Large Rivers Vol. **16**, No. 1–2
Arch. Hydrobiol. Suppl. 158/1–2, p. 95–128, September 2005

Emergent properties of the Lower Danube River System: The consequences for the integrated monitoring system

Virgil Iordache[1] and **Florian Bodescu**[1]

With 6 figures and 4 tables in the text

Abstract: The Lower Danube River Systems (LDRS) is a complex system composed of natural ecological systems (NES) and socio-economic systems (SES). This paper presents the emergent properties of the components of the LDRS (NES, SES, and SES-NES systems) and suggests indicators which would have to be assessed by the integrated monitoring system. The method consists of processing the information about socio-environmental systems, about resources and services provided by fluvial systems, and about indicators of their production, using a set of methodological principles. The results consisted in a refinement of the structural model of the SES, a tentative list of the indicators to be included in an integrated monitoring system of the LDRS, and several principles for structuring the specific information system for macro-landscapes such as LDRS. It is concluded that whether explicit or as a recognized constraint, objectives related to the natural capital have to be considered in the design of integrated management plans at all SES hierarchical levels. Performing this design in an effective way requires a wide range of data, which can be provided by an integrated monitoring system structured as suggested in this paper.

Key words: macro-landscape, fluvial system, Danube, socio-environmental system, monitoring.

Introduction

The Lower Danube River Systems (LDRS) is a socio-environmental system subject to management in view of sustainable development. The objectives of this paper are:

1. to present a structural model of the LDRS,
2. to identify the emergent properties of the components of the LDRS (natural ecological systems - NES, socio-economic systems - SES, and SES-NES composite systems), and

[1] **Authors' address:** University of Bucharest, Dept. of Systems Ecology, Spl. Independentei 91–95, 76201 Bucharest 5, Romania; E-mail: virgil@bio.bio.unibuc.ro

0945-3784/05/0158-0095 $ 8.50

3. to suggest indicators which would have to be assessed by the integrated monitoring system in order to provide needed information for the design of integrated management plans.

Conceptualizing a socio-environmental system is a critical step towards achieving sustainable development for specific parts of the world (MUSTERS et al. 1998). As the word 'system' has a very general meaning ("parts in relation with one another"), in itself it cannot ensure a consistency between the different ways of conceptualizing the socio-environment. There are two dominant models:

- the sectoral model conceives the socio-environment as a set of environmental factors, humans included;
- the ecosystemic model considers that these factors are organized in basic units called ecosystems, which are further organized in a nested hierarchy of ecological systems (Russian puppets style).

The sectoral model has rather a historical importance from the point of view of ecological knowledge, but it is dominant at the institutional level. On the other hand, the ecosystemic model, beyond its general, heuristic acceptance in the scientific community, is not universally accepted with regard to the precise delineation in space and time of the different ecosystems, as well as of the systems of higher hierarchical levels of organization. It seems that we do not have enough knowledge to extract criteria for delineating assemblages of ecosystems (local landscapes), of local landscapes (larger landscapes, such as basins and ecoregions), and so on up to the ecosphere. Thus, there is no recipe available which could be applied to the Danube River Basin in order to obtain its structural hierarchical model. And then how could one design an integrated monitoring system dealing with the Danube River Basin? How could one meaningfully upscale from the level of the measurement to the level of the entire system of interest, which is the management level?

Model perspectives and scaling

One possible answer is given by the fractal approaches (HALLEY et al. 2004). Contrary to hierarchical approaches, which assume each process to act on a narrow range of scales, the fractal approaches assume that the properties of environmental objects are identical or similar over a wide range of ecologically relevant scales (op. cit.). Fractal models can be consistent with both the sectoral (full range of scale fractals), or hierarchical models (hierarchical fractals). Another promising approach is the constructal theory (BEJAN 2000), which aims to surpass the lack of mechanistic link between the (fractal) pattern and the generating processes by proposing a bottom-up, assembling procedure based on local optimizations, and leading to a global pattern. However, these tools are currently in development, far from being ready for transfer towards institutionalized applied monitoring.

A recent review of the math and some conceptual issues of scaling in ecological and economic systems is given by CHAVE & LEVIN (2003). They insist that when developing models across different scales of organizational complexity, the goal should be rather to identify the relevant details than to include as much detail as possible; however, they do not provide criteria for this relevance. From a management perspective the relevance should probably be linked not only to the performance of the model, but also to the usefulness of the generated information. Managers are interested in natural goods (resources) and services provided, and these are the subject of dedicated assessment procedures (so called functional analyses procedures – MALTBY 1998; IORDACHE et al. 2001a). An important aspect is that the values allocated to the environment often do not reduce to quantifiable resources and services (BORSUK et al. 2001), and consequently the environmental decisions are based not only on a scientific assessment, but also on a political aggregation of subjective human preferences. In more abstract terms, value is a relational property, between an entity and an evaluator (a subject), and from this perspective the so called intrinsic value of the environment is only a way of speaking underlining the paramount value allocated by those evaluators to the environment.

Systems have emergent properties at each level of organization (MAHNER & BUNGE 1997). The properties of large and complex ecological systems are structural and functional. The emergent properties of the NES are tightly connected with the offer of resources and services (VADINEANU 1998) which, taking into consideration the multi-level organization of the NES, means that there are specific resources and services at each of the ecological hierarchical levels. Upscaling literature sometimes looks for services performance at large-scale level. For instance, relevant results have been achieved in assessing the service of nutrient retention in catchments (KRONVANG et al. 1999; SEITZINGER et al. 2002; VAN BREEMEN et al. 2002) and even very large river basins such as the Mississippi (ALEXANDER et al. 2000; DONNER et al. 2004) and the Danube (Danubs Project 2004; BEHRENDT & SCHREIBER 2004; and this issue).

But monitoring literature does not explicitly relate its topic with the resources and services provided by the natural capital. We believe that this is a major shortcoming of the current monitoring design, making the use of the monitoring data by the managers more difficult and the monitoring activity less efficient.

In the sectoral view of the environment the natural capital consists of the natural resources (which are more ore less identical with the environmental factors), while in the ecosystemic view the natural capital provides resources and services, but consists of natural and semi-natural ecological systems. Consequently, in the sectoral view, the monitoring of environmental factors is implicitly monitoring of natural resources, while the monitoring of natural services is simply not conceivable.

Empirically, a key issue when extrapolating across scales within an ecological system of interest is to take into consideration the internal spatial and temporal heterogeneity of the system in the course of sampling design (HEWITT et al. 2001;

Englund & Cooper 2003). Extrapolating across hierarchical levels has meaning only for the summative properties, but not for the emergent ones, which individualize each level of organization. The emergent properties are mechanistically explained (at least qualitatively or semi-quantitatively) in terms of the properties of their subsystems, but actually evaluated at their specific hierarchical level. As for their mechanistic prediction, this is a prerequisite for the new trendy adaptive management. And it seems to become more feasible with the intensive development of spatial explicit models at large scales (Hobbs 2003).

The structure and functioning of regional and macro-regional landscapes is studied by two ecological disciplines: biogeography (Gaston 2003) and landscape ecology (Naveh & Lieberman 1990). Biogeography focuses on the active and passive biotic fluxes connecting the ecosystems within the range of a species. In landscape ecology both the connecting abiotic and biotic fluxes are taken into consideration. Integration of the two mentioned disciplines might be desirable. The work on detecting critical scales in fragmented terrestrial landscapes (e. g. Keitt et al. 1997) suggests that the scale at which, for instance, connectivity abruptly changes is species dependent. This seems to impinge on directly applying the nested view of the ecological hierarchy. Moreover, patterns tend to be equivocal, especially when several studies are compared (Bisonette & Storch 2002), in part due to the landscape behaviour as a complex adaptive system, but also due to the use of different landscape metrics (Bogaert 2003).

But in fluvial landscapes, probably due to the more abrupt abiotic gradients, with consequences on the localization of biotic fluxes, the results are more clear-cut. Relevant work has been done in the case of the Danube, too (e. g. Ward et al. 2002). Vadineanu et al. (2001) presented results in the particular case of the Lower Danube River System (LDRS). We reiterate several aspects here. The LDRS is a complex system composed of natural ecological systems (NES) and socio-economic systems (SES). The NES included in the LDRS are organized on three hierarchical levels (from flood plain and river ecosystems up to a regional landscape, as described in Fig. 1, Vadineanu et al. 2001) and “feeds” the SES with their resources and services (as described in Fig. 2, Iordache et al. 2001a). We believe that this is generally applicable to large fluvial systems. The two mentioned sources also present specific results for LDRS, such as types of local landscapes, types of ecosystems, their relative surfaces, homomorphic models of LDRS, of the local landscapes, and of the ecosystems, as well as evaluations of the resources and services provided by each type of landscape and ecosystem, and by LDRS as a whole. Economic evaluations of the natural capital of LDRS and proposals for restoration have also been published (Vadineanu et al. 2003; Iordache et al. 2005).

A more delicate issue is that of the ecological interpretation of the socio-economic systems. There has been a rejection of the classic ecosystems theory by human scientists, but the new concept of ecosystems as complex adaptive systems seems to answer most of the early criticism (Abel & Stepp 2003). However, an

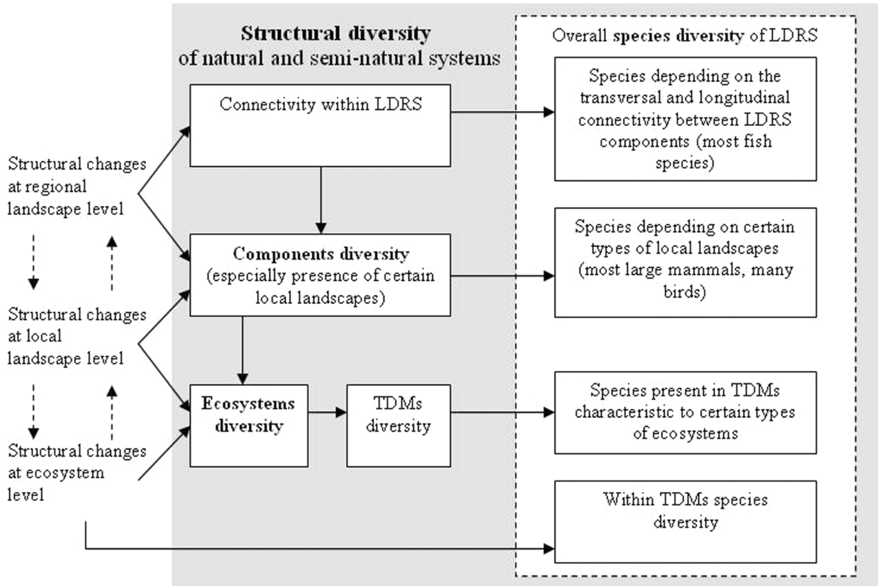

Fig. 1. Conceptual framework for discussing the structure of the natural ecological systems of LDRS. Full lines (arrows) represent control ways. Dashed lines (arrows) represent top-down effects and cumulated bottom-up effects of the structural changes. TDM means trophodynamic modules (after VADINEANU et al. 2001).

integrated theory of the complex socio-economic systems is not yet available (KAY 2000). Due to this situation, to bet on a single way of understanding SES is risky and not acceptable from the point of view of the possible social consequences. Even VON BERTALANFFY (1969), the founder of the general systems theory, remarked the potential danger of the mechanistic models of the society, likely to lead to dehumanization. But this was forgotten. Simplistic approaches such as the thermodynamics of T. H. ODUM tend to represent all human phenomena, including culture and religion, by diagrams and models of energy fluxes (NAVEH & LIEBERMAN 1990). Also forgotten is the fact that a holarchic ecosystem approach does not equate with holism. When KOESTLER (1969, after NAVEH & LIEBERMAN 1990) spoke about holons (systems) and hierarchies of holons (i. e. holarchies), the title of his article was "Beyond atomism and holism". However, in the current ecological literature there is a widespread confusion between holism and systemism (MAHNER & BUNGE 1997; LOOIJEEN 2000; IORDACHE 2003b).

Stating that systemism is different than holism might be considered as a philosophical subtlety. But its consequences on how we conceive the management, and implicitly the monitoring, of socio-economic systems are large. BUNGE (1979) has advocated this difference since long. In view of holism the societal management is

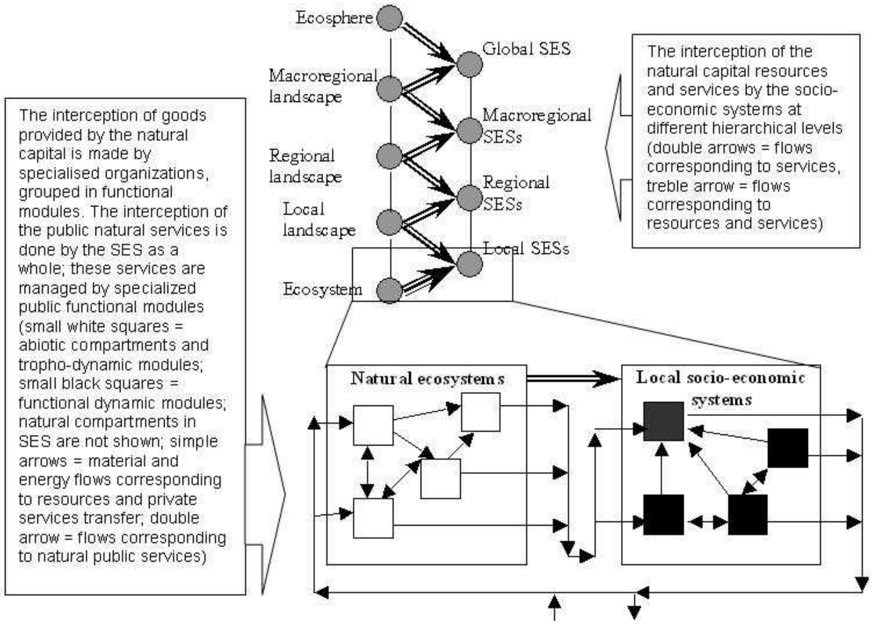

Fig. 2. Simplified theoretical framework of the relationship between natural ecological systems (NES) and socio-economic systems (SES). Basically, the hierarchically organized natural ecological systems produce renewable resources and services intercepted by socio-economic system. NES have their own, partially independent of SES, development, which is reflected by spatial and temporal distribution patterns of the produced resources and services. SES, which are dependent on these resources and services, must take into account the natural development when designing their own development plans. In other words, the development of SES and NES should be **balanced**, i.e. SES have to continuously show an adaptive behavior with regard to NES. Developing and implementing plans for achieving such a balance is the goal of the natural capital management (after Iordache et al. 2001a).

restricted to a full top-down approach. A typical example is the real communist society. The higher hierarchical level fully controls the lower hierarchical levels, these sub-systems not having separate existence status, but only as parts, and as contributors to functioning of the integrating whole. In the case of systemism the decentralization of the power and management is conceivable, as all hierarchical levels have independent existence status. The other extreme is full individualism, of historical interest in the field of ecology, but not in the field of social sciences (as illustrated by libertarian currents, for instance). Wu & David (2002) remark the existing public resistance to the application of the hierarchical approach for socio-economic systems. This would be due to confounding hierarchical approaches with top-down (holistic) control.

When imagining the spatial relation between the natural and semi-natural ecological systems (considered as synonym with the natural capital) and the socio-economic systems, one sees them as occupying well defined positions in the landscape. The natural capital network is conceived as interspersed in the socio-economic network (e. g. VADINEANU 1998). Thus, in this view the socio-environment would be made of two distinct ecological hierarchies in interaction (like in Fig. 2), namely the natural capital and the socio-economic systems.

Decision support systems

As a result of the interaction between the natural capital and the socio-economic systems specific institutions emerge, dealing with the control of the interaction. In order to cope with the natural and man-induced dynamics of the resources and services provided by the natural capital, national SES develop special organizations in their structure, able to intercept signals about the change of the offer of natural resources and services, and to use these signals for the design of appropriate integrated management plans (IORDACHE et al. 2001b; CHARLES 2001). In fact there is a sub-system of interrelated institutions with missions ranging from knowledge development and monitoring to public involvement and education (STAPP 2000; HAMALAINEN et al. 2001). Such a sub-system is proposed by VADINEANU (1999): the decision support system (DSS) for sustainable development. Within the DSS a key component is the integrated monitoring system (or data generation sub-system). This is the component through which DSS receives the above mentioned signals. The role of the integrated monitoring system has two dimensions. Firstly, it has to provide information about the state of the NES as natural capital (i. e. in terms of productivity of resources and services). And secondly, it has to provide information about the socio-economic systems. This information is needed for establishing the portfolio of objectives of the management plans, for adopting the most appropriate portfolio of tactical and operational methods, and for assessing the state of the components of the DSS itself, such as institutions. We understand institutions here both as the set of formal or informal rules, and as the organizations that implement the formal rules (NORTH 1990; WEISBUCH 2000).

Monitoring concepts

Let us now discuss the current state of the monitoring institutions, from the conceptual model point of view. The existing monitoring systems, as well as other instruments for the assistance of decisions (such as environmental impact assessment methods), reflect mostly the sectoral model of the socio-environment, i. e. there is a separate monitoring of water, soil, air, and species, and a separate set of resulting databases, connected nowadays with GIS, however (technical mapping and functional links as well).

Soil monitoring is usually done on a large grid base, ignoring the ecological structure, but taking into consideration the data interpretation in terms of land cover (e. g. DUMITRU 2000). Water monitoring addressed traditionally water quality and quantity, but recently experiences an important change under the pressure of the European Water Framework Directive, toward a monitoring of hydrological systems (BURT 2003), with an impact even outside the EU (AIDAROV et al. 2002).

Species diversity monitoring design takes into consideration, to some extent, the underlying ecological structure, as well as the upscaling issues. The need for observation at landscape scales relevant both to the focal species and conservation decisions is underlined (BAYER & NOSS 1998), including for monitoring at large, an ecoregional scale (MANLEY et al. 2004). Hierarchical approaches have been proposed both in the case of continental (NOSS 1990) and marine systems (ZACHARIAS & ROFF 2000). However, there is a lack of well articulated objectives (YOCCOZ et al. 2001), and it is not clear to what extent the hierarchical approaches are adopted in state-wide monitoring systems.

A special case is the monitoring of renewable resources (e. g. fish stocks, game species). Monitoring of game species is usually included in the monitoring of forests; sometimes it is explicitly related to the monitoring of species diversity (FAILING & GREGORY 2003), and of the causes of population dynamics (OLSEN & SCHREUDER 1997). Monitoring of forests is at the limit between sectoral monitoring and ecological monitoring. It is still sectoral to some extent in the sense that it currently ignores the embedding of forests with other types of ecosystems in the landscapes. The upscaling to European level is done in a summative style (FERRETI & CHIARUCCI 2003). Promising aspects are that forest monitoring has a focus on long-term design (SILSBEE & PETERSON 1993), and that the current system is seen as a possible framework for future monitoring of other terrestrial systems (CORONA et al. 2002). The last mentioned trend is a result of the pressure towards inventories and monitoring of the habitats due to the specific European directive (92/43/CEE).

Independent attempts of developing a monitoring of habitats occurred from the landscape ecology. Some of these attempts are at the interface with the forests monitoring (e. g. STOHLGREN et al. 1995) and try to transfer the landscape ecological knowledge towards the design of forests monitoring. Other attempts aim to develop an integrated countryside and landscape monitoring (ALTERRA 2004). A first meeting of a European forum for landscape ecology took place in 2000, having as objective to promote integrated landscape monitoring at a landscape scale (rather than the sectoral monitoring), but no institutional consequences seem to have followed. Such a network should include a field component and would be very valuable for providing a reliable source of in situ data for earth observation applications (PARR et al. 2002).

In a review based on the results of a European project (NoLIMITS – Networking of Long-term Integrated Monitoring in Terrestrial Systems), PARR et al. (2002) conclude that there is a large number of ecosystem monitoring initiatives in Europe, not only of forests, but of other types of ecosystems as well. However, if one looks at the examples, one can see that with few (but significant) exceptions, the mentioned networks deal with one or a few of environmental factors, even if the sampling is inevitably done in one type of ecosystem or another. Their final intention seems to be the use of bulk accumulated sectoral data in order to characterize the state of the ecosystems, which is like testing hypotheses resulting from a new theory with data obtained before the creation of the theory. One might have some indications, but usually no definite answer can be obtained in this way.

In order to understand the state of an ecosystem, one needs an explicit measurement of ecological processes (Bunn & Davies 2000) and a specific design of the monitoring program (Vos et al. 2000). This kind of monitoring would be an ecological monitoring based on the ecosystemic model of the socio-environment. The ecological monitoring is not a species of monitoring, as water or soil monitoring, but a new genus, as the sectoral monitoring. There is a trend, not only in monitoring, but also in environmental impact assessment (Treweek 1999), towards an ecologically based approach.

Interestingly, Parr et al. (2002) do not cite Vos et al. (2000), although the articles are published in the same journal. This may be due to the differences in their final institutional conclusions. While both teams accept the principle that the existing monitoring and research sites should be a fundamental part of the new network, with regard to the improvements the approaches are different. Parr's team considers that the improvements should be based on formally recognized users' requirements, a pragmatic view, while the other team describes an 'ideal' integrated monitoring to function as an attractor of the current scheme. So the dynamics of the current monitoring schemes should be, according to Parr et al. (2002), based on market level processes without any authoritative intervention (bottom up). This is somehow strange, as long as the most advanced and useful monitoring networks (such as United Nations International Cooperative Programme on Integrated Monitoring, ICP-IM, and International Long Term Ecological Research network, ILTER) are the result of top-down approaches. At least when the user is the public sector, promoting the objective formulation based on the best available knowledge, by appropriate lobby of the scientific community (such as the International Association for Danube Research, IAD), might be desirable. However, speaking of bottom up and top down approaches/mechanisms we think that both are needed in reality, so the question is, how to achieve the best balance. In the chapter of results several suggestions will be made in this respect.

There are two shortcomings of both views discussed above (Parr et al. 2002; Vos et al. 2000). One is that they address explicitly only the ecosystemic level, ignoring the monitoring of higher levels of ecological organizations, which eventually are used only as strata for the organization in space of the monitoring program. And the other is that they do not address the socio-environment, limiting to its natural part. In a later paper Parr et al. (2003) recognize, however, the need to shift towards an understanding of the nature-society system.

To avoid confusion, it should be noted that 'integrated' has two meanings, a sectoral one and a systemic one (Iordache 2005). In the sectoral view 'integrated' frequently means "approaching an environmental factor by all directly and indirectly relevant parameters" (e. g. in the integrated monitoring, or management, of water quality; Varduca 1999). In the systemic view 'integrated' has a different meaning, such as "taking into consideration the relationship between the natural resources and services in terms of the mechanisms of their production in ecological systems" (e. g. in the integrated environmental management, here synonymous with the management of the natural capital, where the natural capital consists of ecological systems). The sectoral approach has historical priority, and all institutions involved in monitoring, as well as the relevant regulations, are based on this conceptual model. The advantage of the systemic approach is that it allows a better understanding of the mechanisms underpinning the production of resources and services, as well as of the full range of resources and services. Its main disadvantage is that it is historically posterior to the sectoral approach, and faces resistance against its adoption at institutional levels, which is inherent due to interests of the existing institutions over the public money. The competition in obtaining public resources is not favourable to the co-operation between the institutions involved in the monitoring of environmental factors, although the public interest, better served by a systems perspective, strongly asks for an intensive co-operation and exchange of information between these institutions (Iordache 2003a).

Technical problems and possible solutions for designing an integrated monitoring

Brock et al. (1997) insist on the planning tools for developing regional monitoring programs, i.e. on the management of the monitoring as a kind of service production. Beard et al. (1999) review the sources of measurement inconsistency, namely changes in technique, in personnel, in environmental external factors, in measurement, in location, in spatial coverage, in frequency and timing of measurement, and propose solutions for data quality maintenance and method harmonization (as exemplified by the activities of ICPDR). Vos et al. (2000) propose to link the monitoring with the ecosystem functions (understood from an anthropogenic point of view), with consequences on the typology of variables assessed, and to put it in the framework of a decision support system. Tegler et al. (2001) report in detail a methodology for establishing the set of variables for the national ecological monitoring network of Canada. Parr et al. (2002) analyse the difficulties related to the current European monitoring networks. They point out the deficiencies in informing the policy level as a result of the sectoral collection of the information. Design issues for a network of long-term integrated monitoring sites in Europe are discussed in detail. Last, but not least, Noss (2003) proposes a checklist for wild lands (nature parks) network design in the USA, with direct relevance for the monitoring design. He points out that the methodology of monitoring should explicitly envisage the testing of simple, phenomenological hypotheses, concerning changes in the state of the system. As a consequence, at least some of the results will be publishable in reputable, peer-reviewed journals, as well as other outlets, enhancing the social prestige of the monitoring institutions, as well as providing an extra check of the data and specific knowledge quality.

Methods

We have used four specific methodological aspects/principles:
1. a multiple inclusion principle;
2. a differentiation between natural ecological systems and natural capital;
3. a coupling of the monitoring of natural capital with management through natural resources and services;
4. a distinction between systemism and holism.

The multiple inclusion principle envisages the fact that an ecological system can be part in more than one integrating system. From a formal point of view this principle was developed in mathematics and is currently used in the math modeling of complex systems (STANKOVIC & SILJAK 2001, 2003). However, to our knowledge its application to ecology is new. For example, a natural ecological system, let us say a riparian forest, represents natural capital for a socio-economic system (SES). The forest is integrated in the SES by fluxes corresponding to natural resources and services. On the other hand, the same system is integrated in a natural macro-landscape (NES, for instance a fluvial system, an ecoregion, or a river basin). In this case the fluxes integrating the forests are different than those intercepted by humans (e.g. hydrological fluxes during floods, or biotic fluxes of mobile organisms). Moreover, a riparian forest of large size can be included in more than one natural integrating landscape. The role of the riparian forest in the different integrating systems will be sustained by different energy and matter fluxes (corresponding for instance to different species). Fig. 3 illustrates the multiple inclusion principle application in an analysis of the place of riparian forests in macro-landscapes (BOLSCHER et al. 2005; IORDACHE et al. 2004).

There is not necessarily a complete spatial (geographic) superposition between the systems integrating an ecosystem. Most frequently the integrating systems have not superposed spatial limits. Just imagine the map of ecoregions in a country, of river basins, and of local SESs. Some of the systems integrating a certain ecosystem have rather sharp limits (river basins, socio-economic systems), other rather diffuse limits (ecoregions). Borders of river basins may be complicated because of groundwater flow from one basin into the other. The identification of the ecological systems which are not sharply delineated by steep gradients is influenced by subjective factors, including political ones (NASSAUER 1992). Fortunately, in

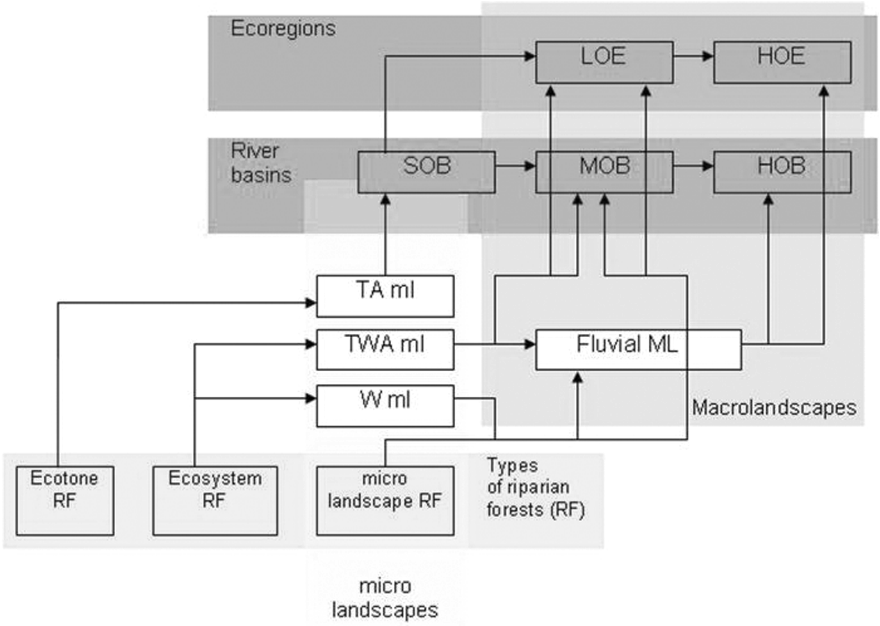

Fig. 3. Inclusion (black arrows) of riparian forests in their integrating systems. The included systems are structural elements of the higher systems in which they are included. It results that at low order ecoregion or medium order river basin level all types of riparian forest should be taken into consideration for the design of the management. At even higher level practically the full river corridor should be considered. **Legend**: ml = micro-landscape, ML = macro-landscape, TA = terrestrial-aquatic, TWA = terrestrial-wetland-aquatic, W = wetland, SOB = small order river basin, MOB = medium order river basin, HOB = high order river basin, LOE = low order ecoregion, HOE = high order ecoregion; a river corridor consists of the TA micro-landscapes, the TWA micro-landscapes, and the fluvial macro-landscapes of a river basin.

Europe the indicative limits of the major high order ecoregions are already publicly accepted (Fauna, Flora and Habitats Directive), as well as those of lower order ecoregions in most countries. The multiple inclusion principle surpasses the strictly nested view (Russian puppets type) of the hierarchies. Its application is not limited to the given examples, but we will not further develop it here. From a technical point of view the information systems based on it can easily be managed using GIS (Bodescu 2001).

Once we have accepted this view one can easily understand the second principle. It deals with the fact that the value allocated to a natural ecological system by humans is related to the fluxes integrating it in the SES. Or integrating at least part of it. We said 'part of it' because often the property limits do not take into consideration the natural limits, as for instance in the case of the transboundary ecological systems. According to the view of strictly nested conceptual models the natural capital and SESs are separate hierarchies. Thus, there are clear spatial, geographical limits between natural capital (NC) and SES (e.g. Odum 1993), or, in other terms, a natural capital component, such as a riparian forest, is **outside** the SES. The view is intuitive and apparently acceptable at low hierachical level (a village vs. the nearby forest). However, the view is not according to the reality, if one looks, for instance, to the administrative boundaries of the village and to the ownership relations. Its unsuitability becomes even more obvious for higher hierachical levels, such as ecoregions and river basins vs. counties and countries. In short, the concept of natural ecological systems does not suppose **necessarily** the presence of humans. One can think of natural ecological systems existing before the human speciation (ignoring here the discussion over ecosystems as instrumental theoretical terms without real referent). However, one cannot think of natural capital in economic and managerial sense in the absence of humans, because the natural capital consists in ecological systems with value for humans. This value adds a cultural dimension to the natural dimension, and the cultural dimension is not reducible to the natural one.

The third methodological aspect is an answer to the frequent requirements of the monitoring literature to provide explicitly relevant information for the managers. As mentioned above, we do this by coupling the monitoring design with the list of 'functions' (i.e. natural services and productions of natural resources) identified by the functional analyses procedures. The fourth aspect, the distinction between holism and systemism, has been already explained in a previous chapter.

Results

Coupling the above mentioned principles with the existing knowledge as described in the introduction has led us to:
– a refinement of the structural model of the socio-environment;
– a tentative list of the indicators to be included in an integrated monitoring system of the Lower Danube River System;
– a decentralization principle for structuring the specific information system for LDRS.

The structural model

The structural model is presented in Fig. 4. The following aspects concerning the structure of the socio-economic systems (SESs) are relevant for our discussion (Iordache 2002):
1. Each human individual and its resources (property) make up a system producing services (and, eventually, resources) and consuming other services and resources. Let us call this system an individual system of production and consumption (ISPC);

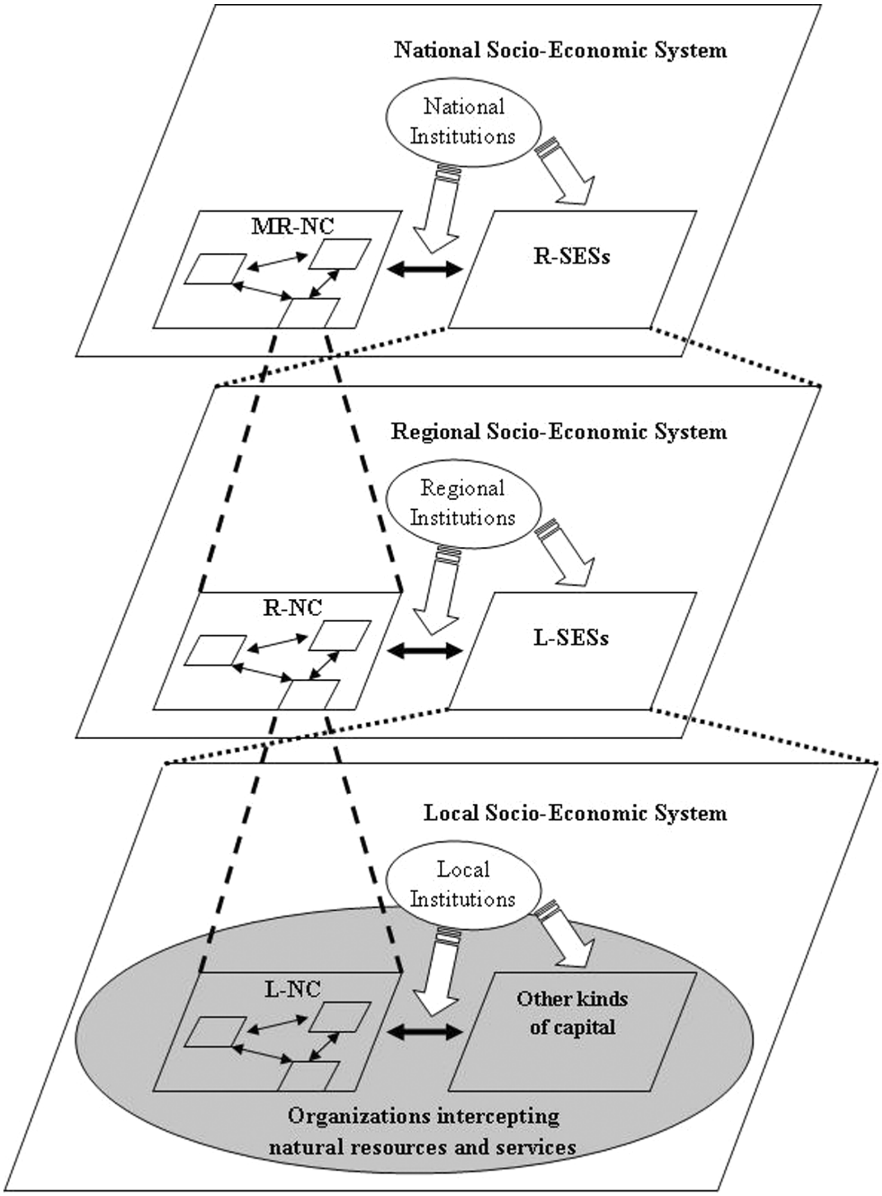

Fig. 4. Schematic representation of the structure of a country (national socio-economic system). At the local level the natural and unnatural capita is included in the structure of specific organizations grouped in functional modules. **Legend***:* NC = natural capital, MR = macro-regional, R = regional, L = local.

2. The basic units of SESs are organizations, consisting of a human part (human capital), a non-human part (different types of non-human capital, including natural capital). The role of the organizations is to transfer the raw material, energy and information flows originating from the natural capital (goods and services) and in ISPC (services, work), to their ecological consumer (ISPC). The transfer is unprocessed (services production) or processed (goods and services production). ISPC is a special type of organization (an organizational view of biological individuals is suggested also by KHALIL 2000).
3. Natural capital is part of SESs in the sense that it consists of natural ecological systems with value (providing resources and services needed by ISPC). By other kind of fluxes, the natural ecological systems are integrated at the same time in the hierarchy of natural ecological systems. Natural capital at lower hierarchical levels (ecosystem, local landscape) can be owned by organizations, but at higher levels (regional, macro-regional) cannot be owned. For this reason, the management of regional and macro-regional natural capital requires specially designed organizations. The design of such organizations is an attempt to internalize in the socio-economic system the external natural driving forces. During the history of socio-economic development there is an expansion of the natural capital both in space and from lower hierarchical levels (ecosystems) towards higher hierarchical levels (up to the ecosphere). This expansion is part of the larger process of the institutional evolution (IORDACHE 2004a). During this evolution new types of functional modules dealing with the natural capital appear. A typology of these functional modules and its consequences for environmental policies is suggested elsewhere (GEORGESCU et al. 2001), but is essentially a matter of further research.
4. The ecological systems identification (PAHL-VOSTL 1995) applied to SESs leads to a homomorphic model in which organizations are grouped (using as criteria the time constant, the space-time location and the functional niche) in functional dynamic modules (FDM). For approaches concerning the ecology of populations of organizations, see for instance BARRON (1999).
5. Similarly to the case of natural ecological systems, the emergent properties of a SES can be structural and functional. Functional dynamic modules consisting of organizations characteristic exclusively to integrating SESs are their emergent structural properties (e. g. the state organizations in a national SES, or global organizations in the global SES). The emergent functional property of regional, macro-regional and global SESs is the enhanced productivity of goods and service as a result of the new FDMs and of the exchanges of goods and services between included SESs through the organizations from their structure.

The following aspects concerning the functioning of SESs are also of interest:

1. All the production of goods and services in a SES takes place within the organizations. States and supranational entities are types of organizations producing specific services.
2. A market is a subsystem consisting of an upstream functional module and a downstream functional module, the last one intercepting the goods/services produced by the first one.
3. The transfer of goods/resources takes place in a market by exchange; plunder takes also place in SESs, which is the natural form of transfer of resources.
4. The transfer of material goods between FDMs (mediated by the included organizations) represents a transfer of structural components. The significance of the material goods transfer is both material (including energetic) and informational.
5. The provision of services is valued not from a material or energetic point of view, but from an informational one (i.e. at the level of the self-regulating function); it has as consequence the maintenance of the control parameters of the organization or SES in a given range of values, acceptable for the proper functioning of the system.
6. Organizations can produce not only material goods, but also conceptual goods (e.g. languages, scientific theories, political ideologies, development models – such as the sustainable development model). Some of the conceptual goods have well defined producers, other are historical products (such as a language). Conceptual goods are either private or public. The mechanism of the services provision and conceptual goods production has a material support.
7. Conceptual goods are involved in the information and self-regulation function of the socio-economic systems, and have indirect consequences on the energy flow and cycling of matter functions of these ecological systems.
8. The emergence of new organizations at national and international levels is tightly linked with the production of conceptual goods such as sociological, political, ecological theories. Such organizations emerge because some preferences of the individuals can be better satisfied by putting private resources together or because some resurces cannot be owned in certain historical moments.
9. Any organization has a trend of maximizing the realization of its goals. This holds also for ISPC. Consequently human individuals working in an organization different than ISPC are in an inevitable conflict of interests. This has various political consequences (Iordache 2004b). Examples of such consequences relevant for one intending to increase the productivity of socio-economic systems are: the need to control the public organizations in order to increase the efficiency of using public funds, the need of private property institutions in order to have resources allowing an effective control by building a civil society. Other consequences are less obvious: the trend of socio-economic systems which crossed a threshold in the productivity of resources and services to accelerate their development, the trend of socio-economic systems with productivity below a certain threshold to slow down their development (this can

be put also in terms of attractors of complex dynamic systems). A last consequence worth mentioning, in this context, is the trend of productive socio-economic systems to absorb resources form low productivity SES, through the organizations from their structure (examples: migration of ISPC, transfer of resources by trading or international organizations). This is a process analogous to the so called natural ecosystem "exploitation" (transfer of energy and matter from early succession to late succession ecosystems, MARGALEF 1991). Its result is the inherent polarization of SES at all hierarchical levels. Human rationality influence some of the mechanisms involved in this self-organization. There is always a trend of reducing the polarization of resources distribution by ignoring and/or changing the institutional settings. In a highly productive and sustainable SES (from local to global) there are (costly) adaptive institutional settings allowing phases of intensive polarizing growth followed by phases of partial redistribution of the resources. A phase of intensive growth **and** of redistribution of resources does not correspond to any attractor of a highly complex socio-economic system. The above statements should be seen as part of a descriptive theory, not of an ideology (an ideologically biased world system theory is suggested for instance by HORNBORG 1998). We believe that these descriptive statements are important for designing effective international institutions specialized in the management of the Danube River macro-landscape.

Thus, the natural capital (NC) is part of the SESs, and the hierarchy of SESs is spatially superposed on, and not spatially distinct from the natural hierarchy of ecological systems. Note that in Fig. 4, for simplicity of the representation, the hierarchy of NC mimics that of the natural ecological systems (NES). This would lead to the impression that the NES hierarchy is fully fitted inside the SESs hierarchy. However, this is not the case, because in fact NC has cultural limits, and one NES is shared by different organizations in terms of property rights. A better image of the relationships can be built by using GIS analyses layers (e. g. BODESCU 2001). In fact one cannot properly speak of a hierarchy of the NC. NC is rather a result of the interactions between two hierarchies: that of NES and that of SESs. We keep speaking, however, about a hierarchy of NC because it has becoming customary. Thus, NC plays conceptually an intermediating role between NES and SES. Beside its ecological significance (in terms of connecting fluxes of energy and matters) the integration of NC in the SESs has also a cultural meaning, in terms of the characteristics of the property rights. Knowledge about this cultural meaning is essential for designing efficient and effective management measures.

Table 1 presents the characteristics of property rights (adapted from BROMLEY 1989; CHARLES 2001), and their presence in the case of ecotones/ecosystems, micro-landscapes, and macro-landscapes. Full ownership involves the presence of all characteristics. Full ownership is present in the case of individual ownership

Table 1. The characteristics of the property right and their presence in the case of the natural capital at different hierarchical levels. Brackets indicate that the right at private level is constrained when there are public management rights at landscapes level.

Characteristic property right	Comments	Relevant with regard to:		
		Ecotone/ ecosystem	Micro-landscape	Macro-landscape
The right to possess	In the absence of this there is no ownership	x	x	x
The right to use	Related to use right (access rights and harvest rights)	(x)		
The right to manage	Related to management rights	(x)	x	x
The right to the income	i.e. to receive the income accruing from owning property	x		
The right to the capital	i.e. to alienate, consume or destroy it	(x)		
The right to security	Notably immunity from arbitrary appropriation	x		
Transmissibility	The ability to transfer the right to a successor	x		
Absence of term	Full ownership runs into perpetuity	(x)		
The prohibition to harmful use	Ownership does not include the ability to harm others	x		
Liability to execution	The liability of the owner's interest to be used to settle debts	x		
The right to residuary character	To govern situations when ownership rights lapse	x		
Rights holder	Currently the right to posses is conceived only at ecotone, and ecosystem level in continental systems. There are no juridical concepts dealing with the public possession of a landscape (e.g. Danube Basin) as distinct from the possession of its subsystems	Private (individual p., group p. – corporate or common, state p.)	private or local public	regional public, and macro-regional public

of, for instance, riparian forests (ecotones/ecosystems) when there are no recognized public rights concerning the landscapes in which these forests are located. Once such public rights are recognized (at local, county, national, or international level), the private ownership of the riparian forest is constrained to some extent by the management right held by the public institution. This public management right will allow management measures concerning the landscape structure in order to preserve the public services provided by that landscape. The prohibition to harmful use at individual level is the basis for justifying the acceptance of landscape management rights at public institutions level.

Depending on the right holder one can have private ownership (property owned by individuals or group-held property), common property (property owned by the members of the community of a local SES, and managed on behalf of its members by the local institutions), and state property (property owned by the members of the nation of a national SES, and managed on behalf of its members by the state institutions). Groups holding common property have collective choice rights: management rights, exclusion rights (rights to allocate use rights), alienation rights (rights to transfer or sale the other collective choice rights). The special case of non-property (lack of property rights) does not currently characterize European fluvial systems (it has characterized, for instances, ‘high seas’ fish stock). Limitations on access and use, an important type of top-down constraint used by the public institutions for influencing the behaviour of social actors, can be performed under any property rights regime.

Having rights over the integrating systems (ecoregions, river basins) does not involve, in our view, having rights over the subsystems (such as riparian forests or other types of ecological systems), because ecoregions and ecosystems are different natural objects, with their own existence status. To negate the independent existence status of ecoregions would be reductionism, and to negate the existence of the ecosystems would be holism. To accept both of them, but recognize their interdependence, is systemism. However, the fact that their functioning is interdependent due to the hierarchies to which they belong, obliges to a cooperation between those holding rights on systems higher up in the hierarchy (public institutions), and those owning the subsystems (private owners).

The international environmental legislation is focused on preserving certain services provided by the macro-landscapes or by the ecosphere (maintenance of water quality, of habitats and species diversity, or global services). This means, in the parlance of this article, that one constrains the rights over the natural capital at lower hierarchical levels based on recognized public international management rights on macro-landscapes. However, this interpretation is not consistent with the fact that there are separate agreements for each service in part. It seems either that only the directly used resources (air, water, species, habitats) were politically perceived when the laws were designed, or that the laws were conceived in reactive manner in agreement with the priority of the different issues. This situation is related to the historical priority of the sectoral approach discussed in the first part of this paper, and reflects the evolution of the institutions for the management of the natural capital. Redesigning the current legislation is an unrealistic goal on the short term. Consequently, what could be done is to promote an integrated interpretation of the existing laws in the sense that they address separate services provided by large international public entities. This would directly imply that the laws must be enforced as a package by institutions that strongly cooperate. In the average term one might also promote the recognition of international ownership rights over somehow abstract, but productive, entities such as macro-landscapes. The rational force of the argument should be very high if it is to surpass the resistance due to the conflicts of interests between existing environmental institutions. The public perception of the rationality of the argument is depending on the degree of agreement within the scientific community, which is undermined to some extent by economic competition between research and academic institutions. In this context a key role in this new interpretation and in decreasing the activation energy of the reaction leading to a systemic approach with regard to the Danube Basin can be played by the civil society, of which IAD is a part. The elaboration of a tactic to achieve such a political goal requires a research activity per se. We have published several ideas in this respect for the case of LDRS (Iordache 2004c). In essence, we linked the proposed systems approach with the Action Plan for the implementation of the National Strategy for Sustainable Development. In the case of the Danube Basin one might refer to the European Strategy for Sustainable Development. As for the tactical plan for achieving the objectives we proposed the coupling of a bottom-up approach (lobbying from local level to Romanian Government) with a top-down approach (from ICPDR to the Romanian Government). In the case of the Danube Basin the tactic might be to organize lobby from national to ICPDR level, and use top-down constraints (in terms of favorable legislations, such as the EU-Water Framework Directive, and funding programmes). This may put the basis for a systemic monitoring of the Danube Basin, because such a monitoring makes sense only in order to serve the decisions for an integrated management.

Coupling the emergent properties with the monitoring system

We can now turn to the Lower Danube River System, a particular case of macro-landscape. Table 2 presents the main resources and services provided by the natural ecological systems of the LDRS and indicators to assess them. Each of these services deserves a comprehensive, systemic discussion in itself. A good example of such a discussion is for instance that done with respect to groundwater services (Griebler et al. 2001; Danielopol et al. 2003). Monitoring the Danube River Basin should also provide the information needed for assessing global services, and in particular for downscaling the global climatic models, which is a procedure dependent on local variables (Bass & Brook 1997). The resources and services stay here for the functional emergent properties of the natural ecological systems,

Table 2. Indicators characterizing the natural ecological systems of LDRS (TDM = trophodynamic module).

Type of system	Resources and services provided to SESs	Indicators to be assessed
Regional landscape	Maintenance of local landscapes diversity	Number of local landscapes of each type and their morphological characteristics
	Maintenance of species diversity associated to TDMs emergent at regional level	Number of populations of migratory species (fish, birds)
	Renewable resources	Sustainable harvest levels of migratory species
	Regional microclimate improve ment and groundwater recharge	Water retention and evapotranspiration
	Water quality improvement	Retention of sediment and pollutants
	Transportation pathway	Morphological characteristics of channels
Local landscape	Maintenance of ecosystems diversity	Number of ecosystems of each type and their morphological characteristics
	Maintenance of species diversity associated to TDMs emergent at local landscape level	Number of populations of species with high mobility at local landscape level (fish, reptiles, amphibians, mammals, birds)
	Contribution to regional micro-climate improvement	Parameters for determining the local water budget
	Contribution to water quality improvement	Sediment retention, pollutants retention, pollutants export by land use, nitrogen export by denitrification
	Renewable resources	Sustainable harvest levels of species with high mobility at local landscape level
Ecosystem	Maintenance of species diversity	Number of TDMs and of low mobility/ sessile populations (macroinvertebrates, plants)
	Renewable resources	Sustainable harvest levels of vegetation (wood, reed, medicinal plants), macro-invertebrates and fish

the energy flow, the cycling of elements and the self-regulation, on which they strictly depend; the connection between the resources and services production and the mechanisms of the functioning of ecological systems is not presented, as not directly relevant here, but can be found, for example, in Vadineanu (1998).

The resources and services produced at higher hierarchical levels of NC cannot be managed at a lower level in the corresponding SES hierarchy, because of the lack of resources needed for managing such large systems, even if the benefits resulting from these resources and services appear also at low SES levels. Consequently, one needs institutions for managing the ecological systems producing these natural resources and services, institutions emerged at the appropriate (high) SES hierarchical levels.

Existing monitoring networks generally envisage only one service or another from this list (e. g., EPDRB (1999) focus on water quality improvement), with few, if any, formal communication between the institutions responsible for the monitoring of different resources and services. As long as the perceived offer of resources and services at high (political) SES level – especially the national one – is not comprehensive, and as long as there is a lack of awareness about the tight interconnection between these resources and services as a result of the fact that they are produced by the same natural capital, it is not likely to have a change in the current approach of monitoring.

Table 3A presents the indicators proposed for assessing the state of local, district or national SES, while Table 3B focuses on the indicators for the relation of SES with NES systems. As already noted, the management institutions emerge as a result of this interaction; because of their key (informational) role in controlling the system, we propose to include in the monitoring also indicators of the functioning of these institutions (Table 3C). We should remark that the indicators presented in Table 3 are general to SES and of their interaction with natural systems, and are not specific to those found in the LDRS. However, they have to be included in the monitoring of any specific component of the natural ecological systems (in our case those of the Lower Danube River) in interaction with SES to allow the design of successful integrated management plans, as well as the assessment of their implementation.

Decentralizing monitoring

These elements have been proposed also in Iordache (2002). There are not compulsory generally relevant indicators, but indicators relevant at a specific hierarchical level and to specific societal objectives. As long as societal objectives differ in part between the hierarchical levels of the socio-economic systems, the monitoring system should differ from local to regional and to national level. In a holistic approach the design of the monitoring systems is done at national level and imposed at regional and local levels, the monitoring being thus useful only for the societal objectives at national level. The regional and local infrastructure of the

Table 3. Indicators characterizing the SESs (all hierarchical levels) (**A**); Indicators characterizing the relation of SESs with natural ecological systems (**B**); Indicators characterizing the managerial institutions emerged as a result of the interaction of SESs with natural ecological systems (all hierarchical levels) (**C**).

A

Emergent properties	Indicators to be assessed
Economic wealth	Size of the economy as measured by gross product, level of infrastructure
Social welfare	Employment rate
Viability	Rate of change of the labor force over time, index of diversity in employment, current sustainable employment relative to population, level of social cohesion
Independence	Percentage of locally based economic activity
Individual wealth	Per capita income relative to the average income in the integrating economy, food supply per capita relative to minimum nutritional needs, probability of sufficient food being available over next 10 years
Equity	Ratio of historical to current coefficients of income and/or food distribution, social stratification, involvement of women in local institutions
Public functional modules	Identified socio-economic objectives, regulatory and enforcement approaches, interaction with upper levels of government

B

Emergent properties	Indicators to be assessed
Ownership status of NC (local level)	Surfaces and morphometry of owned parts of natural capital, for each type of ownership
Functional modules at the interface with the natural capital (all levels)	Number of functional modules, and number and dimension of organizations thereof, including managerial institutions (for the details in the case of managerial institutions, see Table 3C)
Contribution of NC to economic wealth (all levels)	Natural capital rents, cumulated for all used resources and services (originating in LDRS and in the full ecological footprint of SES)
Sustainability (all levels)	Ecological footprint of SES relative to productive surface of owned NC

C

Emergent properties	Indicators to be assessed
Effectiveness	Level of success of stated management and regulatory policies
Viability	**At all levels:** level of financial and organizational viability, extent of capacity building effort **At local level:** extent of incorporation of local socio-cultural factors (community decision making, traditional ecological knowledge and management methods)

monitoring system is strictly depending on the national level. In a systemic approach societal objectives are recognized at all socio-economic levels, with appropriate distribution of the public funds, and monitoring is performed in order to help reaching all these societal objectives. The systemic monitoring at a certain socio-economic level addresses the institutions at that level, and the natural capital and socio-economic systems at the level just below (e. g., for national monitoring, it addresses the national institutions, the ecoregions and the regional socio-economic systems); it also imposes constraints on the monitoring performed at lower level in order to be sure that needed data for computing the indicators of interest are obtained. Resources transfer towards lower monitoring institutions takes place only to cover the extra effort done to obtain the extra data needed at the higher level (similarly with the Global Environmental Fund principle of "incremental costs" applied to funding projects at national level). Systemic monitoring should also include, beside the formal structure, an informal one, that is the possibility of the civil society to check the efficiency of the institutions involved in monitoring, as a final component in the checks and balances system towards and efficient institutional setting. Fig. 5 compares the holistic and systemic approach in monitoring.

Based on the above considerations one can identify the following principles for the design of an integrated, systemic monitoring:

1. **Decentralization of the monitoring**; at each socio-economic level the set of indicators needed for the specific portfolio of the societal objectives should be monitored; this set of indicators should be extended subject to constraints imposed by the monitoring needs for reaching the societal objectives at higher hierarchical socio-economic levels; finances for the monitoring indicators of local interest have to be obtained at local level, finances for the monitoring of the extra indicators have to be provided by the appropriate hierarchical institutions. The development of a competitive market of laboratories could be promoted, which would serve monitoring at all levels. Data bases could be under the direct control of the public institutions (local, regional, and national) responsible for their creation and maintenance. Information not available (legally or practically) to the public could be reduced to a minimum.
2. **Public availability of the data concerning natural ecological systems and socio-economic systems**; the private organizations which have financed directly and indirectly the monitoring could have free access to the databases at the local, regional, and national level; this availability will enhance the possibility to appropriately design the private organizations and the integrated plans for the management of the natural capital.
3. **Openness of the monitoring institutions to civil society control**; the monitoring is part of management. We do not manage ecosystems, we manage natural capital. The reason why we manage is the production of natural resources and services. When we can have private control over this production, we do not need to recognize those services as public and to create and

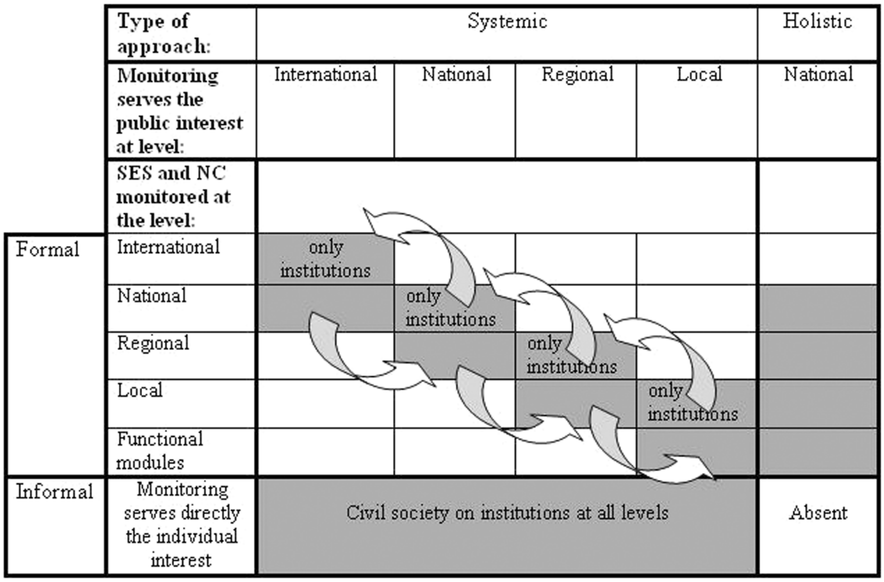

Fig. 5. Comparison of a systemic and a holistic approach in monitoring. The grey areas show which type of a monitoring serves the public interest at a certain level. For instance in the systemic view the public interest at international level is served by monitoring the socio-economic systems – SES (including their natural capital – NC) at national level, as well as by monitoring the international institutions. In the systemic view there are specific monitoring institutions for the different socio-economic levels, serving the specific public interests of those levels. The top-down arrows represent constraints imposed by the requirements related to monitoring indicators relevant for societal objectives at higher levels. The bottom-up arrows represent transfer of information needed for computing indicators at higher societal levels. Not all the information obtained at a lower level is needed at a higher level. The informal monitoring of the civil society serves the public interest at all levels. This informal control is absent in the case of the holistic monitoring. In the case of the holistic monitoring the formal monitoring at all levels historically served only the public national interest (one can compare the novel "1984" by G. ORWELL for a possible way of an international holistic monitoring).

pay institutions for managing them. This is the case of the resources produced in small and medium sized ecological systems, which can be owned in the fullest sense. However, the production of resources and services by large and very large natural systems cannot be de facto, in most of the current socio-economic systems, controlled by private actors. What is the role of globalization and international private enterprises legally bound to the country of their headquarters, and extracting resources from developing countries, in this context? Their role depends on national and European decisions, which in turn depend on the capacity of the civil society to control the public institutions (from local to European level) regulating the activity of the international enterprises. A week civil society such as in the socio-economic systems located in the eastern part of the Danube Basin would lead to a higher export of extractable resources. Depending also on the private environmental policy of the enterprise (which is influenced by the civil society in the home country), the extraction of resource can play or not a role in destabilizing the functioning of the macro-landscape by facilitating for instance over-exploitation, land re-conversion, or blocking the restoration attempts. This destabilization will not be promoted by the enterprise per se, but by the local political actors maximizing their interest instead of the public one. However, in practice river restoration faced difficulties everywhere due to high socio-economic interests associated to these areas (Gore & Shields 1995). When every one is interested in the natural public resources and services and has a certain economic autonomy, the management of the systems producing these resources and services (ecoregions and river basins as public goods) will be a public matter, in the name of the public interest. This management is a public service in itself, and will be performed by public institutions, with resources obtained from the private contributors. Taking these aspects into consideration, it seems that a systems view needs to be adopted more urgently by the scientist from the western countries of the Danube Basin rather than by those from the eastern countries. Fig. 6 presents the relationships between the categories of stakeholders involved in the management of macro-landscapes (private users, public institutions, and the civil society), and Table 4 shortly describes each category.

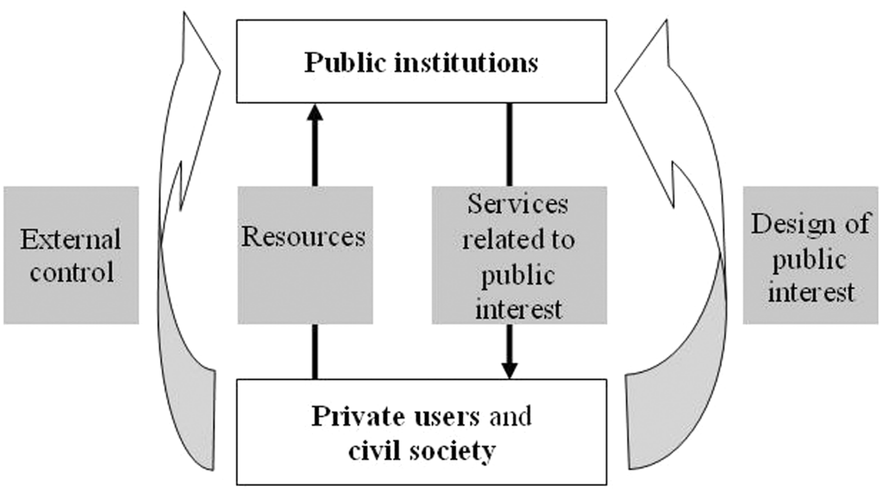

Fig. 6. The relationships between the categories of stakeholders involved in the management of macro-landscapes. Block arrows indicate the role of the civil society.

Table 4. The categories of stakeholders interested in the management and monitoring of macro-landscapes and their subsystems.

Category of stakeholder	**Description**
Private users	Private stakeholders interested in using the subsystems of the macro-landscape for economic and non-economic purposes (including satisfaction of emotional needs). Examples: economic organizations involved in resources harvesting and in the post-harvest sector, individuals (individual systems of production and consumption – ISPC), households, NGOs promoting eco-centric values
Public institutions	Public stakeholders responsible for promoting the recognized public interests related to the maintenance of the natural public services provided by macro-landscapes
Civil society	Private stakeholders (ISPC, NGOs (think tanks), political organizations), involved in: • the continuous process of restructuring the recognized public interest, by promoting the acceptance of new public services, or the elimination/adjustment of recognized public services which proved to have been misconceived; • the external control of the efficiency and effectiveness of the public institutions in using the resources provided by private stakeholders for promoting the recognized public interest

Discussion

While there are undoubtedly other ways of designing the set of indicators to be assessed by a systemic monitoring, these serve to provide an idea about the proposed approach, as well as a base from which to improve the set of indicators. Also, the elements discussed here can be easily developed towards a Danube Basin scale.

There are some methodological limitations to a systems approach in monitoring, arising especially from the following aspects: 1) the information describing illegal functional modules or illegal flows of resources and services is not easily obtainable; thus, the systems identification would generally limit to the legally functioning organizations, and to their legal activities; 2) the information concerning the states functioning are available only to a small degree in not developed SESs; even in advanced SESs, information concerning some aspects of the state functioning are not available for long time.

It is beyond the scope of this paper to discuss in detail the basic parameters to be measured in order to assess the indicators. Once the idea of such a design of the monitoring system becomes more widespread, the step towards establishing the set of parameters to be directly measured, as well as the organization in time and space of the monitoring, can be done. It is worth mentioning that most of the needed data are not, as type of data, very different from those obtained within current monitoring of the natural and socio-economic systems. However, we can anticipate that the organization in time and space of the field activity would be different, as well as the organization of data in appropriate integrated data bases within specific information systems.

There would be average-term costs associated to the extension of the indicators at macro-landscape level towards those proposed here, and to the transition to systemic monitoring. Nevertheless, these would be smaller than the social costs of continued sectoral monitoring at LDRS scale and continued holistic monitoring at national level. The reformation costs can be supported only by advanced socio-economic systems, which can afford a strong civil society, too. Thus, the time span for the development of a systemic monitoring in eastern countries of the Danube Basin will be similar to the time span for the development of their civil society, within the general process of development of the national socio-economic systems. The existence of the European attractor and of the international cooperation in view of an integrated, ecological, monitoring at macro-regional level may accelerate this process. More specifically, this time span might be reduced by cooperation of the civil societies from developed and developing countries of the Danube Basin (and this transboundary cooperation could be catalysed by IAD).

Next operational steps might be:

1. Adopting such a systemic view at the level of IAD. (The article should be seen only as a basis of discussion in view of this and not as a solution.) Obtaining non-governmental funds for developing a proactive activity in this area.
2. Spreading a truly systemic management view in the scientific community of developed countries of the Danube Basin. Much care should be taken by the western colleagues to not fall into the trap of holism (the eastern experience allow us to make this recommendation).
3. Organizing exploratory workshops over the methodology of a systemic monitoring of the Danube's socio-environment. In the first phase the focus could be on the natural capital. The existence of the Transnational Monitoring Network cooperation experience might be used informally in this respect.
4. Lobbying key institutions involved in the monitoring activity in each country to accept this new concept as a research direction. Developing, in local consortiums with these institutions, research projects for absorbing national research funds in this area.
5. Building a pilot network of local landscapes along the Danube for practicing a systemic monitoring on common methodological grounds. The network could also be connected with other existing sites such as ILTER, natural parks.

Conclusions

We consider that there is a need

- to monitor not only some compartments of the ecosystems, but all representative components of the SES-NES systems; a prerequisite is a correct systems identification which should be done by another component of DSS, the knowledge generation subsystem, and
- to explicitly relate, in the design of monitoring systems, the measured parameters with the emergent properties of the systems by the mediation of indicators of the resources and services provided.

For the practical realization of such a monitoring system, we suggest:

- to increase the communication between the actors currently involved in the estimation, in one way or another, of the listed indicators (research and monitoring institutions), and
- to catalyse through lobbying the emergence of better management institutions for relation of SESs to NES systems; by 'better' we mean here 'able to use as efficient as possible the natural capital in a socially optimal way', i.e. institutions which find development strategies for using not only several resources and services, but the whole array of resources and services provided by the natural capital, and at the same time which takes into consideration issues related to the distribution of benefits between and within SES.

Acknowledgements

We would like to thank Dr. Jürg Bloesch for reviewing and helpful comments on an earlier draft of this paper.

References

Abel, T. Stepp, J.R. (2003): A new ecosystems ecology for anthropology. – Conservation Ecol. **7** (3): 12 [online] URL: http://www.consecol.org/vol7/iss3/art12.

Aidarov, I.P., Venitsianov, E.V. & Ratkovich, D.Y. (2002): On the problem of rehabilitation of river basins. – Water Resources **29** (2): 219–229.

Alexander, R.B., Smith, R.A. & Schwarz, G.E. (2000): Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico. – Nature **403** (6771): 758–761.

Alterra (2004): Integrated countryside and landscape monitoring, http://www.alterra-research.nl/pls/portal30/docs/FOLDER/LANDSCAPEEUROPE/LANDSCAPE EUROPE/activities/research/iclm/iclm.htm.

Barron, D.N. (1999): The structuring of organizational populations. – Amer. Sociol. Rev. **64** (3): 421–445.

Bass, B. & Brook, J.R. (1997): Downscaling procedures as a tool for integration of multiple air issues. – Environm. Monitoring and Assessment **46**: 151–174.

Bayer, P. & Noss, R.F. (1998): Do habitat corridors provide connectivity? – Conservation Biol. **12** (6): 1241–1252.

Beard, G.R., Scott, W.A. & Adamson, J.K. (1999): The value of consistent methodology in long term environmental monitoring. – Environm. Monitoring and Assessment **54**: 239–258.

Behrendt, H. & Schreiber, H. (2004): Point and diffuse nutrient emissions and loads in the transboundary Danube River Basin – a modeling approach. – Internat. Assoc. Danube Res. **35**: 139–147.

Bejan, A. (2000): Shape and structure from Engineering to Nature. – Cambridge Univ. Press.

Bissonette, J.A. & Storch, I. (2002): Fragmentation: is the message clear? – Conservation Ecol. **6** (2): 14. [online] URL: http://www.consecol.org/vol6/iss2/art14.

Bodescu, F. (2001): Design and development of the data base for the management of biological and ecological diversity in the lower part of the Danube Ecological System. – PhD thesis, Univ. of Bucharest, Dept. of Systems Ecology.

Bogaert, J. (2003): Lack of agreement on fragmentation metrics blurs correspondence between fragmentation experiments and predicted effects. – Conservation Ecol. **7** (1): r6. [online] URL: http://www.consecol.org/vol7/iss1/resp6.

Bolscher, J., Meixner, H., Schnauder, I. & Iordache, V. (eds.) (2005): Hydraulic, Sedimentological and Ecological Problems of Multifunctional Riparian Forest Management – RIPFOR – Guidelines for End-Users. – Berliner Geograph. Abh. H. **66**, ISBN3-88009-067-x.

Borsuk, M., Clemen, R., Maguire, L. & Reckhow, K. (2001): Stakeholder values and scientific modeling in the Neuse river watershed. – Group Decision and Negotiation **10** (4): 355–373.

Brock, B.B., Hoenicke, R. & Tyrell, C. (1997): Planning tools for developing comprehensive regional monitoring programs. – Environm. Monitoring and Assessment **48**: 297–306.

Bromley, D.W. (1989): Economic interests and institutions: the conceptual foundations of public policy. – Basil Blackwell, New York.

Bunge, M. (1979): A system concept of society: beyond individualism and holism. – Theory and Decision **10**: 13–30.

Bunn, S.E. & Davies, P.M. (2000): Biological processes in running waters and their implications for the assessment of ecological integrity. – Hydrobiologia **422–423**: 61–70.

Burt, T.P. (2003): Monitoring change in hydrological systems. – The Science of The Total Environment **310** (1–3): 9–16.

Charles, A.T. (2001): Sustainable Fishery Systems. – Blackwell Sci., London.

Chave, J. & Levin, S. (2003): Scale and scaling in ecological and economic systems. – Environm. and Resource Economics **26**: 527–557.

Corona, P., Chirici, G. & Marcheti, M. (2002): Forest ecosystem inventory and monitoring as a framework for terrestrial natural renewable resource survey programmes. – Plant Biosystems **136** (1): 69–82.

Danielopol, D.L., Griebler, C., Gunatalika, A. & Notenboom, J. (2003): Present state and future prospects for groundwater ecosystems. – Environm. Conservation **30** (2): 104–130.

Danubs Project (2004): Nutrient management in the Danube basin and its impact on the Black Sea. – Contract EVK1-CT-2000-00051, DG XI, http://danubs.tuwien.ac.at/.

DONNER, S.D., KUCHARIK, C.J. & FOLEY, J.A. (2004): Impact of land use practices on nitrate export by the Mississippi River. – Global Biogeochem. Cycles **18** (1): Art. No. GB1028.

DUMITRU, M. (ed.) (2000): Atlas of soil quality monitoring in Romania. – Ed. GNP, Bucharest, Romania, 53 pp + 24 maps.

ENGLUND, G. & COOPER, S.D. (2003): Scale effects and extrapolation in ecological experiments. – Advances in Ecol. Res. **33**: 161–213.

EPDRB (1999): Transnational monitoring network for the Danube River Basin, publ. by the National Focal Point for Slovakia, Bratislava, Slovakia.

FAILING, L. & GREGORY, R. (2003): Ten common mistakes in designing biodiversity indicators for forest policy. – J. Environm. Managem. **68** (2): 121–132.

FERRETTI, M. & CHIARUCCI, A. (2003): Design concepts adopted in long-term forest monitoring programs in Europe – problems for the future? – The Science of The Total Environment **310** (1–3): 171–178.

GASTON, K.J. (2003): The structure and dynamics of geographic ranges. – Oxford Univ. Press, Oxford.

GEORGESCU, D., IORDACHE, V. & BOTEZATU, M. (2001): Human ecology [in Romanian]. – Ed. Ars Docendi, Bucharest.

GORE, J.A. & SHIELDS, F.D. (1995): Can large rivers be restored? – Bioscience **45**: 142–152.

GRIEBLER, C., DANIEOLOPOL, D.L., GIBERT, J., NACHTNEBEL, H.P. & NOTENBOOM, J. (2001): Groundwater ecology – a tool for management of water resources. – Luxembourg, Office for Official Publications of the European Communities, 413 pp.

HALLEY, J.M., HARTLEY, S., KALLIMANIS, A.S., KUNIN, W.E., LENNON, J.J. & SGARDELIS, S.P. (2004): Uses and abuses of fractal methodology in ecology. – Ecology letters **7**: 254–271.

HAMALAINEN, R., KETTUNEN, E., MARTTUNEN, M. & EHTAMO, H. (2001): Evaluating a framework for muli-stakeholder decision support in water resource management. – Group Decision and Negotiation **10** (4): 331–353.

HEWITT, J.E., THRUSH, S.E. & CUMMING, V.J. (2001): Assessing environmental impacts: effects of spatial and temporal variability at likely impact scales. – Ecol. Applications **11** (5): 1502–1506.

HOBBS, N.T. (2003): Challenges and opportunities in integrating ecological knowledge across scales. – Forest Ecol. and Managem. **181** (1–2): 223–238.

HORNBORG, A. (1998): Towards an ecological theory of unequal exchange: articulating world system theory and ecological economics. – Ecol. Economics **25**: 127–136.

IORDACHE, V. (2002): The coordinates of a systemic monitoring in Romania. – Mediul Inconjurator (The Environment) **2**: 63–71.

– (2003a): The difficulties in assessing the effects of the Yugoslavian conflict in the Lower Danube River System pointed out the need for changing the monitoring system. – J. Environm. Protection and Ecol. **4** (3): 557–563.

– (2003b): Human ecology – a systems perspective. – Analele Stiintifice ale Universitatii “Al. I. Cuza” din Iasi, Serie Biologie Animala **XLIX**: 329–336.

– (2004a): The idea of the evolution of institutions at F. A. Hayek and D. C. North [in Romanian]. – BSc thesis, Univ. of Bucharest, Fac. of Philosophy.

– (2004b): The Constitution from a human ecology point of view [in Romanian]. – Sfera Politicii (Sphere of Policy) **104**: 24–30.

IORDACHE, V. (2004c): Towards the integrated development of Lower Danube Fisheries. – Proc. of the "Deltas and Wetlands" Internat. Symp., Tulcea, Romania, **12**: 82–90.

– (2005): Systemism and management: two needed disciplines in an environmental curriculum. – J. Environm. Protection and Ecol. **6**.

IORDACHE, V., BODESCU, F., CONSTANTINESCU, M. & DUMITRU, M. (2004): The management of riparian forests in a macrolandscape context. – Mediul Inconjurator (The Environment) **2**: 48–58.

IORDACHE, V., BODESCU, F. & DUMITRU, M. (2005): Elements sustaining the lobby for the restoration of Big Island of Braila, Danube floodplain. – Arch. Hydrobiol. Suppl. **155** (Large Rivers **15**): 677–692.

IORDACHE, V., CRISTOFOR, S. & VADINEANU, A. (2001a): Functional analyses of the Lower Danube wetlands by FAEWE/PROTOWET procedure. – Proc. 10th Danube Delta Inst. Symp.: 98–103.

IORDACHE, V., VADINEANU, A. & CRISTOFOR, S. (2001b): Optimization pathways of the decision making process regarding the ecotoxicological effects in the Lower Danube River System. – Proc. 10th Danube Delta Inst. Symp.: 91–97.

KAY, J.J. (2000): Ecosystems as self-organizing holarchic open systems: narratives and the second law of thermodynamics. – In: S.E. JORGENSEN & F. MULLER (eds.): Handbook of Ecosystem Theories and Management: 135–160. CRC Press, Lewis Publ.

KEITT, T.H., URBAN, D.L. & MILNE, B.T. (1997): Detecting critical scales in fragmented landscapes. – Conservation Ecology [online] **1** (1): 4, available from the Internet. URL: http://www.consecol.org/vol1/iss1/art4.

KHALIL, E.S. (2000): Survival of the most foolish of fools: the limits of evolutionary selection theory. – J. Bioeconomics **2**: 203–220.

KOESTLER, A. (1969): Beyond atomism and holism – the concept of the holon. – In: A. KOESTLER & J.R. SMYTHIES (eds.): Beyond Reductionism: New Perspectives in the Life Sciences. The Alpabach Symposium: 192–216. Hutchinson & Co., London.

KRONVANG, B., SVENDSEN, L.M., JENSEN, J.P. & DORGE, J. (1999): Scenario analyses of nutrient management at the river basin scale. – Hydrobiologia **410**: 207–212.

LOOIJEN, R.C. (2000): Holism and reductionism in biology and ecology: the mutual dependence of higher and lower level research programmes. – Kluver Acad., Dordrecht.

MAHNER, M. & BUNGE, M. (1997): Foundations of Biophilosophy. – Springer-Verl., Berlin.

MALTBY, E. (ed.) (1998): FAEWE/PROTOWET procedures (version 1). – Wetland Ecosystem Research Group, Royal Holloway, Univ. of London.

MANLEY, P.N., ZIELINSKY, W.J., SCHLESINGER, M.D. & MORI, S.R. (2004): Evaluation of a multiple-species approach to monitoring species at the regional scale. – Ecol. applications **14** (1): 296–310.

MARGALEF, R. (1991): Ecologia. – Ediciones Omega, Barcelona.

MUSTERS, C.J.M., DE GRAAF, H.J. & TER KEURS, W.J. (1998): Defining socio-environmental systems for sustainable development. – Ecol. Economics **26** (3): 243–258.

NASSAUER, J.I. (1992): The appearance of ecological systems as a matter of policy. – Landscape Ecol. **6**: 239–250.

NAVEH, Z. & LIEBERMAN, A.S. (1990): Landscape ecology. – Springer, New York.

NORTH, D.C. (1990): Institutions, Institutional Change and Economic Performance. – Cambridge Univ. Press, Cambridge.

NOSS, R.F. (1990): Indicators for monitoring biodiversity – a hierarchical approach. – Conservation Biol. **4** (4): 355–364.

– (2003): A checklist for wildlands network designs. – Conservation Biol. **17** (5): 1270–1275.

ODUM, E.P. (1993): Ecology and our endangered life-support systems. – Sinauer Assoc. Inc. Publ., Sunderland.

OLSEN, A.R. & SCHREUDER, H.T. (1997): Perspectives on large scale natural resource surveys when cause-effect is a potential issue. – Environm. and Ecol. Statistics **4** (2): 167–180.

PAHL-WOSTL, C. (1995): The dynamic nature of ecosystems. – J. Wiley & Sons, New York.

PARR, T.W., FERRETI, M., SIMPSON, I.C., FORSIUS, M. & KOVACS-LANG, E. (2002): Towards a long-term integrated monitoring programme in Europe: the network design in theory and practice. – Environm. Monitoring and Assessment **78**: 253–290.

PARR, T.W., SIER, A.R.J., BATTARBEE, R.W., MACKAY, A. & BURGESS, J. (2003): Detecting environmental change: science and society – perspectives on long-term research and monitoring in the 21st century. – The Science of The Total Environment **310** (1–3): 1–8.

SEITZINGER, S.P., STYLES, R.V., BOYER, E.W., ALEXANDER, R.B., BILLEN, G., HOWARTH, R.W., MAYER, B. & VAN BREEMEN, N. (2002): Nitrogen retention in rivers: a model development and application to watersheds in the northeastern USA. – Biogeochemistry **57** (1): 199–237.

SILSBEE, D.G. & PETERSON, D.L. (1993): Planning for implementation of long-term resource monitoring programs. – Environm. Monitoring and Assessment **26** (2–3): 177–185.

STANKOVIC, S.S. & SILJAK, D.D. (2001): Contractability of overlapping decentralized control. – Systems and Control Letters **44**: 189–200.

– (2003): Inclusion principle for linear time-varying systems. – SIAM J. Control. Optim. **42** (1): 321–341.

STAPP, W.B. (2000): Watershed education for sustainable development. – J. Science Education and Technol. **9** (3): 183–197.

STOHLGREN, T.J., BINKLEY, D., VEBLEN, T.T. & BAKER, W.L. (1995): Attributes of reliable long-term landscape-scale studies – malpractice insurance for landscape ecologists. – Environm. Monitoring and Assessment **36** (1): 1–25.

TEGLER, B., SHARP, M. & JOHNSON, M.A. (2001): Ecological monitoring and assessment network's proposed core monitoring variables: an early warning of environmental change. – Environm. Monitoring and Assessment **67**: 29–56.

TREWEEK, J. (1999): Ecological impact assessment. – Blackwell Sci., London.

VADINEANU, A. (1998): Sustainable Development, Vol. **1**. – Bucharest Univ. Press, Bucharest.

– (1999): Decision making and decision support systems for balancing Socio-Economic and Natural Capital Development. – Background paper at Internat. Conf. "Globalization, Economy and Ecology – Bridging worlds", 24–26 November 1999, Tillburg, Olanda.

Vadineanu, A., Adamescu, M., Vadineanu, R., Cristofor, S. & Negrei, C. (2003): Past and future management of Lower Danube Wetlands System: a bioeconomic appraisal. – The Journal of Interdisciplinary Economics **14**: 415–447.

Vadineanu, A., Cristofor, S. & Iordache, V. (2001): Lower Danube River System biodiversity changes. – In: B. Gopal, W.J. Junk & J.A. Davis (eds.): Biodiversity in Wetlands: Assessment, Function and Conservation: 29–63. Backhuys Publ., Leiden, The Netherlands.

Van Breemen, N., Boyer, E.W., Goodale, C.L. Jaworski, N.A., Paustian, K., Seitzinger, S.P., Lajtha, K., Mayer, B., Van Dam, D., Howarth, R.W., Nadelhoffer, K.J., Eve, M. & Billen, G. (2002): Where did all the nitrogen go? Fate of nitrogen inputs to large watersheds in the northeastern USA. – Biogeochemistry **57** (1): 267–293.

Varduca, A. (1999): The integrated monitoring of water quality [in Romanian]. – Ed. H. G. A., Bucuresti.

von Bertalanffy, L. (1969): Chance or law. – In: A. Koestler & J.R. Smythies (eds.): Beyond reductionism: new perspectives in life sciences: 56–84. Hutchinson, London.

Vos, P., Meelis, E. & Ter Keurs, W.J. (2000): A framework for the design of ecological monitoring programs as a tool for environmental and nature management. – Environm. Monitoring and Assessment **61**: 317–344.

Ward, J.V., Malard, F. & Tockner, K. (2002): Landscape ecology: a framework for integrating pattern and process in river corridors. – Landscape Ecology **17** (Suppl. 1): 35–45.

Weisbuch, G. (2000): Environment and institutions: a complex dynamical systems approach. – Ecol. Economics: 381–391.

Wu, J. & David, J.L. (2002): A spatially explicit hierarchical approach to modeling complex ecological systems: theory and applications. – Ecol. Modelling **153** (1–2): 7–26.

Yoccoz, N.G., Nichols, J.D. & Boulinier, T. (2001): Monitoring biological diversity in space and time. – Trend in Ecology and Evolution **16** (8): 446–453.

Zacharias, M.A. & Roff, J.C. (2000): A hierarchical ecological approach to conserving marine biodiversity. – Conservation Biol. **14** (5): 1327–1334.

Received: 20 April 2004; revised; 5 August 2004; accepted: 14 January 2005.