15º CONGRESSO DA ÁGUA

SURFACE EXCHANGE FLOWS IN VELA LAKE AND ITS IMPACT ON HORIZONTAL MIGRATION OF ZOOPLANKTON

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ABSTRACT

Exchange flows established in lake-wetland interfaces driven by temperature horizontal gradients and wind, directly affect lakes ecology. The interaction of thermal forcing, wind effect and drag induced by emergent vegetation are, still, poorly studied. In particular, the mixing processes driven by wind action configure a research need. A field campaign was carried out at Lake Vela (Quiaios, Portugal) to access the impact of wind on surface exchange flows. The modulation of horizontal migration patterns of freshwater zooplankters by these flows was hypothesized and a 48-h field campaign in a shallow lake was carried out for investigation. A weather station and four water temperature probes installed in a littoral-pelagic transects are continuously collecting data allowing the characterization of seasonal and diurnal variations. Superficial flow velocity was computed by Particle Tracking Velocimetry (PTV) and Particle Image Velocimetry (PIV) techniques employing images acquired by a drone equipped with a CMOS sensor camera. Zooplankton samples were collected at the sub-surface in the lake-wetland interface and the pelagic zone for further stereoscopic counting, through two diurnal cycles, every four hours. Total zooplankton abundance does not significantly differ between the interface and the pelagic zone neither during the day nor the night. The results revealed an important role of the wind on exchange flows of vegetated lakes.

Palavras-Chave: Shallow lakes; wind; temperature gradients; zooplankton migration.

1. INTRODUCTION

The Water Framework Directive places emphasis on water resources management, particularly in water quality issues and on the need to protect biodiversity and ecosystem services. The European State Members are compelled to achieve “good status” for surface water bodies by 2027. Lakes play a critical role in the landscape, providing nesting habitat for birds and foraging habitat and a source of water for many terrestrial animals, and they play a substantive role as sources and sinks of carbon and methane. Shallow lakes are characterized by complex interaction of several processes as large-scale convective direct wind impact, wind-induced circulation, non-uniform heating of the water surface in open water/ wetland interface (Bengtsson, 2012). A deep understanding of those processes is of utmost importance to secure the ecological and societal functions of shallow lakes, including zooplankton distribution patterns.

The distribution of aquatic organisms can be shaped by abiotic (passive) or biotic (internal) factors. Transport of zooplankton by passive mechanisms may occur through other animals, anthropogenic activities, wind and temperature gradients (Ermolaeva et al., 2019). Water temperature and wind induced circulation are considered dominant factors that explain spatial variations of some organisms like bacteria and plankton (Rinke et al., 2009).

This work is aimed at assessing the relative impact of water temperature horizontal gradients and wind driven shear on the circulation patterns of a shallow lake. To achieve this objective a field campaign was carried out at Lake Vela (Quiaios, Portugal) where meteorological data, water temperature, superficial flow velocities and zooplankton samples were acquired.

Lake Vela (Fig. 1, N45º05’ W08º08’) is a eutrophic freshwater shallow lake (1.5 m deep), with 70 ha of surface area, included in the Ecological European Net-Rede Natura 2000 (PTCON0055) (Abrantes et al., 2006). Lake Vela holds a permanent vegetated lane of seasonally variable width in the East bank, comprised by perennial hydrophyte grasses (Phragmites australis, Claudium mariscus, Typha latifolia) and is affected by significant wind currents, mostly North wind.

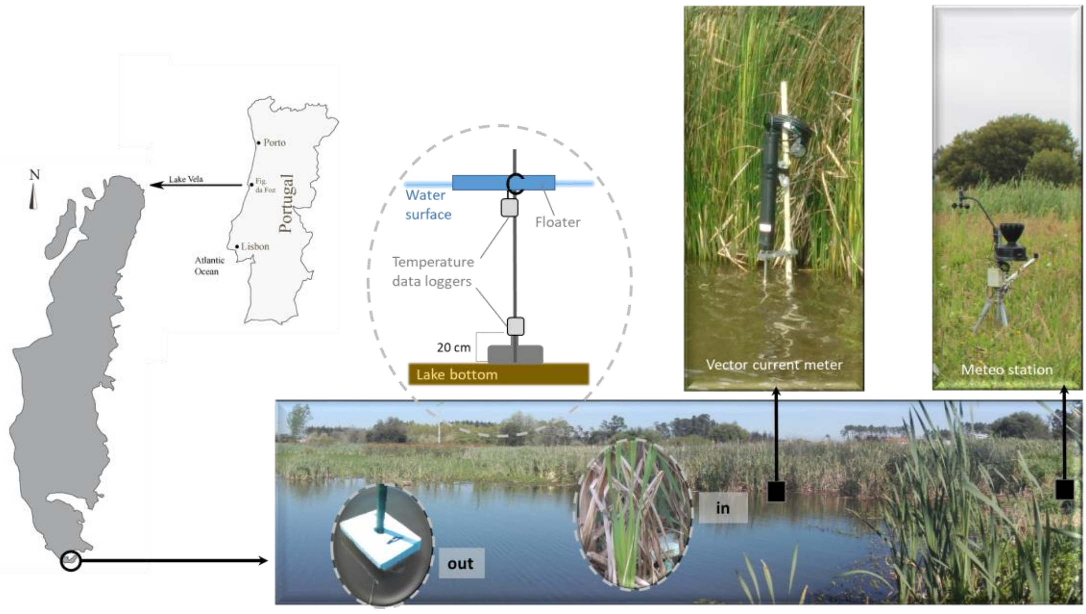

Fig. 1. Location of the Vela Lake in Portugal and location of the intrumentations in the area of study.

2. MEASUREMENTS

A Onset weather station was installed on the field site, near the lake shore. The station is composed by a S-WFC-M003 Davis® Wind Speed/Direction Smart Sensor that acquires gust, wind speed and wind direction; a S-LIB-M003 Solar Radiation Smart Sensor; a S-TMB-M002 Temperature Smart Sensor that acquires air temperature and relative humidity; a S-RGF-M002 Davis® Rain Gauge Smart Sensor; and a HOBO Micro Station data logger that registers all sensors data. The weather station is continuously collecting data every 5 minutes except during the field campaigns in which the sampling rate is increased to one sample per minute.

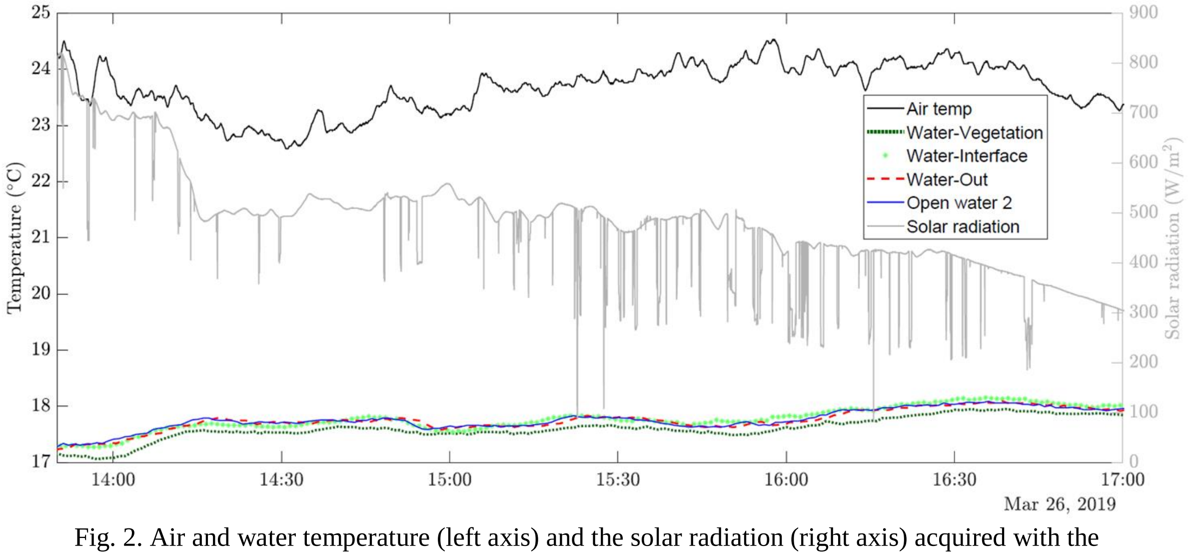

Fig. 2. Air and water temperature (left axis) and the solar radiation (right axis) acquired with the weather station and the temperature sensors.

Four HOBO MX2203 water temperature sensors were placed in a littoral-pelagic transect (two sensors in open lake, one within the wetland and one in the interface lake/wetland). The sensor were set to continuously collect temperature (one sample per minute) allowing the characterization of seasonal and diurnal variations.

Figure 2 presents air and water temperatures and solar radiation during the afternoon of the 26th March 2019.

A Nortek Vector Current Meter was employed to acquire pointwise time series of 3D velocity field within the lake. The Vector has high accuracy (0.5% of measured volume), selectable ranges from 0.01 to 7m/s, sampling rate up to 64 Hz and a sampling volume od 15 mm diameter at 15 cm distance from the probe.

A DJI Phantom 4 Pro drone equipped with a camera was employed to calculate the free surface velocity in the lake by Particle Tracking Velocimetry (PTV) technique. The camera has a 25.4 mm CMOS sensor with effective pixels of 20M; lens FOV 84º, 8.8 mm/24 mm (35 mm format equivalent) and f/2.8 to f/11; mechanical shutter speed between 8 and 1/2000 s. It allows 4K videos of 3840×2160 px^2 at 100Mbps. The drone has GPS/GLONASS satellite positioning systems and Hover Accuracy Range of ±0:5 m in vertical and ±1:5 m in horizontal. To measure superficial flow velocities, corn crackers were used as tracking particles and the principles of PTV and PIV (Particle Image Velocimetry) were employed (Patalano et al., 2017; Ferreira et al., 2018).

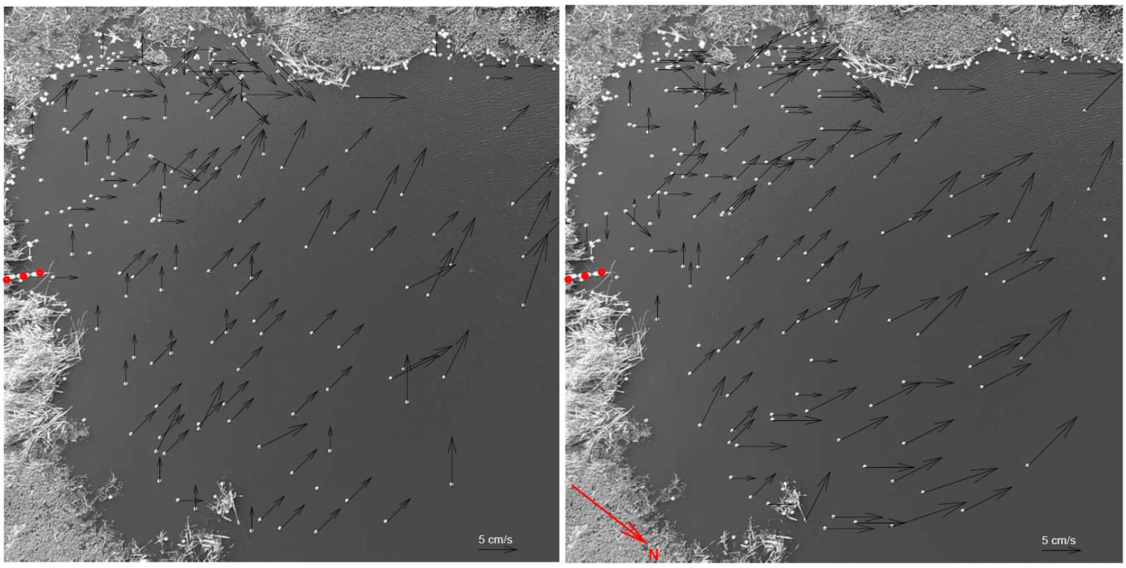

Fig. 3. Vector map of the free surface velocity of the Lake Vela at time instants 13:57:21.63 (left) and 13:57:33.30 (right).

To quantify the superficial flow on the lake, a region of the lake was seeded with corn crackers and a set of images was collected by a CMOS sensor camera mounted in a drone. The seeding particles are much lighter than water and have cylindrical shape with approximately 8:5 cm of diameter and 0:5 cm of thickness. The PTV/PIV principles to compute displacement/velocity was applied by mean of an in-house developed Matlab script. Firstly, the seeding particles are detected in each image pair. Then, a quasi-instantaneous velocity field is obtained by applying a 2D cross-correlation function for interrogation areas of 20 px centered in the particle location. To improve the correlation, the original seeding particles are replaced by artificial particles defined by a Gaussian filter. Figure 3 presents the free surface velocity vector maps overlapped on the second image of the pair for different time instants.

On July 2019, a 48-hours water sampling campaign was carried out to quantify the horizontal distribution of zooplankton. 20 L of lake water were pumped and filtered in situ through a 250-µm mesh size sieve. The sieve was then washed and the retained organisms were preserved with alcohol 70% v/v. Preserved samples were sorted under a stereoscope (Olympus modelo) and the organisms belonging to the four major zooplankter groups (Copepoda, Bosminidae, Daphnidae and Chydoridae) were counted. Aiming at correlating thermally driven surface exchange flows with the special distribution of zooplankters, Figure 4 presents temperature differences between the vegetated litoral and the pelagic zones (top) and the total number of zooplankton individuals in theses zones.

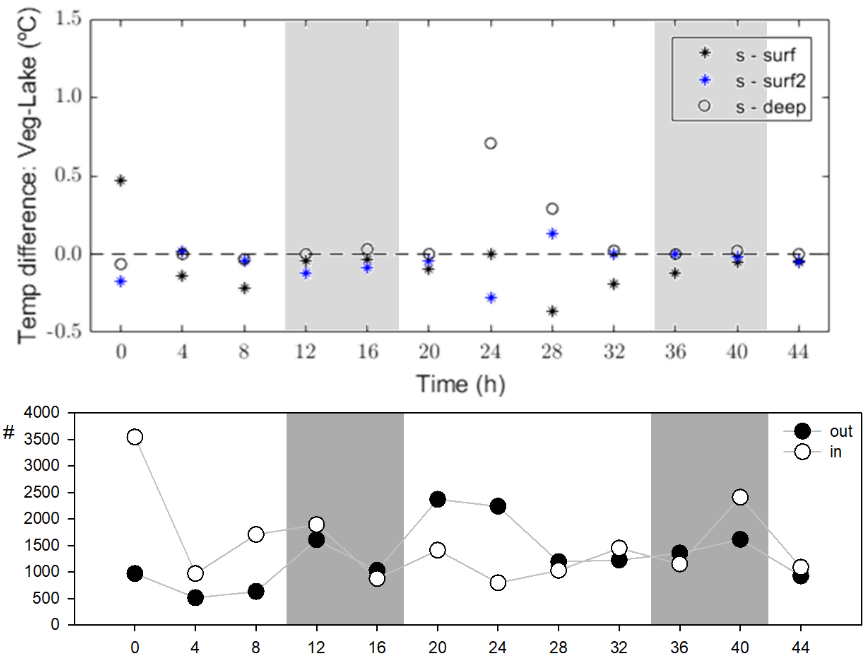

Fig. 4. Top: Temperature differences between litoral and pelagic areas. Bottom: Total number of zooplankters in litoral (in) and pelagic (out) areas.

3. CONCLUSÕES

Total zooplankton abundance does not significantly differ between the interface and the pelagic zone neither during the day nor the night. Only some changes on the zooplankton distribution is correlated with the expected thermally driven currents, what might have several causes, the effect of the wind being one. The surface flow velocities measured by the drone images have shown that the free surface water velocity correlates with the wind direction. It has also showed that the effect of the wind has canceled the expected thermally driven exchange flow from the open lake, where the water reaches warmer temperatures and thus is lighter, to the wetland where due to the shadowing effect, the water temperature is lower and therefore denser.

ACKNOWLEDGMENTS

This work was funded by national funds through Portuguese Foundation for Science and Technology (FCT) project PTDC/CTA-OHR/30561/2017. JN is funded by project PTDC/CTA-OHR/32360/2017.

REFERÊNCIAS BIBLIOGRÁFICAS

Abrantes, N., S. Antunes, M. Pereira, & F. Gonalves (2006). Seasonal succession of cladocerans and phytoplankton and their interactions in a shallow eutrophic lake. *Acta Oecologica* 29(1), 54 – 64.

Bengtsson, L. (2012). *Hydrodynamics of Very Shallow Lakes*, pp. 344–346. Dordrecht: Springer Netherlands.

Ferreira, R., S. Amaral, A. Ricardo, & A. Bento (2018). Assessing the mass flux from a breached model dam with laser imaging and large-scale piv. In *Proc.19th Int.Symp.App.Laser & Imaging Tech to Fluid Mech.*, Lisbon.

Patalano, A., C. M. Garca, & A. Rodrguez (2017). Rectification of image velocity results (river): A simple and user-friendly toolbox for large scale water surface particle image velocimetry (PIV) and particle tracking velocimetry (PTV). *Computers & Geosciences* 109, 323 – 330.

Rinke, K. et al. (2009) 'Lake-wide distributions of temperature, phytoplankton, zooplankton, and fish in the pelagic zone of a large lake', *Limnology and Oceanography*, 54(4), pp. 1306–1322.