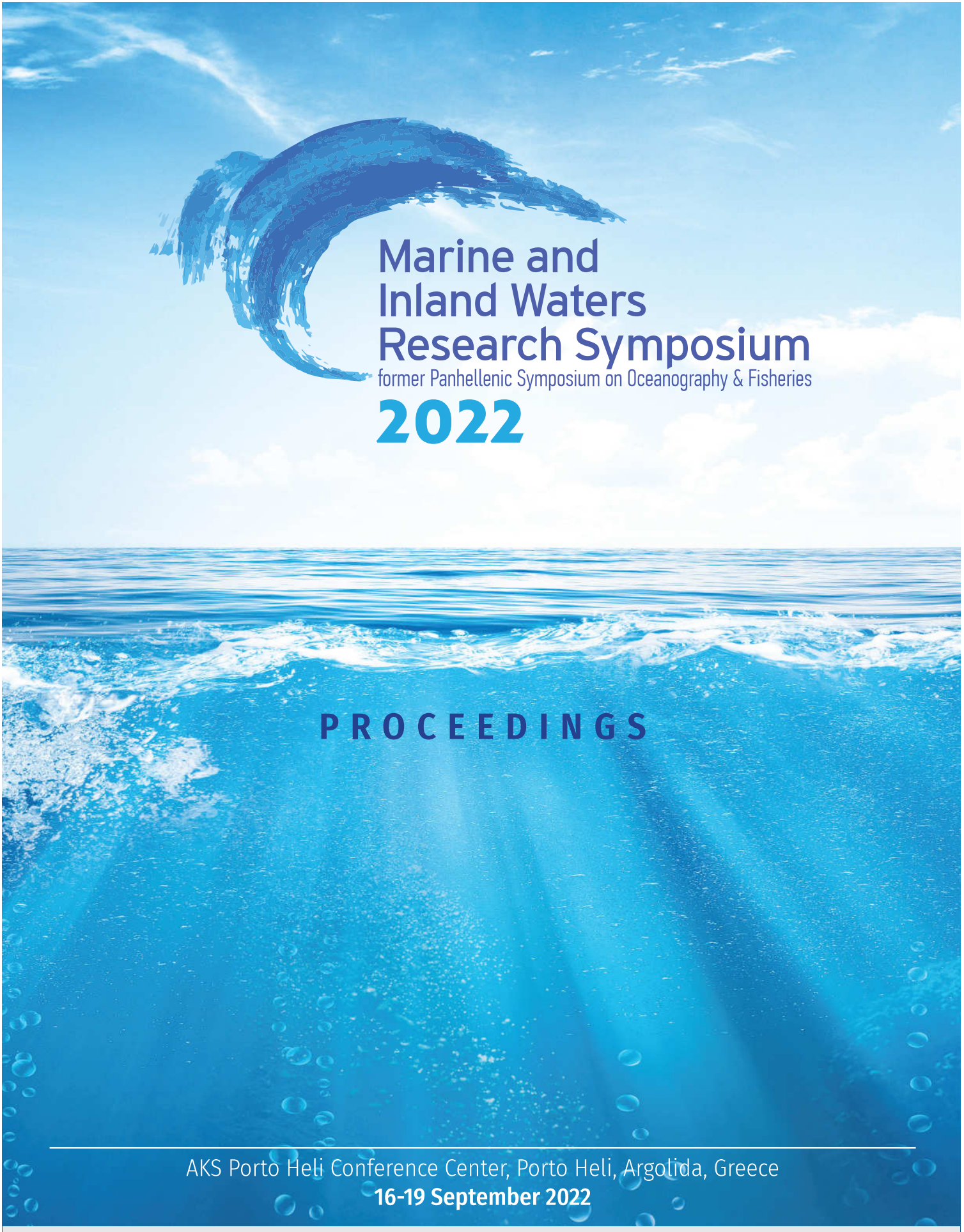

Marine and Inland Waters Research Symposium

former Panhellenic Symposium on Oceanography & Fisheries

2022

PROCEEDINGS

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INNOVATIVE QUALITY MONITORING OF INLAND WATERS IN GREECE WITH THE USE OF UNMANNED BOATS AND HYDRO-TELEMETRIC STATIONS

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Abstract

Unmanned boats and their integrated sensors have been operated from EYDAP's R&D Department since 2019 in order to evaluate this innovative cost-effective tool for environmental monitoring in surface water bodies. Current monitoring programs produce water quality data based on periodical, often spot sampling, from specific points of interest following by laboratory analysis and thus, often give an insufficient temporal picture of the water quality on catchment scale. Automatic, telemetric stations for specific parameters installed by HCMR-IMBRIW in several Greek rivers and lakes offer significant improvements in continuous, temporal monitoring. An extra tool is the application of the unmanned boats that offer high temporal and spatial coverage over specific timescales that can be focused on sites or events of interest. The aim of the present study is to highlight the importance of an improved monitoring strategy, that leads to more reliable datasets and, hence, allowing the prediction of water quality in a large area of a catchment with higher frequency than traditional sampling methods. Here, we present the spatially fluctuations of chl-a and electrical conductivity during a sampling campaign in Lake Koumondourou and Kifissos river. The analysis shows that the use of unmanned boats, using commercially available sensors, can contribute to traditional monitoring programs of inland waters, detecting in time, possible pollution from anthropogenic activities or natural processes.

Keywords: remote sensing, Chlorophyll-a, electrical conductivity, Lake Koumoundourou, Kifissos river.

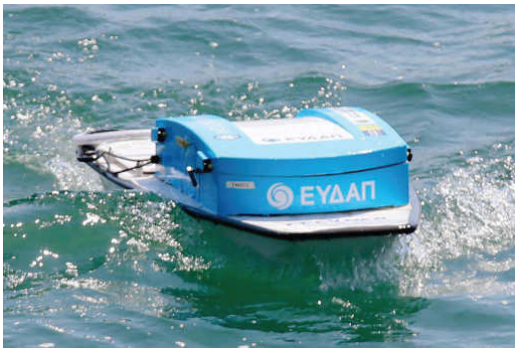
1. Introduction

Current water quality monitoring strategies are highly susceptible to discontinuous and/or unpredictable precipitation and hazardous events, such as direct discharge of sewage, combined sewer overflows or surface run-off from agricultural areas into drinking water resources or water bodies used for recreational purposes (Katsouras *et al.*, 2021). Such events occur occasionally and are usually not reflected by traditional monitoring approaches that are temporal and spatial specific, putting obstacles in assessing the water related pressures, and, thus, deriving effective countermeasures (Moustaka-Gouni *et al.*, 2019). Automatic monitoring stations offer the potential for near-real time monitoring of basic water quantity and quality parameters but they also perform point measurements and thus large investments are necessary to achieve the desirable spatial resolution (Mentzafou *et al.*, 2019). This points out the great importance of an improved monitoring strategy leading to more reliable datasets with higher spatial resolution and, hence, allowing the prediction of water quality on catchment scale as well as paving the way to water quality improvements (Mantzouki *et al.*, 2018; Warner *et al.*, 2018). As part of the activities undertaken by EYDAP and IMBRIW, the aim of the study was to demonstrate that water quality data, obtained from telemetric stations and the more novel unmanned boats, would add value to present monitoring strategies.

2. Material and Methods

2.1 Operation and description of the unmanned boats

The system architecture consists of an unmanned boat, the electronic components that allows to control the boat and to read data from the sensors (Fig. 1a). The unmanned boat can be directly tele-operated through an RC device or controlled with a tablet that provides high level instructions to the system, i.e.: monitor a pre-defined area using autonomous navigation (Steccanella *et al.,* 2019). The data are streamed online to a cloud-based information system (Knutz, 2020). Data stored in the cloud-based information system can be downloaded or visualized via a web-based application. Moreover, data can be visualized during the data collection campaign via a mobile application (Bloisi, 2018; Calisi, 2018). For the visualization of the results, a specific color pattern is followed, which includes the colors Blue, Green, Yellow, Orange and Red (indicating increasing values). The unmanned boat is equipped with sensors for standard parameters monitoring such as Dissolved Oxygen (DO), Temperature (T), pH, Electrical Conductivity (EC) and Chlorophyll–a (Chl–a).

a) 

b) 

Fig. 1: a) Boat equipped with the basic sensor Kit, **b)** Hydro-telemetric station at Koumoundourou lake.

2.2 Hydro-telemetric stations

The Institute of Marine Biological Resources and Inland Waters (IMBRIW) of the Hellenic Centre for Marine Research (HCMR) has developed a network of automatic telemetric stations in lakes and rivers of Greece (https://hydro-stations.hcmr.gr/). Two of these stations have been installed in Koumoundourou lake and Kifissos estuaries and provide high-frequency information concerning water level, pH, EC, T, DO, and ORP, and at Koumoundourou lake also salinity (Table 1).

Table 1. Automatic telemetric stations of IMBRIW -HCMR.

Station	Latitude	Longitude	Altitude	Installation date	Site
Koumoundourou lake	38.0235	23.6018	0.83	28/03/2011	https://hydro-stations.hcmr.gr/koumoundourou-station-koumoundourou-lake/
Kifissos estuaries	37.9472	23.6727	3.35	15/07/2020	https://hydro-stations.hcmr.gr/kifissos_ekv-station/

2.3 Study areas

The campaign with unmanned boats in Lake Koumoundourou took place on 28th May 2019. The lake is located in Attica, close to the municipalities of Elefsis and Aspropyrgos, the main industrial area of Athens. It is a lagoon with mean depth 3.5 m, as it lies upon the sea level, very close to the coasts of the Elefsina Bay. Kifissos River is the main river of Attica region and its last part flows parallel or under the highway 1 linking Athens and Thessaloniki until it reaches the Faliro Bay in the Saronic Gulf. On 16th of

July 2020, a campaign was organized by EYDAP and IMBRIW of the Hellenic Centre for Marine Research (HCMR).

3. Results

3.1 Lake Koumoundourou

Within an hour, the unmanned boats covered much of the inner perimeter of the lake. The concentration of Chl-a ranged from 10.0 to 17.5 μg/l and was elevated in the northeast part of the lake, north of the gate (Figure 2a), probably due to the circulation of water in this direction and the influx of groundwater (Katsouras *et al.*, 2020). The conductivity ranged from 2800 to 3050 μS/cm (Fig. 2b) with its values continuing the steady decreasing trend recorded by HCMR studies from 1984 until today (Dimitriou *et al.*, 2012; Kousouris, 2014; Mentzafou *et al.*, 2016). On 28/05/2019 the telemetric station of Koumoundourou Lake recorded 10820 μS/cm. It should be noted that the monitoring sensors of the telemetric station have been installed near the lake bottom, while the sampling conducted by unmanned boats is surficial. This may explain the difference in the recorded values since the lake's bottom is below the sea level and is mostly affected by seawater while the freshwater coming from springs at the periphery of the lake forms a surface layer which is separated from the underneath saltwater due to their density difference. The maximum values were measured in northeast, indicating a small inflow of seawater mixing through the underground inlets.

Fig. 2: a) Chl-a and b) Conductivity in Lake Koumoundourou, 28/05/2019.

3.2 Kifissos river

During the campaign, the unmanned boat covered almost 2 km under the highway, reaching the mixing zone of the river with the sea, identifying interesting profiles of the physicochemical parameters that were monitored. Chl-a concentrations ranged from 2.0 to 15 μg/l (mean 5.7 μg/l), while two high groups of chlorophyll concentrations were found upstream, the first near Piraeus Avenue and the second near lines of the Electric Urban Railway ISAP (maximum value 15 μg/l). The concentration of conductivity ranged from 1400 μS/cm to 3500 μS/cm, indicating a significant inflow of the sea front. On 24/07/2020, few days after the Kifissos estuaries telemetric station installation and full function, EC was reported to be 3369 μS/cm which is very close to the recorded values with the unmanned boat.

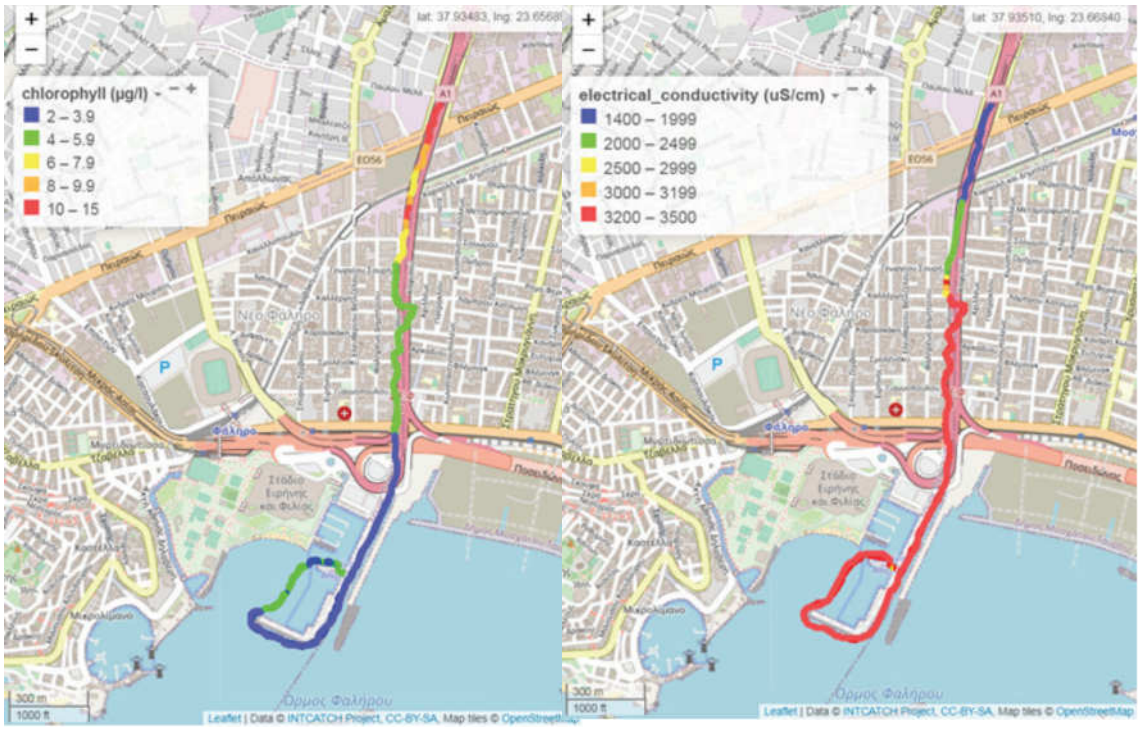


Fig. 3: a) Chl-a and b) Conductivity in Kifissos river, 16/07/2020.

4. Discussion/Conclusion

As reflected by the results obtained by the unmanned boats and the telemetric stations there is a clear trend of steady decrease of conductivity in Lake Koumoundourou while the eutrophic state of the ecosystem is also in accordance with previous studies (Dimitriou *et al.*, 2012; Kousouris, 2014; Mentzafou *et al.*, 2016). Additionally, the application of unmanned boats in Kifissos River provided valuable insights into the distribution of conductivity and chl-a related to environmental pressures.

The use of unmanned boats in parallel with hydro-telemetric stations achieves a thorough monitoring coverage both in space and in real-time providing significantly higher amount of water quality data, even from inaccessible sampling areas, without requiring costly monitoring schemes and subsequently raising alerts in time to take action to protect end users. The systematic, full scale application of unmanned boats and hydro-telemetric stations could support the investigative monitoring programs and represent a valid rapid tool/approach in case of emergencies (e.g., in relation to climate changes events such as flooding). The vision is that EYDAP and HCMR-IMBRIW will provide a service to authorities and organizations interested in assessing water quality in relation to catchment management and the traditional sampling protocols.

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