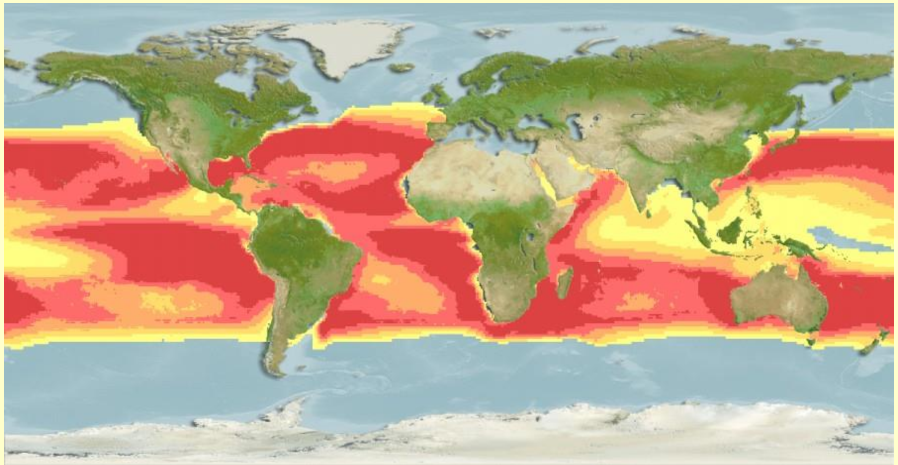
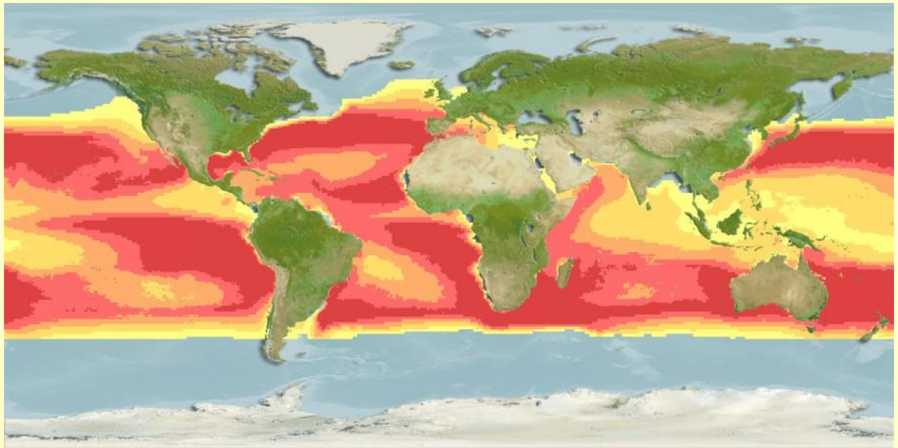
Single-Species Management

– Effective Effort





Catchability – The Critical Concept

Index of Relative Abundance

CPUE   f (N, E, q)

q = catchability

In a theoretical sense, the extent to which a stock is susceptible to fishing.

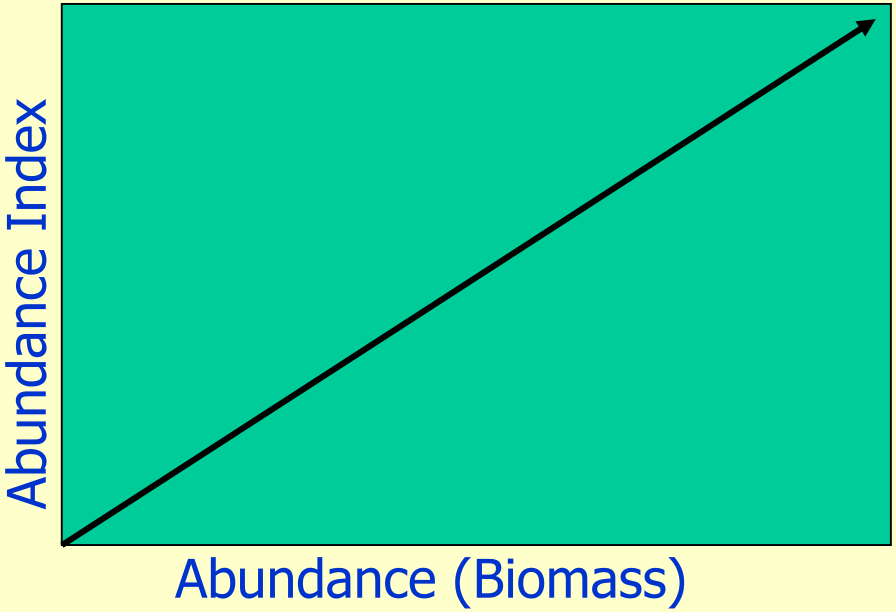
Quantitatively, the proportion of the stock removed by 1 unit of fishing effort.

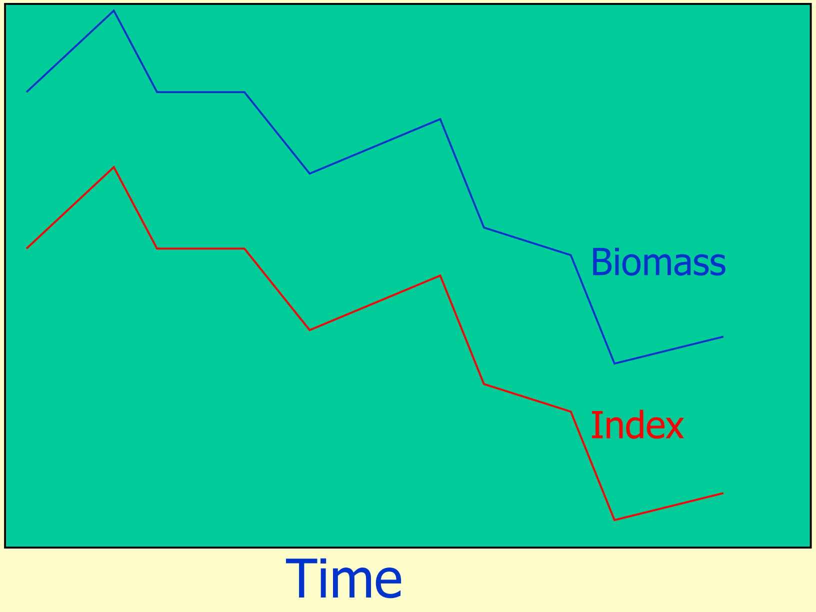
Catchability – The Critical Concept

Key assumptions:

1. Relationship between the index and abundance is linear (proportional).
2. The relationship does not change over time or space.

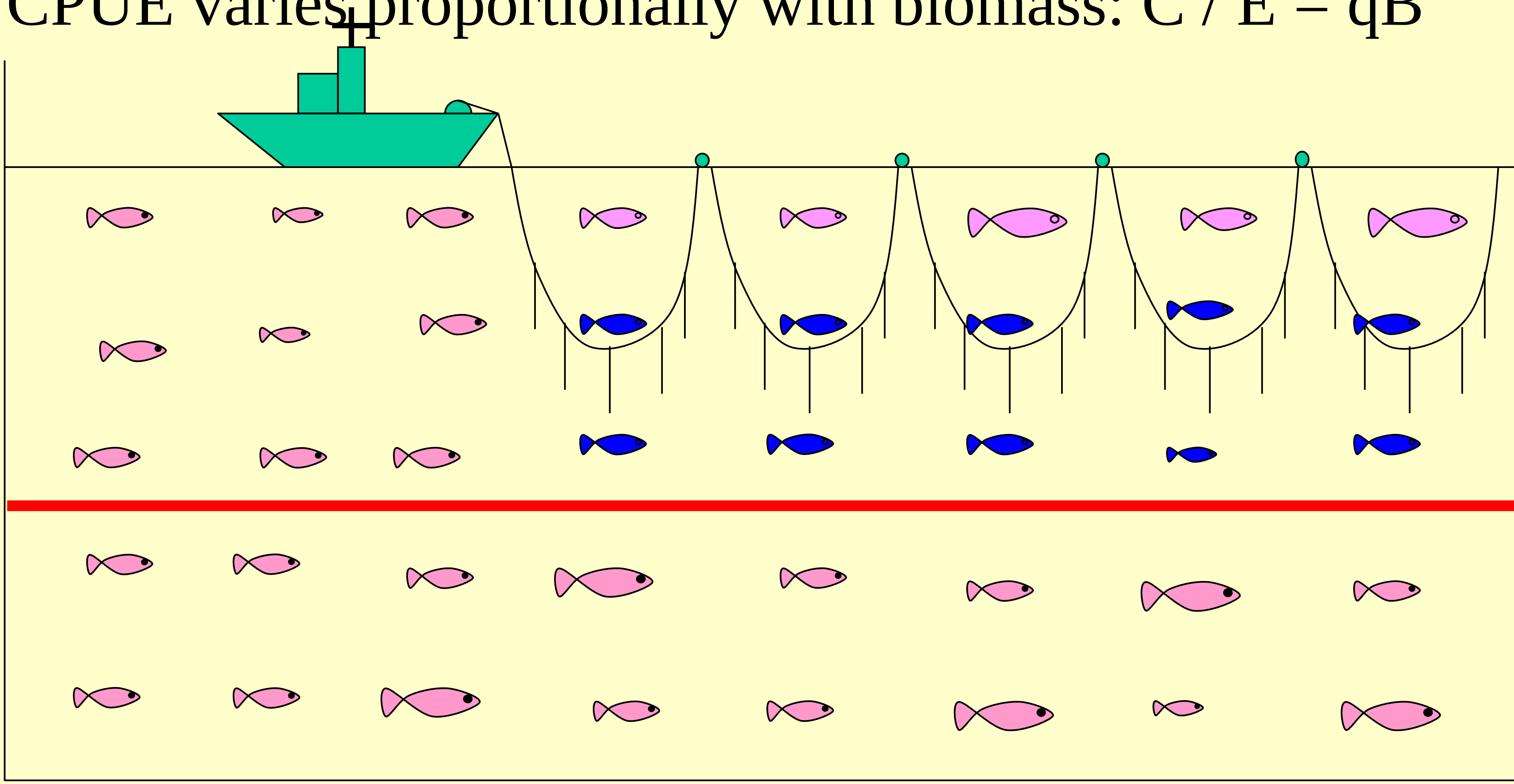
Catch / Effort = Catchability x Biomass





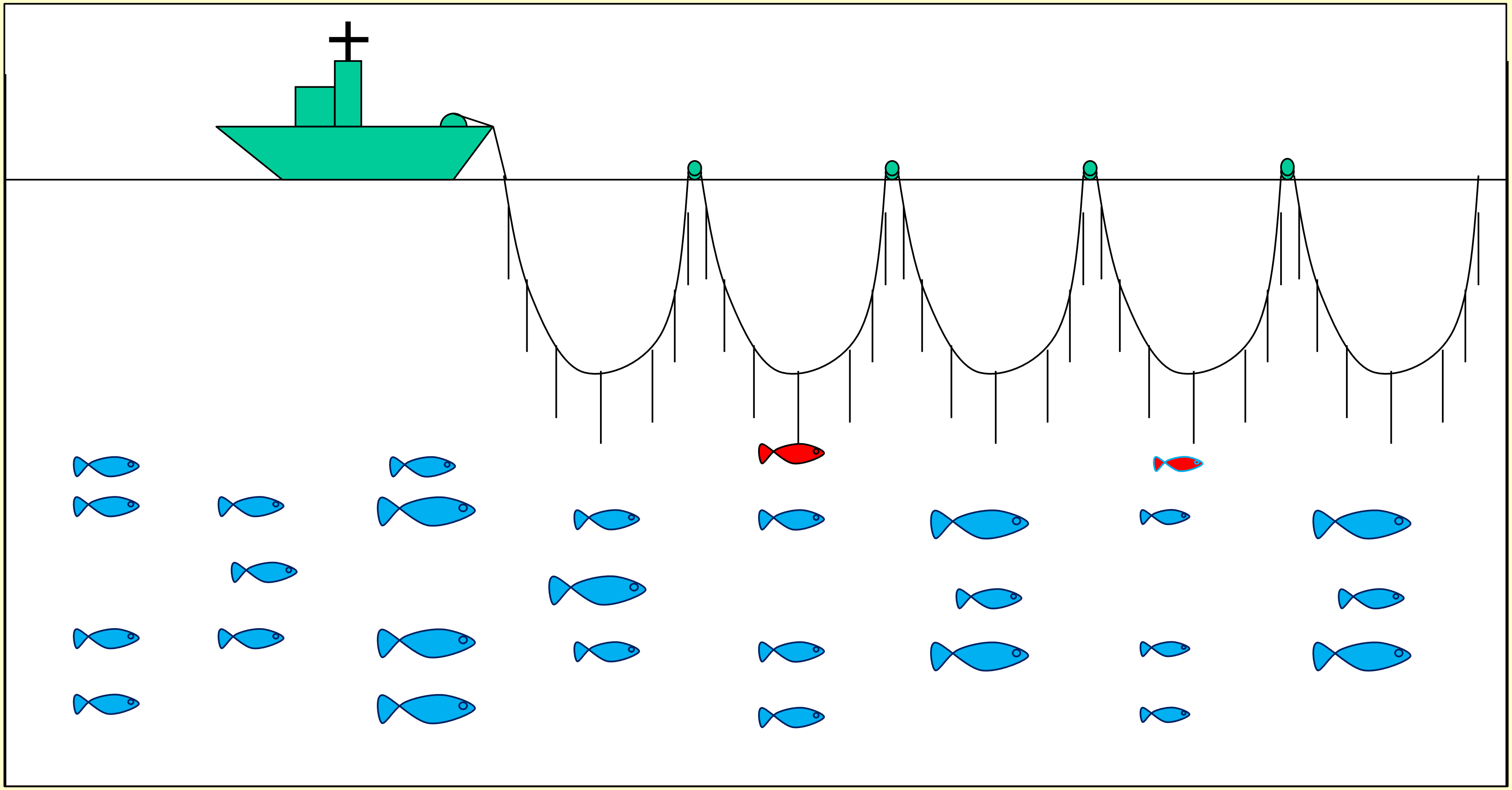
CPUE as an Abundance Index

CPUE used as an index of biomass under assumption that CPUE varies proportionally with biomass: $C / E = qB$



MAIN IDEA: If the number of fish is halved, then the catch rate should also be halved, assuming even distribution of fish and fishing effort (and thus of catchability)

Changes in Catchability

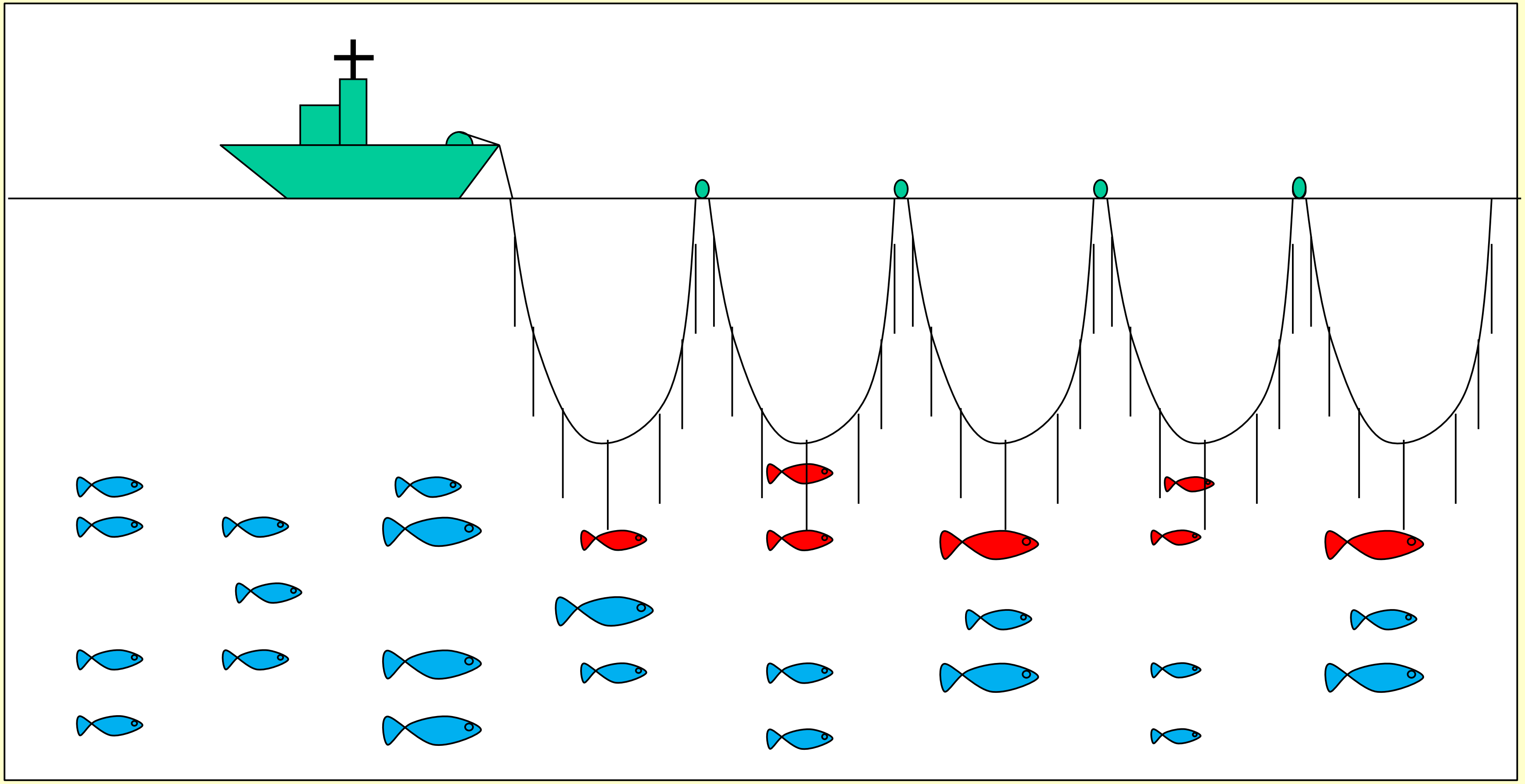


$q = C/EB$

$q = 2/30x28$

=0.00238

Changes in Catchability



$$q = C/EB$$

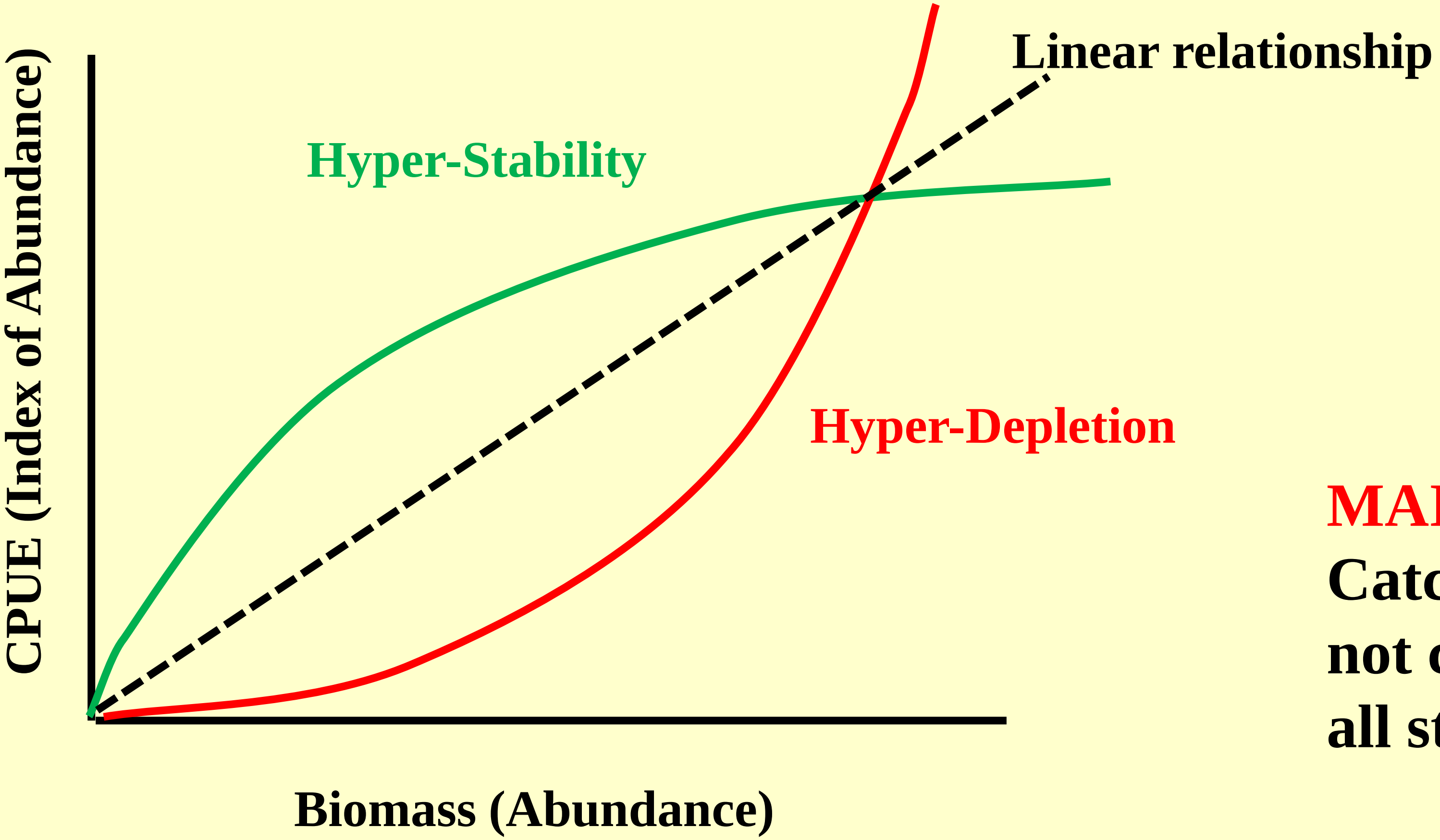
$$q = 7/30x28$$

=0.00833

CPUE as an abundance index

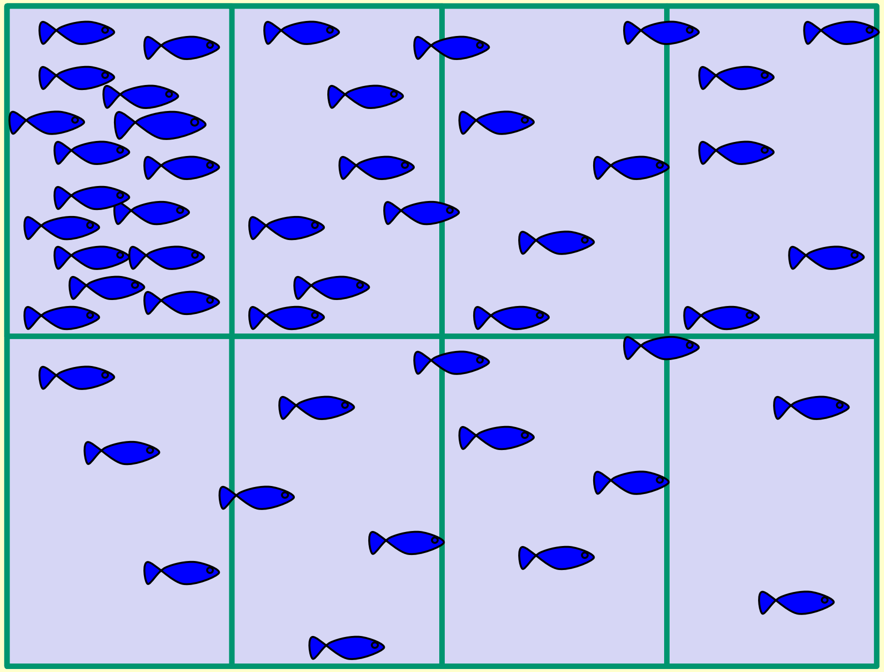
The assumption that catchability (proportion of stock taken by one unit of fishing effort) does not change is rarely met!

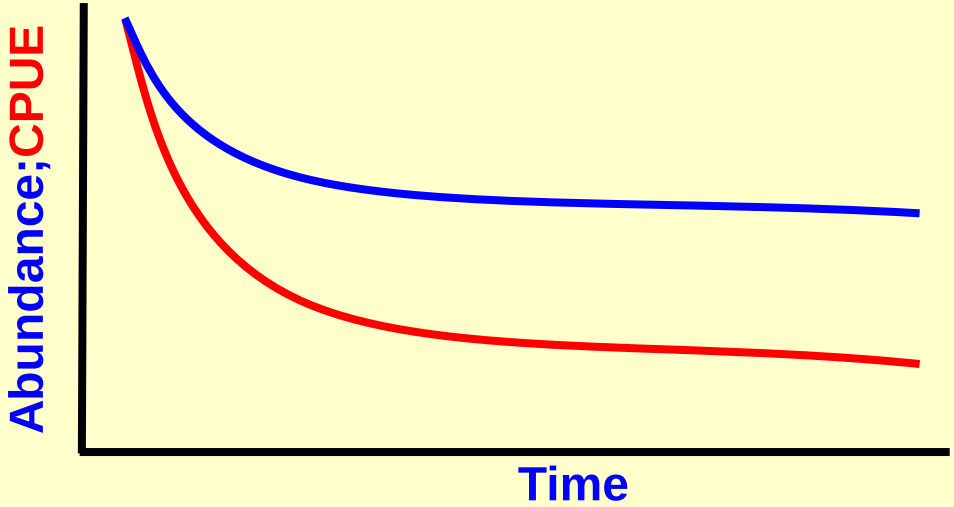
Relationship between abundance and CPUE is non-linear



MAIN IDEA:
Catchability is not constant at all stock sizes

Hyper-Depletion





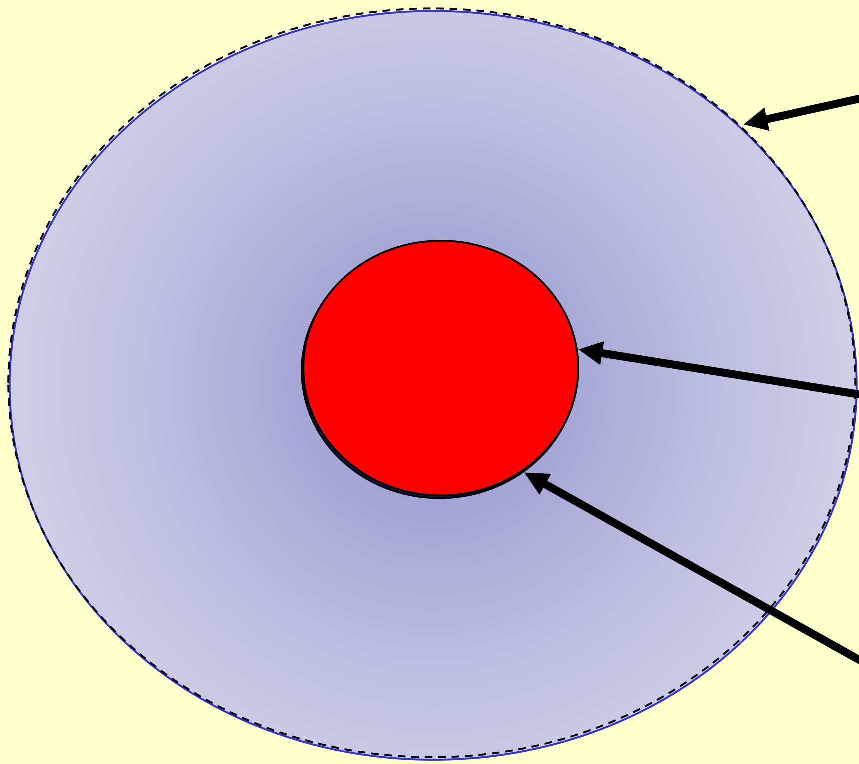
If we divide our stock region into subregions, which subregion would you fish in fisrt?

Expect high initial catch rates in NW subregion. As local abundance declines, fishers move to areas with less abundance, and CPUE rapidly declines

Initial CPUE over inflated (relative to stock abundance) not derived from a random sample.

Hyper-Stability

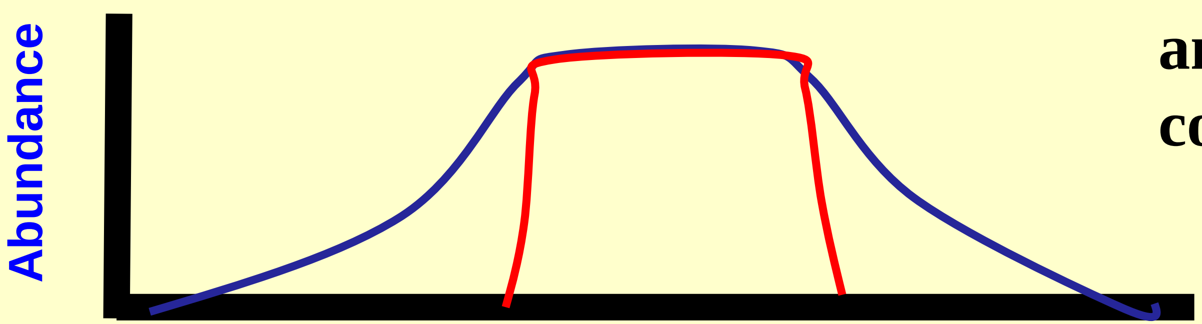
(McCall Basin Theory)



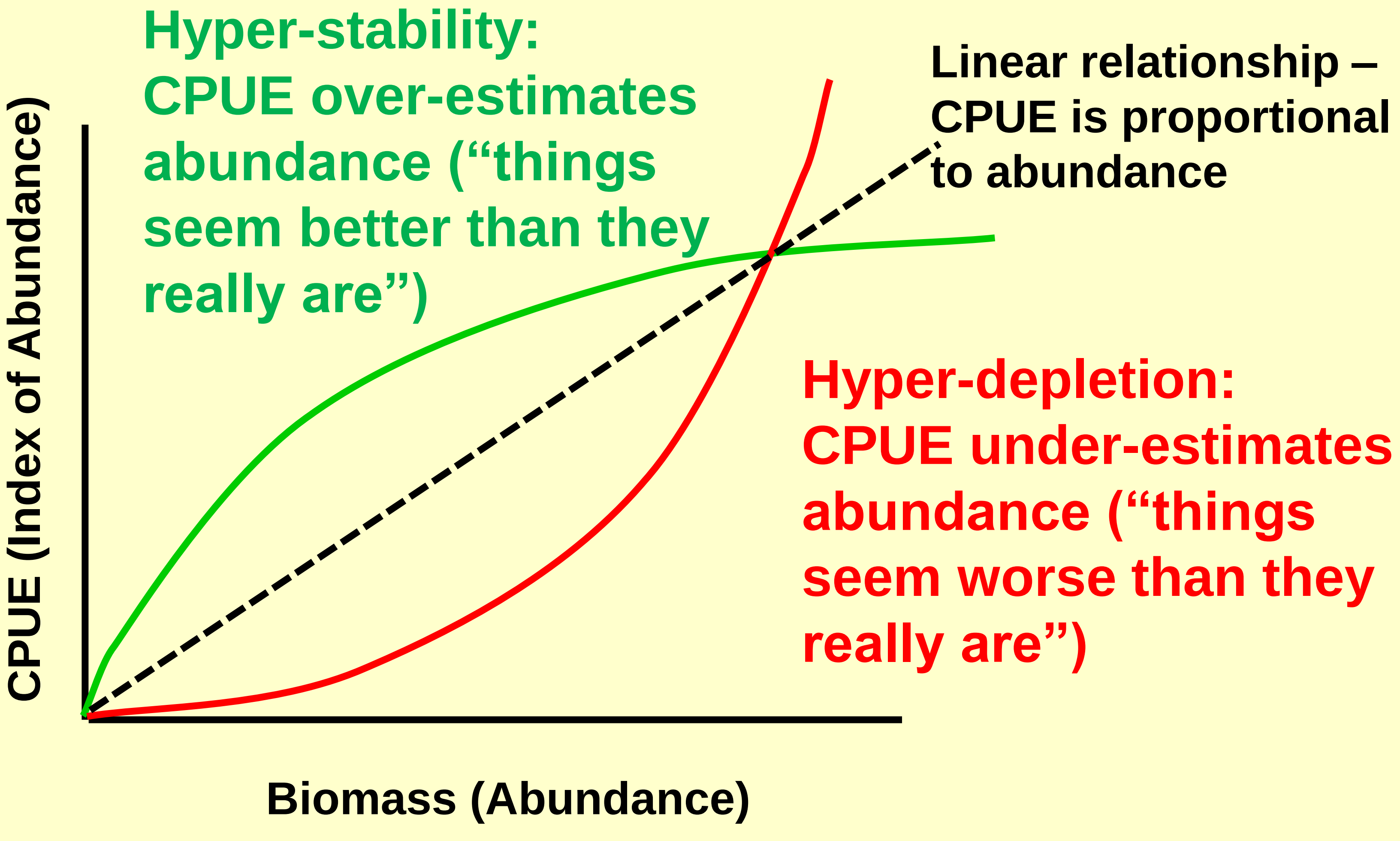
Spatial distribution of stock when abundant

Preferred habitat (prime habitat)

Spatial distribution after stock depletion and contraction to core habitat areas



Deviation of CPUE from Abundance



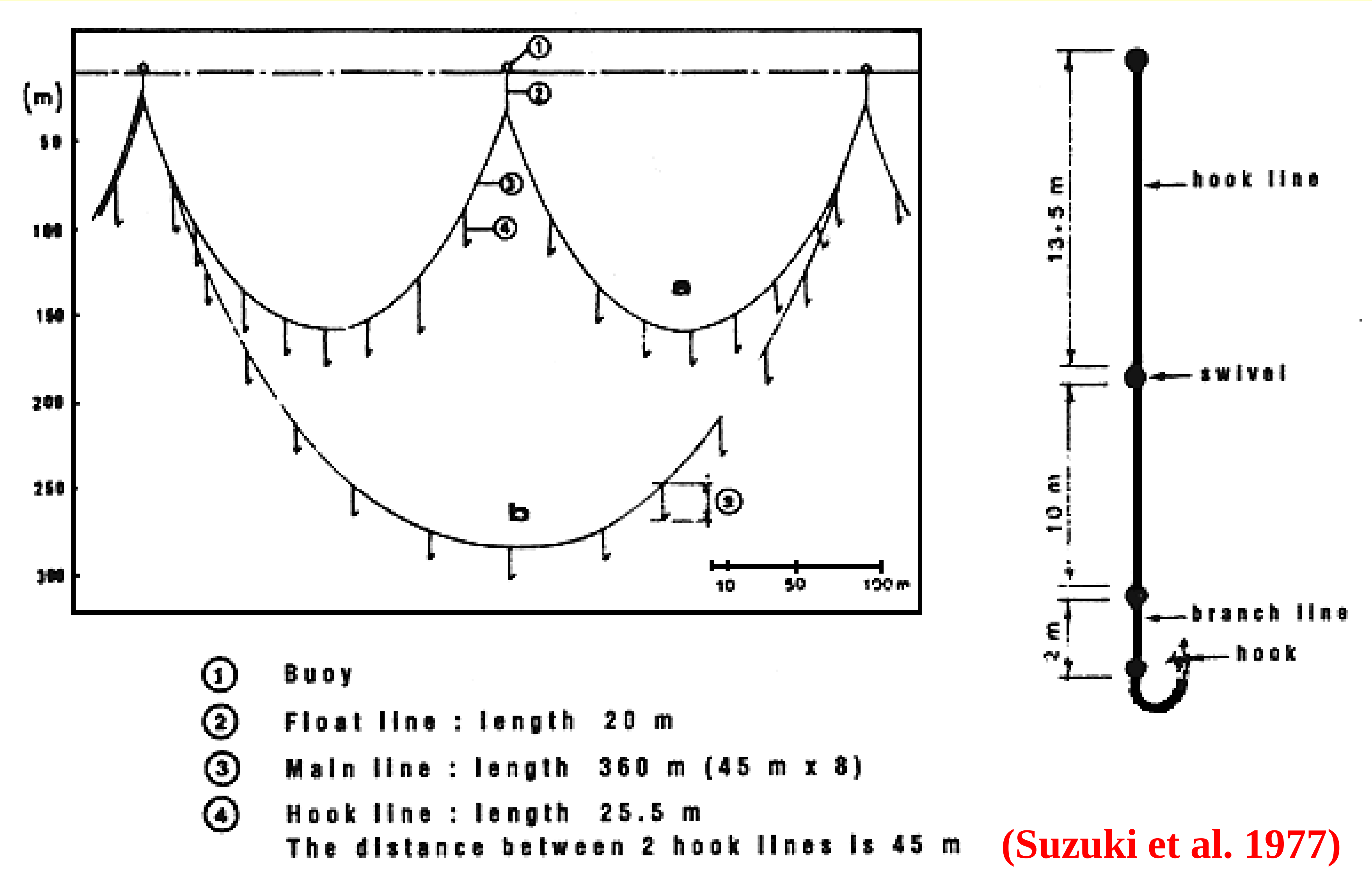
So, can we still use CPUE as an abundance index?

Yes, however, we need to make sure that any spatial / temporal changes in catchability are estimated and accounted for prior to the stock assessment.

Catch rate standardisation can be applied to CPUE data ***prior*** to its use in an assessment model.

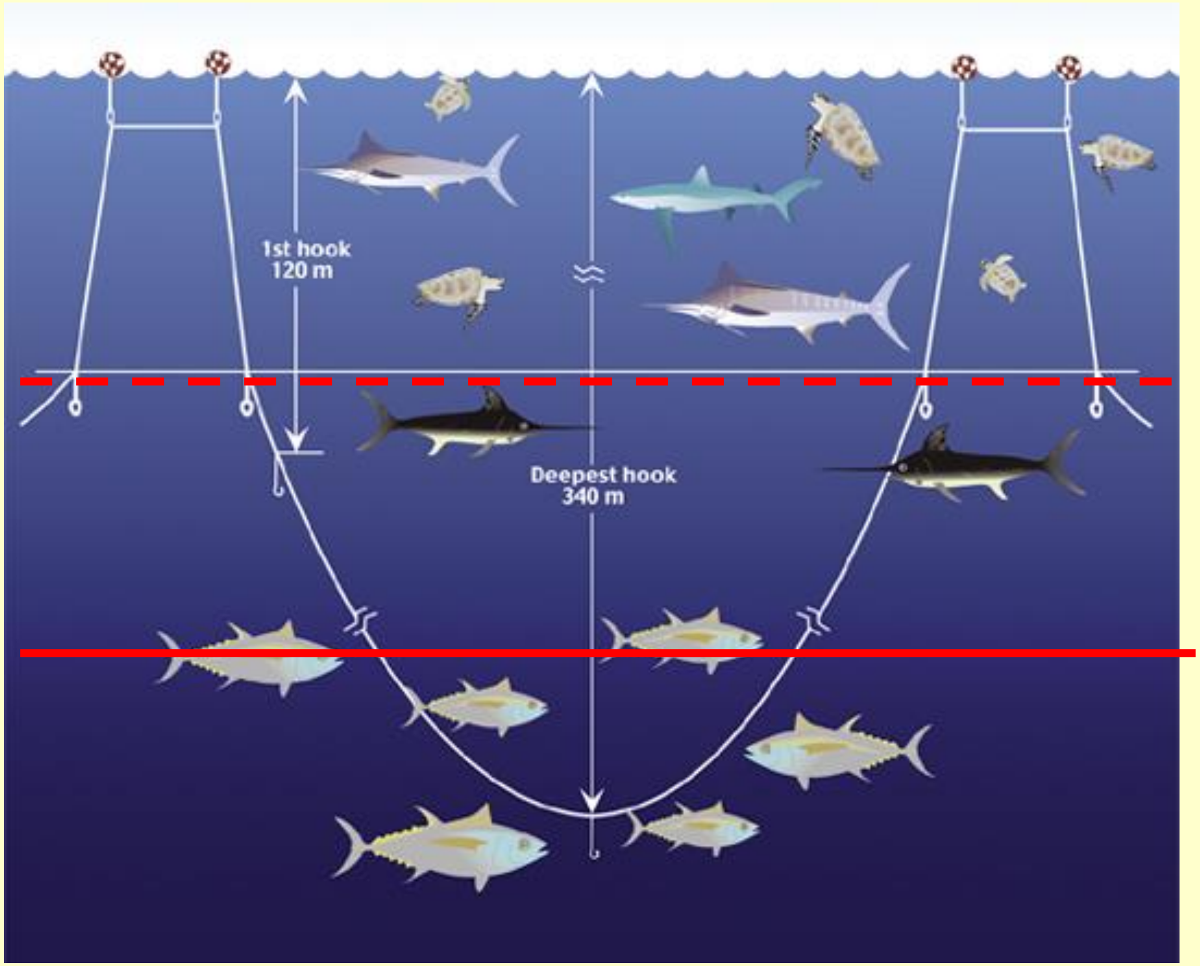
Standardising catch rates is a statistical model-fitting exercise to identify and remove the effect of those factors that appear to shift the relationship between CPUE and abundance away from a simple linear one.

Vertical Longline Fishing Structure



(Suzuki et al. 1977)

Habitat Partitioning – Vertical / Time of Day

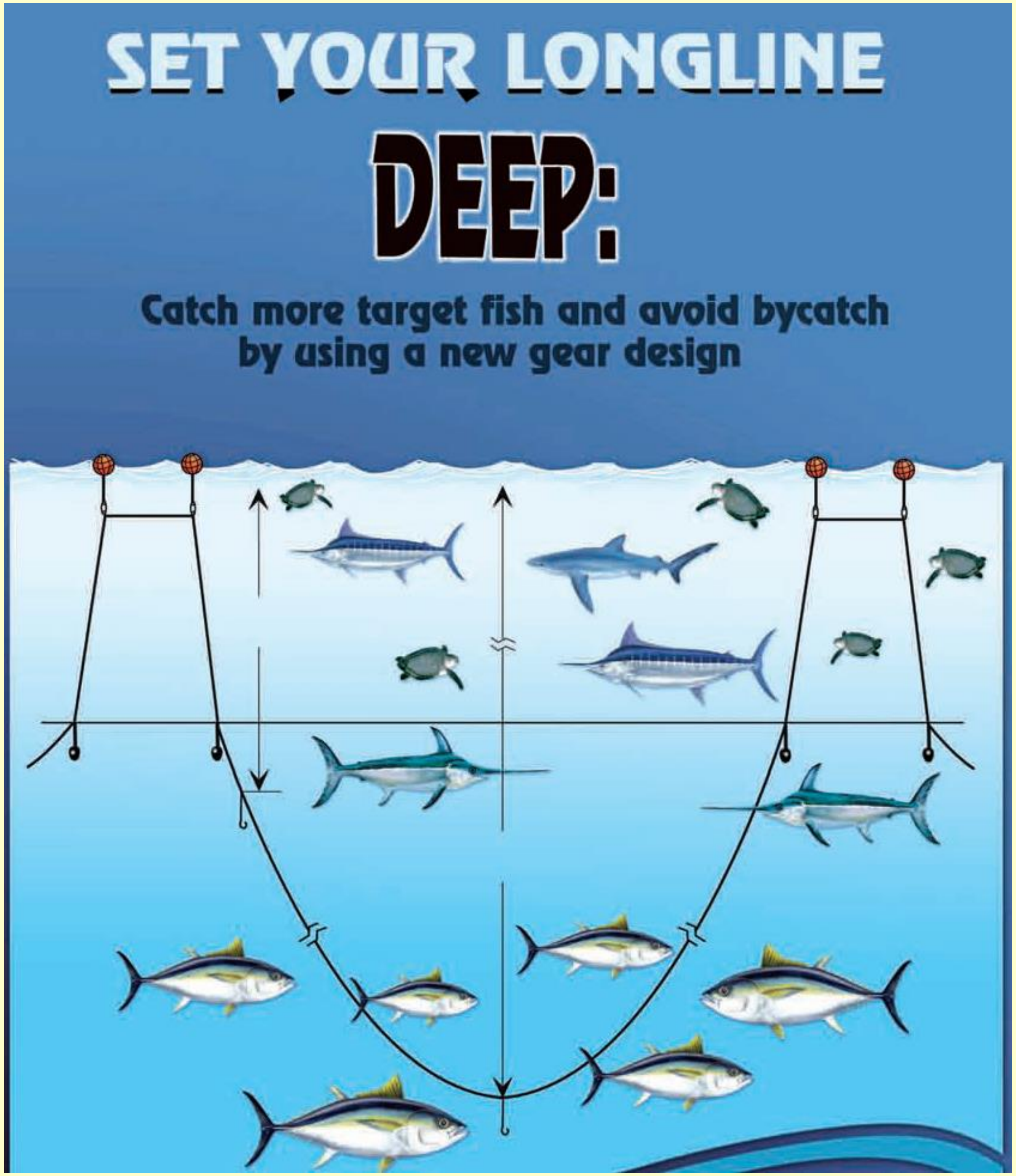


Habitat Partitioning – Vertical / Time of Day

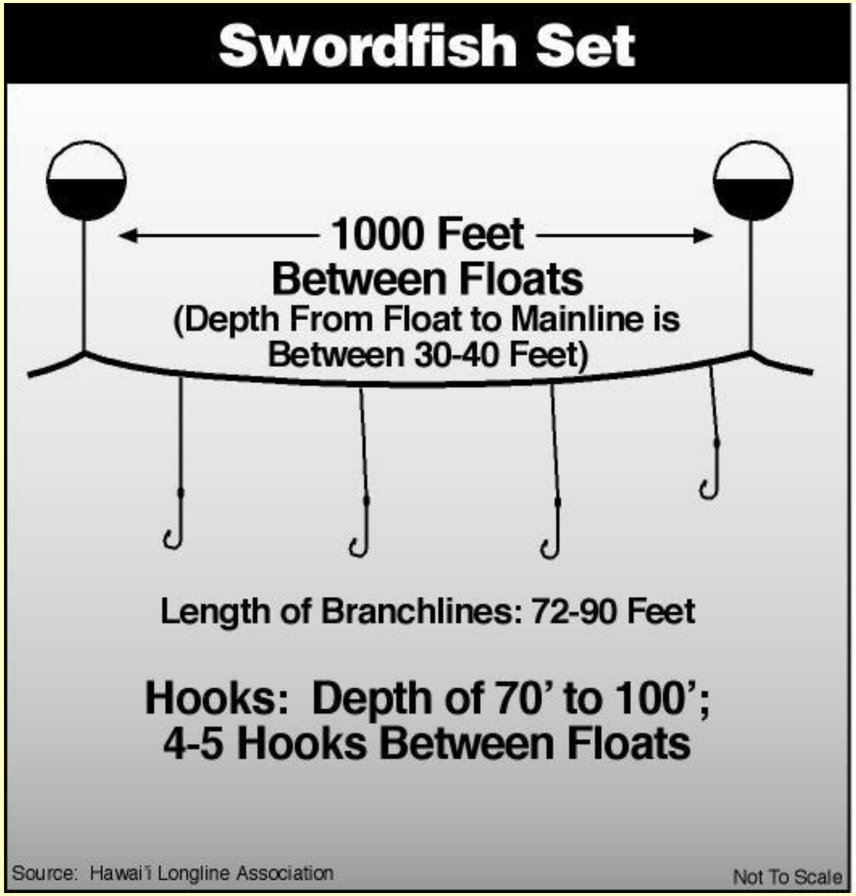
Tuna caught during the day below the mixed layer (100 - 400m).

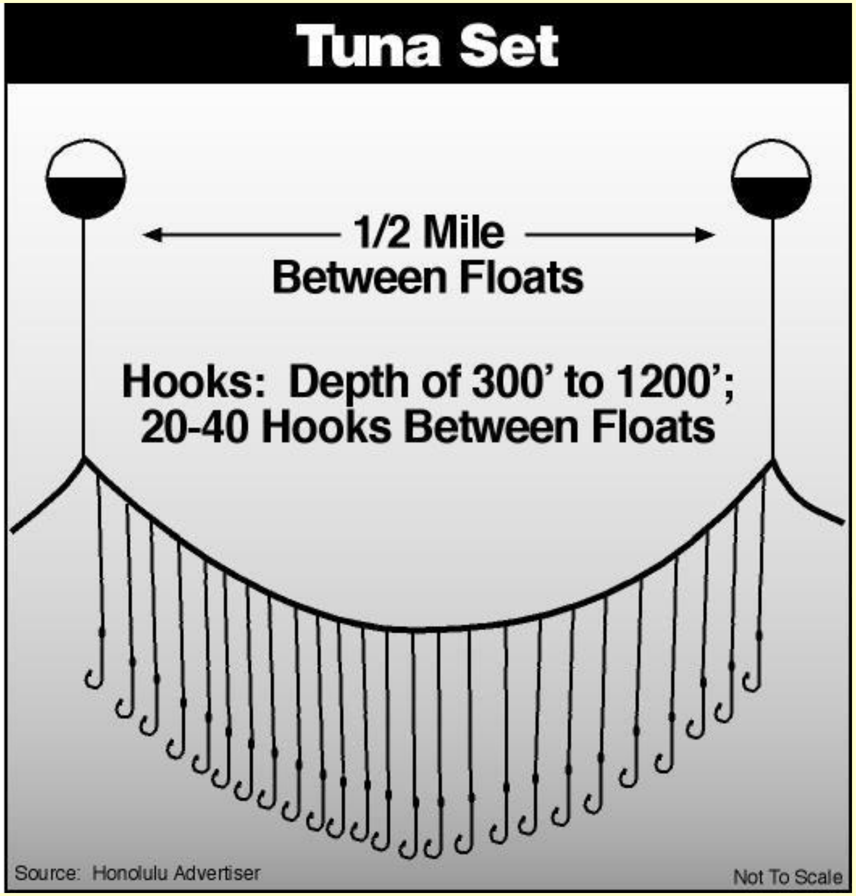
Swordfish caught at night in the intermediate layer, down to thermocline (0 - 100m).

Most bycatch (sharks/turtles) caught in the mixed layer, (upper 100m).



Fishery Partitioning – "Target Species"





Shallow
Night-time
High Float / Hook Ratio
Light-sticks

(NOAA)

Deep
Day-time
Low Float / Hook Ratio

Habitat Partitioning – Vertical / Time of Day

Problem: Even if longlines are set deep to target bigeye tuna, many baited hooks end up in mixed layer – outside of "tuna layer" and where turtle / shark bycatch occurs.

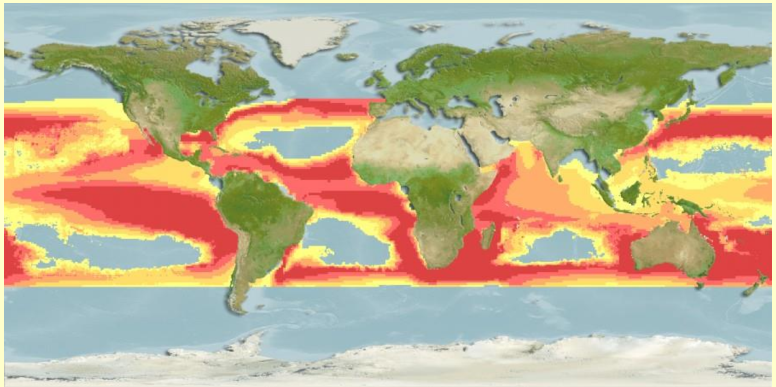
1) What are these hooks fishing for (what is CPUE measuring)?

2) Bycatch is costly (for the fishery) because:

- it takes time to handle unwanted or protected species;
- baits taken by bycatch are not available for target fish;
- gear is lost when sharks bite off hooks;
- potential for fisher injury when handling unwanted species;
- harmful to ecosystem and wasteful …

  could result in fishery closures.

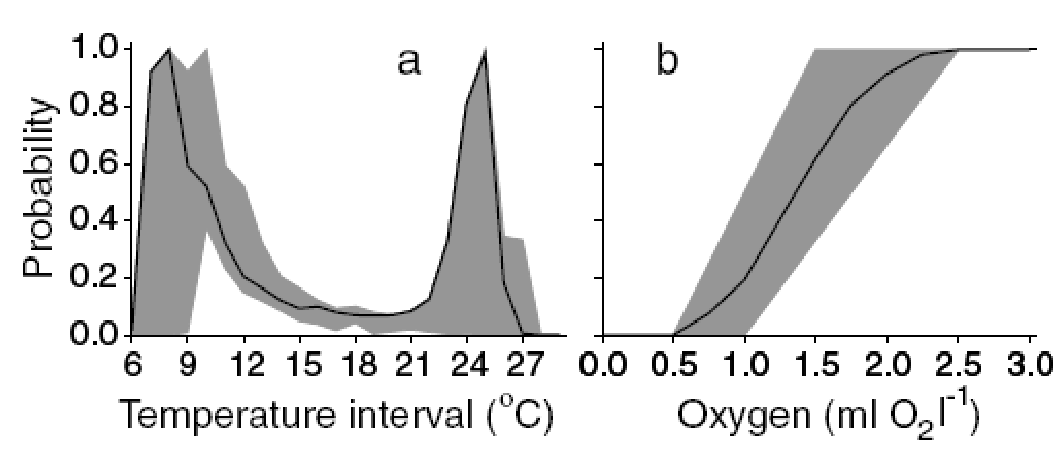
Big-Eye Tuna Fisheries (Bigelow et al. 2002)



The catch of big-eye tuna is related to their preference for temperatures cooler than those in the upper mixed layer.

What other factors can define the habitat of this species ?

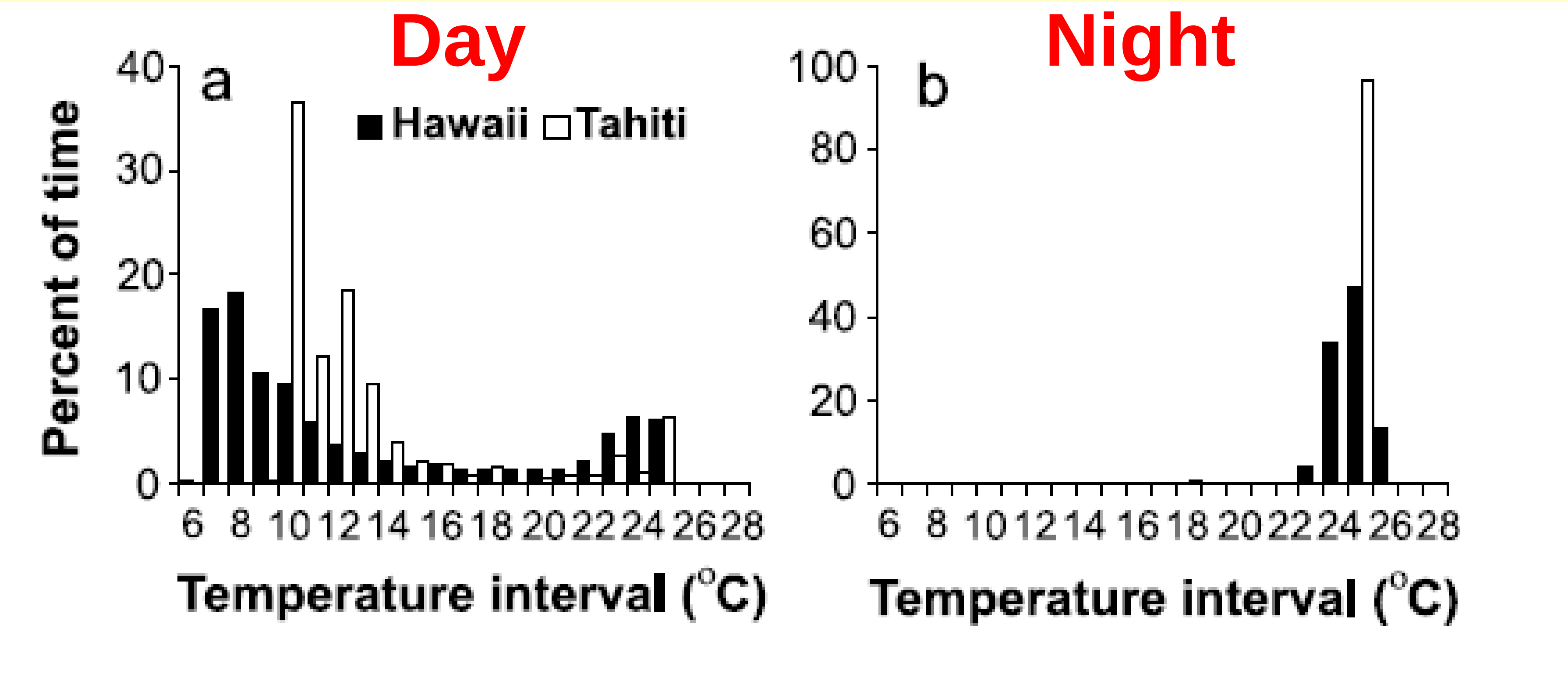
- Oxygen concentration
- Water color (clarity)
- Thermocline depth
- Thermocline strength



Big-Eye Tuna Fisheries (Bigelow et al. 2002)

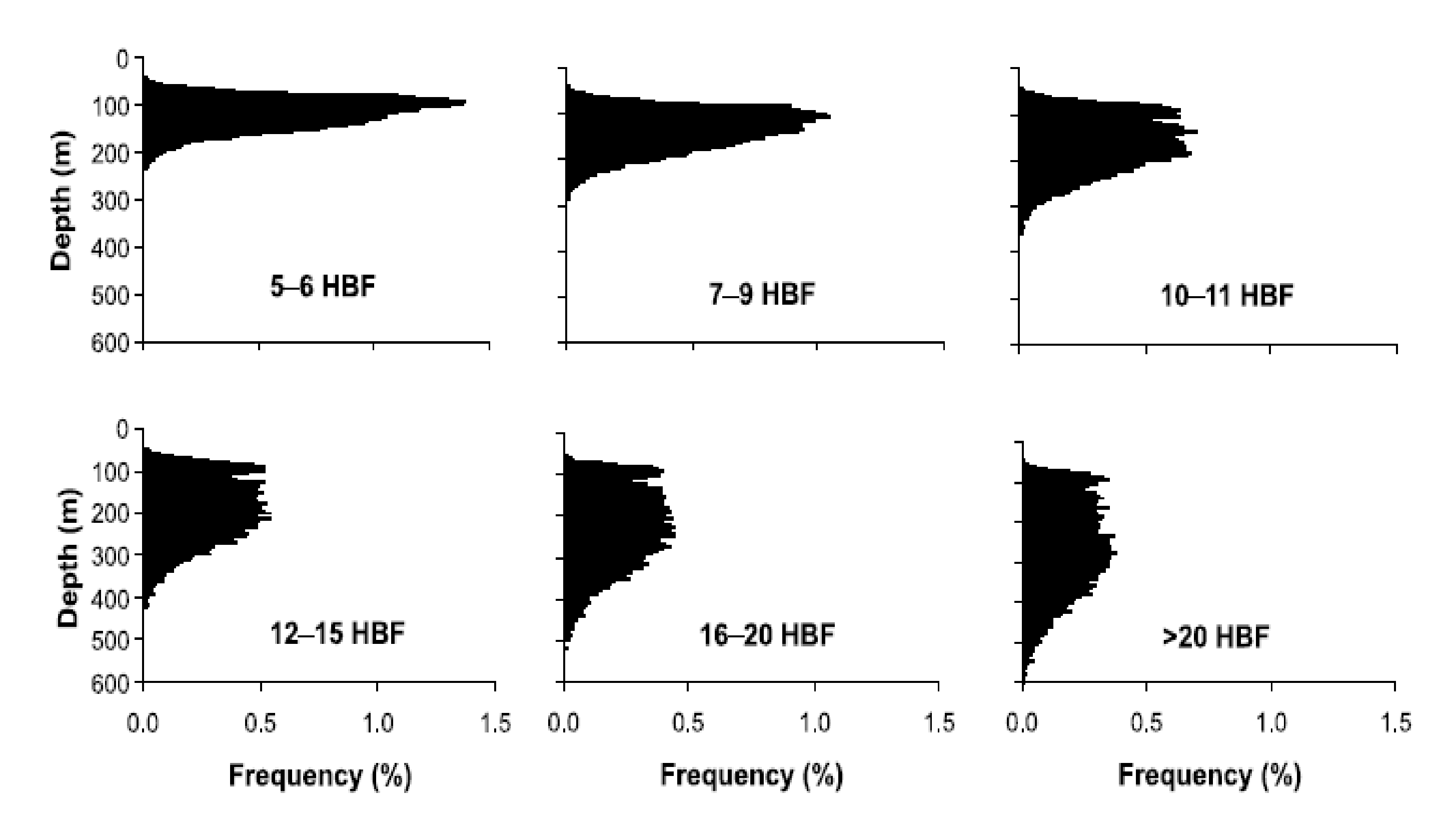
Longline catch of big-eye tuna is strongly affected by fishing depth.

Gear fishing deeper in the water is more effective in catching them.



BigEye Tuna Fisheries (Bigelow et al. 2002)

In the mid-1970s, longliners changed their fishing methods from 'conventional' sets (5 – 6 hooks between floats) fishing a depth range of approximately 90 – 150 m, to 'deep' sets (> 10 hooks between floats) fishing a depth range of 100 – 250 m



Hook depth distribution as a function of the gear configuration

HBF = hooks between floats

Effective Effort
(Bigelow et al. 2002)

Approach:
Variation in fishing depths of longlines and depth of the preferred habitat used to standardize longline CPUE.

Outcome:
Unbiased estimator of bigeye tuna relative abundance.

'effective' longline effort = 'nominal' longline effort

+ habitat use data
+ environmental data

Effective Effort

(Bigelow et al. 2002)

Define effective fishing effort (f) in particular area (a) and time (t) stratum as weighted sum of longline hooks (E) fishing in different depth zones (d) throughout the vertical habitat:

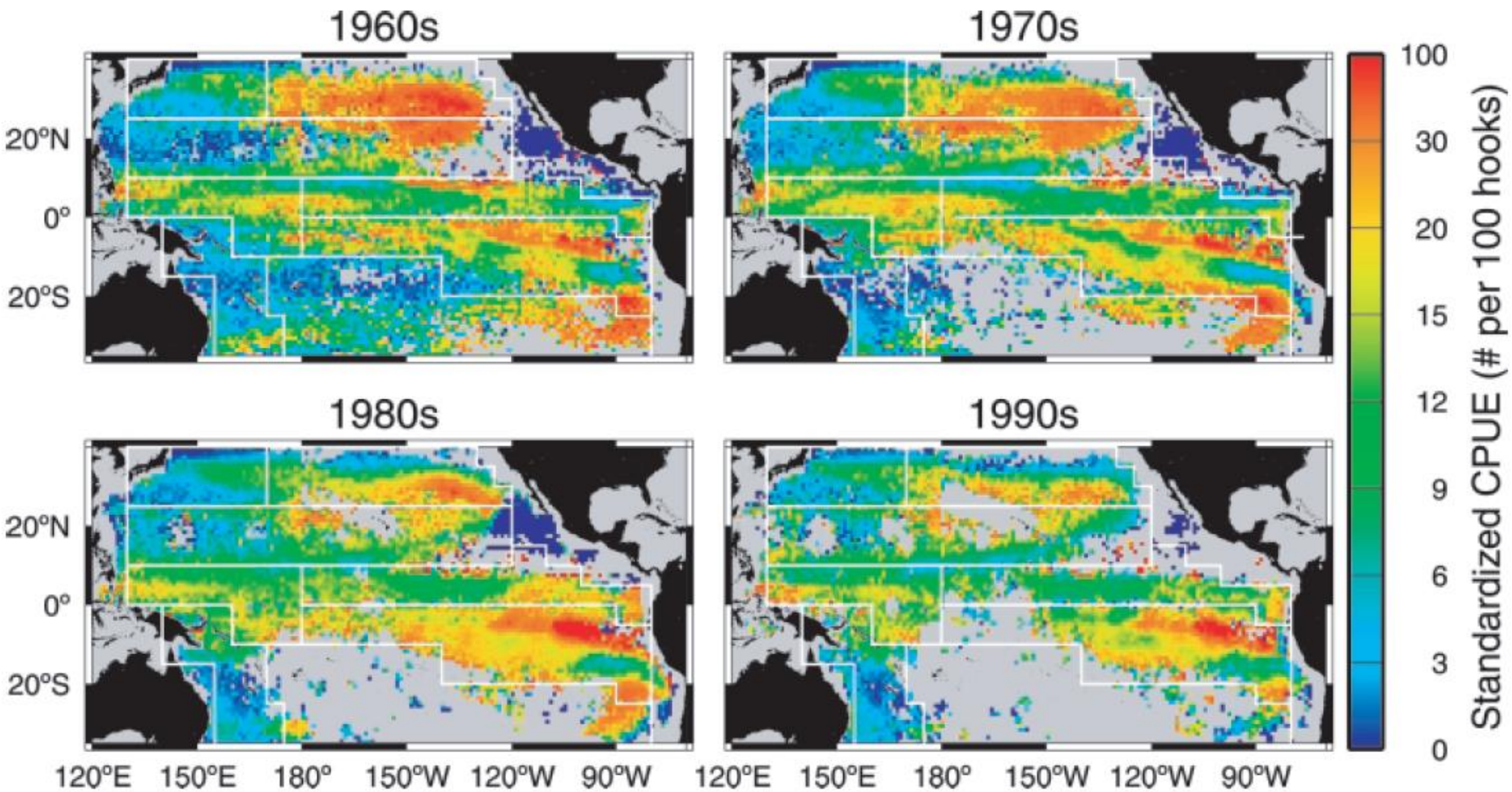
$$f_{at} = E_{at} \sum_{d} h_{atd} \; p_{atd}$$

where h*atd* is proportion of hooks fishing in depth zone d in area a during time period t and p*atd* is the proportion of bigeye tuna in area a during time period t occurring in depth zone d.

This analysis used 15 depth bins of 40 m (range, 0 – 600 m) to define the vertical habitat.

Revised Trends (Bigelow et al. 2002)

Figure 11. Spatial comparison of bigeye standardized CPUE in the Japanese longline fishery during the last four decades.



Improved estimates of relative abundance of Pacific bigeye tuna by incorporating information on the variation in longline fishing depth and depth preferred habitat.

Spatial Shifts in Fishing Effort (Bigelow et al. 2002)

Performance of effective effort estimates of relative abundance of bigeye tuna vary by area (ocean domains)

EPO
(shallower tuna, within fishery range)

WCPO
(deeper tuna, outside of fishery range)

Figure 12. Annual nominal CPUE (line with circles) and standardized CPUE (relative abundance) estimates for bigeye tuna in the western and central Pacific Ocean (WCPO) and eastern Pacific Ocean (EPO). Monte Carlo simulations account for the variation in habitat preference assumptions and illustrate the median standardized CPUE for each year and 95% confidence intervals (shaded area). Time-series of standardized CPUE is normalized to a value of 1.0.

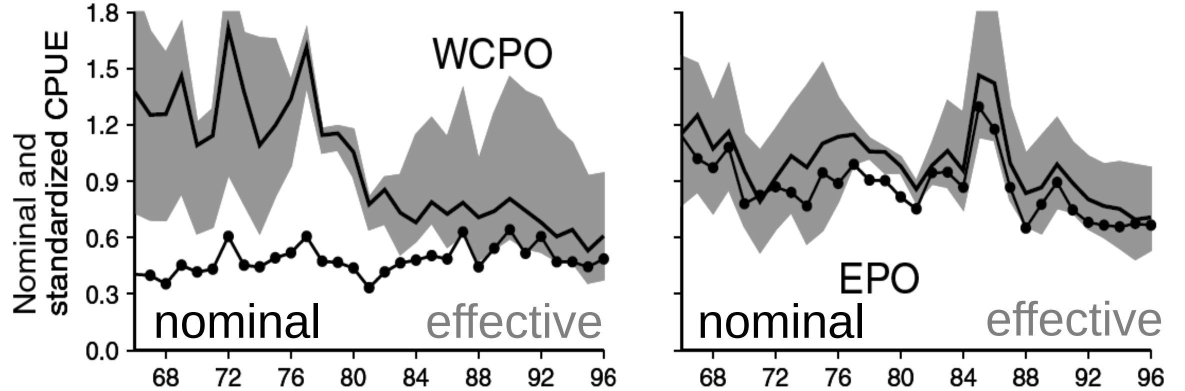
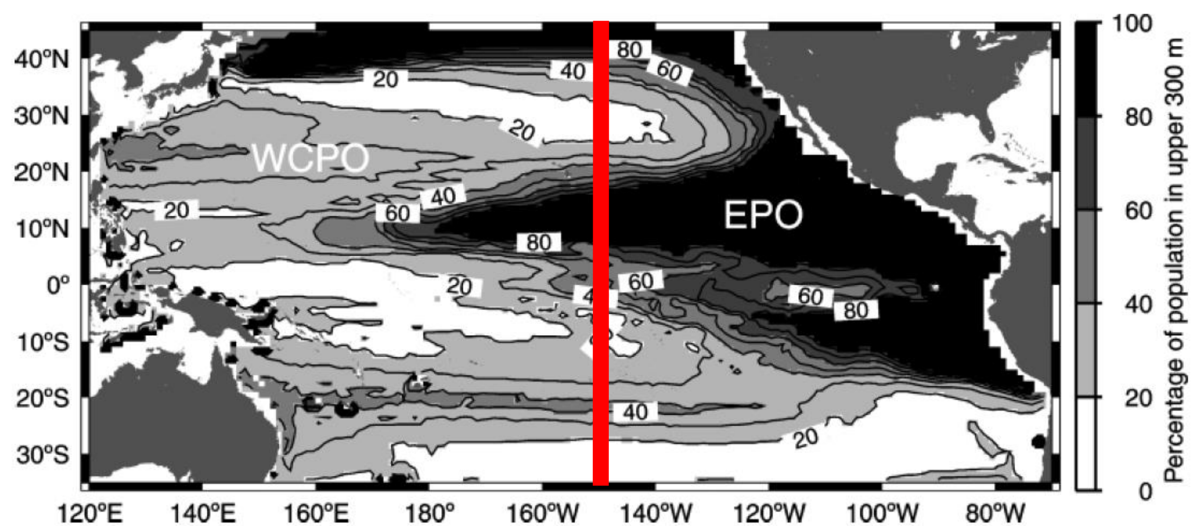


Figure 8. Percentage of bigeye population from 0 to 300 m inferred from the habitat-based model. Bigeye are distributed according to initial temperature and oxygen hypotheses in Fig. 5. The western and central Pacific Ocean (WCPO) and eastern Pacific Ocean (EPO) are separated at 150°W for comparison.



Handling Confounding Factors for Trend Analysis

Bigelow et al. 2002 - Improved estimates of relative abundance of Pacific bigeye tuna by incorporating information on the variation in longline fishing effort by depth and tuna vertical preferred habitat.

- Vertical (depth)

- Horizontal (water masses)

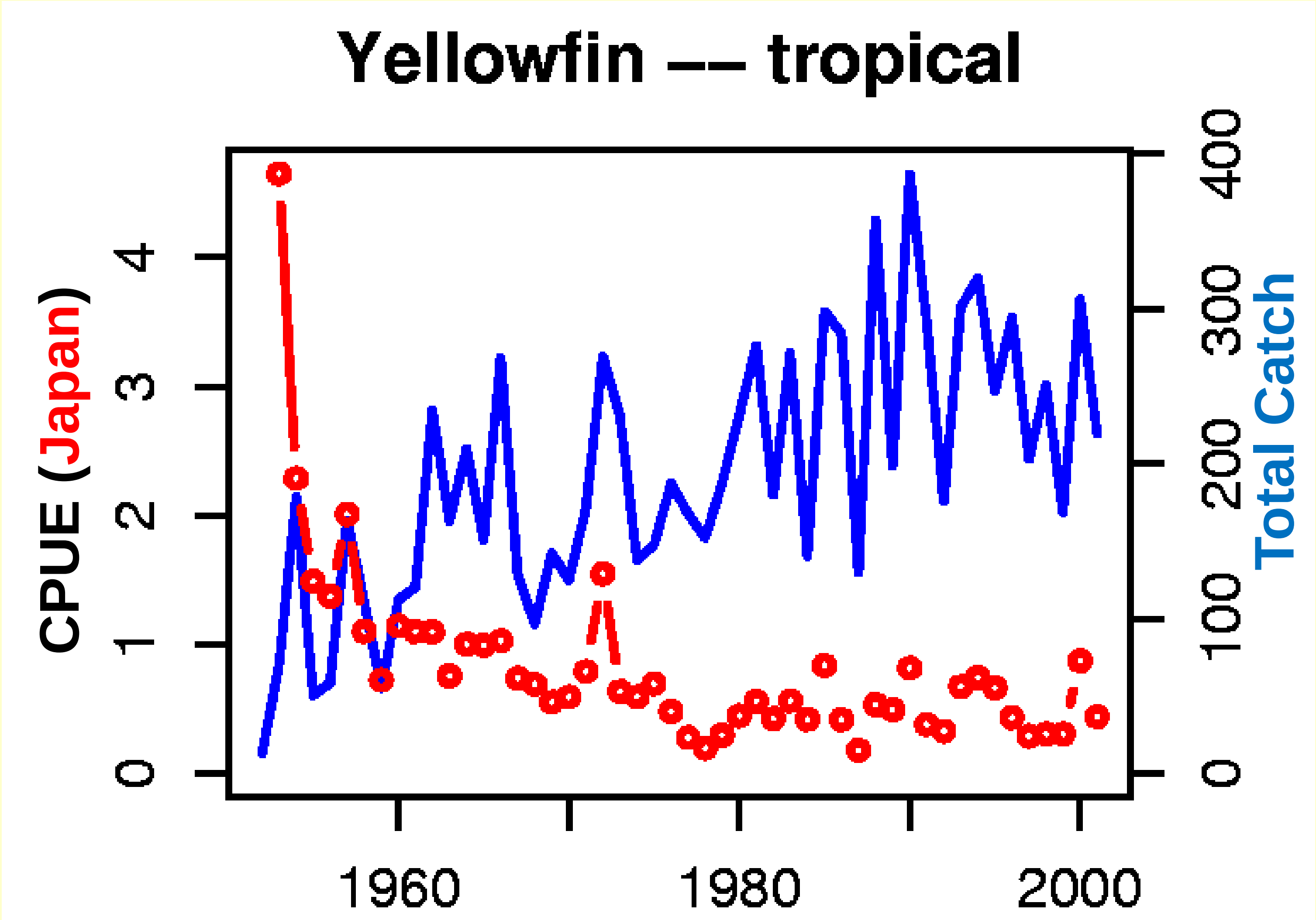
- … and interactions of both factors

Other Confounding Issues for Trend Analysis

Fishery Operations:
Changes in the way the fisheries are prosecuted can confound the analysis of trends in catch and bycatch:

- Fishing locations
- Fishing “targets”
- Fishing methods
- … and interactions of these factors

Other Confounding Factors for Trend Analysis

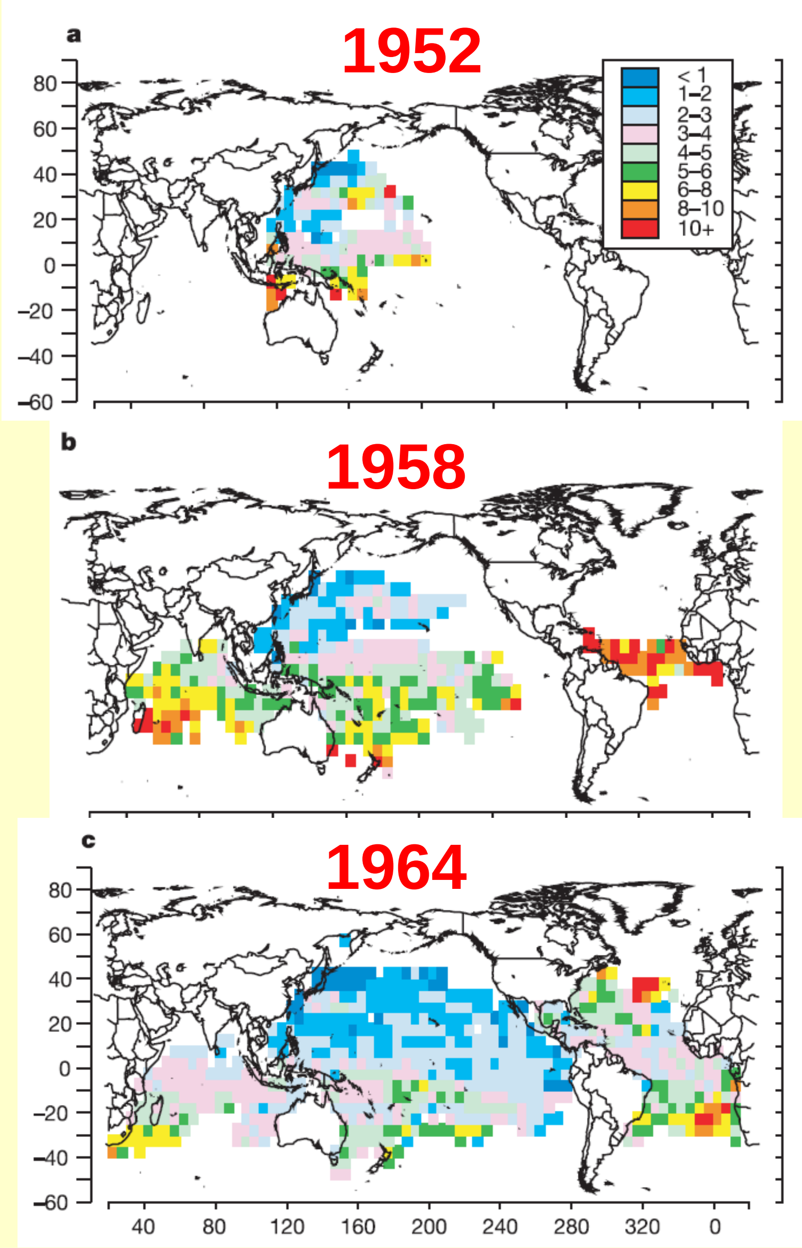


Blue is total catch, red is CPUE

(west of 150° W, south of 20° N)

Rapid worldwide depletion of predatory fish communities

(Myers & Worm 2003)



(fish caught per 100 hooks on pelagic longlines set by the Japanese fleet)

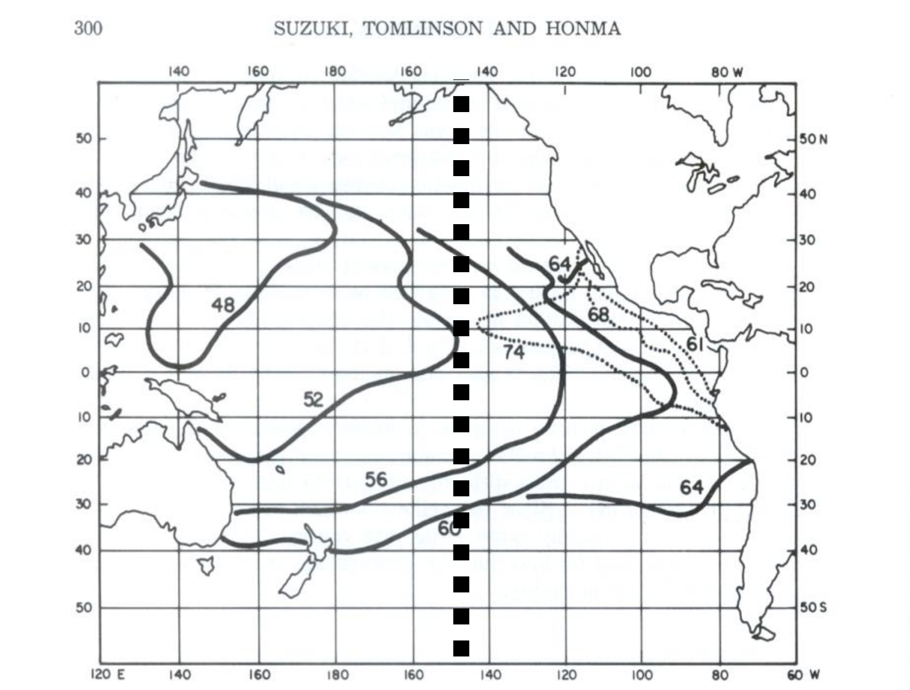
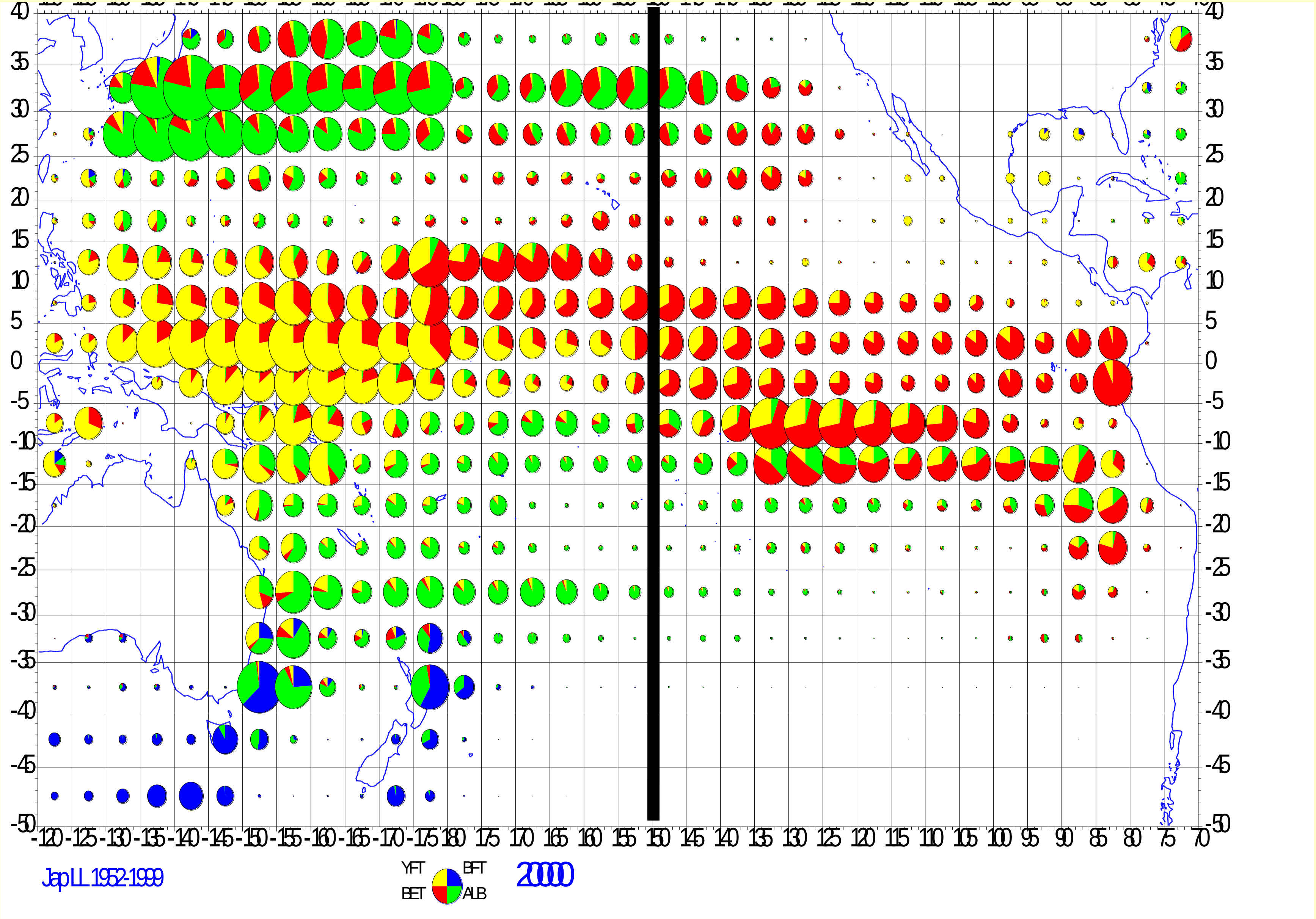


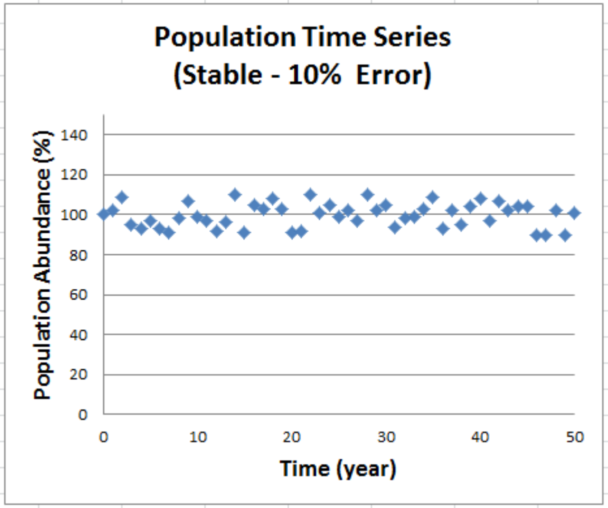
FIGURE 1. Geographical expansion of the Japanese longline fishery (solid curves) and the surface fishery in the eastern Pacific (dotted curves). Numerals denote calendar year.

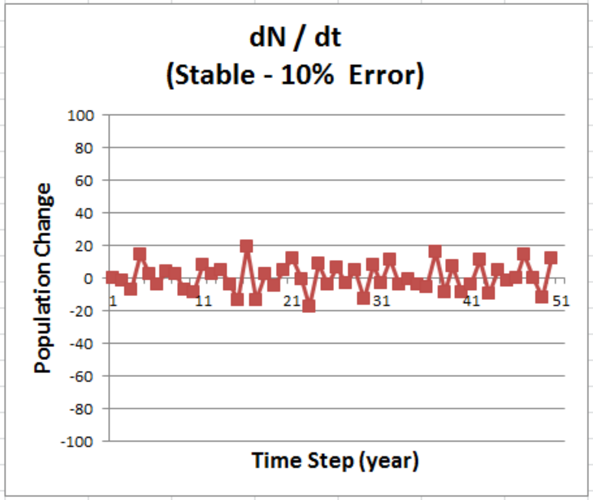
(Suzuki et al. 1977)

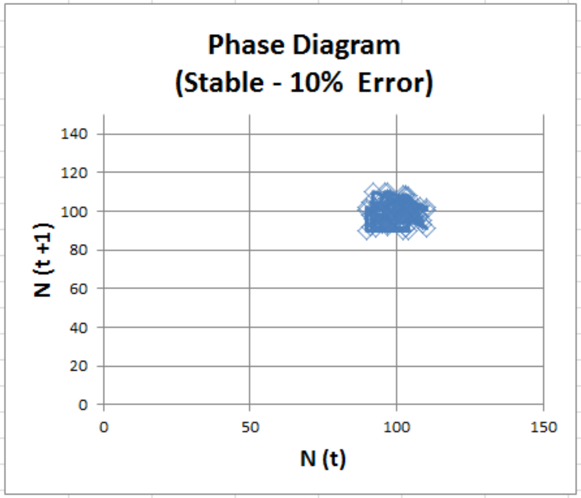
Spatial Distribution of Tuna Catches (Year 2000)



Homework #2 – Building from Hw #1







Math / Stats Refresher:

Coefficient of Variation: CV

The ratio of the standard deviation to the mean.

$$c_v = \frac{\sigma}{\mu}$$

Shows the extent of variability in relation to the population mean.

Geometric Mean:

Calculated using product of the values (as opposed to arithmetic mean which uses the sum).

Defined as the *n*th root of the product of n numbers

$$\left(\prod_{i=1}^{N} x_i\right)^{1/N}$$

Homework #2

ANOVA						
	df	SS	MS	F	Significance F	
Regression	1	1.535	1.535	94.457	0.0002	
Residual	5	0.081	0.016			
Total	6	1.616				
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	49.445	4.746	10.418	0.000	37.244	61.645
Time (year)	-0.023	0.002	-9.719	0.000	-0.030	-0.017

Homework 2 - Reading

7

"Best" Abundance Estimates and Best Management: Why They Are Not the Same

Barbara L. Taylor and Paul R. Wade

Introduction

In *New Principles for the Conservation of Wild Living Resources*, Holt and Talbot (1978) give their second principle as, "Management decisions should include a safety factor to allow for the facts that knowledge is limited and institutions are imperfect." Inclusion of uncertainty in management has been difficult partly because of the failure of scientists to explain adequately the importance of incorporating estimates of uncertainty and the consequences of not accounting for this

Homework 2 - Reading

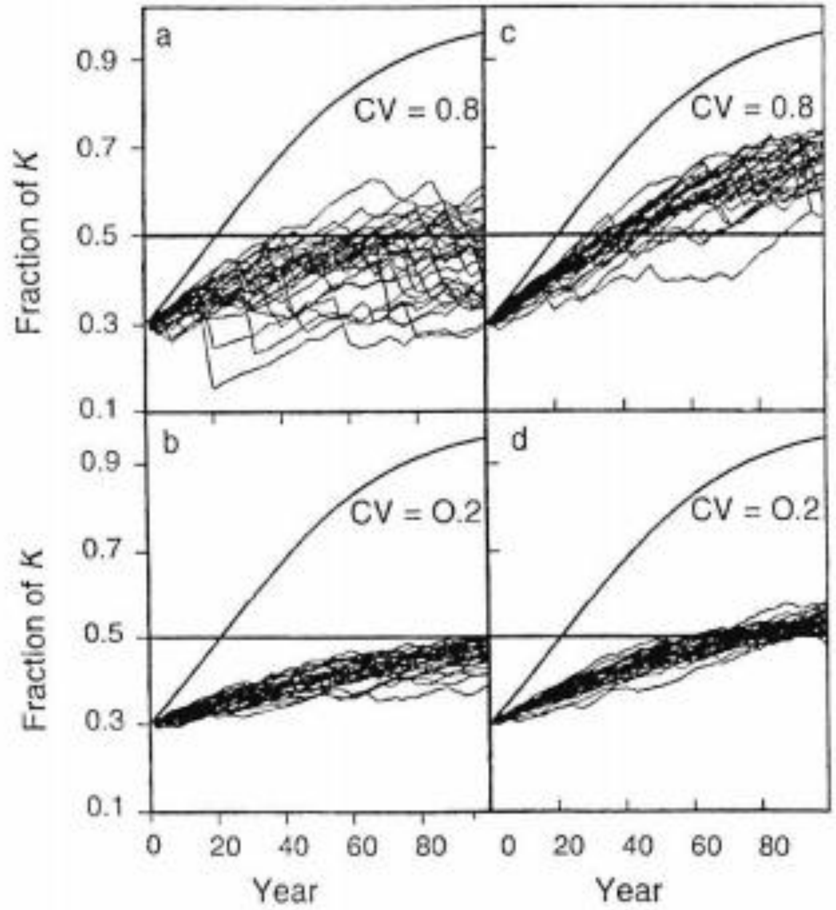


FIGURE 7.4. Sample of 30 simulations for base cases for cetaceans ($R_{MAX} = 0.04$), the N_{MEAN} strategy (a, b) and N_{MIN} strategy (c, d).

Homework #2

	Modelled			Calculated
Lambda_good	Lambda mean	Lambda cv		Lambda realized
1	1.000	0		1.000
1.25				
1.5				
1.75				

Homework #2

Finally, assume that now good and bad years alternate each other for ever. What would be the realized growth rate (lambda) for the four calculated above: (Lambda good = 1.75, 1.5, 1.25, 1)?

Hint: You do not need to make all of these calculations, use algebra to get the right answer. Show me your work.

Lambda_g	Lambda_b	Calculation	Realized Lambda
1	1		1.000
1.25	0.75		
1.5	0.5		
1.75	0.25		