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Development of a previsional model for the ichthyc biodiversity in the Northern Apennine (Italy)

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XIX Course

Introduction

I. The lotic ecosystem

The lotic, or running water, ecosystem is a wide-open system and therefore closely connected to the relevant catchment basin. There is, in fact, a tight system of cause and effect relationships, often with reciprocal consequences, among factors that are even apparently very distant in space and time. Every course of water has, therefore, a series of continuous longitudinal gradients in its geomorphologic structures, chemico-physical characteristics and trophic conditions, accompanied, obviously, by local opposing trends due to a myriad of extremely varying and mutable microenvironments.

Along the journey that water takes, reduced inclination, flow speed and solid transport and increased turbidity, organic substance content, and temperature, are therefore recorded on sufficiently large scales, which characterize the whole watercourse as a single continuum.

A description of this however needs a categorizing approach; therefore we are accustomed to overlapping the concept of fluvial continuum with that of zoning.

I.1. Fluvial zoning

Subdivision into zones can be performed according to various criteria, politico-economic or ecological; several attempts have been made in this respect but often with limited applicability. The best criterion generally seems to be to distinguish the ecotypes due to the fish fauna present.

Concerning the waters of the Adriatic side of the northern Apennine, and more precisely those of the basins east of the Panaro, the last right tributary of the Po, the following subdivision is made: zone of sources, zone of salmonids, zone of reophilous cyprinids, zone of limnophilus cyprinids, and zone of the mouth or estuary.[G] (Zerunian, 1982).

[G] Zerunian, S. 1982. Una proposta della classificazione della zonazione longitudinale dei corsi d'acqua dell'Italia centro meridionale. Boll.Zool., 49:200
Turin, P., 1995. Carta ittica della provincia di Padova. Provincia di Padova, Asessorato alla Pesca.

I.1.1. Sources zone

This is the zone where underground waters come to the surface.

It is characterized by a slight seasonal variation in temperature, low content of dissolved oxygen, limited erosion and extremely poor nutritional content. Consequently, biological colonization is scarce, with a prevalence of algae sessiles and mosses.

Oxygen progressively increases, accompanied by the increase and diversification of both vegetal and animal communities.

I.1.2. Salmonid zone

This zone is characterized by trout and an energetic regime, typically heterotrophic, that sustains a short food chain.

This part of the basin has a steep slope that increases the speed and turbulence of the water, and, therefore, there is marked sedimentation erosion. The river bed is therefore very inhomogeneous and there are more coarse materials, such as rocks and pebbles, than small ones, such as sands and silt, which are confined to the few areas of relative quiet, but have a short duration.

Riparian vegetation is composed of tree species whose roots oppose erosion and that, with their ample coverage, limit the development of the autotrophic component. The water temperature is low, the dissolved oxygen content is very high, and nourishment is scarce. This is mostly due to decomposing exogenous vegetal material. The fish species in the area include trout and bullhead, whereas invertebrates include collectors and filterers.

Going down to the lower part of the salmonid layer the area of the river basin increases and with it, in relationship to washing away, the amount of nourishment. The vegetal coverage, still ample, but more variable, maintains, however, the preponderant heterotrophism. As the gradient decreases the presence of pools[H] and riffles becomes relevant, and the longitudinal and transversal morphological variability increases. All of this is the basis for the formation of a large number of ecological niches that results in the lengthening of the food chain.

[H] A detailed description of conventional definition of running water surface morphology is reported in chapter 2.1.3.

In fact, there are various species of bugs, some gastropods and shellfish, and, sporadically, fish species of the lower layer, such as dace and barbel.

I.1.3. Zone of rheophilous cyprinids

This zone is characterized by the prevalence of lithophilous cyprinidae species, such as Dace, Barbel, Chub, Roach, Goby, Gudgeon, and Loach, a good endogenous production, and, accordingly, well articulated food chains.

In this section with a gentle slope there is a fairly wide river basin, which results in a waterway with low speed, good flow, wide riverbed and meandering course. Therefore, there is a balance between sedimentation and erosion, which are however arranged differentially in a transverse manner. Around the bends, in fact, water travels at an inhomogeneous speed, higher on the external bend and lower on the internal one, so that respectively erosion and sedimentation occur. The lithic materials are also arranged on a transverse gradient according to their granulometry; this ranges in size from pebbles to silt, but most of this material is stones and gravel, the so-called rheos. Thus, the route of the river varies over time and, especially after flooding, islands and branches of smaller water streams can form.

The vegetal coverage is limited, considering the width of the riverbed and the effect the water has on the banks, which causes, as it retreats from them, an association of vegetal communities less and less resistant to such disturbance. Because of this there is a marked increase in light that, together with the slow speed, is the cause of a rise in temperature and therefore, thanks to the availability of nourishment, mainly percolating from the wide basin, a good primary production both of micro and macrophytes. Thanks also to the extreme variety of environments both biodiversity and biomass grow notably, and with them the food chain lengthens.

Among the bentonic invertebrates, besides the populations already seen, forms that will become dominant in the following layer appear, such as bivalves and hirudinea.

The fish fauna, apart from the species already mentioned, includes a large amount of trout, that descend for nutrition, and, the eel as a super predator.

I.1.4. Zone of limnophilus cyprinids

This is the layer of choice for phytophilous cyprinoid species, such as Rudd, Bleak, Carp, Italian nase, Tench and Perch, in a heterotrophic regime, but able to sustain long food chains.

The slight inclination of this section together with the great width of the river basin provides large amounts of water with such a slow speed that, at normal flow, it allows the sedimentation of finer lithic materials, silt to be precise, to far exceed the erosion. The quantity of silt in suspension is such that, although the width of the riverbed ensures an almost constant exposure to the sun, its primary production is limited. Therefore temperatures are high and food chains are based on consumption and, accordingly, the oxygen content is low.

The hydraulic dynamics is partly similar to that of the upper layer, so that the river meanders. This meandering changes over time, especially after flooding, and leads to the formation of large dead branches, known as ox-bows that, despite remaining in contact with the main course, contain stagnant waters.

A peculiarity of this layer is the relationship of mutual exchange of waters between the river and the surrounding plain, known precisely as the alluvial plain. The river, by depositing material continuously, makes its own territory to flow through, which is precisely a plain of sediment material. The amount of water present and the slight inclination of the banks actually favour flooding onto the surrounding land, at intervals that depend not only on the distance from the river bed, but mainly on its own profile.

The destiny of these areas, known as “sweet damp areas,” varies over time according to the competition between subsidence, typical of sediment materials, and the contribution of further deposits. The vegetation is composed therefore of a succession of vegetal communities less and less resistant to the floods, typically reeds on the banks, then softwood trees or shrubs, such as willows and poplars, and finally hardwood trees, such as ashes, elms, oaks and hornbeams.

Therefore, there is a wide variety of environments, limited however by the shortages of oxygen and light, that allow long food chains based on the debris, composed of a fauna more or less resistant to the anoxia. As bentonic species there are therefore collectors and filterers on the riverbeds, and near the banks gastropods, bivalves, shellfish, coleopters and hirudinea. The fish fauna, besides the typifying species already mentioned, includes some from the upper layer superior, such as Chub and Roach, and Eel and Pike as super predators.

I.1.5. Mouth or estuary zone

This area represents the border between the river and the sea and as such has intermediate characteristics of salinity, oxygen concentration, and fauna levels, being characterized, in fact, by Flounder and Mullet. However, the characteristics of these zones cannot be considered as transitional between those of the adjoining zones.

The effects of the two systems, basically antagonistic, in fact, produce a great amount of energy that makes this a particularly luxuriant layer. Here are the largest and most complete food chains seen so far, with the proliferation of all the nutrition levels.

The environment is characterized by a continuous water/land interface, being the sum of the delta movement, due to flooding, and the effects of the sea, very low beds and daily variations dependent on the tides. In addition to this the territories are flooded to varying degrees throughout the year, 'salty wet areas,' that differ from the analogous territories upstream only in salt content.

The land vegetation also here has a succession of changes not only due to its resistance to flooding, but also to the environmental conditions determined by the sea and therefore, above all, to the salinity of both the land and the winds. The aquatic vegetation is richly represented by hydrophilous macrophytes and by algae both macro and microscopic.

Several forms of invertebrates are present such as bivalves, gastropods, shellfish, insects and cephalopods, such as Cuttlefish. The fish fauna is well represented, not only by Flounder and Mullet, but also Needlefish, some species of Gobiidae, Tooth Carp, Eel, and Gilthead, some usual residents, and some migratory with catadromous or anadromous biology.

I.2. River continuum

Therefore, when passing from the source zones of to those of estuary, the lotic ecosystem sees a growth in productivity on a general level, and particularly for the fish communities, and an increase in the number of species, biodiversity, and the general biomass. The temperature and nutrition levels of the water increase, whereas the oxygen concentration decreases.

On a hydraulic level there is an increase in the flow, because of the widening of the river basin and the confluence of larger and larger waterways, which is accompanied, due to the reduction of the gradient, by a decrease in the speed and turbulence, and therefore, also considering the trend of the flow, an increase in the width of the riverbed.

Concerning the transported lithic material, and therefore the type of bed, the source-estuary journey sees a progressive reduction in the size of the particulate that ranges from rocks to silt.

II. Anthropic changes

Humans interfere or have interfered with the river-basin catchment system causing physical modifications of the environment, chemical-physical changes to the waters and qualitative alterations to the native fish populations, that, by inserting themselves in the complicated system of natural cause-effect relationships, have moved the ecosystem towards new points of stable or unstable balance and therefore, respectively and energetically, low or kept high by external flows, and have turned the fluvial continuum into a discontinuum[I].

II.1. Hydraulic optimizing

These are all changes made to contain the water's energy and thus gain land for building or agriculture.

[I] Odum, E.P., 2001, Basi di ecologia. CBS College Publishing. Piccin.

II.1.1. Rectification

This is done with the purpose of reducing the traveling time of the waters flooding the land and decreasing the erosion that occurs in a meandering waterway.

Reducing the length of the river, gradient being equal, however, causes an increase in the speed of the water and therefore a greater erosive force that is exerted both by retreating upstream, with the consequent deposit of materials downstream, and on the banks, thus causing landslides of varying degrees. Then there is the separation of the river and the perifluvial flood areas that, by storing the water in excess, to release it gradually, decrease the magnitude of the floods.

In addition, the shorter time the water stays in the catchment basin, on one hand reduces its capability to purify itself and increases its general eutrophication, and on the other it does not allow replenishment of the aquifers, that in turn, so impoverished, do not feed the water bodies in the dry periods, thus exasperating a natural environmental stress and concentrating possible pollutants.

The consequent reduction in the environmental diversity is reflected by a smaller general productivity and a decrease in biological diversity.

II.1.2. Reshaping

This involves moving clastic material onto the banks to strengthen them and increase the capacity of the riverbed.

Hydraulically, the speed of the water is accelerated, which leads to the consequences already seen for rectification, due to the absence of the braking effect of the irregular bed. This, from a biological point of view, means minimizing shelter areas and ideal areas for hydrophilous macrophytes.

Widening the bed section, causing, flow being equal, columns of lower water, increases stress conditions in times of drought. In the long term there is vertical erosion, which destabilizes once more the status of the riverbed.

II.1.3. Riparian devegetation

This is done to limit the amount of trunks transported by the flood water, to avoid accumulation around bridge pillars, which are liable to yield under the water's push behind the obstacle thus formed.

Again the long-term effect is deleterious because the vegetation is able to hold back the percolating water, limit the erosion of the banks and slow down the outflow of water.

Obviously, also this change, by monotonizing the environment, and decreasing shade and importing exogenous vegetal material, determines a reduction in biotic complexity.

II.1.4. Cementification

This is typically performed in combination with rectification in order to safeguard the banks.

It is a further cause of increasing the speed of the water. It physically separates the riverbed from the surrounding basin, it almost entirely cancels the environmental, and therefore biological, diversity and decreases shade.

II.1.5. Embankments

This is an extreme measure against river overflowing, typical of the whole limicolous area of the rivers.

It also increases the speed of the water during flooding with all the implications mentioned, especially producing erosion where it would not naturally occur, as often unfortunately happens with cementification and rectification. Embankments are mostly responsible for separating the waterway from its basin in an area where it is particularly extensive. Thus, a series of modifications take place. The general productivity of the waters in the river bed decreases, because of the lack of nutrient input due to washing away. The nearby wet areas disappear, and with them, the associated buffer effect on the water hydrographic regimes, while the interfluvial basins, becoming the new collectors of rain waters, change from a regime of occasional flooding to perennial swamping. Finally, the result is to monotonize the environment and diminish the biocenotic complexity.

II.1.6. Reclamations

Reclamation work was carried out between the end of 1800 and the beginning of 1900 to dry up land that was marshy, natural or that had emerged after making embankments, by the construction of a tight network of drainage channels.

As a result the water remains less time in the basin, which increases the nutrition status and the danger for the receiving course in a water emergency. As usual the environment and the living communities are monotonized.

II.1.7. Dykes

Dykes were built to protect against longitudinal erosion due to the normal roughness of the land or following previous rectifications, embankments or excavations, or the presence of bridge pillars.

In the long term they produce marked erosion downstream and an entrapment of the sedimentation materials, even finer ones, upstream. The latter aspect has two important implications, it creates environments typical of lower altitudes at sea level and, by decreasing the quantity of sedimentable material, causes erosion in the estuaries.

Being generally built without appropriate implants for returning upstream, despite a national law that was passed in 1931 (Gandolfi, 1991), they represent a barrier for the free circulation of animals, preventing a lot of species from reaching breeding grounds.

II.2. Exploitation of hydrogeological resources

This has been done indiscriminately for centuries. Regulations, that can still be circumvented easily, have been in place only since the 1970’s (Emilia Romagna Region, 1980).

Exploitation by collecting rocks is combined with using water for energy.

II.2.1. Dams

These are built for hydroelectric purposes or for storing water.

Besides producing the same effects as the dikes, but on a large scale, they are the cause of an unnatural and irregular flow regime, and, on a more than annual basis, the devastating block transfer of the accumulated muddy sediments. They alter all the chemical-physical parameters of the waters and the microclimate, both of the basin in question, and those adjacent, by the diversion of their water resources.

Obviously, with by flooding the land, a drastic transformation of the native habitat occurs.

II.2.2. Collecting the water resource

There is widespread collection of superficial and fault waters, for irrigation, industrial use, or for the aqueducts and sewerage systems essential for human life.

Water is therefore returned to the water system downstream, sometimes a few meters away, sometimes directly in the sea, which contributes to environmental drought. The chemical, physical and biological parameters of the water is therefore modified, according to its use.

II.2.3. Excavating

Excavating can favor the navigation or flow of the waterways, but is are more often performed to collect construction material.

It produces a local solid deficit that is progressively redistributed along the whole river section to achieve a new balance. Because of the broken inclination, the excavated section determines a regressive erosion and a trap for inert material. Downstream there is also erosion since the lack of suspended material does not allow sedimentation and increases the kinetic energy of the water. The lowering of the river bed also causes morphological changes in a transverse way that canalize the section in question. Thus, there is also an increase in the speed of the water, and erosion of the banks or the canalization itself. As all changes that lower the level of the bed, excavating makes the river draining the seam, thus causing a general drying out of the land, the loss of the buffering capabilities against the dry river regime and, in the coastal areas, the intrusion of salty waters. Again the environment is monotonized and the biodiversity is diminished.

II.3. Fish management

Human interest in fish changed, during the 1900’s, from professional fishing to fishing for sport, and from extensive to intensive breeding. Repopulation is also important in the management of this resource.

II.3.1. Fishing

Nowadays, professional fishing is confined to lakes and to some estuarial areas, being mainly practiced in lotic environments for amusement purposes. This has caused an increase in the number of anglers and a decrease in their quality, and has extended their interest to ecosystems previously neglected.

The pressure of fishing, as well as its harmfulness, has therefore increased to the point that, considering the current environmental conditions, few species have the capability to maintain numerical homeostasis. The problem is addressed, without previously calculating the 'ichthyogenetic capability' and the 'theoretical fish productivity' (Gandolfi, 1991), by a series of laws and regional regulations governing the methods, methodologies, periods, time schedules and areas of fishing, maximum quantities, smallest sizes, and species that can be fished. The inadequacy of such provisions is reflected by the necessary and similarly controlled repopulation.

II.3.2. Fish breeding

Fish breeding, in fresh or salt waters, open or dammed, has been being practiced for centuries to provide food. Since the end of the 1800's, there has been a need to counterbalance fishing and, since the second half of the 1900's, there has been a need for fish for sport. These new demands have led to the change in the production regime from extensive to intensive and, with it, the increase in the environmental impact of such activities.

Intensive breeding leads to a food excess and involves large amounts of organic waste that influence the state of eutrophication of the receiving waterway, the breeding plant itself is often realized by modifying radically the natural environment. Although the introduction and the breeding of allochthonous species are restricted, they have often entered our basins because they escape by accident, such as during flooding. Instead, sometimes undesired species have been bred and introduced because they have been mistaken for the young of other species. The breeding conditions and exogenous origin of fish, have sometimes favored the introduction of several diseases. Finally, the density of fish can lead to a concentration of substances harmful to humans, and therefore probably also to natural predators.

II.3.3. Repopulation and introduction

Putting non-endogenous fish into free flowing waters is defined by Gandolfi (1991) as repopulation when it involves autochthonous species and introduction when it involves allochthonous species.

The first documented case of this activity is probably the introduction of the Carp by the ancient Romans due to their resistance and growing capability in comparison with the similar, and autochthonous Tench. With the availability on a worldwide scale of fish breeding, starting from the end of the 1800's, numerous species have been added to internal waterways, voluntarily or not. Some of these, having become acclimated, also with regards to the environmental changes, have proven to be successful competitors, causing irreparable damage to the local fauna. Since the 1970's, due to the increase in human awareness of the ecological problems, introduction has been controlled and limited to more or less rational species. For instance, the herbivorous Carp, incapable of reproducing, has been introduced into areas with high vegetal production, due to its diet.

Therefore, repopulation has become established, which, however, too often, does not achieve its goal. The case of the Brown Trout is known, whose repopulation, undertaken for a long time with material of Atlantic origin, has caused the loss of high intraspecific biodiversity due to replacement and hybridization. Repopulation is therefore inadequately controlled and occurs in vast areas of the native distributional area, once again resulting in excessive introduction, and without criterions aimed at establishing, according to the characteristics of the receiving waterways, types of species, total quantity, articulation of sizes, health conditions and seasons and ways of introduction. The general effect is an increase in the distributional area and the consistency of species wanted by fishermen at the expense of others and a diminution for everybody of the state of health.

II.4. Pollution

Pollution is defined as the change of chemical-physical-biological parameters over the threshold levels for the sensitivity of living species.

As the collector of the waters present in the catchment basin, the lotic environment, concentrating in itself the sum of the changes the waters have undergone, is a system highly sensitive to organic, inorganic, radioactive and thermal microbiological pollution. These factors cause the consumption of dissolved oxygen, toxicity, and the variation of the physical characteristics of the waterway. In a hypothetical natural environment these perturbations are limited in quantity, quality and diffusion and are easily neutralisable, as opposed to stress produced by humans that is distributed over the whole territory, and is continuous and extremely various.

II.4.1. Urban pollution

This is mainly due to compounds of organic materials, whose decomposition by bacteria into mineral salts occurs with the consumption of oxygen. The mineral salts include nitrates, nitrites and phosphates, the latter also introduced directly being a component of detergents, which, as vegetal macronutrients, are at the base of water eutrophization. The algae that grow in this condition further consume the oxygen and impede the penetration of light, which is the primary cause of the death of the vegetation that sustains the food chains. Due to the continuous depositing of decomposing organic material onto the bed, this also becomes anoxic. Sometimes the algae produce toxic substances.

Further polluting factors are the by-products of oil and various inorganic substances channeled by the rains into the sewage system, that can produce toxicity or modify the environmental physical characteristics. The presence of sewage is obviously accompanied by the development or maintenance of various kinds of pathogenic agents.

The environmental impact of urban liquid waste is much greater bearing in mind that, for obvious reasons of public health, sewage cannot be open, and therefore self-purification cannot occur.

II.4.2. Agricultural-livestock pollution

Modern agricultural practice is based on the substantial use of fertilizers, pesticides and herbicides that, washed away by the rain, are quickly transported by the system of channels, thus limiting environmental self-purification capabilities. Whereas for fertilizers the aforementioned point applies, pesticides and herbicides, being poisons can have a direct effect on the living species or after biological magnification.

Instead, breeding produces pollution due to sewage and pathogenic agents.

II.4.3. Industrial pollution

This can be due to the discharge of some waste products, typically inorganic, from manufacturing.

Besides substances that can vary the parameters of waters, such as Ph and salinity, others have a cumulative toxic effect, generally cations of heavy metals, and sometimes radioactive substances.

This is added to the discharge of waters used for cooling that, by increasing the temperature of the receiving waterway, can favor the growth of algae or upset the biological cycles of the animals.

II.4.4. Overall effects on the aquatic fauna

The sum of the pollution stresses reflects on ichthyocenosis at a biological, genetic and ecological level.

The biological effects may be the change of the migration routes or feeding and breeding patterns, a decrease in physiological functionality and an increase in sensitivity to disease and death.

At a genetic level there are various mutagenic substances, such as oil by-products, various organic pollutants, or radioactive substances.

Finally, a different ecological selection is made that rewards the most tolerant species.

II.4.5. General effects on the environment

The ineffectiveness of the regulations on pollution, mostly represented by the Merli law, can be observed directly in the unnatural colors and smells, the abundance of anoxic beds, foams and oil spills, diffused turbidity, and proliferation of algae.

III. Indexes of environmental quality

Evaluating the status of environmental quality is a process of comparison between natural and anthropic factors in the absence of ideal reference conditions, since, especially in the Italian lotic environment, environments unaffected by humans do not exist.

Therefore, empirical judgments formulated by the experts in this field based on their accumulated experience are very important. This occurs by an automatic process that compares the degree of variety and abundance of the sample acquired from impressions of the river landscape combined with past experience. This process of elaboration of experiences, expectations from the environmental characteristics, and comparison with the fished material, cannot easily be standardized and applied generally, above all because of the substantial zoogeographic differences on a reference scale reduced to sub-regional, provincial and sub-provincial level, which add to changes in the ecological characteristics along the course of the river, from upstream to downstream. The limitation of these judgments, which are as reliable as the experience of the operator is specialized, is therefore comparability.

There is, therefore, the need to rationalize the impression obtained after sampling, by the use of quality indexes, which, by summarizing the numerous elements of a biological-ecological analysis, provide objective and operatively usable comparative terms.

Since a living organism reacts to the overall situation of the environment, these indexes have to be representative of the effects, also synergic, of the various environmental conditions. The chemical and/or physical approach, therefore is precise but informatively limited. Without continuous monitoring, it is also ineffective against acute and sporadic alterations of the environmental balance, whose effects are shown instead by the living mass for longer times.

The environmental quality is an extremely subjective concept since it depends on the sensitivity of the considered organisms themselves, so that not even evaluations based on biological markers, organisms particularly sensitive to environmental changes, are exhaustive.

The correct approach seems to be to assess the environmental status by biotic indexes, or based on internal relationships within the communities present, since they are constituted by organisms that react differently to the sum of all the influences that can occur.

The most immediate method is the calculation of diversity indexes, that summarize in a single number the distribution of the individuals of every species inside the community. These indexes, owing to the way they are structured, fail to consider the single species in relationship to its value as a biological indicator. Furthermore, biological diversity does not vary in a linear way with the environmental stresses, so as to be able, for instance, to increase to intermediate levels of eutrophication.

Better informative significance is provided by the comparison of numerical relationships with the qualitative ones that exist within the communities.

The first example in this sense is the so-called saprobiotic system according to Kolkwitz and Marsson 1908[J], based on the quantification of the relationships among the different forms of existing bacterial saprophytes. The index, based on competition among the oxidization and fermentation processes of degradation, i.e. the availability of oxygen, distinguishes four classes of environmental quality: Polisaprobia where there are only reductive processes, Alpha-mesosaprobia where such processes are dominant, Beta-mesosaprobia where oxidation processes are dominant, and Oligosaprobia where these are the only processes detectable. The index has been very successful, also in relationship to the numerous improvements, made in half a century of work by various authors, aimed at increasing the accuracy of the results thanks to the calculation of the different weights for the indicative taxa. These saprobiotic indexes above all, in the later formulations, are not only able to quantify pollution, but also give indications on its quality, due to the ecotypical variety of the numerous taxa considered. Their drawbacks, however, include the laboriousness of determining the organisms in question and sensitivity, not calculated, towards morphological differences, both anthropic and natural, of the basin, and thus the evaluation of the environmental quality is limited to the polluting factors and distorted by

[J] Washington H.G., 1982. Diversity, biotic and similarity indices. A review with special relevance to aquatic ecosystems.

hydrogeological ones. The biggest drawback, however, is that of considering pollution and oxygen consumption as directly proportional, thus neglecting the ecological differences in the various areas of a waterway.

These issues are addressed by the extended biotic index (EBI). By using different systematic categories of macrobentonic invertebrates, but always rigorously higher than the genus, it is extremely practical and comparable in different geographical conditions. The taxa in question are grouped according to their sensitivity to the drop in oxygen concentration, and the environmental quality is determined by the most sensitive taxon present. The existing ecological differences, precisely of the river continuum, and the anthropic changes overlapping them are assessed by parametering the determining taxa to the number of systematic units that represent it, and to the number of total systematic units. The final judgment is deduced thanks to the accessible tables.

Elsewhere as a source of information for the evaluation of the lotico environment quality the fish community is used, as it is a repository, among the different biological conditions of fresh water, of a wider range of information, in the time-space dimension, and is more integrative, with regards to the synergic sum of the existing ecological factors.

In the scarce literature on the subject the ‘fish quality index’ that has been the most successful is surely the ‘index of biotic integrity’ (I.B.I) by Karr et al. (1989). It is based on the analysis of deviation, in twelve parameters, of the sample observed from an ideal condition. For every zoogeographic and hydrological condition the reference model is deduced by the analysis of similar environments that have not undergone anthropogenic changes or where these are marginal. The parameters, mostly with a qualitative character, include species array and the abundance of taxa sensitive to environmental variations, the articulation of nutrition levels and the abundance, and the state of health of the sample. The final judgment, made by adding the combined scores to the deviation from the reference values, puts the sampling station into one of six possible qualitative categories that go from excellent to the absence of fish.

This method also has a fair predictive capability, since depending on the parameters under analysis, we know what to expect from certain hydrogeographic conditions.

In fact the good rationale of this method led to the elaboration of many son indexes in many countries. Often the best metrics to be used were established according to judgement of expert operators, leaving reliability under subjectivity dominion even though these methods could work fine. In that sense the best modified Indexes of Biotic Integrity are those elaborated in the *FAME* (Fish-based Assessment Method for the Ecological Status of European Rivers) PROJECT[K], which are valid for many European ecoregions.

The results of FAME research are by the way inapplicable in the Italic ecoregion, first of all because biotic metrics used (Tab. 1.)[L], seem not to be useful in order to describe variability of italic freshwater fish fauna; in fact it has limited trophic specialization, is mostly composed by potamodromous species and is not well statistically distinguished in terms of tolerance to anthropic disturbance.

European Fish Index – metrics list

	Trend of reaction towards pressure
Trophic structure	
1. Density of insectivorous species	↓
2. Density of omnivorous species	↑
Reproduction guilds	
3. Density of phytophilic species	↑
4. Relative Abundance of lithophilic species	↓
Physical habitat	
5. Number of benthic species	↓
6. Number of rheophilic species	↓
Tolerance to disturbance in general	
7. Relative number of intolerant species	↓
8. Relative number of tolerant species	↑
Migratory species richness	
9. Number of species migrating over long distances	↓
10. Number of potamodromous species	↓

Table 1: Biotic metric list of the European Fish Index.[H]

Moreover, to define reference condition, FAME indexes required sites with low anthropic disturbance; with the exception of mountain catchment basins area, this condition is not met in Italy were the rivers are relatively short and the density of human population is high.

[K] The FAME GROUP, 2005. Development, Evaluation and Implementation of a standardised Fish-based Assessment Method for the Ecological Status of European Rivers (FAME). http://fame.boku.ac.at/

[L] The FAME GROUP, 2005. A standardized presentation. (http://fame.boku.ac.at/downloads/Final_presentation_Feb2005.pdf)

III.1. Water Framework Directive

The Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, also known as *EU Water Framework Directive (WFD),* establish a framework for the Community action in water policy.

This directive is an answer to "the increasing demand by citizens and environmental organisations for cleaner rivers and lakes……. recently been reconfirmed by a representative opinion poll (Eurobarometer) in all 25 EU countries. When asked to list the five main environmental issues that Europeans are worried about, averaged results for the EU25 show that nearly half of the respondents are worried about "water pollution" (47%), with figures for individual countries going up as far as 71%".[M]

"The Water Framework Directive (WFD) aims to protect all European waters (inland surface waters, estuaries, coastal waters and groundwater). Under the Directive, Member States are obliged to prevent further deterioration and to enhance and restore the status of aquatic ecosystems as well as terrestrial ecosystems and wetlands that directly depend on aquatic ecosystems. The purpose is to achieve "good ecological and chemical status" by 2015.

For the first time an EU Directive has addressed not only the chemical aspects of water protection but also its ecological aspects, such as flow regime, composition and abundance of aquatic organisms etc. This means, for example, that the WFD will help rivers to function like rivers, instead of being mere transport canals, as they have become in many parts of Europe. The Directive thus promotes integrated river basin management – considering the balanced use of all waters draining into a single point from the hills to the sea - as the most efficient way to achieve sustainable water use. This, in turn, requires coordinated planning for using land and water resources within the entire river basin covering all surface, coastal and ground waters as well as land-use activities."[N]

The implementation of this directive requires investigation methods for assessing ecological status of surface water by four biological quality elements: phytoplankton, macrophytes and phytobenthos, benthic invertebrate fauna and fish fauna.

[M] http://ec.europa.eu/environment/water/water-framework/overview.html
[N] http://www.eeb.org/press/2005/Big-Jump-PR-140705.pdf

Chapter 1. Aim of the thesis

The objective of this thesis is to construct the necessary background an assessment method for the assessment of the ecological status of surface freshwater, based on hichthyocenosis and in absence of undamaged reference condition.

In order to do that, the following points have been developed:

determination of a protocol for data imputation, checking and reporting,

designing of a relational database containing biotic and abiotic sampling data and geomorphological and human pressures characterization of survey sites,

building of a model without a priori assumptions, which could represent direct association between registered metrics for assessment of the abiotic variables which are determinative and sufficient to explain variation in biological factors,

creating a previsional model to quantify the impact of anthropic and geomorphological factors on biological variables.

The choice of river fish fauna increases sensibility against acute stress because of long *"environmental memory"* due to pluriannual life cycles; moreover, fish fauna occupies highest trophic levels in lotic food chain summarizing and integrating effects of factors, and of interactions between factors, inciding on streams.

Lastly, fishes are, for sure, emotively closer to people than phytoplankton, macrophytes and phytobenthos or benthic invertebrate fauna and therefore seem to be the most useful cenosis to make public opinion aware to river problematics.
It's also true that, between all possible lotic cenosis, fish fauna is maybe the hardest to be sampled because of complexity in capturing, sorting and measuring every single individual without precluding its health; this can be translated in 2-3 sites surveyed per day by 6-9 expert operators working together. Moreover duration of data processing can grow until 1surveyed site per day.

Chapter 2. Materials and methods and study area

2.1. General remarks

The data on which this study is based consists of 461 surveys of the fish fauna of the Adriatic basins of the northern Apennines between that of the Reno to the east and that of the Uso to the west performed in an 18-year period in the provincial territories of Bologna, Ravenna, Forlì-Cesena, Pistoia and Florence; altogether 279 sampling stations have been explored and 79,399 animals have been analyzed.

2.1.1. Sampling

The sampling stations have been explored for a length equal to at least ten times the width of the wet riverbed. The only limiting factor in the choice of the section to sample is its accessibility.

2.1.1.1. Electric stunner

To capture of the fish an electric stunner[o] was used. This tool was composed of a landing-net (positive pole), a "tail" (negative pole), a control panel, and a battery that is worn on the back of the carrier as a simple backpack in fordable waters and on a boat in the others.

The function of this instrument is to create an electric field that attracts the fish and stuns them; the fish are in fact sensitive to the difference in potential and within a couple of meters they are attracted by the anode that they swim towards with involuntary movements. Sensitivity to the electric field is proportional to size and the largest fish are easier to catch than medium-sized or smaller ones.

Depending on the river conditions different types of direct current are used with a potential difference of 150 -200 V power 250 W and intensity of 15-25 A and/or 35-100 impulses/s with a potential difference of 300-600 V and 5-10 KW/impluse. For example, in case of great masses of water or cement banks there is a great dispersion and therefore a greater current and higher impulse frequencies are used.

[o] Electric stunner IG200/6 by SCUBLA AQUACULTURE

The electric stunner, which enables fish to be caught in a short time and does not harm the animals if correctly used, is at present thought to be most efficient means for surveying the fish fauna.

2.1.1.2. Survey of the fish data

Once captured the fish are maintained in tanks where the introduction of oxygenated, fresh water from the river is provided by a current generator[p] and a pump system[q]. The animals are anesthetized, to limit damage during manipulation; currently 2-phenoxyethanol (0.25 cc/l) is used, which is less toxic than the MS222, previously used. Anesthetizing the captured animals facilitates recognizing species, measuring (with an approximation to the millimeter), weighing (with an approximation to the g), evaluating health, and taking photographs, while respecting their individual integrity.

At the end of the data acquisition phase, the fish are released back into the river, but not before stabling them again in tanks with a water circulation to enable the resumption of voluntary activities.

2.1.2. Photographic survey

Besides counting and measuring, the fish are photographed. The samples are fully stretched out, without overlaps, grouped into species, with millimetric reference scales and the abbreviations used for the species and the sampling nearby (identified by the code name of the river, a place-name, the date and progressive number of the sampling itself).

The photographs can be used to check the correctness of the data in the data allocation phase, thus determining by computerized image analysis, standard length (from the tip of the face to the insertion of the caudal fin), total length and height. For this type of analysis Leica equipment is used, model Q500IW, with a semiautomatic program.

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[p] Generator SX2200 by MASE GENERATORS S.p.a.
[q] Single-Phase pump DOC3 by LOWARA

2.1.3. Survey of the physical and environmental parameters

Detailed information, both morphological and physical, about the sampling station and the surrounding environment are collected to have a profile of the environmental complexity.

An appropriate standardized form shows:

- date
- duration of the sampling in hours
- length and width of the waterway section examined measured (± 0.01 m)[r]
- altitude above sealevel (± 1 m)[s]
- geographical coordinates expressed in the reference system WGS 1984 UTM Zone 32N (± 1 m)[b]
- temperature of the air (± 0.1 °C)[t]
- temperature of the water (± 0.1 °C)[c]
- ph (±0.01)[u]
- conducibility (± 0.01 mS /cm)[d]
- overall solids dissolved (± 0.01 PPT)[d]
- soft or thin status
- flow of the current, assessed by timing a vessel to cross a fixed section of waterway (usually 5 meters) through a measured section
- percentage of waterfalls (drops greater than of 1 meter in height)
- percentage of small falls (between 0.5m and 1 meter in height)
- percentage of cascades (less than 0.5m meter in height)
- percentage of riffles (sections of waterways with strong ripples and turbulence)
- percentage of pools (waterways with holes, deeper areas with slow current)
- percentage of runs (sections in which the surface of the water does not have ripples and the depth it is constant)
- percentage of rocks (lithic material with a diameter above 350 mm)
- percentage of boulders (lithic material with a diameter between 100 and 350 mm)

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[r] measured with laser equipment DISTO CLASSIC by LEICA
[s] measured with GPS ETREX by GARMIN
[t] measured with HI98128 by HANNA INSTRUMENTS
[u] measured with HI98312 by HANNA INSTRUMENTS

- percentage of pebbles (lithic material with a diameter between 35 and 100 mm)
- percentage of gravel (lithic material with a diameter between 2 and 35 mm)
- percentage of sand (lithic material with a diameter under 2 mm that sediments in a short time)
- percentage of mud (lithic material with a diameter under 1 mm with long sedimentation)
- composition percentage of the vegetal coverage
- composition percentage of the aquatic vegetation

  percentage of shade, where the sections of river in the shade for most of the day
- abundance of shelter areas, expressed as the percentage of the banks with areas of shelter.
- elements of human influence, such as transverse manufactured articles, reshaping of the river bed cementification of the river bed, discharges, works of water abduction, fords, yards, quarries, roads.

2.1.4. Laboratory technique

Around 4 scales, a little above the lateral line near the dorsal fin, of some samples are collected and stored in water.

The scales were analyzed to determine the individual ages of the fish.

A portion of medial pelvic fin was sometimes removed, and preserved in 70% alcohol, for subsequent molecular analyses.

2.2. Study area

The study was performed in Adriatic catchments of the northeastern Apennine, specifically in the Padano-Venetian district of the Italic ecoregion. Exactly 279 survey sites, all distributed in watersheds of rivers Reno, Lamone, Fiumi Uniti, Savio Rubicone and Uso, were investigated.

2.2.1. Geomorphological and land use data

Geomorphological and land use data were extracted using ESRI software ARCGIS 8.2, CRWR software Arc Hydro Tool 1.1 beta, 1:5000 and 1-10000 topographic maps[v] and CORINE Land Use thematic maps[w].

The following is a list of the performed steps:

Georeferentiation of the survey sites,

Building of a TIN, for the study area; where TIN is an "*acronym for triangulated irregular network. A vector data structure that partitions geographic space into contiguous, nonoverlapping triangles. The vertices of each triangle are sample data points with x-, y-, and z-values. These sample points are connected by lines to form Delaunay triangles*"[x],

Building Aspect and Slope GRID with a cell size of 50m; where GRID is *"an ESRI data format for storing raster data that defines geographic space as an array of equally sized square cells arranged in rows and columns. Each cell stores a numeric value that represents a geographic attribute (such as elevation, slope or aspect) for that unit of space. When the grid is drawn as a map, cells are assigned colors according to their numeric values. Each grid cell is referenced by its x,y coordinate location"*[m]

Digitalization of an hydrographic network,

Calculation of aspect and slope for sampling sites using aspect and slope GRID and the hydrographic network,

Watershed delineation of survey sites with Arc Hydro Tool and manually correction of the outputted SHAPEFILE in the plain zone to fit embankments; where SHAPEFILE is "a vector data storage format for storing the location, shape, and attributes of geographic features",

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[v] CTR: Carta Tecnica Regionale, courtesy of Autorità di Bacino del Reno, Provincia di Ravenna and Provincia di Forlì-Cesena

[w] CORINE Coordination of Information on the Environment; courtesy of APAT Agenzia per la protezione dell'ambiente e per I servizi tecnici

[x] From GIS Dictionary, http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.gateway

Extraction of land use data for delineated watersheds and for upstream half areas with 2 km radius and centres on survey sites.

2.3. Data inputting, checking and reporting

Data from every sampling event were digitalized with Microsoft software Excel 2003.

To prevent inputting errors, for each species, specimen natural logarithm of the length was plotted against natural logarithm of the weight using SPSS 15.0. Data outlying 95% Individual Prediction Interval were then checked. One example plot is shown in Fig. 1.

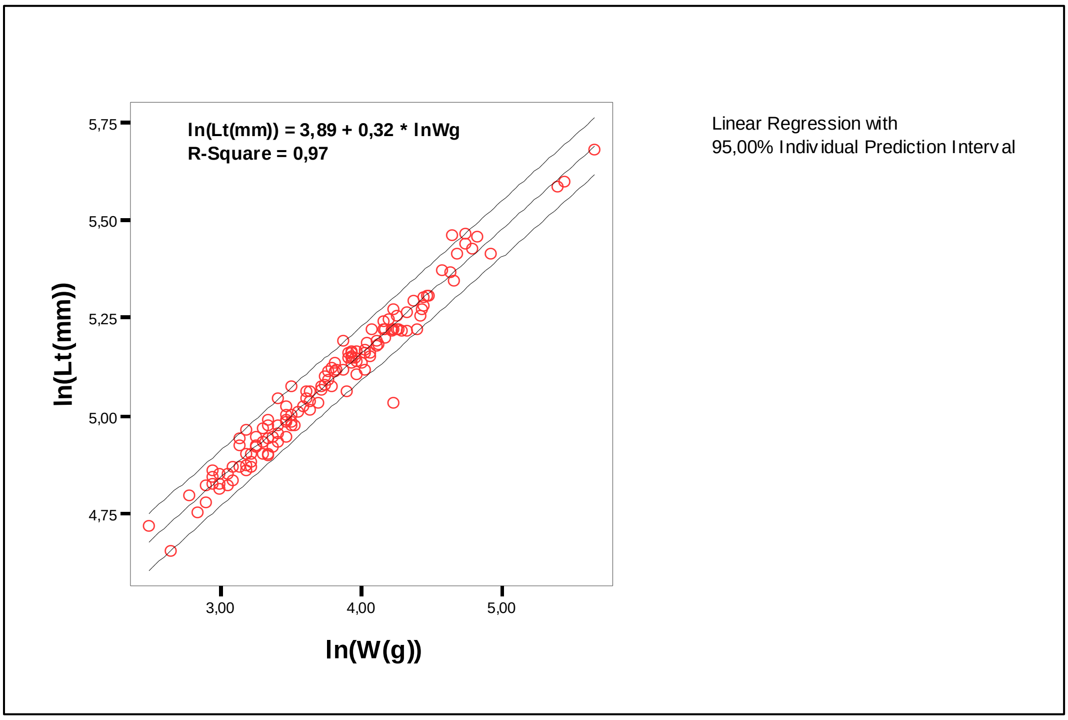

Fig. 1: log-log plot of specimen length (Lt) in millimeters vs weight (W) in grams. Red dots are measured data, black lines are linear fit regression line and lower and upper bounds for the prediction interval.

For each sampling event, automatic data reporting was obtained using Microsoft Excel database functions and a macro written in Visual Basic language. This procedure reduced elaboration time and errors. One example report is shown in Fig. 2.

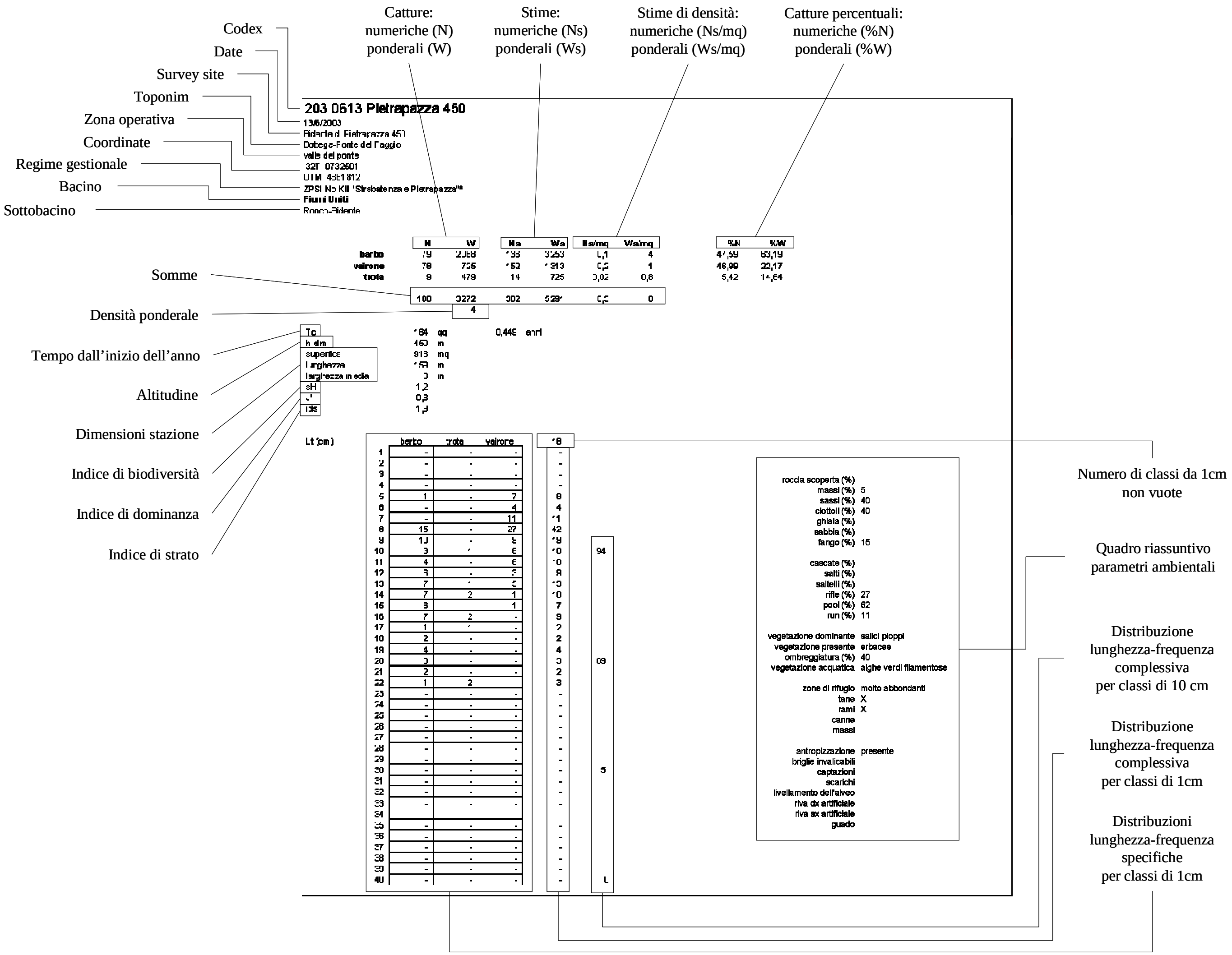

Fig. 2: example report of sampling event data.

2.4. Database designing

Large amount and lack of omogeneity data (sampled biotic and abiotic and geomorphological and land use) needed a relational database to be designed. To accomplish this aim, Microsoft software Access 2003 was used.

This database was structured with 278 fields and four tables (Fig. 3):

Environmental data of survey sites,

Environmental data of the sampling events,

Ichthyological data,

Species autoecology.

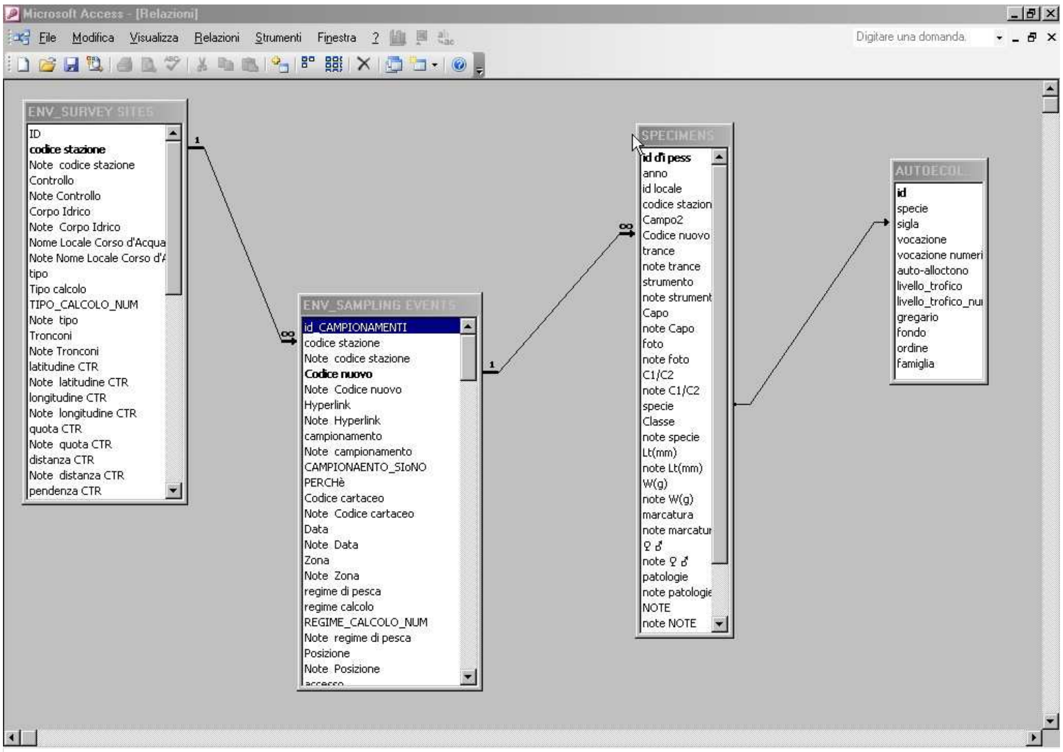

Fig. 3: relationship between tables of the database.

Metric values calculation was obtained with 10 groups of nested queries.

2.5. Statistical analysis

An exploration of conditional association of 50 variables was carried out with Log-linear model analysis as implemented in SAS 9.0[y] software.

The observed direct associations were then represented using Netica 1.12[z] software in a causal Bayesian network; that is a directed acyclic graph with causal relationships.

Netica was also used for training the network with the observed distribution of data probabilities for each dependent variable given values of its associated parent variables.

2.5.1. Log-linear model analysis

Log-linear analysis investigates conditional relationship between discrete variables, all treated as response variables. In other words, that kind of approach can explain the association of two variables by means of an eventually stronger association with a third variable.

This analysis models the natural logarithm of cell counts in contingency tables as linear function of the effects of variables and their interactions.

In a three variable system the full saturated loglinear model is:

$$\log(m_{ijk}) = \lambda + \lambda_i^{X} + \lambda_j^{Y} + \lambda_k^{Z} + \lambda_{ij}^{XY} + \lambda_{ik}^{XZ} + \lambda_{jk}^{YZ} + \lambda_{ijk}^{XYZ}$$

where:

"m" is cell count,

"λ" are the parameters to be estimate,

"i"=1…I, "j"=1…J, "k"=1…K are the levels of the categorical variable.

Parameters are estimate by the maximum likelihood (ML) method, the more they differ from zero, the more the association they refers is strong; furthermore positive values indicates positive correlation and vice versa.

[y] SAS Institute.
[z] Norsys Software Corporation.

In the present work the Poisson distributions of the cell counts were used, and a Delta correction factor of 0.01 was added to observed counts for algorithm convergence; a significance level of 0.05 was chosen. Observed zeros were treated as sampling zeros.

2.5.1.1. Variable categorization

Continuous variables were categorized in order to be analyzed with the Log-linear model limiting sampling zeros in contingency tables. The ranking methods were selcted on the basis of a rationale or data distribution

In the last case:

data with symmetric distributions (skeweness<|1|) were grouped in three subsets with that including 68%of the observations is that including median value,

data with asymmetric distribution (skeweness>|1|) were grouped in two subsets with that including 68%of the observations is that including median value,

data with positive parabolic distribution were grouped in two subsets either having 50% of the observations,

data with evident polimodal distribution were grouped observing histogram plots shape.

2.5.1.2. SAS language macro

The exploration of a large amount of variables is impossible to be performed simultaneously principally because of the need of big amount of data (x^^{n} possible combinations for n variables having x states) and software limitations (actually a maximum of ten factors). To overcome this problem a macro written in SAS language was utilized[aa]..This macro explores association for every possible couple of variables, then significant associations are tested introducing all possible thirds variables and when association is still maintained, by the addition of all possible combinations of other couple of variables.

[aa] Courtesy of Davide Luciani, Unit of Clinical Knowledge Engineering, Laboratory of Clinical Epidemiology, Mario Negri Institute for Pharmacological Research, Bergamo, Italy.

2.5.2. Bayesian network

Probabilistic graphical models are graphs in which nodes represent random variables, and the lack of arcs represent conditional independence or, that is the same, in this kind of graphs a node is independent of its ancestors given its parents. Introducing directionality in arcs following causality and time priority criteria, produces a Bayesian network which can be used to fit data and provide a compact representation of joint probability distributions. The process of learning from data produces a table (CPT or Conditional Probability Table), which lists the probability that the child node takes on each of its different values for each combination of values of its parents.

In the present work the EM (Expectation Maximization) algorithm, as implemented in NETICA, was used to find locally optimal Maximum Likelihood Estimate of the parameters.

In case of node with a great number of parents, the observed data could be not enough to represent all possible state combinations, having not all probability values calculated.

When this situation was found, probability values were calculated using NETICA functions “Normal Distribution” for nodes with more then two states and “Noisy-Or Distribution” for dichotomic nodes. Parameters for this functions were calculated, disregarding interaction between parent variables, using multiple linear regression, carried out with the PROC GLM tool of SAS, for Normal Distribution and using observed probabilities of states combinations, calculated with the PROC FREQ tool of SAS, in 2X2 contingence tables for Noisy-Or Distribution.

Chapter 3. Results

3.1. Survey sites

Distribution of survey sites across the study area, hydrographic network and delineated watersheds are shown in Fig. 4.

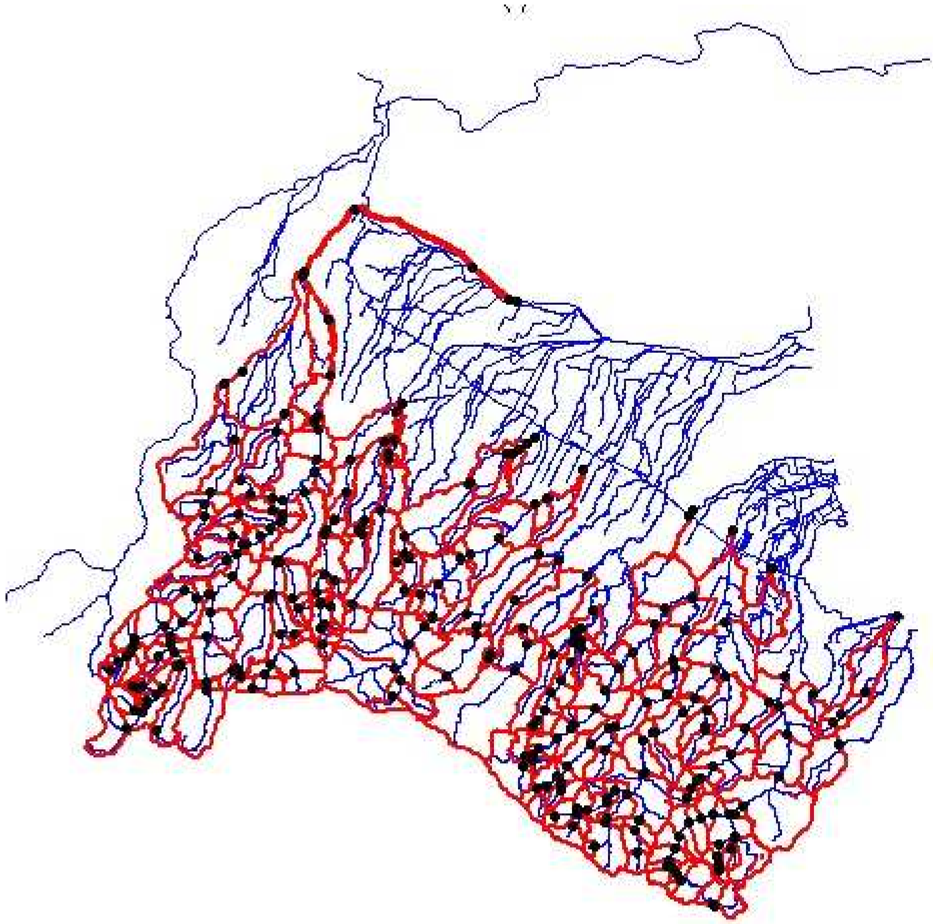

Fig. 4: study area: black dots: survey sites, blue lines: hydrographic network, red lines delineated watersheds.

The study area results of 5983 square km, the 279 survey sites altogether having an altidudinal distribution ranging from 2 to 1070 m above the sea level.

3.2 Extracted metrics

Metrics calculated are 50 and they are reported with abbreviations in square brackets in the following list:

Environmental Variables of the Survey Sites:

Geomorphological:

Elevation [ELEV],
Watershed Area [AREA],

Local Slope [SLOPE],
Local Aspect [ASPECT],

Land Use:

Agricultural Zone Percentage Richness [AGRI],
Urbane Zone Percentage Richness [URB],
High Anthropic Impact Zone Percentage Richness [IND],
Agricultural Zone Local Percentage Richness [AGR_BUF],
Urbane Zone Local Percentage Richness [URB_BUF],
High Anthropic Impact Zone Local Percentage Richness [IND_URB],

Local Environmental Variables of the Sampling Event:

Hydrogeomorphological:

Fall Percentage Richness [FALLS],
Small Fall plus Cascade Percentage Richness [CASC],
Riffle Percentage Richness [RIFF],
Pool Plus Run Percentage Richness [PO_RU],
Exposed Rock Percentage Richness [ROCK],
Boulder Percentage Richness [GREAT],
Pebble plus Gravel plus Sand Percentage Richness [MEDIUM],
Mud Percentage Richness [MUD],
Fish Fauna Refugia Percentage Richness [SHELTER],
Instant Discharge [DISC],
Shading [SHADOW],

Anthropical:

Fishing Management [ZRF_N],
Dike Presence And Position [DYKES],
Channel Alteration [ALTER],

Chemical-Physical:

pH,
Conductivity [COND],
Overall Solid Dissolved Abundance [SOLID],
Temperature of the Water [TH2O],

Time:

Season,
Duration,

Biological variables:

Populating Variables:

Shannon & Weaver Evenness Index [SH][bb],
Autoecological Tendency [IDS][cc],
Total Weight Density [dW],
Number of 1cm Sizes [SIZES],
Allochthonous Specimen Percentage Abundance [ALLOC],

Trophic Level Variables:

Percentage of Predators of 2nd Level [PER_P2],
Percentage of Predators of 1st Level [PER_P1],
Percentage of Omnivorous_Predators [PER_ONP],
Percentage of Omnivorous [PER_ON],
Percentage of Omnivorous_Erbivorous [PER_ONVE],

Specific Level Variables: Number of 1cm Sizes of

Alburnus alburnus (De Filippi, 1844), common name: bleak[AL],
Barbus plebejus (Bonaparte, 1839), common name: Italian barbel [BA],
Carassius auratus (L ., 1758), common name: goldfish [CS],
Cyprinus carpio (L., 1758), common name: carp [CP],
Leuciscus cephalus (L ., 1758), common name: chub [CV],
Chondrostoma genei (Bonaparte 1839), common name: south European nase [LA],
Pseudorasbora parva (Schlegel, 1842), common name: stone morocco [PRB],
Rutilus rubilio (Bonaparte, 1837), common name: Italian roach [RV],
Salmo trutta(L., 1758) subspecie trutta morpha fario, common name: brown trout [TF],
Leuciscus souffia (Risso, 1826), common name: telestes [VA].

[bb] SH = $-\Sigma (n_i/N*\ln (n_i/N))$; where i = an index for the i-esim species, n =number of individuals within a species, N = number of individuals present in the entire sample.
cc IDS = ((n(S)*1+n(CR)*2+n(CL)*3+n(MOU)*4)/(n(S)+n(CR)+n(CL)+n(MOU)); where n(S) = number of specimens with salmonid autoecology, n(CR) = number of specimens with reophilous cyprinids autoecology, n(CL) = number of specimens with limnophilus cyprinids autoecology, n(MOU) = number of specimens with mouth zone autoecology

3.3. Loglinear analysis

The loglinear analysis of variable association was performed separately on three subsets differing for the kind of biological metrics that were used: Populating Variables, Trophic Level Variables and Specific Level Variables.

Tables 3.1., 3.2, and 3.3. show analysis results for the three subsets, only associated variables being reported.

Subset 1: Populating Variables									
		Estimate	ProbChiSq	Significance			Estimate	ProbChiSq	Significance
ELEV	EXTEN	-0.63	0.000	♫	URB	IND_BUF	1.93	0.000	♫
ELEV	SLOPE	0.38	0.000	♫	URB	SHELTER	2.10	0.003	♫
ELEV	AGR	-0.59	0.020	♪	URB	SOLID	2.22	0.008	♫
ELEV	IND	-1.16	0.000	♫	URB	ROCK	-1.41	0.002	♫
ELEV	URB	-1.20	0.000	♫	URB	MUD	1.65	0.001	♫
ELEV	URB_BUF	-0.49	0.002	♫	URB	CASC	-1.98	0.000	♫
ELEV	IND_BUF	-1.67	0.000	♫	URB	sh	0.98	0.000	♫
ELEV	SOLID	-1.89	0.000	♫	URB	IDS	1.11	0.000	♫
ELEV	MUD	-0.83	0.003	♫	URB	dW	1.51	0.000	♫
ELEV	FALLS	1.63	0.002	♫	URB	ALLOC	1.69	0.000	♫
ELEV	CASC	1.42	0.000	♫	URB_BUF	IND	1.64	0.001	♫
ELEV	sh	-0.52	0.000	♫	URB_BUF	IND_BUF	1.61	0.000	♫
ELEV	IDS	-0.68	0.000	♫	URB_BUF	sh	0.46	0.000	♫
ELEV	dW	-0.33	0.027	♪	URB_BUF	IDS	0.39	0.000	♫
ELEV	SIZES	-0.29	0.022	♪	URB_BUF	dW	1.45	0.000	♫
ELEV	ALLOC	-1.23	0.007	♫	IND_BUF	ZRF_N	1.22	0.008	♫
EXTEN	SLOPE	-0.32	0.000	♫	IND_BUF	sh	0.46	0.001	♫
EXTEN	IND	2.00	0.000	♫	IND_BUF	IDS	1.52	0.000	♫
EXTEN	URB	1.42	0.000	♫	IND_BUF	ALLOC	1.96	0.000	♫
EXTEN	URB_BUF	0.95	0.000	♫	ZRF_N	sh	0.12	0.000	♫
EXTEN	IND_BUF	1.28	0.000	♫	SHELTER	ROCK	-2.08	0.010	♪
EXTEN	ZRF_N	0.22	0.000	♫	SHELTER	CASC	-2.19	0.007	♫
EXTEN	sh	0.58	0.000	♫	SHELTER	ALLOC	2.62	0.002	♫
EXTEN	IDS	0.62	0.000	♫	SOLID	IDS	2.11	0.003	♫
EXTEN	dW	0.54	0.000	♫	SOLID	ALLOC	1.79	0.011	♪
EXTEN	SIZES	0.40	0.003	♫	ROCK	FALLS	1.43	0.020	♪
EXTEN	ALLOC	0.88	0.000	♫	ROCK	CASC	0.97	0.031	♪
SLOPE	AGR	-0.36	0.032	♪	ROCK	dW	-2.33	0.027	♪
SLOPE	IND	-0.51	0.000	♫	ROCK	ALLOC	-2.16	0.005	♫
SLOPE	URB	-0.76	0.000	♫	MUD	CASC	-1.27	0.020	♪
SLOPE	URB_BUF	-0.60	0.000	♫	MUD	ALLOC	1.88	0.000	♫
SLOPE	IND_BUF	-0.52	0.003	♫	FALLS	CASC	3.68	0.001	♫
SLOPE	SHELTER	-1.05	0.000	♫	CASC	ALLOC	-2.94	0.005	♫
SLOPE	ROCK	1.16	0.000	♫	sh	IDS	0.57	0.000	♫
SLOPE	MUD	-0.73	0.021	♪	sh	dW	0.45	0.000	♫
SLOPE	FALLS	0.84	0.017	♪	sh	SIZES	0.41	0.002	♫
SLOPE	sh	-0.27	0.000	♫	sh	ALLOC	0.81	0.000	♫
SLOPE	IDS	-0.38	0.000	♫	IDS	dW	0.32	0.035	♪
SLOPE	dW	-0.49	0.000	♫	IDS	SIZES	0.33	0.007	♫
SLOPE	ALLOC	-0.90	0.000	♫	IDS	ALLOC	1.45	0.028	♪
AGR	IDS	0.57	0.026	♪	dW	ALLOC	0.56	0.017	♪
IND	URB	3.68	0.000	♫					
IND	URB_BUF	1.80	0.000	♫					
IND	ZRF_N	0.74	0.002	♫					
IND	SHELTER	3.06	0.006	♫					
IND	SOLID	2.15	0.019	♪					
IND	sh	0.85	0.000	♫					
IND	IDS	1.02	0.000	♫					
IND	dW	0.95	0.000	♫					
IND	ALLOC	1.52	0.000	♫					

Tab. 3.1: loglinear analysis for subset with populating variables: estimate is the value for the LAMBDA parameters, ProbChiSq is the value of the Chi square test, ♪ represents 0.05 significance level, ♫ represents 0.01 significance level.

Subset 2: Trophic Level Variables									
		Estimate	ProbChiSq	Significance			Estimate	ProbChiSq	Significance
ELEV	EXTEN	-0.63	0.000	♫	URB	IND_BUF	1.93	0.000	♫
ELEV	SLOPE	0.38	0.000	♫	URB	SHELTER	2.10	0.003	♫
ELEV	AGR	-0.59	0.020	♪	URB	SOLID	2.22	0.008	♫
ELEV	IND	-1.16	0.000	♫	URB	ROCK	-1.41	0.002	♫
ELEV	URB	-1.20	0.000	♫	URB	MUD	1.65	0.001	♫
ELEV	URB_BUF	-0.49	0.002	♫	URB	CASC	-1.98	0.000	♫
ELEV	IND_BUF	-1.67	0.000	♫	URB	PER_ONV	2.60	0.000	♫
ELEV	SOLID	-1.89	0.000	♫	URB	PER_P1	1.65	0.000	♫
ELEV	MUD	-0.83	0.003	♫	URB	PER_P2	-1.96	0.000	♫
ELEV	FALLS	1.63	0.002	♫	URB_BUF	IND	1.64	0.001	♫
ELEV	CASC	1.42	0.000	♫	URB_BUF	IND_BUF	1.61	0.000	♫
ELEV	PER_ON	-0.75	0.010	♪	URB_BUF	PER_ONV	1.18	0.000	♫
ELEV	PER_ONV	-1.30	0.001	♫	URB_BUF	PER_P1	0.71	0.002	♫
ELEV	PER_P1	-0.77	0.000	♫	URB_BUF	PER_P2	-0.52	0.038	♪
ELEV	PER_P2	1.55	0.000	♫	IND_BUF	ZRF_N	1.22	0.008	♫
EXTEN	SLOPE	-0.32	0.000	♫	IND_BUF	PER_ONV	1.73	0.000	♫
EXTEN	IND	2.00	0.000	♫	IND_BUF	PER_P1	1.14	0.002	♫
EXTEN	URB	1.42	0.000	♫	ZRF_N	PER_P2	-0.44	0.028	♪
EXTEN	URB_BUF	0.95	0.000	♫	SHELTER	ROCK	-2.08	0.010	♪
EXTEN	IND_BUF	1.28	0.000	♫	SHELTER	CASC	-2.19	0.007	♫
EXTEN	ZRF_N	0.22	0.000	♫	SHELTER	PER_ONP	-1.23	0.044	♪
EXTEN	PER_ON	0.68	0.020	♪	SHELTER	PER_ONV	2.00	0.002	♫
EXTEN	PER_ONV	1.28	0.000	♫	SHELTER	PER_P1	2.05	0.002	♫
EXTEN	PER_P1	0.84	0.000	♫	SOLID	PER_ONV	1.99	0.008	♫
EXTEN	PER_P2	-1.42	0.000	♫	ROCK	FALLS	1.43	0.020	♪
SLOPE	AGR	-0.36	0.032	♪	ROCK	CASC	0.97	0.031	♪
SLOPE	IND	-0.51	0.000	♫	ROCK	PER_ONV	-0.94	0.042	♪
SLOPE	URB	-0.76	0.000	♫	MUD	CASC	-1.27	0.020	♪
SLOPE	URB_BUF	-0.60	0.000	♫	MUD	PER_P1	1.01	0.028	♪
SLOPE	IND_BUF	-0.52	0.003	♫	FALLS	CASC	3.68	0.001	♫
SLOPE	SHELTER	-1.05	0.000	♫	FALLS	PER_P2	2.51	0.000	♫
SLOPE	ROCK	1.16	0.000	♫	CASC	PER_ONV	-2.62	0.000	♫
SLOPE	MUD	-0.73	0.021	♪	CASC	PER_P1	-3.07	0.003	♫
SLOPE	FALLS	0.84	0.017	♪	CASC	PER_P2	2.52	0.000	♫
SLOPE	PER_ON	-0.34	0.035	♪	PER_ONP	PER_P2	-2.24	0.000	♫
SLOPE	PER_ONV	-0.53	0.000	♫	PER_ONV	PER_P1	1.08	0.000	♫
SLOPE	PER_P1	-0.52	0.001	♫	PER_P1	PER_P2	-1.69	0.000	♫
SLOPE	PER_P2	0.68	0.000	♫					
IND	URB	3.68	0.000	♫					
IND	URB_BUF	1.80	0.000	♫					
IND	ZRF_N	0.74	0.002	♫					
IND	SHELTER	3.06	0.006	♫					
IND	SOLID	2.15	0.019	♪					
IND	PER_ONV	1.41	0.000	♫					
IND	PER_P1	1.33	0.000	♫					
IND	PER_P2	-2.48	0.000	♫					

Tab. 3. 2: loglinear analysis for subset with trophic level variables: estimate is the value for the LAMBDA parameters, ProbChiSq is the value of the Chi square test, ♪ represents 0.05 significance level, ♫ represents 0.01 significance level.

Subset 3: Specie Level Variables									
		Estimate	ProbChiSq	Significance			Estimate	ProbChiSq	Significance
ELEV	EXTEN	-0.63	0.000	♫	URB_BUF	IND	1.64	0.001	♫
ELEV	SLOPE	0.38	0.000	♫	URB_BUF	IND_BUF	1.61	0.000	♫
ELEV	AGR	-0.59	0.020	♪	URB_BUF	AL	0.90	0.002	♫
ELEV	IND	-1.16	0.000	♫	URB_BUF	CP	0.58	0.040	♪
ELEV	URB	-1.20	0.000	♫	URB_BUF	LA	1.33	0.000	♫
ELEV	URB_BUF	-0.49	0.002	♫	URB_BUF	RV	1.12	0.000	♫
ELEV	IND_BUF	-1.67	0.000	♫	IND_BUF	ZRF_N	1.22	0.008	♫
ELEV	SOLID	-1.89	0.000	♫	IND_BUF	AL	1.88	0.000	♫
ELEV	MUD	-0.83	0.003	♫	IND_BUF	CP	1.48	0.000	♫
ELEV	FALLS	1.63	0.002	♫	IND_BUF	CS	1.84	0.000	♫
ELEV	CASC	1.42	0.000	♫	IND_BUF	LA	1.83	0.000	♫
ELEV	AL	-2.66	0.000	♫	IND_BUF	PRB	1.94	0.000	♫
ELEV	CP	-2.55	0.000	♫	SHELTER	ROCK	-2.08	0.010	♪
ELEV	CS	-3.41	0.003	♫	SHELTER	CASC	-2.19	0.007	♫
ELEV	CV	-0.74	0.017	♪	SHELTER	AL	2.62	0.002	♫
ELEV	LA	-1.51	0.001	♫	SHELTER	CP	1.84	0.006	♫
ELEV	PRB	-3.10	0.006	♫	SHELTER	CS	2.88	0.010	♪
ELEV	RV	-1.05	0.015	♪	SHELTER	LA	1.74	0.004	♫
ELEV	TF	0.85	0.003	♫	SHELTER	PRB	3.34	0.003	♫
EXTEN	SLOPE	-0.32	0.000	♫	SHELTER	VA	-1.52	0.036	♪
EXTEN	IND	2.00	0.000	♫	SOLID	AL	1.71	0.037	♪
EXTEN	URB	1.42	0.000	♫	SOLID	CP	2.64	0.001	♫
EXTEN	URB_BUF	0.95	0.000	♫	SOLID	CS	1.71	0.037	♪
EXTEN	IND_BUF	1.28	0.000	♫	SOLID	LA	2.62	0.002	♫
EXTEN	ZRF_N	0.22	0.000	♫	SOLID	PRB	1.69	0.026	♪
EXTEN	AL	1.90	0.000	♫	ROCK	FALLS	1.43	0.020	♪
EXTEN	BA	0.49	0.041	♪	ROCK	CASC	0.97	0.031	♪
EXTEN	CP	1.44	0.000	♫	ROCK	CP	-1.53	0.010	♫
EXTEN	CS	1.24	0.000	♫	ROCK	CS	-2.40	0.022	♪
EXTEN	CV	0.76	0.009	♫	ROCK	LA	-1.39	0.005	♫
EXTEN	LA	1.41	0.000	♫	ROCK	PRB	-1.76	0.024	♪
EXTEN	PRB	1.46	0.000	♫	ROCK	RV	-1.23	0.017	♪
EXTEN	RV	1.06	0.000	♫	MUD	CASC	-1.27	0.020	♪
EXTEN	TF	-0.65	0.000	♫	MUD	CP	2.15	0.000	♫
SLOPE	AGR	-0.36	0.032	♪	MUD	CS	2.65	0.000	♫
SLOPE	IND	-0.51	0.000	♫	MUD	PRB	1.63	0.002	♫
SLOPE	URB	-0.76	0.000	♫	FALLS	CASC	3.68	0.001	♫
SLOPE	URB_BUF	-0.60	0.000	♫	CASC	CP	-3.19	0.002	♫
SLOPE	IND_BUF	-0.52	0.003	♫	CASC	LA	-2.62	0.000	♫
SLOPE	SHELTER	-1.05	0.000	♫	CASC	RV	-3.48	0.001	♫
SLOPE	ROCK	1.16	0.000	♫	AL	CP	2.60	0.000	♫
SLOPE	MUD	-0.73	0.021	♪	AL	CS	2.65	0.000	♫
SLOPE	FALLS	0.84	0.017	♪	AL	LA	1.74	0.000	♫
SLOPE	AL	-1.16	0.000	♫	AL	PRB	3.20	0.000	♫
SLOPE	CP	-1.02	0.000	♫	AL	RV	0.57	0.048	♪
SLOPE	CS	-1.64	0.000	♫	CP	CS	3.69	0.000	♫
SLOPE	CV	-0.37	0.041	♪	CP	LA	2.47	0.000	♫
SLOPE	LA	-0.57	0.000	♫	CP	PRB	3.60	0.000	♫
SLOPE	PRB	-1.13	0.000	♫	CP	RV	1.70	0.000	♫
SLOPE	RV	-0.47	0.020	♪	CS	LA	1.55	0.000	♫
SLOPE	TF	0.40	0.022	♪	CS	PRB	3.32	0.000	♫
IND	URB	3.68	0.000	♫	CS	RV	0.66	0.027	♪
IND	URB_BUF	1.80	0.000	♫	LA	PRB	1.95	0.000	♫
IND	ZRF_N	0.74	0.002	♫	LA	RV	2.44	0.000	♫
IND	SHELTER	3.06	0.006	♫	PRB	RV	1.23	0.000	♫
IND	SOLID	2.15	0.019	♪	RV	TF	-1.52	0.040	♪
IND	AL	2.38	0.000	♫					
IND	CP	1.43	0.000	♫					
IND	CS	1.83	0.000	♫					
IND	LA	1.35	0.000	♫					
IND	PRB	1.77	0.000	♫					
IND	RV	0.85	0.000	♫					
URB	IND_BUF	1.93	0.000	♫					
URB	SHELTER	2.10	0.003	♫					
URB	SOLID	2.22	0.008	♫					
URB	ROCK	-1.41	0.002	♫					
URB	MUD	1.65	0.001	♫					
URB	CASC	-1.98	0.000	♫					
URB	AL	3.39	0.000	♫					
URB	CP	3.65	0.000	♫					
URB	CS	2.29	0.000	♫					
URB	LA	3.31	0.000	♫					
URB	PRB	3.37	0.000	♫					
URB	RV	2.11	0.000	♫					

Tab. 3. 3: loglinear analysis for subset with species level variables: estimate is the value for the LAMBDA parameters, ProbChiSq is the value of the Chi square test, ♪ represents 0.05 significance level, ♫ represents 0.01 significance level.

Comparison of the three subset show that fifteen variables have no association:

Local Aspect [ASPECT],

Agricultural Zone Local Percentage Richness [AGR_BUF],

Channel Alteration [ALTER],

Dikes Presence And Position [DYKES],

Discharge [DISC],

Season,

Duration,

pH

Shading [SHADOW],

Conductivity [COND],

Temperature of the Water [TH2O],

Boulders Percentage Richness [GREAT],

Pebbles plus Gravel plus Sand Percentage Richness [MEDIUM],

Riffle Percentage Richness [RIFF],

Pool plus Run Percentage Richness [PO_RU].

Moreover, others environmental variables, in spite of different biological metrics used, share the same associations.

3.4. Bayesian networks

The three subsets have been used to build three Bayesian networks (Figs. 5-7).

In these networks every state of every variable (here named node) is associated with a bar representing the probability to observe that value given parent node states, which are determined by the observed frequencies or the imposed values. Values at the bottom of every node are state average and standard deviation.

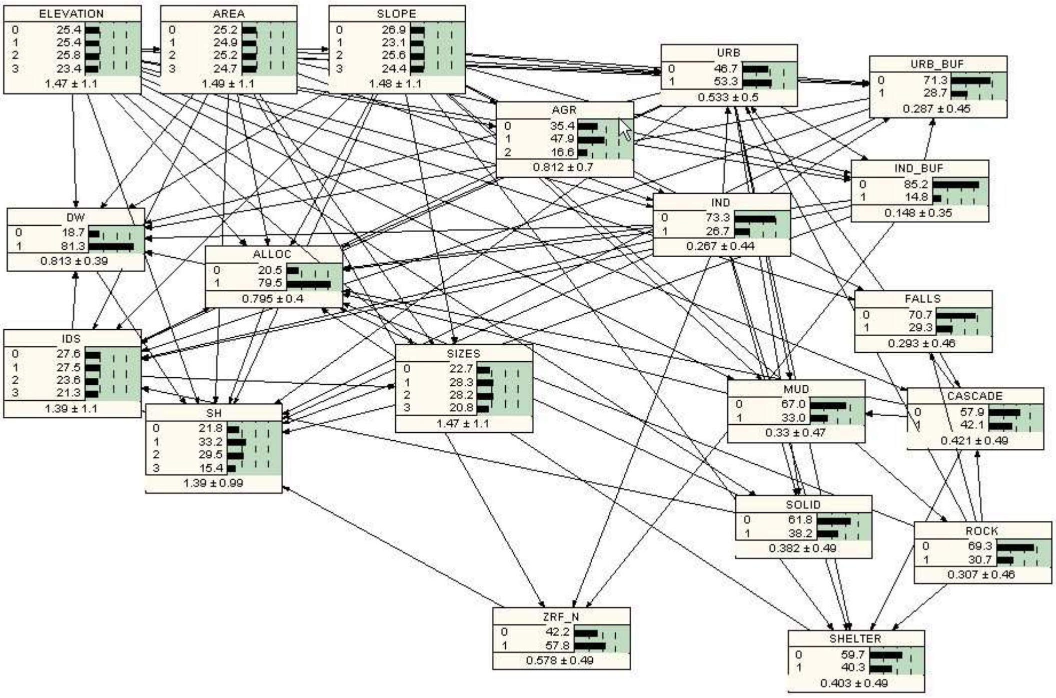

Fig. 5: Bayesian network of the Populating Level Subset.

The populating level network has four variables,

Shannon & Weaver Evenness Index [SH],

Autoecological Tendency [IDS],

Total Weight Density [dW],

Allochthonous Specimen Percentage Abundance [ALLOC],

with too much parents respect to casuistic. The learning process for these variables was then substituted by “Noisy-Or Distribution” for dichotomic nodes and “Normal Distribution” for nodes with more then two states. The latter, practically a multiple linear regression, didn’t return the same significance correlations as loglinear analysis, confirming the non-linearity of the interactions.

Hence Shannon & Weaver Evenness Index and Autoecological Tendency nodes have not to be considered in furthers discussion.

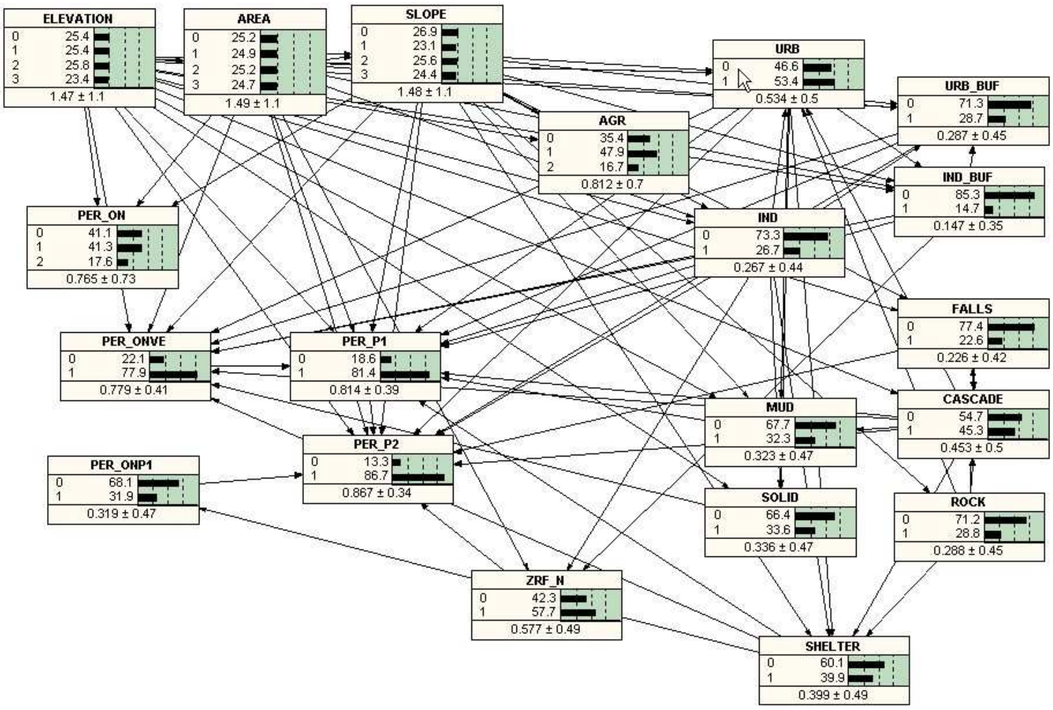

Fig. 6: Bayesian network of the Trophic Level Subset.

The Trophic Level Subset has three variables,

Percentage of Omnivorous_Erbivorous [PER_ONVE],

Percentage of Predators of 2nd Level [PER_P2],

Percentage of Predators of 1st Level [PER_P1],

with an elevate number of parents, the learning machine thus for these dichotomic nodes was assisted by the “Noisy-Or Distribution”.

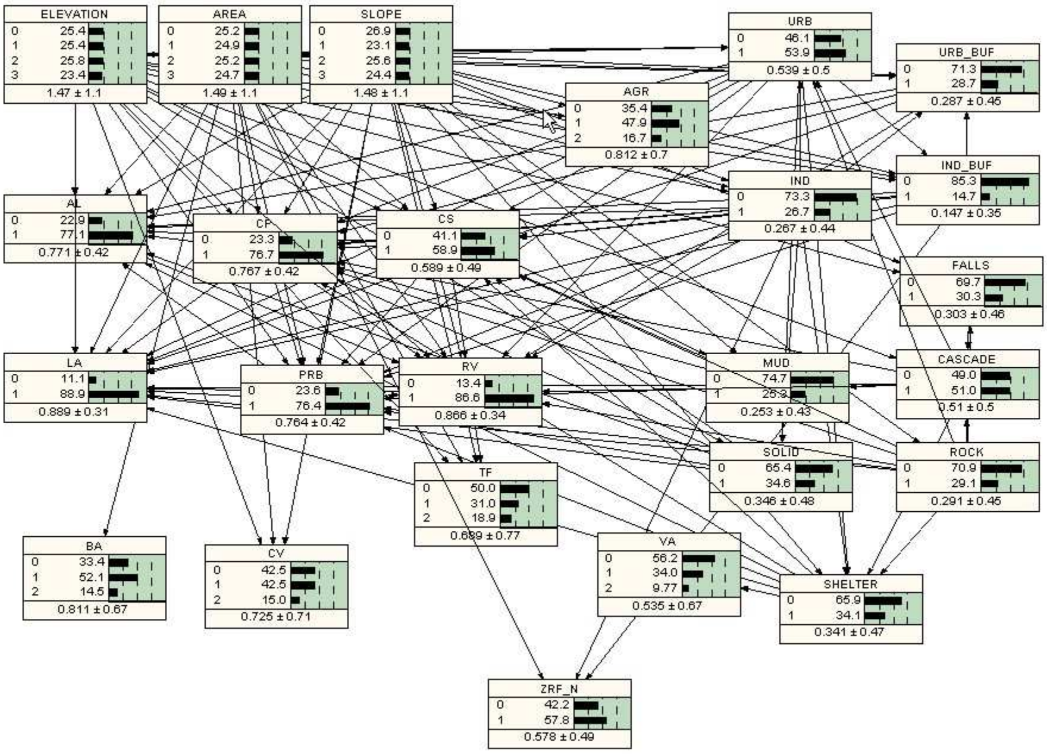

Fig. 7: Bayesian network of the Specific Level Subset.

For 6 dichotomic variables of the Specific Level Subset, the “Noisy-Or Distribution” was needed to obtain a running learning process:

the bleak [AL],

the goldfish [CS],

the carp [CP],

the south European nase [LA],

the stone morocco [PRB],

the Italian roach [RV].

Chapter 4. Discussion

4.1 Loglinear analysis

The sign of the lambda parameters of the loglinear regression indicates positive or negative associations. As expected the anthropic variables show direct correlation with Watershed Area and negative correlations with Elevation and Local Slope; furthermore the Overall Solid Dissolved Abundance decreases naturally with high elevations and increases with increment in Urbane Zone Percentage Richness and High Anthropic Impact Zone Percentage Richness; similarly, Mud Percentage Richness is negatively associated with Elevation, Local Slope and Small Falls plus Cascade Percentage Richness and positively associated with Urbane Zone Percentage Richness. Interesting, Fishing Management values (fishing authorized) become higher when High Anthropic Impact Zone Percentage Richness and High Anthropic Impact Zone Local Percentage Richness increase; this reflect the intuitive capacity of expert administrators to choose sites for management fishing in low anthropized zones and in minor basins.

Finally Fish Fauna Refugia Percentage Richness shows an unexpected positive correlation with High Anthropic Impact Zone Percentage Richness, Urbane Zone Percentage Richness; this positive correlation could be explained the existence of many kind of refugia: dens, roots or branches and reeds, the last being advantaged by eutrophization, which probably creates the observed positive correlation.

Concerning ichthyologic metrics, in populating level subset, natural complication of ichthyocenosis in plane zone is shown by the positive associations of Shannon & Weaver Evenness Index, Autoecological Tendency and Total Weight Density with Watershed Area, and the negative associations with Elevation and Local Slope; it’s interesting to note that this tendency is increased by anthropization because in the case of a river, it often lead to eutrophization and consequently in nutrient increase.

Allochthonous Specimen Percentage Abundance increases in plane zone, in high anthropic zones and in abundance of mud and solid dissolved.

Number of sizes depends only by geomorphological factors and it’s low in mountain and high in plane, probably due to differences in average temperatures; moreover number of size is high in correspondence of big basins, often reflecting more water availability and hence less hydrologic crisis.

Finally, managed zones (fishing prohibited) show low biodiversity values, that reflect an intuitive impression of many operators and can be explained by the Intermediate Disturbance Hypothesis[dd]; this hypothesis proposes that biodiversity is highest when disturbance is neither too rare nor too frequent because in condition of low disturbance, competitive exclusion by the dominant species arises, while in the presence of high disturbance, only stress tolerant species can persist.

The Trophic Level Subset shows, just as the previous subset , the natural complication of ichthyocenosis, which increases from source to mouth zones; in fact Percentage of Predators of 2nd Level is higher in mountains, where productivity is low and nutrients are typically exogenic, while plane zones are characterized by a more complex trophic web. Anthropic activities, again, maximize this tendency for Predators of 2nd and 1st Level and for Omnivorous_Erbivorous, while do not affect Omnivorous; Percentage of Omnivorous_Predators is directly and negatively associated with high levels of refugia.

Looking only at trophic variables, the Trophic Level Subsets show a positive association between Predators of 1st Level and Percentage of Omnivorous_Erbivorous, maybe due to firsts feeding on the seconds, and negative interaction between Predators of 2nd Level and Predators of 1st Level or Omnivorous_Predators, probably because of predation and competition.

The Specific Level Subset displays opposite tendencies for the brown trout on one side and bleak, carp, goldfish, chub, south European nase, stone moroco and Italian roach on the other side, with the abundance of the brown trout increasing in mountain. The Italian barbel is only associated with basin area and hence probably with water. Bleak, carp, goldfish, south European nase, stone moroco and Italian roach are also in different degrees positively associated, and their abundance becomes higher as anthropic land use increases. The Overall Solid Dissolved Abundance correlates positively with bleak, carp, goldfish, south European nase and stone morocco abundance; the Exposed Rock Percentage Richness is negatively associated with carp, goldfish, south European nase, stone morocco and Italian roach abundance; the Mud Percentage Richness has a

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[dd] Connell, J. H. 1978. Diversity in tropical rain forests and coral reefs. Science 199:1302–1310.
Horn, H. S. 1975. Markovian properties of forest succession. Pp. 196–211 in M. L. Cody and J. M. Diamond (editors) Ecology and evolution of communities. Belknap Press,Cambridge, Massachusetts. ISBN 0-674-22444-2.
Johst K., Huth A. 2005. Testing the intermediate disturbance hypothesis: when will there be two peaks of diversity? Diversity and Distributions 11 (1), 111–120. doi:10.1111/j.1366-9516.2005.00133.x

positive correlation with carp, goldfish and Italian roach abundance; Small Fall plus Cascade Percentage Richness negatively influences carp, south European nase and Italian roach abundance. Fish Fauna Refugia Percentage Richness is positively associated with typically plane zone species and negatively with telestes, corroborating the “reeds effect”.

4.2 Bayesian networks

Bayesian networks can be used to produce different scenarios even if theoretical. Some possible scenarios are discussed hereunder and presented in Figures (8-26), where grey nodes have the observations imposed, while the pink nodes produce the associated effects.

4.2.1 Populating Level Subset

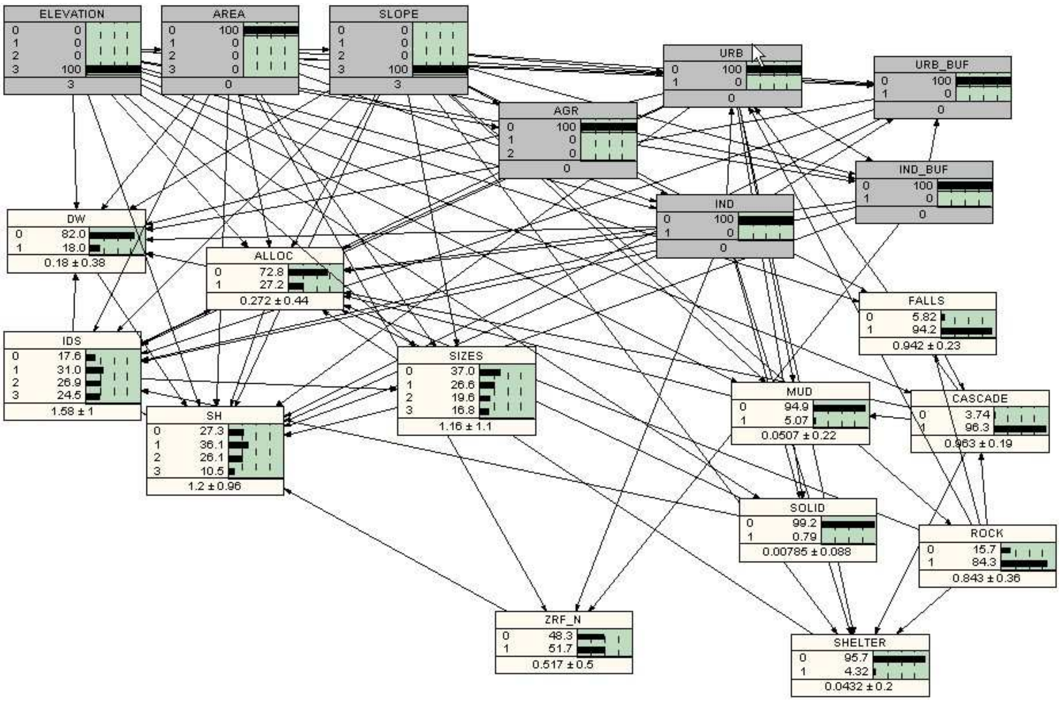

Fig. 8:Populating Level Subset; Scenario 1: mountain survey site with low anthropic land use.

The scenario in Figure 8 represents a mountain survey site with low anthropic land use: as expected, more probable states of local environmental variables are: high values in Falls, Cascade and Exposed Rock and low values of Mud and Solid Dissolved; this situations reflect in low values of Total Weight Density and Allochthonous Specimen Percentage Abundance.

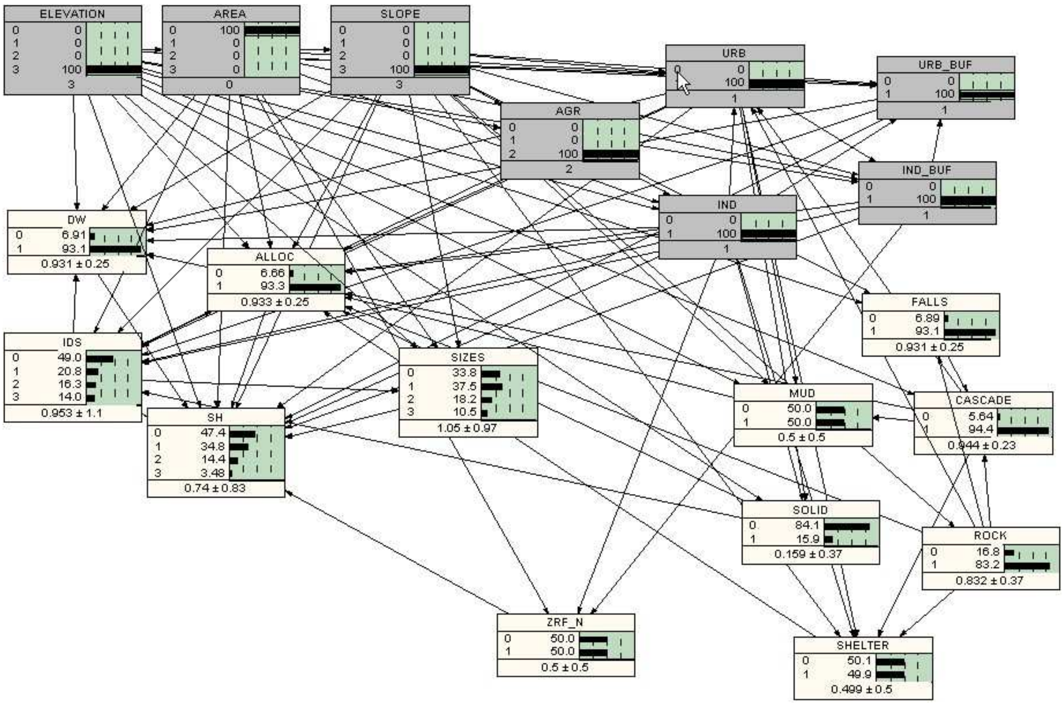

Fig. 9: Populating Level Subset; Scenario 2: mountain survey site with high anthropic land use.

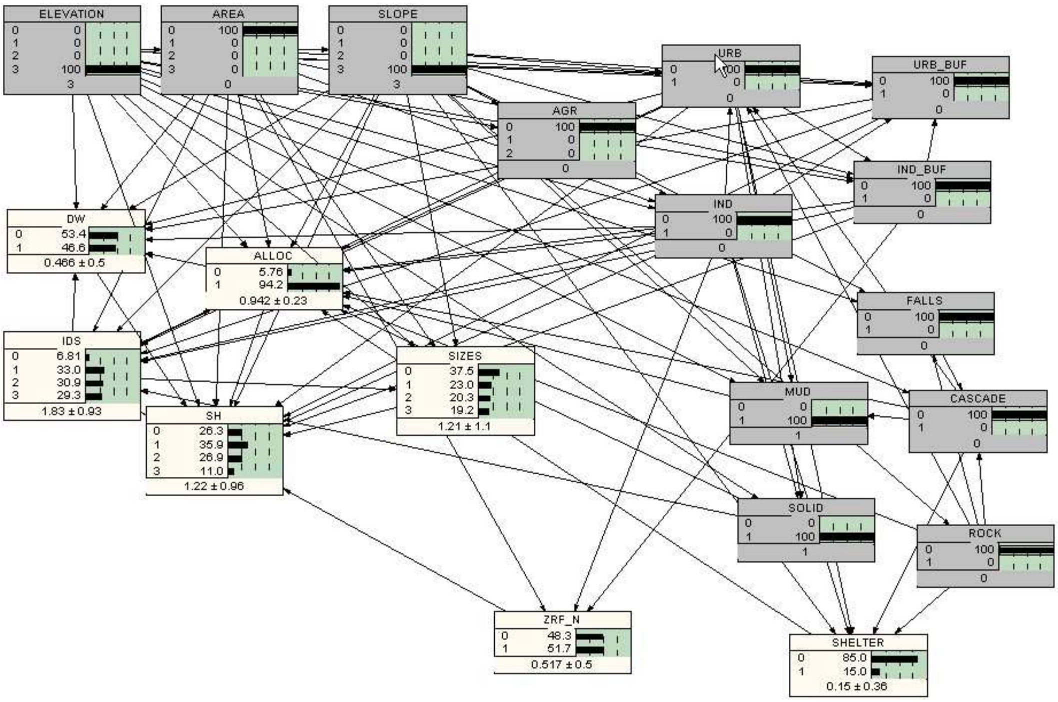

Fig. 10: Populating Level Subset; Scenario 3: mountain survey site with low anthropic land use and high degraded local environment.

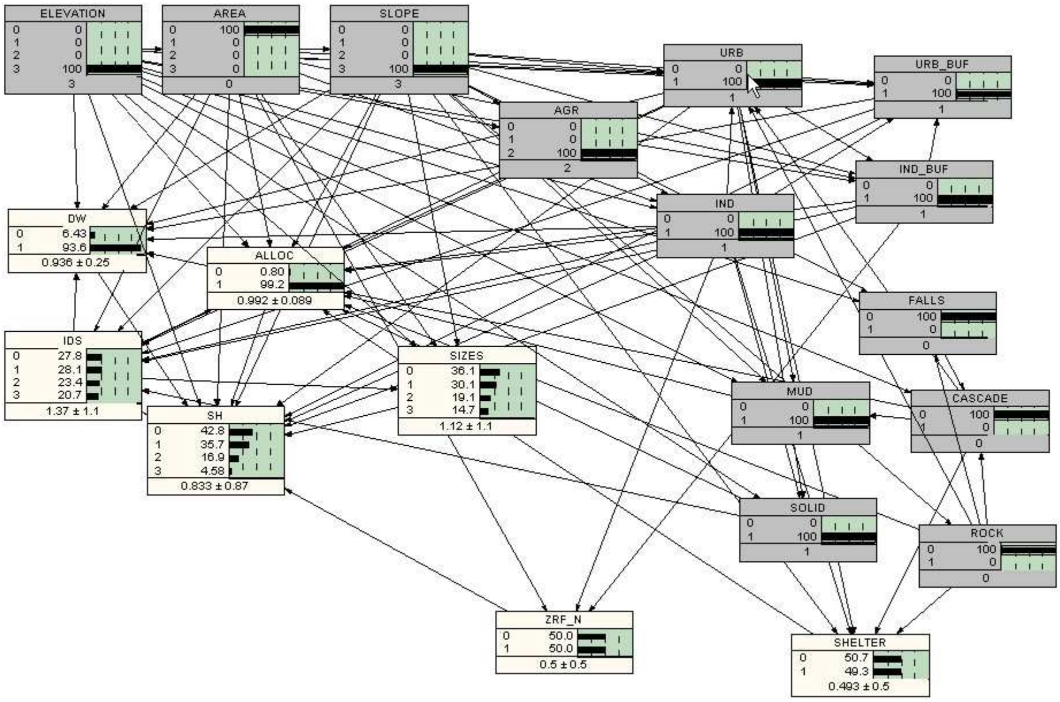

Fig. 11: Populating Level Subset; Scenario 4: mountain survey site with high anthropic land use and high degraded local environment.

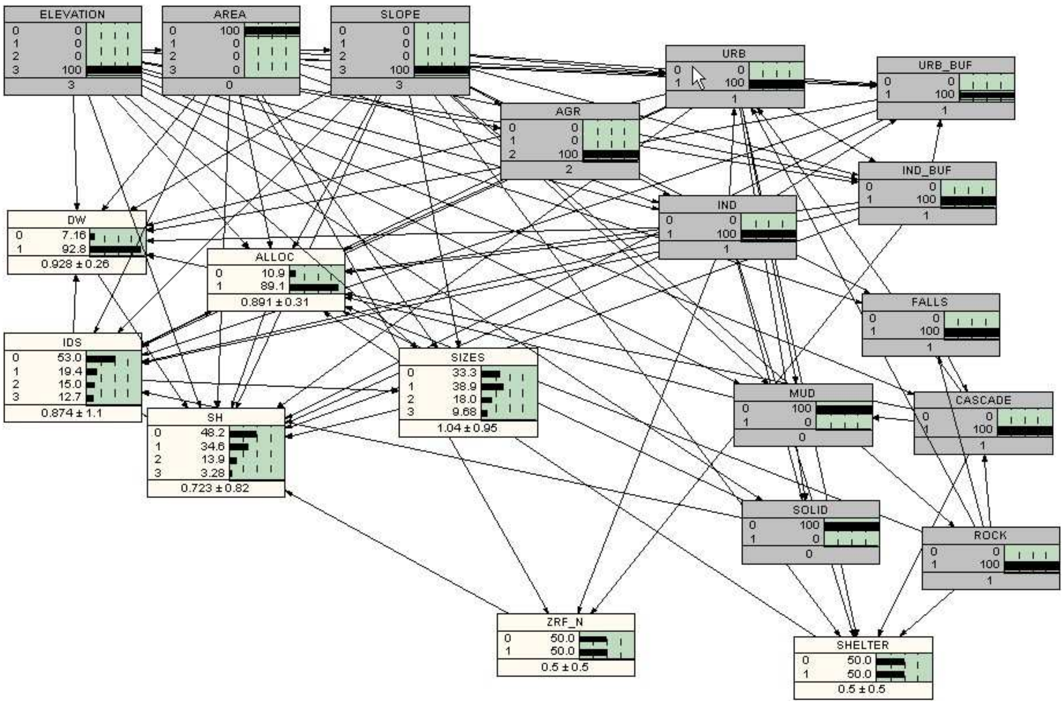

Fig. 12: Populating Level Subset; Scenario 5: mountain survey site with high anthropic land use and not degraded local environment.

Figures 9-12 represents possible alterations of mountain natural environmental conditions. Increasing of anthropic land use (Fig. 9) produces, within local environmental metrics, Mud Percentage Richness inrease.

As shown in Figures 10 and 11, Total Weight Density is mainly increased by high anthropic land use (fertilizing of waters) while Allochthonous Specimen

Percentage Abundance is equally augmented by high anthropic land use and high degraded local environment. The latter observation indicates that Allochthonous species are an effect and not a cause of ecological pollution. Sizes are increased by high anthropic land use but not degraded local environmental variables (Fig. 12); this combination assures enough nutrients to reach higher sizes and channel adequate spatial availability.

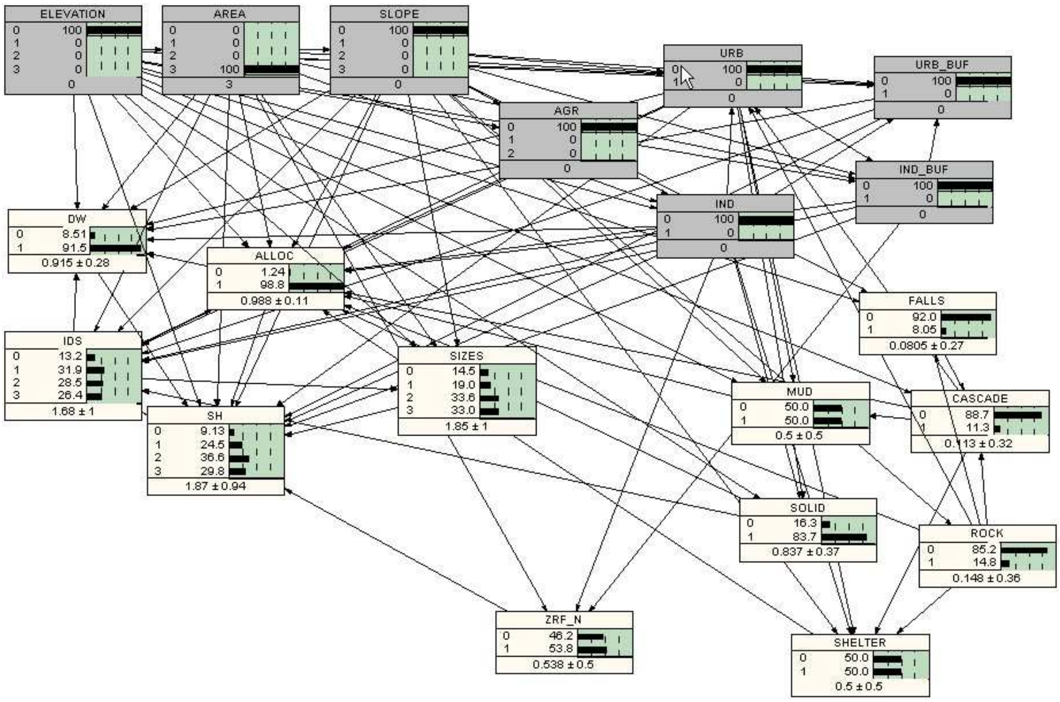

Fig. 13: Populating Level Subset; Scenario 6: plane survey site with low anthropic land use

Scenario 6 (Fig. 13) represents a plane survey site with low anthropic land use: environmental local variables are characterized by lack of Falls, Cascade and Exposed Rock and abundance of Solid Dissolved; the two states of Mud Percentage Richness node are equally probable.

High values of Total Weight Density and Allochthonous Specimen Percentage Abundance have high probability.

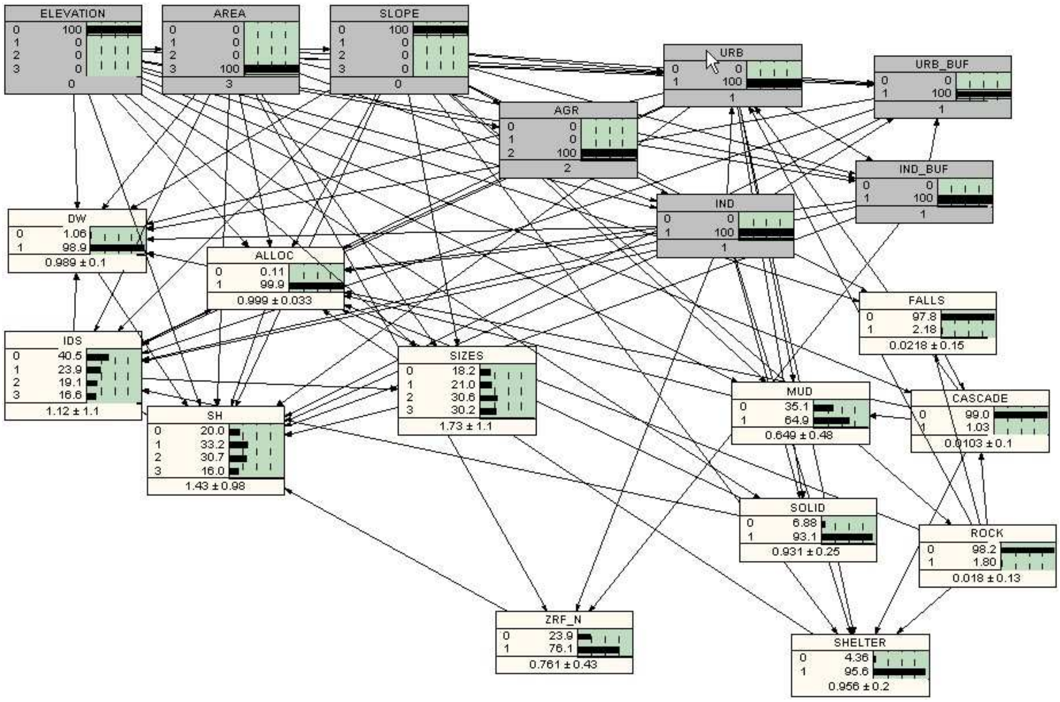

Fig. 14: Populating Level Subset; Scenario 7: plane survey site with high anthropic land use.

High anthropic land use (Fig. 14) causes mud increase and hence sizes decrease and only a little increase of naturally high values of Total Weight Density and Allochthonous Specimen Percentage Abundance.

4.2.2 Trophic Level Subset

Natural situation of mountain zone is represented in Fig. 15: low anthropic land use and fishing management (no fishing). Trophic biological variable values indicate high Percentage of Predators of 2nd Level and similar probability of the two states of Percentage of Omnivorous_Predators, while the probability of the other trophic roles is low

No effects result by imposing no fishing management (Fig. 16).

The increaseof anthropic land use (fertilizing of waters), scenario 3 (Fig. 17), presents Omnivorous_Erbivorous and Predators of 1st Level in place of Predators of 2nd Level.

No effects result by imposing no fishing management (Fig. 18).

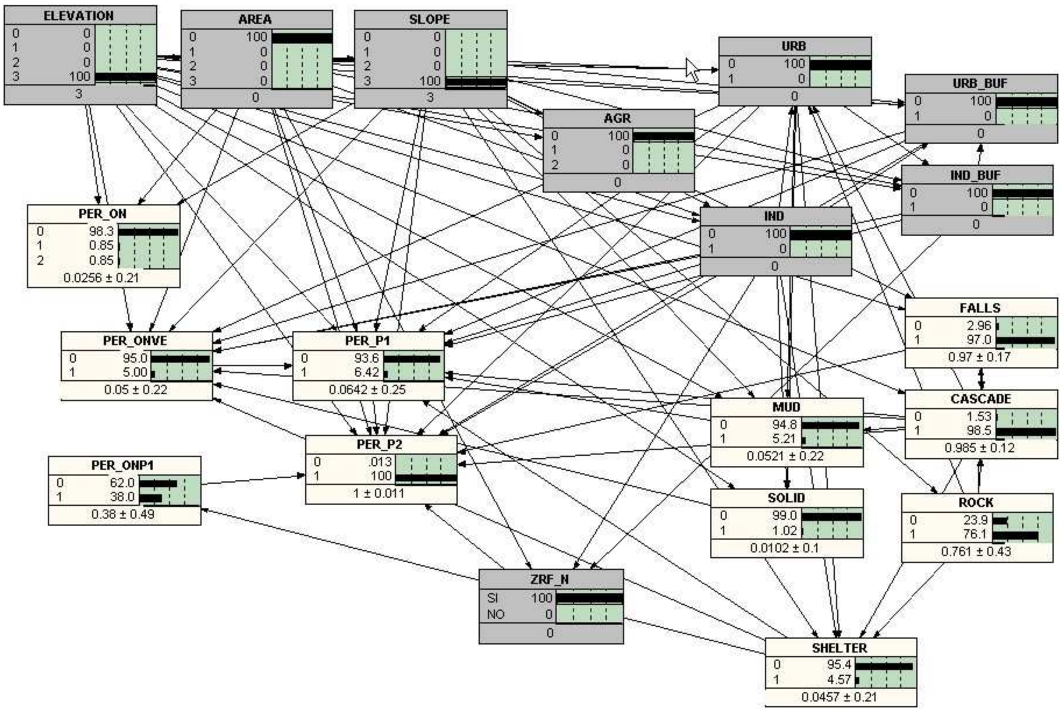

Fig. 15: Trophic Level Subset; Scenario 1: mountain survey site with low anthropic land use and with fishing management.

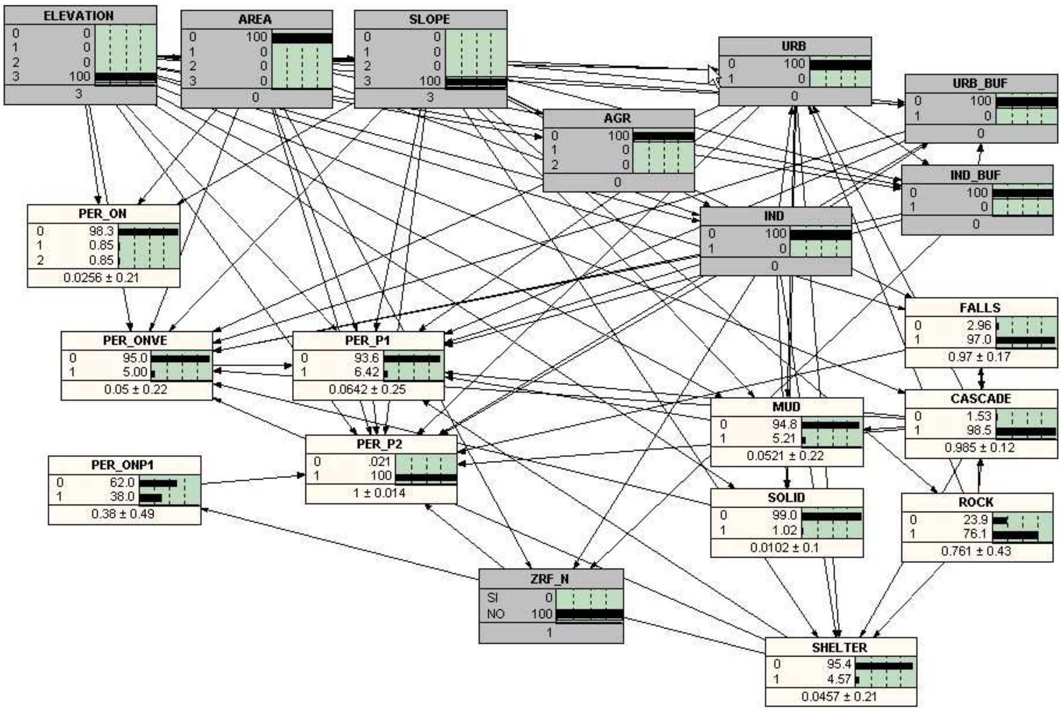

Fig. 16: Trophic Level Subset; Scenario 2: mountain survey site with low anthropic land use and no fishing management.

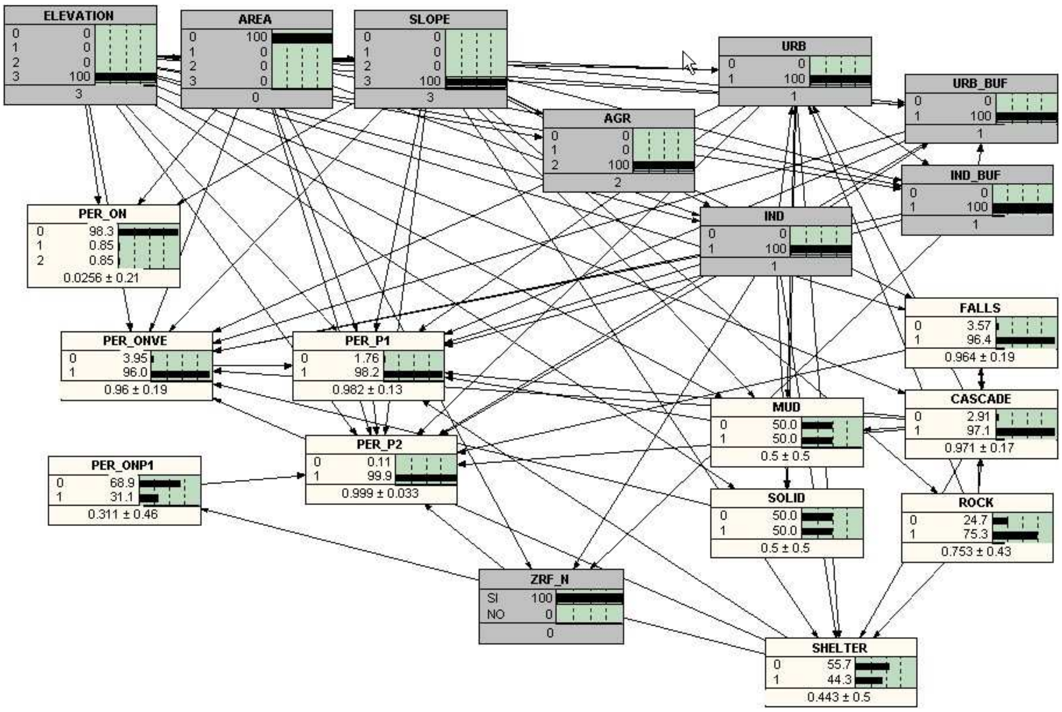

Fig. 17: Trophic Level Subset; Scenario 3: mountain survey site with high anthropic land use and with fishing management.

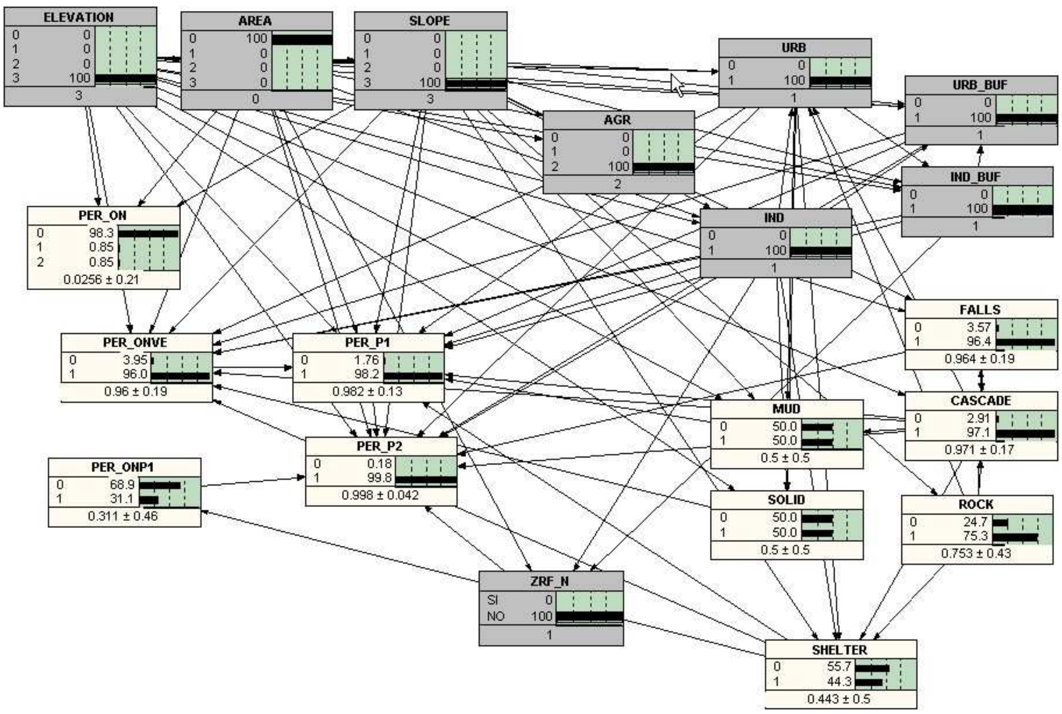

Fig. 18: Trophic Level Subset; Scenario 4: mountain survey site with high anthropic land use and no fishing management.

Plane zone natural situation is show in Fig. 19: the values of mud and solid dissolved are not too high and trophic web is well structured, with no changes resulting by imposing no fishing management.(Fig. 20).

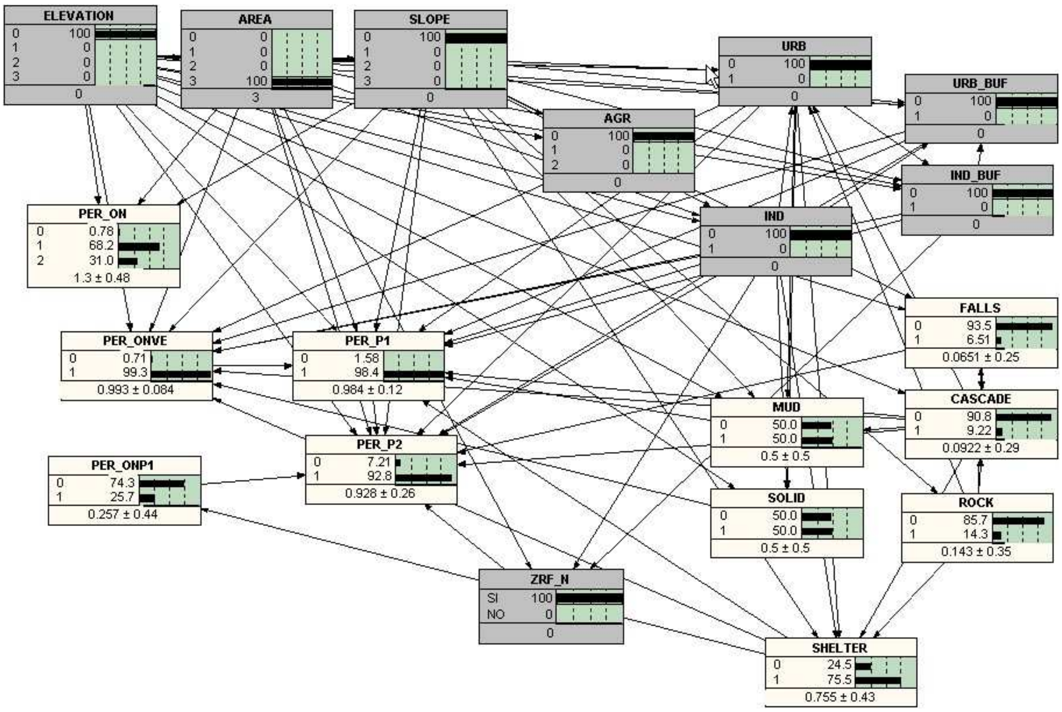

Fig. 19: Trophic Level Subset; Scenario 5: plane survey site with low anthropic land use and with fishing management.

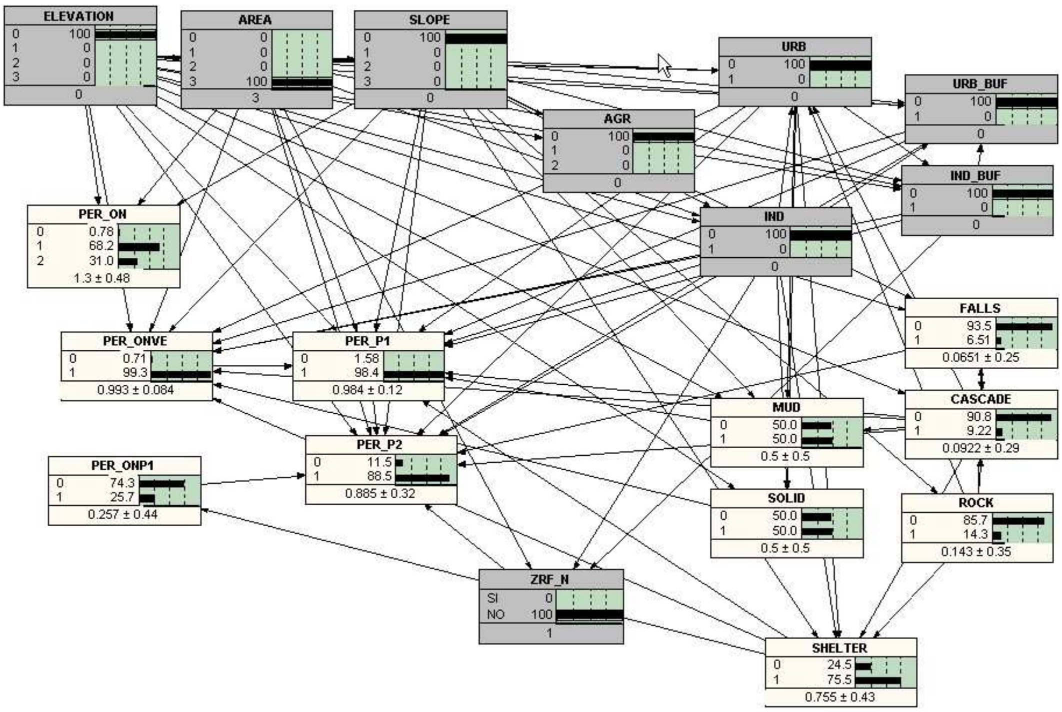

Fig. 20: Trophic Level Subset; Scenario 6: plane survey site with low anthropic land use and no fishing management.

Effects of increased anthropic land use (Fig. 21) are principally suffered by Predators of 2nd Level whose situation is worsen by fishing permission (Fig. 22). This observation can be explained because of fishers exactly are interested in the same kind of species including *Esox lucius* (Linnaeus, 1758) or pike, *Perca fluviatilis* Linnaeus, 1758 or river perch, *Sander lucioperca* (Linnaeus, 1758) or pike-perch, *Micropterus salmoides* (Lacepède, 1802) or black bass and *Silurus glanis* Linnaeus, 1758 or Danube catfish.

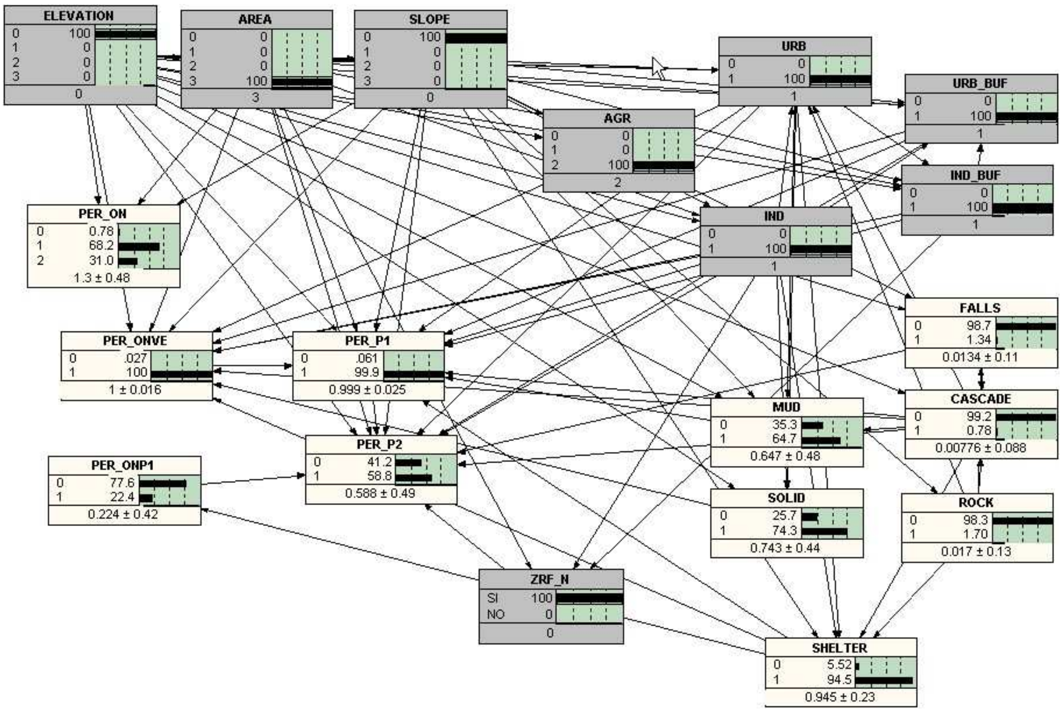

Fig. 21: Trophic Level Subset; Scenario 7: plane survey site with high anthropic land use and with fishing management.

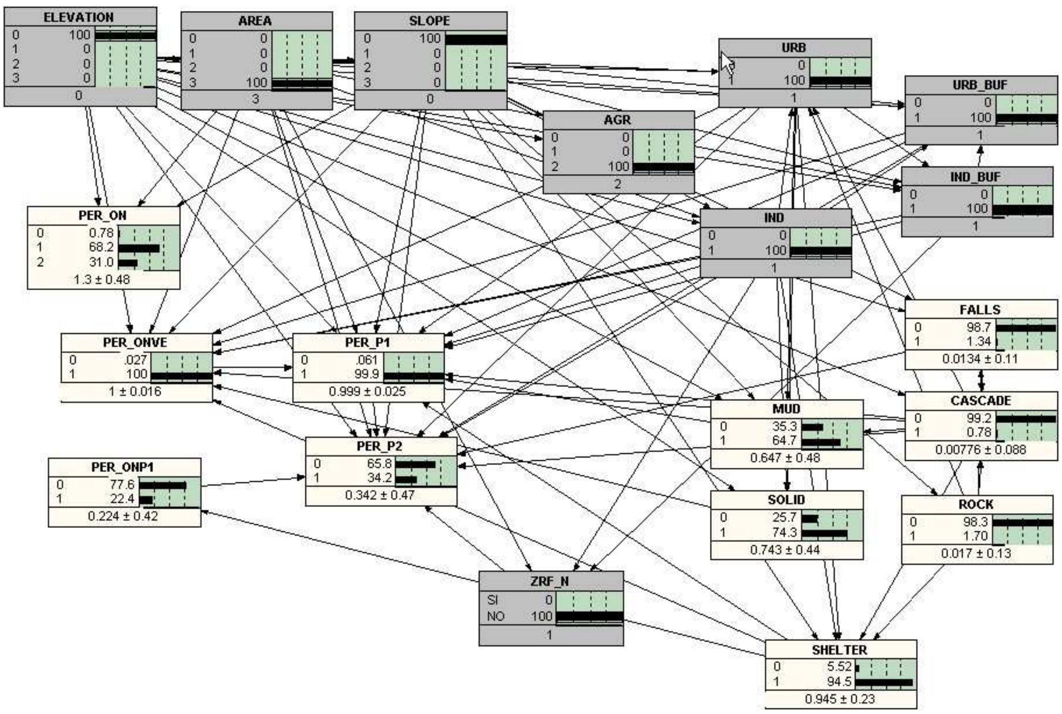

Fig. 22: Trophic Level Subset; Scenario 8: plane survey site with high anthropic land use and no fishing management.

4.2.3 Specific Level Subset

Scenarios presented hereunder show species assortment changes in mountains (Figs. 23-24) and high hills zone (Figs. 25-26), in an hypothetical low anthropic impact situation by imposing either undamaged or degraded local environment.

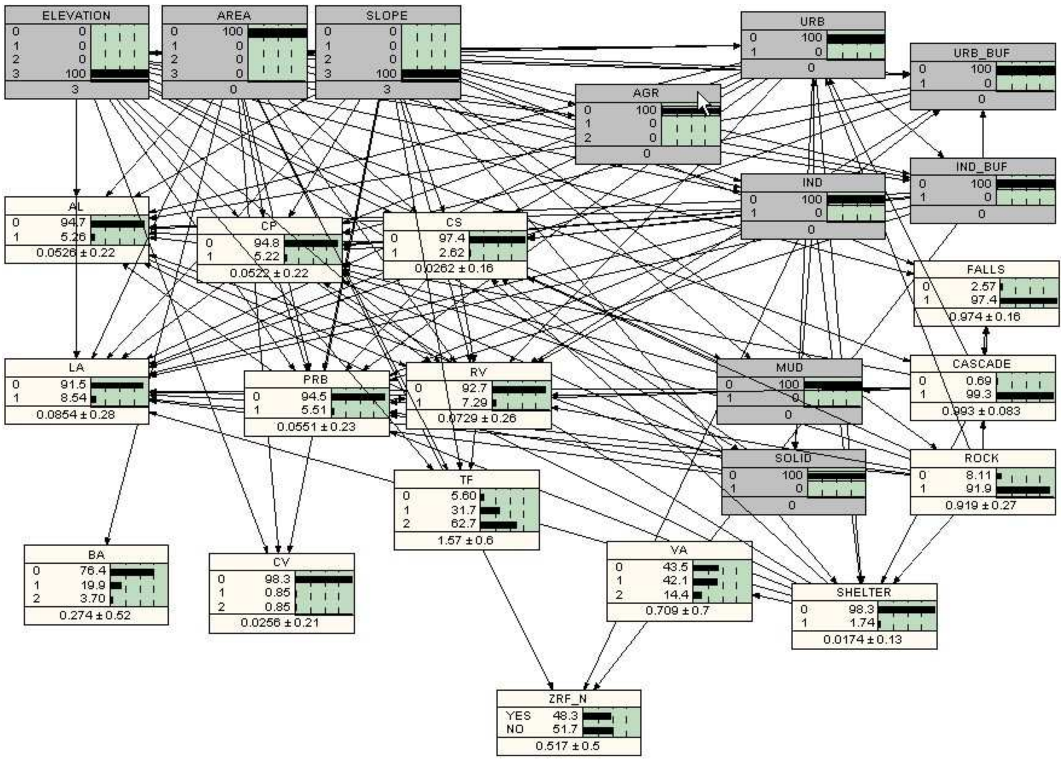

Fig. 23: Specific Level Subset; Scenario 1: mountains survey site, low anthropic land use and undamaged local environment.

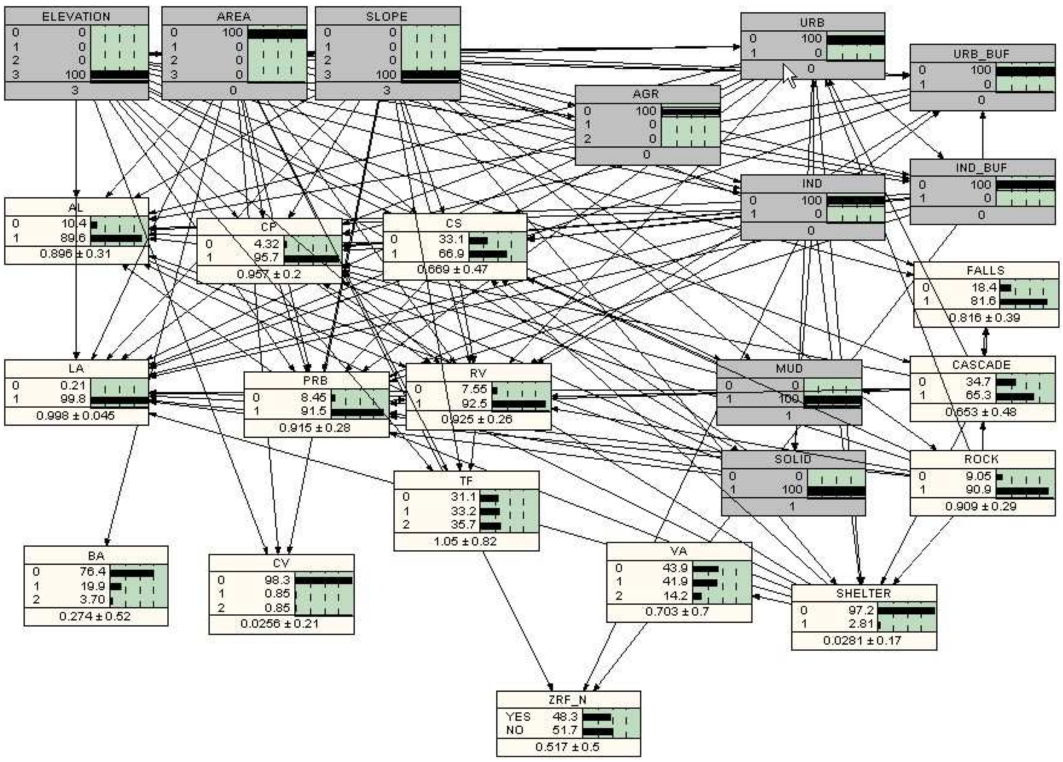

Fig. 24: Specific Level Subset; Scenario 2: mountain survey site, low anthropic land use and degraded local environment.

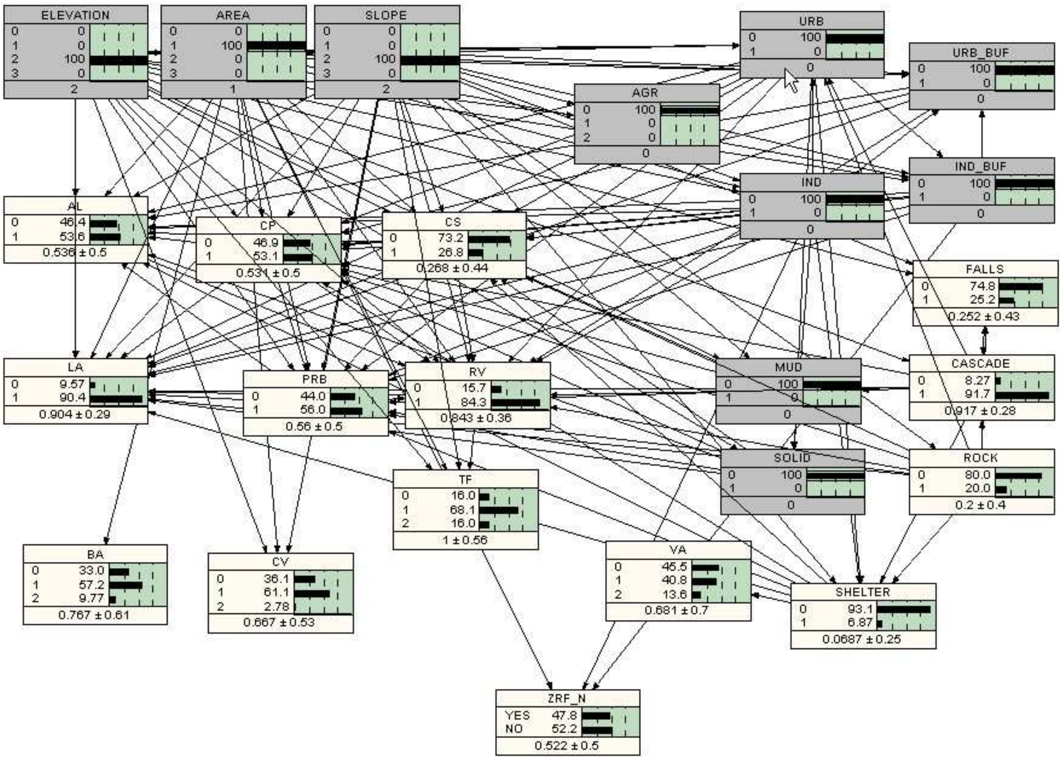

Fig. 25: Specific Level Subset; Scenario 3: high hill survey site low, anthropic land use and undamaged local environment.

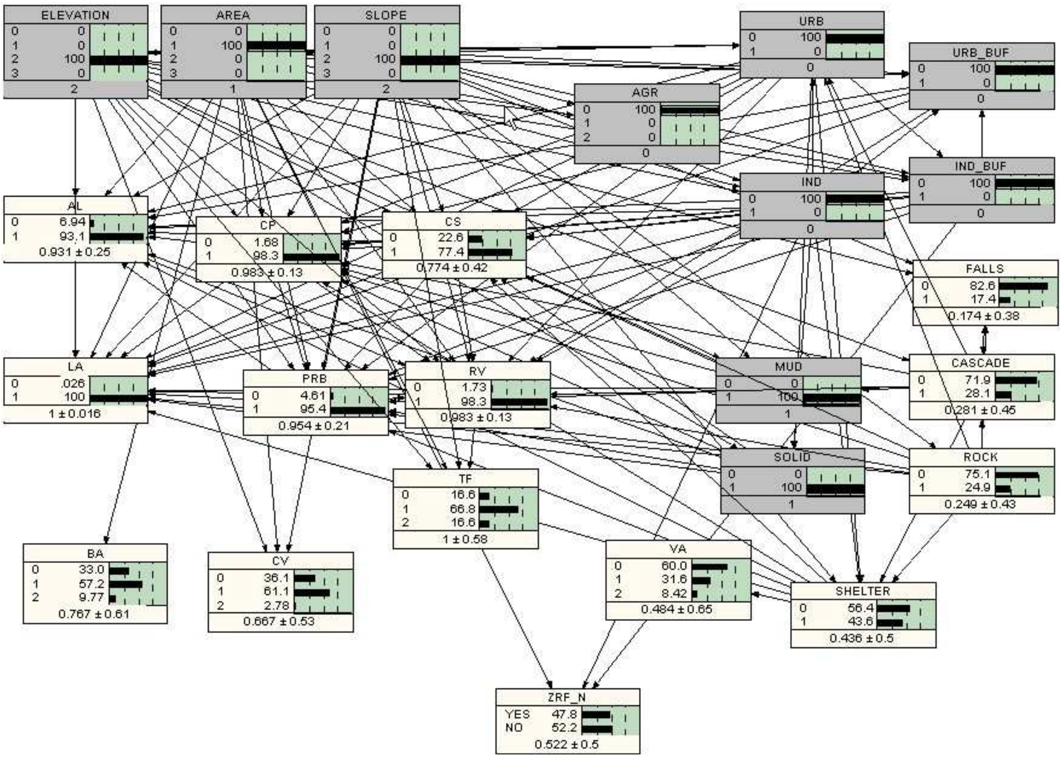

Fig. 26: Specific Level Subset; Scenario 4: high hill survey site, low anthropic land use and degraded local environment.

Scenario 2 states that the invasion of plane zone species disadvantages brown trout; it also shows that the same degradation and invasion of high hills zone (scenario 4) do not influence the Italian barbel, chub and brown trout have no sufferance, while advantage the south European nase and the Italian.

Chapter 5. Conclusions

Loglinear analysis and the macro tool in SAS language manifest the capability to explore large groups of variables even of different kind, without a priori assumptions. A check that the process is correctly carried out is that associations found within environmental variables are always the same even changing biological factors. One variable, Fish Fauna Refugia Percentage Richness, has to be split in Den Percentage Richness, Root or Branche Percentage Richness and Reed Percentage Richness.

Variables that showed no association could have relations with unregistered metrics, consequently new variables can be introduced, icluding water average availability; in study area, only a few discharge-surveyors exist, hence the necessity to build an hydrogeological model based on pluviometry, land use, geology and podology.

Bayesian networks constructed in this work have predictive abilities with the sole exceptions of Shannon & Weaver Evenness Index and Autoecological Tendency. These two variables, in fact, have many parents but used dataset does not represent all possible combinations of parent states; since linear multiple regressions didn’t return satisfactory results, missing data have to be filled.

Moreover, linear multiple regression failure indicates thate difficulty of linear models to explain ecological relationships, therefore appropriate models have to be constructed for couple of variables by “freezing” others.

That having been said, models here produced can discriminate the weight of natural or anthropic environmental variables on fish fauna diversity.

Natural predictors of biological variables can be divided in two groups: large scale geomorphological variables, that are consistent with “river continuum concept”, and local environmental variables, that express local morphology.

Anthropic pressures act principally in two ways: on one side fertilizing waters and hence moving ecological zones towards higher elevations, on the other altering channels morphology and therefore decreasing native fauna environmental fitness in favour of alien species.

This effects can increase biodiversity and trophic chain complexity so that, for streamwater ichthyocenosis, can be affirmed that “rich is not always good”.

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