Lecture 4

Density-dependent population growth

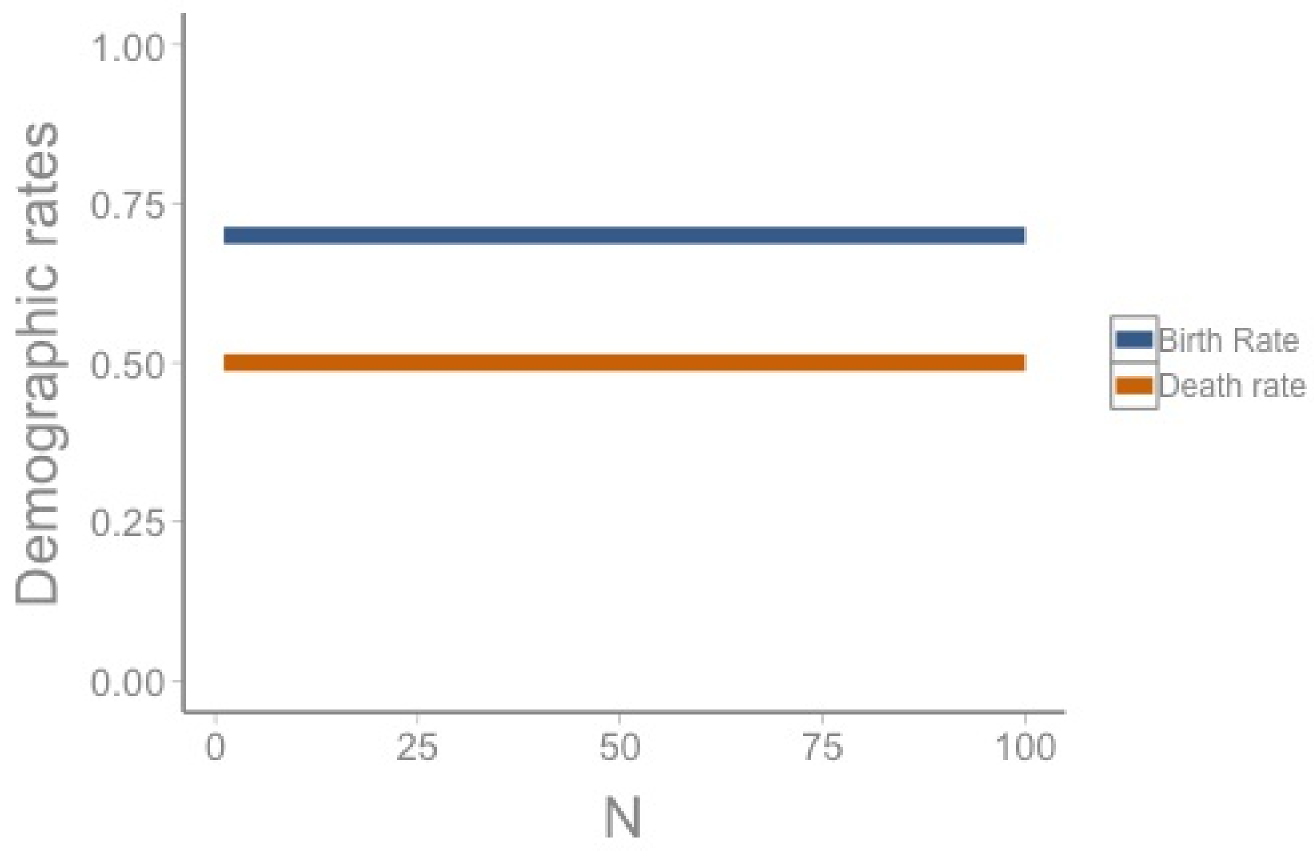
WILD3810 (Spring 2019)

Readings

> Mills 126-141

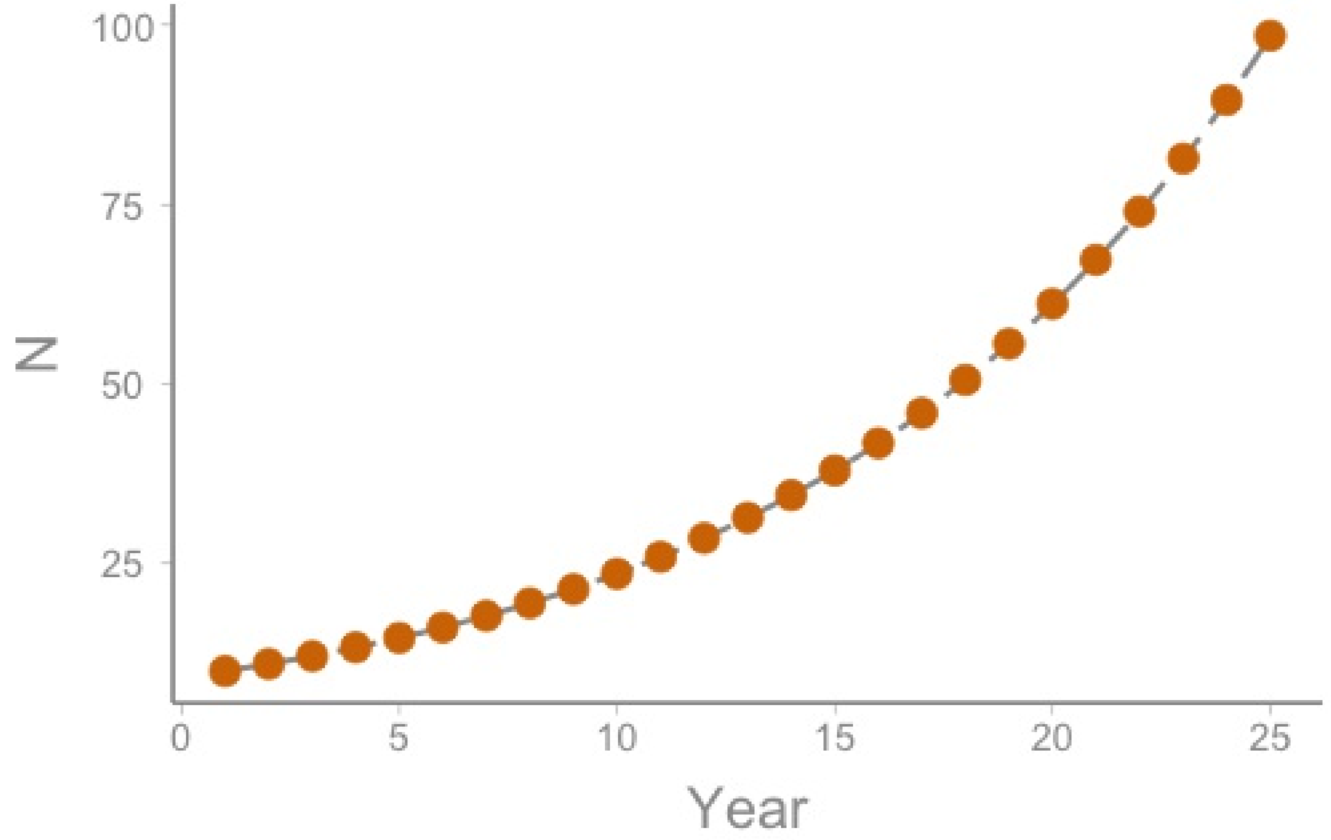
Density-independence vs density-dependence

In the last lecture, we learned about population growth models that assume demographic rates are unrelated to population size



Density-independence vs density-dependence

We also learned that this assumption leads to exponential population growth



Limitless population growth?

No population can grow exponentially forever (or even for relatively short periods of time)

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- At some point, resources will be become limited and populations must either stop growing or decline

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- At some point, resources will be become limited and populations must either stop growing or decline

Malthus' work inspired Darwin (1859) to suggest that limitation of resources is what drives evolution by natural selection

Competition

At small population sizes, individual organisms may be able to acquire all of the resources they need to survive and reproduce

As increases, the availability of resources per organism will decrease, leading to increased competition

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At small population sizes, individual organisms may be able to acquire all of the resources they need to survive and reproduce

As increases, the availability of resources per organism will decrease, leading to increased competition
Intra-specific competition:

> interaction between individuals of a single species brought about by the need for a shared resource

Intra-specific competition can arise in multiple ways:

Animals

- food
- shelter
- breeding sites
- mates

Plants

- space
- light
- water
- nutrients

Competition

Ecologists generally distinguish between two types of competition:

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1) **Exploitation competition**

- consumption of limited resource by individuals depletes the amount available for others
- also known as: depletion, consumption, or scramble competition
- indirect

Competition

Ecologists generally distinguish between two types of competition:

1) **Exploitation competition**

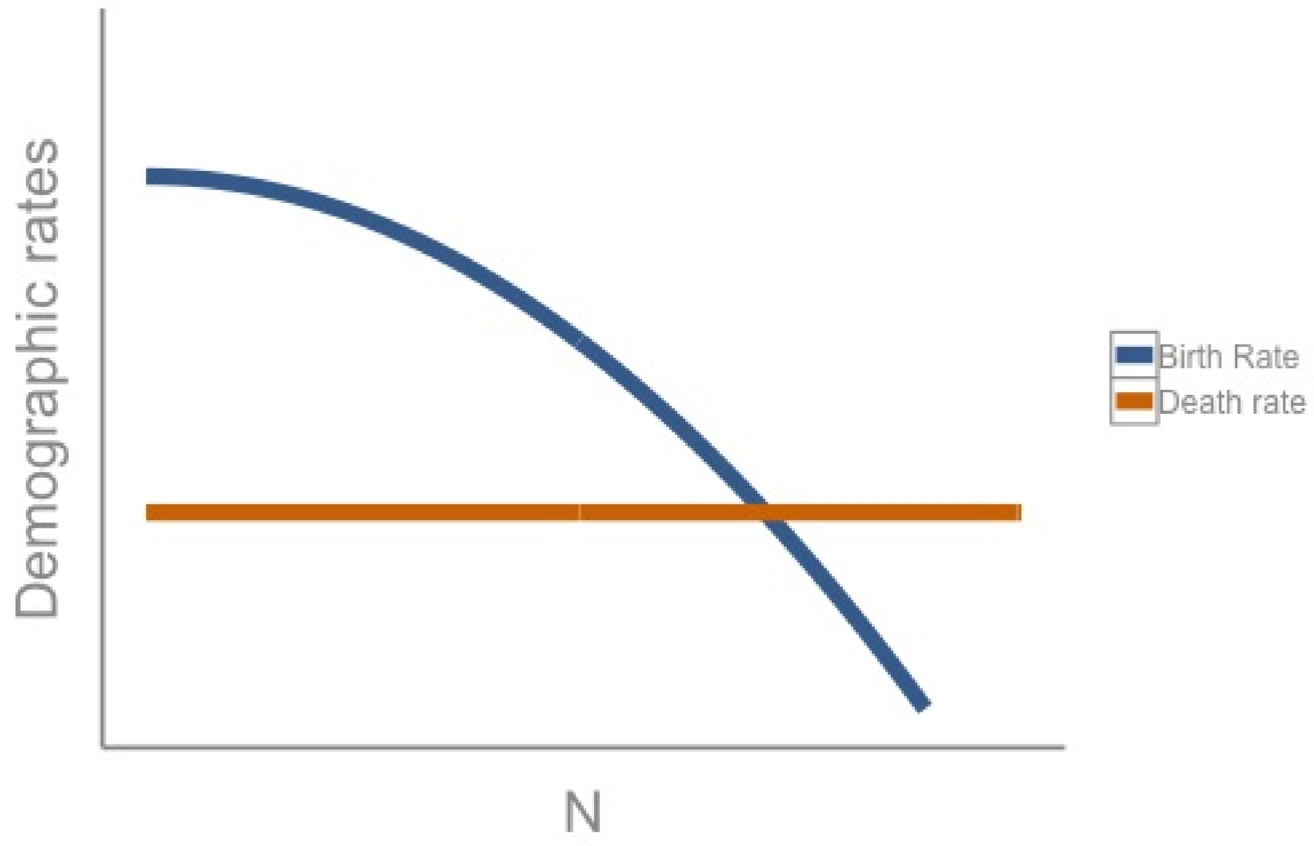
2) **Interference competition**

- individuals actively prevent others from attaining a resource in a given area or territory
- also known as: encounter or contest competition
- direct

Competition

As population size increases, the resources available to each individual will eventually shrink to the point where demographic parameters are negatively effected

- Increased density can also increase rates of disease transmission



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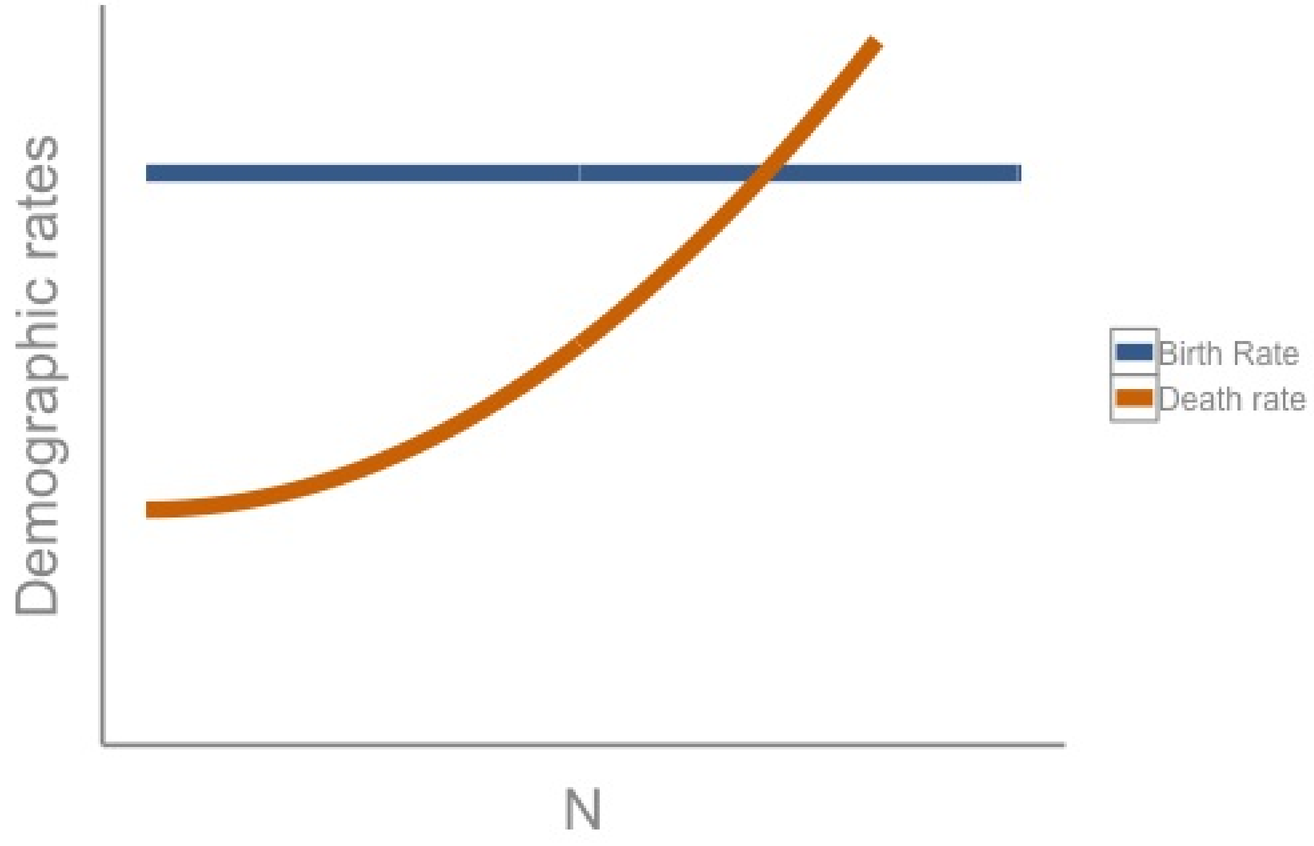

Carrying-capacity

Remember that the population growth rate

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If :

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-

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- population remains stable

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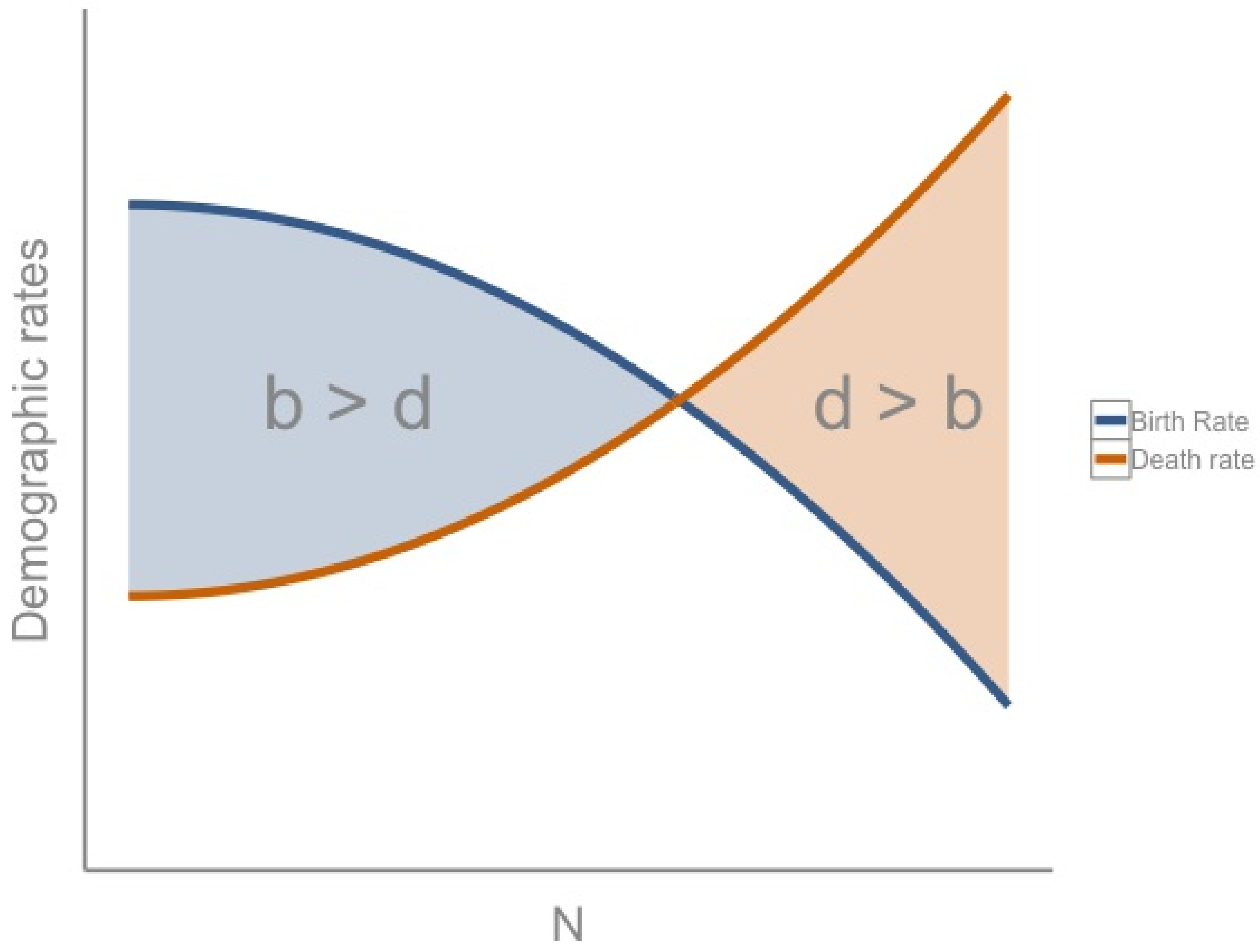
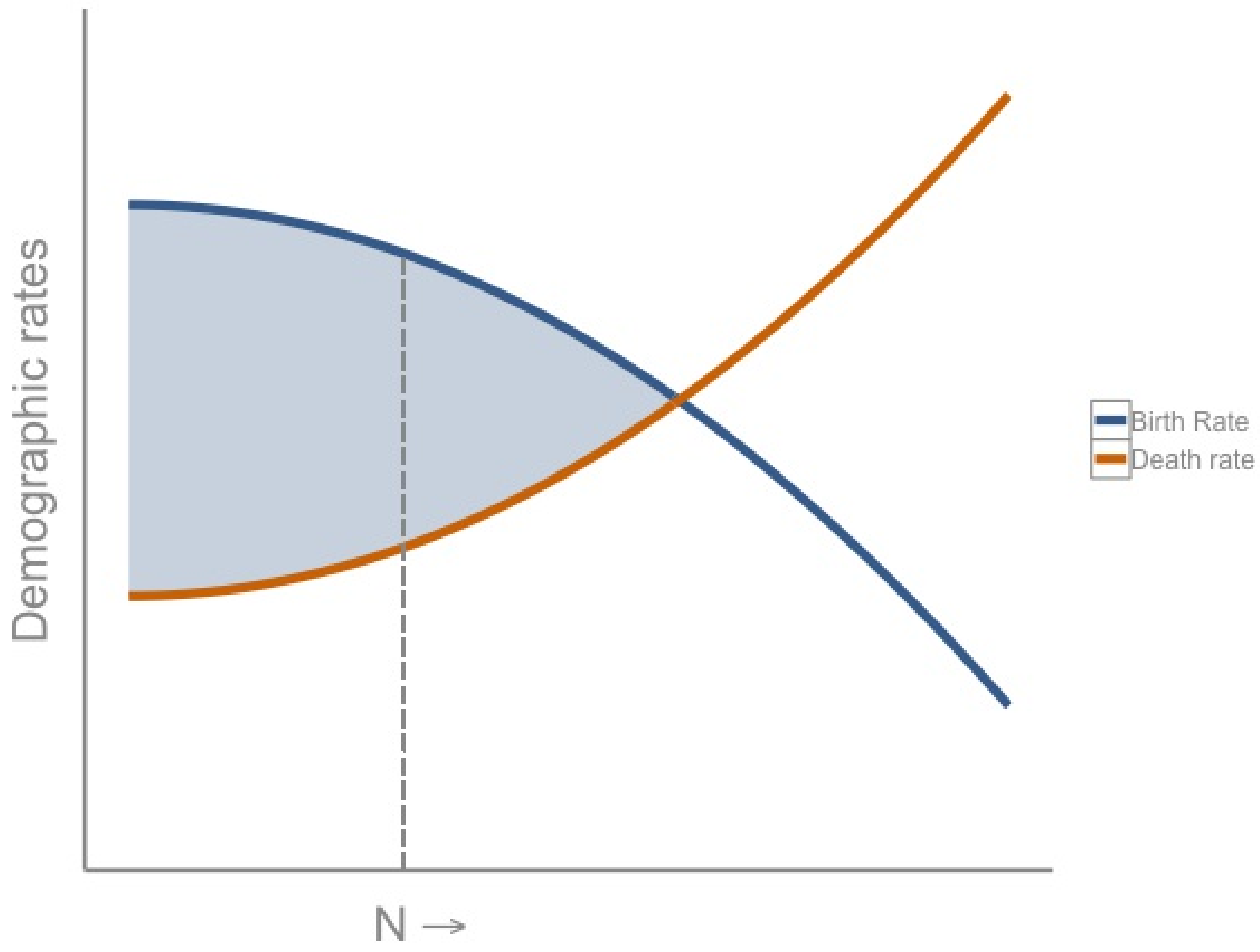


Carrying-capacity



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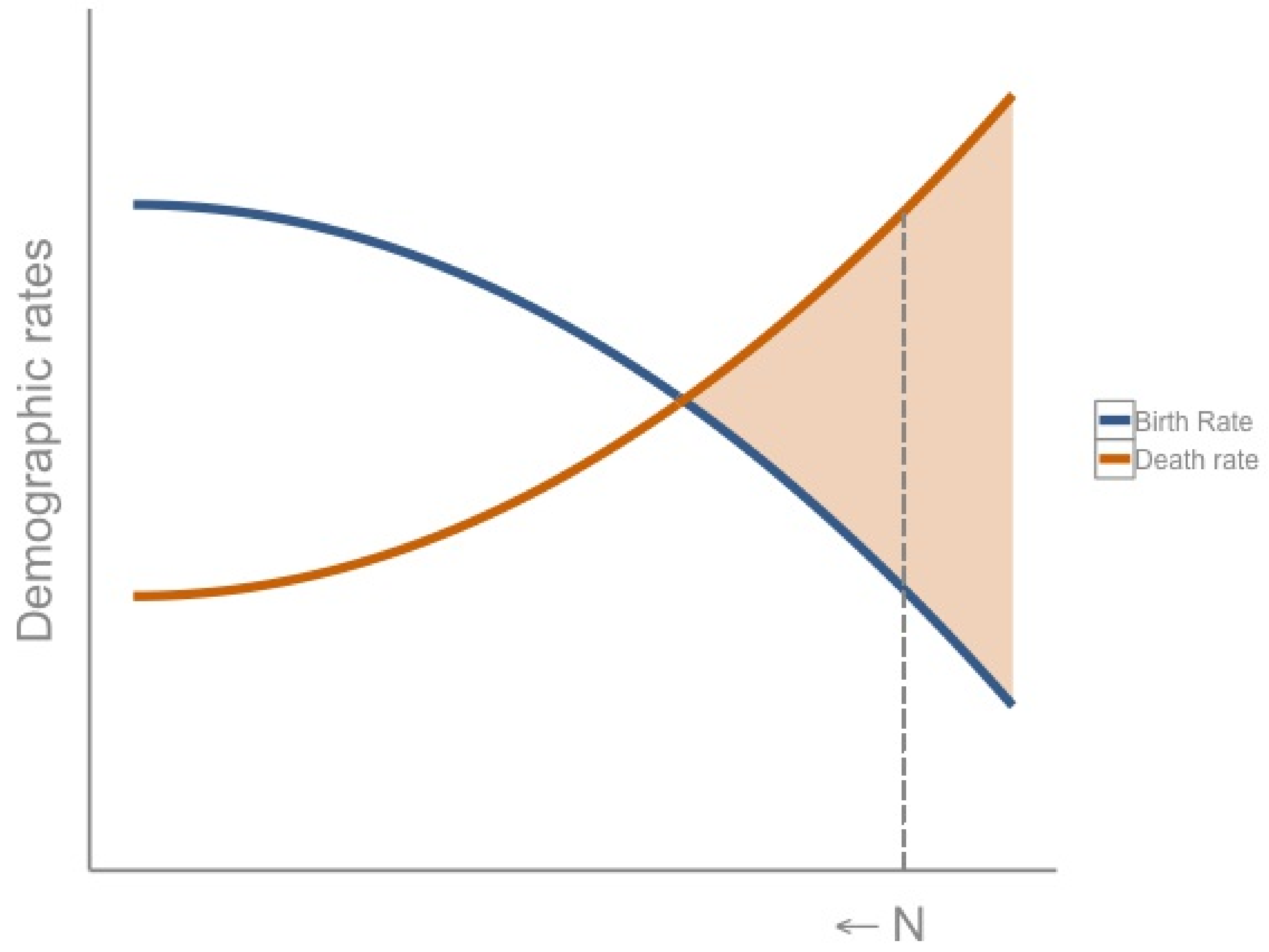
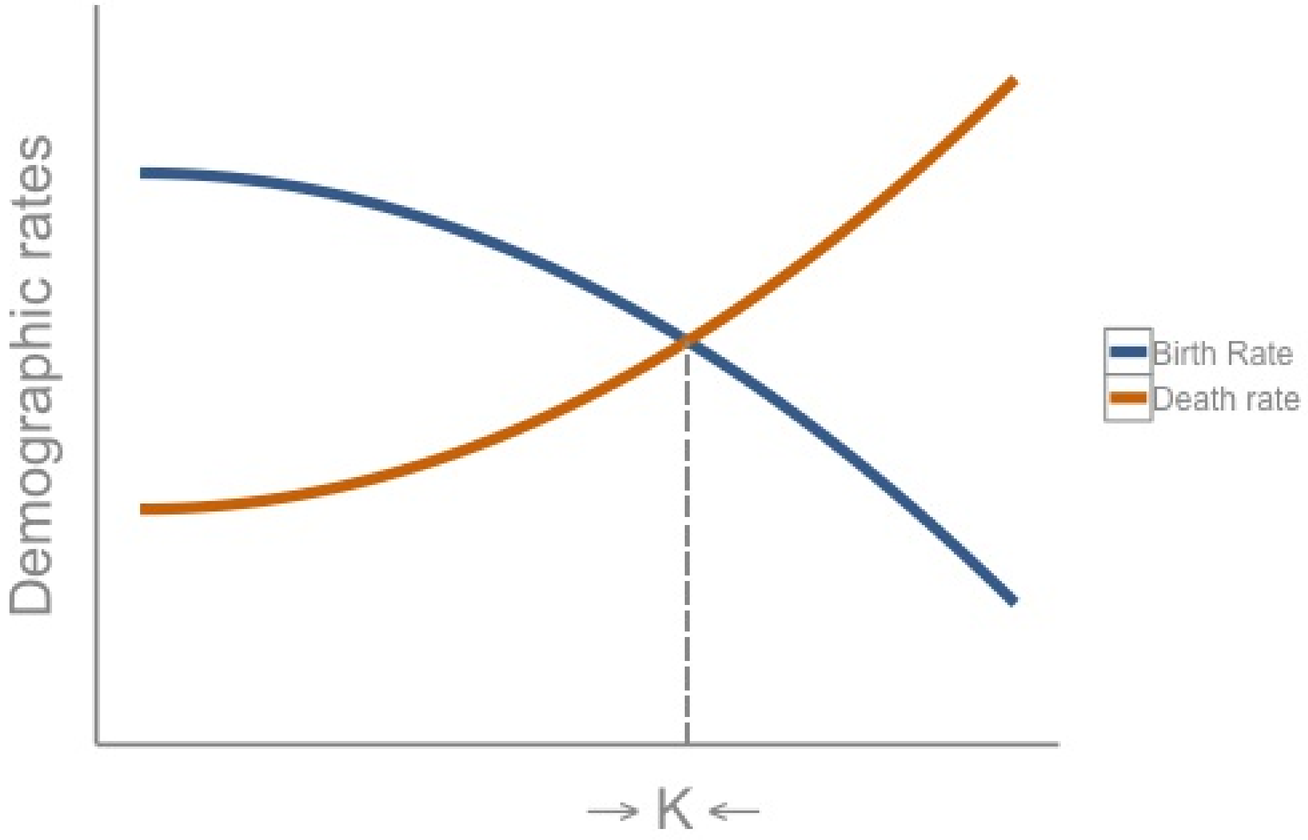


Carrying capacity

Carrying capacity :

> the population size that the environment can maintain



Population regulation vs limitation

The density-dependent processes we just learned about are called **regulating** factors

- Regulating factors keep population size from going too far above or below

Limiting factors determine the actual value of

- Limiting factors can be density-dependent (competition) or density independent (disturbance or extreme weather)

Models of density-dependent population growth

Models of D-D population growth

Remember the (continuous time) density-independent model of population growth:

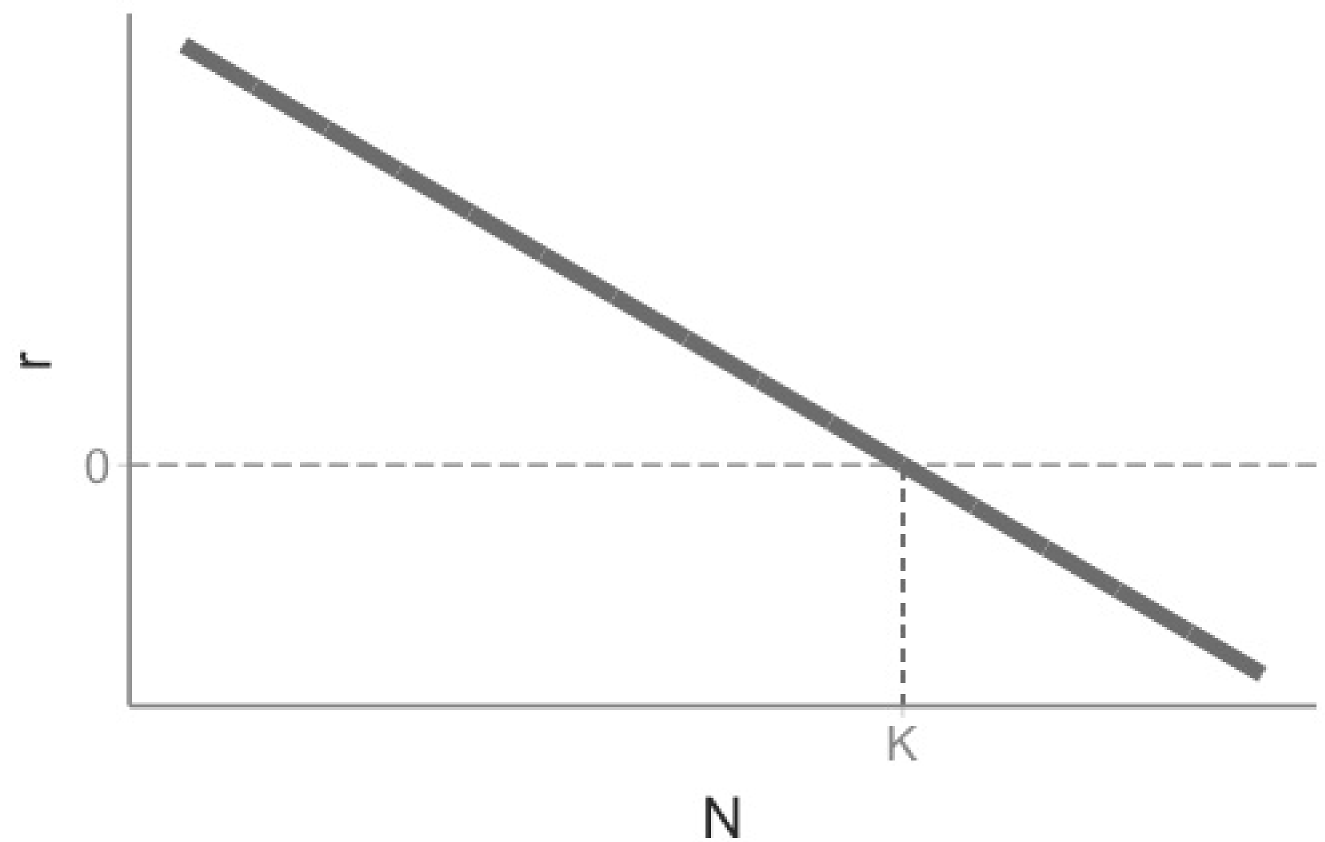
How can we modify this equation to include density-dependence?

To start, remember what density-dependence means:

> the rate of population growth changes as population size increases

Models of D-D population growth

A good starting point for this is a linear response that looks something like this:



Models of D-D population growth

How do we add this relationship to our model?

Models of D-D population growth

How do we add this relationship to our model?

Remember the equation for a line:

Models of D-D population growth

How do we add this relationship to our model?

Remember the equation for a line:

In our model, we can write this as:

.

Models of D-D population growth

In our population model, represents the rate of increase when the population is 0

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We can see in the figure that this is the largest value of the population can experience

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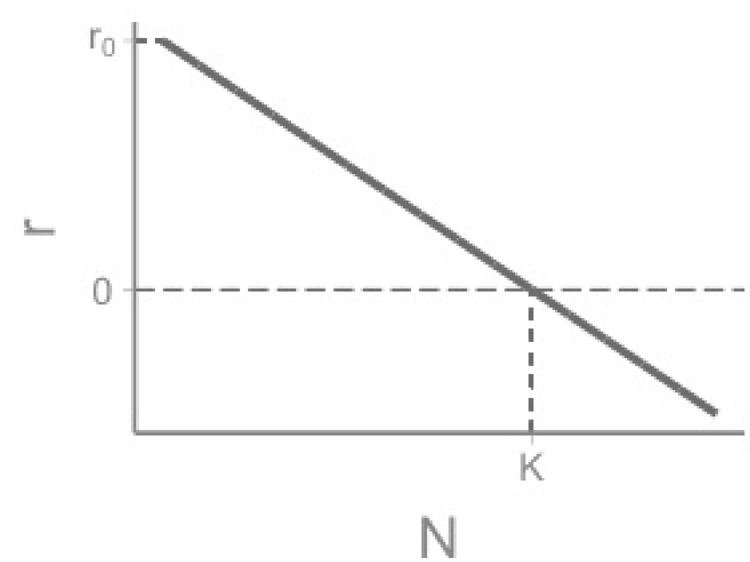
- Because the maximum rate of increase (nothing limiting population growth), it is equivalent to in the D-I model



Models of D-D population growth

What is , the slope of the relationship between and ?

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- It has to be negative has to decrease as increases)

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Remember that when , so:

therefore,

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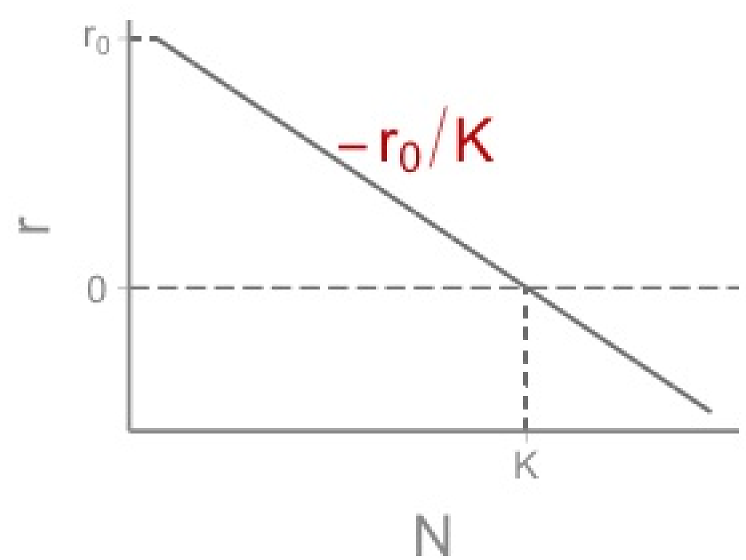

Models of D-D population growth

We now have a full equation for the relationship between and :

which simplifies to:

Models of D-D population growth

How does this work?

Models of D-D population growth

How does this work?

Assume and

Models of D-D population growth

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Assume and

What is the population growth rate when ?

- 0.9

Models of D-D population growth

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Models of D-D population growth

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Models of D-D population growth

Now let's insert our new equation for into the population growth model:

Models of D-D population growth

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This is called the **logistic growth model**

Models of D-D population growth

How does this work? Again, and

Models of D-D population growth

How does this work? Again, and

What is — when ?

- — —— 90

Models of D-D population growth

How does this work? Again, and

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- — — 90

What about when ?

- — — 250

Models of D-D population growth

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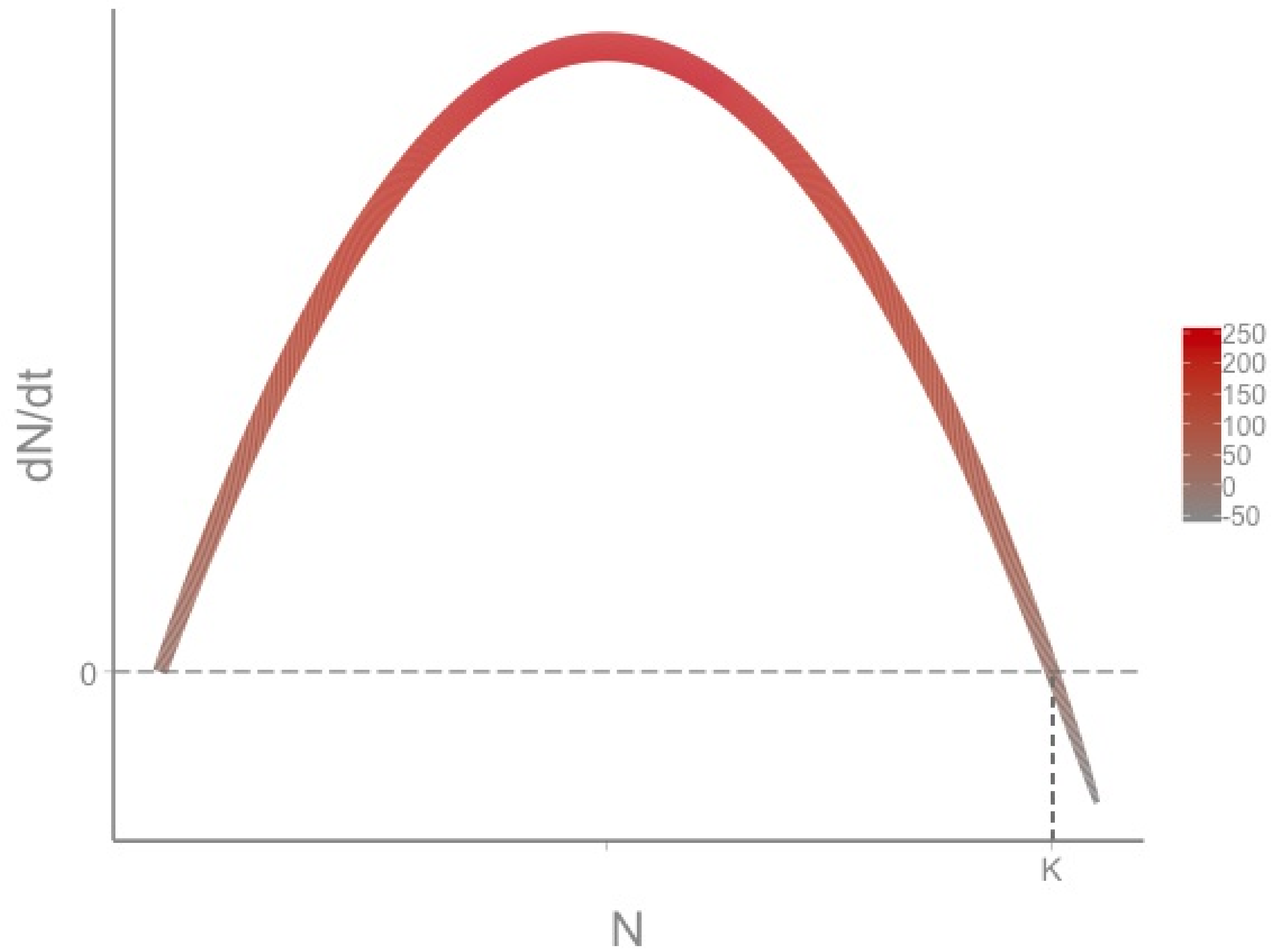
Models of D-D population growth

How does this work?



Models of D-D population growth

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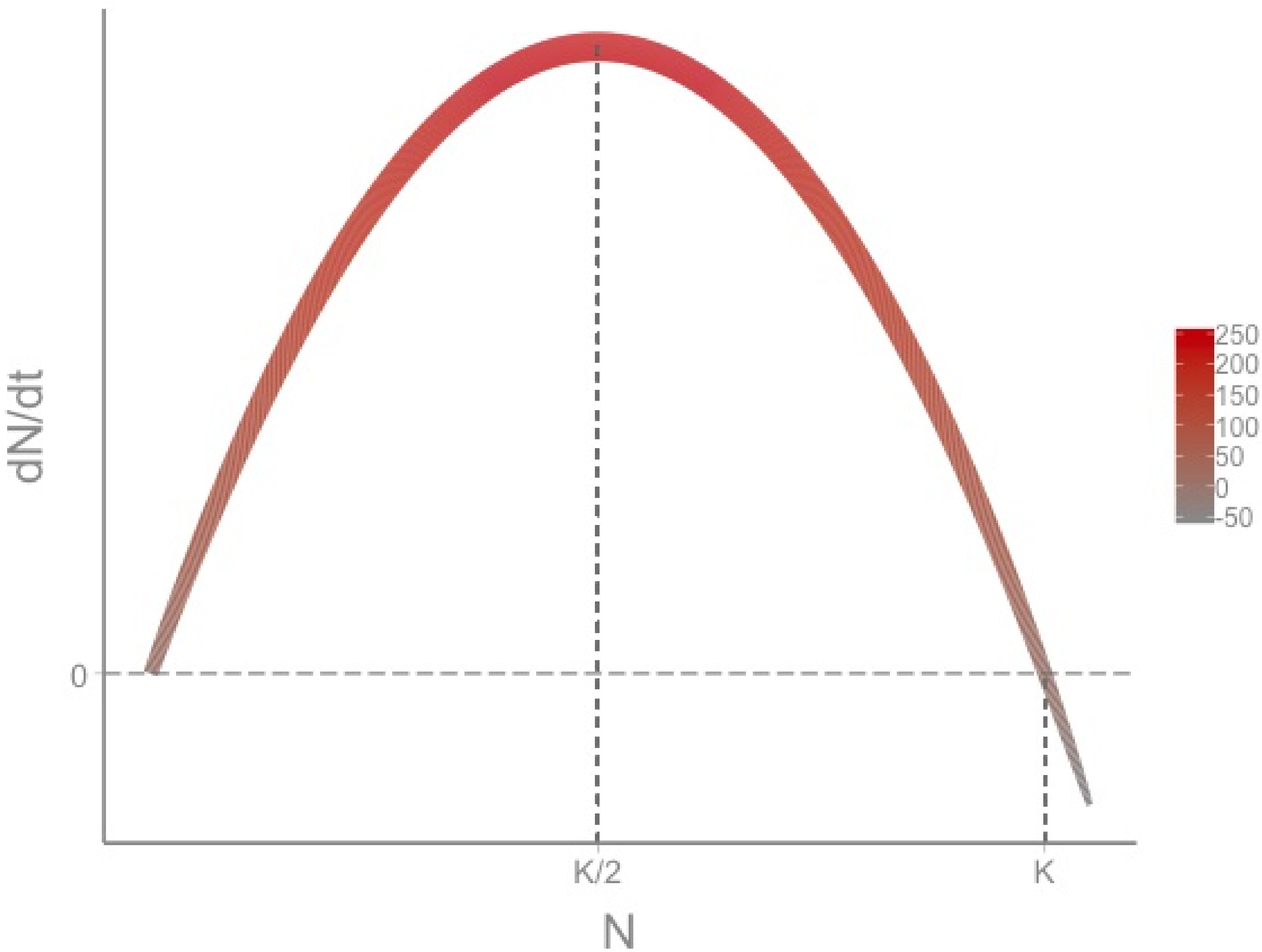
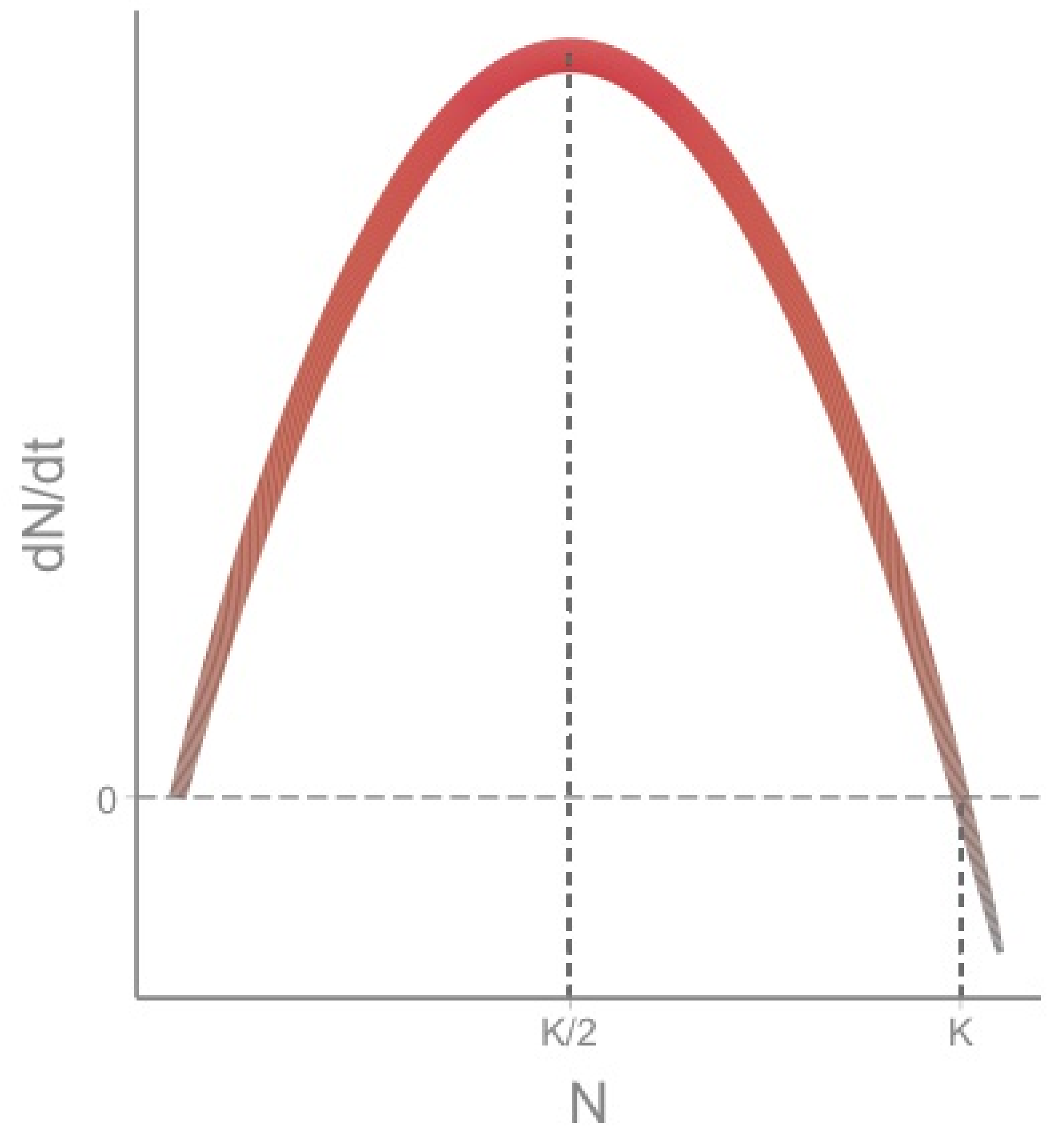
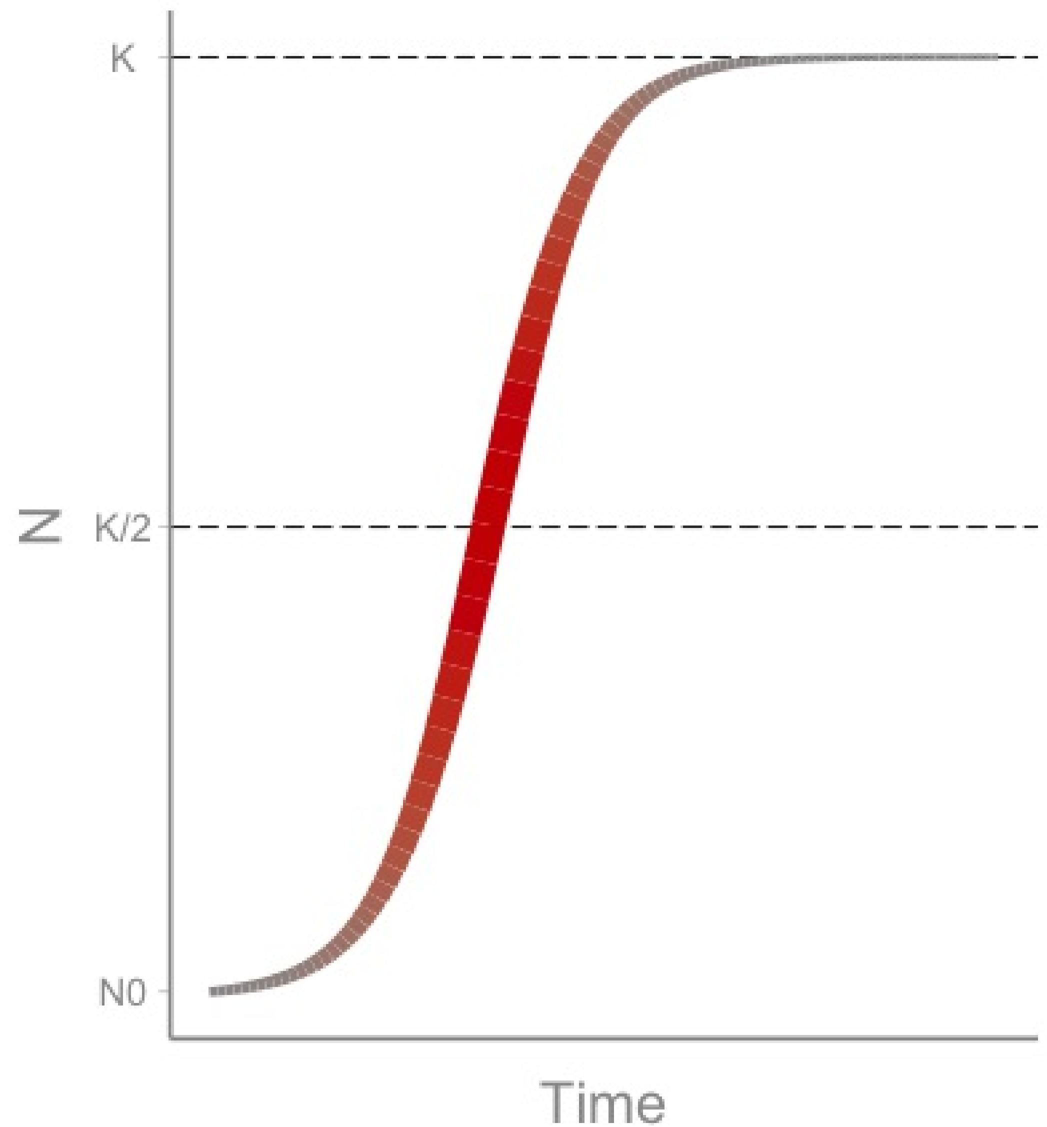


Models of D-D population growth





Non-linear effects

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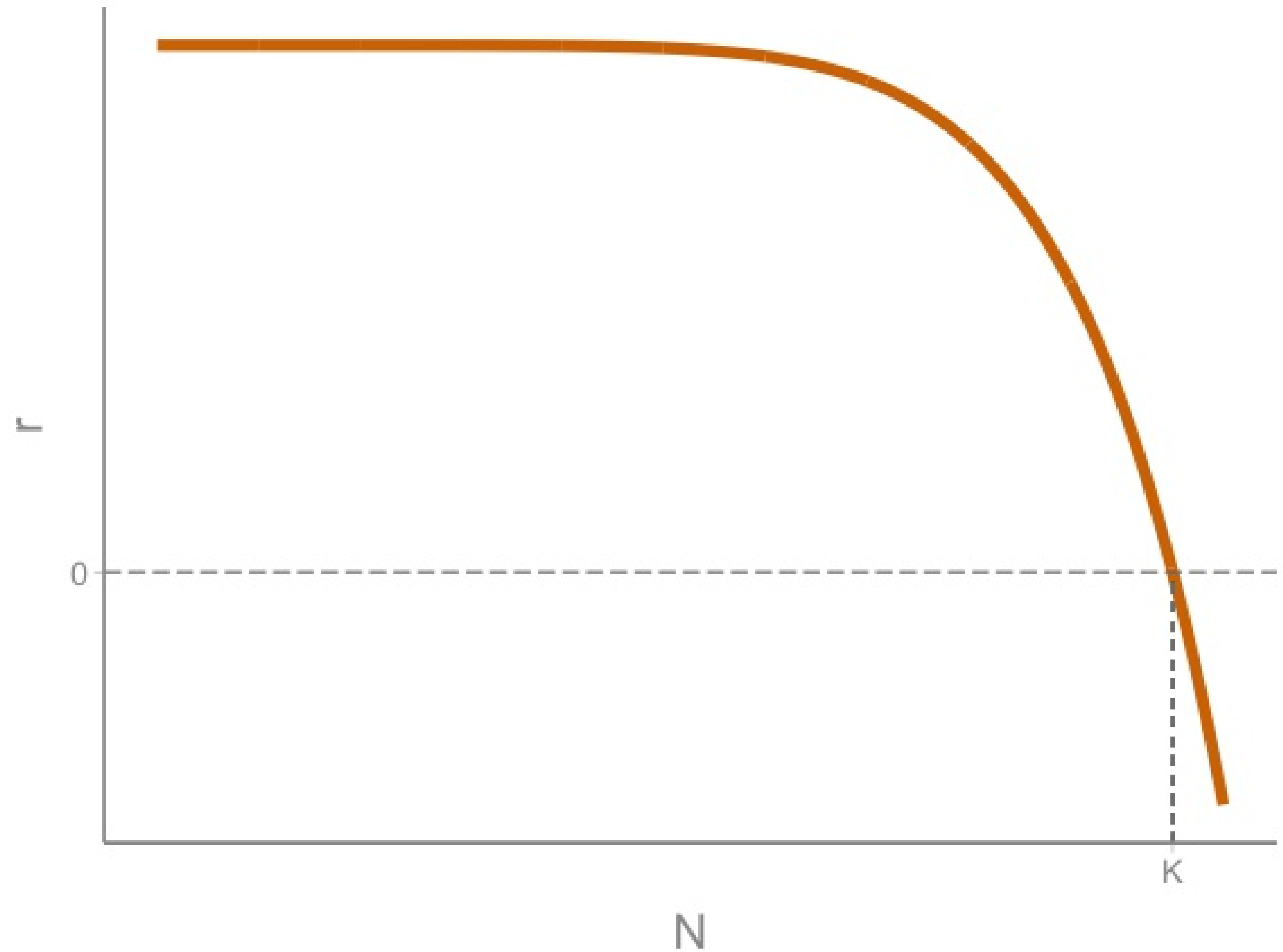
We can make the logistic model more flexible by adding a new term, :

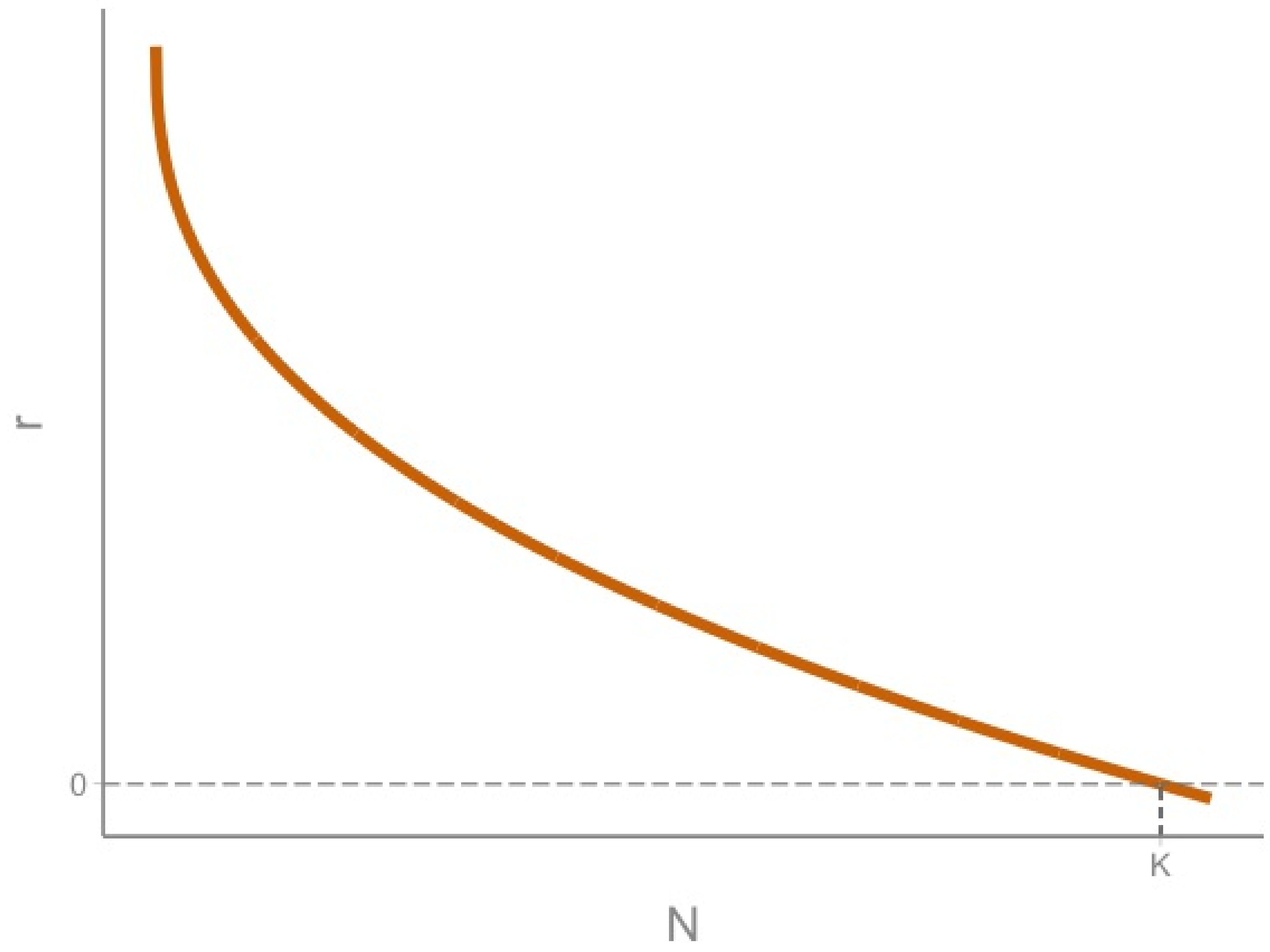
Non-linear effects

When , does not respond to until is big enough that resources become limiting



Non-linear effects

If , resources quickly become scarce, and is suppressed even at low



Allee effects

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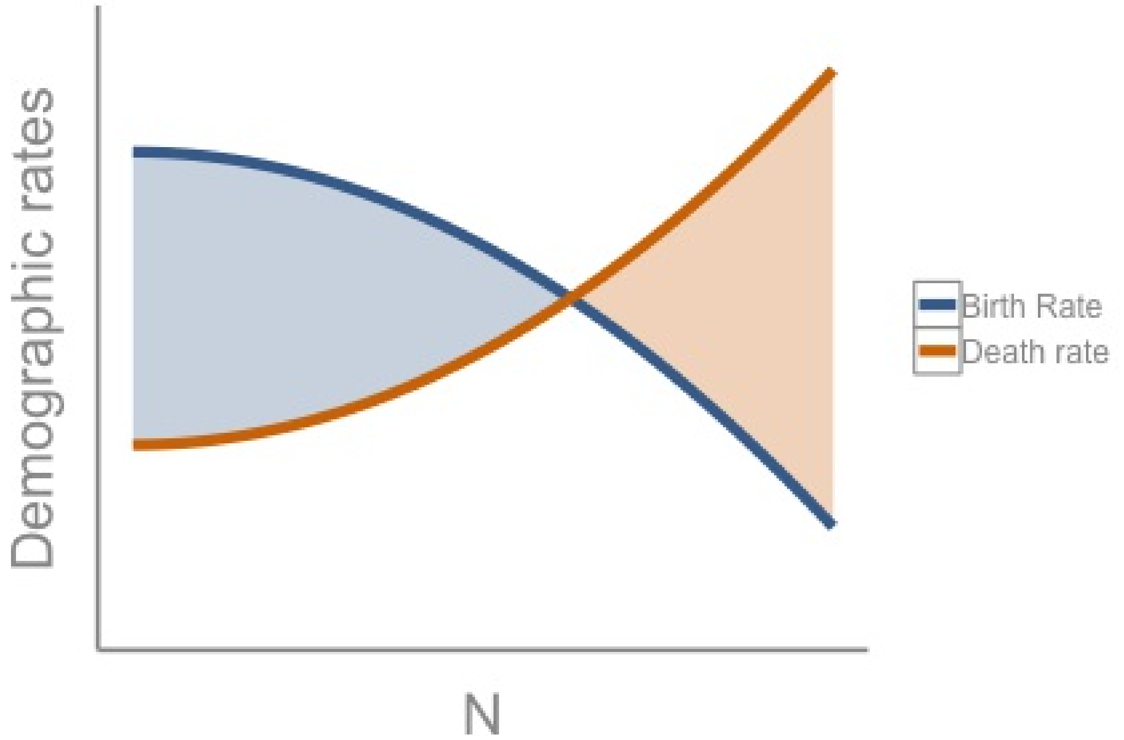
So far, we have assumed that   and   (and therefore   ) decrease as population size increases

- This is called negative density dependence



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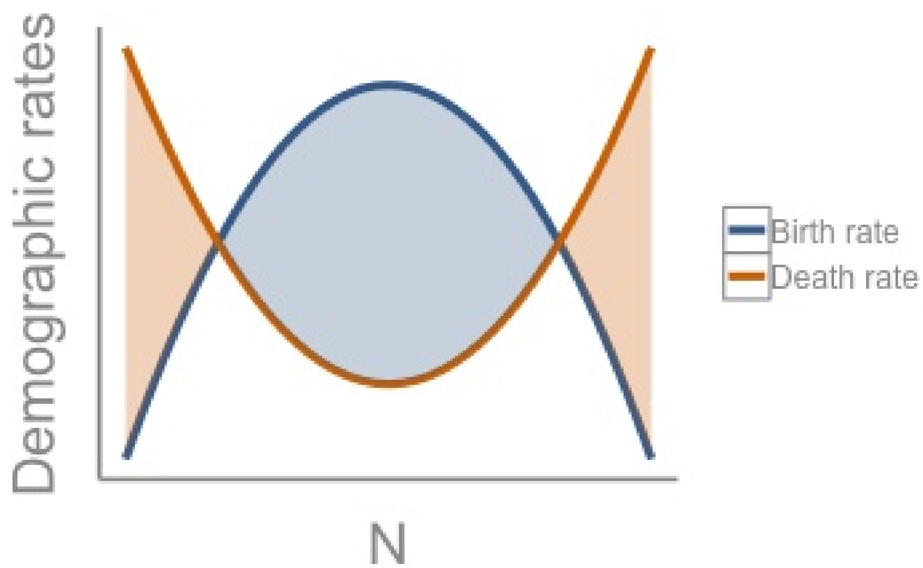
In some cases, the slope could also be positive

- Positive relationships between and or generally occur at small population sizes



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Why might the death rate be high at small ?

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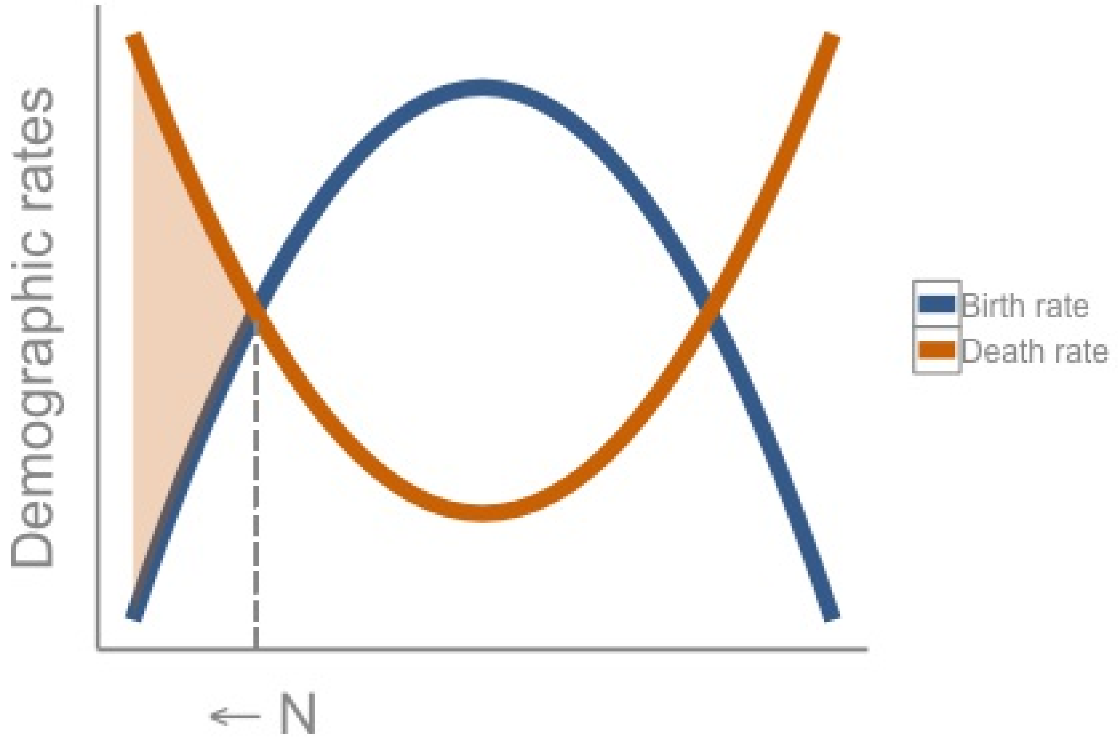
Allee effects

When abundance drops below the minimum viable population (MVP), the population will likely approach extinction without help!



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As before, we need to account for possible changes in caused by changes in population density

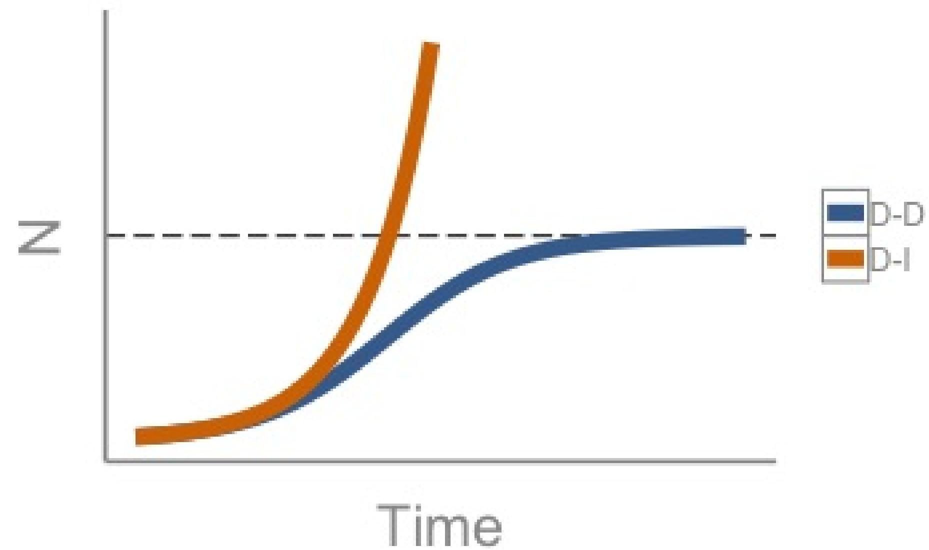
Remember that:

and:

Discrete dynamics

Therefore, one discrete-time density-dependent growth model is:

This known as the **Ricker model**



Discrete dynamics

Any adjustment that can be made to the continuous time logistic model can also be made to the Ricker model