Aquatic Resources Extraction :

Issues Involved in Sustainability and Long - Term Ecological Implications

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We live on a planet with finite quantities of air, water, and land. We can only consume so much, and expand and grow so far before we run out of these resources. If social limits do not first constrain our growth, then at some point ecological constraints will do so. It is also becoming clear that we cannot preserve nature, or freeze it in any particular state. We are all part of a changing and dynamic ecological system that we know as the Earth.

The concept of sustainability has been around for a long time, although it has entered popular culture only relatively recently. The modern roots of sustainability began in the early 20th century theory of renewable resource management, most notably in sustainable agriculture and forestry, and in theories of "sustained yield." The real power of the concept of sustainability lies in its integration of economic, social, and ecological systems, previously studied and dealt with separately.

Two publications appeared in 1980 that brought the term of sustainability into widespread public use: Lester Brown's Building a Sustainable Society (a sustainable society is one which satisfies its needs without diminishing the prospects of future generations - Lester Brown), and the International Union of Conservation of Nature's World Conservation Strategy ('Sustainable growth' is a contradiction in terms: nothing physical can grow indefinitely. 'Sustainable use' is applicable only to renewable resources: it means using them at rates within their capacity for renewal - IUCN) . The modern movement towards sustainability began when The World Commission on Environment and Development, through the Brundtland Commission, released their report Our Common Future in 1987, where it is stated that "Sustainable development is devëlopment that meets the needs of the present without compromising the ability of future generations to meet their own needs." The Brundtland Commission tried to reconcile the interests of economic development with those of environmental conservation. The sustained yield perspective of the early 20th century focused on biological systems, whereas the new theory of sustainability considers human needs and wants as well as ecological functions and processes. The Rio Declaration developed further this sustainability concept, stating that "Human beings are at the centre of concern for sustainable development. They are entitled to a healthy and productive life in harmony with nature" (Principle 1 of Declaration).

There is a growing awareness and acceptance that population growth, resource consumption and increasingly powerful technologies are combining to weaken and simplify the ecological systems and communities of our planet. Problems generated by humans are increasing in number and complexity in virtually every locale and region, and are now for the first time in recorded history demanding our attention on a global level. There is evidence to suggest that we are altering the energy flows and material and nutrient cycles of the planet significantly enough to endanger and threaten a healthy future for humans and many other life forms.

Applying the concept of sustainable development to our aquatic resources, this means that we must balance the present demands on the aquatic resources with future needs and that formal and consistent management plans need to be developed with the concept of long-term sustainability in mind. Unless the management plans that deals with a natural resource, such as an aquatic resource, takes into consideration the ecological implications of resource extraction, actions based on such plans will not be sustainable. This would mean that the extraction of a natural resource can be sustainable in the long-term only if it is ecologically harmonious. Thus, in order to foster the sustainable use of our aquatic resources and to facilitate related trade and commerce, we would have to preserve and protect representative ecosystems and plan out the management of all aquatic resources in an integrated manner.

NATURE OF AQUATIC RESOURCES

Fresh water, capture and culture fisheries for sea weeds, edible fish and shellfish, aquarium fish and aquatic products such as pearls, algae, plants and animals for medical purposes, other marine resources such as marine mineral resources, sand, lime from coral reefs, ocean energy resources, ocean thermal energy conversion, petroleum products and petroleum in submerged lands, hydro-power, tidal power, shipping, water-related tourism, etc., include the range of aquatic and aquatic-related products and resources on which our well-being depend. Some items such as water and fisheries play a leading role in our lives whereas other products may not assume as much importance in the lives of many of us.

Some of these aquatic resources, such as fish, are living and are renewable through reproduction and growth. Others, such as fresh water, are non-living and finite but are recycled. Materials such as petroleum and sand are non-living, non-renewable and cannot be recycled through natural cycles (e.g. water cycle). Still other items, such as recreational and aesthetically-related activities, are services that aquatic resources provide.

SUSTAINABILITY AND ECOLOGICAL IMPLICATIONS OF AQUATIC RESOURCE EXTRACTION

The sustainability of all aquatic resources are dependent on the extraction pressure or rate of extraction. Where an aquatic resource is non-renewable, then sustainability is directly dependent on extraction rates. When a renewable aquatic resource is considered, its sustainability will depend on its regenerating capacity, linked to its reproduction and growth characteristics as permitted by ecological considerations. The sustainability of nonliving recycled aquatic resources, such as fresh water, will also depend on ecological considerations.

EXTRACTION OF THE FRESH WATER RESOURCE: ECONOMIC SUSTAINABILITY

All aquatic resources depend on water and water is central to all life and living. Most of us have become used to regarding water as an ever-present resource that subjects us to temporary inconvenience whenever its supply becomes restricted. Although about three-fourths of the earth is made up of water, about 97 percent of it is sea water. Of the balance 3 percent, another 2 percent is locked in ice-caps and glaciers. Vast reserves of fresh water underlie the earth's surface, but much of it is too deep to be economically tapped, so that the fresh water that is available to us makes up less than 0.5 percent of the earth's total water. It is this limited fresh water resource which is recycled and reused, and on which we all depend. It must therefore be clearly remembered that although fresh water is renewable, it is also finite. The earth has almost the same amount of water today as it did long years ago when dinosaurs roamed our planet. The problem is not the supply of water but rather the increasing numbers of people who need to use it today and the ways in which we use it today. These trends in water use have made fresh water itself to become one of the most imperilled resources from among the extractable aquatic resources that we presently use.

Fresh water is used for many domestic purposes (such as drinking, washing, etc.,), for industrial as well as agricultural purposes. But its largest use is in agriculture, with 70 percent of all the water pumped from under ground or diverted from rivers being used for irrigation for the production of our food crops. It takes 1,000 tons of water to grow 1 ton of grain, the worlds most heavily used food source. Thus, if we face a future of water scarcity, we also face a future of food scarcity. Water scarcity, a matter of growing concern for many governments, is often considered separately from food scarcity, but its associated loss in agricultural and aquatic productivity, may be to the nineties what the oil price shocks were to the seventies: a source of major shifts in our national economies and international conflicts. The imbalance that a water shortage would create in a diversity of ecosystems and the attendant loss of sustainability that would result, would indeed be catastrophic to our national economies and lives.

As world population expands by 2.6 billion over the next 30 years, and as consumption spirals upward, water problems are bound to intensify and the sustainability of our life styles stand threatened. By 2025, just a generation away, 40 percent of the world's people, more than 3 billion in all, may be living in countries experiencing water stress or chronic water scarcity. Already, 26 countries have more people than their water supplies can adequately support. Africa currently has 11 water-scarce countries, nations with renewable supplies of less than 725 gallons per person per day, a minimum benchmark for being able to meet food, industrial, and household water needs while maintaining a healthy aquatic environment. By the end of this decade, four others will join the list, and the total number of Africans living in water- scarce countries will climb to 300 million, one-third of the continent's projected population. The Middle East, where 9 out of 14 countries are water-scarce, suffers the most concentrated scarcity in the world today.

As the world demand for water has tripled since mid-century, it has led to widespread, often massive, over-pumping of water bodies. Water tables are therefore falling in major food-producing regions, including the southern Great Plains of the United States, the Punjab, which is the breadbasket of India, and in central and northern China, Mexico, Thailand, the western United States, north Africa, and the Middle East. Water tables are dropping a meter or more each year beneath a large area of irrigated farmland in north China. Across two-thirds of India's Punjab, they are falling at a rate of 20 centimeters a year.

These trends would put food security and economies at risk because the amount of fresh water that can sustainably be supplied to farmers is nearing its limits, even as 87 million more people are added to the planet each year.

EXTRACTION OF THE FRESH WATER RESOURCE: ECOLOGICAL IMPLICATIONS

As populations expand, there is also a trend in demographic patterns where more people shift to urban and coastal locations, which would thus exert heavier demands on the fresh water resource. With the urban population projected to double to 5 billion by 2025, pressure is mounting to shift water from farms to expanding cities. The diversion of water for farms and cities have long-term ecological implications. It threatens to destroy irreplaceable ecosystems that support valuable fisheries and wildlife resources.

The construction of large dams and reservoirs to meet the increased need for water extraction and hydropower generation has also had ecological implications. Rivers, lakes, and wetlands, along with the life they support, have declined in health because large dams and river diversions have destroyed their vital ecological functions. The resulting ecological implications are diverse and include;

Loss in capacity of many river deltas and coastal estuaries to support fisheries because of the diminished flow of fresh water and nutrients. Fisheries in many Sri Lankan lagoons have declined due to the decreased frequency of lagoon mouths being breached as a result of reduced upstream water flows, thereby depressing recruitment of young fish and shellfish into lagoons from the sea, as is seen, for example, in the decreased prawn fishery production at Rekawa lagoon in the south coast of Sri Lanka. The lower reaches of rivers in many parts of the world, including Sri Lanka, have gone dry for longer periods than during earlier times.

Loss in river area and volume with attendant economic decline. For example, central Asia's Aral Sea has lost half its area and three-fourths of its volume because of excessive river diversions for cotton production. 20 out of 24 fish species have disappeared, along with a fish catch that once totaled 44,000 tons a year and supported 60,000 jobs.

Loss in wetland value. For example, California has lost 95 percent of its wetlands; populations of migratory birds and waterfowl, which depend on such areas for food and habitat, have dropped from 60 million around 1950 to 3 million today.

EXTRACTION OF THE FRESH WATER RESOURCE: THE SUSTAINABLE SCENARIO

Since 1950, global water use has more than tripled. Traditionally, engineers have met rising demands by building larger water projects and drilling ever more groundwater wells. But limits to expanding the supply are swiftly coming to light. The findings from a Ford Foundation-funded study states that building large new dams and river diversions is becoming prohibitively costly and environmentally damaging and that in most cases, measures to conserve water and use it more efficiently are now the most cost-effective and environmentally sound ways of meeting water needs.

The potential effect on future food production of the progressive shift of water from agriculture to cities, combined with groundwater over-pumping, aquifer depletion, and the other forms of water extraction would render such aquatic resource extraction practices as unsustainable and ecologically damaging in the long-term.

Instead of continuously reaching out for more water, human society will have to adapt by conserving and recycling water and using it more efficiently, if water is to be extracted sustainably without adverse long-term ecological implications. It is felt that, with techniques available today, farmers could cut their water demands by 10 to50 percent, industries by 40 to 90 percent, and cities by a third with no sacrifice of economic output or quality of life.

It is therefore imperative that sustainable agriculture practices be adopted and followed to sustain aquatic resource extraction. Sustainable agriculture is an integrated system of plant and animal production practices having a site-specific application that will, over the long term, satisfy human food and fiber needs; enhance environmental quality and the natural resources base upon which the agricultural economy depends; make the most efficient use of both nonrenewable resources and on-farm/ranch resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm/ranch operations; and enhance the quality of life for farmers/ranchers and society as a whole.

FISHERIES AS AN EXTRACTABLE AQUATIC RESOURCE

Water covers seven-tenths of our planet and its fisheries products are the main source of animal protein for many millions of people, particularly in developing countries. World catches have peaked and may even be declining; in the face of ever-increasing demand it is unclear how the predicted shortfall will be met. The need for environmentally sound sustainable approaches to this problem is emphasised by current concern over global warming and its potential impact on sea levels and temperatures, and on marine resources.

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Sustainable extraction of the marine resources is also critical to the nation's public trust responsibility. Oceans provide jobs, recreation, and transportation to coastal communities, where over half of the country's population are expected to reside by the year 2000. The sustainable use of these marine ecosystems, as well as the species that inhabit them, is crucial to the future of these regions and the nation.

Although harvests from capture fisheries outweigh by far the culture fishery harvest, aquaculture offers the possibility for economic benefits in rural and coastal communities with limited economic alternatives. Since the success of an aquaculture industry is dependent on sustainable management, environmentally sound aquaculture practices have to be fostered.

Plans should enable the aquaculture industry to expand and remain competitive, and promote new species development, so that long-term sustainable growth would be facilitated. Aquaculture development must be consistent with habitat and biodiversity management and maintenance of environmental integrity.

PLANNING FOR SUSTAINABILITY OF THE EDIBLE FISHERIES RESOURCE

Planning for a sustainable fishing industry requires the following points to be kept in mind and to be developed in accordance with Sri Lanka's needs;

- integrate fishery management plans with conservation - precautionary principle (that in the face of scientific uncertainty, err on the side of resource conservation) being accorded the first priority in decision making, if long-term sustainability is to entertained;
- fishing capacity must be balanced with the sustainable carrying capacity of the resource, in keeping

with the proper understanding of the underlying ecological causes;
- government and industry must work together for efficient management.

The progress made by other western countries this century in understanding the dynamics of marine stocks and their dependence on other components of the ecosystem has not been followed by Sri Lanka. Sustainability of the fishing industry will depend to a large extent on how Sri Lanka will attempt to understand these fishery dynamics scientifically, making use of personnel and facilities available with agencies such as the National Aquatic Resources Agency, Fisheries Ministry and universities. Continuous improvement in our knowledge of marine ecosystems, including the dynamics of fished stocks and the effects of pollution in an ecosystem context, is central for fisheries conservation and protection initiatives. Changes to ocean conditions (such as global mean temperatures arising from climate change) have been linked to the distribution, growth and recruitment of fish stocks so that studies need to be started in these areas for future sustainability of our fisheries resources. Unfortunately, Sri Lanka has not made any headway in linking effectively with programmes that are present in other countries so that our fisheries and aquatic resource sustainability would be ensured in the decades to come.

Commercial fish stock assessment and its collation into a centralised data base would enable us to have a better understanding of the harvesting, environmental and ecological factors behind the changes in fish landings along our coast. Such an exercise has to commence for sustainability and predictability of our fisheries industry, as also for linking the fishing industry and academic research community to study the responses of fished stocks and to identify the appropriate framework for recasting fisheries strategies as stocks undergo inevitable change.

We may need to reorient our training and recruitment procedures in our research organisations and universities. Overseas funds that are available for research and for training and retooling of staff should be utilised to equip staff with the research capability to address issues towards making our fisheries industry sustainable. Only the highest calibre of qualified staff possessing a breadth of knowledge and understanding in the relevant disciplines should be recruited.

Ecological research is also essential for understanding the dynamics of healthy stocks, such as lobster and crab, in order to provide information and advice for sustainable use of these resources. Research should also collect information on exotic nuisance species introduced into our waters by commercial shipping and also inadvertently spread through the aquarium trade. Biotechnological advances such as the use of polyploid species as affecting our aquatic resource should be evaluated. Research should also address the better understanding of the roles of marine mammals in marine ecosystems, including the impact of predators on commercial fish stocks and aquaculture and the conservation and rebuilding of endangered species stocks such as the dugong and selected species of turtles.

It is also necessary to make fisheries research more understandable and accessible to fishermen, processors, and coastal communities. There is also a need to involve fishermen and make use of local knowledge in stock assessment through such innovative approaches as sentinel fisheries and cooperative surveys.

The sustainability of our fisheries will also be affected by the continuing concern about toxic chemicals in the marine environment, their impact on ecosystem health, and their absorption into the food chain, since wild marine species are a significant part of the daily diet of our people. Scientific efforts will need to be started towards understanding the impacts and significance of pollution and toxicity problems on marine and aquatic ecosystems and their fishery components.

The findings from survey programmes should be channelled to balance the interests of all stakeholders as well as to integrate and coordinate the broad array of legislation, regulations and initiatives; and ensure that interaction with oceans ecosystems respect the principles of sustainable development, integrated management and the precautionary approach to decision making. Scientific informa-

tion on marine ecosystems will be fundamental to the integrated planning process, the evaluation, designation and management of marine protected areas, and the development of marine environmental quality targets.

Sustainable fish production depends on maintaining the integrity of fish habitats. Therefore, the objective of the research policies should be to provide a net gain of habitat for fisheries resources and to increase the natural productive capacity of habitats for the nation's fisheries resources so as to benefit present and future generations. There should be a "No Net Loss" of fish habitat productive capacity by ensuring that any losses of fish habitat productive capacity are offset by the creation of an equal amount of new productive capacity.

Since habitats are under increasing pressure from a wide range of development activities, fish habitat impacts associated with proposed development projects should be assessed as a means to identify habitat management measures which can avoid or minimise fish habitat impacts. This would enable project developers to consider relocating or redesigning and/or to ensure mitigation or compensation measures that could be taken into account in the early stages of project planning so that general development activities are not unduly hampered.

Applying sound, comprehensive scientific information to the development of national fishery policy can reduce or eliminate much of the uncertainty that is impeding protection of freshwater and marine fisheries today. Implementation of science-based fishery management plans will help resolve the problems facing some fisheries, such as overfishing and the loss of spawning and nursery habitat, including fragile freshwater and coastal habitats. But improved management and correction of overfishing alone will not be enough to turn around the decline in fish stocks. Protection and restoration of aquatic ecosystems and proper care of watersheds and riparian habitats are critically important. New policies need to be initiated and existing ones continued and enhanced to eliminate, mitigate, and prevent activities that degrade habitats.

SUSTAINABILITY OF THE AQUARIUM FISHERIES RESOURCE

The export aquarium fisheries industry exports both marine and fresh water organisms extracted from the natural habitats. The fresh water industry also exports fish based on hatchery rearing which would therefore not impact on the naturally available stocks. With regard to the marine export industry, all exported organisms are collected from the reef and associated areas. The collection process, particularly from the reef, removes species inhabiting the reef ecosystem as well as is destructive on the physical structure when collecting is carried out using the "moxy net" technique.

Sustainability of this industry is dependent on assessing the available stocks, assessing permissible extraction rates, developing ecologically sound collection, packing and transport methods, adopting in all cases the precautionary principle. Developing hatchery breeding techniques for marine species should be addressed as a top priority if this industry is not to exert damaging ecological effects on the reef ecosystems and if the industry is to become sustainable. Other causes of reef degradation, such as high rates of sedimentation and pollution-induced effects need also to be adequately addressed for the trade to maintain sustainability. Addressing these impacts need an integrated approach since the impacts are related to other spheres of economic activity in the country.

ARRESTING LONG-TERM ECOLOGICAL UNSUSTAINABILITY: THE INTEGRATED AND ECOSYSTEMS APPROACH

The range of activities that interact with the aquatic habitats highlights the numerous and sometimes competing demands placed on aquatic ecosystems. Many of the resulting environmental impacts on aquatic systems illustrate the need to focus on integrated approaches to ensure sustainability of our aquatic resources. For example, the multiple or conflicting uses of coastal areas, including fishing, aquaculture, tourism, recreation, construction of human habitats, waste discharge, marine mining, and shipping, make the application and success of isolated approaches questionable. Integrated approaches to the planning and management of activities are critical to the continued coexistence of users and the sustainability of the aquatic resources, as for example: controlling soil erosion not only sustains long-term productivity of the land, but also reduces the amount of soil, pesticides, fertilizers, sediments and other substances that can move into the national waters; controlling deforestation leads to decreased rainfall runoff, increased aquifer recharge and decreased soil erosion as well as sediment load.

In nature, nothing exists alone. Living things relate to each other as well as to their non-living but supporting environments. These complex relationships are called ecosystems. Each body of water is a delicately balanced ecosystem in continuous interaction with the surrounding air and land.

Human activities are very much connected to the ecological integrity of a natural system, such as a watershed, and considering their effects within a framework based on a defining natural system can highlight cause-and-effect relationships; identify long-term implications; and lead to solutions that integrate economic, environmental, and equity goals. Construction practices that keep harmful sediments from accumulating in rivers and lakes help protect water quality for drinking and swimming, for example.

In addition, science and experience have shown the importance of ecological processes such as nutrient cycling, fire, and hydrologic cycles, some of which operate over broad geographic areas, in determining the condition of a natural resource in a particular place. Because the role of ecosystem processes was not considered, today there are difficult and costly management decisions to be made to restore the vitality of a region's ecosystems and the local economies that depend on them.

The shift from managing a single resource or a single species to managing an ecosystem for a variety of resources, including the maintenance of its biodiversity, makes sense. And there are numerous advantages to using the best scientific, social, and economic information and fostering collaboration among stakeholders, actions that characterize this new generation of natural resources management. Scientific information is essential in identifying which ecosystem processes are vital to the productivity of a wide array of natural resources, while social and economic information can identify which strategies will best meet public demands and stakeholder objectives.

Concerned about the cumulative impact of numerous local management actions, many scientists and resource managers now believe that biodiversity, water quality, and other natural resources can only be protected through cooperative efforts across large landscapes, landscapes that often cross ownership boundaries. At the same time, conflicting demands for all resources are forcing public agencies to explore new planning and policy mechanisms that would involve broader public participation to minimize conflicts. Also, using adaptive management techniques to monitor results and incorporate lessons learned can ensure that shared goals are met and costly mistakes avoided.

LOSS OF BIOLOGICAL DIVERSITY, SPECIES EXTINCTIONS

Biological diversity provides direct food and free services for humans. It is also necessary protect biodiversity since this would ensure the sustainability of aquatic extraction and would

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also ensure that future generations can enjoy a rich diversity of freshwater and marine life and any benefits that would accrue from this biological diversity

Freshwater ecosystems are both disproportionally rich and disproportionally imperilled and the extinction of freshwater species far outpaces the extinction of mammals and birds. Species extinctions removes from the habitat uncompetitive organisms when extinctions occur naturally. But, when it occurs through human intervention, it removes from the ecosystem a necessary link of biological diversity that is essential for the proper functioning of an ecosystem, usually with long-term undesirable implications for the proper functioning of that ecosystem and depressing ecosystem productivity.

Some 20% of 9,000 known freshwater fish species worldwide are already extinct or imperilled, with the toll much higher where human impact is heavy. In North America and Europe, about 40% of all native fish species are extinct or imperilled. In East Africa's heavily stressed Lake Victoria, 40% of its unique 350 native fish species are at risk, with 60% already extinct.

As alarming as these numbers are, the rate of extinction is even more alarming, a hundred to a thousand times the natural rate. By destroying species faster than nature can create new ones we are running a 'biodiversity deficit' that can never be recovered.

WATER QUALITY AND ITS SUSTAINABILITY

We tend to think of water in terms of a particular purpose: is the quality of the water good enough for the use we want to make of it? Water fit for one use may be unfit for another. We may, for instance, trust the quality of lake water enough to swim in it, but not enough to drink it. Along the same lines, drinking water can be used for irrigation, but water used for irrigation may not meet drinking water standards. It is the quality of the water which determines its uses.

To a scientist water quality is determined by the kinds and amounts of substances dissolved and suspended in the water and what those substances do to inhabitants of the ecosystem. It is the concentrations of these substances that determine the water quality and its suitability for particular purposes. Certain measurements such as temperature, dissolved oxygen, turbidity and conductivity can be taken in the field and living organisms also indicate the quality of the water.

Drinking water, for example, is regulated by guidelines stringent enough to protect human health. Lack of such guidelines can lead to a variety of health problems. It has been estimated, for example, that contaminated water and poor sanitation cause 30,000 deaths around the world daily.

Water is the lifeblood of the environment, essential to the survival of all living things plant, animal and human. Whatever occurs on the land and in the air also affects the water. If a substance enters a river or lake, the water can purify itself biologically but only to a degree. Whether it is in the smallest stream or lake or even in the mighty oceans the water can absorb only so much. It reaches a point where the natural cleaning processes can no longer cope and the water quality will therefore change. This leads to loss in the ability of the aquatic resource to produce the resource which we, as humans, need or it leads to the loss of aquatic productivity. For example, in Sri Lanka a few years ago species of freshwater fish began to suffer from tumours and lesions and died. Pollution and diversion have driven freshwater fisheries into collapse worldwide. The recent collapse of the farmed prawn industry in Sri Lanka was a consequence of degraded water quality. Therefore, any pollutant that we add to the water has to be cleaned up if sustainability of aquatic products is to be ensured.

Most often our waterways are being polluted by municipal, agricultural and industrial wastes, including many toxic synthetic chemicals which cannot be broken down at all by natural processes. Even in tiny amounts, some of these substances can cause serious harm and have long-term ecological consequences by depressing aquatic productivity.

Pollution is not always visible. A river or lake may seem clean, but still

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be polluted. In groundwater, pollution is especially difficult to discern and to clean up. Nor are the effects of pollution necessarily immediate; they may take years to appear. Pollution makes water unsuitable for fisheries, agriculture drinking, industry, recreation and diminishes the aesthetic quality of lakes and rivers. Even more seriously, when contaminated water destroys aquatic life and reduces its reproductive abilities, it eventually decreases the productivity of the water body and affects the economy of the nation so that nobody escapes the effects of water pollution.

Aquatic pollutants include non-persistent (degradable) pollutants and persistent pollutants (which degrade slowly). Other substances such as floating debris, garbage, etc. are also pollutants that affect productivity in the water. Chemical pollutants can cause problems with the taste, odour and colour in water. Fish and wildlife can experience reduced fertility, genetic deformities, immune system damage, increased incidences of tumours, and death.

Acid rain, one of the most publicized LRTAP (long-range transport of airborne pollutants) phenomena, originates with emissions from coal-fired generators, non-ferrous metal smelters, petroleum refineries, iron and steel mills, pulp and paper mills, and from motor vehicle exhaust. The released sulphur dioxide and nitrogen oxides are converted to sulphuric and nitric acids in the atmosphere. These acids return to earth through wet sulphate and/or nitrate deposition (including rain, snow and fog). The damage caused by acid rain deposition occurs in environments that cannot tolerate acidification. Many species of fish, insects, aquatic plants and bacteria develop reproduction difficulties. Some even die. The decline in the population of any of these aquatic organisms affects the food chain. Dwindling populations of insects and small aquatic plants and animals are especially serious because the entire food chain is affected. The death of trees at forest edges in Horton Plains National Park is assumed by many to be a result of acid rain.

Another result of chemical pollution in the aquatic habitat that affects aquatic productivity is seen with eutrophication, which is clearly seen in the Beira Lake in Colombo. The growth and reproduction of aquatic plants is stimulated by eutrophication, a natural process which, over geological time, turns a lake into a bog and eventually into land. But today, in many places, this process is tremendously accelerated by high concentrations of phosphorus and nitrogen (from fertilizer, for example) which enrich the water with nutrients, causing the aquatic plants to bloom. As the plant growth explodes, it chokes off the oxygen supply normally shared with other organisms living in the water. When the plants die, their decomposition uses up even more oxygen. As a result, fish suffocate and die, and bacterial activity decreases. Yet if phosphorus and nitrogen inputs are reduced or stopped, the system can recover by itself.

CONTROLLING WATER POLLUTION FOR ENSURING AQUATIC SUSTAINABILITY

Since water plays such a vital role in life on earth, including aquatic productivity and our capacity to extract aquatic resources, good quality water is a precious resource. Often water quality is more important than water quantity. The quality of the water affects the use we make of it, but the reverse is also true. Once we have used the water, we affect its quality.

The explosion in human population and industrial activities, and the rate at which new chemicals and products are being developed and used pose a global environmental threat. The natural decay processes in water bodies can no longer cope with these loads.

Ideally, polluting contaminants should be prevented from entering the water, which however may not be a practical possibility. If contaminants are not removed, they may be present only in minuscule quantities, but because they are persistent, they can build up to very harmful levels. In such cases we can protect future generations and the ecosystem productivity in only one way: preventing the chemicals from entering the water system.

THE ROLE OF THE STATE AND COLLABORATIVE APPROACHES FOR A SUSTAINABLE AQUATIC ECOSYSTEM

Government plays a critical role in conserving, protecting, and restoring natural resources by setting and maintaining a foundation of strong environmental laws and regulations. Enforcement is an important component, particularly for pollution control. No single government agency or collection of unconnected agencies is sufficient. No set of statutes or regulations, however comprehensive and detailed – can take the place of the commitment by individuals and communities to protect natural resources and ecological integrity. Individuals, communities, and institutions need to work individually and collaboratively to ensure stewardship of natural aquatic systems.

Government agencies at all levels have a pivotal role to play in encouraging stakeholders to search for common goals, resolve conflicts, apply the best available science, inventory and monitor natural resources status and trends, and exercise collective responsibility for overall natural resources conditions.

The State should review and, where necessary, overhaul the wide range of incentives and disincentives affecting sustainable approaches. The challenge is to identify new, market-based approaches to promoting stewardship and participatory planning and to eliminate subsidized programs that promote or encourage unsustainable activities, rather than only reacting to problems after they have become intractable. The challenge also resides in our ability to remove disincentives and establish incentives in distinct areas such as subsidies and taxation.

The long-term goal for strengthening national natural resources information is to bring about better strategic and operational decisions at all levels of government and the private sector based on reliable, high-quality information that integrates economic, environmental, and equity considerations.

RECOGNIZING OCEANS JURISDICTION

Sustainable extraction requires that we are aware of the extraction pressure. With this in mind, it is necessary that the rights of Exclusive Economic Zone (EEZ), extending 200 nautical miles adjacent to our coast, as it relates to fisheries and other aquatic resources management, should be observed by other nations. These rights include our right to explore, exploit and conserve living and non-living natural resources, protect the marine environment, regulate scientific research and control offshore structures in this zone.

ESTABLISHING PROTECTED AREAS AND A MANAGEMENT POLICY

It is essential that an integrated management policy be enunciated, discussed and adopted very early so that managers, conservationists and the developers will all know and come to accept the guidelines that will be applicable over a defined period with regard to aquatic resources extraction. Such a policy can be re-examined and modified over an accepted time scale, such as a 5 year period, so that long-term ecological implications of resource extraction are also incorporated and made known. The development of such a management ethic requires a period of time and needs to be started soon before our aquatic resources regress too much so as to preclude adopting sustainable strategies.

Following the precautionary approach for sustainable development and integrated management, management policies need to be formulated so as to;

establish protected aquatic areas for the conservation and protection of marine and freshwater resources (commercial and non-commercial) and habitats;

develop and implement, with stakeholders, plans for the integrated management of activities in, or af-

fecting, estuaries, coastal and marine waters;
develop measures to conserve and protect marine ecosystem health;
provide disincentives, alternative strategies and mechanisms to minimise damage to aquatic resources (e.g., develop hatchery-rearing of wild-caught aquarium fish and marine invertebrates, develop alternative income and vocational strategies to wean away coral miners from their environmentally unfriendly habits, etc.,).

CONCLUSIONS

There has been widespread calls for a new "water ethic" that has the protection of natural ecosystems and equitable use of water at its core. The success of such a strategy will determine not only the quality but the staying power of human societies since water is the basis of life as we know it. The challenge now is to put as much human ingenuity into learning to live in balance with water as we have put into controlling and manipulating it. In the end, the time available to make this shift may prove as precious as water itself.

It has been convincingly argued that the correct strategy for ensuring the long-term sustainability of our extractable aquatic resources is to establish pricing strategies, policies, and management practices that promote efficiency rather than wastefulness. It has been recommended that incentives should be given for farmers to irrigate more efficiently and to switch to less thirsty crops.

Achieving water balance in some regions will not be possible without a slowdown in population growth. At current growth rates, the populations of 18 of the 20 countries now qualifying as water-scarce in Africa and the Middle East will double within 30 years.

Beyond their obvious benefits for agriculture and industry, intact freshwater, brackish and marine ecosystems are vital to human health and economies worldwide. They provide clean drinking water, natural flood control, as well as income and food from fisheries. Hydroelectric dams, water diversions for agriculture, flood control levees, dredging, air and water pollution, habitat degradation such as logging, as well as exotic species are combining to disrupt and destroy aquatic species and functioning ecosystems worldwide. Logging, dams, flood control, and massive land conversion wind up costing more than they are worth, while destroying forever biological diversity that provides direct food and free services for humans.

Collaborative approaches can apply both to public and private resources when the decisions made on their use have broad implications for the whole community. It has become clear that the conflicts over natural resources increasingly are exceeding the capacity of institutions, processes, and mechanisms to resolve them. Basing collaborative approaches on natural systems encourages people to identify with a particular place and take responsibility for it. Frequently, people do not feel connected to a place or locale and so do not feel responsible for taking care of it. Decisions typically get made in fragmented ways, and the connection between individual lives and the health of an ecosystem can seem remote.

Education, information, and communication are all important for developing a sustainable resources ethic. Also important is the widespread understanding that people, bonded by a shared purpose, can work together to make sustainable development a reality.

The key to stopping this needless destruction and repairing damage already done requires abandoning the fragmented approach to managing rivers and their watersheds. Rather than having dozens of agencies and bureaucracies, each managing a piece or a function of a river within a narrow mandate, integrated ecosystem-based planning at the watershed, national, and international levels is recommended. Managing resources over large enough areas and long enough time scales to allow their species and ecological processes to remain intact while still allowing human activity is a recommended approach. It is also recommended that management policies be built on collaborative approaches; ecosystem integrity; and incentives in such areas as agricultural resources management, sustainable forestry,

fisheries, restoration, and biodiversity conservation.

Without personal and collective commitment, without an ethic based on the acceptance of responsibility, efforts to sustainably manage natural resources protection and environmental quality cannot succeed. With them, the bountiful yet fragile foundation of natural resources can be managed, protected and replenished to sustain the needs of the present generation and those who are to follow.

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