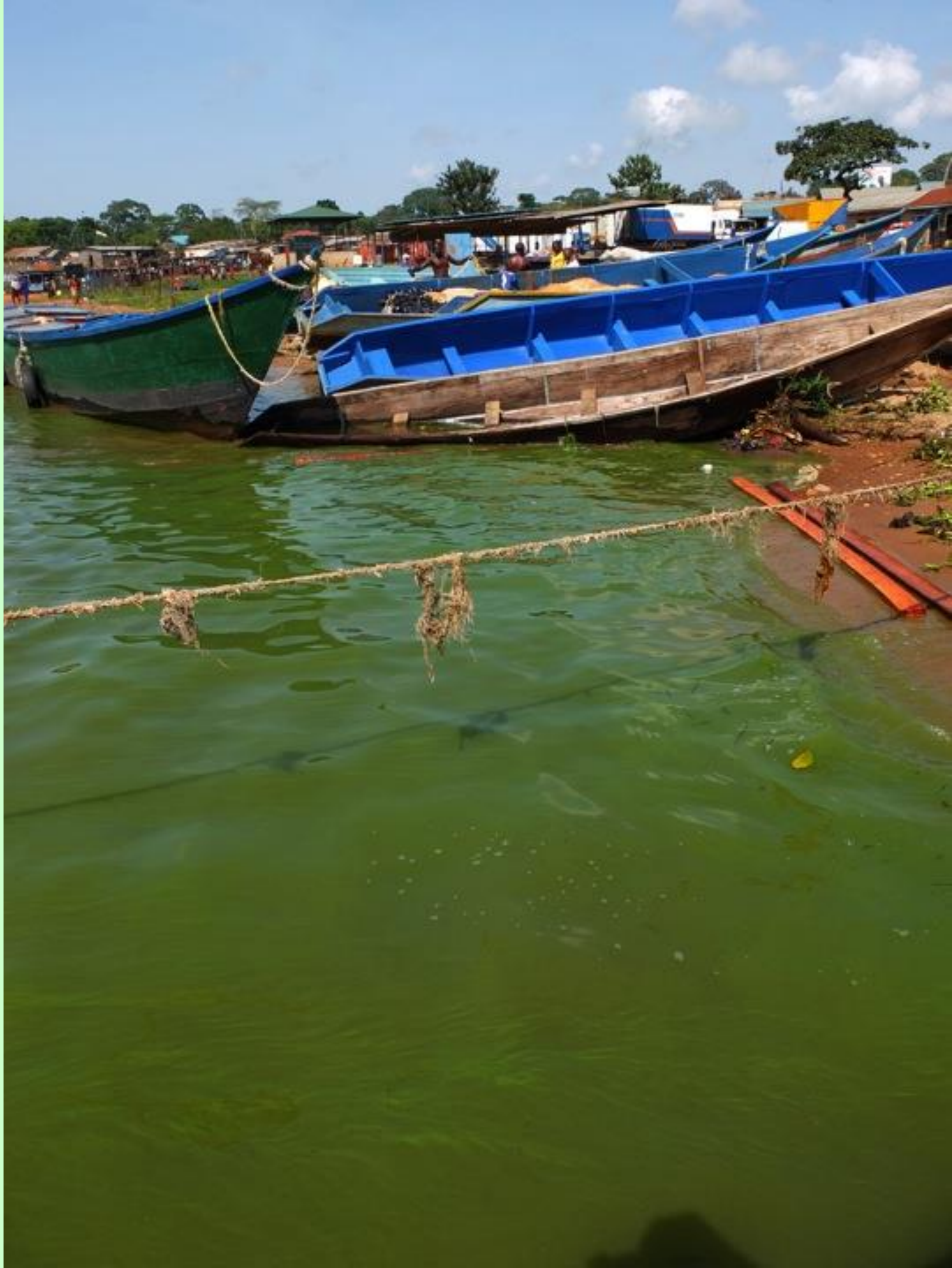
The eutrophication of Lake Victoria:
Consequences on the functioning of the lakes and on its use for the production of drinking water, monitoring strategies

WASaF project team Kampala - Uganda



What are the main functions of lakes?

Lake Victoria

Water supply
(Domestic, industrial, agriculture)

Power production

Food production

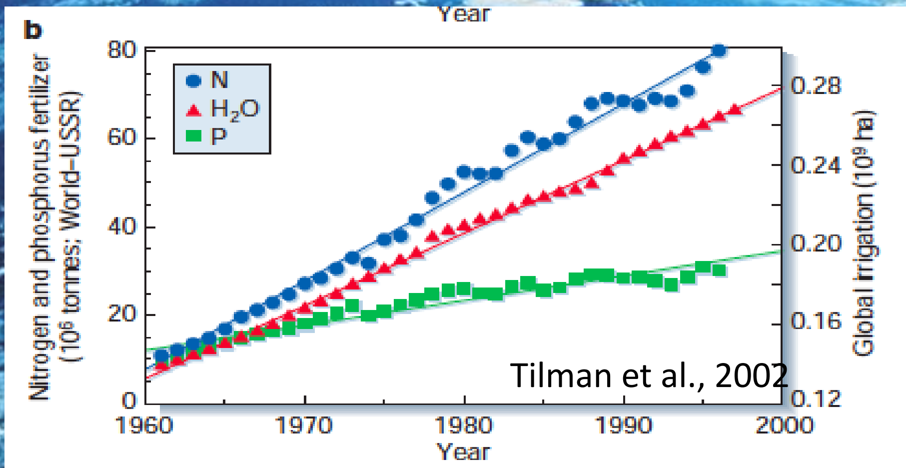
Recreational activities / Existence services

Navigation

Other ecosystem services
(Carbon sequestration, nutrient cycling, wildlife habitats, hydrology…)

The eutrophication of freshwater ecosystems, a worldwide problem

→ Growth of the world human population, with many consequences…



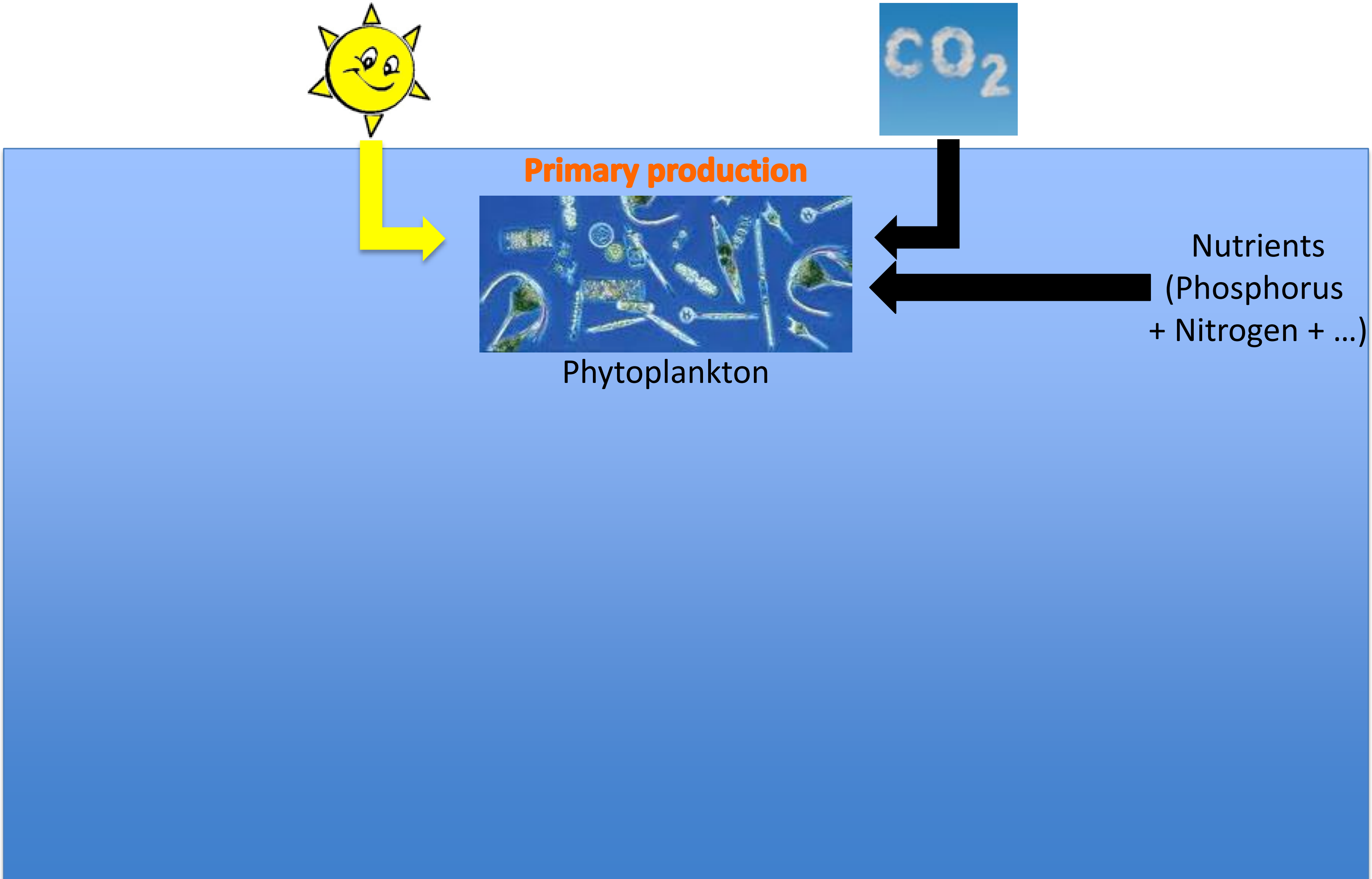
Increase of fertilizer use

Increase of wastewater volumes

Changes in land use

How to describe the process of eutrophication?

Understanding the biological functioning of a lake



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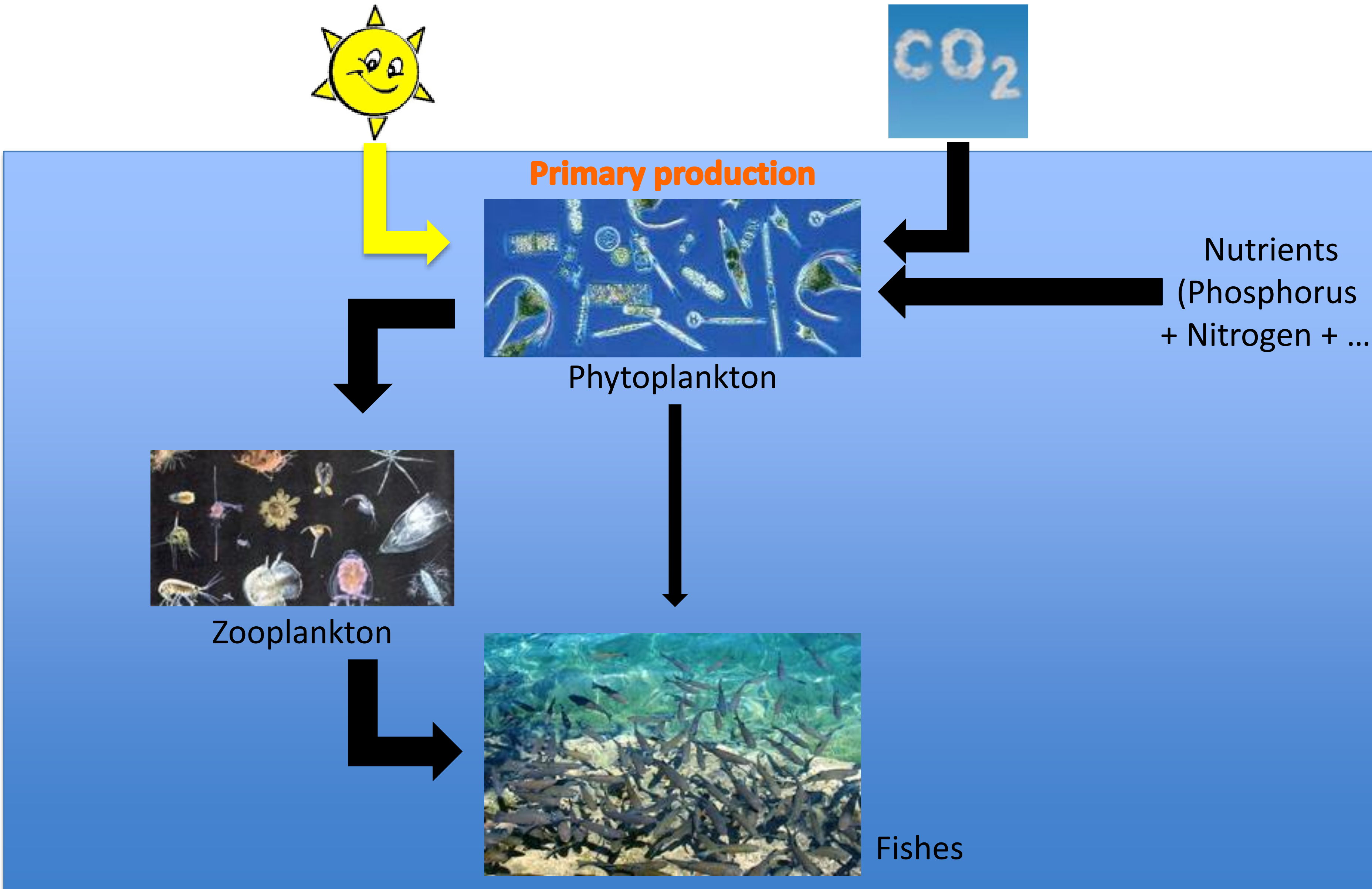
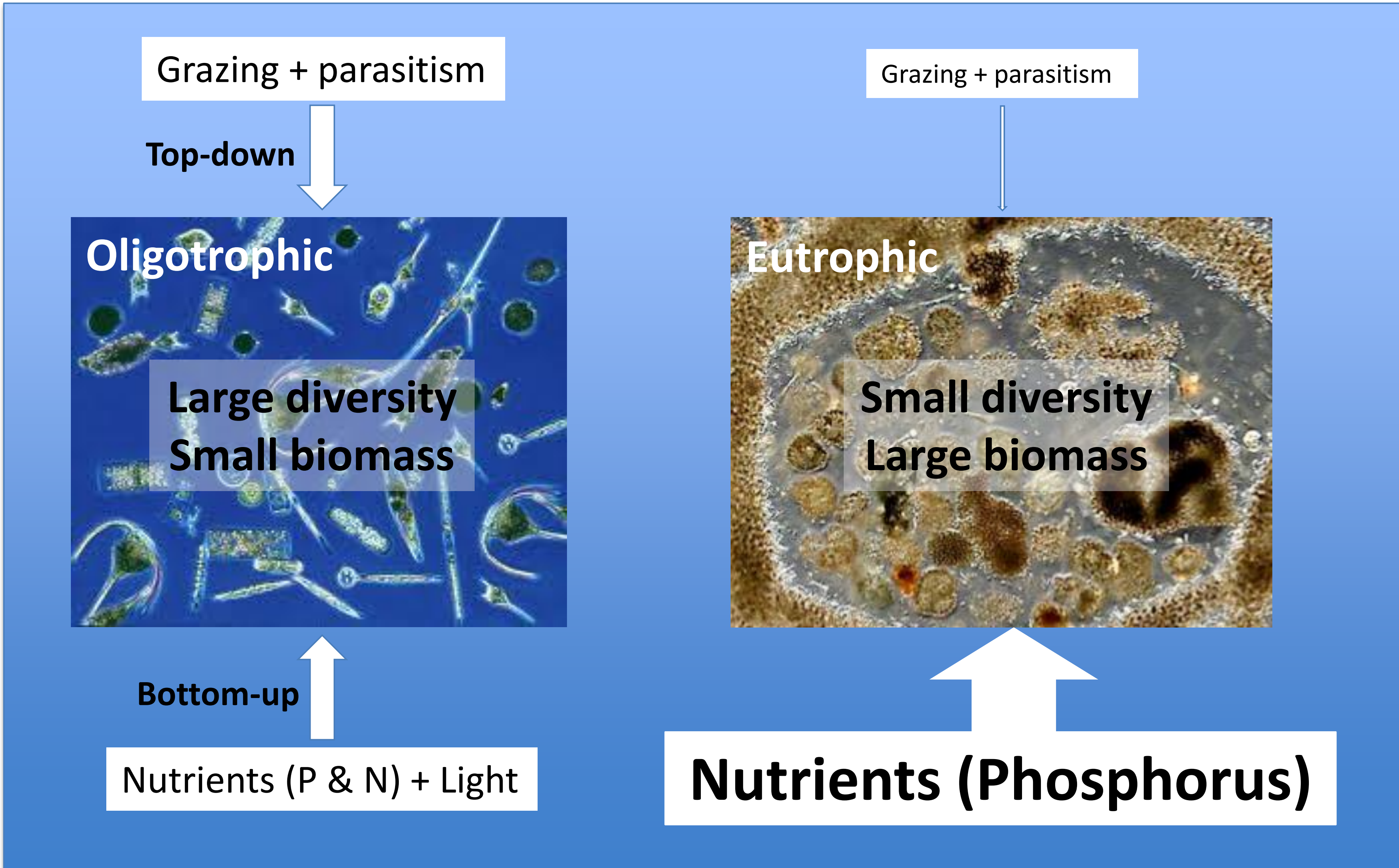


Key factors and processes controlling the phytoplankton communities in lakes



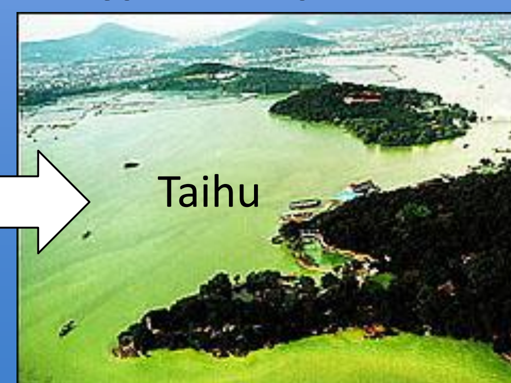
Key factors and processes controlling the phytoplankton communities in lakes?

Trophic levels in lakes

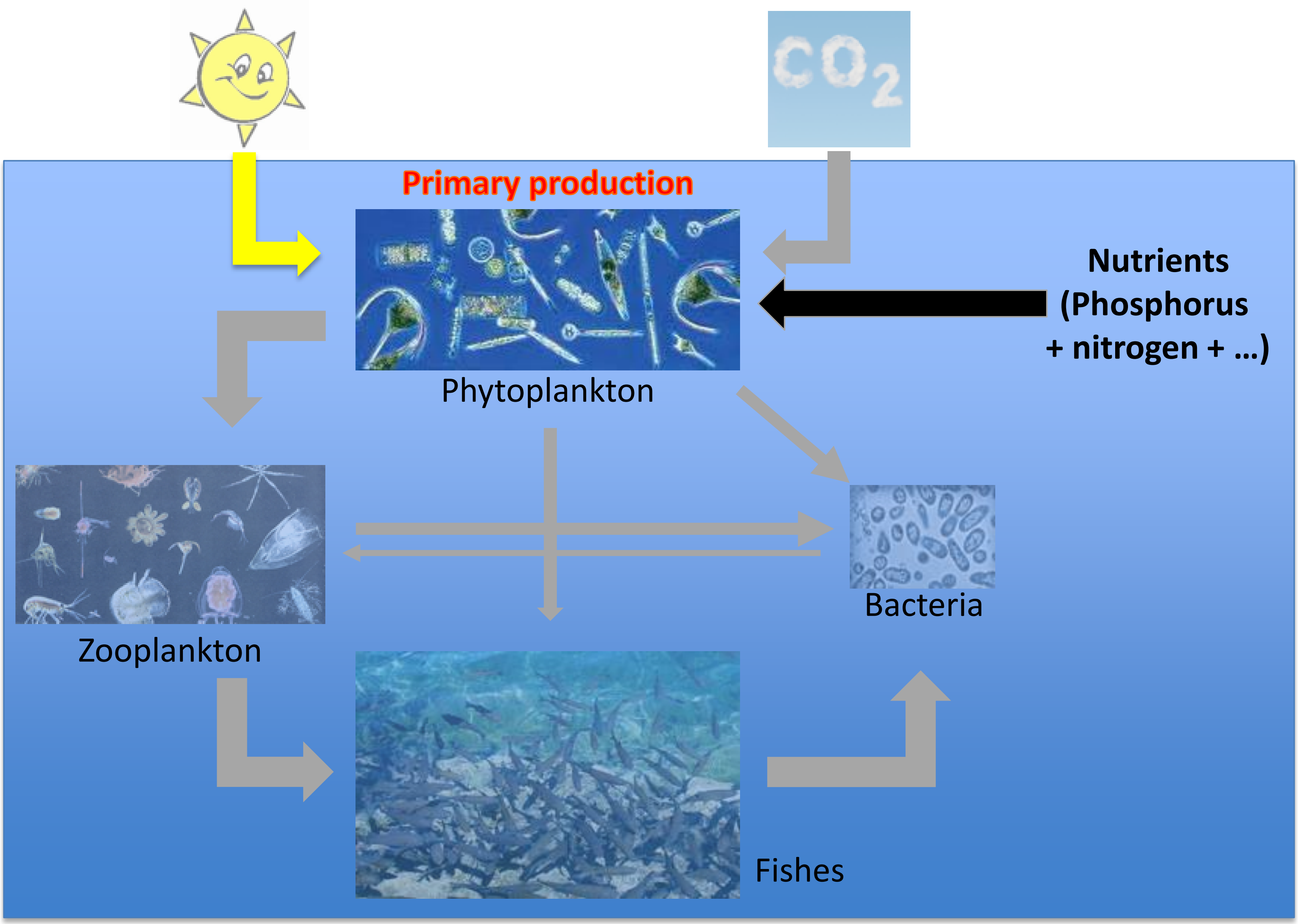
	Phosphorus conc. (µg.L^{-1})	Chlorophyll conc. (µg.L^{-1})
Oligotrophic	0-10	0-3
Mesotrophic	10-30	3-10
Eutrophic	30-100	10-30
Hypereutrophic	>100	30-400

Oligotrophic lake

Hypereutrophic lake



What are the origins of nutrients (N & P) in lakes?



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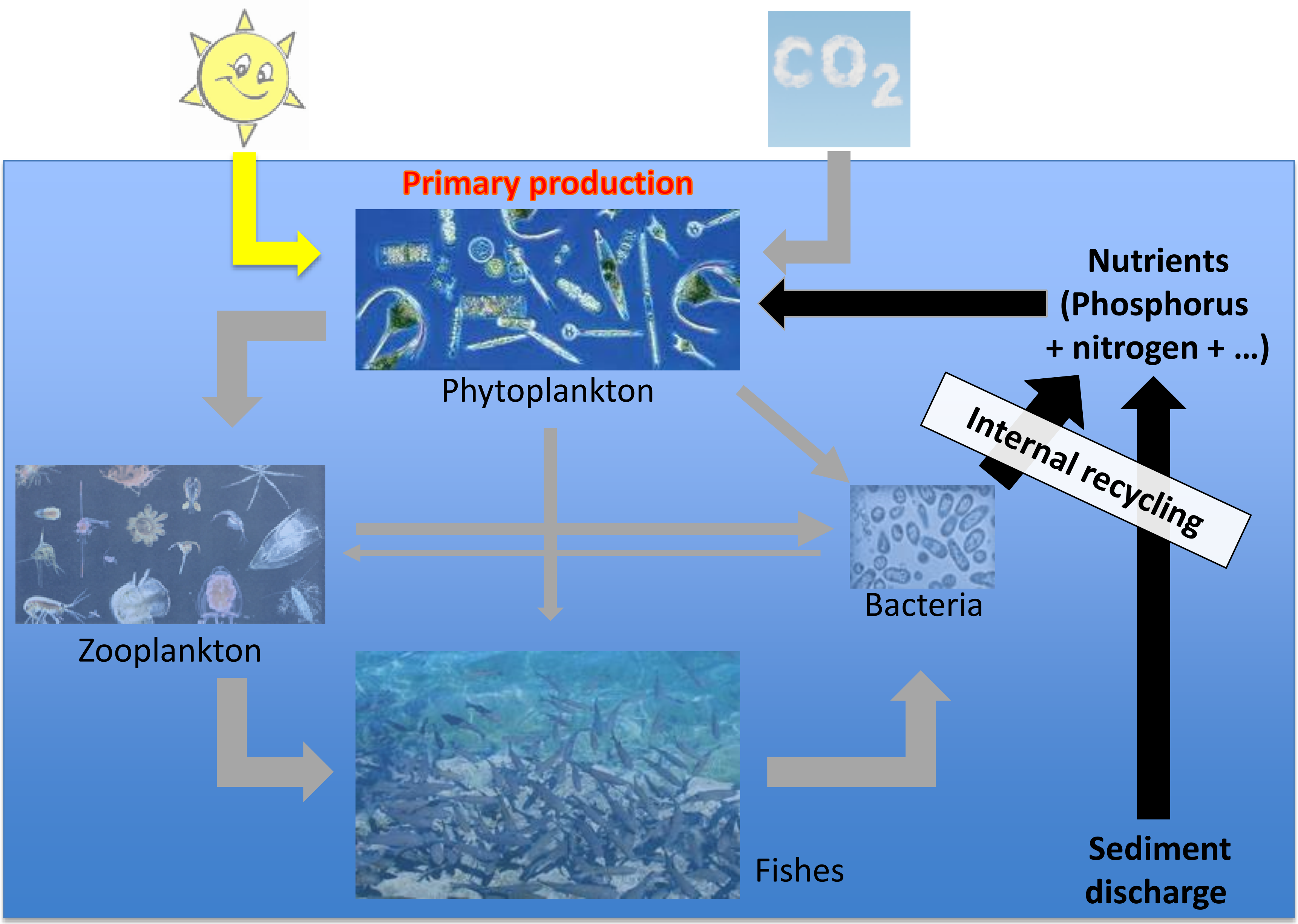

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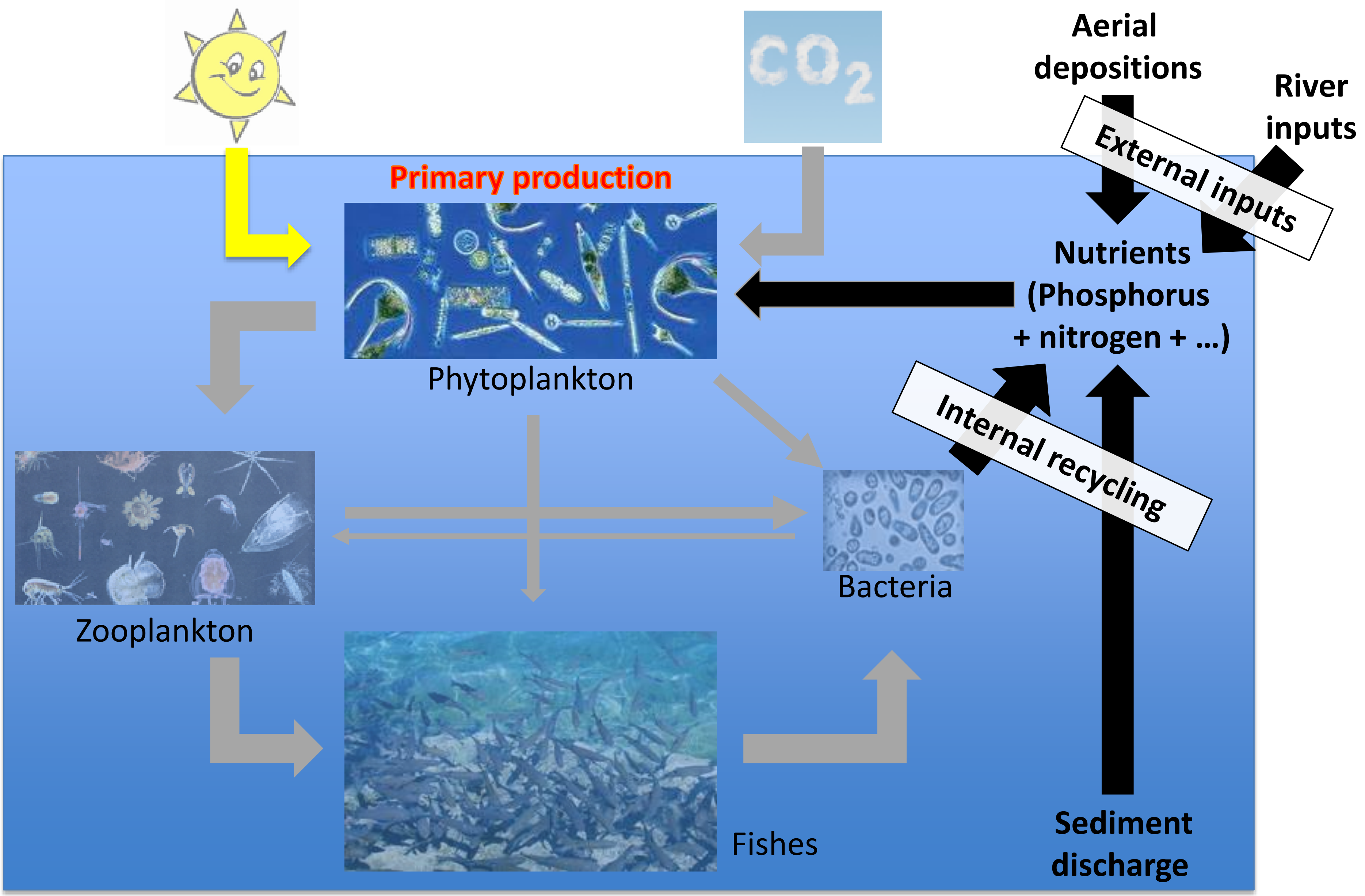
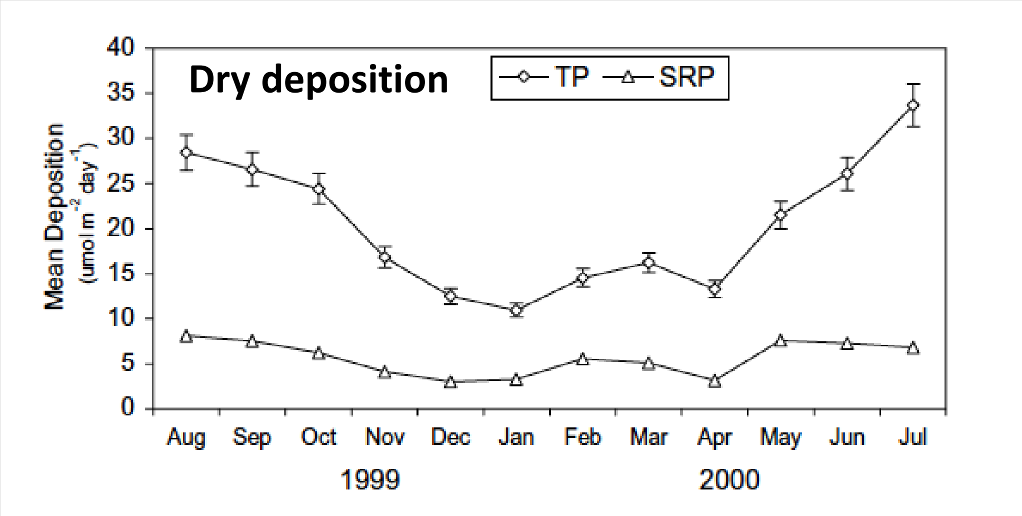


Aerial deposition = Dry and wet deposition



Tamatamah et al., Biogeochem. 2005

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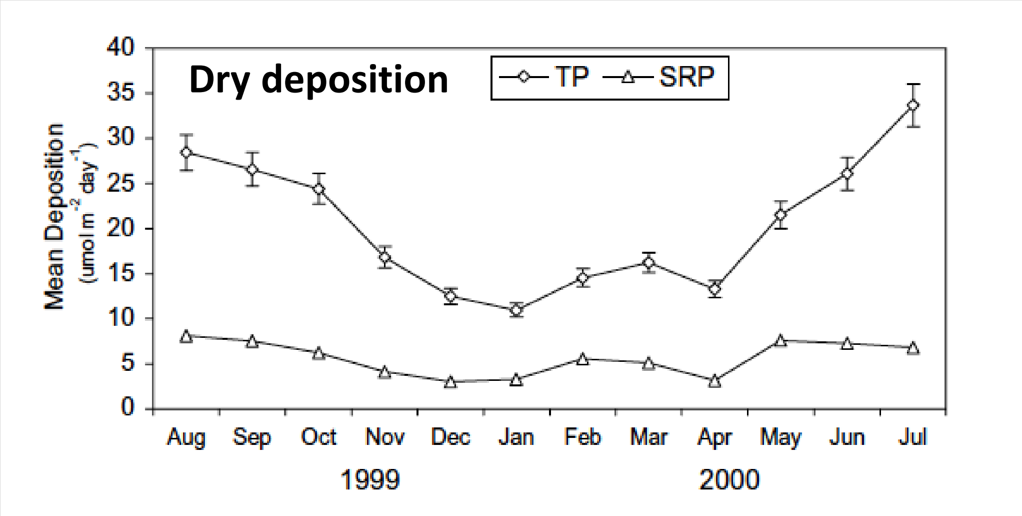
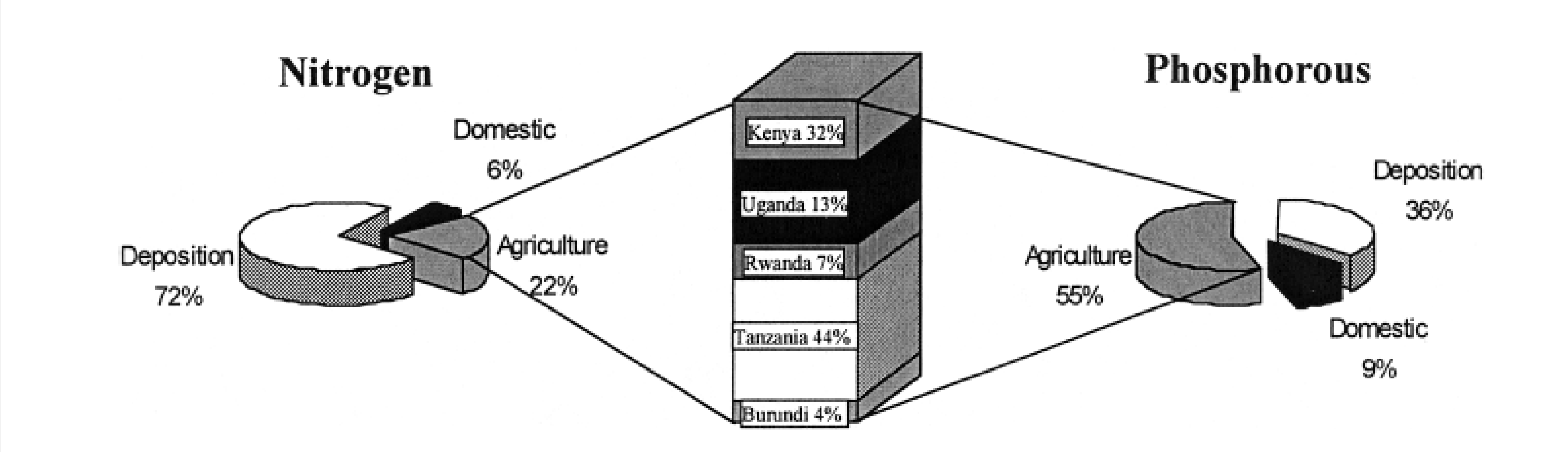


Tamatamah et al., Biogeochem. 2005

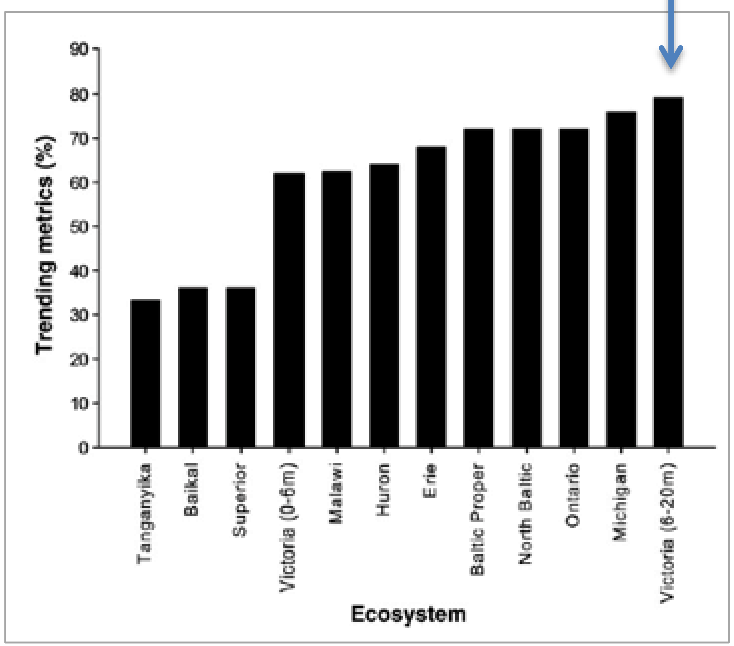
Terrestrial/river inputs



Scheren et al., J. Env. Manag. 2000

How to explain the degradation of Lake Victoria?

Regions:	Boreal		Temperate					Tropical		
Ecosystems:	Baltic Sea	Baikal	Superior	Michigan	Huron	Erie	Ontario	Victoria	Tanganyika	Malawi
Population (million)	85	5	0.6	9.3	3.1	11.9	8.1	39	8.7	7.7
Lake area (km^2)	415,000	31,500	82, 100	57,750	59,800	25,800	19,000	68,800	32,600	29,500
Lake drainage (km^2)	1,700,000	560,000	128,000	118, 100	134,000	61,000	64,000	195,000	220,000	100,500
Volume (km^3)	21,547	23,600	12, 230	4920	3537	483	1637	2760	18,900	7775
Shoreline length (km)	8000	2000	4387	2636	6159	1402	1146	3440	1828	245
Mean depth (m)	53	740	149	85	59	19	86	40	580	264
Maximum depth (m)	459	1741	407	282	229	64	245	79	1470	700
Residence time (y)	30	350	107	59	16.4	2.2	6.7	23	440	114
Age (10^3 y)	15	30,000	10	10	10	10	10	400	12,000	2000



Dobiesz et al., J. Great Lakes Res 2010

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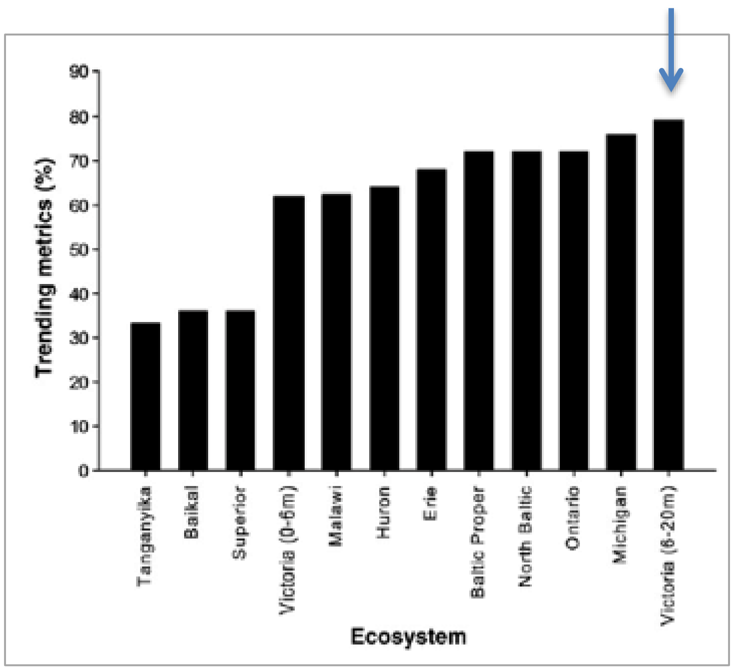

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Large surface / « small » volume

→ Importance of the aerial depositions

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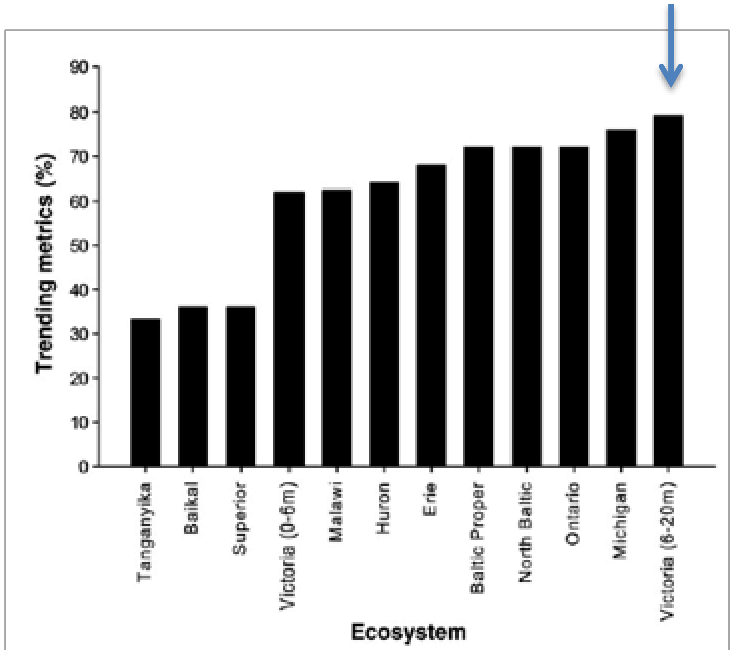


Dobiesz et al., J. Great Lakes Res 2010

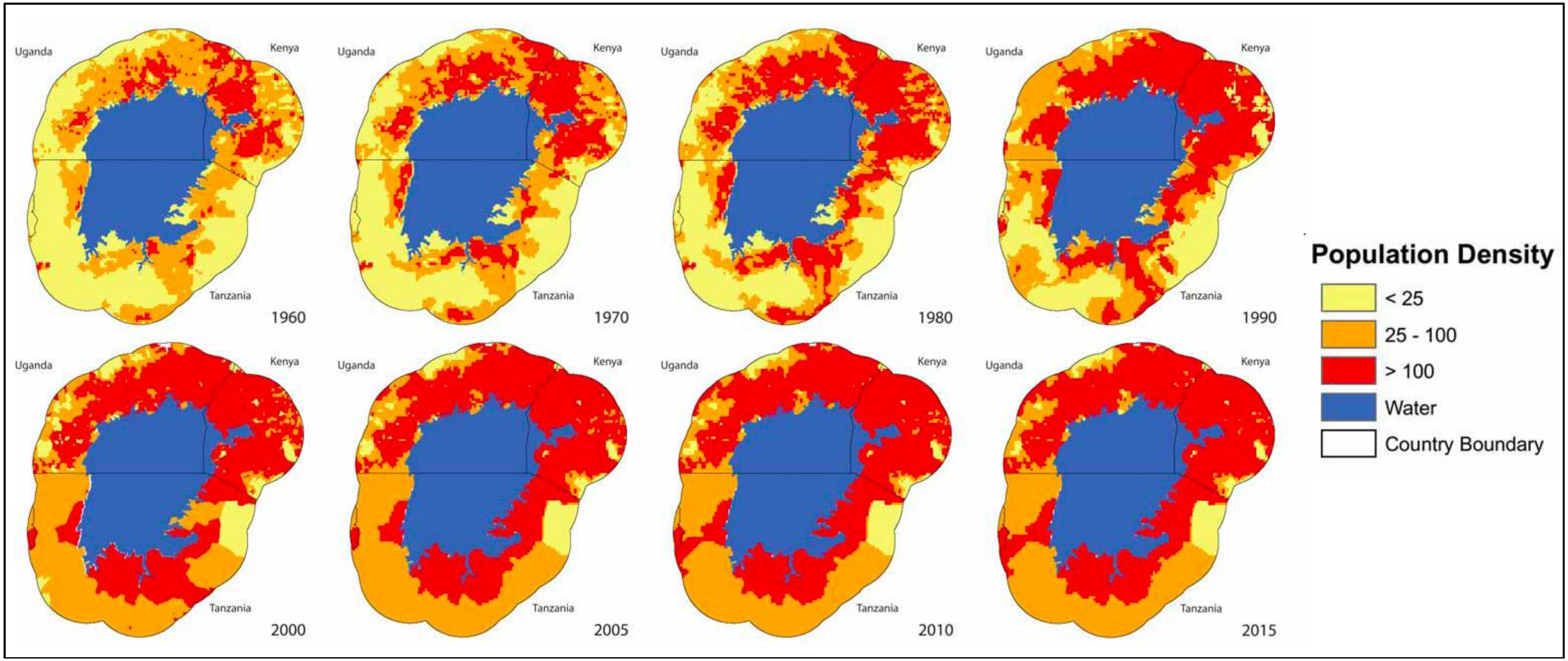
Large surface / « small » volume

→ Importance of the aerial depositions

Very large catchment area and high human population density

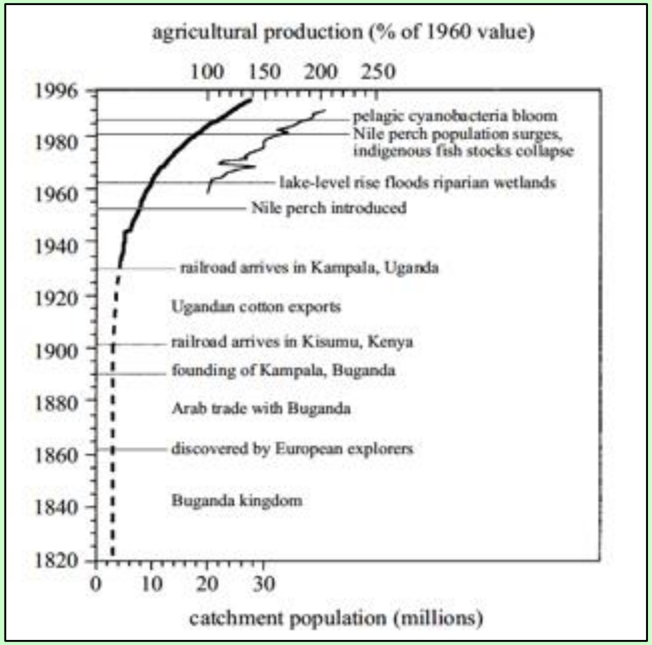
→ Very high anthropogenic pressures

How to explain the degradation of the Lake Victoria?



→ Very strong increase of the population density around the lake

Consequences of the increase of the density of human populations living around Lake Victoria



Verschuren et al., Proc R Soc Lond B 2012

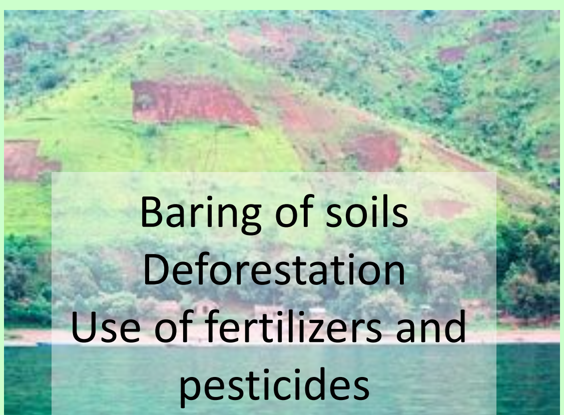


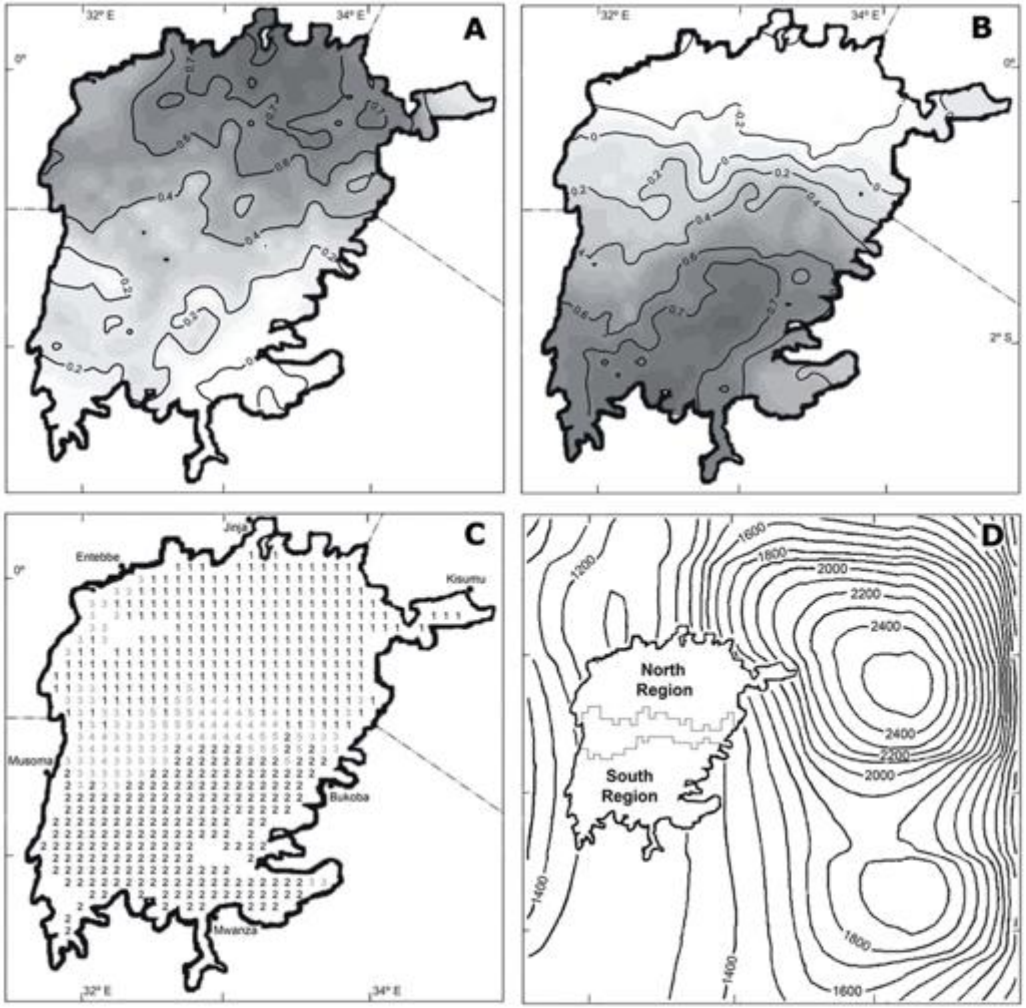
Table 2. Number of sewered and unsewered people in urban populations (from 33).

	Total population (1000 people)	Urban Population (1000 people) Sewered	Unsewered	Number of Towns
Kenya	10 200	390	630	18
Uganda	5600	210	870	9
Tanzania	5200	27	340	4
Rwanda	5900	-	400	5
Burundi	2800	-	140	4
Total	29 700	627	2380	40

Odada et al., Ambio 204

Potential influence of global warming?

Increase of phytoplankton blooms during the periods of lake surface warming and water column stability



Cosar et al., PLoS ONE 2012

What are the main consequences of the eutrophication on the biological functioning and on the production of drinking water?

What are the main effects of eutrophication on the uses of lakes?

Water supply
(Domestic, industrial, agriculture)

Power production

Food production

Recreational activities/Existence services

Navigation (Water hyacinth)

Other ecosystem services
(Carbon sequestration, nutrient cycling, wildlife habitats…)

In light limiting conditions, which species are favored?

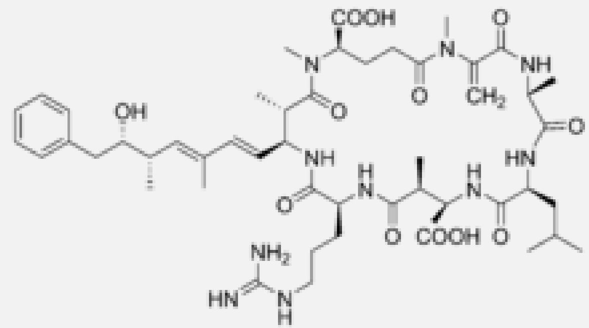
→ Ability to occupy the surface layer of the lakes

Floating plants

What are the main problems due to cyanobacterial blooms?

Health problems:

- Production of harmful cyanotoxins (microcystins)
- Interactions with pathogenic bacteria?



Problems for the production of drinking waters:

- Difficulties to remove cyanobacteria (and their toxins) in the water treatment plants
- High biomasses = high quantities of carbon (Total Organic Carbon) → Many problems for the water production and for the drinking water quality

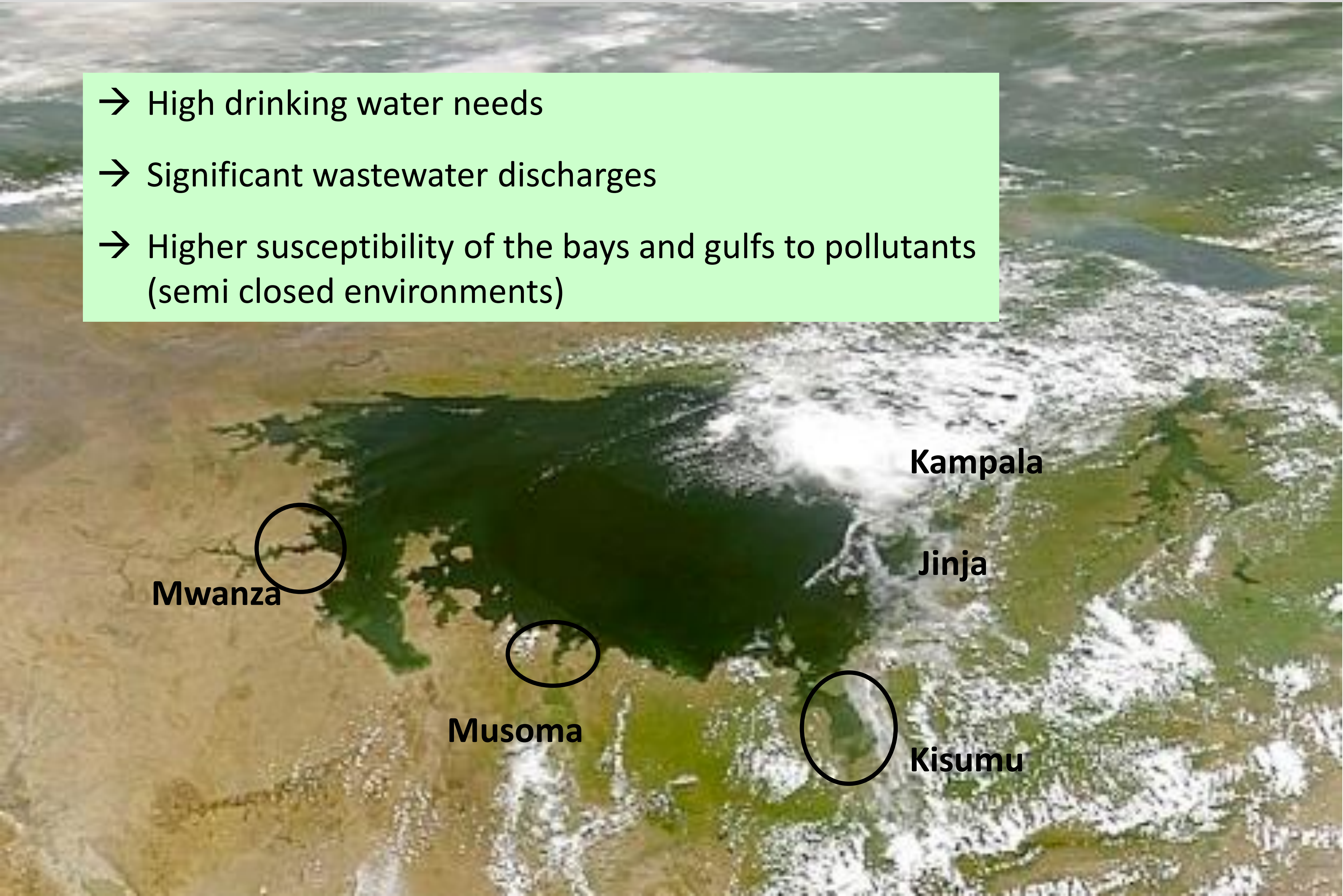
The specific cases of the bays and gulfs in Lake Victoria

Numerous cities located on the shoreline of bays and gulfs

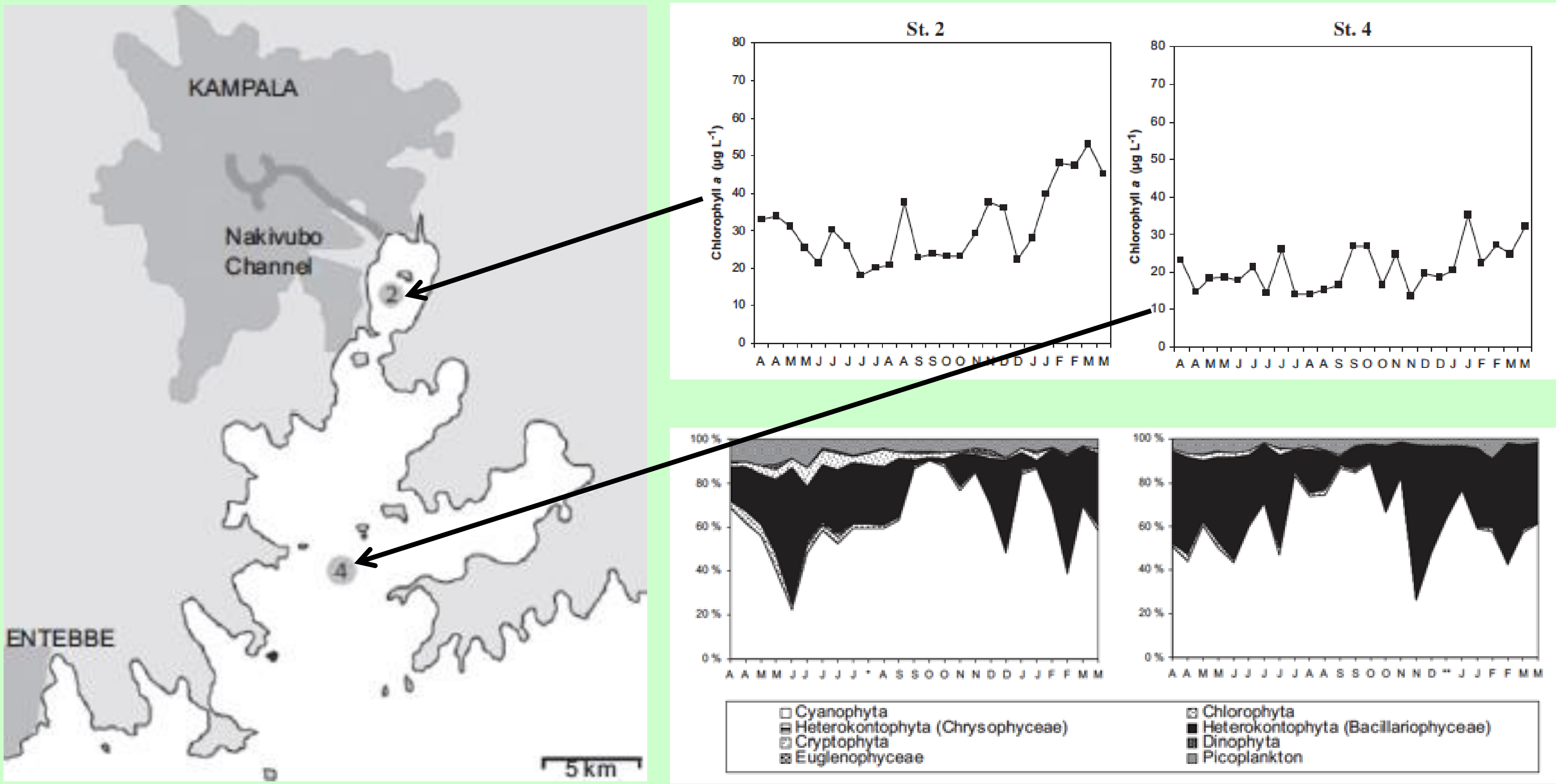
→ High drinking water needs

→ Significant wastewater discharges

→ Higher susceptibility of the bays and gulfs to pollutants (semi closed environments)



The example of Murchison Bay (Uganda)



Haande et al., Limnologica 2010

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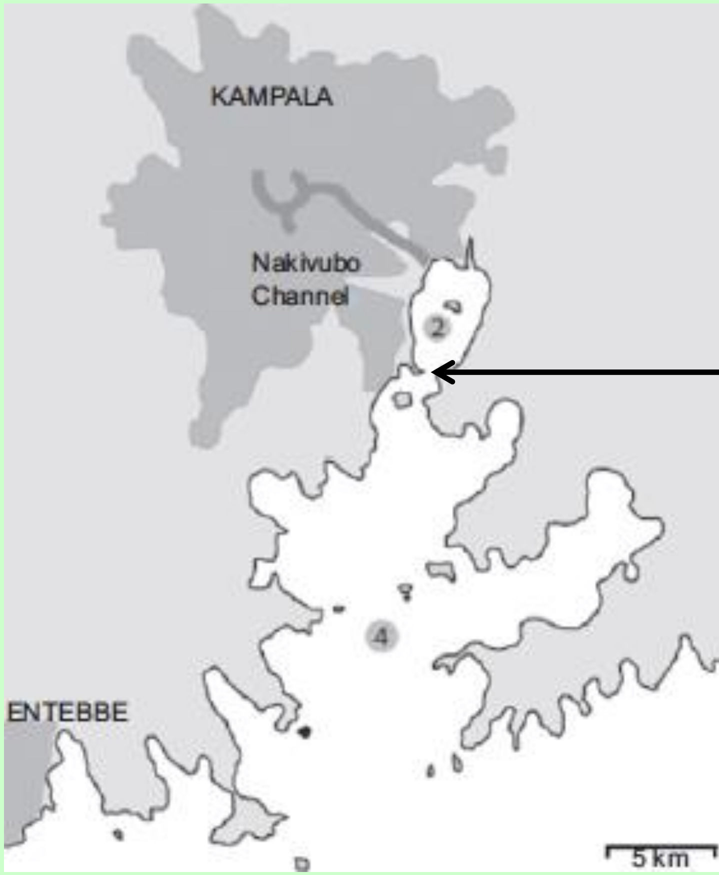


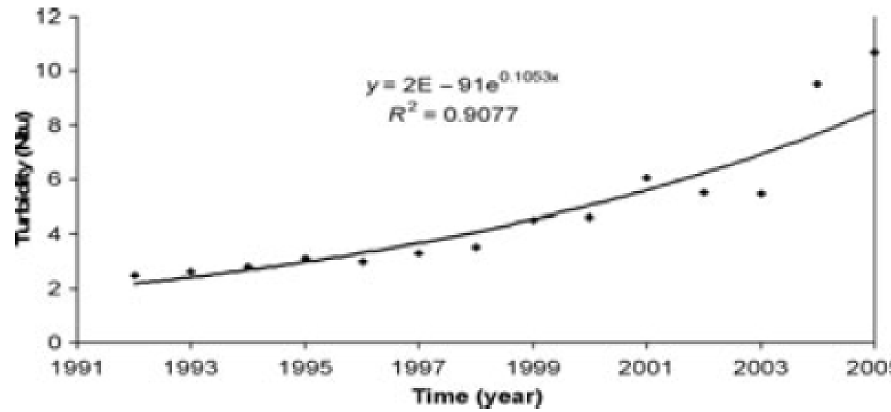
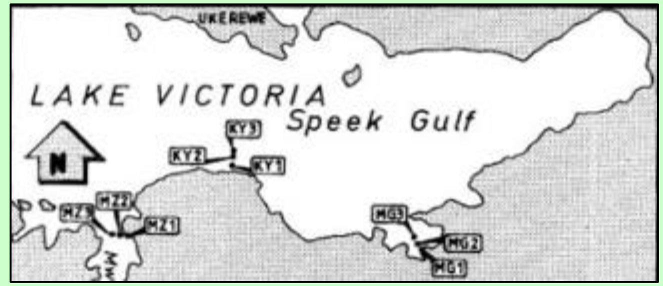
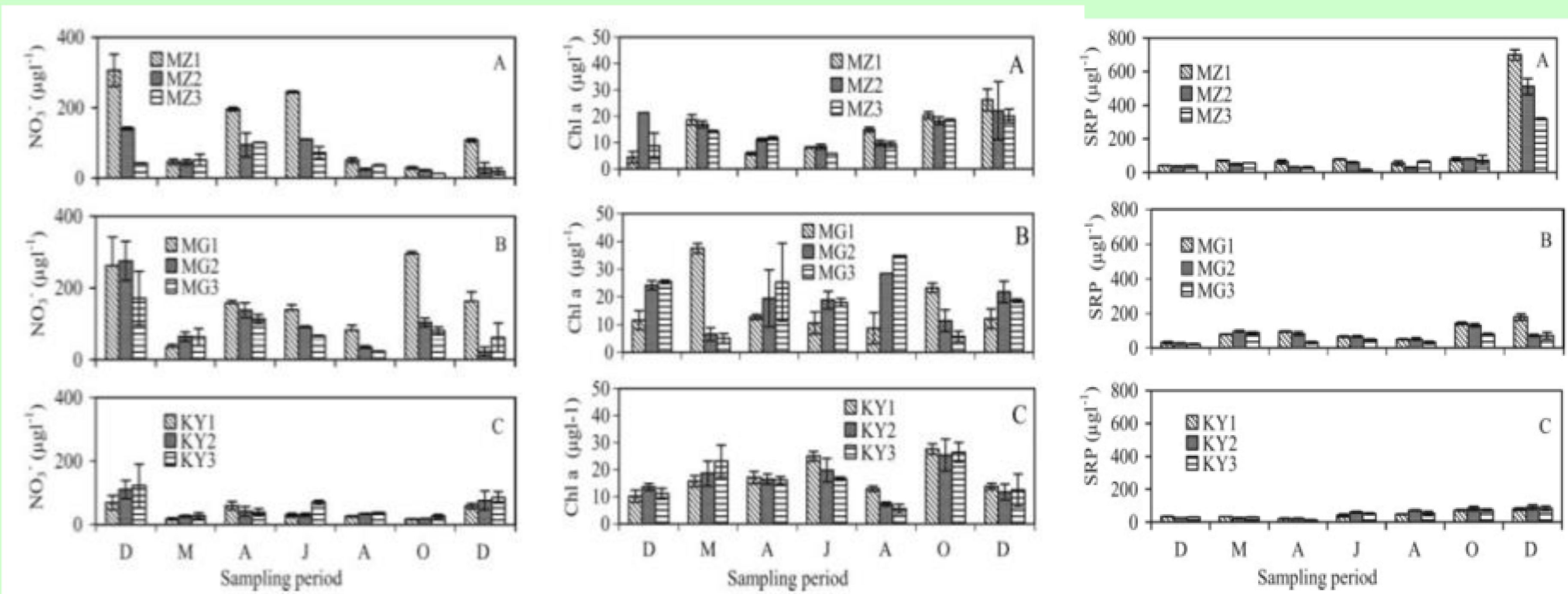


Fig. 3. Turbidity trends for raw water at Gaba waterworks intake, Murchison Bay, Uganda.

The example of Speke Gulf (Tanzania)

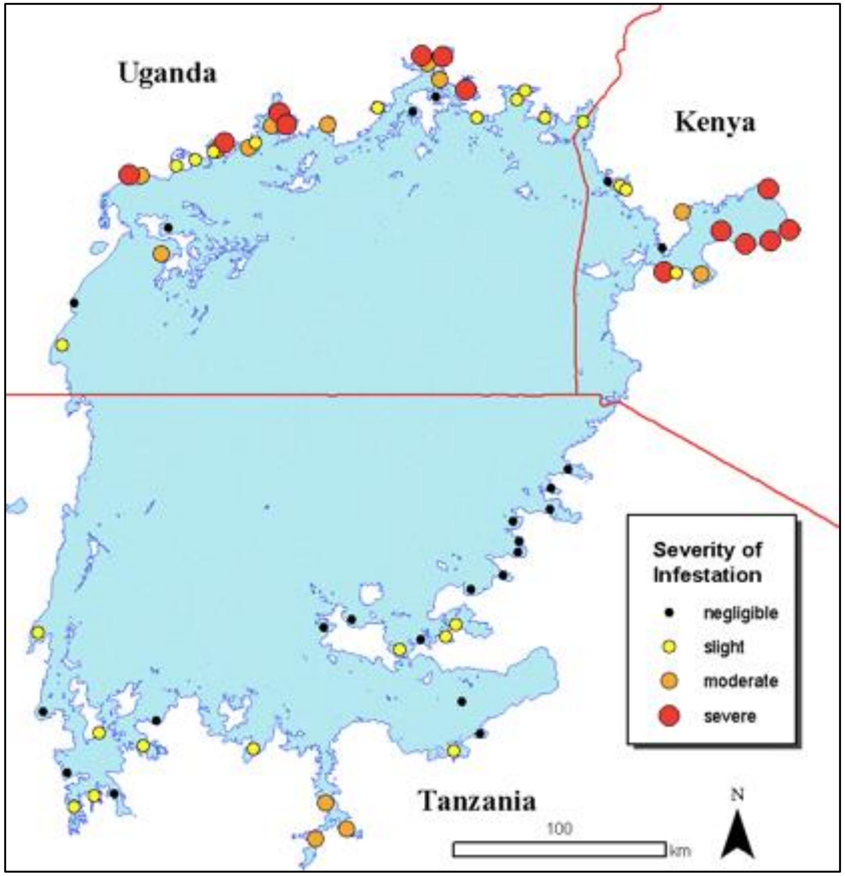
Mwanza North Bay, **urban pollution** (MZ)
Magu Bay, **agricultural pollution** (MG
Kayenze Bay (KY)





Shayo et al., AEHM 2011

The example of Kavirondo gulf (Kenya)



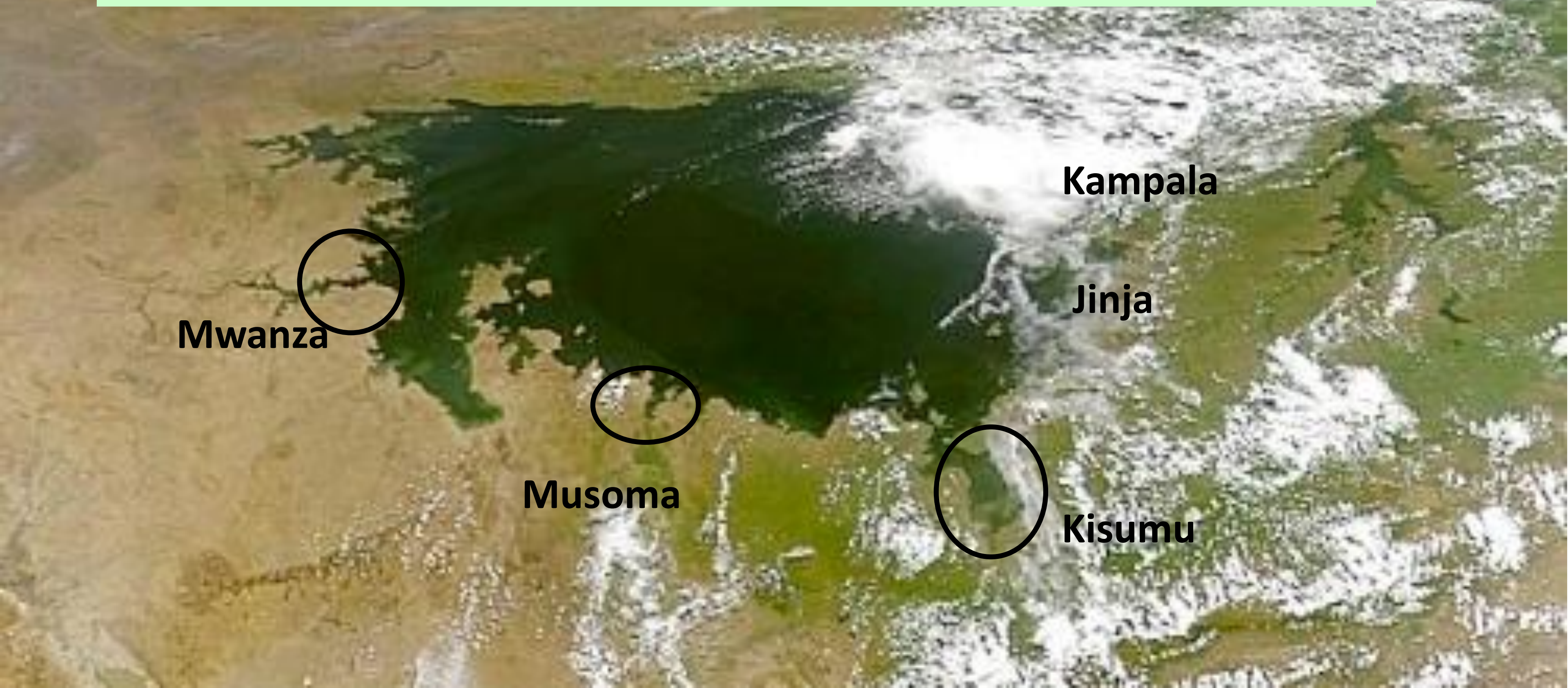
1994-2001

→ Massive development of hyacinth (and cyanobacteria) in bays and gulfs

To conclude on bays and gulfs…

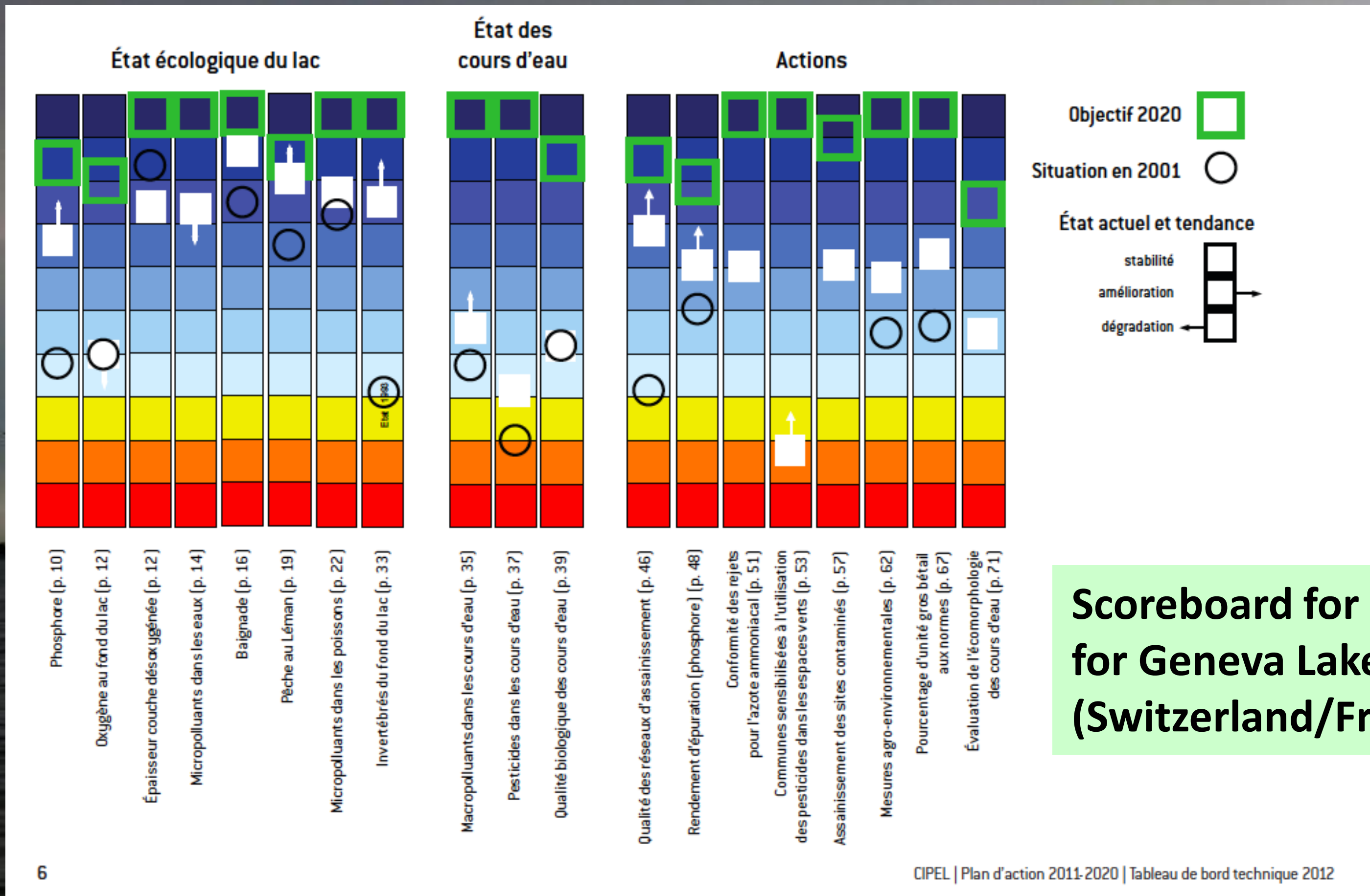
→ The quality of the water in bays and gulfs is strongly influenced by the terrestrial inputs (rivers, wastewater channels…)

→ A particular attention should be paid for the protection of these environments that are critical for many people.



And now, what steps can be taken?

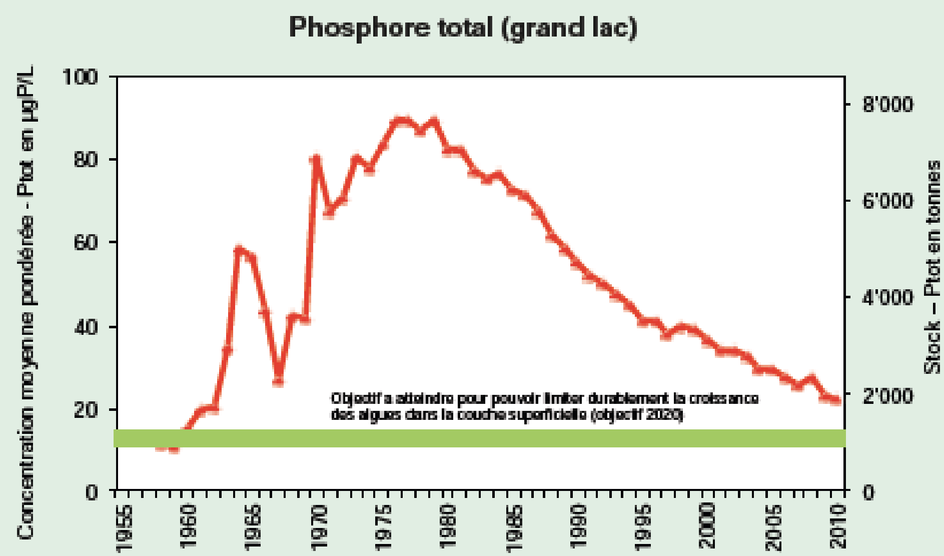
Needs for a land management strategies (implemented on a multinational, basin-wide scale) **severely restricting nutrient input to the lake and its tributaries**

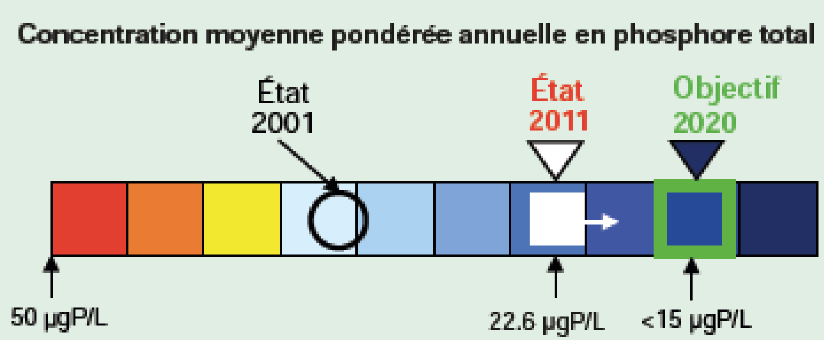


Scoreboard for 2020 for Geneva Lake (Switzerland/France)

And now, what steps can be taken?

Needs for a global long term monitoring of the lake and of the main tributaries in order to detect the global trends in its evolution





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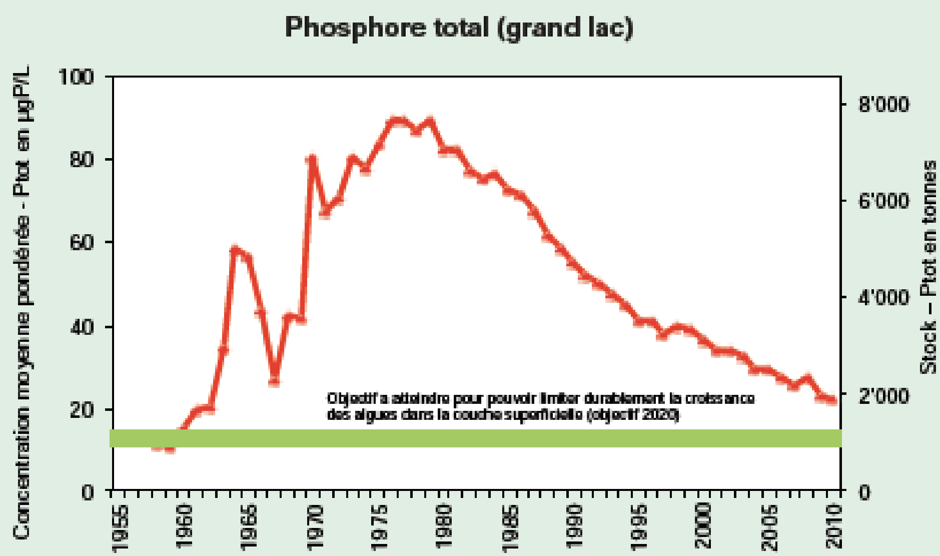
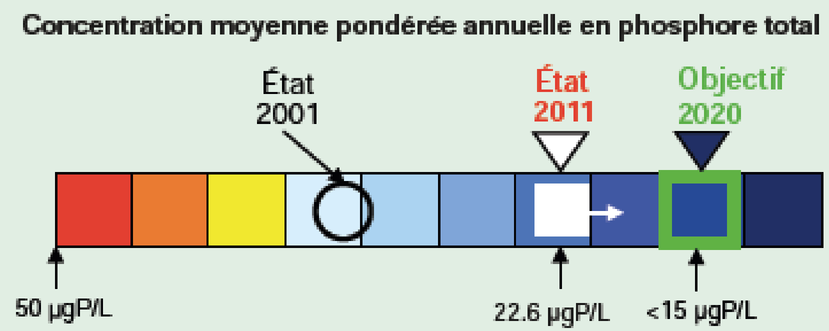
→ **Monitoring of the whole lake**

→ **Specific monitoring of bays and gulfs**





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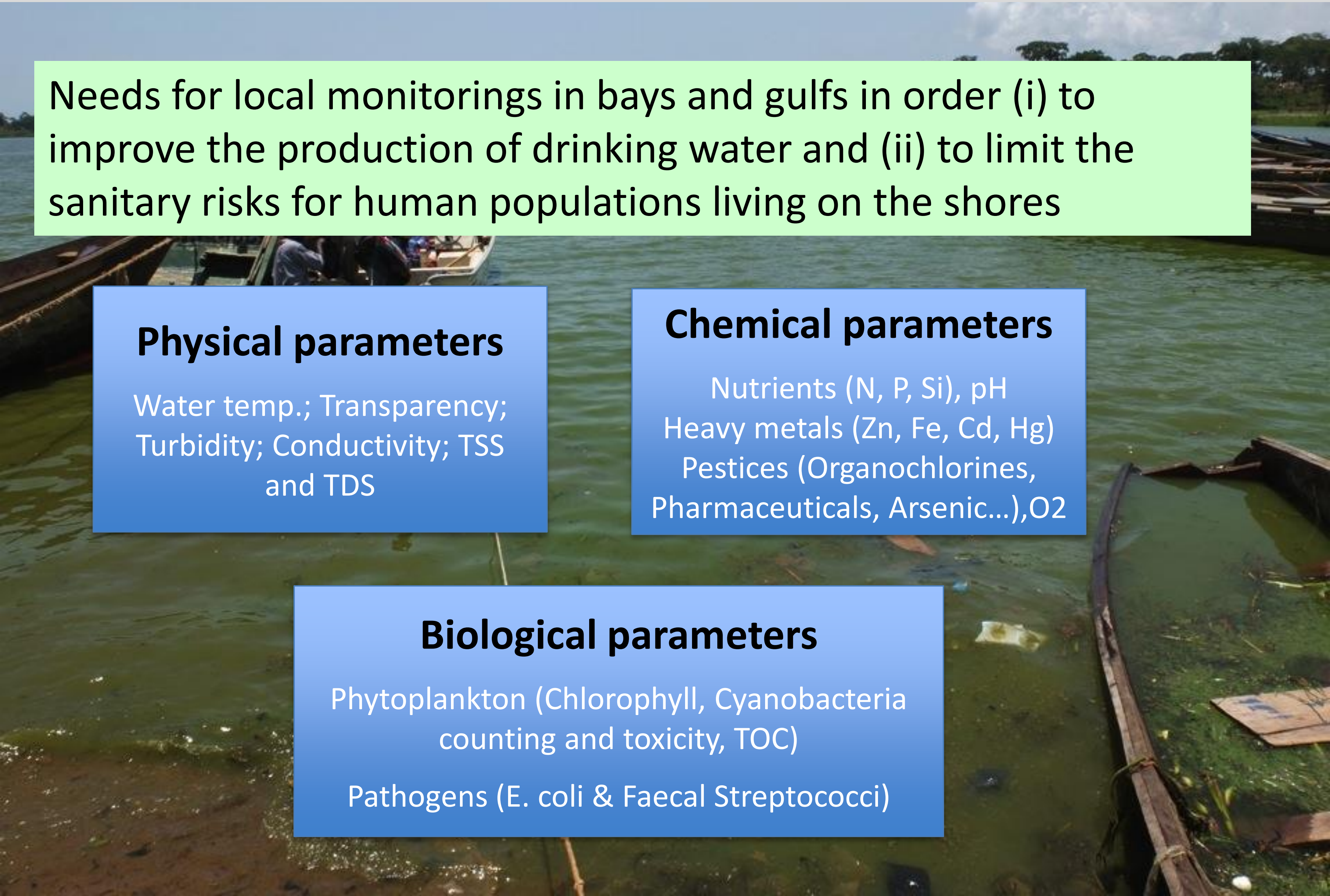


Needs for local monitorings in bays and gulfs in order (i) to improve the production of drinking water and (ii) to limit the sanitary risks for human populations living on the shores

Physical parameters

Water temp.; Transparency; Turbidity; Conductivity; TSS and TDS

Chemical parameters

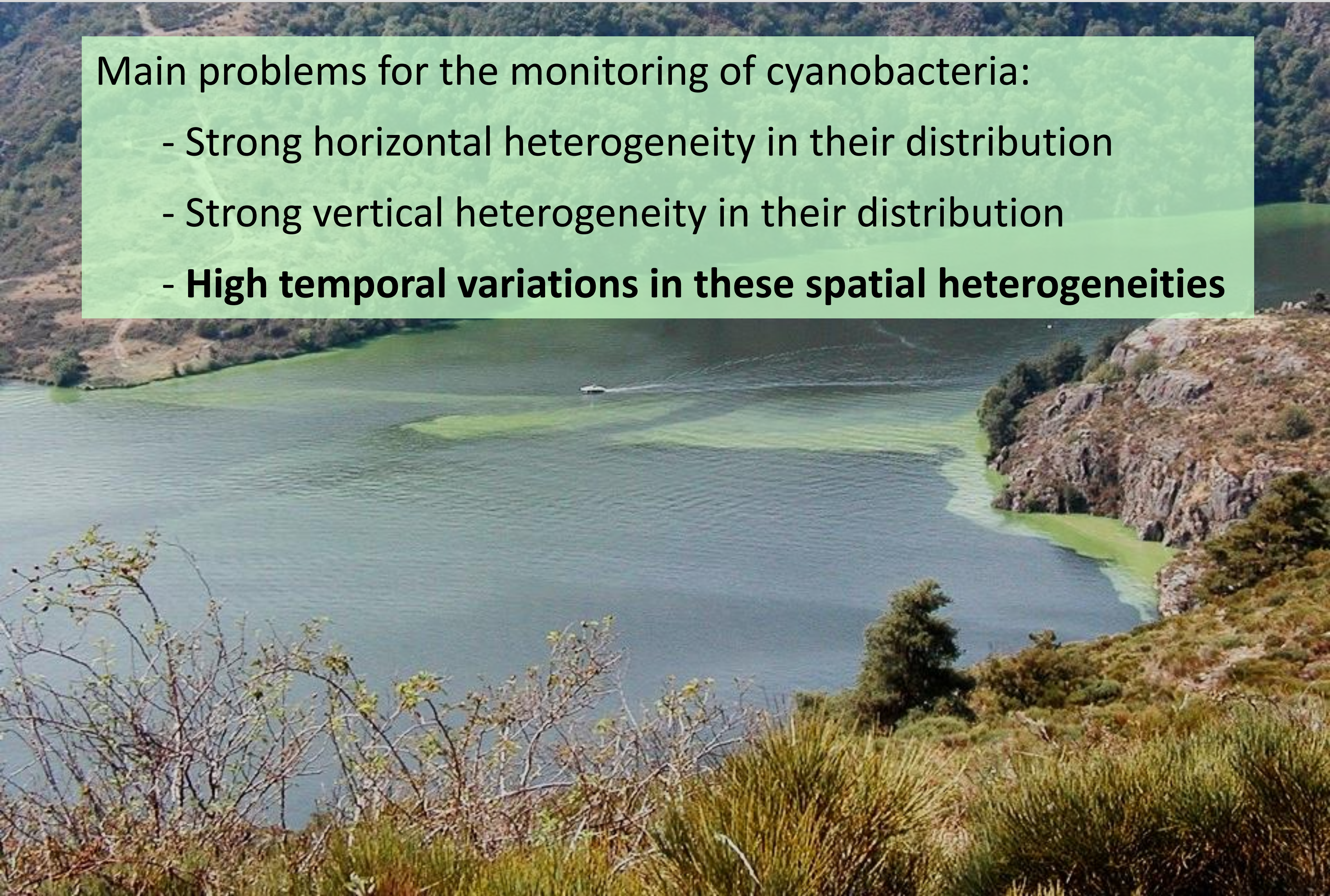
Nutrients (N, P, Si), pH
Heavy metals (Zn, Fe, Cd, Hg)
Pestices (Organochlorines, Pharmaceuticals, Arsenic…),O2

Biological parameters

Phytoplankton (Chlorophyll, Cyanobacteria counting and toxicity, TOC)

Pathogens (E. coli & Faecal Streptococci)

Local monitoring of water quality, including cyanobacteria



Main problems for the monitoring of cyanobacteria:

- Strong horizontal heterogeneity in their distribution
- Strong vertical heterogeneity in their distribution
- **High temporal variations in these spatial heterogeneities**

Local monitoring of water quality, including cyanobacteria

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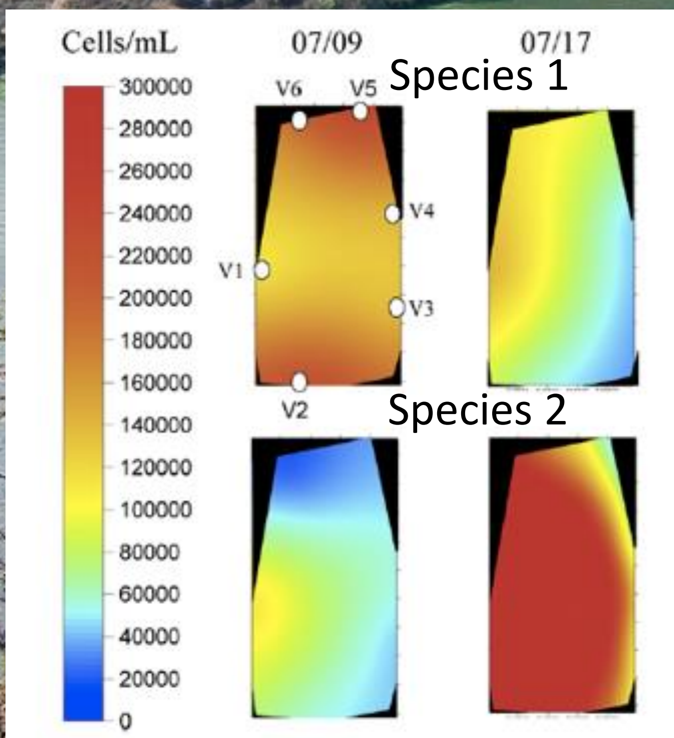

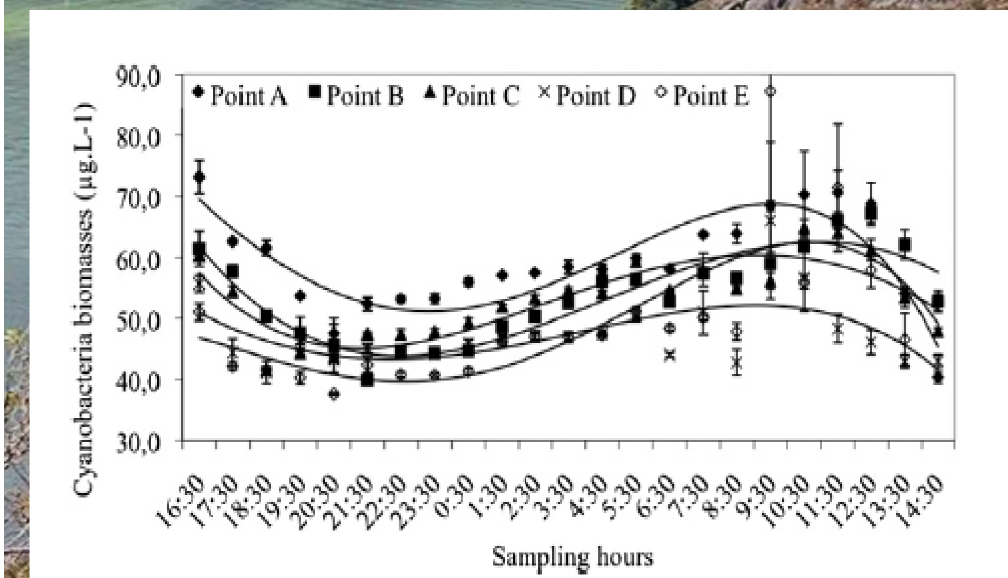

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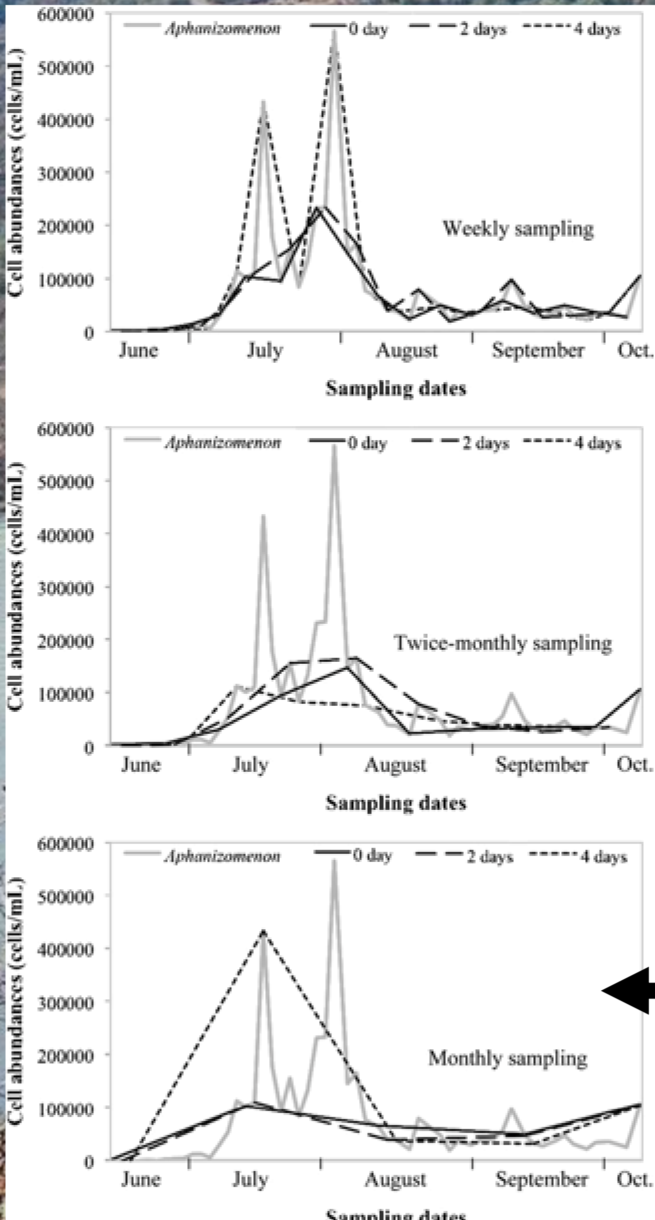

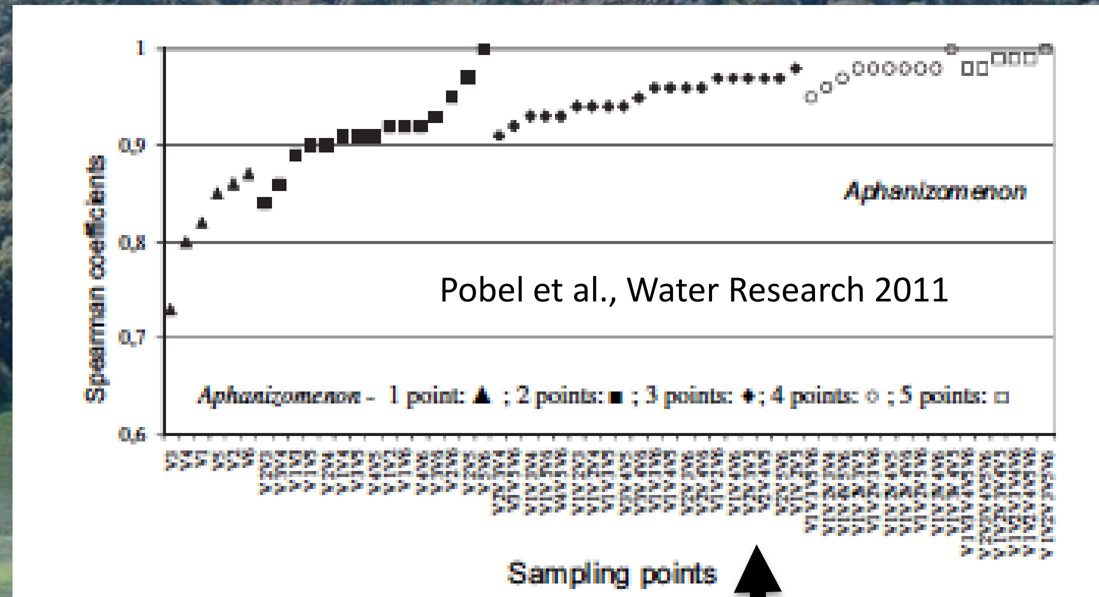

Pobel et al., Water Research 2011

Influence of the sampling effort

Influence of the sampling frequency

Recommendations for the sampling strategy

WaSAf programme (2016 -2019)

Monitoring and Sustainable Management of Surface Freshwater Sources in Africa.

1. Sampling in several points of the monitored area
   - Use of transect
   - More or less distant from the shoreline
2. Sampling at several depths in each sampling point
3. One sampling strategy for all the monitoring period

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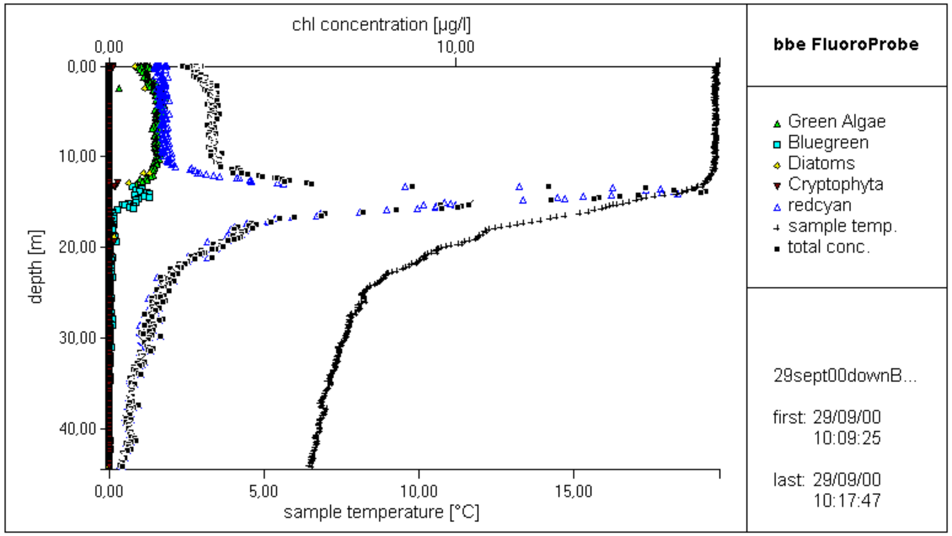
Continuous or semi continuous monitoring of the raw water in the water treatment plant:

1. Detection of short term variations occurring in the cyanobacterial population density

→ Needs for tools allowing to perform *in situ* measurements

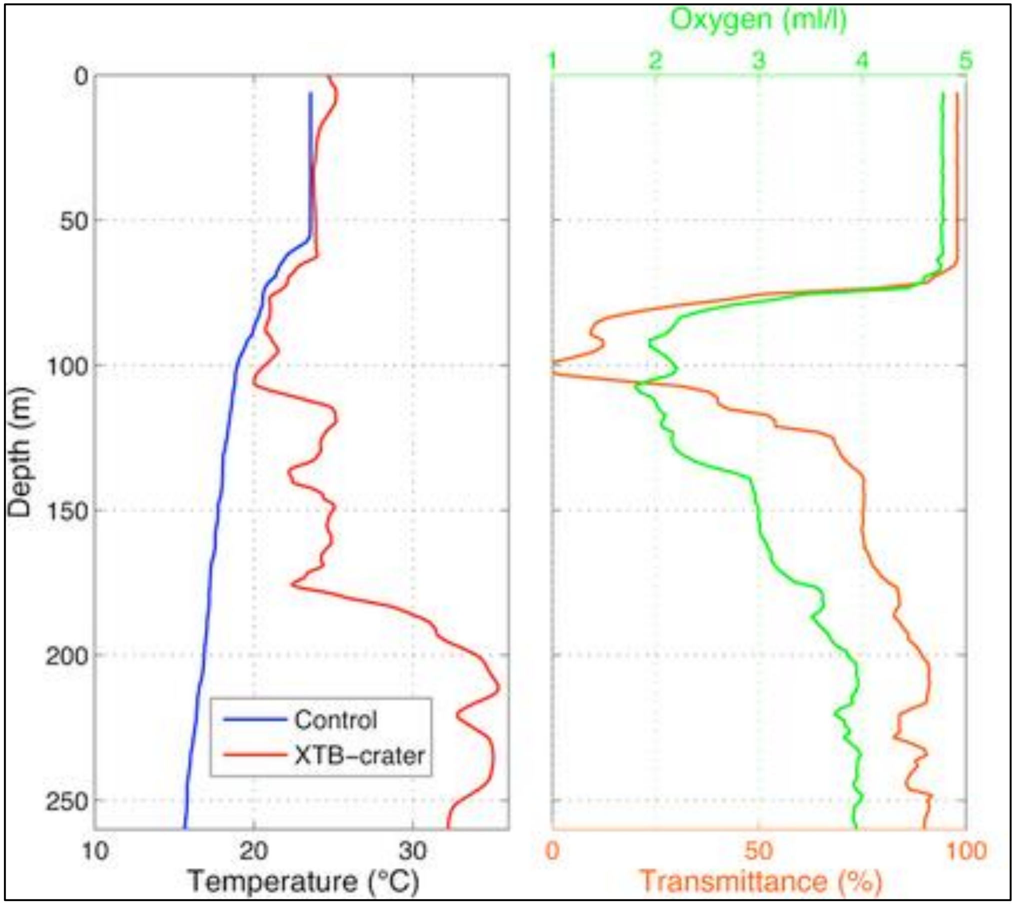
New tools for the monitoring of cyanobacteria and of environmental parameters

→ Spectrofluorimetric and phycocyanin probes for the survey of cyanobacteria



New tools for the monitoring of cyanobacteria and of environmental parameters

→ Multiparameter probes for the monitoring of the water column



Many thanks for your attention