University of Leicester

Long term monitoring of alkaline-saline lakes from satellite observations

Emma Tebbs, David Harper, John Remedios, Sean Avery

University of Leicester

East African Rift Valley

Motivation

- Alkaline-saline lakes have unique ecology
- Poorly studied – particularly their spectral properties
- They support dense blooms of cyanobacteria
    - Chl-a:100 µgl^{-1} to > 1000 µgl^{-1}
- Vital for flamingo conservation – lesser flamingos feed and reproduce only in alkaline-saline lakes
- Lesser flamingos are a near-threatened species and economically important

Objectives

- Use remote sensing to investigate the connection between <u>ecological</u> and <u>hydrological</u> processes in alkaline-saline lakes

- Produce <u>long-term</u> timeseries of ecological and environmental indicators from satellite data

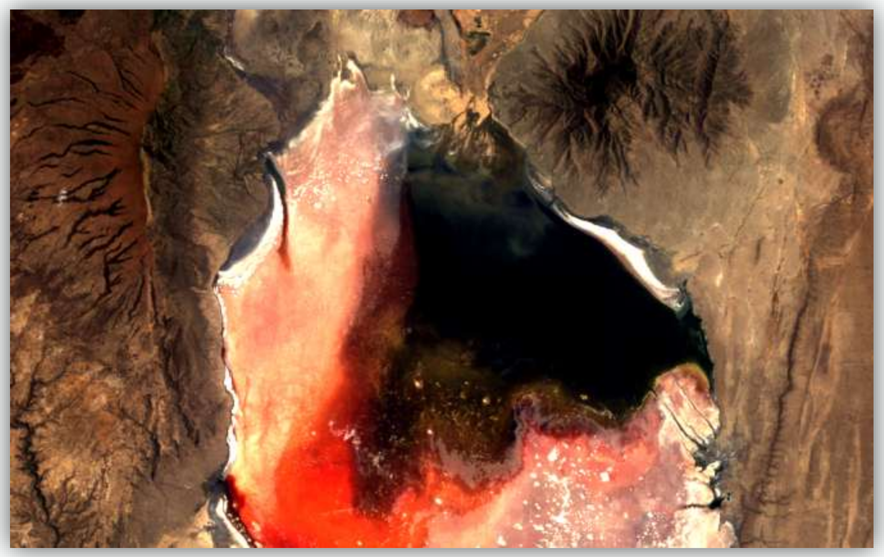
University of Leicester

Study sites

Lake Bogoria	Lake Natron
• Key feeding site for Lesser Flamingos	• Only breeding site for Lesser Flamingos in East Africa
• 10-12 m max depth	• < 3 m deep
• 10 km long, 1 - 3 km wide	• Up to ~ 800 km^2

Both lakes are in remote areas with no *in situ* monitoring.

Lake Bogoria, NASA Landsat ETM+ image

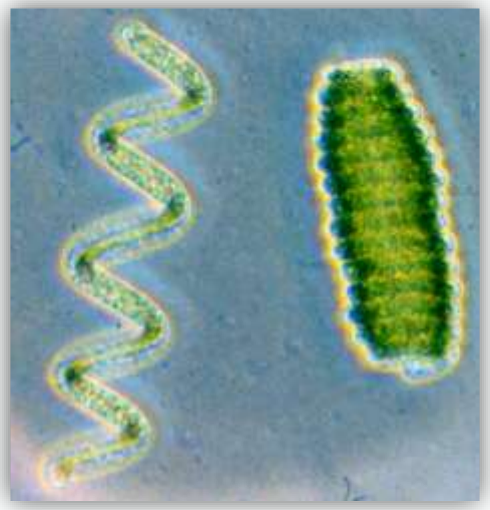


Lake Natron, NASA Landsat ETM+

University of Leicester

Lake Bogoria

- Dominated by one species of cyanobacteria: *Arthrospira fusiformis* (always over 80%)
- Occasionally the lake undergoes a drastic reduction in biomass, known as a die-off event.
- Aim:
  - Develop a Chl-a retrieval algorithm for Lake Bogoria



Cyanobacterium
Arthrospira fusiformis

Lake Bogoria,

Methods

- Field spectroscopy study
  - Characterise optical properties

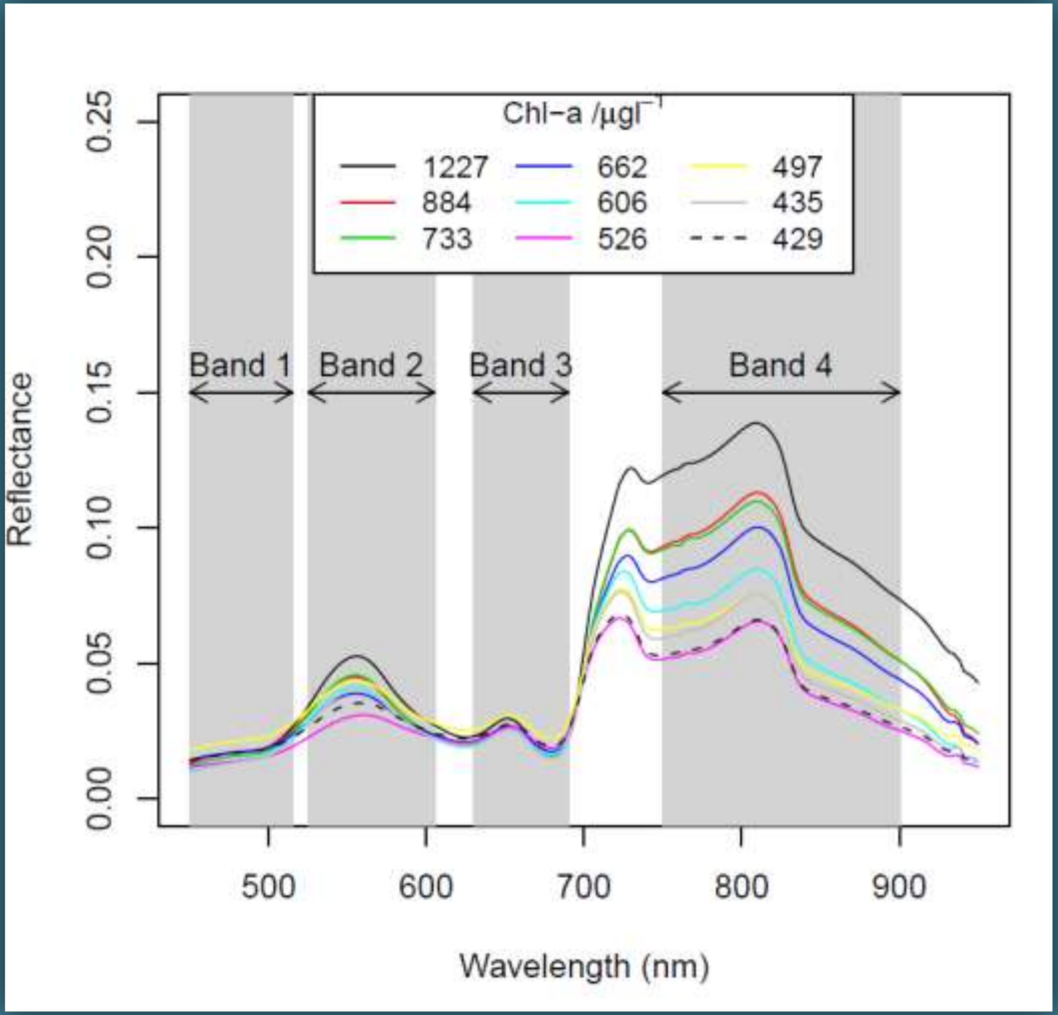
- Landsat ETM+ data and monthly Chl-a data
  - High spatial resolution (30m)
  - Long archive of imagery
  - Limited by low revisit frequency (16 days)

- DMC and MERIS

Field Measurements

Fieldwork

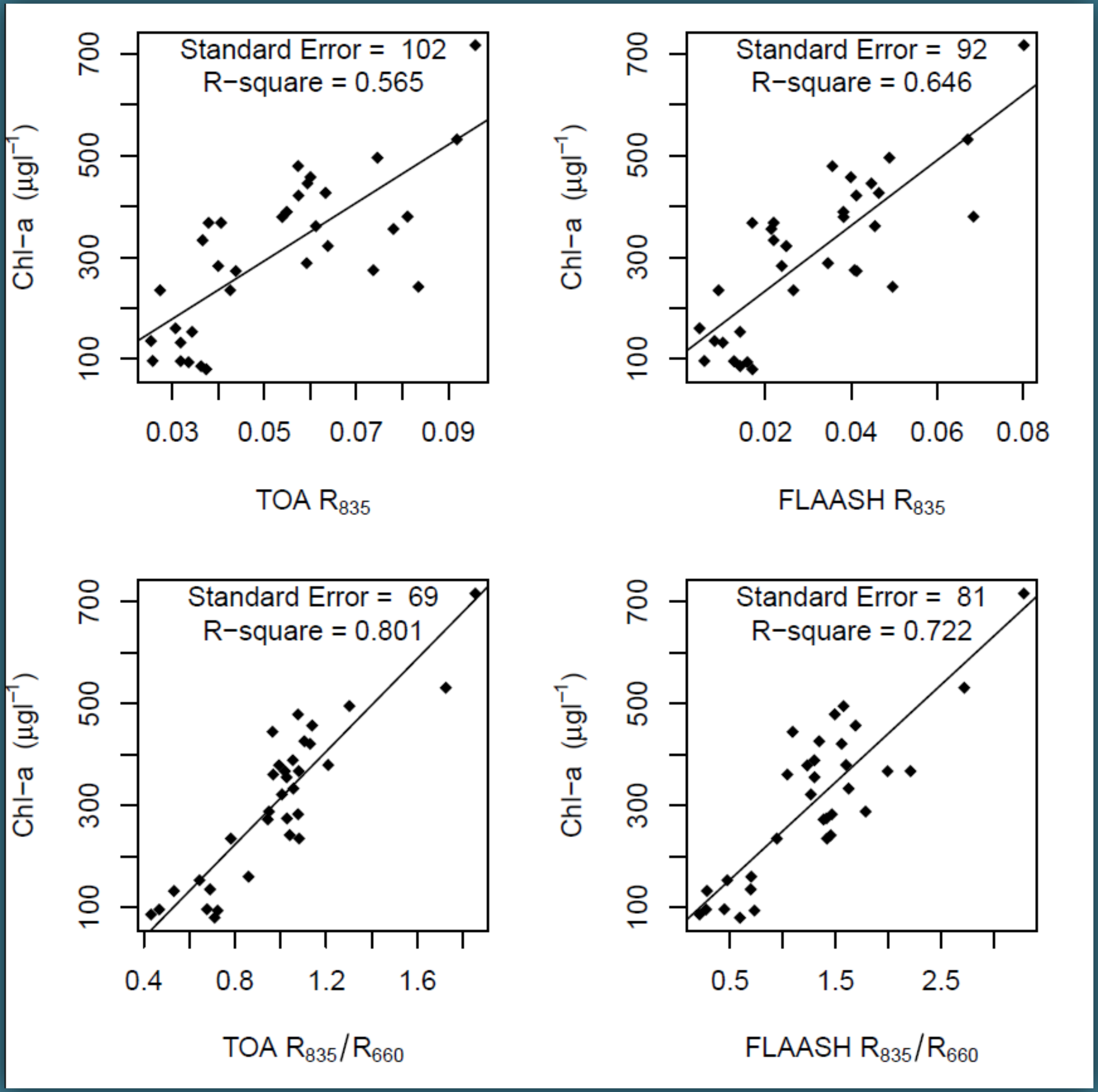
- Confirmed that optical properties of Lake Bogoria are dominated by cyanobacteria
- Also showed high CDOM, $a_{CDOM}(440) = 17\ m^{-1}$, and high attenuation, Kd(PAR) = $12.6\ m^{-1}$.
- *In situ* measured reflectance spectra for Lake Bogoria show that the peak in reflectance in the NIR is correlated with Chl-a concentrations.



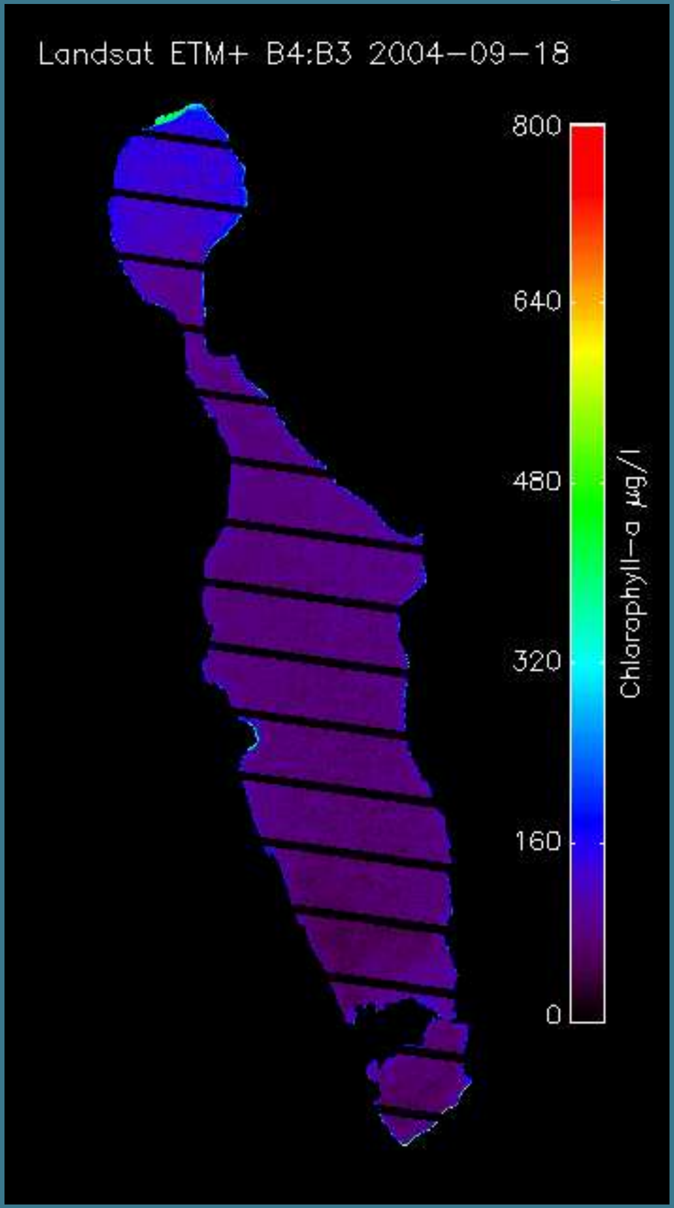
Water leaving reflectance spectra for Lake Bogoria.

Algorithm

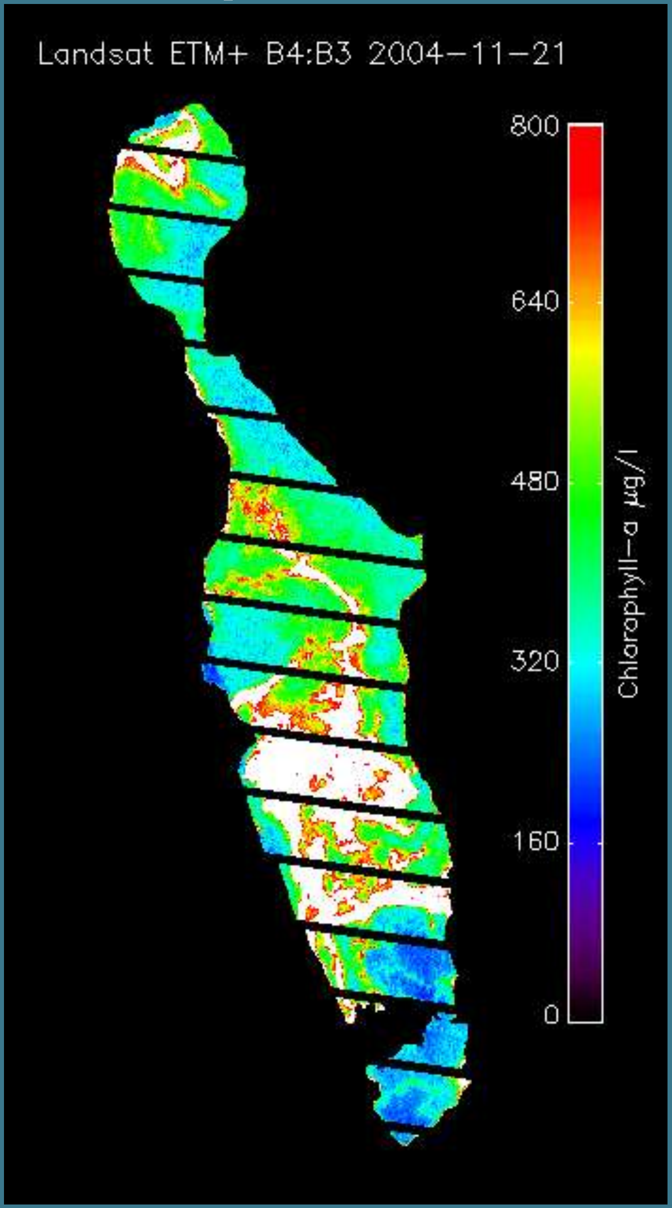
- TOA reflectance ratio R_{835}/R_{660} gave the best correlation with Chl-a
- For Chl-a up to 800 µg/l



Chlorophyll maps

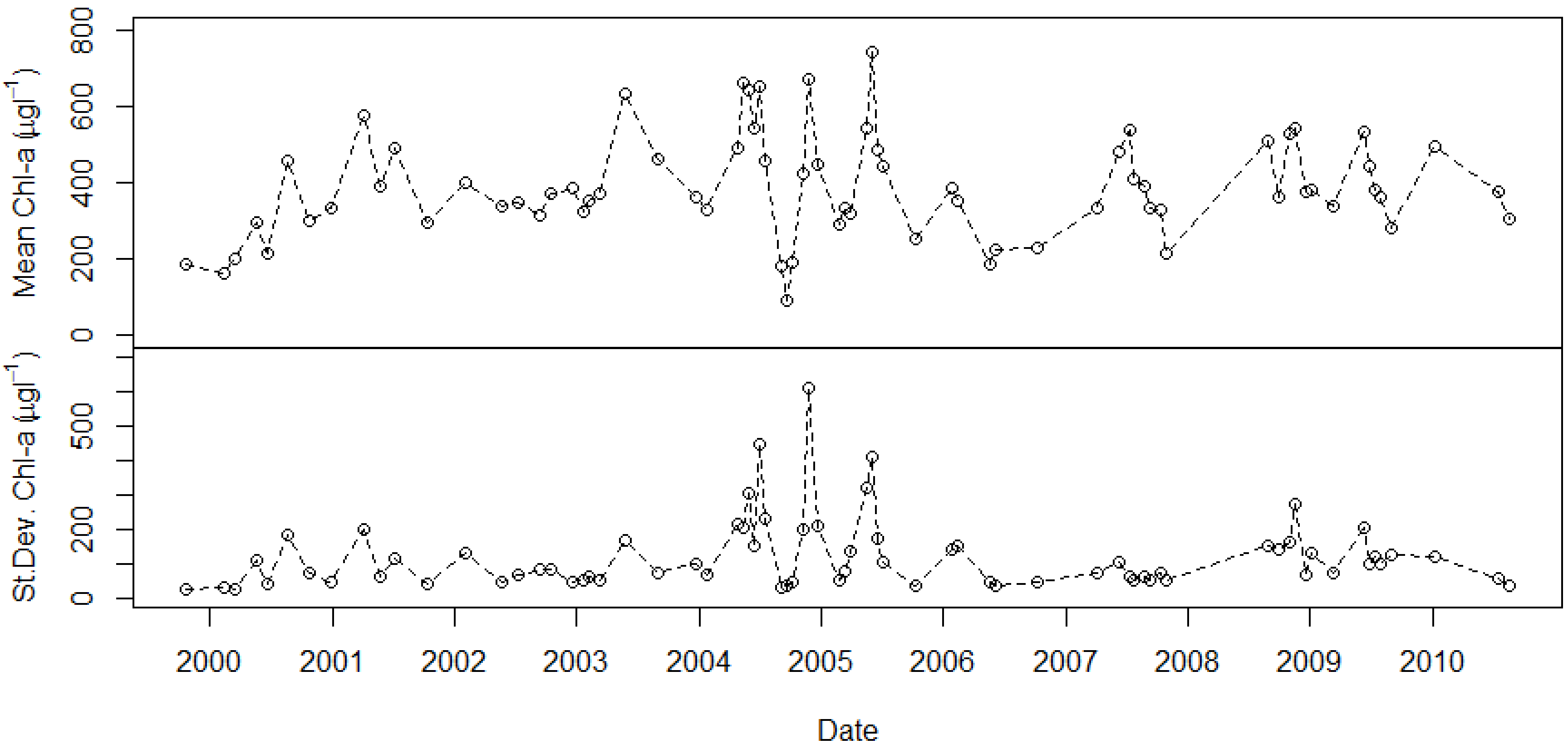


2004 die-off event

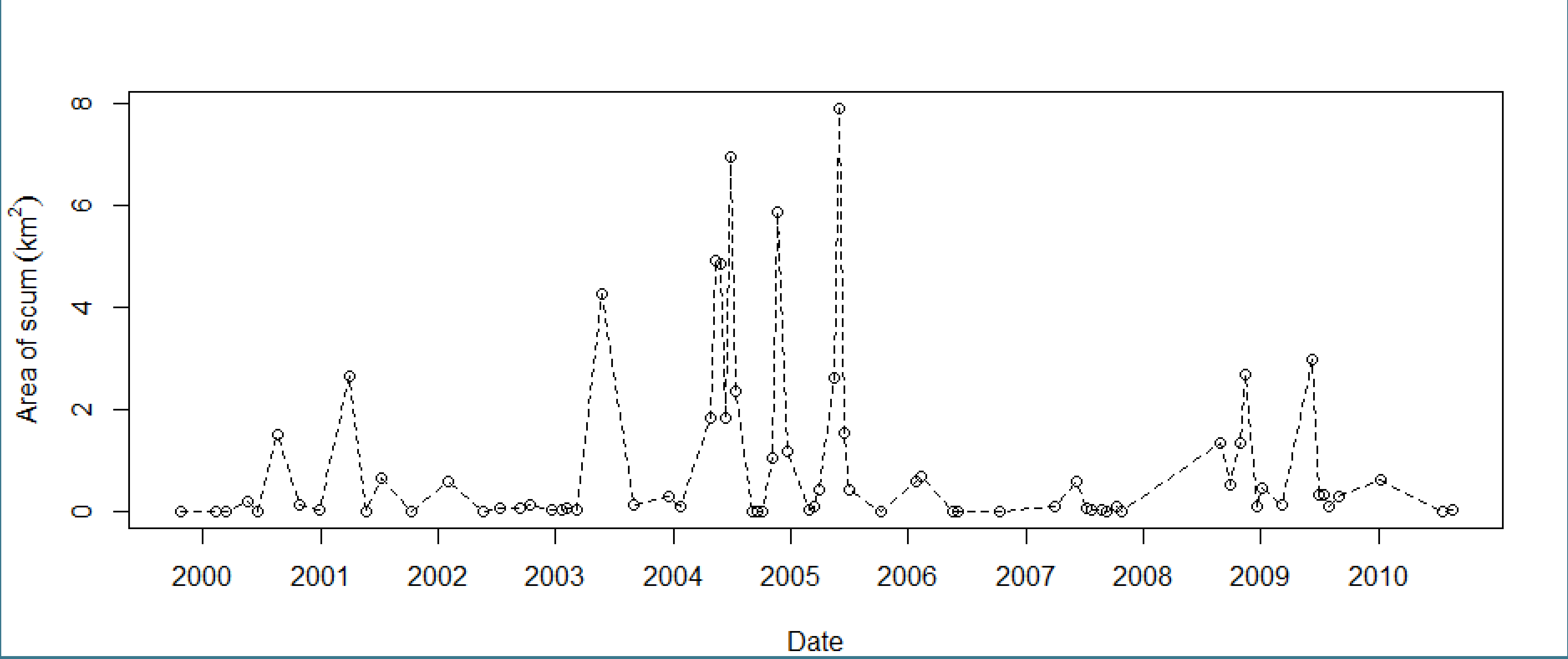


Recovery after die-off event

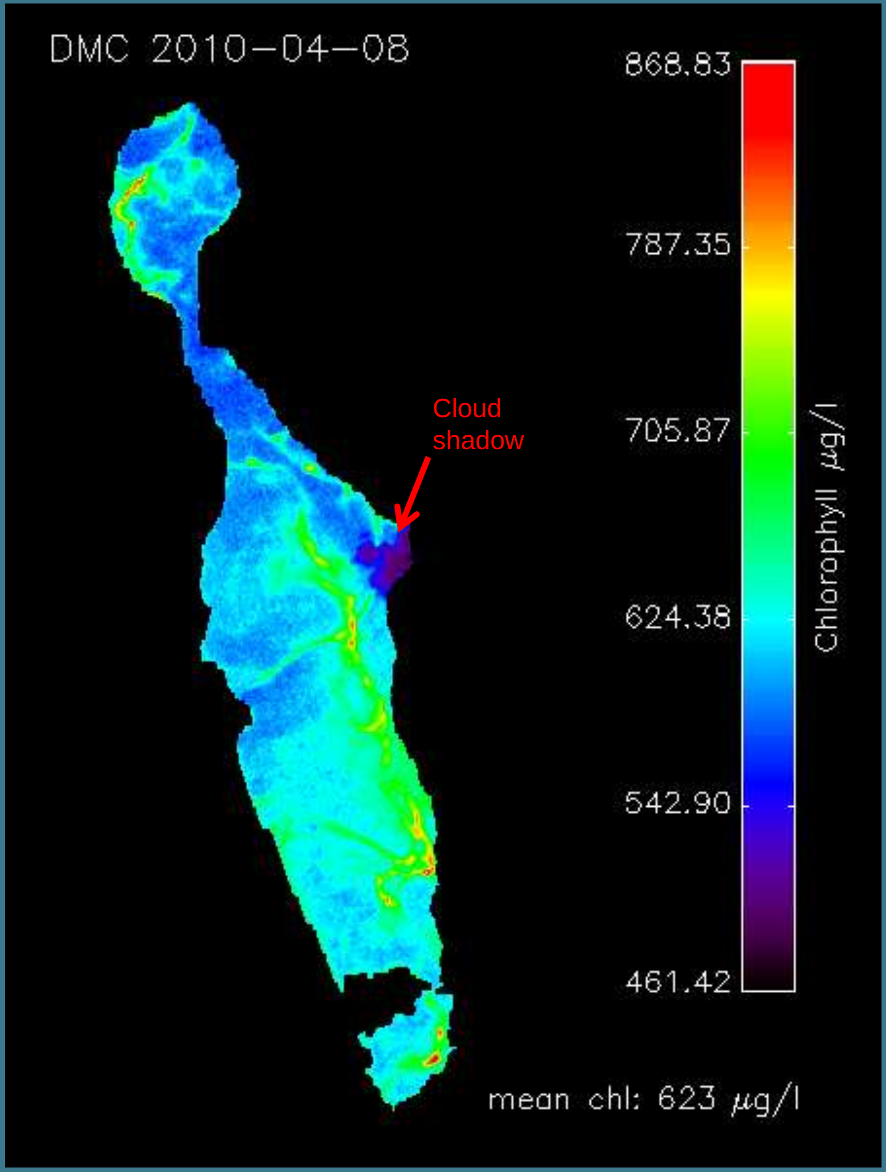
Chlorophyll timeseries

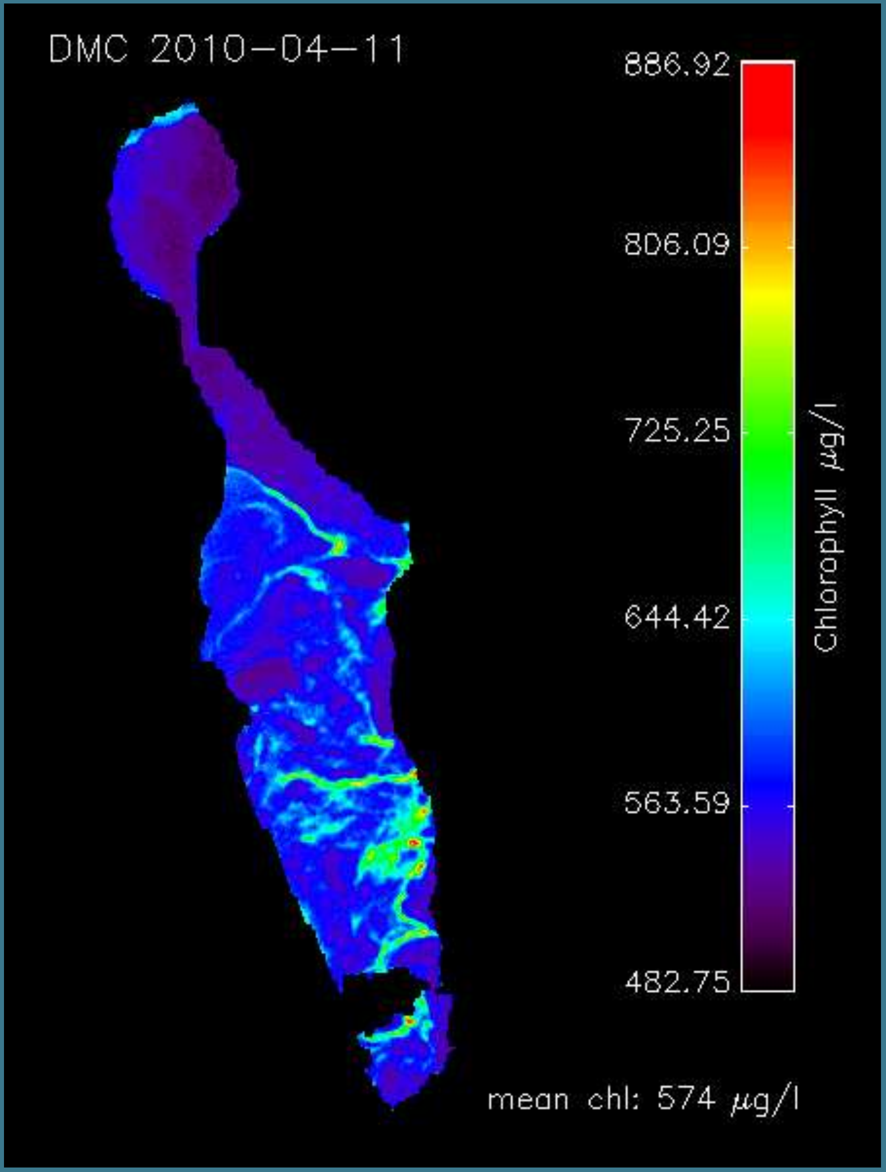


Cyanobacterial scum



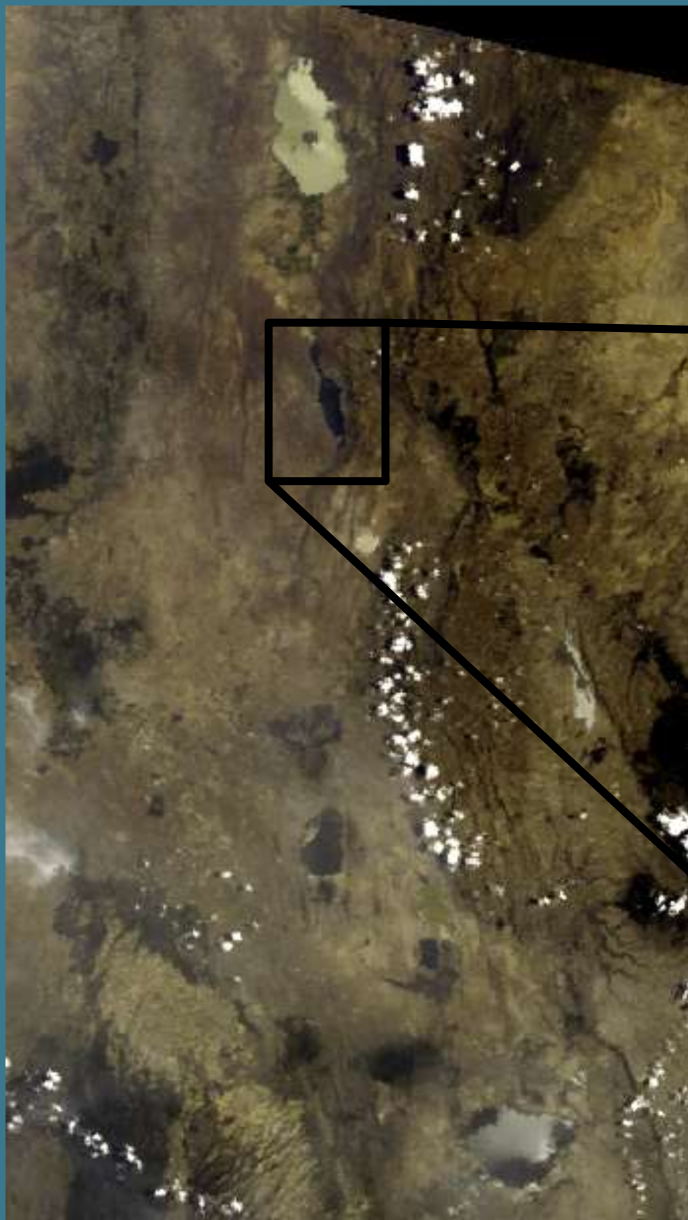
DMC imagery


DMC 2010–04–08
868.83
787.35
705.87
624.38
542.90
461.42
Chlorophyll µg/l
Cloud
shadow
mean chl: 623 µg/l


DMC 2010–04–11
886.92
806.09
725.25
644.42
563.59
482.75
Chlorophyll µg/l
mean chl: 574 µg/l

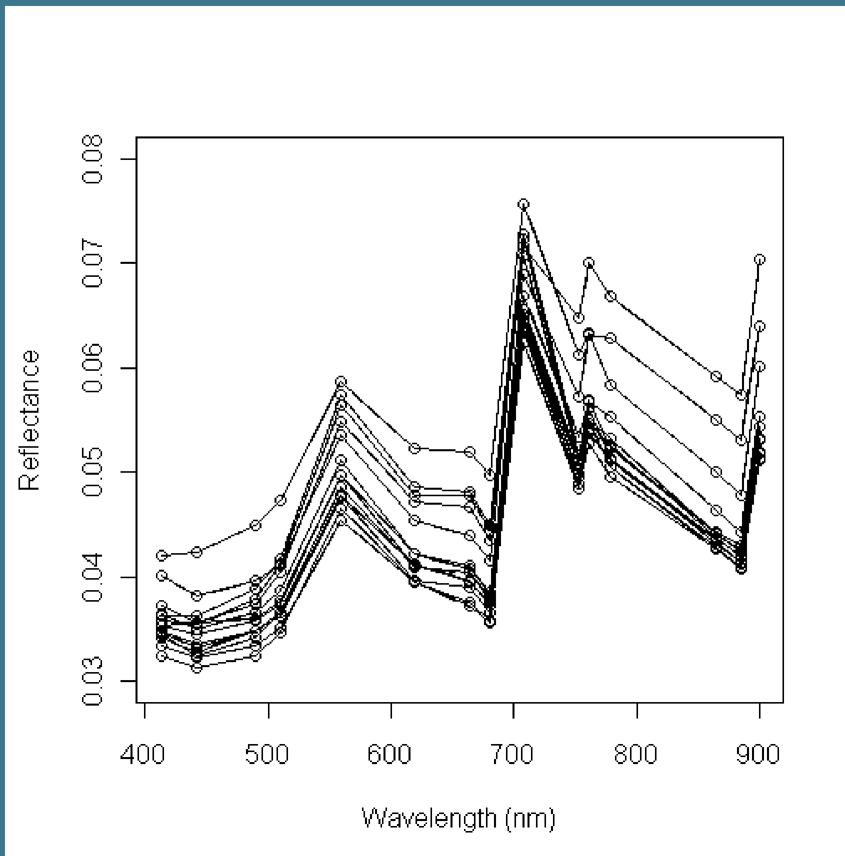
University of Leicester

MERIS imagery

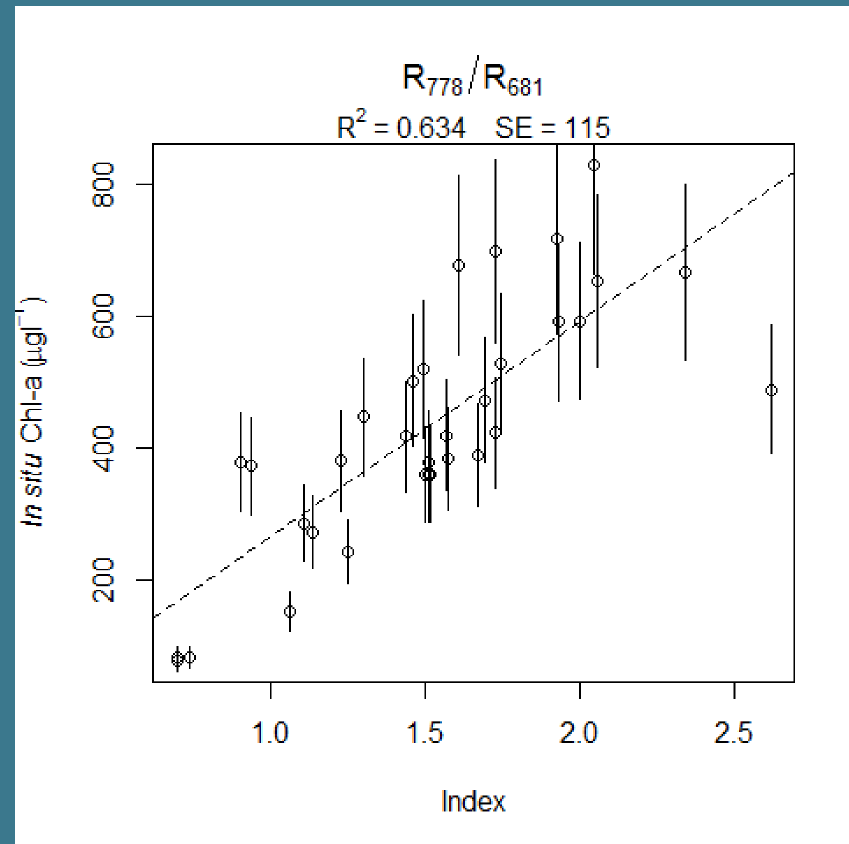


Lake Bogoria

MERIS



MERIS water leaving reflectance spectra. Atmospherically corrected using SMAC (Simple Method for Atmospheric Correction) in BEAM.



MERIS reflectance ratio, R_{778}/R_{681}, versus Chl-a

Lake Natron

- Large changes in surface area due to fluctuations in lake levels.
- Thought to be related to breeding success.
- Threatened by industrial developments
- Aim:
  - Produce a lake surface area timeseries from Landsat data
  - Relate to flamingo breeding events

Lake Natron, NASA Landsat ETM+

University of Leicester

Lake Surface Area

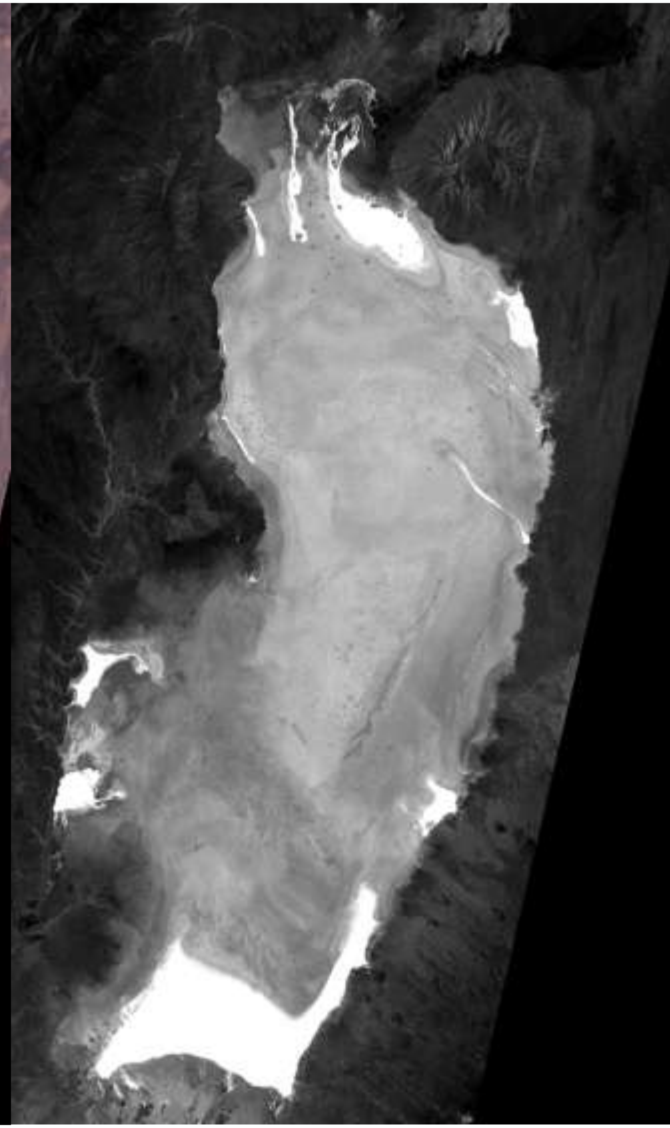
- Modified Normalised Difference Water Index:

$$MNDWI = \frac{Green - MIR}{Green + MIR}$$

- DOS-COST atmospheric correction was applied to images
- A list of observations of flamingo breeding at Natron was compiled

MNDWI results

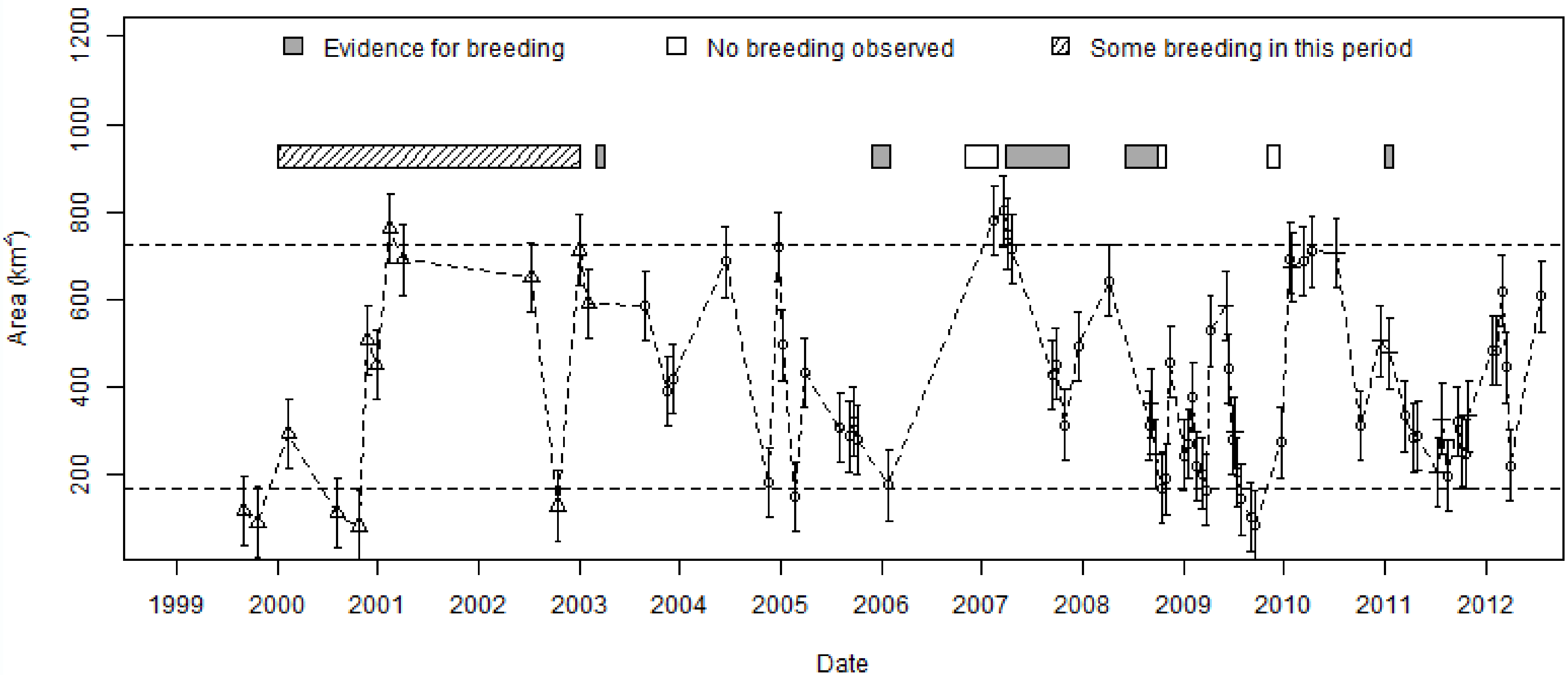
True Colour Image



MNDWI

Lake Area Estimate

Lake area and breeding events



University of Leicester

Conclusions

- High spatial resolution sensors (Landsat, DMC) can provide ecologically useful information about alkaline-saline lakes which cannot be obtained from other sources.
- Moderate spatial resolution sensors (MERIS, OLCI) provide complementary data for the study of these small hypereutrophic waters.
- Fieldwork was extremely valuable for the interpretation of results obtained from satellite data.

University of Leicester

Future work

- Landsat Chl-a retrieval work will be extended to other alkaline-saline lakes.
- Extend lake area work.
- Timeseries of other environmental variables (Temperature, precipitation etc.) will be produced and related to Chl-a.
- Apply MERIS algorithm to produce Chl timeseries and investigate other MERIS algorithms.

University of Leicester

Thanks for listening

Acknowledgements:

- NERC Field Spectroscopy Facility
- Centre for Interdisciplinary Science, University of Leicester
- EOS Group, University of Leicester
- MERIS data provided by the European Space Agency