STRARIFLU: a RIVER RESTORATION STRATEGY for Regione Lombardia (I) ([1])

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Abstract: *River Restoration (RR) is becoming more and more a key concept in river basin management by recognizing that it aims at an important environmental objective –improve the state of rivers in virtue of their existence value- and at the same time it is a means to achieve other important objectives like water supply, recreation and flood risk reduction (environmental services); in addition, it paves the way to pursue economic efficiency because total costs on the long run can be reduced. The Water Framework Directive (WFD) requires moving towards a more integrated assessment of fluvial ecosystems which considers no longer only water quality. We propose a FLuvial Ecosystem Assessment scheme, named FLEA, which defines a "value tree" of the fluvial ecosystem, based on the WFD quality elements for rivers (biological, hydro-morphological and physico-chemical), but integrating some additional key aspects now missing, like the "lateral mobility strip", the "geo-morphological equilibrium", together with the "naturalistic relevance", an important component of the perceived value of a river: The scheme makes possible to build a kind of evaluation index that can be used to measure the very objective of a RR strategy -that is "improving the value of rivers"- so supporting strategic integrated evaluation of plans (on the line of a Strategic Environmental Assessment). The scheme is sufficiently flexible to be adapted to the needs of the particular scale of analysis and case at hand (e.g. availability of data) as it relies on both quantitative and qualitative indicators. The scheme can be applied at different scales; for instance, at the regional scale quick and economic assessment can rely on secondary data available (e.g. water quality) and heavily on remote sensing (aero-photographs and satellite images), which supply information on wide areas with very good detail. The information can then be refined and updated at the local level by local authorities if suitably stimulated (e.g. making the collection and updating of information a pre-requisite to negotiate locally planning decisions made at the upper level.*

To measure and judge the deviation from the reference condition and then to amalgamate/aggregate the indicators up to higher level indices, the powerful Value Function (VF) concept and operational tool is adopted.

We also present an application that develops a complete RR strategy in the Lombardia Region (STRARIFLU project, now part of its legally binding "Piano di Tutela", a regional plan for water bodies protection and management, according to national law 152/99, precursor of the WFD). The strategy builds on the river assessment to identify and measure both the "health gaps" and environmental strengths of river stretches, to define a zoning useful to direct intervention, to specify what kind of action and at which scale to apply it, and to find synergies and potential contradictions deriving from other planning instruments to put into place countermeasures.

INTRODUCTION

Importance of RR

More and more it is recognized that healthy rivers, apart their direct use (e.g. water abstraction, hydropower, navigation, recreation,…), are very important ecosystems because of the significant existence/philanthropic value, and because they provide a number of key environmental services (e.g. flood protection, climate regulation, stabilization of soils, flow of nutrients to lagoons and seas nourishing exploited fishery, cheap and powerful treatment of waste waters, …), i.e. for their indirect use value.

[1] This paper is based on the work of several persons; particularly: Andrea Nardini, Giuseppe Sansoni, Ileana Schipani, Bruno Boz, Marco Monaci,Giulio Conte, Andrea Goltara.

River Restoration is an integrated discipline encompassing river engineering, fluvial geomorphology, ecosystem sciences, land-use and urban planning, amongst others, as well as typical tools of decisional problems like integrated evaluation (cost-benefit, multicriteria), public participation and conflict resolution-negotiation.

It is an objective, in the sense that it aims at improving rivers' conditions, and at the same time a means to achieve other important objectives like the reduction of flood & land-sliding risk, the satisfaction of economic uses (water supply, navigation,…) and, in the long run, even the reduction of investment and management costs (i.e. economic efficiency)([2]).

These considerations motivated the creation of several "river restoration centres" like RRC in the UK (www.therrc.co.uk), the Romanian Centre RCRR (www.rcrr.org), the Italian CIRF (www.cirf.org), organizations that deal with RR on national and international level and also attempts to improve communication and share information and experiences , like the European Centre for River Restoration (www.ecrr.org).

In the end there are at least three good reasons to restore rivers:

- philosophical convincement that this is a correct environmental policy line for a sustainable future
- economic reward (on the medium-long run, in the broad, basin scale)
- legal requirement: the European Water Framework Directive (Dir.2000/60/CE, named "WFD" in what follows) requires member states to bring their water bodies to the "good status" within 2016

Ecological status and its measure: issues raised by the WFD

Characterizing the status of a river, that is, describing it with a set of attributes, is definitely a must in order to understand what are its strengths and its weaknesses and to decide then "what to do". But in many cases we need something more than that.

From characterization to valuation of rivers

We need indeed to measure somehow the *value of the river*, i.e. expressing a value judgment about its status, measured by an index (amalgamation of indicators). In fact, as noted, any river restoration problem is a Multiobjective problem typically involving: nature conservation, costs minimization, flood risk reduction, hydropower exploitation, water supply, and the like (Fig.1). Therefore, if we really address it …as it is, i.e. looking for a choice of a Pareto-efficient trade-off solution amongst multiple and conflicting objectives (Goicoechea et al., 1982), we must be able to measure each objective through a specific index such that higher values of such index must imply higher satisfaction from that point of view.

This is probably also the key to really address the eternal problem of coordinating different plans, each one declaring many objectives, but then putting into place actions that affect them in an unclear and usually contradictory manner: an effective Strategic (Environmental) Assessment ([3]) would definitely benefit from a Multicriteria approach (Nijkamp and Beinat, 1998; also see Nardini, 1997).

[2] See for instance the interesting economic evaluation of Skjerne river (DUBGAARD *et al.*, 2002)
[3] See Dir. 2001/42/EC; EC (1994); Brown and Therivel (2000); Partidário and Clark, Eds.(2000).

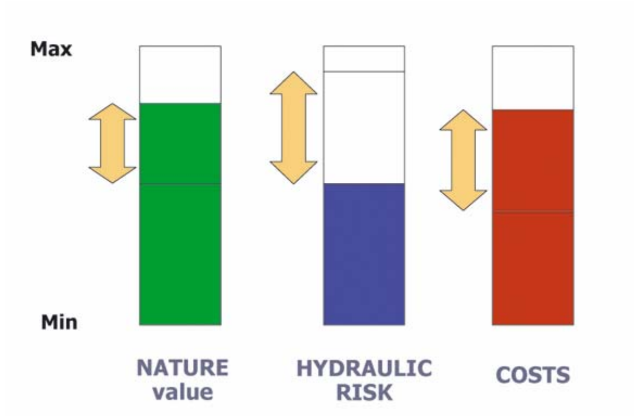

Fig.1 – A typical River Restoration problem involves multiple and conflicting objectives: any solution implies the choice of a particular trade-off amongst them. Being able to measure the objectives, including the ecosystem value, is key to identify efficient solutions in a transparent fashion.

Of course, measuring the river value is not easy at all, beginning from the fact that the value of environmental services (indirect use) can be included in it or rather separated and assigned to other objectives; for instance, the self-purification service provides an important contribution to the objective "cost reduction" because it partly solves –for free- the problem of waste water disposal. Then comes the choice of the numeral adopted to measure the value: one can attempt to measure it in monetary terms by using techniques well established in environmental economics ([4]). But it is also possible and meaningful to just measure it in relative terms, i.e. creating an arbitrary scale where to rank different reaches (or rivers or sets of rivers in a region). Indeed, what counts in the overall Multicriteria evaluation is the relative importance assigned to each objective (index value) by a subjective value judgment, not the absolute value assumed by an index. Pre-condition is however to be able to associate a physical intuitive meaning to each value of the index ([5]).

In the following we use "assessment" in the sense of both characterization and valuation.

Basic criteria for assessing ecological status of a river

What are the basic criteria for assessing the ecological status of a river ([6])? On the one side, we can consider its *ecological integrity* (Karr and Dudley, 1981; Karr, 1993a, 1993 b; Karr and Chu, 1995) or, more precisely, its ***health*** defined here as a measure of closeness to its *reference status* in terms of both structure and functions/processes, the reference status being the status of a similar water body belonging to the same typology within that eco-region, but not impacted by anthropic activities. This criterion is, indeed, adopted by the WFD which specifies, then, that structure and processes must include the traditional attribute of water quality (*physico-chemical*) as well as *biological* and *hydro-morphological* attributes. Notice that we must accordingly conclude that a river very poor in terms of, say, aquatic fauna has a perfect health if naturally (reference status) it is like that, provided the other attributes coincide with their reference status as well. Dually, if a river is showing high functionality while naturally it would not, it cannot be labelled as "healthy".
Health does not tell the whole story, however. In fact, we often assign an extremely high importance to a water body not because it is very close to its reference status, but rather because it is very "special" in a biological or geo-morphological sense. Very often, indeed, river reaches including abandoned sites of extraction of sand/gravel, belonging to the fluvial corridor, are today protected areas (possibly according to the EU Habitats and Species

[4] See for instance Dixon and Hufschmidt, 1986; but also Nardini, 1997 for a discussion on the limitation of the economic evaluation.
[5] This topic is deeply discussed in Nardini (1998) and Nardini (2004).
[6] We are talking about the natural value of rivers thus disregarding completely any cultural-historical- archeological value it may deserve.

Directive, 1992 and the Birds Directive, 1979), because special fauna and flora has installed. In a word, we consider the *naturalistic relevance* of a river and its corridor as a very important criterion of river evaluation. Undoubtedly, it is extremely hard to establish a scale of values to rank different elements (is a peculiar water fall more valuable than two endangered species of flora?), but the conceptual sense of this criterion seems robust and, practically speaking, the classification of protected areas (international, national, regional, local,…) proves that operational protocols are already in use. The WFD, however, does not consider this criterion. Our following discussion concentrates then on *health* only.

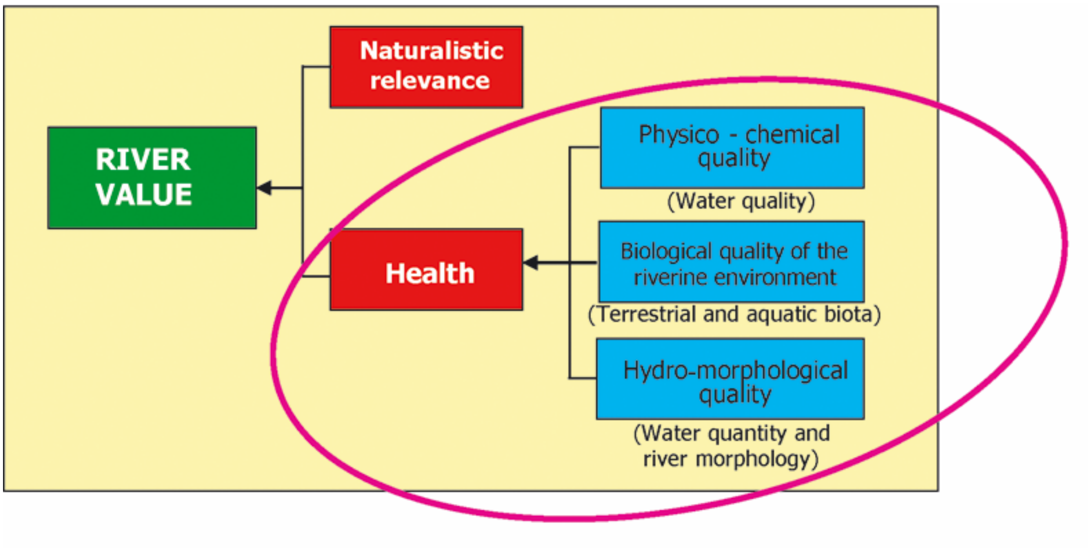

Fig.2 – Basic criteria to evaluate the ecological status of a river (CIRF, 2006)

ASSESSING RIVERS' STATUS

Attributes and FLEA proposal

Elaborating on the line indicated by the WFD, we came up with a scheme that we named FLuvial Ecosystem Assessment ([7]) that we like to propose here as a stimulus to discussion and stressing that it is flexible and open to adaptations to specific cases, but also introducing the "*value tree*" concept (Keeney, 1992) that, in our opinion, clarifies in a strong and intuitive fashion the structure of any proposed scheme.

[7] FLEA (a "jumping flea") to stress ironically its purpose of stimulating discussion and action.

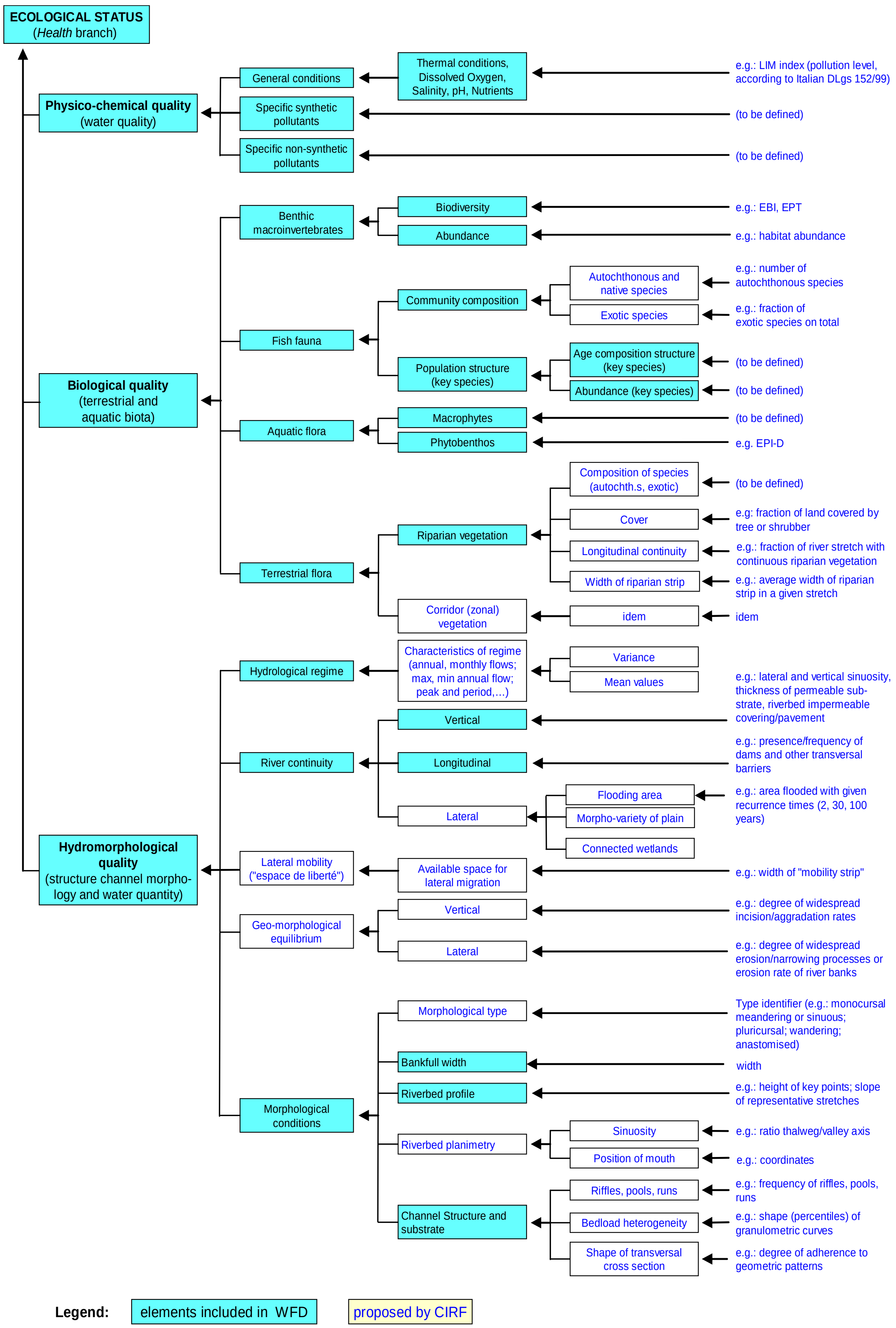

Fig.3 – The *value tree* of the FLuvial Ecosystem Assessment scheme.

This scheme is quite similar to what was already outlined, for instance, in the final draft of the Guidance on Monitoring for the Water Framework Directive (EC, 2002); however, some additional key sub-attributes have been introduced:

- *lateral continuity*: which takes into account the possibility of overbank flows, so ensuring the survival of streamside vegetation and fauna, the development of nutrients dynamic cycles, the distribution of flood volumes along the river length (rather than concentrating then into the river bed downstream), the recharge of the aquifers…
- *geo-morphological equilibrium*: to take into account whether the river is still "alive" rather than blocked (stable moribund) or out of balance (in incision or aggrading), that is altering the sediment transport (and thus the stability of river banks and of any infrastructure)
- *lateral mobility* (space of freedom): considers the fact that rivers, except the fixed bed ones, need to move, and needs hence space for that; this movement allows them to disperse part of their energy and to keep their sediment balance.
- *Plant communities of the riparian zone and river corridor*.

These attributes, not (or marginally) considered by the WFD, are in our view key to take into account the impacts due to artificialization of rivers and associated loss of space.

Indicators and indices

Each lowest-level attribute ("leaf" of the *value tree*) has to be measured by a specific indicator. In most cases, it is not possible to use what is offered by the literature because the concept of measuring the closeness to a reference status is not considered there. On the other hand, it is perhaps more sensible to give up with the idea of fixing the same indicators for all situations (all countries, or just for each given eco-zones, or even for a given river typology) because of the enormous bio-geographic diversity, but also just because different indicators could better fit different scales of analysis (regional, local,..) and data availability which may sometimes prevent to adopt the most desirable indicators. A more flexible approach is welcome, although the comparability amongst situations is a mayor issue.

In any case, it is very important to clearly separate:

i) the descriptive step of measuring the selected attributes, whatever they are, both in the reference condition and in the current condition , from

ii) the step of measuring the closeness between the two values.

The first step should indeed be as far as possible objective (measuring the quality elements for rivers through suitable indicators, rather than through scoring methods based on the subjective judgment of the field operator), while the second step does involve a value judgment, but made explicit and formalized.

At the end of any simple or, more probably, complex analysis of our fluvial ecosystem, we need a very synthetic information that can be operationally be used in making decisions. In particular, we need it to establish to which quality class (from "bad" to "high") a given set of values of the selected indicators is to be assigned (e.g. which are the reaches in good or sufficient or bad conditions); also, we need to know which is the "sickness" of each reach, i.e. which parameters are responsible of a loss of value.
Therefore we need an amalgamation (or aggregation) of the indicators adopted into an *evaluation index*. This, of course, should be accompanied by the original pieces of information, to avoid any possible bias or loss of information (Eisel and Gaudett, 1974; Elliott, 1981). No matter the quantity of data available, this aggregation unavoidably requires a subjective value judgment: even if hundred of thousand of samples are taken and analysed, we will have to decide when that river reach "jumps from one quality class to another"

according to the value assumed by the indicators (even by just one of them). Hence –at the very end- experts judgments have to be involved to accomplish this task.

In order to guarantee repeatability and to make the instrument legally binding, a formalization of such judgments is however required: the Value Function (VF) can do it as it is a mathematical representation of human preferences (Keeney and Raiffa, 1976; Keeney, 1992; totally dedicated to this topic is Beinat,1995 and Nardini, 2004). It is useful to remind that a VF (denoted here with v(•)) can be scalar (function of a single variable), or multi-attribute (function of several variables); in any case, its key property is as follows (denoting with *situation* a physical situation with which a set of values of the selected indicators is associated):

- if *situation* A is preferred to *situation* B, then $v(A) > v(B)$;
- if A is judged indifferent with respect to B (i.e. generates the same *satisfaction*), then $v(A) = v(B)$;
- if A is not preferred to B, then $v(B) \geq v(A)$.

Furthermore, equal increments of the FV numerical value implies equal increments of satisfaction.
When applied to the ecosystem assessment, the best situation, where the VF assumes the maximum value (usually 1), corresponds to the *reference state*; in the worst situation it assumes its minimum value (usually 0).

Many exercises have been undertaken to evaluate the river ecological quality (e.g. within the Aktion Blau programme in Germany, the RHS in UK, the Italian IFF), however we could not find one that were really conceptually and operationally satisfactory, with the exception of the SEQs (France) –that however is quite complex and mixes also a kind of impact analysis on uses and causes identification- as resumed in Table 1.

Table 1 – Comparison of some river evaluation methods

Criteria Experiences	Purpose	Reference conditions	Complies with WFD parameters	Suitable for large-scale, frequent updating	Objective indicators
SEQ_s (1)	Evaluate the state of degradation, (from which quality objectives are defined and planned)	yes	Yes. SEQ (Quality Evaluation System): SEQ_{eau} (for water quality indicators), SEQ_{bio} (for biological indicators), and SEQ_{phy} (for physical indicators)	yes. Cartographic analysis done at a scale of 1:1000000; system based on periodic surveys.	Partially (seems to use a mix of objective indicators and subjective scores) ([8])
Aktion Blau (2)	Characterize and assess the physical structure of rivers	yes	Partially (does not include biological and physico-chemical attributes)	Hard (is born to be applied at a very detailed scale; requires on-site operators)	Yes
RHS (3)	Characterize and assess the physical structure of rivers	yes	Partially (does not include biological and physico-chemical attributes)	Hard (is born to be applied at a very detailed scale; requires on-site operators)	No (uses a subjective scoring system)
IFF (4)	Assess fluvial funcionality	no	Partially (does not include physico-chemical attributes, and only part of the biological and hydro-morphological ones are tackled)	Hard (is born to be applied at a very detailed scale; requires on-site operators)	No (uses a subjective scoring system)
FLEA	Evaluate the ecological status of rivers	yes	yes	yes (can be applied at both regional or local scale)	Yes (although data scarcity may be

[8] Recent updates of the method may have clarified this point.

					substituted by judgment)

(1): Evaluation System of river physical Quality. Agence de l'Eau (1998)
(2): Aktion Blau. Landesamt für Wasserwirtschaft (1999)
(3): River Habitat Survey: Raven et al. (1998a and 1998b); Environment Agency (1997, 2003); Buffagni & Kemp (2002)
(4): IFF: Index of Fluvial Functionality, Siligardi et al. (2000)

DEFINITION OF A STRATEGY: the *STRARIFLU* project

This section briefly presents the River Restoration strategy developed at the regional scale within the *STRARIFLU* project for Regione Lombardia (23.861 km^2) and now part of its "Piano di Tutela delle Acque" recently approved (the required by the national Italian law 152/99 for improving the state of water bodies). It illustrates an application of the concepts discussed above ([9]).

Basic elements in a RR strategy (regional scale)

In essence, the strategy developed is made of few key ideas as depicted in Fig.4:

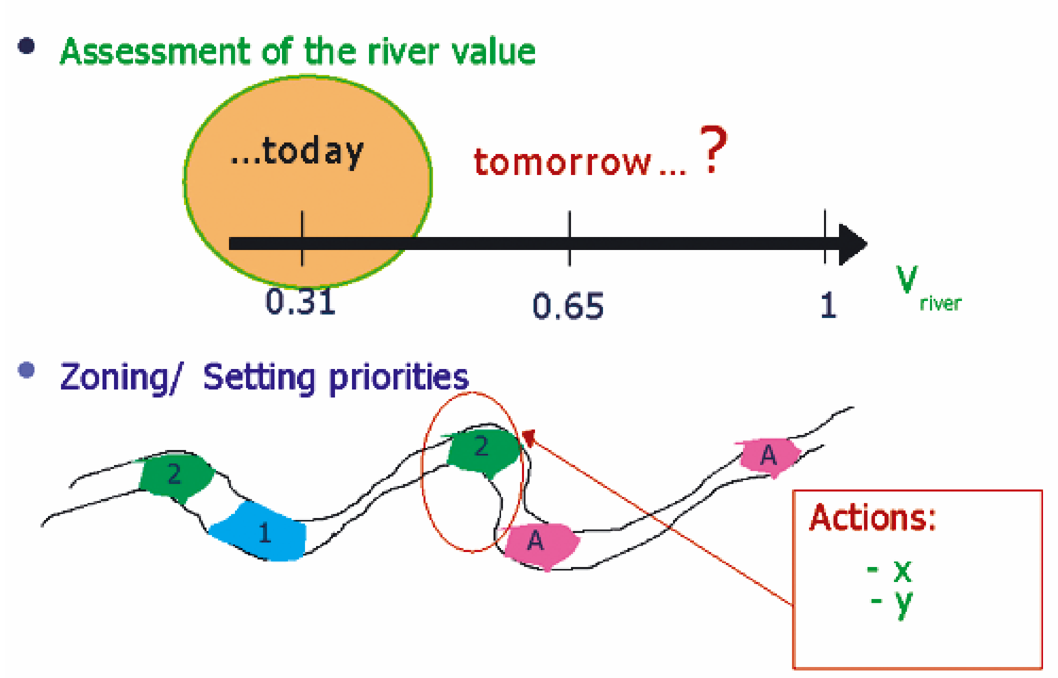

Fig.4 – The STRARIFLU project in synthesis: measures the "river value" today and identifies its "health gaps"; leads to a river zoning and says what to do to increase the value/health - where (ranging from local actions, to river basin actions) and with which priority; finally, specifies implementation tools at the normative level.

<u>Integrated characterization of fluvial ecosystems</u>

The characterization of river status has been carried out according to a scheme very similar to FLEA. Indicators for all attributes have been built according to secondary data availability

[9] Full details (in Italian) can be found in the web site www.ors.regione.lombardia.it/OSIEG/AreaAcque/.

at the regional scale. For instance, for the Hydro-morphological "Lateral mobility" attribute, the simple indicator "width of the mobility strip" (w) has been adopted ([10]).

The corresponding values have been plot as shown in the following Fig.5:

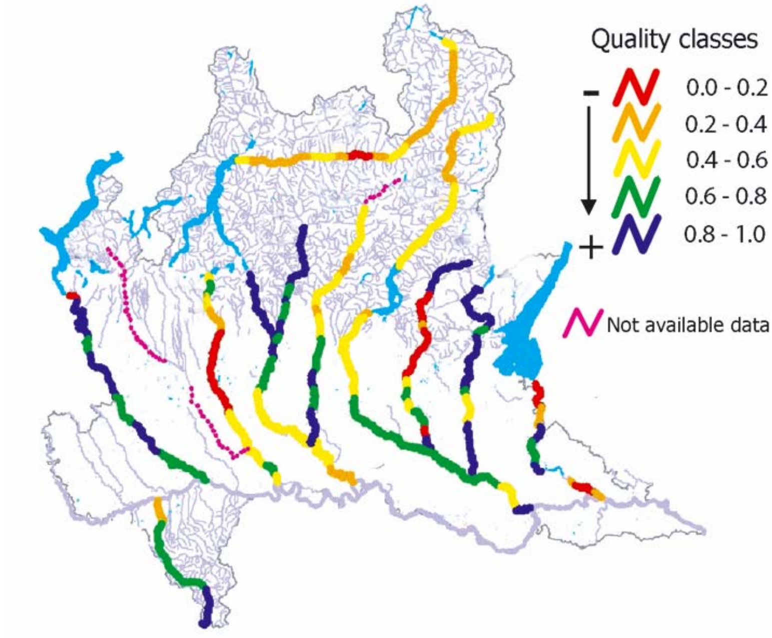

Fig.5 – The resulting map showing the mobility strip indicator adopted in the STRARIFLU project for Lombardia region (2004). The map says that: there still are reaches in good health somewhere; there are reaches in dramatic conditions; on the average, the river network is however not too bad.

Once defined the closeness-indices for each indicator (to measure, at the leaf-attribute level of the value tree, the closeness between the reference and the current values), sub-indices have been built for each higher level attribute. For instance, water quality aggregates a number of physico-chemical leaf attributes (and indicators); in this particular case, we did not develop an ad-hoc Value Function, but rather simply adopted the index already in use by the Italian Law 152/99 ([11]). The result is again a similar map of "coloured reaches".
Another example of sub-index, leading as well to a similar map, concerns the Fish fauna; in this case the indicators adopted are reported in Table 2.

Table 2 – Structure pf the sub-index Fish fauna with corresponding indicators adopted in the STRARIFLU project for Lombardia region (2004).

[10] The "mobility strip" is the space where the river bed can freely move during a management time-scale (10÷100 years); it is determined as the envelop of past river bankfull, plus the zone that is prone to river bank erosion in the close future (say next 20 years); minus those zones, within the previous one, where movement is impeded by some kind of work or infrastructure (typically: defence works, railway lines, highways, or urbanized areas). Basic information comes from remote sensing (air photographs and satellite images), plus spot field checks.
[11] This Index, denoted LIM, strictly speaking does not comply with the internal coherence property that characterizes VFs and therefore may not be correct; but it has obvious operational and normative advantages.

ATTRIBUTE	SUB-ATTRIBUTE	INDICATOR	SCALE
Community composition	Presence of key-species	% of key species in the fish community	Low (0): com < 50% Medium (1): 50% ≤ com ≤ 65% High (2): com > 65%
	Age composition	% of individuals belonging to the youngest age-class	Low (0): young < 5 % High (1): young ≥ 5%
	Peculiarities	Presence of sensitive species	d = 0: No d = 1: Yes
	Native fish species	Non-native fish species richness	Low (0): non nat > 40% Medium (1): 20% ≤ non nat ≤ 45% High (2): non nat < 40%
Abundance	Abundance	Qualitative abundance	Low (0), Medium (1), High (2)

Finally) (Fig.6).

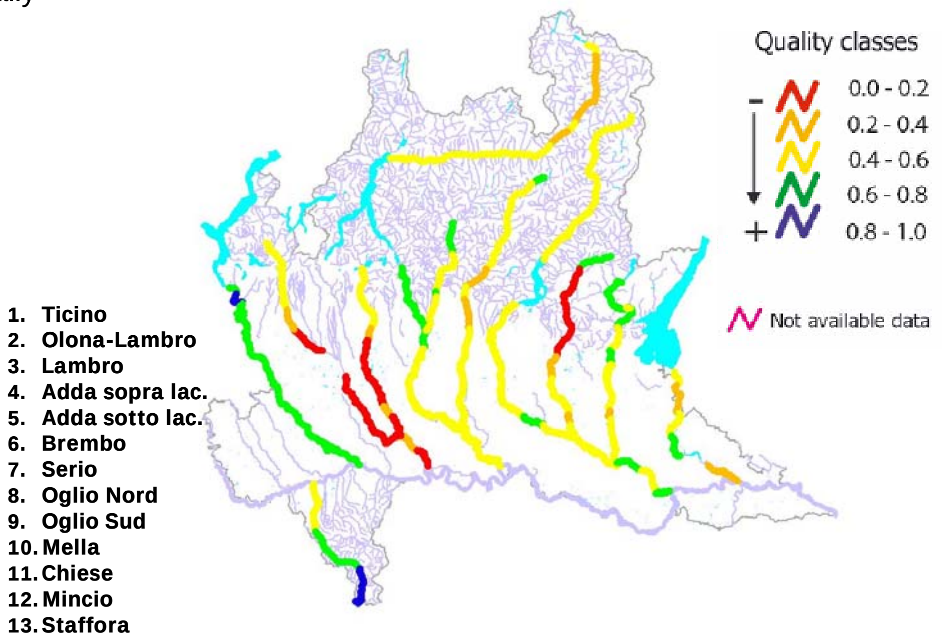

Fig.6 – The final map showing the *river value* index adopted in the STRARIFLU project for Lombardia region (2004). Comments similar to those concerning the previous map hold here.

Strenghts-Weaknesses and Opportunity-Threats analysis (SWOT)

The index-system obtained synthesises a lot of information and offers a lot of possibilities of analysis (automatized on a GIS). In particular, we investigated which were the key problems of each reach, i.e. what attributes were responsible for the larger *health gaps*, as shown in the example of Table 3. This information is key to identify what type of action is needed.

Table 3 –Example of *health-gap* analysis and identification of key Action lines for a given reach of a given river (Δh denotes the whole health-gap of that reach, while Δh_i is the health gap due to attribute i; the attributes are ranked according to the % of ecosystem health missing, as measured by the corresponding index). Notice that often to solve a problem detected in a given reach, one has to act elsewhere: in the whole river corridor, or even at the river basin scale.

HEALTH-GAP ($\Delta H_i/\Delta H$ %)	ATTRIBUTES	KEY ACTION LINES	LOCATION
34%	Vegetation	- Incentives for riparian strips restoration	river basin
		- Plantations of riparian woods and their management	local, corridor

32%	Hydrological regime	- Reservoir regulation - Demand-side management	river basin
		- Water extraction re-allocation	river corridor
17%	Fishes	- Management of fisheries - Controlling sport fishing	river corridor
11%	Water quality	- Woody buffer strips - Creation of outstream wetland…	river basin, corridor
10%	Lateral mobility	- Banks removal	local
		- Avoid new protection from floods of low value areas - Incentive to extend river floodplain	river corridor, river basin
7%	Geo-morphological equilibrium	- re-introduce sediments from reservoirs	river basin
		-abate river bank defences	local
0%	Freshwater macroinvertebrates		

Concerning threats (future negative evolution of the ecosystem), we analyzes in particular the (in)coherence between the strategy defined and the strategies outlined in other land-use planning tools (in particular the PAI of the Autorità di Bacino del Po, that is the plan facing hydraulic and land-sliding risk by the river basin water authority of river Po), leading to another specific table and a map.

Amongst the opportunities we tried to identify those situations (reaches) where it would be worth acting with respect to others because of the possibility to obtain the maximum advantage. For instance, a reach suffering for lack of vegetation and, at the same time, receiving a significant nutrient load is ideal to implement a re-vegetation action (causing a vegetation health gap), provided it disposes of sufficient space to host a buffer strip enough wide to abate significantly that load (an environmental service). Again, a reach suffering from a narrowed lateral flooding area because of river banks or levees (causing a health gap of its *Lateral continuity* attribute), also offers an opportunity to contribute to flood protection downstream (an environmental service), provided that the land-use around it can be reasonably transformed to host rare (or frequent) floods.

A set of such criteria has been defined (see next Table 4), formalized and implemented on a GIS to quantitatively identify this type of opportunities (obtaining a ranking or reaches according to each criterion). For instance, the vegetation criterion is formalized as follows:

$$p = \min\,[1, (A_R/A_N)_0\,]\; N\,(\Delta s_{vr}) \qquad \text{Eq.1}$$

where: A_R = area of the current riparian strip (total on the two banks); A_N = area required to abate 70% of the N-load present by means of a buffer strip; N= mean annual load of Nitrogen incoming in that reach; Δs_{vr} = complement to unity due to the health component „riparian vegetation" (total on the two banks); the notation $(x/y)_0$ represents an operator that, given two numbers x and y, supplies the value in parenthesis (i.e. the ratio x/y), when y >0, 0 otherwise.

Zoning and priorization of actions

We defined three basic types of zones (reaches):

- high value zones (***OK***) where to preserve/conserve
- crises zones (***KO***), where it is necessary to promptly remediate, although possibly it is not sensible to point to a "good status" target (i.e. these are reaches possibly classified as Heavily Modified Water Bodies)
- potentially restorable zones (***R-pot***), where a restoration action is envisaged.

Operationally, such a zoning is obtained by using again the evaluation indices (sub-indices or indicators) described above, through a filtering process. For instance, ***OK*** zones are identified as those reaches where the final index of ecosystem value is higher than a given threshold or the health value is high and the fruition potential is high (measured through an ad hoc index); ***KO*** zones are identified as those reaches where either water quality is bad

and/or geo-morphological equilibrium is at its worst level and/or there is a significant water deficit; ***R-pot*** reaches are the remaining ones.
The choice of the thresholds is a matter of environmental policy of the administration concerned: too rigid thresholds would identify too many reaches to be restored, implying too high investments; vice versa, too relaxed thresholds might overlook real problems.

Combining this zoning map with the SWOT map concerning incoherence with other planning tools, we obtained a different, but important zoning, namely a map of “warning” (Fig.7).

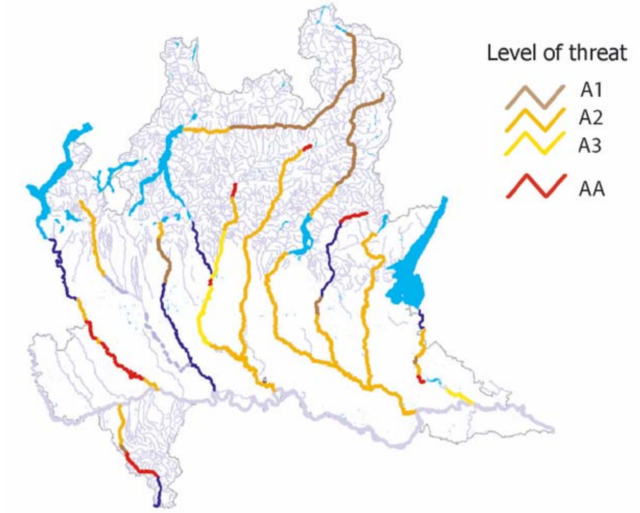

Fig.7 - The map of “warning” highlights reaches whose future ecological status is threatened by some incoherence in planning instruments with regard to the strategy defined. Higher threat (colour red- AA) occurs for reaches of current high value and where other planning instruments foresee some artificialization or exploitation. This map, hence, points out which checks have to be carried out to ensure coherence of plans.

Finally, on the base of the opportunities identified by the SWOT analysis, a priorization of the actions has been carried out which, for each criterion, specifies where the corresponding type of action should be implemented first (Table 4).

The final action plan gives priority to the ***OK*** and ***KO*** zones by recommending to put into place the corresponding identified actions; then, for the ***R-pot*** zones, recommends to combine “what is needed” (as synthesised in Table 3) with “what is worth” (Table 4) to specifically decide what to implement first, according to implementation instruments available.

Table 4 - Priorization of actions: the last column reports the reaches, ranked from the best (left) to the worst but still convenient (right), where the type of action corresponding to a given criterion (row) is worth being applied. P denotes “Prudent” criteria, while “D” denotes “Daring” criteria.

TYPE	**N**	**ACTION CRITERIA**	**Stretch order**
P	1	Restore health through *vegetation cover* in the riparian strip while getting a buffer-strip effect on diffused pollutants	10,9,4,3,6, 1,5,8,2
P	2	Rehabilitate *morphological diversity of stream corridor* by realizing off-stream wetlands while abating pollution loads	4,6,9,5,10, 8,3,1,2
P	3	Restore health through *river continuity*, *vegetation cover* in the riparian strip and *water quality* to foster recreation and the landscape quality	4,3,6,9,10, 5,8
P	4	Restore health through *water quality* and *hydrological regime* for recreation-fruition connected to bathing	6,4,5,8,9,1 0,3
D	1	Restore health through *geomorphological equilibrium* while reducing hazard to infrastructures	3,9,1,2

D	2	Restore health through *lateral continuity* where unnecessary defence structures (e.g. levees) are present, so reducing downstream flooding risk and management costs	6,3,2,5,1,10,9
D	3	Restore health through *lateral mobility* (by removing erosion control structures, changing land-use, relocating settlements, etc.) , so reducing downstream hazard due to stream energy, and reducing management costs	3,4,6,10,2,1,9,5,8

Implementation tools

Implementation tools specified in the norms of STRARIFLU consist of: command and control, economic-financial incentive and dis-incentives, administrative-technical support, participatory tools (public participation, conflict resolution, river basin organizations) and information updating.

Information updating is a key point. At the regional level the information available always is incomplete, somehow rough and not completely reliable; and it gets old terribly quickly. Updating and refining it at the regional level is an impossible task (financially). Here comes the idea to take advantage of local subjects and, at the same time, to provide them with a concrete possibility and an incentive to actually implement the strategy while coordinating with the regional level. The mechanism is like this: "only if you correct, refine and/or update the information concerning your stretches (those falling in you administration), according to the STRARIFLU scheme (i.e. feeding its value tree, possibly with the same indicators or with more detailed ones that nevertheless can be meaningfully placed in the value tree at the leaf level), you are allowed to negotiate the decisions taken by the regional strategy".
Of course, local subjects must be provided with technical support, in the form of both training courses and support staff, and through a webGIS tool made available by the central administration (the one responsible for STRARIFLU).

CONCLUSIONS

In this paper we pointed out that river restoration always involves a multiobjective problem; the characterization of fluvial ecosystem status should therefore lead to measure river value (or at least, river health), even if just in relative terms: only in this way a strategic (multicriteria) evaluation of plan alternatives can be performed to support an informed decision. This is possibly also the key to ensure the coordination of different planning tools.
We presented a proposal for measuring rivers' value which builds on a value tree, named FLuvial Ecosystem Assessment (FLEA) -which fully accomplishes the requirements of the WFD- and at the same time supports the construction of evaluation indices. The value tree is quite similar with what was already outlined, for instance, in the final draft of the Guidance on Monitoring for the Water Framework Directive (EC, 2002); however, in our view, FLEA offers an improved scheme enough robust conceptually and flexible to be used operationally as it:

- points out that aside "how healthy" is our river (i.e. how close to its reference status, what we named *Health*), we should also consider its *Naturalistic relevance*, that says "how special" it is
- introduces some additional key sub-attributes for the Health branch (lateral continuity, geo-morphological equilibrium, lateral mobility) that appear key to take into account the impacts due to artificialization of rivers and associated loss of space

We noticed that being able to use objective indicators is key to separate the description of the status (objective) from its assessment (which involves subjective value judgments). We then recognized that the Value Function is a very suitable and powerful concept and tool for both evaluating the closeness to the reference status, as well as for aggregating several indicators into sub-indices and then a final index.

We also showed an example of river restoration strategy at the regional scale ([12]) to explore what can be done after the step of integrated characterization of fluvial ecosystems.
The WFD may be the start of large scale application of river restoration.

REFERENCES

Agence de l'Eau (1998): SEQ physique: système d'évaluation de la qualité physique des cours d'eau, rapport de presentation. Rapport Iter-Agences, Ministère de l'Environnement.. In : Kondolf G.M. and H. Piégay Eds. (2003): *Tools in Fluvial Geomorphology*. Wiley (Cap.7, pag.189).

Beinat E. (1995), Multiattribute value functions for environmental management (Book n.103 of the Tinbergen Inst. Res. Series, Free University, Amsterdam).

Brown, A.L. and R. Therivel (2000). *Principles to Guide the Development of Strategic Environmental Assessment Methodology*. Impact Assessment and Project Appraisal 18(3): 183-189.

Buffagni A. e Kemp J.L. (2002). Looking beyond the shores of the United Kingdom: addenda for the application of River Habitat Survey in South European rivers. *J. of Limnology* 61 (2):199-214.

CIRF (2006). River restoration in Italy. Guidelines, tools and experiences to manage water courses and territory. A.Nardini, G.Sansoni Eds., Mazzanti Editori, Venezia (in Italian) (all details on the website www.cirf.org).

Dixon, J. and M. Hufschmidt (1986). *Economic valuation techniques for the environment*. Baltimore, Maryland: The Johns Hopkins University Press.

DUBGAARD A., KALLESØE M.F., PETERSEN M.L., LADENBURG J., 2002. *Cost-Benefit Analysis of the Skjern River Restoration Project*. Social Science Series (10). Department of Economics and Natural Resources. Royal Veterinary and Agricultural University. Copenhagen.

EC (1994). *Existing Strategic Environmental Assessment Methodology*. DHV (Environment and Infrastructures BV). European Commission – DGXI, Brussels.

Environment Agency (1997). River Habitat Survey, 1997 Field Survey Guidance Manual. Environment Agency.

Environment Agency (2003). River Habitat Survey in Britain and Ireland, Field Survey Guidance Manual 2003 version. Environment Agency.
.
European Community (2002). Guidance on Monitoring for the Water Framework Directive, Final Draft, 15 November 2002 *Water Framework Directive, Common Implementation Strategy, Working Group 2.7 Monitoring.*

Eisel L., and J. Gaudett (1974), 'Comments on 'An Environmental Evaluation System for Water Resources Planning' by N. Dee et al.' *Water Resources Research*, V.10(2).

Elliott M. (1981), 'Pulling the pieces together: amalgamation in Environmental Impact Assessment' *Environmental Impact Assessment Review*, V.2(1).

Goicoechea,A., D.R. Hansen, and L. Duckstein (1982). Multiobjective Decision Analysis, Wiley: New York.

Karr, J. R. (1993a). Measuring biological integrity: lessons from streams. pp.83-104, IN: S. Woodley, J. Kay and G. Francis (eds.) Ecological integrity and the management of ecosystems. St. Lucie Press, Delray Beach, Florida.

Karr, J. R. (1993b). Defining and assessing ecological integrity: beyond water quality. Environmental Toxicology and Chemistry 12:1521-1531.

[12] Similar examples have already been implemented for instance in Francia (Agence del'eau, 1998) and Germany (Landesamt für Wasserwirtschaft, 1999).

Karr, J.R. and E.W. Chu. (1995). Ecological integrity: Reclaiming lost connections. pp. 34-48. In L. Westra and J. Lemons (eds). Perspectives on Ecological Integrity. Kluwer Academic. Dordrecht, Netherlands.

Karr, J. R. and D. R. Dudley (1981). Ecological perspective on water quality goals. Environmental Management 5:55-68.

Keeney, R. (1992), *Value Focused Thinking* (Harvard University Press, Cambridge, Massachusetts).

Keeney R., and H. Raiffa (1976), *Decisions with Multiple objectives: preferences and value tradeoffs* (Wiley, N.Y).

Landesamt für Wasserwirtschaft (1999). Aktion Blau. Rheinland-Pfalz, Mainz.

Munné A. and N. Prat (2003). Characterization of the river basin according to the WFD. The Catalan Basins a case of small Mediterranean water district. Catalan Water Agency. EPRO, *Steiermark Regional Office (Brussels) (4th June 2003).*

Nardini A. (1997). "A proposal for integrating EIA, CBA and MCA in decision making". *Project Appraisal*, Vo.12, n.3, Sept. 97.

Nardini A. (1998). Improving decision making for land use management: key ideas for an integrated approach built on a MCA based negotiation forum. In Multicriteria Evaluation in Land-use Management: Methodologies and Case Studies. Eds. E. Beinat and P. Nijkamp, Kluwer Academic Press (1998).

Nardini A. (2004) "A Systematic Approach to Build Evaluation Indices for Environmental Decision Making with Active Public Involvement ". *Rivista di Economia delle fonti di Energia e dell'Ambiente* , Anno XLVI – N.1-2/2003, pp.189-215 (IEFE, Bocconi, Milano) (in English)

Nijkamp P. and E. Beinat Eds. (1998). Multicriteria Evaluation in Land-use Management: Methodologies and Case Studies. Kluwer Academic Press (1998).

Partidário, M.R. and R. Clark, Eds. (2000). *Perspectives on Strategic Environmental Assessment,* Boca Raton, FL.: CRC-Lewis.

Raven P.J., Fox P.J.A., Everard M., Holmes N.T.H., and Dawson F.H. (1997). River Habitat Survey: a new system for classyfing rivers according to their habitat quality. In Boon P.J. and Howell D.L. (Eds), *Freshwater quality: Defining the indefinable?*, The Stationary Office, Edinburgh, 215-234.

Raven P.J., Holmes N.T.H., Dawson F.H., and Everard M. (1998a). Quality assessment using River Habitat Survey data. Aquatic Conservation - Marine and Freshwater Ecosystems, 8: 477-499.

Raven P.J., Holmes N.T.H., Dawson F.H., Fox P.J.A., Everard M. Fozzard I.R., and Rouen K.J. (1998b). *River Habitat Quality: the character of freshwater streams and rivers in the U.K. and the Isle of Man*. Report No.2. Environment Agency.

Siligardi M., Bernabei S., Cappelletti C., Chierici E., Ciutti F., Egaddi F., Franceschini A., Maialini B., Mancini L., Minciardi M.R., Monauni C., Rossi G.L., Sansoni G., Spaggiari R., & Zanetti M. (2000). I.F.F. Indice di Funzionalitá Fluviale. Manuale ANPA/2000, 221 pp (in Italian).