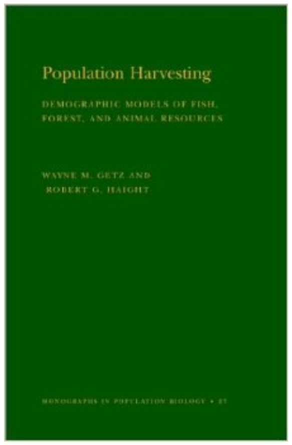
Harvest Models



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Today's topics

Sustainable harvest and geometric growth

Sustainable harvest and logistic growth

Definition of maximum sustainable yield (MSY)

Limitations of MSY

Additive vs compensatory mortality

Sustainable harvest

A sustainable (and large) harvest is a common objective in game management

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

Harvest and geometric growth

$$N_{t+1} = N_t + N_t r - H_t$$

where H_t is the number of animals harvested at the end of year t

What value of H_t achieves equilibrium (i.e., $N_{t+1} = N_t$)?

Sustainable harvest and geometric growth

A sustainable harvest in this context is

$$H_t = N_t r$$

Consequently, the sustainbale harvest rate (h) is:

$$h = \frac{H_t}{N_t} = r$$

Harvest and logistic growth

$$N_{t+1} = N_t + N_t r_{max}\left[1 - \frac{N_t}{K}\right] - H_t$$

What value of H_t achieves equilibrium?

Sustainable harvest and logistic growth

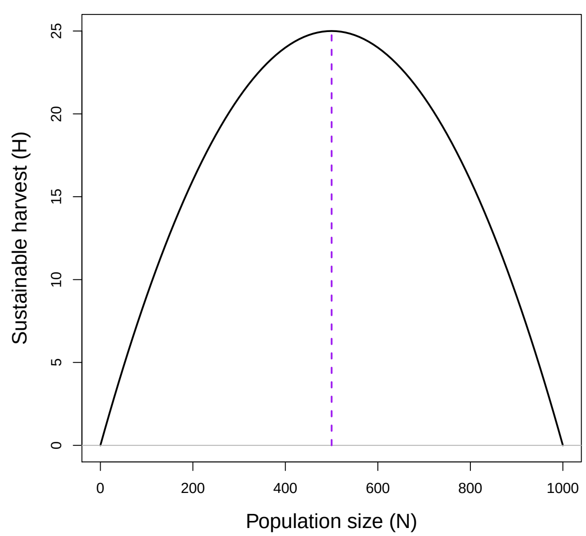
$$H_t = N_t r_{max}\left[1 - \frac{N_t}{K}\right]$$

In this case, the sustainable harvest rate (h) depends on population size

$$h_t = \frac{H_t}{N_t} = r_{max}\left[1 - \frac{N_t}{K}\right]$$

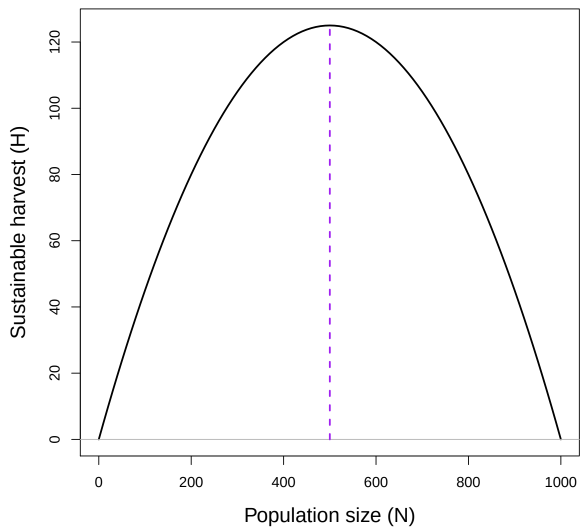
Example when $K = 1000$ and $r_{max} = 0.1$

$$H_t = N_t r_{max}\left[1 - \frac{N_t}{K}\right]$$



Example when $K = 1000$ and $r_{max} = 0.5$

$$H_t = N_t r_{max} \left[1 - \frac{N_t}{K}\right]$$



Maximum sustainable yield

- 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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Issues

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

- Same assumptions as logistic growth model
  - K is constant
  - No age/sex/individual variation
  - No stochasticity
- Ecosystem impacts of reducing a population to half its carrying capacity?
- Evolutionary consequences?

Compensatory mortality

Additive vs. compensatory mortality

- One possible mechanism giving rise to logistic growth is density-dependence in survival
- For example, if population size is reduced, survival of the remaining individuals might increase
- 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.

Compensatory mortality example

Suppose a population of 100 white-tailed deer is subjected to harvest

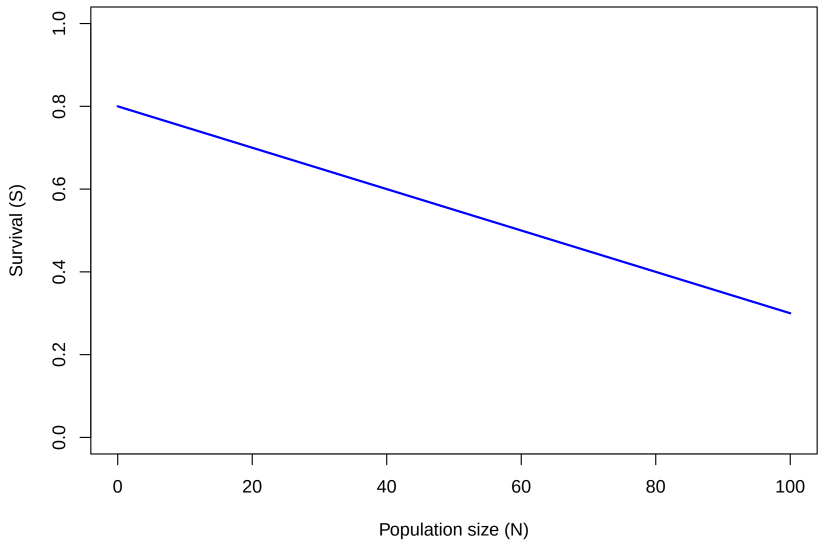
Harvest takes place prior to any natural mortality

Natural mortality occurs in a density dependent fashion, such that survival probability (S) declines as N increases.

A simple model is $S = \beta_0 - \beta 1 \times N$

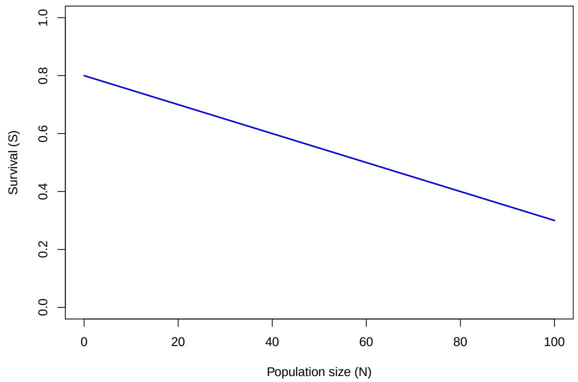
Let's assume $\beta_0 = 0.8$ and $\beta_1 = 0.005$, so $S = 0.8 - 0.005 \times N$

Individual survival vs. population size



$S = 0.8 - 0.005 \times N$

- 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?

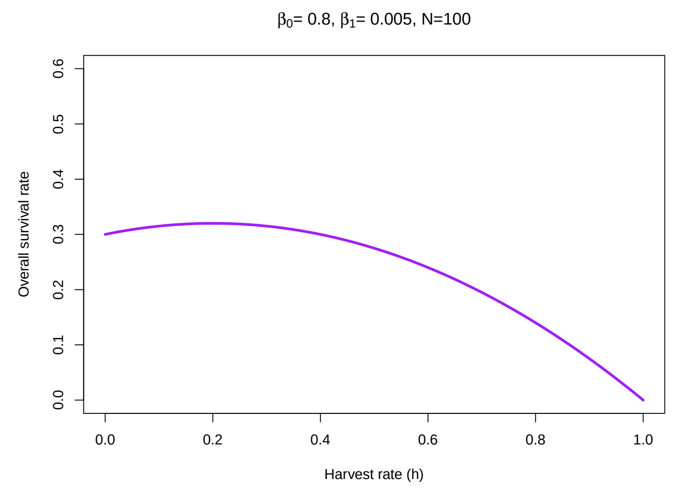


Overall survival vs. harvest rate

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

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

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.

Summary

Key points

- If growth is geometric, sustainable harvest occurs when $h = r$
- If growth is logisitic, 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 understand population dynamics when setting harvest regulations

Assignment

Read pages 22–25 in Conroy and Carroll