Benthic macroinvertebrates as indicators in lakes

I macroinvertebrati bentonici come bioindicatori nei laghi

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Abstract

Benthic macroinvertebrates are considered to be good indicators of the trophic status of lakes but in the Mediterranean area gaps in knowledge on taxonomical and autoecological traits of species hinder their potential as indicators. Seventy-eight Italian lakes were sampled, belonging to 10 types according to morphometrical, geographical and geological parameters. An unsupervised neural network (SOM analysis) was carried out using 65 Chironomid and Oligochaete species collected in 1865 samples. The accordance between lake types and species assemblages was tested. Indicator weight of species was calculated considering their optima for trophic variables (dissolved oxygen, TP, transparency). A Benthic Quality Index (BQI) and a weighted diversity index were then calculated to test their potential as indicators of trophic status of lakes. Alpine, volcanic and large profundal lakes were separated into different clusters, characterized by different communities, chemical and morphometrical parameters. On the contrary, other lake types with similar trophic status were grouped together, showing similar taxa assemblages. BQI values were in agreement with the trophic condition of lakes, while the weighted diversity index showed low values for alpine lakes due to low species numbers.

Introduction

Benthic macroinvertebrates are currently used in lake monitoring and different indexes were proposed to assess the ecological status of lentic ecosystems (Wiederholm, 1980). A weak point in index formulation is the difficulty to correctly define indicators. There is consensus that identification at the species level is needed to detect changes in community composition. Yet taxonomical and autoecological knowledge of macroinvertebrate species is still scanty, especially for what concerns the fauna of the Mediterranean area.

The most commonly used indicators of trophic status of lakes are Chironomids and Oligochaetes inhabiting soft bottom sediments. These taxa are particularly difficult to identify at the species level, especially when larvae (Chironomids) or immature stages (Oligochaetes) are the only material available. For what concerns Chironomids, the collection of pupal exuviae with a Brundin net was recommended (Ruse, 2002) to improve identification, while for Oligochaetes the collection of mature specimens is needed.

A Benthic Quality Index (BQI) was developed (Wiederholm, 1976) using Chironomid species to assign lakes to 5 trophic classes. *Chironomus plumosus* is characteristic of eutrophic lakes and received a low score (1), while *Heterotrissocladius subpilosus* – characteristic of oligotrophic lakes – received a high score (5). Intermediate scores were used for *Chironomus anthracinus* (2), *Sergentia coracina* and *Stictochironomus rosenschoeldi* (3), *Micropsectra* spp. and *Paracladopelma nigritula* (4). Nevertheless *S. coracina, S. rosenschoeldi* and *H. subpilosus* probably were never collected in Italy, while *Micropsectra* includes many species with rather different indicator values (Rossaro et al., 2009). Therefore, other indicator taxa must be selected for Italian lakes.

Another Benthic Quality Index (BQI) was developed (Wiederholm, 1980) considering Oligochaete species. *Stylodrilus heringianus* and *Rhynchelmis limosella* were considered oligotrophic species and scored 4, *Spirosperma ferox* was scored 3 and *Potamothrix hammoniensis* got a score of 2, while *Limnodrilus hoffmeisteri* was considered a eutrophic species and was scored 1.

Except *Rhynchelmis limosella* which is rare in Italy, the other species can be used as indicators because the are common in Italian lakes. Therefore this BQI can be tested using Italian lakes data without substantial modifications of the species list. The key point is that identification at the species level is necessary.

The aim of the present research is to update weights assigned to Chironomid and Oligochaete taxa in a previous publication (Rossaro et al., 2007a) according to new data collected in Italian lakes. Moreover, a new trophic status index based on a modified diversity index which takes into account total abundances and species weights will be proposed.

Sites and data analysis

A total of 1865 samples were collected with a Petersen, Ekman or Ponar grab in 78 Italian lakes between 5 m and the maximum depth, except the 2007 samples in large lakes (see below). The investigated lakes belong to 10 different types according to morphometrical, geographical and geological characteristics (Buraschi et al., 2005). The database includes historical data collected from the 1950s up to recent times. In 2007-2009 further samples (about 30x30 cm^2 area) were collected in large lakes by scuba divers between 5 and 25 m depth; abundances were converted into densities (individuals m^2). Details about the sampling sites, sampling methods and identification protocols were published elsewhere (Rossaro et al., 2006; 2007a). Chironomid and Oligochaete species present in at least 40 samples were selected for further analysis (65 species).

An unsupervised neural network with a Self Organizing Map (SOM) was calculated (Park et al., 2004). Species and sites were ordered and clustered to generate groups of sites with similar species composition. Environmental data were not used for ordination, but were represented in the map after calculation.

For the 65 species optimum values for dissolved oxygen (O_2), total phosphorus (TP) and transparency (Tr) were calculated as weighted means of O_2, TP and Tr values measured in the sites, where each species was found, considering species abundance as weight; optimum values were rescaled between 0 and 1 and used as Benthic Quality Index Weights (BQIW; Rossaro et al., 2007a). BQIW can be used to calculate a BQI for each site (Rossaro et al., 2007a).

A weighted diversity index (H_w) was then calculated; the BQIW weights were included in the following formula (Ozzola et al., 1992):

$$H_w = \sum_{j=1}^{s} [(n_j/\mathrm{N}) * \log_2(n_j/\mathrm{N}) * \mathrm{BQIW}_j]$$

where s is the number of species found at a site; nj is the number of specimens belonging to species j present at a site; N is the total number of specimens at a site; BQIWj is the indicator weight assigned to species j. In this algorithm both indicator values and total abundances are considered.

Results

Indicator weights of trophic status for the 65 more frequent species are given in table I.

Table I: Benthic quality index weights (BQIW) calculated for 65 species.

C. bicinctus	0	*H. marcidus*	0.5895	*U. uncinata*	0.6876	*P. prasinatus*	0.769
G. pallens	0.2172	*P. choreus*	0.5915	*A. aquaticus*	0.6898	*T. fluviatilis*	0.7796
C. flavicans	0.3016	*L. peregra*	0.6128	*T. gregarius*	0.6926	*P. austriacus*	0.7868
C. vermiformes	0.3489	*P. nigrohalteralis*	0.6129	*P. nubeculosum*	0.6933	*H. stagnalis*	0.789
M. atrofasciata	0.3549	*D. digitata*	0.6195	*E. tendens*	0.7006	*R. coccineus*	0.8006
C. plumosus	0.3562	*S. heringianus*	0.6205	*C. anthracinus*	0.7047	*C. scutellata*	0.8033
P. flavipes	0.469	*D. vulneratus*	0.6452	*P. albimanus*	0.705	*S. ferox*	0.8067
P. acuta	0.4896	*P. barbatus*	0.6455	*M. nebulosa*	0.705	*S. bausei*	0.8307
S. lacustris	0.5034	*M. pedellus*	0.6516	*D. tigrina*	0.7072	*P. orophila*	0.8562
P. hammoniensis	0.5068	*Hydracarina*	0.6538	*S. pictulus*	0.7098	*P. bathophila*	0.8584
Sialis	0.5092	*A. monilis*	0.6552	*A. pluriseta*	0.7108	*P. nigritulum*	1
T. tubifex	0.5145	*V. piscinalis*	0.66	*B. vejdoskyanum*	0.7201		
B. sowerbyi	0.5193	*C. defectus*	0.6632	*P. oxyura*	0.7223		
E. tetraedra	0.535	*P. casertanum*	0.6653	*C. atridorsum*	0.7285		
L. hoffmeisteri	0.5473	*B. sanguinea*	0.6677	*B. tentaculata*	0.729		
P. heuscheri	0.5787	*P. olivacea*	0.6708	*P. camptolabis*	0.7305		
C. annulator	0.5825	*E. stammeri*	0.6768	*C. pallidula*	0.7356		
C. viridulum	0.5855	*D. nervosus*	0.6781	*S. lemani*	0.7684		

The SOM analysis emphasized a good separation of some lake types, in particular alpine lakes, AL-1 and AL-2 types (Buraschi et al., 2005), were separated according to the abundance of *Corynoneura scutellata, Heterotrissocladius marcidus* and *Paratanytarsus austriacus*. Volcanic lakes Bolsena, Bracciano and Vico (ME-7 type) were also separated, being some species (e.g. *Branchiura sowerbyi* and *Cryptochironomus defectus*) more common in volcanic lakes than in other lake types. Volcanic lakes were characterized by high mineral content (conductivity in Fig. 1).

Large lakes such as Maggiore, Garda and Como (AL-3 type) were grouped into a cluster, with water depth as a key factor. *Psammoryctides barbatus* and *Potamothrix hammoniensis* characterized this group, showing high abundances at great depths.

Sites belonging to different lake types but characterized by a high trophic status (high phosphorus and low oxygen level) were colonized by tolerant species, such as *Chaoborus flavicans, C. plumosus* and *C. anthracinus*. Most sites in this group were from lowland lakes belonging to different types (AL-4, AL-5 and AL-6).

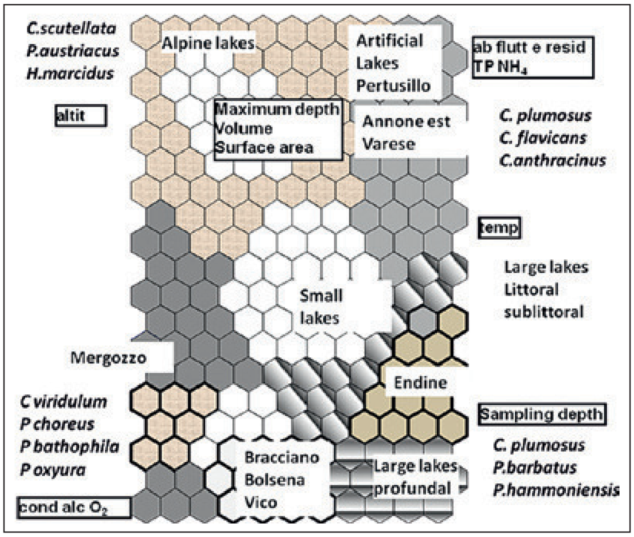

Figure 1: Unsupervised neural networks: Self Organizing Map (SOM) showing site clusters (grey cells), species distribution and environmental variables. altit = altitude, abs flutt = temporary inhabitants, resid = permanent inhabitants, temp = water temperature, cond = conductivity, alc = alkalinity.

Alpine lakes showed the highest BQI index values, whereas small lowland lakes belonging to AL-5 type showed the lowest values, i.e. the most eutrophic status (Fig. 2); the highest values were observed in AL-6 type lakes, here historical data from Mergozzo lake – an oligotrophic lake – were included and contributed to enhance the index; volcanic lakes showed high BQI index values.

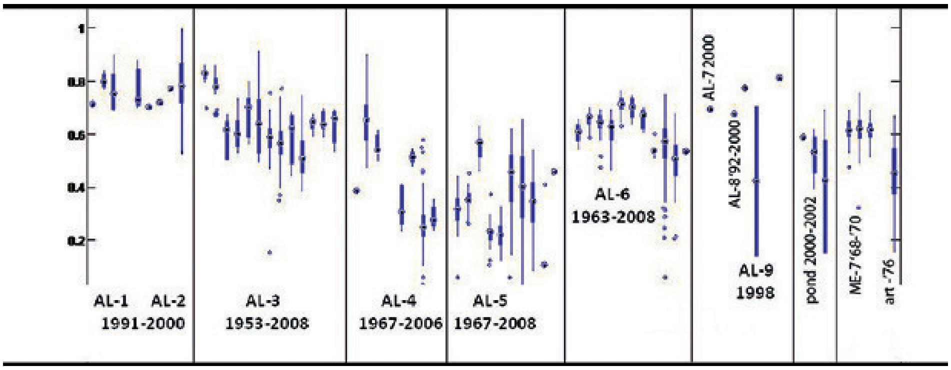

Figure 2: BQI index calculated as mean value for different lake types (Buraschi et al., 2004) and in different sampling years. Points inside bars: median values; points outside bars: outliers; bars: 25 and 75 percentiles.

Diversity weighted index was low for alpine lakes, which showed low species richness due to high altitude and low temperature. The highest values were for the Mergozzo lake (Fig. 3).

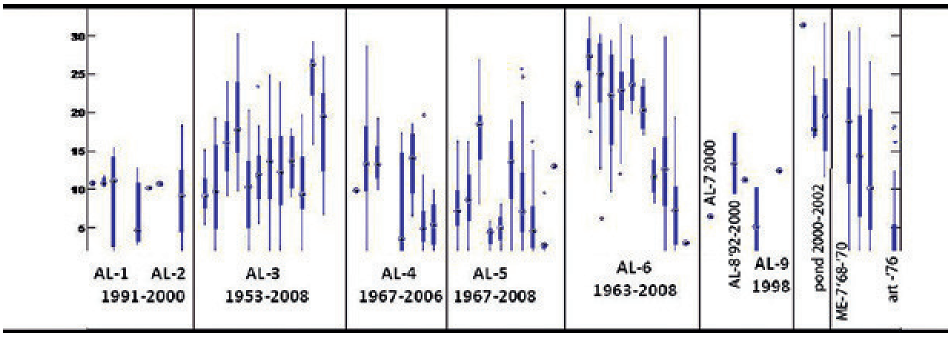

Figure 3: Shannon diversity index modified (see text) calculated for different lake types (Buraschi et al., 2004) and in different sampling years. Points inside bars: median values; points outside bars: outliers; bars: 25 and 75 percentiles.

Discussion

The present analysis emphasized that Chironomids and Oligochaetes are indicators of trophic status of lakes (Wiederholm, 1980) because trophic variables (O_2, TP, Tr, summarized into the BQI index) are strong factors structuring macroinvertebrate taxa composition.

The separation of Italian lakes into types (Buraschi et al., 2005) was supported only in part by benthic macroinvertebrates, since only some types were characterized by different species assemblages. Alpine lakes were separated on the basis of altitude, low temperature and low alkalinity; volcanic lakes were grouped together according to water conductivity (Fig. 1); on the contrary, sublittoral stations from AL-3, AL-5, AL- 6 type lakes were rather similar according to chemical and physical values and according to the macrofauna, therefore it was not possible to separate the three types.

For what concerns the diversity weighted index, the advantage of this algorithm is that both indicator values and total abundances are considered, as requested by the European Water Framework Directive 2000/60/CE. Nevertheless low values were obtained for Alpine lakes notwithstanding the good ecological quality of these lakes (Figs. 2-3). Low values were also obtained for AL-7 and AL-8 type lakes. Moreover, a higher percentile range of the index was obtained in comparison with BQI.

Gaps in taxonomic knowledge are probably the most critical drawback in using benthic macroinvertebrates as indicators of trophic status (and other impacts or pressures) of lakes. Species belonging to the same genus may show a different indicator value, as was emphasized for the genera Orthocladius (Formenti & Rossaro, 2009) and Micropsectra (Rossaro et al., 2009). Recently (Lencioni et al., 2007; Rossaro et al., 2007a; 2007b; Free et al., 2009) an effort was made to fill the gaps in taxonomical and autoecological knowledge, but much research effort is still needed.

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