WATER, LIFE AND MAN

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by

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"WATER, LIFE AND MAN" are distinct and yet interrelated phenomena which I wish to discuss this evening. I have chosen this title as representative of the umbrella encompassing my research and academic interests and endeavours; and as the umbrella of academic policies I envisage for the advancement of zoology in this University in particular, and in Malaysia and South East Asia in general. I will firstly elaborate on the interactions between water and life that preoccupy me as a zoologist, and secondly discuss the interrelationships between water, life and man that concern me as an ecologist and humanist besides that of a zoologist. What I have to say on "WATER, LIFE AND MAN" has been crystallized by the poet, William Wordsworth in the following lines:

"There was a time when meadow, grove and stream,
The earth, and every common sight,
To me did seem apparelled in celestial light,
The glory and the freshness of a dream.

It is not now as it hath been of yore –
Turn wheresoever I may
By night or day,
The things which I have seen I now can see no more"

– *William Wordsworth.*

Water

Water is the most important fluid on Earth. It is a neutral liquid with supreme solvent properties, large heat capacity, high surface tension, and an anomalous behaviour. Water is a necessary condition for organic life forming 60–70% of most organisms. It is therefore essential for sustaining human life. However, in spite of its importance, only 5% of water is in a free state and cycles on Earth, while 95% is chemically bound in rocks (Clapham 1973):

		Amount ($\times 10^{17}$ kg)
(A)	*Chemically bound in rocks* (i.e. does not cycle)	
(1)	Crystalline rocks	250,000
(2)	Sedimentary rocks	2,100
	Sub-total	252,100 (95%)
(B)	*Free water* (100%) (i.e. moves via hydrological cycle)	
(3)	Oceans (97.3%)	13,200
(4)	Icecaps & glaciers (2.1%)	292
(5)	Ground water 4,000 m. (0.6%)	83.5
(6)	Freshwater lakes (0.01%)	1.25
(7)	Saline lakes & inland seas (0.01%)	1.04
(8)	Soil moisture (0.005%)	0.67
(9)	Atmospheric water vapour (0.001%)	0.13
(10)	Rivers (0.0001%)	0.013
	Sub-total	13,578.603 (15%)
	Total	265,678.603

Of the 5% free water, 97.3% occurs in a saline form in the oceans, whereas 2.7% occurs in a fresh form on land. Of the total fresh water, 77.1% occurs as ice-sheet and glaciers, 22.1% as ground water, 0.3% as freshwater in lakes, 0.3% as water in saline lakes and inland seas, 0.2% as soil moisture, 0.03% as atmospheric water vapour and 0.003% as water in rivers.

In view of its low stock in the atmosphere in relation to annual precipitation on Earth, fresh water cycles very rapidly through the biosphere at the rate of at least 32 times/year, or at the most 11.4 days/cycle. This rapid cycling is enhanced by the uneven nature of precipitation over land, which is maximum near the equator. This cycling is possible through three pathways of fresh water transfer: (1) evapotranspiration constituting about 70% of the flow, (2) surface runoff about 27% of the flow, and (3) ground water constituting about 3% of the flow.

Transpiration by plants is related to the mechanism of nutrient uptake by the roots, and forms at least 50% of evapotranspiration. It is higher in aquatic plants such as rice which are important in freshwater swamps. Surface runoff is counterbalanced by differential rates of evaporation and precipitation over land and sea, with more evaporation occurring over the sea and more precipitation over the land, and by the movement of water-bearing clouds from sea to the land. It also facilitates erosion and the movement of nutrients downstream. The latter is counterbalanced by weathering processes in a biogeochemical cycle. Ground water flows are extremely variable, being usually slow and resulting in water storage. Its storage capcity is 60 times that of freshwater lakes.

In view of these three pathways, water retention on land varies from 10-to 100 days, exceeding 100 days only in the case of ground water flows. The natural flow of water through these pathways is a very important natural resource. My interest has focussed particularly on surface runoff by rivers and swamps in South East Asia, which is dependent on the nature of evapotranspiration and ground water flows on the one hand, and on the nature of monsoonal winds and thermal instability governing rainfall, on the other. On the basis of these forces, at least three and up to five hydrological regions can be distinguished in Peninsular Malaysia (Chia 1974; Dale 1959; Stewart 1930; Wycherley 1967). The drainage basins in these regions are characterised by two peak, one-peak or continuous flows per year on the basis of different monsoonal and/or intermonsoonal impacts.

Streams, swamps and rivers form the main drainage system of tropical South East Asia. Except for some volcanic lakes of limited drainage area, there are no natural lakes of major importance to the drainage of this region. There are however some sunken river basins, with the characteristics of both lakes and rivers, such as the great Lake or Tonle Sap in Kampuchea. The drainage system in this tropical region is similar to others on this planet, in that streams and rivers are connected to swamps and flood plains, and that the system is adapted for floods or peak flows. They differ at least in one respect, however, in that the swamps and flood plains in this region have been transformed largely for wet rice cultivation.

The drainage waters of tropical South East Asia are intimately connected to their landscape on a catchment basis, and are dependent on the vegetation, lithology and pedology of the river basin for their nutrient and organic inflows. They are generally acidic, poorly oxygenated, low in biological and chemical oxygen demand, low in suspended solids except during thunderstorms and heavy rains, rich in silicates, and poor in nutrients especially sulphates, calcium and magnesium, because of low nutrient inflows from the landscape and slow mineralization of decomposing organic matter (Johnson 1967a and 1973; Bishop 1971 and 1973; Ho and Furtado 1974; Lim 1974; Cheng 1977; Kobayashi 1959; Mizuno and Mori 1970). These waters may be clear or black in colour depending on the nature of the soils, with the black (or "ayer hitam") colour due to podsols or peat soils. These waters are thus similar to those of other tropical drainage basins (Sioli 1975a & b; Fittkau, Irmler, Junk, Reiss and Schmidt 1975). Nevertheless, very few drainage waters have been studied (e.g. Sungei Gombak, Sungei Langat, Sungei Renggam and some streams in South Malaysia) for a comprehensive understanding of their dynamics in tropical South East Asia, leaving much scope for critically needed research.

In forested water catchments interflows are more important than surface runoff in contributing water, organic matter and nutrients to the drainage system, with a contribution of about 80% (Gounaratnam 1974; Manokaran 1974; Sandhu 1978). This denudation is fairly stable. However, when the forests are manipulated for economic production, surface runoff is the dominant source of these materials with a contribution of about 50%, because of lower rainfall interception by the vegetation. These manipulations critically interrupt the different rates of material cycling for essential nutrients such as nitrogen, phosphorus, potassium and calcium (Golley, McGinnis, Clements, Child and Duever

1975) resulting in changes to the structure and function of both the land and drainage system. It results not only in enrichment of the drainage system with nutrients and organic matter (Ho 1973; Bishop 1971 and 1973) but also in enhancing floods, soil erosion, sediment load and turbidity (Pereira 1962; Ho 1973; Leigh and Low 1973; Low 1972; Leigh 1974; Gunaratnam 1974; Sandhu 1978). It has been estimated that suspended sediment load in the drainage system increases by at least one order of magnitude, from 50–100 tons/sq. mile/year to 300–1000 tons/sq. mile/year, when land is transformed from forest to agriculture (Gunaratnam 1974). The intensity of soil erosion and suspended sediment load depend on the pedology, nature of the storm and slope of the land (Leigh 1974; Leigh and Low 1973). Enrichment of the drainage system, flooding, soil erosion, sediment load and turbidity may be regulated in various ways (Leigh and Low 1973), especially by the use of perennial tree plantation crops (Swank and Douglas 1974) and by increasing the density of trees (Teoh 1974). The landscape vegetation in gross units (i.e. forests, agricultural plantations, and urban areas) is related to water quantity and quality in the drainage system (Sandhu 1978; Sandhu, Gunaratnam & Furtado, in press). However, there is a need to define these relationships in terms of specific plant communities for predictive purposes, using modelling technique.

Although organic matter transfer from the landscape to the drainage system determines the structure and function of rivers, there are no previous studies in tropical South East Asia on the decomposition and fate of this matter, and mineralization processes in the system (Verghese 1975; Verghese and Furtado, in press).

Life and Water

Life is a very special phenomenon. It is a behavioural pattern which matter exhibits when it reaches certain levels of organization and complexity. Living organisms first appeared in the deeper waters of tropical seas about 3.5 billion years ago, where they were protected against the effects of radiation. These early life forms were essentially heterotrophic, dependent on high energy compounds for food. As the availability of these compounds became limiting, there appeared autotrophic life forms in the sea with the capacity for photosynthesis. The appearance of these autotrophs (i.e. plants) facilitated the evolution of consumer heterotrophic organisms (i.e. animals). Furthermore, the evolution of oxygen as a by-product of photosynthesis resulted in the formation of the Ozone layer which shields this Earth from ultra-violet radiation. This radiation shield facilitated the colonization of shallow waters in the seas by both plants and animals, and subsequently the colonization of land.

In this process of evolution, most species have been doomed to loose, to be defeated and to become extinct because evolution itself is an ultimate existential game of groups and populations, in which nature is both the opponent and umpire selecting winners by rules that change unpredictably. Victory is thus a meagre privilege of staying for another round. The species on this planet today are thus only a small group of temporary winners. This process of progressive evolution resulted in the appearance of complex ecological systems in the tropics, and in the appearance of man on land about 3 million years ago. Man is presently the dominant species on this Earth.

Today, the marine environment accounts for 34% of the productivity of the biosphere, while the continental environment inclusive of freshwater systems 66%; and the continental environment accounts for 99.8% of the biomass with the tropical forests predominating (Whittaker and Likens 1973). Freshwater systems particularly rivers and swamps, contribute less than 5% to the continental biological productivity.

The net primary production of tropical drainage systems is low, being of the order of 10–34 grams of carbon/square metre/year in flowing waters (Ho and Furtado 1974; Lim and Furtado 1974; Likens 1973) due to swamp and riparian vegetation cover and to the abundance of allochthonous organic matter. However, inundated swamps with emergent vegetation have a net primary production of 3–8 tons/hectare/year (Ikusima 1974). As a consequence, the drainage waters are essentially heterotrophic below these macrophytes with the detritivore – decomposer food chains predominating. There is an abundance of aquatic insects, detritivorous fish, desmids and other organisms in these drainage systems (Ho and Furtado 1974; Johnson 1973). Several groups of aquatic insects and freshwater fishes have their centre of origin in tropical South East Asia, which is perhaps the only region with a long continuous history of tropical climates. By and large, however these taxa of organisms are poorly known, leaving much want for basic taxonomic studies which are critical for ecological and physiological work, and which are difficult because of intense speciation in this region.

When forests in river basins are manipulated for economic production, the exposure and enrichment of the drainage waters results in a change in their trophic dynamics from heterotrophy to autotrophy. The decomposer – detritivore food chain is disrupted resulting in the impairment of the capacity of the drainage system to process organic wastes, thus causing pollution (Vallentyne 1972, FAO 1969, Vollenweider 1968, WHO 1969). This capacity of the drainage system may also be impaired by other forms of pollution such as from mining and industrial activities (Ho 1973; Cheng 1977; CAP 1976). There are still very few detailed studies on the impact of landscape perturbations on the trophic dynamics of drainage waters in tropical South East Asia.

The drainage waters in tropical South East Asia are colonised by flora and fauna of both terrestrial and aquatic origin (Hynes 1970). By and large, the biology and ecology of these life forms is poorly understood. Nevertheless, these organisms may serve as good indicators of the health or trophic capacity of the drainage systems. In Malaysia, dominant plants (Corner 1940), plant species associations (Merton 1962), fish species associations (Tweedie 1961; Ali 1978; Johnson 1967b) and odonate species associations (Furtado 1969) have been used to classify different drainage water types. Mosquito species associations have been used to typify small containers (Hodgkin 1945; Colless 1956). Studies are in progress to examine the utility of other taxonomic groups of organisms such as mayflies (Lee Yoke Shum, per. comm.) and freshwater fish parasites (Lim and Furtado, in press). The constraints to such studies are taxonomic and physiological. A good indicator species must be integrative of the environmental conditions in an ecosystem, particularly the aquatic system. For example, the interrelationship of some Malaysian drainage waters is demonstrated by odonates which are the dominant predators among invertebrates (Furtado 1969):

(A) *Piptospatha stream:*

Non-torrential	:	Sg. Kongsi Lapan	*Sundacypha petiolata*
			Echo modesta

Torrential	: Sg. Rumput	*Devadatta a. argyoides*
	Sg. Temson	*Euphaea o. ochracea*
		Rhinocypha fenestrella
		Coeliccia albicauda
		Calicnemia chaseni
		Indocnemis orang

(B) *Saraca Stream:*

Upper	: Sg. Gombak trib	*Euphaea o. ochracea*
	Sg. Ampang	*Rhinocypha perforata limbata Zygonyx iris malayana*
Middle	: Sg. Gombak	*Megalogomphus sumatranus*
	Sg. Tanglir	*Neurobasis c. chinensis*
		Gomphidia a. abbotti
		Onychothemis coccineaor O. culminicola

(C) *Saraca stream:*

Lower	Sg. Klang	*Copera marginipes*
	Sg. Chongkok	*Ictinogomphus decoratus melaenops*
		Onychothemis t. testacea
		Libellago l. lineata

Open hill-country ponded stream:

Ampang Reservoir	*Ictinogomphus decoratus melaenops*
Sg. Klang (ponded)	*Nannophya pygmaea*

(D) *Open lowland stream:* (Neram river)

Sg. Pelampas	*Macromia cincta*
	Libellago l. lineata

(E) *Blackwater & forested lowland stream:*

Sg. Lumut	*Prodasineura interrupta*
Sg. Bukit Cherakak	*Libellago aurantiaca*
	Elattaneura analis
	Euphaea impar

Forested hill-country ponded stream:

Sg. Kongsi Lapan (ponded)	*Copera v. vittata*
	Tyriobapta toorida

(F) *Lowland Ponded Streams:*

Mining pool/Fish pond	) Lacking unique species
Sg. pelumut (ponded)	)
Pandanus swamp	*Pseudagrion coomansi*
Sg. Ayer Hitam (ponded)	*Chalybeothemis fluviatilis*
	Rhyothemis obsolescus

There are several points that emerge from this analysis:

(1) Of the 77 species of odonates used in this classification of water systems, only some were of indicator value because of their unique and localised ecological and behavioural relationships to the water. Several species more could not be utilised in this analysis because of inadequate knowledge of their taxonomy, life-history and/or behaviour.

(2) The ponding of a drainage water does not change its relationship to the running water very significantly, because many species inhabiting the pool regions of streams are able to colonise and adapt to the impoundment.

(3) Under (E) there is an artificial relationship between blackwater forested lowland streams and a forested hill-country ponded-stream, due probably to the abundance of common species with wide ecological ranges.

(4) Similarly, under (F), there is an artificial relationship between lowland ponded – streams related to the Neram rivers and lowland Pandanus (Rassau) swamp and blackwater stream related to the Rassau rivers.

(5) In the association analysis utilised, all species have equal weightage contributing thereby to these anomalous relationships between water bodies. There is a need therefore to develop methodologies in which certain species, such as rarer species, may be given greater importance value because of their vital nature to the dynamics of the ecological system.

(6) There is a need to verify such association analysis with others, and with further biological particularly eco-physiological work.

Similarly, algal and acquatic plants (Arumugam 1976; Arumugam and Furtado, in press) and fishes (Yap 1978) have been used to characterise different stages in the eutrophication and recovery of a reservoir.

Besides aquatic organisms, certain terrestrial organisms may be used as indicators of the land-water interactions, especially organisms with a symbiotic organic relationship such as arboreal animals and primates, ant-plants, amphibians and mammals, insect pollinators (Appanah 1979), and soil fauna (Leow 1975). However, in most cases, the taxonomic constraints prevail.

Water, Life and Man

Development or modernization is a continuous progressive process concerning the social evolution of man (Sauer 1971; Alatas 1972). The two critical constraints for this process becoming autonomous and indigenous are: (1) the rapid growth in scientific and technological capabilities of man to intervene in vital ecological processes, and (2) the lag in conceptual understanding of this socio-ecological transformation and of the psychosocial processes for managing change more effectively (McHale and Cordell 1974; Alatas 1971; Wilson 1971). The process of social transformation is the only problem common to both development and environmental conservation, and is rooted in a complex set of socio-cultural conditions in South East Asia (Furtado 1978). Emphasis on economic development is inducing rapid social changes and a variety of impacts on the trophic status of drainage waters:

(1) Effluent discharge of silt and toxic chemicals from mineral mining (Furtado 1978).

(2) Soil erosion and surface runoff from land clearance for timber logging, fuelwood extraction, shifting cultivation, or for increasing agricultural lands (Burgess 1971; Singh 1972).

(3) Nutrient and pesticide runoff from intensive agriculture especially wet ricefields (Farvar & Milton 1972).

(4) Organic effluents from agro-industrial activities, and organic and inorganic effluents from other industries (Ho 1973; Bishop 1971 and 1973).

(5) Impact of major engineering works such as highways, urban development, impoundments, and irrigation systems (Goodland and Irwin 1975; Ackermann, White and Worthington 1973).

Drainage water is thus affected by transportation or consumptive uses, more so by the latter, and by increasing scales of manipulation involving one, more than one or a continental system of river basins. Because of these multiple and often conflicting impacts such as Sungei Juru (CAP 1976) and forest catchments for watersupply, river basin authorities are urgently needed for managing effective water use and control, especially where none exist as in Malaysia.

It is evident from the foregoing that rivers are throughflow systems governed by higher units such as landscapes or biogeocoenoses (Sukachev 1964). They are analogous to the excretory system of the landscape, and thus are invaluable indicators of the development and conservation dynamics of the landscape. It is invaluable therefore to develop dynamic models, incorporating the concept of indicator species, for the estimation and prediction of water quality and quantity in relation to land use manipulation (Sandhu 1978; Whitehead and Young 1979).

Although Malaysia and several South East Asian nations possess a water surplus, already about 20% of runoff is used in various ways (Daniel and Cheong 1976) leaving only a margin of 10–15% for further development. These nations have thus reached a critical threshold where water is a decisive factor in economic development, especially because of high consumptive rates in agriculture (10,000 tons of water/ton of product) and industry (1,000 tons of water/ton of product). Indeed, as noted by E.A. Ackerman of the Carnegie Institute in 1959:

> "The critical factor governing the development of life lies in the availability of sources of water".

These critical signs need to be considered seriously if we are to avoid the same forces that caused the decline of ancient civilizations such as in Mesopotamia, Nile and the Indus Valley, all of which thrived on irrigation systems.

The threat to future development in tropical South East Asia may indeed be an apparent and not a real one, to misunderstanding of the harsh sociobiological conditions surrounding modernisation, the flexible strategies needed for contemporary social change, and the interdependencies for organic growth (Janzen 1973; Furtado 1978). The future prospect for development relies heavily on conservation of resources, research and education for management of resources, and on planning and strategies for the development of resources. Planning for successful modernisation is in turn dependent on (1) a continual focus on the issues pertaining to total human and social development, (2) a continual incorporation of ecological perspectives into socio-economic development plans, and (3) a continual refinement of land capability classifications and regional development plans with information from various branches of research, particularly impacts of resource and social development, and ecological guidelines for development (Dasmann, Milton and Freeman 1973).

Strategies for modernisation need to be flexible for effective development, incorporating ingredients such as (1) the maintenance of a dynamic and sustainable relationship between man and his environment; (2) the nurturing of healthy competition at all levels to discover unique ways of modernisation at low social costs and risks (3) the utilization of a stochastic rather than a deterministic approach for optimising social change; (4) the formation of somewhat autonomous, small-scale, viable human communities for long-term stability; and (5) the incorporation of ecological principles in economic and political decision-making, particularly ecological resilience indicators for managing the unknown in the future (Dasmann, Milton and Freeman 1973; Omo-Fadaka 1975; Watt, Molloy, Varshney, Weeks and Wirosardjono 1977; Jacobs 1977; Furtado 1978). It is in this context that ecology, particularly of drainage systems and of indicator organisms, has an important role; and that biology can be in the forefront of development planning namely in the emerging discipline of landscape planning or ecology, or environmental design. Landscape ecology is not entirely a new science; the term has been used for budgets in Germany for centuries. It embodies the study of the dynamic factors impinging on resources (i.e. matter, energy, space, time and diversity) and the processes governing resource systems, the development and conservation of resources, spatial systems, and distributive systems of power and benefits.

I would like to conclude with this quote from Joseph W. Krutch, a naturalist:

> "There is a paradox at the heart of the necessary 'struggle for existence', and the paradox is simply this: Neither man nor any other animal can afford to triumph in that struggle too completely. Unconditional surrender is a self-defeating formula – even in the war against insect pests. To the victor belong the spoils in nature also, but for a time only. Where there are no more spoils to be consumed, the victor dies."

Overview

In conclusion, it is evident that three aspects of zoology and ecology need academic emphasis:

(1) Taxonomy and ecology especially of animals in drainage waters, and with symbiotic relationships to land-water interactioon.

(2) Ecological dynamics of land-water interactions particularly in relation to organic matter flows, perturbation impacts, and dynamic models for predicting and forecasting.

(3) Biological indicators for development planning particularly those reflecting the trophic status and resilience of ecological systems.

Such emphasis would depend on inputs, support and efforts not only of materials (e.g. museum, equipment) but also of personnel.

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