Eutrophication in TERRA NOVA

About the effect of fertilizers on the ecosystem of a fen lake.

DynaLearn level 2 | Version 1.1

Summary	
In this lesson you will explore Terra Nova, a Dutch fen lake that became species-poor after eutrophication caused by fertilizer runoff from agriculture. You will model the food chain in the turbid, algae-dominated lake and how nutrient enrichment can trigger a trophic cascade that reduces water clarity. Finally, you will examine and model the restoration measures that were taken to help the lake shift back toward a clear-water state.	
Given name	
Surname	
Class	
Date	
Comments by teacher	

1. Introduction

Nature in fen lakes as they existed until the fifties and sixties of the last century is a benchmark for environment managers in the Netherlands. The shallow waters, a few meters of water on remaining fen lakes, offered space for particularly rich flora and fauna. With the start of intensive agriculture around 1960 many fertilizers were used. This caused the concentration of nutrients in the environment to increase slowly but steadily. In our fen lake, the clear water with the ecosystem of predatory fish (such as pike), water fleas (*Daphnia*, algae eaters), and aquatic plants (see Figure 1a) could turn within a few months into a species-poor cloudy water where bream (a species of fish) churns the bottom of the lake and many blue-green algae (producers) appear (see Figure 1c).

Terra Nova in the Netherlands and **the Shannon basin** in Central Ireland are waters with such a history. In this lesson, you will create a **model** in order to learn about these sudden changes.

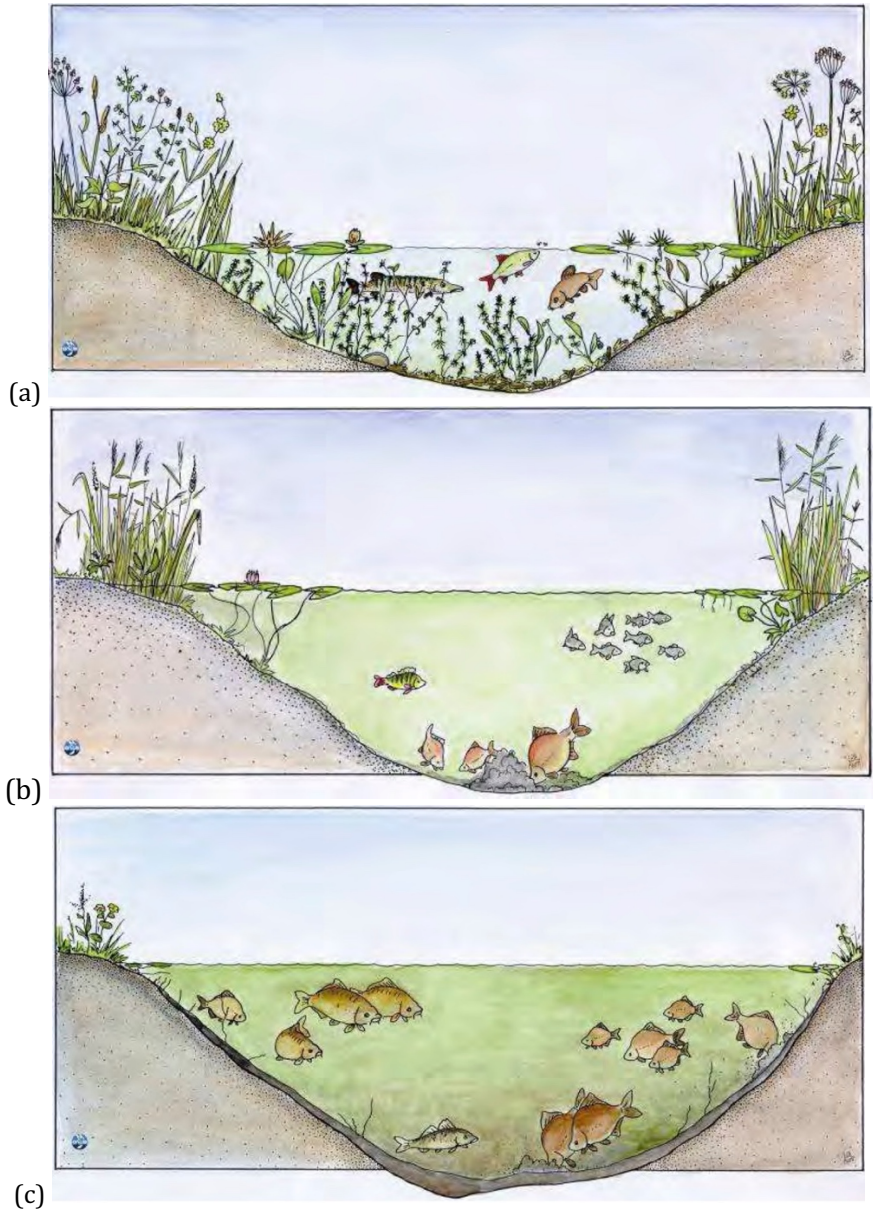


Figure 1. Change from a clear fen lake (a) to a cloudy water (c).

2. Starting DynaLearn

There are several ways to log in. Use one of the two options below. Then check whether the login was successful (see 'Let's check').

Via a code:

1. Go to DynaLearn (https://create.dynalearn.nl/).
2. Click on 'log in with code', at the bottom left.
3. Enter the project code and your (school) email address.
4. Copy the code from the confirmation email received from *dynalearn.nl* (see spam folder if needed) and fill in the other details.
5. Log in to DynaLearn.

By invitation:

1. Copy the login details from the invitation email received from *dynalearn.nl*.
2. Go to DynaLearn (https://create.dynalearn.nl/).
3. Log in to DynaLearn.

Let's check!
After logging in, you will automatically enter the workspace of the assignment. You can recognize it by the question mark on the right side of the screen  . Is the question mark missing? Then first:

- In DynaLearn, click  . Click on 'Select template'.
- Choose 'Terra nova' and press 'Load'.

Save model file and start:

1. Click on  top left. Change the name to 'Terra nova' and click 'Save'.
2. How do you proceed? Just follow the steps in this workbook. Note! You can't skip steps. Ask for help if you can't figure it out at a certain step. The video function  in DynaLearn shows how a model ingredient can be made. The boxes contain a brief explanation about the model ingredient. Put a check mark √ next to the step you performed. This way you keep track of where you left off.

3. Blue-green algae

1. Read Box 1.

Box 1. Entity and quantity

An entity is usually a physical thing in a system (e.g., car, human).
A quantity is a measurable property of an entity (e.g., temperature, length).

2. Create an entity called *Blue-green algae* (see →). The entity *Fen Lake* has already been created.

3. Create the quantity *Number* of the *Blue-green algae* entity (see →).

4. Create a configuration *Live in* between the entity *Fen Lake* and *Blue-green algae* (see →).

5. Read Box 2.

Box 2. Help function

If the question mark or an ingredient in your model is red, then something is wrong. Click the question mark for a hint. Then click on a number, for example to see where the error is in your model. Only use the question mark if you can't figure it out yourself!

6. Try out the help function by making a mistake on purpose. Click to see which notification you get. Fix the error.

4. Water fleas and bream

You now know how to place entities and quantities in your model. Next, you are going to make a food chain with organisms that live in the Terra Nova fen lake in its species-poor state.

1. Read the following text about the ecosystem:

> As noted in the introduction, the lake shifted to a species-poor state with low water clarity, in which bream and blue-green algae (cyanobacteria; producers) become abundant (see Figure 1c). This state can persist because bream feed on water fleas (zooplankton), causing water flea populations to decline. With fewer water fleas, less blue-green algae is grazed, which promotes algal blooms and further reduces water clarity. In addition, bream disturb the lakebed by stirring up sediment, which also lowers water clarity and helps maintain this turbid state.

2. Complete the food chain below with the organisms that appear blue in the text (the arrow means: *eaten by*).

Blue-green algae	→	...	→	...

3. Create an **entity** for **each** organism of the food chain above in your model.

4. You can keep the model organized and clear by using a few buttons at the bottom right of the screen. Click regularly on  to align everything neatly. Click  to make your model fit on the screen.

5. Link the entities together with a configuration  . Select the relationship name in the 'configuration textbox'. Pay attention to the direction of the arrow. (tip: who eats who?).

6. For **each** entity (that represents an organism of the food chain), create a quantity *Number.*

In a food chain, the number (= quantity) of predators (= entity) directly influences the number of the prey.

7. Read Box 3.

> **Box 3.** A cause-effect relationship
>
> In DynaLearn, there are two types of relationships:
> - Positive relationship  : the quantities change in the same direction (if quantity 1 increases, then quantity 2 also increases)
> - Negative relationship  : the quantities change opposite (if quantity 1 increases, then quantity 2 decreases. Or vice versa: if quantity 1 decreases, then quantity 2 increases)

8. How does the predator affect prey? (delete what doesn't apply)

> If the number of predators increases, the number of prey *decreases/remains the same/ increases.*

9. What type of relationship fits the effect of predator on prey? (delete the incorrect response)

The effect of a predator on prey is a *positive/negative* relationship.

10. Make the cause-effect (feeding) relationships between the quantities (see →).

As described in the text above, water clarity is influenced by two organisms. First we will consider **only** the effect of Blue-green algae on water clarity.

11. Create the *Clarity* quantity of the entity *Fen lake*.

12. Make the cause-effect relationship between *Number* of *Blue-green algae* and *Clarity.*

13. Is your screen content a bit messy? For a better organization, click . Click to fit your model on your screen.

5. Running a simulation

The next step is to start the simulation of your model.

1. Read Box 4.

Box 4. Change of a quantity.

A quantity can change. This is indicated by . The delta symbol (δ) is the mathematical sign for change (also called the derivative). The down arrow () is a decrease, the zero (Ø) is constant and the up arrow () is an increase.

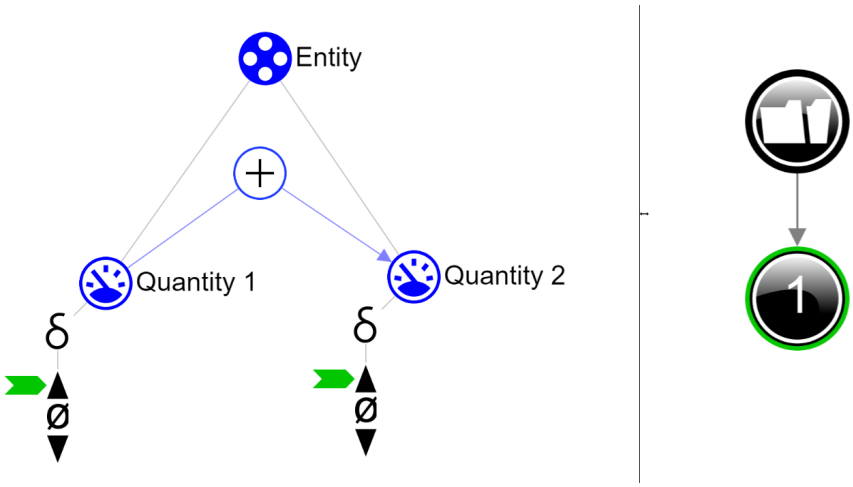
2. Set as initial change (see →):

   a. *Number* of the entity *Bream* is increasing.

3. Read Box 5.

Box 5. Read the outcome of a simulation.

After starting a simulation (with), a window appears on the right in which the possible states of the system are indicated. There is one possible state in this hypothetical example model.



You can click on the state to view the outcome. The state then acquires a green edge. In the model, the change for this state is indicated by a green arrow . The model shows that in state 1 Quantity 1 increases and that therefore Quantity 2 also increases.

4. Read Box 6.

Box 6. Help function

If the explanation mark appears , something is wrong during the simulation. Click on the explanation mark for a hint. Then click on a number, for example 1, to see where the error is in your simulation.

5. Start the simulation .

6. What happens to the other quantities in the outcome of this simulation (delete the incorrect reponses)?

Number of water fleas: decreases/increases
Number of blue-green algae: decreases/increases
Clarity of fen lake: decreases/increases

As described in the text in section 4, bream disturb the lakebed by stirring up sediment, which also lowers water clarity.

7. Make the cause-effect relationship between *Bream* and *Clarity.*

8. Start the simulation again .

9. Explain why adding the cause-effect relationship between *Bream* and *Clarity* does not change the behaviour of the system.

Explanation: [fill in....]

6. The effect of Agriculture

1. Read the following text:

> As mentioned in the introduction, the amount of nutrients in the fen lake increased because large amounts of fertilizer were used in agriculture. Higher nutrient levels have a positive causal effect on blue-green algae: with more nutrients available, they can grow and reproduce faster, increasing their abundance.

2. Create a new entity named *Agriculture*

3. Create a new entity named *Fertilizers* and the quantity *Amount*.

4. Link the new entities together with a configuration named 'Use'.

5. Create a new entity named *Nutrients* and the quantity *Amount*.

6. Link the new entity to the entity *Fen lake* with a configuration named 'Contain'.

7. Make the causal relationship between *Amount* of the entity *Fertilizers* and *Amount* of the entity *Nutrients*.

8. Make the causal relationship between *Amount* of the entity *Nutrients* and *Number* of the entity *Blue-green algae*.

The next step is to start to simulate your model.

9. Set the initial change (see →):
   a. *Number* of the entity *Bream* is constant.
   b. *Amount* of the entity *Fertilizers* increases.

10. Start the simulation .

11. What happens to the other quantities in this outcome of the simulation? In the list below, delete what doesn't apply.

Amount of nutrients: decreases/remains constant/increases
Number of water fleas: decreases/remains constant/increases
Number of blue-green algae: decreases/remains constant/increases
Clarity of fen lake: decreases/remains constant/increases

7. Restoring the fen lake

1. Read the following text:

> To restore the fen lake, several measures were considered. One key measure is to reduce the inflow of nutrients. With fewer nutrients available, blue-green algae grow less, which increases water clarity and allows submerged aquatic plants to return (due to more light availability). These plants stabilise the sediment with their roots and stems, reducing resuspension and limiting the effects of bream stirring up the bottom. Clear, plant-rich water also provides suitable habitat for pike (migrating in from nearby connected lakes). Pike use aquatic plants as cover when hunting and can prey on bream (among other fish).

2. Create the entity *Aquatic plants* with the quantity *Number*.

3. Link with a configuration the entity *Aquatic plants* to the entity *Fen lake*.

4. Create the entity *Pike* with the quantity *Number*.

5. Link with configurations the entity *Pike* to the entity *Bream* and to the entity *Aquatic plants*.

6. Based on the text, add **three** new causal relationships to your model.

7. Read Box 6. Is your model completely finished? (see also point 8 below)

Box 6. Progress bar

At the bottom of the screen is the *progress bar* (see example below).

Entity says: 4/4/0, this means: 4 created, 4 needed, 0 error. For quantity it says: 5/17/1: this means: 5 made, 17 needed, 1 error. If all the numbers are green, that type is settled.

8. You probably noticed that there are still some configurations to be made. Create the missing configurations.

The next step is to start to simulate your complete model.

9. Set the initial change (see →):
   a. Remove the blue arrow at quantity *Number* of the entity *Bream* by clicking on it and clicking on the trash can.
   b. Set *Amount* of the entity *Fertilizers* to **decreases** to simulate the management decision to reduce the use of fertilizers.

10. Start the simulation .

11. What happens to the other quantities in this outcome of the simulation? In the list below, cross out what doesn't apply.

Amount of nutrients: decreases/increases

Clarity: decreases/increases

Number of aquatic plants: decreases/increases

Number of pike: decreases/increases

Number of bream: decreases/increases

Number of water fleas: decreases/increases

Number of blue-green algae: decreases/increases

12. Notice that an exclamation point has appeared (!). Click the exclamation point. This is because there are two positive feedback loops in the model: (1) (2)

    How many positive and negative **relationships** are there in the loops? Can you deduce when there is a positive feedback loop? Enter your answer below

(1)

Number of positive links: [#]

Number of negative links: [#]

(2)

Number of positive links: [#]

Number of negative links: [#]

A positive feedback loop occurs when… [complete.]

8. More ways to restore the lake

1. In the model, you saw that reducing nutrient inflow can improve water clarity. Based on the description and model, what other measures could help restore the lake and increase water clarity? Explain how your proposed measure would affect the causal chain(s) in the system and have a desired outcome.

Solution 1: [fill in....]

Solution 2: [fill in....]