Are the apparent rapid declines in top pelagic predators real?

Mark Maunder, Shelton Harley, Mike Hinton, and others

IATTC

Outline

- Definitions and terms
- Why the declines don’t make sense
  - Japanese longline catch and effort (EP0)
  - Population dynamics
- Explanatory hypotheses
  - Regime change
  - Ecosystem
  - Spatial distribution of effort
  - Habitat and gear distribution
  - Stupid fish hypothesis
- Summary

Definitions

- CPUE = catch-per-unit-of-effort
- Nominal CPUE
- Fitting a model
- Carrying capacity – Average abundance in the absence of fishing

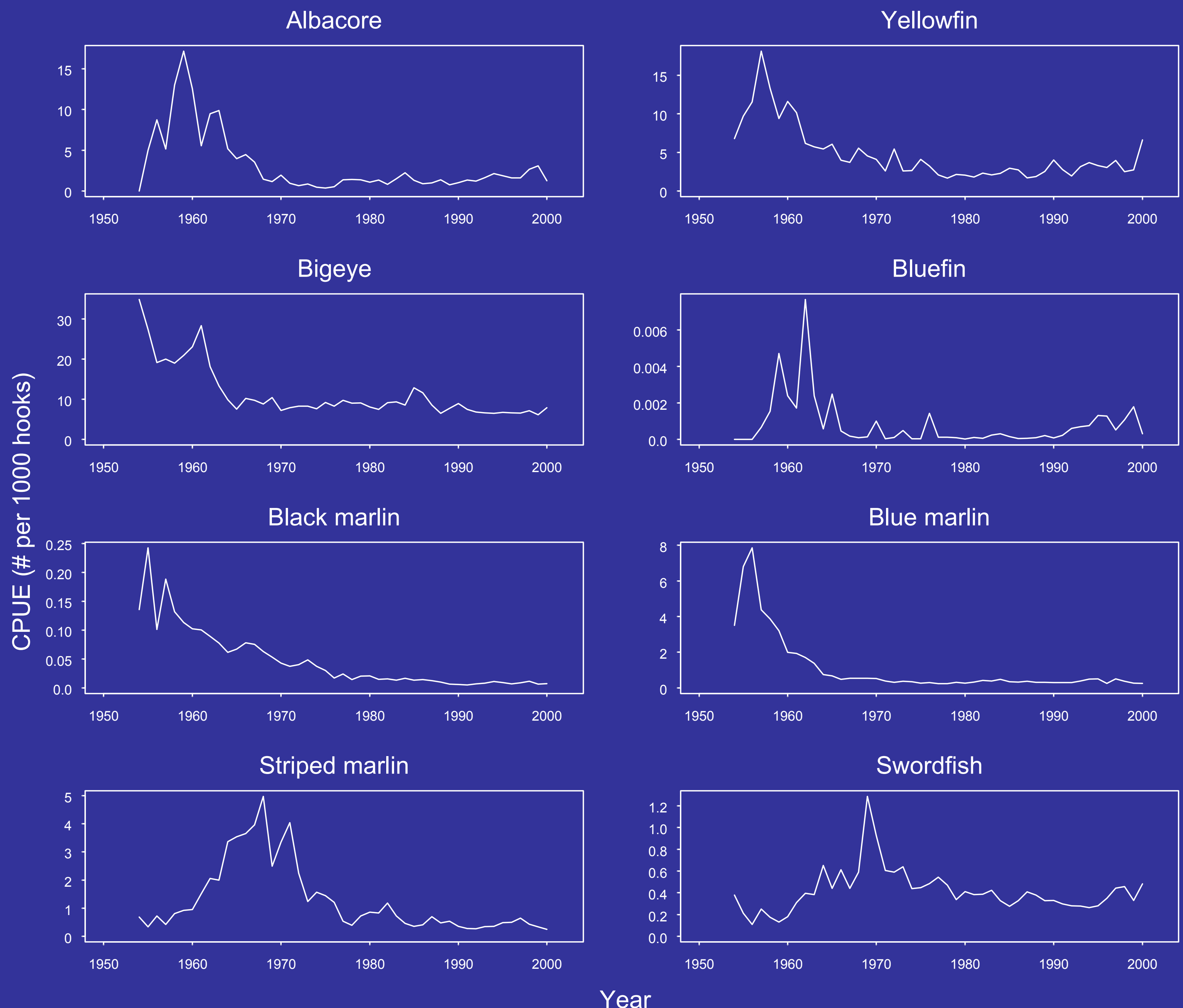
Basic assumption

C = EqA

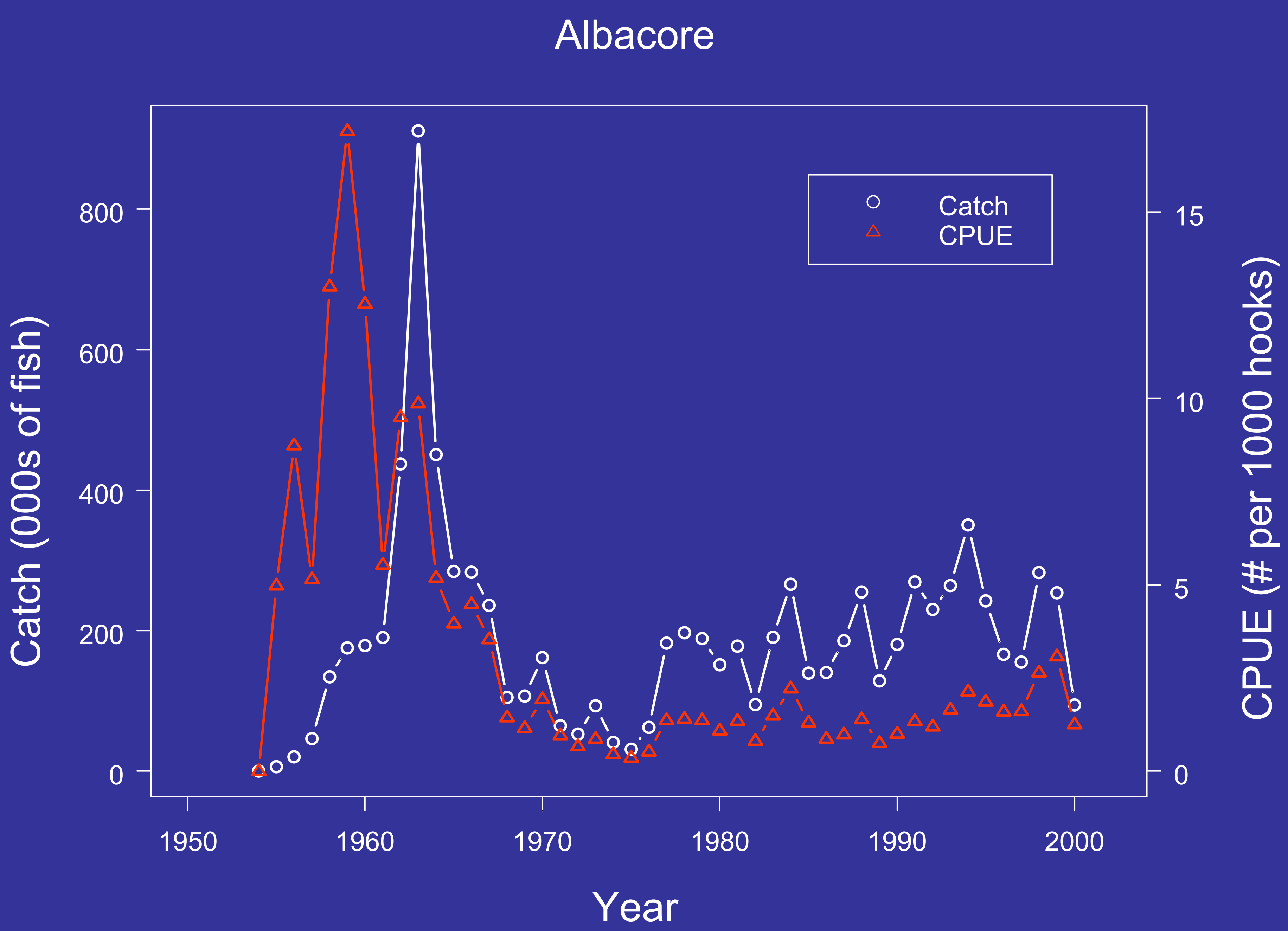
C/E = qA

Where: C= catch, E = effort, and A = abundance

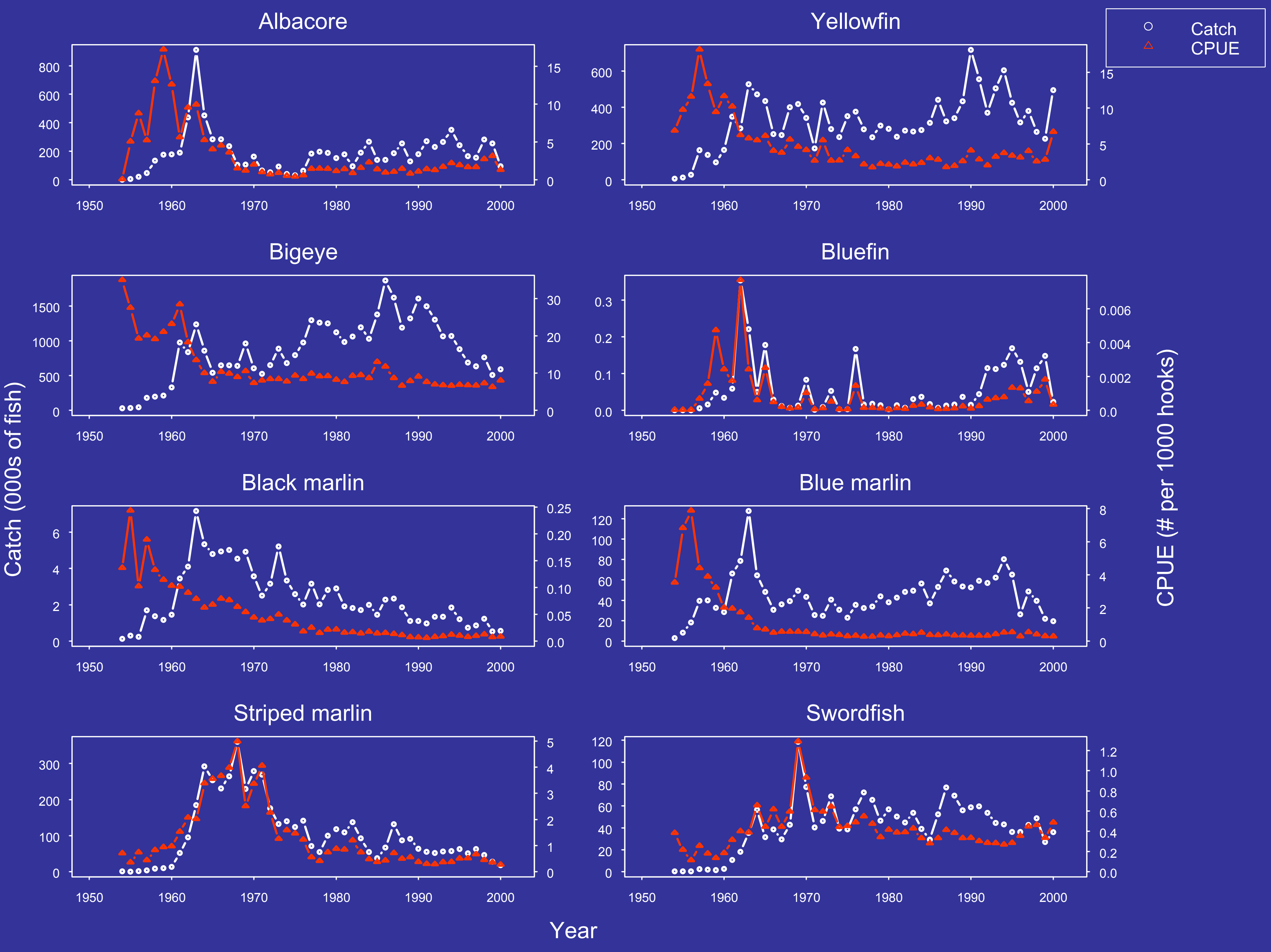
$$CPUE = \frac{\sum_{area} C}{\sum_{area} E}$$



Albacore
Yellowfin
Bigeye
Bluefin
Black marlin
Blue marlin
Striped marlin
Swordfish
CPUE (# per 1000 hooks)
Year
1950
1960
1970
1980
1990
2000

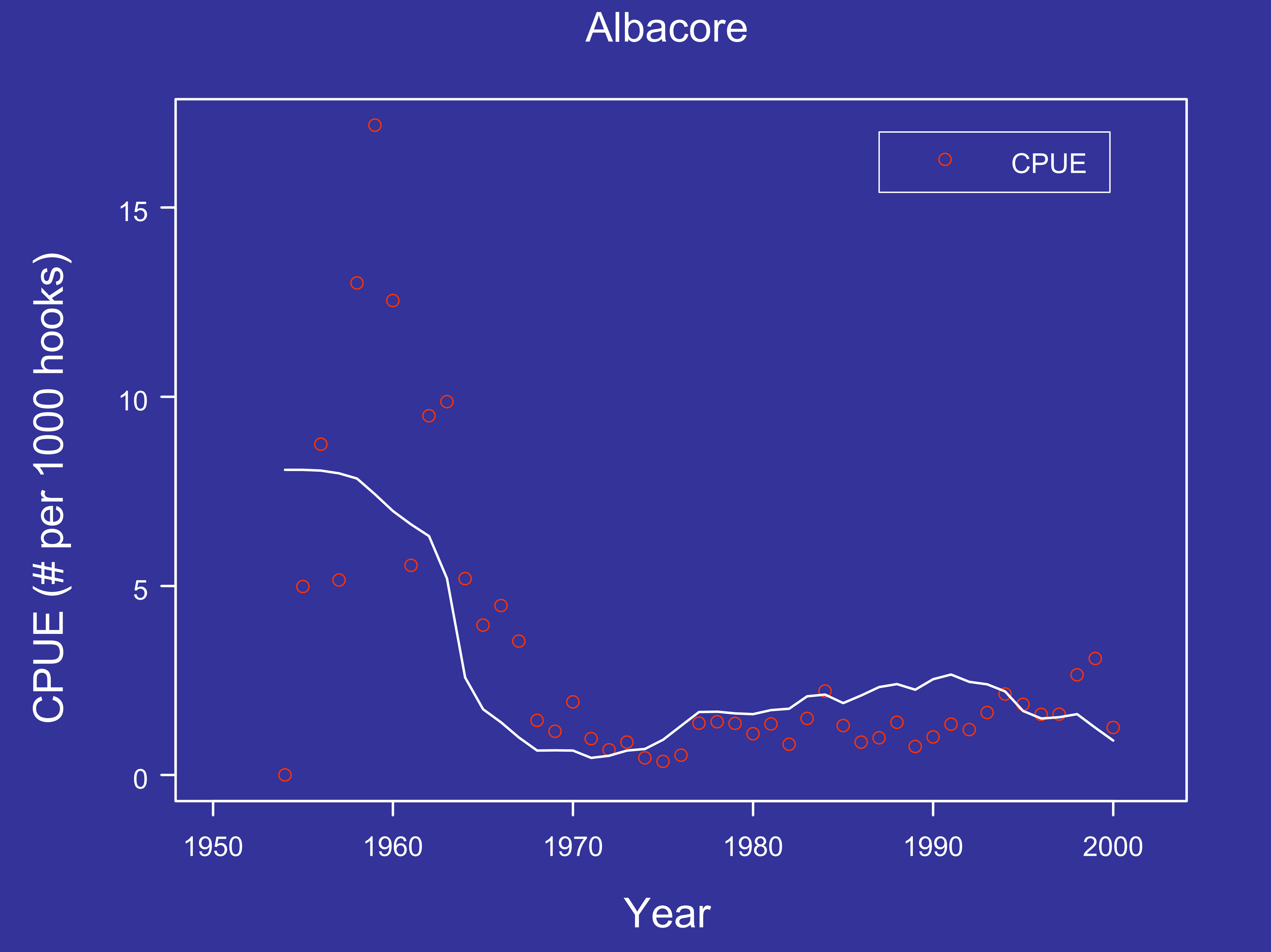


Albacore
Catch (000s of fish)
CPUE (# per 1000 hooks)
Year
Catch
CPUE
0
200
400
600
800
0
5
10
15
1950
1960
1970
1980
1990
2000

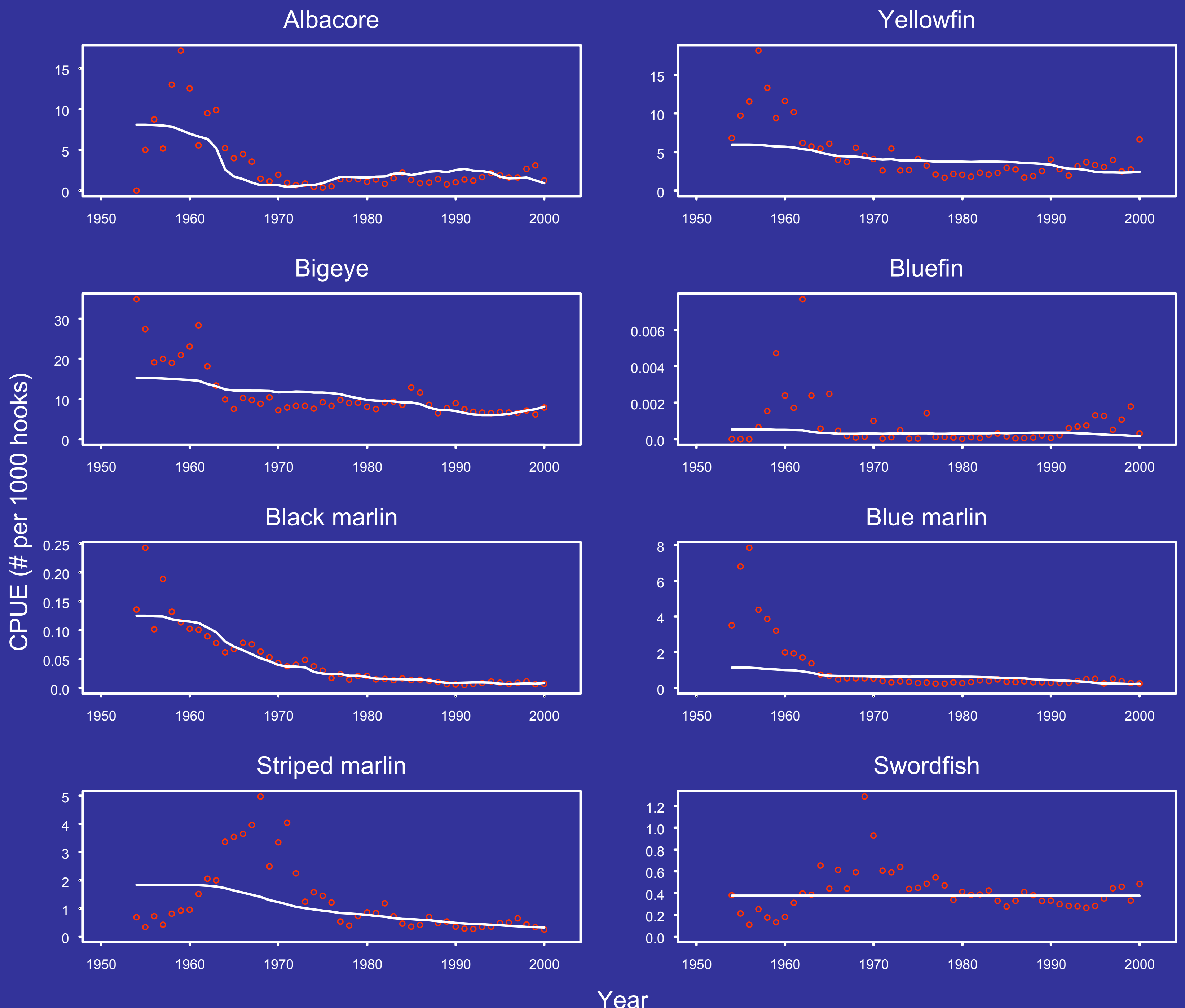

Albacore
Yellowfin
Bigeye
Bluefin
Black marlin
Blue marlin
Striped marlin
Swordfish
Catch
CPUE
Catch (000s of fish)
CPUE (# per 1000 hooks)
Year

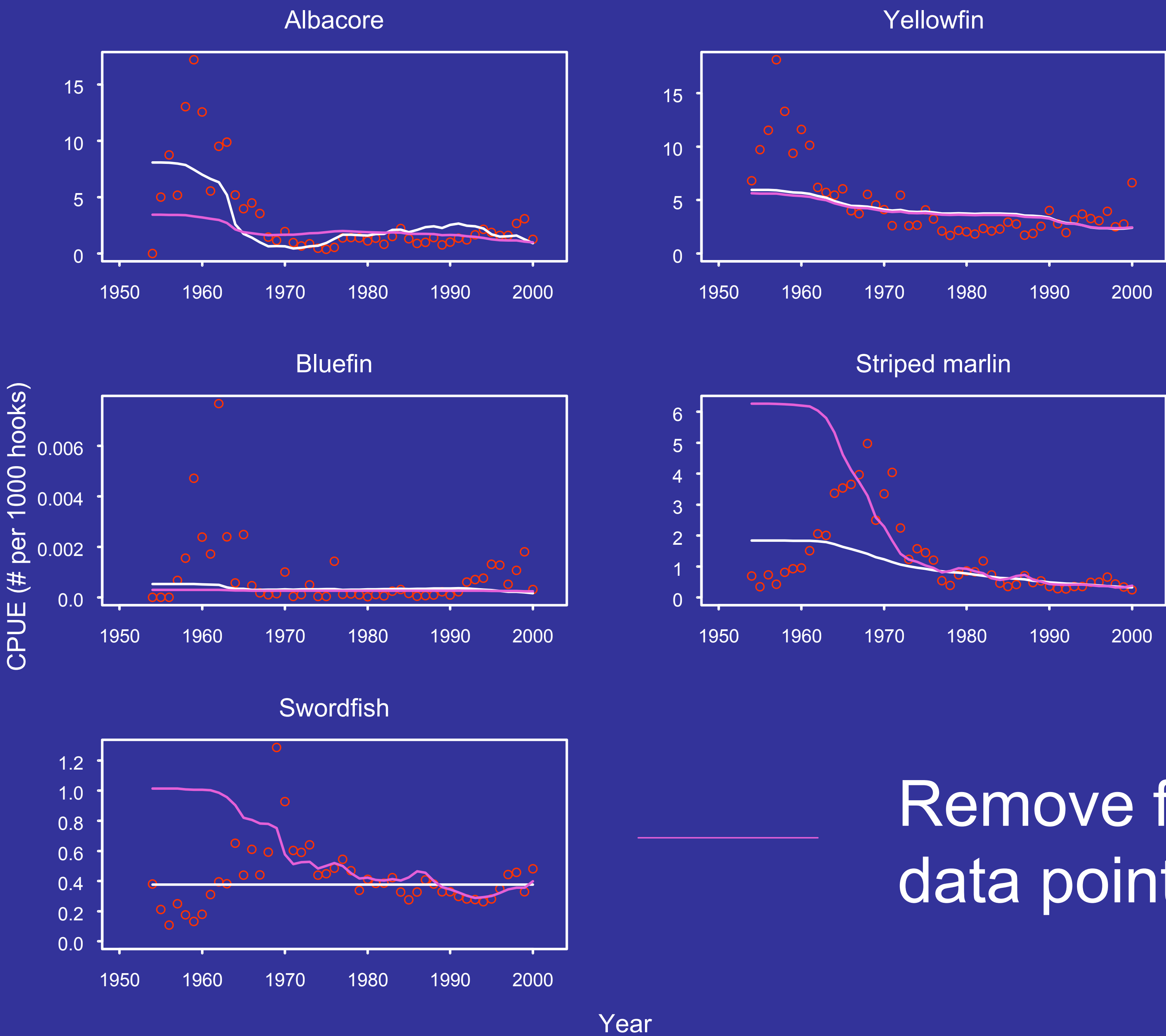
Fit model to data

- PellaTomlinson-model with N_{msy}/N_0 = 30% (based on numbers)
- Project population dynamics from an unexploited condition using observed catch
- Fit to CPUE data as a relative abundance index (assume CPUE proportional to abundance)
- Use only Japanese longline CPUE and Catch data



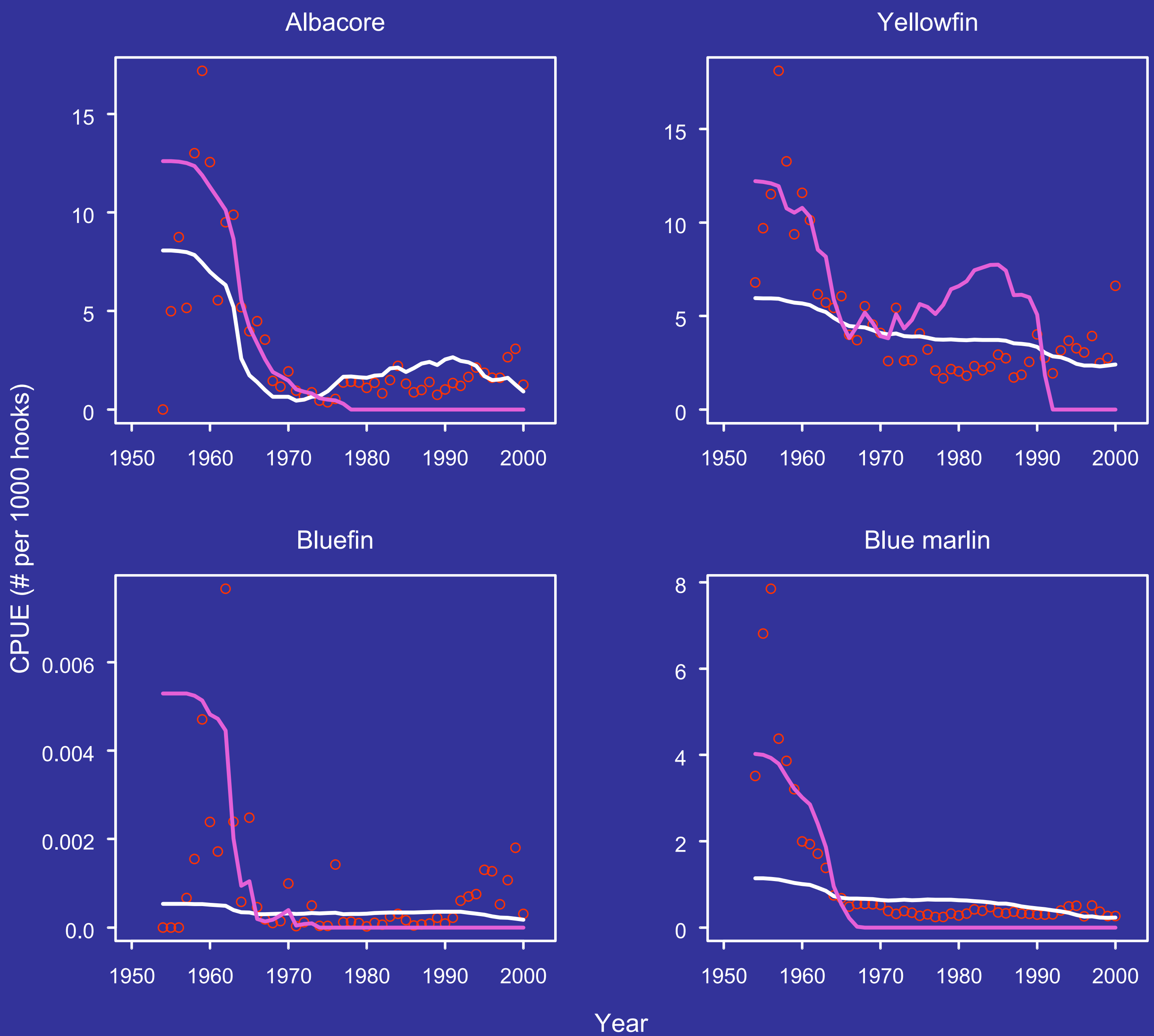
Albacore
CPUE
CPUE (# per 1000 hooks)
0
5
10
15
1950
1960
1970
1980
1990
2000
Year


Albacore
Yellowfin
Bigeye
Bluefin
Black marlin
Blue marlin
Striped marlin
Swordfish
CPUE (# per 1000 hooks)
Year



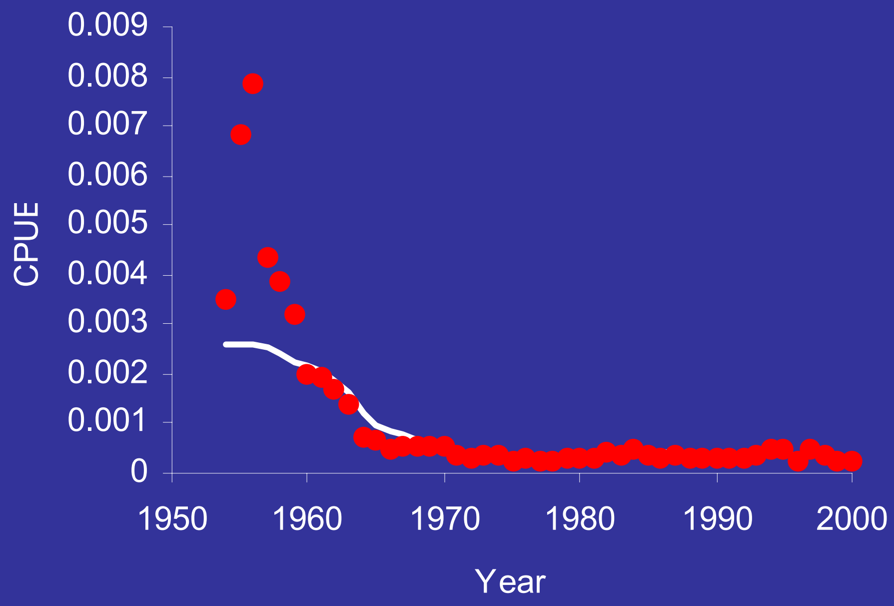
Remove first few data points

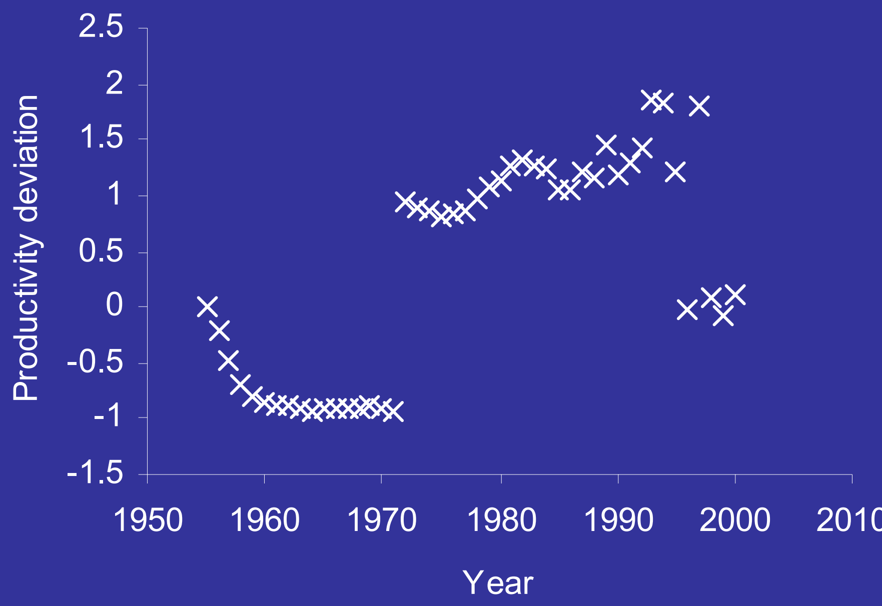
Only fit to decline



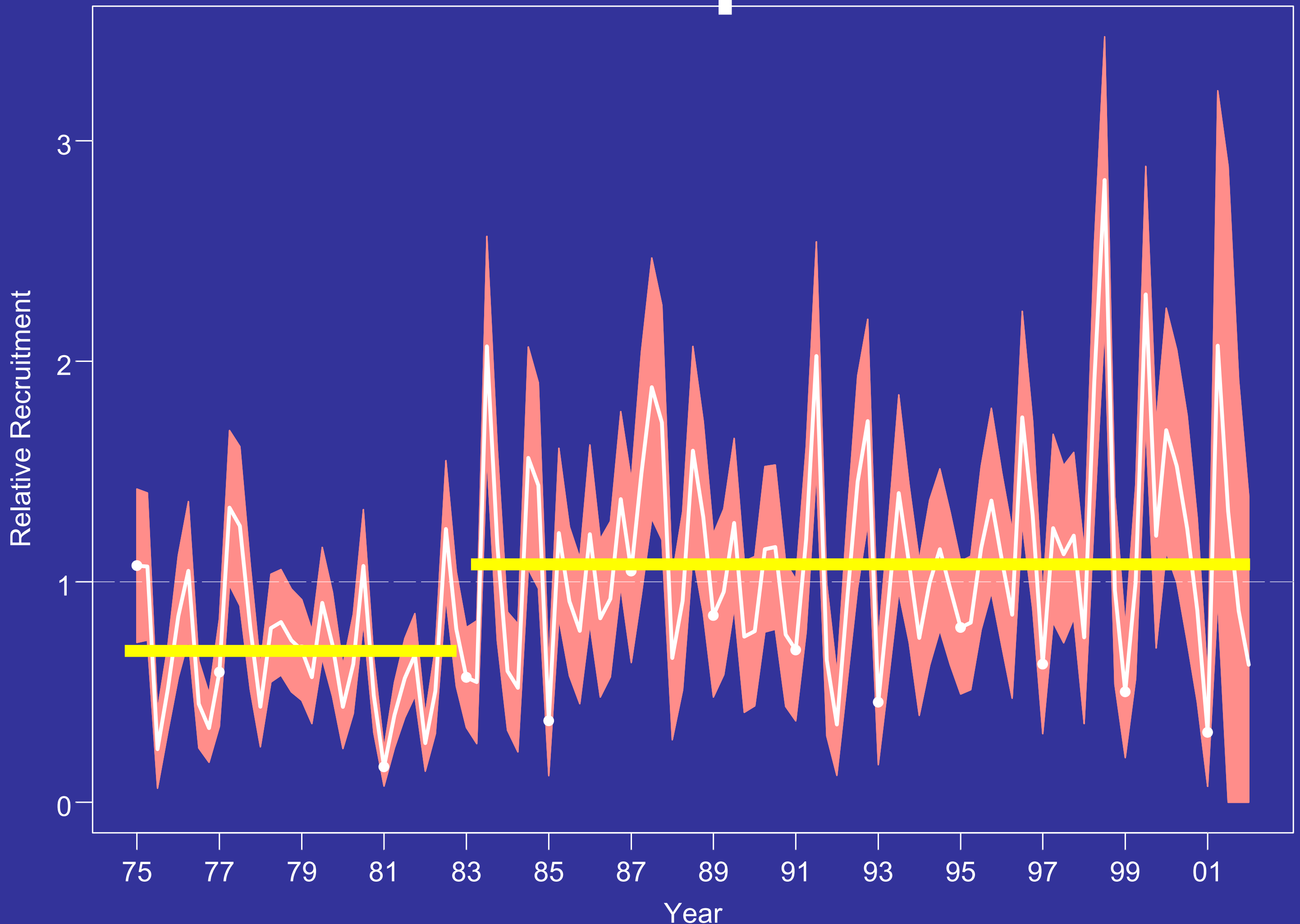
Regime change hypothesis

Blue marlin production residuals



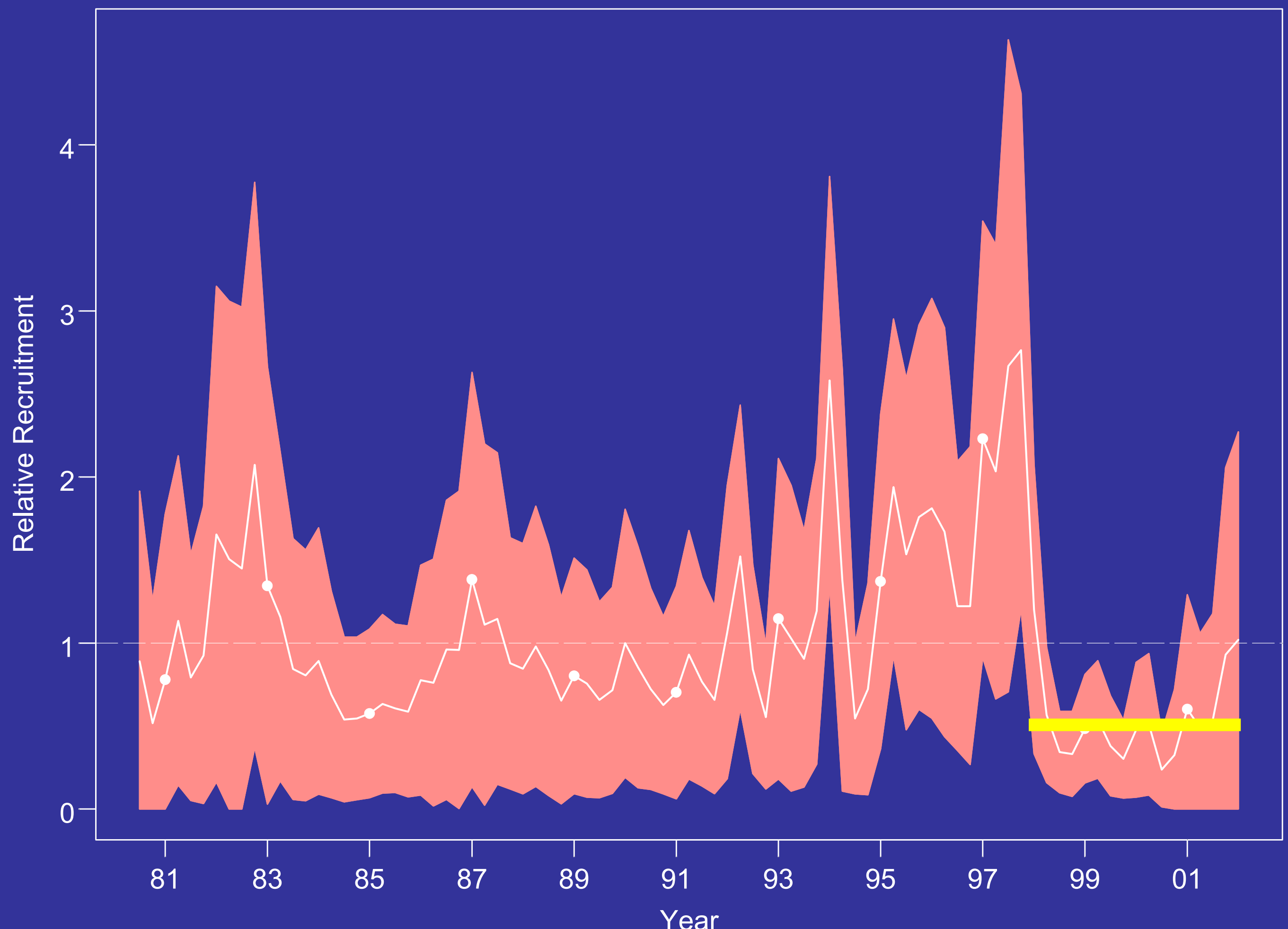


Change in productivity, yellowfin example



Maunder 2002. IATTC Stock Assessment Report 3

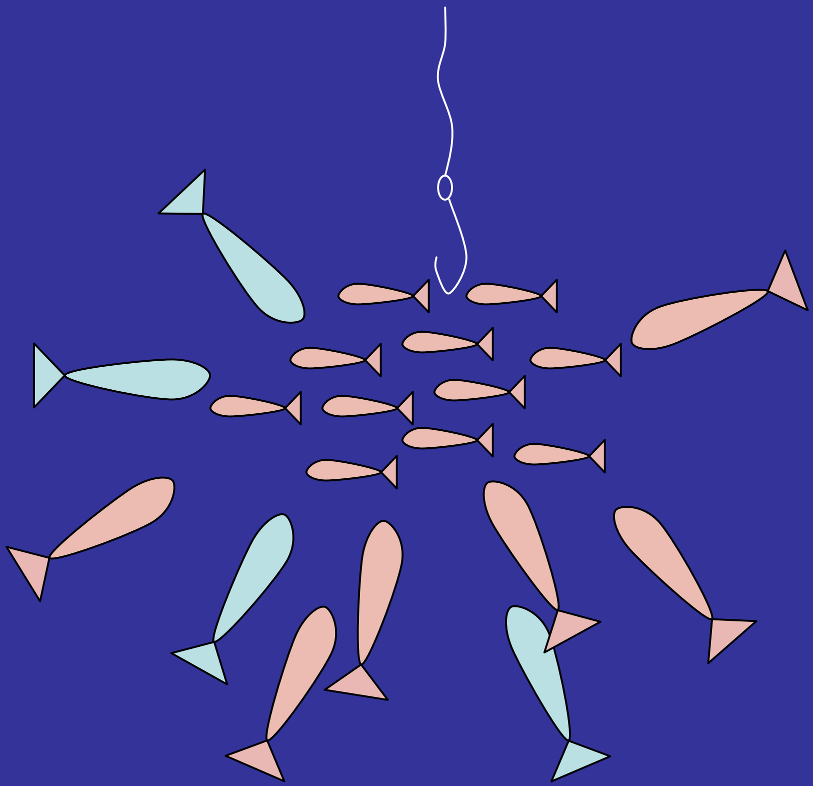
Change in productivity, bigeye example



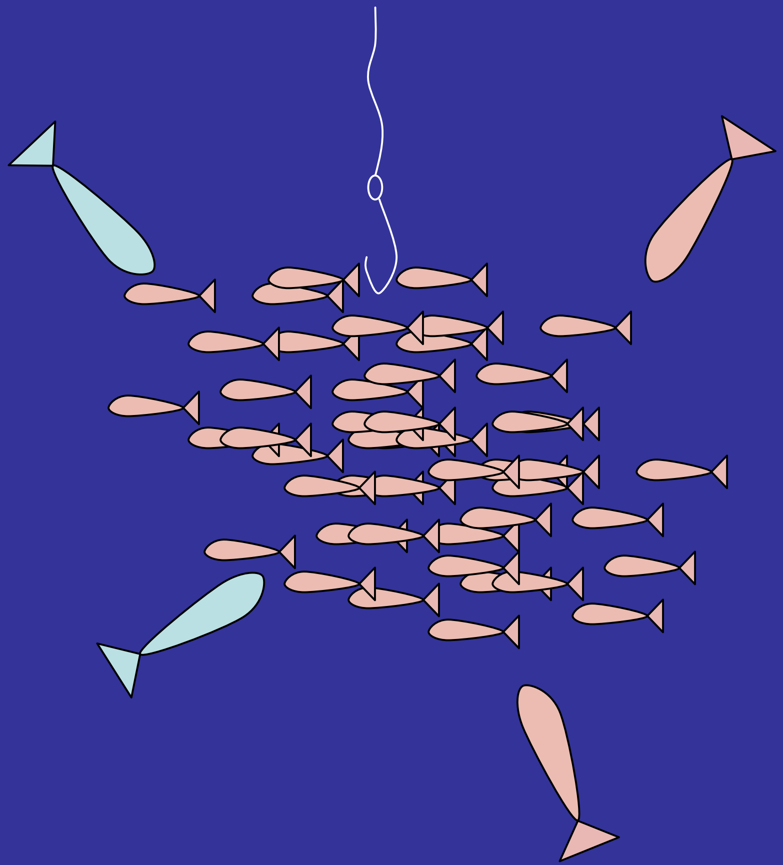
Maunder and Harley 2002. IATTC Stock Assessment Report 3

Ecosystem model

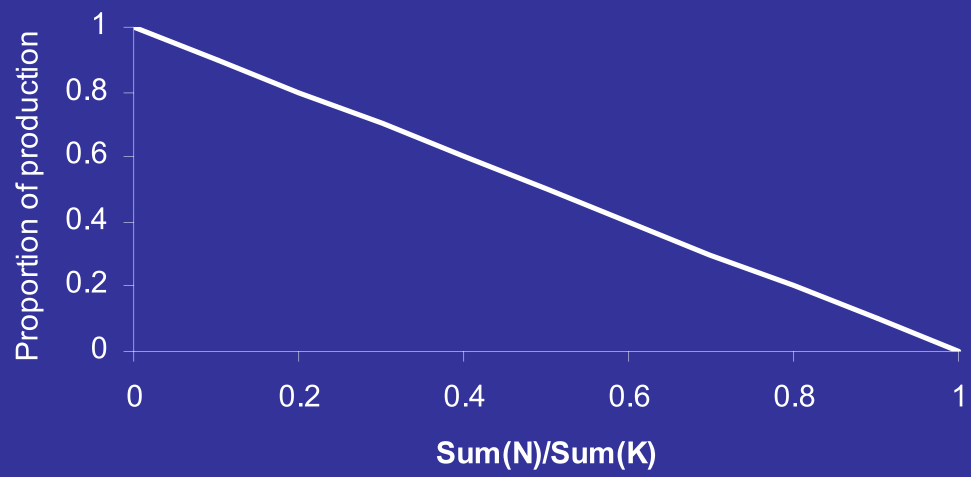
High Adult Biomass



Low Adult Biomass



Ecosystem model



$$f\left(N_t\right)\times\left(1-\frac{\sum_{species} N_t}{\sum_{species} K}\right)$$

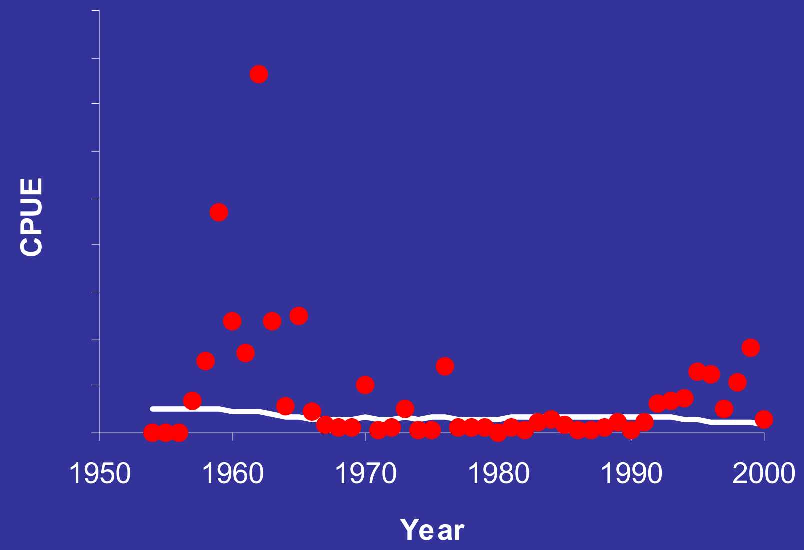
K = carrying capacity N = numbers *f*(N) is the single species production

Ecosystem results

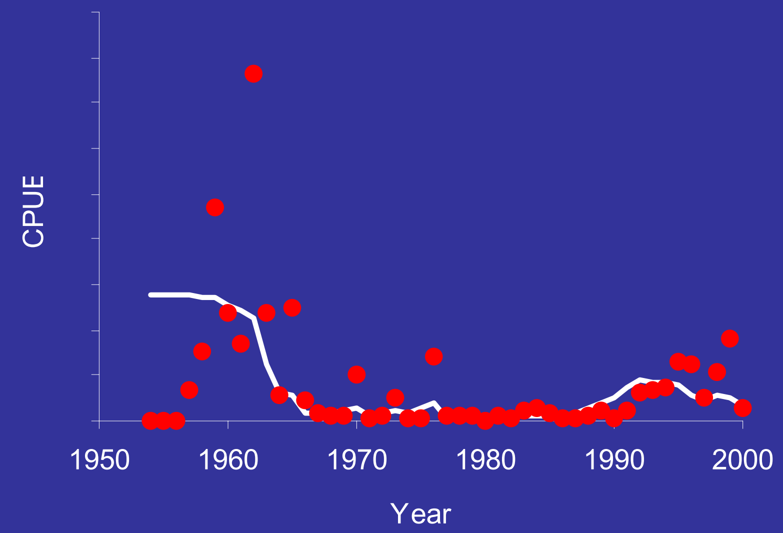
- Fits the data significantly better
- Nearly all improvement from fit to bluefin tuna data
- Also improves fit to blue marlin data

Bluefin tuna

Single Species

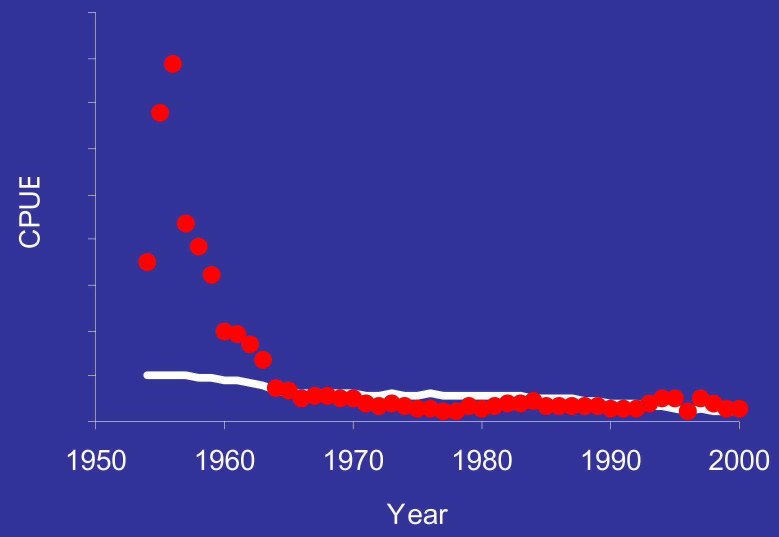


Ecosystem

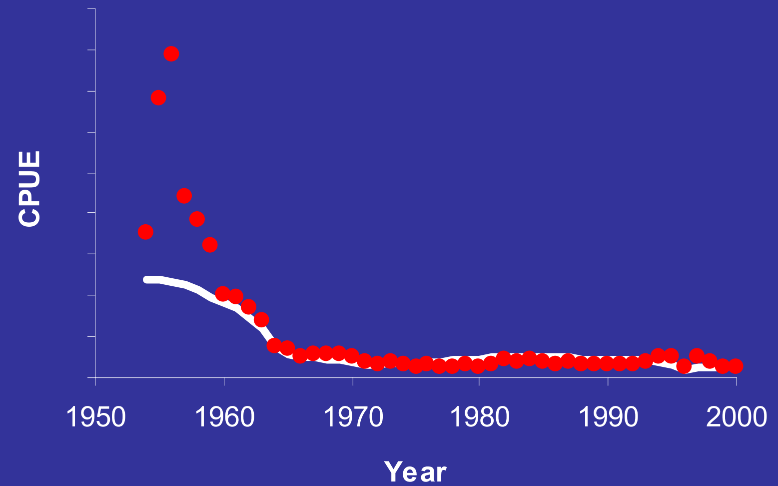


Blue marlin

Single Species



Ecosystem



Spatial expansion of the longline fishery

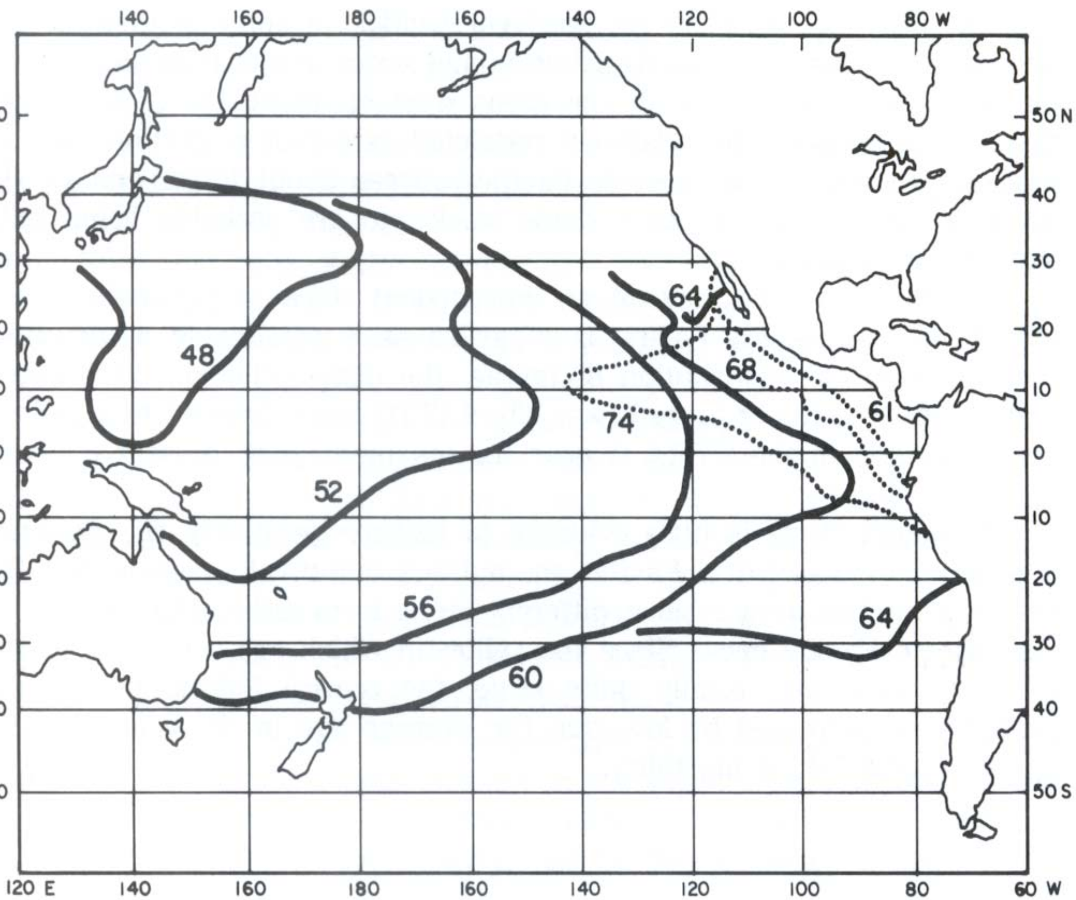
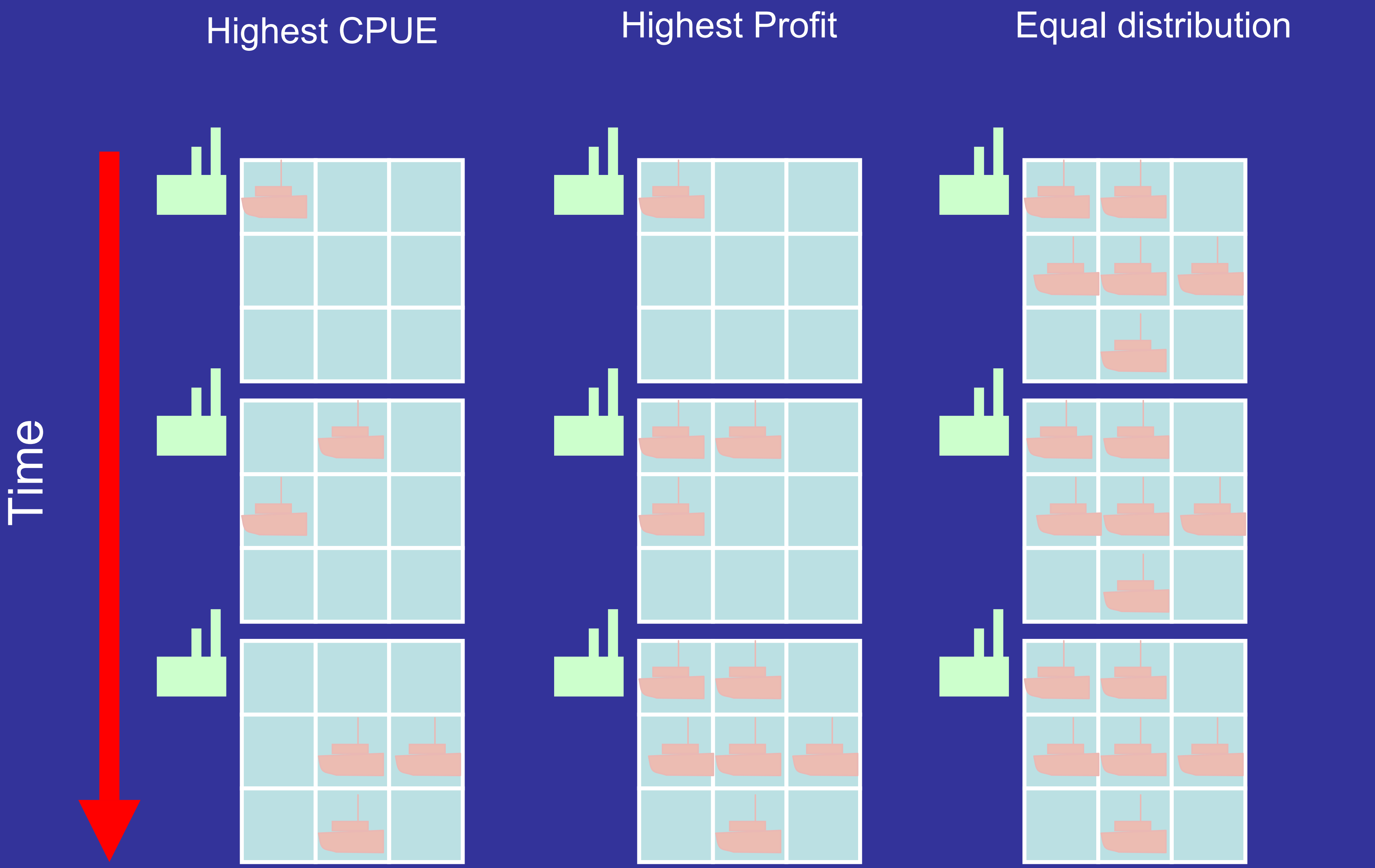


FIGURE 1. Geographical expansion of the Japanese longline fishery (solid curves) and the surface fishery in the eastern Pacific (dotted curves). Numerals denote calendar year.

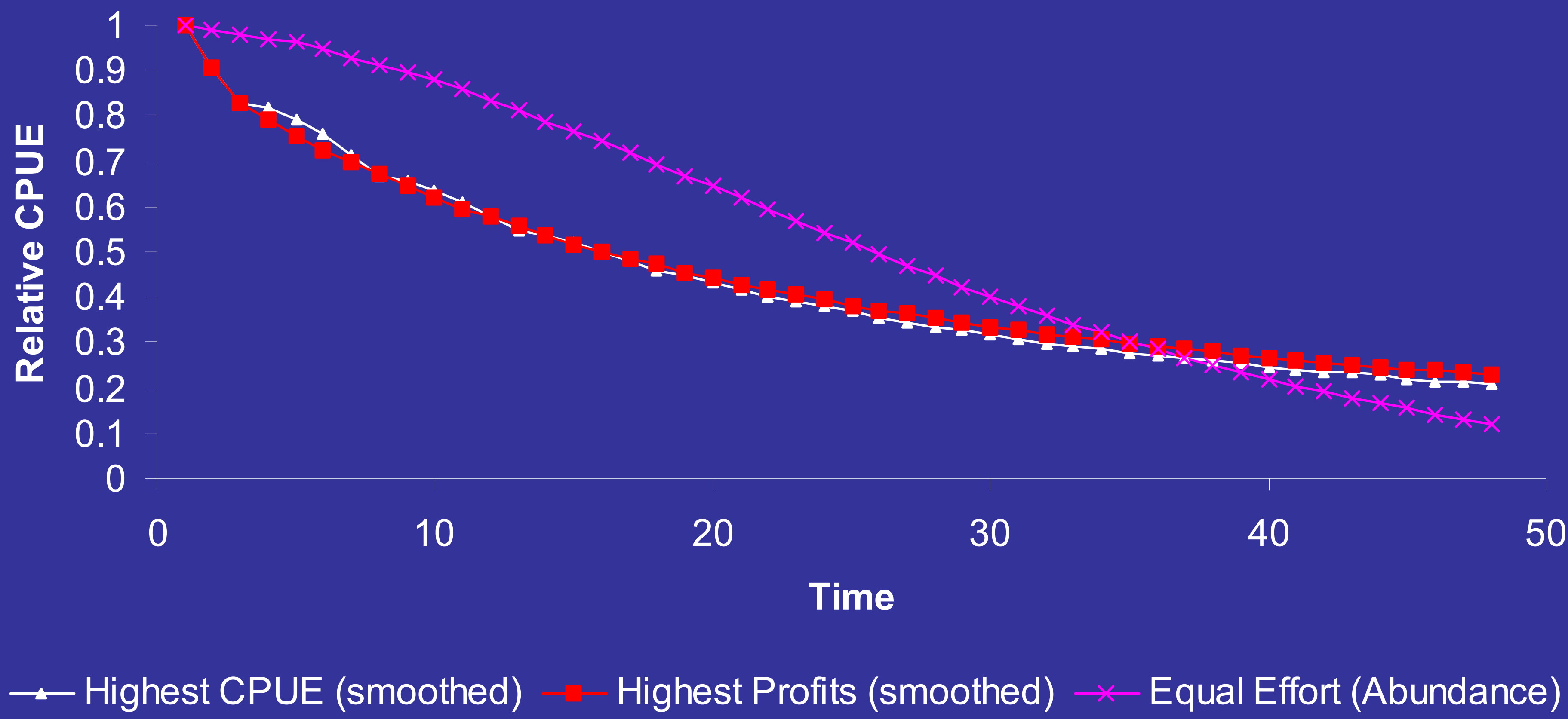
Spatial hypotheses



Simulation of effort expansion

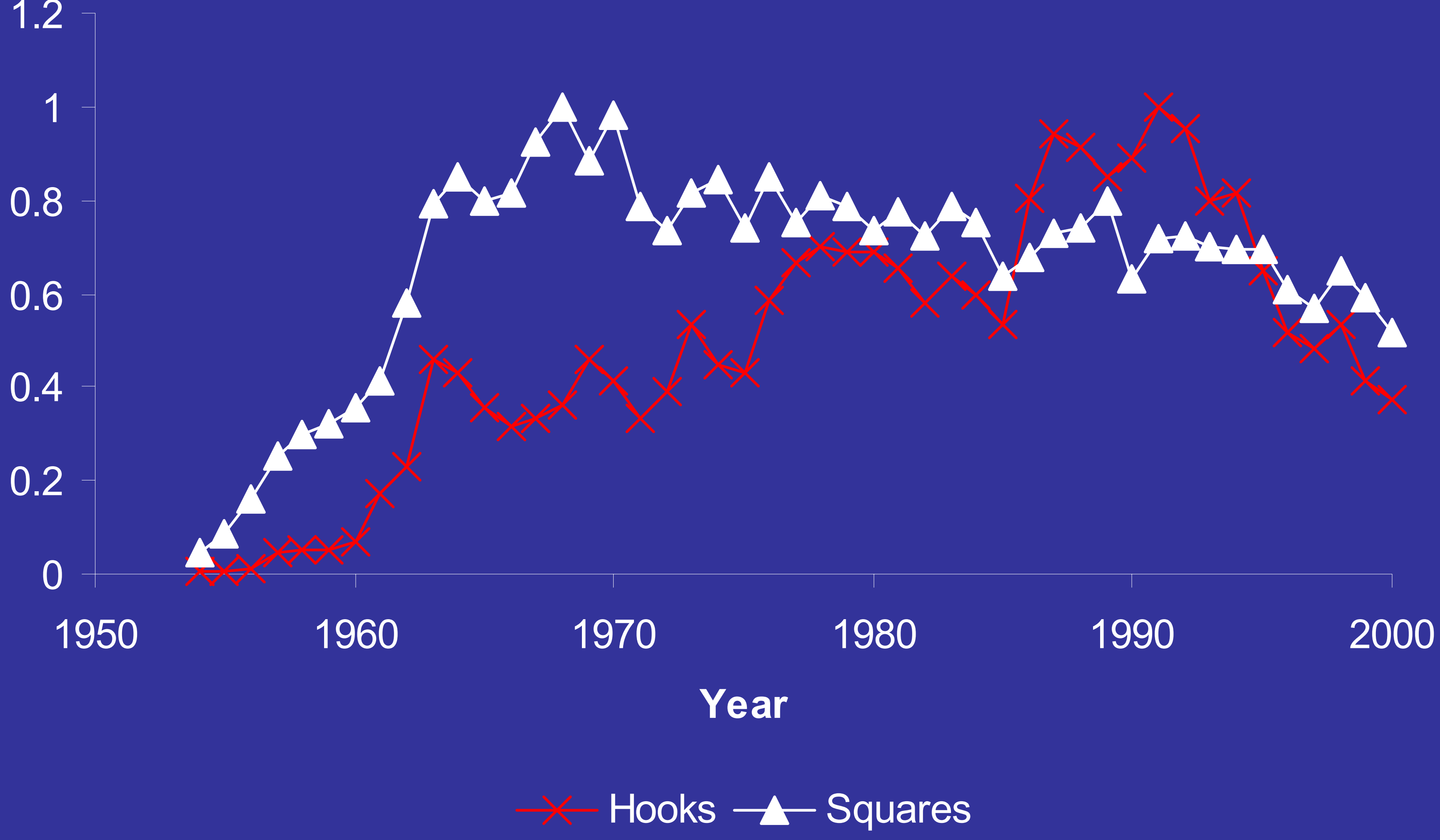
- Effort increases by 100 units every 5 years
- Movement of effort only occurs every five years
- No movement of fish among areas
- In highest profit hypothesis, new effort goes into new area and old effort stays in the same area
- In highest CPUE hypothesis, all effort goes into new area

CPUE trends



Relative CPUE
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
Time
Highest CPUE (smoothed)
Highest Profits (smoothed)
Equal Effort (Abundance)

Expansion of the fishery



30% of striped marlin catch

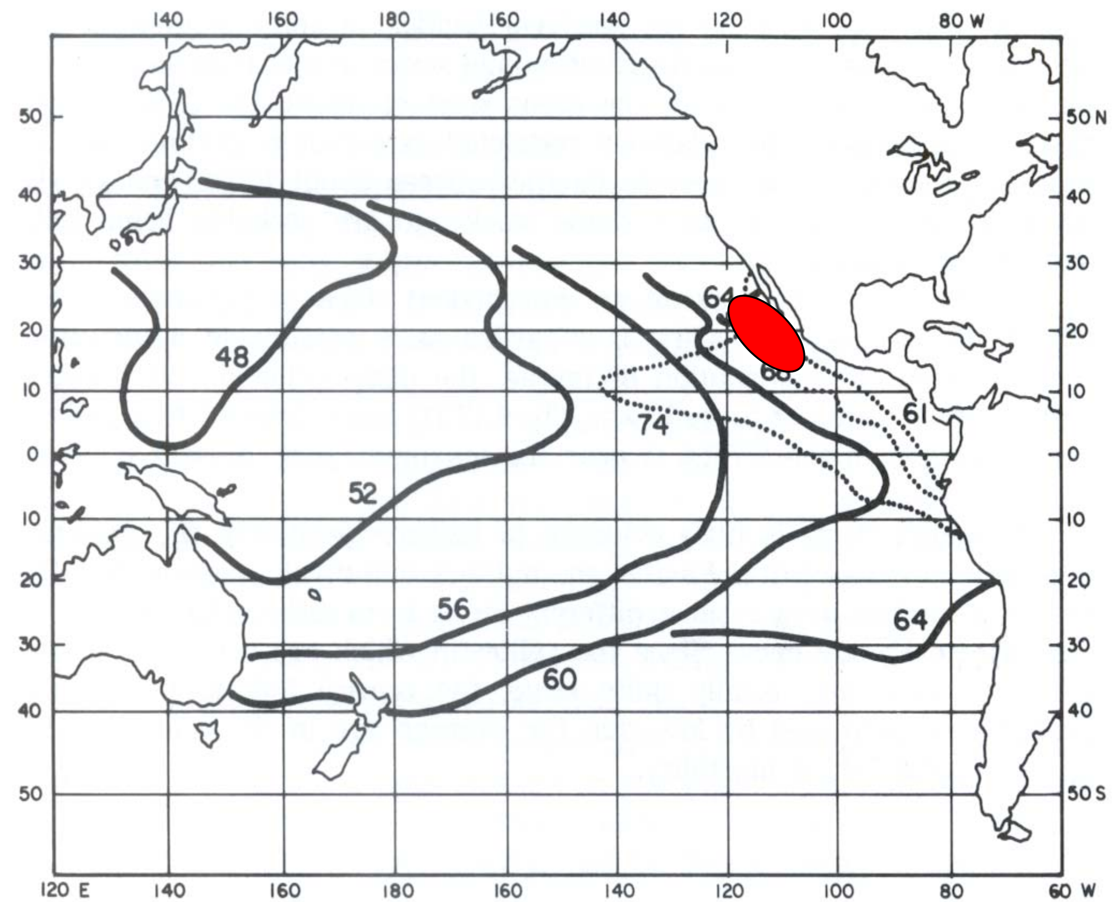
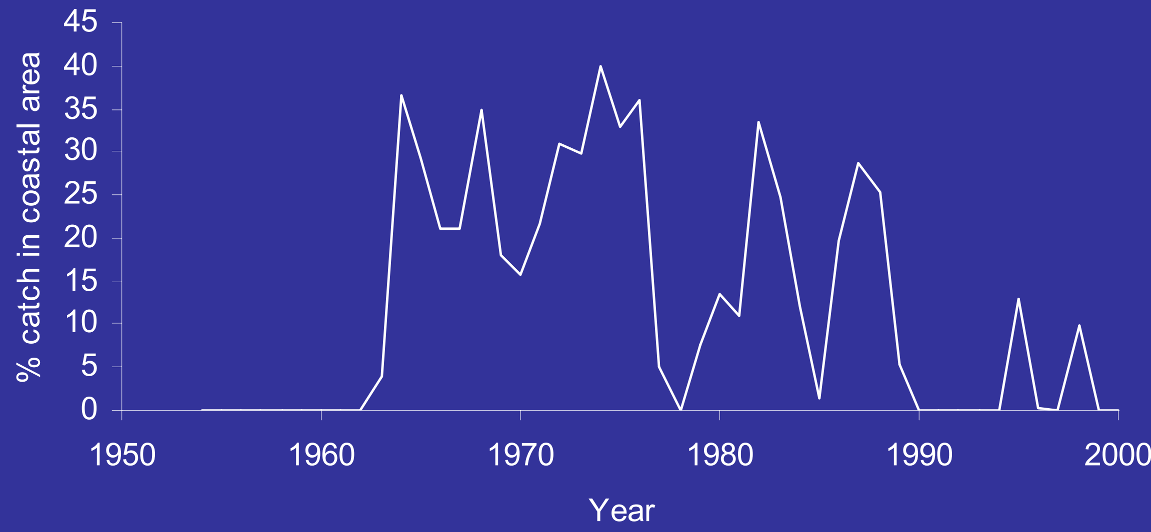
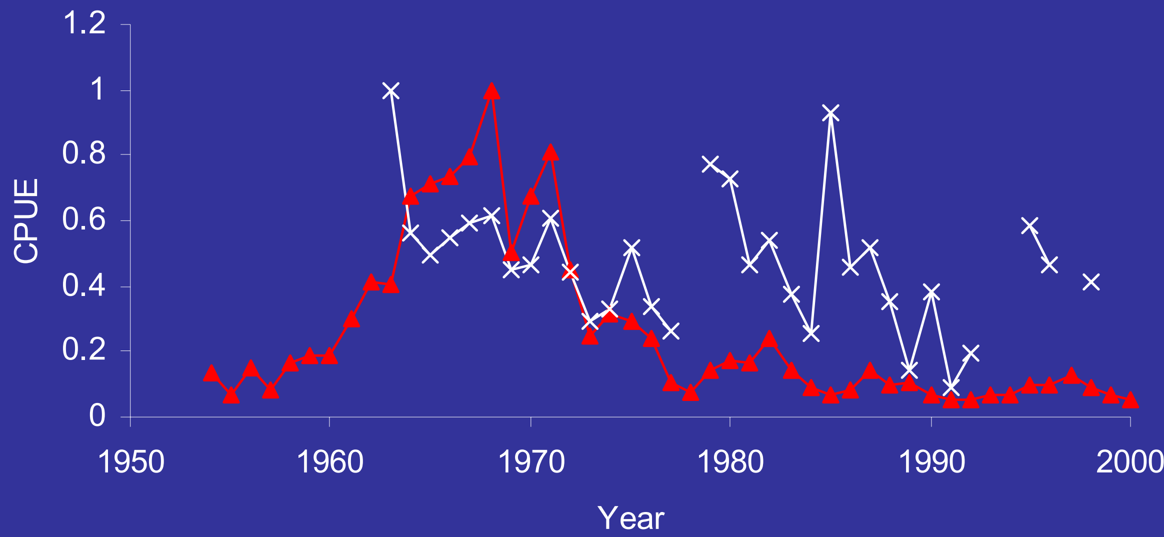


FIGURE 1. Geographical expansion of the Japanese longline fishery (solid curves) and the surface fishery in the eastern Pacific (dotted curves). Numerals denote calendar year.

Limited stock distribution: striped marlin





Habitat, gear, and fish behavior

- Fish have habitats that they prefer
- Habitat changes with the environment
- Fishermen's behavior determines where the gear fishes
- Gear, habitat, and fish behavior have to match for fishing to be successful
- Gear, habitat, and fish behavior have to be taken into consideration when interpreting CPUE

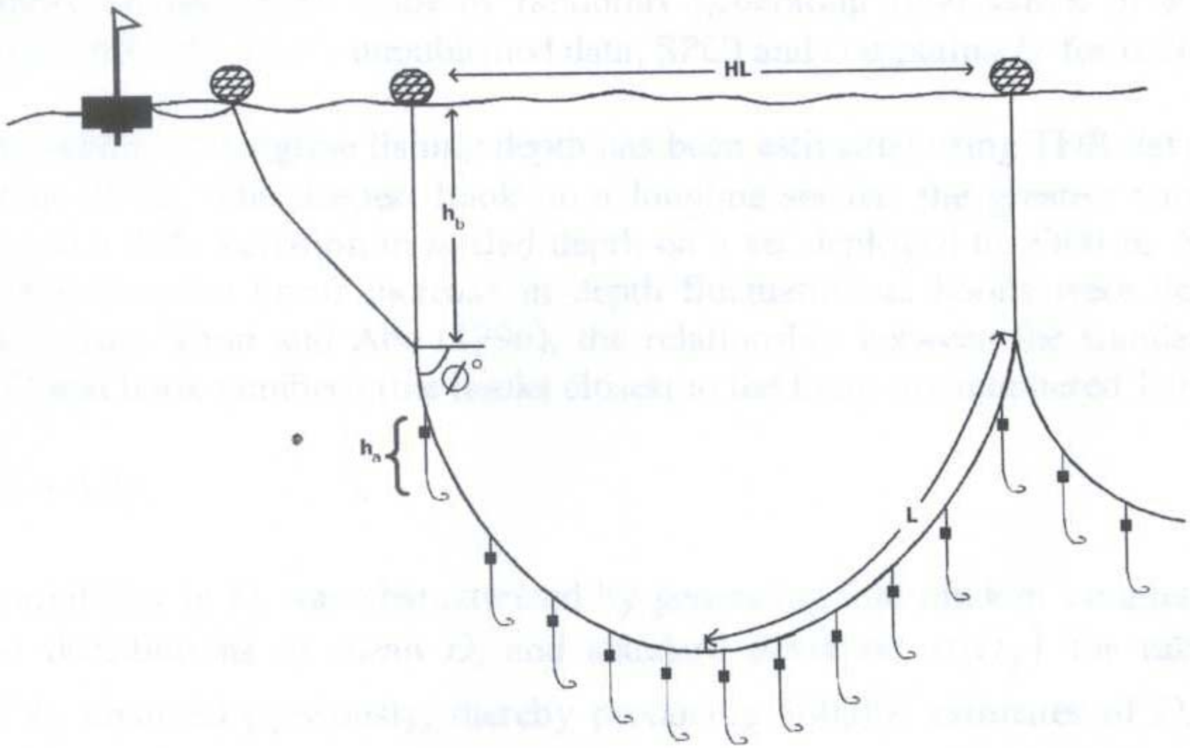


Figure 1. Configuration of a pelagic longline.

Bigelow et al. 2000

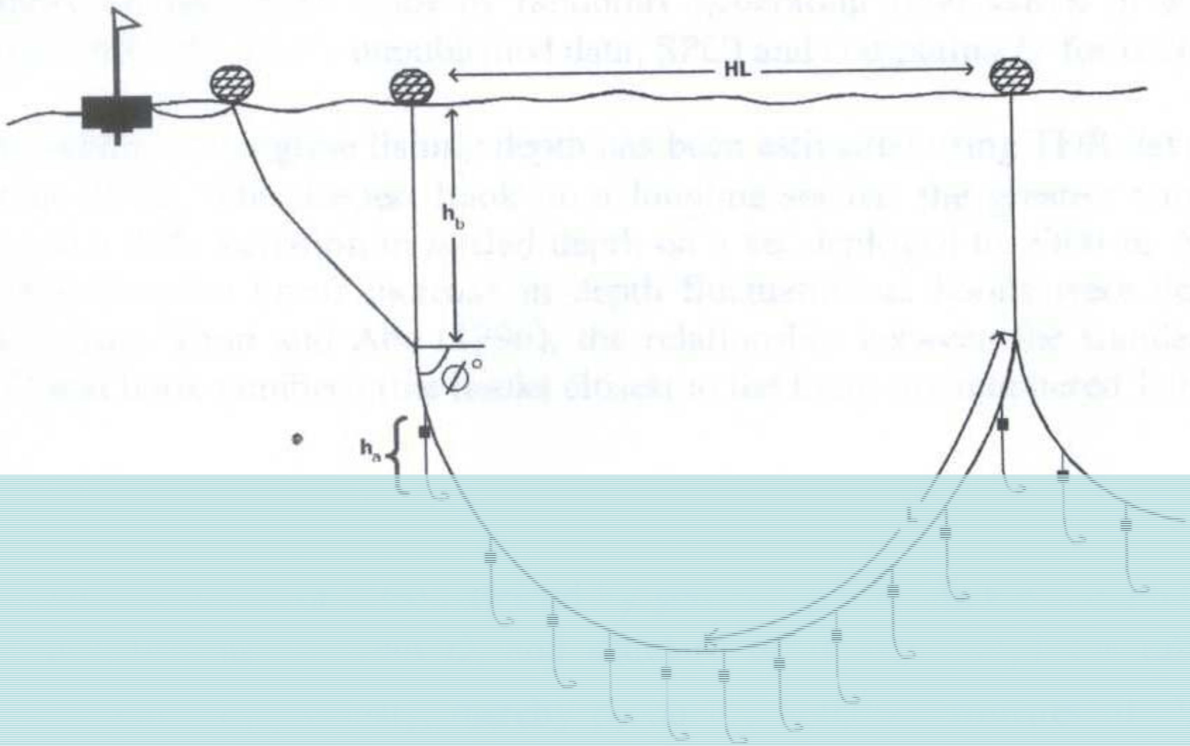


Figure 1. Configuration of a pelagic longline.

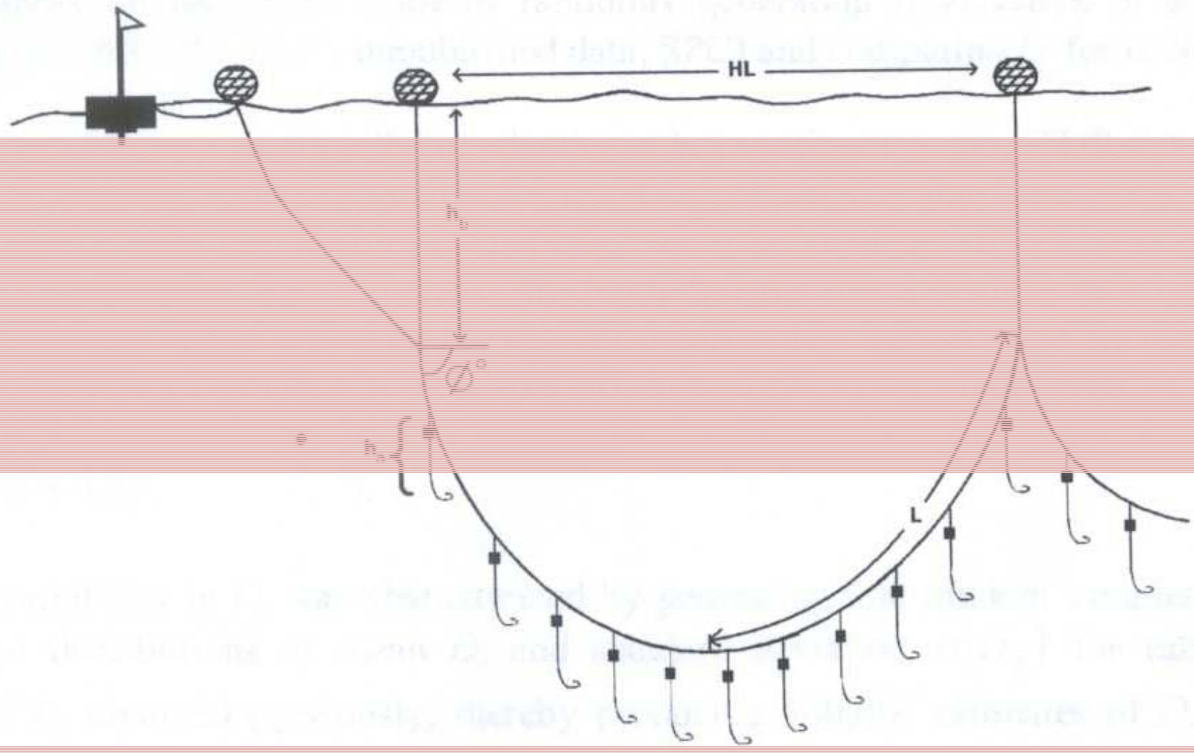
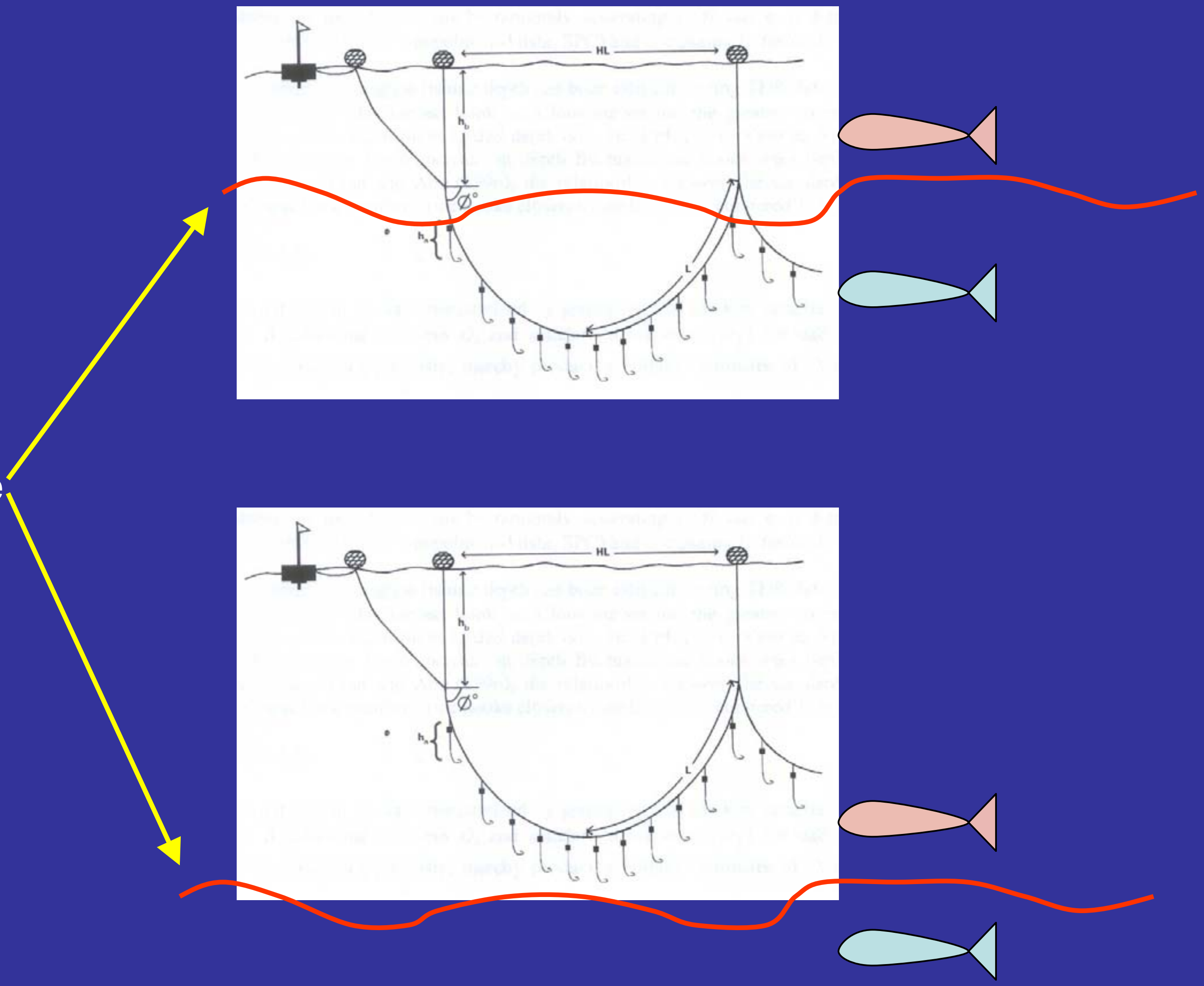


Figure 1. Configuration of a pelagic longline.

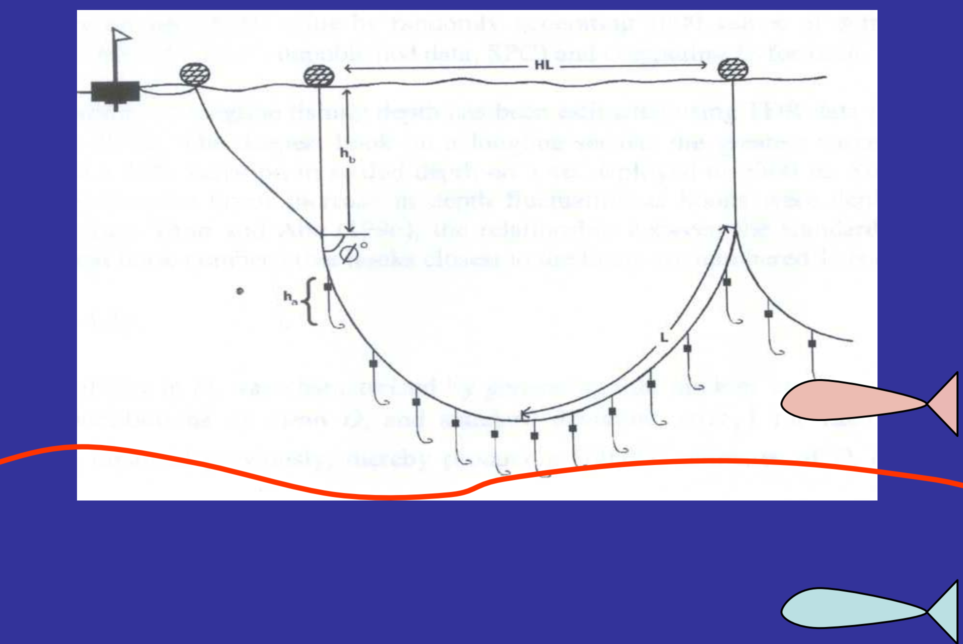
Environment

Thermocline

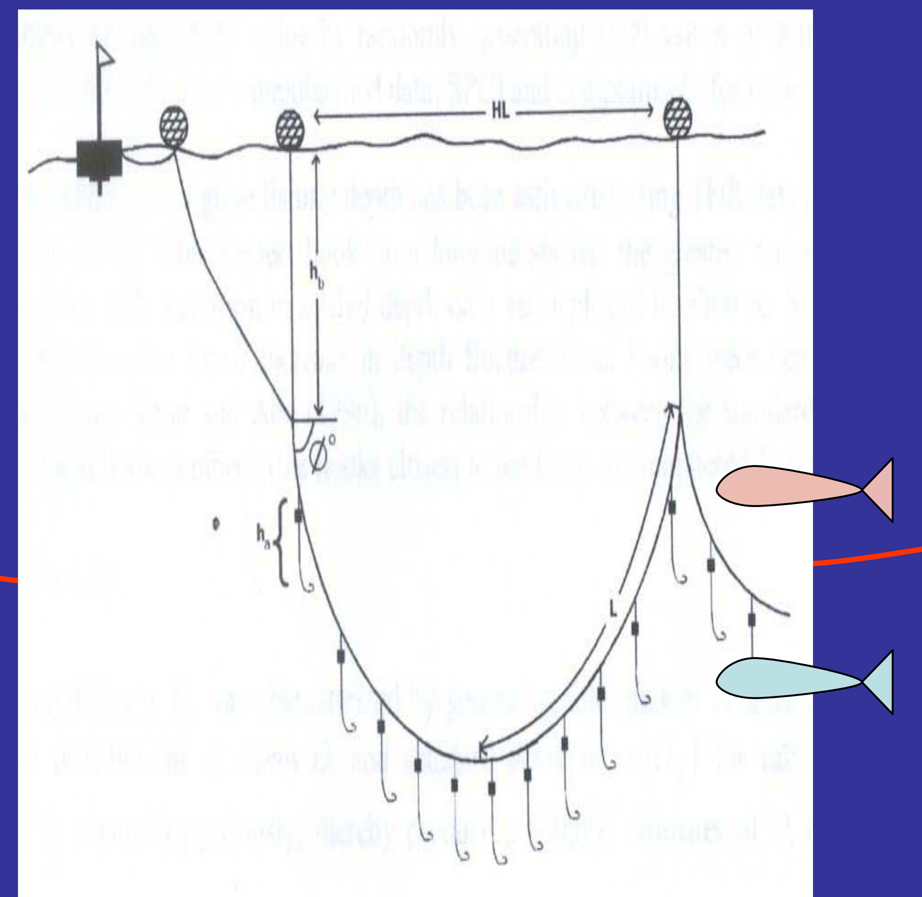


Depth of gear

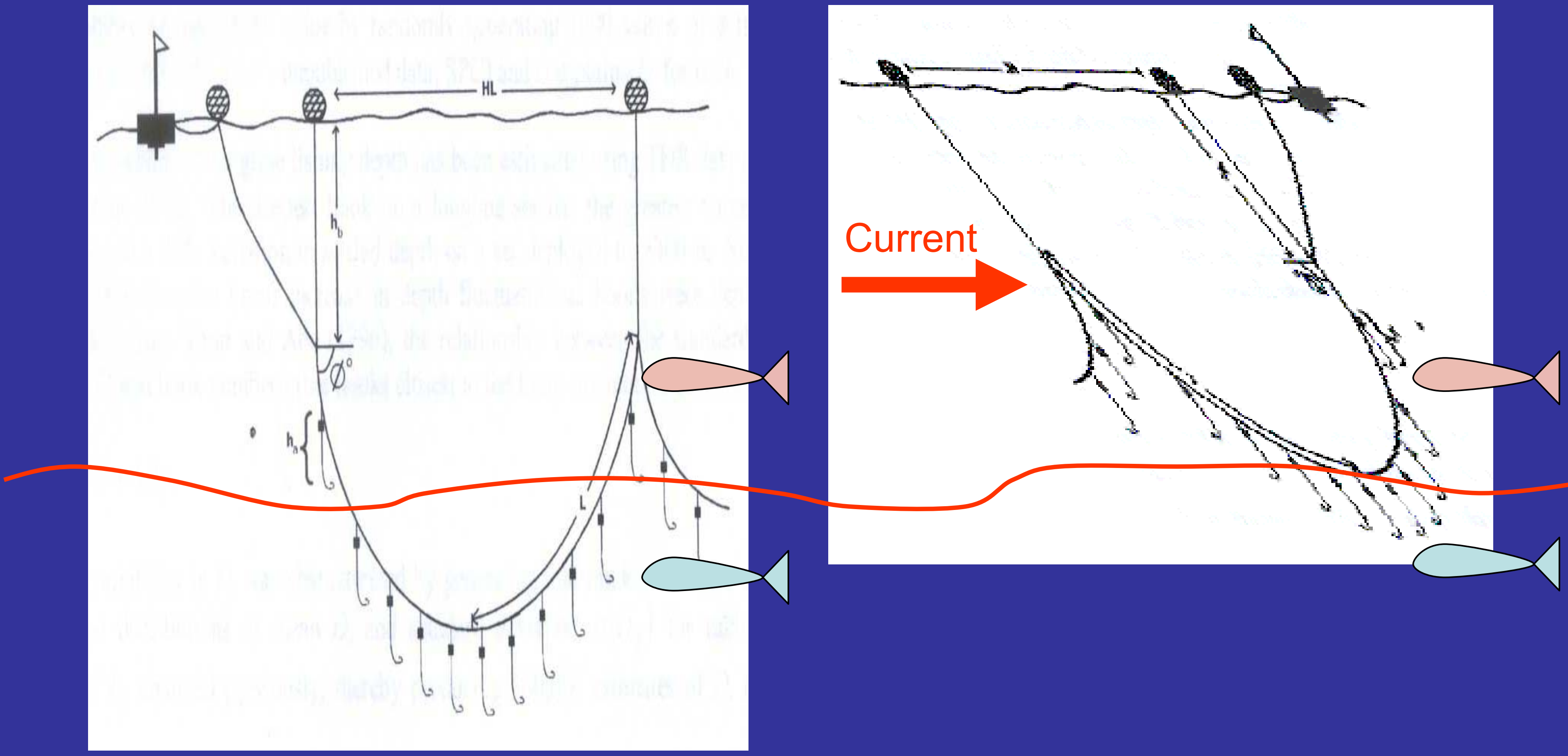
50-150



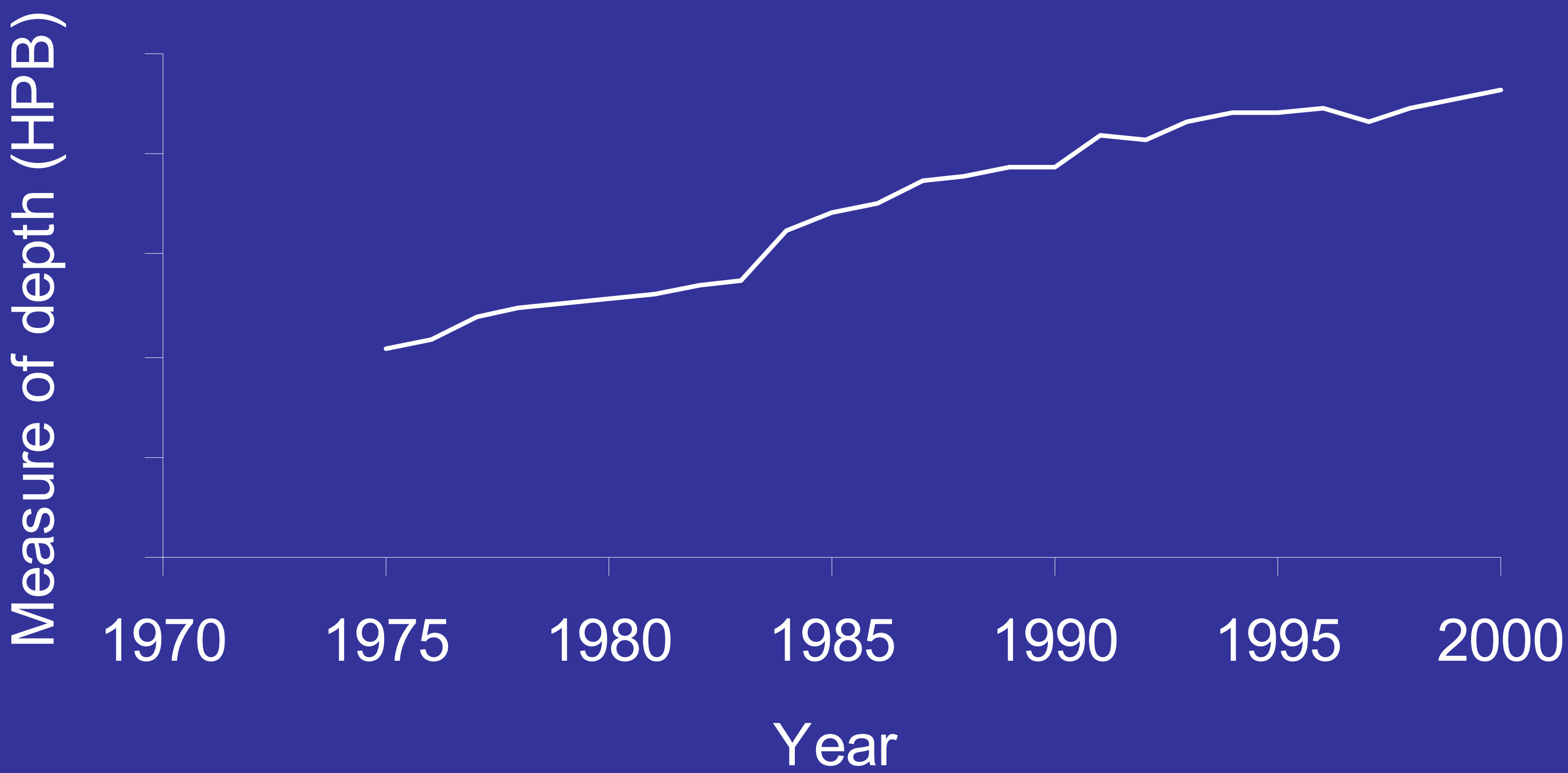
50-400



Current

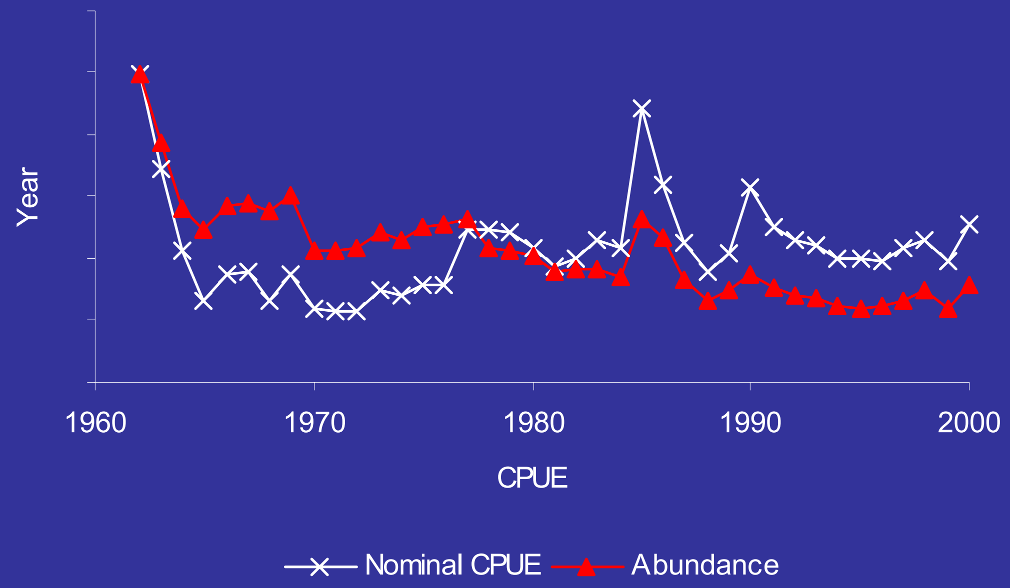


Increasing depth of longlines

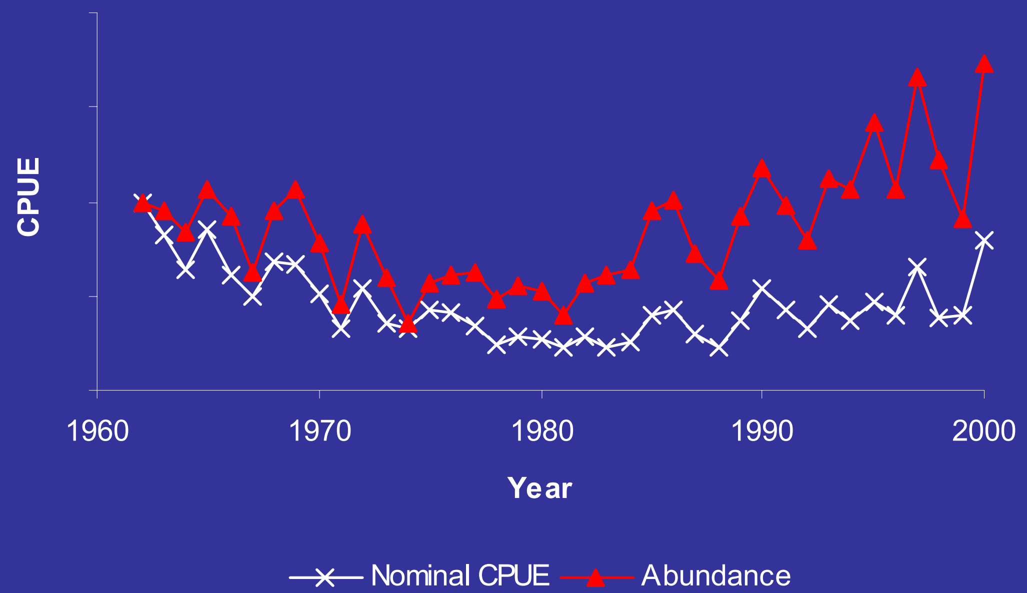


EPO examples

Bigeye tuna



Yellowfin tuna

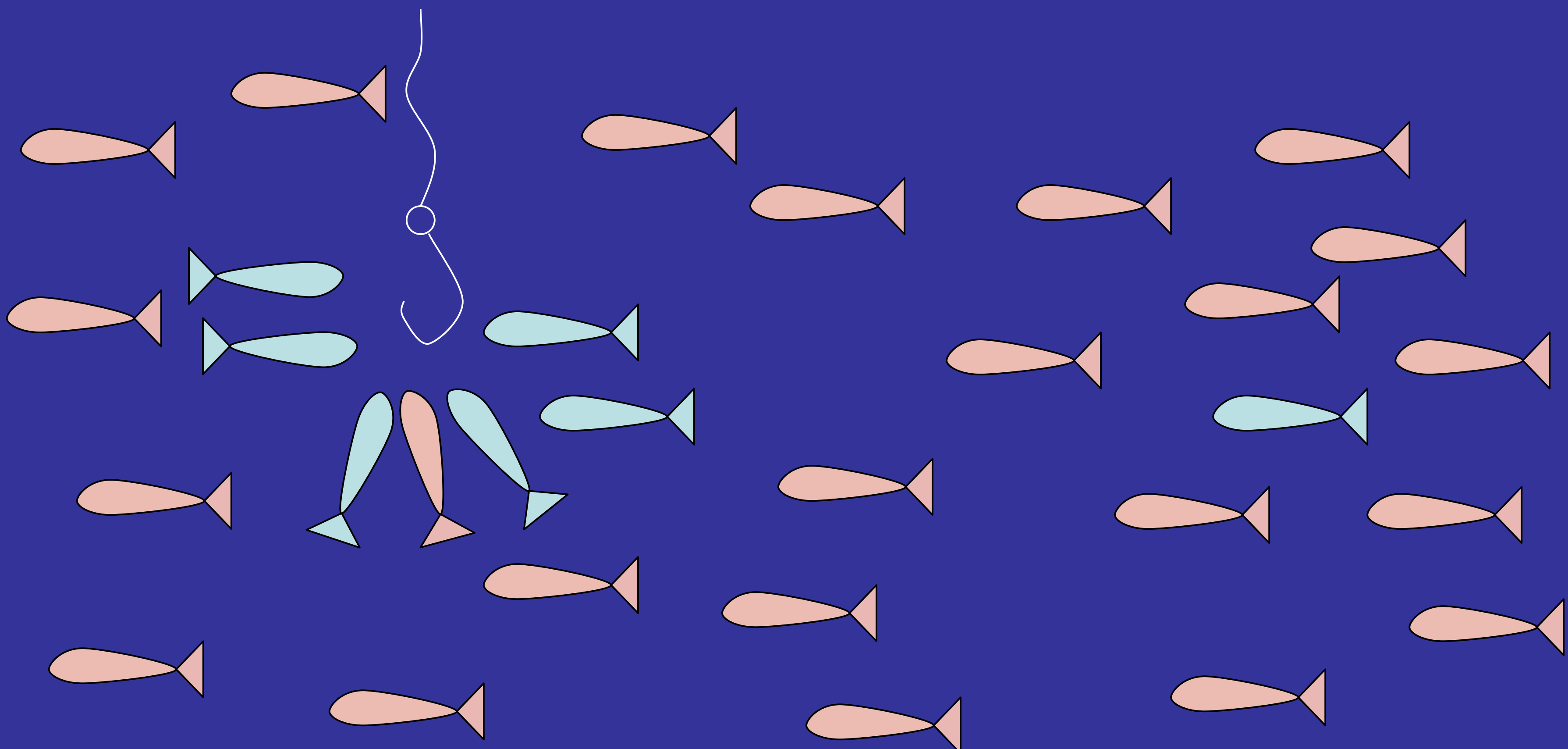


From Keith Bigelow

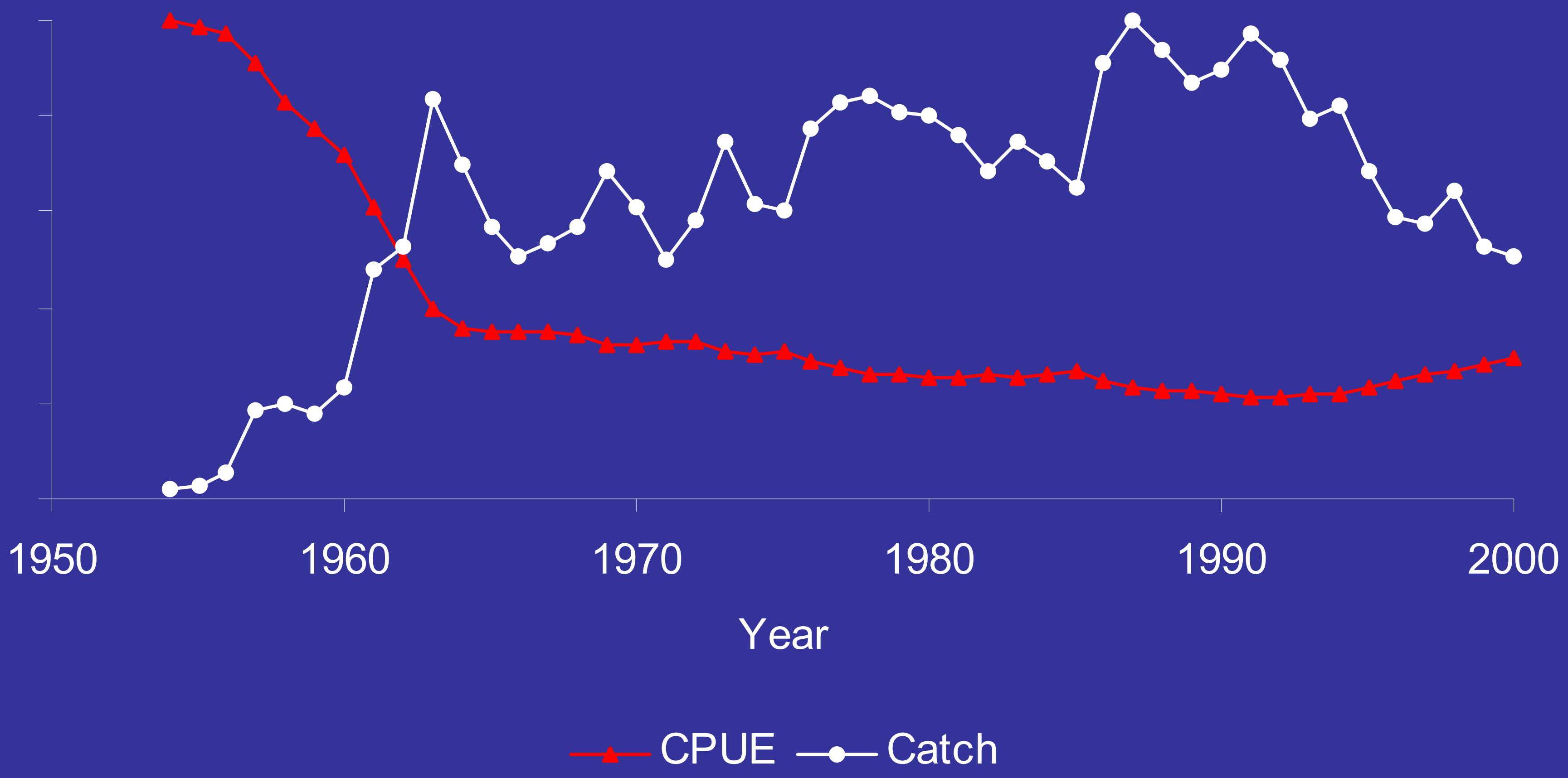
Habitat standardization

- Used to remove the changes of gear depth and the environment from the relative index of abundance
- Method developed by Hinton and Nakano 1996
- Applied to bigeye and yellowfin tuna by Bigelow et al. 2002
- Used in the assessments of yellowfin tuna, bigeye tuna, blue marlin, striped marlin, and swordfish in the EPO

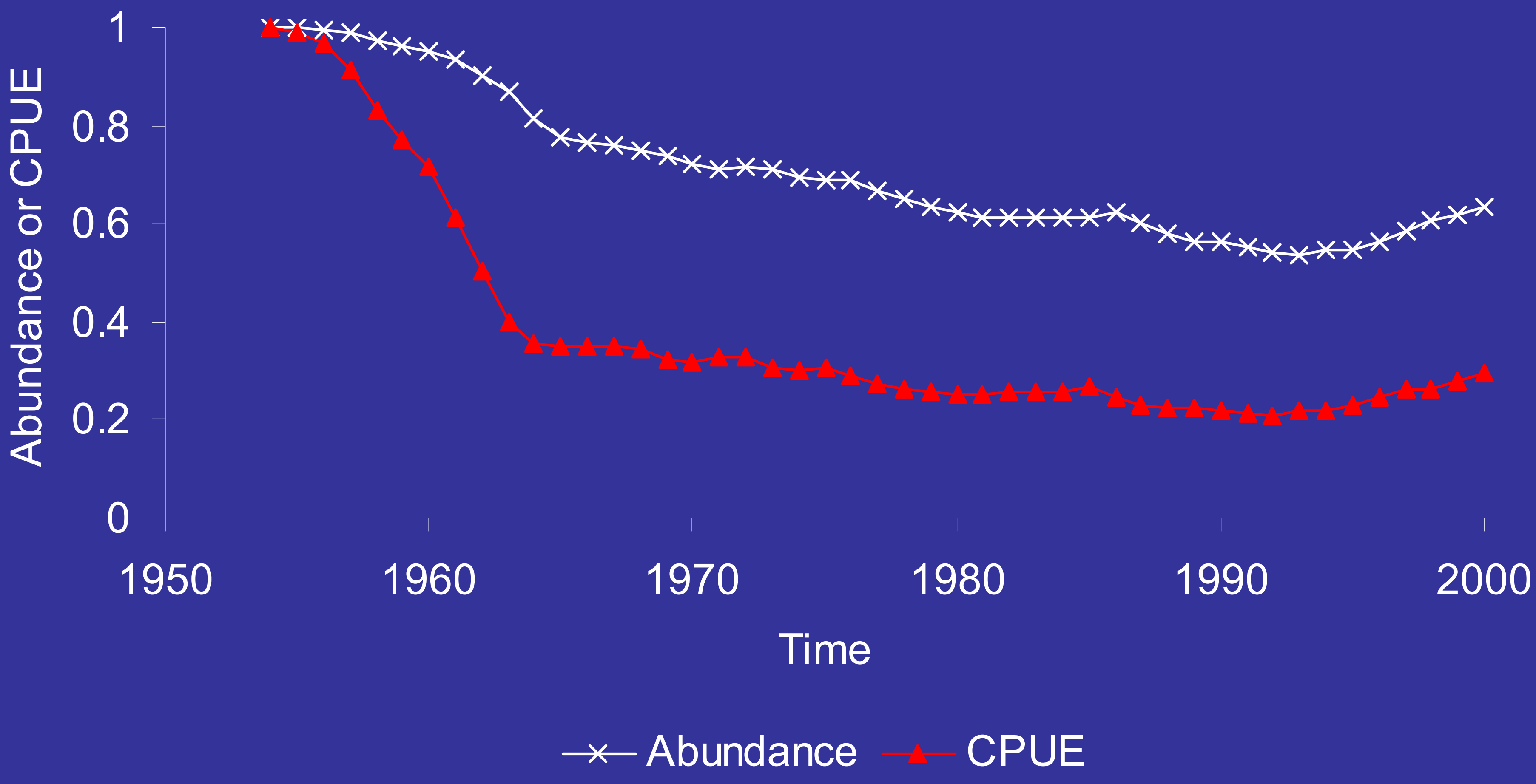
The “stupid” fish hypothesis



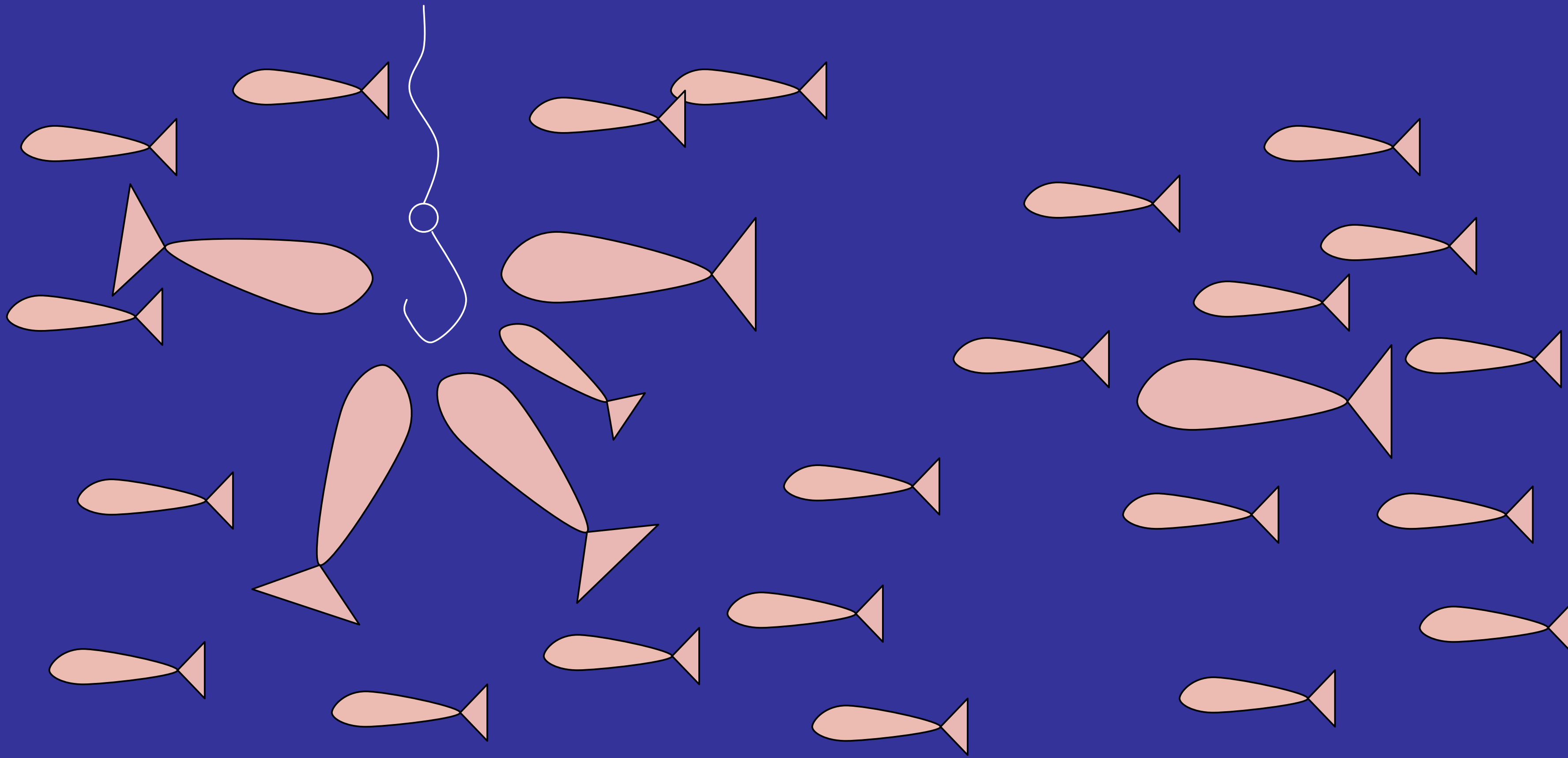
The stupid fish hypothesis under historic effort



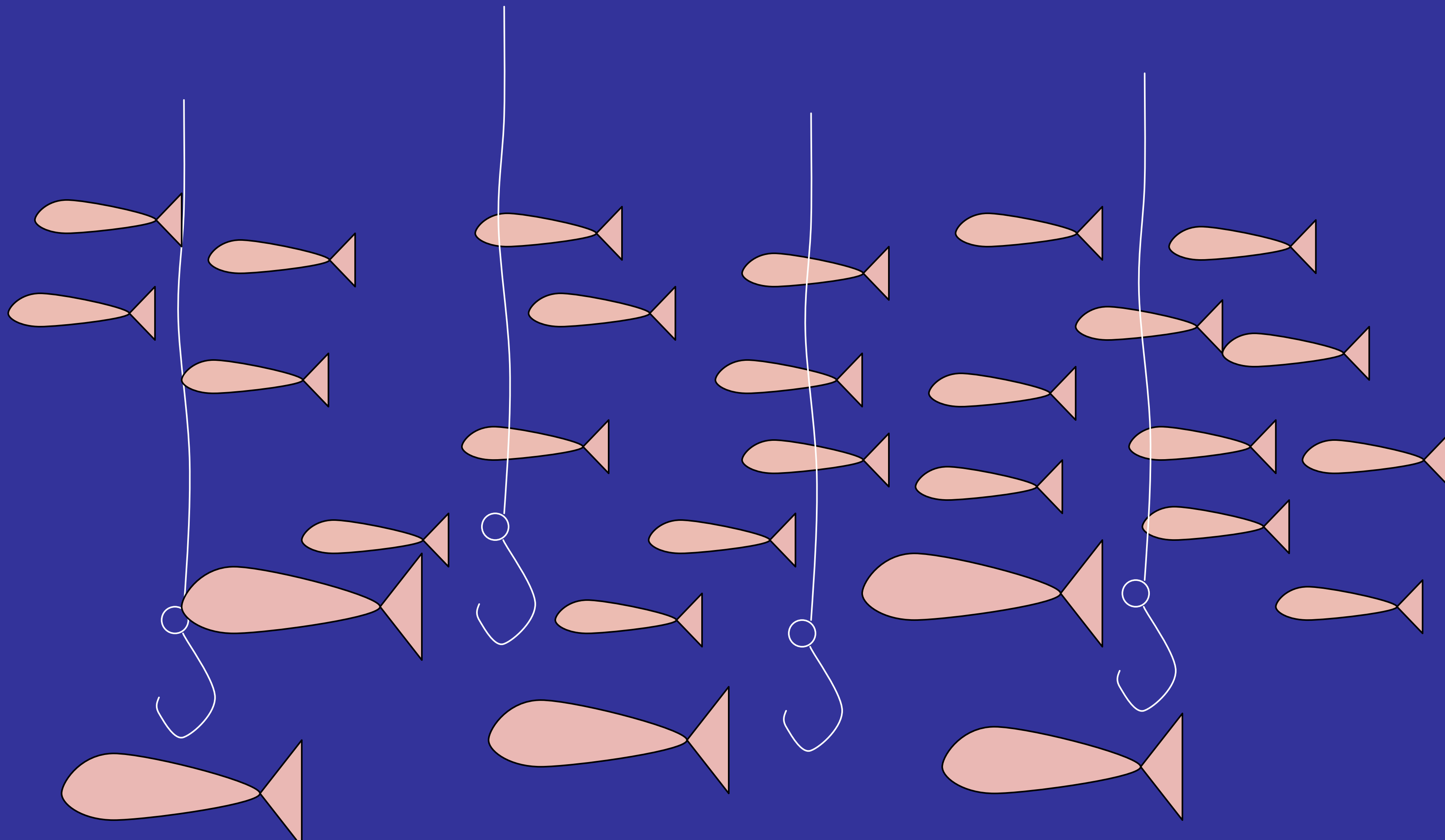
CPUE vs abundance



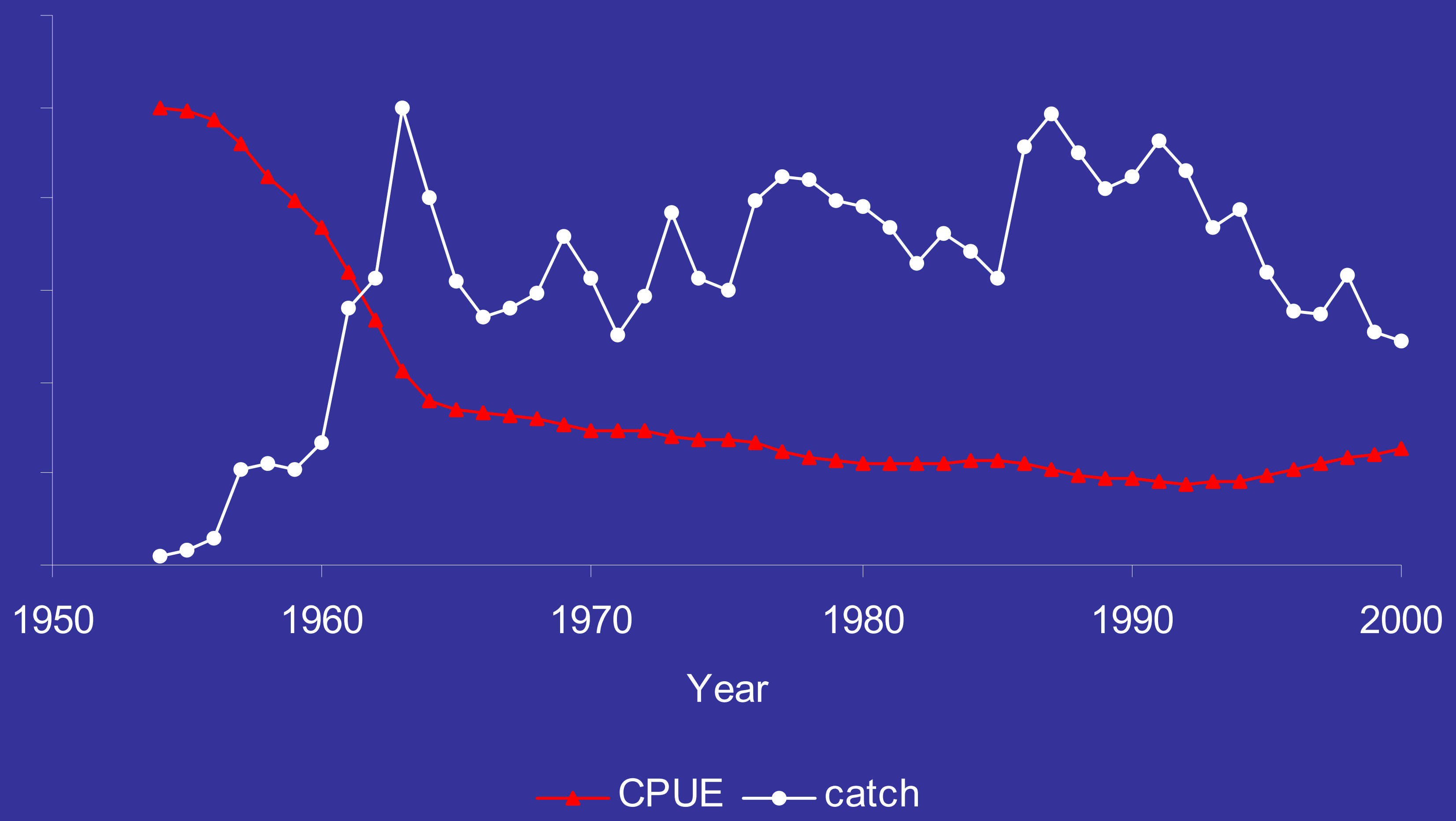
The big “stupid” fish hypothesis (size-specific vulnerability)



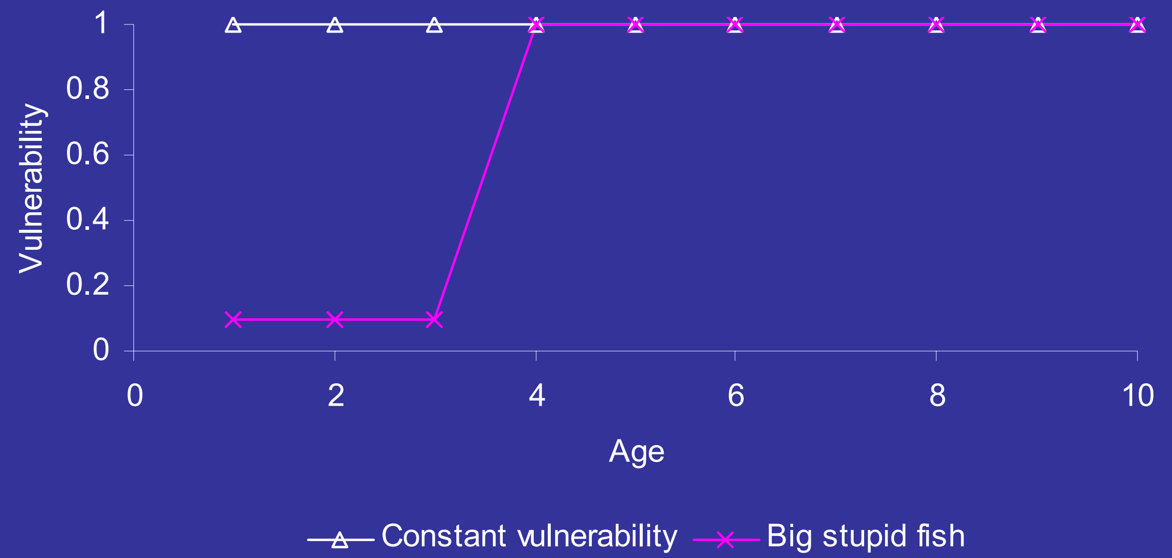
Size-specific vulnerability

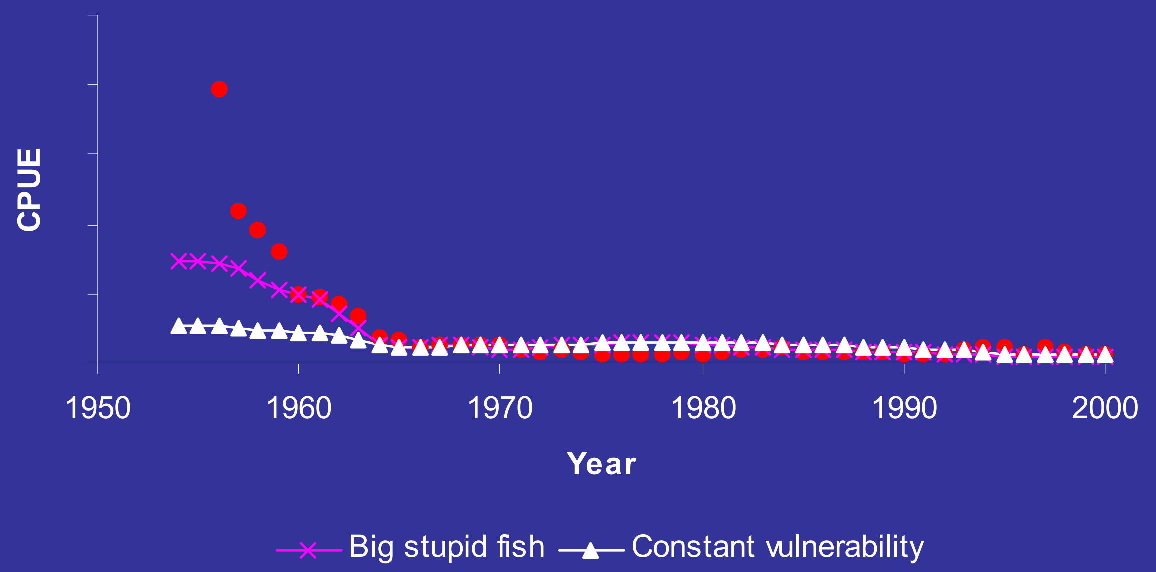


The size specific vulnerable hypothesis under historic effort



Blue marlin example

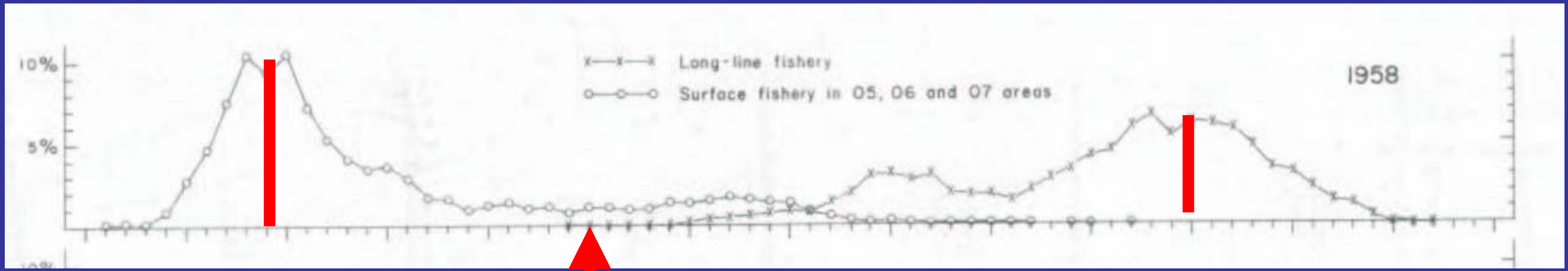




Historic yellowfin length frequency data

Purse seine

Longline



60 cm

150 cm

Size at 50% maturity

Suda and Schaefer 1965

Other Hypotheses

- Multiple stocks (e.g. northern and southern albacore)
- Fraction of stock (bluefin)
- Stock distribution limited (e.g. Striped Marlin, Swordfish, sailfish, shortbill spearfish)
- Gear saturation/interference
- Increase in fishing power
- Targeting (swordfish, bait, setting at night)
- Age specific natural mortality
- Fishing regulations (e.g. EEZ)

Myers Dalhousie Group

- Soak time – increases current CPUE
  - Has slightly increased
  - Increased soak time increases CPUE
- Shark damage – increases current CPUE
  - 25% in early data and about 4% in recent data
  - Lower shark damage increases CPUE
- Hook saturation - increases current CPUE
  - Bait loss due to catching other species has decreased
  - More bait available increases CPUE
- Depth of gear
- Ecosystem
- Also looking at non-pelagic species and dada from trawl
- **World wide patterns similar**

Summary

- Regime change
  - Same for all species?
  - Implies that the stocks are depleted
  - New management values for new regime
- Ecosystem
  - Implies that the stocks are depleted
  - Does not explain all increase in production
- Spatial distribution of effort
  - Spatial expansion occurred when the rapid declines occurred
  - CPUE declines faster than abundance
  - Final depletion level is the same

Summary continued

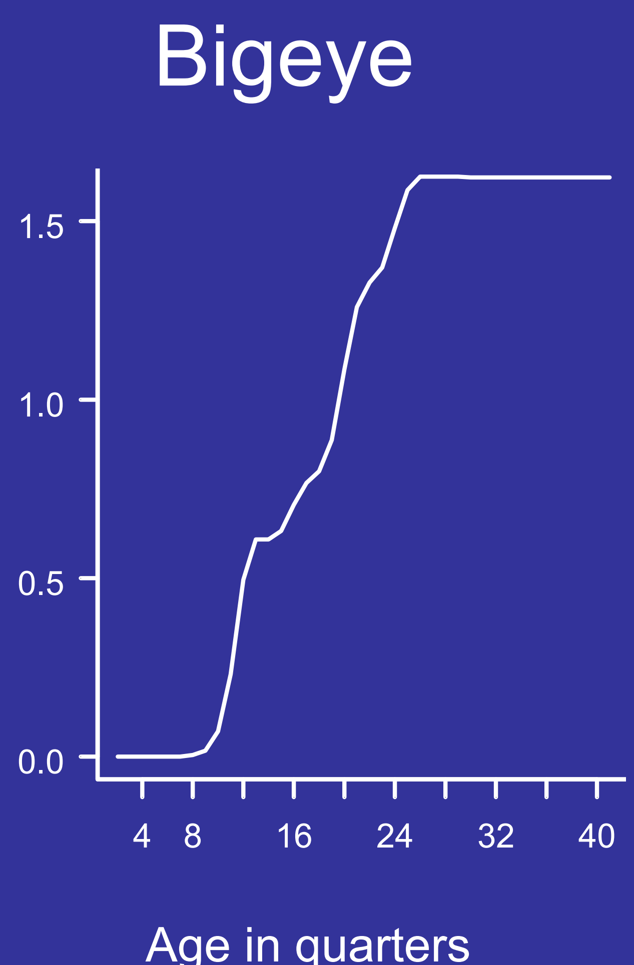
- Habitat and gear distribution
  - Did not change during period of depletion
  - Current abundance may be underestimated for most species explaining current catches
- Stupid fish hypothesis
  - Both stupid fish and age-specific vulnerability could explain some of the decline
  - Indicates stocks are less depleted
- Limited distribution of stock
  - Probably explains increase in CPUE for striped marlin, swordfish, sailfish, and spearfish

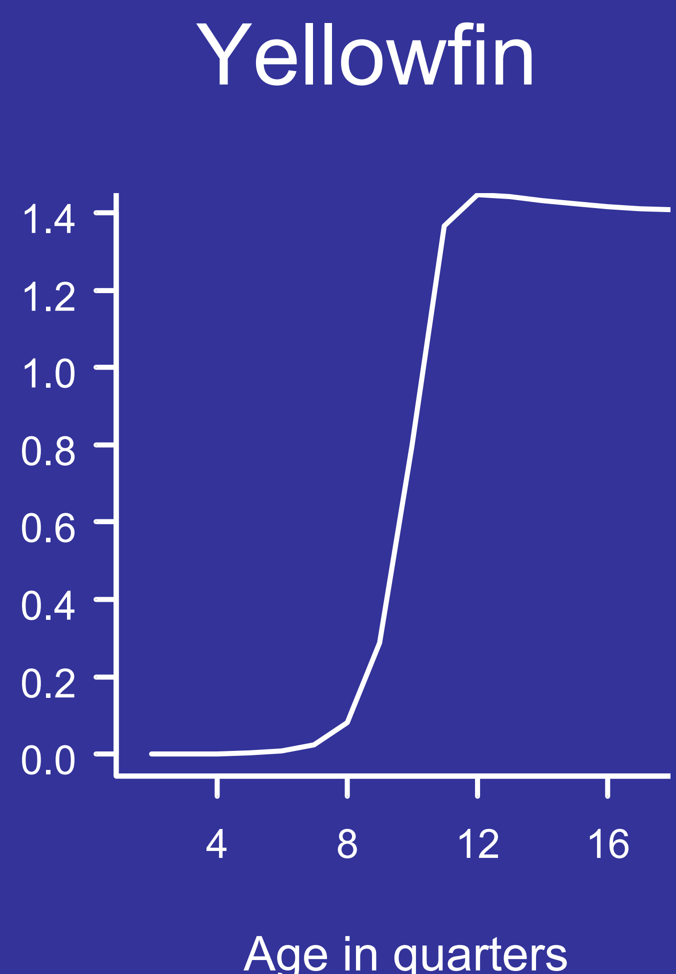
Conclusions

- Regime change, ecosystem, and spatial distribution result in high depletion levels
- Longline depth, stupid fish hypothesis, and age-specific vulnerability result in lower depletion levels
- Ecosystem, spatial distribution, longline gear depth, and age-specific vulnerability most likely

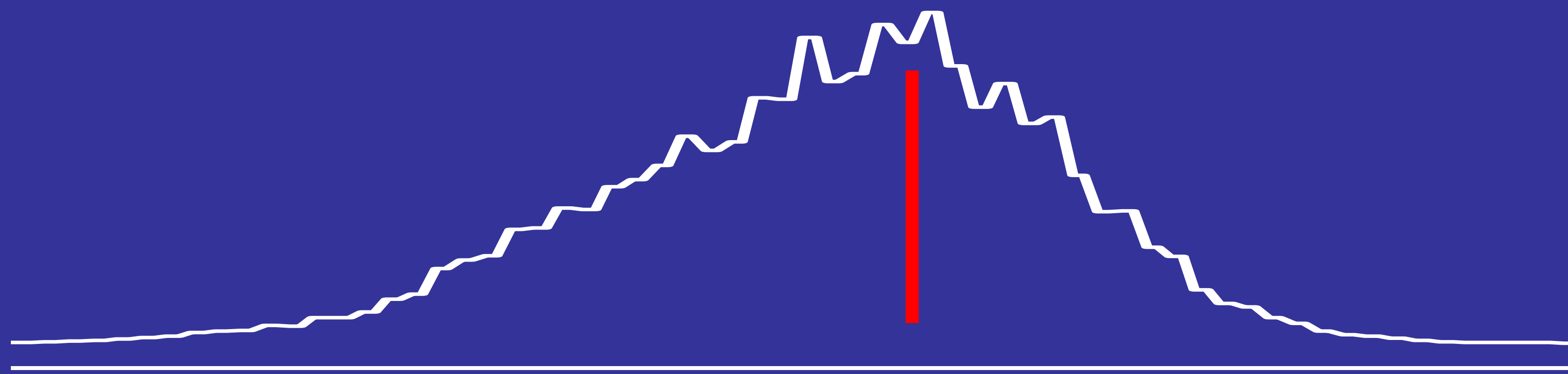
Hypothesis	Current depletion level More	Same	Less	Unknown
Regime change		x		
Ecosystem		x		
Spatial distribution		x		
Gear depth			x (most)	
Stupid fish			x	
Size-specific vulnerability			x	
Multiple stocks				x
Fraction of stock				x
Interference			x	
Increased power	x			
Targeting				Depends
Age-specific M				x
Fishing regulations				x
Soaktime	x			
Shark damage	x			
Hook saturation	x			

Yellowfin and Bigeye selectivity

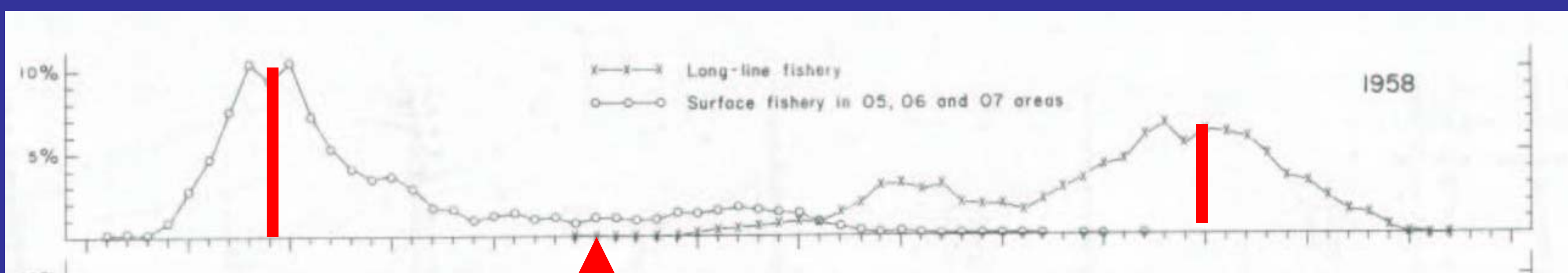




Current yellowfin length frequency data



125 cm



60 cm

150 cm

Size at 50% maturity

Age-specific selectivity and recruitment residuals