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INDICE - *CONTENTS*

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SEASONAL DYNAMIC OF A MOUNTAIN LAKE IN THE NORTHERN APENNINES: THE CASE OF "LAGO NERO" (TUSCANY, PISTOIA)

Abstract - *Seasonal dynamic of a mountain lake in the northern Apennines: the case of "Lago Nero" (Tuscany, Pistoia).* The Lago Nero is a small mountain pond (1730 m a.s.l.) which originated during the last glacial period. It is situated on the Pistoiese Apennine, Abetone Municipality (Pistoia Province). Chemical-physical characteristics were investigated together with some ecological features, from November 2011 until December 2012. A seasonal variance was observed in water electrical conductivity, pH, oxygen and temperature. The local Alpine newt (*Ichthyosaura alpestris* (Laurenti, 1768) subsp. *apuanus*) population has been monitored and the importance of beaked sedge (*Carex rostrata* Stokes, 1787) in the Lago Nero ecology has been evaluated. We concluded that Lago Nero is in good ecological conditions. It would be important to extend the monitoring program to other small ponds in the Pistoiese Apennine.

Key words - water monitoring, pond ecology, Lago Nero, Sestaione Valley, Pistoiese Apennine.

Riassunto - *Dinamica stagionale di un lago montano sull'Appennino settentrionale: il caso del Lago Nero (Toscana, Pistoia).* Il Lago Nero è una piccola raccolta di acqua naturale originatasi durante l'ultimo periodo glaciale e situato sull'Appennino Pistoiese (Abetone, Pistoia) ad una quota di 1730 m s.l.m. Sono stati monitorati alcuni parametri chimico-fisici e aspetti ecologici, dal novembre 2011 fino a dicembre 2012. È stata osservata una variazione stagionale nella conduttività elettrica dell'acqua, nel pH, ossigeno disciolto e temperatura. È stata monitorata la popolazione di tritone alpestre (*Ichthyosaura alpestris* (Laurenti, 1768) subsp. *apuanus*) presente nel Lago Nero e l'importanza della carice rostrata (*Carex rostrata* Stokes, 1787) presente attorno al lago stesso. Si conclude che in base ai parametri esaminati la qualità ecologica del Lago Nero è buona. Sarebbe importante elaborare un programma di monitoraggio a lungo termine sia del Lago Nero sia di altri piccoli laghetti montani dell'Appennino Pistoiese.

Parole chiave - monitoraggio acqua, ecologia lacustre, Lago Nero, Valle del Sestaione, Appennino Pistoiese

Introduction

The mountain area of the Pistoia Province is characterized by the presence of three small ponds of natural origin: the "Lago Nero", the Lago Piatto Lake and the Lago del Greppo, which have been the object of ecological and paleoclimatic research over the years (Moroni, 1961; Balsamo, 1982; Vescovi *et al.*, 2010).
These lakes represent important natural biotopes and – simply because they are located at high altitudes – they are particularly sensitive to anthropogenic impacts at both a local and global level (Cantonati *et al.*, 2006).
Each of these three lakes has different morphogenesis (Provasi, 1926; Losacco, 1982), and they are characterized by peculiar biocenosis (Romagnoli & Foggi, 2005; Foggi *et al.*, 2007). The Lago Nero is within the borders of the SCI (Sites of Community Importance) IT5130001 "Alta Valle del Sestaione", one of the richest areas of biodiversity of the Northern Apennines, with habitats, mushrooms, plants and animals species of huge biogeographical value (Foggi *et al.*, 2007; Foggi *et al.*, 2011). The value is further confirmed by the nearby "Campolino" State Natural Reserve of where there is the only surviving indigenous spruce forest (*Picea abies* (L.) H.Karst., 1881) of all the Appennines. The Lago Nero also represents an economic resource, because in late spring and summer it is visited by a large number of tourists. According to the LIMNO data base (http://www.ise.cnr.it/limno/), no data are available concerning the chemical-physical and biological characteristics of the "Lago Nero".
For these reasons the Lago Nero must be carefully monitored to detect any signs of deterioration (Mosello, 1984; Rast & Thornton, 1996; Gunn *et al.*, 2001; Marchetto *et al.*, 2004). With these assumptions, in October 2011 a monitoring program was started with the primary objective of evaluating the quality of the Lago Nero and to increase knowledge on the seasonal dynamics of this sensitive habitat.

Methods

The "Lago Nero" is of glacial origin (Dallan *et al.*, 1981; Losacco, 1982; Bortolotti, 1992) and it is located in the valley of Sestaione stream (Abetone Municipality, Pistoia Province, 44°06'56''N 10°38'12''E) a trib-

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utary of the Lima river (Lima-Serchio basin), at the bottom of "Alpe Tre Potenze" Mount, at an altitude of 1,730 m a.s.l. (Figure 1). The bedrock consists of the sandstone series known as "Macigno", composed of large rocky shoals rich in quartz and feldspar alternating with thinner layers of shales and siltstones (Dallan *et al.*, 1981; Bortolotti, 1992). In order to characterize the overall dynamics of the "Lago Nero", the following parameters were measured according to a precise protocol during 13 field surveys (see Table 2):

1) Water electrical conductivity (μS·cm^{-1}). Parameters measured directly on the lake with an multifunction oximeter model PCE-PHD 1 (PCE Italy srl) and a probe for the electrical conductivity with temperature compensation. A minimum of 10 measurements have been taken for each survey session, in the same points and with the probe at a depth of about 30 cm. The results are expressed as the mean value (±SD).

2) pH. Parameters measured directly on the lake using a pHmeter PCE-PHD 1 (PCE Italy srl) and the pH probe with temperature compensation. A minimum of 10 measurements have been taken for each survey session, in the same points and with the probe at a depth of about 30 cm. The results are expressed as the mean value (±SD).

3) Water temperature (°C). Parameters measured with a oximeter multifunction model PCE-PHD. A minimum of 10 measurements have been taken for each survey session in the same points at a depth of about 30 cm. The results are expressed as the mean value (±SD).

4) Oxygen (mg·l^{-1}). This parameter was measured directly on the lake using a multifunction oxymeter model PCE-PHD and a polarographic probe model OXHD-04 with temperature compensation (www.pce-italia.it).

5) Alpine newts (*Ichthyosaura alpestris* (Laurenti, 1768) subsp. *apuanus*) population. The estimated number of alpine newts was determined by visual counting the number of newts (adults + immature) on a stretch of 130 m along the lake shore. The count has been repeated every month.

6) Sedge (*Carex rostrata* Stokes, 1787) density (n·m^{-2}). In order to estimate the density of the sedges, on 27th August 2012 random surveys were carried out selecting 30 circular areas of 1 m^2 and counting all the ramet falling into that surface.

7) Maximum water depth reached by sedges. Twenty-seven measurements, on 8th July 2012, of water depth were taken on the edge of the mire. The return value is the mean (±SD).

Lake morphometry has been achieved thanks to the availability of aerial photos in Google Earth Pro and the National Geoportal (www.pcn.minambiente.it).

Each variable was tested for normality distribution and analyzed with parametric statistics (ANOVA one-way), according to normality test results. Relation between temperature and number of newts observed was tested with regression analysis.

For the statistical analysis we used the free software PAST 3.06 (http://folk.uio.no/ohammer/past/) and the SPSS (IBM SPSS 21.0.0., 2012 version).

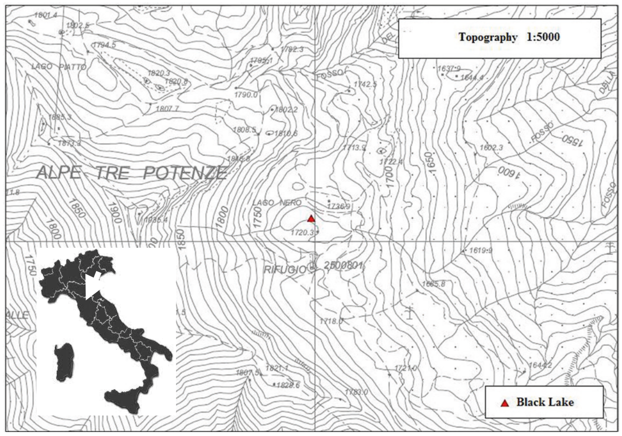

Fig. 1 - Topography of Lago Nero.

Results

The area and the perimeter of the lake are respectively 7858 m^2 and 495 m. The surface of the mire represents about 32% of the total area (Table 1).

The mean annual electrical conductivity of the water was 27.7 μScm^{-1}(±5.3), with a maximum value at end of August (Table 2). Minimum value in conductivity was reached in November, with maximum rainfall and in early June during the melting of snow. We found a strong significant seasonal difference (Table 2); pH annual average value was 7.3 (± 0.6), with a maximum value at end of August (8.7 ±0.05) and a minimum value in late December (6.5 ±0.07) with a strong significant seasonal difference (Table 2).

The mean annual water temperature was 11.1°C (±8.5), with a maximum value in early-August 22.7 ± 0.04 °C (Table 2).

The dissolved oxygen content changed significantly during the seasons (Table 2) with an average annual value of 8.5 mg·l^{-1} (±1.17). In particular, there was a marked oxygen increase in November and a sharp decrease in December.

The lake goes through three stages every year: one in which the surface is completely frozen, one in which it is completely free of ice and an intermediate phase with different percentages of frozen surface. For over six months, the lake is without ice. For about four and a half months it is frozen for over 90% of its surface and for one month and a half ice covers less than 90% of the surface.

Table 1 - Morphometry of Lago Nero achieved thanks to the availability of aerial photos in Google Earth Pro and the National Geoportal

Tot. surf.	Free water surf.	Sedge surf.	Max. lengh	Perimeter
7858 m^2	5392 m^2	2466 m^2	154 m	495 m

Table 2 - Annual change of some parameters measured; mean ± standard deviation; seasonal difference tested with ANOVA one-way. * $F_{12,78}$=1028.2, P< 0.0001; ** $F_{12,104}$=252.3, P<0.0001; *** $F_{8,64}$=427.4, P<0.0001

Day	elect. .cond. (μScm^{-1})*	pH**	T (°C)	Oxygen ($mg \cdot l^{-1}$)***
27/XI/11	21,5 (±0,71) (n=7)	7,2 (±0,07) (n=9)	1,9 (±0,11) (n=7)	-
28/XII/11	23,5 (±0,67) (n=7)	6,8 (±0,17) (n=9)	1,1 (±0,22) (n=7)	-
24/III/12	25,3 (±0,64) (n=7)	7,1 (±0,07) (n=9)	1,1 (±0,19) (n=7)	-
8/V/2012	22,4 (±0,65) (n=7)	7,3 (±0,08) (n=9)	6,7 (±0,15) (n=7)	7,9 (±0,1) (n=8)
5/VI/2012	21,2 (±0,16) (n=7)	7,2 (±0,03) (n=9)	17,7 (±0,26) (n=7)	7,3 (±0,08) (n=8)
8/VII/2012	27,5 (±0,06) (n=7)	7,3 (±0,06) (n=9)	19,5 (±0,23) (n=7)	8,25 (±0,14) (n=8)
26/VII/12	31,8 (±0,38) (n=7)	7,5 (±0,04) (n=9)	20,1 (±0,89) (n=7)	8,8 (±0,24) (n=8)
9/VIII/2012	32,6 (±0,19) (n=7)	8,5 (±0,32) (n=9)	22,7 (±0,04) (n=7)	9 (±0,19) (n=8)
27/VIII/12	35,2 (±0,07) (n=7)	8,7 (±0,05) (n=9)	22,2 (±0,1) (n=7)	8,5 (±0,14) (n=8)
11/IX/2012	33,3 (±0,15) (n=7)	7,4 (±0,08) (n=9)	16,2 (±0,15) (n=7)	9 (±0,15) (n=8)
3/X/2012	32,2 (±0,42) (n=7)	7,1 (±0,08) (n=9)	11 (±0,16) (n=7)	10,8 (±0,16) (n=8)
21/XI/12	23 (±0,13) (n=7)	7,2 (±0,07) (n=9)	4,3 (±0,18) (n=7)	6,5 (±0,23) (n=8)
31/XII/2012	21 (±0,54) (n=7)	6,5 (±0,07) (n=9)	1,2 (±0,17) (n=7)	-

	27/XI/11	28/XII/11	24/III/12	8/V/12	5/VI/12	8/VII/12	26/VII/12	9/VIII/12	27/VIII/12	11/IX/12	3/X/12	21/XI/12	31/XII/12
T °C	1,95	1,2	1,2	6,75	17,675	19,536	20	22,8	22,2	16,178182	11	4,3	1,3
Newts num	0	0	0	10	274	300	365	383	238	217	177	25	0

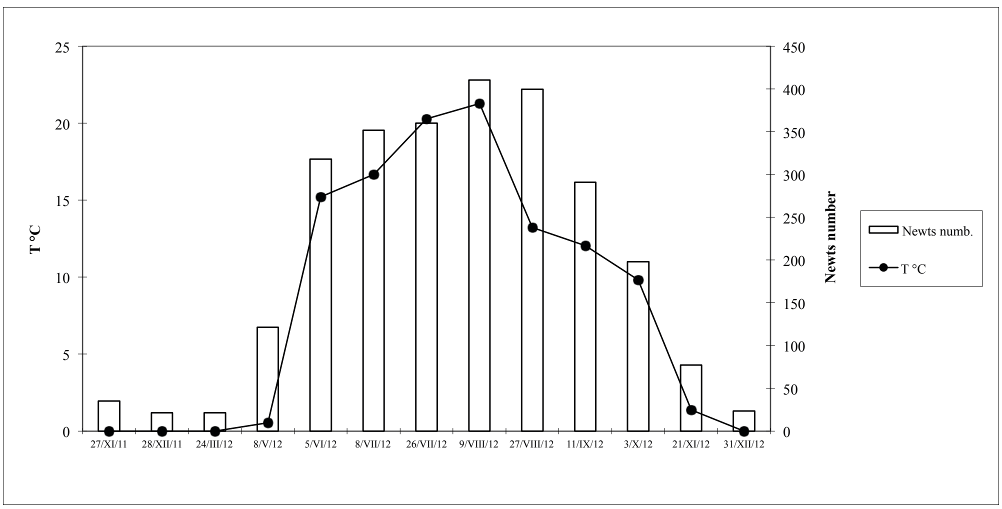

Fig. 2. Relationship between seasonal temperature and number of alpine newts (*Ichthyosaura alpestris apuanus*) observed

The number of Alpine newts (*Ichthyosaura alpestris* (Laurenti, 1768) subsp. *apuanus*) observed varies significantly with temperature during the year (r^2=0.913; df=11, P<0.0001). The largest increase is observed in May and June when the water temperature exceeds 5 °C (Figure 2).
The average value of the density of the mire (*Carex rostrata* Stokes, 1787), where the alpine newts lay eggs, estimated on the basis of 30 measurements, is 145 plants·m^{-2}, with 95% confidence limits between 130 and 160 plants·m^{-2}.
The average water depth beyond which the sedge is unable to colonize the bottom sediments is 35.9 (±3.6) cm (n= 27); maximum recorded depth is 42 cm.

Discussion

The “Lago Nero” is a small mountain lake of glacial origin; oligotrophic, its water being supplied exclusively by precipitation (rain and snow) with very low levels of meteoric pollution (Mantelli *et al*., 1993, 2000). Analyses of the data collected in the course of one year showed an overall good water quality status, as shown for other mountain lakes of the neighboring province of Modena (Viaroli *et al*., 1994; Ferrari *et al*., 1999; Boraldi *et al*., 2005; Ferrari *et al*., 2014).

Water oxygenation reaching the maximum value in October. Oxygen is essential for the biotic communities that live within the lake (Cooper and Andrus, 1994; Marchetti, 1994). This parameter is closely related to photosynthetic activity of algae and submerged sedges and with the atmospheric exchanges. Oxygen decreases significantly during the colder months when the surface of the lake is completely frozen.

During the year, there were variations of other physical parameters such as the electrical conductivity and pH, especially between July and October and in August respectively. In particular, the change in pH was probably related with the photosynthetic activity; the water tended to reduce its acidity during the summer months when the photosynthetic activity was high. The decomposition of the organic material that accumulated on the bottom during the colder months acidified the water again with the production of CO_2, in particular during the period in which the surface was completely frozen and the atmospheric exchanges are very limited (Marchetti, 1994). The electrical conductivity increases slightly when the water level decreases, probably due to a higher concentration of dissolved minerals.

The population of Alpine newt varies over time following the temperature trend. Numerical abundance increases significantly with the increase of water temperature and the highest number of reproductive adults, during first four months, while in the second part of the season the marked decrease was likely linked to the migration of many adults after mating and egg laying (July-October). Sedge, which covers about 31% of the total area, is an important site for alpine newt reproduction and egg laying (Lanza, 1983). Increase or decrease of the mire surface is probably due to medium-long time variations of the water level. The data collected show that a water depth of about 35-40 cm is the limit beyond which the *C. rostrata*, is unable to colonize the bottom of the lake.

In conclusion, it would be advisable to set up a monitoring program on longer periods in order to highlight any changes in physical-chemical and biological characteristics and also extend monitoring to the Greppo and Piatto lakes, two small natural reservoirs with different characteristics compared to the Lago Nero, which would complement the work on the seasonal dynamics of the Pistoiese mountan lakes, as carried out in other regions (Mosello *et al*., 1999; Boraldi *et al*., 2005; Soldati, 1990a; 1990b).

Finally it should be emphasized that these small mountain lakes are not only of great ecological value, but are also part of a scenic and cultural heritage, and they are visited by many hikers. We hope our survey will provide a stimulus for further research with a more globally significant scope, including connections to climate change (Ferrari *et al*., 1974; Giussani *et al*., 1986; Antonietti *et al*., 1996; Marchetto *et al*., 2004; Vescovi *et al*., 2010).

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