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The macrophyte vegetation of running waters in the North-East of Italy: a study of the influence of morphological variables and chemical parameters on the aquatic plant community

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1 INTRODUCTION

In the past few years the approach to river assessment has radically changed. The attention of ecologists shifted from the water to the whole river. If we want to analyse a river, we will not consider only the chemical and biological quality of the water, as it used to be done some years ago, but we will try to evaluate the health of the entire ecosystem, using as many descriptors as possible.

This kind of cultural variation has become definitively explicit with the introduction in Europe of the Water Framework Directive (WFD). The Directive requires the ecological assessment of running waters based on various biotic elements, like macrozoobenthos, diatoms, macrophytes, fishes and phytobenthos (EC, 2000). In all European countries one of the consequences of the WFD was the creation or the improvement of methods to assess river quality, according to the Directive (Haury et al., 2006, Meilinger et al., 2005; van der Molen et al., 2004; Vlek et al., 2004; Buffagni et al., 2001).

Focusing now on macrophytes we must distinguish between countries like Great Britain, French and Germany, where the study on macrophyte community has a long tradition (Butcher, 1933; Haslam, 1982; Kohler, 1975; Kohler 1978; Robach et al., 1996; Trémolières et al., 1994) and many other European countries which had very few data on aquatic vegetation and no methods to record and evaluate the macrophyte component, especially for what concerns the vegetation of running waters. As the WFD was introduced the States of this second group had to work intensively to acquire data on vegetation of lakes and rivers, in order to develop indication methods based on macrophytes, as required by the WFD (Suárez et al., 2005; Friberg et al., 2005).

There are two important facts regarding the fulfilling of WFD demands. The first one is that the WFD, as already said, requires of the Member States to set some methods to evaluate the ecological state of water bodies, based on different biotic elements, including macrophytes (EC, 2000). This aim is still far from being reached, giving that the most part of existing indexes are made to evaluate the trophic status of water, which is something very different from ecological state (Caffrey, 1987; Haury et al., 1996; Newman et al., 1997).

Ecological assessment means to evaluate the distance of the actual community from the community of reference (EC, 2000; Klapwijk et al., 1994). Reference conditions are “a state in the present or in the past corresponding to very low pressure without the effects of major industrialization, urbanization and intensification of agriculture, and with only very minor modification of physicochemistry, hydromorphology and biology” (Wallin et al., 2003). Considering the previous definition, the main problem is that, apart from some States with a long tradition of research about macrophytes, we do not know what the pristine vegetation of European water bodies was (Baattrup-Pedersen et al., 2006). As a consequence it is rather difficult to establish the composition of the reference

communities, considering that in Europe nearly all rivers and lakes are heavily modified (Baattrup-Pedersen et al. 2002; Baattrup-Pedersen et al., 2003; Cristofor et al., 2003; O'Hare et al., 2006).
The problem is really difficult to solve, because for some river types it is actually impossible to find reference sites (Baattrup-Pedersen et al., 2008; Riis and Sand-Jensen, 2008).
The most common solution adopted is to study the best available sites, which are considered to be very close to reference conditions (Nijboer et al., 2004; Riis and Sand-Jensen, 2008; Stoddard et al., 2006).
The second important fact concerning the WFD fulfilling is that we also need an accurate knowledge of the actual vegetation all over Europe, because even if macrophytes are not so much dependent on climate conditions compared to terrestrial vegetation (Bracco, 1998; Den Hartog & Segal, 1964) we cannot ignore the changing of aquatic vegetation with respect to different areas, at least at an Eco-regional scale (Warry & Hanau, 1993, Wasson et al., 2002).
Another question that has to be taken into account is the validity of bioindication methods. There are in fact some authors who criticize this kind of approach (Demars & Edwards, 2008; Moss, 2008), thinking that it is not possible to isolate the effect of nutrients from other variables on species composition (Demars & Edwards, 2008) or to base the evaluation of a water ecosystem only on few indicator species and to generalize the information that these species can give in different contexts (Moss, 2008). Moss also biased the effort made by researchers to meet the requests of the WFD, sustaining that the Directive produced the negative effect of proliferation of evaluation methods, which are not really scientifically sounded.
We can partially agree with such an objection, nonetheless the success of bioindication is due to a real need of synthesizing and integrating complex information given by ecological sciences (Nicolai, 1992; Goethals & De Pauw, 2001). Moreover it provides important instruments (the indexes) to people who work in the environmental field. Such methods are finally useful to evaluate and therefore protect the nature in Europe, which is the main scope of the WFD (EC, 2000).

1.1 MACROPHYTE METHODS: THE INTERNATIONAL CONTEXT

At a European level there are several types of macrophyte metrics that are different from each other because of the plant community aspects they consider (Haury et al., 2000). There are community indexes (HMSO, 1987), diversity indexes (Shannon & Weaver, 1949), saprobic indexes (Sladecek et al., 1981), trophic indexes that derive from specific indexes (Ellenberg, 1979), perturbation indexes and other kind of indexes, not belonging to any category, like the Macrophyte Index Scheme or MIS (Caffrey, 1987), which divides about 30 species into 4 groups, according to their sensitivity to

organic pollution. The species relative abundances are then used to classify the watercourses into 5 quality classes.

Many of the most important European methods are trophic indexes that base the assessment of the river trophic status on the presence and abundance of some species, to each one of which an indicator value is assigned, according to its tolerance to nutrient enrichment.

The Mean Trophic Rank (Holmes, 1995; Holmes, 1996) is the standard method officially adopted by the English Environment Agency (Newman et al., 1997) to assess the running waters for the EU Urban Waste Water Treatment Directive purposes (EEC, 1991). The MTR is a trophic index, which considers 129 indicator species. Moreover the MTR was often used in studies about macrophytes in running waters (Kelly & Whitton, 1998; Ali et al., 1999; Johnson et al., 2006).

Another important trophic index is the Indice Biologique Macrophytique en Rivière or IBMR, the official French method (AFNOR, 2003; Haury et al., 2006), which is based on a list of 208 species and gives to each of them two numerical values, one expressing the indicator value and the other measuring the stenoecy of the species (see **Section 6.7**).

The MTR and the IBMR have also been selected as methods for intercalibration studies (Birk et al., 2006; Staniszewski et al., 2006), in some cases together with the German Reference Index (Meilinger et al., 2005) and the Dutch Macrophyte Score (van der Molen et al., 2004), in the frame of the EU project STAR[1] (Furse et al., 2006), which is an important WFD oriented research project.

Nonetheless, among these widely known methods, the German Reference Index (RI), which is a perturbation index, is the only one to comply the WFD demands. The RI classifies the rivers according to their type and assigns to each typology a reference vegetation, in term of species composition and abundance. The actual community recorded at a certain site is then compared with the reference community to give a measure of the ecological status of the river stretch (Schaumburg et al., 2005).

Beside the methods that we have already cited, there are a lot of European countries that have set new macrophyte indexes for the evaluation of running waters, like the MIR in Poland (Szoszkiewicz et al., 2006), the IVAM in Spain (Moreno et al., 2006) the Multimetric Index in Cyprus (Papastergiadou et al., 2008) and many others under development in other countries (Pieterse et al., 2009).

[1] Standardisation of river classifications: framework method for calibrating different biological survey results against ecological quality classifications to be developed for the Water Framework Directive (http://www.eu-star.at/).

1.2 MACROPHYTE METHODS: THE ITALIAN CONTEXT

In Italy the interest about aquatic vegetation started at the beginning of the 90's, with the first experiences of application of the MIS to some water courses in the North-East of the country (Turin & Wegher, 1991; Wegher & Turin, 1992).
Subsequently, starting from 1996, many applications of different macrophyte methods have been conducted, prevailingly in the North-West of Italy (Toso et al., 2005).
The indexes have been applied to many tributaries of the Po and to some little lowland watercourses in the plain of Vercelli (Azzolini et al., 2003; Minciardi et al., 2004). Other environments have been analysed in Trentino (Fabris, unpublished data) and in the centre of Italy (Morgana et al., 2003).
All these studies had the aim of testing the reliability and applicability of European methods to the Italian fluvial environments. It resulted that the applied indexes are able to reveal the trophic state of lowland watercourses, but are not able to distinguish between natural trophic level and organic pollution. Moreover in sub-alpine and alpine environments most of the indexes are not applicable.
As a direct consequence of the cited experiences the European guidance standard for the surveying of macrophytes in running waters was adopted in Italy as well (UNI EN, 2004), in order to standardize the sampling procedure.
Some years later the official protocol for macrophyte monitoring in rivers was published in a manual of the Italian Environmental Protection Agency (APAT, 2007), but it only considers the way of collecting data about macrophytes.

Figure 1.1: a specimen of *Potamogeton berchtoldii* picked up in the field

Recently some Italian sites have been included in the method intercalibration exercise for the Mediterranean area (Aguiar et al., 2009) and previously 3 sites were part of studies on reference conditions at a European level (Baattrup-Pedersen et al., 2006), but what still lacks is an ecological index for Italian rivers based on macrophyte, which is one of the WFD demands. Because of that, the Italian Ministry of Environment is adopting the French IBMR as official macrophyte assessing method for Italy.

Nowadays many studies are in progress aiming at the creation of a macrophyte index in our country, but nothing official has been published yet.

The present study lies inside this frame, mixing together different needs, interests and objectives. The starting point of this work has been the idea that for setting an Italian macrophyte method it is necessary to have a background of data about aquatic vegetation. Giving that **the aims of the study** are:

- to acquire an accurate knowledge of the aquatic vegetation of running waters in the studied area;
- to analyse the relations occurring between macrophyte community and environmental variables, basing the study on data collected from Italian rivers;
- to classify the running waters into river types, according to the environmental variables that resulted to be relevant for aquatic vegetation;
- to detect some key species for each river type in the perspective of creation of an Italian macrophyte method;
- to detect, if there are any, possible reference sites;
- to verify the relation between macrophyte vegetation and trophic status in the analysed running waters;
- to test the reliability and applicability of the IBMR to the assessed environments.

2 WHAT ARE MACROPHYTES?

The first thing to point out is the definition of macrophytes. Many authors use this word with different meanings. Scott et al. (2000) define them as 'plants observable by the naked eye', without any further specification. Other authors talk about vascular plant species and bryophytes (Riis et al., 2008). The British protocol of Mean Trophic Rank (Newman et al., 1997) identifies macrophyte according to the definition given by Holmes & Whitton (1977 b)), as 'any plant observable with the naked eye and nearly always identifiable when observed', hence including all higher aquatic plants, vascular cryptogams and bryophytes, together with groups of algae which can be seen to be composed predominantly of a single species. A more extensive meaning is that used in the French protocol of IBMR, where macrophytes are an assemblage of aquatic or amphibious plants, which can be observed by the naked eye, or which live usually in colonies observable by the naked eye (filamentous algae). They include phanerogams, bryophytes, lichens, macroalgae and colonies of cyanobacteria, eterotrophic bacteria and fungi that can be seen by the naked eye (AFNOR, 2003). A similar meaning (vascular plants, bryophytes, macroalgae and cyanobacteria) is that adopted in the Spanish sampling protocol (Confederación Hidrografica del Ebro, 2005) and in the proposed Spanish method of IM[2] (Suárez et al., 2005). In the German methods[3] (Meilinger et al., 2005; Schneider & Melzer, 2003) the term macrophytes encompasses charophytes, bryophytes and vascular plants.

A definition of macrophyte frequently reported (Janauer & Dokulill, 2006; Suàrez et al., 2005) is that of Wetzel (2001), considering the macroscopic forms of aquatic vegetation, like macroalgae (e.g. the alga *Cladophora*, the stoneworts such as *Chara*), the few species of pteridophytes (mosses, ferns) adapted to the aquatic habitat and the true angiosperms.

The definition of macrophyte we refer to in the present study is that used in the Italian guidelines for the assessment of aquatic macrophytes in running waters (UNI EN, 2004), i.e. 'larger plants of fresh water which are easily seen with the naked eye, including all aquatic vascular plants, bryophytes, stoneworts (Characeae) and macro-algal growths'.

2.1 CLASSIFICATION OF AQUATIC PLANTS

There are many classifications for water plants, based on different criteria (Den Hartog & Segal, 1964; Mäkirinta, 1978; Pearsal, 1918).

[2] The Indice de Macrofitos is a method proposed to evaluate the ecological quality of rivers in the Segura basin (Suárez et al., 2005).

[3] We are referring here to the Trophic Index of Macrophytes (TIM), assessing the trophic status of rivers (Schneider & Melzer, 2003) and to the Reference Index (RI), evaluating the deviation in macrophyte composition and abundance from reference conditions (Meilinger et al., 2005).

Water plants can be subdivided into 4 groups according to their mode of attachment to the substratum (Luther, 1949):

- haptophytes: all those plants that are attached to a solid substrate (rocks, stones, wood, etc.), but do not penetrate in it. This group comprises most of the benthic algae and aquatic bryophytes (*Fontinalis, Cinclidotus*) and all aquatic lichens;
- rhizophytes: plants that penetrate in the substratum with their basal part (roots or rhizoides). Most of the vascular plants belong to this second group, together with many algae (Charophyta, some Clorophyta etc.);
- pleustophytes: the third group comprises all the plants that are not attached to the substrate (*Lemna, Ceratophyllum,* etc.).

The classification of macrophytes proposed by Den Hartog & Segal (1964), based on their growth forms, is often used. They divided the rhizophytes and pleustophytes of Europe into 11 groups:

- isoetids: rhizophytes with short stems and a rosette of stiff radical leaves (e.g. *Isoetes lacustris, Lobelia dortmanna, Littorella uniflora*);
- vallisneriids: rhizophytes with a short stem and long flabby linear radical leaves (e.g. *Vallisneria spiralis*);
- elodeids: caulescent rhizophytes with undivided submerged leaves (e.g. *Elodea, Najas, Zannichellia* and many species of *Potamogeton*);
- myriophyllids: caulescent rhizophytes with finely dissected submerged leaves and generative parts rising above the water surface (e.g. *Myriophyllum, Hottonia*, *Ranunculus circinatus*);
- batrachiids: caulescent rhizophytes with submerged leaves and specialized floating leaves (e.g. many species of *Ranunculus* subgen. *Batrachium* and of *Callitriche*);
- nymphaeids: rhizophytes with floating leaves with long petioles and the stem a little or not branched. In some cases submerged leaves are present as well (e.g. *Nymphaea, Nymphoides, Nuphar, Potamogeton natans*);
- ceratophyllids: submerged pleustophytes with finely divided leaves, without floating leaves, laying near the surface of water in summer and sinking to the bottom in autumn, surviving the winter in the form of turions (e.g. *Ceratophyllum, Utricularia*);
- hydrocharids: pleustophytes floating on the water surface, with floating leaves, surviving the winter as gemmulae or sporocarps (e.g. *Hydrocharis, Salvinia natans*);
- stratioids: pleustophytes floating on the water surface, with stiff basal leaves, rising above the water surface. In autumn they sink to the bottom and survive the winter as turions (e.g. *Stratiotes*);

- lemnids: small pleustophytes floating on the water surface, with the upper side of fronds adapted to aerial life and the bottom side to water life (e.g. *Lemna minor, Spirodela, Wolffia*);
- ricciellids: small submerged pleustophytes (e.g. *Riccia* subgen. *Ricciella, Lemna trisulca*).

A simple but most used classification of macrophytes is based on their biological type (G.I.S. Macrophytes des Eaux Contnentales 1998, Haury *et al.* 2000, Thiébaut, 2007; Toivonen & Huttunen, 1995):

- hydrophytes: plants which live completely submerged or with some parts floating at the surface of water (*Potamogeton, Ranunculus, Myriophyllum, Lemna,* etc.);
- helophytes: plants having their roots in the sediment under the water surface, but emergent with leaves, inflorescence and the upper part of the stem (*Phragmites, Thypa, Phalaris,* etc.);
- amphiphytes: plants which can live both submerged like the hydrophytes and emergent like the helophytes, thus presenting two different growth forms, sterile or with inflorescence, depending on their habitat (*Sparganium, Berula, Mentha*, etc.).

3 ENVIRONMENTAL FACTORS AFFECTING MACROPHYTE GROWTH AND DISTRIBUTION

When starting studying aquatic plants one of the first questions is about the environmental conditions that determine their presence or absence, their growth and the specific composition of the biocenosis.
The most important habitat variables influencing macrophytes are generally considered to be light availability, substrate type, flow rate and water chemistry (Barendregt & Bio, 2003; Butcher, 1933; Carr et al. 1997; Ferreira & Moreira, 1999; Flynn et al., 2002; Riis et al., 2000; Robach et al., 1996).
Beside these there are other important factors like interaction between different macrophyte species (Haury et al., 2000), between aquatic plants and other biocenosis, e.g. macrozoobenthos (Monahan & Caffrey, 1996; Wright et al., 2002), and the dispersal capacity of aquatic plant species (Riis et al., 2001).

3.1 LIGHT AVAILABILITY

Since macrophytes are photosynthetic organisms the light is their primary source of energy. Therefore the quantity of light reaching the plant surface is extremely important. Obviously for macrophytes the water is not a limiting factor, as for terrestrial plants, because it is superabundant (Butcher, 1933). In a water environment the limiting factor becomes light, because of its low penetration through water (Butcher, 1933; Carr et al., 1997).
The light availability is closely connected to some site characteristics like the shading conditions (Fletcher et al., 2000), the turbidity of water (in turn dependent on flow rate) and its depth (Westlake, 1975).
The quantity of light is one of the features that determine the specific composition of the community, because there are sciaphilous species, like some bryophytes, that occur in shaded habitats (Valanne,1984; Haury etal.,2000; Thiebaut et al., 1998), and heliophilous species, as *Apium repens*, that is a light-demanding taxon (Ellenberg et al.,1992; Grassly et al.,1996).

3.2 SUBSTRATUM TYPE

Many plants are rooted or anchored to the substratum and its stability is therefore crucial for the development of the macrophyte community. The type of river bed is linked to the current velocity and to the discharge (Butcher, 1933; Baattrup-Pedersen et al., 2002). If the substratum is constituted of stones, continually turned over by current and eddies, there will be no rooted vegetation. On the other side a bed of sand or gravel

can be washed away by floods, together with the vegetation rooted in it (Westlake, 1975).
The substratum is also a source of nutrients to the rooted plants and their quantity is related to the kind of river bed, since they are bound to the fine fraction of sediment (Clarke & Wharton, 2001; Madsen & Cedergreen, 2002).
The granulometry of the river bed influences the composition of the macrophyte community, because there are species related to fine-textured substrates like *Alisma plantago-aquatica*, *Groenlandia densa*, *Lemna minor* and *Apium nodiflorum*, others that prefer a more bulky substrate, like *Veronica beccabunga* and *Nasturtium officinale*, and species like *Callitriche stagnalis* which show a slight preference for gravel substrates (Onaindia et al., 1996).

3.3 FLOW RATE

The flow velocity is one of the shaping factors for macrophyte communities of lotic environments, because of its effect on substratum and turbidity (Butcher, 1933; Bracco, 1998), but first of all for its mechanical action on plants that are constantly submitted to a stress tending to tear and transport them downstream (Chambers et al., 1991; Wade et al., 2002). In addition there is also an abrasive effect on plant tissues, due to suspended material (Bracco, 1998; Edwards, 1969).
The current velocity is therefore a selecting factor, determining the community composition. In very fast and turbulent streams there is no macrophyte vegetation, with the exception of rheophilous mosses, presenting structural adaptations to the strength of the flow, like strong rhizoïdes (*Rhynchostegium riparioides*), keeled leaves (*Fontinalis antipyretica*) or multicellular leaf margins (*Cinclidotus*) (Vanderpoorten & Klein, 1999; Vitt & Glime, 1984). In fast flowing waters there are species with strong stems and leaves and efficient rooting systems, like many *Ranunculus* species (Casper & Krausch, 1980 b)), while in very slow or nearly standing water we can find species like those of the genus *Lemna*, laying on the surface and therefore not standing the current (Butcher, 1933; Spink & Rogers, 1996).
The current velocity is not the only hydrological parameter acting on macrophytes. Closely related to it there is also the amount of discharge, the flow variability and flood frequency. All these factors, concurring to determine the flow rate of a water course, affect the stability of the habitat and hence the possibility of colonization by macrophytes (Riis et al., 2008; Wade et al. 2002).

3.4 WATER CHEMISTRY

3.4.1 Dissolved oxygen and carbon dioxide

In the water environment the most important dissolved gases are oxygen and carbon dioxide. The available amount of both in terms of concentration is much lower than in

the terrestrial environment (Butcher, 1933). The concentration of dissolved oxygen in running waters is mainly due to exchange processes with the atmosphere, facilitated from current velocity (Carr et al., 1997), and to the primary production of algae and macrophytes. There is therefore a 24 hour cycle in DO quantity because of photosynthesis production during the day and respiration consumption in the night (Park et al., 2003).

For the development of macrophytes the amount of CO_2 in water is fundamental as inorganic carbon source for the photosynthesis. The total inorganic carbon concentration in water comprises CO_2 (free and dissolved) and the carbonate-bicarbonate system (Maberly & Spence, 1983). Plant photosynthesis and respiration cause carbon to be interchanged between inorganic and organic forms, while decomposition imposes an oxygen demand on stream water that contributes to elevated levels of CO_2 (Wilcock & Croker, 2004). Maberly & Spence (1983) showed as for productive lakes, with low alkalinity, carbon may become a competition factor. Despite in running waters the inorganic carbon is not a limiting factor, owing to a bigger exchange with the atmosphere in respect to lentic ecosystems (Carr. et al., 1997), it is one of the element taken into account as predictors of the macrophyte community composition (Demars & Edwards, 2008; Demars & Thiébaut, 2008).

3.4.2 pH, hardness and conductivity

Hardness, pH and conductivity are other interrelated elements that can determine the species composition of the macrophyte community (Demars & Thiébaut, 2008), as is well represented by the case of vicariant species, like *Potamogeton polygonifolius* and *Potamogeton coloratus,* both living in oligotrophic habitats, the first in non-calcareous environments and the second in calcareous environments, as stated by Robach et al. (1996), who described a trophic sequence of plant communities for acidic waters and a sequence for alkaline waters.

All these factors are, in turn, related to the geology of the catchment which therefore affects the floristic composition of the macrophyte community as well (Thiébaut et al., 1995). The community can change also as a consequence of an anthropogenic process of water acidification (Thiébaut et al., 1998). This phenomenon seems to be related to the lower amount of CO_2 in water, following the pH decrease, and therefore to the different capacity of macrophyte species to use other sources of inorganic carbon (Thiébaut et al., 1995).

3.4.3 Nitrogen and phosphorus

Nitrogen and phosphorus are fundamental nutrients for macrophyte growth. Green plants and algae assimilate nitrogen primarily as ammonium or nitrate. Most nitrogen in aquatic system is bound to organic matter and therefore not available until it is mineralized to ammonium, which can be taken up directly or oxidized to nitrate by

bacteria. Therefore nitrogen can be scarce in some pristine aquatic system, limiting the production (Duff & Triska, 2000).
Despite this, due to its low solubility if compared to nitrogen and its low 'supply to need ratio' (Moss, 1980), phosphorus is generally the limiting nutrient in surface water environments, with the exceptions of some nitrogen-limited lakes and streams where there are abundant geologic sources of phosphorus or where human impact leads to eutrophication (Hendricks & White, 2000).
This important function of phosphorus and nitrogen for the growing and development of macrophytes is at the basis of their large use as indicators of trophic status in lakes and running waters (Caffrey, 1987; Carbiener et al., 1990; Haury et al., 2006; Melzer, 1998; Holmes, 1996; Schneider & Melzer, 2003).
About nitrogen and phosphorus one of the open questions is that of the relative importance of sediment and water column as sources of nutrients to aquatic plants (Barko et al., 1991; Clarke & Wharton, 2001; Madsen & Cedergreen, 2002; Robach et al., 1995), with some studies giving evidence of the dependence of plant uptake on nutrient concentrations in water (Pelton et al., 1998; Robach et al., 1995) and of the relationship between nutrient concentration in the sediment and in the water column (Demars & Harper, 2002; Demars & Harper, 2005 b)), and others demonstrating the nutrient uptake of macrophytes from sediment (Chambers et al., 1989; Xie et al., 2005).
The difficulties in answering to this question is probably due both to a dependence of the plant nutrient uptake (root *versus* shoots) on different nutrient concentrations at different river sites (Madsen & Cedergreen, 2002), and to the effect of macrophytes on enriching the sediment nutrient content (Sand-Jensen, 1998; Schulz et al., 2003), without omitting the connection between phosphorus and nitrogen concentrations and sediment type (Chambers & Prepas, 1994).

3.5 BIOTIC FACTORS

The distribution of macrophytes is strongly dependent on life-history traits of the taxa that, together with competitive interactions among species, determine plant maintenance, recruitment and colonization capacity (Bornette et al., 2008). These factors are particularly important in habitats disturbed by flood events or weed cutting, and are therefore closely connected to frequency and intensity of disturbance (Bornette et al., 2008; Ferreira & Moreira, 1999).
The different capability of macrophyte species to withstand various kinds of pressures is regarded by some authors as a possibility of using aquatic plants as a stress indicator (Sabbatini & Murphy, 1996) or predictive instruments (Bornette et al., 2008).
The presence of a plant at a certain site is also due to its dispersal capacity and mode. There are in fact species, like the obligate submerged ones that primarily disperse through the water flow transporting seeds, turion or shoots fragments from upstream to downstream. The amphibious species (e.g. *Sparganium emersum* and *Berula erecta*) can

disperse both with water and from populations on the banks by ingrowth, like terrestrial plants (helophytes) do (Henmry & Amoros, 1996; Riis et al., 2001).
The rapid recruitment of species after weed cutting or flood disturbances is also playing a crucial role in the recolonization of the water course after disturbance (Bornette et al., 2008; Haury et al., 2000). This aspect is closely related to the competition between species (Riis et al., 2001). For example *Elodea canadensis* becomes predominant in stream reaches that undergo weed cutting, because of its competitive-ruderal strategy (fast growing, efficient dispersal and disturbance resistance) that makes it favoured in respect to other species (Abernethy et al., 1996), like *Potamogeton lucens* and *Potamogeton praelongus,* that have a slow growth (Riis et al., 2001). Likewise *Myriophyllum spicatum*, *Potamogeton pectinatus* and *Vallisneria americana* were found to recover well after a record flood (Spink and Rogers, 1996).
The species interactions are important not only in the case of a disturbance, but also in all other stress or scarcity situations, like for example the competition for space and light that favours terrestrial and amphibious species near the banks, compared to submerged species (Riis et al., 2001), or the competitive success of *Lagarosiphon major* in respect to *Elodea canadensis* and *E. nuttallii* under very stressful conditions of high pH and low free CO_2 (James et al., 1999).
Linked to the dispersal capacity of plants is also the question of spatial isolation between catchments and strongly directional connectivity within a catchment which, according to some authors, play a major role in the construction of the macrophyte community (Demars et al., 2005). The connectivity among the main channel and the side-arms in large river systems seems also to influence the composition and the richness of aquatic plant biocenosis (Bornette et al., 1998).
Another interesting factor that can influence macrophytes is the interaction with the animal compartment. It is generally acknowledged that invertebrate grazer organisms do not feed on macrophytes, hence not explicating a direct control on them (Kelly & Whitton, 1998; Wright et al. 2002; see Lodge, 1991, for a review). Still the grazers have an indirect effect, eating the epiphyton that develops on aquatic plants (Brönmark, 1989; Monahan & Caffrey, 1996) and inhibits their growth by shading (Wright et al., 2002). Exceptions are represented by snails, crayfish (Lodge, 1991) and gammarids which find for example in *Ranunculus* an important source of food (Haury et al., 2000).
Recently there are authors reporting evidences of the strong effect of snails on the ultimate structure of macrophyte communities, by selectively consuming some species at a juvenile stage (Elger et al., 2009).
A further selective grazing pressure on macrophytes can be explicated by fishes and waterfowl (swans, geese and ducks) (Lodge, 1991), like in the study of Wright et al. (2002), where swans feeding on *Ranunculus* held back its increase in cover.
Finally, the fossorial organisms can have an indirect effect on water plants through sediment perturbation (Barko et al., 1991; Haury et al., 2000).

3.6 OTHER FACTORS

Beside the light, substratum, flow and water chemistry there are other factors that indirectly influence macrophyte, some of them having already been mentioned above. The altitude of the site for example concurs to determine the characteristics of macrophyte assemblages, because it is correlated with other variables, like discharge, water quality, depth, substrate, current velocity (Mackay et al., 2003). Depth and width, in turn correlated with distance from source, are also important for macrophytes, like catchment area and groundwater input, influencing quantity and quality of water (Barendregt & Bio, 2003). The geology of the basin also affects the water chemistry and therefore macrophytes (Riis et al., 2000; Robach et al., 1996), while water temperature is one of the variables that have a direct effect on the community, determining its seasonality (Sburlino et al., 2004) and influencing the productivity of aquatic plants by controlling the rate at which chemical reactions take place (Carr et al., 1997). Nonetheless temperature is not as important as for terrestrial plants, because the temperature of water is relatively constant during the year (Butcher, 1933). Aquatic vegetation has in fact quite repetitive aspects, if compared to the terrestrial plant communities, also in different climate zones (Bracco, 1998). Nonetheless there are differences in macrophyte biocenosis due to the geographical area in which the water courses are situated and that can be taken into account through the approach based on ecoregion (Illies, 1978), used in many studies oriented to the definition of stream typologies (according to the WFD requirements; EC, 2000), like that of Wasson et al. (2002) on hydro-ecoregions in France, and in various studies about macrophytes (Baattrup-Pedersen et al., 2006; Szoszkiewicz et al., 2006).

Finally we must not forget the anthropogenic factors that condition macrophytes by modifying water quality, for example through eutrophication or acidification (Carbiener et al., 1995; Daniel & Haury, 1995; Demars & Harper, 1998; Thiébaut et al., 1995), making the more pollution sensitive species like *Potamogeton coloratus* (organic pollution) disappear (Buchwald et al., 2000; Carbiener et al., 1995; Trémolières et al., 1994), but also other kinds of human impacts like flow regulation, channelling and drainage that physically alter the river environment and therefore the macrophyte community (Fabris et al., 2009; Haslam, 1995; O'Hare et al., 2008; Riis et al., 2008).

Two other important variables that derive from human activities are the land use in the area surrounding the stream (Riis et al., 2000), because many species, especially in small streams, derive from the banks (Henry & Amoros, 1996; Henry et al., 1996), and the weed cutting in channels and streams that influence competition between species (Riis et al., 2000; Riis et al., 2001).

4 INFLUENCE OF MACROPHYTES ON RIVER ENVIRONMENT

Macrophytes are conditioned by many factors that we have briefly illustrated and at the same time they condition the river ecosystems in which they grow (Barko et al., 1991; Clarke & Wharton, 2001; Desmet et al., 2008; Sand-Jensen, 1998; Schneider & Melzer, 2004; Schulz et al., 2003).

The presence of vegetation patches in a water course, particularly in medium to small streams, have an important effect on current velocity, which is much slower inside the patches and increases at the boundary between macrophytes and free water (Sand-Jensen, 1998; Green, 2005) The flow reduction, that is dependent on the structure and therefore on the species composition of the macrophyte community (Desmet et al., 2008; Green et al, 2005), results in an increased nutrient retention and sedimentation of fine particles, and as a consequence in a nutrient enrichment of the sediment (Clarke & Wharton, 2001; Madsen et al., 2001; Schulz et al., 2003).

The effect on flow and the growing of aquatic plants itself provide also a high heterogeneity inside the river reach, offering different habitats to macroinvertebrates, fishes and epiphyton thus increasing the general biodiversity of the fluvial system (Butcher, 1933; Green et al., 2005, Minelli & Trevisanello, 1985; Monahan & Caffrey, 1996). Macrophytes constitute a food source for some grazers and waterfowl (Elger et la., 2009; Lodge, 1991), a site of eggs deposition for certain fishes (Butcher, 1993) and enhance the survival of herbivorous organisms, because they provide a substrate for the growth of epiphyton (Wright et al., 2002; Brönmark, 1989).

Figure 4.1: a dense patch of *Ranunculus penicillatus*, growing in the Brenta at Grigno.

The decay and senescence of aquatic plants also play a role, through the enrichment of sediment in organic matter (Chambers e Prepas 1994, Clarke e Wharton 2001).

Macrophytes release oxygen in the rhizosphere through their roots, thus reducing SRP (Soluble Reactive Phosphorus) concentrations in the sediment and sediment porewater and enhancing nitrification and denitrification processes because of the increased sediment redox (Barko et al., 1991; Chambers & Prepas, 1994; Wigand et al., 2001).

The aquatic plants take up phosphorus, nitrogen and carbon (Desmet et al., 2008; Joniak et al., 2007), store them in their tissue and release them at the decay. The temporary storage of these elements is closely dependent on seasonal changes in biomass density (Desmet et al., 2008).

Macrophytes are not only involved in nutrient uptake and recycling but being photosynthetic organisms they are also largely responsible of the oxygen production and of the oxygen cycle in water (Park et al., 2003). Moreover they seem to exert an antagonistic effect on phytoplankton, as demonstrated by studies on *Elodea* and *Chara,* where the two vascular plants were able to reduce significantly the growth of *Scenedesmus* (Lürling et al., 2006).

Beside their role in the geochemistry of P, N, C, macrophytes also act on many other elements, taking them up from water and sediment (Barko et al., 1991). Their ability to accumulate various elements at high concentrations make them widely used in water quality improvement processes, especially for P and N removal from waste water and for heavy metals removal from contaminated water (see Dhote & Dixit, 2009 for a review; Yaowakhan et al., 2005).

5 STUDY AREA

The study area is located within the Trentino and the Veneto regions, in the North-East of Italy. We selected 54 sampling sites on 38 different water courses (**Fig 5.1** and **Fig 5.2**). We assessed a single reach on small running waters and two or more reaches on the main rivers.

The totality of the assessed points belongs to four main hydrographical basins:

- 17 points are located inside the Po basin, but none of them on the River Po;
- 17 points are in the Adige basin, 5 of them directly on the main river;
- 20 sampling stations are in the Brenta - Bacchiglione catchment area, 4 of which on the River Brenta and 2 on the River Bacchiglione.

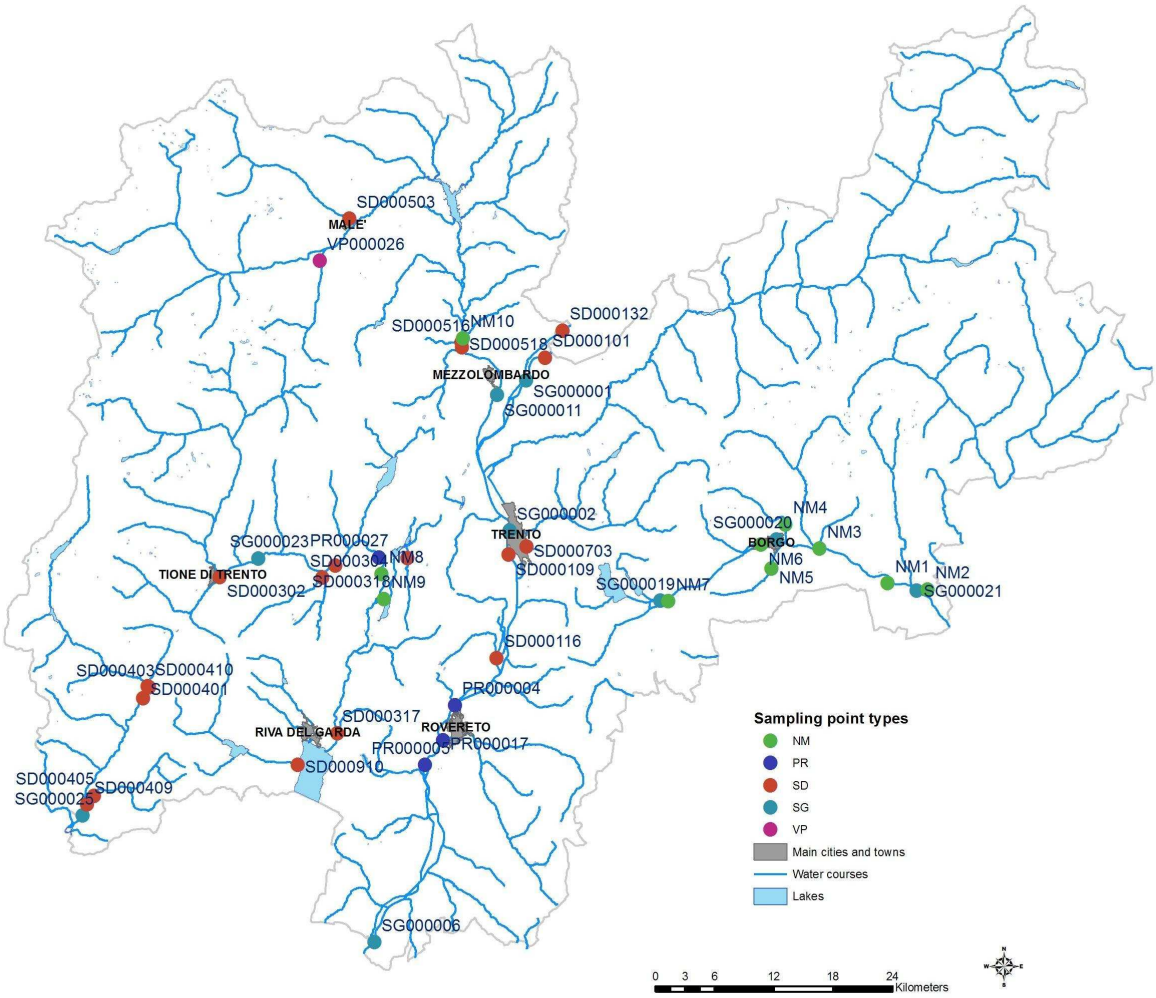

Figure 5.1: Sampling points in Trentino. The type codes refer to the monitoring frequency by APPA Trento. The points indicated with NM are those not monitored by APPA Trento. For the meaning of the codes see **Tab 6.1** and **6.3**.

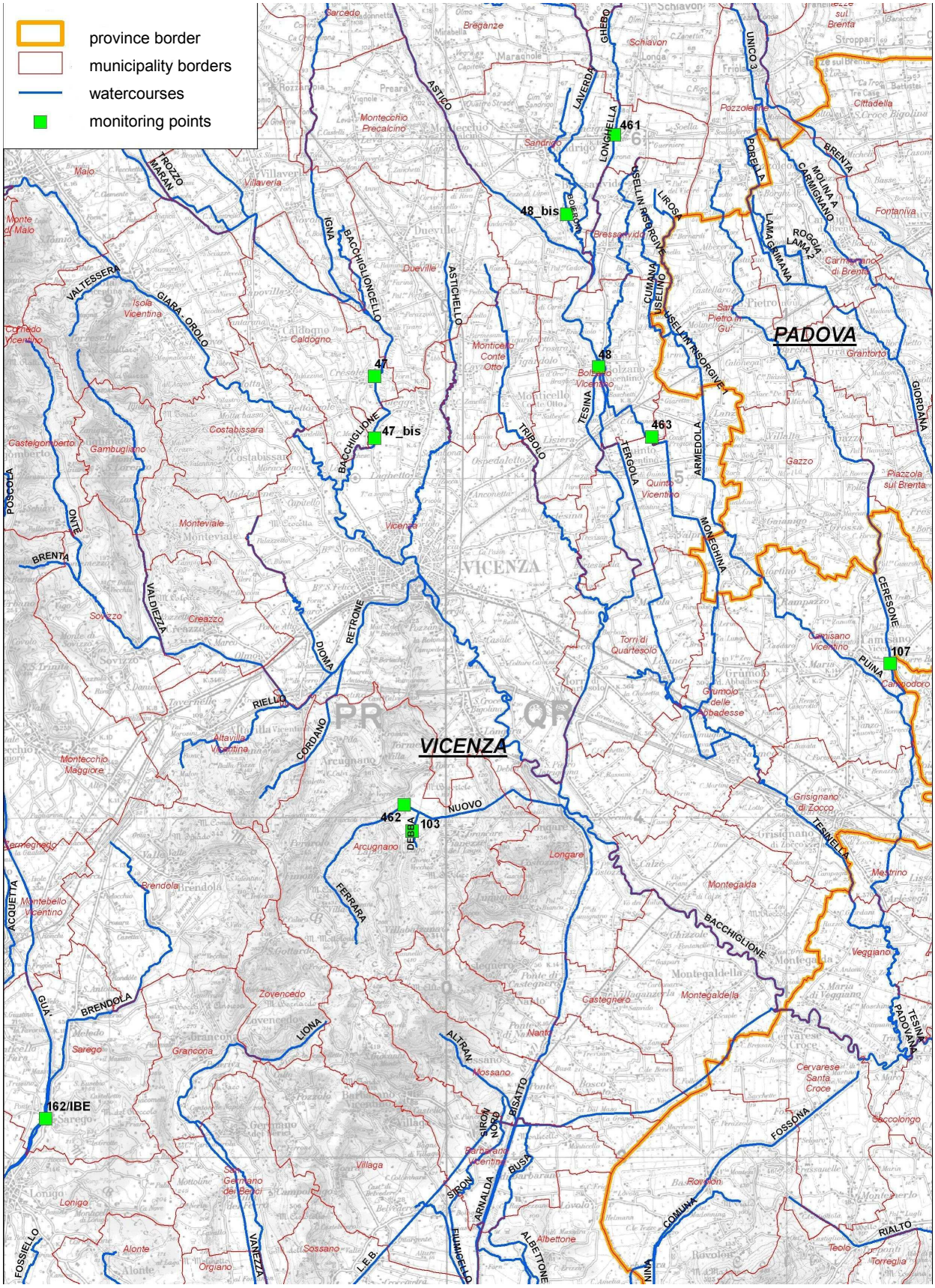

Figure 5.2: Sampling points in the province of Vicenza. For the meaning of codes see **Tab 6.1**.

5.1 THE PO BASIN

Some of the sampling sites are located within the Po basin, because they belong to the sub-basin of the Sarca, flowing into the Lake Garda, of which the Mincio, tributary of the Po, is an outflow, and to the sub-basin of the Chiese, a tributary of the Oglio that in turn flows into the Po.

5.1.1 The River Sarca

The River Sarca has a basin of about 1.250 km^2. It is a typical alpine water course with a glacial flow regime. The Sarca arises from the glaciers of the groups Adamello-Presenella and Brenta Dolomites and flows into the Lake Garda after 74 km. Its slope ranges from 10% in the first reach to 0.15 % in the medium stretch to 0.08% in the last part. The Sarca originates from the joining of three different branches: Sarca di Genova, Sarca di Nambrone and Sarca di Campiglio.

The main tributaries on the right are the Rio Bedù di Pelugo, the Rio Bedù di San Valentino, the Torrente Arnò and the Torrente Duina. On the left there are the Rio di Manez, Rio Val d'Algone, Torrente Ambiez, Rio Bondai and Torrente Salagoni.

The sub-basin of the Lake Idro belongs to the Sarca basin as well, with the lake inflow that is the Torrente Massangla and the outflow Torrente Ponale flowing directly into the Lake Garda.

The Sarca is very rich in water, because it is fed by glaciers and owing to this particular feature it has been heavily exploited for hydroelectric uses with serious consequences on the ecosystem.

The geology of the basin is characterized by two distinct geological formations, the Adamello-Presanella granodiorites and tonalites and the calcareous-dolomitic rocks of the Brenta group that come into contact along the Giudicarie tectonic fault. Furthermore there is a thick layer of alluvial and glacial deposits.

In the high river basin there are 23.899 inhabitants and 46.315 residents in the low basin (www.statistica.provincia.tn.it).

The waste waters are treated by 20 plants, some of them discharging in the Sarca and others in the tributaries (Provincia Autonoma di Trento, 2001).

Another source of impact on the river are the numerous fish-farming discharging in it.

5.1.1.1 The Sarca in Ragoli

Our highest sampling station on the Sarca is localized near Ragoli upstream the discharge of one of the main waste water treatment plant along the water course. The river is approximately 25 m wide with a medium flow velocity with limited turbulence. The average depth is between 30 and 100 cm and the substrate consists predominantly of sand and cobbles.

The banks are natural because the river flows here quite deep in the valley, but the riparian vegetation is reduced to some bushes, with many exotic species. The right side of the river is steep, covered with woods crossed by a main road while on the left side there are maize fields and forage meadows, with scattered houses (see **App 11.3**).

5.1.1.2 The Sarca in Ponte Arche

Some kilometres downstream the first station there is the second one, inside the small village of Ponte Arche, downstream the discharge of two main treatment plants. Here the river has concrete banks and inside them some riparian bushes and hygrophilous grasses are growing.
The water course has a medium depth and a medium water flow velocity with some turbulence and is approximately 35 m wide. The substrate is coarse, with many cobbles and some gravel (see **App 11.3**).

5.1.1.3 The Sarca at Limarò

The third sampling station on the Sarca is at Limarò, in the medium course of the river, after it has crossed a very narrow and deep gorge. The main impact here is represented by the flow rate fluctuations, due to a barrage just upstream the sampling point.
The river is about 35 m wide and shallow with a medium flow velocity and a coarse substratum (cobbles). The banks were stabilized through the construction of concrete walls and the vegetation on both sides is consisting only of some bushes, with many exotic species. The surrounding area shows a diffused urbanization (see **App 11.3**).

5.1.1.4 The Sarca at Ponte del Gobbo

The last sampling site on the Sarca is localized a little upstream from Dro. The river is here about 25 m wide with a medium depth and a medium and laminar flow velocity. The substratum consists essentially of cobbles. Both banks are made of concrete and some reeds and bushes grow inside them. The land use on the left is agricultural, while on the right there are some houses (see **App 11.3**).

5.1.1.5 The Duina

The Duina is one of Sarca's tributaries on the right. It arises in the Val Marcia at about 1500 m a.s.l. and after 8 km flows into the Sarca at Ponte Arche.
In the low course, where our sampling site is located, it shows the impact due to civil and farming waste waters.
At the sampling point, near the mouth, the Duina has concrete dams, is shallow with medium and turbulent flow and has some reeds growing on the left and isolated trees on the right.

On both sides there is the village of Ponte Arche (see **App 11.3**).

5.1.1.6 The Arnò

The Arnò arises from the Val Breguzzo at 2000 m a.s.l. and flows into the Sarca downstream the town of Tione. Its total length is about 12 km.
The water course has a good morphological quality, but near the mouth, where we sampled it, there are walls on the banks to sustain the bridge above and there is therefore no riparian vegetation.
The water flow velocity is here medium and laminar, since the stream is shallow and quite wide (10 m). The substrate is a mix of coarse and fine fractions. The surrounding area is sparsely urbanized with some meadows especially on the right (see **App 11.3**).

5.1.1.7 The Roggia di Calavino

The water course arises from a spring near the small village of Vigo Cavedine, in the Val Cavedine, at about 600 m a.s.l. It flows with a slight slope through the valley down to Calavino, where its path becomes steeper until it flows into the Lake Toblino in the Valle dei Laghi.
The sampling point is located near the mouth, where the water course appears like a narrow straightened and embanked channel, with no riparian vegetation. The water depth is shallow and the current velocity is medium with some turbulence. The site is partially shaded because of the presence of woods on the left side, together with some fields. On the right side there is a fish-farming, discharging in the Roggia di Calavino that also receives the outflow of the Calavino treatment plant (see **App 11.3**).

5.1.1.8 The Rimone

The Rimone is an artificial channel about 10 m wide that connects the Lake Cavedine with the Sarca, a little downstream Pietramurata.
At the sampling site the water is nearly standing, with a mix of coarse and fine substrate, with some artificial concrete boulders on the bottom. Both banks are stabilized through concrete walls and there is only herbaceous vegetation on both sides. The land use is agricultural (see **App 11.3**).

5.1.1.9 The Rio Salone

The Rio Salone is a little tributary of the Sarca that flows down from the Dosso Saiano, at about 1200 m a.s.l, having a high slope in the first part of its course and then becoming a plain stream in the last part. It flows into the Sarca near Arco.

The sampling point is located near the mouth, where the Salone is a narrow straightened channel with artificial banks. The only vegetation consists of non-riparian bushy and herbaceous species.
The flow is medium and laminar and the substratum is coarse.
On the right the land is covered with maize fields, apple cultivations and vineyards, while on the left there is the steep slope of the Dosso Saiano with arboreal vegetation. A little stretch upstream a garbage dump may have an impact on the water course through the leaching (see **App 11.3**).

5.1.1.10 The Ponale

The Ponale is the outflow of the Lake Ledro that flows into the Lake Garda. At our sampling site it shows a natural morphology, with turbulent and very fast flowing waters, a bottom covered with gravel and boulders and arboreal vegetation on both banks. The stream flows through a very narrow and deep valley and the surrounding area has therefore a reduced surface, lying between two steep walls sustaining the road on both sides. Upstream the sampling site, the Ponale receives the outflow of a waste water treatment plant (see **App 11.3**).

5.1.2 The River Chiese

The River Chiese arises at 2500 m a.s.l. under the Vedrette moraines, in the Adamello mountain group. It has a length, up to the Lake Idro, of 50 km (Provincia Autonoma di Trento, 2001) and a basin area of 534 km^2 (Autorità di Bacino del fiume Po, 2006).
Most of the circulating surface water is diverted for hydroelectric uses, through the creation of four artificial lakes. The River Chiese has many tributaries, between them the Adanà and the Palvico on the left.
The geology of the basin is very complex, with calcareous rocks prevailing on the left side of the river and a mixed composition on the right.
The most important localities are Pieve di Bono, Condino, Storo and Darzo with a total population in the Chiese basin of 13.199 inhabitants (www.statistica.provincia.tn.it).
The two main waste water treatment plants discharge directly in the Chiese downstream Pieve di Bono and in the Lora at Storo.

5.1.2.1 The River Chiese upstream Pieve di Bono

The first sampling site is located a little stretch upstream Pieve di Bono. The water course is here a natural stream with limited slope and therefore medium but turbulent flow. The river bed consists of boulders and cobbles and on both sides there is some riparian vegetation, even if with discontinuities.

On the right side there are only rocks and woods, while on the left there are woods together with some houses (see **App 11.3**).

5.1.2.2 The River Chiese downstream Pieve di Bono

The second sampling site is located downstream Pieve di Bono and the inflow of the waste water treatment plant discharge, but just before the artificial Lake Cimego. Upstream the sampling point there is also the inflow of one of the main tributaries, the Adanà.
The Chiese is here about 15 m wide, with fast and nearly laminar water flow, coarse substratum and natural banks. Arboreal vegetation is present on both sides, consisting of a mix of riparian and non-riparian species.
The surrounding area is covered with woods, meadows and some scattered houses (see **App 11.3**).

5.1.2.3 The River Chiese in Storo

The third sampling point on the Chiese is located in Storo, in the last part of its course before the inflow into the Lake Idro. The river is about 40 m wide with fast and laminar flow and cobbley-gravelly bottom. There are levees on both banks but some riparian vegetation is developed. On the right there is the small town of Storo, on the left there are fields and meadows (see **App 11.3**).

5.1.2.4 The Adanà

The Adanà arises at 2508 m a.s.l. on the eastern side of the Monte Corona and flows into the Chiese near Pieve di Bono, after 12 km.

5.1.2.5 The Adanà upstream Pieve di Bono

The Adanà is here fast flowing and turbulent, with natural banks, covered with riparian and non-riparian arboreal vegetation and a bed consisting of boulders and some cobbles. On the right there is a main road passing very close to the stream, while on the left there are woods and meadows (see **App 11.3**).

5.1.2.6 The Adanà in Pieve di Bono

This second sampling site is very different from the previous one. The stream is a little narrower, has a steep rock face with woods on the left and an artificial bank on the right without riparian vegetation. On the right side there is the little town of Pieve di Bono.
The water flow is medium, with some turbulence and the river bed consists of boulders, cobbles and gravel, more or less in the same amount (see **App 11.3**).

5.1.2.7 The Palvico

The Palvico is the outflow of the Lake Ampola, located at 730 m a.s.l., near Tiarno di Sopra.
The stream flows downstream with a series of waterfalls, the last one being the highest (50 m). In its final part it flows through the alluvial plain of Storo.
The sampling site is near the inflow into the Chiese, downstream Storo. The stream is about 6 m wide, with a cobbley bed and artificial banks and little riparian vegetation. The water flow is medium and laminar and the main impact is represented by the total lack of water during some periods because of the diversion for human activities.
On the left side there is a sparse urbanization, while on the right there is the Rio Lora (see **App 11.3**).

5.1.2.8 The Lora

The Rio Lora arises at Storo from the joining of many little brooks arising in the plain of Storo or little above on the mountain. It flows parallel to the Chiese and along its course receives the discharge of an important waste water treatment plant. It flows into the Palvico just a short reach before it flows into the Chiese.
The surrounding area is therefore occupied by the Chiese on the right and by the Palvico on the left, but here there is well developed riparian vegetation with a wetland area. The right bank, instead, has an artificial dyke.
The average width is about 6 m, the water flow is medium and laminar and the river bed consists of cobbles, gravel and sand (see **App 11.3**).

5.2 THE ADIGE BASIN

The river arises not far from the Lake Resia, at 1.550 m a.s.l. The basin, going from Trentino-Alto Adige to Veneto with a little part in Swiss, has a surface of 12.100 km^2 and the total river length is 409 km. The Adige flows into the sea at Porto Fossone between the Brenta and the Po mouths.
The first part of the river has a slope of 53 ‰ going down to 0.10 ‰ in the last stretch. When the Adige flows through the province of Trento it has a slope around 1 ‰ and the altitude ranges from about 230 m a.s.l., at the Alto Adige – Trentino border, to 120 m a.s.l. at the Trentino–Veneto border (www.bacino-adige.it/car_fis.asp).
The geology of the basin is quite complex, with a considerable variety of lithology, but limestone and dolomites are the prevailing rocks (Servizio Geologico PAT, 1999).
In Trentino the Adige receives three important tributaries: the Noce, the Avisio and the Fersina, coming from quite densely populated valleys. The Noce valleys (Val di Non and Val di Sole) in particular show a high impact due to agriculture.

In the Adige plain the river flows through important cities like Trento and Rovereto, each one of them having an important industrial area, and receives the tribute of many channels, draining the surrounding areas, which are covered with vineyards.
The Adige undergoes many discharge fluctuations because of the diversions for hydroelectricity production, which are mainly on its tributaries.

5.2.1 The Adige in San Michele all'Adige

The first sampling point on the Adige is located on the border between Alto Adige and Trentino. The river is here about 70 m wide, has a high flow speed, nearly laminar. The substrate is coarse and the medium depth is over 1 m.
It has levees on both sides, where a narrow strip of riparian tree and bushes grows. The land is cultivated with vineyards and there are some villages (see **App 11.3**).

5.2.2 The Adige in Trento

The Adige in Trento flows around the city and has therefore concrete dykes, with some trees and bushes growing on them. The river is quite wide (80 m) and deep (more than 1 m). The flow is fast and nearly laminar and the substrate consists of cobbles and gravel (see **App 11.3**).

5.2.3 The Adige in Villa Lagarina

The third sampling site on the Adige is located near the small town of Villa Lagarina. Here the Adige is a plain river about 70 m wide, with medium and laminar flow, but it still has quite coarse substrate consisting mainly of cobbles and gravel, with some sand. It has levees on both sides, made of concrete on the left. The riparian vegetation is nearly absent.
On the surrounding area there are some villages and cultivated fields, together with an important road on the right (see **App 11.3**).

5.2.4 The Adige in Mori

The Adige in Mori is about 70 m wide and about 1m deep, with a medium and laminar flow and coarse substrate consisting of cobbles, with some sand and some boulders. Both banks are artificial with extremely reduced riparian vegetation.
The surrounding land is urbanized, with a quarry on the right and a small industrial area on the left (see **App 11.3**).

5.2.5 The Adige in Borghetto

The last sampling station on the Adige is at the border between the provinces of Trento and Verona. Here the river is very wide, about 100 m, with medium and laminar flow. The banks are both artificial, with concrete and rock walls, on which grows sparse riparian vegetation.
On the right side there is the motorway and on the other side the small village of Borghetto, but the land use is essentially agricultural (see **App 11.3**).

5.2.6 The Fossa di Caldaro

The Fossa di Caldaro is one of the main artificial drainage channels that flows trough the Adige plain. It was built in 1774 for the land reclamation of the marshy areas between the Adige and the Noce. It flows out the Lake Caldaro at 214 m a.s.l. in Alto Adige and flows after 24 km into the Adige in San Michele all'Adige at 209 m a.s.l.
The geology of the surrounding mountains is mainly calcareous, with limestone and dolomites.
Along his course the Fossa di Caldaro receives many little drainage channels and ditches. In the past the water quality was very bad, because of the impact of many untreated civil waste waters, but now all the water that flows into the Fossa di Caldaro is treated. It remains a strong impact due to the intensive agricultural land use in the basin.
The sampling site is near Roverè della Luna and the channel is here straightened and embanked, without riparian vegetation with a muddy bed and slow flow (see **App 11.3**).

5.2.7 The Fossa di Salorno

The Fossa di Salorno is an artificial draining channel that belongs to the Salorno basin, in Alto Adige, but flows into the Adige a little downstream from Salorno, in the province of Trento.
The geology of the basin is mixed, both with calcareous rocks (dolomites and limestone) and porfiric quarzifer rocks.
The sampling site is a short stretch upstream the mouth of the channel that flows here through an intensively vineyard cultivated area.
The channel is straightened and embanked, without riparian vegetation (see **App 11.3**).

5.2.8 The Rio S. Zeno

The Rio S. Zeno, that in the highest course is called Torrente Arione, arises in the mountains from two lakes, located in the Monte Bondone chain. In the lowest part of its course it radically changes and becomes a plain channel flowing slowly through the

agricultural land on the right side of the Adige, downstream Trento. It flows into the Adige near Aldeno, where our sampling site is located.
At the sampling point it is straightened and embanked, with no riparian vegetation and muddy substrate (see **App 11.3**).

5.2.9 The Rio Lavisotto

The Rio Lavisotto is a drainage artificial channel that arises from the River Avisio in Lavis and flows into the Adige in the southern part of the city. The first part of its course crosses an important industrial area, located to the north of Trento and the channel showed therefore a heavy industrial pollution, especially for what concern the sediment. During these years the remediation is in progress, but only for the highest part of the Rio Lavisotto, which is the most contaminated one.
Our sampling site is located in the second part, a little upstream the inflow into the Adige. The channel is completely artificial, without riparian vegetation, flowing through the city with slow flow velocity and muddy substrate (see **App 11.3**).

5.2.10 The Rio Salé

The Rio Salé is a small stream that flows into the Fersina that in turn is an Adige tributary. The Salé arises from a little mountain (about 800 m), located south-east of Trento and flows for the terminal part of its course through the city of Trento. It is characterized by a high conductivity (about 1000 μS/cm), because of the calcareous geology of its basin (Servizio Geologico PAT, 1999)**.**
The sampling site is located inside the Gocciadoro Park where the Salé has both concrete banks and bottom, beside a series of little concrete steps across the bed, to diminish its slope.
There is no riparian vegetation and the substrate overlying the artificial bottom is coarse.
The flow velocity is high but nearly without turbulence (see **App 11.3**).

5.2.11 The Leno

The Leno is the last of the main tributaries of the Adige, flowing into it in Rovereto, on the left side.
It arises on the Monte Baffelan at 1300 m a.s.l and is composed of two branches, the Leno di Vallarsa, the principal one, and the Leno di Terragnolo joining the Leno di Vallarsa a little stretch upstream Rovereto. Its total length is about 18 km and its basin has a surface of approximately 150 km^2. Along its course there is the artificial lake S. Colombano, nearly 2 km long and 100 m wide. The most part of the basin lays in a

mountain area without strong human impacts, but the last part of the water course flows through the city of Rovereto.
The sampling site is located not far from the mouth, where the river is about 20 m wide, shallow and slow, with coarse substrate. The banks are both made of concrete, with no riparian vegetation (see **App 11.3**).

5.2.12 The Noce

The Noce is one of the main tributaries of the Adige. It arises on the Corno dei Tre Signori at 3360 m a.s.l., inside the Stelvio National Park and is fed by glaciers so it has a glacial regime, with maximum discharge in summer and minimum discharge in winter. Its total length is 105 km.
The main impacts on the water course are due to the massive water diversion for hydroelectric use. The Noce is split into two parts because of the presence of a 150 m high dam, forming a vast artificial lake.
The geology of the basin is very variable, with sedimentary and metamorphic rocks together with granites tonalites, besides consistent alluvial deposits. Some important tributaries of the Noce, in the high part of its course, are the Meledrio and the Vermigliana on the right and the Rabbies on the left.
The valleys the Noce flows through are intensively cultivated with apples and are characterised by a high tourist presence. There are numerous waste water treatment plants, only two of them discharging directly in the Noce, the others flowing into the tributaries (Provincia Autonoma di Trento, 2001).

5.2.12.1 The Noce at La Rocchetta

The first sampling site on the Noce is located inside a protected wetland area in the low part of the water course, downstream the big dam of S. Giustina.
Here the stream is about 20 m wide, with fast and turbulent flowing waters, natural banks and riparian woods on both sides. The substrate is predominantly gravelly.
On the right side the surrounding area is covered with grasses and trees, while on the left there is a steep rock slope and above that a small village and vineyards (see **App 11.3**).

5.2.12.2 The Noce at La Rupe

The second sampling point on the Noce is located in the lowest part of the stream, very close to the industrial area of Mezzolombardo. The flow rate is here very fluctuating, because of the diversion and releases of water, for hydroelectric use.
The flow velocity is medium and laminar, the river bed is approximately 40 m wide and the substrate consists of cobbles and gravel. The banks have both concrete dykes, with a very narrow strip of riparian trees.

The average water depth is over 1 m. As for the land use, there is the industrial area on the right and cultivated fields and roads on the left (see **App 11.3**).

5.2.12.3 The Rabbies

The Rabbies is one of the main tributary of the Noce. It arises from Ortles-Cevedale group, between 2595 and 2778 m a.s.l. and flows into the Noce in Malé, which is also the main urban centre along the Rabbies course. Its basin has a surface of about 140 km^2. The first stretch of the stream is inside the Stelvio National Park, while downstream the Rabbies flows through a very steep valley (Val di Rabbi) with only little villages at the bottom and woods on both sides.
The sampling site is located near Malé, where the stream has fast and turbulent water flow, the substrate consists principally of big boulders and the banks are natural. Nonetheless the riparian vegetation is reduced to narrow strips of trees, because of the agricultural use of the land with apple cultivations on one side and a steeper slope with woods on the other side (see **App 11.3**).

5.2.12.4 The Meledrio

The Meledrio is an important tributary of the Noce. It flows out the Lake delle Malghette, at 1890 m a.s.l., in the Adamello-Brenta mountain group, and flows into the Noce at Dimaro, its basin covering an area of about 55 km^2. After a reach it receives the waters coming from Campo Carlo Magno, near Madonna di Campiglio.
The sampling site is located near Dimaro, where the stream flows through woods and has natural banks covered with trees. The flow velocity is very high and turbulent and the substrate is very coarse (see **App 11.3**).

5.2.12.5 The Sporeggio

The Sporeggio is one of the main low course tributaries of the Noce. It flows into the Noce a little reach downstream the Rocchetta sampling site.
The stream arises at 1700 m a.s.l. from the Campa and Monte Fausior belonging to the Adamello-Brenta Dolomite group. Its basin covers a surface of about 57 km^2 and in the first part of the course the stream consists of two branches, the Sporeggio and the Rio Molini. A little tributary of the Sporeggio, the Rio Spormaggiore, receives the outflow of the Spormaggiore (the main village) waste water treatment plant.
The sampling site is located very close to the mouth, where the river is shallow, has medium and nearly laminar water flow, coarse substrate, consisting of cobbles, and artificial concrete banks. On the right there is a narrow strip of riparian bushes, while on the left some hygrophilous grasses grow. As for the land use there is a small group of houses on the left and woods and apple cultivations on the right (see **App 11.3**).

5.2.12.6 The Lovernatico

The Lovernatico is a small tributary of the Noce arising from the Busoni springs at about 600 m a.s.l. and receiving the waters of the Rio Cadino after a short reach. It flows into the Noce a little upstream the Sporeggio inflow.
The sampling site is located near the mouth. Here the Lovernatico is shallow, with a medium and nearly laminar flow, a substrate where cobbles are dominant and concrete banks with bushy riparian and exotic vegetation.
On both sides there is a sparse urbanization and in addition, on the right there is an important road and further apple cultivations (see **App 11.3**).

5.3 THE BRENTA – BACCHIGLIONE BASIN

The River Brenta and the River Bacchiglione are two different water courses, having distinct catchment areas that join together just before flowing into the Mediterranean Sea, near Chioggia, in the province of Venice. Because of this joint mouth they are grouped in a single fluvial basin (www.adbve.it).

5.3.1 The River Brenta

The River Brenta rises from Lake Caldonazzo (449 m a.s.l.) and Lake Levico (440 m a.s.l.) in the province of Trento. The two branches, Brenta and Brentella, join together after a short stretch, at 434 m a.s.l., and from here on the Brenta flows through the Valsugana, a glacial valley, with a constant rate flow and limited slope (Provincia Autonoma di Trento, 2001). The whole catchment covers an area of about 1500 Km^2, belonging to five different provinces (Trento, Belluno, Vicenza, Padua and Venice). The biggest surface, about 900 Km^2, is located in the province of Vicenza (ARPAV, 2005).
The main tributaries of the Brenta are the Ceggio, the Maso, the Chieppena, the Grigno and the Cismon, which is the biggest one. All of them have torrential characters, with impetuous water flow, owing to the high slope of their path, and flow into the river in the first part of their course, within or at the border of the Province of Trento.
The geology of the basin is characterized by carbonate rocks on the orographic right and in the eastern part on the left and by igneous and metamorphic crystalline rocks on the left (western part). Because of this fact the alluvial and glacial deposits covering vast surfaces of the basin have a mixed composition.
The climate of the area is temperate-cold, characterized by a pluviometric regime between 1000 and 1500 mm per year, with a main peak in spring (May-June) and a secondary peak in autumn (October-November), having high precipitations in the period between the two peaks as well. The absolute minimum occurs in winter.
The most important settlements are Levico, Borgo Valsugana, and Grigno directly on the Brenta, Telve on the Ceggio, Pieve Tesino and Castello Tesino on the Grigno, Fiera

di Primiero, Imer and Canal San Bovo on the Cismon (Provincia Autonoma di Trento, 2001).
According to the 2008 data, in the area afferent to the upper course of the River Brenta, excluding the district gravitating on the Cismon sub-basin, there are about 44.000 inhabitants and 2.000.000 tourist units, of which 1.500.000 in summer (www.statistica.provincia.tn.it).
In the area that we are considering the waste waters are treated by 2 main plants and other 3 smaller plants localized as follows (www.sois.provincia.tn.it):

- Levico, treating about 50.000 equivalent inhabitants, with a potentiality of 100.000 and discharging directly into the River Brenta;
- Villa Agnedo, receiving waste waters of about 20.000 equivalent inhabitants and with a potentiality of 30.000, discharging in the industrial ditch of Scurelle, an artificial by-pass of the Maso;
- Grigno, with 1.500 e.i. and a potentiality of 3.000, discharging directly in the Brenta;
- Castello Tesino, treating about 1.500 e.i., with a capability of 7.500, discharging in the Grigno;
- Pieve Tesino, treating about 1000 e.i., with a capability of 4.500, discharging in the Rio Solcena, a small tributary of the Grigno.

Along the waterway and its tributaries there are a number of water withdrawals for irrigation, farming, fish-farming and hydroelectric energy production, the most important of them (hydroelectric) with restitution of water downstream after use (www.suap.provincia.tn.it).
The land use along the river in the valley bottom is essentially agricultural, with cultivation of maize, apples, strawberries and blueberries. Moreover there are some industrial settlements, one of them using the Scurelle industrial ditch as source and receiver of processing waters, all the other discharging in the sewage system. The right side of the valley, which is very steep, is mostly covered with woods. On the left side, having a slighter slope, there are some villages, some blackberry fields and vineyards, and many uncultivated areas.

5.3.1.1 The River Brenta in Levico

One sampling station is localized on the River Brenta, downstream the Levico treatment plant. Here the river is still a little stream, because it is very near to the lakes from which it flows out and receives no important tributaries.
As for the morphology, the water course is deeply impacted, being straightened and embanked, with consequences on water flow which is accelerated. In addition the riparian vegetation lacks totally, the river being thus not shaded, and the surrounding area is intensively exploited for maize cultures (see **App 11.3**).

5.3.1.2 The River Brenta in Borgo Valsugana

Another sampling site on the Brenta is located in Borgo Valsugana, a small town the river flows through, after having received a certain amount of water from some minor tributaries. Here the water course is approximately 20 km distant from its origin and therefore is wider and with greater discharge than in Levico.
The river has artificial weirs and artificial track, but the trees and bushes that grow on the banks (some of them being riparian species) provide partially shaded conditions and a source of organic debris.
The land use around the Brenta consists of urbanized areas (see **App 11.3**).

5.3.1.3 The River Brenta in Villa Agnedo

The sampling point on the Brenta in Villa Agnedo is downstream the inflow of some important tributaries and has therefore a considerable discharge and quite high flow speed. One of the tributaries is the industrial ditch of Scurelle that receives the outflow of the waste water treatment plant and also undergoes industrial pollution (Provincia Autonoma di Trento, 2001).
The morphology of the river is more natural than the previous stretch. The banks are in fact not artificial, with the exception of a stretch of riverbank stabilization works on the right. In spite of this the left bank has no riparian vegetation and the shading is limited on the other side as well because of the water course width and the presence of a path between the trees and the river.
As for the land use, on the right side it is partly cultivated and partly covered with trees, on the left there are meadows, cultivations, a deposit of inert materials and some little villages on the slope (see **App 11.3**).

5.3.1.4 The River Brenta in Grigno

The fourth Brenta sampling site is in the area of Grigno, downstream the inflow of an important tributary (the Grigno, which receives also the inflow of the local waste water treatment plant). The river is thus wider, with big flow rate and fast running waters.
The environment is quite natural, especially on the right. On the left bank instead there is a wall of concrete and stones, but since the river bed is wide this stabilization work is rather far from the water. Nonetheless it has the negative consequence of impeding a proper riparian vegetation development.
On the right side there are woods, few cultivations and an inert material deposit. On the left side the land is more impacted, owing to the village of Grigno and a little industrial area (see **App 11.3**).

5.3.1.5 The Rio Vena

The Rio Vena is a small water course flowing through a marshy area on the right side of the Brenta near Levico. The wetland is characterized by a series of perennial springs, fed by groundwater coming from the mountains above and welling up where there are alluvial soils.
The little stream was partially straightened, but it has now well developed riparian vegetation, since it flows inside a protected area (www.areeprotette.provincia.tn.it).
Nonetheless there are human impacts coming from the intensive agricultural use of the surrounding areas (see **App 11.3**).

5.3.1.6 The Ceggio

The Ceggio is a mountain stream originating from the Lagorai chain, in the area of Sette Laghi, at 2056 m a.s.l. and flowing into the Brenta near Borgo Valsugana, at about 350 m a.s.l. (www.gis.provincia.tn.it). The Ceggio basin has an area of approximately 35 Km^2 and is essentially constituted of acid rocks (Servizio Geologico PAT, 1999).
Some kilometres upstream the sampling station there is a consistent withdrawal for a hydroelectric plant, so that the torrent, at our sampling station in Telve, has low discharge, with frequent fluctuations.
The stream is highly impacted from a series of concrete dams, some metres high, which give the stream an artificial step structure, slowing down the water force and avoiding the transport of coarse materials. As a consequence there is a change in the sediment composition which is finer. Moreover there is a fish culture outflow, upstream the sampling site (see **App 11.3**).

5.3.1.7 The Moggio

The Moggio is a mountain stream arising at the foot of Cima Vezzena, on the right side of the Brenta, at 954 m a.s.l., flowing for 15 km through a calcareous little valley, with a basin surface of nearly 42 Km^2. It flows into the Brenta in Borgo Valsugana (www.gis.provincia.tn.it).
The sampling site is located in a river reach with natural morphology and without significant human impacts. The stream bed is here composed of big rocks, boulders and coarse gravel and the surrounding area is covered with woods (see **App 11.3**).

5.3.1.8 The Rosta Fredda

The Rosta Fredda is an artificial little channel, receiving the water diverted from the Brenta about 2 km upstream from Borgo Valsugana and flowing again into the river at the west border of the town, after 3 km. On the right side the area the ditch flows through is characterized by fields and meadows in the first part and by an industrial area

with a steelworks in the last reach. On the left bank there is an important and busy road, right next to the channel. Therefore on both sides there is actually no riparian vegetation.
The Rosta Fredda receives, upstream of our sampling site, the discharge of a fish-farming (see **App 11.3**).

5.3.1.9 The Fosso Selva

It is one of the numerous little brooks that form a water net arising from groundwater springs, connected to the carsic complex of Bigonda and Calgeron, on the right side of the Brenta. The groundwater comes from the drainage of the plateau above the area. The Fosso Selva flows first through cultivated surfaces and then through a riparian wood, in a protected wetland, where our sampling site is located. The second part of the brook is therefore nearly unimpacted (www.areeprotette.provincia.tn.it) (see **App 11.3**).

5.3.1.10 The Resenzuola

The Resenzuola is a little stream collecting the waters coming from a spring fed by groundwater, located in the carsic area at the foot of the Tesino plateau, on the Brenta left side. The groundwater, feeding the perennial spring, comes from drainage of the plateau and has quite a great amount of water. The Resenzuola, which is partially channelled, flows through a protected wetland, covered with meadows, riparian trees and reeds (www.areeprotette.provincia.tn.it).
The sampling site is located at the downstream border of the protected area, next to some little fields and a small number of houses und undergoes a little impact, due to agriculture (see **App 11.3**).

5.3.2 The River Bacchiglione

The River Bacchiglione represents a complex river system receiving both the waters of streams and brooks originating from groundwater springs, and those of mountains streams. The Bacchiglione originates in Dueville (in the province of Vicenza) where the Bacchiglioncello, that collects the upwelling waters in the area of Novoledo, joins to the Torrente Timonchio, the Torrente Igna and the Roggia Verlata. Once it flows into the plain, the groundwater deriving from the drainage of the Asiago plateau comes to the surface, because it penetrates through the alluvial deposits.
The basin of the Bacchiglione covers an area of about 1300 Km^2. Its main tributaries are the Torrente Orolo, the Astichello, the Retrone, the Tesina and numerous other little lateral ditches and canals.
At Longare, after the inflow of the Tesina, the Bacchiglione gives part of its water to the Bisatto irrigation ditch, flowing then into the province of Padua.

The main impacts on the river are due to the tribute of the rills that drain the intensively agricultural land or receive civil and farming discharges (ARPAV, 2005).

5.3.2.1 The River Bacchiglione in Caldogno

The first sampling point on the Bacchiglione is located in Cresole (Caldogno) some km downstream the source, before it flows through the city of Vicenza. The river is here shallow with a quite high current velocity, but with limited turbulence.
There are embankments on both sides, higher and steeper on the right than on the left. The artificial banks do not allow the presence of riparian vegetation and therefore the river is in the sun during the whole day.
The river flows through an agricultural landscape, with maize cultivations, fallow meadows, together with many little villages (see **App 11.3**).

5.3.2.2 The River Bacchiglione at Ponte Marchese (Cresole)

The second sampling point is situated some km downstream the first site and is very similar to it. The flow speed is slower and laminar, both banks are provided with concrete walls and there is no riparian vegetation. The river bed is a little bit narrower than in Caldogno and the sediment is finer.
The land use is once again agricultural with diffused urbanization and the impacts are therefore similar to the first sampling point. The straightening of the waterway is here more severe (see **App 11.3**).

5.3.2.3 The Tesina

The River Tesina, together with the Astico, a mountain stream arising in Trentino which it joins to, represents one of the main sub-basins of the Bacchiglione. It originates from the groundwater plain springs in the area of Sandrigo and along its course receives numerous tributaries, both mountain streams and spring rills, often bearing low quality waters, because of waste water discharges coming from civil and farming settlements.
The Tesina flows into the Bacchiglione in S. Pietro Intrigogna (Longare), after the inflow of the Astico and downstream the city of Vicenza.
The geology of the basin is essentially calcareous in the highest part (Astico) and dominated by alluvial deposits in the plain area (ARPAV, 2005).

The River Tesina in Lupia (Sandrigo)

The Tesina in Lupia is a slow and moderately deep water course, embanked on both sides, the only vegetation on the banks being some isolated trees. The sampling site is quite near to the origin and is located upstream the Astico inflow. The sediment consists essentially of sand and mud.

The land use in the surrounding area is agricultural with very sparse urbanization (see **App 11.3**).

The River Tesina in Bolzano Vicentino

The second sampling site on the Tesina is located in Bolzano Vicentino, downstream the inflow of the Astico. The river is here wide and slow, not very deep, with coarser sediment than at the first station. It is straightened and has dikes on both sides. Nevertheless there are narrow strips of riparian and not riparian arboreal vegetation on the banks, providing a certain degree of shade on the river bed.
The land use is agricultural, with diffused urbanization (see **App 11.3**).

5.3.2.4 The Ghebbo

The Ghebbo is a tributary of the Tesina. Our sampling site is located in Ancignano (Sandrigo), not very far from the inflow into the Tesina. The stream is shallow, narrow and with quite fast but laminar flow. The water course is straightened and embanked and there grow non riparian tree species on both banks.
The Ghebbo flows here through a little village and the surrounding area consists of fallow meadows and diffused urbanization (see **App 11.3**).

5.3.2.5 The Ceresone

The Ceresone sub-basin consists of both spring and drainage water courses, flowing through the land between the Tesina and the Brenta. The river flows into the Bacchiglione in the province of Padua and our sampling site is located at the border of the province of Vicenza.
The water quality of the Ceresone is not bad, even if it receives civil and farming discharges (ARPAV, 2005).
The Ceresone is embanked and straightened, without riparian vegetation. It has very fine sediment and nearly standing waters (see **App 11.3**).

5.3.2.6 The Roggia Moneghina

The Roggia Moneghina is a tributary of the Ceresone, arising from a groundwater spring in the plain. The water quality is good in the first part of its course and gets worse and worse as it flows through the agricultural land (ARPAV, 2005).
The sampling site at Prigioni (Quinto Vicentino) has natural banks with tree riparian vegetation shading the stream. Nonetheless the waterway has an artificial path, being

straightened. The water flow is slow and the sediment fine. The surrounding area consists of maize fields (see **App 11.3**).

5.3.2.7 The Canale Debba

The Canale Debba is an outflow of the Lake Fimon, located among the hills (Colli Iberici). It joins the Canale Ferrara that after a stretch is also fed by the Bacchiglione water, assuming the name of Canale Bisatto and flows then through the province of Padua. The water quality of the Debba is moderately altered (ARPAV, 2005).
Our sampling site is located very near the Lake Fimon, where the Debba is still quite natural, with the exception of the riparian vegetation, which is present only on the left, consisting of some bushes. The waterway path is not yet as straight as it becomes downstream. The sediment is very fine and the water is nearly standing. The land consists of fields and there is actually no urbanization (see **App 11.3**).

5.3.2.8 The Canale Ferrara

The Canale Ferrara is a very slow narrow channel, straight and embanked, with no riparian vegetation, flowing through maize cultivations. It belongs to the Bisatto system like the Debba that joins it. The sediment is extremely fine.
The sampling site is localized near Arcugnano and the surrounding area has a certain degree of urbanization (see **App 11.3**).

5.3.3 The Fratta – Gorzone basin

The Fratta-Gorzone basin is a complex hydraulic system laying in four different districts (Vicenza, Verona, Padua and Venice) and belonging to the Brenta-Bacchiglione basin (ARPAV, 2009). It originates from the joining of two main branches, one arising from the Little Dolomites of Recoaro and the other receiving the waters welling up in the plain (ARPAV, 2005).

5.3.3.1 The Fiumicello Brendola

The Fiumicello Brendola arises at the foot of the Colli Berici, collecting the drainage and spring waters of numerous little ditches. It flows through areas with dense urbanization and high human impacts, owing to the presence of industrial plants and intensively cultivated surfaces. Along its course it receives a number of civil, industrial and farming discharges (ARPAV, 2005).
The sampling site is located in Sarego, where the Fiumicello Brendola is embanked and straightened, without effective riparian vegetation, with a slow flow and gravel substrate. There are maize fields on the right side and an important road and a village on the left (see **App 11.3**).

6 MATERIALS AND METHODS

6.1 SELECTION OF SAMPLING SITES

The sampling points were chosen inside the interest area (Trentino) according to three different criteria:

- choosing sites with macrophyte presence;
- including as many river types as possible;
- availability of chemical data.

On the basis of the first criteria we selected a certain number of sites in Trentino, but in order to fulfil the second criteria we later extended the study area to ten points in Veneto, to include more running waters of the plain area.

As for the third requirement, it was not always possible to choose sites where the chemical data were available. Therefore some additional analyses were conducted on those sites which were considered to be interesting, owing to their macrophyte vegetation, but were not included in the monitoring program of APPA Trento and ARPAV Vicenza.

The water courses are distributed on a wide range, according to the river and site features, on a macro and meso-scale. The most important characters to be considered are the basin area, the altitude of the site, the land use in the surrounding area, the human impacts, the morphology, the riparian vegetation, the flow velocity and kind of flow, the substratum type.

The result was the selection of the 54 sampling sites on the 38 water courses previously illustrated.

6.2 SITE MAPPING

6.2.1 Timing of surveys

The macrophyte assessment was conducted during the main vegetation period, as prescribed by all macrophyte sampling protocols (AFNOR, 2003; Meilinger et al., 2005; Newman et al., 1997; Schneider & Melzer, 2003; UNI EN, 2004). In the surveyed area (North-East of Italy) this means that the aquatic vegetation has to be assessed from late spring until early autumn, provided there are favourable season conditions.

Most of the sites were mapped during summer 2007 and 2008, because the months from June to August are those of minimum discharge, for the water courses with nival-pluvial flow regime. It is in fact extremely important to map the macrophytes with low flow conditions and after several days of low flow, in order to allow the wading of the water course and to have the highest water transparency (AFNOR, 2003). This second feature is important to conduct the survey in the best way, since there are many little plants that could be overlooked, if there is a poor visibility through water.

To our study area belong also some water courses that are fed by glaciers and are therefore in spate or high flow during the summer. These water courses, e.g. the Sarca, do not have natural flow conditions anymore, since their water abundance is exploited for hydroelectric energy production. Therefore these sites have frequent and increased flow fluctuations and they were surveyed as well during the summer, in low flow periods.
Some rivers had to be mapped during the month of October, for technical reasons due to their high discharge. Nevertheless the macrophyte vegetation was still well developed, due to a mild season with favourable climate conditions.
All the sites were surveyed once, with a little number of sites (8) being mapped twice during two or three years, in order to see the variability of the macrophyte vegetation in the medium-long time (one or two years).

6.2.2 Macrophyte mapping

The macrophytes were mapped on a reach about 50 m long. We chose this length, given its wide use in the literature and in our previous studies (Ali et al., 1999; Fabris et al., 2009; Flynn et al., 2002; Haury et al., 1996; Schneider & Melzer, 2003; Spink & Rogers, 1996). The length of the stretch was increased up to 100 m, which is another most used standard length (Baattrup-Pedersen et al., 2006; Clarke & Wharton, 2001; Schaumburg et al., 2004), in case of wide rivers (Newman et al., 1997), having at the sampling site an average width more than 40 m.
The mapped surface was only that covered with water. The water level was the border to discriminate which species had to be taken into account and which not (AFNOR, 2003; Schneider & Melzer, 2003). Therefore we registered all species that had at least the roots in the water, provided that the water level had not recently increased, because of high flow or spate events.
The vegetation was mapped by wading the water course, from a bank to the other, in a zigzag manner, going from downstream to upstream, in order to have a better visibility and to avoid making the water turbid (Newman et al., 1997; UNI EN, 2004).
In large and deep water courses, e.g. the Adige, where it was not possible to cross the river and the water course features are such that no vegetation grows in the middle of the river bed, the macrophyte survey was undertaken from the banks (Newman et al., 1997).
In small water courses too deep to walk through, e.g. Fossa di Caldaro, the macrophyte mapping was conducted from both banks, with the help of a rake (AFNOR, 2003; Newman et al., 1997).
All submerged, floating-leaved and helophyte species were recorded, including bryophytes, charophytes and filamentous green-algae (Haury et al., 2006; Newman et al., 1997). For each species the total abundance was noted down on a field data sheet (see **App 11.1**), together with the abundance of the submerged and emergent form, in

case the taxon occurred in both growth forms (Fabris et al., 2009). Moreover the percent total macrophyte coverage and coverage of algae alone was estimated at each sampling station.

The abundance of the single species was assessed according to a five-degree scale, as follows (Kohler, 1978; Melzer, 1992):

- 1 = very rare;
- 2 = infrequent;
- 3 = common;
- 4 = frequent;
- 5 = abundant, predominant.

Many authors (Baattrup-Pedersen et al., 2006; Brabec & Szoszkiewicz, 2006; Haury et al., 2006; Staniszewski et al., 2006) conduct the macrophyte survey recording the percent cover of every species, as indicated in the British method MTR (Newman et al., 1997) and in the French IBMR and GIS (AFNOR, 2003; Haury et al., 1996). We decided, instead, to follow the Kohler's estimation method based on a half-quantitative scale (Kohler, 1978), more diffused in the German area (Meilinger et al., 2005; Melzer, 1988; Schneider et al., 2001), but used also by non-German authors (Holmes & Whitton, 1977 a); Holmes & Whitton, 1977 b)). Our decision is essentially based on two main reasons. The first one is that when estimating the percent abundance, the percentages are then however converted to a five (AFNOR, 2003) or ten degree scale (Newman et al., 1997) for the calculation of indexes or statistical treatment.

The second and most important reason is that the estimation through percentages, when made in a visual manner, seems to be very variable from one to another, much more than the assessment according to a degree scale.

A sample was taken of all those species that could not be identified with certainty during the field survey.

The successive determination[4] of unidentified species in the laboratory was done through the use of a stereoscope for vascular plants and a microscope for algae and mosses. For the identification we referred to the following taxonomic key and books:

- Bourrelly P., *Les algues d'eau douce,* 1966, Éditions N. Boubée & Cie.
- Streble H., Krauter D., *Atlante dei microorganismi acquatici: la vita in una goccia d'acqua,* (1984) 1992, Franco Muzzio & c. Editore.
- Krause W., (1997) *Süsserwasserflora von Mitteleuropa. Charales (Charophyceae),* 1997, Gustav Fischer Verlag, vol. 18.
- Smith A. J. E., *The Moss Flora of Britain and Ireland,* (1978) 2001, Cambridge University Press.
- Adam G., *Bestimmungschlüssel für Wassermoose im nichtfruchtendem Zustand,* 1989, Wasserwirtschaftsamt Weiden.

[4] The plants were all directly determined by the writer of this thesis. Dr. Filippo Prosser, from the Museo Civico di Rovereto, gave us his expert advice for the dubious cases.

- Casper S. J., Krausch H.-D., *Süsserwasserflora von Mitteleuropa. Pteridophyta und Antophyta: 1. Lycopodiaceae bis Orchidaceae,* 1980, Gustav Fischer Verlag, vol. 23.
- Casper S. J., Krausch H. D., *Süsserwasserflora von Mitteleuropa. Pteridophyta und Antophyta: 2. Saussueraceae bis Asteraceae,* 1980, Gustav Fischer Verlag, vol. 24.
- Pignatti S., *Flora d'Italia,* 1982, Edagricole.
- Dallafior G., *La nostra flora,* 1974, Casa Editrice G. B. Monauni.

All the plants were identified to species level, with the exception of filamentous algae that were identified to genus level, as indicated by some authors (Haury et al., 1996; Newbold & Holmes, 1987), owing to the extreme difficulty of determining the species for people who are not filamentous algae specialists.

6.2.3 Site feature assessment

At every site it was not only the macrophyte community to be assessed, but also many other site characteristics, since we want to relate aquatic vegetation and site features (Johnson et al., 2006; O'Hare et al., 2006; Meilinger et al., 2005; Scott et al., 2002).

The data were collected mainly in a half-quantitative way, in order to have the same data type as that concerning the macrophyte abundance. We created therefore a field data sheet (see **App 11.1**), synthesizing and adapting to our needs two different kinds of data sheet (LfU, 2005; Minciardi et al., 2003).

For every sampling site we recorded the average width of the river stretch, the length of the assessed reach and the altitude of the site.

The average river depth (D) was reported using a three level scale (LfU, 2005; Meilinger, 2003):

- $0 < D \leq 30$ cm;
- $30 < D \leq 100$ cm;
- $D > 100$ cm.

As for the water flow velocity, given its importance in determining the presence and structure of the macrophyte community, it was recorded on the basis of a quite detailed scale, as follows (Minciardi et al., 2003; Meilinger et al., 2003):

- 1 = undetectable or very slow water flow (<0.03 m/s)
- 2 = slow flow (0.03 – 0.1 m/s)
- 3 = medium and laminar flow (0.1-0.3 m/s)
- 4 = medium flow velocity with some turbulence (0.1-0.3 m/s)
- 5 = medium and turbulent flow velocity (0.1-0.3 m/s)
- 6 = high and nearly laminar flow (0.1 – 1 m/s)
- 7 = high and turbulent water flow (0.1 – 1 m/s)
- 8 = very high and turbulent water flow (> 1 m/s)

Another important factor surveyed according to a five level scale is the degree of shading of the sampling station (Fabris et al., 2009; LfU, 2005; Meilinger, 2003):

- 1 = fully sunny (in the sun from dawn till sunset);
- 2 = sunny (in the sun for most of the day and all the time during the central hours of the day);
- 3 = partially sunny (predominantly in the sun, but shaded during the central hours of the day);
- 4 = partially shaded (predominantly shaded and always shaded during the central hours of the day);
- 5 = totally shaded (shaded all day long, under trees).

As for the substrate, we noted the approximate percentage distribution in the following dimensional classes (Scott et al., 2002):

- bedrock;
- boulders;
- cobbles;
- gravel;
- sand;
- silt / clay.

We recorded also the presence of artificial elements in the morphology of the river reach, e.g. banks, weirs, dams, as well as the composition and structure of the riparian vegetation on both sides and the land use on the right and on the left of the river.

6.3 WATER CHEMISTRY

Most of the sampling points are located in coincidence of APPA and ARPAV monitoring sites. Therefore a series of water chemical data are available. Unfortunately the analysed parameters and the frequency of sampling are very variable for the different water courses. The water courses belonging to APPA and ARPAV Vicenza monitoring network are reported in **Tab 6.1**, together with the code for each point and the frequency of analysis.

On ten sites (see **Tab 6.1**) in Trentino no chemical data were available. These points were sampled monthly in the year 2007, from May to September, for a total number of 5 samples. The sampling time was established in order to have data referring to the main vegetation period. On these river stretches the following parameters were analysed, according to the official APAT-IRSA-CNR methods (IRSA, 2003): conductivity, pH, hardness as carbonate and bicarbonate, BOD_5, nitrite, nitrate, total nitrogen, ortophosphate and total phosphorus. The COD and the ammonia nitrogen were analysed through the DR. LANGE kits, respectively LCK 414 and LCK 304. Water temperature and dissolved oxygen were measured in the field through a WTW oxymeter. The analyses of APPA Trento and the analyses of ARPAV Vicenza follow the official APAT-IRSA-CNR methods (IRSA, 2003).

Through the chemical analyses of water we characterized the chemical and trophic state of our sampling stations. The sediment nutrient analyses instead were not possible because of technical reason. We tried to execute some nutrient analyses on 4 sediment samples collected on Fosso Selva, Resenzuola (2) and Rosta Fredda according to the method used in the APPA laboratories for lake sediments, but they did not give satisfying results. Therefore we do not have data for nutrients in sediment that would have been important, since rooted plants seem to take up nutrients from sediment (Barko et al., 1991; Chambers et al., 1989; Xie et al., 2005). Anyway it must be considered that studies at the patch scale have generally not revealed significant differences of sediment nutrient chemistry between species (Clarke & Wharton, 2001) and that nutrient uptake from the sediment by rooted macrophytes seems to depend on water column nutrient concentrations (Robach et al., 1995; Pelton et al., 1998). Moreover sediment physico-chemistry is partially related to sediment physical types (Chambers and Prepas, 1994) and sediment bio-available phosphorus is partially related to phosphorus in the water column ($r^2 = 0.44$ in Demars and Harper, 2002; $r^2 = 0.64$ in Demars and Harper, 2005 b)).

Finally we have to point out that macrophytes have the effect of both increasing the nutrient concentrations in sediment by enhancing fine particles deposition (Sand-Jensen, 1998; Schulz et al, 2003), and depleting the nutrient sediment pools through uptake (Barko et al., 1991), making it difficult to understand the cause-effect relationships between aquatic plant community structure and sediment nutrient content (Clarke & Wharton, 2001). For all these considerations, the importance of the lack of sediment nutrient data is highly reduced (Demars & Edwards, 2009).

6.4 RAW DATA TREATMENT

The species abundance data were put into a site-species array with species names on rows and sites on columns (**App 11.2**). Another matrix was filled in with the raw site features data, reporting sites on rows and features on columns (**App 11.3**). Afterward we classified those site characters that were not coded in a half-quantitative manner. The considered variables were transformed as follows:

1. Average width (W) classes:
   - 1 = W ≤10 m
   - 2 = 10 m < W ≤ 40 m
   - 3 = W > 40 m
2. Substrate classes:
   - if mud ≥ 50% = 1 (muddy substrate)
   - if sand ≥ 50% = 2 (sandy substrate)
   - if gravel + sand ≥ 60% and sand <50 = 3 (gravelly – sandy substrate)

CODE	WATERCOURSE	SITE	MONITORING NETWORK	SAMPLING FREQUENCY
PR000004	Fiume Adige	Villa Lagarina	APPA Trento	monthly
PR000005	Fiume Adige	Mori	APPA Trento	monthly
PR000017	Torrente Leno	Rovereto	APPA Trento	monthly
PR000027	Fiume Sarca	Calavino	APPA Trento	monthly
SG000001	Fiume Adige	San Michele a. A.	APPA Trento	monthly
SG000002	Fiume Adige	Trento	APPA Trento	monthly
SG000006	Fiume Adige	Avio	APPA Trento	monthly
SG000011	Torrente Noce	Mezzolombardo	APPA Trento	monthly
SG000019	Fiume Brenta	Levico Terme	APPA Trento	monthly
SG000020	Fiume Brenta	Borgo Valsugana	APPA Trento	monthly
SG000021	Fiume Brenta	Grigno	APPA Trento	monthly
SG000023	Fiume Sarca	Ragoli	APPA Trento	monthly
SG000025	Fiume Chiese	Storo	APPA Trento	monthly
SD000101	Fossa di Cornedo	Salorno	APPA Trento	2-4 times a year
SD000109	Rio Lavisotto	Trento	APPA Trento	2-4 times a year
SD000116	Rio S. Zeno	Aldeno	APPA Trento	2-4 times a year
SD000132	Fossa di Caldaro	Roverè d. Luna	APPA Trento	2-4 times a year
SD000302	Torrente Arnò	Tione	APPA Trento	2-4 times a year
SD000304	Torrente Duina	Ponte Arche	APPA Trento	2-4 times a year
SD000317	Rio Salona	Arco	APPA Trento	2-4 times a year
SD000318	Fiume Sarca	Ponte Arche	APPA Trento	2-4 times a year
SD000401	Fiume Chiese	Pieve di Bono	APPA Trento	2-4 times a year
SD000403	Torrente Adanà	Pieve di Bono	APPA Trento	2-4 times a year
SD000403_bis	Torrente Adanà	Pieve di Bono	APPA Trento	
SD000405	Torrente Palvico	Storo	APPA Trento	2-4 times a year
SD000409	Torrente Lora	Storo	APPA Trento	2-4 times a year
SD000410	Fiume Chiese	Pieve di Bono	APPA Trento	2-4 times a year
SD000503	Torrente Rabbies	Terzolas	APPA Trento	2-4 times a year
SD000516	Rio Lovernatico	Crescino	APPA Trento	2-4 times a year
SD000518	Rio Sporeggio	Crescino	APPA Trento	2-4 times a year
SD000703	Rio Salè	Trento	APPA Trento	2-4 times a year
SD000905	Roggia di Calavino	Calavino	APPA Trento	2-4 times a year
SD000910	Torrente Ponale	Riva del Garda	APPA Trento	2-4 times a year
VP000026	Torrente Meledrio	Dimaro	APPA Trento	2-4 times a year
NM1	Fosso di Selva	Fontanazzo - Selva	Not monitored	
NM2	Rio Resenzuola	Serafini	Not monitored	
NM3	Fiume Brenta	Villa Agnedo	Not monitored	
NM4	Torrente Ceggio	Telve	Not monitored	
NM5	Torrente Moggio	Val di Sella	Not monitored	
NM6	Rosta Fredda	Borgo Valsugana	Not monitored	
NM7	La Vena	Inghiaie - Levico	Not monitored	
NM8	Fiume Sarca	Dro	Not monitored	
NM9	Rio Rimone	Dro	Not monitored	
NM10	Torrente Noce	Crescino	Not monitored	
47	Fiume Bacchiglione	Caldogno	ARPAV Vicenza	6-12 times a year
47_bis	Fiume Bacchiglione	Ponte Marchese	ARPAV Vicenza	
48	Fiume Tesina	Bolzano Vicentino	ARPAV Vicenza	6-12 times a year
48_bis	Fiume Tesina	Lupia di Sandrigo	ARPAV Vicenza	
103	Canale Debba	Arcugnano	ARPAV Vicenza	4 times a year
107	Torrente Ceresone	Camisano Vicentino	ARPAV Vicenza	4 times a year
162	Fiumicello Brendola	Lonigo	ARPAV Vicenza	6 times a year
461	Torrente Ghebbo	Sandrigo	ARPAV Vicenza	2 times a year
462	Canale Ferrara	Arcugnano	ARPAV Vicenza	2 times a year
463	Roggia Moneghina	Bolzano Vicentino	ARPAV Vicenza	2 times a year

Table 6.1: Sampling points with code, name of the watercourse, name of the site, monitoring network every point belongs to and frequency of monitoring.

- if cobbles < 50% and cobbles + gravel ≥ 60% = 4 (cobbley - gravelly substrate)
- if cobbles ≥ 50% = 5 (cobbley substrate)
- if boulders ≥ 50% or cobbles < 50% and cobbles + boulders ≥ 60% = 6 (substrate consisting of boulders and cobbles)

3. Altitude (A) classes:
   - 1 = A ≤100 m a.s.l.
   - 2 = 100 < A ≤ 300 m a.s.l.
   - 3 = 300 < A ≤ 500 m a.s.l.
   - 4 = 500 < A ≤ 800 m a.s.l.
   - 5 = A > 800 m a.s.l.
4. Water course artificialization classes:
   - 1 = completely natural
   - 2 = partially natural, there is one modified element (e.g. one of the banks)
   - 3 = partially modified, both the banks are modified
   - 4 = modified watercourse, with two modified banks and weirs, or straightened channel, or at least one concrete dyke
   - 5 = heavily modified, both banks are made of concrete or there are high weirs across the river bed
   - 6 = totally artificialized water course, flowing into a concrete bed, tunnel or hanging bed
5. Land use classes (distinct for the left and right side of the river):
   - 1 = big towns or cities, industrial zones, motorways
   - 2 = little towns, villages, roads, fish-farming
   - 3 = agricultural areas, together or not with scattered houses, woods and roads
   - 4 = meadows, partially modified water courses
   - 5 = woods and forests, wetlands
6. Macrophyte total coverage (TC) classes:
   - TC < 5% = 1
   - 5 ≤ TC < 25% = 2
   - 25% ≤ TC < 50% = 3
   - 50 ≤ TC < 75% = 4
   - TC ≥ 75% = 5
7. Algae coverage (AC) classes:
   - AC < 5% = 1
   - 5 ≤ AC < 25% = 2
   - 25% ≤ AC < 50% = 3
   - 50 ≤ AC < 75% = 4
   - AC ≥ 75% = 5
8. Macrophyte coverage without algae (MC) classes:

- MC < 5% = 1
- 5 ≤ MC < 25% = 2
- 25% ≤ MC < 50% = 3
- 50 ≤ MC < 75% = 4
- MC ≥ 75% = 5

Moreover, we added a further variable, giving information about the dimensions (length and basin area) and the importance of the water courses. This variable, which was derived from the GIS of the Provincia Autonoma di Trento (www.territorio.provincia.tn.it/) was called "Basin order" and is codified in the following manner:

- 1 = very short watercourses without a proper basin area, often fed by groundwater
- 2 = small water courses with very small basin area, with a rank order in the GIS database > 3
- 3 = small water courses, 3 rank order in the GIS database
- 4 = medium water courses, directly flowing into the main ones, 2 rank order
- 5 = main water courses with a 1 rank order basin (national level)

The transformed site features were reported in a third matrix, with sites on rows and features on columns (**Tab 7.4**).

Another matrix was compiled for the chemical parameters (columns) characterizing river sites (rows). For every sampling point we considered the median value of the chemical data from 2004 to 2008.

For what concerns water temperature and dissolved oxygen we did not calculate the median value, because some points were sampled only during the summer and the comparison through the different sites would not have been possible. Therefore we excluded the two parameters from the analysis.

The variables that we selected for statistical analysis were conductivity, hardness, pH, BOD_5, ammoniac nitrogen, nitric nitrogen, ortophosphate and total phosphorus.

We excluded nitrous and total nitrogen, because the most important nitrogen species for aquatic plant growth are ammoniac and nitric nitrogen (Duff & Triska, 2000).

The final matrix that we obtained for water chemistry is showed in **Tab 7.5**[5]

6.5 STATISTICAL DATA TREATMENT

The statistical analyses were performed on three arrays: a sites-by-environmental variables table, a water chemistry table and a sites-by-species table. For some analyses the matrix of the chemical data was combined with that of site features. Some tests were run on abundance data, while others were applied on presence-absence data.

[5] The water temperature and dissolved oxygen saturation values reported in the matrix refers to the sampling date listed in column 2 and were not considered in the statistical analysis. All the other parameters are given as median values.

We analysed both the whole matrix with all recorded taxa and the reduced array, where we considered only the taxa that were present at least at 3 sampling points (Baattrup-Pedersen et al., 2008; Vanderpoorten & Klein, 1999), the number 3 corresponding approximately to the 5% of the surveys (Szoszkiewicz et al., 2006)
We applied two different kinds of matching-two-table analyses (Dray et al., 2007) and then compared the results given by each strategy:

- Procrustean rotation (Gower, 1971; Digby & Kempton, 1987)
- Co-inertia analysis (Dolédec & Chessel, 1994; Dray et al., 2003b)

The first approach consists in a PCA, based on correlations, applied both on site-variable array (included nutrients and artificialization level) and on site-species arrays and afterwards a common projection of the two sets of sites after rotation. Procrustes analysis is a method based on rotation, reflection, translation and dilation of set of points in order to fit it to another fixed set of points (Dray et al., 2003a). Two randomization procedures test the association between two tables: PROTEST (Jackson, 1995) and RV (Heo & Gabriel, 1998). Two procrustean tests were used: one on site-species array and water chemistry table and the other on site-species array and a combined matrix containing site features and water chemistry.
Co-inertia analysis is a general approach that can be applied to any pair of duality diagrams having the same row weights. This method is symmetric and seeks for a common structure between two datasets. We performed the co-inertia analysis using a correspondence analysis on the sites-species table and a PCA on the sites-chemistry table. Then we analyzed the matching between site-species array and environmental variables array (without chemistry) through a co-inertia analysis, using correspondence analysis on both matrixes (Dray et al., 2003; Dray et al., 2007).
All the matching-two-table analyses were performed using the ade4 Package version 1.4-11 (Dray et al., 2007) for R software version 2.9.2
Particular attention was dedicated to divide the sites into groups, corresponding to river types. A first discrimination between soft and hard water streams (Horne & Goldman, 1994) was made based on hardness (Adam et al., 2001; Briggs & Ficke, 1977; Pennak, 1971). We classified as soft all watercourses having median hardness, expressed as calcium carbonate, lower than or even to 100 mg/L and as hard all watercourses having median hardness higher than 100 mg/L (Radojević & Bashkin, 2006).
The surveyed sites were analysed through a PCA based on correlations (Podani, 2007), considering only the morphological and hydrological variables. Factors concerning nutrient levels and anthropogenic modifications on rivers were excluded from the analysis, since we wanted to divide the sites into groups without accounting for human impact. The PCA was run using the Statistica software version 7.1.
The hierarchical UPGMA (Unweighted Pair Group Method using Arithmetic Averages) cluster analysis (Sokal & Michener, 1958; Rohlf, 1963) based on Euclidean distance was applied on the river site table in order to obtain another division into groups (Scardi, 2001; Podani, 2007) and then compare the results.

The correlation between single species abundance and water chemical variables (especially nutrient concentrations) was verified through the Spearman's non-parametric rank-order test (Podani, 2007; Szoszkiewicz et al., 2006; Triest, 2006). The test was run on standardized data. The abundance data, which are semi-quantitative data, were divided by the interval obtained through the difference between the maximum and the minimum value, as follows for a matrix were i indicates the cases (rows) and j the variables (columns) (Podani, 2007):

$$x'_{ij} = \left[x_{ij} - \min_i \{x_{ij}\}\right] / \left[\max_i \{x_{ij}\} - \min_i \{x_{ij}\}\right]$$

x_{ij}' = standardized value on the i-th row and j-th column
x_{ij} = value on the i-th row and j-th column
min_i = minimum value on the i-th column
max_i = maximum value on the i-th column

For what concerns our data, since the minimum value is always 0, the formula is reduced to the following:

$$x'_{ij} = x_{ij} / \max_i \{x_{ij}\}$$

The quantitative chemical variables were, instead, standardized according to the standard deviation to make them comparable, even if they have very different measure units (Podani, 2007). The formula is the following:

$$x'_{ij} = \{x_{ij} - \bar{x}_j\} / s_j$$

where:

$$s_j = \left[\frac{\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2}{n-1} \right]^{\frac{1}{2}}$$

$\bar{x}_j$ = average value of the j-th variable
n = number of variables (number of array columns)

The considered chemical parameters are conductivity, hardness, pH, BOD_5, ammonia nitrogen, nitric nitrogen, ortophosphorus and total phosphorus. For this test the Statistica software version 7.1 was used.

The Wilcoxon rank-sum test (Wilcoxon, 1945; Mann & Whitney, 1947) was run on species presence-absence data to search for correlation between species and chemical parameters, because the results given by the Spearman test seemed to be strongly influenced by the big amount of zeros in the matrix. The Wilcoxon rank-sum test performed on a certain species compares the median value of the selected variable at all sites where the species is absent (codified with 0) with the median value at all sites where the species is present (codified with 1) and gives a p value as output, indicating the significance of the difference. The direction (positive or negative) and the entity of the correlation are given by the difference between the medians at presence sites and absence sites.
The Wilcoxon test was run using the R software version 2.9.2.

6.6 COMMUNITY STRUCTURE METRICS

The similarity among species assemblages of the river sites was tested through the calculation of various similarity indexes, like the Bray-Curtis index (Bray & Curtis, 1957), one of the most used indexes in community studies in ecology (Bloom, 1981; Scardi, 2001; Dray et al., 2003), and the Morisita's similarity index (Krebs, 1988), suggested for the analysis of taxa abundance data distributed on different samples (Hammer et al., 2007; Bloom, 1981). The similarity was analysed on presence-absence data, too, through the application of the Bray-Curtis index and the Raup-Crick index (Raup & Crick, 1979), the latter recommended by Hammer et al. (2007) for the analysis of presence-absence data and using a Monte Carlo randomization procedure.
The similarity indexes, that assign value 1 to identical samples and value 0 to completely different samples, were calculated through the PAST software version 1.73 (Hammer et al., 2007).
The similarity between sites on the basis of their macrophyte community and the tendency of species to form definite assemblages at the surveyed sites were explored through the Cluster Analysis. The complete linkage hierarchical clustering was applied both on sites and on species. Moreover a heat map was constructed combining clustering of sites and of species (Ling, 1973; Wilkinson, 1994).
The clustering of sites was obtained with two different kinds of hierarchical cluster analysis: one based on the complete linkage (Sorensen, 1984; Lance & Williams, 1967) and one based on the average linkage (Sokal & Michener, 1958; Rohlf, 1963). The dendrograms were then compared.
A Monothetic Analysis (MONA) was applied to presence-absence data. The MONA is a divisive hierarchical clustering method which operates on a data matrix with binary variables. Each separation is carried out using a well selected single variable and is the reason why the algorithm is called monothetic (Kaufman & Rousseeuw, 1990). The output is a banner representation, easy to interpret, since it shows a series of binary divisions. Each species divides the sites into two groups, the first one consisting of sites

where the species occurs and the second one comprising the sites where the species is absent. On the basis of the banner we selected some species that divide the sites into groups, according to their occurrence. A further representation of their presence-absence pattern is given, in the form of a heat map, allowing us to detect the clusters of sites (Kaufman & Rousseeuw, 1990; van Deursen & Kuipers, 1997).
The Cluster Analysis, the heat map and the MONA were obtained through the R software version 2.9.2 respectively cluster Package and gplots Package.
For every site we calculated the Shannon-Weaver Diversity Index (Shannon & Weaver, 1949), very frequently used in limnology studies (Baattrup-Pedersen et al., 2006; Szoszkiewicz et al., 2006; Staniszewski et al., 2006), according to the following equation:

$$H_s = -\sum_{i=1}^{s} N_i \cdot \ln N_i$$

H_s = Diversity Index
N_i = quantity of the i-th taxon/ total quantity of all taxa
s = number of taxa of the biocenosis

The relationship between the five-degree scale and the plant quantity is described by the function $y = x^3$, where y is the quantity and x is the value of abundance according to the five-degree scale (Melzer, 1988; Kohler and Janauer, 1995). The term ‘‘plant quantity’’ and its estimation were introduced by Tuexen and Preising (1942) especially for hydro-botanical investigations and include both the extent of cover and the abundance (Melzer, 1992).
On the basis of the H_s index we calculated the Evenness (Pielou, 1966) in order to allow the direct comparison of the macrophyte communities at different sites (Baattrup-Pedersen et al., 2006; Szoszkiewicz et al., 2006). The Evenness is a measure of the dominance structure of species inside the community (Odum, 1971), since the maximum value of 1 is reached when all the species have the same abundance. The index was obtained according to the following formula:

$$E = \frac{H_s}{\ln s}$$

E = Evenness
H_s = Diversity Index according to Shannon-Weaver
s = number of taxa of the biocenosis

Subsequently the correlation between H and E indexes on one side and chemical parameters and environmental site variables on the other side was tested through the Pearson’s coefficient (Pearson, 1896).

The composition of the community was described at each sampling site also through the following metrics (Staniszewski et al., 2006; Szoszkiewicz et al., 2006):

- total number of taxa
- number of bryophyte taxa
- number of filamentous algae taxa
- number of amphiphyte taxa
- number of hydrophyte taxa
- number of helophyte taxa
- total % cover of taxa
- % cover of filamentous algae taxa
- % abundance of bryophyte taxa on the total abundance
- % abundance of filamentous algae on the total abundance
- % abundance of amphiphyte taxa on the total abundance
- % abundance of hydrophyte taxa on the total abundance
- % abundance of helophyte taxa on the total abundance

Afterward we investigated if these features are correlated to the chemical parameters and the site characteristics, by calculating both the Pearson's and the Spearman Rank coefficients (Legendre & Legendre, 1983), considering that some metrics (n° of taxa) are expressed as non continuous variables.

6.7 THE MACROPHYTE INDEXES

The macrophyte method that will be proposed by the Ministry of Environment for the monitoring of Italian watercourses (D.lgs. 56/2009), with respect to the WFD, is the Indice Biologique Macrophytique en Rivière IBMR (AFNOR, 2003).
The IBMR is a trophic index, based on a list of about 200 macrophyte taxa, calculated according to the following equation:

$$IBMR = \sum [E_i \cdot K_i \cdot Cs_i] / \sum E_i \cdot K_i$$

Cs_i = species score indicating the sensitivity of species i to the trophic level, with values ranging from 0 to 20
E_i = stenoecy coefficient
K_i =abundance coefficient

The abundance of species is attributed according to the following table:

K_i VALUE	DESCRIPTION	COVERAGE %
1	very rare species	coverage < 0.1%
2	infrequent species	0.1% ≤ coverage < 1%
3	common species	1% ≤ coverage < 10%
4	frequent species	10% ≤ coverage < 50%
5	abundant, predominant species	coverage ≥ 50 %

Table 6.2: correspondence between percent coverage of each macrophyte species and the abundance coefficient attributed to it for the calculation of the IBMR. The adjective describing the species abundance is referred only to its presence at the sampling station (AFNOR, 2003).

The observed IBMR value at a certain site should therefore be divided by the theoretical maximum reference value for that river type, to calculate the RQE_IBMR, a sort of relative IBMR score. But these reference values have not been established yet (Ann.3, D.lgs. 56/2009).

Since the abundance coefficients correspond exactly to the abundance scale used in the present study, this allowed the calculation of the IBMR values for all our sampling stations. Subsequently we calculated the Pearson's r correlation coefficient (Pearson, 1896) between the IBMR results and the phosphorus and nitrogen values, in order to test the reliability of the method for monitoring purposes.

For this calculation the Statistica software version 7.1 was used.

7 RESULTS

7.1 MACROPHYTE COMMUNITY

Altogether 54 sites were surveyed, 8 of them were mapped twice during two growing seasons, while the other 44 points were mapped once.

During the 62 surveys we recorded 95 different taxa of macrophytes, among which:

- 10 genera of filamentous algae
- 2 species of Characeae
- 10 species of Musci
- 1 species of Equisetaceae
- 33 species of Monocotyledoneae
- 39 species of Dicotyledoneae

CODE	DICOTYLEDONS	BIOLOGICAL TYPE
Api.nod	*Apium nodiflorum* (L.) Lagasca	amp
Bar.vul	*Barbarea vulgaris* R. Br.	occ
Ber.ere	*Berula erecta* (Hudson) Coville	amp
Cal.cop	*Callitriche cophocarpa* Sendter	hyd
Cal.spp	*Callitriche* spp. L.	hyd
Clt.pal	*Caltha palustris* L.	hel
Crd.ama	*Cardamine amara* L.	hel
Cer.dem	*Ceratophyllum demersum* L.	hyd
Epi.spp	*Epilobium* spp. L.	occ/hel
Epi.hir	*Epilobium hirsutum* L.	hel
Fil.ulm	*Filipendula ulmaria* (L.) Maximowicz	occ
Hip.vul	*Hippuris vulgaris* L.	amp
Lud.uru*	*Ludwigia uruguayensis* (Cambessèdes) Hara	hel
Lyc.eur	*Lycopus europaeus* L.	hel
Lyt.sal	*Lythrum salicaria* L.	hel
Men.aqu	*Mentha aquatica* L.	amp
Men.lon	*Mentha longifolia* (L.) Hudson	hel
Men.spi	*Mentha spicata* L. em L.	occ
Mim.gut	*Mimulus guttatus* Fischer ex DeCandolle	hel
Myo.pal	*Myosotis palustris* (L.) Hill	amp
Myn.aqu	*Myosoton aquaticum* (L.) Moench	hel
Myr.spi	*Myriophyllum spicatum* L.	hyd
Myr.ver	*Myriophyllum verticillatum* L.	hyd
Nas.off	*Nasturtium officinale* R. Brown	hel
Nup.lut	*Nuphar lutea* (L.) J. E. Smith in Sibthorp et J. E. Smith	hyd
Pet.alb	*Petasites albus* L. Gaertn.	hel
Pet.hyb	*Petasites hybridus* L. Gaertn.	hel
Pol.hyd	*Polygonum hydropiper* L:	hel
Pol.lap	*Polygonum lapathifolium* L.	hel
Pol.mit	*Polygonum mite* Schrank	hel
Ran.pen	*Ranunculus penicillatus* ssp. *pseudofluitans* (Syme) S.D.Webster	hyd
Ran.pxt	*Ranunculus penicillatus* (Dumortier) Babington x *trichophyllus* Chaix in Villars	hyd

Ran.tri	*Ranunculus trichophyllus* Chaix in Villars	hyd
Rum.cri	*Rumex crispus* L.	occ
Rum.obt	*Rumex obtusifolius* L.	occ
Sta.pal	*Stachys palustris* L.	hel
Utr.aus	*Utricularia australis* R. Brown	hyd
Ver.ana	*Veronica anagallis-aquatica* L.	amp
Ver.bec	*Veronica beccabunga* L.	hel
	MONOCOTYLEDONS	
Agr.sto	*Agrostis stolonifera* L.	amp
Ali.pla	*Alisma plantago-aquatica* L.	amp
Car.acu	*Carex acutiformis* Ehrhart	hel
Car.ros	*Carex rostrata* Stokes ex Withering	hel
Car.spp	*Carex* spp. L.	hel
Des.cae	*Deschampsia caespitosa* (L.) Palisot de Beauvois	amp
Elo.can	*Elodea canadensis* Michaux fil.	hyd
Elo.nut	*Elodea nuttallii* (Planchon) St. John	hyd
Gly.max	*Glyceria maxima* (Hartman) Holemberg	hel
Gly.pli	*Glyceria plicata* Fries	hel
Gro.den	*Groenlandia densa* (L.) Fourreau	hyd
Iri.pse	*Iris pseudacorus* L.	hel
Jun.spp	*Juncus* spp. L.	amp
Lem.min	*Lemna minor* L.	hyd
Lem.tri	*Lemna trisulca* L.	hyd
Pha.aru	*Phalaris arundinacea* L.	hel
Phr.aus	*Phragmites australis* (Cavanilles) Trinius ex Steudel	hel
Poa.pal	*Poa palustris* L.	occ
Pot.ber	*Potamogeton berchtoldii* Fieber in Berchtold et Opiz	hyd
Pot.cri	*Potamogeton crispus* L.	hyd
Pot.luc	*Potamogeton lucens* L.	hyd
Pot.nat	*Potamogeton natans* L.	hyd
Pot.nod	*Potamogeton nodosus* Poiret	hyd
Pot.pec	*Potamogeton pectinatus* L.	hyd
Sag.sag	*Sagittaria sagittifolia* L.	amp
Sch.lac	*Schoenoplectus lacustris* (L.) Palla	amp
Sci.syl	*Scirpus sylvaticus* L.	hel
Spa.eme	*Sparganium emersum* Rehmann	hel
Spa.emf	*Sparganium emersum* fo. f*luitans* Godron et Grenier	hyd
Spa.ere	*Sparganium erectum* L. em. Reichenbach	hel
Spi.pol	*Spirodela polyrhiza* (L.) Schleiden	hyd
Typ.lat	*Typha latifolia* L.	hel
Val.spi	*Vallisneria spiralis* L.	hyd
Zan.pal	*Zannichellia palustris* L.	hyd
	HORSETAILS	
Equ.pal	*Equisetum palustre* L.	hel
	MOSSES	
Amb.ten	*Amblystegium tenax* (Hedw.) C. Jens.	hyd
Amb.rip.	*Amblystegium riparium* (Hedw.) Br. Eur.	hyd
Cin.aqu	*Cinclidotus aquaticus* (Hedw.) Bruch et Schimp.	hyd
Cin.fon	*Cinclidotus fontinaloides* (Hedw.) Beauv.	hyd
Cin.muc	*Cinclidotus mucronatus* (Brid.) Mach.	hyd
Cin.rip	*Cinclidotus riparius* (Web. & Mohr) Arnott	hyd

Crat.com	*Cratoneuron commutatum* (Hedw.) Roth	hyd
Fon.ant	*Fontinalis antipyretica* Hedw.	hyd
Hyg.dil	*Hygrohypnum dilatatum* (Schimp.) Loeske	hyd
Rhy.rip	*Rhynchostegium riparioides* (Hedw.) C. Jens.	hyd
	STONEWORTS	
Cha.glo	*Chara globularis* Thuillier	hyd
Nit.muc	*Nitella mucronata* (A. Braun) Miquel	hyd
	FILAMENTOUS ALGAE	
Cla.spp	*Cladophora* spp. Kützing	hyd
Mic.spp	*Microspora* spp. Thuret	hyd
Oed.spp	*Oedogonium* spp. Link ex Hirn	hyd
Osc.spp	*Oscillatoria* spp. Vaucher ex Gomont	hyd
Pho.spp	*Phormidium* spp. Kützing ex Gomont	hyd
Rhz.spp	*Rhizoclonium* spp. Kützing	hyd
Spy.spp	*Spirogyra* spp. Link	hyd
Tri.spp	*Tribonema* spp. Derbes & Solier	hyd
Ulo.spp	*Ulothrix* spp. Kützing	hyd
Vau.spp	*Vaucheria* spp. A. P. de Candolle	hyd

Table 7.1 Species occurring at sampled sites with nomenclature adopted in the text and codes used for identifying the species. In the third column the biological type of each species is reported: hel =helophyte, amp = amphiphyte, hyd =hydrophyte, occ = terrestrial species occasionally growing in the water.

In **Tab 7.1** the species are distinct according to their biological type: helophytes, hydrophytes and amphiphytes. All the mosses and algae were considered as hydrophytes, since they live completely submerged or, in the case of some filamentous algae, on the surface of water. Altogether we recorded 11 amphiphyte species, 47 hydrophyte taxa and 32 helophyte species (*sensu* Casper & Krausch, 1980 a); Casper & Krausch, 1980 b) for vascular plants).

LEAST DIFFUSED TAXA	**N°OF SITES**
Alisma plantago-aquatica, Apium nodiflorum, Callitriche cophocarpa, Caltha palustris, Cardamine amara, Carex acutiformis, Carex rostrata, Carex spp., Chara globularis, Elodea nuttallii, Filipendula ulmaria, Glyceria maxima, Hippuris vulgaris, Hygrohypnum dilatatum, Juncus spp., Lycopus europaeus, Mentha spicata, Mimulus guttatus, Myosoton aquaticum, Nitella mucronata, Oedogonium spp., Oscillatoria spp., Poa palustris, Potamogeton natans, Rumex cripsus, Rumex obtusifolius, Sagittaria sagittifolia, Schoenoplectus lacustris, Spirodela polyrhiza, Stachys palustris, Utricularia australis, Vallisneria spiralis	1
Barbarea vulgaris, Deschampsia caespitosa, Groenlandia densa, Ludwigia uruguayensis, Nuphar lutea, Petasites albus, Ranunculus penicillatus x trichophyllus, Sparganium emersum, Tribonema spp.	2

Table 7.2 Species occurring only at 1 or 2 sites (in this case we considered the number of sampling points and not the number of surveys).

Many taxa (40) were present only at one or two sites (**Tab 7.2**), and were excluded from the calculation of the correlation coefficients between species and chemical parameters.
The most diffused species, with regard to the number of sites in which they occurred, are represented in the histogram below (**Fig 7.1**).
The number of species recorded for each survey is listed in **Tab 7.3**, while the diagram in **Fig 7.2** shows the sites with the highest specific biodiversity.

site code	name of the site	n° of taxa	site code	name of the site	n° of taxa
AdBo	Adige Borghetto	3	LaVe	La Vena	10
Adgt	Rio Lavisotto-Adigetto	8	Leno	Leno	8
AdMo	Adige Mori	5	Lora	Lora	12
Adnl	Adanà at Pieve di Bono (upstream)	6	Love	Palvico	7
AdnP	Adanà Pieve di Bono (downstream)	6	Mele	Meledrio	3
AdSM	Adige San Michele all'Adige	2	Mogg	Moggio	2
AdTN	Adige Trento	11	Mone	Roggia Moneghina	13
AdVi	Adige Villa Lagarina	5	NoRo	Noce Rocchetta	10
Arnò	Arnò	7	NoRu	Noce Rupe	8
BaPM	Bacchiglione Ponte Marchese	20	Palv	Palvico	7
BaSo	Bacchiglione sorgente	28	Pona	Ponale	5
BrB2	Brenta Borgo Valsugana (2nd survey)	10	Rabb	Rabbies	4
BrBo	Brenta Borgo Valsugana	7	Res2	Resenzuola (2nd survey)	5
BrG2	Brenta Grigno (2nd survey)	9	Rese	Resenzuola	7
BrGr	Brenta Grigno	10	Rimo	Rimone	21
BrLe	Brenta Levico	13	RoFr	Rosta Fredda	9
Brnd	Fiumicello Brendola	17	SaDr	Sarca Dro	14
BrV2	Brenta Villa Agnedo (2nd survey)	8	Salè	Salè	7
BrVi	Brenta Villa Agnedo	8	SaLi	Sarca Limarò	15
Cala	Roggia di Calavino	7	Saln	Salone	11
Cald	Fossa di Caldaro	8	Salo	Fossa di Salorno	7
Ceg2	Ceggio (2nd survey)	11	SaPA	Sarca Ponte Arche	6
Cegg	Ceggio	10	SaRa	Sarca Ragoli	16
Cere	Ceresone	10	Sel1	Fosso Selva	9
ChPd	Chiese Pieve di Bono (downstream)	6	Sel2	Fosso Selva (2nd survey)	9
ChPm	Chiese Pieve di Bono (upstream)	10	Spor	Sporeggio	7
ChSt	Chiese Storo	10	SZe2	Rio S. Zeno (2nd survey)	7
Debb	Canale Debba	5	SZen	Rio S. Zeno	9
Duin	Duina	6	TeBo	Tesina Bolzano Vicentino	14
Ferr	Canale Ferrara	20	TeL2	Tesina Lupia di Sandrigo (2nd survey)	19
Gheb	Ghebbo	9	TeLu	Tesina Lupia di Sandrigo	15

Table 7.3 Number of taxa per sampling site. The first column reports the codes used for sites in following tables and figures.

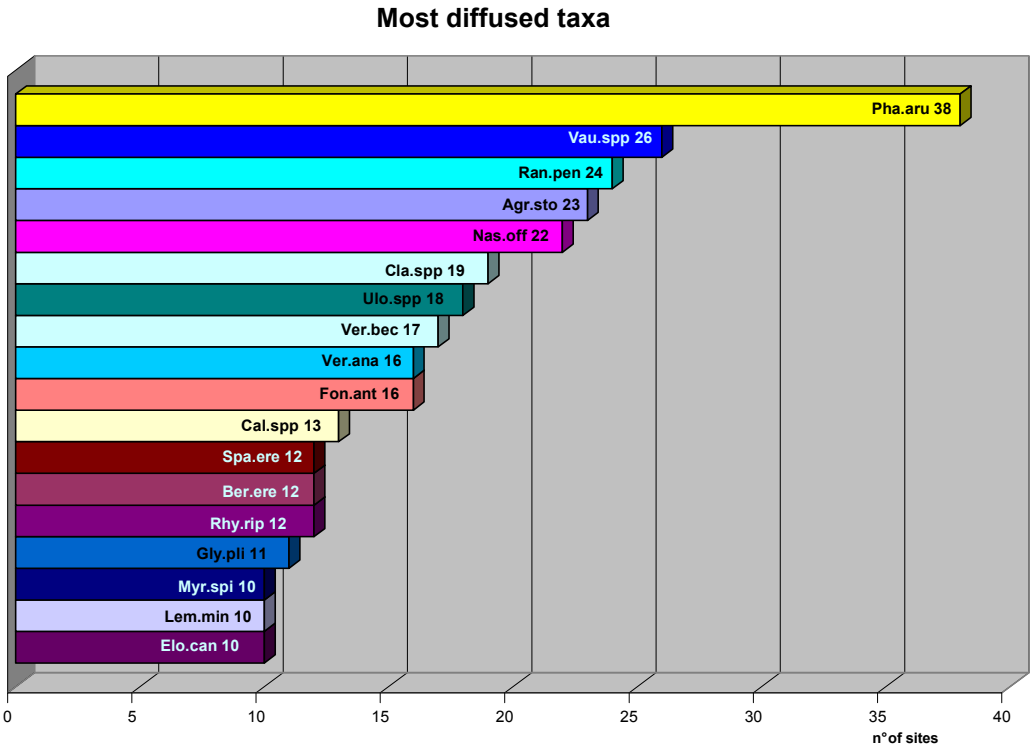

Figure 7.1 Most diffused taxa. On each column is reported the name of the species (see **Tab 7.1** for codes) and the number of sites where it was recorded.

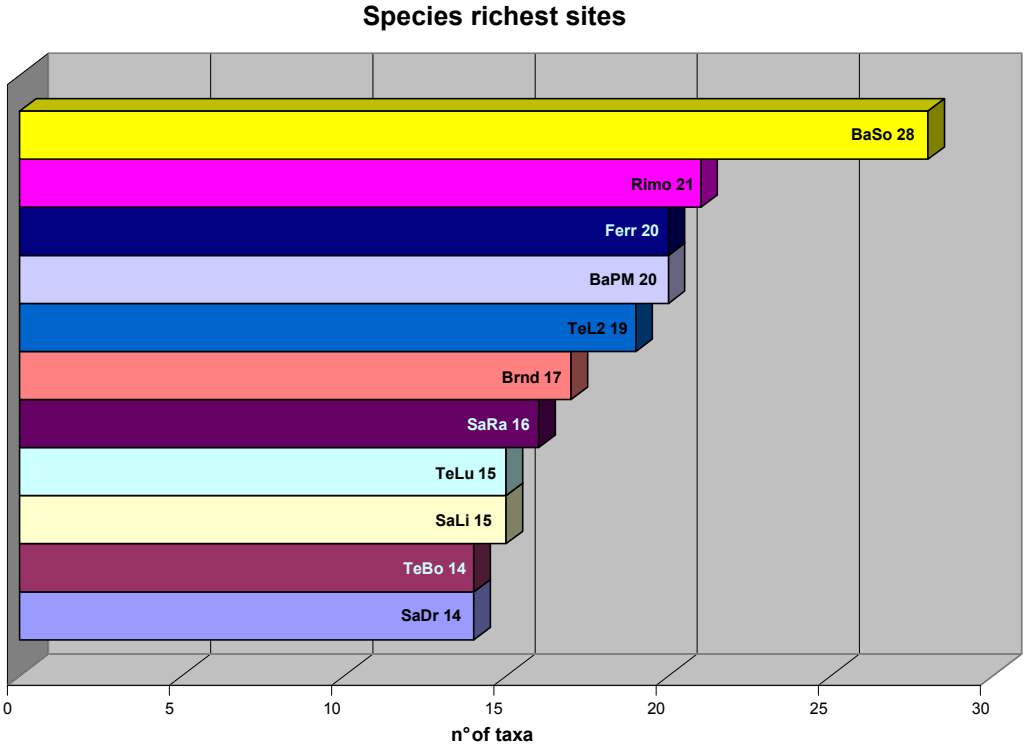

Figure 7.2 Sites having the highest number of taxa. For codes used in the diagram see **Tab 7.3**

7.2 SITE FEATURES

As already pointed out, at the same time of the macrophyte mapping we surveyed various site characteristics too. Some of these were recorded in the field directly as rank values, others were transformed subsequently. The main site features are summarized in the matrix reported in **App 11.3**. In **Tab 7.4** the site variables are listed in the form used for statistical analysis, i.e. transformed as described in section **6.4**.

It can be easily seen that there is a high variability among the sampling sites, with respect to all features. The more constant variable is the one expressing the degree of artificialization (Artif) of the watercourse, which assumes rather high values for most of the sites, while values 1 and 2 are quite rare. Since the rank order of "Artif" goes from 1, corresponding to a natural stream, to 6, indicating a totally modified watercourse, we can soon infer that most of the surveyed running waters are impaired, at least for what concerns their morphology.

SITE	Width	Depth	Speed	Shade	Subst	Tcov	Mcov	Acov	Artif	LUR	LUL	Elev	BDim
AdBo	3	1	3	1	5	2	1	2	3	1	2	2	1
Adgt	1	2	2	4	1	5	5	1	4	1	1	2	3
AdMo	3	2	3	1	5	5	1	5	3	3	1	2	1
Adnl	1	2	7	3	6	3	3	2	3	2	5	4	4
AdnP	1	2	4	4	6	4	2	3	4	2	5	4	4
AdSM	3	3	6	2	5	2	1	2	3	3	3	2	1
AdTN	3	3	6	2	5	2	2	1	5	1	1	2	1
AdVi	3	2	3	1	5	2	2	1	4	3	2	2	1
Arnò	1	1	3	2	4	2	2	0	4	2	2	4	3
BaPM	2	1	3	1	5	3	2	2	5	3	3	1	1
BaSo	2	1	6	1	5	2	2	1	5	3	3	1	1
BrB2	1	1	4	3	5	4	3	2	3	2	2	3	1
BrBo	1	1	6	3	4	4	4	1	3	2	2	3	1
BrG2	2	2	3	1	3	4	3	2	4	4	1	2	1
BrGr	2	2	5	1	5	3	2	2	4	4	1	2	1
BrLe	1	1	6	1	3	4	4	2	4	3	3	3	1
Brnd	2	3	2	1	3	5	5	0	4	3	3	1	3
BrV2	2	2	7	1	6	3	3	1	4	5	4	3	1
BrVi	2	1	7	2	5	4	4	2	4	5	4	3	1
Cala	1	1	4	4	2	5	5	2	5	2	3	2	4
Cald	1	3	2	1	1	5	5	0	4	3	3	2	3
Ceg2	1	1	7	3	6	3	3	1	5	2	3	3	3
Cegg	1	1	6	2	2	5	4	2	5	2	3	3	3
Cere	1	2	1	1	1	5	5	1	4	3	3	1	2
ChPd	2	2	6	3	5	4	4	1	3	3	3	3	2
ChPm	1	2	5	4	5	2	2	2	2	5	3	4	2
ChSt	2	2	6	3	5	2	2	2	3	2	3	3	2
Debb	1	2	1	2	1	4	4	0	3	3	3	1	3
Duin	1	1	5	3	6	2	2	1	5	2	2	3	4
Ferr	1	2	1	2	1	5	5	0	4	3	3	1	4
Gheb	1	1	3	4	3	5	5	1	3	2	2	1	3

SITE	Width	Depth	Speed	Shade	Subst	Tcov	Mcov	Acov	Artif	LUR	LUL	Elev	BDim
LaVe	1	1	6	3	6	5	4	2	1	3	3	3	4
Leno	2	1	3	1	5	3	3	0	5	1	1	2	2
Lora	1	2	3	4	5	4	4	2	2	4	4	3	4
Love	1	1	3	4	5	4	2	4	5	3	3	2	4
Mele	1	2	8	4	6	2	2	0	1	5	5	4	3
Mogg	1	1	8	4	6	2	1	2	1	5	5	4	2
Mone	1	2	2	5	1	4	4	2	4	3	3	1	4
NoRo	2	2	7	4	4	3	2	2	1	5	5	2	2
NoRu	2	3	3	4	5	4	2	4	5	1	3	2	2
Palv	1	1	3	2	5	2	2	1	3	5	3	3	4
Pona	1	2	8	4	3	3	3	2	2	3	3	3	3
Rabb	1	2	7	4	6	1	1	1	3	3	3	4	3
Res2	1	2	2	4	1	5	5	0	4	5	3	2	5
Rese	1	2	3	4	1	5	5	1	4	5	3	2	5
Rimo	1	2	1	2	6	5	4	4	5	3	3	2	4
RoFr	1	2	3	4	1	5	5	0	4	2	2	3	3
SaDr	2	2	3	2	5	4	4	1	5	3	3	2	2
Salè	1	1	6	3	6	4	4	0	5	3	3	2	4
SaLi	2	2	4	2	5	4	4	1	5	3	3	2	2
Saln	1	2	3	4	6	4	4	0	4	3	2	1	4
Salo	1	2	2	1	1	5	5	0	3	3	3	2	4
SaPA	2	2	4	2	5	3	3	1	5	2	3	3	2
SaRa	2	2	4	2	3	4	3	2	2	3	3	3	2
Sel1	1	1	2	5	1	4	4	0	1	3	5	2	5
Sel2	1	1	2	5	3	3	3	0	1	3	5	2	5
Spor	1	1	3	2	5	2	1	1	4	4	3	2	3
SZe2	1	1	2	1	1	5	5	0	4	3	3	2	3
SZen	1	2	2	1	1	5	5	0	4	3	3	2	3
TeBo	2	2	2	3	4	5	3	4	4	2	2	1	2
TeL2	1	2	2	2	2	5	5	0	4	3	3	1	2
TeLu	1	2	2	2	1	5	5	0	4	3	3	1	2

Table 7.4 Site features transformed in rank values (see **Section 6.4**). Width = Average width of the reach; Depth = average depth of the reach; Speed = water speed; Shade = shading condition of the reach; Subst = average granulometric composition of substrate; Tcov = total cover of macrophytes; Mcov = total cover of macrophyte without filamentous algae; Acov = total cover of filamentous algae; Artif = presence and number of morphological artificial elements on the river stretch; LUR = land use on the right side of the river; LUL = land use on the left side of the river; Elev = elevation of the site; BDim = basin dimension rank order.

7.3 WATER CHEMISTRY

The surveyed sites are monitored by the Environmental Agencies with different sampling frequency, according to their importance or to the impact they are subjected to. Moreover the parameters being measured are very variable in time and from site to site. Therefore we selected the most important variables, having no missing values, if

possible, in order to characterize the river stretches. The **Tab 7.5** summarizes the median values of each variable that were used in the statistical analysis, with the exception of water temperature and dissolved oxygen, which were excluded from the datasets and for which only single values are reported (see **Section 6.3**).

It can be noticed that the pH values are all lying in the narrow range of 7.6 and 8.5. We can therefore classify all the rivers as alkaline, since the pH is above 7.0 for all the surveyed water courses (Harrison & Agnew, 1962; Hawkes, 1975).

Conductivity varies from 112 to 1036 µS/cm and hardness from 52 to 530 mg/l of CaCO3. A first classification of the sites can be made on the basis of hardness alone (Butcher, 1933; Wetzel 1975), since it resulted to be strongly correlated with conductivity ($r^2 = 0.95$; $p < 0.001$; $N = 60$). Considering the limit of 100 mg/l of CaCO3 (Radojević & Bashkin, 2006) we divided the sites into the following two groups:

1. soft non-calcareous water courses: River Brenta at Villa Agnedo, Ceggio, Noce at Rocchetta, Rabbies;
2. hard calcareous water courses: all the others.

If we consider classification limits given by other authors (Pennak, 1971; Briggs & Ficke, 1977) we can classify all the sites as medium or hard-water. Substantially our data set does not include rivers where water is extremely soft and hardness and conductivity should therefore result not so decisive in conditioning the macrophyte vegetation.

SITE	DATE	WT °C	COND µS/cm	Hard_ CaCO3 mg/l	pH	DO %	BOD5 mg/l	N_NH4 µg/l	N_NO3 mg/l	P_PO4 µg/l	PTOT µg/l
AdBo	02/10/08	17,5	256	134	8,1	110	2,4	40	0,9	20	40
Adgt	24/09/07	18,4	558	295	8,0	133	1,6	40	8,5	58	88
AdMo	02/10/08	15,5	236	118	8,0	99	2,1	40	0,8	20	40
Adnl	17/09/08		356	208	8,0	101	1,1	70	1,0	20	30
AdnP	17/09/08	10,4	364	204	8,0	101	1,1	80	1,2	20	35
AdSM	02/10/08	14,6	224	114	8,0	102	2,0	40	0,6	10	40
AdTN	02/10/08	15,5	233	120	8,0	99	2,0	50	0,7	20	50
AdVi	02/10/08	15,3	233	120	8,0	100	2,6	40	0,8	20	45
Arnò	28/07/08	14,7	268	146	8,3	100	1,4	33	0,9	15	30
BaPM	26/07/07	18,0	550	313	8,0	105	1,0	8	5,9	35	60
BaSo	26/07/07	18,0	550	313	8,0	105	1,0	8	5,9	35	60
BrB2	03/09/08	17,3	386	208	8,2	106	2,2	35	1,6	40	70
BrBo	20/06/07	18,5	386	208	8,2	110	2,3	30	1,6	40	70
BrG2	03/09/08	16,4	272	150	8,2	108	1,9	30	1,4	20	40
BrGr	20/06/07	18,4	277	151	8,2	106	1,9	30	1,4	20	35
BrLe	12/09/07	16,3	371	207	7,8	100	2,0	130	1,2	20	35
Brnd	16/09/08	14,9	638	346	7,9	72	1,0	73	4,1	50	80
BrV2	25/09/07	16,0	186	56	8,4	124	0,5	43	1,5	143	166
BrVi	28/08/07	17,2	186	56	8,4	100	0,5	43	1,5	143	166
Cala	28/07/08	10,4	299	154	8,4	99	1,6	39	1,5	40	75
Cald	21/03/07	7,6	577	320	7,8	83	1,7	180	1,6	55	95
Ceg2	25/09/07	11,6	190	70	8,2	98	1,0	153	1,7	27	46

SITE	DATE	WT ℃	COND µS/cm	Hard_CaCO3 mg/l	pH	DO %	BOD5 mg/l	N_NH4 µg/l	N_NO3 mg/l	P_PO4 µg/l	PTOT µg/l
Cegg	24/07/07	14,1	190	70	8,2	96	1,0	153	1,7	27	46
Cere	20/08/07	21,0	440	237	7,9	106	2,0	62	1,8	67	100
ChPd	02/10/07	11,0	337	179	8,5	106	1,6	20	2,0	40	40
ChPm	12/11/08	10,1	314	176	8,4	100	1,0	10	1,0	13	20
ChSt	16/10/08	12,4	183	101	8,2	110	1,7	40	0,9	10	20
Debb	21/05/07	23,5	340	193	7,7	67	2,0	40	0,5	11	20
Duin	08/09/08	13,9	444	249	8,5	102	1,6	30	5,8	100	110
Ferr	02/05/07	17,0	450	250	7,8	44	2,0	80	2,5	21	40
Gheb	17/09/07	17,0	600	227	7,7	90	2,0	5	1,8	10	20
LaVe	28/08/07	10,4	423	210	8,2	99	0,4	32	1,9	2	8
Leno	02/10/08	14,6	268	156	8,4	120	2,2	20	0,7	5	20
Lora	28/07/08	12,7	302	143	8,0	95	1,5	40	1,6	34	58
Love	10/11/08	5,2	247	138	8,4	99	1,3	30	0,7	10	20
Mele	07/08/06	7,6	180	102	8,2	100	1,0	8	0,3	3	5
Mogg	24/07/07	10,6	378	168	8,5	90	0,3	29	0,8	1	4
Mone	02/05/07	16,0	470	313	8,2	101	2,0	30	5,9	28	50
NoRo	29/05/07	16,0	210	80	8,5	130	0,9	46	0,7	28	36
NoRu	02/10/08	13,8	220	117	8,1	96	2,2	26	0,9	20	30
Palv	17/09/08	10,4	308	185	8,5	102	1,7	70	1,2	20	20
Pona	28/07/08	15,9	335	185	8,5	99	0,5	10	1,2	10	15
Rabb	15/09/08	9,6	112	52	7,6	100	2,1	40	0,4	5	20
Res2	25/09/07	11,9	314	152	8,3	87	0,5	36	0,8	11	15
Rese	28/08/07	11,7	314	152	8,3	82	0,5	36	0,8	11	15
Rimo	25/06/07	11,6	242	122	8,2	67	0,3	36	1,2	4	8
RoFr	24/07/07	10,1	375	140	8,3	61	1,7	131	1,6	39	72
SaDr	29/05/07	14,2	239	114	8,5	113	1,3	39	1,3	20	40
Salè	19/09/07	14,1	1036	530	8,4	101	0,9	20	2,1	20	30
SaLi	29/05/07	12,5	241	136	8,2	103	1,7	40	1,5	30	50
Saln	28/07/08	17,8	311	128	8,3	96	2,6	69	1,9	6	20
Salo	17/04/07	14,5	428	225	7,8	64	2,8	390	1,2	55	130
SaPA	10/11/08		422	239	8,0	100	2,0	100	4,1	39	60
SaRa	13/06/07	16,4	212	114	8,1	108	2,3	115	1,2	40	60
Sel1	28/08/07	8,3	272	150	8,3	81	0,4	45	0,8	4	11
Sel2	25/09/07	8,3	272	150	8,3	91	0,4	45	0,8	4	11
Spor	10/11/08	6,0	269	147	8,4	98	2,1	50	0,9	20	25
SZe2	30/10/07	10,5	364	192	8,3	94	1,5	30	1,2	15	20
SZen	30/10/07	10,5	364	192	8,3	94	1,5	30	1,2	15	20
TeBo	15/09/08	16,3	470	268	7,9	96	1,0	20	3,8	25	40
TeL2	15/09/08	16,3	470	268	7,9	96	1,0	20	3,8	25	40
TeLu	15/09/08	16,3	470	268	7,9	96	1,0	20	3,8	25	40

Table 7.5 Median values of the main chemical parameters considered in the statistical analysis. The water temperature and the dissolved oxygen saturation are single values referring to the sampling date (DATE) reported in the second column. The two variables were excluded from the data treatment and are here listed only to give an indication on the characteristics of the sites. WT = water temperature in ℃; COND = electrical specific conductance at 20℃, in µS/cm; Hard_CaCO3 = hardness as CaCO3 mg/l; pH = pH; DO % = dissolved oxygen saturation in %; BOD5 = biochemical oxygen demand measured on 5 days, in mg/l; N_NH4 = ammoniac nitrogen in µg/l; N_NO3 = nitric nitrogen in mg/l; P_PO4 = ortophosphoric phosphorus in µg/l; PTOT = total phosphorus in µg/l.

The nutrient concentrations are very variable: ammonium ranges from 5 to 390 μg/l, nitrate from 0.3 to 8.5 mg/l, ortophosphoric phosphorus from traces to more than 140 μg/l and total phosphorus varying from 4 to nearly 170 μg/l. On the contrary the BOD5 concentration does not have great variations, lying between 0.3 and 2.8 mg/l. This means that we have a wide range of trophic conditions, going from oligotrophic to strongly eutrophic (Kelly & Whitton, 1998; Robach et al., 1996), but according to BOD5 concentrations none of the sampling sites have a high saprobic level (Carbiener et al., 1995).

7.4 SIMILARITY INDEXES

The calculation of the similarity indexes gave varying results according to the type of index applied and to the type of data analyzed.

The computation of the Bray-Curtis similarity index and the Morisita similarity index on the species abundance data gave quite low similarity values as output, rarely higher than 0.50. The two indexes are quite coherent and give comparable results, because they tend to classify the same pairs of objects as similar. The complete list of values is reported in **App. 11.4**. The results of the two indexes were combined in one matrix, where the upper part reports the Morisita's index and the lower part the Bray-Curtis index. To make the matrix interpretation easier, all the values equal to 1.00 were marked in grey, the values higher than or equal to 0.50 were marked in red and those higher than 0.25 in yellow. The results of the indexes were also plotted in the two cluster dendrograms showed below (**Fig 7.3** and **Fig 7.4**).

The two plots have a similar structure and in both dendrograms there are some detectable clusters, but the similarity between their elements is very low. If we consider only the clusters with similarity bigger than 0.36, we can detect two groups marked in different colours in each dendrogram.

According to Morisita Index the two clusters are:

- group 1: Adige Mori, Adige Villa Lagarina, Palvico, Brenta Grigno, Chiese Storo, Adige Trento, Noce Rupe, Adanà Pieve di Bono upstream, Adanà Pieve di Bono downstream, Chiese Pieve di Bono downstream, Brenta Grigno 2nd survey, Sarca Limarò, Sarca Ragoli, Lora, Sarca Dro, Sarca Ponte Arche, Leno, Brenta Levico, Rosta Fredda, Noce Rocchetta;
- group 2: Arnò, Lovernatico, Sporeggio, Ceggio 2nd survey, Ceggio.

Considering the Bray-Curtis index the two clusters are:

- group 1: Adige Mori, Adige Villa Lagarina, Palvico, Brenta Grigno, Chiese Storo, Adige Trento, Noce Rupe, Adanà Pieve di Bono upstream, Adanà Pieve di Bono downstream, Roggia di Calavino, Leno, Brenta Grigno 2nd survey, Sarca Ragoli, Sarca Limarò, Lora, Chiese Pieve di Bono downstream, Sarca Ponte Arche, Sarca Dro;
- group 2: Arnò, Duina, Lovernatico, Sporeggio, Ceggio 2nd survey, Ceggio.

The clusters traced out by the two methods are nearly coincident. The Morisita clusters contain the same objects as the Bray-Curtis, with some elements more that could also be excluded from the cluster (see **Fig 7.4**). In fact if we consider the site features we could see that the water courses listed inside each group have similar characteristics.
The Bray-Curtis index was computed for presence/absence data as well and the results are reported in **App 11.5** in the lower half of the matrix, while in the upper part are listed the values of the Raup-Crick index, applied on presence/absence data.
In this case the methods give very different outputs, as it can be easily seen from the colours of the matrix (the same used in the previous one) that highlights the very high values resulting from the calculation of the second algorithm. It is in fact based on a Monte Carlo permutation method and assigns value 1 also to pairs of objects that are not identical according to the Bray-Curtis metric.
The dendrograms in **Fig 7.5** and **7.6** show the clusters based on the Raup-Crick and Bray-Curtis similarity arrays respectively.
If we look at the Raup-Crick index representation we can easily divide all the sites into 3 clusters, with one sampling point (Rabbies) that does not belong to any of them. The groups are the following:

- group 1: Fossa di Caldaro, Adigetto, Fossa di Salorno, Roggia Moneghina, Tesina Bolzano, Ceresone, Canale Debba, Salone, S. Zeno 2nd survey, S.Zeno;
- group 2: Bacchiglione Ponte Marchese, Bacchiglione sorgente, Rosta Fredda, Lora, La Vena, Resenzuola 2nd survey, Resenzuola, Brendola, Ferrara, Tesina Lupia di Sandrigo 2nd survey, Tesina Lupia di Sandrigo, Rimone, Fosso Selva, Fosso Selva 2nd sample;
- group 3: Adige Mori, Adige Trento, Brenta Grigno, Chiese Storo, Brenta Levico, Brenta Borgo 2nd survey, Brenta Borgo, Brenta Villa Agnedo 2nd survey, Brenta Villa Agnedo, Noce Rocchetta, Adige Villa Lagarina, Adige Borghetto, Ponale, Noce Rupe, Adige San Michele, Moggio, Adanà Pieve di Bono upstream, Adanà Pieve di Bono downstream, Calavino, Sporeggio, Leno, Ceggio 2nd survey, Ceggio, Lovernatico, Ghebbo, Arnò, Sarca Limarò, Sarca Ragoli, Brenta Grigno 2nd survey, Sarca Dro, Palvico, Chiese Pieve di Bono downstream, Sarca Ponte Arche, Duina, Salè, Chiese Pieve di Bono upstream, Meledrio.

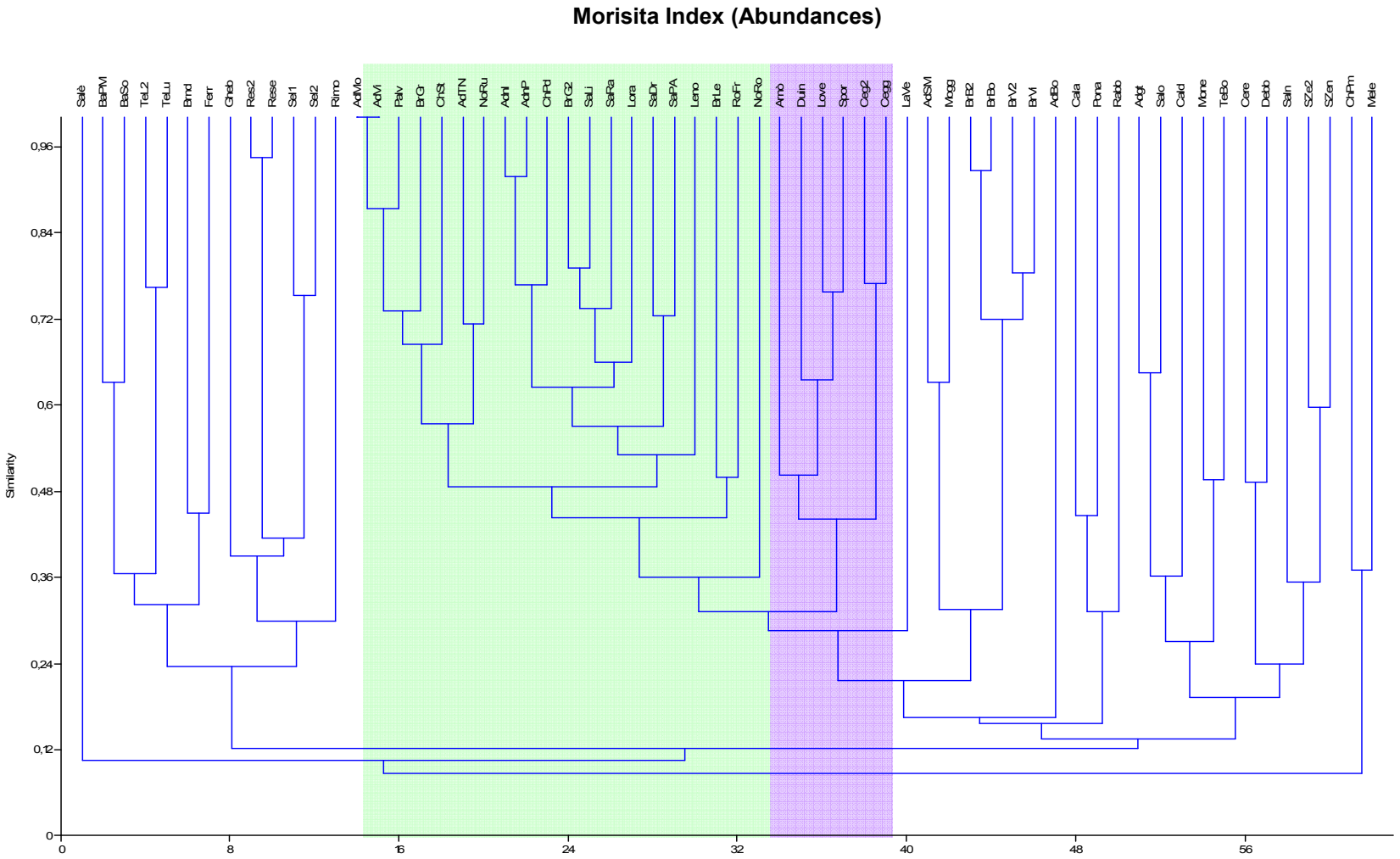

Figure 7.3: Clustering (complete linkage) of sites, using the Morisita similarity index as metric. Distances are calculated on the species abundance matrix.

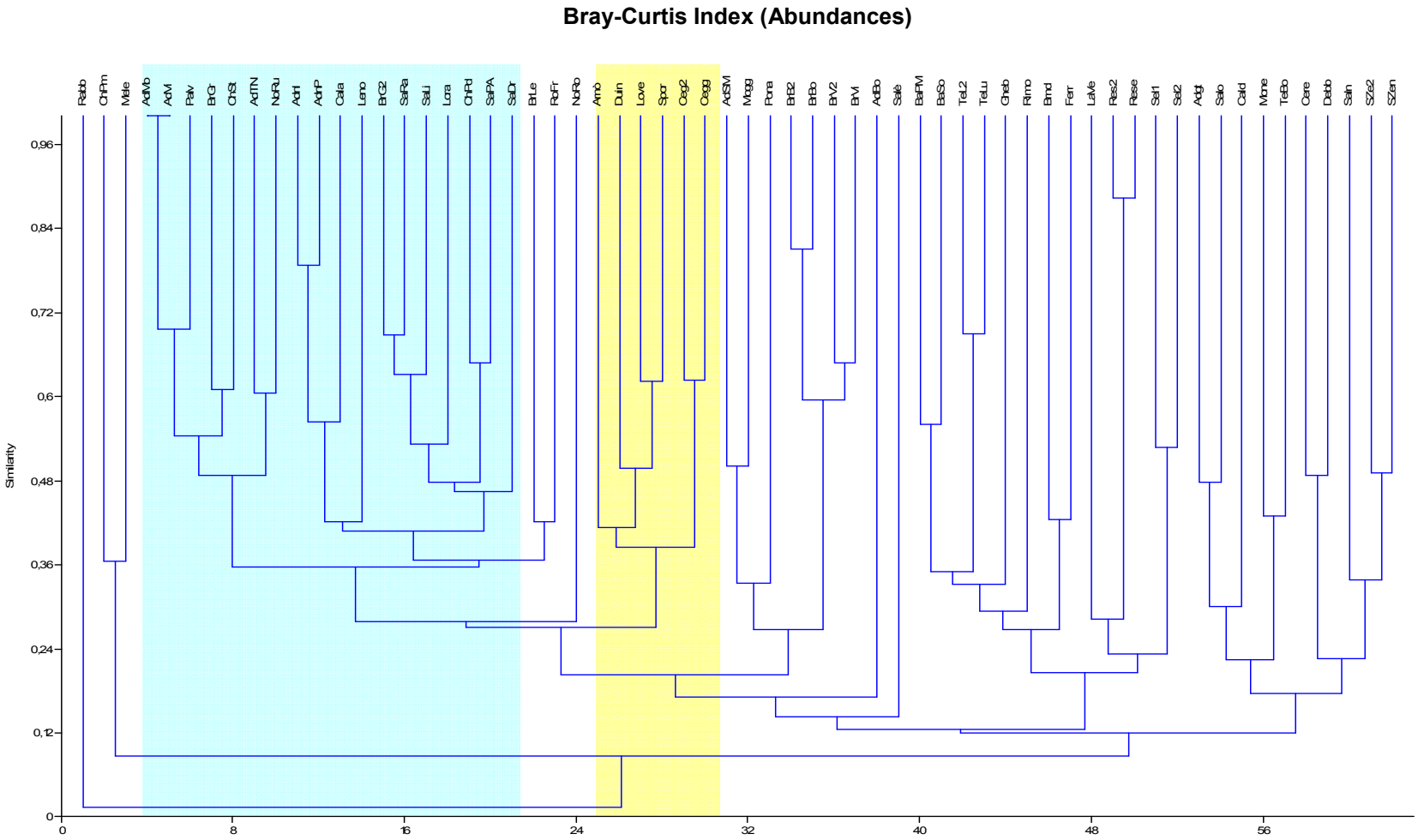

Figure 7.4: Clustering (complete linkage) of sites, using the Bray-Curtis similarity index as metric. Distances are calculated on the species abundance matrix.

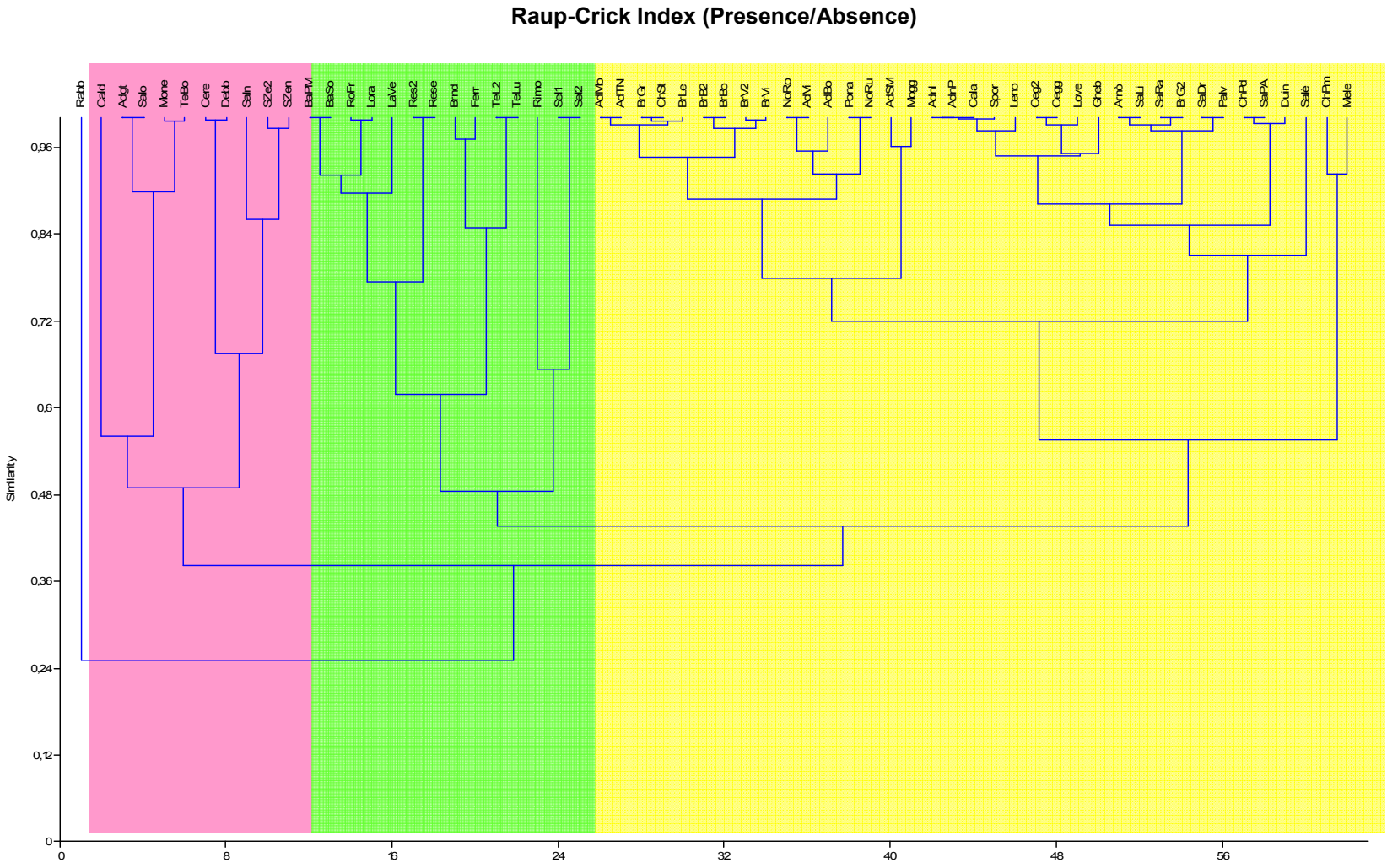

Figure 7.5: Clustering (complete linkage) of sites, based on Raup-Crick similarity index. Distances are calculated on the species presence/absence matrix.

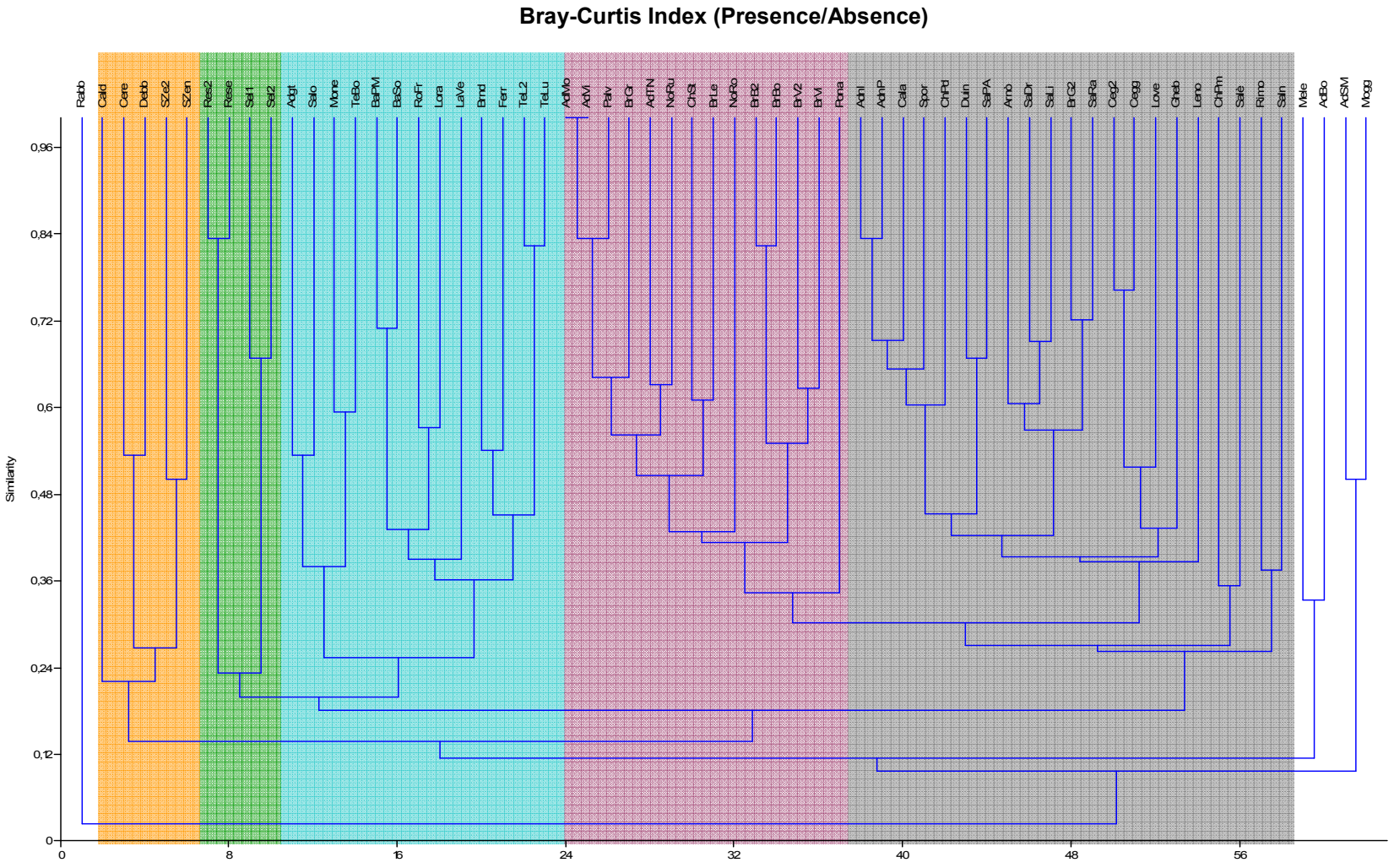

Figure 7.6: Clustering (complete linkage) of sites, based on Bray-Curtis similarity index. Distances are calculated on the species presence/absence matrix.

The elements of the clusters never have a similarity lower than 0.48 and the division of the groups is quite consistent with the characteristics of the watercourses and with the groups worked out through the abundance data. Nonetheless the 3rd group is very wide and comprises sampling points quite different from each other.
Considering the Bray-Curtis metric on species presence/absence data the discrimination between groups is much lower and the similarity among the objects of the detected clusters decreases to about 0.24 as minimum value. A part from some elements (Rabbies, Meledrio, Adige Borghetto, Adige San Michele and Moggio) which are not comprised in any group, we can trace out the following 5 clusters, two of them composed of a small number of objects:

- group 1: Fossa di Caldaro, Ceresone, Canale Debba, S. Zeno 2nd survey, S. Zeno;
- group 2: Resenzuola 2nd survey, Resenzuola, Fosso Selva, Fosso Selva 2nd survey;
- group 3: Adigetto, Fossa di Salorno, Roggia Moneghina, Tesina Bolzano, Bacchiglione Ponte Marchese, Bacchiglione sorgente, Rosta Fredda, Lora, La Vena, Fiumicello Brendola, Canale Ferrara, Tesina Lupia di Sandrigo 2nd survey, Tesina Lupia di Sandrigo;
- group 4: Adige Mori, Adige Villa Lagarina, Palvico, Brenta Grigno, Adige Trento, Noce Rupe, Chiese Storo, Brenta Levico, Noce Rocchetta, Brenta Borgo 2nd survey, Brenta Borgo, Brenta Villa Agnedo 2nd survey, Brenta Villa Agnedo, Ponale;
- group 5: Adanà Pieve di Bono upstream, Adanà Pieve di Bono downstream, Roggia di Calavino, Sporeggio, Chiese Pieve di Bono downstream, Duina, Sarca Ponte Arche, Arnò, Sarca Dro, Sarca Limarò, Brenta Grigno 2nd survey, Sarca Ragoli, Ceggio 2nd survey, Ceggio, Lovernatico, Ghebbo, Leno, Chiese Pieve di Bono upstream, Salè, Rimone, Salone.

The clusters listed above are partially overlapped with those traced out from the Raup-Crick method and are more consistent with the features of the watercourses. The rivers belonging to group 1 are characterized by very slow flowing or nearly standing water, extremely fine sediment, no shade and they could be described as lowland canals and ditches.
Cluster 2 comprises only 2 brooks that are strongly influenced by groundwater, have similar morphological characters (medium flow velocity, fine substrate and small dimensions) and quite natural use of the surrounding land, laying both inside a biotope.
Group 3 collects watercourses rather different from each other, being similar only because they are all running waters with very low steepness, flowing through the lowland or the bottom of the valleys, in a plain zone. Besides, they are all quite impacted by human activity.

The last 2 clusters are not so different one from another and could be jointed in a single cluster, comprising fast flowing rivers and streams, with coarse substrate, but having very variable morphological conditions.
Even if none of the clustering is perfectly coherent with what was observed in the field, these results make clear that the macrophyte community is highly dependent on the river type and its specific composition changes deeply with the changing of the site features.

7.5 CLUSTER ANALYSIS BASED ON EUCLIDEAN DISTANCE

In the last paragraph we have considered some clusters based on similarity indexes. Nonetheless the most diffused clustering metric is the Euclidean distance and we applied it on the species abundance matrix, using two different techniques of hierarchical clustering. **Fig 7.7** reports the dendrogram obtained through the complete linkage method, applied to the grouping of objects (sites), while **Fig 7.8** shows the result obtained through the average linkage method.
The first thing that we can notice is that the complete linkage and the average linkage cluster are quite similar in both cases. The grouping does not depend much on the method adopted to join the groups, but the Eculidean distance gives a different and less structured output compared to the similarity indexes. Despite this, 5 site clusters can be traced, especially if we consider the complete linkage dendrogram (see **Fig. 7.7**):

- group 1: Salone, S. Zeno 2nd survey, S. Zeno, Fiumicello Brendola, Roggia di Caldaro, Adigetto-Lavisotto, Roggia di Salorno;
- group 2: Bacchiglione Ponte Marchese, Bacchiglione sorgente, La Vena, Ghebbo, Resenzuola 2nd survey, Resenzuola, Fosso Selva, Fosso Selva 2nd survey;
- group 3: Sarca Ragoli, Brenta Grigno 2nd survey, Sarca Limarò, Chiese Pieve di Bono downstream, Adanà Pieve di Bono upstream, Adanà Pieve di Bono downstream, Sarca Dro, Sarca Ponte Arche, Brenta Levico, Lora, Rosta Fredda;
- group 4: Ceresone, Canale Debba, Roggia Moneghina, Tesina Bolzano Vicentino;
- group 5: Brenta Borgo 2nd survey, Brenta Borgo, Brenta Villa Agnedo 2nd survey, Brenta Villa Agnedo, Adige Trento, Noce Rupe, Brenta Grigno, Chiese Storo, Palvico, Adige Mori, Adige Villa Lagarina, Lovernatico, Ponale, Rabbies, Adige San Michele, Moggio, Adige Borghetto, Noce Rocchetta, Chiese Pieve di Bono upstream, Ceggio 2nd survey, Ceggio, Roggia di Calavino, Leno, Meledrio, Salè, Arnò, Duina, Sporeggio.

. Finally there are 4 elements (Canale Ferrara, Rimone, Tesina Lupia di Sandrigo 1st and 2nd survey) which do not belong to any cluster.
Even if slightly different from the others, also this distribution of sites is quite correspondent to the environmental traits of the water courses. It could be surprising

that the 2 surveys on the Brenta at Grigno, though referring to the same sampling reach, are displaced in two clusters. The reason has to be found in the extreme variability of the river ecosystem, especially for those reaches having rhithral character, such as the Brenta at Grigno. Over one year these reaches can change their characteristics to a quite large extent, e.g. the substrate composition, and consequently influence the species abundance and distribution.

Fig 7.9 shows the combined representation of sites and species dendrograms in a heat map that make it easier to understand if there is the tendency of species to form typical assemblages, otherwise rather difficult to infer from the cluster dendrograms (see **App 11.6**).

Considering the heat map we can see that there are some groups of macrophyte species that are often associated like:

- *Ranunculus penicillatus* ssp. *pseudofluitans*, *Phalaris arundinacea*, *Agrostis stolonifera* and *Nasturtium officinale*;
- *Sparganium erectum*, *Berula erecta* and *Vaucheria* spp.;
- *Fontinalis antipyretica* and *Cladophora* spp. (many times occurring together with the species of the first group as well);
- *Veronica anagallis-aquatica* and *Veronica beccabunga,* sometimes with *Mentha aquatica* and *Myosotis palustris;*
- *Myriophyllum spicatum* with *Elodea canadensis* and *Potamogeton pectinatus*.

To complete the analysis of the similarity between the macrophyte communities of the surveyed sites we applied the monothetic method MONA to the presence/absence matrix and it gave as output the banner diagram in **Fig 7.10**. The species names on the left, in the empty lines, are a separation step that divides the sites into two groups in which the species is absent (above) or present (below).

On the basis of the banner we traced out 6 clusters, corresponding to the presence/absence of *Ulothrix* spp., *Vaucheria* spp., *Veronica anagallis-aquatica, Berula erecta* and *Callitriche* spp., which is showed in the diagram in **Fig 7.11**.

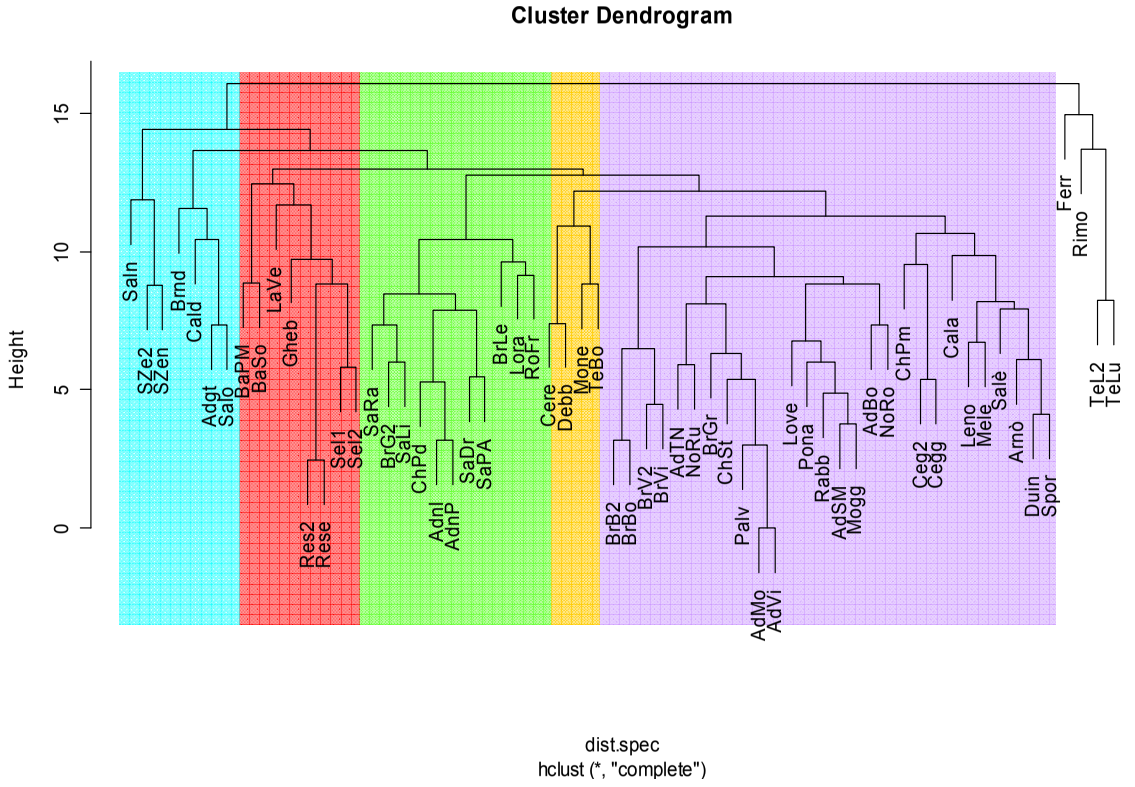

Figure 7.7: Cluster dendrogram of sites based on Euclidean distance and complete linkage method, calculated on the species abundance matrix.

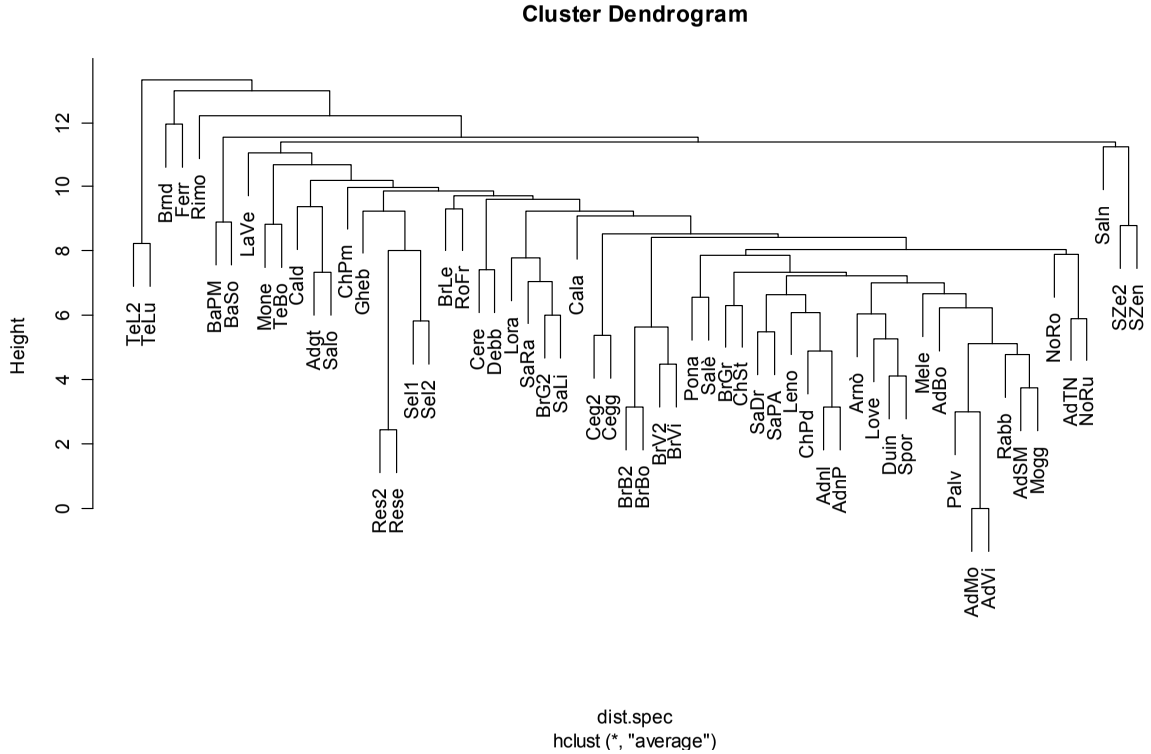

Figure 7.8: Cluster dendrogram of sites based on Euclidean distance and average linkage method, calculated on the species abundance matrix.

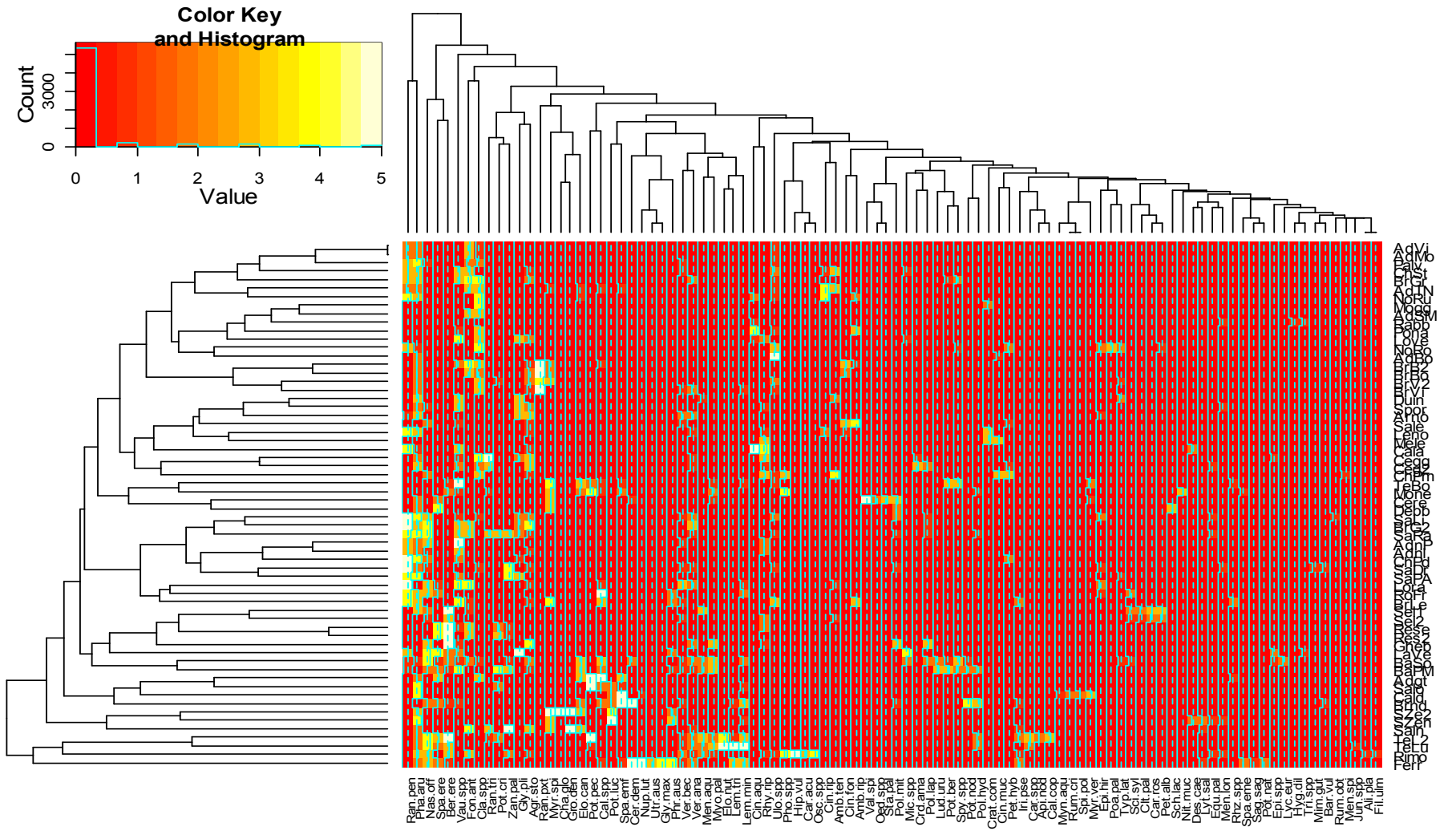

Figure 7.9: Heat map of species and site cluster dendrograms, obtained from the abundance matrix.

The **Fig 7.11** can be translated into the following site clusters, established on the basis of the five species in the diagram:

- cluster 1 (*Berula erecta* and *Ulothrix* spp. present, *Vaucheria* spp. absent): Adige Borghetto, Noce Rupe, Noce Rocchetta, Adige Mori, Adige Villa Lagarina, Palvico, Adige Trento, Brenta Villa Agnedo 2nd survey, Brenta Villa Agnedo, Chiese Pieve di Bono upstream and Sarca Dro;
- cluster 2 (*B. erecta, Vaucheria* and *Ulothrix* all absent): Adigetto, Fossa di Salorno, Fossa di Caldaro, Arnò, Leno, Rosta Fredda, Adige San Michele, Moggio, Meledrio, Rabbies, Brenta Borgo, Salone, S. Zeno 2nd survey, S. Zeno, Ceresone and Canale Debba;
- cluster 3 (*B. erecta* and *V. anagallis-aquatica* absent, *Vaucheria* present): Adanà Pieve di Bono upstream, Adanà Pieve di Bono downstream, Sporeggio, Roggia di Calavino, Lovernatico, Chiese Pieve di Bono downstream, Sarca Ponte Arche, Duina, Chiese Storo, Brenta Borgo 2nd survey, Brenta Levico, Ponale and Salè;
- cluster 4 (*B. erecta* absent, *Vaucheria* and *V. anagallis-aquatica* present): Brenta Grigno 2nd survey, Lora, Sarca Limarò, Sarca Ragoli, Brenta Grigno, Ceggio 2nd survey and Ceggio;
- cluster 5 (*B. erecta* and *Callitriche* spp. present): Bacchiglione Ponte Marchese, Bacchiglione sorgente, Fiumicello Brendola, Canale Ferrara, Roggia Moneghina and Tesina Bolzano Vicentino;
- cluster 6 (*B. erecta* present, *Callitriche* spp. absent): Ghebbo, Rimone, Tesina Lupia di Sandrigo 2nd survey, Tesina Lupia di Sandrigo, La Vena, Resenzuola 2nd survey, Resenzuola, Fosso Selva and Fosso Selva 2nd survey.

Clusters 1, 3, 4, 5 and 6 are rather significant, while group 2 mixes together very different sites. The reason is the fact that cluster 2 is defined only by the joint absence of three species and not by the presence of any, therefore putting together sites that are distinct from the others, as indicated by the absence of some taxa, but quite different from each other as well and thus not having a common characterizing species.

The interesting result of the MONA is the possibility of discriminating among river types on the basis of the occurring of few macrophyte key-species, instead of considering the whole community.

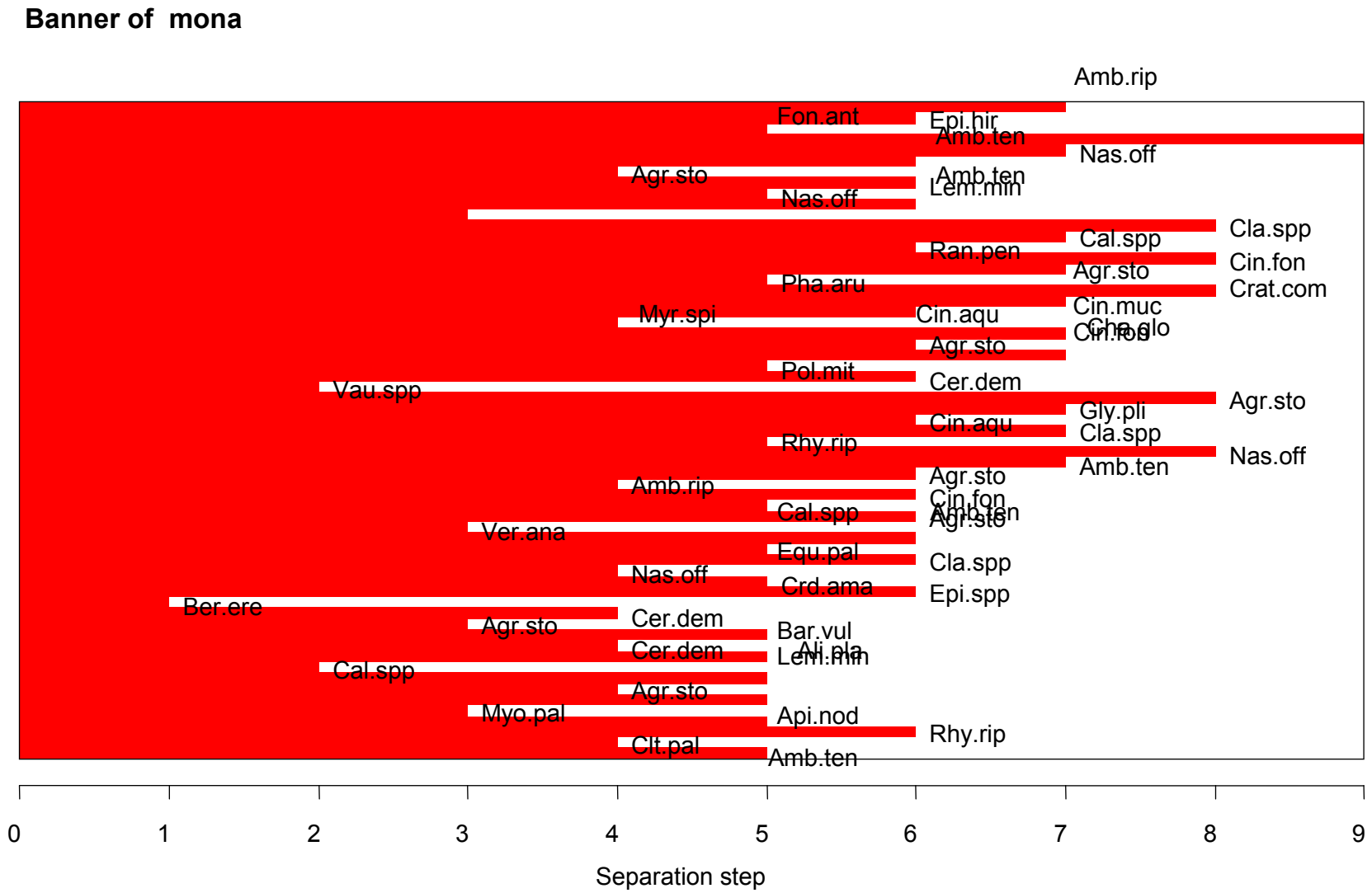

Figure 7.10: Separation banner of MONA. Every empty line separates the sites where that species is absent (above) from those where it is present (below).

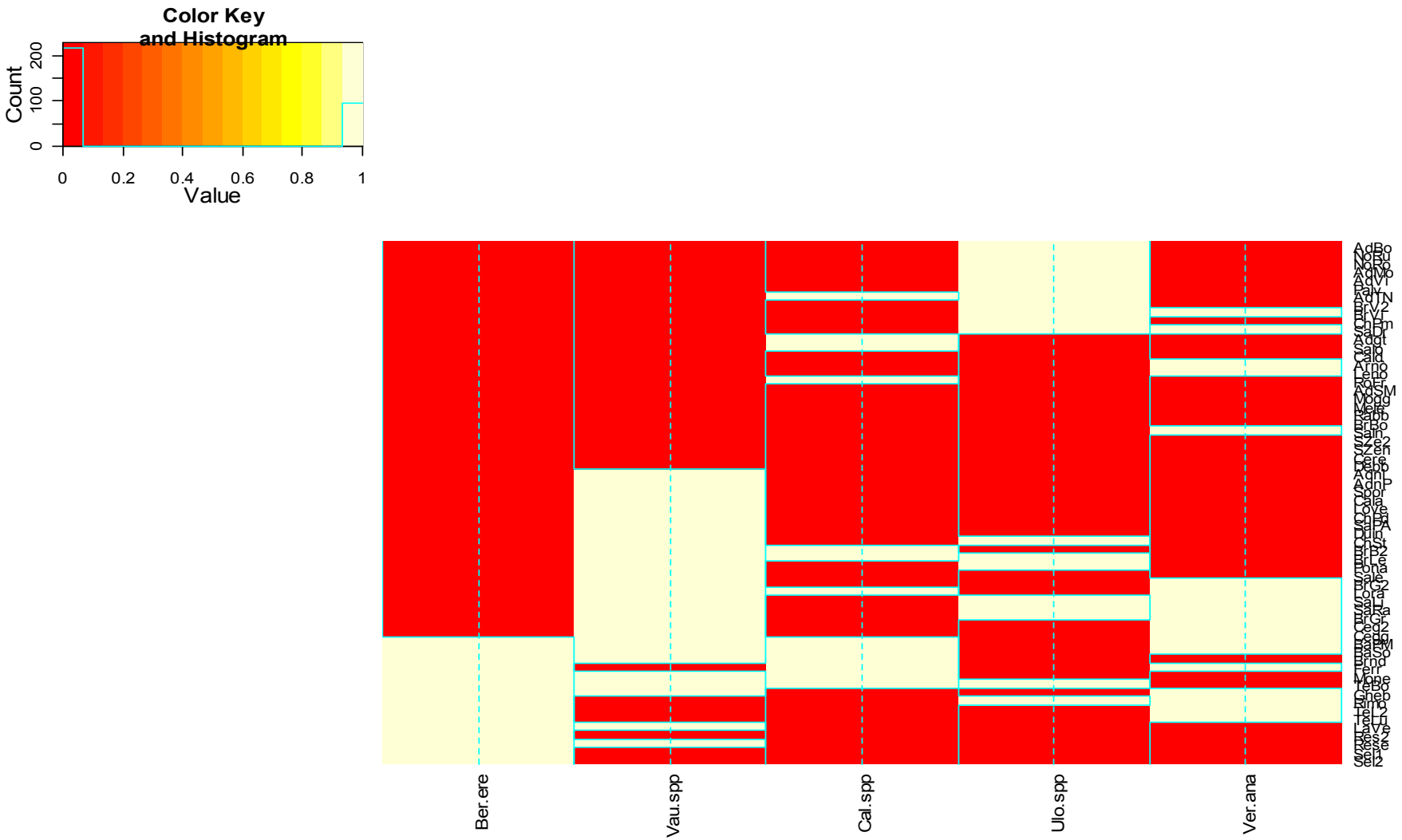

Figure 7.11: Presence/absence diagram of the five key-species. The light colour indicates the presence, while red corresponds to absence.

7.6 SHANNON-WEAVER DIVERSITY INDEX, EVENNESS AND OTHER METRICS

For every sampling point the Shannon-Weaver Index (H) and the Evenness (E) were calculated (see **Tab 7.6**). The former measures the diversity of the community at a certain site, while the latter translates into a number the abundance relationships among the species.

A macrophyte community with high species diversity and a good equilibrium between the different taxa, where none of them is clearly prevailing on the others, should have a high H value and an E value close to 1 (Van Dyke, 2008).

SITE	H	E	SITE	H	E
AdBo	0,27	0,25	**LaVe**	1,80	0,78
Adgt	1,60	0,77	**Leno**	1,32	0,64
AdMo	1,09	0,68	**Lora**	1,69	0,68
AdnI	1,34	0,75	**Love**	1,40	0,72
AdnP	1,12	0,63	**Mele**	1,10	**1,00**
AdSM	0,69	**1,00**	**Mogg**	0,35	0,50
AdTN	1,70	0,71	**Mone**	1,84	0,72
AdVi	1,09	0,68	**NoRo**	1,76	0,76
Arnò	1,56	**0,80**	**NoRu**	1,58	0,76
BaPM	**2,42**	**0,81**	**Palv**	1,17	0,60
BaSo	**2,65**	0,79	**Pona**	1,09	0,67
BrB2	1,53	0,67	**Rabb**	1,39	**1,00**
BrBo	1,22	0,63	**Res2**	1,20	0,75
BrG2	1,84	**0,84**	**Rese**	1,22	0,62
BrGr	1,85	**0,80**	**Rimo**	**2,18**	0,72
BrLe	**2,11**	**0,82**	**RoFr**	1,58	0,72
Brnd	1,85	0,65	**SaDr**	1,08	0,41
BrV2	1,54	0,74	**Salè**	1,03	0,53
BrVi	0,93	0,45	**SaLi**	1,68	0,62
Cala	1,39	0,71	**Saln**	1,81	0,75
Cald	1,32	0,64	**Salo**	1,09	0,56
Ceg2	1,93	**0,80**	**SaPA**	1,46	**0,82**
Cegg	1,46	0,63	**SaRa**	**2,15**	0,78
Cere	1,50	0,65	**Sel1**	1,64	0,75
ChPd	1,07	0,60	**Sel2**	1,55	0,70
ChPm	1,88	**0,82**	**Spor**	1,40	0,72
ChSt	1,85	**0,80**	**SZe2**	1,68	**0,86**
Debb	1,34	**0,83**	**SZen**	1,44	0,66
Duin	1,52	**0,85**	**TeBo**	1,69	0,64
Ferr	**2,23**	0,74	**TeL2**	**2,33**	0,79
Gheb	1,68	0,76	**TeLu**	1,97	0,73

Table 7.6: List of sampling points (SITE) with indication, for each of them, of the Shannon-Weaver Diversity Index value (H) and the Evenness value (E). H indexes higher than two and E indexes higher or even to 0.80 are marked in bold.

For what concerns the H index we can notice that the values are in general quite low, with only about 10% of the sites (7) having values higher than 2. The water courses with more diversity are very different from each other, presenting a wide range of substrate granulometry, flow speed, dimensions, altitude etc. As for the Evenness the sites with value 1.00 are those with very poor macrophyte vegetation, where few species occur, all with the same low abundance (Kohler's coefficient 1 or 2). This information is thus not very significant.

Some sites with high H index have an E value around 0.8 (Bacchiglione Ponte Marchese, Bacchiglione sorgente and Brenta Levico), meaning that their macrophyte community is rich and quite balanced. We calculated the Pearson's coefficient between Shannon-Weaver Diversity and Evenness on one side and all the environmental site variables (included chemistry) on the other side, but we only found weak correlation between H and altitude ($r = -0.35$ $p < 0.01$), H and pH ($r = -0.28$ $p < 0.05$), H and nitric nitrogen ($r = 0.43$ $p = 0.001$) and between E and pH ($r = -0.26$ $p < 0.05$).

SITE	n°tot taxa	n° bryop.	n° algae	n° amph.	n° helop.	n° hydro.	total cover %	algae cover %	bryop. abund. %	amph. abund. %	helop. abund. %	hydro. abund. %
AdBo	3	1	1	0	1	2	15	15	13	0	25	75
Adgt	8	0	2	0	2	6	100	0,1	0	0	20	80
AdMo	5	1	2	0	1	4	80	80	33	0	22	78
Adnl	6	1	1	0	3	3	30	5	17	0	33	67
AdnP	6	1	1	0	3	3	50	35	13	0	38	63
AdSM	2	1	1	0	0	2	10	9	50	0	0	100
AdTN	11	3	2	0	1	10	10	0,1	45	0	9	91
AdVi	5	1	2	0	1	4	5	0,1	33	0	22	78
Arnò	7	0	0	1	5	1	5	0	0	13	80	7
BaPM	20	0	2	4	7	9	30	10	0	16	28	56
BaSo	28	1	4	4	11	13	15	3	4	18	36	46
BrB2	10	3	2	0	2	8	50	5	33	0	13	88
BrBo	7	2	1	0	2	5	60	1	28	0	22	78
BrG2	9	1	1	1	5	3	50	5	11	11	50	39
BrGr	10	1	4	1	2	7	35	20	16	8	20	72
BrLe	13	2	3	0	5	8	60	10	12	0	27	73
Brnd	17	0	1	1	7	9	100	0	0	3	30	68
BrV2	8	0	1	0	3	5	40	0,1	0	0	28	72
BrVi	8	0	2	1	3	4	55	5	0	13	25	63
Cala	7	2	1	1	2	4	85	10	45	10	10	80
Cald	8	0	0	0	2	5	95	0	0	0	25	65
Ceg2	11	1	2	1	6	4	40	0,1	5	5	59	36
Cegg	10	1	2	1	5	4	85	15	13	4	39	57
Cere	10	0	1	1	4	5	80	2	0	4	43	52
ChPd	6	0	1	0	4	2	60	0,1	0	0	56	44
ChPm	10	3	3	0	3	6	15	5	42	0	25	71
ChSt	10	3	3	0	3	7	20	5	33	0	24	76

SITE	n°tot taxa	n° bryop.	n° algae	n° amph.	n° helop.	n° hydro.	total cover %	algae cover %	bryop. abund. %	amph. abund. %	helop. abund. %	hydro. abund. %
Debb	5	0	0	1	3	1	60	0	0	21	57	21
Duin	6	1	1	1	3	2	5	0,1	14	7	57	36
Ferr	20	0	0	3	9	8	100	0	0	8	44	48
Gheb	9	1	1	3	4	2	90	0,1	4	40	52	8
LaVe	10	0	3	1	5	4	80	20	0	7	59	34
Leno	8	4	0	1	2	5	25	0	44	6	25	69
Lora	12	2	1	1	5	6	70	5	18	7	36	57
Love	7	2	3	0	2	5	70	65	19	0	31	69
Mele	3	3	0	0	0	3	15	0	100	0	0	100
Mogg	2	1	1	0	0	2	15	14	33	0	0	100
Mone	13	0	2	2	2	9	60	10	0	15	7	78
NoRo	10	0	3	0	6	4	40	22	0	0	50	50
NoRu	8	3	2	0	1	7	70	50	38	0	14	86
Palv	7	1	2	0	3	4	15	0,1	14	0	43	57
Pona	5	2	3	0	0	5	40	5	58	0	0	100
Rabb	4	2	1	0	1	3	0,1	0,1	50	0	25	75
Res2	5	1	0	1	1	3	85	0	19	31	25	44
Rese	7	2	1	1	1	5	80	0,1	28	28	22	50
Rimo	21	2	3	6	8	6	80	50	9	30	34	34
RoFr	9	0	0	0	6	3	95	0	0	0	54	46
SaDr	14	0	2	1	9	4	50	0,1	0	5	45	50
Salè	7	2	1	0	4	3	70	0	54	0	38	62
SaLi	15	0	3	1	9	4	60	2	0	7	60	30
Saln	11	1	0	1	4	6	70	0	13	3	23	74
Salo	7	0	0	0	1	6	95	0	0	0	24	76
SaPA	6	0	1	0	3	3	40	0,1	0	0	44	56
SaRa	16	1	2	1	8	7	50	5	8	3	42	56
Sel1	9	1	0	2	6	1	60	0	4	33	63	4
Sel2	9	1	0	1	6	2	30	0	21	21	57	21
Spor	7	1	1	0	5	2	5	2,5	8	0	69	31
SZe2	7	0	0	0	2	5	100	0	0	0	19	81
SZen	9	0	0	1	5	3	90	0	0	9	50	41
TeBo	14	0	4	2	0	12	85	50	0	7	0	93
TeL2	19	0	0	5	7	7	85	0	0	28	34	38
TeLu	15	0	0	5	6	4	100	0	0	28	33	40

Table 7.7: For each site the following metrics are reported: total number of taxa (n° tot taxa), number of bryophyte species (n° bryop.), number of filamentous algae genera (n° algae), number of amphiphyte species (n° amph.), number of helophyte species (n° helop.), number of hydrophyte species (n° hydro.), total percentage cover of macrophytes with respect to the total site surface (total cover %), filamentous algae percentage cover on the total surface (algae cover %), bryophyte percentage abundance on the total macrophyte abundance (bryop. abund. %), amphiphyte percentage abundance on the total macrophyte abundance (amph. abund. %), helophyte percentage abundance on the total macrophyte abundance (helop. abund. %) and hydrophyte percentage abundance on the total macrophyte abundance (hydro. abund. %).

The negative correlation diversity-altitude is very significant and the low r values could be explained by the fact that some sites, located at intermediate elevation (e.g. Brenta Levico, 470 m a.s.l.), have a quite various macrophyte community because they flow in plain areas, at the bottom of the valley and have therefore characteristics similar to lowland water courses.

The most significant and strong correlation is that with nitrate concentration, which seems to indicate that an increase in nitric nitrogen concentration enhances the development of a rich aquatic plant community (Bornette et al., 1998; Szoszkiewicz et al., 2006).

Tab 7.7 shows the absolute number of taxa and the percentage abundance, relative to the total abundance, of the various biological types composing the macrophyte community at each sampling site.

We searched for possible correlations between each macrophyte metric and the chemical variables and since the data variables are partially continuous (chemical variables and percentage covers) and partially not continuous, we calculated both the Pearson's and the Spearman Rank correlation coefficients. The results are reported in **Tab 7.8** and **7.9**.

If we compare the two methods we can see that they did not give the same results and the Spearman Rank test gives in general more significant and stronger correlations.

PEARSON	Cond.	Hard.	pH	BOD5	N_NH4	N_NO3	P_PO4	PTOT
n°tot taxa	0,26*	0,29*				0,47***		
n°briop.						-0,38**	-0,33**	-0,33**
n°filam. algae								
n°amph.		0,25*	-0,27*	-0,29*		0,40**		
n°heloph.								
n°hydro.		0,29*	-0,27*			0,44***		
total cover %	0,39**	0,32*			0,25*			
fil. algae cover %								
bryop. abund. %					-0,26*	-0,38**	-0,33*	-0,32*
amph. abund. %				-0,37**				
helop. abund. %								
hydro. abund. %								

Table 7.8: Pearson's correlation coefficients between macrophyte community metrics (see **Tab 7.7** for abbreviations) and chemical parameters: Cond. = electrical specific conductance at 20℃, Hard. = total hardness, pH = pH, BOD5 = biochemical oxygen demand-5 days, N_NH4 = ammoniac nitrogen, N_NO3 = nitric nitrogen, P_PO4 = ortophosphoric phosphorus, PTOT = total phosphorus. Only significant values are reported: *p < 0.05 **p< 0.01 ***p<0.001.

Nonetheless there are many correlations that do not depend on the particular algorithm, since they resulted from the applications of both methods. An important data is the absence of correlation between filamentous algae, both the cover and the number of

taxa, and all the chemical parameters. Moreover it must be pointed out that there are more significant values concerning the number of taxa rather than the percent abundance.

SPEARMAN	Cond.	Hard.	pH	BOD5	N_NH4	N_NO3	P_PO4	PTOT
n°tot taxa						0,51***	0,25*	
n°briop.		-0,31*				-0,44***	-0,42***	-0,36**
n°filam. algae								
n°amph.				-0,28*		0,40**		
n°heloph.						0,41**		
n°hydro.			-0,29*			0,35**	0,31*	
total cover %	0,47***	0,38**	-0,26*			0,42***		
fil. algae cover %								
bryop. abund. %	-0,38**	-0,33**				-0,51***	-0,45***	-0,37**
amph. abund. %				-0,34**	-0,25*			
helop. abund. %								
hydro. abund. %				0,27*				

Table 7.9: Spearman Rank correlation coefficients between macrophyte community metrics (see **Tab 7.7** for abbreviations) and chemical parameters (see **Tab 7.8** for abbreviations). Only significant values are reported: *p < 0.05 **p< 0.01 ***p<0.001.

Once again we found out that the species diversity of the site is positively dependent on the nitrate concentration and the same can be said for the amphiphytes and the hydrophytes.

Both the bryophyte abundance and number of taxa have a highly significant and quite strong negative correlation with nitrate and ortophosphate, while the dependence on total phosphorus concentrations is less significant and lower in value.

The results given by the Spearman Rank test for the macrophyte metrics combined with the environmental variables of sites are shown in **Tab 7.9**. It is interesting to note that no metrics are correlated to the average depth and to the land use of the site. The most significant and strongest correlations are those with the flow speed and therefore with substrate texture as well, since the two factors are in turn highly correlated to each other ($\rho = 0.61$ and $p < 0.0001$). The filamentous algae presence (both the cover and the number of taxa) has a positive correlation with the increasing flow speed and substrate texture and even stronger is that of bryophytes with the same variables, while the total macrophyte cover and the amphiphyte abundance and number of taxa are negatively dependent on the water velocity and the granulometry of the sediment. Similar relations, going in the same direction, are those with the elevation of the site, with the exception of filamentous algae cover and diversity that are not dependent at all on the altitude.

Quite significant seems to be also the negative correlation between the number of filamentous algae taxa and the basin dimension and therefore we could affirm that the

blanket weed preferably colonizes large watercourses with high speed and coarse substrate.

SPEARMAN	Width	Depth	Speed	Shade	Subst	Artif	LUR	LUL	Elev	BaDim
n°tot taxa			-0,26*			0,29*			-0,41***	
n°briop.			0,35**	0,31*	0,37**				0,33**	
n°filam. algae	0,36**		0,40**		0,33**					-0,36**
n°amph.			-0,45***		-0,27*	0,26*			-0,55***	
n°heloph.										
n°hydro.						0,25*			-0,30*	
total cover %	-0,31*		-0,54***		-0,60***				-0,44**	0,31*
fil. algae cover %	0,29*		0,35**		0,34**					-0,30*
bryop. abund. %			0,42***	0,32*	0,40**				0,35**	
amph. abund. %			-0,44***		-0,33**				-0,48***	0,26*
helop. abund. %										0,27*
hydro. abund. %			0,29*							-0,30*

Table 7.10: Spearman Rank correlation coefficients between macrophyte community metrics (see **Tab 7.7** for abbreviations) and site feature: Width = average width of the sampling reach, Depth = average depth of the sampling reach, Speed = flow velocity of the water course at the sampling site, Shade = degree of shading on the surface of water, Subst = substrate granulometric composition, Artif = degree of morphological artificialization on the water course, LUR =land use on the right side, LUL = land use on the left side, Elev = altitude of the site above sea level, BaDim = dimension of the watercourse basin. Only significant values are reported: *p < 0.05 **p< 0.01 ***p<0.001.

7.7 MATCHING-TWO-TABLE ANALYSIS: SPECIES ABUNDANCE AND SITE CHEMICAL PARAMETERS

The Co-inertia Analysis is the first approach that we used in order to match the data about species abundances and data regarding the water chemistry of the sampling sites. The canonical weights were attributed to the species matrix (X array) through a Correspondence Analysis (**Fig 7.12**) and to the chemical variable array (Y array) through a PCA on normalized data (**Fig 7.13**). Finally the projection of sites on the first two axes, on the basis of canonical weights is shown in **Fig 7.14** together with the projection of the principal axes of the two tables (species and chemistry) on co-inertia axes.

The eigenvalues of the Co-inertia Analysis are reported in **Tab 7.11** together with the percentage of variance explained by each factor and **Fig 7.15** shows the eigenvalues screeplot. As can be seen, the first two axes together explain more than 75 % of the variance.

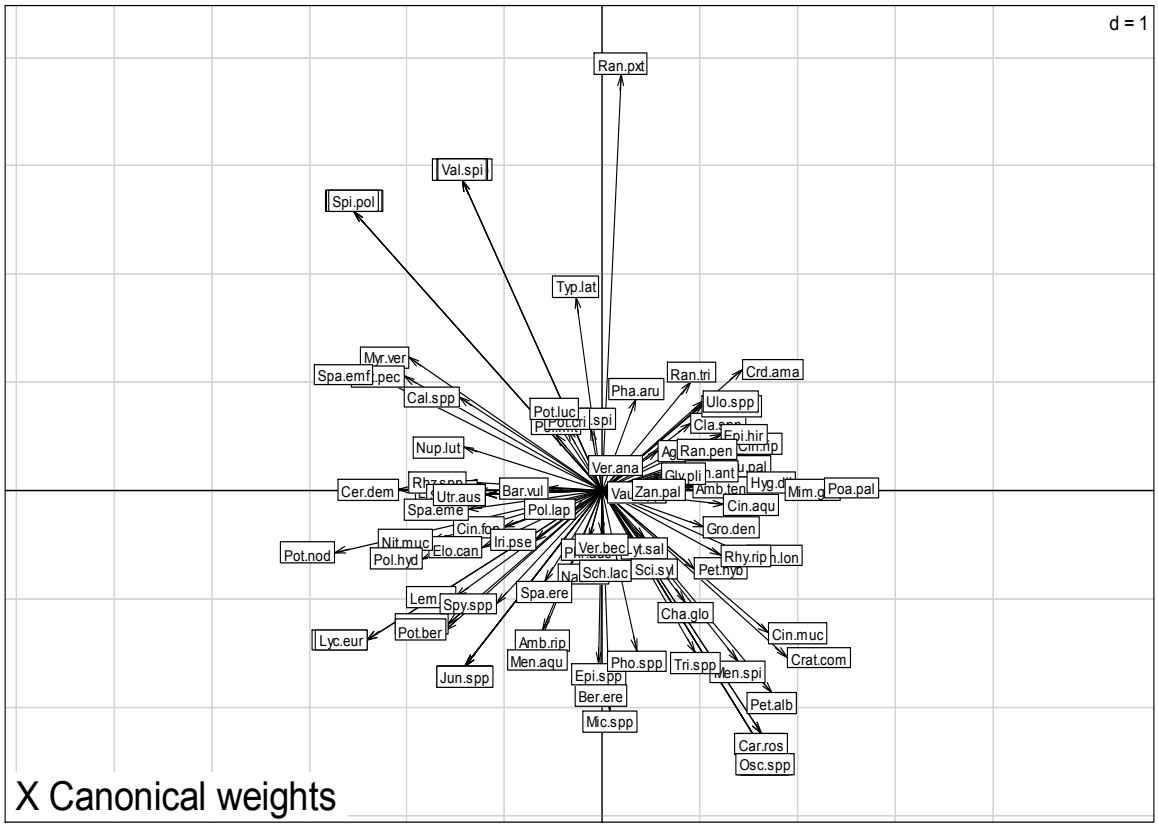

Figure 7.12: canonical weights of species variables for co-inertia on species and chemical variables.

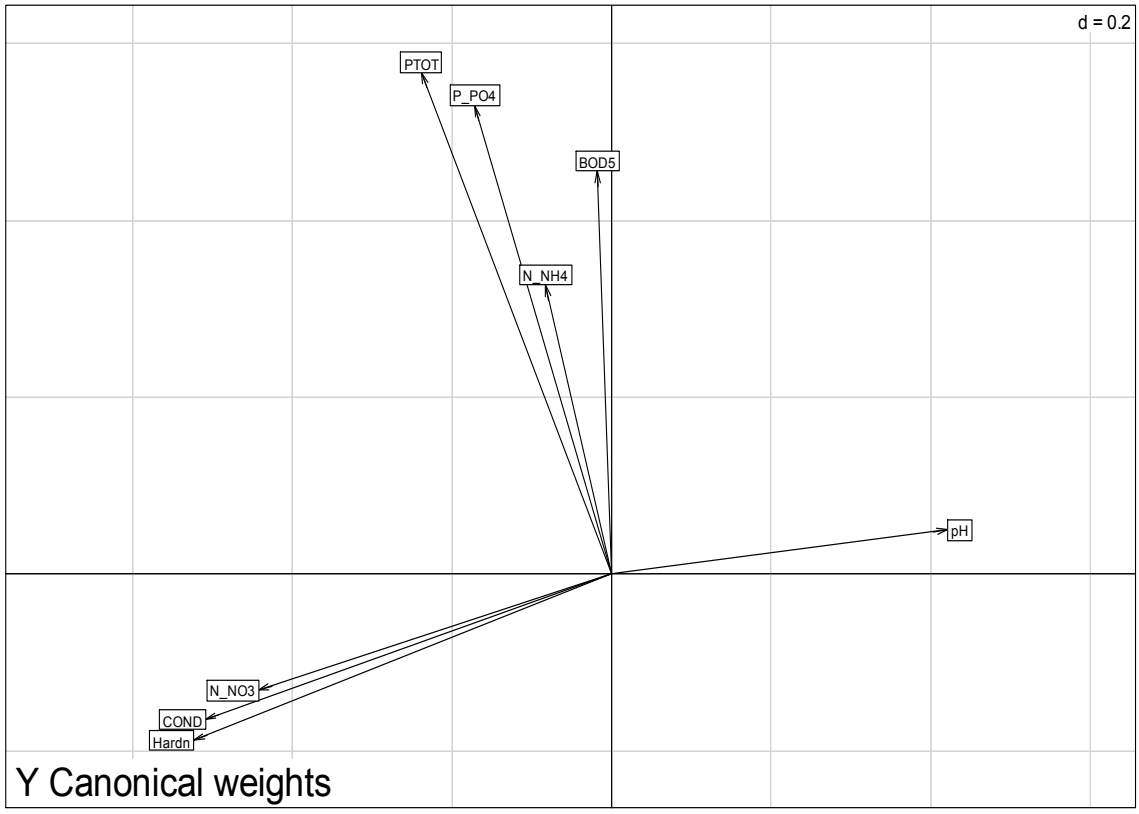

Figure 7.13: canonical weights of chemical variables for co-inertia on species and chemical variables.

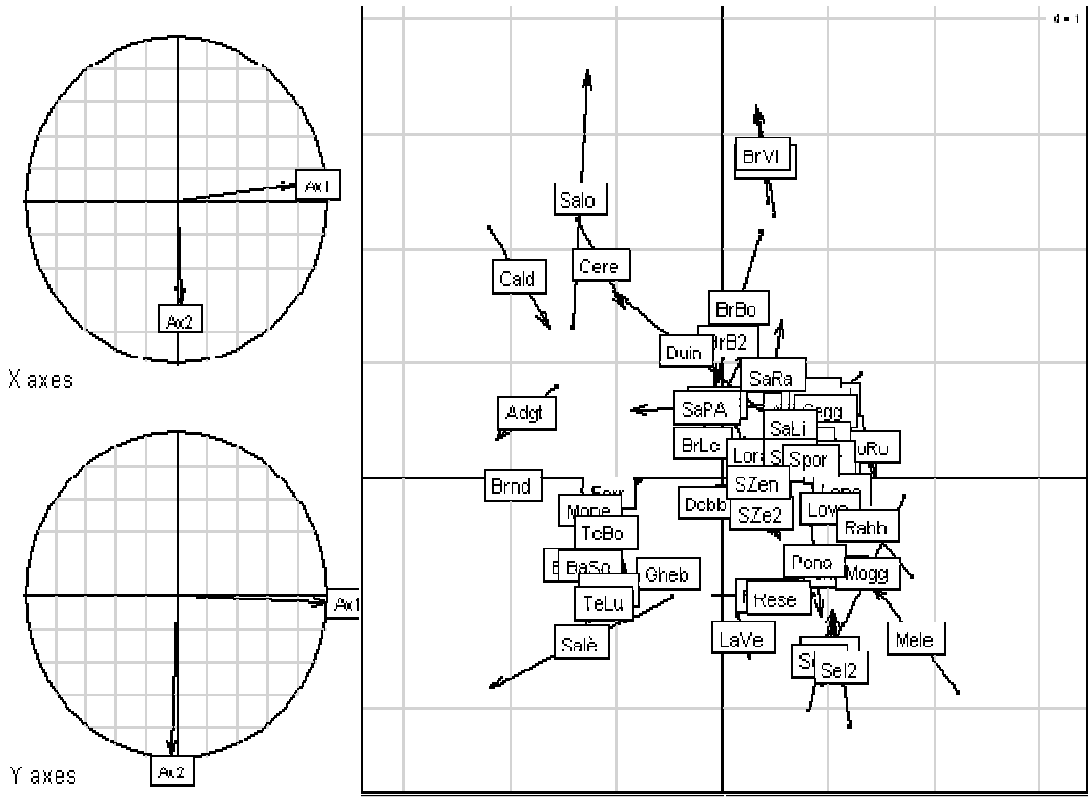

Figure 7.14: Plot of the co-inertia analysis on species and site chemistry arrays: projection of the principal axes of the two tables (species and chemistry) on co-inertia axes and joint display of the sites.

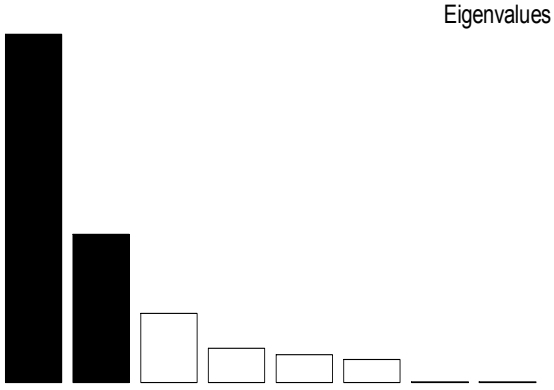

Figure 7.15: Eigenvalues screeplot for co-inertia on species and chemical variables.

Factor	Eigenvalue	Explained variance
1	0.531667345	53.2 %
2	0.226154394	22.6 %
3	0.106430328	10.6 %
4	0.053086543	5.3 %
5	0.043372480	4.3 %
6	0.036280289	3.6 %
7	0.001835217	0.2 %
8	0.001173405	0.1 %

Table 7.11: Eigenvalues of each factor and percentage of variance explained by each factor for co-inertia on species and chemical variables.

The significance of the Co-inertia Analysis was tested through a Monte Carlo test, based on 999 permutations, which gave a significance level p = 0.001 that is the highest possible value for 999 permutations. The results of the Monte Carlo test are shown in **Fig 7.16**, where the simulated values are plotted in the histograms and the observed

value is represented by the vertical line. Since the observed value is very far from those simulated, the test indicates a high significance level of the performed analysis.

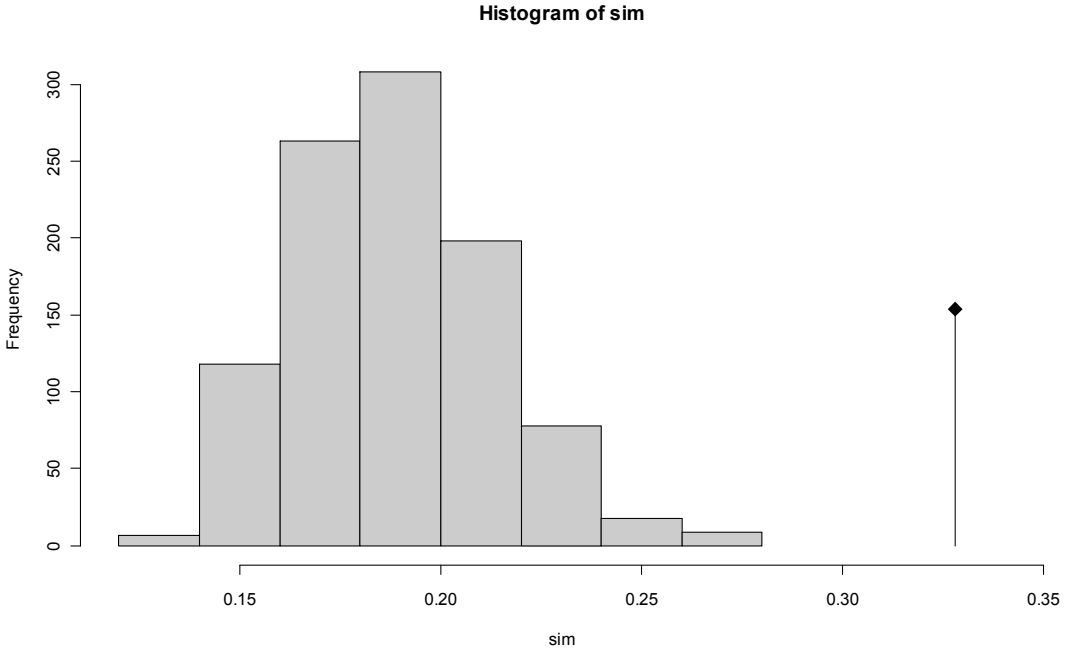

Figure 7.16: Plot of Monte Carlo permutation test for co-inertia on species and chemical variables. Histograms of simulated values and observed value (vertical line).

The distribution of species on the horizontal axis is dominated by hardness and conductivity, which are in turn highly related to each other, and by the nitrate concentration. The latter result is consistent with the correlation coefficients found for the macrophyte metrics.

On the vertical axis the driving force for species distribution is represented especially by phosphor concentration, both ortophosphate and total phosphorus, that are closely related to each other. Even if the species distribution is quite continuous, if we look at the sites in **Fig 7.14** we can see that they are clearly dislocated according to two gradients that can be identified with those reported above.

The Procrustes analysis applied to the same arrays (species and chemistry) gave very similar results. With this method the single arrays are analyzed with a Principal Component Analysis and the results are shown in **Fig 7.17** for species abundance array (Loadings 1) and in **Fig 7.18** for chemical parameters matrix (Loadings 2). Finally the two data sets are displayed in a common projection after rotation in order to obtain the maximum fitting between the two arrays. The common projection is reported in **Fig 7.19**.

The eigenvalues are plotted in **Fig 7.20** and listed in **Tab 7.12**, with the percentage of variance explained by each component. The eigenvalues of the procrustean rotation are quite similar to those of the co-inertia analysis, proving that the results are sound. The first two components explain more than 80 % of the variance.

For the procrustean rotation a random test, called Protest was run to verify the significance of the analysis and it gave p = 0.001 as a result. The Protest is plotted in **Fig 7.21** and shows a high significance of the Procrustes analysis.

The loadings of chemical variables are very similar to the canonical weights attributed in the co-inertia analysis, and the same driving forces with nearly the same directions of vectors are detected.

The species projection presents some differences from the co-inertia, concerning the length of arrows; still the species are distributed in a very similar manner to that traced out by the co-inertia analysis.

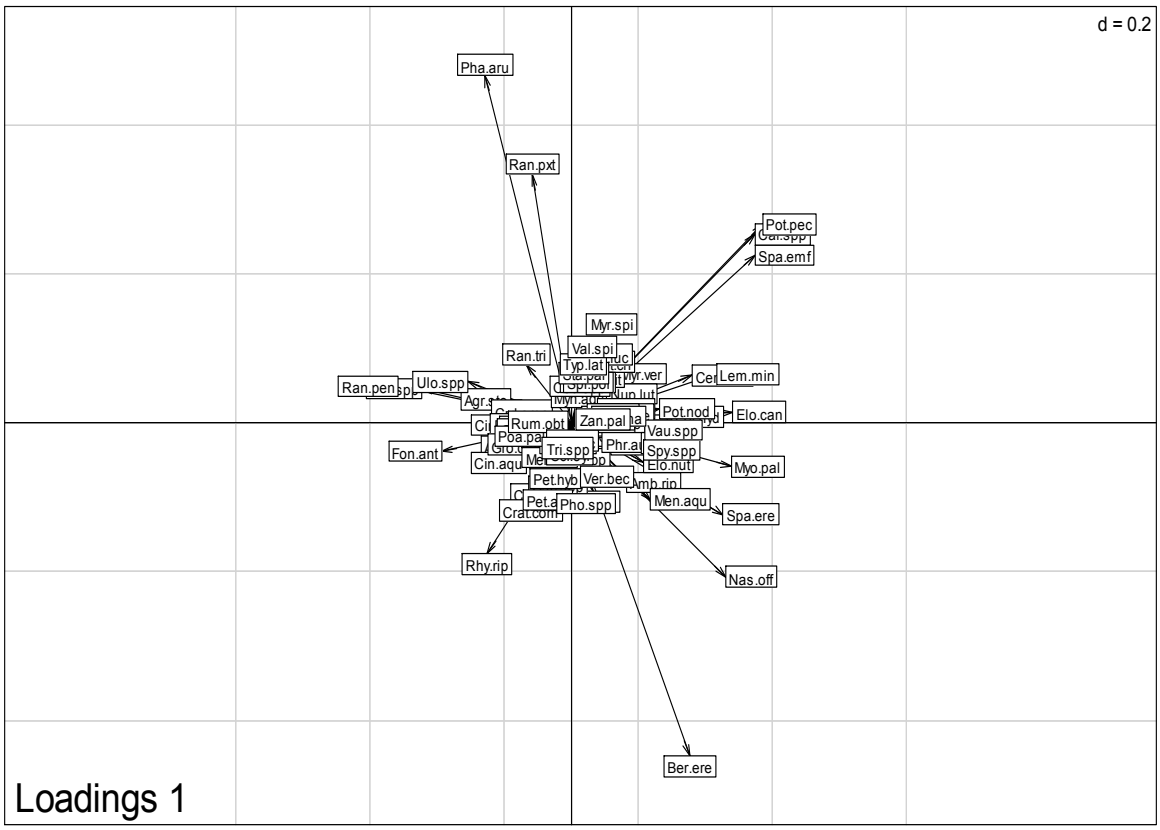

Figure 7.17: Procrustes analysis on species and chemical variable arrays: loadings for species.

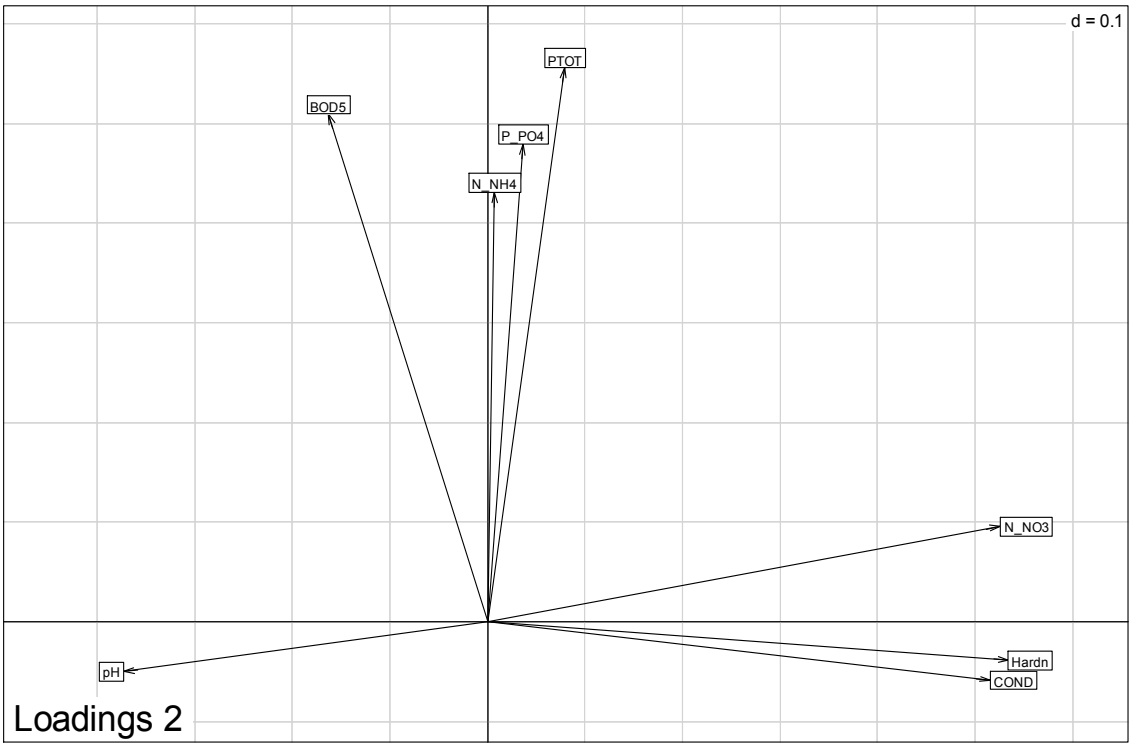

Figure 7.18: Procrustes analysis on species and chemical variable arrays: loadings for chemical variables.

In the common projection of sites there is a pattern similar to that represented by the co-inertia analysis and the majority of the sampled stations lies in a dense cloud near the origin that indicates their similarity with respect to the two plotted components. This means that most of the sites are not significantly differentiated either by their phosphor, ammonium and BOD5 levels or by the nitrate concentration or hardness. On the vertical axis we have a minimum of nutrient concentration represented by sites like Fosso Selva and La Vena, corresponding to a low trophic value for *Berula erecta*, and a maximum for Fossa di Salorno and Brenta Villa Agnedo, corresponding to species like *Ranunculus pencillatus x trichophyllus, Phalaris arundinacea, Potamogeton pectinatus, Sparganium emersum* fo. *fluitans* and *Callitriche* spp. On the horizontal axis there is a group of sites which is distinct from the other, because of a higher conductivity or nitrate concentration. It includes Fiumicello Brendola, Roggia Moneghina, Tesina Bolzano Vicentino, Tesina Lupia di Sandrigo 1st and 2nd sample, Canale Ferrara, Bacchiglione Sorgente, Bacchiglione Ponte Marchese, Salè and Ghebbo, while the Adigetto, being more upwards, has also increased phosphorus concentrations. The species are distributed along the horizontal axis quite close to each other, meaning that there is not a clear conductivity (or hardness) and nitrate gradient for the recorded species. Nonetheless some distinctions are still possible, for example between *Ranunculus penicillatus* ssp. *pseudofluitans* on the left side, corresponding to lower conductivity, hardness and nitrate concentration, and *Elodea canadensis* on the right

side and therefore preferring higher conductivity and nitrate levels (Demars & Thiébaut, 2008).

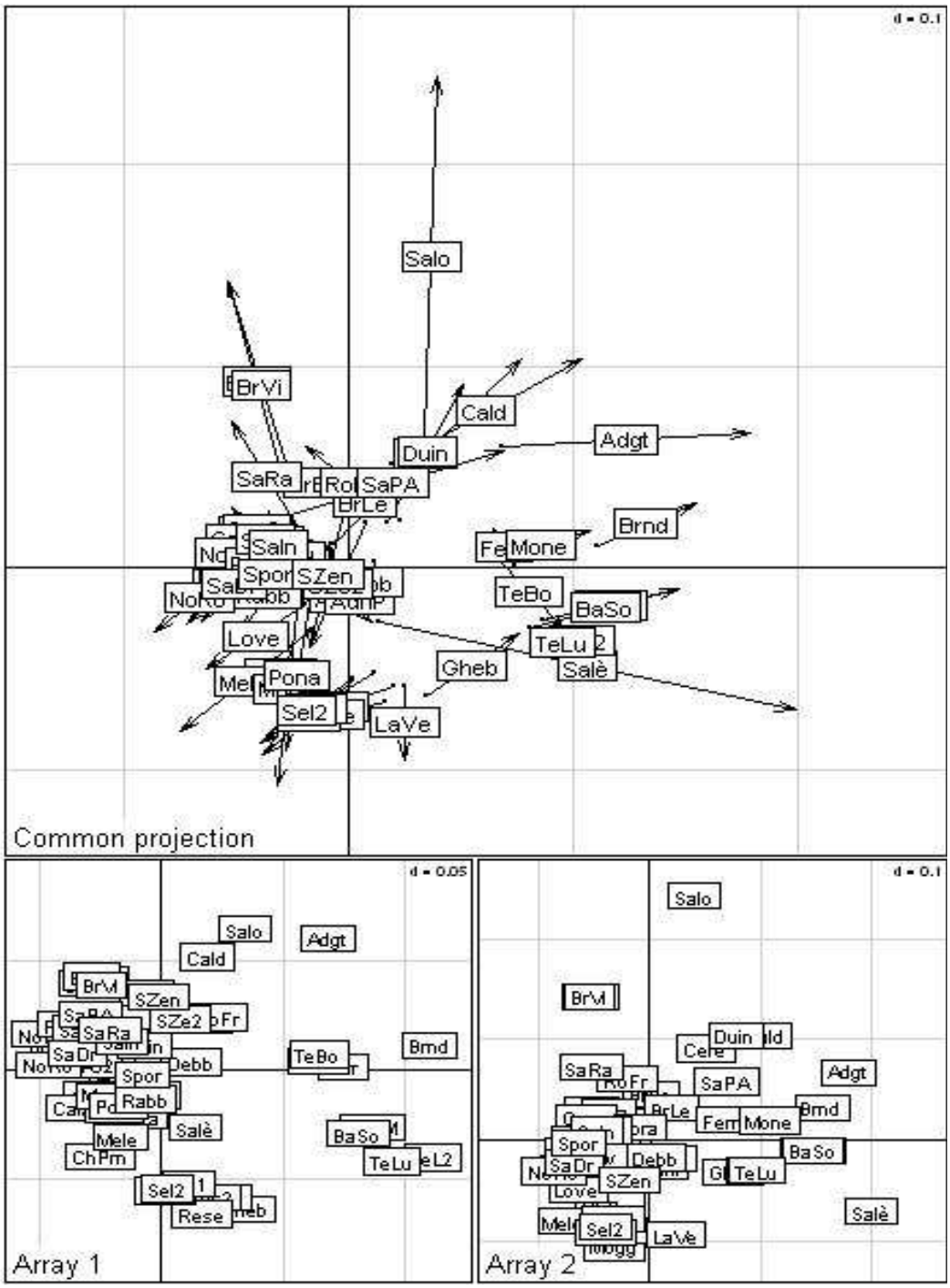

Figure 7.19: Plot of the Procrustes analysis on species and chemical variable arrays: scores of sites for the two data sets (Array 1 and Array 2), and projection of the two sets of sites after rotation (arrows link chemistry site score to the species site score).

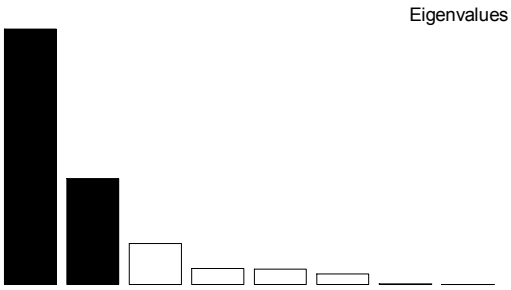

Figure 7.20: Eigenvalues screeplot for procrustes analysis on species and chemical variable arrays.

Factor	Eigenvalue	Explained variance
1	0.572027829	57.2 %
2	0.237632932	23.8 %
3	0.091743489	9.2 %
4	0.036491573	3.6 %
5	0.034869529	3.5 %
6	0.024547854	2.4 %
7	0.001683376	0.2 %
8	0.001003418	0.1 %

Table 7.12: Eigenvalues of each factor and percentage of variance explained by each factor for procrustes analysis on species and chemical variable arrays.

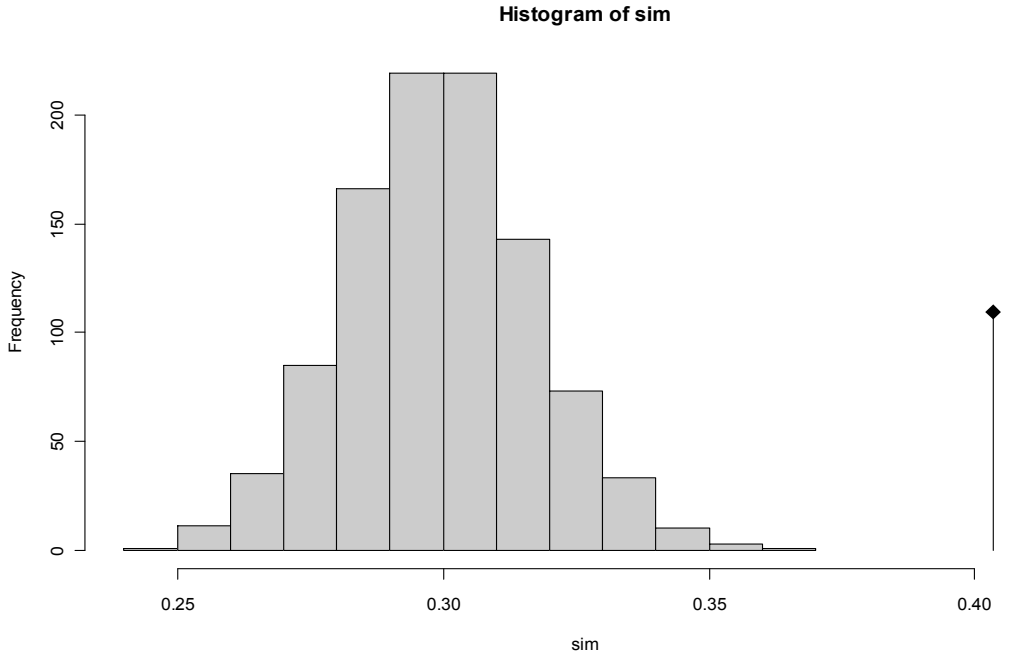

Figure 7.21: Plot of the Protest for procrustes analysis on species and chemical variables. Histograms of simulated values and observed value (vertical line).

7.8 MATCHING-TWO-TABLE ANALYSIS: SPECIES ABUNDANCE AND SITE FEATURES

The co-inertia analysis was applied also to the species abundance matrix and the site feature matrix, in order to find the main driving forces for macrophyte vegetation composition and distribution among the various abiotic characters of the site.

In **Fig 7.22** and **7.23** we can see the canonical weights attributed to the species array (X array) and the site feature array (Y array).

Figure 7.22: canonical weights of species variables for co-inertia on species and site variables.

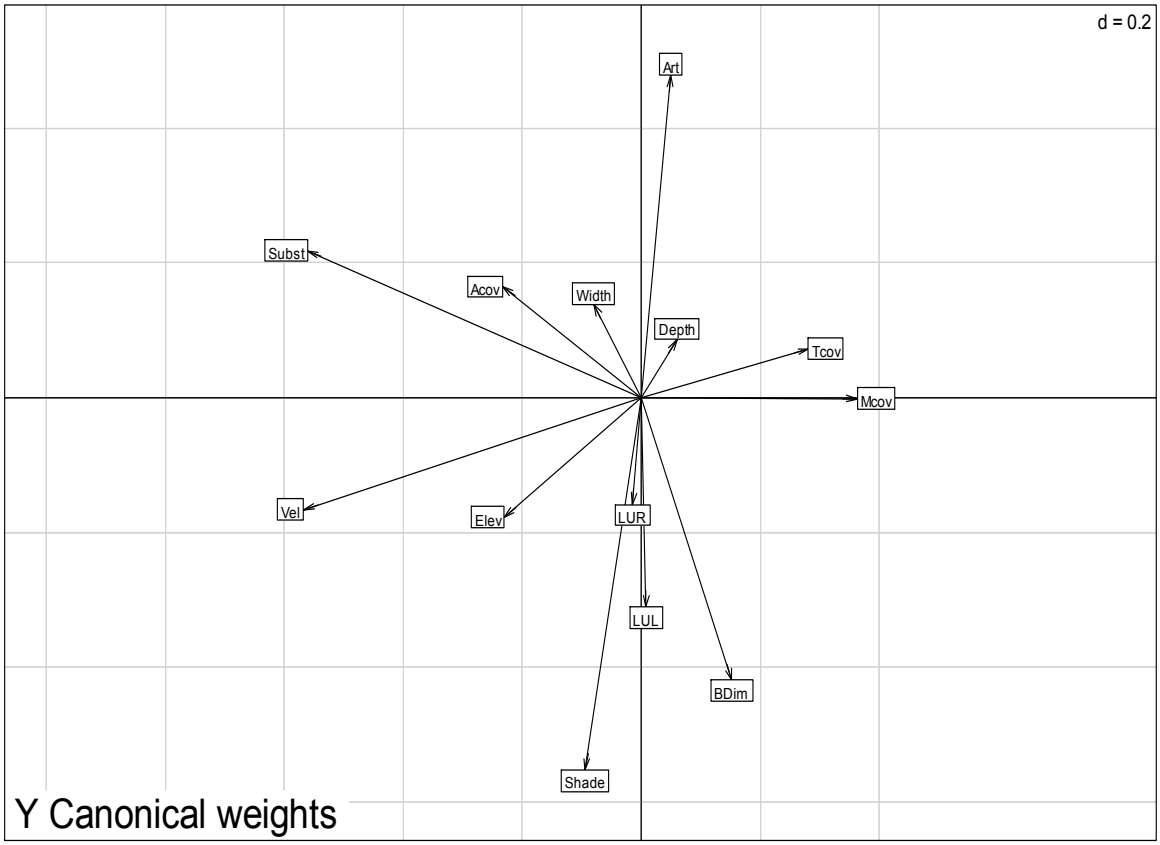

Figure 7.23: canonical weights of site variables for co-inertia on species and site variables.

As for the species, most of them are distributed into two groups with regards to the horizontal axis and the remaining ones are more conditioned by the vertical gradient.
Considering the loadings for site variables, it is extremely evident that the increase of the total cover of aquatic vegetation is right opposite to the increase of water velocity and, to some extent, to the substratum coarseness. Of course the macrophyte cover is closely related to the total cover, but the algae cover is directly and positively influenced by the increase of sediment granulometry and the width of the watercourse. The relation with the coarse substrate is due to the fact that often the blanket weed grows on boulders and cobbles.
Moreover the development of macrophyte patches is negatively dependent on the elevation of the site.
If flow speed and substratum type are the main factors on the horizontal direction, the degree of artificialization of the river is the main driving force on the vertical axis, in opposition to the increase of shade, the naturalness of the land use on both sides and the decrease of the dimension of the basin or sub-basin[6]. The depth of the river does not play an important role, as shown by the reduced length of the arrow.
Fig 7.24 shows the joint display of sites on the first two axes and the projection of the principal axes of the two tables (species and site features) on co-inertia axes and it is very easy to see that many sampled stations are distributed along the same direction of the velocity variable. Besides, there is a group that seems to be more influenced by the increase of substrate coarseness and by a more human-impacted fluvial morphology.
The eigenvalues of the co-inertia analysis are plotted in **Fig 7.25**. As can be seen in **Tab 7.13** that reports the eigenvalues and the explained variance for each factor, the first axis alone accounts for more than 63 % of the variance. It means that the main driving force for macrophyte vegetation, both in terms of abundance and specific composition, is represented by two important factors, such as the water velocity and the granulometry of the river bottom.
We applied a Monte Carlo permutation test, based on 999 permutations, in order to verify the significance of the results obtained through the co-inertia analysis. The results are plotted in **Fig 7.26** where the histogram represents the simulated values and the vertical line the observed value. The test points out a high significance of the co-inertia analysis.
On species abundance array and site feature array we applied the procrustes analysis as well. The loadings 1 for species are shown in **Fig 7.27**, while the loadings 2 for site features are represented in **Fig 7.28**. The results of the procrustean rotation for site variables are nearly identical to those of the co-inertia analysis. As for the species distribution, it is very similar to the previous one, even if the length of the arrows for some species changes according to the method used (co-inertia or procrustes). **Fig 7.29**

[6] This variable has been codified in such a manner that 1 corresponds to the main rivers and streams, having bigger dimension, and 6 to the smallest brooks and streams. The arrow direction in **Fig 7.23** indicates therefore the decrease of the basin dimension.

shows the scores of sites for the two data sets (species array and site variable array) and the common projection of the two sets of sites after rotation. The eigenvalues and the explained variance are showed in **Fig 7.30** and in **Tab 7.14**. The significance of the analysis was tested through the Protest, which gave the diagram in **Fig 7.31** as output and a value p = 0.001 indicating the high significance of the procrustean rotation.

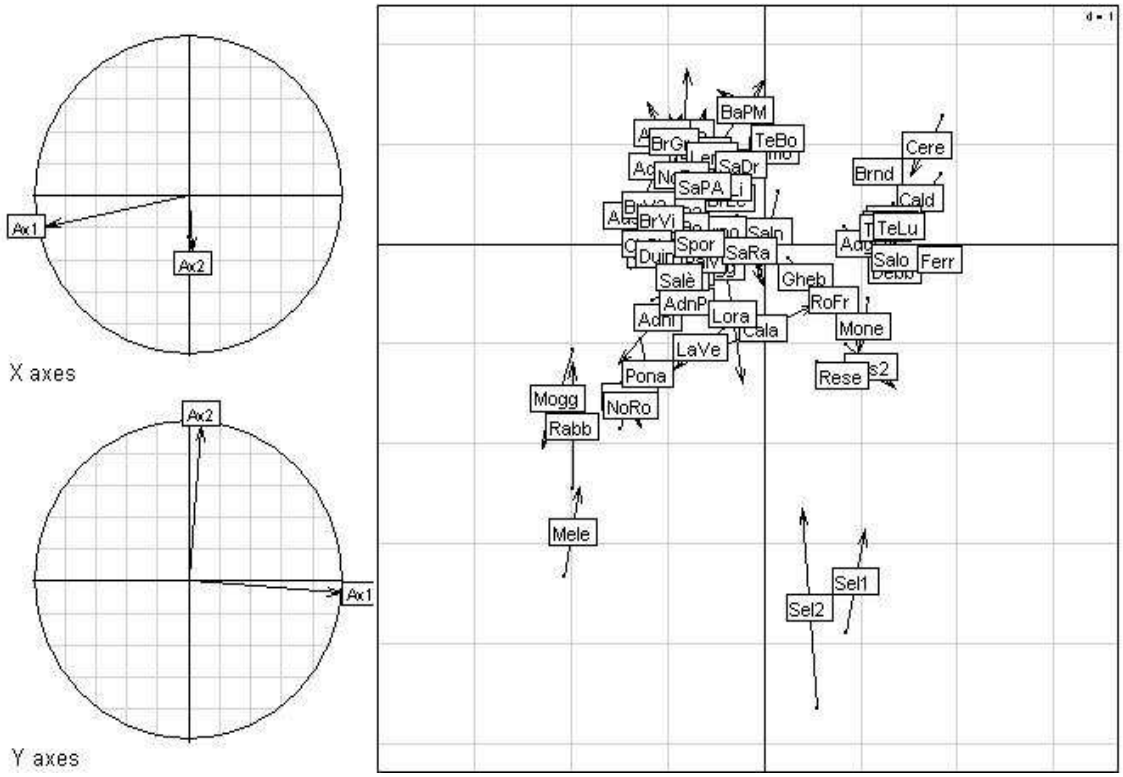

Figure 7.24: Plot of the co-inertia analysis on species and site feature arrays: projection of the principal axes of the two tables (species and site features) on co-inertia axes and joint display of the sites.

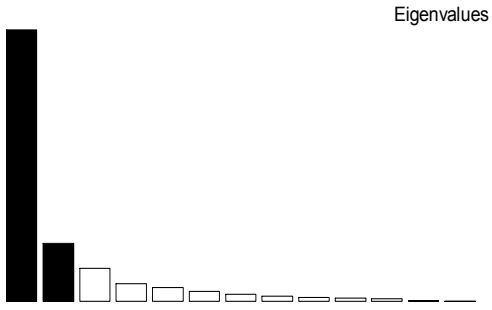

Figure 7.25: Eigenvalues screeplot for co-inertia on species and site variables.

Factor	Eigenvalue	Explained variance
1	0.6348616718	63.5 %
2	0.1356607542	13.6 %
3	0.0772341551	7.7 %
4	0.0413036428	4.1 %
5	0.0325123452	3.3 %
6	0.0236594220	2.4 %
7	0.0171630431	1.7 %
8	0.0116381922	1.2 %
9	0.0094727934	0.9 %
10	0.0074739330	0.7 %
11	0.0059805333	0.6 %
12	0.0022113307	0.2 %
13	0.0008281832	0.1 %

Table 7.13: Eigenvalues of each factor and percentage of variance explained by each factor for co-inertia on species and site variables.

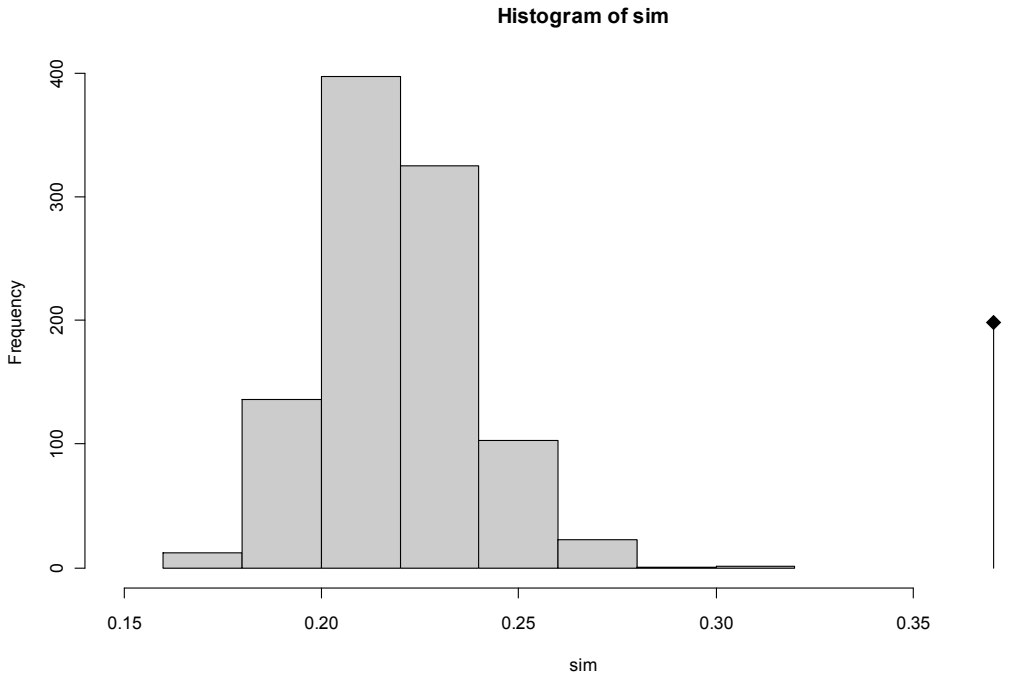

Figure 7.26: Plot of Monte Carlo permutation test for co-inertia on species and site variables. Histogram of simulated values and observed value (vertical line).

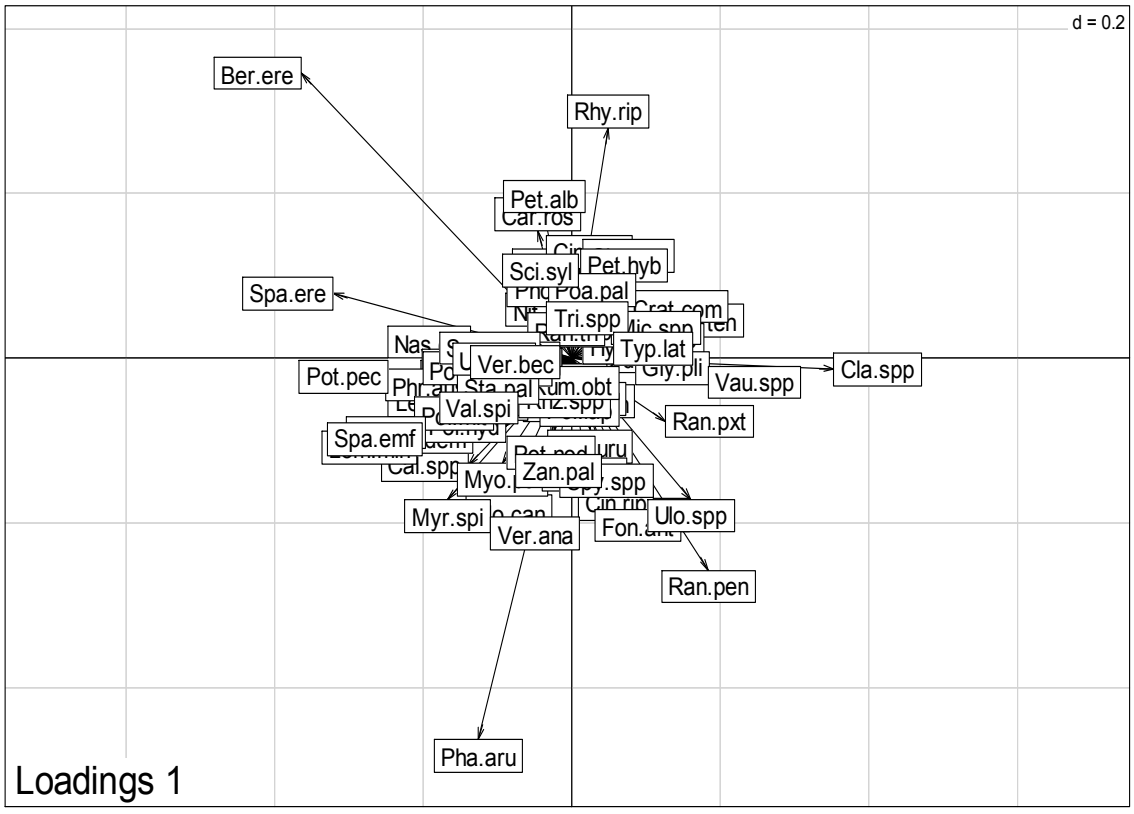

Figure 7.27: Procrustes analysis on species and site features arrays: loadings for species.

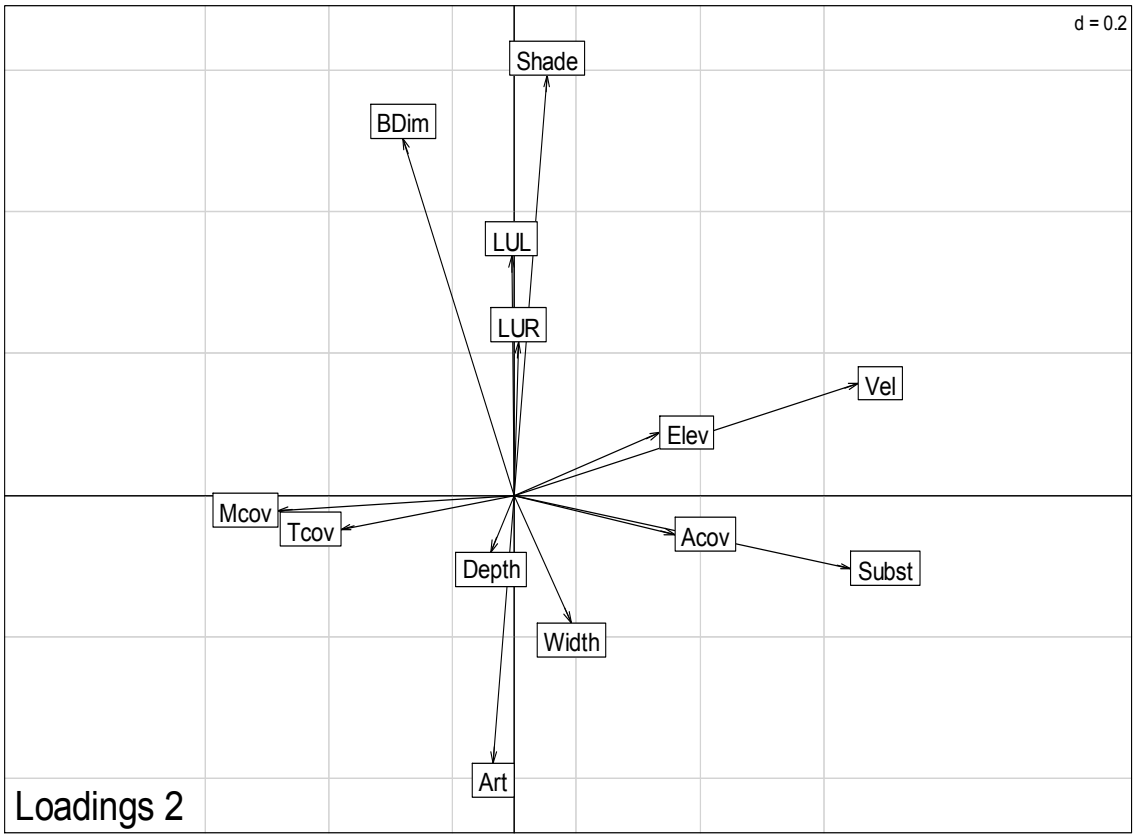

Figure 7.28: Procrustes analysis on species and site features arrays: loadings for chemical variables.

The eigenvalues of the procrustes analysis are very similar to those of the co-inertia analysis and in both cases the first two axes together account for about 80 % of the variance. This means that the macrophyte vegetation is determined largely by those site variables identified above, that are nearly corresponding to axis 1 and 2.

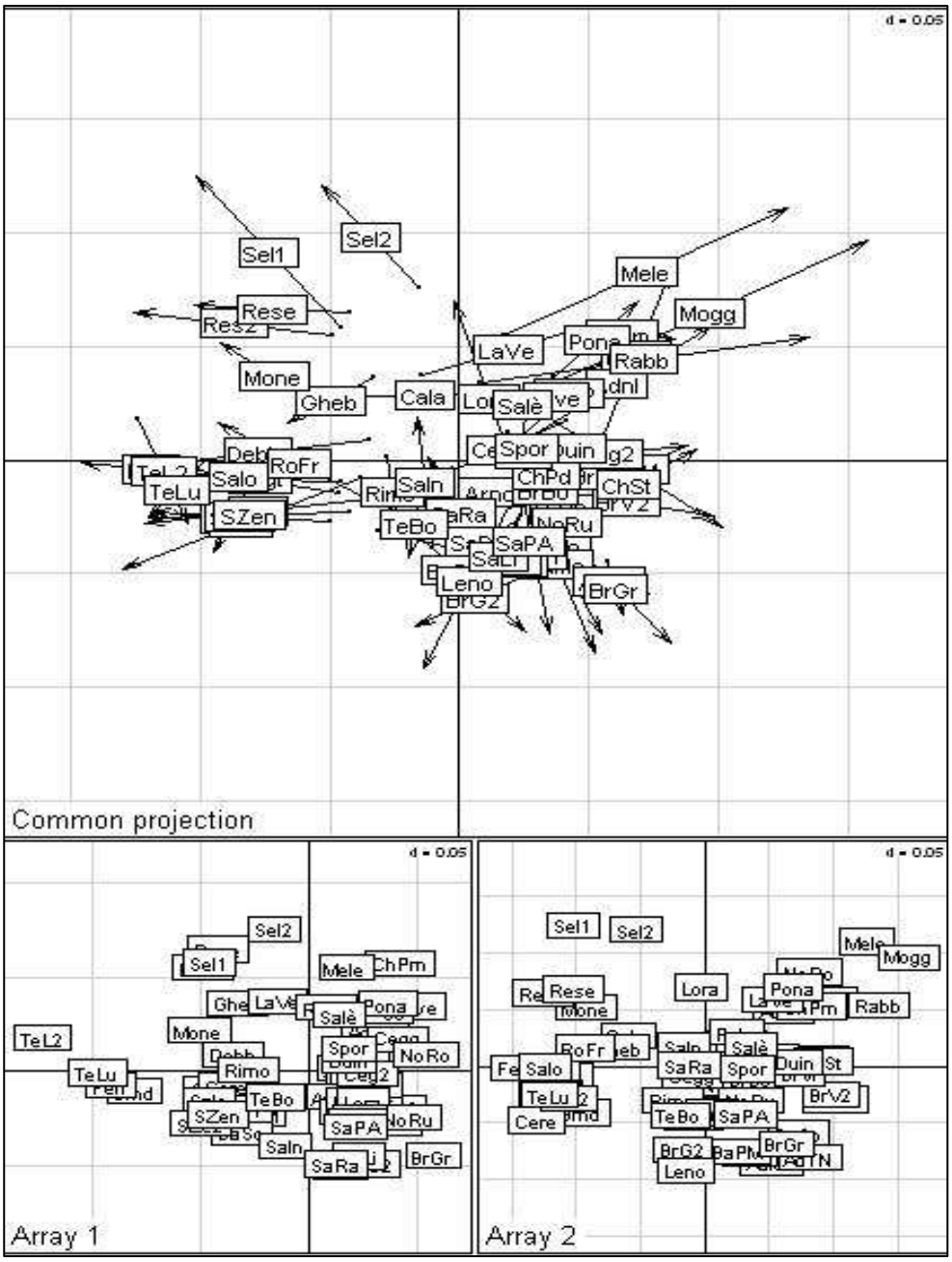

Figure 7.29: Plot of the Procrustes analysis on species and site features arrays: scores of sites for the two data sets (Array 1 and Array 2), and projection of the two sets of sites after rotation (arrows link feature site score to the species site score).

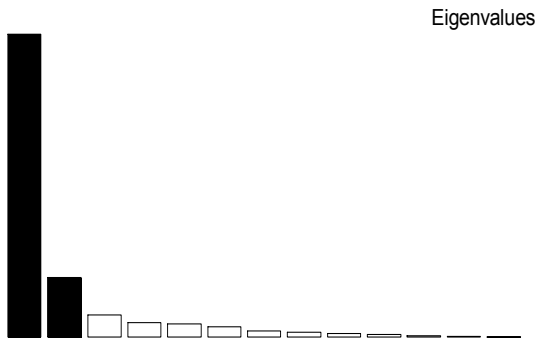

Figure 7.30: Eigenvalues screeplot for procrustes analysis on species and site variables.

Factor	Eigenvalue	Explained variance
1	0.6797456922	68.0 %
2	0.1338784897	13.4 %
3	0.0509245115	5.1 %
4	0.0336034230	3.4 %
5	0.0309194015	3.1 %
6	0.0235978663	2.3 %
7	0.0154341044	1.5 %
8	0.0112175370	1.1 %
9	0.0083266016	0.8 %
10	0.0062197771	0.6 %
11	0.0038327009	0.4 %
12	0.0016914338	0.2 %
13	0.0006084609	0.1 %

Table 7.14: Eigenvalues of each factor and percentage of variance explained by each factor for procrustes on species and site variables.

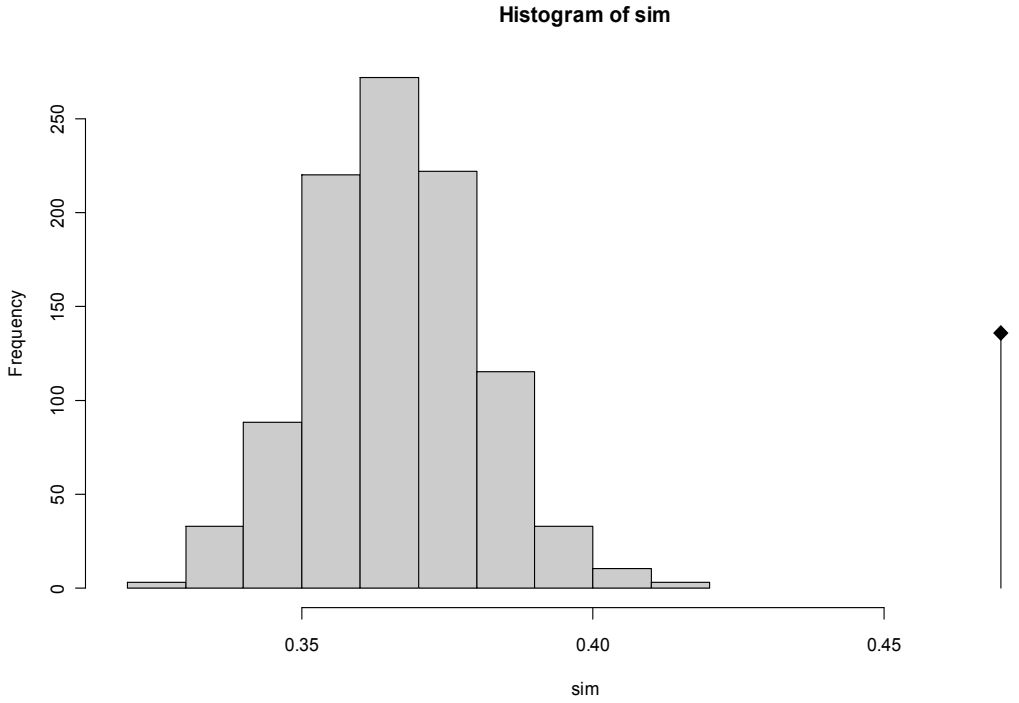

Figure 7.31: Plot of the Protest for procrustes analysis on species and site variables. Histograms of simulated values and observed value (vertical line).

7.9 MATCHING-TWO-TABLE ANALYSIS: SPECIES ABUNDANCE, CHEMICAL PARAMETERS AND SITE FEATURES

The last analysis on two tables was applied to the species array and to a matrix obtained from the combination of chemical data and site variables. Since the results of co-inertia and procrustes analysis showed to be very similar, in this case we used the procrustes analysis alone for the working out of data.

Fig 7.32 shows the loadings for species (loadings 1) while **Fig 7.33** reports the loadings for site variables (included chemical parameters).

Most species are distributed around the origin of the axes, meaning that their occurrence at different sites cannot be clearly related with one of the driving forces corresponding with axis 1 or 2.

As for the site variables we can see that they are mainly correspondent with the 1st and the 2nd axis. On the horizontal direction the coarseness of substrate, the flow velocity and the altitude of the river reach are oriented in opposition with increasing conductivity and hardness. On the vertical axis the artificialization of the site (hidden behind the ammonium arrow) and the nutrient concentrations (ammonium, ortophosphate and phosphorus) are in the opposite direction of the degree of shade, the naturalness of the land use and the decreasing basin dimension.

Combining together the two arrays we obtain **Fig 7.34**, showing the scores of sites for the two data sets and the common projection of the two sets of sites after rotation. The sampling stations can be divided into three groups, which were highlighted in the figure. The group marked in red consists of lowland watercourses, with slow flow and fine to medium substrate, with different levels of phosphorus and ammonium concentrations and high conductivity and hardness. None of them has natural conditions and well developed riparian vegetation. The group marked in green includes small streams, well shaded, surrounded by a quite natural landscape and having low nutrient concentrations. The sites marked in blue constitute a large group of fast flowing streams and rivers, with coarse substrate, distributed along a vertical gradient going from the biggest and most impacted ones (upwards) to the most natural and smallest watercourses (downwards). Finally there are some points (Rimone, Salè, Ghebbo and Salone) with intermediate features.

The characteristic species for the red cluster are *Callitriche* spp., *Sparganium emersum* fo. *fluitans*, *Potamogeton pectinatus*, *Lemna minor*, *Ceratophyllum demersum*, *Elodea canadensis* and *Myriophyllum spicatum*. For the green group the key-species is *Berula erecta*, followed by *Sparganium erectum*, *Nasturtium officinale* and *Mentha aquatica*, while for the blue cluster we have to make a distinction between the sites in the high part and those in the low part of the diagram. The characterizing species for the bigger streams and the rivers are *Ranunculus penicillatus* ssp. *pseudofluitans*, *Cladophora* spp., *Ulothrix* spp., *Cinclidotus riparius*, *Agrostis stolonifera* and *Fontinalis antipyretica*. As for the smaller streams the typical species are *Rhynchostegium*

riparioides, *Cratoneuron commutatum*, *Cinclidotus mucronatus* (hidden behind *C. commutatum*) and *Petasites hybridus*.

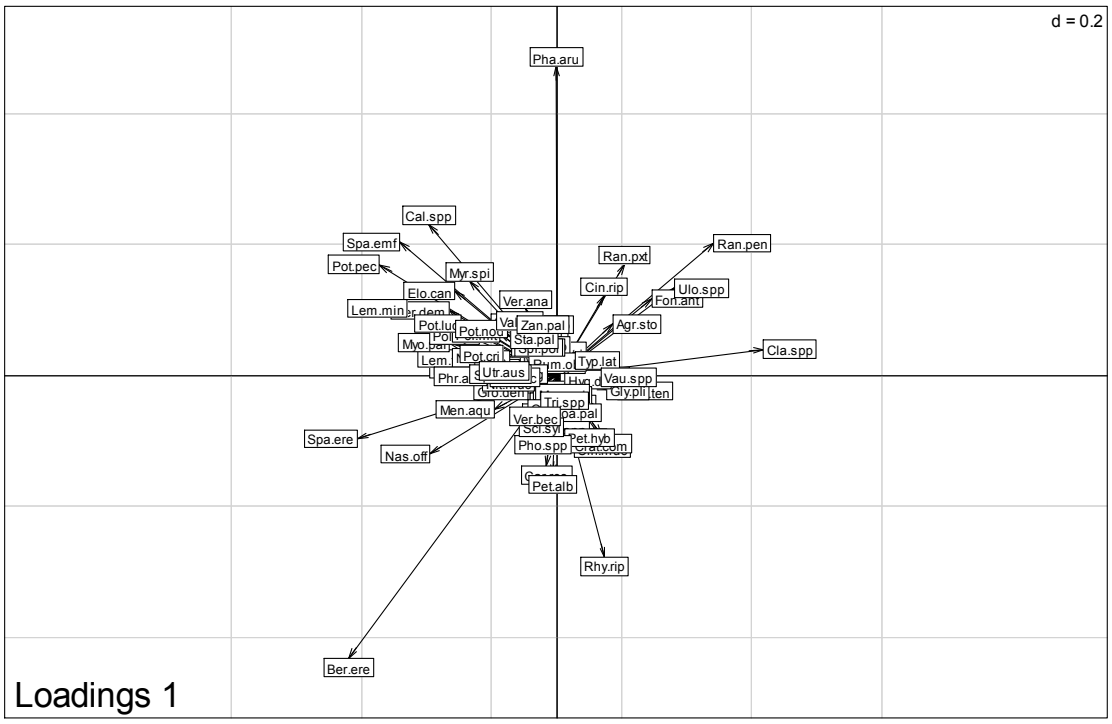

Figure 7.32: Procrustes analysis on species and combined chemistry-site feature arrays: loadings for species.

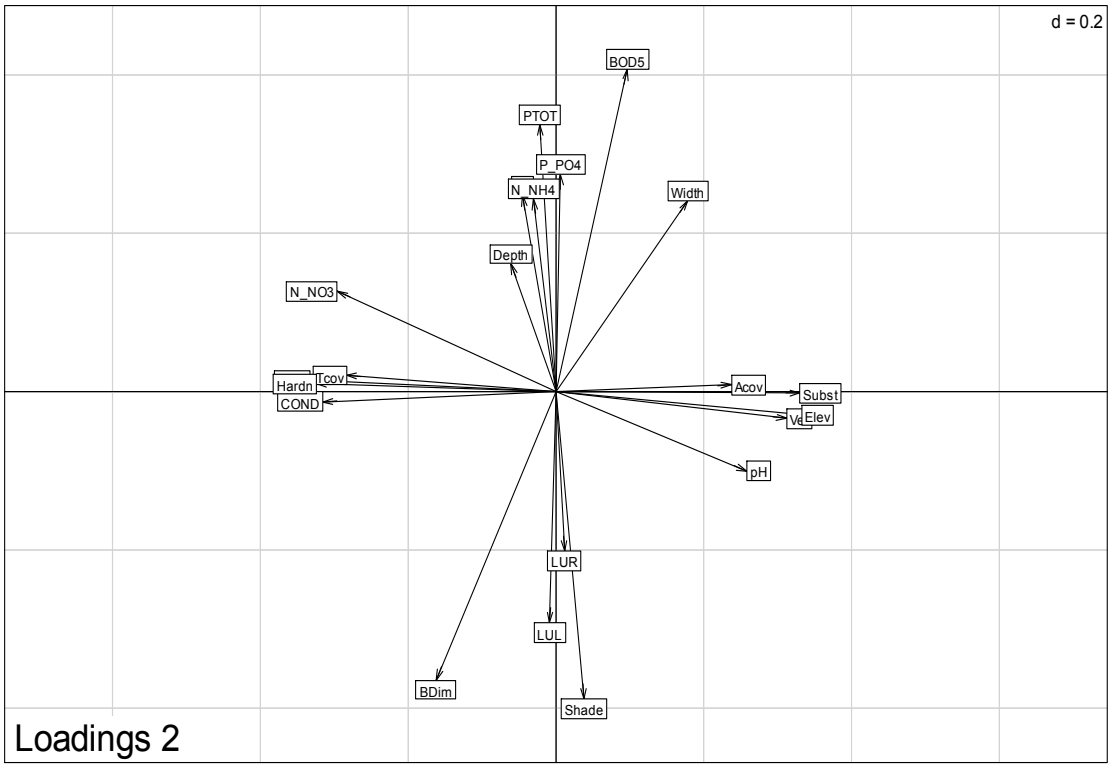

Figure 7.33: Procrustes analysis on species and combined chemistry-site feature arrays: loadings for site variables.

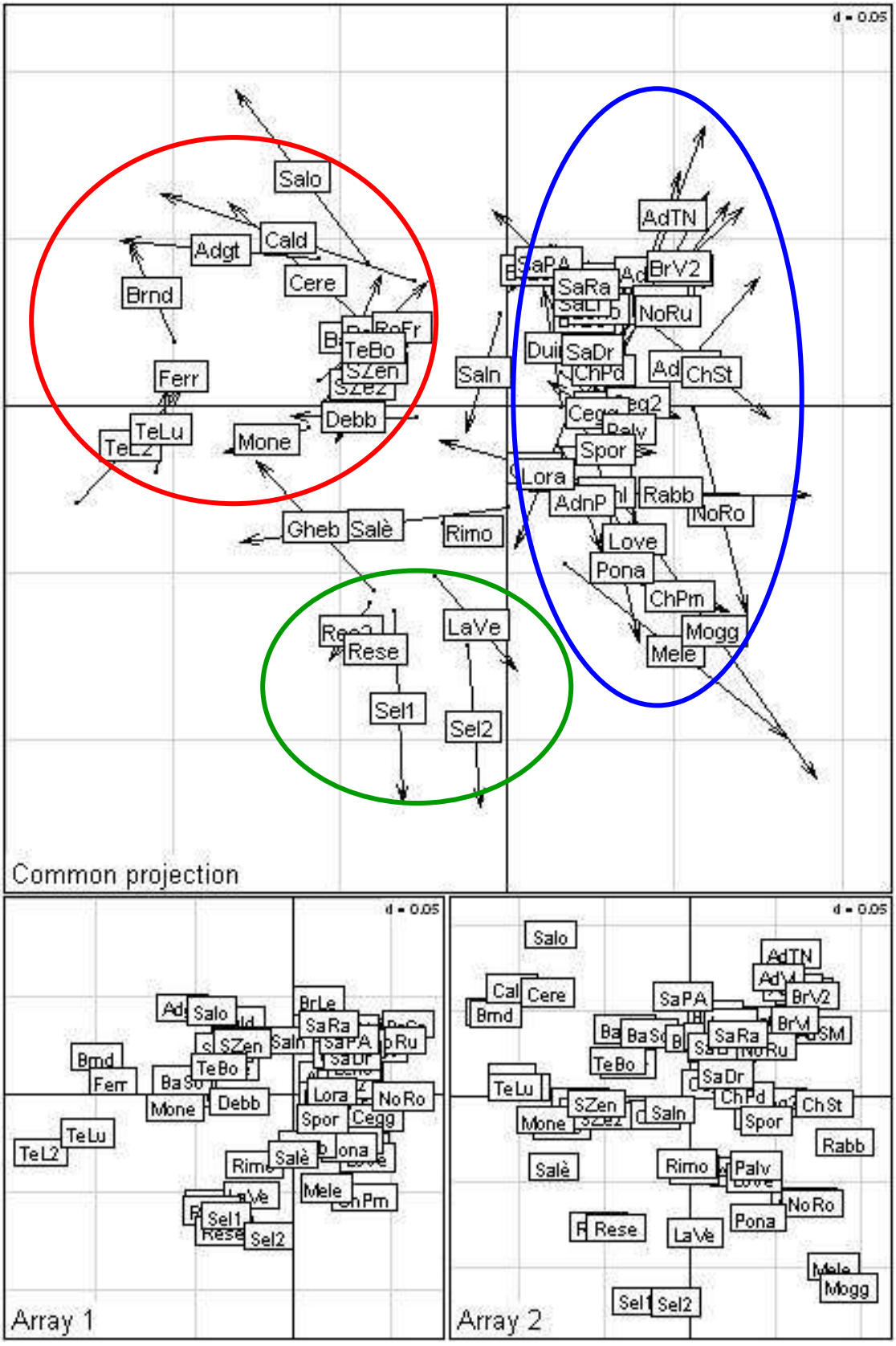

Figure 7.34: Plot of the Procrustes analysis on species and combined chemistry-site feature arrays: scores of sites for the two data sets (Array 1 and Array 2), and projection of the two sets of sites after rotation (arrows link feature site score to the species site score). The three main groups of sites are marked with different colours.

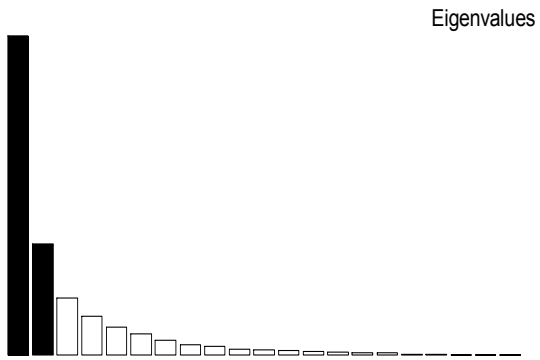

Figure 7.35: Eigenvalues screeplot for procrustes analysis on species array and combined chemical and site variable array.

Factor	Eigenvalue	Explained variance
1	0.4972066342	49.7 %
2	0.1733549394	17.3 %
3	0.0895295600	9.0 %
4	0.0607360375	6.1 %
5	0.0438015879	4.4 %
6	0.0331664207	3.3 %
7	0.0236246359	2.4 %
8	0.0159852429	1.6 %
9	0.0143994682	1.4 %
10	0.0094834215	0.9 %
11	0.0087359551	0.9 %
12	0.0073392132	0.7 %
13	0.0064001980	0.6 %
14	0.0047973244	0.5 %
15	0.0038308105	0.4 %
16	0.0037137333	0.4 %
17	0.0017259183	0.2 %
18	0.0013724712	0.1 %
19	0.0003963252	0.0 %
20	0.0002271981	0.0 %
21	0.0001729046	0.0 %

Table 7.15: Eigenvalues of each factor and percentage of variance explained by each factor for procrustes analysis on species array and combined chemistry-site feature array.

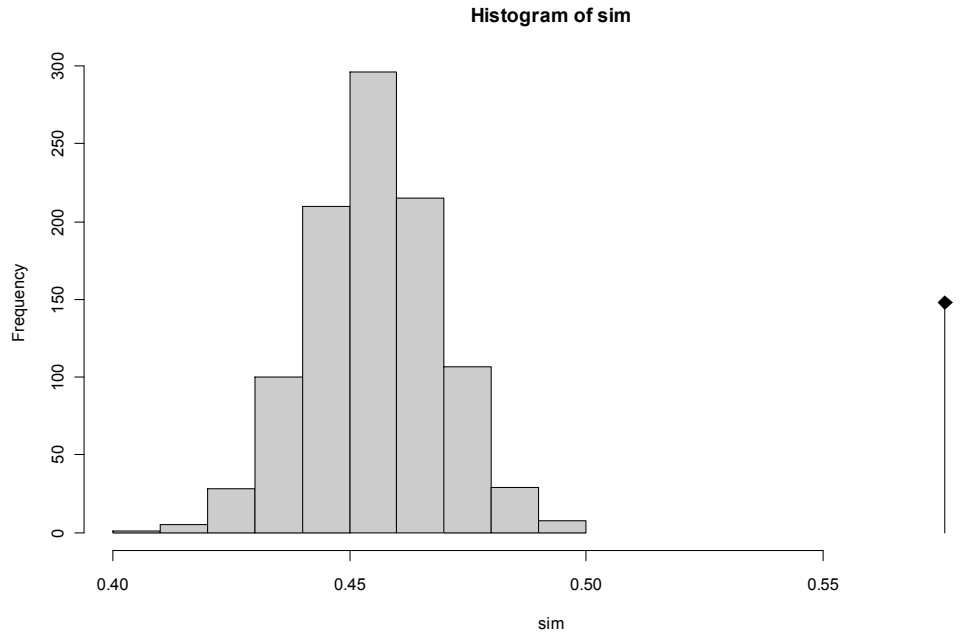

Figure 7.36: Plot of the Protest for procrustes analysis on species and combined chemical variables and site features. Histogram of simulated values and observed value (vertical line).

The eigenvalues of the procrustes analysis are plotted in **Fig 7.35** and are listed in **Tab 7.15**.
The first two axes together account for about 67 % of the total variance, but the first factor alone represents nearly 50 % of the variance. Therefore the effect of morphological variables like flow speed or kind of substrate and river basin depending conditions like conductivity and hardness, is much more important in influencing the macrophyte vegetation than the effect of human induced changes like nutrient concentration or artificialization of the watercourse.
The significance of the procrustes analysis was tested, like it was done for the other cases, through the Protest, which gave a value of $p = 0.001$ corresponding to a high significance level, as shown by the diagram in **Fig 7.36**.

7.10 CLASSIFICATION OF RIVER TYPES

We have already seen that it is possible to divide all the sampling points into groups on the basis of their macrophyte vegetation and that these groups correspond to the river types observed in the field.
The classification of watercourses into types, according to their abiotic features, was obtained through the application of a PCA based on correlations. For the analysis we considered only the morphological and hydrological variables, i.e. average width, average depth, velocity, substrate, altitude and basin dimension. The projection of cases on the factorial plane is shown in **Fig 7.37**, while the projection of variables on the same plane is plotted in **Fig 7.38**. In both diagrams the percentage of total variance explained by the first and second component is specified.
Even if the separation between groups is not always so clear, with some sites being in an intermediate position, we can trace out 3 main groups:

- green cluster: medium to small watercourses, with very slow to medium flow speed, with fine sediment. It includes: Ceresone, Fossa Caldaro, Fossa Salorno, Canale Debba, Canale Ferrara, Roggia Moneghina, Tesina Lupia di Sandrigo 1st and 2nd survey, Adigetto, Ghebbo, Salone, Rimone, S. Zeno 1st and 2nd survey, Rosta Fredda, Resenzuola 1st and 2nd survey, Fosso Selva 1st and 2nd survey;
- red cluster: main watercourses, moderately to very wide, fast flowing, with coarse substrate. It includes: Adige San Michele, Adige Trento, Adige Villa Lagarina, Adige Mori, Adige Borghetto, Sarca Ragoli, Sarca Dro, Sarca Limarò, Sarca Ponte Arche, Noce Rupe, Chiese Storo, Chiese Pieve di Bono downstream, Noce Rocchetta, Bacchiglione sorgente, Bacchiglione Ponte Marchese, Brenta Grigno 1st and 2nd survey, Brenta Villa Agnedo 1st and 2nd survey;
- blue cluster: medium to small watercourses, very fast flowing, with coarse or very coarse substrate. It includes: Lovernatico, Sporeggio, Lora, Roggia

Calavino, Palvico, Ceggio 1st and 2nd survey, Salè, Arnò Adanà Pieve di Bono upstream and downstream, Chiese Pieve di Bono upstream, Duina, La Vena, Ponale, Brenta Borgo 1st and 2nd survey, Brenta Levico, Rabbies, Meledrio, Moggio.

Two sites, Fiumicello Brendola and Tesina Bolzano Vicentino, have intermediate characters between the green and the red group.

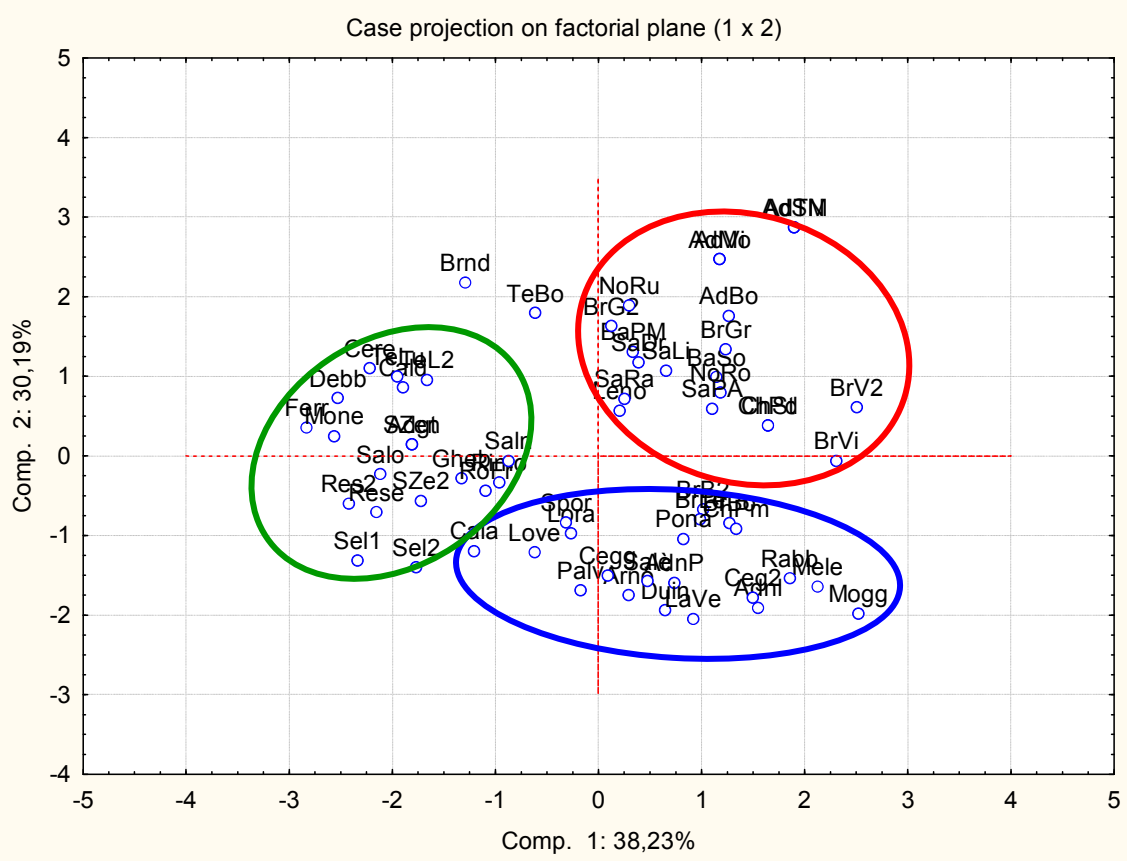

Figure 7.37: PCA on site features: plot of cases on factorial plane (1st and 2nd components). For each axis the percentage of explained variance is shown.

We tried to divide the sites into groups through the UPGMA Cluster Analysis as well and we still obtained 3 clusters, one of which identical to the green one. The two remaining clusters are similar to the red and blue ones, but some elements are inverted. This is due to the intermediate characteristics of some sites that allow their allocation to more than one group. The Cluster diagram is reported in **Fig 7.39**.

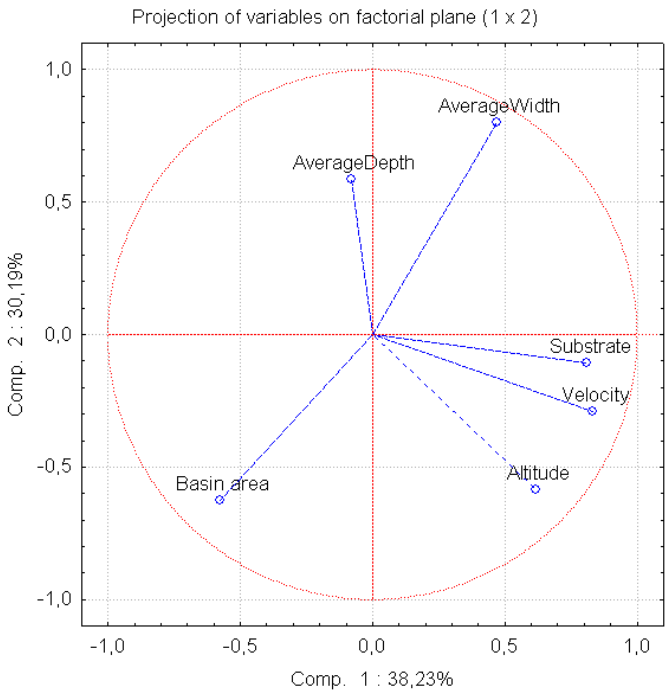

Figure 7.38: PCA on site features: plot of variables on factorial plane (1st and 2nd component). For each axis the percentage of explained variance is shown.

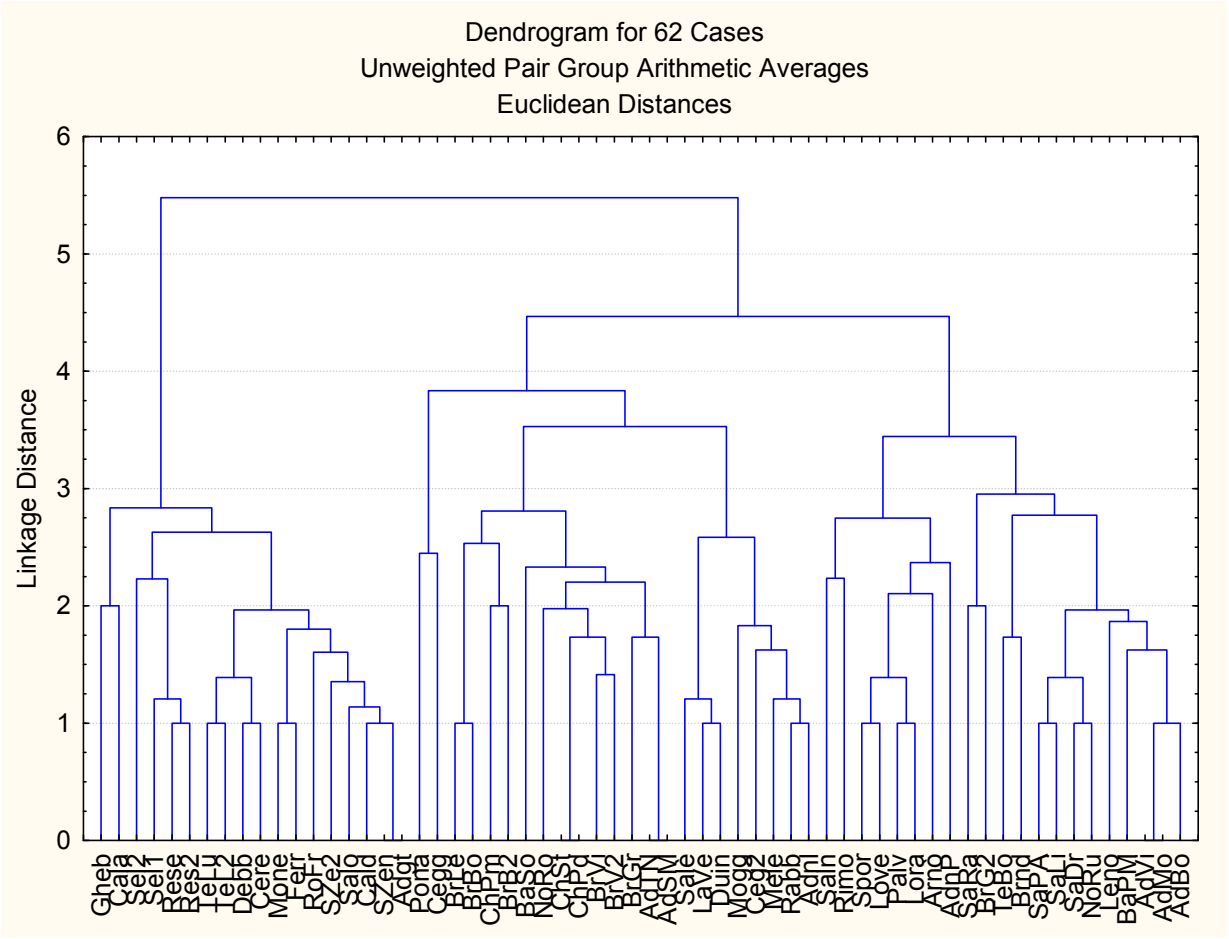

Figure 7.39: UPGMA Cluster dendrogram of sites, based on site abiotic features.

7.11 CORRELATION BETWEEN SPECIES ABUNDANCES AND NUTRIENTS

The correlation between the single macrophyte species and the nutrient concentrations was tested through the Spearman Rank coefficient. The method was applied to abundance data of all species occurring at least in 3 surveys and in **Tab 7.16** are listed all the results with a minimum significance level $p < 0.05$. As we can see, the coefficient values are all very low, probably because the algorithm is influenced by the big amount of zeros in the matrix, even if the absence of a species at a certain site is more frequently due to the lack of morphological favourable conditions, rather than being related to an unsuitable trophic state.

The following species are positively correlated with total phosphorus and ortophosphate concentrations: *Callitriche* spp., *Ceratophyllum demersum, Lemna minor, Lemna trisulca, Myriophyllum verticillatum, Polygonum mite, Potamogeton pectinatus, Ranunculus penicillatus* x *trichophyllus, Sparganium emersum* fo. *fluitans* and *Typha latifolia*.

A negative correlation with both total phosphorus and ortophosphate results only for two mosses (*Cratoneuron commutatum* and *Rhynchostegium riparioides*) and for *Mentha longifolia* for ortophosphate.

As for the BOD_5, *Berula erecta* and *Mentha aquatica* show a weak negative correlation with it, while *Cinclidotus riparius* and *Polygonum mite* are positively correlated. *Cinclidotus mucronatus, Cratoneuron commutatum* and *Potamogeton nodosus* have a negative coefficient for ammoniac nitrogen, while the coefficients of *Ranunculus trichophyllus* and *Sparganium emersum* fo. *fluit*ans are positive.

A higher number of species is correlated, positively or negatively, with nitric nitrogen concentration and with hardness and conductivity. This result confirms what already found for the various macrophyte metrics (see **Section 7.6**).

SPECIES	Cond	Hardn	pH	BOD5	N_NH4	N_NO3	P_PO4	PTOT
Agr.sto			0,34**					
Ber.ere	0,33**	0,34**		-0,26*				
Cal.spp	0,48***	0,40**	-0,42***			0,42***	0,33**	0,32*
Cer.dem	0,32*	0,33**	-0,36**			0,28*	0,29*	0,26*
Cin.muc					-0,30*	-0,26*		
Cin.rip	-0,27*			0,26*		-0,33**		
Cla.spp	-0,31*	-0,34**						
Crat.com			0,31*		-0,27*	-0,29*	-0,35***	-0,30*
Elo.can	0,31*	0,31*	-0,27*			0,31*		
Fon.ant	-0,30*	-0,30*				-0,27*		
Iri.pse						0,25**		
Lem.min	0,37**	0,29*	-0,27*			0,39**	0,42***	0,38**
Lem.tri	0,32*	0,32*				0,33**	0,33**	0,30*
Men.aqu	0,26*	0,28*		-0,29*		0,29+		
Men.lon							-0,26*	
Myo.pal	0,39**	0,41***	-0,27*			0,38**		
Myr.ver	0,28*	0,29*					0,31*	0,29*
Nas.off	0,25*	0,26*				0,34**		
Pet.alb								
Pet.hyb			0,30*					
Phr.aus	0,28*							
Pol.hyd	0,31*	0,33**				0,36**		
Pol.mit				0,26*			0,36**	0,35**
Pot.luc	0,27*	0,28*	-0,26*					
Pot.nod	0,33**	0,33**	-0,26*		-0,32*	0,31*		
Pot.pec	0,41***	0,41**	-0,26*			0,38**	0,31*	0,27*
Ran.pxt							0,30*	0,32*
Ran.tri					0,36**	0,25*		
Rhy.rip	-0,26*					-0,25*	-0,33**	-0,34**
Rhz.spp	0,27*	0,26*						
Spa.emf	0,41***	0,41***	-0,41***		0,28*	0,29*	0,35**	0,34**
Spa.ere	0,46***	0,36**				0,27*		
Typ.lat						0,30*	0,25*	0,26*
Ulo.spp	-0,42***	-0,39**						
Vau.spp						0,31*		
Ver.ana						0,34**		
Ver.bec						0,30*		

Table 7.16: Spearman Rank coefficients for species and nutrients: *p < 0.05 ** p < 0.01 *** p <0.001. Only the species having significant values are reported.

7.12 CORRELATION BETWEEN SPECIES PRESENCE-ABSENCE AND NUTRIENTS

The investigation about the existence of a correlation between macrophyte species and nutrient concentrations in water was worked out on the presence-absence data as well.

We applied the Wilcoxon rank-sum test and the results are listed in **Tab 7.17**. For each species and for each variable there are two values. The first one is the difference between the variable median value of all sites where the species is present and the median of all sites where the species is absent. The second row reports the significance level p. If the first value is positive it means that the species is positively correlated with the increasing value of the variable. For each chemical parameter the higher is the difference between the median values (Mpresence-Mabsence) and the stronger is the correlation, but we cannot make a comparison between variables, since the magnitude of the difference between the median values depends on the magnitude of the variable and the unit of measurement.

We can notice that the results are similar to those of the Spearman test, but not identical. For example the taxa positively correlated with phosphorus and ortophosphate concentrations in this case are the followings: *Callitriche* spp., *Ceratophyllum demersum, Lemna minor, Phalaris arundinacea, Polygonum hydropiper, Ranunculus penicillatus* x *trichophyllus, Sparganium emersum* fo. *fluitans* and *Typha latifolia*. The species having a negative correlation with phosphorus are *Cratoneuron commutatum* and *Rhynchostegium riparioides*.

According to the Wilcoxon test the taxa having a negative response to the increase of ammonium are *Berula erecta, Cratoneuron commutatum, Mentha aquatica, Myosotis palustris, Potamogeton berchtoldii* and *Spirogyra* spp.

Once again there are a lot of species the occurrence of which can be related to the nitrate concentration, as well as to the hardness and conductivity of the water at a certain site.

On one hand, since for many species the two methods gave similar results, it means that the correlations found for such taxa are sound. On the other hand we have to remark that in some cases the abundance of a species, and not only its occurrence, could give us information about the trophic state of a watercourse. This is the case of *Potamogeton pectinatus* that results to be positive correlated with phosphorus if we consider the abundance data, but no significant correlation appears if we analyze the presence-absence data.

SPECIES	COND	Hardn	pH	BOD5	N_NH4	N_NO3	P_PO4	PTOT
Ber.ere	171,00	100,00	-0,20	-0,70	-8,00	1,30		
p value	0,0009	0,0012	0,0491	0,0010	0,0450	0,0150		
Cal.spp	173,00	99,00	-0,20			1,30	15,00	30,00
p value	0,0007	0,0021	0,0023			0,0020	0,0028	0,0008
Cer.dem	190,50	129,50	-0,30			2,10	22,50	32,00
p value	0,0091	0,0074	0,0176			0,0110	0,0435	0,0453
Cin.rip	-98,00					-0,60		
p value	0,0227					0,0279		
Cla.spp	-120,00	-64,00						
p value	0,0062	0,0053	0,0440					
Cra.com					-20,00	-0,70	-17,00	-35,00
p value					0,0262	0,0142	0,0064	0,0122
Elo.can	165,00	129,50				2,75		
p value	0,0277	0,0328				0,0085		
Epi.hir		-39,50						
p value		0,0372						
Iri.pse			-0,30					
p value			0,0486					
Lem.min	151,00	98,00	-0,30			1,30	14,00	23,00
p value	0,0082	0,0310	0,0237			0,0039	0,0117	0,0160
Lem.tri	160,50	116,00	-0,30			2,60		
p value	0,0080	0,0068	0,0092			0,0097		
Men.aqu	159,00	116,00		-0,70	-20,00	2,60		
p value	0,0452	0,0327		0,0123	0,0179	0,0203		
Myo.pal	168,00	117,00	-0,30		-20,00	2,60		
p value	0,0007	0,0010	0,0049		0,0020	0,0004		
Myr.ver	159,00	116,00	-0,30					
p value	0,0291	0,0257	0,0232					
Nas.off	41,50			-0,60		0,35		
p value	0,0468			0,0444		0,0265		
Pet.alb				-1,20		-0,60		
p value				0,0141		0,0366		
Pet.hyb			0,20					
p value			0,0126					
Pha.aru				0,70	10,00		10,00	20,00
p value				0,0032	0,0019		0,0024	0,0040
Phr.aus	73,00							
p value	0,0355							
Pol.hyd	160,50	138,50	-0,25			2,75	11,50	
p value	0,0202	0,0120	0,0459			0,0036	0,0480	
Pot.ber		137,50			-26,00	3,65		
p value		0,0404			0,0085	0,0199		
Pot.luc	120,00	73,00						
p value	0,0229	0,0245						
Pot.nod	239,00	161,00				4,70		
p value	0,0095	0,0071				0,0073		
Pot.pec	165,00	116,50	-0,30			2,60		
p value	0,0019	0,0015	0,0137			0,0037		
Ran.pxt							71,50	80,00
p value							0,0037	0,0042
Ran.tri						0,60		
p value						0,0335		
Rhy.rip							-8,50	-20,00
p value							0,0150	0,0096

SPECIES	COND	Hardn	pH	BOD5	N_NH4	N_NO3	P_PO4	PTOT
Rhz.spp			-0,30					
p value			0,0450					
Spa.emf	165,00	130,00	-0,30			1,95	19,00	30,00
p value	0,0025	0,0016	0,0019			0,0249	0,0123	0,0052
Spa.ere	173,00	93,50	-0,20			1,00		
p value	0,0003	0,0015	0,0068			0,0065		
Spy.spp					-20,00			
p value					0,0430			
Typ.lat							19,00	20,00
p value							0,0086	0,0214
Ulo.spp	-125,00	-72,00						
p value	0,0003	0,0007						
Vau.spp						0,50		
p value						0,0024		
Ver.ana						0,40		
p value						0,0165		
Ver.bec				-0,65				
p value				0,0229				

Table 7.17: Wilcoxon rank-sum test results. For each species and each variable the first value represents the difference between median values of the variable at all sites where the species was present and all sites where the species was absent. The second row shows the p significance level. Only the species having significant values are reported.

7.13 APPLICATION OF THE IBMR

For every river reach we calculated the IBMR value (see **Section 6.7**), in order to compare the results given by the French macrophyte trophic index (**Tab 7.18**) with the chemical data available for each sampling stretch.

Beside the index values, **Tab 7.18** reports the trophic classification for each surveyed point, together with the colour assigned according to the IBMR method.

Through the colours it is possible to understand at first sight that nearly all the mapped reaches have a medium to very high trophic level and only 4 sites (5 surveys) are classified as oligotrophic and this is only partially correspondent to the real situation showed by the chemical analyses.

The calculation of the Pearson's correlation coefficient gave us the following r values, which are all highly significant, except the correlation between IBMR and BOD_5:

- IBMR-BOD_5: r = -0.16 p = 0.222
- IBMR-N_NH4: r = -0.37 p = 0.003
- IBMR-NO3: r = -0.40 p = 0.001
- IBMR-PO4: r = -0.39 p = 0.001
- IBMR-PTOT: r = -0.47 p = 0.0001

The scatterplots referring to each variable are reported in **Fig 7.40-7.44** and they show us that, even if the correlations are significant, the risk of misclassification of a site in a wrong trophic category remains quite high.

SITE	IBMR	trophic level	colour	SITE	IBMR	trophic level	colour
AdBo	10	high		LaVe	11	medium	
Adgt	6	very high		Leno	13	low	
AdMo	11	medium		Lora	11	medium	
Adnl	10	high		Love	9	high	
AdnP	10	high		Mele	14	low	
AdSM	8	very high		Mogg	11	medium	
AdTN	11	medium		Mone	9	high	
AdVi	11	medium		NoRo	10	high	
Arnò	11	medium		NoRu	11	medium	
BaPM	9	high		Palv	11	medium	
BaSo	10	high		Pona	10	high	
BrB2	9	high		Rabb	16	very low	
BrBo	10	high		Res2	11	medium	
BrG2	11	medium		Rese	11	medium	
BrGr	10	high		Rimo	11	medium	
BrLe	8	very high		RoFr	11	medium	
Brnd	7	very high		SaDr	10	high	
BrV2	8	very high		Salè	8	very high	
BrVi	9	high		SaLi	11	medium	
Cala	12	medium		Saln	10	high	
Cald	9	high		Salo	6	very high	
Ceg2	9	high		SaPA	9	high	
Cegg	10	high		SaRa	10	high	
Cere	8	very high		Sel1	13	low	
ChPd	11	medium		Sel2	13	low	
ChPm	12	medium		Spor	8	very high	
ChSt	11	medium		SZe2	9	high	
Debb	9	high		SZen	8	very high	
Duin	10	high		TeBo	8	very high	
Ferr	9	high		TeL2	9	high	
Gheb	12	medium		TeLu	10	high	

Table 7.18: IBMR value, trophic classification and colour assigned for each sampling point (AFNOR, 2003).

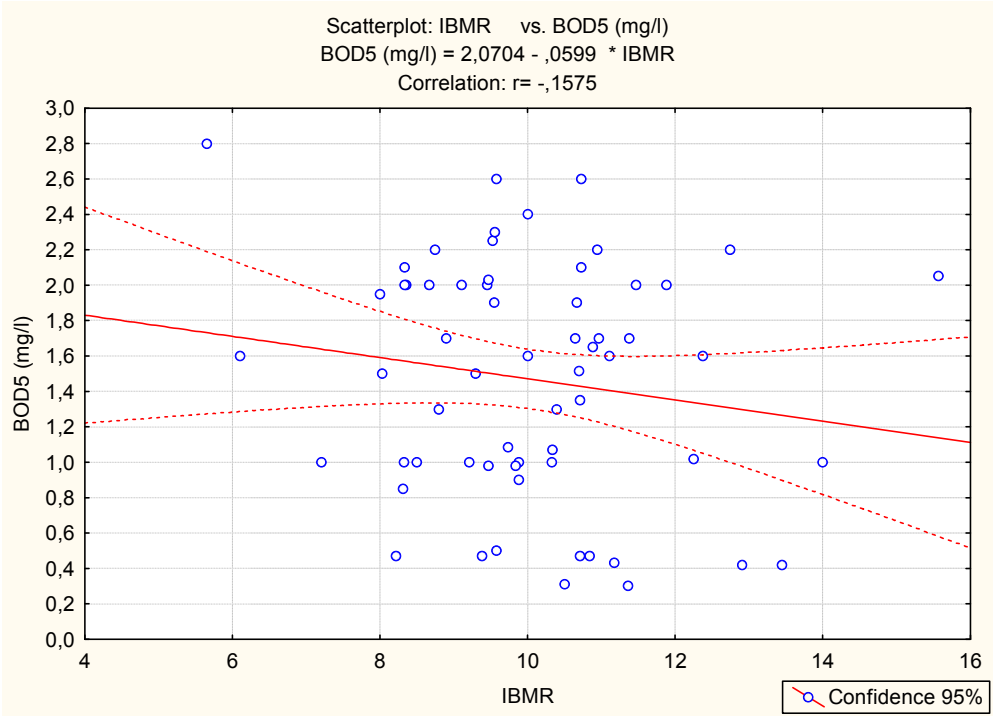

Figure 7.40: scatterplot of IBMR values vs. BOD_5 values for all surveyed sites.

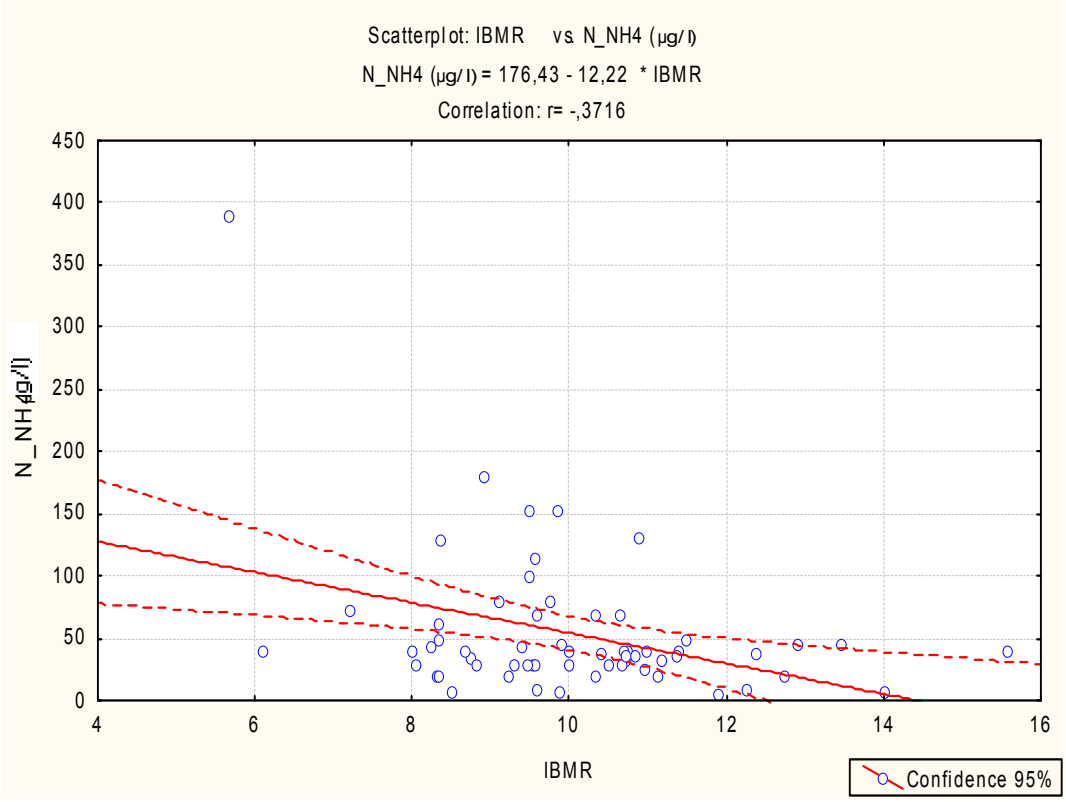

Figure 7.41: scatterplot of IBMR values vs. N_NH4 values for all surveyed sites.

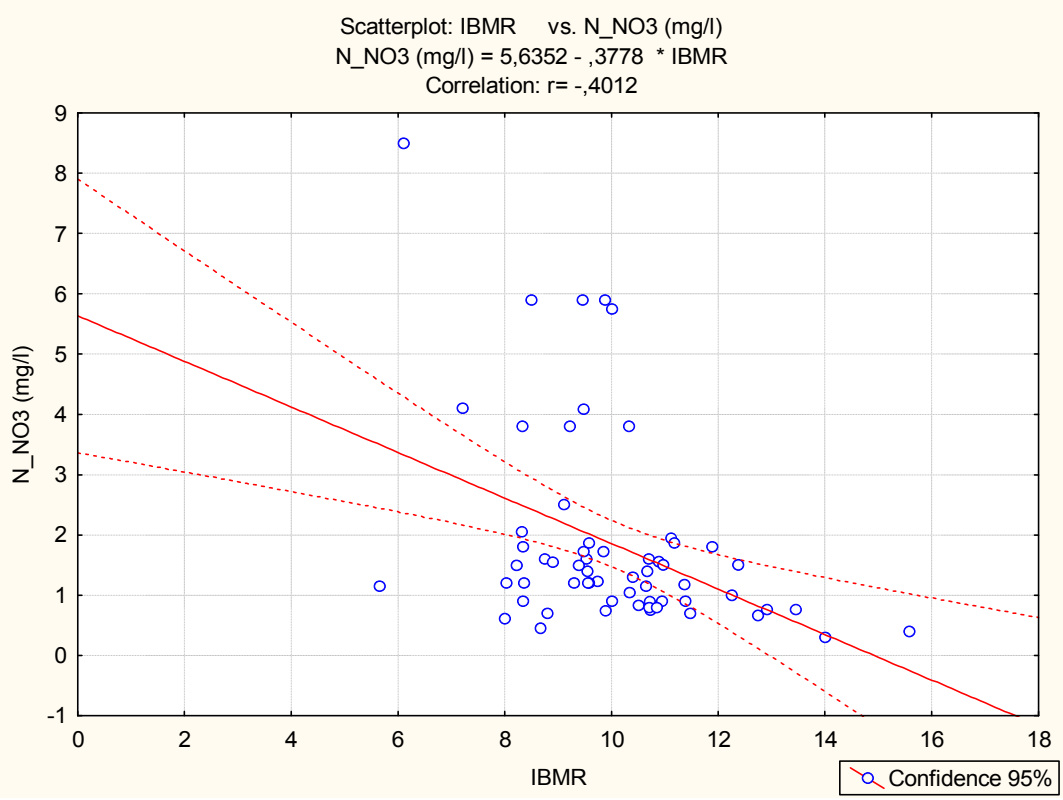

Figure 7.42: scatterplot of IBMR values vs. N_NO3 values for all surveyed sites.

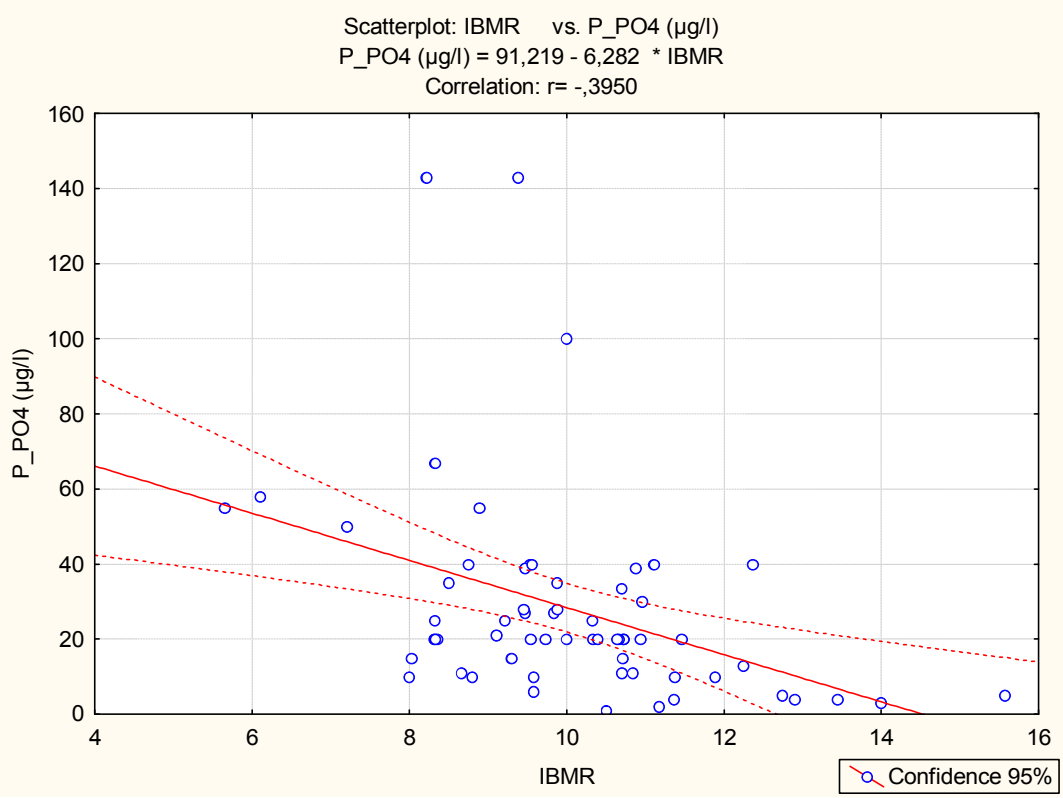

Figure 7.43: scatterplot of IBMR values vs. P_PO4 values for all surveyed sites.

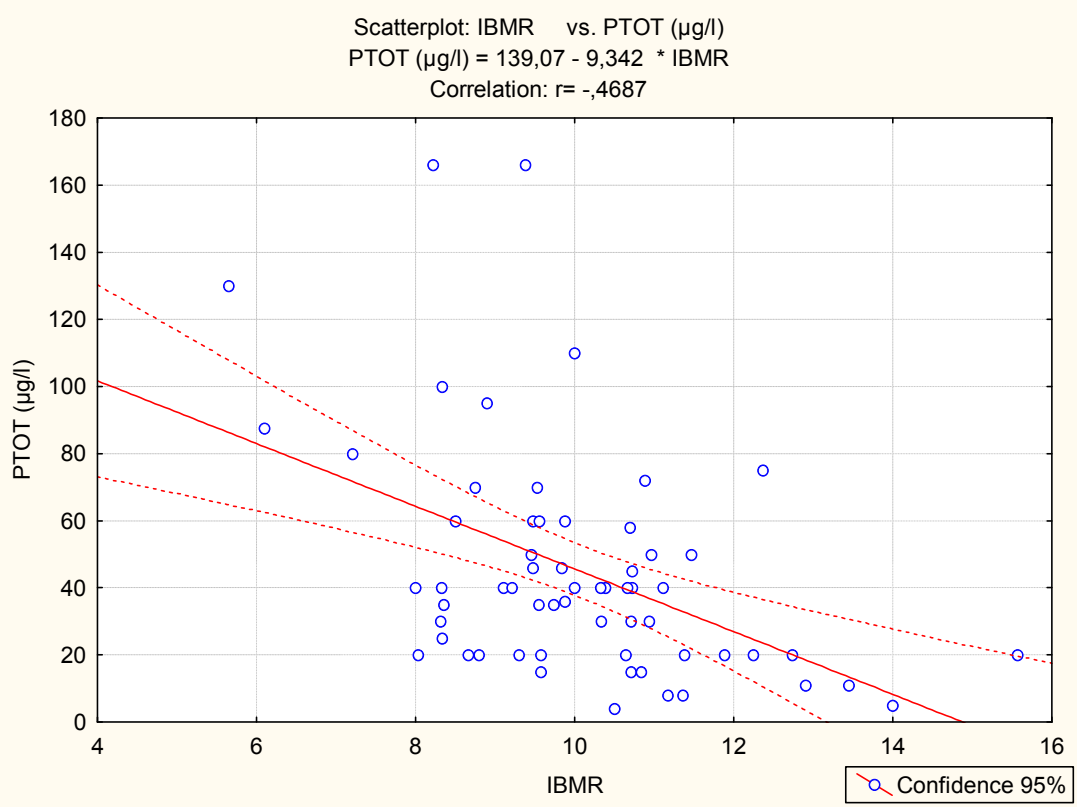

Figure 7.44: scatterplot of IBMR values vs. P_PTOT values for all surveyed sites.

8 DISCUSSION

As we have already pointed out, the macrophyte community is dependent on many biotic and abiotic factors closely related to each other (e.g. Barendregt & Bio, 2003; Carr et al., 1997; Dawson et al., 1999; Riis et al., 2000). The task of setting a macrophyte method, as well as other metrics, to assess the ecological status of running waters is therefore particularly difficult, because it requires considering many different aspects of the watercourse and quantifying the effect of each variable on the community (Baattrup-Pedersen et al., 2003; Nõges et al., 2009). The results presented here constitute an effort in this direction.

The first evident output of the study is the extreme scarcity of reference sites for running waters, especially for certain river types, as already showed by many other authors (Baattrup-Pedersen et al., 2008; Nijboer et al., 2004). Even when we found some very natural sites, we could describe them as minimally disturbed sites, but not as reference sites for biological integrity if, by the term "reference", we mean a site in a pristine state (Stoddard et al., 2006).

Nijboer et al. (2004) established the following conditions in order to detect the possible reference sites for lotic ecosystems:

- floodplain not cultivated;
- presence of coarse woody debris;
- presence of standing water bodies;
- no bank fixation;
- no bed fixation;
- no migration barriers;
- no flood protection;
- presence of natural floodplain vegetation;
- natural discharge regime;
- no sediment retention;
- no water diversion;
- no point-source pollution;
- no point-source eutrophication;
- no diffuse impacts;
- no acidification;
- no liming;
- natural thermal conditions;
- natural salinity;
- no introduced species.

If we consider our study sites, none of them meets all the criteria. We can identify a small number of sites, which satisfy most of the conditions mentioned above and which are reported in **Tab 8.1**.

CRITERIA SITES →	BrGr	ChPm	LaVe	Mele	Mogg	Mone	NoRo	Rabb	Rese	Sel1
Floodplain not cultivated	/	X	/	X	X		/	X	/	/
Presence of coarse woody debris	X	X	X	X	X	X	X	X	X	X
Presence of standing water bodies	X		X				X		X	X
No bank fixation	/	/	X	X	X	X	X	X		X
No migration barriers	X	X	X	X	X	X	X	X	X	X
No flood protection	X	X	X	X	X	X	X	X	X	X
Presence of natural floodplain vegetation	/	/	/	X	X	/	/	/	/	X
Natural discharge regime	X		X	X	X	X		X	X	X
No sediment retention	/		X	X	X	X			X	X
No water diversion	/		X	X	X	X		X	X	X
No point-source pollution	X	X	X	X	X	X	X	X	X	X
No point-source eutrophication		/	X	X	X	X		X	X	X
No diffuse impacts				X	/			/		/
No acidification	X	X	X	X	X	X	X	X	X	X
No liming	X	X	X	X	X	X	X	X	X	X
Natural thermal conditions	X	X	X	X	X	X	X	X	X	X
Natural salinity	X	X	X	X	X	X	X	X	X	X
No introduced species	X	X	X	X	X	X	X	X	X	X

Table 8.1: less disturbed sites with list of criteria to be met in order to be selected as a reference site: empty cell = criterion not met; / = criterion partially met; X = criterion totally met.

The weak points for reference site selection are the diffused impacts, the land use for human activities and the morphological modifications on water courses that are basically present everywhere, in particular on the bigger lotic systems (Baattrup-Pedersen et al., 2008; O'Hare et al., 2006), especially in a densely populated country like Italy (Buffagni et al., 2001; Nijboer et al., 2004; Hering & Strackbein, 2001).
The main problem is finding unimpaired sites for lowland rivers and streams, because of the intensive exploitation of the plain areas, while it is generally easier to detect highland or mountain streams in unimpacted conditions (Baattrup-Pedersen et al., 2008). In fact almost all the sites listed in **Tab 8.1** are mountain or highland streams, which are usually quite poor in aquatic vegetation and therefore less interesting for macrophyte assessment.
Considering our data it is clear that the overall species richness of the surveyed sites is quite low and if we divide the total number of taxa by the number of surveyed sites we obtain an average number of taxa per site equal to 1.8. This fact is partially due to the high similarity among many of the mapped watercourses, but it is emphasized by the human induced homogenisation and simplification of running water environments

(Baattrup-Pedersen & Riis, 1999; Bornette et al., 1998; Bornette et al., 2008; Demars & Harper, 2005a).

The poor specific diversity at many sampled sites is partially related to the natural state of upland watercourses, as demonstrated by the negative correlation that we found between the Shannon-Weaver diversity index and the elevation of the sites ($r = -0.35$ $p < 0.01$), which indicates that the diversity increases with the decreasing elevation of the site and is hence higher in lowland rivers and streams. The altitude was found to have a negative influence on the total macrophyte cover, the number of hydrophyte taxa and even more on the number of amphibious taxa and their total abundance, while it has a positive influence on the bryophyte diversity and abundance, the bryophyte being in fact characteristic of mountain streams (Scarlett & O'Hare, 2006). The altitude has been already identified as a variable of primary importance for the distribution of plant communities in Europe (Haslam, 1987; Mackay et al., 2003) and other authors have found similar relations between certain macrophyte species or taxonomic groups and the altitude of the site (Baattrup-Pedersen et al., 2006; Dawson & Szoszkiewicz, 1999; Kawecka & Szcesny, 1984; Onaindia et al., 1996).

Nonetheless in such environments where the hydrophytic vegetation is naturally poor in species number, an important role is played by the amphibious populations and the helophytes (Baattrup-Pedersen & Riis, 1999; Baattrup-Pedersen et al., 2003; Henry & Amoros, 1996), their presence being connected to the morphological naturalness of the watercourse (Ferreira & Moreira, 1999; Riis et al., 2000; Vanderpoorten & Klein, 1999). The last sentence could sound in contrast with the weak but positive correlations that we found between the total number of taxa, the number of amphibious taxa and the number of hydrophyte taxa on one side and the artificialization of the watercourse on the other side (respectively $\rho = 0.29$ $\rho = 0.26$ and $\rho = 0.25$; $p < 0.05$), but these correlations are probably "false results", due to the fact that the most artificialized sites are the lowland ones that are also the richest in species.

An interesting result of our study is the significant correlation between Shannon-Weaver index and nitrate concentration in water ($r = 0.43$ $p = 0.001$). Similar relations resulted for other metrics as well, i.e. the total number of taxa and the total macrophyte cover, the number of amphiphytes, hydrophytes and helophytes. Even more interesting is the fact that the bryophytes are negatively correlated to the water nitrate level, exhibiting a trend similar to that showed for the altitude of the site.

A similar relationship between species richness and nitrate concentration was found by other authors (Demars & Edwards, 2009), both for riverine wetland macrophytes (Bornette et al., 1998; Janauer, 2003) and for mountain river plant communities (Szoszkiewicz et al., 2006), while for polluted lowland sites an opposite relation was found (Szoszkiewicz et al., 2006). Bornette et al. (1998) related the higher number of species to the more accentuated influence of hillslope groundwater, rather than river water, on the wetland. High nitrate concentrations, high conductivity and alkalinity were found to characterize hillslope aquifer, compared to river seepage (Bornette et al.,

1998). In our study, that focuses on rivers and not on wetlands, we found a clear positive relation between species richness and nitrate concentration, which in turn was found to be directly related to conductivity and hardness (see **Section 7.9**). The similarity of trend showed by various macrophyte metrics with regards to nitrate concentration and altitude could be due either to an increase of hillslope aquifer influence with the decreasing elevation of the site (Carbiener et al., 1995), or to the impact of agriculture becoming more intensive when moving from the mountain to the lowland (Carbiener et al., 1990; Duff & Triska, 2000; Mackay et al., 2003). When considering the latter hypothesis we have thus to keep in mind that the nitric nitrogen concentrations characterizing our sites are all below 10 mg/l, therefore not indicating a severe organic burden coming from anthropogenic activities (Adam et al., 2001).

According to our results the macrophyte community is negatively affected by the increasing water velocity and coarseness of the substratum, since the total aquatic plant cover and the abundance and number of amphiphyte taxa decrease. The diversity of the community, in terms of taxa total number, is influenced by velocity, as reported in other studies (Butcher, 1933; Chambers et al., 1991; Makkay et al., 2008; Madsen et al., 2001) but not by substrate. On the other side the taxa number and the abundance of bryophytes and the cover of filamentous algae are positively related to water speed and coarse substrate and these two components will therefore characterize rhithral environments with fast flowing waters, boulders and cobbles. The fact that mosses colonize preferably this kind of running waters is generally acknowledged (Janauer & Dokulill, 2006; Baattrup_Pedersen et al., 2006; O'Hare et al., 2006; Vanderpoorten & Klein, 1999), while for what concerns filamentous algae the authors usually focus on the correlation between blanket weed development and low flow conditions (Flynn et al., 2002; Wade et al., 2002) but some studies also identify streams with high velocity as the ideal habitat for filamentous algae (Hrivnák et al., 2004).

It is interesting to underline that we found no relation between the various metrics and the degree of shading of the site that is instead usually identified by many authors as a determinant factor for macrophyte vegetation (Fletcher et al., 2000; Janauer & Dokulill, 2006; Langford et al., 2001). The only exception is constituted by the number of taxa and the cover of mosses, most of which are in fact sciaphilous species (Valanne, 1984; Haury et al., 2000; Thiebaut et al., 1998).

The coverage of macrophytes at a certain river site is strongly linked to the flow velocity, and the highest cover corresponds to very slow flowing waters ($\rho = -0.54$, $p < 0.001$), but the species diversity is not really dependent on lentic conditions inside the stream. In fact we found no significant correlation between the Shannon index and the velocity, and the Spearman coefficient for total number of taxa and water speed is quite low ($\rho = -0.26$, $p < 0.05$). The diversity of the community can be rather related to the instream diversity of the site, providing many different habitats, which in turn allow the development of a high number of aquatic plant species, both typical of lentic and lotic environments (Baattrup-Pedersen & Riis, 1999; Makkay et al., 2008). Such a situation

occurs at Sarca Ragoli and Bacchiglione Sorgente that have in fact higher Shannon index values compared to the other sites, even if they are fast flowing rivers.
As for the Evenness, we did not find any significant relations with the chemical variables, a part from the very weak correlation with pH ($r = -0.26$ $p < 0.05$). Some studies showed that very high ammonium and phosphorus concentrations, corresponding to hypertrophic conditions, lead to a poor community, dominated by few species with high biomass (Carbiener et al., 1995; Cristofor et al., 2003; Thiébaut & Muller, 1999) and therefore having a low evenness. In our study there is no statistical evidence of that, probably because of the small number of hypetrophicated sites. Some of these sites (Fossa Salorno, Brenta Villa Agnedo) have low evenness values, but others (Duina) have a high E index. In our study the evenness, that means the equilibrium between species within the community, seems to be more connected to the disturbance of the site by high flow velocity or high discharge conditions, which keep the biocenosis in an initial state, where the competition for space and other resources is low and as a consequence there are no favoured species becoming dominant (Bornette et al., 1998; Bornette et al., 2008; Henry et al., 1996).
Considering now the similarity among sites on the basis of their aquatic vegetation, we obtain an important result. Independently on the applied method, the assemblages of plant species allow us to divide the sites into groups highly correspondent to the different river types. It is a demonstration of the fact that the macrophyte community, both in terms of species composition and abundance, is primarily determined by the morphological and hydrological features of the site and only to a less extent by the nutrient concentrations. Nowadays this idea is supported by several studies (Baattrup-Pedersen et al., 2006; Johnson et al., 2006; Triest, 2006), even if most of the studies on macrophyte still focus on nutrients as the main driving force (Haury et al., 2006; Holmes, 1996; Robach et al., 1996, Thiébaut & Muller, 1999).
The multivariate analysis on species matrix and combined chemistry-site feature matrix confirms this theory, since most of the variance (49.7 %) is explained by the first axis, highly correlated with three morphological and hydrological variables of the river, like velocity, substratum and altitude. The second axis, related to the phosphorus and ammonium concentrations accounts for only 17.3% of the variance. Furthermore, if we look at the procrustean and co-inertia analysis on site features and species abundances, we will see that the first axis, highly correlated with flow speed and substratum coarseness, accounts for more than 63% of the variance, while in the co-inertia and procrustean analysis on water chemistry and species abundances the first axis, explaining over 53% of the variance, is not related with the phosphorus and ammonium concentrations, being instead evidently correlated with nitrate, conductivity and hardness. The prevailing of conductivity and alkalinity or hardness on nutrients in determining the composition and structure of the macrophyte community has been already showed in other studies (Demars & Edwards, 2009; Demars & Thiébaut, 2008,

Triest, 2006). As a consequence, before making any consideration about aquatic plant communities, it is necessary to take into account the type the sampled river belongs to.
As observed by other authors as well (Demars & Thiébaut, 2008; Demars & Edwards, 2009; Moss, 2008), the result expressed above seriously questions the ability of the current macrophyte indexes or vegetation-based methods for ecological diagnosis, especially in running waters, where the main driving force seems to be the water flow (Butcher, 1933; Chambers et al., 1991; Riis et al., 2008; Wade et al., 2002), which is instead absent in lentic environments, where the macrophyte vegetation is much more determined by trophic conditions and macrophyte indexes work well (Melzer, 1988; Melzer, 1993).
If we look now at the clustering of sites on the basis of their macrophyte vegetation, putting together the different analysis both on abundance and on presence/absence data, we can identify some different aquatic plant communities, characterising the various clusters (see **Section 7.4** and **7.5**).
The first group of sites (1) consists of channelized watercourses with fine sediment and slow to medium laminar flow, crossing intensively agricultural exploited areas or industrial zones. The macrophyte cover is always very high, between 70% and 100%. The community is characterised and dominated by species like *Potamogeton lucens, P. pectinatus, Myriophyllum spicatum, Elodea canadensis, Groenlandia densa* and *Sparganium emersum* fo. *fluitans*. In the lentic reaches species not anchored to the bottom like *Ceratophyllum demersum, Lemna minor* and *L. trisulca* can dominate the vegetation. The species richness is quite variable, in dependence on the altitude of the watercourse, going from less than 10 species at the Rio S. Zeno, to 20 taxa at the Canale Ferrara.
The second cluster (2) includes shallow streams, with laminar flow and a quite various river bottom, presenting different portions of fine and coarser sediment (cobbles, gravel, sand, mud), somehow influenced by groundwater, flowing on calcareous rocks. The sites of this group have a quite natural morphology and are shaded by riparian vegetation. The vegetation cover is lower than in the previous group, but still high, usually more than 50%, with few species (between 5 and 10). The community is dominated and characterized by *Sparganium erectum* and the submerged form of *Berula erecta*. If hard substrates are present the mosses *Rhynchostegium riparioides* or *Fontinalis antipyretica* can occur. The presence of species like *Zannichellia palustris* or *Potamogeton crispus* could be an indicator of perturbed conditions (O'Hare et al., 2006; Riis & Sand-Jensen, 2001).
A further group (3) puts together sites with very slow flowing water and fine sediment, from 30 to 100 cm deep and partially turbid. The morphology is not natural but the degree of artificialization is variable from case to case. The aquatic community has medium species richness (10-15 taxa) but high coverage, between 60% and 90%. *Sparganium erectum* and *Myriophyllum spicatum* are characterising species, but never predominant. In dependence on the degree of perturbation on the watercourse, species

like *Potamogeton pectinatus, Vallisneria spiralis* or *Vaucheria* spp. can be very abundant (Benson et al., 2008; Riis & Sand-Jensen, 2001).

A 4th group (4) is represented by turbulent and fast flowing brooks, in mountain areas, with very coarse substrate. These sites have low macrophyte cover, usually variable from less than 1% to 15%. The aquatic plant community consists of mosses and filamentous algae and little species richness (2-10 taxa). *Cicnclidotus aquaticus* (or other *Cicnclidotus* species), *Cratoneuron commutatum* and *Cladophora* spp. are the characterising species. In perturbed conditions, for example due to organic pollution, the cover of macrophyte can increase up to 50-70%, with a high presence of filamentous algae.

The 5th group (5) includes medium to fast flowing waters, with laminar or turbulent flow, but always with coarse and mixed substrate, consisting of gravel, cobbles, sand and some boulders. The macrophyte cover is very variable, going from 5% up to 85%, but never reaching 100%. The coverage depends on the river dimension, being higher in smaller watercourses with lower discharge and decreasing in the big rivers, like the Adige, where the vegetation is localised near the banks. The species richness is low, usually less than 10 taxa, and the characterising species are *Ranunculus penicillatus* ssp. *pseudofluitans, Agrosits stolonifera, Phalaris arundinacea, Glyceria plicata* and *Veronica anagallis-aquatica* or *Veronica beccabunga* (or both). Some mosses should be present on hard substrate, more frequently *Rhynchostegium riparioides* or *Cinclidotus aquaticus,* but in some cases other *Cinclidotus* species or *Amblystegium* spp.

Cladophora spp. is very often associated with this kind of macrophyte community, sometimes together or replaced by *Vaucheria* spp. and *Ulothrix* spp. The presence of *Ranunculus trichophyllus* or its hybrid instead of *R. penicillatus* ssp. *pseudofluitans* seems to indicate a perturbed condition.

The last group (6) is composed of sites similar to the previous ones, but the flow velocity is a little slower and as a consequence there is a bigger amount of sand in the substrate. The macrophyte cover is therefore quite high, always above 50% and the species richness is higher (from 10 to 15 species). The characteristic species are the same, together with *Nasturtium officinale* and *Callitriche* spp. that in very small watercourses with finer sediment (mud) can become predominant (Rosta Fredda). *Zannichellia palustris* occurs as well at the most human impacted sites.

Some outlier situations are represented by the Tesina at Lupia that has intermediate characteristics between the first and the second group, with a community dominated both by *P. pectinatus* and *B. erecta,* by the Rimone, which has a particular macrophyte vegetation, more similar to that of a lentic ecosystem, of which it is the artificial outflow. The Rimone has a high species richness and coverage and the dominant species is *Hippuris vulgaris*, usually belonging to the vegetation of lakes. Another special case is constituted by the two sites of the Bacchiglione, which are morphologically similar to those of group 5, with medium or high flow velocity and substrate consisting of cobbles and gravel. Because of these features the aquatic

vegetation cover is limited, between 15% and 30%, with a certain amount of filamentous algae (*Cladophora* spp. or *Vaucheria* spp.), but due to the lowland localisation of the river, the macrophyte community is different from that of group 5, having high species richness (between 20 and 30 taxa) and not being characterised by *R. penicillatus* ssp. *pseudofluitans* and having many emergent species like *Nasturtium officinale, Mentha aqautica* and *Myosotis palustris*. What distinguishes this kind of community is the presence at the same sites of all the species characterising the other groups (*B. erecta, Callitriche* spp., *E. canadensis, R. penicillatus* ssp. *pseudofluitans, Z. palustris,* etc.) and without any species dominating the biocenosis.

If we consider now not only the floristic data, but the site features and chemistry as well, we can see that our previous hypotheses, based on species composition and abundances, correspond to the results obtained through the matching-two-table analysis (see **Section 7.9**). The main discriminating taxa are *P. arundinacea, R. penicillatus* ssp. *pseduofluitans, R. penicillatus* x *trichophyllus, C. riparius, Ulothrix* spp., *Fontinalis antipyretica, A. stolonifera, Caldophora* spp., *R. riparioides, B. erecta, N. officinale, S. erectum, M. aquatica, L. minor, P. pectinatus, E. canadensis, M. spicatum, S. emersum* fo. *fluitans, Callitriche* spp (see **Fig 7.32**).

The presence of *P. arundinacea,* and *R. trichophyllus* and *C. riparius* to a lower extent, are related to the increasing of phosphorus and ammonium concentration, while *R. pencillatus* ssp. *pseudofluitans* is more related to fast flow conditions. *Cladophora* spp. has nearly no correlation with the nutrient levels in water, but is characteristics of streams with high flow velocity. *A. stolonifera, Ulothrix* spp. and *F. antipyretica* show a similar trend to that of *R. pencillatus* ssp. *pseudofluitans*, but are less linked to fast flowing waters. *R. riparioides* and *B. erecta* are typical in shaded and quite natural sites with low nutrient concentrations, the first one in softer waters and the second one in more calcareous and smaller streams. *N. officinale, S. erectum* and *M. aquatica* are present in waters rather poor in phosphorus and ammonium, but with higher conductivity and hardness, occurring at sites with quite slow flow and fine substrate. *L. minor, P. pectinatus, E. canadensis, M. spicatum, S. emersum* fo. *fluitans* and *Callitriche* spp. exhibit a similar trend, but occur in more eutrophicated watercourses.

As we have seen, it is extremely important to establish a certain number of river types, according to those features that strongly affect the macrophyte community, determining its composition and abundance.

From the matching-two-table analyses on our data sets (see **Section 7.7-7.9**) it is evident that the main driving forces for the biomass of the aquatic vegetation in running waters are the flow velocity and the dimension of substrate granules. The species composition and distribution is firstly determined by these two aspects, together with the type of water (calcareous or not), and only secondarily by nutrient concentrations in water, degree of shading and naturalness or artificialization of the site. Similar results were obtained by other authors (Daniel et al., 2005; Demars & Edwards, 2009; Demars & Thiébaut, 2008).

Given the huge influence of morphology and hydrology on the macrophyte vegetation, it is extremely important to establish some river types corresponding to different macrophyte communities.
The factors that have to be considered are the ecoregion the watercourse belongs to, the hardness or alkalinity of the water, the altitude and the slope of the sampled site, the water velocity and the substrate of the site that are highly correlated to each other, the width and the depth of the river, since they affect the discharge. We worked out a dicotomic key to classify the rivers according to their macrophyte type:

1.	Acidic rivers (hardness ≤ 100 mg/l CaCO3)	Not defined
	Calcareous or neutral rivers (hardness > 100 mg/l CaCO3)	2
2.	Lowland watercourses (altitude < 150 m a.s.l.)	3
	Upland watercourses (altitude ≥ 150 m a.s.l)	7
3.	Average width < 40 m	4
	Average width ≥ 40 m	Type 1
4.	Average depth < 30 cm	5
	Average depth ≥ 30 cm	6
5.	Flow velocity[7] ≥ 5	Type 2
	Flow velocity < 5	Type 3
6.	Flow velocity ≤ 2	Type 4
	Flow velocity > 2	Type 5
7.	Average width < 40 m	8
	Average width ≥ 40 m	Type 6
8.	Flow velocity ≥ 5	9
	Flow velocity < 5	11
9.	Substrate class[8] = 6	Type 7
	Substrate class < 6	10
10.	Substrate class ≥ 4	Type 8
	Substrate class < 4	Type 9

[7] The number refers to the classification adopted in the field data sheet. See **Section 6.2.3** for details.
[8] The number refers to the classes listed in **Section 6.4**.

11.	Flow velocity ≥ 3	12
	Flow velocity < 3	14
12.	Substrate class ≥ 3	15
	Substrate class < 3	13
13.	Average depth < 30 cm	Type 3
	Average depth ≥ 30 cm	Type 5
14.	Substrate class ≥ 3	Type 5
	Substrate class < 3	Type 4
15.	Substrate class > 3	Type 8
	Substrate class = 3	Type 9

The river types for acidic rivers were not defined, because nearly all of our sites are neutral or calcareous watercourses. Nonetheless it is possible to describe the same types for hard and soft waters, but the species composition is different. For example species like *C. commutatum* or *P. coloratus* and nearly all the Characeae are typical of calcareous waters (Carbiener et al., 1990; Buchwald et al., 2000; Krause, 1997), while *Ranunculus penicillatus* var. *penicillatus* (Dumortier) Babington subsitute *R. penicillatus* var. *calcareus* (R. W. Butcher) in acidic waters (Agences de l'Eau, 1997).
The river types listed in the dicotomic key are characterized as follows:

- Type 1: Main lowland rivers, with helophytes along the banks and some hydrophytes limited to the lentic portions of the river (Meilinger et al., 2005).
- Type 2: Shallow lowland streams and rivers with a bottom of cobbles, gravel and sand. The macrophyte cover is low but the species richness is high. Many amphibious species are present in the emergent form, like *M. palustris, M. aquatica* and *N. officinale.* Mosses, filamentous algae and hydrophytes are present as well (Baattrup-Pedersen & Riis, 1999).
- Type 3: Shallow streams with medium to slow flow and medium to fine substrate. The aquatic plant community is well developed and has quite high coverage. It consists especially of amphibious species (*B. erecta*) and helophytes (*Carex* spp., *S. erectum*) (Baattrup-Pedersen et al., 2006; Riis et al., 2000; Tremp, 2007).
- Type 4: Slow flowing watercourses, with very fine sediment. The macrophyte cover is nearly 100% and consists mainly of hydrophytes like various *Potamogeton* spp., *Chara* spp., *S. emersum* fo. *fluitans, M. spicatum, Callitriche* spp. and many others in dependence on the trophic conditions (Dawson et al., 1999; Tremp, 2007).

- Type 5: Streams with medium flow velocity and fine sediment (sand or mud). The macrophyte cover is lower than in type 4, but still high. Hydrophytes like *Callitriche* spp. or amphibious species like *B. erecta* (usually in the submerged form) and *S. erectum* are often present and dominant (Baattrup-Pedersen et al., 2003; Haury & Aïdara, 1999).
- Type 6: Main upland rivers, with high water flow rate. The macrophyte vegetation is extremely reduced or absent, usually limited to the bank zones.
- Type 7: Upland turbulent streams with a very coarse and stable bottom (big boulders and cobbles). The macrophyte community consists of bryophytes (French & Chambers, 1996), e.g. *C. commutatum, C. aquaticus, C. mucronatus, R. riparioides* (Scarlett & O'Hare, 2006), has low cover and low species richness. Filamentous algae like *Cladophora* spp. can also be present.
- Type 8: Upland fast flowing streams. Because of the unstable bottom, consisting mainly of cobbles, the macrophyte vegetation is actually absent, with the exception of some species like *P. arundinacea, A. stolonifera* and *G. plicata* near the banks. Sometimes *R. penicillatus* ssp. *pseudofluitans* is present with low cover values (Garbey et al., 2004)
- Type 9: Upland streams and rivers with medium flow velocity and substrate made of gravel, sand and cobbles. The aquatic vegetation cover is quite high, around 50% and the community is characterised by *R. penicillatus* ssp. *pseudofluitans* (in neutral rivers or by *R. penicillatus* var. *calcareus* in calcareous rivers), *Cladophora* spp., *Agrosits stolonifera* and *Phalaris arundinacea* (Lumberas et al., 2009). Some mosses, like *F. antipyretica* or *R. riparioides,* occur as well (Green, 2005; Hrivnák et al., 2006, Scarlett & O'Hare, 2006).

On the basis of the matching-two-table analyses on species and river features (see **Section 7.8**) we can divide the taxa, according to their preferences in terms of habitat:

- very fast flowing waters and high altitude: *Cratoneuron commutatum, Cicnlidotus aquaticus, C. mucronatus, Hygrohypnum dilatatum, Rhynchostegium riparioides, Tribonema* spp., *Mentha spicata* (Hrivnák et al., 2006; Scarlett & O'Hare, 2006)*;*
- medium or fast flowing wide watercourses: *Ulothrix* spp., *Ranunculus penicillatus* ssp. *pseudofluitans, R. penicillatus* x *trichophyllus, Polygonum lapathifolium, Cladophora* spp., *Cardamine amara, Amblystegium riparium, Epilobium* spp., *Vaucheria* spp., *Microspora* spp., *Amblystegium tenax* (Lumberas et al., 2009; Madsen et al., 2001)*;*
- artificialized watercourses: *Lycopus europaeus, Cinclidotus riparius, Ludwigia uruguayensis, Rumex obtusifolius, Potamogeton nodosus, P. berchtoldii, Mimulus guttatus, Barbarea vulgaris, Spyrogyra* spp., *Carex acutiformis*, *Alisma plantago-aqautica.* These are probably species mostly present in impacted sites,

because they are tolerant to disturbance compared to the other species (Baattrup-Pedersen et al., 2002; Baattrup-Pedersen et al., 2003);

- slow flowing watercourses: *Vallisneria spiralis, Ceratophyllum demersum, Polygonum hydropiper, Myriophyllum verticillatum, Sparganium emersum* fo. *fluitans, S. erectum, S. emersum, Iris pseudacorus, Nuphar lutea, Utricularia australis, Schoenoplectus lacustris, Potamogeton pectinatus, P. lucens, P. natans, Phragmites australis, Deschampsia caespitosa, Lemna minor, L. trisulca, Spirodela polyrhiza, Stachys palustris, Groenlandia densa, Elodea nuttallii, E. canadensis, Chara globularis, Oedogonium* spp. (Demars & Edwards, 2009; French & Chambers, 1996; Madsen et al., 2001);
- shallow shaded small streams with little or no morphological modifications: *Berula erecta, Nitella mucronata, Scirpus sylvaticus, Petasites albus, Carex rostrata, Caltha palustris.*

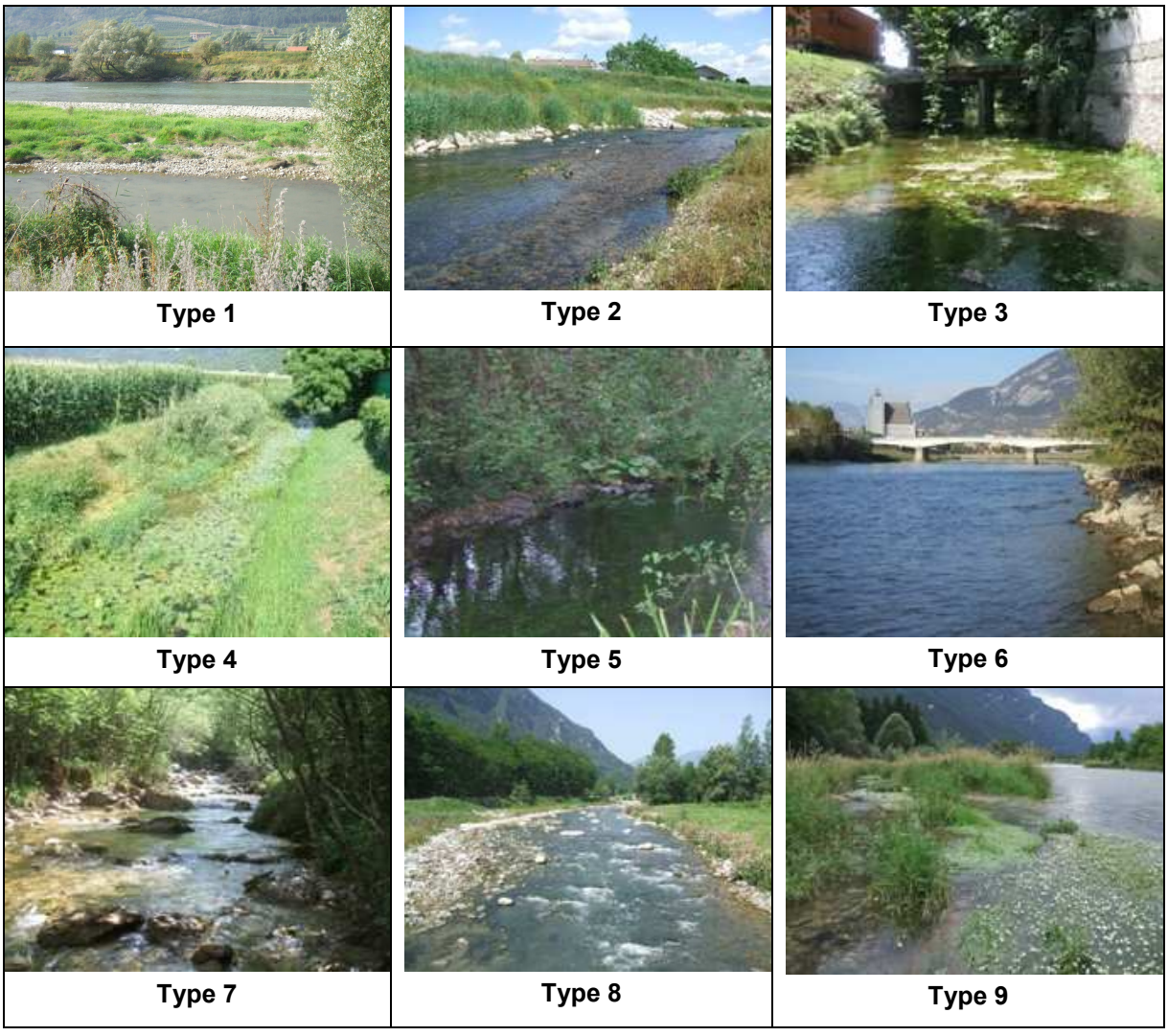

Figure 8.1: images of some sampling sites belonging to the different river types.

Another important theme is that of the invasive species. In the 62 surveys we registered 3 invasive non-indigenous species: *Elodea canadensis, E. nuttallii* and *Ludwigia uruguayensis* (Thiébaut, 2007). The first species is quite common and was recorded at 10 different sites, but it was never predominant, reaching the maximum abundance value of 3. This fact is due to the preference of *E. canadensis* for standing or weakly running waters (Agences de l'Eau, 1997; DAISIE, 2006) that make it more problematic in lentic waters (Sarvala et al., 2009). *E. nuttallii* was found in one lowland watercourse, where it was really abundant, while it was absent in the upland streams and rivers. *L. uruguayensis* was recorded at two sites in the Bacchiglione, but it was not very abundant.

Various studies found out that *E. nuttalli* has a greater competitive success than *E. canadensis,* which was displaced by the former species at many places (Abernethy et al., 1996; Rolland & Trémolières, 1995; James et al., 1999). Our data proves that upland running water environments are not suitable for the development of *E. nuttallii,* which to date has not yet colonised the watercourses in Trentino. It is instead present in lowland rivers, but since we sampled only ten sites in the province of Vicenza we could not really assess its invasiveness in those environments.

Particular attention has to be paid to the presence of *L. uruguayensis* in the Bacchiglione, because of the high invasive potential of this species, which can represent a serious problem for lakes and rivers, as proved by numerous studies conducted in France (Coudreuse et al., 2009; Lambert et al., 2009; Sourisseau et al., 2009; Amri et al., 2009).

If we focus now on the phosphorus and ammonium influence on the macrophyte community, we can see that from procrustean and co-inertia analyses a clear distribution of species in relation to water nutrient levels does not come out (see **Section 7.7**). Considering the Spearman correlations the results are similar, since only few species seem to be correlated with phosphorus and ammonium, while most of them do not show significant correlations with the nutrient concentrations in water.

The Spearman correlation, calculated on the species abundances (see **Section 7.11**), allowed us to identify the following taxa as preferring eutrophic conditions[9]: *Callitriche* spp., *Ceratophyllum demersum, Lemna minor, L. trisulca, Myriophyllum verticillatum, Polygonum mite, Potamogeton pectinatus, Ranunculus trichophyllus, R. penicillatus* x *trichophyllus, Sparganium emersum* fo. *fluitans* and *Typha latifolia* (Schneider & Melzer, 2004; Szoszkiewicz et al., 2006). The information about *Callitriche* spp. has to be regarded with caution, because inside the genera *Callitriche* there are species with very different ecology (Casper & Krausch, 1980b, Kohler, 1975). In our study, given the impossibility of correct identification of *Callitriche* spp. without fruiting specimens, we could not determine the plants down to species level (except at the Tesina at Lupia

[9] When referring to the trophic state of the watercourse we consider both the concentrations of phosphorus, total and ortophosphate, and ammonium (Carbiener et al., 1995).

di Sandrigo) but it is likely that all of our records belong to species occurring in eutrophic habitats. On the other side the oligotrophic species are *Cratoneuron commutatum*, *Cinclidotus mucronatus, Rhynchostegium riparioides*, *Mentha longifolia* and *Potamogeton nodosus*. The result obtained for the last species is in contrast with what has been indicated by other authors, who describe *P. nodosus* as a eutrophic (Carbiener et al., 1995; Schneider & Melzer, 2003) or hypertrophic species (Haury et al., 2006). In effect we found a weak negative relation only with ammonium concentration and no relation with phosphorus. Moreover the result was not confirmed by the Wilcoxon test on presence-absence data. Nevertheless the fact that we found it in non eutrophicated sites makes it more reasonable to classify *P. nodosus* as a euryecious species.

C. riparius and *Polygonum mite* resulted to be species able to stand an increase in organic substance load[10] (measured by BOD5), while *Berula erecta* and *Mentha aquatica* live only in extremely oligosaprobic conditions (Daniel et al., 2005; Carbiener et al., 1995).

The correlations were tested also through the Wilcoxon test on presence-absence data and the species identified as eutrophic are *Callitriche* spp., *Ceratophyllum demersum, Lemna minor, Phalaris arundinacea, Polygonum hydropiper, Ranunculus penicillatus* x *trichophyllus, Sparganium emersum* fo. *fluitans* and *Typha latifolia* (Bini et al., 1999; Daniel et al., 2005; Szoszkiewicz et al., 2006). The oligotrophic species are *Berula erecta, Cratoneuron commutatum, Mentha aquatica, Myosotis palustris* (Szoszkiewicz et al., 2006), while *Potamogeton berchtoldii, Rhynchostegium riparioides*, and *Spirogyra* spp. can be identified as mesotrophic (Daniel et al., 2005; Egertson et al., 2004; Carbiener et al., 1995).

The differences in the results are probably due to the fact that some species, like *P. pectinatus*, can be present in a very wide range of trophic conditions (Chambers et al., 1991; Egertson et al., 2004) but become really abundant only with high nutrient levels (Dawson & Szoszkiewicz, 1999). Therefore the positive correlation results only when analysing the abundance data. On the other hand there are species, e.g. *B. erecta*, the abundance of which is more related, in the surveyed area, to the conductivity and hardness of the water than to the phosphorus and ammonium concentration (Buchwald et al., 2000; Haslam, 1995). For species like these, the correlation with ammonium or phosphorus can be masked by other factors, when considering the abundance data, but it emerges when analysing only the species occurrence at the sampled sites.

When trying to outline the correlations of species with phosphorus and ammonium, it is also important to remember that the submerged and the emergent form of many amphibious species show very different tolerance to nutrient enrichment. For example the underwater form of *Nasturtium officinale* is more oligotrophic than the emergent one, while for *Sparganium emersum* it is exactly the opposite (Carbiener et al., 1995).

[10] When referring to the organic matter in water we consider the BOD5 parameter (Carbiener et al., 1995).

Talking about macrophytes and the trophic state of running waters we have to point out that the analysis of the correlation between the IBMR (AFNOR, 2003; Haury et al., 2006) and the nutrient levels in water gave quite satisfying results, from the statistical point of view. In a short time the IBMR will be adopted as official macrophyte method in Italy, by law. The correlations with ammonium, ortophosphate, total phosphorus and even with nitrates are all highly significant and varying from -0.37 to -0.47. However in some cases the IBMR can be misleading for example when it identifies a site like the Rio S. Zeno (see **Fig 7.41-7.44**) as having a high trophic level, even if its median value of ammonium is 30 µg/l, the median total phosphorus concentration is equal to 20 µg/l and the ortophosphate is 15 µg/l. Another case is that of the Chiese at Pieve di Bono, at the upstream sampling station, classified as a site having a medium trophic level by the IBMR, but having respectively 10, 13 and 20 µg/l median values of ammonium, ortophosphate and total phosphorus.
It is evident that the result given by a biotic index such as the IBMR cannot be identical to that obtained through the chemical analysis and maybe the macrophyte vegetation is able to tell us something more about the assessed watercourse and to detect something that the chemical analyses of water are not able to reveal, for example a phosphorus enrichment in the sediment.
Moreover a species can show different trophic preferences in mineralised and weakly mineralised waters, e.g. *Amblystegium riparium* that is regarded as a eutrophic species in weakly mineralized waters and as a mesotrophic one in mineralized rivers (Thiébaut & Muller, 1999) or being less pollution-tolerant when occurring away from its centre of distribution, like *Sparganium erectum* (Haslam, 1995).
Given these considerations, the IBMR showed to be a very good trophic index, nonetheless in a perspective of classification of watercourses compliant to the WFD "one-out all-out" principle, we must remember that what we have to aim at is to develop biological methods for the assessment of the ecological state of watercourses. In fact all rivers and streams that will not reach a good ecological state by the 2015 have to be restored (EC, 2000). It is important to remark that the ecological state is something very different from the trophic state, the latter being naturally high in some situations, for example in lowland slow flowing canals, and therefore our objective is not that of making all watercourses oligotrophic. The problem will be partially solved by the future introduction of the Ecological Quality Ratio, at the moment not defined yet. Despite this we think that Italy should not give up developing a methodology to assess the distance between the theoretical macrophyte community for a certain river type and the actual community recorded at the sampled site.

9 CONCLUSIONS

The macrophyte community of a river is determined in its specific composition and abundance by many different factors and this study showed that flow velocity and substrate granulometry are the most important driving forces for aquatic plants.

The ammonium and phosphorus concentrations have a subordinate role, if compared to the morphological characters of the river site, in determining the species occurring at a certain sampling station. However some species have a significant correlation with nutrient levels in water. The main variables affecting the diversity of the biocenosis, for what concerns our study, are the altitude of the site and the nitrate concentration.

When analyzing the macrophyte community as indicator of the trophic state of running water environments it is essential to define the river type the sampling site belongs to. In this study some typologies, correspondent to different kind of aquatic plant communities, were established.

The IBMR method seems to be a good indication system for the trophic state of watercourses, but it is necessary to work out an indication method for Italian rivers in order to assess the ecological status of our running waters, fulfilling the WFD demands.

A correct assessment of the macrophyte community ecological state should include not only the species composition and abundance, but also other metrics such as the species richness, occurring of different taxonomical groups (algae, bryophytes, vascular plants) and different biological forms (helophytes, hydrophytes, amphiphytes), occurring of emergent or submerged form of taxa, diversity and evenness of the community.

The main problem, in order to establish type dependent reference community for macrophytes, is the lack of real undisturbed sites, especially for some river typologies, that can be regarded as reference sites. The only solution seems to be the detection of the best available sites, as done by other European countries.

Once a certain number of best available sites have been found for each river type all over Italy, the future step will be that of describing the reference aquatic plant community in term of species composition, allowing thus the creation of an ecological macrophyte index for Italian rivers.

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11 APPENDIX

11.1 SAMPLING DATA SHEET: MACROPHYTES – RUNNING WATERS

Watercourse :_____ Code:_____
Site:_____ Basin:_____
Altitude:_____m a.s.l. Date_____ Coordinates:_____
Photos:_____ Surveyors:_____
Reach length:_____ m Average reach width:_____ m

Average depth:	Water transparency:	Water discharge trend:
☐ I 0-30 cm	☐ total	☐ increasing
☐ II 30-100 cm	☐ partial	☐ stable
☐ III >100 cm	☐ none	☐ decreasing

Was the sampling possible across the whole width of the watercourse?

☐ yes ☐ no

Was the river bottom visible?

☐ yes ☐ no

Hydrological conditions at the survey time:

☐ in spate ☐ high flow ☐ moderate flow

☐ low flow ☐ exceptionally low flow

Flow velocity:

☐ I undetectable or very slow flow ☐ II slow flow

☐ III medium and laminar flow ☐ IV medium flow with some turbulence

☐ V medium and turbulent flow ☐ VI high and nearly laminar flow

☐ VII high and turbulent flow ☐ VIII very high and turbulent flow

Shading conditions:

☐ 1 fully sunny ☐ 2 sunny ☐ 3 partially sunny

☐ 4 partially shaded ☐ 5 totally shaded

Substrate granulometry:

bedrock_____% boulders_____% cobbles _____%

gravel _____% sand_____% silt/mud_____%

River bottom structure:

☐ uniformly steady ☐ diversified and steady ☐ partially movable

☐ easily movable ☐ compact because of artificialization

Watercourse artificialization:

☐ river bottom _____

☐ right bank _____

☐ left bank _____

Presence of anaerobiosis on the river bottom:

☐ absent ☐ traces ☐ localised ☐ diffused

Periphyton:

☐ absent ☐ not detectable by touch, but visible ☐ detectable by touch

☐ not well developed ☐ moderately developed ☐ thick

Erosion:

Right bank

☐ not relevant ☐ localised ☐ very evident

Left bank

☐ not relevant ☐ localised ☐ very evident

Riparian strips:

Right bank_____

_____

Left bank_____

_____

Surrounding land use:

Right bank_____

Left bank_____

MACROPHYTES	Cover		
Species	Submerged form	Emergent form	Total

% total macrophyte cover	
% macrophyte cover without filamentous algae	
% filamentous algae cover	

NOTES:_____

_____

11.2 SPECIES ABUNDANCE MATRIX[11]

SITE	Ad Bo	Ad gt	Ad Mo	Ad nl	Ad nP	Ad SM	Ad TN	Ad Vi	Ar nò	Ba PM	Ba So	Br B2	Br Bo	Br G2	Br Gr	Br Le	Br nd	Br V2	Br Vi	Ca la	Ca Id	Ce g2	Ce gg	Ce re	Ch Pd	Ch Pm	Ch St	De bb	Du in	Fe rr	Gh eb
Agr.sto				1					3	1	2	1	2	4	2	1		2	1	1		3	3			1	1				4
Ali.pla																															
Amb.ten							3																			4	3		2		
Amb.rip.												1				3															
Api.nod																															
Bar.vul																	1														
Ber.ere										1	2						1													1	5
Cal.cop																															
Cal.spp		5					1			2	3	1				3	2													1	
Clt.pal																															
Crd.ama																						3	1								
Car.acu																															
Car.ros																															
Car.spp																															
Cer.dem											2						5							1						5	
Cha.glo																															
Cin.aqu																				5											
Cin.fon												3	2																		
Cin.muc	1																									3					
Cin.rip							4																				1				
Cla.spp		3	1			3	3	1			1	3	2		4			3	3			2	4			3					
Crat.com																															
Des.cae																				2											
Elo.can		3					1			3	3						2														
Elo.nut																															
Epi.spp											1												1								
Epi.hir									1																						
Equ.pal																						1									
Fil.ulm																															
Fon.ant			3			3	3	3			2	4	3	3	4	1											3				
Gly.max																														4	
Gly.pli									3					2									2		1				3		
Gro.den																															
Hip.vul																															
Hyg.dil																															
Iri.pse																2	1													2	
Jun.spp																															
Lem.min											2						3		1											3	
Lem.tri																	1													3	
Lud.uru										3	2																				
Lyc.eur											2																				
Lyt.sal																														1	
Men.aqu										2	2																		1		
Men.lon																															
Men.spi																										1					
Mic.spp											2																1				

SITE	La Ve	Le no	Lo ra	Lo ve	Me le	Mo gg	Mo ne	No Ro	No Ru	Pa Iv	Po na	Ra bb	Re s2	Re se	Ri mo	Ro Fr	Sa Dr	Sa lè	Sa Li	Sa In	Sa lo	Sa PA	Sa Ra	Se l1	Se l2	Sp or	SZ e2	SZ en	Te Bo	Te L2	Te Lu
Agr.sto		1	1	2											1		1	1	2	3			1			2					
Ali.pla															1																
Amb.ten			1																						1						
Amb.rip.									2		3							4													
Api.nod																														2	
Bar.vul																	1														
Ber.ere	2						2						5	5	3									5	3				1	5	3
Cal.cop																														3	
Cal.spp			1				1									5					2								1		
Clt.pal																								2	1						
Crd.ama																															
Car.acu															3																
Car.ros																								3	2						
Car.spp																														3	2
Cer.dem																															
Cha.glo																											5				
Cin.aqu				1					2		4	1																			
Cin.fon		1																3													
Cin.muc					3																										
Cin.rip		2							4																						
Cla.spp				3		4		4	4	2	3						1		1												
Crat.com		3			3	2																									
Des.cae																												2			
Elo.can							2		1											3							3		3		
Elo.nut																														4	5
Epi.spp	2																														
Epi.hir			2					2								1	1		2												
Equ.pal															1				1				1					1			
Fil.ulm															1																
Fon.ant			4							2			3	3	3					4			3	1							
Gly.max																															
Gly.pli	5			3															2			3	2			3					
Gro.den																				5							5				
Hip.vul															5																
Hyg.dil												1																			
Iri.pse															1					1										2	
Jun.spp																															1
Lem.min			1													2					1							1	1	3	5
Lem.tri																														1	5
Lud.uru																															
Lyc.eur																															
Lyt.sal																				1								2			
Men.aqu															2									3						3	2
Men.lon												1			1		1									1		1			
Men.spi																															
Mic.spp	4			1																											

[11] The abundance values in the matrix correspond to the coefficients listed in **Section 6.2.2**

SITE	Ad Bo	Ad gt	Ad Mo	Ad nl	Ad nP	Ad SM	Ad TN	Ad Vi	Ar nò	Ba PM	Ba So	Br B2	Br Bo	Br G2	Br Gr	Br Le	Br nd	Br V2	Br Vi	Ca la	Ca ld	Ce g2	Ce gg	Ce re	Ch Pd	Ch Pm	Ch St	De bb	Du in	Fe rr	Gh eb
Mim.gut																															
Myo.pal										3	3													1							3
Myn.aqu																					1										
Myr.spi							1					2	2			4		3						3				3			
Myr.ver																					3			1							
Nas.off				1	3					2	4			4			2								2	2				3	3
Nit.muc																															
Nup.lut																					1									5	
Oed.spp																								2							
Osc.spp																															
Pet.alb																															
Pet.hyb																						1			2	3					
Pha.aru	2	2	2	2	2		2	2	3		1	2	2	3	3	3		2	2	1	4	3	2	2	4		3	2	3	2	
Pho.spp																										3					
Phr.aus										1						2														4	
Poa.pal																															
Pol.hyd										2							3														
Pol.lap											2			1								2									3
Pol.mit																	1							3				2			3
Pot.ber										3	1				1																
Pot.cri										4								1													
Pot.luc																	2				2										
Pot.nat																														2	
Pot.nod										2	1						4														
Pot.pec		5																													
Ran.pen			2	3	3		2	2	1	1	1			5	3	4				4					5		3				
Ran.pxt												5	5					4	5												
Ran.tri																						3	5								
Rhy.rip				2	2															4		1	3			3					1
Rhz.spp		1														2															
Rum.cri																					2										
Rum.obt																															
Sag.sag																														1	
Sch.lac																												3			
Sci.syl											1																				
Spa.eme																														2	
Spa.emf		3					1										5				5									1	
Spa.ere		3								2	1						2							2				4		2	
Spi.pol																					2										
Spy.spp										2	3				2																
Sta.pal																								3							
Tri.spp																															
Typ.lat											1							1											2		
Ulo.spp	5		1				1	1							1	3		2	1							1	2				
Utr.aus																														3	
Val.spi																								5							
Vau.spp				3	5					4	1	2		3	3	4	1			3		2	1		2		3		3		1
Ver.ana									2	1	2			3	2				2			1	1							2	2
Ver.bec					1				2	1	1					1	1		1								1			1	
Zan.pal										3	1																				

SITE	La Ve	Le no	Lo ra	Lo ve	Me le	Mo gg	Mo ne	No Ro	No Ru	Pa lv	Po na	Ra bb	Re s2	Re se	Ri mo	Ro Fr	Sa Dr	Sa lè	Sa Li	Sa In	Sa lo	Sa PA	Sa Ra	Se l1	Se l2	Sp or	SZ e2	SZ en	Te Bo	Te L2	Te Lu
Mim.gut																	1														
Myo.pal							2								1														1	2	3
Myn.aqu																															
Myr.spi							3													3							5	3	4		
Myr.ver																													2		
Nas.off	4		3							1					3	3	1	2	3				4	2	1	1				4	4
Nit.muc							3																								
Nup.lut																															
Oed.spp																															
Osc.spp															4																
Pet.alb								1																3	2						
Pet.hyb								2										1													
Pha.aru		3						1	3	4					3	3	2		4	2	4	4	4	3		2	3	4		2	2
Pho.spp							4								4																
Phr.aus	2															2											2	3			
Poa.pal								3																							
Pol.hyd							1																1							2	2
Pol.lap																			1				1								
Pol.mit																	1		2				1								
Pot.ber																													3		
Pot.cri													3	2							2		3							2	
Pot.luc																					2						4	5			
Pot.nat																															
Pot.nod																															
Pot.pec							4														5								2	5	1
Ran.pen	3	4	5					3	4	3						4	5		5			4	4								
Ran.pxt																															
Ran.tri							1													3			3							1	2
Rhy.rip		1		2	3									2	1										2	1					
Rhz.spp																													1		
Rum.cri																															
Rum.obt																			1												
Sag.sag																															
Sch.lac																															
Sci.syl																2								2	1						
Spa.eme							1																								
Spa.emf							2														1								1		
Spa.ere	4		1										4	4		2														3	2
Spi.pol																															
Spy.spp								1																					3		
Sta.pal																															
Tri.spp	1											1																			
Typ.lat								2														1									
Ulo.spp								3	1	1	1				1		1		2				1						1		
Utr.aus																															
Val.spi																															
Vau.spp	2		4	4			1				1			1				1	1			2	3			3			5		
Ver.ana		1	2												1		1		2	1			1							2	
Ver.bec			3							1					2		1	1	1						1					1	1
Zan.pal													1	1	2		4			5		4	3								

11.3 SITE FEATURE MATRIX

SITE[12]	Average Width	Average[13] Depth	Velocity[8]	Shade[8]	Substrate %	Total Cover %	Macrophyte Cover % (without algae)	Algae Cover %	Land use (right bank)	Land use (left bank)	Elevation (m a.s.l.)
AdBo	70	1	3	1	cobbles(80)/gravel(20)	15	0,1	15	motorway	village	120
Adgt	4	2	2	4	mud(100)	100	100	0,1	Adige	city	190
AdMo	50	2	3	1	cobbles(50)/stones(20)/sand(20)	80	0,1	80	agriculture and scattered houses	motorway	170
AdnI	7	2	7	3	stones(70)/cobbles(30)	30	25	5	road	woods and meadows	560
AdnP	4	2	4	4	stones(30)/cobbles(30)/gravel(30)	50	15	35	village	woods	520
AdSM	70	3	6	2	cobbles(80)/gravel(10)/sand(10)	10	1	9	agriculture and scattered houses	agriculture and scattered houses	230
AdTN	70	3	6	2	cobbles(60)/gravel(30)	10	10	0,1	city	city	190
AdVi	80	2	3	1	cobbles(50)/gravel(30)/sand(20)	5	5	0,1	agriculture	village	180
Arnò	10	1	3	2	gravel(40)/stones(20)/cobbles(20)	5	5	0	village	village	540
BaPM	12	1	3	1	cobbles(50)/gravel(50)	30	20	10	agriculture and scattered houses	agriculture and scattered houses	40
BaSo	15	1	6	1	cobbles(80)/gravel(20)	15	12	3	agriculture and scattered houses	agriculture and scattered houses	44
BrB2	10	1	4	3	gravel(50)/cobbles(20)/sand(25)	50	45	5	village	village	370
BrBo	10	1	6	3	cobbles(39)/gravel(39)/sand(20)	60	59	1	village	village	370
BrG2	25	2	3	1	cobbles(30)/gravel(30)/sand(35)	50	45	5	meadows	industrial zone	250
BrGr	25	2	5	1	cobbles(60)/stones(30)/gravel(10)	35	15	20	meadows	industrial zone	250
BrLe	5	1	6	1	gravel(50)/cobbles(20)/sand(10)	60	50	10	agriculture	agriculture and scattered houses	470
Brnd	15	3	2	1	gravel(70)/sand(30)	100	100	0	agriculture	agriculture and road	46
BrV2	15	2	7	1	stones(30)/cobbles(30)/sand(20)/gravel(15)	40	40	0,1	woods and meadows	meadows	330
BrVi	15	1	7	2	cobbles(50)/gravel(20)/sand(15)/stones(10)	55	50	5	woods and meadows	meadows	330
Cala	2,5	1	4	4	sand(50)/cobbles(30)/stones(20)	85	80	10	fish-farming	agriculture	260
Cald	4	3	2	1	mud(60)/sand(30)/gravel(10)	95	95	0	agriculture	agriculture	250
Ceg2	3	1	7	3	cobbles(40)/sand(30)/stones(20)	40	40	0,1	woods and fish-farming	scattered houses	500
Cegg	5	1	6	2	sand(55)/gravel(20)/stones(15)	85	70	15	woods and fish-farming	scattered houses	500
Cere	8	2	1	1	mud(100)	80	78	2	agriculture	agriculture	25
ChPd	15	2	6	3	cobbles(70)/stones(30)	60	60	0,1	woods and scattered houses	woods and scattered houses	460
ChPm	8	2	5	4	cobbles(60/stones(30)/gravel(10)	15	10	5	woods	woods and scattered houses	540
ChSt	40	2	6	3	cobbles(60)/gravel(40)	20	15	5	meadows and village	meadows and agriculture	380
Debb	3,5	2	1	2	mud(100)	60	60	0	agriculture	agriculture	25
Duin	5	1	5	3	gravel(50)/stones(40)/cobbles(10)	5	5	0,1	village	village	400
Ferr	4	2	1	2	mud(100)	100	100	0	agriculture	agriculture	27
Gheb	5	1	3	4	gravel(45)/sand(45)/cobbles(10)	90	90	0,1	village	village	60
LaVe	2	1	6	3	stones(40)/cobbles(20)/sand(20)/gravel(20)	80	60	20	agriculture	agriculture	470
Leno	20	1	3	1	cobbles(50)/gravel(30)/stones(20)	25	25	0	city	city	170
Lora	6	2	3	4	cobbles(50)/sand(30)/gravel(20)	70	65	5	river	river and wetland	380
Love	6	1	3	4	cobbles(60) /gravel(30)	70	5	65	agriculture and scattered houses	scattered houses	250
Mele	8	2	8	4	stones(50)/cobbles(20)/gravel(20)	15	15	0	woods	woods	800
Mogg	6	1	8	4	stones(50)/cobbles(30)/gravel(20)	15	1	14	woods and meadows	woods and meadows	600
Mone	4	2	2	5	mud(50)/sand(40)/gravel(10)	60	50	10	agriculture	agriculture	37
NoRo	20	2	7	4	gravel(50)/sand(20)/cobbles(20)	40	18	22	woods and meadows	woods and meadows	270
NoRu	40	3	3	4	cobbles(50)/gravel(40)/stones(10)	70	20	50	industrial zone	agriculture	220
Palv	6	1	3	2	cobbles(80)/gravel(10)	15	15	0,1	wetland	scattered houses	380
Pona	7	2	8	4	gravel(40)/stones(30)/sand(20)	40	35	5	road and woods	road and woods	350
Rabb	7	2	7	4	stones(60)/cobbles(30)	0,1	0,1	0,1	quarry	agriculture	720
Res2	5	2	2	4	mud(50)/gravel(40)/cobbles(10)	85	85	0	wetland	agriculture and scattered houses	250
Rese	5	2	3	4	mud(50)/gravel(30)/cobbles(20)	80	80	0,1	wetland	agriculture and scattered houses	250
Rimo	10	2	1	2	cobbles(40)/sand(30)/stones(20)	80	60	50	agriculture	agriculture	210

[12] For the codes used to identify the sampling sites see **Tab 7.3**.
[13] For the significance of numbers used to express the variables “Average Depth”, “Velocity” and “Shade” see Methods section **6.2.3**.

SITE	Average Width	Average Depth	Velocity	Shade	Substrate %	Total Cover %	Macrophyte Cover % (without algae)	Algae Cover %	Land use (right bank)	Land use (left bank)	Elevation (m a.s.l.)
RoFr	2,5	2	3	4	mud(100)	95	95	0	fish-farming and steel mill	main road	380
SaDr	30	2	3	2	cobbles(50)/sand(25)/gravel(25)	50	50	0,1	scattered houses	agriculture	200
Salè	3,5	1	6	3	gravel(40)/stones(30)/cobbles(30)	70	70	0	scattered houses	scattered houses	220
SaLi	35	2	4	2	cobbles(80)/gravel(20)	60	58	2	scattered houses	scattered houses	260
Saln	2	2	3	4	cobbles(45)/stones(30)/mud(25)	70	70	0	agriculture	woods and rubbish dump	80
Salo	3	2	2	1	mud(50)/sand(30)/gravel(15)/stones(5)	95	95	0	agriculture	agriculture	250
SaPA	35	2	4	2	cobbles(50)/gravel(25)/sand(10)	40	40	0,1	village	scattered houses	380
SaRa	25	2	4	2	sand(45)/cobbles(30)/gravel(15)/stones(10)	50	45	5	woods and road	agriculture and scattered houses	480
Sel1	3	1	2	5	mud(70)/gravel(20)/cobbles(10)	60	60	0	woods and road	wetland	260
Sel2	2,5	1	2	5	sand(40)/gravel(30)/mud(20)/cobbles(10)	30	30	0	woods and road	wetland	260
Spor	6	1	3	2	cobbles(70)/gravel(20)	5	2,5	2,5	woods and agriculture	scattered houses	280
SZe2	4,5	1	2	1	mud(100)	100	100	0	agriculture	agriculture	180
SZen	6	2	2	1	mud(100)	90	90	0	agriculture	agriculture	180
TeBo	20	2	2	3	cobbles (35) /gravel(35)/sand(30)	85	35	50	village	village	40
TeL2	8	2	2	2	sand(50)/mud(30)/gravel(20)	85	85	0	agriculture and scattered houses	agriculture	53
TeLu	10	2	2	2	mud(80)/sand(20)	100	100	0	agriculture and scattered houses	agriculture	53

11.4 SIMILARITY MATRIX: BRAY-CURTIS INDEX AND MORISITA INDEX ON SPECIES ABUNDANCE DATA[14]

SITE	AdBo	Adgt	AdMo	AdnI	AdnP	AdSM	AdTN	AdVi	Arnò	BaPM	BaSo	BrB2	BrBo	BrG2	BrGr	BrLe	Brnd	BrV2	BrVi	Cala	Cald	Ceg2	Cegg	Cere	ChPd	ChPm	ChSt	Debb	Duin	Ferr	Gheb	LaVe	Leno	Lora	Love	Mele	Mogg	Mone	NoRo	NoRu	Palv	Pona	Rabb	Res2	Rese	Rimo	RoFr	SaDr	Salè	SaLi	Saln	Salo	SaPA	SaRa	Sel1	Sel2	Spor	SZe2	SZen	TeBo	TeL2	TeLu
AdBo	1,00	0,07	0,36	0,13	0,09	0,00	0,17	0,36	0,16	0,00	0,02	0,07	0,09	0,09	0,19	0,28	0,00	0,32	0,22	0,04	0,16	0,12	0,07	0,07	0,18	0,14	0,32	0,10	0,16	0,04	0,00	0,00	0,15	0,00	0,00	0,10	0,00	0,00	0,33	0,21	0,36	0,14	0,00	0,00	0,00	0,12	0,10	0,17	0,00	0,27	0,06	0,18	0,17	0,16	0,10	0,00	0,12	0,09	0,15	0,08	0,04	0,05
Adgt	0,12	1,00	0,16	0,08	0,06	0,19	0,33	0,16	0,10	0,23	0,27	0,22	0,14	0,06	0,22	0,24	0,35	0,20	0,20	0,02	0,30	0,17	0,20	0,13	0,11	0,11	0,09	0,25	0,10	0,14	0,00	0,13	0,10	0,09	0,14	0,00	0,23	0,45	0,19	0,27	0,24	0,15	0,00	0,16	0,16	0,05	0,44	0,10	0,00	0,13	0,13	0,64	0,11	0,08	0,07	0,00	0,08	0,15	0,10	0,32	0,29	0,13
AdMo	0,35	0,18	1,00	0,43	0,32	0,61	0,61	1,00	0,30	0,04	0,18	0,48	0,46	0,55	0,73	0,41	0,00	0,29	0,27	0,27	0,23	0,24	0,21	0,11	0,56	0,11	0,69	0,14	0,23	0,06	0,00	0,13	0,49	0,50	0,10	0,00	0,19	0,00	0,43	0,52	0,87	0,15	0,00	0,27	0,26	0,27	0,35	0,46	0,00	0,48	0,33	0,25	0,46	0,51	0,23	0,00	0,17	0,13	0,21	0,02	0,06	0,07
AdnI	0,20	0,11	0,38	1,00	0,92	0,00	0,24	0,43	0,37	0,27	0,20	0,24	0,15	0,71	0,56	0,55	0,08	0,16	0,14	0,71	0,19	0,43	0,35	0,09	0,80	0,20	0,63	0,12	0,47	0,09	0,24	0,35	0,61	0,60	0,51	0,21	0,00	0,06	0,27	0,41	0,57	0,09	0,00	0,00	0,17	0,18	0,45	0,51	0,20	0,61	0,12	0,20	0,62	0,57	0,17	0,18	0,63	0,11	0,18	0,29	0,10	0,12
AdnP	0,17	0,10	0,32	0,79	1,00	0,00	0,18	0,32	0,25	0,33	0,23	0,22	0,08	0,65	0,47	0,50	0,14	0,08	0,10	0,60	0,14	0,33	0,24	0,07	0,74	0,19	0,57	0,09	0,48	0,14	0,24	0,42	0,43	0,67	0,50	0,16	0,00	0,08	0,19	0,30	0,48	0,11	0,00	0,00	0,16	0,20	0,42	0,41	0,29	0,54	0,05	0,15	0,53	0,58	0,19	0,21	0,62	0,08	0,13	0,36	0,16	0,18
AdSM	0,00	0,19	0,53	0,00	0,00	1,00	0,44	0,61	0,00	0,00	0,11	0,46	0,42	0,17	0,52	0,05	0,00	0,26	0,28	0,00	0,00	0,15	0,27	0,00	0,00	0,20	0,23	0,00	0,00	0,00	0,00	0,00	0,00	0,23	0,28	0,00	0,63	0,00	0,29	0,29	0,42	0,33	0,00	0,26	0,24	0,12	0,00	0,07	0,00	0,06	0,21	0,00	0,00	0,14	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00
AdTN	0,20	0,34	0,58	0,24	0,21	0,43	1,00	0,61	0,17	0,08	0,22	0,43	0,38	0,34	0,58	0,36	0,11	0,34	0,27	0,15	0,21	0,22	0,25	0,11	0,31	0,36	0,66	0,14	0,26	0,06	0,00	0,08	0,45	0,37	0,18	0,00	0,27	0,13	0,40	0,71	0,59	0,21	0,00	0,15	0,15	0,18	0,29	0,32	0,00	0,34	0,28	0,19	0,26	0,34	0,14	0,08	0,10	0,17	0,17	0,15	0,04	0,05
AdVi	0,35	0,18	1,00	0,38	0,32	0,53	0,58	1,00	0,30	0,04	0,18	0,48	0,46	0,55	0,73	0,41	0,00	0,29	0,27	0,27	0,23	0,24	0,21	0,11	0,56	0,11	0,69	0,14	0,23	0,06	0,00	0,13	0,49	0,50	0,10	0,00	0,19	0,00	0,43	0,52	0,87	0,15	0,00	0,27	0,26	0,27	0,35	0,46	0,00	0,48	0,33	0,25	0,46	0,51	0,23	0,00	0,17	0,13	0,21	0,02	0,06	0,07
Arnò	0,17	0,10	0,25	0,30	0,26	0,00	0,16	0,25	1,00	0,11	0,21	0,17	0,27	0,63	0,42	0,28	0,03	0,28	0,36	0,19	0,25	0,45	0,45	0,12	0,44	0,06	0,38	0,15	0,49	0,15	0,29	0,29	0,46	0,34	0,37	0,00	0,00	0,00	0,17	0,26	0,47	0,00	0,00	0,00	0,00	0,24	0,26	0,41	0,14	0,65	0,26	0,27	0,52	0,41	0,17	0,06	0,64	0,14	0,24	0,00	0,14	0,16
BaPM	0,00	0,21	0,04	0,22	0,27	0,00	0,09	0,04	0,14	1,00	0,63	0,11	0,02	0,29	0,27	0,28	0,34	0,07	0,05	0,16	0,00	0,15	0,08	0,08	0,18	0,05	0,21	0,10	0,19	0,16	0,29	0,28	0,08	0,36	0,23	0,00	0,00	0,24	0,06	0,07	0,08	0,05	0,00	0,28	0,30	0,22	0,26	0,26	0,14	0,21	0,24	0,13	0,25	0,45	0,15	0,10	0,25	0,09	0,03	0,51	0,35	0,28
BaSo	0,03	0,24	0,17	0,16	0,21	0,11	0,19	0,17	0,22	0,56	1,00	0,19	0,15	0,42	0,36	0,23	0,40	0,12	0,16	0,09	0,04	0,23	0,16	0,09	0,19	0,13	0,23	0,07	0,13	0,33	0,45	0,33	0,13	0,40	0,15	0,00	0,04	0,21	0,14	0,14	0,23	0,05	0,00	0,19	0,21	0,36	0,40	0,24	0,15	0,34	0,26	0,12	0,14	0,38	0,30	0,19	0,19	0,09	0,06	0,35	0,41	0,42
BrB2	0,13	0,24	0,36	0,28	0,20	0,40	0,43	0,36	0,15	0,12	0,19	1,00	0,93	0,33	0,57	0,38	0,04	0,69	0,66	0,12	0,12	0,31	0,29	0,14	0,18	0,14	0,40	0,17	0,23	0,05	0,08	0,05	0,18	0,32	0,33	0,00	0,24	0,12	0,21	0,28	0,42	0,26	0,00	0,17	0,21	0,19	0,15	0,12	0,32	0,19	0,32	0,15	0,17	0,30	0,14	0,00	0,26	0,17	0,19	0,24	0,03	0,04
BrBo	0,15	0,19	0,44	0,20	0,12	0,42	0,40	0,44	0,24	0,03	0,18	0,81	1,00	0,31	0,47	0,25	0,00	0,78	0,74	0,06	0,14	0,29	0,29	0,16	0,15	0,13	0,31	0,21	0,14	0,04	0,12	0,00	0,21	0,20	0,21	0,00	0,21	0,09	0,18	0,23	0,41	0,13	0,00	0,16	0,16	0,19	0,09	0,14	0,19	0,20	0,36	0,15	0,14	0,24	0,14	0,00	0,20	0,20	0,23	0,12	0,04	0,04
BrG2	0,11	0,08	0,38	0,50	0,50	0,18	0,28	0,38	0,51	0,23	0,36	0,31	0,30	1,00	0,70	0,48	0,10	0,20	0,23	0,42	0,15	0,45	0,34	0,07	0,70	0,15	0,64	0,09	0,40	0,19	0,44	0,48	0,56	0,76	0,39	0,00	0,00	0,04	0,24	0,36	0,61	0,05	0,00	0,11	0,15	0,32	0,47	0,57	0,26	0,79	0,32	0,16	0,55	0,75	0,23	0,08	0,61	0,09	0,14	0,17	0,21	0,24
BrGr	0,18	0,20	0,53	0,49	0,39	0,39	0,47	0,53	0,40	0,26	0,35	0,49	0,42	0,60	1,00	0,49	0,03	0,40	0,42	0,35	0,17	0,50	0,46	0,09	0,50	0,21	0,69	0,10	0,34	0,09	0,19	0,18	0,45	0,61	0,48	0,00	0,32	0,04	0,51	0,54	0,72	0,29	0,00	0,17	0,22	0,26	0,28	0,47	0,10	0,57	0,34	0,18	0,43	0,56	0,18	0,00	0,41	0,10	0,17	0,32	0,09	0,10
BrLe	0,24	0,21	0,29	0,40	0,41	0,05	0,29	0,29	0,25	0,26	0,22	0,35	0,24	0,39	0,41	1,00	0,12	0,37	0,15	0,36	0,14	0,28	0,15	0,22	0,50	0,05	0,60	0,26	0,33	0,18	0,09	0,24	0,39	0,50	0,26	0,00	0,00	0,23	0,31	0,40	0,47	0,24	0,00	0,03	0,09	0,18	0,50	0,41	0,29	0,51	0,26	0,23	0,43	0,46	0,12	0,02	0,36	0,30	0,35	0,48	0,09	0,06
Brnd	0,00	0,29	0,00	0,08	0,15	0,00	0,10	0,00	0,04	0,38	0,34	0,07	0,00	0,09	0,03	0,14	1,00	0,00	0,05	0,03	0,33	0,03	0,01	0,14	0,07	0,05	0,05	0,13	0,04	0,45	0,15	0,19	0,00	0,20	0,05	0,00	0,00	0,25	0,00	0,02	0,04	0,01	0,00	0,14	0,16	0,10	0,27	0,06	0,09	0,11	0,06	0,19	0,02	0,14	0,10	0,11	0,08	0,12	0,14	0,23	0,28	0,34
BrV2	0,31	0,23	0,30	0,20	0,12	0,25	0,35	0,30	0,24	0,07	0,15	0,57	0,67	0,17	0,37	0,31	0,00	1,00	0,78	0,07	0,14	0,36	0,38	0,23	0,15	0,23	0,24	0,28	0,19	0,04	0,13	0,00	0,18	0,03	0,28	0,00	0,32	0,15	0,41	0,35	0,38	0,26	0,00	0,05	0,04	0,12	0,10	0,21	0,05	0,30	0,26	0,19	0,16	0,20	0,10	0,00	0,21	0,29	0,29	0,22	0,06	0,05
BrVi	0,25	0,24	0,32	0,21	0,19	0,27	0,32	0,32	0,39	0,10	0,21	0,55	0,59	0,23	0,44	0,20	0,08	0,65	1,00	0,05	0,15	0,34	0,36	0,07	0,16	0,19	0,20	0,09	0,15	0,13	0,13	0,00	0,20	0,14	0,24	0,00	0,34	0,00	0,32	0,34	0,39	0,24	0,00	0,00	0,00	0,14	0,13	0,23	0,05	0,31	0,12	0,18	0,15	0,16	0,10	0,03	0,16	0,08	0,16	0,03	0,12	0,17
Cala	0,07	0,04	0,21	0,63	0,50	0,00	0,14	0,21	0,17	0,16	0,11	0,18	0,11	0,38	0,36	0,34	0,04	0,11	0,11	1,00	0,06	0,25	0,28	0,03	0,48	0,18	0,40	0,04	0,24	0,02	0,14	0,21	0,44	0,40	0,48	0,26	0,00	0,04	0,20	0,42	0,31	0,45	0,29	0,00	0,17	0,07	0,25	0,35	0,08	0,36	0,05	0,06	0,39	0,32	0,04	0,18	0,37	0,03	0,11	0,19	0,02	0,02
Cald	0,14	0,22	0,14	0,13	0,11	0,00	0,14	0,14	0,17	0,00	0,03	0,09	0,11	0,13	0,13	0,11	0,25	0,11	0,11	0,05	1,00	0,20	0,12	0,17	0,27	0,00	0,20	0,15	0,25	0,17	0,00	0,00	0,23	0,00	0,00	0,00	0,00	0,14	0,06	0,18	0,33	0,00	0,00	0,00	0,00	0,12	0,17	0,13	0,00	0,21	0,09	0,42	0,25	0,18	0,17	0,00	0,19	0,24	0,39	0,15	0,07	0,08
Ceg2	0,13	0,17	0,19	0,35	0,26	0,14	0,18	0,19	0,38	0,12	0,22	0,30	0,30	0,40	0,43	0,22	0,03	0,30	0,32	0,24	0,14	1,00	0,77	0,10	0,32	0,25	0,34	0,12	0,33	0,09	0,35	0,06	0,29	0,19	0,45	0,07	0,18	0,08	0,24	0,28	0,36	0,17	0,00	0,00	0,07	0,18	0,14	0,22	0,14	0,42	0,33	0,22	0,27	0,46	0,14	0,05	0,48	0,12	0,21	0,15	0,12	0,09
Cegg	0,13	0,21	0,19	0,34	0,26	0,21	0,22	0,19	0,42	0,09	0,19	0,30	0,29	0,35	0,42	0,14	0,03	0,34	0,36	0,28	0,09	0,62	1,00	0,06	0,19	0,34	0,20	0,07	0,29	0,05	0,23	0,17	0,24	0,11	0,60	0,19	0,34	0,08	0,28	0,32	0,31	0,25	0,00	0,00	0,11	0,13	0,08	0,19	0,08	0,32	0,33	0,13	0,24	0,38	0,08	0,14	0,48	0,07	0,11	0,06	0,10	0,06
Cere	0,13	0,17	0,13	0,11	0,10	0,00	0,13	0,13	0,11	0,09	0,11	0,17	0,20	0,08	0,08	0,18	0,13	0,24	0,10	0,05	0,14	0,09	0,09	1,00	0,13	0,00	0,10	0,49	0,12	0,12	0,16	0,10	0,11	0,03	0,00	0,00	0,00	0,16	0,03	0,09	0,16	0,00	0,00	0,12	0,12	0,07	0,14	0,11	0,00	0,19	0,15	0,13	0,12	0,13	0,09	0,00	0,09	0,24	0,25	0,20	0,11	0,11
ChPd	0,17	0,10	0,32	0,57	0,56	0,00	0,21	0,32	0,32	0,17	0,15	0,20	0,12	0,59	0,39	0,37	0,11	0,12	0,13	0,39	0,22	0,32	0,21	0,10	1,00	0,16	0,59	0,17	0,48	0,13	0,12	0,42	0,67	0,54	0,22	0,00	0,00	0,03	0,40	0,52	0,75	0,05	0,00	0,00	0,04	0,19	0,58	0,61	0,19	0,71	0,10	0,29	0,74	0,62	0,25	0,05	0,48	0,15	0,26	0,14	0,15	0,17
ChPm	0,13	0,12	0,12	0,22	0,20	0,20	0,30	0,12	0,05	0,09	0,11	0,17	0,14	0,12	0,20	0,07	0,07	0,24	0,25	0,18	0,00	0,22	0,30	0,00	0,20	1,00	0,25	0,00	0,16	0,06	0,17	0,10	0,07	0,14	0,31	0,37	0,25	0,17	0,33	0,19	0,18	0,19	0,00	0,00	0,09	0,24	0,08	0,11	0,16	0,17	0,03	0,00	0,00	0,12	0,06	0,28	0,15	0,00	0,00	0,01	0,07	0,08
ChSt	0,28	0,09	0,53	0,55	0,49	0,22	0,56	0,53	0,33	0,19	0,23	0,36	0,31	0,53	0,61	0,52	0,07	0,26	0,27	0,39	0,15	0,28	0,18	0,09	0,43	0,22	1,00	0,12	0,54	0,08	0,11	0,26	0,50	0,67	0,31	0,00	0,00	0,05	0,32	0,45	0,67	0,11	0,00	0,15	0,21	0,27	0,33	0,46	0,12	0,56	0,28	0,22	0,51	0,59	0,19	0,11	0,43	0,12	0,20	0,26	0,07	0,08
Debb	0,18	0,26	0,17	0,15	0,13	0,00	0,17	0,17	0,14	0,07	0,06	0,21	0,25	0,10	0,10	0,21	0,12	0,31	0,13	0,06	0,12	0,11	0,11	0,49	0,13	0,00	0,11	1,00	0,15	0,13	0,10	0,24	0,14	0,06	0,00	0,00	0,00	0,15	0,04	0,11	0,21	0,00	0,00	0,32	0,32	0,07	0,24	0,12	0,00	0,19	0,18	0,17	0,16	0,13	0,10	0,00	0,11	0,30	0,31	0,19	0,16	0,14
Duin	0,18	0,10	0,17	0,38	0,33	0,00	0,22	0,17	0,41	0,14	0,13	0,21	0,13	0,38	0,31	0,26	0,04	0,19	0,13	0,24	0,18	0,28	0,27	0,11	0,40	0,11	0,46	0,14	1,00	0,07	0,05	0,34	0,23	0,24	0,53	0,00	0,00	0,06	0,15	0,18	0,33	0,08	0,00	0,00	0,06	0,14	0,17	0,13	0,09	0,37	0,09	0,27	0,61	0,41	0,23	0,06	0,74	0,14	0,24	0,26	0,10	0,11
Ferr	0,07	0,16	0,07	0,10	0,19	0,00	0,11	0,07	0,16	0,20	0,29	0,08	0,06	0,18	0,11	0,20	0,42	0,06	0,19	0,03	0,12	0,09	0,08	0,14	0,13	0,06	0,09	0,13	0,06	1,00	0,15	0,24	0,09	0,19	0,00	0,00	0,00	0,07	0,02	0,06	0,14	0,00	0,00	0,11	0,12	0,18	0,34	0,11	0,09	0,20	0,07	0,13	0,07	0,18	0,15	0,11	0,10	0,10	0,23	0,05	0,31	0,40
Gheb	0,00	0,00	0,00	0,22	0,24	0,00	0,00	0,00	0,25	0,26	0,40	0,08	0,09	0,42	0,20	0,07	0,16	0,09	0,15	0,13	0,00	0,34	0,25	0,17	0,15	0,16	0,09	0,10	0,05	0,16	1,00	0,26	0,12	0,24	0,23	0,06	0,00	0,22	0,00	0,00	0,05	0,02	0,00	0,34	0,39	0,31	0,11	0,18	0,21	0,37	0,15	0,00	0,03	0,28	0,40	0,43	0,30	0,00	0,00	0,15	0,38	0,37
LaVe	0,00	0,11	0,11	0,29	0,36	0,00	0,08	0,11	0,18	0,25	0,30	0,08	0,00	0,39	0,19	0,23	0,18	0,00	0,00	0,20	0,00	0,08	0,15	0,08	0,36	0,08	0,24	0,19	0,23	0,21	0,22	1,00	0,18	0,42	0,40	0,00	0,00	0,07	0,12	0,15	0,21	0,03	0,05	0,32	0,35	0,16	0,41	0,26	0,17	0,43	0,00	0,00	0,38	0,43	0,21	0,20	0,46	0,04	0,07	0,13	0,29	0,26
Leno	0,17	0,10	0,32	0,50	0,38	0,00	0,32	0,32	0,39	0,10	0,12	0,20	0,24	0,41	0,39	0,33	0,00	0,18	0,25	0,39	0,17	0,32	0,26	0,10	0,44	0,10	0,43	0,13	0,20	0,09	0,15	0,13	1,00	0,37	0,09	0,34	0,17	0,00	0,30	0,62	0,62	0,00	0,00	0,00	0,04	0,15	0,44	0,57	0,11	0,59	0,15	0,25	0,55	0,43	0,16	0,06	0,26	0,13	0,22	0,00	0,09	0,10
Lora	0,00	0,08	0,27	0,40	0,50	0,18	0,28	0,27	0,33	0,34	0,36	0,31	0,17	0,61	0,49	0,39	0,22	0,04	0,23	0,33	0,00	0,16	0,12	0,04	0,41	0,15	0,49	0,05	0,19	0,24	0,26	0,32	0,27	1,00	0,28	0,00	0,00	0,06	0,27	0,26	0,50	0,07	0,00	0,21	0,27	0,28	0,49	0,51	0,25	0,60	0,21	0,04	0,37	0,61	0,12	0,15	0,33	0,00	0,01	0,26	0,20	0,24
Love	0,00	0,15	0,08	0,43	0,38	0,27	0,16	0,08	0,32	0,17	0,15	0,30	0,24	0,32	0,39	0,20	0,04	0,29	0,25	0,39	0,00	0,37	0,51	0,00	0,19	0,30	0,27	0,00	0,40	0,00	0,20	0,27	0,13	0,23	1,00	0,16	0,34	0,07	0,23	0,26	0,15	0,42	0,07	0,00	0,16	0,05	0,00	0,10	0,16	0,27	0,08	0,00	0,33	0,28	0,00	0,12	0,76	0,00	0,00	0,32	0,00	0,00
Mele	0,12	0,00	0,00	0,19	0,16	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,21	0,00	0,06	0,19	0,00	0,00	0,36	0,00	0,00	0,00	0,00	0,06	0,00	0,32	0,00	0,16	1,00	0,25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,14	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,10	0,00	0,00	0,00	0,00	0,00
Mogg	0,00	0,19	0,13	0,00	0,00	0,50	0,21	0,13	0,00	0,00	0,04	0,20	0,17	0,00	0,26	0,00	0,00	0,25	0,27	0,00	0,00	0,14	0,28	0,00	0,00	0,20	0,00	0,00	0,00	0,00	0,00	0,00	0,18	0,00	0,27	0,27	1,00	0,00	0,36	0,36	0,26	0,41	0,00	0,00	0,00	0,00	0,00	0,09	0,00	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mone	0,00	0,35	0,00	0,05	0,05	0,00	0,16	0,00	0,00	0,23	0,21	0,16	0,09	0,04	0,04	0,17	0,25	0,13	0,00	0,04	0,09	0,08	0,08	0,16	0,05	0,12	0,04	0,15	0,05	0,11	0,19	0,11	0,00	0,07	0,05	0,00	0,00	1,00	0,00	0,03	0,00	0,02	0,00	0,14	0,16	0,25	0,07	0,00	0,02	0,01	0,20	0,36	0,03	0,08	0,14	0,14	0,06	0,23	0,13	0,50	0,34	0,18
NoRo	0,27	0,17	0,32	0,24	0,21	0,21	0,32	0,32	0,16	0,06	0,14	0,17	0,15	0,16	0,43	0,25	0,00	0,35	0,26	0,19	0,05	0,18	0,22	0,04	0,32	0,26	0,28	0,06	0,17	0,03	0,00	0,12	0,21	0,20	0,16	0,00	0,29	0,00	1,00	0,54	0,51	0,31	0,00	0,00	0,00	0,07	0,26	0,46	0,04	0,48	0,03	0,07	0,29	0,24	0,09	0,05	0,05	0,04	0,06	0,09	0,02	0,02
NoRu	0,21	0,26	0,40	0,30	0,27	0,22	0,60	0,40	0,22	0,06	0,11	0,27	0,21	0,29	0,48	0,37	0,03	0,31	0,32	0,34	0,15	0,23	0,27	0,09	0,38	0,18	0,38	0,11	0,17	0,06	0,00	0,12	0,49	0,16	0,22	0,00	0,30	0,04	0,42	1,00	0,67	0,53	0,12	0,00	0,00	0,10	0,35	0,50	0,17	0,50	0,10	0,20	0,43	0,33	0,13	0,00	0,14	0,14	0,18	0,05	0,05	0,06
Palv	0,27	0,21	0,70	0,46	0,47	0,40	0,50	0,70	0,34	0,11	0,22	0,32	0,38	0,43	0,56	0,38	0,08	0,31	0,40	0,24	0,24	0,28	0,22	0,11	0,53	0,21	0,57	0,14	0,21	0,13	0,05	0,19	0,40	0,33	0,13	0,00	0,20	0,00	0,39	0,51	1,00	0,19	0,00	0,13	0,13	0,31	0,51	0,61	0,09	0,68	0,25	0,36	0,59	0,59	0,31	0,06	0,28	0,19	0,32	0,02	0,15	0,17
Pona	0,10	0,16	0,19	0,08	0,07	0,33	0,24	0,19	0,00	0,04	0,06	0,28	0,13	0,05	0,27	0,22	0,04	0,27	0,29	0,31	0,00	0,18	0,23	0,00	0,07	0,22	0,12	0,00	0,08	0,00	0,05	0,05	0,00	0,05	0,36	0,00	0,33	0,05	0,24	0,48	0,23	1,00	0,33	0,00	0,02	0,01	0,00	0,08	0,37	0,10	0,00	0,00	0,04	0,06	0,00	0,00	0,09	0,00	0,00	0,10	0,00	0,00
Rabb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,00	0,00	0,10	0,00	0,00	0,00	0,00	0,08	0,00	0,13	1,00	0,00	0,00	0,04	0,00	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,09	0,00	0,06	0,00	0,00	0,00
Res2	0,00	0,15	0,24	0,00	0,00	0,27	0,16	0,24	0,00	0,24	0,18	0,15	0,18	0,14	0,15	0,04	0,11	0,06	0,00	0,00	0,00	0,00	0,00	0,10	0,00	0,00	0,16	0,27	0,00	0,09	0,24	0,27	0,00	0,18	0,00	0,00	0,00	0,09	0,00	0,00	0,13	0,00	0,00	1,00	0,94	0,25	0,11	0,06	0,00	0,00	0,20	0,10	0,07	0,23	0,40	0,36	0,00	0,00	0,00	0,06	0,36	0,23
Rese	0,00	0,14	0,22	0,20	0,18	0,25	0,15	0,22	0,00	0,23	0,21	0,19	0,17	0,17	0,19	0,08	0,15	0,06	0,00	0,16	0,00	0,10	0,15	0,10	0,06	0,10	0,21	0,25	0,06	0,09	0,33	0,30	0,06	0,22	0,18	0,15	0,00	0,13	0,00	0,00	0,13	0,07	0,00	0,88	1,00	0,28	0,12	0,07	0,02	0,01	0,20	0,07	0,10	0,24	0,41	0,47	0,12	0,00	0,00	0,13	0,37	0,24
Rimo	0,12	0,06	0,23	0,18	0,23	0,12	0,18	0,23	0,24	0,25	0,32	0,18	0,19	0,31	0,26	0,21	0,12	0,13	0,20	0,09	0,09	0,21	0,15	0,09	0,17	0,24	0,28	0,07	0,14	0,20	0,29	0,14	0,20	0,28	0,07	0,04	0,00	0,20	0,06	0,12	0,28	0,04	0,04	0,23	0,26	1,00	0,17	0,26	0,12	0,30	0,27	0,13	0,20	0,38	0,38	0,26	0,19	0,07	0,14	0,05	0,34	0,29
RoFr	0,13	0,37	0,24	0,33	0,40	0,00	0,22	0,24	0,26	0,24	0,32	0,13	0,10	0,38	0,24	0,42	0,26	0,10	0,15	0,23	0,14	0,13	0,09	0,17	0,45	0,08	0,27	0,21	0,16	0,33	0,12	0,38	0,35	0,42	0,00	0,00	0,00	0,04	0,22	0,31	0,37	0,00	0,00	0,10	0,10	0,18	1,00	0,46	0,12	0,54	0,07	0,37	0,40	0,44	0,25	0,11	0,19	0,14	0,27	0,09	0,26	0,31
SaDr	0,20	0,13	0,39	0,41	0,37	0,07	0,27	0,39	0,38	0,25	0,22	0,17	0,20	0,40	0,38	0,33	0,14	0,25	0,37	0,29	0,10	0,23	0,22	0,13	0,42	0,17	0,37	0,17	0,11	0,14	0,17	0,16	0,42	0,40	0,11	0,00	0,07	0,00	0,32	0,37	0,50	0,12	0,08	0,05	0,05	0,30	0,35	1,00	0,09	0,71	0,36	0,14	0,72	0,62	0,12	0,05	0,19	0,07	0,14	0,01	0,11	0,12
Salè	0,00	0,00	0,00	0,24	0,28	0,00	0,00	0,00	0,14	0,18	0,16	0,32	0,19	0,20	0,11	0,26	0,16	0,06	0,14	0,12	0,00	0,17	0,11	0,00	0,28	0,22	0,18	0,00	0,07	0,10	0,21	0,14	0,14	0,24	0,14	0,00	0,00	0,05	0,06	0,12	0,15	0,32	0,00	0,00	0,06	0,14	0,11	0,17	1,00	0,18	0,05	0,00	0,04	0,19	0,08	0,10	0,23	0,00	0,00	0,09	0,11	0,12
SaLi	0,21	0,11	0,31	0,38	0,43	0,06	0,23	0,31	0,53	0,19	0,33	0,19	0,21	0,66	0,47	0,38	0,15	0,29	0,35	0,28	0,16	0,38	0,34	0,15	0,57	0,19	0,43	0,18	0,27	0,21	0,40	0,31	0,39	0,52	0,26	0,00	0,06	0,04	0,35	0,35	0,50	0,14	0,00	0,00	0,04	0,30	0,41	0,58	0,23	1,00	0,17	0,22	0,58	0,71	0,23	0,09	0,47	0,12	0,22	0,09	0,22	0,24
Saln	0,10	0,18	0,25	0,14	0,09	0,16	0,26	0,25	0,26	0,22	0,25	0,33	0,37	0,31	0,32	0,25	0,09	0,29	0,17	0,08	0,08	0,34	0,33	0,19	0,09	0,04	0,23	0,22	0,09	0,13	0,14	0,00	0,17	0,20	0,09	0,00	0,00	0,21	0,04	0,12	0,18	0,00	0,00	0,17	0,16	0,27	0,07	0,30	0,05	0,16	1,00	0,10	0,33	0,44	0,11	0,00	0,17	0,49	0,22	0,22	0,08	0,05
Salo	0,16	0,48	0,15	0,14	0,12	0,00	0,21	0,15	0,19	0,13	0,12	0,15	0,11	0,13	0,14	0,20	0,22	0,17	0,18	0,05	0,38	0,15	0,10	0,10	0,24	0,00	0,16	0,13	0,19	0,15	0,00	0,00	0,18	0,09	0,00	0,00	0,00	0,27	0,05	0,16	0,26	0,00	0,00	0,12	0,11	0,10	0,29	0,10	0,00	0,17	0,08	1,00	0,27	0,27	0,18	0,00	0,20	0,25	0,43	0,20	0,37	0,19
SaPA	0,15	0,09	0,30	0,47	0,41	0,00	0,20	0,30	0,42	0,20	0,15	0,19	0,11	0,48	0,37	0,35	0,04	0,17	0,12	0,37	0,21	0,25	0,24	0,10	0,65	0,00	0,41	0,13	0,56	0,06	0,05	0,34	0,41	0,26	0,29	0,00	0,00	0,04	0,25	0,36	0,44	0,07	0,00	0,06	0,11	0,16	0,33	0,50	0,06	0,46	0,24	0,23	1,00	0,64	0,17	0,00	0,54	0,14	0,24	0,13	0,07	0,08
SaRa	0,14	0,07	0,36	0,42	0,42	0,14	0,28	0,36	0,31	0,38	0,30	0,27	0,22	0,69	0,49	0,38	0,14	0,19	0,19	0,32	0,14	0,41	0,34	0,10	0,50	0,13	0,49	0,12	0,32	0,14	0,26	0,34	0,35	0,47	0,23	0,00	0,00	0,10	0,17	0,28	0,44	0,08	0,00	0,27	0,26	0,38	0,33	0,48	0,16	0,61	0,39	0,23	0,56	1,00	0,26	0,07	0,49	0,10	0,19	0,17	0,29	0,24
Sel1	0,13	0,08	0,18	0,17	0,20	0,07	0,13	0,18	0,15	0,15	0,24	0,13	0,14	0,23	0,16	0,14	0,10	0,10	0,10	0,05	0,14	0,13	0,09	0,09	0,25	0,08	0,18	0,11	0,21	0,14	0,29	0,15	0,15	0,12	0,00	0,00	0,00	0,08	0,09	0,13	0,26	0,00	0,00	0,30	0,29	0,32	0,29	0,13	0,11	0,19	0,11	0,15	0,14	0,20	1,00	0,75	0,17	0,10	0,17	0,06	0,42	0,34
Sel2	0,00	0,00	0,00	0,23	0,27	0,00	0,06	0,00	0,07	0,11	0,16	0,00	0,00	0,05	0,00	0,04	0,12	0,00	0,07	0,12	0,00	0,06	0,11	0,00	0,07	0,21	0,11	0,00	0,07	0,10	0,26	0,14	0,07	0,14	0,13	0,17	0,00	0,10	0,06	0,00	0,14	0,00	0,00	0,20	0,31	0,21	0,11	0,11	0,15	0,09	0,00	0,00	0,00	0,04	0,53	1,00	0,11	0,00	0,00	0,06	0,29	0,23
Spor	0,19	0,11	0,18	0,64	0,48	0,00	0,11	0,18	0,50	0,18	0,16	0,27	0,26	0,49	0,37	0,26	0,08	0,26	0,21	0,36	0,12	0,40	0,44	0,11	0,41	0,16	0,35	0,15	0,59	0,10	0,26	0,29	0,28	0,24	0,62	0,09	0,00	0,05	0,06	0,12	0,22	0,08	0,12	0,00	0,13	0,21	0,16	0,29	0,23	0,37	0,18	0,13	0,45	0,37	0,16	0,15	1,00	0,10	0,20	0,29	0,10	0,12
SZe2	0,11	0,19	0,11	0,10	0,09	0,00	0,16	0,11	0,14	0,11	0,10	0,16	0,18	0,11	0,12	0,30	0,13	0,22	0,09	0,04	0,21	0,12	0,08	0,20	0,14	0,00	0,13	0,24	0,15	0,11	0,00	0,07	0,14	0,00	0,00	0,00	0,00	0,19	0,04	0,17	0,15	0,00	0,00	0,00	0,00	0,08	0,20	0,08	0,00	0,11	0,45	0,23	0,13	0,10	0,12	0,00	0,10	1,00	0,60	0,29	0,04	0,05
SZen	0,13	0,09	0,13	0,12	0,11	0,00	0,14	0,13	0,16	0,03	0,06	0,17	0,20	0,12	0,13	0,29	0,10	0,25	0,16	0,14	0,29	0,18	0,09	0,22	0,21	0,00	0,14	0,28	0,17	0,20	0,00	0,08	0,16	0,04	0,00	0,00	0,00	0,12	0,05	0,14	0,22	0,00	0,08	0,00	0,00	0,15	0,26	0,14	0,00	0,19	0,23	0,36	0,20	0,17	0,13	0,00	0,17	0,49	1,00	0,17	0,10	0,13
TeBo	0,05	0,30	0,05	0,15	0,22	0,00	0,20	0,05	0,00	0,42	0,30	0,19	0,09	0,11	0,26	0,35	0,21	0,17	0,09	0,12	0,12	0,08	0,04	0,19	0,09	0,04	0,16	0,14	0,14	0,10	0,11	0,10	0,00	0,21	0,18	0,00	0,00	0,43	0,08	0,08	0,05	0,10	0,00	0,04	0,09	0,08	0,08	0,04	0,05	0,07	0,20	0,22	0,09	0,12	0,04	0,05	0,14	0,25	0,16	1,00	0,17	0,12
TeL2	0,07	0,27	0,07	0,10	0,18	0,00	0,06	0,07	0,15	0,32	0,34	0,05	0,06	0,21	0,11	0,12	0,30	0,09	0,18	0,03	0,06	0,11	0,11	0,14	0,12	0,05	0,08	0,16	0,09	0,35	0,32	0,23	0,09	0,21	0,00	0,00	0,00	0,26	0,03	0,06	0,13	0,00	0,00	0,30	0,29	0,30	0,24	0,14	0,10	0,20	0,12	0,30	0,06	0,26	0,32	0,16	0,10	0,05	0,08	0,13	1,00	0,76
TeLu	0,08	0,15	0,08	0,12	0,21	0,00	0,06	0,08	0,18	0,34	0,40	0,06	0,07	0,24	0,12	0,08	0,31	0,07	0,21	0,03	0,07	0,10	0,10	0,16	0,14	0,06	0,10	0,15	0,11	0,39	0,34	0,23	0,11	0,24	0,00	0,00	0,00	0,18	0,03	0,07	0,15	0,00	0,00	0,18	0,17	0,31	0,28	0,16	0,11	0,23	0,08	0,14	0,07	0,21	0,28	0,19	0,11	0,06	0,10	0,12	0,69	1,00

[14] The Bray-Curtis index values are listed in the lower half of the matrix, while the Morisita index values are liste in the upper half. Values between 0,25 and 0,50 are marked in yellow, values higher or equal to 0,50 are marked in red and values equal to 1,00 are marked in grey.

11.5 Similarity Matrix: Bray-Curtis Index and Raup-Crick Index on Species Presence/Absence data[15]

SITE	AdBo	Adgt	AdMo	Adnl	AdnP	AdSM	AdTN	AdVi	Arnò	BaPM	BaSo	BrB2	BrBo	BrG2	BrGr	BrLe	Brnd	BrV2	BrVi	Cala	Cald	Ceg2	Cegg	Cere	ChPd	ChPm	ChSt	Debb	Duin	Ferr	Gheb	LaVe	Leno	Lora	Love	Mele	Mogg	Mone	NoRo	NoRu	Palv	Pona	Rabb	Res2	Rese	Rimo	RoFr	SaDr	Salè	SaLi	Saln	Salo	SaPA	SaRa	Sel1	Sel2	Spor	SZe2	SZen	TeBo	TeL2	TeLu
AdBo	1,00	0,74	1,00	0,78	0,80	0,42	0,92	0,98	0,76	0,10	0,29	0,67	0,76	0,69	0,95	0,88	0,13	0,95	0,94	0,74	0,71	0,61	0,68	0,63	0,78	0,91	0,91	0,81	0,82	0,45	0,25	0,25	0,74	0,20	0,28	0,89	0,45	0,17	0,93	0,98	0,96	0,84	0,38	0,36	0,27	0,73	0,65	0,87	0,28	0,89	0,65	0,78	0,81	0,84	0,69	0,23	0,74	0,74	0,70	0,52	0,41	0,52
Adgt	0,18	1,00	0,85	0,48	0,49	0,84	0,99	0,89	0,41	0,39	0,69	0,86	0,76	0,30	0,55	0,70	0,79	0,73	0,67	0,38	0,74	0,49	0,58	0,61	0,46	0,26	0,25	0,87	0,48	0,69	0,06	0,26	0,39	0,51	0,42	0,25	0,84	0,90	0,58	0,95	0,76	0,53	0,19	0,51	0,43	0,04	0,91	0,40	0,13	0,38	0,55	1,00	0,49	0,11	0,30	0,07	0,42	0,79	0,32	0,98	0,43	0,62
AdMo	0,50	0,31	1,00	0,92	0,93	0,99	1,00	1,00	0,90	0,15	0,87	0,97	0,99	0,98	1,00	1,00	0,05	0,98	0,98	0,92	0,61	0,79	0,82	0,43	0,90	0,80	1,00	0,68	0,60	0,17	0,15	0,44	0,85	0,74	0,57	0,30	0,87	0,09	0,99	1,00	1,00	0,95	0,29	0,72	0,59	0,78	0,83	0,99	0,16	0,99	0,76	0,57	0,94	0,97	0,83	0,17	0,63	0,60	0,48	0,31	0,20	0,31
Adnl	0,22	0,14	0,36	1,00	1,00	0,38	0,71	0,92	0,97	0,87	0,92	0,92	0,85	1,00	0,99	0,97	0,49	0,82	0,81	1,00	0,46	0,98	1,00	0,41	1,00	0,92	1,00	0,64	0,88	0,36	1,00	0,93	0,99	0,98	0,98	0,78	0,35	0,29	0,71	0,83	0,98	0,65	0,23	0,21	0,87	0,88	0,94	0,95	0,97	0,99	0,69	0,45	0,98	0,99	0,78	0,80	1,00	0,54	0,42	0,23	0,35	0,55
AdnP	0,22	0,14	0,36	0,83	1,00	0,37	0,69	0,94	0,98	0,87	0,91	0,72	0,53	1,00	0,93	0,96	0,77	0,46	0,83	1,00	0,44	0,90	0,91	0,35	1,00	0,76	1,00	0,65	0,86	0,64	0,95	0,91	0,97	0,98	0,88	0,79	0,37	0,27	0,75	0,81	1,00	0,65	0,25	0,23	0,86	0,85	0,95	0,98	0,98	1,00	0,37	0,53	1,00	0,96	0,75	0,94	1,00	0,50	0,43	0,24	0,70	0,80
AdSM	0,00	0,20	0,57	0,00	0,00	1,00	0,98	0,99	0,37	0,16	0,85	0,97	0,98	0,81	0,97	0,67	0,17	0,81	0,86	0,34	0,33	0,74	0,73	0,30	0,35	0,77	0,78	0,39	0,38	0,17	0,34	0,29	0,34	0,75	0,82	0,43	0,96	0,24	0,77	0,77	0,98	0,89	0,42	0,86	0,82	0,52	0,31	0,70	0,32	0,67	0,74	0,35	0,40	0,61	0,76	0,34	0,36	0,31	0,30	0,20	0,19	0,23
AdTN	0,29	0,53	0,63	0,24	0,24	0,31	1,00	1,00	0,61	0,16	0,57	0,99	0,98	0,71	0,97	0,98	0,31	0,94	0,83	0,58	0,53	0,32	0,45	0,37	0,73	0,65	1,00	0,77	0,71	0,16	0,02	0,16	0,81	0,81	0,26	0,23	0,76	0,76	0,88	1,00	1,00	0,78	0,19	0,41	0,27	0,12	0,73	0,70	0,05	0,66	0,83	0,86	0,68	0,51	0,47	0,19	0,26	0,84	0,39	0,87	0,00	0,03
AdVi	0,50	0,31	1,00	0,36	0,36	0,57	0,63	1,00	0,87	0,18	0,85	0,97	0,99	0,98	1,00	1,00	0,03	0,97	0,95	0,86	0,56	0,78	0,78	0,49	0,91	0,79	0,99	0,73	0,65	0,18	0,14	0,51	0,88	0,71	0,60	0,32	0,86	0,08	1,00	1,00	1,00	0,94	0,27	0,73	0,59	0,75	0,85	0,98	0,20	0,98	0,72	0,62	0,94	0,97	0,88	0,18	0,54	0,58	0,47	0,32	0,22	0,29
Arnò	0,20	0,13	0,33	0,46	0,46	0,00	0,22	0,33	1,00	0,78	0,85	0,63	0,81	1,00	0,99	0,96	0,13	0,72	0,99	0,96	0,42	0,86	0,97	0,30	0,97	0,32	0,99	0,62	0,82	0,51	0,66	0,65	1,00	1,00	0,83	0,29	0,34	0,06	0,88	0,77	0,97	0,19	0,25	0,21	0,16	0,77	0,92	1,00	0,79	1,00	0,90	0,47	0,97	0,97	0,36	0,35	0,98	0,49	0,35	0,02	0,56	0,73
BaPM	0,00	0,21	0,08	0,31	0,31	0,00	0,19	0,08	0,30	1,00	1,00	0,21	0,07	0,79	0,94	0,70	0,91	0,16	0,45	0,51	0,01	0,15	0,18	0,08	0,62	0,06	0,47	0,17	0,33	0,39	0,95	0,91	0,39	0,98	0,18	0,10	0,16	0,66	0,09	0,17	0,51	0,17	0,05	0,94	0,92	0,54	0,79	0,59	0,79	0,46	0,40	0,25	0,69	0,86	0,28	0,36	0,48	0,29	0,03	0,78	0,79	0,87
BaSo	0,06	0,28	0,24	0,29	0,29	0,13	0,31	0,24	0,29	0,71	1,00	0,69	0,59	0,99	1,00	0,56	0,73	0,43	0,87	0,57	0,01	0,50	0,68	0,18	0,64	0,07	0,87	0,27	0,71	0,23	0,91	0,85	0,41	0,99	0,48	0,04	0,46	0,14	0,47	0,43	0,97	0,25	0,02	0,88	0,79	0,44	0,93	0,68	0,51	0,78	0,50	0,29	0,92	0,59	0,79	0,27	0,51	0,08	0,02	0,71	0,29	0,80
BrB2	0,15	0,33	0,40	0,38	0,25	0,33	0,48	0,40	0,24	0,20	0,32	1,00	1,00	0,96	0,99	1,00	0,16	0,99	0,96	0,88	0,24	0,90	0,91	0,47	0,72	0,47	0,92	0,79	0,73	0,06	0,52	0,17	0,86	0,89	0,89	0,20	0,79	0,60	0,47	0,86	0,92	0,96	0,16	0,48	0,64	0,15	0,48	0,52	0,97	0,76	0,87	0,64	0,73	0,68	0,52	0,04	0,90	0,70	0,51	0,51	0,04	0,04
BrBo	0,20	0,27	0,50	0,31	0,15	0,44	0,44	0,50	0,29	0,07	0,23	0,82	1,00	0,87	0,97	0,95	0,01	1,00	0,99	0,83	0,34	0,87	0,87	0,66	0,52	0,62	0,86	0,90	0,53	0,07	0,39	0,06	0,93	0,58	0,79	0,28	0,83	0,24	0,66	0,75	0,95	0,60	0,20	0,64	0,49	0,55	0,34	0,73	0,82	0,69	0,98	0,47	0,60	0,71	0,71	0,07	0,83	0,81	0,71	0,22	0,06	0,20
BrG2	0,17	0,12	0,43	0,67	0,53	0,18	0,30	0,43	0,63	0,34	0,43	0,42	0,38	1,00	1,00	0,97	0,20	0,66	0,89	0,99	0,30	0,98	0,99	0,18	1,00	0,54	1,00	0,51	0,95	0,29	0,99	0,94	0,98	0,99	0,93	0,23	0,29	0,11	0,48	0,62	0,99	0,52	0,17	0,50	0,69	0,79	0,82	0,95	0,90	1,00	0,90	0,37	0,99	1,00	0,84	0,25	1,00	0,32	0,25	0,10	0,36	0,49
BrGr	0,31	0,22	0,67	0,50	0,38	0,33	0,48	0,67	0,47	0,40	0,47	0,50	0,47	0,63	1,00	0,99	0,02	0,98	1,00	0,97	0,24	0,97	0,98	0,16	0,92	0,71	1,00	0,47	0,75	0,07	0,77	0,44	0,96	0,95	0,90	0,23	0,78	0,09	0,98	0,97	1,00	0,97	0,15	0,44	0,62	0,69	0,49	0,99	0,73	1,00	0,87	0,33	0,93	1,00	0,52	0,03	0,91	0,32	0,17	0,76	0,06	0,26
BrLe	0,25	0,29	0,44	0,42	0,42	0,13	0,50	0,44	0,40	0,36	0,34	0,61	0,40	0,45	0,52	1,00	0,37	0,90	0,90	0,93	0,16	0,53	0,60	0,25	0,86	0,30	1,00	0,67	0,60	0,40	0,33	0,53	0,72	0,96	0,52	0,17	0,22	0,41	0,62	0,91	0,99	0,93	0,10	0,33	0,51	0,60	0,87	0,78	0,95	0,90	0,93	0,55	0,86	0,82	0,38	0,13	0,78	0,75	0,66	0,79	0,08	0,14
Brnd	0,00	0,32	0,00	0,17	0,26	0,00	0,21	0,00	0,08	0,49	0,44	0,15	0,00	0,15	0,07	0,27	1,00	0,01	0,25	0,10	0,23	0,02	0,02	0,35	0,48	0,01	0,18	0,52	0,16	0,97	0,71	0,69	0,01	0,85	0,12	0,12	0,22	0,85	0,00	0,09	0,36	0,24	0,06	0,55	0,70	0,03	0,73	0,28	0,66	0,24	0,10	0,87	0,14	0,19	0,18	0,40	0,36	0,36	0,18	0,70	0,82	0,87
BrV2	0,36	0,25	0,46	0,29	0,14	0,20	0,42	0,46	0,27	0,14	0,22	0,56	0,67	0,24	0,44	0,38	0,00	1,00	1,00	0,76	0,36	0,81	0,82	0,57	0,49	0,86	0,85	0,86	0,82	0,04	0,31	0,04	0,69	0,20	0,75	0,25	0,84	0,17	0,96	0,93	0,95	0,86	0,21	0,53	0,42	0,39	0,28	0,86	0,42	0,82	0,82	0,73	0,84	0,84	0,27	0,06	0,76	0,77	0,64	0,37	0,17	0,10
BrVi	0,36	0,25	0,46	0,29	0,29	0,20	0,32	0,46	0,53	0,21	0,33	0,44	0,53	0,35	0,56	0,38	0,16	0,63	1,00	0,75	0,35	0,92	0,96	0,25	0,44	0,84	0,98	0,56	0,49	0,71	0,62	0,05	0,92	0,94	0,77	0,27	0,79	0,02	0,79	0,91	1,00	0,87	0,18	0,17	0,12	0,89	0,66	0,99	0,77	1,00	0,79	0,74	0,46	0,81	0,33	0,29	0,77	0,41	0,61	0,34	0,71	0,88
Cala	0,20	0,13	0,33	0,77	0,62	0,00	0,22	0,33	0,43	0,22	0,23	0,35	0,29	0,50	0,47	0,40	0,08	0,27	0,27	1,00	0,43	0,98	0,97	0,30	0,99	0,72	0,99	0,64	0,85	0,06	0,93	0,65	1,00	0,84	1,00	0,77	0,33	0,17	0,66	0,96	0,82	0,90	0,69	0,20	0,80	0,47	0,70	0,75	0,81	0,88	0,63	0,46	0,97	0,90	0,37	0,34	1,00	0,45	0,73	0,20	0,08	0,13
Cald	0,18	0,25	0,15	0,14	0,14	0,00	0,21	0,15	0,13	0,00	0,06	0,11	0,13	0,12	0,11	0,10	0,16	0,13	0,13	0,13	1,00	0,22	0,25	0,59	0,42	0,06	0,24	0,60	0,43	0,40	0,09	0,06	0,37	0,04	0,10	0,27	0,32	0,16	0,28	0,33	0,47	0,15	0,21	0,17	0,13	0,04	0,31	0,14	0,09	0,10	0,20	0,95	0,47	0,09	0,28	0,08	0,41	0,73	0,61	0,40	0,04	0,12
Ceg2	0,14	0,21	0,25	0,47	0,35	0,15	0,18	0,25	0,33	0,19	0,31	0,38	0,33	0,50	0,48	0,25	0,07	0,32	0,42	0,44	0,11	1,00	1,00	0,12	0,89	0,92	0,69	0,44	0,73	0,05	0,99	0,11	0,96	0,55	0,98	0,64	0,73	0,24	0,67	0,49	0,64	0,77	0,15	0,12	0,57	0,59	0,17	0,67	0,87	1,00	0,86	0,29	0,67	0,99	0,17	0,16	0,97	0,27	0,48	0,05	0,20	0,13
Cegg	0,15	0,22	0,27	0,50	0,38	0,17	0,19	0,27	0,47	0,20	0,32	0,40	0,35	0,53	0,50	0,26	0,07	0,33	0,44	0,47	0,11	0,76	1,00	0,15	0,93	0,76	0,73	0,46	0,93	0,08	0,93	0,73	0,95	0,57	1,00	0,67	0,76	0,26	0,45	0,56	0,69	0,78	0,15	0,10	0,64	0,48	0,20	0,72	0,64	0,98	0,88	0,31	0,93	0,95	0,22	0,19	1,00	0,32	0,21	0,06	0,29	0,22
Cere	0,15	0,22	0,13	0,13	0,13	0,00	0,19	0,13	0,12	0,13	0,21	0,20	0,24	0,11	0,10	0,17	0,22	0,22	0,11	0,12	0,22	0,10	0,10	1,00	0,39	0,03	0,16	1,00	0,39	0,23	0,50	0,18	0,23	0,09	0,06	0,22	0,27	0,24	0,13	0,29	0,37	0,10	0,19	0,47	0,32	0,07	0,47	0,30	0,05	0,21	0,38	0,32	0,44	0,17	0,19	0,04	0,31	0,64	0,48	0,48	0,29	0,46
ChPd	0,22	0,14	0,36	0,67	0,67	0,00	0,24	0,36	0,46	0,23	0,24	0,25	0,15	0,67	0,38	0,32	0,17	0,14	0,14	0,46	0,14	0,35	0,38	0,13	1,00	0,70	0,93	0,63	0,99	0,30	0,80	0,99	0,85	0,92	0,87	0,34	0,36	0,29	0,94	0,84	0,96	0,65	0,28	0,22	0,48	0,30	0,92	0,83	0,99	0,99	0,36	0,56	1,00	0,98	0,74	0,48	1,00	0,48	0,43	0,24	0,41	0,51
ChPm	0,31	0,11	0,27	0,38	0,25	0,17	0,29	0,27	0,12	0,13	0,16	0,20	0,24	0,21	0,30	0,17	0,07	0,33	0,33	0,24	0,00	0,38	0,30	0,00	0,25	1,00	0,74	0,13	0,38	0,01	0,80	0,18	0,60	0,63	0,89	0,92	0,76	0,10	0,71	0,50	0,86	0,80	0,14	0,15	0,33	0,66	0,22	0,78	0,88	0,70	0,13	0,05	0,11	0,39	0,19	0,78	0,85	0,05	0,03	0,06	0,00	0,05
ChSt	0,31	0,11	0,53	0,50	0,50	0,17	0,57	0,53	0,47	0,27	0,37	0,40	0,35	0,53	0,60	0,61	0,15	0,33	0,44	0,47	0,11	0,29	0,30	0,10	0,38	0,30	1,00	0,48	0,95	0,06	0,52	0,71	0,98	0,99	0,88	0,20	0,30	0,10	0,74	0,97	1,00	0,78	0,17	0,48	0,64	0,69	0,49	0,89	0,88	0,98	0,65	0,31	0,91	0,97	0,51	0,56	0,89	0,30	0,19	0,20	0,11	0,19
Debb	0,25	0,31	0,20	0,18	0,18	0,00	0,25	0,20	0,17	0,08	0,12	0,27	0,33	0,14	0,13	0,22	0,18	0,31	0,15	0,17	0,15	0,13	0,13	0,53	0,18	0,00	0,13	1,00	0,66	0,44	0,51	0,45	0,55	0,40	0,16	0,35	0,37	0,31	0,49	0,51	0,62	0,28	0,29	0,74	0,62	0,17	0,82	0,64	0,20	0,65	0,80	0,65	0,65	0,59	0,53	0,17	0,63	0,91	0,84	0,29	0,46	0,65
Duin	0,22	0,14	0,18	0,33	0,33	0,00	0,24	0,18	0,31	0,15	0,24	0,25	0,15	0,40	0,25	0,21	0,09	0,29	0,14	0,31	0,14	0,24	0,38	0,13	0,50	0,13	0,38	0,18	1,00	0,12	0,45	0,73	0,47	0,64	0,83	0,28	0,37	0,26	0,68	0,48	0,56	0,70	0,28	0,21	0,51	0,31	0,45	0,23	0,53	0,82	0,30	0,56	1,00	0,76	0,77	0,43	0,98	0,59	0,47	0,24	0,38	0,52
Ferr	0,09	0,29	0,08	0,15	0,23	0,00	0,19	0,08	0,22	0,35	0,38	0,13	0,07	0,21	0,13	0,30	0,54	0,07	0,29	0,07	0,21	0,13	0,13	0,20	0,15	0,07	0,13	0,16	0,08	1,00	0,29	0,47	0,16	0,76	0,01	0,09	0,17	0,21	0,01	0,03	0,55	0,02	0,06	0,48	0,25	0,14	0,93	0,19	0,26	0,14	0,40	0,76	0,10	0,02	0,30	0,32	0,25	0,24	0,57	0,18	0,84	0,86
Gheb	0,00	0,00	0,00	0,53	0,40	0,00	0,00	0,00	0,25	0,41	0,38	0,21	0,13	0,56	0,32	0,18	0,31	0,12	0,24	0,38	0,00	0,50	0,42	0,21	0,27	0,32	0,21	0,14	0,13	0,21	1,00	0,79	0,88	0,87	0,94	0,65	0,33	0,65	0,03	0,07	0,36	0,49	0,19	0,52	0,92	0,94	0,24	0,82	0,90	0,99	0,47	0,10	0,43	0,98	0,55	0,79	0,99	0,07	0,06	0,67	0,63	0,77
LaVe	0,00	0,11	0,13	0,38	0,38	0,00	0,10	0,13	0,24	0,40	0,37	0,10	0,00	0,42	0,20	0,26	0,30	0,00	0,00	0,24	0,00	0,10	0,30	0,10	0,50	0,10	0,30	0,13	0,25	0,27	0,32	1,00	0,29	0,86	0,92	0,20	0,28	0,24	0,20	0,26	0,63	0,44	0,54	0,82	0,91	0,05	0,96	0,26	0,64	0,75	0,02	0,07	0,93	0,67	0,51	0,52	0,91	0,30	0,21	0,25	0,24	0,48
Leno	0,18	0,13	0,31	0,57	0,43	0,00	0,32	0,31	0,53	0,21	0,22	0,33	0,40	0,47	0,44	0,29	0,00	0,25	0,38	0,53	0,13	0,42	0,44	0,11	0,29	0,22	0,44	0,15	0,14	0,14	0,35	0,11	1,00	0,72	0,74	0,96	0,78	0,03	0,58	0,91	0,75	0,17	0,20	0,16	0,42	0,65	0,68	0,90	0,77	0,83	0,80	0,46	0,80	0,84	0,31	0,35	0,97	0,44	0,29	0,02	0,18	0,34
Lora	0,00	0,20	0,24	0,44	0,44	0,14	0,35	0,24	0,53	0,50	0,50	0,36	0,21	0,57	0,45	0,48	0,41	0,10	0,40	0,32	0,00	0,26	0,27	0,09	0,33	0,27	0,55	0,12	0,22	0,38	0,38	0,36	0,30	1,00	0,58	0,17	0,25	0,20	0,29	0,15	0,96	0,36	0,14	0,74	0,84	0,51	1,00	0,94	0,96	0,99	0,55	0,58	0,65	0,91	0,39	0,66	0,84	0,05	0,14	0,28	0,57	0,80
Love	0,00	0,13	0,17	0,46	0,31	0,22	0,11	0,17	0,29	0,15	0,23	0,35	0,29	0,38	0,35	0,20	0,08	0,27	0,27	0,57	0,00	0,44	0,59	0,00	0,31	0,35	0,35	0,00	0,31	0,00	0,38	0,35	0,27	0,21	1,00	0,76	0,83	0,23	0,30	0,77	0,46	0,98	0,68	0,19	0,79	0,22	0,06	0,47	0,81	0,90	0,27	0,13	0,85	0,71	0,09	0,34	0,99	0,14	0,08	0,20	0,01	0,02
Mele	0,33	0,00	0,00	0,22	0,22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,14	0,15	0,00	0,00	0,31	0,00	0,00	0,00	0,00	0,17	0,00	0,36	0,00	0,20	1,00	0,90	0,16	0,23	0,24	0,34	0,33	0,33	0,34	0,75	0,38	0,24	0,14	0,30	0,15	0,20	0,29	0,32	0,11	0,24	0,72	0,77	0,29	0,23	0,16	0,09	0,18
Mogg	0,00	0,20	0,29	0,00	0,00	0,50	0,15	0,29	0,00	0,00	0,07	0,17	0,22	0,00	0,17	0,00	0,00	0,20	0,20	0,00	0,00	0,15	0,17	0,00	0,00	0,17	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,00	0,22	0,40	1,00	0,25	0,75	0,81	0,82	0,91	0,42	0,38	0,33	0,16	0,33	0,71	0,35	0,70	0,26	0,33	0,35	0,22	0,30	0,32	0,33	0,32	0,29	0,23	0,17	0,22
Mone	0,00	0,38	0,00	0,11	0,11	0,00	0,33	0,00	0,00	0,36	0,24	0,26	0,10	0,09	0,09	0,23	0,40	0,10	0,00	0,10	0,10	0,17	0,17	0,17	0,11	0,09	0,09	0,11	0,11	0,24	0,27	0,17	0,00	0,16	0,10	0,00	0,00	1,00	0,01	0,13	0,05	0,35	0,11	0,32	0,52	0,06	0,11	0,01	0,20	0,01	0,46	0,78	0,23	0,22	0,14	0,13	0,20	0,55	0,09	1,00	0,51	0,49
NoRo	0,31	0,22	0,53	0,25	0,25	0,17	0,38	0,53	0,35	0,13	0,26	0,20	0,24	0,21	0,50	0,26	0,00	0,44	0,33	0,24	0,11	0,29	0,20	0,10	0,38	0,30	0,30	0,13	0,25	0,07	0,00	0,10	0,22	0,18	0,12	0,00	0,17	0,00	1,00	0,97	0,97	0,81	0,19	0,11	0,06	0,04	0,79	0,94	0,38	0,93	0,11	0,30	0,93	0,38	0,56	0,24	0,29	0,31	0,21	0,25	0,02	0,05
NoRu	0,36	0,38	0,62	0,29	0,29	0,20	0,63	0,62	0,27	0,14	0,22	0,33	0,27	0,24	0,44	0,38	0,08	0,38	0,38	0,40	0,13	0,21	0,22	0,11	0,29	0,22	0,44	0,15	0,14	0,07	0,00	0,11	0,38	0,10	0,27	0,00	0,20	0,10	0,44	1,00	0,99	1,00	0,61	0,16	0,12	0,20	0,63	0,89	0,43	0,84	0,54	0,42	0,80	0,56	0,34	0,06	0,44	0,75	0,29	0,33	0,06	0,08
Palv	0,40	0,27	0,83	0,46	0,62	0,44	0,56	0,83	0,43	0,22	0,34	0,35	0,43	0,50	0,59	0,50	0,17	0,40	0,53	0,29	0,13	0,22	0,24	0,12	0,46	0,35	0,59	0,17	0,15	0,22	0,13	0,24	0,27	0,42	0,14	0,00	0,22	0,00	0,47	0,53	1,00	0,90	0,19	0,60	0,44	0,92	0,91	1,00	0,80	1,00	0,63	0,47	0,85	0,98	0,90	0,68	0,78	0,50	0,43	0,18	0,56	0,67
Pona	0,25	0,15	0,40	0,18	0,18	0,29	0,25	0,40	0,00	0,08	0,12	0,40	0,17	0,14	0,40	0,33	0,09	0,31	0,31	0,33	0,00	0,25	0,27	0,00	0,18	0,27	0,27	0,00	0,18	0,00	0,14	0,13	0,00	0,12	0,50	0,00	0,29	0,11	0,27	0,62	0,33	1,00	0,79	0,26	0,61	0,16	0,16	0,67	0,89	0,88	0,12	0,21	0,66	0,56	0,13	0,14	0,60	0,19	0,13	0,59	0,03	0,07
Rabb	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,18	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,14	0,00	0,00	0,18	0,00	0,00	0,00	0,00	0,17	0,00	0,22	1,00	0,29	0,22	0,26	0,20	0,41	0,23	0,08	0,13	0,21	0,27	0,12	0,17	0,19	0,65	0,23	0,59	0,09	0,05	0,09
Res2	0,00	0,15	0,20	0,00	0,00	0,29	0,13	0,20	0,00	0,32	0,24	0,13	0,17	0,14	0,13	0,11	0,18	0,15	0,00	0,00	0,00	0,00	0,00	0,13	0,00	0,00	0,13	0,20	0,00	0,16	0,14	0,27	0,00	0,24	0,00	0,00	0,00	0,11	0,00	0,00	0,17	0,00	0,00	1,00	1,00	0,76	0,56	0,32	0,21	0,06	0,77	0,60	0,66	0,85	0,85	0,50	0,18	0,19	0,18	0,33	0,83	0,65
Rese	0,00	0,13	0,17	0,31	0,31	0,22	0,11	0,17	0,00	0,37	0,29	0,24	0,14	0,25	0,24	0,20	0,25	0,13	0,00	0,29	0,00	0,22	0,24	0,12	0,15	0,12	0,24	0,17	0,15	0,15	0,38	0,35	0,13	0,32	0,29	0,20	0,00	0,20	0,00	0,00	0,14	0,17	0,00	0,83	1,00	0,72	0,34	0,16	0,49	0,14	0,59	0,49	0,86	0,85	0,71	0,72	0,78	0,14	0,07	0,47	0,54	0,40
Rimo	0,17	0,07	0,23	0,30	0,30	0,09	0,19	0,23	0,29	0,39	0,41	0,19	0,21	0,33	0,32	0,35	0,21	0,21	0,34	0,21	0,07	0,31	0,26	0,13	0,15	0,32	0,32	0,08	0,15	0,29	0,40	0,13	0,28	0,30	0,14	0,08	0,00	0,18	0,13	0,14	0,36	0,08	0,08	0,23	0,29	1,00	0,11	0,91	0,47	0,70	0,79	0,08	0,33	0,77	0,79	0,52	0,92	0,05	0,26	0,06	0,58	0,62
RoFr	0,17	0,35	0,29	0,40	0,40	0,00	0,30	0,29	0,38	0,34	0,38	0,21	0,13	0,33	0,21	0,36	0,31	0,12	0,24	0,25	0,12	0,10	0,11	0,21	0,40	0,11	0,21	0,29	0,13	0,41	0,11	0,42	0,24	0,57	0,00	0,00	0,00	0,09	0,32	0,24	0,38	0,00	0,00	0,14	0,13	0,13	1,00	0,81	0,38	0,78	0,14	0,93	0,79	0,51	0,84	0,52	0,74	0,67	0,82	0,28	0,61	0,81
SaDr	0,24	0,18	0,42	0,40	0,40	0,13	0,32	0,42	0,57	0,35	0,38	0,25	0,29	0,43	0,50	0,37	0,26	0,36	0,55	0,29	0,09	0,32	0,33	0,17	0,30	0,33	0,42	0,21	0,10	0,24	0,35	0,17	0,36	0,46	0,19	0,00	0,13	0,00	0,42	0,36	0,57	0,21	0,11	0,11	0,10	0,46	0,35	1,00	0,77	1,00	0,72	0,17	0,84	0,98	0,31	0,27	0,94	0,15	0,28	0,02	0,20	0,41
Salè	0,00	0,00	0,00	0,46	0,46	0,00	0,00	0,00	0,29	0,30	0,23	0,47	0,29	0,38	0,24	0,40	0,25	0,13	0,27	0,29	0,00	0,33	0,24	0,00	0,46	0,35	0,35	0,00	0,15	0,15	0,38	0,24	0,27	0,42	0,29	0,00	0,00	0,10	0,12	0,13	0,29	0,33	0,00	0,00	0,14	0,21	0,13	0,29	1,00	0,92	0,30	0,10	0,52	0,66	0,38	0,68	0,96	0,15	0,10	0,17	0,28	0,43
SaLi	0,22	0,17	0,40	0,48	0,48	0,12	0,31	0,40	0,64	0,34	0,42	0,32	0,27	0,67	0,56	0,43	0,25	0,35	0,52	0,36	0,09	0,54	0,48	0,16	0,48	0,32	0,48	0,20	0,29	0,23	0,50	0,32	0,35	0,52	0,36	0,00	0,12	0,07	0,40	0,35	0,55	0,30	0,00	0,00	0,09	0,39	0,33	0,69	0,36	1,00	0,34	0,17	0,95	1,00	0,26	0,27	0,98	0,14	0,28	0,05	0,19	0,35
Saln	0,14	0,21	0,25	0,24	0,12	0,15	0,36	0,25	0,33	0,26	0,31	0,38	0,44	0,40	0,38	0,42	0,14	0,32	0,32	0,22	0,11	0,36	0,38	0,19	0,12	0,10	0,29	0,25	0,12	0,26	0,20	0,00	0,32	0,26	0,11	0,00	0,00	0,25	0,10	0,21	0,22	0,00	0,00	0,25	0,22	0,38	0,10	0,32	0,11	0,23	1,00	0,29	0,70	0,94	0,48	0,02	0,60	0,96	0,76	0,21	0,45	0,17
Salo	0,20	0,53	0,17	0,15	0,15	0,00	0,33	0,17	0,14	0,15	0,17	0,24	0,14	0,13	0,12	0,20	0,33	0,27	0,27	0,14	0,40	0,11	0,12	0,12	0,15	0,00	0,12	0,17	0,15	0,30	0,00	0,00	0,13	0,21	0,00	0,00	0,00	0,30	0,12	0,13	0,14	0,00	0,00	0,17	0,14	0,07	0,38	0,10	0,00	0,09	0,11	1,00	0,51	0,36	0,35	0,08	0,45	0,80	0,90	0,94	0,81	0,72
SaPA	0,22	0,14	0,36	0,50	0,50	0,00	0,24	0,36	0,46	0,23	0,29	0,25	0,15	0,53	0,38	0,32	0,09	0,29	0,14	0,46	0,14	0,24	0,38	0,13	0,67	0,00	0,38	0,18	0,67	0,08	0,13	0,38	0,29	0,22	0,31	0,00	0,00	0,11	0,38	0,29	0,31	0,18	0,00	0,18	0,31	0,15	0,27	0,30	0,15	0,38	0,24	0,15	1,00	1,00	0,44	0,13	0,98	0,52	0,42	0,30	0,12	0,20
SaRa	0,21	0,08	0,38	0,45	0,36	0,11	0,30	0,38	0,43	0,44	0,41	0,31	0,26	0,72	0,54	0,41	0,24	0,33	0,33	0,35	0,08	0,52	0,46	0,15	0,45	0,23	0,46	0,19	0,27	0,17	0,48	0,31	0,33	0,43	0,26	0,00	0,00	0,21	0,23	0,25	0,43	0,19	0,00	0,29	0,35	0,43	0,24	0,53	0,26	0,71	0,44	0,17	0,45	1,00	0,52	0,06	0,99	0,08	0,21	0,04	0,50	0,29
Sel1	0,17	0,12	0,29	0,27	0,27	0,18	0,20	0,29	0,13	0,21	0,32	0,21	0,25	0,33	0,21	0,18	0,15	0,12	0,12	0,13	0,12	0,10	0,11	0,11	0,27	0,11	0,21	0,14	0,27	0,21	0,22	0,21	0,12	0,19	0,00	0,00	0,00	0,09	0,21	0,12	0,38	0,00	0,00	0,29	0,25	0,33	0,33	0,17	0,13	0,17	0,20	0,13	0,13	0,24	1,00	1,00	0,74	0,37	0,25	0,10	0,65	0,82
Sel2	0,00	0,00	0,00	0,27	0,40	0,00	0,10	0,00	0,13	0,21	0,22	0,00	0,00	0,11	0,00	0,09	0,23	0,00	0,12	0,13	0,00	0,10	0,11	0,00	0,13	0,32	0,21	0,00	0,13	0,21	0,33	0,21	0,12	0,29	0,13	0,17	0,00	0,09	0,11	0,00	0,25	0,00	0,00	0,14	0,25	0,27	0,22	0,17	0,25	0,17	0,00	0,00	0,00	0,08	0,67	1,00	0,72	0,09	0,05	0,09	0,35	0,53
Spor	0,20	0,13	0,17	0,77	0,62	0,00	0,11	0,17	0,43	0,22	0,23	0,35	0,29	0,63	0,35	0,30	0,17	0,27	0,27	0,57	0,13	0,44	0,59	0,12	0,62	0,35	0,35	0,17	0,46	0,15	0,50	0,35	0,40	0,32	0,57	0,20	0,00	0,10	0,12	0,13	0,29	0,17	0,18	0,00	0,29	0,36	0,25	0,38	0,43	0,45	0,22	0,14	0,46	0,43	0,25	0,25	1,00	0,46	0,70	0,18	0,27	0,44
SZe2	0,20	0,27	0,17	0,15	0,15	0,00	0,33	0,17	0,14	0,15	0,11	0,24	0,29	0,13	0,12	0,30	0,17	0,27	0,13	0,14	0,27	0,11	0,12	0,24	0,15	0,00	0,12	0,33	0,15	0,15	0,00	0,12	0,13	0,00	0,00	0,00	0,00	0,20	0,12	0,27	0,14	0,00	0,00	0,00	0,00	0,07	0,25	0,10	0,00	0,09	0,44	0,29	0,15	0,09	0,13	0,00	0,14	1,00	0,99	0,47	0,08	0,23
SZen	0,17	0,12	0,14	0,13	0,13	0,00	0,20	0,14	0,13	0,07	0,11	0,21	0,25	0,11	0,11	0,27	0,15	0,24	0,24	0,25	0,24	0,20	0,11	0,21	0,13	0,00	0,11	0,29	0,13	0,28	0,00	0,11	0,12	0,10	0,00	0,00	0,00	0,09	0,11	0,12	0,13	0,00	0,15	0,00	0,00	0,20	0,33	0,17	0,00	0,17	0,30	0,38	0,13	0,16	0,11	0,00	0,25	0,50	1,00	0,31	0,13	0,23
TeBo	0,12	0,45	0,11	0,10	0,10	0,00	0,40	0,11	0,00	0,41	0,38	0,25	0,10	0,09	0,33	0,37	0,39	0,18	0,18	0,10	0,18	0,08	0,08	0,25	0,10	0,08	0,17	0,11	0,10	0,24	0,26	0,17	0,00	0,23	0,10	0,00	0,00	0,59	0,17	0,18	0,10	0,21	0,00	0,11	0,19	0,17	0,17	0,07	0,10	0,14	0,16	0,38	0,10	0,13	0,09	0,09	0,10	0,19	0,17	1,00	0,23	0,41
TeL2	0,09	0,22	0,08	0,16	0,24	0,00	0,07	0,08	0,23	0,46	0,38	0,07	0,08	0,21	0,14	0,19	0,44	0,15	0,30	0,08	0,07	0,20	0,21	0,21	0,16	0,07	0,14	0,17	0,16	0,46	0,29	0,21	0,15	0,32	0,00	0,00	0,00	0,31	0,07	0,07	0,23	0,00	0,00	0,25	0,23	0,40	0,29	0,24	0,15	0,24	0,27	0,31	0,08	0,34	0,29	0,21	0,15	0,08	0,14	0,24	1,00	1,00
TeLu	0,11	0,26	0,10	0,19	0,29	0,00	0,08	0,10	0,27	0,46	0,42	0,08	0,09	0,25	0,16	0,14	0,44	0,09	0,35	0,09	0,09	0,15	0,16	0,24	0,19	0,08	0,16	0,20	0,19	0,46	0,33	0,24	0,17	0,37	0,00	0,00	0,00	0,29	0,08	0,09	0,27	0,00	0,00	0,20	0,18	0,39	0,33	0,28	0,18	0,27	0,15	0,27	0,10	0,26	0,33	0,25	0,18	0,09	0,17	0,28	0,82	1,00

[15] The Bray-Curtis index values are listed in the lower half of the matrix, while the Raup-Crick index values are liste in the upper half. Values between 0,25 and 0,50 are marked in yellow, values higher or equal to 0,50 are marked in red and values equal to 1,00 are marked in grey.

11.6 CLUSTER DENDROGRAMS OF SPECIES

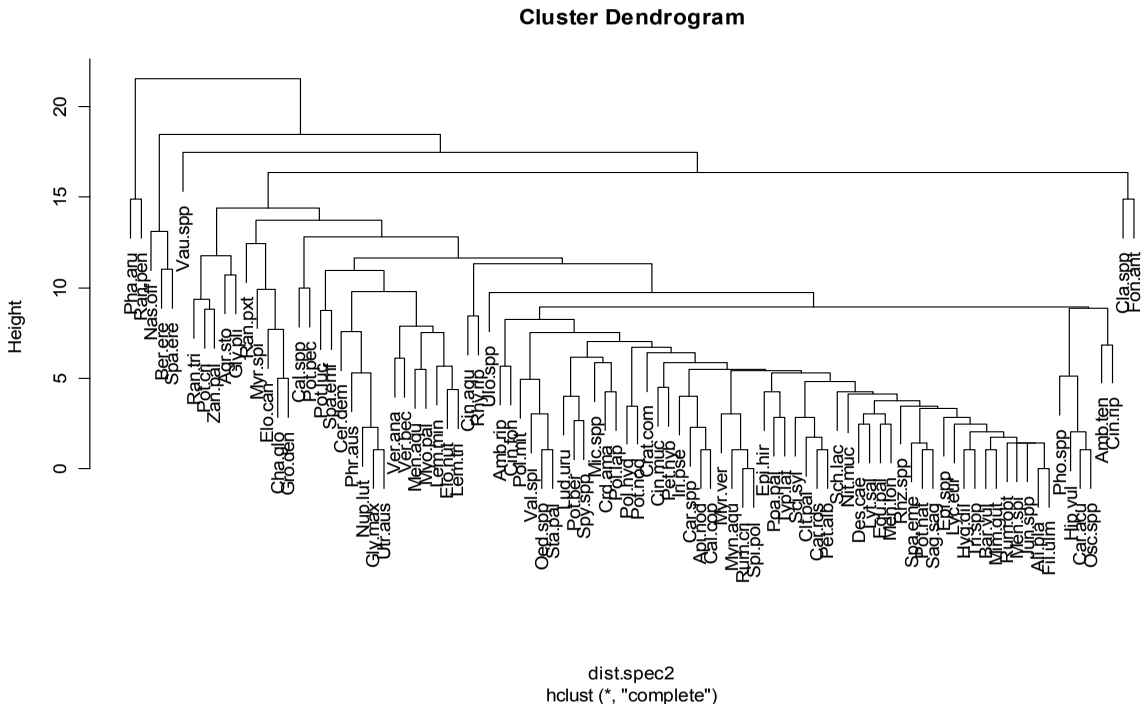

Figure 11.6.1: Cluster dendrogram of species based on Euclidean distance and complete linkage method, calculated on the species abundance matrix.

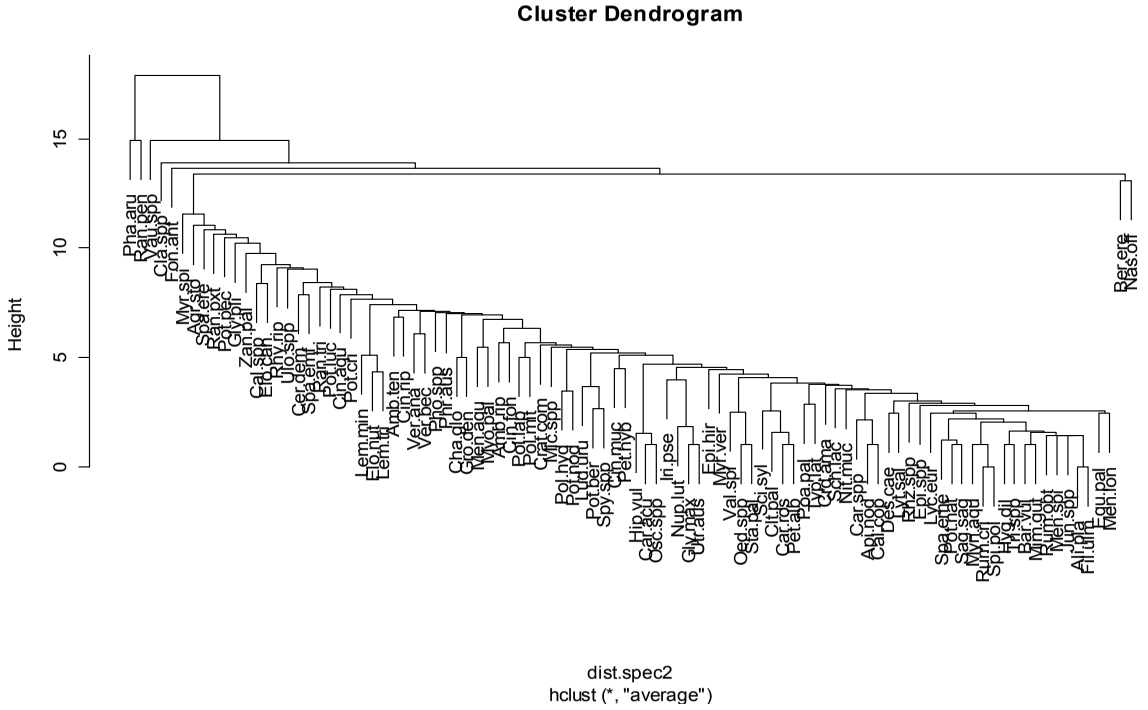

Figure 11.6.2: Cluster dendrogram of species based on Euclidean distance and average linkage method, calculated on the species abundance matrix.

12 ACKNOWLEDGMENTS

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Fabris M. & Ghetti P.F. – *Applicazione e sviluppo di metodi basati sulle macrofite, per la bioindicazione della qualità dell'acqua in ambiente fluviale* – oral presentation

- 16-21 June 2008 S.Servolo Island (Venice) - Italy

4th ECRR Conference on River Restoration

Fabris M. & Ghetti P.F. – *Application and development of river quality bioindication methods based on macrophytes* – oral presentation

- 24-28 August 2009 Jyväskylä - Finland

12th EWRS International Symposium on Aquatic Weeds

Fabris M., Ghetti P.F., Melzer A. & Siligardi M. – *Aquatic plants of running waters in the North-East of Italy (Trentino and Veneto)* – oral presentation

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ESTRATTO PER RIASSUNTO DELLA TESI DI DOTTORATO

Studente: Margherita Fabris matricola: 955153

Dottorato: Scienze Ambientali

Ciclo: XXI

Titolo della tesi:
The macrophyte vegetation of running waters in the North-East of Italy: a study of the influence of morphological variables and chemical parameters on the aquatic plant community

13 ABSTRACT

The WFD requires the assessment of the running waters based on various biotic elements, one of them being macrophytes. In Italy there is no official bioindication method based on aquatic vegetation and the data about it are still few.
The present work focuses on the relationships between macrophyte biocenosis and environmental variables of the river ecosystem, in order to understand which are the most important factors, in determining the presence and kind of aquatic plant community.
The detected variables are then used to characterize and describe different river types, with reference to their aquatic community. Particular attention is devoted to the relation between plant species and nutrient concentration in water that is the base of many trophic macrophyte indexes.

The study was conducted on 54 sites localised along different water courses in the North-East of Italy (Trentino and Veneto). The macrophyte vegetation has been mapped according to Kohler's method (Kohler, 1978). We mapped not only the vascular plants, but also the bryophytes and the filamentous algae.
The main river characters, like flow velocity, river width and depth, substrate composition, degree of shade and many others, were surveyed according to a field data sheet, mainly in a half-quantitative way.
The chemical analyses about nutrient concentrations in water were acquired for every river site.

Through the application of cluster analyses based on different methods and similarity indexes, we established that the assessed sites can be grouped according to their

macrophyte vegetation and this division largely corresponds to the one obtained through the clustering of sites, on the basis of river morphological and hydrological variables.
The macrophyte community is therefore mainly conditioned by some important variables, like flow speed and flow kind, substrate granule dimension, river width and depth and altitude of the site.

We described the composition of the community not only with the calculation of the Shannon-Weaver diversity index and the Evenness, but also through the percentage abundance and the taxa number of different components, such as hydrophytes, helophytes, amphiphytes, bryophytes and filamentous algae. Then we looked for a correlation between this metrics and the variables of the sites and the results confirmed what previously obtained. Moreover we found that nitrate concentration and hardness are the most important water chemical parameters in determining the composition and abundance of the macrophyte biocenosis.
All these result were further validated by two different kinds of matching-two table analyses, procrustean rotation and co-inertia analysis, applied on macrophyte species array and on site variable array. At the same time, these analyses proved the relatively little importance of water nutrient concentrations (phosphorus and ammonium) in determining the aquatic plant community, for the assessed environments. This fact seriously questions the application of trophic indexes on running waters, at least for the typologies that we have studied.

The calculation of correlation coefficients between species presence and abundance and trophic and saprobic indicators in water (phosphorus, nitrogen and BOD5) showed that only few among the recorded taxa have indicator value of trophic conditions.
The IBMR (Indice Biologique Macrophytique en Rivière; AFNOR, 2003) has been applied to our dataset, since it will be the official macrophyte method for Italy, according to the decision of the Ministry of Environment. The French index resulted to be quite good in classifying the river sites, for what concerns the trophic level, but in some cases it gave false outputs.

Finally we described 9 different river types, into which the running water environments of the studied area can be classified. Every type is characterized by a certain kind of macrophyte community, in terms of coverage and biological forms, while the species composition can vary in dependence on site specific conditions, one of them being trophy.
From the dataset it is evident that there are no real reference sites inside the considered area and this has prevented us from establishing the reference species composition of the macrophyte community for each type. Anyway the future step for the setting of an Italian macrophyte ecological method has necessarily to be that of finding at least the best available sites for each fluvial type in order to describe the “reference” vegetation.

14 RIASSUNTO

La Direttiva 2000/60/CE richiede la valutazione dei corsi d'acqua sulla base di diversi elementi biotici, tra cui le macrofite. In Italia non vi è, ad oggi, un metodo ufficiale di bioindicazione basato sulla vegetazione acquatica e i dati su tale componente sono ancora piuttosto scarsi.
Il presente lavoro è incentrato sulle relazioni tra biocenosi macrofitica e variabili ambientali dell'ecosistema fluviale, per capire quali siano i fattori più importanti nel determinare il tipo di comunità vegetale presente negli ecosistemi lotici.
Le variabili così individuate vengono poi utilizzate per caratterizzare e descrivere alcune tipologie fluviali, con riferimento alla vegetazione acquatica che in esse si sviluppa. Una particolare attenzione è dedicata al rapporto tra specie vegetali e concentrazione dei nutrienti principali nella colonna d'acqua, dal momento che questa relazione costituisce il fondamento di molti indici trofici basati sulle macrofite

Lo studio è stato condotto su 54 punti di campionamento, localizzati lungo diversi corsi d'acqua dell'Italia nord-orientale (Trentino e Veneto). Le macrofite sono state mappate secondo il metodo Kohler (Kohler, 1978), includendo non solo le piante vascolari, ma anche le briofite e le alghe filamentose.
Le principali caratteristiche dei siti campionati, quali velocità di corrente, larghezza e profondità del fiume, composizione granulometrica del substrato, grado di ombreggiamento ecc., sono state registrate in modo semi-quantitativo, sulla base di una scheda di campo.
Per ciascun sito sono state inoltre acquisite le analisi chimiche relative alla concentrazione dei nutrienti nella fase acquosa.

I siti di campionamento sono stati raggruppati, in base alla loro comunità macrofitica, attraverso l'applicazione della cluster analysis, basata su diverse misure di distanza e indici di similarità. I cluster ottenuti sono in larga parte corrispondenti a quelli risultanti dal clustering dei siti sulla base delle loro caratteristiche morfologiche e idrologiche.
La vegetazione acquatica è quindi principalmente condizionata da alcune importanti variabili, quali ad esempio la velocità di corrente, la granulometria del substrato, la larghezza e la profondità del corso d'acqua e l'altitudine del sito.

La composizione della biocenosi è stata descritta sia attraverso il calcolo dell'indice di diversità di Shannon-Weaver e della Evenness, sia tramite le percentuali di abbondanza e il numero di taxa delle idrofite, delle elofite e delle anfifite, oltre a quello delle sole briofite e alla copertura delle alghe filamentose. Il calcolo della correlazione tra tali metriche e le variabili caratterizzanti il sito ha fornito una conferma di quanto ottenuto

precedentemente, tramite la cluster analysis. È inoltre risultato che, tra i parametri chimici analizzati nella colonna d'acqua, la concentrazione dell'azoto nitrico e la durezza dell'acqua sono le principali determinanti della composizione e abbondanza della comunità a macrofite.
Tutti i risultati ottenuti sono stati ulteriormente confermati dall'applicazione di due diversi tipi di matching-two table analysis, la procrustean rotation e la co-inertia anlaysis, alla matrice delle abbondanze delle specie da una parte e a quella delle caratteristiche delle stazioni di campionamento dall'altra. Questo tipo di analisi statistica ha contemporaneamente dimostrato la minore importanza della concentrazione dei nutrienti (fosforo e azoto ammoniacale) in acqua nel determinare la comunità macrofitica degli ambienti indagati. Ciò mette seriamente in discussione l'uso degli indici trofici per la valutazione delle acque correnti, almeno per quanto concerne le tipologie oggetto del presente studio.

Il calcolo dei coefficienti di correlazione tra presenza ed abbondanza delle specie e indicatori trofici e saprobici delle acque (fosforo, azoto e BOD5) ha fornito solo pochi taxa aventi un valore indicatore delle condizioni di trofia.
L'IBMR (Indice Biologique Macrophytique en Rivière; AFNOR, 2003)è stato applicato al nostro data set, poiché esso diverrà il metodo ufficiale per la componente macrofitica, secondo quanto deciso dal Ministero dell'Ambiente. L'indice francese classifica abbastanza bene i siti, per quanto riguarda il loro livello trofico, ma fornisce, in alcuni casi, anche dei "falsi" risultati.

Infine sono state descritte 9 tipologie fluviali, alle quali possono essere attribuiti i siti fluviali dell'area di studio. Ogni tipologia è caratterizzata da una certa comunità macrofitica, in termini di copertura e di forme biologiche presenti, mentre la composizione in specie varia in base alle condizioni sito-specifiche, tra cui la trofia.
Dal data set di questo studio è evidente la mancanza di veri siti di riferimento nell'area analizzata e ciò ha reso impossibile stabilire la composizione specifica di riferimento della comunità a macrofite per ogni tipologia fluviale. In ogni caso, in futuro, sarà indispensabile individuare almeno i migliori siti disponibili (best available sites) per ciascuna tipologia, per poter arrivare alla definizione di un indice ecologico basato sulle macrofite, per i fiumi italiani.

15 ZUSAMMENFASSUNG

Die WRRL erfordert die Bewertung der Fließgewässer aufgrund der verschiedenen biotischen Elemente, unter anderem der Makrophyten. In Italien gibt es bis heute noch keine offizielle Methode für die Bioindikation, die auf Wasservegetation basiert und die Daten darüber sind noch knapp.
Die vorliegende Arbeit konzentriert sich auf das Verhältnis zwischen Makrophytenbiozönose und Variablen des Ökosystems der Fließgewässer, um zu verstehen, welche sind die wichtigsten Faktoren zur Bestimmung des Pflanzengesellschaftstyps, der in Fließgewässerökosystemen vorkommt.
Die so bestimmten Variablen werden dann genutzt, um einige Fließgewässertypen zu charakterisieren und zu beschreiben, mit Bezug auf den Wasserpflanzentyp, der sich in ihnen entwickelt.
Besondere Aufmerksamkeit wird dem Verhältnis zwischen den Pflanzenarten und der Konzentration der Hauptnährstoffe im Wasser, da viele trophische Indizes auf dieses Verhältnis basieren.

Die Studie wurde an 54 Probestellen durchgeführt, die sich entlang verschiedener Fließgewässer Nordostitaliens (Trentino und Veneto) befinden. Die Makrophyten wurden nach der Kohler-Methode kartiert (Kohler, 1978). Sie beziehen nicht nur die Gefäßpflanzen, sondern auch Bryophyten und Fadenalgen ein. Die Hauptmerkmale der Probestellen, wie Fließgeschwindigkeit, Flussbreite und –tiefe, Korngrößeverteilung des Substrates, Beschattung usw., wurden semiquantitativ nach einem Feldprotokoll erfasst.
Außerdem wurden für jede Stelle die chemischen Analysen der Nährstoffkonzentration im Wasser erworben.

Die Probestellen wurden aufgrund deren Wasserpflanzengesellschaft durch die Anwendung der Clusteranalyse gruppiert, die nach verschiedenen Distanzmessungen und Ähnlichkeitsindizes ausgewertet wird. Die erhaltenen Clusters entsprechen zum großenteils denen, die aus der Clusteranalyse der morphologischen und hydrologischen Merkmale der Stellen hervorgehen.
Die Wasserpflanzen werden also hauptsächlich von einigen wichtigen Variablen beeinflusst, wie zum Beispiel Fließgeschwindigkeit, Korngrößeverteilung des Substrates, Flussbreite und –tiefe und Stellenhöhe.

Die Biozönosezusammensetzung wurde sowohl durch die Rechnung des Shannon-Weavers Diversitätsindex und der Evenness berechnet, als auch durch die Prozentabundanz, die Hydrophyten-, Helophyten-, Amphiphyten- und Bryophytentaxazahl und die Deckung der Fadenalgen. Die Rechnung der Korrelation zwischen diesen Messungen und den Stellemerkmalen hat die vorher durch die

Clusteranalyse erhaltenen Daten bestätigt. Zudem ist hervorgegangen, dass unter den betrachteten chemischen Parametern die Nitratstickstoffkonzentration im Wasser und die Wasserhärte die Zusammensetzung und die Abundanz der Makrophytengesellschaft am meisten bestimmen.
Die erhaltenen Ergebnisse wurden durch die Anwendung zwei verschiedener matching-two table analyses Typen, procrustean rotation und co-inertia anlaysis, auf die Artabundanzmatrix und die Matrix der Probestellenmerkmale weiter bestätigt. Gleichzeitig hat diese Analyse die mindere Bedeutung der Nährstoffkonzentration (Phosphor und Ammoniumstickstoff) im Wasser für die Bestimmung der Makrophytengesellschaft des untersuchten Milieus bewiesen. Das stellt die Anwendung der trophischen Indizes für die Bewertung der Fließgewässer ernsthaft in Frage, zumindest was die hier untersuchten Fließgewässertypen betrifft.

Die Berechnung der Korrelationskoeffizienten zwischen Artenvorkommen und –abundanz und den trophischen und saprobiellen Anzeigern der Gewässer (Phosphor, Stickstoff und BOD5) hat nur wenige Taxa mit einem Indikatorwert der Trophie angegeben. Der IBMR (Indice Biologique Macrophytique en Rivière; AFNOR, 2003) wurde bei unseren Daten angewendet, da er gemäß dem Umweltministerium die offizielle Makrophytenmethode sein wird. Der französische Index klassifiziert die Stellen relativ gut in Bezug auf den trophischen Zustand, liefert jedoch in manchen Fällen „falsche“ Ergebnisse.

Zum Schluss werden 9 Fließgewässertypen beschrieben, zu denen die Stellen des untersuchten Gebietes zugeschrieben werden können. Was die Deckung und die vorhandenen biologischen Formen betrifft, ist jeder Fließgewässertyp von einer bestimmten Makrophytengesellschaft gekennzeichnet, während die Artenzusammensetzung nach den stellenspezifischen Bedingungen, unter anderen der Trophie, variieren kann.
Die Daten dieser Studie machen offensichtlich, dass in dem untersuchten Gebiet echte Referenzstellen fehlen. Deswegen war eine Bestimmung der Referenzartenzusammensetzung der Makrophytengesellschaft für jeden Fließgewässertypen nicht möglich. Auf jeden Fall wird es in der Zukunft unerlässlich sein, wenigstens die bestverfügbaren Stellen (best available sites) für jeden Fließgewässertypen zu finden, um zu einem ökologischen Makrophytenindex für die Fließgewässer in Italien zu gelangen.

Firma dello studente

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Firma del tutore

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Firma del coordinatore

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