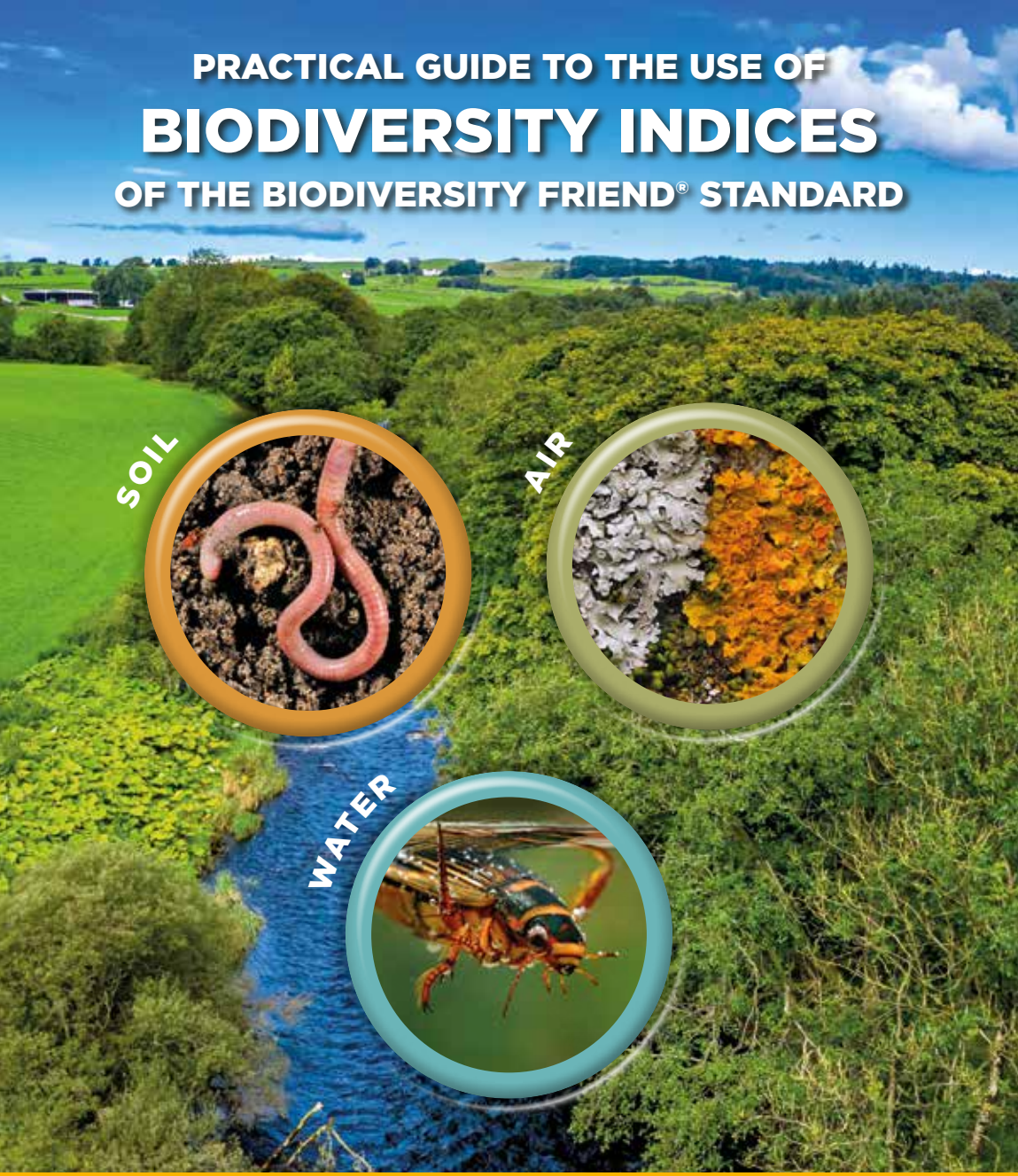
PRACTICAL GUIDE TO THE USE OF BIODIVERSITY INDICES OF THE BIODIVERSITY FRIEND® STANDARD



G. Caoduro, R. Battiston, G. Lazzarin, E. Ruzzier, N. Tormen

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WBA HANDBOOKS 14
Practical Guide to the Use of Biodiversity Indices of the Biodiversity Friend® Standard
ISBN 978-88-902816-6-2
ISSN 1973-7815

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This work may be cited as:
Caoduro G. *et al.*, 2025. Practical Guide to the Use of Biodiversity Indices of the Biodiversity Friend® Standard. WBA Handbooks 14, WBA Project Ed., Verona: 1-160.

Director Responsible: Simone Bellini - Authorization n. 116753 - 08/06/2006

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WBA HANDBOOKS 14

PRACTICAL GUIDE TO THE USE OF BIODIVERSITY INDICES OF THE BIODIVERSITY FRIEND® STANDARD

G. CAODURO, R. BATTISTON, G. LAZZARIN, E. RUZZIER, N. TORMEN

wbabooks

Verona, 2025

... But the good functioning of ecosystems also requires fungi, algae, worms, insects, reptiles and an innumerable variety of microorganisms.

Father Francis, Encyclical Letter *Laudato Sí* (34)

Foreword

The conservation of ecosystems and the protection of biodiversity have been officially pursued by the global community for over 30 years, more precisely since the first World Summit in Rio de Janeiro in 1992. However, this commitment has been largely ignored, as biodiversity loss and climate change continue to represent global emergencies.

One of the obstacles that, over the decades, has hindered a real change of course, through the adoption of measures capable of limiting the growing human impact on ecosystems, has been the limited involvement of the scientific community in identifying effective tools to assess the consequences of human impact on the planet's biogeochemical balance.

Providing objective evidence of the damage inflicted on land and ecosystems should have been a primary goal for scientific institutions, in order to raise awareness among policymakers and public opinion about the seriousness of the situation and the urgent need for change. Nonetheless, in recent decades, several innovative biomonitoring techniques have been proposed to assess, the environmental quality of ecosystems and agrosystems at various levels.

Indices capable of evaluating human impacts on the environment have existed since the mid-20th century. In particular, the Lichen Biodiversity Index (LBI) and the Extended Biotic Index (EBI) which were used to assess, respectively, air quality through epiphytic lichen communities and the quality of surface watercourses through aquatic macroinvertebrates.

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Acknowledgments

This volume was published thanks to the commitment of many people who contributed in various ways. In particular, the authors express their heartfelt thanks to Camilla Marangoni and Chiara Caoduro for editing, Valentina Corbellari for layout design, Corso Tarantino for the watercolor illustrations, Enrico Lana, Valentina Balestra and Andrea Tagliapietra for the images of soil invertebrates, and Pier Mauro Giachino and Andrea Tagliapietra for the critical review of the texts. Many thanks also to Paul Tout for the revision of the English text.

Ardea alba

1. Biodiversity and Territory

1.1. Biodiversity and Its Values

Biodiversity can be defined as the variety of organisms at all levels, from the genetic variation within individuals of a species (*intraspecific biodiversity*), to the differences between species and taxonomic groups (*interspecific biodiversity*); to these levels we can also add the variety of ecosystems present in a given territory (*ecosystem biodiversity*).

To date, about two million species have been catalogued on Earth, but naturalists estimate that the total number of species is at least ten million, three-quarters of which are concentrated in tropical rainforests. This means that only a fifth of the animal and plant species on our planet are currently known. Zoologists and botanists describe thousands of new species for science each year, but the destruction of tropical rainforests causes the extinction of tens of thousands of species annually!

Therefore, biodiversity loss, along with climate change, is the greatest environmental emergency of our time. Biodiversity represents the most important resource of the planet's natural systems, and all human activities depend on it, directly or indirectly.

This biodiversity resource has multiple values, which can be divided into direct and indirect values. Direct values include productive value, that is the commercial value of raw materials and food, or consumptive use value, such as the direct use of wood, wildlife, and other natural resources.

1.5. The Biodiversity Indices of the Biodiversity Friend® Standard

Certain organisms are particularly well-suited to monitor environmental changes, whether minor or major, in the areas they inhabit. This is because they are highly sensitive to pollutants, are widely distributed, have low mobility, and an ability to accumulate contaminants in their tissues. As such, they are considered *biological indicators* and can be used to assess the quality of soil, water, and air, including in agricultural environments.

The ***Soil Biodiversity Index*** (SBI-bf) is based on the analysis of the presence of major groups of macroinvertebrates in the soil environment, used as biological indicators. Each group is assigned a score based on its degree of morphological specialization for underground life and its sensitivity to various forms of soil disturbance (such as frequent tillage, pesticide use, compaction, etc.).

The ***Freshwater Biodiversity Index*** (FBI-bf) is a surface water quality index that considers three aspects: the hydromorphology of the watercourse, the taxonomic diversity of aquatic macroinvertebrate communities present, and each group's tolerance to environmental alterations. Many groups of aquatic organisms, like stoneflies, mayflies, caddisflies, crustaceans, and molluscs, can serve as biological indicators for determining the health of surface waters in agrosystems. Each group exhibits different levels of tolerance to disturbed conditions. The FBI-bf also measures key physico-chemical parameters such as pH, temperature, electrical conductivity, and dissolved oxygen.

The ***Lichen Biodiversity Index*** (LBI-bf) monitors the presence and frequency of lichens on the bark of trees within farms or in nearby areas. Lichens, symbiotic organisms formed by a fungus and an alga, are extremely sensitive to air pollution because they lack an excretory system. These characteristics make lichens *excellent biological indicators*, often used in air quality biomonitoring across both urban and rural settings.

Lumbricus terrestris

2. Soil Biodiversity Index (SBI-bf)

2.1. The Soil

Our planet is a geoid, flattened at the poles, with an average radius of approximately 6,370 km (3,960 miles). It is composed of three concentric layers. The outermost is the ***crust***, made of solidified rock, with a limited thickness ranging from 6 to 70 km. The intermediate layer, the ***mantle***, consists of semi-fluid rocks and is about 2,900 km (1,800 mi.) thick. The innermost layer, the ***core***, is very dense, partly solid and partly liquid, with a radius of over 3,400 km (more than 2,150 mi.). The most superficial part of the crust is largely covered by oceans, while the remaining portion is formed of solid materials composed of rocks and debris of varying grain sizes.

Soil can be defined as *a natural formation of variable thickness that covers much of the Earth's emerged crust, resulting from the physical disintegration and chemical and biological decomposition of the parent rock and living organisms*.

Pedology, or soil science (from the Greek *pédon*=soil, and *lógos*=study), is the discipline that studies all aspects of soil, both as a natural soil and agricultural soil. In particular, it examines its physical and chemical properties, biological characteristics, morphology, evolution, and distribution across different regions of the planet. The main factors influencing soil formation include living organisms, parent rock, climate, time and geological position.

The ***parent rock***, also called the pedogenetic substrate, rep-

Among arachnids, they are the group with the least direct interaction with the soil, but they are frequently found in the topmost layer, particularly under stones and in the litter, where they hunt their prey.

Scorpions are arachnids of varying sizes (9-230 mm), with claw-shaped pedipalps used to capture prey and for defence. The body is divided into two main parts: the cephalothorax and the abdomen. The cephalothorax is covered by a carapace with two median eyes and two to five pairs of lateral eyes. Some cave-dwelling species are blind. The abdomen consists of 12 segments, the last five of which form what is commonly called the "tail," ending in the telson, an enlarged structure containing a sting and venom glands. They live under stones, partially buried, and feed on insects, spiders, and other soil invertebrates. About 2,000 species are known worldwide (about 75 in Europe).

Opiliones (Harvestmen), with 6,500 species currently known worldwide (350 in Europe), resemble spiders but have very long legs and a segmented, non-pedunculated opisthosoma. They do not build webs but roam in search of small arthropods. Endogeic forms, such as those from the Trogulidae family, have shortened legs and special adaptations to subterranean life.

Pseudoscorpions are small predatory arachnids with venom glands located in their pincers, unlike scorpions, which have them in the tail. Around 3,300 species are known worldwide (approximately 760 in Europe). They are found in woods, meadows, under stones, in bird nests, ant nests, and caves. They feed on small invertebrates such as enchytraeids, mites, small insects, and other arthropods. Their presence in the soil indicates a high level of maturity and stability of the substrate.

Mites (30,000 known species worldwide, around 400 in Italy), together with springtails, represent one of the most important groups of soil fauna and play a fundamental role in the processes of humification and mineralization of organic matter. They are small in size, with a body that is often globular and sometimes elongated. Their diet is highly varied, and they may be detritivores, fungivores, parasites of invertebrates, or pred-

Figure 6. Spiders (A), scorpions (B), pseudoscorpions (C), harvestmen (D), mites (E) and palpigrades (F) are common arachnids in forest soil as well as in agricultural ones, if correctly managed (photos by V. Balestra, E. Lana).

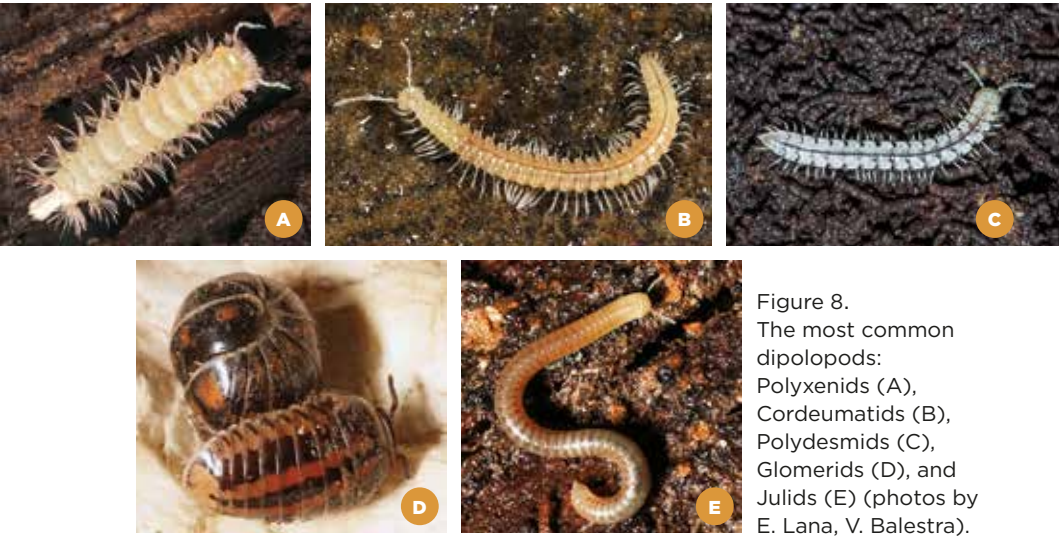

Figure 8.
The most common dipolopods: Polyxenids (A), Cordeumatids (B), Polydesmids (C), Glomerids (D), and Julids (E) (photos by E. Lana, V. Balestra).

13 segments. They are phytosaprophagous, commonly found on woody debris and in forest litter. Just under 200 species are currently known worldwide.

Glomerida. These have a body made up of 13 segments (the second and third segments are fused) and do not exceed 2 cm in length. As with many isopods, with which they can be confused, they are capable of rolling into a ball, and males of some species can emit stridulating sounds. The species found in the Mediterranean basin are also well adapted to rather arid environments.

Chordeumatida. The body has a cylindrical or sub-cylindrical cross-section, or is equipped with modest upper lateral extensions (paranota), and consists of 26 to 32 segments (in most species, 30). Like other millipedes (e.g., Callipodida and Polydesmida), they have organs on the last segment that produce silken threads, which are useful for lining the soil cells where they shelter during molting. They usually have long legs and prefer humid environments.

Polydesmida. The bodies of this group are always covered with

Figure 9. Schematic cross-sections of the metameric structures of the main millipede orders.

very prominent upper lateral extensions, and consist of 18 to 21 segments (in most species, 20). The gonopods (legs transformed into copulatory organs) are derived from the front legs of the 7th segment and make it easy to distinguish males from females. This is the largest order of millipedes, with over 3,000 described species, exhibiting a wide range of sizes (from 3 mm to 30 mm).

Julida. Characterized by a long, cylindrical body, they are mainly found in temperate regions (over 600 species). The body segments can be very numerous (from 30 to 90). On the sides of the body, they have odoriferous glands that secrete repellent substances that are active against predators. The male gonopods are formed from both pairs of legs on the 7th segment. In addition, the first and sometimes the second pair of legs in the male may be modified into secondary sexual structures.

Chilopods. They have a single pair of legs per segment; the first two pairs are transformed into large forcipules (connected to the venom glands) used to grasp and immobilize prey. They are very fast-moving predators. The hind legs (last pair) are often larger and function as sensory appendages. About 3,400 species of chilopods have currently been described worldwide. They are divided into five distinct orders: Lithobiomorpha, Scutigeromorpha, Scolopendromorpha, Geophilomorpha, and Craterostigmomorpha, with the latter found only in Oceania.

Lithobiomorpha. They have a moderately short, reddish-brown body with 18 segments, 15 pairs of legs and long posterior appendages. On the head is a circular pit between the eyes and

tionship with true insects but, for simplicity, will be treated here as such.

Collembola, recently placed along with Protura and Diplura in the new class Entognatha, these are small soil insects (0.5-6 mm), wingless, and often equipped with a ventral organ composed of two parts (the retinaculum and the furcula) that allows them to perform sudden jumps (fig. 14). The head is equipped with antennae and often reduced eyes. The mouthparts are modified for chewing, and are usually entognathous, with segments recessed into the head. The abdomen has six segments; on the ventral side of the first segment is an organ with respiratory, water-absorption, and substrate-adhesion functions called the ventral tube.
Reproduction occurs without copulation; the female, in fact, in-

Figure 14. Springtails with varying degrees of adaptation to subterranean life: Sminthuridae (A), Entomobryidae (B–C) and Onychiuridae (D) (photo by E. Lana).

Figure 28. A schematic representation of a pitfall trap for soil invertebrates. The buried jar contains vinegar (as an attractant) and a saturated salt solution to preserve the specimens caught. After placing the trap, it is covered with a large flat stone.

However, the application of the above-described procedures, although offering a significant picture of the soil biodiversity of the area being examined, generally does not allow for the evaluation of the biological quality of the soil. Furthermore, their application is complicated by the difficulty of classifying the invertebrates collected to the species level, requiring the work of specialist zoologists.

One of the first methods for evaluating the biological quality of soil was proposed by Prof. Vittorio Parisi of the University of Parma in 2001. It is called QBS-ar (Biological Soil Quality - arthropoda) originally used to identify a method capable of characterizing the maturity of forest soil environments.

Figure 29. (A) Positioning of a pitfall trap for soil invertebrates. (B) A pitfall trap full of soil invertebrates.

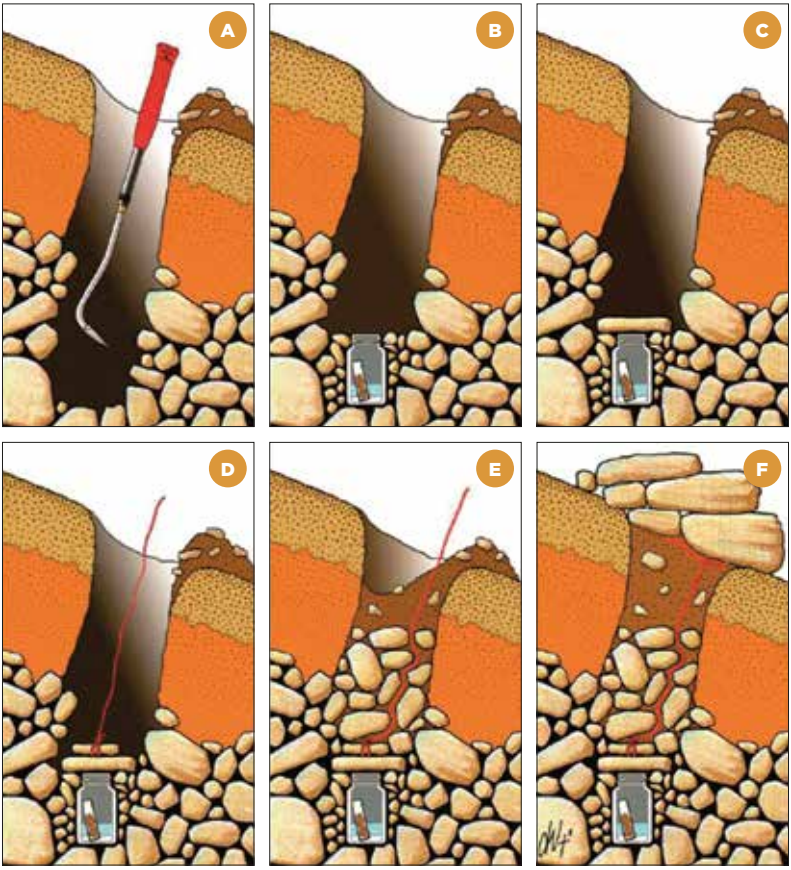

Figure 30. A schematic representation of the phases of positioning a trap in the MSS: (A) excavation of the hole, (B) placement of the jar containing water, salt and a vial of attractant substance, and securing it with soil and gravel up to the rim, (C) covering the trap with a flat stone, (D) positioning over the flat stone another little stone with the "Ariadne's thread", (E) filling the hole with rocky debris and soil, (F) final closure of the hole, camouflaging the excavation on the surface with soil and stones.

According to Parisi, **high levels of biological quality of the soil correspond to a high number of microarthropod groups that are well adapted to endogean life**.

Figure 31. Positioning of a trap in the MSS.

Using the established ecological concept of biological form (or ecotype), analogous to that of Systematic Unit in the calculation of the Extended Biotic Index, and analyzing the morphological-functional convergences of edaphic microarthropods, Parisi assigned different weights to the groups that characterize the structure of the soil community, defining the so-called Ecomorphological Indices (EMI). Higher scores are assigned to the groups with greater morphological specialization to the particular environmental conditions of the soil ecosystem. For certain groups (e.g. Protura or Blattodea), the EMI has a unique value since all species belonging to these taxa show similar adaptation to underground life. In other groups (e.g. Coleoptera or Collembola), the EMI ranges between 1 and 20, depending on the different levels of adaptation of the various species to underground life (fig. 32).
Distribution and density of the soil fauna in soil samples may be heterogeneous depending on climatic conditions and the non-uniform distribution of different microarthropod taxa. To limit the effects of this heterogeneity, the QBS-ar (Biological Quality of Soil - Arthropoda) method provides for collecting three different soil samples in the survey area, at a variable distance of 5-10 m from each other. The three collected samples

Figure 36. The different phases of soil sample extraction for SBI-bf survey: 1) Sampling a block of soil using a spade; 2) Separation of plant debris and coarse mineral components using an entomological sieve (10 mm mesh); 3) Use of a 4 mm mesh sieve to spread the sieved soil onto a white cloth.

ment of the various invertebrates will soon be visible, since their exposure to light, high temperatures and especially to an air humidity much lower than that in the soil interstices, will trigger their activity, making them easy to detect. Many endogeic animals, however, rely on thanatosis to escape dangerous situations. Therefore, after sieving, it is necessary to wait a few

value of 85 points is obtained, this value must be multiplied by 1,25 to obtain the actual score to report on the survey sheet (85×1,25=106,5 rounded to 105). The application of this procedure must be indicated in the notes at the bottom of the sheet.

Glossary of Soil Life

Acidity: characteristic of a soil's aqueous solution where hydrogen ions (H^+) prevail over hydroxide ions (OH^-), and therefore the pH is lower than the neutral value (pH=7). See also Reaction and pH.

Alkalinity: characteristic of a soil's aqueous solution where hydroxide ions (OH^-) prevail over hydrogen ions (H^+), and therefore the pH is higher than the neutral value (pH=7). See also Reaction and pH.

Bacteriophages: trophic group of the soil fauna including consumers of bacteria present in the soil.

Biocenosis: the biotic component of an ecosystem. In the case of the soil ecosystem, the biocenosis is characterized by a very complex microbiological component (bacteria, algae, fungi, protozoa) and a macrobial component consisting of animals and plants living both on the surface and at depth.

Clay: the finest mineral component of the soil (<0,002 mm), composed of phyllosilicate minerals that result from the complete transformation of the parent rock constituents. Clays typically have colloidal behaviour and, along with organic colloids, influence the fundamental chemical characteristics of the soil much more than other particle-size constituents.

Detritivores: Trophic group of the soil fauna including consumers of organic matter of vegetal and/or animal origin in decomposition. Also defined as saprophages.

Ecosystem: a structured set of living beings, in relationships with one another and with their inorganic environment, completely open and capable, to a certain extent, of self-regulation. Soil can also be considered an ecosystem.

Lithic soil: Soil that does not present a true pedogenetic profile;

Dytiscus marginalis

3. Freshwater Biodiversity Index (FBA-bf)

3.1. Biomonitoring of Surface Waters

There are various methods to carry out a qualitative environmental analysis of surface waters, each suitable for highlighting different aspects and critical issues. These methodologies can be divided into two main groups: direct methods (i.e. physical-chemical analyses) and indirect methods, represented by biotic indices.

In general, physical-chemical analyses offer high detail but address only simple and linear problems, highlighting individual criticalities in a punctiform fashion, in time and space. Chemical investigations detect the presence of specific substances but may not record the presence of intermittent or periodic pollutants, or substances not detectable outside the analysis range.

To analyze complex systems, such as the ecological network of a river or watercourse, biotic indices and river functionality indices offer great opportunities. The strategy of biotic indices is based on the identification of aquatic macroinvertebrates, since their sensitivity to water quality is well known. For this reason, they are considered good bioindicators. The benthic macroinvertebrate community of a watercourse is particularly suitable for use in bioindication, as it occupies an environment with limited seasonal variations, is easy to sample, is abundant (under optimal conditions) and generally always available.

River functionality, on the other hand, assesses the stability and diversification of the river environment in order to correct-

ful clues for identifying different species. The larvae move by extending their head and legs from the case, with which they walk along the bottom. Species that do not build cases have free-living larvae that often construct nets from silky materials, which they anchor to the bottom or vegetation, inside which they shelter and feed on trapped debris.

Odonata: include more than 6.000 species distributed in temperate and warm regions (about a hundred known in Italy). Dragonflies and damselflies are excellent fliers in the adult stage and aquatic in the juvenile stages. The head of adults is large and equipped with highly developed eyes and short, filiform antennae. The mouthparts are chewing, with very robust mandibles. The thorax bears large membranous wings, rich in veins, and legs used only for support and for grasping prey. Hemimetabolous, they have aquatic juvenile forms that breathe through tracheal gills and possess an extendable mouthpart derived from the lower lip, called a mask (fig. 43), which allows

Figure 42. Nymphs and adults of Odonata (A-B Anisoptera; C-D Zygoptera).

Figure 43. Dragonfly nymph mask at rest (left) and extended to capture prey (on the right) (illustration by Gabriele Gheza).

them to catch small invertebrates and even young fish and amphibians. Adults are also active predators, especially of dipterans. Odonata include species that prefer slow or still water environments.

Hemiptera: are heterometabolous insects traditionally divided into two suborders: Homoptera and Heteroptera the so-called "true bugs". The latter (almost 100,000 known species worldwide and 2,700 in Italy) include some families adapted to aquatic life. They are characterized by having piercing/sucking mouthparts and modified forewings called hemelytra. They are voracious predators of other invertebrates and small aquatic vertebrates. The most common belong to the families Nepidae (*Nepa* sp. and *Ranatra* sp., with long abdominal siphons to

Figure 44. Aquatic Hemipterans (Nepidae, Notonectidae and Gerridae).

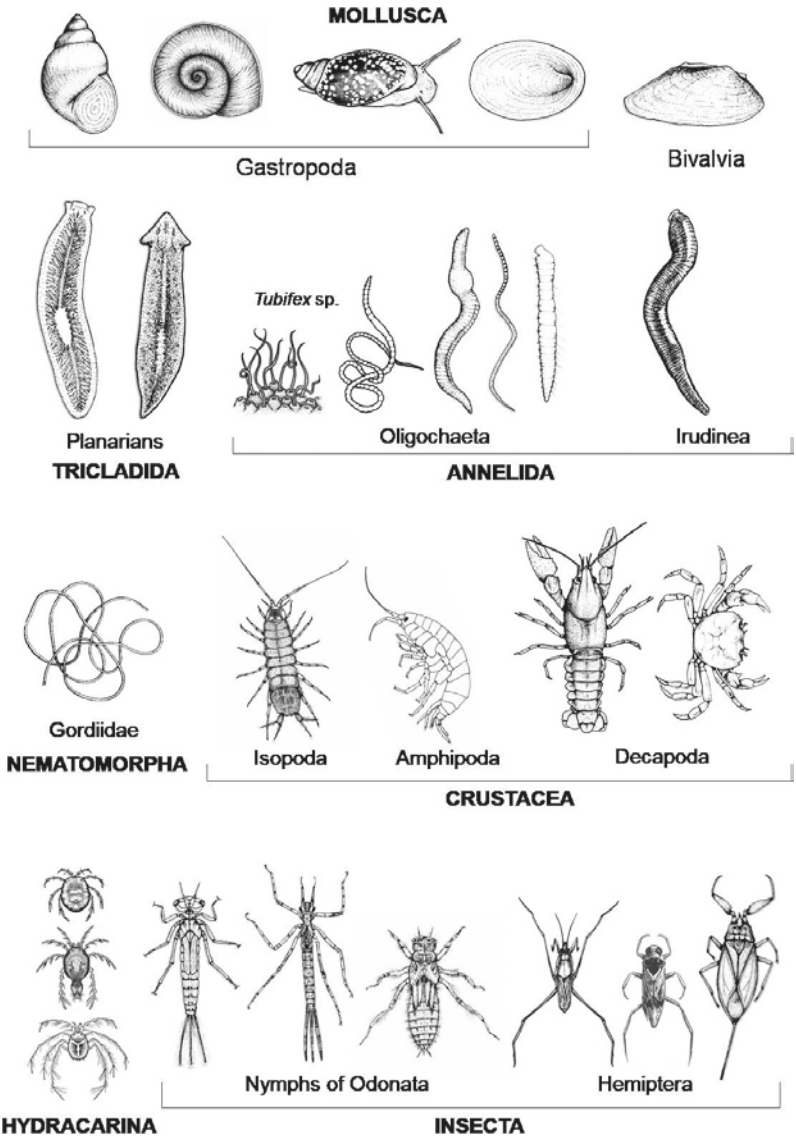

Figure 48. Some groups of aquatic macroinvertebrates commonly found in inland waters of Italy (ARPA Umbria, 2008) (illustration by Francesco Capponi).

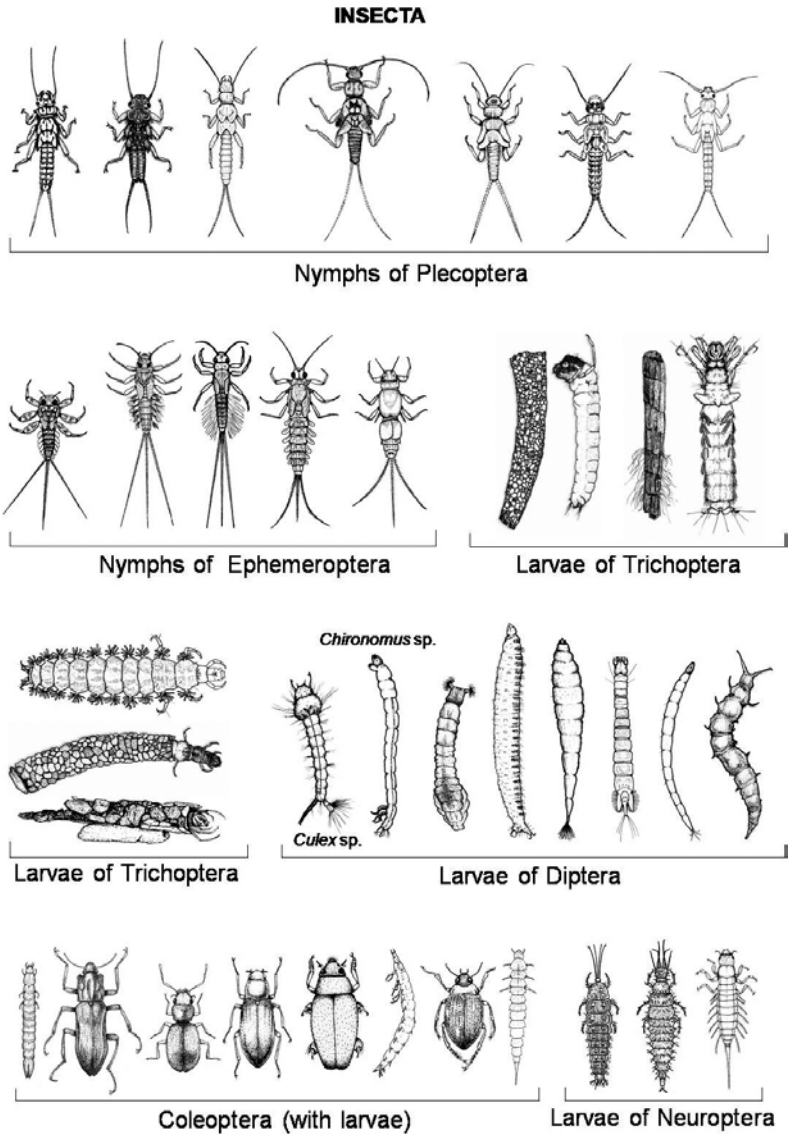

Figure 49. Various types of aquatic insects (ARPA Umbria, 2008) (illustration by Francesco Capponi).

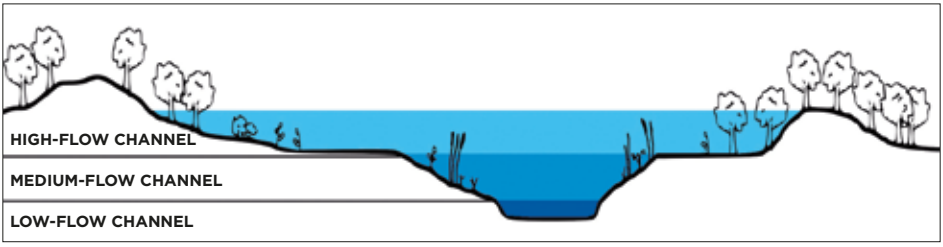

Figure 51. Different channel widths: low-flow channel (dark blue), medium-flow channel (blue), high-flow channel (light blue).

pied by water under conditions of good water availability. The soft bed, under normal conditions (thus neither in flood nor drought) includes the portion occupied by water plus a riparian strip devoid of trees and shrubs, plants that would have difficulty developing under conditions of frequent submersion and substrate abrasion caused by flood currents.
During drought periods, part of the soft bed may be colonized by pioneer herbaceous vegetation of the riverbed. It is therefore important to assess whether the width of the soft bed coincides with the space occupied by water or whether it should be sought beyond, by carefully observing the vegetation of the banks as described above.
The width must be considered transversely, from one outer margin of the soft bed to the other. The watercourse is considered "artificial" if the banks and bottom are completely cemented, if water flow variations are regulated by drainage interventions for periods exceeding three months per year, or if riverbed dredging is carried out more than twice a year.

River Morphology. Channeling works and water management systems increasingly tend to artificially control surface watercourses, with the aim of reducing flooding and erosion phenomena. However, the sizing of such works is not always adequate, and in many agricultural areas of Europe, intense anthropization and urbanization interfere with the natural flow conditions. Moreover, highly artificial management tends to homogenize

Scientific name	Common name	Large-sized tree	Medium-sized tree	Shrub
Acer campestre	Field maple		•	
Alnus glutinosa	Black alder		•	
Alnus incana	Grey alder		•	
Carpinus betulus	European hornbeam	•		
Cornus sanguinea	Common dogwood			•
Corylus avellana	Common hazel			•
Crataegus monogyna	Whitethorn			•
Euonymus europaeus	Spindle			•
Fraxinus excelsior	Major ash	•		
Ligustrum vulgare	Wild privet			•
Platanus orientalis	Oriental plane		•	
Populus alba	Silver poplar	•		
Populus nigra	Black poplar	•		
Populus tremula	Common aspen	•		
Rosa arvensis	Field rose			•
Rosa canina	Dog rose			•
Salix alba	White willow	•		
Salix caprea	Goat willow		•	
Salix eleagnos	Bitter willow			•
Salix purpurea	Purple willow			•
Salix triandra	Almond willow			•
Sambucus nigra	Black elder			•
Ulmus minor	Field elm		•	

Figure 53. Tree and shrub species commonly found along watercourses.

Figure 54. Some common tree, shrub and herbaceous species in riparian areas: Black alder (1), Silver poplar (2), Purple willow (3), Black elder (4), Common reed (5), and Bulrush (6).

Bidens frondosa, Bidens tripartita, Brachypodium sylvaticum, Calystegia sepium, Cardamine amporitana, Carex sp. pl., *Chaerophyllum tumulentum, Chenopodium ambrosioides, Chenopodium polyspermum, Clematis vitalba, Dactylis glomerata, Daucus carota, Dipsacus fullonum, Dittrichia graveolens, Dittrichia viscosa, Echinochloa crus-galli, Epilobium hirsutum, Equisetum arvense, Equisetum telmateja, Eupatorium cannabinum, Euphorbia platyphyllos, Galeopsis speciosa, Galium aparine,*

both daily and seasonally, not only due to anthropogenic pollution but also due to particular biotic or abiotic activities, plant productivity, intense precipitation or specific local geological conditions. For this reason, to understand the real causes of an alteration, it will be appropriate to contextualize the observed ecological situation not only with individual point measurements but also with literature data or local databases that may be available (e.g., Reclamation and Drainage Authority, Surface Water Quality Maps, etc.).
Another important aspect in evaluating the quality of a watercourse is the presence of different trophic groups. The presence of stable ecological relationships, such as those established between predators and grazers, will indicate a more complex ecosystem compatible with high biodiversity.

Glossary of Aquatic Life

Acidity: a characteristic of a watercourse linked to the prevalence of hydrogen ions (H^+) in solution compared to hydroxide ions (OH^-). Acidic water has a pH value lower than the neutral value (pH = 7). See also *Reaction* and *pH*.

Alkalinity: a characteristic of a watercourse linked to the prevalence of hydroxide ions (OH^-) in solution compared to hydrogen ions (H^+). Alkaline water has a pH value higher than the neutral value (pH = 7). See also *Reaction* and *pH*.

Cerci: paired appendages inserted at the sides of the last segment of many aquatic insects. They vary in shape and development and are often rich in sensory receptors, but may also serve other functions.

Collectors: a trophic group of macroinvertebrates that feed on minute particles of organic matter (< 2 mm) present on the bottom.

Filter feeders: a trophic group of aquatic macroinvertebrates that filter fine organic particles suspended in water.

Grazers: a trophic group of aquatic macroinvertebrates with

4. Lichen Biodiversity Index (LBI-bf)

4.1. Lichens

Lichens are peculiar living organisms, resulting from the symbiosis between a fungus and an alga. The union of the two organisms leads to the formation of a living being with its own characteristics, the lichen thallus, endowed with its own metabolism that allows it to produce new substances that the two symbionts would not be able to produce if isolated from one another.

The algae involved in the symbiosis belong to the Chlorophytes (green algae) or, more rarely, to the Cyanophytes or Cyanobacteria (also called blue-green algae). These are unicellular algae, although rare lichens formed by filamentous algae do exist. The fungi, on the other hand, belong to the Ascomycetes and, only in a few cases, to the Basidiomycetes.

In the morphological constitution of a lichen, the participation of the fungus is dominant compared to that of the alga, and what we commonly call lichen (the thallus) is nothing more than a dense intertwining of fungal hyphae. According to several authors, lichens should be part of the Fungi Domain, under the name of *lichenized fungi*.

The fungi involved in lichen symbiosis reproduce sexually through the production of spores and are never found in nature isolated, without algae. The algae, however, also live as independent organisms and, in the lichen, reproduce only vegetatively.

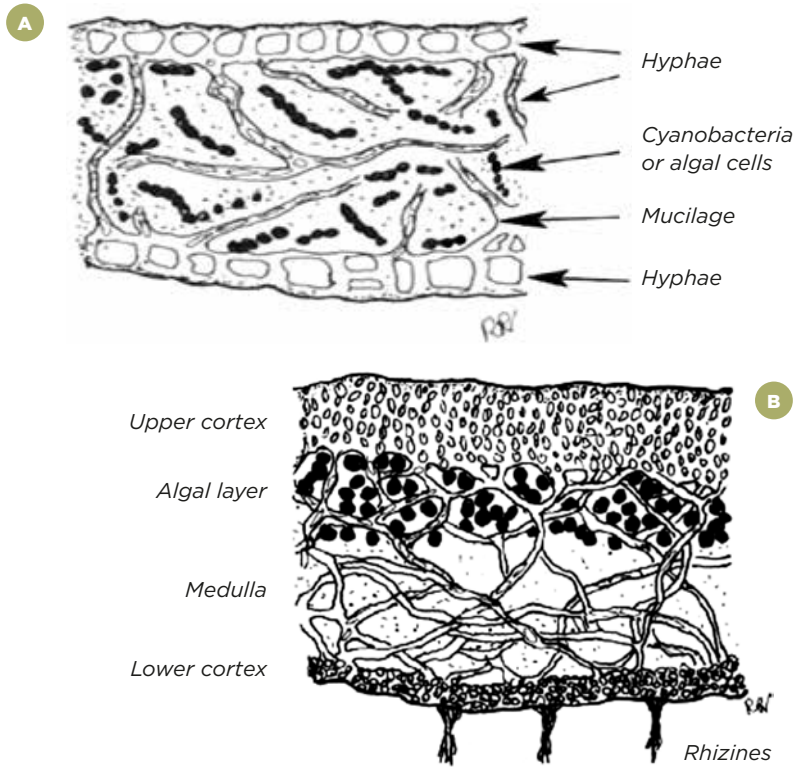

Figure 58. Comparison between the homeomeric structure (A) and the heteromeric structure (B) (from ANPA Manual, 2001).

are known, a third of which are epiphytes, living on the bark of trees and shrubs. Based on their appearance, three main growth forms of lichens are recognized: crustose, foliose, and fruticose (fig. 59).

Crustose lichens appear as films or crusts tightly adhering to the substrate and lack a lower cortex. The thalli may also have a scaly or powdery appearance, formed by an undifferentiated mass of hyphae and algae.

In **foliose lichens** the thalli are made up of flattened laminae with wavy or jagged margins, arranged parallel to the substrate

Figure 59. The three main growth forms of lichens: crustose (A), foliose (B) and fruticose (C).

and anchored to it by rhizines. The size of the lobes varies from a few millimeters to several centimetres.

Fruticose lichens, finally, appear as small upright, prostrate or hanging little shrub-like structures, attached to the substrate by a small basal portion.

The reproduction of lichens is peculiar in that only the fungus is capable of reproducing sexually. The sexual reproductive organs of the fungus (apothecia and perithecia) produce unicellular structures called spores, which, upon germination, give rise to new individuals. The lichen symbiosis occurs when the fungal spore germinates on a surface where algae are available, which will be incorporated into the intertwining of the hyphae.

Apothecia (fig. 60) are organs of various shapes (disc-shaped, with more or less evident margins, elongated, branched, etc.) in

Figure 60. Structure of a disc-shaped apothecium and apothecia of *Lecanora chlarotera*.

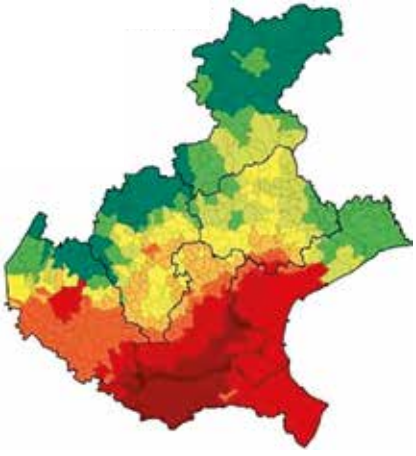

Figure 65. Air quality map of the Veneto Region developed using epiphytic lichens (Cislaghi, Nimis, 1997). NB: the classes of lichen biodiversity are prior to those defined by the ANPA method.

The methodology used in Italy in recent decades is identified as the "ANPA Method" (ANPA, 2001). It is an approach aimed at eliminating the subjectivity present in early efforts, giving specific attention to the selection of sampling sites, the trees to be monitored and the positioning of the sampling grid. The method estimates the state of lichen diversity through the identification of species and their frequency. Field detection of Lichen Biodiversity is carried out using a sampling grid (fig. 66) consisting of a linear series of five 10x10 cm squares, which must be placed vertically on the tree trunk, with the lower part positioned one metre above the ground.

Figure 66. Survey of the presence and frequency of epiphytic lichen species using a sampling grid.

- *L.B. values between 1 and 15.* Identifies areas with a high degree of alteration of lichen communities. These areas are assigned very poor air quality.
- *L.B. values between 15 and 30.* Corresponds to situations of medium alteration of lichen communities. These areas are assigned poor air quality.
- *L.B. values between 30 and 45*. Highlights areas where lichen communities show a low degree of alteration/naturalness, corresponding to low air quality.
- *L.B. values between 45 and 60.* Highlights areas where lichen communities show medium naturalness. These are associated with fair air quality.
- *L.B. values between 60 and 75.* Indicates areas in which lichen communities show high naturalness. In these areas, air quality is considered good.
- *L.B. values above 75.* Indicates a situation reflecting very high naturalness of lichen communities. These are assigned very good air quality.

Classes	LBI Values	Colour
1. Very high naturalness	> 75	Blue
2. High naturalness	61 - 75	Ligth Blue
3. Medium naturalness	46 - 60	Green
4. Low alteration/naturalness	31 - 45	Yellow
5. Medium alteration	16 - 30	Orange
6. High alteration	1 - 15	Red
7. Very high alteration (lichen desert)	0	Grey

Figure 70. Scale of LBI values for each class and corresponding colours, valid for the Padano-Adriatic bioclimatic region (Castello, Skert, 2005).

Lichens in agrosystems

Below is a list of epiphytic lichen species frequently encountered in agricultural environments, along with some indications on how to recognize the most common ones.

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Hyperphyscia adglutinata (7): foliose, grey to light brown, very thin, orbicular, smooth. Lobes <0.5 mm, elongated, flat, smooth, pressed to substrate. Powdery soredia, grey/yellow-brownish. Spot-like, linear soralia. Rare apothecia, lecanorine, sessile, up to 1 mm, brown disc.

Phaeophyscia orbicularis (8): foliose, grey to grey-brownish. Lobes 0.5-1 mm, flat, pressed to substrate. Powdery green-greyish soredia. Abundant black rhizines at margins. Rare apothecia, lecanorine, sessile, brown disc.

Physcia adscendens (9): foliose, white to light grey; whitish speckles on older parts. Lobes 0.5-1 mm, flat, linear, ascending. Cilia at lobe margins. Powdery soredia, white/white-greenish. Hood-shaped, apical soralia. Simple, pale rhizines. Rare apothecia, lecanorine, sessile, black disc.

Physconia grisea (10): foliose, brownish, often appearing whitish due to dense pruina. Broad lobes 1-3 mm, flattened, elongated, contiguous and pressed to substrate. Granular grey soredia. Linear, marginal soralia. Lower surface whitish, pale simple rhizines. Rare apothecia, lecanorine, sessile, up to 5 mm diameter, black disc.

Punctelia subrudecta (11): foliose with broad lobes, grey to grey-brown. Broad lobes 6-10 mm, elongated, contiguous and with rounded margins, dot-like pseudocyphellae; powdery whitish soredia. Spot-like soralia. Lower surface pale, especially at margins. Simple, pale rhizines. Rare apothecia, lecanorine, sessile, strongly constricted, brown disc.

Flavoparmelia caperata (12): foliose thallus with broad lobes, yellow-greenish colour. Broad lobes 6-10 mm, elongated, flattened, contiguous, pressed to substrate, rounded margins. Diffuse granular yellow-greenish soredia. Laminar soralia. Lower thallus surface black, brown at margin. Abundant simple black rhizines at margins. Rare apothecia, lecanorine, sessile, brown disc.

Lichenological Glossary

Apothecium: reproductive structure of the fungus, cup- or disc-shaped, containing sterile hyphae (paraphyses) and fertile hyphae (asci) that form spores. Lecanorine apothecia have a margin of different colour to the central disc, while lecideine apothecia have margin and disc of the same colour.

Ascus: mother cell of the spores in Ascomycetes, found in fruiting bodies (apothecia or perithecia), where ascospores originate.

Bioaccumulator: living organism capable of accumulating pollutants in its tissues.

Bioindicator: living organism with specific traits (wide distribution, sensitivity to pollutants, etc.) that shows evident changes in function and structure when environmental conditions are altered.

Biomonitoring: analysis of environmental health using living organisms called bioindicators.

Border (or margin): peripheral region of the apothecium surrounding the central part (disc or cup).

Cilia: filamentous appendages made of hyphal bundles. Cilia may be present at the margins of lobes in foliose and fruticose lichens and generally differ in colour from the thallus.

Compound: thallus formed by a crustose or foliose basal part and upright fruticose structures (podetia).

Cortex: upper or lower layer of the lichen thallus, made of tightly packed hyphae.

Corticicolous: refers to lichens that live on the bark of trees and shrubs.

Crustose: thallus with a crust-like appearance, strongly adhering to the substrate.

Disc: central part of the apothecium, bordered by the margin.

Epiphyte: refers to lichens growing on the surface of plants (stems, branches, leaves).

Epilithic: refers to lichens growing on mineral substrates (rocks, stones, etc.).

Fibril: similar to long cilia, but of the same colour as the thal-

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CHECK-LIST BIODIVERSITY FRIEND® STANDARD

Survey Form of the Soil Biodiversity Index (SBI-bf)

Farm: _____

Locality: _____ Province: _____

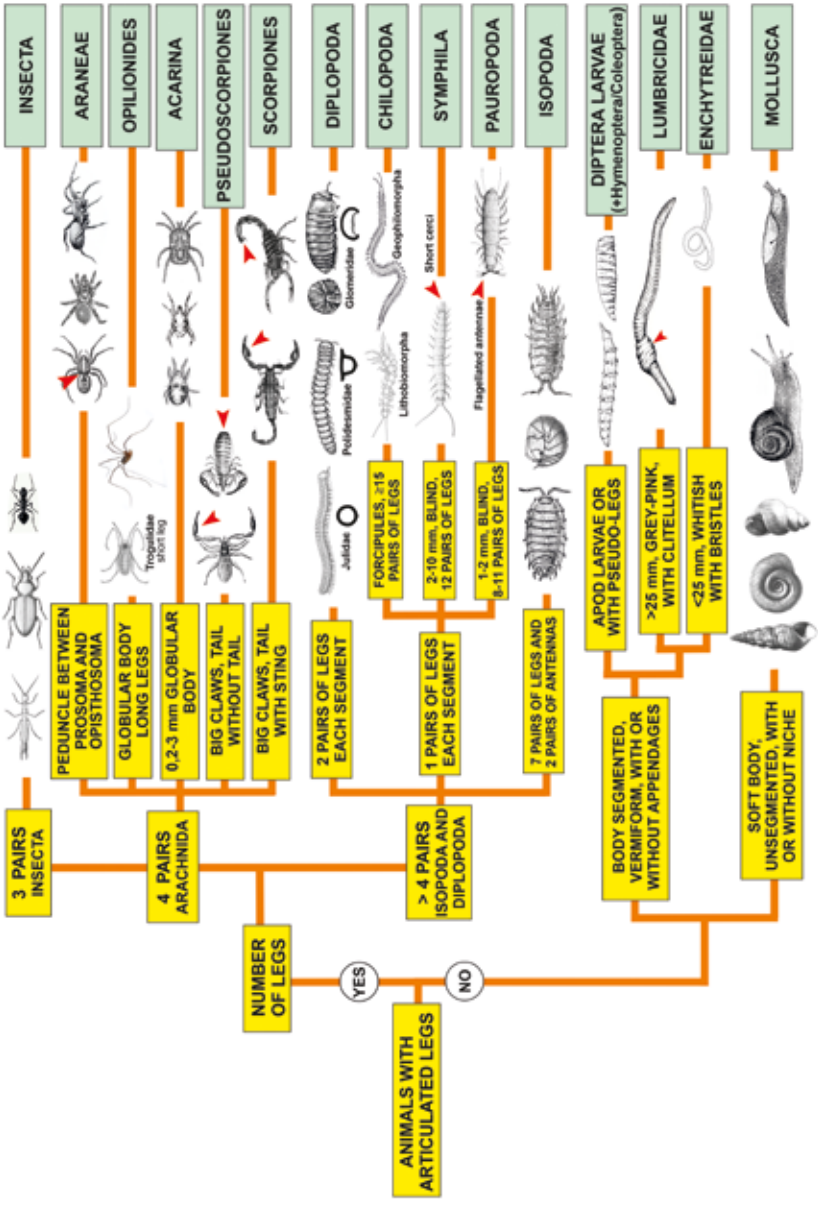
Relief date: _____ Auditor: _____

Site UTM Coordinates: _____ Altitude m: _____ a.s.l.

Weather conditions: ____ sunny ____ little cloudy ____ cloudy t = ____ °C

Soil texture: ____ clay ____ clay-loam ____ silt-loam ____ sandy-loam ____ sandy % skeleton = ____

PHYLA	CLASSES	ORDERS (or families)	Score	Presence
Mollusca	**Gastropoda**	Pulmonata and Prosobranchia	10	
Annelida	**Oligochaeta**	Enchytraedidae	10	
		Lumbricidae	20	
Arthropoda	**Arachnida**	Pseudoscorpionida	20	
		Scorpionida	5	
		Araneae	5	
		Opilionida	10	
		Acarina	20	
	Crustacea	Isopoda	10	
	Myriapoda	Chilopoda Lithobiomorpha, Scutigeromorpha and Scolopendromorpha	10	
		Chilopoda Geophilomorpha	20	
		Pauropoda	20	
		Symphyla	20	
		Diplopoda	15	
	Insecta	Collembola (epigeal species with furca)	10	
		Collembola (hypogeal species without furca)	20	
		Protura	20	
		Diplura	20	
		Thysanura (Microcoryphia and Zygentomata)	10	
		Blattoidea (Blattodea and Isoptera)	5	
		Embioptera	10	
		Dermaptera	5	
		Orthoptera (Gryllotalpidae and Glyllidae)	20	
		Psocoptera	5	
		Hemiptera	5	
		Thysanoptera	5	
		Coleoptera	10	
		Hymenoptera (Formicoidea)	5	
		Larvae of Coleoptera	10	
		Larvae of Diptera	5	
		Larve of other Holometabola and nymphs of Cicadidae	10	
		Total score SBI-bf	370	

NOTES:

Rapid Identification Key for Soil Invertebrates