Joint European Research Infrastructure Network for Coastal Observatories

# WP10  Deliverable 10.4

## Report on Potential New Sensors (Fishing Vessels and Voluntary Opportunity Ships)

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**Involved Institutions:** MI, Ifremer, NOC, SYKE, NERC, CNR

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# 3. Executive Summary

The Jerico Project is the first step of a pan-European coastal Infrastructure, open to all providers and users. Work package 10 is dedicated towards improvement of existing and emerging technologies on coastal observatories The WP description identified three issues which if addressed would result in a quality improvement of a European Observatory of coastal ecosystems.

This report focuses on the documentation and testing of emerging sensor technologies looking at the improvements and development of emerging new technologies and sensors, along with the use and development of platforms allowing for the optimal deployment of novel sensors. These include emerging profiling technology, gliders and ships of opportunity.

One of the key objectives is to examine the extent to which emerging technologies can be utilised and/or adapted to the benefit of coastal operational oceanography and to document and test technology will underpin future operational oceanographic systems in Europe's coastal seas.

This report includes a description of Potential new sensors developed in relation to Tasks 10.3/10.4 - (Emerging Technology) and links the development of these potential new sensors for deployment on ships of opportunity (Volunteer Opportunity Ships – VOS) – including fishing vessels.

This report includes a description of potential new sensors and emerging technologies and links the development of these potential new sensors for deployment on ships of opportunity (Volunteer Opportunity Ships - VOS) – including ferry boats and fishing vessels.

For many years Voluntary Opportunity Ships such as commercial shipping vessels or ferry boats are used to acquire physical data of the surface of the ocean. In order to use other kinds of VOS, we are producing new generation of sensors such as RECOPESCA for fishing boats and CANOE for sailing boats. The Villefranche workshop[1] presented this new generation of sensors and the future opportunities. The discussions and information from the workshop served to make appropriate modifications to the use of existing systems to meet identified objectives to expand and upgrade ships of opportunity initiatives using available state of the art instrumentation.

The report on the new sensors and other emerging technologies is structured and presented as follows:

- Description of technology (sensor)

- Appropriate platform for the sensor (Ferrybox, Glider, Fixed platform, other)

- Future steps

  o Integration into operational system

  o Timescale of integration

  o Cost implications

  o Other operational considerations.

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[1] http://www.jerico-fp7.eu/attachments/article/297/workshop%20WP10%20report%20gnolan%

# 4. Description of new sensors and emerging technology

## 4.1. Potential new Sensors Developed at NOC

The following contribution describes Biogeochemical sensors that have been developed at NOC Southampton (NERC) within (pH for Ferrybox) and parallel to the Jerico project. These emerging sensors are assessed for use in FerryBoxes and in alternative platforms in terms of technology readiness level (TRL see Table 1)

Table 1 Technology readiness levels (adapted from NASA as in [1])

| 1 | Basic principles of technology observed & reported |
|---|---|
| 2 | Technology Concept and/or Application Formulated |
| 3 | Analytical and Laboratory Studies to validate analytical predictions |
| 4 | Component and/or basic sub - system technology valid in lab environment |
| 5 | Component and/or basic sub -system technology valid in relevant environment |
| 6 | System/sub -system technology model or prototype demo in relevant environment |
| 7 | System technology prototype demo in an operational environment |
| 8 | System technology qualified through test & demonstration |
| 9 | System technology 'qualified' through successful mission operations |

### 4.1.1. Generic sensor technology elements

Most of the sensors developed at Southampton use a common set of components and are based around our platform around our platform technology that uses microfluidics and reagent based analytical assays with spectrophotometric or spectrophotometric or fluorescence readout. This is known as our *in situ* lab-on-chip platform. The common elements common elements (see

Figure 1) include:

1) an optofluidic (microfluidic) **chip** [2, 3] which forms the endcap of the sensor and in which reagents are mixed with sample (usually seawater), standards or blanks, and the optical signal read using LED light sources and optical detectors (typically glued into the chip)

2) pressure tolerant electronics that control and interrogate the sensor and log data;

3) solenoid valves that mount onto the chip for controlling fluid routing; and

4) a syringe pump that consists of a frame with a sliding plate that drives multiple plungers (pistons) inside cylindrical barrels to enable precision dosed pumping of fluids to, from and inside the chip.

These components are housed inside an enclosure that is filled with oil and is connected to a flexible bladder in direct contact with the environment. This arrangement gives electrical insulation to electronics and communicates the external pressure to all parts of the system. This pressure balanced design necessitates that all components can withstand the expected pressure ranges. Whilst in FB application we expect only modest pressure (a few atmospheres) the common components are rated to 6000 m enabling most oceanographic applications.

An additional housing encases flexible fluid bags containing the reagent, standards (typically two with one higher than the highest expected concentration) and a blank.
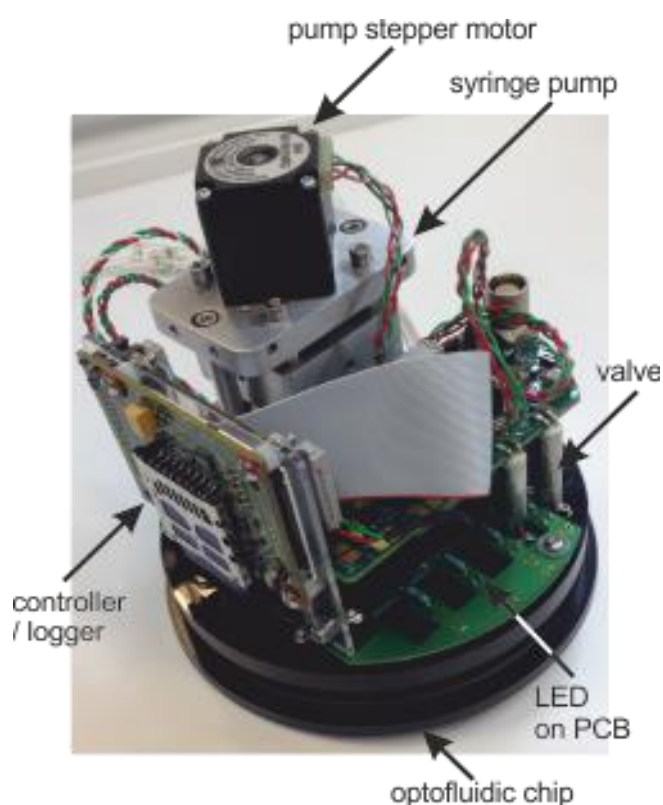


**Figure 1: labelled photograph of an assembly (12 cm tall) of the major components of the NOC microfluidic sensors including: the optofluidic (microfluidic chip) formed in tinted PMMA which forms the endcap of a water tight oil filled container; electronics including a microcontroller based controller and data logging**

Currently each optofluidic chip uses only one reagent chemistry and therefore can only measure one chemical target. The exception is the nitrate / nitrite sensor where a Cadmium column is included to reduce nitrate to nitrite and hence the Griess assay can be used to analyse both parameters. However, a typical installation has a sensor at either end of a cylindrical enclosure and hence up to three parameters can be sensed with a single cylindrical housing. As shown in Figure 2
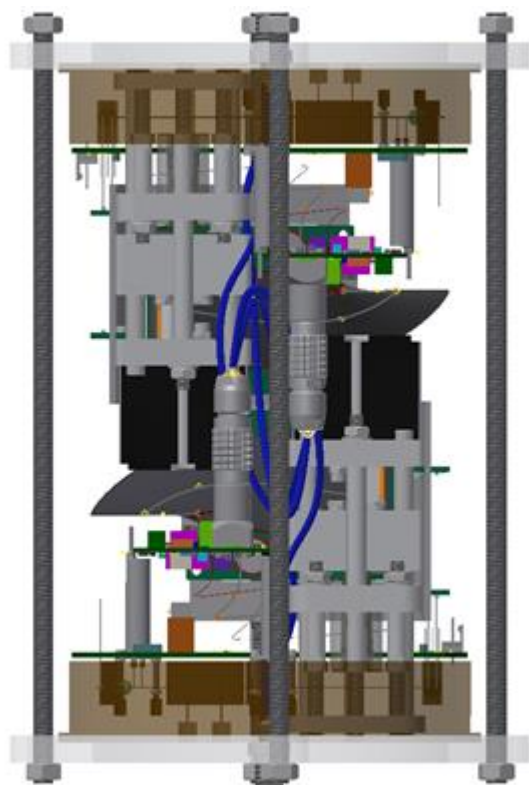


**Figure 2: 3D CAD model of two sensors installed at either end of a cylindrical enclosure with outer cylinder removed for clarity. Note the sensors overlap to produce a compact platform. This arrangement has been used for installations in iRobot / Kongsberg seagliders.**

We implement modest antifouling measures including some use of copper. However, we have found that even in high fouling environments the sensors are resilient and are unaffected during ~3month deployments. We employ a 0.45 μm inline filter on the sample inlet, and in independent testing this has shown to last for six months even when spanning the high growth period in a coastal / estuarine setting in Southampton. We have not observed clogging of the microchannels subsequent to the filter due to fouling, or any noticeable effect on the measurement.

In most applications power is provided by the platform. However, we have developed a pressure balanced battery pack that fits alongside the sensor in a single sensor implementation. This gives an

operational life of 3 to 6 months depending on measurement frequency.

The maximum measurement frequency depends on the assay, as most require a significant reaction time prior to the optical determination. However, it is possible to multiplex the microfluidics (i.e. have multiple measurements / reactions running in parallel) to improve measurement frequency. This is not currently implemented in the latest version of the sensor (V3.2) but could be used to increase measurement frequency by 4 to 10 times [4]. Typically the sensors without multiplexing make a measurement every 6 minutes, though lower temperatures and more frequent measurement of standards reduces this throughput.

### *4.1.2. Wet chemical Lab on chip nutrient sensors: Nitrate, nitrite, phosphate, ammonia and silicate*

#### 4.1.2.1.    Description of technology

These *in situ* lab-on-chip sensors use the common components listed above. Nitrate, nitrite, phosphate and silicate all use colourimetric assays (either Greiss or Molybdenum Blue method) whereas the ammonia sensor uses the OPA fluorescence method. See publications for previous versions of these instruments [5-8].

The nitrate/nitrite sensor is the most mature (TRL 7 for mooring applications) as it is now being used routinely to deliver data in field campaigns and has delivered high quality data for third party (GEOMAR) scientists without any of our technical team present. Phosphate is at TRL 5/6 as whilst components and previous versions have operated in coastal waters, the current version remains unproven in and operational environment (though we expect to do this in the next six months). The silicate sensor is almost indistinguishable from the phosphate sensor, but uses a variant of the same assay which we have only run in the lab. Hence the silicate sensor is currently at TRL4/5 though we expect to progress to TRL 6 within 6-12 months. The ammonia sensor has been demonstrated on the bench top and is therefore at TRL 4 we plan to reach TRL 6 within 12 months.

#### 4.1.2.2.    Appropriate platform for the sensor

The lab-on-chip sensor is designed to operate on a wide range of platforms from profiling floats to fixed moorings. The sensor currently consumes approximately 1.5 W during operation, or 300 J / measurement. Whilst we are working to reduce this consumption further, this is tolerable by all platforms for short and medium term deployments, with longer deployments enabled by larger platforms with greater stored or available power. The pressure tolerant electronics included in the sensor have hardware connections for RS232, RS485, and USB with firmware enabling adaptation of communication protocols to suite the target platforms. The sensor can also be programmed to operate with varying degrees of autonomy to suite each platform. It can either act as a master or slave (i.e. supplying data on request, or triggering the platform to give and take data), and can change its behaviour in response to given inputs. E.g. it can initiate measurement at predetermined depths in response to CTD data supplied by a platform or other sensor.

#### 4.1.2.3.    Ferrybox

The sensor is well suited to FB applications, with connection to the controller / data logging usually

arranged via RS232 with the sensor acting as a slave. The platform technology is TRL7 in this application, but with individual sensors at TRLs as described above. Whilst we do not expect fouling to be an issue in FB applications (because it does not cause us difficulty in high fouling coastal deployments) we have not yet completed long deployments proving this. The limitations for FB applications include the number of measurements that can be made and the duration between servicing. The number of measurements is limited by the volume of reagent stores and waste bags (we process a total of 200 μL per measurement) giving ~5000 measurements per litre of waste bag. The ultimate duration between servicing is limited by the stability of the standards and reagents. An additional challenge of FB applications is that these may be stored at elevated temperatures (room temp or higher) depending on the installation. We are currently optimising and evaluating the lifetime of each reagent system and standard, but initial tests suggest that 3 months is achievable. With cooling (<5 °C) this can be extended to 6 months.

### 4.1.2.4.    Glider

We have recently completed the integration of nitrate and phosphate sensors into an iRobot / Kongsberg seaglider. This has been deployed and we have initial data and proven data transmission through the satellite communications link (Iridium). The lab-on-chip platform sensors are therefore TRL 6/7 for this platform, but with each variant at the TRLs described above. Power and storage volume restrictions within the cowling of the glider limit the number of measurements to ~2000. Our current implementation uses sensor autonomy to initiate measurements at predetermined depths in response to CTD data supplied by the glider.

We have begun the projects to integrate the sensor with other gliders available on the market (e.g. Webb Slocum) but these integrations are currently at TRL 3/4

### 4.1.2.5.    Fixed platform

The nitrate sensor is routinely reporting data from fixed platforms in the Christchurch Estuary, Dorset, UK in three locations. It is interfaced with a commercial YSI multiparameter system and Storm Logger for data transmission, and acts as a slave in this application. Data is returned in near real time to the internet at hourly intervals. The technology is therefore TRL 7 in this application. To date no integrations have been undertaken into deep platforms though we have deep deployment data on CTD rosettes and proven operation in pressure testing facilities to 6000 m.

### 4.1.2.6.    Other

We have integrated previous versions of the nitrate sensor with an NKE Provor float which we deployed in a Scottish sea loch. Integration of our current nitrate sensor / lab-on-chip platform is underway. This is currently at TRL 3, but we hope to make rapid progress with a number of funded projects in this area.

### 4.1.2.7.    Future steps

To enable scale up into operational programmes the sensors need to be produced in greater volume and after sales support provided. This is likely best achieved by this work being undertaken by an instrument manufacturer. This is the route we are exploring. Until this is set up,the sensors can be produced and supported in small number (<50 per year).

### 4.1.2.8. Integration into operational system

The primary barriers to use in operational systems are: 1) the number of sensors available; 2) access to technical support; 3) insufficient numbers of demonstration deployments (because of 1&2 and TRL of some sensors); 4) completion of some sensor types to TRL 6/7; 5) completion of integration with platforms

### 4.1.2.9. Timescale of integration

We expect problems 1&2 to be resolved by partnership with a company within 12 to 24 months. Problems 3 to 5 are being tackled as part of our R&D programme with resolution expected in 6-24 months depending on the sensor. Nitrate and phosphate could be supported in operational programmes on fixed platforms, FB or iRobot / Kongsberg gliders within 6 months if numbers are limited to tens of units. Further parameters, and more deployments, are possible in 12-36 months.

### 4.1.2.10. Cost implications

Production and support of a single sensor currently costs approximately £10-15k at full economic cost (no profit). We expect commercial versions of the sensor to retail for a similar figure although there is considerable potential for cost reduction in manufacture / scale up into the future. The developments and proof of concept deployments are currently supported by EU and UK research projects and therefore progress is contingent upon a continued flow of research funding to support this activity. Scale up into operational systems, and the associated network support will require additional research / operational funding at FEC.

### 4.1.2.11. Other operational considerations

Long term (usually greater than 3 or 6 months) use of reagent based sensors will require refresh of fluid stores and collection of the waste. To achieve this in the field we are working on plug and play stores. Until this technology is available, we find it more practical to have a spare unit that is used to replace units in the field on a rolling basis to ensure continuity of measurement.

### 4.1.3. Wet chemical Lab on chip trace metal sensors: Fe/Mn

### 4.1.3.1. Description of technology

These *in situ* lab-on-chip sensors also use the common components listed above. However, the previous versions did not use all of the common components, the differences were particularly in the housings and the geometry and the channel widths of the microfluidic chip. The Mn analyser uses the PAN (1-(2-pyridylazo)-2-naphthol) assay and the Fe analyser Ferrozine for the direct measurement of Fe(II) and with an additional reagent (ascorbic acid) to reduce Fe(III) to Fe(II) is able to measure Fe(II) plus Fe(III).

The Fe sensor is the most mature (TRL 7 for river / coastal applications) as it has been being used for a field study in both the Baltic and UK rivers. The manganese analyser is TRL 6 and has had limited deployments.

### 4.1.3.2. Appropriate platform for the sensor

The latest version of the trace metal sensors use the common components described above and are hence able to operate with a wide range of platforms (as for the nutrient sensors above)

### 4.1.3.3. Ferrybox

Whilst the common components are at TRL 7 for this application, neither the Fe or the Mn sensors have been used in this mode and are hence TRL 4/5. In addition the limits of detection for both sensors are ~30nM. Whilst this is sufficient for profiling applications, and in areas of high trace metal concentration (e.g. the Baltic, near to major river inputs) typical open ocean concentrations are significantly lower than the technology can resolve. We are tackling this issue by coupling preconcentration columns to the device, but this is currently at TRL 3 or 4.

### 4.1.3.4. Glider

Whilst the common components have been integrated into gliders (see nutrients above), neither of the trace metal sensors has been integrated and are hence TRL 3 in this application.

### 4.1.3.5. Fixed platform

The Fe sensor is currently being prepared for application to fixed platforms in the Christchurch Estuary, Dorset, UK interfaced with the same commercial YSI multi-parameter system and Storm Logger for data transmission as used for the nutrients (above). This follow laboratory prototyping and testing and hence this sensor is TRL 4/5 in this application. The Mn sensor has not been integrated with fixed platforms and is hence TRL 3.

### 4.1.3.6. Future steps

To transition the Fe and Mn sensors to TRL 7 requires further prototype development and testing which we are undertaking. Initially we target environments where these parameters are found in high concentration (e.g. glacial melt streams, rivers, the Baltic). In parallel we continue to develop a column base pre-concentration step to access other environments where concentrations are lower. The iron analyser (with or without pre-concentration) currently on measures "free" Iron and therefore does not measure particulate, colloidal or ligand bound Fe fractions. The development of pre-processing steps to enable these fractions to be determined is laborious in the lab, and is currently not possible for the *in situ* lab-on-chip platform though this is a fruitful area of research.

### 4.1.3.7. Integration into operational system

The lower TRL of the trace metal sensors means that further R&D is required before scale up to inclusion in operational systems can be considered.

### 4.1.3.8. Timescale of integration

The timescales will be broadly similar to the nutrient sensors (above) with the addition of a two year

prototyping and testing period before work on scale up can be started.

### 4.1.3.9. Cost implications

The trace metal analysers are the same in cost as the nutrient sensors. The addition of pre-concentration columns will add a small (10%) additional cost.

### *4.1.4. Wet chemical Lab on carbonate system sensors: pH, Total Alkalinity (TA) and DIC*

### 4.1.4.1. Description of technology

These *in situ* lab-on-chip sensors also use the common components listed above. pH is measured with the spectrophotometric method, typically with the dye Thymol Blue or Meta Cresol Purple (MCP). Total alkalinity is measured by observing pH after acid addition to the sample (with the pH indicator Bromocresol Green), DIC is measured by acidification of the sample to drive $CO_2$ into a sodium hydroxide solution where conductivity detection is used.

The pH sensor is the most mature (TRL 7 for FB applications) as it is has been repeatedly used on FB / underway applications and has been developed as an *in situ* sensor for the Wendy Schmidt Foundation "X-Prize" and for parallel science and industry projects. TA is currently a benchtop system (TRL 4) as is DIC (i.e. TRL 4).

### 4.1.4.2. Appropriate platform for the sensor

Theses sensors use the common components described above and are therefore applicable to multiple platforms (see above). One advantage of the carbonate sensors is that the pH indicating dyes, and conductivity based assays are very stable. Deployments over 12 months are possible if the engineering is able to accommodate this. High levels of accuracy and low drift (not measurable with standards certified to 0.004 pH) are achievable

### 4.1.4.3. Ferrybox

The sensors are well suited to FB applications, with the previous version of the pH sensor used extensively in the ship board / underway mode (TRL 7) [9]. DIC and TA remain at TRL 3 or 4 for this application as they are laboratory prototypes.

### 4.1.4.4. Glider

Whilst we have produced an in situ version of the pH sensor,and this uses the common components that have been integrated with gliders (see above), no actual integration has yet been undertaken and hence pH is TRL 4/5 for this application. DIC and TA remain TRL 3.

### 4.1.4.5. Fixed platform

Whilst well suited to use on fixed platforms this has not yet occurred. pH is TRL 4/5, DA and TA are

TRL 3

### 4.1.4.6. Future steps

To transition the carbonate sensors to TRL 7 requires further prototype development and testing which we are undertaking. Scale up will follow successful prototype demonstrations.

### 4.1.4.7. Integration into operational system

The lower TRL of the carbonate system sensors means that further R&D is required before scale up to inclusion in operational systems can be considered.

### 4.1.4.8. Timescale of integration

The timescales will be broadly similar to the nutrient sensors (above) with the addition of a two to three year prototyping and testing period before work on scale up can be started.

### 4.1.4.9. Cost implications

The carbonate system analysers are the same in cost as the nutrient sensors.

### 4.1.4.10. Other operational considerations.

The accuracy and precision of the carbonate system sensors requires careful calibration and the preparation of high quality standards. The latter is currently led by the Dickson lab at SCRIPPS.

### 4.1.5. Optodes: pH and $pCO_2$

#### 4.1.5.1. Description of technology

These sensors use pH and $pCO_2$ sensitive optical foils purchased from Presens GmbH. Similar technology is in development (TU Graz), or available from Pyroscience (Germany). The foils are fluorescent with a decay (or luminescence lifetime) that is perturbed by the target. Our contribution has been to develop optoelectronics that interrogates the optical foils and produces a readout and to use this system to perform high accuracy characterisations of the fiol's behavior. The unique aspect of our system is the use of dual luminophore referencing [10], very low light levels for illumination, and time domain analysis of the luminescence lifetime. This feature give us immunity to photo-bleaching of the optical foils, which is otherwise problematic.

Both systems are benchtop / underway systems with deployments limited to FB / underway operations. The sensor produced by the combination of optoelectronics and optical foils is often termed an optode. Optodes for oxygen sensing are now widely available and commercially successful in a wide range of applications.

### 4.1.5.2. Appropriate platform for the sensor

Optodes are inherently well suited to a wide range of applications as they typically have low drift, require infrequent intervention, and only consume power. In commercially available versions, the optoelectronics are usually placed in a pressure vessel with the foil placed in the environment separated from the optoelectronics by a window. In our design foils are currently mounted on an optical fibre, and the optoelectronics have not been packaged for submersion or pressure. Whilst this is possible, currently our sensors are limited to low pressure applications or where the optoelectronics can be kept dry and at atmospheric pressure.

### 4.1.5.3. Ferrybox

The sensors are well suited to FB applications, but currently require connection to a PC for data logging and sensor control (data is not logged in the current optoelectronics package). This arrangement has been used successfully on two cruises to produce data from ship board systems measuring surface waters on a pumped supply. Integration with standard FB hardware has not been attempted but is low risk.

### 4.1.5.4. Glider

No integrations have been attempted. Pressure tolerant optoelectronics and interfacing with our existing data logger / control board would be required before this could be attempted.

### 4.1.5.5. Fixed platform

No integrations have been attempted. Pressure tolerant optoelectronics and interfacing with our existing data logger / control board would be required before this could be attempted.

### 4.1.5.6. Future steps

The next step is to evaluate the performance we have achieved and to compare to other offerings in the market and the research literature. The field is currently moving fast, but if there is an opportunity to provide capability with our technology, then the next step is to develop pressure tolerant optoelectronics and data logging and to scale up demonstrations.

### 4.1.5.7. Integration into operational system

As has been proven with oxygen optodes which are becoming ubiquitous in operational observation systems, the pH and $pCO_2$ optodes have the potential to be integrated with a wide range of operational systems. The barrier is the creation of a product and company support to enable deployment in number.

### 4.1.5.8. Timescale of integration

Our optode programme is run through a single PhD studentship limiting the speed at which we can

achieve operational status. However, we estimate three person years of effort is required to prove the prototypes to TRL 6/7 and a further 12-24 months to arrange production with a company. Hence timescales depends on a) the availability of new funding to develop the technology and b) progress made by other developers / companies such as Pyroscience, Aanderaa and Contros.

### 4.1.5.9.    Cost implications

The optodes are potential low-cost. Oxygen optodes currently retail for ~€3k and potentially the pH and $pCO_2$ systems could achieve the same price. Once in operation servicing requirements are limited and include biofouling mitigation and infrequent (>6 months, and potentially much longer) foil change.

### 4.1.6. Lab on chip micro flow cytometer

### 4.1.6.1.    Description of technology

These lab-on-chip sensors are currently research devices in the laboratory [11, 12] but have been designed for eventual deployment *in situ.* The principle of microflow cytometry is to pass cells one at a time through a measurement region where multiple parameters such as optical fluorescence and scatter are measured. There are numerous commercial benchtop microflow cytometers, but our innovations are to 1) design for eventual *in situ* deployment and 2) to include measure both optical properties (multiple fluorescence and scatter parameters) *and* the impedance of single cells in the measurement region. These innovations mean that we can provide accurate cell size measurements and detailed fingerprinting of up to 5000 cells per second in a miniature device that with development could be deployed *in situ.*

Because the device is currently an early benchtop prototype it is TRL 4 in FB / ship based applications and TRL 3 for all other platforms.

### 4.1.6.2.    Appropriate platform for the sensor

Currently this sensor is a bench top (not deployable) prototype only. However, the design is suitable for harsh environments and could be deployed to depth. The sensing lab on chip device is designed to be immersed and at the pressure of the environment whilst the optics and electronics are designed to be in an air filled pressure case. Initial concept drawings for the *in situ* version produce a device of approx 15 cm in height and diameter. Power is anticipated to be in the order of 2 W when operating which is tolerable for all platforms if the on time is managed.

### 4.1.6.3.    Ferrybox

Whilst suitable for this application no integration work or prototyping has occurred and the device is therefore TRL 3 in this application.

### 4.1.6.4. Glider

Whilst suitable for this application no integration work or prototyping has occurred and the device is therefore TRL 3 in this application.

### 4.1.6.5. Fixed platform

Whilst suitable for this application no integration work or prototyping has occurred and the device is therefore TRL 3 in this application.

### 4.1.6.6. Future steps

To transition the micro flow cytometer sensor to TRL 7 requires extensive prototype development, marinization and testing which requires further funding. Scale up will follow successful prototype demonstrations.

### 4.1.6.7. Integration into operational system

The low TRL of the sensor means that further R&D is required before scale up to inclusion in operational systems can be considered.

### 4.1.6.8. Timescale of integration

Progress towards operation is currently limited by funding for this project. We anticipate that a preproduction prototype is 2-8 years off, dependant on levels of funding.

### 4.1.6.9. Cost implications

The cytometer requires high data rate electronics and high performance optical detectors and is likely to be more expensive than the wet chemical systems. At the current TRL it is hard to estimate eventual price.

### 4.1.6.10. Other operational considerations.

The microflow cytometer does not consume reagents or sheath fluid and because the sample and processed waters are exchanged with the environment at *in situ* pressure there is no limit on the volume of sample over time. This enables long deployments. The device uses fluidic channels that give best signal to noise when the particles (cells) analysed are between 1 and 80% of the diameter of the channel. Hence for very wide size ranges multiple channels are used. For larger cell size ranges imaging is an advantage and can be included in the system.

### 4.1.7. Lab on chip Nucliec acid analysis

#### 4.1.7.1.    Description of technology

This lab-on-chip sensor is in transition from using bespoke components (developed in the EU project Labonfoil [13-15]) to using the common components listed above. This will take the device from a benchtop / laboratory instrument to an *in situ* device. The device analyses nucleic acids (RNA and DNA) from (micro)organisms that can be collected on a filter substrate. The device includes a module for the lysis of cells and the extraction of nucleic acids which feeds sample into the analytical device that uses nucleic acid amplification and fluorescence detection to quantify the concentration of nucleic acid targets. Typically gene or species specific primers and molecular beacons are used to amplify and detect only very specific targets, however mixtures of primers / beacons or those coding for sequences common to many species can be used to broaden the number of targets detected.

The significant differences with the nutrient sensors include: Multiple wavelength detection, multiple single use detection cells, and reagents that are stored in a gell or dry state on the chip. The latter is required as when fully hydrated the reagents have a short useable lifetime, one hour is not uncommon. With dehydration we have achieved reagent lifetimes of 6 months. The reagents are also too expensive to be stored in large reagent stores.

The labonfoil platform has only one reaction (with up to two targets) per chip. A repeat measurement requires the user to manually change the chip in a "reader". The new platform has multiple measurements before requiring a chip change. The new analyser is currently at TRL 3 whereas the labofoil platform is at TRL 7.

#### 4.1.7.2.    Appropriate platform for the sensor

The labonfoil platform is suitable for attended field studies including coastal and small vessel surveys. The new analyser will be suitable for a wide range of platforms, but will be limited in the number (<1000) and frequency (once per 30 minutes) of measurement making it best suited for short term deployments or deployments on fixed platforms.

#### 4.1.7.3.    Ferrybox

The current TRL (3) of the *in situ* analyser means that considerable development is required before deployment, but it will be suitable for this platform.

#### 4.1.7.4.    Glider

The current TRL (3) of the *in situ* analyser means that considerable development is required before deployment, but it will be suitable for this platform.

#### 4.1.7.5.    Fixed platform

The current TRL (3) of the *in situ* analyser means that considerable development is required before deployment, but it will be suitable for this platform.

### 4.1.7.6.    Future steps

To transition the carbonate sensors to TRL 7 requires further prototype development and testing which we are undertaking. Scale up will follow successful prototype demonstrations.

### 4.1.7.7.    Integration into operational system

The lower TRL (3) of the sensor means that further R&D is required before scale up to inclusion in operational systems can be considered.

### 4.1.7.8.    Timescale of integration

The timescales will be broadly similar to the nutrient sensors (above) with the addition of a three year prototyping and testing period before work on scale up can be started.

### 4.1.7.9.    Cost implications

The analysers are broadly the same in cost as the nutrient sensors however the reagents are more expensive (hundreds of Euro, vs tens).

### 4.1.7.10.    Other operational considerations.

Whilst there are published primer and beacon sequences for a large number of target genes and species, new applications and targets will require development of new sequences either by the customer or the supplier of the device.

### *4.1.8. Miniature / low cost CT (salinity) and dissolved oxygen sensor*

### 4.1.8.1.    Description of technology

These sensors do not contain fluidic channels, but are manufactured using microfabrication techniques. They consist of a platinum resistance thermometer, a four electrode conductivity cell (platinum) and an array of recessed microelectrodes for the measurement of dissolved oxygen concentration. These sensors are all formed on a glass substrate to form a sensor chip which is interfaced with electronics and a commercial pressure sensor to create a miniature CTD-DO (Conductivity, Temperature, Depth and Dissolved Oxygen) sensor (approx 200 mL in volume with pressure case, 15 mL with potted electronics). The current specification is an accuracy of 0.003 mK, 0.01 mS/cm, and 5 $\mu$M $O_2$. This is achieved in a device that is a development of the design by Huang et al. [16]. The device is being evaluated for manufacture by a company.

### 4.1.8.2.    Appropriate platform for the sensor

The sensors are appropriate where they have advantages over existing CTD and oxygen sensors this will include where miniaturisation is required (e.g. animal tags) or where low-cost is an advantage.

### 4.1.8.3. Ferrybox

Suitable (TRL 6) and could be a direct swap for existing sensors given consideration to price and required accuracy.

### 4.1.8.4. Glider

Suitable (TRL 6) and could be a direct swap for existing sensors given consideration to price and required accuracy.

### 4.1.8.5. Fixed platform

Suitable (TRL 6) and could be a direct swap for existing sensors given consideration to price and required accuracy.

### 4.1.8.6. Future steps

Requires the commercial production and support via a company. Further R&D will target improved performance and additional parameters.

### 4.1.8.7. Integration into operational system

Suitable (TRL 6) and could be a direct swap for existing sensors

### 4.1.8.8. Timescale of integration

Only minor software changes are required to technically enable integrations and this can be performed quickly (weeks). Timescales for integration into operational systems depend upon scale. A small scale (10 or so units) integration could be can be completed within research projects within 6 months, larger numbers require industrial production, and hence require take up by a company as a product. This could be in 9 to 18 months.

### 4.1.8.9. Cost implications

The CTDO sensors will be low-cost – perhaps similar to optode sensors once in volume production.

### 4.1.8.10. Other operational considerations.

Regular recalibration / access to climatology data will be required to maximise accuracy in an operational setting as is completed for current state of the art sensors.

**4.2.        Potential new Sensors developed at SYKE – Finnish Environment Institute**

**SYKE have identified and trialled new sensing technologies in the analysis of the fluorescence properties of phytoplankton. Deliverable WP  10.1[2] documents a field trial of one of these sensors. Ferryboxes are the main platform type that is used by SYKE when operating this sensing technology.**

*4.2.1.  Description of Technology - LED fluorometers for phycobilins and CDOM*

Phycobilin fluorometers are used to measure distribution of phycobilin pigments, which are found in some taxonomic phytoplankton classes. CDOM (Coloured Dissolved Organic Matter) fluorometers track the fluorescent fraction of the dissolved organic matter. In principle, the technology used in both applications is identical to Chlorophyll *a* fluorometry, which is widely used in various platforms, but the excitation and emission wavelengths and spectral bandwidths of the instruments are tuned based on the optical properties of the phycobilin pigments or CDOM studied.

Phycobilin pigments are abundant in cyanobacteria, though they can also be found in other phytoplankton classes (e.g. red algae, cryptophytes, some dinoflagellates and ciliates) depending on the location. Based on their optical setup, phycobilin fluorometers may be divided to phycoerythrin and phycocyanin fluorometers. When selecting an instrument for a specific application, it is important to know the pigment composition of phytoplankton communities studied. For example, in the Baltic Sea phycocyanin fluorescence mainly reflects large filamentous cyanobacteria while phycoerythrin fluorescence signal originates from small picocyanobacteria, cryptophytes, dinoflagellates and ciliates. In addition, it is important to select an instrument which is specific to phycobilins to be studied and which is not influenced by fluorescence from other pigments present in study site (See Jerico Deliverable 4.4.)

CDOM fluorescence shows relatively large excitation-emission peaks at UV- or blue part of VIS-range. LED CDOM fluorometers use only one wavelength and the quality of CDOM cannot be determined, but only the bulk variations are recorded. Different manufacturers use quite different wavelength settings in their CDOM fluorometers and it is important to understand how well these settings match fluorescence properties of CDOM found at given study area.

Phycobilin and CDOM fluorometers have in principle the same size as Chlorophyll-a fluorometers, and they have same characteristics for power consumption, integration and cost. Typical power supply is from 5 to 18 V (dc) with power consumption 0.2-1 W during the measurements. Instruments provide either analog (0-5V) or digital (RS232/RS422) output, or sometimes both. Gain control may be static or automated, depending on the manufacturer. Digital data resolution varies from 11 to 14 bits. Some instruments also provide internal data storage.

Instrument depth ratings vary between 300m and 6000 m, depending on the pressure housing, which may be plastic, stainless steel or titanium. The weight of instruments in the air varies from 100 g to 1.3 kg and they have a diameter of 2.2 - 6.3 cm and length of 6.7- 28 cm. Operating temperature is typically from 0-30°C to -2 to +50°C. The cost of instruments is in the range 1000-4000 € and they are available from various manufacturers.

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[2] http://www.jerico-fp7.eu/deliverables/d10-1-report-on-trials-and-deployments

Integration to third party control and data logging systems is relatively straight-forward and instruments use common water-proof connectors. Some instruments can be equipped with anti-fouling systems, e.g. nano-coated optical lenses, wipers or copper coatings. Many of the instruments have also flow-through caps available from manufacturer, and some have shade cap to be used in shallow waters with high ambient light level.

Major challenges for phycobilin and CDOM fluorometers are the calibration and validation of data. For all instruments in the market, the instrument readout is said to be linear for the whole range. The measurement itself is fluorescence intensity at given wavelengths, while the preferred result is concentration of phycobilins or CDOM. However, there is no simple and comprehensive conversion from fluorescence to concentrations.

There are no generally agreed standards for phycobilin measurements. Some manufacturers use phycobilins dissolved in buffer solutions in their primary calibration, however the fluorescence of purified phycobilins varies depending on the pH, temperature and ionic strength of the buffer. Some other manufacturers use correlation between fluorescence readings and cell counts, which are not, however, readily convertible to other species abundant in natural water samples. Additional complication arises, as with Chlorophyll a fluorometers, that the fluorescence measured from living cells is not directly related to pigment concentrations. Besides, the true concentrations of phycobilins are difficult to measure from natural samples and thus information on the pigment- specific variability of fluorescence is not available. Cell counts of phycobilin containing species or estimation of phycobilin concentration with lab-techniques are used in field validation of phycobilin fluorescence records.

CDOM fluorescence is often related to fluorescence intensity of quinine sulphate solution or some other substance (e.g. perylene) when excitation is given at UV-range, which is not practical for quinine sulphate. Presenting CDOM results as quinine sulphate (or perylene) equivalents allow easy calibration and validation of instruments and reliable comparison of various instruments using similar optical setup. The concentration ranges for various instruments vary typically from 0-200 to 0-1250 µg quinine sulphate $L^{-1}$. CDOM fluorescence validation may be carried out using reference fluorescence methods in laboratory, by analysing CDOM absorption, or by measuring DOC concentrations. Temperature dependency of CDOM fluorescence has been observed and it should be studied for each instrument type separately and corrected for before analysing the results.

Solid secondary standards are available for many instruments, and they can be used in tracking the instrument stability. Solid secondary standards cannot, however, be used in primary calibration as all instruments show different values, due to their small instrument specific optical variations. Further, the solid standards are specific to given instrument type and cannot be used to compare different models.

It is noteworthy that even is careful calibration has been carried out, due to differences in optical setups between different instrument models (excitation and emission wavelengths, bandwidths and type of optical filters) the values measured with one type of instrument are not readily convertible to values measured with another type of instrument. Thus, inter-calibration between different types of instruments may be unpractical as the results are usable only for the reference material used in the inter-calibration. In other words, if the spectral properties of the samples differ from those used in inter-calibration, instruments do not show identical values.

#### 4.2.1.1. Appropriate Platform

**Ferry Box  flow through Systems/Coastal buoys**

## 4.2.1.2. Future Steps

The main tasks for future work include
i)      finding and agreeing the suitable standards for phycobilin fluorometers,
ii)     evaluation of differences between various optical setups and significance of such differences in optically varying waters,
iii)    evaluation dynamics of pigment specific phycobilin fluorescence for major phycobilin containing specie
iv)     evaluation of DOC and absorption specific CDOM fluorescence, and its seasonality, in various sea areas.

### 4.2.2. Description of Technology Spectral fluorometers for phytoplankton taxonomy

Several manufacturers provide instrument packages, which include several fluorometers e.g. for Chlorophyll a, phycocyanin and phycoerythrin, to be used in various platforms. Integrated spectral fluorometers for taxonomic phytoplankton studies are, however, available only from few companies. The technique use several excitation LEDs to excite various accessory pigments and measure the subsequent Chlorophyll *a* emission. The obtained fluorescence spectra can be decomposed into known taxonomic spectral signals or analysed statistically.
Based on literature, the maximally 4-6 phytoplankton classes can be discriminated using excitation spectra (e.g. different cyanobacteria groups, green algae, brown algae, cryptophytes) and additionally estimates of CDOM fluorescence may be obtained. In special cases higher taxonomically resolution may be obtained. However, due to mathematical constraints the amount of taxonomic spectral classes that can be separated is less than or equal to the number of used wavelength combinations.

Instruments in the market use 6-9 LEDs with peak wavelengths from 370 to 610 nm, which excite various photosynthetic accessory pigments (various chlorophylls, carotenoids and phycobilins). These pigments transfer the energy towards Chlorophyll *a*, which emits fluorescence around 680 nm. This emission is measured with photodiode. The measured spectra contains overlapped signals from CDOM, phytoplankton pigments, water (raman scattering) and possible other fluorescing compounds present in the sample. During the data processing, signal of the water (with or without CDOM) may be subtracted using reference measurements, which are done with samples not containing phytoplankton (i.e. distilled or ultrafiltered water). The measured excitation spectra may be deconvoluted into various spectral components, representing the excitation spectra of different taxonomic phytoplankton groups (and CDOM if not already subtracted). Based on calibration dataset, Chlorophyll a content in each taxonomic group may be estimated. Such analyses are, however, strongly affected by selection of calibration spectra. The default factory calibration most likely does not include main species found in the study area. The alternatives are then building a site specific calibration using either phytoplankton cultures or natural samples with known taxonomy. Yet another alternative for data analysis is multivariate calibration using calibration data from other observations (e.g. species distribution). In addition, the spectral fluorescence data may be used in estimating total chlorophyll a concentration of samples, in analogy with Chlorophyll a fluorometers but using multiple regression and data from additional wavebands. Yet another possible way to analyse the data is measuring similarity-dissimilarity of observed spectra or classify them (e.g. principal component analyses), and use the information in detecting environmental gradients, which may e.g. assist defining locations for more detailed sampling.

There are two main instruments in the market: Multiexciter (JFE Advantech Co. Ltd) and FluoroProbe (bbe Moldaenke GmbH). Due to integration of several LEDs in one instrument, these multiwavelength devices are somewhat larger than single wavelength devices. Multiexciter weight 1.6-1.8 kg and has dimensions 79 mm x 244-301 mm, depending on the model. FluoroProbe weight 4.5-7.2 kg depending on the model and has dimension 140 mm * 450 mm. Depth range of the instruments vary from 0-50 to 0-1000 m depending on the materials of pressure housing. Instruments are either battery driven or require input of 12-24 V (dc). Multiexciter is available either as a logger-type or a cable-type device, while FluoroProbe can be configured for both modes. Instruments use RS485 standard to transmit the data to PC. Both instruments have inbuild temperature sensor. Multiexciter has a turbidity sensor measuring near infrared backscattering while FluoroProbe measures turbidity using light transmission. For FluoroProbe, there is a specific flow-through chamber available and also a workstation for laboratory work.

Primary calibration of Multiexciter is done measuring 100ppb Rhodamine solution at 570 nm excitation. It could be possible to adopt similar calibration procedure for FluoroProbe. Both instruments take the use of reference spectra of different phytoplankton classes, which are used in deconvolution of the observed excitation spectra. These spectra may be re-done by the user, with the species most likely occurring at the study site. Both instruments provide also raw fluorescence data as output.

### 4.2.2.1.   Appropriate Platforms

**Ferry Box  flow through Systems/Coastal Buoys**
Integration to other systems has not been clearly demonstrated, and this needs to be communicated further with the manufacturers.

### 4.2.2.2.   Future Steps

Future challenges in multi-wavelength systems include
i)      calibration of the instrument response using reference solutions
ii)     quantum correction of spectral output, to get comparable spectral shapes for various instruments,
iii)    creation of database for different phytoplankton species to be used with full spectra instruments and with multi-wavelength devices and
iv)     development of a suite of analytical tools for spectral analysis, including visualization of results.

### *4.2.3. Description of Technology Variable fluorescence measurements  - Emerging Technology*

The aim of variable fluorescence measurements is to determine the health of phytoplankton and ultimately to get an estimate on the rate of primary production. The first aim may be achieved with relatively simple instrumentation, while the second is still requiring more research. In principle, variable fluorescence measurement is carried out by recording minimal or steady-state Chlorophyll a fluorescence intensity and by recording maximal fluorescence intensity. Minimal fluorescence may be achieved after sample has been dark acclimated, steady state fluorescence is measured at actinic light level, and maximal fluorescence is achieved when all photosystems in the phytoplankton cells have been closed using chemicals or saturating light pulse(s). Instruments available on the market

vary a lot in technical details, and thus in the ability to provide different Chlorophyll a fluorescence parameters, ratios and coefficients, and, of course, in price. The main characteristics of available instruments are given in table 1.

Measurement of minimal fluorescence, $F_0$, is obtained when phytoplankton cells have been dark acclimated long enough (minutes) ensuring that all photosystem II reaction centres will be open (and ready to photosynthesize), and that all non-photochemical quenching mechanisms are relaxed. In Pulse Amplitude Modulation technique (PAM), $F_0$ is measured after dark acclimation using weak measuring flashes that do not influence the fluorescence quenching. In PAM technique, the maximum fluorescence, $F_M$, is measured after long (milliseconds) saturating light pulse. The other common technique to measure variable fluorescence, Fast Repetition Rate (FRR) fluorometry, uses short (microsecond) and very intense light flashes to cumulative close photosystems and $F_0$ and $F_M$ are modelled from the raise of fluorescence intensity. The fluorescence kinetics obtained in FRR technique allows also calculation of effective absorption cross-section of photosystem II, which is usable in estimation of electron transport rate. If the minimal fluorescence is measured without dark acclimation at actinic light, steady state fluorescence, F, is obtained. It is largely influenced by the light history of cells and light intensities.

Basic parameters to be calculated from variable fluorescence measurements are variable fluorescence ($F_V = F_M - F_0$) and maximum quantum yield of photosystem II photochemistry ($F_V/F_M$), representing potential of photochemical efficiency and it is related to the health of organisms. The maximal values of $F_V/F_M$ for healthy cells are close to 0.65 (FRR technique) or 0.7-0.8 (PAM technique). Lower values indicate that cells are stressed, e.g. by nutrient limitation or due to light levels. Additionally fluorescence parameters may be obtained with some instruments, describing for example non-photochemical or photochemical quenching of chlorophyll fluorescence, photosystem re-oxidation kinetics and effective absorption cross-section of photosystem II.

Instruments typically have single excitation band, around 440-470 nm and detection of Chlorophyll a emission at red wavebands. It has been noted that especially with FRR fluorometry, such optical configuration is not suitable for detection of cyanobacteria and subsequently some recent instruments have additional wavebands which are more suitable for discriminating different phytoplankton taxonomic groups. Profound research on the topic is still required. Some instruments also allow direct measurement of variable fluorescence at preselected actinic light levels, producing a fluorescence-irradiance response curve, in analogy with production-irradiance curves, allowing closer examination of in situ light acclimation status of cells and calculation of electron transport rate at varying irradiances, and thus prediction of electron transport rate at varying natural irradiances.

### 4.2.3.1. Appropriate Platform

Several manufacturers provide instruments which are suitable for profiling e.g. on buoys and can be modified to fit in flow-through systems (Ferry Boxes). There are also some instruments which are specifically designed for flow-through applications, some having dedicated pump systems allowing automated recording of fluorescence-irradiance response curves. Instruments that measure only $F_0$ and $F_M$ are easily integrated in existing datalogging systems. Some instruments provide huge amount of information (fluorescence at µs-scale, fluorescence-light curves, model fittings) making the interfacing more challenging.

Table 2 Specifications of Chlorophyll a fluorometers capable of measuring variable fluorescence parameters and designed for profiling or flow-through applications. Data is obtained from manufacturers web sites 18.12. 2014. List of available instruments may not be complete.

| Manufacturer | Chelsea Instruments | Turner Designs | Satlantic | PSI | PSI | Waltz |
|---|---|---|---|---|---|---|
| Instrument | FastOcean | PhytoFlash | In Situ, FIRe | Algal Online Monitor | OnlineFlow Fluorometerr FFL-2012 | Water Pam |
| Type | FRRF | Solid state | FRRF | PAM like | FRRF | PAM |
| Power | 5 -16 W | <1 W | 7 W | | 20 W | |
| Supply voltage | 18-36 V | 8-30V | 6-18 or 19-72 V | 12/24 V | 24 V | |
| Excitation wavelenght/s (bandwidth) | 450, 530, 624 nm | 475 (110) nm or 635 (10) nm | 450 (50) nm | 455 and 630 nm or 455 and 590 nm | 450 and 590 nm | 460 or 635 nm |
| Detection wavelength (bandwidth) | 682 (30) nm | 680 (80 nm) or $\geq$ 695 nm | 678 ( 22) nm | 660 - 750 nm | 690 (20) nm | >710 nm |
| Fluorescence parameters | F0, Fm, F', Fm', Fv/Fm, $\sigma$PSII , p, [Chl], $\tau$; With dark sensor included: F0', qP, NPQ, [RCII], ETR | Fo, Fm, Fv/Fm | F0, F0', Fm, Fm', Fv/Fm, $\sigma$PSII , $\tau$ | Fo or Fo' and Fv/Fm or Fv'/Fm' , OJIP-fixed area | F0, F0', Fm, F', Fm', Fv/Fm, $\sigma$PSII , p, $\tau$, qP, NPQ, [RCII], ETR, RLC | F0, Fm, F', Fm', Fv/Fm, qP, NPQ, ETR, RLC |
| Dimensions | min. 31.6 x 29.2 x 68.5 cm | 30.5 x 7.6 cm | 50.3 x 10.2 cm | 20 x 23 x 11 cm | 2 boxes: each 30 x 20 x 10 cm | 15 x 12.5 x 13 cm |
| Weight | 2.9 - 16 kg | 1.47 kg | 3.8 kg | 3.4 kg | 2 x 5 kg | 1.45 kg |
| Flowthrough | Flow cell available | Flow cell available | Flow cell available | Flow through instrument | Flow through instrument with pumps and light acclimation chamber | Flowthrough instrument |
| Depth rating | 600 m | 600 m | 200 m | Not submergible | Not submergible | Not submergible |

### 4.2.3.2. Future plans

Determination of primary production, in terms of $O_2$ evolution or C-fixation, is still not reliable using variable fluorescence techniques. While variable fluorescence provides information on the phytoplankton physiology and electron transport rates, yet additional information on natural light levels and rate of light absorption are required to model primary production. Several studies show varying relationships between primary production modelled from variable fluorescence measurements and rate of photosynthesis, and the major details behind the variability of conversion factors, and possibilities to predict or model this variability are still under scrutiny.

### 4.2.4. Description of Technology - Fast-repetition rate fluorometry in autonomous monitoring systems

Primary production measurements of marine phytoplankton using the benchmark technique of $^{14}$C uptake are increasingly less common due to the necessity for sea-going laboratories, cost of consumables and trained technicians, and increasing legislative obstacles in using radioisotopes in several countries. Methods to assess photosynthetic parameters and contributing to modelled primary production, which are based in optics are increasingly sought. Examples of such methods are pulsed-amplitude fluorometry (PAM) and fast-repetition rate fluorometery (FRRf). These methods do not generate waste, can be automated, and without the need for supervision they offer significant cost-reductions and increased spatiotemporal coverage. FRRf instruments are more costly than PAM but offer a stricter interpretation of photosynthetic parameters. FRRf uses inducible fluorescence to infer electron transport rate for photochemistry at a high time-resolution. It is now believed that a quantum-calibrated FRRf can be used to directly assess gross primary production in terms of fixed Carbon, provided that samples are first acclimated to darkness which allows their full capacity for photochemistry to be measured with the fluorometer (Oxborough et al. 2012, Silsbe et al. *in prep*).

The estimation of gross photo primary production from FRRf is based on interpreting the fluorescence response to progressively emerging light stress upon the photosynthetic machinery of the phytoplankton assemblage. This stress leads the phytoplankton to exhibit various photoprotective measures and eventually – after the full photoprotective capacity has been exhausted – photoinhibitory responses. This so-called rapid light curve (RLC) approach is comparable to the collection of P-I (photosynthesis-irradiance) curves with incubators for $^{14}$C uptake rate measurements. The result of the RLC measurement with an FRRf is a model of the electron transport rate rather than Carbon uptake. **The trial and description is described in more detail in the WP10.1 deliverable - Fast-repetition rate fluorometry in autonomous monitoring systems – the** trial focuses on the implementation and data handling of the first commercially built FFL-40 unit, on MS *Finnmaid*, a ship-of-opportunity in the Algaline network and describes the implementation and data handling of the first commercially built FFL-40 unit, on MS *Finnmaid*, a ship-of-opportunity in the Algaline network.

During the implementation trial, we focus on the following aspects:

- Integration of the FRRf with existing systems

- Measurement protocols

- Software development for instrument control, synchronization, and data handling

- Field tests on the sensitivity of the FRRf during summer 2013

We report here on the first field tests done in summer 2013, the subsequent definition of measurement protocols, and efforts to implement the FRRf measurements in a ferrybox environment.

### 4.2.4.1. Appropriate Platform

FerryBox flow through system Environment: The sensor deployed was a Phycoerythrin fluorometer (Unilux, Chelsea Technologies Group) and was installed in the flow-through system (Ferry Box) of RV Aranda in 2012 on a cruise which covered Gulf of Finland, northern Baltic Proper, Gulf of Bothnia and Archipelago Sea.

### 4.2.4.2. Future Steps

Within the scope of future MSFD monitoring there is room to consider emerging methods to enhance the efficacy of monitoring efforts. Particularly, activities that allow better upscaling of *in situ* measurements to large spatial coverage by remote sensing or through ecosystem models are of significant interest in current and future indicator development. Also, methods that allow deeper insight into core indicator responses will continue to be developed. It is therefore expected that optical methods/models to assess marine primary production such as FRRf will rapidly mature in the coming years, to be implemented in regular monitoring practices.

WP10.1 [3] has a description on a trial which focuses on the implementation and data handling of the first commercially built FFL-40 unit, on MS *Finnmaid,* a ship-of-opportunity in the Algaline network.The trial describes the implementation and data handling of the first commercially built FFL-40 unit, on MS *Finnmaid,* a ship-of-opportunity in the Algaline network. During the implementation trial, we focus on the following aspects:

- Integration of the FRRf with existing systems

- Measurement protocols

- Software development for instrument control, synchronization, and data handling

- Field tests on the sensitivity of the FRRf during summer 2013

The trial documents the first field tests done in summer 2013, the subsequent definition of measurement protocols, and efforts to implement the FRRf measurements in a ferrybox environment.

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[3] http://www.jerico-fp7.eu/deliverables/d10-1-report-on-trials-and-deployments

# 5. Appropriate platform for the sensor(Ferrybox,Glider,Fixed platform other)

## 5.1. Introduction

One of the main objective of JERICO Task 10.4 was the evaluation of various typology of existing commercial sensors to be installed on vessels of opportunity (VOOs), including fishing vessels. This section documents the activities and analysis carried out by Jerico partners in the use of new developments in coastal observing platforms as well as an evaluation of different typology of commercial sensors to be used on fishing gears.

## 5.2. Ships of opportunity

A workshop was held mid part of the JERICO project on using ships of opportunity. An overview of unmanned surface vehicles (USVs) was presented at this workshop to highlight some of the developments and emerging technologies that have taken place in that regard.

During the dedicated workshop, four categories of USV platforms have been presented:

- - USV for shallow water.

- - ASMV (Autonomous Self Mooring Vehicle).

- - Coastal USV.

- - UOV (Unmanned Ocean Vessel).

USV for shallow water are dedicated to Hydrographic survey, most of the time their specific specification is a compact size and a reasonable weight that allows handling by one or two persons. Quite rapid, this kind of USV allows fast survey mapping with few sensors on board and real time telemetry. Commonly, echo sounders, GPS and camera are part of the set up. There is very little feed back on chemical sensors in the literature. In this category, we can mention the Z-Boat 1800 from ocean science group.

ASM (Autonomous Self Mooring Vehicle) is a very specific category in which there are not many candidates. We can mention the C endure platform from ASV Limited (UK). It consists of a medium size platform that can hold various kinds of sensors (passive acoustic, meteocean, seismic and environmental). The idea is to get 3 months autonomy with the help of solar panels and windmill. The platform can remain in a stationary position and has still some possibilities to move at low speed (4 knots) over a 4000 miles range.

Coastal USV and UOV (Unmanned Ocean Vessel) are two categories that overlap and which are

actually developing quickly. The main purpose of these systems is to perform environmental survey over a specific area, or around an oceanographic vessel or for some quite still very specific campaign along transects across large areas. Commonly, these systems are designed in order to be able to use environmental oceanographic sensors, to transmit data in pseudo real time via satellite and offer a large autonomy. Some systems are noticeable in terms of energy harvesting. The most common one is an automatic sailing boat (Vaimos) equipped with a windmill that consequently can theoretically navigates without any limit. Another very promising system is the Wave Glider from liquid robotic which uses the movement of the surface wave to animate some underwater parts which make the system to move on. This US Company is very engaged in this technology since they are the only one to offer to customers the possibility to control and manage the wave gliders at sea from a central office from their company. Finally, we must mention the Mobesens electric USV which is the only one to offer the possibility to perform vertical profiles with the on board sensor pack and with the water withdraw unit.



Figure 3 Images of emerging Autonomous monitoring platforms

The reader should refer to the workshop presentations (PDF file) for more detailed and illustrated information.

### 5.3.  Fishing Vessels - Next Generation fishing vessel probes

Considerable progress was reported for the Italian Fisheries Operational Oceanographic System (FOOS) where equipping fishing vessels with sensors (e.g. temperature, salinity, catch weight and net drum rotations) is becoming a mature and well understood technology. The focus is shifting towards making useful products for fishermen from the data collected from sensors on board fishing vessels.

### Rationale

Faced with the lack of data to assess precisely the spatial distribution of catches and fishing effort and for the environmental characterization of the fishing area, Ifremer has been implemented the

Recopesca project. The project consists in fitting out fishing vessels representative of the whole fishing fleet with sensors on the fishing gears and aboard the vessel itself. These sensors record data on fishing effort (and at mid-terms catches) and physical parameters such as depth, temperature, salinity or turbidity. Recopesca aims at setting up a network of sensors, for scientific purposes, to collect data allowing improving resources assessment and diagnostics on fisheries, as well as environmental data required for an ecosystem approach to fisheries.

Moreover, the local environmental conditions and their variability, especially on the continental shelf, are often insufficiently sampled, mostly because of the specific conditions: low depth, significant current (especially tidal current), various human activities (professional and recreational) making vulnerable the measure devices. Thus, even for basic parameters such as temperature or salinity, most of the available measures are limited to oceanographic campaigns.

Recopesca is a concrete achievement of participative approach: scientists and fishermen team up to give to the voluntary fishermen a role of scientific observer. It provides an innovative tool to collect data. The collected data can be used by both fisheries scientists and physicists, who dispose of information for areas non- or little-accessible till now.

**Instrument set up, platform used and Methodology**

Recopesca constitutes an innovative tool to collect data and contributes to supply the existing information systems. It must be considered as a means and not as a goal in itself.

The physical environmental data of Recopesca are used for operational oceanography studies or hydrodynamics models. They represent an important perspective of vertical profiles even near the coast and on large areas.
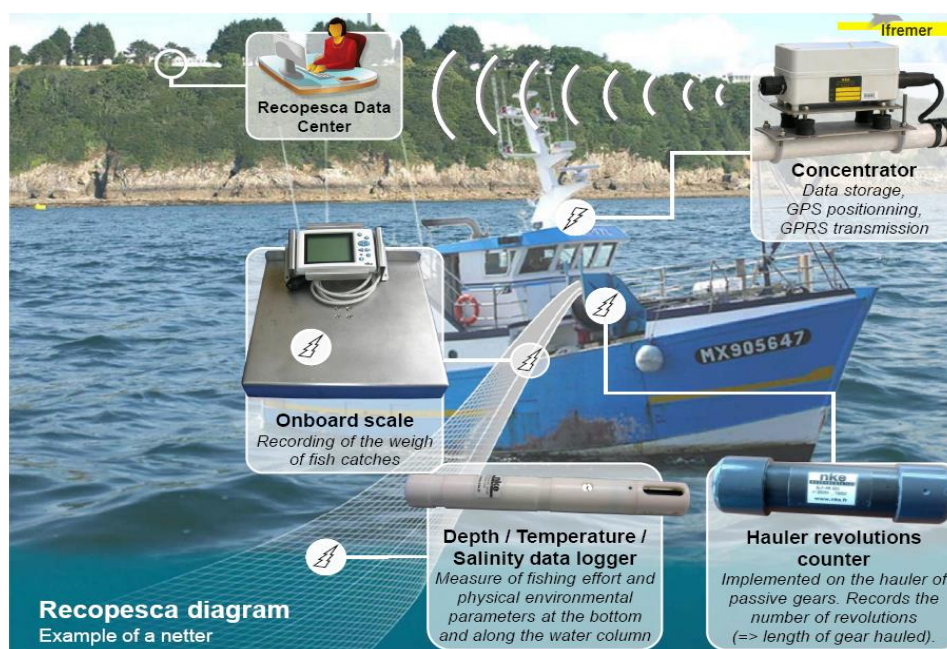


**Figure 4 Recopesca Diagram – example of a netter**

The fisheries data (activity, fishing effort and catches), resulting from direct measures, and no more from fishermen's declarations or estimation by survey, supply the Fisheries Information System of Ifremer. Moreover, the association of the different Recopesca sensors and devices allows linking

fishing effort and catches at the finest scale of the fishing operation. Through the FIS, the fisheries Recopesca data can contribute to the whole fisheries research projects, especially in the framework of an ecosystem approach to fisheries, and assessments. They are complementary with log-books and VMS data.

The Recopesca observations are restricted to limited regions with a good temporal frequency. It allows a seasonal to annual monitory depending of fishing activities of the basic hydrological parameter. It gives a description of the whole water column, from the surface to the bottom. It allows a first monitoring of the bottom temperature which is of great importance for the analysis of the benthic ecosystem and the repartition of demersal and benthic fishes.

Since 2003, CNR-ISMAR is running a program aimed at using Italian fishing vessels as VOOs for the collection of scientifically useful datasets. In the framework of the EU-FP5 project MFSTEP, 7 commercial vessels fishing for small pelagic species in the northern and central Adriatic Sea were equipped with an integrated system for the collection of data regarding catches, position of the fishing operation, depth and water temperature during the haul (Falco et al. 2007); this system was named "Fishery Observing System" (FOS) and until 2013 produced a great amount of data that could be helpful both for oceanographic and fishery biology purposes (Falco et al 2011; Martinelli et al. 2012; Sparnocchia et al 2013).

In 2013, CNR upgraded the FOS to FOOS, the Fishery & Oceanography Observing System (Martinelli et al. 2013). New sensors for the collection of oceanographic and meteorological data allow nowadays the FOOS to collect more parameters, with higher accuracy, and to send them directly to a data center in near real time. The FOOS represents thus a multifunction system able to collect data from the fishing operation and to send them to an inland data center, but also to send back to the fishermen useful information, as for instance weather and sea forecasts, etc. through an electronic logbook with an ad hoc software embedded (Patti et al. 2013). The FOOS implementation allowed a spatial extension of the monitored area and the installation on various kind of fishing vessels such as coupled pelagic trawlers, bottom trawlers, purse seiners etc. This point is of particular interest because of the multiplicity of fishing gears used in the Mediterranean and the variety of target species and exploited areas.

Taking advantage of this platform, and the considerable experience gained with a long-term use of fishing vessels as VOOs, CNR ISMAR fulfilled the objective of Task 10.4 by performing an evaluation of the typology, precision, accuracy and suitability for the purpose of different commercial sensors.

### 5.3.1. Description of technology (sensors)

Among the most important characteristic for the sensors to be used on fishing gears there are size and robustness; in fact the probes should not represent a problem during the fishing operations and must be robust enough to resist to impacts especially during the deployment and recovery of the gears.

The sensors used with the FOS ("Star-Oddi DST centi-TD" probes) and the FOOS ("NKE RECOPESCA" probes) share the common characteristic to be small enough to be easily mounted on different parts of the fishing gears.

The Star-Oddi probes have been designed for other purposes (e.g. tagging; Grabowski et al 2014) and then they need to be adapted to use with fishing vessels. In particular, they should be equipped with ad hoc protections against shocks (rubber and steel case). They are implemented only for measuring depth and temperature.

On the other hand, the NKE sensors were specifically developed for use on fishing gears (Leblond et al. 2010), so they are already provided by the manufacturer with a rubber protection. The only

additional precaution was to protect them with a nylon case that, on the contrary of steel cases, allows radio link. There are several options for measured parameters with this brand of probe, in particular they can record physical parameters such as depth, temperature and salinity.

To compare these probes, inferring on their performances while mounted on the fishing gears, and testing the characteristics declared by the manufacturers, the sensors were tested during a series of scientific surveys and trials were performed both using them on fishing gears and deploying them together with a multiparametric CTD probe.

### 5.3.2. Evaluation of sensors (and dataset produced) for eventual oceanographic use

This document is specifically aimed at reporting on the evaluation performed on the Star-Oddi and NKE probes in order to assess their capability to be used for physical oceanography purposes. The sensors mounted on fishing gears can retrieve, almost daily, a huge amount of physical data, such as temperature, depth and salinity, spanning a very large spatial region both horizontally and vertically.

The possibility of establishing the accuracy of these data would be of extreme importance for physical oceanography studies since it would be almost impossible to obtain the same amount of data with normal cruises onboard a R/V.

In order to accomplish this task, tests were performed in the Adriatic Sea during several surveys taking place on board of R/V Dallaporta within the JERICO project duration; furthermore also data previously collected were used in order to achieve the results reported in this document, which are related to the performances of several StarOddi and NKE sensors compared to those of a calibrated CTD instrument.

### 5.3.3. Experimental section

The analyzed sensors were of three types:

- Star-Oddi DST centi-TD temperature depth recorder with Logic feature (Star-Oddi, Iceland; http://www.star-oddi.com/products/4/temperature-depth-recorder/default.aspx). In the following this type of sensor will be identified with the sensor label L#### where #### is a specific number that univocally identifies the sensor.

- RECOPESCA NKE SP2T-R temperature and depth recorder (NKE Marine Electronics, France). In the following this type of sensor will be identified with the sensor label SP####.

- RECOPESCA NKE STPS-R temperature, conductivity and depth sensors (NKE Marine Electronics, France). This sensor has the same components for detection of temperature and depth of the NKE SP2T-R to which the conductivity probe has been added. In the following this type of sensor will be identified with the sensor label STPS####.

Hereafter, if not diversely specified, we will refer to these sensors as FOS-FOOS sensors. Figure 5 shows a sensor for each listed type

**Figure 5 Example of StarOddi sensor (right) and NKE SP2T-R (center), NKE SP2T-R (left) with the protection provided by the manufacturer**

To evaluate the accuracy of the FOS-FOOS sensors, several casts were made with different profiles, i.e. with different maximum or permanence depths and with or without a dwell time at the maximum or permanence depth. In each of these casts, some of the FOS-FOOS sensors were deployed with a calibrated CTD instrument (mod. SBE9/11 plus, SeaBird Electronics, USA) taking care to vertically align the sensors, see Fig.2. It was not possible to always deploy all the Star-Oddi and all the NKE sensors with the CTD instrument.

The main features of each sensor are reported in Table 1 along with the features of the CTD instrument.

Table 3 Main characteristics of the Star-Oddi and NKE sensors and CTD probe. All data as declared by the manufacturer.

| Type of sensor | Star-Oddi DST centi-TD (with Logic feature) | NKE | CTD SBE9/11 plus |
|---|---|---|---|
| Manufacturer | Star-Oddi | NKE | SeaBird Electronics |
| Temperature range (°C) | -2 to +40 | -5 to +35 | -2 to 35 |
| Temperature accuracy (°C) | +/- 0.1°C | +/- 0.05°C | +/- 0.001°C |
| Temperature response time 63% (s) | 20 | <0.5 | 0.065 |
| Depth range (m) | 1 to 270 | 0 to 300 | 0 to 6800 |
| Depth accuracy | +/- 0.4% f.s. | +/- 0.3% f.s. | 0.015% f.s. |
| Salinity range (psu) | --- | 2 to 42 | 0 to 45 |
| Salinity accuracy (psu) | --- | +/- 0.1 | +/- 0.02 |

The CTD SBE9/11 plus probe is a reliable profiler of the water column. Its acquisition rate is 24 Hz while that of the FOS-FOOS sensors is maximum 1 Hz. In the CTD cell where conductivity is measured, the water flow is maintained constant by a water pump while in the FOS-FOOS sensors the water flow is that of the surrounding environment (no flow if the sensor is at rest or the flow rate due to the cast speed or sensor drag). Moreover, in the CTD instrument, the raw depth and salinity data are post-processed by a low-pass filter.

Cast data were collected in the Adriatic Sea at different locations and dates (March 2007, August 2007, October 2008, July 2011, March 2012, May 2012, February 2014, April 2014, May 2014 and October 2014).

The FOS-FOOS sensors performances were evaluated as the difference (offset) between their readings and the CTD reading. However, as it will be clearly shown in the next section, due to the different response time of the sensors, see Table 1, the offset between the FOS-FOOS sensors reading, in particular for the Star-Oddi sensors, and the CTD reading observed during the descendent or ascendant part of a cast was considered meaningless for the accuracy assessment. The offset of the FOS-FOOS sensors was therefore evaluated in correspondence of a depth permanence. In this way all the effects of time and vertical gradient of the water property, temperature or salinity, are eliminated. The dwell time as well as the depth value of the depth permanences were varied respectively from very few to several hundred seconds, and between 2 m and 270 m. The depth offset was then calculated as the difference between the depth data mode (most frequent value) of the FOS-FOOS sensor depth readings and the mode of the CTD depth readings. In correspondence of the depth permanence, the offset of temperature and salinity were calculated accordingly. When the depth permanence was too short to allow the stabilization of the FOS-FOOS sensor reading, the median value was considered instead of the mode for depth, temperature and salinity. Only in very few cases, and just for the depth value, the maximum value measured by the FOS-FOOS sensor was

taken.

The data mode/median was calculated using a commercial software (Excel 2013, Microsoft, 2013, USA). All the other statistical evaluations were carried out using a commercial statistical software (STATISTICA ver. 10, StatSoft Inc., 2011, USA).

In total, 26 Star-Oddi sensors and 18 NKE sensors, nine of which with the salinity measurement capability, were compared with CTD probe, and 1260 different offsets for depth and temperature and 213 offsets for salinity were analyzed.

The reader is referred to WP10Deliverbale 10.3 for full results and discussion on the Start-Oddi and NKE fishing vessel trials and 10.1 for a description of the trial

### 5.3.4. Conclusions

Several Star-Oddi sensors and NKE sensors, collectively indicated as FOS-FOOS sensors, were deployed together with a calibrated CTD SBE9/11plus instrument in occasion of different casts performed at different dates and different locations in the Adriatic Sea. The purpose was to evaluate the offset between the reading of the FOS-FOOS sensor and the CTD reading regarding depth, temperature and salinity.

Due to the different time response of the sensors with respect to the CTD instrument, the offset between the FOS-FOOS sensors and the CTD instrument was calculated in correspondence of a depth permanence to avoid transient effects.

The Star-Oddi sensors have a depth offset which, in many cases, is larger than 2 m. In two cases, values higher than 7 m were also observed. The general offset is not depth- or time-dependent. The depth measurement of some sensors was not repeatable.

In most cases, the Star-Oddi sensors have a temperature offset in the range ±0.1°C, which is the nominal accuracy range of the sensor. However, several extreme offset values were also calculated. These extreme values have been shown to derive from a negative combination of the long time response of the temperature sensor and the short dwell time at the depth of the depth permanence. It was observed that in order to obtain a temperature reading according to the nominal accuracy, the dwell time should not be shorter than 50 s which is however longer than the nominal time response indicated by the manufacturer (20 s).

The NKE sensors have a depth offset which in most case is less than 1 m. Only for two sensors, the offset was larger than 2 m. No influence of depth or dwell time was observed on the depth offset.

The NKE sensors have a temperature offset which is in most cases inside the nominal accuracy range of the sensor (±0.05°C). Also in this case, however, the reading of the sensor is slightly time-dependent. When the dwell time of the NKE sensors was longer than (50 s), almost all the offset values fall inside the nominal accuracy range of the sensor.

The NKE sensors have a salinity offset which in most of cases is outside the nominal accuracy range of the sensor. No influence of the depth or the dwell time was observed for the salinity offset. Moreover, the salinity reading of the NKE sensors is greatly influenced by the operating conditions, i.e. the water flow inside the sensor, which can cause a noisy reading. This noisy reading, when present, can be eliminated or greatly reduced by a post-processing of the raw data.

Summarizing the above results, it can be assessed that for oceanographic purposes, the data collected by Star-Oddi sensors are useful only considering the data portion where a dwell time at a fixed permanence is longer than 50 s. In this condition, the temperature offset is inside the nominal

accuracy range of the sensor. Nor the descendent or ascendant part of a cast can be usefully corrected. Thus, when using them on a fishing gear, it is possible to be confident only in the dataset collected when the net/gear is actively fishing (which happens usually at a stable depth) and not during the deployment and recovery of the gear.

The data collected by NKE sensors seem to be generally quite accurate both for depth and temperature, especially when the sensor is allowed to rest for more than 50 s. The weak point of the NKE sensors is the salinity measurement for which there seem to be no specific indication of operating conditions which could allow a better performance in particular for the offset which is in most cases outside the nominal accuracy of the sensors. The spiky salinity reading of the NKE sensor can be instead reduced by a simple post-processing of the raw data.

The offsets calculated by means of the above analyses will allow to correct (at least for the sensors here evaluated) the original values contained in the large dataset collected firstly by the FOS (from 2003 to 2013) and then by the FOOS (from 2014), thus making it more precise and reliable.

However the offsets here calculated were obtained in almost ideal conditions: all the sensors were rinsed with fresh water before any cast and their handling was definitely more "gentle" than those expected on a fishing ship. From this point of view, the performances of the FOS-FOOS sensors, in particular the conductivity ones, during fishing operations can be negatively affected, unfortunately in unpredictable way, by their cleaning conditions and handling.

Due to their very large response time, the data collected by the Star-Oddi sensors in the descendent or ascendant part of the casts cannot be corrected in any reliable way. In case of the NKE sensors, while considering the descendent or ascendant part of the casts, which correspond to the deployment and recovery of the fishing gear, besides the temperature offset, also the eventual depth inaccuracy of the sensor should be taken into account to obtain a reliable temperature-depth profile. In addition, during trials on the fishing gears, it was noticed that sometimes the NKE sensors need a longer stabilization period when entering the water if the air temperature is very different (e.g. after being left outside in strong sun irradiation conditions), thus the firsts given values should be considered carefully.

For what may concern the use of the conductivity data collected during the descent phase of the casts, it would be possible to correct them using a low pass filter, and then applying the calculated offset, it would be possible to consider the data with the accuracy in salinity declared from the manufacturer. Even in this case, the performance of the sensor improves in stationary phase. In Appendix A, we have reported the median values of the depth, temperature and salinity offset of the tested sensors. The figures are rounded to the CTD accuracy (1 m for depth, 0.001°C for temperature and 0.02 for salinity). For the Star-Oddi sensors, the offsets are those calculated on casts with dwell time longer than 50 s, see text.

**The authors of this report strongly suggest to other users, intended to use any kind of probes measuring oceanographic parameters for purpose similar to those here declared, to perform comparison analysis with CTD for every single probe before their usage, and then repeat them periodically.**

### 5.3.5. Future Steps

In the near future, sensors able to collect more parameters (oxygen and chlorophyll-a fluorescence), designed specifically to be mounted on fishing gears and compatible with the systems in use nowadays (RECOPESCA, FOOS), will be available (Martinelli et al. 2014). Therefore, hopefully, the approach described in this report and developed in order to test sensors and moreover qualify the acquired data might be considered of interest for further developments.

**5.4.		Description of Technology Autonomous profiler platform in coastal water (EOL3)**

Another trial lead by Alurent Coppola

The new EOL buoy version 3 has been deployed in March 29th 2013 in the Villefranche bay. The new version is larger and bigger than the previous one: 4 tons & 8m height & 3.6 diameterThe CTD profiler has been re-integrated in the buoy which provide one T&S profile every day (0-100m)

Additionally a cytometer has been also integrated for picoplankton & bacteria analysis - Concerning the cytometer (Cytosense) there is a web link on the instrument deployed on EOL buoy: http://www.cytobuoy.com/company/news/show/article/cytosense-on-leobuoy-marseille/

### 5.4.1. Appropriate Platform - Coastal buoy

Rapid processes appear in the coastal waters which required a high frequency observation system. To perform such observation, coastal buoys are the best platforms: they can deliver data in real-time and detect any rapid changes that appear in the water column (e.g. bloom). Coastal buoys allows users to plug any power hungry sensors (thanks to solar panels) and can offer an anti-biofouling system to limit sensors drift.
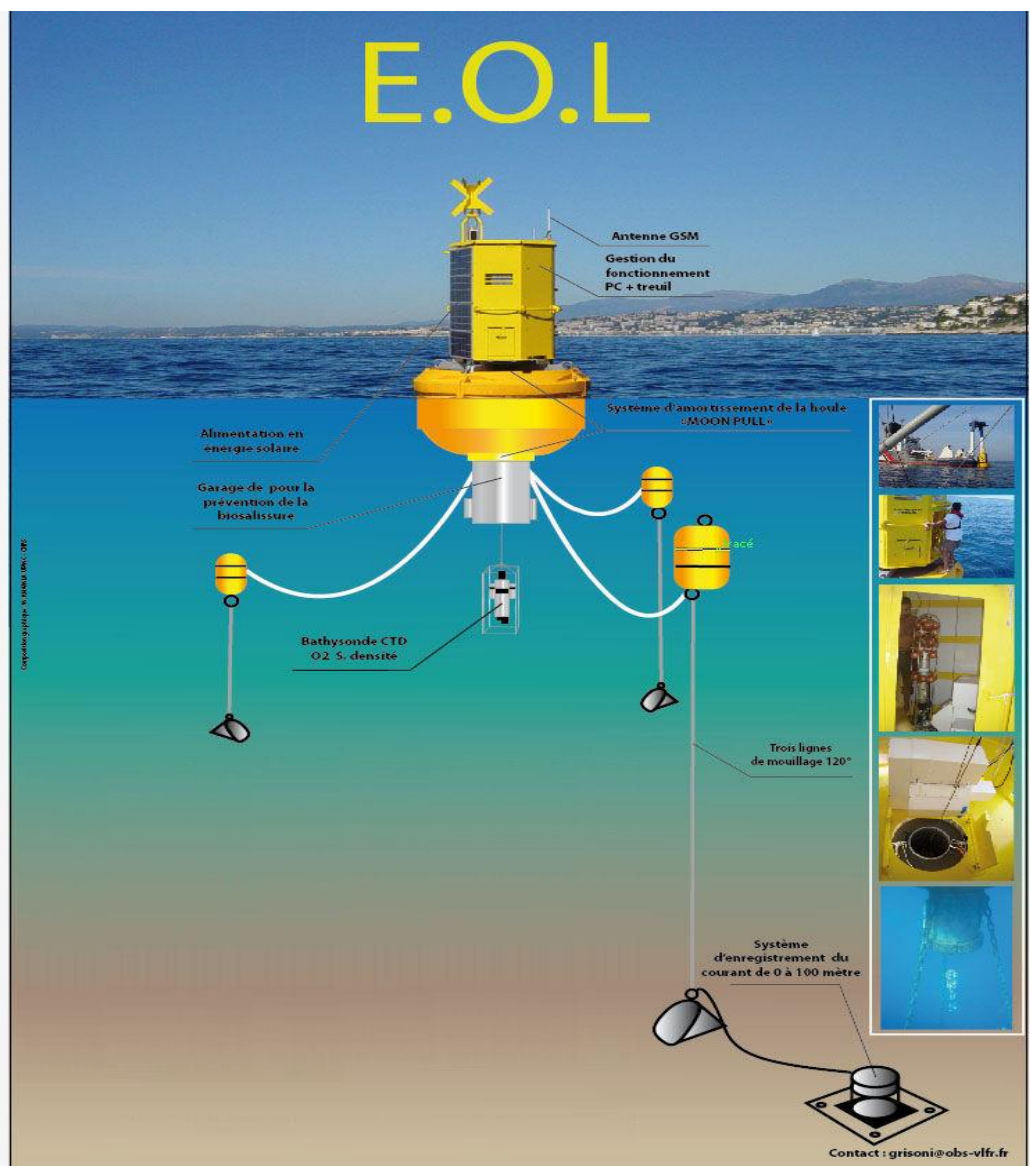
Figure 7 *Schematic of EOL coastal observation buoy.*

In the Villefranche/Mer Oceanological Observatory (CNRS-UPMC)a new type of coastal buoy (MOBILIS) with an autonomous profiler (down to 100m depth) equipped with an anti-biofouling system (chlorination by electrolysis) was developed since 2004 – Figure 7 This concept has been tested for 4 years: buoyancy, winch, energy and software have been validated as well as data transmission system (GMS and wireless). The robustness of the chlorination system has been also validated through the test of the conductivity accuracy (post calibration slope around 1.0001454 after 5 years deployment). Weather station has been implemented on the top of the EOL3 buoy with real-time transmission of data weather

The data is accessible on the web site: http://vtslite.siitech.com/vtslite/AView.aspx and full details of the trial are presented in Deliverable 10.1

### 5.4.2. Future Steps

Since the first version, three versions of the EOL buoy have been developed. The last version, which has been deployed in April 2013, is larger and higher and allow the installation of more sensors. Since the installation, EOL3 is performing a daily CTD profile near the monitoring site Point B (SOMLIT station). The next plan is to install biogeochemical sensors (O2, fluorescence) on the profiler and to implement $pCO_2$ and pH sensors under the buoy. The buoy has demonstrated its capability as a robust platform for the deployment of standard and state of the art sensing technology.

### 5.5. Decription of Technology  -  Emerging Imaging Technolgies

One of the aims of Jerico was to strengthen the use of image analysis techniques to monitor biological compartments and processes that are recorded either at high frequency and/or over large spatial scales using automated or semi-automated procedures.

**Four principal techniques were developed  during the Jerico project**:

> $1^{st}$  development is on in situ video images of the sediment interface acquired using ROV or other mobile systems

> $2^{nd}$ development is on in situ sediment profiler camera system

> $3^{rd}$ development: video sequences, obtained with fixed platform

> 4th development: dealing with pelagic ecosystems analysis of images obtained with Flowcam, Cytoflow and Zooscan systems.

- These imaging technologies are described in detail in Deliverable 10.2[4]

One of the imaging tools - AviExplore provides a unique environment to analyse videos. AviExplore presents a user-friendly interface developed for dynamic image analysis on fast moving environments as well as long-time series of images.

AviExplore can work with images generated by any image acquisition system though its performance depends on the size of the images, the acquisition speed, and the characteristics of the acquisition frame.One of the key features of AviExplore is the possibility of doing a fast image extraction from a video that leads to a straightforward image comparison. Image comparison is the core of AviExplore mobile module. AviExplore provides with the ScriptEdit module and the real time acquisition working modes a wide range of video analysis possibilities which not only fulfil the initial objectives stated at the beginning of JERICO but oversteps them.

### 5.5.1. Appropriate Platform - Mobile Platforms and Coastal buoys

Depending on the objectives of the study , imaging devices for epibenthos surveys can be carried out on different platforms. Static platforms like benthic landers or mobile platforms like ROVs and AUVs. Each type of platform provides imaging recordings that may deal with different issues. Static platforms produce long series of images acquired under different light conditions, different water turbidity produced by sediment suspension and different degrees of biofilm development. Those parameters reduce directly the visibility and affect the quality of images. Mobile platforms need to take the position and speed of the platform so that the exact position of the observed object is

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[4]Deliverable 10.2  - Set of Software - http://www.jerico-fp7.eu/deliverables/d10-2-development-of-set-of-software-for-image-analysis

located.The AviExplorer mobile module has been developed to overcome these difficulties and can be used on mobile and fixed platforms as detailed below, providing a unique environment for video analysis. It is intended that AviExplore become a standard tool for the analysis of benthos video surveys.

### 5.5.1.1. Mobile platforms

AviExplore mobile module has been specifically developed within the frame of Jerico to analyse films coming from underwater mobile vehicles like ROVs, AUVs, etc. The Script editor module allows building adapted scripts to analyse video and count not only epibenthos organisms but other objects present on or around the sea floor. One of these objects can be garbage (**Fig. 8**).

Filters, coupled with geo-localisation and image segmentation help extracting information on the presence of organisms and structures present on the sediment.
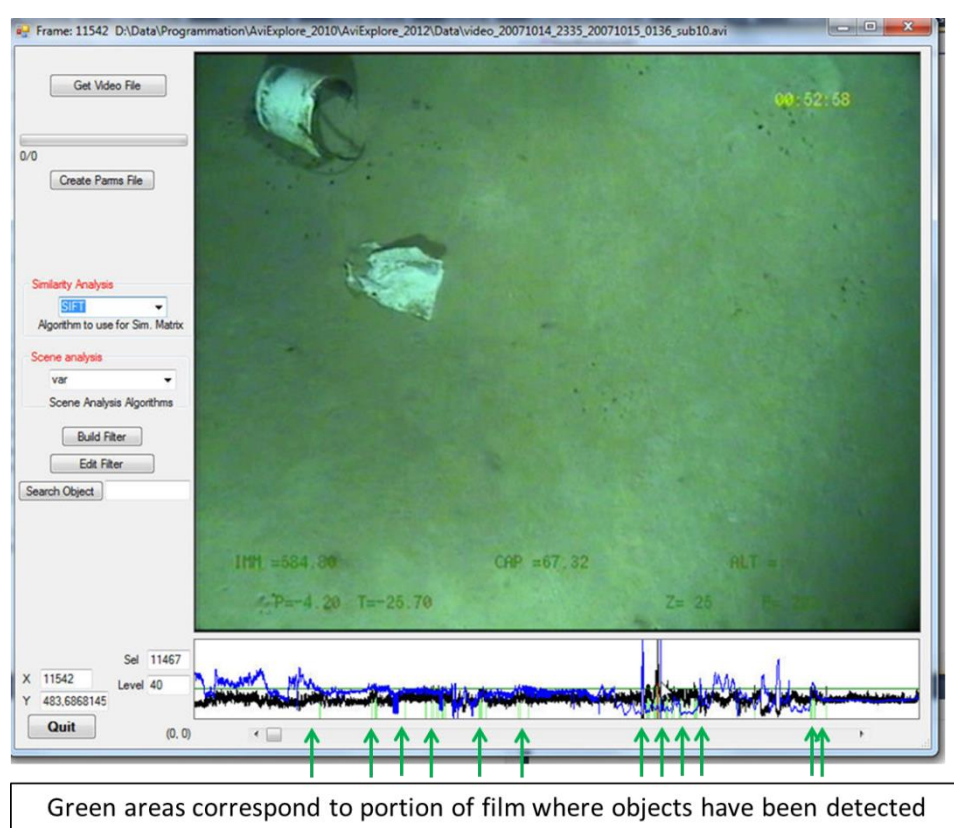


**Figure 8** Example of the use of AviExplore mobile module for garbage location.

### 5.5.1.2. Fixed platforms

AviExplore fixed module has been specifically developed within the frame of Jerico to allow the survey of recruitment on substrates, as well as the growth characteristics of fouling organisms. Image analysis is also used to track the animals settling on the substrate, measure their interactions and growth rates (**Fig. 9**). The key feature of this module is image subtraction that can be combined with the selection of areas to analyse (**Fig. 10**). Based on our experience, and due to the fact that AviExplore has been optimised for fast image extraction, image subtraction

can be first used to identify the regions where there is the most activity and a second time for more detailed information on those regions.
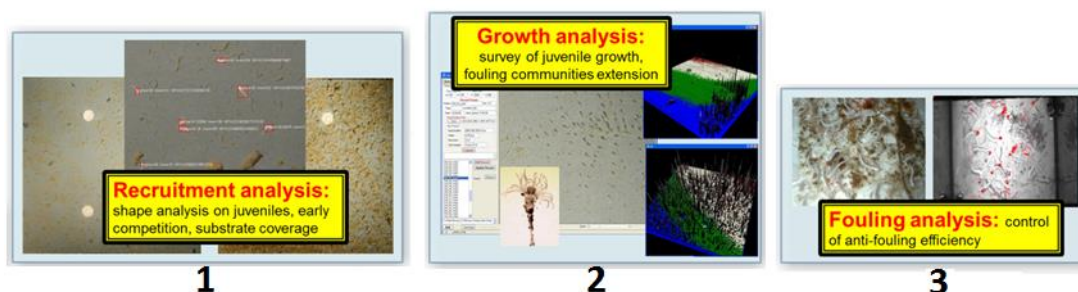


**Figure 9 Examples of the use of AviExplore fixed Module.**



**Figure 10 Example of use of AviExplore  Fixed Module for the identification of regions whith high activity. 1) Gray-scale image, 2) Result of the overall addition of moved pixels, 3) Identification of three regions**

### 5.5.2. Future Steps

Future developments of this module will include the possibility of using a 3D camera in order to have not only surface information but volume estimation.

# 6.     Conclusions

Coastal systems are highly dynamic both from a physical and a biological standpoint. They are also highly heterogeneous in space. Coastal ecosystems are also highly productive and more exposed to human perturbations relative to their open ocean counterparts. There are therefore several key issues for the quality improvement of a European observatory of coastal ecosystems.

This report documents the improvements and the development of new tools and sensors used by Jerico partners allowing for:

(1) The measurements of a new set of parameters (including biological ones)

 (2) A better precision of already available measurements (e.g., in relation with the monitoring of rising threats such as ocean acidification)

(3) The automation of parameter's acquisition, which will allow for operating at higher frequency and on wider geographical scales. This last point is also important in view of reducing the time lag between raw data measurements and the delivery of relevant end products (i.e., in developing operational observatories).

A key issue covered in this deliverable involved analysis of the use and the development of platforms allowing for the optimal deployment of sensors. This includes emerging profiling technology, gliders and ships of opportunity.

 It is clear from analysis of the future steps that in many cases there is a requirement that the technology be improved and/or further adapted before it will be of wide ranging benefit to underpin future operational oceanographic systems in Europe's coastal seas.

It is recommended that Standardised Technology Readiness assessments of all the Jerico sensor technologies and Platforms need to be developed, completed and evaluated. NOC have done this for a number of biogeochemical sensors in Chapter 3 of this report – It is recommended that this type of approach be done for all the others as part of Jerico Next .

There is not a clearintegrated technology roadmap for the future development of the new sensors and emerging technologies developed in Jerico. This road map needs to be completed for technologies developed in Jerico and for other emerging technologies such as those under development under the 'Oceans of Tomorrow' programme of DG Mare. These gaps are described in more details in Deliverable 1.11[5]

The Jerico project has identified the major importance of biological compartments and processes in monitoring the coastal ocean as well as the difficulty in coupling the observations.  This report illustrates the highly significant progress was made in terms of technological development and use of emerging technologies in establishing an operational service for the timely continuous and sustainable delivery of environmental data and information products related to the marine environment in European coastal seas.

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[5] Jerico Deliverable 1.11**Future Strategy for Coastal Observatory – http://www.jerico-fp7.eu/deliverables**

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| 10.1 | Report on trials and deployments: | 10 | MI | http://www.jerico-fp7.eu/deliverables/d10-1-report-on-trials-and-deploym |
| 10.2 | Set of software: | 10 | MI | - http://www.jerico-fp7.eu/deliverables/d10-2-development-of-set-of image-analysis |
| 10.3 | Report on data analysis | 10 | MI | http://www.jerico-fp7.eu/deliverables/ |
| 10.4 | **Report on Potential new sensors** | 10 | MI | http://www.jerico-fp7.eu/deliverables/ |
| 10 | **Jerico Work package 10 Villefranche Workshop Report** | 10 | MI | http://www.jerico-fp7.eu/attachments/article/297/workshop%20WP10%20report%20gnolan |
| 3.4 | **Report on New sensor Developments** | 3 | HZG | **http://www.jerico-fp7.eu/deliverables/d3-4-report-on-new-sensor-deve** |
| 1.11 | **Future Strategy for Coastal Observatory** | 1 | Ifremer | http://www.jerico-fp7.eu/deliverables/ |

**Table 4 Links to relevant Jerico Deliverables**