Teacher´s guide

This teacher´s guide includes background information about the Matoseuranta app and earthworms in Finland. There are also ideas and materials for lessons and instructions for sampling. Teachers can plan their lessons freely, although the instructions for sampling (data collection and uploading) should be followed precisely.

Matoseuranta

Matoseuranta has three goals: The first one is to collect information about earthworms in Finland. With this information, researchers will investigate where different earthworms are found in Finland, what factors are driving earthworm distributions and what impact climate change may have on earthworm distributions in the future. The second goal is to evaluate the use of citizen science in biological education. The third goal is to develop methods for species identification which could be used in future citizen science projects.

Distributions of species that live belowground are often not well known, because studying them is quite laborious. Investigating distributions of earthworms is important because they play a major role in ecosystems. Earthworms are called ecosystem engineers, because they change the physical and chemical properties of soil. In addition to investigating their current distributions, Matoseuranta´s objective is to investigate how those distributions may change under future climate change.

Data for this research is being collected across Finland. Citizen science is well-suited for this kind of research where data is collected from a large area and over long period of time. With help from citizens, data is collected more efficiently than if researchers alone collected all the data. However, citizen science benefits not only researchers but also the citizens who collect data (often students) as well. They get to participate in biological research, which inspires students to participate in research also in the future and increases their environmental awareness.

The popularity of citizen science has grown in recent years and one reason behind this growth is the developing technology which has made it possible and easy to send and share information between the researchers and the citizens. Also, the benefits to both participants and researchers

has increased the popularity of citizen science (Silverton 2009). However there are few studies that have examined the benefits to students who participate in citizen science. In particular, there is a need for studies that measure the possible benefits with some kind of scale or other repeatable method (Brossard et al. 2005).

The second objective of Matoseuranta is to collect information about how citizen science should be used in education, what factors should be taken into account when researchers and teachers work together and how to maximize benefits of citizen science for every participant.

Citizen science often includes species identification. This can be very difficult for people who are not used to it. It is hard to recognize the features that help you to identify what species is in question. This is one reason why in citizen science programs the individuals of investigated species are often sent to researchers for identification. The third objective for Matoseuranta is to develop new ways to identify species. In Matoseuranta, students identify the three types of earthworms by themselves and in some cases will also send samples to researchers for DNA extraction. In addition students will take a picture of each earthworm they have collected.

Schools all over Finland will collect data by sampling different areas. At each location, they will collect data about the surrounding environment and about the three different earthworm types. Feedback and opinions about Matoseuranta and citizen science will be collected from schools.

Brossard, D., Lewenstein, B., Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. International Journal of Science Education 27: 1099-1121

Silverton, J. (2009). A new dawn for citizen science. Trends in ecology and evolution 24: 467-471

Matoseuranta and the Finnish curriculum

In this section you will find information about how to include Matoseuranta into the national core curriculum for basic education 2014, the former curriculum 2004 and also for the curriculum for upper secondary school 2015. How to align Matoseuranta with the curriculum for upper secondary school is presented first, and after that comes the curriculum 2014 for grades 3-6 and 7-9. Finally the former curriculum is introduced for grades 7-9. More information about the topics that can be discussed in lessons is presented in the lessons section.

Curriculum for upper secondary school 2015: biology

Contents of Matoseuranta align with courses ”Life and evolution (B11)” and ”Ecology and environment (B12)”.

One objective in the course ”Life and evolution (B11)” is for students to gain knowledge about the nature of information acquisition and research in biological study and about how to present biological information. During Matoseuranta students have the opportunity to collect data from

the field about earthworms and to observe the results from Matoseuranta´s website. One objective in this course is that students can have new experiences that will increase their interest towards biology, which is also one objective of Matoseuranta.

An objective in the course ”Ecology and environment (B12)” is to go through the principles of ecology and learn about the diversity of nature. These themes can be discussed also during Matoseuranta, where students get to go to the field and learn about the ecology of earthworms. To upload the collected data, students will have to identify different habitats and in the data analysis–phase students will have to draw conclusions from the results using information about earthworm ecology.

Planning and executing a small research project is included in both courses' (B11, B12) contents. It is not possible for students to entirely plan and execute their own research, but before going into field they can formulate research questions and consider how they would find out the distributions of earthworms in Finland. Students are then able to participate in collecting and analysing the data in Matoseuranta.

National core curriculum for basic education 2014: biology

During Matoseuranta, students will participate in different phases of a biological research study and use a variety of methods for acquiring information in the class and in the field. Using information and communication technology is included in Matoseuranta. The 2014 curriculum emphasizes inquiry-based learning and working outdoors. ICT (information and communication technology) competence is also included in the curriculum's transversal competence objectives for both grades 3-6 and grades 7-9.

Matoseuranta can be modified by teachers so that students who need special support can participate in all phases of Matoseuranta. Sampling can be executed in multiple different locations and the teacher can choose whichever place fits the best for the class. Sampling can be carried out for example in a school backyard or in some other place that is easy to reach. Sampling is carried out in small groups so that there is not too much pressure for a single student. Students can also be given different roles in sampling depending on their interests and capabilities.

In the national core curriculum for basic education 2014, the key content areas that should be included in the curriculum for the grades in question are given first. After that, there are objectives of instruction which are divided into different sections depending on the grade in question. Below you can find out how Matoseuranta is related to the key content areas and objectives of instruction.

Grades 3-6: environmental studies

1. Key content areas
    - **C4** Exploring the environment
    - **C5** Structures, principles and cycles of nature

In Matoseuranta, students have a chance to learn about their own environment and practice different phases of conducting biological research. Students are introduced to different habitats and how to study soil organisms. In addition they learn how to identify species (**C4**). Other topics such as foodchains and relationships between organisms and their habitats can be discussed in lessons (**C5**).

2. Objectives of instruction
    a. Significance, values and attitudes
        - **O1** to spark and maintain the pupil´s interest in the environment and environmental studies and to help the pupil experience all fields of knowledge of the subject as significant for himself or herself
        - **O2** to guide and encourage the pupil to set personal study goals and to make persistent efforts to achieve them and recognise his or her own competence of environmental studies
        - **O3** to support the development of the pupil´s environmental awareness and to guide the pupil to act and become involved in his or her surroundings and community in order to promote sustainable development and to appreciate the significance of sustainable development to himself or herself and the world

Working in the field and participating in a real study increases students' interest towards environmental decision making in their own communities and increases their desire to understand the environment and environmental sciences (**O1**, **O2**, **O3**).

    b. Research and working skills
        - **O4** to encourage the pupil to formulate questions on various topics and to use them as the basis for research and other activities
        - **O5** to guide the pupil to plan and carry out small-scale research projects and to make observations and take measurements in versatile learning environments using different senses and research and measuring equipment
        - **O6** to guide the pupil to recognise causal relationships, to make conclusions based on his or her results, and to present the results and research in different ways
        - **O9** to guide the pupil in exploring and acting as well as wandering around and going on field trips in nature and the built environment
        - **O10** to offer the pupil opportunities to practise acting in a group in different roles and interactive situations, to inspire the pupil to express himself or herself, and to listen to others as well as to support the pupil in recognising, expressing, and regulating his or her emotions
        - **O11** to instruct the pupil to use information and communication technology responsibly, safely, and ergonomically for acquiring, processing and presenting information as a means of interaction

In Matoseuranta, students can participate in different phases of biological research, compare different study methods and analyse the results using the information they have learned (**O4**, **O5**, **O6**). Sampling is executed in the field using biological research equipment as well as information and communication technology (the Matoseuranta website and app). In addition, students can practise working in groups and being in charge of their own areas of responsibility (**O9**, **O10**, **O11**).

c. Knowledge and understanding

- **O12** to guide the pupil in perceiving the environment, human activities, and the related phenomena using the concepts of environmental studies and in developing his or her conceptual structures from preconceptions towards accurate use of concepts
- **O14** to guide the pupil in obtaining reliable information, expressing and justifying different views and interpreting and critically evaluating information sources and viewpoints
- **O15** to guide the pupil in exploring nature, identifying organisms and habitats, and thinking ecologically as well as to guide the pupil in understanding the structure, vital functions and development of humans

The structure and function of ecosystems can be discussed in the lessons with a focus on the ecology of earthworms and students can practise using accurate concepts related to ecosystems (**O12**). Matoseuranta´s website and app offers an reliable source of information that students can use (**O14**). In the field, students observe nature and identify different habitat and earthworm types in the sample area (**O15**).

Grades 7-9: Biology

1. Key contents
    - **C1** Biological research
    - **C2** Field trips to nature and surroundings
    - **C3** The basic structure and function of an ecosystem

During Matoseuranta, students participate in a biological research project by collecting data and analyzing it. Students can also practise making a research plan for themselves (**O1**). Data is collected in the field where students observe nature and identify different habitat types (**O2**). Students also learn about the ecology of earthworms and what impact earthworms have on their surrounding environment (**O3**).

2. Objectives of instruction
    a. Biological knowledge and understanding
        - **O1** to guide the pupil to understand the basic structure and function of the ecosystem as well as to compare different ecosystems and recognise species
        - **O2** to help the pupil describe the structures and vital functions of organisms and to understand the structure of the biological taxonomy

- **O3** to guide the pupil to examine the adaptation of organisms to various habitats and to understand the significance of diverse habitats for biodiversity

The teacher can go through the structure of the soil ecosystem and its three main trophic groups (producers, consumers, decomposers), after which the class can concentrate on the role of earthworms as decomposers (**O1**). Also the structure of earthworms is observed in lessons and the impacts of earthworms on their environment (**O2**). In the field, it is important that students can recognize different environments and in the data analysis phase students can consider how the environment affects the amount and type of earthworms found in that area (**O3**).

b. Biological skills

- **O7** to guide the pupil to develop his or her scientific thinking skills and understanding of causal relationships
- **O8** to guide the pupil to use biological research equipment and information and communication technology
- **O10** to guide the pupil to conduct research both in and outside of school
- **O11** to encourage the pupil to apply biological knowledge and skills in his or her own life and in societal discussion and decision-making

In the last lesson, data analysis, students consider possible reasons behind the distributions of earthworms based on the information they have learned in the previous lessons (**O7**). Students also consider what effects earthworms have on their surrounding environment. The teacher can give examples that are related to the students' own life (for example fishing, gardening and compost…)(**O11**). Students are able to participate in a biological study in which they use biological research equipment and information and communication technology (**O10**, **O8**).

c. Objectives related to attitudes and values in biology

- **O12** to inspire the pupil to deepen their interest in nature and its phenomena and to strenghten his or her relationship with nature as well as his or her environmental awareness
- **O13** to guide the pupil to make ethically founded decisions
- **O14** to inspire the pupil to become actively involved in building a sustainable future

Participating in authentic biological research increases students' interest towards participating in environmental decision making in the future and deepens the students' environmental awareness and relationship with nature (**O12**, **O13**, **O14**).

National core curriculum for basic education 2004 : biology

Grades 7-9

1. Core contents

Matoseuranta aligns with the core content ”**Nature and ecosystems**”. Students have a chance to learn about the basic structure and function of ecosystems, the diversity of nature, especially different types of habitats, and learn how to identify different species.

2. Objectives

- learn to use concepts and methods of information acquisition and research that are characteristic of biology
- learn to identify species, to appreciate biodiversity, and to take a positive stance towards its preservation
- learn to discern the structure and operation of ecosystems

In Matoseuranta, students participate in a biological research study, in which they use biological research methods (for example using quadrats and mustard water extraction) and they can practice different skills that are needed in information acquisition and species identification. Matoseuranta´s website offers a reliable source of information for students to use. During Matoseuranta, students learn about the ecology of earthworms and structure and function of ecosystems. In the field, students will observe different habitats which increases their interest towards preserving living environments and deepens their relationship with nature.

Core curriculum for basic education 2004. Finnish national board of education. http://www.oph.fi/english/curricula_and_qualifications/basic_education

National core curriculum for basic education 2014. Finnish national board of education. Publications 2016:5

Opetushallitus (2015). Lukion opetussuunnitelman perusteet 2015. Helsinki: Opetushallitus

http://www.oph.fi/saadokset_ja_ohjeet/opetussuunnitelmien_ja_tutkintojen_perusteet/lukiokoulutus

Earthworm ecology

Earthworms belong to the family *lumbricidae* (=lierot). In Finland, the word ”kastemato” is often used when talking about any earthworm species in the *lumbricidae* family. However ”Kastemato” or ”Kasteliero” is a single species *Lumbricus terrestris*.

There are three general categories of earthworms: deep burrowing (anecic), soil dwelling (endogeic), and litter dwelling (epigeic). These categories are based on which soil layers the earthworms are most active in. The top layer is leaf litter which consists of all kinds of organic matter that has not yet decomposed. This layer is quite thin in Finnish forests (about 3 cm). Beneath the leaf litter layer there is humus layer, which is partially decomposed organic matter.

Earthworms break down organic matter in the leaf litter layer which creates humus. After humus layer there is a-horizon (=huuhtoutumiskerros) and b-horizon (=rikastumiskerros).

This distribution of earthworm types in different areas of the soil minimizes resource competition between earthworms. It also affects the overall distributions of earthworm species, because epigeic species are more easily transferred to new areas with human activities or natural phenomena such as wind or floods.

Anecic worms are deep burrowing worms that build permanent burrows as deep as 2 m (6 ft) into the ground. You can identify these burrows by the pile of excrement around the surface called a midden. Adult anecic worms are normally larger (up to 15 cm) and pigmented (coloured) on their front end. Anecic worms feed on dying leaves, grass, and other organic matter, and turn them into humus. For example earthworm *L. terrestris* is an anecic worm. When you use worms as fishing bait, you would normally be using anecic worms. The word anecic is greek for “out of the earth”. Anecic worms are active in the night. They come to the surface of the soil to feed and mate.

Endogeic worms are soil dwelling worms that build complex horizontal burrows in the upper layers of soil and rarely come to the surface. Adult endogeic worms are normally small and unpigmented (not coloured). Endogeic worms feed on soil, which helps to mix minerals and air into the soil. Endogeic worms do not normally come to the surface unless there has been a heavy rainfall. The word endogeic is Greek for “within the earth”.

Epigeic worms do not build permanent burrows but prefer to remain in the leaf litter and humus layers, which is made up of decaying leaves, branches, pine needles and other organic matter. Adult epigeic worms are normally small (2 – 7 cm) and pigmented (coloured). Like anecic worms, epigeic worms also feed on dead leaves, grass and other organic matter and turn them into humus. When you use worms for vermicomposting, you would normally be using epigeic worms. The word epigeic is Greek for “on the earth”.

Most of the earthworms, including *L. terrestris*, are hermaphrodites, which means that they have both male and female reproductive organs. Earthworms exchange sperm with other individuals by placing their clitellums against each other. After fertilization the cells of clitellum excrete a protective coat over the fertilized eggs forming earthworm cocoons.

Earthworms are called ecosystem engineers, because they change the physical and chemical properties of the soil. Earthworms burrow in the ground, mix mineral soil with leaf litter, deposit feces and break down organic matter. The result is that the quality of the soil often improves for plants. This is very useful in fields and gardens. The effects of earthworms can also be negative for some species, especially in environments without human impact.

Earthworms have many impacts on ecosystems and their dispersal to new areas continues. Arrival of earthworms can be harmful to some species in areas that haven´t yet adapted to their presence. For example, in North America the arrival of earthworms to forest ecosystems has had negative effects on some forest species. In 2011 earthworm invasions were listed in ”Trends in Ecology and Evolution” as one of the top 15 emerging global conservation issues. This is because of the impacts that earthworms can have on North American forests. Although a single earthworm does not have much of an impact on an ecosystem, an entire population of earthworms can have significant impacts.

a) Impacts of earthworms on leaf litter

Earthworms are decomposers which break down the organic matter on the ground such as leaves and dead organisms. They can sometimes consume the entire leaf litter layer in an area. Earthworms also mix different soil layers. For example, some species mix organic (leaf-litter) soil layers and mineral soil (just below the surface of the soil) layers with major effects on the species that rely on those soils. In a forest with a large amount of leaf litter, the main decomposers are often fungi (e.g. mushrooms). In forests where earthworms have removed much of the leaf litter layer, the primary decomposers in the forests may change from fungi to bacteria. This change in primary decomposers can have an impact on nutrient cycles. In North American forests, depending on the earthworm species invading, the forest floor may shift from a place where carbon dioxide is absorbed to a place where carbon dioxide is produced. This is due to increased microbial activity where earthworms are present in soil. This is a concern because carbon dioxide is a gas that can contribute to climate change.

Along with the reduction in fungi, researchers also often find a reduction in the invertebrates found in the forest floor after earthworms invade. The result of these changes is that the forest's litter layer no longer decomposes in the same way as it did before the earthworms' arrival.

b) Impacts of earthworms on vegetation

When earthworms invade a forest, one of the most noticeable changes is in the forest vegetation. Earthworm invasions in forests have resulted in changes to the vegetation where plants that used to be only found at the forest edge are now also found deep inside the forests. Normally the forest edge plants would be not be able to survive deep in the forest, because they would face competition from the plants that live in the leaf litter layer. However, when the leaf litter layer is removed by earthworms, the vegetation is reduced and the forest edge plants can become established due to reduced competition. This kind of research on earthworms has been conducted mostly in the northeastern United States.

Trees in areas that have been invaded by earthworms also have increased sensitivity to drought. We don't fully understand the mechanisms behind these shifts in forest ecosystems but the thickness of the leaf litter on the forest floor seems to be a major factor.

c) Impacts of earthworms in gardens

Earthworms have a significant impact on garden soil. When earthworms eat, they do two important things: They shred organic matter in the soil and till the soil by tunneling through it. This aerates the soil, allows more water into the soil, and helps to allow beneficial bacteria in the soil to flourish, which in turn also helps to break down organic matter in the

soil. As earthworms tunnel through soil, they also help to mix microorganisms and organic matter into the soil and produce tiny bits of excrement called “castings”. All of these things mean that worms help plants to get the air, water and nutrients that they need, and also support plant root growth.

Matoseuranta has been executed before in Canada with a slightly different objective. Earthworms are not native in most of Canada either and their dispersal is being facilitated by human activities. Earthworms cause serious damage especially to Canada´s forest ecosystems, where the native species are not adapted to the presence of earthworms. The most harmful effect of earthworms is the loss of the leaf litter layer, which harms the species depending on it. This is why it is important to define the earthworm species distributions and add knowledge about earthworms. For example, citizens in Canada are reminded not to throw earthworms used in fishing to the ground so that they won´t spread to new areas.

Karaca, A. (2011). Biology of earthworms. Soil biology 24: 141-158

http://worms.educ.ualberta.ca/

Earthworms in Finland

There are at least sixteen different species of earthworms in Finland (family lumbricidae). However, no earthworm species is native in Finland, because the last ice age wiped out all the previous earthworms from Northern Europe. After the ice age earthworms have been introduced to new areas mostly by human activities and natural phenomena, such as floods and winds. There are many differences in the distribution of Finnish earthworms. Some species are found quite evenly throughout Finland, but some species have more individuals in the southern Finland than in the north. Some species are found only in southern Finland (Tehrivuo, 1998). Factors that influence species distributions include:

- Species’ own ability to disperse
    - Earthworms can disperse to new areas as an adult or as a cocoon.
    - The ability of earthworms to disperse actively is quite poor. Populations are estimated to expand at a maximum of seventeen meters per year.
    - Earthworms live in different layers of soil, which has an influence on earthworm species distributions. The litter dwelling species are distributed to new areas more easily than deep burrowers, because they are more easily carried away to new areas by human activities, winds and floods. Litter dwelling species are likely to be found nearly everywhere in Finland, but deep burrowers should have more narrow distributions.
- Species dispersal history (continental drift, extinctions, speciation)
    - Earthworms arrived in Finland after the latest ice age, likely from the south.
- Species habitat requirements

    - Earthworms are found in nutrient rich soils that have high concentrations of organic matter for earthworms to eat. Deciduous forests, gardens and agricultural lands are good examples. Fewer species are found in pine forests, because the leaf litter layer is very thin and the soil tends to be sandy and dry.
    - Soil should be quite moist, because earthworms breathe through their skin which requires a moist surface.
- Impact of other species
    - Human activities have had a great influence on earthworm distributions. Humans have had a direct impact by transferring earthworm individuals (in worm or cocoon form) to new areas. Humans have also had an indirect effect by increasing the amount of suitable habitats for earthworms. For example, transforming pine forests to agricultural land has had a positive effect on earthworm dispersal to new areas.
    - The distributions of deep burrowers are clearly connected to human activities especially in the northern parts of Finland where the deep burrowers are found only in or near agricultural lands.
    - The distributions of litter-dwelling earthworms may be less connected to human activities.
- Chance
    - Earthworms can be carried long distances by water. Earthworms can survive many days in water and can thus be transferred to new areas for example with floods and rivers.

In Finland and other northern countries earthworms face some environmental challenges. For example, in northern Finland at summer time, the nights get shorter until the sun doesn´t set at all. This is challenging especially for deep burrowers like *L. terrestris* which are night active. Deep-burrowers rise to the ground at nights, because the risk of predation is smaller in the dark and moisture conditions are better at night than during the day. On the ground, earthworms eat, mate and build middens. During these periods in summer with very few dark hours the activity of deep burrowers is greatly limited.

However, in winter, there are more dark hours in the north than in the south and this might compensate for the loss of activity during summers (Nuutinen et al. 2014). The only problem with this is that the activity of earthworms in winter is limited by temperature. Temperature limits the activity of earthworms because most of the earthworms in Finland cannot survive at temperatures under -0.2 -0.4 °C (a few earthworm species can survive under -20°C) (Holmstrup & Overgaard 2007). It is forecasted that average temperatures in Finland will rise 2°C by the year 2040 compared to temperatures measured in 1900 (Ilmasto-opas, 19.6.2016). This rise in the temperature is greatest in winter which means that earthworms might be able to be active for longer periods of time due to climate change (Nuutinen et al. 2014).

Holmstrup, M. & Overgaard, J. (2007). Freeze tolerance in Aporrectodea caliginosa and other earthworms from Finland. Cryobiology 55: 80-86

www.ilmasto-opas.fi 19.6.2016

Nuutinen, Visa., Butt, R. K., Jauhiainen, L., Shipitalo, M., Sirén, T. (2014). Dew-worms in white nights: High-latitude light constrains earthworm (*Lumbricus terrestris*) behaviour at the soil surface. Soil Biology and Biochemistry 72: 66-74

Terhivuo, J. (1988). The Finnish lumbridicae (Oligochaeta) fauna and its formation. Annales Zoologici Fennici 25: 229-247

Terhivuo, J. (1989). The Lumbricidae (Oligochaeta) of southern Finland: species assemblages, numbers, biomass and respiration. Annales Zoologi Fennici 26: 1-23

Lesson plans

Matoseuranta consists of three separate lessons, during which the students will be working in class and in the field. Students will learn the ecology of earthworms and get to collect data for Matoseuranta. After data collection, students have the possibility to consider the factors that influence the distributions of Finnish earthworms and what impact climate change can have on those distributions.

There are many different topics that are linked to Matoseuranta like climate change, earthworm ecology, structure and function of ecosystems as well as distribution of species which could be included in lesson plans. Matoseuranta provides a very good opportunity to introduce different phases of biological research and earthworm ecology so the materials are concentrated on these topics. Materials include both instructions and ideas for lesson plans. The instructions that should be followed are for the sampling and data uploading. There are also ideas for lessons that could be included in lesson plans.

The structure of the lesson plan introduction is following: Objective of the lesson is described first. Secondly, there are different topics that could be discussed in lessons. Below the topics there are ideas and materials for the topics in question.

Lesson 1: Introduction

The objective of the first lesson is to introduce Matoseuranta and earthworms to students. The following topics and assignments could be included in this lesson:

1. Introduction to Matoseuranta

    a) Matoseuranta´s objective

The objective of Matoseuranta is to collect information about the distributions of earthworms in Finland. Knowing the distributions is important, because earthworms can have a major impact on ecosystems. In the future, climate change may influence these distributions.

b) The role of students

The role of students is to collect the data required to map the distributions of earthworms. Students will collect data about what kinds of earthworms are found in different habitats across Finland.

In some schools students will also take a genetic sample which is sent to the researchers. The sample is used to identify earthworm species by extracting earthworm DNA from the sample.

The objective for students is to learn about earthworm ecology and identify different earthworm types. Students will collect data in groups and analyze the results using the information they have learned about earthworms.

The purpose of these lessons is also to enjoy the new experience and being in nature!

c) Taking a look to the following lessons

Showing students the timetable of the next three lessons: 1. introduction 2: sampling in the field 3: data analysis

2. Earthworms

a) Finding out what students already know about earthworms

The teacher discusses with students what they already know about earthworms. The whole class can have this discussion together or they can discuss it in groups. The class can be divided into groups and in these groups the students can write down everything they know about earthworms. Answers can be written for example in one shared document (google docs) and the teacher goes through the answers with the class and

corrects possible misconceptions. There is a list of common misconceptions in the website.

b) Ecology and identification of different earthworm types

In order to collect data, students have to identify three earthworm types, which is quite simple. For example, teacher can bring earthworms to class for practising identification and use these materials about earthworm identification:

- PowerPoint-presentation about earthworm identification
- Information is found also in the website page ”worm classification”
- Species identification pamphlet

It is important that students have a basic understanding of earthworm ecology so they can analyze the data for themselves and consider the factors that are driving the distributions of earthworms. One way to get to know earthworms is to build a vermicompost. Compost is made up of decayed organic material and is a very good fertilizer for plants. Worms are often used to produce compost using a process called vermicomposting. This type of composting uses red worms to break down household food waste and can be done either indoors or outdoors. Red worms are used instead of the common earthworm, because the common earthworm prefers garden soil over compost.

3. Matoseuranta app

The Matoseuranta app should be downloaded and tested before going to field (one app per group).

4. Biological research

Students learn about the different phases of biological study:

1. Observations
2. Making a hypothesis
3. Planning the study
4. Data collection
5. Data analysis

During Matoseuranta, students can participate in almost every phase of biological study. For example, teacher can give students a mission to plan for themselves how they would investigate the distributions of earthworms (what kind of information they would need? How to collect this information? How to analyze it?). This can be started with students by

finding out what they already know about earthworms. After going through the answers they could think in the same groups how they would carry out this study. The importance of biological study could also be brought up and different objectives of biological study can be mentioned, like:

- investigating how people can live on planet earth without destroying it for other species
- sustainable use of natural resources
- distribution of species , so changes can be forecasted
- developing nutritional and medical innovations

Lesson 2: Sampling

In this lesson students go to the field to collect the data.

1. Earthworm collection preparation can be done in the first lesson or at the beginning of the second lesson.

- The mustard water solution can be prepared in advance or at the sampling site. The mustard powder is mixed with water (2L / 20 g)
- Making quadrats. This can be done with students either at school or at the sampling site. The quadrats should be 25 cm x 25 cm. Alternatively, instead of making a quadrat the corners of the plot can be marked so that the hole is the correct size.
- Download the Matoseuranta app on iOS or Android (link). One phone with Matoseuranta per group is enough. The phone should be gps-enabled.
- The class can be divided into groups that have 3-5 students in one group.
- Finding suitable places for sampling (one open area and one forested area). From the website, you can find examples of different habitats where earthworms can be found.

2. These things should be discussed with students before the sampling.

- Identification of three different earthworm types and the difference between an adult and juvenile earthworm. Materials for earthworm identification:
    - Powerpoint-presentation - identification of earthworms
    - Descriptions of three earthworm types in the website
    - Species identification pamphlet
- How to use the Matoseuranta app
- Sampling
    - Written instructions in the website
    - Video about sampling that shows every step
- Safety instructions when working in the field

3. The sampling

After all preparations have been made, students can start to collect data about earthworms. In groups, students will mark their own sampling sites with the quadrat. Quadrats are used so that every sampling site is the same size (25 cm x 25 cm). Alternatively you can mark the corners of the plot so that the hole is the correct size. You can build a quadrat using

- PVC piping. Cut four 25 cm long pipes and connect them together with elbows
- pipecleaners (twist the pipecleaners together to make a 25 cm square quadrat). You can also use straws to make it a bit more sturdier.
- string and popstickle sticks. To set up quadrats this way, students will each require 4 popsicle sticks per quadrat, a roll of twine, a ruler, and a pair of scissors. Students will first push one popsicle stick into the ground and then will measure 25 cm away from that popsicle stick. Students will repeat this process to create a rough square of popsicle sticks. Finally students will join the popsicle sticks together with twine.

After this students can save information about location to the app. One student can also write down results manually. At this point they can choose the correct habitat, insert coordinates (the location of your sample should be provided automatically by your mobile device as long as the GPS is enabled) and investigate if there are some human or terrain features.

The students will also have to check the moisture level of the ground: Take a small piece of soil and squeeze it together. Select ”medium” if it forms a ball. The ground should be damp in this case. If water runs out of the soil in your hand, select ”wet”. If you can't make a ball at all, select ”dry”.

When all information about the location is saved students can start the sampling. The midden count should be done first. Each midden (2 cm - 5 cm in diameter and 1 - 2 cm high) inside the quadrat is counted and the number marked to the app.

After the soil moisture test and midden count, earthworms are searched by mustard water extraction and hand-sorting. First students can use a trowel or shovel to dig a 25 x 25 cm hole and put the soil on a garbage bag. The hole should be 10 cm deep. After this they can do the mustard extraction. Mustard extraction should be done first, before the hand sorting, because digging the hole and walking around the area creates some vibrations which could disturb the worms that are deeper in the soil. After the mustard exctraction students can sort the soil that was dug up form the hole. When working in groups it is possible that one person starts the hand sorting of the soil (dug up from the sample area) while the other does the mustard extraction.

Mustard extraction:

After digging your hole, you will use mustard to find deep burrowing earthworms. The mustard acts as an irritant to the skin of the earthworms, but it does not hurt them. Here is how to do a mustard extraction:

1. Add 20 g of mustard powder to 2 L of water. Make sure you shake the bottle to mix it up!

2. Pour half of the mustard solution on the ground in your plot.

3. Set a timer for 5 min. During this time, collect any earthworms that come up into a container (a different one than the one for the hand-sorting). It’s important to wait for the earthworms to come almost all the way out before you try to pick them up so that you don’t break them.

4. After your timer goes off, add the other half of the mustard water to the plot and set your timer for another 5 min. Collect any worms that come up during this time.

Hand-sorting:

Pick up a handful of soil from the pile on your garbage bag and look through it for worms. If you find a worm, put it in a container. Use different containers for the earthworms you collect from hand-sorting and the earthworms you collect from mustard extraction. Discard your handful of soil to the side after looking and do this until you have looked through all of the soil. When all earthworms are found, the numbers are written in the app. Students will take a photo of each earthworm separately next to a measuring tape.

The app has a maximum number of 12 photos per one plot. If you have more than 12 worms, please take one picture for each category listed in the table in the app (e.g. include all hand-sorted juvenile litter dwelling earthworms in one picture, rather than taking individual pictures).

Some schools will take a genetic sample, which is put in a bag marked with an ID code. The sample is mailed to researchers. The envelope with a stamp comes with the other materials.

At the end the earthworms can be released.

Lesson 3. Data analysis

In the last lesson, students can analyse the data they have collected as well as the data collected by other schools. Students can consider the factors that are driving earthworm distributions in Finland.

1. Data analysis

   The data that different schools and other citizens have collected can be observed in the form of an interactive map that is found in the website. With the map, students can compare the results of their area to other areas. For example students can answer to questions that are found in the data analysis –sheet.

2. Species distribution

   Students can compare different habitats and what earthworm types there are and how many earthworms are found. After this they can consider the reasons behind the distributions. They can use the information found in the Matoseuranta website.

   Examples that might come up in results:

   - Only a few earthworms or none are found in pine forests
     - In pine forests there is quite a thin leaf litter layer. The leaf litter layer is the main source of nutrition for earthworms.
     - Pine forests tend to have sandy soil, which earthworms often avoid.
   - More earthworms are found in deciduous forests than pine forests
     - Leaf litter layer is thicker in leaf forests and soil has a higher nutrient content than in pine forests.
   - Large numbers of earthworms in fields and gardens
     - There is a high concentration of nutrients and organic matter for earthworms to break down

3. Biological study

After students have carried out the sampling for themselves, they can compare the different methods they used:

- Midden count
    - relatively easy, but you have to identify the middens
    - one earthworm per midden
    - why won´t you get the correct number of earthworms in the area if you count only middens?
        - you will underestimate the number, because only deep burrowers live in middens
        - it is possible that some middens are empty, so you might overestimate the number
- Mustard water extraction
    - irritates the skin of earthworms, so they come to the surface
    - requires some preparation
    - most effective because you can collect all three worm types at the same time
    - why do you have to wait for five minutes?
        - so that every worm has come to the surface
    - why are worms collected only inside the quadrat?
        - The number of worms is counted only inside the quadrat so that a consistent area is sampled each time. This allows the number of worms to be compared between groups and even across schools.
- Sampling by hand
    - easy and you only need a shovel and a plastic bag
    - Deep burrowers are less likely to be found with this method, as they are often deeper in the soil.

- Why are earthworms collected from different spots in the same area?
        - to get the average number of earthworms in that area

Lesson plans are adapted from the Alberta Worm Tracker Project, University of Alberta

http://worms.educ.ualberta.ca/