Achieving the first eDNA sampler embedded in a micro-unmanned underwater vehicle

Luc SIMON, SEABER SAS, Lorient, FRANCE

ABSTRACT

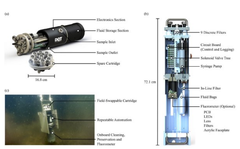
Monitoring of biodiversity requires regular sampling, often in off-shore locations and underwater.
At present, large-scale sampling and monitoring of marine habitats and organisms requires the deployment of major campaigns and resources, including boats, divers, lifting equipment and specialized operators.Environmental DNA (eDNA) sampling, i.e. the DNA traces left by all living organisms in their direct environment, is carried out by transects of standardized water sampling/filtration pairs on the surface, or by divers. The bathymetric limits of these methods are between 0 m and 60 m depth, which reduces the range of results. It should be noted that the use of divers to carry out these samplings is increasingly being ruled out, particularly by industrial companies, due to the cost of such dives and the danger to operators.Moreover in offshore environments a high quantity of cells, by gravity are encountered in greater concentration encountered close to the sediment core. In addition some species whether rare, protected or invasive are encountered on the seabed.

A micro-underwater vehicle carrying eDNA sampler:
This paper will present the results of co-development of the first micro-UUV that carries a peristaltic pump for eDNA – YUCO-eDNA micro-UUV is 300 meter depth capable. Given the dimensions of the UUV, 1 meter long and less than 10kg with 12cm diameter various challenges were to be faced. First, the pump interference with the AUV's inertial navigation, second size against pump capacity with objective to reach 60 liters of water pumped in salt water and 30 liters in fresh water. And finally optimizing pumping management with development of flow-meter in order is essential to know precisely the number of liters of water filtered and implementing pumping management into UUV mission planner.

INTRODUCTION

For many disciplines, measurements in lakes and coastal environments call for a combination of fixed and mobile instrumentation. Where fixed stations enable monitoring over long periods, mobile measurement solutions enable data from fixed stations to be complemented, spatialized and validated.
The advantages of micro-UUVs are manyfold. On the one hand, it considerably reduces the resources required for launching and recovery, and on the other, the low cost of the technology means that a fleet of micro-UUVs can be deployed in the same area, equipped with different sensors and combining all type of sensing methodologies acoustic, imaging, physico-chemical, etc.
The same is true for DNA, but until now there have been few fixed solutions, and even fewer mobile ROV or AUV solutions, none of which are able to survey the seabed at great depths and in close proximity to the seabed.
In fact, in most cases, for reasons of cost and complexity, most mobile measurements carried out on the surface or at depth require human intervention, mainly by divers in charge of sampling, which considerably increases the risk of measurement contamination.

eDNA sampling solutions we found were not fully matching our objectives[1][2]so we opted to develop a dedicated sampler



DOT eDNA sampler, submersible to 50meters of depth with 16cm diamter, 70cm long including auto-cleaning system for long term monitoring.

The sub-surface automated environmental DNA (eDNA) sampler (SASe) submersible to 55 meters of depth.

ViGiLife operator carrying out a surface transect.

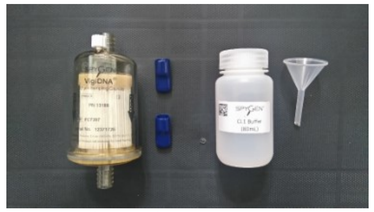
Developments of static autonomous eDNA samplers – even the most recent ones, presented two main limitations that prevented them of being integrated on a micro-UUV platform for lake and coastal waters. First the size factor and then the water depth limitations at maximum 60meters depth. We want to achive a mobile solution that can perform mobile transect close to the bottom and have best accumulation of data at depth not yet reached.
This DNA sampler must be able to be carried on board of an underwater mini-drone - YUCO - and withstand 300 meters of immersion.The YUCO-eDNA shall be capable of filtering 50 liters of water and preserving the eDNA, which will then be extracted and analyzed by metabarcoding to identify fish and crustacean taxa.

Main challenges:
- **300meters depth rated**
- **Compact and fit in a 12cm diamter**
- **Pumping capacity >50L**
- **Preventing contamination of the filter**
- **Low impact on UUV navigation accuracy**

MATERIAL AND METHODOLOGY

The eDNA filtration kit

The VigiDNA-YUCO filtration kit, used in conjunction with the YUCO eDNA sampler, is designed for the collection and analysis of environmental DNA (eDNA) samples. The kit consists of a sterile capsule containing a membrane with a porosity of either .2 µm for marine waters or .45 µm for freshwater and estuaries. This allows for the filtration of large volumes of water to capture DNA.After filtration, the capsule is filled with CL1 buffer solution to preserve the DNA at ambient temperature until it can be analyzed in the laboratory. The VigiDNA-AUV tubing kit includes two tubing systems, one on each side of the filtration capsule, which prevent macroparticles from entering and allow for easy connection to a flowmeter.
It is recommended to collect duplicate samples at each sampling station to increase chances of detecting rare species.



ViGi-Life filter 10cm long - 8cm diameter

The micro-UUV platform and wet-payload section

The YUCO-CARRIER is a micro-UUV platform of a length of 98 cm, body diameter of 12 cm, weight in air of 8 kg, depth rating of 300 m, speed range between 3 to 6 knots, endurance of 10 hours at 3 knots or 6 hours at 4 knots with a Li-Ion battery. The navigation accuracy is within ±2% distance traveled with DVL (Doppler Velocity Logger). The YUCO-CARRIER wet-section allows for flexible implementation of waterproof sondes or sensors. One option includes a DVL to compensate for current, improve positioning, and maintain altitude from the sea floor.
The challenge was to fit a complete sampling system, including both the pump system and the DNA filter, into a wet-section of max 50cm long and 12cm in diameter. It must also allow easy access to the filter and its replacement, while minimizing the risk of contamination. The whole system had to be able to withstand 300 meters of immersion, and be powered and controlled by the YUCO, while minimizing the impact on its navigation.
Faced with the challenge of immersion depth, numerous pump models were tested and developed. In the end, a peristaltic model proved to be the most balanced in terms of size/energy consumption/performance.
The pump is located in the most forward part of the drone, away from the navigation sensors and in particular the inertial unit inside the YUCO's central section.
In the middle is a space 8cm in diameter and around 10cm long, where the filter can be installed. Protected by an external cover. The water inlet at the top is protected by a strainer to prevent clogging of the pump.
The whole unit is connected to the YUCO dry-section, which controls pump start and stop.

YUCO-Carrier dry-section

eDNA filter inside opened wet-nose section for YUCO-eDNA

Installing a second filter inside the YUCO-eDNA nose section
picture credits - IUEM - UBO, Brest

YUCO-eDNA and SEACOMM UHF hand-held radio command unit.
pticure credtis, MARBEC Institute, Montpelier.

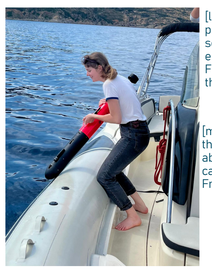
Filling the filter with CL1 buffer solution from ViGiLife.
picture credits - IUEM - UBO Brest

Planning and running the micro-UUV mission

A YUCO-eDNA flight mission is programmed upstream on a dedicated YUCO software interface. The SEAPLAN interface makes programming easy, even for first-time users. An autonomy of 10 hours at 4 knots makes it possible to measure in remote areas. Once deployed, the YUCO arrives at the given position and depth and performs a measurement transect, which can be either longitudinal or circles around a given point. Thanks to its inertial unit, on-board sensors and DVL, the YUCO-eDNA is able to maintain a distance close to the seabed, while navigating with precision even in areas with weak currents.

SEAPLAN mission planner interface

Deploying and recovering the YUCO-eDNA micro-UUV



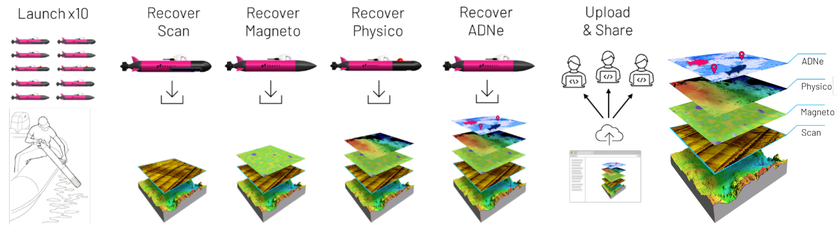
[left-side picture] Operator performing the arming sequence of the YUCO-eDNA prior to launching. Following LED indicators in the mast

[middle picture] Launching the YUCO from a small boat above 200meter depth canyon in Calvi bay area, France.

[right-side picture] Cheking the data from 2 x YUCC-eDNA, 1 x YUCO-CTD and a YUCO-SCAN micro-UUV fleet deployed together.

CONCLUSION

The development of the pump system has been successfully completed, and the first measurements both in the Atlantic Bay and Mediterranean sea canyon respectively at a depths of 30meters and 200meters in an underwater have been conclusive. The measured data will be processed in June 2024.
To our knowledge, YUCO eDNA is the first micro autonomous platform ever developed with an eDNA sampler
As for improvements, some new capabilities of the eDNA pump section of the YUCO are considered in particular in order to monitor water quantity actually pumped, such as flowmeter. Interoperability with other eDNA filters can also be considered.



GOING FURTHER

It is now possible to think about fleets of 10 AUVs, each micro-UUV covering a dedicated mission of up to 50km distance range, eDNA, Sonar Scanning, Imagery, Magnetometer, etc.
By combining data from specialized platforms, mission costs can be minimized while data sets can be enhanced.
Aonther objective is to develop an online service with a web interface for pooling and sharing georeferenced oceanographic data from AUVs. To guarantee access to this data for a greater number of people and organizations, it will be an Open Data business model.

REFERENCES

[1] Truelove, N.K., N.V. Patin, M. Min, K.J. Pitz, C.M. Preston, K.M. Yamahara, Y. Zhang, B. Raanan, B. Kieft, B. Hobson, L.R. Thompson, K.D. Goodwin, and F.P. Chavez (2022). Expanding the temporal and spatial scales of environmental DNA research with autonomous sampling. Environmental DNA. May 20224(373), DOI:10.1002/edn3.299. LicenseCC BY 4.0
[2] Hendricks, A., Mackie, C.M., Luy, E. et al. Compact and automated eDNA sampler for in situ monitoring of marine environments. Sci Rep 13, 5210 (2023). https://doi.org/10.1038/s41598-023-32310-3
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