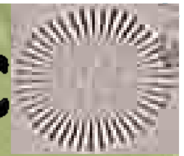
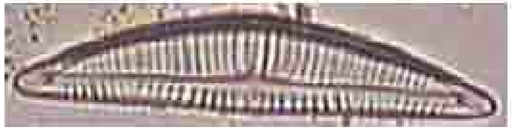
Biological monitoring of lotic systems: the role of diatoms

Taurai Bere

PhD Student: UFSCar (MSc, BSc.Hons)





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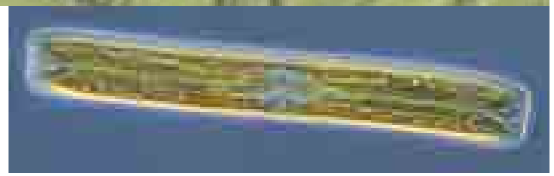

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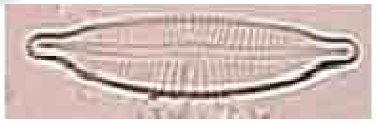

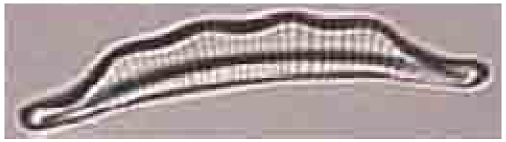

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Objective of the presentation

- To summarise the basic concepts associated with biological monitoring using benthic diatoms
- To give my personal experiences on the use of diatoms as indicators of ecological conditions in rivers

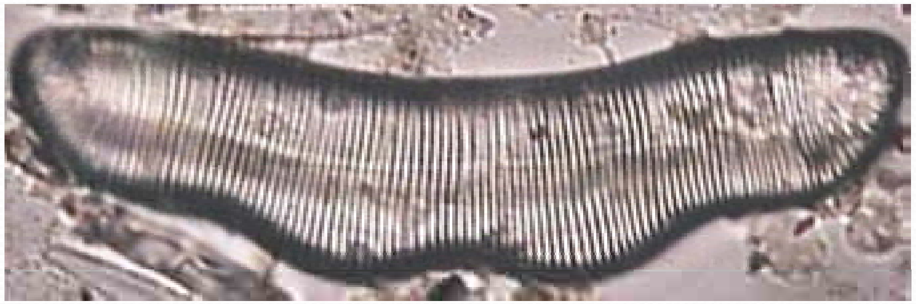
Introduction

- Increasing anthropogenic influence, climate change, dynamic nature of lotic systems – complicates management
- Need for robust and innovative approaches
- Two basic approaches

  - Physical and chemical methods
    - allows only instantaneous measurements, therefore restricting the knowledge of water conditions to the period when the measurements were taken.
  - Biological Methods (biological monitoring)
    - Biotic indices – provide direct measure of ecological integrity by using the response of biota environmental changes
    - Make use of autecology and synecology to infer environmental conditions in an ecosystem
    - The key to use of the aquatic biota as reliable indicators of the changes in lotic environmental conditions is deciphering the integrated environmental information in species rich assemblages

Introduction -cont

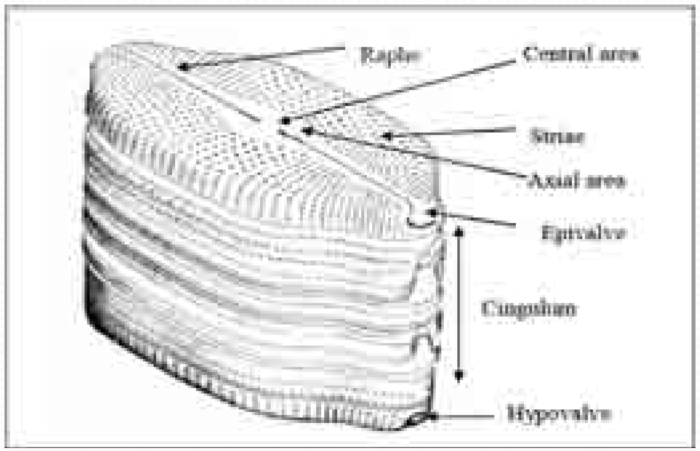
- Long-term data gathered about the tolerances of a species are used to compile an index that can, in turn, be used to deduce environmental conditions from the species composition by taking into account the specific tolerances of the species in the community surveyed
- These indices can be constructed to measure specific pollutants or general environmental conditions.
- Many indices have been developed using fish, macroinvertebrates, zooplankton and phytoplankton and especially benthic diatoms
    - the later gave the most precise data, though in some cases aquatic macroinvertebrates have been demonstrated to be superior

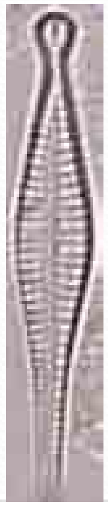


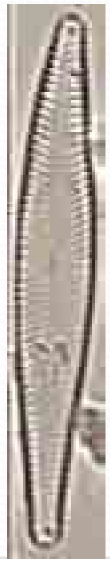

Diatoms and biomonitoring of lotic systems

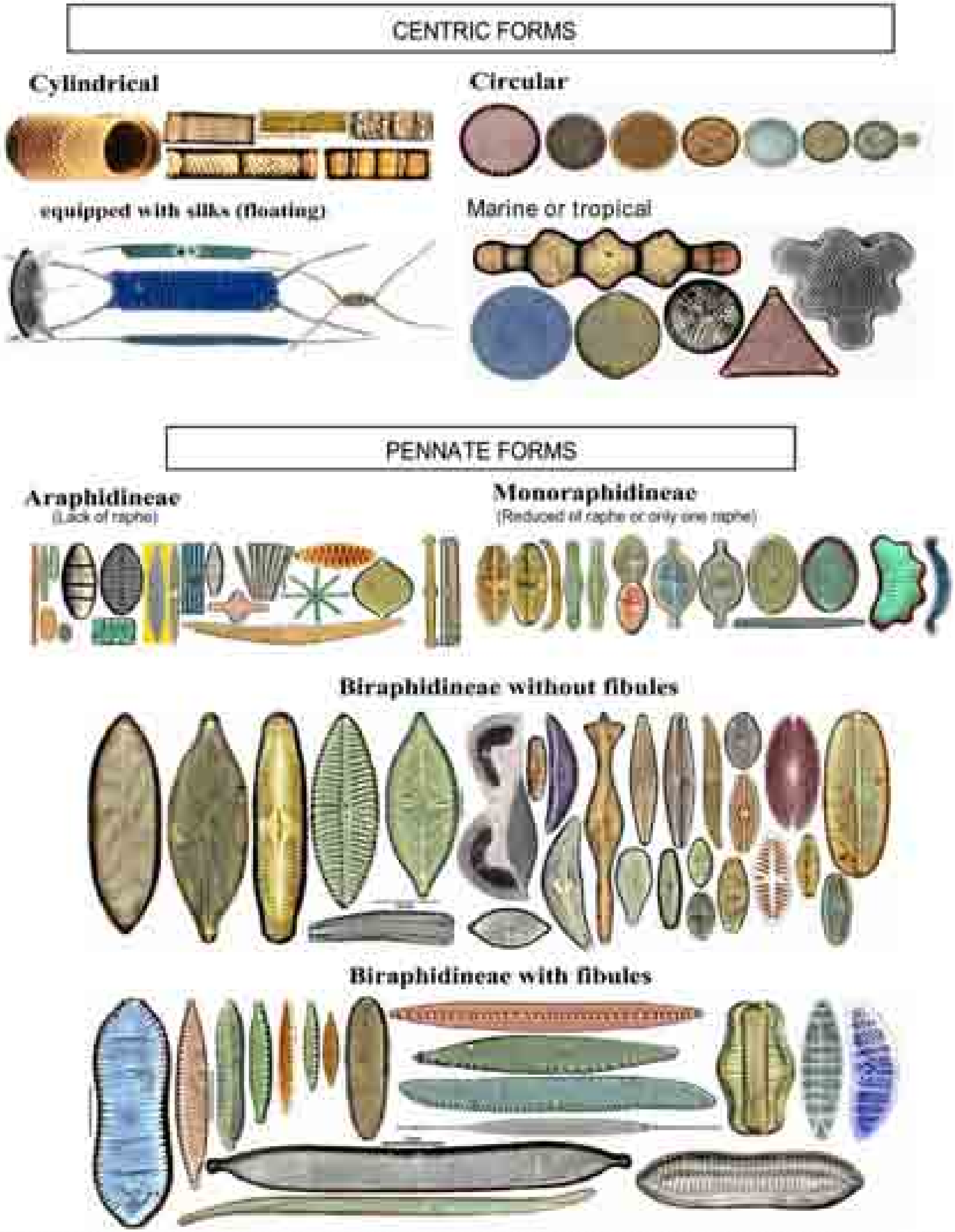
What are diatoms?

- microscopic one-celled or colonial members of the algal division or phylum Bacillariophyta, of the class Bacillariophyceae, having cell walls of silica consisting of two interlocking symmetrical valves = A major part of periphyton



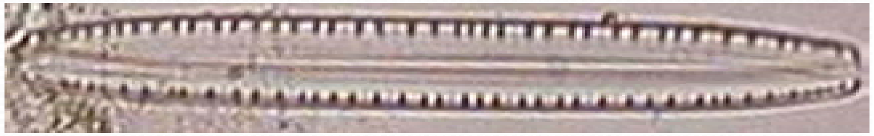




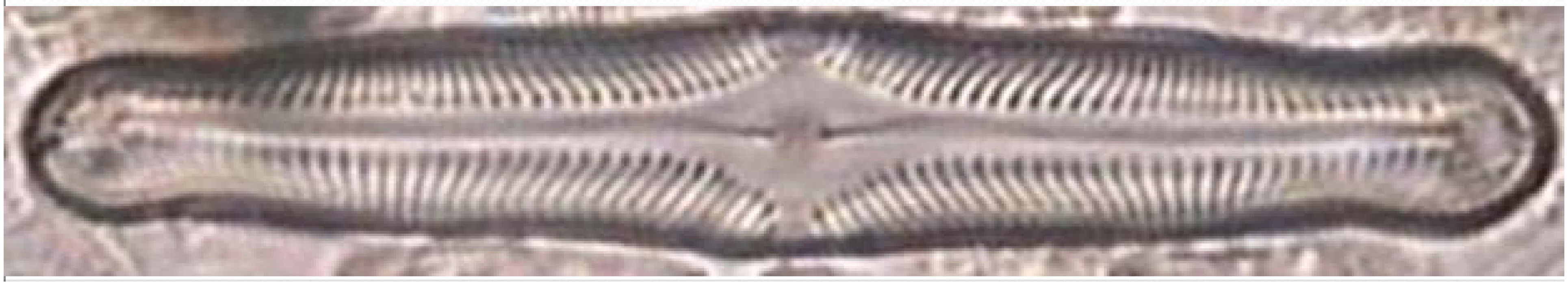

CENTRIC FORMS
Cylindrical
Circular
equipped with silks (floating)
Marine or tropical
PENNATE FORMS
Araphidineae
(Lack of raphe)
Monoraphidineae
(Reduced of raphe or only one raphe)
Biraphidineae without fibules
Biraphidineae with fibules

Diatoms and biomonitoring of lotic systems

- Dates back to 1908, Kolkwitz and Marsson
- Robust and quantifiable relationships between diatoms and environmental condition – excellent indicators of water quality
- Particular species requires different structural, physical and chemical characteristics intrinsic to its habitat

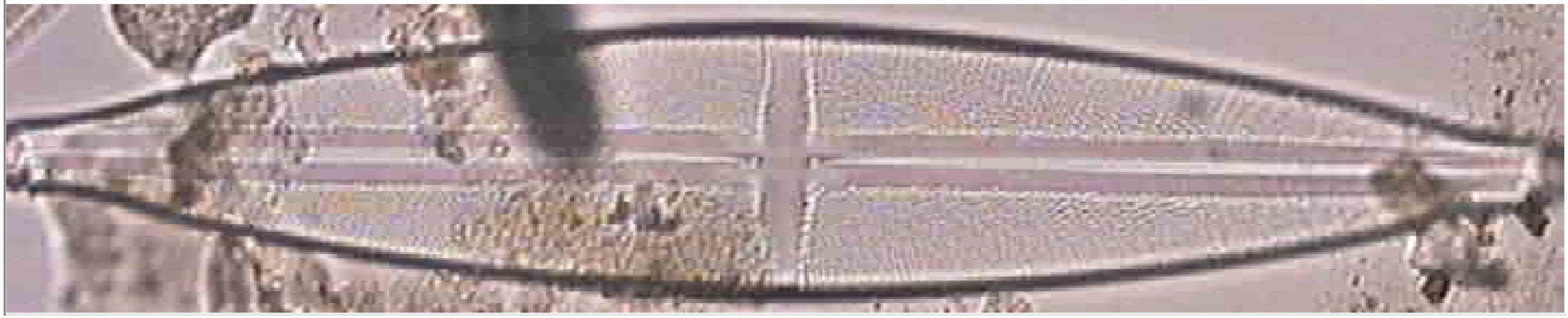


- Variation of these factors affects the composition of the niche
- species vary in their sensitivity and those more may be favoured by selection
- Need for understanding the effects of geographical and environmental factors



Distribution of diatoms in lotic systems

- universally distributed with others being endemic to specific regions = 'subcos-mopolitan', i.e. they occur anywhere in the world if certain environmental conditions are fulfilled
- Maintain a dynamic population of varying size depending on the prevailing environmental conditions.
- most species rich group of algae



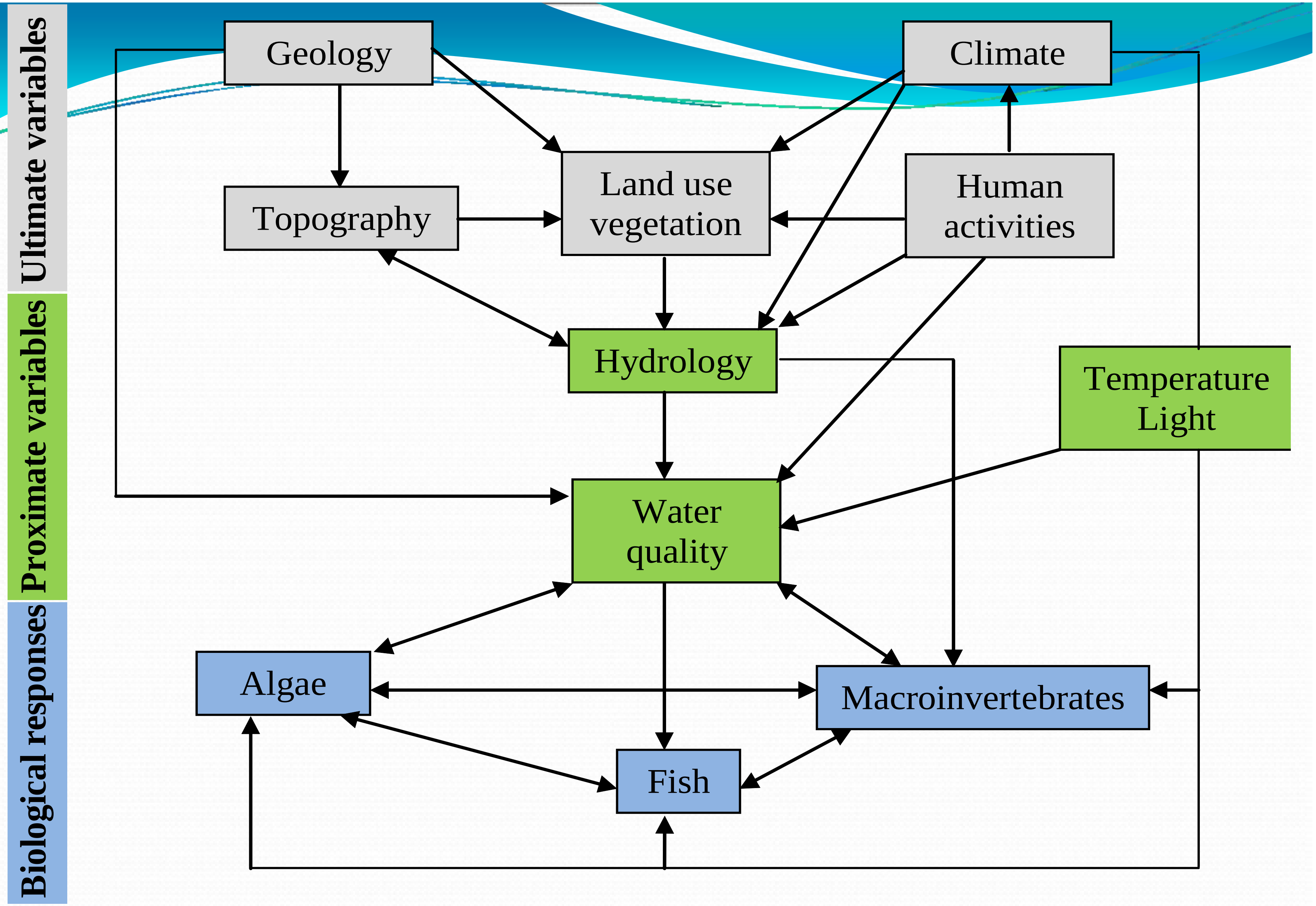


Figure 6: Interaction of biological, proximate and ultimate factors (Modified from Biggs 1996).

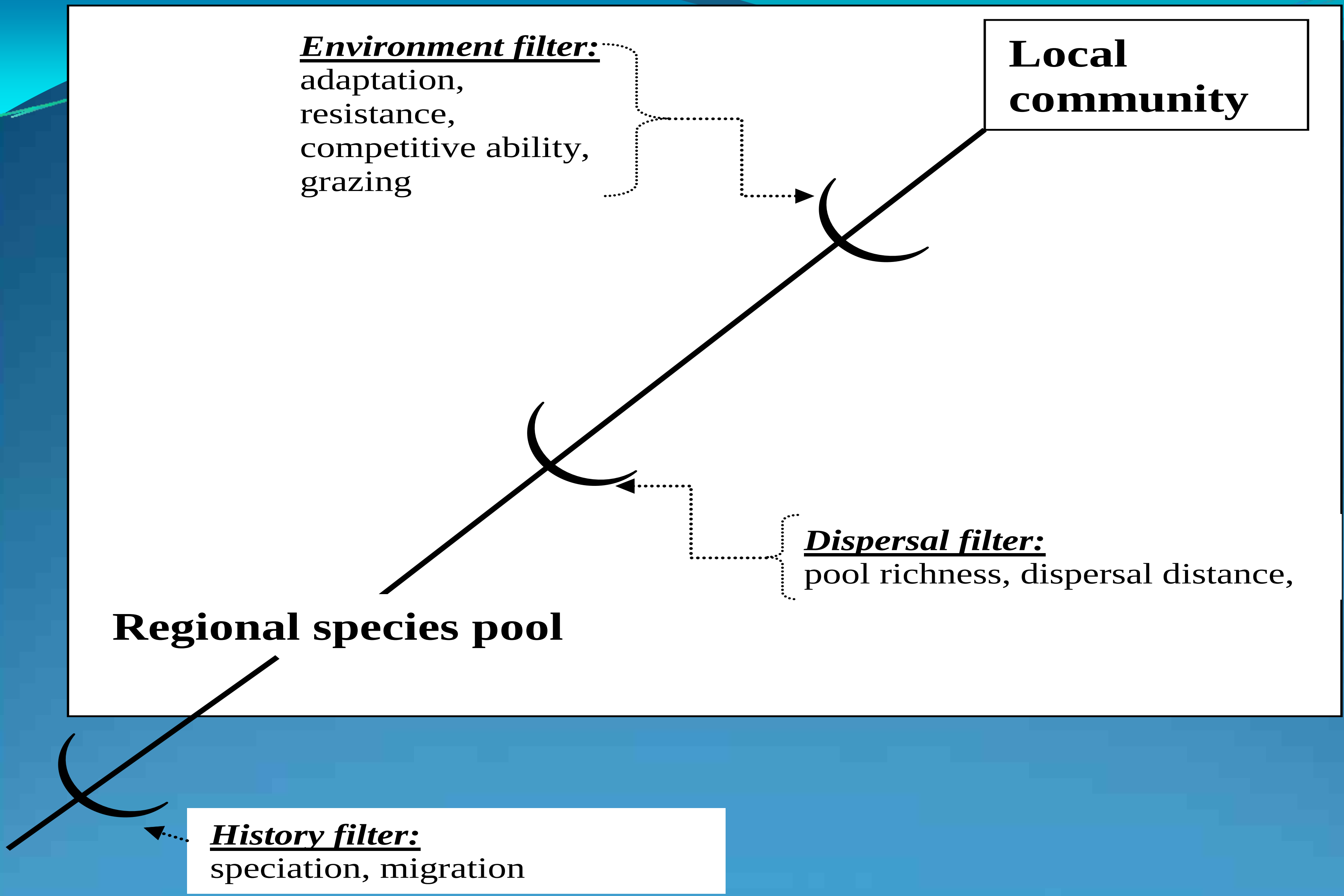
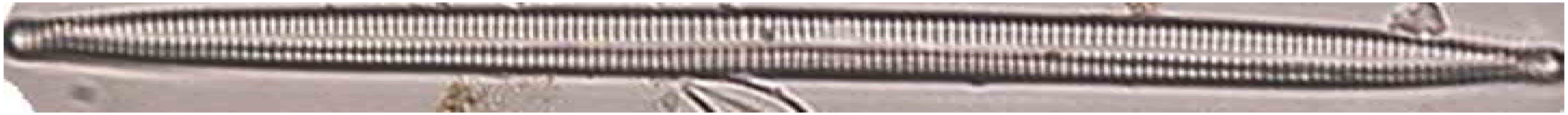


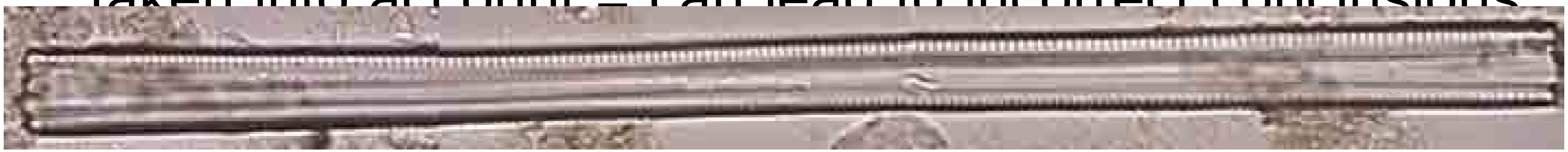
Figure: Conceptual model visualizing the assembly of local communities through series of nested filters (modified from Hillebrand & Blenckner, 2002)



- Complexity of factors = diatom-based river metrics should first be developed for limited geographical areas with the most uniform environmental variables possible

- Carefully factoring in natural variation. Even if communities are developed in very similar environments, there is considerable variation (30-35 %) attributed to unaccounted-for natural factors= can be easily mistaken for the effects of the perturbation under study

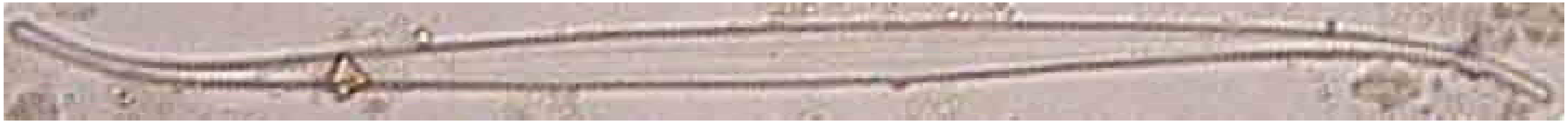
- Correlations among environmental factors should be taken into account = can lead to incorrect conclusions



Despite all this, however, diatoms represent outstanding bio-indicators for different degrees of pollution.

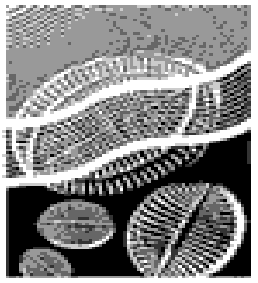
Advantages:

- methods are cost effective
- data is comparable
- techniques are rapid and accurate
- they lie at the base of aquatic food webs and are among the first organisms to respond to environmental change
- have a short life cycle allowing rapid respond to environmental stress



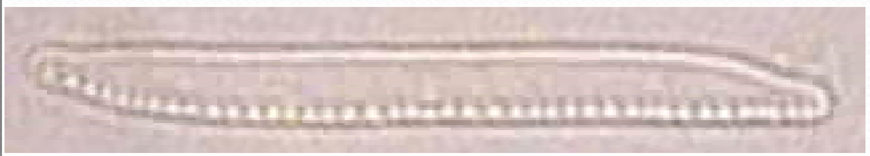
Used in:

- Europe
- North America
- Central America
- South America
- Australia
- Africa (Schoeman, 1979; Pieterse and Van Zyl, 1988; Gasse et al., 1995; Bate et al., 2004; Teylor et al., 2007; de la Rey et al., 2007 and 2008).
- Some of the studies are focused on inferring past hydrochemical characteristics



Examples of indices developed elsewere:

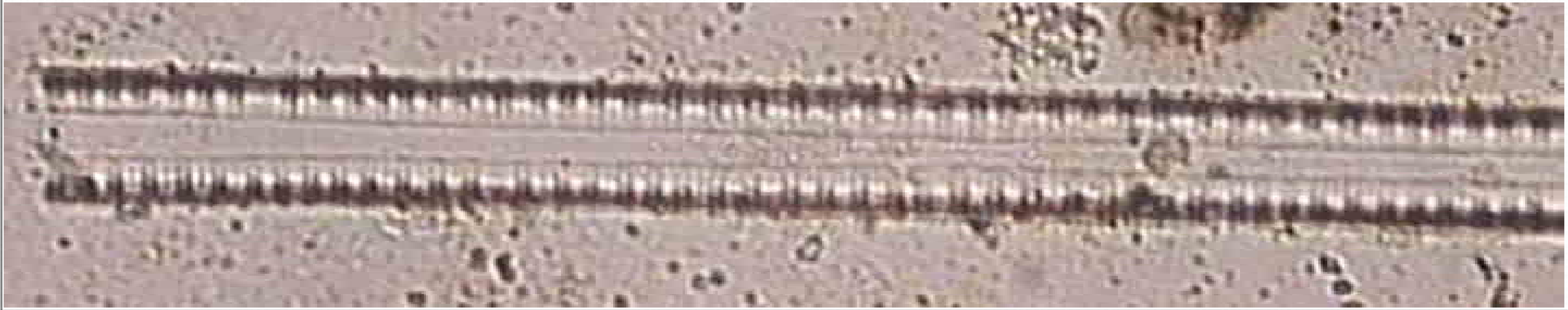
- Schiefele and Schreiner’s index or SHE (Schiefele and Schreiner, 1991),
- Specific Pollution sensitivity Index or SPI (Coste in Cemagref, 1982),
- Biological Diatom Index or BDI (Lenoir and Coste, 1996),
- Artois-Picardie Diatom Index or APDI (Prygiel *et al.*, 1996),
- Sla´decˇek’s index or SLA (Sla´decˇek, 1986),
- Generic Diatom Index or GDI (Coste and Ayphassorho, 1991),
- Rott’s Index or ROT (Rott, 1991),
- Leclercq and Maquet’s Index or LMI (Leclercq and Maquet, 1987),
- Trophic Diatom Index or TDI (Kelly and Whitton, 1995),
- Watanabe index or WAT (Watanabe *et al.*, 1986)



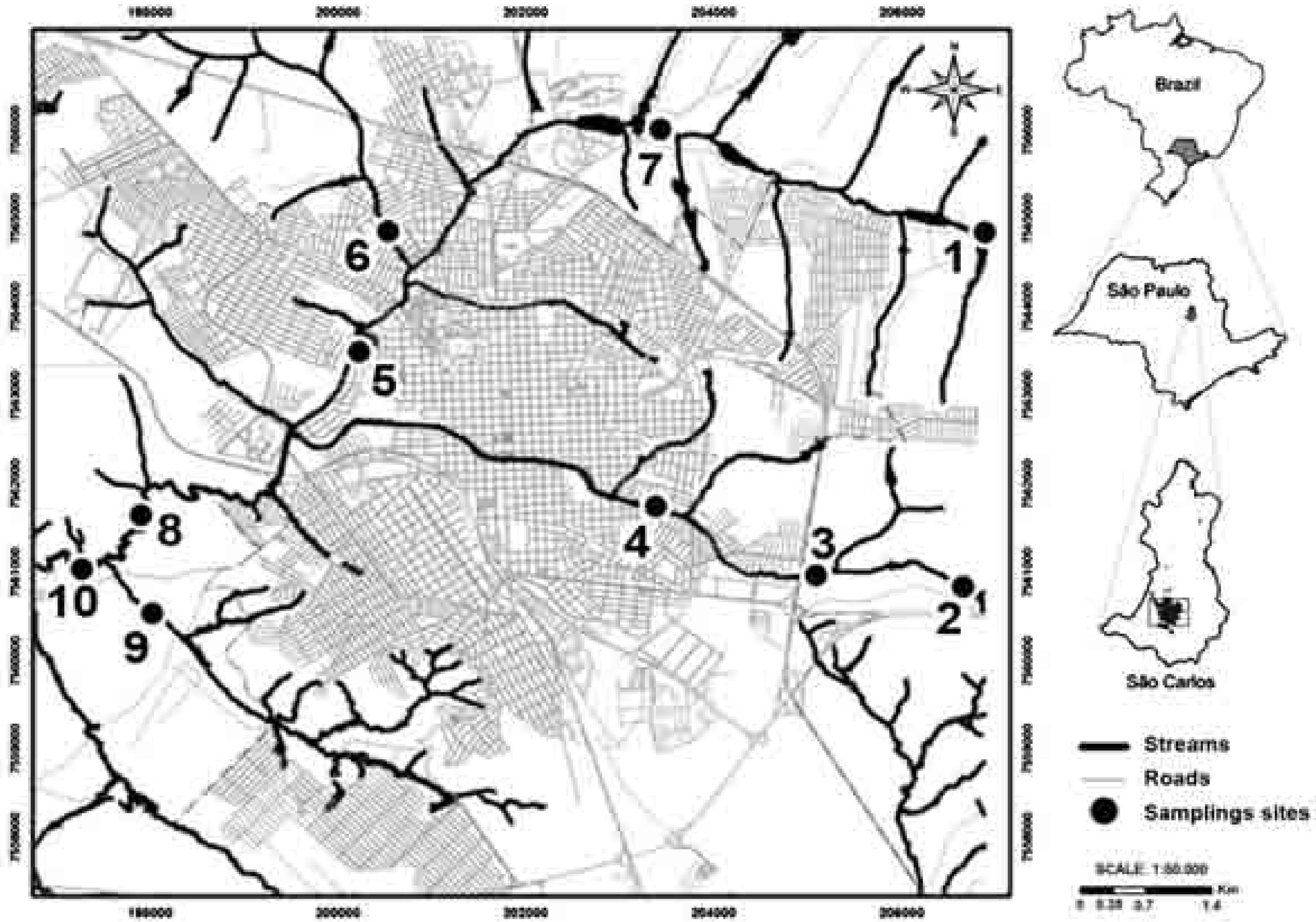
Calculation of the index uses the weighted average equation of Zelinka and Marvan (1961):

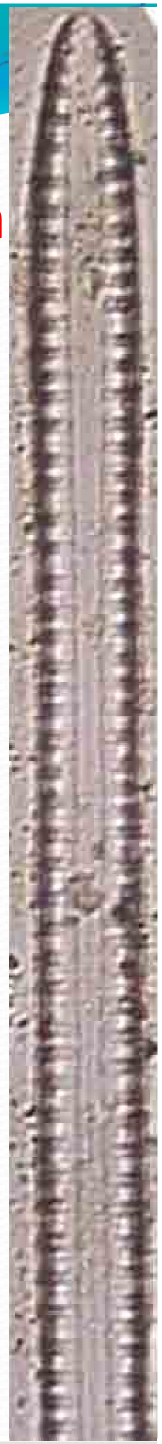
$$index = \frac{\sum_{j=1}^{n} a_j v_j i_j}{\sum_{j=1}^{n} a_j v_j}$$

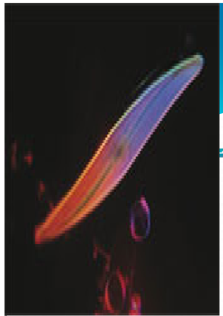
where a_j = abundance (proportion) of species j in sample, v_j = indicator value and i_j = pollution sensitivity of species j.



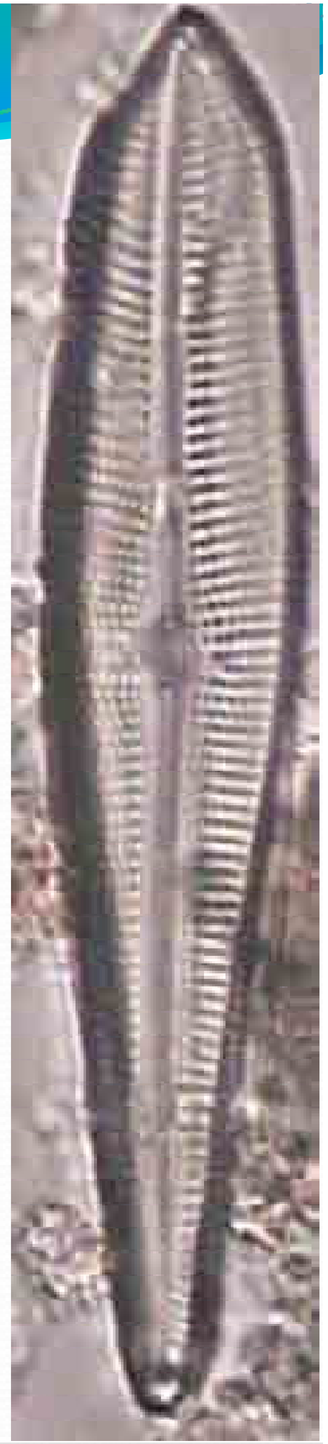
The diatom assemblages as indicators of ecological conditions in streams around São Carlos –SP Brazil





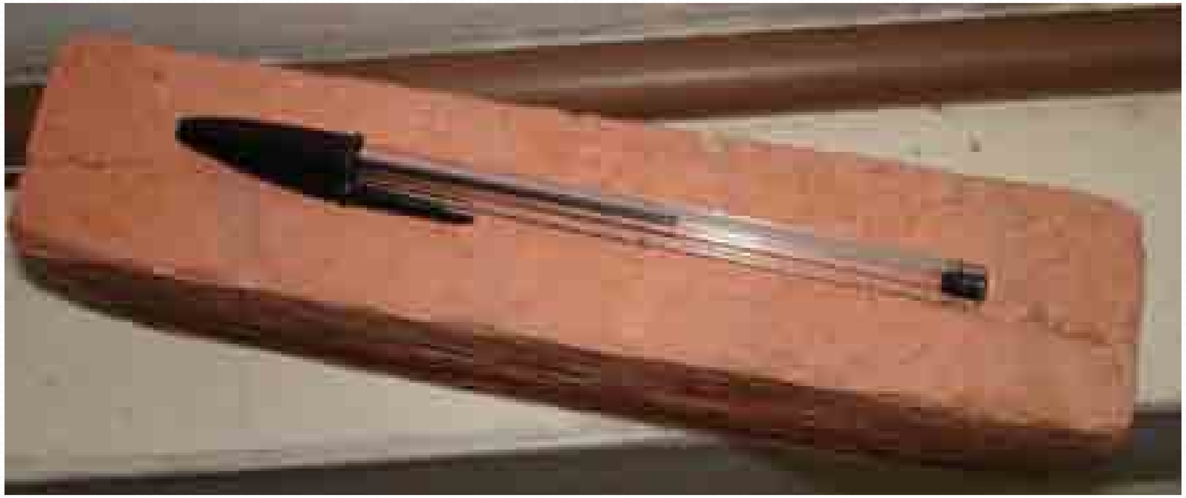


METHODS OF INVESTIGATION



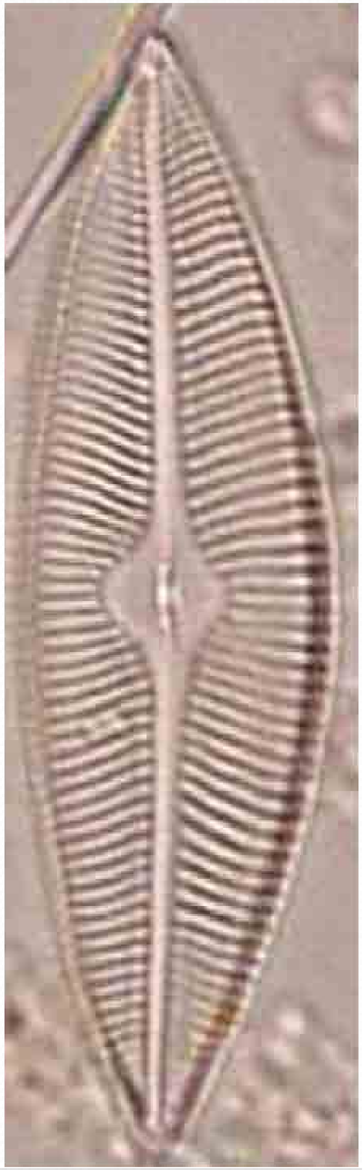
- **Analysis of literature**
- **Diatom sampling**
  - Natural substrates
    - Epiliton – silt-clay
    - Epipelion - sand
    - Epipsamic - sand
    - Epiphytic - vegetation
  - Artificial substrates (field experiments)
    - Glass
    - Bricks
- **Laboratory treatment of diatoms**
- **Laboratory experiments**





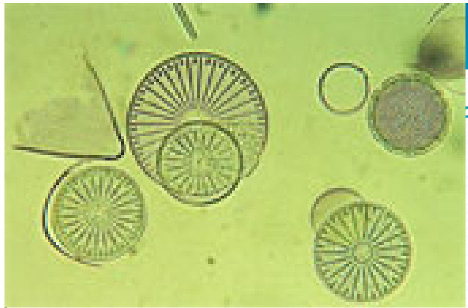
Physical habitat characteristics

- Flow velocity (m/s)
- Depth (m)
- Substrate composition
- Embeddedness (%)
- Basin-scale characteristics
- Water management feature types
- Bank Vegetation (%)
- Canopy closure (%)
- Light intensity
- Water surface slope
- Elevation



Water chemical and physical characteristics

- Temperature (°C)
- pH
- DO (mg/L)
- BOD/COD
- Turbidity
- Conductivity (mS/cm)
- Alkalinity (mg/L as $CaCO_3$)
- Nutrients (P, N)
- Metals
- Ionic composition



- **Biomass analysis** (Biggs and Kilroy, 2000)
  1. Chlorophyll a method
  2. Ash-free dry mass (AFDM)
- **Data analysis**
  - OMNIDIA version 3.1 (Lecointe *et al.*, 1993) – processing and storing of diatom count + analysis of historical data.
  - Principle distribution patterns explored using DCA and CCA (CONOCO version 4.5 for WINDOWS (ter Braak & Šmilauer, 1998).

Results and conclusions

Site	1	2	3	4	5	6	7	8	9	10
Temperature °C	18.3	20.9	20.6	21.2	21.2	20.39	24	24.8	23	21.3
BOD_5 (mg L^{-1})	0.9	1	2.6	6.9	1.2	7.2	1.6	19.5	24.5	26.2
DO (mg L^{-1})	7.3	8.2	7.6	6.9	7.6	7.2	6.8	1.9	2.1	0.4
Conductivity (μScm^{-1})	45	20	53	89	103	30	28	715	322	283
pH	6.6	6.4	6.3	6.8	7.2	6.8	6.7	7.2	7.2	7.1
TDS (g L^{-1})	29.4	13.4	22.6	57.4	66.5	19.3	18.1	457.8	206.1	182
Turbidity(NTU)	5.1	4.2	4.7	19.5	11.1	13.2	7.3	45.3	53.2	60.4
TN (mg L^{-1})	0.65	0.18	0.24	1.29	1.41	0.93	1.72	38.32	14.87	10.17
TP (mg L^{-1})	0.007	0.008	0.012	0.16	0.062	0.017	0.034	2.965	1.106	0.746
Chloride (mg L^{-1})	1.51	4.32	2.34	16.54	9.34	2.39	2.12	11.29	18.3	22.21

Results and conclusions

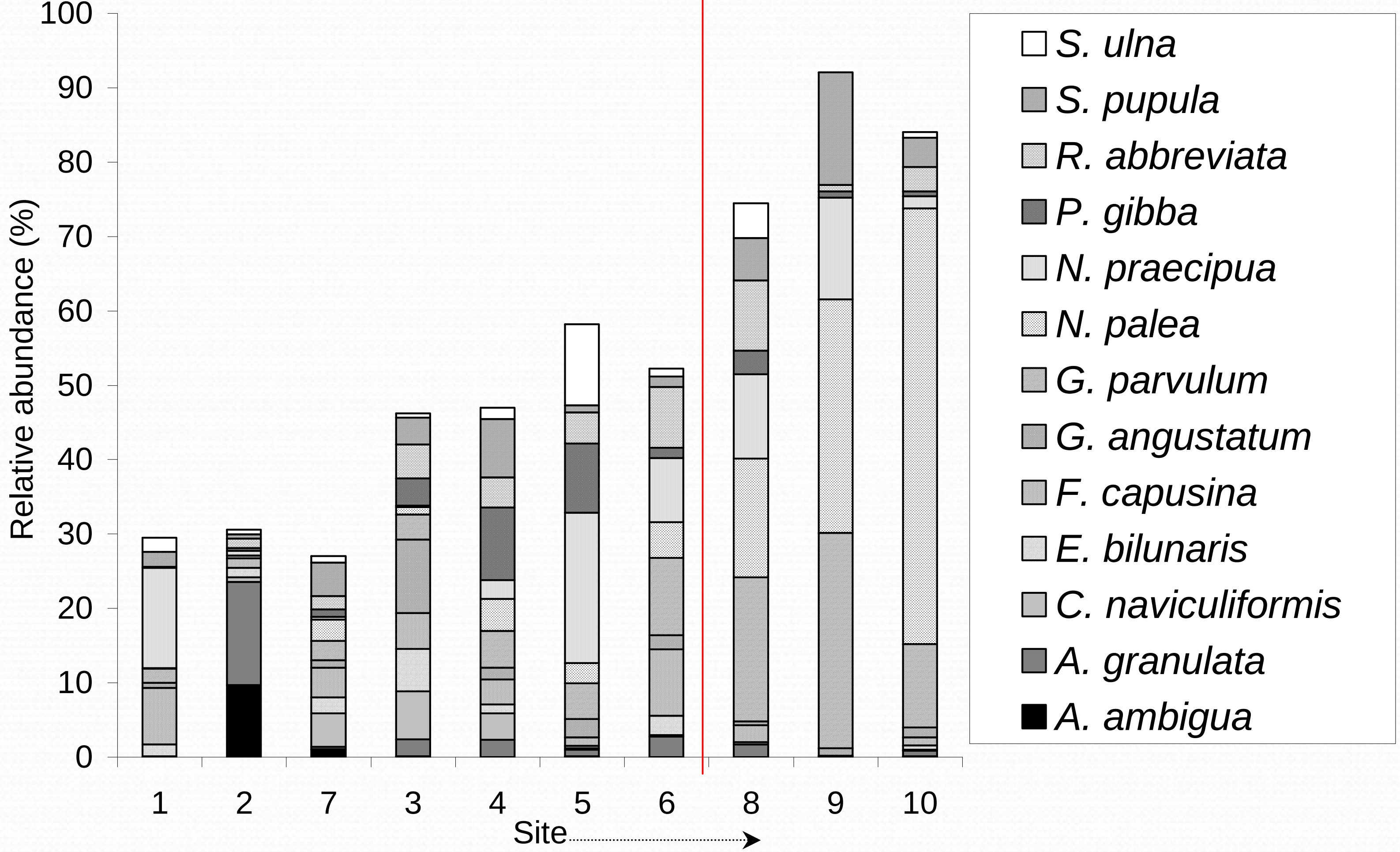


Figure 2. The relative abundances of most frequently occurring diatom. The arrow indicates a general increase in pollution.

Results and conclusions

Table: The mean species richness (*S*), diversity (*H'*) and evenness (*E*) for the different substrates sampled during the study period. * indicates a missing substrate.

	Substrate											
	Silt/clay			Sand			Stones			Vegetation		
Site	***S***	***H'***	***E***	***S***	***H'***	***E***	***S***	***H'***	***E***	***S***	***H'***	***E***
1	39	2.67	0.81	*	*	*	*	*	*	50	2.75	0.71
2	36	3.28	0.92	*	*	*	30	2.77	0.82	37	3.3	0.92
3	41	3.24	0.88	48	3.22	0.84	*	*	*	50	3.29	0.85
4	19	2.54	0.86	43	2.97	0.8	34	3.04	0.88	28	2.93	0.9
5	33	2.64	0.76	46	3.22	0.84	30	2.8	0.84	41	3.04	0.83
6	39	2.66	0.83	28	1.91	0.89	39	2.74	0.75	41	2.81	0.76
7	67	3.35	0.8	57	3.55	0.88	45	3.59	0.94	65	3.4	0.81
8	27	1.8	0.55	29	2.27	0.68	20	1.65	0.56	22	2.49	0.81
9	17	2.04	0.73	20	1.93	0.64	14	0.97	0.41	13	1.23	0.48
10	36	2.61	0.73	27	2.6	0.79	14	0.76	0.29	23	1.48	0.45

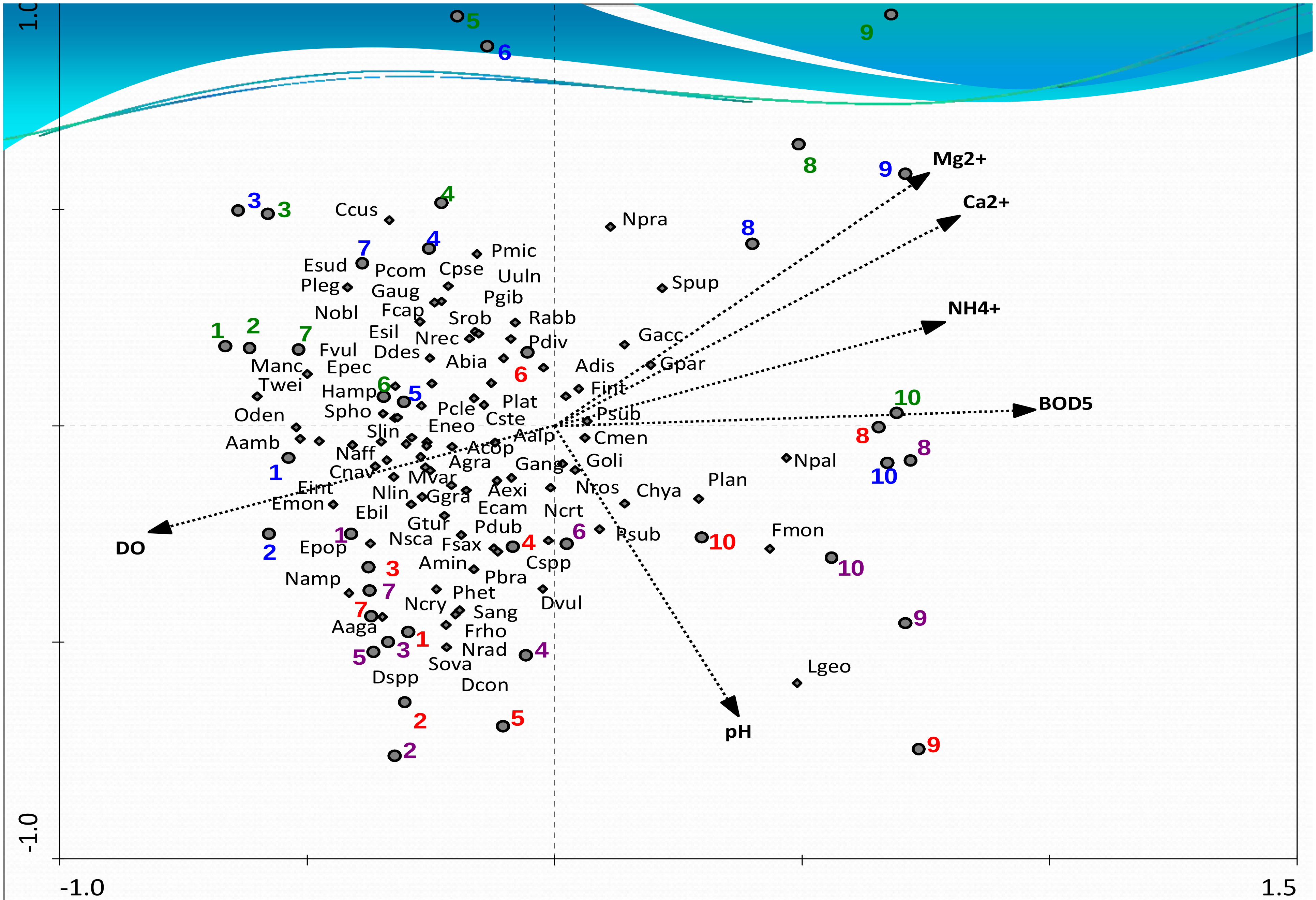


Figure 3: Canonical correspondence analysis (CCA) diagram showing simultaneous effects of ion concentrations and other variables on most frequently occurring diatom taxa in the ordination

Results and conclusions

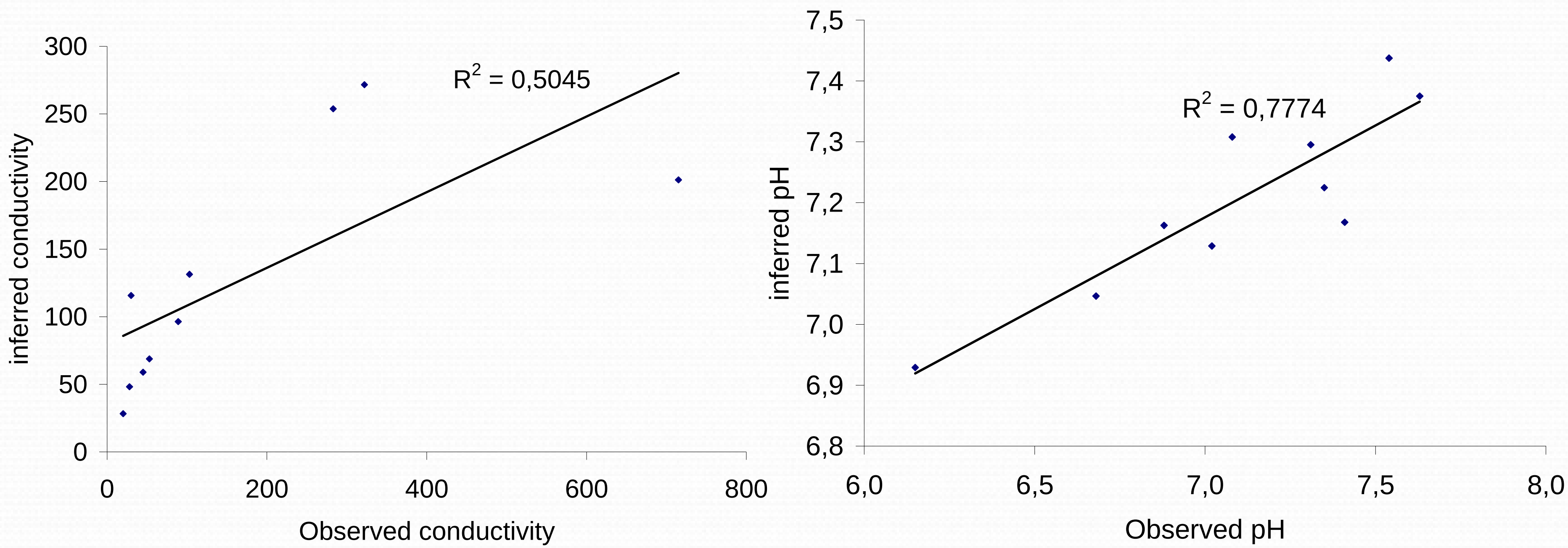


Figure: Relationship between observed and inferred; (a) conductivity and (b) pH.

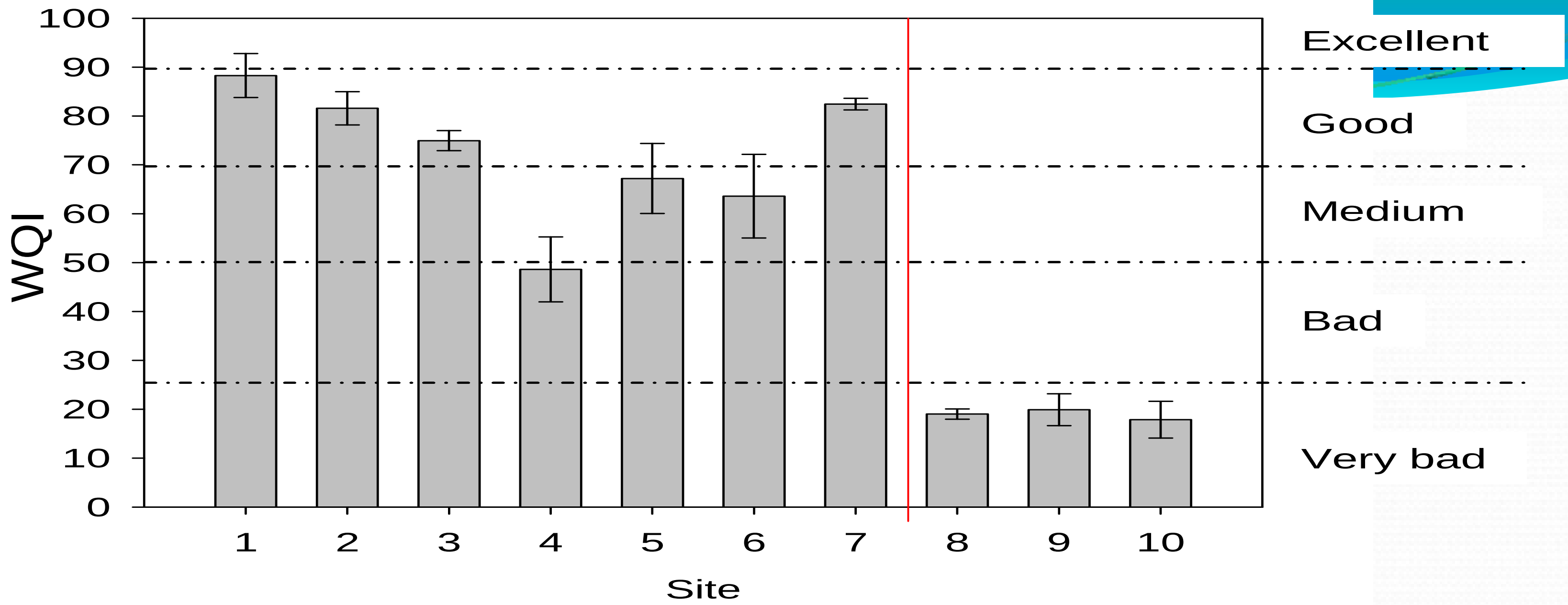


Figure: The mean values and standard deviations of water quality index (WQI) recorded at all sites.

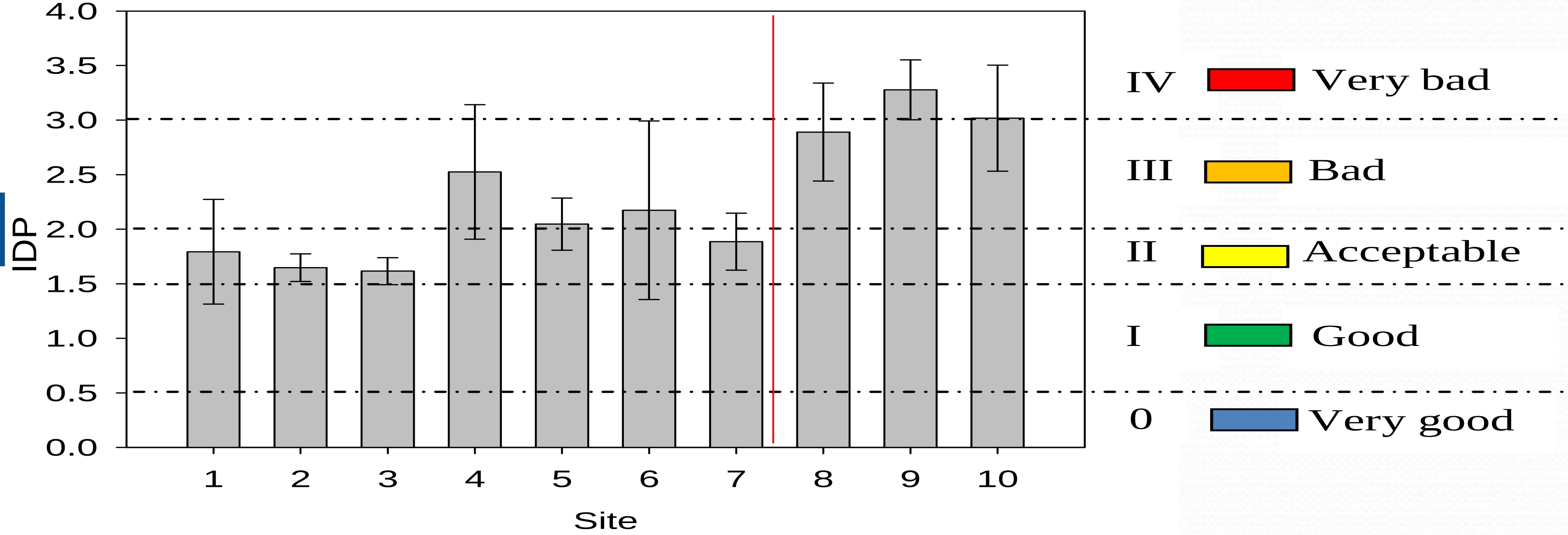


Figure: IDP Pampean Diatom Index, The water quality class, colour code and significance is indicated on the right side of the graph.

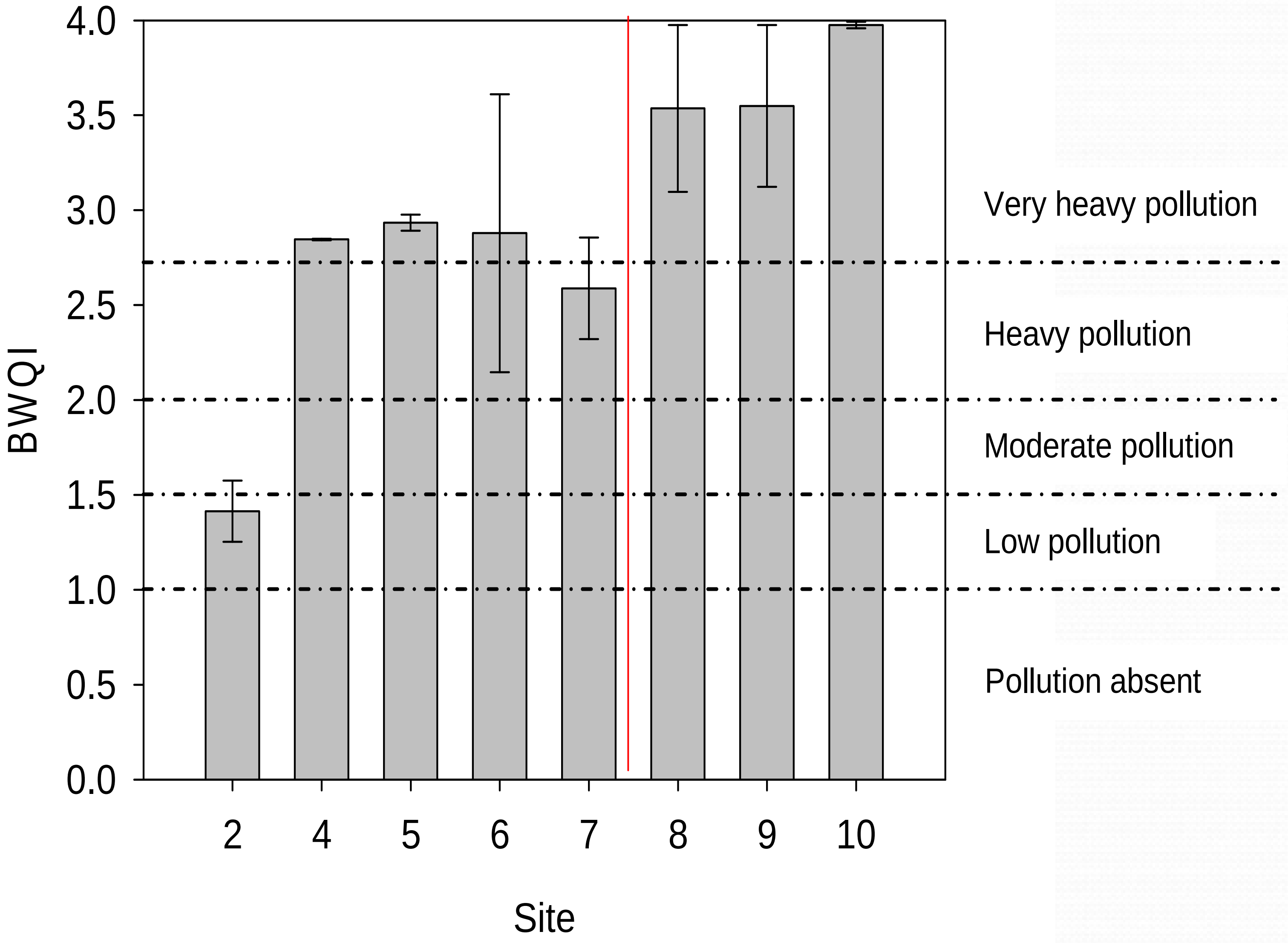
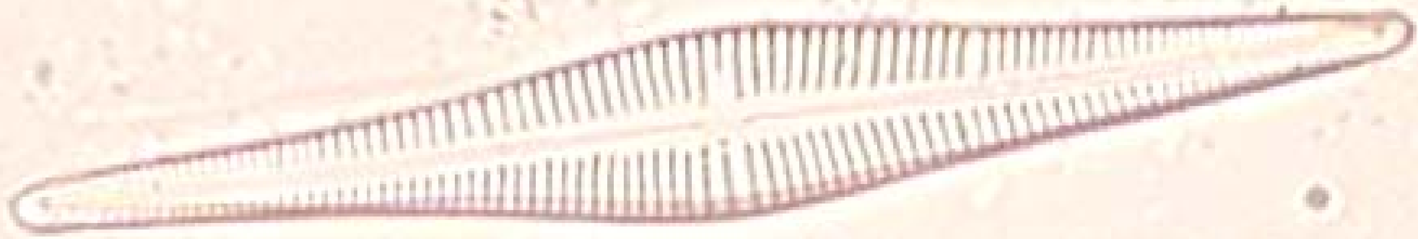


Figure BWQI, The water quality class, colour code and significance is indicated on the right side of the graph.

Table: Correlation between environmental variables and two diatom-based water quality assessment indices.



	Cond	DO	TP	Cl^-	PO_4^{3-}	SO_4^{2-}	Na^+	NH_2^+	K^+	Mg2+	Ca^{2+}	Cd	Pb	WQI	TSI	Saprobity
IDP	**0.94**	**-0.91**	**0.85**	**0.93**	**0.78**	**0.87**	**0.93**	**0.89**	**0.94**	**0.93**	**0.93**	**0.89**	**0.89**	**-0.96**	**0.96**	**0.97**
BWQI	**0.80**	**-0.90**	**0.70**	**0.84**	**0.66**	**0.72**	**0.84**	**0.72**	**0.77**	**0.79**	**0.86**	**0.76**	**0.76**	**-0.87**	**0.85**	**0.83**

Expected outcome

- Biomonitoring protocol unique to the study area
- Complementation of decision making – assist policy makers and decision takers in marking informed choices about appropriate water governance and management reforms.

➢ ***designed to support the rational management of lotic systems.***


Thank You!!!