# The importance of hydraulic conditions in determining ecological equilibrium in an alpine lake: Lake Tovel (Trentino-Italy).

G. Flaim, F. Corradini, A. Borsato, P. Ferretti, E.Eccel, U. Obertegger, B. Borghi

## Introduction

Oligotrophic Lake Tovel is famous for its past blood red *Glenodinium sanguineum* summer blooms in the 'Red Bay'. A unique feature of the lake is its very dynamic water regime; BALDI (1941) considered the lake to be fluvial – lacustrine. The area's catchment is pseudocarsic and the main surface inflow disappears ca. 1 km from the lake into a porous aquifer feeding the peri-littoral springs in the Red Bay (Fig. 1). High catchment to lake area ratio, together with high mean elevation, contribute to fast water renewal in spring and early summer concomitant with snow melt. The aquifer's volume (> 50% lake volume), guarantees a continuous inflow of cold (~5°C) water to the lake, however in very dry periods, inflow does not compensate outflow, causing a decrease in lake level particularly evident in the Red Bay (FERRETTI & BORSATO 2004).

The lake is the object of a three-year study (SALTO) aimed at finding the cause(s) for bloom cessation that had important economic implications for tourism in the area. Although DODGE (1970), PAGANELLI (1992) and CAVALCA et al (2001) discuss many of the reasons that through the years have been entertained as causing lack of bloom, it is only within the SALTO project that an in-depth study of pasture management in the lake's catchment has indicated that significant changes in animal husbandry practices during 1963-64 substantially reduced nutrient inflow to the lake (BORGHI et al in prep) and presumably eliminated the cause(s) of bloom formation. An

examination of the literature and of available photos however underscored how bloom was not only tied to a specific alga and nutrients but also to dry summers. So it is still an open question which factors govern the occurrence of the red dinoflagellate. Is it just the presence of nutrients?
MARGALEF (1978) sustains that dinoflagellate red tides are the result of a rare condition of high nutrients combined with low turbulence, characteristic of border situations with inflow from land. More recently, SMAYDA & REYNOLDS (2003) have elaborated nine dinoflagellate bloom "types" according to combinations of mixing-irradiance- nutrients and C-R-S strategies. The Lake Tovel bloom falls into a Type I life form (gymnodinoids) characteristic of near shore, high irradiance levels, shallower mixed layer and high nutrient levels.
The rainy 2002 summer and the dry 2003 one determined different hydraulic conditions in the lake particularly in the Red Bay, influencing ecological equilibrium. We describe some changes produced by these conditions and hypothesise that stable water conditions favoured the growth of the red dinoflagellate.

**Keywords** water renewal time, turbulence, dinoflagellates, Lake Tovel

## Study site and Methods

Lake Tovel, 1177 m asl (A= 0.38 $km^2$, V= 7.37 $10^6$ $m^3$) has a deep ($z_{max}$ = 39 m) NE basin and a smaller ($z_{max}$ = 4.5 m) SW basin (Fig.1), usually dry in winter. Land use in the catchment (40 $km^2$) is forest and alpine pasture.
Pertinent literature was scanned for documented red bloom/no bloom years, which were correlated with summer rainfall. A detailed description of the lake's geohydromorphology is given in FERRETTI & BORSATO (2004); CORRADINI et al (2001) describe the lake's limnology. Renewal time for the Red Bay and lake inflows and level are according to FERRETTI & BORSATO (2004). Chemical and biological analyses were performed by standard methods. Quantitative phytoplankton and zooplankton samples were taken biweekly; live plankton tows from the Red Bay were regularly examined for red dinoflagellates.

## Results

The few certain observations on bloom/no bloom years are presented in Fig. 2 with summer rainfall data. Five blooms fall in < 50%ile years while the sixth (1956) had little rain in July-August; the three no bloom years all had at least 120 mm of rain during August and two fall in the > 75%ile. For the two summers considered, Fig. 3 shows the difference between theoretical Red Bay renewal time of app. 8 days in 2002 and app. 45 days in 2003. This is reflected in lake level that decreased sharply in summer 2003 because the aquifer no longer compensated for outflow. The situation produced significant changes in some chemical profiles such as reactive silica (Tab. 1). Diatoms were more abundant during periods of higher water flow (Fig. 4), while *Bosmina* was more abundant during calmer periods (Fig 5). Red morphs of *Glenodinium sanguineum sensu* Baldi were only found in 2003 live samples, while green morphs were abundant both years.

## Discussion

Hydrology is a major driving force in ecological equilibrium of water bodies (MARGALEF 1978; BARANYI 2002). This is evident in the two years considered for Lake Tovel. The lake has a rather scarce plankton community dominated by diatoms and rotifers in normal to rainy years such as 2002. In dry summers such as 2003 the much longer water renewal time is responsible for a series of cascading events. Silica values fall drastically, a condition that limits further diatom growth but also favours *Cyclotella* over pennate diatoms (WETZEL 2001). Zooplankton also respond to slower renewal time by shifting dominance from rotifers in 2002 to clacoderans (Fig. 5). More stable water conditions favoured the growth of *Bosmina,* a condition similar to that found in the Danube River (BARANYI et al 2001).

Changes seen in Lake Tovel between 2002 and 2003 confirm MARGALEF's (1978) hypothesis that the composition of the plankton community is less sensitive to factors such as temperature, salinity and light and much more dependent on turbulence and secondarily on general nutrient availability; population sequence is basically controlled by the physical environment. This is also underlined by documented past blooms (Fig. 2) all of which occurred in dry years. Photographic evidence also indicates that they occurred with low lake water levels. Dry years will result in less water inflow into the Red Bay providing more stable conditions with less turbulence. In our experience, summer 2003 was the first year we saw the red form; even if nutrient levels in the lake were not sufficient to sustain an algal bloom, hydraulic conditions were such that the red series was able to achieve sufficient density to be noticed. This alga seems to conform to the C strategy, characterised by small, round, invasive, competitive, fast growing forms. On going laboratory studies will better characterise its autoecology. The green series (very similar in form to the red dinoflagellate) seems to be a R-strategist (slower growing, saturates at lower levels of resource and can better tolerate periods of resource stress (SMAYDA & REYNOLDS, 2003). This green morph, is persistently abundant, tolerant of sheer/stress forces, phototaxic and mixotrophic. In short, it is better adapted to living in an environment of higher turbulence and low nutrient levels which presently characterise Lake Tovel.

## Acknowledgements

This study is part of SALTO, a research project funded by the Province of Trento (I). The authors thank V. Pinamonti and G. Leonardi for sampling.

## References

BALDI, E., 1941: Ricerche idrobiologiche sul lago di Tovel. - *Mem. Mus. St.Nat. Ven. Trid.* **6**: 1-297.

BARANYI, C., HEIN, T., HOLAREK, C., KECKEIS, S. & SCHIEMER, F., 2002: Zooplankton biomass and community structure in a Danube River floodplain system: effects of hydrology. - *Freshwater Biol.*

**47**: 473-482.

CAVALCA, L., FERRARI, P. & V. ANDREONI, 2001: *Glenodinium Sanguineum* March. and the reddening phenomenon of Lake Tovel: biological and environmental aspects. - *Ann. Microbiol.* **51**: 159-177.

CORRADINI, F., FLAIM, G. & PINAMONTI, V., 2001: Five years of limnological observations on Lake Tovel (1995-1999): Some considerations and comparisons with past data. - *Atti dell'Ass.Ital.Ocean. Limnol.* **14**: 209-218.

DODGE, J. D., 1970: Report of limnological investigation of Lake Tovel (Trentino - N. Italy). - *St.Trent.Sc. Nat.* **47**: 91-94.

FERRETTI P.& BORSATO A., 2004: Monitoraggio idrologico del bacino e del Lago di Tovel (Trentino Occ.). - *Proc. XXIX Convegno di Idraulica e Costruzioni Idrauliche, Trento,* **in press**.

MARGALEF, R., 1978: Life-forms of phytoplankton as survival alternatives in an unstable environment. - *Oceanologica Acta* **1**: 493-509.

PAGANELLI, A., 1992: Lake Tovel (Trentino): Limnological and hydrobiological aspects. - *Mem. Ist. ital. Idrobiol.* **50**: 225-257.

SMAYDA, S. J.& REYNOLDS, C. S., 2003: Strategies of marine dinoflagellate Survival and Some Rules of Assembly. - *J. Sea Res.* **49**: 95-106.

WETZEL, R., 2001. *Limnology - Lake and River Ecosystems.* Academic Press, 3rd ed. New York.

Authors' addresses:

Flaim G., Corradini F., Eccel, E., Obertegger U., Borghi B. Dipartimento RNA, Istituto Agrario, 38010 S. Michele a/A (TN) Italy (email: flaim@ismaa.it)

Borsato A., P. Ferretti - Museo Tridentino di Scienze Naturali, via Calepina, 38100 Trento, Italy

Figures

Figure 1. Lake Tovel. Aquifer (white), gauge positions (double lines), surface flow (solid line), underground flow (dotted line), major (cones) and minor (dots) springs are indicated.

Figure 2. Rainfall for June (lower), July and August (higher) for the period 1921-1965; bloom years (black) and no bloom years (gray) and 25, 50 and 75%ile are indicated (dotted lines).

Figure 3. Lake water level (m) and Red Bay theoretical renewal time (days). Active surface outlet level is indicated (dotted line).

Figure 4. Total phytoplankton, *Fragilaria* and *Fragilaria+Cyclotella* biovolume (0-25 m in the main basin).

Figure 5. Total zooplankton and *Bosmina* dry weight (0-35 m in the main basin).

Table 1. Mean silica values in Lake Tovel: inlets for all seasons; lake values for August.

| | inlets | Lake Tovel central basin (0-15m) | | |
|---|---|---|---|---|
| | 1995-2003 | 1995-2000 | 2002 | 2003 |
| $SiO_2$ mg $l^{-1}$ | 0.81 | 0.54 | 0.62 | 0.16 |
| SD | 0.14 | 0.13 | 0.05 | 0.05 |
| no. Samples | 148 | 24 | 8 | 8 |