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# Identification of the self-purification stretches of the Pinios River, Central Greece

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## Abstract

*The Pinios River basin in Thessaly, Greece, is intensively farmed and heavily polluted with poorly treated domestic and industrial waste. The river was divided into 35 homogenous stretches. We investigated the self-purification capacity along the different stretches of the Pinios based on the responses of the benthic macroinvertebrate community to municipal, industrial and agricultural pollution in the basin. Water quality was assessed by the performance of six diversity and biotic indices and scores for assessing water quality. Self-purification found by the downstream amelioration of water quality was evident at five stretches. These stretches should be safeguarded and priority should be given to restoration projects along the most water-quality-degraded stretches that lack the capacity for self-purification.*

**Keywords:** Self-purification; Benthic macroinvertebrates; Pinios (Thessaly).

## Introduction

As stated by LAFONT (2001) in the Ecological Ambience System concept (EASY) if the river ecosystem is viewed as a mosaic, its overall ‘ecological defenses’ will also depend on self-purification capacity. Self-purification is the complex phenomenon that underlies the waste assimilation capacity of rivers and streams; it is a dynamic phenomenon reflecting hydrologic and biologic variations (VELZ, 1970). In highly polluted rivers the composition of the biological community changes rapidly due to lack of oxygen, which is consumed by waste assimilative bacteria for the degradation of organic matter (HARPER, 1995). Depleted oxygen results in the dominance of pollution-tolerant species, such as the alga *Cladophora glomerata* and the macroinvertebrate oligochaets, and the elimination of clean water species, such as the pollution-sensitive stone flies and the majority of fish (HYNES, 1966). Benthic macroinvertebrates can contribute to the regulation of processes associated with the eutrophication of water bodies and mass blooming of toxic plankton species. A demonstration of self-purification (e.g. control of eutrophic conditions) is water filtering by the removal of algal cells from the water column by bivalve mollusks (OSTROUMOV, 2002a).

Shifts in the benthic macroinvertebrate community structure reflect even relatively small variations in water chemistry induced by organic pollution (including nutrients) (ARMITAGE *et al.,* 1983; WIEDERHOLM, 1984; CAIRNS & PRATT, 1993) and also reflect the impacts from various pollutants (heavy metal and pesticide contamination) (CLEMENTS *et al.,* 1992; ANDERSON *et al.,* 2003). Macroinvertebrates have lifecycles of suitable length for short-term seasonal or annual investigations and are commonly used to evaluate water quality (e.g. DE BILLY *et al.,* 2000; PARR & MASON, 2003; AZRINA *et al.,* 2006). While much research has been undertaken on the exact mechanisms and factors that control self-purification (e.g. COOPER *et al.,* 1919; STREETER & PHELPS, 1926; POCH *et al.,* 1986; SKURLATOV, 1988; OSTROUMOV, 2002a; OSTROUMOV, 2002b; SABATER *et al.,* 2002; TEISSIER *et al.,* 2002; OSTROUMOV, 2005) few studies exist so far that assess the manifestation of self-purification by utilizing benthic macroinvertebrate responses.

The aim of the study was (i) to assess water quality in the Pinios River and (ii) to identify the segments of the polluted Pinios River where self-purification (SP) of pollution inputs was under process through the use of benthic macroinvertebrates.

***Study area***

The River Pinios rises in the Pindos mountains in central Greece. Its length is 235 km with a mean slope of 6.92‰ and it drains 11318 km$^2$ (Fig. 1) in the Thessaly

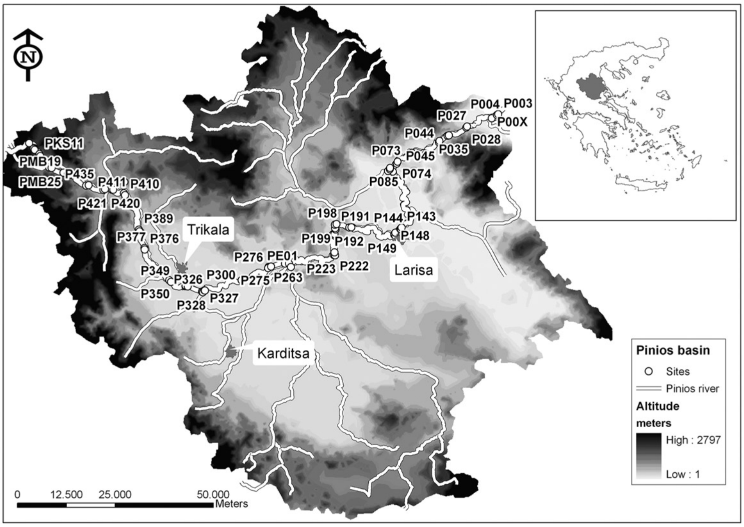


***Fig. 1:*** The 80 sampling sites for benthic macroinvertebrates located in the main Pinios river and the downstream end of its tributaries and canals.

basin. The average annual discharge at the river mouth is 108 $m^3$/sec (FYTIANOS *et al.,* 2005). It runs for about a quarter of its length over a mixed zone of Eocene flysch, mesozoic limestones and basic and ultra-basic rocks (ophioliths). At Kalambaka it enters the Thessaly plain, which consists of Holocene alluvial deposits (STAMATIS, 1999). Three soil types were identified in the catchment basin and classified into recent alluvial Entisols and Inceptisols and hilly region Entisols (FYTIANOS *et al.,* 2002). The climate is continental Mediterranean with a mean annual rainfall of 700 mm (LOUKAS & VASILIADES, 2004). 529244 inhabitants live in the Pinios basin (GSNSSG, 2002) of which 40.6% are served by Waste Water Treatment Plantations (personal communication to local Environmental Agencies). 96% of the used water concerns the agricultural uses, 3.3% the water supply and 0.2% industrial uses (HMEPPPW, 2005). Important point sources of pollution are the localized industries situated close to the cities of Larissa, Trikala, Karditsa and Farsala. The agricultural cultivations located in the plain (main produce: cotton, sugar and corn) compete with animal husbandry, at the expense of a diminishing riparian buffer strip in the Pinios floodplain. The plain of the river basin is designated as a 'nitrate vulnerable zone' according to criteria 91/676/EC Directive (EC DIRECTORATE-GENERAL FOR ENVIRONMENT, 2002).

## Materials and Methods

In order to obtain basic information on pollution removal rate through the rivers' self-purification, a monitoring scheme was applied during the end of the low flow period, September-October 2002, since pollution problems and water abstraction are most likely to occur during the low flow period (TITTIZER & KOTHE, 1979; DE PAUW *et al.,* 1986; CHATZINIKOLAOU *et al.,* 2006). Although SP may also take place during the high flow, the relative importance of SP processes is higher during low flow because effects of dispersion, for instance, are less important.

The main stem of the river was split into homogenous segments hereafter named stretches. Initially the river was divided into 500 m reaches, numbered from the river mouth to the furthermost source and coded according to a previous study in the Axios-Vardar River by CHATZINIKOLAOU *et al.* (2006). The criteria and the means used to merge the successive 500 m reaches in order to form homogenous stretches, were based on an extension of the 'fluvial hydrosystems approach' (i.e. confluence of tributaries) (AMOROS, 1987). A single stretch can vary from 0.5 km to 27.5 km, has only one geological underlying type according to a 1:1000000 scale hydrolithological map (1996) from the Hellenic Ministry of Development, has no tributary confluence or draining channel and no dramatic shift in slope gradient according to 1:50000 (1970) topographic maps from the Hellenic Military Geographical Service, a similar land use according to 1:30000 air-photographs (1995) from the Hellenic Military Geographical Service (natural: forested area, rocks and scree, sand dunes; semi-natural: pasture land, shrubs, olive trees; non-natural: intensive agricultural, urban development, roads etc.) and no discontinuity from human induced alterations to the channel flow according to a 2002 pre-sampling field survey.

Benthic macroinvertebrate samples

were taken only once from both the upstream and downstream end of each stretch during the period from 21/09/2002 to 14/10/2002. Samples were also taken from tributaries and canals.

Pollution inputs are difficult to detect by classical physical and chemical water quality monitoring, as the sampling frequency would have to be continuous to detect the chemical changes associated with these inputs (RUEDA *et al.,* 2002). The benthic macroinvertebrate sampling method employed was the semi-quantative 3-minute kick and sweep (ARMITAGE & HOGER, 1994), using a standard pond net (surface 575 $cm^2$, mesh size 0.9 mm, depth 40 cm). All existing instream habitat types at each site (macrophyte beds, woody snags, bars, natural or artificial substrates at riffles, runs and pools) were sampled, according to the Greek Habitat Richness Matrix (CHATZINIKOLAOU *et al.,* 2006). At non-wadeable sites both banks were sampled. Macroinvertebrate samples were preserved in a 4% formaldehyde solution and transferred to the laboratory where they were sorted and identified down to the taxonomic level of family, except Oligochaeta and Lepidoptera.

We used the Hellenic Evaluation System and its scores (HBMWP, HASPT) (ARTEMIADOU & LAZARIDOU, 2005) standardised for the sampled habitat quality according to the Greek Habitat Richness Matrix (CHATZINIKOLAOU *et al.,* 2008) as well as metrics and indices from the Inter-calibration Common Metrics (BUFFAGNI *et al.,* 2005) and various others presented in Table 1. Non parametrical Spearman correlation was used to test the consistency of the different biotic indices used. SP was assumed to take place at stretches where the downstream (output) water quality index presented an increase when compared to the upstream one (input) without the input of a tributary with a better water quality. Due to the lack of background information water quality improvement was assumed when all downstream indices and scores had concurrently rising values in comparison to the upstream ones.

## Results

35 homogenous segments were produced from the main stem of the Pinios River (Table 2). 20069 individuals were

**Table 1**
**Metrics and indices used in the water quality assessment of The Pinios River at the low flow period 2002. HBMWP is the Hellenic Biological Monitoring Working Party, HASPT is the Hellenic Average Score per Taxon, HES is the Hellenic Evaluation System, and EPTD is the Ephemeroptera, Plecoptera, Trichoptera and Diptera.**

| Indices, metrics & Scores | Reference |
|---|---|
| Total abundance | |
| Total number of families | e.g. OFENBÖCH *et al.,* 2004 |
| HBMWP | ARTEMIADOU & LAZARIDOU, 2005 |
| HASPT | ARTEMIADOU & LAZARIDOU, 2005 |
| HES | ARTEMIADOU & LAZARIDOU, 2005 |
| Log10(Selected EPTD+1) | BUFFAGNI *et al.,* 2004 |
| Number of EPT families | e.g. OFENBÖCH *et al.,* 2004 ; BÖHMER *et al.,* 2004 |
| H’ Shannon-Weaver diversity | SHANNON & WEAVER, 1963 |

**Table 2**
**The attributes of the 35 homogenous identified stretches of the Pinios River.**
**The 'Limit upstream' column defines the criteria for the split among the segments.**
**D: discontinuity, G: geology, L: land-use, S: slope, T: tributary.**

| No | Section | Tributary | Length (km) | Mean Elevation (m) | Geology | Mean Slope (m/km) | Land Use | Limit Upstream |
|---|---|---|---|---|---|---|---|---|
| 35 | PKS23-16 | | 4 | 860 | ophiolite | 4.52 | Natural | S |
| - | PRA01 | Kriasa | | | ophiolite | | Natural | |
| 34 | PKS15-11 | | 2.5 | 715 | ophiolite | 16.45 | Semi-natural | T & S |
| - | PCH01 | Anilio | | | ophiolite | | Semi-natural | |
| 33 | PKS10-05 | | 3 | 573 | limestone | 21.59 | Semi-natural | T |
| 32 | PKS04-01 | | 2 | 455 | ophiolite | 17.22 | Semi-natural | G |
| - | PMB26 | Malakasiotiko | | | flysch | | Semi-natural | |
| 31 | PMB25-20 | | 3 | 405 | flysch | 3.29 | Semi-natural | T |
| 30 | PMB19-16 | | 2 | 375 | flysch | 2.16 | Semi-natural | S |
| 29 | PMB15-01 | | 7.5 | 320 | flysch | 7.74 | Semi-natural | S |
| - | P436 | Kastaniotiko | | | flysch | | Natural | |
| 28 | P435-425 | | 5.5 | 270 | alluviums | 3.27 | Semi-natural | T & S |
| 27 | P424-421 | | 2 | 254 | alluviums | 6.75 | Non-natural | L & S |
| 26 | P420-411 | | 5 | 239 | alluviums | 3.3 | Non-natural | T & S |
| - | PHP01 | Tranos Lakkos | | | sandstones | | Non-natural | |
| 25 | P410-389 | | 11 | 197 | alluviums | 5.96 | Non-natural | T |
| 24 | P388-377 | | 6 | 147 | alluviums | 5.36 | Non-natural | D |
| 23 | P376-350 | | 13.5 | 119 | alluviums | 2.73 | Non-natural | D & S |
| 22 | P349-340 | | 5.5 | 106 | alluviums | 1.52 | Non-natural | D & S |
| - | PTR01 | Lithaios | | | alluviums | | Non-natural | |
| 21 | P339-328 | | 6 | 101 | alluviums | 0.93 | Non-natural | T |
| - | PPM01 | Pamisos | | | alluviums | | Non-natural | |
| 20 | P326-301 | | 13 | 96 | alluviums | 0.64 | Non-natural | T |
| 19 | P300-276 | | 12.5 | 91 | alluviums | 0.47 | Non-natural | D |
| - | PCE01 | Canal | | | alluviums | | Non- natural | |
| 18 | P275-267 | | 4.5 | 89 | alluviums | 0.41 | Non-natural | T |
| 17 | P266-264 | | 1.5 | 88 | alluviums | 0.39 | Non-natural | D |
| - | PE01 | Enippeas | | | alluviums | | Non-natural | |
| 16 | P263-223 | | 20.5 | 86 | alluviums | 0.44 | Non-natural | T |
| - | PVU01 | canal | | | alluviums | | Non-natural | |
| 15 | P222-206 | | 8.5 | 82 | alluviums | 0.47 | Non-natural | T |
| 14 | P205-202 | | 2 | 81 | limestone | 0.44 | Semi-natural | G & L |
| 13 | P201-199 | | 1.5 | 81 | alluviums | 0.43 | Non natural | G & L |
| 12 | P198-192 | | 3.5 | 80 | limestone | 0.42 | Semi-natural | G & L |
| 11 | P191-149 | | 21.5 | 76 | alluviums | 0.48 | Non-natural | G & L |
| 10 | P148-144 | | 2.5 | 72 | alluviums | 0.53 | Non-natural | D |

(continued)

**Table 2 (continued)**

| No | Section | Tributary | Length (km) | Mean Elevation (m) | Geology | Mean Slope (m/km) | Land Use | Limit Upstream |
|---|---|---|---|---|---|---|---|---|
| - | P144a | canal | | | alluviums | | Non-natural | |
| 9 | P143-088 | | 27.5 | 62 | alluviums | 0.54 | Non-natural | T |
| - | PT01 | Titarisios | | | alluviums | | Non-natural | |
| | P086 | | 0.5 | 48 | schists | 0.67 | Non-natural | T |
| 8 | P085-074 | | 6 | 44 | schists | 0.77 | Semi-natural | L |
| 7 | P073-069 | | 2.5 | 39 | schists | 1.26 | Semi-natural | S |
| 6 | P068-062 | | 3.5 | 34 | alluviums | 1.35 | Non-natural | G & L |
| 5 | P061-045 | | 8.5 | 26 | alluviums | 1.38 | Non-natural | D |
| 4 | P044-036 | | 4.5 | 18 | schists | 1.29 | Non-natural | G |
| 3 | P035-028 | | 4 | 14 | marbles | 1.21 | Natural | G & L |
| 2 | P027-004 | | 11.5 | 7 | alluviums | 0.77 | Non-natural | S & L |
| 1 | P003-001 | | 2 | 1 | alluviums | 0.54 | Semi-natural | L |

found and identified as belonging to 68 different taxonomic families.

Despite the pristine state of the river close to its source, the water quality according to the HES values was not excellent. The hyper-alkaline ophiolithic geology seems to have had an impact on pH (STAMATIS, 1999) and limits the presence of sensitive macroinvertebrates which cannot tolerate hyper-alkaline water conditions. Nevertheless, the EPT taxa values were high in comparison to the lowlands (Table 3), since sensitive-to-pollution families such as the Plecoptera Chloroperlidae, Leuctridae, Perlodidae, Perlidae and the Trichoptera Beraeidae and Sericostomatidae were present. According to the various benthic macroinvertebrate metrics and indices used, the water quality of the Pinios River declined in the plain of Thessaly (site P411). The land-use progressively shifts from forested areas to intensive agricultural use. The land-use shift coincided with a drop in the abundance of the Chrysomelidae family beetle, the caddis fly Sericostomatidae and the stone fly Nemouridae family. Total abundance peaked in the area P411-P377, including the tributary Tranos Lakkos (PHP01), due to an increase of the medium-tolerant to pollution (according to HES) families of Gammaridae, Baetidae and Hydropsychidae. The degradation of water quality was not as dramatic as in the immediate upstream part (Table 3). At the point where the Trikala municipality's sewage treatment plant discharges (PTR01) the tolerant-to-pollution family of Chironomidae were found in their highest abundance. In the P339-276 section, down to the Klokotos canal confluence, (PCE01) the first demonstration of self-purification occurred at segment P326-300 (Figure 2). Further downstream, bank water quality improved and thus self-purification was considered to be taking place at segment P275-266. Next, in the city of Larissa (126076 inh.) flood protection works such as embankments and a resection of the channel (by flood protection diversion) occurs. At P148 a newly established weir caused scouring of the river bed and generated suspended parti-

**Table 3**
**Metrics and indices at the studied sites (N=80) in the Pinios River during the period from 21/09/2002 to 14/10/2002.**

| Site | Abundance | Families | HBMWP | HASPT | HES | HESII | Log10 (Sel_EPTD+1) | EPT taxa | H'-Shannon |
|---|---|---|---|---|---|---|---|---|---|
| PKS24 | 112 | 14 | 822 | 58.71 | 3 | Moderate | 1.398 | 7 | 1.933 |
| PKS23 | 219 | 18 | 1244 | 69.11 | 4 | Good | 1.724 | 11 | 2.298 |
| PKS16 | 197 | 15 | 830 | 55.33 | 3.5 | Good | 1.833 | 7 | 2.402 |
| PRA01 | 21 | 9 | 516 | 57.33 | 3 | Moderate | 0.699 | 5 | 2.058 |
| PKS15 | 96 | 13 | 901 | 69.31 | 4 | Good | 0.845 | 8 | 1.711 |
| PKS11 | 480 | 17 | 971 | 57.12 | 3.5 | Good | 1.869 | 8 | 1.972 |
| PCH01 | 55 | 5 | 284 | 56.80 | 2.5 | Moderate | 0.000 | 3 | 1.059 |
| PKS05 | 261 | 13 | 691 | 53.15 | 2.5 | Moderate | 1.279 | 5 | 1.645 |
| PKS04 | 564 | 14 | 754 | 53.86 | 2.5 | Moderate | 1.663 | 6 | 1.440 |
| PKS01 | 306 | 16 | 873 | 54.56 | 3.5 | Good | 1.462 | 6 | 1.982 |
| PMB26 | 104 | 4 | 244 | 61.00 | 2.5 | Moderate | 0.000 | 4 | 0.944 |
| PMB25 | 46 | 8 | 513 | 64.13 | 3 | Moderate | 0.477 | 6 | 1.638 |
| PMB20 | 84 | 12 | 803 | 66.92 | 3.5 | Good | 0.903 | 7 | 1.967 |
| PKO01 | 33 | 7 | 416 | 59.43 | 3 | Moderate | 0.301 | 3 | 1.291 |
| PMB19 | 165 | 12 | 655 | 54.58 | 3 | Moderate | 0.699 | 7 | 1.760 |
| PMB16 | 150 | 9 | 481 | 53.44 | 3.5 | Good | 0.477 | 4 | 1.033 |
| PMB15 | 395 | 21 | 1225 | 61.25 | 3.5 | Good | 1.505 | 9 | 1.814 |
| P436 | 234 | 5 | 238 | 47.60 | 2 | Poor | 0.000 | 1 | 0.460 |
| P435 | 473 | 8 | 537 | 67.13 | 3.5 | Good | 0.778 | 6 | 0.796 |
| P425 | 481 | 14 | 830 | 59.29 | 3.5 | Good | 1.716 | 6 | 1.891 |
| P424 | 278 | 9 | 647 | 71.89 | 3.5 | Good | 1.204 | 6 | 0.979 |
| P421 | 102 | 8 | 561 | 70.13 | 3.5 | Good | 1.204 | 5 | 1.465 |
| P420 | 595 | 10 | 666 | 66.60 | 3.5 | Good | 1.623 | 5 | 1.550 |
| P411 | 622 | 14 | 761 | 54.36 | 2.5 | Moderate | 2.029 | 5 | 1.543 |
| PHP01 | 1137 | 8 | 276 | 34.50 | 1.5 | Poor | 0.000 | 2 | 0.641 |
| P410 | 449 | 10 | 524 | 52.40 | 2.5 | Moderate | 1.431 | 4 | 1.380 |
| P389 | 1765 | 8 | 318 | 45.43 | 1.5 | Poor | 0.000 | 3 | 0.198 |
| P388 | 816 | 3 | 115 | 38.33 | 1.5 | Poor | 0.000 | 1 | 0.027 |
| P377 | 989 | 1 | 35 | 35.00 | 1.5 | Poor | 0.000 | 1 | 0.000 |
| P376 | 416 | 2 | 88 | 44.00 | 1.5 | Poor | 0.000 | 1 | 0.075 |
| P350 | 15 | 9 | 188 | 26.86 | 1 | Bad | 0.000 | 0 | 1.800 |
| P349 | 33 | 8 | 259 | 37.00 | 1.5 | Poor | 0.301 | 1 | 1.371 |
| P340 | 54 | 3 | 59 | 19.67 | 1 | Bad | 0.000 | 1 | 0.771 |
| PTR01 | 59 | 8 | 304 | 38.00 | 2.5 | Moderate | 0.000 | 1 | 1.664 |
| P339 | 62 | 4 | 100 | 25.00 | 1 | Bad | 0.000 | 0 | 0.416 |
| P328 | 727 | 6 | 147 | 24.50 | 1 | Bad | 0.000 | 1 | 0.313 |
| PPM01 | 20 | 7 | 210 | 35.00 | 1.5 | Poor | 0.000 | 0 | 1.691 |
| P327 | 188 | 8 | 185 | 26.43 | 1 | Bad | 0.000 | 1 | 1.403 |
| P326 | 688 | 11 | 227 | 22.70 | 1 | Bad | 0.000 | 1 | 1.463 |

(continued)

**Table 3 (continued)**

| Site | Abundance | Families | HBMWP | HASPT | HES | HESII | Log10 (Sel_EPTD+1) | EPT taxa | H'-Shannon |
|---|---|---|---|---|---|---|---|---|---|
| P300 | 232 | 11 | 364 | 36.40 | 2 | Poor | 0.000 | 3 | 1.877 |
| P276 | 67 | 11 | 321 | 32.10 | 1.5 | Poor | 0.000 | 0 | 2.092 |
| PCE01 | 136 | 10 | 373 | 37.30 | 2 | Poor | 0.000 | 1 | 1.759 |
| P275 | 98 | 7 | 166 | 27.67 | 1 | Bad | 0.000 | 1 | 1.194 |
| P266 | 232 | 8 | 399 | 49.88 | 2.5 | Moderate | 0.000 | 3 | 1.129 |
| P263 | 244 | 3 | 145 | 48.33 | 2 | Poor | 0.000 | 0 | 0.167 |
| PE01 | 10 | 7 | 260 | 37.14 | 2.5 | Moderate | 0.000 | 0 | 1.887 |
| P223 | 31 | 9 | 334 | 41.75 | 1.5 | Poor | 0.000 | 4 | 1.935 |
| PVU01 | 1462 | 14 | 597 | 42.64 | 3 | Moderate | 0.301 | 3 | 1.337 |
| P222 | 47 | 9 | 336 | 42.00 | 2.5 | Moderate | 0.000 | 0 | 1.255 |
| P206 | 117 | 6 | 249 | 41.50 | 2.5 | Moderate | 0.000 | 1 | 0.838 |
| P205 | 15 | 7 | 288 | 41.14 | 2.5 | Moderate | 0.000 | 2 | 1.732 |
| P202 | 13 | 6 | 270 | 45.00 | 1.5 | Poor | 0.000 | 1 | 1.672 |
| P201 | 17 | 6 | 250 | 41.67 | 2.5 | Moderate | 0.000 | 0 | 1.447 |
| P199 | 29 | 7 | 266 | 38.00 | 2.5 | Moderate | 0.000 | 2 | 1.383 |
| P198 | 208 | 12 | 550 | 45.83 | 2.5 | Moderate | 0.301 | 4 | 1.472 |
| P192 | 11 | 6 | 174 | 29.00 | 1 | Bad | 0.000 | 1 | 1.720 |
| P191 | 248 | 13 | 546 | 42.00 | 2 | Poor | 0.301 | 4 | 1.598 |
| P149 | 128 | 3 | 146 | 48.67 | 2 | Poor | 0.000 | 0 | 0.091 |
| P148 | 870 | 16 | 831 | 55.40 | 3.5 | Good | 0.954 | 4 | 0.472 |
| P148a | 136 | 2 | 86 | 43.00 | 2 | Poor | 0.000 | 0 | 0.043 |
| P144 | 8 | 3 | 158 | 52.67 | 2.5 | Moderate | 0.301 | 1 | 0.736 |
| P144a | 6 | 2 | 59 | 29.50 | 1.5 | Poor | 0.000 | 0 | 0.451 |
| P143 | 12 | 5 | 234 | 46.80 | 3 | Moderate | 0.000 | 1 | 1.474 |
| P088 | 156 | 10 | 379 | 42.11 | 2 | Poor | 0.000 | 1 | 1.550 |
| PT01 | 47 | 7 | 265 | 37.86 | 1.5 | Poor | 0.000 | 3 | 1.078 |
| P086 | 11 | 3 | 37 | 18.50 | 1 | Bad | 0.000 | 1 | 0.760 |
| P085 | 70 | 6 | 213 | 35.50 | 1.5 | Poor | 0.000 | 1 | 1.190 |
| P074 | 113 | 9 | 426 | 47.33 | 2.5 | Moderate | 0.301 | 4 | 1.267 |
| P073 | 37 | 7 | 234 | 33.43 | 1.5 | Poor | 0.000 | 3 | 1.552 |
| P068 | 203 | 8 | 297 | 42.43 | 1.5 | Poor | 0.000 | 3 | 1.165 |
| P062 | 26 | 8 | 374 | 46.75 | 2.5 | Moderate | 0.000 | 1 | 1.571 |
| P061 | 21 | 8 | 236 | 33.71 | 1.5 | Poor | 0.000 | 2 | 1.831 |
| P045 | 81 | 8 | 394 | 49.25 | 2.5 | Moderate | 0.301 | 3 | 1.566 |
| P044 | 102 | 9 | 424 | 47.11 | 2.5 | Moderate | 0.000 | 1 | 1.870 |
| P036 | 124 | 11 | 476 | 47.60 | 2.5 | Moderate | 0.301 | 6 | 1.833 |
| P035 | 155 | 9 | 427 | 47.44 | 2.5 | Moderate | 0.903 | 3 | 1.593 |
| P028 | 67 | 4 | 83 | 27.67 | 1.5 | Poor | 0.000 | 0 | 0.232 |
| P027 | 604 | 2 | 96 | 48.00 | 2 | Poor | 0.000 | 1 | 0.040 |
| P004 | 242 | 11 | 451 | 41.00 | 2 | Poor | 0.000 | 1 | 1.705 |
| P003 | 142 | 8 | 322 | 40.25 | 2.5 | Moderate | 0.000 | 1 | 1.632 |

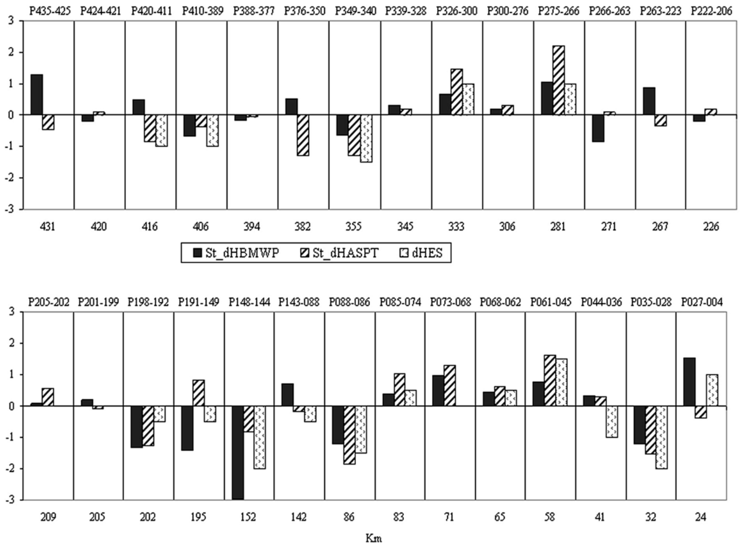


*Fig. 2:* Downstream water quality difference within stretches according to HBMWP, HASPT and HES biotic scores and indices. Bars represent standardized values of differences. Self-purification areas of the Pinios River are identified as the stretches where the water quality recovery is witnessed by positive values for all three indices and scores. Only the Pinios plain stretches are shown. The lower axis refers to the distance from the river mouth.

cles in the river water. As the river continues along the Thessaly plain significant amounts of pollution loads were flowing in from the industrial area located downstream of Larissa. The Titarisios tributary (PT01) receives the waste from the town of Tirnavos and nearby industries. Downstream of the Titarisios confluence, the Rhodia narrows are located (P086-062). At the segments P085-074, P068-062 and P061-045 according to HES values, SP occurred (Figure 2). In the forested area of the Tempi Gorge (P044-028) the significant pollution inputs from the untreated domestic waste from the Agia Paraskevi recreation area prevented the amelioration of water quality. Downstream of the Tempi Gorge, the river enters the delta area where intensive agriculture takes place.

**Table 4**
**Non parametrical (Spearman) correlations of metrics and indices throughout the studied sites (N=80). Marked with a double asterisk are the significant correlations at the P<0.01 level.**

| | HBMWP | HASPT | HES | Number of taxa |
|---|---|---|---|---|
| HBMWP | - | 0.730** | 0.804** | 0.894** |
| HASPT | 0.730** | - | 0.870** | 0.424** |
| HES | 0.804** | 0.870** | - | 0.543** |
| Number of taxa | 0.894** | 0.424** | 0.543** | - |
| Log10(Sel_EPTD+1) | 0.821** | 0.746** | 0.747** | 0.697** |
| EPT taxa | 0.830** | 0.733** | 0.688** | 0.681** |
| H'-Shannon | 0.596** | 0.201 | 0.365** | 0.681** |

All indices and metrics used were significantly correlated ($p < 0.01$) to the 3 Greek indices (Table 4). Therefore the rest of the analysis was carried out solely with the use of family diversity, abundance, and the Greek index and scores.

## Discussion

Self-purification is an important ecosystem function for rivers and should be regarded as an ecological aim for river restoration (LAFONT, 2001; AMOROS, 2001). The rapid yet extensive spatial coverage was an objective of the current study, since sampling the whole river offers among others an identification of the river reaches which have a retention capacity of nutrients, or an increased self-purification capacity (SALVIA *et al.,* 1999). The water quality of the Pinios River progressively degraded from the source to the mouth. According to HES, good water quality samples were taken only from the mountainous area close to the river's source. Forty kilometers downstream, at site P411, the river enters the large plain of Thessaly and the land-use shifts to non-natural. The HES values were low and indicate that medium-low water quality is sustained until the river mouth. However, five stretches of the Pinios (P326-300, P275-266, P085-074, P068-062 and P061-045) were identified as parts of the river where self-purification processes was evident.

Since 90% of the natural floodplain areas of european rivers has been reclaimed and now lacks river-riparian dynamics (PEDROLI *et al.,* 2002) the golden age of restoration science has arrived (ORMEROD, 2004). The perspective of process-oriented restoration approach has been recommended by several authors in the restoration of river systems (AMOROS, 2001; KONDOLF *et al.,* 2006) and self-purification is one of those processes. But, if restoration projects are to succeed and not further harm the riverine processes a comprehensive knowledge that can provide sound criteria for the best techniques must be achieved. Therefore, the impacts the restoration and rehabilitation works have on self-purification must be considered in the management of aquatic systems, particularly in the context of the Water Framework Directive (2000/60/EC) (EU, 2000) which emphasizes conservation or restoration of ecological quality (LAFONT, 2001).

In conclusion, benthic macroinvertebrates helped in the identification of the self-purification stretches of the Pinios river due to their life cycle and their low mobility. The use of biotic indices showed that although the Pinios River is heavily polluted (good or excellent quality is never achieved in the lowland part) self-purification processes do occur. Self-purification stretches must be safeguarded from unjustified works along the river that can harm this process. In order to achieve good water quality in the context of the Water Framework Directive (2000/60/EC) priority should be given to restoration projects along the most degraded stretches, lacking a self-purification capacity.


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