CPUE as an index of relative abundance: the issues

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Workshop to improve the longline indices of abundance of bigeye and yellowfin tunas in the eastern Pacific Ocean

Outline

- Reasons CPUE is needed
- Issues with CPUE
- Spatio-temporal models
- Appropriately dealing with length composition data related to CPUE

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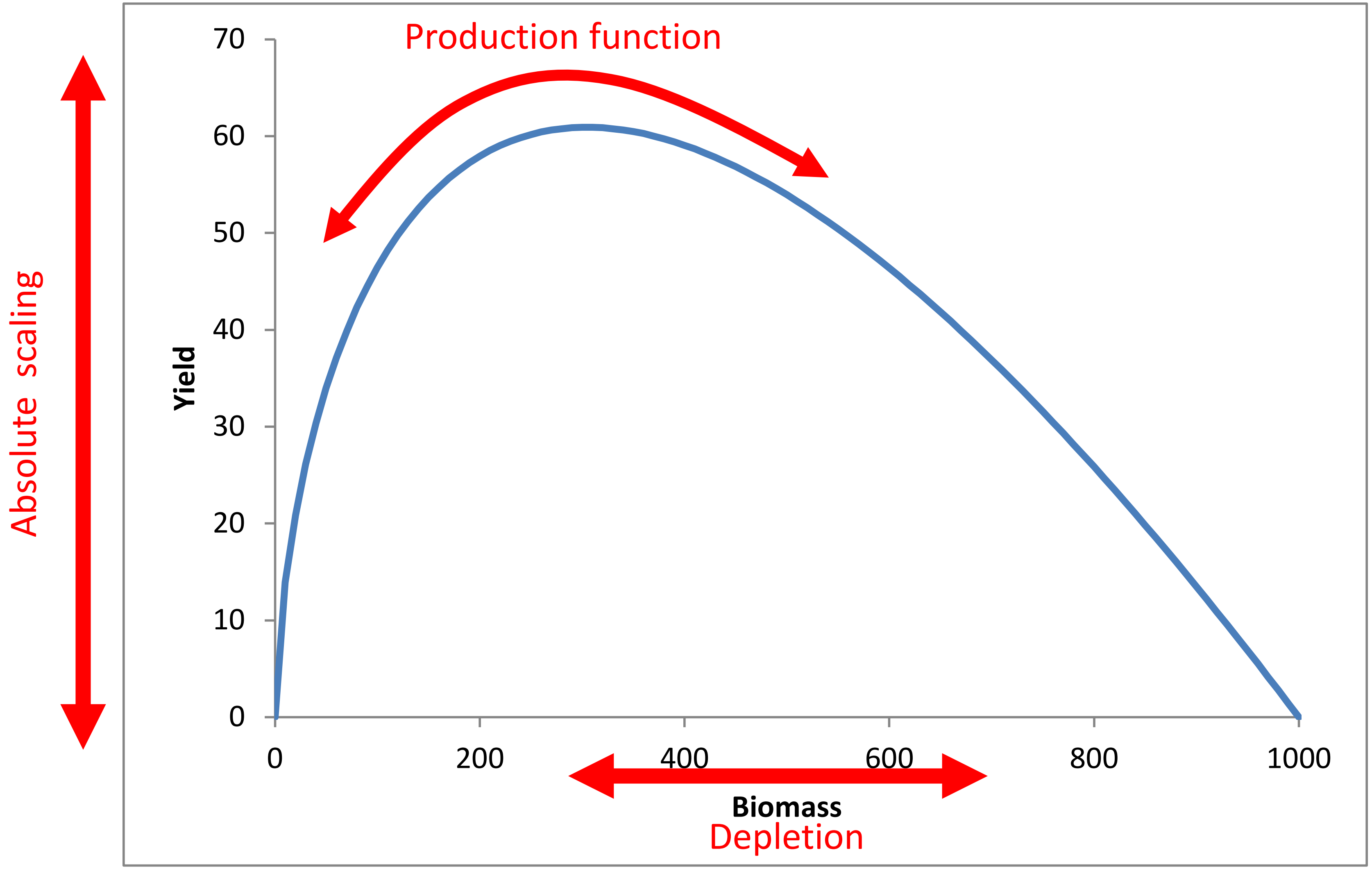
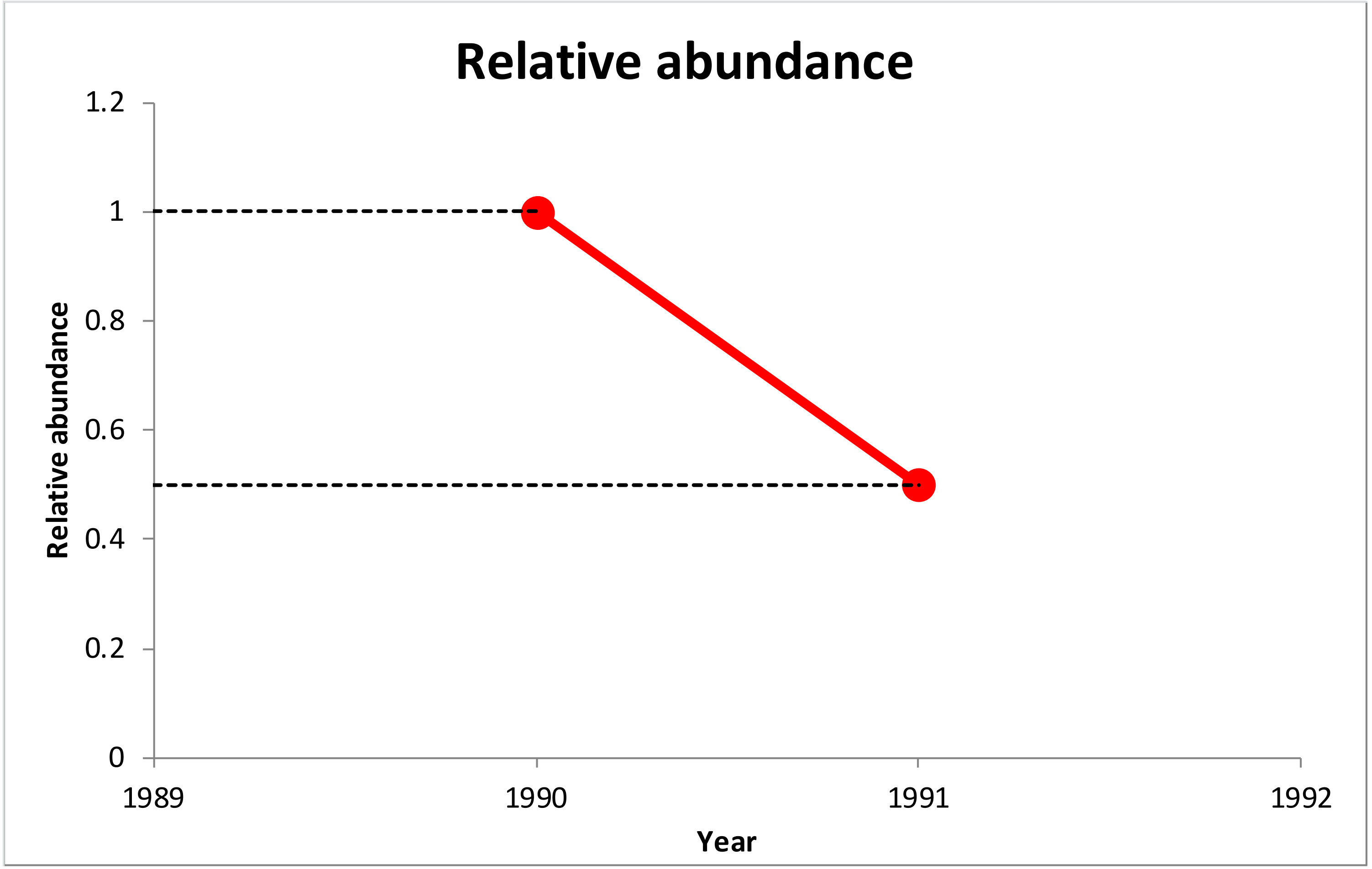
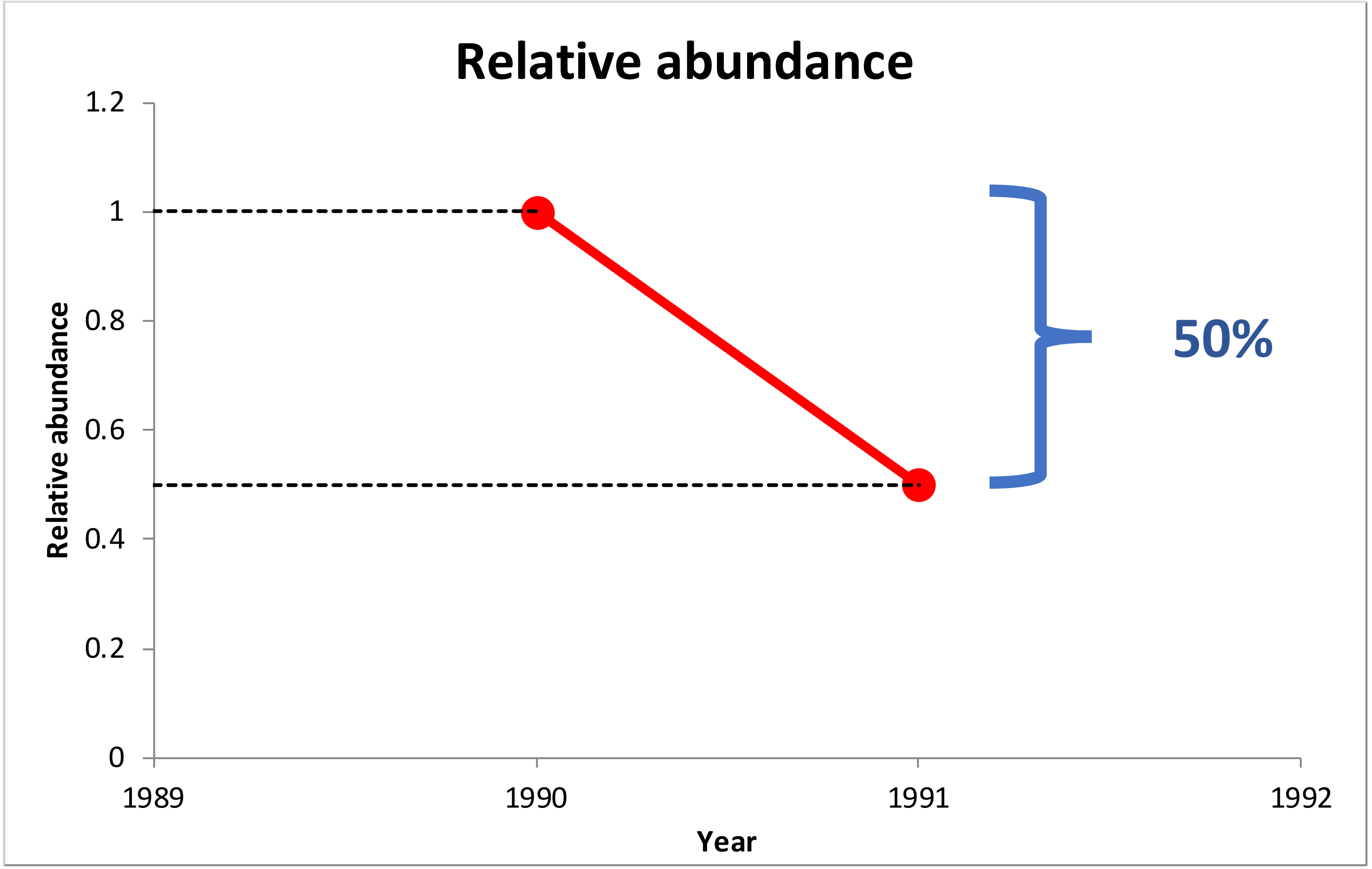
The surplus production function



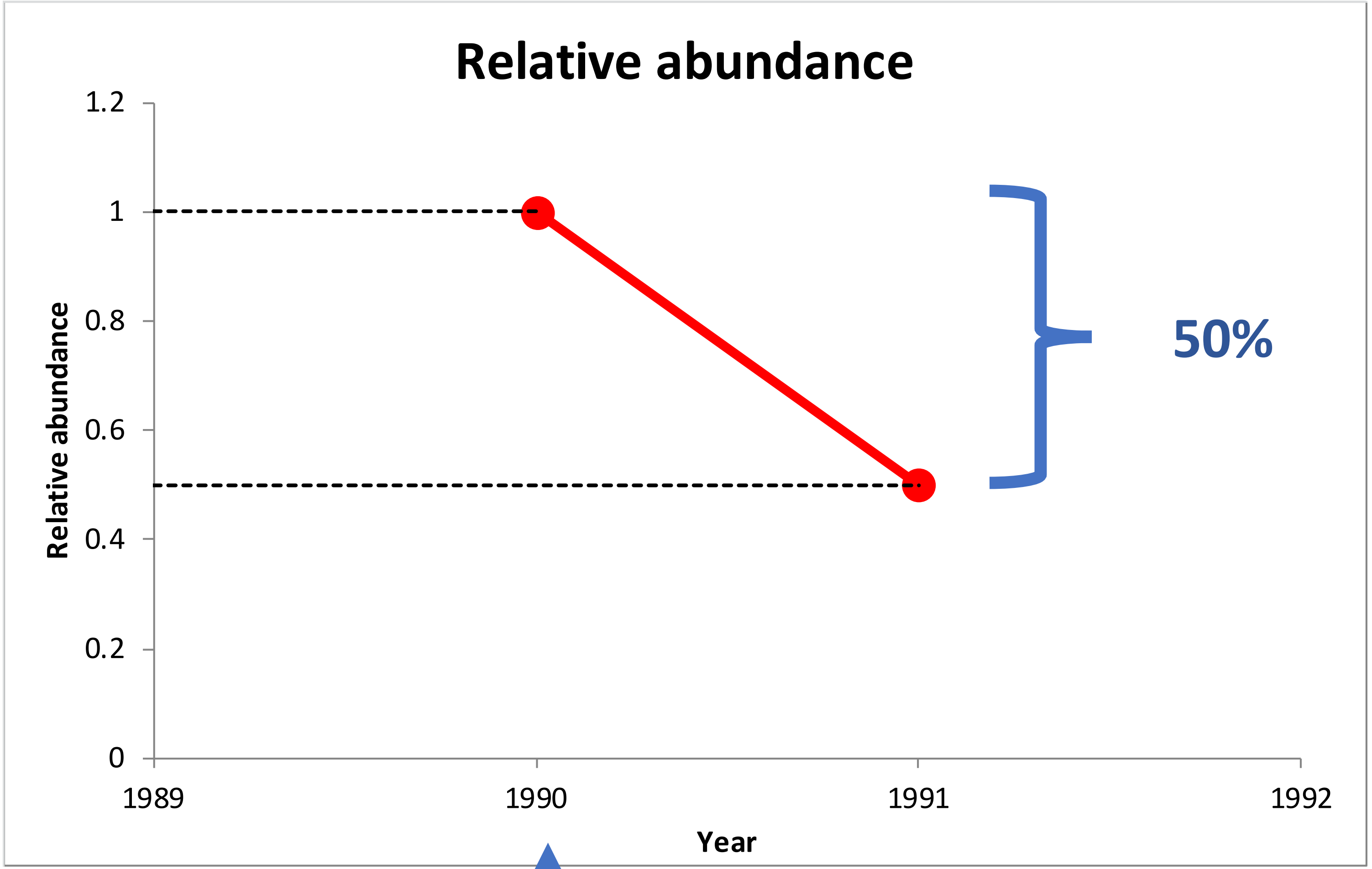
Estimating depletion from an Index of relative abundance



Estimating depletion from an Index of relative abundance



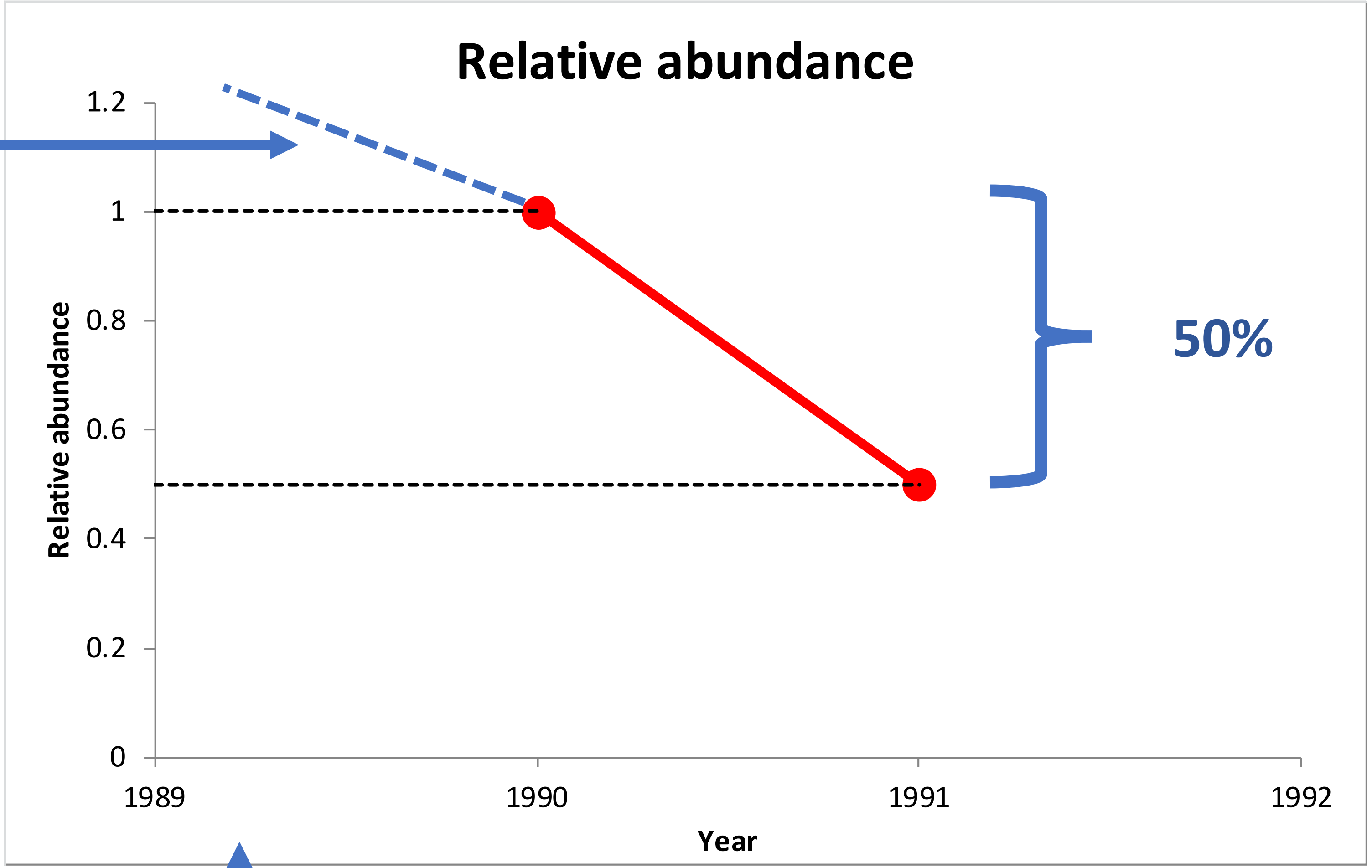
Estimating depletion from an Index of relative abundance



Unexploited

Estimating depletion from an Index of relative abundance

Recreate biomass
Using catch history



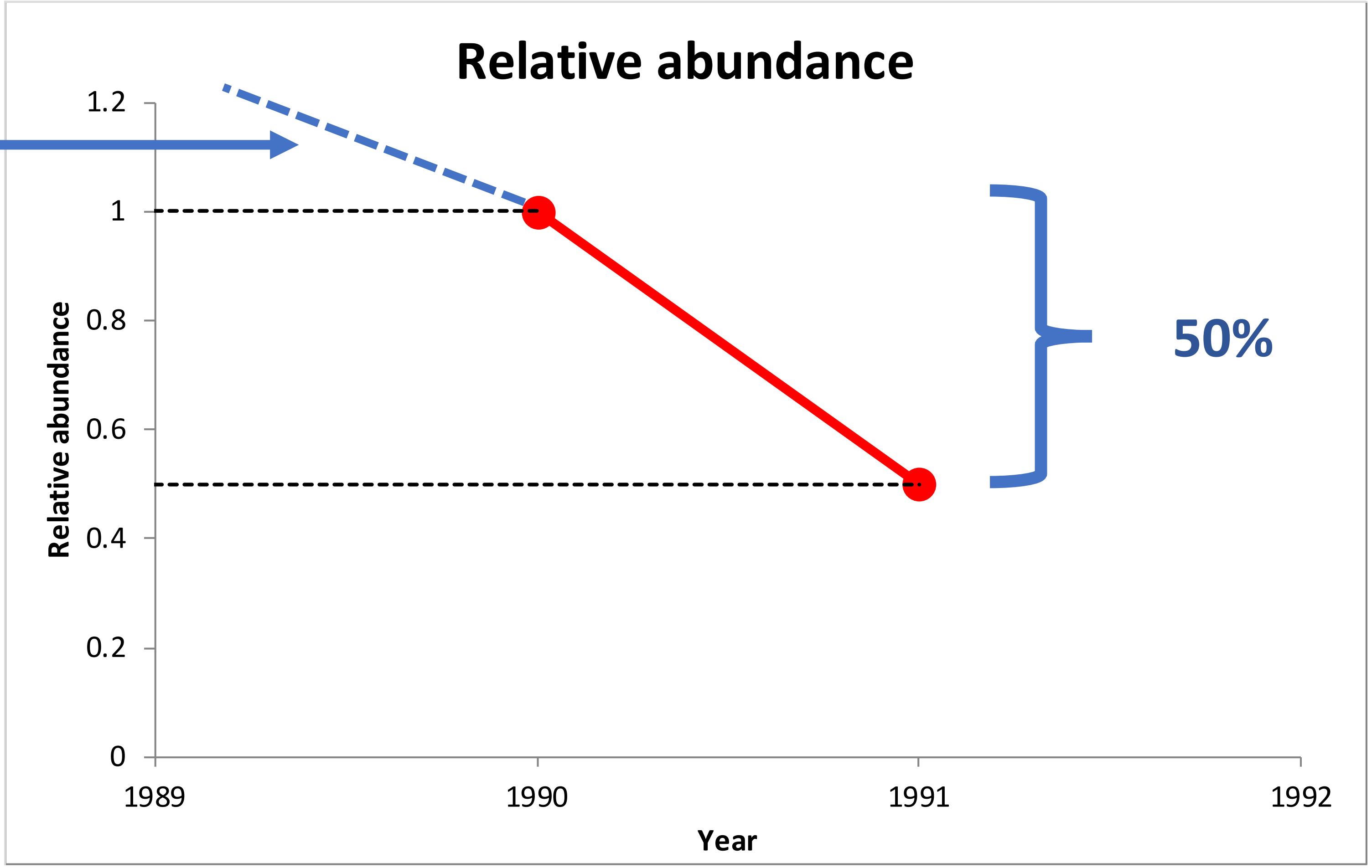
50%

Unexploited

Estimating depletion from an Index of relative abundance

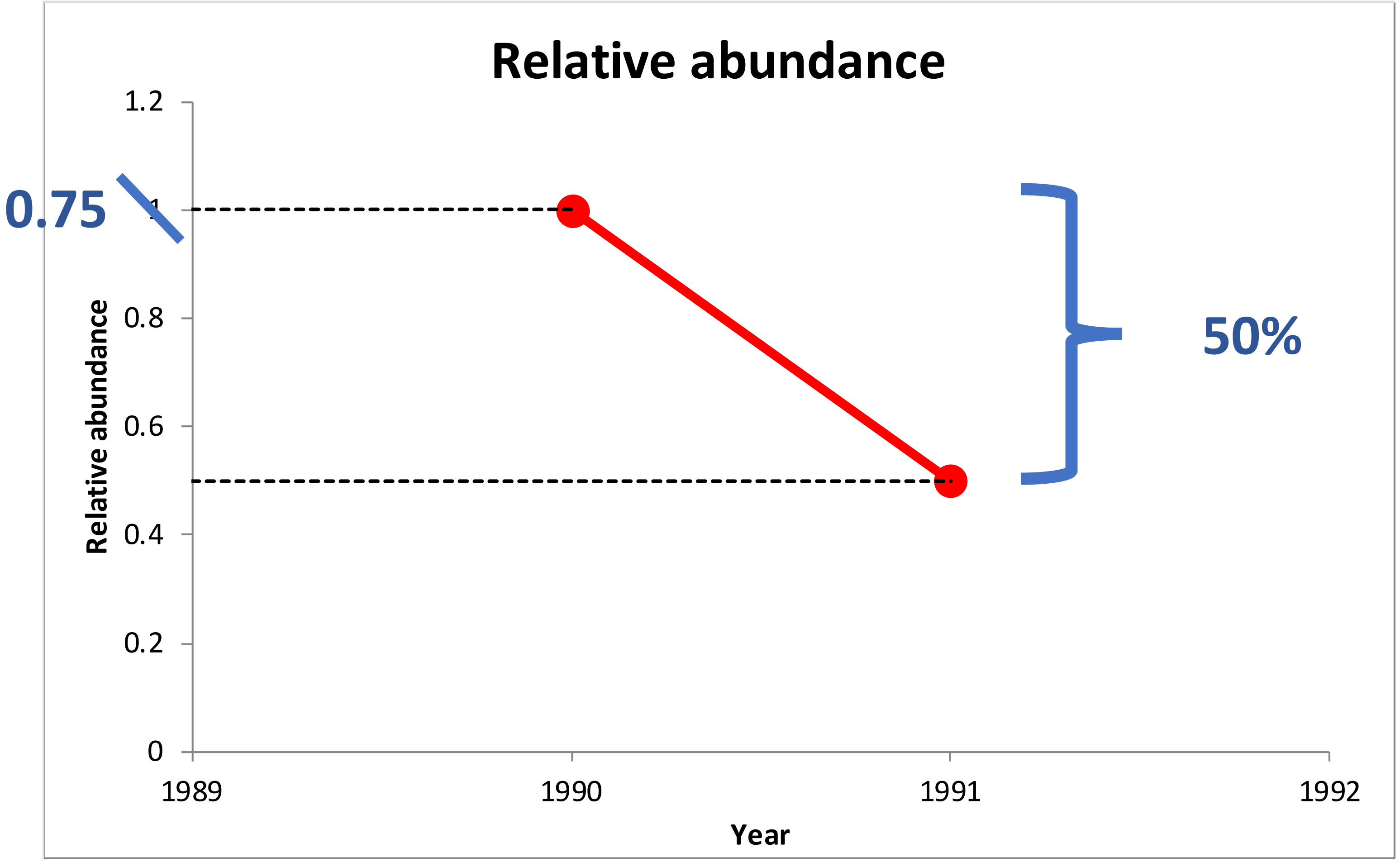
Recreate biomass
Using catch history

Adjusted for
R, G, and M

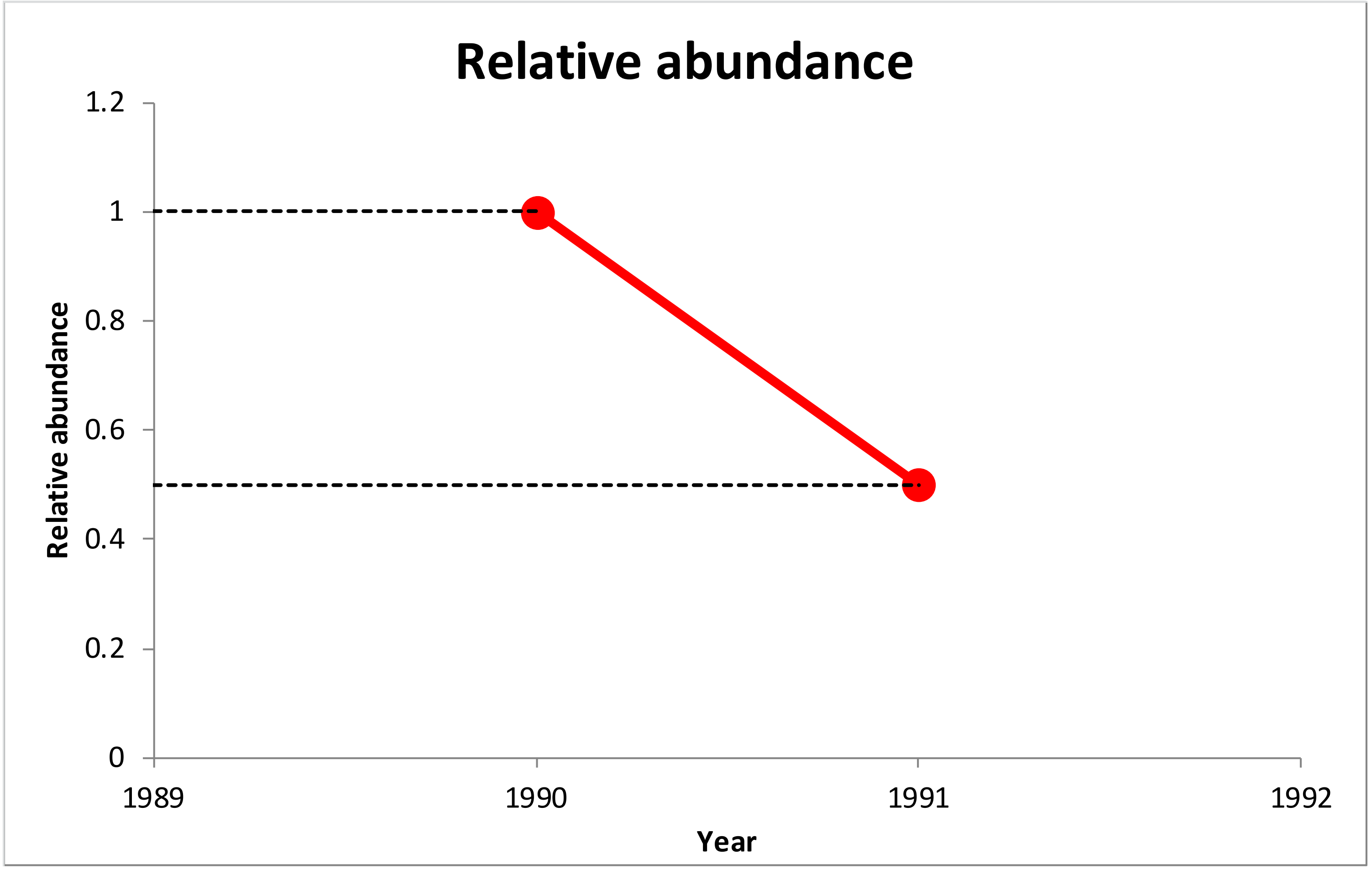


Estimating depletion from an Index of relative abundance

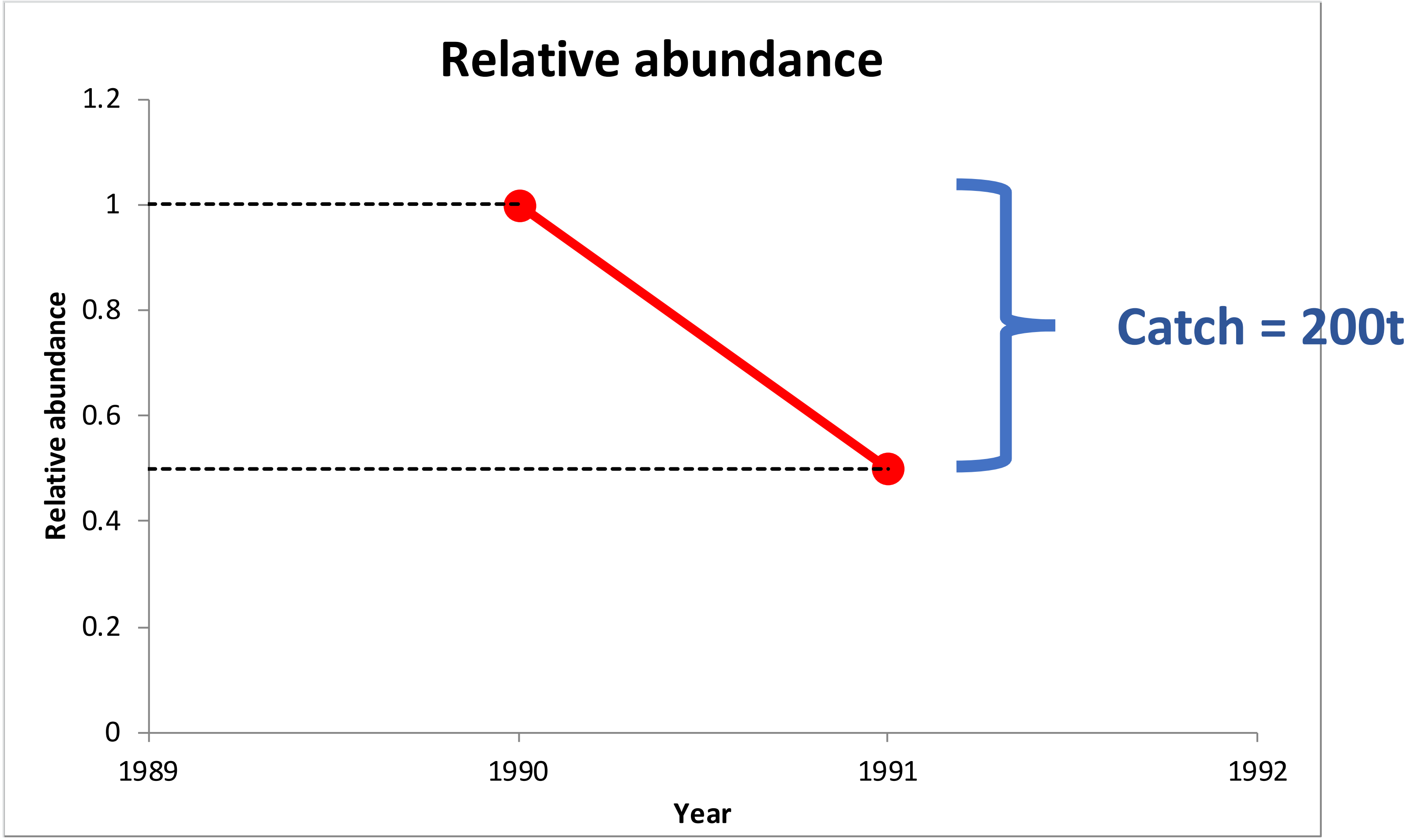
Estimate initial Depletion level



Estimating absolute abundance from an Index of relative abundance

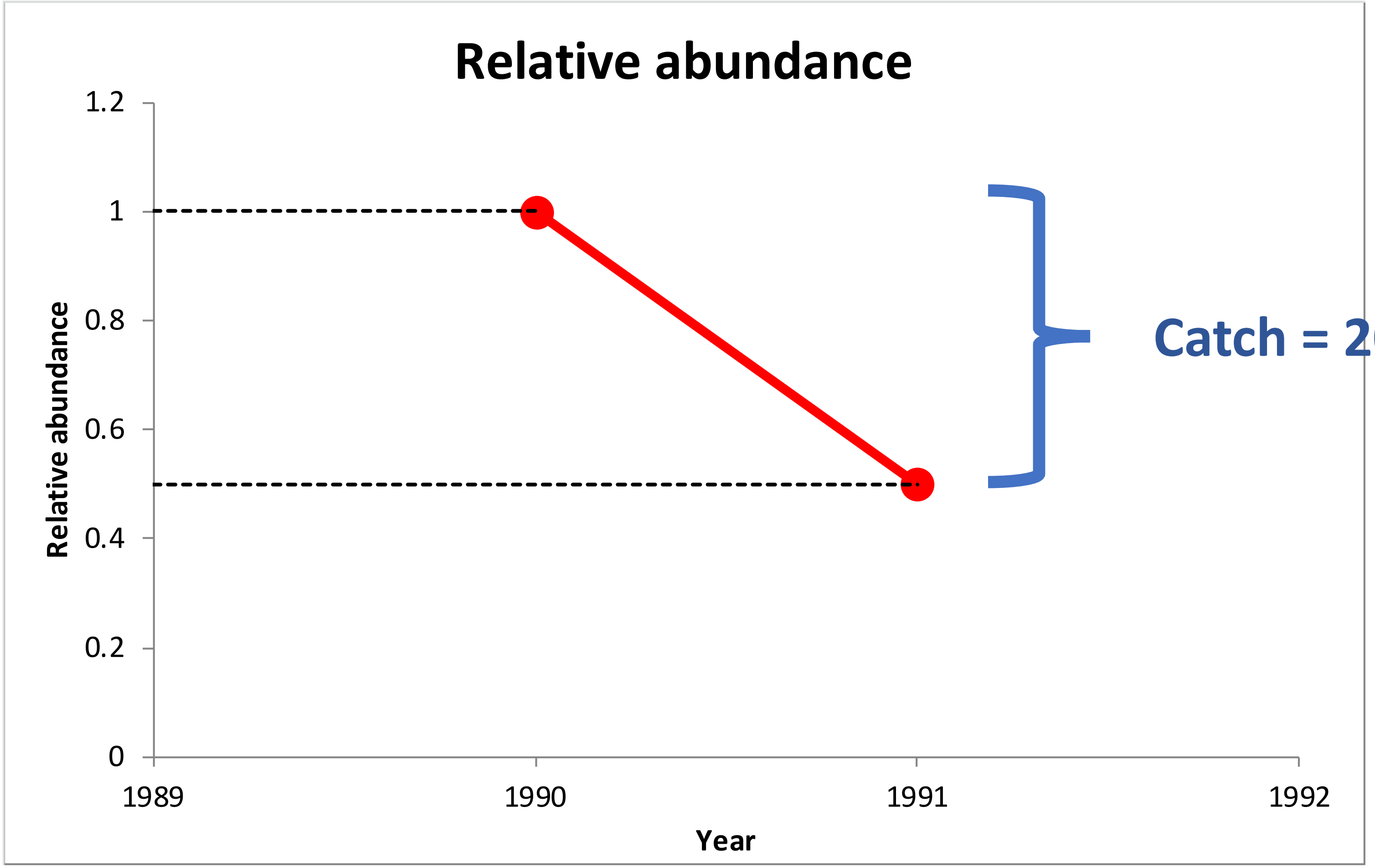


Estimating absolute abundance from an Index of relative abundance



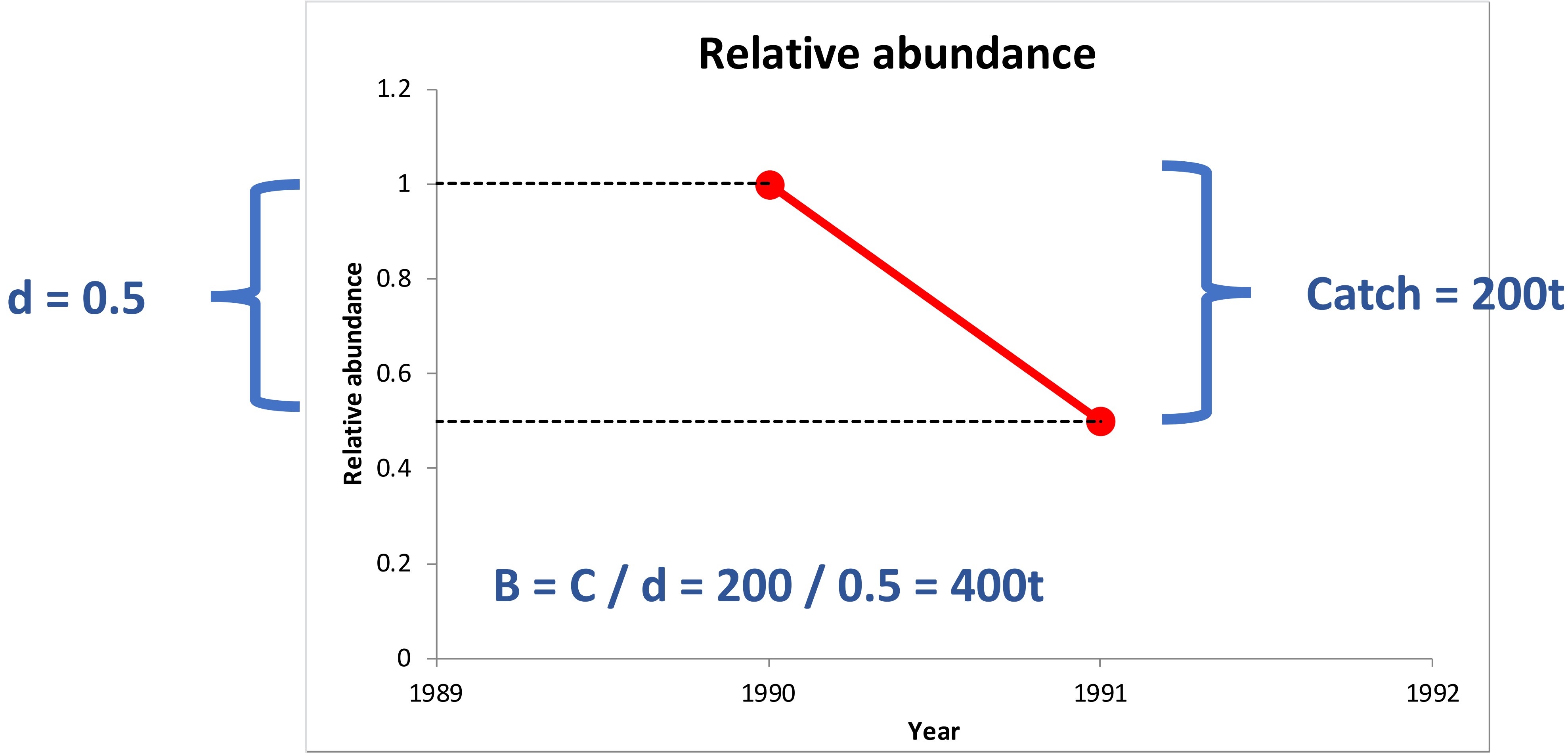
Estimating absolute abundance from an Index of relative abundance

d = 0.5

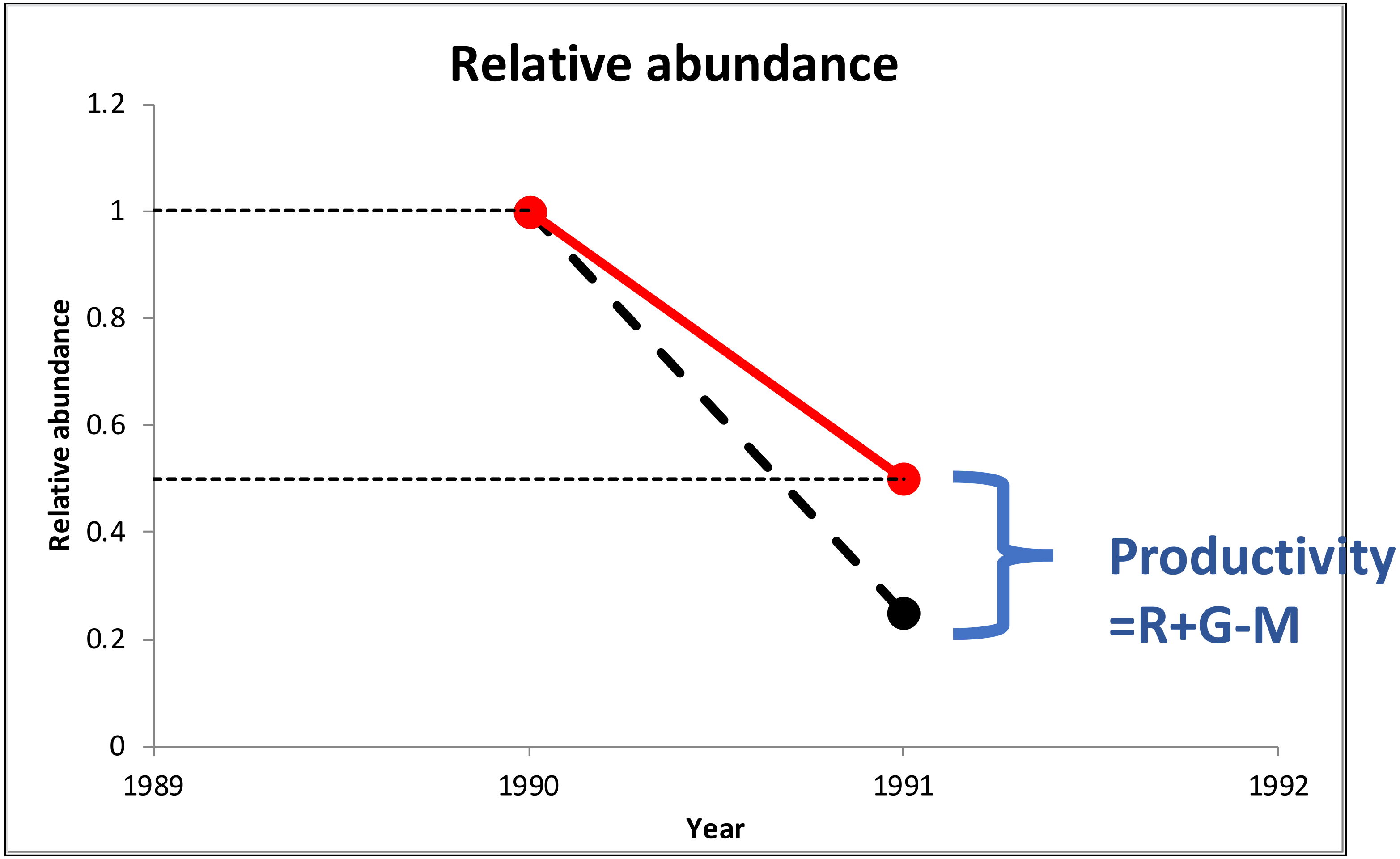


Catch = 200t

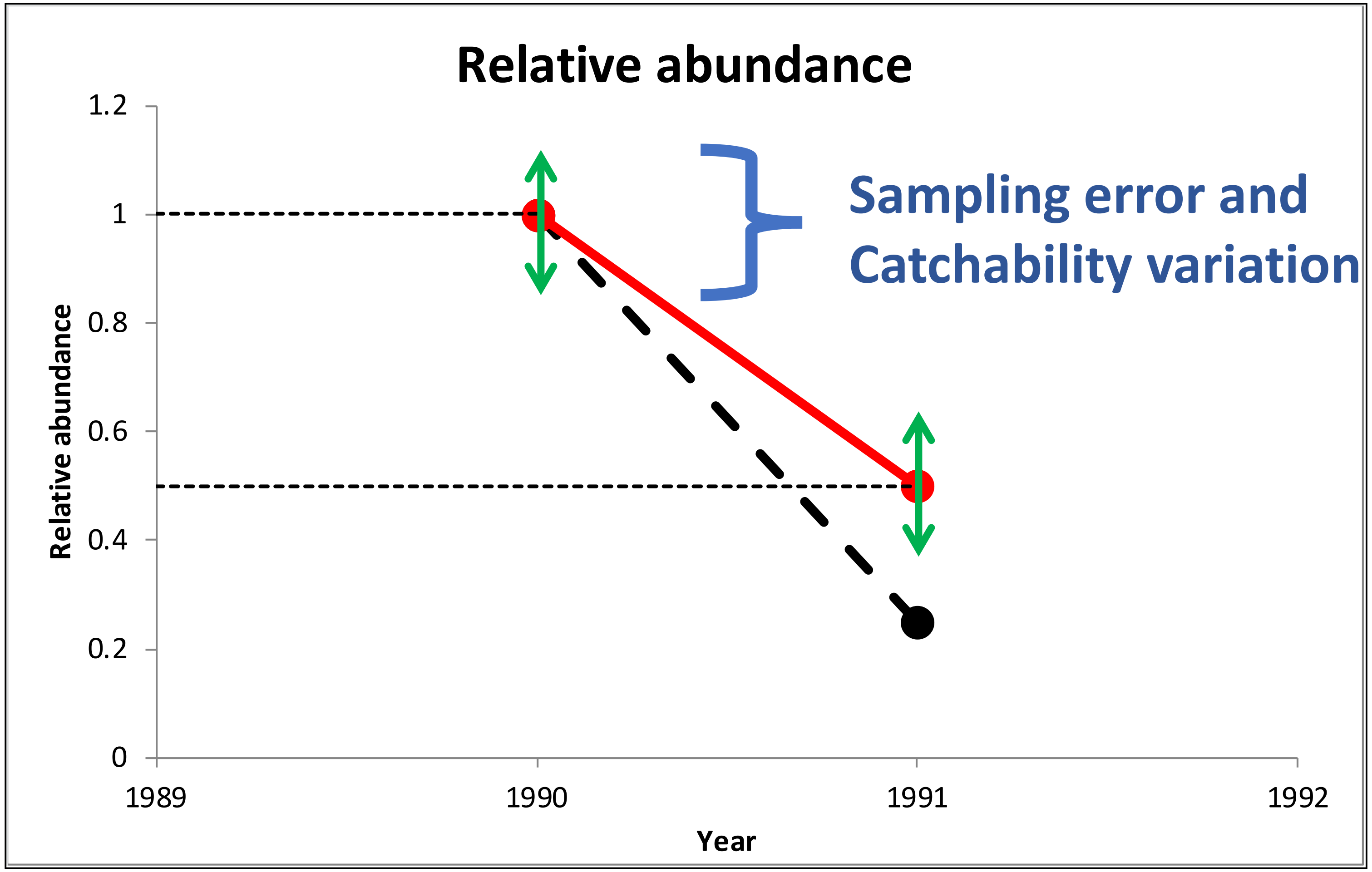
Estimating absolute abundance from an Index of relative abundance



Estimating absolute abundance from an Index of relative abundance



Estimating absolute abundance from an Index of relative abundance



Why is CPUE needed?

- Many stocks do not have surveys or tagging studies
- A index of relative abundance is needed to estimate
  - Depletion level
  - Absolute abundance

- A population dynamics model is needed to adjust for R, G, and M
- Precision is important
  - Sampling error
  - (random) Process error

- Model misspecification related to the index

CPUE issues: assumptions

CPUE is proportional to abundance

Catchability does not change systematically over time

The proportion of the population (size, sex, …) represented by the CPUE is known, or can be estimated, and does not change systematically over time

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CPUE issues: CPUE is proportional to abundance

$$\frac{C_t}{E_t} = qN_t$$

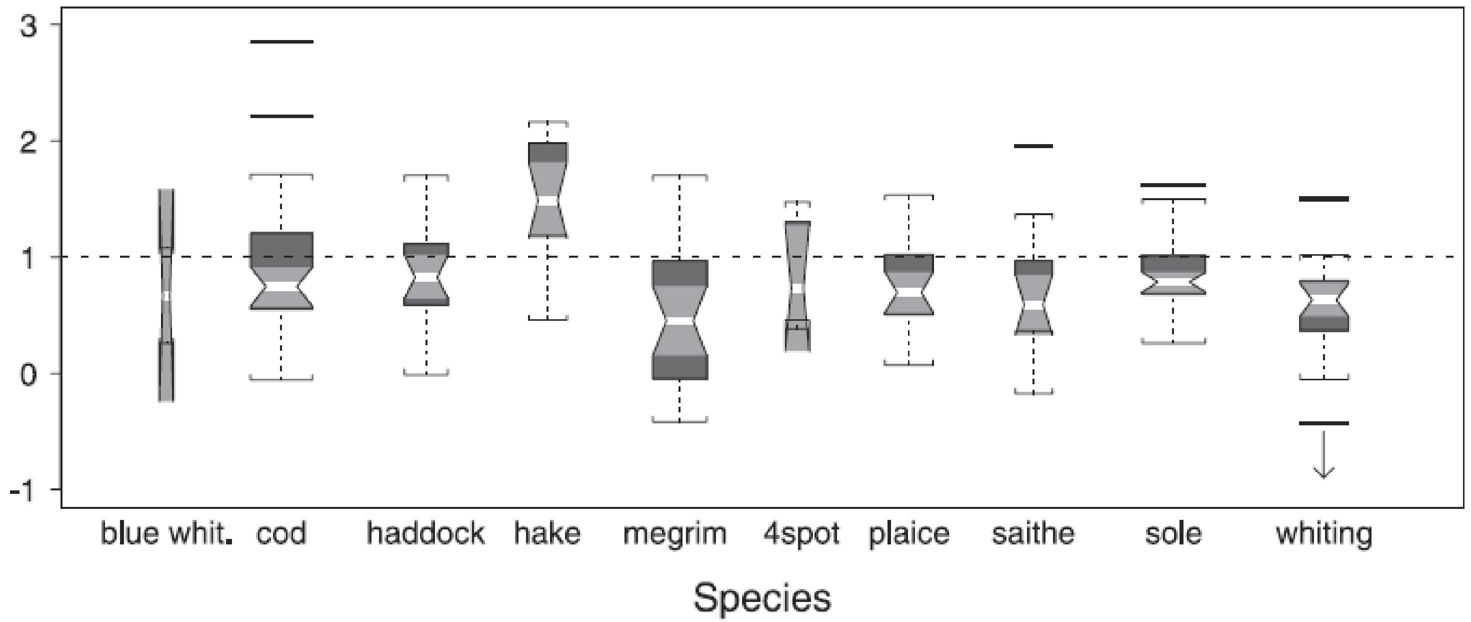
Catchability is
constant over time

CPUE issues: Hyperstability

Fig. 3. Summary of shape parameter β by species, age, and gear type. The boxplots show the limits of the middle half of the data (the line inside the box represents the median). The amount of data is shown as the width of the boxes that are proportional to the square root of the number of data points. The notches are the approximate 95% confidence intervals of the median. If the notches on two boxes do not overlap, this indicates a difference at a rough 5% significance level. The upper quartile and lower quartile provide the outline of the box. Whiskers are drawn to the nearest value not beyond 1.5(interquartile range) from the quartiles; points beyond are drawn individually as outliers. The arrows indicate the outlier with $\hat{\beta} = -3.23$ (details given in text). Details of the species and gear types are given in Tables 1 and 2, respectively.

Hyperdepletion

Hyperstability



Harley, S. J., Myers, R. A., and Dunn, A. 2001. Is catch-per-unit-effort proportional to abundance? Canadian Journal of Fisheries and Aquatic Sciences, 58: 1705-1772.

CPUE issues: factors that cause q to change over time

- Change in the efficiency of the fleet
  - Learning about the location and behavior of fish, or how to operate gear
  - New technology
- Species targeting
  - Catchability increases for the new target species
  - Catchability decreases for the previous target species
- Environmental variation
- Dynamics of the population or fishing fleet
  - Catchability related to abundance. If fish aggregate, it may be easy to find them when abundance is low
  - May depend on how effort is defined
  - Spatial expansion/contraction of the fleet can cause the relationship between cpue and abundance to be non-linear
- Management measures
  - Spatial closures, gear limitations, catch quotas, size limits
- Other factors
  - Depredation, gear saturation, gear interference, misreporting, stock structure (e.g. harvesting multiple stocks together, or fishing only a small portion of a stock), capture of more vulnerable individuals in initial stages of the fishery, age- or size-specific selectivity, individual variability in natural mortality

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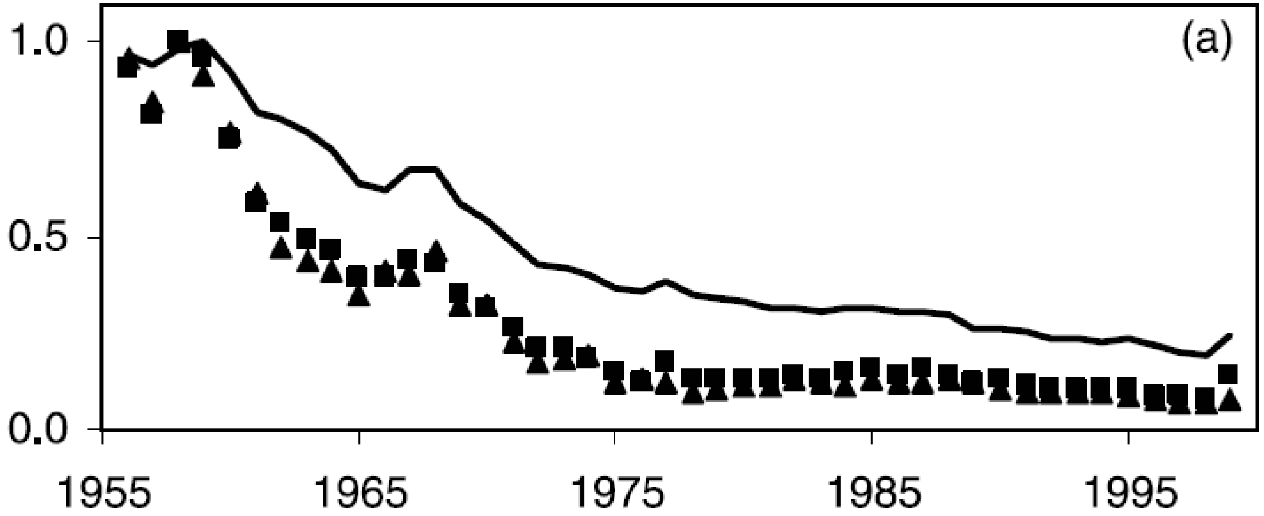
CPUE issues: what portion of the stock does the CPUE relate?

- CPUE measures only the component of the population that is vulnerable to the gear
- It may be proportional to this component of the population, but not to the total population.
- The proportion of the population that is vulnerable to the fishery depends on:
  - size and age of fish
  - horizontal and vertical distribution of fish
- The amount of overlap of spatial distribution of the fish population and the fishing fleet can have a considerable influence on how cpue relates to abundance
- If the fishery operates on only a fraction of the population and the mixing rates of fish among areas is low, there will be little relationship between cpue and total population abundance.

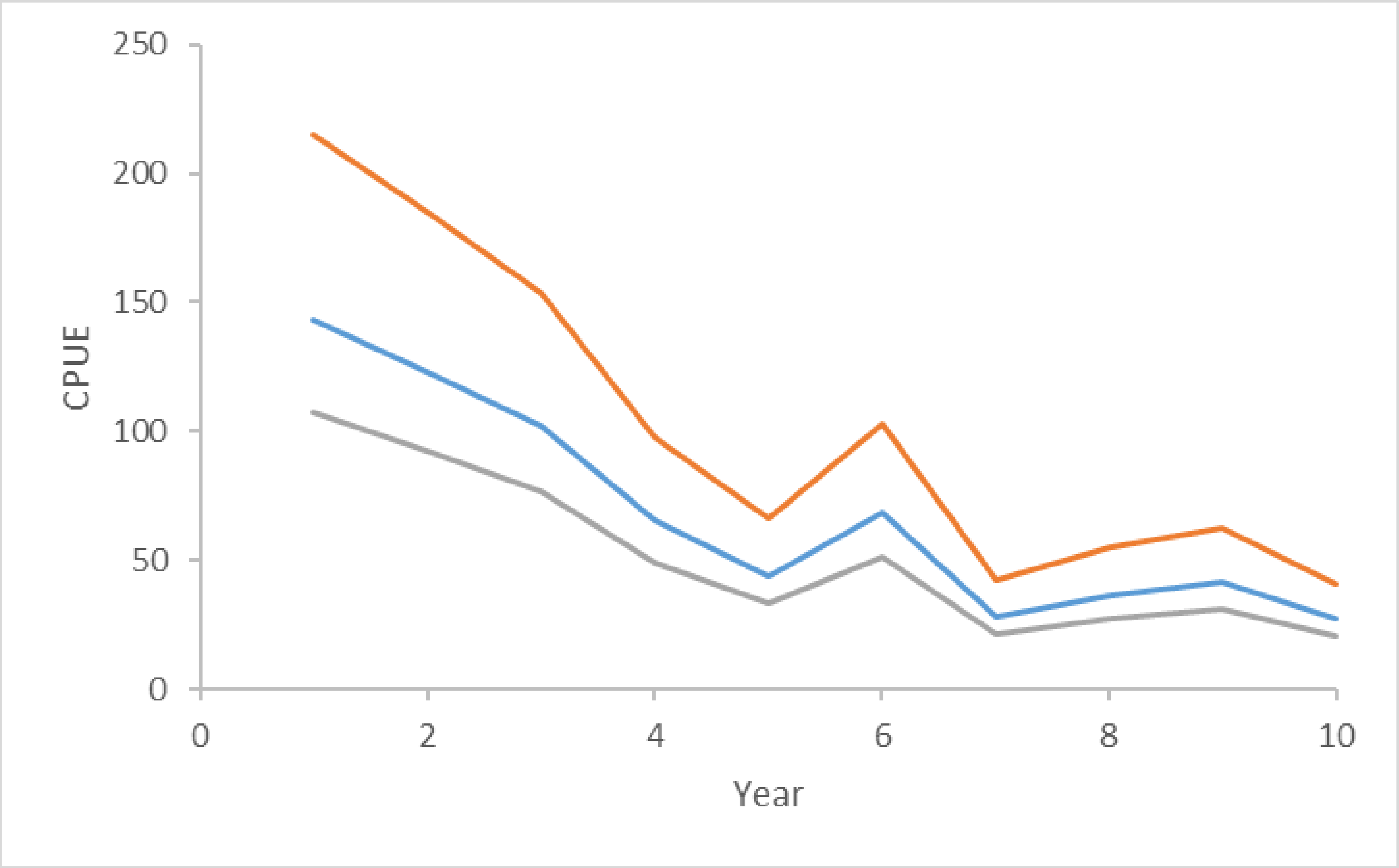
CPUE issues: Hyperstability

Fig. 1. Catch per unit effort (CPUE) trends for large tuna and billfish (total number of fish per hook) from the 5 × 5 degree cell Japanese long-line database (Myers and Worm 2003), estimated by three alternative methods for (*a*) Atlantic, (*b*) Pacific, and (*c*) Indian oceans. Full spatial (solid line) assigns mean of first three observed catch rates to each cell for years before it was first fished and the last observed catch rate for years after it was last fished. Restricted spatial (▲) is the mean catch rate over only those cells that were actually fished each year. Ratio (■) is simply total catch summed over all cells divided by total effort.

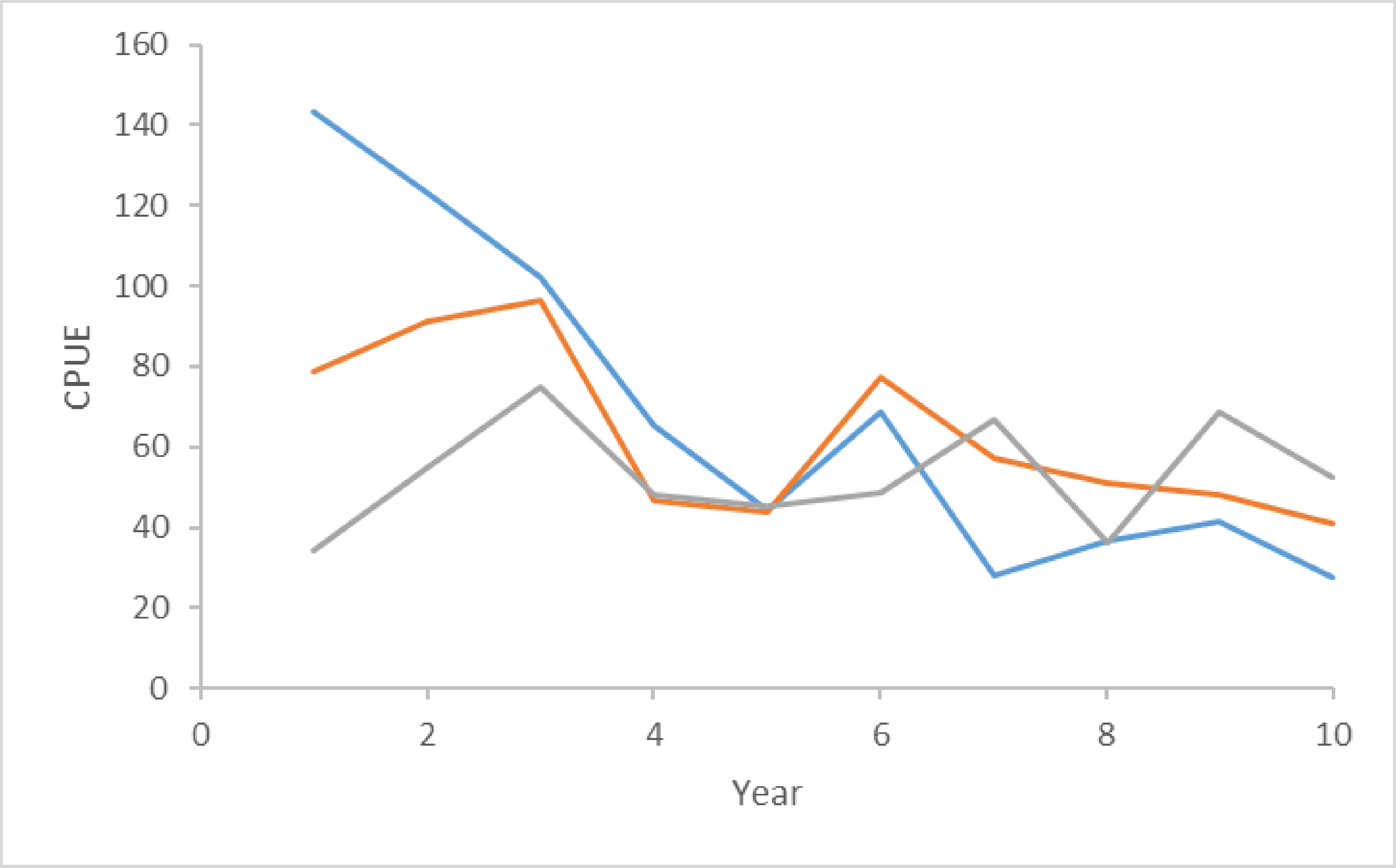


Walters, C. J. 2003. Folly and fantasy in the analysis of spatial catch rate data. Canadian Journal of Fisheries and Aquatic Sciences, 60: 1433-1436.

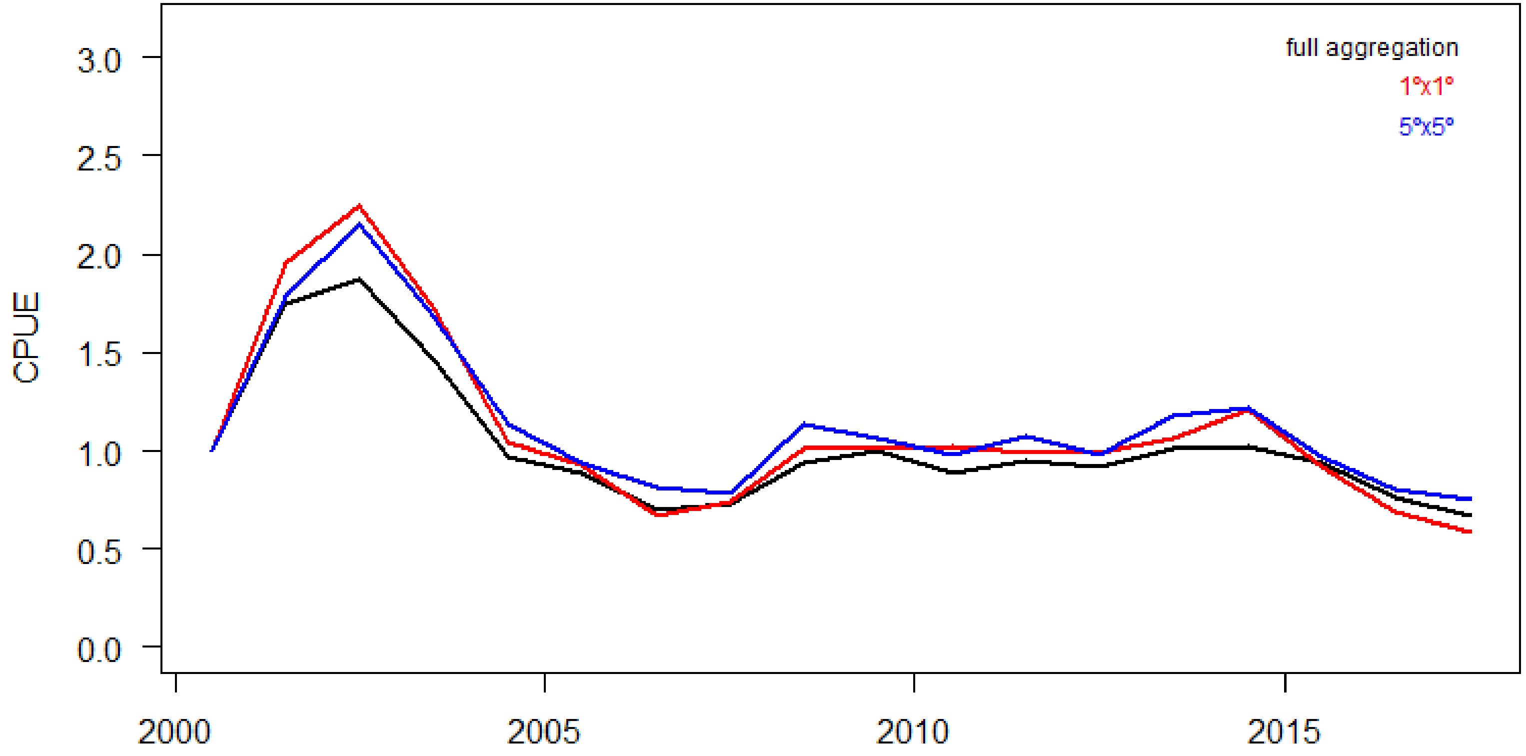
CPUE issues: GLM area main effect



CPUE issues: GLM area year interaction



Spatio-temporal modelling: Spatial weighting



Data weighted

Spatially weighted

Figure 2. Annual yellowfin nominal CPUE calculated by the three alternative methods. Black = data weieghted, red = spatial weighting using 1x1 degree resolution, blue = spatial weighting using 5x5 degre resolution. Purse seine sets used in the analysis only include those form vessels that make 50% or more dolphin sets, 25% or less floating-object sets, and north of the equator. The CPUE is calculated over squares with effort (> 0.1 days) for all years.

Spatio-temporal modelling: missing at random

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Spatio-temporal modelling: missing on the edges

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Spatio-temporal modelling: missing in patches

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0	0	0	1	1	0	1	1	0	0	1	0	0	0	0	0	1	1	0	0	0	1

Density vs catchability

- Separate effects into population density and catchability
- Density used to create index of relative abundance
- Complicated, habitat could attract more fish or could make it easier to catch the fish

Spatio-temporal modelling of composition data

- The composition data is used both for the removal of catch and the CPUE based index of abundance
- “selectivity” in the stock assessment model does not simply represent contact selectivity, but also availability, which is a consequence of the spatial structure of the fleet relative to the stock.
- Fishery catch is not necessarily distributed spatially in proportion to abundance.
- In cases where the size composition differs among areas, the “selectivity” in the stock assessment model for the fishery-dependent index and the fishery catch could be different.
- The index selectivity should represent the contact selectivity
- The catch selectivity should represent both contact selectivity and availability, and will change over time with spatial changes in the fishery and/or stock distribution.

Spatio-temporal modelling: length composition

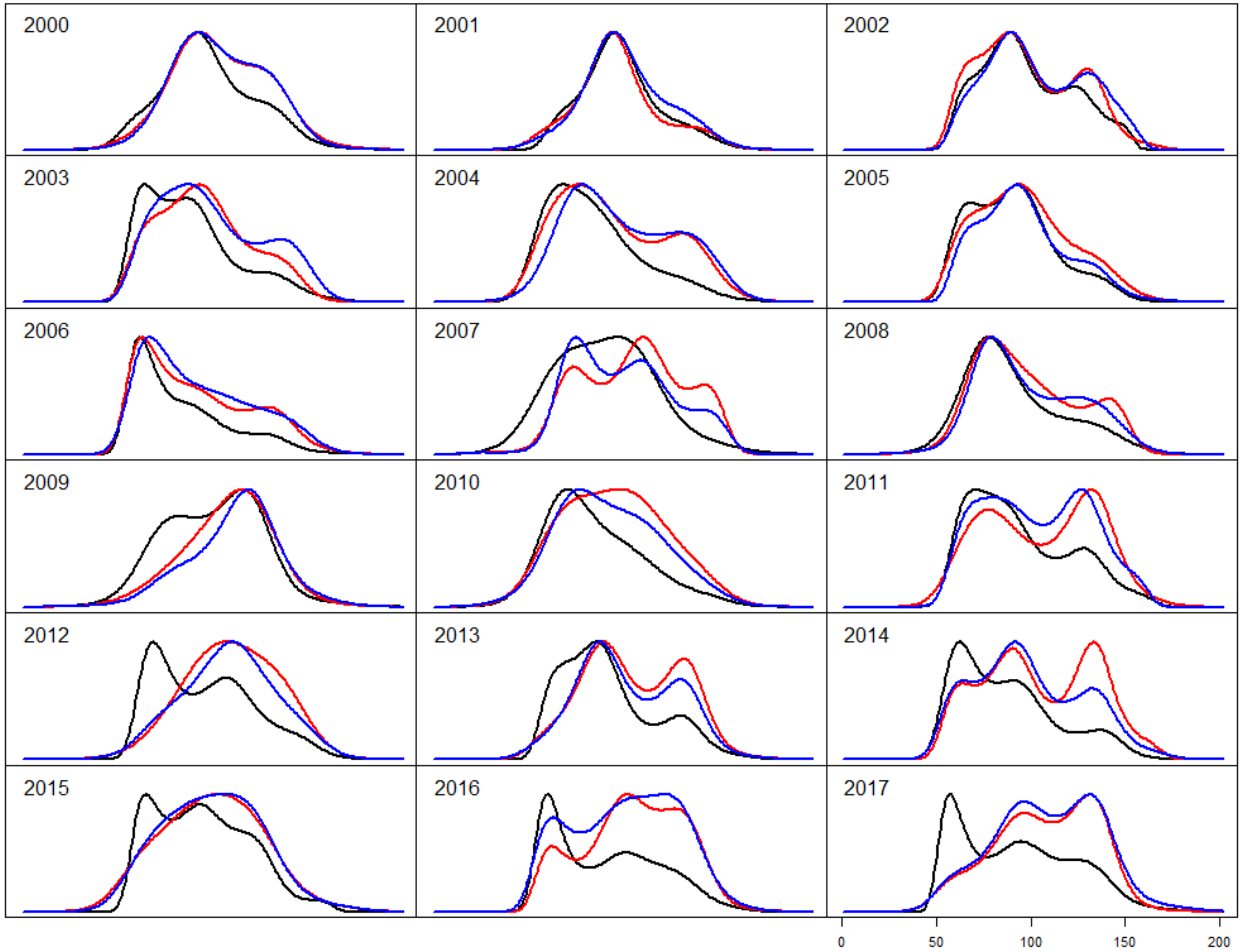

Figure 5. Length composition of the yellowfin catch calculated by the three different methods. Black = data weighting (each well sampled is given equal weight), red = spatial weighting by CPUE, blue = spatial weighting by catch.

Spatio-temporal modelling: length composition

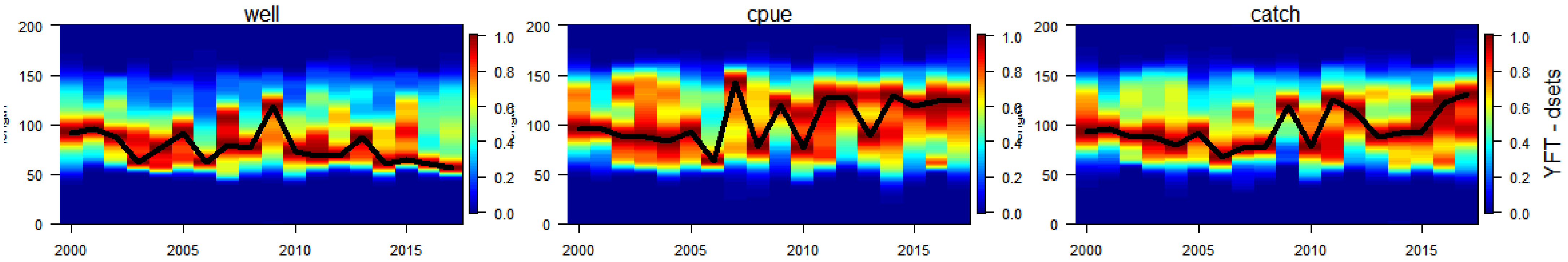

Figure 6. Length composition of the yellowfin catch calculated by the three different methods. Left = data weighting (each well sampled is given equal weight), middle = spatial weighting by CPUE, right = spatial weighting by catch. The black line is the mean length.

Spatio-temporal modelling: length composition

- The index and the estimated size composition should both be derived using the same spatio-temporal model.
- The catch composition should be weight by catch
- The index composition should be weighted by CPUE
- Issues with fitting it in Stock Synthesis due to double use of the data and likelihood structure

Remaining issues

- Increased vessel efficiency
- Targeting
- Preferential sampling
- Non-random missing cells
- Computational demands

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Thank you!