The quality of the air: 
Lichens as Bioindicators of Air Pollution 

Subject: Biology 

Grade level: Upper Secondary Schools 

Anticipated time: 8 hours (lessons and outdoor activities) 

Developers: L. Brancaleoni, O. De Curtis, U. Thun Hohenstein, M.C. Turrini 
Institution: Dipartimento di Biologia ed Evoluzione – Ferrara University 
Country: Italy
CENTRAL IDEA AND DRIVING QUESTION: What is the quality of the air in our town? Can we use lichens as bioindicators of the quality of the air?

DURATION: 3 hours for the preparation in the classroom (in), 2 hours for the outdoor activity (out), 3 hours for the post-field work (in).

LEVEL: Upper secondary Schools

PEDAGOGICAL FRAMEWORK

Documentation is both a process and a product involving discovery, extension, reflection and communication (Glass et al., 2007). Besides, it is a tool to make learning concrete and observable (Capello, 2007). Advanced technologies involved in the study of science are a new tool of documentation (Lee, Hatherly & Ramsey, 2002; MacNaughton & Williams, 2004; Fleer et al., 2006).

This module proposes the study of the quality of the air with living organisms that work as bioindicators. Therefore the botanical knowledge becomes a profitable tool to verify, in a simple and inexpensive way, how pure the air we breathe is. Lichens are the living organisms that can indicate the quality of the air simply counting the presence of different species in a grid area placed on a tree. Repeating the same sampling on a number of trees, will lead to the lichen biodiversity index, that is the index of air quality. Then, the sample area will be displayed on a georeferenced map and, by calculation made by the GIS software, a colour scale shows the characteristic of the air and how these characteristics vary in the area.

The module does not need a specific knowledge of the lichens species because it is only necessary to distinguish that one lichen is different from the other, based on morphology and colour. Anyway, the module is also useful to study directly in the field the morphology and the features of the tallophytes and cormophytes.

PREREQUISITE KNOWLEDGE: notions about algae, fungi and trees; notions about pollution of the air.

BACKGROUND KNOWLEDGE

A lichen is a symbiosis of two organisms: a fungus (the mycobiont) and an alga (or a cyanobacterium, the photobiont). The photobiont produces food for the fungus from photosynthesis and the fungus protect the alga by retaining water and providing mineral nutrients.

Most of the lichens take the external shape of the fungal partner: some lichens have the aspect of leaves (foliose lichens), others cover the substratum like a crust (crustose lichens) or have shrubby forms (fruticose lichens). A typical foliose lichen thallus is formed by four layers. The uppermost layer (the cortex) is formed by fungal hyphae building a protective outer layer. Beneath the cortex there is an algal layer composed of algal cells embedded in rather densely interwoven fungal hyphae. Beneath this layer there is the medulla, a third layer of loosely interwoven fungal hyphae without algal cells. The lower cortex resembles the upper surface and consists of densely packed fungal hyphae and often presents rootlike fungal structures known as rhizines, which attach the thallus to the substrate.

Many lichens reproduce asexually with soredia, small groups of algal cells surrounded by fungal filaments (without cortex), and by isidia, extensions of the surface of the thallus for the wind dispersion. Many lichen fungi also reproduce sexually producing spores in apothecia, perithecia as normal fungi.
Because lichens are poikilohydric organisms, without true organs, their hydration status is related to the humidity of the air, from which depends also the mineral nutrition. For these characteristics, lichens are very sensitive to gaseous pollutants, particularly sulphur dioxide, and are widely used throughout the world as pollution indicator organisms. Lichen characters measured in air pollution studies include observations of population changes and morphological effects because the chlorophyll is destroyed and photosynthesis is inhibited.

MATERIALS
- Palm handheld computer or Laptop
- GPS
- Folding rule or tape measure
- Hand made grid (the grid is formed by a series of 5 squares of 10x10 cm) (see Appendix 1)
- Book for the lichens identifications
- Little knife and small paper bags for the collection of the lichens
- Digital camera
- GIS software
- Georeferred map

CONTEXT
This module can be developed in any area with trees. It is possible to choose small areas as the garden of the school, the park of the city or larger areas as the whole city, the countryside, woodland and so on. We chose one of the larger parks of the city of Ferrara which is an Unesco Heritage site from 1995. It is a Renaissance town with the indelible signs of splendour of the Estense court.
In the city of Ferrara there are two green areas of considerable extension and a lot of private gardens, but in the outskirts there is a chemical industry that can have some negative effects on the quality of the air and therefore on the health of the lichens.

INSTRUCTIONAL ACTIVITIES

Lesson 1: In (Preparatory)

Duration: 3 hours

Goals: The students study what is a lichen and prepare the tools for the data collection in the field.

- Teacher checks ideas and preconceptions that students have on how to measure air pollution. Then she/he illustrates the method based on the presence of lichens living on the tree bark, using a video that shows this method.
- Students have an introduction lesson to the use of Palm Handheld Computers and GPS.
- Students get confident with the recognition of lichens based on their colours and shape, using pictures and/or manuals or by an internet research.
- Students prepare the grid (see appendix 1), the check-list of the lichens (see appendix 2) and the spreadsheet for the calculation of the Lichen Biodiversity Index (LBI) (see appendix 3).
- The students record the information about the heritage site involved in the sampling.
Lesson 2: Out (of classroom)

Duration: 2 hours

Goals: The students check and record the lichen frequency of the study area in order to examine the purity of the air

If the module takes place in a protected area the teacher must ask the income permission and/or the permission to pick up the samples. The students are divided in small groups so that all of them can participate in the collection of the data. Every group is responsible for the data of one station of survey.

Every group checks at least three trees in order to calculate the LBI of the station. The chosen trees are characterised by sour bark e.g. lime (*Tilia*) or oak (*Quercus*), while trees with subneutral bark (e.g. conifers) are possibly avoided.

The tree should have the following characteristic:
- circumference of 60 cm at least;
- trunk inclination <10°;
- absence of evident phenomena of trouble.

Then students put the grid on the tree at about 1 m of height from the ground level, more or less exposed as the cardinal points (N, E, S, W). Damaged areas of the bark and areas with excessive coverage of mosses or algae must be avoided.

In order to repeat the study whenever (e.g. maybe the following years), it is necessary to record:
- the location of the tree by the GPS;
- the exposure of the grid, with the aid of GPS or a compass;
- the quote of the grid referred to the base of the trunk;
- the circumference of the trunk where the grid is put on, that is at about 1 m of height from the ground level.

Every tree is also photographed for its correct identification without doubt and whenever.

Therefore students record the presence of the lichen species in the 5 unities of the grid (frequency values from 0 to 5): if the same lichen specimen is present in more than one unity, its frequency value is the same as the number of unities where it is present (see fig. 1 at the end of the module).

Lichens are distinct based on their morphology and colour or, if known, based on their species.

Eventually, for the identification of the species in laboratory, the students pick up a small sample and take pictures of lichens.

For every tree checked, the Lichen Biodiversity Index (LBI) is the sum of the lichens frequencies, for every cardinal point, while the LBI of the station is the average of the LBI of all the checked trees. The calculations (see appendix 3) can be made directly in the field or later in the classroom using a spreadsheet prepared during the preparatory lesson.

After the lichens count is made and recorded, instructor leads the students in a brief discussion and analysis of the data which they have just collected.

Lesson 3: In (Follow-up)

Duration: 3 hours

Goals: The students calculate and interpret the lichen biodiversity index as an indirect index of the purity of the air and visualize the result in a map by GIS technology

In the classroom students visualize the georeferred map, where are the sampled areas, by GIS software. They load the coordinates of checked trees and calculate the LBI, if not already done in the field.

GIS can identify every checked point by different colours based on the LBI value, so having the chance of seeing immediately where the air is pure or not (see figure 2).

After having projected on a screen the image of the map with LBI, teacher leads students in a discussion on the results obtained, having in mind the safety of living beings, and on other methods of monitoring the air quality, eventually with the help of an internet research.

Students can compare the data that they have collected on different trees and in different areas of the town.

Students can observe lichen samples with microscopy and identify the species by the use of manuals and/or internet.

POSSIBLE EXSTENSIONS

Students can compare the calculated LBI with the official data recorded by environmental agencies.
They can send their results to the local environment agency, urging some countermeasures if they are needed.
Students can repeat the same survey in different places, closer and farther from potential sources of air pollution.
Students can repeat the survey in different condition of weather.
Students can compare different techniques (direct and indirect) to monitor the air pollution.

Objectives:
At the end of the module the students will know:
- how quality of the air influences living organisms;
- how some living organisms can be used to study the quality of the air;
- how to study the pollution of the air;
- the direct influence of human activity on the environment.

Students will learn how to use Palm Handheld Computers, GPS and GIS technology.

ASSESSMENT

In small groups, students present their findings to the class in order to demonstrate:
- their skills in the use of Palm handheld computers and GPS;
- their skills in the use of GIS
- their skills to make hypothesis to explain the results.
To check the competence level of the student the teacher can:
- ask for the interpretation of the maps
- to repeat the experiment in the garden of the school or in their own garden
- ask questions about lichens and trees identification and morphology

- verify the ability to use the GIS software with the creation of a map, or of a new attribute table.
- final test

BIBLIOGRAPHY

http://digilander.libero.it/licheninrete/informazioni/ibl.htm
Sample grid

Material:
2 fillets of wood (or plastic, bamboo) 52 cm long, 1-2 cm thick, nylon string (2-2.5 mm Ø), drill

Procedure:
Make 6 holes at 10 cm of distance on the two fillet of wood. Join the two fillets with the string at every hole, keeping 10 cm of distance between the fillets. Fix the string with a knot.
You can construct also a single grid to orient contemporarily at all the 4 cardinal points, simply construct in the same way 4 grids and join they with a sliding string.
If the lichen species are not known, then a practical method has to be used in order to distinguish different species, based on their colour and/or morphology (crustose, foliose and fruticose morphology)
Lichen Biodiversity Index:

LBI of the sample (one tree): sum of the lichen present in the single unity of the grid for every cardinal point

LBI of the station cardinal point (all the trees): sum of all the LBI sampled in the same cardinal point

LBI of the station (all the trees and all the cardinal points): sum of the LBI of the cardinal points divided for the number of the sampled trees

Figure 1 – Example of LBI calculation
Figure 2 - Colours assigned to different Lichen Biodiversity Index (LBI)

<table>
<thead>
<tr>
<th>LBI</th>
<th>COLORS</th>
<th>LBI</th>
<th>NATURALITY/ALTERATION</th>
<th>COLOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td>0</td>
<td>Very high alteration</td>
<td>Dark Red</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>$1 \leq \text{LBI} \leq 15$</td>
<td>high alteration</td>
<td>Red</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>$16 \leq \text{LBI} \leq 30$</td>
<td>medium alteration</td>
<td>Orange</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>$31 \leq \text{LBI} \leq 45$</td>
<td>Low naturality/Low alteration</td>
<td>Yellow</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>$46 \leq \text{LBI} \leq 60$</td>
<td>Medium naturality</td>
<td>Green</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>$61 \leq \text{LBI} \leq 75$</td>
<td>High naturality</td>
<td>Dark green</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>$\text{LBI} &gt; 75$</td>
<td>Very high naturality</td>
<td>Blue</td>
</tr>
</tbody>
</table>

http://www.flickr.com/photos/martinlabar/141606181/

http://www.perspective.com/nature/fungi/lichens.html

foliose and fruticose lichens