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JERICO-S3 MILESTONE

Joint European Research Infrastructure network for Coastal Observatory
Science, Services, Sustainability

MS#, WP# and full title	JERICO-S3 MS.26 - WP5 - "Considerations for SOP development of a WASP to be provided to WP7"
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→ Please specify the type of milestone:

- Report after a workshop or a meeting (TEMPLATE A)
- Report after a specific action (TEMPLATE B) (test, diagnostic, implementation,...)
- Document (TEMPLATE B) (guidelines,...)
- Other (TEMPLATE B) (to specify) TABLE

Diffusion list

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TABLE OF CONTENT

TABLE OF CONTENT	1
A) TEMPLATE B - Other cases (not a workshop or meeting report)	2
1. B - Objectives	2
2. B and implementation process	2
3. B - Main report	2
4. B - Conclusion	10
4.1. Synthesis of main conclusion	10
4.2. Next steps (work plan)	10



A) TEMPLATE B - Other cases (not a workshop or meeting report)

1.B - Objectives

To compile a table with the existing automated DNA samplers, so that a diagnostic of the potential and drawbacks of each type can be drawn.

2.B and implementation process

A bibliographic search was performed to identify these scientific publications reporting development and/of use of automatic DNA samplers and analysis devices.

3.B - Main report

(see table in next page)



Paper / link	Year	Institute	Type of study	Organisms targeted	Autonomous sampling equipment / device	Sampling capacity	In-device storage	Molecular profiling or biosensors on device	Device readiness and use in monitoring	In-lab analysis	Summary of results
Jones et al. (2008) A robotic molecular method for in situ detection of marine invertebrate larvae. https://doi.org/10.1111/j.1471-8286.2007.02021.x	2008	MBARI	Larvae monitoring proof of concept	Invertebrate spp.	Moored ESP	Continuous	-	SHA for 5 invertebrate spp.	ESP commercially available	Validation	SHA profiles validated by lab-based assays
Scholin et al. (2009) Remote Detection of Marine Microbes, Small Invertebrates, Harmful Algae, and Biotoxins using the Environmental Sample Processor (ESP). <i>Oceanography</i> . https://doi.org/10.5670/oceanog.2009.46	2009	MBARI	Technical development	(depends on configuration)	1G? and Deep ESP	Varies with specs	RNALater	SHA and ELISA	ESP commercially available (see above)	-	
Preston et al. (2011) Underwater Application of Quantitative PCR on an Ocean Mooring. <i>PLoS ONE</i> . https://doi.org/10.1371/journal.pone.0022522	2011	MBARI	Technical development / Proof of Concept	Prokaryotic (total RuBisCo and Synechococcus)	1G? ESP. Moored	Here RT monitoring for 28 days every 12 minutes with qPCR. 1L filtered and 0.5 mL lysate used for	(samples for Ottesen et al collected in same deployment)	DNA extraction and RT-qPCR (Proof of concept). Also nutrient sensor and fluorometer	ESP commercially available (but likely not RT-qPCR module, developed at Lawrence Livermore Nat Lab.	-	First successful proof of concept of DNA extraction and RT-qPCR underwater, using algal bloom in Monterey Bay



						extractio n					
Ottesen et al. (2011) Metatranscriptomic analysis of autonomously collected and preserved marine bacterioplankton. ISMEJ. http://doi.org/10.1038/ismej.2011.70	2011	MIT (MA, USA)	Metatranscriptomic time series (weekly)	Prokaryotic diversity	1G?-ESP from MBARI. Moored	5 filtered samples	RNALater	Not used	ESP commercially available	Metatranscriptomics	Temporal variation of plankton metatranscriptome
Pargett et al. (2013) Deep water instrument for microbial identification, quantification, and archiving. Proceedings of 2013 OCEANS - San Diego. https://doi.org/10.23919/OCEANS.2013.6741066	2013	MBARI	Technical development / Proof of Concept	Prokaryotic spp. and total abundance	Deep-ESP (benthic lander)	Deep-sea version of ESP operating to 4000m. Filtering and on-device molecular assays	Not specified	RT-qPCR (?) and SHA	Developed in-house. Research use only (so far?)	-	Deployed at Axial Seamount Hydrothermal Emissions Study (ASHES) and used for sample collection an on-device assays (unclear which)
Seegers et al. (2015) Subsurface seeding of surface harmful algal blooms observed through the integration of autonomous gliders, moored environmental sample processors, and satellite remote sensing in southern California. Limnol Oceanogr. https://doi.org/10.1002/lno.10082	2015	UCLA and MBARI collaboration	Temporal monitoring of algal blooms / Proof of concept	HAB spp.	Moored ESPs at 10m depth, AUV monitoring of chlorophyll in 4D, and satellite	2 ESPs used for continuous monitoring	.	SHA and ELISA	Commercially available ESPs (MBARI) and AUVs used	-	Indicated importance of subsurface population st to source for "seeding" surface Pseudo-



					remote sensing						nitzschia HABs in S California.
Pargett et al. (2016) Development of a mobile ecogenomic sensor. Proceedings of OCEANS 2015 - MTS/IEEE Washington. https://doi.org/10.23919/OCEANS.2015.7404361	2016	MBARI	Technical development	(depends on configuration)	2G-ESP	Continuous RT for up to 3 month, max depth 50m	100+ pucks but only 3 for storing filters (?)	SHA and Immunoserbent assays (cELISA; for toxins) w ready to use assays for specific HABs	Commercially available from McLane Labs and used in routine monitoring in the US: https://mclanelabs.com/environmental-sample-processor/	-	-
Yamahara (2019) In situ Autonomous Acquisition and Preservation of Marine Environmental DNA Using an Autonomous Underwater Vehicle. Front Mar Sci. https://doi.org/10.3389/fmars.2019.00373	2019	MBARI	Benchmarking of eDNA filter preservation in ESP	Range of microbial to macro (fish) spp.	3G-ESP mounted on LR-AUV	15 x 1L ESP samples (1h each)	RNA Later	Not used	3G-ESP still not commercial (?)	qPCR of ESP and traditionally collected samples	No significant differences in eDNA densities observed between ESP and traditionally collected
Ribeiro et al. (2019) Development of an autonomous biosampler to capture in situ aquatic microbiomes. PLoS ONE, https://doi.org/10.1371/journal.pone.0216882	2019	Portugese consortium: CIIMAR, INESC TEC,	Technical development and proof of concept	Prokaryotic and phytoplankton	eDNA sampling by pumping and filtering with the developed IS-ABS field prototype	2L samples. Distinct size fractions. Unclear how many	Unclear	No	In development	Metabarcoding with both autonomously and manually	



		and others				samples (0.2 uM or custom)				collected sample	
Zhang et al. (2020) Persistent Sampling of Vertically Migrating Biological Layers by an Autonomous Underwater Vehicle Within the Beam of a Seabed-Mounted Echosounder. IEE J Ocean Eng. https://doi.org/10.1109/JOE.2020.2982811	2020	MBARI	Proof of concept of acoustics guided eDNA sampling	Invertebrates	3G ESP mounted on LR-AUV	24 samples taken (out of 60)	RNALater	acoustic modem	3G-ESP still not commercial (?)		
Hansen et al. (2020) Remote, autonomous real-time monitoring of environmental DNA from commercial fish. Sci Rep, https://doi.org/10.1038/s41598-020-70206-8	2020	DTU Aqua (Denmark)	Evaluation of ESP monitoring of fish	4x commercial fish spp.	2G-ESP on land, with pump, in large mesocosm	Continuous RT, 3x1L samples @ .2 uM (may be too little vol.)	-	RT-qPCR	ESP commercially available	qPCR validation	Only the most abundant species (mackerel) was detected consistently with enough accuracy (not only due to ESP)
Sepulveda et al. (2020) Robotic environmental DNA bio-surveillance of freshwater health. Sci Rep, https://www.nature.com/articles/s41598-020-71304-3	2020	US Geol. Survey	Proof of concept for freshwater	Pathogen and invasive fish spp.	2G (?) ESP on land with pump	1L samples	RNALater	-	ESP commercially available	qPCR (from stored samples instead of on ESP. Why?)	Detects equally well but not better in spite of more samples so less sensitive. Still advantageous due to



											reduced effort. A later article also takes into account env parameters and eDNA persistence / distribution modelling
Knapik et al. (2020) Metatranscriptomic Analysis of Oil-Exposed Seawater Bacterial Communities Archived by an ESP. Microorganisms. https://www.mdpi.com/2076-2607/8/5/744	2020	NORCE (Norway)	Mesocosm / indicator identification	env. MRNA	2x 2GESP w oil exposure mesocosm	7x 0.7L samples @ .2 uM	RNALater	-	ESP commercially available	Metatranscriptomics and 16S metabarcoding	
Tang et al. (2020) New insights into the distributions of nitrogen fixation and diazotrophs revealed by high-resolution sensing and sampling methods. The ISME journal. Doi: 10.1038/s41396-020-0703-6	2020	National Oceanography Centre (NOC)	Description of distribution of nitrogen fixation and diazotrophs	Prokaryotes	Robotic Cartridge Sampling Instrument —RoCSI	High-frequency filtering of between 1.5-4L of seawater	RNALater		Don't know if it is sold. It is being used in the frame of iAtlantic and TechOceans projects.	RT-qPCR and metabarcoding	



<p>Zhang et al. (2021) A system of coordinated autonomous robots for Lagrangian studies of microbes in the oceanic deep chlorophyll maximum. Science Robotics. http://doi.org/10.1126/scirobotics.abb9138</p>	2021	MBARI	Multi-robot monitoring system proof of concept	Prokaryotic diversity	LR-AUV ("Aku") w 3G-ESP for DCM sample collection at 260m	0.2 + 0.45 +5 uL filters (1.6L during 1h)	RNALater	ChIA, nutrients	3G-ESP still not commercial (?)	Metabarcoding	"Deployed in the N Pacific Ocean within the core of a cyclonic eddy, this coordinated system autonomously captured fundamental characteristics of the in situ DCM microbial community in a manner not possible previously"
<p>Moore et al. (2021) An Autonomous Platform for Near Real-Time Surveillance of Harmful Algae and Their Toxins in Dynamic Coastal Shelf Environments. J Mar Sci Eng. https://doi.org/10.3390/jmse9030336</p>	2021	MBARI, NOAA, etc.	HAB monitoring proof of concept	HAB spp.	Moored ESP	Continuous (up to 7 weeks)	.	SHA: 7 spp. Of HABs	ESP commercially available	-	Possible connection bloom formation – nutrients-wind-forced coastal-trapped waves.



Formel et al. (2021) Subsurface automated samplers for eDNA (SASe) for biological monitoring and research. HardwareX. https://doi.org/10.1016/j.ohx.2021.e00239	2021	NOAA, Uni. Of Miami, Mississippi State Uni.	Technical specs for automated open source low cost water sampler	(sampling only)	eDNA sampling by pumping and filtering	Down to 50 m (shallow only) and up to 4 samples but for a price of <300€	DNAgard	No	Freely available speces (but not built?)	qPCR, dPCR, metabarcoding ...	-
Flanigan et al. (2021) Proc from OCEANS 2021 San Diego, https://doi.org/10.23919/OCEANS44145.2021.9705708	2021	SeaSatellites (USA), Scripps institute	Technical development	(depends on configuration)	Programmable surface water AUV with solar power	6 individual pumps, for one sample each. Does not filter but collects up to 1L/sample	No	Not currently	Commercially available (or soon) from SeaSats	Both filtering and molecular	-
Yoerger et al. (2021) A hybrid underwater robot for multidisciplinary investigation of the ocean twilight zone. Sci Robotics. https://doi.org/10.1126/scirobotics.abe1901	2021	Woods Hole, MBARI, Stanford	Technical development report for mesopelagic AUV. ROV for positioning	(depends on configuration)	eDNA sampling by pumping and filtering	Down to 1000 m depth able to track diel migrators. Up to 12 samples	RNALater?	-	In development	-	https://www.whoi.edu/what-we-do/explore/underwater-vehicles/a-uvs/mesobot/
Truelove et al. (2022) Expanding the temporal and spatial scales of environmental DNA research with autonomous sampling. Env DNA. https://doi.org/10.1002/edn3.299	2022	MBARI (CA, USA)	Proof of concept / benchmarking	Microbial to macro (fish) diversity	ESP (3G-ESP) mounted on long range AUV (Tethys?)	1L filtering at 0.2 uM Millipore (slowly, "sipping")	Flushed with N2, then in RNALater. Max 60 samples	Not used in this study but see below for 2G ESP	3G-ESP and LR-AUV developed in-house at MBARI. Reasearch use so far (?)	Metabarcoding (12S, 16S, 18S, COI)	Results were comparable to samples taken from boat with Niskin bottle concurrentl



											y. Some differences may be explained by cells not lysing as with vacuum pump
Govindarajan et al. (2022). Improved biodiversity detection using a large-volume eDNA sampler with in situ filtration and implications for marine eDNA sampling strategies. Deep-Sea Research I. doi: 10.1016/j.dsr.2022.103871	2022	Woods Hole (and others)	Evaluation of biodiversity detection by large-volume (40-60L) eDNA sampler compared to CTDs (2L)	Global diversity (v9-18S rRNA)	eDNA sampling by pumping and filtering	12 samples of 40-60L collected between 20-400 m depth (but can go deeper). Filters seawater at a rate of 2 l/min.	No	Machine-vision monochrome stereo cameras, color camera, and high-sensitivity radiometer (in the AUV)	No information in the paper, but Yoerger (developer of Mesobot AUV; Yoerger et al. 2021) is co-author here.	Metabarcoding of autonomously and CTD-collected samples	The higher the seawater liters filtered the higher the diversity detected. They detected 66% more diversity filtering 40-60L using the large-volume eDNA sampler in a the Mesobot AUV than filtering only 2L using the CTD.
https://dartmouthocean.com/products/edna-sampler	-	Dartmouth Ocean Techno	Commercial product	(depends on configuration)	eDNA sampling by pumping and filtering	Up to 9 samples, max 20 m depth,	RNA Later	Fluorometer (optional)	Commercially available	qPCR, dPCR, metabarcoding ...	-



		logies Inc. (Canada)				0.2 uM polycarb (or different)					
https://www.eomoffshore.com/environmentalsamplingprocessor	-	EOM Offshore	Website describing routine monitoring of HABs in the Gulf of Maine	HABs	2G ESP (moored)	Routine near-realtime monitoring of HABs	-	SHA or qPCR	Deployed for monitoring	-	

4.B - Conclusion

4.1. Synthesis of main conclusion

The table showcases examples of developments and applications of devices for DNA sampling and/or analysis. This table will set the basics for future discussion and for the preparation of a review/synthesis document that will be shared with the relevant agents within and outside the consortium in form of a technical paper or a manuscript submitted for publication.

4.2. Next steps (work plan)

The table will be contrasted with the relevant scientist and end-users so that it is kept up to date. Additionally, Naiara Rodriguez-Ezpeleta has been invited as expert to the Marine Omics Instrumentation and Technology Workshop taking place October 10th - 12th, 2023 at the Monterey Bay Aquarium Research Institute (MBARI), whose goal is to survey the technology landscape for ocean deployable biomolecule sampling and sensing instrumentation by convening technology innovators. The workshop is aimed at catalyzing instrument development through discussions regarding the challenges and obstacles associated with semi-autonomous to autonomous, deployable instrumentation developed for omics based sample collection, processing and in-situ analysis. To realize and attain the workshop objectives we are promoting a non-competitive and open dialogue among the participants with the aim of accelerating the progress of the field.

This workshop (<https://sites.google.com/mbari.org/moti-workshop/home>) will be an opportunity for knowledge sharing and community building of which JERICO-S3 will benefit as contributor to the roadmaps that will be defined as a result.