9th International Congress on Environmental Modelling and Software

1st International Congress on Environmental Modelling and Software - Lugano, Switzerland - June 2002

Jul 1st, 12:00 AM

ArcheoRisk: a Decision Support System on the Environmental Risk for Archeological Sites in the Venice Lagoon

C. Carlon

Antonio Marcomini

Luigi Fozzati

Petra Scanferla

Stefania Bertazzon

See next page for additional authors

Presenter/Author Information
C. Carlon, Antonio Marcomini, Luigi Fozzati, Petra Scanferla, Stefania Bertazzon, Sara Bassa, Francesca Zanovello, Foramiti Stefano, Roberto Chiarlo, and Francesco Penzo

ArcheoRisk: a Decision Support System on the Environmental Risk for Archeological Sites in the Venice Lagoon

Claudio Carlon[1], **Antonio Marcomini**[2], **Luigi Fozzati**[3], **Petra Scanferla**[1], **Stefania Bertazzon**[1], **Sara Bassa**[1], **Francesca Zanovello**[1], **Foramiti Stefano**[1], **Roberto Chiarlo**[4], **Francesco Penzo**[4]

[1] *Consorzio Venezia Ricerche, Venice, cla.cvr@vegapark.ve.it*
[2] *Dept. of Environmental Sciences, University of Venice*
[3] *NAUSICAA - Soprintendenza Archeologica del Veneto*
[4] *Thetis SpA, Venice*

Abstract: More than 250 submerged archaeological sites were identified in the Lagoon of Venice, which account for an historic and artistic heritage of extraordinary value. These sites are endangered by several environmental and human factors: erosion, chemical pollution, organisms (mainly wood borers), motor-boat traffic, fishery activities, and robbers. A Decision Support System (DSS), named ArcheoRisk, was developed to include the safeguarding of archaeological sites within the environmental management of the Venice lagoon and to select most effective safeguarding/rehabilitation interventions, whenever needed. The DSS relies on a Geographical Information System platform (Arcview) and is composed of two modules: (1) assessment of archaeological risk, (2) selection of interventions. An environmental-archaeological geo-referenced database was constructed and an environmental risk assessment methodology for archaeological sites was developed, based on the conventional source-pathway-receptor scheme. The two-steps procedure includes (1) Screening Risk Assessment and (2) Site Risk Assessment. Screening Risk Assessment provides risk maps and priority of intervention based on risk sources and archaeological sites location and value. Site Risk Assessment is a ranking procedure requiring the user to fill a scoring questionnaire about type of risk sources, exposure and material vulnerability of artefacts present at the site. Based on the risk assessment, the selection of intervention (investigations and safety measures) is supported by an Intervention Selection Matrix, i.e. environmental features *vs* risk types, and an archive of intervention costs. In its prototype format, the ArcheoRisk DSS is being submitted to a wide testing activity and will be adopted by the Cultural Heritage Authority in Venice for communication, programming, and planning of interventions. It can be easily applied to different case studies and environments, thus providing a promising reference of GIS-based DSS and risk analysis application for the integrated management of environmental and cultural heritage.

Keywords: Decision Support System, Archaeology, Risk Analysis, Environmental management, Archaelogical management

1. INTRODUCTION

Nowadays, more than 250 submerged and semi-submerged archaeological sites were identified in the Lagoon of Venice, which represents an historic and artistic heritage of extraordinary value.

The in situ conservation of this archaeological heritage is endangered by several environmental and human factors, such as erosion, chemical pollution, organisms (mainly wood borers), motor-boat traffic, fishing activities, and robbers.

These factors are highly inter-related, for example, fishery and motor-boat traffic may accelerate the erosive processes. The safeguarding of the archaeological sites has to be integrated with other environmental management issues.

This integrated approach can be highly demanding in terms of coordination of multiple expertise, time and costs: different types of information have to be collected, validated and assessed by specialists, before to be integrated and transformed in easy indicators for the decision makers to compare options. Tools are required to archive, transform and combine the available information into a manageable form, as well as to enhance the integration and assessment capabilities.

For this purpose, a research project was undertaken to develop a Decision Support System (DSS) prototype. The DSS, named ArcheoRisk, was conceived to support the Cultural Heritage Authority and other institutions in charge of the Venice Lagoon management for communication and integrated planning. The project involved a close collaboration among experts in information technology, archaeology and environmental sciences.

2. TOOLS AND METHODS

2.1 Information technology

The DSS prototype was developed in a GIS environment by using ArcView release 3.2 and Avenue as programming language. Access 2000 was used for database management.

2.2 DSS structure

The basic DSS structure is shown in Figure 1. It is based on two databases, one for archaeological and one for environmental data, and includes three assessment modules, for risk assessment, intervention selection and cost analysis, respectively.

The archaeological and environmental information is integrated by the evaluation of the "Environmental Risk for Archaeological Sites" (ERAS), intended as the potential of

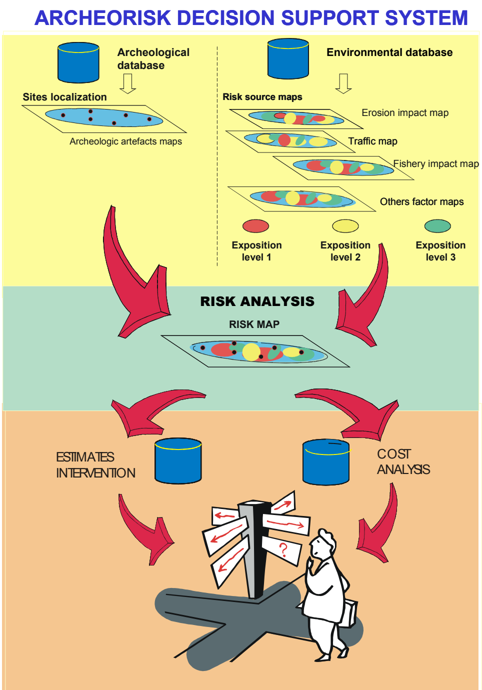

Figure 1. Structure of the ArcheoRisk DSS.

environmental factors to cause adverse effects onto the archaeological sites. ERAS assessment provides relevant information to define priorities and supports the selection of rehabilitation/safeguarding interventions, which is carried out on a risk-reduction basis in the intervention option module. Finally, the cost analysis module allows the economic comparison of different interventions.

The ArcheoRisk DSS users should be aware of the archaeological and environmental major issues of the lagoon of Venice. Basic knowledge of the GIS tool is required, as the DSS shows an easy and friendly user inter-face. Basic instructions of the ArcheoRisk application software and Arcview tools are provided in two manuals.

2.3 The archaeological database

The **archaeological database** collects information about 250 archaeological sites of the Venice lagoon into a relational logical data scheme. For each site, the following attributes are reported: archaeological codes, site code number, east and north coordinates (Gauss-Boaga – National geographical reference system), site name, site location (description), historical period of the site, surveys data (including dates, authors and documents), types of archaeological findings, archaeological value (this index is defined in the risk assessment procedure), relevant multimedia documents. A logical link provides a relationship between the GIS environmental database and the archaeological database.

2.4 The environmental database

The **environmental database** includes base-maps, data, thematic maps and their pertinent attribute data. A number of environmental factors were regarded as **risk sources**: erosion processes, the presence of specific physical-chemical conditions and wood-borer organisms, the pressure of motor-boats traffic, fishing activities and robbers.

Based on experimental data, the distribution of risk sources in the Venice lagoon was mapped. The risk sources intensity was referred to a four-level qualitative scale: high, medium, low and none, with 3-2-1-0 value, respectively.

As an example, the erosion intensity map (figure 2) was realized on the basis of bathymetric maps recorded in the 70's and 90's. Intensity classes were obtained by applying the following criteria:

- none, emerged land;

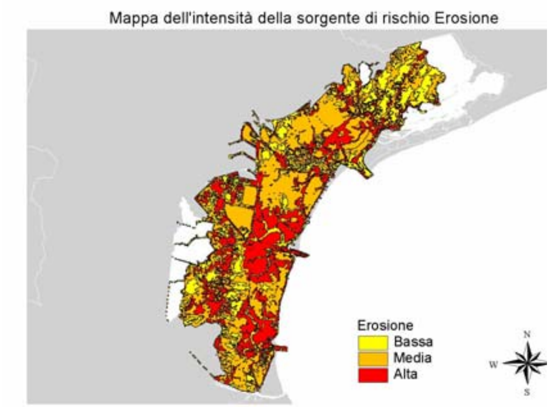

Figure 2. Erosion risk map

- low, > 20 cm sedimentation
- medium, < 20 cm erosion
- high, > 20 cm erosion

In case experimental data were not available, expert judgment was included into the mapping exercise. An example was the fishing activity map. The fishing of mussels, in particular the *Tapes philippinarum*, in the Lagoon of Venice is very productive as well as heavily impacting the surface sediment (and any archaeological manufacture in it). Although this activity is regulated, and either some areas of the Lagoon and certain instruments to collects mussels are not allowed, illegal fishing is common and difficult to control. Institutional data on the distribution and methods of these legal and illegal practices are not available, therefore the knowledge of lagoon specialists and practitioners was considered. The judgement of two teams, one of biologists and one of technical workers, was separately obtained. Two zoning maps of the fishing practice (high, medium and low intensity) were drawn by the two teams. The two maps were very similar and only few zones were not corresponding, which have been retained by giving intermediate intensities. Moreover, the information about commonly used collectors with respect to the water depth was transformed into the following criteria:

Water depth	Instrument	Impact
> 1.5 m	Aspirators-like	high
1.5-0.5 m	Plough-like	medium
< 0.5 m	Rake-like	low

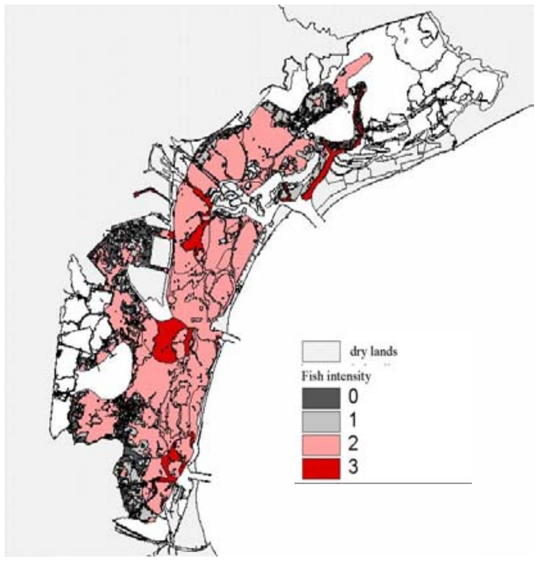

Figure 3. Fishing activity map

Finally, the fishing activity map was overlayed onto the bathimetry map, and the "fishing activity risk source" map was obtained (figure 3).

2.5 The risk assessment

A risk assessment procedure for archaeological sites was developed (ARASA). The main methodological references were the environmental and human health risk assessment procedures (US-EPA, 1989; ASTM – RBCA, 1995; US-EPA, 1998).

Risk assessment was based on a conceptual model, by which risk sources of concern, impacting actions and effects are identified, and the cause-effect chain is described. The conceptual model scheme for the archaeological risk assessment in the lagoon of Venice is represented in figure 4. It shows that fishing activities and motor-boat traffic play a double role, by affecting the surface archaeological sites, and accelerating erosion processes.

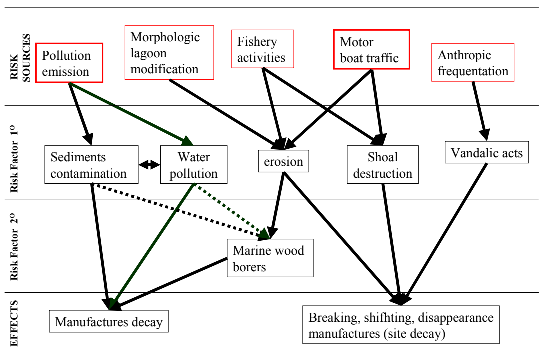

Figure 4. Environmental risk conceptual model for the Lagoon of Venice archaeological sites.

A three-level **risk assessment** procedure was developed:

1. exposure assessment;
2. screening risk assessment;
3. site risk assessment.

Exposure assessment is an overlaying exercise of risk sources maps. The exposure in each point is calculated as the weighted sum of different risk sources intensities at the point.

The Screening Risk Assessment provides risk maps and priority of intervention based on risk sources and archaeological sites location and value. The Screening Risk (SR) estimation is based on the following formula:

$$\boldsymbol{SR = exposure \times W_{av} \times archaeological\ value \times P}$$

where:
exposure is the weighted sum of risk sources intensity;
$\boldsymbol{W_{av}}$ is a weight for the archaeological value;
archaeological value is an index of the archaeological value based on the conservation *status* of the archaeological site;
P is an uncertainty factor.

In strictly archaeological terms, all manufactures have the same value; however, in operational terms, we can expect some can give more historical information than others. It has been assumed that the potential for historical information is proportional to the *conservation status* of the manufacture/site. The conservation status of each site/group of manufactures has been evaluated by the expert team of the Archaeological Council based on these criteria:

- (0) unknown
- (1) destroit, one or few manufactures without continuity (some manufactures may be not in their original context),
- (2) low conservation degraded, low physical and historical continuity,
- (3) medium conservation, sufficient continuity for a coherent interpretation,
- (4) good conservation, high continuity leading to an easy interpretation,
- (5) excellent conservation, high continuity without lacks, leading to an evident interpretation.
-

W_{av} was used to adjust the archaeological value scale to that of the exposure, thus giving them the same relevance in the risk calculation.

The P-value is 0 if any exposure factors in that location is unknown/uncertain, otherwise it is 1. The P-value is used as a label for the selection of sites that warrant further investigations and precautionary evaluations.

Site Risk Assessment is a ranking procedure requiring the user to fill a scoring questionnaire about type of risk sources, exposure and vulnerability of artefacts present at the site. The analysis highlights four aspects: (1) type of sources at the site, (2) type of artefacts present at the site, (3) effective exposure to the source, (4) vulnerability of the artefacts. Therefore~~,~~ matter, shape and durability of artefacts are taken into account.

A comprehensive and detailed description of this procedure will be object of a different scientific paper. Major applications of the three risk assessment levels are reported in table 1.

Table 1. Major applications and scale of analysis of the three risk assessment levels in ArcheoRisk

Analysis	Major applications	Scale
Exposure assessment	To highlight the zones with a relevant presence of risk sources, both in terms of number and intensity	Regional
Screening risk assessment	To provide a priority list of most endangered archaeological sites To identify the most relevant risk sources To model the archaeological risk variation due to risk sources changes	Regional
Site risk assessment	To assess the specific risk for a site To evaluate the best intervention options to reduce the total risk at a site	Local

2.6 Interventions

Interventions include archaeological surveys and safety measures. In fact, a detailed description of archaeological findings is usually necessary before to undertake safety measures. Most common safety measures intervene by covering the site with sheet piles, gabions, sand sacks, silty or clayey strata. In other cases, regulatory measures (e.g. prohibitions, access restrictions, etc.) are undertaken. Which measure to consider depends either on the risk source and the morphological location of the site: e.g. against the motorboat traffic, gabions or sheet piles would be required if the site is next to a navigable canal, whereas sand sacks would be indicated in a salt marsh where low hydrodynamic forces are present; against borer organisms anoxic conditions are required and the cover with silty or clayey strata are indicated, but sheet piles or sand sacks might be also necessary if erosion processes are present. Moreover, intervention restrictions can be present in some part of the lagoon to preserve the natural habitat.

The intervention module provides a matrix to select the best safety measure according to the most relevant risk sources and the location of the site (salt marsh, island, canal, embankment, special restrictions etc.). The matrix has been compiled by a team work of archaeologists and biologists.

The user can evaluate the best options according to the most relevant risk assessment.

2.7 Cost analysis

The **cost analysis** module supports a preliminary calculation of selected intervention costs. It considers both personnel, e.g. the work of archaeologists, divers, photographers, topographer, etc., and equipments, e.g. boats, pumps, etc..

3. EXAMPLE OF APPLICATION

ArcheoRisk has been submitted to a testing activity in collaboration with the Council for Cultural Heritage.

Two testing applications are here reported:
- the identification of the most endangered archaeological sites;
- the ex-ante impact assessment of the new Fishing Regulatory Plan.

The screening risk assessment was applied to all archaeological sites in the Lagoon of Venice. A useful ArcheoRisk output was the pie-chart screening risk map, here represented in figure 5.

For each archaeological site, the pie chart dimension is proportional to the total risk, while the slices express the contribution of each source. The screening risk intensity was considered to provide a ranking list of the most endangered sites.

Ten sites over 250 warranted a field survey to verify their actual exposure and 4 over ten actually showed the need for safety intervention. Moreover, the most relevant risk factors appeared to be the vandalism in the northern lagoon, the erosion and wood borer organisms in the central lagoon. This information raises the needs for interventions against erosion processes in the central lagoon and the uncontrolled recreational use of the northern side.

With regard to the fishing activity, it is currently

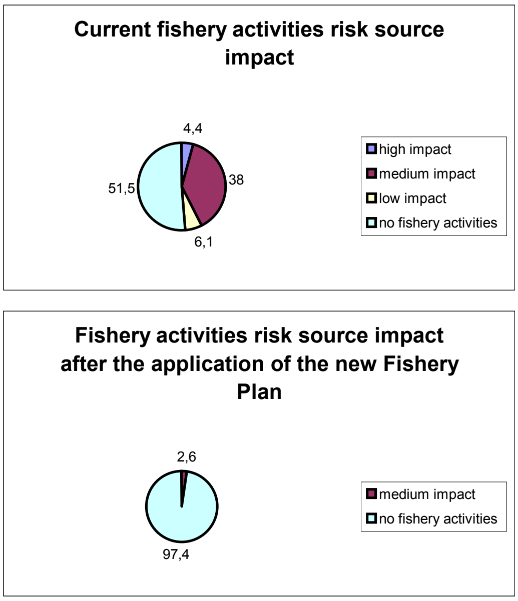

Figure 6. Fishing activity impacts before and after the application of the New Regulatory Plan

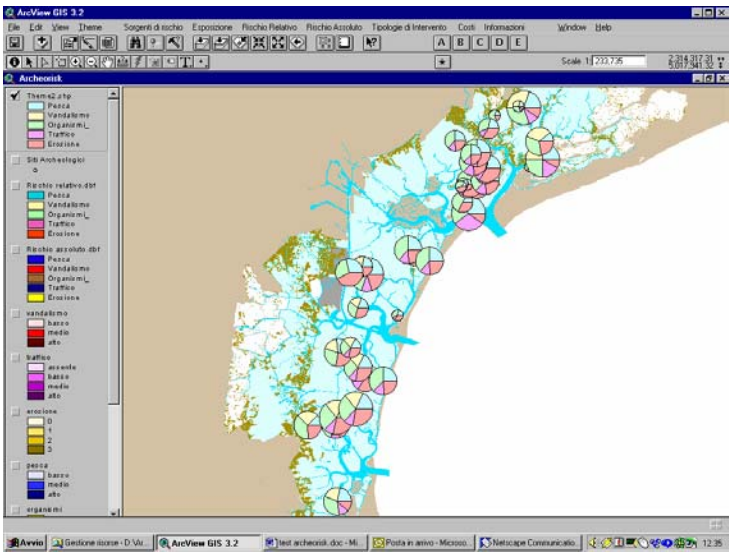

Figure 5 . Screening Risk Analysis result

allowed in almost all the lagoon. In particular, the use of aspirator-like and plough-like collectors heavily impacts the surface sediment and any archaeological remains in it.

A new Regulatory Plan is intended to restrict the total surface allowed for the fishing activity. The fishing areas was defined by the Fishing Authority of Venice Province on the basis of sediment and water quality criteria. The Supreme Council for Cultural Heritage was asked to tune the definition of the fishing area in order to minimize the impact onto archaeological sites. For this purpose, ArcheoRisk screening risk assessment was used to compare different scenarios. The ex-ante calculation of the number of archaeological sites exposed to the fishing risk source before and after the application of the definitive Plan are shown by means of pie charts in figure 6.

4. CONCLUSIONS

The evaluation phase in collaboration with the Council for Cultural Heritage has proved the ArcheoRisk potential for integrating the archaeological safeguarding within the environmental management of the Venice lagoon. ArcheoRisk facilitated the communication flows between the Supreme Council for Cultural Heritage and other Institutions responsible for environmental policies. It also provided a common technical platform for environmental scientists and archaeologists to analyse the system.

One of the major ArcheoRisk achievements is the development of a conceptual model of archaeological risk, based on the definition of operational attributes for archaeological environment sites and artefacts.

The ArcheoRisk outcomes will implement the archaeological database including the information required for management and research purposes. A digital format for data collected in archaeological surveys will be defined, and activities for up-dating and up-grading the available database will be planned.

The DSS structure will be also implemented to increase the integration of different environmental management activities. ArcGis 8.1 will be used to develop a client/server-structured architecture, including a multi-user Geodatabase, different authorization levels, and DBMS technology.

5. ACKNOWLEDGEMENTS

The ArcheoRisk project has been co-funded by the Italian Ministry of Scientific and Technological Research, under the law 488/92, cluster C29.

6. REFERENCES

ASTM. Standard Guide for Risk Based Corrective Actions Applied at Petroleum release Sites, E-1739-95, 1995

U.S. Environmental Protection Agency. Risk Assessment Guidelines for Superfund: Volume 1 – Human health evaluation manual, EPA/540/1-89/002, 1989.

U.S. Environmental Protection Agency. Guidelines for ecological risk assessment. Washington DC: Risk Assessment Forum. EPA/630/R-95/002F, 1998., Canberra, 1998.