EXPLORING CLIMATE-LINKED SHIFTS IN ZOOPLANKTON COMMUNITIES & WATER QUALITY PARAMETERS USING HISTORICAL MESOCOSM DATA

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INTRODUCTION

Aquatic mesocosms can provide controlled, ecologically relevant insights into responses to environmental stressors[1]. Here we have analysed 16 years (2009 - 2025) of historical control data, including zooplankton abundance (organisms/L) and 6 water quality parameters (chlorophyll, conductivity, DO, pH, temperature and turbidity) from Cambridge Environmental Assessments, to investigate climate driven trends in water quality and zooplankton dynamics.

Consistent mesocosm sampling protocols, semi-natural conditions and detailed monitoring enable the assessment of long-term patterns in baseline water qualities and zooplankton community structure.

OBJECTIVES & DATA ANALYSIS

Quantify & assess the significance of long-term temporal trends in water quality parameters:

- Temporal trends in water qualities were visualised by plotting annual means and day of year measurements with a locally weighted regression (LOESS) smoothed fit.
- Generalised additive models (GAMs) were used to determine the probability of observed trends not being explained by natural variability.

Visualise and assess significant changes in zooplankton community structure & zooplankton – water quality relationships:

- Non-metric multidimensional scaling (NMDS) was used to group similar communities by rank order of dissimilarities, with temporal differences tested using multivariate general linear models.
- Redundancy analysis (RDA) was used to link changes in community composition with water quality parameters. With permutation tests used to assess if the magnitude of relationships was greater than would be explained by random chance.

RESULTS

Figure 1: Water Quality Parameters

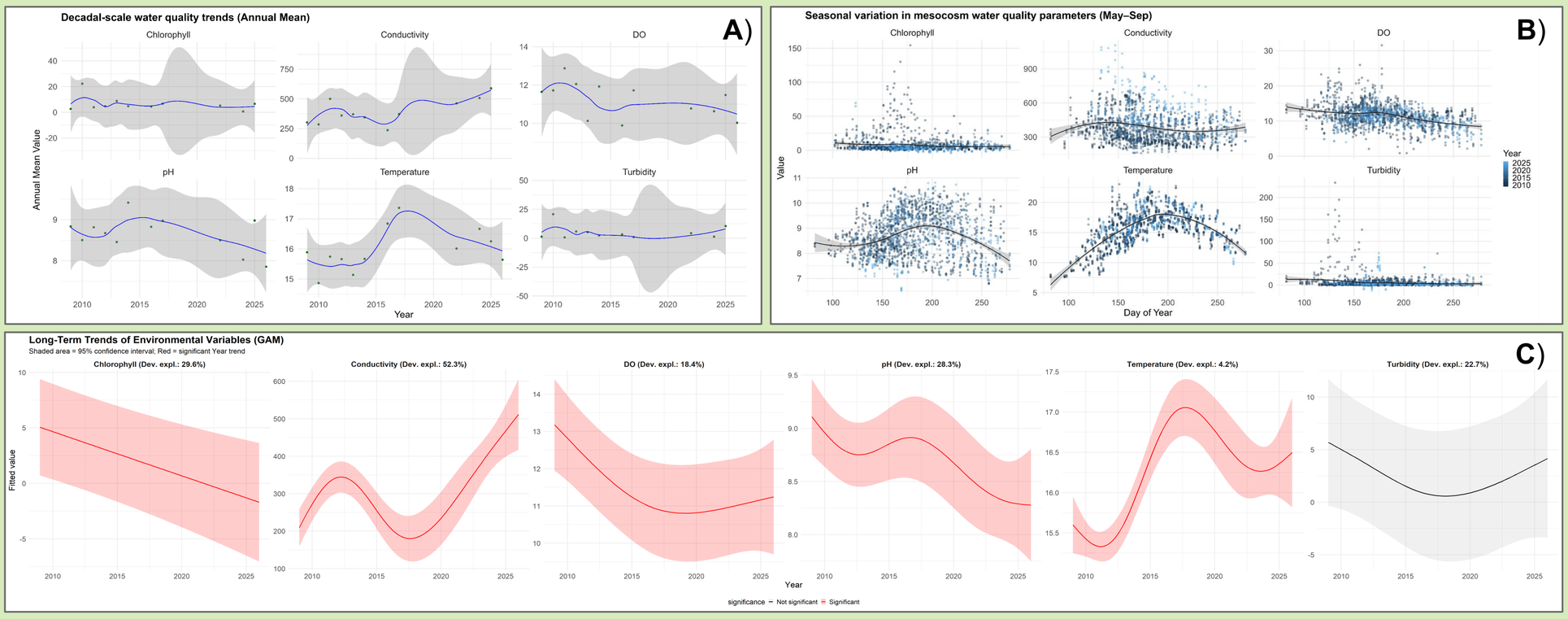

***Figure 1*:**

A) Yearly averages of 6 water quality parameters (blue points) from 16 years (2009-2025) of control data (18 aquatic mesocosm studies). LOESS (blue line, span = 0.6) highlights decadal trends (shaded area = 95% CI).

B) Same dataset plotted by day of year (blue points). LOESS (black line, span = 0.6) applied to highlight seasonal trends. (shaded area = 95% CI).

C) Long term trends modelled using Generalised Additive Models (GAMs, k = 5, fitted using REML, random effect = pond). Shaded areas represent 95% CIs. Red lines = significant temporal trends ($p < 0.05$), black lines = non-significant trends ($p > 0.05$). Explained deviation is listed for each parameter.

Figure 2: Zooplankton Community Analysis

Scan to view 3-Dimensional NMDS

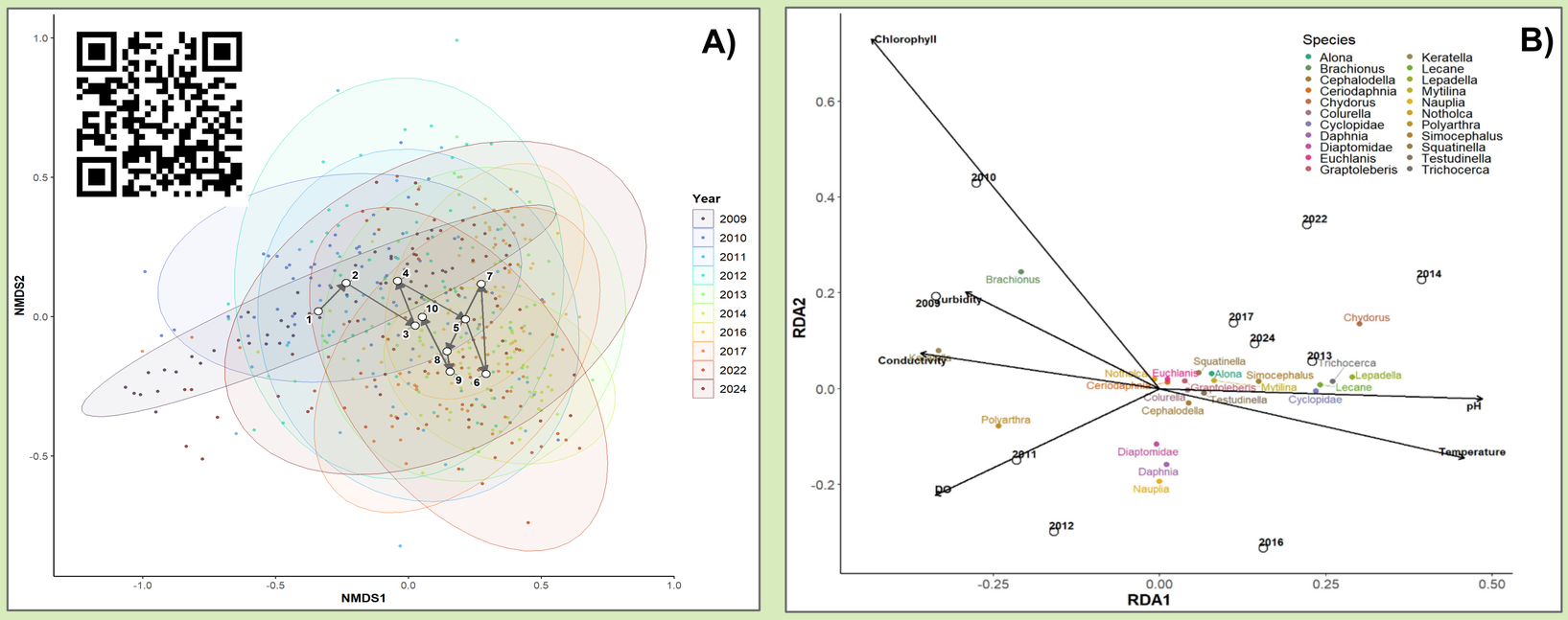

***Figure 2*: A)** NMDS (stress 0.18) of zooplankton communities (Bray-Curtis dissimilarities, Hellinger transformed, family abundance) from 15 years of aquatic mesocosm control data (17 studies). Ellipses (colour = year) represent 95% CIs. Points = position of samples (colour = year). Centroids = mean community composition for each sampled year. Grey arrows = trajectory of community changes over time. Inset QR code shows 3-dimensional trajectory of centroids. **B)** RDA triplot displaying relationships between zooplankton community composition and 6 water quality parameters (environmental variables standardised (z-scores) abundance data Hellinger transformed). Axes explained a total of 75% of constrained variance (RDA1 = 58.7%, RDA2 = 16.3%). Coloured points = individual taxa, centroids = annual mean. Arrows = environmental variables, with arrow length proportional to relationship with community composition and direction = gradient.

KEY FINDINGS:

Water Quality dynamics:

- Clear non-linear decadal trends and strong seasonality observed in some parameters (***Fig 1A-B***).
- Gam analysis (***Fig 1C***) showed non-linear increasing relationships for conductivity and temperature, non-linear decreasing relationships for pH and conductivity. Chlorophyll displayed a linear decrease.
- Turbidity was the only non-significant water-quality trend.

Zooplankton Community analysis:

- Directional shifts in centroid position imply gradual temporal shifts (***Fig 2A***).
- Significant overlap of 95% Confidence interval likely due to seasonal variation.
- Community composition significantly varied with year ($p = 0.001$).
- Year was a significant driver of variation ($p < 0.05$) in almost all families, excluding Gastropodidae, Nauplia and Synchaetidae.

Environmental Drivers:

- Environmental variables explained 16.3% of variation (75% of this represented in RDA1-2), model & axis were both significant ($p<0.03$).
- Turbidity was the only non-significant parameter ($p > 0.05$).
- RDA 1 driven by temp and pH, with Cyclopidae, Lecane and Lepadella positively associated.
- RDA 2 driven by Chlorophyll, with Brachionus positively associated, and Cladocerans and Copepods negatively associated. Conductivity was strongly associated with Keratella.

CONCLUSION:

Long term changes in water qualities, notably temperature, pH and conductivity, correspond with gradual shifts in zooplankton community composition, although significant variability implies interaction between multiple factors in place of a single dominant driver.

These analyses highlight how long-term mesocosm data can be leveraged beyond their regulatory purpose.

References:
1 EFSA PPR Panel (EFSA Panel on Plant Protection Products and their Residues) (2013). Scientific Opinion - Guidance on tiered risk assessment for plant protection products for aquatic organisms in edge-of-field surface waters. EFSA Journal 2013; 11(7): 3290.
2 Bacca, R. G., and Arnett, R. C. (1976). A limnological model for eutrophic lakes and impoundments. Battelle, Inc., Pacific Northwest Laboratories, Richland, pp. 89–95.