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Performance of a New Ecotoxicological Index to Assess Environmental Impacts on Freshwater Communities

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In general, aquatic environmental factors are stabilized and uniformized according as a river goes down from its source. This gradual stabilization exerts a direct control on the population dynamics of aquatic communities, being able to be differentiated characteristic biological communities within that ecological succession (Illies and Botosaneanu 1963; Hawkes 1975; Margalef 1983; Hellawell 1986). In this way, a natural river can be considered as a functional continuum (Margalef 1960; Vannote et al. 1980). However, human activities are causing environmental impacts on freshwater ecosystems, breaking the functional continuum and modifying the structure of their aquatic communities.

Most environmental factors and pollutants act at level of the individual organism (Lockwood 1976; Hellawell 1986). If an aquatic organism is not adapted to thrive in an environmental disturbance, its ability to grow, reproduce, or compete in the biological community will be affected negatively, being substituted for another one more resistant and better adapted to environmental stress. Nevertheless, the number of species will decrease if the environmental disturbance is excessive and aquatic organisms can not be replaced. So, the cumulative effects of environmental perturbations on many organisms will produce shifts in the species composition.

In this paper is described the performance of a simple ecotoxicological index to assess environmental impacts produced by man's activities on freshwater communities. Some recommendations to facilitate use and interpretation of this new index are indicated.

MATERIALS AND METHODS

The new ecotoxicological index (EI) was derived by totaling the species deficit index (Kothé 1962) and a new species substitution index. The first index measures the percentage difference between the number of species occurring above and below the disturbance point, being equal to "(A-B) × 100/A". The second index measures the species substitution percentage between both places, being equal to "(A-C) × 100/A". The variable "A" is the number of species upstream from the disturbance point, "B" is the number of species downstream from the disturbance point, and "C" is the number of common species to both places. So, this new index measures the rate of environmental impact or toxicity produced by a disturbance point (discharge of pollutants, sewage effluents, dams) on biological communities, assessing generated shifts in number and kind species. This ecotoxicological index takes percentage values between 0 (no environmental impact or toxicity) and 100 (maximum environmental impact or toxicity).

Thus, the mathematical expression of this new ecotoxicological index is equal to:

$$EI = \frac{(2A - B - C) \times 50}{A}$$

This new index was applied to a field research to verify its suitable functional character. The data used in this paper were collected in the regulated and industrial area of the Duratón River (Segovia, Spain) in July of 1987. A sample of the benthic riffle macroinvertebrate community was taken at each of five sampling stations (Figure 1), using a cylinder sampler (Hellawell 1986) which enclosed a sampling area of 0.1 sq m and had a mesh size of 250 µm. All samples were preserved in Formalin (4 %) until their separation, determination, and counting. Fifth (5) and fourth (4) sampling stations were placed about 7.5 and 2.4 km, respectively, downstream from dam and industrial effluent, the third (3) was placed about 300 m downstream from the dam and 50 m downstream from the industrial effluent, the second (2) was placed between dam and industrial effluent, and the first (1) was placed upstream from the dam.

The following biological parameters and indices were calculated: the number of species or species richness, the organism density, the number of common species, the Margalef's diversity index (Margalef 1951), the Shannon's diversity index (Shannon and Weaver 1963), the species deficit index (Kothé 1962), the species substitution index, and the ecotoxicological index. These three last indices were calculated between first and rest of sampling stations.

RESULTS AND DISCUSSION

From Table 1 it can be seen that *Dugesia gonocephala*, *Echinogammarus calvus*, *Oligoneuriella rhenana*, *Protonemura meyeri*, *Agapetus laniger*, *Chimarra marginata*, *Hydropsyche lobata*, *Cheumatopsyche lepida*, *Brachycentrus subnubilus*, *Allogamus ligonifer*, and *Rheotanytarsus sp.* appeared at the first sampling station only.

Species richness, organism density, common species, Margalef's diversity and Shannon's diversity respond inversely with regard to deficit, substitution and ecotoxicological indices (Table 2).

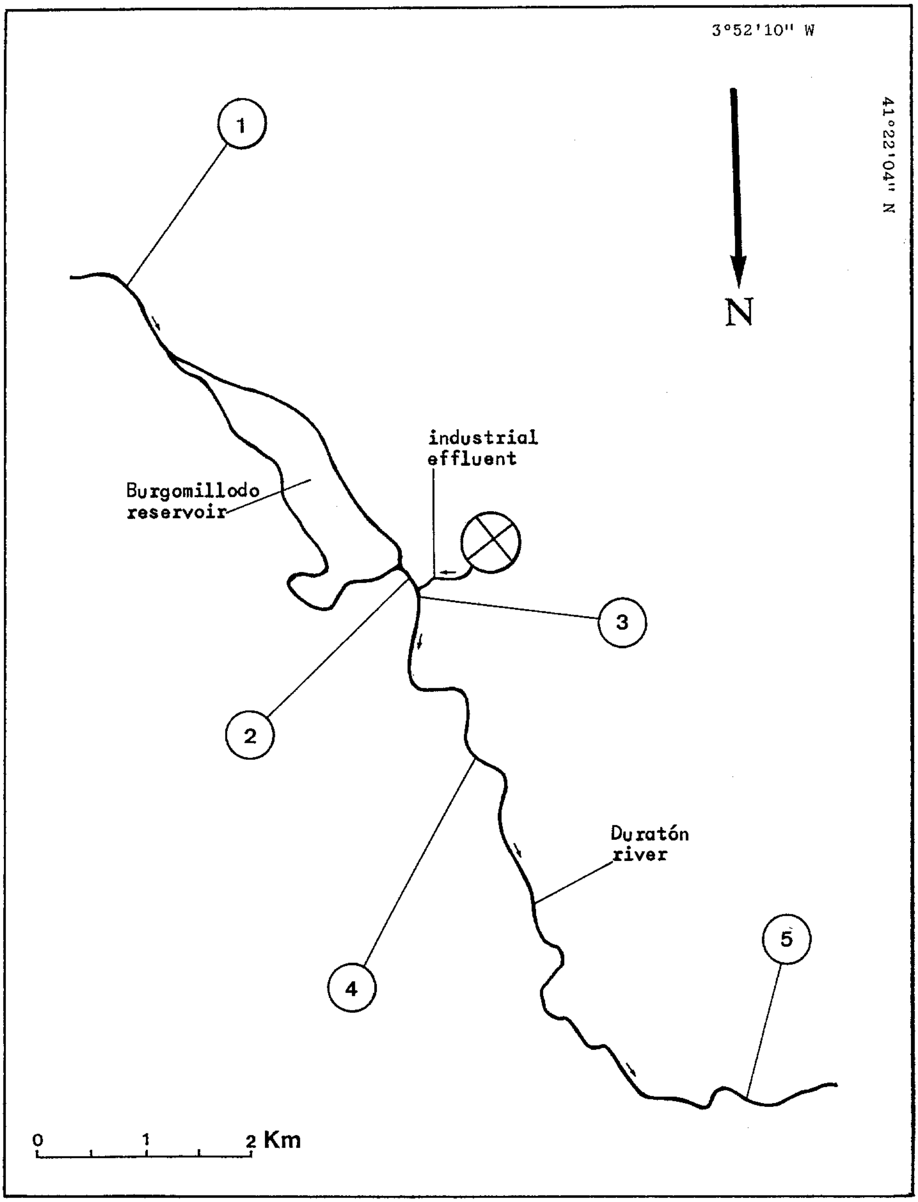

Figure 1. Map of sampling stations in Duratón river.

Linear correlation coefficients between ecotoxicological index and Shannon's and Margalef's indices are r= -0.848 and -0.976 (P<0.01) respectively.

This ecotoxicological index takes intermediate values between deficit and substitution indices, being equal to the species deficit index when there is no substituted species.

Table 1. Abundances of taxonomic groups collected at each of five sampling stations.

Taxonomic groups	Sampling stations 1	2	3	4	5
Dugesia gonocephala	10	–	–	–	–
Ancylus fluviatilis	12	9	–	10	10
Tubificidae	–	3	–	–	–
Erpobdella monostriata	–	20	–	–	3
Echinogammarus calvus	9	–	–	–	–
Baetis fuscatus	12	6	–	14	31
Baetis rhodani	21	3	–	3	18
Oligoneuriella rhenana	148	–	–	–	–
Ecdyonurus sp.	15	–	–	–	4
Ephemerella ignita	20	26	1	21	18
Caenis moesta	6	41	–	4	5
Potamanthus luteus	–	5	–	7	–
Protonemura meyeri	9	–	–	–	–
Capnia bifrons	14	–	–	9	21
Orectochilus villosus	1	–	–	–	1
Elmis maugetii	17	–	–	6	5
Esolus angustatus	10	–	–	–	3
Limnius intermedius	12	–	–	3	7
Limnius opacus	2	–	–	2	–
Oulimnius troglodytes	15	–	–	2	3
Rhyacophila meridionalis	4	–	–	–	1
Rhyacophila munda	1	–	–	1	4
Rhyacophila relicta	1	–	–	2	3
Agapetus laniger	3	–	–	–	–
Chimarra marginata	34	–	–	–	–
Hydropsyche bulbifera	6	–	–	41	23
Hydropsyche exocellata	5	–	–	20	15
Hydropsyche lobata	2	–	–	–	–
Hydropsyche pellucidula	40	–	–	3	–
Hydropsyche siltalai	–	–	–	23	31
Cheumatopsyche lepida	4	–	–	–	–
Polycentropus flavomaculatus	–	7	–	11	3
Psychomyia pusilla	3	–	–	3	13
Brachycentrus subnubilus	2	–	–	–	–
Allogamus ligonifer	1	–	–	–	–
Tipula sp.	1	–	–	–	1
Eusimulium sp.	20	2	–	4	2
Odagmia sp.	48	7	–	10	7
Ablabesmya sp.	–	2	–	–	–
Prodiamesa olivacea	–	6	–	–	–
Diamesa sp.	–	2	–	2	2
Potthastia sp.	2	–	–	–	2
Orthocladius sp.	19	17	6	8	28
Cricotopus sp.	6	10	10	6	21
Camptocladius sp.	8	2	–	3	7
Eukiefferiella sp.	4	3	–	1	1
Rheotanytarsus sp.	4	–	–	–	–
Tanytarsus sp.	3	4	–	–	–
Pentapedilum sp.	1	6	–	2	–
Polypedilum sp.	2	10	1	–	–
Anthomyidae	–	1	–	–	–

Table 2. Values of biological parameters and indices obtained at each of five sampling stations.

Biological parameters	Sampling stations 1	2	3	4	5
Species richness	42	22	4	27	30
Organism density	557	192	18	222	293
Common species	42	14	4	23	26
Deficit index	0.0	47.6	90.5	35.7	28.5
Substitution index	0.0	66.6	90.5	45.3	38.1
Ecotoxicological index	0.0	57.1	90.5	40.5	33.3
Margalef's index	6.49	3.99	1.04	4.81	5.11
Shannon's index	4.28	3.83	1.46	4.10	4.27

The highest value of the ecotoxicological index corresponded with the smallest diversity because effects of dam and industrial effluent act simultaneously on the benthic macroinvertebrate community at the third sampling station. However, the rank of environmental impact decreased with the distance to disturbance points.

For a suitable functional character of this new index it is necessary to use same sampling techniques and habitats at all sampling stations.

The taxonomic identification of species is perhaps the only and major problem in using this index. An alternative to this problem may be to use a similar technique to the sequential sampling method developed by Cairns et al. (1968).

Although this ecotoxicological index is based on the assumption that environmental disturbances produced by human activities decrease the number of species in freshwater communities (Kothé 1962; Rosenberg and Wiens 1976), it could take negative values. This might imply that environmental perturbations can produce beneficial effects on biological communities increasing species diversity.

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