Case Study 44

# Innovative Scientific and Technological Support System for Coastal Management in Xiamen, PR China

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## Key Message

- The effectiveness of scientific and technological support to coastal management can be greatly enhanced through timely provision of critical and reliable information, and techniques or technologies that can be utilized for policy and/or management interventions.
- Incorporating scientific/expert advice into the planning and management processes of an integrated coastal management (ICM) program can improve mutual understanding and enhance cooperation between scientists and managers, increase cost-effectiveness, and generate environmental and socioeconomic benefits.

## Abstract

In 1994, Xiamen City was chosen by the GEF/UNDP/IMO Regional Programme for Marine Pollution Prevention and Management of the East Asian Seas Region (MPP-EAS) as a pilot site for demonstrating the feasibility of ICM as an effective approach in achieving sustainable coastal development. Recognizing the important role of science and technology in the design and implementation of management interventions, a Marine Experts Group (MEG) comprising key leaders/representatives from educational, technical, and scientific research institutions in Fujian province was established and incorporated as part of the ICM Coordinating Mechanism; thus, facilitating closer interactions between policymakers/managers and scientists.

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Through the MEG, various scientific and technological support was provided in the process of ICM program development and implementation.

This case study highlights several key scientific and technological support that contributed significantly to: (a) the development and implementation of a marine functional zoning scheme in Xiamen through the application of integrated environmental impact assessment (IEIA) and geographical information system (GIS), in addition to mobilizing multidisciplinary research teams for undertaking field surveys and analysis; (b) application of strategic environmental assessment (SEA) in coastal planning and management interventions; (c) application of numerical modeling to determine the hydrodynamics of the sea areas and the impacts of coastal reclamation resulting in a series of long-term engineering interventions/improvement to restore the water quality of the coastal seas; and (d) the development and implementation of an integrated marine environmental monitoring system (IMEMS) to provide in-situ information on the sea conditions and water quality of the coastal waters.

Key lessons drawn from over 20 years of operation include: (i) the incorporation of a representative scientific community (e.g., MEG) into the standing ICM Coordinating Mechanism greatly enhanced cost-effective policy and management interventions; (ii) the Xiamen experience showcased how scientific and technological support could be effectively mobilized in achieving management objectives; (iii) due to current and new challenges to the sustainable management of the coastal areas, scientific institutions continue to play a proactive role, and as such, MEG continues to function especially for addressing new challenges; and (iv) a long-term IMEMS is an indispensable component of the environmental management system in Xiamen.

## Background

In order to achieve effective response to the increasing challenges of climate change and human activities on the sustainable development of the coastal and marine areas, most recent national and international efforts have adopted holistic and ecosystem-based management approaches, requiring the use and integration of scientific information and knowledge as well as utilizing innovative technologies in developing effective science-based management programs (GESAMP, 1996; Hong and Xue, 2002). Since 1994, as one of the demonstration sites of the GEF/UNDP/IMO Regional Programme for Marine Pollution Prevention and Management of the East Asian Seas Region (MPP-EAS), Xiamen has successfully applied the above approaches in the development and implementation of ICM programs (Chua, et al., 1997; Hong and Peng, 2002; McCleave, et al., 2003; Xue and Hong, 2005; Peng, et al., 2006b).

One of the successful experiences of Xiamen ICM was the effective science-management interface through a scientific support mechanism, which facilitated effective utilization of science and technologies for policy and management interventions. Such scientific mechanism was strategically incorporated as a multidisciplinary MEG within the Interagency Coordinating Committee for the development and implementation of the ICM program established since 1994 (Hong and Xue, 2002). The MEG consisted of leaders of various educational and scientific research institutions located in Xiamen City or in Fujian Province. Through the committee, matters concerning the environment and sustainable development were discussed and acted upon. The MEG was therefore able to interact with managers and leaders of various agencies and understand their management challenges so as to provide or mobilize the needed scientific or technological support for facilitating policy and management decisions. Over the long duration of working together, there was better appreciation of the contribution of science and technology in addressing many of the management challenges.

This case study outlines how scientific and technological support was utilized in policy and management decisions in the development and implementation of some coastal initiatives in Xiamen.

## Approach and Methodology

**Integrate MEG as an essential component of the ICM institutional mechanism.**

In line with the design of the ICM system in developing a science-based management program, MEG was incorporated in the Coordinating Committee. The MEG was responsible for providing scientific and technological advice and expertise in the development and implementation of the ICM program. Its members were familiar with local conditions and management challenges. As such, MEG was able to interact freely with all concerned agencies and other stakeholders in identifying and securing needed information for management interventions.

**Identify management needs for scientific and technological support.**

By following the structure of the ICM framework and the program development process (PEMSEA, 2006), the ICM project office was able to utilize MEG to undertake information gathering and analysis activities. This step included the preparation of the Xiamen Environmental Profile, State of the Coasts report, coastal zoning, environmental risk assessments, and ecosystem valuation. With the support of the leadership of the Coordinating Committee, MEG was in a better position to organize the needed field surveys and research investigations. It was also comparatively easier for them to secure the needed financial resources.

**Mobilize experts and scientific institutions.**

With clear mandates from the Coordinating Committee, MEG was able to select qualified experts from institutions within the province. National or international experts could also be drawn whenever necessary. Such approach enabled MEG to effectively address local concerns. The MEG formed research teams to implement agenda through contractual agreements. As much as possible, technical expertise from each relevant agency was involved throughout the process, thus ensuring close and timely linkage with the scientific teams.

**Provide accurate scientific data to support management decisions.**

Research teams were responsible for organizing their own protocols, gather primary and secondary information, analyzing available data and submitting their findings to MEG and subsequently to the Coordinating Committee.

## Results

ICM is largely area-based and hence, has to address a wide spectrum of socioeconomic and environmental management challenges using various scientific and management tools. The following are examples of key scientific and technological support that were employed for addressing some of the coastal planning and management issues in Xiamen.

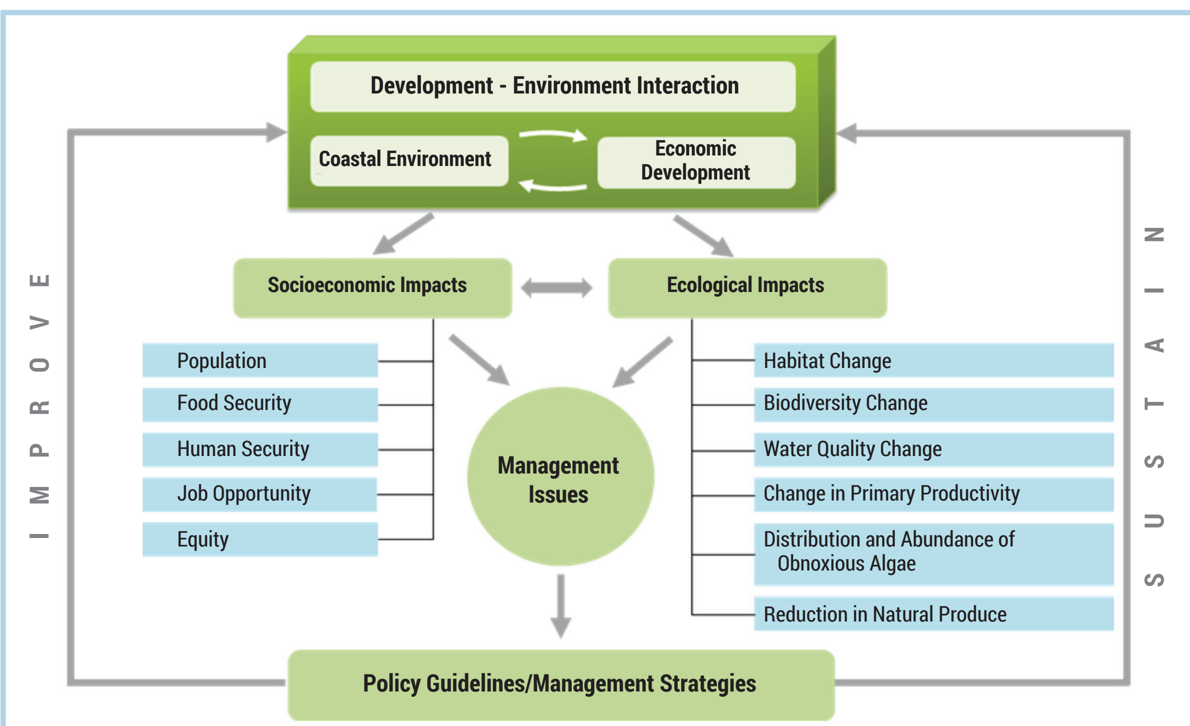
### Development and implementation of marine functional zoning scheme

The marine functional zoning (MFZ) scheme was conceived as an arbitrary yet practical approach to reducing use conflicts in the coastal and marine areas by promoting key economic activities in designated areas based on best use of their ecological characteristics (Ruan and Yu, 1999; Dong, et al., 2006; Fang, et al., 2011). Hence, reliable scientific information is necessary to identify coastal areas: (a) essential for conservation and protection of habitats, spawning or nursery grounds of endangered species; (b) suitable for specific dominant economic activities; and (c) suitable for limited but compatible economic activities, etc. The scientific and technological tools used included, among others, IEIA and GIS. These made use of primary and secondary data on the social, economic, and environmental characteristics of the coastal areas. Through careful data analysis, the ecological functions of the coastal areas and their subsequent zoning scheme could be determined.

**IEIA.** The IEIA is an advanced technique to identify the nature of the cumulative impacts of economic development and their consequences; prioritize the issues; and provide guidance for the prevention and mitigation of existing and future negative consequences. The incorporation of IEIA in the initial stage of Xiamen's ICM program provided critical inputs for identifying and quantifying overall major environmental and social impacts that could be taken into account in the development of management measures (Xue, et al., 2004).

Based on an IEIA framework developed earlier (Hong and Xue, 1998; Figure 1), the cumulative impacts of the economic development activities in Xiamen waters were identified and mitigation measures suggested. The IEIA is an ecological approach focusing on the physical, chemical,

**Figure 1. Framework for assessing ecological and socioeconomic impacts of economic development (After Hong and Xue, 1998).**



and biological elements of the coastal ecosystem. Management measures for harmonizing economic development and the coastal environment were then proposed. For example, a series of projects involving reclamation of coastal areas (e.g., filling in wetlands, diking, building dams and other barriers, to exclude coastal waters) were assessed.

The IEIA results showed that the various reclamation activities had negative cumulative and aggregate impacts over time. The overall long-term impacts could accelerate erosion, severe siltation and sedimentation causing blockage of drainage outlets, loss of fish spawning grounds, and hindrance to navigational passage (Xue, et al., 2004). Suggested mitigation measures were: (a) widening of the sluice gates of Maluan Dike; (b) developing a numerical model to predict water alteration; (c) controlling reclamation practices; (d) increasing sewage treatment control; and (e) implementing a functional zonation scheme to regulate economic activities.

**Establishing MFZ scheme.** Although understanding and assessing the cumulative environmental and social impacts are a challenge to the scientific community, mitigating such cumulative impacts can be even more so for the economic and environmental managers. In addressing these challenges, it was important to note that these challenges arise not only from the overexploitation of natural resources, increasing population, and/or pollutant discharges, but also from conflicting multiple uses between sectors and inadequate management measures (Chua, et al., 1997). Hence, the development and implementation of coastal zoning presented a useful option to identify and address unregulated activities in the coastal areas.

The Xiamen MFZ scheme was initiated in 1997 by way of an administrative order designated to promote rational development and utilization of marine resources and contribute to the resolution of multiple use conflicts (Chua, 2006). It was implemented within the sector programs and mandates of the 23 line agencies of the government. The basis for designating primary, compatible or limited functions of each zone was largely based on careful consideration of: (a) existing uses; (b) ecological characteristics; (c) environmental risk analysis; and (d) socioeconomic consequences. Involvement of line agencies and stakeholders' consultation were prerequisites (Box 1).

**Box 1. MFZ scheme.**

- The Xiamen MFZ scheme (Figure 2) defined the dominant (use high priority), compatible (maximum benefit for multi-resource uses), and restricted functions of each sea area.
- Prioritization was determined based on the estimated socioeconomic benefits and related environmental impacts of the uses under the assessments of the cumulative effects of current and potential activities in Xiamen's marine areas.
- The direct result of the zoning scheme was:
  (1) The removal of the flourishing aquaculture practice in the East Sea areas and its replacement as a tourism and recreational zone; and
  (2) The integrated management of the West Sea areas including the removal of aquaculture practices in place of a shipping zone and conservation site for endangered species.
- These initiatives turned around Xiamen's disorderly marine management practices, not only in terms of ecosystem conservation and restoration but also an orderly relocation of sea use based on ecosystem functions.

**GIS for MFZ scheme implementation.** In May 1999, an IIMS was completed by experts from Xiamen University. GIS software was used to map the sea and land areas of Xiamen, providing visual information that improved the development and implementation of the functional sea use zonation scheme. The utilization of the high-precision GPS and application of the satellite remote sensing helped to secure information and monitor sea conditions and changes in the marine environment. These technologies, in a way, helped the city government to constantly improve the precision of the zonation scheme (PEMSEA, 2006). With a scale of 1:5,000, the GIS system enabled the effective operation of MFZ.

Furthermore, based on MFZ, a market-based instrument in the form of permit user fee scheme was enacted through two sets of legislation: (a) the Regulations on the Protection and Management of the Marine Environment; and (b) the Xiamen Marine Use Fee System. The relatively high fees imposed dissuaded incompatible activities in the location where they were applied, controlling access to and exploitation of resources (Chua, 2006). In order to evaluate the fees for different types of marine special usage, two separate models were developed to estimate the price of marine spaces, based on production factors and environmental capacity recourses, respectively. For example, the user of reclaimed sea areas would not only pay the usage charge but also the ecological damage cost (Peng, et al., 2006a).

A management system for Xiamen sea areas and islands (Figure 3) integrating MFZ, coastlines,

**Figure 2. Xiamen MFZ scheme** (Fang, et al., 2011).

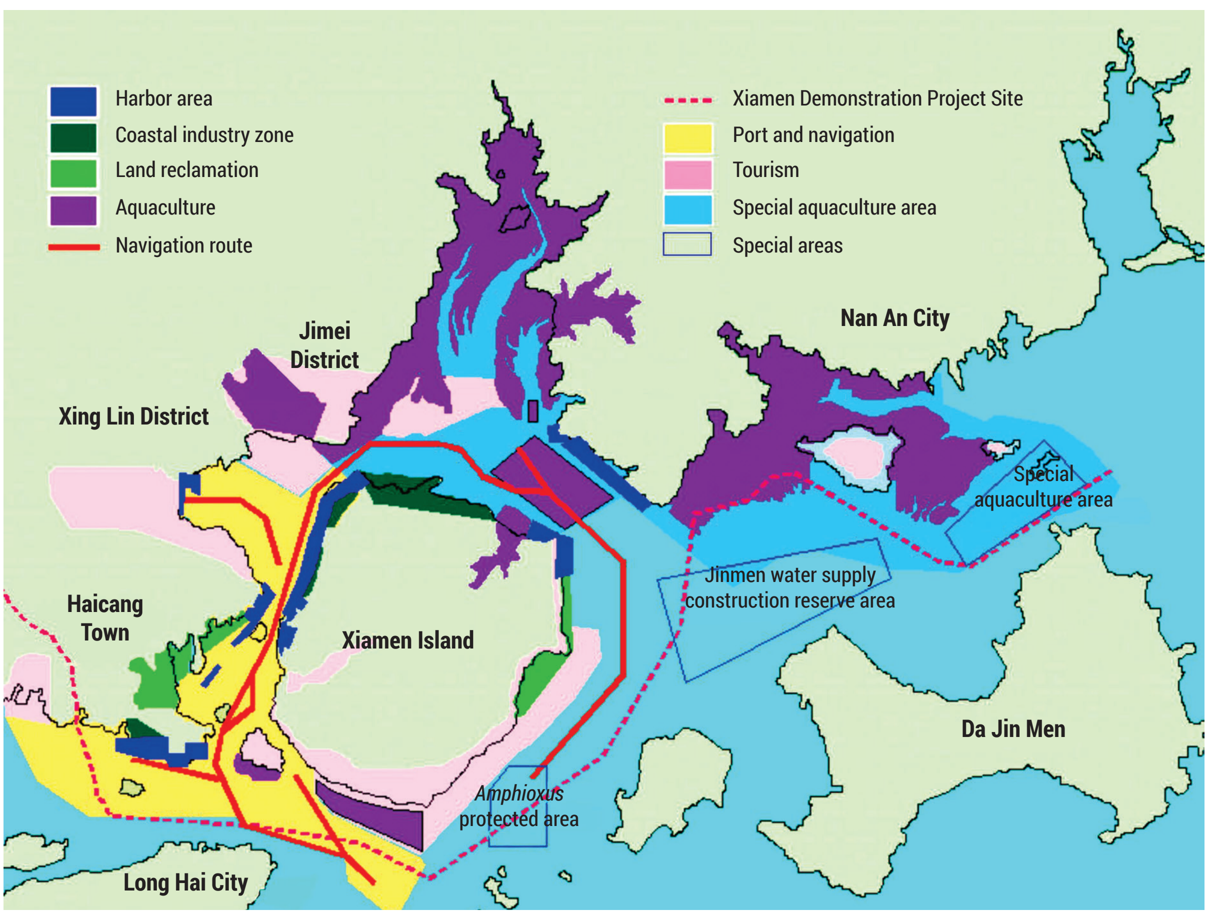
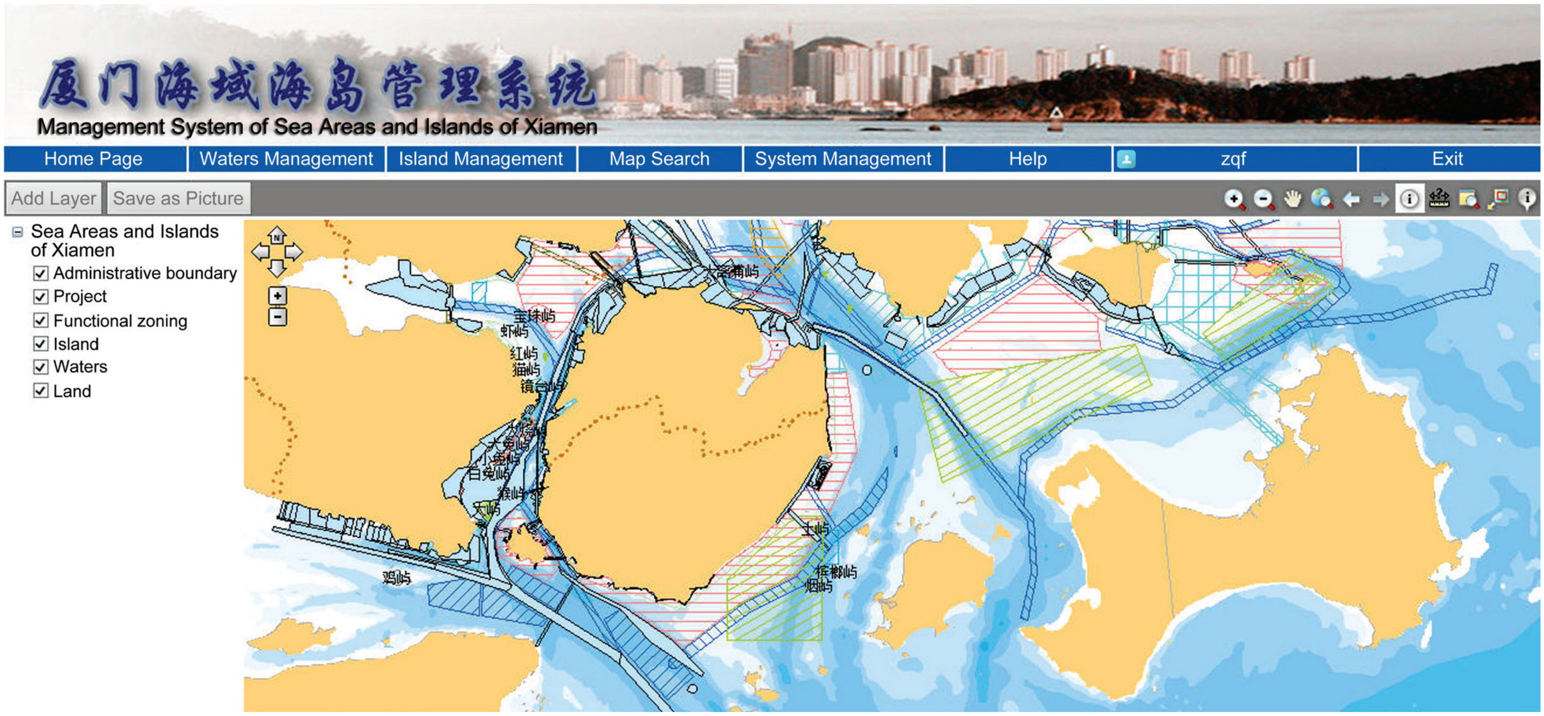


**Figure 3.** **Management system of seas areas and islands of Xiamen.**




and permit-fee schemes and user fee schemes was an effective tool for management of sea area uses. The system covered issuance of permits, zoning scheme compliance and enforcement, and avoidance of overlaps among primary sea uses.

### Strategic environmental assessment of the development plan

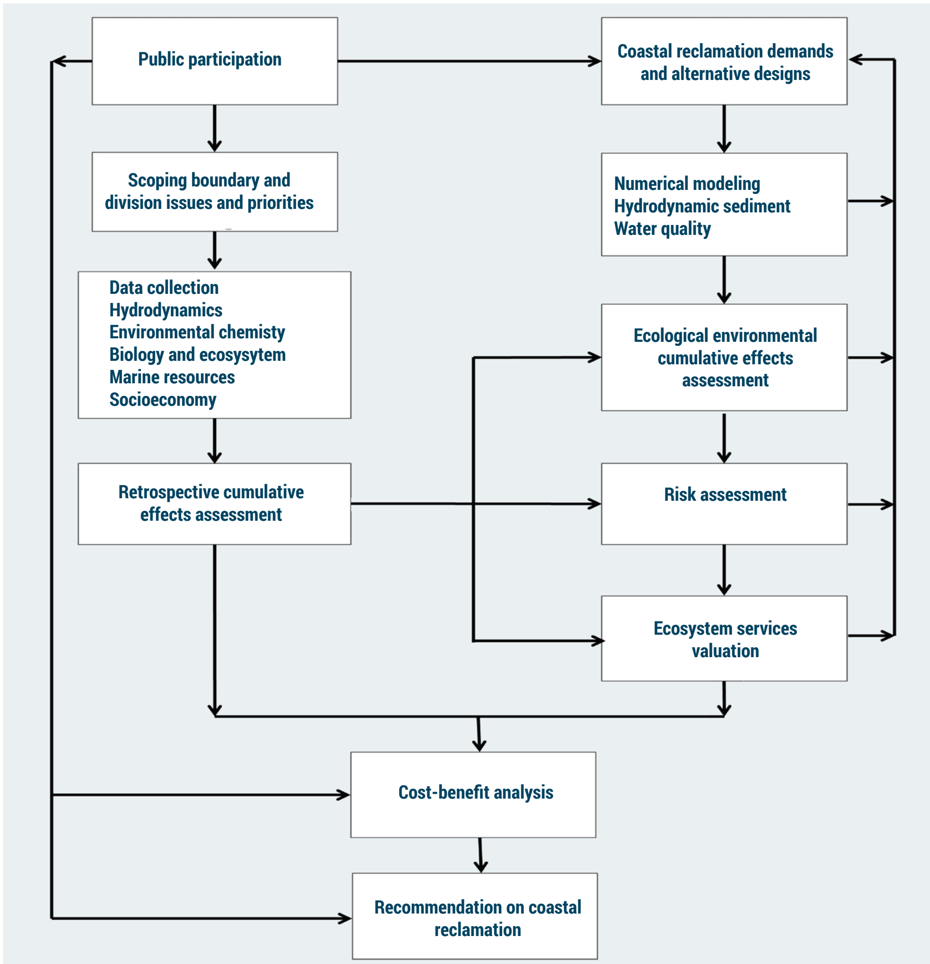
A strategic environmental assessment (SEA) of the reclamation plan was conducted to strictly regulate coastal reclamation projects with the procedure shown in Figure 4 (Fang, et al., 2009). From the assessment results of the reclamation plan, permitted or nonpermitted areas for reclamation or areas requiring cautious and strict control with respect to EIA recommendations were identified. Hence, demands for coastal reclamation projects were subject to careful evaluation of the ecological risks and socioeconomic benefits before any reclamation could be approved, thus underscoring the important role of science in decisionmaking.

### Restoring coastal environments

Since the 1950s, large-scale coastal reclamation and dike constructions were permitted in Xiamen bay and coastal area. These works, especially in the western and eastern sea areas altered the hydrodynamic conditions and caused water quality deterioration as a result of restricted waterflow and exchange (Hong and Wang, 2009).

A two-way nested-grid numerical model was developed by Xiamen University to study the general hydrodynamic indexes of the western and eastern seas in Xiamen Bay and analyze the accumulative effects of coastal reclamation activities covering the period 1938–2007. The model was developed based on the Princeton Ocean Model (POM). Modeling results showed that the average tidal velocity and tidal flow capacity decreased by about 40% and 20%, respectively, compared to that of 1938. The study also estimated the level of hydrodynamic improvement that could be attained from the implementation of environment restoration projects. Based on the

**Figure 4.** **SEA procedure** (Fang, et al., 2009).




high linear correlation between tidal area and hydrodynamic indexes, the model forecasted that the hydrodynamic status could return to the 1972 conditions through the interventions of restoration projects (Hong and Wang, 2009).

Based on the above scientific findings, a series of environmental restoration projects were proposed by the experts as follows:

1. Open the Gaoji dike with an 800 m bridge in order to enhance the water exchange between West and East seas.
2. Open Maluan dike, Xinglin dike, and Dongkeng dike by 200 m, 250 m, and 700 m, respectively. This would improve the hydrodynamic condition in Xiamen Bay.
3. Dredge the deposited sediments in West and East seas to the level of low slack tide, which would increase the tidal prism and hydrodynamic condition.
4. All aquaculture activities should be removed from Xiamen Bay and sewage from residences and industries should be collected and treated to achieve the allowable standard water quality before flushing out.

The Xiamen City government accepted the experts' proposal and implemented a series of environmental restoration projects including sea area desilting, opening up bays by means of transforming causeways into bridges, or constructing gates to facilitate waterflow. The demolition of the Dadeng causeway contributed to improving the hydrodynamic conditions of the eastern and western sea areas. The Zhongzhai causeway as well as the transformation of Jixing causeway with water gates were also completed while the openings of Gaoji causeway and Maluan causeway are still in progress.

Hence, the opening of causeways, when fully completed and the desilting of sea areas around them, will result in the flushing out of pollutants from the West Sea area. The water quality of East and West Sea areas is expected to improve. The opening of the Jixing Causeway is expected to minimize the flood control recurrence period from the current 10-year to a 50-year interval. Meanwhile, the opening of the Gaoji causeway can restore the connection between East and West Sea areas by improving the daily water exchange of 71 million $m^3$ and reducing the water exchange cycle to two days.

These restoration projects dramatically improved the ecological environment of Xiamen's seas, maintained the marine ecological balance, restored marine resources, improved the marine landscape, and thus contributed to boosting port development, shipping transportation, coastal tourism, coastal industries, and other emerging high-tech marine industries. These leading marine industries contributed more than 60% of the added value to the marine economy and accounted for 80% of Xiamen's coastal economy. The added value to the marine economy was estimated at US$ 14.71 million per $km^2$.

The ecological, social, and environmental benefits achieved through the above environmental improvement projects demonstrated that the ocean can regulate its own functions given ample assistance to enable its recovery.

### Integrated marine environmental monitoring system

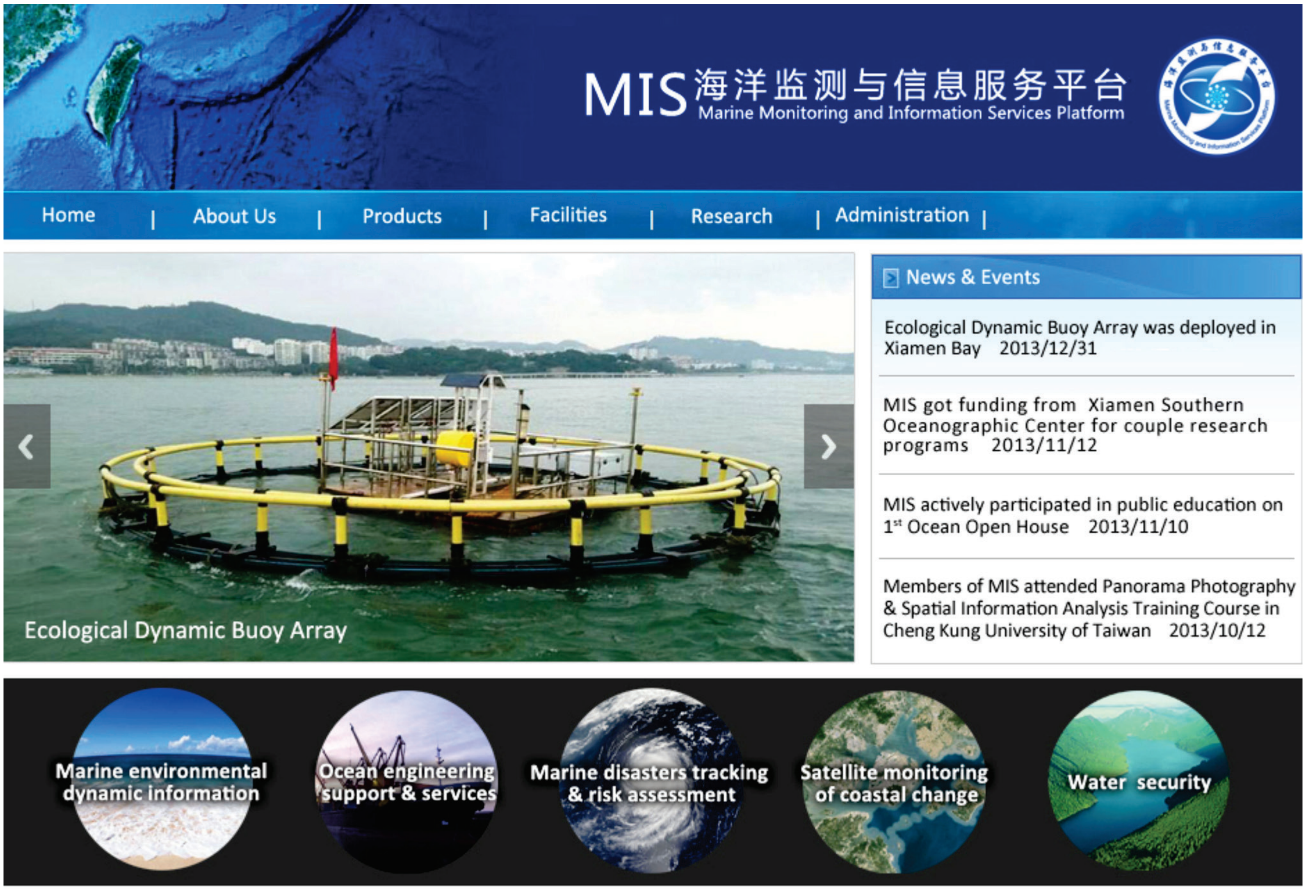
A sustained and integrated environmental monitoring system acquires and disseminates data and information to serve policy, management, and other specific needs of many user groups (government agencies, industries, scientists, educators, NGOs, and the public). This can be achieved by linking in-situ observations to a system of data management and analysis that will generate timely information on the status of the environmental condition of a given area.

An integrated marine environmental monitoring system (IMEMS) was established by incorporating the routine sampling stations and buoys (YSI and LOBO) deployed by various concerned agencies in Xiamen Bay. An array of buoys with precise instruments was installed in the bay to enhance the monitoring capacity for obtaining multiple real-time in situ data covering meteorological, oceanographic, and ecological parameters (Figure 5).

In order to provide the high-quality data to ensure sustainable management of Xiamen's coastal areas, a Xiamen Marine Monitoring and Information Services Platform (MIS) was established with the joint efforts of the Southern Ocean Research Center of Xiamen University and the Xiamen Oceans and Fisheries Bureau. Through this platform, collaboration between scientists and managers was greatly enhanced with effective use of information arising from the monitoring devices, numerical models, remote sensing, and GIS applications technology.

With this platform, relevant information was readily utilized for supporting ocean engineering projects, disasters prevention, fishery management, pollution control, and habitat management, as well as for monitoring long-term coastal changes.

**Figure 5.** **The marine monitoring and information services platform (MIS).**




## Lessons Learned and Suggestions for Future Development

1. The MEG, since its formation nearly 20 years ago, has been generally recognized as a good consultative mechanism whereby scientific views and advice were seriously considered in policy and decisionmaking. It enabled continuous communication and working relationship among scientists, policymakers, and managers. It facilitated institutional collaboration among sectors resulting in increased local government support and ICM application (Xue and Hong, 2005; PEMSEA, 2006). Through MEG, applied and problem-oriented research were able to make positive contributions and provide relevant knowledge to coastal managers to respond more effectively to the changing environmental conditions. As such, effective utilization of such mechanism should be sustained.

2. Xiamen's experience in the utilization of scientific research results and innovative technologies (e.g., IEIA techniques, MFZ, GIS, numerical modeling, IMEMS, etc.) was a showcase on how science and technology could help to ensure environmental quality in the context of increasing development pressure and global climate change.

3. Like other coastal cities, Xiamen has to prepare itself to face the increasing impacts of climate

change, unsustainable economic development, and population growth. It is therefore critical to draw upon the collective wisdom, experiences, and human resources towards developing appropriate mitigating measures. Toward this end, coastal leaders might wish to make full use of the expertise of natural and social scientists as well as engineers in providing technical solutions and listen to their advice before making policy and management decisions. It might also be necessary for the scientific community to better understand the needs and responsibilities of the policy and decisionmakers and strive to provide appropriate technical advice or solutions that can be easily understood by them. Thus, there is this urgent need to increase local capacity in coastal governance and management (Hong and Xue, 2006). The efforts of PEMSEA to identify and mobilize key institutions involved in ICM into a Network of Learning Institutions for ICM Development might be worth greater attention and investment.

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