

# Harvest Models

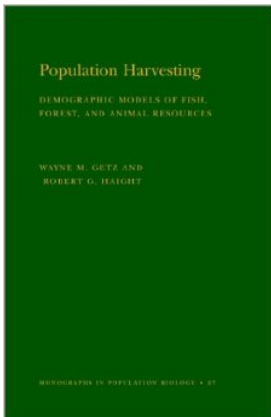


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Sustainable harvest and geometric growth

Sustainable harvest and logistic growth

Definition of maximum sustainable yield (MSY)

Limitations of MSY

Additive vs compensatory mortality

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Sustainable harvest: A harvest that is balanced by population growth such that  $N_{t+1} = N_t$

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$$h = r$$

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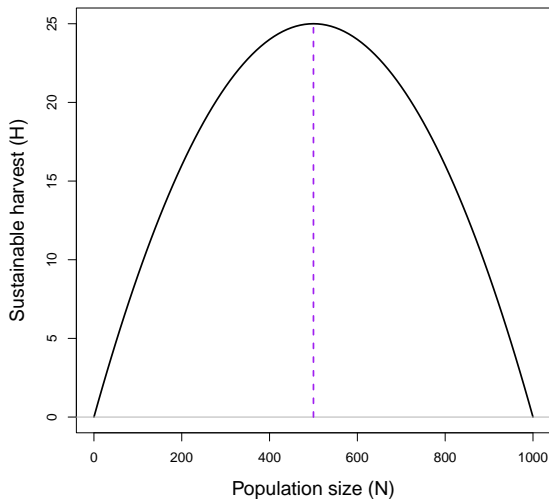
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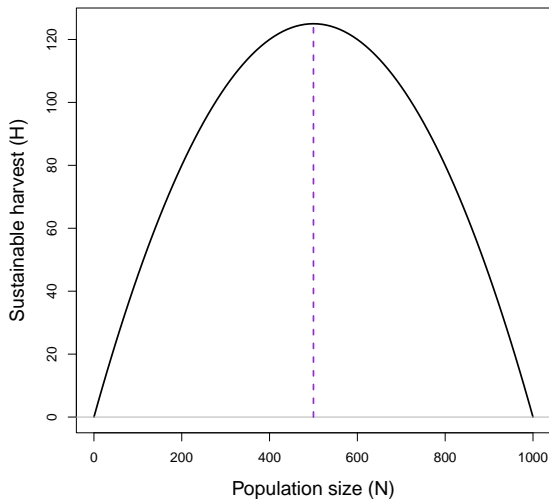
# EXAMPLE WHEN $K = 1000$ AND $r_{max} = 0.1$

$$H_t = N_t r_{max} \left( 1 - \frac{N_t}{K} \right)$$



# EXAMPLE WHEN $K = 1000$ AND $r_{max} = 0.5$

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- MSY is found when  $N = K/2$
- The actual maximum yield is  $H = r_{max}K/4$
- The optimal harvest rate is  $h = r_{max}/2$

# IS MSY USEFUL IN PRACTICE?



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Larkin, P.A. 1977. An epitaph for the concept of maximum sustained yield. Transactions of the American Fisheries Society 106: 1-11.

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- Evolutionary consequences?

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- If harvest is compensated for by improved survival, harvest is a form of **compensatory mortality**
- However, if harvest is not compensated for by improved survival, harvest is a form of **additive mortality**

If harvest mortality is additive, extra caution is needed to ensure that harvest doesn't cause long-term population declines.

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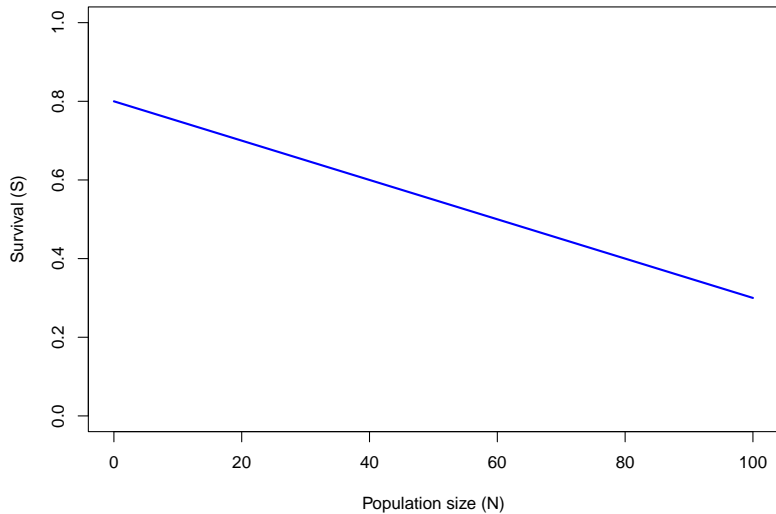
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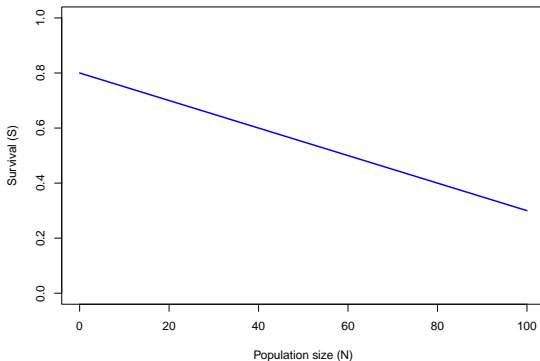
Let's assume  $\beta_0 = 0.8$  and  $\beta_1 = 0.005$ , so  
 $S = 0.8 - 0.005 \times N$

# INDIVIDUAL SURVIVAL VS. POPULATION SIZE



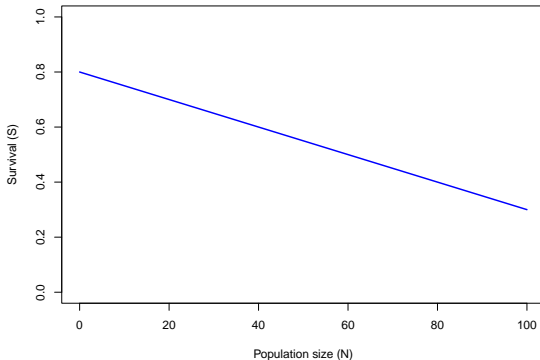
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- If 20 individuals are harvested, what is  $S$  for remaining individuals?



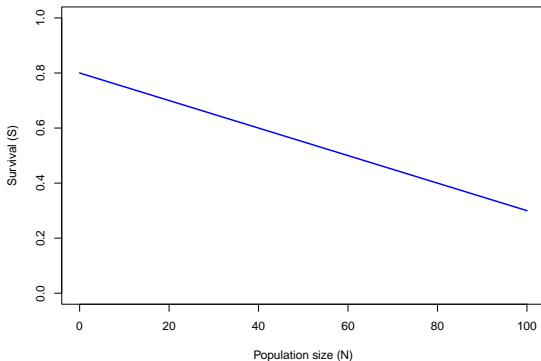
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- If 20 individuals are harvested, what is  $S$  for remaining individuals?
- How many individuals will remain at the end of the year?
- How many would remain at the end of the year if no hunting occurred?



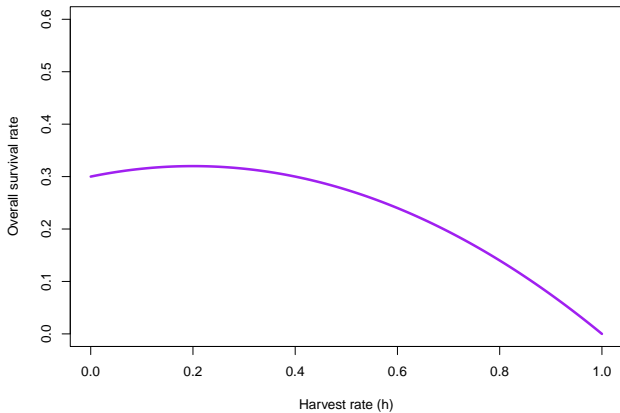


The overall survival rate ( $\bar{S}$ ) is product of survival throughout the hunting season ( $1 - h$ ) and survival after the hunting season

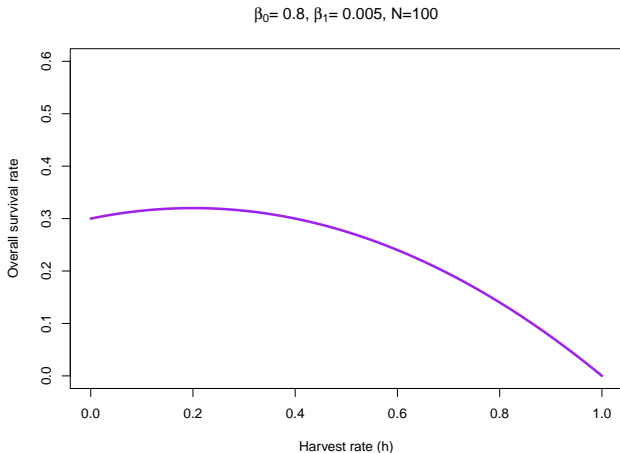
$$\bar{S} = (1 - h)(\beta_0 - \beta_1(N - Nh))$$

# OVERALL SURVIVAL VS. HARVEST RATE

$\beta_0 = 0.8$ ,  $\beta_1 = 0.005$ ,  $N=100$



# OVERALL SURVIVAL VS. HARVEST RATE



**Conclusion:** Because harvest mortality is compensatory, the harvest rate ( $h$ ) can be as high as 0.2 without negatively impacting overall survival.

## Key points

- If growth is geometric, sustainable harvest occurs when  $h = r$ .
- If growth is logistic, maximum sustainable yield occurs at  $N = K/2$ .
- If survival is density-dependent, harvest mortality can be compensated for by increased survival of remaining individuals (up to a point).
- If mortality is additive, extra caution is needed because harvest is adding to natural mortality without any compensation.
- Managers need to know if harvest mortality is additive or compensatory when setting harvest regulations.

Read pages 22–25 in Conroy and Carroll