Climate-sensitive health risks (water and food)

Climate change impacts on water and increasing risk of human exposure to toxic cyanobacteria

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Projected impacts of climate change for this century

✓Increases of temperature and CO_2 concentrations → major changes in **ecosystem structure** and **function**, **species interactions** and **geographical ranges**

✓Heavy precipitation events: increasing **frequency**, increasing **flood risk**

✓High latitudes and some tropical areas: increase by 10-40% annual average **river runoff** and water availability

✓Dry regions, mid-latitudes and dry tropics (presently water-stressed): decrease by 10-30%

✓Larger drought-affected areas

IPCC 2007

Climate change effects on water quality

✓**Increasing temperature**

- Prolonged **stratification** and **residence time**
- changing hydrological regime

↓

Increasing **floods and droughts** → changes in **nutrients concentration**

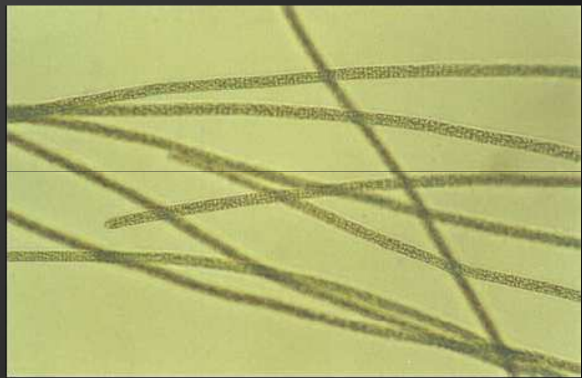
poleward and upward **shift in ranges** in plant and animal species

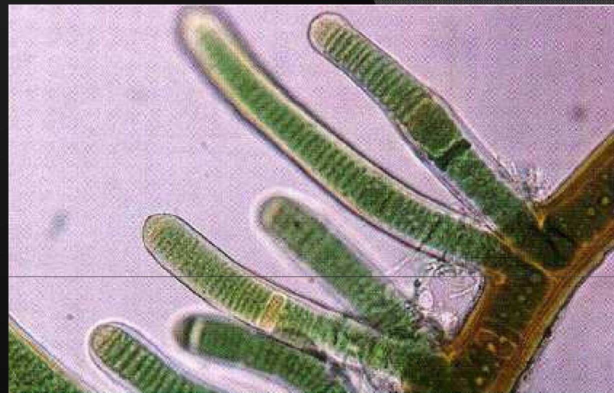
✓**Increase in surface pCO_2** → Acidification

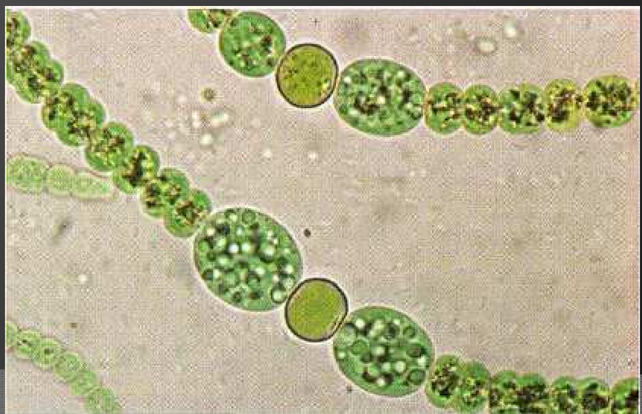
IPCC 2007

Cyanobacteria

- incredibly diverse group of prokaryotes
- many aquatic and terrestrial niches
- 2 - 40μm







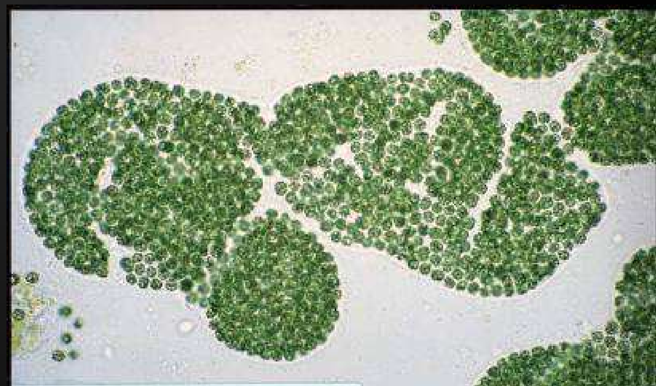


Fig. 1 Water bloom forming cyanobacterium, *Microcystis aeruginosa.*

Cyanobacteria habitats

Lyngbya cf. *aestuarii* in hypersaline intertidal flats, Mexico

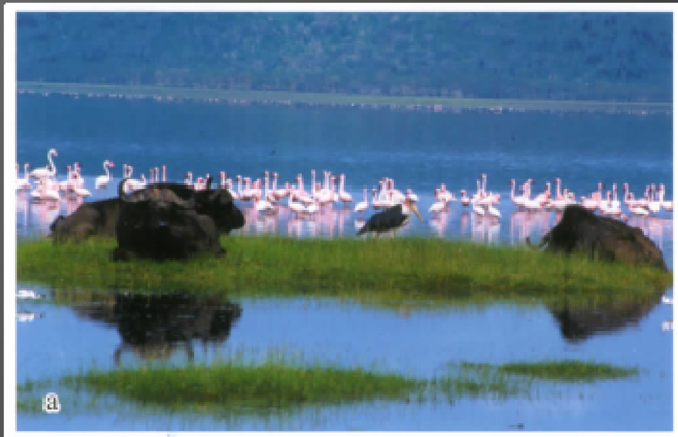
Nostoc in melt stream in Antarctica

desert crust with *Nostoc*, *Scytonema*, in Utah.

a) *Calothrix* in tepid hot spring Yellowstone National Park; b) sheath-pigmented cyanobcteria Norway;

(Whitton and Potts, 2002)

Cyanobacteria blooms



Microcystis, *Anabaena*, *Aphanizomenon* in Southern Sweden

Arthrospira fusiformis, Lake Nakuru, Kenya

Cylindrospermopsis raciborskii, Brasilia, Brazil

Cyanobacteria

- primary producers – clorophyll *a* and other pigments – low light intensity
- single or colonial cells – mechanisms of buoyancy – calm stratified water, long residence time
- mainly eutrophic water basin
- **toxin producers**

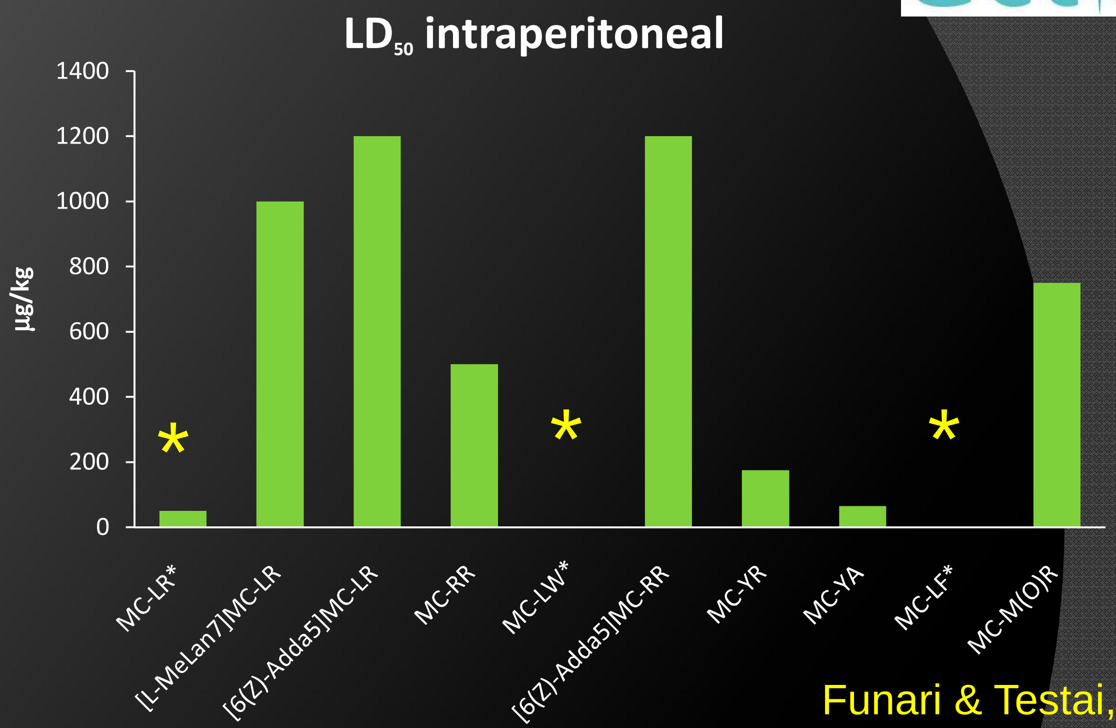
Cyanotoxins

Chorus & Bartram Eds, 1999.

Toxin group[1]	Primary target organ in mammals	Cyanobacterial genera[2]
Cyclic peptides		
Microcystins	Liver	*Microcystis, Anabaena, Planktothrix (Oscillatoria), Nostoc, Hapalosiphon, Anabaenopsis*
Nodularin	Liver	*Nodularia*
Alkaloids		
Anatoxin-a	Nerve synapse	*Anabaena, Planktothrix (Oscillatoria), Aphanizomenon*
Anatoxin-a(S)	Nerve synapse	*Anabaena*
Aplysiatoxins	Skin	*Lyngbya, Schizothrix, Planktothrix (Oscillatoria)*
Cylindrospermopsins	Liver[3]	*Cylindrospermopsis, Aphanizomenon, Umezakia*
Lyngbyatoxin-a	Skin, gastro-intestinal tract	*Lyngbya*
Saxitoxins	Nerve axons	*Anabaena, Aphanizomenon, Lyngbya, Cylindrospermopsis*
Lipopolysaccharides (LPS)	Potential irritant; affects any exposed tissue	All

MCs acute toxic potential is congener-dependent

80 congeners up to now; half-life 21 days/2-3 months (Jones & Orr, 1994, Ressom et al 1994)



Funari & Testai, 2008

✓Variation in toxicity ⟹ differences in MC toxicokinetics and toxicodynamics

✓Congener profile species-dipendent/affected by environmental parameters

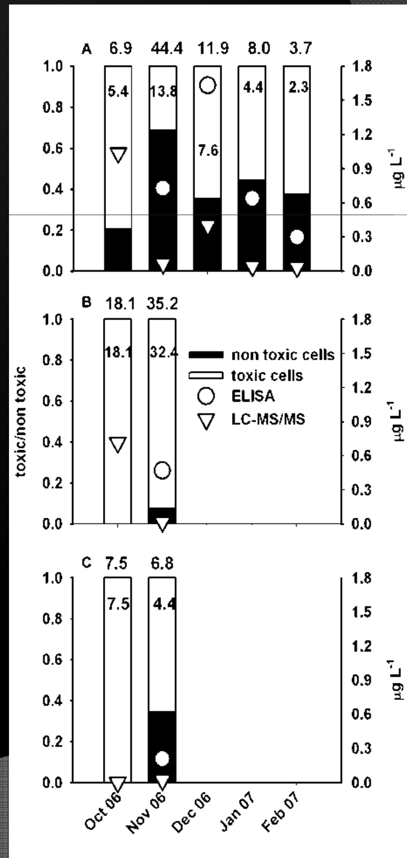
✓*Observed neurotoxic effect, congener dependent MC-LF>MC-LR (Feurstein et al., 2010)

Bloom toxicity

✓Cyanobacteria toxin production:

- Toxic/non-toxic genotype (Briand et al., 2008; Okello et al., 2010; Orr et al., 2010)

P. rubescens



P. rubescens

Manganelli et al., 2010

Bloom toxicity

✓Cyanobacteria toxin production:

- Expression of toxin gene (Kurmayer et al., 2004; Wood et al., 2010; Fewer et al., 2010)
- Growth rate

  -Nutrient concentration (Oh et al., 2000)

  -Light intensity (Wiedner et al., 2003)

Bloom toxicity

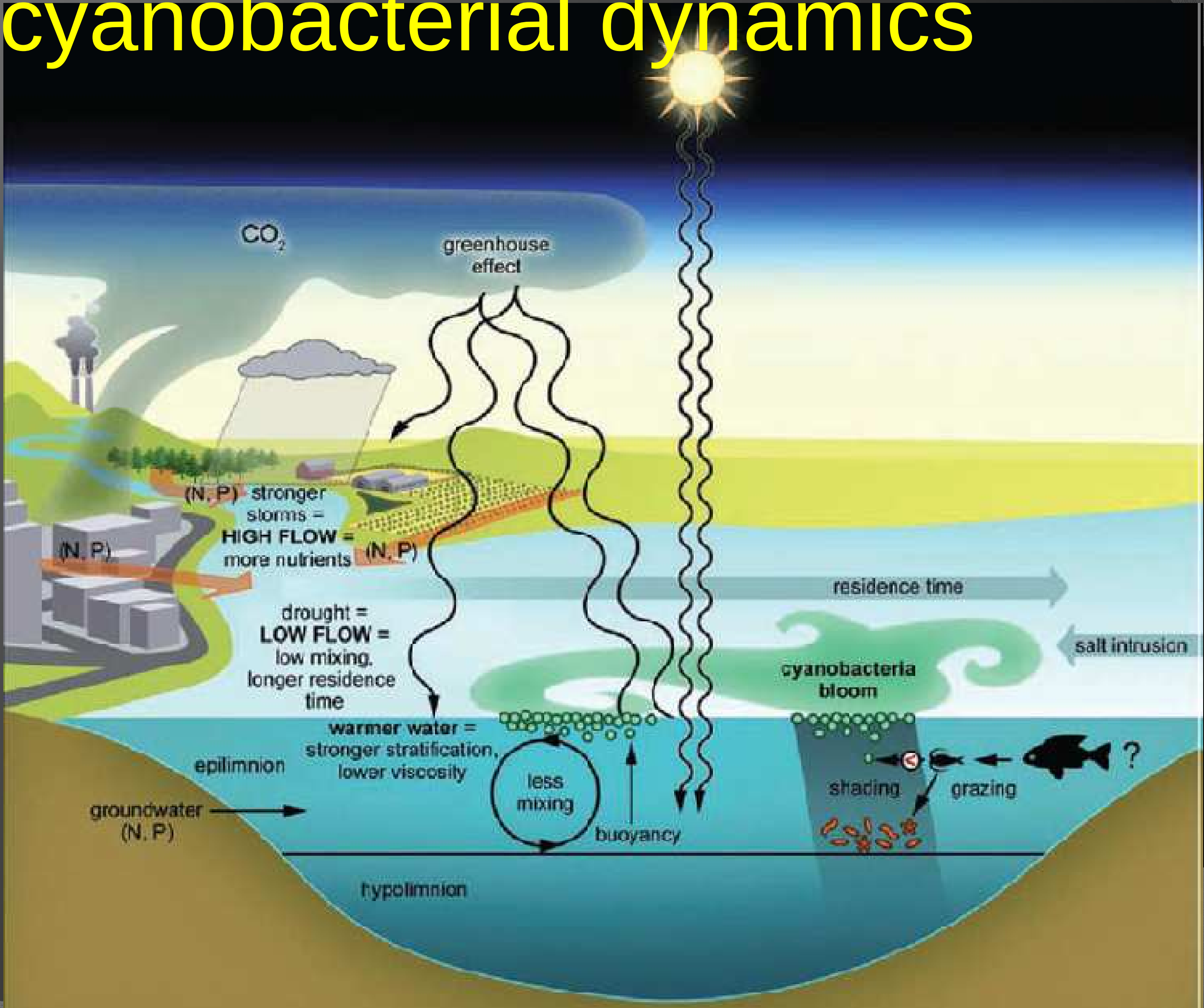
✓ Pathogen reservoir:

- *Vibrio* spp., associated to *Anabaena*, *Nostoc Hapalosiphon* (Islam et al., 2004; Eiler et al., 2007)
- *Legionella* cyanobacteria mat (Tison et al., 1980)
- Pathogenic *Aeromonas* (Berg, 2009)

Route of exposure to cyanotoxins

- Oral
  - contaminated drinking water/food
  - swimming
- dermal inhalation
  - recreational, sport, professional activities in infested water
  - showering
- parental
  - hemodialysis

Climate change and cyanobacterial dynamics



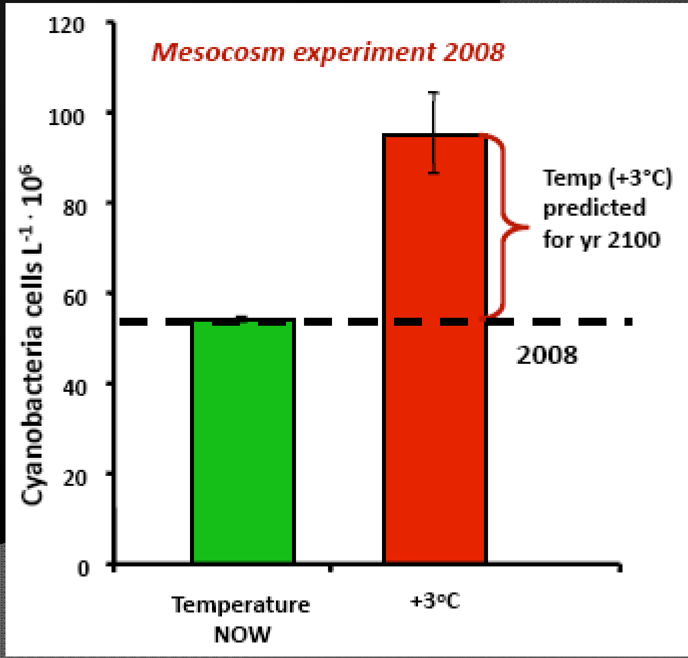
Paerl and Huisman, 2009

Increasing temperature/stratification

✓Abundance and diffusion

- Optimum growth rate at temperature higher than eukaryotic algae in lakes (Johnk et al., 2008; Elliot, 2010)

Increased temperature will increase cyanobacterial blooms in the Baltic Sea



Granéli, Romero, Salomon (in prep)

Increasing temperature/stratification

- ✓ **Density and ratio of toxic/non toxic strains**

  - *Anabaena* and *Aphanizomenon* (Rapala et al., 1993); *Microcistys* (Davis et al., 2009)

- ✓**Toxin/s production**

  -Decrease in CYN produced by *A. flos-aquae* and *C. raciborskii* (Preußel et al., 2009; Saker & Griffiths, 2000); most optimum T between 20-25℃, decreasing at higher T (Sivonen & Jones, 1999)
  -Variation in MCs variant profile (*Planktothrix aghardii*, Light intensity, Tonk et al., 2005)

- ✓**Control by predators/viruses/lysing-bacteria**

  –*Synechococcus* (Chu et al., 2010)

CO_2 - pH

✓**Abundance**

Buoyant species are favoured; *Trichodesmium* increase (Levitan et al., 2007)

✓**Density and ratio of toxic/non toxic strains**

??

✓**Toxin/s production**

MCs congener profile according to limiting factor (Van de Waal et al., 2009)

Floods and droughts

- ✓ Elevated winter-spring run-off and protracted droughts → nutrients and bloom capacity (Paerl and Huisman, 2009)
- ✓ Washout of cyanobacteria to coastal environment from freshwater systems (Carmichael, 1997) and possible cyanotoxin accumulation in seafood

Floods and food contamination

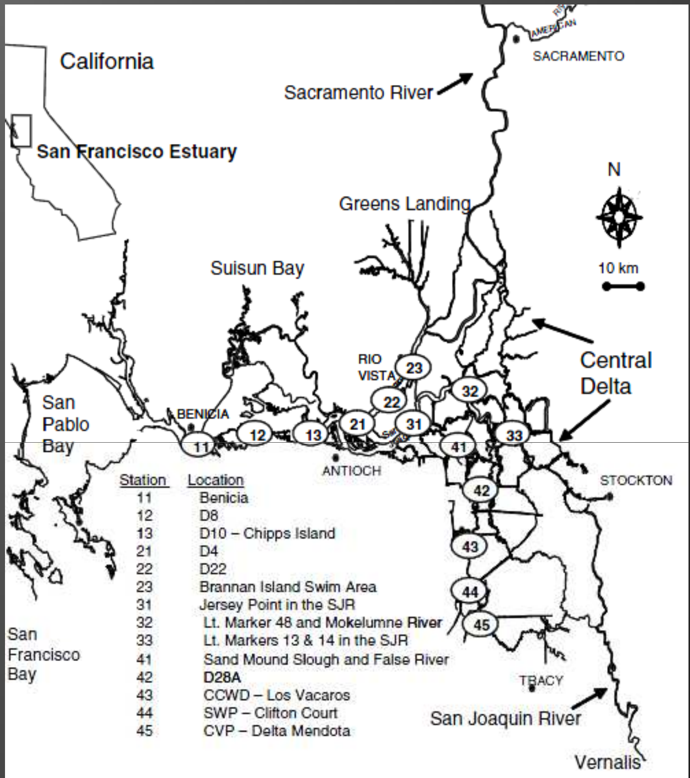
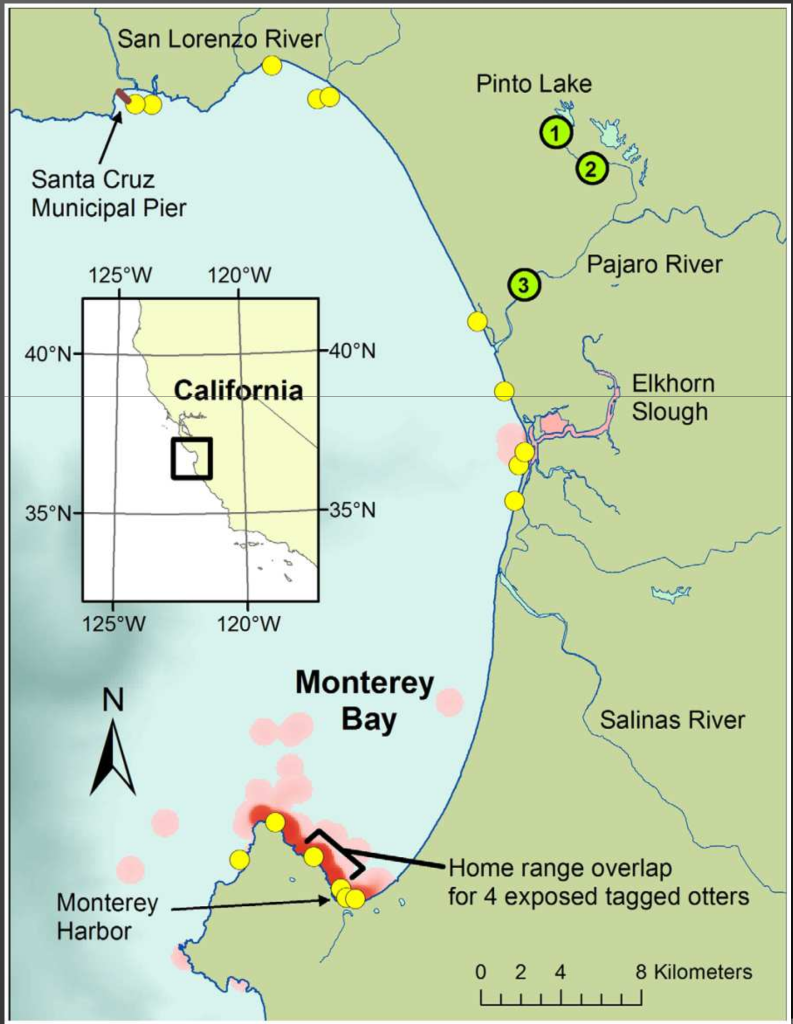


Figure 1. Map of upper San Francisco Bay Estuary with sampling station location.

Max concentration of MCs in brackish water
Biomagnification of MCs in edible fishes

Lehman et al. 2005/2010

Floods and food contamination

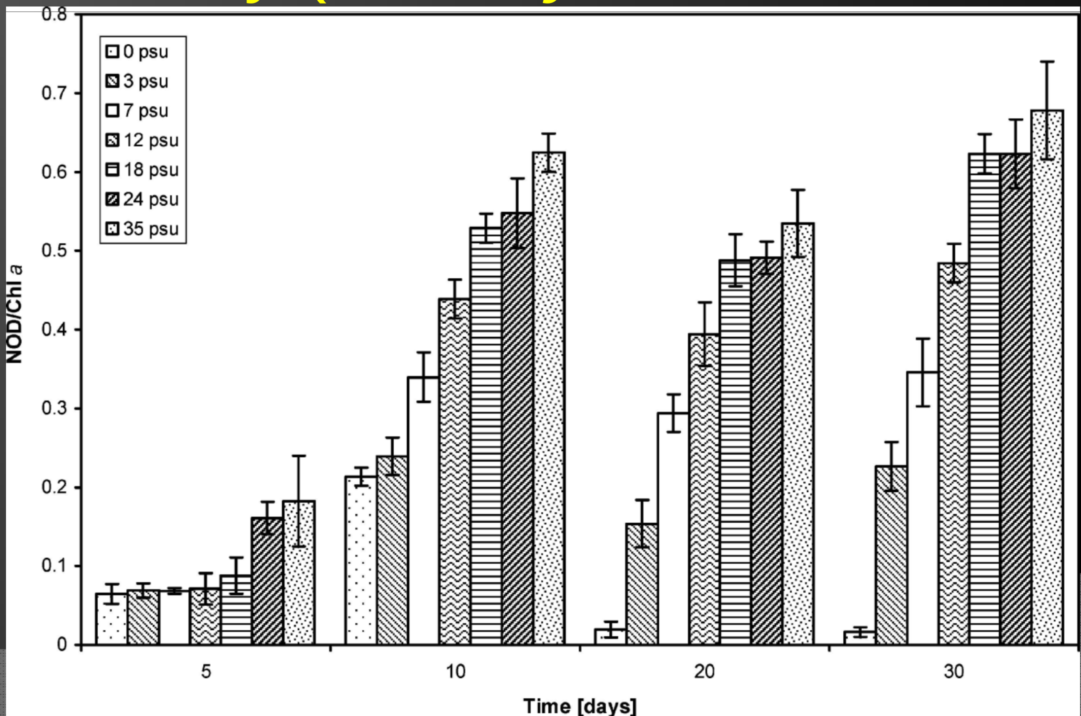


Deaths of marine mammals through ingestion of contaminated farmed and free-living marine clams, mussels and oysters – biomagnification of MCs

Miller et al. 2010

Increasing salinity

- ✓ Salt tolerant species (*Microcystis*, *Nodularia*, *Aphanizomenon*, Tonk et al., 2007)
- ✓ Toxicity (*Microcystis*, Mazur-Marzec et al., 2005)



Highest toxicity at highest salinity

Human vulnerability

- ✓ Magnitude of the <u>exposure to the climate-related hazard</u>
- ✓ <u>intrinsic characteristics of the population itself</u>

Fig. 4. People from a village at the outlet of Lake Pequenos Libombo, Mozambique. The water in this river is used for cooking, drinking, swimming and washing clothes. When the photo was taken, September 2002, the phytoplankton community was dominated by microcystin-producing *Microcystis*. (Photo: *Annadotter*).

Conclusion 1- Research needs

Temperature - CO_2 increase (pH) - Salinity

- ✓Toxicity
- ✓Congener profile

Prediction

Management measures to prevent increasing exposure

Fig. 1. A bloom of cyanobacteria in the recreational Lake Finjasjön, Sweden. (Photo: *Cronberg*).

Polymorphism of GST system

MC-LR concentration range used (0.25–50 μM)

	Vmax[a]	Km[b]	Cli[c]
T1-1	6.96	108.6	0.064
A1-1	2.69	67.89	0.040
M1-1	--	--	0.029
A3-3	--	--	0.025
P1-1	4.71	831.3	0.006

a = pmolGSMC/(μg prot • min), b = μM, c = pmolGSMC/(μg prot • min • μM) Cli was obtained or as Vmax/ Km ratio, either as the slope of linear regression

Buratti et al., 2011

Conclusion 2 - Research needs

- ✓ Open and developing field needed to better constrains risk evaluation

Acknowledgments

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