AN ECOLOGICAL DECISION TOOL FOR NEW SMALL HYDROELECTRIC PLANTS ON ALPINE RIVERS AND STREAMS IN TRENTINO, ITALY

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In the over the past few years as well as foreseen in the future, there is a constant increase of electricity demand. This is leading to new constructions of hydroelectric plants especially of small dimensions (20-3000 kW) built on low order (and therefore more fragile) Alpine streams.

The aim of this paper is to describe the ecological evaluation process applied in Trentino in order to grant new plan construction permission. This methodology uses the results of Fluvial Functioning Index the Italian fluvial functionality index applied to the stretch of the river on which a small hydroelectric plant is planned.

The Fluvial Functional Index (FFI) is a method that allows the collection of information about the main ecological characteristics of watercourses, and is able to find functional aspects and interrelations between eco-topes. Through the description of morphological, structural and biotic parameters of the fluvial ecosystem, it is possible to determine the associated functionality of the river. The construction request is rejected if:

1. *the stretch interested by the construction of the new plant has a mean score in high functionality level, or*
2. *at least 70% of the stretch is in high functionality level, or*
3. *at least 500 meters of the stretch on which the new plant is due to be constructed reaches a high functionality level.*

In this way the Provincial Government of Trento (Italy) has been able to control the great number of requests of new small hydroelectric plants and to protect the Alpine watercourses with highest ecological value.

Keywords: river ecology, hydroelectric plants, water management.

1. Introduction

Mountains supply the European continent with much of its freshwater resources. They intercept water from air masses and store it as snow or in lakes, glaciers and reservoirs before discharging it into the lowlands via some of Europe's major rivers (Danube, Rhine, Po, Tisza and Rhone). However, this vital water resource is threatened by a number of factors. Most alpine rivers have been canalized, deepened, dammed or straightened to control floods, provide hydroelectricity and create or protect farmland in the valleys. Destabilising the

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natural processes has led to unexpected decreases in groundwater levels, drying out of agricultural land, unpredictable floods, mud slides etc.

In the Province of Trento, there have been many requests and the public administration needs a tool to decide whether new hydropower plants are compatible with the impact on the stream ecosystem and with the provisions of the Water Framework Directive 2000/60/CE. The Provincial Agency for Environmental Protection of Trento has developed a methodology based on the Fluvial Functioning Index (F.F.I.) which allows a quick and effective appraisal of the impact of new small hydropower plants (20-3000 kW) on the river environment and of the problems of ecosystemic stability, ecological functioning ability and self-purification capacity of the aquatic environment.

It can be determined in a relatively short period whether the river stretch affected by the new construction is ecologically compatible [1-2]. Following this appraisal, an ongoing and comprehensive environmental impact assessment of the new construction is required by law.

2. The Fluvial Functioning Index (the FFI): the principles

The objectives of the F.F.I. [3] is the evaluation of the whole river ecosystem with particular attention to its functionality in terms of retention and cycling capacity of the fine and coarse particulate organic matter (short FPOM and CPOM) [4], of buffer potential of the riparian ecotones [5] as well as of morphological structure able to support and sustain well diversified and stable biological communities [6]. Secondary objectives but not less important are the F.F.I. results which can be used in order to plan, forecast and verify the policy and strategy applicable for the river and land management. Through the description of morphological, hydraulic and biological parameters interpreted in the light of the principles of the river ecology, it is evaluated the associated functionality. The integrated reading of the riverine environment is able to define its comprehensive functionality. It must be underlined that the F.F.I. does not want to substitute the existing river quality evaluation methods but it is another tool which can be useful in order to support an integrated strategy fro river protection, management and restoration.

2.1. The field activity: the F.F.I. questionnaire

The F.F.I. should be applied to the whole river starting from the mouth to the source. Before starting to apply the method in the field it is important to gather information regarding the major pressures in the catchment, data about the hydrological regime and biological and chemical analysis, and aerial pictures and maps in order to have a better understanding of the threats and strengths of the area under evaluation.

The river should then be divided in “homogeneous” stretches –this being stretches which have no variation in terms of functionality. The river is provisionally split into stretches based on the information described above and a field survey. This initial split is confirmed (verified) during the application of the full method which normally involves covering the whole length of the river on foot, where physically possible. The river stretches range between a few tens of meters to some kilometres.

For each stretch a F.F.I. form, which is divided into 14 questions (table 1), is filled in There are 4 possible responses to each question and for each answer there is a fixed score. There is a progression apparent in the sequence of the questions. The first four concern bank vegetation, the extent of the riparian area and the land use pressure. The next two questions refer to the physical and morphological structure of the banks, due to the importance of the role that these have for the conservation of the river shape. Questions 7 to 11 are about the structure of the river bed, identifying the features related to the capacity of the river for self-purification (being self-sustaining). The last three questions evaluate some key biological characteristics of the river ecosystem: periphyton, macrophytes and macrobenthos, and the state of the coarse particulate organic matter. This, normally called CPOM, is considered to be the energy input contributing to the trophic web of the ecosystem [7]. The fact that there only three questions reserved for biotic aspects should not be taken as an underestimate of its importance, but rather as the balancing of the information contributing towards the assessment of the quality of the whole aquatic ecosystem and its surroundings.

Table 1

Summary of the issues investigated applying the FFI method

The FFI question: a whole river ecosystem approach	
1. Land use of the surrounding area	2. Vegetation of primary perifluvial fluvial (zone along the watercourse)
3. Extention of the perifluvial vegetation zone	4. Continuity of the perifluvial vegetation zone
5. Water conditions of the river bed	6. Stream bank structure
7. Retention structures of trophic matter	8. Erosion
9. Stream bottom	10. Cross-section shape
11. Riffles, pools or meanders	12. Vegetation in the wet river bed
13. Coarse organic particulate matter	14. Macrobenthonic community

2.2. The calculation of the functionality levels

The sum of the score of the single answers gives the final evaluation of the functionality of the right and left side of the river stretch, as the structure and the riparian formation type may change in the two watercourse banks. This total score represents the FFI value, which can vary from 18 (the minimum) to 300 (the maximum value), each represented in map form by a specific colour. These categories are summarised in table 2.

Table 2

Functionality levels divided in different categories

F.F.I. Value	Functionality level	Functionality evaluation	Colour
261 – 300	I	High	**Blue**
251 – 260	I-II	high – good	**Blue-green strips**
201 – 250	II	Good	**Green**
181 – 200	II-III	Good – moderate	**Green – yellow**
121 – 180	III	Moderate	**Yellow**
101 - 120	III – IV	Moderate – scarce	**Yellow – orange**
61 – 100	IV	Scarce	**Orange**
51 – 60	IV – V	Scarce – bad	**Orange – red**
14 – 50	V	Bad	**Red**

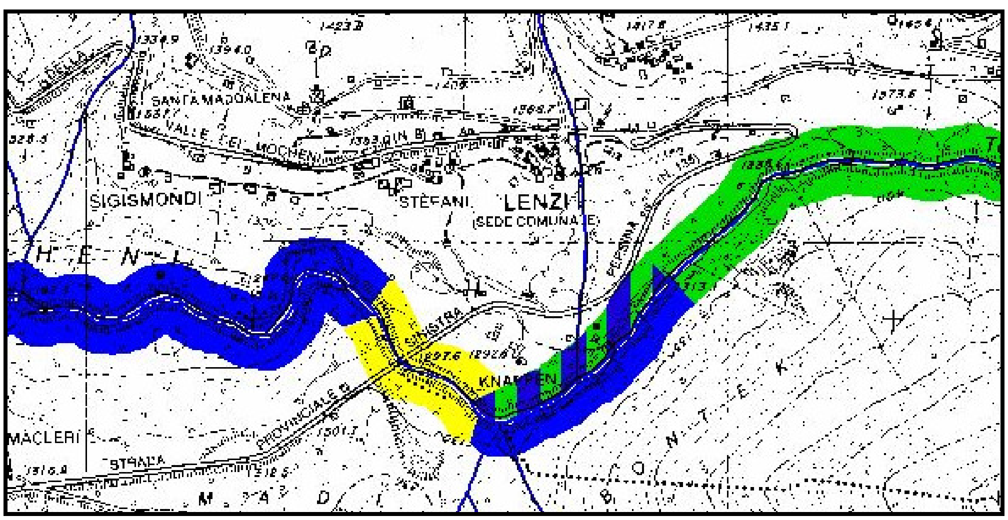

Fig. 2. An example of map with the F.F.I functionality level expressed with different coloured stretches.

The results of the F.F.I. Method can be directly displayed on maps using a GIS software. For each river stretch, two lines are drawn corresponding the left and the right bank and representing the functionality levels according to table 1. In this way the river is mapped completely as shown in figure 2. The maps are produced with a scale which is normally either 1:10.000 or 1:25.000 for a detailed perspective, and a 1:100.000 scale for a overall representation.

Of course along with the F.F.I. information, there are other maps that can be shown illustrating other aspects such other monitoring results or major pressures. These are normally in a report which accompanies the maps. The report explains and describes the functionality of the river underlining which are the ecological compounds that should be improved or preserved.

3. The Fluvial Functioning Index as decision tool for new hydropower plant

The Autonomous Province of Trento (Italy) has approved a regulation that obliges all applicants for authorisation to exploit watercourses for hydropower purposes to apply the FFI (Fluvial Functioning Index). The results of this application will be used as preliminary screening to decide whether a new project is acceptable or not. Rejected applications cannot be resubmitted, whereas those accepted must then be subjected to EIA (environmental impact assessment).

This approach consists of 3 different ways of processing the FFI data, which in turn determine criteria of different degrees of acceptability, namely:

1) Combined model: the hydropower plant authorisation can be granted if the FFI score per kilometre of the river stretch (streach value: SV) effected by the new construction (upstream the off take canal and downstream the discharge area) is more that a "ideal" FFI (reference value: RVscore) calculated to the minimum FFI score for this level (261 points) for the length considered, multiplied by the total length of watercourse considered, expressed in kilometres. This is summarised in the following equation:

$$SV = \sum_{i}^{n} S(\text{FFI})_i * L_i$$
$$RV = 261 * \sum_{i}^{n} L_i \qquad (1)$$

where:

SV = FFI score per kilometre

$S(\text{FFI})_i$ = FFI score per each "i" river streach

Li = length of the "i" river streach

RV = Reference Value

The “261” is the minimum FFI score for first (and the hightest) functionality level.

In order to define whether an application is acceptable or not, the streach value (SV) must be compared against the theoretical reference value (RV). In other terms:

if SV > RV the application is NOT ACCEPTABLE

if SV < RV the application is ACCEPTABLE

If the plant project is deemed acceptable by the *combined model*, the application may still not be deemed acceptable in case of failing to meet any one of the following conditions:

2) Continuous functionality, in other terms, the length of watercourse attaining an FFI functionality rating of level 1 for both banks must simultaneously not exceed 500 metres;

3) Assessment percentage: the percentage of the length of watercourse with a functionality rating of level 1 must not be greater than 70% of the total length affected by canalisation.

A few applicative examples have been given as clarification.

Table 3

Example 1

length (km) of each river stretch	FFI score		mean FFI score of each river stretch	score*km	RV reference value
	right bank	left bank			
1,064	295	260	278	295,3	
1,281	255	240	248	317,0	
0,583	300	260	280	163,2	
0,361	164	182	173	62,5	
Total length 3,289 km				838	858
				SV	RV

In the case above (see Table 3):

SV = 838 RV = 3,289 * 261 = 858.

On the basis of this calculation the application for a new plant is deemed **acceptable** as the **SV** (stream value) is lower than the **RV** (reference value) (as it is described in the *combination model*).

In the case below (see Table 4):

SV= 964 RV = 3.787 * 261 = 988.

On the basis of the combined model, the application for a new plant is deemed **acceptable** as the **SV** value is lower than the **RV** value.

Table 4

Example 2

length (km) of each river stretch	FFI score		mean FFI score of each river stretch	score*km	RV reference value
	right bank	left bank			
1,383	241	221	231	319,5	
0,575	246	241	244	140,0	
0,274	280	280	280	76,7	
0,734	300	295	298	218,4	
0,295	266	231	249	73,3	
0,095	227	270	249	23,6	
0,431	250	270	260	112,1	
Total length 3,787 km				964	988
				SV	RV

The limiting condition "2" (*continuous functionality)* also permits **acceptability** as the stretch of watercourse with a high functionality rating for both banks (in green) is less than 70% of the entire length of watercourse subject to canalisation.

The limiting condition "3" (*assessment percentage)* however, **does not permit acceptability** as the stretches of watercourse with high fluvial function ratings on both banks exceed the specified limit for continuous functionality (500 metres). In this case, the total length of watercourse with a functionality rating of 1 is 1008 metres, given by the sum of two sections measuring 274 and 734 metres respectively.

4. Conclusions

Following the experience gained in Italy as well as the participation European research project [8] it has been demonstrated that the F.F.I. method can be a useful tool in order to support an appropriate river basin management.

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