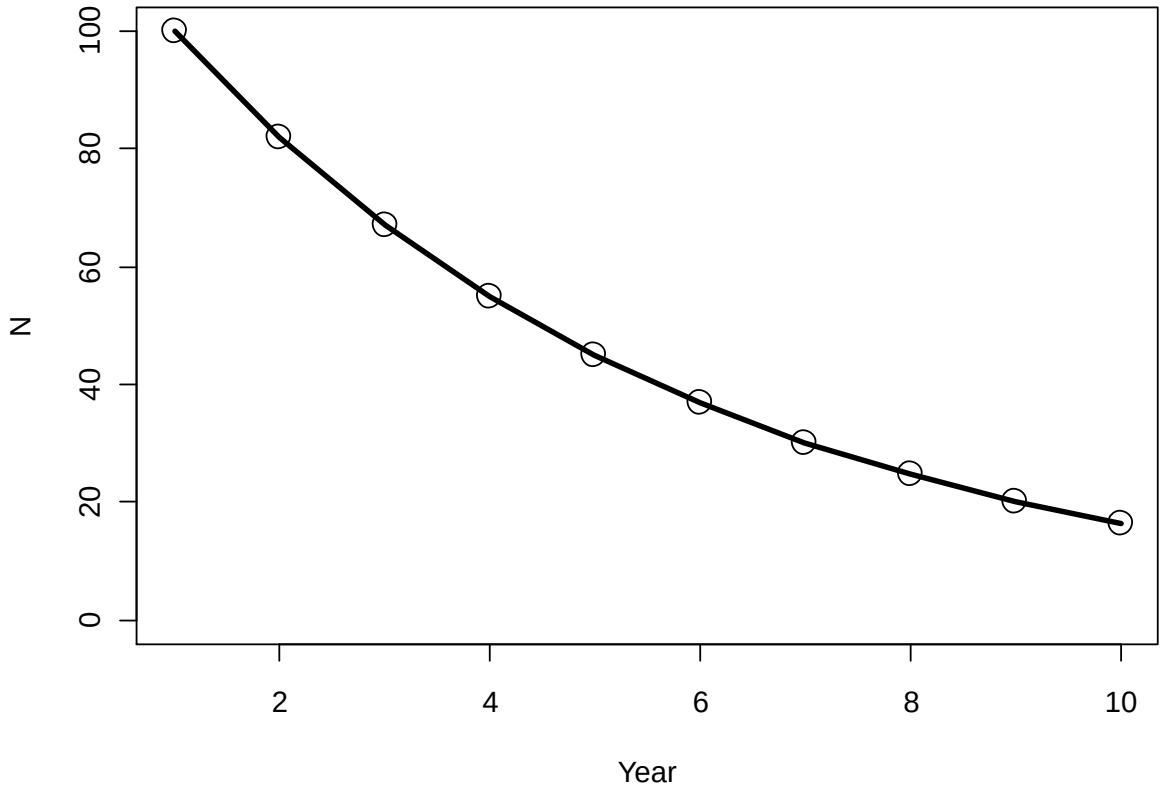
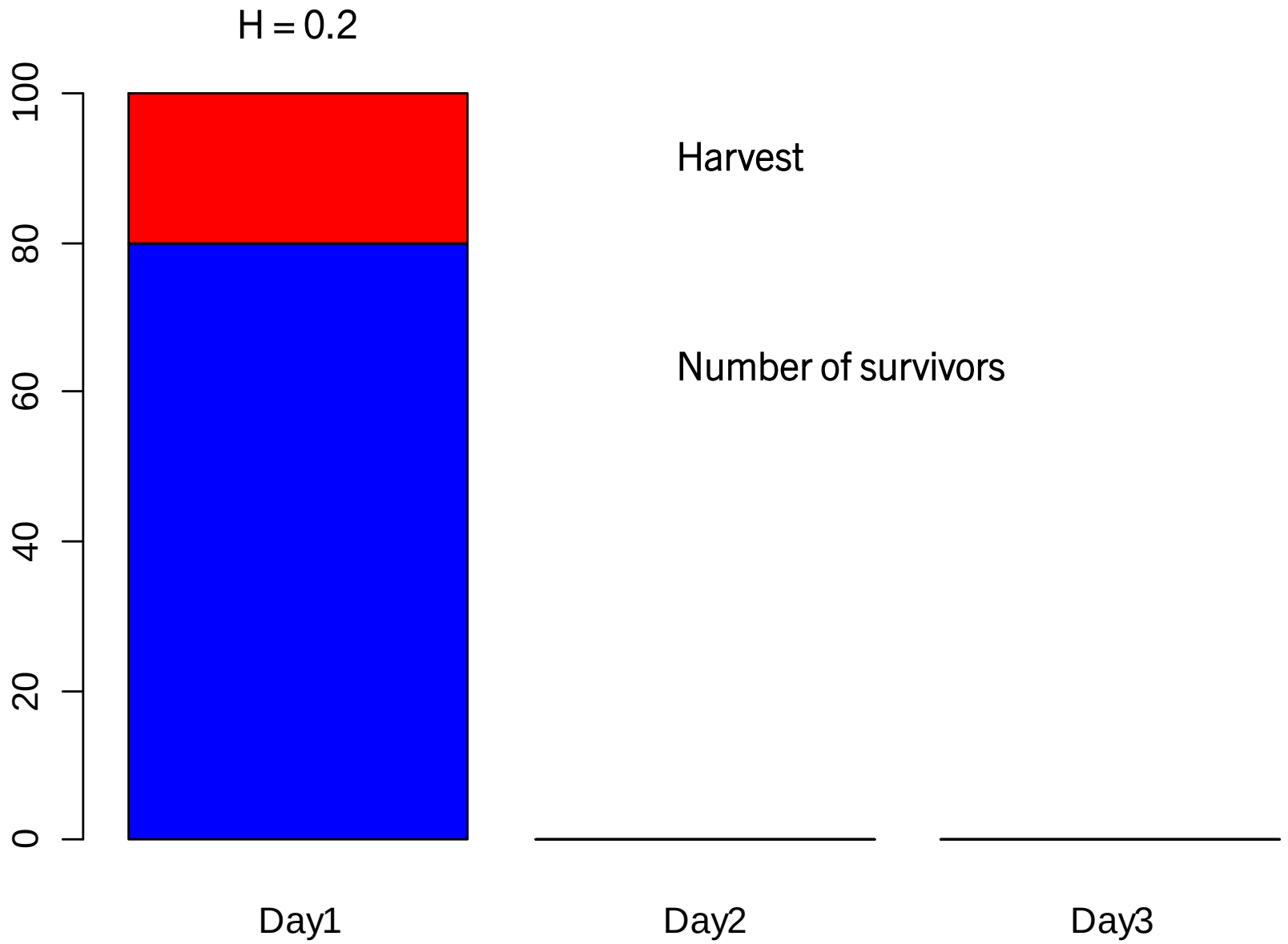
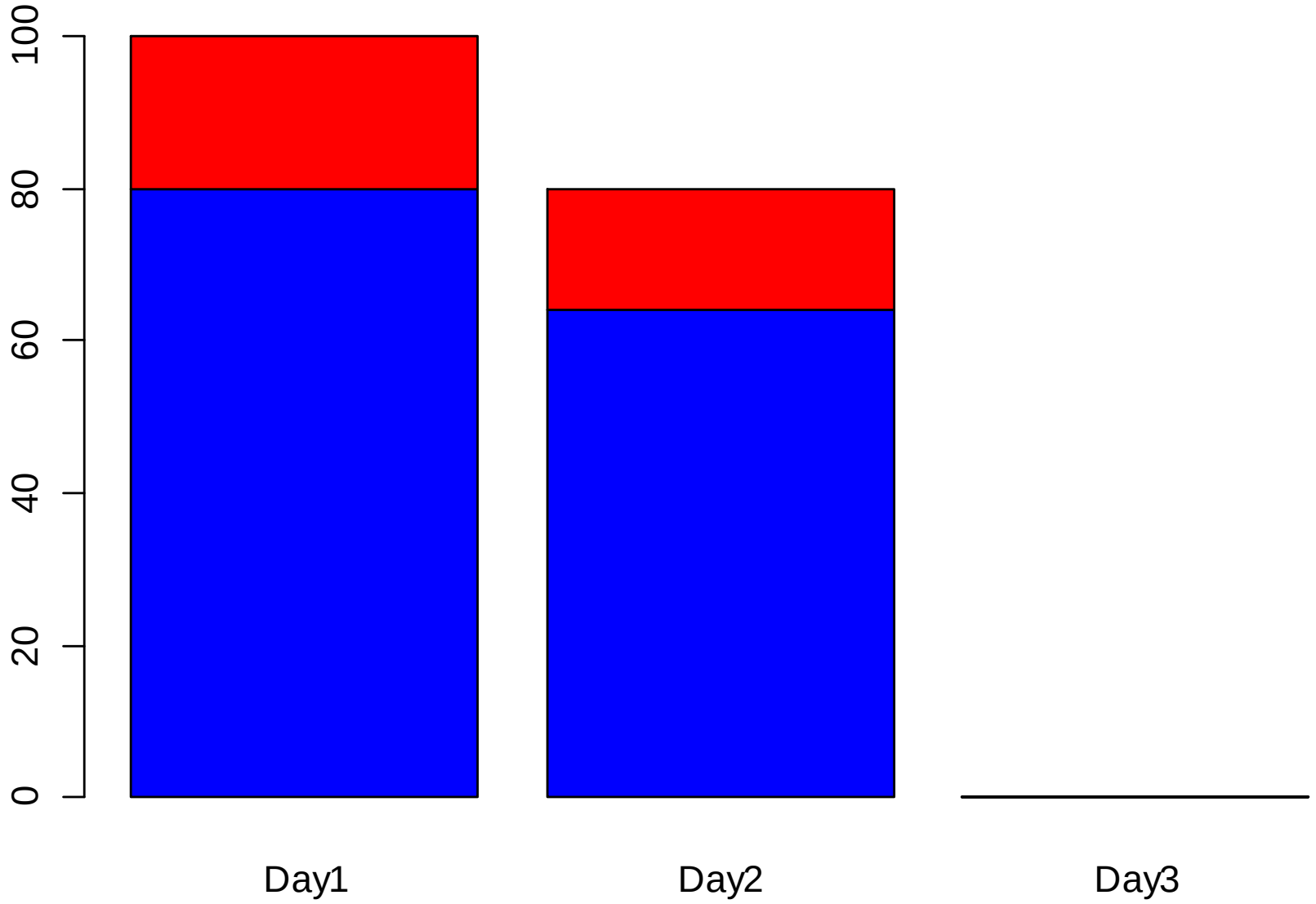
THEORY OF HARVEST

EXPONENTIAL DECLINE

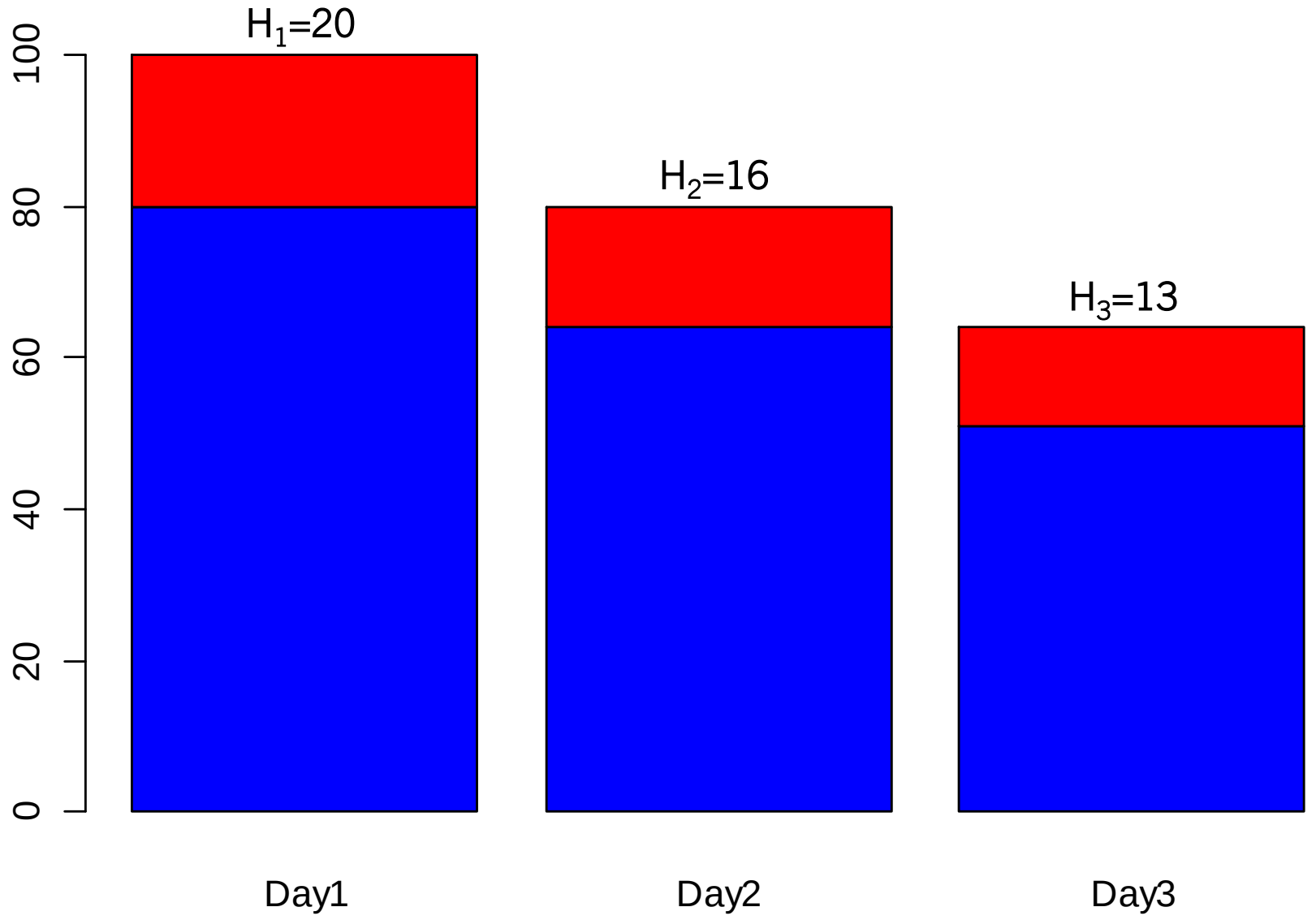
```
N = rep(0,10)
N[1] = 100
Year = seq(10)
for(i in 1:9) N[i+1] = N[i]*exp(-0.2)
plot(Year, N, cex = 2, ylim = c(0,100))
lines(Year, N, lwd = 3)
```




H = 0.2
100
80
60
40
20
0
Harvest
Number of survivors
Day1
Day2
Day3


100
80
60
40
20
0
Day1
Day2
Day3

```
barplot(height = cbind(Day1=c(80,20), Day2=c(64,16), Day3=c(51,13)), col=c("blue","red"))
```

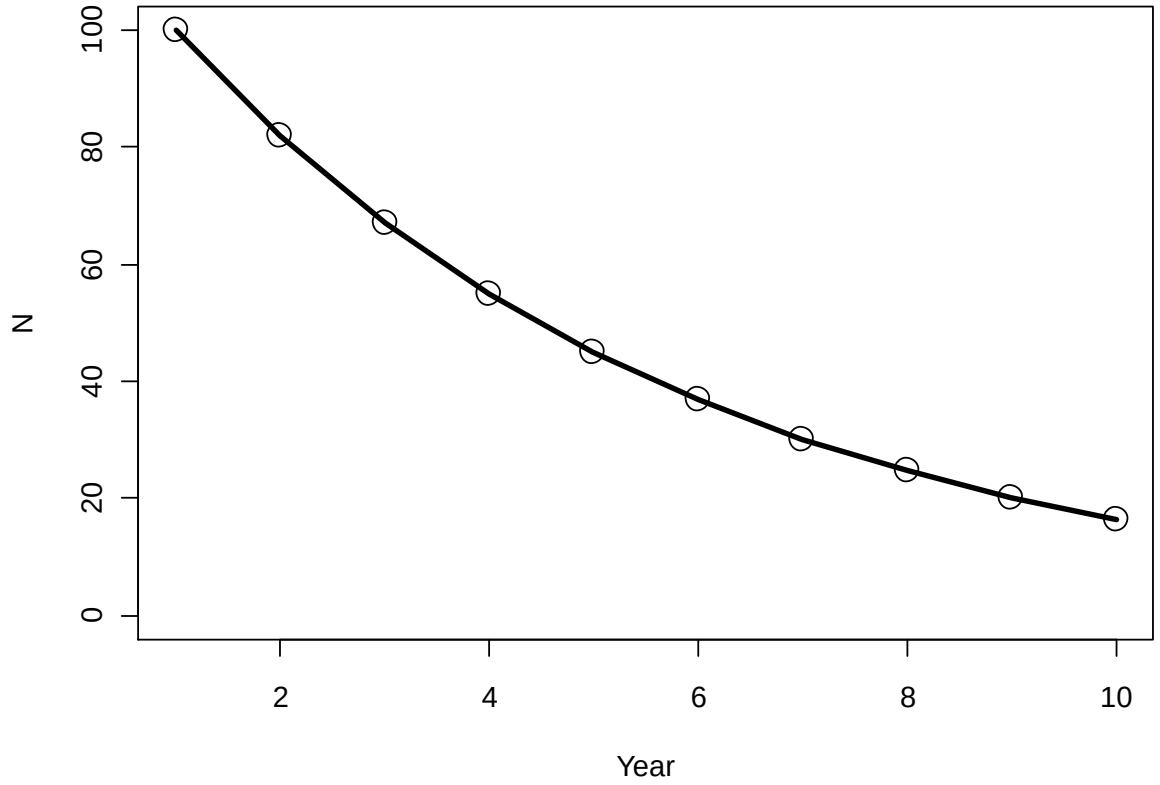


TOTAL HARVEST

$$H = \sum_t H_t$$

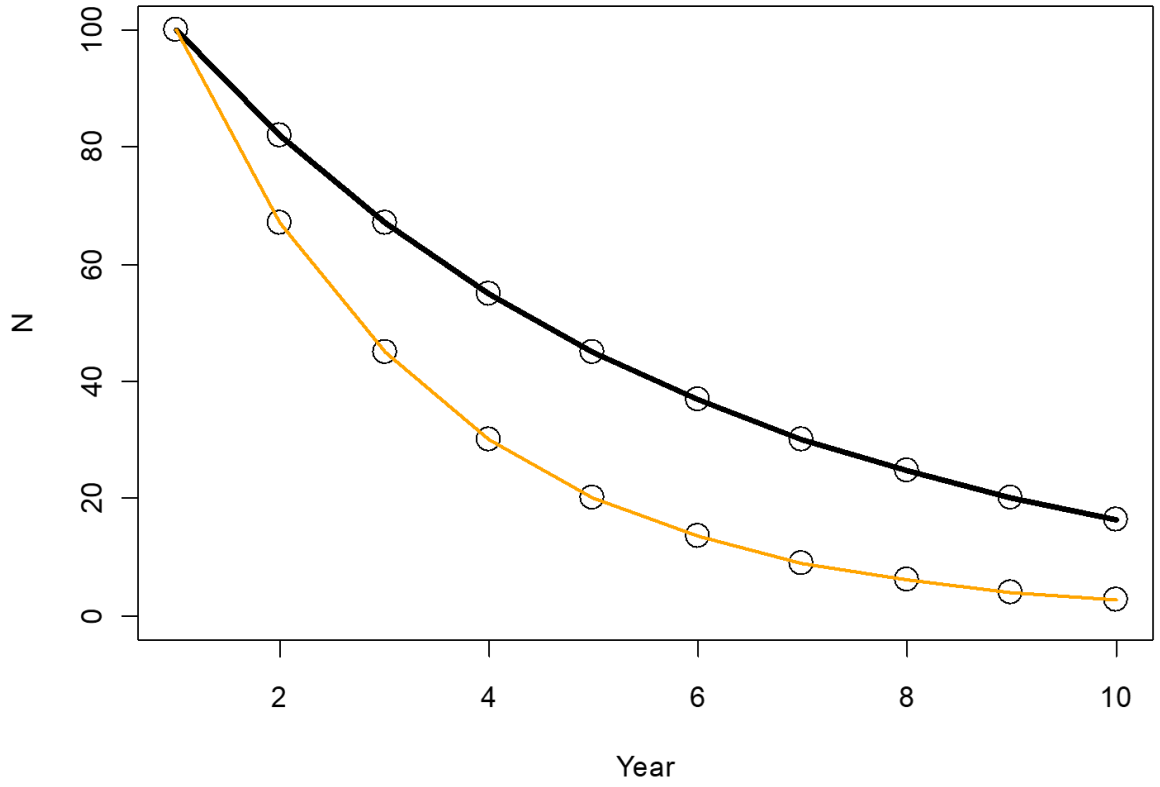
$$= \sum_t aN_t$$

EFFECT OF HARVEST MORTALITY ONLY



$$N_t = N_0 \exp(-at)$$

EFFECT OF HARVEST AND NATURAL MORTALITY



$$N_t = N_0 \exp(-(a + M)t)$$

TOTAL HARVEST = SUM OF INCREMENTAL HARVEST

$$\int_0^H dH = \int_0^t aNdt$$

TOTAL HARVEST = SUM OF INCREMENTAL HARVEST

$$\int_0^H dC = \int_o^t aN_0 \exp(-(a+M)t)\, dt$$

TOTAL HARVEST = SUM OF INCREMENTAL HARVEST

$$H = \frac{a}{(a+M)} N_0 \exp(-(a+M)t)$$

BARANOV CATCH EQUATION

The fraction of those animals that do not survive that are harvested.

$$H = \frac{a}{Z} N_0 \exp(1 - \exp(-Z))$$

Baranov, 1918 T.I. Baranov, On the question of the biological basis of fisheries, *Nauch. Issledov. Iktiol. Inst. Izv.* **I** (1918) (1), pp. 81–128 (Moscow).

AVERAGE (DISCRETE)

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i$$

AVERAGE (CONTINUOUS)

$$\bar{N} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} N_t dt$$

$$= \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} N_0 \exp(-Zt) dt$$

$$H = a\bar{N}$$

ASSUMPTIONS

- Mortality is constant
- Change is deterministic
- Harvest occurs continuously throughout the year
- Alternatives

  It takes place at the beginning of the year

  It takes place in the middle

  It takes place at the end

  It varies

HOW CAN WE RELATE HARVEST MORTALITY TO EFFORT?

- We might assume that harvest mortality is related to effort

$$a = qE$$

$$H = qE\bar{N}$$

$$\frac{H}{E} = qE\bar{N}$$

HOW CAN WE USE HARVEST RELATIVE TO EFFORT?

- Relative abundance indices

  We assume that the value of q (called vulnerability or catchability) is constant

- Estimate total abundance from harvest
- We can quantify the amount of effort and how it should change to achieve population goals