ESA Diversity II Biodiversity Story
Emma Tebbs, Centre for Ecology and Hydrology
Sean Avery, Kenya Wetlands Biodiversity Research Team & University of Leicester
Daniel Odermatt, Odermatt & Brockmann GmbH

Lake Turkana – monitoring the 'Jade Sea' from space

Threats to the world's largest desert lake: An African Aral Sea disaster in the making?

Lake Turkana is globally renowned as the world's largest permanent desert lake. It is endhoreic, and its waters are semi saline. Unlike other regional lakes that are affected by exotic fish species introductions, Lake Turkana's unique indigenous ecology still flourishes. However, encroachment by exotic plant species is an emerging threat.

The region's cultural diversity is extraordinary, and the Turkana Basin is known as the "Cradle of Mankind", and the lake's national parks are a World Heritage site. However, the people of the area are among the region's poorest. The lake and existing traditional livelihoods are threatened by major development projects including a cascade of major hydropower dams along the Omo River, the main tributary of Lake Turkana, which provides 90% of the lake's freshwater inflow. The filling of dam reservoirs will cause a decline in lake levels, and thereafter the river flows will be regulated. The elimination of the existing highly pulsed natural hydrology will have a significant impact on the lake's ecology and will potentially destroy the indigenous fisheries (Avery, 2012 & 2013). The regulated flows from the dams are enabling major commercial agricultural development downstream. The water abstraction for the irrigation of these large schemes will deplete the river causing a catastrophic reduction in lake levels, leading to a shrinking of the lake similar to what has happened to the Aral Sea, one of Europe's major contemporary environmental disaster areas.

Lake Turkana is vast, remote and insecure, so *in situ* data is difficult to collect. Remote sensing offers exciting opportunities for effective and continuous monitoring throughout the lake of physical and water quality changes. Satellite-based measurements have already been successfully used as the basis for the lake's water balance baseline modelling (Avery, 2012 & 2013), and the methods are being developed to define an ecological baseline for Lake Turkana and to quantify the natural spatial and temporal variability of the lake. These satellite based tools will be the basis for monitoring future changes in Lake Turkana that will result from the ongoing and planned major developments. The Gibe III dam nearing completion on the Omo River is Africa's biggest dam, and it will start filling its reservoir in mid 2015. This will be the trigger for the changes about to take place. Hence, there is some urgency to establish effective monitoring.

Figure 1. Landsat EMT+ image of the southern portion of Lake Turkana, 1999-10-23. Credit: NASA

Kenya's jade jewel in the desert

Lake Turkana is popularly known as the 'Jade Sea' due to its remarkable algal colouration (Fig 1). Less than 10,000 years ago this lake was 100 metres deeper than today, the climate was humid, and its waters were fresh, and were overflowing to the Nile River basin. The lake's semi-saline waters are well-mixed, with constant temperatures and abundant sunshine throughout the year. The resultant ecology supports a thriving, diverse, and indigenous fishery. The fish species are found throughout the Nile, apart from some endemic species specific to Lake Turkana. The lake also supports populations of Nile crocodile and hippopotamus. The lake provides diverse and important habitats for birds, including passage migrants from Europe and birds moving up and down the Rift Valley between Kenya and Ethiopia.

Lake Turkana's catchment is split roughly 50:50 between Kenya and Ethiopia, covering an area of 138,000 km^2, and it lies in an extremely arid and remote region in northern Kenya, on Ethiopia's southern border. The lake itself measures over 250 km from north to south. It is about 30 km wide, and its depth averages 30 metres, but is over 100 metres at its deepest point. This is Kenya's largest and northernmost lake.

A baseline for assessing future change in Lake Turkana

Remotely sensed data on water quality and quantity can provide an ecological and hydrological baseline dataset for assessing future change in Lake Turkana. Satellite-based water level estimates for Lake Turkana, from radar altimetry, have already been used to show both long-term trends and seasonal variability in water levels (Fig 2). The lake level peaks in November

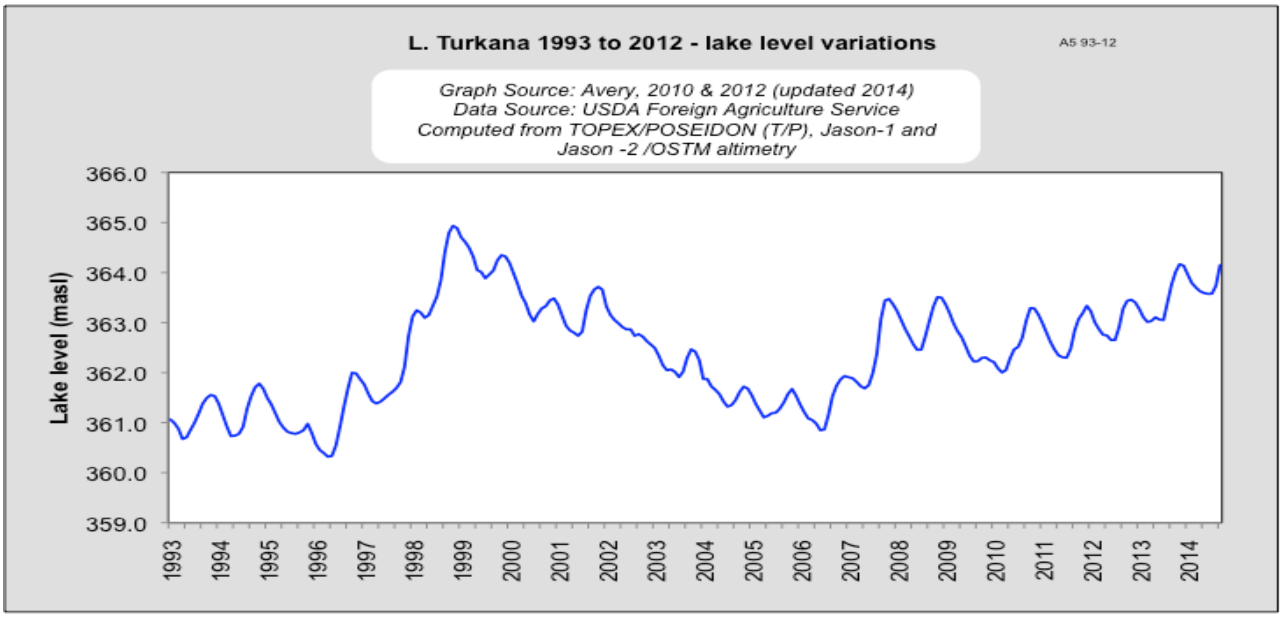

Figure 3. USDA - FAS water level time series for Lake Turkana

each year following the peak flow of the Omo River, which occurs in August (Avery, 2012). The flood pulses trigger breeding of fish populations within the lake and hence they are vital for maintaining local fisheries.

MERIS archive satellite imagery covering the period to 2002 to 2012 has been used to investigate changes in Chlorophyll-a concentration in Lake Turkana over the last decade. The Maximum Peak Height algorithm was used to produce Chlorophyll-a maps and time series. The monthly Chlorophyll-a maps show a phytoplankton bloom, which occurs at the north end of the lake where the Omo River enters through its delta (Fig. 2). The majority of the lake has a Chlorophyll-a concentration of around 100 mg m^{-3}, while within the bloom the concentrations can be as high as 800 mg m^{-3}.

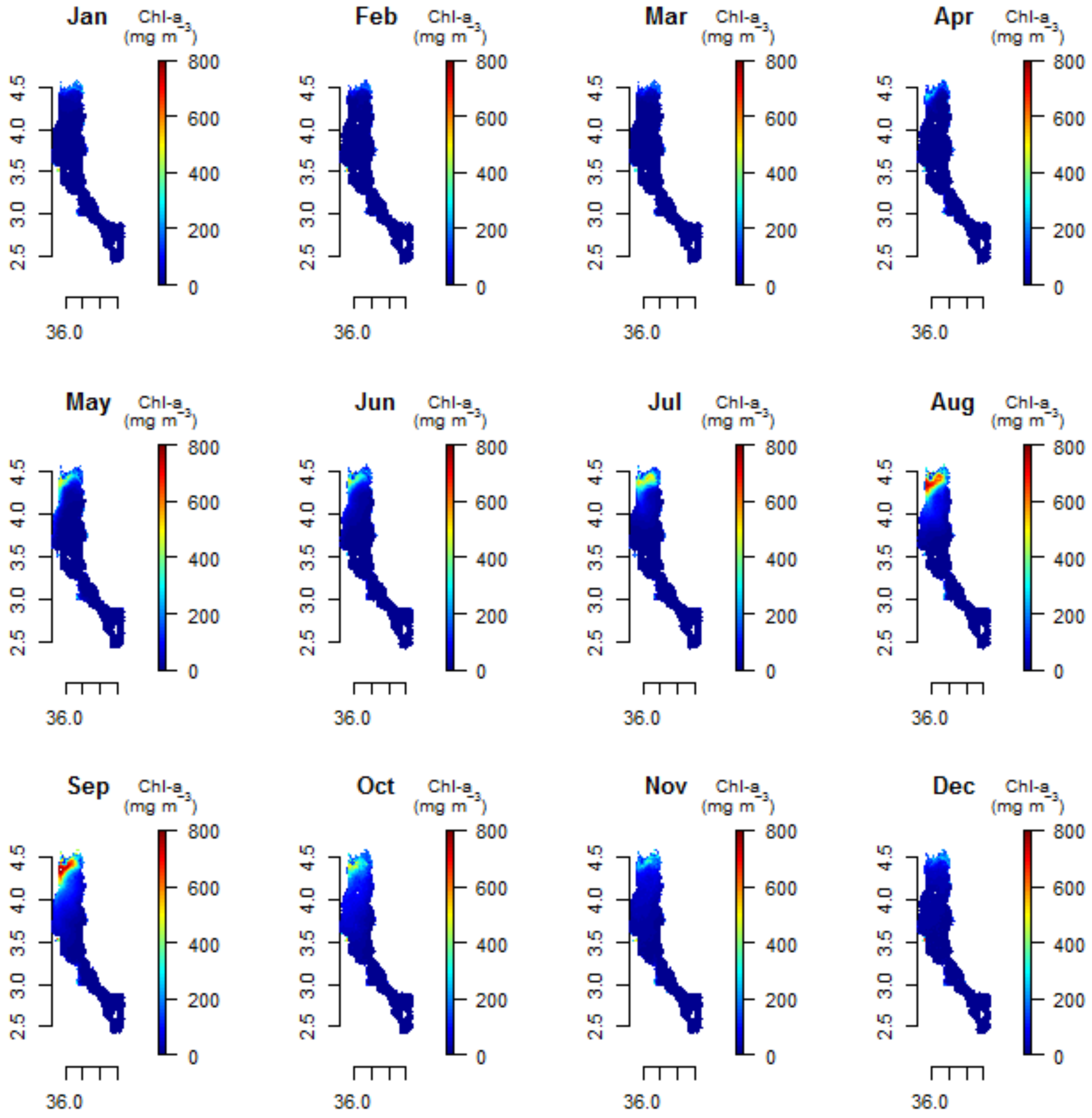

Figure 2. Monthly Chl-a maps for Lake Turkana from the MPH algorithms averaged over the period 2002 to 2012.

Chlorophyll-a concentrations in Lake Turkana show a seasonal cycle with a peak in August – September (Fig. 3), which closely matches the period of peak flow in the Omo River (Avery, 2012). This peak in Chlorophyll-a is to be expected, and follows the influx of nutrients carried into the lake at this time. During flood periods, the river will overtop its banks upstream of the lake and will collect nutrients from the flood plains and carry these to the lake. The sediment plume can extend 100 kilometres into the lake.

The construction of large reservoirs along the Omo River will not only regulate the Omo's important floods to the detriment of the lake ecology, but will also permanently capture sediments and nutrients that would otherwise be transported to feed the lake. The productivity of the lake would be significantly altered.

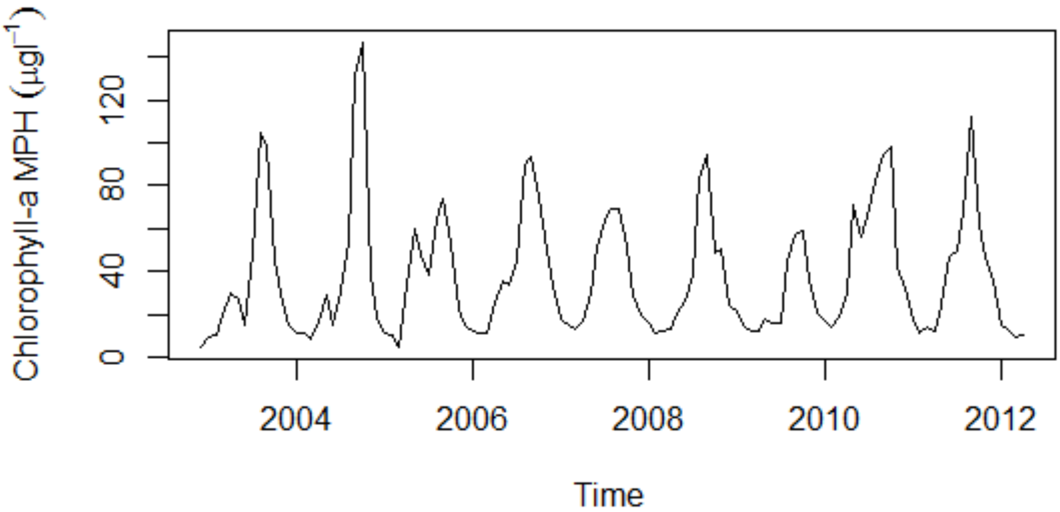

Figure 3. Time series of chlorophyll-a in Lake Turkana from the Maximum Peak Height algorithm.

Conclusions

Earth Observation can provide highly valuable data for monitoring natural and man-made changes in inland waters. In the case of Lake Turkana, the results have allowed us to observe the seasonal fluctuations in chlorophyll and lake levels, which are being driven by the cyclical variation in Omo River inflows. Once the Gibe III dam is completed these oscillations in flow, which drive the ecology of the lake, will be dampened, posing a serious threat to local fisheries and the communities depending on them. Work is ongoing in this project to investigate the spatial and temporal patterns of other water quality parameters in Lake Turkana. Remote sensing is the most effective way to collect this information due to the remoteness and large scale of the lake, and also insecurity. Data from the future Sentinel-3 mission will also be used to investigate the impact of the hydropower dam after its completion, and to determine the extent to which it will modify natural ecological processes within the lake. The present project will run through to the end of 2016.

Acknowledgements

This work forms part of the 'Lake Turkana ecological/hydrological baseline' project, which is being funded by the MacArthur Foundation.

Further Reading

Avery, Sean (2014). What future for Lake Turkana and its Wildlife? SWARA (Magazine of the East African Wildlife Society. January-March 2014. www.eawildlife.org

Avery, Sean. (2013). What future for Lake Turkana? The impact of hydropower and irrigation development on the world's largest desert lake. Booklet published by African Studies Centre, University of Oxford.

Avery, Sean. (2012). Lake Turkana & The Lower Omo: Hydrological Impacts of Gibe III & Lower Omo Irrigation Development, African Studies Centre, University of Oxford.

Avery, Patrick (2012). Kenya's jade jewel in peril from Ethiopia plans. SWARA (Magazine of the East African Wildlife Society). May-June issue, pp 16-21.