Temporal Water Quality and Phytoplankton Dynamics: A Basis for Environmental Monitoring of Cage Aquaculture in Napoleon Gulf, Lake Victoria, Uganda

GRŌ · FTP
Fisheries Training Programme

Jessy Lugya[1]*, Rakel Guðmundsdóttir[2], Amanda G. Vang[3], Mark Olokotum[1]

[1] National Agricultural Research Organisation, Uganda, [2] Marine and Freshwater Research Institute, Iceland, [3] University of the Faroe Islands

Introduction

Background

Cage fish farming was introduced in Lake Victoria in 2006 and expanded rapidly to over 12,000 cages by 2019. It can affect water quality through localized organic waste from uneaten feed and feces, leading to oxygen depletion and algal blooms that compromise fish health.

Recent mass fish mortalities have raised concern among farmers and environmental stakeholders. Combined with ongoing land-based pressures and seasonal hydrodynamic variability, this underscores the need for environmental monitoring and regulation based on long-term ecological studies at cage sites.

Objectives

- Determine temporal changes in key water quality parameters (2011 – 2018)
- Assess spatial and temporal variability in phytoplankton community composition and abundance
- Evaluate relationships between phytoplankton communities and water quality gradients
- Develop a framework for environmental monitoring of cage aquaculture on Lake Victoria

Methodology

Study area and design

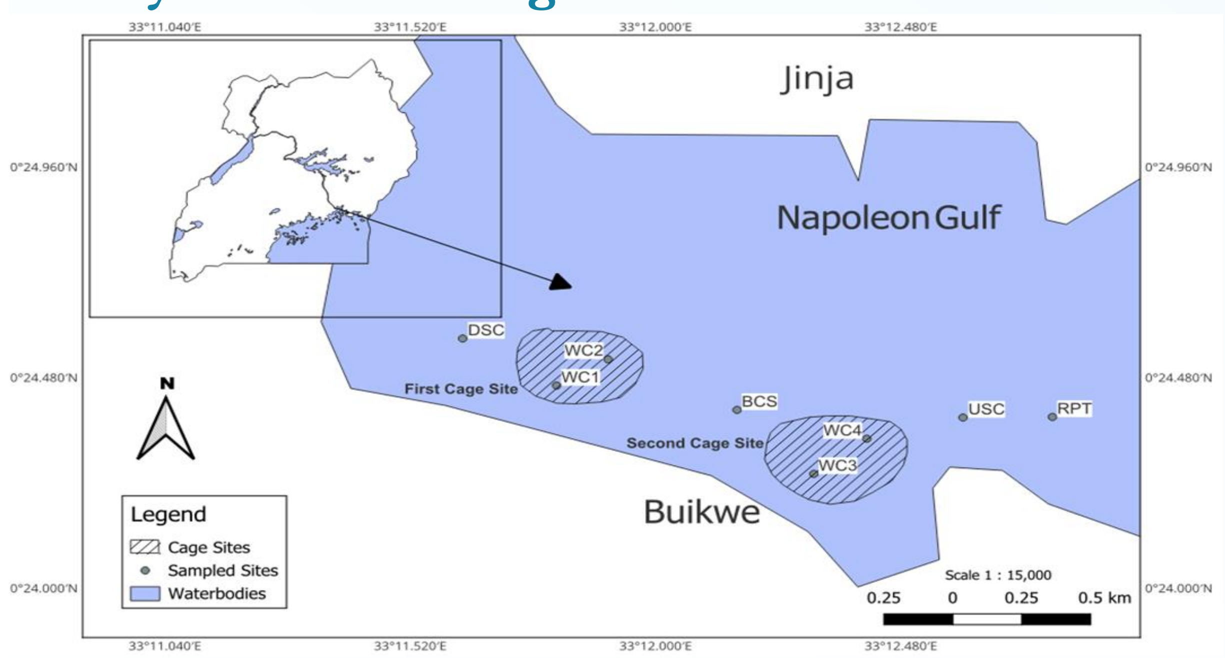

Fig. 1. Location of sampling points on Lake Victoria, Uganda. RPT = reference point; USC = upstream; WC = within cages; DSC = downstream cages.

Sampling and analysis

- Handheld portable echo sounder, Secchi disk, and seabird instruments for physical and chemical parameters
- Van Dorn water sampler, Lugol´s iodine and microscopy for phytoplankton
- LMM, GAM, PCA, Spearman correlation, and diversity indices for data analysis
- Some sites and years had data gaps, limiting trend analysis

Key Findings – Water Quality

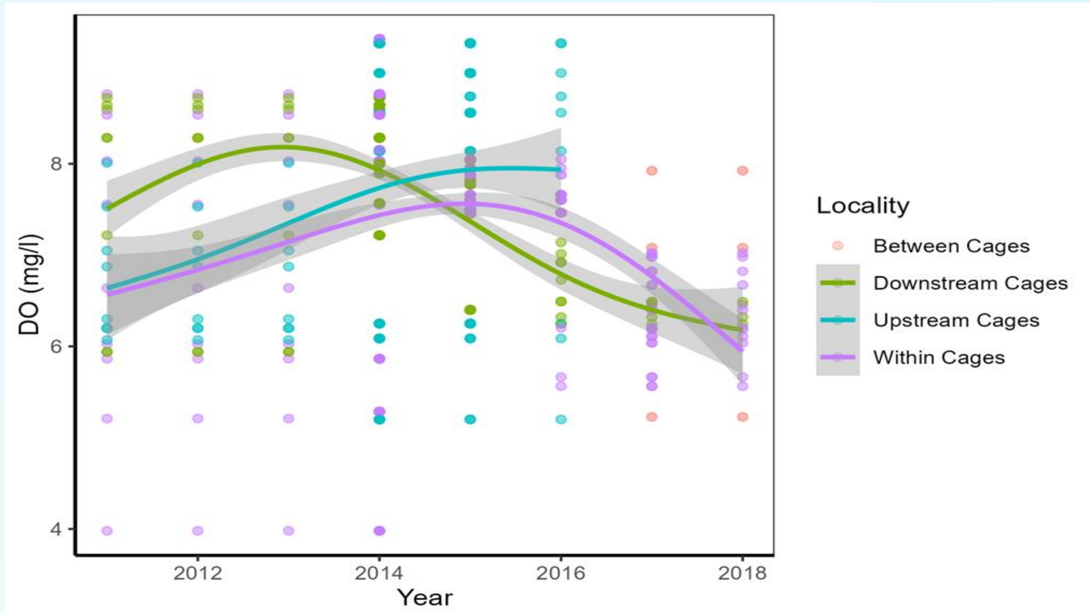

Fig. 2. Fitted smooth trends in dissolved oxygen (DO) across sampling locations.

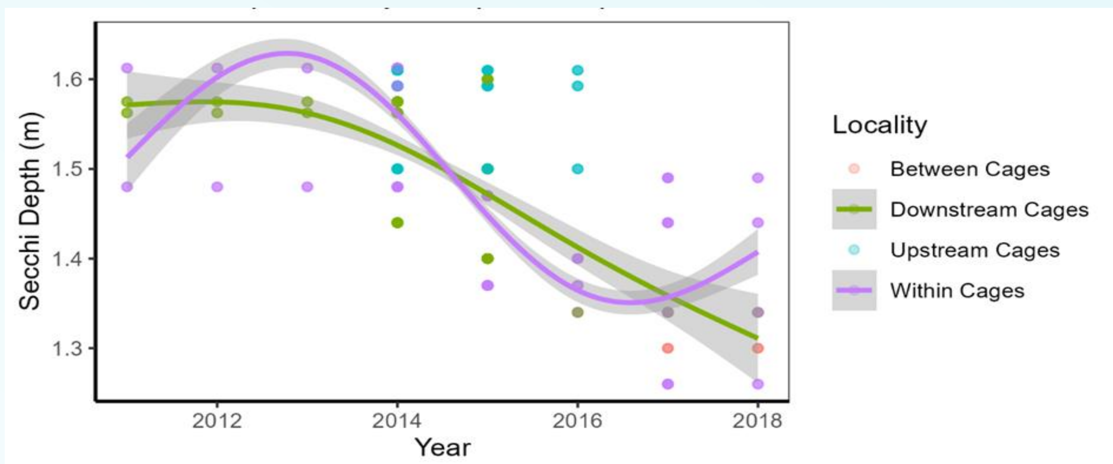

Fig. 3. Fitted smooth trends in Secchi depth (SD) across sampling sites in Napoleon Gulf over time.

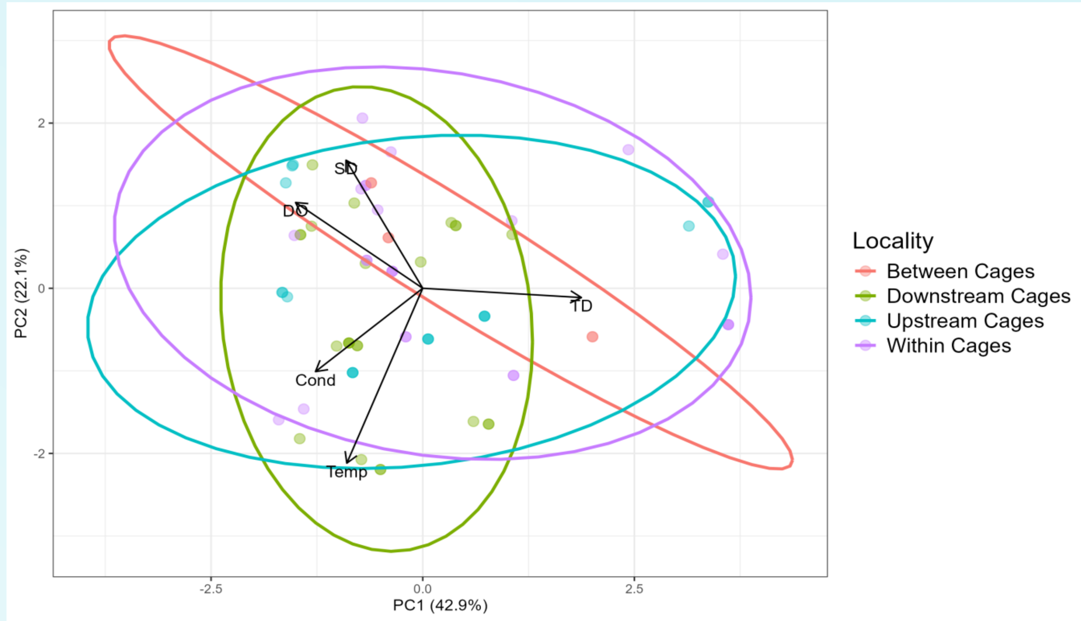

Fig. 4. PCA biplot showing relationships among sampled parameters and site dispersion.

- DO declined within and downstream of cages by 0.0438±0.021 mg/L annually (Fig. 2)
- SD decreased by 0.033 m per year, reduced water transparency over time, mainly downstream of cages (Fig. 3)
- Very clear water (high SD), well oxygenated (high DO) at lower temperatures (Fig. 4)
- Between cage sites highly dispersed, environmental variability
- Downstream sites had higher conductivity and lower DO (Fig. 4)

Key Findings – Phytoplankton Communities

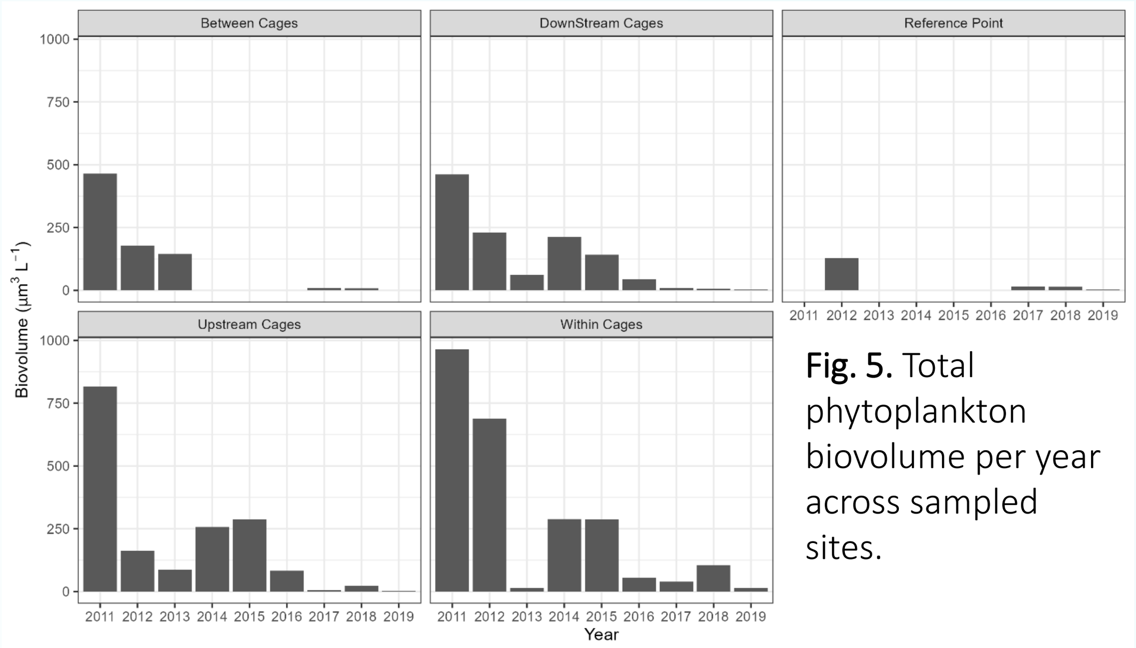

Fig. 5. Total phytoplankton biovolume per year across sampled sites.

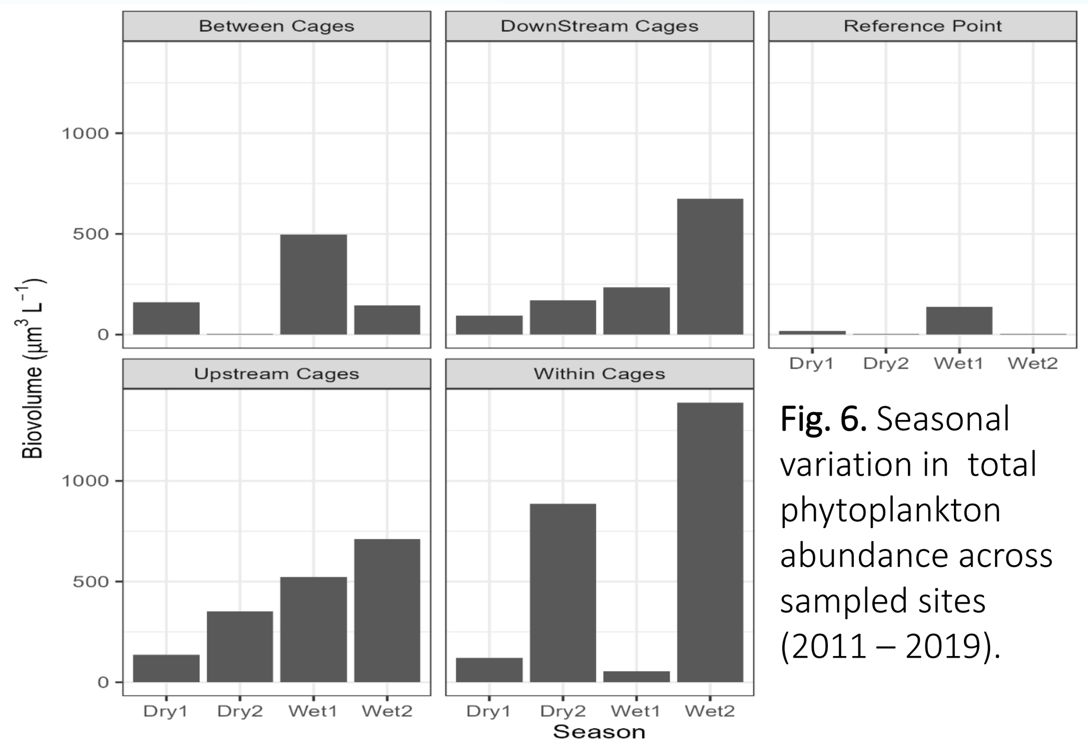

Fig. 6. Seasonal variation in total phytoplankton abundance across sampled sites (2011 – 2019).

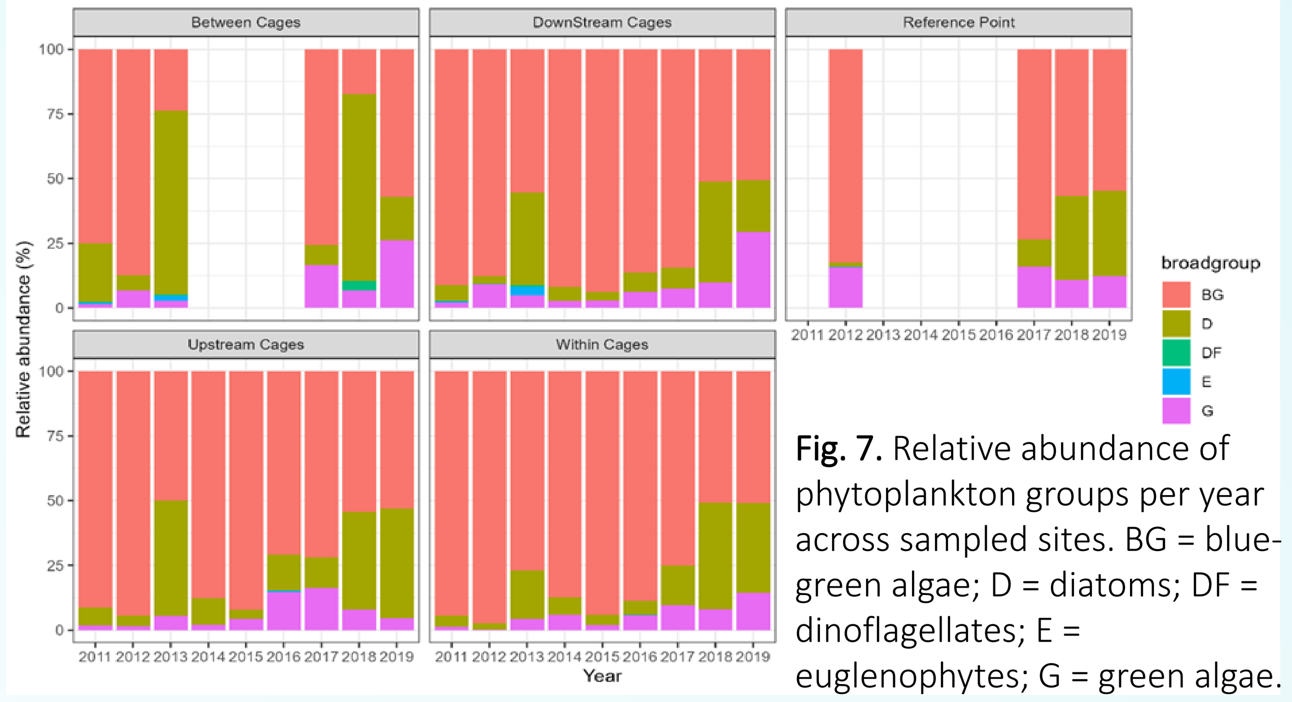

Fig. 7. Relative abundance of phytoplankton groups per year across sampled sites. BG = blue-green algae; D = diatoms; DF = dinoflagellates; E = euglenophytes; G = green algae.

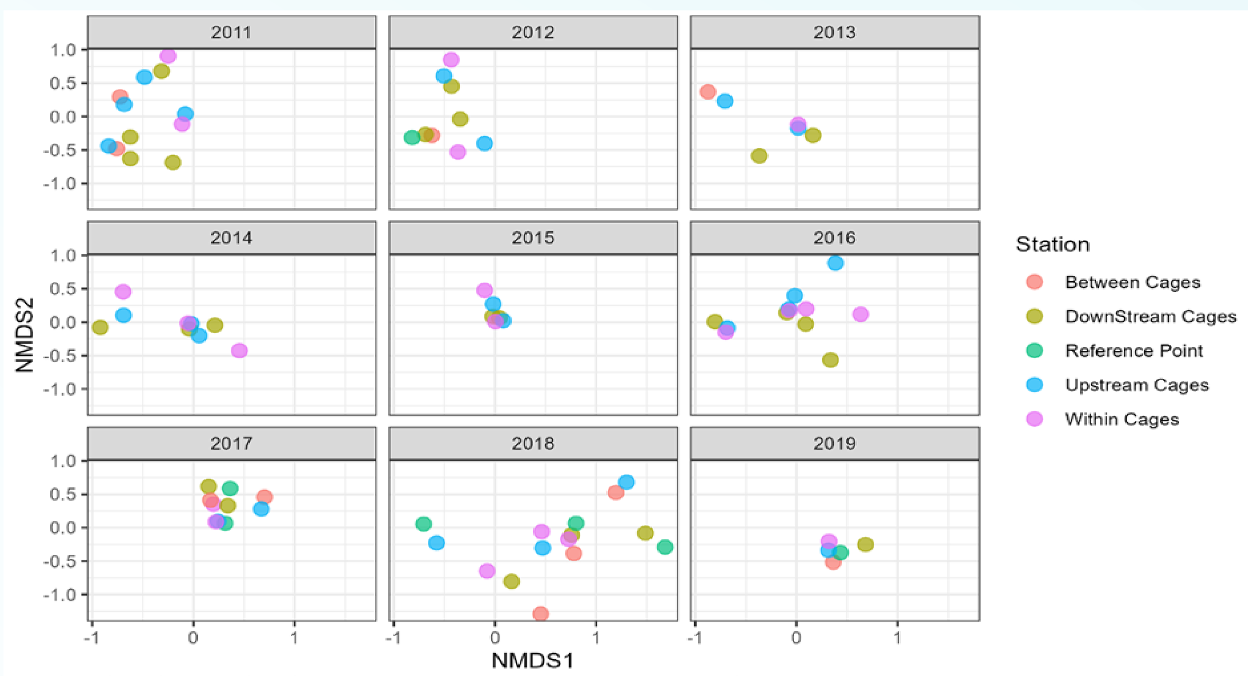

Fig. 8. Phytoplankton community NMDS site clustering per year.

Key Findings - Correlation of Variables

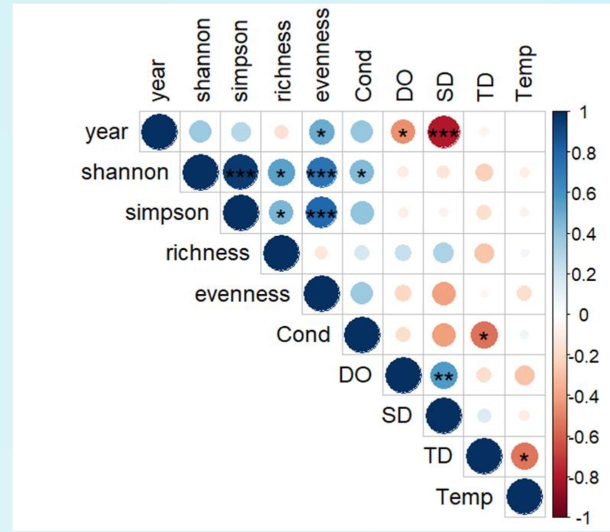

Fig. 9. Relationships between phytoplankton diversity and water quality parameters, 2011 - 2018, significant levels (***p =0, **p =0.001, *p= 0.01).

- Algal biovolume declined across all sites from 2011 to 2019 (Fig. 5)
- Higher algal biovolumes during wet seasons (Fig. 6)
- Blue-green algae (*Anabaena, Microcystis*) dominated across all sites (Fig. 7)
- Community restructuring through years: 2011, 2016, 2018 more dispersed; 2015 & 2019 homogeneous (Fig. 8)
- Elevated conductivity and reduced water transparency linked to community imbalance (Fig. 9)

Conclusion

- DO and SD declined within and downstream of cages, indicating organic waste effects
- Spatial gradients in sampled parameters driven by cages
- Community shifts associated with environmental stress and nutrient loading
- Higher dissolved ions and lower transparency favor cyanobacteria dominance
- Seasonal and hydrodynamic variability mask spatial differences, reinforcing the need for temporal analysis

Recommendations

✓ Continuous monitoring at all cage sites is essential to capture trends and support sustainable aquaculture

✓ Farmers should synchronize harvesting with dry seasons

✓ Policymakers should develop and enforce strict environmental regulations, monitor farms, and promote sustainable practices

✓ Establish cage biomass limits per farm, gulf, or bay

Acknowledgements

Field sampling and laboratory analyses were conducted by the National Fisheries Resources Research Institute and funded by SON Fish Farm Ltd.

MARINE & FRESHWATER RESEARCH INSTITUTE

FRÓÐSKAPARSETUR FØROYA

SCAN ME!