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ΘΕΣΣΑΛΟΝΙΚΗ

ARISTOTLE UNIVERSITY
SCHOOL OF BIOLOGY
DEPARTMENT OF
ZOOLOGY
THESSALONIKI-GREECE

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Study of the impacts of the works on Pinios River (Thessaly, Greece)

Pinios River, August 2004

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SUMMARY

The Pinios River :

Pinios River is located in Thessaly (Greece), and its basin was chosen to implement the Pinios Pilot River Basin Project, of which objective is to identify the technical and management problems generated by the implementation of the EU Water Framework Directive 2000/60/EC in Greece.

The Pinios Pilot River Basin Project requires identifying the pressures and impacts on hydrosystems, in order to find a response to these problems and develop solutions for an integrated water resources management. Thus the study of the impacts induced by the works on Pinios River takes part in the Pinios Project, with trying to find a way of studying and quantifying the river ecosystem perturbations.

Materials and methods :

A protocol was set up on the occasion of the study of the impacts provoke by the works on Pinios River and applied for a survey of Pinios River. The first step of the protocol is the assessment of river ecosystem parameters : water physicochemical parameters, hydrodynamics, geomorphodynamic parameters, and aquatic vegetation. The second step is the data providing about the works studied. In addition to this protocol, two indexes were used to study the instream and riparian habitat quality.

Results and discussion :

A way to study the data collected during the field work had to be found. In this aim, a scoring of hydrodynamics parameters and a ratio calculation of water quality and geomorphology were established. They both permit to create a five-class range, to express which level of disturbance the works induce on the Pinios River ecosystem.

ABSTRACT

The Pinios River (216 km) is located in the central section of mainland Greece, in the Thessaly Water Region. Its river basin takes place a land area submitted to high anthropic pressures. Thus many works are built on the river. In order to determine which impacts these works induced on the different river ecosystem parameters, a study was established. The first step of this study was the creation of a river survey protocol, to provide data concerning river environment components : water quality, geomorphology, hydrodynamics. The next step was the setting up of a method to quantify the impacts from the collected data, in order to obtain a five-class range of the perturbation level induced by the works on the river ecosystem.

Keywords : Pinios River, impacts, works, survey protocol, perturbation level.

RESUME

La Rivière Pinios (216 km) est située dans la partie centrale de la Grèce continentale. Son bassin versant occupe une zone soumise à de fortes pressions anthropiques. Ainsi, de nombreux ouvrages sont construits sur la rivière. Afin de déterminer quels impacts ces ouvrages provoquent sur les différents paramètres de l'écosystème, une étude a été mise en place. La première étape de cette étude a été la création d'un protocole d'étude sur le terrain, pour recueillir des données concernant les composantes du milieu 'rivière' : qualité de l'eau, géomorphologie, hydrodynamique. L'étape suivante a consisté en l'établissement d'une méthode de quantification des impacts à partir des données recueillies, dans le but d'établir une gamme de cinq classes de niveau de perturbation provoqué par les ouvrages sur l'écosystème de la rivière.

Mots-clés : rivière Pinios, impacts, ouvrages, protocole d'étude, niveau de perturbation.

INTRODUCTION

This report is the result of the practical time I carried out from May till September 2004 at the Department of Zoology, in the Aristotle University, Thessaloniki, Greece. This practical time is an obliged part of my "Continental Hydrosystems Engineering in Europe" Diploma (DESS) at François Rabelais University, Tours, France.

The subject of my practice is : "Study of the impacts of the works on Pinios River". This study comes within the scope of the Pinios Pilot River Basin Project. The Departement of Zoology, at Aristotle University, was chosen to manage the study as it is one of the rare structures in Greece which study the hydrosystems with a biological approach.

This kind of study was never done before in the Department of Zoology; then the objective of my practice was to define how studying the impacts, and more exactly how providing data for this study and how using these data after.

The scope of this report can be divided in two aspects : firstly the protocol set up in the occasion of the study of the impacts; secondly the interpretation of the data collected according to this protocol.

The protocol setting up was divided in two parts. The first part consists of the creation of two forms, one for the assessment of the river ecosystem parameters and another for the works studied, in order to provide data for the study of the impacts of the works. The second part is the establishment of the procedure for preparing and realizing the field work, achieved for the study on Pinios River in August 2004.

The objective of the use of the data collected on Pinios River was to find a way to quantify the impacts of the works, in order to establish a five-class range of levels of river perturbation.

CHAPTER 1 : THE PINIOS RIVER

1.1. Pinios River and its basin

1.1.1. Location in Greece

Pinios River is located in the central section of mainland Greece, in the Thessaly (Thessalia) Water Region (figure 1).

The Thessaly Water Region is located in the EU Water Framework Directive Ecoregion 6 for rivers and lakes (Greek Western Balkans) and Ecoregion 6 for transitional and coastal waters (Mediterranean Sea).

The climate of the Thessaly Water Region is Mediterranean continental climate. The summers are hot and the winters cold (snowfall is very often in the mountains), and the temperature differential between the two seasons is large. The mean annual rainfall is 779 mm and the mean annual relative humidity is 67%-72%.

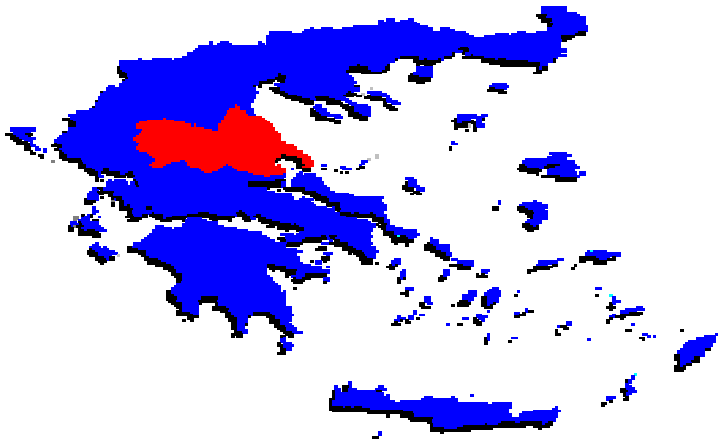

Figure 1 : Localisation of Thessaly Water Region (Ministry of Environment, Physical Planning and Public Works of Greece)

1.1.2. Hydrography, topography, geology

Pinios River rises in the Pindos Mountains and outflows in the Aegean Sea after 216 km (figure 2). Its main tributaries are Titarisios, Enipeas, Kalentzis and Litheos. The river flows on the western slopes of Pindos Mountains, crosses the alluvial basin of the Thessalic plain and eastwards the gorges of the Valley of Tempi, and discharges into the Aegean Sea. The mean annual discharge of the river is 3 500.10^6 m^3/s. Extreme hydrologic events as floods and droughts are common in the river basin area.

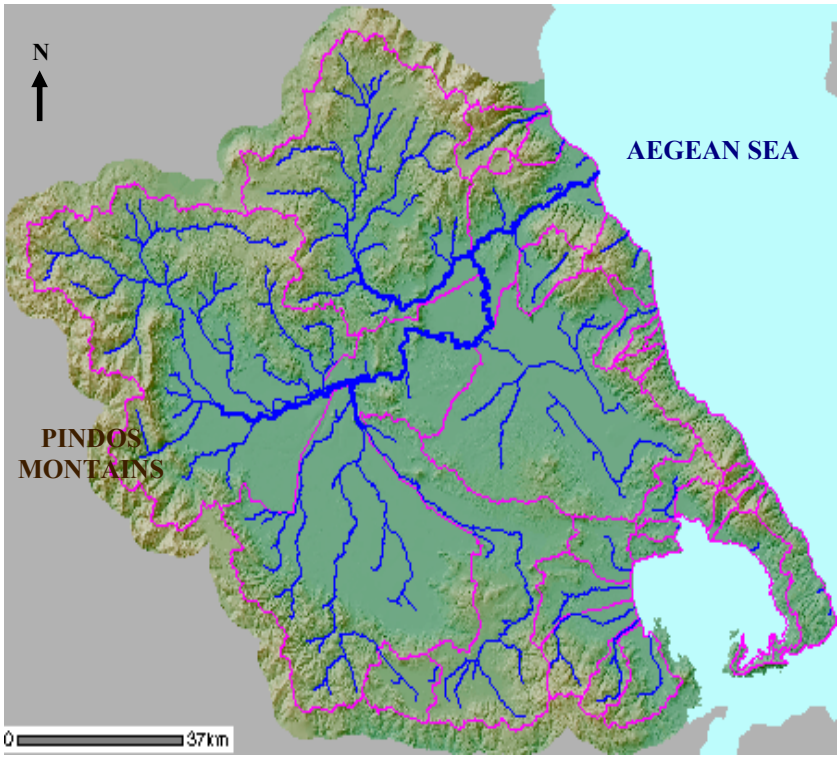

Figure 2 : Pinios River Basin – topography

(Ministry of Environment, Physical Planning and Public Works of Greece)

Legend :

Pinios River

tributaries of Pinios River

mountains

plain

sea

The surface area of Pinios River basin is 9 500 km^2, 10 550 km^2 with the drainage basin of the former Lake Karla.

The Lake Karla was located at the south-eastern side of Thessaly Water Region and occupied its lower depression plain. In 1962, the lake was drained mainly for agricultural purposes. But the drainage of the lake created bigger problems than the ones it was supposed to solve : the cultivation in a part of the former lake bed had mediocre results, the climate changed for the worse, chemical degradation of the soil was detected, and the hydrological regime was severely disturbed with considerable lowering of groundwater levels. Moreover, about 100 hm^3 of water was abstracted every year from Pinios River to comply with the irrigation demands in its area. At present a project for a partial restoration of the Lake Karla is in elaboration.

The total area of Pinios River basin is covered by 30,6 % of impermeable geological structures, 14,5 % of karstic aquifers and 42,7 % of permeable structures, which occur mainly on the plain. The Thessalic plain consists of aquiferous, essentially sand intercalations separated by stratums of clay or silty clay, and Neogene deposits of marls and conglomerates; and is bounded by schists and karstic limestones or marbles.

1.1.3. Land uses

The Pinios River basin includes a mountainous terrain with altitudes more than 2000 meters, agricultural plain (the Thessalic plain) and urban areas. The population in the river basin area is about 700 000 inhabitants. The major cities are Larissa and Volos (figure 3).

Pinios River basin is located in an area of intense agricultural activity. The region is not much industrialised; the main industries are food transformation and metal production. Breeding, fisheries and forestry are the other economic activities of the region. The coastal area is a destination for many tourists during summer, consequently the water supply requirements increase during this period.

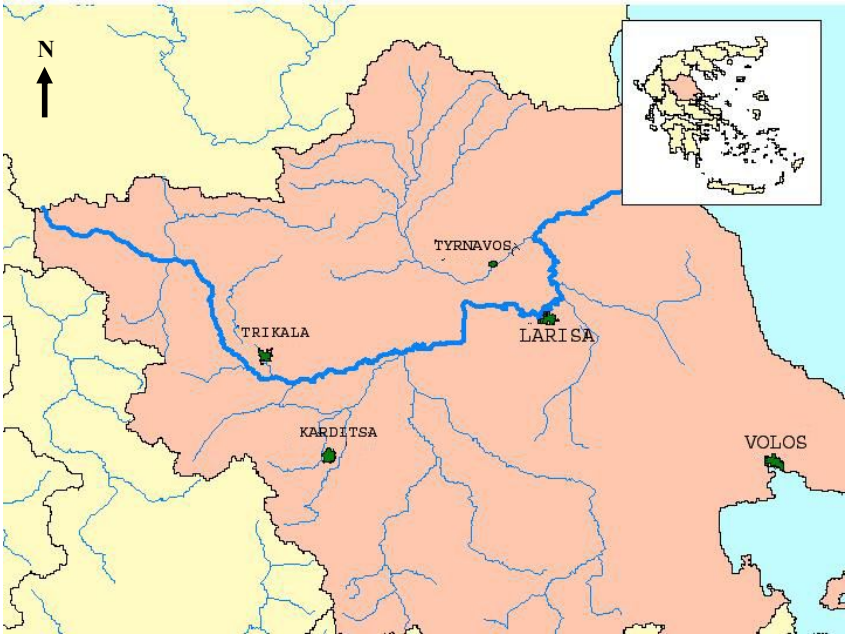

Figure 3 : Pinios River Basin – urban areas

Legend :

- Pinios River
- tributaries of Pinios River
- Pinios River basin
- urban centres

1.1.4. Water resources and uses

The total water availability in Pinios River basin area is about 3 209 hm^3, with 2 596 hm^3 from surface water and 613 hm^3 from groundwater.

The agricultural activities use about 96 % of the water supply for irrigation, which correspond to about 3,3 % of the total water consumption in the area; and cause significant

water quantity and quality problems. Cultivation, with application of nitrogen-containing fertilizers, and breeding are the cause of significant diffuse pollution.

Pollution in the watercourses is caused also by point sources like municipal waste water and industry. However the pollution loading from urban waste water, which is a major source of pollution in the area, has been reduced thanks to urban waste water treatment equipments, installed during the last decade in the major cities of Thessaly.

The water abstraction for irrigation and the intensive use of groundwater created problems of over-exploitation in some aquifers. Thus groundwater levels are strongly controlled by the exploitation of the resources during the summer irrigation period. Also saline water intrusion also occurs in parts of the aquifers near to the coastline, where the water levels are lower than the mean sea level.

Moreover, the aquatic environment is affected by drainage channels, water level and flow regulations for flood protection, and tourist infrastructures in the coastal area.

1.2. The Pinios Pilot River Basin Project

1.2.1. Initiative

The EU Water Framework Directive (2000/60/EC) (WFD) was transposed into the Greek national legislation in December 2003, with the Law 3199/9-12-2003 (OJG 280A/2003) on the “protection and the sustainable management of the water resources”.

This new framework Law introduces an innovative approach concerning water management with recognizing explicitly the ecological function of water. The Law also incorporates the “polluter pays principle” and the objective of maintaining or reaching a “good ecological status” for all water resources through control of pollution by use of thresholds levels and standards. It lays emphasis on management of water on river basin level, and introduces innovative approaches concerning protection of water quantity and cooperation on transnational level. Moreover the Law 3199/03 sets up water pricing so that it reflects its full costs.

Furthermore, the Law 3199/03 foresees a radical reorientation of the respective administrative capacities. According to the Law, Regional Water Directories and Councils, supervised by the National Water Agency, will be established for each one of the 13 River Basin District / Water Region of the country. Their role is the coordination of water policy activities and the implementation of specific Programmes of Measures and Action Plans for achieving the environmental objectives of the WFD for each River Basin District. Representation of interested parties in regional Water Councils ensures an active public involvement in the process.

1.2.2. Objectives

Within the framework Law 3199/03, the Pinios Pilot River Basin Project is being implemented. The overall aim of this project is to identify the technical and management problems that may come up in real cases of the WFD implementation in the country, in order to develop pragmatic solutions for their addressing, to test the practicability and efficiency of the technical and supporting Guidance Documents on key aspects of the WFD before they are applied in the country, to attain a concrete example of the application of these technical Guidance Documents, and to inform the interested parties on the implementation of the WFD. The project, tested in Pinios River basin, started in mid-2003 and is expected to run for 4 years, until the end of 2006. Once the project is completed, the results will be readily applicable to all other river basins in Greece.

The Hellenic Ministry for Environment, Physical Planning and Public Works and the Regional Directory of Planning and Development in Thessaly have jointly the role of promoting and implementing this project. At the beginning of July 2003, technical assistance will be provided (after the completion of a competition procedure) in order to ensure the successful implementation of the Pinios Pilot River Basin Project.

The project will be supervised by a Steering Committee formed with representatives from local authorities within the Pinios River Basin District, regional and national authorities. The role of this Committee will be to oversee and advise on the development of the Pinios Pilot River Basin Project testing and the implementation of works necessary for the execution of the project.

Public consultation and participation by local stakeholders and NGOs are seen as essential requirements for the successful implementation of the project. Thus active involvement of all stakeholders during the project implementation is guaranteed through the establishment of a working group with the participation of all local and regional authorities, NGOs, educational institutes, scientists, the Greek Biotope-Wetland Centre, WWF, MedWet (Mediterranean Wetlands Program), regional agricultural administrations, etc.

During the first phase of the WFD implementation in Greece, the main problems encountered were related to compatibility issues with the administrations and a lack of information and data, especially for biological quality elements. Nevertheless, the implementation of Law 3199/03, the establishment of new operational monitoring networks and, most importantly, the implementation of Pinios Pilot River Basin Project will permit to identify problems and develop sustainable solutions (United Nations Environment Program, 2004). Studying the impacts induced by the works on the Pinios River comes within the scope of the Pinios Pilot River Basin Project.

CHAPTER 2 : MATERIALS AND METHODS

2.1. Objective of the study

The Pinios Pilot River Basin Project requires identifying the pressures and impacts on freshwater ecosystems, in order to response to these problems and develop solutions for an integrated water resources management. The study of the impacts of the works on Pinios River is a part of this project.

An **impact** is "a change in the chemical, physical (including habitat) or biological quality or condition of a waterbody caused by external sources" (US Environmental Protection Agency). Then an impact is the environmental effect induced by an anthropogenic activity on the river ecosystem parameters.

The objective of this study is to determine the impacts of the works, what means how and how much the works perturb the river ecosystem. In this aim, two kinds of survey were achieved on the Pinios River :

- Measurements and estimations of parameters for water chemistry, flow disturbance, channel and banks geomorphology, and aquatic vegetation, according to the protocol established on the occasion of this study;
- Assessment of the fluvial habitat using the Fluvial Habitat Index (IHF), and of the riparian habitat with the Riparian Habitat Quality index (QBR).

2.2. Protocol set-up

2.2.1. Why creating a protocol ?

Pinios River was surveyed in 2003 with the River Habitat Survey (RHS) (RHS form in appendix 1, part 1). RHS is a method established by the Environment Agency of United Kingdom, and designed to characterise and assess the physical structure of freshwater streams

and rivers. For the Pinios River assessment, 350 sites were surveyed. The sites were referenced with a letter and a number :

- P for Pinios river
- number according to the distance of the site from the sea, with 1 unit = 500 meters. For example, the site P001 is located at 500 meters from the sea, the site P002 at 1000 meters, the site P003 at 1500 meters, etc…

The objective of River Habitat Survey is to study the habitat quality of the river, according to a Habitat Quality Assessment scoring system (appendix 1, part 2), and the modifications of the habitat, with a Habitat Modification Score (appendix 1, part 2). The Habitat Modification Score counts the presence of the works located in the channel, but doesn't detail the impacts that the works create on the river ecosystem.

Therefore, the establishment of a protocol to study the impacts of the works responds to the necessity of providing enough detailed data to determine which modifications of the river ecosystem are induced by the work.

The protocol was created as detailed as possible, because the way of studying the results to determine the impacts of the works was not defined when the protocol was setting up.

2.2.2. Protocol forms

Two protocol forms were created :

- an 'Impacts Form', to survey different parameters of the river ecosystem and provide data for the study of the impacts;
- a 'Work Form', to collect information about the works studied.

These two forms are presented in the following pages; they are detailed in paragraph 2.3 for the general data, paragraph 2.4 for the assessment of river ecosystem parameters, and paragraph 2.5 for the assessment of the works.

The protocol was used for the first time during the field work achieved on Pinios River from 6th to 13th August 2004, in the context of this study.

FIELD SURVEY DETAILS

River : …….....

Site reference : …… Site coordinates : …….…….....

Work reference : …… Altitude : ……..

Site location : upstream the work □ downstream the work □ ……. / ……. / ……. meters

Date : …..…../……...../20……. Time : …….

Surveyor(s) name(s) : ……...……..…

Adverse conditions affecting survey ? no □ yes □ if yes, state : ……..……...……...……

Atmospheric pressure : ……..….. mm Hg

WATER QUALITY

	I	II	III
water temperature (°C)			
dissolved oxygen (mg/L)			
dissolved oxygen (%)			
pH			
pH (mV)			
redox (mV)			
conductivity (mS/cm)			
TDS (g/L)			
salinity (ppt)			
turbidity (NTU)			
chlorophyll (µg/L)			
Cl^- (mg/L)			
NO_3^- (mg/L)			
NH_4^+ (mg/L)			
NH_3 (mg/L)			

HYDRODYNAMICS

Hydrological data : method used : flow meter □ estimated (floating object) □

	I	II	III
velocity (m/s)			

Flow disturbance :

Reduction of channel capacity : none □ partial □ complete □

Work established to block the flow ? no □ yes □ periodical flow lack ? no □ yes □

Jammings ? no □ yes □

if yes, percent of water width with jammings : ……. %

large woody debris □ other vegetal debris □ rubbish □

Migration barrier for fishes ? no □ yes □ …… meters

if yes, □ no structure for migration

□ structure for migration : ……..……... functional □ not functional □

GEOMORPHODYNAMICS

CHANNEL FEATURES

	I	II	III
bankfull width (m)			
water width (m)			
water depth (m)			

Channel type :

single thread □ side channel(s) □ number of sub-channels : ..… braided channel □

Channel sinuosity :

straight □ slightly sinuous □ moderately sinuous □ meandering □

Channel gradient :

	I-III	IIu-IId
channel slope (%)		
channel slope (degrees)		

Morphology types : proportion of the reach

pools : .....% riffles : .....% runs : ……... %

Sediment deposition : percent of riverbed width

	I	II	III
mature island(s)			
mid-channel bar(s)			
side bar(s)			
point bar(s)			

Channel modifications : (date of the last intervention)

not modified □

dredging □ …../…../……. widening, deepening □ …../…../…….

realigning, straightening □ …../…../……. bed reinforcement □ …../…../…….

IMPACTS FORM - Page 3 of 4

Channel substrate : sediment size distribution : percent of the channel bed substrate

	I	II	III
bedrock			
boulders (≥ 256 mm)			
cobbles (64-256 mm)			
pebbles (16-64 mm)			
gravels (2-16 mm)			
sand (0.06-2 mm)			
silt (0.004-0.06 mm)			
clay (≤ 0.004 mm)			
artificial material			

Embeddedness rating : percent of gravel, cobble and boulder particles surface covered by fine sediment : rating : 5 = 0-5% 4 = 5-25 % 3 = 25-50 % 2 = 50-75 % 1 = 75-100 %

	I	II	III
embeddedness rating			

BANKS FEATURES

	I		II		III	
	left bank	right bank	left bank	right bank	left bank	right bank
bankfull height (m)						
banktop height (m)						

Bank stability : percent of the bank

	I		II		III	
	left bank	right bank	left bank	right bank	left bank	right bank
bank erosion						
bank vegetative cover						

Bank modifications : percent of the bank

	I		II		III	
	left bank	right bank	left bank	right bank	left bank	right bank
unmodified						
resectioned (reprofiled)						
reinforced						
embanked						
height of embankment (m)						
distance embankment-channel (m)						

IMPACTS FORM - Page 4 of 4

Bank material : percent of the bank substrate

	I		II		III	
	left bank	right bank	left bank	right bank	left bank	right bank
bedrock						
boulder						
cobble / pebble						
gravel / sand						
earth						
sticky clay						
concrete						
sheet pilling						
wood pilling						
gabion						
brick / laid stone						
rip-rap						
tipped debris						
fabric						
bio-engineering material						

AQUATIC VEGETATION

portion of the transect with aquatic vegetation (%) (if known, indicate dominant species present)

	I	II	III
rooted emergent			
rooted submerged			
rooted floating			
free floating			
floating algae			
attached algae			

WORK FORM

FIELD SURVEY DETAILS

River : …….....

Site reference : ……..…… Site coordinates : …….……..…….....

Work reference : …… Altitude : ……..

Date : …..... /...../20…... Time : …..…….

Surveyor(s) name(s) : ……...…..……

Adverse conditions affecting survey ? no □ yes □ if yes, state : ……..……...……

DESCRIPTION OF THE WORK

Nature of the work : ……..……

Objective of the work :

□ Constructive work

□ Flood protection

□ Erosion control, bank stabilization

□ Irrigation : intake capacity :……. m^3/s

□ Material extraction

□ Others (shipping, leisure activities...) : ……..

Location : channel □ left bank □ right bank □

Photograph(s) : no □ yes □ if yes, references : ……...

Type of work :

Work permanent □ temporal □

Material used : ……..……..…… civil engineering □ bioengineering □

Dimensions of the work : length : …… m width : …… m height : …… m

Status of the work : out of service □ functioning □ maintained □ damaged □

Authority materializing the work : (name)……...……..

public authority : european □ national □ regional □ local □

private company □ users □ illegal work □

Date of establishment : …..../…..../…..…..

2.3. General procedure

2.3.1. Selection of the sampling sites

2.3.1.1. Study areas

For the RHS assessment, the river was divided in 6 areas, according to the morphology, the geology, and the vegetation characteristics. These areas were used again for the study of the impacts.

The area 1 (sites P001 to P026) is located downstream the river delta, in a gentle-sloped land. The main land use is cultivation. Riparian vegetation is present along the river. The river discharge remains a sufficient level during summer.

The area 2 (sites P027 to P040) is the gorges of Tempi. It is a natural protected area, with a status of Natural Park. The geology is diverse and the slope is rough. The river channel may dry out during summer.

The area 3 (P041 to P066) is an agricultural area, without riparian vegetation along the river. Waste from the industrial area of Larissa causes water pollution. During summer, the river may have no flow due to irrigation.

In the area 4 (sites P067 to P085), the land is exploited by non-intensive agricultural activities (like pasture) and riparian vegetation is present. The topography is characterised by a steep slope and a bit of gorges. During summer the river channel may be dry out.

The areas 5 (sites P086 to P206) and 6 (sites P207 to 350) have a gentle slope. They are agricultural areas with urban centres. There is riparian vegetation along the river, and the channel may have no flow during summer due to irrigation.

2.3.1.2. Selection of the sampling sites

Studying the impacts of the works necessitated to find a reference with which comparing the sites where a work is located, in order to determine to which extent the works create changes in the river ecosystem. For this purpose, one ‘reference site’ was selected for each study area.

A **reference site** is “a specific locality on a waterbody which is unimpaired or minimally impaired and is representative of the expected biological integrity of other localities on the same waterbody or nearby waterbodies” (US Environmental Protection Agency). Thus, the sites chosen to be reference sites have no modification of the channel and the banks, and are not affected by an impoundment of the water created by a dam, according to the RHS data. However, because of the difficulties for having access to the river, the reference site selected for area 2 was a site with a reprofiled left bank.

To study the impacts of the works, each kind of work listed in the RHS was investigated. Five kinds of works were studied : bridges, fords, weirs and dams, sand extraction, and pump for water abstraction. Two sites were selected for each kind of work in each area (only one was surveyed), in case a site should be inaccessible or a work should have been destroyed. Furthermore each selected work should be enough away from others works, to avoid the impacts of a work adding to other ones.

On the whole 17 sites with works were selected for the study.

2.3.1.3. Sampling reach and measurement points

A **reach** is a sampling unit for collecting data : it represents a length of fifty meters of the stream. Each reference site constitutes one reach; the sites with a work are divided in two reaches, one upstream the work and one downstream. So the upstream and downstream of the work can be compared with the reference site.

In every reach 3 **measurement points** are set (figure 4) :

- for the reference sites, the first point is located where the coordinates of the site are measured, the second and third points are respectively at 25 and 50 meters from the first point.
- for the sites with a work, the first point is located at 1 meter from the work, the second and the third at 25 meters and 50 meters from the first point. So each site has 6 measurement points : 3 upstream the work and 3 downstream.

The measurement points are located on the same bank for the whole site. They will permit to study the extent of the impacts along the river stream.

The parameters based on an observation of the latitudinal profile of the river are measured on **transects** with a width of 2 meters. Transects are transverse lines perpendicular to the water flow; they are definite with standing on every measurement point and looking at the opposite bank (figure 4).

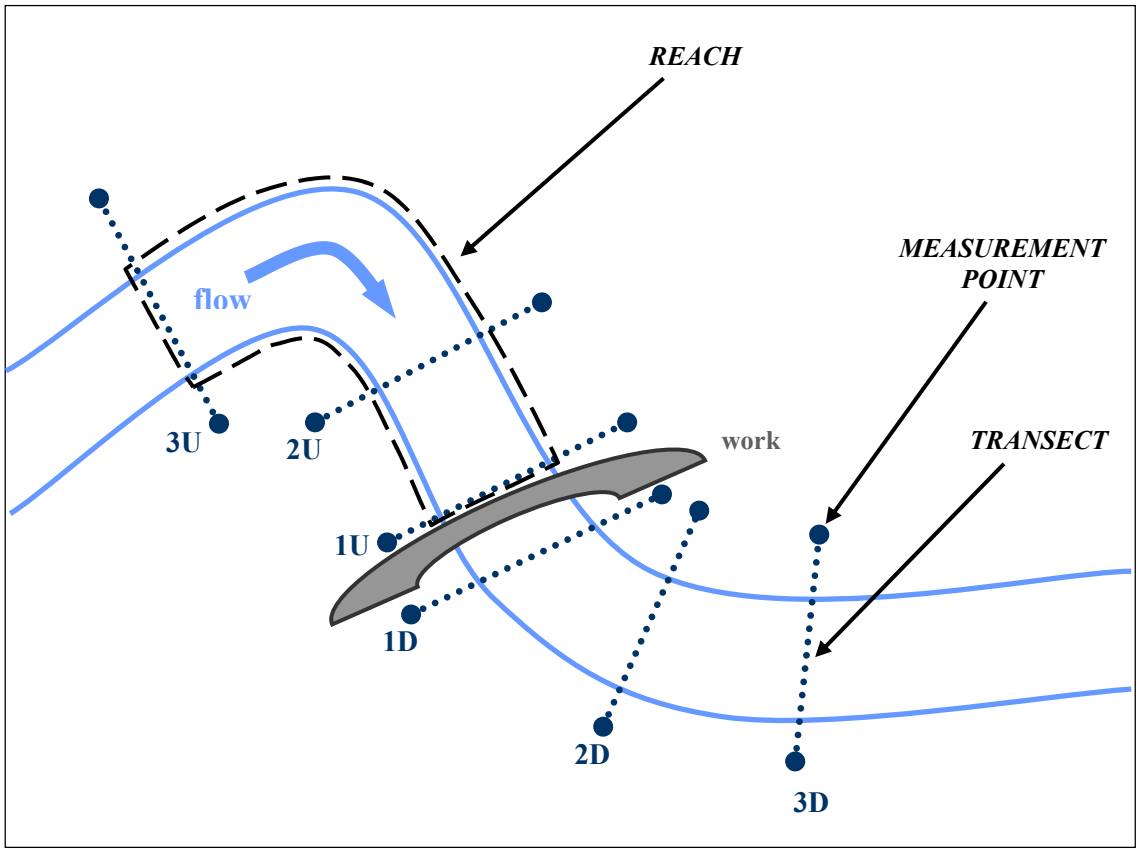

Figure 4 : Location of the measurement points and transects in a reach

2.3.2. General data : field survey details

The first step in the protocol is to detail the survey site and the sampling conditions. This information has to be filled up in both Impacts Form and Work Form.

The requested details about the site are :

- River name
- Site reference : the references used for the survey on Pinios River are the RHS sites references.
- Work reference : in case of there are several works studied on the same site.
- Site coordinates and altitude : they are measured on or nearest the work, or on the first measurement point for reference sites. A GPS Garmin 76S was used to measure these parameters during the survey.
- Site location : it specifies if the survey is made upstream or downstream the work, and at which distance from the work are the measurement points (in case of the measurement points cannot be located at 1 meter, 25 meters and 50 meters from the work as it is advised, or if three measurements cannot be made).

The details concerning the survey work are :

- Date and time of the survey
- Surveyor(s) name(s)
- Are adverse conditions affecting the survey (if yes, state) : the weather conditions can affect both the accuracy of the survey results and above all the safety.
- Atmospheric pressure (in milli-inches of mercury mm Hg) : it was measured at the same time as the physicochemical parameters, using a sonde YSI 650.

2.4. River survey : assessment of the river ecosystem parameters

The objective of the river survey is to determine the impacts induced by the works on the river ecosystem. In this aim, the physical and biological components of the river habitat have to be studied :

- water physicochemical parameters
- hydrodynamics
- geomorphodynamic processes
- aquatic vegetation

2.4.1. Water quality : physicochemical parameters

Physicochemical parameters were measured in situ, on the 3 measurement points for each reach (results in appendix 2), with a sonde Multiparameter Display System YSI 650 (the details concerning the physicochemical parameters are provided by the manual of the sonde YSI) :

- Water temperature (in degrees Celsius °C)
- Dissolved oxygen : is the oxygen dissolved in water and available for living organisms to use for respiration. The dissolved oxygen was measured in concentration dissolved oxygen (in milligrams per litre mg/L) and percent saturation dissolved oxygen (in percentage %)
- pH : two values were provided concerning pH : the pH in standard units, a numerical measure which indicate the alkalinity or the acidity of the water; and the millivolts associated with the pH reading.

The relationship between pH and the millivolts output is calculated by the software of the sonde, as it is defined by a variation of Nernst equation : $E = E_0 + (2.3\ RT / n\ F)*pH$

where E is the millivolts output

E_0 is a constant associated with the reference electrode

T is the temperature of measurement in degrees Kelvin

R, n, F are invariant variables (constants)

- Oxydation reduction potential, shortened redox or ORP (in millivolts mV)
- Conductivity (in milliSiemens per centimetre mS/cm) : is the measure of the ionic strength or concentration in water.
- Total dissolved solids, shortened TDS (in grams per litre g/L) : the electrical conductivity of environmental water is due to presence of dissolved ionic species.
- Salinity (in parts per thousand ppt)
- Turbidity (in nephelometric turbidity units NTU) : is the measurement of the content of suspended solids (cloudiness) in water, and is indicating the presence of some suspended sediments, dissolved solids, natural or man-made chemicals, algae, etc.
- Chlorophyll (in micrograms per litre µg/L) : is bound within the living cells of algae, phytoplankton, and other plant matter found in environmental water. It is a key biochemical

component in the molecular apparatus that is responsible for photosynthesis, the process in which the energy from sunlight is used to produce life-sustaining oxygen.

- Chloride Cl^- (in milligrams per litre mg/L)
- Nitrate NO_3^- (in milligrams per litre mg/L)
- Ammonium NH_4^+ (in milligrams per litre mg/L)
- Ammonia NH_3 (in milligrams per litre mg/L)

2.4.2. Hydrodynamics : flow disturbance

To define if the work creates an impact on the river flow, several characteristics have to be studied for both reaches upstream and downstream the work (results in appendix 3) :

- Flow velocity (in meters per second m/s), measured on the 3 transects (specify the method used : flow meter or estimation with a floating object).

A velocity slowing down can point out an impoundment of the water created by the work.
The velocity was not measured for this study.

- Reduction of channel capacity (condition at the time of the survey) : is the surface of the water, on the river latitudinal profile, partially or totally blocked by the work location in the river, or by jammings appeared because of the work ?

- Is the work established to block the flow ?

- Is the work creating a periodical flow lack ? (condition at the time of the survey)

- Are jammings formed because of the work location in the river ? Jammings are accumulation of coarse materials (e.g. trees, branches, waste) which block the flow.

If jammings are present, specify the percent of water width with jammings, and the nature of the jammings :

- large woody debris : woody debris in contact with stream water with a length above 3 meters and a diameter more than 30 centimetres (Ecomorphological Survey of Large Rivers, 2002).
- other vegetal debris (smaller than large woody debris)
- rubbish

- Is the work a migration barrier for fishes ? The work stops the free migration of fishes if it creates a water level difference (like dams and weirs do).

If the work is a migration barrier, specify how many meters high it is, and if there is a structure for migration to reduce the "barrier effect" of the work (indicate which kind of structure and if it is functional or not).

2.4.3. Geomorphodynamics - channel features (results in appendix 4, part 1)

2.4.3.1. General features

Dimensions of the channel features were measured for each reach on the 3 transects, with a rangefinder Ranging 400. The measures are made on the same bank for both reaches of a sampling site, standing on the measurement points and looking at the opposite bank.
The dimensions to measure are (figure 5) :

- Bankfull width (in meters) : the bankfull is "the point where river first spills on to floodplain" (River Habitat Survey - Field Survey Guidance Manual, 2003).
- Water width (in meters)
- Water depth (in meters). *The water depth was not measured for this study, because the river was not wadeable in the majority of the sites.*

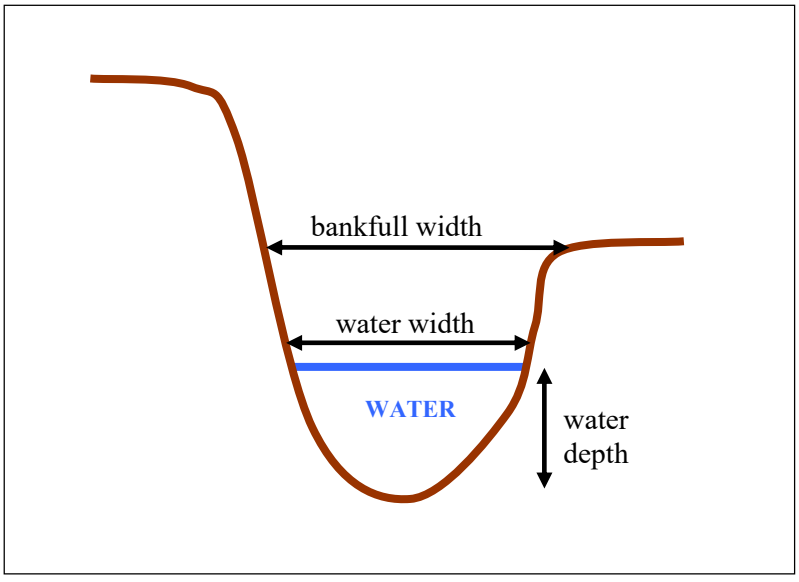

Figure 5 : Channel dimensions guidance – channel features (from River Habitat Survey - Field Survey Guidance Manual, 2003)

2.4.3.2. Channel type

The channel type is described for each reach. The different types of channel are :

- Single thread : single channel river
- Side channel(s) : presence of one main channel and one or more other little channel(s). The number of side-channels has to be specified.
- Braided channel : channel divided into several sub-channels separated by active mid-channel bars along most 50 % of the riverbed (Ecomorphological Survey of Large Rivers, 2002).

2.4.3.3. Channel sinuosity

Sinuosity is helpful in describing energy conditions, and is related to the gradient and the diversity of habitat. In general a low sinuosity is associated with a steep gradient, uniform cross-sections, and few pools. A high sinuosity indicates flat channel gradient, asymmetrical river cross-sections, overhanging banks, and pools located on the outside bend of the meander (US Geological Survey, 1998).
An estimation of the sinuosity of the reach is made according to four categories :

- straight channel
- slightly sinuous channel
- moderately sinuous channel
- meandering channel

2.4.3.4. Channel gradient

The channel gradient is an indication of the amount of energy available for the movement of water and sediment through the reach. Thus, it has a direct influence on

streamflow and substrate characteristics and on the types of aquatic habitats present (US Geological Survey, 1998).

The slope of the channel is measured (in percent or degrees) between :

- the measurement points 1 and 3, for every reach.
- the point 2 upstream the work and the point 2 downstream, for the sites with works, to know if the work create or not a break in the general slope of the river.

A clinometer Suunto PM5/360PC was used to measure the channel gradient.

2.4.3.5. Morphology types

Three types of habitat are differentiated according to velocity and the water depth (US Geological Survey, 1998) :

- Pool : areas of the channel with reduced velocity, little surface turbulence, and deeper water than surrounding areas.
- Riffle : a relatively shallow area of the channel where water flows swiftly over completely or partially submerged obstructions to produce surface agitation.
- Run : area with moderate depth, high or low velocity, and little or no surface turbulence.

A percentage is given for each morphology type, according to its proportion in the reach length.

2.4.3.6. Sediment deposition

The riverbed features, islands and bars, are the results of the accumulation processes in the river. Sediment accretion like side-bars and mid-channel bars are an indication of a dynamic riverbed; while islands are the result of channel widening or of branching of the river (Ecomorphological Survey of Large Rivers, 2002).

The riverbed is delimited by the occurrence of terrestrial vegetation (generally herbaceous vegetation) on the respective banks. Bars and islands are part of the riverbed (Ecomorphological Survey of Large Rivers, 2002).

Four types of sediment deposition features are distinguished (River Habitat Survey - Field Survey Guidance Manual, 2003). The proportion of each type in the reach is expressed in percent of the riverbed width for the 3 transects :

- mature island : permanent in-channel depositional feature with the surface at the same height or above the bankfull height, usually vegetated with mature scrub and trees.
- mid-channel bar : a distinctive, in-channel, depositional feature composed of unconsolidated riverbed material, exposed at low flow, usually with shallow sloping sides into the water.
- side bar : a distinctive depositional feature composed of unconsolidated sediment, located along the margins of rivers, exposed at low flow, usually with a shallow slope into the water.
- point bar : a distinctive depositional feature composed of consolidating riverbed material, located on the inside of distinct meander bends, exposed at low flow, usually with a shallow slope into the water.

2.4.3.7. Channel modifications

The modifications of the channel have to be recorded, because they have an impact on the morphodynamic processes of the river, and can increase the impact of a work :

- dredging
- widening, deepening
- realigning, straightening
- bed reinforcement : when the channel bed is reinforced with an artificial material.

The modifications have to be recorded only if they are evident.

2.4.3.8. Channel substrate

The sediment size distribution of the riverbed substrate is described for each transect (on a width of 1 meter), according to Wentworth scale (table 1). This parameter exclusively shows the disturbances affecting the composition and/or the stability of the riverbed substrate.

The distribution of the sediment classes is expressed with a percent given to each class present on the transect. In the same way, if artificial material is present in the channel bed, its proportion of the channel substrate is expressed by a percent. The percentages should be added up to 100 %.

The categories of channel substrate are :

- bedrock : underlying solid rock
- boulders
- cobbles
- pebbles
- gravels
- sand
- silt
- clay
- artificial material : man-made structure placed in the river bed

Wentworth size class		size (millimetres)
boulder		256
cobble		64
pebble		4
gravel		2
sand	very coarse	1
	coarse	0,50 = 1/2
	medium	0,25 = 1/4
	fine	0,125 = 1/8
	very fine	0,0625 = 1/16
silt		0,0039 = 1/256
clay		

Table 1 : Sediment-size scale (from Wentworth, 1922).

When assessing the substrate size, the intermediate axis of the substrate materials has to be used, and not the long axis (figure 6).

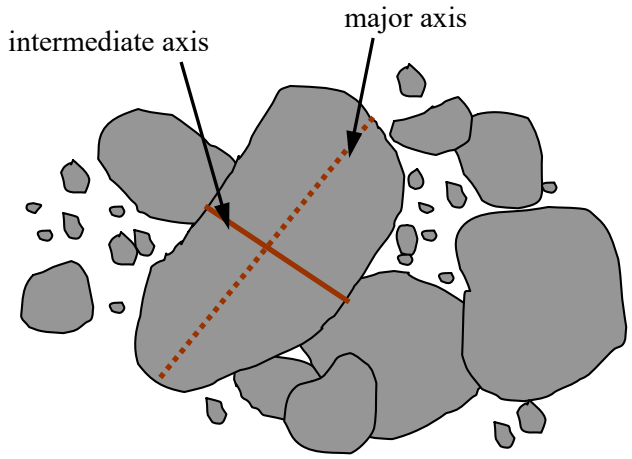

Figure 6 : Illustration of the correct use of the "intermediate axis" for channel substrate assessment (from River Habitat Survey- Field Survey Guidance Manual, 2003)

The evaluation of the sediment size distribution was made with a metal stake drilling the channel material, to determine the categories of sediment present under the surface stratum. The channel substrate assessment was done as far away as possible in the middle of the channel when the river was wadeable. When the water was too deep, the substrate was investigated from the bank.

2.4.3.9. Embeddedness rating

The embeddedness rating is “the degree that the larger particles (boulders, gravels, cobbles) are surrounded or covered by fine sediment” (Platts, Megahan and Minshall, 1983) (figure 7, on following page). This rating is expressed with a percentage. As the percentage of embeddedness decreases, the biotic productivity is thought to decrease.

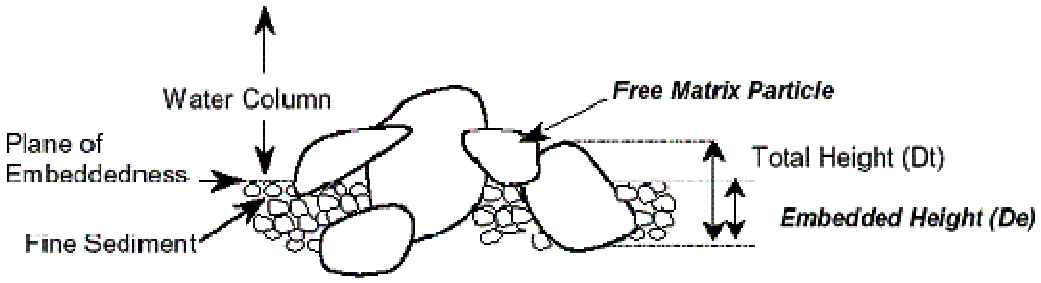

Figure 7: Schematic representation of embeddedness (Sylte and Fischenich , 2002).

The method to determine the embeddedness rating is a visual estimation of how much the surface of the larger sized particles is covered by fine sediment. This method gives a rating of embeddedness with five classes (Platts, Megahan and Minshall, 1983) (table 2).

RATING	RATING DESCRIPTION
5	< 5 percent of surface covered by fine sediment
4	5 to 25 percent of surface covered by fine sediment
3	25 to 50 percent of surface covered by fine sediment
2	50 to 75 percent of their surface covered by fine sediment
1	> 75 percent of surface covered by fine sediment

Table 2 : Embeddedness rating for gravel, rubble (pebble and cobble), and boulder particles (from Platts, Megahan and Minshall, 1983)

2.4.4. Geomorphodynamics - banks features (results in appendix 4, part 2)

Every parameter is studied for both left bank and right bank of the river. 'Left' and 'right' banks are determined by facing downstream.

2.4.4.1. General features

A bank is the permanent side to the river channel; it starts at the water's edge and gives way to the 'banktop' where the break of the slope allows cultivation or development to take place (River Habitat Survey - Field Survey Guidance Manual, 2003).

The dimensions of the banks features were measured on the 3 transects for each reach. The measures are made successively on the 3 measurement points, standing on the bank and looking at the opposite bank. A rangefinder Ranging 400 was used for these measures.
The dimensions measured are (figure 8) :

- Bankfull height (in meters)
- Banktop height (in meters) : the banktop is "the first major break in slope above which cultivation or development is possible" (River Habitat Survey - Field Survey Guidance Manual, 2003).

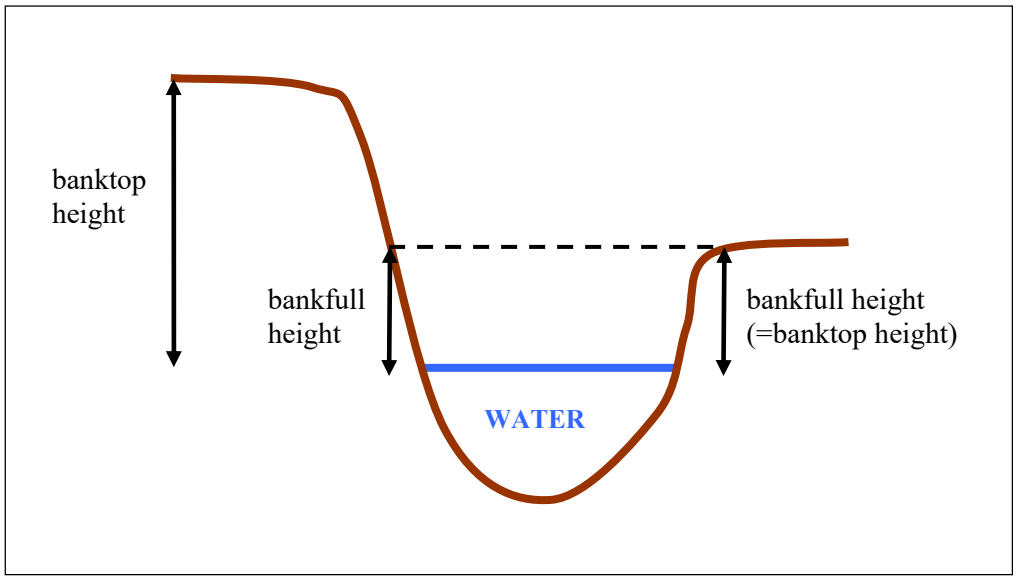

Figure 8 : Channel dimensions guidance – banks features (from River Habitat Survey - Field Survey Guidance Manual, 2003)

2.4.4.2. Bank stability

The bank stability is studied on the 3 transects of the reach by :

- the bank erosion : the signs of bank erosion are crumbling, exposed soil, absence of vegetation, and exposed tree roots (Barbour M. T., Gerritsen J., Snyder B. D., and Stribling J. B. ; 1998). The erosion of the bank is expressed in percent of the bank surface affected by erosion.

Damage to the bank caused by livestock is not considered as bank erosion.

➢ the bank vegetative cover : the amount of vegetative protection is measured with the percent of the bank covered by vegetation. This parameter supplies information on the ability of the bank to resist to erosion; indeed the root systems of the plants growing on the bank help to hold the soil in place (Barbour M. T., Gerritsen J., Snyder B. D., and Stribling J. B. ; 1998).

2.4.4.3. Bank modifications

The bank modifications are studied for the 3 transects of the reach. The percent of the bank profile modified is specified for each obvious modification (River Habitat Survey - Field Survey Guidance Manual, 2003) :

➢ resectioned (reprofiled) : when the bank profile is modified (but not necessary reinforced. This re-profiling produces a relatively smooth, uniformly angled bank slope.

➢ reinforced : when whole or part of the bank is artificially strengthened for bank protection purposes.

➢ embanked : when the bank is artificially raised. If the bank is embanked, specify the height of embankment (in meters) and the distance between the embankment and the channel (in meters) for the set-back embankments.

2.4.4.4. Bank material

The bank materials are distinguished among natural materials, of which categories are based on the Wentworth size-sediment scale, and artificial materials. A percent of each kind of material present on the bank is recorded for the 3 transects (on a width of 1 meter); the percents should be added up to 100 %.

Natural materials :

- bedrock
- boulder
- cobble / pebble
- gravel / sand
- earth
- sticky clay

Artificial materials :

- concrete
- sheet pilling
- wood pilling
- gabion
- brick / laid stone
- rip-rap
- tipped debris
- fabric
- bio-engineering material

2.4.5. Aquatic vegetation

Besides being an ecological assemblage that responds to perturbation, aquatic vegetation provides refugia and food for aquatic fauna. The assessment of channel aquatic vegetation gives information on the range of functional habitats that channel vegetation may be providing for invertebrates, fishes, amphibians, etc (River Habitat Survey - Field Survey Guidance Manual, 2003).

Only an estimation of the extent of aquatic vegetation in the channel is made for the 3 measurement points (results in appendix 5), on a 5 meters-wide transect. The estimation of the portion of transect covered by aquatic vegetation (in percentage) distinguishes types of aquatic vegetation :

- Rooted emergent : plants rooted on the river bed or along the water's edge; leaves and flowers grow above water level.
- Rooted submerged : rooted plants totally submerged, or with the majority of the plant submerged.
- Rooted floating : plants rooted on the river bed but with floating leaves.
- Free floating : plants floating on or just under the water surface, and not rooted to the riverbed.
- Floating algae : algae floating on the water.
- Attached algae : algae attached on the channel substrate.

If the species are known, they have to be listed.

2.5. Works

2.5.1. Types of works

Five types of works were surveyed on Pinios River :

- Bridges (pictures 1, 2, 3)
- Fords : crossing places for vehicles or machinery, located in the riverbed (pictures 4 and 5)
- Weirs and dams (pictures 6, 7, 8)

  A dam is a structure designed to hold water back in order to make a pond, a lake or a reservoir.

  A weir is a low dam built in the river to control water level or water flow, for abstracting water, trapping sediment or for recreational purposes.
- Sand extractions (picture 9)
- Pump for water abstraction (picture 10)

Picture 1 : road bridge (site P009), August 2004

Picture 2 : road bridge (site P062), August 2004

Picture 3 : bridge (site P277), August 2004

Picture 4 : ford (site P052), August 2004

Picture 5 : ford (site P287), August 2004

Picture 6 : dam (site P012), August 2004

Picture 7 : dam (site P067), August 2004

Picture 8 : weir (site P125), August 2004

Picture 9 : sand extraction (site P051), August 2004

Picture 10 : pump (site P117), August 2004

2.5.2. Works data

The protocol form concerning the work survey provides information about the work characteristics and the work management (data in appendix 6) :

- What is the objective of the work ?
- Where is the work located in the river (channel, left bank and/or right bank) ?
- What are the dimensions of the work ?
- Is the work permanent or temporal ?
- What is the material used to built the work ? What is the engineering used (civil engineering or bioengineering) ?
- What is the status of the work : is the work functioning or out of service, maintained or damaged ?
- Which authority materialized the work : is it a public authority (European, national, regional, or local), a private company, the users of the work; or is the work illegal ?
- When was the work established ?

Therefore, these questions permit to have indications if the work could have or not reversible impacts on the river ecosystem : the impacts of a temporal work could be more restrictive in time than a permanent work; or if the work could become “integrated” in the river ecosystem functioning according to its material and its length of service.

2.6. River quality indexes

To define the river ecological status, two indexes were used during the survey of Pinios River :

- the Fluvial Habitat Index for Mediterranean streams : IHF index (from its initials in Spanish “Indice de Habitat Fluvial”), a rapid bio-assessment measure of instream river habitat (figure 9).
- the QBR index (from the initials of its Spanish name “Qualitat de los Ecosistemas de Riberia”), an index of the riparian habitat quality (figure 9).

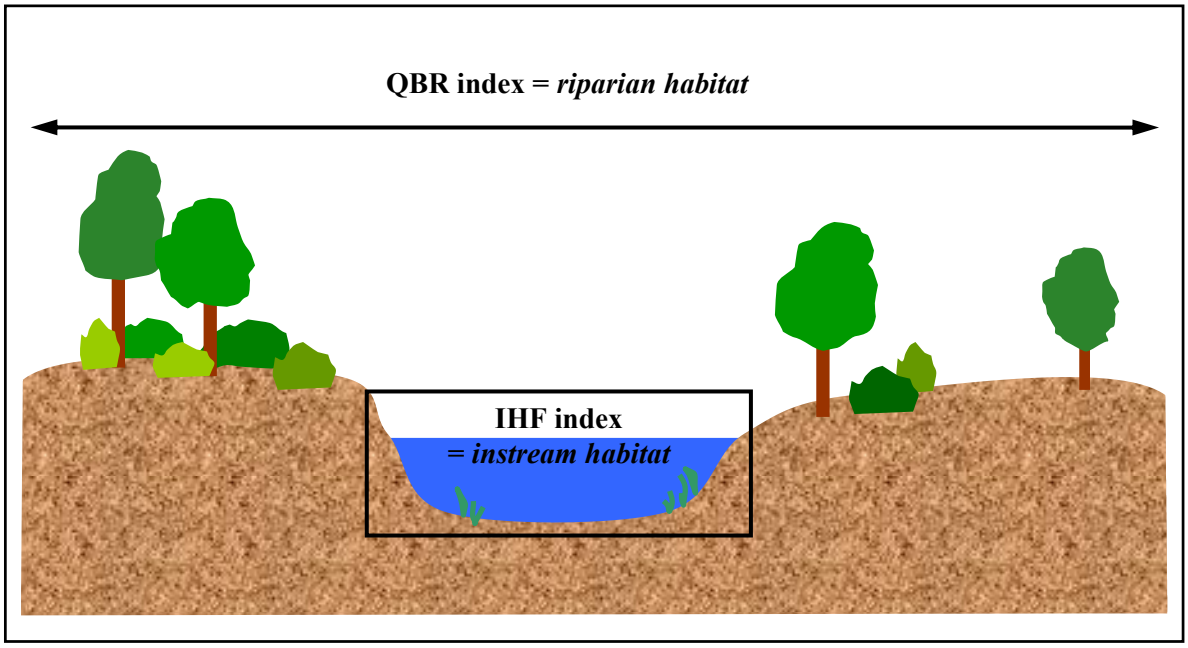

Figure 9 : Observation areas for IHF index and QBR index.

Theses indexes are part of the ECOSTRIMED methodology (ECOlogical STatus RIver MEDiterranean), established in Spain and intended to establish the ecological status of Mediterranean streams and rivers.

The IHF index (appendix 7) is based on the diversity and complexity of the instream characteristics of the river channel. It is calculated according to the observation of a number of habitat features in the sampling area.

The QBR index (appendix 8) studies the connectivity of the river ecosystem with the surrounding land ecosystem. This index is used in the ECOBILL protocol, developed to study the ecological status of the Mediterranean rivers (Prat et al., 2002).

The length of the observation area recommended for both indexes is 100 meters; thus they were applied on the 2 reaches together for the sites with a work, and on the reach with additional 50 meters upstream for the reference sites.

CHAPTER 3 : RESULTS AND DISCUSSION

3.1. Results of the indexes

The quality of instream habitat and riparian habitat is classified in 5 levels, according to the scores of respectively the IHF index and the QBR index (table 3).

ranges		level of quality	colour
score IHF	score QBR		
81-100	95-100	high	**blue**
61-80	75-90	good	**green**
41-60	55-70	moderate	**yellow**
21-40	30-50	bad	**orange**
0-20	0-25	very bad	**red**

Table 3 : Quality ranges according to the IHF and QBR indexes

Higher is the score of the index, better is the quality of the habitat; which means a riparian habitat undisturbed for the QBR index and a high diversity of the instream habitat for the IHF index.

areas	sites		IHF values
1	P009-u	road bridge	**46**
	P009-d		**46**
	P012-u	dam	**48**
	P012-d		**48**
	P021-u	sand extraction	**32**
	P021-d		**32**
	P023-R	*reference*	***45***
2	P027-u	road bridge	**31**
	P027-d		**31**
	P033-u	weir	**45**
	P033-d		**45**
	P036-R	*reference*	***39***
3	*P038-R*	*reference*	***24***
	P051-u	sand extraction	**24**
	P051-d		**24**
	P052-u	ford	**42**
	P052-d		**42**
	P062-u	road bridge	**38**
	P062-d		**38**
4	P067-u	dam	**45**
	P067-d		**45**
	P071-R	*reference*	***40***
5	P092-u	ford	**32**
	P092-d		**32**
	P117-u	pump	**24**
	P117-d		**24**
	P125-u	weir	**47**
	P125-d		**47**
	P143-u	road bridge	**25**
	P143-d		**25**
	P188-R	*reference*	***54***
6	P217-u	sand extraction	**20**
	P217-d		**20**
	P228-R	*reference*	***32***
	P239-u	weir	**51**
	P239-d		**51**
	P277-u	bridge	**41**
	P277-d		**41**
	P287-u	ford	**57**
	P287-d		**57**

Table 4 : Results of the IHF index

The instream habitat on the sites studied on Pinios River have a quality moderate to bad (table 4), so a habitat diversity and complexity not very high. One site has a very bad quality : this site (P217) is a sand extraction, indeed this work has a big impact on the river ecosystem because it takes material from the channel bed. This sand extraction has a higher impact than the two others (sites P021 and P051) because these both extraction just started when the sites where surveyed, on the contrary of the first one which was finished (see works data, appendix 6).

But this index cannot be used to study the impacts of the works, because it is based on the diversity of the instream habitat. Some works create breaks of the longitudinal profile of the river, like the works located in the channel as fords, dams and weirs do. Thus the perturbation caused by the work becomes a positive element for this index ! That is the reason why the reference sites have not an instream habitat quality as good as sites with a work in the areas 2, 3, 4 and 6.

areas	sites		QBR values
1	P009-u	road bridge	10
	P009-d		10
	P012-u	dam	10
	P012-d		10
	P021-u	sand extraction	35
	P021-d		35
	P023-R	*reference*	*25*
2	P027-u	road bridge	85
	P027-d		85
	P033-u	weir	90
	P033-d		90
	P036-R	*reference*	*85*
3	*P038-R*	*reference*	*30*
	P051-u	sand extraction	0
	P051-d		0
	P052-u	ford	0
	P052-d		0
	P062-u	road bridge	10
	P062-d		10
4	P067-u	dam	45
	P067-d		45
	P071-R	*reference*	*70*
5	P092-u	ford	10
	P092-d		10
	P117-u	pump	5
	P117-d		5
	P125-u	weir	0
	P125-d		0
	P143-u	road bridge	5
	P143-d		5
	P188-R	*reference*	*65*
6	P217-u	sand extraction	15
	P217-d		15
	P228-R	*reference*	*65*
	P239-u	weir	5
	P239-d		5
	P277-u	bridge	30
	P277-d		30
	P287-u	ford	25
	P287-d		25

Table 5 : Results of the QBR index

The values of the QBR index (table 5) are linked with the characteristics of the study areas, particularly with the land uses. So the area 2 has a good riparian habitat quality because it is located in a natural park. The other areas are located in an agricultural plain with more or less intensive activities, therefore the riparian habitat is disturbed (the quality is bad or very bad). In these areas, the only sites which have a better quality (moderate quality) are the reference sites of the areas 4, 5 and 6 : these sites, because of their status of 'reference site', were located in sectors of the river without perturbation of the channel and the banks, and so where human pressures on the river ecosystem are less strong.

3.2. Study of the survey parameters

Two ways of studying the parameters measured on Pinios River were used : a scoring of the flow disturbance parameters, and a statistical analysis to establish levels of disturbance for water quality and geomorphology parameters.

The objective is to create a range of five classes (from a low level of disturbance to a high level) for each group of parameters, as the EU Water Framework Directive recommends.

3.2.1. Scoring of the flow disturbance parameters

The flow disturbance parameters are studied by a scoring. Each parameter has several possibilities, at each possibility corresponds a value. This value depends on the more or less important part that the parameter has in the perturbation of the river flow :

- Reduction of channel capacity: none = 0, partial = 3, complete = 6
- Work established to block the flow: no = 0, yes = 4
- Periodical flow lack: no = 0, yes = 4
- Percent of water width with jammings: none = 0, <25% = 1, 25-49% = 2, 50-75% = 3, >75% = 4
- Nature of the jammings: large woody debris = 2, other vegetal debris = 1, rubbish = 3
- Migration barrier for fishes: none = 0, < 1m = 3, > 1m = 6
- If barrier for migration, structure for migration: functional = 0, not functional = 2, none = 4

The score is obtained with the sum of the values of every parameter (scoring details in appendix 9).

Five classes of disturbance level are defined according to the total extend of the sum values (table 6). These five classes have equal extend. Higher is the score; higher is the perturbation of the river flow induced by the work.

score	level of disturbance	colour
0-6	none- very slight	**blue**
7-13	slight	**green**
14-20	medium	**yellow**
21-27	high	**orange**
28-34	very high	**red**

Table 6 : Range of disturbance levels for flow disturbance scoring.

areas	sites		score flow
1	P009-u	road bridge	5
	P009-d		3
	P012-u	dam	22
	P012-d		20
	P021-u	sand extraction	6
	P021-d		6
	P023-R	*reference*	*0*
2	P027-u	road bridge	0
	P027-d		0
	P033-u	weir	16
	P033-d		7
	P036-R	*reference*	*0*
3	*P038-R*	*reference*	*0*
	P051-u	sand extraction	13
	P051-d		13
	P052-u	ford	13
	P052-d		13
	P062-u	road bridge	3
	P062-d		3
4	P067-u	dam	20
	P067-d		24
	P071-R	*reference*	*0*
5	P092-u	ford	13
	P092-d		13
	P117-u	pump	3
	P117-d		3
	P125-u	weir	20
	P125-d		20
	P143-u	road bridge	12
	P143-d		3
	P188-R	*reference*	*0*
6	P217-u	sand extraction	0
	P217-d		0
	P228-R	*reference*	*0*
	P239-u	weir	10
	P239-d		10
	P277-u	bridge	16
	P277-d		15
	P287-u	ford	10
	P287-d		6

Table 7 : Scores of flow disturbance parameters.

The scores are obtained with summing the values correspondent to each characteristic (table 7).

The works located in the entire river channel width like fords, dams and weirs, create a perturbation of the river flow because they constitute a barrier for the flow. Dams and weirs are built to block the flow, that's why the river flow is perturbed for both upstream and downstream of the work.

The main reason of the flow disturbance on the sites with a bridge (sites P143 : slight disturbance level, and P277 : medium disturbance level) is the presence of jammings, all the more as the jammings on these sites are formed with large woody debris and occupy 50 percent or more of the water width.

A sand extraction can create a perturbation for the river flow, when a crossing of the river is made with the channel material, to permit the machines working on the extraction place and circulating between the two banks, as it was the case for the sand extraction on site P051 (which has a medium level of disturbance for both reaches).

3.2.2. Ratios calculation for the water quality and geomorphology parameters

To establish a five-class range of disturbance level, the other parameters were studied by a statistical analysis, in order to calculate a ratio representing the difference between the reference sites and the sites with work.

For this analysis :

- the physicochemical parameters and the aquatic vegetation data were grouped together, as they both an indication of the water quality.
- the geomorphologic parameters of the channel and the banks were not dissociated, to study the general geomorphology processes of the river.

3.2.2.1. Choice of the parameters for the ratio calculation

To calculate a ratio, the parameters which distinguish the most the sites have to be chosen among all the parameters. This choice is made by a Discriminant Function Analysis (DFA). The DFA was made with a SPSS (Statistical Package for Social Sciences) program.

DFA uses a set of independent variables (here the river ecosystem parameters) to separate cases based on groups defined by a grouping variable, which is the dependent variable and is categorical. DFA creates a new variable from the independent variables. This new variable defines a line onto which the group centres would plot as far apart as possible from each other. In other words, this new variable is defined such that is separate the groups of cases as far apart as possible.

To run the DFA, the parameters have to be grouped by a categorical variable. The grouping variable used for the analysis was the categories of works. At each type of work corresponds a category number :

- 1 = no work (reference site)
- 2 = bridge
- 3 = ford
- 4 = dam / weir
- 5 = sand extraction
- 6 = pump

Some parameters have missing values; these missing values have to be replaced for each parameter by the mean of the values, otherwise the data are insufficient to have a correct discriminant analysis (the DFA program calculates the means of each parameter and replaces the missing values).

The DFA defines functions on to the variables are plotted. The Discriminant Function Coefficients of the variables indicate their position on the axes representing the functions on a multi-dimensions graph. The higher is the value of the coefficients (positive or negative value), the further is the variable apart from the other variables, and so the most discriminant is the parameter correspondent to this variable.

The parameters with at least one coefficient upper than 0.5 were kept for the ratios calculation (the Standardized Canonical Discriminant Function Coefficients were used for this choice). The parameters chosen for water quality and geomorphology parameters are detailed respectively in the appendices 10 and 11.

3.2.2.2. Ratios calculation

To know the difference between the reference sites parameters and the parameters of the sites with works, a ratio is calculated.

The ratio is a comparison between the reference site and the reaches of the sites with a work (reach upstream the work and reach downstream). When a parameter is measured at the scale of the reach, its value is used. When the measures are made on 3 measurement points or transects, the average of the values is calculated and used for the ratio calculation.

The sum of the 'single' values (when there is one value for the whole reach) and the averages is made for the values of the parameters chosen by the Discriminant Function Analysis. Then the ratio is calculated with the formula :

ratio (%) = ABS (1-(sum 'site with work' / sum 'reference site'))*100

The ratio is expressed with a percentage, as it represents the difference between the values sum of the reference site and the values sum of the other reaches. The calculus result has to be an absolute value (ABS), because the difference between the sums can be positive (sum of the

reach with the work inferior to the sum of the reference site) or negative (sum of the reach with the work superior to the sum of the reference site.

The ratio was calculating for each reach according to the reference site of the study area where the work is located.

The ratios were calculated for the water quality parameters and the geomorphology parameters (details of the calculation in respectively appendix 10 and appendix 11). They expressed how each reach of the sites with a work is different from the reference site : higher is the percentage of the ratio, the more the reach is different from the reference site. This difference expresses a disturbance of the river ecosystem parameters.

3.2.2.3. Levels of disturbance

The disturbance level of the sites is the percent of difference (ratio) between the reference site and the site with a work. Five levels of disturbance are defined, with ranging the ratio values in five equal classes (table 8).

ratio value	level of disturbance	colour
0-20	none- very slight	blue
21-40	slight	green
41-60	medium	yellow
61-80	high	orange
81-100	very high	red

Table 8 : Range of disturbance levels for the ratios of water quality and geomorphology parameters.

areas	sites		ratios water quality
1	P009-u	roadbridge	72
	P009-d		100
	P012-u	dam	3
	P012-d		3
	P021-u	sand extraction	4
	P021-d		14
	P023-R	*reference*	*0*
2	P027-u	roadbridge	22
	P027-d		19
	P033-u	weir	2
	P033-d		8
	P036-R	*reference*	*0*
3	*P038-R*	*reference*	*0*
	P051-u	sand extraction	6
	P051-d		33
	P052-u	ford	10
	P052-d		39
	P062-u	roadbridge	33
	P062-d		22
4	P067-u	dam	8
	P067-d		no water
	P071-R	*reference*	*0*
5	P092-u	ford	lost data
	P092-d		3
	P117-u	pump	7
	P117-d		3
	P125-u	weir	18
	P125-d		40
	P143-u	roadbridge	11
	P143-d		13
	P188-R	*reference*	*0*
6	P217-u	sand extraction	30
	P217-d		9
	P228-R	*reference*	*0*
	P239-u	weir	1
	P239-d		8
	P277-u	bridge	6
	P277-d		0
	P287-u	ford	23
	P287-d		9

Table 9 : Ratios of the water quality parameters.

In the majority of the sampling sites, the water quality is not or slightly perturb (table 9). But the part that the work has in the water quality perturbation cannot be certainly asserted. Indeed the modification of the parameters can be induced by pollution sources which were not evident when the sites were surveyed (specially diffuse sources).

Thus the water parameters for the sites P027, P062, and P009 are slightly to very highly perturbed : neither the bridges located in these sites perturb the river flow (table 6, in paragraph 3.2.1), which could be linked to the water quality disturbance; nor they were a source of pollution by rejecting substances in the river for example. But the bridges were located in areas with habitations, intensive agriculture, and 'wild' rubbish dump on the river banks, particularly the bridge in the site P009 which has high perturbation of water quality. So the degradation of the river water quality can depend more on the surrounding land uses than on the work itself.

areas	sites		ratios geomorphology
1	P009-u	roadbridge	7
	P009-d		19
	P012-u	dam	2
	P012-d		4
	P021-u	sand extraction	17
	P021-d		6
	P023-R	*reference*	*0*
2	P027-u	roadbridge	12
	P027-d		14
	P033-u	weir	68
	P033-d		53
	P036-R	*reference*	*0*
3	*P038-R*	*reference*	*0*
	P051-u	sand extraction	22
	P051-d		14
	P052-u	ford	35
	P052-d		6
	P062-u	roadbridge	23
	P062-d		11
4	P067-u	dam	22
	P067-d		no water
	P071-R	*reference*	*0*
5	P092-u	ford	8
	P092-d		4
	P117-u	pump	3
	P117-d		10
	P125-u	weir	48
	P125-d		42
	P143-u	roadbridge	22
	P143-d		29
	P188-R	*reference*	*0*
6	P217-u	sand extraction	33
	P217-d		30
	P228-R	*reference*	*0*
	P239-u	weir	13
	P239-d		6
	P277-u	bridge	4
	P277-d		2
	P287-u	ford	4
	P287-d		15

Table 10 : Ratios of the geomorphologic parameters.

The geomorphology parameters are few disturbed for the majority of the sites (table 10). The highest perturbation is caused by the dams and weirs (sites P033, P067, P125) because these kinds of work form a barrier for the sediment movement in the river. In the same way, bridges and fords can modify the sediment transportation in the channel because they reduce the channel capacity (appendix 3).

The sand extractions (sites P217 and P051) perturb the geomorphology of the river, as they take material from the channel bed and modify the river channel by the settlement of the exploitation. The sand extraction located on the site P021 has no obvious impact on the geomorphology, because it just started when the river was surveyed.

However, the ratio doesn't distinguish the perturbation between the banks and the

channel, so in which proportion the processes of lateral erosion of the banks, sedimentation and erosion of the channel bed are perturb by the work.

3.2.3. Total disturbance

A level of “total disturbance” of the river ecosystem was determined, from the scores of flow disturbance levels and the ratios of water quality and geomorphology perturbation. This “total disturbance” is found by choosing the higher level of disturbance among the 3 groups of parameters: hydrodynamics, water quality, and geomorphology (table 11, on following page).

areas	sites		flow disturbance	water quality	geomorphology	total perturbation
1	P009-u	roadbridge	5	72	7	
	P009-d		3	100	19	
	P012-u	dam	22	3	2	
	P012-d		20	3	4	
	P021-u	sand extraction	6	4	17	
	P021-d		6	14	6	
	P023-R	*reference*	*0*	*0*	*0*	
2	P027-u	roadbridge	0	22	12	
	P027-d		0	19	14	
	P033-u	weir	16	2	68	
	P033-d		7	8	53	
	P036-R	*reference*	*0*	*0*	*0*	
3	*P038-R*	*reference*	*0*	*0*	*0*	
	P051-u	sand extraction	13	6	22	
	P051-d		13	33	14	
	P052-u	ford	13	10	35	
	P052-d		13	39	6	
	P062-u	roadbridge	3	33	23	
	P062-d		3	22	11	
4	P067-u	dam	20	8	22	
	P067-d		24	no water	no water	no water
	P071-R	*reference*	*0*	*0*	*0*	
5	P092-u	ford	13	lost data	8	
	P092-d		13	3	4	
	P117-u	pump	3	7	3	
	P117-d		3	3	10	
	P125-u	weir	20	18	48	
	P125-d		20	40	42	
	P143-u	roadbridge	12	11	22	
	P143-d		3	13	29	
	P188-R	*reference*	*0*	*0*	*0*	
6	P217-u	sand extraction	0	30	33	
	P217-d		0	9	30	
	P228-R	*reference*	*0*	*0*	*0*	
	P239-u	weir	10	1	13	
	P239-d		10	8	6	
	P277-u	bridge	16	6	4	
	P277-d		15	0	2	
	P287-u	ford	10	23	4	
	P287-d		6	9	15	

Table 11 : Total disturbance level of the river ecosystem.

The signification of the five-classes disturbance levels is summarized in the table 12 :

colour of the class	level of disturbance - signification
blue	none or very slight disturbance level : unmodified river ecosystem, or ecosystem close the “natural” ecosystem
green	slight disturbance level : moderate anthropic pressure on the ecosystem
yellow	medium disturbance level : considerable modifications of the ecosystem
orange	high disturbance level : disturbed river ecosystem
red	very high disturbance level : completely “artificialised” river

Table 12 : Disturbance levels of the river ecosystem

To know if the five-classes range is a good way to express the level of river disturbance, a Discriminant Function Analysis was run, with using the classes of disturbance level as grouping variable. Each class is represented by a number :

- 1 = none or very slight disturbance level
- 2 = slight disturbance level
- 3 = medium disturbance level
- 4 = high disturbance level
- 5 = very high disturbance level

The analysis was made with both water quality and geomorphology parameters. According to the results of the analysis :

=> 73,3 % of the sites are correctly classified for the geomorphology parameters.

=> 60,8 % of the sites are correctly classified for water quality parameters.

A variable necessitates classifying at least 30-40 % of the variables analysed to be a correct way of classification. Thus the five-class range is proper to classify the levels of disturbance induced by the works on the river ecosystem parameters.

CONCLUSION

The study of the impacts of the works on Pinios River was the first study of this kind managed in the Laboratory of Zoology, Aristotle University. Thus the objective of my practice, more than giving results, was to find a way to study the impacts.

The way chosen to study the impacts was quantification by scoring and ratios calculation. This quantification gives a level of disturbance induced by the works on the river ecosystem components : water quality, geomorphology and hydrodynamic parameters, but without giving details of the precise parameters perturbed. Moreover the level of disturbance was calculated in the scale of the reach : more details could be given by a calculation for each measurement points of every reach.

In the same way, the range chosen for the disturbance level was a range with five equal classes. It could be interesting to compare it with a range divided in five classes according to the values mode : the values superior to the mode are divided in two classes of slight level of disturbance, and the values inferior to the mode are divided in three classes of medium or high level of disturbance.

My practice was the first step of the study of the impacts of the works on Pinios River, with creating a protocol for the river survey and trying to find the most adequate way to use the data. So this report is the basis for a deepener study of the impacts that the works provoke on Pinios River.

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