Trees (2002) 16:235–238
DOI 10.1007/s00468-002-0168-4

ORIGINAL ARTICLE

Zafar Adeel · Robert Pomeroy

Assessment and management of mangrove ecosystems in developing countries

Received: 12 July 2001 / Accepted: 21 December 2001 / Published online: 5 March 2002

Abstract There is limited information available on the status of and threats to mangroves in developing countries in the Asia-Pacific region. In the recent years, there has been a significant increase in scientific and volunteer surveys. However, this information is usually not well integrated with information on human activities that have the potential to contribute to the degradation of these ecosystems. A project "Coastal Habitats at Risk" is being developed jointly by the United Nations University (UNU) and the World Resources Institute, and in partnership with UNESCO and the International Society for Mangrove Ecosystems (ISME), in an effort to ameliorate this situation through standardized assessment of anthropogenic threats to mangroves in East and Southeast Asia. The geographic focus of the project includes Brunei, China, Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Taiwan, Thailand and Vietnam. Threats from pollution, over-harvesting, aquaculture development, boating/shipping, flooding/freshwater input, siltation and other coastal development are examined with this map-based analysis. The study particularly emphasizes information regarding the human element of these ecosystems, with an eye towards community-based management and action. A geographic information system (GIS)-based tool will be developed to examine different coastal development and management scenarios and their implications for mangrove health, diversity and value. The results will serve as an indication of the threats to these ecosystems, not as an actual measure of degradation. This information generation can be seen as a first step toward assessing global needs for the world's mangrove ecosystems that to date remain largely unassessed. The analysis is intended to recommend policies, participatory approaches and management strategies to promote integrated coastal ecosystem approaches. It will help fill an information void through much-needed policy guidance on management and priority setting.

Keywords Mangrove habitats · Sustainability · Assessment · Geographic information system

Z. Adeel (✉)
Environment and Sustainable Development,
The United Nations University, 5-53-70 Jingumae, Shibuya-ku,
Tokyo 150-8925, Japan
e-mail: Adeel@hq.unu.edu
Tel.: +81-3-34992811, Fax: +81-3-34067347

R. Pomeroy
World Resources Institute, 10 G Street, NE,
Washington, DC 20002, USA

Introduction

The sustainability of coastal and marine resources and ecosystems is plummeting just when human populations are at the peak of a massive migration to these coastal zones. Coastal zones currently provide living space for some 55% of the world's population. Humans draw heavily on coastal and marine ecosystems for food including aquaculture and shrimp farming, construction sites for urban and industrial uses; transportation, recreational and tourism uses and waste disposal. The potential impact of the degradation of coastal and marine ecosystems on communities, human health, food security, biodiversity conservation, and local economies will be multiplied as population increases. The need for systematically collecting information for evaluating the status and impacts on these habitats is obvious.

In tropical areas, mangrove forests are vital for healthy coastal ecosystems. Mangrove leaf-litter detritus provides a principal source of nutrients for the trophic food web and juvenile fisheries. Mangroves are characterized by particularly high productivity of organic matter (leaf litter input average 10 ton/ha per year), in spite of relatively low standing biomass (average 150 ton/ha). Often exposed to high-energy systems, mangroves provide protective habitat as spawning, nursery, and feeding grounds for juvenile fish, crabs, shrimps and mollusks. Estimates indicate that nearly 90% of all marine organisms spend some portion of their life cycle within mangrove systems. Mangroves are also prime nesting sites for hundreds of bird species.

Table 1 Mangrove area estimates for Asia by WCMC (Source: Spalding et al. 1997, figures derived from maps and other published sources)

Country	Area (km^2)
Bangladesh	5,767
Brunei Darussalam	171
Cambodia	851
China and Taiwan	366
Hong Kong	2.82
India	6,700
Indonesia	42,550
Japan	4
Malaysia	6,424
Myanmar	3,786
Pakistan	1,683
The Philippines	1,607
Singapore	6
Sri Lanka	89
Thailand	2,641
Vietnam	2,525
Regional total	75,173

Traditionally, mangrove ecosystems have been sustainably managed by local populations for the production of food, medicines, tannins, fuel wood, and construction materials. In other words, mangroves offer food, shelter and livelihoods to millions of coastal dwellers. The protective mangrove buffer zone also helps to minimize damage to property and loss of life from storms. While geographical distribution is highly variable, mangroves line approximately 8% of the world's coastline in terms of length. Approximately 112 countries and territories have mangroves within their borders; see Table 1 for an overview of Asia.

Naturally resilient, mangrove forests are now being lost through human encroachment. Mangrove forests are among the most threatened habitats on Earth, disappearing at an alarming rate, with little public notice. Mangrove forests are disappearing as a result of extraction, oil spills, pollutants, attacks by parasites, and prolonged flooding and freshwater intrusion, often as a result of artificial dams and causeways. Charcoal and timber industries have also severely impacted mangrove forests, as have other coastal developments. The rapidly expanding shrimp aquaculture industry poses a major threat to the world's mangroves. Until recent better ecological understanding, mangrove forests have been classified by many governments as useless swamps or "wastelands". This erroneous designation has made it easier to exploit forests as cheap and unprotected sources of land for development.

Although there are general statistics available on the global status of mangrove forests, the exact extent of the remaining forests and the exact rate of their loss are not known. Estimates of current mangrove extent vary widely, possibly due to differences in definition, assessment methodology, or other inconsistent land cover information sources used. Fast declines continue at an assumed rate of 2–8% loss per year. It is clear that given its low contribution to the world's forest cover and correspondingly high contribution toward global fisheries production and marine biodiversity, the mangroves that remain are one of Earth's most valuable and threatened natural systems.

There are no global or even regional maps which show the "original" distribution of mangroves with sufficient resolution and degree of confidence, to measure the temporal differences in mangrove distribution. While scientists have no way of knowing exactly how extensive mangroves were before people began to alter coastlines, based on historical records it is known that mangrove area has declined considerably. It is estimated that anywhere from 5% to 80% of original mangrove area in various countries, where such data are available, has been lost (see Table 2 for a region-by-region overview). It can be said that the general trend for areas covered by mangroves is clearly downward, but in some regions mangrove area is actually increasing. This is most likely as a result of plantation forestry and small amounts of natural regeneration and improved management through private and communal property rights regimes.

A project "Coastal Habitats at Risk" is being developed jointly by the United Nations University and the World Resources Institute, and in partnership with UNESCO and the International Society for Mangrove Ecosystems, in an effort to ameliorate this situation through standardized assessment of anthropogenic threats to mangroves in East and Southeast Asia. The project focuses on the East and Southeast Asian region. Threats from a number of anthropogenic sources in the region will be examined with this map-based analysis. The study will be undertaken with an eye towards community-based management and action. It is anticipated that the results will also enable quantification of threats to these ecosystems.

Materials and methods

The geographic focus of Coastal Habitats at Risk is on East and Southeast Asia: Brunei, China, Cambodia, Indonesia, Japan, Malaysia, Myanmar, the Philippines, Singapore, Taiwan, Thailand and Vietnam. This regional focus is based on the high coastal and marine biodiversity in this region; the high level of threat to coastal and marine resources and ecosystems; and the high level of competence of the partner institutions to implement the project.

In cooperation with regional and international partner institutions, a regional scale analysis will be undertaken to link human activities with mangrove habitat condition, and to support protection and conservation priority setting through a systematic, data-rich analysis. This approach relies upon incorporating existing information on current threats to the habitats, the condition and characteristics of the habitats, and the level of management and protection afforded these habitats (such as protected areas and regulations), coupled with economic and ecological value. Base maps on mangrove locations have been published in the World Mangrove Atlas (Spalding et al. 1997).

The analyses of mangroves undertaken during the project will comprise the five categories listed below. Although the overall emphasis will be on preparing regional-scale synthesis, localized case studies will be undertaken in areas with potentially high level of threats or on sites with extended rehabilitation and conservation

Table 2 Mangrove loss. Selected countries with available data from the World Resources Institute 1991, 2001

Region and country	Approximate percent lost	Period covered	Source
Africa			
Angola	50	Original extent to 1980s	a
Ivory Coast	60	Original extent to 1980s	a
Gabon	50	Original extent to 1980s	a
Guinea-Bissau	70	Original extent to 1980s	a
Kenya	4	1971–88	b
Tanzania	60	Original extent to 1980s	a
Latin America			
Costa Rica	–6 (gain)	1983–90	c
El Salvador	8	1983–90	c
Guatemala	72	1983–90	c
Mexico	65	1970s to1992	d
Panama	67	1983–90	c
Peru	25	1982–92	d
Asia			
Brunei	20	Original extent to 1986	e
Indonesia	55	Original extent to 1980s	e
Malaysia	74	Original extent to 1992–93	e
Myanmar	75	Original extent to 1992–93	e
Pakistan	78	Original extent to 1980s	a
Philippines	67	1918 to 87–88	f
Thailand	84	Original extent to 1993	e
Vietnam	37	Original extent to 1993	d, g
Oceania			
Papua New Guinea	8	Original extent to 1992–93	e

Sources:
a. World Resources Report 1990–91; b. UNEP (1997); c. Davidson and Gauthier (1993); d. Spalding et al. (1997); e. Mackinnon (1997); f. World Bank (1989); BAP (1993)

activities. The project also involves spatial and statistical analysis of the integrated data sets. This analysis will rely on more detailed local area modeling of the relationship between socioeconomic activities and mangrove forest condition but will also permit model implementation over a wider area. All data integration and model results will be evaluated and revised based upon scientific review and a workshop held in the region. Based on the model implementation and results, a geographic information system (GIS)-based planning tool will be developed which allows examination of different coastal development and management scenarios and their implications for mangroves.

I. *Location and status of mangroves.* The analysis will incorporate information about specific mangrove areas within the geographical coverage. The following elements will be emphasized:

1. Information from experts and existing management/monitoring programs about the location and condition of mangroves
2. Information on type and size, including historical information
3. Information on biological diversity (species richness and endemism) would be incorporated at the highest resolution possible

II. *Evaluation of threats to mangroves.* Threats will be examined through the development of refined decision rules, using high-resolution data sets to reflect threat, and socioeconomic background information to provide context and to differentiate threats. Threats to mangroves include, but are not limited to:

1. Inland pollution and marine oil spills
2. Over-harvesting
3. Aquaculture and shrimp farming development
4. Flooding/freshwater, dam/causeway development
5. Residential/commercial development
6. Extraction for charcoal and construction materials use

Distance relationships with human activity (city/town, population, industrial activity) and land and water uses will be identified and correlated with predicted risk zones of likely environmental degradation. The distance rules define threat zones around the habitat. Zones of high, medium and low threat will be estimated for each of the threat factors, and combined in spatial overlay with a data set reflecting the location of the habitat.

III. *Documentation and modeling of ecosystem protection.* Current information on management, protection and conservation of mangroves is poor. Particularly, the socio-economic impacts on communities are overlooked or inadequately addressed. A richer and more detailed data set on management, including institutional arrangements, participatory approaches, locations, extent and effectiveness, will be developed in conjunction with local partners. This data "layer" is invaluable for examination of conservation priorities. Additionally, information on coastal zone management and other policies relevant to pressures on coral reefs and mangroves will be integrated.

IV. *Policy and management recommendations.* The study will recommend policies, participatory approaches and management strategies to promote integrated coastal ecosystem protection. Management measures to protect and conserve mangrove forests will be enhanced through the recommendation of alternative management strategies.

V. *Dissemination of information and awareness raising.* A significant component of the project will be devoted to the dissemination of the key findings of the project to the target audience identified earlier. This will be achieved primarily in three ways. Firstly, the workshops and a regional conference included in the project will explicitly involve local communities. This will enhance the level of awareness of the general public and scientific community alike. Secondly, more conventional approaches of dissemination including books, workshop proceedings, CD-ROM and internet distribution will be fully utilized. Thirdly, a major public campaign will accompany the first two. Full-color brochures and handbooks will be useful in the last approach.

Discussion

Coastal Habitats at Risk will undertake a standardized assessment of anthropogenic threats to mangroves in East and Southeast Asia. While other projects have attempted to provide an overview of the distribution of mangroves, the potential risk associated with human activities has not been measured before. The GIS-based tool will examine different coastal development and management scenarios and their implication for mangrove health, diversity and value. Threats from pollution, over-harvesting, aquaculture development, boating/shipping, flooding/freshwater, siltation and other coastal development will be examined within this map-based analysis.

The study is intended to help fill an information void through needed policy guidance on management and priority setting. The study will particularly emphasize on gathering information regarding the human element of these ecosystems. The study will recommend policies, participatory approaches and management strategies to promote integrated coastal ecosystem protection. The results of this study will be used as an indicator of potential threat (risk), not a measure of actual condition. In some place, particularly where good management is practiced, mangrove forests may be at risk, but remain relatively healthy.

Expected outcomes

A number of outputs will be generated by the project, including:

1. Hardcopy maps reflecting best available and consistent extent of mangrove habitats in the region, as well as quantifying the threats.
2. Digital data sets reflecting best estimates of threats, value, protection and management status.
3. Policy brief with recommendations on policies and management strategies to promote integrated ecosystem approaches to protect and conserve mangrove ecosystems.
4. Internet-based dissemination of results.
5. GIS-based planning tool for scenario evaluation, linking human activities with ecosystem degradation.

The most important impact of Coastal Habitats at Risk will be long-term through improvements in the conservation and protection of mangrove forests in East and Southeast Asia. Awareness about the ecological importance and threats to mangroves will be increased among the public, policy-makers, environmental officials and managers, NGOs, the scientific community, and international lending and development institutions, foundations and other funding organizations. The project is anticipated to lead to improvements for mangroves in priority setting, decision-making and donor coordination for conservation, protection, and research. These improvements will benefit national and local governments in the region, international lending and development institutions and donor institutions for these ecosystems. Management measures to protect and conserve mangrove forests will be enhanced through the recommendation of alternative management strategies such as ecosystem-based management, co-management, property rights regimes, and adaptive management. Most importantly, this study will contribute to livelihood security of the people dependent on mangroves. It is anticipated that local case studies will quantify the worth and success of community based approaches for conservation and protection.

References

BAP (1993) Biodiversity action plan (BAP) for Vietnam. BAP Planning Team, Hanoi, Vietnam

Davidson I, Gauthier M (1993) Wetland conservation in Central America. North American Wetlands Conservation Council, Ottawa, Canada

Mackinnon J ed. (1997) Protected areas systems review of the Indo-Malayan realm. Asian Bureau for Conservation, Canterbury, UK

Spalding M, Blasco F, Field C (eds) (1997) World mangrove atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan

UNEP (United Nations Environment Programme) (1997) *Eastern African coastal and marine environment resource database.* – Geographical Information Systems (GIS) data. UNEP Global Resource Information Database, Nairobi, Kenya

World Bank (1989) Philippines: Environment and natural resource management study. World Bank, Washington DC, USA

World Resources Institute (1991) World Resources Report 1990–91. World Resources Institute, Washington, D.C. USA

World Resources Institute (2001) World Resources Report 2000–2001. World Resources Institute, Washington, D.C. USA