LIMNOLOGICAL AND BIOLOGICAL CHARACTERISTICS OF THE ALPINE LAKES OF PORTUGAL

M. J. Boavida & Z. M. Gliwicz
Departamento de Zoología, Faculdade de Ciências, Universidade de Lisboa, Campo Grande C2, 1700 Lisboa, Portugal.
Department of Hydrobiology, University of Warsaw, Banacha 2, 02-097 Warsaw, Poland.

Key words: alpine lakes, zooplankton, planktivorous fish.
Palabras clave: lagos de alta montaña, zooplacton, peces planctivoros.

ABSTRACT
This is the first limnological description of the so far unknown alpine lakes of Portugal. All located above 1500 m above sea level on granitic soil, these are small lakes of glacial origin and acidic nature. The biological structure is simple. The phyto- and zooplankton communities of the lakes without fish were compared with those of the lakes where trout (Oncorhynchus mykiss Walbaum) has been introduced. This study was undertaken for a short period of time (September and October of 1993) and therefore it should only constitute a starting point for studies leading to preservation of these ecosystems of unique nature in the country.

INTRODUCTION

The scientific interest of this set of lakes stems from the fact that these are the only lakes of glacial origin in Portugal and also the only lakes located above timberline in the country. Serra da Estrela is a 2000 m altitude mountain in the central part of Portugal, following the Sierras which in central Spain separate Castilla-la-Nueva from Castilla-la-Vieja (RIBEIRO 1941). Snow and ice cover remains usually from January to May in the higher peaks. Precipitation usually starts in October (rain) and ends in May (below circa 800 m, rain, above that and starting in January, snow). Annual precipitation in Serra da Estrela is 2000-2800 mm (ATLAS DO AMBIENTE, 1975). The high precipitation of Serra da Estrela in the relatively arid Iberian Peninsula is attributed to the fact that this is a large, massive mountain reaching high altitude at only about 100 Km from the sea; the high altitude, the closeness to the sea, and the predominance of winds from west (i.e. from the sea) have as a consequence the observed high precipitation (RIBEIRO, 1941). Annual insolation corresponds to 2200-2500 hours (ATLAS DO AMBIENTE, 1975). Annual mean of daily temperature is below 10°C (ATLAS DO AMBIENTE, 1975).

Above 1500 m vegetation is characterized by a mosaic-like covering of shrublands where Juniperus communis L. subsp. alpina is dominant, at times in co-dominance with Erica arborea L. and also of mat grass lawns, open grass fields, and both ripiculous and lake communities (JANSEN, 1992). Both the flora and the climate correspond to the Mediterranean mountain type. Being all small, the lakes of Serra da Estrela are therefore subjected to a strong influence of the rigorous climatic conditions.

With the exception of a study on zooplankton and fish relationships (GLIWICZ & BOAVIDA, 1996) and fish population studies (VALENTE et al 1994) there are no limnological data on the alpine lakes of Portugal. The first limnological description of ten of these lakes is made in this paper based on field measurements and samples collected on four occasions in September and October of 1993. The aim of this preliminary examination is to establish a starting point for long-term studies of trophic status and biodiversity, leading to the preservation and conservation of the lakes in the near future. This kind of study is actually very pertinent to the interests of the official authorities, suiting their objectives of protecting the natural patrimony of Serra da Estrela.

DESCRIPTION OF SITES STUDIED

Among the ten lakes sampled in Serra da Estrela five are natural lakes (Redonda, Escura, D. Angelo, Paixão, Salgadeiras), two are artificial (C. Ferro, Viriato), and three are impounded natural lakes (Comprida, Serrano, C. Quelhas). The natural lakes are round shaped and mostly shallow, the artificial lakes (with the only exception of C. Ferro) and those natural which have been dammed have an elongated shape.

All located above an altitude of 1500 m (more precisely between 1550 m and 1840 m a.s.l. - Table 1) on granitic soil,

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the lakes can be separated into two groups: (1) those of River Mondego watershed - Redonda, Comprida, Escura, D. Angelo, Serrano, C. Quelhas; and (2) those of River Zezere watershed - Paixão, Salgadeiras, C. Ferro, Viriato. The drainage pattern is very interesting, being natural and artificial lakes alike related through intermittent and permanent streams eventually flowing into the two main rivers already mentioned. Both R. Mondego and R. Zezere originate in Serra da Estrela. R. Mondego flows into the Atlantic, R. Zezere is a tributary of R. Tejo, a large Iberian river flowing into the Atlantic also. A general description of the lakes is shown on Table 1.

The natural lakes of Serra da Estrela were originally fishless and remained so until recently. It was only after 1983 that fish - Oncorhynchus mykiss Walbaum (former Salmo gairdneri Richardson) - was first introduced in a regular fashion. The small reservoirs have been only sporadically stocked with fish since their impoundment until 1983. According to the information gently supplied by the state institutions superintending fish stockings in the region, Oncorhynchus mykiss released into the lakes belong to the size range 5-8 cm, which corresponds to fish 4-6 months old; stockings were done particularly in the reservoirs Comprida, Viriato, and C. Ferro in the last three years before this study was undertaken. One of the natural lakes, Escura, was stocked in 1992 and a couple of times before that (unknown dates). Therefore the ichthyofauna of these lakes consists uniquely of Oncorhynchus mykiss, with the exception of Comprida where Leuciscus spp. were accidentally introduced by fishermen.

Because all of these lakes are located inside the perimeter of a natural park - "Parque Natural da Serra da Estrela", with an area as large as 100,000 ha, fishing is allowed only with restrictions. Such restrictions are defined every year, following a governmental law of 30 July 1982, and they determine in which days of the week fishing is allowed, how many fish each fisherman is allowed to catch, the dimensions beyond which fish caught will have to be released back to the water, and the exact days of beginning and ending the annual fishing season (e.g. when this study was undertaken the fishing season started on 10 June and ended on 27 September, fishing was allowed for three days a week, and every fish smaller than 22 cm would have to be released). Moreover, fishing is allowed only from the shore, with no bait.

Mostly the lakes are devoid of littoral zone, being the rocky shores naked of macrophyte vegetation. Exceptions among those studied are Redonda, Paixão, and Escura.

MATERIALS AND METHODS

Water for total phosphorus and chlorophyll determinations was collected from 0.3-0.4 m depth directly into acid rinsed polyethylene bottles. Total phosphorus was determined after strong acid digestion at high temperature and pressure of whole water samples, followed by the molybdate blue test. Water for chlorophyll determination was filtered (Whatman GF/C) a few hours after collection, filters were dried and stored for later extraction in acetone. Samples for phytoplankton study were also taken from the upper stratum as referred previously. The unfiltered samples were preserved immediately upon collection with Lugol’s iodine solution. Identification and enumeration were done under a Nikon inverted microscope with a magnification of 200 X.

Zooplankton samples were taken with a conical tow net of 100 pm mesh size and 9.5 cm mouth diameter. In deep lakes and when possible vertical tows were taken from a boat over the deepest part of the lake. In shallow lakes horizontal tows

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Table 1: Some morphometric, physical, and chemical characteristics of Serra da Estrela lakes.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Area, ha</th>
<th>Max. depth, m</th>
<th>pH</th>
<th>Sodi, cm</th>
<th>Stratification</th>
<th>Upper halocline, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redonda</td>
<td>16.20</td>
<td>3</td>
<td>6</td>
<td>52</td>
<td>no</td>
<td>6</td>
</tr>
<tr>
<td>Comprida</td>
<td>16.00</td>
<td>51</td>
<td>16</td>
<td>55</td>
<td>yes</td>
<td>6</td>
</tr>
<tr>
<td>Escura</td>
<td>16.00</td>
<td>2</td>
<td>6</td>
<td>60</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>D. Angelo</td>
<td>17.40</td>
<td>7</td>
<td>3</td>
<td>55</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Serrano</td>
<td>17.90</td>
<td>5</td>
<td>3</td>
<td>41</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>C. Quelhas</td>
<td>18.10</td>
<td>5</td>
<td>4</td>
<td>58</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Paixão</td>
<td>16.70</td>
<td>2</td>
<td>2.5</td>
<td>58</td>
<td>yes</td>
<td>2</td>
</tr>
<tr>
<td>Salgadeiras</td>
<td>18.40</td>
<td>1</td>
<td>3</td>
<td>59</td>
<td>yes</td>
<td>4</td>
</tr>
<tr>
<td>C. Ferro</td>
<td>15.80</td>
<td>6</td>
<td>15</td>
<td>58</td>
<td>yes</td>
<td>1.5</td>
</tr>
<tr>
<td>Viriato</td>
<td>15.50</td>
<td>21</td>
<td>9.5</td>
<td>8.0</td>
<td>yes</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Maximum depth for impoundments refers to sampling date.

* When applicable.
were taken from a boat keeping the net between 1 and 2 meters depth, or by throwing the weighted net from shore and pulling it close to the surface in those lakes where the more difficult access would prevent us from carrying the boat. Immediately upon collection samples were fixed in 4% formalin, sugar saturated aqueous solution. Later in the laboratory identification was performed under a Leitz Riomed microscope, at 40 X and 100 X, and a Sedgewick-Rafter chamber was used for quantification.

Temperature and dissolved oxygen concentration of lake water were measured with a YSI model 57 meter, pH was approximately determined with Johnsons indicator pH paper range 3.9 to 6.7, and water transparency was evaluated with a 20 cm black and white Secchi disk.

Areas of the lakes were determined by planimetry on a 1:25000 topographical map.

RESULTS

Water pH was acid in all lakes, varying between 4.1 and 6.0 (Table 1). However, since this parameter could only be estimated with indicator paper, the values determined could be a little underestimated, being the actual, values slightly less acid than field measurements indicate. Surface dissolved oxygen concentrations were always high, close to saturation, in all lakes.

Littoral zone and macrophyte vegetation: In the three lakes where macrophyte communities can be found (Redonda, Paixão, and Escura) these were constituted of very similar, although non coincident, plant associations. More important variation, though, was observed in the dimensions of the littoral zone which was evaluated by the extension covered by macrophytes: In Redonda the littoral zone corresponded to about one third of the total area of the lake and completely encircled the open water; in Paixão the littoral zone corresponded to a narrow (2-3 meters) ring surrounding the whole lake; in Escura only about two thirds of the lake perimeter were covered by macrophytes (to about 1.5-2 meters from shore) being the remaining shore constituted of bare rock. The description of the phytosociological characteristics of these three lakes follows, always from open water to shore.

Redonda: Potamogeton polygonifolius Pourret, Antinoria-Ranunculus association (constituted by Antinoria agrostidea (DC.) Parl., occurring the aquatic variant subsp. naturalis (Hackel) Rivas Martinez only in Serra da Estrela and central Spain, and by Ranunculus ololiucos Lloyd), Junco Sphagnetum association (constituted by Junco bulbosus L. and Sphagnum sp.) and Juncus effusus L.

Paixão: Antinoria-Ranunculus, Junco-Sphagnetum, Carex nigra (L.) Reichard and Juncus effusus L. In this lake the water fluctuation was appreciable; on the wet half-meter ring surrounding the whole lake we found Sphagnum sp. with Viola palustris L. and Carex nigra (L.) Reichard sometimes interrupted by spots of Polytrichum sp.

Escura: Antinoria-Ranunculus, Junco-Sphagnetum, and Junco bulbosus L.

| Table 2. Chlorophyll a and total phosphorus (both in µg/L) of ten lakes of Sierra de la Estrella and their phytoplankton communities (algal densities as cells or colonies per ml). |
|---------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| chlorophyll a µg/L              | REDONDA | COMPRIDA | ESCURA | D'ANGELO | SERRANO | C'QUELHAS | PAIXAO  | SALGADERAS | FERRO  |
| total phosphorus µg/L            | 3.9     | 0.7      | 2.7     | 0.7      | 22      | 22       | 17      | 0.9       | 15      | 2.6     |
| Cryptomonas sp. µg/L             | 140     | 23       | 140     | -        | 14      | 17       | 12      | 22        | 9       | 22      |
| Mallomonas sp. µg/L              | -       | -        | 1793    | 1164     | -       | -        | -       | -         | -       | 2900    |
| Dinobryon sp. µg/L               | 47      | 582      | 582     | 124      | 1116    | 1116     | 582     | 582       | -       | 47      |
| Peridinum sp. µg/L               | 180     | 233      | 163     | 47       | -       | -        | -       | -         | -       | 2900    |
| Micrasterias sp. µg/L            | -       | 23       | -       | -        | -       | -        | -       | -         | -       | -       |
| Spongiocystis sp. µg/L           | -       | -        | 93      | 23       | -       | -        | -       | -         | -       | -       |
| Chroococcus sp. µg/L             | 1956    | 279      | 140     | 163      | 1863    | 675      | 163     | 23        | -       | -       |
| Brachiospongia sp. µg/L          | -       | -        | -       | -        | 93      | -        | -       | -         | -       | -       |
| flagellates* µg/L                | 5263    | 908      | 466     | -        | 2329    | 2631     | 280     | 186       | 746     | -       |
| nanophycea* µg/L                 | -       | -        | -       | 93       | -       | -        | -       | -         | -       | 548000  |
| Bacillariophyceae µg/L           | 186     | 47       | -       | 628      | 93      | 116      | -       | 70        | -       | -       |
| Shannon index (H')               | 0.94    | 1.36     | 1.46    | 1.30     | 1.38    | 1.24     | 1.49    | 1.08      | 0.99    | 0.17    |

* unidentified
Diversity indexes of the two groups of lakes 

0.05 and impounded lakes 
differences respecting H’ for phytoplankton between natural 

Of these, three are natural lakes, one with fish (Escura), two 

alga was found to be a relevant 

keeps a fairly high density.

Botryococcus 

dimensions to be consumed by herbivore zooplankters.

lakes: 

Cyanophyceae. The only colonial alga present in all lakes was 

which was most abundant in Serrano and C. 

Quelhas (28.0%) and Viriato (43.5%). Daphnia pulicaria was the most abundant zooplankter in Salgadeiras (40.8%). 

Phytoplankton and related parameters: The phytoplankton 

community of each lake (H’, Table 2) was low for all lakes and 

small reservoirs frequently stocked with fish and in which trout 

abundance were Salgadeiras, Comprida, Paixão, and Escura.

Regarding the analyses of lakes with fish vs. lakes with no 

fish, however, a significant difference was found between 

diversity indexes of the two groups of lakes (F = 8.52, 

0.05 > P > 0.02).

Similarly to what happens with other mountain lakes, both chlorophyll n and total phosphorus (Table 2) were low in Serra da Estrela lakes.

Zooplankton communities: The number of species 

constituting the zooplankton community of each of the lakes 

varied between 4 and 8. In the whole set of lakes four 

Cladocera, one Copepoda, and four Rotifera were identified (Table 3). In lakes D. Angelo, Serrano, C. Quelhas, Paixão, and Salgadeiras, there was only one cladoceran, in C. Ferro two cladocerans, and in lakes Redonda, Comprida, Escura, and Viriato, three cladocerans. In the lakes with only one 

cladoceran species this was Daphnia pulicaria, which was present in all lakes but Comprida. Daphnia pulicaria was the only cladoceran found in all fishless lakes but Redonda, where Diaphanosoma brachyurum and Alona sp. together made up a fraction of 73.6 % of the cladocerans.

The most abundant zooplankter was a rotifer in almost all 

lakes. Keratella quadrata was the most abundant in lakes Redonda (48.1%), Comprida (53.1%), Serrano (37.7%) and Paixão (39.3%). Polyarthra dolichoptera was the most abundant in lakes Escura (27.2 %) and D. Angelo (59.9 %). Brachionus angularis was the most abundant in C. Ferro (89.1 %). Only in three of the studied lakes the most important 
zooplankter was not a rotifer. The copepod Tropocyclops prasinus (both adults and copepodes) was the most abundant in lakes C. Quelhas (28.0%) and Viriato (43.5%). Daphnia pulicaria was the most abundant zooplankter in Salgadeiras (40.8%).

<table>
<thead>
<tr>
<th>REDONDA</th>
<th>COMPRIDA</th>
<th>ESCURA</th>
<th>D'ANGELO</th>
<th>SERRANO</th>
<th>QUELHAS</th>
<th>PAIXAO</th>
<th>SALGADEIRAS</th>
<th>CIF</th>
<th>VIRIATO</th>
</tr>
</thead>
<tbody>
<tr>
<td>554 (9.71)</td>
<td>351 (26.9)</td>
<td>567 (43.5)</td>
<td>59 (1.27)</td>
<td>3 (0.23)</td>
<td>10 (0.19)</td>
<td>4 (0.72)</td>
<td>57 (10.3)</td>
<td>65 (2.74)</td>
<td>77 (5.91)</td>
</tr>
</tbody>
</table>

* copepodes included

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Phytoplankton and related parameters: The phytoplankton 

communities of Serra da Estrela lakes are very simple (Table 2) and comprised mainly of unicellular algae of suitable 
dimensions to be consumed by herbivore zooplankters. Cryptomonas, Mollamo::as, as well as other flagellates, were 

abundant in most lakes. There were practically no 

Cyanophyceae. The only colonial alga present in all lakes was 

Dinobryon which was most abundant in Serrano and C. 

Quelhas, two fishless impounded natural lakes connected 

through a very small channel. Next to these lakes in 

Dinobryon abundance were Salgadeiras, Comprida, Paixio, and Escura. Of these, three are natural lakes, one with fish (Escura), two with no fish (Salgadeiras and Paixão) Only one large colonial alga was found to be a relevant presence in the set of studied 
lakes: Botryococcus (B. braunii), The only lakes where Botryococcus was not found were C. Ferro and Viriato, two small reservoirs frequently stocked with fish and in which trout 

keeps a fairly high density.

Shannon diversity index concerning the phytoplankton community of each lake (H’, Table 2) was low for all lakes and it was comprised between 0.17 and 1.49. There were no 
differences respecting H’ for phytoplankton between natural and impounded lakes (F= 8.52, 0.05 > P > 0.02).

Regarding the analysis of lakes with fish vs. lakes with no 

fish, however, a significant difference was found between 

diversity indexes of the two groups of lakes (F= 8.52, 0.05 > P > 0.02).
Shannon diversity index concerning zooplankton community of each lake ($H'$, Table 3) was relatively low for all lakes and it was comprised between 0.52 and 1.57. Likewise with respect to phytoplankton, no significant differences concerning $H'$ for zooplankton communities were found when comparing natural with impounded lakes ($F_{(2,14)} = 2.91, 0.05 > P > 0.20$). On the other hand, and unlike what happened for phytoplankton with respect to presence and absence of fish, no significant difference was found in $H'$ for zooplankton between the two groups of lakes ($F_{(2,153)} = 4.73, 0.20 > P > 0.10$).

Ichthyofauna: Fish are found only in a few lakes, since, as stated before, all lakes were originally fishless. Lakes with fish are Comprida, Escura, C. Ferro, and Viriato. In all of these fish officially introduced was rainbow trout *Oncorhynchus mykiss* Walbaum. In Comprida there are also *Leuciscus* spp. which have been introduced by fishermen and have been reproducing to large quantities.

Stockings apparently were not done with the purpose of keeping a more or less constant density - there are no trends in the last three years in which stockings have been consecutive (Table 4). There are no data on fishing efficiency taking place every season on each lake.

With no means to estimate actual fish density in the four lakes - no echo sounder, not even empirical data to calculate differences between number of stocked fish and number of fish caught by fishermen - only direct observation underlies the judgments that fish density is much higher in Comprida, followed by lakes C. Ferro and Viriato, where fish density is intermediate, being finally Escura the only one with lower fish density. If these observations were considered as being quantitatively expressed by abstract numbers, so that a gradient could be established, one would say that Comprida corresponds to level 3 in fish density, C. Ferro and Viriato correspond to level 2, and Escura corresponds to level 1.

Relating what was just stated to presence and abundance of the larval cladoceran: I. among the lakes with no fish *Daphnia pulex* is the only cladoceran (100% of the cladocerans) in the zooplankton community in all lakes but Redonda; II. where fish density corresponds to level 1 *Daphnia pulex* constitutes more than 80% of the cladocerans; III. where fish density corresponds to level 2 *Daphnia pulex* constitutes a fraction lower than 50% of the cladocerans; IV. where fish density corresponds to level 3 *Daphnia pulex* was not found in any of the lakes.

Trophic State of the lakes: Computed values for the three components of Carlson's Trophic State Index (CARLSON, 1977) are elucidative of the quality of the water of the studied lakes. Because significant changes in total phosphorus, chlorophyll, and Secchi disk transparency were not expected to occur during the study period in these almost left alone lakes, the index was calculated with basis on one single measurement of each of the three parameters for each lake. Only in the cases where the calculations would not make sense (i.e. the transparency component when Secchi disk was visible to the bottom) the transparency component of the index is not indicated. The only high value of the Trophic State Index is that obtained for the transparency component in Viriato (Table 5). The values of the index for both the chlorophyll component and the phosphorus component for the same lake, however, are low. This is an indication that turbidity of the water in Viriato was probably caused by inorganic seston brought from the surrounding land rather than by live phytoplankton.

With the only exception of the above cited transparency index for Viriato, all of the calculated indexes for all lakes are included within the oligotrophic range for Vollenweider's lakes. In fact, the three components of the index were computed for minimum and maximum values of a table modified from VOLLLENWEIDER (1979) and published in WETZEL (1983). Carlson's index calculated with minimum and maximum values of the referred table for total phosphorus, chlorophyll, and Secchi disk for oligotrophic lakes determined a range for each of the corresponding components of the index for lakes classified by Vollenweider as oligotrophic. Based on this all lakes studied in Serra da Estrela can be classified as oligotrophic.

Table 4: Poblaciones de peces (n° por ha) en los lagos en que ha sido introducida la trucha.

<table>
<thead>
<tr>
<th></th>
<th>COMPRIDA</th>
<th>ESCURA</th>
<th>C. FERRO</th>
<th>VIRIATO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>471</td>
<td>-</td>
<td>-</td>
<td>643</td>
</tr>
<tr>
<td>1987</td>
<td>20</td>
<td>-</td>
<td>-</td>
<td>48</td>
</tr>
<tr>
<td>1991</td>
<td>1275</td>
<td>500</td>
<td>6667</td>
<td>2381</td>
</tr>
<tr>
<td>1992</td>
<td>1291</td>
<td>500</td>
<td>959</td>
<td>1768</td>
</tr>
<tr>
<td>1993</td>
<td>-</td>
<td>-</td>
<td>8417</td>
<td>1902</td>
</tr>
</tbody>
</table>
DISCUSSION

Both phytoplanktonic and zooplanktonic communities are very simple in all of the studied lakes, as should be expected. In a survey of the algal flora of 87 lakes located in the High Tatra Mountains (Slovakia) LUKAVSKY (1994) reported, for summer phytoplankton and among others, the following genera which were also found in Serra da Estrela: Merismopedia, Chroococcus, Cryptomonas, Dinobryon, Peridinium, Mallomonas, and Botryococcus. The lakes referred to in the above cited study, such as those reported here, are of glacial origin, most of them are oligotrophic, and the area where they are located is constituted of granitic rock. Among the algae common to both Tatra Mountains and Serra da Estrela lakes, Cryptomonas is considered to be very good food for Daphnia pulex, favoring high levels of survival and reproduction (C. reflexa was the species used in experiments: STUTZMAN, 1995). The zooplanktonic communities of other oligotrophic lakes in the Tatra Mountains are even simpler (GLIWICZ, 1985) than those of the lakes reported in the present study. In the lakes studied by GLIWICZ (1985) there were only one copepod and two rotifers - no cladocerans at all. In Serra da Estrela lakes even the simplest zooplanktonic community (that of D. Angelo) was composed of 4 species. It is interesting, however, that in lake D. Angelo there is one copepod and two rotifers (being the rotifiers the same genera as in Tatra lakes). In addition to these 3 species there is also one cladoceran in D. Angelo: Daphnia pulex. This difference could be attributed to the fact that there is no fish in the Estrela lake, unlike what happens in the referred Tatra Mountains lakes, all stocked with salmonid fish. By virtue of its large dimensions, Daphnia pulex becomes very much vulnerable to fish predation.

On the other hand, the percentage of the largest cladoceran in the lakes Redonda and C. Quelhas, both with no fish, was low (0.60 and 1.19 of the zooplankton, respectively). This could be an indication that planktivorous fish was not the only predator on Daphnia pulex. In both lakes Tropocyclops prasinus was very abundant. Therefore, and similarly to what has been observed with respect to other cyclopoid copepods (GLIWICZ & UMANA, 1994; GLIWICZ & LAMPERT, 1994) the copepod Tropocyclops prasinus may be an important predator on Daphnia pulex in these fishless lakes.

It may be argued that different ways of sampling zooplankton, impossible to avoid in this study, might also have influenced these results. However, in the most contrasting lakes with respect to the relationships zooplankton/fish and D. pulex/T. prasinus, namely lakes Escura, Viriato, Serrano, C. Ferro, Redonda, and C. Quelhas, zooplankton was sampled in the same way: by means of horizontal tows.

Values found for parameters such as chlorophyll a and total phosphorus in Serra da Estrela lakes are of the same order of magnitude as those found for similar mountain lakes, e.g. FAAFENC & HESSEN (1993). The same is true for parameters such as pH; even considering that the estimated pH could be somehow lower than the actual pH of the lakes, values determined for Serra da Estrela lakes match those found in the literature for the same type of ecosystems (KOPACEK et al., 1995). In fact, subsequent comparison between the values estimated with the indicator paper used in the field and those read out of a pH meter in the laboratory evidenced very small differences: 0.1-0.3 of a pH unit; since differences between pH values determined with a pH meter and those estimated by pH paper (both done later in the laboratory) were very low, it was assumed that pH estimated in the field for Serra da Estrela lakes was not too far from the exact values.

As to the ichthyofauna of Serra da Estrela lakes, it would have been interesting, in order to see the effects of stocking, to compare the biological (phytoplanktonic and zooplanktonic, especially) communities of the time before trout with the communities of the same lakes after fish introduction. Since that could not be done due to lack of previous studies, the only alternative was to compare the communities of the lakes with fish with those of the lakes without trout.

Our findings corroborate the scientific literature on the subject. The non existence of Daphnia pulex in Comprida, which is the lake with highest fish density among those studied.

| Tabla 5. Índice de estado trófico de Carlson para los diez lagos alpinos estudiados en la Sierra de la Estrella. TP = componente fósforo del índice Ch.- componente chlorophyll del índice SD = componente transparencia del índice. |
|---|---|---|---|---|---|---|---|---|---|
| REDONA | COMPRIDA | ESCURA | D. ANGELO | SERRANO | C. QUELHAS | PADIÑO | SALGADIEIRAS | C. FERRO | VIRIATO |
| TP | 24 | 0 | 18 | 9 | 12 | 7 | 16 | 7 | 16 |
| Chl | 36 | 22 | 35 | 27 | 38 | 36 | 30 | 35 | 37 |
| SD | 43 | 30 | 30 | ns | ns | 43 | ns | 30 | 54 |

ns = no sense in determining the index (Secchi disk visible down to the bottom of the lake).
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