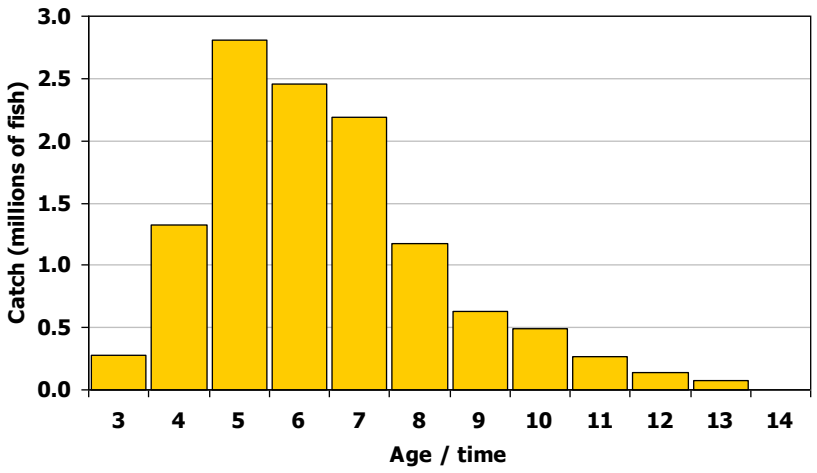
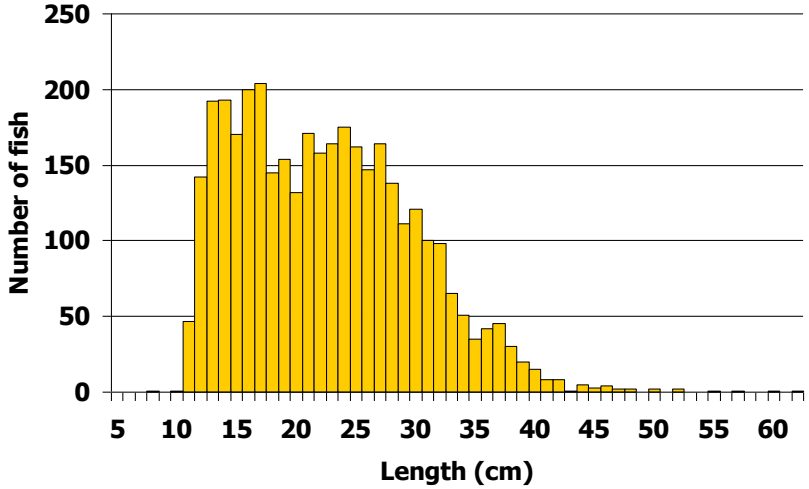
USP

Estimating mortality

Estimating Z: Catch curve analysis

- Data requirements:
  - A reliable method to determine age or growth rate of stock of interest
  - Relative or absolute numbers of fish by age/length group
    - Temporarily snapshots: pseudocohort analysis
    - Series of measurements through time: cohort analysis

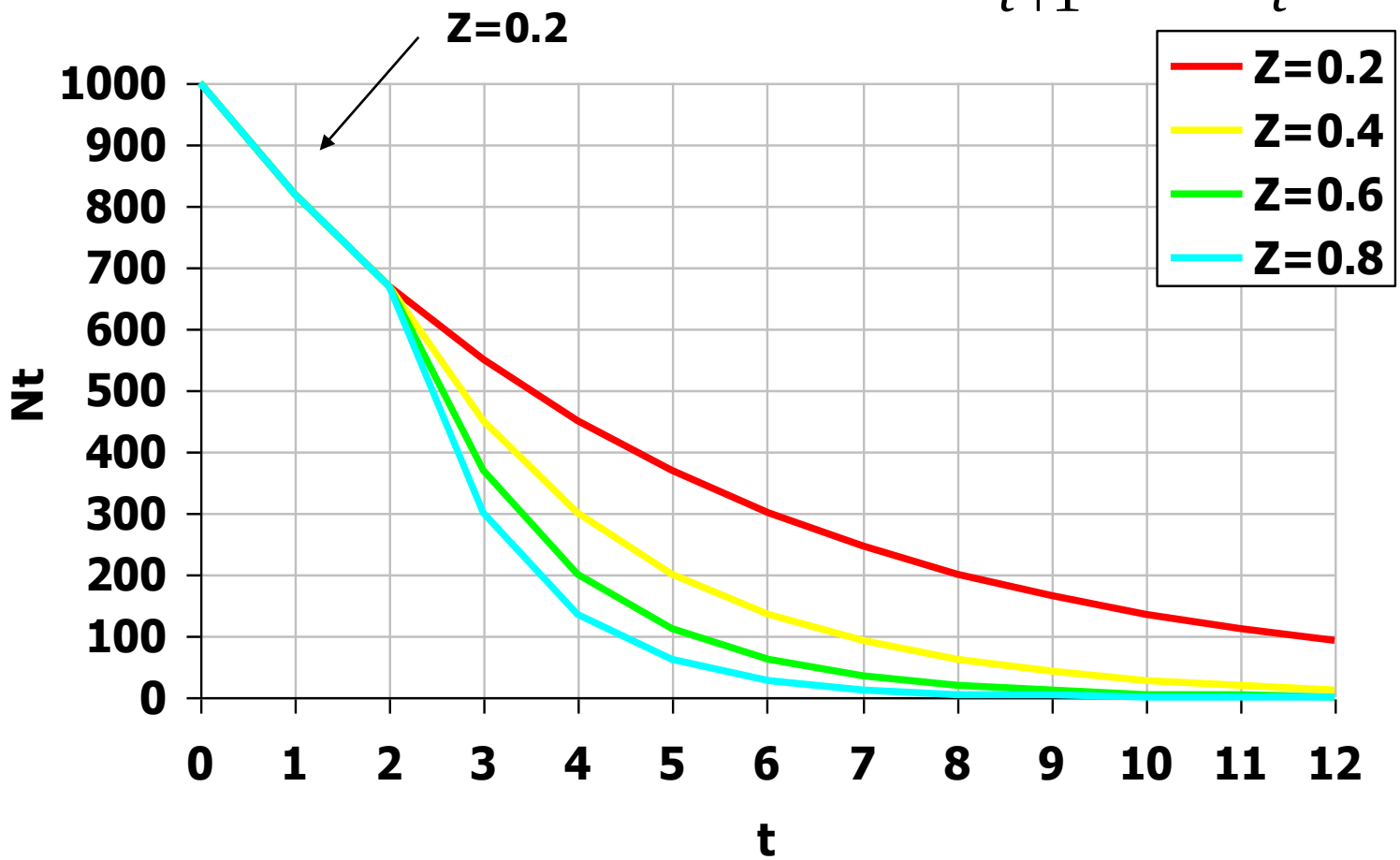




Revision: The stock equation

Z=M+F

$$N_{t+1} = N_t e^{-M_t + F_t}$$



Estimating total mortality (Z): Part 1

- Lets pretend we have information on age of the fish. The stock equation for a cohort, over a short time interval is then:

$$N_{a+1,y+1} = N_{a,y} e^{-Z_{a,y}}$$

  - $N_{a+1,t+1}$: Abundance of age a+1 in the beginning of time t+1
  - $N_{a,t}$: Abundance of age a in the beginning of time t
  - $Z_{a,t}$: Total mortality of age a over the time period t to t+1
- Taking a logarithm of an exponential function gives:

$$\ln N_{a+1,y+1} = \ln N_{a,y} - Z_{a,y}$$

$$Z_{a,y} = \ln N_{a,y} - \ln N_{a+1,y+1}$$

$$Z_{a,y} = \ln\left(\frac{N_{a,y}}{N_{a+1,y+1}}\right)$$

If we have a relative measure of population size we can estimate Z

Estimating total mortality (Z): Part 2

- The math:

$$CPUE_{a,y} = \frac{C_{ay}}{E_{ay}}$$

$$\text{Assume: } E_y = E_{y+1} \text{ and } q_a = q_{a+1}$$

$$Z_t = \ln\left(\frac{N_t}{N_{t+1}}\right)$$

$$= \ln\left(\frac{C_{ay} / E_y q_a}{C_{a+1} / E_{y+1} q_{a+1}}\right)$$

$$= \ln\left(\frac{C_{a,y}}{C_{a+1,y+1}}\right)$$

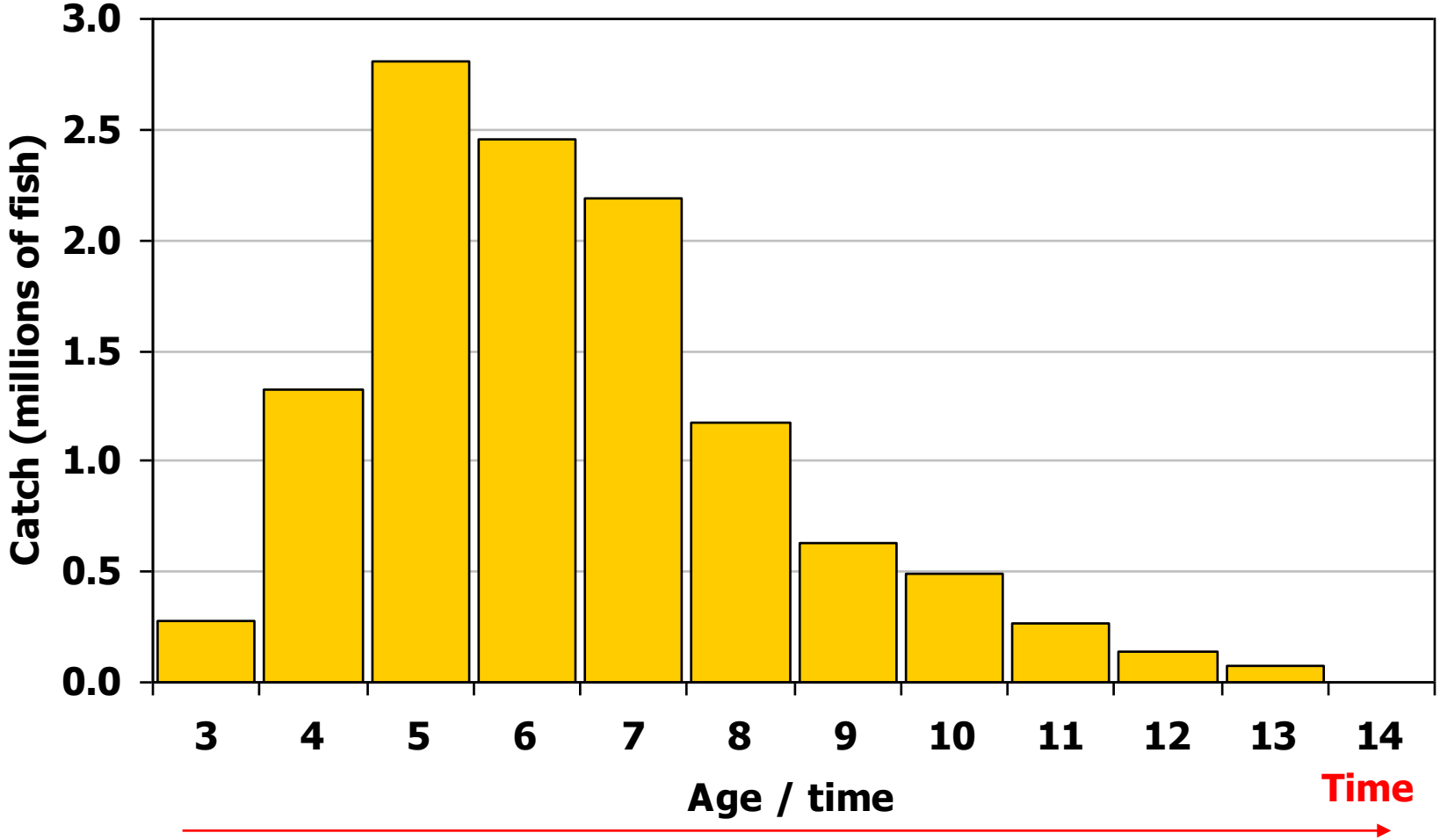
- If there has been no change in effort over time or in catchability by age (size) one can use the log ratio of the number of fish caught at each to estimate the total mortality.
- This derivation show that if we have some measurement of catches by age (or length) we can estimate Z.
- E: Effort
- q: Catchability

The catch development of one cohort

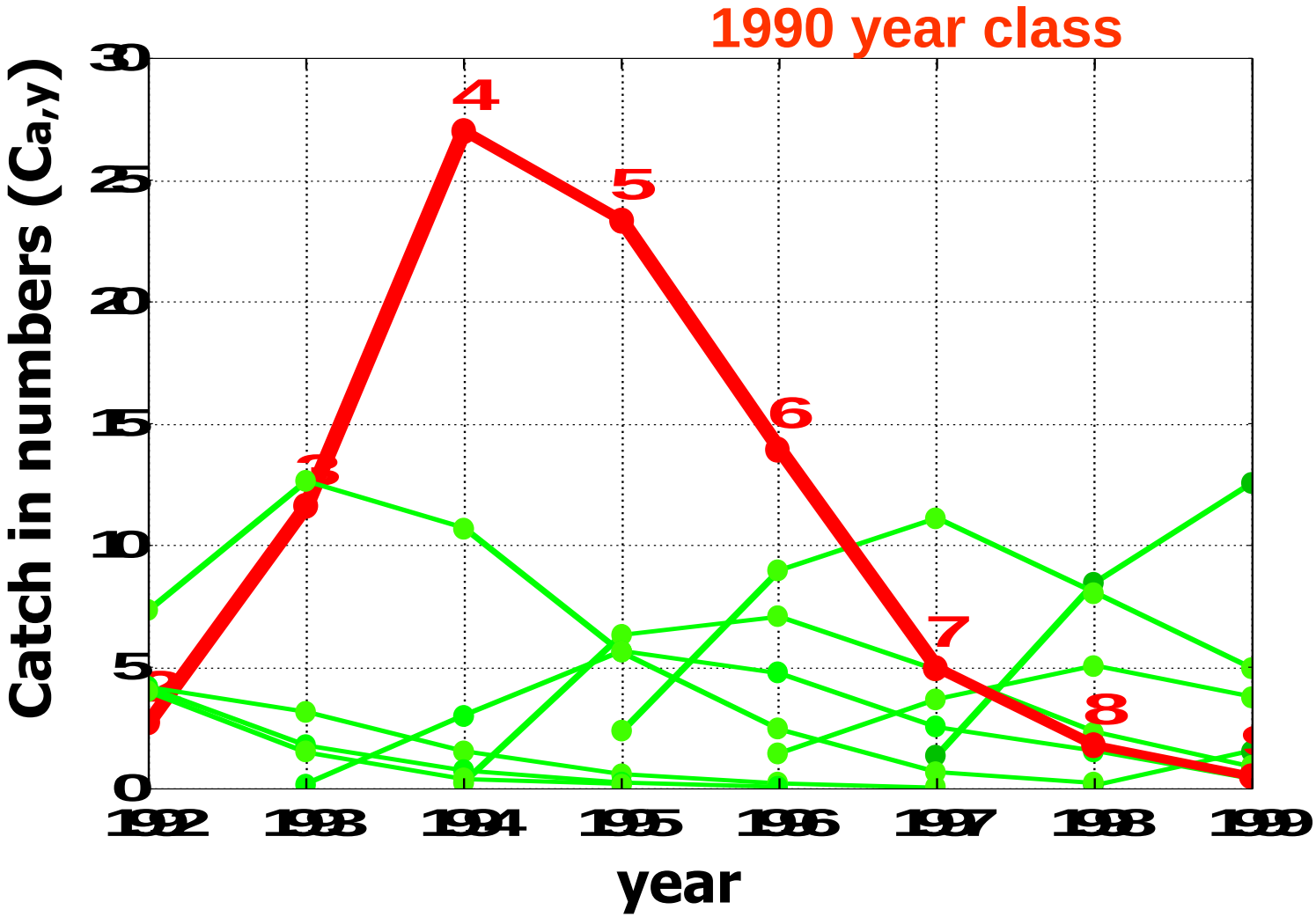
Catch per time unit

Younger fish less available (qa changes with age)

Decline in older ages due to mortality if qa does not change with age

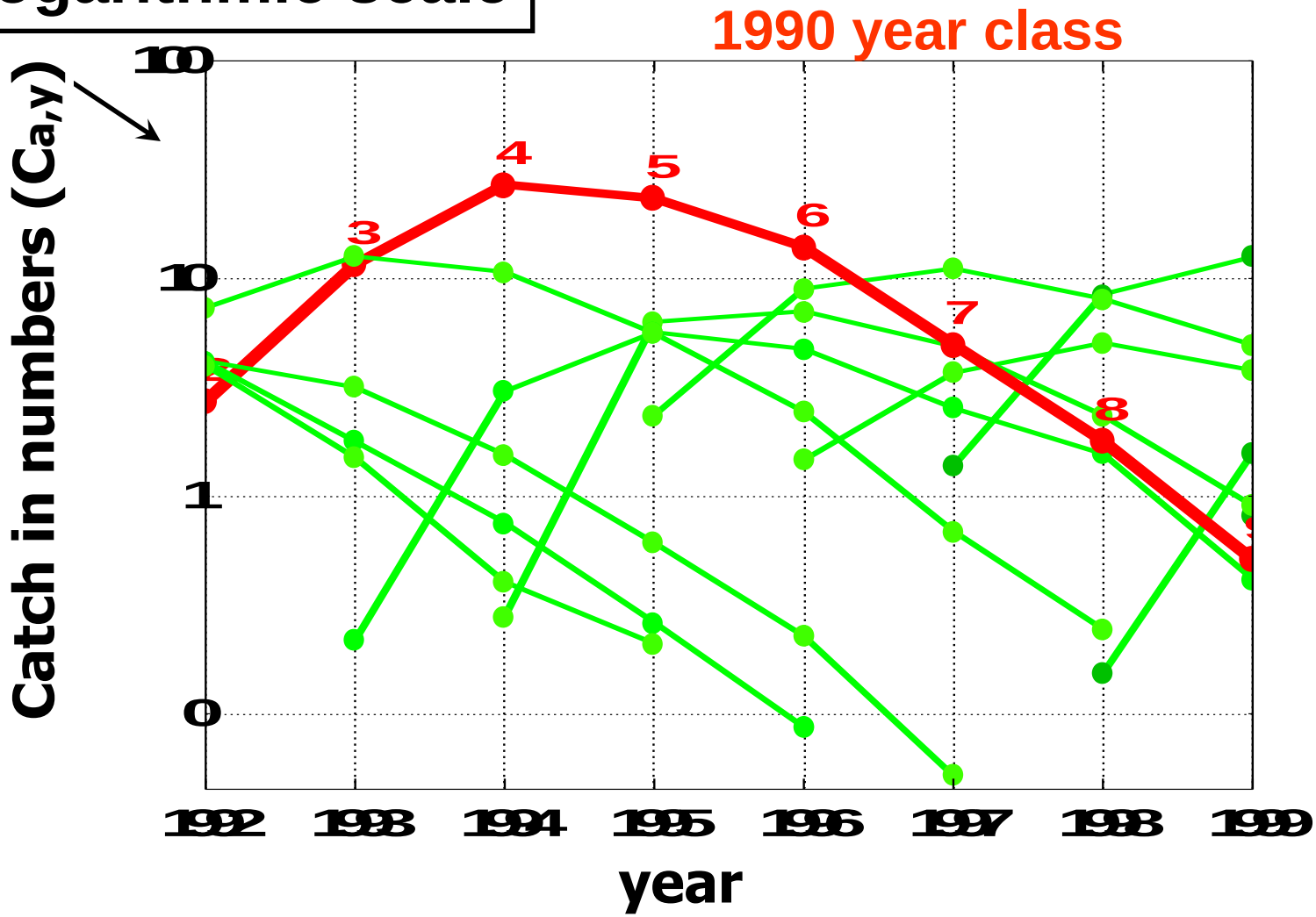


Estimating total mortality of older fish 1

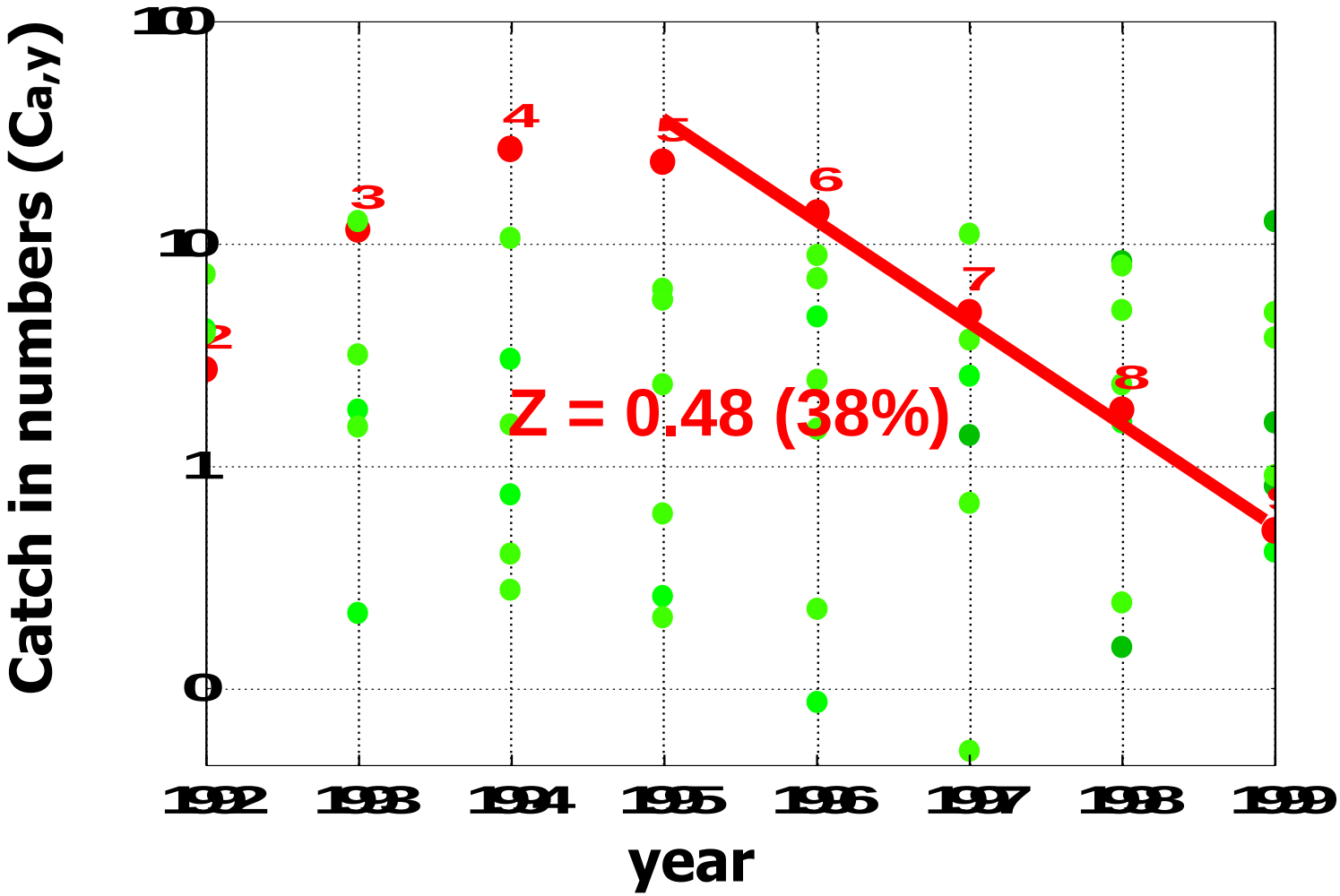


Estimating total mortality of older fish 2

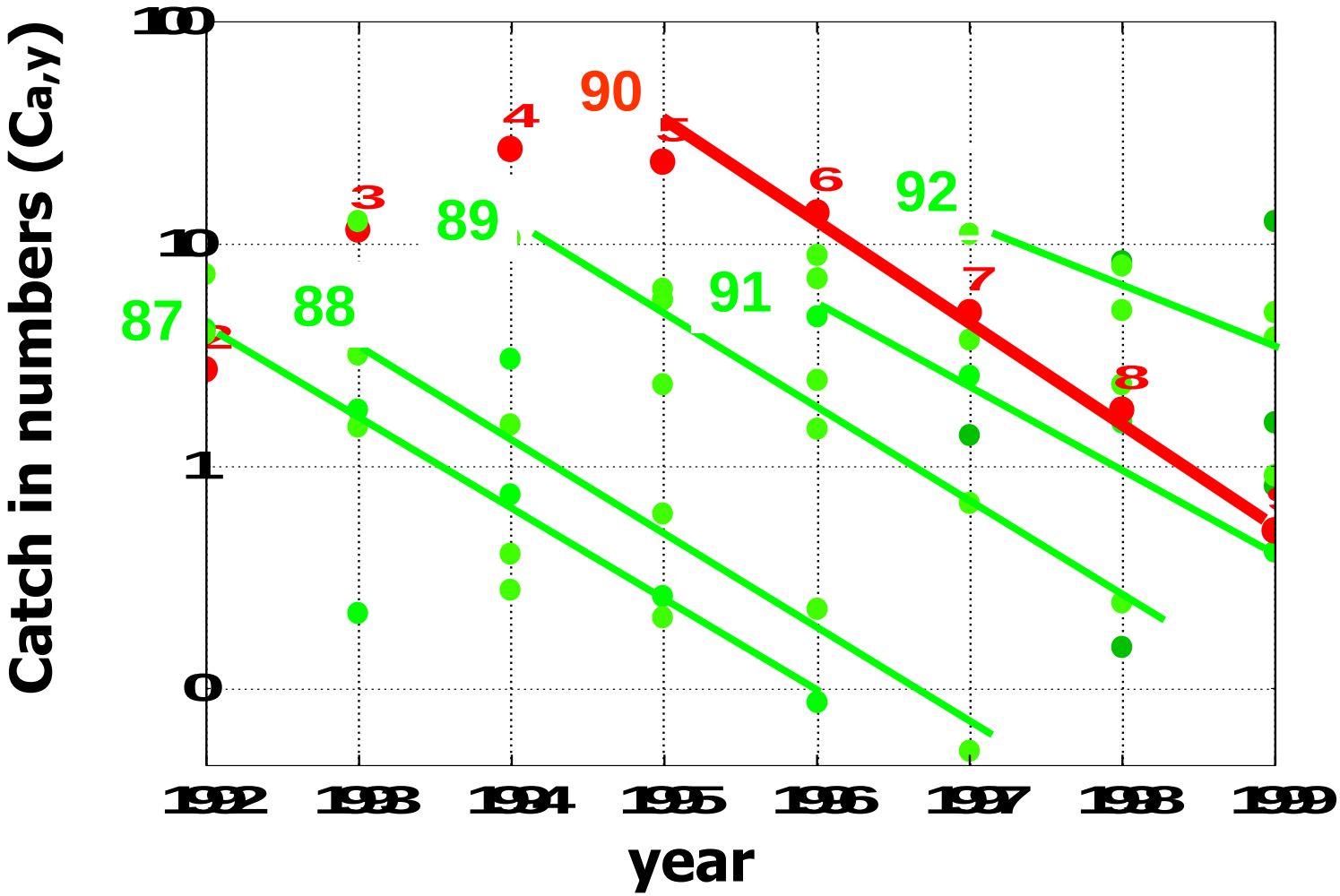
Logarithmic scale



Estimating total mortality of older fish 3

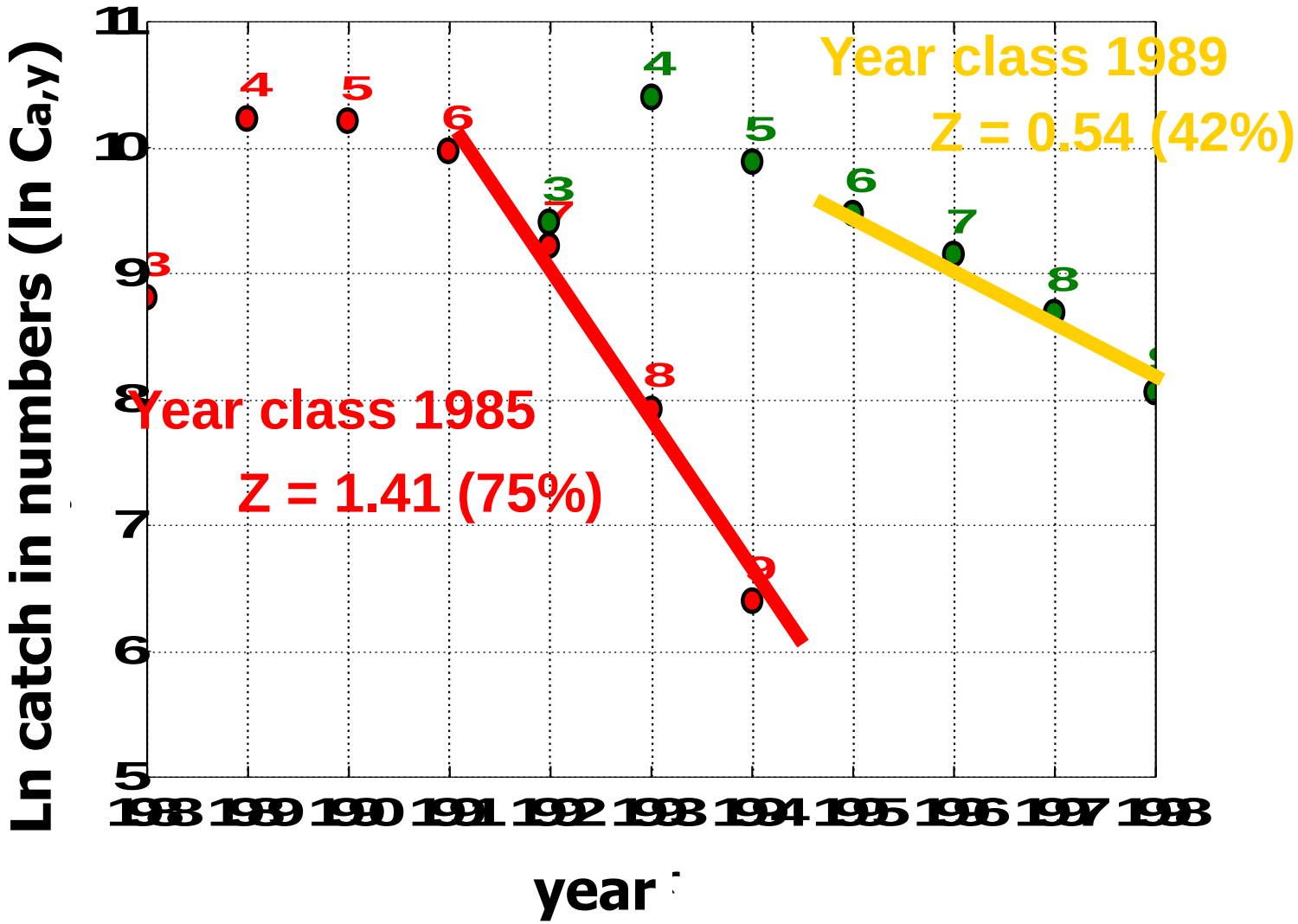


Estimating total mortality of older fish 4



Cod: Estimates of total mortality (Z)

Z = F + M

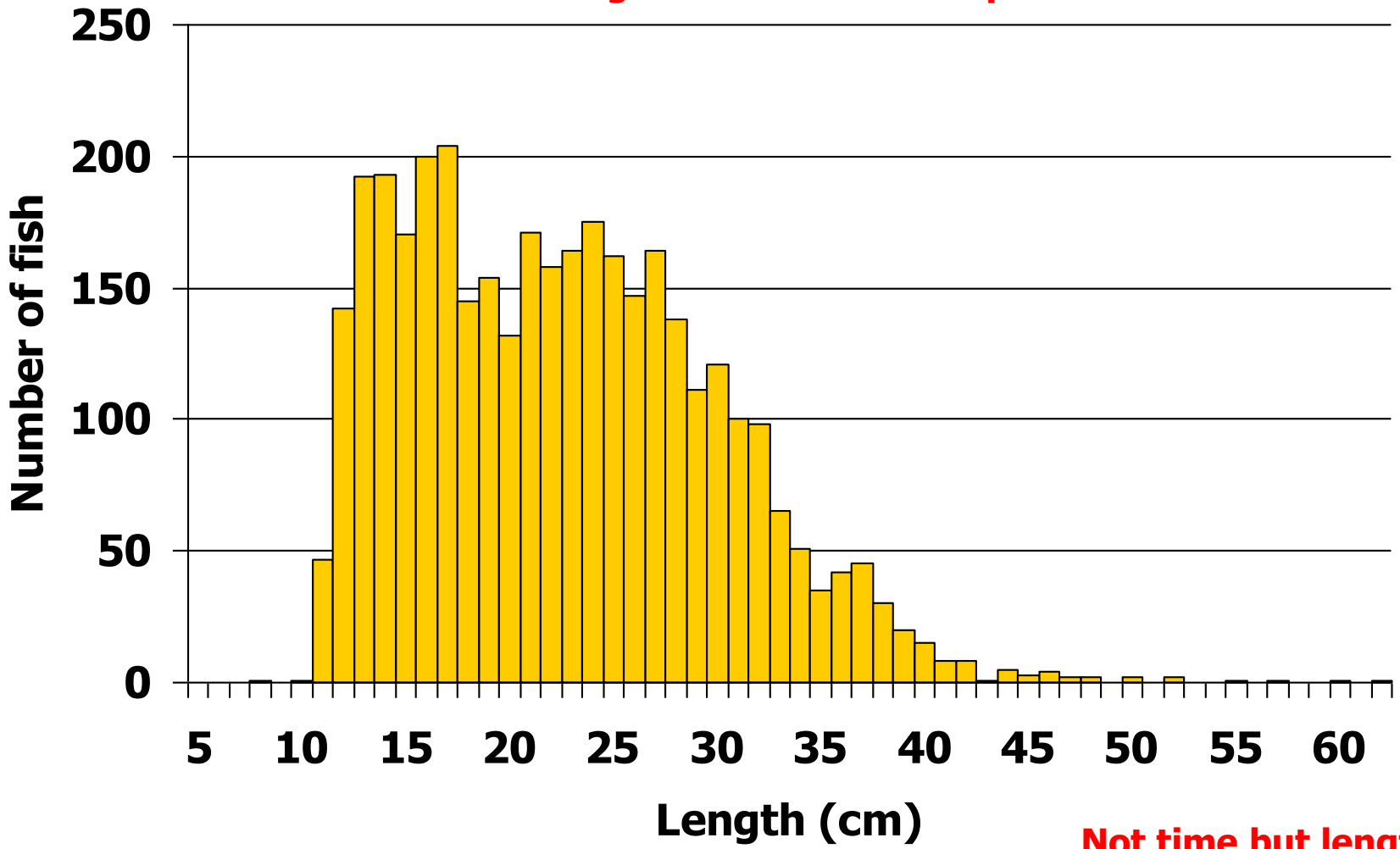


Catch curves from length data

How do we estimate mortality from length distributions?

Catch per effort, not per time

Need to convert length to time and catch per length interval to catch per time interval



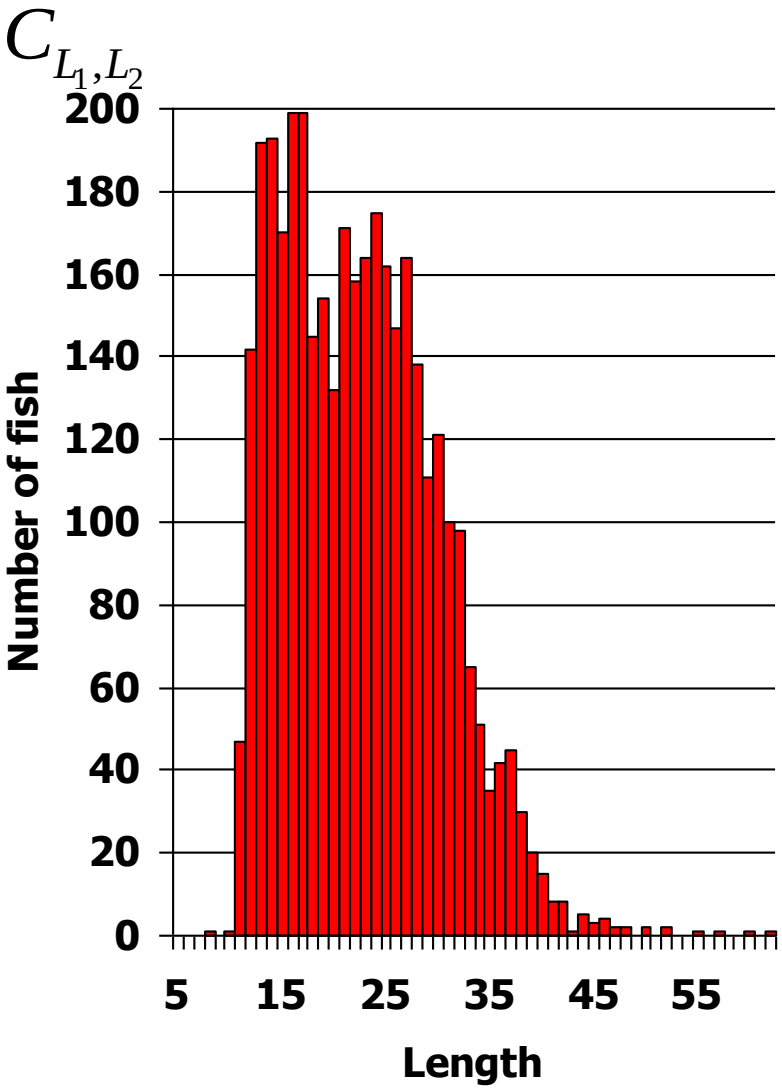
Not time but length

How do we estimate mortality from length distributions?

- Mortality is a rate measure relative to time
- Since relationship between time and length is nonlinear we need to transform the length frequency distribution
- Lets first define the number of fish caught in length interval from L_1 to L_2 as:

$$C_{L_1,L_2}$$

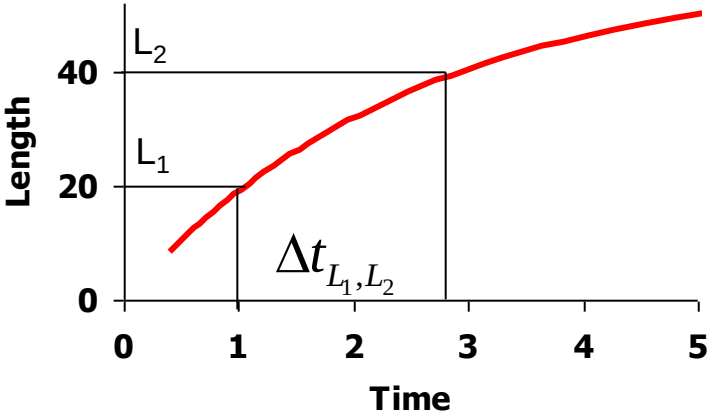
- We refer to this as catch from hereon



The inverse VBGF: Converting length to time

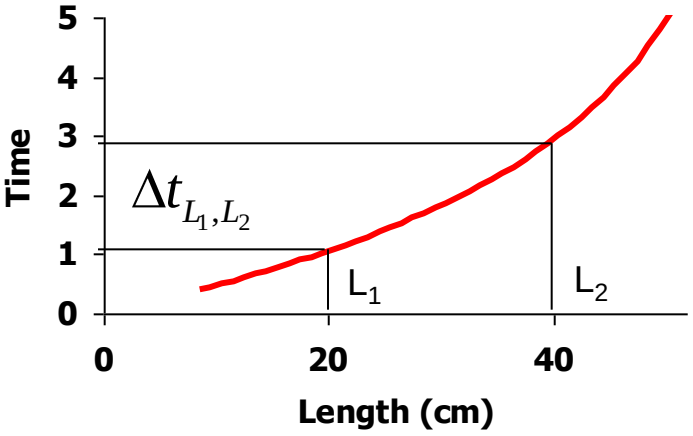
- If one has estimates of K and L∞ from the VBLF one can convert length intervals to time intervals by the following formula:

$$\Delta t_{L_1,L_2} = \frac{1}{K}\ln\left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)$$



- This is the time it takes a fish to grow from length L_1 to L_2
- The relative age at length L can be calculated by:

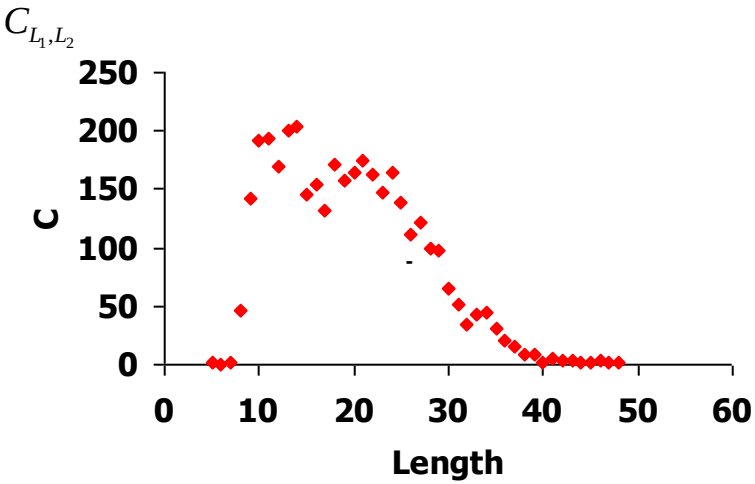
$$t_{L_1} = \frac{1}{K}\ln\left(\frac{L_\infty - L_1}{L_\infty}\right)$$



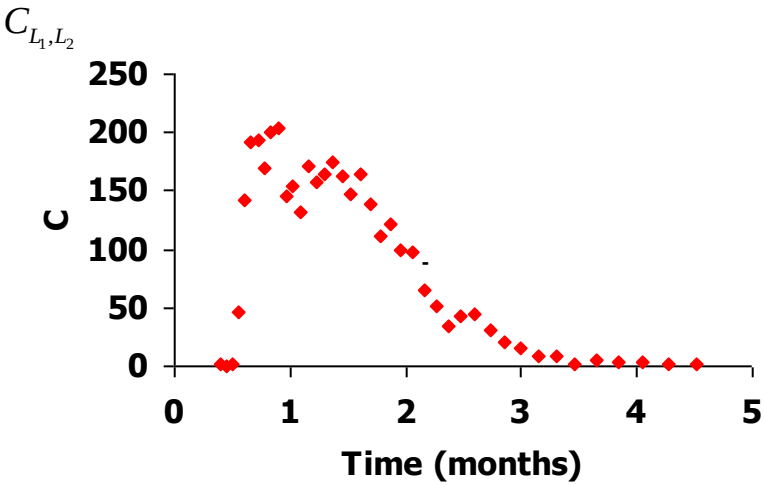
Converting length to time

- The age at midlength of the interval L_1 to L_2 is:

$$t_{0.5\ L_1+L_2} = \frac{1}{K}\ln\left(\frac{L_\infty - 0.5\ \ L_1 + L_2}{L_\infty}\right)$$



- This is used to convert length to age for a length frequency distribution

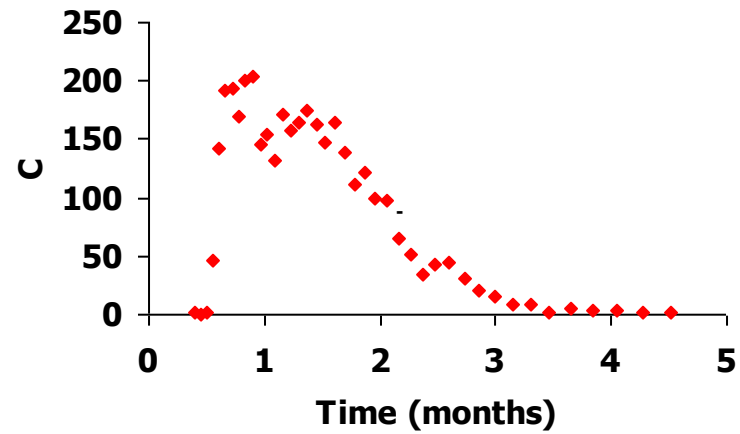


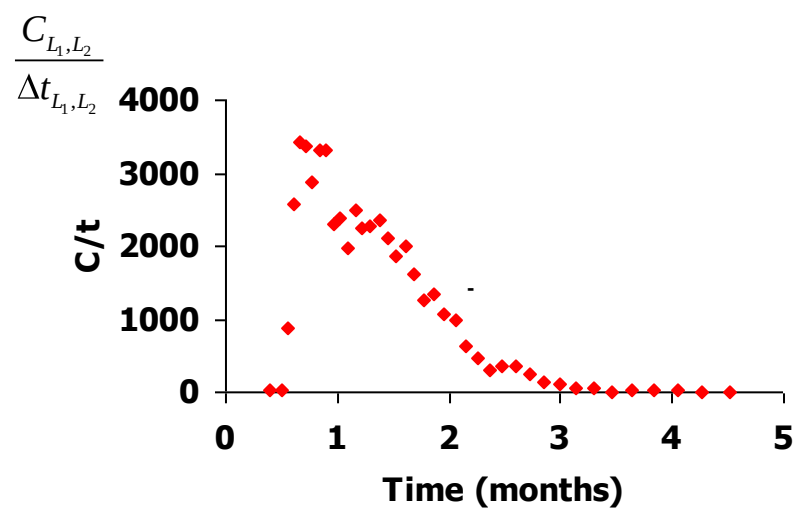
Normalising the length frequency distribution

- To take into account that a length distribution contains data where the time unit within each length interval is not constant we divide the catch with the time duration that it takes the fish to pass through the length interval

$$\frac{C_{L_1,L_2}}{\Delta t_{L_1,L_2}}$$

- We now have a plot which is equivalent to the age based data



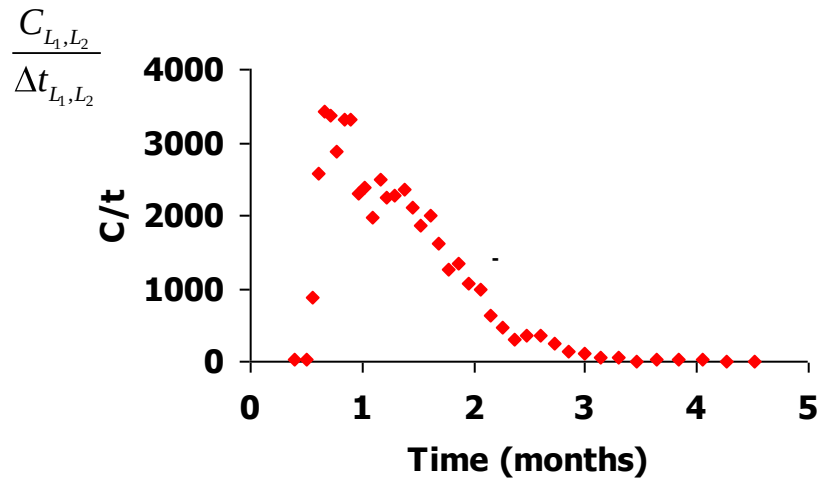


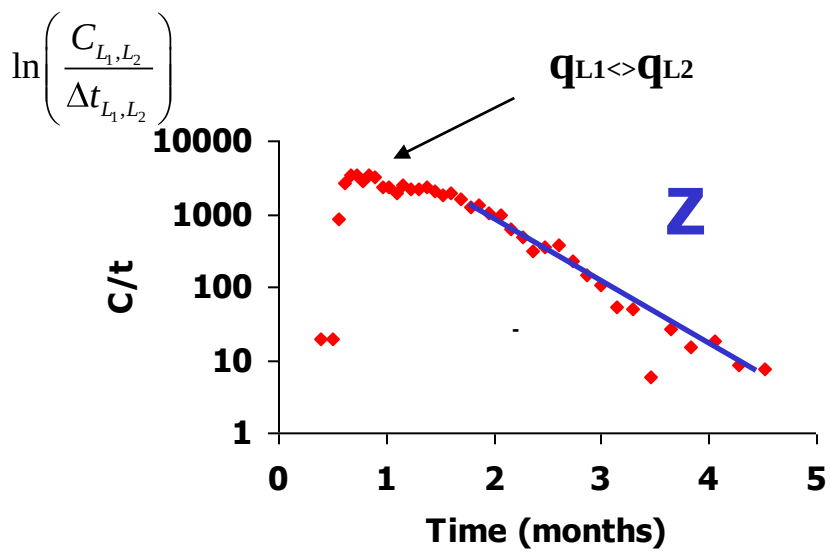
Estimating Z

- To estimate Z we take the logarithm of the of the catches per time unit and estimate the slope
- The formula in full is:

$$\ln\left(\frac{C_{L_1,L_2}}{\Delta t_{L_1,L_2}}\right) = a + Zt_{0.5(L_1+L_2)}$$

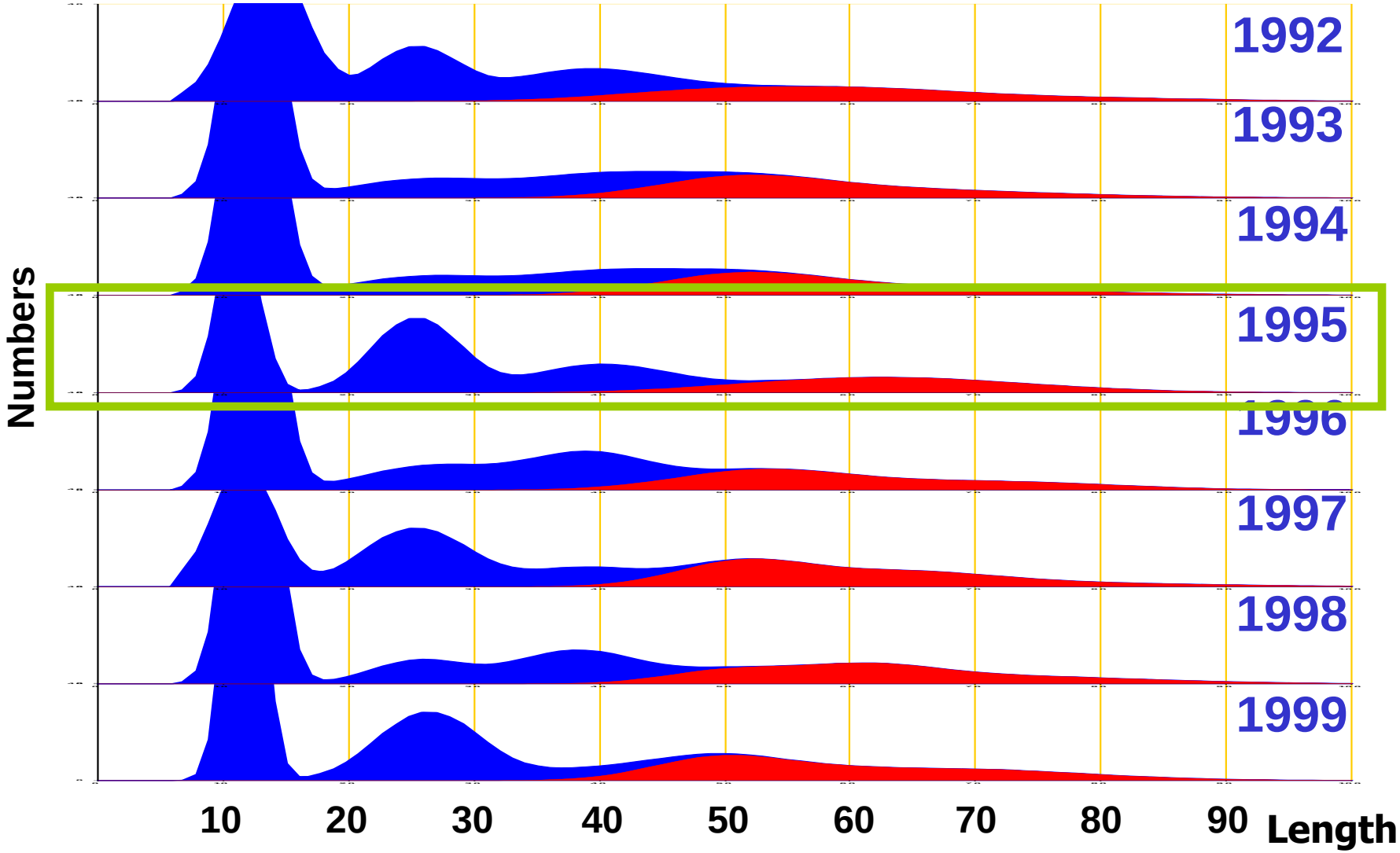
- Same assumption apply as for the age based catch curves:
  - i.e. $q_{L1} = q_{L2}$
  - Since there is gear selectivity at younger length we can only use the larger size ranges to estimate Z





Length based measurements

Snapshots (pseudochorts) most common



Estimating Z from a pseudocohort

- When operating on pseudocohorts the additional assumption is that the recruitment has been constant for the cohorts that are in the snapshot sample.
  - Ideally would take some length frequency samples over time and take some kind of an average value.

- Length based Z calculation are very sensitivity to the value of K and L_{inf} used
  - Best is to estimate K and L_{inf} on the stock of interest
  - If use value from literature, make sure they are appropriate for the stock in question

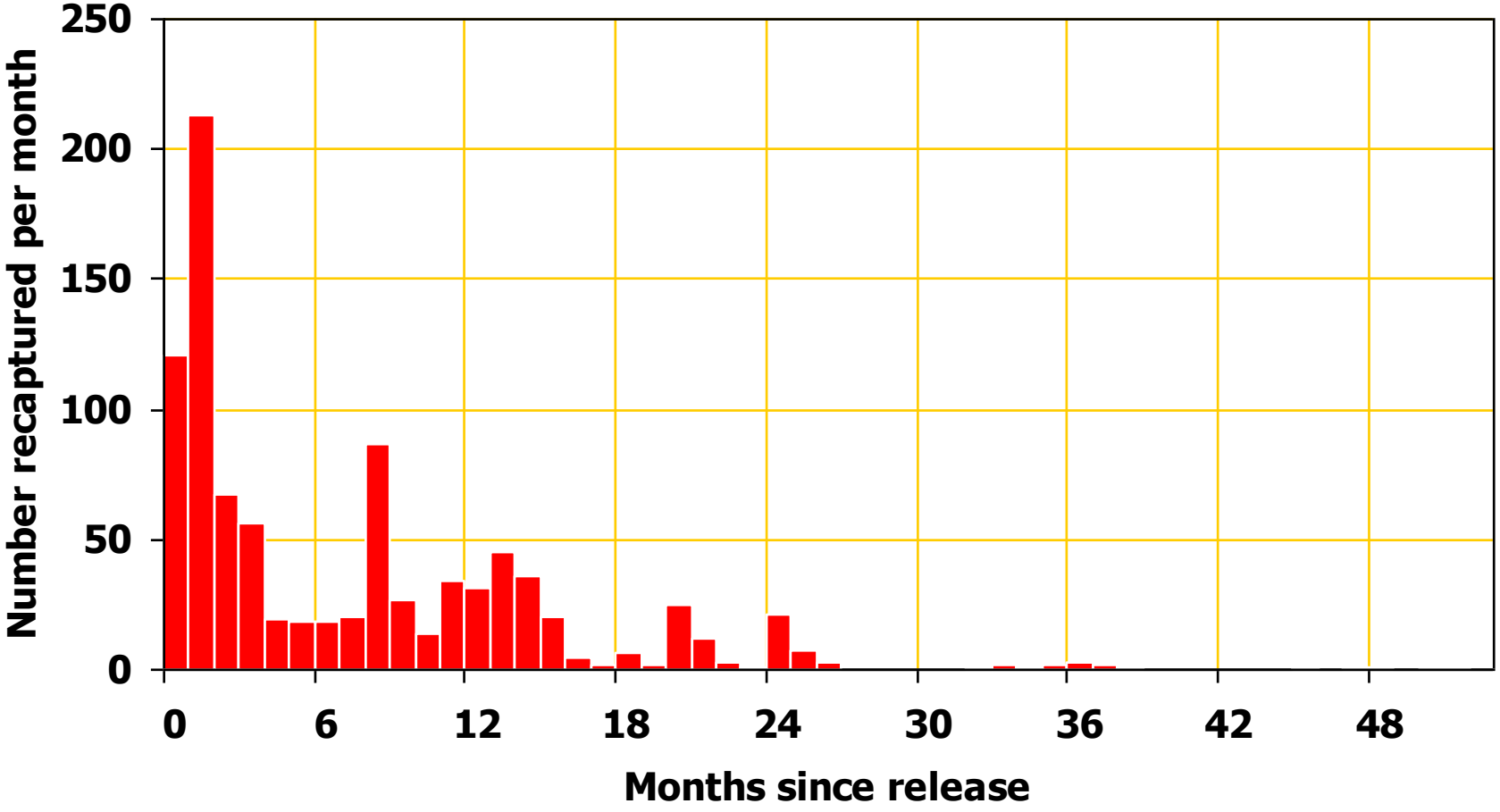
USP

Mark recapture experiments

(only the concept introduced here)

Number of recapture since release

Example: Dab



Number of recaptures since release

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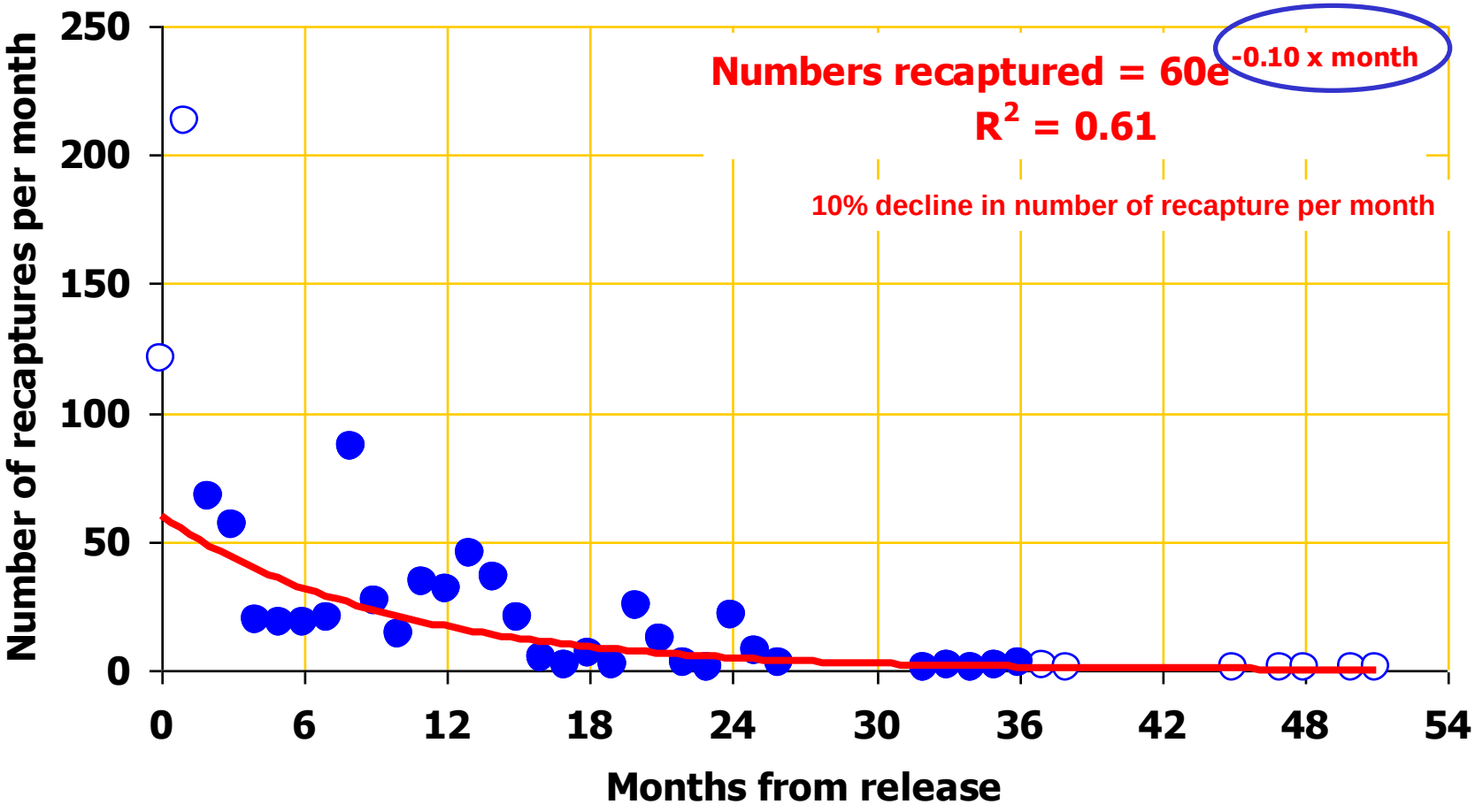
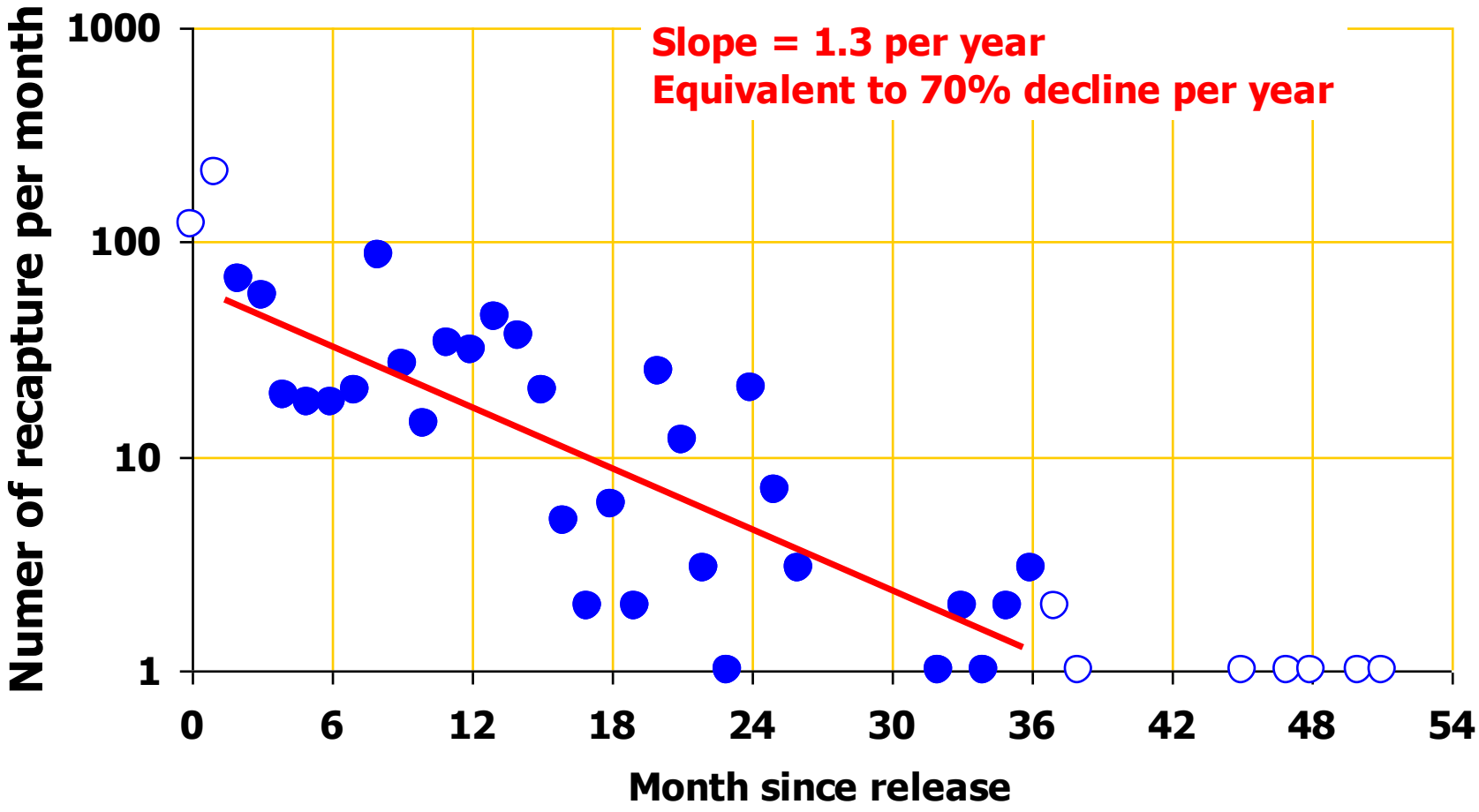


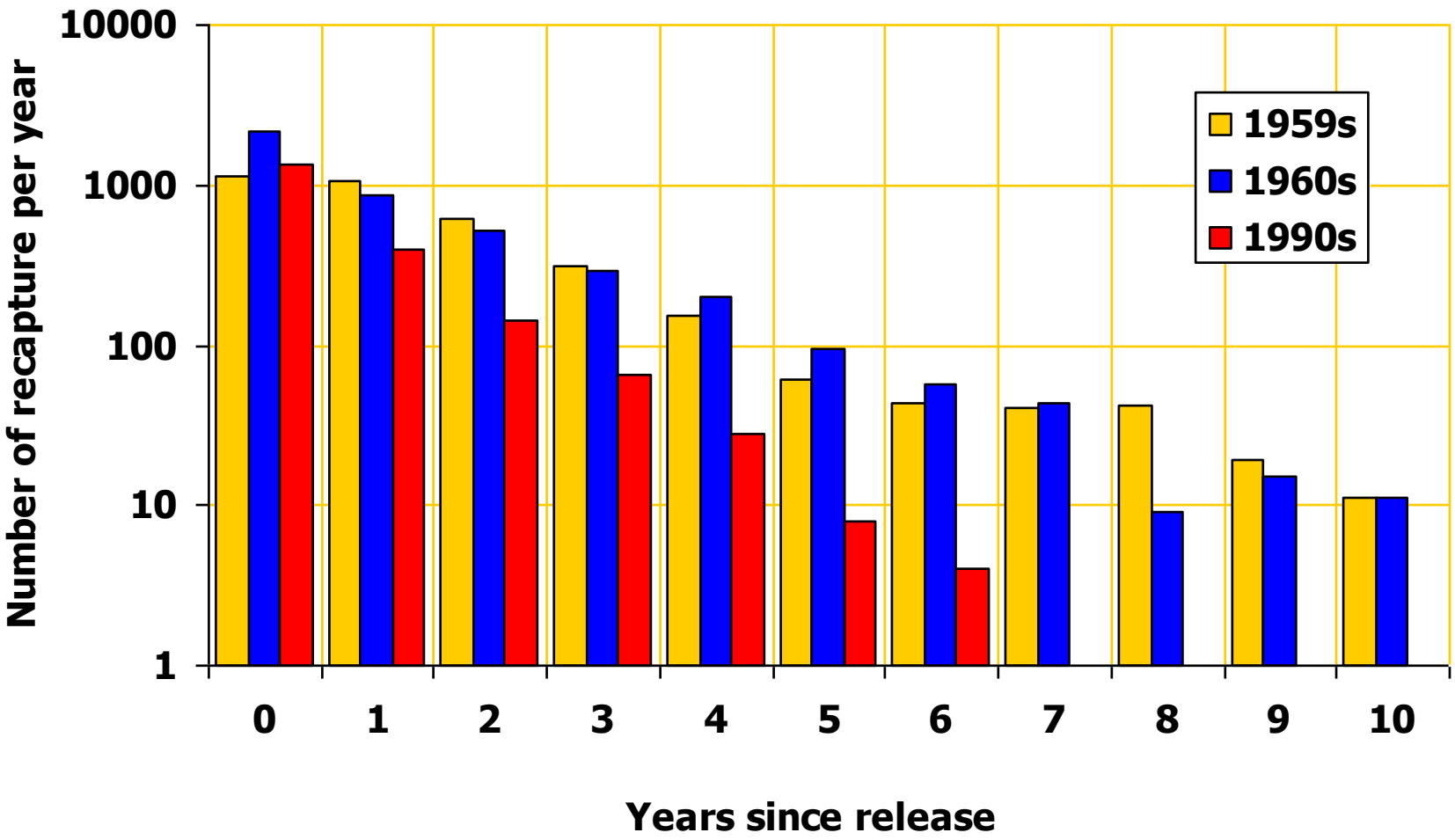
Number of recapture since release: Ln transformation

Example: Dab



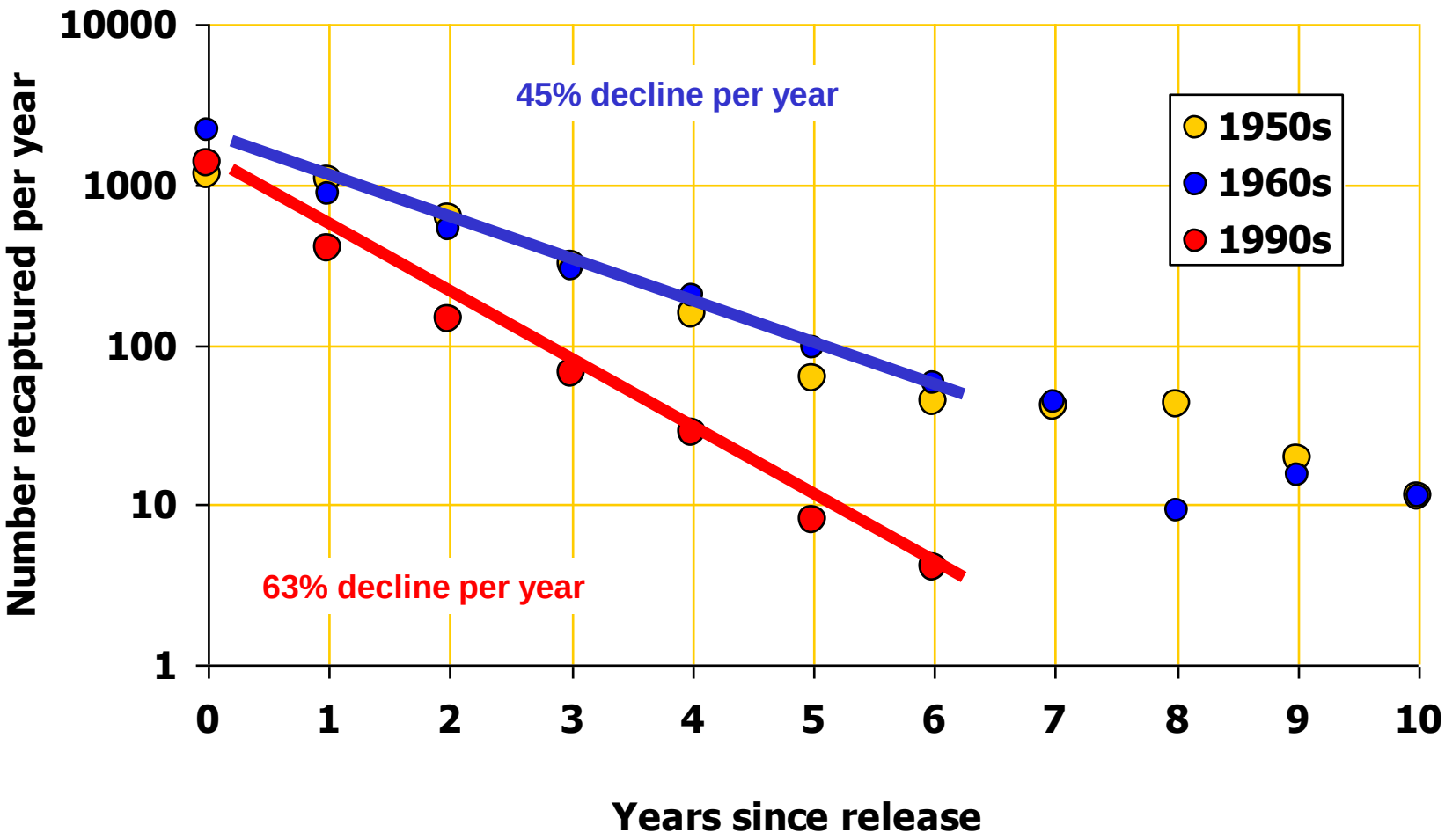
Number of recapture since release

Example: Plaice



Number of recapture since release

Example: Plaice



Natural mortality

The nature of M

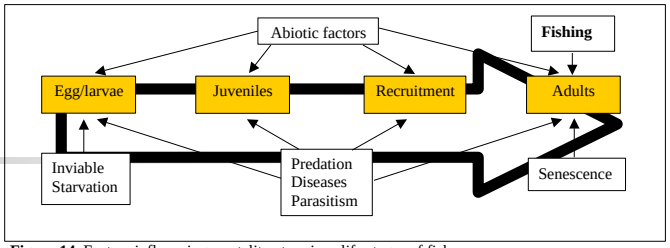


Figure 14. Factors influencing mortality at various life stages of fish.

- M is a function of the following factors:
  - Growth and therefore indirectly to K and L_{inf}
  - Size/weight, which is partly a function of longevity
  - Age at maturation, partly a function of longevity
  - Reproductive effort (relative energy distribution into gonad vs somatic tissues)
  - Temperature, which determines metabolic rate and thus growth
  - Intrinsic population growth rate (r)

- Estimation of natural mortality is very difficult.
  - Any measure will be mostly be a rough "gestimate"
  - The our interest in knowing natural mortality relates to the fact that $F = Z - M$
    - We can estimate Z from catch curve analysis but without an estimate of M we can not estimate F

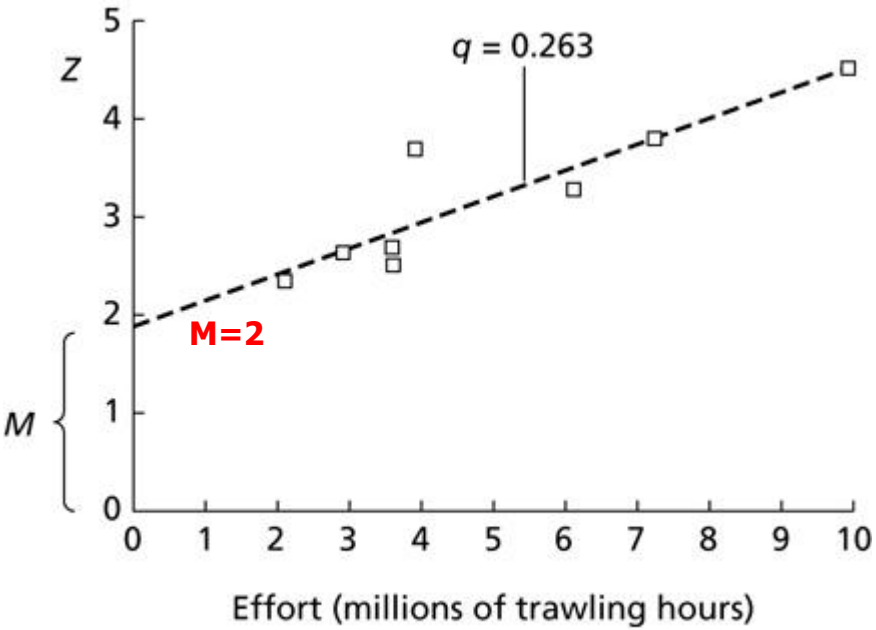
Z = M + q Effort

- Since fishing mortality is a function of effort we can derive the following: $Z = M + F$

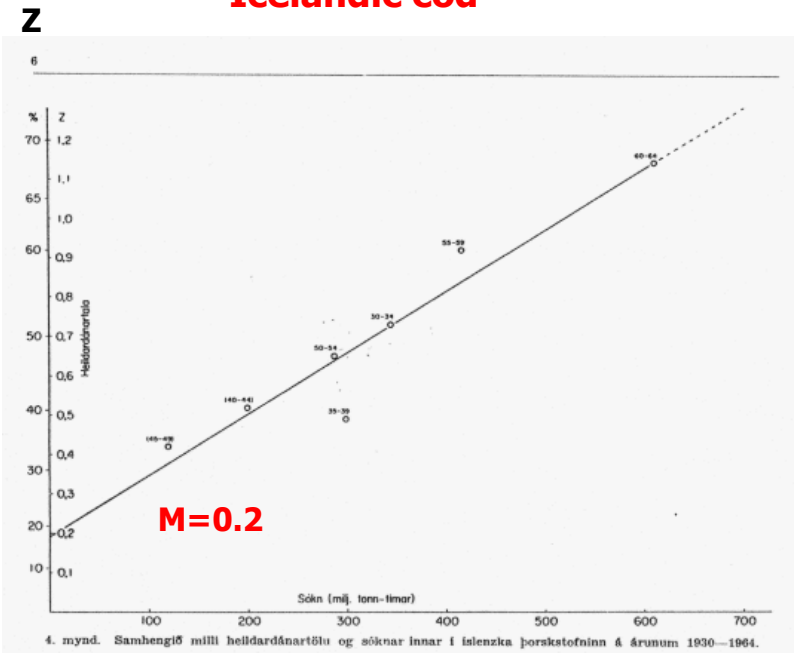
$$Z = M + q \text{ Effort}$$

Need a range of effort levels
Is limited to estimating M of adults

Smooth-tailed trevally



Icelandic cod



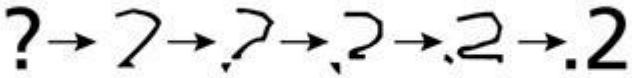
Effort

Empirical derivations

- Pauly 1980
  - $Ln(M) = -0.0066-0.297 \ln(L_{inf})+0.6543 \ln(K) + 0.463 \ln(T)$
- There are others:
  - Rikhter and Efanov: M = f(Age of maturity)
  - Gunderson and Dygert 1988: M = f(gonad somatic index)
  - Hoening 1984: M = (longevity)

  - Pope:

The evolution of $M = .2$

$M = ?$  EUREKA !