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Nota breve – Short note

Dinoflagellate diversity in Lake Tovel

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RIASSUNTO - *La diversità dei dinoflagellati nel Lago di Tovel* - Viene descritta sinteticamente la comunità dei dinoflagellati del Lago di Tovel, come rilevata nel triennio 2002-2004. Si presentano le distribuzioni delle specie e le loro dinamiche. Sono presentate, in particolare, alcune differenze fra due specie di dinoflagellati, *Baldinia anauniensis* gen. inedit. sp. inedit. Hansen *et al*. e *Glenodinium sanguineum sensu* Dodge, che per lungo tempo sono state confuse sotto il nome di *Glenodinium sanguineum March.*

Key words: dinoflagellates, Lake Tovel, biodiversity
Parole chiave: dinoflagellate, Lago di Tovel, biodiversità

1. INTRODUCTION

During the last century there has been a significant quantity of research concerning phytoplankton state and succession in Lake Tovel (Largaiolli 1907; Baldi 1941; Dodge 1970; Paganelli *et al.* 1981; Paganelli 1992; Cantonati *et al.* 2003). However, unlike other environments that have been the subject of extensive studies, in this case it is difficult to form a picture of the evolution and changes that the phytoplankton might have undergone. This is particularly true for dinoflagellate species, one of which caused the red blooms that have made the lake famous. Past studies have been hampered by erroneous interpretations given by different and uncoordinated research teams that have worked on the lake. As a result, many processes attributed to the species *Glenodinium sanguineum* March., were in fact caused by three different dinoflagellates as described by Flaim *et al.* (2004). These three species, presently under study, are *Tovellia sanguinea* sp. inedit. (Moestrup *et al.* in press), *Baldinia anauniensis* gen. inedit. sp. inedit. (Hansen *et al*. in prep.) and *Glenodinium sanguineum sensu* Dodge (Dodge *et al.* 1987).

Another problem has been the intrinsic difficulty in the identification of dinoflagellate species in fixed samples using light microscopy (Flaim *et al.* 2003). In these samples, depending on the presence of a more or less rigid theca, dinoflagellates may lose many distinguishing characteristics. Fixatives like Lugol's solution may also heavily stain the cells, making it difficult to recognise the original colour of the species or its internal structure, like form and number of chloroplasts, etc.

The aim of this contribution is to provide a brief report of dinoflagellate diversity and abundance in the lake, based on three years of observations. For a description of the study site and the hydrodynamics of the lake see Borsato & Ferretti (2006); for sampling and counting methodology see Tolotti *et al.* (2006).

2. RESULTS

The dinoflagellate community shows important differences between the main basin (station A) and the Red Bay (station B) both in number and abundance of species present (Appendices 1, 2). Species richness was usually higher at station A, while biovolume, excluding the months in which Red Bay is empty (winter/early spring) or is filling (late spring) was higher in station B. In the main basin the highest dinoflagellate biovolumes are reached in winter/spring, while in the Red Bay maximum values usually occur between June and August.

The two generally dominant dinoflagellate species (or groups of species) in the lake were: *Gymnodinium uberrimum* complex and *Baldinia anauniensis* (Fig. 1). Station A showed higher biovolume values of the *G. umberrimum* complex while station B showed higher biovolume values of *B. anauniensis*. In 2004 however, the most abundant species were *Glenodinium sanguineum sensu* Dodge and *Peridinium aciculiferum*, species that occurred with low biovolumes in the two previous years.

Among the non dominant species, aff. *Gymnodinnium cnecoides* was present in almost every sampling date both at station A and B, while *Gyrodinium helveticum* was present only at station A. Also *P. penardiforme* and *P.* cf. *dinobryonis* were very frequent at station A. On the contrary, *Glenodinium* sp., another quite frequent species, was more abundant at station B. This might not be an independent species, but a stage of *P. umbonatum*'s life cycle, since it resembles *P. umbonatum* in form (triangular epicone, larger than the rounded hypocone), though an evident theca could not be seen. *Tovellia sanguinea*, present in low densities from June to October, was always more abundant in the Red Bay. In this case, we have to take into account the difficulty in recognising this species in fixed samples. So its abundance is probably underestimated. The

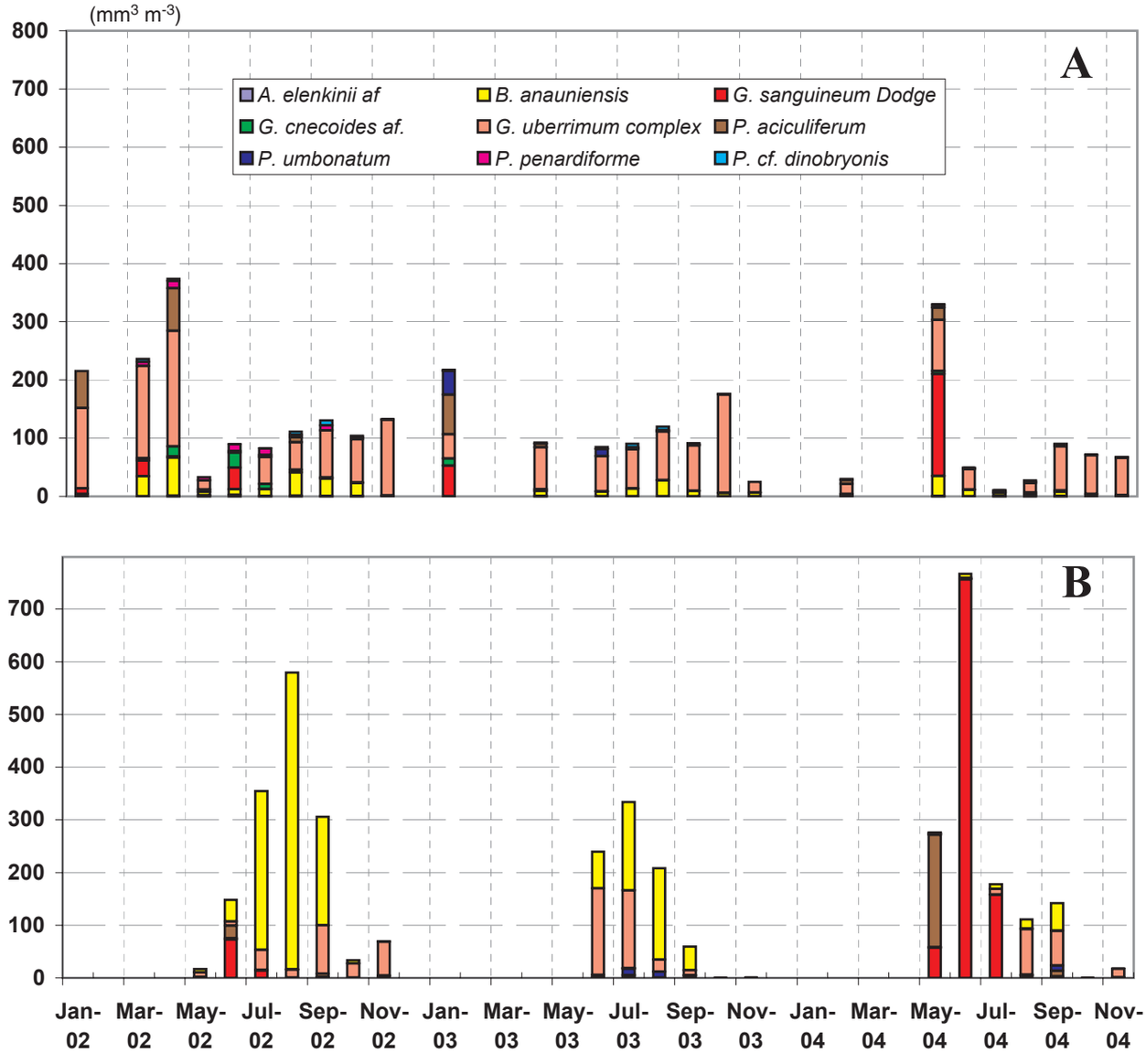

Fig. 1 - Average biovolume ($mm^3\ m^{-3}$) of main dinoflagellate species in stations A and B for each sampling date.
Fig. 1 - Biovolumi medi ($mm^3\ m^{-3}$) delle principali specie di dinoflagellati nei punti A e B per prelievo.

only way to identify it unequivocally has been by the observation of live samples (Calliari *et al.* 2006) or the presence of cysts or division stages in fixed samples. Aff. *Amphidinium elenkinii* is practically absent from station B, while at station A it showed its highest abundance in 2002. Other dinoflagellate species present in the lake, such as *Peridinium* cf. *allorgei*, *P. willei*, *P. cinctum*, and *Katodinium* cf. *montanum*, are essentially littoral species (Calliari *et al.* 2006).

Lake Tovel is basically a cold water lake (Corradini & Boscaini 2006) and most of the species found did not show a very marked seasonal pattern. Exceptions are the winter species *G. sanguineum sensu* Dodge and *P. aciculiferum* and the summer species *Tovellia sanguinea*.

2.1. *Ecological diversity of* G. sanguineum sensu *Dodge and* B. anauniensis

Until recently, a misconception on the identity of these species hindered an understanding of their ecological preferences. In samples from the period 2002-2004, i.e. before confirmation that they were two different species (Flaim *et al.* 2004), they were distinguished on the basis of some morphological differences present in fixed samples, like size and colour pattern, and it was possible to see how their presence and abundance show different temporal patterns. The most important environmental factor that permits distinguishing *G. sanguineum sensu* Dodge from *B. anauniensis*, however, seems to be temperature (Fig. 2).

Thus, *G. sanguineum sensu* Dodge is found at highest abundance during winter or spring. It might also be present in the summer, but then usually limited to the deeper layers of the Red Bay, where temperatures are ≤ 5-6 °C (Corradini & Boscaini 2006). At station A *G. sanguineum sensu* Dodge only reaches significant abundance in winter or spring but not in the surface layers.

B. anauniensis shows a more continuous temporal distribution of biovolume, with maximum values in the warmest months, between June and October. Higher biovolumes occur always in the uppermost part of the water column, both in station A and in the Red Bay. However, *B. anauniensis*, or a morphologically very similar dinoflagellate, did also occur in significant biovolume at station A (Fig. 2) at depths of 10 to 25 m.

2.2. *Key features of the distribution and abundance of the most abundant dinoflagellate species present in the lake and of other species with particular distributions*

See also Calliari *et al.* (2006) for the photographs of the species.

- *Baldinia anauniensis*: This species generally reaches its highest abundance at station B in summer, where it seems to avoid the cold water layer. It may also occur at lower densities in spring and autumn. This is one of the most abundant dinoflagellates present in the lake.
- *Glenodinium sanguineum sensu* Dodge: Its presence is usually limited to brief periods, in winter during ice cover and some years also in spring - early summer, when it may achieve high biovolumes and even be dominant. In early summer it occurs in high abundance mainly in cold water strata. On July 6th 2004, *G. sanguineum sensu* Dodge formed a brownish coloured bloom on the north-western shore of the Red Bay, reaching a biovolume of 4,000 mm^3 m^{-3}. On that particular date it was also abundant in the cold deep layers of station B.
- The *Gymnodinium uberrimum* complex: This represents at least two species, *G. uberrimum* and *G. palustre* Schilling, that we could not distinguish in fixed samples. This complex is present all year round but highest abundances are usually found in spring and autumn. At station A it is present in the whole water column but is usually more abundant between 10-20 m. Observations of live samples indicate that *G. uberrimun* reaches higher abundances than *G. palustre.*
- *Peridinium aciculiferum* briefly dominated the dinoflagellate community in January 2003 at station A and in May 2004 at station B. This species only reaches high abundance during winter or early spring when cold water coming from snow melting in the basin flows into the lake, confirming its cold water species status.
- *Katodinium* cf. *montanum*: this littoral species was observed in September 2004, with limited abundance. It is the first record of this species for Lake Tovel.
- *Peridinium* cf. *allorgei*: This species was very abundant in September 2004 littoral samples, but rare in the two lake sampling stations.
- *Peridinium umbonatum*: generally it is present all year long, especially from winter to late summer, but with low biovolume.

3. CONCLUSIONS

Continuous observations for a three year period permitted a clearer definition of the dinoflagellate community present in Lake Tovel. Differences were seen in species composition and abundance between the two lake basins. Some ecological parameters are suggested which better define dinoflagellate species distribution in the lake.

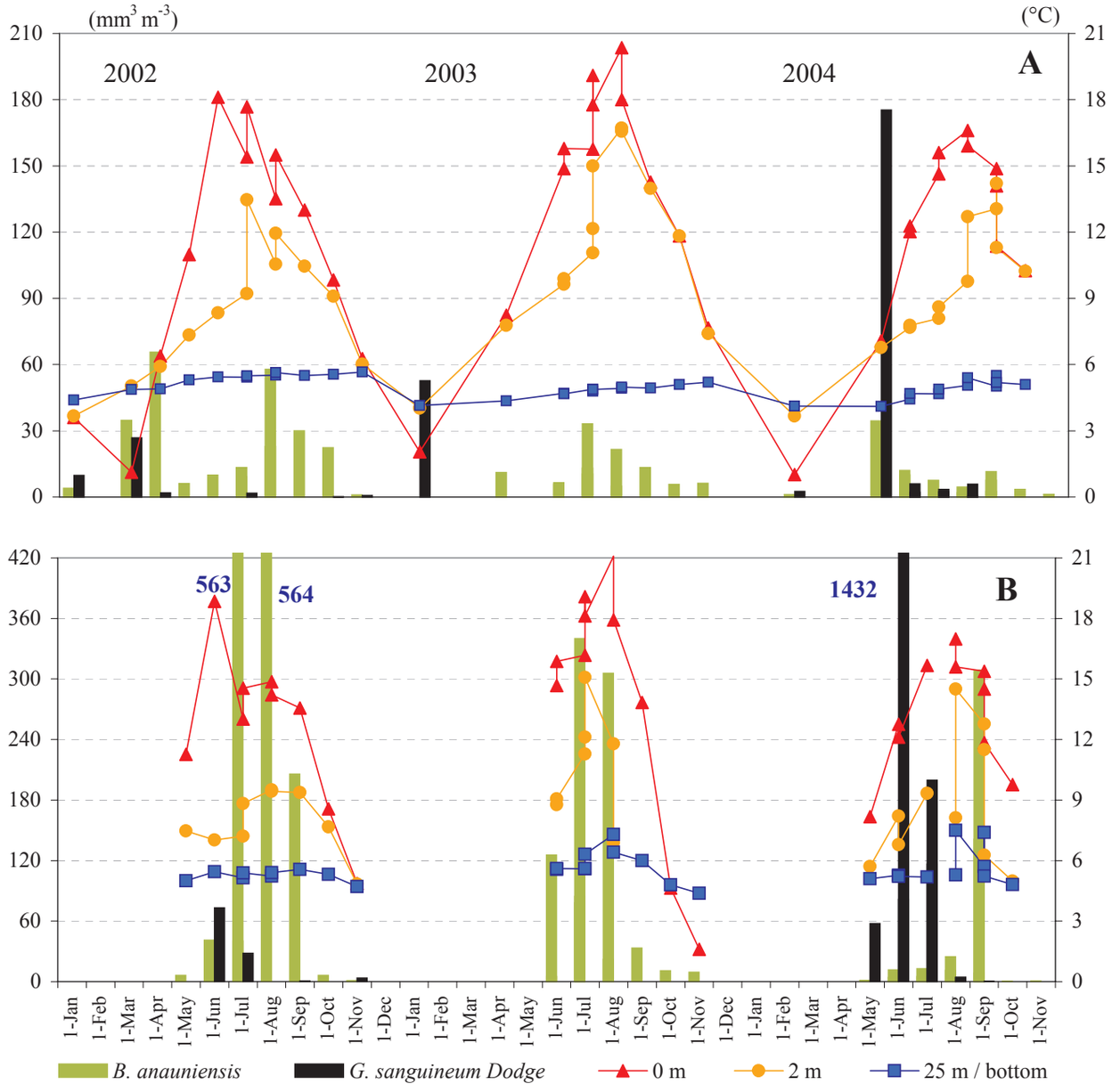

Fig. 2 - Average biovolume ($mm^3\ m^{-3}$) of Baldinia anauniensis and *Glenodinium sanguineum sensu* Dodge in stations A and B for each sampling date and temperature (°C) at surface, 2 m and 25 m (station A) or bottom (station B).
Fig. 2 - Biovolumi medi ($mm^3\ m^{-3}$) di Baldinia anauniensis *e* Glenodinium sanguineum sensu *Dodge nei punti A e B per ogni prelievo e temperatura (°C) in superficie, a 2 m e a 25 m (punto A) o fondo (punto B).*

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Appendix 1 - Mean densities (cells ml^{-1}) of dinoflagellates present at station A. P (presence) indicates < cells ml^{-1}.
Appendice 1 - Densità medie (cellule ml^{-1}) dei dinoflagellati presenti nel punto A. P (presenza) indica biovolume < cellule ml^{-1}.

STATION A	Year	Jan-Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Amphidinium elenkinii af. Skorcov	2002			6	7	13	4	4	3	2	
	2003	P		2		P		P			
	2004				2	1	2	1	1	P	P
Baldinia anauniensis gen. inedit. sp. inedit. Hansen *et al.*	2002	1	7	13	1	2	2	8	6		P
	2003			2		2	3	5	2	1	1
	2004	P			7	2	1	1	1	1	P
Glenodinium sp.	2002							P			
	2003					2	1	2	1	2	P
	2004				P	P			1	P	
Gymnodinium cnecoides af. Harris	2002	P	11	45	11	68	22	12	5	2	P
	2003	32		8		1	1	1	2	1	1
	2004	1			13	1	5	8	7	2	3
Gymnodinium sanguineum sensu Dodge	2002	4	11	1		15	P			P	P
	2003	21									
	2004	1			71						
Gymnodinium uberrimum comlplex (Allman) Kofoid & Swezy	2002	3	4	5	P		1	1	2	2	4
	2003	1		2		1	2	2	2	4	P
	2004	P			2	1		P	2	2	2
Gyrodinium helveticum (Penard) Takano & Horiguchi	2002	P	P	P	P	P	P	P	P	P	P
	2003			P			P	P		P	P
	2004	1			P	P	P	P			
Katodinium cf. *montanum* Schiller	2004	Present in the littoral (Calliari *et al.* 2006)									
Peridiniopsis cf. *dinobryonis* (Woloszynska) Bourrelly	2002		1	1	P	P	P	1	2	P	P
	2003	P		P		1	1	1	P	P	
	2004	P			P	P	P	P	P	P	P
Peridiniopsis penardiforme (Lindemann) Bourrelly	2002	P	4	7	3	7	6	2	5	1	
	2003	1		P		P	1	1	1	P	
	2004	P			2	1	1	1	1	P	P
Peridinium aciculiferum Lemmermann	2002	4		5		P	P	1		P	
	2003	5		1							
	2004	P			1						
Peridinium cf. *allorgei* Lefèvre	2002										
	2003										
	2004								P	P	P
Peridinium cinctum (O.F. Müller) Ehrenberg	2004	Present in the littoral (Calliari *et al.* 2006)									
Peridinium umbonatum Stein	2002										
	2003	10				3	P	P	P		
	2004				P	P			P	P	
Peridinium willei Huitfeld-Kaas	2004	Present in the littoral (Calliari *et al.* 2006)									
Tovellia sanguinea sp. inedit. Moestrup *et al.*	2002										
	2003						P				P
	2004										

Appendix 2 - Mean densities (cells ml^{-1}) of dinoflagellates present at station B. P (presence) indicates < cells ml^{-1}.
Appendice 2 - Densità media (cellule ml^{-1}) dei dinoflagellati presenti nel punto B. P (presenza) indica < cellule ml^{-1}.

STATION B	Year	Jan-Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Amphidinium elenkinii af. Skorcov	2002				1			2		1	
	2003						1				
	2004				1	1		5	1		
Baldinia anauniensis gen. inedit. sp. inedit. Hansen *et al.*	2002				1	8	59	110	40	1	P
	2003					14	33	34	9	P	P
	2004				P	2	2	3	10	P	P
Glenodinium sp.	2002										
	2003					25	4	P	3		P
	2004				1	P		1	3	P	P
Gymnodinium cnecoides af. Harris	2002				1	6	2	1	2	1	
	2003					3	13	1	1	1	
	2004				2	1		3	6	P	
Gymnodinium sanguineum sensu Dodge	2002					30	6		P		1
	2003										
	2004				23	306	64	2	P		P
Gymnodinium uberrimum complex (Allman) Kofoid & Swezy	2002				P	P	1	P	2	1	2
	2003					4	4	1	P		
	2004					P	P	2	2		P
Gyrodinium helveticum (Penard) Takano & Horiguchi	2002 - 2004	Not found in the Red Bay									
Katodinium cf. montanum Schiller	2004	Present in the littoral (Calliari *et al.* 2006)									
Peridiniopsis cf. *dinobryonis* (Woloszynska) Bourrelly	2002										P
	2003						P		P		
	2004				P			P			P
Peridiniopsis penardiforme (Lindemann) Bourrelly	2002				P			P			
	2003										
	2004				P	P		P	P		
Peridinium aciculiferum Lemmermann	2002				P	2			P	P	P
	2003										
	2004				15				1		P
Peridinium cf. *allorgei* Lefèvre	2002										
	2003										
	2004								1		P
Peridinium cinctum (O.F. Müller) Ehrenberg	2004	Present in the littoral (Calliari *et al.* 2006)									
Peridinium umbonatum Stein	2002										
	2003					1	3	3	1		P
	2004				P	P	P	P	3		
Peridinium willei Huitfeld-Kaas	2004	Present in the littoral (Calliari *et al*. 2006)									
Tovellia sanguinea sp. inedit. Moestrup *et al.*	2002							P			
	2003					P	P	P	P	P	
	2004						P	P	P		