ISSN 0919-2646

ISME
International Society for Mangrove Ecosystems

mangrove ecosystems technical reports

volume 5

TWO PAPERS ON MANGROVE ECOSYSTEMS

Part I

Asian Pacific Mangrove Information Network (APMIN) - a Conceptual Model

by Vishwas S. Chavan, Tanaji G. Jagtap and Arvind G. Untawale

Part II

Atoll Mangroves and Associated Flora from Republic of Maldives, Indian Ocean

by Tanaji G. Jagtap and Arvind G. Untawale

June 1999

International Society for Mangrove Ecosystems

ISME Mangrove Ecosystems Technical Reprots Volume 5

Two papers on Mangrove Ecosystems

Part I

Asian Pacific Mangrove Information Network (APMIN) - a Conceptual Model
by Vishwas S. Chavan, Tanaji G. Jagtap and Arvind G. Untawale

Part II

Atoll Mangroves and Associated Flora from Republic of Maldives, Indian Ocean
by Tanaji G. Jagtap and Arvind G. Untawale

Editor: M. Vannucci

June 1999

International Society for Mangrove Ecosystems

Asia Pacific Mangrove Information Network (APMIN) A Conceptual Model

Vishwas S. Chavan*; Tanaji. G. Jagtap** and Arvind. G. Untawale**

* Center for Cellular and Molecular Biology, Hydcrabad - 500 007, India
** National Institute of Oceanography, Dona Paula, Goa 403 004, India

First submitted May 1994; finally revised May 1999

Abstract

Asia Pacific Mangrove Information Network (APMIN), its structure and scope, is discussed in this paper. Establishment of National Mangrove Information Centers (NMIC) in 20 Asia-Pacific countries, would contribute towards development of databases related to mangrove environments, which would lead to production of computer-based learning and awareness packages. These packages would greatly help in formulating strategies for the conservation and management of mangrove resources on a sustainable basis.

Key Words: Mangrove Ecosystem, Asia-Pacific, Information Network, National Data Center, Database, Internet, Conservation, Management.

Introduction

Mangroves, a common feature of coastal tropics and subtropics, are of vital economic and ecological importance (MacNae, 1968, Odum *et al.*, 1972). Mangrove forests of 20 countries in the Asia-Pacific region cover about 480,000 sq. km. (Snedaker, 1984). They serve as nutrient resource and nursery grounds (Jagtap *et al.*, 1993) for the juvenile stages of numerous commercial species of fishes and shrimps. Down the ages mangrove regions have been exploited for capture and captive fisheries and various other products (Durante, 1992). Furthermore, mangrove forests protect the shore from high waves and tropical storms, stabilize the substrate by compacting sediments and thus may keep pace with sea level rise. However, these valuable habitats are being destroyed (Rao, 1987, Untawale, 1991) mainly for agricultural and urbanization purposes. The socio-economic, commercial and ecological importance of mangroves has been recognized during the last few decades, and coastal zone managers have emphasized the need for immediate conservation of mangroves. Over 150 organizations in the Asia-Pacific region have generated a vast amount of information (Jara *et al.*, 1987) on mangroves. However, this information is scattered and not easily accessible. Computerization of data on the mangrove ecosystem is therefore essential for effective management. A review (Chavan, 1993, Chavan *et al.*, 1995) of the world databases reveals no subject-specific database on mangroves, hence even bibliographic information needs to be searched in different databases. A global bibliography on mangroves (Rollet, 1981) accounts for only 1567 out of 6000 entries from the Asia-Pacific region for the period 1600-1975 and these figures appear to be an underestimate. For instance, a bibliography of Indian mangroves (Untawale *et al.*, 1982) documents 404 references until 1975, whereas Rollet (1981) records only 262 references for the same period. This discrepancy suggests that most of the literature compiled by Rollet (1981) probably represents original publications in the archives of major libraries in Europe and that many references in the form of theses, in-house publications, project reports etc., are not included. The same may be the case with Aquatic Sciences and Fisheries Abstract (ASFA) (Jara *et al.*, 1987), which

publishes information on mangroves generated after 1975. Similarly, no textual or numeric databases exist on mangrove ecosystems, which collate hard scientific facts. Internet, a network of networks spread across the globe reaches to 100 million people and is growing at the rate of 10% per month. Information retrieval tools and search engines (Chavan *et al.*, 1997 and Chavan, 1998), provide various ways to access the vast amount of public information available across the Internet. Extensive surfing on the cyberspace reveals that very few resources related to mangroves are being hosted (Table 1) indicating the need for establishing National Mangrove Information Centers (NMIC) in the countries of the Asia-Pacific region. These Data Centers will facilitate information exchange/sharing among mangrove researchers, and coastal zone managers in the region. An inter-connection of NMICs through Internet would automatically form the Asia-Pacific Mangrove Information Network (APMIN).

Scope of APMIN and the Infobase(s)

Various kinds of information on mangrove ecosystems could be acquired in the form of databases, analyzed and disseminated to the end users. Research and surveillance (Figure 1) of mangrove research produces a huge amount of data, which is multi-elemental-componental-seasonal-locational (4m) in nature. These data could be bibliographic, referral or factual in nature. Factual data can be in text, numeric, graphics and audio-video form. The scope and content of a variety of mangrove databases (Figure 2) which form the base for Computer-Aided Taxonomy (CAT) (Chavan *et al.*, 1998), Computer-Based Learning Modules (CBLM) and awareness packages on mangroves are described in the following sections. Species Database and Taxonomic Identification System A correct identification of species is absolutely essential for monitoring diversity, ecotypic change and preservation. Inadequate taxonomic information hampers research and conservation initiatives hence there is a need (Schalk, 1992; Duellman, 1992 and NOAA, 1984) for directly accessible taxonomic information and expertise. The species database would include taxonomic information on mangroves. A Numerical Taxonomic Code (NOAA, 1984 and Chavan *et al.*, 1991) based on taxonomic information could be allotted to individual species, which would facilitate identification and easy comparison among groups. A Numerical Taxonomic Code is a hierarchical system of upto 12 digits, which identifies an organism to the level of species and subspecies or variety (Table 2a). The code links the Linnaean system of biological nomenclature to a numerical scheme that facilitates data storage and retrieval (Chavan *et al.*, 1991). For example: *Sonneratia alba*, a mangrove plant is coded with 10 digits 3250010101 to identify and address every record of this species also in different databases (Table 2b). Furthermore, Object-oriented modeling provides the tools for modeling realistically complex biological domains such as taxonomy. Saarenmaa *et. al.* (1995) demonstrated a combination of object-oriented databases and World Wide Web (WWW) front-ends for managing taxonomic biodiversity information. Chavan *et al.* (1998a, 1998b) demonstrated the use of web interfaced RDBMS (Relational Database Management System) such as mSQL and MS-ACCESS in developing databases for collating and disseminating multimedia information on taxonomy. Vargiki - Plantae (HYPERLINK http://dolphin.nio.org/plantae/ http://dolphin.nio.org/plantae/) and Vargiki - Animalia (http://www.nio.org/animalia/) collates information on marine plants and animals (Chavan *et al.*, 1998).

Vargiki - Plantae (Figure 3-5) currently collates information on mangroves of India in multimedia form and allows experts irrespective of once physical location to add or edit the data in real time (Figures 3-5). Retrieval of information from such a database (Figures 6-7) enhances the user-friendliness of the information resource and thereby ensures its early enrichment. Such a database with added search features prevents

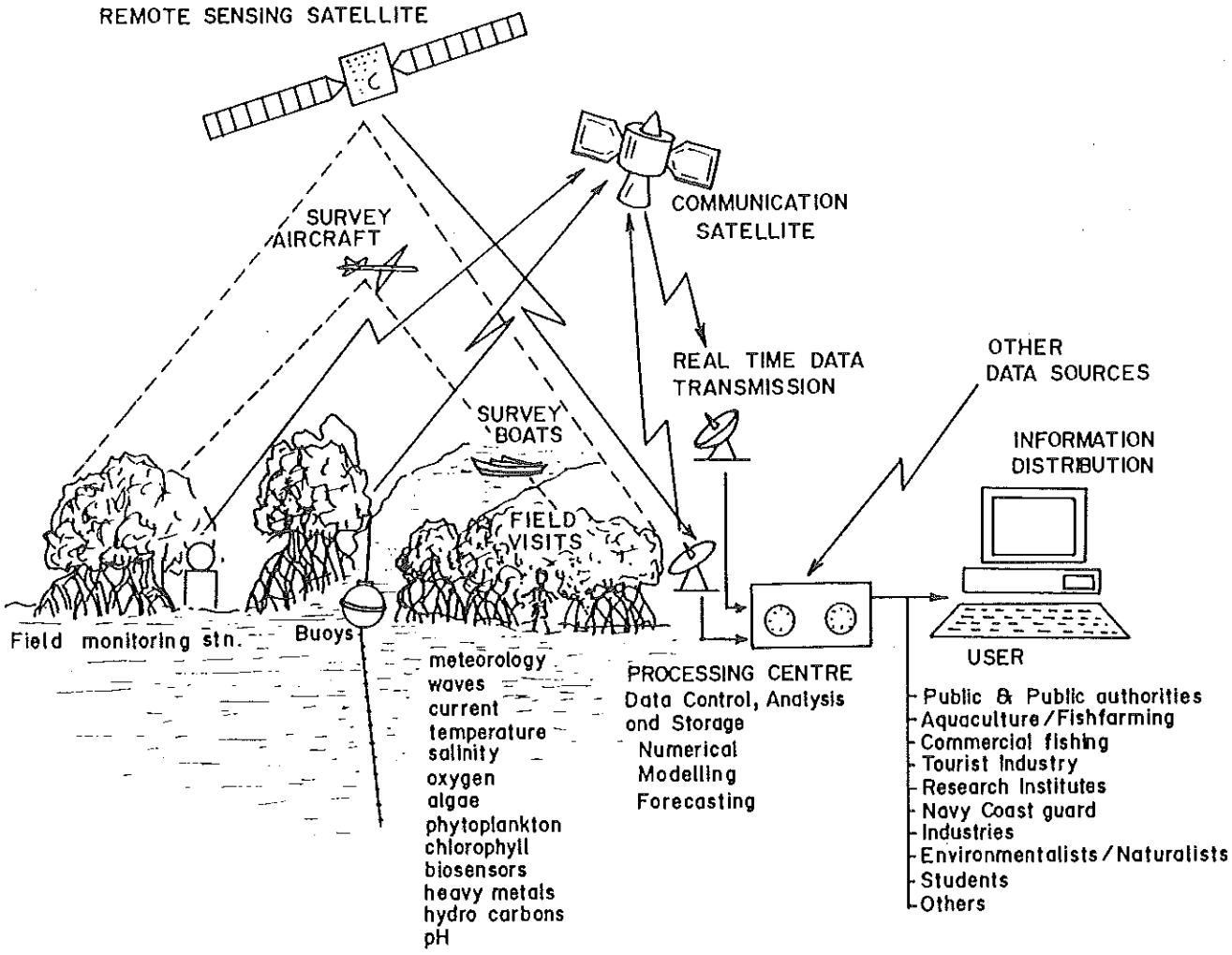

Figure 1. Mangrove Ecosystem Surveillance

taxonomists or systematicians from repeatedly identifying the same species. It would makes taxonomy, which is a basic block of biological sciences, "easy-to-understand" for students and researchers. In addition to taxonomic data, morphological, anatomical, phenological, cytogenetical and biochemical features of the species along with the *in situ* and *ex situ* identification keys can also be stored in the database (Figures 4-5). Biogeographic details would cover the distributional status of a mangroves (composition, extent, density, frequency etc.) and techniques used for collection, studies and interpretation. The database would also include the ecological parameters and subsequent morphological, physiological, biochemical, cytogenetical and reproductive adaptations of the species. (ii) Associate Biota Database: A database for biota associated with mangroves could be developed on similar lines to emphasize the ecological role of these associated species in the mangrove ecosystem. (ii) Database on Mangrove Ecosystem Degradation: The impact of natural and man made causes of degradation of mangrove ecosystems could be collated under this database. The extent and nature of pollution in future years could also be estimated along with a review of the present strategies adopted to mitigate or curb degradation. Future strategies required could also be listed. (iv) Socio-economic Database: The exploitation of mangrove ecosystems and attendant cost benefit analysis, the impact of human settlements and land use patterns will be included in this database. Data on different communities and impact of

Table 1. Web based Mangrove Resources

Resource Title Resource Locator
Mangrove Action Project (MAP) HYPERLINK http://www.earthisland.org/map/ http://www.earthisland.org/map/
Mangrove Replenishment Initiative HYPERLINK http://mangrove.org http://mangrove.org
The Western Australian Mangrove Page HYPERLINK http://possum.murdoch.edu.au/~mangrove/ http://possum.murdoch.edu.au/~mangrove/
Indonesian Mangrove Foundation HYPERLINK http://www.mangrove-f.org http://www.mangrove-f.org/
Mangroves and Salt Marshes Journal HYPERLINK http://ibm590.aims.gov.au/reports/masm.html http://ibm590.aims.gov.au/reports/masm.html
Cairns Online Environment Guide HYPERLINK http://www.env.gld.gov.au/environment/ http://www.env.gld.gov.au/environment/
Coral Reefs and Mangroves: Modeling and Management HYPERLINK http://ibm590.aims.gov.au/ http://ibm590.aims.gov.au/
Mangrove Outfitters - Flyshop / Guide Services HYPERLINK http://www.mangroveoutfitters.com http://www.mangroveoutfitters.com
John Pennenkamp Coral Reef State Park Web Site HYPERLINK http://www.redmoon.net/outdoor/jpsp.htm http://www.redmoon.net/outdoor/jpsp.htm
Everglades Plant Diversity HYPERLINK http://www.biol.andrews.edu/everglades/plant.htm http://www.biol.andrews.edu/everglades/plant.htm
Nutrient Exchange Between Florida Bay and Everglades Salinity Transition Zone: Work Plan HYPERLINK http://www.lsu.edu/guests/wwwcei/nutrient/title.html http://www.lsu.edu/guests/wwwcei/nutrient/title.html
Mangrove Ecology at Northern Territory University HYPERLINK http://www.ntu.edu.au/faculties/science/sbes/research/mangrove-ecol.htm http://www.ntu.edu.au/faculties/science/sbes/research/mangrove-ecol.htm
Sevari Mangrove Park HYPERLINK http://theory.tifr.res.in/bombay/leisure/travel/mangrove.html http://theory.tifr.res.in/bombay/leisure/travel/mangrove.html
Pichavaram Mangrove Wetland HYPERLINK http://www.mssrf.org/gpbmain.htm http://www.mssrf.org/gpbmain.htm
Mangrove Research Discussion List HYPERLINK http://206.109.1.6/internet/paml/groups.m/mangrove.html http://206.109.1.6/internet/paml/groups.m/mangrove.html

Table 1. (continued)

Resource Title Resource Locator
Coral Reef, Mangrove, Seagrass and CMZ Web Sites
HYPERLINK http://www.ncl.ac.uk/tcmweb/tcm/mglinks.htm http://www.ncl.ac.uk/tcmweb/tcm/mglinks.htm
The coastal management Web
HYPERLINK http://www.coastweb.com.au/subjectsf.html http://www.coastweb.com.au/subjectsf.html
Florida Plants Online
HYPERLINK http://www.floridaplants.com/mangrove.htm http://www.floridaplants.com/mangrove.htm

mangrove ecosystem on their life style and status of urbanization or industrialization could be fed into the database and predictions obtained for future years. (v) Management-Conservation Database: This database could review the status of the environment and list the need and scope for protection, conservation and sustainable resource utilization. It would also collate the present conservation and management techniques along with lacunas, attitude and participation at different levels. (vi) Bibliographic Database: A bibliographic database could cover publications pertaining to the mangrove ecosystem. For this purpose, the internationally recommended formats like Aquatic Sciences and Fisheries Abstracts (ASFA), could be followed to increase exchange/sharing possibilities. (vii) Expertise and Project Databases: These databases would store information on the experts, various completed and ongoing projects, organizations involved in funding, research, conservation and management of mangrove ecosystems. Such web interfaced directories (Chavan *et al.*, 1998) would help in preventing duplication of efforts, maintain the quality of research and allow selection of potential institutes and experts to undertake special tasks.

Information Analysis and Packaging

The problem of managing mangrove resources is complicated by the lack of communication between oceanographers, biologists, resource managers and environmental educators. Information Technology has enabled great advances such as data mining, merging multidisciplinary data sets, and computer visualization of complex data sets from the field and models. IBM International Foundation's project on modeling of coral reefs and mangroves [http://ibm50.aims.gov.au/reports/year3_report/executive.html] in collaboration with Australian Institute of Marine Sciences (AIMS) has demonstrated how to answer the questions arising from the pressing needs of mankind. The above referred information bases individually or in combination with modeling and visualization techniques, would produce user-friendly information packages for education and awareness purposes. Computer-Based Learning Modules (CBLM) could be developed to interpret the complexity of this important ecosystem (Gautier *et al.*, 1990, Troost *et al.*, 1991). Computer-Aided Taxonomy (CAT) could be a concrete solution towards taxonomy for promoting taxonomists. Ecological and physiological mechanisms, association and energy circulation within the ecosystem could be made simpler through such modules (Hopkins *et al.*, 1998, McManus, 1990) in the form of floppies or audio-visuals. Virtual Reality applications may also be built to simplify these complex processes for understanding.

Table 2. Numerical Taxonomic Code

a. Scheme of Numerical Taxonomic Code 15,18,19	
02 Digits	Sub Kingdom, Phylum, Sub Phylum, Class, Superorder, Order.
04 Digits	Superclass, Class, Subclass, Superorder, Order Suborder, Infraorder, Superfamily.
06 Digits	Class, Order, Suborder, Infraorder, Superfamily, Family, Subfamily, Infrafamily.
08 Digits	Genus
10 Digits	Species
12 Digits	Subspecies, Variety.

b. Numerical Taxonomic Code for few mangrove species. (parenthesis indicates the taxonomic level)	
32	Anthophyta (P)
3201	Magnoliatae (SP)
3247	Rosidae (C)
3250	Myrtales (O)
325001	Sonneratiaceae (F)
32500101	Sonneratia (G)
3250010101	*Sonneratia alba*
32	Anthophyta (P)
3201	Magnoliatae (SP)
3247	Rosidae (C)
3256	Euphoriales (O)
325602	Euphorbiaceae (F)
32560201	Excoecaria (G)
3256020101	*Exocecaria agallocha*

Abbreviations. (P): Phylum; (SP): Sub Phylum; (C): Class; (O): Order; (F): Family; (G): Genus.

Data Acquisition

Data could be acquired through and checked by a network of scientists, sociologists, economists, naturalists and environmentalists (Figure 8), and through publications, personal communication and purchase and exchange programs. Data collation could be achieved by both online and offline ways. For offline data collection Data Entry Program (DEP) on diskettes or CDROM would be provided to the potential information generators to enlist their active involvement and rapid acquisition of data. Returned data would be fed into database(s) being developed by NMIC's at national level and into Meta-database(s) at the headquarters of APMIN. Data Entry Program should be platform independent. Data sets would be reviewed and updated regularly for quality control of the products, as is the case with publications in scientific journals. Standardized glossaries and thesaurus need to be built to increase the user-friendliness of database(s), and thus their accessibility. For online data collection web interfaced modules should be hosted at each national web site and also at the headquarters of APMIN. Enough security measures should be taken to prevent any tampering and loss of accumulated information. Structure of various databases should be open-ended so that addition of new parameters could be incorporated. In order to maintain

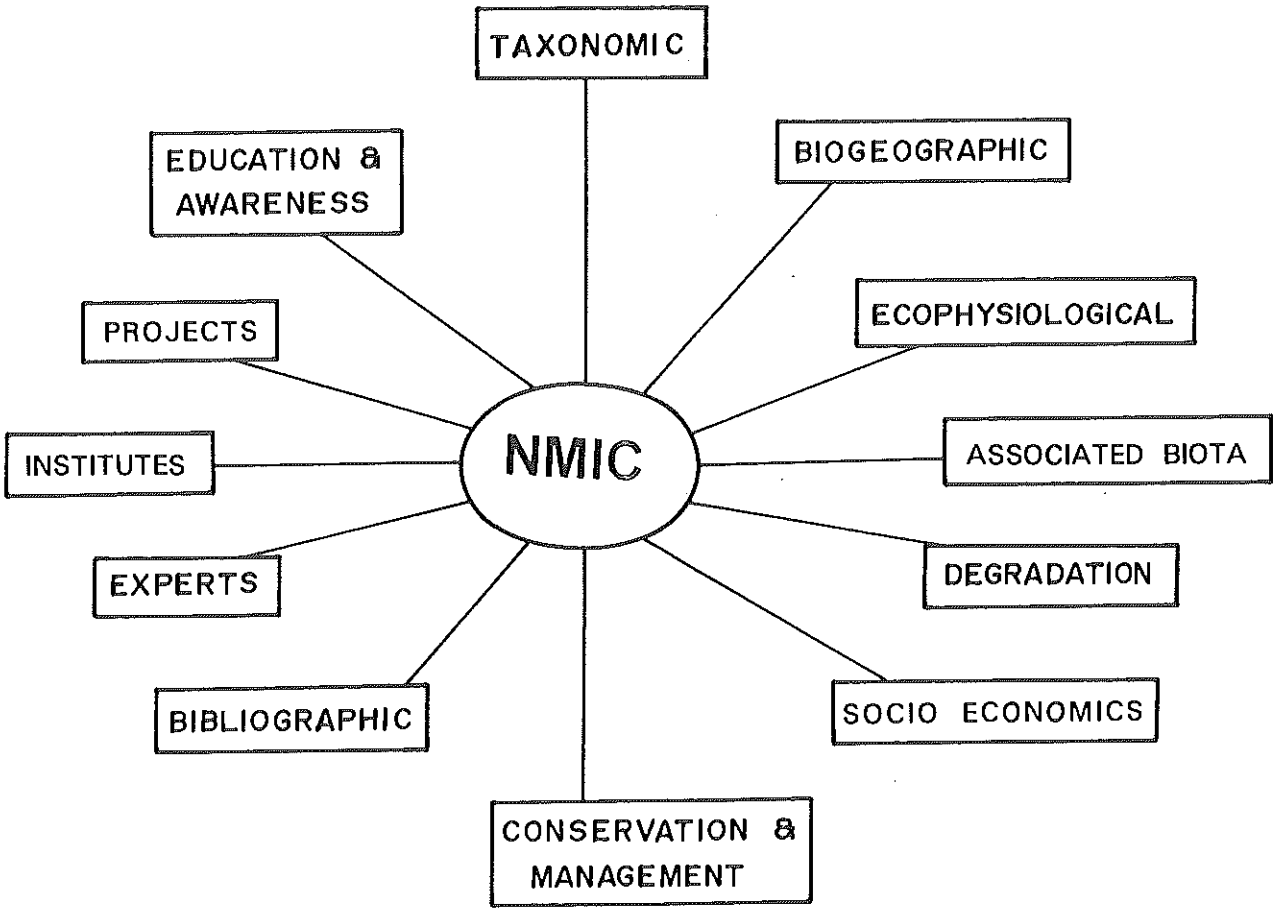

Figure 2. Database(s) development scope to APMIN

quality of collated standardized terminology as well as validity and authentication, mechanisms needs to be derived.

Dissemination

Information generated by APMIN would be disseminated offline to potential users in the form of publications, Topic-Oriented Sub-sections (TOS) on floppy and CDROMs, Awareness packages, CBLM. Speedy retrieval of data should be possible on a "need-to-know" basis. TOS should be platform-independent and run at any time, any place on a relatively simple PC. Hypertext based multimedia information packages such as "Mangroves of India" (Bioinformatics Centre, National Institute of Oceanography, Goa, India ISSN 0971-9466) would be the best example of such TOS. Online information dissemination could be achieved by accessing the web sites of NMICs and headquarters of APMIN over the Internet. Each NMIC web site could perform dual role, first online collation of data on mangrove ecosystem under its jurisdiction and second perform as the national mirror site of APMIN headquarter. This would offer higher degree of flexibility, ease and efficiency in collation and dissemination of data across the globe.

Potential cites for APMIN headquarters and NMICs could be established at the NATMANCOM's (National Mangrove Committee) secretariat of each participating country. However, the International Society for Mangrove Ecosystem (ISME), which aims to develop a "Mangrove Information Network" at the global level, is in the process of identifying information centers in each

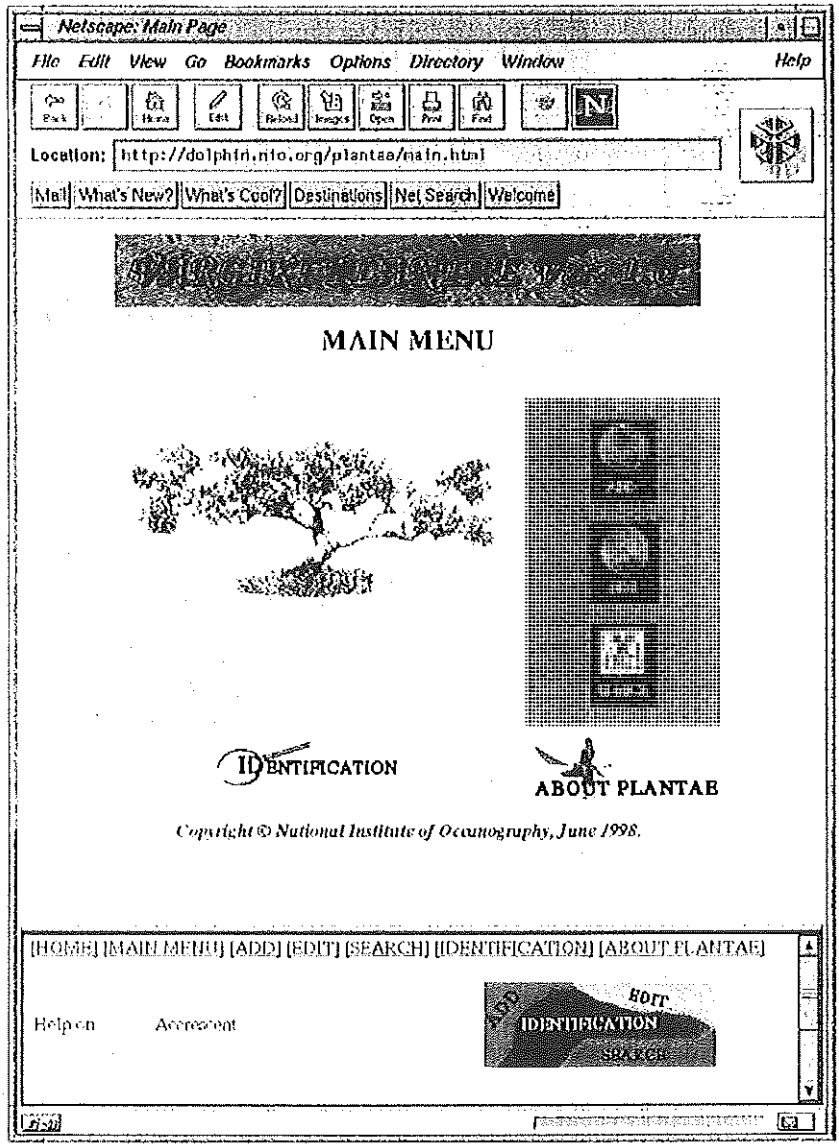

Figure 3. Main Menu of Vargiki - Plantae

country. One of the NMIC under APMIN could be identified as APMIN Headquarters, which will coordinate the collection and distribution of information within and outside the network. The Headquarters would manage the meta-database(s). However, it would be beneficial to apply basic qualifying standards for selecting these nodal agencies, for successful implementation of the network. The lead agency or organization in the field of mangrove ecosystem research, conservation and management with sufficient data/information repository should be nominated as NMIC. It would be beneficial if the potential NIMC has experience in the area of computation, data management, networking, Internet publishing, information packaging and marketing.

Internet as APMIN Intranet

Information collation and dissemination availability of free flowing physical network is essential. Considering the wide-spread of APMIN in the Asia-Pacific region, it would be advisable to use the existing Internet infrastructure as APMIN intranet. Further, info-bases of this nature should

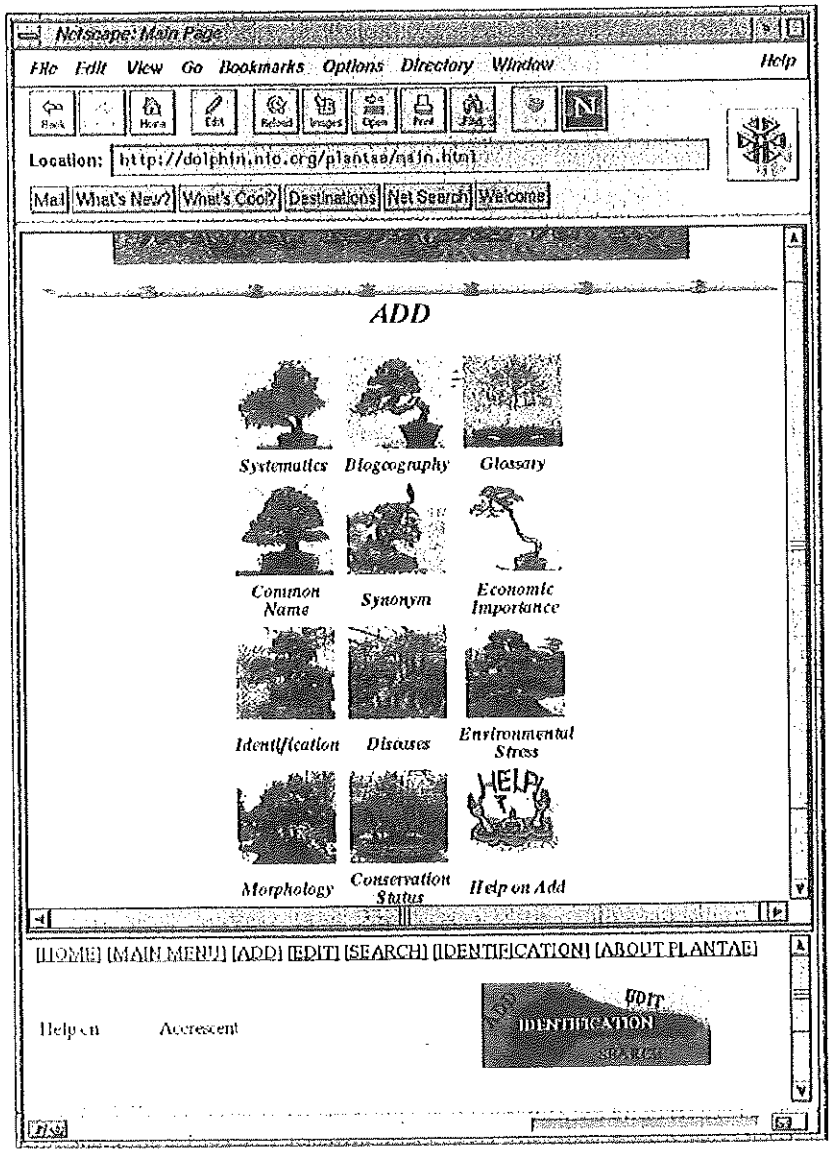

Figure 4. Add Menu of Vargiki - Planate

have web interface for wide dissemination of the collected data and to provide hardware and software independent front end to the database. With a WWW interface all interaction with the database is done through the client browser. Browser's are available on almost all types of hardware and software combinations. Thus the database becomes virtually independent of the client accessing system, additional data may be entered by experts all over the world, thus an expert can contribute in real-time irrespective of his physical location. Each of the NIMC should be equipped with minimum of dedicated 64 Kbps connectivity to Internet. Mode and speed of such connectivity would be dependent on the infrastructure of national Internet Service Providers (ISP) in these nations and also the cost required for setting up such a link. This would build the virtual APMIN intranet over Internet. Commissioning of national APMIN web site by these countries will facilitate regional data/information collection and global information dissemination.

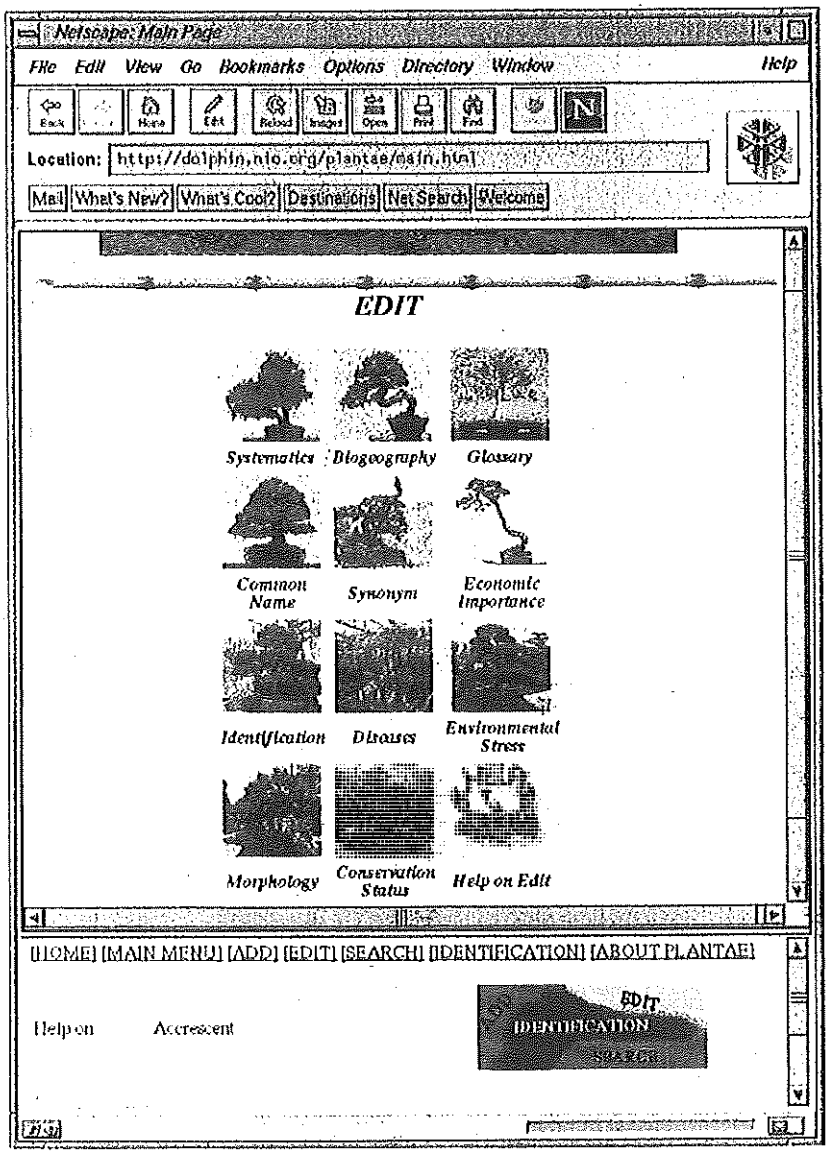

Figure 5. Edit Menu of Vargiki - Planate

Hardware and Software Requirements

It is beyond the scope of this paper to suggest the configuration of the hardware and software requirements of APMIN network because of the speed of the new innovations in the area of information technology. Decision of the exact hardware and software would be dependent on the quantum of anticipated data, nature of data analysis and processing, cost-benefit and trends in Information Technology (IT). Apart from the hardware and software for data assimilation, processing, networking, NMIC should be equipped with state-of-the-art reprographic and desktop publishing facilities. Apart from storage and processing of information, quantitative and qualitative analyses and retrieval of desired data in multivariate combination and format is possible through RDBMS. Geographical Information System (GIS) software could be utilized for maintaining biogeographical status of mangroves and its associated biota. Variety of other modeling, simulation, expert system packages could be employed to achieve high-precision forecasting based on the accumulated information.

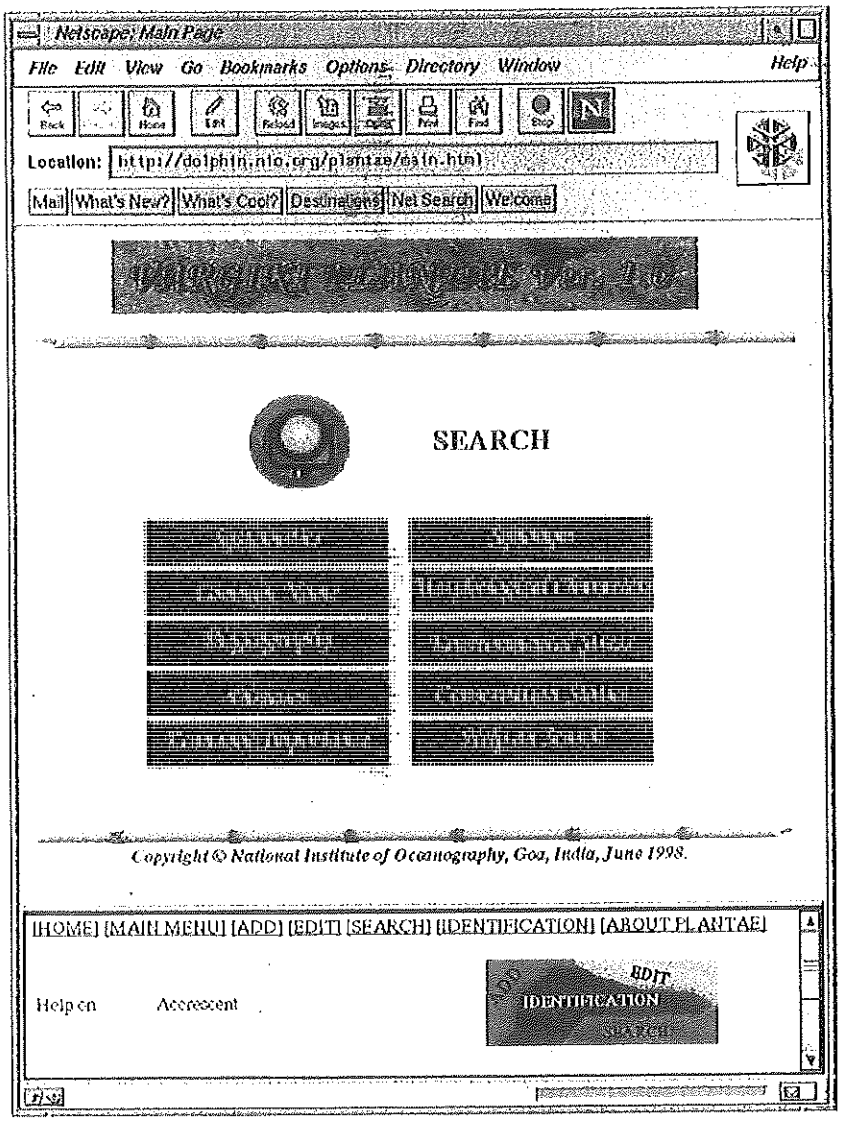

Figure 6. Search Menu of Vargiki - Plantae

Human Resource in APMIN Management

In order to develop user-friendly database(s), software(s) and educational awareness packages, without compromising the subject and text quality, high accessibility, multivariate analysis and process facilities; much care should be taken in appointing the staff. The team should comprise of subject experts, information scientists, documentation specialists, computer software developers, hardware engineers (IOC/UNESCO, 1991).

Coastal zone managers, mangrove managers, environmentalists must be trained in data collection, validation and authentication, data management, information dissemination and packaging, information analysis, interpretation and prediction, specialized software development and packaging as well as networking. It would be appropriate to designate some of the NMICs as Mangrove Information Management Institutes where frequent training programs to upgrade skills of APMIN staff can be held. These measures could also be extended to potential information generator or accumulator.

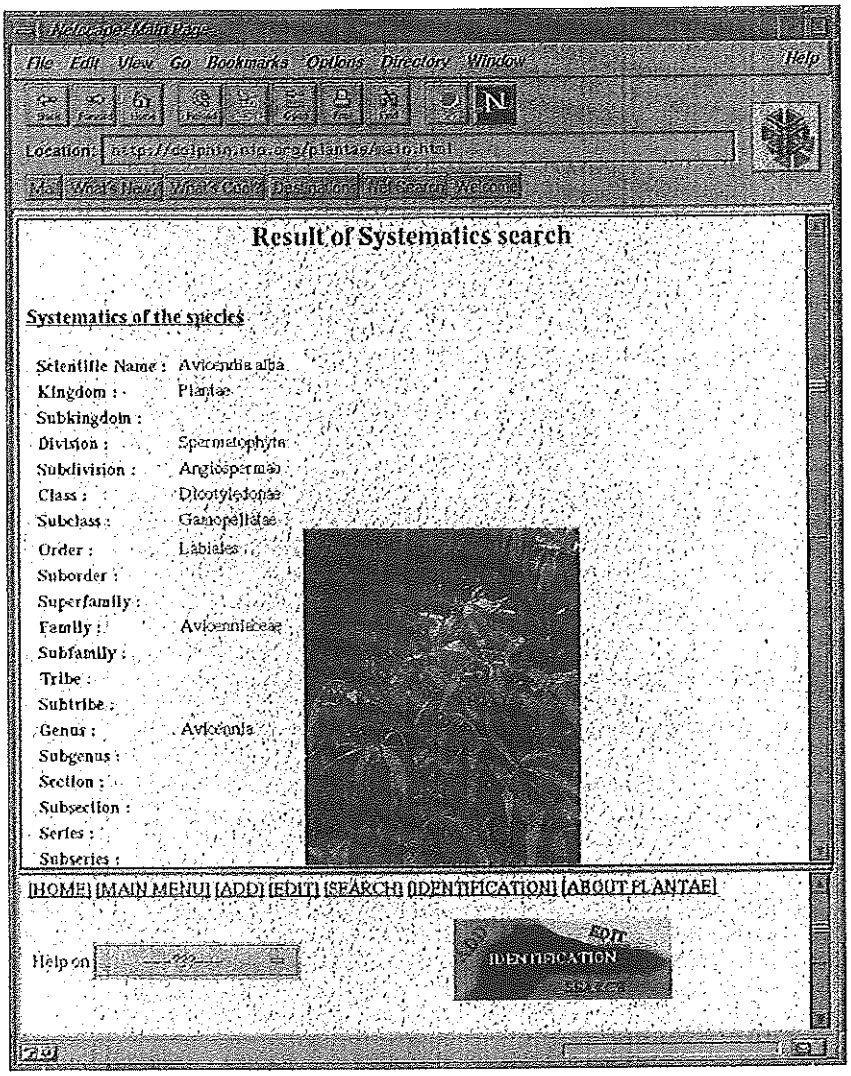

Figure 7. Systematics Search screen of Vargiki - Plantae

Advantages of APMIN

(i) Efficient exchange/sharing data at national and international levels within and outside APMIN. Rapid dissemination of desired information to the end-users. (ii) Easy access as well as qualitative and quantitative analysis of information. (iii) Enable policy makers to arrive at the most suitable and widely acceptable plan and alternatives for specific mangrove sites. For example, selection of sites for aquaculture, germplasm preservation and afforestation, wildlife and bird sanctuaries and other land use planning pertaining to the mangrove ecosystem, could be facilitated as desired data would easily be acquired through APMIN. Acquisition, storage, analysis, dissemination of bibliography, ecology, socio-economy, degradation, biogeography of mangroves and experts, institutes and projects related to it. (iv) Help to systematicians and taxonomists to enhance their interest in taxonomy.

Conclusion

Formation and implementation of APMIN would facilitate recollection and redistribution of data as well as exchange of views. It would help in formulating strategies for conservation,

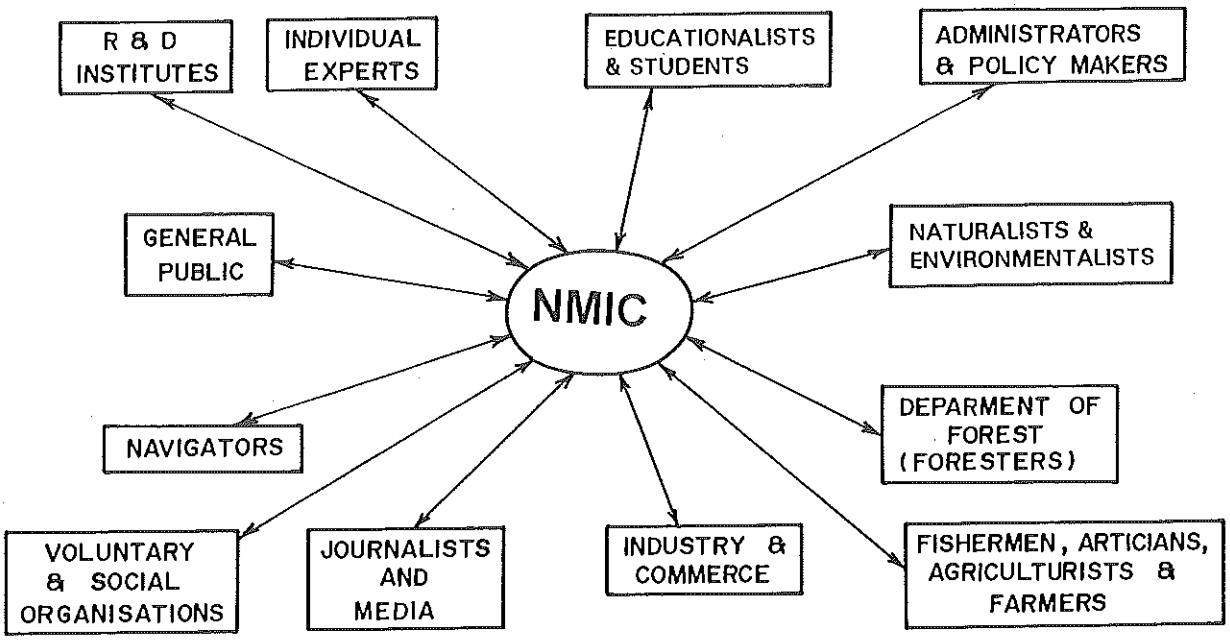

Figure 8. APMIN information acquisition and dissemination

management and sustainable utilization of the mangrove ecosystem in Asia-Pacific region.

Acknowledgement

Authors are grateful to Director, National Institute of Oceanography, Dona Paula, Goa 403 004 (India), for encouragement.

References

Chavan, V.S. (1993). Databases for Marine Biologists and Biotechnologists: The State-of-the-Art and Prospects. *Online & CDROM Review* Vol. *17*(2), pp. 1-6.

Chavan, V. S. (1998). Internet vis-a-vis Marine Biolology. *Natl. Sem. Recent Adv. in Mar. Biol.*, May 29-31, 1996, NIO, Goa, India. (accepted for Ind. J. Mar. Sci. special volume), pp. 8.

Chavan, V. S.; A. Agarwal; R. Das and A. Ghosh (1998). Daryavardi ver. 1.1: Web Directory of Oceanographic Community in India. Int. Symp. Information Technology in Oceanography (ITO 98), 12-16 Oct. 1998, NIO, Goa, India [Available at http://members.tripod.com/~ito98/ and http://www.nio.org/ito98/]

Chavan, V.S.; D. Chandramohan and A.H. Parulekar. (1991). Computerizing a Marine Biota: A Rational Approach. Biology Education Vol. 8(4), pp. 302-305.

Chavan, V. S. and D. Chandramohan. (1995). Databases in Indian Biology: The state of the art and prospects. *Current Science*, Vol.*68*(3), pp. 273-279.

Chavan, V. S. and A. K. Ghosh. (1997). Tools and Techniques for Searching the Web : Status and Potentials. *Internet for India* (IEEE Hyderabad Section), pp. 7-15.

Chavan, V. S. and L. Bothelho (1998). Vargiki - Animalia ver. 1.0: Web interfaced Taxonomic Identification System for Marine Animals Int. Symp. Information Technology in Oceanography (ITO 98), 12-16 Oct. 1998, NIO, Goa,

India [Available at http://members.tripod.com/~ito98/ and http://www.nio.org/ito98/]

Chavan, V. S.; D. P. Kavlekar and D. Chandramohan (1996). Computer Aided Taxonomy (CAT): Approach for understanding systematics of marine biota. *Natl. Sem. Recent Adv. in Mar. Biol.*, May 29-31, 1996, NIO, Goa, India. (accepted for Ind. J. Mar. Sci. special volume), pp. 11.

Chavan, V. S.; A. Nahar and P. R. Rao (1998) Computer Aided Taxonomic Identification System for Marine Plants - An experience with Vargiki - Plantae ver. 1.0. Int. Symp. Information Technology in Oceanography (ITO 98), 12-16 Oct. 1998, NIO, Goa, India [Available at http://members.tripod.com/~ito98/ and http://www.nio.org/ito98/]

Duellman, W. E. (1992). Addressing the Biodiversity crisis: The Neotropical biological diversity programme. ASC Newsletter Vol. 20(1), pp. 85-88.

Durante, L. (1992) Malaysia's "Sleeping Giant" could wake up on the wrong side. Bay of Bengal News, BOBP *Progr. Fisheries. Devlop.* Vol *48*, pp. 19-21.

Gautier, C. and C. Berstein. (1990). Computer science and biology. Impact of science on society Vol. 156, pp. 281-289.

Hopkins, K.D.; J. E. Lannan and J.R. Bowman. (1988). Managing a database on pond research data : the CRPS experience. 1 Aquabyte Vol. 1(1), pp. 3-4.

IOC/UNESCO. (1991). Marine Information Center Development: An Introductory Manual. IOC/UNESCO manuals & Guides No. 23 (SC/91/WS/57), pp. 1-32.

Jagtap, T.G.; V.S. Chavan and A.G. Untawale (1993). Mangrove ecosystems of India : a need for protection. *AMBIO*, Vol *22* (4), pp. 252-254.

Jara, R.S. and P.G. Tan. (1987). Mangrove information management. Mangr. As. & Pacific - Status & Manag. (*Tech. Rep. UNDP/UNESCO Res. & Trg. Pilot Prog. on Mangr. Ecosys. in As. & Pacific - RAS/79/002*), pp. 513-529.

MacNae, W. (1968) A general account of the fauna and flora of mangrove swamps and forests in the Indo-West Pacific regions. *Adv. Mar. Biol.* Vol. *6*, pp. 73-270.

McManus, J.W. (1990). Ecological computer programmes: The importance of being friendly. NAGA, the ICLARM quarterly, April 1990, pp. 5-7.

NOAA (1984). National Oceanographic Data Center Taxonomic Code. U.S. Dept. of Commerce/National Oceanic & Atmospheric Administration, U.S.A. Documentation No. 15 Vol. 1, pp. vii-xvii.

Odum, W.E. and E.J. Heald (1972). Trophic analyses of an estuarine mangrove community. *Bull. Mar. Sci.* Vol. *22*, pp. 671-738.

Rao, A.N. (1987). Mangrove ecosystems of Asia and the Pacific. Mangr. As. & Pacific: Status & Manag. (*Tech. Rep. UNDP/UNESCO Res. & Trg. Pilot Prog. on Mangr. Ecosys. in As. & Pacific - RAS/79/002*), pp. 1-33.

Rollet, B. (1981). *Bibliography on Mangrove Research 1600-1975*. UNESCO, Paris, pp. 1-479.

Saarenmaa, H.; S. Leppajarvi; J. Perttunem and J. Saarikko (1995). Object-oriented taxonomic biodiversity databases on the World Wide Web. Workshop on Internet Applications and Electronic Information Resources In

Forestry and Environmental Sciences (Eds. Kempf, A. and Saarenmaa, H.) European Forest Institute, Joensuu, Finland, August 1-5, 1995. EFI Proceedings 3 (in print).

Schalk, P.H. (1992). Systematics goes Multimedia: Computerizing Biological Knowledge. Expertise Center for Taxonomic Identification, Amsterdam, The Netherlands, pp. 1-5.

Snedaker, S.C. (1984). The mangroves of Asia and Oceania : status and research planning. *Proc. As. Symp. Mangr. Env. - Res. & Manag.* (Eds. E. Soepadmo, A.N. Rao and D.J. Macintosh), pp. 5-15.

Troost, D.; D. Blackburn.; I. Robinson and R. Collison. (1991). A PC based text book for marine sciences: A case study of global collaboration. Impact of science on society. Vol.164, pp.339-357.

Untawale, A.G. (1991). Research and management of mangrove ecosystems in India. *Proc. proj. formulation workshop for establishing a global network of mangrove genetic resource center for application to sea level rise*. 15-19 Jan. 1991. CASARD, Madras, India. (Eds. S.V. Deshmukh and R. Mahalingam), pp. 27-34.

Untawale, A.G. and S. Wafer. (1982). *Bibliography of Indian mangroves*. National Institute of Oceanography, Goa, India, pp. 1-79.

Atoll mangroves and associated flora from Republic of Maldives, Indian Ocean

T. G. Jagtap and A. G. Untawale

Biological Oceanography Division, National Institute of Oceanography, Donapaula, Goa-403004, India

Abstract

Coral islands from the Republic of Maldives were surveyed for their mangroves and feasibility of large scale mangrove afforestation to restore the coastal habitats and stabilize the shore. Extensive mangrove formations were observed from the islands of the north atolls. Male' atoll was totally devoid of mangroves due to their large scale reclamation mainly for urbanisation and tourism. Mangrove flora comprised of 12 species and was dominated by *Bruguiera cylindrica* followed by *Lumnitzera racemosa*, *Ceriops tagal* and *Rhizophora mucronata*. Many of these islands exhibited luxuriant and tall (7-20 m) forests of *B. cylindrica* with an average density of 7 trees 100 sq. m^{-1}. Production and establishment of mangroves seedlings was observed to be very high in all the members of Rhizophoraceae, as well as in *Avicennia marina*.

Associate mangrove flora was commonly represented by *Thespesia populnea*, *Hibiscus tiliaceus*, *Pandanus* spp., *Pemphis acidula*, *Scaevola taccada* and *Tournefortia argentea*. *Pemphis acidula*, was observed to act as a pioneer species on newly formed islands. Seagrass beds in the shallow lagoons and in the vicinity of mangroves were dominated by *Cymodocea rotundata* and *Thalassia hemprichii*. Seagrass meadows in the lagoons of southernmost Addu atoll were relatively more dense. Mangrove debris harboured 39 spp of manglicolous fungi. In general management status and awareness level of mangrove and adjacent ecosystems were observed to be very poor. Reclamation of mangroves, has caused severe erosion at a few of the islands particularly in the Haa Dhaalu in the north. *B. cylindrica* is commercially exploited for fish sticks and wood for boat building and construction and cultivated on small scale. Islanders are well verged with plantation techniques and generally dense plantations particularly of *B. cylindrica* are practised in the intertidal swampy regions. There is good potential for developing mangrove nursery and afforestation, and aquaculture in the mangrove influenced environments. It is required to create necessary awareness regarding the ecological and socioeconomic importance of the mangroves and seagrass ecosystems among the islanders.

Introduction

Mangroves, an important constituent of the tropical and subtropical marine ecosystem, are of great ecological, socio-economic and commercial value (Odum and Heald, 1972). Various kinds of anthropogenic activities have resulted in the reclamation of lowlying coastal regions and particularly mangroves and salt marshes all over the world. Degradation and loss of these ecosystems have caused severe erosion and flooding of the land and adverse impact on the marine environment. Besides, low lying coastal areas and islands of recent origin could be the first victims of the increased sea level due to global warming (US EPA, 1983). Coastal zone management therefore, has become imperative in the overall land use planning.

Mangroves, salt marshes and seagrass beds being natural barriers, stabilize and protect the shoreline and sea bottom from erosion during adverse weather conditions. Similarly, they play significant role in land building by enhancing sedimentation and thus keeping the pace with sea

level rise (Untawale and Jagtap, 1992). Very recently, great efforts have been made for the assessment, conservation and management of the mangrove resources from Asia and Oceania (Malaya Univ. and UNESCO, 1984). Mangrove area in Asia and Oceania, had been estimated to be 478 X 10^5 hectares (Rodin *et al.*, 1975). However, it does not include the mangrove area from many of the oceanic islands. Lately, considerable amount of data have been generated on mangroves from islands in the Indian ocean (Untawale and Jagtap, 1984; 1989; Jagtap, 1992). However, many of the low lying oceanic islands, particularly, of Laccadive archipelago in the Indian ocean, which are more unstable and are threatened of possible sea level rise, have been very poorly known for mangroves (Hackett, 1971; Fosberg, 1976). Hence the mangroves from the Maldives atolls were evaluated for their status and feasibility of afforestation. The data would be of help to formulate conservation and management strategies on the basis of sustainable utilisation.

Description of the Study Area

Geology and geomorphology:

The Republic of Maldives consists of 26 atolls comprising, 1190 islands on the Chagos Laccadive Bank (appro. 0° 42' S - 7° 05' N Lat) along 73° E Meridian (Fig.1). The length of the archipelago is ca 823 km and average width of ca 130 km. Atolls are mostly circular coral reefs enclosing lagoons (Hackett. 1971). Islands are for the most part transient, eroding rapidly and are enclosed by coral reefs with deep, natural channels and shallow lagoons (Stoddart, 1973). Most of the islands are 2 m above sea level and do not possess typical windward and seaward sides. Soil is generally young, vigorous and shallow, composed mainly of coral debris admixed with sandy loam with top layer containing humus. Due to excess of Ca, soil is alkaline and water retaining capacity is very poor (Fosberg, 1976).

Climatology (IMD, 1931-60):

Maldives's atolls lie outside the cyclone zone. The climate is warm and humid. Daily atmospheric temperature varies from 25.7-30.4°C. Though monsoon is not well defined, average annual rainfall is ca 1950 mm, mainly received from the south-west monsoon (May - October). North-east monsoons occur during November to April. Mean tide is about 0.7m and spring tide reaches to 0.9m

Materials and Methods

Nineteen islands of Male' (Central), Shaviyani and Haadhaalu (North) and Addu (South) atolls from Maldives (Fig. 1) were evaluated during September-October, 1991, for mangroves and adjacent ecosystem and their ecological status. Qualitative observations were made on the associated flora in the mangrove influenced regions. Floral specimens were preserved in 4% formaldehyde and also mounted on herbarium sheets. Specimens were identified by using standard literature mentioned elsewhere (Untawale and Jagtap, 1984; 1989; Jagtap, 1991; 1992.)

The quantitative data (density, DBH and height) of the dominant mangroves and their seedlings were collected along the transects. The transects were laid randomly, from seaward to landward and length varied from 20-1500m. The interval between sampling plots varied from 10-150 m, depending upon the quality and extent of mangroves. Densities of seedlings and trees were measured in triplicate, by using 10 sq. m and 1 sq. m quadrats, respectively. DBH was measured with a Vernier caliper by considering the trees with DBH > 2.5 cm only. Heights of the trees were measured approximately by comparing objects of known height. The results were expressed on an average basis. The concerned government and nongovernment personnel and islanders residing in the vicinity of mangroves were interviewed to know the awareness and utilisation levels of mangroves in various atolls.

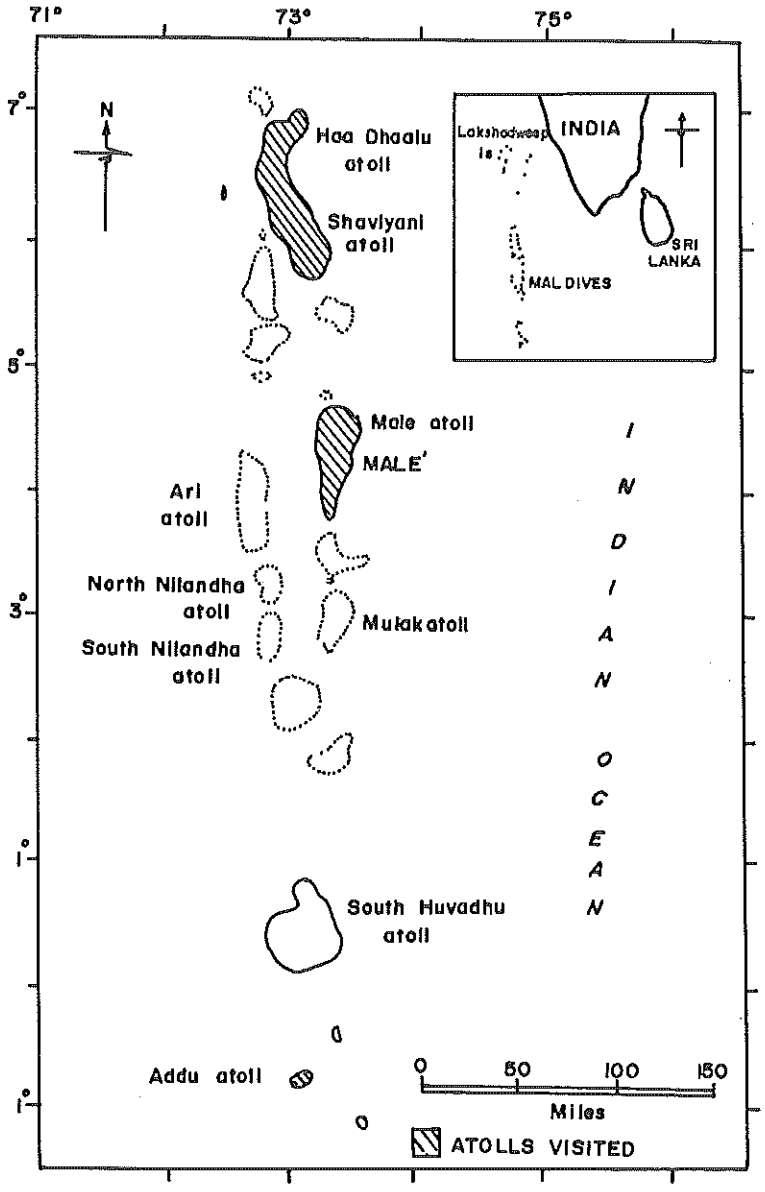

Figure 1 Geographical map of study area.

Results and Discussion

The composition of mangroves mainly depends upon the geomorphological and topographical features of landforms and the climatic conditions (Fosberg, 1976). The tropical belt between 32°N to 38°S, provides warm and humid climate which is quite ideal for the establishment and growth of mangroves. However, the best mangrove formations occur in the belt of 25°N to 25°S latitudes. Volcanic islands in the Indian ocean support qualitatively and quantitatively a rich mangrove flora (Jagtap, 1985; 1992; Untawale and Jagtap, 1989). However, emerging islands of recent origin on Chagos Laccadive archipelago, in the Arabian Sea harbour relatively few number of species with a limited extent (Untawale and Jagtap, 1984; Jagtap, Chavan and Untawale, 1993). Most of these islands have limited land and natural resources and therefore, mangroves form an important asset of their ecosystem. Islands, particularly of Maldives atolls on Chagos Laccadive archipelago although old formations, are quite unstable (Ahmad, 1972) and

Table 1. Mangroves and major associate flora from republic of Maldives.

Species Botanical Name	Local Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Rhizophora mucronata Lamk	Thakarathi	-	-	-	-	-	VR	-	R	ST	C	-	-	-	D	-	-	-	D	ST
Rhizophora sp.		-	-	-	-	-	-	-	-	-	-	R	-	R	R	-	-	-	-	-
Rhizophora sp.		-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Bruguiera cylindrica (L.) Bl.	Khandu	-	-	D	-	D	D	ST	D	D	-	D	CD	D	-	-	-	-	R	-
B. gymnorhiza (L.) Lamk	Bodavaki	-	-	-	-	-	-	-	-	R	-	R	-	D	-	-	-	-	-	-
Bruguiera Sp.		-	-	-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-
Ceriops tagal (Perr.) C.B.Robins	Kharnana	-	-	-	-	-	-	D	-	-	-	-	-	-	-	-	-	-	-	-
Avicennia marina Vierh		-	-	-	-	-	-	-	-	-	-	-	D	-	-	-	-	-	-	-
Lumnitzera racemosa L. Gaertn.	Burehi	-	-	-	-	-	-	-	C	D	D	C	-	C	D	-	-	-	-	-
Sonneratia caseolaris (L.) Eng.	Kullhavah	-	-	-	-	-	-	R	R	C	R	R	-	-	-	-	-	-	-	-
Execoecaria agallocha L.	Thella	-	-	-	-	-	-	-	R	C	-	-	R	R	-	-	-	-	-	-
Acrostichum aureum L.	Maakeha	-	-	-	-	-	-	-	C	C	-	C	-	C	-	-	-	-	-	-
Derris heterophylla (L.) Merr.		-	-	-	-	-	-	-	C	C	C	C	-	C	-	-	-	-	-	-
Thespesia populnea Cav.	Hirundhu	C	-	VC	VC	VC	VC	VC	VC	VC	VC	VC	C	C	C	C	C	C	C	VC
Hibiscus tiliaceous L.	Dhiggaa	C	-	VC	VC	VC	VC	VC	VC	VC	VC	VC	C	C	C	C	C	C	C	VC
Pandanus spp.		-	-	C	C	VC	VC	VC	C	VC	VC	C	C	C	VC	VC	C	C	VC	C
Pemphis acidula Forst	Kuredhi	-	R	C	D	D	D	C	C	C	C	C	D	D	D	D	D	D	D	D
Scaevola taccada (Gartn.)		C	R	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Tournefortia argentea Roxb. L.f.		-	-	-	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

LEGENDS:

1. Male' 2. Hulefrulla 3. Kundhiurrd 4. Kurandhaa 5. Maaugaadhoo 6. Ariadhaa 7. Funadhaa
8. Maakandhdhoo 9. Gooldhoo 10. Kulhudhufushoo 11. Kumundhoo 12. Keylakunu
13. Neykurendhoo 14. Hithadhoo 15. Maradhoo 16. Peydho 17. Gan 18. Willgill 19. Huthudhoo

- Absent , VR- Very rare, R-Rare, C-Common, VC- Very common, D- Dominant.

Table 2. Ecological and socioeconomic aspects of mangroves from various islands of Republic of Maldives.

Islands	Dominant Sp.	Status	Number of Trees 100sq.m^{-1} (Seedling sq.m^{-1})	AV.height (m)	AV. BH (cm)	Coverage (%)	Faming	Soil type	Tidal flushing	Profile gradient	Awareness	Afforestation potential	Aquaculture potential
Male'		VP	-	-	-	-	No	-	-	-	-	-	-
Hulehulle		VP	-	-	-	-	No	-	-	-	-	-	-
Konikhurra	Bc	P	3	4.5	3	80	No	SC	EH	DP	-	-	-
Kurendhoo		VP	-	-	-	-	No	-	-	-	-	-	-
Maaugoodhoo	Bc	P	10(08)	18	15	10	Yes	S	A	N	CU	G	NO
Ariadhoo	Bc	G	7(25)	-	-	-	No	S	A	Fr, Br	-	NO	NO
Funadhoo	Ct	VG	4(08)	3	-	-	No	SM	R	DP	-	VG	NO
Maakandhoo	Bc	G	20(30)	7.5	5	90	No	SC	EH	-	-	NO	NO
Gooldhoo	Lr	VG	15(28)	3	-	80	No	SC	EH	D, Br	CU	NO	NO
Kulhudhufusehu	Lr	VP	4(30)	3	-	80	Yes	SC	A	DP	-	G	VG
Kumundhoo	Bc	G	10(32)	20	15	80	No	SC	EH, SP	DP	CU	NO	NO
Keylakunu	Am, Bc	VG	20(30)	12	5	80	Yes	SC	EH, SP	DP	-	NO	NO
Naykurendhoo	Bc	VG	3	20	15	90	No	SC	R	DP	CU	NO	NO
Hithadhoo	Rm	P	-	6	-	90	Yes	-	R	Br	-	G	VG
Varadhan	-	VP	-	-	-	-	Yes	-	-	-	-	-	-
Feydho	-	VP	-	-	-	-	-	-	-	-	-	-	-
Gan	-	VP	-	-	-	-	-	S	-	-	-	-	-
Hulhudhoo	-	VP	-	-	-	-	-	S	R	-	-	G	-
Willgili	-	G	-	-	3	-	-	SC	A, SP	D	-	-	-

LEGENDS:

BC- Bruguiera cynnarica, G-Good, SC- Sandy clay, A-Absent, DP- Depression, S- Sandy, Ct- Ceriops tagal, VG- very good, R- Regular, N-Normal, Lr-Lumnitzera recemosa, P-Poor, SM-Sandy muddy, EH- Extreme, Fr- Fringing, Am-Avicennia marina, VP-Very poor, High tide, Br-Brackish, Rm-Rhizophora mucronata, SP-Seepage, CU-Commercial.

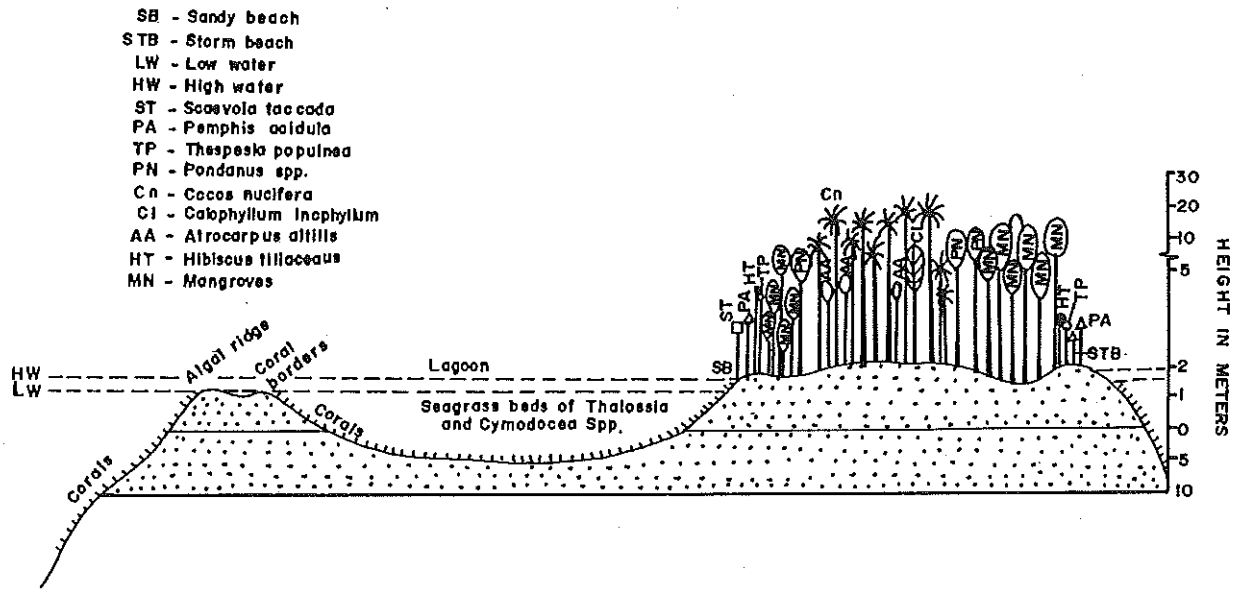

Figure 2 Schematic representation of the Island profile depicting major types of vegetation.

are of immediate concern from the possible sea level rise. Mangroves would be of considerable importance in providing stability to these islands, by enhancing sedimentation and avoiding erosion during adverse conditions. However, very little is known as regards the mangrove composition, extent and their status from these atolls.

Earlier (Fosberg, 1949, 1976; Hackett, 1971) stray reports of a few mangrove species have been made from Maldive. During the present investigations 12 species of mangroves were recorded from these atolls (Table 1). Islands of Shaviyani and Haa Dhaalu atolls, in the north, were represented by all the 12 species and the extent too was more, as compared to only three species and poor cover from Addu atoll, in the south. Male' atoll was totally devoid of mangroves, which could be attributed to large scale reclamation mainly, for urbanisation and tourism. Mangroves on the islands of Shaviyani and Haa Dhaalu atolls form pure stands of one or two species in the basins or shallow depressions, and mostly extends below the fluctuating water table (Fig. 2). Frequently the seawater enters and leaves through underground porous coralline debris. Mangroves were generally observed to grow on hard substratum having large quantities of humus on the surface. Occasionally, few shrubs or trees of different mangrove species occur in the pure stands. In a few of the islands, like Funadhoo and Hithadhoo in the Shaviyani and Addu atolls, respectively, fringes of mainly, *Ceriops tagal* and *Rhizophora* spp. occur along the brackish water or lagoon shores.

The mangrove flora of the north was dominated by *B. cylindrica* and *C. tagal*, while *Rhizophora* spp. were dominant at Addu atoll in the south. However, *L. racemosa* was dominant at few islands of north and south atolls. Many of the islands in the north were represented by tall (height 7-20 m) thickets of *B. cylindrica* with average density of 7-10 trees 100 sq. m^{-1} with DBH ranging from 3 - 15 cms, respectively (Table 2). The seedling establishment was higher in *B. cylindrica* and *C. tagal* and densities varied from 20-40 sq. m^{-1} (Table 2). *Avicennia marina*, was restricted only to Keylakunu island in the north and mixed with stray *B. cylindrica* plants. Stray and tall (20-30 m) trees of *Sonneratia caseolaris*, occurred towards the land in the thickets of *B. cylindrica* and *L. racemosa*. *Acrostichum aureum*, *Excoecaria agallocha* and *Derris*

heterrophylla, were common to most of the islands in the north. General distribution pattern of mangroves from these atoll, revealed that, *Bruguiera* spp. and *A. marina*, occurred in the depression which get regularly flushed with mean (0.7 m) tide. *Ceriops tagal* and *L. racemosa*, grew in the supratidal landward regions (salt encrusted) of high salinities. Intertidal zones under daily inundations harboured *Sonneratia caseolaris*, *E. agallocha* and *A. aureum*, which grew landwards mixed with terrestrial flora (Fig. 2), indicating their preference for lower salinity.

Islands of Maldives atolls on Chagos Laccadive archipelago are relatively older formations than those of Lakshdweep islands which are of very recent origin and emerging (Ahmad, 1972). The pattern of mangrove formations from Lakshdweep (Untawale, and Jagtap, 1984; Jagtap, Chavan and Untawale, 1993) and Maldives group of islands were compared and found to be very similar. However, mangroves in Lakshdweep have been established recently and are still in the process of genesis; they are limited to the southernmost (Minicoy) islands, in a very small patch (Untawale and Jagtap, 1984). Seedlings might probably be transported from the northernmost Haa Dhaalu islands of the Maldives to the Minicoy island of Lakshdweep, which are at a distance of ca 110 km. The mangroves at Minicoy are dominated by *Bruguiera cylindrica* and stray plants of *C. tagal* and A. marina. Number of species reported during present investigations commonly occur in the countries bordering the Arabian Sea (Untawale, Wafar and Jagtap, 1992). The surface current pattern (US Navy, 1976) and the similarity in the floral constituents, suggest close proximity of Maldives atolls to the coasts of Sri Lanka, India, Gulf countries, as regards the transport of early seedlings of mangroves.

Other coastal flora, above high tide level, was dominated by *Pemphis acidula*, and *Scaevola taccada* growing on coral debris and sand mixed with clay and humus (Table 1 and 2). The same species occur in a few islands of Lakshadweep above highest high tide level, though growing to a lesser, extent. Sand dunes were dominated by *Ipomea pes-caprae*, *I. macrantha* and *Sesuvium portulacastrum*. *Pemphis acidula* was commonly observed to be pioneer on newly formed rocky islands. Associated mangroves like *Thespesia populnea* and *Hibiscus tiliaceus*, commonly occurred in the landward mangroves. Seagrass beds were dense and extensive in the shallow (0- 4 m) sandy lagoons at Addu atoll. *Thalassia hemprichii* and *Cymodocea rotundata*, dominated the seagrass flora, while *Thalassodendron ciliatum*, was rarely observed beyond 2.5 m depth. The seagrass ecosystem from Addu atoll was more prominent than the mangrove ecosystem, as in Lakshdweep and Seychelles groups of islands (Untawale and Jagtap, 1984; 1989; Jagtap, 1987; 1991). Manglicolous fungi, responsible for converting detritus into organic matter, was represented by 39 spp in the atoll mangroves and were dominated by *Dactylospora haliotrepha, Lineolata rhizophorae, Lophiostoma mangrovei, Massarina thalassiae* and *Verruculina enalia.*

Maldives, particularly in the north atolls, have luxuriant mangroves, however the islanders by and large are unaware of the importance of these ecosystem. *Bruguiera cylindrica* is exploited commercially for wood and fishing poles, and dense plantations of this species has been practised for ages. Tender propagules of *Bruguiera* spp. and *C. tagal*, are consumed as vegetable after drying. Many of the islands, particularly from Male' atoll, have been totally reclaimed of mangroves, mainly for urbanisation and tourism developments. Reclamation has resulted in severe erosion at many of the islands, however, it is more prominant in Haa Dhaalu island in the north. These atolls which are emerging and unstable are likely to suffer immediate impacts from adverse conditions of the sea. Therefore, natural flora such as mangroves, seagrass meadows, sand-dunes flora forms an asset of the country from the ecological point of views. Mangroves of poorly inhabited and uninhabited islands are still in their pristine glory which need to be protected and conserved immediately. Brackish and shallow

water regions at Funadhoo, Kulhudhoofushu and Hithadhoo islands of Shaviyani, Haadhaloo and Addu atolls, respectively, have a great potential for the development of mangrove nurseries, afforestation and aquaculture.

Acknowledgements

Authors are grateful to Director, National Institute of Oceanography (C.S.I.R.), Dona Paula, Goa, India, for facilities and encouragement. Thanks are also due to, the Ministry of External Affairs, Govt. of India and Govt. of Maldives, for fundings.

References

Ahmad, E. 1972. *Coastal Geomorphology of India*, Sangam Press, Poona, pp. x-222.

Anon, 1976. *Marine Climatic Atlas of the World*, NAVAIR 50 - IC - 530, Vol. III, Pub. Director of the Commander Naval Weather Service Command, US Govt. Printing Office, Washington, DC.

Chinnaraj, S. 1993. Manglicolous fungi from Maldives atolls, Indian Ocean, *Ind. J. Mar. Science, 22*: 141 - 142.

Fosberg, F.R. 1949. Atoll vegetation and salinity. *Pacific Sci.*, 3 : 89 - 92.

Fosberg, F.R. 1976. Coral Island vegetation In : O. A. Jones and R. Endeam (Editors) *Biology and Geology of Coral Reefs*, Academic Press, N. Y. Vol. III; Biol., *2*: 256-279.

Hackett, H. E. 1977. Marine algae known from Maldives island. *Atoll Res. Bull.*, No. 210.

Hoffman, J.S. Keys, D. and Titus, J.G. 1983. *Projecting Future Sea Level Rise, Methodology, Estimates to the year 2100, and Research Needs*, US Environmental Protection Agency, Washington, USA.

Jagtap, T.G. 1985. Studies on littoral flora of Andaman islands. In : V. Krishnamurty (Editor), *Marine Plants, their biology, chemistry and utilisation, Proc. All India Symp. Marine plants*, pp.45 - 50.

Jagtap, T.G. 1987. Distribution of algae, seagrasses and coral communities from Lakshdweep islands, eastern Arabian sea. *Ind. J. Mar. Sci., 10*: 402-404.

Jagtap, T.G. 1991. Distribution of seagrasses along the Indian coast. *Aquatic Bot.*, 40: 379 - 386.

Jagtap, T.G. 1992. Marine flora of Nicobar group of islands, Andaman sea. *Ind. J. Mar. Sci., 22*: 56 - 58.

Jagtap, T.G.; Chavan, V.S. and Untawale, A.G. 1993. Mangrove Ecosystems of India: A need for protection. *Ambio, 22*: 252-254

Odum, W.E. and Heald, E.J. 1972. Tropic analysis of an estuarine mangrove community. *Bull. Mar. Sci., 22*: 671 - 738.

Rodin, L.E.; Barilevich, N.I. and Rozov, N.N. 1975. Productivity of the world's main ecosystem. *Natn. Acad. Sci.*, Washington.

Stoddart, D.R. 1976. Coral reefs of the Indian Ocean. In : O.A. Jones & R. Endean (Editors) *Biology and Geology of Coral reefs* Vol. 1 : Geology 1 : 51 - 92. Academic Press, N.Y.

Untawale, A.G. and Jagtap, T.G. 1984. Marine macrophytes of Minicoy (Lakshdweep) coral atoll of the Arabian sea. *Aquat. Bot., 19*: 97 - 103.

Untawale, A.G. and Jagtap, T.G. 1989. Observation on marine macrophytes of Republic of Seychelles. *Bot. Mar., 32*: 115 - 119.

Untawale, A.G. and Jagtap, T.G. 1991. Floristic composition of the deltaic regions of India. *Memoirs Geol. Soc.*, India *22*: 243 - 263.

University of Malaya and UNESCO. 1984. *Proc. As. Symp. Mangr. Env. Res. & Manag.* (Eds. E. Ssoepadmo, A.N. Rao and D.J. Macintoch), organised by Univ. Malaya and UNESCO, Kuala Lumper, 25 - 29 Aug. 1980, pp. i-828.

ACTIVITIES OF
THE INTERNATIONAL SOCIETY FOR MANGROVE ECOSYSTEMS (ISME)

ISME was founded in 1990 as a society to promote study and research concerning mangrove ecosystems, with the ultimate goal of laying the bases for rational, sustainable use and management of these resources. A non-governmental and non-profit-making organization, ISME brings together interested scientists, professionals and institutions working for the conservation and better use of the mangroves of the world.

The Society is affiliated to the ICSU family of organizations as a constituent part of the International Union of Biological Science (IUBS) through the International Association of Biological Oceanography (IABO), and has observer status with several organizations of the United Nations.

ISME organizes and cosponsor conferences, seminars, symposia and working group meetings; to organize lectures and courses; to publish both scientific and popular articles. ISME promote mangrove ecosystems research and extension activities for sustainable management, rational utilization, rehabilitation and conservation of mangrove ecosystems. Since 1995, ISME has been implementing a two month mangrove training course, financed by JICA. The number of participants for the last three years sums up to 20 from 17 countries. As of March 1998, ISME has 667 individual members and 34 institutional members from 73 countries.

While its Secretariat is located in Okinawa (Japan), ISME undertakes to implement projects anywhere in the world where the expertise of its members can be of service. Through its newsletter, the Society provides an open forum for discussion leading to the optimum modalities of attaining its objectives. In addition, ISME has co-operated with the International Tropical Timber Organization (ITTO) to promote mangrove research.

As well, ISME organizes annual training courses, sponsored by the Japan International Cooperation Agency, and publishes educational and professionals papers as well as videos. Thus far, the following have been produced:

ISME Mangrove Ecosystems Occasional Papers

No. 1. 1993. Mangrove Nurseries in Bangladesh, by N. A. Siddiqi, M. R. Islam, M. S. S. Kahn, and M. Shahidullah;

No. 2. 1998. Trace Metals Biogeochemistry and Diffuse Pollution in Mangrove Ecosystems, by Luiz Drude de Lacerda.

ISME Mangrove Ecosystems Proceedings

No. 1. 1993. Proceedings of a Workshop on Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions, Niteroi, Brazil 28-30 May 1993;

No. 2. 1993. Proceedings of a Workshop on Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions, Dakar, Senegal, 20-22 January 1993;

No. 3. 1994. Proceedings of VII Pacific Science Inter-Congress Mangrove Session, Okinawa, Japan, 1-2 July 1993;

No. 4. 1997. Proceedings of Symposium on Significance of Mangrove Ecosystems for Coastal People, Hat Yai, Songkla, Thailand, 19-20 August 1996.

ISME Mangrove Ecosystems Technical Reports

Vol. 1. 1993. The Economic and Environmental Values of Mangrove Forests and their Present State of Conservation in the South-east Asia/Pacific Region. (an ITTO/ISME Project);

Vol. 2. 1993. Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions, Part I - Latin America. (an ITTO/ISME Project);

Vol. 3. 1993. Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions, Part II - Africa. (an ITTO/ISME Project);

Vol. 4. 1994. Study of Chokoria Sundarbans Using Remote Sensing Techniques, by A.M. Choudhury, D.A. Quadir, and Md. Jinnahtul Islam. (with the support of AEON Foundation).

Vol. 5. 1999. Two Papers on Mangrove Ecosystems: Part I - Asian Pacific Maugrove Information Network (APMIN) - a conceptual model, by V. S. Chavan, T. G. Jagtap and A. G. Untawale; Part II - Atoll mangroves and associated flora from Republic of Maldives, Indian Ocean, by T. G. Jagtap and A. G. Untawale.

Slide Set Programme for Children

1994 - A Slide Programme of Environmental Education for Vietnamese Children, entitled "Know Your Mangroves", 73 slides and textbook;

1995 - A Slide Programme of Environmental Education for Children, entitled "Know Your Mangroves", 2nd edition, 76 colour slides aud textbook;

1996 - Video on mangroves of Fiji, entitled "What the Tides Bring";

1997 - Video on mangroves of Thailand, entitled "Living with Mangroves".

Outputs of ITTO/ISME Project:
"Manual and a world natural mangrove atlas for mangrove ecosystem restoration

- Non-technical publication: Journey Amongst Mangroves;
- Technical manual: Restoration of Mangrove Ecosystems;
- Atlas: World Mangrove Atlas.

For more information and purchase, contact:

ISME Secretariat
c/o Faculty of Agriculture
University of the Ryukyus
Okinawa 903-0129 Japan

Telephone: (81-98) 895-6601
Facsimile: (81-98) 895-6602