History, development and results of the interdisciplinary project conducted 1996-1999

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1.1 Background: IGBP, LOICZ and START

The International Council of Scientific Unions established the International Geosphere-Biosphere Programme (IGBP) in 1986 to focus on the study of global change in the earth system including the extent to which these changes are influenced by human activities. In 1992 START (the Global Change **S**ys**t**em for **A**nalysis, **R**esearch and **T**raining) was established to implement the IGBP programme, and to act as the executive body of IGBP. START has divided the global research community in six regions, one of them being Southeast Asia. The head office of START is located in Washington DC, USA. The regional offices of START, through their committees, maintain close contact with the key researchers in the field of global change. Both the head office and the regional offices of START are in close consultation with the IGBP core offices.

Also in 1992, the Land-Ocean Interactions in the Coastal Zone (LOICZ) project was approved as one of eight programme elements of the IGBP, with the goal of characterizing the role of coastal systems in modulating changes occurring at the land, air, sea interface. In particular, LOICZ was and is expected to determine and assess at regional and global scales:

- the nature of the dynamic interaction across coastal boundaries,
- how changes in various components of the earth system are affecting coastal zones and altering their role in global cycles;
- how future changes in these areas will be generated by the people and in turn affectthe sustainability of coastal resource use by the people. This in particular aims to provide a sound scientific basis for future integrated management of coastal areas on a sustainable basis.

LOICZ commenced operations in 1993 with the establishment of the International Project Office at the Netherlands Institute for Sea Research on Texel, and with support from the Dutch Government.

One major impulse for the design of the LOICZ operation came from the apparent lack of studies that integrate the socio-economic and biophysical dimensions of environmental changes in the coastal areas at the regional scale. To meet this challenge LOICZ, through an initiative of its first Executive Officer, Dr. John Pernetta, established in 1993 a collaboration with the Southeast Asia Regional Committee for START, SARCS, and the Netherlands Foundation for the Advancement of Tropical Research (WOTRO), to design and implement a holistic pilot project in Southeast Asia. SARCS at that time had developed four foci for its research agenda and its Focus 2 on "integration of natural-social science assessments of changes in coastal zones of the SARCS region" fitted very well in LOICZ Focus 4 on the "economic and social impacts of global change in coastal systems". They both provided the research context for the new regional project, which from this time onwards carried the acronym SWOL (**S**ARCS/**WO**TRO/**L**OICZ)

WOTRO's mandate to promote tropical research and its considerable experience in Southeast Asia made it the logical sponsor for this initiative. It was envisioned that the project would serve as a model for the development of scientifically integrated projects in other regions, and that the data generated would contribute to the further development of a global typology of coastal systems and change scenarios. Dr Renée van Kessel, Secretary of the Board of WOTRO, and Dr Beverly Goh, then a Project Officer of SARCS, worked with Dr Pernetta to formulate the framework and to map out the process of planning and implementing the regional project.

1.2 SWOL: Team Composition and Research Methods

To have a reasonable regional coverage of typical coastal system with a potential to later upscaling, appropriate research sites and teams had to be identified. It was a critical requirement that the teams had already been involved in medium- to long-term studies of coastal ecosystems in Southeast Asia. During a general regional workshop held in Jakarta in May 1994, and a SARCS meeting in Singapore in August 1994, the major research topics and four research institutions were identified:

- the University Sains Malaysia Centre for Marine and Coastal Studies,
- the University of the Philippines Marine Science Institute,
- the Chulalongkorn University Marine Science Department, and
- the Vietnam National University Centre for Natural Resources and Environment Studies.

The core research sites (Figure 1) were the Sungai Merbok mangrove system (Malaysia), Lingayen Gulf with an extensive reef system (Philippines), Bandon Bay, mangrove-dominated (Thailand), and the Red River Delta, mangrove-dominated (Vietnam). All groups had at least ten years of research experience in their study sites. Each team was composed of natural and social scientists (mostly economists). The principal investigators included Prof. Ong Jin-Eong (Malaysia), Dr. Liana Talaue-McManus (Philippines), Dr. Gullaya Wattayakorn (Thailand) and Dr Nguyen Hoang Tri (Vietnam).

Hence the SARCS/WOTRO/LOICZ (SWOL) Regional LOICZ core project in Southeast Asia was born and Phase 1 began with meetings in Manila, Philippines, in April 1995 and Penang, Malaysia, in December 1995. The goal was to determine and standardize the methods the project would use across the study areas. Resource persons from the LOICZ Scientific Steering Committee (SSC) included the then SSC Chair Prof. Edgardo D. Gomez and SSC members, Prof. Stephen Smith, Prof. Fred Wulff, Dr Donald Gordon and Dr Jahara Yahaya. The latter meeting was in fact critical for the development of a corporate design of the four studies. It was decided to adopt the LOICZ Biogeochemical Modelling Guidelines (finally published the following year by Gordon *et al.* 1996) as a first approach in formulating stoichiometrically linked water-salt-nutrient budgets at the sites. For validation of this mass-balance approach other models could be employed.

During the meeting in Penang, the country teams further discussed possible approaches for doing the economic assessments and linking these with the biogeochemical models. Not surprisingly, the search for integrated modelling that would link economics with biogeochemistry (one of LOICZ's most challenging targets) was less straightforward. Consequently the SWOL regional project became a major partner in the efforts of LOICZ to evaluate and standardize the various possible approaches useful in the analyses of human influences on the functioning of the coastal ecosystems. SWOL researchers attended two LOICZ meetings that aimed to compile relevant principles and methods. The first meeting was held at the University of East Anglia (Norwich, England) in March 1997 with Prof. Kerry Turner, then the LOICZ SSC Focus 4 leader, as the main organizer. A follow-up workshop was convened in Kuala Lumpur, Malaysia in July of the same year. Conceptual modelling frameworks were presented in the latter meeting and a publication, focusing on principles and practices on integrated modelling, was released the following year (Turner *et al.* 1998).

In December 1997, during the third annual meeting of country teams in Bolinao, Philippines, the research partners agreed to use the economic Input-Output modelling tool as a method to quantify the impact of economic activities on the coastal zone. Specifically, the model allowed for the estimation of C, N and P residuals generated by economic activities. These estimates could be compared with empirical measures of ambient nutrient concentrations to determine the contribution of wastewater generated by economic activities to the ambient nutrient load as first approximations.

Among the technical resource persons who have interacted with the SWOL research team are Prof. Stephen Smith and Dr Bradley Opdyke for the LOICZ Biogeochemical Modelling Guidelines and Dr Jean Luc de Kok for approaches in dynamic modelling. In the field of economics, Dr Neil Adger and Prof. Jahara Yahaya facilitated discussions on integrated modelling approaches.

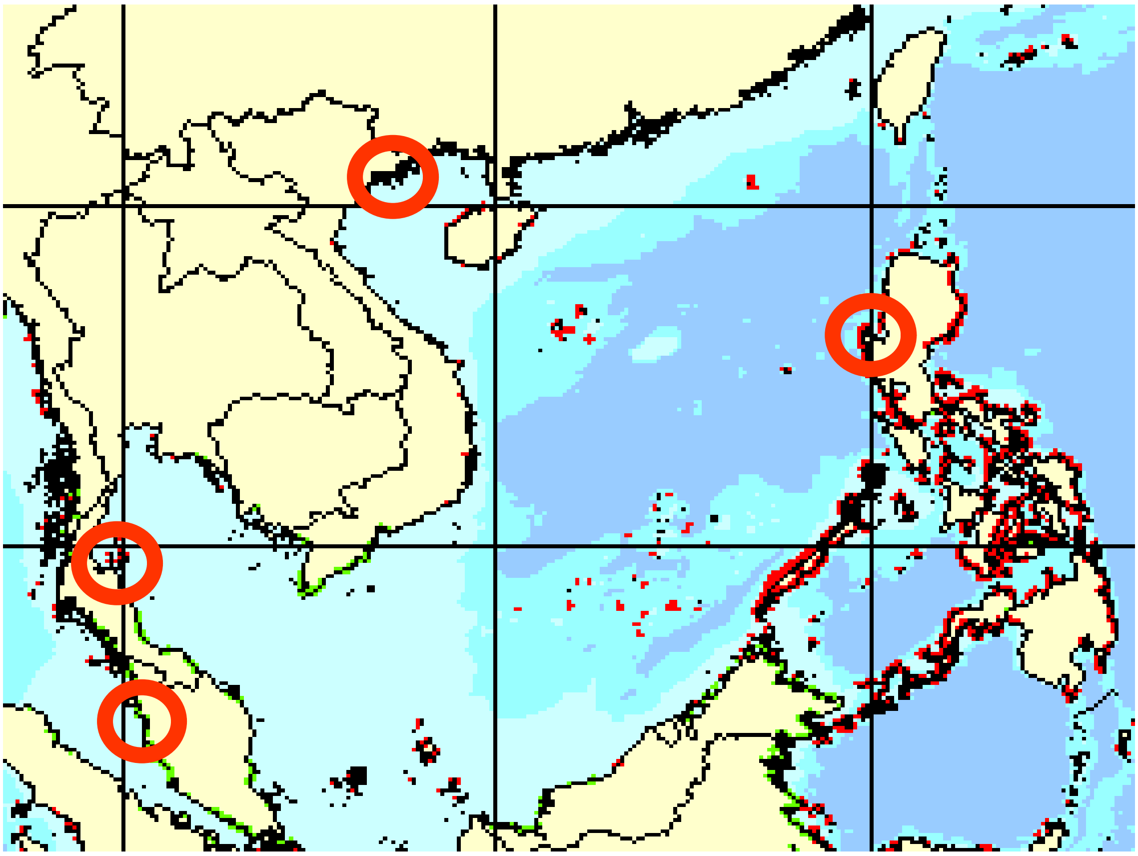

Figure 1: Study sites for the project.

1.3 Project Structure and Management

As the methods and approaches for integrative modelling were evolving, so did the manner through which the scientific work in SWOL was coordinated. With the overall mandate of describing the biophysical system using biogeochemical parameters (fluxes of nutrients and suspended solids) and of analyzing waste load derived from economic activities, each country team was autonomous in implementing its individual programme, with field work campaigns being one of the major components of the research. Annual regional project meetings were the main venue for discussion of both scientific and administrative concerns with the scientific resource persons and with those who provided the administrative support from the three partner institutions. Following the Penang meeting in 1995, the second annual meeting was held in Hanoi, Vietnam, in 1996 to discuss project coordination as well as modelling approaches that would allow the research team a first upscaling of site-specific results and obtain a scenario of coastal change for Southeast Asia. The 1997 annual meeting was held in Bolinao, Philippines, and the fourth in 1998 in Surat Thani, Thailand. Where appropriate, SWOL meetings were held in conjunction with international fora such as the 3rd LOICZ Open Science Meeting in Noordwijkerhout, the Netherlands in October 1997, and the 4th LOICZ Open Science Meeting in Bahia Blanca, Argentina, in November 1999. These meetings provided the SWOL team members and the challenging methodology involved in this project with global scientific exposure and were explicitly supported by the funding agencies as a means of capacity building.

In the 1997 annual meeting in Bolinao, it was agreed that the principal investigators would rotate in their various functions. Their task was to coordinate the science, represent the SWOL project in international meetings as well as to liaise with the research partners in accessing both scientific and logistical support. For 1998, Prof. Ong Jin Eon and Dr. Gullaya Wattayakorn served as project coordinators. In 1999, Dr. Liana Talaue-McManus and Dr. Nguyen Hoang Tri took over.

For project monitoring, annual reports were submitted to LOICZ, WOTRO and SARCS. WOTRO reviewed the annual reports using its network of scientists as a source of reviewers. For fiscal monitoring, semi-annual financial reports were provided to WOTRO and were used as bases for the annual release of funds. Dr. Renée van Kessel was the major resource and contact person from WOTRO. Drs Amador Argete and Tolentino Moya served as liaison and resource persons during their stint as Program Officers with SARCS. At the LOICZ International Project Office Dr. John Pernetta and Mr Paul Boudreau were the initial contacts, succeeded by Dr. Hartwig Kremer in 1998, who together with Dr Liana Talaue-McManus saw the project through to completion of Phase 1 and prospective transition towards a second phase.

1.4 Project Accomplishments

In implementing both the biogeochemical budget protocols and the input-output economic modelling, the country teams had to consider the applicability of these approaches given the spatial scale and geomorphology of their respective study areas. In addition, the data requirements of the models were reconciled with information that was available and useful. In most cases, primary data were generated to fill in the gaps. However, in looking at the results awareness of the inherent differences among the study areas was necessary, in terms of both the biophysical and socioeconomic aspects. The overall objective was to capture the diversity of biogeochemical scenarios in the Southeast Asian region and the overriding influences of human activities.

Table 1 shows an overview of the major accomplishments of SWOL-Phase 1. All research partners have developed C, N and P budgets for the four study sites. In the cases of Bandon Bay and Lingayen Gulf, the morphology of these embayments allowed for the identification of distinctive landward and seaward boundaries and was most amenable to budget modelling. Both systems are nitrogen sinks with nitrogen fixation exceeding denitrification, and net autotrophic at 5.4 moles m^{-2} yr^{-1} for Bandon Bay and 6.0 moles m^{-2} yr^{-1} for Lingayen Gulf. For the Merbok mangrove system and the Red River Delta, the difficulties involved in defining the spatial boundaries and in determining the water budgets within artificially defined spatial domains indicated the limited applicability of the budget modelling approach to these sites. The spatial boundaries may need to be redrawn to better meet the model requirements, e.g., at scales where salinity gradients would be significant for defining the seaward limits of the study areas.

The computation of an economic input-output table enabled preliminary assessments of wastewater generation by economic activities. The household sector, when endogenized in the economic modelling, was seen to contribute 15% to waste carbon generation in the watershed of Bandon Bay, and 18% to that of Lingayen Gulf. The natural resources sectors (agriculture, fishery, forestry and mining) together accounted for 74% and 92% of total residual carbon production in the Red River Delta and Merbok Mangrove system, respectively. These sectors produced carbon waste in the order of 23% of the total residual carbon production around Bandon Bay and 38% of the total in Lingayen Gulf.

A number of case studies and scenario simulations were produced by integrating economic parameters in the analyses of coastal resource use (see final country reports for details). For the Merbok system, an optimization model of mangrove timber extraction was developed. A valuation of carbon flows in a mangrove system and the latter's role in oyster production was assessed for the Bandon Bay study. In the Red River Delta, nitrogen loading was partitioned among economic sectors. For Lingayen Gulf, the contributions of economic activities in current and prospective scenarios were estimated.

1.5 Impacts of and Future Directions for the SWOL Approach

Having adopted a pioneering framework that integrates the natural and social sciences, the SWOL project has been adapted as a model for global change research at the regional scale. SWOL scientists have helped and continue to assist in training, capacity building and workshops on biogeochemical budgeting and socio-economic modelling and on analyses of human impacts in the coastal zone for other regions including South Asia and the Caribbean. In a thematic session of the 4^{th} LOICZ Open Science Meeting, in November 1999, other studies following the SWOL approach were identified as potential demonstration sites for the coastal module of the Global Ocean Observing System (C-GOOS), an initiative of the International Oceanographic Commission (IOC) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). In Southeast Asia, prospective interactions between the SWOL project and the recently approved South China Sea Project of the United Nations Environment Programme under the sponsorship of the Global Environment Facility and other regional projects are expected to continue.

A second phase of the project, consisting of two components, has been proposed. One component comprises continued process-oriented studies that would validate the empirical models developed in the first phase for sites along gradients of socio-economic pressures such as population and extent of urbanization. The second component would deal with a typology of the Southeast Asian coastal zones, taking into account both their biophysical and socioeconomic features. The typology approach is under continuous development by LOICZ as a major tool in upscaling site-specific estimates to regional and global assessments of biogeochemical fluxes and coastal change. Its capacity is to identify and visualize similarities and differences of coastal systems considering various sets of forcing functions with primary and secondary data. This part of a tentative SWOL II complemented by the site based scenario simulations in SWOL would provide not only a comprehensive Southeast Asian picture but also a better understanding of systems interactions with special significance for coastal management on various scales.

In conclusion, the development of analytical methods for integrating the human and natural dimensions of processes and forcing functions affecting the coastal zone in the study of global environmental change has been most challenging. The results obtained and insights gleaned through the SWOL project indicate the need for refining tools that would allow for the prediction of coastal ecosystem state changes and the formulation of appropriate management measures to ensure that these systems continue to function optimally in the long term. One strength of the approach used is that the determination of pressures and calculation of residual fluxes affecting the coastal zone applies the catchment scale as the integral part of the water cascade. Along with the growth and continuous development of global change science, the infrastructure needed to support and nurture international scientific collaboration has to evolve from that seeded by the committed partnership between WOTRO, LOICZ and SARCS.

Table 1. Summary of results obtained in SWOL – 1996-1999.

Results	Merbok mangrove system, Malaysia	Lingayen Gulf, Philippines	Bandon Bay, Thailand	Red River Delta, Vietnam
1. Biogeo-chemical budgets and processes	Budgets for inorganic and organic N and P in the Merbok system over tidal cycles formulated using LOICZ, mixing diagram, and mouth cross-section computation methods	Multiple-box model of inorganic N and P for dry season and annualized one-box models developed for Lingayen Gulf using LOICZ methods, including the influence of groundwater. Assessment of carbon production and support for fisheries using empirical measurements and ECOPATH.	Seasonal one- & two-box models developed for Ban don Bay using LOICZ methods; Mixing diagrams used for Tapi River during estuarine mixing in dry and wet seasons. Mouth cross-section method used to determine discharge over each tidal cycle. Primary production, fishery production, trophic relationships	Monthly and annual balance of water and salt were obtained using STELLA 2. Budgets of C, N & P were developed.
2. Socio-economic studies and integrated modelling	An 11- and 3-sector IO model (forestry, fisheries and agriculture). Identification of 5 approaches to integrated modelling (SWOL Meeting, 1998). An ecologic-economic model for optimal management of mangrove timber extraction.	A seagrass-based fishery model reflecting changes in seagrass cover and its impacts on fishery production. Estimates of economic residuals using WHO rapid assessment method and their contribution to ambient concentrations of DIN, DIP and suspended solids. A 12-sector IO (with household sector endogenized) model and comparisons of residual coefficients estimated through rapid assessment and those generated by the IO model.	Correlations between socio-economic characteristics and observed land use and cover change. An 11-sector IO model to obtain residuals. Valuation of carbon flows.	Modelling included the construction of IO model and estimating economic residuals, estimating GDP using 3 scenarios of economic growth by sectors, linking residuals with economic activities using STELLA, the WHO rapid assessment guidelines, and the National Monitoring Network for Environmental Assessment

Reference

Turner, R.K., Adger, W.N. and Lorenzoni, I. 1998 Towards integrated modelling and analysis in coastal zones: principles and practices. *LOICZ Reports and Studies* No. **11**, iv + 122 pages, LOICZ, Texel, The Netherlands.