

SENSORS AND SAMPLERS

ROADMAP

National Oceanography Centre

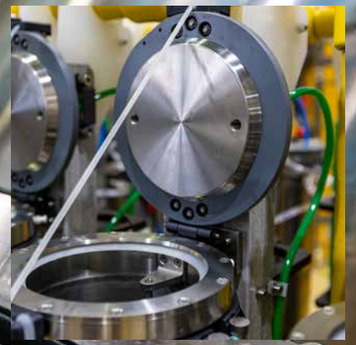
INCUBATORS

NOC's incubators capture seawater and add tracers for in situ manipulation, to measure rates of processes including carbon and nitrogen cycling.

Using representative water column communities maintained under in situ light, chemistry and pressure, pelagic incubators enable the addition of substrates and can measure rates duringthe incubation, or by collection of biomass for post-deployment processing.

Example use cases: Rates of primary production, respiration, pH change, nitrification, eDNA, omics and biomass; Especially useful for oxygen minimum zones, where sample collection alone can impact rates.





TRL 4 winch-deployed.
TRL 3 mooring-based.

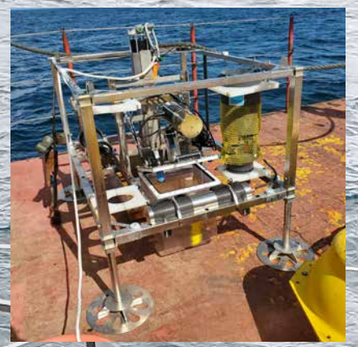
BENTHIC CHAMBERS

Benthic chambers isolate portions of the seafloor and sediment to measure changing chemistry and thereby rates of biogeochemical change.

Deployed at the seafloor, benthic chambers are linked to lab-on-a-chip sensors, enabling the measurement of biogeochemistry for isolated communities under in situ conditions.. They also enable the addition of substrates or tracers to quantify fluxes.

Example use cases: Rates of primary production, denitrification, respiration without disturbing the community at the seabed.





TRL 7 benthic chambers.

LAB-ON-A-CHIP WET CHEMICAL SENSORS

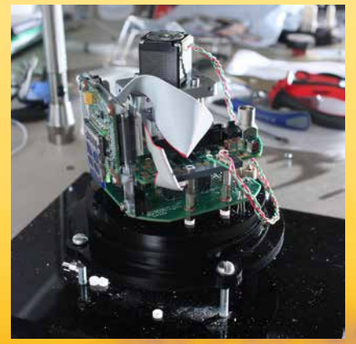
Lab-on-a-chip (LoC) chemical sensors are miniaturized, pressure-balanced, high-performance sensors that utilise established laboratory assays.

Merging analytical chemistry with on board standards for long-term performance and a submersible design, LoC sensors provide near-real time data on nitrate, nitrite, phosphate, silicate, pH, total alkalinity, dissolved inorganic carbon, sulphide, ammonia and iron and combinations of the above (dual-analyte sensors).

Successfully demonstrated across the globe, including polar environments and the deep sea; sampling the oligotrophic surface ocean to sediment pore waters.

TRL 2-9 *(see p.12 for specific analytes)*; **total size with reagents: 20cm ø x 60cm h; 2 Watts; versatility in integration across platforms and vehicles.**







MINIATURE AND ELECTROCHEMICAL SENSORS

Miniaturised, multi-parameter sensors designed to capture variability in dynamic environments and on autonomous platforms.

Reagent-free sensing of conductivity, temperature, pressure, pH, oxygen, and redox potential (Eh) in compact, low-power packages suitable for deployment on a range of vehicles, including gliders and autonomous underwater platforms. Developed in collaboration with the University of Southampton.

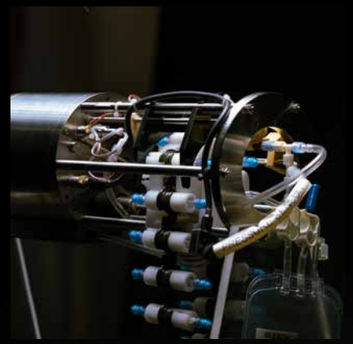
Configurations include pressure-tolerant housings, custom epoxy casting, and platform-specific integration (e.g. common ports in glider science bays). Conductivity, temperature, pressure, oxygen, pH, and Eh sensing demonstrated through CTD deployments and autonomous vehicle operations. Conductivity and temperature sensors have been deployed on fixed moorings for periods exceeding 12 months.







TRL 8 for CTD systems; TRL 7 for oxygen, pH, and Eh sensors. Future developments will focus on system optimisation and the integration of additional parameters.





AUTOSAMPLERS

NOC's range of autosamplers ensure high-resolution, sterile, and/or gas-tight sampling for the preservation of seawater, microbes and particles.

Autosamplers improve the spatiotemporal resolution of eDNA and omics, dissolved gases, and sinking particle flux sample collection from the surface ocean to the deep sea.

The RoCSI eDNA autosampler has sampled deep sea coral ecosystems and polymetallic nodule fields, on AUVs, ROVs and ASVs. Gas-tight samplers have been demonstrated in sustained fixed-point and ship based Atlantic observing programmes. Snowcatchers have been deployed hundreds of times across the world's oceans.

TRL 9 RoCSI; TRL 8 gas tight sampler; TRL 9 snowcatcher; TRL 4 subglacial lake probeTrace-metal -clean, multi-chambered, and smart snow catchers in design / development.

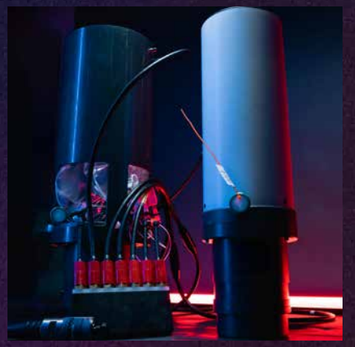
THE SENSOR HUB

NOC's Sensor Hub: A programmable multi-channel hub for interfacing sensors into oceanography platforms

The Sensor Hub provides transmission of both power and serial communications. Rated to full ocean depth, the device has a small form factor and very low power consumption. It can perform various functions including power distribution, schedule management, port multiplexing, protocol translation, telemetry and data logging.

- A pCO2 sensor networked to enable command and control using Waveglider telemetry
- Delivered comms to ROV and AUVs, and triggered LoC sensor start at depth threshold
- Synchronisation of independent sensors using a common timestamp; data logged to SD card
- eDNA autosampling triggered based on increases or decreases in sensor chlorophyll concentration

The Hub is currently programmable by software engineers at NOC for new applications, with the ambition to make it user-programmable.



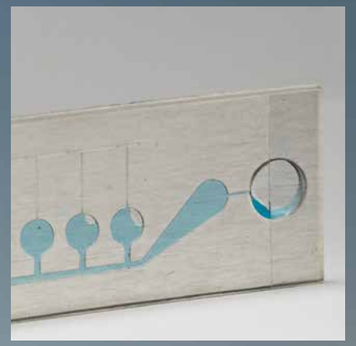


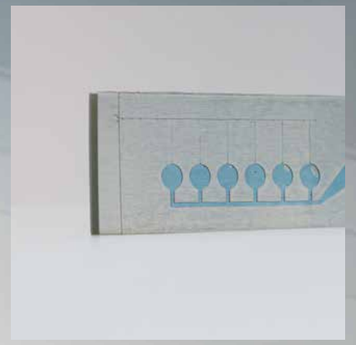
FLEXIBLE FLUIDICS

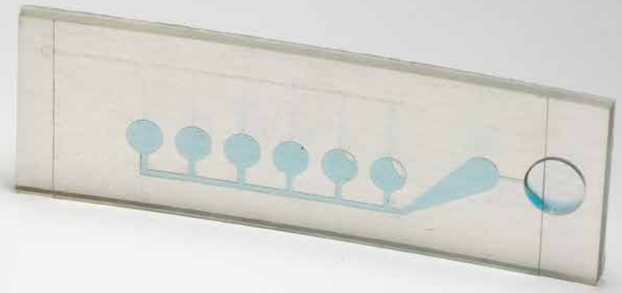
Flexible fluidics enables sequential, multiplexed analyses using discrete test elements, efficiently scaling data collection by orders of magnitude.

The hardware design enables rapid prototyping and development. This technology has been demonstrated as a biosensor for pollution, toxin and genetic testing, with the potential for library preparation for sequencing.

Genetic targets trialled include faecal indicator bacteria, harmful algae and invasive species, alongside detection of the pollutant bifenthrin.







TRL 4 for toxins and pollutants; future plans to develop for library preparation for sequencing.

CYTOMETRY

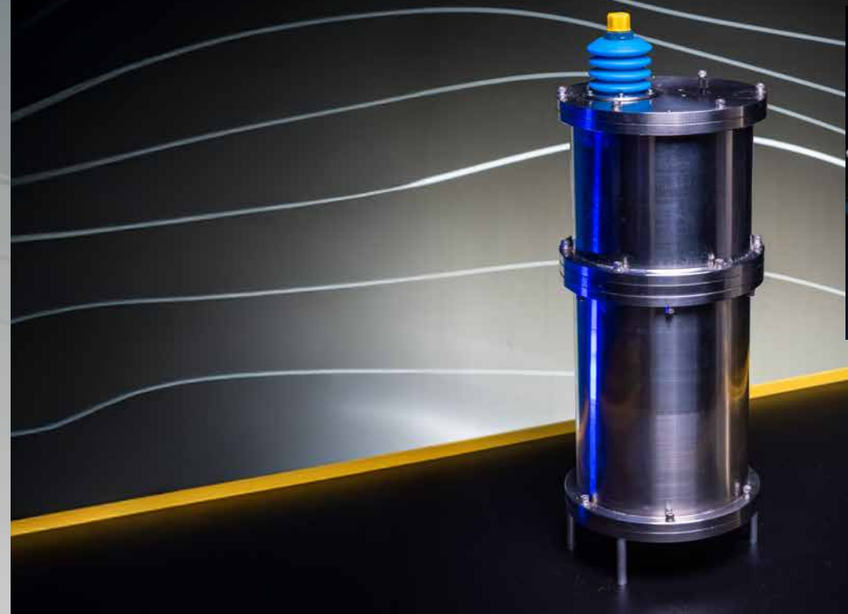
The cytometer characterizes and enumerates plankton and microplastics in situ, at high throughput.

NOC's cytometer uses impedance and two fluorescence channels, measuring plankton cell size, abundance, and pigments, to optically and chemically characterise particles, and to quantify microplastics.

Demonstrated for cyanobacterial, picoeukaryotic, and eukaryotic phytoplankton and microplastics.







TRL 7 in current configuration. Future iterations to include forward and side scatter.

MAP OF OTE DEPLOYMENTS OF LAB-ON-CHIP SENSORS



FOOTNOTES

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Sensors at highest TRL are commercialised with Clearwater Sensors.
Mowlem, M., Beaton, A., Pascal, R., Schaap, A., Loucaides, S., Monk, S., Morris, A., Cardwell, C.L., Fowell, S.E., Patey, M.D. and López-García, P., 2021. Industry partnership: lab on chip chemical sensor technology for ocean observing. Frontiers in Marine Science, 8, p.697611.

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Beaton, A. D.; Schaap, A. M.; Pascal, R.; Hanz, R.; Martincic, U.; Cardwell, C. L.; Morris, A.; Clinton-Bailey, G.; Saw, K.; Hartman, S. E.; Mowlem, M. C. Lab-on-Chip for In Situ Analysis of Nutrients in the Deep Sea. ACS Sens. 2022. https://doi.org/10.1021/acssensors.1c01685.

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Yin, T.; Papadimitriou, S.; Rérolle, V. M. C.; Arundell, M.; Cardwell, C. L.; Walk, J.; Palmer, M. R.; Fowell, S. E.; Schaap, A.; Mowlem, M. C.; Loucaides, S. A Novel Lab-on-Chip Spectrophotometric pH Sensor for Autonomous In Situ Seawater Measurements to 6000 m Depth on Stationary and Moving Observing Platforms. Environ. Sci. Technol. 2021. https://doi.org/10.1021/acs.est.1c03517.

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Iron
Geißler, F.; Achterberg, E. P.; Beaton, A. D.; Hopwood, M. J.; Clarke, J. S.; Mutzberg, A.; Mowlem, M. C.; Connelly, D. P. Evaluation of a Ferrozine Based Autonomous in Situ Lab-on-Chip Analyzer for Dissolved Iron Species in Coastal Waters. Front. Mar. Sci. 2017, 4. https://doi.org/10.3389/fmars.2017.00322.

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The RoCSI eDNA and the Marine Snowcatcher have been commercialized with McLane Labs, Woods Hole, MA, USA Evans, Susan; Birch, Jim; Breier, John; Jakuba, Michael; Saito, Mak; Robidart, Julie (2019) Ocean robots uncover microbial secrets [in special issue: Oceans] Microbiology Today, 46 (1). 22-25
Williams, J.R., Giering, S.L.C., Baker, C.A., Pabortsava, K., Briggs, N., East, H., Espinola, B., Blackbird, S., Le Moigne, F.A.C., Villa-Alfageme, M. and Poulton, A.J., 2025. Inefficient transfer of diatoms through the subpolar Southern Ocean twilight zone. Nature Geoscience, 18(1), pp.72-77.

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Cryer, S. E., Evans, C., Fowell, S. E., Andrews, G., Brown, P., Carvalho, F., ... & Loucaides, S., 2023. Characterizing Reef Net Metabolism Via the Diel Co-Variation of pH and Dissolved Oxygen From High Resolution in Situ Sensors. Global Biogeochemical Cycles, 37(9), e2022GB007577.

GOOS ESSENTIAL OCEAN VARIABLES

TRL of technologies for important variables.

	PARAMETER	LAB-ON-A-CHIP	ROCSI	FLEXIBLE FLUIDICS*	CYTOMETER	MINIATURE AND ELECTROCHEM SYSTEMS	PARTICULATE SAMPLER	MARINE SNOWCATCHER
Physics	Temperature	-	-	-	-	8	-	-
	Salinity	-	-	-	-	8	-	-
Biogeochemistry	Oxygen	-	-	-	-	7	-	-
	Nutrients	8	-	-	-	3	-	-
	Inorganic Carbon	8	-	-	-	2	-	-
	Particulate Matter	-	9	-	-	-	4	9
	Transient tracers	-	-	-	-	-	4	-
	Nitrous oxide	2	-	-	-	-	-	-
	Stable carbon isotopes	-	-	-	-	-	-	-
	Dissolved organic carbon	-	-	-	-	-	-	-
Biology and ecosystems	Phytoplankton biomass and diversity	4	9	5	7	2	4	-
	Zooplankton biomass and diversity	-	9	-	-	-	-	-
	Fish abundance and distribution	-	8	-	-	-	-	-
	Marine turtle, bird, mammal abundance and distribution	-	4	-	-	-	-	-
	Coral cover and composition	-	8	-	-	-	-	-
	Seagrass cover and composition	-	4	-	-	-	-	-
	Macroalgal canopy cover and composition	-	-	-	-	-	-	-
	Mangrove cover and composition	-	-	-	-	-	-	-
	Microbe diversity and biomass (pilot)	-	9	5	7	-	-	-
	Marine debris (pilot)	-	-	-	-	-	-	9

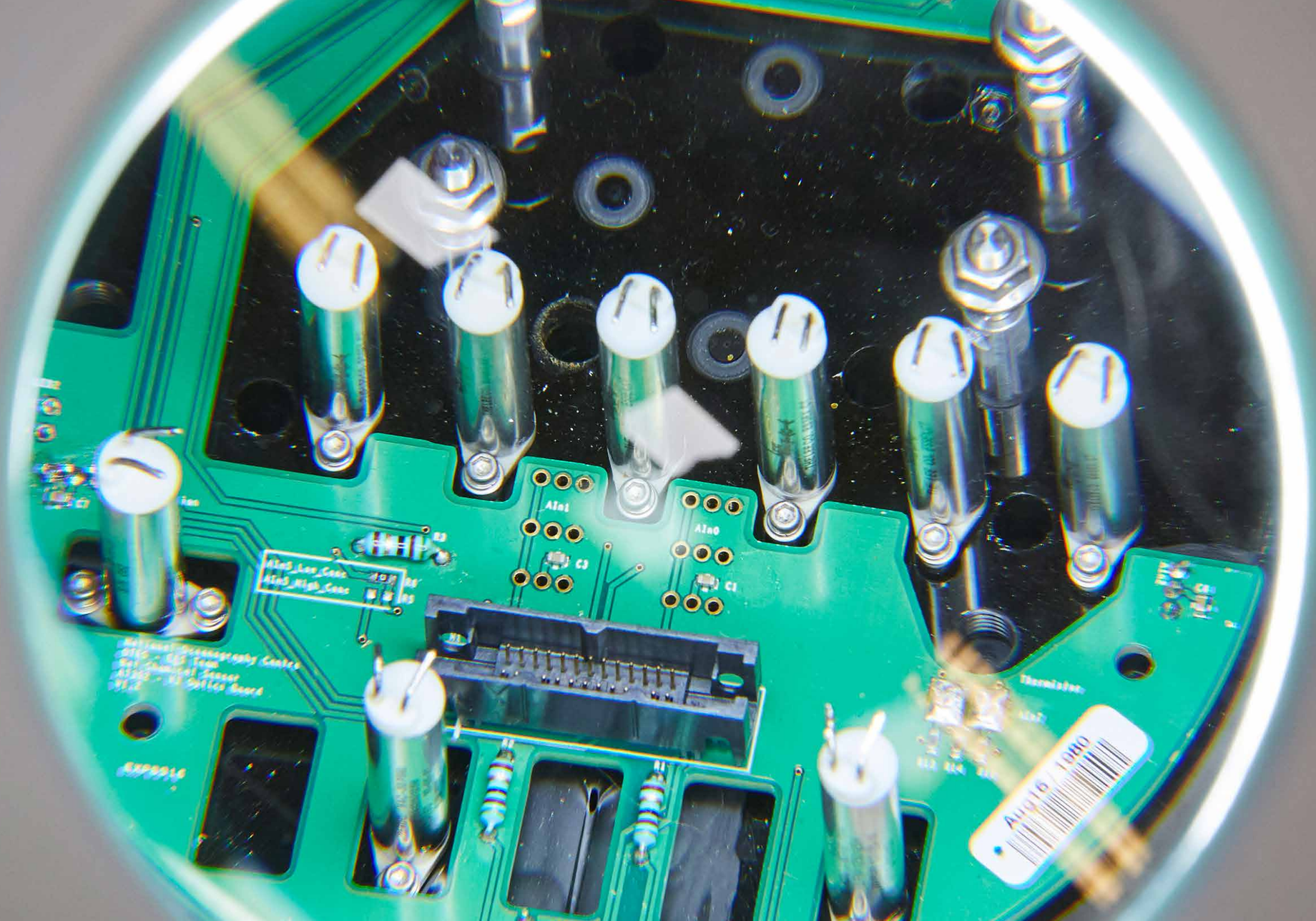
* TRL for flexible fluidics is for a portable device, not deployable

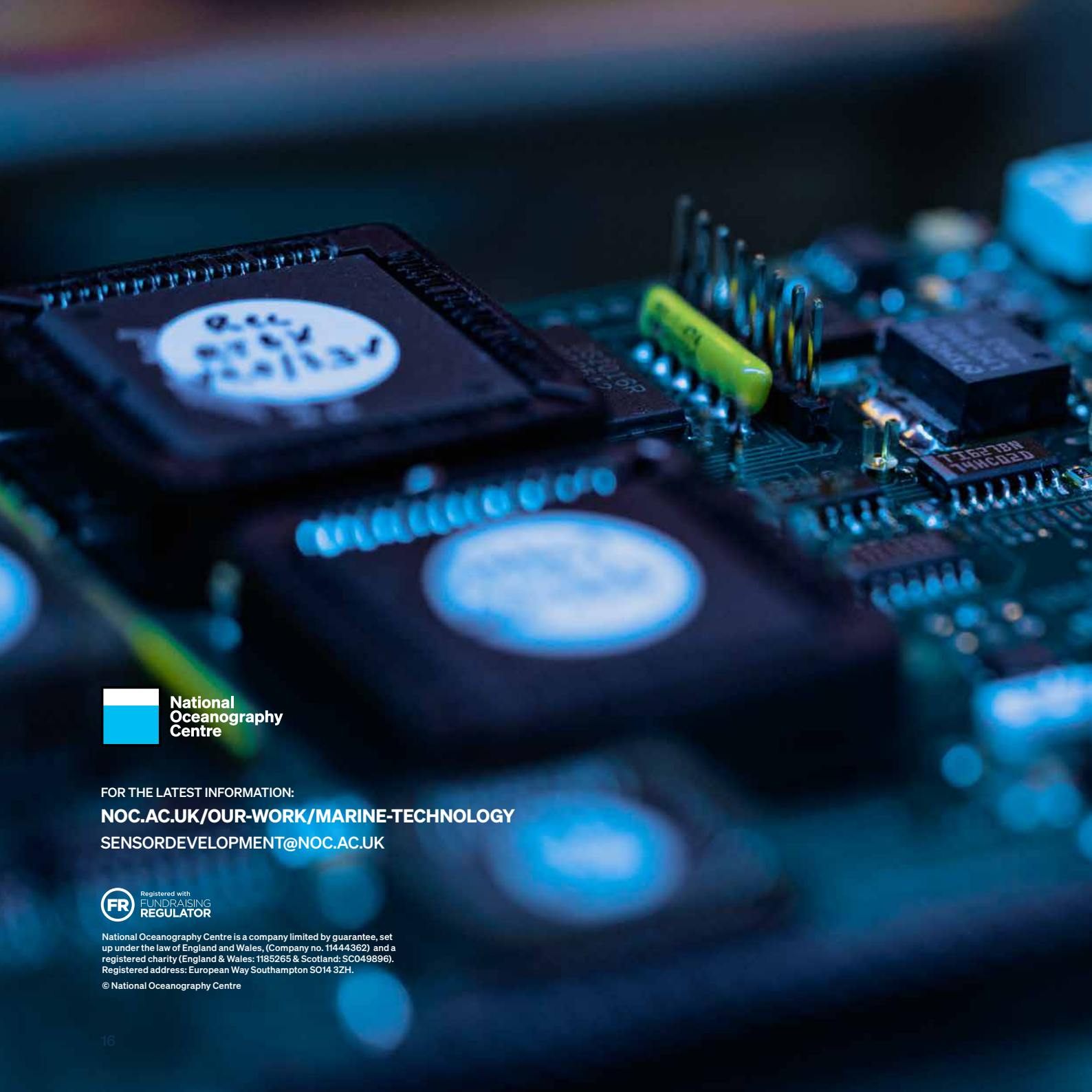
EUROPEAN REGIONAL SEAS AND ECOSYSTEM MODEL

TRL of technologies for important variables.

	PARAMETER	LAB-ON-A-CHIP	ROCSI	FLEXIBLE FLUIDICS*	CYTOMETER	MINIATURE AND ELECTROCHEM SYSTEMS	PARTICULATE SAMPLER	MARINE SNOWCATCHER
Chemistry	NH4	5	-	-	-	-	-	-
	NO3	9	-	-	-	-	-	-
	PO4	9	-	-	-	-	-	-
	Si04	9	-	-	-	-	-	-
	Fe	9	-	-	-	-	7	-
	Subnanomolar Fe	4	-	-	-	-	-	-
	H2S	6	-	-	-	-	-	-
	O2	-	-	-	-	7	-	-
	DIC	7	-	-	-	-	-	-
	pCO2	**	-	-	-	-	-	-
	pH	9	-	-	-	7	-	-
	TA	8	-	-	-	-	-	-
	DOM	4	-	-	-	-	-	-
	POM	-	-	-	-	-	9	9
Biology	Pico-flagellates	-	8	-	7	-	-	-
	Flagellates	-	9	-	-	-	-	-
	Coccoliths	-	9	-	-	-	-	-
	Diatoms	4	9	5	-	-	-	-
	Bacteria	-	9	5	7	-	-	-
	Heterotrophs	-	8	-	-	-	-	-
	Microzooplankton	-	-	-	-	-	-	-
	Mesozooplankton	-	9	-	-	-	-	-
	Aerobic Bacteria	-	-	-	-	-	-	-
	Anaerobic Bacteria	-	-	-	-	-	-	-
	Suspension feeders	-	-	-	-	-	-	-
	Meiobenthos	-	-	-	-	-	-	-
	Deposit feeders	-	-	-	-	-	-	-

** Partially - the in-water component


AIn1
AIn0
C3
C1
Thermistor



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