Monitoring algal blooms and associated human health risks at local to global scales

Overview and potential linkages with ReBALAN:CE

Peter D. Hunter[1], Andrew N. Tyler[1], Vagelis Spyrakos[1], Steve Groom[2], Stephanie Palmer[1,3] and Geoffrey A. Codd[1,4]

[1] *Biological and Environmental Sciences, School of Natural Sciences, University of Stirling, UK*
[2] *Plymouth Marine Laboratory, Plymouth, UK*
[3] *Department of Geography, University of Leicester, UK*
[4] *Division of Molecular Microbiology, College of Life Sciences, University of Dundee, UK*

email: p.d.hunter@stir.ac.uk

ReBALAN:CE workshop | University of Stirling | 29-30th August 2013

University of Stirling | PML Plymouth Marine Laboratory | Natural Environment Research Council

Outline

Recent and on-going research projects

1. Monitoring algal blooms in lakes

(a) Earth observation

- NERC GloboLakes, EU FP7 INFORM and MTA KTAMOP

(b) Citizen science

- Environment Agency Algal Blooms Pilot Project

2. Cyanobacteria, cyanotoxins and human health

- NERC Cyanobacteria, Environment and Human Health (CEHH)
- EU COST Action ES1105 – “CyanoCOST”

1a. Monitoring algal blooms in lakes

- Earth observation

GloboLakes - consortium

GloboLakes (Global Observatory of Lakes Responses to Environmental Change) is a 5-year NERC-funded consortium project

1. University of Stirling
Andrew Tyler (PI), Peter Hunter, Vagelis Spyrakos

2. Plymouth Marine Laboratory (PML)
Steve Groom, Victor Vicente-Martinez, Gavin Tilstone, Giorgio Dall'Olmo

3. University of Reading
Christopher Merchant

4. University of Dundee
Mark Cutler, John Rowan, Terry Dawson, Eirini Politi

5. Centre for Ecology and Hydrology (CEH)
Stephen Maberly, Laurence Carvalho, Stephen Thackery, Alex Elliott

6. University of Glasgow
Claire Miller, Marion Scott, Ruth Haggarty

Earth observation scientist | Bio-optical oceanographer | Ecosystem modeler
Freshwater ecologist | Environmental statistician

GloboLakes - background

Lakes are under increasing pressure from climate and other drivers of environmental change

- >304 million lakes – important to global biogeochemical cycles (e.g. Bastviken et al. 2011, *Science*)
- Concern over water security (85% of freshwater resource) and provision of ecosystem goods and services
- Global increase in the incidence, magnitude and duration of toxic cyanobacterial blooms
- Very small proportion of lakes globally are routinely monitored (<0.0003%) and standardised approaches are lacking

GloboLakes – objectives

GloboLakes is investigating the status of lakes globally and their responses to environmental change

What controls the differential sensitivity of lakes to environmental perturbation?

- Determine spatial and temporal trends and attribute causes of change for 1000 lakes worldwide
- Forecast lake sensitivity to environmental change using ecosystem models
- Use knowledge to inform lake management and policy formation

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Lakes as sentinels of climate change

Rita Adrian,[a,*] Catherine M. O'Reilly,[b] Horacio Zagarese,[c] Stephen B. Baines,[d] Dag O. Hessen,[e] Wendel Keller,[f] David M. Livingstone,[g] Ruben Sommaruga,[h] Dietmar Straile,[i] Ellen Van Donk,[j] Gesa A. Weyhenmeyer,[k] and Monika Winder[l]

[a] Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
[b] Biology Program, Bard College, Annandale, New York
[c] Laboratorio de Ecología y Fotobiología Acuática, Instituto Tecnológico de Chascomús (INTECH), Chascomús Provincia de Buenos Aires, Argentina
[d] Department of Ecology and Evolution, Stony Brook University, Stony Brook, New York
[e] Department of Biology, University of Oslo, Oslo, Norway
[f] Cooperative Freshwater Ecology Unit, Ontario Ministry of the Environment, Laurentian University, Sudbury, Ontario, Canada
[g] Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland
[h] Laboratory of Aquatic Photobiology and Plankton Ecology, Institute of Ecology, University of Innsbruck, Innsbruck, Austria
[i] Limnological Institute, University of Konstanz, Konstanz, Germany
[j] Department of Aquatic Food Webs, Netherlands Institute of Ecology, Centre for Limnology, Nieuwersluis, The Netherlands
[k] Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences, and Department of Ecology and Evolution, Uppsala University, Uppsala, Sweden
[l] John Muir Institute of the Environment, Tahoe Environmental Research Center, University of California, Davis, California

Abstract

While there is a general sense that lakes can act as sentinels of climate change, their efficacy has not been thoroughly analyzed. We identified the key response variables within a lake that act as indicators of the effects of climate change on both the lake and the catchment. These variables reflect a wide range of physical, chemical, and biological responses to climate. However, the efficacy of the different indicators is affected by regional response to climate change, characteristics of the catchment, and lake mixing regimes. Thus, particular indicators or combinations of indicators are more effective for different lake types and geographic regions. The extraction of climate signals can be further complicated by the influence of other environmental changes, such as eutrophication or acidification, and the equivalent reverse phenomena, in addition to other land-use influences. In many cases, however, confounding factors can be addressed through analytical tools such as detrending or filtering. Lakes are effective sentinels for climate change because they are sensitive to climate, respond rapidly to change, and integrate information about changes in the catchment.

Currently, climate change is considered to be one of the most severe threats to ecosystems around the globe (ACIA 2004; Rosenzweig et al. 2007). Monitoring and understanding the effects of climate change pose challenges because of the multitude of responses within an ecosystem and the spatial variation within the landscape. A substantial body of research demonstrates the sensitivity of lakes to climate and shows that physical, chemical, and biological lake properties respond rapidly to climate-related changes (ACIA 2004; Rosenzweig et al. 2007). Fast turnover times from organismal to ecosystem scales in lakes are prerequisite for detecting such rapid changes. Previous studies have suggested that lakes are good sentinels of global climate change because they are sensitive to environmental changes and can integrate changes in the surrounding landscape and atmosphere (Carpenter et al. 2007; Pham et al. 2008; Williamson et al. 2008). However, a more thorough analysis of the potential for lakes to act as sentinels for the rapid rates of current climate change is lacking.

Studies of lakes provided some of the early indications of the effects of current climate change on ecosystem structure and function (Schindler et al. 1996*a*; Magnuson et al. 2000; Verburg et al. 2003) and the consequences for ecosystem services (O'Reilly et al. 2003). Some climate-related signals are highly visible and easily measurable in lakes. For instance, climate-driven fluctuations in water level have been observed on a broad scale in North America (Williamson et al. 2009), and shifts in the timing of ice formation and thawing reflect climate warming at a global scale (Magnuson et al. 2000). Other signals may be more complex and difficult to detect in lakes, but they may be equally sensitive indicators of climate forcing or equally informative regarding effects on ecosystem services. Available long-term historical records and reconstructions from sediment cores have yielded insight into less visible climate-related changes and provided us with an understanding of the mechanisms that give rise to these changes. Paleolimnological records, in particular, have been crucial in developing climate records over recent geologic timescales, allowing us to interpret current climate change and predict its effects (Smol 2008; Leavitt et al. 2009).

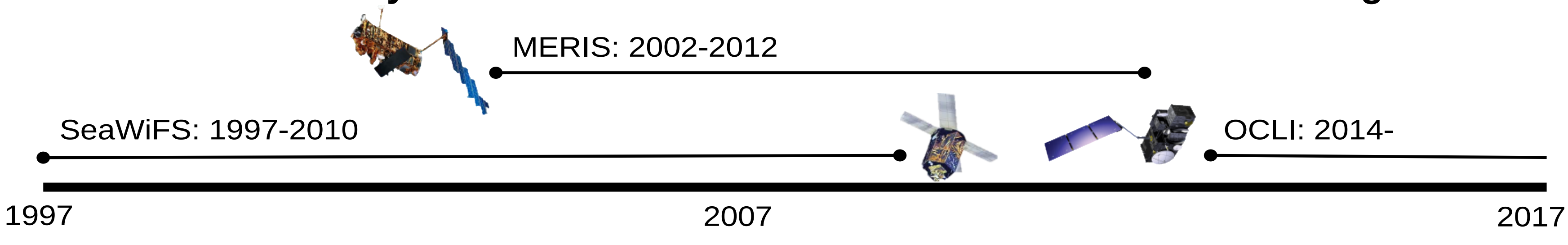
In many ways, lake ecosystems appear to be valid sentinels for current climate change. Lake ecosystems act as sentinels because they provide indicators of climate change either directly or indirectly through the influence of climate

* Corresponding author: adrian@igb-berlin.de

GloboLakes – our approach

Satellite-based observatory with near real-time processing for over 1000 of world's largest lakes

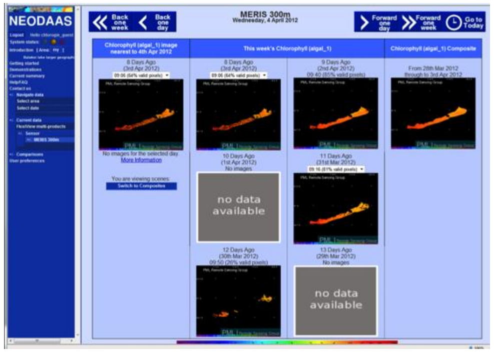
Near-continuous 20-year time series of lake variables from Earth observing satellites



Core products
Lake surface water temperature (LSWT)
Total suspended matter (TSM)
Coloured dissolved organic matter (CDOM)
Chlorophyll-a (Chla)
C-phycocyanin (CPC)

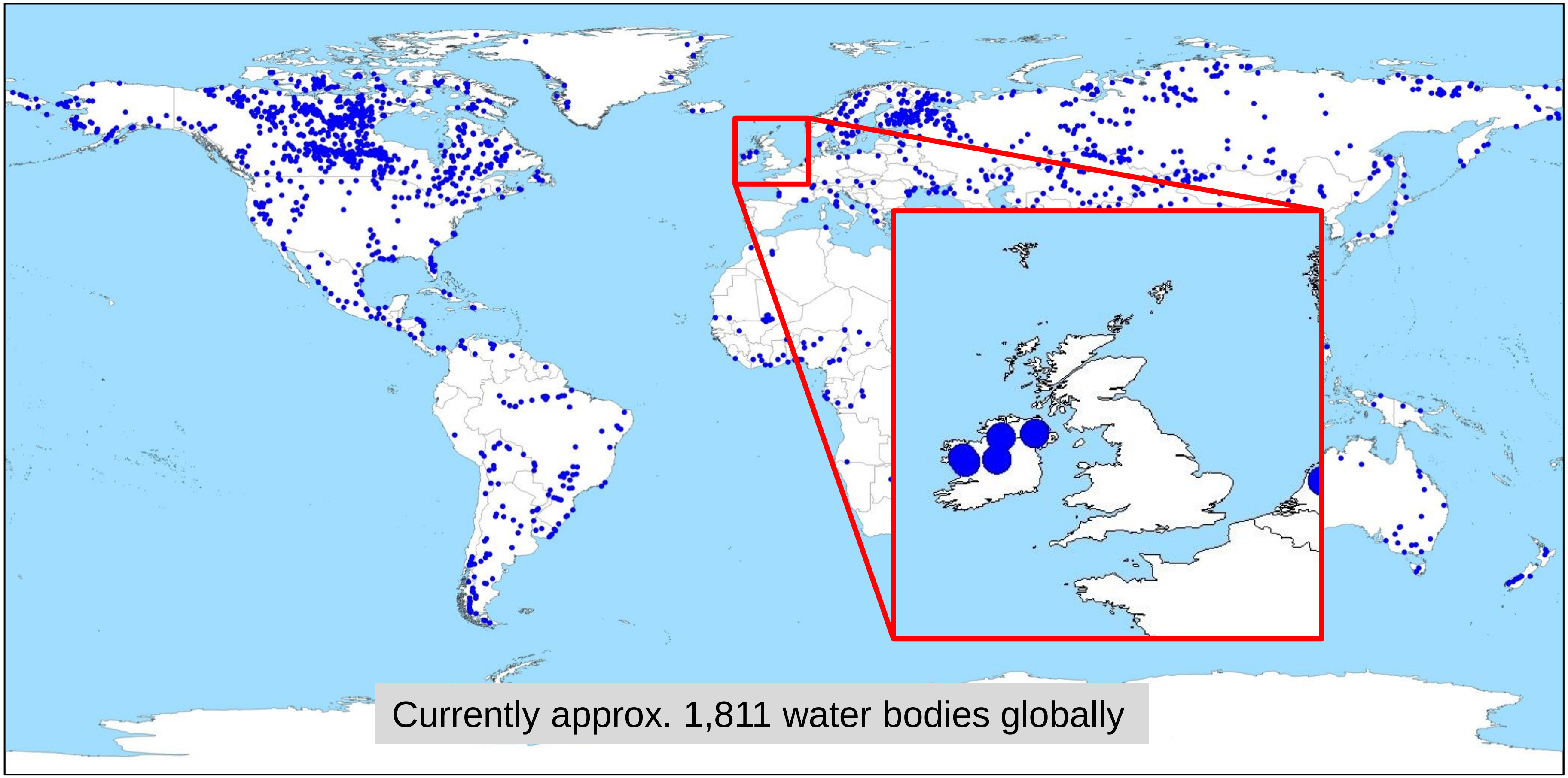
Secondary products
Phytoplankton primary productivity
Lake phenology metrics

Web-based GIS portal
OR
ftp

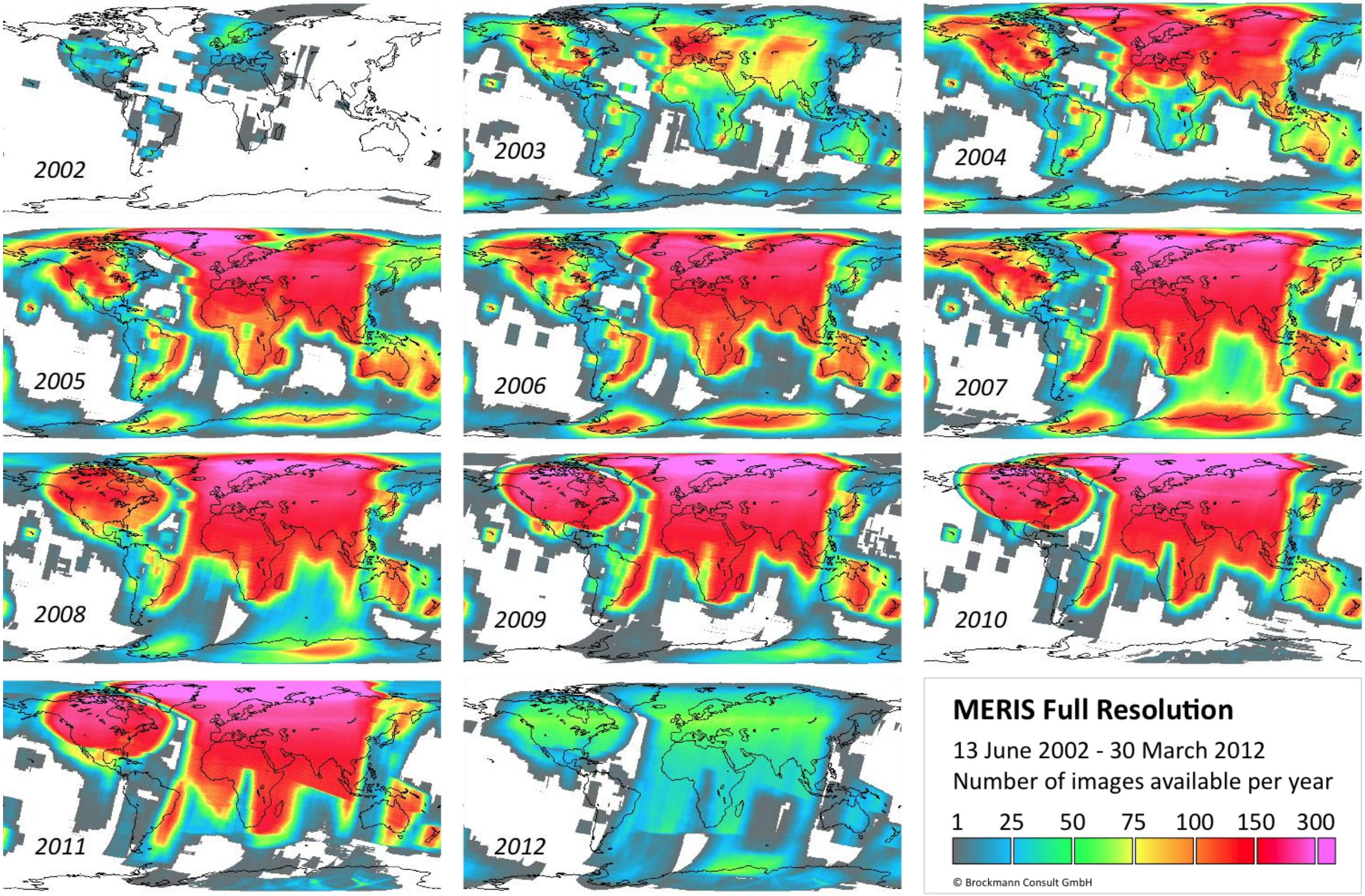


GloboLakes – target lakes

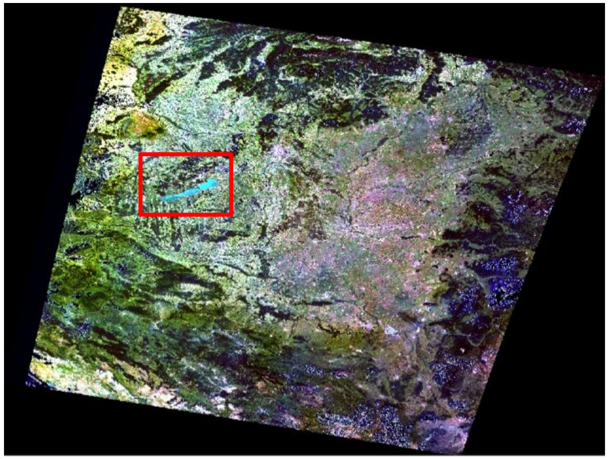
Satellite-based observatory with near real-time processing for over 1000 of world's largest lakes and reservoirs



GloboLakes – example products

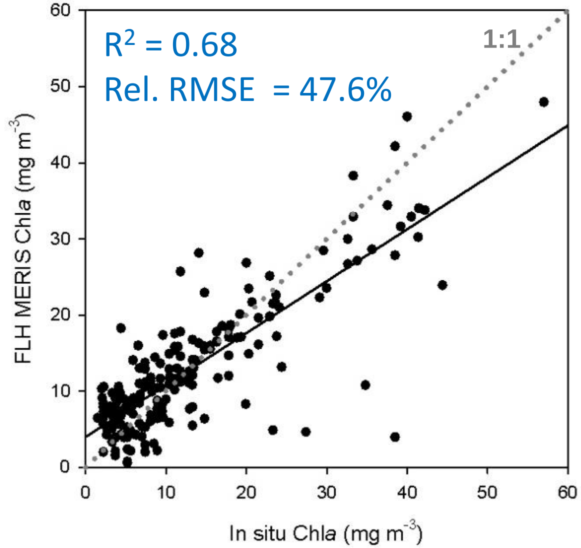


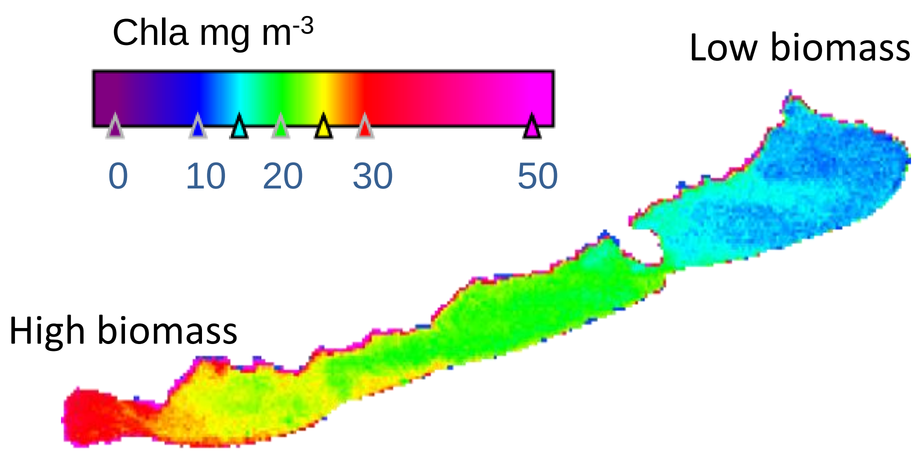
GloboLakes – example products

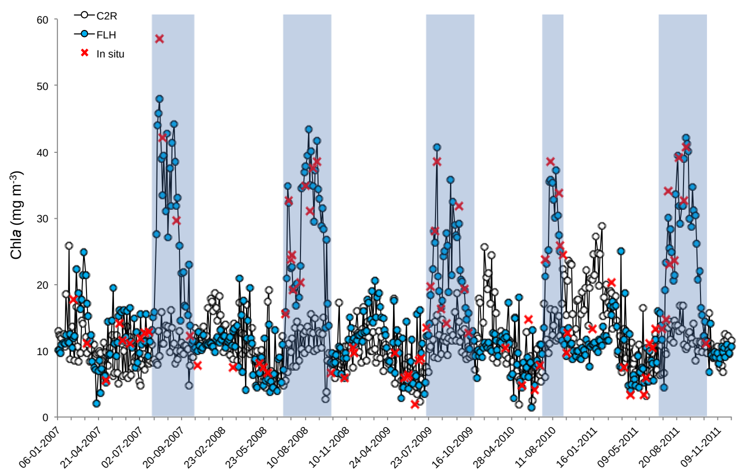


Raw L1b MERIS image

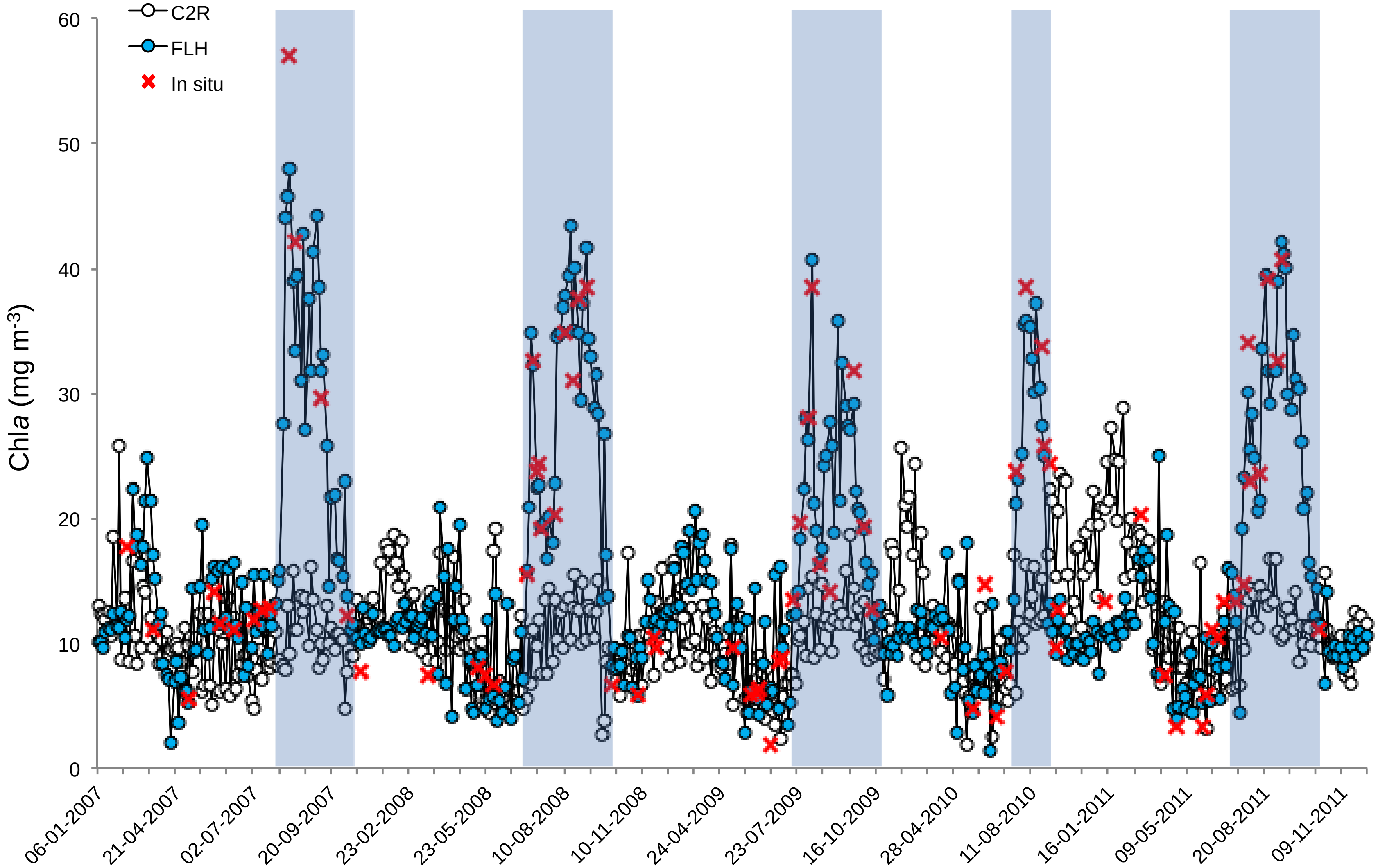
Raw L1b MERIS subset





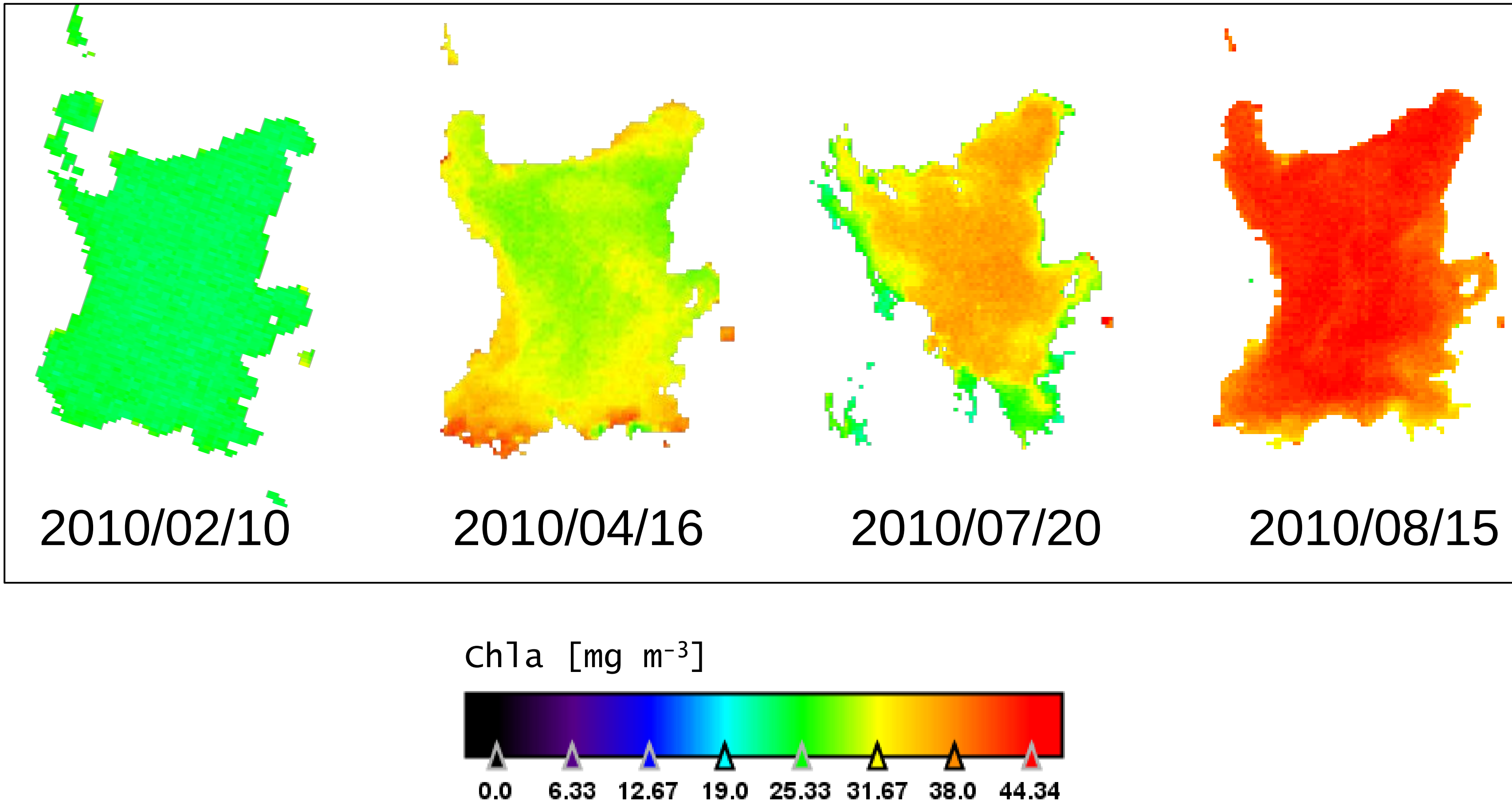


GloboLakes – example products



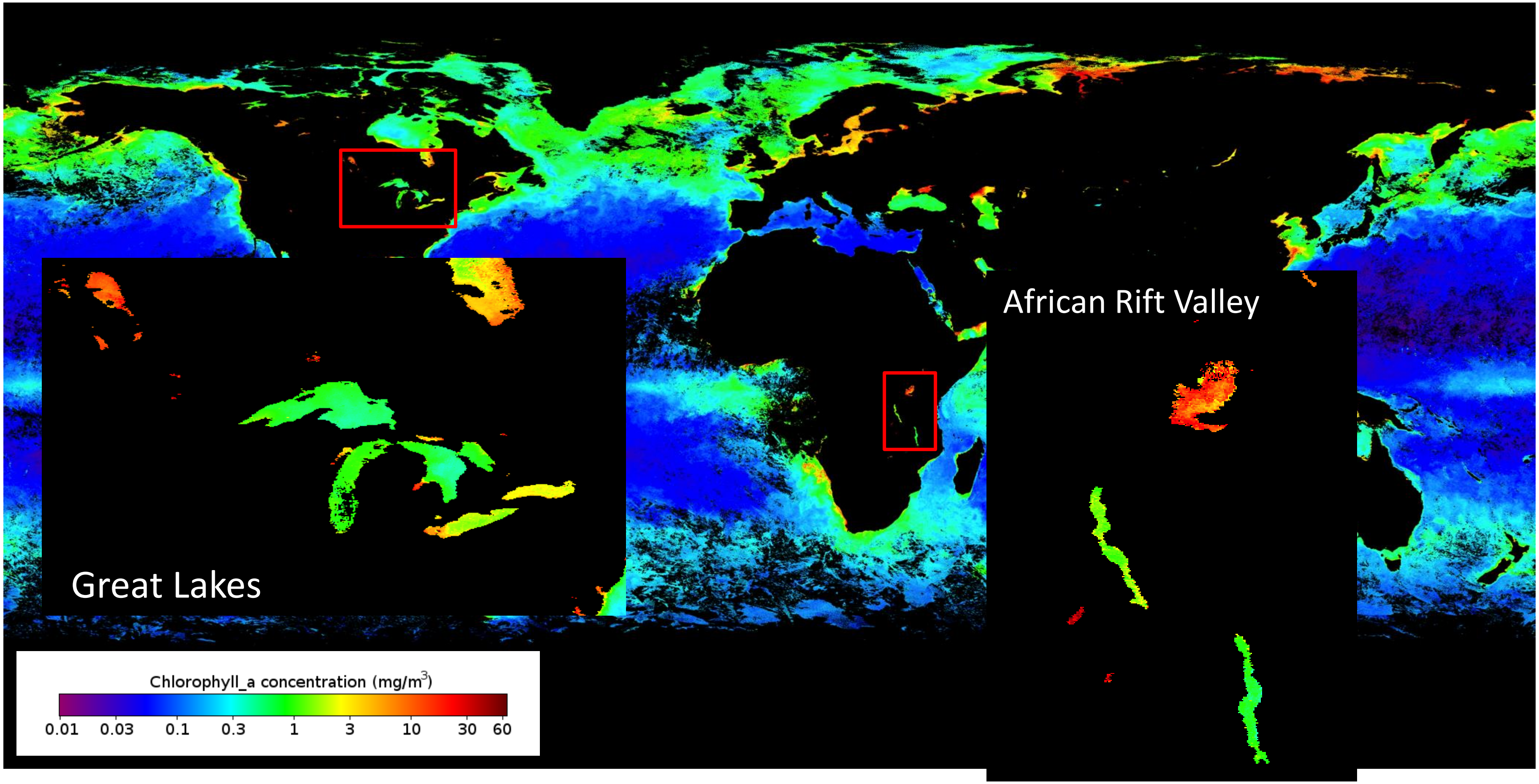
GloboLakes – example products

Temporal evolution of a cyanobacterial bloom in Lough Neagh during summer 2010

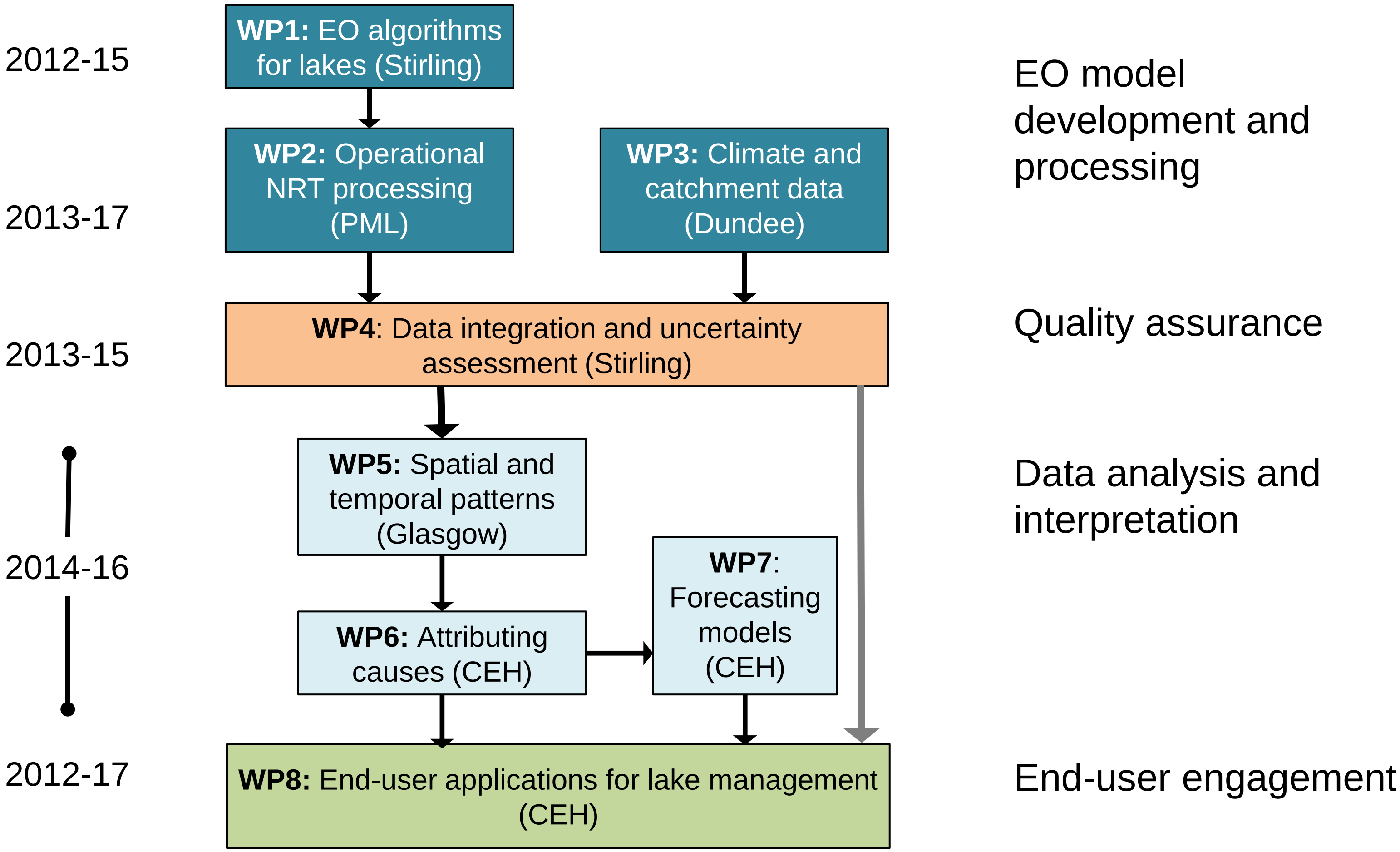


GloboLakes – example products

Global Chla product (v.-1) – SeaWiFS 4km monthly composite for Aug 1998 (produced by PML for ESA OceanColour-CCI)



GloboLakes – workpackages



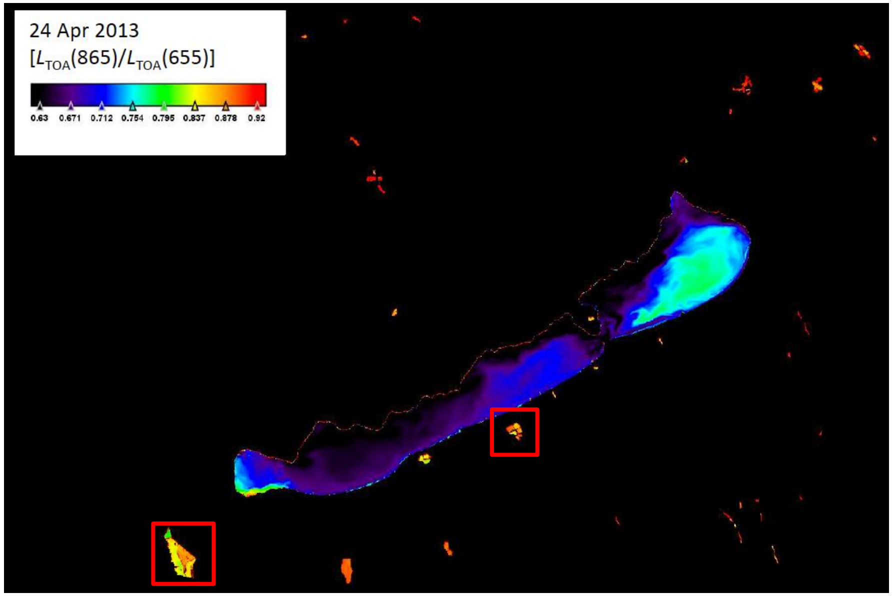
GloboLakes – wider engagement

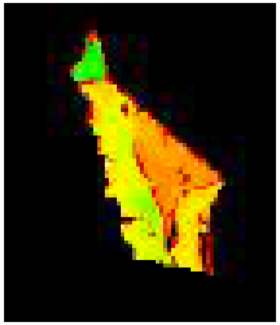
Contributions from across the scientific and end-user communities key to success of wider impact

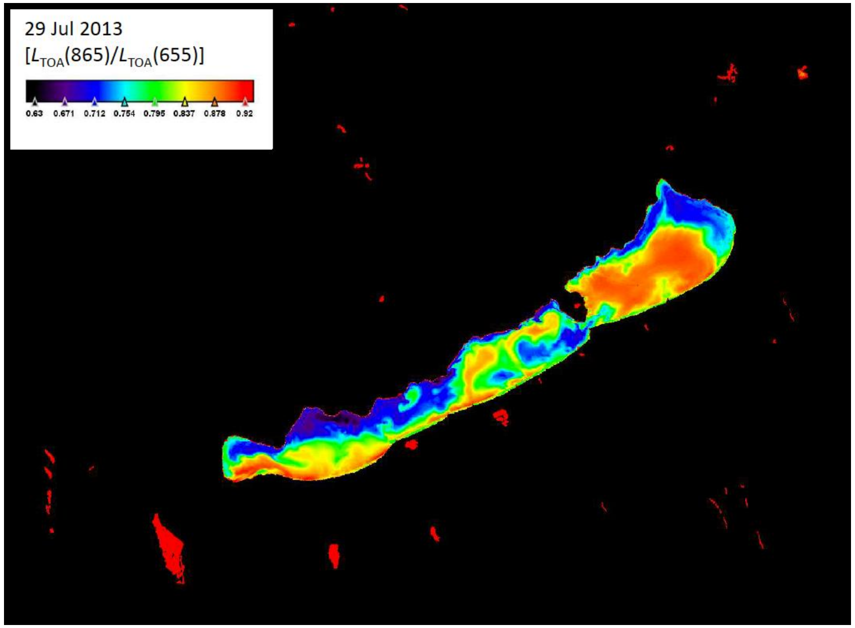
- Currently, more than 25 scientific partners from over 15 nations
  - CSIRO, Australia; CSIR, South Africa; VITO, Belgium
  - Environment Canada; Estonian Marine Institute;
  - EC Joint Research Centre; CNR-IREA, Italy;
  - INTA, Spain; CUNY, USA; Creighton, USA
  - South Florida, USA; Institute of Limnology, Nanjing…
- Several end-user partners including UK environmental regulators (EA, SEPA, NIEA)
- Engagement with UK National Centre for Earth Observation (NCEO), European Environment Agency, ESA and GEO

KTAMOP – overview

Sustainability and environmental impact of communities living in Lake Balaton's southern watershed







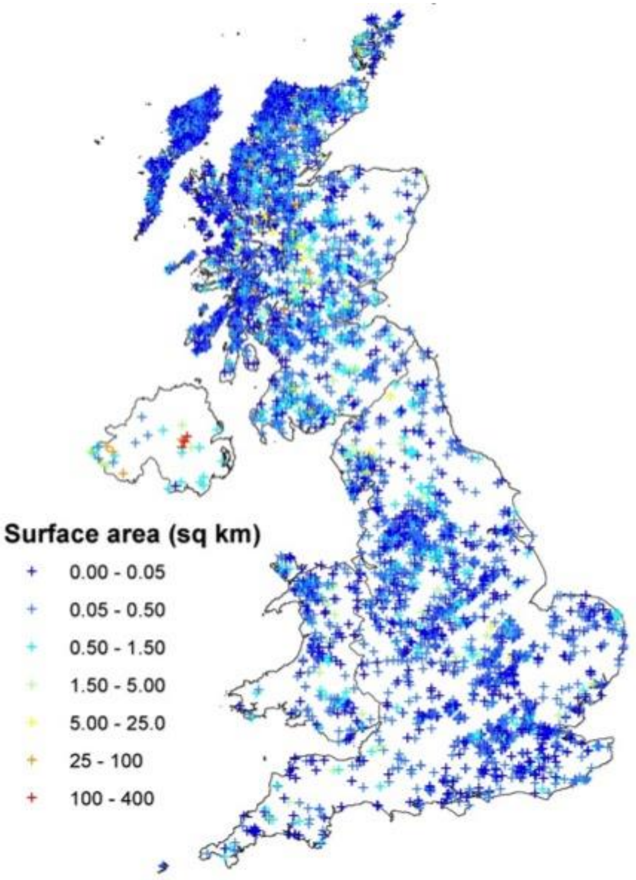
1b. Monitoring algal blooms in lakes

- Citizen science

EA Algal Blooms Project

Pilot study looking at feasibility of citizen science (and remote sensing) for bloom monitoring in UK

- EA has statutory duty under national and European legislation to monitor water quality monitoring and algal bloom incidents
- 43,738 waterbodies in UK; ~740 WFD lakes; 440 are currently “monitored”
- England & Wales 2006-2010: 11 (Cat-1), 60 (Cat-2) and >300 (Cat-3) cyanobacteria-related incidents (Environment Agency)
- Scotland 2008-2010: 458 reported incidents with 181 exceeding WHO thresholds (cell numbers) (SEPA)
- WFD now requires data on bloom intensity and frequency

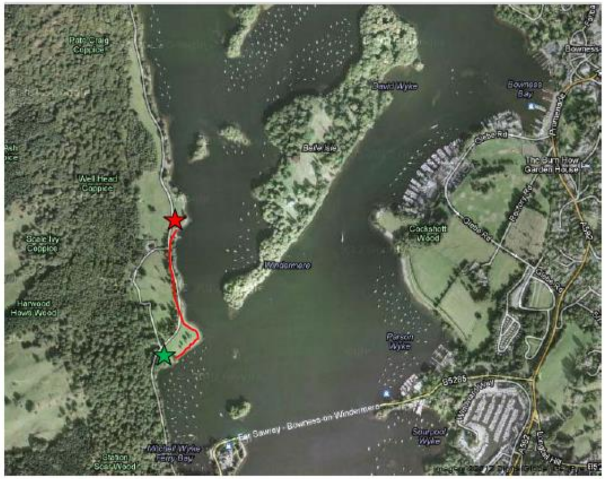


EA Algal Blooms Project

Pilot study looking at feasibility of citizen science (and remote sensing) for bloom monitoring in UK

- 70 volunteers recruited through Cumbria Wildlife Trust
- Task with monitoring 3 waterbodies (Windermere, Derwent Water and Bassenthwaite) every 2-3 days from 01 Jun to 01 Nov
- Walked shoreline transect, with visual assessment of water appearance (and stick test!)
- If water discoloured by algae or scums visible – samples sent to EA for microscopic inspection
- Comparison against data from conventional monitoring programmes (~weekly)

Map of designated survey area



Red lines indicate areas of shoreline to be walked.

★ Indicates start point. Grid reference – SD 388 959.

★ Indicates finish point. Grid Reference – SD 389 963.

Walked transect at Harrowslack Bay, Windermere

EA Algal Blooms Project

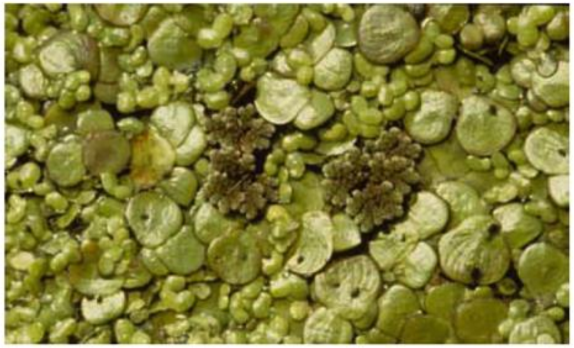
Algal Bloom Pilot Project
Stick Test Method

Environment Agency | University of Stirling | The Wildlife Trusts Cumbria | CEH Centre for Ecology & Hydrology, Natural Environment Research Council | fba Freshwater Biological Association

Use this quick identification method to decide if you need to take a sample or not (presence/absence of a bloom).
A. Dip the stick into the water up to the marked point, if water depth allows, or as far as it will go if not.
B. Look at the colour and opacity of the water against the white stick.
C. Lift the stick out and check whether any leaves, filaments or particles adhere to it.
D. Go through the four questions on this chart, and take a sample if required.

1. Can you see leaves without the aid of a microscope, in the water or on the stick?

YES - Aquatic higher plants - NO SAMPLE REQUIRED



There are a number of aquatic higher plants that might look like a bloom e.g. Duckweed (*Lemna* sp.), vivid green with smooth-edged leaves, and water fern (*Azolla* sp.), darker greenish-red with wavy-edged leaves in centre of photo.

NO - Go to question 2a

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2a. Can you see strands or filaments without the aid of a microscope, in the water or on the stick?

YES - Filamentous algae, go to question 2b

NO - Go to question 3

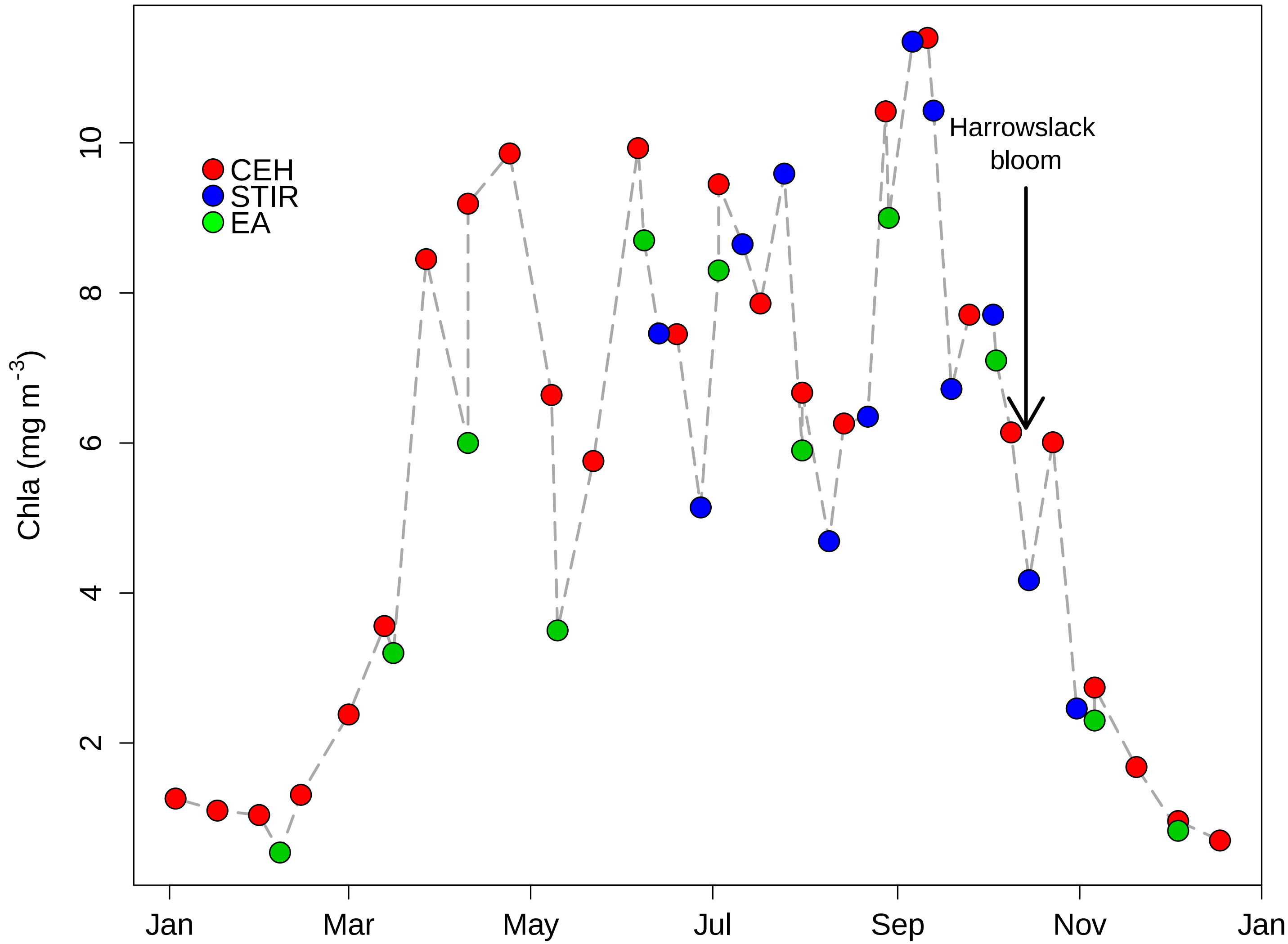
2b. Are they attached to the lake bed or stones i.e. not free-floating?

YES - Benthic filamentous algae - NO SAMPLE REQUIRED

e.g. *Cladophora*, a common benthic filamentous alga.

NO - Free-floating filamentous algae - TAKE SAMPLE

EA Algal Blooms Project



Comparison of volunteer recorded blooms against in situ monitoring data

2. Cyanobacteria, cyanotoxins and human health

Cyanobacterial toxins

- Mass populations of cyanobacteria (blooms, scums, biofilms) often develop in warm, poorly flushed nutrient-rich waters

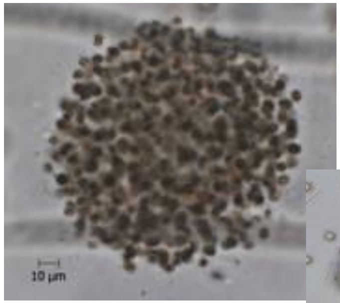
- Many species and strains produce potent toxins as secondary metabolites

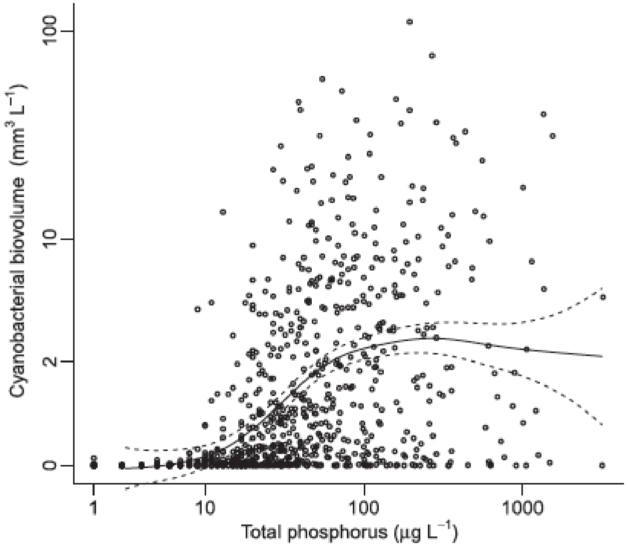
  Hepatotoxins: microcystins, nodularins, cylindrospermopsins

  Neurotoxins: anatoxin-a, homoanatoxin, anatoxin-a(s), saxitoxins, BMAA

  Irritants and allergenic toxins: aplysiatoxins, lipopolysaccharide (LPS), endotoxins

- Exposure routes: (i) skin contact; (ii) inhalation of spray during recreational activities; (iii) ingestion of **contaminated foodstuffs** or drinking water



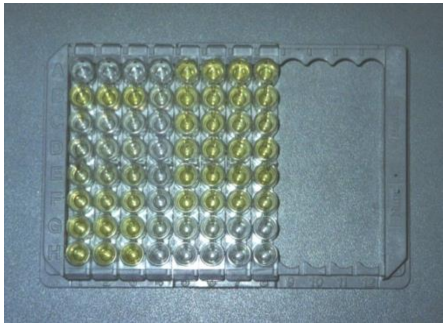


Carvalho et al. (2013) J. Appl. Ecol.

NERC CEHH project

Investigating the potential for toxin transfer to crops intended for human consumption

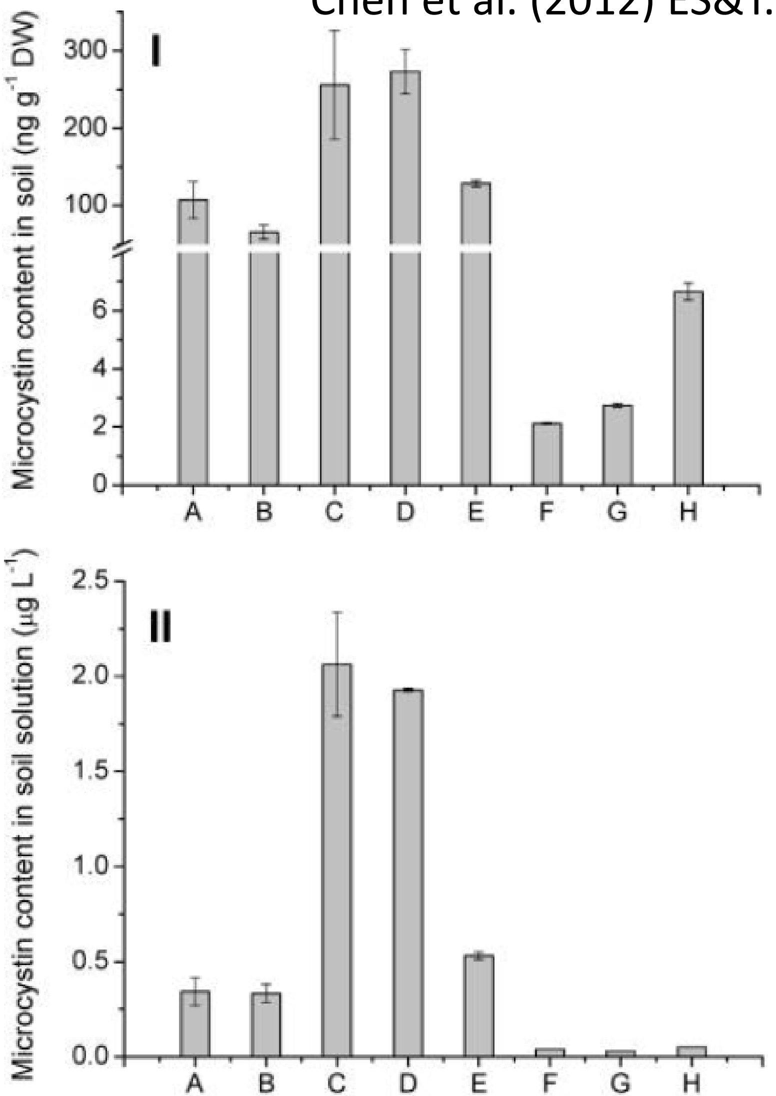
- Potato plants cultivated in greenhouses at SCRI, Dundee under spray irrigation
- Irrigation water spiked with purified microcystins (MC) harvested from cyanobacteria cultures at 0 (water only control), 0.126, 1.26, 12.6 and 126 µg L^{-1} with/without wetting agent
- Potato plants harvested at maturity and at several time steps during growth
- MC in potato tubers, roots and leaves analysed by ELISA (against UoD antibodies) and HPLC-PDA
- MCs were detected by ELISA in the leaves of plants subject to highest dose (approx. 1 ng MC g dry wt^{-1} plant tissue)



Other studies

Chen et al. (2012) ES&T.

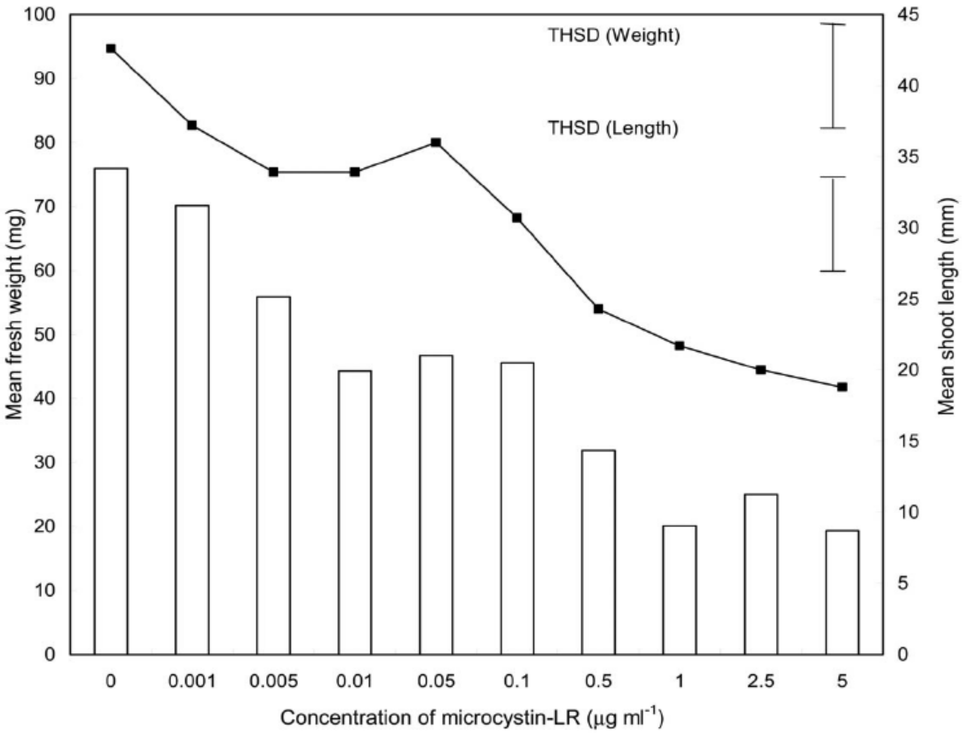
- Half-life of toxins in plant-soil systems varies from a few days to a few months
- Uptake and persistence depends of toxin variant, plant species, microbial community,…
- Vast majority of studies focus on microcystins



Phytotoxic effects

Several studies have shown cyanotoxins (microcystins) to have phytotoxic effect on agricultural crops

- Tomato, mustard, broccoli, green pea, sugar pea, chick pea, mung bean, French bean, soya bean, alfalfa, lentil, maize, wheat,..



Effect on MC on fresh weight (columns) and length (line) of tomato shoots. McElhiney et al. (2001) Toxicon.

CyanoCOST

Cyanobacteria blooms and toxins in water resources: Occurrence, impacts and management

WP1 Occurrence and monitoring; WP2 Fate, impact and health effects; **WP3 Prevention and control measures**; WP4 End-user engagement and outreach tools


CYANOCOST

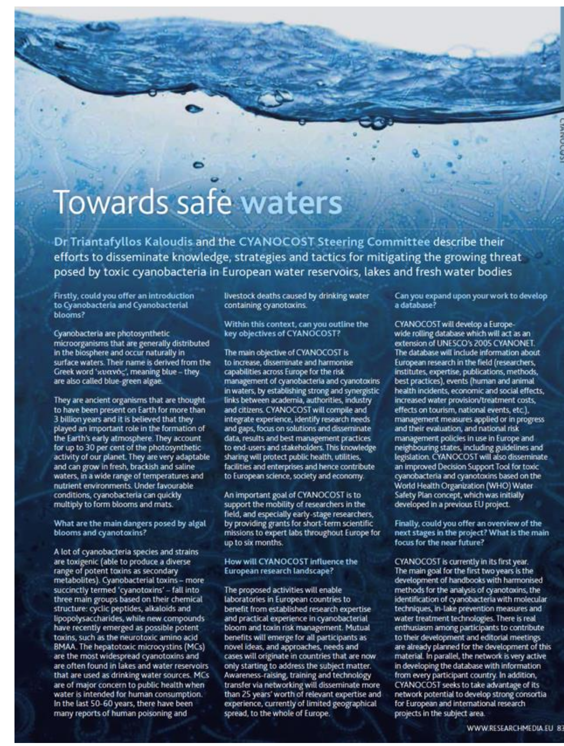
Aquatic detox

The CYANOCOST Action (COST ES 1105) is consolidating expertise and knowledge of detection and management approaches towards harmful cyanobacteria and their toxins in water sources to ensure best practices in water safety are consistently achievable across all of Europe

INTELLIGENCE

CYANOCOST (COST ACTION ES1105)

CYANOBACTERIAL BLOOMS AND TOXINS IN WATER RESOURCES: OCCURRENCE, IMPACTS AND MANAGEMENT


Towards safe waters

Dr Triantafyllos Kaloudis and the CYANOCOST Steering Committee describe their efforts to disseminate knowledge, strategies and tactics for mitigating the growing threat posed by toxic cyanobacteria in European water reservoirs, lakes and fresh water bodies

Thank you

Peter D. Hunter
Lecturer in Earth Observation
University of Stirling
Biological and Environmental Sciences

t +44 1786 466538
e p.d.hunter@stir.ac.uk
w www.stir.ac.uk

UNIVERSITY OF STIRLING
PML Plymouth Marine Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL