Diel Vertical migration of marine organisms and the biological carbon pump

Jerome Pinti1, Tim DeVries2,3, Tommy Norin1, Camila Serra-Pompei1, Roland Proud4, David A. Siegel2,3, Thomas Kiørboe1, Colleen M. Petrik5, Ken H. Andersen1, Andrew S. Brierley2, and André W. Visser1

1Centre for Ocean Life, DTU Aqua, Technical University of Denmark, Denmark (jppi@aqua.dtu.dk)
2Department of Geography, University of California in Santa Barbara, USA
3Earth Research Institute, University of California in Santa Barbara, USA
4Pelagic Ecosystem Research Group, Gatty Marine Laboratory, School of Biology, Scottish Oceans Institute, University of St Andrews, UK
5Department of Oceanography, Texas A&M University, USA

Diel Vertical Migration (DVM) is a key feature of pelagic and mesopelagic ecosystems, mainly driven by predator-prey interactions along a time-varying vertical gradient of light. Marine organisms including meso-zooplankton and fish typically hide from visual predators at depth during daytime and migrate up at dusk to feed in productive near-surface waters during nighttime. Specific migration patterns, however, vary tremendously, for instance in terms of residency depth during day and night. In addition to environmental parameters such as light intensity and oxygen concentration, the migration pattern of each organism is intrinsically linked to the patterns of its conspecifics, its prey, and its predators through feedbacks that are hard to understand—but important to consider.

DVM not only affects trophic interactions, but also the biogeochemistry of the world's oceans. Organisms preying at the surface and actively migrating vertically transport carbon to depth, contributing to the biological carbon pump, and directly connecting surface production with mesopelagic and demersal ecosystems.

Here, we present a method based on a game-theoretic trait-based mechanistic model that enables the optimal DVM patterns for all organisms in a food-web to be computed simultaneously. The results are used to investigate the contributions of the different food-web pathways to the active component of the biological carbon pump. We apply the method to a modern pelagic food-web (comprised of meso- and macro-zooplankton, forage fish, mesopelagic fish, large pelagic fish and gelatinous organisms), shedding light on the direct effects that different trophic levels can have on the DVM behaviours of each other. The model is run on a global scale to assess the carbon export mediated by different functional groups, through fecal pellet production, carcasses sinking and respiration.

Finally, the model output is coupled to an ocean inverse circulation model to assess the carbon
sequestration potential of the different export pathways. Results indicate that the carbon sequestration mediated by fish is much more important than presently recognised in global assessments of the biological carbon pump. The work we present relates to contemporary ecosystems, but we also explain how it can be adapted to fit any pelagic food-web structure to assess the contribution of the active biological pump to the global carbon cycle in past ecosystems.