COMPOSITION AND STRUCTURE OF THE INVERTEBRATE FAUNA IN LITTORAL SANDY SHORES OF LAKE BRACCIANO (CENTRAL ITALY) AND WATER QUALITY MONITORING.

L. Mastrantuono
Department of Animal and Human Biology, Viale dell'Universita 32,00185 Rome, (Italy).

Palabras clave: litorales arenosos, estructuras zoobentos, biomonitorización, lagos.
Keywords: sandy shores, zoobenthos, composition, biomonitoring, lake.

ABSTRACT

The invertebrate fauna associated with littoral sandy substrata in the volcanic Lake Bracciano (Italy), utilized as water supply for the city of Rome, was analysed for one year in twelve sampling stations distributed along the entire lacustrine perimeter. The zoocoenosis comprised 103 identified taxa mainly belonging to oligochaetes, chironomids, nematodes and cladocerans. Oligochaetes and nematodes accounted for most of the collected organisms (76%), followed by a high proportion of copepods (13%). Several other smaller but important groups ensured the diversification of the community. The analysis of a series of simple parameters (diversity indices, N/T ratio, densities of bioindicator taxa), that previous investigations revealed as useful for quality monitoring, provided a diagnosis of acceptable water quality in the marginal area ofthe lake, and contributed to indicating a mesotrophic condition.

INTRODUCTION

Lake Bracciano is one of the largest (51 km^2) and deepest (max. depth: 165 m) italian lakes, located in the volcanic area in the northern part of Lazio Region. The utilization of the lake as a water supply for the city of Rome dates back to ancient times (Emperor Trajan's Aqueduct, built in 110 A.D.). This aqueduct, used uninterruptedly up to the present, has been periodically restored and, during the XVIIIth century, enriched with superficial lacustrine waters in order to compensate for a decrease of the flow. In recent years (1968) the water is purified to make it drinkable in the Rome area. This utilization plan made it necessary, in the years '82-'84, to construct around the lake an o-ring collector of wastes of the surrounding villages. This sewerage system, connected with a sewage treatment plant (BRUNO, 1985; MARTINI, 1985), discharges the waters into the Arrone river, the only effiuent of the lake.

In spite of the absence of substantial organic discharges and of industrial activities along the shores, the presence of some cultivated areas, the increasing use for tourist purposes of the larger sandy beaches and the existence of several inlets discharging into the lake also wastes of private buildings not connected to the sewarege system, represent elements of local microdeterioration of water quality which call for environmental monitoring especially in the littoral, directly subjected to possible pollution phenomenon. Moreover, it must be stressed that the low turnover time of the water (137 years, one of the highest times so far calculated in Italian lakes, GAGGINO *et al.*, 1985), could cause serious problems of lake recovery in the case of heavy pollution.

Given the importance of Lake Bracciano from numerous points of view and also considering its unquestionable role for fishing activities, the small number of papers on its lacustrine fauna is somewhat surprising. The first analyses (LOSITO, 1904; SOMMANI, 1961) referred only to the zooplanktonic community, while multidisciplinary research was carried out in the years 1970-71 by the Hydrobiological Institute of Pallanza (northern Italy) regarding both the chemical and the biological aspects (BARBANTI *et al.*, 1971). The results indicated a good water quality, which was partially confirmed by investigations carried out later by different authors on zooplankton (FERRARA,1982), littoral and profundal macrobenthos (BAZZANTI, 1981) and physico-chemical analyses (GAGGINO *et al.*, 1985).

Such a picture suggested the advisability of undertaking a first analysis of the zoobenthos associated with littoral sand, a community that had already been object of a series of investigations in different lakes of Central Italy (Nemi, Vico, Albano). These studies (MASTRANTUONO, 1986; MASTRANTUONO & LA ROCCA, 1988; MASTRANTUONO,

1995) carried out using the same method and plan in order to facilitate comparison of results, have so far adressed at two aspects: the first aimed at the qualitative characterization of the community (a total of about 200 species have so far been identified), the other one to identify parameters (especially bioindices and boindicators) useful in an environmental diagnosis of both different littoral sites and the marginal lacustrine area as a whole. The results so far obtained have also proved how this type of monitoring can provide valid support for the evaluation of quality status of the entire water body.

STUDY AREA, MATERIALS AND METHODS

Lake Bracciano is located at a height of 164 m a.s.l. in Central Italy (North of Rome). Most of the lacustrine perimeter (31.5 km) is characterized by a week bottom slope and the presence of large sandy zones (Fig. 1) used for bathing activities (the localities of Anguillara, Vigna di Valle, Quarto del lago, Bracciano, Trevignano).

Limited farming activities are carried in the areas of Bagni di Vicarello and Acquarella around the lake. The pipeline of the Paolo-Traiano aqueduct that draws water at a depth of about 50 m is located at station 12 (Fig. 1).

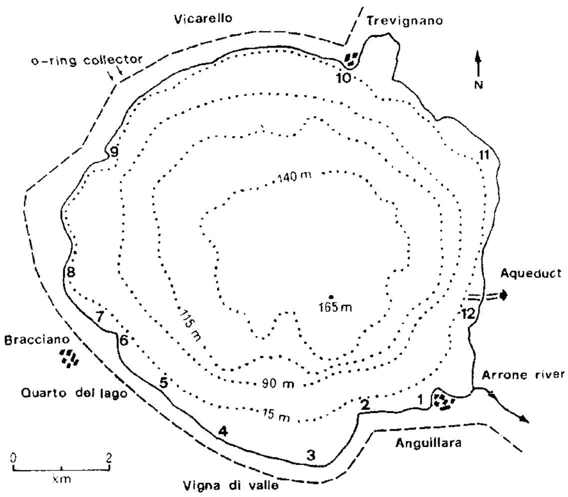

FIGURE 1. Map of Lake Bracciano and location of the sampling sations.

Littoral sandy sediments were collected bimonthly from July 1989 to July 1990 in 12 stations distributed along the entire lacustrine perimeter (Fig. 1). Three replicated samples for each station and date (total: 252 samples) were taken at a depth of 0.5-1 m using a grab (surface area: 42 cm^2) made several years ago by a specialized laboratory (Thalassia - Trieste) according to our indications. 168 samples were used for fauna analysis, the remaining ones for grain size analysis of the sediments. The samples utilized for fauna analysis were preserved in 10% formalin, coloured with bengal rosa and filtered through a net with a mesh size of 180 μm in order to reduce fine sediments. All the invertebrates were then sorted under a stereomicroscope at low magnification. Only when necessary subsamples representing 1/2 or 1/4 of the entire sample were also made.

Numerical data of the two replicated samples for each date and station were averaged. The following indices were applied to the annual mean values: Shannon diversity (MARGALEF, 1957), evenness (PIELOU, 1966), quantitative similarity (PSc, RENKONEN, 1938). PSc data were represented by UPGMA clustering method (SNEATH & SOKAL, 1973).

In order to analyse grain size composition, the samples referring to each station and date (each sample corresponding to 250 gr.) were sieved through the following mesh sizes: 10mm, 5mm, 1mm, 0.5mm, 0.25mm, <0.25mm. The grain size categories were dried at 60 °C for twelve hours to obtain the dry weight. The obtained values were grouped in only four categories to simplify data interpretation.

RESULTS

Physico-chemical characteristics

Temperature and pH values were measured at each date of sampling only in a single station (st. 9). Over the investigation period temperature varied from a minimum of 9°C (January 1990) to a maximum of 27°C (July 1990, Fig. 2), a typical range of variation of surface waters in our regions. Basic pH

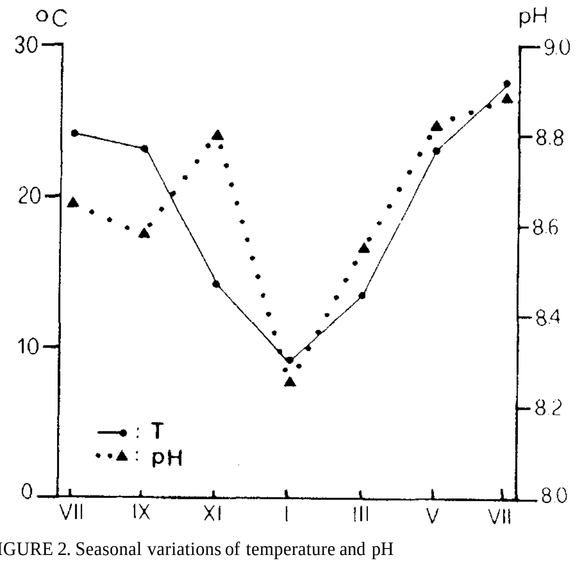

FIGURE 2. Seasonal variations of temperature and pH

values were observed in all seasons, with minimum values in winter according to the trend of the temperature (Fig. 2).

The grain size composition at the sampling stations (Fig. 3) showed a quantitative dominance of fine gravel (5-1 mm) and coarse sand (1-0.25 mm) (according to WEBER's classification, 1973) in the majority of the stations (1, 2, 3, 4, 6, 8, 11, 12). High proportion of fine material were found primarily at st. 9 and secondly at stations 7 and 6. Only st. 8

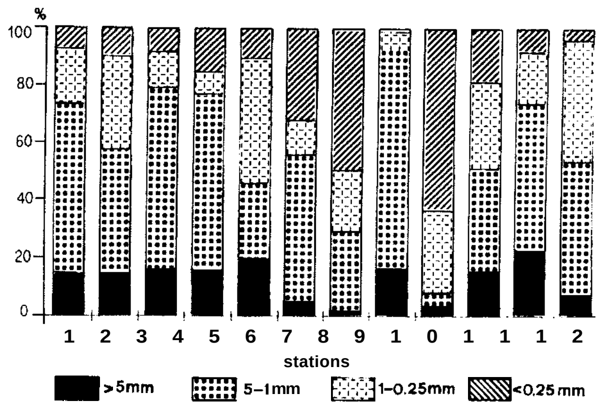

FIGURE 3. Grain size composition (annual means) at the sampling stations.

was characterized by negligible quantities of fine sediments and by high presence of coarse sand.

Fauna composition

The invertebrate fauna is composed of 15 zoological groups comprising a total of 103 identified taxa (63 species, 14 genera and 26 higher taxa, Tab. 3) belonging for the most part to oligochaetes (26 taxa), chironomids (19), nematodes (18) and cladocerans (11).

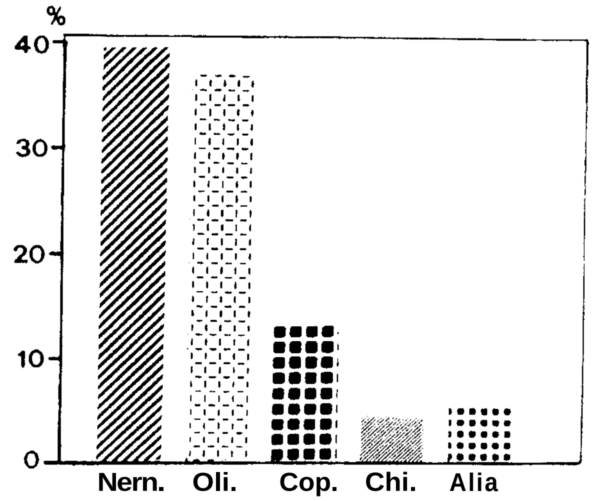

FIGURE 4. Percentage composition of the total fauna (cumulative data). Nem.: Nematoda; Oli.: Oligochaeta; Cop.: Copepoda; Chi.: Chironomidae.

As extensively documented in my previous investigations (MASTRANTUONO, 1986, MASTRANTUONO & LA ROCCA, 1988; MASTRANTUONO, 1995, MASTRANTUONO & BALDETTI, 1996a, 1996b), the community structure of lacustrine sandy substrata is strongly characterized by an Oligochaeta-Nematoda-Crustacea-Chironomidae association, followed by several faunal groups which represent a smaller but important component. In Lake Bracciano oligochaetes and nematodes, both characterized by a high degree of diversification, together represented about 76 % of the total fauna (Fig. 4). These dominant groups are associated with a remarkable abundance of copepods (13%), while chironomids, which generally represent a typical and important component of the sediment community, were found to be scarce (5%).

Table 1 Annual mean densities (ind. m^{-2}) of the zoological groups found in littoral sand of Lake Bracciano

Stations	1	2	3	4	5	6	7	8	9	10	11	12
Turbellaria	1819	4641	102	374	1717	340	935	2618	544	629	1717	1513
Nematoda	8908	2295	4624	16694	30107	2516	291652	2006	43775	9146	35003	1955
Oligochaeta	13209	43367	3451	6409	140420	8602	107270	25959	9350	6987	31331	24752
Hirudinea	-	-	17	-	-	-	-	-	-	17	-	-
Gastropoda	-	-	-	-	-	17	221	102	119	68	102	-
Bivalvia	-	17	-	-	-	-	34	17	-	-	-	51
Hydracarina	204	17	289	119	595	5066	272	663	2686	544	510	1377
Cladocera	255	68	238	187	238	153	5695	340	136	663	2771	357
Copepoda	2091	136	1700	1989	1224	4216	109599	5746	5202	6443	12240	1207
Ostracoda	153	204	442	272	136	5151	10302	391	1037	306	629	1105
Amphipoda	-	85	272	357	136	323	2465	170	646	85	544	68
Ephemeroptera	17	-	17	-	-	-	391	391	-	34	102	-
Trichoptera	-	-	17	-	-	-	34	-	-	-	34	-
Diptera Chironomidae	323	136	527	986	2244	1258	41548	935	2346	714	6460	306
Diptera Ceratopogonidae	-	-	17	17	68	-	-	51	34	-	51	17
Total	26979	50966	11713	27404	176885	27642	570418	39389	65875	25636	91494	32708

Table 2. Percentage values of the zoological groups found in littoral sand of Lake Bracciano

Stations	1	2	3	4	5	6	7	8	9	10	11	12
Turbellaria	6.7	9.1	0.9	1.4	1.0	1.2	0.2	6.6	0.8	2.4	1.9	4.6
Nematoda	33.0	4.5	395	609	17.0	9.1	51.1	5.1	664	357	38.3	6.0
Oligochaeta	49.0	85.0	29.5	23.4	79.4	31.1	I8 8	65.9	14.2	27.2	34 2	75 7
Hirudinea		-	0 2	-					-	0.07	-	
Gastropoda					-	0.06	0.04	0.3	0 2	0 3	0.1	-
Bivalvia	-	0.03	-			-	0.01	0.04	-		-	0.2
Hydracarina	0.8	0.03	2.5	0.4	0 3	183	0.05	1.7	4.0	21	0.6	4.2
Cladocera	1.0	0.1	2.0	0.7	0.1	0.6	1.0	0.9	0.2	2.6	3.0	1.9
Copepoda	7.7	0.3	14.5	7.3	0 7	15.2	192	14.6	7.9	25 1	13 4	3 7
Ostracoda	0.6	0.4	3.8	1.0	0.08	18.6	1.8	1.0	1.6	1.2	0.7	3 4
Amphipoda	-	0.2	2.3	1.3	0.08	1.2	0.4	0.4	1.0	0 3	0.6	0.2
Ephemeroptera	0.06	-	0.2	-		-	0.07	1.0	-	0 1	0.1	-
Trichoptera		-	0.2	-		-	0.01	-		-	0.04	-
Diptera Chironomidae	1.2	0 3	4.5	3.6	1.3	4.6	7.3	2.4	3.6	2.8	7 0	0.9
Diptera Ceratopogonidae	-	-	0.2	0.06	0.04	-	-	0.1	0.05	-	0 06	0.05

Oligochaetes is the predominant group both qualitatively and quantitatively (Tables 1-2-3). Naidids comprise most of the oligochaete species (18), followed by tubificids (5) and aeolosomatids (1). All tubificid species found during this study had already been recorded in the lake in previous investigations on littoral and profundal macrobenthos (NOCENTINI, 1973, BAZZANTI, 1981; BONACINA et al., 1992), while most part of the naidid species have been identified in the lake for the first time during this study and it is probably related to both a major presence of these worms in marginal sediments and a more extensive sampling. The distribution of the species at the stations have shown considerable differences because some of them were widely colonized by oligochaetes (stations 11, 8 and 7 with 22, 20 and 18 taxa respectively), while in several others a low number of taxa was observed (at st. 2 only 4).

Quantitatively the group reached its highest densities at station 5 (a.m.: 140420 ind.m^{-2}, 73.4% of the total fauna) where Enchytraeidae constituted nearly the total of the oligochaetes (95%), and then at station 7 (a.m.: 107270 ind.m^{-2}, representing only 18.8% of the total fauna) mainly due to high abundances of some naidids (Chaetogaster diastrophus, Amphychaeta leidygii and Nais elinguis). Other stations have shown presences of oligochaetes remarkably lower except for st. 2 (a.m.: 43367 ind. m^{-2}) characterized by high abundances of Enchytraeidae (78% of the total oligochaetes). This latter group, immature tubificids with hair chaetae and Chaetogaster diastrophus have found to be the dominant taxa, present everywhere (Tab. 3). Moreover, naidids have shown densities higher than tubificids in 7 of the 12 stations (from st. 2 to st. 8).

Nematoda were the other largely dominant component. Exceptionally high densities of these organisms characterized the station 7 (a.m.: 201652 ind.m^{-2}, the highest value of the entire study), but high abundances were observed also in some other stations (9, 11 and 5, Tables 1 and 2). The percentages of the group showed a trend inversely related to that of the oligochaetes ($r=-0.80$, $p<0.01$). This inverse correlation, already observed in both Lake Vico and Lake Albano, certainly points to opposite ecological role of the two groups, a phenomenon that still awaits explanation, mainly as a consequence of scanty data on the ecological requirements of nematodes in lacustrine waters. Nematoda, identified in Lake Bracciano for the first time, comprise several taxa (18) extensively distributed along the shores. *Theristus setosus, Tobrilus stefanski* and *Ethmolaimus pratensis* represent the dominant species (Tab. 3). Secondly, some other species *(Morzhystera stagnalis, Tripyla glomerans, Chromadorita leuckarti* displayed both wide distribution and considerable densities almost at some of the colonized stations. A tendency of nematodes toward major dispersion along the shores in comparison to oligochaetes (Tab. 3) is another aspect already recorded in other lakes (Albano and partly Vico) and which could represents a further indication of a different relationship of the two faunal groups with the sediments from both the spatial and the trophic points of view.

Copepoda (13% of the total fauna, range at the stations: 0.3-25.1%), constitute the third large component of the community. As shown in Tab. 2, the higher percentages were found in stations located in only one part of the lake (st. 6-7-8-10- 11) and the maximum densities at st. 7 (109599 ind.m^{-2}). *Harpacticoida,* which are mainly associated with sandy substrata, represented in densities the dominant copepods, but also cyclopids, characterized by species which inhabit different freshwater environments and types of substrata, displayed a substantial although localized presence (Tab. 3).

Other crustaceans showed a non secondary qualitative and quantitative presence in the lake. Among them, Ostracoda (6 taxa, 1.7% of the total fauna), *Cladocera* (9 taxa, 1% of the total fauna) and *Amphipoda (Echinogammarus* sp.), the latter found in such densities only in the sandy littoral of Lake Albano (MASTRANTUONO, 1995).

Chironomids attained in Lake Bracciano very low percentages *(5%* of the total fauna, range: 0.3%- 7%) and abundances with the sole exception of st. 7 (41548 ind. m^{-2}). All genera, excluding *Paratanytarsus* sp., *Einfeldia* sp. (?) and *Paracladopelrna* sp., had already been found in the lake. *Polypedilum breviantennatum* is the only chironomid present everywhere and also the most abundant one. Other *Chironominae (Einfeldia* sp. (?), *Cryptochironornus* sp., *Paracladopelrna* sp. and *Stictochironomus* sp.) displayed wide distribution but high densities only in some stations, while *Orthocladiinae* and *Tanytarsini* showed reduced presence.

Of other faunal groups *Turbellaria* (1.5% of the total fauna) and *Hydracarina* (1%) contribute to forming a diversified community structure. Gastropods occurred instead in only one sector of the lacustrine perimeter (stations from 6 to 11), while all the remaining faunal groups showed occasional presence.In order to test the degree of similarity among stations PSc analysis was applied (calculated on the annual mean densities of the taxa). The cluster representation of the PSc matrix (Fig.

Table 3. List of the identified taxa and densities (annual **mean,** ind. m-') at the sampling stations of Lake Bracciano.

Stations	1	2	3	4	5	6	7	8	9	10	11	12
Turbellaria	1819	4641	102	374	1717	340	935	2618	544	629	1717	1513
Nematoda												
Monhystera stagnalis Hastian	-	-	17	-	17	17	42194	17	578	306	3638	17
Theristus flevensis Schuurmann-Stekkoven	-	-	119	187	5474	34	-	-	748	68	85	-
Theristus setosus (Bütschli)	4284	1717	3128	14382	11254	1598	158899	561	21760	918	14229	1377
Aphanolaimus aquaticus Dadav	34	-	17	-	136	68	102	17	289	17	-	68
Ethmolaimus pratensis De Man	68	51	119	612	748	289	72386	935	578	1105	1428	68
Chromadorita leuckarti (De Man)	34	17	17	527	629	34	6069	-	289	51	391	51
Tripyla filicaudata De Man	-	-	-	-	918	-	-	-	1411	-	-	-
Tripyla glomerans Bastian	2176	153	34	-	289	221	4352	306	306	170	1853	17
Tobrilus pellucidus (Bastian)	17	-	-	-	6851	17	1547	-	425	17	340	-
Tobrilus stefanski (Micoletski).	2159	323	1139	969	952	17	4845	119	13736	3893	11934	187
Ironus tenuicaudatus De Man	17	17	-	-	1938	-	204	-	85	-	459	17
Mononchus aquaticus Coetzee	-	-	-	-	17	-	-	-	-	-	-	85
Mylonchulus sigmaturus (Cobb)	-	-	-	-	-	-	-	-	34	34	-	17
Paractinolaimus macrolaimus (De Man)	-	-	-	-	-	17	-	-	-	-	-	-
Tobrilus sp.	-	-	-	-	-	-	-	-	2890	2414	51	-
Plectus sp.	-	-	-	-	85	-	-	-	85	34	34	-
Dorylaimina gen sp	119	17	34	17	799	204	1054	51	204	119	561	51
Chromadorida undet.	-	-	-	-	-	-	-	-	357	-	-	-
Oligochaeta												
Aeolosoma *hemprichi* Ehremberg	340	-	-	-	2482	493	2601	238	867	969	561	17
Chaetogaster diastrophus (Gruithuisen)	1309	2295	374	119	1734	4726	45713	7531	1649	595	6460	901
Chaetogaster diaphanus (Gruithuisen)	-	-	17	-	17	17	170	340	-	102	34	-
Amphichaeta leydigii Tauber	-	-	289	2397	357	34	30379	51	952	17	34	-
Uncinais uncinata (Oestedt)	17	-	-	-	-	-	-	-	-	-	34	-
Pristina aequiseta Bourne	-	-	-	-	119	34	17	51	-	51	-	-
Pristina longiseta Ehremberg	-	-	-	-	17	-	-	17	-	204	442	51
Pristina foreli Piguet	34	-	-	-	-	34	17	102	-	102	340	34
Aulophorus sp.	-	-	-	-	-	-	-	-	-	119	34	-
Dero digitata Udekem	-	-	-	-	-	-	-	-	-	-	34	-
Stylaria lacustris (L.)	-	-	-	-	-	-	-	-	-	17	-	-
Nais communis Piguet	-	-	-	-	-	17	-	102	-	-	34	-
Nais variabilis Piguet	-	-	119	272	102	187	34	187	357	289	340	-
Nais christinae Kasparzak	85	-	187	204	34	17	187	1054	-	187	187	-
Nais *pardalis* Piguet	-	-	-	-	-	17	4284	85	-	-	-	-
Nais bretscheri Michaelsen	-	-	-	-	-	34	1054	153	-	-	51	
Nais elinguis Müller	85	-	-	-	170	102	11322	4913	-	68	4386	68
Nais simpler Piguet	-	-	-	17	17	-	-	-	-	-	17	-
Nais barbata (Müller)	-	-	-	-	102	-	1037	510	-	136	170	-
Branchiura sowerbyi Beddard	-	-	17	-	-	-	34	68	-	-	51	-
Psammoryctes barbatus (Grube)	-	-	-	-	-	-	85	51	510	-	136	-
Potamothrix heuscheri (Bretscher)	102	-	-	-	-	-	-	-	-	-	-	-
Potamothrix hammoniensis (Michaelsen)	136	-	-	-	-	68	102	102	-	-	102	34
Limnodrilus hoffmeisteri Claparède	17	17	-	-	119	17	5066	1989	-	2125	6341	187
Imm. tubificids with hair chactae	4403	1003	204	17	2448	2499	4981	6936	4590	1309	11084	2754
Enchytraeidae	6681	40052	2244	3383	132702	306	187	1479	425	697	459	20706
Hirudinea												
Erpobdella sp	-	-	17	-	-	-	-	-	-	17	-	-
Gastropoda												
Theodoxus fluviatilis (L)	-	-	-	-	-	-	153	51	17	-	-	-
Bithynia tentaculata (l,.)	-	-	-	-	-	-	34	-	-	68	102	-
Lymnaea peregra (Müller)	-	-	-	-	-	-	34	34	102	-	-	-
Viviparus sp	-	-	-	-	-	17	-	17	-	-	-	-
Bivalvia												
Pisidium sp.	-	17	-	-	-	-	34	17	-	-	-	51

Table 3. continued

Hydracarina											
Lebertia sp.	-	-	-	-	17	-	221	-	272	-	187
Limnesia sp.	-	-	-	34	-	-	-	-	-	-	17
Neumania sp	-	-	17	-	-	-	-	-	34	-	-
Arrhenurus sp.	-	-	-	-	-	34	-	-	-	-	-
Oribatei	204	17	272	85	578	5032	51	663	2380	544	306
Cladocera											
Bosmina longirostris (O.F.Müller)	17	17	68	51	-	-	-	34	-	306	17
Iliocryptus agilis Kurz	-	-	-	-	-	-	238	-	-	17	-
Alonella excisa (Fisher)	85	-	51	-	-	-	-	34	34	-	-
Chydorus sphaericus (O.F Müller)	51	34	-	34	-	34	-	51	34	17	-
Monospilus dispar Sars	-	-	17	-	-	-	68	-	-	119	85
Leydigia acanthocercoides (Fischer)	-	-	-	-	-	-	1343	-	-	-	136
Acroperus harpae (Baird)	51	17	34	85	-	85	-	85	-	34	17
Alona rectangula Sars	51	-	34	-	17	-	1071	17	-	17	2329
Copepoda											
Macrocyclops albidus (Jurine)	-	-	-	-	-	-	17	17	-	-	-
Eucyclops serrulatus (Fisher)	-	17	918	255	-	-	-	-	-	-	-
Eucyclops macruroides (Lilljegorg)	425	-	-	17	17	-	204	-	-	68	-
Paracyclops fimbriatus (Fisher)	34	-	425	1037	-	-	1666	51	-	782	4539
Diacyclops bisetosus (Rehberg)	102	-	-	-	-	-	-	408	17	-	-
Harpacticoida	1530	119	357	680	1207	4216	107712	5270	5185	5593	7701
Ostracoda											
Darwinula stevensoni (Br. & Rob.)	68	102	391	187	17	2601	5916	136	901	102	425
Cyprio ophtalmica (Jurine)	-	-	-	-	-	374	-	51	17	-	-
Cypridopsis vidua (O.F. Müller)	-	-	-	-	-	102	51	68	-	136	-
Lymnocythere sp.	34	34	51	51	119	2023	1479	85	85	34	-
Ilyocypris sp	17	68	-	-	-	34	2720	17	-	17	170
Candona sp.	34	-	-	34	-	17	136	34	34	17	34
Amphipoda											
Echinogammarus sp.	-	85	272	357	136	323	2465	170	646	85	544
Ephemeroptera											
Boetis sp.	-	-	17	-	-	-	-	-	-	-	-
Caenis sp.	17	-	-	-	-	-	391	391	-	34	102
Trichoptera											
Ecnomus tenellus (Rambur)	-	-	17	-	-	-	34	-	-	-	17
Diptera Chironomidae											
Psectrocladius sp.	-	-	-	-	-	-	-	17	17	-	-
Cricotopus sp	-	-	-	-	901	102	1496	510	-	272	238
Orthocladiinae indet.	51	-	17	17	17	17	-	119	-	119	17
Procladius sp	-	-	-	-	-	-	289	-	-	-	136
Pentaneurini	17	-	-	17	-	-	-	-	-	-	-
Tanytarsus sp.	-	-	17	-	34	-	833	34	-	-	34
Cladotanytarsus sp.	-	-	-	17	204	17	17646	-	-	-	34
Paratendipes sp	-	-	34	-	-	119	391	-	238	-	-
Paratanytarsus sp.	-	-	-	-	-	-	34	-	-	-	-
Stictochironomus sp.	34	51	34	85	459	85	1428	-	170	-	1853
Endochironomus sp	-	-	-	-	-	-	17	-	-	-	17
Polypedilum breviantennatum Chernovski	85	51	136	119	221	459	11679	102	1003	187	3536
Polypedilum bicrenatum g.	68	17	-	-	-	-	17	-	-	-	17
Dicrotendipes nervosus gr.	-	-	-	17	-	-	-	-	-	34	-
Einfeldia sp. (?)	-	17	187	629	340	391	3400	102	680	-	204
Cryptochironomus sp.	68	-	51	51	34	34	3196	34	153	34	357
Pamcladopelmo sp.	-	-	34	17	34	34	986	17	85	68	34
Parachironomus sp.	-	-	-	17	-	-	-	-	-	-	-
Cladopelma laccophila g.	-	-	-	-	-	-	153	-	-	-	-
Diptera Ceratopogonidae	-	-	17	17	68	-	-	51	34	-	51

5) displayed a dishomogeneous association of the stations, unrelated to their spatial localization.

Four groups of stations were identified, three of which characterized by a similarity lying between 50% and 60%. Only the stations 2-5-12 were found to be very similar and clearly different from the others. In order to account, at least partially, for this unexpected aggregation among distant stations, PSc analysis was applied also to grain size data (based on annual mean values of all four categories). As can be observed in Fig. 5 cluster representation shows some partial but interesting correspondences with PSc analysis on faunal data. The comparison highlights the existencc of three groups (principally the stations 2-5- 12 but also the stations 1 -34 and 7-9) which in both cases proved to be associated. It thus seems possible to consider sediment composition as one important factor that can influence the structure of the community as a

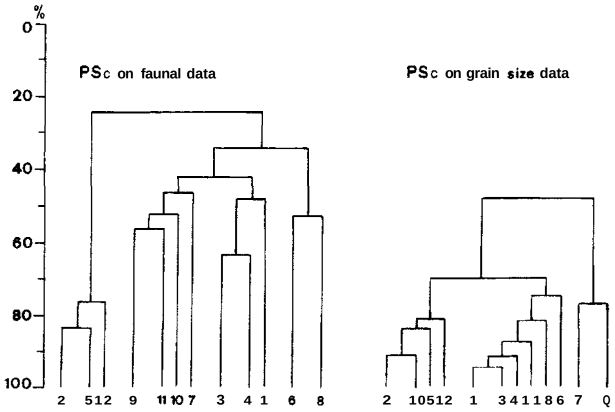

FIGURE 5. Cluster representation of PSc analysis on faunal data (annual mean densities of the taxa) and on grain size data (annual means).

whole, while the attempt to identify single species or faunal groups more strongly influenced by grain size composition using PSc analysis gave results not completely reliable. As a matter of fact, the complex issue of relations between sediment composition and benthic community, which has been studied by several authors from different viewpoints (JUGET, 1979; COLE & WEIGMANN, 1983; McMURTRY et al, 1983; VODOPICH & COWELL, 1984; WINNELL & JUDE, 1984; MASTRANTUONO & BALDETTI, 1996b) unfortunately produced discordant elements of evaluation and the ensuing wide-ranging discussion is still far from indicating any resolution. So, in spite of the obvious existence of these relations, it appears very difficult explain at present how sediment composition influences the organisms who live in.

DISCUSSION

The role that sediment-associated communities play in the evaluation of trophy or of environmental quality of a lake has been defined in the specialized literature from many years by a large

Table 4. Some significant parameters of the zoobenthos living in littoral sand of Lake Bracciano in an evaluation of environmental quality. (O/O+C: Wiederholm index).

Stations	1	2	3	4	5	6	7	8	9	10	11	12
Number of taxa	42	27	45	39	49	51	66	61	48	57	67	37
Diversity (H)	3.4	1.3	3.8	2.8	1.8	3 7	3.5	3.8	3.5	4.2	4.1	2.3
Evenness	0.6	0 3	0.7	0.5	0.3	0 7	0.6	0.6	0.6	0.7	0.7	0.4
O/O+C (%)	93.5	96.1	69.6	75.4	77.5	86.8	72.0	96.3	79.2	89.8	827	930

body of evidences (SAETHER, 1979, 1980; KANSANEN et al., 1984; CROZET, 1985; SARKKA, 1992, 1994; GERSTMEIER, 1989: PETRIDIS, 1993: RAZZANTI et al, 1994). The extension of this approach also to littoral nTUONO, 1995) which has been made to verify the application of some evaluation criteria (bioindices and bioindicators) widely tested for sublittoral and profundal zoobenthos.

Oligochaeta and *Diptera Chirorzomidae,* the dominant organisms in the sediments, represent the main organisms used for quality monitoring. However, in marginal areas the community structure is more complex due to the presence of several faunal groups. The complexity of the system, associated with less restrictive environmental conditions, makes it difficult to identify significant evaluation parameters. The investigations I have carried out so far on this biocoenosis (literature cited) allow a combined series of simple parameters to be selected that proved some indication of quality with sufficient reliability as regards both the sampling site and the entire lacustrine perimeter.

A summary of some of these parameters is given in Tab. 4. They consist of bioindices (species richness, Shannon diversity, evenness, Wiederholm index) and density values (expressed as annual means) of bioindicator taxa. In addition, a simple index (NIT ratio) recently proposed will be used (MASTRANTUONO, 1995).

Species richness has a meaning especially if we consider the total number of identified taxa, which in Lake Bracciano (103) is partly satisfactory if we take into account the considerable size of the lake. The number of taxa at the stations (Tab. 4) showed a good longshore dispersion, although greater species richness can be observed in the North of the lake (st. 7-8-10-11, range: 37-66 taxa), while several stations (1-2-3-4-5) located in the large beaches of the southern part are characterized by a lower number of taxa (range: 27-49). A particularly low value was observed only at st. 2 (27 taxa), probably as a consequence of the large quantitative prevalence of *Erzchytraeidae,* which strongly affect the community composition. The values of H and evenness, that proved to be a good parameter of evaluation, were found to be relatively high everywhere (Tab. 4): H actually reached values higher than 3.4 in 8 of the 12 stations and also higher than 4 in two of them. Only the stations 2-5-12 were characterized by low diversity and evenness due to the large quantitative predominance of Enchytraeidae. If we examine these first observations referring to species composition, the commu-nity appears to be, excluding a few stations, quite well diversified and quantitatively well structured, with some sites characterized by excellent situation.

Table 5. Comparison of some parameters of evaluation in the studied lakes. Tub ind.: indicators tubificids. Diversity and evenness are expressed as mean value among stations. Data of Lake Vico refers to a recent, still unpublished study.

Lakes	Nemi	Albano	Vico	Bracciano
number of taxa	65	79	100	103
Diversity (H)	2.7	3.2	3.0	3.2
evenness	0.5	0.6	0.6	0.6
N/T ratio	2.0	2.6	2.4	3.6
Total fauna (range, ind/m²)		8789-29257	27314-94381	11719-570418
Tub.ind. of eutrophy (ind/m²)		884-4658	536-12376	17-17527
Tub.ind. of eutrophy (%)	1.6-71.9	3.0-27.0	3.0-13.1	0.06-19.1
number of molluscan taxa	0	4	5	5
number of cladoceran taxa	1	5	7	8
trophic level	eutrophy	mesotrophy	mesotrophy	mesotrophy

The total densities of invertebrates, which can provide general but interesting information on the productive level of the substrate, covered a wide range (11719-570418 ind.m^{-2}) varying from values typical of oligotrophic condition (st. 3) to exceptionally high values (st. 7-5-11), that can be considered characteristic of a productive situation. But, in the majority of stations the observed densities were typical of a rich community indicative of a mesotrophic condition (range: 25636-65875 ind. m^{-2}), as can be seen also from the comparison with previously collected data for lakes in Central Italy (Tab. 5 and, for detailed data, see also literature cited).

Oligochaeta, both as group and species, have so far proved to be the best bioindicator taxa. Moderate density values (annual mean) of these organisms were observed in most of the stations except for st. 5 and 7 (Tab. 3). Three species of tubificids *(Limnodrilus hoffmeisteri, Potarnothrix heuscheri, Potamothrix hammoniensis)* and one naidid *(Nais elinguis)* considered in high densities as indicators of eutrophy (LANG & LANG-DOBLER, 1979; LEARNER 1979; MILBRINK, 1983; LANG, 1984; JONASSON. 1984; BAZZANTI & SEMINARA, 1985) are found in Lake Bracciano. The immature tubificids, belonging to Potamothrix species were relatively abundant (Tab. 3) in almost all stations, while both N. *elinguis* and *I. hoffrneisteri* displayed relatively high densities only in a few stations and were completely absent in several others. In any case, the presence of each species of bioindicator oligochaetes was found to be less than 20000 ind. m^{-2} (annual mean) and 25% of the total fauna, that are the values proposed, on the grounds of all my previous studies, as the limit for identifying an eutrophic condition in a littoral site.

A further indication of quality level in sandy shores can be represented by the NIT ratio (number af naidid species/number of tubificid species, calculated only on all the identified oligochaete taxa). My observations point to a tendency towards a reduction of naidid species (typical of littoral zones) and an increase of tubificid species (more typical of profundal sediments) with increasing trophy. The interest of such a simple qualitative ratio may be related to the observations of other authors who evidenced increasing densities of tubificids in littoral zones subject to eutrophication (SARKKA, 1983). The N/T ratio in Lake Bracciano (3.6), the highest so far observed in lakes of Central Italy (Tab. 5), seems indicative of a non alteration of the natural composition of the oligochaete community. A separate discussion should be devoted to the notable presence in these sediments of *Oligochaeta Enchytraeidae,* whose trophic role is far from having been clarified, although some authors (MAITLAND & HUDSPITH, 1974; WHITESIDE & LINDEGAARD, 1982) have recognized that this group, for its abundance, can be considered an important component in littoral sediments.

Exceptionally low densities and percentages of chironomids have been recorded in the lake. Also the presence of *Procladius* sp., the only chironomid indicator of eutrophy (SAETHER, 1980) found in the community, was scarce and rare. The low densities of these dipterans cause a rise in the values of the O/O+C index *(Oligochaeta* density/*Oligochaeta+Chironomidae* density, WIEDERHOLM, 1980) which exceeded 90% in some stations (1-2-8-12) *(Enchytraeidae* density was excluded from the computation as being completely unrelated to the formula of the index). Such situation supports some observations already emerged in my previous analyses that indicated the reduced importance of this index for sandy sediments. where chironomids have revealed quantitative presence strongly variable. But, in spite of the low abudances of chironomids observed in the lake, the high number of chironomid taxa (19) must be considered a positive element for the quality evaluation.

With reference to bioindicators, it must be emphasized the positive presence of molluscan taxa. As extensively discussed in a previous paper (MASTRANTUONO, 1995) several studies have clarified the role of these organisms as bioindicators of good quality mainly in sublittoral and profundal sediments (CLARKE, 1979a, 1979b; MOUTHON, 1981, 1986, 1992; SAVAGE & GAZEY, 1987). Although the abundance of these organisms is generally low in lacustrine sandy littoral, their finding is in any case significant because in Lake Bracciano have been found 5 molluscan taxa (4 gastropods and 1 bivalve), a number that characterizes other lakes in good environmental conditions (Tab. 5), while only one taxa was recorded in the eutrophic Lake Nemi.

Another interesting bioindicator group is represented by cladocerans, whose role in water quality evaluation have been widely stressed for the zoobenthos associated with submerged macrophytes (BERZINŠ & BERTILSSON, 1989; MASTRANTUONO, 1990, 1991). However, the presence of numerous species in sandy shores of the lakes Albano, Vico and Bracciano, and of only one cladoceran (Chydorus sphaericus), considered as indicator of high trophy, in the eutrophic Lake Nemi (Tab. 5), point to a possible importance of these organisms also in this substrate.

A further positive indication is also the considerable abundance in the lake of some nematode species (Theristus setosus. Ethmolaimus pratensis, Chromadorita leuckarti, Aphanolaimus aquaticus, lronus tenuicaudatus and Trypila filicaudata) recorded in clear and oxygenated waters (ZULLINI, 1976, 1982; COLOMBA & VINCIGUERRA, 1979) and of the amphipod Echinogammarus sp., considered typical of oligo-mesotrophic conditions and whose presence in the lake was already recorded (BAZZANTI. 1981).

As a synthesis. all the results referred to community parameters and to bioindicators and bioindices converge to indicate a rich and diversified community, characterized by presence of several bioindicators of good environmental condition. Although it is impossible to compare these results directly with previous investigations that concerned with zoobenthos of much deep waters associated or not with aquatic vegetation, the overall evaluation seems in good agreement with the diagnosis of mesotrophy expressed in investigations carried out in the past decade. In fact, the fauna structure described during this study may represent an indication that no considerable modifications of the water quality have occurred in the littoral. But, an observed tendency towards a lower species richness and diversity in several stations located in the wider sandy shores of the southern zone, used extensively for sporting and bathing activities, and the high densities of total fauna registered in some sites may represent early signs of possible deterioration of quality in some littoral areas of the lake and point to the need for maximum surveillance.

REFERENCES

BARBANTI, L., BONOMI, G., CAROLLO, A., CHIAUDANI, G. FERRARI, I., GERLETTI, M., NOCENTINI, A.M., RUGGIU, D., & L. TONOLLI, 1971. Limnologia ed ecologia dei laghi di Bolsena, Bracciano, Trasimeno e Vico: situazione attuale e prevedibili conseguenze derivanti da una loro utilizzazione multipla. *Ist.Ital.Idrobiol.,* Verbania Pallanza, 263 pp.

BAZZANTI, M., 1981. Survey of the macrobenthic community in an area of Lake Bracciano (Central Italy). *Boll.Zool,* 48: 295-303.

BAZZANTI, M. & M. SEMINARA, 1985. Seasonal changes of the profundal macrobenthic community in a polluted lake. *Schweiz.Z.Hydrol,* 47: 57-63.

BAZZANTI, M., SEMINARA, M. & C. TAMORRI, 1994. Depth distribution and relationships to the trophic state of sublittoral and profundal macrobenthos in Lake Vico (Central Italy). *Limnologica,* 24: 13-21.

BERZINŠ & J. BERTILSSON, 1989. On limnic micro-crustaceans and trophic degree. *Hydrobiologia,* 185: 95-100.

BONACINA, C., BONOMI, G. & A. PASTERIS, 1992. Some remarks on the macrobenthos community of the profundal zone of the large Italian lakes. *Mem.lst.Ital.Idrobiol,* 50: 79106.

BRUNO, G., 1985. Bracciano sewerage system amd sewage treatment plant automatic control. *Proc.Int.Congress* "Lakes pollution and recovery" (ANDIS), Roma: 194-198.

CLARKE, A.H., 1979a. Gastropods as indicators oftrophic lake stages. *The Nautilus,* 94: 138142.

CLARKE, A.H.. 1979b. Sphaeriidae as indicators oftrophic lake stages. *The Nautilus,* 94: 178184.

COLE, A. & D.L. WEIGMANN, 1983. Relationships among zoobenthos, sediments, and organic matter in littoral zones of western Lake Erie and Saginaw Bay. **J.** *Great l,akes Res.,* 9: 568-581.

COLOMBA, G. & M.T. VINCIGUERRA, 1979. Nematodi d'acqua dolce della Sicilia. I: Nematodi dell'Anapo. *Animalia,* 6: 89-120.

CROZET, B., 1985. Infiuence of the sewage treatmet plant effluents on the structure of the benthic communities of Lake of Geneva. *Verh. Internat.Verein.Limnol,* 22: 2327-2331.

FERRARA, O., 1984. Struttura e dinamica della comunita zooplanctonica in un'area del lago di Bracciano (Lazio). ***Riv.*** *Idrobiol.*: 23: 145-158.

GAGGINO, G.F., MARCHETTI, R., CAPPELLETTI, E. & T. CALCAGNINI, 1985. La qualita delle acque dei laghi italiani negli anni '80. In: Inquinamento e recupero dei laghi. *Atti Congr.Internat.* EWPCA, ANDIS ed.: 5-44.

GERSTMEIER, R., 1989. Lake typology and indicator organisms in application to the profundal chironomid fauna of Starnberger See (Diptera Chironomidae). *Arch. Hydrobiol,* 116: 227-234.

JONASSON, P.M.. 1984. Oxygen demand and long term changes of profundal zoobenthos. *Hydrobiologia,* 115: 121-126.

JUGET, J., 1979. La texture granulometrique des sédiments et le régime alimentaire des oligochetes limicoles. *Hydrobiologia,* 65: 145-154.

KANSANEN, P.H., AHO, J. & L. PMSIVIRTA, 1984. Testing the benthic lake type concept based on chironomid associations in some Finnish lakes using multivariate statistical methods. *Ann. Zool. Fennici,* 21: 55-76.

LANG, C., 1984. Eutrophication of Lakes Léman and Neuchatel (Switzerland) indicated by oligochaete communities. *Hydrobiologia,* 115: 131 - 138.

LANG, C. & B. LANG-DOBLER, 1979. The chemical environment of tubificid and lumbriculid worms according to the pollution level of the sediment. *Hydrobiologia,* 65: 273-282.

LEARNER, M.A., 1979. The distribution and ecology of the Naididae (Oligochaeta) which inhabit the filter-beds of sewage-works in Britain. *Wat. Res.,* 13: 1291-1299.

LINDEGAARD, C. & P.C. DALL, 1988. Abundance and distribution of Oligochaeta in the exposed littoral zone of Lake Esrom, Denmark. *Arch. Hydrobiol. /Suppl.,* 81: 533-562.

LOSITO, C., 1904. Entomostraci pelagici del Lago di Bracciano. Tipografia Nazionale di G. Bertero e C., Roma.

MAITLAND, P.S. & P.M.G. HUDSPITH, 1974. The zoobenthos of Loch Leven, Kinross, and estimates of its production in the sandy littoral area during 1970 and 1971. *Proc. R. Soc. Edinb.,* B, 74: 219-239.

MARGALEF, R., 1957. La teoria de la information en ecologia. *Mem. Real Acad. ciencias y artes de Barcelona,* 32: 373-449.

MARTINI, P., 1985. The project CO.B.I.S. plants. *Proc. Int. Congress* "Lakes pollution and recovery" (ANDIS), Roma: 194-198.

MASTRANTUONO, L., 1986. Littoral sand zoobenthos and its relation to organic pollution in Lake Nemi (Central Italy). *Hydrobiol. Bull,* 19: 171-178.

MASTRANTUONO, L., 1990. Composition and distribution of the zoobenthos associated with submerged macrophytes in Lake Albano (Italy) and environmental quality in the littoral. *Riv. Idrobiol.,* 29: 709-727.

MASTRANTUONO, L., 1991. The zoobenthos associated with submerged macrophytes in littoral areas of LakeVico (Italy): some relations between fauna structure and water quality. *Limnetica,* 7: 153- 162.

MASTRANTUONO, L., 1995. The invertebrate community of littoral sandy shores in Lake Albano (Italy): fauna composition and ecological remarks. *Ecol. Mecliter,* 21: 101-112.

MASTRANTUONO, L. & C. LA ROCCA. 1988. The invertebrate fauna in sandy shores of Lake Vico (Italy): its use in a trophic evaluation of littoral sedimcnts. *Ecol. Mecliter,* 14: 121 129.

MASTRANTUONO, L. & P. BALDETTI, 1996a. Composizione della comunita ad Invertebrati dei sedimenti litorali del lago di Vico (Italia Centrale) e qualita ambientale in differenti periodi di studio. 57° Congresso U.Z.I., 34.

MASTRANTUONO, L. & P. BALDETTI, 1996b. Influenza della tessitura granulometrica dei sedimenti sulla di stribuzione dello zoobentho s associato al litorale sabbio so del lago di Vi co (Italia Centrale). XII Congresso A.I.O.L., Isola di Vulcano, 18-21 settembre.

McMURTRY, M.J., RAPPORT, D.J. & K.E. CHUA, 1983. Substrate selection by Tubificid Oligochaetes. *Can. J. Fish. Aquat. Sci.,* 40: 1639- 1646.

MILBRINK G., 1983. An improved environmental index based on the relative abundance of oligochaete species. Hydrobiologia, 102: 89-97.

MOUTHON, J., 1981. Les mollusques et la pollution des eaux douces: ébauche d'une gamme de polluosensibilité des especes. *Bij. Dierkd.,* 51: 250-258.

MOUTHON, J., 1986. Principes généraux pour une méthode d'appréciation de la qualité globale des sédiments lacustres a l'aide d'une analyse simplifiée des malacocénoses. *Annls. Limnol,* 22: 209-217.

MOUTHON J., 1992. Snail and bivalves populations analysed in relation to physico-chemical quality of lakes in eastern France. *Hydrobiologia,* 245: 147-156.

NOCENTINI, A.M., 1973. La fauna macrobentonica litorale e sublitorale dei laghi di Bolsena, Bracciano e Vico (Italia Centrale, Lazio). *Mem. Ist. Ital. Idrobiol.,* 30: 97-148.

PIELOU, E.C., 1966. Species-diversity and pattern-diversity in the study of ecological succession. J. *Theoret. Biol.,* 10: 370-383.

PETRIDIS, D., 1993. Macroinvertebrate distribution along an organic pollution gradient in Lake Lysimachia (Western Greece). *Arch. Hydrobiol.,* 128: 367-384.

RENKONEN, O., 1938. Statistisch-okologische Untersuchungcn uber die tcrrestrische Kaferwelt der finnischen Bruchmoore. *Ann. Zool. Soc. Zool. Bot. Fenn. Vanamo.* 6: 1-231.

SAETHER. O.A., 1979. Chironomid communities as water quality indicators. *Holarctic Ecol.*, 2: 65-74.

SAETHER, O.A., 1980. The influence of eutrophication on deep lake benthic invertebrate communities. *Prog Wat. Tech.,* 12: 161-180.

SÄRKKÄ, J.. 1983. A quantitative ecological investigation of the littoral zoobenthos of an oligotrophic finnish lake. *Ann. Zool. Fennici*, 20: 157- 178.

SÄRKKÄ, J., 1992. Lacustrine profundal meiobenthos as an environmental indicator. *Hydrobiologia*, 2431244: 333-340.

SARKKA, J., 1994. Lacustrine profundal meiobenthic oligochaetes as indicators of trophy and organic loading. *Hydrobiologia*, 278: 231-241.

SAVAGE, A.A. & G.M. GAZEY, 1987. Relationships of physical and chemical conditions to species diversity and density of gastropods in english lakes. *Biol. Conserv,* 42: 95-113

SNEATH P.H.A. & R.R. SOKAL, 1973. Numerical taxonomy. Freeman & Co., San Francisco, California, 573 pp.

SOMMANI, E., 1961. Osservazioni sulle variazioni quantitative di Entomostraci planctonici ne lago di Bracciano. *Boll. Resca Piscic.Idrobiol.,* 16: 87-94.

VODOPICH, D.S. & B.C. COWELL, 1984. Interaction of factors governing the distribution of a predatory aquatic insect. *Ecology,* 65: 39-52.

WEBER, C.T., 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. EPA, 67014-73-001.

WHITESIDE. M.C. & C. LINDEGAARD, 1982. Summer distribution of zoobenthos in Grane Langso, Denmark. *Freshwat. Invertebr. Biol.,* 1: 2-16.

WIEDERHOLM, T., 1980. Use of benthos in lake monitoring. J. War. *Rollut. Cont. Fed.*, 52: 537-547.

WINNELL, M.H. & D.J. JUDE, 1984. Associations among Chironomidae and sandy substrates in nearshore Lake Michigan. *Can. J. Fish. Aquat. Sci,* 41: 174-179.

ZULLINI, A., 1976. I Nematodi come bioindicatori. I. Studio di una successione. *Rend. Acc. Lincei,* 61:503-507

ZULLINI, A., 1982. Nematodi. Guide per il riconoscimento delle specie animali delle acque interne italiane. C.N.R., AQ/1/190, 117 pp.