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目　次　Contents

Mangrove Science Vol. 3 ; 1－4. 2004

日本マングローブ学会創設者故杉二郎先生追悼

－日本のマングローブ研究草創期と杉二郎先生－

中 村 武 久

Prof. Jiro Sugi and the daybreak of Mangrove research by Japanese scientists

Takehisa Nakamura

1999年マングローブ学会懇親会（学会に出席された最後）で挨拶される　杉　二郎先生

東南アジアマングローブ研究を興隆した二人（サンガ・サバシ博士と）

杉先生追悼のことば

日本マングローブ学会の創設者でもあり，初代学会長であった東京大学名誉教授、東京農業大学名誉教授、農学博士　杉二郎先生は，2002年９月24日未明89歳の生涯を閉じられました。我々マングローブ研究に取り組む者にとっては、大きな支えを失ったことになり，誠に痛恨の極みです。

杉先生は、マングローブだけでなく，我が国における農学系科学者として極めて旺盛な研究意欲と且つ広範な研究分野に目を開かれ、ことに研究者を育てることに優れた能力を持っておられました。先生は農業工学が専門でしたが、塩にもまた関心が深く，日本海水学会長を歴任されたり、ソルトサイエンス財団の運営に関わったり、またそれらの集約学際的分野として日本生物環境調節学会を創設され、自らの研究を進めると共に、若手研究者を指導し、多くの優れた関連科学者を育成されておられます。

1982年，沖縄で開催された国際マングローブセミナーの折り，かねてから杉先生が発案されていた日本マングローブ学会が設立されました。しかしこの学会が設立されるまでには、それ以前からのマングローブ研究への胎動があったからであります。その最も大きな一つとして，後述するISME（国際マングローブ生態系協会）の誘致とその前提となった日本国際マングローブ協会の設立が関わっていました。それらの組織化もさることながらマングローブ研究の大きな流れを作り出したのは、他ならぬ杉先生でした。

我が国でマングローブが分布するのは琉球列島のみで、しかも生育面積も僅かで、本来熱帯の植物であるマングローブの北限分布地として知られている程度であり，我が国が熱帯の国と肩を並べるマングローブ国とは言えないのに関わらず、杉先生は我が国に多くのマングローブ研究者を育てると同時に，東南アジア諸国のマングローブ研究を興隆し、また一般社会へのマングローブ普及に多大な貢献をされました。

こうして日本でのマングローブ研究を興し、且つマングローブを普及された、今は亡き杉二郎先生の追善にと思い、以下日本におけるマングローブ研究の草創の頃について述べ、極めて多くの研究指針を頂いた杉先生の墓前に、感謝の気持ちを捧げる次第です。

1．マングローブ研究の発端

1971年，文部省の傘下である日本学術振興会（JSPS）の、拠点大学方式による途上国との研究協力プロジェクトが発足し，このプロジェクトの中心的役割を担っていた杉二郎先生は，再々タイ国を始め、インドネシア、フィリッピンへ出かけ，相手国の研究機関や研究者に会って，農林水産及び環境科学研究プロジェクトの展開を計っていた。

そのプロジェクトが立ち上げられて間もなく、1976年，杉教授がタイ国を訪れた折り、当時N.R.C.T.の局長であった前カセサート大学林学部教授のProf. Sanga Sabhasri博士に会い、日－タイ学術交流についての話し合いの中で、Sanga教授より次の提案があった。「現在タイのマン

グローブ林が薪炭用伐採、錫採掘のための伐採等が行われ、壊滅的な状態にある。この荒廃したマングローブ林の修復造林を思索しているが、その為のマングローブに関する学術的な情報に乏しい。そこで日本でマングローブに関心を持つ研究者とタイ国の研究者との共同研究プロジェクトを発足させたい。」というものであった。

丁度その頃、杉先生は文部省科研費特定研究「温帯熱帯の比較農学的研究」を持っておられ、そのプロジェクトの幹事会の折り、私にマングローブについての認識を質し、これへの参加を指示された。マングローブというより熱帯への関心が強かった私は即座に快諾し、この特定研のプロジェクトの中に一部取り込んでもらうことを計った。しかしこの特定研は最終年度でもあったことから、取り込みは無理であることになり、先生は別途マングローブ研究プロジェクトを発足させることを考えていた。そして1978年、生憎私は参加出来なかったが、JSPS の派遣で、当時横浜国立大学の宮脇昭教授、鹿児島大学水産学部の野沢恰治教授、京都大学農学部の荻野和彦助教授、東京農大の畑山好和教授、檜垣宮都助教授(当時の所属)等と共にタイ国半島部のマングローブ視察に出かけた。

これ等の視察を通じてその後、宮脇昭教授はタイ国でのマングローブ研究プロジェクトを科研費申請し採択され、1981年から調査に入った。また84年に荻野和彦助教授の科研費プロジェクトが開始され、その1年後、杉先生をヘッドに中村武久が幹事役の科研費タイ国でのマングローブ研究を開始した。こうしていよいよ我が国における近代マングローブ研究が始動したのである。

カセサート大学サニット教授と（1996年8月）

国内的には、これより2年ほど前から琉球大学の中須賀常雄助教授等の沖縄におけるマングローブ研究がスタートしていた。

2．研究交流の開始

前項に示すように、我が国のマングローブ研究の発足に大きく関わった、日本ータイ国の学術研究交流事業が、これより数年前から始まっていた。その中の具体的事業の一つとして、マングローブ関連の研究交流事業が取り上げられるようになったのである。ここではそのマングローブ研究の発展につながった、杉先生が中心となって開催された研究交流事業の概要を以下に記す。

1979年9月、京都大学荻野和彦博士の招聘で、タイ国のマングローブ研究者，Dr. Sanit, Mr. Jitt, 及び Mr. Suchin の3名が来日、京都大学会館においてマングローブ研究推進の話し合いがおこなわれた。この会議に東京から杉二郎先生、檜垣宮都、中村武久が参加した。会議後、タイからの3名は東京へ同行し、日本の森林研究の現状等について情報交換を行った。

1980年3月、東京農大において、杉二郎先生が研究代表者の文部省科研費特定研究総括セミナー「温帯熱帯の比較生物生産 (SCATT)」が開催され、これに集まったタイ、インドネシア、フィリッピンの研究者のなかに、マングローブ問題を取り上げた研究者がいて、マングローブ研究の必要が論じられた。

1980年11月琉球大学において国際マングローブセミナーが開催 (JSPS と SAEDA の共催) された。このセミナーにタイ国からの出席者は Dr. Sanit, Dr. Jitt, Mr.Suchin, Mr. Sopon, Mr. Pen, Mr. Prachim, の6名。そのうちの Mr.Sopon, Mr. Pen, Mr. Prachim, の3名は、宮脇昭教授がホストとなり約1ヶ月横浜国大で研修を受けた。Dr. Sanit Dr. Jitt と Mr. Suchin は杉先生の招聘で東京農大を訪問し、今後の研究交流について討議したが、これがタイ国よりのマングローブ研究交流招聘の最初である。

1981年10月、農業の研究と農業教育に関するアジアセミナー (SAREA) が東京農大で開催され、この中に1セッションをマングローブ研究が含められていた。結果的にはインドネシアからの出席予定者が欠席となり、タイからの2名と日本側の3名で、いずれもマングローブの利用に関する演題の学術討議を行った。

1981年12月、中村武久は杉先生に同行し、タイ国東北部の塩性土壌研究プロジェクト（高井）の視察後、檜垣宮都，長野敏英、加藤茂と合流し、ソンクラ、プーケット、ラノンの3ヶ所のマングローブを予備調査。具体的なマングローブ研究プロジェクトの立ち上げ計画について検討した。なお帰路沖縄西表島へ寄り，タイ国マングローブ植物3種の胎生種子の移植試験をおこなった。

1982年8月、タイ国王政200年記念 自然科学とマングローブ資源に関するセミナー (NRCT-JSPS RATTANAKOSIN BICENTENNIAL JOINT SEMINAR ON SCIENCE AND MANGROVE RESOURCES) が JSPS と NRCT の共催でバンコクにて開催された。これに杉先生を団長として、大勢の日本人マングローブ研究者が参加した。

1983年10月、JSPS と SAEDA の共催の東南アジア国際マングローブセミナーを広島大学において開催。タイ国より Dr. Sanga Sabhasri, Dr. Sanit, Dr. Jitt, Ms. Prapasri, Dr. Thawachai, Dr. Amorn, Dr. Anant, Mr. Somchai Dr. Nittharatana 他総勢21名を招聘して開催した。この内 JSPS の研究交流で Mr. Sa-ngob （中村)、Mr. Naris(檜垣)、Ms.

琉球大学における国際マングローブ生態系セミナー
懇親会場にて（タイ国からの出席者らと1980年11月）

Sauapa（丸茂）、Mr. Vipak（荻野）、Mr. Somsak（中須賀）、Ms. Arunee（野沢）の6名はカッコ内の日本側ホストのもとで約1ヶ月の研修を行った。

1984年以降89年まで、毎年2～4名のタイ国マングローブ研究者の招聘研修が続き、正確には把握していないが、当時広島大学の倉石晋教授、その後愛媛大学に移籍された荻野和彦教授、香川大学の井上裕雄教授、鹿児島大学の野沢恰治教授、横浜国立大学の宮脇昭教授、及び東京農大の前記3教授の元で研修した者、30名を越える。これらの研修を受けた者は、それぞれにタイ国のマングローブ保全管理の現場で責任ある立場に着き、また日本を含む外国からのマングローブ研究調査に大きな役割を演じている。

これらの研究交流の実績は、全て杉二郎先生のマングローブ研究推進へ払われた努力の賜であるといってよい。

これらの中で、杉先生直接ではないが、杉先生の提言やらタイ国との研究協力が大きく働いて日本国際マングローブ協会（JIAM）の設立（設立時会長は斉藤鎮男元国連大使、杉先生は副会長。途中で斉藤氏がISME副会長に就任したので、杉会長となる）。この日本国際マングローブ協会が、国際NGOとしてのISMEの招致に関わったのである。またISME発足後、国際的にはISMEが存在するので、それまでのこの協会名の国際を削除して、日本マングローブ（JAM）として改組した。

文部省科研費で最初のタイマングローブの調査に入った横浜国大　宮脇　昭チーム（1982年）

3．日本マングローブ学会の設立とマングローブ研究

JIAM設立の2年前、ISME設立の前年、すなわち1980年、結果としてISME設立の準備会議でもあった、前述の沖縄で開催された「国際マングローブセミナー」の開催中に、杉先生の提案で、急遽日本マングローブ学会の設立を準備する事になり、中村は暫定会則案を作製し、セミナーの最終日、セミナーに参加した日本人マングローブ研究者が集合し、そこで杉二郎先生から設立趣旨の説明があり、会長杉二郎、副会長宮脇昭、幹事役員中村武久、荻野和彦、倉石晋、檜垣宮都、中須賀常雄の5名。事務局は東京農大に置く。会費は会員の殆どがJIAM会員でもあることから、たとえ一方の会員でも年額5,000円。という大綱を決め、すなわち形式的には1980年11月、日本マングローブ学会が新発足したのである。

しかしこの方式は大変不都合で、会費は全てJAMに払い込まれる。JAMでは元々の会費であるから、学会費としての部分が区分出来ず、そのため学会には経費が廻ってこない。さらには、それまでのJAM専務理事であった堀建治氏が名古屋へ居を移されたため、後任に今は亡き井上静男氏に代わり、井上氏はそれまで堀氏が1人で処理していた協会事務を3人体制で行うようにしたため、運営上の不都合を生じた。

そんなトラブルがあって、学会分離独立の意見があったが、協会（JAM）自体が国際を外したこともあって、活動機能がかなり収縮している。そこでむしろ協会の主たる活動は国内的なマングローブ研究に絞られてくる。という見地から、協会の会則一部変更し、日本マングローブ協会の中に、事業部と学術部とを設置し、当分の間学会活動に集中することを決めた。そのため、一昨年までの学会年次大会は、日本マングローブ協会学術部会アカデミック・ミーテイングとして開催してきた。そしてようやく昨年から協会から切り離して、日本マングローブ学会年次大会とした。

日本マングローブ学会の出発は古く1982年であるが、学会活動として形を作るようになったのは、1984年1月、日本のマングローブ研究者による「マングローブ　ワークショップ'84,」を東京農大グリーンアカデミーホールで開催したことである。この学術集会は、農大総合研究所とJSPSの援助で開催されたもので、発表件数26題、参加者56名という盛況な集会であった。しかし、予算を持たない学会としては、こうした外部の援助がなければ運営もおぼつかない。結果的には杉会長の号令で、文部省科研費を始め、他機関からの研究助成を得て、沖縄方面のみならず東南アジア、南太平洋、中南米、アフリカ等でいくつかの研究チームが調査研究に取り組んだ。

その1例が前1項の終わりにも述べた、宮脇昭らのタイ国のマングローブ植生生態学的研究、荻野和彦らによるマングローブ生態系の森林生態学的研究ーマングローブ林のバイオマスー。そして杉・中村らの東南アジアマングロー

ブの生理生態学的研究。その他年次的に推定20件以上の助成研究が行われた。

こうして今や我が国は国際的にも、マングローブ研究については主要な地位を占めており，ISME の活動と共にマングローブ研究は熱心に続けられている。

こうした経過を省みると、まさに杉先生の先見の明というか慧眼というか、はたまた先生の未知なる事象への研究意欲の強烈さの現れかと、只々頭の下がる思いに駆られるのみである。

Mangrove Science Vol. 3 ; 5−6. 2004

Professor Dr. Jiro Sugi

A man who devotes his time to creating research and promoting young scientists in the field of mangroves

Dr. Sanit Aksornkoae
Professor Emeritus, Faculty of Forestry,
Kasetsart University, Bangkok, Thailand

The National Research Council of Thailand (NRCT) and Japan Society for Promotion of Science (JSPS) joint scientific cooperation programme on mangroves started in 1978 by the agrement and signed the memorandum of understanding between Professor Dr. Jiro Sugi from JSPS and Professor Dr.Sanga Sabhasri, Secretary-General, NRCT. Since 1978, the cooperation Programme on mangroves has grown very fast by the strong support of Professor Sugi. Almost 20 years, Professor Sugi devotes his time to creating research and promoting young scientists in the field of mangroves and other related research projects. Three main important research programs crested by Professor Jiro Sigi carried out in Thail and are 1) research on productivity of mangroves 2) brackish water ecosystems and 3) ecosystem dynamics of the outer Songkhla Lake.

The cooperative research on productivity of mangroves werw carried out in different parts along the coastal areas of the country. Professor Sugi, the team leader of Japanside with more than 20 Japanese scientists worked together with Professor Sanga Sabhasri, the team lesder of Thaiside and more than 30 Thai scientists. Approximately 15 years of this joint research projescts, the research findings were applied to develop the National Policy on Conservation and Sustainable Management of Mangroves in Thailand.

The cooperative research on brackish water ecosystems was carried out in northeastem region of Thailand by professor Sugi, the team leader of Japanese scientists and Professor Dr. Chaitat Prairinta from Khon Kaen Univeraity, the team leader of Thai scientists. This cooperative studies mainly related to the survey of salt affected area and agiculture. The experiment on mangrove species introduced to improve saline soil in this region was also couducted. The research findings on this project including the distribution of saline soil, classification of salt affected areas, cropping in salt affected areas, crop species and varieties grown on saline soil and land reclamation of the salt affected areas were applied in improving the salt affected areas in northeastem Thailand successfully.

Professor Sugi and plays very important role in supporting the joint projest entitled "Ecosystem Dynamics of the outer Songkhla Lake, Soutem Thailand" which carried out by Professor Yusho Aruga, the team leader of Japan scientists and Associate Professor Saowapa Augsupanich from Prince of Songkhla, the team leader of Thai scientists. This joint research studies related to physical and biological characteristics including mangroves, nutrient fluxes, accumulation of organic matter and heavy metals and socio-economic activities. The research findings of this program were applied in improving environmental conditions and managing sustainability of natural resources of Songkhla Lake successfully.

In addition to the joint research projects, Professor Jiro Sugi also strongly supported in arrangement of various scientific seminars and workshops among Japanese, Thai and regional scientists. Each seminar and workshop created a closed relationships among the scientists in the region particularly Japanese and Yhai.

Professor Jiro Sugi plays an important role in supporting RONPAKU(Dissertatin Ph. D.) program in Thailand. Many Thai scientists from different govemment agencies received Ph. D. in the field of mangroves and agriculture under this program.

Professor Jiro Sugi not only supported the important activities already mentioned earlier, he was one of the founders of the two societies of mangroves "International Society for Mangrove Ecosystems, ISME" and "Japan Association for Mangroves, JAM" and later he was the Vice-President and President of these two societies respectively.

From his strong support and devoted himself on cooperative research and other activities related to mangroves which was significant in improving environment and managing natural resources in Thailand sustainability, Professor Gr. Jiro Sugi was awarded Ph. D. Honerary from therr universities, Kasetsart University, Khonkaen University and Prince of Songkhla University.

Professor Dr. Jiro Sugi was a great human being. I have always been impressed by observing Professor Sugi when he was involved and dealing with other scientists and othe people. Professor Sugi was always so very patient, work hard, kindliness and a perfect gentleman. Dr. Jiro Sugi was our belovde professor and we are always thinking ofhim and forever.

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Phytosociological Study of Mangrove Vegetation in Byone-hmwe Island, Ayeyarwady Delta, Myanmar — Relationship between Floristic Composition and Habitat —

Myint AUNG[1], Kazue FUJIWARA[1] and Yukira MOCHIDA[2]

Abstract : The recent situation of mangrove forests in the Ayeyarwady delta, Myanmar, is that they are cut, destroyed, and transformed to settlement or rice field, with some restoration area. Byone-hmwe Island has been protected since 1992, and mangrove vegetation has recovered to a relatively natural condition. A phytosociological survey, based on Braun-Blanquet (1964) and Fujiwara (1987), was carried out with line transects and freely chosen sites to investigate the actual mangrove vegetation. The mangrove vegetation can be classified into two categories: river-bank communities and inland communities. The river-bank communities include *Sarcolobus globosus-Brownlovia tersa* community, *Ipomoea tuba-Hibiscus tiliaceus community, Rhizophora apiculata community, Leptochloa filiformis-Kandelia candel* community, and *Acanthus ilicifolius-Avicennia officinalis* community. The inland communities consist of *Bruguiera sexangula-Bruguiera gymnorrhiza community, Excoecaria agallocha-Heritiera fomes* community, *Aegiceras corniculatum-Ceriops decandra community, and Phoenix paludosa* community. This is the first report of the mangrove communities in the Ayeyarwady delta. This study can clarify whether the floristic composition of the Ayeyarwady mangrove is different from other areas in Southeast Asia. Heritiera fomes and Excoecaria agallocha are characteristic species and can be seen as main species in most parts of the delta. Rhizophora spp., which are considered as main species in other Southeast Asia, can be seen in a very narrow zone on muddy flat banks along the stream.

Key words : actual mangrove vegetation, Ayeyarwady Delta, floristic composition, Myanmar, phytosociological survey

Introduction

The Union of Myanmar shows an ecological spectrum of almost unique variety, from tropical rain forests, mangrove forests and coral reefs in the south to temperate forests of conifers, oaks and rhododendrons in the far north, where snow-capped mountains up to 5,729m high mark the eastern edge of the Himalaya. The west Rakhine coast and southern Taninthayi portion of the country consist of narrow coastal plains backed by paralleling mountain ranges of moist forests, with a wide delta and mangrove area around the mouth of the Ayeyarwady. The total land area of Myanmar is 675,553 ㎢, about 50.87% of which was covered by forest (1989 Landsat TM images Forest Department). Mangroves in Myanmar can be seen in three regions, namely Rakhine, Ayeyar wady, and Taninthayi along the coast of the Bay of Bengal and Andaman Sea. The Ayeyarwady delta comprises very extensive mangal areas that are of considerable commercial value.

Mangrove vegetation defines the landscape and takes part directly or indirectly in the ecological development that happens in this ecosystem (Lugo and Snedaker 1974 ; Hamilton and Snedaker 1984 ; Tomlinson 1986). Therefore, accurate information of plant species composition of mangrove is a fundamental and important requirement to understanding all aspects of structure and function of mangroves, as well as their biogeographical similarities and their conservation and management. The past and present distribution of mangroves has been evaluated by several authors worldwide (e.g. Tomlinson 1986; Ricklefs and Latham 1993 ; Duke *et al.*, 1998 ; Ellison *et al.*, 1999). In this paper we focus on the distribution of mangroves in Byone-hmwe Island, which has kept the most natural condition and has one of the highest levels of species richness in the Ayeyarwady delta. The objectives of this paper are to present information on the mangrove vegetation and to understand the vegetation types and species composition of mangrove vegetation in the Ayeyarwady delta.

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Study Site and Environmental Data

The Union of Myanmar is located in the northern part of continental Southeast Asia, extending north- south over 2000km from 28° to 10° N latitude and lying between 92° and 102° Elongitude. The Ayeyarwady delta is a flat swamp, with river banks slightly raised due to higher silt deposits from the initial river overflow. The Ayeyarwady delta receives large volumes of fresh water from the Ayeyarwady river flowing from the north and saline tide water from the sea on the south. The pH of the soil is about 5.0 to 7.2 and the dominant soil type is silty clay or clay. The environmental condition and delta formation of the Ayeyarwady delta is very similar to the Sundarbans area of Bangladesh, and both areas have luxuriant stands of *Heritiera fomes* and *Excoecaria agallocha*.

Byone-hmwe Island is the most natural mangrove area in the Ayeyarwady delta and is located at 15° 54'-59' N and 95° 14'-16' E (see Fig. 1). The total area of the island is 1060 hectares. From north to south it is 8.1km long; the east-west width is 1.6km at the widest portion. The island is 12km distant from the sea. Mean annual temperature in the study area is 27.2℃, and mean annual rainfall is 2616.4mm. The tidal amplitude in spring tide is 2.7m in dry months (November to April), but the tidal water is much higher in the rainy season. Water salinity is 0.1 psu (practical salinity unit) in the rainy season and 17 (psu) in the dry season.

Methodology

A phytosociological survey (Braun-Blanquet 1964, Fujiwara 1987) was carried out with line transects and freely chosen sites to investigate the actual vegetation of the mangrove forest. In order to obtain essential data for predicting site structure and environment conditions, four quadrats were set up and observed. The positions of all sample trees in the quadrats were recorded, and the following were measured: the crown width (W), tree height (H) and diameter at breast height (DBH), for Rhizophora spp., stem diameter at 30cm above highest prop root ($D_{0.3r}$). The weight of sample trees was evaluated by an allometric relationship $W = aX^b$, in which W is dry weight, X is a variable corresponding to stem diameter, a and b are constants. X is $D_{0.3r}{}^2 H$ for the *Rhizophora* spp. and DBH^2H for other species. The values of a and b for all

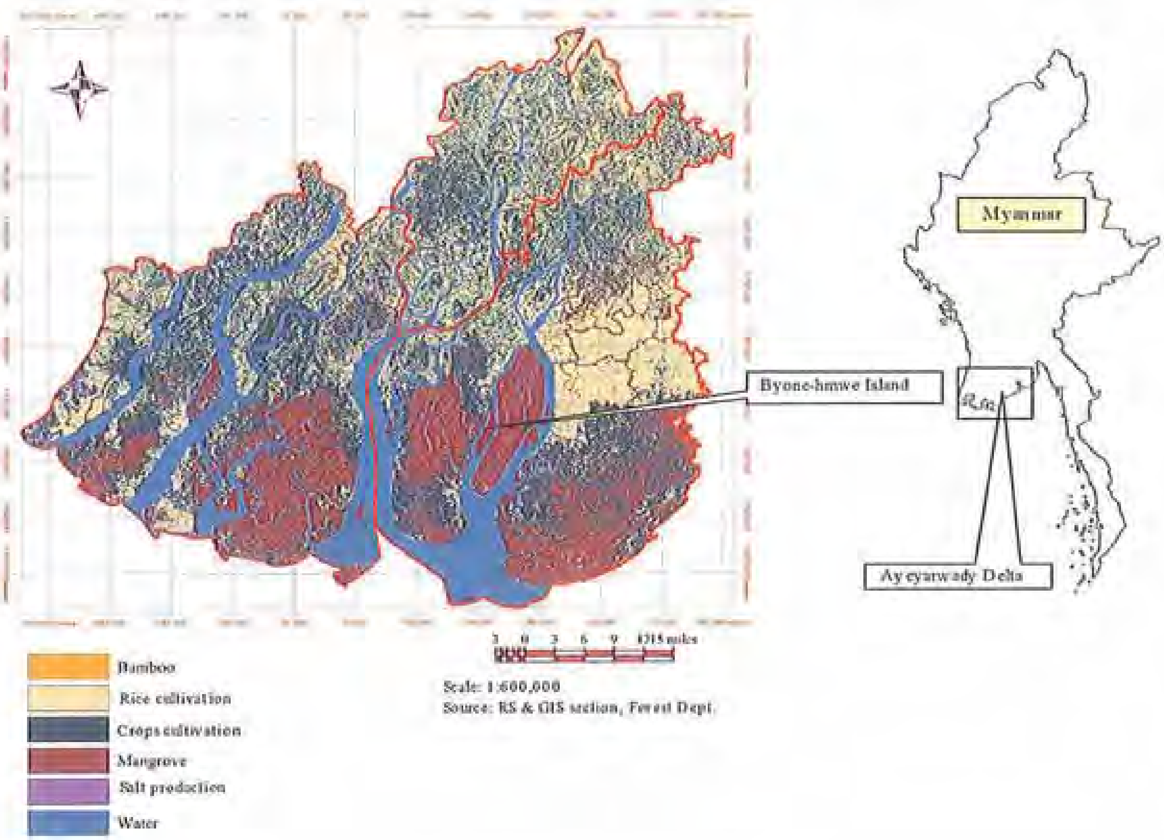

Fig. 1. Forest cover map of Ayeyarwady Delta in 2001

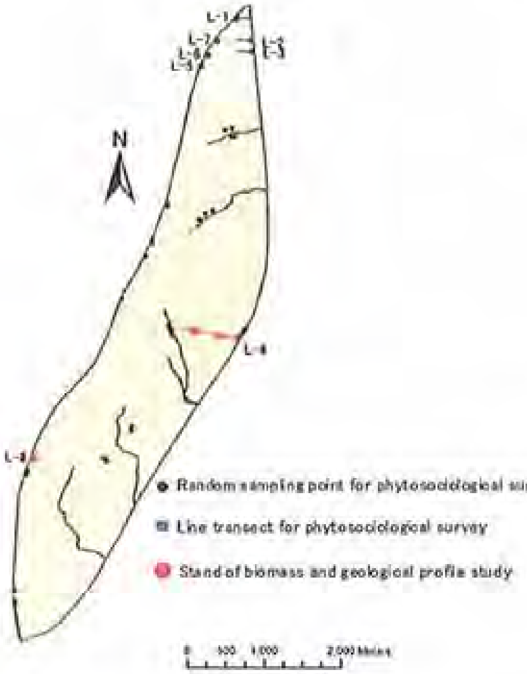

Fig. 2. Location of study points

mangrove species are 0.1177 and 0.8866 (Komiyama *et al*., 1988). Water salinity, topography, and sediments were also studied. Water salinity was measured by using handy salinity meter S / Mill-E (ATAGO). A topographical survey was conducted by using a reversible level, MODEL TRACON L5-25 (USHIKATA). The water level at each study site was calculated from tidal tables of the Ayeyarwady Division, using the measurement time and the elevation of the water surface in the river. Highest high water level (HHWL), mean water level (MWL), mean high water level (MHWL), and mean low water level (MLWL) at the study area were used. Sediments were examined by boring, using a hiller type soil sampler (Makabe Co.). In addition, soil samples from various mangrove stands were taken from the soil surface (0-10cm) and analyzed in the Laboratory of Land Use Section, Myanmar Agriculture Service. Soil analysis was conducted for soil texture.

Results

1. Mangrove communities of Byone-hmwe Island

The phytosociological survey on the mangrove vegetation in Byone-hmwe Island was carried out during December 2001, January to March 2002, and January to February 2003. As a result of preliminary phytosociological analysis, as well as the relationship of species assemblages and site conditions, the mangrove communities of the study areas can be classified into nine communities. Theses communities are summarized in Tables 1-7. To clarify the tidal amplitude at the study site, the level of low and high tide was measured from Jan. 3 to Feb. 1, 2003. Based on these data and observations of Kogo (1992), the tide-water level was evaluated (Table 8).

1.1. The river bank communities

1) *Sarcolobus globosus-Brownlowia tersa* community

The *Sarcolobus globosus-Brownlowia tersa* community occurs along eroded banks (photo 1), at medium ground (level 2), which is flooded 3-4 days a month (Table 8). The community consists of 3 or 4 species, to compare with other communities it has the less species component (Table 7). Brownlowia tersa is the main species and is 2.5 to 3m tall, with narrow, lanceolate to elliptic-lanceolate leaves, the apex gradually narrowed, often bluntly rounded. It occurs mainly on eroded riverbanks and most often occurs in the understorey under other tree species. Total community coverage is 85 to 90% (Table 1). The soil in this area is generally silty clay (Table 9).

2) *Ipomoea tuba-Hibiscus tiliaceus* community

The Ipomoea tuba-Hibiscus tiliaceus community was surveyed along an eroded bank (photo 2) (sequential releves 8-12) and inside the island (sequential releves 13-16), on medium ground (level 2), which is flooded 3-4 days a month (Table 8). This community has layers from herb layer to tree layer; tree height is up to 7m, and total cover of the tree layer is 70-90%. The soil in this community is generally silty clay (Table 9). The site condition of the community is similar to that of the *Sarcolobus globosus-Brownlowia tersa* community, and so both communities can be seen alternately along the eroded bank. Occasional patches of *Hibiscus tiliaceus* occur inside the island, especially on the cut-over areas and primarily on the higher and drier areas. The community includes a typical subunit and a *Phoenix paludosa* subunit.

The typical subunit occurs on eroded sites along the river bank and is mainly differentiated by *Hibiscus tiliaceus*,

Photo 1. Sarcolobus globosus-Brownlowia tersa community along the river bank

Ipomoea tuba, and *Flagellaria indica*.

The *Phoenix paludosa* subunit occurs inside the island and is differentiated by *Phoenix paludosa, Cynometra ramiflora, Heritiera fomes,* and *Caesalpinia crista* (Table 1). The site of the *Phoenix paludosa* subunit is inundated by tidewater less frequently than that of the typical subunit.

3) *Rhizophora apiculata* community

This community occurs along the muddy flats and gentle slopes of the river bank (photo 3), on low ground (level 1) that is flooded by every high tide (Table 8). The height of the T_2 layer is 9m, and its total coverage is 65 to 75% (Table 2). This community occurs along the west-facing river fringe of the island and is supported by silty clay (Table 9). The range of the community is very narrow, extending up to 8m from the river bank.

Photo 2. Ipomoea tuba-Hibiscus tiliaceus community along the river bank

Table 1 Sarcolobus globosus-Brownlowia tersa community (1)and Ipomoea tuba-Hibiscus tiliaceus community (2)

(1) *Sarcolobus globosus-Brownlowia tersa* community
(2) *Ipomoea tuba-Hibiscus tiliaceus* community
a. Typical subunit
b. *Phoenix paludosa* subunit

Community types		1							2								
									a					b			
Sequential relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Original relevé number (in field)		B-17	B-18	B-19	B-20	B-15	B-16	B7-1	B5-3	B5-2	B5-1	B5-5	B5-4	B4-25	B6-1	B4-15	B5-3
Date of relevé year		2003	2003	2003	2003	2003	2003	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002
month		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
date		25	25	25	25	25	25	9	9	9	9	9	9	8	9	8	7
Relevé size (m×m)		8x8	8x8	7x6	8x5	6x4.5	6x4.5	4x10	17x10	8x10	3.5x10	14x10	9x10	6x10	8x10	15x10	9x12
Height of Tree layer (T), (m)		-	-	-	-	-	-	-	-	-	-	-	-	7	6	8	-
Cover of Tree layer (T), (%)		-	-	-	-	-	-	-	-	-	-	-	-	90	70	90	-
Height of shrub layer (S), (m)		2.5	2.5	2.5	2.5	3	3	1.5	3	6	6	3	6	2.5	-	2	7
Cover of shrub layer (S), (%)		90	90	90	90	90	90	85	95	90	85	75	80	5	-	5	90
Height of herb layer (H), (m)		0.5	0.5	0.5	0.5	0.5	0.5	-	1	0.9	2	0.8	1	0.8	1.5	0.5	0.8
Cover of herb layer (H), (%)		2	2	3	2	2	1	-	3	3	2	3	3	3	5	5	1
Number of species		3	4	4	4	4	3	3	13	5	8	14	9	14	12	8	12
Differential species of communities:																	
Brownlowia tersa	S	4.5	4.4	4.4	4.4	3.5	3.5	3.5	.	.	.	.	.	.	.	.	+
	H	+	+	+	+	+	+	.	.	.	+	.	.	.	.	.	+
Sarcolobus globosus	T	.	.	.	.	.	.	.	.	.	.	.	.	1.1	.	.	.
	S	+.2	+.2	2.2	1.1	1.2	+.2	+.2	+	.	.	1.2	+	+	.	.	.
	H	+	+	+	+	+	+	.	+	.	.	.	.	+	.	.	.
Hibiscus tiliaceus	T	.	.	.	.	.	.	.	.	.	.	.	.	3.5	3.3	3.5	.
	S	.	.	.	.	.	.	.	3.3	5.4	5.4	5.4	5.4	.	.	.	4.4
	H	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.
Ipomoea tuba	T	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
	S	.	.	.	.	.	.	.	1.2	.	+.2	+.2	+	+	.	.	.
	H	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.
Flagellaria indica	S	.	.	.	.	.	.	.	1.1	1.2	1.2	.	.	1.1	.	.	+
	H	.	.	.	.	.	.	.	.	+	.	.	1.1	+	1.2	.	.
Differential species of subunits:																	
Phoenix paludosa	T	.	.	.	.	.	.	.	.	.	.	.	.	1.2	1.3	.	1.2
	S	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+.2	+
	H	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+
Cynometra ramiflora	T	.	.	.	.	.	.	.	.	.	.	.	.	1.2	+.2	1.2	2.2
	S	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	+
	H	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.
Heritiera fomes	T	.	.	.	.	.	.	.	.	.	.	.	.	1.2	.	1.2	1.2
	S	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+
Caesalpinia crista	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
	H	.	.	.	.	.	.	.	+	.	.	.	.	+	+	.	+
Companion species																	
Acanthus ilicifolius	S	.	2.3	1.1	2.3	.	.	.	.	.	.	.	.	.	.	.	.
	H	.	+	+	+	+	.	.	.	+	.	+	+	+.2	+.2	.	.
Derris trifoliata	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.1	.
	S	1.2	+	1.2	+	+.2	1.2	.	1.2	.	+	1.2	+	.	.	.	.
	H	+	+	+	+	+	+	.	.	.	.	.	.	.	.	+	+
Salacia prinoides	S	.	.	.	.	.	.	.	.	.	.	+	.	+.2	.	.	.
	H	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.
Cayratia trifolia	S	.	.	.	.	.	.	.	+	.	.	.	+	+	.	.	.
Mucuna gigantea	S	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Acrostichum aureum	H	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.
Barringtonia racemosa	H	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.
Danin nwe	T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+.2
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Clerodendron inerme	S	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+
Dalbergia pinnata	S	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
	H	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Intsia bijuga	T	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.

Additional species occurring once in sequential relevé number 7, Kyee-baung S-+; in 8, *Allophylus cobbe* H-+, *Anamirta paniculata* H-+; Nga-dan-pain H-+; *Pongamia indica* S-+; in 9, Me-nyo S-+; in 11; *Dalbergia spinosa* H-+, *Pluchea indica* H-+; Tal-pe S-+; *Premna integrifolia* S-+, H-+; *Scirpus* sp. H-+; in 13; *Amoora cucullata* H-+, *Avicennia officinalis* H-+; in 14, *Dalbergia spinosa* S-+; *Finlaysonia maritima* H-+; in 15; *Ceriops decandra* S-+, *Aegiceras corniculatum* S-+, H-+; in 16; *Excoecaria agallocha* S-+.2.
Location of the relevé number 1-12 is along the erosion site of river bank and 13-16 is inside of the island.
Relevé by Myint Aung (M.A), Kazue Fujiwara (K.F), Kun Hkun (K.H): (7-16), M.A (1-6).

4) *Leptochloa filiformis-Kandelia candel* community

The *Leptochloa filiformis-Kandelia candel* community occurs along the muddy flats and gently sloping river banks, on low ground (level 1) that is flooded by every high tide (Table 8). The height of T_2 in the community is 5-10m, and its total coverage is 60 to 80%. This community occurs along the river fringe and is supported by silty clay (Table 9). It is the characteristic community of accretion banks in Byone-hmwe Island. The range of the community is very narrow, extending just up to 6m from the river bank.

5) *Acanthus ilicifolius-Avicennia officinalis* community

A well growing *Acanthus ilicifolius-Avicennia officinalis* community occurs along the east-facing river bank of the island, behind the *Leptochloa filiformis-Kandelia candel* community. There are three *Avicennia* species (*Avicennia officinalis, Avicennia alba,* and *Avicennia marina*) in the Ayeyarwady delta, but only *Avicennia officinalis* on Byone-hmwe Island. The community occurs on low ground (level 2) that is flooded 16-21 days a month (Table-8). The height of the community is 13-14m, and the average number of species is 6 (Table 7). Crown coverage by the T_1 layer is 70-80%. The understorey layer is occupied by *Acanthus ilicifolius. Avicennia officinalis* can be seen as massive trees along the accretion site of the island (photo 4), on silty clay (Table 9). The community includes a *Kandelia candel* subunit and a typical subunit.

The *Kandelia candel* subunit occurs before the typical subunit of *Acanthus ilicifolius-Avicennia officinalis* community.

Table 2 Rhizophora apiculata community (1) and Leptochloa filiformis-Kandelia candel community (2), and Acanthus ilicifolius-Avicennia officinalis community (3)

(1) *Rhizophora apiculata* community
(2) *Leptochloa filiformis-Kandelia candel* community
(3) *Acanthus ilicifolius-Avicennia officinalis* community
a. *Kandelia candel* subunit
b. Typical subunit

Community type		1			2						3			
											a		b	
Sequential relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13
Original relevé number (in field)		B8-1	B8-2	B8-3	B4-1	B-25	B-22	B-23	B-21	B-24	B4-2	B4-3	B4-4	B4-5
Date of relevé year		2002	2002	2002	2002	2003	2003	2003	2003	2003	2002	2002	2002	2002
month		12	12	12	1	1	1	1	1	1	1	1	1	1
date		30	30	30	7	25	25	25	25	25	7	7	7	7
Relevé size (mxm)		5x5	7x15	7x12	3x10	8x5	12x7	8x8	7x6.5	12x8	4x15	10x15	10x20	8x20
Height of Tree layer 1 (T1), (m)		-	-	-	-	-	-	-	-	-	14	13	14	14
Cover of Tree layer 1 (T1), (%)		-	-	-	-	-	-	-	-	-	80	80	80	70
Height of Tree layer 2 (T2), (m)		-	9	9	6	7	6	5	8	10	8	5	8	8
Cover of Tree layer 2 (T2), (%)		-	65	75	80	80	70	60	70	60	15	15	5	3
Height of shrub layer (S), (m)		5	5	1.5	2	3	2	2	2	3	2.5	2	2.5	3
Cover of shrub layer (S), (%)		80	5	15	10	20	20	20	20	10	10	35	50	25
Height of herb layer (H), (m)		0.9	1	0.6	0.5	0.8	0.7	0.6	0.9	0.8	1	0.7	1	1.2
Cover of herb layer (H), (%)		1	3	3	1	3	5	5	5	5	10	5	40	90
Number of species		3	8	5	4	8	3	2	3	6	7	7	7	9
Differential species of communities														
Rhizophora apiculata	T2	+	3.3	4.4	·	·	·	·	·	·	·	·	·	·
	S	5.4	1.2	·	·	·	·	·	·	·	·	·	·	·
	H	+	1.1	+	·	·	·	·	·	·	·	·	·	·
Kandelia candel	T2	·	2.2	·	3.4	4.4	4.4	3.4	4.4	3.4	1.2	1.2	·	·
	S	2.2	·	2.2	1.2	1.2	2.2	2.2	1.2	1.1	1.2	+	·	·
	H	+2	+2	·	·	·	·	+2	·	·	·	·	·	·
Leptochloa filiformis	H	·	·	·	+2	·	·	+	·	·	·	·	·	·
Avicennia officinalis	T1	·	·	·	·	·	·	·	·	·	5.4	3.4	3.4	4.4
	T2	·	·	·	·	·	·	·	·	·	·	1.2	1.2	1.1
	S	·	·	·	·	·	·	·	·	·	·	·	1.1	·
	H	·	·	·	1.2	·	·	·	·	·	2.2	·	1.2	·
Brownlowia tersa	S	·	·	1.1	·	·	·	·	·	·	·	+2	+	2.2
	H	·	·	·	·	·	·	·	·	·	+	+	1.1	2.2
Companion species														
Acanthus ilicifolius	S	·	·	·	·	+2	·	·	1.2	+2	+2	3.3	4.3	2.2
	H	·	·	·	·	·	·	·	·	·	1.1	·	3.4	5.5
Derris trifoliata	T1	·	·	·	·	·	·	·	·	·	·	·	·	1.1
	T2	·	·	·	·	·	·	·	·	·	·	·	·	·
	S	·	+2	·	·	·	·	·	·	·	·	·	·	·
	H	·	+2	·	·	·	·	·	·	·	·	·	·	·
Sarcolobus globosus	T1	·	·	·	·	·	·	·	·	·	·	+2	·	·
	T2	·	·	·	·	·	·	·	·	·	·	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	·	·	·
Finlaysonia maritima	T1	·	·	·	·	·	·	·	·	·	·	·	·	+2
	T2	·	·	·	·	·	·	·	·	·	·	·	·	·
	S	·	1.2	·	·	·	·	·	·	·	·	·	·	·
	H	·	1.2	·	·	·	·	·	·	·	·	·	·	+2
Aegiceras corniculatum	H	·	·	·	·	·	·	·	·	·	·	·	·	·
Caesalpinia bonduc	T2	·	·	·	·	·	·	·	·	·	·	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	·	·	·
Amoora cucullata	S	·	·	·	·	·	·	·	·	·	·	·	·	1.1
	H	·	·	·	·	·	·	·	·	·	·	·	·	·
Nypa fruticans	S	·	·	·	·	·	·	·	·	·	·	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	·	·	·

Additional species occurring once in sequential relevé number 12; *Heritiera fomes* H-+, in 13, *Mucuna gigantea* H-+, in 5, *Sonneratia griffithii* T2-+, S-+, *Sonneratia caseolaris* S-+, H-+, Nga-dan-pein H-+; in 3, *Xylocarpus granatum* T2-1.1.

Location of the relevé number 1-3 is accretion site of west facing river bank (upto 10m from bank), 4-9 is along the accretion site of east and west facing river banks (upto 5m from bank), 10-13 is accretion site of east facing river bank (3-38m from bank).
Relevé by M.A, K.F, K.H. (4, 10-13); M.A (1-3, 5-9).

It is mainly differentiated by *Kandelia candel*, *Avicennia officinalis*, *Brownlowia tersa*, and *Acanthus ilicifolius*.

The typical subunit is mainly differentiated by *Avicennia officinalis*, *Acanthus ilicifolius*, and *Brownlowia tersa*. It is located just behind the *Kandelia candel* subunit.

1.2. The inland communities

1) *Bruguiera sexangula-Bruguiera gymnorrhiza* community

This community was surveyed in the interior of the island near a small creek, where *Bruguiera gymnorrhiza* and *Bruguiera sexangula* can be found mixing in depressions. The community grows on medium ground (level 1), so it is inundated 10-15 days a month (Table 8). T_1 height is 12 to 13m; total T_1 cover varies from 70 to 85% (Table 3). The soil in this area is silty clay (Table 9). The community comprises two subunits, a typical subunit and an *Excoecaria agallocha* subunit.

The typical subunit is mainly differentiated by *Bruguiera gymnorrhiza*, *Bruguiera sexangula*, *Heritiera fomes*, *Flagellaria indica*, *Sarcolobus globosus*. The average number of species in the typical subunit is 8, far fewer than the 16 in the other subunit (Table 7).

Photo 3. Rhizophora apiculata community along a muddy flat bank

Photo 4. Acanthus ilicifolius-Avicennia officinalis community along a muddy flat bank

The *Excoecaria agallocha* subunit is differentiated by *Excoecaria agallocha*, *Cynometra ramiflora*, *Amoora cucullata*, *Merope angulata*, *Aegiceras corniculatum*, *Hibiscus tiliaceus*, and Damin-nwe. The *Bruguiera sexangula-Bruguiera gymnorrhiza* community occurs as patches near the small creek, surrounded by other mangrove plants, such as *Excoecaria agallocha*, *Cynometra ramiflora*, and *Amoora cucullata*. The *Excoecaria agallocha* subunit represents the transitional zone to the pure *Bruguiera sexangula-Bruguiera gymnorrhiza* community.

2) *Excoecaria agallocha-Heritiera fomes* community

This community is the major component and can be seen in every part of the island, on medium ground (level 1 to level 2). So tidal water reaches these sites at least 4-6 days a month even in the dry season (Table 8). The height of the T_1 layer is from 9 to 15m, and total T_1 cover varies from 20 to 80% (Table 4). The soil in this area is generally heavy clay (Table 9). *Heritiera fomes* is a characteristic species of the Ayeyarwady delta and is also useful for local people in various ways. As a result illegal cutting is more frequent than for other species, and it is replaced by substitute species *Hibiscus tiliaceus*, *Acrostichum aureum*, *Phoenix paludosa*, etc. The community comprises a typical subunit and a *Hibiscus tiliaceus* subunit.

The typical subunit is mainly differentiated by *Heritiera fomes*, *Excoecaria agallocha*, *Amoora cucullata*, Damin-nwe, *Barringtonia racemosa*, and *Finlaysonia maritima*. The typical subunit represents the less human-impacted *Heritiera fomes* stand.

The *Hibiscus tiliaceus* subunit is differentiated by *Hibiscus tiliaceus*, *Acrostichum aureum*, *Flagellaria indica*, *Sarcolobus globosus*, and *Clerodendron inerme*. This subunit shows the human stress on *Excoecaria agallocha-Heritiera fomes* community.

3) *Aegiceras corniculatum-Ceriops decandra* community

This community occurs inside the island (330m from the riverside in line transect 4), especially in small depressions. The community grows generally on medium ground (level 1), so it is inundated 10-15 days a month (Table 8). The height of the community is 7 to 9m. The total coverage by the tree layer is 45-75%. The soil in this area is heavy clay (Table 9). The community comprises a typical subunit and a *Heritiera fomes* subunit.

The typical subunit is mainly differentiated by *Ceriops decandra* and *Aegiceras corniculatum*. The average number of species in the typical subunit is 14, fewer than the 16 in the Heritiera fomes subunit (Table 5, 7).

The *Excoecaria agallocha* subunit is differentiated by *Ex-*

Table 3 Bruguiera sexangula-Bruguiera gymnorrhiza community

(1) *Bruguiera sexangula-Bruguiera gymnorrhiza* community
a. Typical subunit
b. *Excoecaria agallocha* subunit

Community type	Layer	a				b					
Sequential relevé number		1	2	3	4	5	6	7	8	9	10
Original relevé number (in field)		B-7	B-8	B-5	B-10	B-6	B-9	B-1	B-3	B-2	B-4
Date of relevé year		2002	2002	2002	2002	2002	2002	2002	2002	2002	2002
month		12	12	12	12	12	12	12	12	12	12
date		30	30	30	30	30	30	28	28	28	30
Relevé size (m×m)		15x20	15x20	15x15	15x20	15x15	15x20	25x25	20x25	20x25	20x20
Height of Tree layer 1 (T1), (m)		-	-	-	-	-	-	12	13	12	13
Cover of Tree layer 1 (T1), (%)		-	-	-	-	-	-	85	75	80	70
Height of Tree layer 2 (T2), (m)		8	8	7	7	7	8	7	6	6	6
Cover of Tree layer 2 (T2), (%)		80	75	85	80	75	80	15	30	35	25
Height of shrub layer (S), (m)		3	3	3	3	3	3	3	3	3	3
Cover of shrub layer (S), (%)		20	10	20	15	20	15	10	5	10	10
Height of herb layer (H), (m)		0.8	0.8	0.8	0.8	0.8	0.5	0.5	1	0.8	0.8
Cover of herb layer (H), (%)		3	2	3	3	2	3	5	10	10	5
Number of species		11	16	19	16	18	14	19	21	22	18
Differential species of communities:											
Bruguiera gymnorrhiza	T1	·	·	·	·	·	·	2.2	2.2	2.2	2.2
	T2	3.4	3.4	3.3	2.2	3.4	2.2	+	1.2	1.1	+
	S	2.2	2.3	1.1	1.1	2.2	1.2	·	·	·	1.1
	H	+	+	+	+	+	+	+	+	+	1.2
Bruguiera sexangula	T1	·	·	·	·	·	·	+	+	+	1.2
	T2	·	·	+	+	+	1.2	+	1.2	1.2	2.2
	S	·	·	+	+	+	+	+	+	+	1.2
	H	+	+	+	+	+	·	·	+	+	1.2
Heritiera fomes	T1	·	·	·	·	·	·	2.2	2.1	2.2	1.2
	T2	1.2	1.1	2.2	+	1.2	1.1	1.2	·	2.2	1.1
	S	1.2	1.1	2.2	+	1.1	1.1	+2	+	+	+
	H	+	+	+	+	+	+	+	+	1.1	+
Flagellaria indica	T2	·	·	+	·	+	+	1.1	+	·	·
	S	·	·	+	+	+	+	·	·	+	·
	H	·	·	·	+	·	·	+2	·	+	·
Sarcolobus globosus	T2	·	+	+	·	+	·	·	+	·	+
	S	·	+	+	·	·	·	·	·	+	+
	H	·	·	·	·	+	·	+2	+	+	+
Differential species of subunit:											
Excoecaria agallocha	T1	·	·	·	·	·	·	1.2	1.2	1.2	·
	T2	·	·	·	·	·	+2	2.2	+	1.2	+
Cynometra ramiflora	T1	·	·	·	·	·	·	+2	·	·	·
	T2	·	·	·	·	+	1.2	·	1.1	2.2	+
	S	·	·	·	·	+	1.1	+	+	1.2	+
	H	·	·	+	·	+	+	+2	+2	1.1	+
Amoora cucullata	T2	·	·	·	·	·	+	1.2	2.2	2.2	1.1
	S	·	·	·	·	+	+	+	+	1.2	+
	H	·	·	·	·	·	·	+	+2	+	1.1
Merope angulata	T2	·	·	·	·	·	1.1	·	·	·	·
	S	·	·	·	·	·	+	+	+	1.2	+
	H	·	·	·	·	·	·	+2	+	+	+
Aegiceras corniculatum	T2	·	·	·	·	·	·	+	1.1	+	1.1
	S	·	·	·	·	·	·	+	·	·	+
	H	·	·	·	·	·	·	·	·	+	+
Hibiscus tiliaceus	S	·	·	·	·	+	+	+	1.1	1.1	·
	H	·	·	·	·	·	+	·	·	·	+
[illegible]	T2	·	·	·	·	·	·	·	+	1.2	·
	S	·	·	·	·	·	·	+	·	·	·
	H	·	·	·	·	·	·	+	+	+2	·
Companion species											
Brownlowia tersa	S	+	+	+	1.1	+	+	+2	·	1.2	1.1
	H	+	+	·	·	+	+	·	+2	·	·
Derris trifoliata	T2	+	+	·	+	+	+	·	+	·	·
	S	+	+	+	+	+	+	+	·	·	+
	H	+	+	+	·	·	+	+2	+	+	+
Salacia prinoides	S	+	·	+	·	·	·	+	·	+	·
	H	·	·	+	·	·	·	+	·	·	·
Ceriops decandra	T2	·	·	+	1.2	·	+	·	·	·	·
	S	·	·	·	+	·	·	·	·	·	·
	H	·	·	+	·	·	+	·	·	·	·
Avicennia officinalis	S	+	·	·	·	+	·	·	·	·	·
Acrostichum aureum	S	·	·	·	·	·	+	·	+	·	·
	H	·	·	·	·	·	+	·	+	·	·
Caesalpinia crista	T2	·	·	·	·	+2	·	·	·	·	·
	S	·	·	·	·	+	·	·	·	·	·
	H	·	·	·	·	·	·	·	·	+2	·
Finlaysonia maritima	S	·	·	+	·	·	·	·	·	·	·
	H	·	·	+	·	·	·	·	·	·	·
Barringtonia racemosa	T2	·	·	+	·	·	·	·	·	1.1	·
	S	·	·	+	·	·	·	·	·	+	·
	H	·	·	·	·	·	·	·	·	+	+

Additional species occurring once in sequential relevé number 7; *Cerbera odollam* S-+; in 8; *Intsia bijuga* T2-1.1; in 9; *Rhizophora apiculata* T2-1.1; *Phoenix paludosa* S-1.1, H-+; *Clerodendrum inerme* S-+; in 10; *Acanthus ilicifolius* H-+.
Location of the relevé number 1-10 are inside of the island, near the small channel with low ground area.
Relevé by M.A. (1-13).

coecaria agallocha, *Cynometra ramiflora*, and *Finlaysonia maritima*. Because the *Aegiceras corniculatum-Ceriops decandra* community occurs as patches, it is surrounded by other mangrove plants, such as *Heritiera fomes*, *Excoecaria agallocha*, and *Cynometra ramiflora*.

4) *Phoenix paludosa* community

The *Phoenix paludosa* community occurs in the interior of the island, *Phoenix paludosa* grows mainly on medium ground (level 2) to high ground, so the community is inundated 3-4 days a month to 2-4 times in the dry season (Table 8). The height of the tree layer is 6 to 9m, and total coverage is 65 to 80%. Due to the over-exploitation of the mangrove forest, Phoenix paludosa can be recognized as a substitute community, since it is very aggressive and forms dense thickets of seedlings on open, disturbed sites. The soil in this community is generally silty clay (Table 9).

2. Forest structure and above-ground biomass

To investigate forest structure and above-ground biomass four quadrats (varying from 10x20m² to 20x20m² depending on stand condition) were established on different vegetation stands. The height and diameter of trees were measured for estimating stem weight, then the crown position in each stand was drawn (Figs. 5-9, Tables 10-13). Tidal inundation is related to ground-level classes (Table 8).

Avicennia officinalis stand: The *Avicennia officinalis* stand can be seen along the fringe of the island, where the soil is organic silty clay or silty clay loam (Fig. 3a). The location of the stand is low ground (level 2), so the stand is flooded 16-21 days a month (Table 8). The total number of trees in 20mx20m plot was scaled up to suggest 1850 trees / ha, of which 43.2% were *Avicennia officinalis*, which was dominant in the tree layer. Some other species are mixed in the understorey layer, including *Kandelia candel* (4.1%),

Table 4 Excoecaria agallocha-Heritiera fomes community

(I) *Excoecaria agallocha-Heritiera fomes* community
a. Typical subunit
b. *Hibiscus tiliaceus* subunit

Community types		a					b										
Sequential relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Original relevé number (in field)		B1-3	B7-2	B3-1	B1-2	B3-2	B4-21	B3-4	B1-1	B3-3	B3-7	B2-3	B7-3	B1-4	B2-1	B3-6	B2-2
Date of relevé	year	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002
	month	1	1	1	1	1	1	1	1	1	1	12	1	1	12	1	12
	days	6	9	6	6	6	8	7	6	6	7	27	9	6	27	7	27
Relevé size (mxm)		15x10	9x10	15x20	25x10	15x15	9x10	11x15	9x10	24x10	7x10	6x15	15x15	20x15	15x20	10x15	15x15
Height of Tree layer 1 (T1), (m)		13	12	15	11	14	13	–	11	13	11	12	9	14	13	13	13
Cover of Tree layer 1 (T1), (%)		75	80	65	70	30	45	–	60	75	25	20	40	40	75	25	80
Height of Tree layer 2 (T2), (m)		7	7	10	7	7	7	9	6	9	7	6	6	8	7	7	7
Cover of Tree layer 2 (T2), (%)		20	20	10	10	30	65	45	10	20	40	20	15	60	15	50	20
Height of shrub layer (S), (m)		2	2.5	4	7.5	4	3	3	3	4	3	3	3	4	3.5	2.5	3
Cover of shrub layer (S), (%)		10	5	25	15	25	5	35	40	30	30	60	10	20	40	15	15
Height of herb layer (H), (m)		0.8	0.5	1.2	1.2	1	0.8	0.8	1	1	1	0.8	0.8	1.5	1	0.6	1
Cover of herb layer (H), (%)		30	3	5	65	25	5	5	50	30	20	30	5	65	10	5	15
Number of species		14	18	19	15	14	7	16	25	16	19	17	16	22	17	17	15
Differential species of communities:																	
Heritiera fomes	T1	4.4	4.4	2.2	4.4	3.3	2.2	.	4.3	3.2	2.2	2.3	1.1	3.3	4.4	2.2	4.4
	T2	.	2.2	1.1	+	2.2	1.1	2.3	+	.	2.3	1.1	.	4.4	2.2	1.2	.
	S	+	.	.	.	.	.	+	.	.	.	.	.	.	.	+	+
	H	.	.	+	1.1	.	+	+	+2	+	.	+	+	.	1.2	+	+2
Excoecaria agallocha	T1	2.2	.	2.2	1.2	.	2.3	.	2.2	.	.	.	.	.	1.1	+	.
	T2	.	.	+	+	.	3.3	1.1	.	+	2.2	.	+	1.1	.	1.2	1.2
	S	.	.	.	.	.	.	.	.	.	.	1.1	.	+	.	+	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Amoora cucullata	T1	+	.	.	+2	.	.	.	1.1	+	.	.	.	.	1.2	.	1.1
	T2	+	+	+2	+	1.1	.	+2	.	+	.	.	.	.	1.1	.	.
	S	.	+	+	+	.	.	.	.	.	+	.	+2	.	.	.	.
	H	+	+	+2	+	1.1	.	+	+	+	.	.	.	.	+2	.	1.2
Dumin-rowe	T2	1.1	.	+	+	.	.	+	.	+	+	.	.	.	.	.	1.2
	S	+	.	.	.	+2	.	.	.	1.2	.	.	.	.	1.2	.	.
	H	.	.	.	+	1.2	.	1.2	.	.	.	1.2	.	.	+2	.	+2
Barringtonia racemosa	T2	+2	+	.	+2	+	.	.	+	.	.	.	.	.	.	+	.
	S	+	.	.	+	+	.	.	+	+	+	.	.	+	+	.	.
	H	+	+	+	+	.	.	.	+	.	+	+	+2	+	.	.	+2
Finlaysonia maritima	T1	.	+2	.	.	.	.	.	.	.	+	.	.	+2	.	.	.
	T2	+	1.2	.	+	.	.	.	+2	.	+	.	.	+	.	.	.
	S	.	+2	+	+	.	.	+	.	.	+	.	.	.	.	+	.
	H	1.1	.	+	1.1	+	.	.	1.1	.	1.2	+	+	+	+2	+	.
Differential species of subunits:																	
Hibiscus tiliaceus	T2	.	.	.	.	.	+2	2.2	+	.	.	.	3.3	.	.	.	.
	S	.	.	.	.	.	.	+	.	.	1.2	+	.	+	.	.	.
	H	.	.	.	.	.	+	+	.	.	+	+	.	.	+	.	.
Acrostichum aureum	S	.	.	.	.	.	.	+2	.	+	.	.	.	.	+	.	.
	H	.	.	.	.	+2	.	.	.	+2	1.2	.	+	.	+	+2	1.1
Flagellaria indica	T1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.
	T2	.	.	.	.	.	.	+	+	.	.	+	.	.	1.1	+	1.1
	S	.	1.2	.	.	.	.	.	+	+	.	+	+	+	.	.	.
	H	.	.	.	.	.	.	+	+	+	1.2	.	+	.	1.2	.	+
Sarcolobus globosus	T2	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.
	S	.	.	.	.	.	.	.	+	.	.	.	.	+	.	+	.
	H	.	.	.	.	.	.	.	+2	.	.	1.2	.	+	.	.	+
Clerodendron inerme	T2	.	.	.	.	.	.	.	.	.	1.2	.	.	+	.	+2	.
	S	.	.	.	.	.	.	+	.	.	.	.	1.2	+	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	+2	+	+	.	.	.
Companion species																	
Phoenix paludosa	T2	.	.	.	.	1.2	+2	.	.	2.2	1.2	+	1.2	.	2.3	1.2	1.2
	S	+2	.	.	.	+2	.	.	2.2	.	1.2	+	.	.	2.2	+2	+2
	H	1.2	.	+2	+	+	.	.	.	+2	+	+2	.	2.2	+2	+	+
Cynometra ramiflora	T1	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	2.2
	T2	+	.	+	.	+	2.2	2.2	+	.	.	1.1	.	+	1.1	2.3	1.2
	S	.	+	+	.	.	1.1	.	.	1.2	.	.	1.2	+	+	1.2	+2
	H	1.1	+	+	1.1	1.1	1.2	+2	.	+	.	1.2	+2	1.1	1.2	1.2	.
Acanthus ilicifolius	S	1.2	.	.	2.2	.	.	.	1.2	.	.	+	.	.	.	.	.
	H	2.3	+	+	4.4	+	.	.	1.2	+	+	2.2	+2	4.4	+	+2	1.2
Derris trifoliata	T1	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.
	T2	+	+2	.	+	+	1.1	.	+	.	.	.	.	+2	+	+	.
	S	+	+	.	.	.	.	.	.	.	+	2.3	.	+	.	.	1.2
	H	+	+	+	+	.	.	.	+	+	1.2	2.2	+	+	+	.	+2
Merope angulata	T2	.	.	+	.	.	.	.	.	.	.	.	.	.	1.1	.	+2
	S	.	.	1.1	.	.	.	+	.	+	+	1.1	.	+	1.2	+	+
	H	.	+	+	.	1.1	.	1.1	+	.	.	.	.	.	+	+	.

Caesalpinia crista	T2	.	.	.	.	.	.	.	.	.	.	.	+.2	.	.	.	.
	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+.2
	H	.	+	1.1	.	.	.	.	.	.	.	.	.	.	.	+.2	.
Brownlowia tersa	S	.	1.2	.	+.2	+.2	.	.	.	1.2	+.2	.	+.2	.	.	.	.
	H	.	+.2	.	.	.	.	.	.	+.2	.	.	.	+.2	.	.	.
Dalbergia spinosa	T2	.	.	.	.	.	.	.	.	+.2	.	.	.	.	.	1.2	.
	S	.	2.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Xylocarpus moluccensis	T1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	T2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Xylocarpus granatum	T2	.	+.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acanthus volubilis	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhizophora apiculata	T1	.	2.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	T2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bruguiera gymnorrhiza	T1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	T2	.	.	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mucuna gigantea	T2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ceriops decandra	T2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cerbera odollam	T2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hoya diversifolia	T2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cayratia trifolia	T2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dalbergia pinnata	S	.	.	.	.	.	.	.	.	.	+.2	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dolichandrone spathacea	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eupatorium odoratum	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Phragmites karka	T2	.	.	.	.	.	.	.	.	.	.	2.2	.	.	.	.	.
	S	.	+.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nypa fruticans	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Intsia bijuga	T2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anamirta paniculata	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nga-dan-pain	H	.	.	.	.	.	.	.	.	.	.	.	+.2	.	.	.	.
unknown 1	S	.	.	.	.	.	.	.	.	+.2	.	.	.	.	.	+.2	.

Additional species occurring once in sequential relevé number 2; *Crinum asiaticum* H-+, in 7; Apocynaceae T2-+, in 10, *Avicennia officinalis* H-+, Kyee-baung T2-+.2.
Location of the relevé number 1-16 are interior of the island with medium to high ground area.
Relevé by M.A, K.F, K.H. (1-10), 12, 13, 15, 16; M.A. (11, 14)

Brownlowia tersa (41.9%), *Amoora cucullata* (6.8%), and *Excoecaria agallocha* (4.1%). The maximum height of *Avicennia officinalis* is 16m, and the minimum height is 4.5m. The DBH range is 3.0-28.5cm. Estimated biomass of *Avicennia officinalis* is 139.9 t / ha, and the total estimated biomass in the stand is 143.4 t / ha (Table 10).

Heritiera fomes stand: The *Heritiera fomes* stand is on riverbank or fluvial deposits, where the soil is hard, yellowish gray clay (Fig. 3a). The stand is situated on medium ground (level 2), so the stand is flooded 10-15 days a month (Table 8). The total number of trees in 20mx20m plot was scaled up to suggest 4550 trees / ha, and 49.5% of which were *Heritiera fomes*. Some other species are mixed together, such as *Excoecaria agallocha* (21.4%), *Ceriops decandra* (21.4%), *Cynometra ramiflora* (3.3%), *Bruguiera gymnorrhiza* (2.7%) and *Amoora cucullata* (1.6%). The maximum height of the *Heritiera fomes* is 13.5m and the minimum height is 2.1m, with DBH of 1.0-13.0cm. Estimated biomass of *Heritiera fomes* is 69.4 t / ha, and the total estimated biomass of the stand is 114.5 t / ha (Table 11).

Bruguiera gymnorrhiza stand: The *Bruguiera gymnorrhiza* stand is on fluvial deposits on the side of a small channel, where the soil is wet, soft, yellowish gray clay (Fig. 3c). The stand is on medium ground (level 1), so tide water reaches 10-15 days a month. The total number of trees in 20mx20m plot was scaled up to suggest 3789 tree / ha. Bruguiera gymnorrhiza was 61.4% and dominant in the tree layer. Some other species are mixed together, including *Heritiera fomes* (24.6%), *Excoecaria agallocha* (3.5%), *Ceriops decandra* (4.4%), *Amoora cucullata* (3.5%), and *Cynometra ramiflora* (2.6%). The maximum height of *Bruguiera gymnorrhiza* is 11.7m, and the minimum height is 3.3m. The DBH range is 2.5-11.0cm. Estimated biomass of *Bruguiera gymnorrhiza* is 44.0 t / ha, and the total estimated biomass in the stand is 97.7 t / ha (Table 12).

Rhizophora apiculata stand: *Rhizophora apiculata* grows on organic deposits, as found on the fringe of the island, where the soil is wet, soft, silty clay or silty clay loam (Fig. 4). The stand is situated on low ground (level 1), so it is flooded by every high tide. The total number of trees in 10mx20m plot was scaled up to suggest 3800 tree / ha, 46.1% of which were *Rhizophora apiculata*. *Heritiera fomes* (39.5%), *Xylocarpus granatum* (9.2%), and *Kandelia candel* (5.3%) are also found in this stand. The maximum height of the *Rhizophora apiculata* is 9.9m, and the minimum height is 1.0m, DBH range is 2.5-11.5cm. Estimated biomass of

Table 5 Aegiceras corniculatum-Ceriops decandra community

(I) *Aegiceras corniculatum-Ceriops decandra* community
a. Typical subunit
b. *Excoecaria agallocha* subunit

		a								b								
Sequential relevé number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Original relevé number (in field)		B4-22	B4-18	B4-17	B4-21	B4-8	B4-9	B4-6	B4-13	B4-20	B4-24	B4-14	B4-10	B4-19	B4-11	B4-12	B4-16	B4-7
Date of relevé	year	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002	2002
	month	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	date	8	8	8	8	7	8	7	8	8	8	8	8	8	8	8	8	7
Relevé size (mxm)		12x10	10x10	8x8	8x15	12x10	12x13	10x10	8x10	8x8	9x10	10x10	15x10	16x18	8x9	12x10	9x10	8x8
Height of Tree layer (T), (m)		7	9	8	8	9	7	7	7	8	7	9	7	7	7	7	7	8
Cover of Tree layer (T), (%)		65	75	45	75	60	70	45	50	45	55	60	70	75	45	45	45	60
Height of shrub layer (S), (m)		2	3	2	2	4	2.5	2.5	3	4	3	3	4	3	3	3.5	4	2.5
Cover of shrub layer (S), (%)		5	10	5	5	20	5	10	10	5	15	35	5	10	10	15	10	15
Height of herb layer (H), (m)		0.8	1	0.9	1	0.8	0.8	0.6	1	0.5	0.8	0.8	1	1	1	1	1	1
Cover of herb layer (H), (%)		5	10	20	5	5	5	3	5	10	10	10	10	15	5	5	10	25
Number of species		7	6	8	6	8	9	9	9	9	9	11	8	9	8	9	9	9
Differential species of communities																		
Ceriops decandra	T	4.4	4.4	3.3	4.4	2.2	4.3	3.2	3.3	2.3	3.3	2.2	3.3	4.4	3.3	3.3	3.3	2.2
	S	.	.	1.1	.	.	.	+	+	.	+	.	1.1	.	.	+	.	1.2
	H	.	1.1	.	+	.	+	.	.	+	.	+	+	.	+	+	+	.
Aegiceras corniculatum	T	1.1	2.2	1.2	2.2	.	+	+	.	1.1	1.1	2.2	1.1	.	2.2	1.2	+	.
	S	.	.	.	.	.	.	.	.	+	+	+	.	+	.	.	.	+
	H	+	.	.	.	+	.	.	+	.	.	.	.	+	.	.	.	+
Differential species of subunits																		
Excoecaria agallocha	T	.	.	.	.	.	.	+	.	+	+	+	.	.	.	.	.	.
	S	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.
	H	.	.	.	.	.	+	.	.	.	.	+	.	+	.	.	.	+
Cynometra ramiflora	T	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	+
	S	.	.	+	.	.	.	.	.	.	+	+	+	.	.	+	+	.
	H	.	.	+	.	.	.	.	.	.	+	+	+	.	+	+	+	+
Finlaysonia maritima	T	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.
	S	.	.	.	.	.	.	.	.	.	+.2	.	+	.	+	.	.	.
	H	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.
Companion species																		
Heritiera fomes	T	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.
	S	.	.	.	+	+	.	.	.	.	+	.	.	+	.	.	+	.
	H	.	.	.	+	+	.	+	.	+	+.2	.	+	+	+	.	+	+
Derris trifoliata	T	.	+	+	.	.	.	.	.	.	+	.	+	+	.	+	.	+
	S	.	.	.	+	.	+	.	+	.	.	+	+	.	+	+	+	.
	H	+	.	+.2	.	.	+	+	+	.	.	+	+	+	+	+	+	+
Flagellaria indica	T	.	+	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.
	S	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.
	H	.	+	+	.	+	.	.	.	+	+	+	.	.	.	.	+	.
Acrostichum aureum	S	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
	H	+	.	.	+.2	+.2	.	.	+	.	.	+	.	.	+	.	.	+
Amoora cucullata	H	.	.	.	.	.	+	+	.	.	.	.	.	.	.	+	.	.
Dalbergia pinnata	S	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
	H	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.
Acanthus ilicifolius	H	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+
Merope angulata	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Cerbera odollam	S	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Cayratia trifolia	T	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
	S	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
	H	.	.	+	.	.	.	.	.	+	+	+	.	.	.	+	.	.
Phoenix paludosa	T	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S	.	.	.	+	.	.	.	.	.	.	.	+	+	.	.	.	.
	H	+	.	.	+	+	.	.	.	.	.	.	.	+	.	.	.	.
Sarcolobus globosus	S	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Dalbergia spinosa	S	.	.	.	.	+	.	+	.	.	.	.	.	.	+	+	.	.
	H	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.
Hoya diversifolia	S	.	.	.	.	.	+	.	+	.	.	.	.	.	.	+	.	.

Additional species occurring once in sequential relevé number 1; *Intsia bijuga* H-+, *Hibiscus tiliaceus* T-+; in 11; Apocynaceae S-+; in 12; *Hibiscus tiliaceus* S-+, H-+; in 13; Danin-nwe T-+, *Dolichandrone spathacea* S-+; in 8; Danin-nwe S-+, Kyee-haung H-+; in 7; *Brownlowia tersa* H-+.

Location of the relevé number 1-17 are interior of the island with medium ground area

Relevé by M.A., K.F., K.H. (1-17)

Rhizophora apiculata is 39.1 t / ha, and the estimated total biomass in the stand is 80.6 t / ha (Table 13)

Discussion and Conclusion

The mangrove communities of the study areas can be classified into two categories: 1) river-bank communities and 2) inland communities. The river-bank communities include (1) *Sarcolobus globosus-Brownlowia tersa*, (2) *Ipomoea tuba-Hibiscus tiliaceus*, (3) *Rhizophora apiculata*, (4) *Leptochloa filiformis-Kandelia candel*, and (5) *Acanthus ilicifolius-Avicennia officinalis*. The inland communities consist of (1) *Bruguiera sexangula-Bruguiera gymnorrhiza*, (2) *Excoecaria agallocha- Heritiera fomes*, (3) *Aegiceras corniculatum-Ceriops decandra*, and (4) Phoenix paludosa. Watson (1928)

Table 6 Phoenix paludosa community

(I) *Phoenix paludosa* community					
Community type		I			
Sequential relevé number		1	2	3	4
Original relevé number (in field)		B-14	B-15	B11	B12
Date of relevé year		2003	2003	2003	2003
month		1	1	1	1
date		28	28	24	24
Relevé size (mxm)		9x12	8x12	10x10	10x10
Height of Tree layer (T) (m)		7	6	8	9
Cover of Tree layer (T) (%)		70	70	65	80
Height of shrub layer (S), (m)		2.5	2	3	3
Cover of shrub layer (S), (%)		10	10	20	20
Height of herb layer (H), (m)		0.7	0.5	0.5	0.6
Cover of herb layer (H), (%)		5	3	7	5
Number of species		5	8	3	5
Differential species of communities:					
Phoenix paludosa	T	4.4	4.4	3.4	4.4
	S	+	+.2	2.2	2.2
	H	+	·	1.2	+.2
Heritiera fomes	T	1.2	1.2	1.1	+
	H	·	+	·	·
Excoecaria agallocha	T	·	·	·	1.1
	S	·	·	+	·
Acrostichum aureum	S	1.2	+	·	·
	H	+	+	·	·
Flagellaria indica	T	·	+	·	·
Cynometra ramiflora	T	·	·	·	1.1
	H	·	+	·	+
Derris trifoliata	T	+	+	·	·
	H	+	+	·	+
Hibiscus tiliaceus	T	·	1.2	·	+
	S	·	+	·	+
Acanthus ilicifolius	S	+	·	·	·
Dumin-nwe	S	·	+	·	+
	H	·	+	+	+

Location of the relevé number 1-4 are in the high interior of the island.
Relevé by M.A. (1-4).

considered that the chief determining factors for the distribution of mangrove communities are 1) frequency of inundation, 2) drainage, 3) soil character, 4) age of swamp, and 5) degree of exposure insofar as it affects erosion or accretion. The *Rhizophora apiculata* community, *Leptochloa filiformis-Kandelia candel* community and *Acanthus ilicifolius-Avicennia officinalis* community occur along accreting banks. The ground level is low, a little below the mean water level (MWL) to mean high water level (MHWL), so it is flooded by every high tide. These communities form on an organic deposit, the soil consists of wet and generally silty clay or silty clay loam.

Another factor that affects the community is its location in the island. The *Acanthus ilicifolius-Avicennia officinalis* community is located along the fringe of the island, so it gets the direct exposure to light and grows well. This supports the opinion of Chapman (1976) that *Avicennia* species are generally 'light demanders'. *Brownlowia tersa and Hibiscus tiliaceus* grow along eroding banks, and *Kandelia candel, Avicennia officinalis, and Rhizophora apiculata* occur along accreting banks of the island. River-bank dynamics (accretion or erosion) is one of the important factors determining the mangrove formations of the Ayeyarwady delta. The *Excoecaria agallocha-Heritiera fomes* community occurs over a very wide range and so has admixtures of other species, such

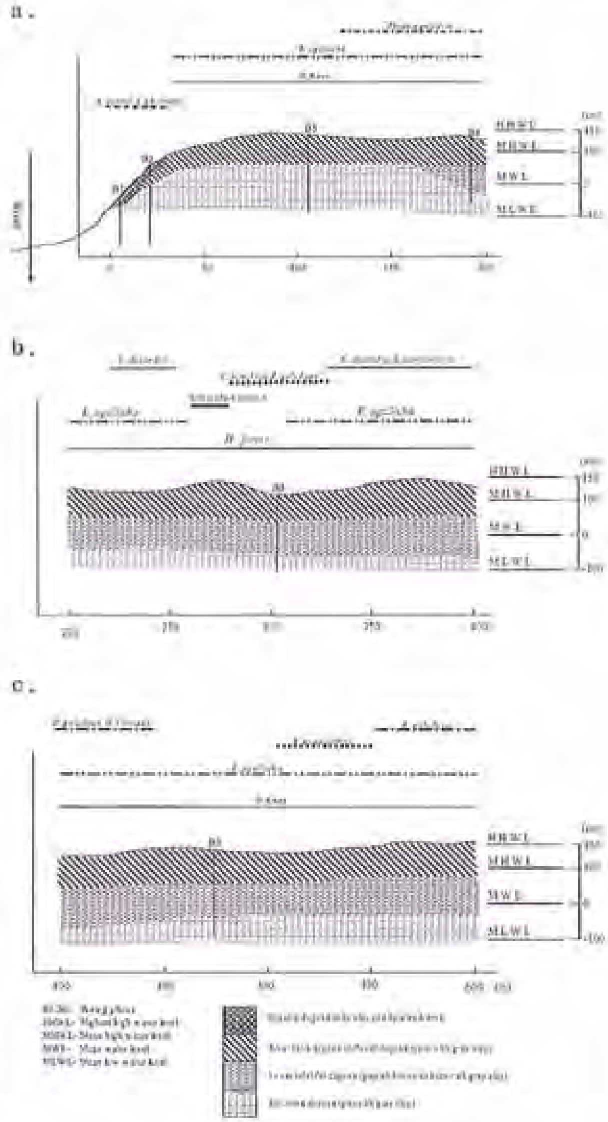

Fig. 3. Vegetation, land form and geological profile on the line transect 4

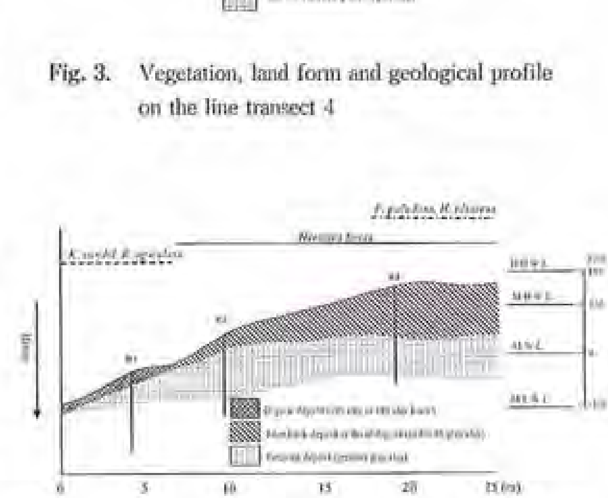

Fig. 4. Vegetation, land form and geological profiles on the line transect 8

Table 7 Summary table of mangrove communities in Byone-hmwe Island, Ayeyarwady Delta, Myanmar.

Community number	1	2	3	4		5		6		7	8		9
Number of relevé	3	6	4	5	5	5	11	11	6	4	4	5	7
Average no. of species	5	8	6	8	16	18	16	16	14	5	14	11	2
Differential species of *Rhizophora apiculata* comm.													
Rhizophora apiculata	3	·	·	·	I	I	+	·	·	·	·	·	·
Differential species of *Leptochloa filiformis-Kandelia candel* comm.													
Kandelia candel	3	V	2	·	·	·	·	·	·	·	·	·	·
Leptochloa filiformis	·	III	·	·	·	·	·	·	·	·	·	·	·
Differential species of *Acanthus ilicifolius-Avicennia officinalis* comm.													
Avicennia officinalis	2	II	4	I	·	·	+	·	·	·	I	·	·
Differential species of *Bruguiera sexangula-Bruguiera gymnorrhiza* comm.													
Bruguiera gymnorrhiza	I	·	·	V	V	III	+	·	·	·	·	·	·
Bruguiera sexangula	·	·	·	V	V	·	·	·	·	·	·	·	·
Differential species of *Excoecaria agallocha-Heritiera fomes* comm.													
Amoora cucullata	·	I	I	I	V	V	IV	II	II	·	I	·	·
Damin-nwe	·	+	+	+	III	IV	III	+	·	I	I	I	·
Merope angulata	·	+	+	+	V	III	V	+	·	·	+	·	+
Barringtonia racemosa	·	·	·	I	I	V	V	·	·	·	I	I	·
Finlaysonia maritima	I	·	2	I	·	V	IV	III	·	·	I	·	·
Clerodendron inerme	·			·	I		III				I	I	·
Differential species of *Aegiceras corniculatum-Ceriops decandra* comm.													
Ceriops decandra	·	·	·	II	I	II	+	V	V	·	I	·	·
Aegiceras corniculatum	I	II	I	·	IV	·	·	V	V	·	I	·	·
Differential species of *Phoenix paludosa* comm.													
Phoenix paludosa	·	·	·	·	II	V	V	I	III	4	4	·	·
Differential species of *Ipomoea tuba-Hibiscus tiliaceus* comm.													
Hibiscus tiliaceus	·	·	+	I	V	I	IV	+	I	2	4	V	·
Ipomoea tuba	·	·	·	·	·	·	·	·	·	·	2	IV	·
Differential species of *Sarcolobus globosus-Brownlowia tersa* community													
Brownlowia tersa	1		4	V	V	IV	IV	+			I	I	V
Sarcolobus globosus			3	III	IV		IV		III		I	III	V
Other species													
Heritiera fomes	1	·	I	V	V	V	V	V	II	4	4	I	·
Excoecaria agallocha	·	·	·	I	V	IV	IV	IV	I	I	I	·	·
Acrostichum aureum					II	I	IV	III	IV	2	2		
Cynometra ramiflora					V	V	V	IV	I	2	4	I	
Xylocarpus granatum	1					II	+						
Xylocarpus moluccensis						II	+						
Acanthus ilicifolius		V	4	I	I	V	V	I		I	2	III	III
Derris trifoliata	1	I	4	V	V	V	V	V	V	3	2	IV	V
Flagellaria indica				III	IV	I	V	II	III	I	3	IV	
Caymnatia trifolia						I	+	II	II		I	II	
Caesalpinia crista				I	I	II	IV				3	I	
Dalbergia spinosa						II	II	I	I		I	I	
Dalbergia pinnata						I	II	II	I		I	I	
Mucuna gigantea			I			I	I				I	I	
Cerbera odollam					I	II	+	+					
Hoya diversifolia						II	+	I	II				
Salacia prinoides				II	II						I	II	
Intsia bijuga					I		I	+	I			II	
Kyee-baung							I	+					I
Nypa fruticans			2			I	I						
Anamirta paniculata						I	+					I	
Nga-dan pain		I					I					I	
Acanthus volubilis						I	+						
Phragmites karka						I	+						
Caesalpinia bonduc		II	I										
Dolichandrone spathacea							I	+					
Apocynaceae							+	+					
The rest are omitted													

as *Cynometra ramiflora*, *Phoenix paludosa*, *Amoora cucullata*, and *Bruguiera gymnorrhiza*. *Sonneratia* spp. are scattered in the delta, generally as one or two large trees in front of river banks, as compared with their massive occurrence on muddy banks of the river mouth at Ranong, Thailand (Miyawaki *et al.*, 1985). We suppose that *Hibiscus tiliaceus*, *Phoenix paludosa* and *Acrostichum aureum* emerge after clear cutting. When they invade it is difficult for other mangrove species to regenerate, since these invaders grow rapidly and prevent light from reaching the ground. Because of the broad area of *Phoenix paludosa*, *Hibiscus tiliaceus* and other bush types, it can be concluded that the area was severely affected by human activities. The small stem diameter and prevalence of dwarf trees with coppice also identifies the area as secondary forest. The rivers are extremely active, and so a fresh cover of silt is deposited every year. The physical characteristics of the soil vary slightly depending on different vegetation stands. The soil in the study area is generally silty clay or clay, plastic and sticky. The surface layer of the soil can be seen to have cracks during the dry season, and there is less moisture in the soil. *Avicennia officinalis* can be seen to grow well along the flat muddy river bank. According to our investigation, the *Avicennia officinalis* stand shows the greatest height, largest stem diameter and most biomass, suggesting that the site conditions are suitable for this species.

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Table 8 Frequency of tidal inundation relative to ground-level classes

Tidal inundation	Mangrove land area classes	Water level (m)	Days of flooding/month in dry season	Watson's inundation class
Flooded by all high tides	Low ground, level 1	0.1-1.6 above admiralty datum	22-31	1
Medium high tides (MHT)	Low ground, level 2	1.6-2.0	16-21	2
Normal high tides (NHT)	Medium ground, level 1	2.0-2.4	10-15	3
Spring high tides (SHT)	Medium ground, level 2	2.4-2.7	3-4	4
Flooded by equinoctial tides	High ground	2.7-2.8	2-4 times in dry season	5
Flooded in rainy season	Extremely high ground	2.8-3.3	wet-season floods only	6

Source : modified from Kogo (1992)

Table 9 Morphology and nutrient contents of soil in Byone-hmwe Island

Stand in field	No. of sample	Depth (cm)	Texture	Sand %	Silt %	Clay %
Rhizophora apiculata	5	0-10	silty clay	6.58	48.60	44.82
Kandelia candel	5	0-10	silty clay	5.07	49.95	44.99
Avicennia officinalis	5	0-10	silty clay	12.93	58.61	28.45
Bruguiera gymnorrhiza	5	0-10	silty clay	8.63	49.88	41.49
Heritiera fomes	5	0-10	heavy clay	4.92	43.95	51.12
Ceriops decandra	2	0-10	heavy clay	5.46	39.66	54.87
Phoenix paludosa	2	0-10	silty clay	4.63	60.19	35.17
Hibiscus tiliaceus	3	0-10	silty clay	4.65	55.97	39.39
Brownlowia tersa	3	0-10	silty clay	6.16	49.25	44.59

Table 10 Size of sample trees and estimated biomass in the Avicennia officinalis stand

	Avicennia officinalis	*Kandelia candel*	*Brownlowia tersa*	*Amoora cucullata*	*Excoecaria agallocha*	Total
No. trees/ha	800 (43.2%)	75 (4.1%)	775 (41.9%)	125 (6.8%)	75 (4.1%)	1850
Max. DBH (cm)	28.5	7.5	3.5	6.5	9.0	
Minimum DBH (cm)	3.0	6.0	1.4	1.3	3.9	
Max. height (m)	16.0	9.4	8.5	1.9	12.2	
Minimum height (m)	4.5	7.2	2.5	5.9	2.5	
Average DBH (cm)	15.7	6.9	2.1	4.0	6.2	
Average height (m)	12.3	8.1	3.5	3.7	6.4	
Estimated biomass t/ha	139.9	1.4	0.5	0.5	1.1	143.4

Table 11 Size of sample trees and estimated biomass in the Heritiera fomes stand

	Heritiera fomes	*Excoecaria agallocha*	*Ceriops decandra*	*Cynometra ramiflora*	*Bruguiera gymnorrhiza*	*Amoora cucullata*	Total
No. trees/ha	2250 (49.5%)	975 (21.4%)	975 (21.4%)	150 (3.3%)	125 (2.7%)	75 (1.6%)	4550
Max. DBH (cm)	13.0	14.5	5.5	8.0	6.5	4.5	
Minimum DBH (cm)	1.0	1.0	1.0	1.0	3.0	5.0	
Max. height (m)	13.3	11.3	7.4	7.4	7.6	8.9	
Minimum height (m)	2.1	3.0	3.0	3.0	6.3	5.7	
Average DBH (cm)	6.1	6.0	5.1	5.1	4.6	4.7	
Average height (m)	8.5	7.7	5.9	5.9	6.9	7.0	
Estimated biomass t/ha	69.4	36.8	5.1	2.0	0.9	0.4	114.6

Table 12 Size of sample trees and estimated biomass in the Bruguiera gymnorrhiza stand

	Bruguiera gymnorrhiza	*Heritiera fomes*	*Excoecaria agallocha*	*Ceriops decandra*	*Amoora cucullata*	*Cynometra ramiflora*	Total
No. trees/ha	2333 (61.4%)	933 (24.6%)	133 (3.5%)	166 (4.4%)	133 (3.5%)	100 (2.6%)	3798
Max. DBH (cm)	11.0	18.0	14.0	5.5	8.0	3.5	
Minimum DBH (cm)	2.5	1.5	2.5	1.5	1.2	2.0	
Max. height (m)	11.7	12.0	10.8	6.4	7.4	3.7	
Minimum height (m)	3.3	2.1	4.5	3.4	2.1	4.8	
Average DBH (cm)	6.7	8.3	9.9	4.6	3.7	2.8	
Average height (m)	8.0	11.5	8.1	5.7	4.3	4.3	
Estimated biomass t/ha	44.0	40.4	10.3	1.4	0.6	1.0	97.7

Table 13 Size of sample trees and estimated biomass in the Rhizophora apiculata stand

	Rhizophora apiculata	*Heritiera fomes*	*Xylocarpus granatum*	*Kandelia candel*	Total
No. trees/ha	1750 (46.1%)	1500 (39.5%)	350 (9.2%)	200 (5.3%)	3800
Max. DBH (cm)	11.5	16.0	16.0	10.0	
Minimum DBH (cm)	2.5	2.0	3.2	3.0	
Max. height (m)	9.9	11.9	9.1	7.5	
Minimum height (m)	1.0	2.1	4.7	1.5	
Average DBH (cm)	5.9	5.8	8.2	5.8	
Average height (m)	6.3	5.8	7.0	4.9	
Estimated biomass t/ha	39.1	25.0	8.7	7.8	80.6

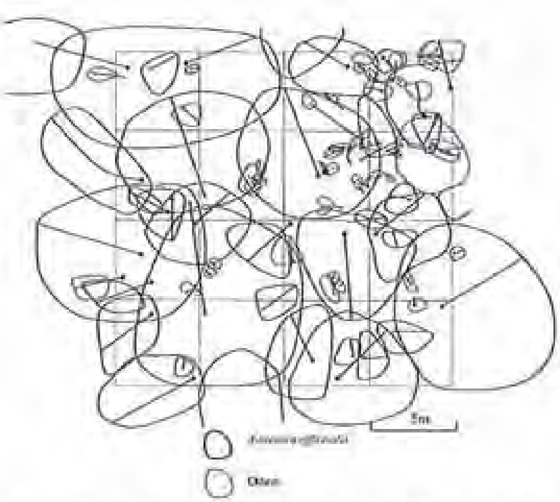

Fig. 5. Crown projections in the Avicennia officinalis stand

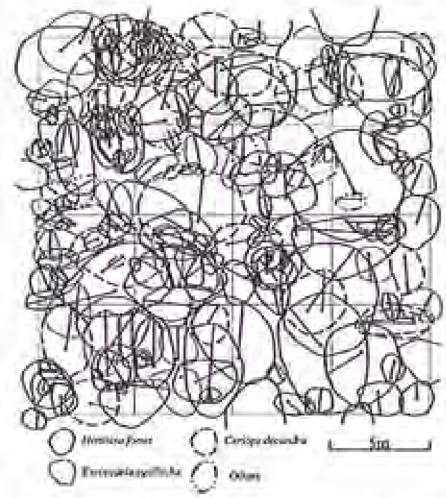

Fig. 6. Crown projections in the Heritiera fomes stand

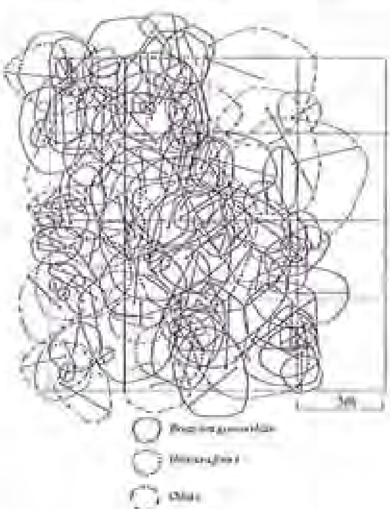

Fig. 7. Crown projections in the Bruguiera gymnorhiza stand

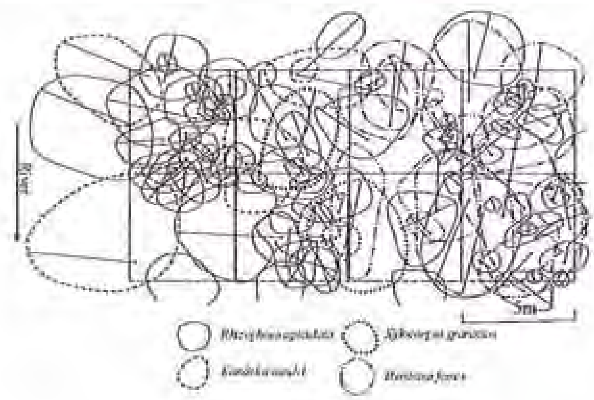

Fig. 8. Crown projections in the Rhizophora apiculata stand

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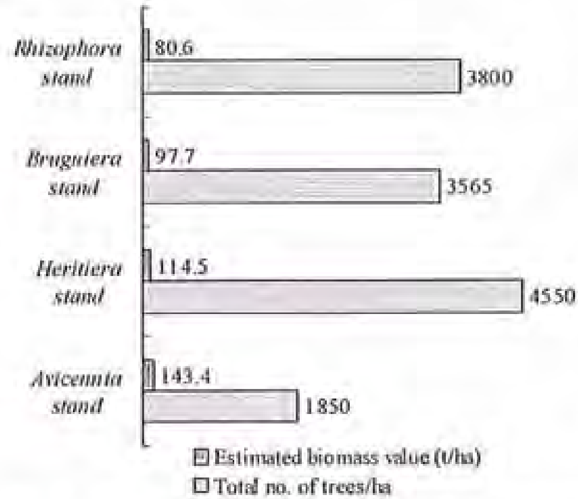

Fig. 9. Estimated biomass and total number of trees in four different stands

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ミィン　アウン[1]・藤原　一繪[1]・持田　幸良[2]：ミャンマー国エーヤーワディデルタ　ピョンムエ島のマングローブ植生の植物社会学的研究－とくに種組成と立地環境について－

ミャンマー国エーヤーワディデルタにおけるマングローブ林の現状は、その多くの部分が伐採あるいは破壊され、居住地域や水田に代えられているが、一部では植生回復のための植林が行われている。ピョンムエ島は1992年より保護区とされ、マングローブ林は自然の状態に戻りつつある。マングローブ林の現存植生の把握と立地環境把握のため Braun-Blanquet(1964) や Fujiwara(1987) を用いた植物社会学的調査とライントランセクト法を用いた調査を行った。

調査の結果マングローブ林は、河岸上の群落型と内陸側の群落型に大別された。前者は *Sarcolobus globosus-Brownlowia tersa community, Ipomoea tuba- Hibiscus tiliaceus community, Rhizophora apiculata community, Leptochloa filiformis-Kandelia candel community* の5型に、後者は *Bruguiera sexangula-Bruguiera gymnorrhiza community, Excoecaria agallocha-Heritiera fomes community, Aegiceras corniculatum-Ceriops decandra community, Phoenix paludosa community* の4型にまとめられた。本報告はミャンマー国エーヤーワディデルタのマングローブ植生を対象とした初めての植物社会学的研究報告である。エーヤーワディデルタの大部分は *Heritiera fomes* と *Excoecaria agallocha* に被われ、他の東南アジアで広く見られる *Rhizophora spp.* は流水沿いに細く点在して見られるのみであることが明らかにされた。

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Appendix 1

No.	Botanical name	Family	Growth form	Myanmar name
1	*Acanthus ilicifolius* L.	Acanthaceae	S	Kaya
2	*Acanthus volubilis* Wall.	Acanthaceae	S	Kaya
3	*Acrostichum aureum* L.	Filiaceae	F	Hnget-gui-daung
4	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae	T	Ye-kaya
5	*Anamirta paniculata* Colebr.	Menispermaceae	C	?
6	*Allophyllus cobbe* (L.) Bl.	Sapindaceae	S	?
7	*Amoora cucullata* (Roxb.)	Meliaceae	T	Pant-tha-ka
8	*Avicennia officinalis* L.	Avicenniaceae	T	Thame-gyi
9	*Barringtonia racemosa* (L.)S preng	Lecythidaceae	T	Ye-kyi
10	*Brownlowia tersa* (L.)	Tiliaceae	S	Ye-tha-man
11	*Bruguiera gymnorrhiza* (L.) Lamk.	Rhizophoraceae	T	Byu-u-talone
12	*Bruguiera sexangula* (Lour.) Poir.	Rhizophoraceae	T	Byu-shwe-wa
13	*Caesalpinia bonduc* (L.) Roxb.	Leguminosae	C	Kyee-kalain
14	*Caesalpinia crista* L.	Leguminosae	C	Alo-lay
15	*Cayratia trifolia* (L.) Domin	Vitaceae	C	?
16	*Cerbera odollam* Gaertner	Apocynaceae	T	Za-lut
17	*Ceriops decandra* (Griff.)Ding Hou	Rhizophoraceae	T	Madama
18	*Clerodendron inerme* (L.) Gaertn	Verbenaceae	C	Taw-kyaung-pan
19	*Crinium asiaticum* L.	Amaryllidaceae	H	Ko-yan-gyi
20	*Cynometra ramiflora* L.	Leguminaceae	T	Myin-ga
21	*Dalbergia pinnata* (Lour.)	Leguminosae	C	Ye-magyi-nwe
22	*Dalbergia spinosa* Roxb.	Leguminosae	C	Byeik-suu
23	*Derris trifoliata* Lour.	Papilionaceae	C	Mi-chaung-nwe
24	*Dolichandrone spathacea* (L.f.) K. Schumann	Bignoniaceae	T	Tha-khyut
25	*Eupatorium odoratum* L. *E. conyzoides* VAHL.	Compositae	H	Bee-sat
26	*Excoecaria agallocha* L.	Euphorbiaceae	T	Tha-yaw
27	*Finlaysonia maritima* Backer ex K. Heyne	Asclepiadaceae	C	Kha-mon-nwe
28	*Flagellaria indica* L.	Flagellariaceae	C	Myauk-kyein
29	*Heritiera fomes* Buch.-Ham.	Sterculiaceae	T	Kanazo
30	*Hibiscus tiliaceus* L.	Malvaceae	S	Thin-ban
31	*Hoya diversifolia* BL.	Asclepiadaceae	C	?
32	*Intsia bijuga* (Colebr.) O. Kuntze	Leguminosae	T	Saka-lun
33	*Ipomoea tuba* (Schlecht.) G. Don.	Convolvulaceae	C	Bon-sein-nwe
34	*Kandelia candel* (L.) Druce	Rhizophoraceae	T	Byu-baing-daunt
35	*Leptochloa filiformis* (Lam.)	Gramineae	H	Myet-khar
36	*Merope angulata* (Willd.) Swingle	Rutaceae	S	Taw-shauk
37	*Mucuna gigantea* DC.	Leguminosae	C	Khwe-lay-nwe
38	*Nypa fruticans* (Thunb.) Wurmb.	Palmae	S	Dani
39	*Phoenix paludosa* Roxb.	Palmae	S	Thin-baung
40	*Phragmites karka* (Roxb.)	Gramineae	H	Kyu
41	*Pluchea indica* Less.	Compositae	H	Kha-yu
42	*Pongamia pinnata* (L.) Pierre	Leguminosae	T	Thau-thet
43	*Premna integrifolia* Lam.	Verbenaceae	C	Taw-taung-dan-gyi
44	*Rhizophora apiculata* BL.	Rhizophoraceae	T	Byu-u-talon
45	*Salacia prinoidies* DC. *S. chinensis* L.	Hippocrateaceae	C	Bu
46	*Sarcolobus globosus* WALL.	Asclepiadaceae	C	Byauk-nwe
47	*Scirpus* sp.	Cyperaceae	H	?
48	*Sonneratia caseolaris* (L.) Engler	Sonneratiaceae	T	Lamu
49	*Sonneratia griffithii* Kurz	Sonneratiaceae	T	Laba
50	*Xylocarpus granatum* (Lamk.) Roem.	Meliaceae	T	Pin-le-ohn
51	*Xylocarpus moluccensis* König	Meliaceae	T	Kya-na

Growth form: T- tree, S- shrub, H- herb, and C- climber, F- fern

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Leaf Protoplast Isolation from Eight Mangrove Species of Three Different Families; Avicenniaceae, Rhizophoraceae and Sonneratiaceae

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Abstract : A wide range of high osmotic conditions from sorbitol solution was effective in isolating leaf protoplasts from young seedlings and plants of seven mangrove species from three different families, i.e. *Avicennia alba Blume, A. marina* (Forsk.) Vierh., *A. officinalis* L. (Avicenniaceae); *Bruguiera gymnorrhiza* (L.) Lamk., *Ceriops tagal* Perr. C. B. Robinson, *Kandelia candel* (L.) Druce (Rhizophoraceae); and *Sonneratia alba* J. Smith (Sonnearatiaceae). In contrast, *Rhizophora apiculata* BL. (Rhizophoraceae), similar to osmotic optimum condition of a non-mangrove tree species, Populus alba, had a lower osmotic optimum for protoplast isolation. In general, all mangrove materials tested preferred Cellulase RS than Cellulase R-10 as a major cell wall degrading enzyme. The addition of Driselase 20 to Cellulase RS was proven to be the most effective treatment in protoplast isolation. Macerozyme R-10 was effective for *A. alba, C. tagal* and *S. alba,* and Pectolyase Y-23 and Hemicellulase were effective for *R. apiculata.* The surveying method using small volume of different combinations of six cell wall degrading enzymes in a 24-well culture plate was effective to determine optimum osmotic conditions for leaf protoplast isolation of mangroves.

Key Words : Cell wall degrading enzymes, Leaf protoplast, Mangrove, Osmotic condition,

Introduction

Mangrove plants are highly salt tolerant tree species growing along coastal regions in tropical and subtropical zones. Many species of different families are included as mangroves (Tomlinson, 1986). In order to speed up the breeding of mangrove species, protoplast fusion for somatic hybridization is one of the promising tools for the tree breeding program (Pattanavibool et al., 1998, Sasamoto et al., 2000). In order that the potential use of the protoplast in tree improvement programs is expected, reliable protocols of protoplast isolation and regeneration need to be established. By present, only a few reports regarding isolation of mangrove protoplasts have been published from; leaves in *Bruguiera gymnorrhiza* (Eguchi et al., 1995) and *Kandelia candel* (Iijima et al., 1996) and cotyledons in *Avicennia marina and A. lanata* (Sasamoto et al., 1997). However, no axenic leaf protoplast cultures have been established.

In this report, using multi-well culture plates, we determine the optimum enzymatic and osmotic conditions to isolate leaf protoplasts of mangrove plants from three different families. Similarities and dissimilarities in isolation conditions of leaf protoplasts among different species, genera, and families, and some aspects of protoplast research of mangroves are also discussed.

Materials and Methods

1. Plant material

Mangroves: Seeds of Avicennia marina (Forsk.) Vierh., *Bruguiera gymnorrhiza* (L.) Lamk., *Kandelia candel* (L.) Druce and *Sonneratia alba* J. Smith, were collected in Iriomote Island, Japan. Seeds of *Avicennia alba* Blume and *A. officinalis* L. were collected in Myanmar. Seeds of *Ceriops tagal* Perr. C. B. Robinson and *Rhizophora apiculata BL.*, were collected at Can Gio, Vietnam. Seedlings were grown in 1.4 L pots with vermiculite or 0.5-2L plastic pet bottles with river sand in water baths. Liquid nutrient (Hyponex, N:P:K = 5:10:5) was supplied in water bath once every two weeks. Two months old seedlings of *A. alba* and *A. of-*

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ficinalis, eight months old plants of *S. alba* and K. *candel*, 1.5 years old *C. tagal*, *R. apiculata* plants, and four years old *A. marina* plants were used as experimental materials. Seedlings of *B. gymnorrhiza* were cultured using pet bottles for 1.5 years in water and leaves were used as a source for protoplast isolation.

Populus alba : Young leaves of two months old shoot culture were used for protoplast isolation for an out-group comparison. The explants were maintained in a condition similar to that described previously (Sasamoto et al., 2000), except for the use of a continuous light regime at 23℃.

2. Leaf Protoplast Isolation

Protoplast isolation was performed similar to cotyledons of *A. marina* as described previously (Sasamoto et al., 1997). Briefly, leaves of *K. candel* were sterilized in 1% sodium hypochlorite for 45 min. Other plants were treated without sterilization. The explants were sliced into thin sections (1-2 mm thick) in water or sugar (sorbitol or mannitol) solution in petri dish. One or two sections were put in each 0.4 ml sorbitol solution (concentrations tested ranged from 0.2-1.2 M for P. alba and 0.6-1.8 M for other mangrove species) containing cell wall degrading enzymes in a well of a 24-well plastic culture plate. In preliminary experiments, enzyme combinations in 0.6 M mannitol solution were first studied. In subsequent experiments, in order to test the effect of higher concentrations of osomoticum, sorbitol solutions were used in combination with various concentrations of enzymes. Combinations of six enzymes, such as Celllulase RS, Cellulase R-10 (Yakult Honsha Co. Ltd.), Driselase 20 (Kyowa Hakko Kogyo Co.Ltd.), Hemicellulase (Sigma H-2125), Pectolyase Y-23 (Seishin Corp.) and Macerozyme R-10 (Yakult Co. Ltd.) were tested.

The micro-well plates were incubated at 30℃ in static condition for 24 hrs. After swirling the plates occasionally, they were examined under an inverted microscope (Olympus CK40). Remaining protoplasts in leaf sections were released using a pair of tweezers. Each solution was transferred into a 1.5 ml micro tube using a Pipetman and the residue was washed with 0.4 ml of sugar solution of each concentration. After centrifugation at 100g, 5 min, 20-100 μl sorbitol solution of each concentration was added to the residual pellet. As for *A. alba and A. officinalis*, centrifugation at 150g for 4 min was performed. The number of protoplasts was counted with a hemocytometer. Viability of protoplasts was determined using an inverted fluorescent microscope, after mixing with an equal volume of 0.02% Fluorescein diacetate solution in each concentration of sorbitol or mannitol solution. Data were calculated from at least twice counting of wells in repeat experiments.

Results

1. Selection of enzyme combinations for protoplast isolation.

Different combinations of six cell wall degrading enzymes, *e.g.* Cellulase RS or Cellulase R-10, Hemicellulase, Driselase 20, Macerozyme R-10, and Pectolyase Y-23, in each concentration of sorbitol or mannitol solution, were studied. In all of the materials tested in this report, Cellulase R-10 was not effective compared with Cellulase RS, or it had deleterious effects in combination with Driselase 20 and Pectolyase Y-23. The enzymatic combination resulting in both high yield and high viability of protoplasts was selected for each species and the results are indicated as follows.

Avicennia alba : A combination of 1% each of Cellulase RS, Driselase 20, and Macerozyme R-10 was selected at 1.4 M sorbitol solution. Combinations of Cellulase RS with Driselase 20 and Hemicellulase gave lower yield and viability. A much lower viability was obtained in 0.25% Pectolyase Y-23.

Avicennia officinalis : A combination of 1% each of Cellulase RS and Driselase 20 was selected at 1.2 M sorbitol solution. Although the number of protoplasts obtained was the highest in the combination of Driselase 20 and 0.25% Pectolyase Y-23, a much lower viability was observed. Addition of Hemicellulase and Macerozyme R-10 had little effects on both the yield and viability.

Avicennia marina : A combination of 2% each of Cellulase RS and Driselase 20 was selected at 1.4 M sorbitol, which is the best for the isolation of protoplasts from cotyledons (Sasamoto et al., 1997).

Bruguiera gymnorrhiza : A combination of 2% each of Cellulase RS and Driselase 20 at 1.4 M sorbitol was selected. Less effect on yield and viability was obtained with addition of Hemicellulase and Macerozyme R-10. Pectolyase Y-23 (0.5%) had a deleterious effect after a long incubation time. Macerozyme R-10 or Pectolyase Y-23 in combination with Cellulase RS gave a very low yield.

Ceriops tagal : A combination of 2% each of Cellulase RS, Driselase 20, and Macerozyme R-10 was selected at 1.4 M sorbitol. Pectolyase Y-23 (0.5%) had a deleterious effect in combination with Driselase 20. Macerozyme R-10 or Pectolyase Y-23 in combination with Cellulase RS gave a very low yield.

Kandelia candel : A combination of 1% each of Cellulase RS and Driselase 20 was selected in 0.6 M mannitol solution. Pectolyase Y-23 and Driselase 20 were more effective than Macerozyme R-10. Hemicellulase had no additive effect. A higher viability was obtained with Driselase 20 than with Pectolyase Y-23 in combination with Cellulase RS

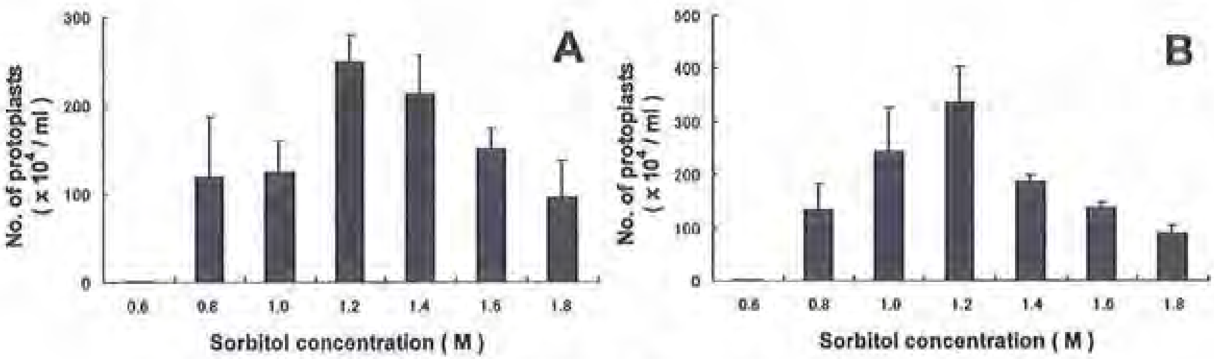

Fig. 1. Effects of sorbitol concentrations on isolation of protoplasts of *Avicennia*. a : *A.alba*, b : *A. officinalis*. Data are mean ± SE.

Rhizophora apiculata : A combination of 4% of Cellulase RS and 2% each of Hemicellulase, Diselase 20 and 0.25% of Pectolyase Y-23 was selected at 0.6 M mannitol solution. When 1% Cellulase RS was used in combination with other enzymes, a very smaller number of protoplasts was obtained. When the enzyme concentration was increased to 2%, although cells had separated, the yield of protoplasts was again low. A 4% concentration of Cellulase RS gave the best result.

Sonneratia alba : A combination of 1% each of Cellulase RS and Macerozyme R-10 was selected at 1.2 M mannitol, which was the best for the isolation of cotyledons (data not shown).

Populus alba : A combination of 1% of Cellulase RS and 0.25% of Pectolyase Y-23 was selected at 0.6 M mannitol solution.

2. Effects of sorbitol concentrations

Avicennia alba : As shown in Figure 1a, only a very low number of protoplasts was obtained at 0.6 M sorbitol. A much higher number of protoplasts was isolated at 0.8-1.8 M sorbitol solutions. The yield at 1.2 M was the best within this wide range of concentrations. A 90% viability was obtained at 1.4-1.8 M sorbitol. Protoplasts isolated at 1.6 M sorbitol is shown in Fig. 2a. Based on our calculation, approximately 1.6 x 10^7 protoplasts could be obtained from one leaf.

Avicennia officinalis : As shown in Fig. 1b, a similar pattern was obtained as *A. alba* leaves. A wide range (0.8-1.8 M) of sorbitol concentrations was suitable for protoplast isolation. A 1.2 M sorbitol solution gave the highest number of protoplasts. Viability of protoplasts was 80-90% at 0.8-1.8 M sorbitol. Protoplasts isolated at 1.4 M sorbitol are shown in Fig. 2b. Based on our calculation, approximately 2.4 x 10^7 protoplasts could be obtained from a single leaf.

Avicennia marina : Protoplasts were readily isolated using a 1.4 M sorbitol solution. Both 1.2 and 1.4 M sorbitol solutions were effective, but not the 0.7 M sorbitol solution.

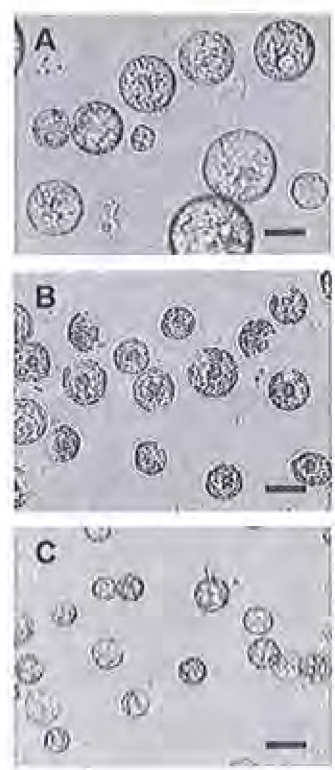

Fig. 2 Photographs of isolated protoplasts of *Avicennia*. a : A.alba, b : A. officinalis, c : A.marina. Sorbitol concentrations were 1.6, 1.4 and 1.4 M, respectivly. Bar=20μm.

Protoplasts isolated at the 1.4 M sorbitol are shown in Fig. 2c. Approximately, 6.8 x 10^7 protoplasts could be obtained from one leaf.

Bruguiera gymnorrhiza : As shown in Fig. 3a, only a very low number of protoplasts was found at 0.6M sorbitol. A much higher number of protoplasts was isolated at 0.8-1.8 M sorbitol with a viability ranged from 40-80%. The yield was optimum at 0.8 and 1.6 M respectively in independent experi-

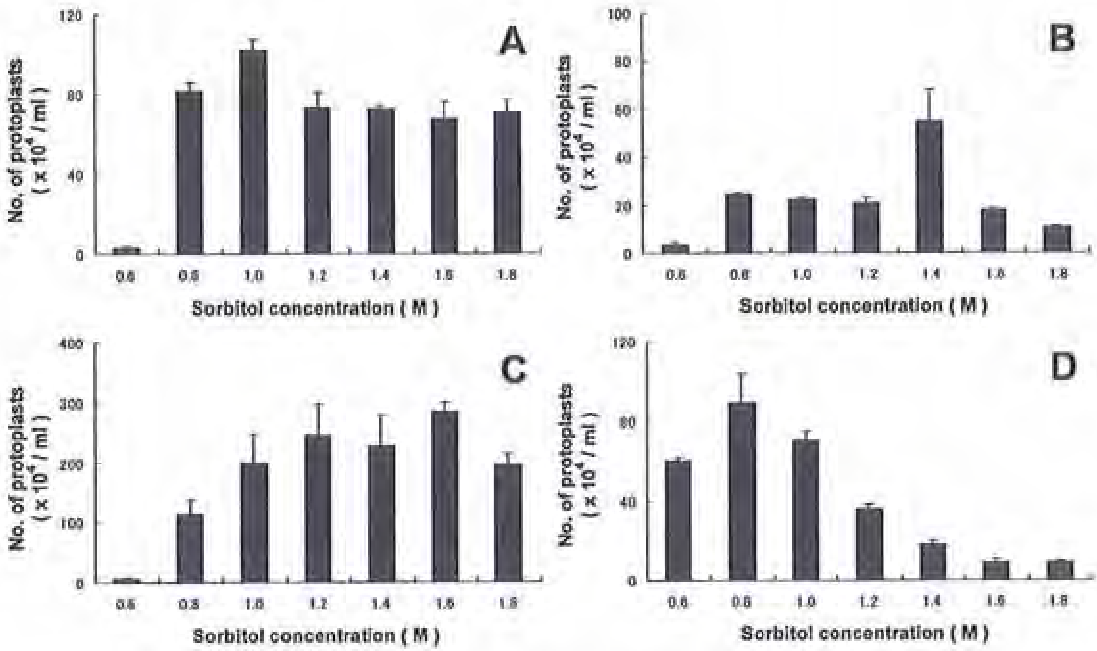

Fig. 3 Effects of sorbitol concentrations on isolation of protoplasts of Rhizophoraceae.
a : *B. gymnorrhiza*, b : *Ceriops tagal*, c : *K. candel*, d : *R. apiculata*. Data ars mean ± SE.

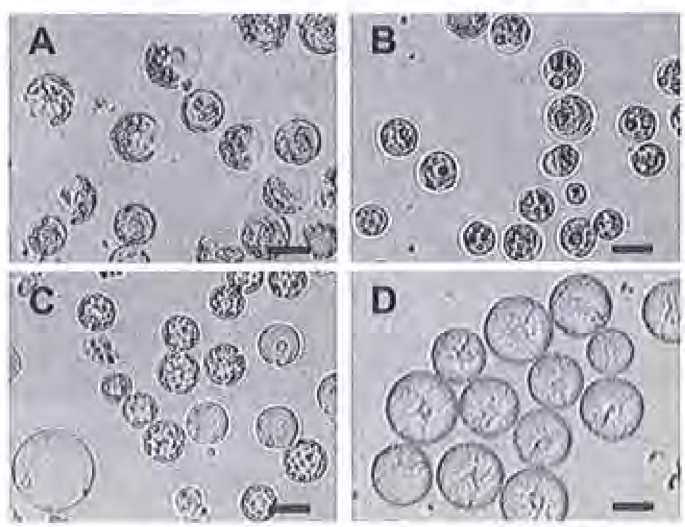

Fig. 4 Photographs of isolated protoplasts of Rhizophoraceae.
a : *B. gymnorrhiza*, b : *Ceriops tagal*, c : *K. candel*, d : *R. apiculata*,.
Sorbitol concentrations were 1.8, 1.4, 1.4 and 1.0 M, respectivly. Bar=20μm.

ments. Viability of protoplasts was high (80%) at 1.4 and 1.6 M sorbitol. A photograph of the protoplasts is shown in Fig. 4 a. Approximately, 8.3 x 10^6 protoplasts could be obtained from a leaf.

Ceriops tagal : As shown in Fig. 3b, 1.4 M sorbitol gave the best isolation of protoplasts. A lower number of protoplasts was obtained at other sorbitol concentrations. Approximately, 3.5 x 10^6 protoplasts could be obtained from a leaf. Viability was low (10-20% at 0.8-1.6 M sorbitol) compared to other species, although 70% was obtained at 1.4 M sorbitol in a repeat experiment. A photograph of protoplasts isolated at 1.4 M sorbitol (Pectolyase Y-23 was used instead of Macerozyme R-10) is shown in Fig. 4b.

Kandelia candel : As shown in Fig. 3c, protoplasts were well isolated at a wide range of sorbitol concentrations from 0.8-1.8 M with the viability ranging from 60-100%. A photograph of protoplasts isolated at 1.4 M is shown in Fig. 4c. Approximately, 2.0 x 10^7 protoplasts could be obtained from a leaf.

Rhizophora apiculata : As shown in Fig. 3d, the optimum concentration for protoplast isolation was 0.8 M and also a considerable number was obtained at 0.6-1.0 M, however, at higher sorbitol concentrations, fewer protoplasts were isolated. Viability of protoplasts at 0.6-1.0 M was 60-70%. A photograph of protoplasts isolated at 1.0 M is shown in Fig. 4d. Large, shiny protoplasts were prominent. Approximately, 1.0 x 10^7 protoplasts could be obtained from a leaf.

Sonneratia alba : As shown in Fig. 5, a large number of protoplasts was obtained at higher concentrations of sorbitol, *i.e.* 1.2 to 1.8 M. Fewer protoplasts were isolated at lower than 1.0 M sorbitol solutions where the lowest number was obtained at 0.6 M sorbitol. Protoplasts isolated at 0.8 M sorbitol are shown in Fig. 6. Approximately 9.4 x 10^5 protoplasts could be obtained from a leaf. Protoplast viability was 80-100% at 0.8-1.8 M.

Populus alba : As shown in Fig. 7, 1.0 M sorbitol was optimum for protoplast isolation of *P. alba*. The number of

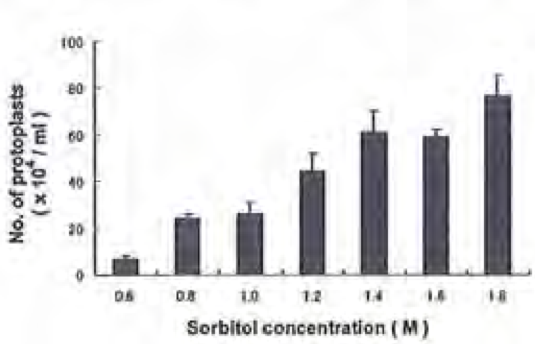

Fig. 5 Effects of sorbitol concentrations on isolation of protoplasts of *Sonneratia alba*.
Data ars mean ± SE.

Fig. 6 Photograph of isolated protoplasts of *Sonneratia alba*. Sorbitol concentration was 0.8 M. Bar=20 μm.

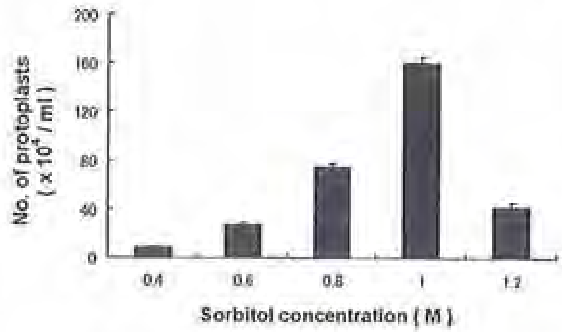

Fig. 7 Effects of sorbitol concentrations on isolation of protoplasts of *Populus alba*.
Data ars mean ± SE.

protoplasts was much reduced at 1.2 M sorbitol and lesser numbers were found at and below 0.6 M sorbitol. Protoplast viability of *P. alba* was 80-90% at 0.6-1.0 M sorbitol conditions and less than 50% at 1.2 M sorbitol.

3. Yield of protoplasts at the fresh weight base

The yields (g fresh weight base) of protoplasts were as follows; 3.6 x 10^7 (*A. alba*), 1.8 x 10^8 (*A. marina*), 8 x 10^7 (*A. officinalis*), 2.1 x 10^7 (*B. gymnorrhiza*), 1.5 x 10^7 (*C. tagal*), 5.7 x 10^7 (*K. candel*), 9.8 x 10^6 (*R. apiculata*), and 10^7 (S. alba).

4. Size of protoplasts

As shown in the photographs, the diameters of mangrove protoplasts ranged from 10-55 μm, depending on the species and tissue origin. Protoplasts of *A. marina* were the smallest in size in the three species of *Avicennia*. Larger sized protoplasts (40-55 μm in diameter) were obtained from *A. alba*, *R. apiculata*, and *S. alba*.

Discussion

Obtaining viable protoplasts is the first step towards the establishment of a protoplast regeneration system. In this report, we developed an efficient surveying method for the optimization of enzymatic and osmotic conditions for mangrove protoplast isolation. Small volumes of different combinations of five cell wall degrading enzymes, *i.e.* Cellulase RS, Driselase 20, Hemice llulase, Macerozyme R-10, and Pectolyase Y-23 in a 24-well culture plate were effective in determining the optimum concentrations of enzymes used for the isolation of leaf protoplasts of mangroves. This approach also reduces the quantities of enzymes used, and hence, it is a cost effective method.

In all of the mangroves tested, the combination of Cellulase R-10 and Maceorzyme, which is commonly used in the isolation of leaf protoplasts of a herbaceous plant, tobacco, was not effective in mangroves. The optimal enzymatic condition, i.e. the combination of Cellulase RS and Driselase 20 for leaf protoplast isolation was similar in three species of *Avicennia* and four genera in Rhizophoraceae but not of *S. alba*. In *A. marina* and *S. alba*, the optimum condition for cotyledon protoplast isolation was also applicable for the isolation of leaf protoplasts. *Sonneratia alba* preferred the combination of Cellulase RS and Macerozyme R-10. A much higher concentration of Cellulase RS (4%), Driselase 20, Hemicellulase and Pectolyase Y-23 was needed to be effective in *R. apiculata*.

In leaf protoplast isolation from *Bruguiera* and *Kandelia*, the use of a specific enzyme, Acremoniumcellulase, was recommended (Eguchi et al., 1995, Iijima et al., 1996). Generally, leaf or cotyledon protoplast isolation of mangroves needs strong enzymatic conditions compared to those used for a non-mangrove tree species, poplar (1% Cellulase RS plus 0.25% Pectolyase Y-23, Sasamoto et al., 1989) and of birch (1% each of Cellulase R-10 and Driselase, Wakita et al., 1996). Therefore, by optimizing the enzyme combination and by increasing the quantity of enzymes up to four times the usual amount, it was possible to isolate a considerable amount of leaf protoplasts in the eight mangrove species of three different families without the need of using the special enzyme.

Different concentrations of sorbitol solutions were effective in the isolation of mangrove leaf protoplasts from the three different families studied. In this report, sorbitol was the main osmoticum used. This is due to the fact that its solubility is much higher than mannitol and hence, solutions with a wider range of osmotic conditions can be created. It is clear from this study that a high osmotic condition was necessary for the isolation of mangrove leaf protoplasts, except for *R. apiculata*. In *R. apiculata*, a lower osmotic optimum similar to a non-mangrove tree, *Populus alba*, is preferred.

Sasamoto et al. (1989) stated that 0.6 M mannitol and 0.7 M sorbitol were successful for both the isolation of poplar protoplasts and callus regeneration. The best sugar condition for protoplast isolation might not necessarily be the same condition for the subsequent culture of protoplasts, because other components, *e.g.* nutrient salts and sugars are included in media. Both sorbitol and mannitol are not supposed to be metabolized by plant cells, however, some plants might have the ability to metabolize these sugars (Thompson et al., 1984). Hence, the osmotic condition may change during the course of the study. Compatible solute in cells of mangroves, glycinebetaine, which is found not to inhibit cellular enzymes of *A. marina* (Ashihara et al., 1997), might be considered as an osmotic agent in mangrove protoplast cultures.

The yield of protoplasts on a fresh weight basis of eight species of mangroves was 1-18 x 10^7. This value is high enough when compared with the yield from a poplar leaf (0.2-2 x 10^7), which was succeeded in the establishment of a plant regeneration system. Therefore, the high viability (80%) is needed for culture of leaf protoplasts of *P. alba*. A high yield and high viability of protoplasts are essential to somatic cell fusion (Sasamoto et al., 2000).

As we succeeded in protoplast isolation, several aspects, *e.g.* effects of salts, exogenous plant growth regulators on cell divisions, can be studied using 96-well culture plates. Also, endogenous levels of plant hormones (Sasamoto et al., 2002) and compatible solutes, *e.g.* amino acids and sugars can be measured after simple purification steps to determine optimal combinations of plant hormones and nutrients for further callus culture and regeneration of recalcitrant mangrove species.

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マングローブ3科（クマツヅラ科，ヒルギ科，ハマザクロ科），8種の葉プロトプラストの単離

ウラジロヒルギダマシ、ヒルギダマシ、マルバヒルギダマシ（クマツヅラ科），オヒルギ、コヒルギ、メヒルギ（ヒルギ科）およびマヤプシキ（ハマザクロ科）の計7種のマングローブ葉からのプロトプラスト単離において，ソルビトールによる広範囲高濃度の浸透圧条件が効果的であった。一方，フタバナヒルギ（ヒルギ科）は低濃度の浸透圧条件で単離され，マングローブ種でない木本植物，ポプラに似た結果を示した。細胞壁分解酵素として6種類を用い、24穴シャーレ中で，少量の酵素液の濃度組み合わせにより最適条件を決定した。全ての材料においてセルラーゼRSがセルラーゼR-10より優れ，マヤプシキを除いてセルラーゼRSとドリセラーゼ20の組み合わせが効果的であった。マセロザイムはウラジロヒルギダマシとコヒルギおよびマヤプシキにおいて，ペクトリアーゼY-23とヘミセルラーゼはフタバナヒルギにおいて効果的であった。

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ミャンマー国エーヤワディーデルタの主要マングローブ樹種 *Heritiera fomes* の萌芽特性

大野勝弘[1)]・藤原一繪[1)]

Sprouting Characteristics of *Heritiera fomes*, the Main Mangrove Species in the Ayeyarwady Delta, Myanmar

Katsuhiro ONO[1)] · Kazue FUJIWARA[1)]

Abstract : In order to explore the capacity and guidelines for sprouting regeneration of *Heritiera fomes* in the future, the following were examined: the environmental and internal factors related to sprouting ability and its change; the sustentation of stump sprouts and survival of the stumps; and the dynamics of the dominant stump sprouts. As a result, it was recognized that the sprouting ability of *H. fomes* was fairly good, as compared with other mangrove species, and that regeneration by sprouting seemed possible. As the stump size increases, the sprouting rate and the number of stump sprouts tend to decrease. The greatest sprouting ability, assessed by the longest stump sprout, seems to be at little less than 10cm in stump diameter. The locations of the dominant sprouts on the stumps show a certain tendency, based on the felling height. It was suggested that relative maximum water level is involved in the death of stumps and in shifting the height of the dominant sprouts, through the suppression of the tidal water. Thus it could be necessary to control the felling height, based on the submergence level on the trunk together with tree size in diameter.

Key Words : dominant stump sprouts, *Heritiera fomes*, mangrove, sprouting ability, submergence level

は じ め に

ミャンマーのエーヤワディーデルタでは，商業伐採によってマングローブ林面積の減少や劣化が進み，住民が燃料材や用材を持続安定的に利用するのが困難な状態にある．Tsuda & Ajima (1999) は，タイとマレーシアのマングローブ林調査から，資源の持続利用のために，萌芽特性を考慮した森林管理の必要性を指摘しているが，マングローブの萌芽研究は少ない．日本の薪炭用広葉樹については，紙谷 (1986) や中村 (1988) らが，萌芽率や株当りの萌芽枝本数，最大萌芽枝長等を指標に，伐採後の萌芽力の評価を行なっている．本研究では，エーヤワディーデルタの優占種である *H. fomes* 林で，萌芽更新を図る際の基礎的な情報の提供を目指し，同様の手法で萌芽力の評価とその消長の把握を行なった．また，萌芽枝本数や比較的優位な萌芽枝の動態などの萌芽特性に関する知見は，将来 *H. fomes* の萌芽更新施業を検討する際の基礎データとして必要と考えられる．そこで，マングローブ域特有の潮汐の萌芽枝動態への影響を探求し，あわせて萌芽特性の生態的な意味の検討を行なった．

調査地と方法

エーヤワディー管区 Bogalay 郡区 Byonehmwe 島の２ヶ所，Meinmahla 島の５ヶ所，Pyindaye 地区の２ヶ所の，計９ヶ所の盗伐林分において，2002年８～９月，2003年２～３月と８～９月に調査を行なった（Fig. 1）．対象は全て単幹の切り株とし，調査林分において無作為に選んだ．ただし，盗伐直後の *H. fomes* の切り株の内，伐採位置が自

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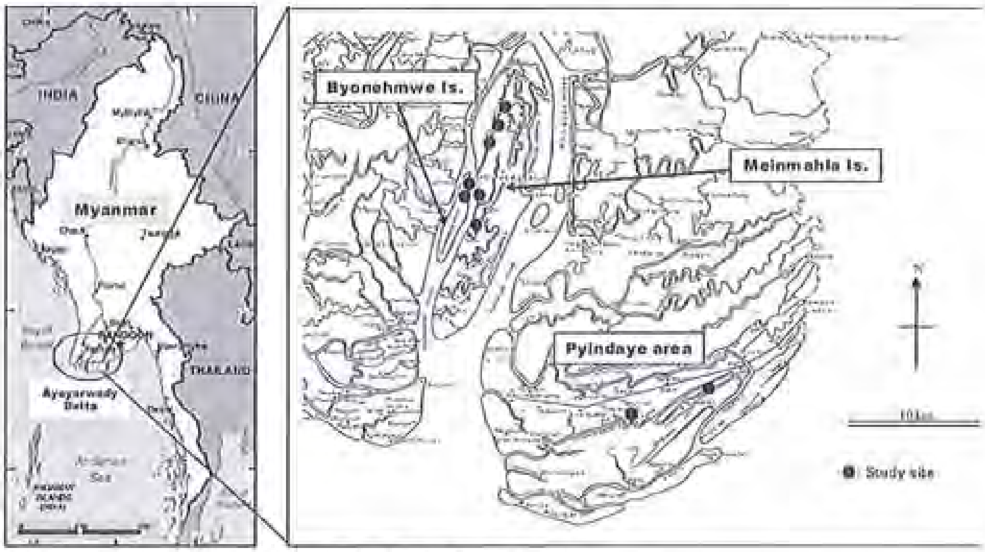

a: Ayeyarwady Delta in Myanmar　b: Study site in Bogalay Township

Fig. 1. Location of study site in Ayeyarwady Delta, Myanmar

然の分枝位置より高いために，複数の幹があった32株を，分枝位置より下部で伐採しサンプルに加えた．また，サンプルの少ない伐根径階級で，伐採を受けていない10個体の試験伐採を行った．これらの伐採は現地森林局係官の了解を得て実施し，半年後に他のサンプルと同様の調査を行った．

本研究ではまず，萌芽率と株当り萌芽枝本数によって，*H. fomes* の萌芽力を他の主要な木本マングローブ樹種と比較するために，2～3年前に切り倒されたと考えられる様々なマングローブの切り株の，萌芽の有無と萌芽枝本数の記録を行った．なお，調査時に萌芽枝を持って生残していた切り株を萌芽株，萌芽枝を持っていなかった切り株を枯死株とし，全切り株に占める萌芽株の割合を萌芽率とした．

次に *H. fomes* の萌芽力および萌芽の生態的特性を調べるため，切り株の特性・形質として，切り株幹周囲長，伐採高，株当り萌芽枝本数，優勢な萌芽枝（実長上位5本）の長さと切り株幹上での出芽位置（出芽高）を測定した．切り株幹周囲長の測定は原則として切り株の高さ60cmで行ない，板根を持つ切り株ではその張り出し最上位置から30cm上部で計測した．伐採高の関係で板根を有する部位にて計測する場合は，張り出し部位を除く円筒を仮想しその周囲長とした．高さが60cm以下の切り株では，伐採高における幹周囲長とした．周囲長は直径に換算し，伐根径として解析に用いた．伐採断面が地表面と平行でない場合は，断面の最低位置を伐採高とした．

また切り株萌芽に影響する要因として，伐採後の経過期間，切り株の場所の最高水位および林冠閉鎖度を記録した．伐採後の経過期間は，切り株の切り口の変色や腐食の進行具合を観察し推定した．また，最高水位は年間で最も水位の高い雨季の満潮時を目安に，幹上のコケや泥の付着線の読み取りにより判定した．伐採後の経過期間と最高水位の判定は，林内作業経験の豊富な複数の地元住民とともに行なった．解析には，伐採高に対する最高水位の相対百分率を，相対最高水位として用いた．林冠閉鎖度は，切り株を中心に半径5mの仮想円直上の閉鎖度を目視によって判定した．

冠水の程度が優勢な萌芽枝の動態に与える影響を推定するため，萌芽枝の分布位置で萌芽株のタイプ分けを行ない，相対最高水位の高低別に経過時間ごとの各タイプの出現比率を調べた．解析は5本以上の萌芽枝を持つ萌芽株で行なった．萌芽株は，優勢な萌芽枝の内5本もしくは4本が幹の上半分の高さから出芽する「上部萌芽型」，下半分から出芽する「下部萌芽型」，それ以外の「全体萌芽型」の3タイプに区別した．株当り萌芽枝本数は時間経過により，多いグループと少ないグループに二極化したとみられたが，両者の平均相対最高水位の差の有無の判定には t 検定を用いた．

調 査 結 果

1．マングローブ樹種の萌芽力比較

H. fomes の萌芽率は75.2%，株当り萌芽枝本数は7.2本であった．調査地の *Excoecaria agallocha* はほとんどが株立ち樹形で，調査対象にできた単幹の3個体も全て萌芽枝を持っており，株当り萌芽枝本数も19.3本と最も高い値を示した．*Avicennia officinalis* や *Sonneratia apetala*, *S. caseolaris* も株立ち個体が多く，複数回の伐採を受け，多くの萌芽枝を生じている様子が調査地でしばしば観察された．一方，ヒルギ科の種では萌芽せず，伐採によって枯死している切り株が多く観察され，特にオヒルギ属やヤエヤマヒルギ属の種では，萌芽がまったく確認されなかった（Table 1）．

Fig. 1. Location of study site in Ayeyarwady Delta, Myanmar.

species	family	N*	Ns**	Ns/N(%)	ns***	ns/N
Avicennia officinalis	Avicenniaceae	10	9	90.0	77	7.70
Excoecaria agallocha	Euphorbiaceae	3	3	100.0	58	19.33
Barringtonia racemosa	Lecythidaceae	3	3	100.0	7	2.33
Cynometra ramiflora	Leguminosae	1	1	100.0	11	11.00
Amoora cuculata	Meliaceae	20	12	60.0	32	1.60
Bruguiera sp.	Rhizophoraceae	17	0	0.0	0	0.00
Ceriops decandra	Rhizophoraceae	2	2	100.0	11	5.50
Kandelia candel	Rhizophoraceae	10	4	40.0	22	2.20
Rhizophora apiculata	Rhizophoraceae	11	0	0.0	0	0.00
Rhizophora mucronata	Rhizophoraceae	1	0	0.0	0	0.00
Sonneratia apetala	Sonneratiaceae	25	12	48.0	130	5.20
Sonneratia caseoralis	Sonneratiaceae	1	1	100.0	3	3.00
Heritiera fomes	Sterculiaceae	476	358	75.2	3421	7.19

*N: Number of sample stumps. **Ns: Number of stumps resprouted. ***ns: Number of sprouts.

2. Heriliera fomesの切り株萌芽

総サンプル数は476株で，切り株の特性・形質データの平均値と標準偏差はそれぞれ，伐根径9.29cm±4.32，伐採高84.55cm±42.84，株当り萌芽枝本数7.19本±7.55であった。また，環境要因を平均するとそれぞれ，伐採後の経過期間はおよそ26ヶ月，切り株の場所の最高水位は約40cm，林冠閉鎖度は約36%であった。

1）萌芽力の消長

萌芽率の変化をみると，伐根径が大きくなるに従って，時間経過による萌芽率の低下が顕著であった。伐根径が10cm以上の切り株では，25ヶ月以降の萌芽率が6割程度に低下していた。一方，伐根径が6cm以下の株では萌芽率の低下はみられず，25ヶ月以降も切り株の9割程度が萌芽株であった（Fig. 2）。伐採高と萌芽率の関係をみると，伐採後12ヶ月以下で，伐採高が40～60cmと60～80cmの2つの階級に枯死株が集中し，萌芽率は伐採後13～24ヶ月を経過した，同じ伐採高階級の切り株より低かった。この2つの階級を除けば，伐採高に関わらず，時間経過にしたがって萌芽率は低下していた（Fig. 3）。伐採後12ヶ月以下の期間で，枯死した23株の平均伐採高は55.05cm±1.52（SE）で，内17株の場所の最高水位は50cm以上であった。

株当り萌芽枝本数は，枯死や交代の影響が少ないと推定される，伐採後初期の12ヶ月以下の萌芽株で調べた。その結果，萌芽枝本数は萌芽率と同様に，伐根径が大きくなるにしたがい減少する傾向がみられた（Fig. 4）。なお，林冠閉鎖度と萌芽率，株当り萌芽枝本数に関係はみられなかった。

最大萌芽枝長は，伐採後6ヶ月では伐根径の大小に関わらず，100cm程度を上限にばらついていた。伐採後18ヶ月と36ヶ月では，伐根径が10cmよりやや小さなとき，100cm以上の長い最大萌芽枝を持つ萌芽株が多く出現する傾向が見られた（Fig. 5）。

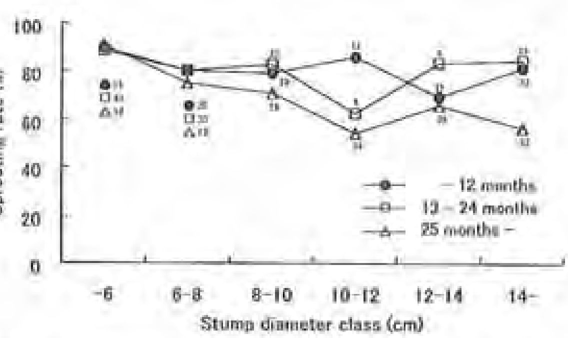

Fig. 2. Relationship between stump diameter and sprouting rate by time after felling. Legend symbols represent elapsed time since felling. Each percentage is computed by using the indicated total sample number as a denominator, in the elapsed time-diameter class category.

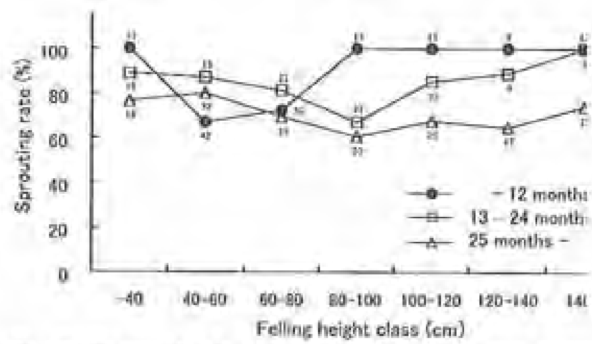

Fig. 3. Relationship between felling height and sprouting rate by time after felling. Legend symbols represent elapsed time since felling. Each percentage is computed by using the indicated total sample number as a denominator, in the elapsed time-felling-height class category.

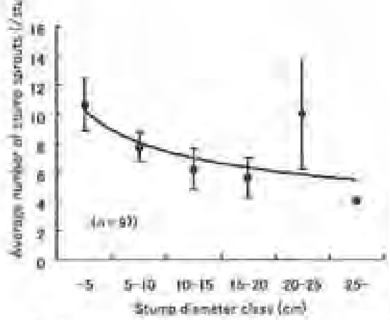

Fig. 4. Relationship between stump diameter and number of stump sprouts per stump up to 12 months after felling, with standard error and approximated curve.

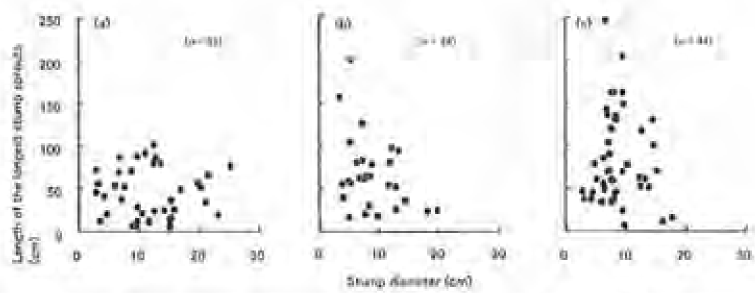

Fig. 5. Relationship between stump diameter and length of the longest stump sprouts at the stumps. The graphs (a), (b), and (c) show the stumps at 6 months, 18 months, and 36 months after felling, respectively.

2）株当り萌芽枝本数の時間経過による変化

萌芽枝本数は伐根径の影響を受けていたため，伐根径が５～10cmの167萌芽株をサンプルとして，株当り萌芽枝本数の変化を調べた．伐採後12ヶ月までの萌芽株では，１～５本と６～10本の階級比率が41.0%，38.5%と高く，11本以上の各階級の比率は低かった．１～５本までの萌芽枝本数階級の比率は，13ヶ月以降には減少し，その後も25%程度でほぼ一定になっていた．６～10本の階級比率は，伐採後の初期から35～40%程度と常に高く，変化はほとんどなかった．11～15本の階級比率は，伐採後13～24ヶ月，25～36ヶ月に増加しピークがみられた．伐採初期から36ヶ月まで低かった16本以上の各階級比率は，37ヶ月以降，21～25本と26～30本の２つの階級で増加していた（Fig. 6）．

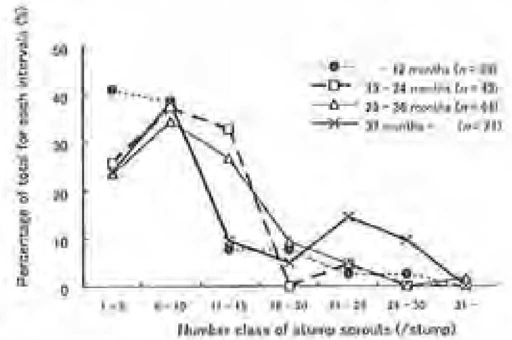

Fig. 6. Number of stump sprouts in different intervals after felling, with percentage of total for each interval. Legend symbols represent elapsed time since felling.

3）優勢な萌芽枝の分布と動態

優勢な萌芽枝は，特に切り口に近い幹上端部30cm程の部位に集中する傾向がみられた．また，伐採高がおよそ150cm以上で，切り株の中程の高さでの分布が少ない傾向があった．一方，伐採高が70～80cm以下では，萌芽分布の集散傾向は不明瞭であった（Fig. 7）．

次に，萌芽枝の動態を明らかにするため，相対最高水位の高低別に経過時間ごとの萌芽株タイプの出現比率を調べた（Fig. 8）．伐採後初期の12ヶ月以下では，相対水位が高い場合（a），低い場合（b），ともに上部萌芽型の比率がそれぞれ42.5%，50.0%で最も多く，全体萌芽型がこれに続いていた．下部萌芽型の比率は，相対水位が高い場合18.2%，低い場合11.5%でともに低かった．相対水位が高い場合，上部萌芽型の比率が25ヶ月以降60.0%に増加し優占していたが，下部萌芽型，全体萌芽型は減少していた．一方相対水位が低い場合は，上部萌芽型は25ヶ月以降24.3%まで減少し，全体萌芽型が58.6%に増加し優占していた．下部萌芽型の比率は，17.1%に微増していた．

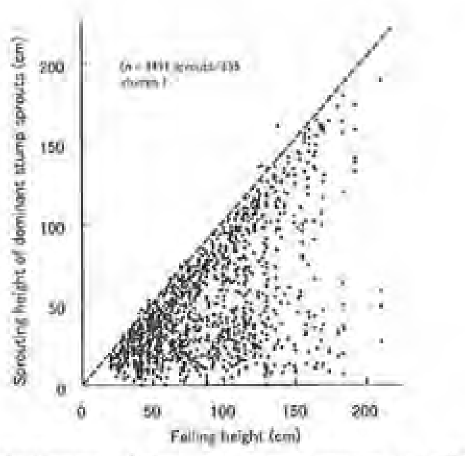

Fig. 7. Distribution of dominant stump sprouts, in relation between felling height and sprouting height within stumps. The broken line (y=x) represents the lowest edge of felling face on the stumps. Dominant stump sprouts, of which sprouting height have been recorded, are indicated in this figure.

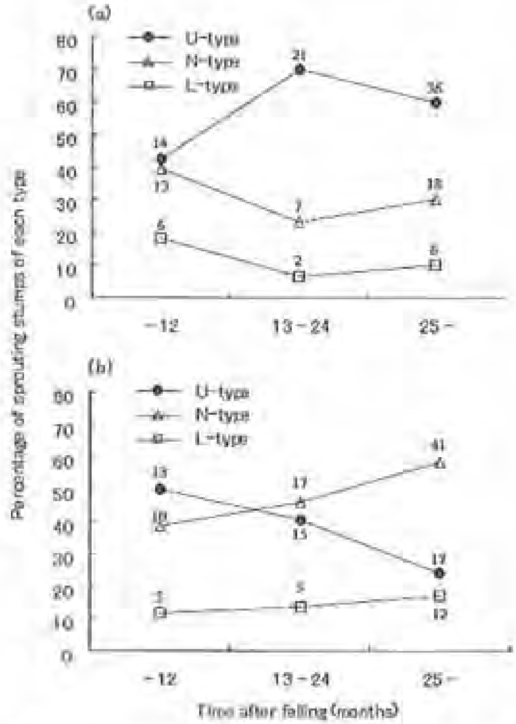

Fig. 8. Relationship between time after felling and the ratio of stump-sprouting types. The geaph (a) shows the case of relative maximum water level with more than 50%. The graph (b) shows the case with less than 50% at the stumps. The graphs show the change of the ratio by time after felling . U-type, N-type and L-type ata the legend mean the upper stump-sprouting type, the neutral stump-sprouting type, and the lower stump-aprouting type, respectivly. Each percentage is computed by using the indicated total sample number as a denominator, in the elapsed time-type category. Only the stumps, which have more than five stump sprouts are used for analysis.(n=256)

考　　　　察

1．萌 芽 力

萌芽率と株当り萌芽枝本数からみた *H. fomes* の萌芽力は，他の木本マングローブ樹種と比べて高いといえる（Table 1）．日本の薪炭用樹の報告では，伐採1年後のコナラの萌芽率は60～90%（外舘 1988），コジイ，タブ，アラカシなどで52～100%（中村 1988），株当り萌芽枝本数はコジイやスダジイ，アカガシ，コナラなどで6～12本（三善 1956）とされている．これらの薪炭用樹と比べても *H. fomes* の萌芽力は劣らず，萌芽更新施業の可能性があると考えられる．伊藤（1996）は，単幹の樹体で老齢林の高木層を構成するミズナラが，一斉撹乱後に大きな萌芽力を持つ理由を，樹種特性として強い萌芽促進力とそれを上回る抑制力を持ち，撹乱によって抑制が解除されるからであるとした．通常単幹で直立し，高木層を形成し優占する（Myint Aung *et al.* 2003）*H. fomes* が，群落内の他のマングローブ樹種と比較して高い萌芽力を持つのは，同様の萌芽機構によって自然状態では萌芽を発生させず，一斉撹乱に対して旺盛な萌芽力を発揮し，ギャップを埋めてゆく樹種であるからだと推察される．

2．萌芽力の消長

切り株からの萌芽力は，樹齢や親木サイズによって消長することが多くの広葉樹で報告されている（中村1988，紙谷1986など）．*H. fomes* では，伐採後25ヶ月以降でみると，伐根径が大きいほど萌芽率が低い傾向があった（Fig. 2）．また，一般に伐採高が高い場合に切り株からの萌芽力は低下するという指摘がある（片岡 2000）．しかし *H. fomes* では，12ヶ月以下で枯死株が集中した2つの階級を除き，伐採高に関わりなく時間経過による萌芽率の低下がみられた（Fig. 3）．従って，*H. fomes* の切り株が萌芽を生じない，もしくは萌芽を維持できず枯死するのは，伐採高より親木のサイズとの関係が大きいといえる．また，伐採後初期の萌芽株では，伐根径が小さいとき多くの萌芽枝を有し（Fig. 4），時間経過とともに伐根径が10cmよりやや小さいとき最大萌芽枝の長い株が出現する傾向があった（Fig. 5）．伊藤（1996）は，萌芽力の解析には切り株根系の養分貯蔵，養分吸収，呼吸消費のバランスと時間による変化の把握が必要なことを指摘している．*H. fomes* は仮根と，それに連なり地下部を水平方向に曲がりくねって伸びている根系，根系から立ち上がる多くの大きな筍根を持っており（Tomlinson 1986），萌芽力の消長に関する詳細な検討には，大きな切り株のストックと消費の把握が必要になると考えられる．

3．外的要因と萌芽

本研究では，冠水の萌芽への影響を検討した．伐採後初期の枯死は，最高水位が伐採高に近い場合に集中して起こっていた（Fig. 3）．また，相対水位が高い場合に，伐採後の時間経過にしたがって，下部萌芽型と全体萌芽型の萌芽株比率が減少し，代わって上部萌芽型の比率が増加し，優占していた．一方，相対水位が低い場合は，下部萌芽型の比率が減少していなかった（Fig. 8）．これらのことから，対象切り株の場所で調査した最高水位を，各切り株にとっての冠水の程度とすると，冠水が萌芽枝の伸長を阻害もしくは萌芽枝を枯死させ，切り株自身の枯死をまねいたり，優勢な萌芽枝の切り株の下部から上部への交代を促していたと考えられる．

4．時間経過と萌芽枝本数の変化

Fig. 6から，伐採後13ヶ月以降の萌芽株は，10本弱の萌芽枝を持つ株のグループと，21本以上の萌芽枝を持つグ

ループに別れていったと考えられる。伐採後37ヶ月以降の21株の内，萌芽枝が10本以下の株の相対最高水位は平均52.9%（SE：6.42）で，21本以上の株の28.1%（SE：6.91）と有意な差があった（t 検定，P＜0.05）。嶋ら（1989）は，コナラなど6種の広葉樹で，株当り萌芽枝本数は萌芽の発生が完了する1年目までは増加し，それ以降は萌芽間の競争により減少に転ずるとした。伐採後13ヶ月以降に多くの萌芽枝を持つ *H. fomes* の切り株は，冠水で被圧されない幹の部位で長期に渡り少しずつ萌芽を生じさせていると推察され，萌芽間競争により萌芽枝が減少する時期はコナラなどと比較して遅いと考えられる。

5．萌芽の分布，交代とその生態的意味

H. fomes 切り株の伐採高は様々であったが，幹上の優勢な萌芽枝は一定の集散傾向を示していた（Fig. 7）。萌芽の発生機構は，株の下方から萌芽を促進するサトカイニン様物質と，頂芽から流転し萌芽を抑制するオーキシン様物質のバランス変化とされている（橋詰・今村 1985，伊藤 1996）。*H. fomes* の萌芽枝の集散も，同様な化学物質の影響によるものであろう。萌芽の一つの機能は，上部に撹乱を受けたときの個体の樹高を回復させる反応とされる（伊藤 1996）。切り口近くの高い位置での萌芽は，樹高を回復させる際，上方への伸長生長のためのコストを最小化できる意味があるといえる。一方，自根の形成による新しい萌芽幹の栄 養的な独立には，地表に近い低位置からの萌芽が有利（中川 2001，神奈川県自然環境保全センター 2001）と考えられる。したがって，伐採高が高いとき，切り株幹の中程で萌芽に投資をしないことは，個体の資源配分上合理的だといえる。また，相対水位が高い場合，優勢な萌芽枝が切り株の幹の上方に交代し，相対水位が低い場合に，下部の優勢な萌芽枝が維持されたことは，冠水という外的な要因が萌芽に阻害的に働いたことを示唆していた。一方，下方からの冠水の阻害が小さいと考えられる相対水位が低い場合に，上部萌芽型の萌芽株比率が減少し，全体萌芽型の比率が増加し優占していた（Fig. 8 b）。これは，初期に優勢であった切り株上部の萌芽枝が良好な伸長を続けず，時間経過とともに，下部の萌芽枝の伸長が大きくなる株が増加したことを示している。このような萌芽枝の交代は，樹高の回復のための上部の萌芽枝より，むしろ地面に近い下部の萌芽枝が早期に自根を形成することが，個体もしくは *H. fomes* 個体群にとって生態的に重要である可能性を示唆している。ただし，下部の萌芽枝のみに樹体の修復を頼ると，冠水による萌芽枝の枯死という結果的に無駄な資源配分や，萌芽枝を失うことで個体自身の枯死をまねくリスクがあると考えられる。

6．萌芽の特性と萌芽更新施業

親木のサイズが小さいとき，萌芽率と伐採後初期の株当り萌芽枝本数は大きく，伐根径が10㎝よりやや小さいとき，最大萌芽枝の長い萌芽株の出現が多かった。したがって，このピーク付近の親木サイズで伐採されたときに，多くの萌芽枝の発生と伸長生長が期待できるので，*H. fomes* の萌芽更新を目指す場合の目安となるといえる。また，萌芽枝の数と分布動態への冠水の影響が示唆され，生態的な特性を考慮した萌芽更新施業では，親木の場所の最高水位によって伐採高を管理する必要があると考えられる。

謝　　辞

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Mangrove Science Vol. 3 ; 39−41. 2004

マングローブ保全における国連大学の役割について

国連大学　　塚本　久美子

Kumiko Tsukamoto[1)]

Abstract : The United Nations University (UNU) is an international community of scholars engaged in research, postgraduate training and knowledge dissemination to promote the United Nations' aims of peace and progress. With its Charter adopted by the General Assembly of the United Nations on 6 December 1973, the UNU Headquarters commenced its work in Tokyo in September 1975. It is a voluntary funded United Nations organization. The UNU undertakes multidisciplinary research on pressing global problems, provides advanced training through workshops and postgraduate fellowships, and disseminates knowledge by way of conferences, publications, and other information vehicles. The UNU conducts these activities through a multidisciplinary network of its own research and training centers and programmes (RTC / Ps), and of individual scientists and institutions the world over.

背　　　景

国連大学は、国連憲章の目的と原則を追求・促進するための研究と大学院レベルの研修、そしてその成果の普及に携わる、学者、研究者らの国際的共同体として機能しています。こうした形での国際機関の構想を打ち出したのは、ウ・タント元国連事務総長で、彼は1969年に「真に国際的な性格を有し、国連憲章が定める平和と進歩の諸目的に合致する国際連合の大学」の必要性を訴えました。その後、いくつかの経緯を経て、国連本部とユネスコの共同支援を受ける国連総会傘下の独立機関として国連大学が誕生し、1975年、東京を本部に活動を開始しました。

目 的 と 使 命

国連大学の目的は、国連大学憲章にうたわれている通り、世界の学者・研究者の知識を融合して「人類の存続、発展および福祉にかかわる緊急かつ世界的な問題」を理解し、その解決に資する研究を行なうことになります。また、世界中の学者や研究者が参加する国連大学の世界的研究ネットワークに、途上国の学者や研究者を率先して参加させ、かれらの知的孤立状態の解消を図ることも重要な責務であると考えています。

国連大学は次の４つの基本的機能を果たします。

- 学者・研究者の国際的共同体
- 国連と世界の学術社会の「架け橋」
- 国連システム全体のシンクタンク
- 能力育成、とくに途上国における能力育成支援

組　　　織

国連大学は、東京の大学本部、複数の研究・研修センターあるいは研究・研修プログラム (RTC / P) に加えて、提携あるいは協力関係にある世界各地の学術機関あるいは個々の学者からなるネットワークで構成されています。

学長は、国連大学の学術・管理両面の最高責任者であり、大学の事業活動全般の指揮、企画、運営に関して責任を負っています。

研究・研修活動の方向性

人間の活動がかつてない規模で世界を変えつつあります。国連大学は、人間活動がもたらす影響、とりわけ途上国にみられる影響に関して、学術的考察を進めています。これらの学術活動は、大学本部と各地に国連大学研究・研修センターあるいはプログラム、そして世界の学術機関や学者のすべてを結ぶグローバルな学術ネットワークを通じて展開されています。

国連大学本部（所在地：東京）

国連大学本部の活動は、「環境と持続可能な開発」と「平和とガバナンス」の２領域に分かれています。「環境と持続可能な開発」プログラムは、人間の活動と自然環境との相互作用に焦点を絞り、とくに途上国が直面する課題を重視しています。「平和とガバナンス」プログラムは、研究と能力育成を通じて、平和と正しい統治（ガバナン

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ス）の促進に寄与することを目指しています。大学本部は、能力育成事業と研修プログラムの業務全般の調整も行なっています。後者は基本的に途上国の若手研究者に対する研修助成金の提供が中心となります。

国連大学ホームページ http: // www.unu.edu 参照

「環境と持続可能な開発」プログラム

「沿岸水圏プロジェクト」の活動について

A．沿岸水圏における環境ホルモンの監視

この活動の目的は、沿岸汚染のレベルを測定し、沿岸汚染の原因となる陸上からもたらされる汚染源を特定することにあります。現在このプロジェクトには、中国、韓国、インドネシア、マレーシア、シンガポール、フィリピン、タイ、ベトナム、日本の計９カ国が参加しています。この活動では、モニタリングの方法やデータの共有、汚染物質とその汚染源に関する情報交換などを通して、地域の一体化を促進してきました。また国連大学は、高度な分析装置の提供、若い科学者に対する実践型研修の開催など、参加国の研究機関および研究者の能力育成にも多大な貢献をしてきました。

B．研究者の国際ネットワーク形成

国連大学は、東京大学海洋研究所、岩手県と協力して、沿岸・海洋における様々な研究に携わる若い専門家達のネットワーク形成を推進してきました。その一環として、専門的研修を定期的に開催しています。昨年度より、日本学術振興会や ASPACO（アジア太平洋における生物圏保存地域と同様の管理下にある地域の再生可能な自然資源の持続可能な利用のための協力）プロジェクトもこの活動に加わり、日本の研究者と海外の研究機関との協力を援助してきました。この研究ネットワークにおける研究の成果は、沿岸水圏プロジェクトのホームページ「Land　Base」や出版物等で広く公開されています。

C．マングローブの保全

国連大学では、マングローブの保全・復旧のための研究や能力育成に特に注目し、様々な活動に着手してきました。

１）国際研修 "*Asia-Pacific Cooperation on Research for Conservation of Mangroves*"

・2000年３月26－30日　沖縄にて開催

・開催者：国連大学、国際マングローブ生系協会、UNESCO-MAB

・目　的：マングローブの保全と持続可能な管理に関する経験を分かち合い、アジア太平洋地域のこの研究分野での協力を促進すること。

２）ASPACO プロジェクトの立ち上げ

2001年に開催された、このプロジェクトは、1999年にブダペストで催されたユネスコ「世界科学会議」の結果、特に「科学アジェンダ：行動のための枠組み」の中の「第２章：平和と開発のための科学」を踏まえて、ユネスコ、国連大学、国際マングローブ生態系協会が協力をし、科学教育における提言の実現を目的としています。

保全と開発両方を促進する媒体として、生物圏保存地域 (Biosphere Reserves) の役割に重点をおいており、主に下記の分野に焦点を当てています。

・経済水域を含む沿岸域の一体化した管理と持続可能な開発、倫理的ツーリズム (Ethical Tourism) を通しての自然的・文化的遺産の保護

・マングローブの保護

・国の権限下での再生可能な自然資源の持続可能な利用と保全

・国際的・地域的協力、強調の強化

活動の一環として、参加機関が各自あるいは協力して、様々なプロジェクトや研修等を開催しています。

３）国連大学・ユネスコによる国際トレーニング・ワークショップ

・開催者：国連大学、ユネスコ、アナマライ大学

・開催地：アナマライ大学（インド、タミル･ナデュ州）

・第三回研修：2003年３月10－24日

・目的

１：発展途上国の研究者・研究施設の能力向上により、危機的状況にあるマングローブや沿岸生態系のモニタリング・研究・保全に貢献すること。

２：この分野で活躍する、発展途上国の研究者達のネットワーク形成を推進する。

・内容

１：講義・実技（生物の多様性の役割、マングローブの分布、マングローブに影響を与える要因、マングローブの種類・見分け方、マングローブの減少、マングローブ保全のための政策、GIS についてなど）

２：グループ・ディスカッション

３：参加者による各々の国のマングローブの状況説明

４：マングローブ視察

D．情報の普及

様々なターゲットに情報を普及することは国連大学の主活動のひとつです。この情報普及は、主に下記の３つの手段を通して行なわれます。

１）出版物―本、ポリシー・ブリーフ、パンフレット、CD-ROM など。

２）インターネットにおける情報普及―ホームページ「Land　Base」、年４回発行のメールマガジン「East Asia Monitor」

3）国際シンポジウムと研修―陸上からもたらされる沿岸汚染に関するシンポジウムを定期的に開催：

・2000年：東アジア沿岸水圏における環境ホルモン―マレーシア、クアラルンプールにて開催

・2001年：工業と環境ホルモン汚染―韓国、ソウルにて開催

・2002年：農芸化学利用からの汚染をたどる―ベトナム、ハノイにて開催

・ホームページ

「Land Base」http: // landbase.hq.unu.edu 参照

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