System monitoring in the Coastal Zone

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Abstract

This article describes the necessity to monitor environmental systems in the context of the SPICOSA project and the SAF framework. It also suggests the use of advanced monitoring technologies that can improve the input data for the SAF modeling.

Contents

1. Introduction:

The SAF (Systems Approach Framework) provides a comprehensive and interdisciplinary view of coastal systems, including ecological, social and economic dimensions of the coastal zones together with emerging concepts on system complexity.

In general, the main approach in the SPICOSA project is to identify coastal problems and explore policy options that might alleviate these problems by applying existing and new data to test models. An improved understanding of the processes that cause environmental deterioration or loss of ecosystem services may ultimately lead to solutions to these problems. The ultimate aim of the project is to improve the status of the coastal environment in the most efficient way. This may be done by means of generic assessment methodologies, decision-support tools and models that may facilitate Coastal Zone

Management. One of the key methods that enable us to assess the status of the coastal system is monitoring.

2. The issues requiring monitoring:

The SPICOSA project tests, improves and disseminates its tools and the SAF throughout Europe, using a diverse set of eighteen coastal study sites. These sites encompass a wide variety of coasts that differ in geomorphology, environmental conditions, cultures, and human activities. Most of the environmental influences are related to human activities such as industrial wastes, intensive agriculture, tourism, fisheries, etc. Anthropogenic pressures on the environment may be direct or indirect, acute or long term, and can cause numerous impacts, such as: Pollution, Eutrophication, Overfishing, Change or reduction in biodiversity, Habitat destruction, Pathogens, Erosion, Food-web changes, etc.

Every one of the 18 Study Sites was affected by human activities and although some sites had numerous stressors, most were not affected by more than a few of the abovementioned impacts simultaneously. In order to correctly assess and prioritize the coastal problems in, coastal monitoring is needed.

Environmental monitoring includes all of the activities and actions that need to take place to characterize and monitor the quality of the environment. Monitoring of environmental quality parameters is a key activity in managing the environment, recovering polluted environments and predicting the effects of anthropogenic changes on the environment. The design of monitoring programs must correspond to the final use of the data, i.e. unlike environmental research, monitoring must include only those data that will be used to meet the program objectives.

Table 1: "Traditional" variables that are monitored in the marine environment[(1)] (from Johnstone et al., 2008).

Physical	Chemical	Biological
Temperature	Total Phosphorous	Fluorescence Chl
Salinity	Phosphate (PO_4^{3-})	Fluorescence Phyco
Conductivity	Nitrogen	Turbidity
Currents	Nitrate (NO_3^-), Nitrite (NO_2^-)	Yellow Substances
Radioactivity	CO_2	Phytoplankton
Pressure	Ammonia (NH_4^+)	Zooplankton
Water level	Silicate (SiO_4^{4--})	Secchi Depth
Wave direction	PH	Nutrients
Wave height	Heavy Metals	Photosynthetic light
Solar Radiation	Hydrocarbons	PAR

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The SAF is based on existing knowledge and evolves with new knowledge and its limitations may be defined by the availability of data. Whereas national databases may be an important source of information, these are often of limited use, due to problems of scale.

SPICOSA deals with issues on local scales whereas most national coastal monitoring programs focus on larger (e.g. basin) scales. These types of data are therefore incompatible with the models run by SPICOSA and therein lies the problem. Where such local-scale coastal data do exist these are usually proprietary and are therefore hard to obtain. In such cases, it is necessary to search for other approaches to obtain the required information. It is possible to improve our access to environmental data by employing "advanced" monitoring technologies such as smart sensors and remote sensing.

3. Advanced monitoring:

There are a few points that characterize the transition from traditional monitoring to advanced monitoring, including:

- *Improved public access to data, and on-line internet products.*
- *Implementation of new and state of the art technologies (advanced monitoring and smart systems).*
- *Fast-response data gateway and documented methods.*

Advanced monitoring may be achieved by employing new instrumentation or sampling methods for monitoring new variables or to improve the (efficiency or accuracy of) acquisition of traditional data required by modelers. Some of the advanced monitoring technologies are still inferior or equal to the traditional ones, but they can be used to supplement and improve ongoing environmental monitoring in terms of data quality and/or data availability. Some of the advanced technologies were unavailable until recently, mainly as a result of cost, but the technologies are improving and prices are dropping in recent years, making these more attractive.

Advanced technologies can help overcome logistical problems, reduce the need for manpower and increase the spatial coverage and availability of data. At the same time, some of the technologies (e.g. remote sensing) still have low resolution as compared with traditional methods and they cannot be used as independent sampling units. In addition, there are still objective technological barriers to some of the environmental monitoring issues.

Examples of advanced monitoring technologies:

3.1 Smart sensors [1] [2] [3]

Smart sensors networks provide advanced technology that monitors and stores environmental data and simultaneously enabling users to interact with the network and system operation as part of the coastal management.

Advanced sensor technology and wireless communications enable smart sensors networks (including individual environment sensors) to join forces and establish composite environmental data alignment. The superiority of sensors networks over traditional sampling methods is enormous. These do not require human effort in the field, are easy to deploy in-situ, they can organize and process incoming data, and operate as a communicated system with access to all of the sensors. In fact, the meaning of "Smart sensor" is the ability to communicate with other sensors and create a network, that enables the collection, processing and transfer of data in the most efficient way to the end user.

Smart monitoring networks are often called intelligent monitoring. Such sensor networks provide an advanced state of the art system through which the end-user can observe and interact with the environment in real time.

The ability of Intelligent monitoring to adapt to different and changing environmental conditions (and potentially adjust management tactics accordingly) can lead to higher model accuracy, and therefore to better prediction and wiser coastal environment management.

What is Intelligent Monitoring?

Monitoring systems generally produce data which is often useless to the end-user, because it needs to be interpreted or converted by means of experts or expert systems into intelligible data, i.e. information. The conversion of data to information often involves the compilation of different types of data or data obtained from different sources. Because it deals with information, Intelligent Monitoring can be used to evaluate the quality of the data (self-evaluation), to provide recommendations on current environmental status, and to evaluate trends in the data for predictive purposes. In the SPICOSA project, expertise and understanding gained from the study of each of the SSAs may be used toward the implementation of intelligent monitoring systems.

Example of intelligent monitoring: Algal blooms are characterized by an abrupt increase in algal biomass. The database at an SSA that monitors chlorophyll a concentrations should include the normal seasonal rate of change in chlorophyll a and if this rate is exceeded, the intelligent monitoring system should notify the coastal managers of the likelihood of an algal bloom.

3.2 Smart buoys

These are floating monitoring platforms (buoys) that include several sensors and record environmental data in real time. The buoy transmits the data to computers, thereby enabling online access to these data from anywhere in the world. What makes the buoys "smart" is that these systems are programmed to evaluate the data (self-evaluation), and to flag the system if there is a sudden change in the environment that may threaten a given region or activity.

The sensor network usually includes a few nodes that gather data autonomously, and transmit these to a sea surface transmission station, that forwards the data to a sensor network server as shown in Figure 1.[(1)]. The transmitting station has a large storage capacity, high electric power, internet accessibility and high-speed radio communications in order to send the data to the base station [(1)]. These network buoys improve the process of environmental monitoring by creating an easier and more efficient process for collecting multiple types of information, and providing better access to the data, thereby enabling enhanced management possibilities.

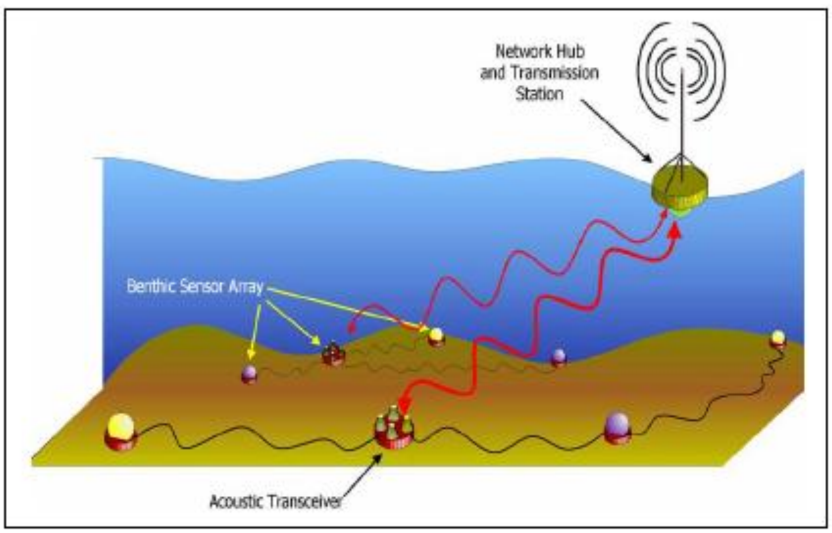

Figure 1: Sensors network with several nodes, each collecting data autonomously and transmitting the data acoustically to the transmission station (buoy), located on the sea surface. The buoy forwards the data to a sensor network server, at the base station and from there to the end users (from Johnstone et al., 2008).

Smart sensors enhance the scope for monitoring and may record many of the variables conventionally measured in the marine environment including: temperature, pH, salinity, chlorophyll, nitrate, dissolved oxygen, etc. and weather conditions, e.g. wave high, wind, etc.

Figure 2: Smart buoy being used in a NOAA project (from Malthus et al., 2003).

3.3 Remote sensing

Remote sensing involves the use of satellite and airborne sensors for imaging and for monitoring purposes. The combination of remotely-sensed data, in-situ data, and interactive analysis techniques is a powerful way to examine marine environments, and to understand better the relationships in coastal systems. Remote sensing techniques are not limited by location and can serve the coastal as well as oceanic purposes.

Remote sensing data (RSD) can be an asset to coastal resource managers by providing a pictorial representation of coastal processes [6]. Remote sensing may be used to monitor shoreline changes, quantify coastal erosion, map coastal features such landscapes and vegetation, study sediment transport, map coastal features for geographic information system (GIS) input, and evaluate the effects of human impact on a given area.

Large scale oceanic features and processes such as ocean circulation, current systems, upwelling and turbulence, can be better understood by using remote sensing and can lead to better ocean resources management. Additional oceanographic variables, such as chlorophyll concentrations, water temperature, wave heights, sea surface winds, sea ice coverage, etc. may be more clearly visualized and integrated by means of satellite imagery. Indeed, as specified in some of the SPICOSA SSA case studies, the monitoring process would benefit from the incorporation of advanced technologies, such as remotely-sensed data, in order to improve the environmental database and modeling input.

Examples of SPICOSA SSA comments related to RSD:

Izmir Bay - the use of remote sensing to identify red tides

Himmerfjarden and Gulf of Gdansk - the use of remote sensing as a diagnostic tool for eutrophication

3.4 Bioindicators

A Bioindicator is the use of a biological response (e.g. presence, absence or change in the status of an indicator species) to indicate environmental change. Monitoring changes in bioindicators informs us of the changes that have occurred in their environments and provide a rough indication of the health of the ecosystem. Although it may seem intuitive, it is not easy to find organisms that are suitable for use as reliable bioindicators. This generally requires preliminary research, long term ecological studies and considerable experience with the candidate organisms.

In the Venice Lagoon, an SSA in the SPICOSA project, bioindicators were monitored successfully.

See also:

Internal links: (all the others are hyperlinks)

Instruments and sensors to measure environmental parameters.

Monitoring the water quality of coastal waters with automatic equipment

Monitoring coastal morphodynamics using high-precision multibeam technology

Determining coastal water constituents from space

Real-time algae monitoring

Space geodetic techniques for coastal zone monitoring

Coastal observatories

More advanced monitoring technologies:

Elemental mass spectrometry a tool for monitoring trace element contaminants in the marine environment.

[Argus video monitoring system](#)

[Video technology](#)

[Monitoring coastal morphodynamics using high-precision multibeam technology](#)

External links: *(all the others are hyperlinks)*

Remote sensing (Wikipedia)

More advanced monitoring technologies:
An in situ flow cytometer for the optical analysis of individual particles in seawater

Examples of real time data from smart buoys:
USA- http://www.buoybay.org/site/public/
Ireland- http://www.marine.ie/home/publicationsdata/data/buoys

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2. *Akyildiz, I.F., Su, W., Sankarasubramaniam, Y., Cayirci, E. 2002. Wireless sensor networks: a survey. Computer Networks: The International Journal of Computer and Telecommunications Networking 38: 393-422.*
3. *Wang, J. Wang, J. Electrochemical Sensors for Environmental Monitoring: a Review of Recent Technologies. National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.*
4. *Proll G., Tschmelak J., Gauglitz G. 2006. Advanced Environmental Biochemical Sensor for Water Monitoring,* Soil and Water Pollution Monitoring, Protection and Remediation. Springer Verlag
5. *Malthus T.J & Mumby P.J. 2003. Remote sensing of the coastal zone: an overview and priorities for future research, International journal of Remote Sensing 24(13): 2805-2815.*