Sustainable Utilization of Inland Water Resources: An Integrated Program for Research and Management

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In both developed and developing countries, there is increased competition for water resources, resulting in deficiencies in supply and in various forms of pollution. In developing countries, the nutritional potential of aquatic resources is very important. To realize this potential, integrated research and management for sustainable water resource use are needed.

Such a strategy is particularly important in the developing countries of Asia, because: inland water resources are expected to increase considerably over the next two decades via the construction of various types of man-made storages (Table 1); the inland fisheries sector contributes significantly to the total fish supply in most countries; and the major inland water resource, being artificial multiple-use reservoirs, is subject to far greater pressures by humans than is the situation elsewhere.

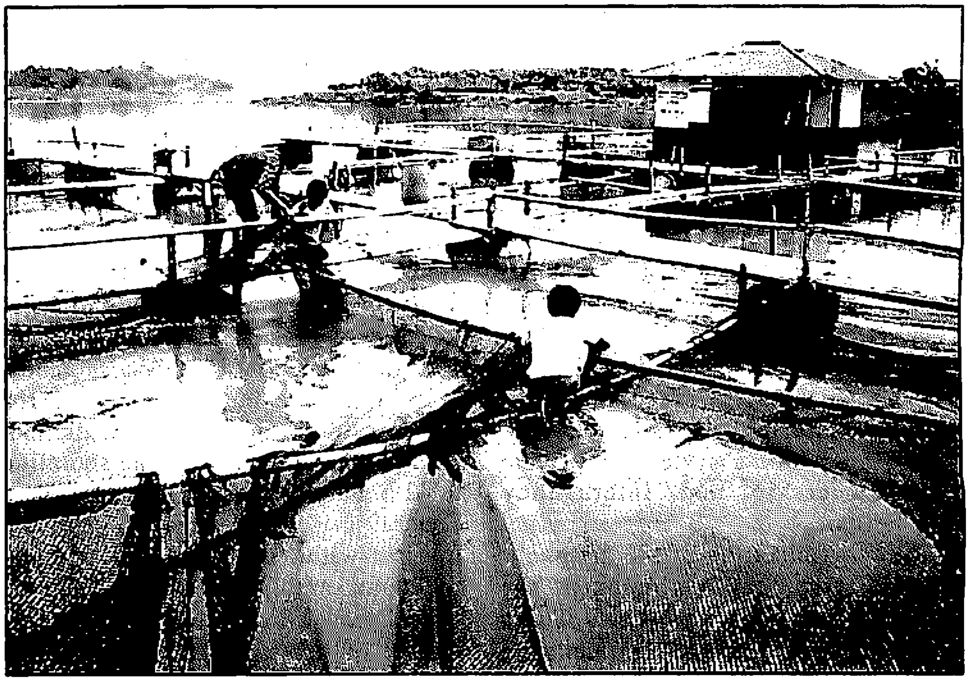
Use of Inland Waters

Over the years, the reliance on rivers in Asia for fish production has declined markedly. Presently, only a few viable fisheries exist in the major water river systems of the Indian subcontinent. Similarly, with the development and wide application of artificial propagation techniques for the major cultivable species, particularly the cyprinid species indigenous to IndoChina, reliance on river systems as a source for fry and fingerlings for farming has declined.

For geological reasons, the natural lake resource in Asia is not extensive. However, the reservoir resource is relatively large and, more importantly, it is increasing in most countries. Inland fish production in Asia has been steadily increasing over the last fifteen years and contributes over 55% to the world's inland fish production. Although the bulk of this production comes from reservoir fisheries, yields are far below optimal levels in some countries. In addition, the growth of human populations in Asia has had indirect influence on the productivity of inland water bodies, primarily by making them eutrophic in a short period of time.

Lack of Integration

The development of inland water resources in developing Asian countries has been characterized by a lack of interdisciplinary communication and research collaboration. This has resulted from the failure to link the various disciplines of limnology, hydrology, aquaculture, fisheries ecology and management, catchment management and pollution ecology into an integrated and overall program for the study and ultimate management of inland aquatic resources for sustainable use. This situation has been worsened by poor communication



Aquaculture potential being assessed in Saguling Reservoir, Indonesia. (Photos by B.A. Costa-Pierce)

Table 1. The extent of natural lakes and reservoir available in some Asian countries and the estimated current fish yields.

	Natural lakes		Reservoirs		
			Area (ha)		
Country	Area (ha)	Yield (kg/ha/year)	Current	Future	Current yield (kg/ha/year)
Bangladesh	4,268,740[1]	136	58,300	800,000	46
Burma	33,130	NA	80,000	1,500,000	NA
China	7,426,000	200-300	1,400,000	NA	75-1,265
India	720,000	NA	3,000,000	6,000,000	100-202
Indonesia	13,700,000	19	53,000	500,000	15-380
Kampuchea	1,000,000	NA	80,000	2,000,000	NA
Korea (Rep.)	53,000	NA	41,000	NA	NA
Laos	500,000[2]	NA	50,000	5,000,000	NA
Malaysia	2,093[3]	NA	92,038	150,000	NA
Nepal	5,000	NA	1,500	80,000	NA
Pakistan	0	0	15,000	NA	NA
Philippines	200,000	10-3,900	19,294	500,000	NA
Singapore	0	0	2,000	3,000	NA
Sri Lanka	0	0	139,214	250,000	72-1,345
Thailand	300,000	179	285,272	3,000,000	73
Vietnam	334,000	NA	60,000	1,500,000	NA

[1] Openwater capture fisheries area.
[2] Includes freshwater swamps.
[3] Very few natural lakes in peninsular Malaysia, nearly all from Sabah and Sarawak.
NA = Not available.
Source: Costa-Pierce, B.A. 1991. Small waterbodies for sustainable fisheries production. Naga, ICLARM Q. 14(1): 3-5.

between experts from western nations and workers in the developing countries.

The lack of interdisciplinary communication, as conceptualized in Fig. 1, provides a barrier to the integration of the outcomes of various research programs. This is an impediment to the development of management strategies for sustainable utilization. Problems that arise in the attempt to use resources on a sustainable basis stimulate research. Although this research may be initiated to solve a broad problem, by its very nature it tends to become fragmented into distinct disciplines such as, for example, physicochemical limnology, biological limnology, land use, fisheries assessment, hydrology and so on. The final outcomes of specialized research programs more often than not tend to be narrow and restrictive. Although it is possible to integrate such specialized outcomes to provide the basis for the development of management strategies, a holistic approach during the *design* of research programs is also necessary to facilitate subsequent integration. This integration frequently does not occur at either stage or, if it does, it is incomplete.

An integrated approach to inland water resource management is often promoted and simple, pictorial models in relation to the management of specific water resources have been proposed as, for example, in the case of integrated reservoir fisheries management in Indonesia (*Naga*, January 1987). However, most of these models tend to focus on the integration of production and utilization aspects but pay little attention to the integration of research into the development of the management strategies required to bring about effective, optimal utilization and sustainable development of the resource(s).

This problem is not unique to inland water resources; it characterizes attempts

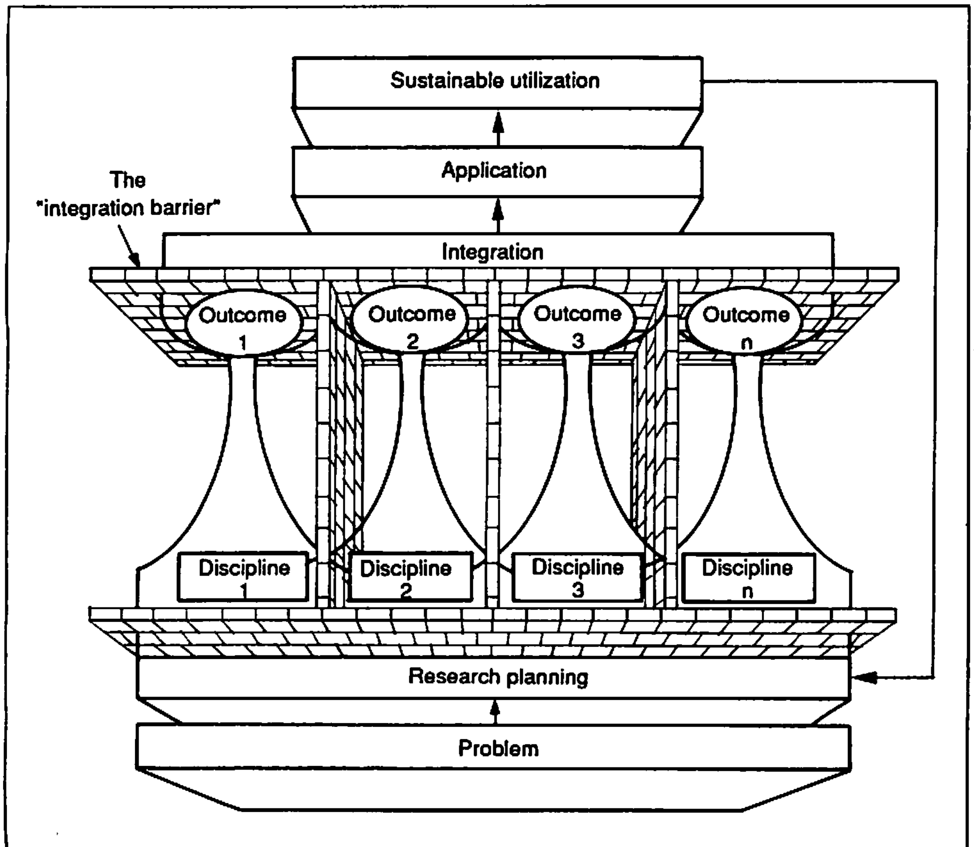


Fig. 1. ***Conceptualization of impediments to the integration of information in multidisciplinary studies. The "integration barrier", shown as a series of brick walls, operates at both the research planning and completion stages.***

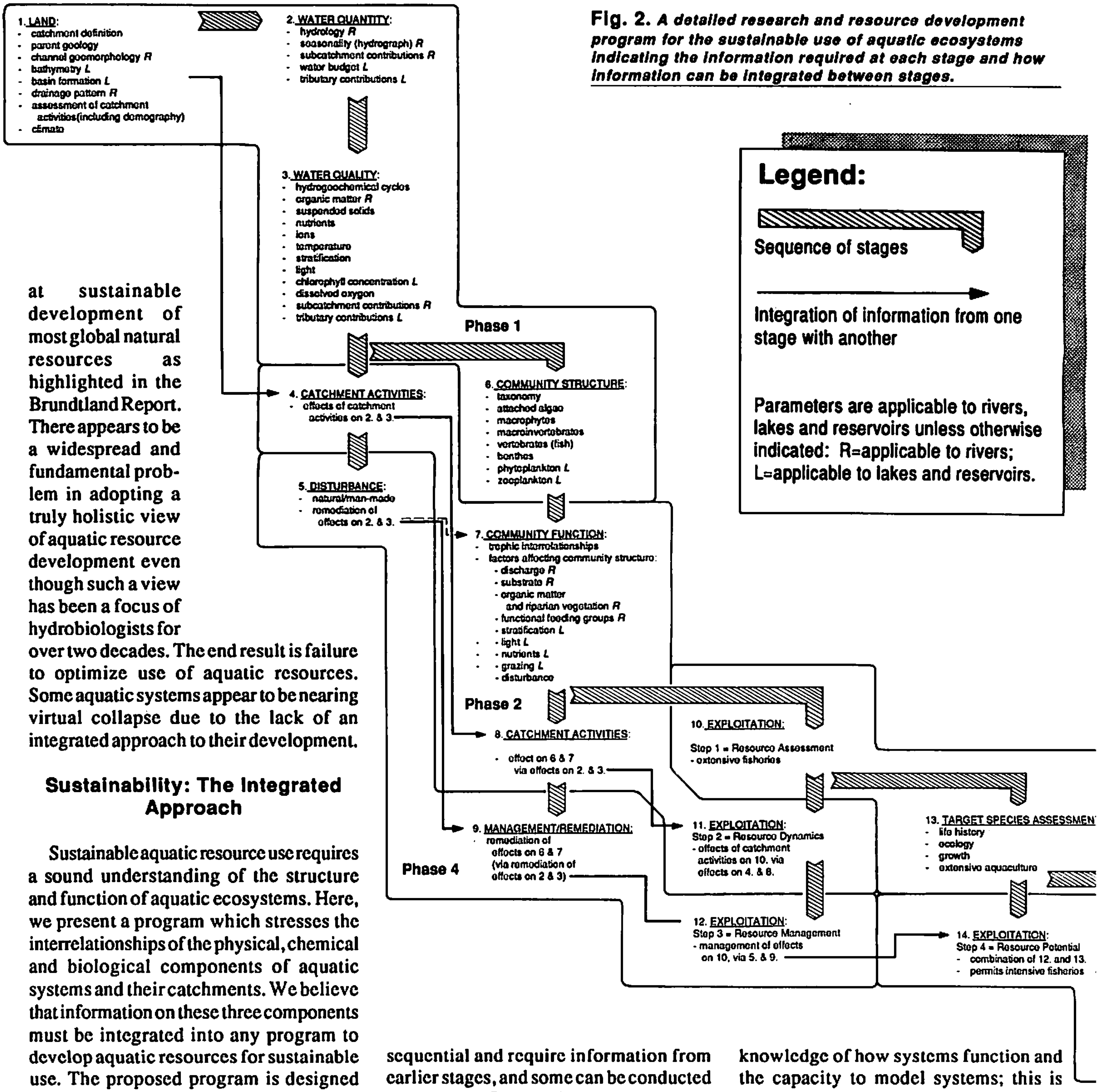


Fig. 2. ***A detailed research and resource development program for the sustainable use of aquatic ecosystems indicating the information required at each stage and how information can be integrated between stages.***

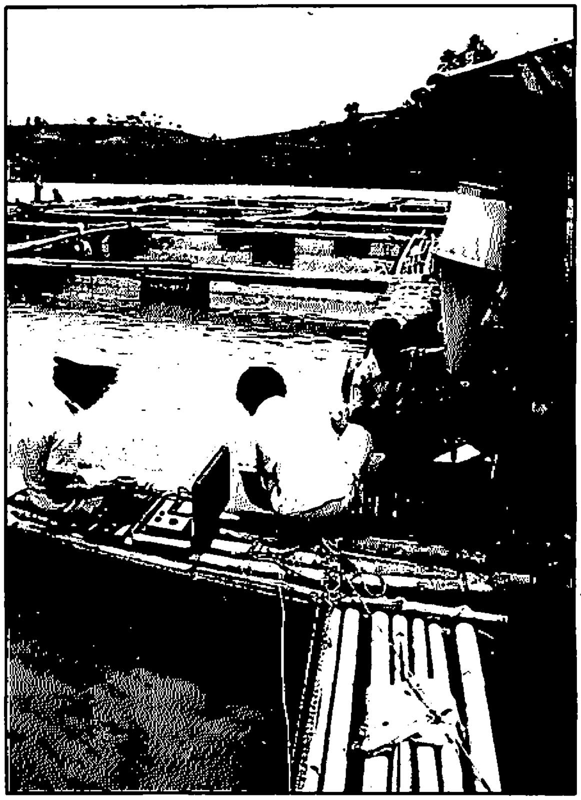
at sustainable development of most global natural resources as highlighted in the Brundtland Report. There appears to be a widespread and fundamental problem in adopting a truly holistic view of aquatic resource development even though such a view has been a focus of hydrobiologists for over two decades. The end result is failure to optimize use of aquatic resources. Some aquatic systems appear to be nearing virtual collapse due to the lack of an integrated approach to their development.

Sustainability: The Integrated Approach

Sustainable aquatic resource use requires a sound understanding of the structure and function of aquatic ecosystems. Here, we present a program which stresses the interrelationships of the physical, chemical and biological components of aquatic systems and their catchments. We believe that information on these three components must be integrated into any program to develop aquatic resources for sustainable use. The proposed program is designed to facilitate the accumulation and integration of this information. In our treatment, however, we have essentially restricted ourselves to the biophysical components of management which, in most situations, will have to be integrated into a broader socioeconomic framework.

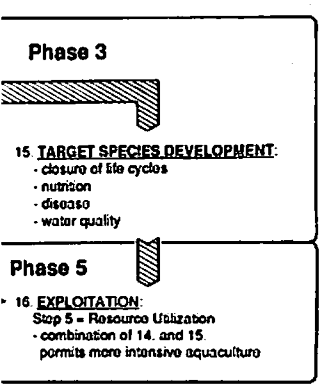
The program consists of 16 stages in 5 phases (see Fig. 2); some stages are sequential and require information from earlier stages, and some can be conducted concurrently. Phase 1 (System Description) is concerned with the description of the physical, chemical and biological attributes of systems. With this information, investigation of how systems function can be undertaken; that is, the factors which are important in controlling systems and in influencing the nature of systems can be determined. This results in knowledge of how systems function and the capacity to model systems; this is Phase 2 (System Function and Modelling). On completion of Phase 2 it should be possible to predict the extent to which systems can be loaded before major changes in the nature of those systems occur. Knowing the nature of systems (Phase 1) and the factors which influence the function of systems (Phase 2) leads to Phase 3.

Exploiting small pelagic fish in a Thai reservoir.



Limnological studies.

Phase 3 (Resource Assessment/ Dynamics) involves identifying components of the system that can be used (e.g., particular species such as fish) and studying, in detail, the factors which limit growth and production of those species. This enables an assessment of the extent of the resource and an understanding of the factors which influence the dynamics of the resource. This phase, which also focuses on interrelationships, puts the resource or target species into the context of the overall system. Having reached this point, and with an understanding of the effects of disturbance on physicochemical and biological components of the system derived from



Phase 4 (Resource Potential), the resource can be managed because decisions can be made to ameliorate the effects of disturbance. By the end of Phase 4, the ability to manage the resource for sustainable utilization has been developed and the resource is potentially exploitable. Management can then be combined with the assessment of the resource and an understanding of resource dynamics in Phase 5 (Resource Utilization for Sustainability) which provides the basis for appropriate sustainable use of the resource, such as through aquaculture activities.

The program enables workers within different disciplines to identify how their expertise contributes to the overall research requirements to support resource development. It also indicates how workers can combine their expertise with that from other disciplines.

The two major features of this program are:

- Phases may overlap to some degree and some parts of different phases may be conducted simultaneously. However, the later phases of resource management and utilization are dependent upon the earlier phases of system description and function, and resource assessment. Exploitation of aquatic resources, as in the later stages of the program, without the knowledge derived form the intermediate stages, is unlikely to be sustainable.
- The program requires an integrated multidisciplinary approach. Effective and efficient execution of the program requires the combination of expertise from many disciplines and cooperative studies within and between institutions. The disciplines that must be involved to conduct the program successfully include geology, geography, remote sensing, climatology, hydrology, physical-chemical-, and biological-limnology, aquatic pollution ecology, catchment management, and aquaculture research and development.

The program may be executed in several ways. One way is to adopt a catchment approach; that is, to have coordinated multidisciplinary teams working on one or more stages of the program for each of one or more catchments. A team could be truly interdisciplinary and focus on all aspects of a single catchment; an alternative is to have several specialist teams each investigating a particular aspect of several catchments at one time. The output from all teams would then need to be integrated according to the broad overview of the entire project that is provided by our proposed program.

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