**Final Publishable Summary Report for CIG PCIG14-GA-2013-630917 Acronym: ZooMix**

Biogenic turbulence or biomixing refers to the contribution of living organisms towards the mixing of waters in oceans and lakes. Our project focused on the stirring generated by *Daphnia spp.* in a small lake. This very common zooplankton species is engaged in a vertical migration (DVM) at sunset, with many organisms crossing the thermocline despite the density stratification. During the ascension they may create hydrodynamic disturbances in the lake interior where the stratification usually suppresses the vertical diffusion. While turbulence and mixing from DVM have been studied in the ocean, only theoretical and laboratory experiments have been conducted using typical lake species. Thus far, a clear picture has not emerged of the role of biomixing in lakes, thus the objectives of this project were to conduct the first ever measurements of turbulence in the thermocline induced by zooplankton in a lake environment.

During the grant, we made the first direct measurements of turbulence through migrating zooplankton in a lake, which showed a negligible increase in dissipation during the migration. Recent laboratory and numerical experiments by others since the start of this project indicate that zooplankton concentration is key if any mixing is to be expected. While very high concentrations of small zooplankton have been showed to generate mixing in the lab, we did not observe these concentrations in the field (Figure 1). Our work has shown that there is are still many remaining research questions regarding how small zooplankton swim collectively in situ before laboratory experiments can be applied to the field.

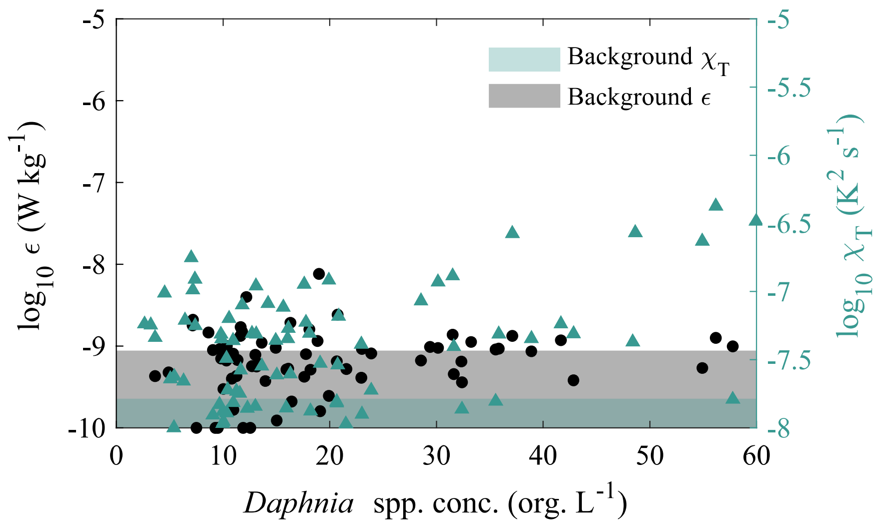


Figure 1: Turbulence as a function of Daphnia concentration (reproduced from Simoncelli et al. 2018, Aquatic Sciences)

We repeated our measurements under a variety of conditions throughout three summers and still observed the same negligible turbulence. Thus, our research trajectory led us to try and better understand the drivers of vertical migrations and give insight into the swimming hydrodynamics of Daphnia. Our extensive datasets allowed us to robustly show that temperature is a significant determinant of upward migration velocity of Daphnia (Figure 2). We also developed a new theoretical model of Daphnia sinking that incorporated the drag of the appendages that better matched observations (Figure 3). Through this, we showed that Daphnia sink at sunrise rather than swim downward.

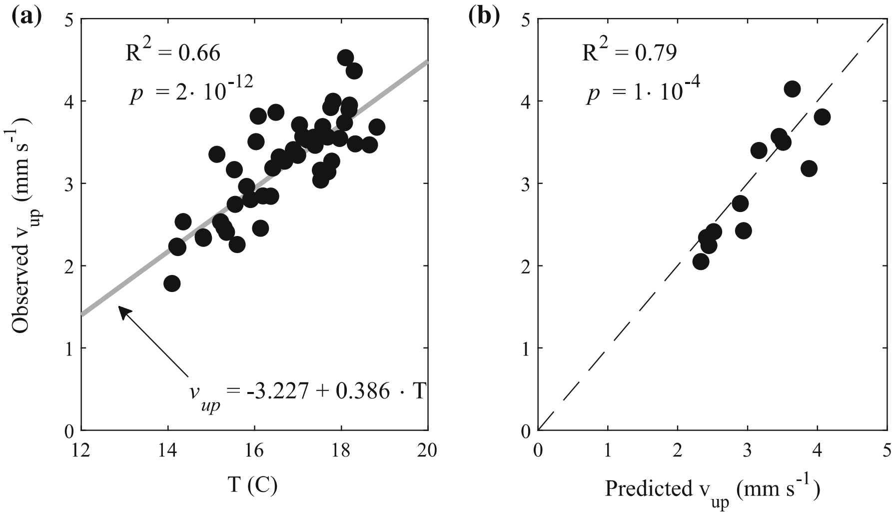


Figure 2: (a) Daphnia upward swimming velocity versus temperature, (b) observed velocity versus statistical model (reproduced from Simoncelli et al. 2018, Hydrobiologia)

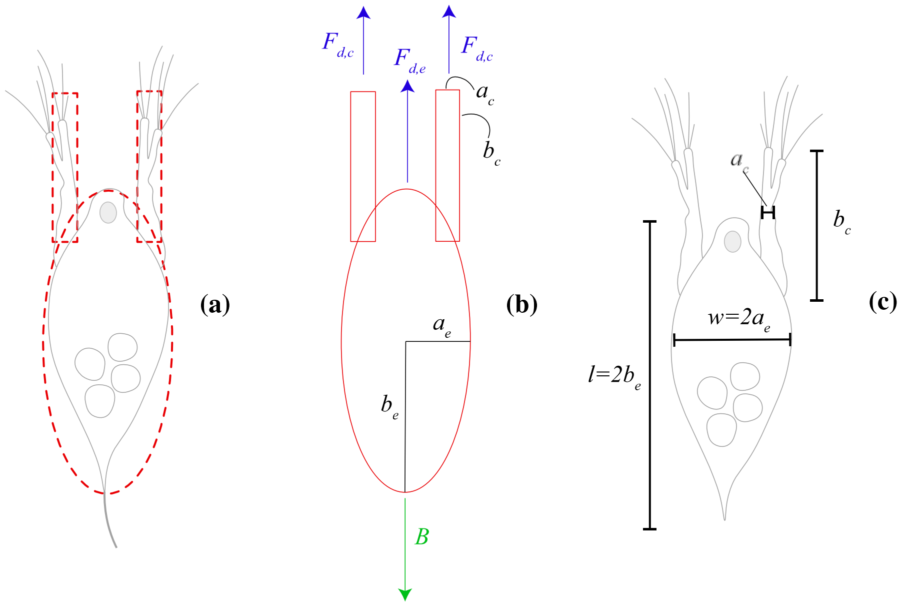


Figure 3: New model of drag forces on Daphnia that includes the appendages (reproduced from Simoncelli et al, 2018, Hydrobiologia)

This project led to the successful completion of a PhD by one student who is now continuing in research as a postdoc in Europe, and training of 6 undergraduate research assistants, 2 of whom have gone on to pursue PhDs in Europe. These results have been disseminated through peer reviewed publications and presentations at international conferences. The equipment and resources provided by this grant allowed the PI to expand their research agenda on biophysical interactions in stratified lakes (funded through the UK Royal Society and the EU Aquacosm Project) and develop a complementary research stream related to the water quality impacts of destratifying reservoirs by artificial mixing (funded by the UK Natural Environment Research Council).