Disrupted growth and production periodicities of the warm-adapted copepod in Lake Biwa, Japan

Xin Liu¹, Gael Dur², Syuhei Ban¹

¹, The University of Shiga Prefecture, Japan
², Shizuoka University, Japan
Introduction

• Lake ecosystems have been considered sentinels of climate change.

• Copepods are important secondary producers that support higher trophic levels in both freshwater and marine ecosystems.

• Large-scale climate events such as climate oscillations (AO, NAO, PDO etc.) and global warming forcing on physical and chemical conditions in aquatic ecosystems might regulate zooplankton production through physiological and biochemical processes.

• Clarify the periodicities of secondary production associated with environmental parameters palys a key role to evaluate aquatic ecosystem responses to human related climate changes.
Lake Biwa: the largest and the oldest lake in Japan, water source of 14 million people in Kansai region

Environmental parameters and zooplankton samples were collected monthly from 1950s, allowed us to evaluate how the zooplanton production related to environmental changes.
Water temperature, TP and fish catch in Lake Biwa from 1960s to 2010


- Increasing 1°C
- Fish catch decreasing from 1980s
- Eutrophication
Zooplankton biomass

Species composition

Body size and biomass of zooplankton in Lake Biwa

The long-term trend of secondary production in Lake Biwa depends on water temperature? primary production? Fish predation? climate change?
Long-term trends and short-term periodicities of demographical parameters in copepod *E. japonicus*
Cluster analysis in seasonal dynamics of copepod demographic parameters

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Years</th>
<th>Type</th>
<th>Predation</th>
<th>Food Av.</th>
<th>Food Lim. (%)</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1971, 1973, 1983, 1989, 1992, 1998, 1999, 2000, 2004</td>
<td>unimodal</td>
<td>57.05 (±7.49)</td>
<td>7.48 (±0.65)</td>
<td>91.42 (±0.86)</td>
<td>14.61 (±0.22)</td>
</tr>
<tr>
<td>C2</td>
<td>1966, 1970, 1972, 1974, 1986</td>
<td>plurimodal</td>
<td>99.74 (±27.21)</td>
<td>4.19 (±0.33)</td>
<td>91.42 (±1.32)</td>
<td>13.68 (±0.20)</td>
</tr>
</tbody>
</table>
Seasonal patterns of copepod biomass: probability distributions of fish catch, food conditions and water temperature

Plurimodal seasonal pattern under high predation pressure

Plurimodal seasonal pattern under low temperature

Fig. 6. Raincloud plot showing the probability distribution and boxplot of the annual values of environmental data for the group exhibiting unimodal and plurimodal seasonal cycles. See Table 1 for the years gathered in each group. On each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers. Data points are jittered for visual clarity.

Dur, Liu et al. (2022) J Great Lakes Res.
Copepod biomass and TP or phytoplankton biomass showed different long-term trends.
The relationship between body length and environmental factors can be used to establish a predictive food model.

Phytoplankton cannot explain copepod food levels in situ, we need to establish valid food index for copepod, and evaluate the population production.

Copepods are omnivorous.

Prof. Syuhei Ban
Histgram of *E. japonicus* female body size (1971-2020)

Female body size, Skewness of size distribution, fish catch
Long-term trend of food index \( f \) of copepod in Lake Biwa

\[ f = \frac{P_{L_{\text{obs}}}}{P_{L_{\text{max}}}} \]

\( f < 1 \) indicates food limitation

Size-Based Model

\[ f = \frac{P_{L_{\text{obs}}}}{P_{L_{\text{max}}}} \] (1)

\[ P_{L_{\text{max}}} = 1.077T^{-0.0547} \] (2)

\[ g = (0.1074T - 0.8587)f - 0.09078T + 0.7556 \] (3)

\[ P_m = B_j \times g_j \times d_{mj} \times 0.447 \] (4)

\[ P_k = \sum P_{mj} (j = 1, 2, ..., 12) \] (5)
Environmental factors might affect copepod food conditions: Arctic Oscillation, wind speed, water temperature, precipitation, solar radiation, etc?

Wavelet Analysis: Oscillation periodicities of the food index (f) and Arctic Oscillation (AO)

Both copepod food index and AO showed 8-year oscillation periodicity during the past 40 years. The oscillation periodicity weakened after 1990s. Disturbed by global warming?

Wavelet & Wavelet coherence analysis: body size, growth rate, biomass, production
Remove the irregular and low frequency long-term period components using Ensemble Empirical Mode Decomposition (EEMD).

Example: copepod body size

Oscillation periodicity of copepod production disappeared after 1990s

The global climate and ecosystem experienced a regime shift after the 1980s including Lake Biwa.
Conclusions

• Disruption of the short-term cycle of *E. japonicus* resulted mainly from the interaction and strength of bottom-up and top-down control rather than temperature.

• Long-term quasi-decadal periodicities (8 years) were detected in the food index (f) and demographic parameters such as growth and production for this copepod throughout the study period.

• These long-term periodicities were highly correlated with the Arctic Oscillation, implying that long-term trends in climate could regulate copepod food availability and production.
Conclusions

- The correlation weakened after 1990, which might be due to a regime shift in the lake environment induced by the rapid warming after the mid-1980s.

- Our results support the hypothesis that aquatic ecosystems subjected to global warming are less stable because of weakened causal interactions among ecosystem components, including nutrient cycling and plankton producers.

- Global warming might now be disrupting historical periodicity in secondary production in large temperate lake.
Acknowledgments

This work was supported by grants from the Ministry of Agriculture, Forestry and Fisheries, Japan, for a research project entitled *Development of technologies for mitigation and adaptation to climate change in Agriculture, Forestry and Fisheries*, and from Grants-in-Aid for Scientific Research (18H03961) from the Japan Society for the Promotion of Science (JSPS), to S. Ban. The Japan Student Services Organization provided a Japanese government scholarship to X. Liu (2014–2016), and G. Dur was supported by a JSPS postdoctoral long-term fellowship. This work is a contribution to the FASCICLE project of the French BioAsia program.
Thank you for your attention!