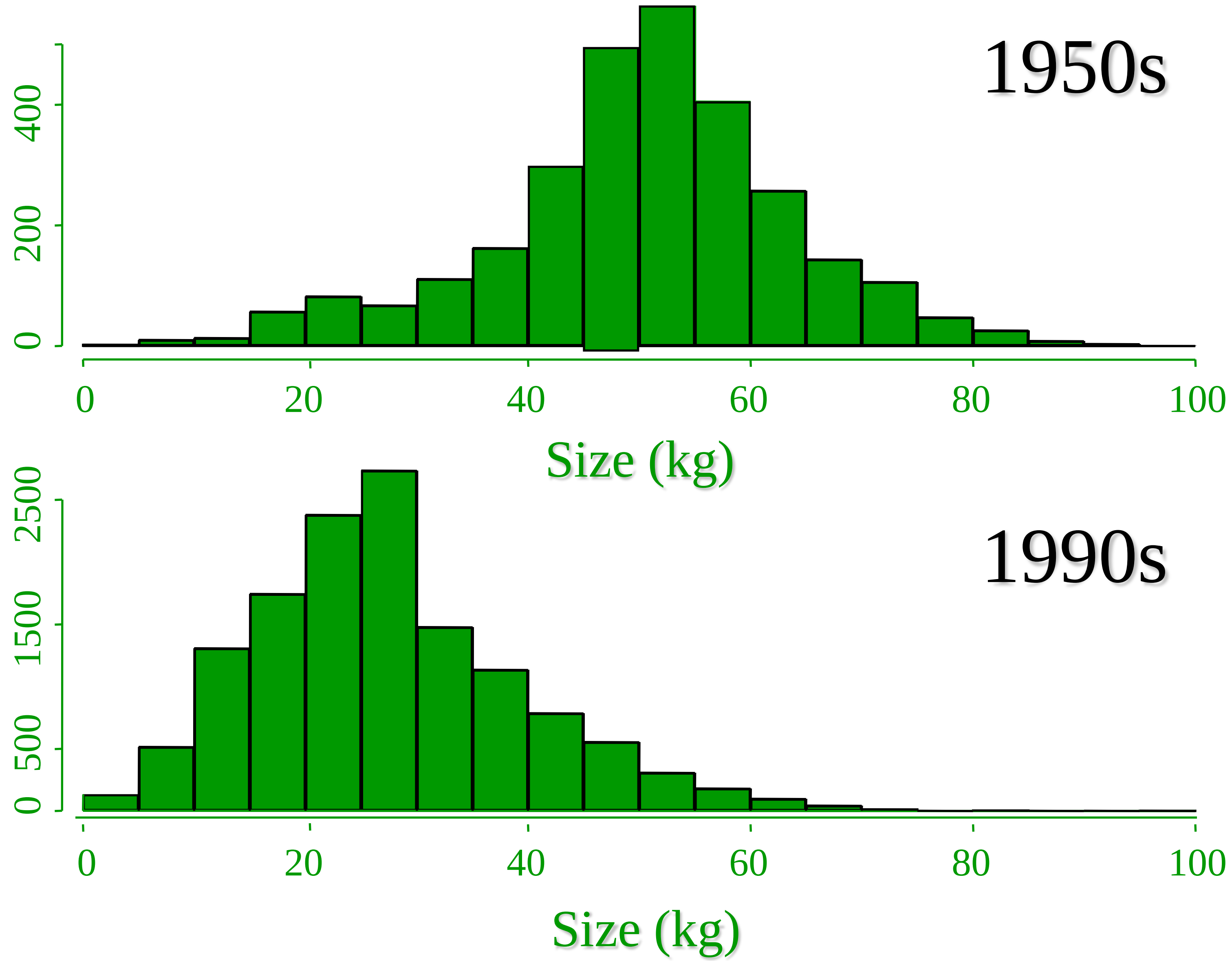


Scenario C
Abundance (true or estimated)
cell 1
cell3
cell5
cell 7
cell9
Spatially-averaged mean
0
5
10
15
20
2
4
6
8
10
Year
True population
Abundance estimate from CPUE
Abundance estimate, Walters' method

These estimates are conservative: 1.

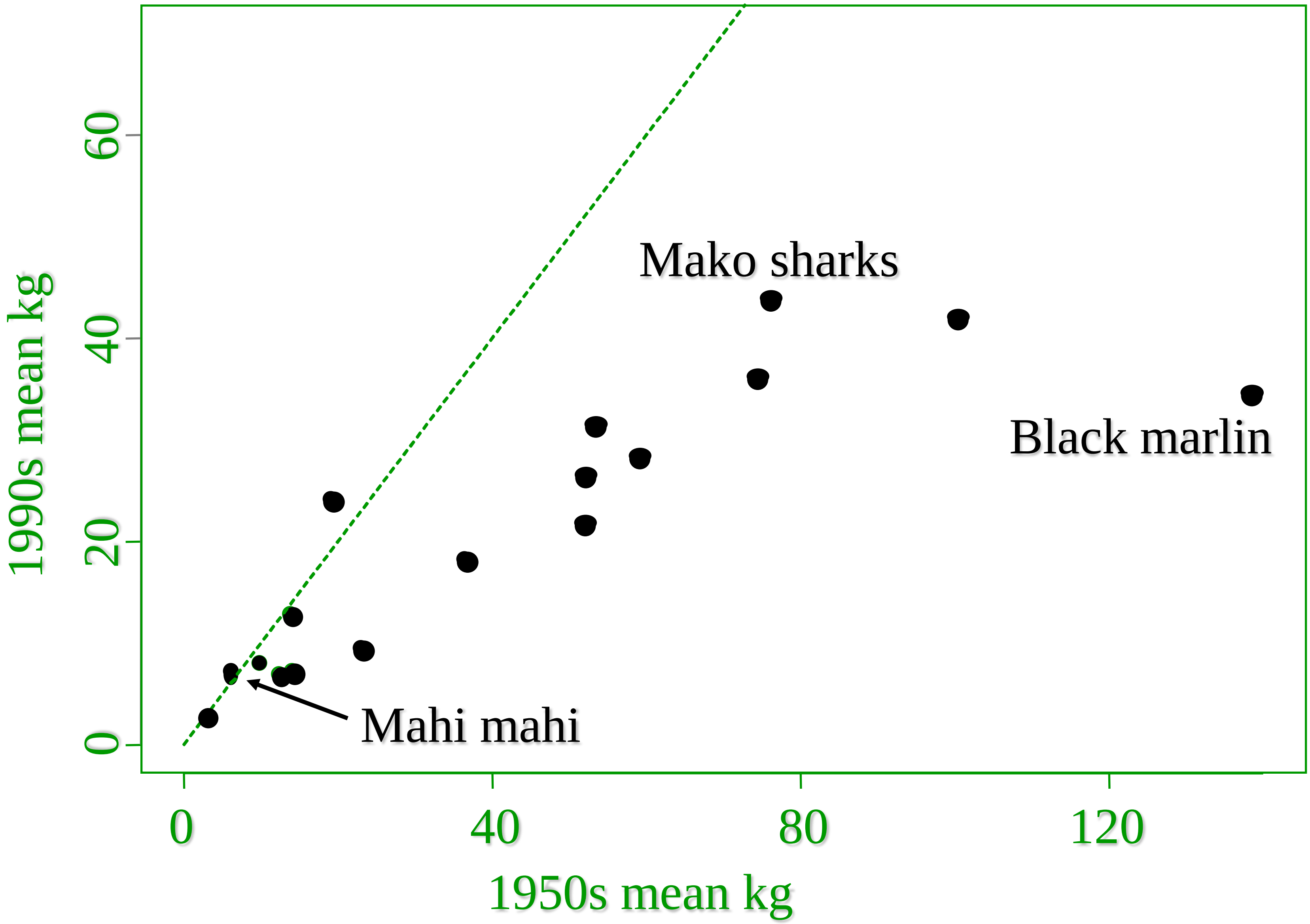
Bits of tuna did not count; ~25-30% of tropical tunas were initially not counted because of shark damage.

These estimates are conservative: 2 (fish are smaller)



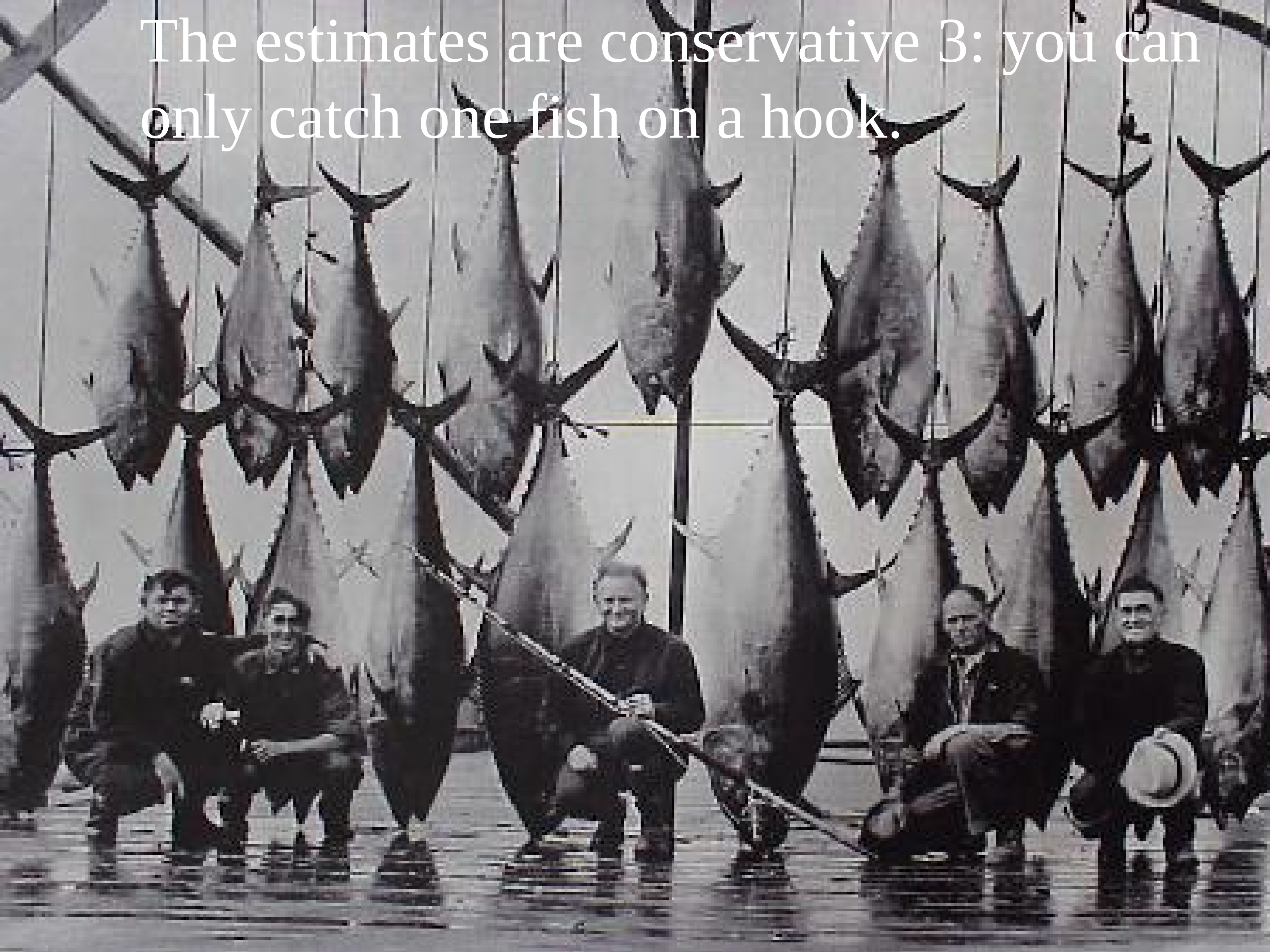
Yellowfin tuna – equitorial Pacific

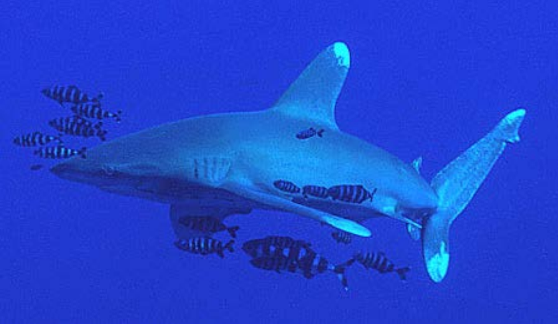
Change in body size




555
lbs.
Cabo Blan
LBS.
1135
CABO
BLANCO

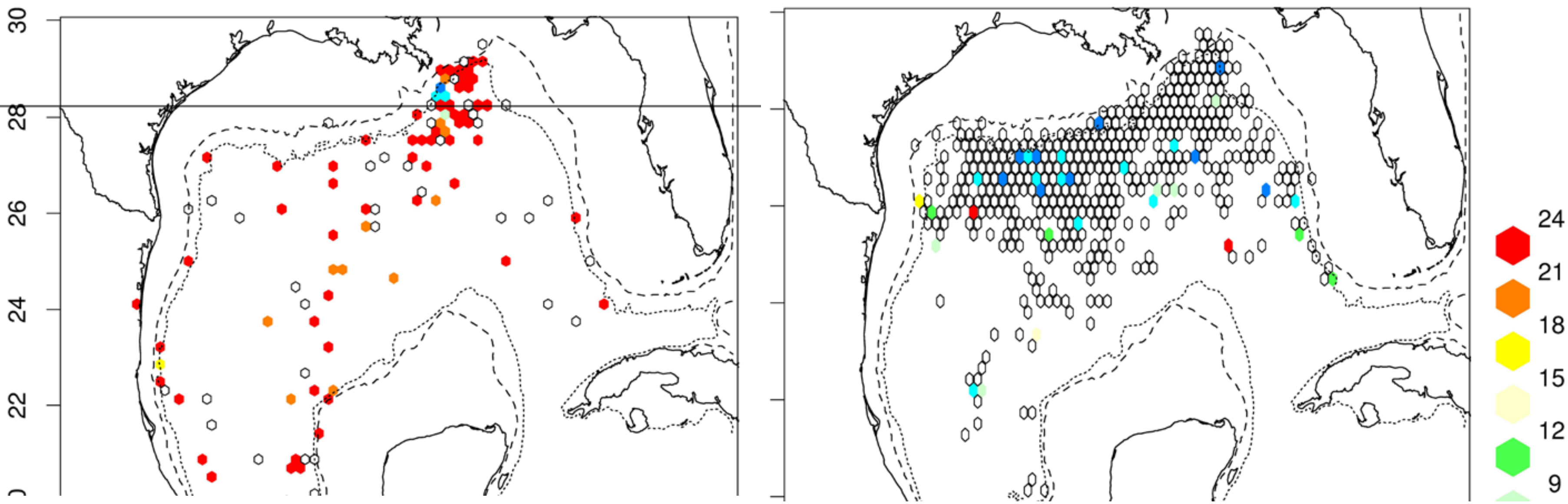
The estimates are conservative 3: you can only catch one fish on a hook.





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

[redacted]



1950’s

1990’s

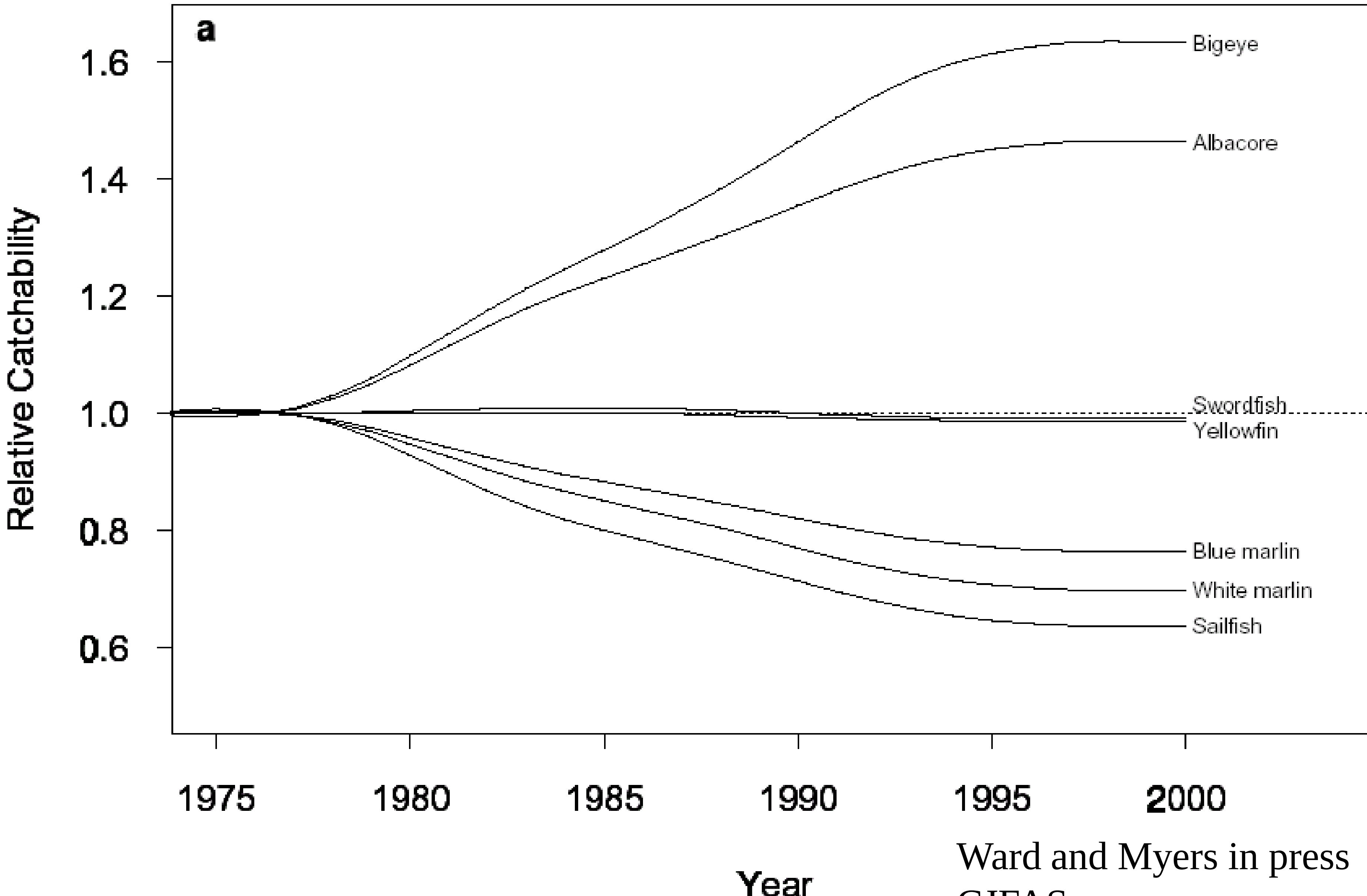
Oceanic Whitetip captures per 10,000 hooks

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.

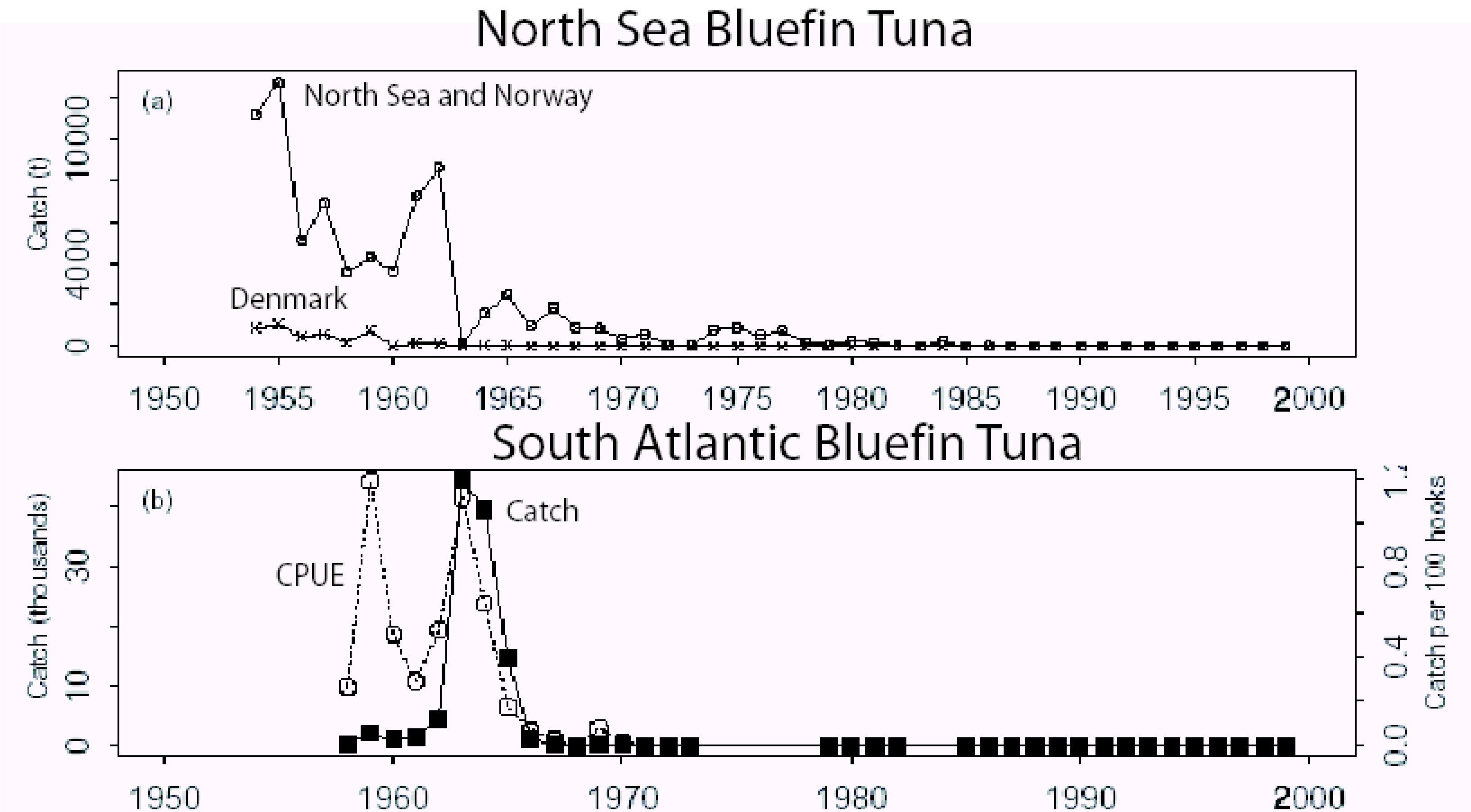


Ward and Myers in press
CJFAS

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

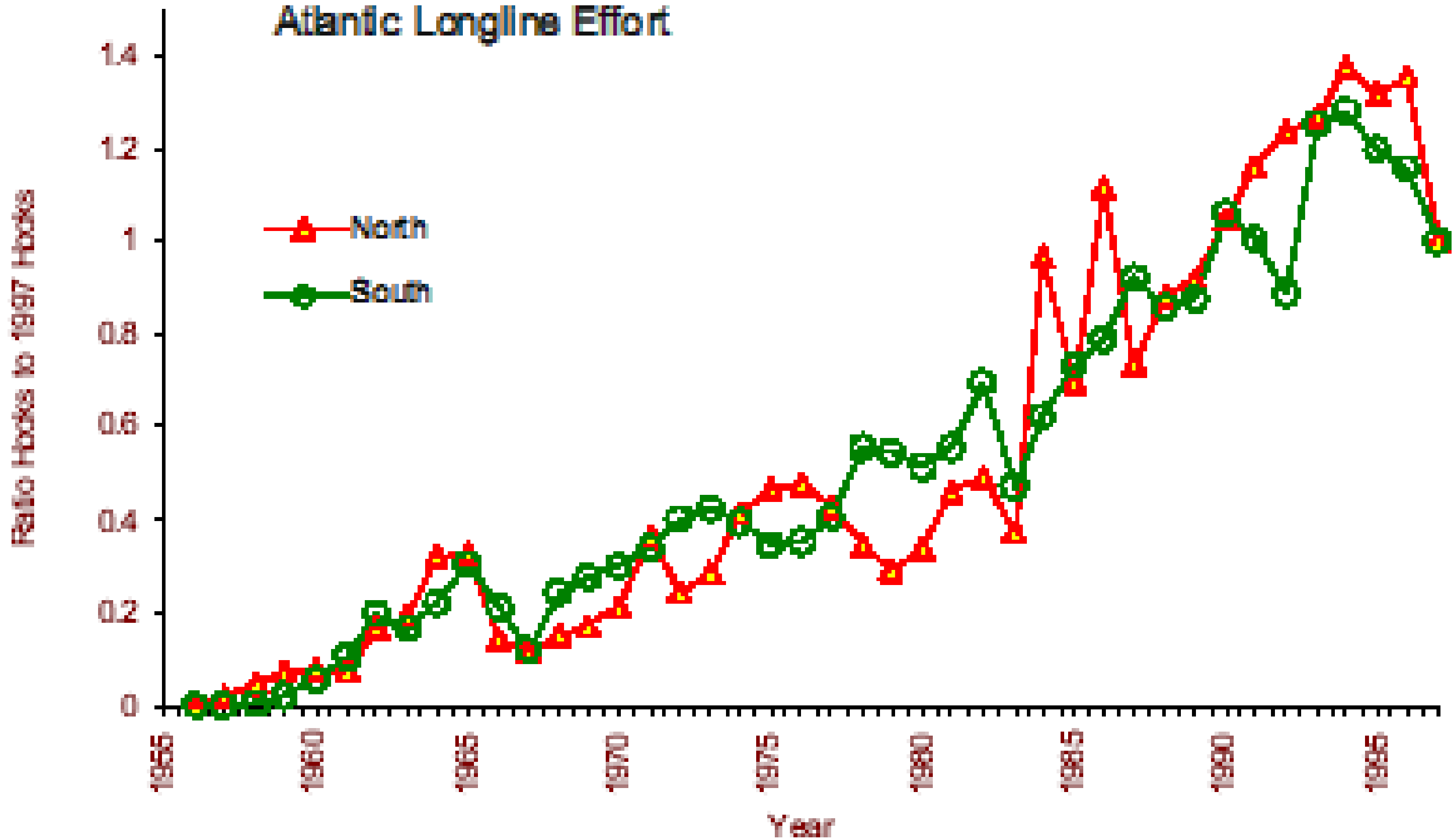


Perceived Contradiction in Initial Rapid Decline in CPUE

- 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

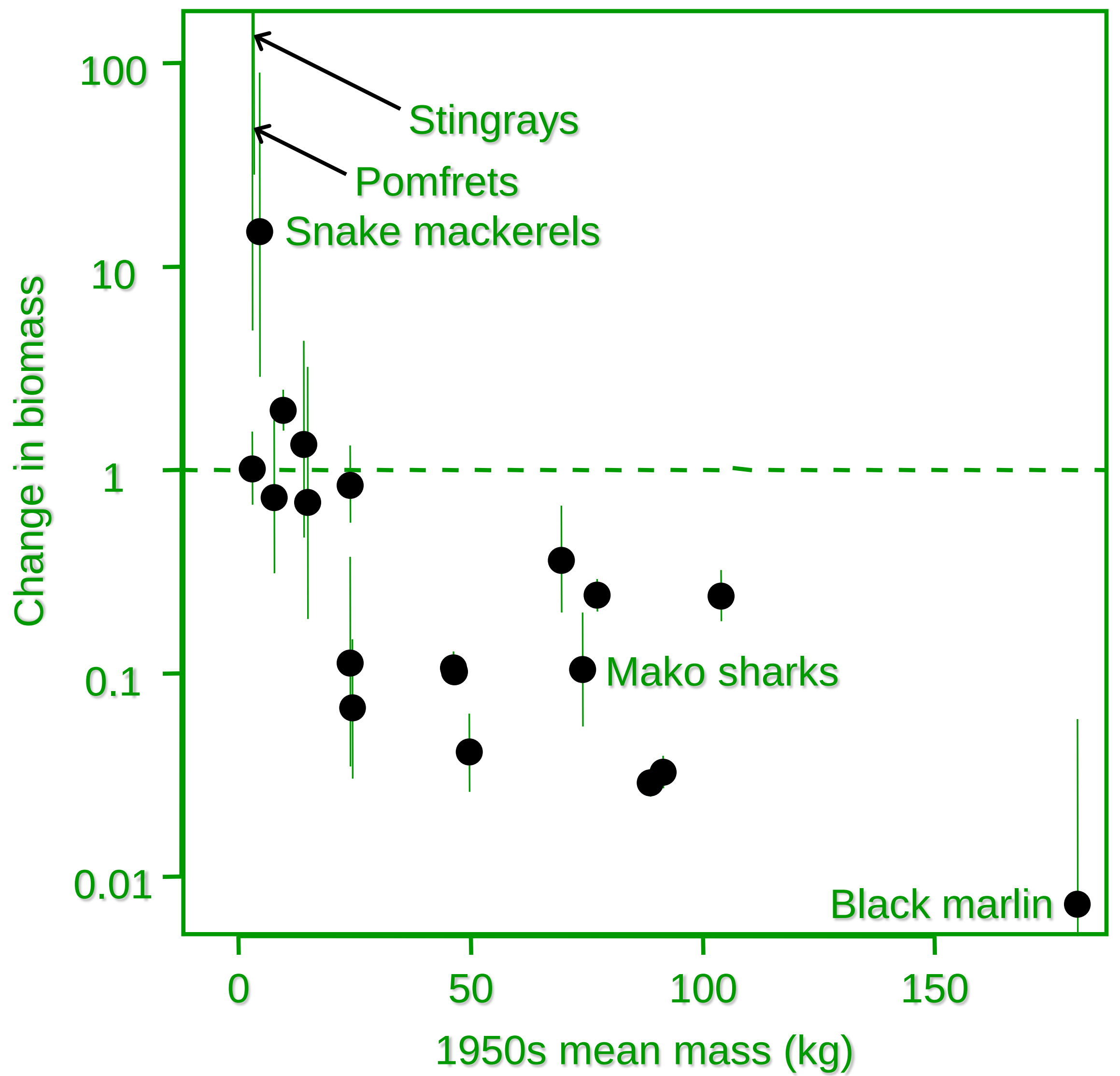
3. Present fishing mortality due to longlines is around 0.6

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

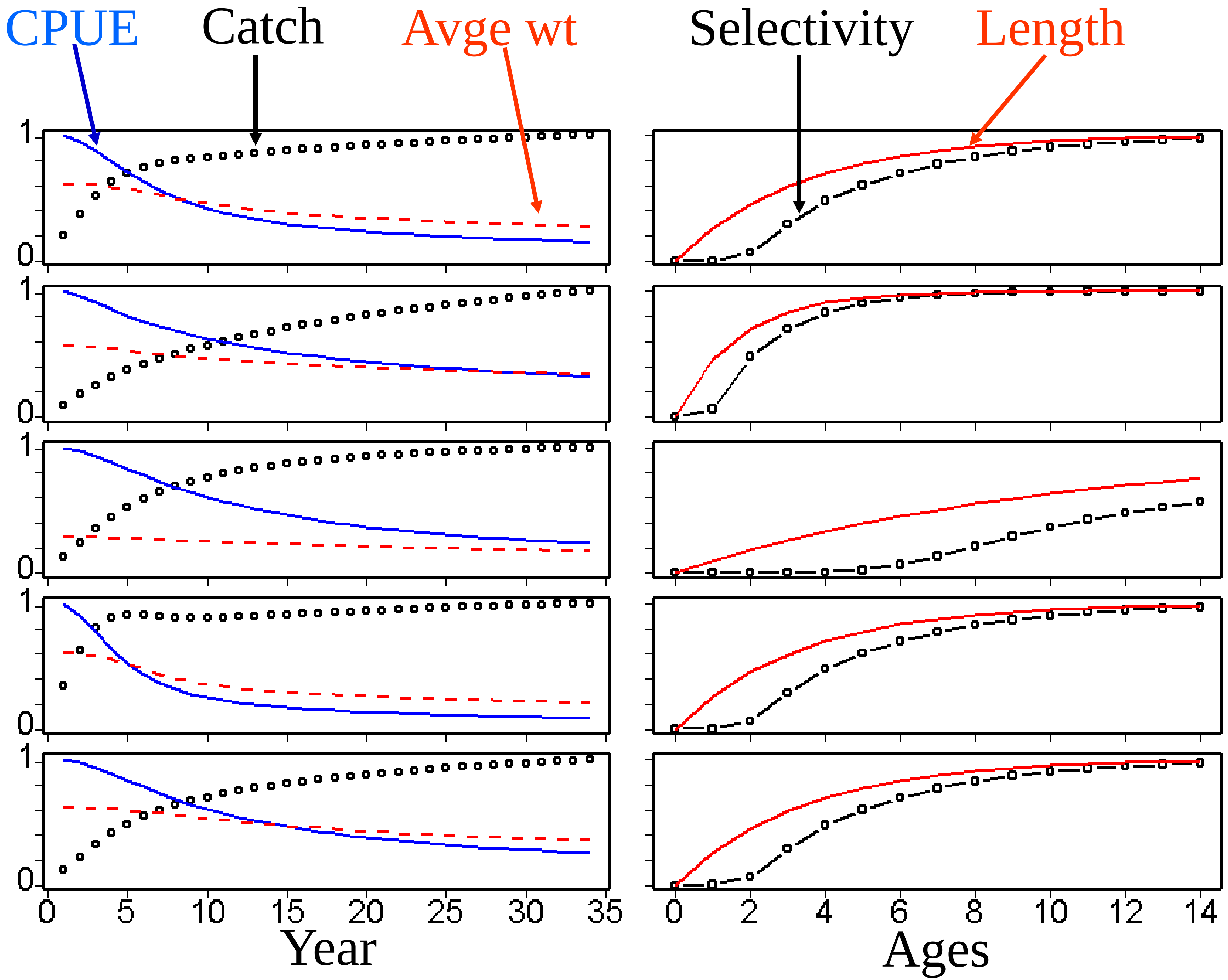


Stingrays
Pomfrets
Snake mackerels
Mako sharks
Black marlin
100
10
1
0.1
0.01
Change in biomass
0
50
100
150
1950s mean mass (kg)

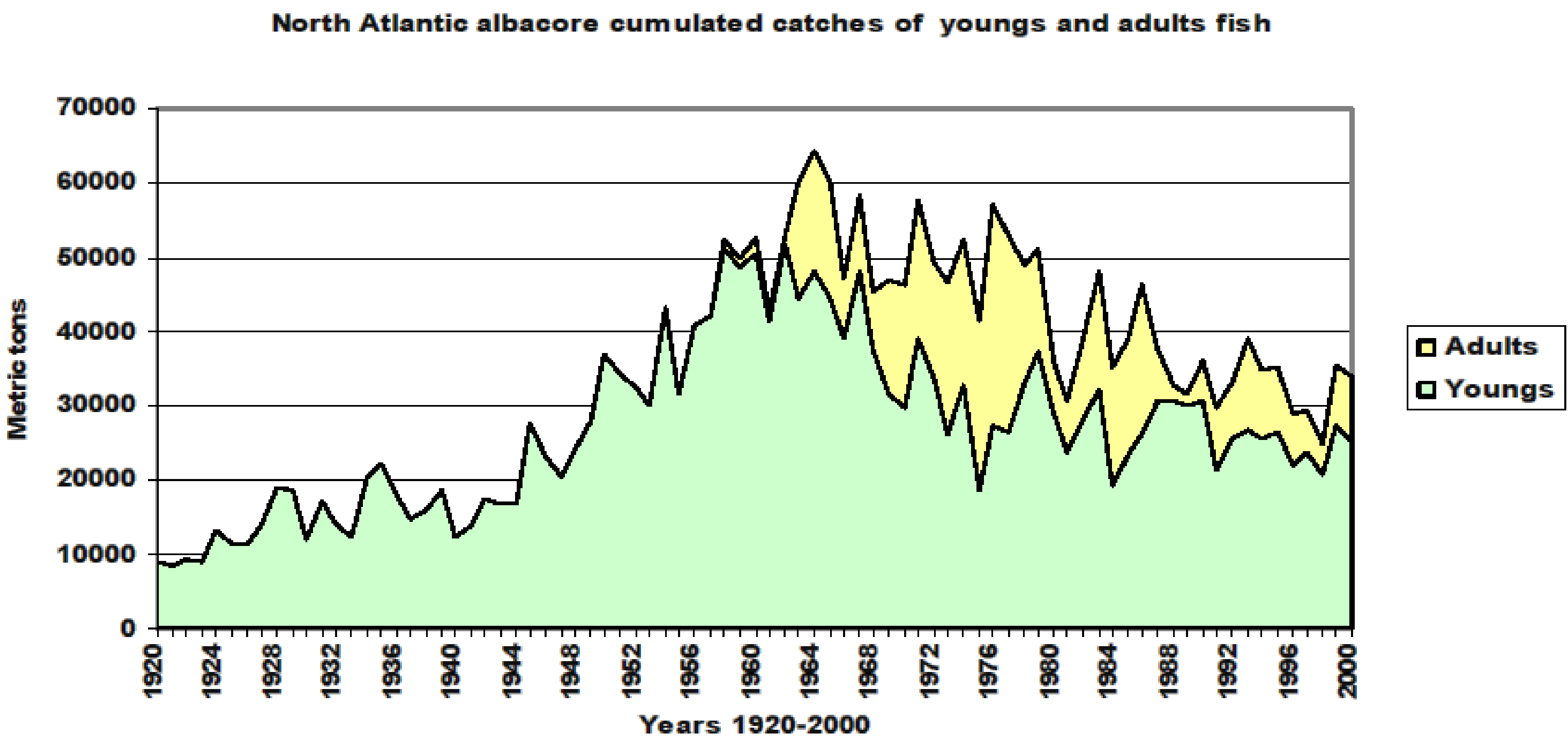

555
lbs.
LBS.
1135
CABO
BLANCO

A Toy Model

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



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



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

Conclusion

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

Acknowledgements

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

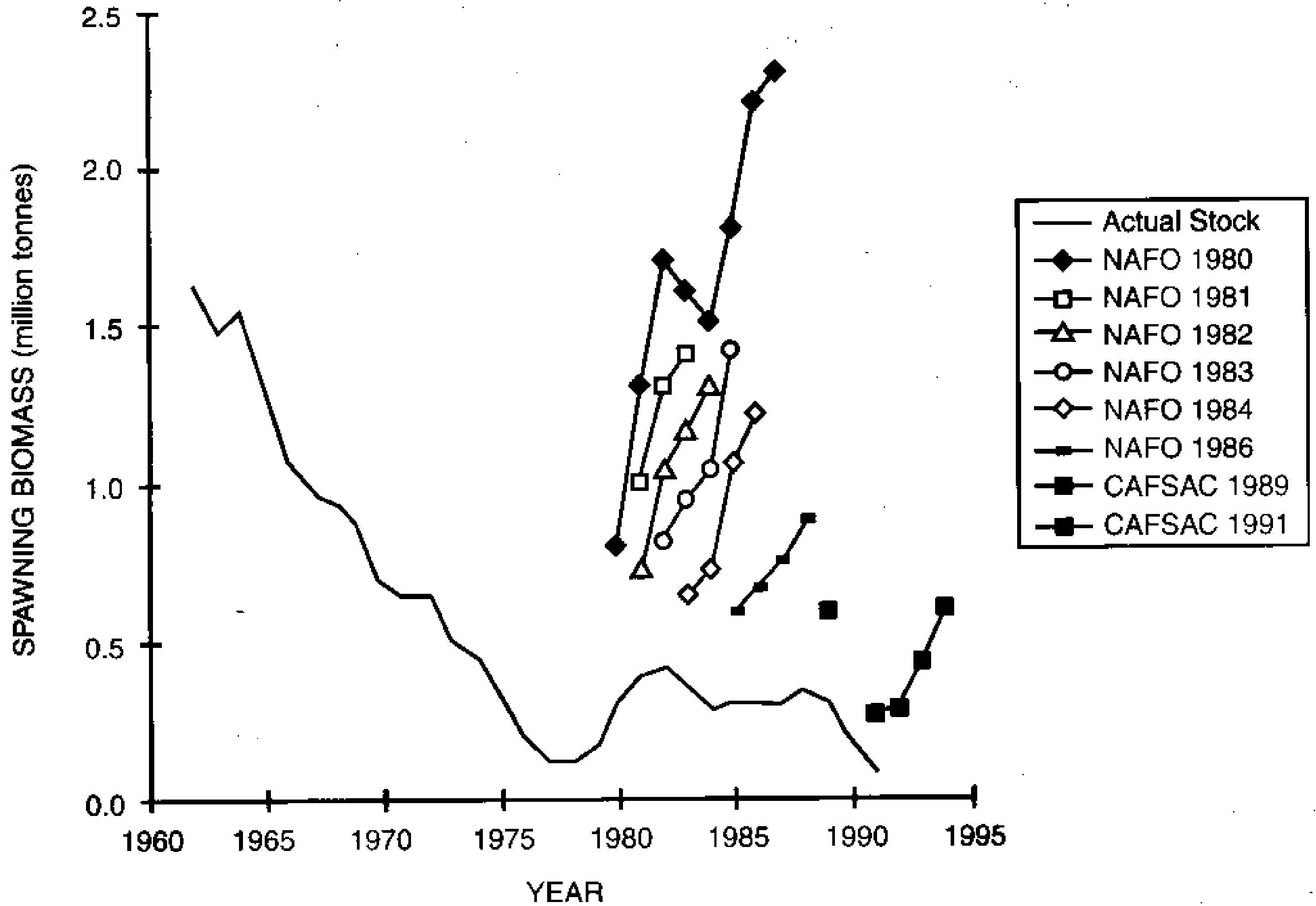


Fig. 3. **Recent reconstruction, using virtual population analysis, of the Newfoundland northern cod** decline, compared with estimates and projections published in various years after Canada took over the fishery under extended jurisdiction. VPA estimates based on data in Baird *et al.* (1992) (see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

Rapid decline in older albacore.

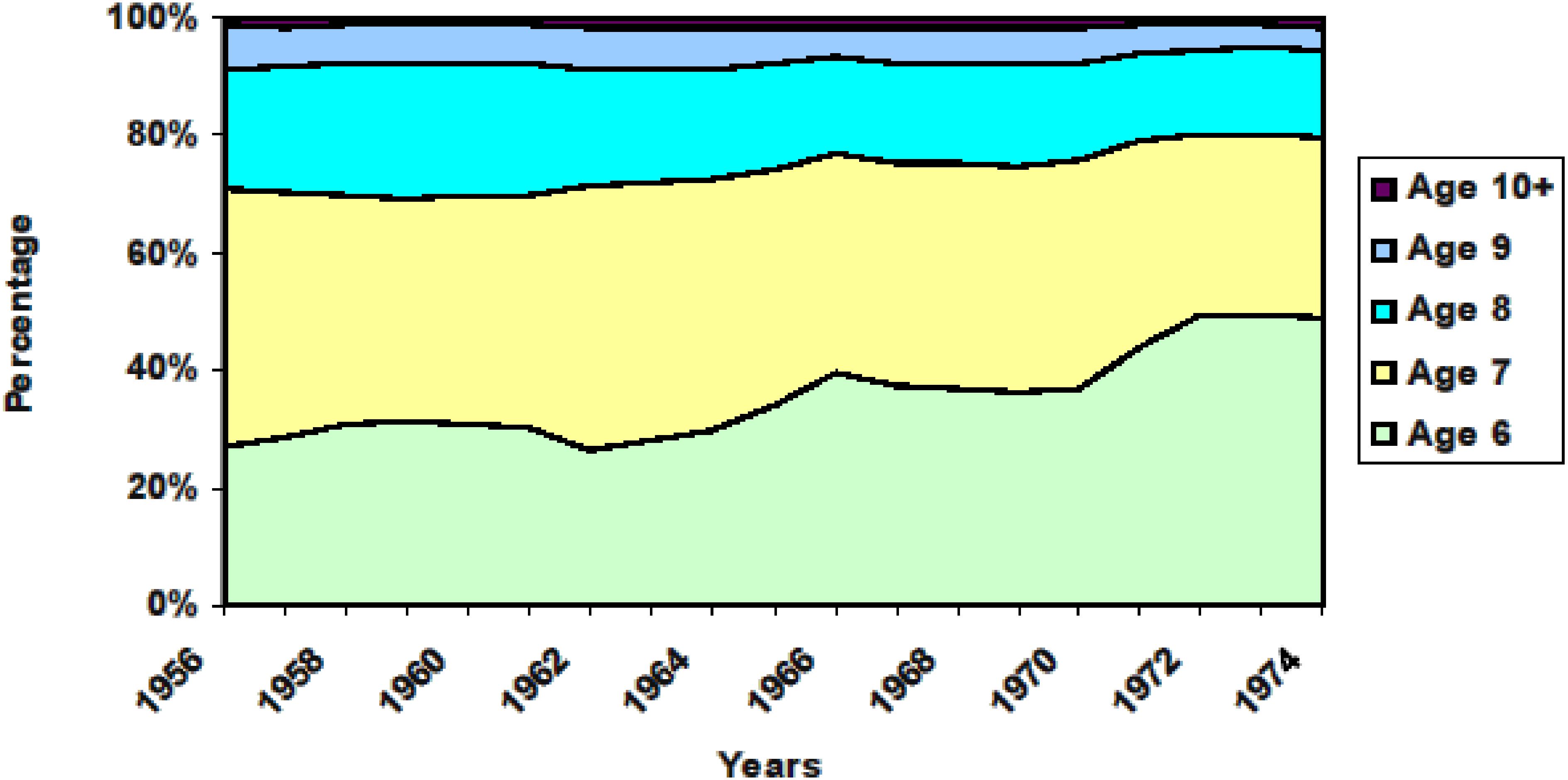
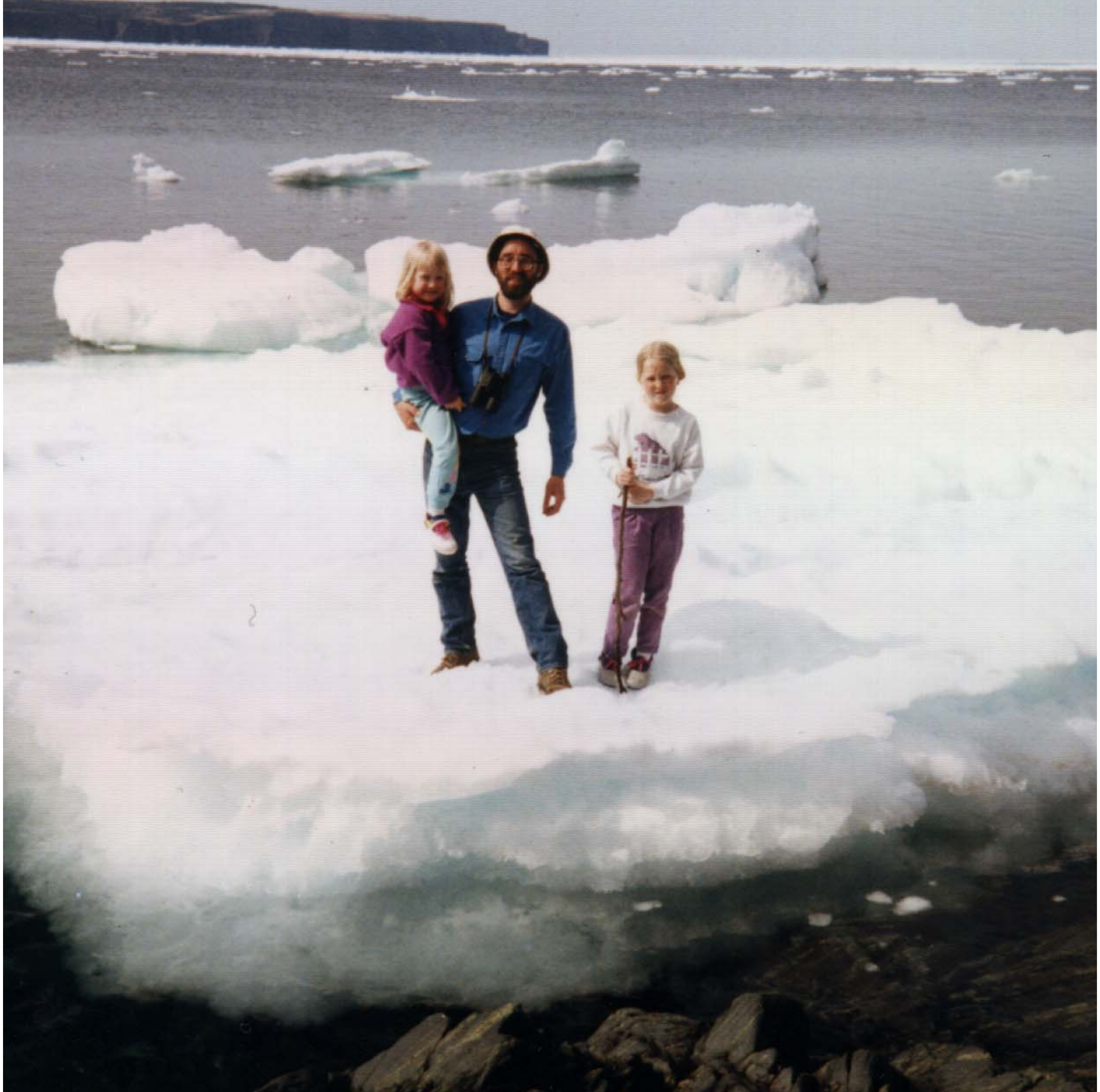


Figure 7 : Evolution of contribution of age classes 6 to 10+ computed by Morita (1977) in longliners albacore catches, 1956-1974.



Marine ecosystem robustness and the collaps marine fisheries

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

One hypothesis:

Fishing mortality ↑

↓

Predation on sailfish juveniles ↓

↓

Survivorship of sailfish juveniles ↑

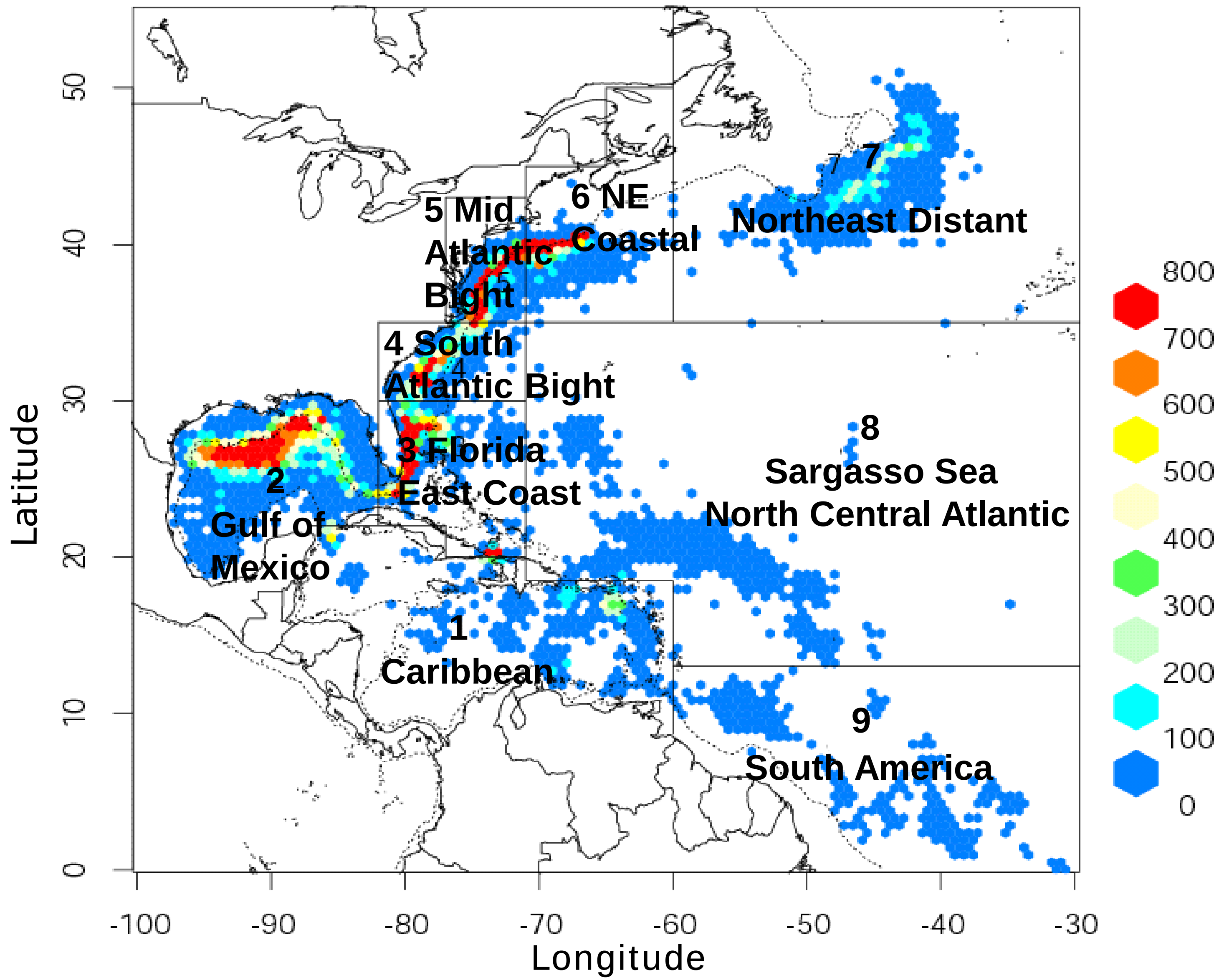
↓

Sailfish population ↑

Collapse and Conservation of Shark Populations in the Northwest Atlantic

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

U.S. Atlantic pelagic longline sets 1986-2000



Political action is costly for any scientist.

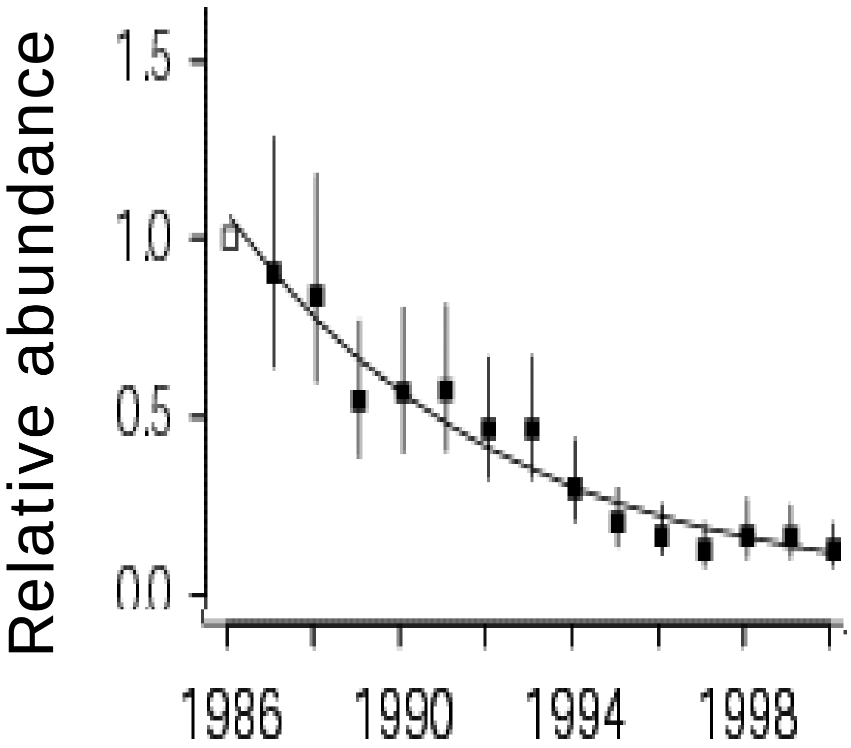
However, it also has great benefits.

To act is to live.

To be suppressed is to die.

Hammerhead sharks

Sphyrna lewini



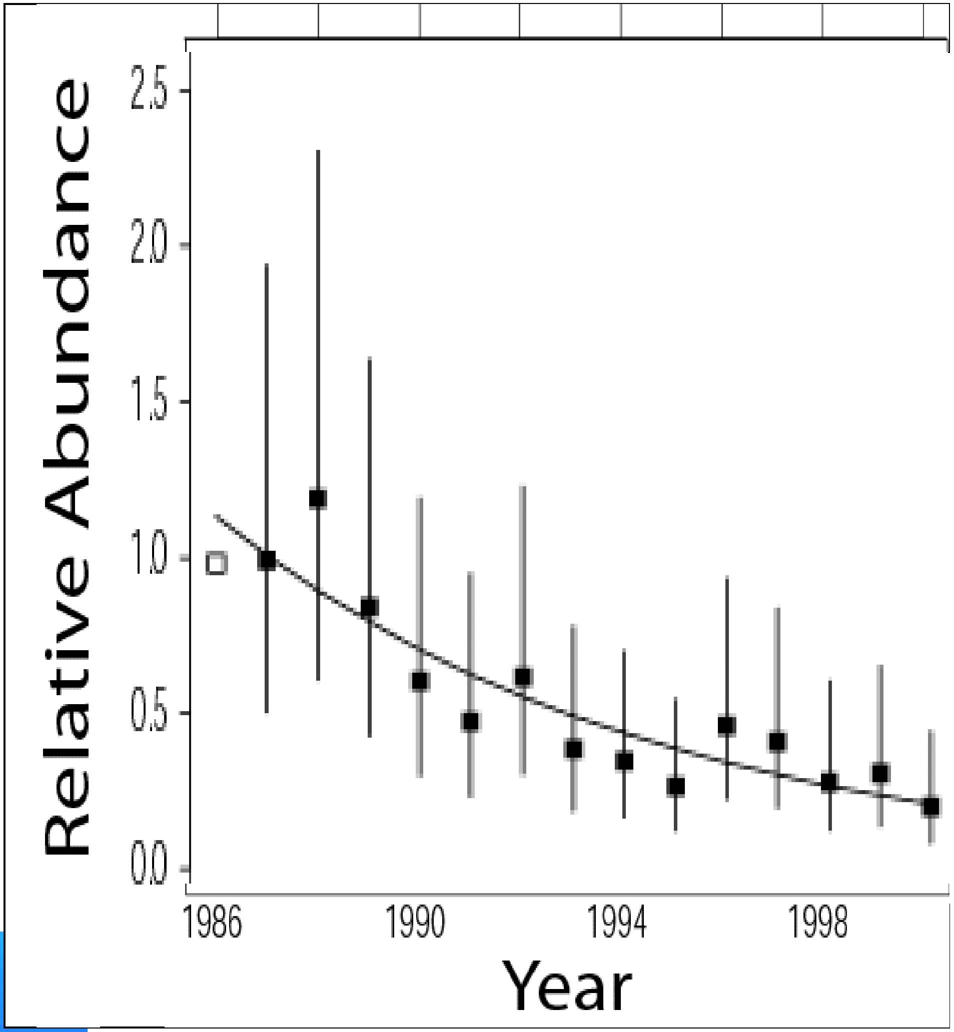
Science. Jan. 2003. J.K. Baum, R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, P.A. Doherty

The rest of the slides are back up.


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

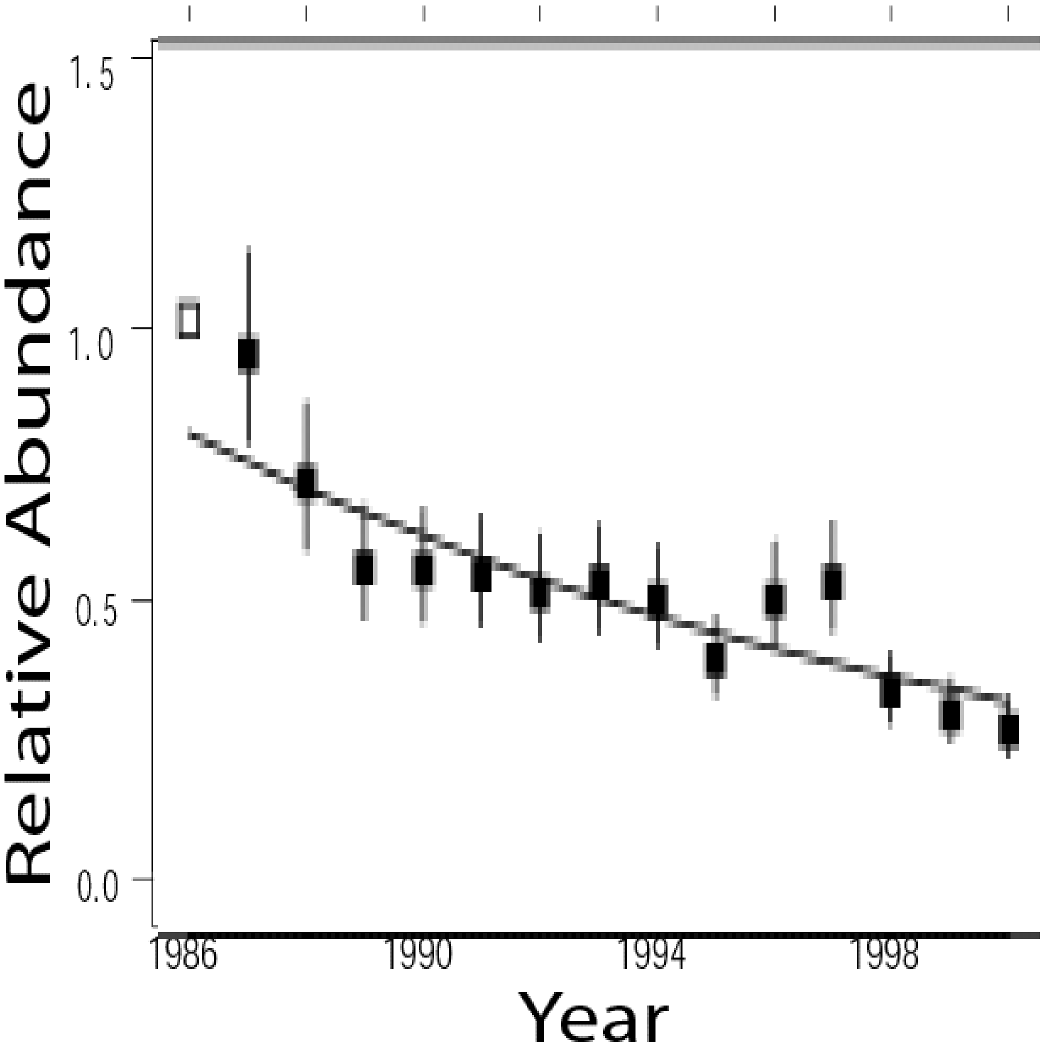
Thresher
sharks

Alopias spp.

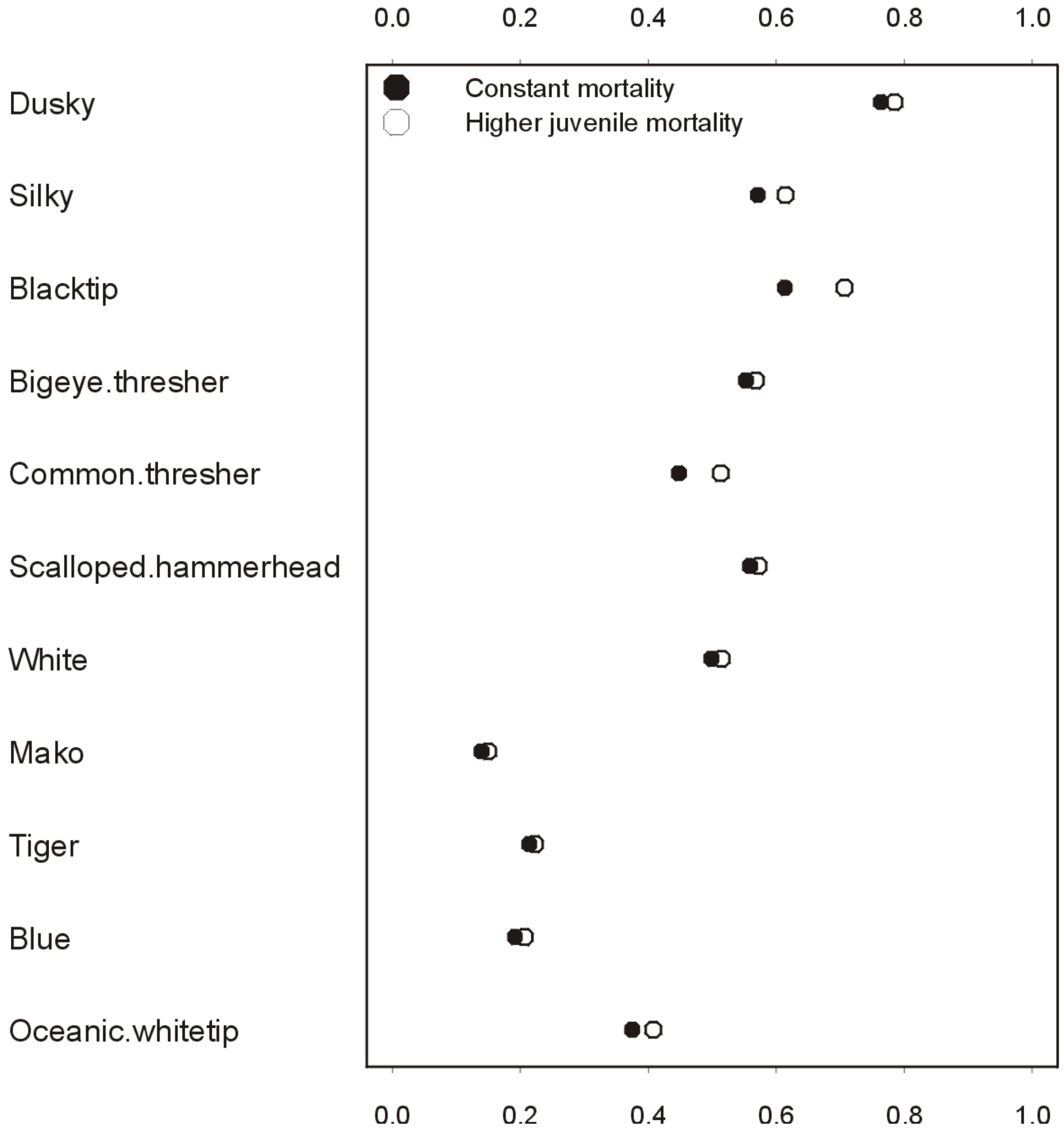


Blue sharks

Prionace glauca

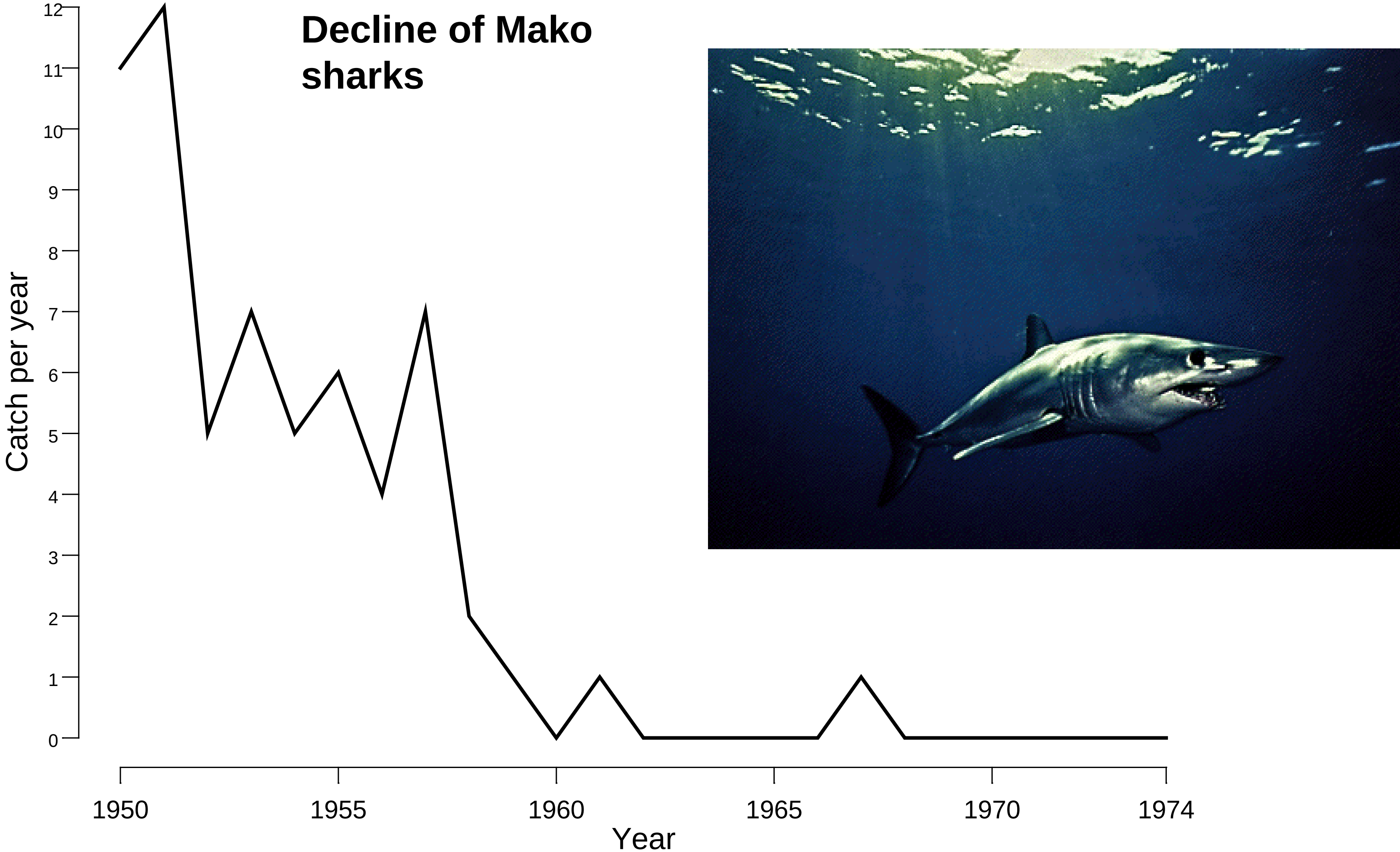


Proportional reduction in current fishing mortality needed to ensure survival of shark populations



Letter from senate

Put in cod

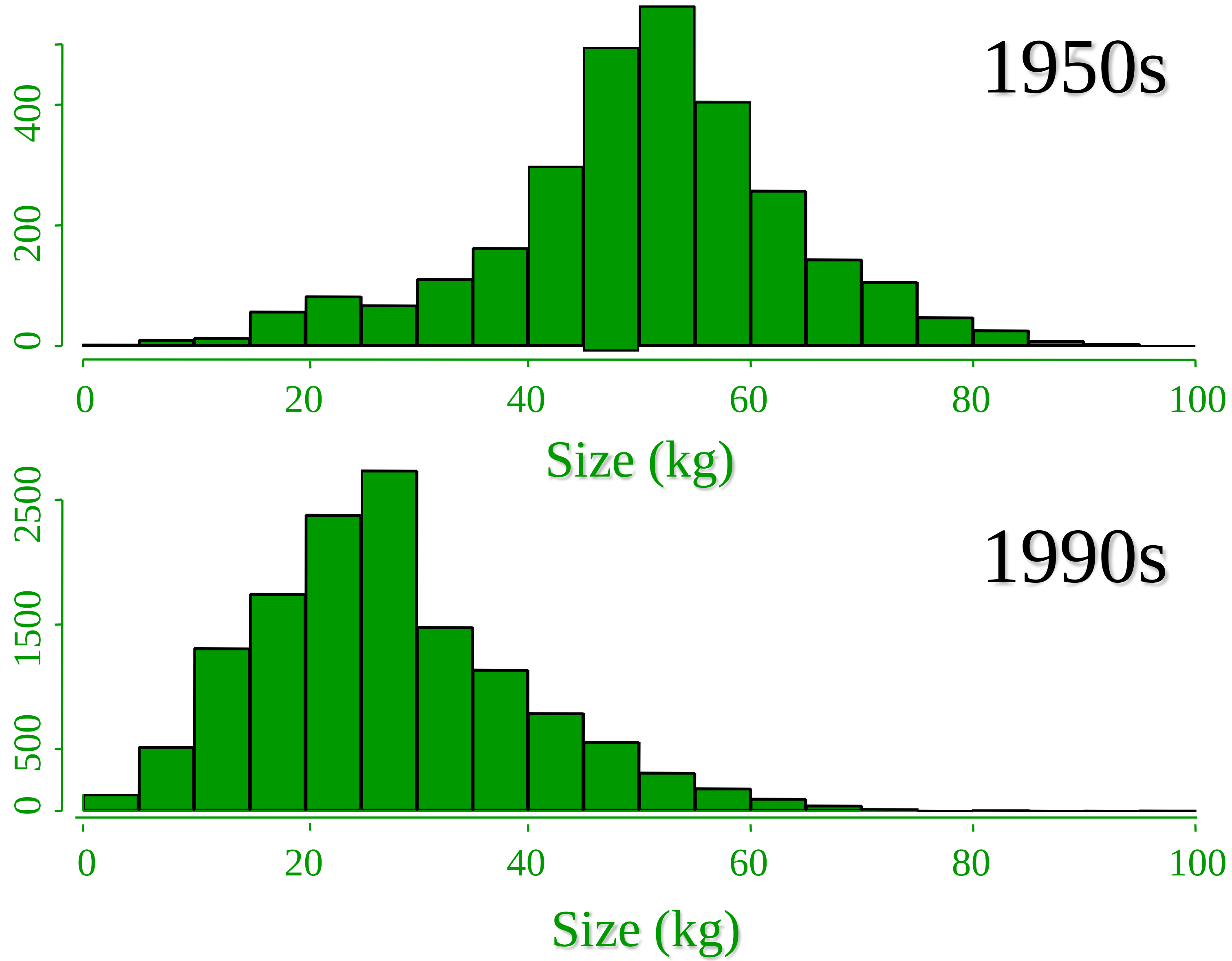


Boero F. & A. Carli 1979 – Boll. Mus. Ist. Biol. Univ. Genoa (47)

These estimates are conservative: 1.

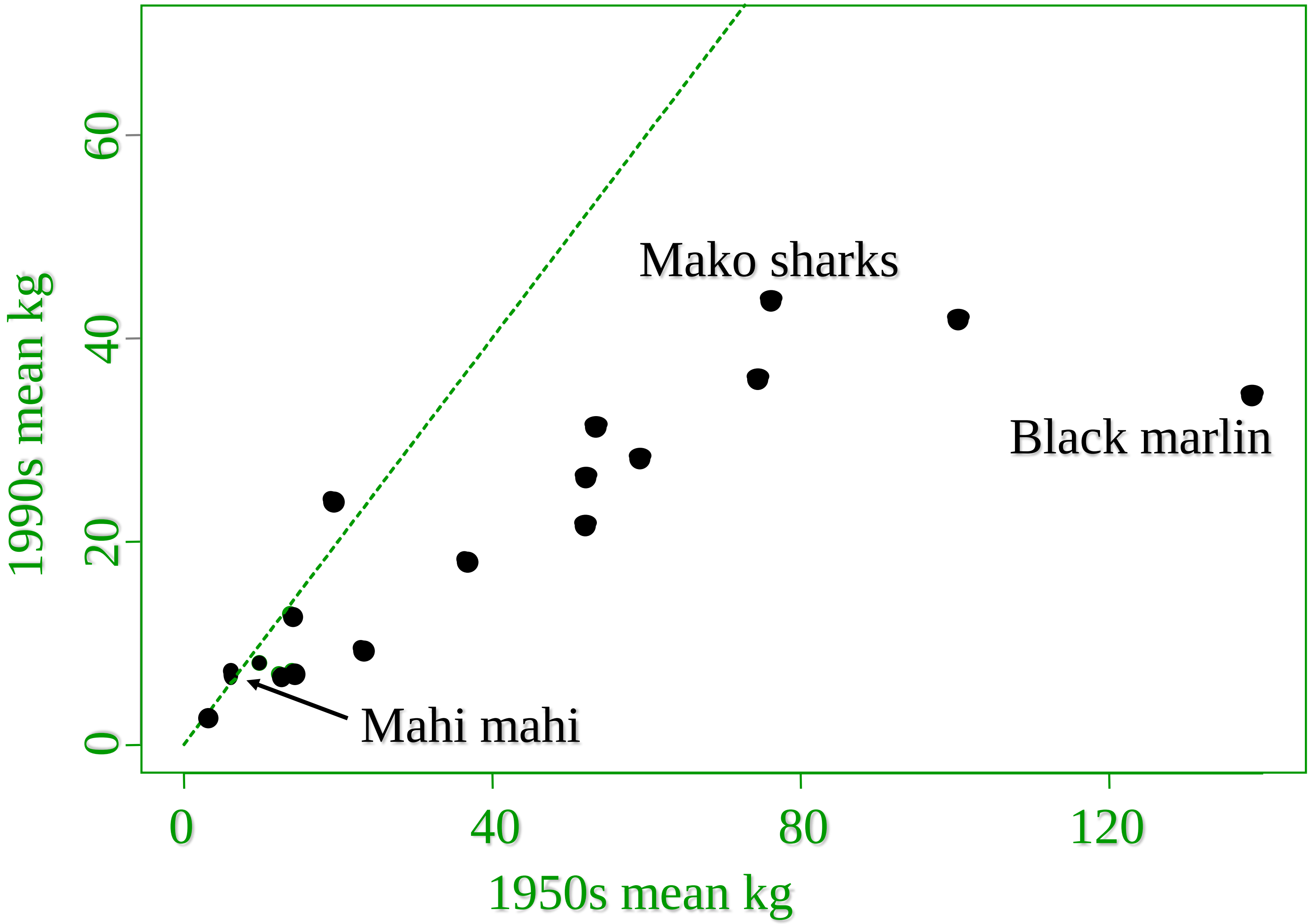
Bits of tuna did not count;
~25-30% of tropical tunas were initially not counted because of shark damage.

These estimates are conservative: 2 (fish are smaller)



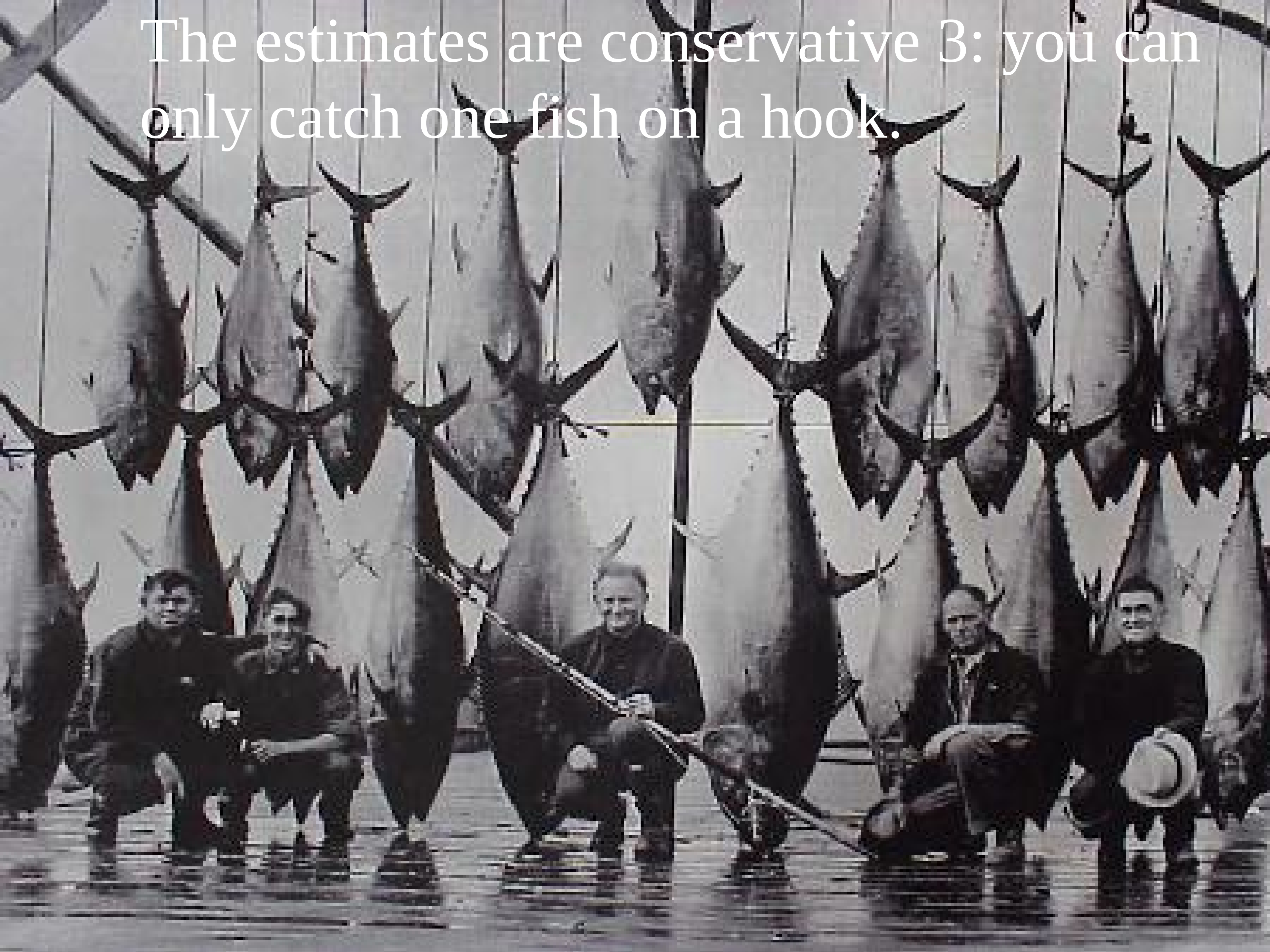
Yellowfin tuna – equitorial Pacific

Change in body size




555
lbs.
LBS.
1135
CABO
BLANCO

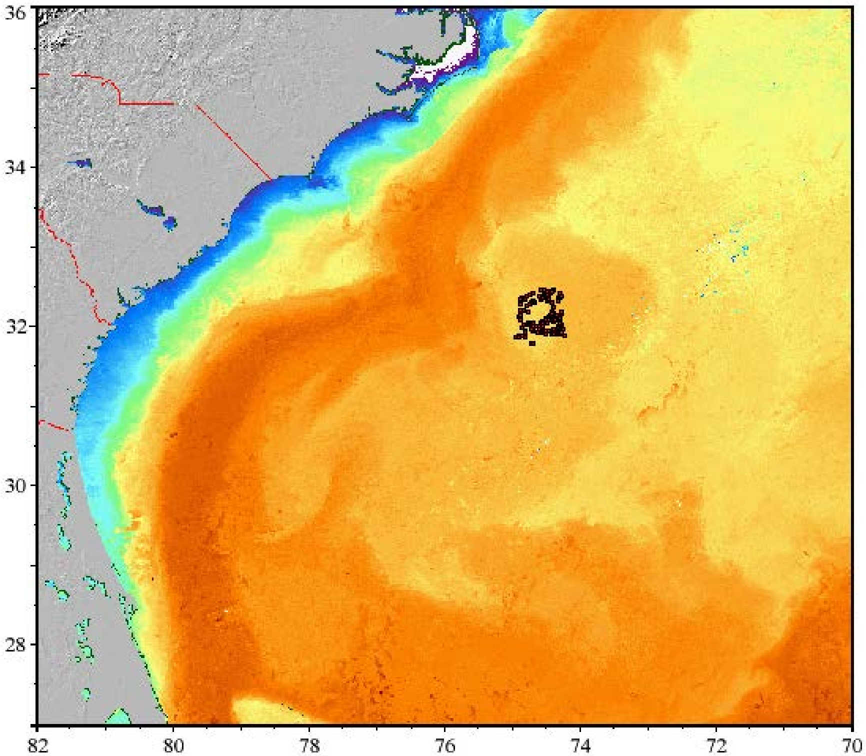
The estimates are conservative 3: you can only catch one fish on a hook.

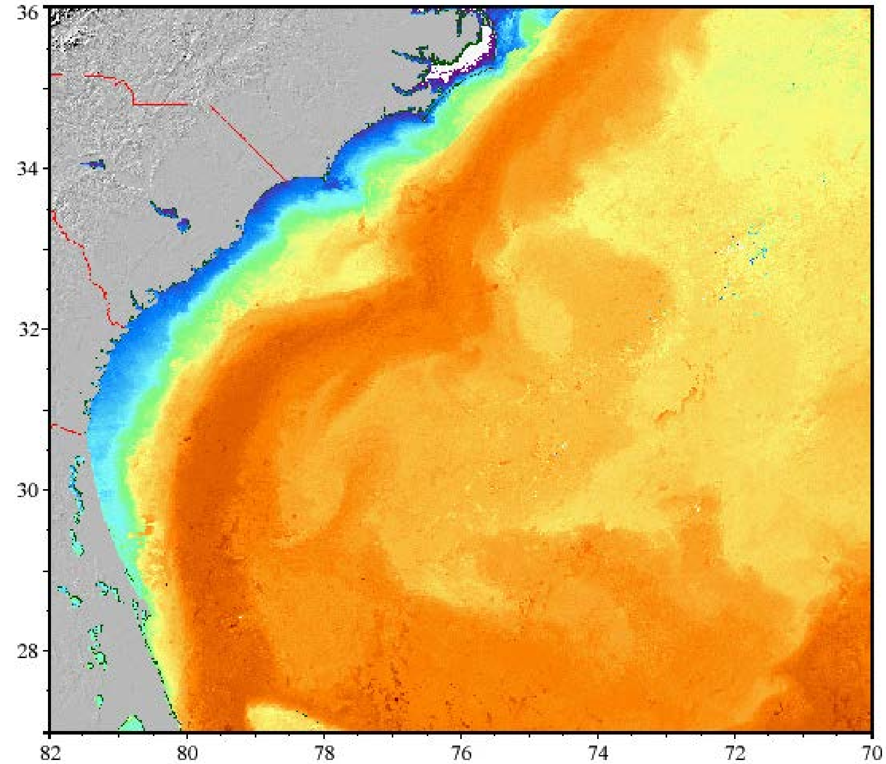


These estimates are conservative 5: The oceans were not virgin.

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





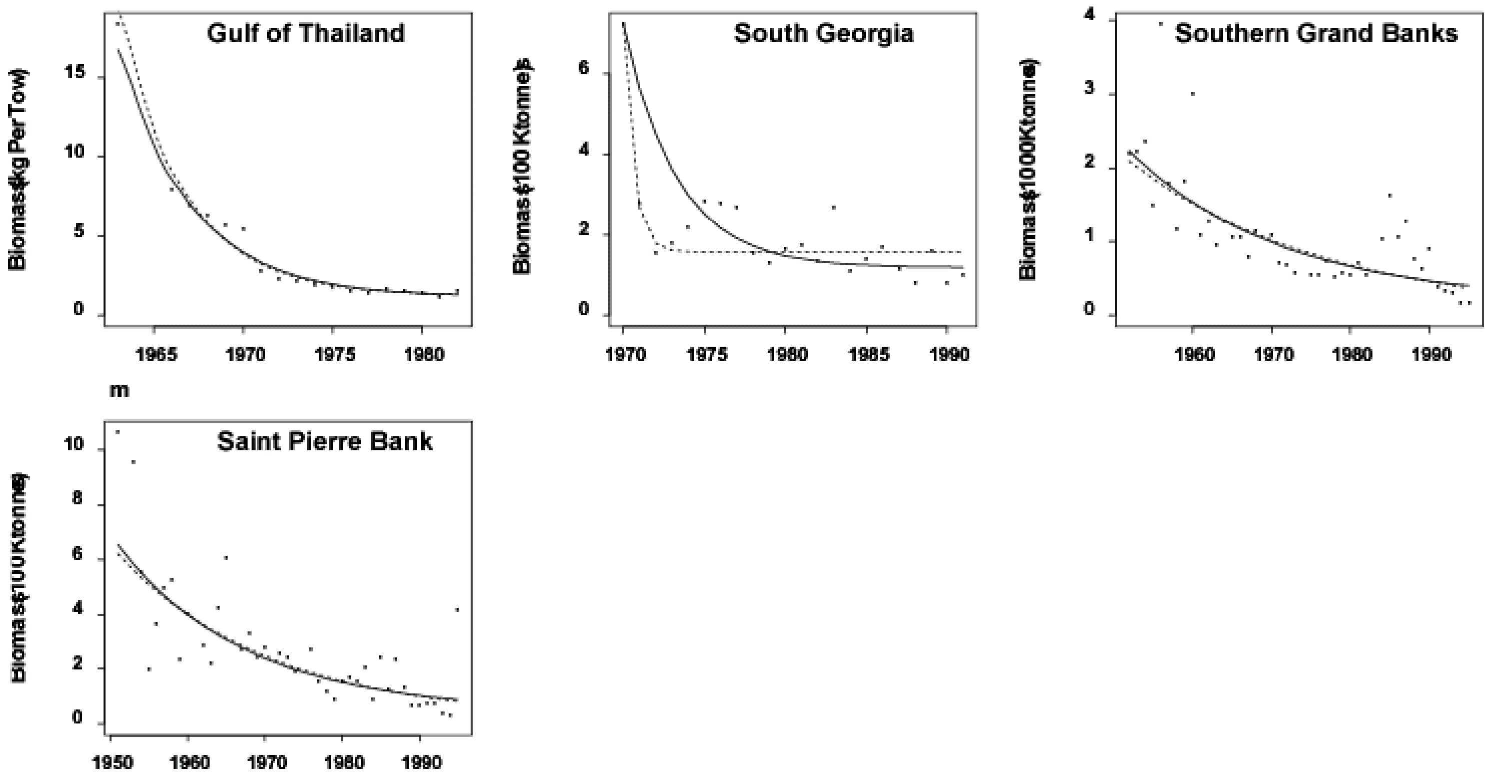
Locations of a leatherback turtle over a two week period tagged by my student Mike James that maintains its position within a cold core ring (somehow).

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

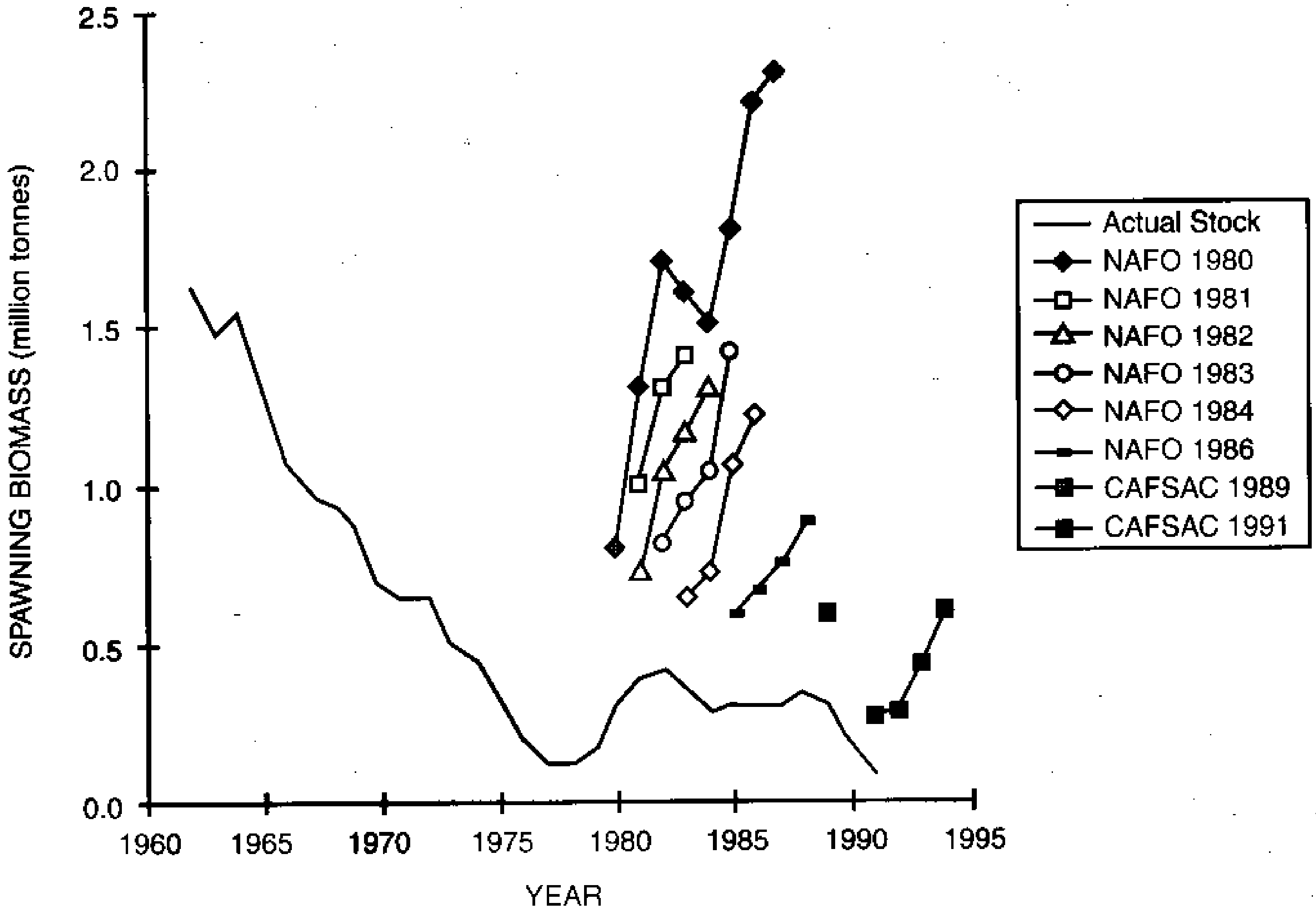
Step 8: You need emotional support. Support from colleagues and family is essential. You cannot do it (for long) by yourself.

Why is it so important.
What makes them work.

Shelf seas


Gulf of Thailand
South Georgia
Southern Grand Banks
Saint Pierre Bank

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

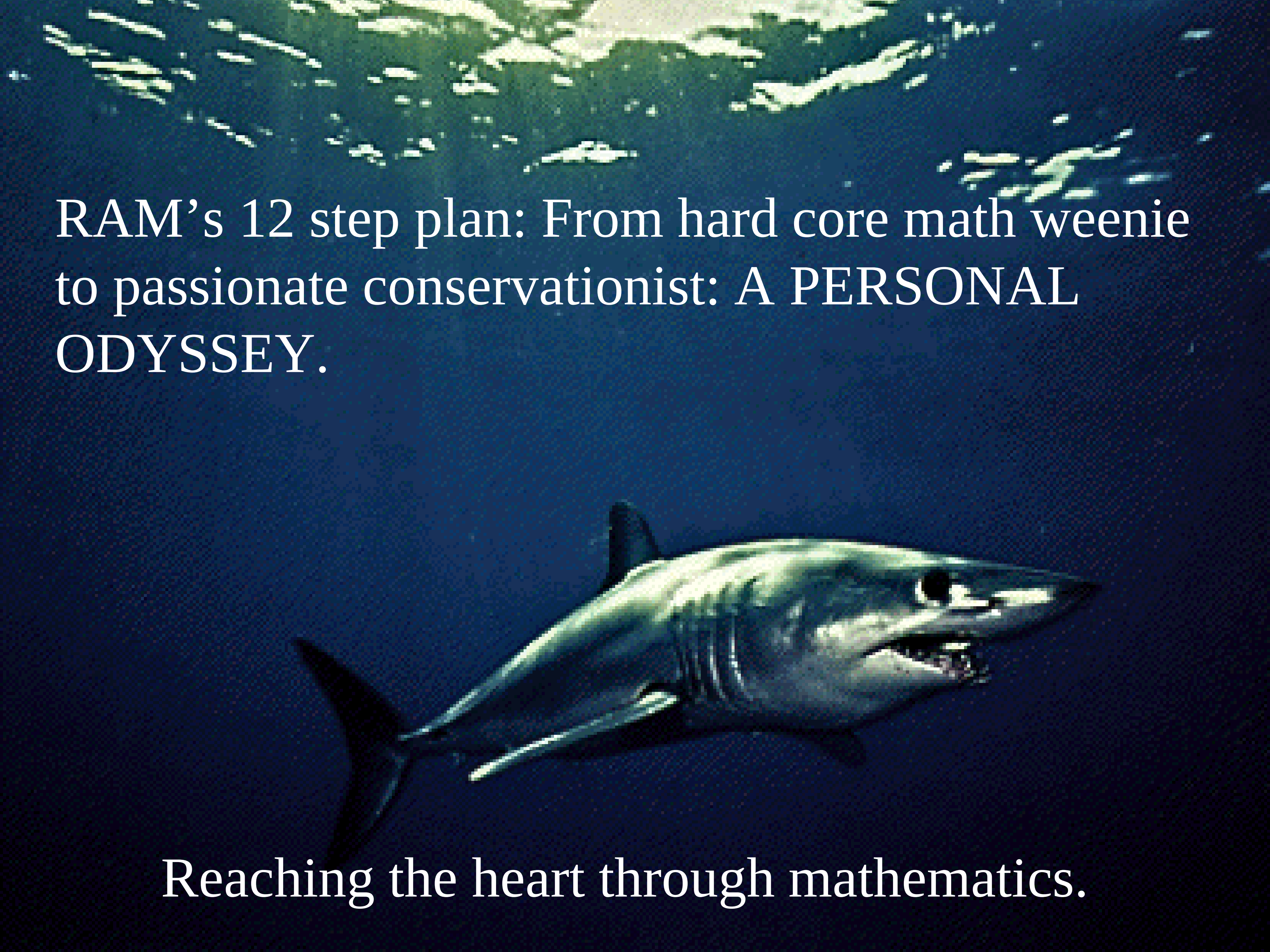


Lessons I Learned from the Cod Disaster:

- 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.

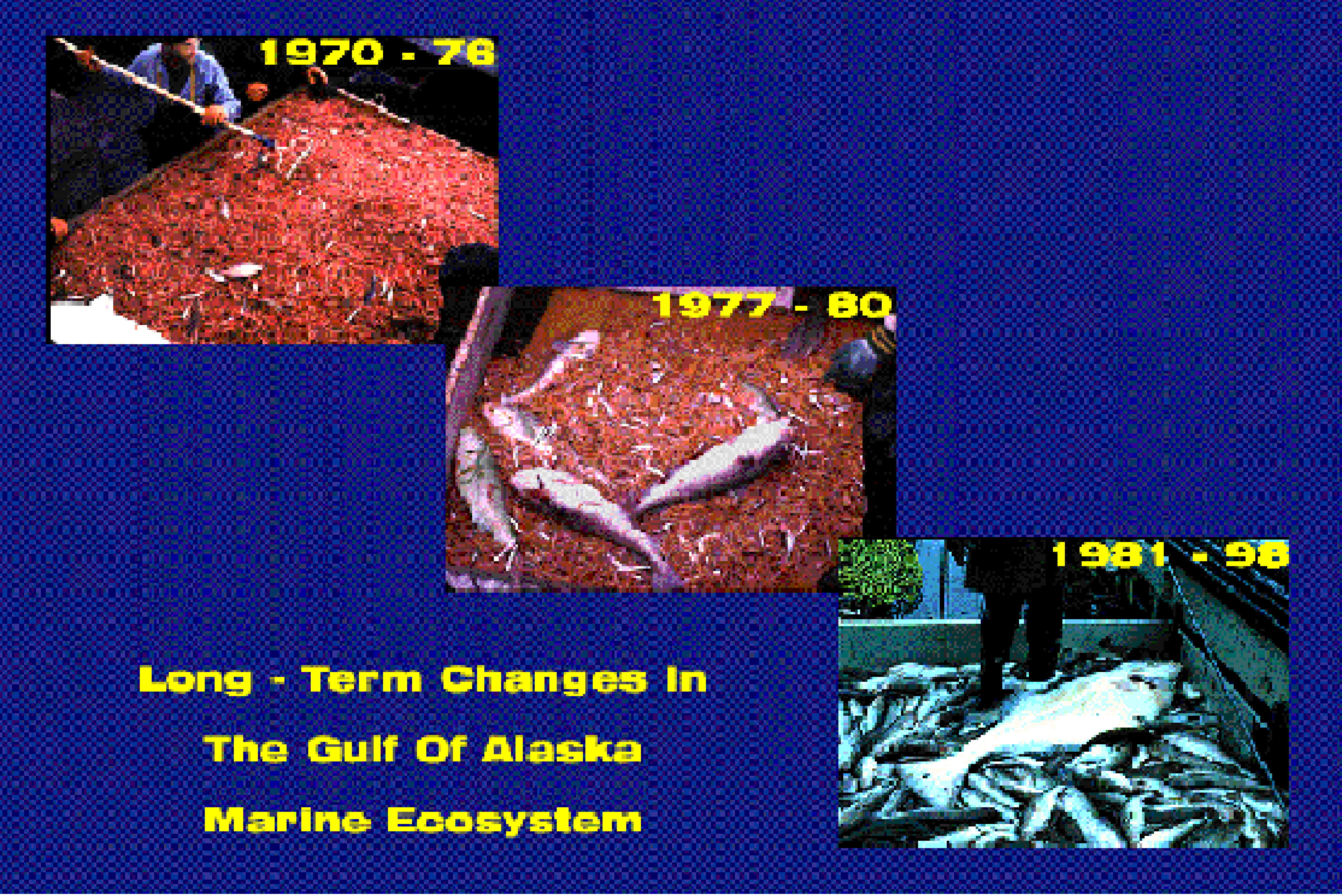
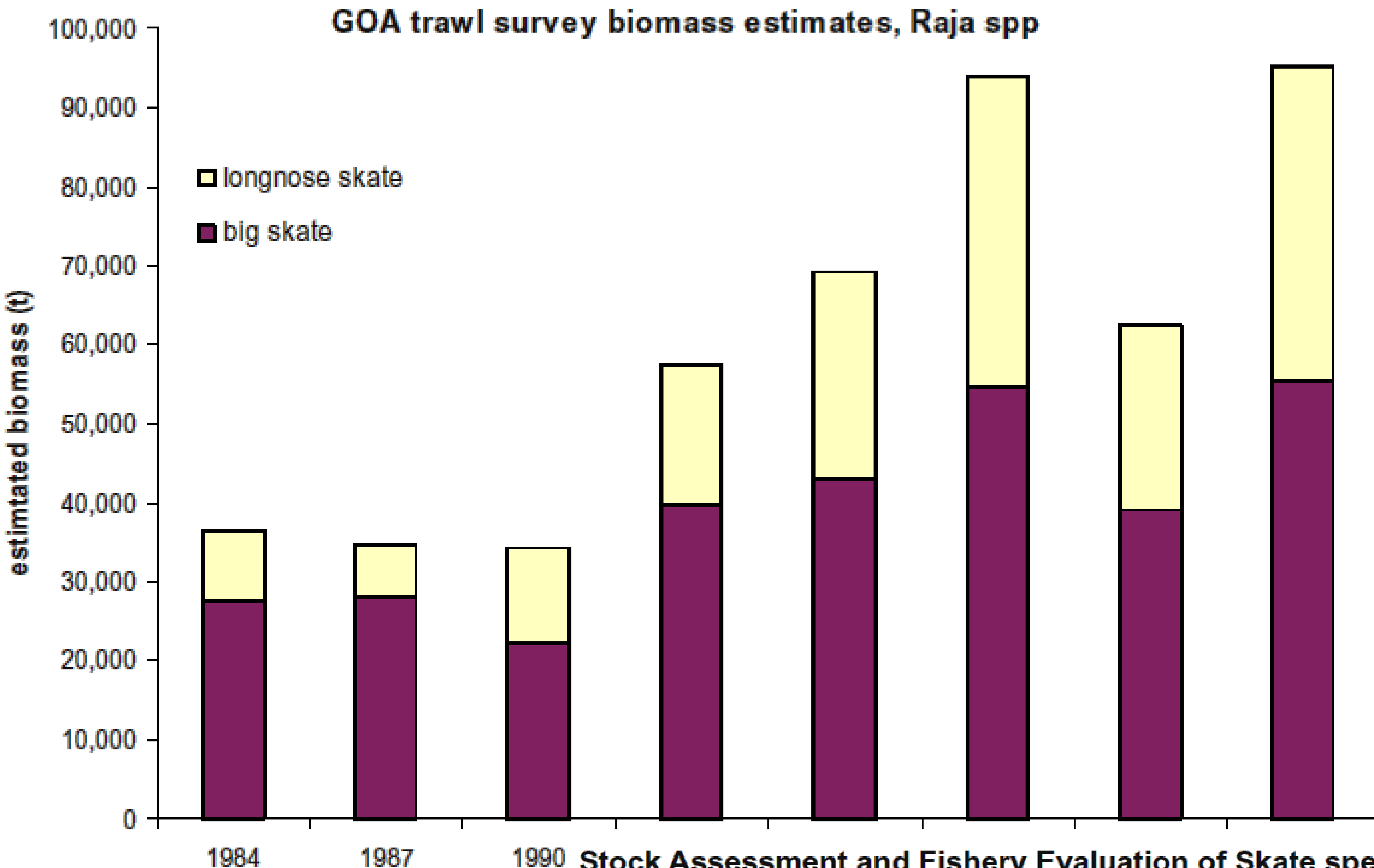


Figure stolen from Paul Anderson

- 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

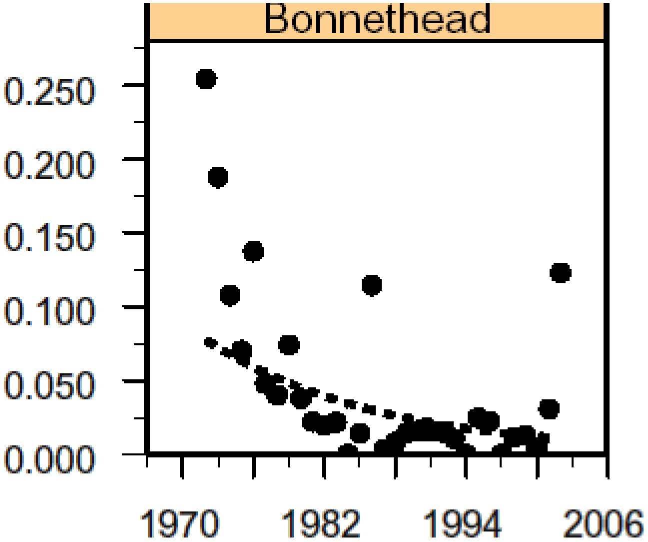
by
Sarah Gaichas[1], Michael Ruccio[2], Duane Stevenson[1], and Rob Swanson[3]

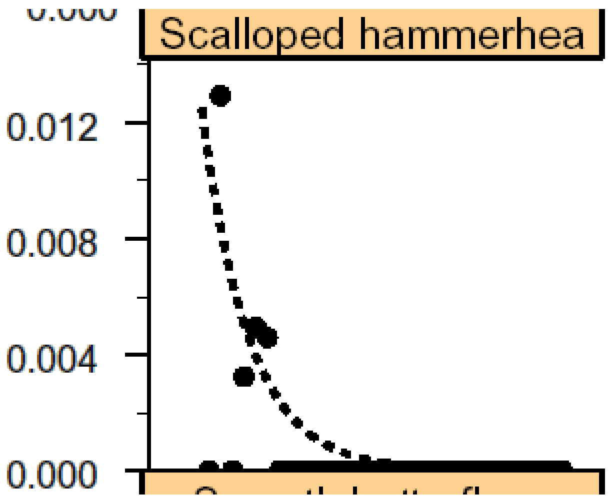
Figure 1. Big skate, *Raja binoculata*, with stock assessment author for scale.

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

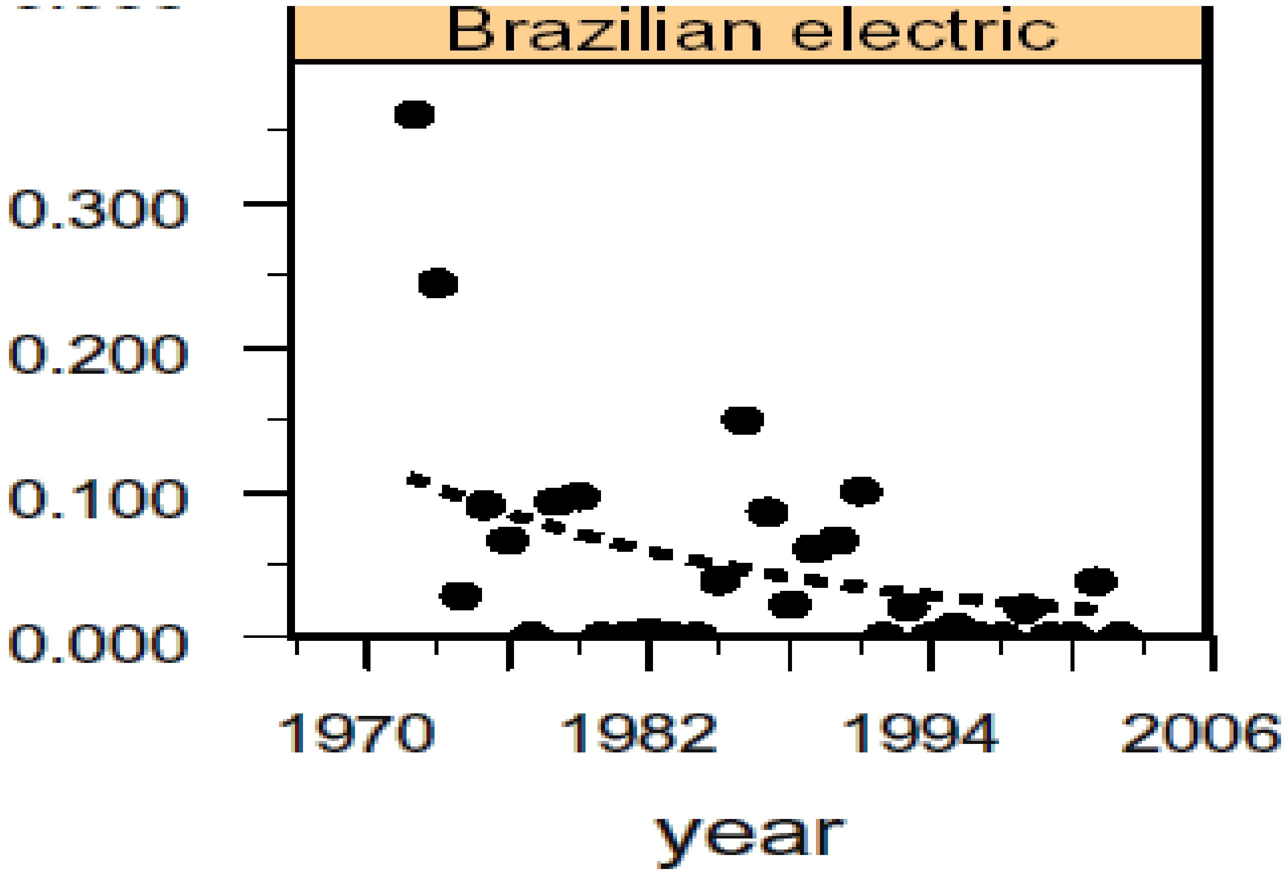
by
Sarah Gaichas[1], Michael Ruccio[2], Duane Stevenson[1], and Rob Swanson[3]

All large sharks declined



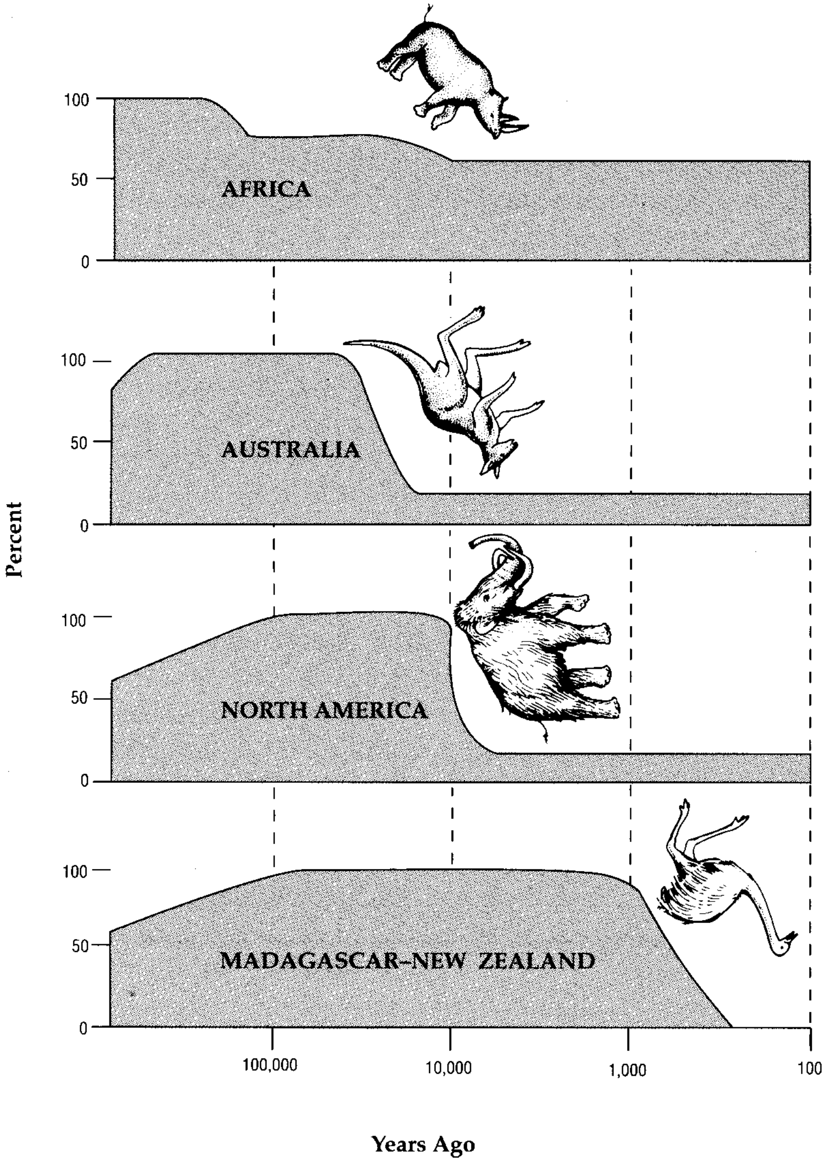


Shallow water species that do not survive discarding: large declines:



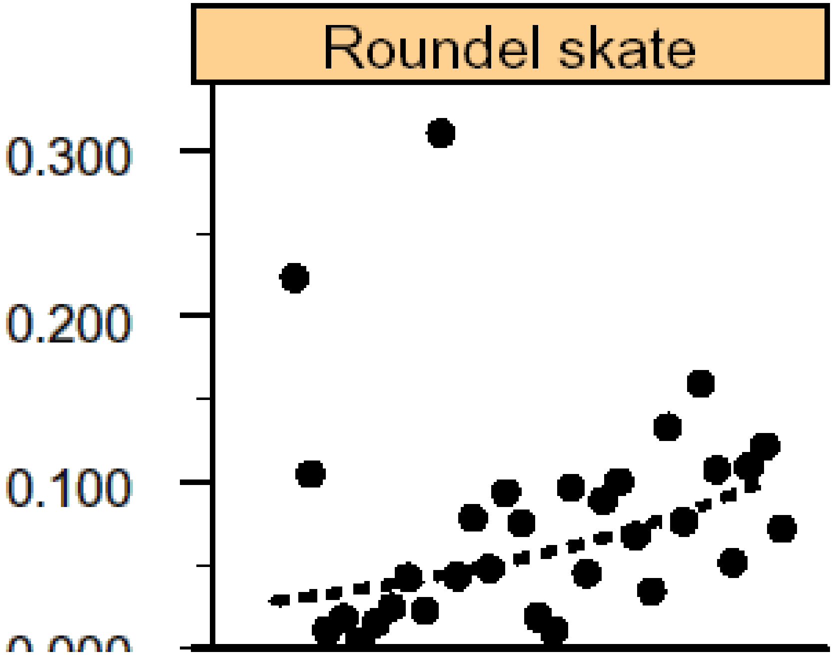
Are the pleistocene extinctions* going to be repeated in the ocean?

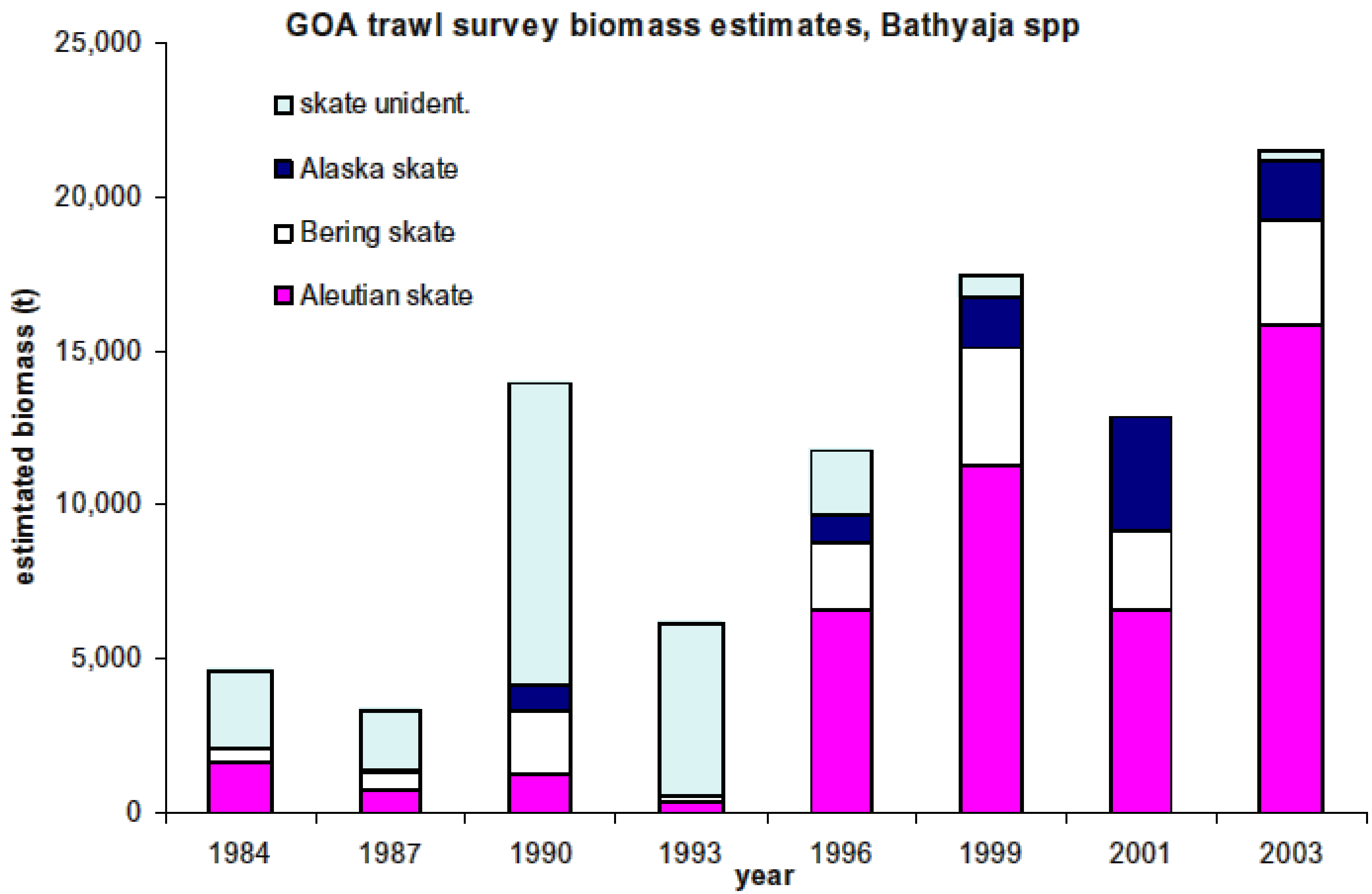
*Present North American biota has lost almost all large species –
We have no mammoths, mastodons, giant ground sloths, giant beavers, and 65 other species that weighted more than 100 kilograms.



The 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.

Deeper skate species that survive discarding increased





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

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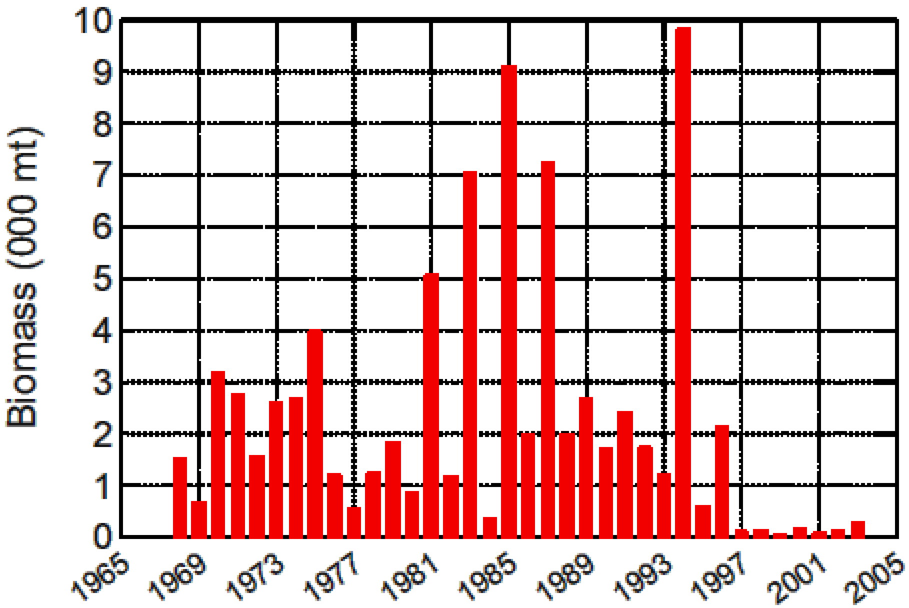
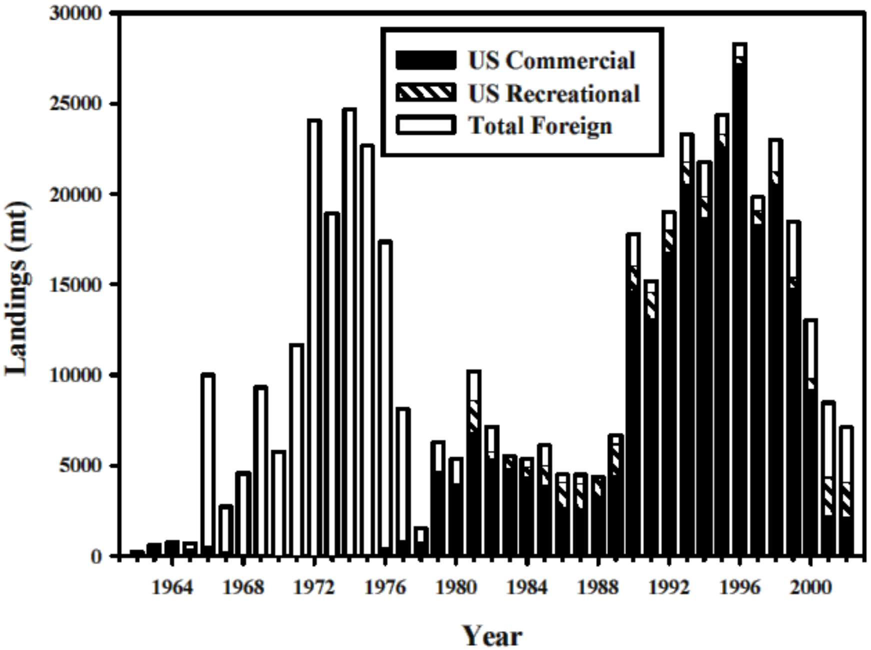
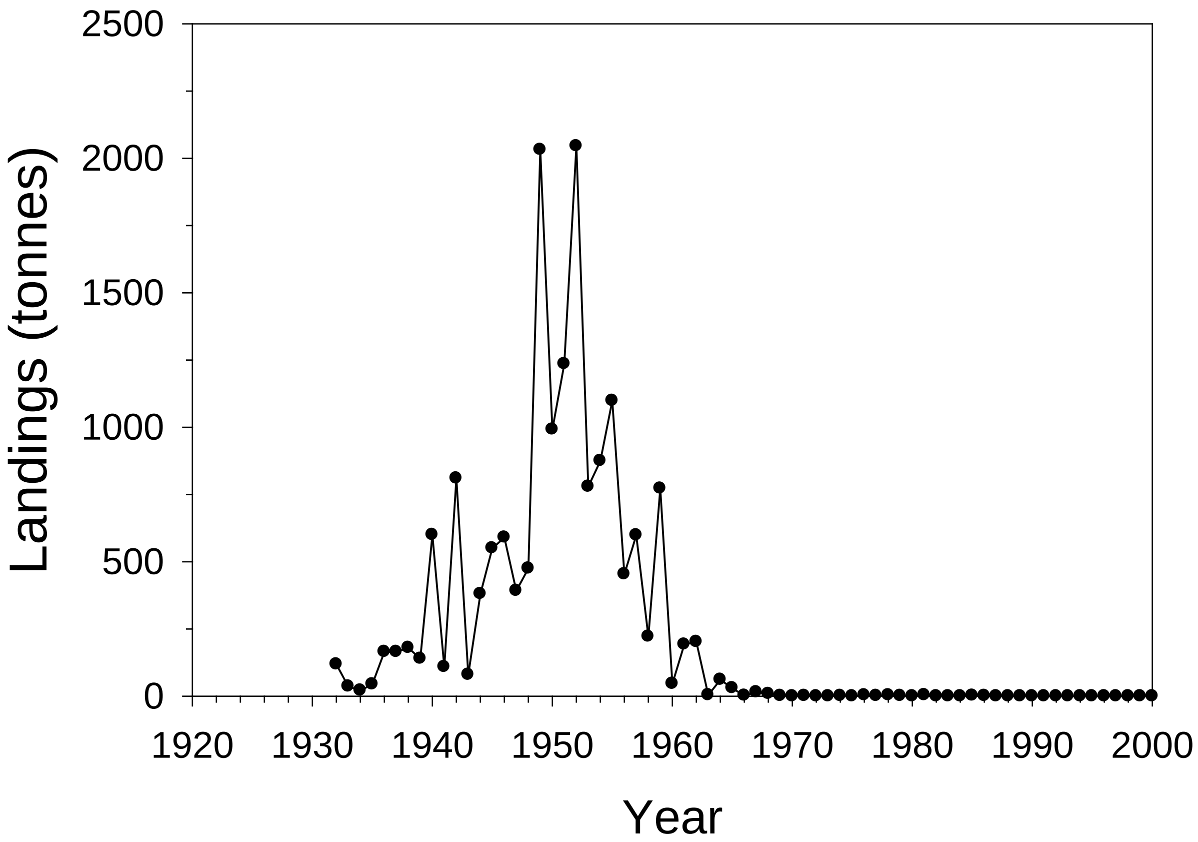
Spiny Dogfish, Northwest Atlantic: Good Science – Ugly Decisions





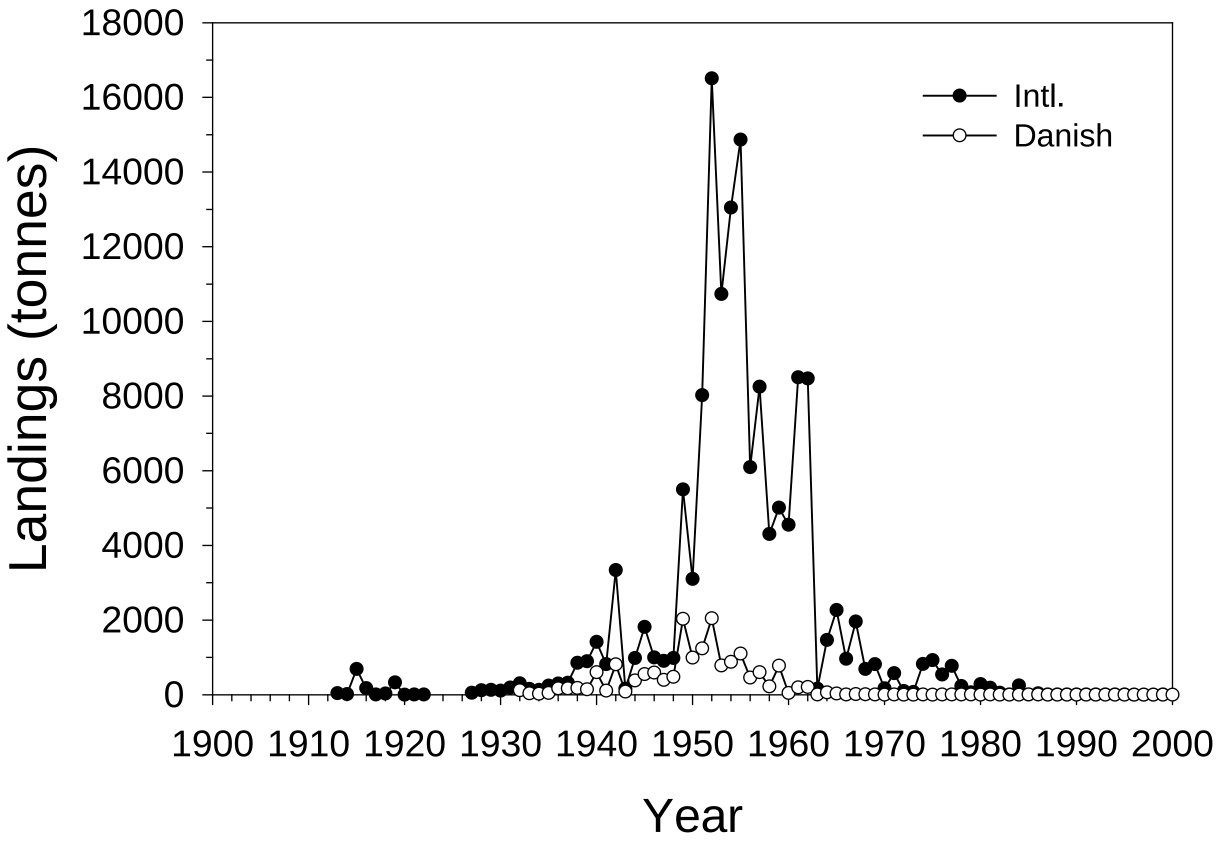
Danish Landings of Bluefin Tuna
Thunnus thynnus



DIFRES

Data source: DIFRES, ICES, FAO

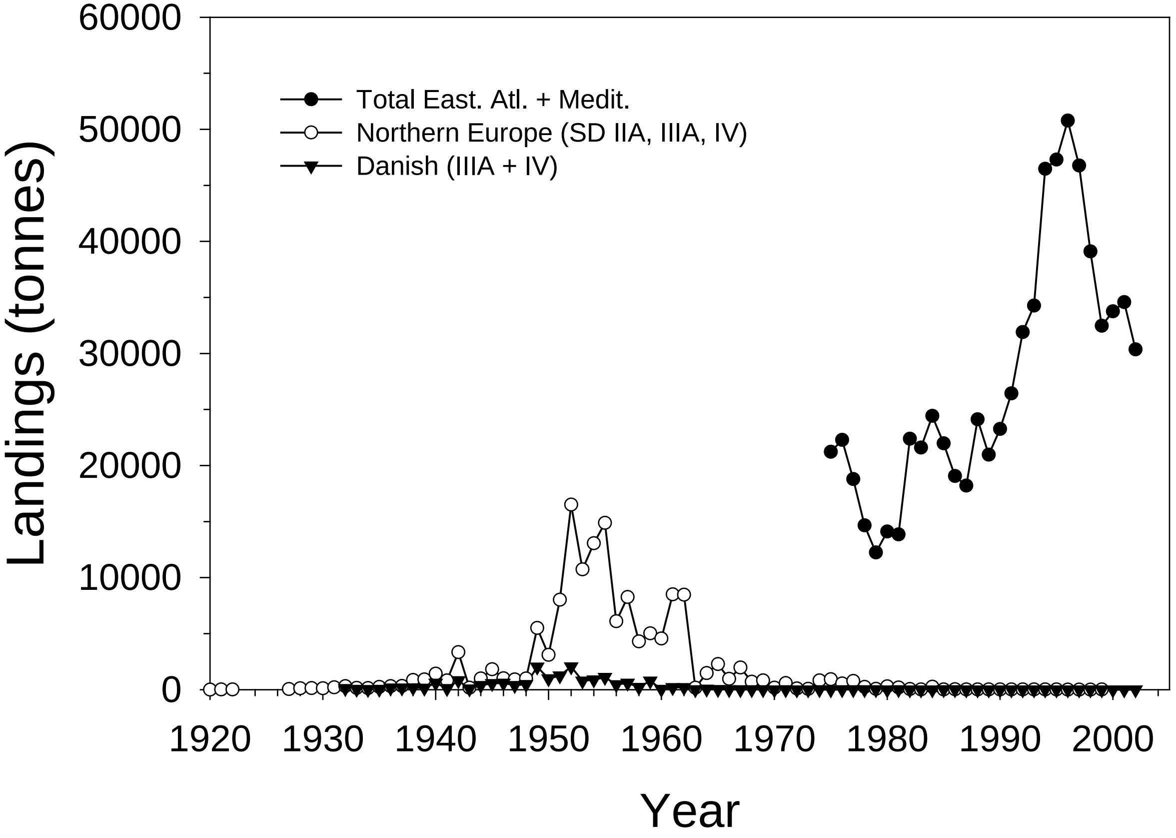
Landings of Bluefin Tuna *Thunnus thynnus* in Northern Europe*



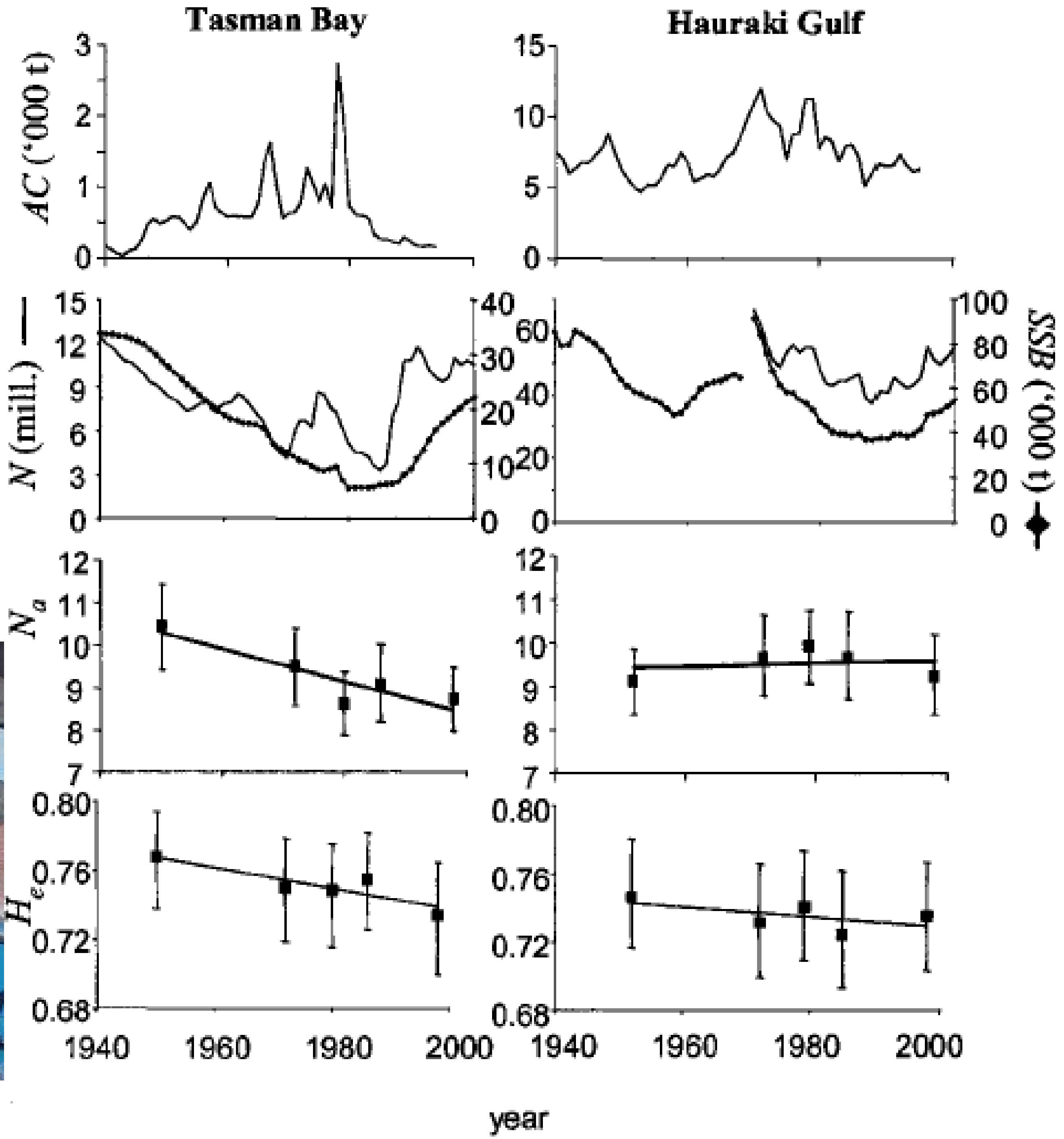
* = Norwegian Sea, North Sea, Skagerrak, Kattegat, Øresund

DIFRES

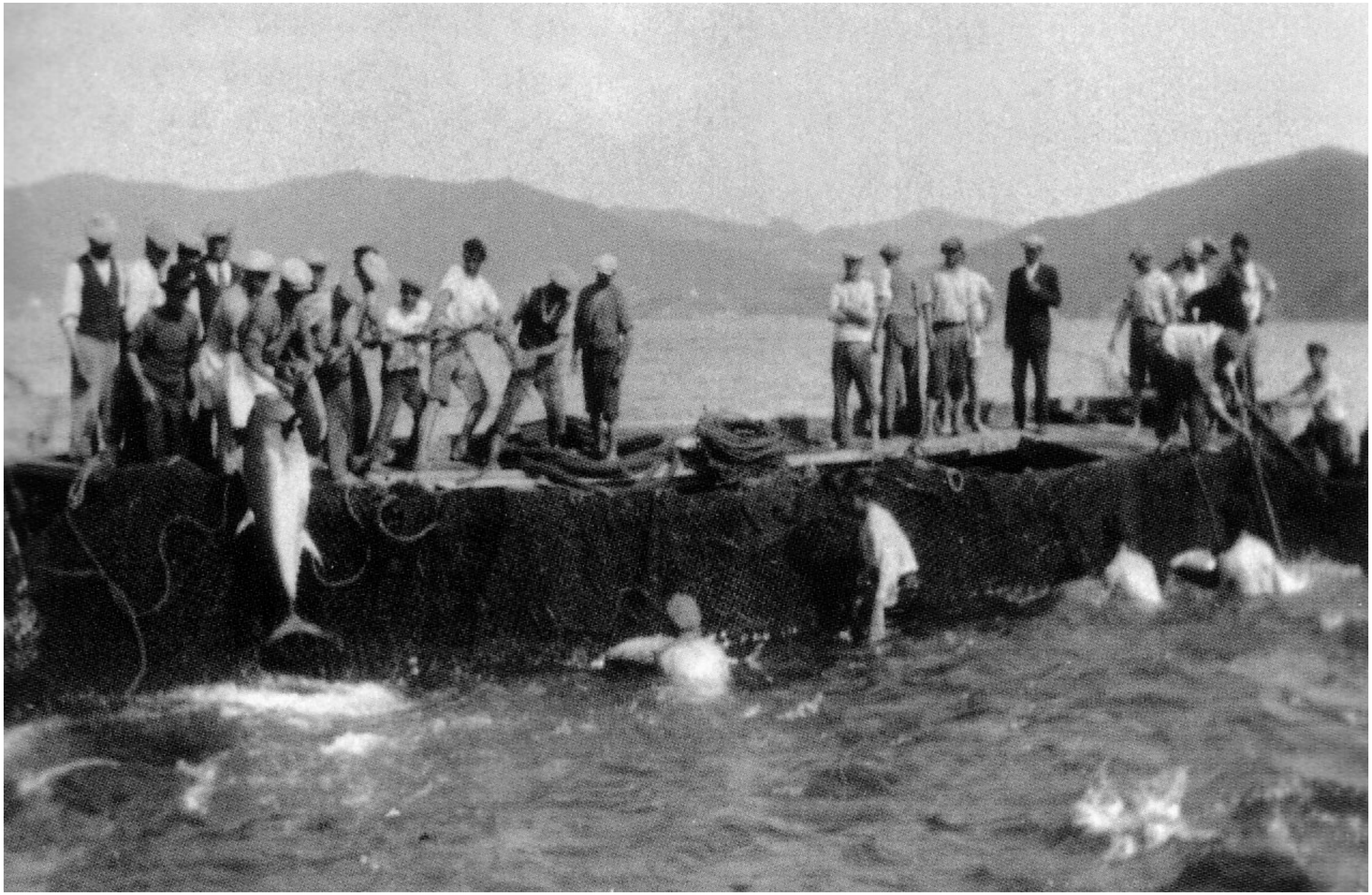
Landings of Bluefin Tuna
Thunnus thynnus in Northeast Atlantic

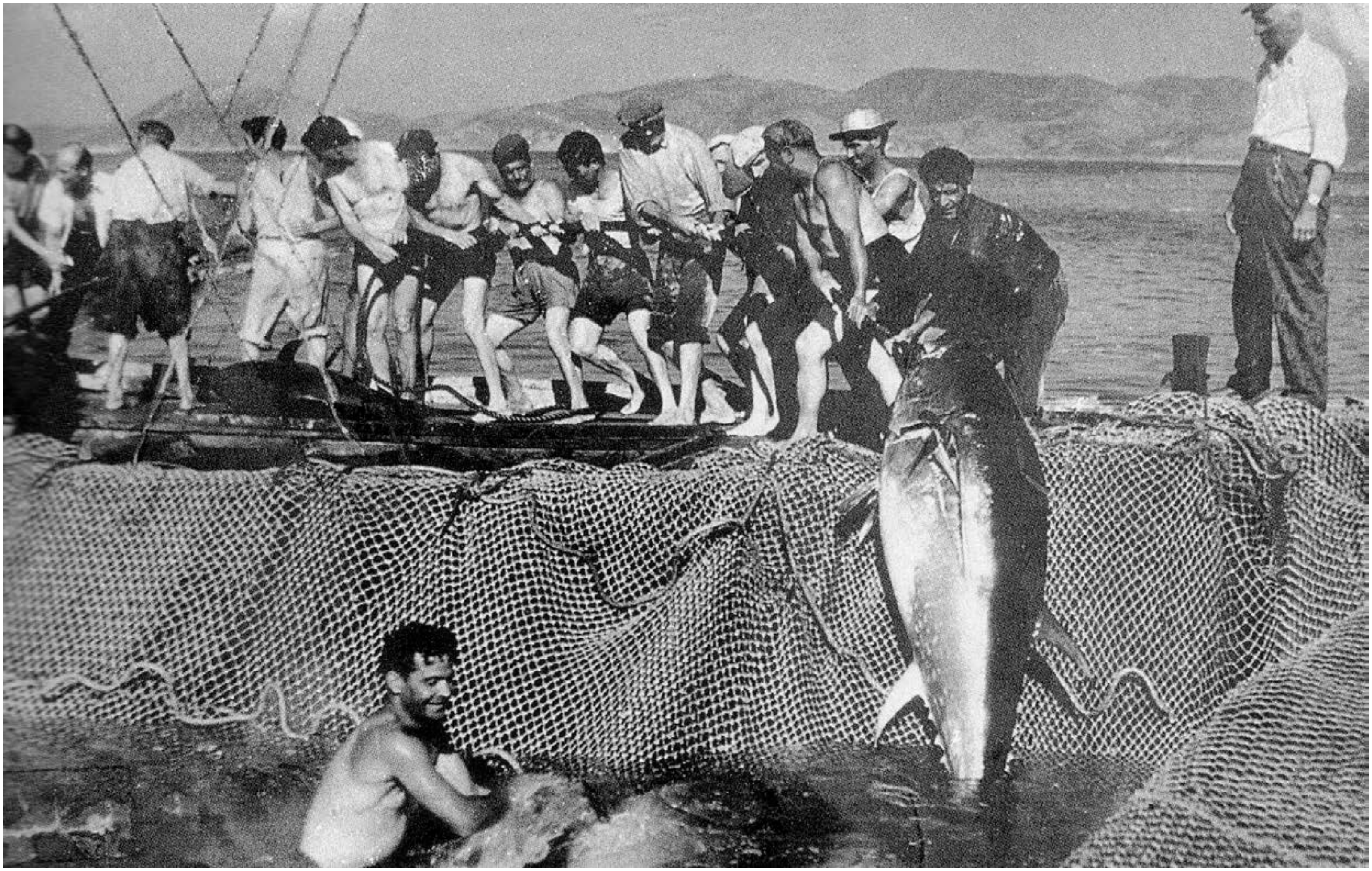


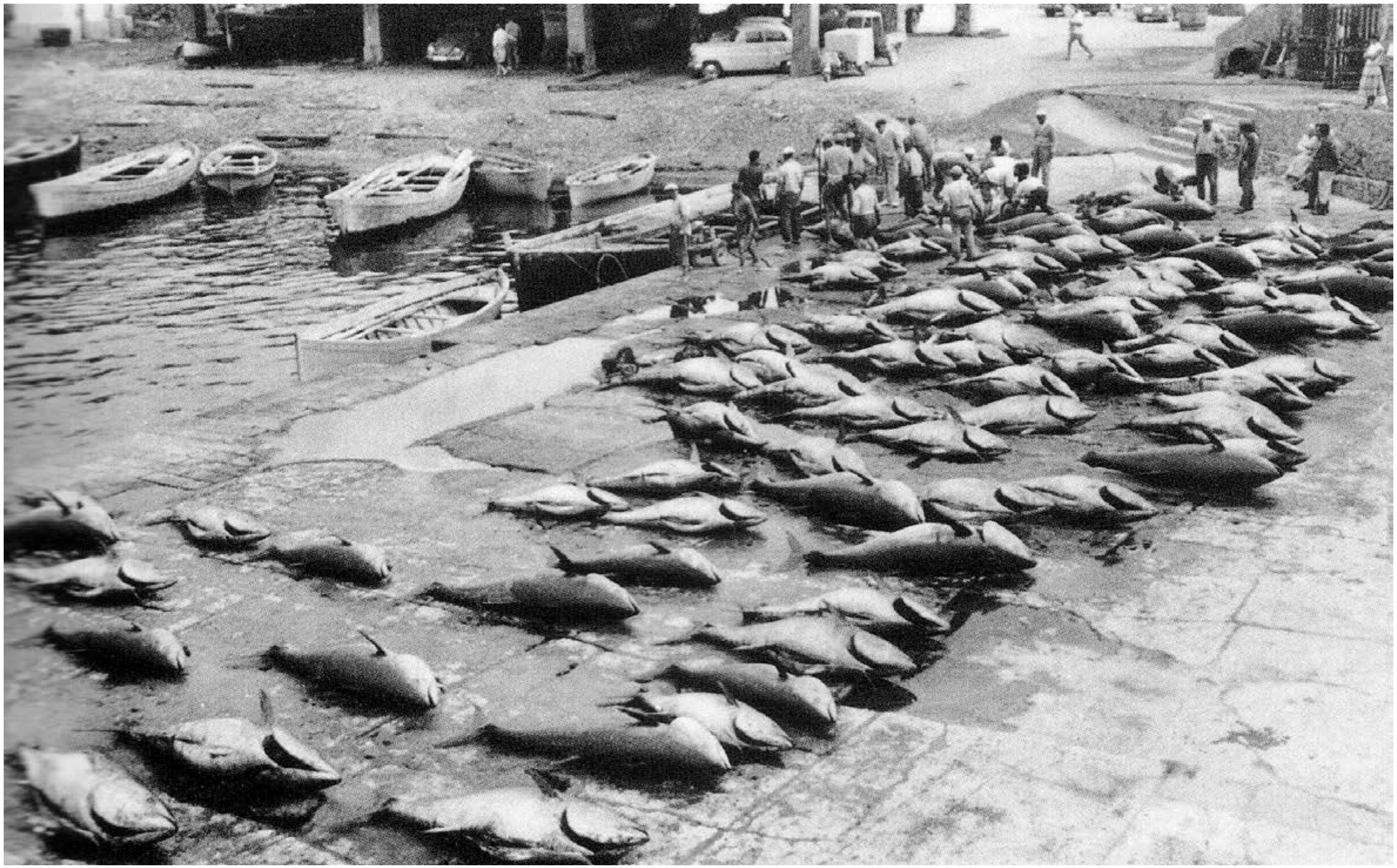
DIFRES



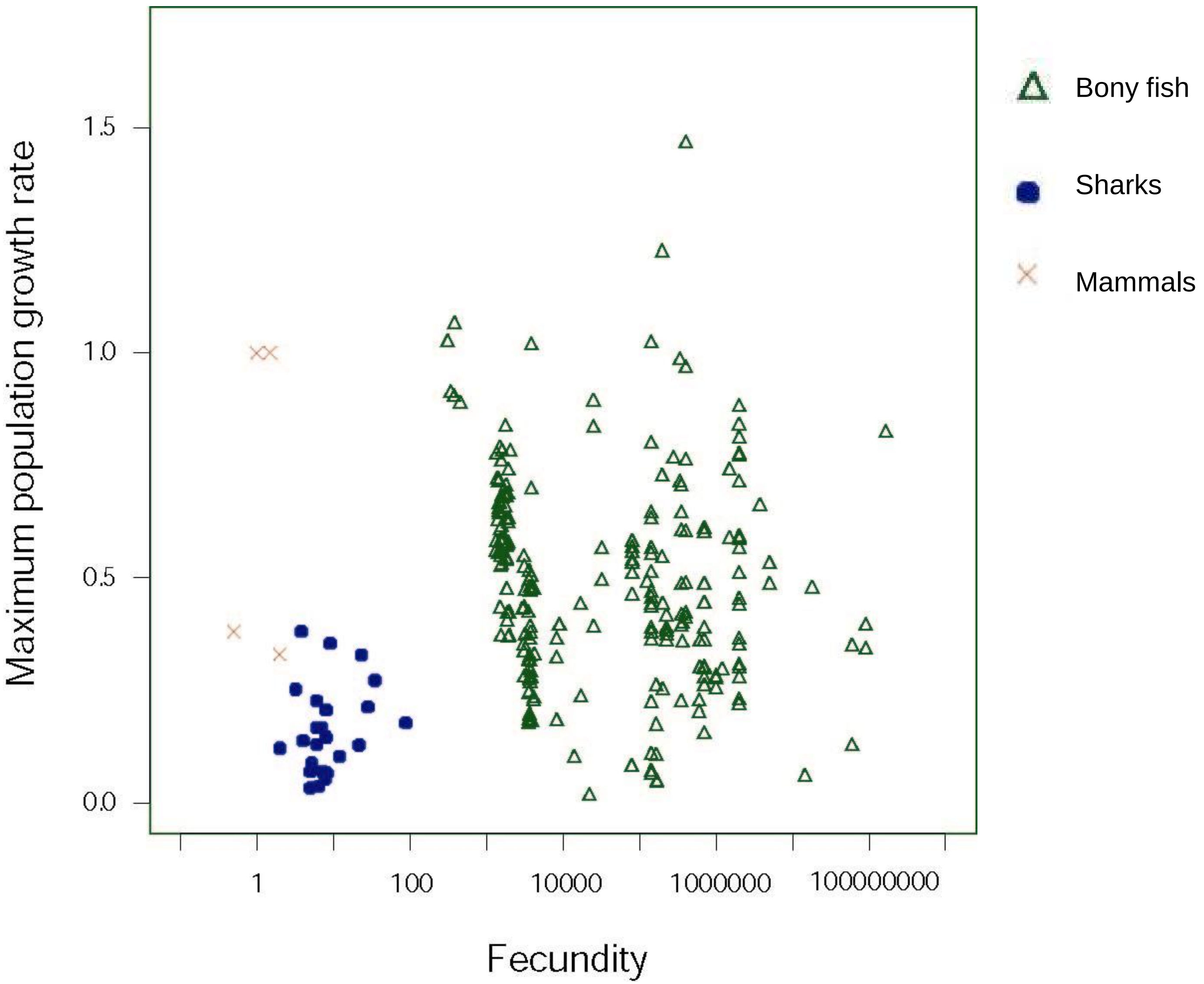
Hauser, et al. PNAS, 2002

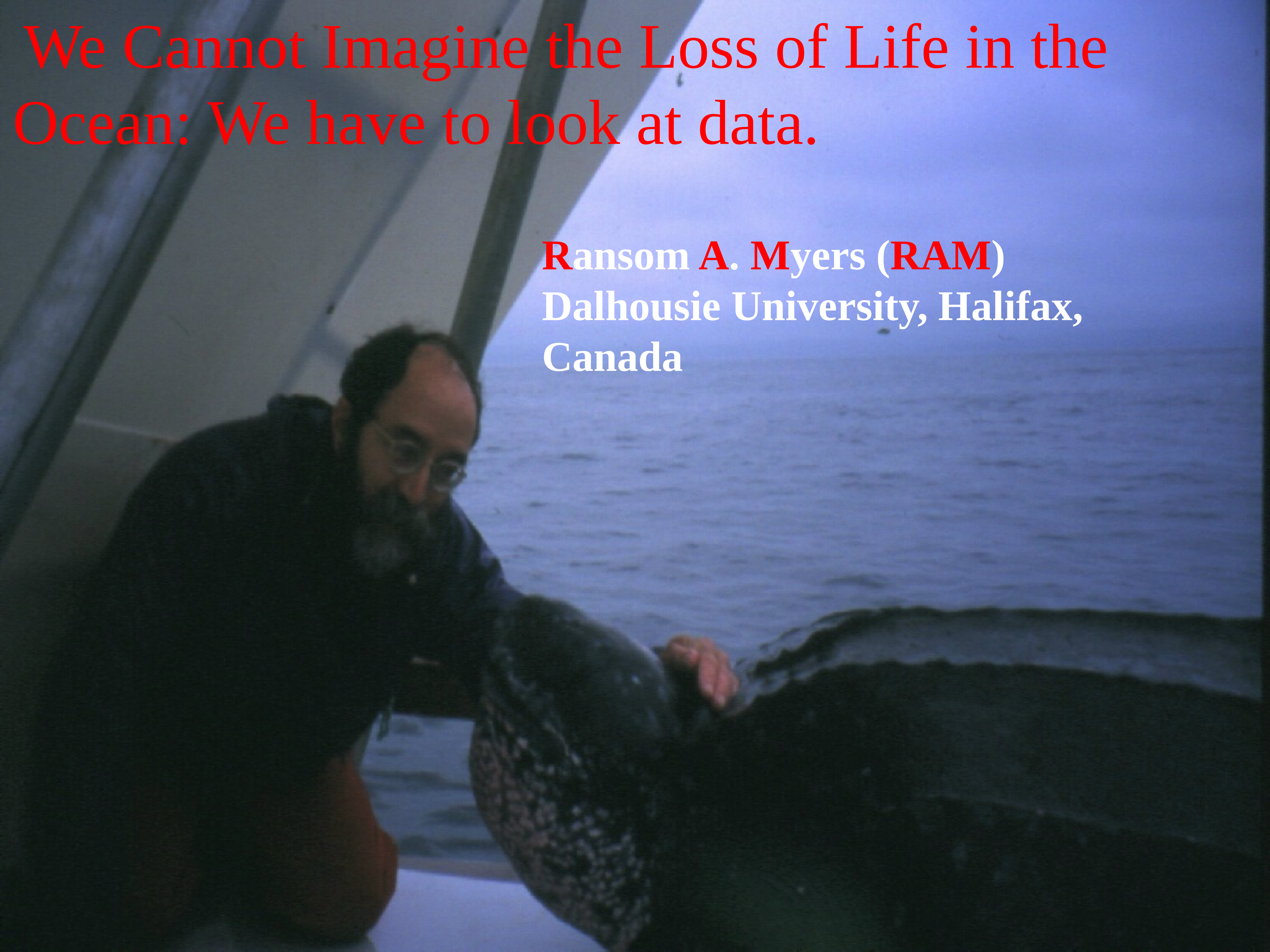




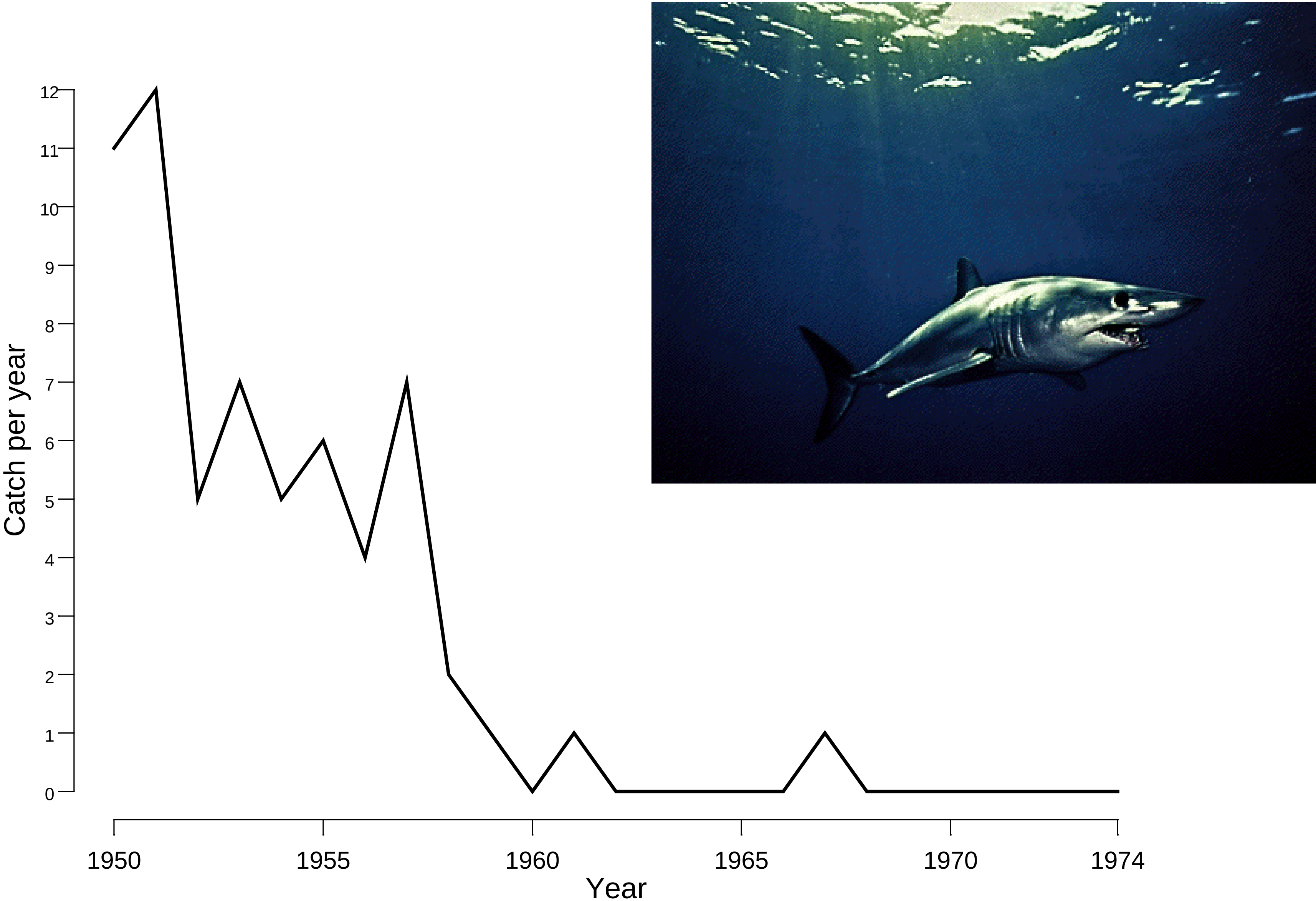


Life history of sharks...




We Cannot Imagine the Loss of Life in the Ocean: We have to look at data.
Ransom A. Myers (RAM)
Dalhousie University, Halifax, Canada

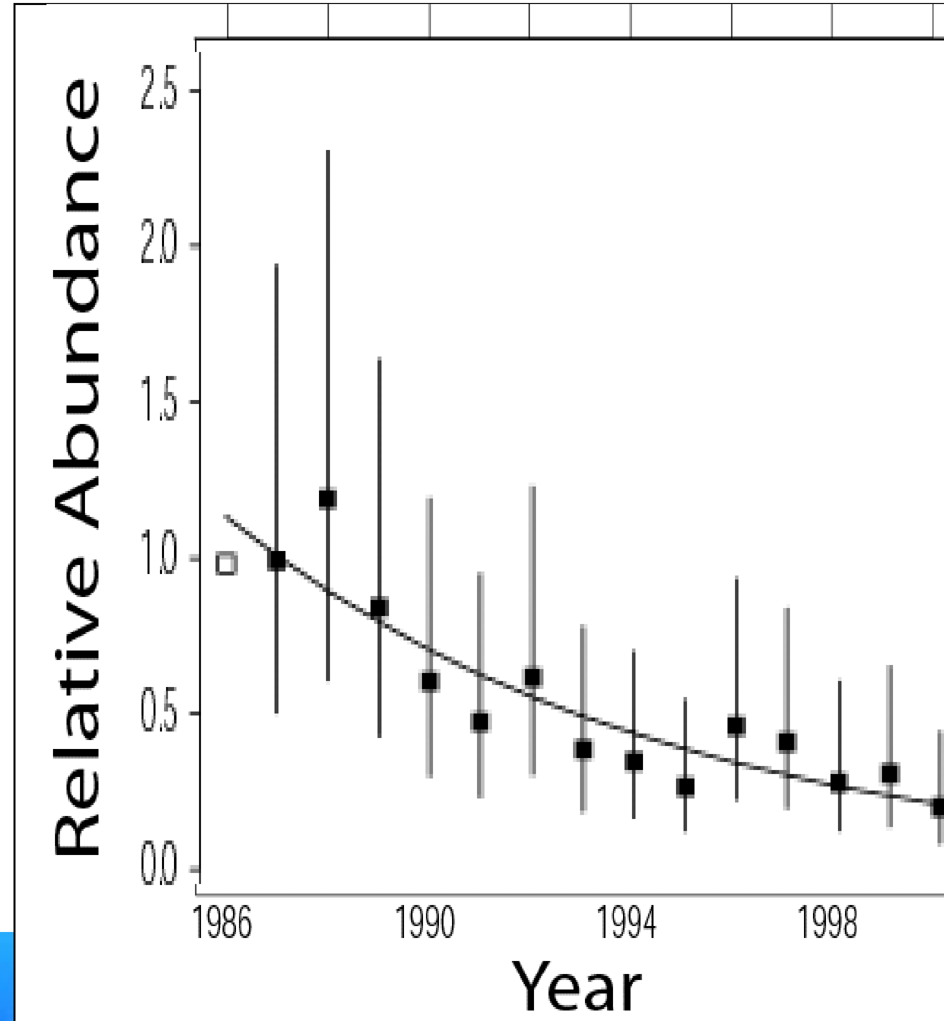
Decline of Mako sharks



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

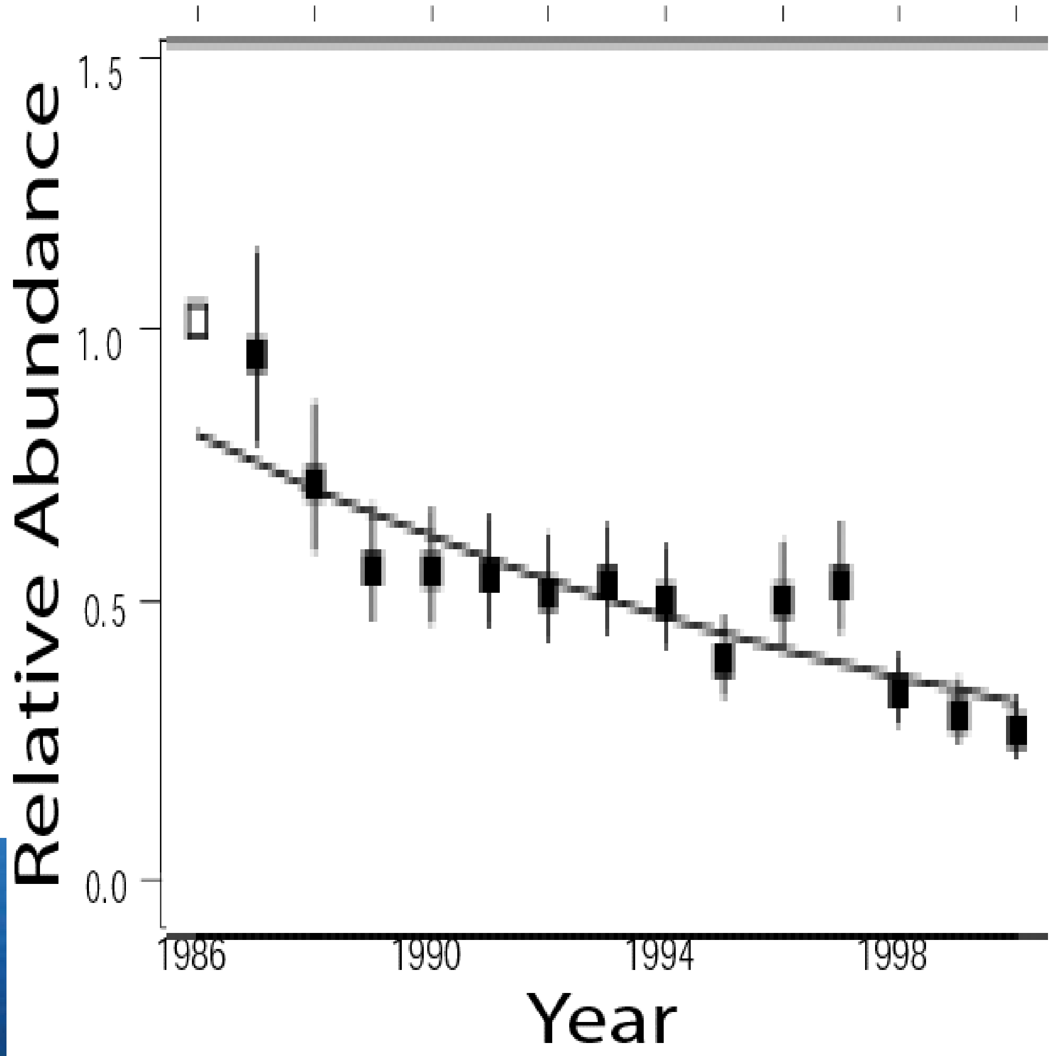
Thresher sharks

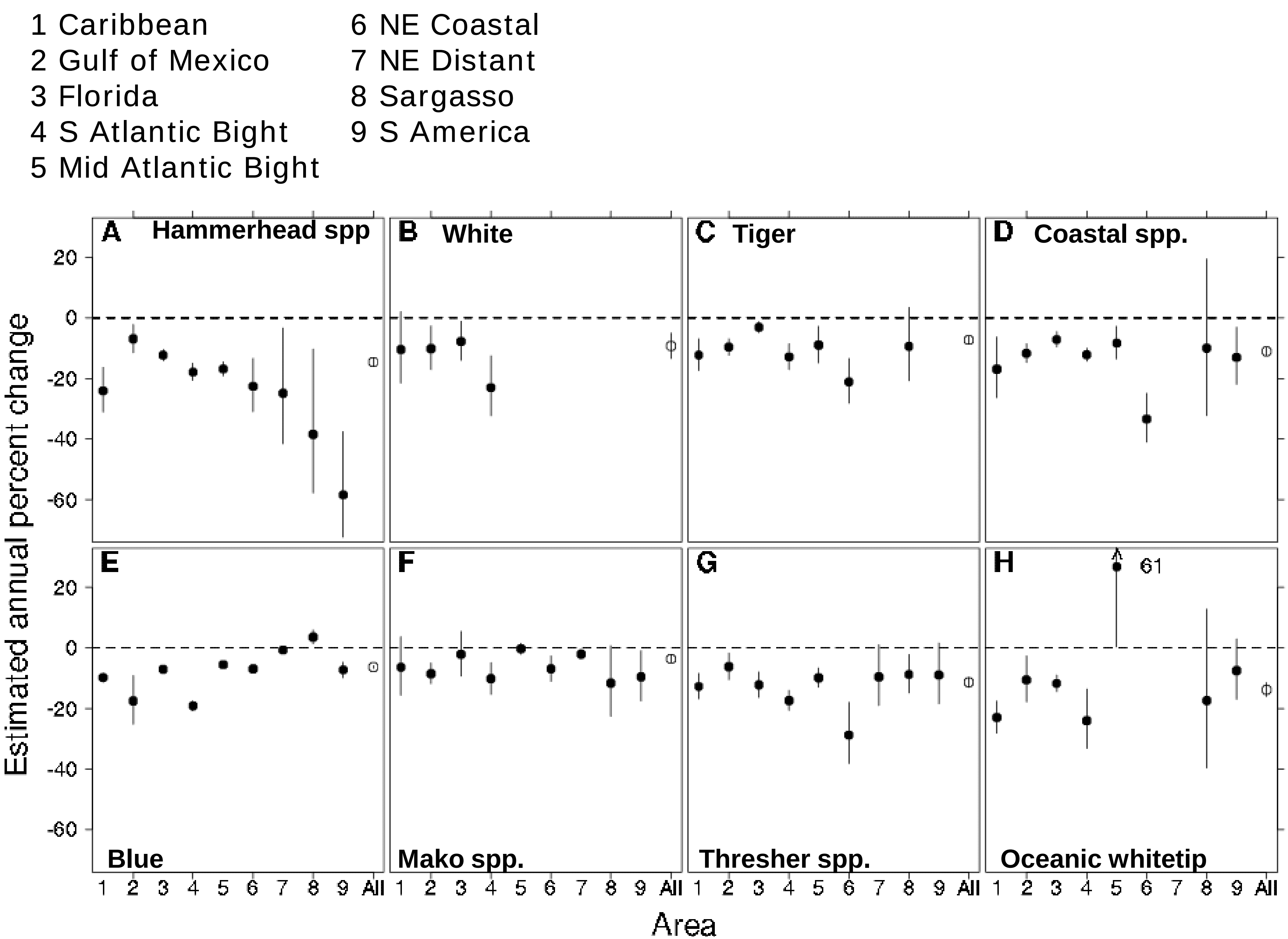
Alopias spp.



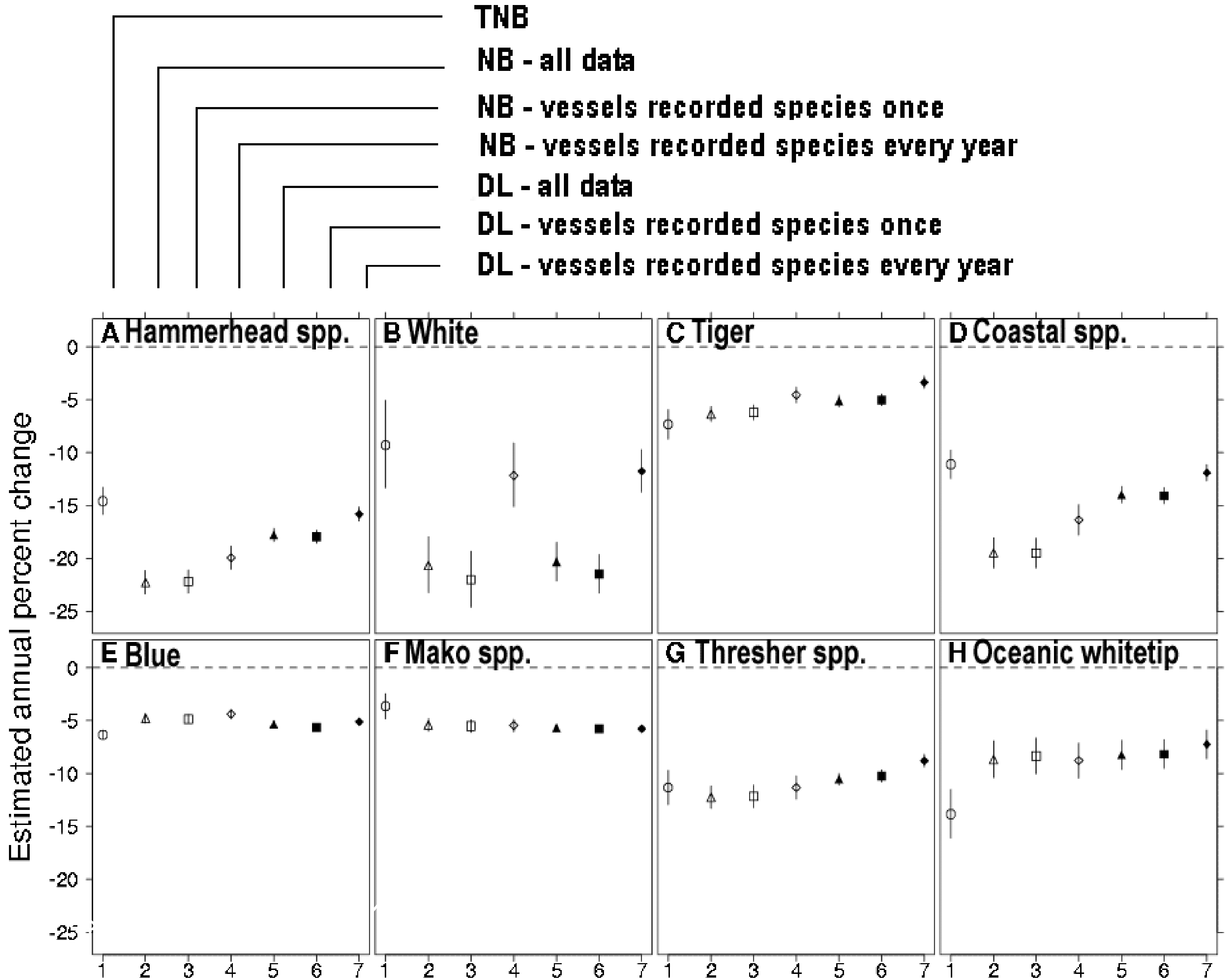
Blue sharks

Prionace glauca



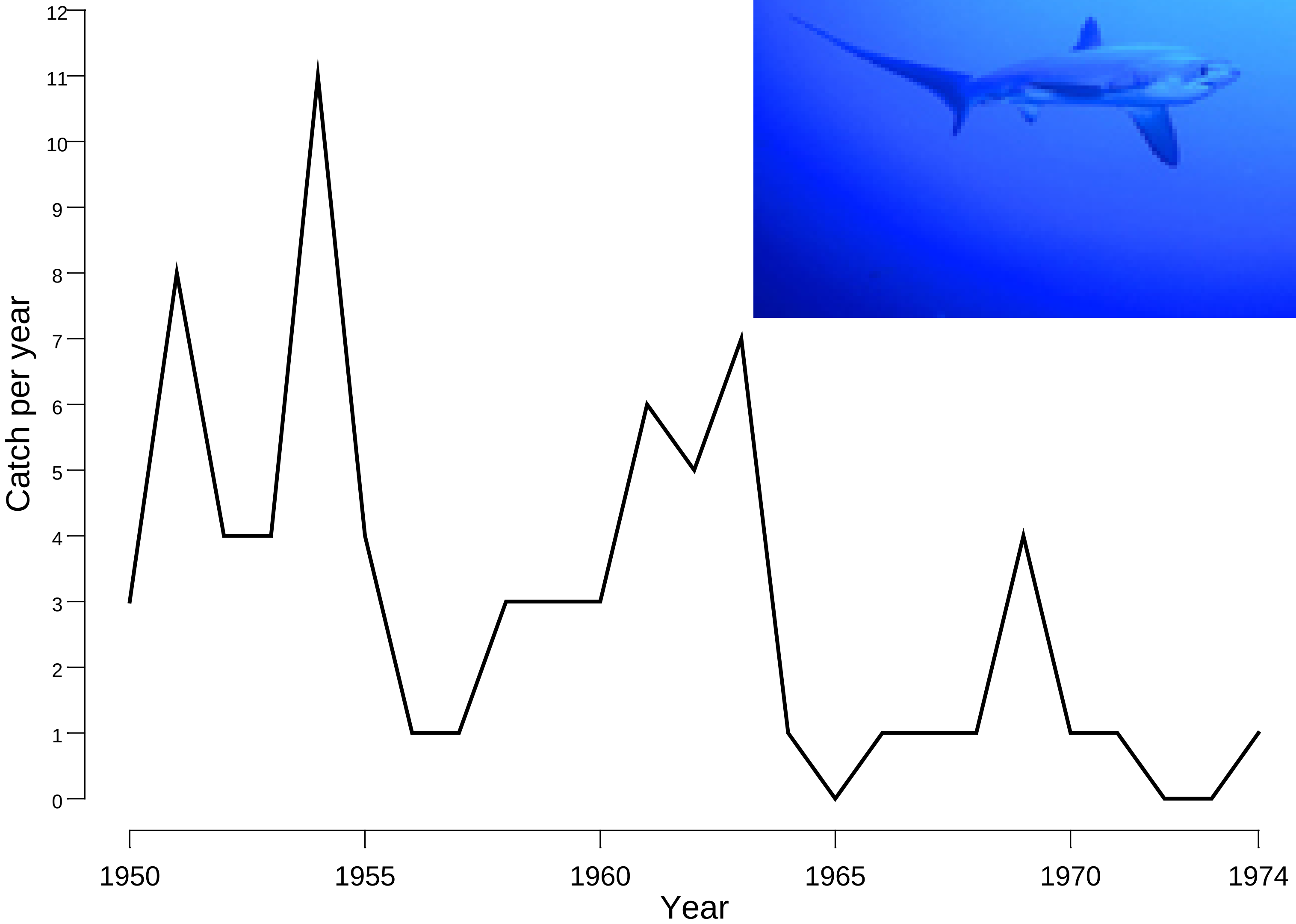


1 Caribbean
2 Gulf of Mexico
3 Florida
4 S Atlantic Bight
5 Mid Atlantic Bight
6 NE Coastal
7 NE Distant
8 Sargasso
9 S America
A Hammerhead spp
B White
C Tiger
D Coastal spp.
E Blue
F Mako spp.
G Thresher spp.
H Oceanic whitetip
61
Estimated annual percent change
20
0
-20
-40
-60
1 2 3 4 5 6 7 8 9 All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



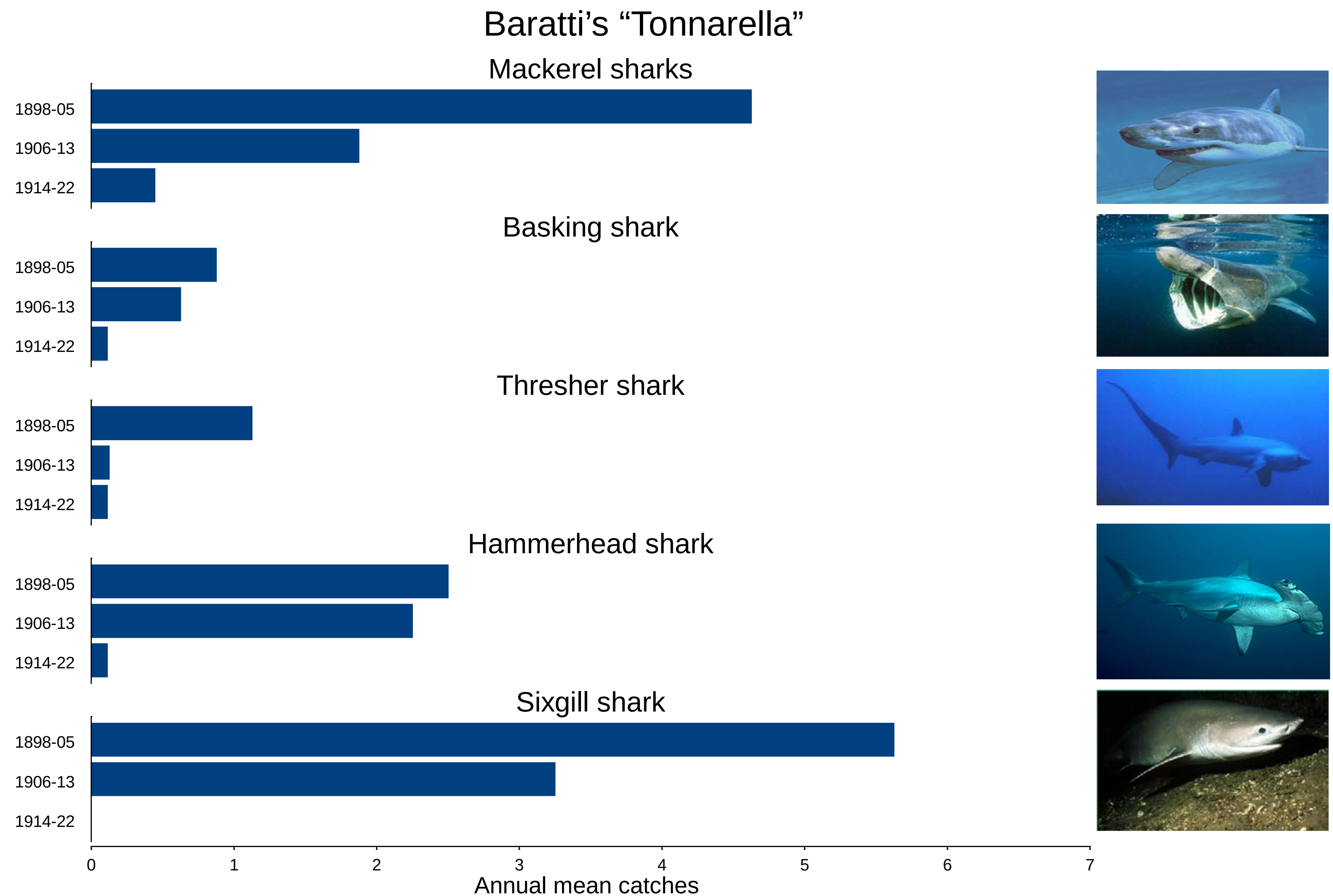
TNB
NB - all data
NB - vessels recorded species once
NB - vessels recorded species every year
DL - all data
DL - vessels recorded species once
DL - vessels recorded species every year
A Hammerhead spp.
B White
C Tiger
D Coastal spp.
E Blue
F Mako spp.
G Thresher spp.
H Oceanic whitetip
Estimated annual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

Decline of Thresher sharks



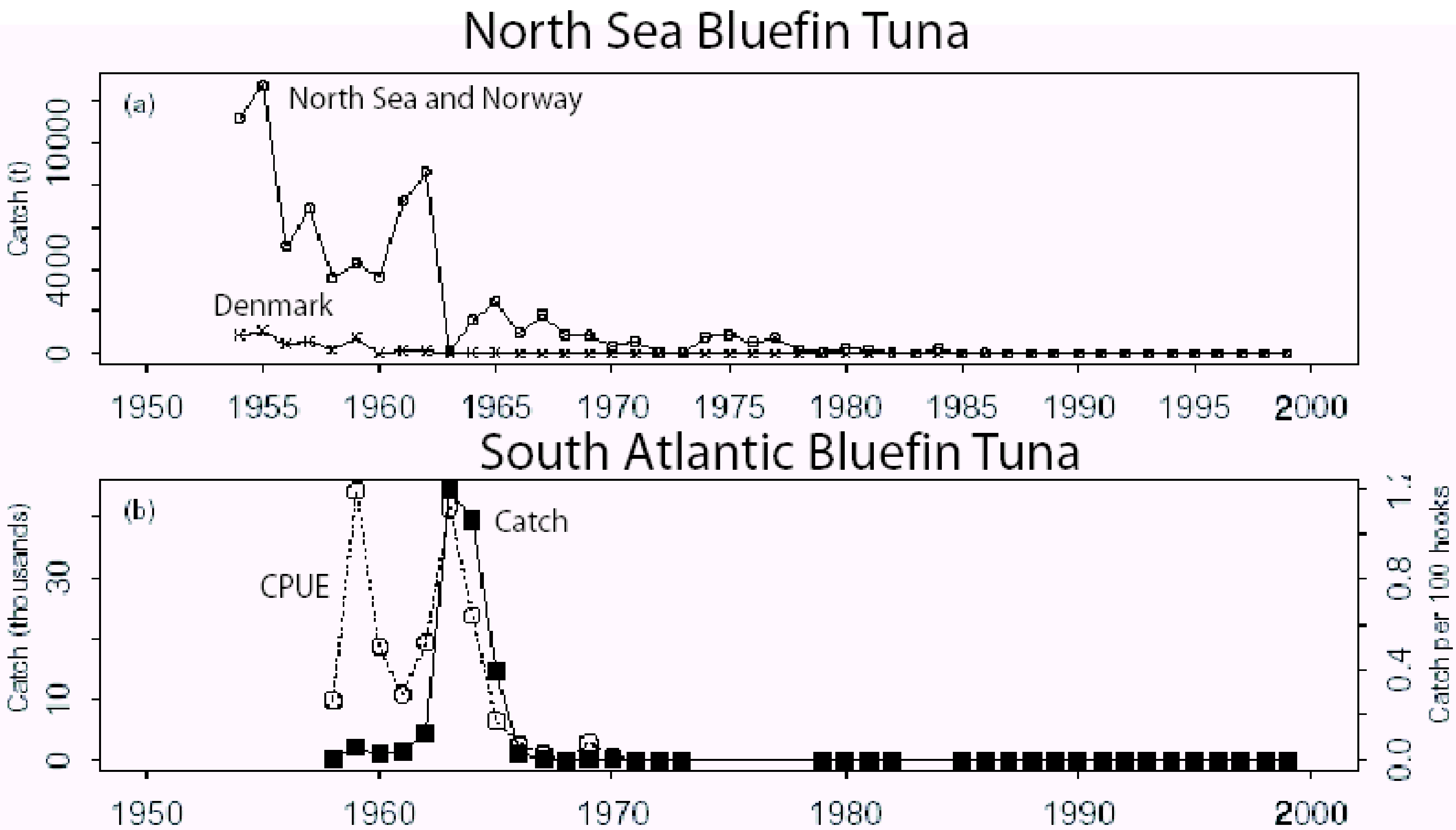
Boero F. & A. Carli 1979 – Boll. Mus. Ist. Biol. Univ. Genoa (47)

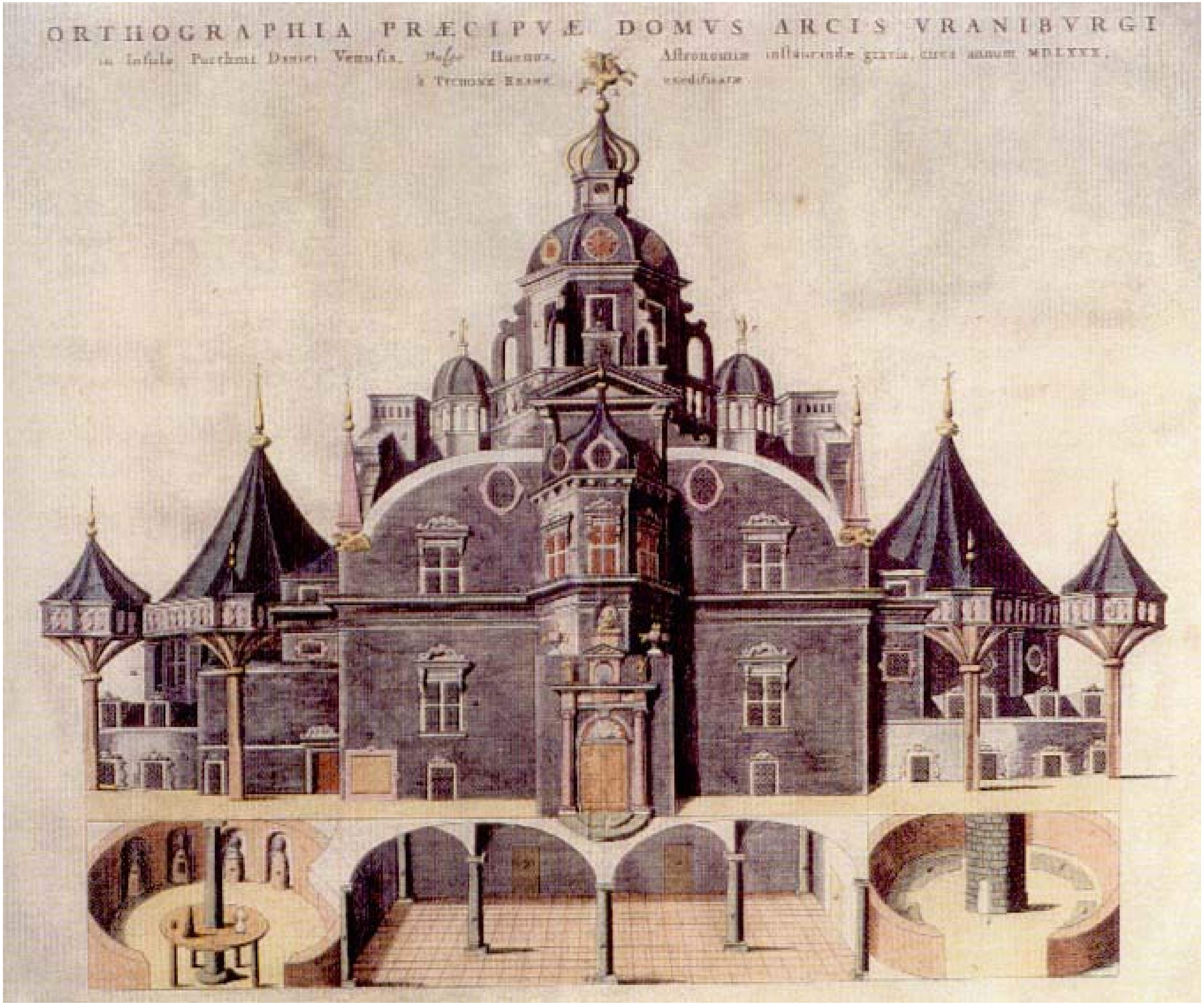
Decline in Large Sharks's Catches by an Italian Tuna Trap



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

Loss of Bluefin Tuna Populations in the Atlantic




ORTHOGRAPHIA PRÆCIPVÆ DOMVS ARCIS VRANIBVRGI