Autonomous Underwater Lander for Sampling and Monitoring

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AUV	Autonomous Underwater Vehicle
C/F	Chlorophyll/Fluorescence
DVL	Doppler Velocity Log
EIA	Environmental Impact Assessment
HC	Hydrocarbon
ICZM	Integrated Coastal Zone Management
MBE	Multibeam Echosounder
O/N/P	Oxygen/Nitrogen/Phosphorous
SBP	Sub-bottom profiler
SSS	Sidescan sonar

1. Introduction

The feasibility of using AUVs for EIA, monitoring and ICZM surveys is currently being investigated on different coastal locations in the Baltic, Mediterranean and Atlantic Sea. The aim of using AUVs for EIA, monitoring and ICZM surveys is to reduce operational costs, improve safety and provide high data quality.

An AUV is being instrumented for EIA and ICZM surveys under a European funded project called SEABEE *(contract EVK3-CT2001-00050)*. The AUV will be launched for sea trials in 2003. The AUV selected for the project is the Maridan 600 well known from seabed mapping in the offshore industry. The AUV shall be equipped with chemical sensors and a core sampler. All AUV operations shall be completely autonomous without the need for communication with the support vessel.

The AUV shall be able to dive and transit to the survey area after being launched from a support vessel, a harbour or a helicopter. It shall perform surveys by following a pre-defined path and switching payload sensors on and off according to the survey plan. The AUV shall take sediment and water samples at programmed locations, and record environmental and geological data while performing the survey.

2. AUV instrumentation and sampling method

The payload instruments for the AUV include different packages for different applications:

- Survey instruments for seabed mapping *(* SSS, MBE, SBP, *camera)*
- Chemical sensors for in-situ monitoring *(CTV*, O/N/P, C/F, HC*)*
- Samplers *(core sampler, water sampler and water filter)*

Various sampling concepts shall be investigated including landing, heading into the seabed and sampling on the fly by hovering.
Table 1 outlines the parameters of interest and the sensors required to provide the parameters. As can be seen in the table, we are down to relatively few sensors, coupled with water sample and core sample capacity.

Parameters	Sensors
Bathymetry	MBE
Geological profile	SBP
Seabed classification	Core sampling
Hydrology *(current patters)*	DVL,ADCP
Water chemistry	CTV
Water quality	Water samples
Particles	Water filter
Fauna and flora survey	Camera
Habitat mapping	Camera, SSS
Resource assessment or stock assessment	Camera, SSS, MBE
Nutrients *(eutrophication, meaning*	O/N/P sensors
O/N/P *measurement determining*	
the oligo/eutrophic status of the environment)	
Fluorescence/Chlorophyll	C/F sensor
Seabed oil deposition or leak inspection	Camera, HC sensor

Table 1: Outline of parameters and corresponding sensors

We shall now examine the requirements that these instruments must meet for EIA, monitoring and ICZM surveys.

3. Survey requirements for EIA, monitoring and ICZM survey

There are many possible impacts to be investigated in EIA surveys, and many different factors to consider in ICZM surveys. Indeed, ICZM stands for Integrated Coastal Zone Management. And "integrated" means that a proper ICZM study has to take into account all the factors potentially affecting a given portion of the coast: Continental waters, coastal waters, the coastline itself *(including beaches and the dune system behind them, and human activities taking place on the coast)*, estuaries and rivers, and even ideally the whole of the river basin as surface waters *(potentially polluted by human activities such as agriculture)* run into rivers and end up in the sea.

To start with, we are only concerned, obviously, with the "water" part of these studies *(continental and coastal waters, estuaries)*. But, as mentioned above, the number of different impacts potentially affecting the coastal zone is numerous; and to be thorough, our approach should include ideally all possible impacts. As this could still quickly prove to be an impossible task, we need to consider the basis of an impact assessment, which can be done by measurement of a limited number of geophysical and ecological parameters.

Impact	Geophysical parameters	Ecological parameters
Fish farming	Bathymetry	Fauna and flora survey
	Current	Eutrophication
Sewage outfall	Bathymetry	Fauna and flora survey
	Current	Habitat mapping
		Eutrophication
Pipeline/cable laying	Bathymetry	Fauna and flora survey
	Geological profile	
Artificial reefs	Bathymetry	Fauna and flora survey
	Seabed classification	
Offshore constructions	Bathymetry	Fauna and flora survey
	Seabed classification	
Dredging/sediment disposal and mining	Current	Fauna and flora survey
		Habitat mapping
Coastal works *(harbour, pier, hotel complexes, desalination plants)*	Current	Fauna and flora survey
		Habitat mapping
		Eutrophication
Oil spills	Current	Fauna and flora survey
		Sea floor oil deposition
Ship wreck/leaks	Current	Fauna and flora survey
	Leak inspection	Eutrophication
	Seabed inspection	
Tourism related activities *(e.g. water sports, diving etc.)*	Bathymetry	Fauna and flora survey
	Seabed nature	Habitat mapping

Table 2: Typical assessments and parameters measures in EIA and monitoring surveys

Geophysical parameters are mainly bathymetry, seabed nature and hydrology *(current pattern, tidal currents, and wave dynamics)*. Ecological parameters are mainly fauna and flora survey and/or stock assessment, habitat mapping, water chemistry *(mainly salinity and pH)* and pollution status.
The parameters listed in Table 2 are what EIA and monitoring surveys would have to cover, whatever the impact is from aquaculture, sewage ocean outfall, harbour construction, coastal erosion, agricultural or industrial pollution. Again, "pollution" covers many things, so we need to simplify. Generally, what is done is to look for signs of eutrophication *(by measuring nutrient concentration in the water - through nitrate and phosphorus mainly - and dissolved oxygen)* and looking at metal concentration in sediments.

Assessment	Geophysical parameters	Ecological parameters
Establishment of a Marine protected area	Bathymetry mapping	Fauna and flora survey
	Seabed nature	Habitat mapping
	Current pattern	Stock assessment of target species
		Eutrophication
		Water chemistry
Natural resources assessment	Bathymetry mapping	Habitat mapping
	Seabed nature	Stock assessment of target species
State of the environment	Seabed nature	Fauna and flora survey
		Habitat mapping
		Eutrophication
		Water chemistry
Pollution assessment	Current pattern	Indicative species survey
		Eutrophication
Coastal erosion	Bathymetry mapping	
	Seabed nature	
	Current pattern	

Table 3: Typical assessments and parameters measured in ICZM surveys

Table 3 outline typical assessments *(non exhaustive, but covering the most common ones)* and the parameters to be measured for ICZM studies.

4. Sensor and sampling requirements

The requirements for sensors and sampling equipment has been set-up based on the following information:

- Questionnaire distributed to European scientists
- Own experience from using conventional survey methods

Number of water and/or sediment samples	10
Volume of water samples	1000 cc
Core diameter	40 mm
Core length	300 mm

Table 4: Required sampling specifications

Parameter	Range	Accuracy	Resolution
Conductivity	0-70 mS/cm	0.005 mS/cm	0.0001 mS/cm
Temperature	-2/+32 °C	0.005 °C	0.0001 °C
Oxygen	0-130 %	1 %	0.1 %
Turbidity	0.04-100 FTU	0.02 FTU - 3 %	0.01 FTU
Fluorescence	0.03-100 _g/l	0.02 _g/l - 3 %	0.01 _g/l
Chlorophyll	0.03-100 _g/l	0.02 _g/l - 3 %	0.01 _g/l
Current direction	0-360°	2°	1°
Current velocity	0-200 cm/s	0.5 cm/s	0.005 cm/s
Nutrients *(nitrate)*	0-300 _M/l	2 % FSR	0.05 _M/l
Hydrocarbon	0.001–10 _g/l	3 % FSR	0.001 _g/l or 1 %

Table 5: Required sensor specifications

Table 4 and Table 5 show the required specifications to be met by the AUV instrumentation.

5. Scientific test surveys

The planned scientific tests involve geophysical sensors *(SSS, DVL, camera)*, biochemical sensors *(salinity, oxygen, suspended matter, nutrients etc.)* and the simultaneous collection of sediment and water samples. The trials have been designed to illustrate typical EIA and ICZM surveys.
The scientific test surveys are summarized in Table 6.

Area	Location	Environment	Target
Atlantic coast,	Lima and Douro	Shallow water, salinity variations,	Estuary research in
North Portugal,	river systems	high turbidity, sandy sediment,	estuarine and adjacent
		high nutrient concentration, con-	coastal zones
Baltic coast, Germany	Tourist beach,	taminants	Monitoring of water
	Fehmarn	Shallow water, wide salinity range,	quality
North Sea coast,	German Bay	muddy to sandy sediment	Monitoring of water
Germany		Shallow water, wide salinity range,	quality
	Calvi Bay	muddy to sandy sediment	
Mediterranean coast,		Depth 150 m, high salinity, low	Coralligène reefs
Corsica		nutrient concentration, islands of	
		hard bottom within soft sediment	

Table 6: Outline of scientific test surveys

The main objectives of the tests are

- Test of the sampling concept on different types of seabed
- Data quality assurance by comparison with corresponding data obtained by conventional methods
- Estimation of the feasibility of using AUVs for EIA and ICZM surveys.

Atlantic test survey

Background for selection of survey site:

- Estuaries are nursery grounds for economically important marine species
- Influence of exported matter *(particulate and dissolved)* on marine regions reaches far beyond the estuary

Scientific survey objectives:

- Quantify nutrient fluxes between bottom and water column
- Biodiversity of sediment organisms
- Influence of estuary on adjacent coastal zone
- Eutrophication potential of estuary and adjacent coastal zone

Baltic and North Sea test survey

Background for selection of survey site:

- The region has a great importance for tourism
- Monitoring of marine species leads to indications of environmental changes

Scientific survey objectives:

- Determination of bathing water quality
- Macrophyte monitoring as part of a long- term monitoring programme in the Baltic Sea Protected Areas
- Seagrass mapping in the Baltic Sea and blue mussel in the North Sea as part of Coastal Zone Management

Mediterranean test survey

Background for selection of survey site:

- Reefs are high-productivity zones, therefore of interest for fishery
- Data important for Coastal Zone Management

Scientific survey objectives:

- Mapping of the Coralligène reefs
- Determination of their biodiversity and productivity

The sensors requirements for each test survey are outlined in Table 7.

Instruments	Atlantic test	Baltic and North Sea tests	Mediterranean test
Still camera	X	X	X
SSS	X	X	X
MBE	X	X	X
SBP			X
Multicore sampler	X	X	X
Water sampler	X	X	
Water filter		X	
Light sensor	X		
CTD *(Salinity, temperature)*	X	X	X
Oxygen sensor	X	X	
Turbidity sensor			X
Fluorescence/chlorophyll sensor	X		
DVL			X
Nutrient sensor	X		

Table 7: Instruments and sensors required in the planned scientific test surveys

The sea trials also involve several capabilities and technical specifications for the SEABEE vehicle to be able to perform these trials in a truly autonomous way. They are listed in Table 8.

AUV capabilities and specifications	Atlantic test	Baltic and North Sea tests	Mediterranean test
Combination of survey and sampling	X	X	X
No communication during the survey	X	X	X
No need of supporting ship	X	X	X
Obstacle avoidance	X	X	X
Onboard landing control system	X	X	X
Landing without operator control	X	X	X
Landing on various seabed surfaces	X	X	X
Undisturbed sediment samples	X	X	
Range: Minimum 30 km	X		
Accurate navigation *(max 1 m error)*		X	X
Modular instrument packages	X	X	X

Table 8: Outline of required AUV capabilities for planned scientific test surveys

6. Conclusion

The requirements for typical EIA and ICZM surveys are defined including in-situ monitoring, sampling and surveying. Instruments have been selected for integration on an AUV. Scientific test surveys are planned in 2003 to test the feasibility of using AUVs for EIA and ICZM surveys.

7. References

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