The effect of Increased Water Level on *Isoetes lacustris* L. in Lake Baciver, Spain

E. GACIA\(^1\) AND E. BALLESTEROS\(^2\)

**ABSTRACT**

Ten months after flooding lake Baciver, water levels were 5.5 m higher than the previous normal and the area formally occupied by the *Isoetes* population was reduced. All *Isoetes* originally present below 0.6 m died, and only plants standing 5.8 and 6.1 m (new depth) survived. As irradiance decreased, remaining individuals produced fewer leaves, but their biomass production was higher, as leaf length increased in response to the diminished available irradiance. Because leaf mortality was excessive, regeneration capacity, population performance and dynamics were adversely affected. In 1992, no new production occurred in *Isoetes lacustris* individuals surviving after the winter. We suggest that low surface oxygen levels at the water column under the ice, and total anoxia below 6 m depth, caused the demise of the *I. lacustris* population in Lake Baciver.

**Key words:** Pyrenees, oxygen, light, leaf primary production, water level fluctuations, anoxia.

**INTRODUCTION**

*Isoetes lacustris* L. is a widely distributed macrophyte in Pyrenean high mountain lakes of oligotrophic and soft waters (Gacia et al. 1994). Population structure and dynamics of this species have been extensively studied in lake Baciver (Gacia and Ballesteros 1993; 1995) where beds occupied more than 50% of lake bottom (Ballesteros et al. 1989) prior to October 1991, when the Lake was dammed. As a result of water level increases, significant variation in bathymetric limits and physico-chemistry of the water column occurred (Gacia and Ballesteros, in press). In the present work we describe changes in the *Isoetes lacustris* population structure (e.g., densities, above vs. below ground biomass ratio, size classes), and leaf primary production during the two summers that followed dam construction (1991 and 1992).

**MATERIAL AND METHODS**

Lake Baciver is located in the Central Pyrenees (42°41′46″ N, 0°59′1″ E) at an elevation of 2120 m. Lake area was originally 26629 m\(^2\) and maximum depth 7.5 m (Ballesteros et al. 1989). However, after dam construction in the fall of 1990, water levels rose 5.5 m and lake area increased to 51301 m\(^2\) (Gacia and Ballesteros, in press).

Fifteen transects were examined during the ice-free period in 1991 and 1992 to evaluate changes in the *Isoetes lacustris* populations resulting from increased water levels. Structural samples (collected in July), and primary production measurements (early July and late October) were taken in 1991 and 1992. Biomass, structure, and density of the population were obtained from 400 cm\(^3\) samples collected by SCUBA. In the laboratory, individuals were sorted into size categories (Gacia and Ballesteros 1993) and number of leaves per shoot and maximum leaf length were determined. Primary production of *Isoetes* was measured by tagging leaves of 96 individuals with copper wire rings to assess leaf production time and loss over a one year period (see Gacia and Ballesteros 1991). Leaf biomass production was estimated from leaf growing function (Gacia and Ballesteros 1995) and values of biomass and production were expressed in a dry weight basis (24 h at 105°C). Photon Flux Density (PFD) in the water column was measured with a spherical quantum sensor Licor SPQA coupled to a Licor Li-1000 datalogger. Water samples were collected from the centre of the Lake at one meter intervals with a Ruttner bottle. Temperature was measured in situ and oxygen content of the water was determined in the laboratory following the Winkler method modified by Grasshoff et al. 1983. Voucher specimens of *Isoetes* plants collected are available in CEAB Herbarium (Blanes, Spain).

**RESULTS**

After flooding, populations of *Isoetes lacustris* previously located at 0.2 to 2.3 m were now at a depth of 3.7 to 7.8 m and underwent substantial reduction (Table 1), only *Isoetes* plants originally living above 0.6 m depth (now 6.1 m) survived.

Biomass of surviving *Isoetes lacustris* populations tended to increase while density decreased from July 1990 to July 1991 (Table 2). Surviving plants also showed some morphological changes: maximum leaf length and biomass (above: below ground ratio) significantly increased (Table 2). Suez diversity of initial shallow water populations increased becoming similar to that of the original deep-water population (Figure 1). Number of leaves per plant produced by *I. lacustris* in summer 1991 was lower, and leaf loss was also unusually high (Table 3). Nevertheless, new above-ground biomass and total biomass production was higher after dam construction (Table 3).

In June 1992, two winters after water levels increased, remaining *I. lacustris* appeared unhealthy (e.g. areas of

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The total depletion in oxygen content of the water column down to 6.1 m depth (Figure 2) caused the *Isoetes* lacustris to die off, since this species has been reported to be very sensitive to low oxygen levels (Rørslett and Brettum 1989). 

Overall increase in leaf length recorded in the summer of 1991 is related to the decrease in available irradiance, since low light levels enhance leaf length in *Isoetes lacustris* (Gacia and Ballesteros 1993). Longer leaves seem to account for the increase in the above:below ground biomass ratio (Table 2).

The original shallow water *Isoetes lacustris* population in Lake Baciver consisted of small plants, homogenous in maximum leaf length. Strong, shore-related disturbances such as natural water level fluctuations and ice-scor, would damage shallow water individuals preventing size diversity in the plants (Gacia and Ballesteros 1993). With the increase in water level, shallow water disturbances were ameliorated and leaves of *Isoetes* individuals increased in length (stimulated also by low light levels) and developed a greater size diversity similar to the original deepwater population (Gacia and Ballesteros 1993).

Decrease in light availability in summer 1991 could explain the lower number of leaves produced by surviving *Isoetes lacustris* plants. However, major leaf loss in the same period indicates the possibility of other stressful conditions in these individuals. Increase in new leaf biomass, due to longer leaf size, resulted in higher biomass production (Table 3) similar to the original deepwater populations (Gacia and Ballesteros 1993).
**TABLE 3.**: NUMBER OF LEAVES PRODUCED AND LOST PER YEAR, AND ANNUAL BIOMASS PRODUCTION FOR THE SURVIVING *Isoletes lacustris* POPULATION AFTER DAM CONSTRUCTION.

<table>
<thead>
<tr>
<th>Production</th>
<th>Year</th>
<th>1989 (0.8 m)</th>
<th>1991 (6.1 m)</th>
<th>1992 (6.1 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of leaves</td>
<td>Produced</td>
<td>6.69</td>
<td>6.65</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lost</td>
<td>9.90</td>
<td>16.28</td>
<td>all</td>
</tr>
<tr>
<td></td>
<td>g dry m^-2</td>
<td>53.5</td>
<td>111.1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Corms</td>
<td>8.0</td>
<td>11.6</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Roots</td>
<td>14.7</td>
<td>6.8</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>76.5</td>
<td>129.5</td>
<td>---</td>
</tr>
</tbody>
</table>

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**REFERENCES**


