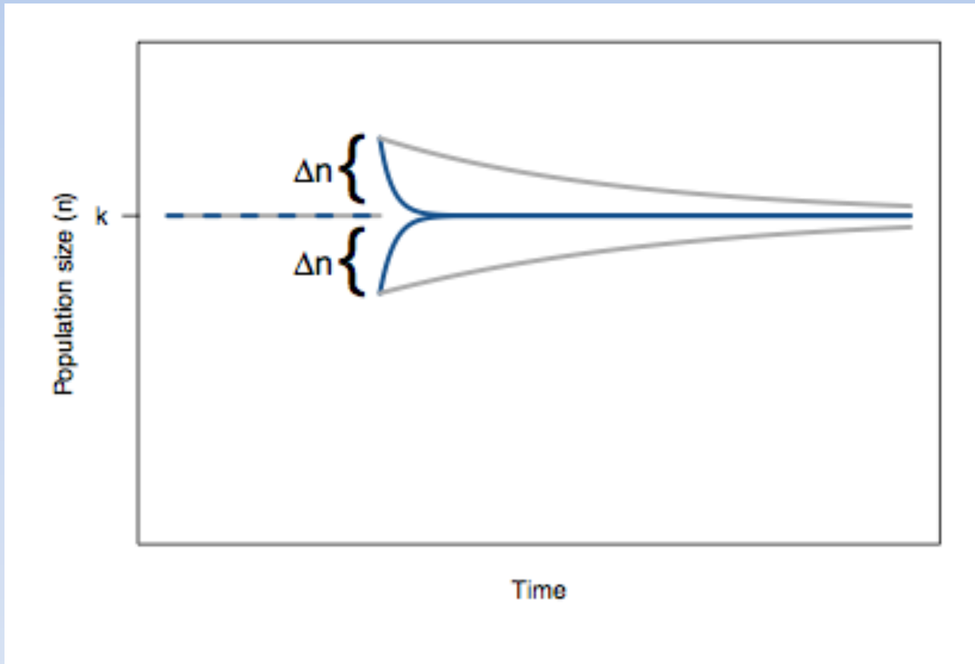
# Quiz1: For each statement, write True or False
# e.g. A: True, B: True



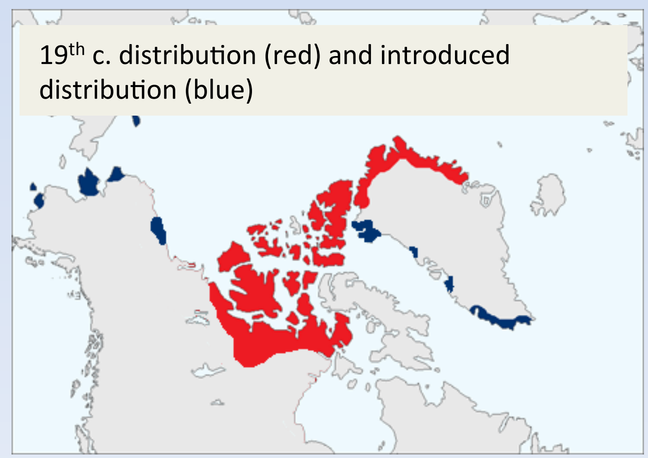

A: intrinsic growth rate for "gray" population > intrinsic growth rate for "blue" population
B: "blue" population is more resilient than "gray" population

# Muskox on Nunivak Island

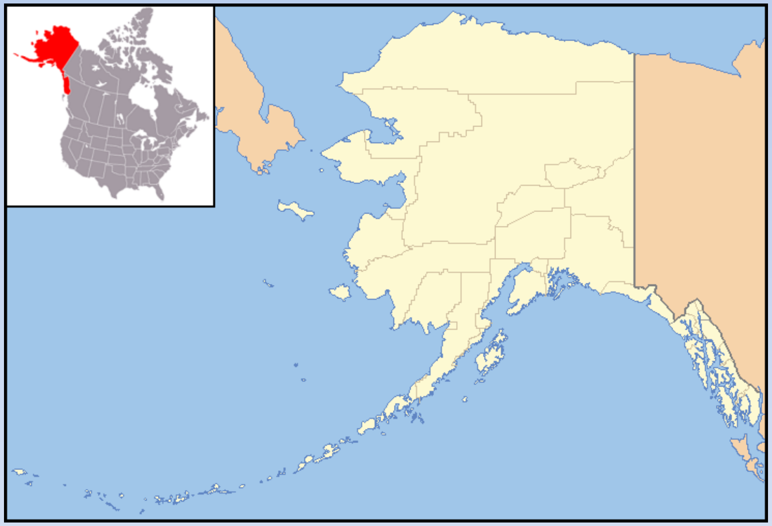
*Ovibos moschatus*

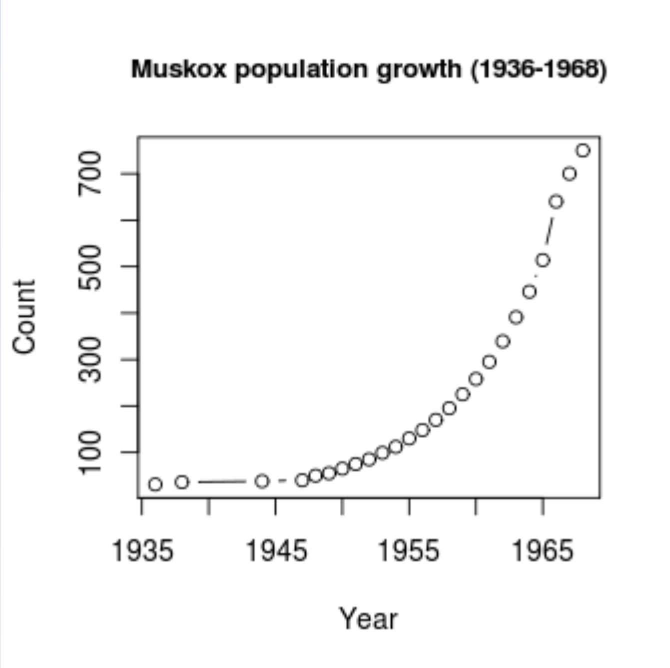
- Related to goats and sheep
- Large-bodied herbivore
  - -200 cm in length
  - -285 kg in weight
- Migrated to North America during Pleistocene (contemporary of Wooly Mammoth)

Muskox exhibiting social defense behavior



# Muskox on Nunivak Island



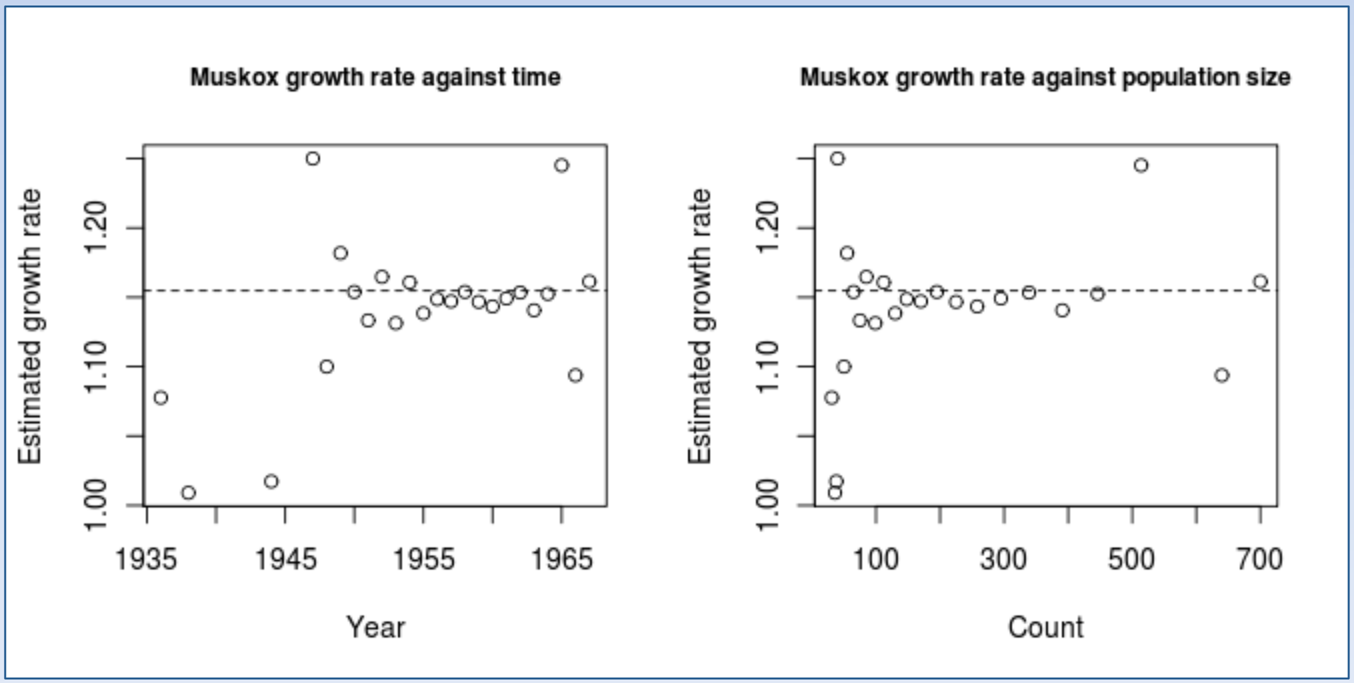



- Extirpated in 19th c.
- 31 animals introduced in 1936 by USFWS
- ~650 animals in 1970

# Muskox on Nunivak Island

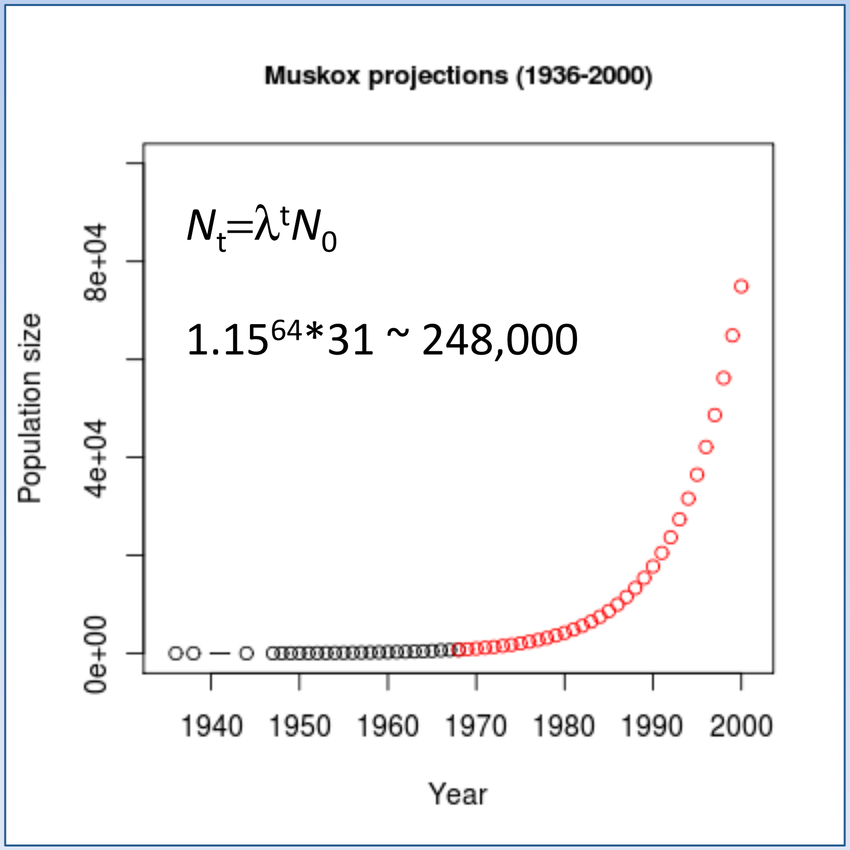
$$e^{\frac{\log(N_t/N_0)}{t}} = \lambda$$

(1) Estimate year-to-year growth rate from formula derived in first class
(2) Average estimated growth rate is λ=1.15
(3) Plot alternately against time and population size



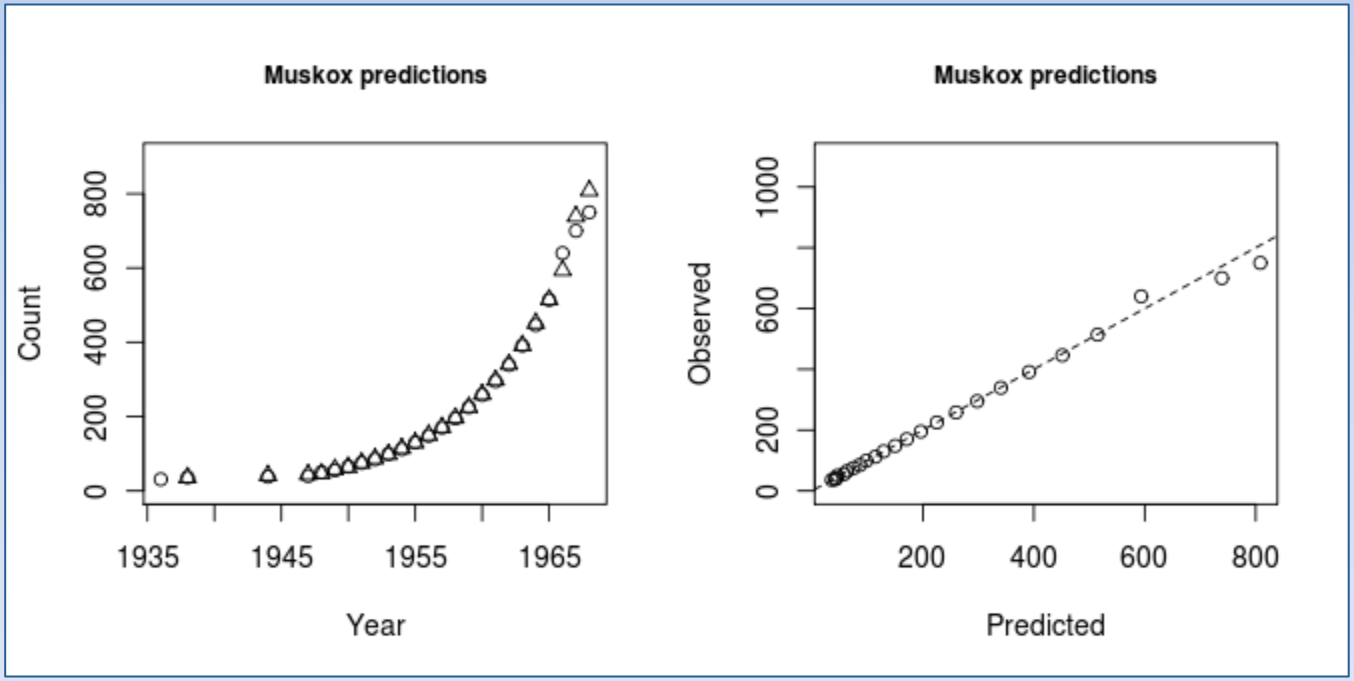

How many muskox do you suppose there are on Nunivak Island now?

# Muskox on Nunivak Island



# Muskox on Nunivak Island

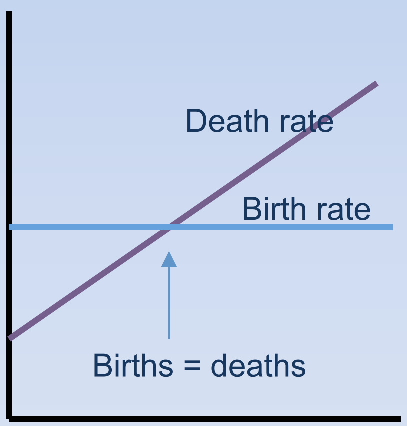
Two ways to compare the model and observations




What do these plots say about Muskox population dynamics?

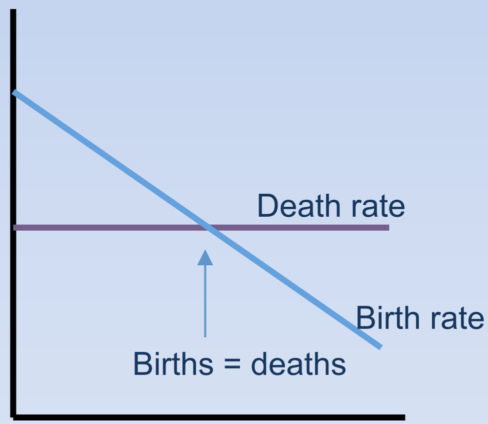
# Density dependence

Density dependent death rate



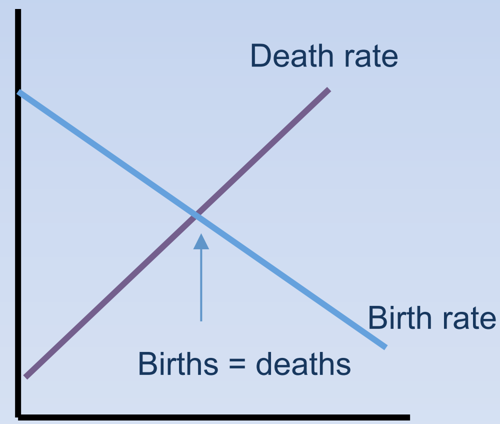

**Population size or density (N)**

Density dependent birth rate




**Population size or density (N)**

Density dependent birth & death rate




**Population size or density (N)**

Relationship between population size and per capita birth rate/per capita death rate could be linear or nonlinear

# Adding density dependence

Define λ as a function of *N* and substitute for the old constant growth rate

$$N_{t+1} = \lambda\{N_t\}N_t$$

Recall: In the first lecture λ was defined by $\lambda = B - D + 1$

Note: It may no longer be easy (or even possible) to find a general expression for $N_t$. But, we can always iterate the model on a computer.

What function should we use?

# Three models for density dependence

$$\lambda(N) = \frac{R}{1 + aN_t}$$

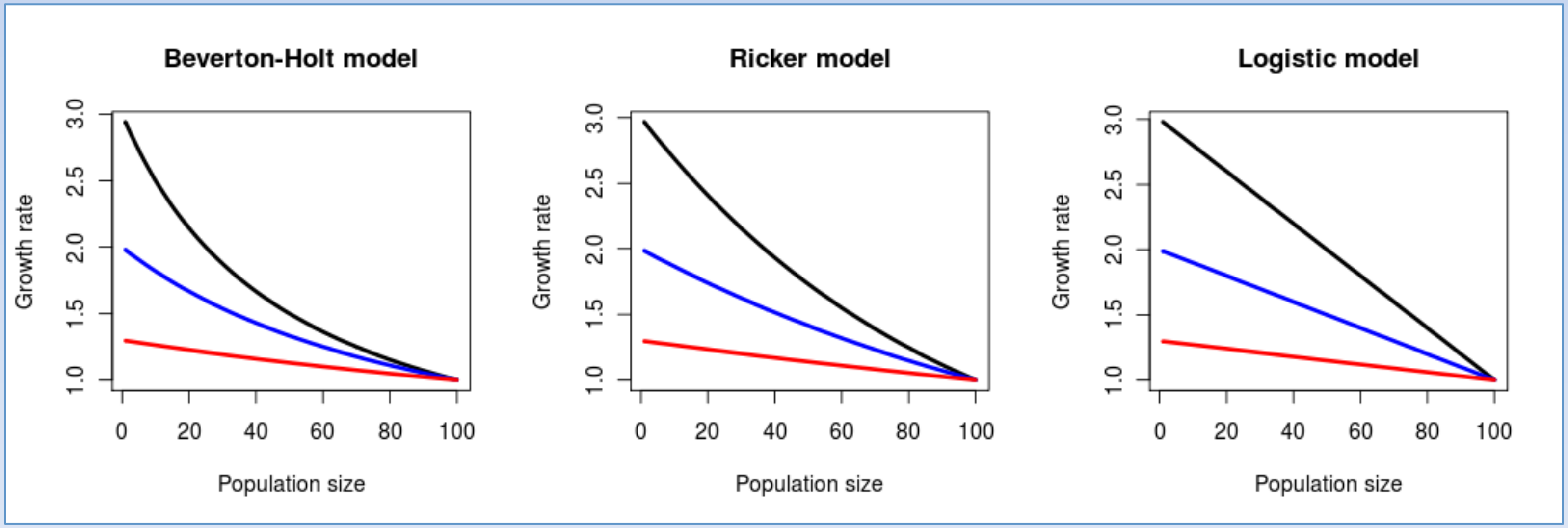
$$N_{t+1} = N_t \frac{R}{1 + aN_t}$$

$$\lambda(N) = \lambda_0 e^{bN_t}$$

$$N_{t+1} = N_t \lambda_0 e^{bN_t}$$

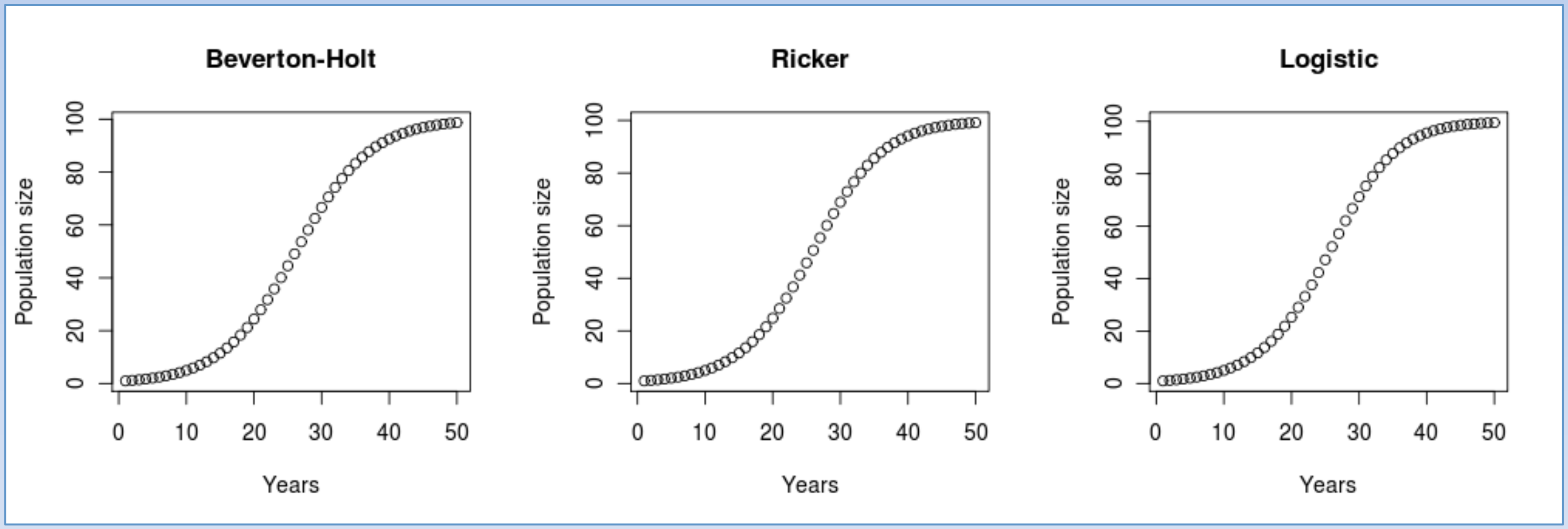
$$\lambda(N) = R(1 - N/K)$$

$$N_{t+1} = N_t R(1 - N/K)$$




How do these models differ?
What do solutions of these models looks like?
(What do we mean here by "solutions"?)

# Solutions of these models



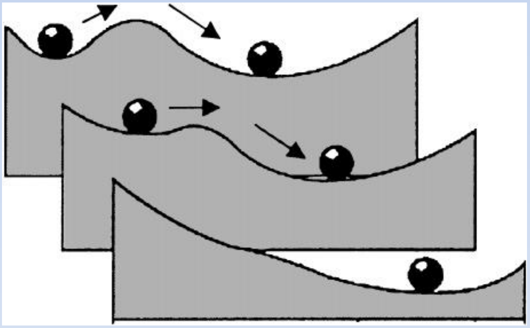

How are these trajectories different from density-independent growth?

- Growth is *bounded* (a necessary condition for *regulation*)
- Population size reaches a *carrying capacity*

# Equilibrium

Carrying capacity is a special case of *equilibrium*

What is an equilibrium?



Challenge question: What are the carrying capacities of our three models of density dependent dynamics?

# Practice question (previous exam question)

Consider a population with density-dependent growth given by the Beverton-Holt model with growth rate ,

$$\lambda(N) = \frac{R}{1 + aN_t}$$

parameters $R$=2.3, and $a$=0.005 , and initial population size $N_0$=80. What will the population size be after 2 years (i.e. what is $N_2$)? What is the carrying capacity of this population? Is the carrying capacity stable?