

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.

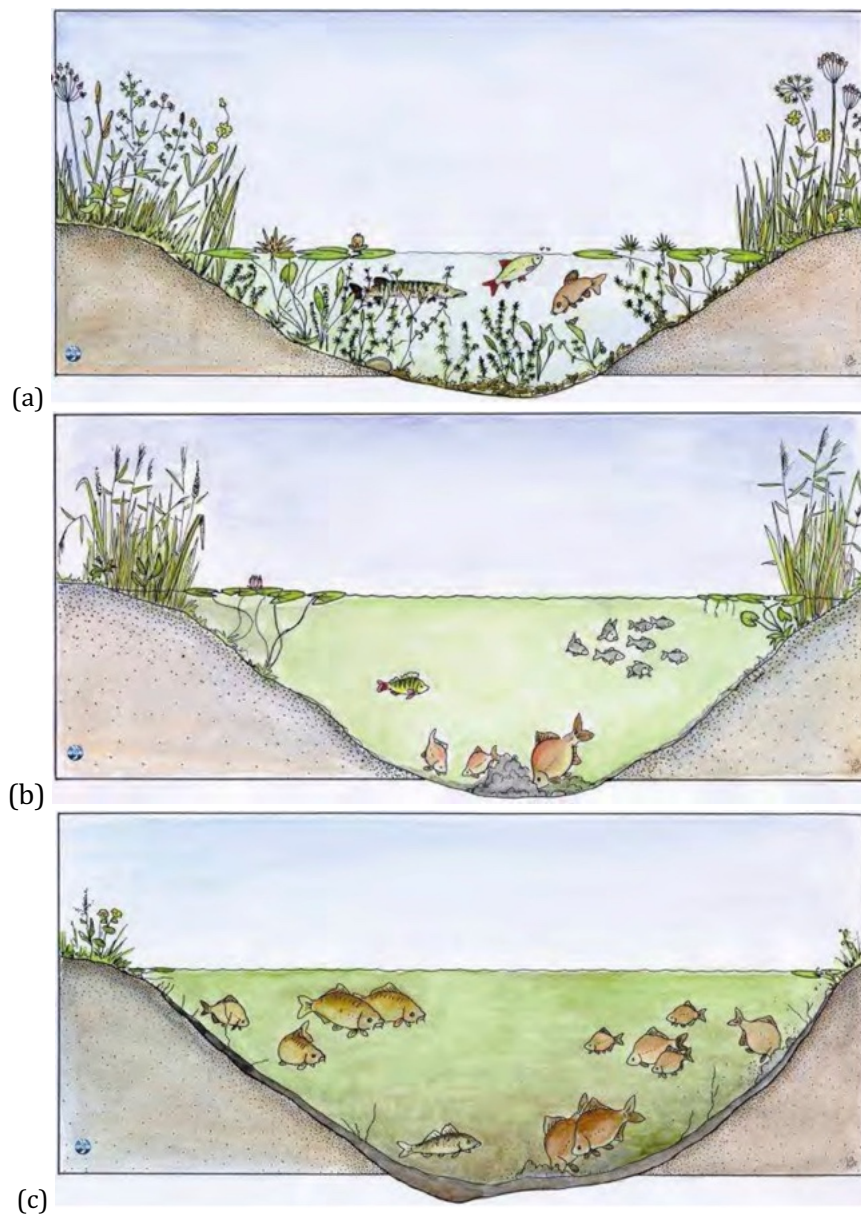


Figure 1. Change from a clear fen lake (a) to a cloudy water (c).

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 \checkmark 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	→	...	→	...
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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 () is constant and the up arrow () is an increase.


2. **Set** as initial change (see  \rightarrow ):

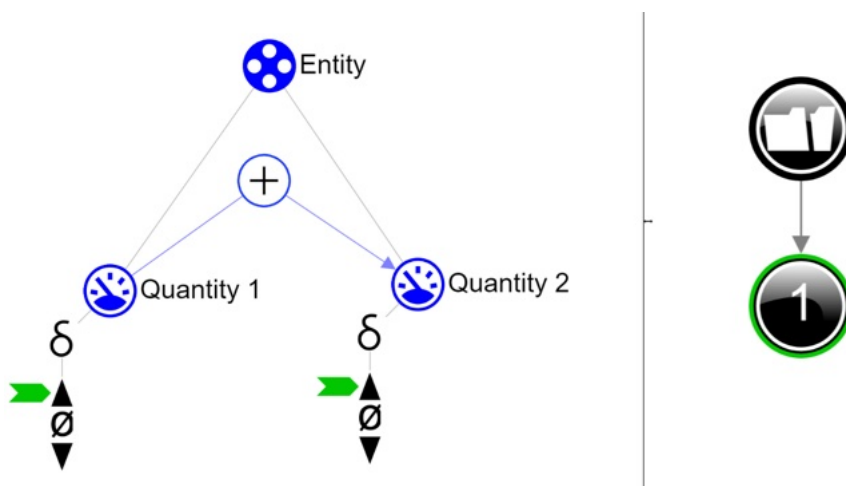
a. *Number of the entity *Bream* is increasing.*





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  Quantity 1 increases and that therefore Quantity 2 also increases.

4. **Read** Box 6.


Box 6. Help function

If the exclamation mark appears , something is wrong during the simulation. Click on the exclamation mark  for a hint. Then click on a number, for example , 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 responses)?

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:

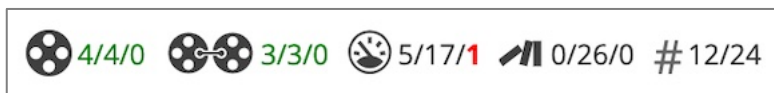
To restore the fen lake, several measures were considered. One key measure is to reduce the inflow of **nutrients**. With fewer **nutrients** available, **blue-green algae** grow less, which increases water **clarity** and allows submerged **aquatic plants** to return (due to more light availability). 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:  

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



Number of positive links: [#]

Number of negative links: [#]



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....]