LABILITY OF ORGANIC CARBON IN LAKES OF DIFFERENT TROPHIC STATUS

A. P. Ostapenya, A. Parparov, and T. Berman

Ostapenia A., Parparov A. & Berman T. 2009. Lability of organic carbon in lakes of different trophic status. *Freshwater Biology,* **54**, 1312–1323

Guillemette F, McCallister SL, del Giorgio PA. 2013. Differentiating the degradation dynamics of algal and terrestrial carbon within complex natural dissolved organic carbon in temperate lakes. Journal Of Geophysical Research: Biogeosciences, Vol. 118, 963–973

Operationally TOC in natural waters has been characterized as a labile fraction (OC_L) which is biologically available over the short term (days to several weeks) and a fraction (OC_R) which is refractive over a much longer period. The labile fractions of DOC and POC are degraded within a relatively short period due to activity by free living or attached bacteria, and protista while the refractory fraction is much more biologically inert. In most aquatic systems DOC is in higher concentration than POC and appears to be more refractive than POC (Wetzel, 1984; Ostapenya, 1989).

Partition of Organic Carbon in natural waters

$$TOC = DOC + POC$$

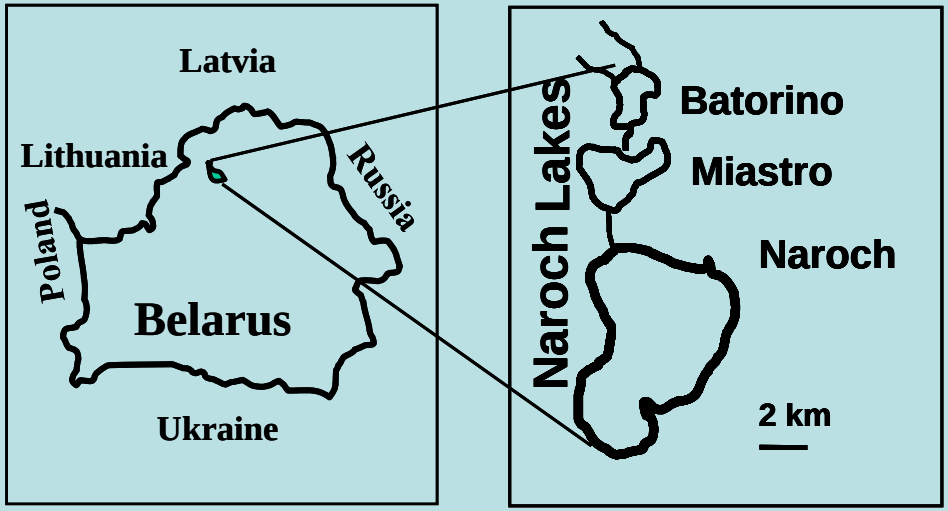
$$TOC = OC_L + OC_R$$

We present and analyze both previously published and new experimental data for the **Naroch Lakes**, (Belarus) and **Lake Kinneret**, (Israel) together with published data (Tregubova and Kulish, 1982) for **Ladoga Lake**, (Russia) in order to examine the following :

1. What are the relative contributions of labile and refractory organic carbon fractions within the TOC of the various lake environments?
2. What portion of both the dissolved and particular fractions of the TOC is labile in these lakes?
3. Is there any relationship between the lability of these organic carbon pools and lake trophy?
4. BOD5 as a measure of labile organic carbon.

- ***In other words, we should be ready to reply the following questions:***
- ***1. How much LABILE organic matter is contented in water?***
- ***2. How LABILE is this organic matter?***

Sites description: Belarus Lakes



Naroch Lake, Belarus


1 2:09 AM

Lake Kinneret, Israel

Limnological characteristics of the investigated lakes (Serruya, 1978,Berman et al., 1995; Yacobi, 2006; Ostapenya, 2000, Pettrova, 1982); water column averages for Lake Kinneret, and ice free season for Naroch Lakes and Ladoga Lake

Parameters	Naroch	Miastro	Batorino	Kinneret	Ladoga
Surface area, km^2	79.6	13.1	6.3	170	17900
Volume, km^3	0.71	0.07	0.02	4.1	1486
TOC, mg l^{-1}	5.38	8.71	14.6	5.08	10.3
POC, mg l^{-1}	0.49	1.68	4.81	1.48	0.7
DOC, mg l^{-1}	4.89	7.03	9.75	3.6	9.6
Chl, µg l^{-1}	4.9	20.0	50.1	18.0	2.3
Prim. Prod., gC m^{-2} yr^{-1}	80	180	170	650	

METHODS

- **BOD-kinetics was obtained from a time series of oxygen demand in unfiltered, near surface lake water. The sampling time intervals for the BOD determinations were: 2, 4, 8, 16 and 20 days and 1, 3, 5, 10, 15 and 20 (or 25) days for the Naroch Lakes and Lake Kinneret respectively.**

The OC_L pool can be quantified using the biological oxygen demand test:

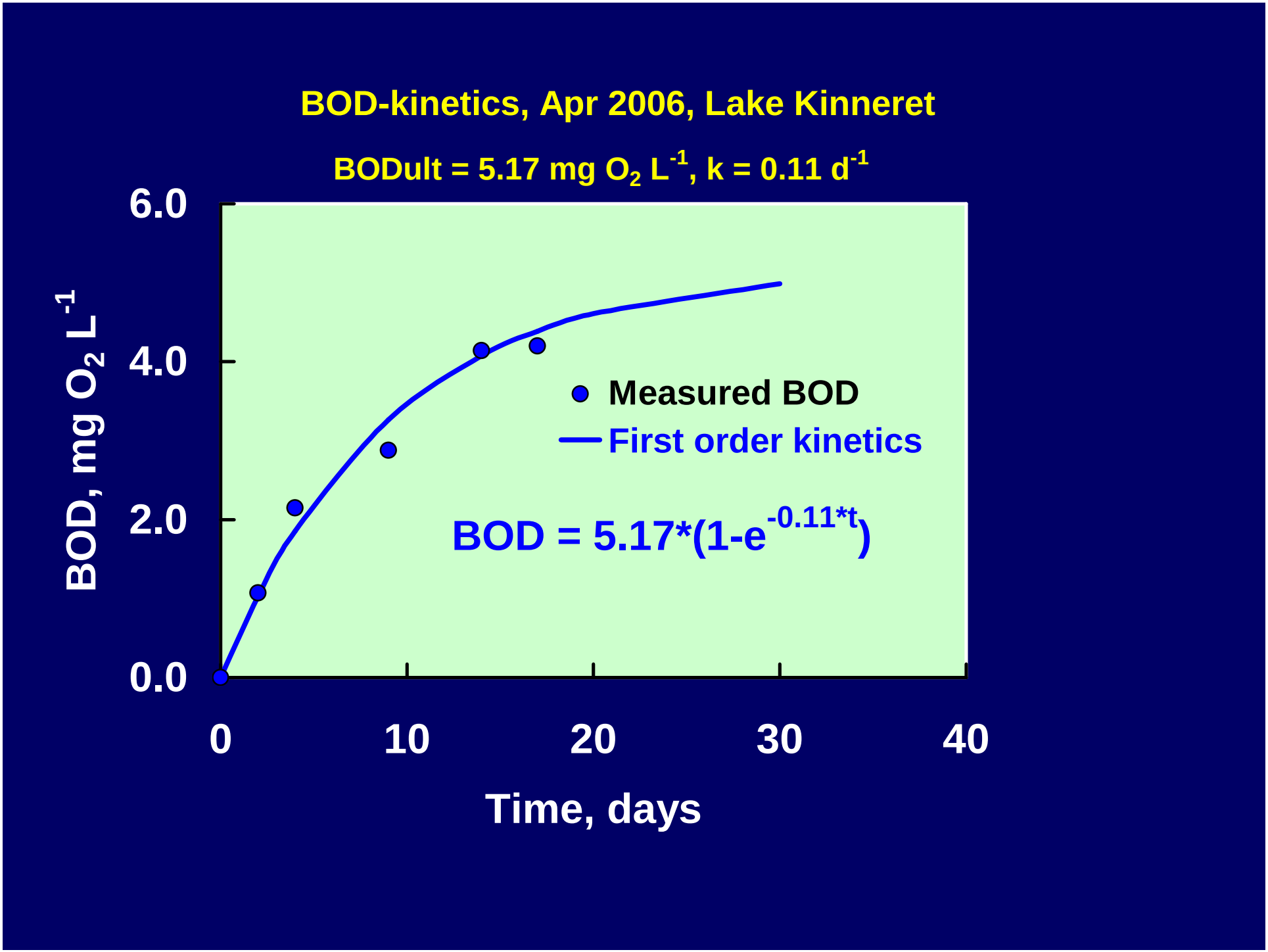
$$BOD_t = BOD_{ult}(1 - e^{-kt})$$

where BOD_t (mg O_2 l^{-1}) is the biological oxygen demand at time t (days),

BOD_{ult} - the ultimate or total BOD, is asymptotic at $t \rightarrow \infty$, an estimate of quantity of total labile OC

(1 mg O_2 l^{-1} = 0.3 mgC l^{-1})

k (d^{-1}) is the reaction constant, *the lability per se*.


BOD-kinetics, Apr 2006, Lake Kinneret
BODult = 5.17 mg O2 L-1, k = 0.11 d-1
6.0
4.0
2.0
0.0
BOD, mg O2 L-1
0
10
20
30
40
Time, days
Measured BOD
First order kinetics
BOD = 5.17*(1-e-0.11*t)

METHODS *(continued)*

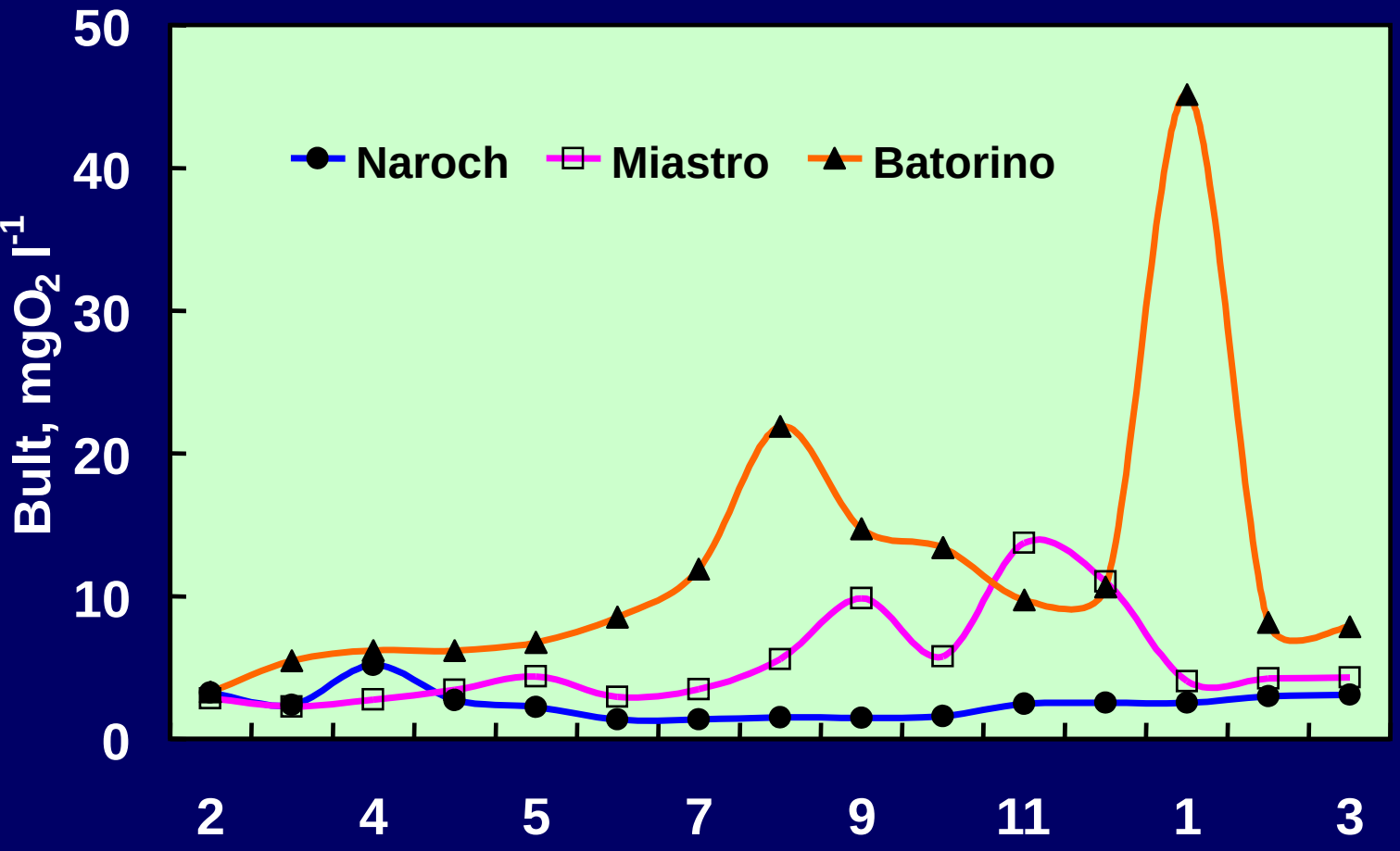
- At the Naroch lakes, BOD was also determined simultaneously in unfiltered and in 0.8 μm filtered water samples providing an estimate of DOC_L kinedtics. For these experiments we assumed that

- $$TOC_L = POC_L + DOC_L$$
-
- The parameters of BOD-kinetics associated with particulate POC were obtained from the curves calculated as a difference:

- $$BODultp = BODult - BODultd$$

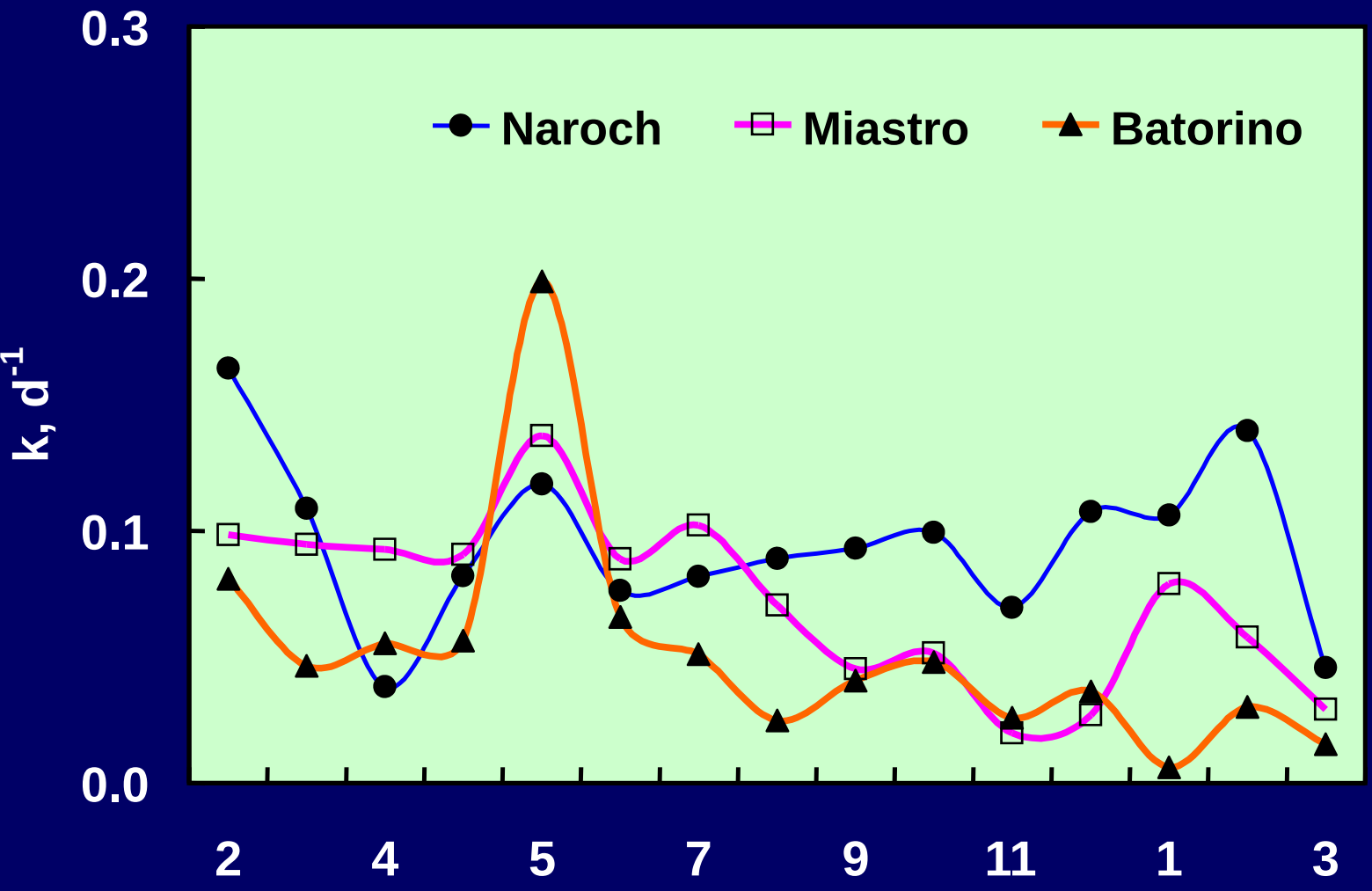
RESULTS: non-filtered water (TOC_L)

Seasonal dynamics of parameters of the BOD-kinetics (BODult) in the Naroch Lakes



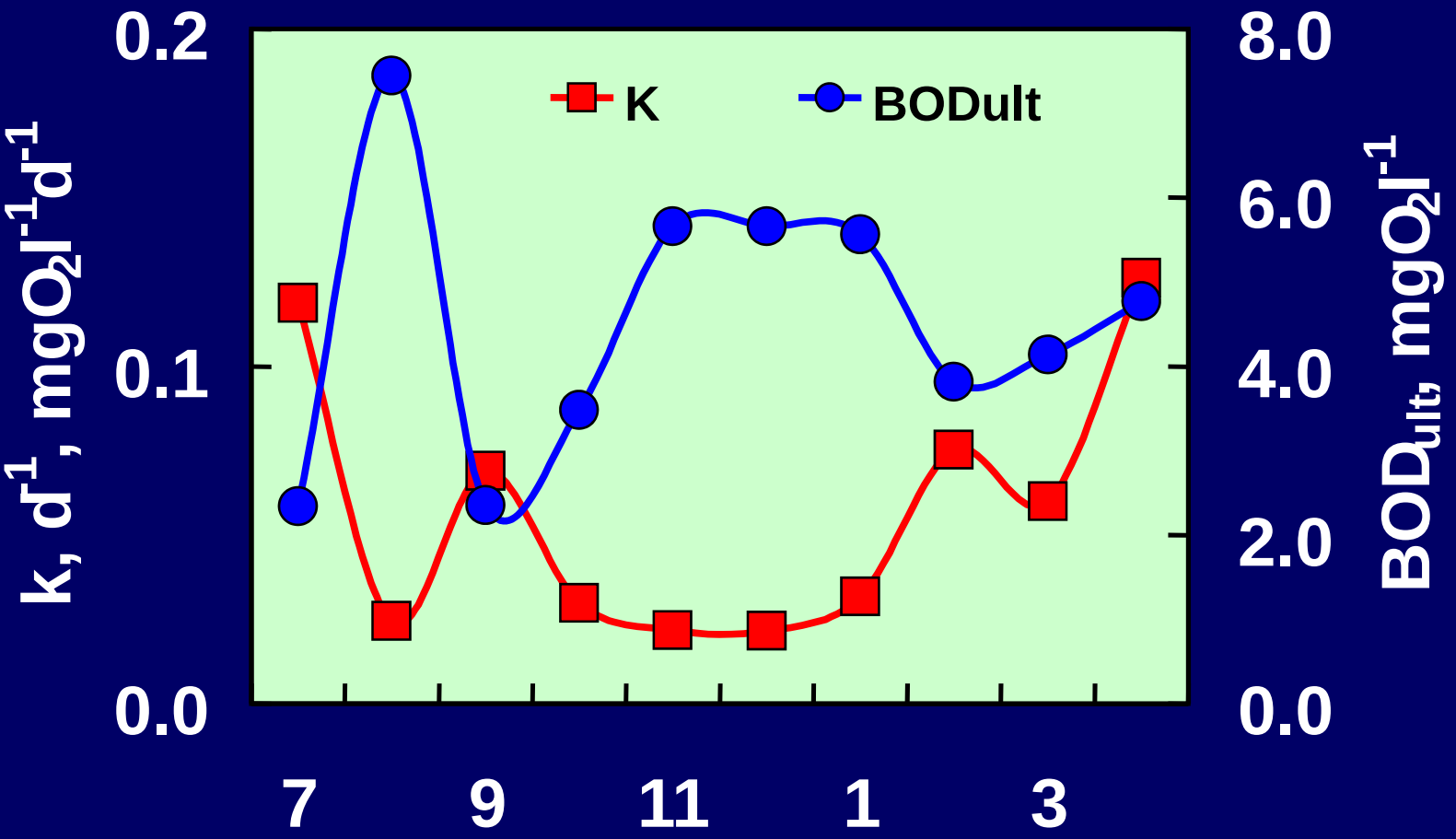
RESULTS: *non-filtered water (TOC_L)*

Seasonal dynamics of parameters of the BOD-kinetics (BODult) in the Naroch Lakes



RESULTS: *non-filtered water (TOC_L)*

Seasonal dynamics of parameters of the BOD-kinetics (BODultd and k) in Lake Kinneret



RESULTS: non-filtered water (TOC_L)

Variability of the parameters of the BOD-kinetics (non-filtered water) in studied lakes: Avg (C.V.)

Variables	Naroch	Miastro	Batorino	Kinneret	Ladoga*
BOD_{ult}, mg O_2 l^{-1}	2.44 (0.41)	5.37 (0.64)	11.7 (0.43)	4.55 (0.34)	5.24 (0.30)
k, d^{-1}	0.095 (0.34)	0.072 (0.46)	0.043 (0.62)	0.058 (0.34)	0.140 (0.28)

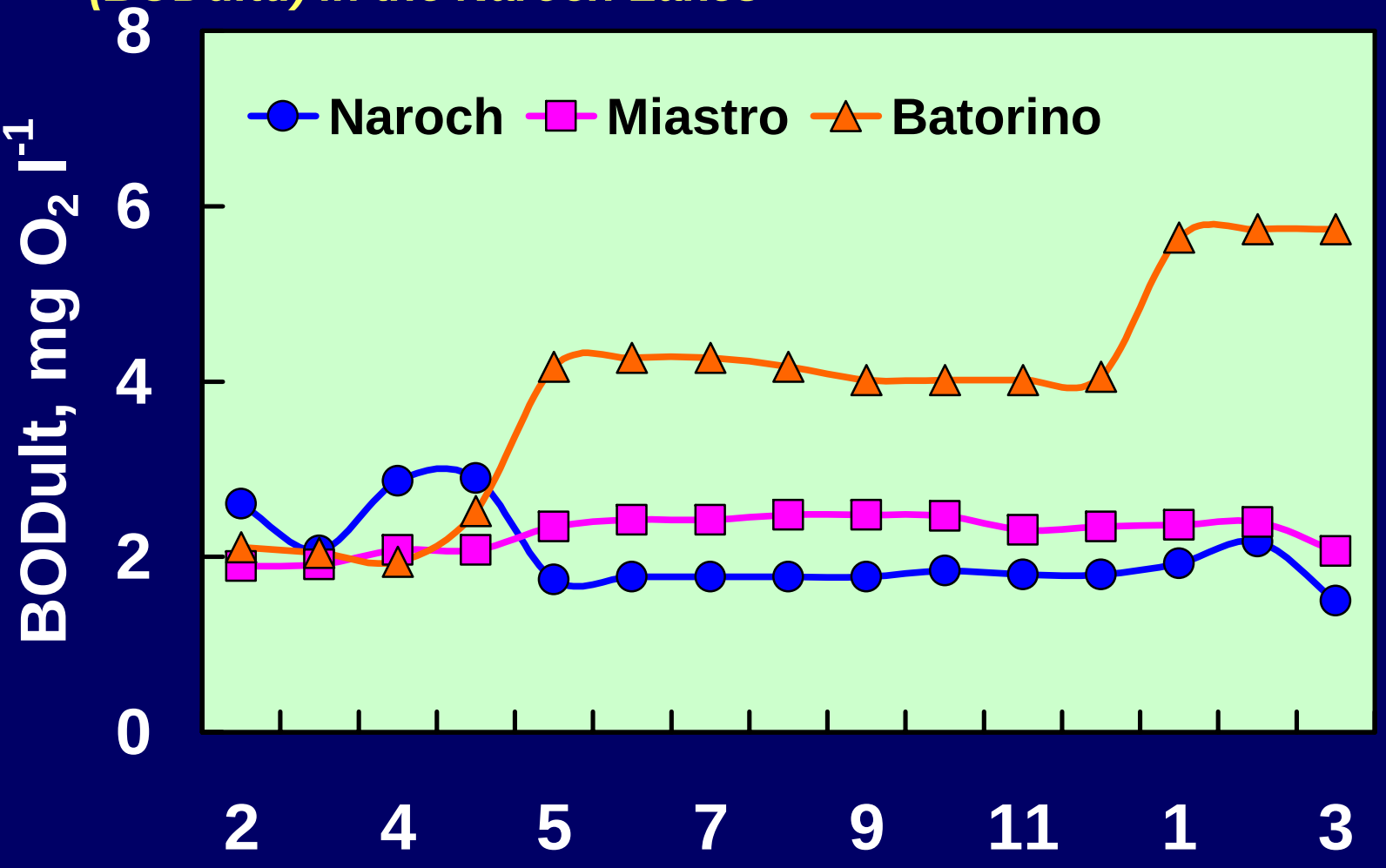
Wetzel (1992) and Sondergaard et al. (1995):

k = 0.02 to 0.05 d-1

**Tregubova T.M. & Kulish T.P. (1982) The kinetics of the biochemical oxygen demand in water of Lake Ladoga. In: Anthropogenic Eutrophication of Ladoga Lake (Ed. N.A. Petrova), pp. 106–116. "Nauka" (in Russian), Leningrad*

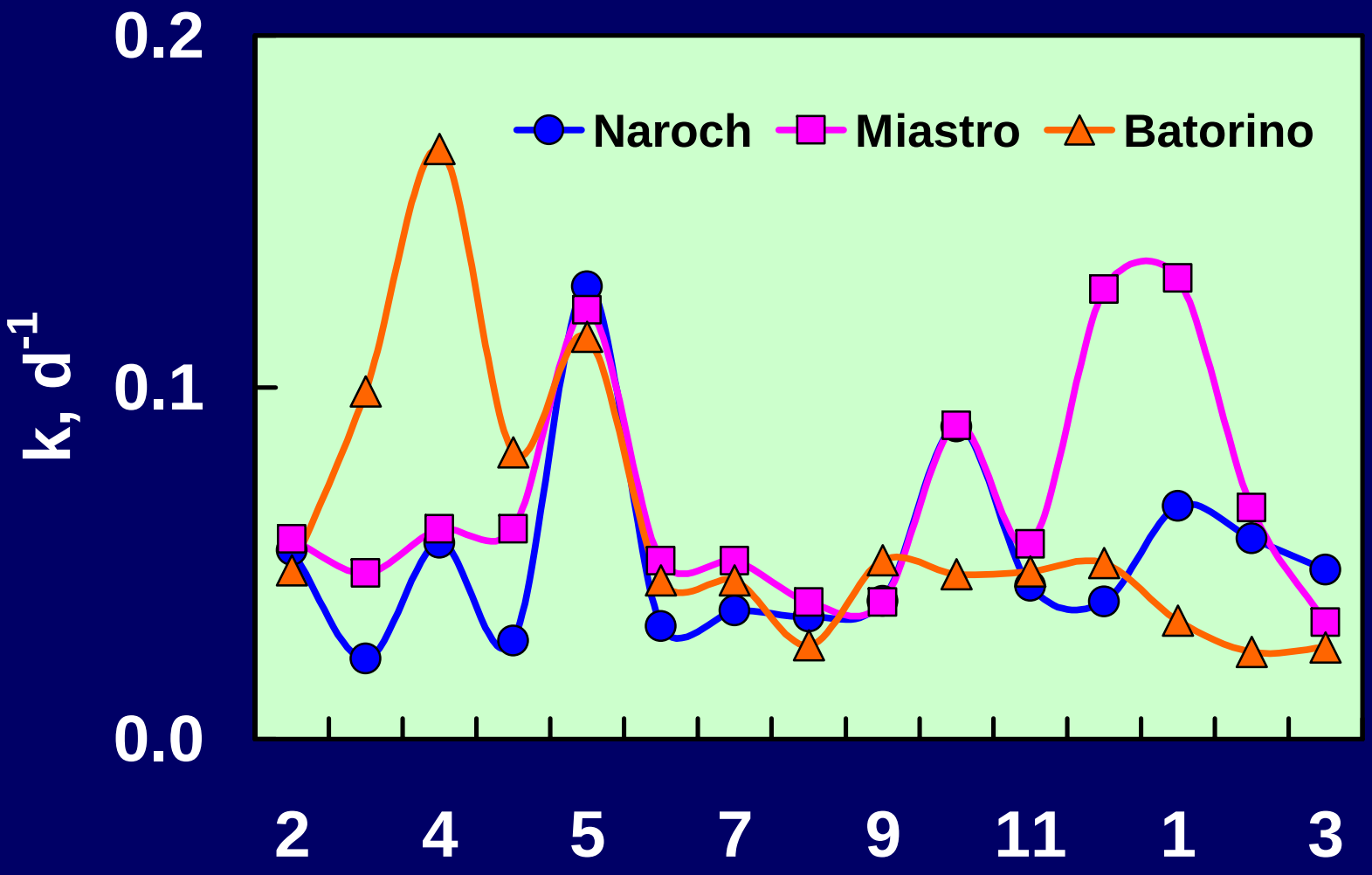
RESULTS: *0.8 μm-filtered water (DOC_L)*

Seasonal dynamics of parameters of the BOD-kinetics (BODultd) in the Naroch Lakes



RESULTS: *0.8 μm-filtered water (DOC_L)*

Seasonal dynamics of parameters of the BOD-kinetics (k) in the Naroch Lakes



Variability of the parameters of the BOD-kinetics in Naroch Lakes: filtered water (I, DOC_L), Avg (C.V.) and calculated avg values for particulate component (II, POC_L)

Variables	Naroch		Miastro		Batorino	
	I	II	I	II	I	II
BODult, mg O_2 l^{-1}	**2.02** (0.21)	**1.60**	**2.27** (0.09)	**3.43**	**3.91** (0.32)	**11.4**
k, d^{-1}	**0.052** (0.52)	**0.054**	**0.068** (0.48)	**0.049**	**0.061** (0.65)	**0.043**

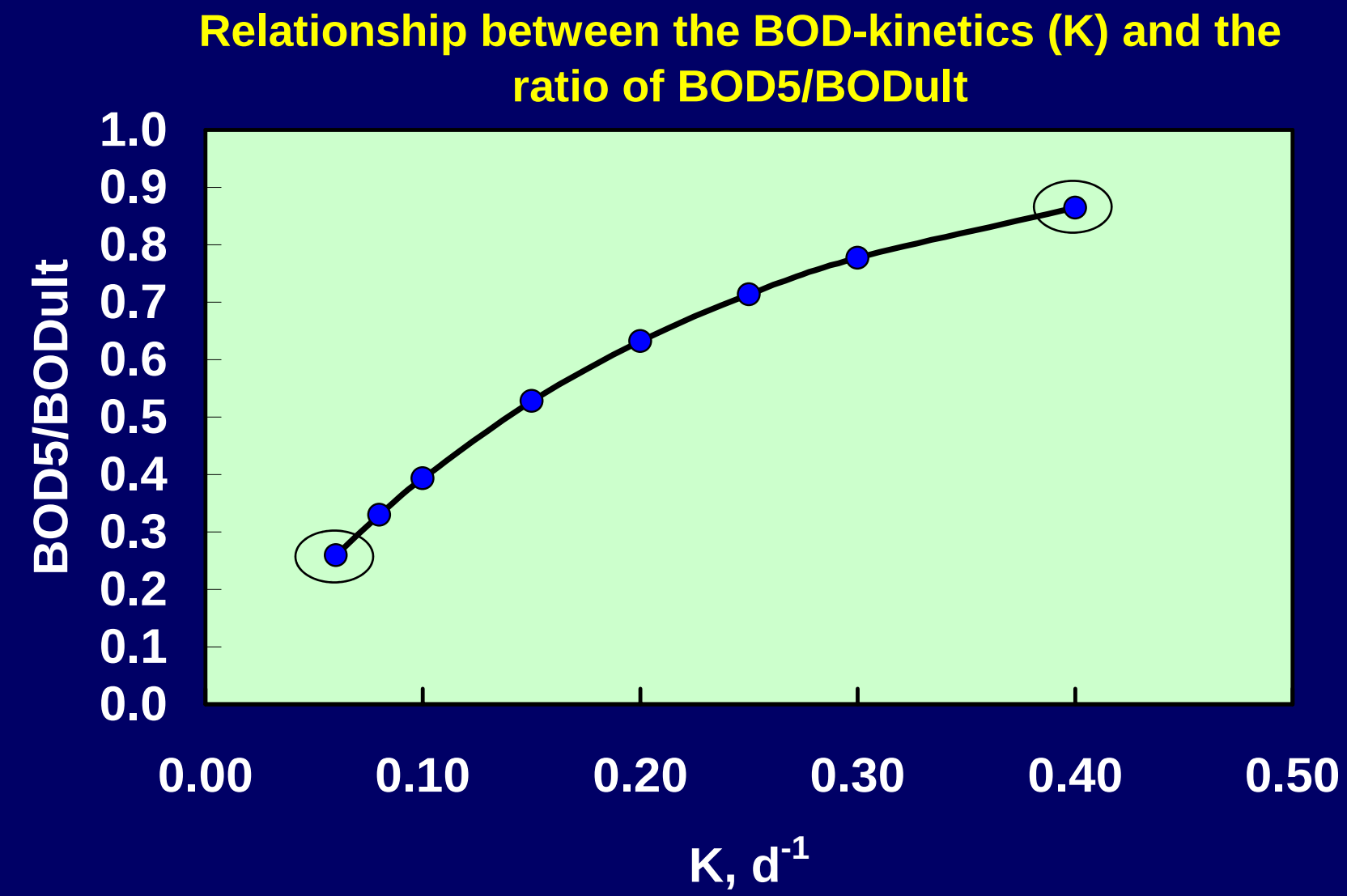
Variables	**Naroch**	**Miastro**	**Batorino**
BODult	**2.44**	**5.37**	**11.7**
k	**0.095**	**0.072**	**0.043**

Notice: these are estimates, not measured values!!

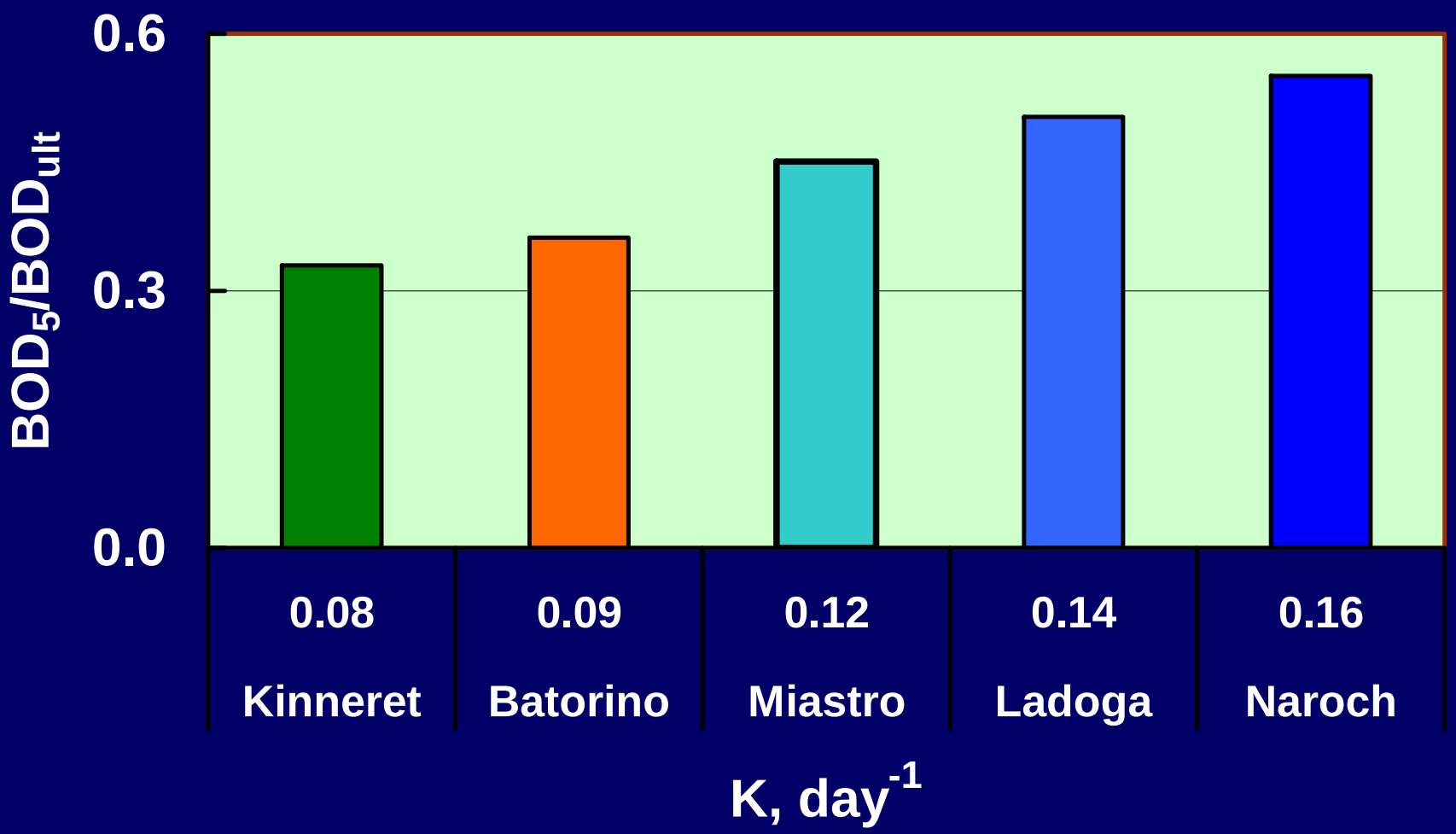
BOD_5 as an index of lability of OM

- Traditionally, the OC_L pool has been quantified using the five-day biological oxygen demand test (BOD_5) as a minimal estimate of labile OC in aquatic ecosystems, mostly in wastewaters (Standard Methods, 2002). Based on the kinetics of oxygen depletion, it has been suggested that BOD_5 comprises about 0.7 of “ultimate BOD" i.e. $OC_L = 1.5*BOD_5$ (Scopintsev, 1978; Jonas and Tuttle, 1990).

BOD_5 as an index of lability of OM



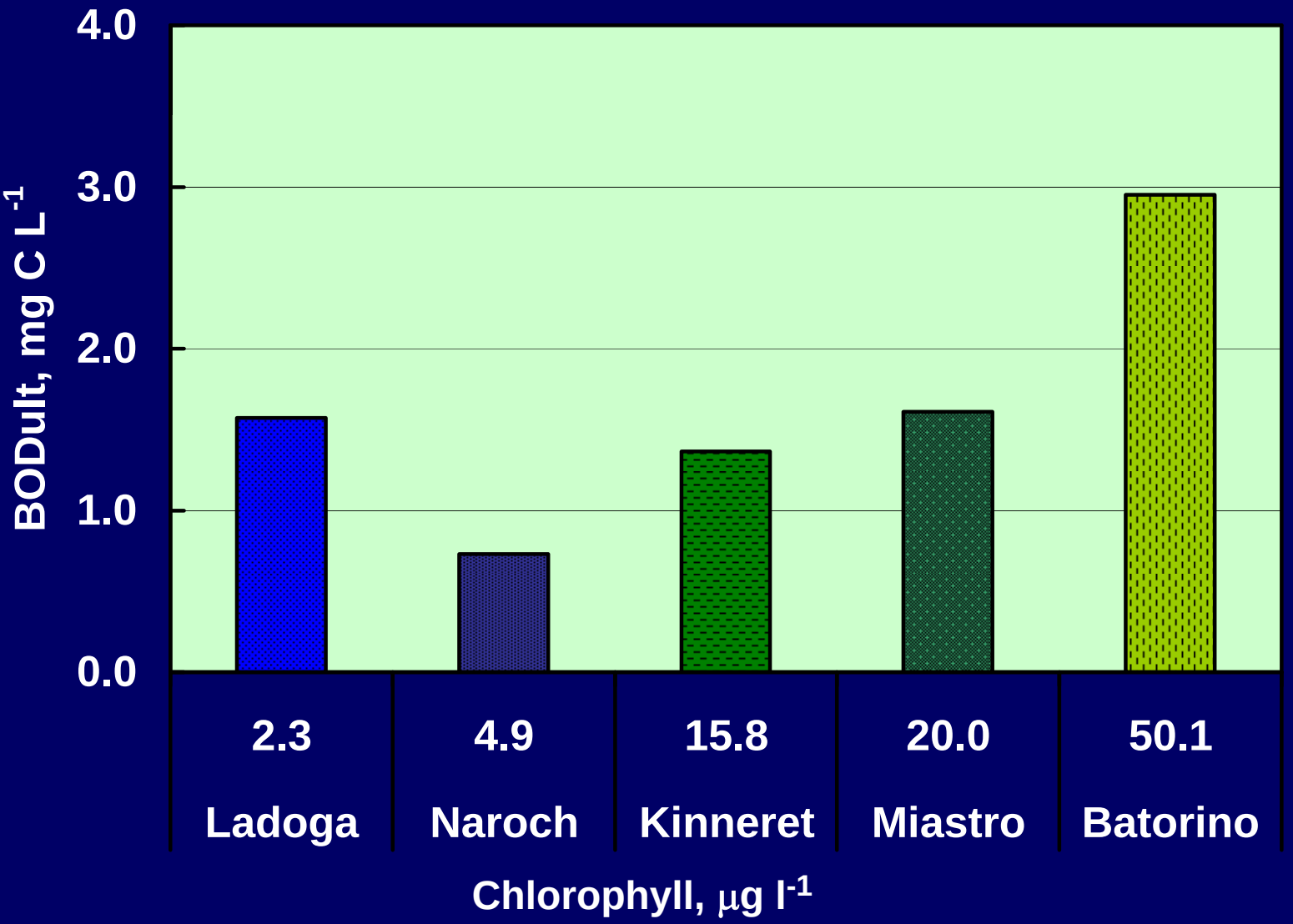
BOD_5 as an index of lability of OM



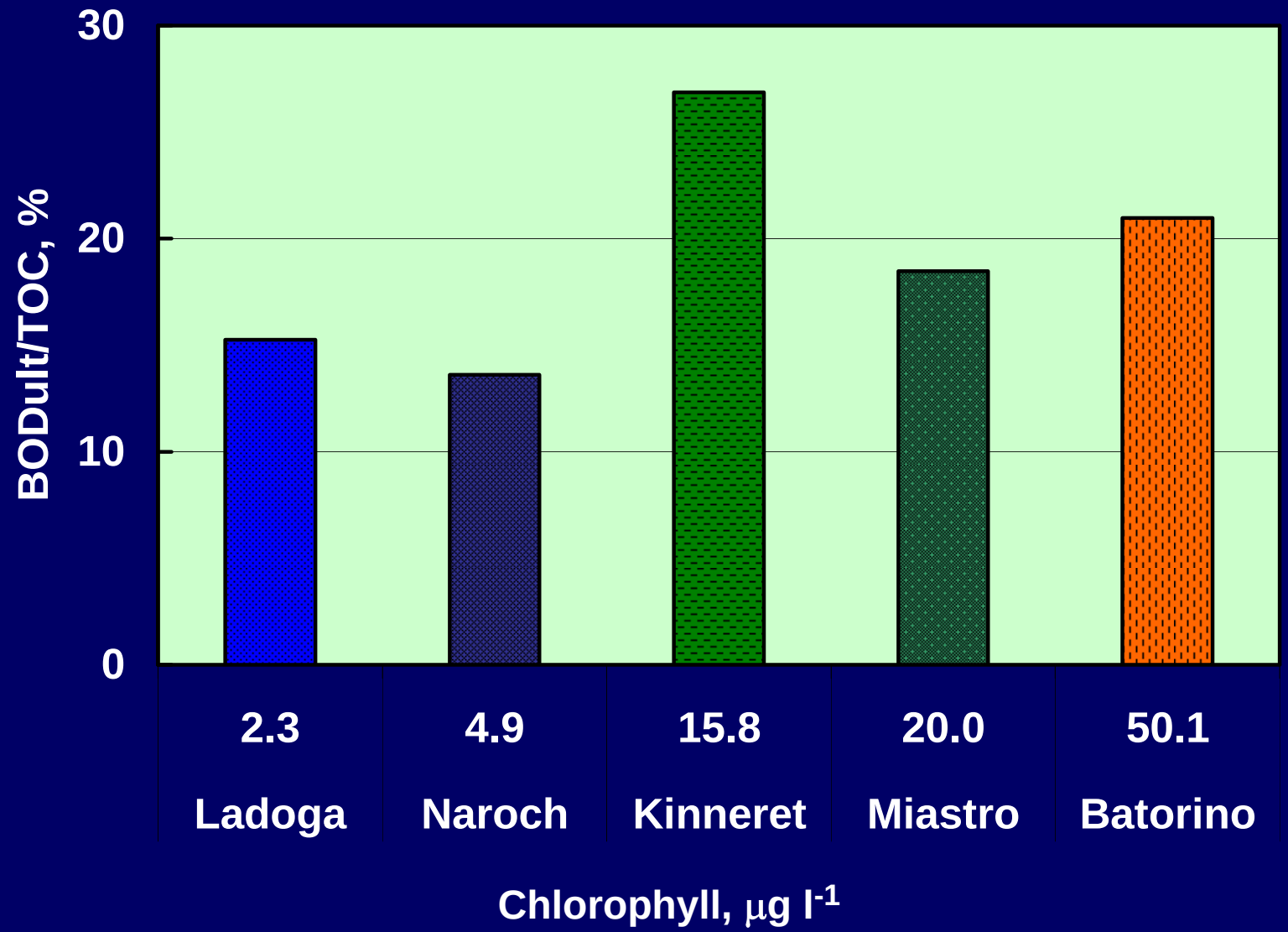
Sub-conclusion (methodological):

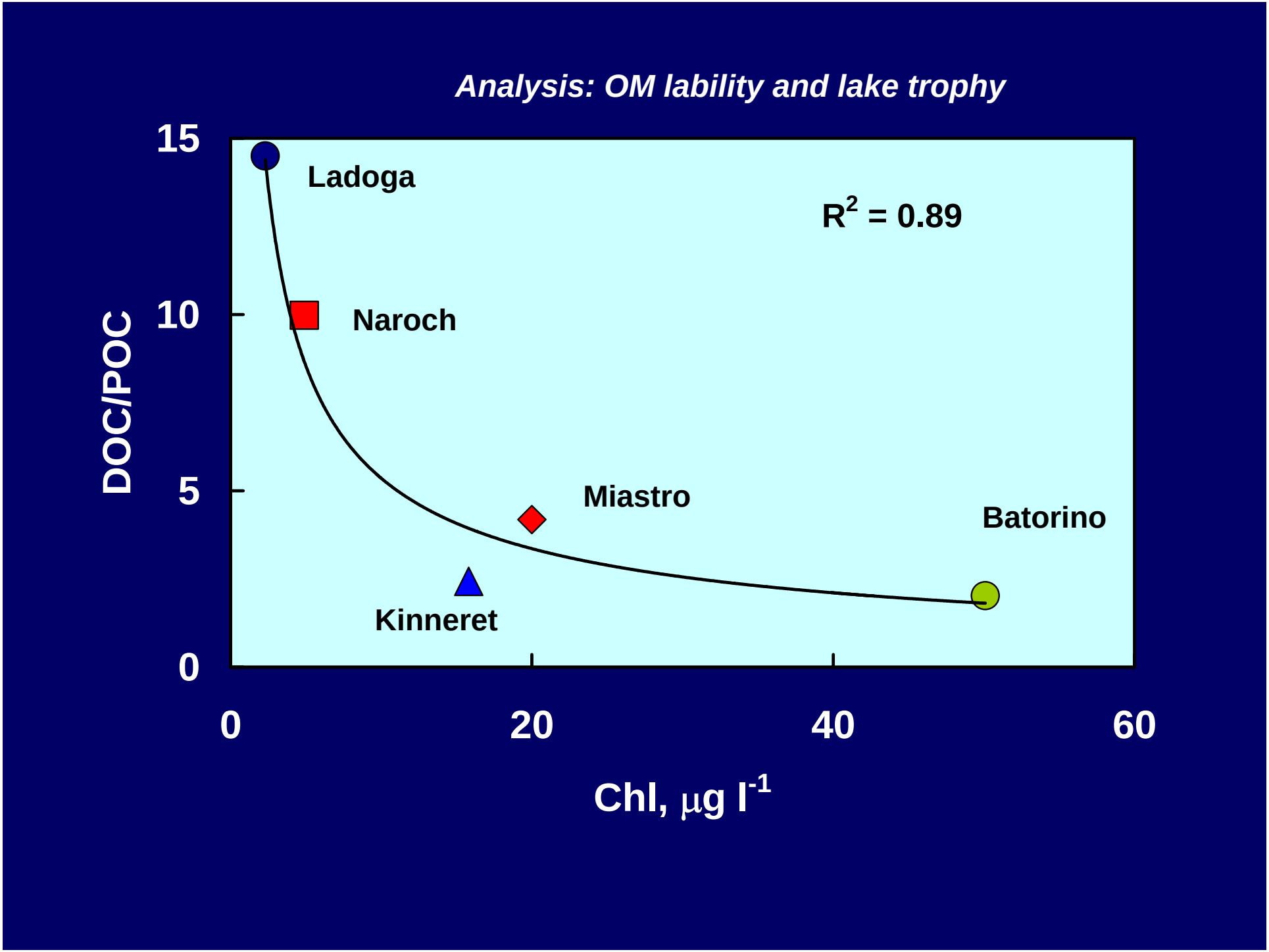
- **BOD_5 is a variable portion of BOD_{ult} and therefore it can be used for quantifying of the lability only in the case of stable composition of organic matter;**
- **BOD_5 is not suitable for chatacterizing of OM lability in natural waters**

Analysis: OM lability and lake trophy

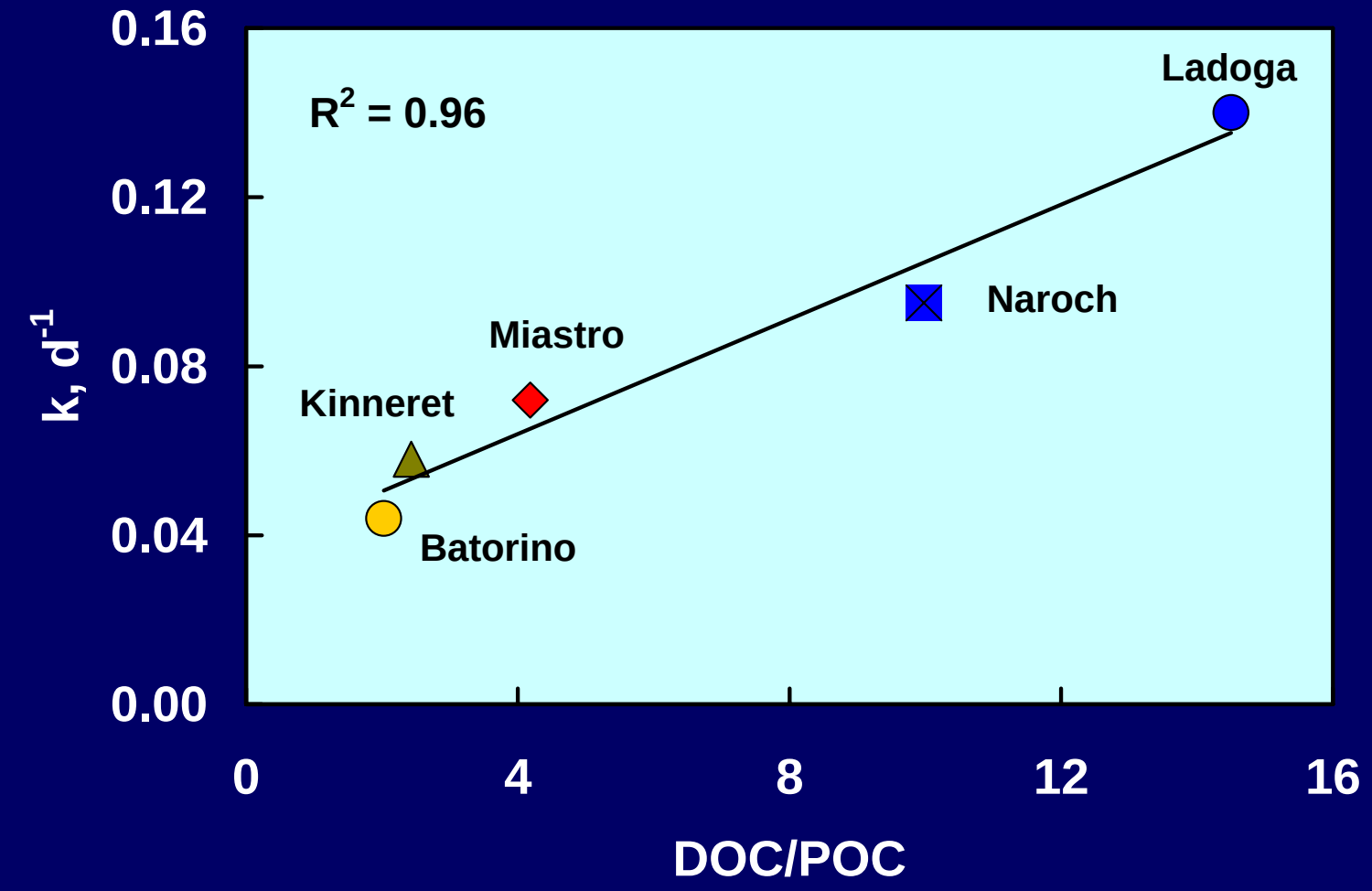


Analysis: OM lability and lake trophy

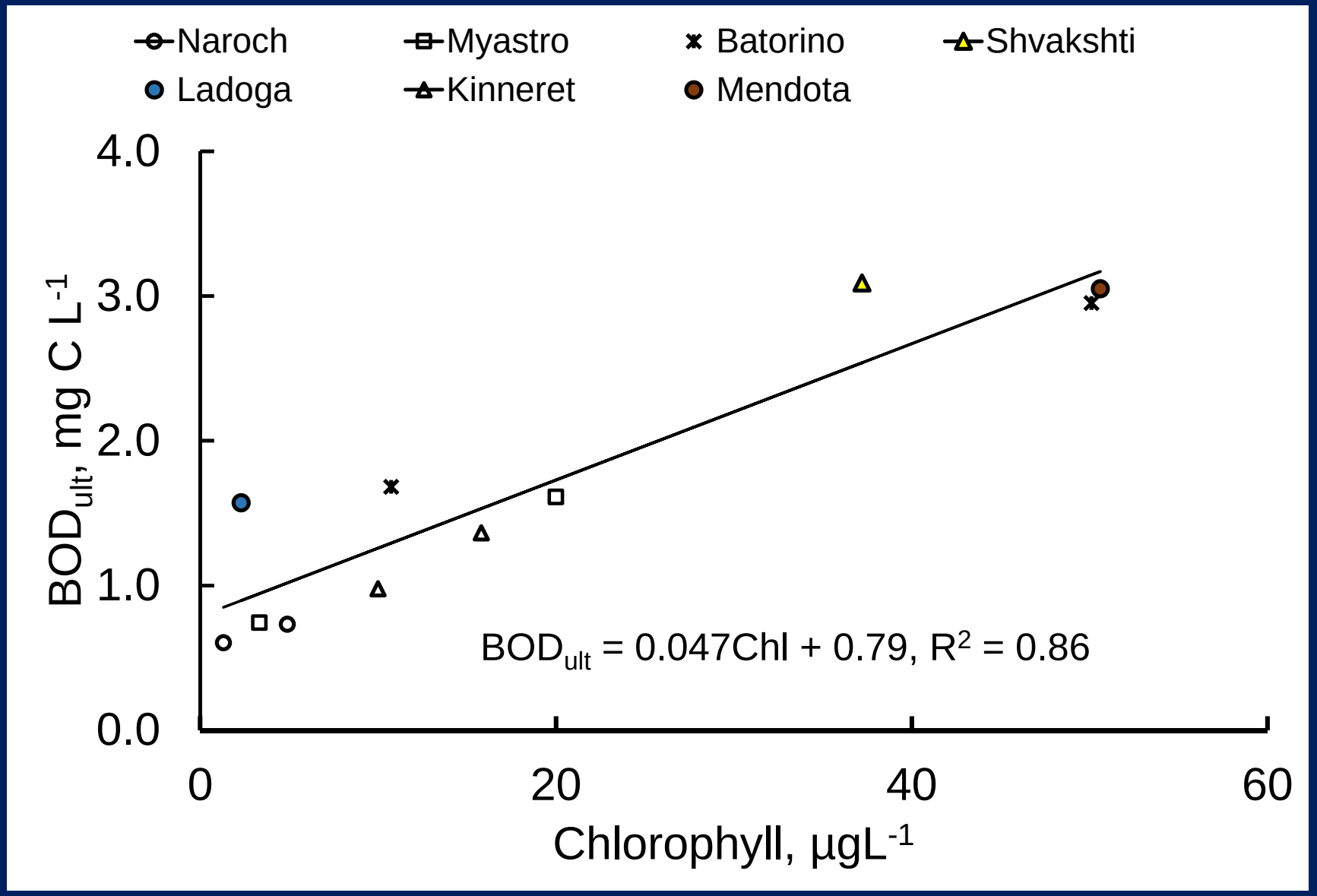



Analysis: OM lability and lake trophy
15
10
5
0
DOC/POC
Ladoga
Naroch
Miastro
Batorino
Kinneret
R2 = 0.89
0
20
40
60
Chl, μg l-1

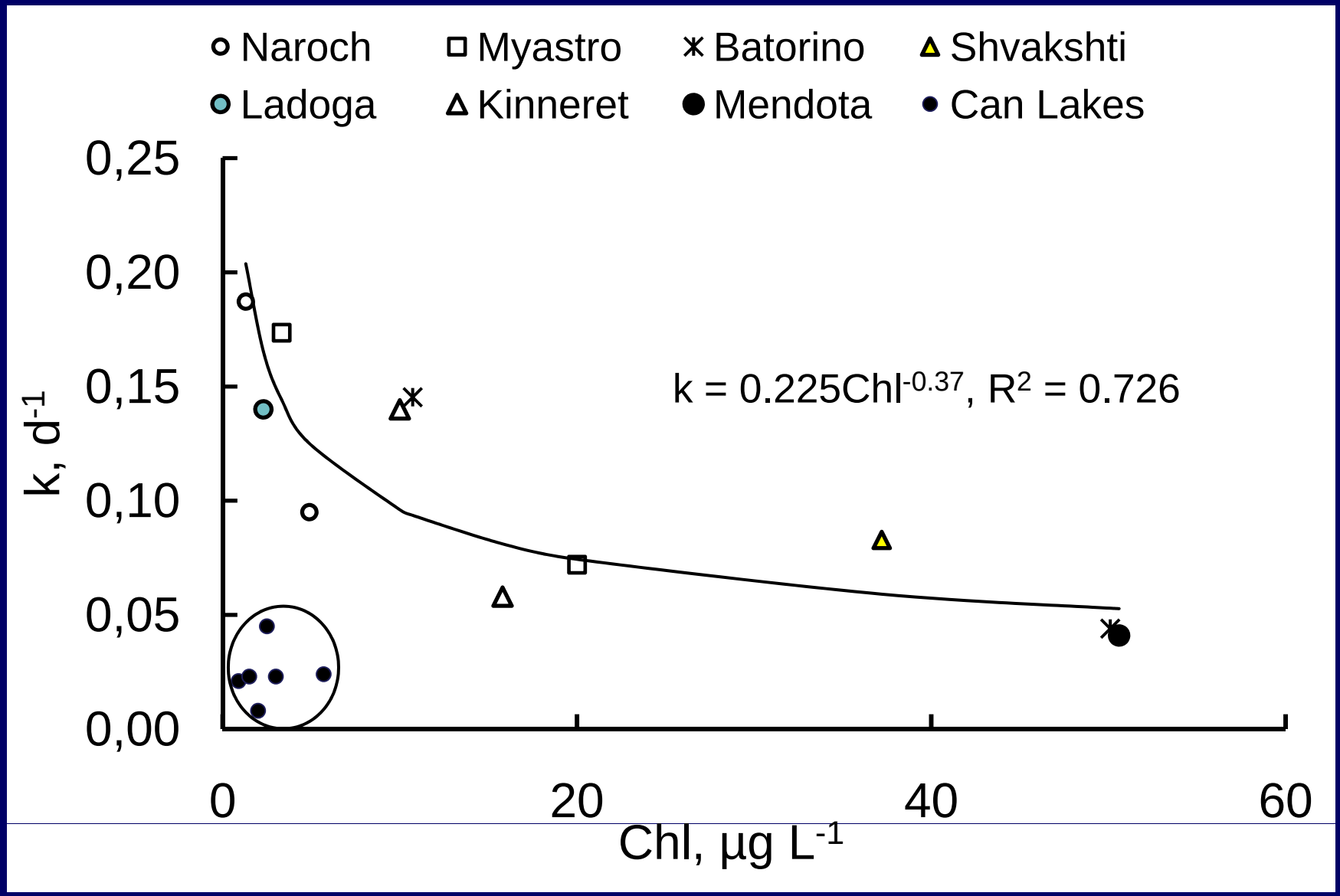
Analysis: OM lability and DOC/POC ratio

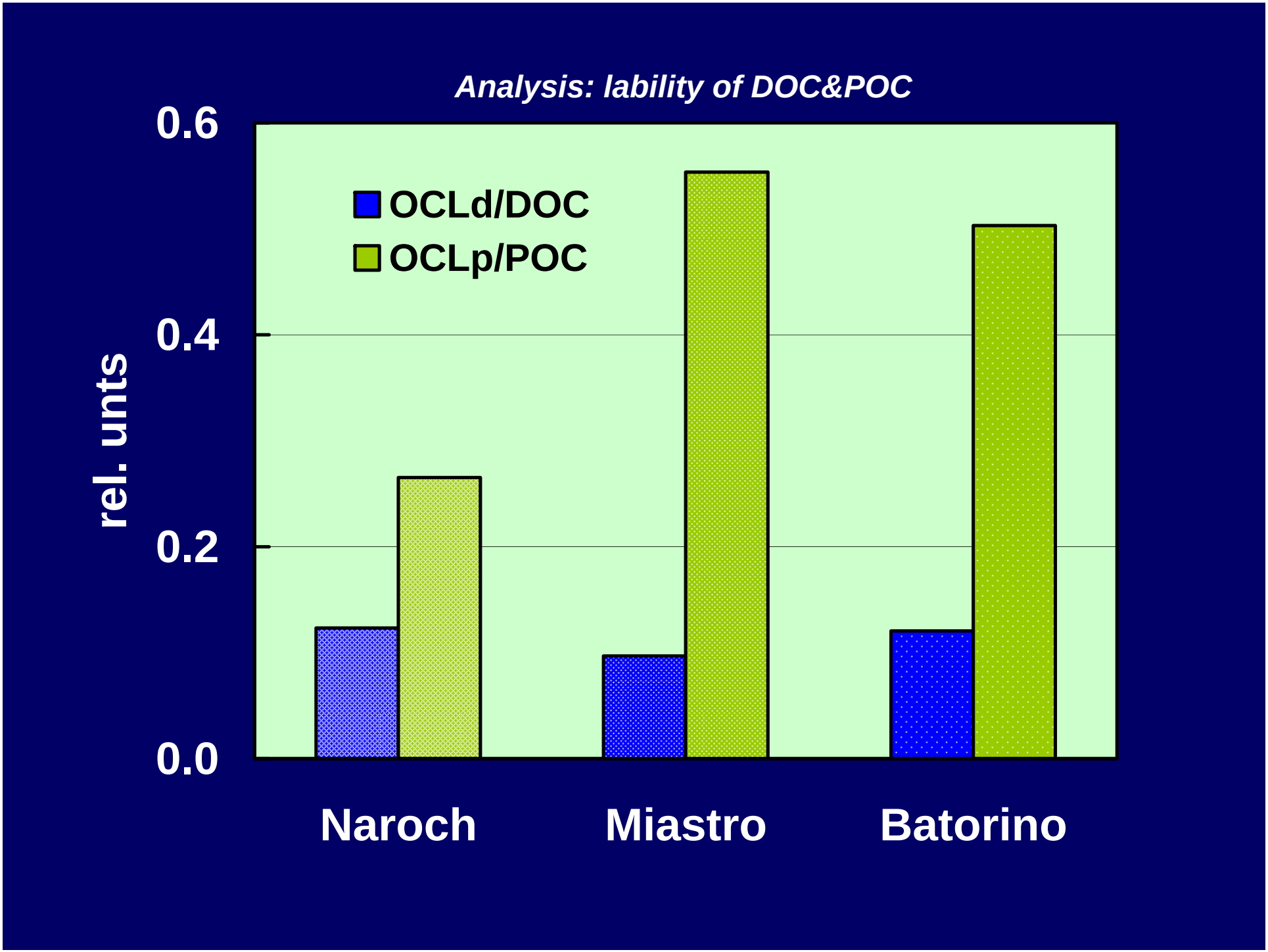


Analysis: OM lability and lake trophy

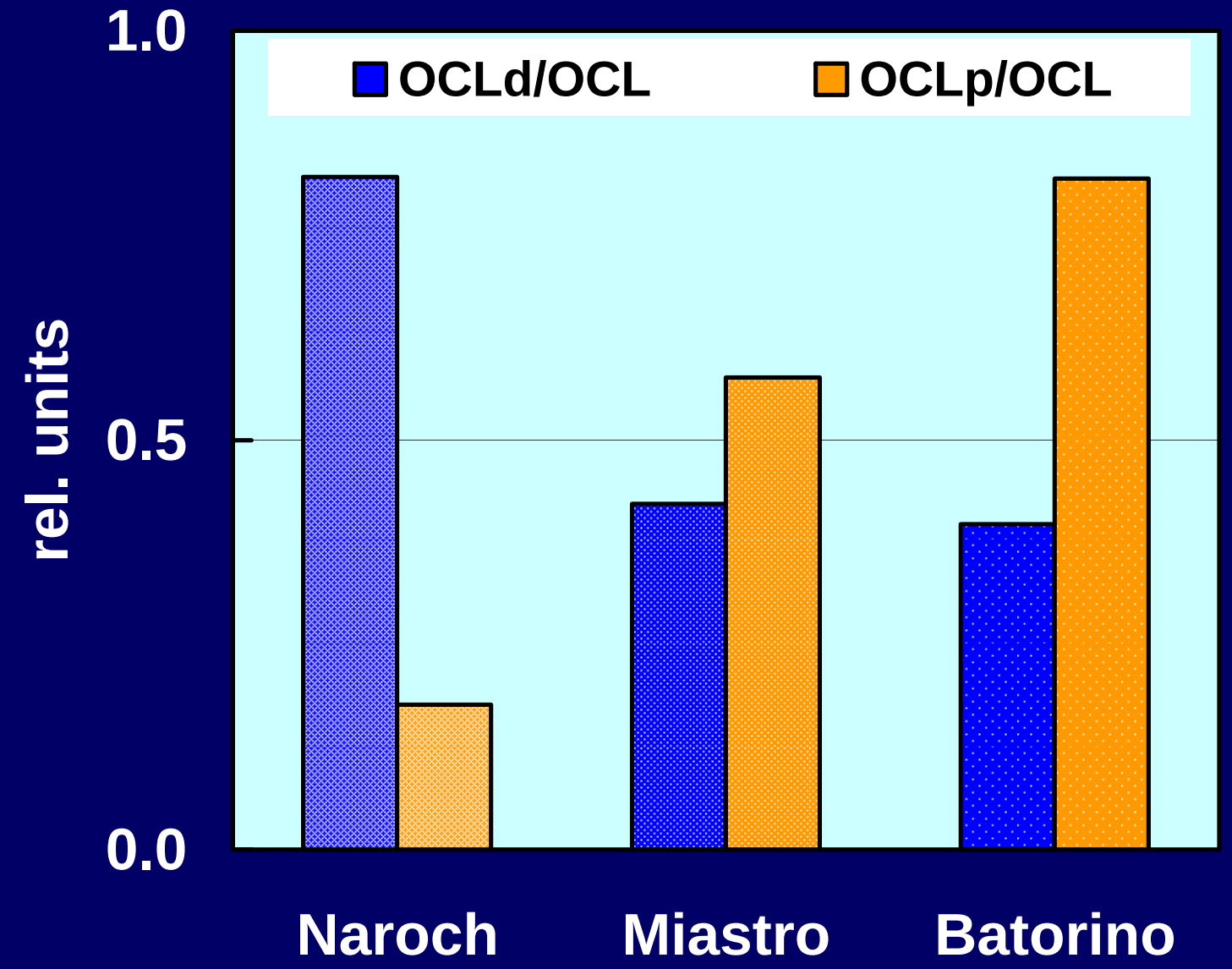


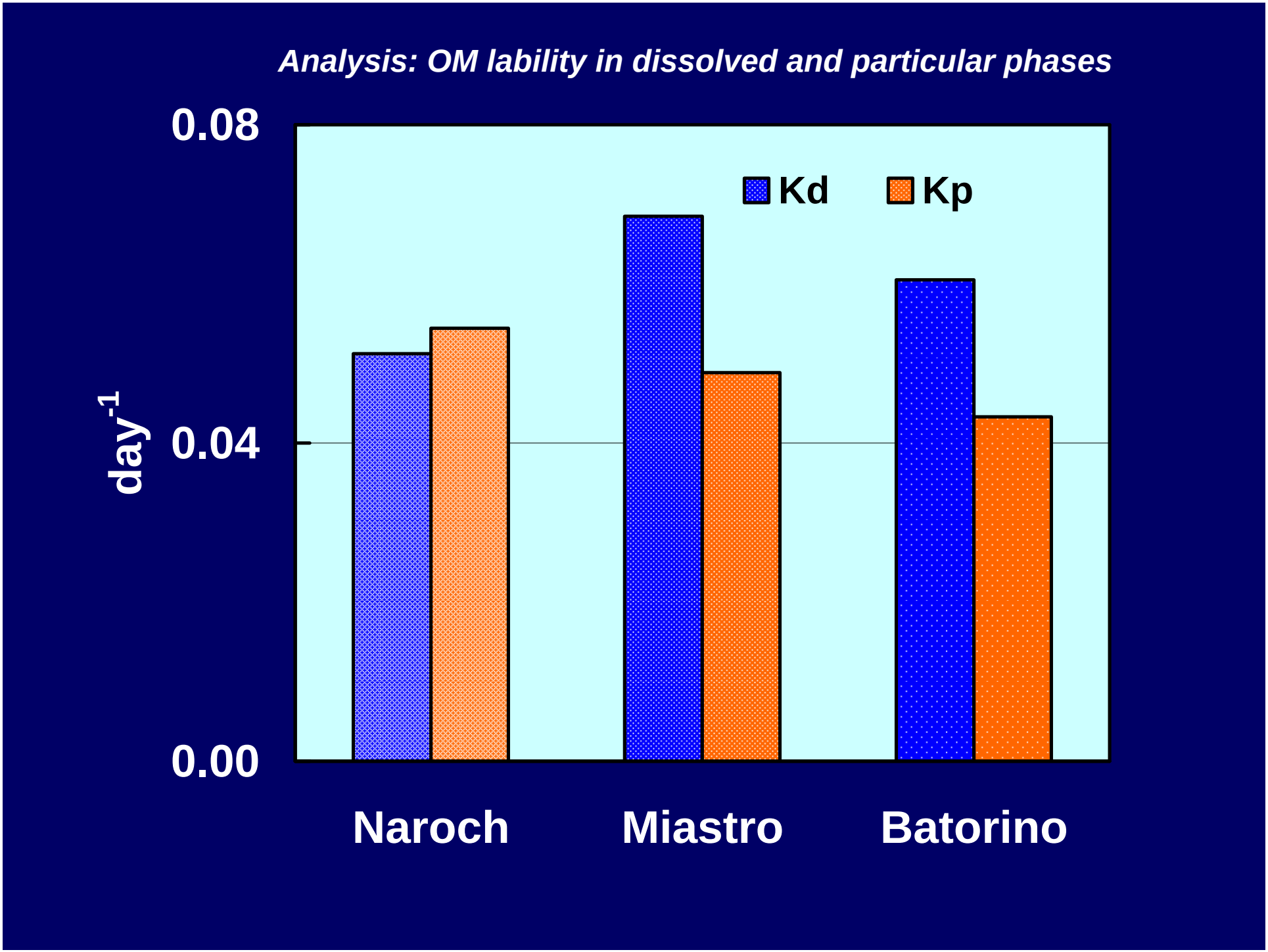
Analysis: OM lability and lake trophy




Analysis: lability of DOC&POC
0.6
0.4
0.2
0.0
rel. units
OCLd/DOC
OCLp/POC
Naroch
Miastro
Batorino

Analysis: the relative contributions of dissolved and particular labile fractions within the labile organic carbon




Analysis: OM lability in dissolved and particular phases
0.08
0.04
0.00
day-1
Kd
Kp
Naroch
Miastro
Batorino

CONCLUSION

We have characterized the lability of organic carbon pools using BOD-kinetic parameters (BODult and k) in five lakes of different trophic state. This approach leads us to the following conclusions:

1. **The average concentration of the labile organic carbon in studied lakes varied from 0.75 to 2.95 mg C l^{-1}, while the constant of the aerobic decomposition varied from 0.044 to 0.14 d^{-1}.**

2. **Our data suggest that as lake trophy increases there are greater concentrations of labile organic carbon (BOD_{ult}), although the actual rate of breakdown of labile component (*k*) decreases.**

3. **In all cases OC_L was a minor component of the TOC pool: on average about 20% irrespective of lake trophy.**

4. **In all the lakes, most (~85%) of the DOC pool was refractory. Of the POC pool, from 27 to 55% was labile, while of the DOC pool only 10 to 12% was labile.**

THANK YOU FOR
ATTENTION AND PATIENCE