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Venice Sustainability Advisory Panel



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# Venice Sustainability Advisory Panel

FINAL REPORT

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## Final Report

**Prepared for Thetis S.p.A.**

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The Venice Sustainability Advisory Panel (VSAP), an international group of experts in environmental sustainability put together by UC San Diego's Sustainability Solutions Institute, was created to advise key authorities and decision-makers on how to prepare regular formal assessments of the environmental sustainability of the Venice Lagoon and its surrounding regions, taking into account the specific social and economic drivers of environmental change in the region. Assessment is regarded as a critical initial step in achieving adaptive management capability. The VSAP met three times - twice in Venice (in June 2008 and September 2008) and once in La Jolla (in January 2009).

# Executive Summary

The Sustainability Solutions Institute of the University of California, San Diego has assembled an international panel of expert advisors to examine the readiness of Venice to make adaptive management decisions based on formal assessments of the sustainability of the Lagoon and its ecosystems.

We have examined the ecology and physics of the Lagoon, and the present capacity to monitor and model them. We find that the environmental monitoring and research presently being done provides a strong platform for the further development of modern sustainability management techniques. We have recommended technical, policy, and institutional innovations that are needed to strengthen the capacity for adaptive management. Our specific aims have been, first, to advance and focus the bio-physical monitoring and modeling of the Lagoon, and, second, to recommend ways to ensure feedbacks among environmental assessments, policy decisions, and management actions.

The key threats to the ecology of the Venice Lagoon are sediment loss, nutrients, fishing, habitat destruction and chemicals. We recommend that these threats be prioritised and key management responses, already developed by Magistrato alle Acque through its plan of interventions, be improved and integrated to avert major ecological change.

The growing recognition of human dependence on ecosystems has focused attention on the value of ecosystem services. Enhanced valuation, understanding, and communication of the inter-connections within the Lagoon social-ecological system promote sustainability. It is important, therefore, to describe, quantify, and value (ecologically, culturally and economically) the importance of the goods and services provided by the ecosystems and biodiversity in the Lagoon.

From a physical/chemical viewpoint, the whole Lagoon is interconnected, and sustainability can only be a 'whole-lagoon' concept. It is difficult, if not impossible, to assess the Lagoon holistically from an array of point measurements separated in space and time. Modelling connects monitoring data together and relates individual ecological events to the overall circulation.

Modelling is central to the management of the Lagoon. Models provide an organizational structure for monitoring (e.g., consistency of inputs, planning of measurement deployments), a basis for monitoring data analysis, a methodology for hypothesis testing, a means of assessing potential adaptation measures, and a unifying way to assess the state of the whole Lagoon.

Integration of modelling and monitoring is needed on both the multiyear sustainability time scale and the short time scale associated with high water events and gate openings. Today's models mostly treat the short time scale, and monitoring mostly follows the long time scale. To support adaptive management, modelling and monitoring must be brought together on both time scales. Furthermore, the integration of modelling and monitoring enables the feedback required to assess, improve and update the systems as research and technology advance, and key issues change.

Social and economic changes are happening in complex and dynamic ways, climate is evolving, and decisions about an uncertain future are best made iteratively. Venice has the talent and technology to manage its Lagoon adaptively, but in our view it needs three institutional innovations- periodic independent assessments, a professional monitoring and modelling organization, and an advanced study program or school devoted to sustainability issues.

Ultimately, the creation of operational and research organizations that are designed to work closely together could establish Venice as a world centre for studies of the sustainability of human-dominated lagoon ecosystems. By leading the way in connecting interdisciplinary science with practical use, the scientific and social technology developed for assessment and adaptive management could nucleate a cluster of academic programs and consultancies in broad areas of sustainability science, technology, and policy.

Venice is developing a 21st century capacity to manage its waters. The Venice MOSE floodgates, when completed, are designed to protect against high water events. Since high water events are expected to grow in frequency and intensity as sea level rises over the century, the gates will make a definite contribution to sustainability. Although not directly assessed by the present study, operation of the gates at other times could enable a degree of control over the circulation of the waters in the Lagoon, potentially permitting, integrated with appropriate safeguards, new ways to manage the ecological and economic systems using the Lagoon. Of more immediate concern, we note that the sophisticated engineering and management capacities brought to Venice by the gates project could be applied to a decision-support system for adaptive ecosystem management that could match any in the world.


# Summary Recommendations

## I. Physics

1. *Integrate modelling, monitoring and management of the Lagoon*
2. *Improve evaluations and assessments of whole-Lagoon budgets of sediments, salinity, and nutrients.*
3. *Continue and improve monitoring and modelling of long-term and short-term developments and their interactions.*

## II. Ecology

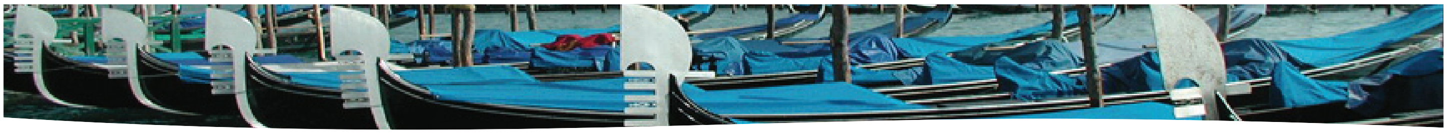
1. *Use existing and new survey data to establish environmental baselines against which changes can be measured*
2. *Develop a more integrative and cost-effective ecological monitoring strategy*
3. *Establish a central data repository, analysis, synthesis and reporting facility*
4. *Establish environmental goals with respect to quality elements used to assess ecological status.*

## III. Policy and Institutional

1. *Commit to a published schedule of assessments*
2. *Commit to ongoing comprehensive monitoring and research*
3. *Create a governing board*
4. *Magistrato alle Acque to be established as a Governance Secretariat that, among other things:*
   a. Oversees the relationships among MOSE management, the new monitoring organization, and the advanced study program;
   b. Designs, facilitates, and oversees the assessment process;
   c. Convenes the independent science, technology, and management panels that report to the governing board;
   d. Monitors regulatory compliance;
   e. Promotes effective decision support; and
   f. Acts as the board's interface with policy makers, stakeholders, and the public.

5. *Magistrato alle Acque to be established as an Operational Monitoring and Modelling Organization that would:*
   a. Plan, maintain, validate, and update modelling and monitoring systems;
   b. Collect and provide data relevant to managers and stakeholders;
   c. Ensure continuity of time-series data;
   d. Provide decision-support products – indices, thresholds, decision algorithms-defined by management goals;
   e. Provide uniform access to information via online portal; and
   f. Organize intensive sampling periods and rapid response teams.

6. *An Advanced Study School or Program to:*
   a. Review, condense, and unify research findings;
   b. Prepare research, monitoring, and modelling results for assessment;
   c. Connect the research, monitoring, and modelling communities;
   d. Suggest introduction of new monitoring variables and technologies;
   e. Aggregate research funds and sponsor external research projects;
   f. Incubate collaborations amongst research groups; and
   g. Undertake interdisciplinary research related to sustainability.



# I. Physics

Like any ecosystem, the ecosystem of Venice Lagoon dwells upon and within the physical and chemical structures that comprise the Lagoon. Those structures include both the solid geomorphic setting and the fluid hydrodynamic circulation system. The sustainability of the Lagoon as an ecosystem depends on the sustainability of the geomorphology and estuarine waters just as much as it depends on the biological processes in the ecosystem. Our aim here is to identify some of the most basic challenges to the sustainability of Venice Lagoon, from a physical/chemical perspective, and to suggest some scientific strategies for ensuring that the Lagoon can be monitored, regularly assessed, and ultimately managed sustainably long into the future.

### 1.1 Summary of Physical/Chemical Recommendations

1) Establish environmental baselines of physical/chemical properties
2) Develop a whole Lagoon-scale approach and improve update the Lagoon budgets, especially for sediments and nutrients as designed by Magistrato alle Acque
3) Maintain much existing monitoring to track and assess long term sustainability
4) Develop mostly new monitoring capabilities for finite duration events (e.g., effects of MOSE experiments and operations)
5) Expand and assess operational models and forecast/scenario model runs
6) Integrate numerical modelling directly with monitoring and adaptive management
7) Establish formal mechanisms to ensure model and monitoring improvements

### 1.2 Key Issues

In terms of the long-term sustainability of the Venice Lagoon, the physical/chemical changes that may be of most concern are those that threaten habitat loss. Apart from pollution events, these foreseeable changes in physical and chemical properties in the Lagoon are in themselves not likely to be significant. The main challenges that we recognize are:

- Controlling the overall sediment budget;
- Preserving intertidal areas;
- Developing a framework to respond to pollution and other short-term threats; and
- Accommodating or adapting to sea-level rise and other physical changes (e.g. temperature increase) associated with climate change.

### 1.3 Status

Venice Lagoon is an estuary that has been all but disconnected from its watershed, freshwater sources, and replenishment from land for hundreds of years. This has been sufficient time for many aspects of the Lagoon system to change and accommodate those past insults, but now the Lagoon and the people of Venice are facing challenges brought on by modern developments in the watershed, in the Lagoon, at the outlets to the sea, and by anticipated rapid climate changes in the next century. Long-term sustainability will not be achieved by maintaining the procedures and practices of the past, and the Consorzio Venezia Nuova (CVN) has been proactive in developing the MOSE Project and in developing measures to safeguard the Lagoon as one way of taking greater control of the Lagoon system. Because of the strong circulatory interconnectedness within the Lagoon, broad whole-lagoon science and strategies will be also be needed to assess and track longest-term trends in the Lagoon, to maintain long-term sustainability.

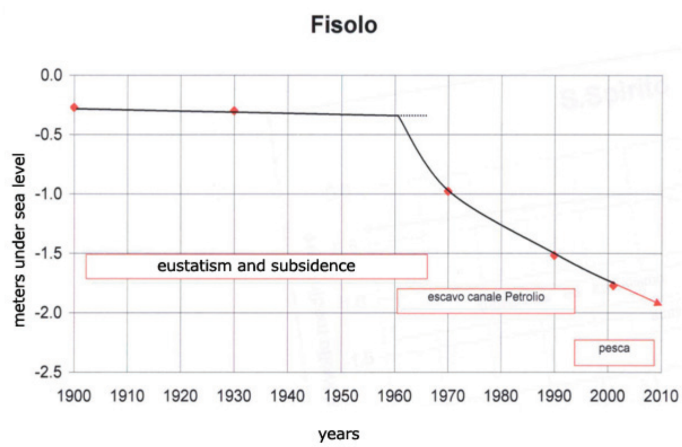
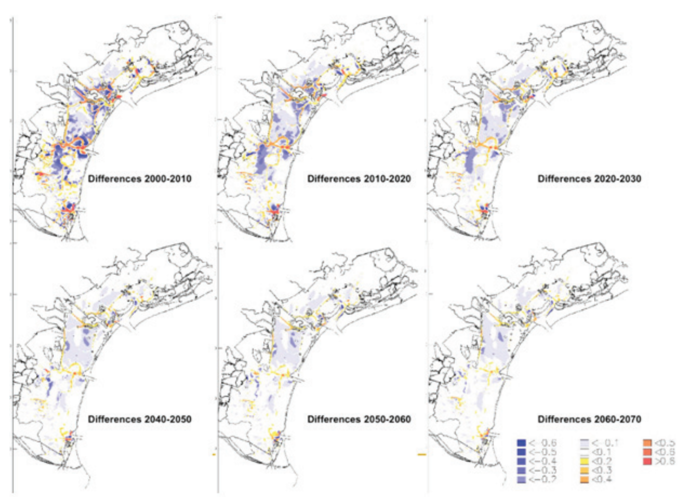
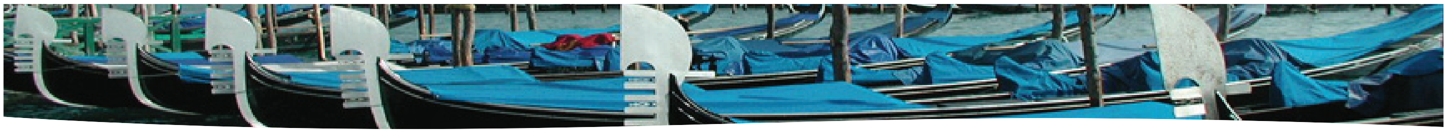



*Fig. 1 (above): Measured depth of Lagoon at Fisolo during 20th century; Fig. 2 (below): Simulated changes in depth of Lagoon in 21st century (blues are erosion, oranges are aggradation)*





In the long term, the major challenge to sustainability of the Lagoon structure is the loss of sediment from the Lagoon. The natural supply of sediment from rivers to the Lagoon was diverted several hundred years ago, even as a slow trickle of sediments has been continuously lost to the Adriatic through the three coastal outlets of the Lagoon.
Such an imbalance between input of sediment (now all but stopped) and export of sediments (to the sea) is not sustainable and, as a result, the Lagoon will continually become deeper. Over the past 70 years, nearly 60% of the Lagoon's intertidal areas (-0.6 to 0.0m below mean sea level) have been lost. The loss shows no sign of slowing (Fig. 1) and models indicate that the loss will continue for the foreseeable future (Fig. 2). Projected sea-level rise associated with climate change will exacerbate this problem. Although this problem has been recognized and actions are being taken to ameliorate the effects, the scale of the loss is a major concern. Remedial action to date has accounted for a restoration of less than 10% of the lost intertidal area.

Meanwhile, in the 21st century, climate change driven by increasing concentrations of greenhouse gases in the global atmosphere is expected to include globally warmer temperatures and, as a result of expansion of sea waters and melting of the Earth's ice caps, global and likely regional rise of mean sea levels. This rise of sea levels will be persistent and, short of permanent closure of the Lagoon's MOSE sea gates, will undoubtedly result in a deepening of the Lagoon's waters in addition to the deepening caused by the long-term net loss of sediments. Viewed from another perspective, the erosion, loss and deepening of sediments from the Lagoon's floor—unless the sediment budget is somehow closed—will continue into a new era when sea level is likely to rise at unnaturally rapid rates; managing for sustainability in the face of this sea-level rise will be considerably more difficult unless the whole-Lagoon sediment budget, the precipitous changes in Lagoon depth and loss of its intertidal areas and character are properly managed.

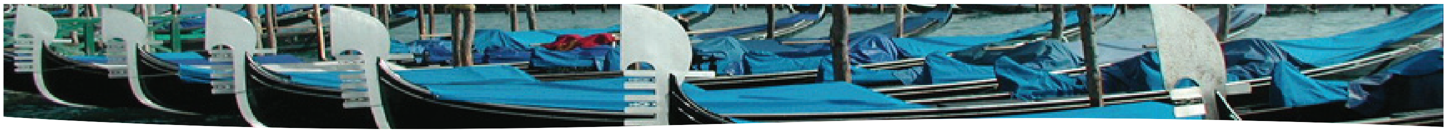
Deepening of the Lagoon is of concern because of potential impacts that it might have on shoreline erosion, turbidity of the Lagoon waters, residence times of waters and pollutants, and resilience and preservation of important habitats, including the intertidal habitats that have seen such large losses during the past century. We considered potential deepening of the Lagoon, on average, by perhaps another 0.5 to 1 meter in the next hundred years or so. Such deepening would allow greater transmission of waves within the Lagoon, which could aggravate erosion of structures and shorelines. Deepening of the Lagoon (in absence of other considerations) would be likely to reduce respuspension of sediments, resulting in less turbidity overall, clearer waters, and greater light penetration. Changes in turbidity would change some of the character of the Lagoon, both in terms of ecosystems and the tourist experience of the city's canals.

A deeper lagoon would have a larger volume and, consequently, longer residence times of water that must be circulated through the system under the forcing of tides and wind, before making its way back out to sea. Longer residence times, in a nutrient rich system, can increase the opportunities for eutrophication and pollutant exposures to ecosystems and humans alike. Most significantly, continued and even accelerated deepening of the Lagoon will challenge all attempts to halt and reverse the 20th century trends towards loss of intertidal zones and intertidal habitats. The impact of deepening on other habitat types, and ecosystem functions, is less certain, but continued deepening must inevitably mark continued changes in the character, distribution and ultimately function within the Lagoon's ecosystem, in ways that may eventually limit ecosystem sustainability.

Pollution remains a concern, although point sources, especially of heavy metals, appear to have been largely controlled or to be being reasonably well managed. In the long term, the more pervasive problem of high nutrient levels is the primary pollution concern[1]. The Lagoon receives nutrients in runoff from its watershed, from groundwater rising beneath it, from the atmosphere, from the City of Venice, and even from the Adriatic Sea (which is notably nutrient-rich for a marine source)[2]. The deepening of the Lagoon increases residence time causing issues associated with pollutant events, algal blooms etc to become more prominent.

<u>Climate Change scenario for Venice area</u>

A review of projections from 12 global climate models[3] used in the IPCC Fourth Assessment indicated that air temperatures in the vicinity of Venice are likely to increase by from +3 to +5ºC by 2100. The median of the 12 precipitation projections indicates about a -10% reduction in precipitation along with an attendant increase in solar insolation on the Lagoon. These changes, along with higher sea levels at the marine outlets of the Lagoon, suggest that salinity, water temperatures, and probably nutrient concentrations in the Lagoon are likely to increase during the 21st Century, unless society intervenes using MOSE or some other mechanisms to flush Lagoon waters more often than under natural conditions. Warmer and more nutrient-rich waters are likely to facilitate increased algal blooms and eutrophication in the Lagoon. Left unchecked, the drift towards high nutrients, warmer waters, and longer residence times would be expected to yield more algal blooms, smelly waters, and degradation of the aquatic habitats throughout the Lagoon.



## 1.4 Conceptual Framework for Assessing, and Managing for, Sustainability

From a physical/chemical viewpoint, the circulations and transports in the Lagoon span sufficient distances over short enough time scales so that the Lagoon is a tightly interconnected whole. Thus the sustainability of the Lagoon will only be maintained at a 'whole-lagoon' level; no subset of the Lagoon's physical structure or ecosystem is likely to be sustainable if other parts are allowed to fail. It is difficult, if not impossible, to manage and assess the state of the lagoon from an array of measurements separated in space and time. An integrated hydrodynamic model provides the capacity to connect these data and to relate individual events to overall circulation within, and the overall state of, the Lagoon. Indeed, we consider model simulations to be central to sustainable management of the Lagoon. Models can provide an organizational structure for planning and assessing monitoring programs, a basis for analysis of monitoring data, a methodology for developing and screening hypotheses, a means of comparing potential adaptation measures, and a way to assess the state of the whole lagoon. Overall, assessment of the longest term trends and sustainability of the Lagoon will depend on more synthesis of 'whole lagoon' descriptions of the Lagoon of the sort that monitoring supports, but only model building and use enable budgets of salinity, nutrients, and especially sediments.

We recognize two primary time scales of concern in the management of the Lagoon: the long-term (multiyear) sustainability time scale and the short-term event scale. Although they are closely interlinked, success on one of these time scales does not guarantee success on the other. Management of short-term events (like acqua altas) can be undertaken with short-term considerations, but in the long-term will depend on preservation of the physical structure of the Lagoon from longer term challenges, like erosion and sea-level rise; conversely, long-term maintenance of the physical structure of the Lagoon will surely reflect impacts from a myriad of short-term management actions and events. At present, though, model capabilities are better developed for short-term applications and monitoring capabilities are positioned better for long-term purposes. There is a need to develop long-term modelling capabilities and to develop short-term observational and monitoring capabilities that integrate effectively with both the existing long-term monitoring program and the models. Adaptive management will be necessary for sustainable management of the Lagoon given current information, advanced by still imperfect levels of understanding of the Lagoon system. Both monitoring and modelling should be integrated to provide the basis for this management approach. An essential feature in adaptive management is feedback to assess, improve and update the modelling/monitoring capabilities as research advances; such feedback does not necessarily occur automatically and so formal mechanisms to facilitate and, ultimately, ensure the feedback occurs and is used are needed.

## 1.5 Monitoring

Measurements of the physical and chemical variables that characterize the Lagoon are needed to monitor the current state, provide temporal trends and to inform and to be compared with modelling studies. Consistent with the concerns for both the long-term sustainability of the Lagoon and short-term events such as those caused by storms, pollutant spills, operation of the MOSE gates, it is necessary to have monitoring capabilities on these two time scales.

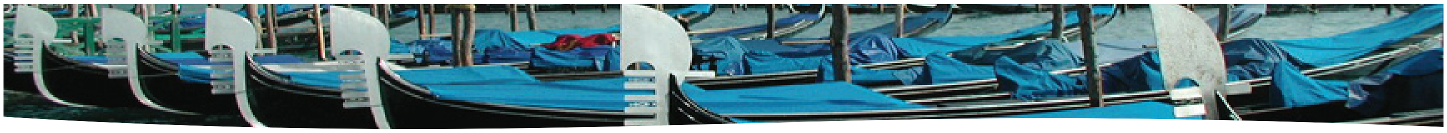
<u>Long-term</u>

These measurements will provide data for the 5-year assessments, and provide historical trends on the response of the Lagoon over annual and decadal time scales. Current plans for monitoring physical/chemical variables as described to the panel[4] provide comprehensive coverage of the Lagoon. It is recommended that particular attention be paid to bathymetry. Monitoring, and especially synthesis of monitoring results, to develop Lagoon-scale budgets is particularly important. In the long-term, small but persistent imbalances in Lagoon budgets of sediments, salinity, and nutrients will determine much of the sustainability of the Lagoon, but can be masked by the much larger, short-term fluctuations on storm, tide and even seasonal time scales unless great care is used in establishing, maintaining, and analyzing monitoring results. The success of regular sustainability assessments will depend on the extent to which these lagoon-scale quantities and imbalances are determined.

Magistrato alle Acque through Consorzio Venezia Nuova has carried out a comprehensive water quality monitoring program from 2000-2008 involving multiple stations with either monthly or bimonthly sampling frequency. These include stations at generic locations in deep and shallow water, in the canals and at sea. In order to support future assessments of the sustainability of the Lagoon, long-term monitoring needs to be enhanced to improve the characterization of the fluxes of nutrients, water, and eventually sediments between the Lagoon and its watershed.

A program of regular sustainability assessments will require that this program be continued indefinitely, using much the same network of stations and variables to provide consistency in space and time.

These data will also be used for adaptive management.



Short-term

Monitoring is needed to provide data for short-term adaptive management, to predict responses to short-term events such as pollutant spills, and to assess the effects of the operation of the MOSE gates. These data need to be integrated with the modelling capabilities of the DELFT 3D model to allow for scenario testing, and emergency response. Furthermore the short-term observational and monitoring activities need to be designed to complement and enhance the long-term monitoring program.
The specifications of these monitoring requirements are beyond the scope of this assessment, but will need to be planned as part of an integrated modelling-monitoring capability.

## 1.6 Modelling

Magistrato alle Acque through Consortio Venezia Nuova has developed models for:

- Hydrodynamics
- Transport and fate of pollutants
- Transport of suspended sediments
- Water quality and ecology
- Morphological model

This suite of models, based on DELFT3D, represents an ambitious attempt to provide a comprehensive modelling capability for the Lagoon.

The DELFT3D model is used to predict the circulation within the Lagoon. This is a highly resolved three-dimensional state-of-the art model from a respected source. The model has been implemented for the Lagoon bathymetry and the model output compared with measured flow near the inlets. The model contains realistic representations of the important physics of the Lagoon circulation, and we consider it to provide a reliable estimate of the circulation.
Extensions of DELFT3D are used to provide the other models listed above. In particular, DELFT3D-ECO is used for water quality modelling and ecology. As for the circulation, these models are state-of-the-art, and provide a powerful set of tools to interpret the monitoring data and to manage the Lagoon, as discussed above.
One concern of the DELFT3D model is the treatment of intertidal areas. This is an extremely difficult issue for numerical models and is the weakest part of the representation of the physics by the model. A second issue concerns the resolutions and approximations required to obtain numerical predictions over long time scales (months, years, decades), and whether the calibrations made from short-term runs and data comparisons are valid on longer time scales. Once long-term morphological evolution of the Lagoon can be predicted with a certain degree of confidence, we urge to further analyze the corresponding changes in residence times (a key parameter for adaptive management decisions to be made). Finally, in the long term, a modelling capability that also includes the watershed of the Lagoon, even though it is largely disconnected from the Lagoon, will be necessary for sustainable management of the Lagoon, especially as regards to nutri-

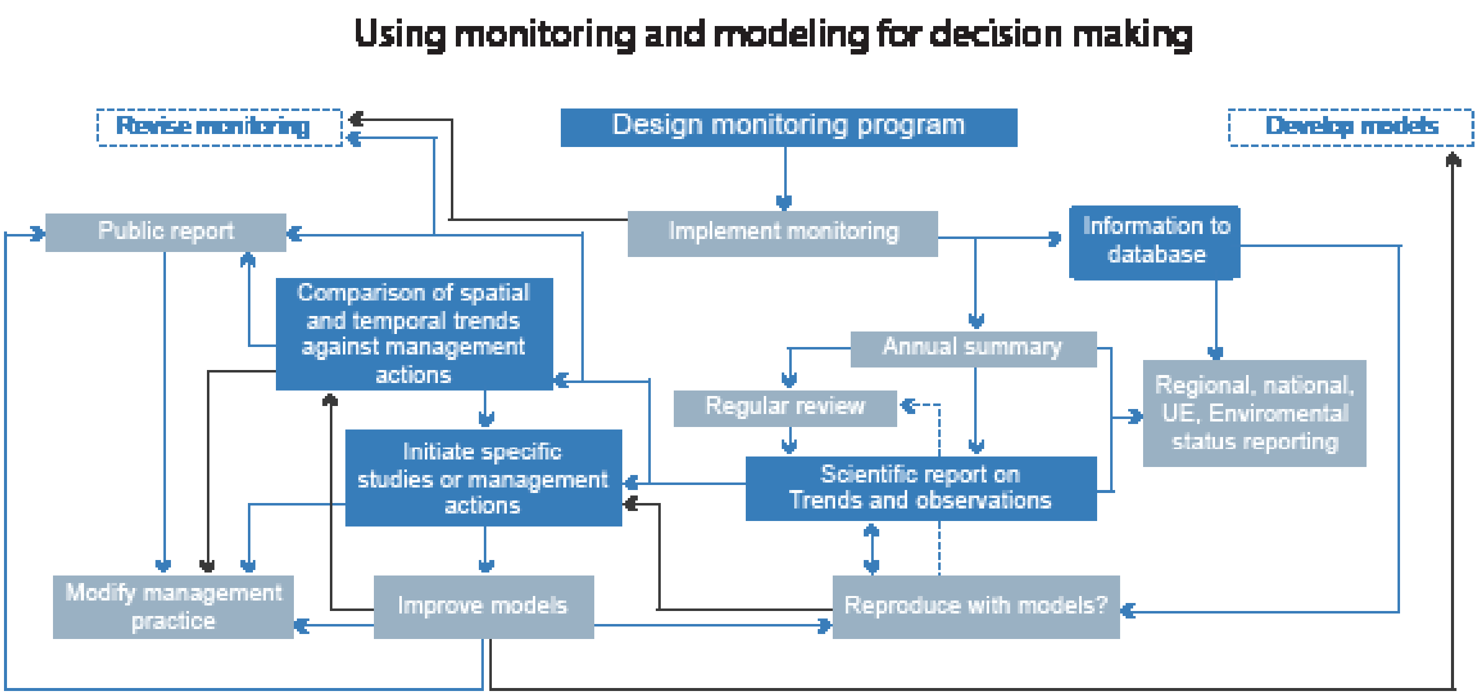
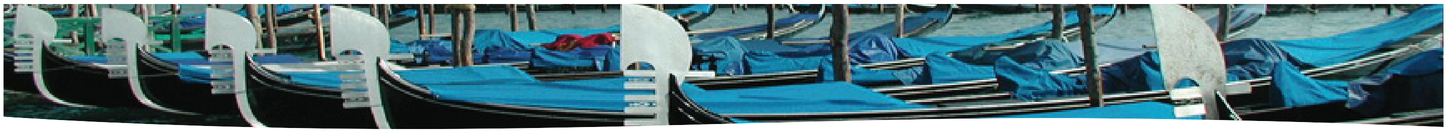



*Fig. 3: Flow chart linking monitoring, modelling and informing decision-making for adaptive management*



ent and pollution loads in the Lagoon. Each of these issues needs further research and exploration using monitoring data.

Model development and improvement

Although the DELFT3D model is considered to be the state-of-the-art commercially available model, a number of other models have been developed to simulate the circulation within the lagoon from institutions in the Veneto region and elsewhere[2,3,4,5]. These models use other methodologies such as finite element representations and also include links with ecological modules.

We consider that the expertise represented in these models is a considerable resource and that mechanisms need to be established to support and promote these models and also to incorporate improvements in the science that they represent into the institutional model.

There is a need to maintain the integrity of the operational model so that there is transparency in the modelling assumptions etc., and consistency of the model over time. This is particularly important when a major concern is prediction and modelling of changes to the lagoon over long periods of time.

This tension between the need to maintain control of an operational model and the need to keep it up to date scientifically requires careful consideration. One suggestion is to use the Advanced Institute to provide funding for modelling improvement projects and to provide the link to incorporate them into the operational model. A similar relationship exists between the UK Meteorological Office and the European Centre for Medium Range Weather Forecasting, which could serve as a model in this regard.

Model uncertainty

Every model makes assumptions to represent the biogeophysical/chemical processes, many of which are very complex and poorly understood. As a result placing bounds on uncertainties is extremely difficult, particularly in a context when the inputs are not known exactly. One way to address this issue is to run multiple models so that intercomparison of model results, linked to critical assessment with regards to field measurements, provides some information in the spread of possible predictions. At present, several other models have been developed of the various components of Venice Lagoon by other researchers[5,6,7,8]. Such parallel model developments are a useful foundation for adaptive management under uncertainties and for future sustainability assessments, and a mechanism for ensuring that a diversity of models continues to develop needs to be established.

The role of models in adaptive management

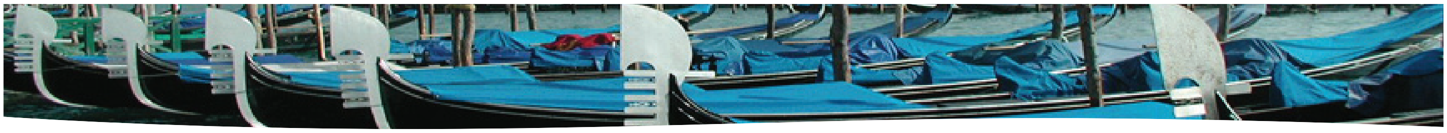
As discussed previously, models are a key component of adaptive management of the Lagoon. They provide a framework within which monitoring data can be analyzed and by which areas of particular sensitivity can be identified. They also provide a means to make predictions of future developments both in the long term under changing conditions such as those induced by climate change, and in the short term to investigate scenarios and for emergency response.

It is essential that a modelling capability be established that provides information for management decisions (see Fig. 3). This capability requires a mechanism for:

- routine model runs;
- event-oriented model runs;
- periodic data comparisons and model calibration;
- updates for monitoring plans and deployment;
- improvements to the model through interactions with the research community; and
- plans to respond to predicted (and observed) long-term changes.

The above requires real-time inputs to the model forcing parameters and some provision is needed for close collaboration between the modelling and monitoring agencies.

While models and their routine operation provides an organizing principle for an assessment of the lagoon – requirements for consistent input data, a framework for comparison of outputs with observations and useful for hypothesis generators and a quantitative synthesis of data – for the reason discussed above (approximate representations of processes, uncertainty in parameters) they need to be tightly constrained by monitoring data.



# II. Ecology

## 2.1 Overall Summary Recommendation

The extensive history of environmental monitoring and research in the Lagoon facilitates the development of modern sustainable management initiatives. Our overall aim is to advance and focus the bio-physical monitoring of the Lagoon and ensure appropriate feedbacks between environmental status and management actions and policy. We consider the key threats to the Lagoon to be sediment loss, nutrients, fishing, habitat destruction and chemicals. We recommend that these threats need to be prioritised and key management responses determined as current activities are insufficient to avert major ecological change. Further, we see enhanced education, valuation and understanding of the inter-connections within the Lagoon social-ecological system as beneficial for sustainability. We recommend the following specific practical actions:

1. Use existing and new survey data to establish environmental baselines against which changes can be measured.
2. Develop a more integrative and cost-effective ecological monitoring strategy.
3. Establish a central data repository, analysis, synthesis and reporting facility.
4. Establish environmental targets.

Key issues to address that threaten the ecology of the Venice Lagoon:

- Control sediments
- Control nutrients
- Control chemicals
- Control fishing
- Enhance ecosystem resilience (by improving biodiversity, habitat maintenance and enhancing connectivity)
- Enhance capability in integrative and information-based resource management
- Enhance education, valuation and understanding of the inter-connections within the Lagoon social-ecological system

## 2.2 Introduction

Similar to many coastal ecosystems around the world, Venice Lagoon has been modified by a wide variety of human activities over its long course of human habitation. Nevertheless, the Lagoon maintains many ecological values and delivers a diversity of ecosystem goods and services. In this section of the report we identify the status of technical knowledge needed to underpin ecologically sustainable management of the Venice Lagoon ecosystem and the translation of this knowledge into information for management agencies and society. We aim to estimate and improve the 'readiness' of Venice to assess and manage the future sustainability of the Lagoon in the context of future natural and human induced change. Within this context we recognise the aspiration for sustainable management of the Lagoon to represent a flagship project for Europe and beyond.

## 2.3 Definition of Ecological Sustainability

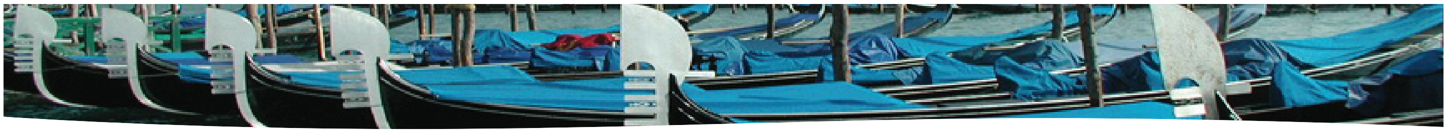
Sustainability means different things to different people, and this can cause confusion and miss-direction of management actions. From the perspective of ecological science, sustainability and sustainable management require a broad view integrating historical, current and future ecosystem responses to human and natural changes. To achieve this it is necessary to implement ecosystem-based approaches to management (EBM). This is driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem structure and function. EBM should seek to balance the needs and values in an inclusive fashion, rather than focus on the delivery of benefit to specific resource users. Explicitly it focuses on the sustainability of ecosystem structures and processes necessary to deliver goods and services[9,10].

From the perspective of ecological science sustainable ecosystem management should include:

- Long-term sustainability as a fundamental value;
- Clear operational goals;
- Sound ecological models and an understanding of complexity and interconnectedness;
- Recognition of the dynamic character of ecosystems;
- Attention to context and scale;
- Acknowledgment of humans as ecosystem components; and
- A commitment to adaptability and accountability.

These issues have important implications across the scientific process from framing questions, to gathering and interpreting data, developing models, recognising the value of understanding and forecasting ecosystem responses. Adaptive management is an integral approach to EBM.

Any sustainable management plan should have some environmental baselines and such criteria are also implicit in the EU Water framework directive. These are needed because of the potential for chronic impacts to have cumulative effects on the resilience of the ecosystem. Such effects may occur where the recovery potential of the ecological community in a specific part of the Lagoon following disturbance is negative-



ly affected by the status of ecological communities in other parts of the Lagoon. Chronic impacts may also contribute to broader-scale and diffuse impacts such as changes in suspended sediment concentrations that impact on the structure and function of ecological communities. Furthermore, the potential for interaction between stressors increases as we move from the detection of immediate stressor effects to broader consequences on ecosystem function and changes in ecosystem services. Finally, it is unclear at the moment whether current and historical stressors and future changes will lead to slow degradative change in a specific ecosystem which is potentially easy to restore or to drastic 'regime shifts' that markedly change the potential of ecosystems to deliver a diversity of ecosystem services from which restoration of services will be very difficult.

There is tremendous opportunity for Venice Lagoon to be a flagship for ecological sustainability. Although sustainability is a common policy and management goal, the application of ecosystem based approaches to management are still in their infancy. There are many knowledge gaps and uncertainties, nevertheless management actions that ensure the resilience of these ecosystems are imperative. Because of its political visibility and economic importance, there is a great deal of base line data against which changes can be measured. For the same reason, there has been a considerable amount of excellent research defining the most important environmental stressors and the critical strong biological interactions through which the ecosystem will maintain its resilience.

## 2.4 Ecological Status of the Lagoon

To provide policy relevance to our assessment of the Lagoon we developed a series of questions derived from EU Directives [2000/60/CE and COM (2005) 505].

To address the ecological assessment of environmental status of waters, pressures and impacts we questioned the status and trends in the Lagoon, specifically:

- Temporal dynamics of phytoplankton; frequency of algal blooms and Harmful Algal Blooms (HABs)
- Spatial distribution and diversity of macroalgae and macrophytes (marshes, reed belts, seagrass beds etc) and their temporal dynamics
- Frequency and distributions of blooms of benthic macrophytes (e.g., Ulva and Enteromorpha)
- Species composition of macrofauna and temporal dynamics; spatial and temporal changes in functional attributes (to be judged against information on environmental drivers)
- Exploited fish and shellfish temporal trends

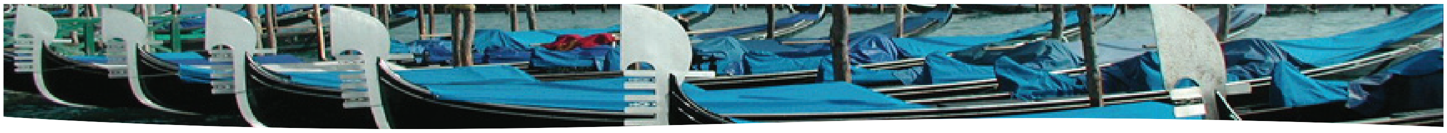
We provide specific comments below based on the information presented to us, but first an overall comment on the Lagoon and the quality and quantity of data available.

We are aware of the large amount of information on the ecologic and environmental conditions in the Lagoon. This information is spread across a range of grey literature reports as well as in books and scientific journals. In this section of the report we draw on examples of the available data to illustrate ecological patterns and trends. Within the last two or more decades, there have been extensive ecological surveys of the Lagoon. These surveys are often spatially intensive and provide a good picture of the ecological status of the Lagoon as a whole at a particular point in time. The methods employed in these surveys are reasonable and the analytic procedures used to describe patterns are appropriate. While we can see some temporal trends in key ecological variables though the comparison of these time slices it is often difficult to resolve the temporal dynamics. Yet understanding the temporal dynamics is critical if we are to identify the interactions of natural and human induced change or identify clues as to the mechanisms that underpin these changes. While the available information does document some major shifts in the ecosystem, early warning signs or improved understanding of the links between particular processes or stressors and ecological dynamics are more difficult to determine. This raises two important issues: (1) The need to develop a more integrative and cost-effective ecological monitoring strategy; (2) The need for a central data repository, analysis, synthesis and reporting facility. We return to these issues in subsequent paragraphs.

## 2.5 Specific Comments on Status and Trends

Chlorophyll a concentration and phytoplankton abundance (cells. ml) have been collected since the 1970s. These are important indicators of eutrophication along with other variables such as macroalgal biomass, vascular plants, concentrations of nutrients, organic matter and dissolved oxygen. The decadal-scale trend is for increasing primary production in the water column. The increase of phytoplankton abundance during the last 30 years is one of the main results to come from the comparison of recent and old data performed in the framework of ICSEL B Project. This trend has been interpreted by the authors as the result of several changes occurred in the Lagoon in the same period:

- The decrease of macroalgal biomass (substituted by vascular plants) since the 1990s, leaving more nitrogen available in the water column for phyto plankton assimilation and changing competitive interactions between macroalgae and phyto plankton;



- The increase of sediment resuspension due to fishing activities and erosion can transfer benthonic cells to the water, or mobilising silicon for diatom growth.

Nevertheless, this trend cannot be considered as unequivocally demonstrated for the Lagoon. Other studies suggested the presence of specific phytoplankton dynamics, for example the rapid decrease of macroalgae in the Central Lagoon. A significant decrease of phytoplankton has been observed between the summers of 1993, 1998 and 2002 in the central Lagoon. This has been linked to the increase of water turbidity that occurred in the same period. On the other hand, very intense phytoplankton blooms occurred in summer of 2001, illustrating that multi-year variability can be obscured by a shorter time variability, mainly if the sampling frequency is not adequate. There are in fact variations of space-time blooms rarely overlapping from one year to another and often of very short duration, that can easily escape the sampling[11,12].

Over the last 30 years the concentrations of nitrate, ammonia and phosphate have dropped markedly in the vicinity of the Porto Marghera industrial zone. Critically, ammonia concentrations have dropped by about two orders of magnitude in this region, while for the Lagoon as a whole no clear temporal trend is apparent between 2001-2005[13]. These trends reflect management intervention to improve waste water treatment and elimination of phosphorus from detergents. There are decreasing trends in the concentration of nitrate and nitrite in the water column over the Lagoon as a whole (between 2001- 2005). These effects are strongest in regions of the Lagoon with high coastal water exchange and 'hot spots' (e.g., Chioggia in 2004). Nevertheless, the water column concentration of nitrate and nitrite appears to be correlated with rainfall over the Lagoon. The spatial-temporal distribution of N-NOx correlates well with the river flow and precipitation (low in 2003 and high, especially in winter, in 2002 and 2004). Recent values of chlorophyll, phosphorus and nitrogen reported from the Lagoon would be classified as high by recent Swedish EPA standards.

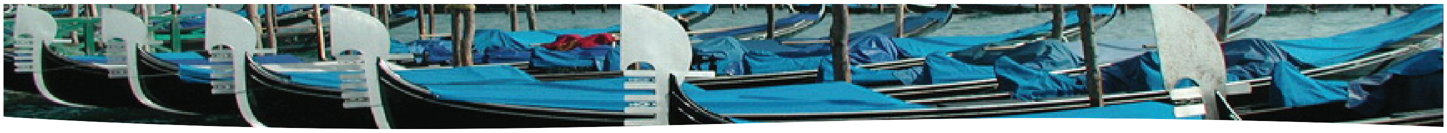
The general (time averaged) seasonal cycle in phytoplankton species composition has been described for the Lagoon, although no trends indicating changes in the cycle or increased prevalence of HABs, have been discussed, nor does this appear to have been investigated[14].

Macrophyte species composition and production are also important indicators of trophic/eutrophic status in shallow coastal systems. The rapid growth, drift and decomposition of algal mats cause ecological and aesthetic problems. Macroalgae proliferation has been reported as a serious problem in the 1980's, although from the 1990's the situation has apparently improved leading to the increased compaction and oxidation of sediments and increased diversity of benthic plants and animals. Recent macroalgae distribution maps (2002) show the species composition and spatial coverage of macroalgae varies around the Lagoon, but is still dominated by ephemeral opportunistic species that prefer high nutrient conditions. The temporal changes in blooming macroalgae biomass may well reflect localised changes in nutrient concentrations associated with improved urban and industrial area management, but they may also reflect changes in water clarity and bathymetry in the centre of the Lagoon influencing light limitation for the fast growing green macroalgae.

Macroalgae also have the potential to compete for light and nutrient with seagrasses, and the distribution of seagrass and macroalgae species overlap extensively in the southern part of the Lagoon. Seagrasses in the central and southern parts of the Lagoon are probably currently limited by sediment stability and turbidity. Although previous deposition and decomposition of algal mats would have certainly adversely affected any smothered seagrasses. Information on the temporal trends in seagrass reveals a slight decline (1-2%) in total seagrass coverage between 1990 and 2002. In this time period Cymodocea nodosa and Zostera marina substantially increase in cover (between 1000-2000 ha each) while the overall slight negative trend is driven by the loss of Zostera nolti. However, between 2002 and 2003 major changes due to the increasing spatial dominance of Cymodocea and a rapid decline in Z. marina were apparent. These shifts although rapid could be related to climate change effects as Zostera marina is more-or-less at the southern end of its range in Venice Lagoon.

The macrofauna of the Lagoon have been extensively studied general patterns emerge associated with increasing diversity to the south and from the landward to seaward sides of the Lagoon. However, we are not aware of a complete analysis of macrobenthic communities in relation to environmental drivers, nor have we seen an analysis of temporal trends for specific locations/habitats. An analysis of functional or biological traits may well be useful in synthesising this complex data and helping to reveal the importance of natural v human induced drivers of change.

Various indices have been applied to the macrobenthic data generated in the extensive spatial surveys of the Lagoon (e.g., EQR). These are relevant because of the need to apply appropriate indices to define status and trends under the EU Water Framework Directive (see below). This analysis of the relevance and appropriateness of different indices is proactive and should be extended. It highlights important problems with the interpretation of these indices along the strong environmental gradients that are naturally found in Lagoon ecosystems. This is important information when considering the appropriateness of specific indices, their regional appli-



cation (e.g., back Lagoon, shallows, sea inlets, channel margins), and especially the context for agreement on appropriate reference conditions and environmental baselines.

Finally, of relevance to the ecological status of the benthic communities in the Lagoon are the benthic habitat changes. It is important to note that there is often strong bio-physical coupling in the formation and maintenance of soft-sediment habitats. This is illustrated by the studies conducted in Venice Lagoon demonstrating the interactions between salt marsh plants and hydrodynamics that affect the topography and dynamics of saltmarsh habitats. The monitoring and description of broad-scale habitat change is directly useful for management. Habitats defined by their biogenic characteristics can act as a as a proxy for benthic communities and their functional attributes. The effectiveness of this proxy could be assessed from the extensive data available for Venice Lagoon. In particular it can be cost-effective if combined with limited detailed sampling and used in scaling up to map the overall conditions and changes in the Lagoon. It is apparent from the information presented to us that the diversity and distribution of habitats in the Lagoon are changing. This has resulted in a loss of saltmarsh, topographic complexity and shallow subtidal areas. Such changes are likely to influence habitat suitability for charismatic species such as shorebirds and seabirds and the availability of nursery habitat for fish. Deepening of shallow subtidal areas due to the net loss of sediment from the Lagoon will influence light availability in turbid waters and thus affect macrophytes and the microphytobenthic assemblages that are important in limiting the resuspension of fine sediments and thus the potential loss of sediment from the Lagoon.

## 2.6 Suspension Feeding Bivalves: Fisheries, Aquaculture and Natural Populations

Mussels

For about the last 10 years mussel culture in the open Lagoon has diminished significantly, only about 42 hectares of the Lagoon surface area are used and it is estimated that about 220 workers are currently employed. Most of the sector operators have established new plantations in the sea (off-shore): the duration of the productive cycle in the Lagoon is about 18 months versus the 9 months in the sea.

Clams

One of the main issues related to aquaculture sector is the exploitation of clam banks, which represents one of the main sources of environmental disturbance in the Venice Lagoon. The Manila clam, Tapes philippinarum, is an invasive species introduced in 1983 which well adapted in the Lagoon, replacing the indigenous species Tapes decussatus. The morphological impact in the Lagoon is considerable. At low tide, it is possible to observe the furrows left behind by the fishing equipment. The furrows reach depths of 15 to 20 cm and form micro-environments which later become stagnation zones. The continuous ploughing up of the sediment, its re-suspension, and the continuous re-settling, results in a gradual impoverishment at several levels and a simplification of both the flora and the fauna.

The well known negative effects:

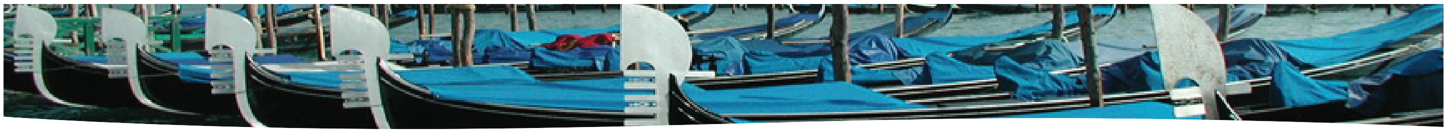
- Change the morphology and composition of the sea-beds;
- Modified the granular gradients and the texture of the sediments,
- Re-suspended large amounts of sediment, rendering the water turbid.

Clam fishing in non-authorized zones (e.g., in front of Porto Marghera) causes re-suspension of the fine sediment fraction and associated nutrients and pollutants. At present, the local administrations have promoted a conversion program with the aim of eliminating free and uncontrolled clam harvesting in order to minimise the environmental and socio-economical consequences.

While there is a fishery for infaunal shellfish in the Lagoon (predominantly the introduced Tapes philippinarum), we note that worldwide most of the Lagoons such as the Venice Lagoon had extensive beds of suspension seeding shellfish (such as oysters, tellinids, venerids, cockles, mussels and pinnid bivalves). Ecologists speculate what the Lagoons must have looked like with that many filter feeders. In Chesapeake Bay and San Francisco Bay it has been estimated that historically bivalves would have filtered the bay water at a faster rate than tidal exchange. This would have significantly contributed benthic macrophyte growth. In addition, dense beds of bivalves would limit sediment erosion, and in fact their shell production could have significantly contributed to the sediment production within the Lagoon. Surely the oysters would have been removed from the Venice Lagoon very early in its history, but it is important to realize that their ecological roles have been lost and processes that result in the erosion of sediments have been changing the character of the Lagoon and continue to do so in an accelerating fashion.

## 2.7 Conclusion

In summary, some of the trends reported to us indicate improving environmental conditions, such as the trends in nutrient concentrations around Porto Maghera. Other trends may be generated by a combination of both Lagoon-scale and broader phenomena, such as the loss of the Zostera



marina in the early part of this decade. The trends in habitat change are particularly worrying as these changes will undoubtedly interact with other stresses and in many instances exasperate adverse ecosystem responses.

As well as seeking to define the current ecological status and trends within the Lagoon, to meet the EU Directives [2000/60/CE and COM (2005) 505] it is also necessary to:

- Determine the characteristics of good environmental status by identifying spatial gradients or temporal trends in the above variables:
  - (a) within the Lagoon,
  - (b) between other Italian Lagoons,
  - (c) a comparison of 'similar' systems across Europe; in order to justify definitions of ecological reference conditions.
- Establish environmental targets by describing the ecosystem services derived from the Lagoon; describing ecosystem bottom-lines (e.g., state ments about protecting species or habitats; either quantitative or qualitative); describing temporal variance in ecological variables and how they change along stress gradients; describing historic conditions to help in the discussion defining the 'natural' status of the Lagoon. These issues are important as defining environmental targets within an EBM framework should be an inclusive process. Science addressing these issues will help engage with different sectors of society that have specific values (Venice, Venito, Italy, EU, UN) and inform decision making.

Addressing these issues is always difficult but will be necessary to implement the EU directives and advance the sustainable management of the Lagoon. Nevertheless, there has already been some relevant analysis of ecological data. For example, there is information contrasting elements of the ecological status of Venice Lagoon with others that drain into the north-eastern Adriatic. Compared to other Lagoons, located in the eastern side of the Adriatic Sea, the Venice Lagoon has a greater exchange of water with the sea.

Over the last decades, most of the Adriatic Lagoons were subjected to a decrease of seagrass coverage (*Zostera* and *Cymodocea*), replaced by macroalgae (mainly *Ulva*), which limited phytoplankton growth. These eutrophic events were common in all the Lagoon of the Po river, where the input of nutrients, organic matter and pollutants caused an increase of vegetal biomass, which, in turn, is the cause of anoxic and distrophic events.

The Venice Lagoon shows a different trend compared to the other Adriatic Lagoons. The temporal trend from the '90s shows a decrease of macroalgae and an increase of seagrass coverage and phytoplankton in the water column[15].

We are aware of the large quantity and high quality of the data available for the Lagoon. To help frame ecologically sustainable management actions, we think that in the near future the maximum information should be gained from the analysis of this data. To this end an analytical workshop defining relevant questions and performing detailed analysis would be helpful in developing reference conditions, environmental baselines and ecological targets. We also identified the difficulty of interpreting temporal trends due to the lack of time-series monitoring. An improved and integrated monitoring design should be considered in order to facilitate comprehensive analysis of changes in patterns and processes in space and time. This would also help untangle multiple cause and effect relationships and along with other lines of evidence drawn from appropriate ecological experiments help key problems for management action.

### 2.8 Indicators of Good Environmental Status in the European Water Framework Directive

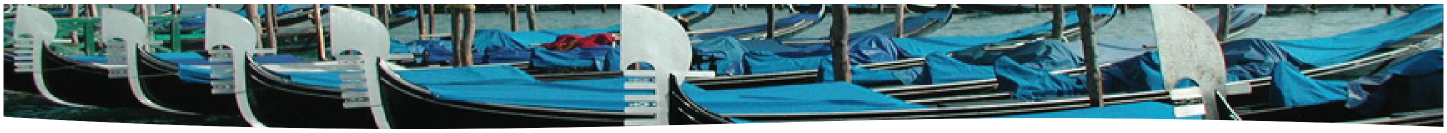
We are agreed that a biological-physical ecosystem approach to assessment and monitoring should be taken. However, clearly an entire ecosystem and all its interactions cannot be monitored, and we have to identify key symptoms, or indictors, of how well the system is performing, i.e. indicators of ecological status. Ecological status is an expression of the quality of the structure and functioning of ecosystems as indicated by the condition of a number of 'quality elements'. The European Water Framework Directive uses the term "quality elements" to refer to the different indicators of ecological quality comprising its ecological status classification schemes.

The quality elements used to assess ecological status are:

(i) biological quality elements;
(ii) chemical and physicochemical quality elements, including general physicochemical quality elements and pollutants being discharged in significant quantities, which are referred to as 'specific pollutants'; and
(iii) hydromorphological quality elements.

There are five classes for ecological status; 'high', 'good', 'moderate', 'poor' and 'bad'.

The Directive identifies five biological quality elements for transitional waters; benthic invertebrates, fish, phytoplankton, macroalgae and angiosperms. Good data are available on all these elements for the Venice Lagoon. Reference values may be determined using:



(1) Networks of reference sites;
(2) Modelling approaches; or
(3) Where 1 and 2 are not possible (even in combination), "expert judgment".

However, the Lagoon is in an enviable position in that data are probably available to assess spatially the current status of all of these quality elements, and to some extent the historical evolution of these elements.

Particular quality elements are appropriate for specific environmental pressures such as organic enrichment, pollution by toxic chemicals, fishing, aquaculture etc. For the Venice Lagoon these will need to be adapted to address changes in habitat type, climate change and other pressures that may be specific to the Lagoon. Tools for assessing the status of the quality elements may vary from country to country and region to region, but will probably be specified and will be a statutory obligation, so that it will be sensible to adopt strategies that fulfil this obligation, whilst not neglecting additional more novel research-based tools that might be developed. For soft sediment infaunal communities the AZTI Marine Biotic Index (AMBI) gives a score for ecological status from high to bad that can be compared with other European sites, but other metrics must be compared to a reference value specified for that habitat type. Maximum values for habitat and sample type have to be established using historic data and expert judgement. Establishment of environmental targets with respect to these quality elements will depend on local conditions and opportunities. If the current status is not high, we need to assess whether high condition is practically achievable, and how. In this evaluation, we need to bear in mind that shifts in baselines and possible functional regime shifts may dictate new environmental targets to be defined in order to analyse the effects of future environmental remedies taken in and around the Lagoon.

## 2.9 Evolution and Integration of Current Monitoring Programs

Monitoring is invaluable for any ecosystem based management program as it defines the state of the environment, provides feedback on the efficacy of management actions and provides data and generates ideas to develop and improve models. When the results of monitoring programs are reported in an appropriate fashion to the public it can also be a powerful tool for education and community buy-in. Thus a key management action is the design, implementation and commitment to a comprehensive long-term monitoring program. For Venice Lagoon this should be seen as the evolution of the history of good monitoring rather than an entirely new process.

Currently there are a large number of programs monitoring different variables at different space and time scales. All are collecting useful data, but it appears to us that what is needed is an improved understanding of temporal dynamics and integration across individual programs. A technical workshop would be an appropriate way to develop these ideas, the data already collected should be used to ensure that data are collected from appropriate locations, with sufficient power to develop an overall monitoring strategy to maximise the potential value from the currently available and future data (Fig. 4 below). This should also include consideration of monitoring different variables at different scales and how quantitatively to integrate these different measures. There is a need to keep long-term monitoring cost effective, and this can be achieved by good design and by maximising the value from the data generated. We do not know the current cost of monitoring, but based on the quality and quantity of data we have seen, we think it should be possible to accommodate modifications in current designs without increases in real costs.

It is important that the monitoring program of the Venice Lagoon be compatible with these European-wide conventions, but it should stand as a benchmark for the ecologically sustainable management of the Lagoon.

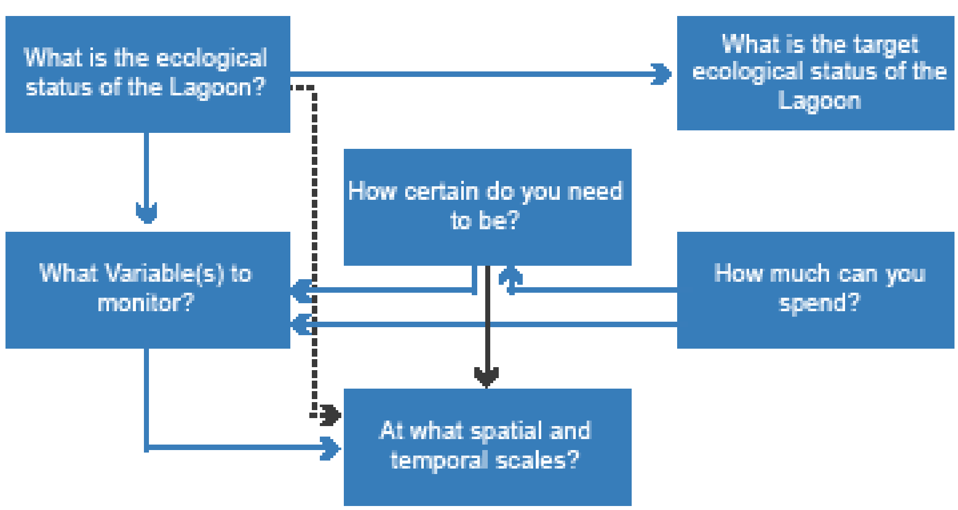
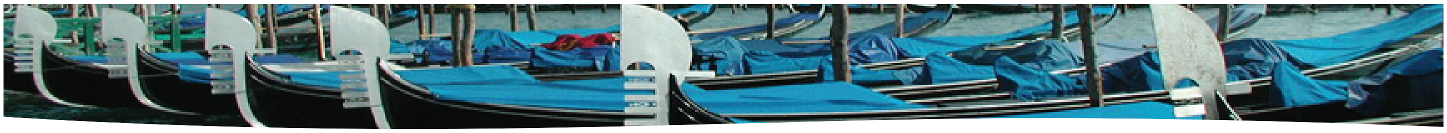



*Fig. 4: Workshop framework for advancing ecological monitoring of Venice Lagoon*

As we understand it, the current monitoring is focused on either specific issues/ location or spatially intensive sampling of the whole Lagoon, but with an irregular and multiyear inter-sample interval. We see a need to improve the temporal resolution of the monitoring data and think that this could be achieved by reductions in the number



of sites or variables measured in the intensive spatial surveys and the gathering of data at a greater frequency (e.g., every 2 months) from a few selected sentinel sites. This would then provide a core monitoring program providing detailed information on temporal trends at selected locations and occasional broad-scale surveys of the whole Lagoon.

As part of a sustainable management plan a monitoring strategy be defined, and so should the data management and QA/QC for monitored variables. This could most easily be achieved via a coordinated data base and data repository. From a scientific point of view the monitoring program should be reviewed at regular intervals to identify spatial and temporal trends and consider the potential to modify the program or tools developed from the data (e.g., environmental trigger points or risk assessment models). Most importantly the way in which the monitoring program integrates with management also need to be defined as part of the sustainable management strategy. This will be achieved through the integration of policy management and science (e.g., Fig. 3).

### 2.10 Defining Environmental Targets

In this section we offer some general advice on how it would be possible to move forward with defining environmental status and targets and the more holistic issues of EBM and sustainability.

Clearly this is not a new path for resource management agencies in Venice. The extensive Ecosystem Report uses the Drivers Pressures States and Responses (DPSR) model to characterise the Lagoon ecosystem and its response to stresses. This analysis reveals the potential for complex and indirect interactions between natural and human induced drivers and the feedbacks between pressures, states and responses. In effect this analysis could be developed into a tool for contrasting how scenarios of different management actions could affect the ecosystem. However, to do this it would be necessary to ensure that all key variables are encompassed by the DPSR model and define the strength of connections between different factors. The latter feature is especially important to make any scenario analysis tractable in relation to the ecological and societal values derived from the Lagoon.

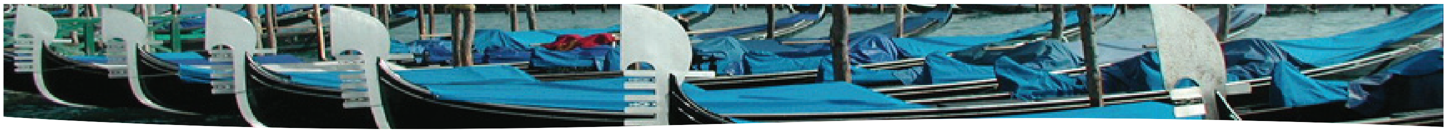
Ecosystem services derived from the Venice Lagoon can be broadly categorised to include:

- Production and quality of food resources
- Shoreline protection
- Climate change mitigation
- Nutrient cycling
- Contaminant processing
- Sediment stability and creation
- Resilience and biodiversity
- Mitigation of harmful algal blooms
- Supporting science and education
- Underpinning natural aesthetic values
- Tourism
- Cultural values

These services are generated by a diverse array of ecosystem functions. The recognition of the value of these functions involves linking ecosystem function and service to the various identifiable societal values that are dependent upon a healthy ecosystem. This translation is difficult because of complexity in the mechanisms that connect ecosystem function to service, the limits of our current understanding of these processes and how they are influenced by different external drivers. But some progress in this area is possible, we currently have no information on the actual valuation (non-monetary or monetary) for these services through social research in Venice. We think this is an important issue because many of the EU directives to which resource managers must respond are clearly linked to the maintenance of ecosystem function and the concomitant services.
Such valuations could be based around:

- Contact recreation
- Quality of experience
- Smell
- Observing Nature
- Beach walking
- Incidence of medical interventions due to exposure to pathogens and HABs (health risk)
- Bird watching
- Tourist view of the Lagoon
- Changes in the predictability of ecosystems response to change
- Prevalence of invasive species
- Landscapes (aesthetics)
- Research
- Education
- Intrinsic value
- Diversity of life
- Options for future use
- Decreased potential for erosion of shores
- Changes in bathymetry (storm and flood protection)
- Filtration roles
- Contaminant burial/transformation roles
- Fish / shellfish taste and looks
- Fish / shellfish size and quantity
- Harvesting commercial/recreational opportunities

Identifying societal values of the ecosystem is an extremely complicated socio-ecological process. One strategy that may be useful here is to define environmental outcomes that are not acceptable, for example stinking mats of decomposing algae, turbid water, loss of saltmarsh. Once such fea-



tures are identified it is possible to then use tools such as those that might be developed from the DPSR model to work back and identify the key processes and ecosystem functions that should be protected.

A large range of threats that face the Lagoon have been identified in the material presented to us, including:

- Sediment loss: Habitat change, elevated turbidity
- Fishing impacts: Habitat change; community change; loss of key species; lack of sustainability in fisheries
- Industrial contaminants
- Nutrient and Organic matter
- Sewage
- Non-Point Source Urban contaminants
- Invasive species
- Boat/ship wakes
- Dredging
- Climate change
- Plastics
- Shot, lead pollution
- Human pathogens
- HABs
- Loss of groundwater inputs of water and increased contaminant inputs
- Atmospheric inputs of contaminants

These individual threats will need to be prioritised based on their spatial extent, degree of impact on specific components of the ecosystem, potential for recovery/restoration, probability and time scale of occurrence. Nevertheless, we acknowledge the good identification the issues and interrelationships. These identify a series of key issues that will need to be addressed in the development and implementation of the sustainable management plan of the Lagoon:

- Control sediments
- Control nutrients
- Control chemicals
- Control fishing
- Enhance ecosystem resilience (by improving biodiversity, habitat maintenance and enhancing connectivity)
- Enhance capability in integrative and information-based resource management
- Enhance education, valuation and understanding of the inter-connections within the Lagoon social-ecological system

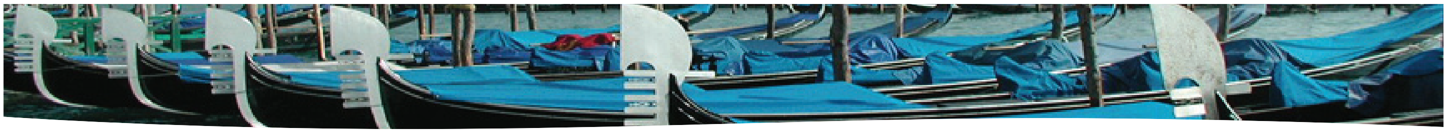
Our scenario matrix integrates across ecological and physical factors to illustrate how different management actions related to Habitat diversity, Depth/ climate change, Eutrophication, Fishing impacts, Suspended sediment concentration are likely to influence ecosystem services in Venice Lagoon.

### 2.11 Scenario Matrix

Table 1 shows how we rate the effects of different management options on ecosystem services. Our purpose is to show how management actions can influence ecosystem services and our certainty in their relationships. This is necessarily a simplified and 'homogeneous' approach. This could be developed in a formal risk assessment framework and used to create open dialog about management actions, research and monitoring. The headings along the top of the table identify the factors affecting the Lagoon ecosystem that need to be managed, and the headings down the side identify the services that the Lagoon provides. In the cell contents, the first figure indicates our evaluation of the strength of effect of the management factor on the service, on a scale of 0-3 (none to very strong). The second figure indicates how certain we are of that evaluation, again on a scale of 0 (a pure guess) to 3 (very certain). The + or - symbols indicate whether the effect on that service is beneficial (+) or detrimental (-).

| Service | Habitat Diversity | Depth / Climate Change | Eutro-phication | Fishing Impacts | Suspended Sediment Concentration; Erosion and Deposition |
|---|---|---|---|---|---|
| Production and quality of food resources | 2,2 + | 0,3,0 | 3,3 - | 3,3 - | 3,3 - |
| Shoreline protection | 3,3 + | 3.2 - | 2,1 - | 1,3 - | 3,3,0 |
| Climate change mitigation | 1,1 + | 0,2,0 | 3,3 - | 3,3 - | 0,3,0 |
| Nutrient cycling | 2,2 + | 2,1 - | 3,3 - | 2,2 - | 2,1 - |
| Contaminant processing | 2,2 + | 2,1 - | 3,3 - | 3,3 - | 3,2,-,+ |
| Sediment stability and creation | 2,2 + | 3,3 - | 2,1 - | 3,3 - | |
| Resilience and biodiversity | 3,3 + | 2,0 + | 3,3 - | 2,1 - | 3,3 - |
| Mitigation of harmful algal blooms | 3,2 + | 0,2,0 | 3,3 - | 2,1 - | 3,1 - |
| Supporting science and education | 3,3 + | 0,2,0 | 3,3 - | 0,2 - | 0,2,0 |
| Underpinning natural aesthetic values | 3,3 + | 0,2,0 | 3,3 - | 2,2 - | 3,3 - |
| Tourism | 3,3 + | 0,2,0 | 3,3 - | 3,3 - | 3,3 - |
| Cultural values | 3,3 + | 0,1,0 | 3,3 - | 3,3 - | 0,1 - |

*Table 1. Rating the effects of different management options on ecosystem services*



# III. Policy and Institutional

### 3.1 Introductory Remarks

The waters of the Venice Lagoon have been actively managed for more than half a millennium in order to ensure the security and commerce of the citizens of Venice and its region. In the 21st century, Venice's primary concerns are environmental and economic security, and not military security. What was once the center of Venice's military power, the Arsenale, has become a center for environmental defence. Protecting against inundation from high water events, but also avoiding toxic pollution, ensuring human health, enhancing esthetic values, and maintaining sustainable ecosystems, fisheries, and aquaculture have replaced military security as primary concerns. In short, managing the waters remains as critical to achieving a secure future for Venice as in past centuries. To this goal we must now add the sustainable management of the ecosystems in the Lagoon.

Venice is developing a 21st century capacity to manage its waters. The Venice gateswill protect against high water events. High water events are expected to grow in frequency and intensity as sea level rises over the century. Although not directly assessed by the present study, judicious operation of the gates at other times could enable an unprecedented degree of control over the circulation of the waters in the Lagoon, potentially permitting new ways to manage the ecological and economic systems using the Lagoon. But most important of all, the human and intellectual capital assembled to carry out the MOSE project could bring modern techniques of science, engineering, and organization to the management of the ecosystems of the Lagoon.

This human and intellectual capital must not be allowed to dissipate after the gates are completed. It must live on, for the future is uncertain. Venice is not immune to the problems of the 21st Century. How can it decide what it must do when we all live in a world of accelerating climate change and rising sea levels? Their impacts are not entirely clear but will certainly be profound. How should it make environmental decisions when human activity may have an impact that is different but perhaps even more profound in the future?

Even now, the health of the ecosystems in the Venice Lagoon is not assured. How can Venice make decisions about the future of its Lagoon when the only sure thing is that there will be change? Decisions taken today will be amended tomorrow. New technologies will be needed and old ones scrapped. Science will advance, society will change, people will make their livings in new ways. The best humans can do is to manage adaptively- to return over and over again to the key issues and make incremental decisions based on the best information available. This is the only way we know how to achieve sustainable ecosystem management.

Venice is unique, and how it decides to face its great issues is visible to the entire world-for good or ill. It has a perishable opportunity to make a major advance. The sophisticated engineering and management brought to Venice by the great project to build the gates could be applied to a decision-support system for adaptive ecosystem management that could match any in the world. Venice has three years to decide whether it wants to seize the opportunity.

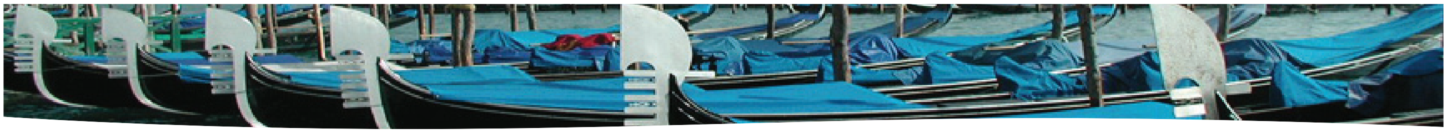
### 3.2 Assessment, Policy, Action: The Path to Adaptive Management

In medicine, "diagnosis" is precursor to "prescription" and "treatment". These are medical terms of art. For sustainability issues, the analogous terms are "assessment", "policy", and "adaptive management". Just as humans need periodic checkups to maintain their health, so also must the health of the Venice Lagoon be periodically assessed. Everything starts with assessment. Venice will not be able to make good adaptive decisions unless it commits to periodic formal assessments of the state of the Lagoon. Furthermore, the monitoring, modeling, and scientific analysis brought together to carry out assessments will be usable in day-to-day decision support once policy directions are set.

This committee, or any other group of outsiders, cannot design Venice's assessments by itself, since the subsequent policy development requires the involvement of local decision-makers. What we can do is evaluate Venice's readiness to undertake assessments that meet world standards, and to suggest ways it might wish to prepare to assume its responsibility for adaptive management.

We have examined the level of scientific understanding of the circulation, sediment dynamics, and ecosystem structure and services in the Lagoon. We have considered the adequacy of the monitoring and modeling systems to provide information that is important for regulatory compliance and decision support. We have done so in awareness of the intensive human and economic uses of the Lagoon, but with one exception we are not economists, and we have focused on the issues of environmental sustainability. At all stages in our work, we have been supported in highly professional ways by the principals and staff of the Thetis Corporation and the Consorzio Venezia Nuova.

We are aware of the scope and importance of the MOSE project, but we have not critiqued its rationale or operational scenarios. Our responsibility has been to ask the following question. Assuming the project is completed, what is needed to manage the waters and ecosystems in the Lagoon sustainably?



### 3.3 Requirements for Successful Assessments

A great deal has been learned about how to conduct assessments since the Intergovernmental Panel on Climate Change (IPCC) was founded in 1988. Appendix A contains a brief discussion of its rationale and methods of working. The experience of the climate change community, together with our own, leads us to state unequivocally that the key to a successful assessment is credibility. Rigorous attention to how the assessments are conducted is crucial.

1.) Assessments must be based on up-to-date scientific understanding and monitoring;
2.) All aspects of the assessment process must be open and transparent;
3.) Assessments must be kept independent of politics and economic interest;
4.) The development of policy recommendations should be kept separate from the assessment process, but…
5.) Scientists should proactively communicate with those who develop policy options.

The independence of the scientific assessment is the sine qua non of adaptive management. Once an assessment is completed, it is critical to structure the dialog between those who assess and those who decide. A carefully structured dialog enables scientists to give the best answers they can to policy questions, and for policy-makers to understand what science can and cannot do.

What follows are recommendations for what Venice must do to improve the capability and credibility of its approach to the management of the waters and ecosystems in the Venice Lagoon.

### 3.4 Policy Initiatives

We recommend that the relevant authorities establish three major policy initiatives.

1.) *Commit to a published schedule of assessments.* The interval between assessments should be set by considerations of practicality, regulatory requirements, and political decision-making, but in no case should be longer than ten years.
2.) *Commit to ongoing comprehensive monitoring and research*. Monitoring and research programs should be specifically designed to support assessments and decision-making.
3.) *Create a governing board.* The Governing Board would, among other things, work with external management authorities, structure policy, set ecosystem management goals, evaluate the organizations reporting to it, and communicate with stakeholders and the public. It would have the special responsibility to ensure the independence of the assessments it commissions.

### 3.5 Institutional Initiatives

If policy decisions like those recommended above are made, another international group returning to Venice in five years might ask whether effective supporting institutions have been put in place. We believe there is a need for Magistrato alle Acque to develop roles and institutions to work closely together, such as:

1.) *A Governance Secretariat that, among other things:*

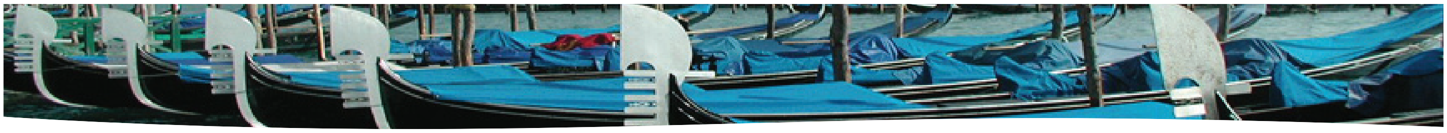
   a. Oversees the relationships among gates management, the new monitoring organization, and the advanced study program
   b. Designs, facilitates, and oversees the assessment process
   c. Convenes the independent science, technology, and management panels that report to the governing board.
   d. Monitors regulatory compliance
   e. Promotes effective decision support
   e. Acts as the board's interface with policy makers, stakeholders, and the public.

2.) *An Operational Monitoring and Modeling Organization*

   Information about the Venice Lagoon must be regularly collected, integrated, and disseminated to support adaptive management. To that end, a professional organization is needed to:

   a. Plan, maintain, validate, and update modeling and monitoring systems,
   b. Collect and provide data relevant to managers and stakeholders
   c. Ensure continuity of time-series data
   d. Provide decision-support products – indices, thresholds, decision algorithms-defined by management goals set by the governing board
   e. Provide unified open portal information access.
   f. Organize intensive sampling periods and rapid response teams

3.) *An Advanced Study School or Program*



The general scientific understanding of the state of the Lagoon is good. There is sufficient natural and social science capacity in the Venice region to support assessments. However, a new institution that brings researchers together to reach unified conclusions that decision-makers can take seriously is sorely needed. Without a partner institution with the responsibility to suggest the introduction of new modeling and monitoring technologies, the operational organization would eventually get out of date.

The Advanced Study Program should not compete with existing programs, but should:

a. Review, condense, and unify research findings;
b. Prepare research, monitoring, and modeling results for assessment;
c. Connect the research, monitoring, and modeling communities;
d. Suggest introduction of new monitoring variables and technologies;
e. Aggregate research funds and sponsor external research projects;
e. Incubate collaborations amongst research groups; and
g. Undertake interdisciplinary research related to sustainability.

The monitoring agency and the advanced study school would jointly support the assessment process.

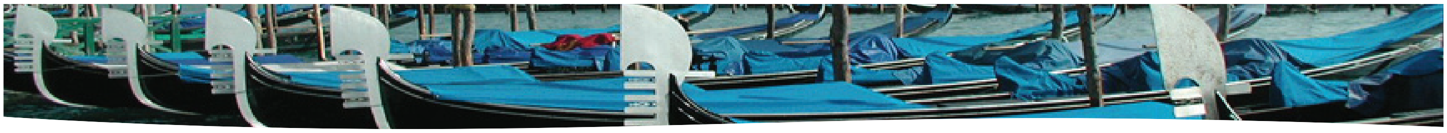
### 3.6 A Vision for the Future

When the gates are completed, well-equipped space in the newly renovated Arsenale will become available. Because of the engineering facilities already in place, it might be logical to house the monitoring agency there, close to the operators of the gates. The operational monitoring agency will manage observing and modeling infrastructure more professionally than individual research groups can. It would work directly with decision makers and the operators of the gates. People seeking information about the state of the Lagoon would use its information portal. Since the monitoring agency would communicate its awareness of practical issues to the scientific community via the advanced study school, it would also make sense to house the headquarters of the school in the Arsenale, close to the monitoring agency and its facilities.

The advanced study school should not compete with other research organizations in the Venice region, but build linkages between them by focusing their efforts on practical problems, sponsoring workshops, holding seminars, and promoting collaborative research. Together with the operational agency, it would prepare information for evaluation by assessment teams. It would have a small faculty to ensure program stability, but most of its research funding would go to external organizations. It would convene international meetings, workshops and study periods to bring the best ideas and newest technologies to Venice. It would partner with organizations in other regions with sustainability challenges.

While start-up investments will be needed, we believe that the financial commitments required to establish these new organizations are consistent with the level of expenditures already made in the case of monitoring and modeling or are otherwise reasonable in light of the projected cost of operations of the Venice gates project.

Ultimately, the creation of separate operational and research organizations designed to work closely together could establish Venice as a world center for studies of the sustainability of human-dominated Lagoon ecosystems. By leading the way in connecting interdisciplinary science with practical use, the scientific and social technology developed for assessment and adaptive management could nucleate a cluster of research and development programs and consultancies in broad areas of sustainability science, technology, and policy.



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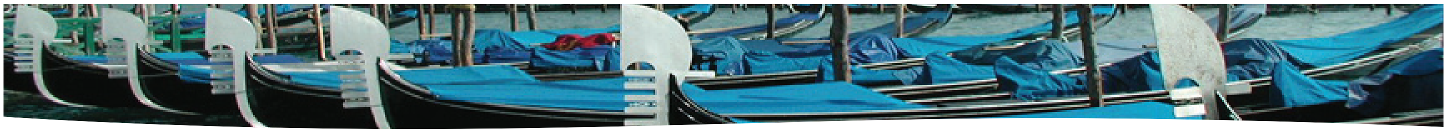


## Appendix A

## Intergovernmental Panel on Climate Change

When do we know we know something? Scientists must be able to know when knowledge is secure enough to be conveyed responsibly to non-scientists. At what point does research become established knowledge? Any expert community will encompass differing opinions about active research topics. When can the non-expert assume that most researchers in the field believe that a question has been answered? How can the non-expert know whether the views of a particular scientist are representative of the majority of the research community?

Scientists are trained to grapple with the frontiers of their fields and are comfortable speculating about what remains to be discovered. They believe that the scientific method and not consensus establishes truth. Aside from consolidating recent progress in review articles and monographs, scientists by and large have relied on the change of generations for issues to settle out and knowledge to be considered established.

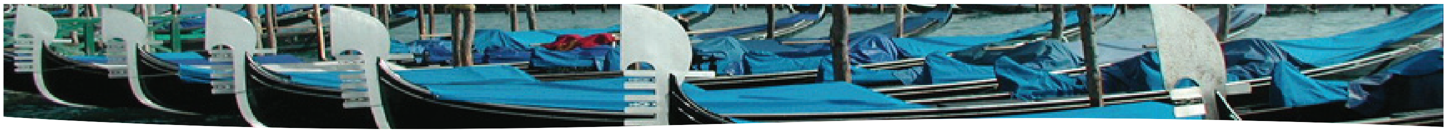
Not until the climate change clock started ticking was there a serious need to accelerate the coalescence of research into knowledge. This task, once left to the passage of time, has been formalized. Making knowledge “text-book ready” is not enough. Stopping there relies again on the passage of time for established knowledge to be turned into useful knowledge. The climate urgency required accelerating the process by which recently acquired knowledge becomes decision-ready.

New questions arise. Is established knowledge the same as decision-ready knowledge? How can scientists best convey their specialized conclusions to the decision-maker? Is the scientific community doing all the studies needed for policy analysis? What is the best way to convey the meaning of scientific uncertainty to policy makers and the public?

In 1988, the World Meteorological Organisation established the Intergovernmental Panel on Climate Change (IPCC) to provide “an objective source of information about climate change.” The IPCC devised transparent processes that promote trust. Its reviews were restricted to the information found in the open peer-reviewed literature. Review panels were chosen with great attention to balance amongst countries, established points of view, and economic and institutional interests. Successive panels recruited a majority of new participants, to avoid an institutionalized IPCC point of view. The IPCC created rigorous ways to convey its conclusions in forms policy-makers could use. It created uniform language to describe degrees of scientific uncertainty.

The IPCC’s most important innovation was to separate their assessment of the state of the science from their discussion of policy implications. After the scientific assessment was complete, the IPCC engaged in a separate process to develop summaries for policy makers, in which scientists and policy-makers together composed, line-by-line, conclusions drawn for their pertinence to policy, with careful attention to the uniform characterization of uncertainty and risk. The IPCC thus structured a mode of communication between scientists and decision-makers that both preserves the independence and rigor of science and accelerates the delivery of useful knowledge into the decision arena.

IPCC assessments transformed the international public debate about climate. Their influence grew progressively as succeeding reports communicated the scientific community’s growing understanding of climate change. The return over and over again to the same issues proved to be essential. The IPCC shared the Nobel Prize for Peace only a few months after its 2007 report was released. Nearly every government in the world now has to pay attention to IPCC reports. Assessment has taken its place alongside experiment, theory, and modeling as a basic scientific activity wherever science and public concerns overlap. It is the most important social technology devoted to science invented in the 20th century.



## Appendix B

# Venice Sustainability Advisory Panelists

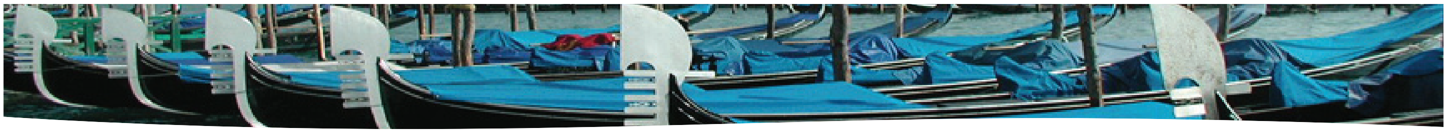
**Charles F. Kennel** was born in Cambridge, Massachusetts, was educated in astronomy and astrophysics at Harvard and Princeton. He then joined the UCLA Department of Physics, developed a research career in space plasma physics and astrophysics, and chaired the department for three years. From 1994 to 1996, he was Associate Administrator at NASA for Mission to Planet Earth, the world's largest Earth science program. He was the UCLA Executive Vice Chancellor, its chief academic officer, from 1996-1998. His experiences at NASA convinced him to return to Earth and environmental science in 1998.

Kennel was the ninth Director of Scripps Institution of Oceanography and Vice Chancellor of Marine Sciences at the University of California, San Diego, from 1997 to 2006. Dr. Kennel was the founding director of the UCSD Environment and Sustainability Initiative, embracing teaching, research, campus operations, and public outreach, and is now the chair of its international advisory board.
A member of the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society, Kennel has chaired the NRC Committee on Solar and Space Physics, the NRC Board on Physics and Astronomy, The NRC Committee on Global Change Research, the NRC Fusion Sciences Assessment Committee, and he co-chaired the recent NRC Beyond Einstein Program Assessment Committee. He was a member of the Pew Oceans Commission from 2000-2003, the NASA Advisory Council from 1998 to 2006, and its chair from 2001-2005. He is presently chair of the California Council on Science and Technology, and the NRC Space Studies Board. He has had visiting appointments to the International Centre for Theoretical Physics (Trieste), Ecole Polytechnique (Paris), Caltech (Pasadena), Princeton, Space Research Institute (Moscow), and the University of Cambridge. He is a recipient of the James Clerk Maxwell Prize (American Physical Society), the Hannes Alfven Prize (European Geophysical Society), the Aurelio Peccei Prize (Accademia Lincei), and the NASA Distinguished Service and Distinguished Public Service Awards.

**Paul F. Linden** is the chair of the Mechanical and Aerospace Engineering Department at the UC San Diego Jacobs School of Engineering, where he is the Blasker Professor of Environmental Science and Engineering. He is a fellow of the Royal Society, the American Physical Society and the Royal Meteorological Society. Prior to joining UC San Diego in 1998, Linden was a faculty member in the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge, where he earned his Ph.D. in 1971. Linden has more than 160 publications in peer-reviewed journals on geophysical, environmental and industrial fluid dynamics. He has received a great deal of recognition for the application of his work in fluid dynamics to environmental engineering to create more energy efficient buildings - many of which are located in the United Kingdom. He is a member of the scientific advisory board for San Diego County.

**Farooq Azam** is a professor of microbial oceanography at Scripps Institution, UCSD. Azam and his students study the ecology of marine bacteria and viruses, their diversity, and their population dynamics. His studies focus on the biochemical and molecular adaptations of bacteria for life in the ocean, at spatial scale ranging from nanometer to ocean basins, and the integration of microbial processes into the functioning of marine ecosystems. Of particular interest is the role played by marine microbes in the oceanic carbon cycle through their influences on the fate of the primary productivity, e.g. regulation of the biological carbon pump. This knowledge is needed to build mechanistic and prognostic models of global climate change and biodiversity conservation. Azam's research group has also been studying how climate change might influence the survival and proliferation of the human pathogenic bacterium Vibrio cholerae. As member of World Bank Coral Disease Working Group Azam, together with his students and postdoctoral fellows, has been investigating the effects on coral reef health due to human perturbations of coastal marine ecosystems such as the citing of mariculture systems or sewage outfalls in proximity of coral reefs. Azam and his graduate students were participants in the SIOSED experiment to study the ecological effects of sediment transplantation in the Venice Lagoon.

**Erik Bonsdorff** (Ph.D., 1985) is Full Professor of Marine Biology at the Department of Biology (Environmental and Marine Biology), at the Åbo Akademi University. He has lead and/or participated in numerous research projects regarding Baltic Sea ecology, on (i) zoobenthic community succession and recovery from environmental perturbations,
(ii) experimental studies on zoobenthic ecology (competition, predation, functional biodiversity, disturbance, behaviour), (iii) structural and functional biodiversity-aspects, including the role of invasive species, (iv) large scale processes and long-term changes in the Baltic Sea ecosystems related primarily to eutrophication, and (v) developing decision-support systems in relation to the environmental problems (eutrophication, hypoxia/anoxia, pollution and climate change) within multinational projects (the MARE-project and the Baltic Nest-model; the EU-project CHARM, etc). Erik Bonsdorff has been an active supervisor at all academic levels, and between 1992 and 2007 18 PhD students completed their degrees under his supervision. He has published about 100 papers in international peer-reviewed journals and edited volumes, and has written numerous articles in



popular science, and actively participated in presenting scientific information to society via media (newspapers, radio, TV) and by giving oral presentations.

**Giovanni Coco** received a PhD in Physical Oceanography at Plymouth University (U.K.) for a thesis on morphodynamics in the nearshore, he then spent 3 years as a post-doctoral fellow at Scripps Institute of Oceanography (USA) working with Prof. Werner on beach dynamics and complexity. He has also spent 1 year at the University of Barcelona (Spain) working with Prof. Falques on nearshore hydrodynamics Currently he is a research scientist at the National Institute of Water and Atmospheric Research, NIWA (NZ) leading research on beach dynamics and coastal hazards, and collaborating with ecologists on complexity, biophysical interactions and ecosystem function modeling. In the past 3 years he has published more than 20 papers in international peer-reviewed journals, has been an invited speaker at 3 international conferences and has become Honorary Lecturer at Waikato University.

His role in leading the research group at NIWA focuses on coastal hazards and involves interactions with stakeholders, managers and practitioners in the translation of research findings into management practice and policy. His research interests include coastal engineering, coastal processes with an emphasis on sediment transport, estuarine ecology, geomorphology, marine geology, natural hazards, coastal monitoring using remote sensing techniques, complexity, time series analysis and wave dynamics. At present, his research focuses in the area of biogeomorphology where some of his most recent work aims at unraveling the effect(s) of biota on sediment transport and mixing in estuarine and nearshore environments.

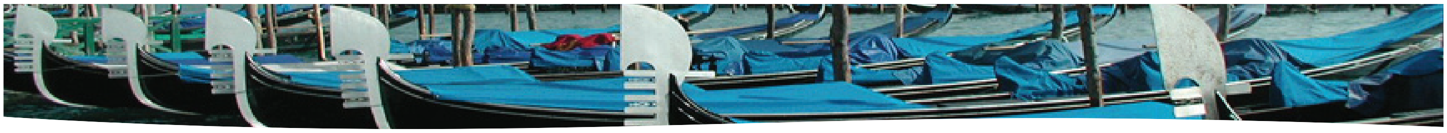
**Paul Dayton** is a professor at the Scripps Institution of Oceanography at the University of California, San Diego. His work has focused on overfishing of target species, impacts on air-breathing species and elasmobranchs, destruction of benthic habitat, generation of lethal debris, and management options. Currently, his work focuses on oceanographic shifts and anthropogenic impacts on the Point Loma kelp forest off San Diego. He is a recipient of the Louise Burt Award for excellence in oceanographic writing from Oregon State University and the George Mercer Award from the Ecological Society of America. Dr. Dayton is a fellow of AAAS and a PEW Conservation Scholar (1995-98). He is a member of the U.S. Marine Mammal Commission; the Group of Specialists on Southern Ocean Ecology, Scientific Committee on Antarctic Research.

**Michael Dettinger** is a research hydrologist for the U.S. Geological Survey, Branch of Western Regional Research, and a research associate of the Climate Research Division at Scripps Institution of Oceanography, La Jolla. He has degrees from the University of California, San Diego, Massachusetts Institute of Technology, and a Ph.D. from the University of California, Los Angeles (Atmospheric Sciences). Dettinger has monitored and researched water resources of the West for over 25 years, focusing on regional surface water and groundwater resources, watershed modeling, causes of hydroclimatic variability, and climatic-change influences on water resources.

Dettinger has authored over 60 scientific articles in scholarly journals, 20 government reports, and another 60 articles in outreach and less formal scientific outlets. He is on the Science Steering Group of the US Climate Change Science Program's Water-Cycle Working Group, Climate Advisor and State of Science Editorial Board for the CALFED Bay-Delta Restoration Program, Science Board for California State-wide Watershed Program, and founding member of the Consortium for Integrated Climate Research in Western Mountains. He received the Vice President's National Performance Review Award in 1996 for interagency planning for Mojave Desert ecosystems, received the US Department of the Interior's Superior Service Award in 2005, earned the California Department of Water Resources Climate Service Award in 2007, and won the NOAA Office of Oceanic and Atmospheric Research Outstanding Scientific Paper Award in 2007.

**Simon Thrush** is the Science leader for Coastal Ecosystems research and principal scientist in Benthic Ecology at the National Institute of Water and Atmospheric Research, New Zealand.  He has over 20 years of experience in the development and implementation of strategic research to influence resource management and improved societal valuation of marine ecosystems.  His research interests include coastal and estuarine marine ecology; scale dependent processes in heterogeneous environments; the influence of disturbance events on populations and communities and the implications for recovery and resilience; ecological impact assessment, particularly of diffuse source and/or broad-scale effects; the design and implementation of ecological monitoring programmes; the environmental effects of fishing; organism-sediment interactions; organism-hydrodynamic interactions; functional biodiversity and biocomplexity. He has contributed to over 150 publications in the peer reviewed scientific literature and 100 consultancy reports.

Simon's research has involved collaboration with a variety of other scientific disciplines (statisticians, environmental chemists, sedimentologists and oceanographers) in problem solv-



ing and the transfer of research implications to resource users, managers, policy makers and society in general. His research has been applied to address a number of strategic resource management issues. His work on diffuse source contaminant impacts has lead to actions by resource managers to reduce contaminant loads and monitor the ecological condition of receiving environments. Research on the environmental effects of fishing helped to bring a broader perspective to fisheries management and marine conservation and contributed to the development of environmental baselines. While studies on sediment impacts, in conjunction with long-term monitoring, has lead to the implementation of ecological risk assessment frameworks for catchment development and catchment wide restoration of degraded estuaries by resource managers. His research has involved extensive international collaboration with colleagues in USA, Canada, Britain, Norway, Finland, Netherlands and Italy. He is currently on an EU fellowship working with colleagues at the University of Genoa (Italy) on a project concerning the biodiversity, connectivity and resilience of Ligurian coastal communities

**Margherita Emma Turvani** is an Associate Professor of Political Economy and Economic Policy,at the University IUAV of Venice within the Department of Planning. Past academic positions include University of Torino and University of Urbino. She studied at University of Torino, and was a Visiting Fellow at the CEPR, Stanford University, Stanford, USA and more recently a Visiting Fellow at the Tsinghua University Department of Environmental Engineering, Beijing, China. Margherita is currently the Vice-Director of the PhD Program Analysis and Governance of Sustainable Development, School for Advanced Studies in Venice (SSAV) jointly organized by the University IUAV of Venice and the University of Ca Foscari, Venice.

She has won and is responsible for many research grants such as ESF (European Science foundation) Exploratory Workshop, The reuse of Contaminated sites for local sustainable development strategies (2008); Joint Research Center EU, External Costs of Transportation: the maritime mode (2008); CORILA Research Consortium for Venice Cost Benefit Analysis of Public Project for the safeguard of the Lagoon of Venice (2004-2007), (2002-2004); APAT - National guideline for Economic valuation of Public policy for Brownfield remediation and Reuse (2005)
Research projects of National Interest (PRIN): 2005-2007 Economic valuation of cleanup and reuse of urban derelict and contaminated land; 2002-2004 Mathematics and economic theory: the challenges of old and new institutionalism. Professor Turvanis main areas of interest are Sustainable development & Institutional Economics. She has written in the field of: labor economics, history of economic thought, institutional economics, economics of innovation and technological change, and environmental economics.

**Richard M. Warwick** received his BSc (1965), PhD (1968) and DSc (1984) from the University of Exeter. He has worked at the Plymouth Marine Laboratory since 1972 where he is an Individual Merit grade 6 and has been Project leader of their Marine Biodiversity Research group since 1992. He is an honorary professor at the University of Plymouth, UK and the Ocean University of Qingdao, China. He is the managing editor of the Journal of Experimental Marine Biology and Ecology and on the editorial boards of Marine Ecology Progress Series and Estuarine, Coastal and Shelf Science. His research interests include the ecology of marine benthos including production, community structure, community responses to pollution, taxonomy and biodiversity. He has published more than 120 papers in international journals and 5 books.

## Acknowledgments

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