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STRATEGIES FOR CONSERVATION OF ENDANGERED ECOSYSTEMS

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Abstract

The planet Earth is known to host a rich biodiversity owing to its suitable environmental conditions for life and at a larger scale it is regarded as a major ecosystem. Healthy existence of living organisms in this ecosystem depends on proper functioning of all the associated environmental factors. Since millennia, living organisms have adapted to thrive under a limited range of environmental conditions. Nevertheless previous history of the earth and fossil records indicates that the biodiversity housed by the planet earth has experienced five major catastrophic extinctions due to change in physical environment. Even currently, it is undergoing sixth major extinction event mainly due to anthropogenic activities. The human activities are proving a dual menace for biodiversity. On the one hand, it is causing habitat loss through intensive deforestation, conversion of different natural plant communities for agriculture, and urbanization and industrialization. Moreover, it is resulting in habitat degradation by polluting both terrestrial and aquatic ecosystems, emitting air pollutants resulting in acid rains, ozone layer depletion, global warming, heavy metal contamination and eutrophication of water bodies. As a result, healthy existence of both terrestrial and aquatic ecosystems and their associated biodiversity is altogether threatened. Worldwide efforts are underway to conserve the threatened ecosystems and their related biodiversity. A number of international conventions have been held to conserve natural ecosystems. Pakistan being a signatory of these conventions has its obligation to join hands with international community to conserve the endangered ecosystems within as well as outside its bounds. Under the existing scenario the objective of organizing this symposium was to pinpoint the threats to endangered ecosystems of the world in general and those in Pakistan in particular, and to develop suitable strategies for conservation of such paralyzed ecosystems.

Introduction

The term "ecosystem" was introduced by Roy Clapham in 1931 to describe both physical and biological factors of an environment closely interrelated and functioning as a unit (Willis, 1997). Afterwards, Arthur George Tansley (1935) a botanist and pioneer in the science of ecology, championed the term *ecosystem* as the interactive system established between biocoenosis (a group of living creatures) and their biotopes (the environment in which they live). Nevertheless, Christopherson (1997) defined it as a natural system consisting of all plants, animals and microorganisms (biotic factors) in an area functioning together with all the non-living physical (abiotic) factors of the environment. Within an ecosystem living organisms continually remain engaged in a set of relationships with every other element constituting their environment that makes the central theme of ecosystem concept. Following the Convention on Biological Diversity (CBD), signed by almost 200 nations of the world the ecosystem concept has emerged as: "Ecosystem means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Anon., 1992). Sometimes an ecosystem is confused with a biome which is actually a climatically and geographically defined area of ecologically similar climatic conditions such as communities of plants, animals, and soil organisms, often referred to as ecosystems. In the hierarchical level of organization ecosystem occupies the central position following greater than a community but lesser than a biome (Fig. 1; Solomon *et al*., 2010).

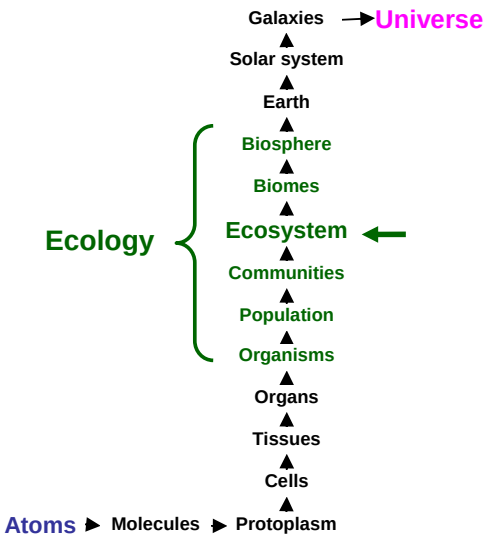

Fig.1. Hierarchical level of biological organization (Solomon *et al*., 2010).

Ecosystem size: There is no conceptual restriction on how large or small a space or an area must be to host an ecosystem, nor on the minimum numbers of species or individual organisms to be present therein. Ecosystems can be as small as a drop of water from protozoan point of view, single tree for beetles or as large as an entire forest or ocean. Ecosystems are classified in to two major catagoris identified by factors like temperature, rainfall, soil type and altitude. The current size of various ecosystems occupied worldwide is given in Table 1 (Atjay *et al*., 1979; De Vooys, 1979):

Table 1. Ecosystem type and surface area covered by world's major ecosystems.

Ecosystem type	Surface area ($\times 10^6$ km^2)
Forest	31
Woodland, grassland, and savanna	37
Deserts	30
Arctic-alpine	25
Cultivated land	16
Human area	2
Other terrestrial (chapparral, bogs, swamps, marshes)	6
Subtotal terrestrial	147
Lakes and streams	2
Marine	361
Subtotal aquatic	363
Total	**510**

Source: Vitousek *et al.*, 1986

Ecosystem classification: The identification, demarcation description and classification of ecosystems are necessary for better understanding of conservation strategies. Ecosystems can be conveniently recognized by field survey and through satellite imagery. As such, the IUCN task force on Protected Areas System Composition and Monitoring (Vreugdenhil *et al*., 2003) has classified ecosystems based on physiognomic and ecological bases. This classification is also based on structure, seasonality, prevailing disturbance, dominant vegetation type, seasonality of the vegetation and leaf-morphology, geophysical data (elevation, humidity, drainage), salinity of water, and characteristics of water bodies which act as modifiers to separate distinct sets of species. Following two major classes of ecosystems have been based on water factor:

Natural ecosystems: Following are the major types of the natural ecosystem found on planet earth:

Terrestrial	Aquatic
Grassland	Pond
Shrubland	Lake
Forest	River
Tundra	Wetland
Taiga	Estuary
Desert	Ocean
Island	Hot water springs

Anthropogenic ecosystems: With the development of civilization following terrestrial and aquatic ecosystems have been artificially created by human beings as well:

Terrestrial	Aquatic
Agricultural Forms	Fish forms
Botanical gardens	Aquaria
Zoos	Artificial lakes
Urban settlements	Ponds

The dynamic nature of ecosystem: Ecosystems have dynamic nature and balanced by natural phenomena like seasonal changes, natural fires, windstorms, epidemics, and herbivory/predation which bring critical changes in their structure. The fragile ecosystems readily get influenced by any natural or anthropogenic disturbance. The natural ecosystems are resilient i.e., have the tendency to automatically return to pre-disturbed conditions depending upon the severity and frequency of disturbance. The frequently and severely disturbed ecosystems relatively take more time to return to pre-disturbed conditions (Pahl-Wostl, 1995).

Ecosystem productivity: In an ecosystem, the connections between species are generally related to food production and consumption by different organisms and their role in the food chain. As such a typical ecosystem comprises three categories of organisms. The producers usually are capable of photosynthesis but some other organisms such as bacteria around ocean vents are also capable of chemosynthesis. The consumers, almost all animals, may be further categorized as primary consumers (herbivorous), or secondary or tertiary consumers (carnivorous). Nevertheless, decomposers include bacteria and mushrooms which degrade organic matter of all categories (Perera *et al*., 2001; Lemaire *et al.*, 2011).

Importance of ecosystems: Ecosystems provide a vast variety of services which are difficult to comprehend and estimate in economic terms. Some common services provided by the ecosystems and the benefits achieved may be classified into the following categories (Daily, 1997; Hester & Harrison, 2010):

Provision services

1. Provide commodities like food, timber, and water
2. Provide pollination services ~$4-6 billion per year only in US
3. Seed dispersal (zoochory)

Regulation services

1. Maintain rich biodiversity - ecosystems provide unique habitats on which the plants and animals within them depend. They host habitats for a huge variety of endemic and endangered species, and are refuges for important medicinal plants.

2. Moderate weather extremes and their impacts
3. Protect people from the sun's harmful ultraviolet rays
4. Recycle and move nutrients to maintain/preserve soils and renew their fertility

Supporting services

1. Support geochemical and biological processes on earth
2. Protect streams and river channels and coastal shores from erosion. The damages caused by the alteration of wetlands have been estimated worth $ 12 billion.
3. Control agricultural pests and regulate disease carrying organisms
4. Detoxify and decompose wastes

Cultural services

1. Provide physical and aesthetic enjoyment for human communities
2. Provide employment opportunities

Ecosystem stability and balance: Ecosystem having a dynamic nature i.e. change from day to day, season to season, and year to year. If the changes remain small then ecosystems remain stable. Only mature ecosystems are stable because of having resilience and inertia. The ecosystem remains stable and balanced only through proper maintenance of inputs and outputs. The inputs in a natural ecosystem include solar radiation supplied by sun, water supplied by rainfall, and nutrients supplied by rock weathering or through use of fertilizers. Animals migrate from other areas while plant propagules and seeds are carried by wind, water, animals, etc. The output from ecosystems includes biomass through emigrating animals, hunting, predation and disintegration of animal/plant parts after their death.

Worldwide highly endangered ecosystems: Ecosystems with the richest biodiversity are greatly threatened. The following anthropogenic threats can be identified among the major ones:

1. Tropical rainforests are being deforested for opening land for agricultural purposes
2. Grasslands are losing their richness and productivity due to grazing pressure
3. Wetlands and coastal areas are being filled for agriculture/urbanization
4. Water bodies (rivers, lakes, wetlands, mangroves, estuaries, etc.) are being polluted through eutrophication and contamination by industrial effluents and sewage water
5. Agricultural lands are being converted into urban areas and industrial estates

Threats to ecosystems: There are generally nine major threats to the stability of ecosystems on earth (Cramer, 2001). The following factors may be equally threatening the world ecosystems:

1. Climate change and loss of biodiversity have received more attention during the current era and is very well documented
2. Vast spread of agriculture and other human activities into natural habitats pose a large threat to ecosystems
3. Disruption of fresh water systems through damming and diversion make vast habitats dry and barren
4. Chemical pollution released by industries, and urban settlements have devastating effects on the health of both aquatic and terrestrial ecosystems
5. Release of greenhouse gases and aerosols into the atmosphere by burning fossil fuels which damage ecosystems in numerous ways e.g. global warming and ozone layer depletion allows ultraviolet rays to reach earth surface; and acid rain results in acid deposition, thereby threatens biodiversity
6. Acidification of the oceans is a potential threat to global ecosystems that has not received much attention. This is due to increased carbon dioxide in the atmosphere, which greatly influences the ocean chemistry
7. Inorganic fertilizers especially nitrogen and phosphorus from agricultural sources lead to eutrophication of water bodies and reduces their species diversity by promoting the growth of a few dominant species
8. Thermal pollution through pouring warm water released by nuclear power plants also threatens the aquatic ecosystems and their flora and fauna
9. Over-harvesting of aquatic and terrestrial animals for international trade is posing not only a threat to some endangered top predators but also to the ecosystem functioning

   Unfortunately, majority of these threats are interlinked and if one threat goes unchecked and gets out of control, the others are likely to follow the suit.

Human impact on world ecosystems: Humans affect ecosystems in an unimaginable way. Even by walking out in the wilderness or by bulldozing land for a new parking lot we disrupt the food chain, the carbon cycle, the nitrogen cycle, and the water cycle. We need not interfere in these ecosystems and let nature take its toll. The most devastating factor emerged as a result of rapid increase in human population is that many ecosystems are endangered through the tragedy of commons (Cao & Woodward, 1997).

Ecosystems degradation under "tragedy of the commons": If everyone has access use of natural resources under the "tragedy of the commons" it begins with unregulated access to a resource owned by no one such as a pastureland, an oyster bed or offshore fisheries. The harvest of large amount of a natural resource over short time period results in resource depletion if no attention is paid to its sustainable harvests. Then it usually ends with no resource for anyone and destruction of entire ecosystem. For the prevention of "tragedy of the commons" in any ecosystem under private ownership, access to the resources should be regulated through legislation thereby achieving sustained benefits from such ecosystems. Additionally, the equity of rights for resource use through mutual consent of the stakeholders works best when ecosystems are under local control. Human impact on terrestrial ecosystems is greater than on aquatic

ecosystems. Only one species (*Homo sapiens)* currently commands about 40% of total terrestrial NPP, which probably never occurred in earth's history (Hackett & Moore, 2011).

In 1991, David Orr stated that "If today is a typical day on planet Earth, we will lose 116 square miles of rainforest, or about an acre a second. We will lose another 72 square miles to encroaching deserts, as a result of human mismanagement and overpopulation. We will lose 40 to 100 species, and no one knows whether the number is 40 or 100. Today the human population will increase by 250,000. And today we will add 2,700 tons of chlorofluorocarbons and 15 million tons of carbon to the atmosphere. Tonight the Earth will be a little hotter, its waters more acidic, and the fabric of life more threadbare" (http://www.context.org/ICLIB/IC27/Orr.htm visited on March 26, 2012). Afterwards almost 23 years have elapsed and the degradation of ecosystem has not been halted but gradually increased despite many efforts by international community.

Expected adverse effects of ecosystem degradation: Ecosystem degradation may have drastic and long lasting effects like:

1. Large scale shifts in global distribution of vegetation may take place in response to anthropogenic climate change
2. With doubling of amount of atmospheric CO_2 climate will change more rapidly then plant migration can keep up
3. Grassland will change to deserts or shrub lands
4. Loss of vegetation exposes greater amounts of soil to climatic adversaries leading to increased soil temperature, poor soil nitrogen content and ultimately reduced plant growth
5. Rapid soil erosion resulting into windstorms causing more trapping of infrared waves – another potential cause of global warming
6. Higher latitudes (Northern Canada & Alaska) already experiencing rapid warming and reduction of ice cover
7. Vegetation will be replaced with temperate forest species
8. Tundra, taiga and temperate forests will migrate pole ward
9. Plants will face extinction as habitat becomes unsuitable
10. Phonological changes in vegetation may take place

Adverse effects of climate change on world's ecosystems: Ecosystems host a unique set of plant and animal species well adapted to the environmental conditions. Hence the effects of ecosystem degradation may be more dramatic and rapid when any species cannot adapt to such change in its habitat. Hence, the endangered ecosystems may lose many species of both plants and animals (Walther *et al.*, 2002; Andreas & Wang, 2006). However, each ecosystem may be affected differently as follows:

1. Many forest species may need migration to cooler climates in a northern direction but such migration normally happens over a period of millions of years so some forests may lose species while others may disappear totally
2. Due to rapid climate change, growing seasons and shifts in the habitat boundaries may lose some fauna and flora, as some species may not migrate due to natural or man-made barriers
3. The melting of mountain glaciers may affect hydrological cycle like water supply to rivers, creating adverse effects for hydroelectric dams and agricultural areas down-stream of a glacier. It may also raise sea levels in coastal areas and some areas may experience reduction in permafrost
4. In mountainous regions, some species need to move higher up mountains; some species that only survive in certain high regions could become extinct
5. The changes in wetland water temperatures may increase some species while reduce others. The water quality may also decline due to increases in the occurrence and length of floods or droughts
6. The coastal areas may by rapidly eroded increasing salinity of estuaries and freshwater aquifers, salt water marshes, mangrove areas, coastal wetlands, coral reefs and atolls and river deltas
7. A change in atmospheric temperature due to climate change may alter the ocean movements
8. The agro-ecosystems may experience problems with food production and sustainability due to global warming. The reason could be that under higher temperature, photosynthetic rate will get reduced but respiration will continue, causing poor grain filling and reduced plant production especially in wheat crop

Strategies for ecosystem conservation: Ecosystems are regarded the living natural capital within which human beings along with many other species depend for survival and well-being. Ecosystems are the natural basis for the development of sustainable resource uses, including forestry, farms, renewable energy, urban land use, fisheries and other coastal and marine uses. During the last two centuries, depletion of natural ecosystem has increased many folds that show its effects even at global levels, such as climate change, large ecosystem fragmentation and degradation, and species extinctions. Although there are multinational concerns and talks for ecosystem conservation, but the negative momentum is as yet only barely affected. The efforts should include planning, monitoring and enforcement related to both terrestrial and aquatic ecosystems and about their resource uses, environmental assessment, pollution and species at risk. The need for conservation action be given priority both nationally and globally (Schwartz *et al*., 2000; Lindenmayer *et al*., 2006; Eigenbrod *et al*., 2009).

Conservation issues that need to be addressed in the short-, medium- and long-term include:

Risk assessment

1. Identification of both terrestrial and aquatic ecosystems at greater risk due to habitat loss and habitat degradation

2. Identification of causes of ecosystem degradation (pollution, overgrazing, land clearing, illegal hunting, etc.)
3. Identification of mechanisms for the sustainability of resource uses and practices to find alternatives; managing the material, energy and spatial efficiency of demands on biodiversity and ecosystems
4. Practical application of the principles for maintaining ecological integrity, ecosystem management and resilience.

Public awareness

1. Promoting the need to adopt ecofriendly life style/mind-set
2. Public participation in ecosystem conservation through NGOs, local governments and professional groups (such as farmers, fishers) as well as the general public to be more involved in order to change the gear and to bridge scientific knowledge with policies
3. Awareness of academic students, teachers, scientists and public about the ecosystem values and need for their sustainability
4. Associating students, academia, scientists and general public for ecosystem conservation
5. Organize seminars/walks and symposia for developing ecosystem conservation strategies

Management practices

1. Promoting *in-situ* conservation and if crucial, *ex-situ* conservation of endangered species
2. Regulating invasion of alien invasive species
3. Managing/regulating the ecosystem use not exceeding its service capacity
4. Ensuring continuity in ecosystem resource regardless of human utility. If possible need to invoke a "no use" strategy of threatened resources
5. Patterns of human use of ecosystem sources be based on consumptive and productive use with maximum sustainable yield (MSY)
6. Reducing threats to ecosystems under tragedy of the commons
7. To promote the importance of soil and water protection

Control of pollution

1. Exploitation of environment-friendly energy resources
2. Reducing emission of greenhouse gases
3. Discourage emitting pollution by imposing a carbon emission tax

Habitat protection

1. To set more quantitative targets for nature conservation (climate change or pesticide reduction)
2. Controlling desertification through overgrazing, waterlogging and soil salinity
3. Conservation strategies require establishing an interconnected network of water bodies, wetlands, woodlands, wildlife habitats, parks and other conservation lands, ranches and forests, wilderness and other open spaces that support native species
4. Controlling habitat fragmentation through man-made structures (roads, railway tracks, gas pipelines, canals, etc.)
5. Establishing protected areas
6. Provision of wildlife corridors/greenways

Conclusion

It is amply clear that world's ecosystems are being degraded by human activities. The problem is worst in developing countries like Pakistan, where the ecosystems of international importance are being degraded at an accelerated rate due to increasing influence of exploding human population. We need to adopt an immediate conservation measure to protect these ecosystems. As a first conservation strategy, students, teachers, scientists and general public should have awareness about the threats to endangered national and international ecosystems and importance of their conservation and sustainability. Secondly, we need to develop strategies to overcome/minimize anthropogenic threats to ecosystems such as extensive habitat loss (unplanned urbanization, deforestation, intensive agriculture, etc.) and habitat degradation (industrial pollution, extensive use of fossil fuels, pesticides and fertilizers, etc.). The threats to biodiversity in our natural and anthropogenic should be monitored and *in-situ* and *ex-situ* conservation strategies opted for protection of endangered species. Wildlife reserves, protected areas and wildlife sanctuaries need to be defined and monitored for protection of endangered ecosystems. In this way can ensure the healthy existence of these systems for our future generations.

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