Presentation by the Councillor responsible for the Mediterranean, Puglia Regional Authority

The protection and enhancement of the socio-economic value of the Aterno, Idro and Drin river basins, in Abruzzo, Puglia and Albania respectively, is the main theme of the RiverNet Project, financed as part of EU Programme Interreg III A (Cross-border Adriatic); it involves institutions, regions, Research centres and Universities in a rich array of partnerships, and is designed to promote environmental awareness, especially among the young and local communities.

In the history of mankind, rivers have always represented a source of contacts, wealth and civilisation: in the past, cities grew up and flourished on their banks and as the waters flowed they established material and cultural links between different regions, in some cases highly distant from each other. They also evoked, in symbolic, poetic, literary and musical terms, the desire of human beings to communicate, among themselves and with nature: places of beauty, life and socialisation. In modern society, characterised by the drive for profit at all costs, by fast transport, technology and real-time communication, river systems everywhere have gone into decline: environmental decay, over-exploitation of the territory, uncontrolled construction of dams and barrages, building of concrete banks, neglect and pollution have turned rivers of all sizes in developed countries into dumping sites for waste of all kinds, gradually turning the waters sterile, contributing to desertification, and leading to dangerous flooding.

The biology of the rivers is affected nearly everywhere by processes of extinction: fish, aquatic animals, and wild flora have disappeared, while pernicious colonies of insects, mice and other biological forms typical of environmental decay have developed.

As we know, nature, if not respected, will take its revenge on mankind for its betrayal: therefore, teaching the younger generations awareness and respect, encouraging people to participate and to play a role in a programme of socio-economic enhancement, protection and re-appropriation of the rivers in the life of the community is a highly important objective.

Greater contact between the world of research, institutions and the young brings additional benefits in this context, in that it enables the simultaneous development, together with environmental education, of scientific knowledge and a more sophisticated civil awareness.

For all these reasons then, I express my hopes that this great project will yield positive results for the future and will progressively disseminate knowledge and values in all the regions involved.

La valorizzazione e la tutela dei bacini fluviali dell'Aterno, dell'Idro e del Drin, in terra d'Abruzzo, di Puglia e di Albania, costituisce il tema portante di questa importante azione del Programma d'Iniziativa Comunitaria Interreg III A Transfrontaliero Adriatico; essa coinvolge istituzioni, territori, centri di Ricerca, Università in un ricco contesto di partenariati, ed è rivolta a promuovere consapevolezza ambientale e riappropriazione della problematica da parte dei giovani e delle comunità locali.

I fiumi, nella storia dell'umanità, hanno sempre rappresentato una fonte di relazioni, di ricchezza e di civiltà: sulle loro rive in passato fiorivano le città, le acque fluivano costruendo legami materiali e culturali tra territori diversi e a volte molto distanti tra loro, ed evocavano anche in forma simbolica, poetica, letteraria, musicale, i desideri di comunicazione degli uomini, tra loro e con la natura: luoghi di bellezza, dunque, di vita e di socialità.

Nella società contemporanea, caratterizzata dalla spinta verso il profitto a tutti i costi, dal trasporto veloce, *dalla tecnologia e dalla comunicazione in tempo reale, i sistemi fluviali un po' ovunque hanno sfiorato o raggiunto la decadenza: degrado ambientale, sfruttamento dissennato del territorio, costruzione incontrollata di dighe e sbarramenti, cementificazione delle rive, abbandono, inquinamento, hanno fatto dei fiumi piccoli e grandi dei Paesi sviluppati delle autentiche discariche di rifiuti, volta a volta isterilendone le acque, desertificando i territori, o determinando pericolose inondazioni.*

Anche la vita biologica dei fiumi quasi ovunque si è estinta: pesci, animali acquatici, flora spontanea, sono spariti, mentre si sono sviluppate perniciose colonie di insetti e di topi e altre forme biologiche tipiche del degrado ambientale.

Come sappiamo la natura, se non rispettata, si vendica del tradimento degli uomini: e dunque tornare a educare alla conoscenza e al rispetto le giovani generazioni, attivarne la partecipazione e il protagonismo in un programma di valorizzazione, di tutela e di riappropriazione della dimensione fluviale nella vita collettiva è obiettivo di grande valore.

Il contatto tra il mondo della ricerca, le istituzioni e i giovani si presenta inoltre, in questo contesto, quale valore aggiunto, in quanto consente di sviluppare in pari tempo, accanto alla educazione ambientale, la conoscenza scientifica e una più elevata consapevolezza civile.

Per tutte queste ragioni, dunque, mi auguro che questo bel progetto possa davvero sortire dei risultati positivamente orientati verso il futuro e riesca a disseminare progressivamente e stabilmente i suoi esiti e i suoi valori all'interno di tutti i territori coinvolti.

Silvia Godelli
Councillor responsible for the Mediterranean,
Puglia Regional Authority

Presentation by the Councillor responsible for Ecology, Puglia Regional Authority

The environment, understood as a complex structure made up of heterogeneous elements, requires holistic approaches that are able to deal with the multiform interactions that regulate the dynamic and evolutionary processes of our planet. Water, in all its forms and in the whole of its cycle, is at the heart of environmental equilibria, as a precondition and as a mediator of life itself, but also as part of the common heritage of mankind and nature.

Rivers, whether they are visible, subterranean, or artificial, are elements that connect life, experience and culture, constitute an integral part of our past, and are an essential pre-condition for our future; investment in sustainable development and reconciling issues of economic growth and environmental protection have thus today become a duty which we neglect at our peril.

For this reason, Puglia Regional Authority has sought to protect the river Ofanto by setting up the first river park in Puglia, the procedures for which are currently being activated.

To achieve this result it is necessary to tackle the water question in context of its environmental, social, cultural, ethical dimensions, placing particular emphasis on the issue of information and education regarding the conservation of our environmental heritage, the historic "memory" of water, and the knowledge and expertise that goes with it.

By achieving increasing levels of sustainability, not only does the community gradually reduce its impact on the local and global environment, but it also promotes an increasingly advanced integration of natural ecosystems with socio-economic and cultural life and ever more highly evolved and sustainable equilibria.

The results of the research and the experience set out in this volume demonstrate the clear links and interaction between public awareness of natural heritage in terms of aquatic and river environments and human activities, which, if carefully orientated, can lead to advantages and better protection, but can also lead to deterioration and irreversible damage if not managed in an informed way.

In the belief that reading this volume can contribute to a better understanding of the complex interactions between the human and the river environment, I invite the reader to draw useful indications regarding how to implement behaviours, actions and strategies that aim to improve the quality of the environment and the ecological value of aquatic ecosystems.

L'Ambiente, inteso come un apparato complesso composto da elementi tra loro eterogenei, richiede approcci globali in grado di cogliere le multiformi interazioni che regolano i processi dinamici ed evolutivi del nostro pianeta. L'acqua, in tutte le sue forme ed in tutto il suo ciclo, è al centro degli equilibri ambientali, come presupposto e come mediatore di vita, ma anche come patrimonio comune per l'uomo e per la natura.

I fiumi, siano essi visibili, sotterranei, artificiali o immateriali, sono elementi di connessione di vita, di esperienze e di culture e costituiscono parte integrante del nostro passato e condizione imprescindibile per il nostro futuro, per cui, puntare sullo sviluppo sostenibile e conciliare i temi dello sviluppo economico e della tutela ambientale è oggi un dovere dal quale non è possibile esimersi.

Anche per questo la Regione ha voluto tutelare *l'Ofanto con la costituzione del primo parco fluviale della Puglia le cui procedure sono in corso di attivazione.*

Per raggiungere tale risultato è necessario inquadrare la problematica dell'acqua nella dimensione ambientale, sociale, culturale, etica, ponendo particolare riguardo anche alla dimensione informativa ed educativa verso la conservazione del patrimonio, della memoria dell'acqua e dei saperi che l'accompagnano.

Pervenendo a livelli crescenti di sostenibilità, la comunità, non solo riduce via via il proprio impatto sull'ambiente locale e globale ma promuove una sempre più avanzata integrazione degli ecosistemi naturali nella vita socio-economica e culturale e verso equilibri sempre più evoluti e sostenibili.

I risultati delle ricerche e le esperienze rappresentate nel volume evidenziano quanto siano evidenti i legami e le interazioni tra le sensibilità ed i patrimoni naturali espressi dagli ambienti acquatici e fluviali e l'azione umana che, può apportare vantaggi e tutele, se ben orientata, ma può provocare deterioramenti e danni irreversibili se non gestita consapevolmente.

Con l'auspicio che la lettura del volume possa contribuire a comprendere le complesse interazioni tra ambiente fluviale ed antropico, invito i gentili lettori a ricavare utili indicazioni per porre in atto comportamenti, azioni e strategie finalizzate a migliorare la qualità dell'ambiente ed il valore ecologico degli ecosistemi acquatici.

Michele Losappio
Councillor responsible for Ecology,
Puglia Regional Authority

Presentation by the Councillor responsible for the implementation of EU Policies, Lecce Provincial Authority

By introducing the principle of "non deterioration" of water bodies and adopting the principles of precaution, prevention and "making the polluters pay", the Water Framework Directive obliges Member States to protect their inland surface waters, transitional waters, coastal waters and subterranean waters.

Specifically, by 2015, these waters must be managed by means of specially prepared plans that take account of the water cycle rather than administrative and provincial boundaries or regional and national borders. These plans must aim to optimise the ways in which the waters are used and promote the integration of existing norms regarding water and the environments that depend on it. The plans also envisage the active participation of all parties with an interest in the implementation of the Directive. The Province of Lecce therefore decided to participate in the RiverNet project because of its innovative nature and because it enabled a comparison of the systems and techniques used for the conservation, management and use of the inland waters in the territories of the various partners, particularly Puglia and Albania.

We believe that the results achieved can be of great service to our region.

La Direttiva quadro Acqua, introducendo il principio di "non deterioramento" dei corpi idrici e facendo propri i principi di precauzione, prevenzione e di "chi inquina paga", obbliga gli Stati membri alla protezione delle acque superficiali interne, delle acque di transizione, delle acque costiere e sotterranee.

In particolare, entro il 2015, deve essere raggiunto l'obiettivo di una gestione delle acque attraverso appositi piani, che tengano conto del ciclo delle acque, e non dei confini amministrativi di province, regioni o stati, perseguendo l'ottimizzazione degli usi e promovendo l'integrazione delle normative esistenti riguardanti l'acqua e gli ambienti che da questa dipendono. I piani prevedono la partecipazione attiva di tutte le parti interessate all'attuazione della direttiva. La Provincia di Lecce ha, pertanto, aderito al progetto RiverNet per la sua portata innovativa e perché metteva a confronto nei diversi territori partner, in particolare di Puglia ed Albania, i sistemi e le modalità di conservazione, gestione e fruizione delle acque interne.

Crediamo che i risultati raggiunti possano essere di grande utilità per il nostro territorio.

Cosimo Durante
Councillor responsible for the Implementation
of EU Policies, Lecce Provincial Authority

Introduction

Rivers and streams have key ecological properties, at ecosystem level, which affect the development of human culture, history, population distribution, demography and economics. Biodiversity and the goods and services derived from river ecosystems depend on the catchment area and the forces governing the exchange of nutrients, organic matter, waste waters, sediments, materials and species over a range of temporal scales across the land/water interface. These mechanisms inspired the traditional exploitation and adaptive management of river resources; nowadays however, increasing urbanisation, chemical pollution, power generation, fisheries and tourism are leading to a shift away from adaptive to unsustainable management strategies. In Mediterranean rivers, climate change is contributing significantly to increased disturbance of structures and functions due to summer drought. The management and conservation of ecosystem health in rivers and streams is a major ecological and environmental issue, as well as a socio-economic priority. In this context, the responsibility of the scientific community has increased and the integration of all components, i.e. institutional, administrative, managerial and scientific, is increasingly required. This was the main objective of the RiverNet Project, financed by the INTERREG IIIA Cross Border – Adriatic New Neighbourhood Programme, and this book represents the result of scientific cooperation between Italian and Albanian researchers and administrations. The themes of the chapters vary from the role of chemical pollution in benthic invertebrate community features, to the spatial variation of the abiotic and biotic characteristics of the main Albanian rivers, to ways of involving local communities in the decision-making processes of administrations regarding conservation strategies, and the use of software to define the chemical impact at catchment area level. This book is also the result of the work and contribution of many people. The editors would like to thank all the authors and Prof Llukan Puka, Dr Piacentino Ciccarese, Dr Vincenzo Mangialardo, Dr Simona Romiti and Dr Mimoza Frasheri for their enthusiastic approach to all the activities of the RiverNet project . Finally, the editors would like to thank all the staff of the Abruzzo Regional Authority involved in the RiverNet project for their support.

The editors

General considerations on the flora and vegetation of Albania's rivers

1

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Abstract

The studied region is characterised by its rich flora, vegetation, and diversity of habitats, from constantly submerged areas, moving on to areas subject to tidal movements, and ending in areas that are always above water level. In many cases the relations between these various types of habitat are of great ecological importance. All of these areas are specific to the area's rivers and cannot be found anywhere else. The relatively modest density of the vegetation is due to human pressure exerted on the area: cementing, building embankments, and poplar fields have greatly changed the original landscape. Where human influence has been reduced, thickets of common reed (*Phragmites australis*) can often be found, as well as populations of floating species such as the duckweed (of the *Lemna* species), the giant duckweed (*Salvinia natans*) and the water chestnut (*Trapa natans*). On the edges, in other words in transitional areas between aquatic and terrestrial habitats, there are varieties of sedge (*Carex elata, C. riparia*) water lilies (*Iris pseudoacorus*), purple-loosestrifes (*Lythrum salicaria*), and sometimes summer snowflakes (*Leucojum aestivum*). Mesophyte woods, characterised less by Mediterranean and more by continental features, grow in less protruding areas, where conditions are cooler and more humid. The dominant species of these woods are: *Alnus glutinosa*, *Fraxinus angustifolia*, the bay-oak (*Quercus robur*) and the elm (*Ulmus minor*). In the low areas close to the water table, and in the floodplains not given over to the growing of poplars, there are small hygrophilous woods whose main species are the willow (*Salix alba*) and the white poplar (*Populus alba*).

Introduction

Albania is rich in natural aquatic resources. There is a dense hydrographic network composed of streams and rivers. All the rivers flow from east to west and all debouch in the Adriatic and Ionian seas. The two biggest rivers in Albania (the Drin and the Vjosa) flow across national borders. The high density of the hydrographic network is the result of broken relief and intensive rains. This network has an average density about D=1.4 km/km^2. The distribution of Albania's river network is determined by the physical and geographic characteristics of the watersheds and especially by its morphological characteristics, the lithological nature of the territory, the action of the rains, and evaporation. In mountain areas, all the rivers are characterized by gravel or rocky beds, their size determined by flow regimes. The bottom flow is characterized by an eroded layer with low and variable landscape.

Material and methods

The main plant communities of the area were identified; the sites of the surveys varied from 0.25 m^2 (for aquatic vegetation) to 200 m^2 (for forest). More than 150 surveys were carried out in the area, according to the Zurich-Montpellier approach.

The floristic nomenclature and the degree of threat are respectively based on Flora Europaea (Tutin *et al.,* 1968 - 1980), Flora of Albania (Paparisto *et al.,* 1984 - 2000), and The Red Book (Vangjeli *et al.*, 1995). The classification of the vegetation was based on the higher phytosociological units of the Braun-Blanquet (1952) system (order, alliance, association) and the classification of vegetation of SE Europe according to Horvat *et al.* (1972).

Results

The flora and vegetation of Albania's rivers can be easily distinguished into two different fundamental types; those of a strictly aquatic nature that live in or on the river-bed, and riparian vegetation growing along the banks.

Aquatic vegetation

Most of the aquatic flora consist of algae and higher plants, which are suited for humid environments and sometimes even complete immersion, if temporary.

Aquatic plants depend on a fluvial environment, and their existence is influenced by many factors. For example, periods of submersion, the water table, the force of the current, the composition of the riverbed, and the transparency of the water all play a role. Some plants are completely submerged while others root in the riverbed and emerge from the water at various heights, and others still are without roots and float on the water.

In stretches of the river where the water flows with force and speed, the plants are sparse, the riverbed is unstable and moves continuously, and only a small community of algae is able to form colonies. Some of these algae are microscopic, the diatomeae and the chyanophyceae, and form coloured films on the substrate (e.g. the rocks). Where the current reduces its speed and the water is calm, several species of algae, including floating algae and higher plants such as crowfoot proliferate.

The Aquatic Plant associations can be grouped as follows:

- Underwater or aquatic bed plant associations dominated by different kinds of algae, especially by *Chara* sp.
- Submerged plant associations (Rooted Vascular plants) including mainly species of the following genera: Pondweed (*Potamogeton*), Parrot Feather (*Myriophyllum*), Naiad-wort (*Najas*), Tape-grass (*Vallisneria*) etc.
- Halophyte plant associations; these plants have roots and a part of the stem submerged, but most of the plant is above water. These are called persistent emergent plants. The main associations in this category are reeds (*Phragmites australis*) and bulrushes (*Typha*).
- Floating leaved plants, typically dominated by Water Lily (*Nymphaea alba* and *Nuphar luteum*), Water Chestnut (*Trapa natans*) *Lemna minor* or *L. trisulca*. In general these associations are found in optimal conditions in the lower stretches of rivers, especially in sheltered areas.

The most widely diffused marsh vegetation in the area of the rivers is the common reedbed (*Phragmites australis*). This is fairly ubiquitous, in the sense that it can be found in slightly salty waters near river mouths (together with halophile species, i.e., species that prefer salty environments like the *Puccinellia festuciformis*, a variety of saltmarsh-grass), in fresh waters (together with fresh water species such as *Lythrum salicaria*, commonly known as the purple loosestrife), and even in terrestrial environments (on the shores of embankments). Generally speaking, as the salinity increases the reedbed tends to become monospecific, in other words to be completely dominated by the common reed. When the salinity becomes excessive, the reed is replaced by decidedly more halophile species such as sea-lavender (*Limonium spp.*) and saltmarsh-grass (*Puccinellia palustris*).
Associated *species* with equally high abundance values include hygrophytes such as the Lesser Bulrush, Purple Loosestrife, Fen Sedge, Water Plantain, and Branched Bur-Reed.

Riparian vegetation

Riverbanks are characterized by high species richness, which is mainly based on habitat diversity in cross-section and periodic disturbances, such as floods. The total species richness of a given river depends on the habitat diversity along the water course. Riparian vegetation includes shrubs and arboreal species (willows, alders, poplars), which are found in areas between aquatic plants and other plant species farther away from the river. They are hygrophilous species, whose roots are connected with the groundwater. Riparian forests, or alluvial forests, are generally wooded areas suited to moist soils that cover both the river banks and the areas which are periodically submerged by flooding.
In the mountains, riparian vegetation principally consists of humid meadows which are gradually replaced

by riparian woods of alders as the slope of the ground decreases. The various species of willows (white willow, riparian willow) and poplars, which prevail on the valley floor or plain, slowly replace the alders. A rich undergrowth, characterized by grasses, bushes, reedbeds, and sometimes orchids, grows beside the riparian woods. The vegetation of this belt belongs to the classes *Alno-Populetea* and *Salicetea purpurea*. The main species of the riparian vegetation are: *Populus alba, Salix alba, Salix purpurea, Salix amplexicaulis, Salix elaeagnos* subsp. *angustifolia, Alnus glutinosa, Alnus incana, Platanus orientalis* etc.

Another interesting association which thrives in humid and regularly flooded environments in this belt is the White Poplar. The forest physiognomy is determined by the White Poplar, which is found along the river valleys from the coast up to the mountain areas. In low humidity environments the White Poplars are characterised by weak development and very often do not grow above the shrub level. Where water flows are strongest, the substrate is characterised by gravel and these environments are predominated by Oriental Planes (*Platanus orientalis*), associated with hygrophilous shrubs such as the Grey Willow and Small Flower Tamarisk. On dry gravel, this association is characterized by fewer associated shrubs, whereas in humid places the Oriental Plane is associated with many other shrubs such as the Common Alder, White Poplar, White Willow, Hawthorn, as well as herbaceous types such as the Round-Leaved Birthwort, Pennyroyal, Ivy, White Butterbur, Hairy Buttercup, Maidenhair Fern, and Long-Leaved Mint.

Close to the riverbank, the Oriental Plane is associated with Walnut trees, especially in the upper valley of the Vjosa and Shkumbini Rivers, and with Oleanders in the valley of the Qeparo stream.

The most important parts of the river's vegetation, from the mouth up to the high mountain area, are the associations of White Willow, and herbaceous plants such as the Spiny Rush, Self-Heal, Greater Plantain, and Dove's Foot Cranesbills.

Discussion and conclusions

The results show a relatively rich flora and vegetation. 125 plant species (vascular plants) have been registered so far. Most of them belong to hydrophile or hygrophilous plant species and the cosmopolitan element (Fig. 1, 2). Some hydro- and hygrophytes are included in the Red Book of Albania (Tab. 2). The results based on the phytosociological investigations indicate the presence of 18 associations belonging to six different classes and eight orders, distributed in alternating zones of vegetation. A summary of this classification is shown in Tab. 1.

The role played by this kind of vegetation is fundamental for the balance of the river: the riparian vegetation works

Table 1 - Phytosociological classification

Charetea	Nymphaeetum albae-luteae	Alno-populetea
Charetalia	Trapetum natantis	Alnetalia glutinosae
Charion	Nymphoidetum peltatae	Alnion glutinosae
Communities with Chara sp.		Alnetum glutinosae
	Phragmiti – Magnocaricetea	Alno-Quercion roboris
Lemnetea	Bolboschoenetalia maritimi	Quercetum roboris
Lemnetalia	Bolboschoenion maritimi	Fraxinion angustifoliae
Lemnion	Bolboschoenetum maritimi	Alno - Fraxinetum angustifoliae
Lemnetum trisulcae,	Phragmitetalia australis	Ulmo - Fraxinetum angustifoliae
Lemnetum minoris		Junco (acuti) - Fraxinetum angustifoliae
	Phragmition australis	
Isoeto – Nano juncetea	Phragmitetum	Leucojo – Fraxinetum angustifoliae
Isoeto - Nano juncetalia	Scirpo - Phragmitetum	Alno – Populetalia
Nanocyperion	Bolboschoeno - Phragmitetum australis	Alnion incanae
Juncetum bufonii	Typhetum angustifoliae	Alnetum incanae
Bidention tripartitae	Typhetum latifoliae	Populetalia albae
Eleocharitetum palustris	Cyperetum longi	Populetum albae balcanicum
	Oenanthion aquaticae	Platanion orientalis
Potametea	Butomo-Sagittarietum angustifoliae	Platanetum orientalis
Potametalia	Glycerio-Sparganietum neglecti	Juglando - Platanetum orientalis
Potamion	Sparganietum erecti	
Myriophyllo-Potametum,	Butometum umbellati	Salicetea purpureae
Potameto-Najadetum,	Oenantho-Rorippetum amphibiae	Salicetalia purpurea
Ceratophyllo-Potametum,	Equisetetum fluviatilis	Salicion eleagni
Elodeetum canadensis,	Rorippo-Phalariditetum arundinaceae	Salicetum triandrae balcanicum
Polygonetum amphibii	Ranunculion aquatilis	Salicion albae
Nupharo-Potametalia	Veronico beccabungae-Callitrichetum stagnalis	Tamarici - Salicetum purpureae
Nymphaeion	Hydrocharition	Nerio – Tamaricetum parviflorae
Myriophyllo-Nupharetum,	Hydrocharitetum morsus-ranae	

Figure 1 - Floristical Spectrum

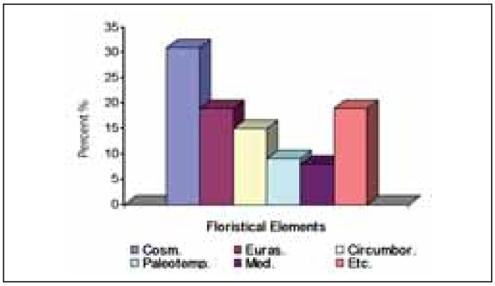
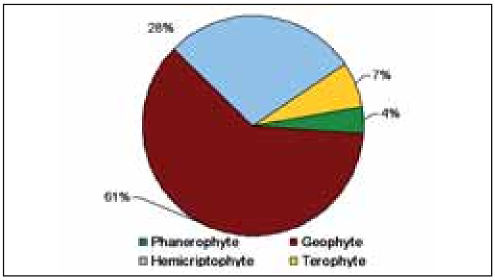


Figure 2 - Biological Spectrum



as a filter and therefore plays a key role in the purification of the water. Through their roots, aquatic plants are able to absorb polluting inorganic materials such as phosphates and nitrates which are found in detergents (soap, washing powder, etc.) and fertilizers used in agriculture. For this reason, a "buffer" zone of natural vegetation between rivers and farmland is extremely important.
Roots from these plants have another important function: they preserve the riverbanks from erosion caused by flowing water. Alders and willows, for example, have large and deep root systems, which consolidate and

Table 2 - List of Endangered and Threatened species in river's area

Hydrocotile vulgaris	Ex?	Nymphaea alba	V
Quecus robur	Ex?	Nuphar lutea	V
Symphytum officinale	Ex?	Nymphoides peltata	V
Fraxinus exelsior	E	Ranunculus lingua	V
Adiantum capillus-veneris	V	Ulmus laevis	V
Butomus umbellatus	V	Baldellia ranunculoides	V
Caltha palustris	V	Conium maculatum	R
Cladium mariscus	V	Typha shuttleworti	V
Hydrocharis morsus-.ranae	V	Salix fragilis	V
Salix triandra	V	Trapa natans	V
Osmunda regalis	V	Sagittaria sagittifolia	V
Phyllitis scolopendrium	V	Ranunculus fontanus	V

make the banks resistant to the force of the current. Vegetation found along the course of the river, often called a "green corridor", provides necessary shade to keep the water temperature stable. Water temperature influences the amount of available dissolved oxygen in the water on which aquatic life forms depend.

In addition, the variety of vegetation gives refuge and sustenance to many species of animals, insects, birds, reptiles, and amphibians.

Thus, these bordering areas between water and land have a great ecological value. When intact, the riparian zones cross and link the land with the river, which serves as a biological corridor and is vital for vertebrate and invertebrate fauna. Unfortunately, these important areas have been severely reduced and fragmented for reasons of development for housing, roads, bridges, and construction; flood regulation; and the desire for new and better farmland. As a result of using such resources without regulation, many hygrophilous taxa and their associations are currently at risk of extinction or significant reduction. Moreover, human intervention, such as reclamation, dam building, unregulated use of the waters and industrial pollution, has damaged flora and vegetation of very high value not only in ecological but also in economics.

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2

Trophic state of Albanian water ecosystems based on phytoplankton photosynthetic pigments

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Abstract

Data on the trophic state of some Albanian water bodies (the Adriatic lagoons of Vilun, Kune-Vain, Patog, Karavasta and Narta, and the ecosystem of Ohrid-Prespa) are presented. Evaluation of trophic state is based on chlorophyll *a* content in water and distribution of photosynthetic pigments, monitored from March to October. The lagoons of the Adriatic coast have different trophic states. The lagoons of Vilun, Kune-Vain and Patok are oligotrophic, but the Karavasta and Narta lagoons are characterized by a higher trophic state, estimated as mesotrophic. Lake Ohrid is oligotrophic, whereas Lake Prespa is mesotrophic. Vertical profiles of Chl *a* content demonstrated different distribution in the Ohrid and Prespa lakes.

Key-words: chlorophyll, lake, lagoon, phytoplankton, trophic state.

Introduction

The trophic state of water bodies can be divided into three categories: oligotrophic, mesotrophic and eutrophic. These categories reflect the nutrient and clarity levels, or the level of nutrients and algae in the water. Counting individual algae cells in water bodies is difficult; these categories are most easily determined by measuring the chlorophyll content of the water. Chlorophyll, a plant pigment found in algae, indicates the quantity of algae present in the water, providing an indication of the amount of nutrients present. Therefore, chlorophyll makes it possible to classify water bodies according to their trophic status as oligotrophic, mesotrophic, eutrophic and hypereutrophic (Tab. 1). A primary nutrient responsible for algae growth is phosphorus, and a direct relationship between phosphorus concentrations, chlorophyll *a* (algal biomass), and clarity has been established: phosphorus drives algal growth which then affects water clarity (Jarry *et al.,* 1991; Sanders *et al.,* 2001; Vidal *et al.,* 1999).

Trophic State	Chlorophyll (mg/m^3)	Total phosphorus (mg/m^3).
Ultraoligotrophic	← 1	
Oligotrophic	← 2.5	←10
Mesotrophic	2.5 - 8	10-30
Eutrophic	8 - 25	30-100
Hypereutrophic	→ 25	→100

Table 1 - Characterization of trophic state via Chlorophyll content.

Chlorophyll a is the green pigment in plants that is used for photosynthesis. Chlorophyll *a* is a good indicator of the total quantity of algae in a lake. Large amounts of algae in a lake can decrease the clarity of the water, alter the colour of the water (making it greener), form surface scum, reduce dissolved oxygen, alter the pH of the water, and produce unpleasant tastes and smells.
The aim of this study was to monitor and to evaluate the trophic state of the water bodies of the Ohrid-Prespa lakes and some Adriatic lagoons.

Material and methods

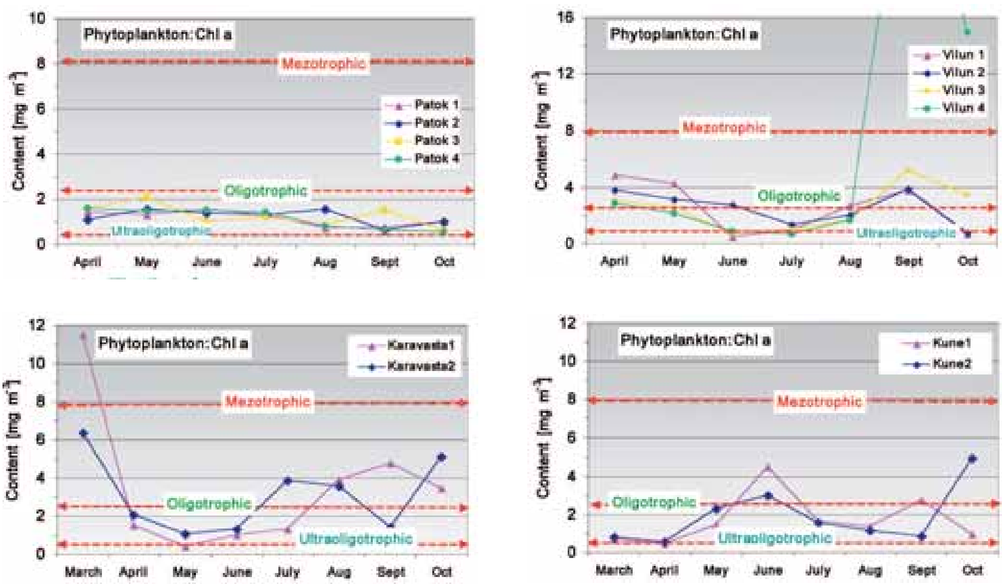
Chlorophyll "*a*", "*b*", and "*c*" content was determined by acetone trichromatic methods using the equations based on the absorption maxima for each component respectively (with coefficients of Jeffrey and Humphrey). All absorbance values are corrected by taking into consideration the turbidity of acetone extracts (Jarry and Legendre 1991, Jeffrey and Humphrey 1975, Lorenzen 1967, Ston and Kosakowska 2000).

Results

Adriatic coastal lagoons - Chlorophyll content

The chlorophyll content of Karavasta, Vilun, and Narta lagoons demonstrated the highest values on March. After that, the Chl content decreased until August and then increased in September-October (Fig. 1). The dynamics of Chl content in the Kune lagoon is different, demonstrating higher values during the summer May-July (Fig. 1).

The selected monitoring stations in each lagoon are characterized by different water connections to the sea. The dynamics of Chl content in the selected sta-



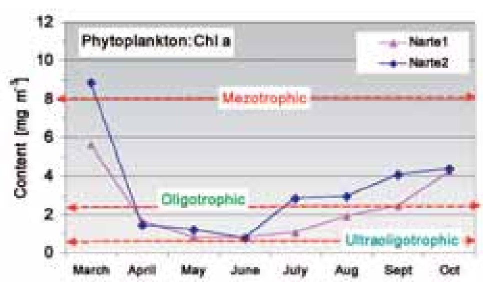


Figure 1 - Dynamics of chlorophyll a content in some Adriatic lagoons

tions demonstrated almost the same variation from March to October, especially in the Narta, Kune and Patok lagoons. A very high Chl content was observed in one of the stations in the Vilun lagoon (Fig. 1, Vilun 4), which can be explained by a poor connection of this station to the sea in this period as well as by higher pollution, especially during the summer. This station was near the beach.

Trophic state of Adriatic lagoons

Based on the trophic state characterization (Table 1), the trophic state of the Patok lagoon can be characterized as oligotrophic, and that of the Vilun lagoon as mesotrophic (Tab. 2). The trophic state at all selected stations (every year) in the Patok lagoon was similar. The trophic state of three of the selected stations in the Vilun lagoon was the same, whereas a very high trophic state was observed in one station (Tab. 2, Vilun 4). There was an improvement in the trophic state in 2005 in comparison to 2004 in both lagoons, excluding station 4 in Vilun, (Tab. 2). This improvement can be explained by the different climate conditions in these years and the better communication of both lagoons with the sea in 2005.

Table 2 - Characterization of trophic state by Chlorophyll content of Patok and Vilun lagoons.

	Chl a	2004	Mean	2005	Mean
Lagoon	Patok 1	1.921	1.859	1.141	1.187
	Patok 2	1.798		1.214	
	Patok 3	-		1.254	
	Patok 4	-		1.139	
	Vilun 1	3.563	3.788	2.526	3.803
	Vilun 2	4.013		2.515	
	Vilun 3	-		2.503	
	Vilun 4	-		7.670	

The trophic state of the Patok, Kune and Karavasta lagoons can be evaluated as oligotrophic, and the trophic state of the Vilun and Narta lagoons as mesotrophic,

Table 3 - Characterization of trophic state by Chlorophyll content of Adriatic lagoons

	Chl a	2002	2003	Mean
Lagoon	Karavasta	1.98	2.59	2.28
	Kune	1.51	1.95	1.73
	Narta	8.89	2.87	5.88
	Chl a	**2004**	**2005**	**Mean**
	Patok	1.86	1.19	1.52
	Vilun	3.79	3.81	3.80

taking into consideration the mean Chl content of all selected stations over a period of two years (Tab. 3).

Ohrid-Prespa ecosystem - Chlorophyll content

The chlorophyll *a* content in two lakes, Ohrid and Prespa, shows how much photosynthesising plant material is present in the lake water, as it is considered an expression of phytoplankton biomass (Fig. 2). The lakes have the following geographical coordinates: Ohrid - N-40º 55' 28.5"; E-020º 41' 20.2"; Prespa - N-40º 52' 27.0"; E-020º 58' 0.87".

Chlorophyll content demonstrated the highest values in March for lake Ohrid. After that, Chl content decreased until June, increased slightly in July and then decreased again (Fig. 2). The Chl content of lake Prespa is much higher than that of lake Ohrid. Chl content in lake Prespa decreased from March to June, and the Chl values in July and October are higher than those of March.

Vertical profile of Chl content

The vertical distribution of chlorophyll in the Ohrid and

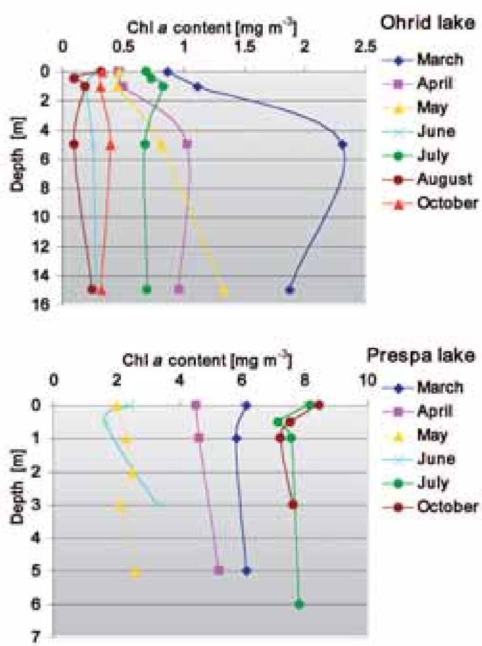


Figure 2 - Chlorophyll a content in Ohrid and Prespa lakes, March-October 2004.

Prespa lakes was different (Fig. 2). The Chl content of lake Ohrid increased from the surface to a depth of 5 m and then decreased. In contrast, in lake Prespa the Chl content is almost the same from 0 to 5 m depth.

Trophic state of the Ohri-Prespa lakes

Based on the trophic state characterization (Tab. 4), lake Ohrid can be characterized as oligotrophic, and lake Prespa as mesotrophic.

Table 4 - Characterization of trophic state by Chlorophyll content in Ohrid and Prespa lakes.

Chl a	lake Ohrid		lake Prespa	
	Lake	**Mean**	**Lake**	**Mean**
May	0.89	1.03	3.23	2.81
July	1.25		1.33	
October	0.94		3.86	
	Shore	**Mean**	**Shore**	**Mean**
May	3.80	5.7	3.85	5.71
July	11.82		5.97	
October	1.50		7.32	

The trophic state of the selected station on the shore near urban areas indicates a higher level, characterized as mesotrophic. It can be observed that the trophic state of lake Ohrid stations is higher in July and after that it decreases to an oligoptrophic level. In contrast, the trophic state of the selected station near the shore of lake Prespa increased from May to October, remaining mesotrophic. The high trophic state at the selected station near the shore can be related to higher pollution from urban areas especially during summer.

Photosynthetic pigments of phytoplankton.

The distribution of chlorophyll a and accessory pigments, Chl b and Chl c, as well as the ratios of Chl "*a*" to Chl "*b*" and Chl "*c*" was different in the two lakes (Fig. 3). The content of Chl *a* relative to Chl *b* and Chl *c* was higher in lake Prespa than in lake Ohrid.

The distribution of pigments in the algae groups is quite unique. The kinds of chlorophylls are characteristic for each phytoplankton family and they can be used as potential taxonomic biomarkers of phytoplankton organisms. It is known that chlorophyll *b* is peculiar to green algae and chlorophyll *c* characterises Diatoms and Dinoflagellates. In contrast, in Cyanophyceae only chlorophyll *a* is present. The relative chlorophyll content shows the higher quantity of Cyanophyceae in the waters of lake Prespa than lake Ohrid, indicating higher eutrophication of lake Prespa (Schlüter *et al.* 2000).

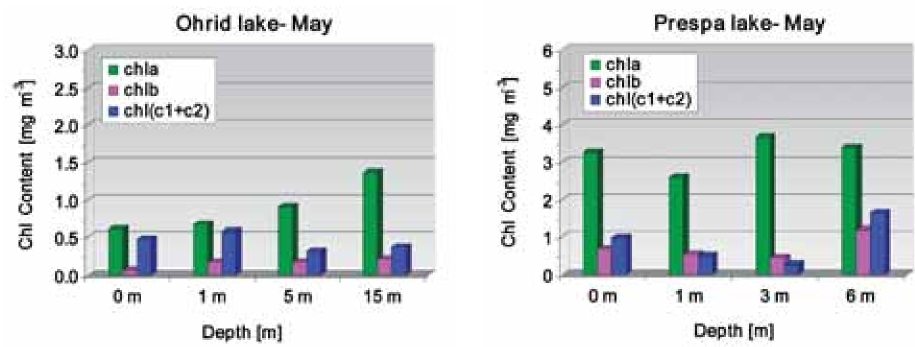


Figure 3 - Variation of content of chlorophyll a, b *and* c *in different depths in Ohrid and Prespa lakes, May 2005 (similar in other months).*

The relative distribution of chlorophylls in the station near the shore of lake Ohrid is different from that of the station in the middle of the lake, showing higher Chl a content, and thus a greater presence of Cyanophyceae in the water and a higher trophic level (Fig. 4). The differen-

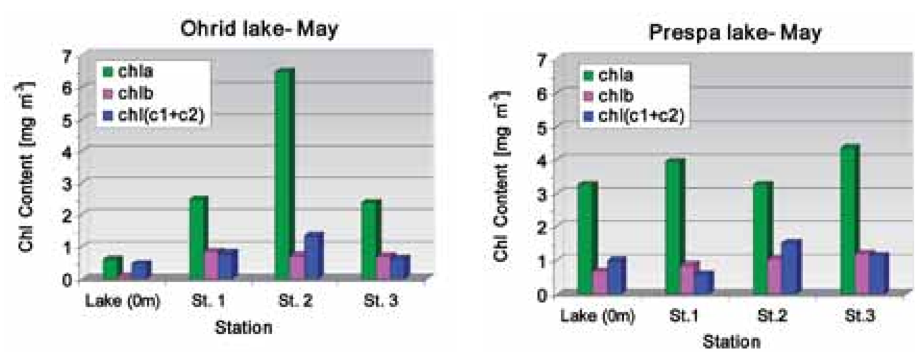


Figure 4 - Variation of content of chlorophyll a, b *and* c *in shore stations of Ohrid and Prespa lakes, May 2005.*

ces between the lake and shore stations in lake Prespa are less marked, showing approximately the same relative content of the three kinds of algae (Fig. 4).

Conclusions

1. The trophic state of the Patok, Kune and Karavasta lagoons is characterized by a low level, evaluated as oligotrophic.
2. The trophic state of the Vilun and Narta lagoons is characterized by a higher level, evaluated as mesotrophic.
3. Based on Chl content, lake Ohrid is characterized by a low trophic state, evaluated as oligotrophic.
4. Based on Chl content, lake Prespa is characterized by a high trophic state, evaluated as mesotrophic.
5. Chl content was highest in March in both lakes, which corresponds to the beginning of the phytoplankton vegetation stage.
6. Vertical profile of Chl content demonstrated different distribution in Ohrid and Prespa lakes.

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3

Regional importance of the fauna of the cross-border River Buna

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Abstract

This paper presents some compiled data on the values of the River Buna, mostly in terms of its fauna. These values are presented here together with the geographical, hydrological and ecological characteristics of the Buna area, emphasizing the regional importance of this area as a migration corridor and biodiversity reserve. Data on several animal groups (molluscs, amphibians, reptiles, fishes, birds and mammals) are given, focusing on the most significant species of regional importance (migratory, rare, endangered) and their most important habitats.

Introduction

The River Buna runs along the Albanian – Montenegrin border. It springs from Lake Shkodra, between the hill of "Rozafa" Castle and Mount Taraboshi and flows towards the Adriatic Sea, with its delta lying between Velipoja (Albania) and Shtoj (Montenegro). The Buna is the only emissary of Lake Shkodra and has a length of 44 km.

The Buna area, including its delta, marshes and Lake Shkodra on both sides, Albanian and Montenegrin, has been evaluated as an important area in terms of biodiversity, due especially to the avifauna and ichthyofauna. These groups have been the subject of several studies, inventories and monitoring. Less is known about the situation of the other animal groups, especially invertebrates.

This paper highlights the importance of the fauna of the area in a regional context, based on the analysis of existing data on biodiversity assessments.

Material and methods

The data on flora, fauna, hydrology and geography were taken from publications and technical reports. The data on invertebrates and the ecological interpretations are the work of the authors.

As well as the publications, data collected from several pro-

Figure 1 - Watershed of the River Buna

jects on the Buna area were investigated (Fig. 1). The main sources of information on the Buna and its surrounding area were the "Report on biodiversity of the River Buna" (Dhora and Beqiraj, 2001), a publication in the framework of the project called "Restoration of regional faunistic role of transboundary River Buna" (APAWA, Kalimera, REC Hungary), implemented in 2000 – 2001, and the project called "Rapid assessment of the ecological value of the Bojana-Buna Delta (Albania/Montenegro)" (EURONATURE, APAWA), implemented in 2003 – 2005 (Fig. 2).

Figure 2 - Photo of the Buna-Drin connection site (Photo Euronature)

Results and discussion

Hydrological importance of the River Buna

The Buna plays an important role within the hydrographic network of Lake Shkodra – River Buna – River Drin – Velipoja Coast. The connection between Lake Shkodra, the Buna and the Drin plays a very important role in terms of hydrological values. This connection determines the hydrologic regime of Lake Shkodra, the River Buna itself, and their tributaries in the catchment area. It also has an important impact on the morphology of the Buna delta in Albania and Montenegro (Dhora *et al.*, 2001). Lake Shkodra serves as a retention basin for surplus waters coming from its mountainous catchment area. On its south-eastern edge, the Buna acts as a drainage channel, evacuating the surplus waters from the lake. In this way the Buna prevents and reduces the risks of heavy flooding of the area around the lake (Dhora and Sokoli, 2000). The Buna plays the same role for the Drin and its catchment area, at least in its lower stretches. Alluvial forests in the Velipoja area, with their marshes and the surface and underground communication of the Buna with a system of marshes and the Viluni Lagoon serve as discharging basins for Buna waters, keeping the water balance and reducing flooding.

Regional importance of the River Buna as a migration corridor

The connection between Lake Shkodra, the River Buna, the River Drin and the river mouth of the combined Buna and Drin rivers in the Adriatic Sea plays a very important role as a migration corridor for aquatic species on a regional scale. So, the Buna-Lake Shkodra connection and the Buna-Drin connection, with one branch of the Drin (Black Drin) from Lake Ohrid and the other branch (White Drin) from Kosova, play the role of a "bridge" between the Adriatic Sea and the hydrographic network of the South-western Balkans (Dhora *et al.*, 2001). This network includes four cross-border lakes: Shkodra, Ohrid, Macro Prespa and Micro Prespa (the Prespa lakes provide water for Lake Ohrid), involving 5 countries: Albania, Montenegro, Kosova, FYROM of Macedonia and Greece. The Buna is thus a very important migration corridor to and from the sea for migratory aquatic animal species of the hydrographic network mentioned above.

Faunistic values of the River Buna

Molluscs (Mollusca) **-** Data on molluscs are based on Dhora *et al.,* 2001 and Beqiraj and Dhora 2001. Molluscs are the most well-known group among the invertebrates of the Buna. The Prosobranchia Theodoxus, Viviparus, Valvata, Bithynia, Holandriana and other species, such as *Dreissena blanci*, *Planorbis planorbis*, and *Stagnicola palustris* are often found among submerged macrophytes. In the marshes and ponds of the Buna, the most common are

Viviparus mamillatus, *Planorbarius corneus*, *Lymnaea stagnalis*, *Stagnicola palustris*, *Radix auricularia* etc. In the shallow waters with little vegetation, *Radix ovata*, *Galba truncatula*, *Physella acuta*, *Planorbis planorbis* etc are more common. Bivalves of the Unionidae family are found mostly in sandy-silt substrates and in the marshes. *Theodoxus fluviatilis* and *Dreissena blanci* are also found on hard objects in water or rocks. It is important to emphasize the fact that three species Unio crassus, Unio elongatus and Microcondylaea compressa are considered to be globally endangered. The Buna estuary is also rich in molluscs. Particularly the malacofauna of the estuary is dominated by bivalves, a result of the abundance of phytoplankton in this area.

Fish (Pisces) **-** Data and assessment of fish populations are taken from Dhora *et al.,* 2001, Beqiraj and Dhora 2001, Rakaj 1996 and Schneider-Jacoby *et al.*, 2005. It is rare for the Mediterranean sub-region, but also on a large scale, that a field river, very short, in the temperate climatic belt, has such a rich ichthyofauna. The Buna is an ideal case, which connects not only the waters, but also the ichthyofauna of some ecosystems of regional importance. Through the Buna 13 species and subspecies of migratory fish pass from Shkodra Lake to the Adriatic Sea and vice-versa: *Lampetra fluviatilis, Lampetra planeri, Petromyzon marinus, Acipenser sturio, Acipenser naccarii, Acipenser stellatus, Alosa falax nilotica, Anguilla anguilla, Dicentrarchus labrax, Mugil cephalus, Liza ramada, Platichthys flesus luscus and Citharus linguatula*. Among these is the sturgeon *Acipenser sturio*, which is a globally endangered species. Another group, with at least 30 species of freshwater fish, populates the Buna. Almost all these species are also found in Lake Shkodra. Almost 70% of the fish species of the river belong to the Cyprinidae family. This fact shows the Mediterranean character of the ichthyofauna of the Buna. Among the most important fish are the carp (*Cyprinus carpio*), the most characteristic fish of the Shkodra area, *Carassius* *auratus gibelio*, imported from Asia to the lake three decades ago, which has already occupied many European waters, *Alburnus alburnus alborella, Scardinus erythrophthalmus scardafa, Leuciscus cephalus albus* and *Perca fluviatilis*, which entered the Buna through the Drin. Also of particular interests is *Pachychilon pictum*, as a local endemic species. In the Buna, there are also fish species which entered through the Drin from the Ohrid and Prespa lakes, such as Barbus meridionalis petenyi, *Alburnoides bipunctatus ohridanus, Chondrostoma nasus ohridanus, Rutilus rubilio rubilio, Rutilus prespensis vukovici, Gobitis taenia ohridana* etc. Another interesting group of fish is that of marine species found in the mouth of the Buna. A huge amount of alluviums is discharged at the river mouth. Substances rich in nitrogen and phosphorus, transported by the Drin and Buna, make the Buna estuary the most productive estuary in the Eastern Adriatic. This is the reason for the abundance of fish, about 50 species, in the river mouth. The most common fish of the Buna estuary are *Lichia amia, Thunnus thynnus thynnus, Argyrosomus regius, Engraulis encrasicholus, Aphanius fasciatus, Syngnathus tenuirostris, Sciaena umbra, Umbrina cirrosa, Diplodus sargus sargus, Lithognathus mormyrus, Symphodus cinereus, Gobius niger, Atherina hepsetus* and *Solea vulgaris.* When assessing the ichthyofauna of the Buna, consideration should also be made of the waters connected to the Buna, such as the Lagoon of Viluni, Lake Shas, Porta Milena, the Marshes of Domën, Murtemza etc.

Amphibians (Amphibia) **-** Data on amphibians are taken from Crnobrnja-Isailovic and Dzukic, 1997; Dhora *et al.,* 2001 and Haxhiu, 2003. The Buna and its surrounding marshes, ponds and channels are ideal habitats for amphibian fauna. This area is characterized by an abundance of amphibians, taking into account the catchment area, too. The predominant species are *Bufo viridis*, *Rana lessonae* and *Rana balcanica*. The list of amphibians of the Buna includes 11 species, but the actual number might be higher. Here there are 3 species of tailed amphibian (Caudata) and 8 tailless species (Anura). Of particular biogeographical importance is the presence of three endemic taxa in the Buna and its drainage basin: *Rana balcanica* is endemic to the Balkans; *Bombina variegata* scabra is endemic subspecies of the Balkans and *Triturus vulgaris graecus* is a sub-endemic subspecies of the Balkans.

Reptilians (Reptilia) **-** Data on reptiles are based on Crnobrnja-Isailovic and Dzukic, 1997; Dhora *et al.,* 2001; Haxhiu, 1998 and Haxhiu, 2003. Three aquatic species of reptile have been reported for the River Buna: *Emys orbicularis, Natrix natrix persa and Natrix tessellata*. Most reptiles in the Buna and its catchment area are terrestrial. 18 reptile species have been reported in the drainage basin of the Buna. The highest density belongs to the genera Lacerta, Elaphe and Coluber. The high diversity of reptiles is favoured by the hot summer temperatures, the diversity of habitats, structural formations of the ground, vegetation which shelters them and the abundance of food. The regional importance of the Buna area for reptiles is evident when evaluations are made on a larger taxonomical and zoogeographical scale. This area is an important reserve for endemic Balkan species: *Podarcis muralis albanica* is a subendemic form of the Balkans; *Telescopus fallax fallax* is an endemic species of the Balkans; *Elaphe quatuorlineata* quatuorlineata is a subendemic subspecies of the Balkans; *Elaphe situla* is also a subendemic species of the Balkans; *Coluber najadum* dahli represents a subspecies of *Coluber najadum*, which is endemic to the Balkans.

Birds (Aves) **-** Data and assessment of birds are based on Beqiraj and Dhora, 2001; Bino, 2003; Dhora *et al.,* 1998; Dhora *et al.,* 2001; Hagemeijer *et al.,* 1994; Kayser *et al.,* 1995; Schneider-Jacoby et al., 2005. Assessment of the avifauna of the Buna should take into consideration the avifauna of the wetland areas around the river and the habitats where birds nest and take shelter. Along the banks of the Buna there is a forest belt, which is an important habitat for birds. Especially in its lower stretches, the Buna is connected to a water complex, including the marshes of the Velipoja Reserve, Murtemza, Domën, Shtoj i Poshtëm, Lake Shas, the Saltpan of Ulcinj and many connecting channels. These areas are rich in trees, reed beds and large-leaf floating plants. These habitats are very rich in wintering, nesting and migratory waterfowl. The total number of individuals counted in winter along the river banks is 8,000, but a much larger area should be considered. In Velipoja, quite close to the Buna, 5,000 individuals were counted. At its other extreme, the Buna is connected to Lake Shkodra. The Buna is an interesting migration corridor through which the avifauna of the wetlands around the lower stretches of the Buna communicate with the avifauna of Lake Shkodra. This lake has a significant capacity as a shelter and nesting site for birds. In its Albanian part about 24,000 individuals were counted and in its Montengerin part 224,000 individuals. The avifauna of this area communicates with that of the Viluni Lagoon, the wetland Complex of Kune-Vain and also with many wetlands connected to the River Drin.

On the river banks and in the surrounding wetlands about 170 bird species have been counted. Half of these are Passeriformes, the rest being mainly Falconiformes and Anseriformes. In the wetland area of Buna over 50 species of waterfowl have been counted, the most abundant being *Tachybaptus ruficollis, Phalacrocorax pygmaeus, Anas penelope, Anas platyrhynchos, Anas clypeata, Anas crecca, Aythya ferina, Bucephala clangula, Fulica atra, Vanellus vanellus,* and *Larus ridibundus*. Referring to the bird counts for the years 1993 and 1995 in the Albanian part of the river, some species are of great importance on the regional scale, despite the low number of individuals. For example, the 19 individuals of Larus miutus counted in the Buna area represent 11% of the total number of this species in the whole Mediterranean. The 51 individuals of *Sterna sandvicensis* represent 85% of the total number of this species in Albania. For other species, such as *Anas* *penelope, Anas clypeata, Bucephala clangula* and *Phalacrocorax pygmeus*, comparing the small area of the Buna valley with the total distribution area of these species, it can be assumed that the individuals counted in Buna represent a high percentage on the global or regional scale. Over 76% of bird species in the Buna valley are migratory. This area has an important biogeographical position. It is an important site in one of the three migratory roads of the birds of Europe, the flyway passing over the Balkans. About 29% of bird species in the Buna valley are nesting species. Nearly half the waterfowl species are included in the lists of birds that are endangered on the local, regional and international scale. Of these, *Aythya nyroca* and *Phalacrocorax pygmeus* are globally threatened species. With its wetland areas, the Buna represents a rare case in Europe in terms of bird biodiversity values, high dynamics and high generative potential.

Mammals (Mammalia) **-** Data on mammals are based on Bego, 2003, Dhora *et al.,* 1998, Dhora *et al.,* 2001, Schneider-Jacoby *et al.,* 2005. The otter (*Lutra lutra*) is a rare aquatic mammal of the Buna River. This globally threatened species has been recorded several times in the Buna over the last few decades. On the two sides of the river, large terrestrial mammals include *Lepus capensis, Vulpes vulpes, Canis aureus, Meles meles, Mustela nivalis, Mustela putorius, Sus scrofa*, the insectivorous *Crocidura leucodon, Crocidura suaveolens, Suncus etruscus*, and *Erinaceus concolor*, as well as the rodents Apodemus, Mus, Pitymys and Microtus. It is interesting to mention the presence of the dolphin *Delphinus delphis* in the mouth of Buna and bottlenose dolphin *Tursiops truncatus*, which has been recorded even in the middle stretches of the river, chasing schools of fish. As well as *Lutra lutra*, other endangered mammals of the Buna area are *Mustela putorius*, *Delphinus delphis* and *Tursiops truncatus*.

Diversity of habitats in the Buna area **-** Description of the habitats is mostly based on Dhora *et al.,* 2001, Schneider-

Jacoby *et al.,* 2005. The Buna area, including the wetland areas connected with the river (Note: Shkodra Lake is excluded from this description) contains a wide variety of habitats, communities and landscapes. They consist of cross-border freshwater ecosystems (lake and river), the Buna delta, the coast (Velipoja), sand dunes, a coastal lagoon (Viluni), floodplain and alluvial forests, alluvial islands, freshwater marshlands, calcareous and karst formations, subterranean waters, artificial ponds, irrigated lands, pastures, arable lands, etc. All these habitats shelter a high diversity of flora and fauna and make the relevant area one of the most diverse and abundant sites in the South Balkans and Adriatic coast.
In the following there is a short description of the most important habitats of the Buna area in Albania and Montenegro.

Forest of Velipoja (Albania) - This is a natural reserve situated between the Buna delta and the Adriatic Sea. In the reserve there are four shallow marshes, provided with water from the Buna. Most of the vegetation of the water is made up of the associations of Phragmites and Typha. In deeper water there are also associations of Nymphaea, hosting the endangered plants *Baldelia ranunculoides, Hydrocharis morsus- ranae* and *Utricularia vulgaris.* The most prominent characteristic of the vegetation of this reserve is the forest. All over the reserve there are areas of Tamarix and various bushes. In the part of the reserve near Buna, there is a mixed, dense forest of Alnus, Ulmus, Cornus, Fraxinus etc.The reserve hosts many species of birds, of which the most abundant are those of genera Aythya, Anas, Fulica, Podiceps, Phalacrocorax, Egretta etc.

Franz Joseph Island (Albania) - This is a sandy island in the Albanian part of the Buna delta, of variable shape and size, about 4.5 ha. In recent years its surface has diminished because of erosion. Among the aquatic macrophytes, the halophytes Phragmites, Typha, *Iris pseudocorus*, *Alisma plantago aquatica* predominate. The island is covered by forest vegetation dominated by Populus and Alnus. In the island several species of wetland birds feed and nest, but, because of the human impact of the last two decades, the former colonies of herons and cormorants have left the island and have moved to more suitable habitats on the Montenegrin side.

Ada Island (Montenegro) - Ada is an island of about 4 km^2, in the Montenegrin part of the Buna delta. This island has some small marshes, whose vegetation is dominated by the associations of *Phragmites australis, Typha angustifolia*, the families Juncaceae and Cyperaceae, as well as species of the genus Iris and Alisma. The most interesting forest vegetation consists of Fraxinus and Alnus. On this island there are also Pinus, Populus and other decorative trees. Among the most abundant birds on the island are *Tachybaptus ruficollis, Aythya ferina, Fulica atra, Phalacrocorax pygmeus, Ardea cinerea, Egretta garzetta, Egretta alba* etc.

Marsh of Domni (Albania) - This marsh is provided with water by the Buna River. In this marsh 60% of the surface is covered by the associations of *Phragmites australis* and *Typha angustifoilia*. The main accompanying species are *Sparganium erectum*, *Schoenoplectus lacustris, Myriophyllum spicatum, Ceratophyllum demersum, Utricularia vulgaris* etc. Here are present endangered and rare species for Albania, such as *Sagittaria sagittifolia*, *Hydrocharis morsus-ranae, Lemna trisulcata, Spirodella polyrhiza, Nymphaea alba*, and in the channels near this marsh, the association of *Trapa natans*. In the shallower water of the marsh are found several species of Charophyceae. There is no forest vegetation in the Domni Marsh. The most common birds of the marsh are *Tachybaptus ruficollis, Phalacrocorax pygmeus, Egretta garzetta, Egretta alba, Gallinago gallinago,* and *Larus* *ridibundus*. The reed beds shelter many passeriformes and falconiformes, of which the most abundant are those of the genus Circus.

Lake Shas (Montenegro) - This is a small lake connected to the Buna through a channel. It is relatively well protected and has rich biodiversity, especially for birds and fish. *Saltpan of Ulcinj (Montenegro)* **-** Although some distance from Buna, this saltpan is connected to freshwater sources, which communicate with the Buna. It is important to emphasize that the ornithofauna of this saltpan communicate with the ornithofauna of all the wetland areas of the Buna and the waters connected to this river. The saltpan of Ulcinj is a very suitable nesting site for many bird species, some of them endangered on a regional scale.
Lagoon of Viluni (Albania) **-** This is a coastal lagoon with an area of 390 ha. In its eastern part it receives a large amount of freshwater from the marshes of the Buna River. This lagoon is known for its abundance of fish (*Anguilla, Mugil, Dicentrarcus* etc) and birds, especially Anas, Fulica, Larus and Charadrius.
Marsh of Murtemza (Albania): this is a small water body, a remnant of the former wetland complex of Domni-Çasi-Pentari-Murtemza and is provided with water by the Buna River. Formerly this complex was well-known for fish, ducks and aquatic vegetation, especially *Nymphaea alba* and *Phragmites australis*. Of this system only one marsh remains, which can be still considered a small lake with interesting biodiversity.

Conclusions

The River Buna plays an important role on the regional scale within the hydrographic network of Lake Shkodra-River Buna - Velipoja Coast. In terms of hydrology, the Buna plays a very important role in the regime of Lake Shkodra, the River Drin, their tributaries in the drainage basin and the Buna delta in Albania and Montenegro. In terms ofbiodiversity, the Buna and its surrounding wetland area is an important natural reserve, as a site with high potential for nesting and sheltering of many animal groups.

The most important feature of the Buna River is its role as a migration corridor for aquatic animals between the Adriatic Sea and the hydrographic network of the south-western Balkans, as well as for the avifauna of the wetland areas around the river and Shkodra Lake. An inventory and continuous monitoring of the most important habitats of the Buna area and its wildlife is needed, in order to make a full assessment of their values and importance on a regional scale.

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Assessment of the environmental situation of Albanian rivers based on physico-chemical analyses

4

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Abstract

Water quality parameters and heavy metal levels were monitored during 2002–2004 on eight campaigns along the most impacted rivers of the Albanian Adriatic lowlands: the Mati with its tributary Fani, Ishmi with its tributaries Lana and Tirana, the Shkumbini, and the Semani with its tributaries Gjanica and Osumi (Fig. 1). Water samples were analysed for general physico-chemical parameters, concentrations of nutrients, and levels of heavy metals (Pb, Cd, Cu, Zn, Fe, Mn, Cr, Ni, Hg). Several sediments and biota (algae) samples were analysed for heavy metals, too. Assessment of environmental quality of waters is based on two "quality standards": the classification of the Norwegian Institute for Water Research (NIVA 1997) [4] and the European Community Directive (EEC/EEAC/EC 78/659) on "Quality of fresh waters supporting fish life" [5]. Obtained data have been reported recently [1,2,3].

The most critical chemical parameters for nearly all studied rivers found: (a) Total suspended solids (TSS) in excess of 25 mg/L in many sampling points, due to the intensive erosion of the land; (b) High nutrient concentrations in rivers near big towns. Very low dissolved oxygen (eutrophication) was found in the river Ishmi near Tirana city and the river Semani near Fieri city, caused by the discharges of untreated sewage wastewaters. The most polluted rivers for nearly all parameters were the Lana (tributary of the Ishmi) and the Gjanica (tributary of Semani). The conclusions from the chemical analyses are very similar to those found in a parallel study of biological parameters for diatoms in the framework of this study.

Systematic monitoring programs are urgently needed to understand the present environmental state of Albanian rivers and other aquatic ecosystems to characterize the main sources of pollution and to lay the basis for political guidelines to improve the ecological situation.

Introduction

Albania is rich in water resources including lakes, rivers, springs, and lagoons, with a high quantity of available water. The Albanian territory covers about 65% of a total watershed area of 43,905 km^2. More than 152 torrents and small rivers finally form the eight large rivers: Buna (41 km), Drini (285 km), Mati (115 km), Ishmi (74 km), Erzeni (109 km), Shkumbini (181 km), Semani (281 km), and Vjosa (272 km), which run southeast to northwest towards the Adriatic coast [7]. Albanian rivers are characterized by a high flow rate: the total annual mean flow is 1,308 m^3 s^{-1}, which corresponds to an annual water volume of 42.25x109 m^3 of which 30% belongs to subterranean waters. This accounts for more than 13,000 m^3 per capita per year [6]. The rivers, fed mainly by precipitation (69%), show a typical Mediterranean regime, with seasonal variation in the flow rate, and high flow from October to May [7].

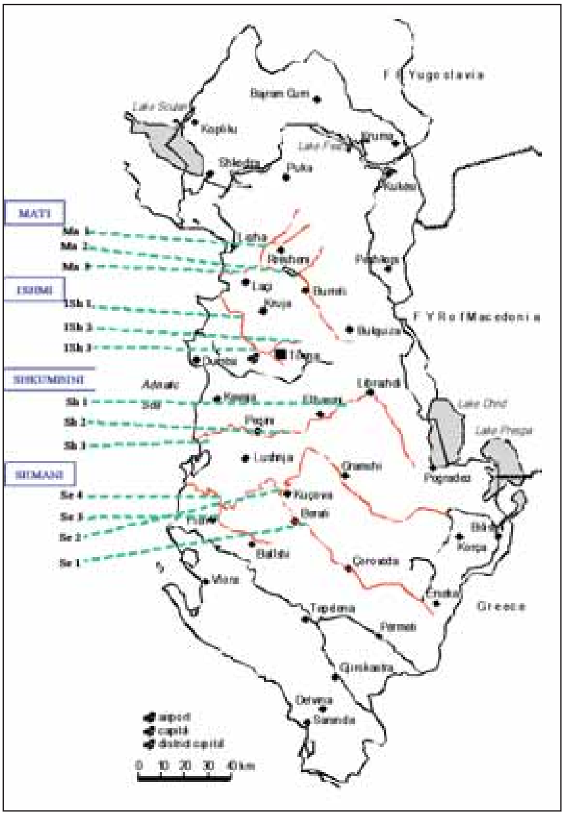

Figure 1 - Map of Albania and monitored rivers

The transformation of the Albanian economy into an open market during the past decade has caused significant damage to the natural resources of the country, mainly to natural waters, especially the most exposed and unprotected ones. The situation is especially dramatic in the Albanian western lowlands through which most of the rivers pass. This region has become heavily populated and most urban and industrial waste is discharged directly into the rivers. Many current environmental problems are directly or indirectly linked to aquatic ecosystems, including urban and industrial waste management, water pollution or land erosion. Neither liquid nor solid waste is controlled, nor are samples taken regularly of surface and ground waters [8, 10].

During the past decades, mining, enrichment and metallurgy industries have produced high quantities of solid or liquid waste, often dumped on riverbanks or directly into rivers. Forest mismanagement has given rise to erosion, another increasing problem. The WB report (1997) confirmed that from 1950 to 1995, the naturally forested area in Albania decreased from 46% to 35%. Erosion is not only favored by the mountainous relief and climate, but also by unsuitable human activities [9].

In this study, water quality parameters (pH, electrical conductivity, dissolved matter, dissolved oxygen, total suspended solids and nutrients) were monitored in 13 stations along the various rivers. The level of heavy metals (Pb, Cd, Cu, Zn, Mn, Fe, Cr, Ni, and Hg) were measured in water, sediment and algae. Microscopic algae (diatoms Bacillariophyta) were also examined. The trophic state was calculated from chemical and biological data. A complete report is published by Miho *et al.* [2].

Material and methods

Sampling

The sampling stations (13) are shown in figure 1. The stations present various levels of human impact, from near river sources (the least polluted) to near outfall. Eight sampling campaigns were carried out at intervals of 3 to 5 months between May 2002 and March 2004. Sampling was implemented according to standard operation methods [11, 12]

Methods of chemical analysis

All analytical methods used are standard ones, recommended by APHA [11], EN/ISO standards [12] and European Community Directives [5]. Temperature, pH, conductivity, TDS and DO were measured directly using Hach multiparameter apparatus (Sension 156), TSS was determined after filtering through a 0.45 μm glass membrane filter; DO was measured by the Winkler method. All nutrients were determined by spectrophotometry using a Shimadzu 2401 UV-VIS Spectrophotometer. Heavy metals in the water were determined by Atomic Absorption Spectrometry: Cu, Pb, Cd, Ni, Cr, Mn by Graphite furnace, Fe, Zn, Mn by the flame technique and Hg by CV-AAS.

Quality assurance

Quality control was implemented by use of SRM and the standard additions method.

Results

General data for physico-chemical parameters and levels of nutrients and heavy metals in water are presented in tables 1, 2, 3, 4 and 5. Detailed data for each campaign are reported in [2].

Table 1 - Physico-chemical parameters of water samples
Median; 10% Percentile; 90% Percentile

River	PH			Conductivity, µS/cm			TSS, mg/L			DO, mg/L		
	Mean	10%	90%	Mean	10%	90%	Mean	10%	90%	Mean	10%	90%
Mati	8.01	7.78	8.46	261	100	302	38	19	76	9.03	8.1	11.3
Ishmi	7.7	7.41	8.3	550	365	694	89.3	47.3	128	4.04	0.5	9.6
Shkumbin	8.1	7.8	8.46	316	226	412	78.4	45.6	328	9.47	7.9	11.1
Semani	8.01	7.59	8.4	437	230	814	108.9	46.4	351	8.02	2.06	9.3

Table 2 - Nutrient levels in river waters

River	$N\text{-}NO_3$(mg/L)			$N\text{-}NO_2$(µg/L)			$N\text{-}NH_4$(mg/L)			$P\text{-}PO_4$(µg/L)		
	Mean	10%	90%	Mean	10%	90%	Mean	10%	90%	Mean	10%	90%
Mati	0.51	0.21	0.88	13.6	3	30	0.14	0.05	0.39	5.0	3.0	9.0
Ishmi	1.12	0.41	1.57	278.5	7	830	6.64	0.09	13.0	417	5	950
Shkumbin	1.44	0.57	1.85	41.5	4	80	0.24	0.08	0.54	25.5	4.0	28
Semani	1.26	0.31	1.41	108.3	6	136	1.84	0.07	1.70	43.8	4.0	120

Table 3 - Maximum values for heavy metals in river waters (in µg/L except Fe in mg/L)

River	Pb	Cd	Cu	Zn	Ni	Cr	Mn	Fe	Hg
Mati	3.6	1.2	3.7	40	3.5	4.3	60	0.09	0.11
Ishmi	2.9	2.9	9.8	30	7.9	5.2	260	1.05	0.15
Shkumbin	2.5	0.8	3.2	20	13.1	7.6	190	1.37	0.11
Semani	2.9	3.2	2.7	20	16.8	10.0	110	0.83	0.21

Table 4 - Values ranges for heavy metal concentrations in river sediments (in mg/kg DW, except Fe in g/kg DW)

River		Pb	Cd	Cu	Zn	Ni	Cr	Mn	Fe	Hg
Mati	Min.	1.5	← 0.02	96.5	33.7	103	184	577	3.32	0.12
	Max.	10.8	0.13	575	98.4	194	584	1627	4.43	0.28
Ishmi	Min.	2.94	0.03	106	32.8	73.3	86.6	273	2.21	0.12
	Max.	16.4	0.15	223	133	162	214	1165	3.98	0.20
Shkumbin	Min.	1.9	0.03	41.5	20	181	195	533	3.21	0.08
	Max.	13.6	0.11	163	75	328	504	1079	4.21	0.16
Semani	Min.	1.03	0.02	38.4	17.9	131	101	556	2.37	0.08
	Max.	9.46	0.06	144	47.4	289	429	990	3.82	0.17

Table 5 - Maximum heavy metal concentrations in Chladophora algae (in mg/kg DW, except Hg in μg/kg)

River	Pb	Cd	Cu	Zn	Ni	Cr	Mn	Fe	Hg
Mati	3.6	1.2	3.7	40	3.5	4.3	60	0.09	0.11
Ishmi	2.9	2.9	9.8	30	7.9	5.2	260	1.05	0.15
Shkumbin	2.5	0.8	3.2	20	13.1	7.6	190	1.37	0.11
Semani	2.9	3.2	2.7	20	16.8	10.0	110	0.83	0.21

Discussions

Assessment of the environmental quality of waters is based on two "quality standards": the Classification of the Norwegian Institute for Water Research (NIVA 1997) [4], and the European Community Directive (CEE/CEEA/CE 78/659) regarding "Quality of fresh waters supporting fish life" [5]. The NIVA classification is more complete, because it is based not only on the levels of the usual physico-chemical parameters and nutrients, but also on the content of heavy metals in water, sediments and fish. Under this scheme, natural freshwater bodies are classified into five quality status levels, from very good (class 1) to very bad (class 5).

(a) Physico-chemical parameters of waters (Tab. 1)

There is no problem concerning the pH values of the studied rivers: all data are between 6 and 9 (the limits of the EU Directive), and higher than the level for the best quality class of the NIVA classification (pH=6.5). There are no limits for conductivity in watercourses, but relatively higher values were observed in the Semani and the Ishmi, indicating higher content of dissolved substances in their waters.

Solid matter (TSS) in all the studied rivers is really a crucial problem. Median and mean levels of TSS in all rivers exceed limits. Only about 4% of all our samples had TSS levels below 25 mg/L, the guide limit of the EU Directive, and all results were much higher than 10 mg/L, the limit for class 5 (very bad) according to the NIVA classification. Particularly high TSS values were recorded on the Semani (max. 436 mg/L) and the Shkumbini (max. 521 mg/L). The primary cause is soil erosion, caused by several natural factors, geographical (average slope of all territory is more than 27%), pedological, climatic (rainfall 1800-2300 mm/year) and hydrological, and some human factors such as deforestation, poor maintenance of the hillside terraces, etc.). Some studies estimate erosion at 20 tons/ha/year or 1.6 mm soil layer on average, and about 60 million tons of solid particles are discharged into the sea every year [13].

Dissolved oxygen (DO) is a very important quality parameter indicating the “health” of the water environment. A critical situation was observed at the two last stations of the Ishmi and Semani (most of the values were below 2 mg/L, which means “very bad” status according to the NIVA classes). Untreated sewage discharged from the cities of Tirana (700,000 inhabitants) and Fieri (60,000 inhabitants) leads to rapid and severe deoxygenating of the water and hence to the disappearance of aquatic invertebrates, "killing" the rivers in these sites. For the other rivers (sites), the situation is relatively good, in the 2nd or even 1st quality class according to the NIVA classification, and meeting the norms of the EU Directive. The same conclusions derive from the oxygen saturation of waters (data not shown).

(b) Nutrient levels in river water (Tab.2)

Most of our rivers have “bad” or “very bad” status according to the NIVA classification. This means that there is distinct pollution from nitrogen compounds, largely due to agricultural activities and runoff from soil pollution. The mean value of all our data is 1.1

mg/L $N\text{-}NO_3$, less than half the mean concentration of 2.63 mg/L for 654 river stations in Europe [6]. The best situation is seen in the river Mati, with nitrate levels about half those of other rivers.

The presence of nitrite is an indicator of sewage pollution of waters, but there are no limits for nitrite content in fresh waters. Very high levels were observed especially in the two last sampling stations of the Ishmi and the Mati, caused by sewage discharges from large towns.

Except the river Mati (average concentration 0.144 mg/L) all rivers exceed the ammonium limit of 0.16 mg/L $N\text{-}NH_4$ of the EU Directive for cyprinid waters. The mean value of all our samples is 1.84 mg/L, nearly three times higher than the average concentration of 0.66 mg/L reported for 580 European river stations [6]. The main contribution to this is from the rivers Ishmi and Semani, particularly their tributaries, respectively Lana and Gjanica. The former collects urban effluent from Tirana, including untreated sewage, and the latter collects urban discharges from the city of Fieri and a large oil refinery and oilfield. It is well-known that levels as high as 1 to 5 mg N/L when converted to ammonia may be very toxic to fish and other river fauna. This is the case of the Lana (av. 14.1 and max. 32.7 mg/L) and Gjanica (av. 2.2 and max. 4.3 mg N/L).

Generally, the majority of phosphate measurements are very low, much lower than the limit of 65.3 μg/L $P\text{-}PO_4$ of the EU Directive for salmonid waters. Important exceptions are the Ishmi and Gjanica (tributary of Semani), which are heavily polluted by urban effluent. Especially low phosphate concentrations were found in samples from the Mati due to the limited human activity (including agriculture). According to the NIVA classification, most of our rivers belong to quality class 3 or 4, whereas the Ishmi and Gjanica are in class 5 ("very bad").

(c) Heavy metals in water

General assessment of the state of HM pollution of rivers is difficult, primarily because measurement of metals is rarely included in monitoring programmes, but also because concentration levels are usually so low that problems arise with sample preparation and the precision of analytical results. Comparison and assessment of the state of HM in rivers is therefore more difficult than for most of the other water quality variables. The following evaluation of HM in rivers must be looked at with these reservations in mind.

Based on the NIVA classification, nearly all our data relative to HM levels belong to quality class 2 ("moderately polluted"). Relatively higher HM content was found in samples collected in the Lana and Gjanica, which are "markedly polluted" (class 3) with Pb, Cd and Cu. No evident pollution was observed in the waters of the Mati and Shkumbini.

(d) Heavy metals in sediments and algae

It is relatively easy to determine HM content in sediments and algae compared to water, but it is very difficult to use the data for environmental quality assessment. Total metal content in sediments does not reflect the bioavailable fraction, and it is not possible to find everywhere the same species of alga and in a similar biological state. For this reason, the evaluation of HM levels in sediments and the biota is only very rarely included in river monitoring programs of.

Our evaluation of HM in sediments is based on the NIVA classification [4]. The majority of our data place our rivers in the 1st ("slightly polluted") and 2nd ("moderately polluted") quality classes, belonging to the "high diffuse background level". Relatively high concentrations of copper in the sediments and algae of the river Mati reflect the natural pollution from copper-containing minerals found in this area and also pollution from dumping of solid wastes from mines and former metallurgical plants.

(e) Assessment of environmental quality

The environmental quality of the rivers studied is assessed in two ways: (i) based on chemical data, and (ii) based on biological data for diatoms.

An environmental quality evaluation for each river station was performed, calculating the "average" quality class using mean concentrations of four nutrients, three physico-chemical parameters (pH, TSS and DO) and seven HMs (maximum content) in water samples by using the formula:

Average class=Σ(Quality class)/no. of parameters

Results are presented in table 6.

Table 6 - Quality evaluation of rivers according to the NIVA classification

River	*Station*	*Evaluation based on*			
		Physico-chemical parameters		*Heavy metal concentrations*	
		Av. class	*Evaluation*	*Av. class*	*Evaluation*
Mati	Ma 1	2.0	Good	2.2	moderately polluted
	Ma 2	2.2	Good-Fair	2.7	moderately polluted
	Ma 3	2.3	Good-Fair	2.2	moderately polluted
Ishmi	Ish 1	2.7	Good-Fair	3.1	markedly polluted
	Ish 2	4.5	Bad-Very Bad	3.4	markedly polluted
	Ish 3	4.2	Bad-Very Bad	3.4	markedly polluted
Shkumbini	Sh 1	2.7	Good-Fair	3.0	markedly polluted
	Sh 2	2.8	Good-Fair	3.0	markedly polluted
	Sh 3	2.7	Good-Fair	2.9	moderately polluted
Semani	Se 1	2.2	Good-Fair	2.6	moderately polluted
	Se 2	2.5	Good-Fair	3.0	markedly polluted
	Se 3	4.3	Bad-Very Bad	3.6	markedly polluted
	Se 4	3.0	Fair	3.1	markedly polluted

Conclusions

1) The most critical general physico-chemical parameters for the studied rivers are:
   - total particulate content (TSS) exceeds all environmental limits in all rivers, caused by very high erosion rates;
   - very low dissolved oxygen concentration in some stations of the Ishmi and Semani, caused by discharge of untreated liquid urban waste from big cities (Tirana and Fieri).

2) Levels of nutrients are relatively high in most rivers, especially near the inhabited areas, caused mostly by urban waste and agricultural effluent.
3) Heavy metals content in the water is relatively low and generally does not present a threat to the biota.
4) The chemical and biological data support the evaluation of the trophic state of our rivers in various stations, as presented in table 6. The situation is critical for the two last stations of the Ishmi and Semani. The main cause is discharge of untreated sewage from large towns.
5) Eutrophication of the rivers may strongly influence their deltas, nearby lagoons (Patoku and Karavasta) and the Eastern Adriatic seacoast.

In summary, Albania is in a lucky situation to have so many water resources, but the responsibility to protect and use them properly must be taken extremely seriously, because the present state of water pollution in Albania is a real risk for the economy and human health. Taking the appropriate measures in important and sensitive watershed areas will help to prevent further damage to biodiversity and humans, and will help regain the original beauty of the landscape. The Albanian territory is also important for the supply of water to the Eastern Adriatic coast. Sustainable watershed management guarantees the fulfillment of these tasks on regional and international levels.

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The environmental state of important aquatic habitats in Albania based on algal assessment - a review

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Abstract

Albania is rich in aquatic resources with high natural and biological values. Nevertheless, the waters still continue to be endangered, especially in western Adriatic Lowland areas. The structure of microscopic algae may give a better idea of water quality than traditional indicators. Systematic control of water quality will help to develop new strategies of wastewater management. It will allow Albania to reach international standards in environmental protection.

Keywords: Albanian waters, microscopic algae, biomonitoring, eutrophication, trophic index, saprobic index.

Introduction

Albania possesses many water resources with high natural and biological values, i.e. the Ohrid, Prespa and Shkodra lakes, glacial lakes, river valleys, coastal lagoons, etc. An overview of aquatic ecosystems and the related human impact is given by Cullaj *et al.* (2005) and by UNEP (2000). The water resources still continue to be endangered, especially the in western Adriatic Lowland areas through which most of the rivers run, and where the most densely inhabited and industrial areas lie, together with the areas most affected by intense agriculture and tourism.

The microscopic structure of periphyton or phytoplankton may give a better idea of water quality than the traditional chemical approach. The biological communities summarize the response of the biota to a range of pollutants occurring in waters over time (Sládeãek, 1986; Hofmann, 1994; Rott *et al.*, 1997; 1999; Passy and Bode, 2004).

After the 1990s, Albanian experts started to consider biological data as an important tool to evaluate the quality of waters, in rivers (Cake 1996; Miho *et al.*, 2005a and b; Kupe, 2006), lakes (Miho and Lange-Bertalot, 2001; 2003; Rakaj, 2002) and lagoons (Miho, 1994; Miho and Mitrushi, 1999; Dedej, 2006). A review of the most important aspects of these studies is reported here, focusing on the water quality of the related habitats, also highlighting diatom-based monitoring as a new experience in Albania.

Materials and methods

The biological studies of water quality cover almost the most representative habitats, as shown in the map in figure 1. They started with the study of macrophyte algae along the coast by Kashta (1986). The phytoplankton of Butrinti lagoon was studied during the period 1987-1991 (Miho, 1994); net and/or bottle samples in

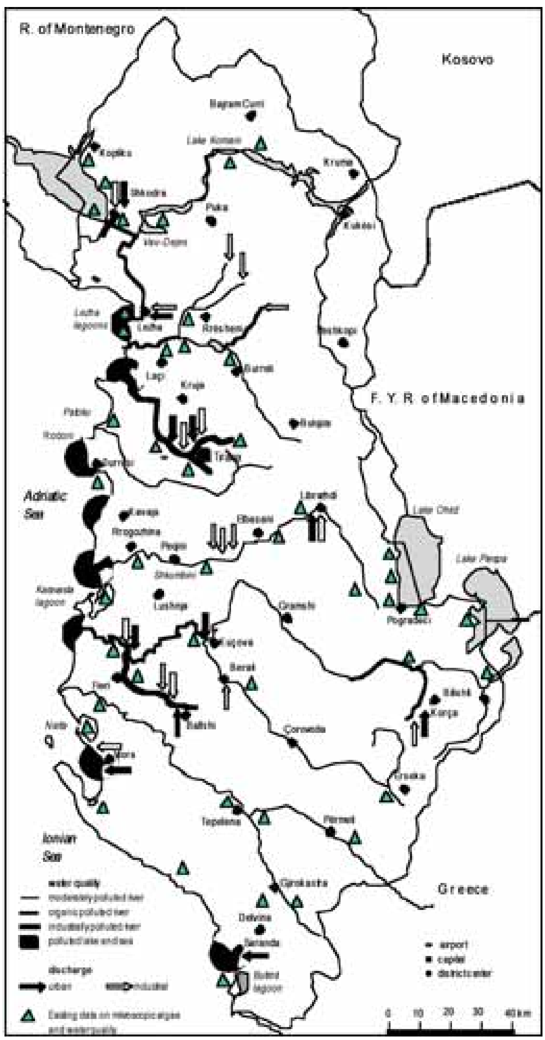

Figure 1 - Hydrological map of Albania showing pollution sources as described by UNEP (2000), modified by Miho et al. (2005b). The aquatic habitats for which data on microscopic algae and water quality are available are shown with a triangle.

six stations in the lagoon and the sea were examined. Other sporadic studies continued along the coast (Miho and Mitrushi, 1999; Dedej, 2006), covering the period 1987-2005, and almost all the important lagoons, including Butrinti, Narta, Lezha (Ceka and Merxhani) and Karavasta. Meanwhile, other studies in lagoons still continue (Miho and Xhulaj, 2005).

During sporadic campaigns in the period 1993-2000, littoral benthic and plankton samples were evaluated in the Albanian part of the cross-border lakes of Ohrid (Driloni, Tushemishti, Pogradeci, Guri-Kuq, Lini) and Prespa (Macro and Micro Prespas) (Miho and Lange-Bertalot, 2003). In July 1993, net samples were collected from 15 glacial lakes of Lura, Ballgjaj and Dhoksi, situated in the mountainous central part of Albania (over 1500-1700 m a.s.l.). Rakaj (2002) reports data on the phytoplankton of Lake Shkodra (Albanian part). Net plankton samples were collected in 8 stations (Zogaj, Shirokë, Peshkimi, Bishti-Qenisë, Grizhë, Stërbeq, Kamicë, Shegan), during the period 1997-99. The fish of the River Shkumbini were studied by Cake (1996), in the period 1988-93. In addition, the digestive apparatus of barbells (*Barbus meridionalis*) was used to evaluate the diatoms and trophic level of different stretches of the river (Miho *et al.*, 2005a). The first attempt to extend biomonitoring in Albania to assess water quality based on benthic diatoms was carried out during the period May 2002 - March 2004 (Miho *et al.*, 2005b; Kupe, 2006). Seven trips, in 13 stations in the most impacted rivers of the Adriatic Lowlands: the Mati (Shkopeti, Miloti), with its tributary Fani (Rubiku); the Ishmi (Fushe-Kruja), with its tributaries Tirana (Brari) and Lana (Kashari); the Shkumbini (Labinoti, Paperi, Rrogozhina); the Semani (Mbrostari) with its tributary Gjanica (Fieri); and the Osumi (Berati, Ura-Vajgurore). It involved cooperation of the sections of Analytical Chemistry and Botany of Tirana University, and the Department of Agronomy, Tirana

Agricultural University, under the qualified assistance of experts from the Institute of Plant Biology, Institute of Environmental Sciences and the Limnological Station, University of Zurich, supported by the Swiss National Foundation for Research, within the joint project called SCOPES: Scientific Co-operation between Eastern Europe and Switzerland.

The study, performed through the SCOPES Program, was intended firstly to assess heavy metals (Pb, Cd, Cu, Zn, Mn, Fe, Cr, Ni and Hg) in waters, sediments and algae from the most impacted rivers of the Adriatic Lowlands. Additional parameters were measured, including conductivity, dissolved matter, pH, temperature, oxygen, suspended solids, nitrates, nitrites, ammonium and phosphates. Moreover, microscopic algae (diatoms - *Bacillariophyta*) were examined, and the trophic state and saprobic state were calculated. More information is given in Cullaj *et al.* (2003; 2005), Miho *et al.* (2005b; 2006), Miho and Kupe (2005), Kupe (2006) and on the website of the Faculty of Natural Sciences, UT: www.fshn.edu.al.

Generally, the periphyton was sampled often by scrubbing the top surface of selected rocks, or collection of thalli of *Cladophora*, or other submersed biota. Samples were often preserved in 4% formaldehyde or in Lugol. Diatom frustules were cleaned from organic and inorganic materials by boiling in HClcc, followed by boiling in H_2SO_4cc, adding a few crystals of KNO_3. Permanent slides were prepared using Naphrax as a medium. In a diatom-based approach, more than 400 valves were counted. Identification of diatoms, as well other steps, were based mainly on Krammer and Lange-Bertalot (1986-2001). The trophic diatom index (TI_{DIA}) and saprobic index (SI) for the diatoms were calculated using the formula of Zelinka and Marvan (1961). Trophic classes were based on Rott *et al.*, 1997; 1999). Often the diversity index of Shannon and Weaver (1949) was also calculated.

Results and discussions

Studies on Albanian algae started only after the 1990s, by the working groups in Tirana University and other universities (Shkodra, Elbasani) or research institutions.

The most complete study of macrophyte algae along the coast was carried out by Kashta (1986), which is also a taxonomic and ecological work. About 136 species were described along the coast and its wetlands, where species from *Rhodophyta* were dominant. About 70% of species were found on rocky substrates, most of them on the Ionian coast, including 8 species of Cystoseira, as well as *Padina pavonica, Acetabularia acetabulum, Laurenzia obtusa, Corallina elongata, Haliomeda tune, Cladophora proliphera*, etc. The sandy substrate of the infra-littoral, mainly along the Adriatic, was inhabited by the seagrasses, *Posidonia oceanica* and *Cymodocea nodosa*, together with *Caulerpa proliphera*, *Bangia fuscopurpurea, Nemalion heminthoides, Porphyra leucosticte*, etc. In a recent study of the distribution of *Posidonia oceanica* along the Albanian coast, Kashta *et al.* (2005) confirm that habitats of this sensitive seagrass (endemic to the Mediterranean Sea) are seriously disturbed along the Adriatic. It is almost absent from Velipoja to Rodoni Promontory, and from Durresi to Vlora, probably as a consequence of the impact from the Buna, Drini, Mati and Ishmi rivers, in the former stretch, and the Semani and Vjosa rivers, in the latter. In those zones, *Posidonia* seems to be substituted by the other marine grass, *Cymodocea nodosa*, considered less tolerant of ecological factors and substrate, but which never grows in dense meadows.

Nevertheless, the Albanian coast still conserves interesting and important wetlands, characterized by a high diversity of microscopic algae. About 440 taxa of diatoms were already known in different coastal habitats, where Butrinti, Armura, Karavasta, Lalzi and Merxhani are particularly important (Miho and Witkowski, 2005; Dedej, 2006). Butrinti (Fig. 2) contains typically meromictic habitats; therefore, phytobenthos only grows intensively in limited areas of the shorelines, dominated by *Enteromorpha* prolifera (Miho, 1994). The rest of the bottom is anaerobic, characterized by strong sedimentation of organisms in decomposition. According to Miho (1994), the phytoplankton of the upper layers (up to 5-7 m of depth) is the main primary producer. However, this is dominated (often more than 90%) by one or two species of centrics: *Ch. cf. wighamii* and *Cyclotella cf. choctawhatcheeana*. The phytoplankton showed seasonal dynamics, with a high peak in spring and another lower one in autumn. The decrease in phytoplankton in summer was accompanied by a relative increase of peridinieae. During April-June 1987, an abnormal bloom was observed: *Pseudonitzschia seriata* followed by *Prorocentrum micans* and *P. minimum*, the last one mentioned as toxic.

In the period 1992-93, about 75 species of diatoms were found in the Orikumi wetland, where pennatae dominate (Dedej, 2006). Here too, centrics of *Chaetoceros* and *Cyclotella* were abundant, with a similar structure as in Butrinti, but with lower quantity; peridinieae increased during summer, too. Miho and Mitrushi (1999), in July 1996 observed relatively high diversity of microscopic algae in Merxhani lagoon (Lezha). In Ceka, an algal bloom was observed, dominated by *Nitzschia reversa*, *Peridinium spp.*, *Goniaulax monacantha* and

Figure 2 - View of Butrinti lagoon (Saranda) (Photo: L. Shuka)

Prorocentrum minimum. In Kenalla, a relatively deep pond, close to the shallow lagoon of Merxhani, a centric diatom, *Chaetoceros muelleri* was found to be very abundant. There were also abundant filamentous colonies of blue-green algae, i.e. *Anabaenopsis circularis*, Oscillatoria sp. and a small peridinieae, Gimnodinium sp. Other preliminary examinations were also carried out in other Albanian wetlands, i.e. Karavasta, Patoku, Viluni, Butrinti, Armura, Saranda and Durresi harbours; more detailed discussion from the ecological point of view is given in Dedej (2006). High species diversity was observed in Armura, Butrinti and Karavasta. In November 2004, blooming of filamentous cyanobacteria were observed in Narta lagoon, close to the wastewater discharge from Narta village (Miho and Xhulaj, 2005).

Rakaj (2002) gives data on the phytoplankton of Shkodra Lake (Albanian part) (Fig. 3). About 468 species of microscopic algae were reported, the areas of Kamica and Shegani (Kopliku) having the highest diversity. Generally, the phytoplankton was dominated by oligo-mesotraphentic species, i.e. *Cyclotella ocellata, Asterionella formosa, Fragilaria capucina,* etc, often accompanied by tolerant or eutraphentic species, such as *Fragilaria ulna, F. construens, Gyomphonema acuminata, Navicula capitatoradiata, N. reichardtiana var. crassa, N. trivialis, N. cryptotenella, N. menisculus var. grunowii, Nitzschia*

Figure 3 - Sunset in Shiroka, Shkodra Lake. (Photo: L. Shuka)

recta, etc. The density of eutraphentic species increases during summer, as seen in the Buna outflow and along the western shoreline of the lake (Shiroka and Zogaj).
More than 430 species diatoms were found in 15 glacial lakes of Lura, Ballgjaj and Dhoksi, where more than 100 belong to the red list of Europe (Miho and Lange-Bertalot, 2001). The most common species were *Cyclotella cyclopuncta, Achnanthes minutissima gr., Cymbella sylesiaca, C. cesatii, C. microcephala fo. minores, Fragilaria construens, F. nanana, Nitzschia denticula* etc. The Lura lakes represent rare habitats, where Lake Flowers can be distinguished; about 200 species of diatoms were found in one sample only. They are mostly oligotraphentic species, dominated by *A. minutissima* (fo. *gracillima*) and *C. cesatii*, characteristic of very clean waters with scarce nutrients. Allamani Lake can be also considered interesting in that it contains rare and even new species. New species for science have already been described by Miho and Krammer and Miho and Lange-Bertalot, including *Cymbella (Cymbopleura) albanica, C. lura, C. lata var. lura, Navicula pseudoppugnata* (Lange-Bertalot, 2001; Krammer, 2003). Still others are of taxonomic interest, too, e.g. *Geissleria sp., Sellaphora sp.,* etc. Lake Black in the Dhoksi region is distinguished not only by its interesting floristic values but also by its special and attractive drainage basin.
Microscopic algae are also interesting in Lake Ohrid. More than 350 diatoms were found in littoral samples in the Albanian part of Lake Ohrid (Miho and Lange-Bertalot, 2003). About 1/4 of taxa are rare or endemic. More than 15 taxa are considered interesting or new for science. Six of them, *Aneumastus albanicus, A. rosettae, A. humboltianus, Navicula pseudoppugnata, N. parahasta and N. hastatula*, were described by Lange-Bertalot and Miho as new taxa (Lange-Bertalot, 2001). Miho and Lange-Bertalot (2005), in a recent publication related to the diversity of the genus Placoneis in Lake Ohrid, describe two additional new

species: *Placoneis juriljii* and *Placoneis neoexigua.*

Most of the species observed in Ohrid were oligotraphentic, growing only in clean waters with quite low nutrients. However, in littoral habitats, especially nearby Pogradeci town, tolerant species that dominate in eutrophic waters were observed. Some poly-hypertrophic species of diatoms and high presence of *Cyanophytes* were also observed in plankton samples. The trophic diatom index varied from 1.5 to 2.5, changing from oligo-mesotrophic to eutrophic, showing worse water quality near the shore than in the deeper waters. The worst state was in Driloni, a sensitive spring wetland, where the trophic value was very high (2.5, eutrophic), probably caused by the high nutrient loading from urban settlements and agriculture (Miho and Lange-Bertalot, 2003).

Cake (1996) evaluates the distribution of fish along the Shkumbini River; about 17 fish species were reported, *Cyprinids* being dominant. The upper and middle mountainous flow was richer, mainly with *Alburnus bipunctatus, Barbus meridionalis* and *Nemachilus barbatulus ssp. sturanyi.* Barbell (*B. meridionalis ssp. peteny*) and mountain trout (*Salmo trutta ssp. macrostigma*) were found only in the upper part, showing a good natural state. Fish were scarce downstream of Elbasani Town; before 1992, especially in nearby Paperi, fish were almost absent, due to waste discharge from the industrial complex in Elbasani plain; a slight increase in fish species was observed after summer 1992, the period when the steelworks was closed. During this study, the digestive apparatus of barbells (*Barbus meridionalis*) from different parts of the Shkumbini (Fig. 4) was studied to assess the diatoms. Miho et al. (2005a) report more than 95 species of diatoms (mainly pennatae), mostly of benthic origin. The most common and abundant species were: *Diatoma moniliformis* (up to 84%: Paperi and Proptishti), *Achnanthes minutissima, Fragilaria capucina, Fragilaria ulna*, etc. TIDIA varied from 1.6 (mesotrophic) to 3.4 (polytrophic). High trophic values were found

Figure 4 - Shkumbini River in Labinot - Fushe (Elbasani) (Photo: L. Shuka)

in the plain part of the river (Paperi and Peqini), showing heavy inorganic pollution, probably caused by Elbasani town and its industrial activities; the lowest values were found in the upstream parts: Labinot-Fushe and Proptishti.

Except for *Cladophora glomerata*, macroscopic algae were not usually found along the rivers in the coastal lowlands. This might be due to the increased turbidity with high content of solid matter and, in some cases, even the high organic pollution, e.g. in the Ishmi, Lana, Gjanica and Osumi rivers. The SCOPES study showed that metal accumulation by macroscopic algae is not a suitable tool to measure the annual fluctuations of heavy metals in the rivers of the region (*Miho et al.*, 2005b; 2006; Kupe, 2006). However, the quantity of heavy metals in the water and the biota was unexpectedly low; therefore, their effect on water quality seems to be negligible today, as a consequence of the closure of the mining industry.

More than 250 species of diatoms were found in periphyton samples, of which only 15 were centrics (Miho *et al.*, 2005b; Kupe, 2006). *Achnanthes minutissima, Amphora pediculus, Cocconeis pediculus, Diatoma moniliformis, Fragilaria capucina, Gomphonema tergestinum* and *Nitzschia dissipata* dominated in the Mati (all stations), in upstream stretches of the Tirana, Shumbini and Osumi; a relatively high number of species and high diversity were found too. In the Lana, Ishmi and Gjanica rivers, the diatom structure was dominated by saprotrophic or tolerant species, such as *Nitzschia palea, N. incospicua, Gomphonema parvulum, G. olivaceum, Navicula accomoda, N. veneta* and *N. saprophila.* The diversity index was mainly between 2.5 and 3.5; it was higher (more than 3.5) in the Shkumbini (mainly in Paperi and Rrogozhina), as well as in the Osumi and Semani. In the Semani (Mbrostar) the diversity index reached 4.53 (May 02) and in Shkumbini (Paperi) it reached 4.30. The lowest diversity values were found at Lana and Ishmi stations (as low as 0.32). Most of the species were common and not taxonomically interesting; nevertheless, *Caloneis* sp., probably a new species, was often found in the less polluted parts of the rivers, as an epiphyte on *Chadophora*.

Miho *et al.* (2005b) report that the TIDIA varied from 1.6 (mesotrophic,) in the Mati to 3.4 (polytrophic), in the Ishmi, Lana and Gjanica. High values were observed in the Lana and Ishmi, and in downstream parts of the Shkumbini (from Elbasani to Rrogozhina) and the Gjanica; it showed strong inorganic pollution of urban origin, from the discharge of untreated wastewaters from the towns of Tirana, Elbasani and Fieri. Compared with the TIDIA values calculated by Miho and Cake (2005) for the Shkumbini river, it seems that pollution from inorganic nutrients (nitrogen and phosphorus) is unchanged today. In mountainous parts, the rivers can be considered only slightly polluted, as observed in Bushkashi (1.4, oligo-mesotrophic). The mean SI values oscillate from 1.7 (oligo- to beta-mesosaprobic), in the Mati, to 2.8 (alfa-mesosaprobic), in the Ishmi. The Lana and Ishmi rivers always have high saprobic values, also showing high organic pollution.

Not only in the Lana and Ishmi rivers (Tirana region) and the Gjanica (Fieri), but also in the Mati, downstream stretches of the Shkumbini (Elbasani, Rrogozhina) and the Osumi (Berati), nutrients were higher than the EC guideline quality values for fresh waters for Cyprinid waters (EC Directive 78/659: BMZ, 1995): nitrite and ammonium values reached 4.047 mg NO_2/l in the Lana (November 03), 42.05 mg NH_4/l in the Lana (November 02). Furthermore, the O_2 values were below the BE limits in those rivers, too (Miho *et al.*, 2005b). Correlations performed with SigmaPlot 8.0, considering the mean TI_{DIA} values and the mean values for phosphates, nitrites, nitrates and ammonium, show a hyperbolic trend, with a saturated level, characteristic in relations of nutrient level to biota (Kupe, 2006). This means that there is a certain critical value where the trophic index reaches the maximum. To decrease the trophic values, hence decrease the pollution, the level of nutrients must be below the critical value. There is also a linear positive correlation between the two trophic indexes, TI_{DIA} and SI (99.9%).

The high content of suspended solids in the waters was a striking aspect observed during the monitoring of rivers in the Adriatic Lowlands (Miho *et al.*, 2005b). Except for the Mati, suspended solids often exceeded by many times the value of 25 mg/l, established by EC Directive 78/659 for the third class limit on the quality of fresh water needing protection or improvement in order to support fish life (BMZ, 1995). It was observed not only during the wet season in autumn, but also in late spring at low water level. It highlights the high rate of soil erosion, caused probably by the large deforestation in the respective drainage basins; it leads to massive deposition of solid material in the coastal areas, especially in the coastal lagoons. It also results in unfavourable conditions for aquatic life in rivers and on the marine coast, as mentioned previously for *Posidonia* (Kashta *et al.*, 2005). Related activities, such as agriculture, fishing and tourism are also seriously disturbed, with economic consequences.

In the period 1993-2004, sporadic periphyton samples were examined, collected in the Vjosa (Kelcyra, fig. 5, and Mifoli), Shalsi (Germenj, a Vjosa tributary), Devolli

(Zvezda), Tirana (Brari), and Shkumbini (Librazhdi) rivers, and in the springs of Kelcyra, Ujit të Ftohtë (Tepelena), Syri i Kaltër (Bistrica), Shalsi (Gërmenj), Sotira (Gjirokastra) and Borshi (Saranda). About 96 species of diatoms were found in these rivers and springs (Kupe, 2006). The TI_{DIA} oscillated from 2.51 (Shalsi-Germenj) to 3.29 (Kelcyra), the lowest value being observed in Novosela (1.9). The trophic state in these habitats varies form oligo-mesotrophic (Novosela) to mesotrophic in Germenj and Kelcyra (Kupe, 2006). The most common species found in those rivers were: *Achnanthes minutissima* (up to 40.5% in Germenj), *Diatoma moniliformis, Fragilaria biceps, Cocconeis placentula, Gomphonema tergestinum*. The most abundant species in the springs were: *Achnanthes minutissima*, *Cocconeis placentula, Diatoma moniliformis, D. mesodon, Fragilaria ulna,* etc. *A. minutissima* reached up to 92.9% of the diatom community in all stations, followed by *F. ulna* and *D. moniliformis* (up to 78.6%). The TI_{DIA} in the springs oscillates from mesotrophic to polytrophic (Syri i Kaltër). The SI oscillates from 1.4 (Borshi) to 2.1 (Devollin, Erseke and Kelcyra), from oligo-beta-meso-

Figure 5 - The spring of Ujit të Fhohtë in Keleyra (Përmeti) and Vjosa River

saprobic to alfa-beta-mesosaprobic. Low SI values and high TI_{DIA} values show that the waters suffer from serious inorganic pollution.

There is currently increasing demand for water for drinking, irrigation, aquaculture, hydro-electric power production and tourism in Albania. Therefore, a greater awareness and control of water quality is strongly needed, accompanied by better management and protection of the water resources. After 1990, the industrial impact was reduced, and municipal waste waters became the dominant source of water pollution. In the Western Lowlands (mainly close to Tirana and Durresi), the increased and uncontrolled discharge of domestic wastewater, and of solid waste as well, visible to the naked eye, continuously contaminate the waters of rivers, lagoons and the sea. It is a real risk for the economy and human health, as well. Wastewater treatment and waste disposal management should be of the highest priority. Reforestation activities and sustainable land use of the watershed areas must also be of high priority. The restoration of the rivers of Lana, Tirana and Ishmi would surely decrease the health risks for about 1 million inhabitants. The altered regions will benefit and regain their original beauty, too. Monitoring programs may help to understand better the present environmental state, characterize the main and most dangerous sources of pollution, and set up the basis for policy guidelines to improve the ecological situation; study of the aquatic biodiversity may also provide useful information. Albania is an important supplier of water into the Adriatic and Ionian seas; therefore, sustainable watershed management would guarantee the fulfilment of the obligations stipulated by regional and international agreements and programs.

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6

Aquatic macrophytes in the Lake Shkodra - River Buna wetlands complex

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Abstract

The Lake Shkodra - River Buna wetlands complex is rich in aquatic flora. 145 macrophytes have been found. Of these, 12 species are stoneworts (Charophyceae), while the others are vascular plants.
Four basic formations of plant assemblage are described.
Nineteen taxa of aquatic and other hydrophilous macrophytes found in this area which are rare or threatened within Albania are enumerated. Some of these species, i.e. *Trapa natans, Nymphoides peltata, Sagittaria sagittifolia, Hydrocotyle vulgaris, Hydrocharis morsus-ranae, Baldellia ranunculoides* and *Marsilea quadrifolia* are found only in 2 or 3 localities in Albania.
Spirodella polyrhiza and *Caldesia parnassifolia*, are found only in Lake Shkodra. Comments on some of the taxa are given.

Introduction

Lake Shkodra is the largest lake in the Balkans, shared with Montenegro. The River Buna runs along the south-west segment of the Albanian-Montenegrin border. This river springs from Lake Shkodra, quite close to the city, between the hill of "Rozafa" Castle and Mount Taraboshi. The river has a length of 44 km and flows through the fields of Bregu i Bunës towards the Adriatic Sea. Buna is the only river with a real natural delta in Albania. 1.3 km from its source in Lake Shkodra, the Buna joints the River Drin.
The Lake is geographically and ecologically connected with other aquatic habitats (River Buna, Velipoja Reserve and Domni marshes, Buna Delta and Viluni Lagoon), thus creating an ecological complex of wetlands.
It is the most important wetland system along the Adriatic Sea and one of the best preserved in the Mediterranean (Stumberger *et al.*, 2005).
Aquatic macrophytes are one of the essential ecologi-

cal components wherever they occur in lakes and watercourses

Taking into account the importance of protecting rare and endangered plants, recently their distribution in the Lake Shkodra - River Buna wetlands complex has been studied.

Material and methods

The material was collected in several localities along the shore of Lake Shkodra, along the Buna and in the marshes connected with it (Domni marsh and marshes of Velipoja).

Data on the number of rare and endangered species for each of the localities in the area are represented in the map below. Information as to whether the plants are known to be threatened was taken from Red Data Book of Albania (Vangjeli *et al.*, 1995); categories and abbreviations taken from this book are: Ex (extinct), E (endangered), V (vulnerable).

Results

The Lake Shkodra - River Buna wetlands complex is rich in aquatic flora. 145 macrophytes are found. Of these, 12 species are algae (fam. Characeae), while the others are vascular plants.

Four basic formations of plant assemblage can be distinguished in the different habitats of the area:

Floating plants

This vegetation is composed of freely floating macrophytes of small size, floating on the water surface. This community is represented by plants of the genus Lemna (*L. minor* and *L. gibba*) and *Spirodela polyrhiza*, which grow in small summer ponds near the banks of the Buna and the Domni Marsh. This group also includes larger hydrophytes such as Hydrocharis morsus-ranae which grow in marshes (Domni and Velipoja) as well as in channels and ditches near the lake.

Floating leaved macrophytes

This includes macrophytes with floating leaves such as *Nymphaea alba, Nuphar lutea, Trapa natans, Caldesia parnassifolia* and *Nymphoides peltata* (Fig. 1). These communities are present in shallower water, in the north-eastern shore of the lake and the upper stretches of the Buna, Domni Marsh, Velipoja Reserve and some channels connected to the Buna. Of this group, *Caldesia parnassifolia* grows only in a small area in the lake.

Very interesting is the community of *Trapa natans* in the part of the river near its outflow from Lake Shkodra, below the Castle (Fig. 2). It covers the whole surface and represents the only typical association of *Trapetum natantis* in Albania. In some parts of the lake it is accompanied by *Nuphar lutea, Potamogeton lucens, Ceratophyllum demersum* and *Polygonum amphibium.*

Submerged macrophytes

The group of submerged macrophytes includes mainly species of the genus Potamogeton (*P. perfoliatus, P. lucens, P. crispus), Myriophyllum verticillatum, M. spicatum Ceratophyllum demersum, Najas marina, N. minor, Vallisneria spiralis* etc. These are plant associations found in deeper water, most abundant in the north-eastern part of the lake and the upper stretches of the Buna.

Emergent macrophytes

This group includes halophytes, half-submerged, with roots and a part of the stalk in the water, but most part of the plant above water. Among the main species of this group are *Phragmites australis, Schoenoplectus lacustris, Typha angustifolia* and *Sparganium erectum.* These plants are abundant on the north-eastern shore of the lake and along the banks of the Buna, especially in the marshy areas.

There is also a dense community of helophytes at the outfall of the river there, including especially *Phragmites australis, Typha angustifolia* and in some places *Vallisneria spiralis, Potamogeton crispus, Groenlandia densa* and *Myriophyllum spicatum*, as well as a dense bed of stoneworts (Characeae).

Along the Buna, above the junction with the River Drini, the aquatic vegetation is poorer. The most common species in this part are *Potamogeton nodosus, Potamogeton pectinatus, Potamogeton perfoliatus* and *Groenlandia densa*.

On a small island there is an association of *Leucojum aestivum*, which is one of the most important populations of this species in Albania.

Figure 1 - Floating leaved vegetation in northeastern part of Lake Shkodra

Figure 2 -The locality of Trapetum natantis association in the upper stretch of the Buna

Data on 19 rare and endangered species found in the Lake Shkodra - River Buna wetlands complex are given below. 12 of these species are included in the Red Data Book with different status. Some species (*) have a limited distribution.

List of species

MARSILEACEAE

**Marsilea quadrifolia* L.

Reported for Lake Shkodra (Shütt, 1945). According to the Red Data Book distribution map, this species grows in Shkodra and Lezha, although for many years it has not been found in the reported areas. Its presence is thus considered doubtful.

POTAMOGETONACEAE

Groenlandia densa (L) Foureau

Found along the River Buna and in some localities of Lake Shkodra. In Albania it is mentioned in relation to Lake Prespa (Paparisto and Qosja, 1981; Mersinllari, 1997). Not mentioned in the Red Data Book.

**Potamogeton gramineus* L.

This species is found only in the north-eastern part of the lake. Not mentioned in the Red Data Book.

ALISMATACEAE

**Caldesia parnassifolia* (Bassi) Parlatore

The presence of Caldesia parnassifolia is reported only for the northeastern shore of Lake Shkodra as a new species for Albanian flora (Kashta and Rakaj, 2003).

**Baldellia ranunculoides* (L.) Parlatore.

Found in Velipoja. According to Paparisto and Qosja (1981) and Vangjeli *et al.*, (1995), it has been found only in Lake Prespa. Later it is also reported in Vlora (Mullaj *et al.*, 1998). Baldellia ranunculoides is a European paleoendemic plant species. Vulnerable (V) according to the Red Data Book.

**Sagittaria sagittifolia* L.

Found in some localities in Lake Shkodra and Domni marsh. Rare species in Albania: Lake Prespa and Lake Shkodra (Vangjeli *et al.*, 1995). In the Red Data Book it is considered as vulnerable (V).

BUTOMACEAE

Butomus umbellatus L.

The species is distributed throughout Lake Shkodra, the Buna and the channels of the area; widespread in the Lowlands of West Albania, in channels and wetlands. Vulnerable (V) according to the Red Data Book.

HYDROCHARITACEAE

**Hydrocharis morsus-ranae* L.

Found in the Domni and Velipoja marshes as well as in channels and ditches near the lake. According to the Red Data Book (V), it is found only in Lake Prespa.

**Hydrocotyle vulgaris* L.

Found in the delta of the Buna River and along the northeastern shore of the lake. It is considered extinct (Ex) in the Red Data Book. According to Buzo et al. (1997) it is rarely found in several localities of the low coastal area, while according to Mullaj (1988) it is found in the Lagoon of Kune-Vain.

LEMNACEAE

Lemna trisulca L.

Found in the Domni marsh, accompanied by Spirodela polyrhiza, Hydrocharis morsus-ranae, Nymphaea alba, etc. Paparisto and Qosja (1981), report that it has been found in Korça and Maliqi, in wetlands and ponds. It is not mentioned in the Red Data Book.

**Spirodela polyrhiza* (L.) Schleiden

Found in the Buna and the Domni marsh accompanied by Trapa natans and Hydrocharis morsus-ranae (Kashta and Rakaj, 1999a). Not included in Flora of Albania.

NYMPHAEACEAE

Nymphaea alba L.

Found in Lake Shkodra and the Domni and Velipoja marshes. Vulnerable (V) according to the Red Data Book.

Nuphar lutea (L.) Sibth. Et Sm.
Widespread in Lake Shkodra, while rarely found in the Buna. Vulnerable (V) according to the Red Data Book.

TRAPACEAE

Trapa natans L.
Found in some localities in Lake Shkodra, often in dense communities or accompanied by *Nuphar lutea* and *Nymphaea alba*. It is also found in the upper stretches of the Buna, in the Domni marsh, and, less frequently, near the delta of the Buna. Vulnerable (V) according to the Red Data Book, it is found in Lake Shkodra and Lezha. Mersinllari (1997) reports it for Lake Prespa.

HIPPURIDACEAE

Hippuris vulgaris L.
Found in marshy areas of the northeastern part of the lake and in the Domni marsh. This species is also found in Lake Prespa. It is not mentioned in the Red Data Book.

MENYANTHACEAE

**Nymphoides peltata* (S. Gmelin) Kuntze.
Found in several localities of Lake Shkodra as well as in the upper stretches of the Buna. Vulnerable (V) according to the Red Data Book, with sparse distribution in Lake Shkodra, Lezha and Lake Prespa.

CYPERACEAE

Cladium mariscus (L.) Pohl.
Sparsely found along the eastern shore of Lake Shkodra. Vulnerable (V) according to the Red Data Book.

AMARYLLIDACEAE

Leucojum aestivum L.
Found in wet meadows surrounding Lake Shkodra. and the delta of the Buna. In Albania it is reported for a few other localities: Lake Ohrid (Markgraf, 1927;

1930), Mamurras (Markgraf, 1931) and near Korça, at 1300m a.s.l. (L. Shuka, personal communication). It is not mentioned in the Red Data Book.

FAGACEAE

Quercus robur L.

This hygrophilous species, previously widely distributed in the Velipoja area, is now limited to few individuals. Mentioned as nearly extinct (Ex ?) in the Red Data Book.

Discussions and conclusions

The value of a given community or a given site is greater if it contains species that are lacking in other areas or are considered to be rare. From this point of view, the Lake Shkodra - River Buna wetlands complex, last year designated as a Ramsar Site, has special importance.

Aquatic plants, as an entire ecological group, are seriously endangered throughout Europe (Cook, 1983). According to the Red Data Book (Vangjeli *et al.*, 1995), 27 hydro- and hygrophilous plant species are rare or endangered in Albania. Some of these species have a very limited distribution: *Trapa natans* (Lake Shkodra, Lezha) *Nymphoides peltata* (Lake Shkodra, Lezha), *Sagittaria sagittifolia* (Lake Shkodra, Lake Prespa), *Hydrocotyle vulgaris* (Ex), *Hydrocharis morsus-ranae* (Lake Prespa), *Baldellia ranunculoides* Parlatore (Lake Prespa), *Marsilea quadrifolia* (Lake Shkodra).

The Lake Shkodra - River Buna wetlands complex represents one of the few refuges in Albania for many rare and endangered plant species. 19 rare or endangered aquatic and hygrophilous plant species of Albania are found in this area (Fig. 3).

Two of these species: *Caldesia parnassifolia* and *Spirodela polyrhiza* have not been found elsewhere in Albania up to now. In our opinion, *Spirodela polyrhiza* will also be distributed in other lakes and ponds of the country.

Five species (*Groenlandia densa, Potamogeton gramineus, Hippuris vulgaris, Lemna trisulca* and *Leucojum aestivum*) are not included in the Red Data Book, although they have been found in few localities in Albania.

Three species – *Trapa natans L., Marsilea quadrifolia L.* and *Caldesia parnassifolia* (Bassi) Parlatore – are included in the Bern Convention as regionally endangered.

Baldellia ranunculoides is a European paleoendemic plant species.

Marsilea quadrifolia, reported for this area many years ago, has not been found for several years and its presence now is doubtful.

For the conservation of the rare and endangered species of the area, as well of the other groups of living organisms, a working plan should be implemented, including description of the biotopes, species demography and continuous monitoring.

Having acknowledged that wetlands provide many sorts of resources, their conservation should be considered a more complex issue rather than simply the protection of the species and habitats.

Figure 3 - Map of distribution and the number of rare and threatened macrophyte species for each locality in the Lake Shkodra - River Buna wetlands complex.

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Impact of urban wastewater discharges on the microbiological pollution of rivers debouching into the Adriatic Sea

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7

Abstract

In this paper are represented some results of microbiological pollution of Albanian rivers that run off into the Adriatic Sea. Microbiological examination of water samples collected from 16 stations of 7 rivers in four seasons of the year before and after urban discharges indicates that river waters before urban discharges are generally pure from point of view of microbiological pollution, while after urban wastewater discharges the number of Feacal Coliforms and Faecal Streptococci is high or very high. This for the reason that urban wastewaters are not treated before discharge. It is strong recommended to begin as soon as possible the disposal and treatment of urban wastewater before discharging to the rivers, lakes, sea etc.

Introduction

The microbiological examination of water is used worldwide to monitor and control the quality and safety of various type of water. Microbiological examination of water samples is usually undertaken to ensure that the water is safe to drink or bathe in [1].

Coliform bacteria, which normally live in the intestines of humans and warm-blooded animals, although were not known to cause any illness, are referred as indicator organisms since a quantity of their presence is used to indicate the potential presence of pathogens in waters [9]. Coliforms get out through the excrements and if do not exist the necessary precautions about the disposal and treatment of the wastewaters, these bacteria pass in the environment or in waters causing their pollution. If the water contains such bacteria over the recommended limits, this indicates the pollution of this water.

The principal indicator of suitability of water for domestic, bathing, industrial or other uses is the presence-absence and number of bacteria like:

- Thermotolerant (Faecal) Coliforms (E. coli), indicators of faecal pollution.

- Faecal Streptococcal group (enterecocci), their presence is the other indicator of faecal pollution [1, 9].

If the Faecal Coliforms in water are over 200 germs/100 ml, there are great probabilities to be present even pathogenic organisms like bacteria, viruses, and parasites etc., which are present with the Faecal Coliforms in the infected persons.

WHO and different countries over the years had introduced various standards and guidelines for surface (bathing, inland) waters, including rivers, some of them have become legally enforceable, while others have been recommended by appropriate bodies and trade associations.

UNEP/WHO has established 100-1000 faecal coliforms per 100ml bathing water [8].

Council Directive of 8 December 1975 of the European Communities (Directive 76/160/EEC) has established microbiological quality for bathing water as follows [2]:

	Microbiological parameters	Guideline level	Alert level
1	*Total coliforms/100 ml*	500	10 000
2	*Faecal coliforms/100 ml*	100	2 000
3	*Faecal streptococci/100ml*	100	-

In the year 2006 The European Parliament and of the Council has adopted the Directive 2006/7/EC of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC. Microbiological standards for inland waters and coastal and transitional waters are as follows [5]:

For inland waters

	Parameter	Excellent quality	Good quality	Sufficient
1	Intestinal enterecocci (cfu/100ml)	200	400	330
2	Escherichia coli (cfu/100ml)	500	1000	900

For coastal and transitional waters

	Parameter	Excellent quality	Good quality	Sufficient
1	Intestinal enterecocci (cfu/100ml)	100	200	185
2	Escherichia coli (cfu/100ml)	250	500	500

Material and methods

Materials: Water samples from rivers Drini, Kiri, Ishmi, Erzeni, Shkumbini, Semani and Gjanica.

Methods: Samples were collected in the same points during all the time of monitoring. The quantity of water was 0.5 liters. Sample bottles are sterilized in an autoclave for 20 minutes at 121°C. [5, 6].

Transport and storage of samples before analysis was carried of in a cool box or refrigerator at a temperature of 4°C ± 3°C. The samples were analyzed on the same working day [5].

Sampling frequency is seasonal, four times a year.

The selection of monitoring stations is based on monitoring scheme of liquid discharges. In that scheme collector is considered the source of pollution to receiving surface waters. The samples are taken at the collector and also in distance 500-1000 m from point of discharge after mixing and dilution with receiving waters.

In order to analyze the impact of urban discharges to receiving waters samples are collected in:

- Water bodies with little or no human impact, which are found in downstream of rivers before entering into the city.
- Water bodies, which are under pressure of urban and industrial liquid discharges and usually are found in populated areas of cities.

For all the samples was checked number of Faecal coliforms and Faecal streptococci. For analysis were used standard methods internationally recognized such Multiple-Tube Fermentation Technique and Membrane Filter Technique [3, 6, 7].

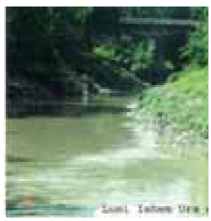
Results

The samples are collected in seven rivers that run off in the Adriatic Sea, in four seasons of the year in two or three stations lengthwise running:

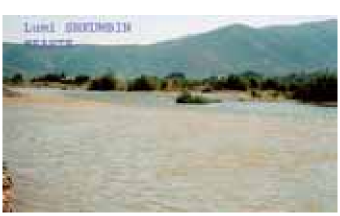
River Drini: Before and after discharge of urban wastewaters of Shkodra city.

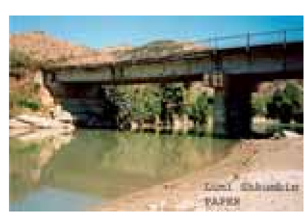
Kiri River: Before and after urban wastewaters discharge of city Shkodra.

Ishmi river: Rinas bridge, Gjolës bridge, Ishëm (after urban wastewaters discharge of city Tirana).



Erzeni river: Mullet, (before urban wastewater discharge) and Beshiri bridge, (after urban wastewater discharge).





Shkumbini river: Krasta (before urban wastewater discharge) Toplias and Paper (after urban wastewater discharge)

Semani river: Mbrostar bridge (after urban wastewater discharge)

Gjanica river: After urban wastewater discharge of city Fier

Semani-Gjanica river: Mujalli (after urban wastewater discharge)

Results

Results are represented in tables 1 and 2.

Table 1 - Faecal Coliforms, MPN/100 ml

Nr.	Sampling stations	MPN/100ml			
		15.06.2005	14.09.2005	24.11.2005	12.04.2006
1	Drini river before pollution	230	400	230	2300-2400
2	Drini river after pollution	$1.1x10^7$	430	240	9300
		22.06.2005	21.09.2005	30.11.2005	19.04.2006
3	Mouth of Drini river	$1.5x10^4$	$4.3x10^4$	430	$4.3x10^4$
		15.06.2005	14.09.2005	24.11.2005	12.04.2006
4	Kiri river before pollution	210	400	90	2400
5	Kiri river after pollution	$1.1x10^4$	4300	240	9300
		04.05.2005	27.07.2005	20.10.2005	07.03.2006
6	Ishmi river, Rinas bridge	$1.1x10^6$	$4.6x10^6$	$2.1x10^6$	$9x10^5$
7	Ishmi river, Gjolës bridge	$4.6x10^5$	$2.3x10^5$	$9.3x10^5$	$4.3x10^4$
8	Ishmi river, Ishmi	$2.8x10^4$	$9.3x10^4$	$2.3x10^5$	$9.3x10^5$
		01.06.2005	31.08.2005	02.11.2005	29.03.2006
9	Erzeni river, Mullet	2100	2300	4300	2300
		25.05.2005	20.07.2005	25.10.2005	23.03.2006
10	Erzeni river , Beshiri bridge	$2.1x10^5$	9300	$1.5x10^4$	$2.4x10^5$
		01.06.2005	31.08.2005	02.11.2005	29.03.2006
11	Shkumbini river, Krasta before pollution.	900-930	9300	930	400-430
12	Shkumbini river, Toplias after pollution.	4300	$2.3x10^4$	4300	2300
13	Shkumbini river, Paper	$2.4x10^4$	2300	$9.3x10^4$	$1.5x10^4$
		08.06.2005	07.09.2005	09.11.2005	05.04.2006
14	Semani river, Mbrostari bridge	$2.4x10^5$	1.1-$1.2x10^5$	$3.9x10^4$	$1.5x10^4$
15	Gjanica river after pollution	$1.1x10^6$	$2.4x10^6$	$4.6x10^5$	$7.5x10^4$
16	Gjanica+Semani, Mujalli, after pollution	$9.3x10^4$	$2.1x10^5$	$1.5x10^4$	$9.3x10^4$

Table 2 - Faecal Streptococci, MPN/100ml

Nr.	Sampling stations	MPN/100 ml			
		15.06.2005	14.09.2005	24.11.2005	12.04.2006
1	Drini before pollution	150	90-93	40	430
2	Drini after pollution	2.4x10^6	240	900	900-930
	Mouth of Drini	22.06.2005	21.09.2005	30.11.2005	19.04.2006
3		93	2.4x10^4	230	9300
		15.06.2005	14.09.2005	24.11.2005	12.04.2006
4	Kiri before pollution	4	40	40-43	230-240
5	Kiri after pollution	4600	930	400	2400
		04.05.2005	27.07.2005	20.10.2005	07.03.2006
6	Ishmi, Rinas bridge	2300	1.5x10^6	1.5x10^5	9.3x10^4
7	Ishmi, Gjolës bridge	930	2.4x10^4	4.3x10^4	4x10^4
8	Ishmi, Ishmi	430	930	2000	1.1x10^5
		01.06.2005	31.08.2005	02.11.2005	29.03.2006
9	Erzeni, Mullet	2400	930	2300	2300
	Erzeni, Beshiri bridge	25.05.2005	20.07.2005	25.10.2005	23.03.2006
10		2100	2400	2300	9.3x10^5
		01.06.2005	31.08.2005	02.11.2005	29.03.2006
11	Shkumbini, Krasta before pollution.	750	390	230	230
12	Shkumbini, Toplias after pollution.	280	930	210	930
13	Shkumbini, Paper	4600	230	4600	1.2x10^4
		08.06.2005	07.09.2005	09.11.2005	05.04.2006
14	Semani, Mbrostari bridge	2.4x10^4	2.3x10^4	930	4300
15	Gjanica after pollution	2.4x10^4	2.1x10^5	4.6x10^5	4.6x10^4
16	Gjanica+Semani, Mujalli, after pollution	9300	7.5x10^4	930	2300

Discussions and conclusions

If we present graphically results of tables 1, 2 we can show clearer the variation in time (Fig. 1, 2, 3, 4) and level of pollution (Fig. 1/1, 2/1, 3/1, 4/1) with faecal coliforms and faecal streptococci of waters Drini, Kiri, Erzeni and Shkumbini rivers. Ishmi, Semani and Gjanica rivers have very high level of microbiological pollution in all stations and all periods of analysis (level 104-106 cfu/100ml for faecal coliforms and 103-105 cfu/100ml for faecal streptococci). This happens because the samples are collected after urban waste-waters discharge of city Tirana and Fier.

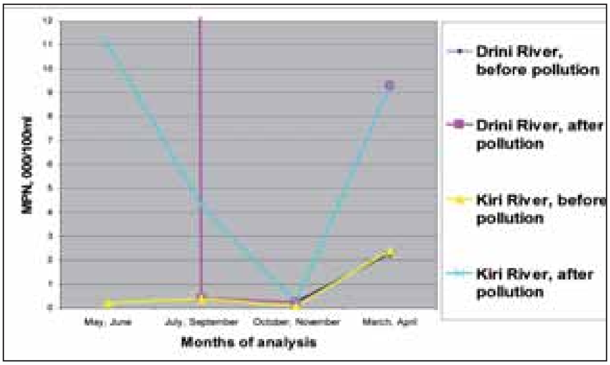


Figure 1 - Faecal Coliforms, Drini and Kiri rivers

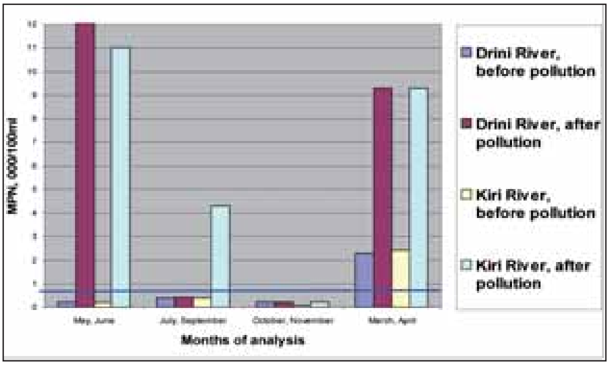


Figure 1/1 - Faecal Coliforms, Drini and Kiri rivers

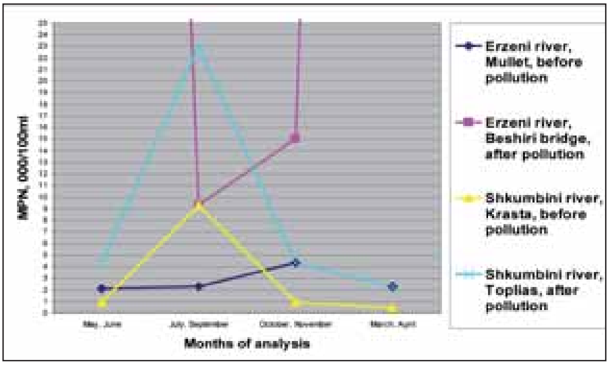


Figure 2 - Faecal Coliforms, Erzeni and Shkumbini rivers

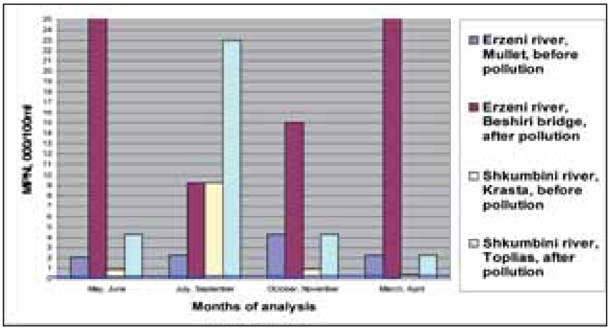


Figure 2 /1 - Faecal Coliforms, Erzeni and Shkumbini rivers

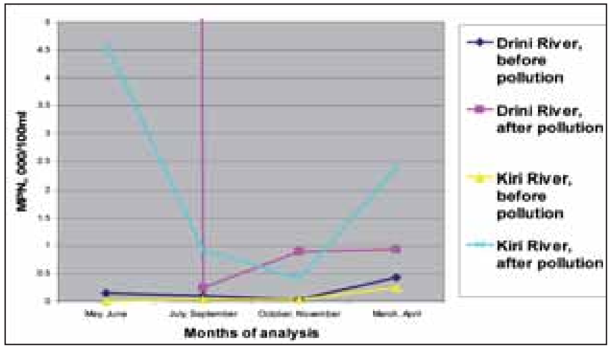


Figure 3 - Faecal streptococci, Drini and Kiri rivers

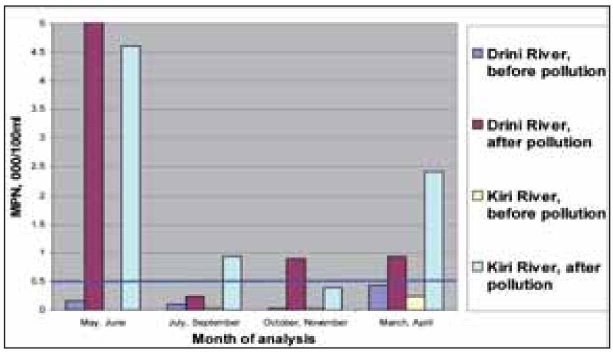


Figure 3/1 - Faecal streptococci, Drini and Kiri rivers

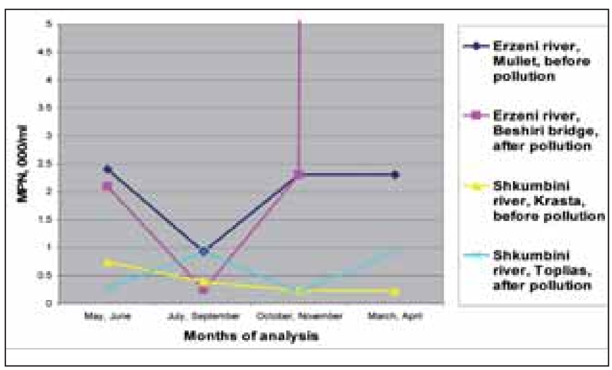


Figure 4 - Faecal streptococci, Erzeni and Shkumbini rivers

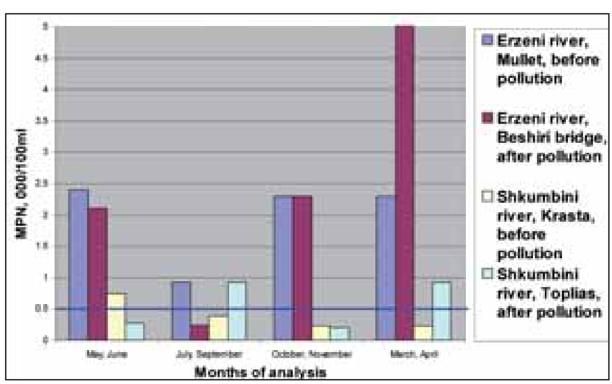


Figure 4/1 - Faecal streptococci, Erzeni and Shkumbini rivers

Drini and Kiri waters (Fig. 1, 1/1, 3, 3/1) before urban wastewater discharge contain 90-400 faecal coliforms per 100ml and 4-150 faecal streptococci per 100ml (within recommended limits). Only in April 2006, the number of faecal coliforms is 2300-2400 cfu/100ml near the imperative level. [2].

Meanwhile after urban wastewater discharge the number of faecal coliforms per 100ml surpasses several times the standards for microbiological quality of bathing waters except September and November (Fig. 1, 1/1). The exception can be explained by large fluxes during this month as a result of precipitations.

Erzeni river, Mullet (Fig. 2, 2/1, 4, 4/1) is not as much polluted, but over the standard limits (2100-4300 faecal coliforms/100ml, and 930-2400 faecal streptococci/100ml), because discharge of rural wastewaters, meanwhile in Beshiri bridge after urban wastewaters discharge, the pollution is very high (level 104-105cfu/100ml for faecal coliforms and 103-105 for faecal streptococci).

Waters in Shkumbini river, Krasta the faecal coliforms are within standards for good bathing quality, except the August, meanwhile in Toplias and Paper after discharge of wastewater of city Elbasan the level of microbiological pollution is much higher than recommended limits (Fig. 2, 2/1). Nearly the same situation is for faecal streptococci except the June (Fig. 4, 4/1).

In conclusion, referring the standards of UNEP/WHO, Directive 76/160/EEC, and Directive 2006/7/EC concerning the management of bathing water quality, waters of rivers of Albania that run off into the Adriatic Sea before wastewater discharge are generally pure from point of view of microbiological pollution, while after urban wastewater discharge are high or very high polluted, except of Drini and Kiri rivers in November.

Referring the seasons (months), with some exceptions, higher pollution is detected in July-August, while lower pollution is detected in October-

November. This is explained by large fluxes during these months as a result of precipitations.
The data of this work show clearly, that urban wastewaters are not treated before discharge.

It is strong recommended to begin as soon as possible the disposal and treatment of urban wastewater before discharging to the rivers, lakes, sea etc.

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Response of benthic macroinvertebrate community descriptors to chemical pollution in the aquatic ecosystems of Fiume Grande and Punta della Contessa saltpans (Brindisi, Italy).

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Abstract

The anthropogenic activities that take place in an area are reflected in the quality of the waters in the water bodies into which the area drains; these water bodies thus represent natural tools for monitoring the state of health of the whole catchment area. The objective of this study is to evaluate the sensitivity of benthic macroinvertebrate communities in aquatic ecosystems to perturbations linked to chemical pollution. To this end a study was conducted in the aquatic ecosystems located within the Site of National Interest of Brindisi, performing seasonal samplings in 9 field sites. The analysis of the benthic macroinvertebrate communities entailed taxonomic identification, determination of biomass and evaluation of the body condition of each individual sampled. Taxonomic and non-taxonomic community indices were derived, and their models of variation were described and compared on gradients of concentration of chemical contaminants in the area.

The results indicate significant relations between the concentration of heavy metals and descriptors of the size spectra of benthic macroinvertebrates, suggesting that in aquatic ecosystems, descriptors linked to size can be a useful tool in support of bio-monitoring and assessment of ecological risk, considering their ease of application and sensitivity to perturbation pressures in an industrial area.

Introduction

Anthropogenic activities, particularly those linked to industry, represent important potential sources of perturbation for the structure and functions of ecosystems due to the possible introduction of harmful chemical substances that are used in production processes or are derived from them.

The environmental consequences of these activities are reflected in the abiotic and biotic characteristics of water bodies receiving the run-off waters of the catchment area and the surrounding terrain. Rivers, canals and coastal lakes thus become "key" ecosystems for the monitoring of the state of health of the entire surrounding area. Because of their capacity to respond in a predictable way to diverse pressures of both natural and anthropogenic origin (Basset *et al.*, 2004; Basset, 1995; Cattaneo *et al.*, 1995; Dadea *et al.*, 1996; Mercier *et al.*, 1999; Ravera, 2001; Solimini *et al.*, 2001; Stead *et al.*, 2005), benthic macroinvertebrate guilds have been incorporated into the regulations concerning the safeguard of waters as biological elements of quality for the evaluation of the ecological state. Although there are numerous studies available that demonstrate the role of ecological forcing factors on the taxonomic characteristics of benthic macroinvertebrate communities, we know little of these relations inside heavily polluted areas or of the dimensional descriptors of these communities.

The aim of this study is to evaluate the sensitivity of high-level descriptors to perturbations linked to chemical pollution of the aquatic ecosystems, using communities of benthic macroinvertebrates. The Site of National Interest of Brindisi was used as a model system, given that the characterization studies conducted under Italian Law DLgs 471/99 have provided us with detailed knowledge of the distribution and concentration of the pollutants present in the site.

Specifically, in this study, the models of spatial variation of taxonomic and non-taxonomic descriptors of the benthic macroinvertebrate guilds were analysed and compared in an area at high environmental risk, and the influence of environmental forcing factors on these models and the response of the taxonomic and dimensional descriptors to these variations were evaluated.

Material and methods

The study was conducted in the aquatic ecosystems present on the land side of the Site of National Interest of Brindisi, lying to the South of the city (Puglia region, Italy). Inside the site, the industrial activities are located

Figure 1 – Area of study and location of field sites. The areas bounded by hashed lines contain the potential sources of pollution.

both in the Northern part (chemicals factories, a power station and smaller factories) and in the Southern part (a second power station), and are connected by a dedicated transport link used for the movement of coal (Fig. 1).

These two areas may be regarded as the main sources within the site of chemical pollutants. The aquatic ecosystems present in the Site are the canals known as Siedi, Foggia di Rau and Fiume Grande, characterized by the presence of moderately brackish waters, and the Punta della Contessa, a saltpan characterized by high levels of salinity. The canals intersect at various points with the transport link and also flow close to the industrial areas. For this reason they are particularly affected by surface contamination.

The site was the subject of characterization studies carried out to assess the state of contamination of the area; these studies provided detailed information on the concentration in the soil and in the waters of numerous pollutants (e.g. heavy metals, hydrocarbons, chloride-based solvents) linked to the industrial activities that take place in the area (Basset *et al.*, unpublished data).

This study was based on seasonal samplings (2 samplings per season) carried out between September 2003 and August 2004 in 9 sampling field sites, located on the Siedi canal (field site 1), the Foggia di Rau canal (field sites 2 and 3), in the Punta della Contessa saltpans (field sites 4 and 5) and along the course of the Fiume Grande canal (field sites 6, 7, 8, 9) (Fig. 1).

At each sampling, using a multi-parametric probe, the main chemical and physical parameters, i.e. temperature, salinity, dissolved oxygen and pH, were recorded, and samples of water were gathered for analysis of content in terms of nutrients (NO_2, NO_3, PO_4, NH_3) (Tab. 1).

The benthic macroinvertebrate communities were sampled using artificial food traps made up of leaves of *Phragmites australis* (leaf-pack technique, Petersen and Cummins, 1974). At seasonal intervals, six packs of reed leaves containing 15 grams dry weight (obtained

	Temperature (°C)	Salinity (PSU)	D.O. (mg/l)	pH	NH_3/NH_4^+ (mM)	NO_2^- (mM)	NO_3^- (mM)	PO_4^{3-} (mM)	Arsenic (mg/Kg)	Cadmium (mg/Kg)	Nickel (mg/Kg)	Lead (mg/Kg)
1	17.25	3.56	11.12	7.59	7.17	11.07	204.83	0.28	5.08	0.06	46.15	3.53
2*	18.67	2.17	10.78	8.02	5.37	3.26	810.13	8.75	6.35	0.03	13.75	5.80
3*	17.27	2.26	11.04	8.08	6.69	7.65	1102.78	10.33	6.35	0.03	13.75	5.80
4#	20.84	14.09	9.69	7.97	13.40	1.58	265.25	4.75	0.50	0.003	1.30	0.50
5#	20.93	10.16	10.31	7.62	5.84	3.48	474.57	1.09	0.50	0.003	1.30	0.50
6	18.67	3.79	10.72	8.10	12.06	6.61	790.25	2.05	14.45	0.78	26.57	15.50
7	20.67	11.44	11.77	7.99	3.45	3.59	852.56	3.84	11.90	1.46	25.55	13.89
8	18.35	2.68	7.95	7.89	3.52	2.96	826.09	4.34	16.76	0.26	25.84	17.69
9	23.15	31.22	7.46	7.85	32.27	0.80	307.49	11.62	25.06	0.40	33.35	21.51

*Table 1 – Values for chemical-physical, nutrient and heavy metal concentration parameters observed in each sampling site. * # : sites 2-3 and 4-5 have similar values for contaminants since they come from the same area.*

after drying at 60°C for 72 hours), held in bags made of plastic netting with a 0.5 cm mesh, were immersed in the water at each field site and recovered 30 days later. In the laboratory, the benthic macroinvertebrates were separated from the vegetable detritus and fixed in a 10% solution of formalin; subsequently, each individual was identified at the lowest taxonomic level possible, oven-dried at 60°C for 72h and weighed on a micro-analytical scales (Sartorius, ± 1μg). The individuals, grouped by taxa, were incinerated in a muffle furnace at 500°C for 6h to obtain the content in ash. All biomass values were expressed as Ash-Free Dry Weight in mg.

The quantification of the chemical pressures on the benthic macroinvertebrate communities in the aquatic ecosystems considered was based on the data for the concentration of chemical contaminants detected within a radius of 1 Km upstream of each field site. In this preliminary study, the chemical contaminants considered were the main heavy metals: Arsenic, Cadmium, Nickel and Lead (Tab. 1), since these are easily introduced into the aquatic ecosystems via mechanisms of fall-out and surface run-off, and just as easily combine with organic compounds and enter the food chain.

Data Analysis

The study of the taxonomic structure of the benthic macroinvertebrate communities was carried out by analysing: abundance, taxonomic wealth, diversity (Shannon and Weaver, 1949) and distinctness (Warwick and Clarke, 1995), while for the dimensional structure, the analysis encompassed the main statistical descriptors of the size spectra: average, standard deviation, skewness and kurtosis. An empirical measure of statistical width was also considered, obtained as the difference between the maximum and minimum biomass values.

The comparison between taxonomic and dimensional structure was conducted using the Bray-Curtis similarity index (Bray and Curtis, 1957).

Canonical analysis (CCA, Ter Braak 1986) was used to quantify the effect of the environmental variables (metals, nutrients and chemical-physical parameters) on the taxonomic and dimensional structure.

The analysis of the variation of the taxonomic and dimensional characteristics in relation to environmental forcing factors, and specifically to the normalized concentration of the metals, was carried out by means of correlations.

Results

Taxonomic Structure

The benthic macroinvertebrate communities sampled were composed of 40 taxa, considering adult and larval phases as distinct, grouped into 5 classes, with a total of 19,504 individuals (Tab. 2). The Insect class accounted for 28 taxa and constituted 31.1% of the total numerical abundance; the Gastropod class accounted for 6 taxa and was the most abundant, with 51.2% of the individuals; this was followed by the Crustacean class with 4 taxa and 15.1% of the abundance; Polychaeta and Hirudinea accounted for just one taxon each and a total abundance of 2.6%. The sampled taxa are shown in table 2 and are ordered by decreasing relative abundance; more than 90 % of the individuals belong to just 7 taxa. The taxonomic indices of the of benthic macroinvertebrate guilds do not exhibit significant variation over time; they do however exhibit significant models of spatial variation in terms of numerical abundance, wealth and taxonomic diversity (one-way ANOVA, $F(8)= 2.643$, $P<0.05$; $F(8)=4.436$, $P<0.05$; $F(6)=5.168$, $P<0.05$) (Fig. 2).

TAXON	A	B	TAXON	A	B
Sadleriana sp	28.235	0.266	Berosus sp (A)	0.103	2.609
Chironomus sp	14.648	0.195	Dytiscidae	0.097	1.239
Hydrobia sp	13.761	0.365	Hydrophilidae	0.087	1.073
Caenis sp	13.351	0.146	Diptera (Pupa)	0.072	0.605
Tanais sp	8.901	0.216	Stratiomyidae	0.046	5.431
Physa sp	6.665	0.216	Ephyhdridae	0.031	0.077
Gammarus sp	5.686	0.489	Hydraenidae (A)	0.031	0.868
Planorbis sp	2.538	0.358	Hydrobius sp	0.026	2.073
Hediste sp	1.538	4.572	Simuliidae	0.026	0.199
Erpobdella sp	1.051	2.164	Baetis sp	0.021	0.774
Lestes sp	0.754	1.273	Tipulidae	0.015	9.825
Proasellus sp	0.492	0.517	Aeshnidae	0.010	5.475
Berosus sp	0.385	1.133	Ancylidae	0.010	0.877
Tanypodinae	0.303	0.143	Ovatella sp	0.010	0.914
Ephydra sp	0.272	0.691	Tabanidae	0.010	19.121
Crocothemis sp	0.215	2.918	Ceratopogonidae	0.005	0.089
Hydrophilidae (A)	0.174	3.139	Limnephilidae	0.005	14.794
Dytiscidae (A)	0.149	0.741	Notonectidae	0.005	0.045
Syrphidae	0.144	1.306	Ochthebius sp	0.005	0.197
Haliplidae (A)	0.118	1.008	Titanethes sp	0.005	1.191

Table 2 – List of sampled taxa with relative abundance (A) and average individual biomass (AFDW mg) (B).

On the basis of the taxonomic indices, the field sites seem to fall into three groupings; specifically, field sites 2 and 3 have high values for taxonomic wealth, diversity and abundance; field sites 6 and 9 have consistently lower values; field sites 4 and 7 have intermediate values.

Dimensional Structure

The average individual biomass of the sampled taxa varies between a minimum value of 0.045 mg and a maximum value of 19.120 mg (Tab. 2). On a bi-logarithmic scale, the average individual biomass of each taxon is negatively correlated with numerical abundance (Regression Analysis: $y=-0.69x+8.23$; $r=0.371$; g.l.=38; $P<0.05$); the slope value observed is in agreement with the expected models of energetic equivalence between coexisting species. The individuals are distributed in 11 size classes with a logarithmic width of one, and the modal classes are 5 and 6 (Tab. 3). In all the study sites, the size spectra are unimodal and mainly follow a log-normal model. The descriptors of the size structure of

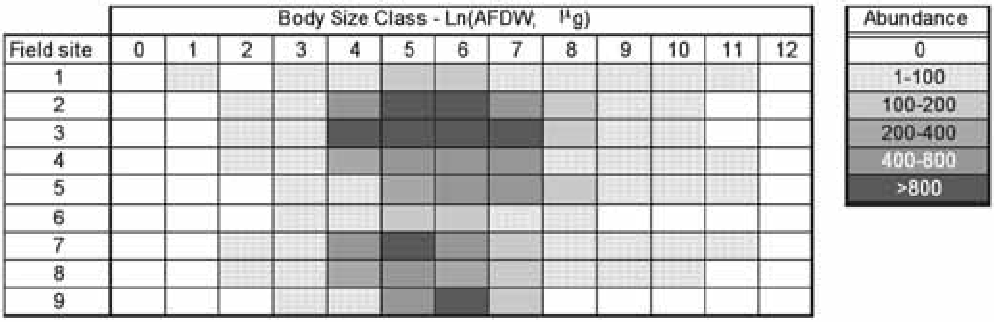

Table 3 - Schematic representation of the distribution in size classes at each sampling site.

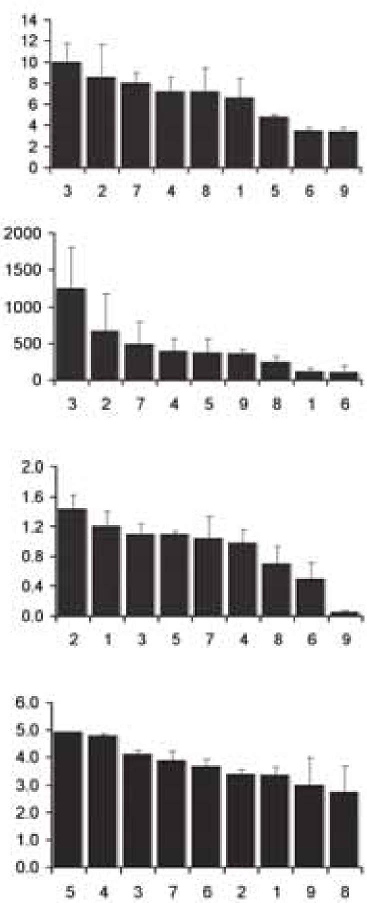

Figure 2 –Spatial variation of taxonomic descriptors. The field sites are listed in decreasing order of observed values.

the of benthic macroinvertebrate communities do not exhibit significant variation over time, while they do exhibit significant models of spatial variation reflected in the standard deviation, skewness and statistical width (one-way ANOVA: $F(8)=2.239$, $P<0.05$; $F(8)=3.585$, $P<0.05$; $F(7)=5.134$, $P<0.05$ respectively). Figure 3 shows the spatial variations in the descriptors considered. On the basis of the dimensional descriptors, the field sites seem to fall into two large groupings that reflect the North-South distribution of the site; specifically, field sites 6, 7, 8 and 9 (in the Northern part) exhibit lower values than field sites 1, 2 and 4, 5 (in the Southern part), which exhibit higher values (Fig. 3).

Community Structure and environmental forcing factors

The comparison of the taxonomic and dimensional structure of the macro-zoological benthic communities shows that the similarity in size among the stations is significantly higher than the similarity in terms of taxonomy (Similarity (size) = 60%; Similarity (taxa) = 27%; student's t-test, $t = 10.99$; $df= 70$; $P<0.01$).

Although the variability of the dimensional structure is lower than that of the taxonomic structure, 74.4% of it is explained by the environmental forcing factors considered in the canonical analysis –chemical, physical, nutrient and metal parameters; in contrast the same environmental forcing factors explain only 52.4% of the variability of the taxonomic structure. Among the environmental forcing factors, a significant role is played by the concentration of heavy metals. The field sites are spread out along the gradient of concentration of the metals in a spatially explicit way; sites 6, 7, 8 and 9, located along the Fiume Grande canal, have the highest concentrations; sites 1, 2 and 3 have intermediate values; finally, sites 4 and 5 have the lowest values.

The taxonomic and dimensional descriptors considered were correlated with the normalized concentration values for the metallic contaminants; only the measures relating to the dimensions, especially the average, standard deviation and statistical width, exhibit significant patterns of inverse variation with the concentration of the heavy metals measured in the soils immediately surrounding the sites considered (correlation analysis in Fig. 4).

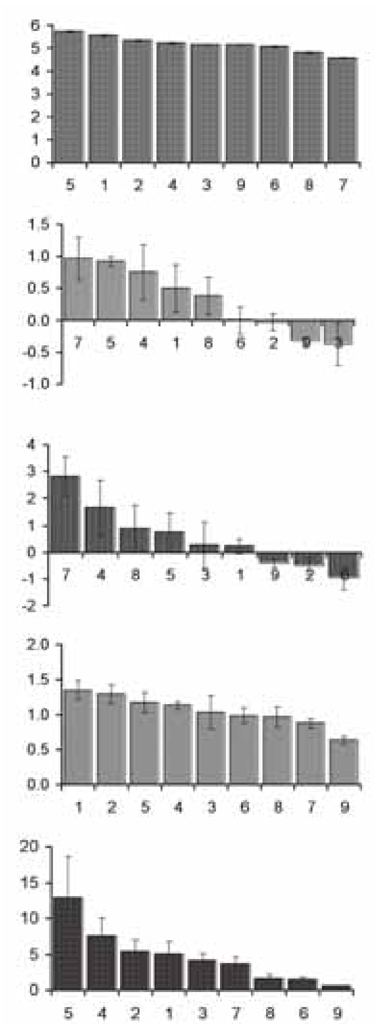

Figure 3 - Spatial variation of dimensional descriptors. The field sites are listed in decreasing order of observed values.

Conclusions

The study conducted inside the Site of National Interest of Brindisi shows that the benthic macroinvertebrate community varies significantly between sites while it does not appear to be affected by seasonal variability. The spatial variation of the descriptors, used for the analysis of the benthic macroinvertebrate community, leads to the identification of groups of stations which tend to exhibit similar values. For the dimensional descriptors in particular it is possible to identify a group of stations, distributed along the Fiume Grande, that have lower values than the field sites that are further away from the industrial estate and the transport link.

The field sites are arranged in a spatially explicit way along the gradient of concentration of the heavy metals considered: the stations placed along the Fiume Grande have the highest concentrations; the field sites placed along the Foggia di Rau and Siedi, which flow through the agricultural area and intersect with the transport link have intermediate values, and the field sites inside the saltpans have the lowest values.

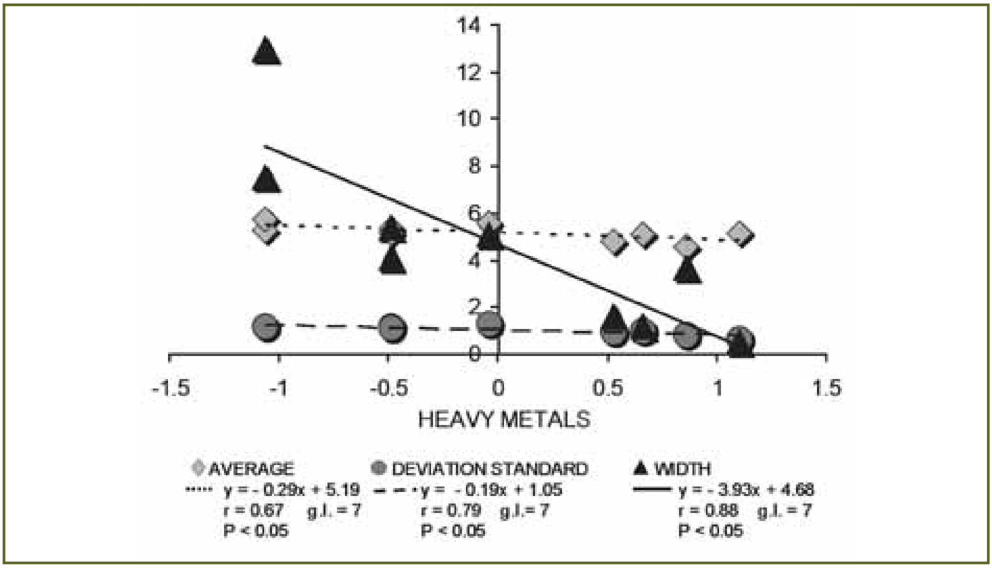

Figure 4 - Analysis of the correlation between the normalized concentration of heavy metals and the descriptors of the dimensional structure of macroinvertebrate communities.

The comparison of the taxonomic and dimensional structures, performed by using the similarity values, shows that the dimensional structure is less variable than the taxonomic structure but that this variability is explained to a greater extent by environmental forcing factors. As already shown by other authors (Basset, 1995; Pinna and Basset, 1997, Basset *et al.*, 2004), in the aquatic ecosystems that are the object of this study the dimensional structure of the benthic macroinvertebrate community is more conservative than the taxonomic structure, showing the importance of body size in the mechanisms of community organization.

The relationship between contaminants and descriptors of the dimensional structure of the benthic macroinvertebrate communities shows that the analysis of body size characteristics, being on a high hierarchical level and not requiring taxonomic identification, make it possible, in a simple, fast and inexpensive way, to measure the response of communities to perturbations induced by anthropogenic activities carried out in an industrial area. Therefore, it is suggested as a useful tool for biomonitoring and the evaluation of ecological risk.

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9

The litter bag technique for studying detritus decomposition in aquatic ecosystems. A case study in the South of Italy (Lake Alimini)

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Abstract

Leaf litter decomposition rates in aquatic ecosystems are known to be related to many different abiotic and biotic factors. A comparative analysis of inter- and intra-habitat variations of detritus decay rates across ecosystem types was carried out in the Alimini lake complex (Italy) to assess the relevance of major ecosystem features to detritus processing rates. Overall, the spatial variability of leaf decomposition rates was more pronounced than temporal variability, decomposition rates in the stream being 3.6 and 5.2 times faster than in the freshwater lake and saltmarsh, respectively. Overall, environmental features were relevant factors affecting intra- and inter-habitat variation of reed decay rates.

Introduction

Allochthonous organic matter constitutes the main source of energy in aquatic ecosystems (Fisher and Likens 1973), which is made available through decomposition processes. In aquatic ecosystems, only a small part of submerged aquatic macrophyte production is directly consumed by herbivores (Mann, 1975), while a large part of macrophyte biomass has a major function in the detritic pathway.

Decomposition processes of plant detritus in aquatic ecosystems have received increasing attention in the last three decades. Most of these studies have been based on three major approaches, focusing on the influence of detritus decomposition on water chemistry (Gupta *et al.*, 1996), chemical changes in leaf detritus during processing (Robertson, 1987; Bärlocher *et al.*, 1995) and energetic aspects of detritus processing (Petersen and Cummins, 1974). The third approach was developed mainly utilizing detritus breakdown rates as descriptors of detritus processing (Gessner, 1991).

Plant breakdown rates in aquatic ecosystems have been found to be affected by internal factors, i.e. leaf species and chemical-physical characteristics of the leaves themselves (Kok *et al.*, 1990; Canhoto and Graça, 1996), and by external environmental factors such as water temperature and salinity (Reice and Herbst, 1982), pH (Thompson and Bärlocher, 1989), nutrients (Sharma and Gopal, 1982), or regional characteristics such as climate (Murphy *et al.*, 1998) and solar radiation (Denward and Tranvik, 1998). In addition, plant decomposition rates have been described relative to biotic factors, highlighting the role of microfungi and invertebrates (Rossi, 1985; Gessner and Chauvet, 1994).

It has been proposed that leaf degradation rates could be used as a tool to evaluate environmental quality, as leaf litter breakdown is a complex process in which biotic and abiotic factors are involved (Graça, 1993). A thorough understanding of this process is critical, not just to grasp the essence of ecosystem functioning but also to predict the consequences of global environmental changes at various scales (Graça *et al.*, 2005).

Given the significance of the process, it is not surprising that ecologists have studied litter decomposition at least since Darwin. Methods have since been substantially broadened and refined, although some basic approaches such as the mesh-bag technique are still useful and widely employed.

Here we describe very briefly the main steps of an experimental study on decomposition of plant organic matter in aquatic ecosystems with a simple study case of decomposition processes of *Phragmites australis* leaf detritus in the lake complex of Alimini (Italy).

Material and methods

Detritus processing of *P. australis* leaves can be studied using the leaf bag technique (Bocock and Gilbert, 1957; Petersen and Cummins, 1974; Melillo *et al.*, 1983), based on the estimate of mass loss of plant material from litterbags.

Leaves of *P. australis* need to be collected at the beginning of autumn, air-dried and stored in a dark room at standard temperature and low humidity until needed. Before use, leaves are cut into roughly 8-cm-long fragments and oven-dried to constant weight (60±°C for 72 h). Lots of 3±0.005g dry weight are placed in 5 mm mesh bags.
The ash free dry weight (AFDW) of leaf packs is determined on a sub-sample of leaf packs to obtain an estimate of the biomass at the beginning of the experiment. Leaf packs are anchored to the bottom with bricks, steel or pegs, and collected at different sampling times (e.g., 1, 3, 30 and 90 days) in according to a pre-planned schedule (depending on leaf type).
At each sampling time, some leaf packs (e.g., 5) are sampled, placed in a plastic container separately and rapidly brought to the laboratory. Here, leaves are gently washed to remove sediments and macroinvertebrate colonizers. Leaves from each pack are dried in an oven at 60°C for 72 h, weighed, burned in a muffle furnace at 500°C for 6 h and weighed again.
It is important to measure the physical and chemical characteristics of the water (e.g., dissolved oxygen, pH, salinity, temperature, nitrate, nitrite, ammonium and phosphate) at each station during the sampling period. Physical characteristics can be measured with field instruments in situ, while nutrient concentrations can be determined in the laboratory from water samples. Moreover, it is advisable to measure some structural ecosystem characteristics such as the organic content of the bottom sediment at each sampling station.
Mass-loss data can be processed using non-linear regression analysis of the exponential model (Olson, 1963):

$$M_t = M_0 e^{-kt}$$

where M_t is the mass remaining at time t, M_0 the initial mass and k the breakdown coefficient (days^{-1}); k values can be used as a measure of reed processing rates. Moreover, it is possible to run an analysis of covariance using time as a covariate if data from more than one series have been collected.

Case study

Study area

The study was carried out in the drainage basin of the lake complex of Alimini, in southern Italy on the Adriatic coast (Fig. 1). This basin includes three different types of aquatic ecosystems: a salt-marsh lake (Alimini Grande), a freshwater channel (Zuddeo) and a freshwater lake (Alimini Piccolo or Fontanelle). Alimini Grande receives three main freshwater inputs: one from Alimini Piccolo, a second from a small stream (Zuddeo) and another from three small channels entering the north side of the lake, carrying water from the Traugnano Swamp.

Figure 1 - Map of Lake Alimini

Sampling

The study was performed using leaves of *P. australis* (Cav) Trin. ex Steudel, and was carried out at a total of 20 sampling sites: nine in Alimini Grande, five in Alimini Piccolo and six in the Zuddeo channel. The field work was carried out in four seasonal periods, and datasets on detritus decomposition were collected at four times from the start of the experiment in each season. Detritus processing of *P. australis* leaves was studied using the leaf pack technique, based on the estimate of mass loss from litterbags of reed leaves. For more details see Methods.

Results

Inter-habitat variation

Overall, *P. australis* processing in the Alimini complex fits a negative exponential model ($y=89.6e^{-0.018x}$; r =0.700; d.f.=16; P<0.05). Considering all sampling stations in both lotic and lentic ecosystems, we calculated an average daily reed detritus weight loss of 1.75% and a reed detritus half-life of 39 d.

Ecosystem types and seasons were sources of heterogeneity, and spatial variation of reed decay rates among ecosystem types was significantly more important than temporal variation (two-way ANOVA, $P<0.001$) (Tab. 1). Reed leaves decayed faster in the Zuddeo channel ($k=0.036$) than in the two lentic ecosystems, Alimini Piccolo ($k=0.010$) and Alimini Grande ($k=0.007$) (ANCOVA, $F(2,12)=5.9$, $P<0.05$). The remaining leaf pack biomass at the end of the field experiments (day 90) was 5.6±8.1% in the lotic ecosystem (Zuddeo), 39.5±2.5% in Alimini Piccolo and 47.2±4.7% in Alimini Grande.
On a temporal scale, the processing rates of P. australis leaves varied significantly among seasons in both lentic ecosystems, Alimini Grande and Alimini Piccolo (one-way ANOVA, $P<0.001$), while in the lotic ecosystem, reed processing rates were not affected by seasonal differences. In Lake Alimini Piccolo and Lake Alimini Grande, reed leaf decomposition was 1.3–1.5 times faster in summer than in the other seasons, respectively.

Table 1 - Two-way ANOVA results for ecosystems and seasonal periods of decay-rate data in the drainage basin of Alimini.

Two-way ANOVA				
Source	Sum of Squares	d.f.	Mean Squares	F
Systems	0.070	2	0.035	59.904**
Time	0.001	3	0.000	0.850
Systems*Time	0.006	6	0.001	1.582
Error	0.040	68	0.001	

Intra-habitat variation

Reed detritus decay rates also showed patterns of spatial variation within each ecosystem type. Temporal variance of reed decay rates explained 65% of the overall variance in Alimini Grande, 79% in Alimini Piccolo but only 14% in Zuddeo.
Spatial heterogeneity of reed decomposition rates, expressed as the coefficient of variation among sampling stations, was higher in the freshwater stream (c.v.=61%) than in the freshwater lake (38%) and the salt-marsh lake (33%).

Taking account of the structural features and abiotic characteristics of the ecosystems (Tab. 2), environmental variables explained 74% of variance of leaf decay rates in Alimini Grande ($r=0.858$; $d.f.=8, 26$; $P<0.001$) and 93% in Alimini Piccolo ($r=0.963$; $d.f.=7, 12$; $P<0.001$; Tab. 3).

When data were pooled on an annual basis, most of the decay rate variation was found to be due to physical features both in Alimini Piccolo (77%) and in Alimini Grande (45%). On the other hand, when data were analyzed on a seasonal basis, most of the decay rate variation was due to chemical factors, which accounted for up to 93% and 85% of decay rate variance in Alimini Grande and Alimini Piccolo, respectively.

Station	Temp. (°C)	Sal. (PSU)	DO (mg/l)	NH_3 (µM)	NO_2 (µM)	NO_3 (µM)	PO_4 (µM)	Cl *a* (µg/l)
1°	18	29.4	8.2	8.03	0.61	55.76	0.13	2.60
2°	18	28.3	8.1	8.61	0.63	47.51	1.49	3.53
3°	19	21.0	7.5	14.01	0.88	55.28	0.10	2.57
4°	14	10.0	7.6	14.90	1.25	70.69	0.15	3.24
5°	19	30.6	7.5	6.99	0.61	50.06	0.10	3.36
6°	18	30.2	7.7	8.82	0.67	49.34	0.05	3.62
7°	19	29.0	7.1	10.46	0.65	56.10	0.12	4.09
8°	19	28.0	9.8	10.50	0.65	78.27	0.06	3.83
9°	18	31.0	9.3	9.68	0.70	49.54	0.03	3.73
10°°	18	0.3	7.7	2.23	0.16	38.89	0.10	20.84
11°°	18	0.4	7.7	0.55	0.14	27.29	0.16	32.66
12°°	18	0.5	8.3	7.89	0.47	58.07	0.08	13.40
13°°	18	0.4	7.7	1.95	0.23	29.94	0.14	33.04
14°°	16	0.5	8.3	1.88	0.23	38.28	0.10	32.52
15°°°	17	0.2	9.1	1.18	0.26	168.4	0.13	-
16°°°	17	0.2	8.3	1.16	0.41	193.0	0.13	-
17°°°	18	0.2	7.5	0.72	0.32	226.1	0.14	-
18°°°	18	0.3	6.5	0.75	0.23	229.0	0.14	-
19°°°	17	0.2	4.8	0.37	0.20	237.0	0.14	-
20°°°	17	0.2	4.2	1.14	0.21	211.1	0.09	-

°Alimini Grande, °°Alimini Piccolo, °°°Zuddeo.

Table 2 - Physical–chemical parameters measured at each sampling station in the three ecosystems.

In the lotic ecosystem, the Zuddeo, the distance of each sampling station from the channel mouth in the salt-marsh lake, physical features and nutrients together accounted for 56% of decay rate variance ($r=0.745$; $d.f.=7, 16$; $P<0.05$; Tab. 3). On an annual basis, a similar percentage (30%) of decay rate variation was due to structural characteristics and physical features; while on a seasonal basis a pattern was identified only for physical features, which explained 98% of decay-rate variance in summer–autumn and 45% in winter–spring.

Table 3 - Multiple regression analysis of litter breakdown rates in relation to abiotic factors in the lentic and lotic ecosystems.

Multiple regression analysis					
	r	r^2	D.F.	P	S.E.
ALIMINI GRANDE					
All features	0.858	0.736	8, 26	**	0.001
Nutrients	0.809	0.654	5, 29	**	0.001
Physical features	0.668	0.446	3, 31	**	0.002
ALIMINI PICCOLO					
All features	0.963	0.927	7, 12	**	0.001
Nutrients	0.372	0.139	5, 14	n.s.	0.004
Physical features	0.876	0.771	2, 17	**	0.002
ZUDDEO					
All features	0.745	0.555	7, 16	*	0.799
Nutrients	0.319	0.102	4, 19	n.s.	1.043
Physical features	0.544	0.296	2, 21	*	0.878
Structural features	0.543	0.295	1, 22	**	0.858

Discussions and conclusions

The analysis of the results concerning the spatial variability of reed detritus decomposition rates in the Alimini lake complex highlights two important points: **1.** decomposition processes of *P. australis* leaves are characterised by both inter-habitat and intra-habitat heterogeneity; **2.** the structural features and physico–chemical parameters of each ecosystem are factors which influence the spatial heterogeneity of reed processing rates.

The first point is supported, first of all, by evidence that reed decomposition processes are faster in the stream than in the two lakes, and faster in the freshwater than in the brackish lake, in every seasonal period. Here, the three ecosystems investigated have the same climate and natural rock substrate and do not have permanent physical barriers to the dispersion of either invertebrates or micro-fungi, at least between the two freshwater ecosystems. The salinity barrier is broken in the winter period when the salinity of Alimini Grande remains very low along the shoreline between the mouths of the freshwater stream and the channel connecting it to the freshwater lake (Basset, 2000). Accounting for these structural and physical–chemical features of the Alimini complex, it can be regarded profitably as a natural mesocosm in which there is experimental evidence of differences in detritus decomposition processes between lentic and lotic ecosytems, and between freshwater and brackish ecosystems.

The second point concerns the identification of factors limiting reed processing rates in the two lakes compared with the stream. The results highlight the different importance of structural features and physico-chemical parameters to reed leaf decomposition processes in different ecosystem types. A higher percentage variation of reed decay rates is accounted for by abiotic factors in the two lakes than in the stream. In addition, a seasonal pattern of physico-chemical features and litter breakdown was observed in each ecosystem. The most important difference between lotic and lentic ecosystems is current velocity, which can affect processing rates directly, through leaf fragmentation (Witkamp and Frank, 1969; Hodkinson, 1975; Gurtz and Tate, 1988), and indirectly, by renewing oxygen and favouring microbial activity (Reice, 1974; Godshalk and Wetzel, 1978). The spatial heterogeneity of litter breakdown observed in the Alimini complex cannot be due to the direct influence of current velocity, since average freshwater inflow was low in the Zuddeo ($6.2*10^3 m^3 g^{-1}$), and the leaf packs were protected from fragmentation by the net. Moreover, superficial sediments in both lakes are generally well-oxygenated throughout the year, as is the water of the stream (Basset, 2000).

In conclusion, the present investigation emphasizes the differences in reed decomposition processes in ecosystems of different types and suggests that a complex ecosystem made up of a plurality of ecosystem types, such as the Alimini basin, constitutes an interesting field laboratory in which to test directly hypotheses concerning factors that limit and regulate detritus processing in aquatic ecosystems.

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Local knowledge to support environmental resource management in data-poor regions

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Abstract

The importance of shared decision-making processes in water management derives from the awareness of the inadequacy of traditional – i.e. engineering – approaches in dealing with complex and ill-structured problems. It is becoming increasingly obvious that traditional problem-solving and decision support techniques, based on optimisation and factual knowledge, need to be combined with stakeholder-based policy design and implementation. The aim of our research is the definition of a Community-based Decision Support System (CBDSS), able to facilitate integration of local and scientific knowledge. The system has been applied to support public involvement in the drawing up of the river Idro management plan.

Introduction

Today there is an ever-increasing interest in enhancing public participation in water resource management. Public participation is seen as a way to enhance the democratization of environmental resource management, allowing all possible stakeholders to participate in the decision-making process. The role of the participatory process in water management has also been established by the European Community Water Framework, which strongly encourages the active involvement of all affected parties in resource management (Pahl-Wostl, 2002).

One way for people to be involved is to provide *local knowledge* of their environment (Robertson and McGee, 2003). Local knowledge is increasingly recognized as an important source of information for environmental resource management. It can fill important information and data gaps, particularly in data-poor regions, contributing to a fuller picture (Ball, 2002). There is a wide range of literature on the relevance of local knowledge, its use and the importance of integrating local knowledge into more formal research activities (Oudwater and Martin, 2003). Local knowledge can be used to corroborate scientific data and to fill in gaps in scientifically-generated data

(Scholz *et al.*, 2004). Indeed, scientific knowledge cannot always provide satisfactory answers at the local scale, usually because of the site-specificity, which can lead scientists to ignore local macro-variation and to ask the wrong questions through a lack cultural understanding (Ball, 2002).

Local environmental knowledge refers to the body of knowledge held by a specific group of people about their local environmental resources (Scholz *et al.,* 2004; Robertson and McGee, 2003). Local knowledge should not be seen as the simple counterpart of scientific knowledge; the two may be combined as fractions of all knowledge, leading to a broad, hybrid view of local resource management issues (Robbins, 2003).

Involving local communities in environmental management is not just a matter of using participatory approaches within a conventional monitoring framework. It's mainly about a radical rethink of who initiates and undertakes the process, and who learns and benefits from the findings. Incorporating local knowledge into the decision-making process and creating community-based resource management can have several benefits for both the communities and the water management agencies (Gouveia *et al.*, 2004). From the communities' point of view, the benefits obtainable through public involvement are mainly related to the promotion of public awareness of environmental issues, the enhancement of collaboration and cooperation, and the promotion of a "two-way" information exchange. On the other side, water management agencies can increase the available information and base their strategies on a more integrated knowledge; the implementation phase will also be facilitated, since conflicts would be reduced.

Many efforts have been made to utilize local knowledge in environmental management (see for example: Robertson and McGee, 2003; Scholz *et al.*, 2004; Hellier *et al.*, 1999; Danielsen *et al.*, 2000; Danielsen *et al.*, 2005; Oudwater and Martin, 2003).

Nevertheless, the use of local knowledge in environmental resource monitoring and management is still limited because of several shortcomings, such as data credibility, difficulties in comparing the knowledge collected by local communities with those coming from other sources, and the scale of local knowledge. The contribution of local knowledge is limited due to a general lack of understanding on what local knowledge is and how it can be explored and used (Oudwater and Martin, 2003).
Our research aims to define methods and tools to resolve the above-mentioned shortcomings of local knowledge. All of them are used to define the architecture of a Community-based Decision Support System (CBDSS) which can promote access to, and exploration of, pre-existing data and information; it can facilitate the input of local knowledge and the integration of community-based information with data from "scientific" monitoring systems. Moreover, CBDSS needs to enhance the accessibility of local knowledge for the decision makers.

Material and methods

Given the drawbacks of local knowledge described above, it is unrealistic to expect water managers to make use of it as generally presented, because it is not systemically set out and its contents are too vague for them to access and use easily. Therefore, a Community-based Decision Support System has to be able to both support the collection of local knowledge through the involvement of local communities in environmental management, and enhance the accessibility of this knowledge for decision makers. Concerning the latter group, structuring local knowledge is a fundamental step in overcoming their scepticism. Various methods for structuring qualitative knowledge are mentioned in the scientific literature. In our research, Problem Structuring Methods (PSMs) and GIS technology have been taken into account in terms of their potential in making qualitative knowledge suitable for the decision-making process.
Mostly, PSMs have been used to facilitate group work

within business organisations. New approaches are attempting to apply these methods in more complex, shared decision-making processes such as participatory natural resource management (e.g., Hjorsto, 2004; Ozesmi and Ozesmi, 2003). PSMs aim to discover each stakeholder's point of view and knowledge on a particular issue, their perception of the related problems and which of the alternative solutions are suitable in their opinion.

To structure the knowledge expressed by the different stakeholders, making it comprehensible for decision-makers and functional for the decision process, we refer to SODA methodology. SODA is a general problem identification method that uses cognitive mapping as a modelling device for eliciting and recording individual views of a problem situation. The cognitive maps are defined using verbal protocols, allowing the contents of a discourse to be structured and the qualitative data to be analysed (Cerreta *et al.*, 2004).

The Cognitive Map aims to uncover individual perceptions of the consequences and explanations associated with concepts, and it is used by participants to communicate their understanding of the nature of the problem (Hjorsto, 2004). A Cognitive Map can be defined as a map made up of concepts, linked to form chains of action-oriented argumentation (Eden and Ackermann, 2004). Cognitive maps have been used to represent cognition at both individual and group levels.

Very often, local knowledge has a strong geographical connotation. Therefore, local knowledge has to be "spatially" represented, creating "indigenous GISs" (Robbins, 2003) that can support the use of local knowledge in the environmental resource management process.

Many efforts have been made to create GIS maps based on local knowledge (e.g., Oudwater and Martin, 2003; Anuchiracheeva *et al.*, 2003; Hellier *et al.*, 1999; Scholz *et al.*, 2004). The incorporation of local knowledge into a GIS can be used either to challenge the existing "scientific" spatial document, or to supplement the existing information (Robbins, 2003). In the latter case, the GIS is the platform to integrate local and scientific knowledge, leading to a hybrid and broad view of local resource management (Oudwater and Martin, 2003; Robbins, 2003). However, extending GIS access to grassroots groups and other non-traditional users is beneficial because it enables development of alternative knowledge and its inclusion in decision-making (Elwood, 2002).

Some researchers, recognizing the exclusion of certain types of knowledge, have sought ways of extending the representational capacities of traditional GISs to include "non-traditional" knowledge, such as narratives, alternative cartographies, videos, pictures (Elwood, 2002; Gouveia *et al.*, 2004). These "extended" GISs help non-traditional users to construct and to promote their own perspective or to re-examine those produced by others (Elwood, 2002). Most of the extended GISs have multimedia functions. The use of multimedia techniques can help non-expert users to understand GIS information, providing tools to read interactive maps and associated data (Ball, 2002). Moreover, they can assist the users in publishing their information, drawing other peoples' attention to their findings (Gouveia *et al.*, 2004).

The use of local knowledge in environmental management guarantees equal access to data and information for all sectors of the community, and equal possibilities of providing knowledge in a way that can be understood by other members (Ball, 2002). Therefore, a Community-based Decision Support System (CBDSS) should promote access to, and exploration of, pre-existing knowledge; it should facilitate the input of local knowledge and the integration of this knowledge with scientific knowledge. Moreover, the CBDSS should promote communication between stakeholders, facilitating cooperation and the creation of synergies. The creation of virtual monitoring communities should enable all stakeholders to share their perspectives on the state of the environment, increasing their knowledge and their desire to improve it.

Given the properties of a system able to incorporate local knowledge to be used in environmental management, the architecture of the CBDSS can be schematized as in figure 1:

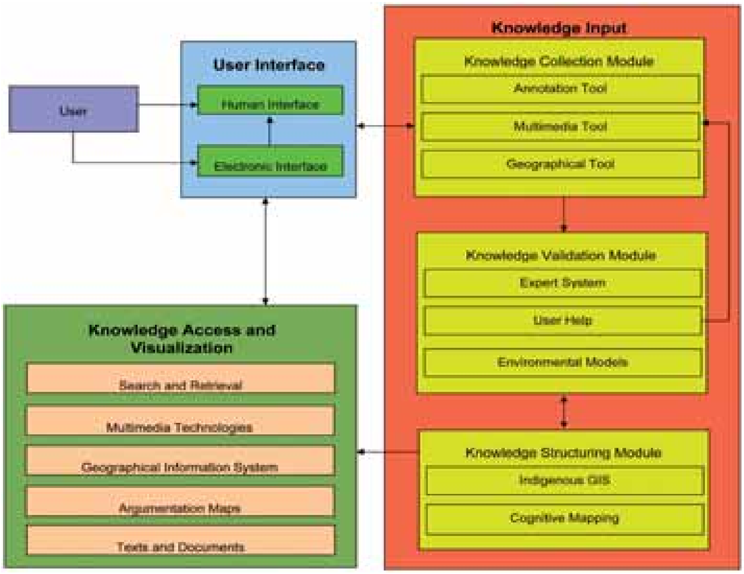

Figure 1 - CBDSS architecture

At the current state of the research, only knowledge acquisition and structuring have been implemented.

Results

The methods on which CBDSS is based have been applied to collect local knowledge in order to support the decision-making process in the recovery of the Idro river in Puglia (Southern Italy). The research was developed under the RiverNet project, focusing on the re-creation of links between the population and the rivers.

The experimental phase is divided into three main modules: Individual interviews and public forums to collect local knowledge; Structuring of local knowledge and conflict analysis; Negotiation. At the current stage of project implementation, only the first two modules have been implemented.

Concerning knowledge collection, many stakeholders have been identified, considering those who may participate in the decision-making process and those who may

be influenced by the results of the decisions. Therefore, several individual interviews were conducted with: environmentalists, local cultural associations, tourism agencies, farmers' associations, local administrators, landowners, politicians, etc.
In accordance with the method described above, the knowledge expressed by the stakeholders has been structured into individual cognitive maps. Figure 2 shows an example of a cognitive map.

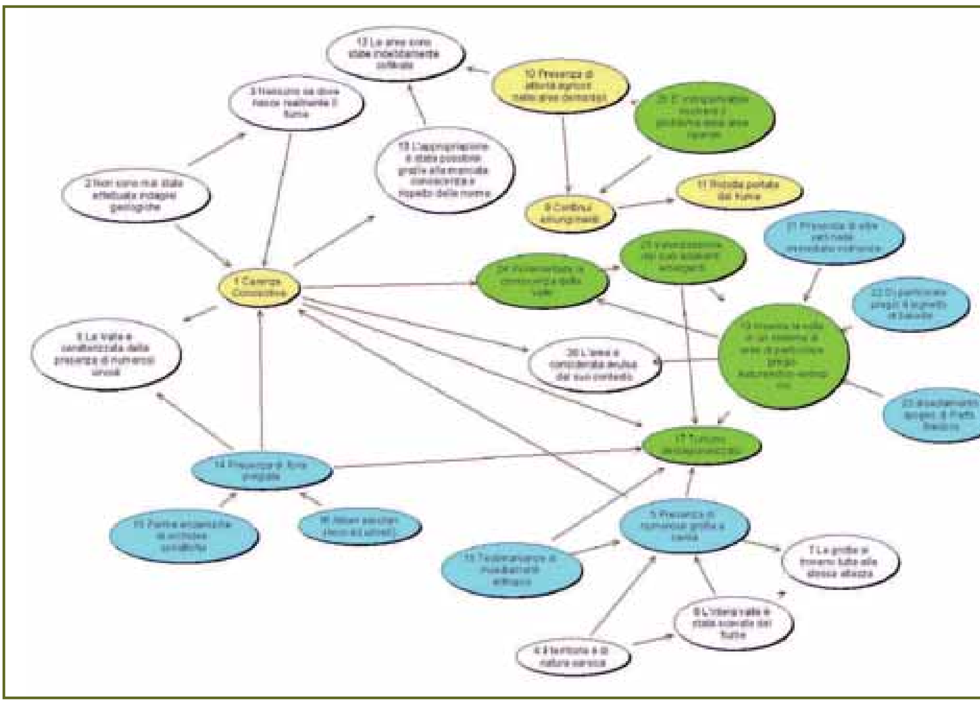

Figure 2 - Individual Cognitive Map

Four types of concepts were used:

- criticality (yellow): the most pressing problems in the study area;
- key elements (white): the elements characterizing the study area;
- potential (blue): the elements that need to be considered as the basis of the recovery project;
- Proposal (green): ideas to promote the Idro valley.

From the analysis of the cognitive maps it emerged that the Idro Valley is considered by the local community members as a "system", composed of both natural-environmental resources and human activities. Specifically, most of the interviewees considered it important to take account of the archaeological sites in any plans concerning the Idro Valley. One of the most popular strategies was to create thematic itineraries leading tourists from the city centre to the most interesting sites in the valley.

There is no consensus on the agricultural activities. Indeed, many stakeholders consider these activities as highly damaging to environmental resources. They wish to re-naturalize the whole area. On the other hand, other interviewees consider agricultural activities as a fundamental aspect of the link between the local community and the territory. In their opinion the valley must not become a museum.

Conclusions

It is increasingly obvious that in order to face the complexity of water resource management problems, technical approaches are not enough. The nature of these problems and the approaches to dealing with them is changing. New management schemes combine the technological dimension with the social dimension, based on stakeholder involvement. Moreover, we are witnessing a change in the role of decision-support tools in the environmental domain, from a single decision-maker perspective to a process of debate with a number of stakeholders. The decision tools are becoming the shared platform through which the debate is organised and the different sources of knowledge are integrated.

In this perspective, the architecture of a Community-based Decision Support System, able to collect local knowledge to support environmental resources management, has been proposed. Different forms of knowledge are taken into account to obtain the complete picture of the local environmental, adopting a social approach to the construction of reality. According to the Soft System perspective, individuals continually negotiate and re-negotiate with others their perceptions and interpretations of the real world outside themselves. According to this assumption, each individual has his own perspective in defining and interpreting a problem situation. The expected outcome of an SSM study is a set of insights that emerge from the comparison of individual perspectives, forming the richest possible picture of the problem situation.

The integration of local and scientific knowledge leads to the achievement of hybrid knowledge and a nuanced understanding of environmental, social and economic system interactions, which are required to provide more informed inputs to sustainable local water resource management.

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11

Management of a river basin: a demo-software for the identification of the potential source of pollutants.

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Introduction

In recent years the correct management of all natural resources became a very urgent need. The new attitude of living at the present while looking at future time has generated the ethical problem of our responsibility towards future generations. As a result, new concepts such as "sustainable development" and "integrated management of the resources" were proposed. However, a new value was attributed to natural resources in general, and to water in particular.

Water has always been considered a precious good. Nevertheless, since the beginning of the industrial era, the water resource has undergone an irrational use and excessive exploitation worldwide. The demographic growth and the increase of the industrial and agricultural production have had so far negative consequences on the environment, especially on the river areas. Fortunately, in the last years the environmental protection and the conservation of water resources have had a high priority in all national and international programs, and this has prevented some more negative consequences.

Rivers are dynamic systems made of a succession of habitats, different from the source to the mouth. Such complex system allows the life of a large variety of animals and plants. Also, the river environment has many uses and is characterized by the presence of various human activities. Like the sea-coast, the river is much exposed to the pressure of such human activities.

As mentioned above, the "sustainable development" concept leads to the sustainable use of resources so to make them available for the future generations. The protection of water resource requires that regulations are respected in order to avoid the environmental degradation. The constant monitoring of water basins: the systematic collection of data may allow the understanding of the environmental dynamics. Such knowledge should promote the implementation of actions that may prevent irreversible damages to the water resource and guarantee that biodiversity is maintained. The new attitude has produced new Laws such as the italian D.Lgs 152/2006, (European Directive 2000/60) relevant to water protection from chemical and bacteriological pollution and the maintenance of the river quality. The main target is to avoid the depletion of the biological processes that sustain the natural self-depuration of a river.

The ecosystem structure of a river depends on its relationship with the surrounding environment, and this is true from the source down to the mouth of the river in conjunction with the continuous natural transformations there occurring. The various sectors and branches of the river are characterized by a variability of the flow and turbulence, by different sediment typology and chemical composition of the water and by morphological difference of the river bed (straight, winding, wide, etc.). The different sectors of the river are also characterized by different water depth and bed type that contribute to influence, together with other factors, the interrelation and the exchange between the upper layer and the sediment. Additionally, the erosive action of water and the ability to deposit sediments contribute to model and to transform the territory.

The river is an "alive organism", in a slow and continuous transformation under very complex equilibrium conditions that are easily alterable. The whole ecosystem is vulnerable by actions such as:

- Construction of barriers (dikes, bridles, cemented river bed etc.) that in general interrupt the spatial continuity.
- Excessive external inputs produced by human activities, in a “point” or “diffuse” mode.
    - Kinds of “diffused” sources of pollutants are the acid rains, the draining water from agricultural soils, traffic and similar. The diffused sources are difficult to monitor and identify because the pollutants cannot be followed from the source to the water basin.
    - Kinds of “point” sources are factories, water treatment plants, mines, oil wells, reservoirs for oil and some specific agriculture applications. They can be easily located and traced.

The various anthropic activities influence the equilibrium of a river basin as they are sources of several polluting substances that reach the water.

In table 1 some polluting substances are listed.

Table 1 - Kinds of pollutants

Degradables Pollutants	Sulphides, Sulphites, Sulphates, Ammonia, Fats, Oils and some kinds of Soaps	Such substances cause modification of water pH, colour, smell and they also affect the sediment and increase the need of O_2 for the biochemical and chemical oxidation (BOD, COD)
Toxic Contaminants, non Degradable Organics	Aluminum, Barium, Cr (III), Copper, Iron, Nickel, Zinc, Chlorine, some Surfactants	
Toxic Contaminants, non Degradable that may cumulate in water, in soil and in the food chain	Arsenic, Cadmium, Cr (VI), Mercury, Lead, Selenium, Phenols, Pesticides, PVC, Organoalogenates, Plastics	

As a matter of fact, the numerous human activities can produce several different polluting substances, but some of them are characteristic of a given activity.

Table 2 shows the variety of activities and anthropogenic emissions that can influence a river basin.

Table 2 - Anthropic activities and their emissions

INDUSTRIAL POLLUTION
CHEMICAL, PETROCHEMICAL AND PHARMACEUTICAL INDUSTRY
Emission on ground and in water: Oils, Hydrocarbons, Tars, Acids, Bases, Catalysts, Metals (Fe, Cu, Cr, Zn), Sulphides, Polymers, Phenols, Organochlorinated compounds, Paraffins, Solvents (hexane, benzene, dichloromethane, others), culture broths etc.   Immission into the atmosphere: Oxides of N, C, S, some Pb and Hg compounds, volatile organic compounds, PCB, etc.
MINING, METALLURGICAL, GALVANO-PLASTIC INDUSTRY
Metals (Cu, Zn, V, Al, Mo, Fe, Ni, Pb, Cd, Hg); Acids (nitric, sulphuric, hydrochloric, perchloric); Salts (nitrates, nitrites, cyanides); Polymers.
TEXTILE AND TAN INDUSTRY
Dyes, Solvents, Soaps, Catalysts, Metals, Acids, Bases.
FERMENTATION AND EXTRACTION INDUSTRY (BEER, WINE, VINEGAR, DISTILLERIES, SUGAR, OIL)
Microrganisms, Organic degradable substances with high COD and BOD, Solvents
FOOD INDUSTRY, SLAUGHTERHOUSE, ZOOTECHNIC BREEDINGS
Organic products and putrescible substances (a pigsty of 10.000 heads, pollutes like a city of 30.000 - 40.000 inhabitants).

URBAN POLLUTION
Waste water
Accumulation of organic and inorganic compounds, hardly degradable substances
Smokes and vapours from combustions, Pb, Hydrocarbons, Oxides of N and C, SO_2.
AGRICULTURAL POLLUTION
Due to the practice of intensive agriculture. The increase of high quality production requires the control of the illness of plants and parasites by means of pesticides and fertilizers. Compounds accumulating in the environment are particularly dangerous.

Exogenous substances may cause the modification of the morphology and the alteration of the natural ability of the river (self-depuration action) to metabolize the organic (natural and anthropogenic) compounds released from the surrounding territory. The substances that are not metabolized cause alteration of the ecosystem.
Examples of the toxic activity of two important classes of pollutants are presented in table 3.

Table 3 - Toxic activity of two classes of pollutants

HYDROCARBONS	METALS
The heavy aliphatic hydrocarbons are easily degradables. Lighter aliphatic hydrocarbons are more toxic. The aromatic compounds can be carcinogenic (benzopyrene, anthracene, benzoanthracene, etc.). In water, these substances cause surface alteration, arrest of the photosynthesis, O_2 depletion, death or contamination of the fish fauna making them not edible.	They can be present in waters and in the ground as ions (usually the most toxic form), organic complexes, precipitates (oxides or sulphides). Cu, Zn, Pb, Cd, Hg in ionic form have acute toxicity. Fishes suffer irritating action of the lamellar structures of the gills. This leads to the alteration of the oxygenation and then to death. Metals are often organicated and made liposoluble by the microrganisms present in water or ground. Under this form they cause more easily chronic toxicity since they can cross cellular membranes and reach sensitive organs (e.g. brain).

The sustainability principle demands the conservation of the biodiversity and of the ecosystems.
The human society should avoid river degradation by limiting those impacts that may produce irreversible effects. This requires to maintain a constant level of the water quality with decisions that may reduce the pressure on the river system through a modification of the economic use of the basin.
A sustainable use of the river areas optimizes the equilibrium between the social and economic benefits.
Figure 1 shows the relationships among the social-economic-ecology (SEE) aspects of the management of a river basin. The actors involved in the management and the effects of the actions are shown.
One of the key issues in the SEE Scheme is the usability of the data collected through analy-

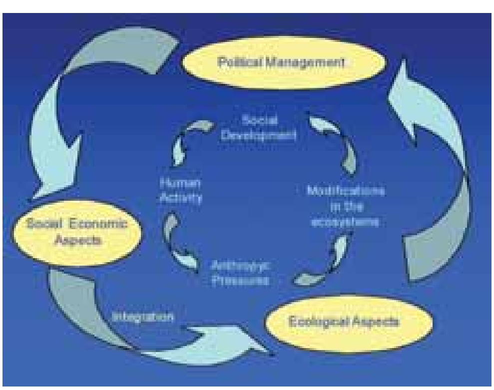


Figure 1 - System scheme of the entities and their complex relationship relevant to the management of a river basin.

ses of samples of water. It may happen that such data find a limited (if any) use in the decision process because they are too technical and the information they contain cannot be used by decision makers or their consultants. One of the most complex problems to solve is the lack of links of the figures representing the pollution level to the pollution sources. The work done in this Project was performed in the direction of building a handy tool that may help in finding the source of pollutants and to link the potential source to production activities within the territory.

The Metea Centre contribution to the "RiverNet" Project

The aim of the work developed by the Centro Interdipartimentale METEA of the University of Bari within the RIVERNET Project is summarized in this paragraph. It has been intended to provide a suitable technical tool to a competent organization implicated in the management of hydro-basins in the context of a Strategic Environmental Assessment (SEA).

Based on the model DPSIR of the European Agency for the Environment, the METEA activity has been focused on the evaluation of the Driving Forces that influence the quality of the river water resource.

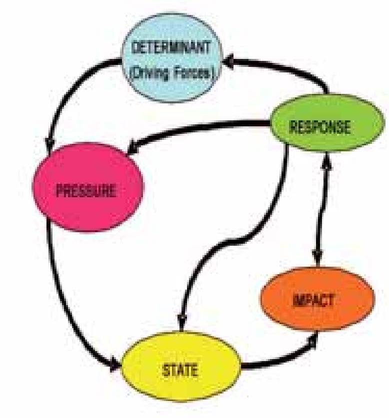
Scheme 1 shows the DPSIR model by The European Agency for the Environment (EEA), that takes into account a model proposed by the OECD. The DPSIR model connects the different classes of environmental indicators.

These classes are divided in:

- **Primary generating causes** (Driving forces): are primary anthropic activities as agriculture, industry, transport, etc.
- **Pressures**: as the discharge in water, production of waste, etc.
- The Pressure determines changes of **State** of the environment and particularly of its quality (changes of water quality, of the biodiversity of the ecosystem).
- The pressures produce an **impact** on the ecosystem and, eventually, on human health.
- The **responses** of the society against modifications of

ecosystems consist of a set of rules and plans of intervention which reduce the pressures. Such measures are aimed at the safeguard of the environmental resources (i.e. water use, fish resources) preventing irreversible damages.

DPSIR model



Sheme 1 - The DPSIR model connects the different classes of environmental indicators. For example: Determinant (Driving Forces): population - economy - uses of the territory - social development in the specific industry and manufacturing sector - energy - agriculture - domestic transport-sector - tourism - recreational activity. Pressure: immission into the air, water and ground - waste production/disposal - use of natural resources. State: quality of waters, ground and air – influence on biodiversity. Impact: on ecosystems, human health, other functions of natural systems. Response (Political Decision): directives and prescriptions - measures and environmental politics.

The knowledge of the environmental dynamics and of the driving forces is useful to define the territorial distribution of the load ability and the environmental sensibility.

The environmental sensibility is the whole of the characteristics of a bio-ecological or physical system. These characteristics determine the greater or smaller vulnerability under external Pressures (produced by the Driving Forces). Therefore, the vulnerability of an environmental system depends not only on its intrinsic sensibility to the external pressure, but also on its recovery capacity.

The sensibility of a system is a multidimensional quality and it is strictly related to the kind of the applied pressures. As a matter of fact, the same pressure applied to two different systems, produces different effects related to the specific sensibility of the systems.

Environmental sustainability is the association between the vulnerability of the system and the economical and social development. One should also consider that a natural environment is a dynamic system. Therefore, the peculiar characteristics of the territory and its vulnerability should be analyzed.

Principles of sustainability are implemented according to the following methods of investigation and intervention policies:

1. An extensive and detailed description of the environmental conditions of a territory is necessary and the thresholds of sustainability must be defined. The knowledge of the environmental conditions and of the social and economical context in which the water basin is inserted, is needed as a basis for investigation, assessment and decision making.
2. Critical sensitive components of the environmental

system (vulnerabilities) and factors of pressure must be defined.

3. Relations cause–effect between the anthropogenic drivers and the change of the ecosystem must be quantified.
4. Anthropic activities should be installed and managed taking into account the environmental sustainability of a territory.
5. Appropriate methodologies must be identified for the evaluation of the ecological, economic and social aspects, for a sustainable development.
6. The cause-effect relationship between the stress agents and their impacts (biodiversity, erosion, anoxia, evolution of trophic chains) must be quantified.
7. The identification and use of the correct political tools (regulations, territorial planning) is at the basis of decisions about economical incentives, or persuasive actions aimed at the implementation of the environmental sustainability.
8. The timely development of strategies and specific indicators for the cost-benefit or cost-efficiency analysis is a need in order to implement an ex-ante evaluation of decision processes for the correct management of the environment.
9. The river community should be mostly involved. It is essential that the community is informed about the quality of the river basin so that people may constructively collaborate to reaching the sustainability objectives.

An important source of information about the quality of a river basin is the water analysis. The key point is that if the chemical or microbiological analyses of samples point out to a poor quality of the river system, the causes of the degradation must be timely identified and a political action must be taken in order to modify the economical and social asset and future development of the area, so that irreversible effects on the water resource are avoided.

Most data are usually very little informative because it is

Figure 2 - Issues considered for a sustainable planning

hard to go back to the causes of the pollution due to the difficulty of identifying the sources and the dynamics of a river system. The work done at METEA within RIVERNET has been aimed to provide a tool for linking the analytical data to potential sources of the identified pollutants. It is obvious that should the sources of pollution be identified the decisional making process is made easier.
Also, if it turns out that it is impossible to set a link between the pollutants and the sources as the latter are not present among the anthropic activities within the river basin, then there is enough reason for suspecting an illegal disposal.
Finally, the knowledge of the Driving Forces and of possible evolutionary trends of a river water quality facilitate the discovery of environmental criticities, providing tools for the correct planning and management of the territory.
Figure 2 schematically shows the path and key points that should be considered in the decision process for guaranteeing a sustainable management of a river basin.

Activity developed by the Research Centre METEA

METEA is an Interdepartmental Research Centre devoted to developing innovative methodologies and environmental technologies. The Centre is composed by several Research Units of the University of Bari having a variety of competences (chemistry, informatics, biology, geology, applied mathematics, etc.). The mission of METEA is to deal with and solve complex environmental problems, using a multi-disciplinary approach.

The core action of the RiverNet project is the sustainable management of a river basin. The activity of the METEA Research Centre inside the RiverNet project, as mentioned above, has been to develop a tool that might be used in supporting ecological, social and economical assessments for implementing a policy of sustainability within the river area.

Moreover, the METEA Research Unit had a fruitful collaboration with the Ecology Group of the University of Lecce for a combined chemical–biological analysis on water samples of the IDRO river at Otranto.

Inside this collaboration, the METEA has carried out chemical analyses of the samples, while the Ecology Group has investigated the biological properties.

The METEA work within the RiverNet project has been oriented to:

- develop cause-effect correlation as a tool that may be used, in conjunction with others, for a correct management of complex ecosystems;
- Identify social necessities and promote the environmental sustainability by improving the relationship between science and politics.
- Build infrastructures for an effective prevention, by fostering the international and multidisciplinary integration.

For developing such tool, the METEA Centre has taken into consideration the many anthropic activities that may produce pressures on a river basin. A software was developed that may be used for identifying Driving Forces that may cause a given pollution.

The analysis of potential Driving Forces brings to identify the main anthropic sources of pollutants through the identification of:

1. Macro areas of anthropic activities
2. Sorting of the main factors of pressure inside each of the macro areas

3. Searching of available databases
4. Harvesting data on the environmental impact of different pressures.

Based on such analysis, an operational software was developed that may be used as a decisional support for the evaluations of the Driving Forces and their effects.

The demo software for linking pollutants to sources

The DPSIR model

The guidelines traced by the DPSIR model of the European Environment Agency, were described above. Such model requires a deep knowledge of the external factors producing the environmental pressures.

Figure 3 identifies six macro areas that can influence the ecosystem of a river basin:

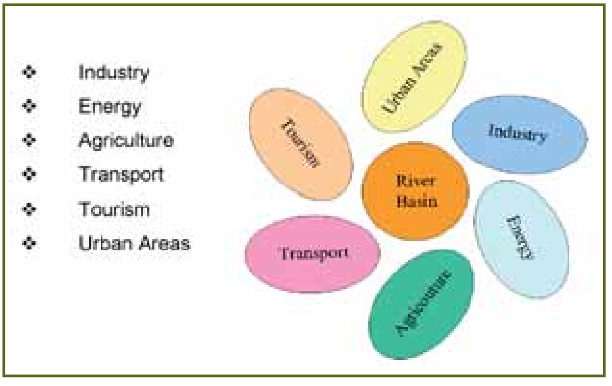


Figure 3 - Macro Areas that influence a river basin

Each macro area produces a set of pressures (in the form of waste or compounds released to the atmosphere or hydrosphere) that cause changes of the environmental quality. In some cases the emissions are a kind of "fingerprint" of the activity. Therefore, a list of substances released by each macro area has been prepared. Such substances may be released as flue gases into the atmosphere or as liquid waste or as disposed solids.

The search of the pollutants produced by each macro area was carried out with the help of databases. The data collected have importance for their environmental pressure. The Databases utilized in this work were:

- Database of the National Informative Service of the Italian Agriculture Ministry, containing data about Agrochemicals;
- The EPER Database - The European Pollutant Emission Register (Register of the Pollutant Emission in Europe);
- The Australian Government Database - National Pollutant Inventory.

Sources of Data

The Database of the National Informative Service of the Italian Agriculture Ministry correlates phyto-drugs to different crops for which they are used. The information present in the Agrochemicals Database are provided by the Experimental Institute for the Vegetal Pathology in Rome. The enquiry of the database is feasible either on the basis of active substances/principles or searching for an agrochemical product specific for a given cultivar. Selected data were assembled in our software and can be now used as an "identification marker" for targeted productive activities of the macro area "agriculture".

The European Register of the Pollutant Emissions allows different searches such as: an enquiry for "industrial activities" or for "polluting agent". Depending on the particular enquiries, it is possible to get an information about, for example:

- The industrial activities that emit the same polluting agent.
- The industrial sectors producing a particular set of emissions.
- The emissions of pollutants grouped on the basis of the industrial activity.
- The percentage weight of various pollutants related to a single productive activity.
- The weight of the European emission per each single member State.

The data obtained from the above Database have been used for setting the reference frame for the macro area

"Industry" and for that of "Energy". Unfortunately the European Register contains only data about pollutants produced by large companies within the European Union; it does not take into consideration the pollution derived from Urban areas and Transports.
To find the emissions of the two latter macro-areas we have searched the Australian Government Database. In this specific case, only qualitative and not quantitative data were used for a correlation between the different pollutants and their sources. In fact, the style and standard of life in Australia may be quite different from that of European Contries and, consequently, numerical values contained in the Databases may not be correct for the EU and, thus, have not been considered.
The list of parameters contained in all the searched Databases was adapted to the national/local territory.
Table 4 shows examples of the possible relationship between sources and pollutants.

Table 4 - Relationship source - pollutants

INDUSTRY	POLLUTANT
PAPER FACTORIES	Chlorides, Ammonia, Carbon dioxide, Arsenic, Nitrogen, BOD, Cadmium, COD, Halogenated organic compounds, etc....
TANNERIES	Nitrogen compounds, BOD, total organic carbon, chrome and its compounds, pH, etc....

CROPS	PHYTOIATIC ACTIVITY	AUTHORIZATION	ACTIVE PRINCIPLE
CITRUS FRUITS	ACARICIDE	NO	AZOCICLOTIN CIEXATIN
		YES	DICOFOL ETOXAZOLE
CITRUS FRUITS	HERBICIDE	NO	FLORASULAM PYRAFLUFEN ETHYL
		YES	DIQUAT DIURON
APRICOT	FUNGICIDE	NO	CLOROTALONIL FENARIMOL
		YES	CAPTANE CIPROCONAZOL

Unlike other macro areas, where only the direct link between the "Typology of Source" and the "Pollutants" exists, the Agriculture area emissions are organized on the basis of the:

- Nature of the active principle
- Phytoiatic activity of the agrochemical used
- Kind of crops for which a given agrochemical is best suited

- Need to have a specific authorization for the use of compounds.

The "active principles" mentioned here are the substances commercially used for fighting, preventing and/or curing plant diseases. Moreover, such substances are used to fight or to eliminate undesired weeds. Such chemicals are grouped by categories of "Phytoiatic Activity" – i.e. insecticide, acaricide, herbicide, etc.. and can be linked to the specific kind of crops (citrus fruit, cereals, apricots, etc.) for which they are used. Besides such link, an information is included that says if there is or not a need to have a specific authorization for the use of such active principles. Table 5 shows an example of classified information.

Table 5 - Example of classifical Information

CROPS	PHYTOIATIC ACTIVITY	AUTHORIZATION	ACTIVE PRINCIPLE
CITRUS FRUITS	ACARICIDE	NO	AZOCICLOTIN CIEXATIN
		YES	DICOFOL ETOXAZOLE
CITRUS FRUITS	HERBICIDE	NO	FLORASULAM PYRAFLUFEN ETHYL
		YES	DIQUAT DIURON
APRICOT	FUNGICIDE	NO	CLOROTALONIL FENARIMOL
		YES	CAPTANE CIPROCONAZOL

The whole information can be used with a double function:

- To correlate the information obtained through the analyses of water samples to the potential sources of pollutants.
- To verify that the river basin includes within a given territorial extension the potential source of pollutants.

For instance, the typology of dominant crops in a territory will give a list of active principles that could potentially be found in water samples. Obviously further information must be gathered through an enquiry within the considered area concerning the:

- list of active principles really applied to agricultural crops in the territory;
- quantitative information on their market;
- environmental diffusion of such substances.

The collected data allow also to identify eventual illegal

activities such as spilling or disposal of pollutants in a territory.
The acronym of the software is **LIPTOS** (**L**ink **P**ollutants **TO** **S**ource). It results to be an useful tool for managers of the river basin. In fact, it allows a direct, simple and rapid consultation for checking the link between pollutants identified through the analysis of samples of water and potential Driving Forces or human activities responsible for the emission.

The operative software LIPTOS

The operative software **LIPTOS** (a copy of which is attached to this book as a CD) allows to quickly relate a particular pollutant to a source. The software facilitates the identification of the anthropic activity that produces such pollutant (classified on the basis of the driving forces).
The used software is a DaeQP tool running on a Java platform. Therefore, a relevant application (also included in the CD or downloadable from Internet) is required for using the software.
Polluting substances are related to anthropic activities. The list of pollutants, is divided in four categories of Driving Forces: Industry, Urban area, Transports and Agriculture (for the latter, the moment being, only phytosanitary substances have been considered).

How LIPTOS works

Figure 4 - First page of the Operative DaeQP Software

After opening LIPTOS, a first choice is possible among the four macro areas: one can select either "Agriculture" or one area among Industry-Transport-Urban Areas. (Fig. 4 shows the magnified window).
In the Agriculture macro area, phytosanitary substances are related to categories as Phytoiatic Activity, Kind of crop, Authorization. Polluting substances in other categories of driving forces (Industrial Activity, Transport, Urbanization) are related to different categories.
In the following window (Fig. 5) of LIPTOS, a choice is possible for linking a pollutant to different sources.

Figure 5 - Second window of the Software.

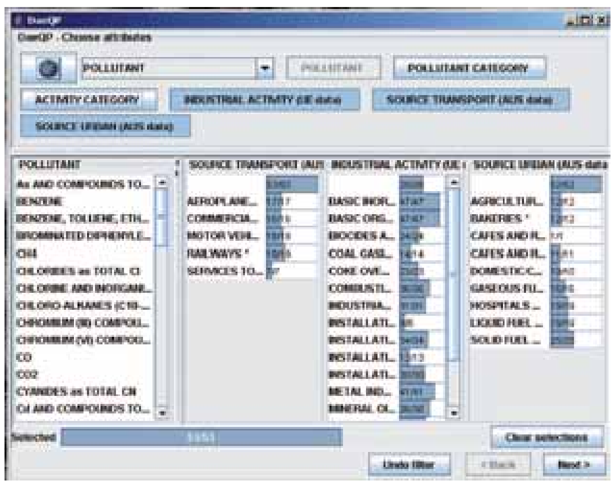


Figure 6 - Third window of DaeQP in which several parameters can be selected

Once such choice is made, a new window will open, in which a list of selected primary attributes is shown on the extreme left (i.e. Pollutants), while secondary attributes are shown on the right (Fig.6). Initially the first column has a narrow field, so it should be manually widen. In order to select a species, it is enough to type its name in the field "SEARCH" that is on the top of the first column. The selection of an item (i.e. in the column "POLLUTANT") will filter further items in the other columns.

A click on the "right key" of the mouse in correspondence of each of the secondary attributes allows to select an option that gathers the items filtered in the upper part of the list. Horizontal bars placed on each of the single items

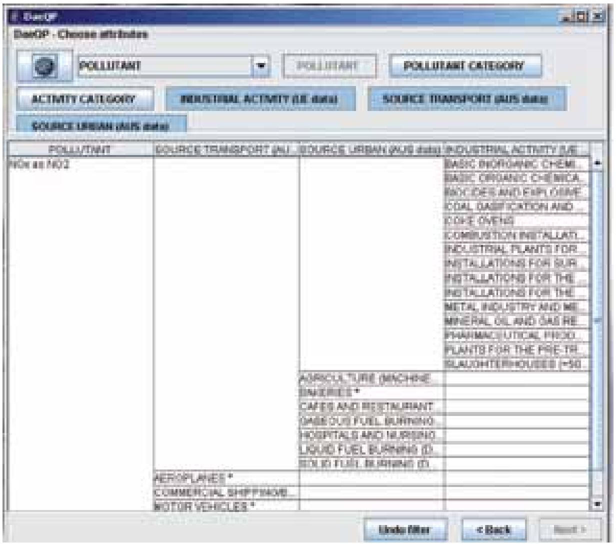


Figure 7 - Fourth window of DaeQP for a more effective visualization of the selected parameters.

of the secondary columns present some numbers (X/Y):

- X indicates the number of filtered items
- Y indicates the totality of possible items of connection.

The "NEXT" key allows to open a fourth window in which the data are better shown (Fig.7).

The "UNDO FILTER" key allows to remove the filter deselecting the considered parameters. At this point it is possible to start again with a new selection.

The described software is demonstrative. It is undergoing further setup and upgrades such as:

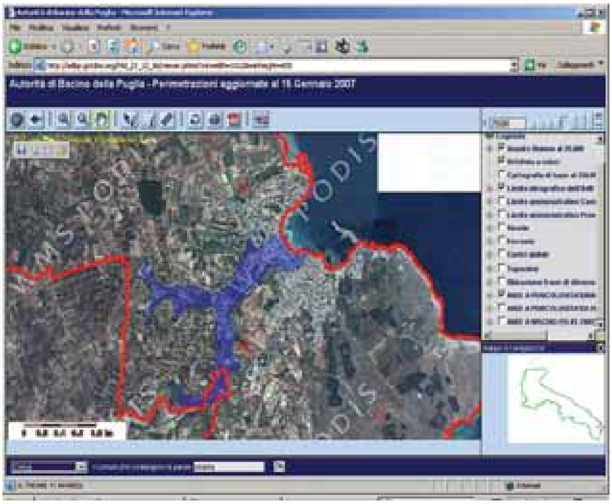
- The unification of all worksheets employed in the structure of the software in a single worksheet;
- The completion of useful information with the insertion of other data (i.e. by adding Fertilizers in the macro area of Agriculture);
- The connection between the gathered information and geographical maps for a spatial analysis of the existing cultures/industries and the localization of a potential source of the pollutants.

Applicative use of LIPTOS

The software has been tested by using real data from a river basin and shown to be quite informative.

The information obtained by using LIPTOS must be integrated with the search for the presence or absence of the specific productive activities indicated by LIPTOS in the considered territory. To this end a "Map of the Economic Activities of the Basin-MEAB" (from the source to the mouth of the river) should be built per each territory under analysis (Fig.8).

Figure 8 - Map of the Idro River Basin



The scheme in figure 9, summarizes the use of the software described above, when applied for the identification of the pollutant sources present in the river basin.

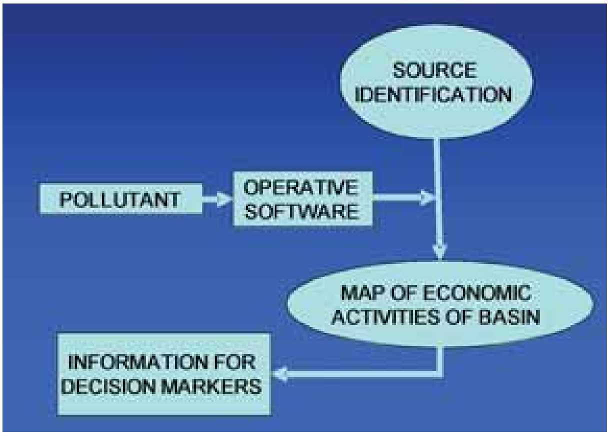
The cross-link of LIPTOS with MEAB allows:

- to correlate a pollutant to a specific productive activity;
- to discover possible illegal release/discharge of pollutants, in the case the analytical data do not have any correspondence with the productive activities existing in the territory.

In conclusion the integrated information derived from:

- the knowledge of the ability and limits of self-depuration of the river basin;
- its actual level of stress;
- the anthropic activities present in the river basin;
- the social demand for an economic development of the area;

Figure 9 - Summary of the applicative use of LIPTOS



- the information derived from the use of LIPTOS (as a decisional support),

would allow the managers of the river basin to be able to plan a sustainable and optimized use of the territory, while guaranteeing the good quality of the water.

References

Informations used in building the operative software are derived from:

Internet site of Servizio Informativo Agricolo Nazionale Italiano – http://www.sian.it –containing a Database of Phytodrugs;

Internet site of EPER – The European Pollutant Emission Register - http://eper.cec.eu.int

Internet site of Australian Government - http://www.npi.gov.au/ - National Pollutant Inventory.

12

Assessment of river quality within the context of the EU's Water Framework Directive (2000/60/EC): the RiverNet experiences

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Abstract

The purpose of the EU's Water Framework Directive (WFD) is the achievement of ecological good status for all its superficial water bodies and courses. However, the most controversial and difficult aspect is the choice of an appropriate method to define a "reference condition", the expected value upon which comparisons are to be made and quantitatively expressed as EQR metric (ecological quality ratio). A major burden is the adjustment of national standards to assess the quality of aquatic habitats according to the technical specifications explicitly stated in the WFD. This aspect is also one of the major objectives within the RiverNet project. We compared standard methods used in Italy (not compliant with WFD requirements) with those currently under study by the pan-European intercalibration panel. Data spanning one year (2002) from the Abruzzo monitoring program were used. Data from 229 samples (78 sites and 38 water courses) were reanalyzed using both Italian (LIM, IBE, SECA) and other metrics (family richness, BMWP, ASPT, EPT, EPT%). Resulting ecological status assessments were compared quantitatively and expressed as EQR. Indices based on benthic invertebrates were closely interrelated (R^2=0.71–0.88 for pairwise correlations), and performed better than the abiotic LIM index. The BMWP index seems better suited than the non-WFD-compliant IBE index to describe ecological status. Though the dataset was relatively limited, we were able to identify 13 class-1 (least impacted) sites that can be used as reference sites for Abruzzo. Additionally, EQR-based range and threshold values for each tested metric were quantified for the high, good and moderate quality classes. Utilization of historical data may be a cost- and time-effective approach potentially leading to a regional and nationwide establishment of reference conditions and range quality-class values for riverine systems.

Introduction

The Water Framework Directive (WFD) of the European Union (EU) is an innovative piece of legislation because of its holistic approach, treating aquatic habitats as indivisible ecological units. The WFD also defines environmental quality goals for several types of water bodies and courses.

The WFD principles and goals, despite their general clarity, may not be that easy to incorporate into national legislations by EU Members States (MSs) because of their technical complexity and sometimes flexible interpretation. In order to facilitate the implementation of the WFD, the EU has issued a Common Implementation Strategy (CIS) to harmonize methods across MSs. Panels of experts appointed by the EU's MSs, called Working Groups (WGs), have been created to develop guidelines, whose applicability to regional conditions are to be later verified by each MS (e.g., EC 2003 a, b, c).

A major burden on MSs is the adjustment of national standards to assess the quality of aquatic habitats according to the methods and technical specifications explicitly stated in the WFD [2000/60/EC: Annex V (EU 2000)].

For superficial water courses (rivers and streams), the WFD defines five classes of environmental quality, based on the Ecological Quality Ratio (EQR): the ecological status of a water course is to be related to a reference condition, i.e., the optimal status that it would have in the absence of human pressure or human-related disturbance (Fig. 1).

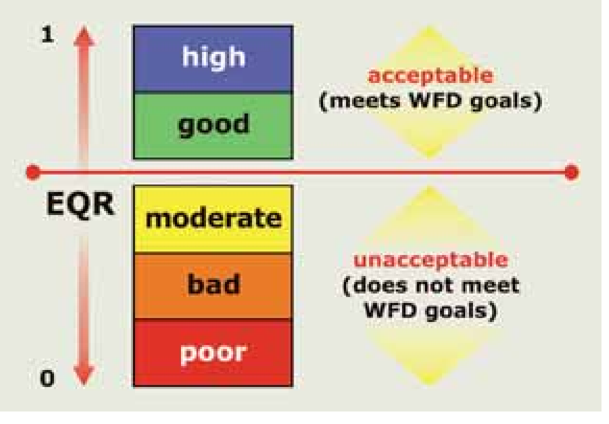


Figure 1- Classification of running waters based on the Ecological Quality Ratio (EQR) principle. See text for major details.

The parameters that define the biological, hydromorphological, and physicochemical aspects of the ecology of a water course have to be measurable and need to be expressed in a form relative to the reference condition. In such an assessment system, an EQR value of zero would express the highest degree of human-related alteration, while a value of 1 would express absent or negligible human-related alteration (Fig. 1).

The Italian Scenario

A fundamental aspect of the WFD implementation at national scale is the choice and subsequent use of the parameters that define the ecological status of a water course. Current Italian standards in this regard – especially those concerning the biological part of the assessment – are drastically different from WFD requirements. River and stream classification in Italy follows the directives of the national law D.Lgs 152/99 and subsequent amendments.

The physicochemical (LIM), macroinvertebrate-based (IBE), and comprehensive ecological indices (SECA, SACA) (Fig. 2) do not comply with WFD criteria. The few preliminary intercalibration efforts have pointed out the inherent difficulty in the choice of appropriate metrics to establish reference conditions (Buffagni *et al.* 2004).

The RiverNet Experience

The ecological status and "health" of River Aterno have been investigated in detail within the inter-catchment

Figure 2- Classification scheme of Italian running waters based on current legislation (D.Lgs. 152/99 and subsequent amendments).

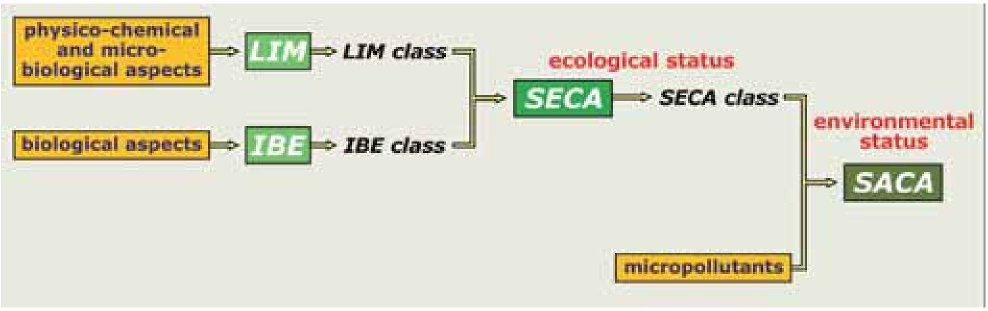


Table 1- Biological assessment of River Aterno (RiverNet project sites). Top: sites listed in ascending order of IBE scores. Bottom: sites listed in ascending order of BMWP scores. QC = IBE-based quality class; fam = Family richness; uWTP= upstream of water treatment plant; dWTP= downstream of water treatment plant. Colors follow quality classes as in Fig.1.

	fam	BMWP	ASPT	IBE	QC
Fossa	12	38	3.17	3	5
Piedicolle dWTP	17	63	3.71	6	3
Fontecchio dWTP	14	47	3.36	8	2
Tione dWTP	14	67	4.79	8	2
Acciano dWTP	14	73	5.21	8	2
Fontecchio uWTP	22	106	4.82	9	2
Tione uWTP	24	111	4.63	9	2
Piedicolle uWTP	26	140	5.38	9	2
Acciano uWTP	23	102	4.43	10	1
Casale	25	109	4.36	10	1
Molina	26	163	6.27	10	1
Cagnano	31	166	5.35	11	1

	fam	BMWP	ASPT	IBE	QC
Fossa	12	38	3.17	3	5
Fontecchio dWTP	14	47	3.36	8	2
Piedicolle dWTP	17	63	3.71	6	3
Tione dWTP	14	67	4.79	8	2
Acciano dWTP	14	73	5.21	8	2
Acciano uWTP	23	102	4.43	10	1
Fontecchio uWTP	22	106	4.82	9	2
Casale	25	109	4.36	10	1
Tione uWTP	24	111	4.63	9	2
Piedicolle uWTP	26	140	5.38	9	2
Molina	26	163	6.27	10	1
Cagnano	31	166	5.35	11	1

project RiverNet. In particular, the investigation allowed to compare the assessment indices currently used in Italy (IBE, LIM, IFF: D.Lgs 152/99) with some of the indices used in the ongoing pan-European WFD-related intercalibration (Sandin and Hering, 2004)

The River Aterno investigation showed that site classification based on either the IBE or the BMWP index may be quite different (Tab. 1). For example, the station located just downstream the Fontecchio water treatment plant exhibited the lowest BMWP value, but was classified as in "good ecological status" (class 2) by the IBE index. Similar discrepancies are evident also for other IBE-based class-2 and class-1 stations, as well as between the IBE and ASPT indices. Such small-scale (few sampling stations along an individual water course) inconsistencies in assessment methods led us to attempt a larger-scale evaluation of the reliability of Italian standard indices (LIM, IBE, SECA) relative to other indices.

We have recalculated the IBE, LIM, and SECA indices using the data of the 2002 monitoring year for the Administrative Region of Abruzzo (Turin *et al.* 2003). The dataset includes 229 samples collected at 78 stations, encompassing 38 distinct water courses. After an appropriate transformation of the original dataset we also applied other indices currently under study in the intercalibration WGs, namely: BMWP, ASPT, EPT, EPT% and Family richness (for a detailed description of the indices see Barbour *et al.* (1999); Armitage *et al.* (1983); Alba-Tercedor and Sanchez-Ortega (1988).

The physicochemical index LIM yielded a verdict of "good ecological status" for most samples (Fig. 3). However, the LIM results were not comparable with those from the biology-based index IBE. LIM-based class-2 samples were

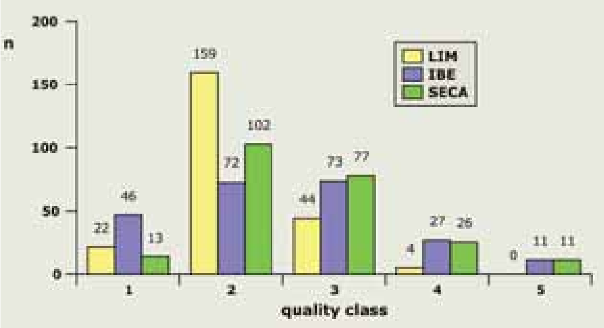


Figure 3 - IBE, LIM and SECA classification of the 229 samples from 38 water courses in the Abruzzo administrative region (data from the 2002 monitoring year).

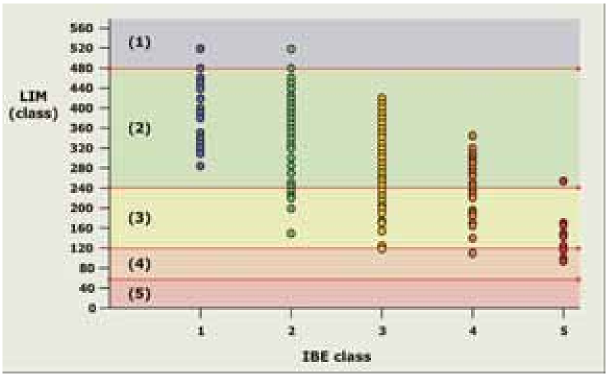


Figure 4 - Quality class comparison between the IBE and LIM indices. Color codes as in Fig. 1.

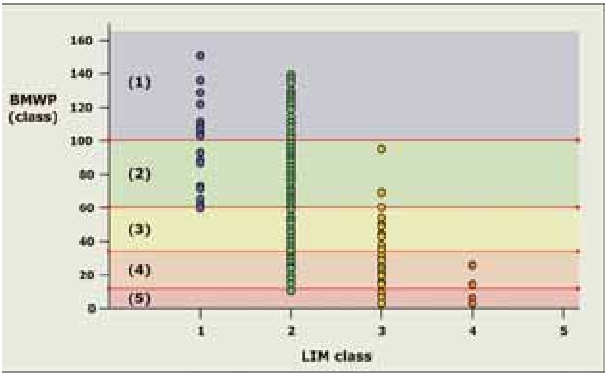


Figure 5 - Quality class comparison between the BMWP and LIM indices. Color codes as in Fig. 1.

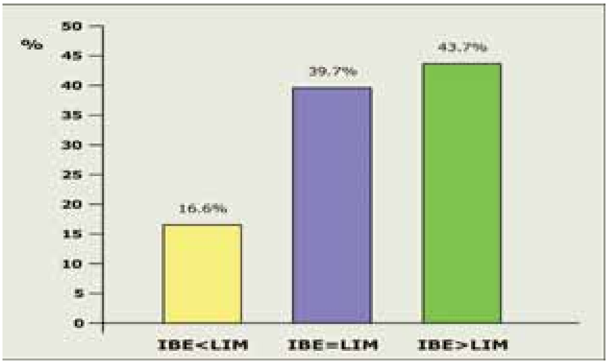


Figure 6 - Comparison of LIM- and IBE- based class-values as percent of the 229 samples examined.

categorized as class-1 to class-5 according to the macroinvertebrate-based IBE and BMWP indices (Figs. 4 and 5). The IBE and LIM results agreed for only ~39% of the investigated monitoring events, and the IBE index alone defined the comprehensive ecological status (SECA) for 100 out of the 229 events (~44%) (Fig. 6).

The overrepresentation of class-2 samples in the LIM classification system (Fig. 3), along with limited, inadequate validation efforts with respect to the better-tested biological indices, suggest that the latter are a more reliable tool to estimate water course ecological status. Therefore, we have expanded our investigation to include other biological indices.

The BMWP, EPT, ASPT, and IBE indices were closely interrelated (Fig. 7). R^2 values ranged from 0.71 and 0.88, while R^2 between such biological indices and the LIM index was only in the 0.31- 0.39 range, further highlighting the discrepancy between biology-based indices and the

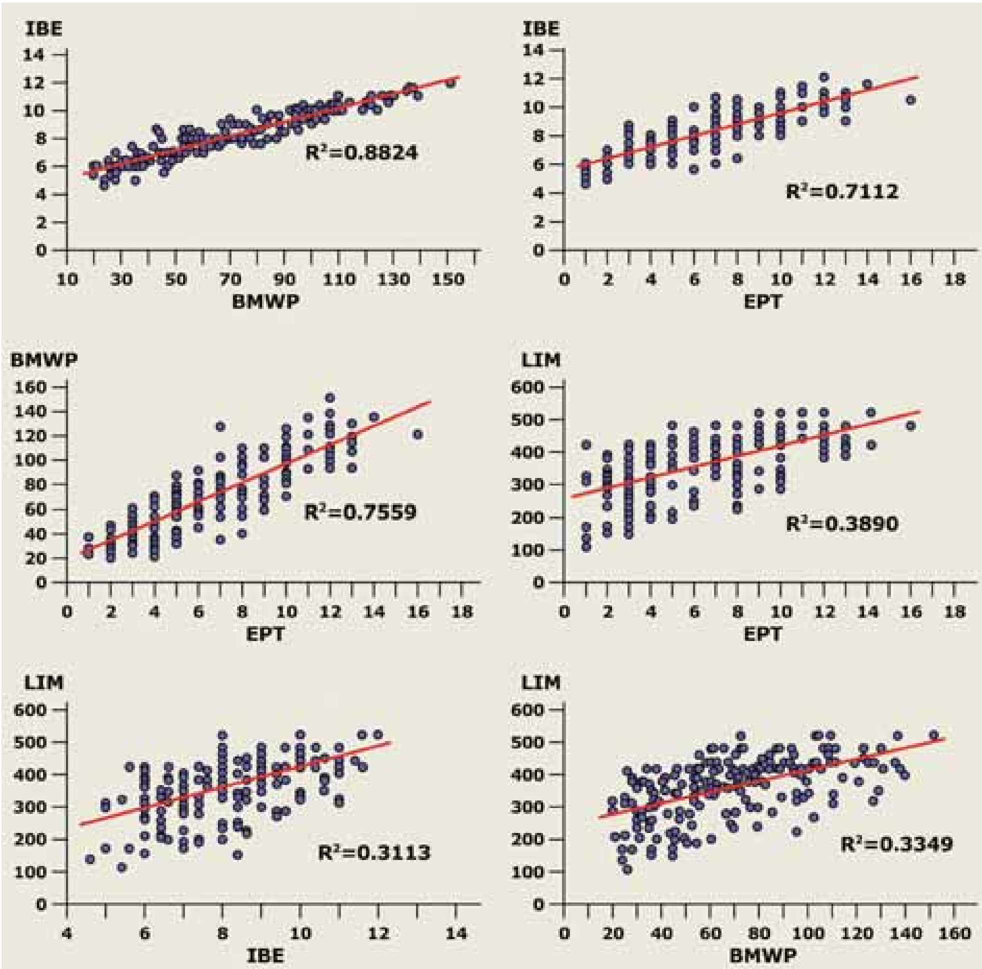


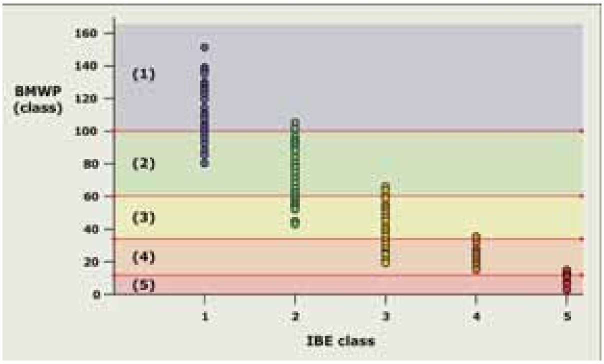
Figure 7 - Pairwise correlations between biological (IBE, BMWP, EPT) and physicochemical indices (LIM) (n = 229 for each).

physicochemical metric used to define ecological status in Italy.

The small discrepancies between BMWP- and IBE-based class identification (Fig. 8) may be due to the yet undertested BMWP within-class range values in Italian running waters, or to a better performance of either index in describing the ecological status of a water course.

Ongoing research (Buffagni *et al.* 2005; Hering *et al.*, 2004; Sandin and Hering, 2004) suggests a broader applicability of the BMWP and the derived ASPT index (intercalibra-

Figure 8 - Quality class comparison between the BMWP and IBE indices. Color codes as in Fig. 1.



ted across several MSs) than the Italy-based, non-WFD compliant, IBE.

The most controversial and difficult aspect of the WFD is the choice of an appropriate reference condition for each category of running-water ecosystem. Reference conditions should represent the basis, the "expected value" upon which comparisons are to be made and threshold values for each class are to be chosen for each parameter (Bailey *et al.* 2003; Wallin *et al.* 2003; Nijboer *et al.* 2004).

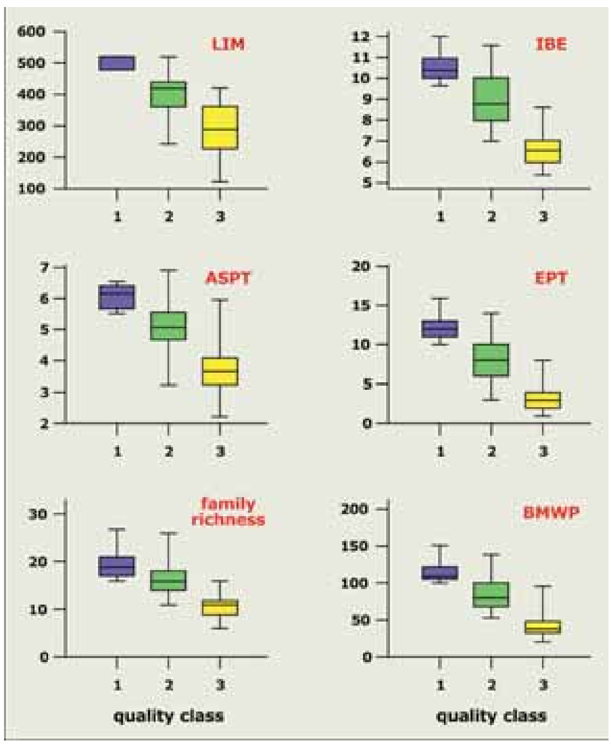
Our dataset identified only 13 samples, out of the 229 examined, with physicochemical and biological parameters agreeing on a class-1 SECA categorization. Though too few to allow a reliable statistical elaboration, such class-1 samples may be chosen as reference sites. After an analysis of the variability of the individual indices within each of the first three SECA classes, we have defined reference site values and class value ranges by adopting the same procedures used by the Intercalibration WGs (EC 2003; Wallin *et al.* 2004): the median of each index across the 13 class-1 samples was chosen as the reference value upon which to carry out data normalization, and the 25th percentile within each class was chosen as the class lower threshold value (Tab. 2). Non-overlapping index scores within each class (Fig. 9) legitimated our choice.

Ranges and threshold values were also expressed as EQR by applying the same principles to all indices (Fig. 10). Furthermore, the minimum threshold value can be

Table 2- Median and interquartile range of biological and physicochemical indices for the first three SECA qality classes.

	quality class 1 (n=13)			quality class 2 (n=102)			quality class 3 (n=77)		
	75th percentile	median	25th percentile	75th percentile	median	25th percentile	75th percentile	median	25th percentile
fam	21	19	17	18	16	14	12	11	9
IBE	11	10.4	10	10	8.8	8	7	6.6	6
LIM	520	480	480	440	420	360	360	290	225
BMWP	122	109	106	99.7	80.5	68.25	47	37	31
ASPT	6.42	6.14	5.6	5.56	5.08	4.66	4.07	3.66	3.25
EPT	13	12	11	10	8	6	4	3	2
%EPT	0.56	0.53	0.5	0.47	0.39	0.33	0.33	0.27	0.18

Figure 9 – Box plot showing the variability of selected indices in the first three SECA quality classes.



identified for each individual index above which a site can be classified as in "good ecological status" sensu WFD, thus becoming exempt from ameliorative intervention (Fig. 11).

Figure 10 - Range-values expressed as EQR for selected indices.

Figure 11 - Minimum threshold value of selected indices above which a site should be classified as in "good state".

Conclusions

Utilization of historical data, from successive monitoring years, will enlarge the database upon which a statistically more robust EQR can be extrapolated. Furthermore, the same approach could be adopted by other Administrative Regions. Harmonization of methods across the Regional agencies responsible for the WFD-related monitoring programs, but with regionally-calibrated class ranges and threshold values, should lead to a relatively fine-scale, Region-based, yet comparable, nationwide identification of reference sites. Ultimately, this cost- and time-effective approach would lead to the establishment of reference conditions across river typologies.

Acknowledgements

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