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Lobelia gloria-montis

In This Issue

Invasive Mangroves in Hawai'i: GIS and Physiological Studies

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Abstract. After their introduction to Hawai'i at the beginning of this century, mangroves have become a dominant coastal vegetation on nearly all of the Hawaiian islands. The negative impacts of mangroves in Hawaii range from the degradation of endangered waterbird habitat, to the deterioration of important archeological sites, to the extreme alteration of coastal ecosystem function and structure. Several efforts to control and eradicate mangrove have been undertaken, yet prove to be expensive and ephemeral in result. In this study, a Geographical Information System (GIS) is created to serve as a model for mangrove inventorying and area calculation. Auxiliary outputs of the GIS include informative maps of mangrove expansion and an available spatial data base for further scientific or management uses. In addition, chlorophyll fluorescence measurements of mangrove seedlings growing in a gap and in the understory were conducted as an indirect indicator of photosynthesis capacity. Seedlings of *Rhizophora mangle* growing in the understory had lower light saturated rates of electron transport and dissipated a higher proportion of energy through non-photochemical quenching. These results suggest high acclimation potential of mangrove seedlings to gap formation and could partially explain the differential distribution of seedlings and saplings on the understory as well as the rapid and continual recolonization of mangrove propagules after clearing. Implications of these results for conservation and management are discussed.

The term mangrove refers to a taxomically diverse association of trees and shrubs that form a dominant vegetation class in the intertidal zone along tropical and subtropical coastlines. These areas are characterized by relatively sheltered water and diurnal and seasonal fluctuations of

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flooding and salinity. Plants under these conditions show morphological, anatomical and physiological adaptations to cope with salt and flooding stress.

While it is difficult to reconstruct the composition of Hawaiian intertidal wetlands prior to human contact, it is believed that the intertidal zone in Hawai'i had few species of vascular plants, despite the availability of habitats suitable for many of them (Allen, 1998). In spite of the capability of mangrove seedlings for long distance dispersal, none of them were successful in colonizing the Hawaiian Islands. This can most likely be explained by the low survival rate of seedlings after prolonged immersion in salt water and the configuration of ocean currents surrounding Hawai'i (Wester 1981). Mangroves were introduced to Hawai'i at the beginning of this century mainly to reduce sedimentation from the slopes near grazing land and sugar plantations and to supplement honey flora. Since their introduction, mangroves have become a dominant invasive species of the intertidal zone on all main Hawaiian islands, except Kaho'olawe and Ni'ihau (Fig. 1). Of the seven mangrove species introduced to Hawai'i, *Rhizophora mangle* and *Bruguiera gymnorrhiza* are the only successful colonizers.

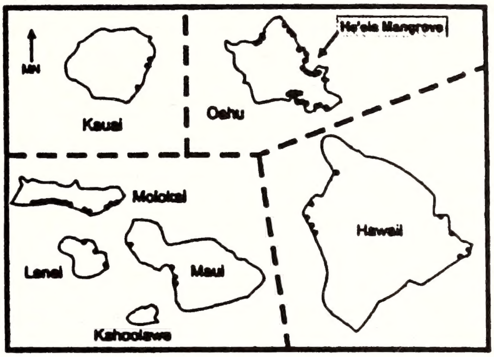

Fig. 1. Distribution of Mangroves in Hawai'i (adapted from Allen 1989 and Wester 1981).

Ecological Release

The success of mangroves colonizing coastal areas in Hawai'i can be explained in terms of the concept of ecological release (Steele 1998). When introduced to Hawai'i, mangroves encountered easily inhabitable natural coastal areas or fallow agricultural lands and near perfect growing conditions. At the time, Hawaii's lack of native vascular plants adapted to the harsh coastal environment and lack of mangrove predators, herbivores, and diseases allowed for the swift dispersion of mangroves to select coastal sites throughout the islands. Although it is believed that mangroves have displaced Polynesian-introduced coastal plants such as hau (*Hibiscus tiliaceus*) and milo (*Thespesia populnea*), it is not clear whether these species had the same ability to occupy the range of distribution of mangroves, and, therefore, their competitive capacity is questionable. A notable characteristic of mangroves in Hawai'i is a very high propagule production and survival when compared to its natural range and growing conditions. This quality is mostly attributed to a lack of local predators and disease (Steele, 1998).

Impacts of Mangroves in Hawai'i

While mangroves are often associated with ecological and human related benefits in most coastal areas of the world, in Hawai'i there are many negative impacts related to invasive mangrove establishment and they are often viewed as invasive pests. Occupation by mangroves has dramatically altered the ecology of the coastal zone of Hawai'i (Allen, 1998). An important concern about mangrove establishment in Hawai'i is the adverse effect on native communities. Most of the areas now occupied by mangroves in Hawai'i were once dominated by aquatic plants, herbaceous or small shrubs and primarily by algae and fungi. Those communities provided very different ecosystem functions and structure than current mangrove stands, and the invasion of mangroves is expected to create very dramatic changed in the ecology of Hawaiian coastal environments (Ewel & Bigelow, 1995).

Ecosystem impacts range from a degradation of water quality to 'severe modifications of habitat. Alteration and congestion of water flow patterns and high levels of organic inputs from leaf and propagule production has led to drastic modification in native ecosystem nutrient cycling. In areas with restricted water flow, high nutrient inputs are the suspected cause for a reduction in dissolved oxygen and subsequent reduction in water quality (Cox and Jokiel, 1996). Furthermore, well adapted dispersal mechanisms allow mangroves to expand their range of colonization in Hawai'i to atypical sites, including anchialine ponds. Although not well documented, occupation of mangroves in anchialine ponds increases shading and organic inputs, adversely affecting the highly specialized alga and fauna community associate with these pools (Allen, 1998).

Mangrove habitat modification from the invasion of wetlands is one of the factors involved in the population decline of four of the endemic Hawaiian waterbirds. These include the Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica alai*), Hawaiian duck (*Anas wyvilliana*) and Hawaiian moorhen (*Gallinula chloropus sandwicensis*). The optimal foraging and nesting habitats of most of these waterbird species consist of shallowly flooded marshlands and exposed mud flats. Mangroves not just colonize and adversely modify potential sites for waterbird nesting and feeding grounds, but provide shelter for common predators of these birds including the black-crowned night heron and introduced black rat, cattle egret, and Indian mongoose.

Besides these impacts, mangrove naturalization in Hawai'i has additional negative social ramifications. Mangrove establishment and occupation in Hawai'i creates difficulties for the conservation and management of important Hawaiian archeological sites. Mangrove establishment on and around Hawaiian archeological structures, including traditional Hawaiian fishponds, is an important cause of deterioration of these culturally important sites. Mangroves, if left unchecked, easily colonize banks and channels of stream and the shorelines of harbors. Mangroves are also associated with offensive odor production and increases in mosquito populations (Allen, 1998).

Management Problems/Concerns of Alien Mangroves in Hawai'i

There are many concerns related to the control and management of mangroves in the state of Hawai'i. While at some locations the rate of expansion of mangroves has ceased due to environmental limitations or extensive control methods, the expansion of *R. mangle* continues in areas such as eastern Hawai'i and west Maui (Allen, 1998). Up-to-date knowledge of the distribution of mangroves is important to land managers and decision-makers concerned with their effects. Presently, no state-wide assessment of the areal extant and characterization of mangroves has been accomplished (Allen, 1998). In 1977, the USFWS completed Hawai'i phases of the National Wetlands Inventory (NWI) which locates areas of wetland features throughout the State; however, the classification system it uses does not provide necessary descriptive detail for precise mangrove delimitation or monitoring. Based on the NWI classifications "estuarine forest" and "estuarine scrub-shrub", Allen (1998) estimates that 450 ha or 72% of all Hawaiian estuarine intertidal habitat are occupied by mangroves. Since 1977, mangrove distribution throughout the state has undoubtedly changed (Bigelow et al. 1989) and is of interest to managers and scientists alike.

In addition to the lack of areal information, the aggressive re-colonization by abundant propagules after gap formation from clearing is a concern for managers who wish to control mangroves in sensitive areas. While the complete eradication of mangrove from the Hawaiian environment is unlikely, some have proposed focusing on strategies for the long-term control of mangroves at sensitive sites -- while conceding the continued existence of mangroves on other sites. With the high cost of removal estimated as high as $100,000 – 377,000/ha. (Allen, 1998), managers are interested in developing 'best-practice' and efficient methods for not only the removal of mangroves from select sites but also site protection from future colonization. Several expensive mangrove removal efforts in Hawai'i, while successful in the removal of adult trees, have been plagued with rapid and continual re-colonization by mangrove propagules (Allen 1998). Thus, information on re-colonization and propagule production, establishment, and dispersal is of particular value to land managers who wish to protect restoration efforts and their investments. Once priority sites are identified and modified, it is likely that managers will desire to monitor both the spread of mangrove and their efforts to control and protect sensitive areas.

The objectives of this project are designed to help address some of the above concerns by creating a model Geographical Information System (GIS) of mangrove data and conducting experiments on the physiological response of mangrove seedlings under different light conditions. A simple GIS will be created to demonstrate how these computer tools can be used to map the spatial distribution and calculate trends of mangrove expansion at a particular site. This GIS is intended to have the capabilities to inventory and display data, calculate mangrove coverage and spread, and model spatial information for further site specific investigations. Additionally, this study will examine light energy utilization and dissipation by mangrove seedlings under artificial gap and canopy conditions. Because mangrove control often creates gap conditions, the photosynthetic response of *R mangle* growing under gaps is crucial to the understanding of how mangroves respond to drastic changes in light environment, their acclimation potential, and implications for growth and re-colonization.

GIS and Mangroves

The creation of a model GIS for the mangroves could prove useful in several scientific and management capacities. Thus, the GIS component of this project is intended to 1) demonstrate the ease and effectiveness of a relatively simple method for calculating areas of mangrove coverage through aerial photography and GIS software; 2) construct a time series model that displays and calculates expansion rates of invasive mangroves at a specific site based on historic data; and 3) provide a spatial data base and series of relatively accurate base maps of mangrove stands from and to which information can be added and/or derived for further scientific or management uses.

Understanding Geographic Information Systems

Computer tools such as Geographic Information Systems (GIS) have become fundamental for environmental assessment, regional planning, ecosystem conservation, and natural resource management. With GIS, biological and ecological data can be integrated with social, economic, and physical environmental data—then displayed visually on maps—to help scientists in their studies and decision-makers better understand and solve conservation problems. While GIS is becoming more prevalent in ecological studies and to simulate and model systems spatially, one of GIS's more standard use is for basic spatial inventory keeping and a convenient form of map overlay and display. A basic view of a GIS is as a spatial data base (like a Dbase, Access, Info or other relational data bases) that can be used to structure, query, and manipulate spatial and attribute data.

The ultimate objectives of GIS are not limited to the creation of a searchable database of digital representations geographic phenomena, but to also provide a means of selecting, retrieving, and analyzing spatial information. Once location, attributes, and topology (or how elements link together) are combined, GIS allows the use of standard position and topological query functions to ask simple and complex questions of the data set. Available functions include calculating statistics (sums, averages, deviations, etc.) and creating new features and categories based on attribute data (for example classifying new areas based on the occurrence of species sighting in a given habitat type and slope). The selection of features and the execution of operations based on topology include additional functions like finding line intersections and points in areas, creating buffer zones and area intersections, and selecting nearest neighbors.

Uses of GIS related to resource management and conservation biology are many. Beyond basic inventorying and the creation of habitat or preserve maps, GIS is being used more frequently to simulate or predict parameters that are of concern to conservation biologists and wildlife managers. The US Fish and Wildlife Service currently uses the GAP analysis program to identify areas used by various species by overlaying habitat maps with land use and ownership maps to determine areas and species that are poorly protected. GIS is now being used in conservation biology to link spatial information with meta-population models for population viability analysis and extinction risk assessments. GISs can also be designed to incorporate system dynamics into scientific models that are used in the prediction of future events. For example, GIS can be used to spatially model high-order relations, including habitat dynamics that result from forest logging, invasive species encroachment, and habitat suitability due to climate change. Recently, the introduction of tracking software can enable GIS to be used for animal tracking or dispersal studies.

Population Structure and Physiology of Mangrove Seedlings

Physiological plant ecology is a multidisciplinary field that provides tools for studying how interacting environmental resources control plant growth and survivorship. Basic information about ecological and physiological mechanisms of invasive plant establishment and distribution has proved to be a critical key in the development of effective conservation and management plans. One of the most useful physiological parameters is photosynthesis. Photosynthetic responses to the environment can yield important information, not only about the ability of tree seedlings to survive and grow under a given suite of environmental conditions, but also about their acclimation potential to long term changes in environment, such as gap formation. It has been suggested that the natural low frequency of gap formation in the Hawaiian mangroves compared to native mangroves swamps is one of the most important factors limiting seedling growth (Allen, pers. com.). Gap creation typically increases light or photon flux density (PFD) by a factor of 25 (Chazdon and Fetcher, 1984). Plants exposed to such a drastic change in light regime must be able to develop mechanisms to deal with the excess energy, otherwise they will experience photoinhibition: the light dependent reduction in photosynthesis which occurs when light energy exceeds the required for C fixation. The ability of rainforest seedlings to acclimate to new light conditions, as the encountered after a gap formation, is crucial for their ultimate survivorship. Gap formation will then indirectly influence patterns of individuals distribution and population structure. It is then interesting to study ecophysiological responses of *Rhizophora mangle* seedlings growing in contrasting light environments in order to understand how a drastic change in light regime can influence growth and ultimately, population dynamics of these introduced species.

The objective of this project component is to study the photosynthetic response of seedlings of *Rhizophora mangle* growing under an artificial gap and in the understory. The photosynthetic response differences between them will be measured by comparing chlorophyll fluorescence emissions. We hypothesize that seedlings of *R. mangle* will show a high acclimation potential to light, which will be expressed by: (i) seedlings growing in a gap having higher capacity to utilize light energy (higher Electron Transport Rate) compared to seedlings growing in the understory; and (ii) seedlings in the understory dissipating a higher proportion of excess energy by non-photochemical processes.

Materials and Methods

Study Site

The mangrove stand at He'eia Swamp was chosen as a study site due to ease of accessibility and the level of scientific study that has occurred there specifically on mangroves over the last 30 years. The He'eia Swamp, lower Stream, and State Park occur contiguously in a lowland depression adjacent to Kaneohe Bay on the island of Oahu (see Fig. 1). The swamp occupies approximately 14ha where He'eia Stream one of the main drain arteries of the Ko'olau Mountain Range enters the ocean (Walsh, 1967). The area was once used for taro and rice cultivation (Wester 1981), but over the last eighty years, cession of agricultural activity has reverted fields to freshwater marshland and mangrove forest stand.

The swamp also boarders He'eia Fishpond, a traditional Hawaiian fishpond that is currently in small scale commercial use. The mangroves occurring in this area have spread rapidly and become well-established do to ideally suited conditions of the sheltered waters and low marshland. Occurring along the fishpond and inland into the marsh, this largely monospecific stand has been the focus of a number of descriptive and ecological studies (Walsh,1967; Lee 1971; Wester 1981, Steel 1998). Although there is little finances within the State Department of Parks and Recreation to attempt to control mangroves at this location, some clearing of area is conducted on a limited basis by a community association (Allen, per. com).

GIS

To address the relevant spatial objectives of this project, a vector model GIS was produced using ArcView software to allow different year coverage areas to be overlaid as individual themes. The first step in the creation of this GIS was the selection of appropriate base maps to use for geo-referencing additional levels. Geo-referencing allows images, shapes, or files from different scales and coordinates to be referenced to one or a set of known positions on the earth's surface; thereby making future overlay functions possible. USGS Digital Line Graph files of the Kaneohe roads and hydrological features were converted to ArcView 'shapefiles' using ArcInfo software. These map themes were then overlaid in ArcView to provide a suitable base map in UTM (Universal Transverse Mercator) coordinates.

Aerial photography was acquired to produce specific year coverage 'themes.' Black and white aerial photographs were selected for years 1928, 1949, and 1971 (Devaney et al 1982). More recent false infra-red aerial photography of the area provides data for 1991. On November 23rd, 1998, the He'eia Swamp area was ground-truthed with aerial photographs in hand to confirm the presence of mangrove species and distinguish these areas from other features. For obvious reasons, it was not possible to ground-truth the presence or absence of mangroves in the more historic images and some assumptions had to be made concerning possible mangrove coverage at the time of the photograph.

Aerial photographs were scanned using a desktop scanner then digitized on-screen to create polygon 'shapefiles' for each theme of a certain year's mangrove coverage (i.e. Mangroves 1941). Since the aerial photographs were scanned in and digitized at different scales and aspects, it was necessary to perform affine transformations to move the polygons into aligning positions. Affine transformations involve translating points to known coordinate positions, rotating objects for alignment, and then scaling for appropriate sizing. At this point, all themes were overlaid on top of the base map and evaluated for accuracy in registration. Mis-registration levels were judged to be acceptable for current application. After these assessments, the areas contained within polygons of a specific theme were summed to calculate a year's coverage total.

Species

The species we worked with is *Rhizophora mangle* (Rhizophoraceae), a salt-excluding mangrove widely distributed in three biogeographic regions (West America, East America and West Africa) described by Robertson and Alongi (1992). Tolerant of a wide range of salinity and temperature, ubiquitous and often dominant (Hutchings and Saenger, 1987).

Population Structure

Population structure of a portion of the low intertidal zone in the He'eia State Park was analyzed by quantifying the total number of individuals by size classes in a 35×3 m transect. The transect consisted of 7, 3×3 m plots separated by 2 m from each other. In each plot the individuals were classified by species and size classes divided into seedling, sapling and adult. Two of the plots fall under or at the edge of an artificial gap, while the remaining five were found under the closed canopy. We wanted to include any pattern of individual distribution under those two contrasting light environments.

Physiological Measurements

Chlorophyll fluorescence emissions of 3 leaves of seedlings growing under an artificial gap and in the understory were measured using a Portable Chlorophyll Fluorometer (Mini-PAM, Heinz Walz, Effeltricht, Germany). Fluorescence was measured under ten different light intensities: 0, 20, 50, 70, 100, 200, 400, 600, 800, 1200 and 2000 $\mu mol\ m^{-2}\ s^{-1}$ after 10 minutes of exposure. In principle, chlorophyll fluorescence can function as an indicator of different levels of the photosynthesis process. Fluorescence emission is complementary to the pathways of photochemistry and heat. Values of Electron Transport Rate (ETR) -- as an indicator of energy utilized to photosynthesis -- and Non-photochemical quenching (NPQ) -- as indicator of energy dissipated -- were registered. Leaf age was controlled by always selecting the first full developed leaf in each plant. Differences in flooding conditions were reduced by selecting

Table 1. Mangrove coverage calculated from aerial photogrphy at He'eia Swamp, O'ahu, Hawai'i.

Year	Mangrove Coverage (m^2)	Coverage Change (m^2/yr)
1902	0	-
1928	5906	227.15
1949	66,025	2862.51
1971	124,041	2637.09

plants located more or less in the same portion of the intertidal zone.

RESULTS

Area Trends

Values calculated for the yearly mangrove coverage and overall rate of change is shown in (Table 1).

Population structure

Table 2 summarizes the results of population structure from the transect area. Two species of mangrove were found: *Rhizophora mangle* and *Bruguiera gymnorrhiza*. *R. mangle* was the dominant species in the studied transect (1899 individuals) when compared to *B. gymnorrhiza*. (41 individuals). Seedlings of *R. mangle* accounted for 95% of the total number of individuals of that species.

When compared by plots, it is interesting to note that all the saplings of *R. mangle* were only found in the plots that were under or at the edge of the artificial gap (Fig. 2).

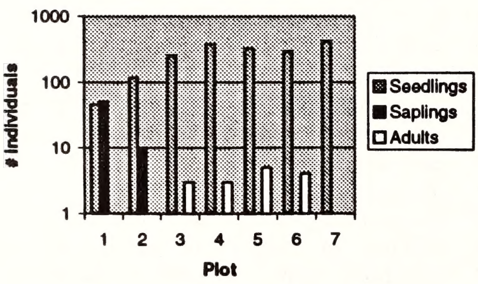

Fig. 2. Number of Rhizophora mangle individuals by size class in seven 3 × 3m plots at He'eia State park.

Table 2. Total number of individuals of mangrove by species and size class in 7, 3×3 m plots in the low intertidal zone of the He'eia State Park, Hawai'i.

Species	Size Class Seedling	Sapling	Adult
R. mangle	1822	61	16
B. gymnorrizha	6	33	2

Physiological measurements

Seedlings of *Rhizophora mangle* growing in the understory had lower light saturated rates of Electron Transport rate which were achieved at low PFDs (Fig.3). In addition, for a given light intensity less than 2000 µmol m^{-2} s^{-1}, seedlings in the understory showed higher Non-photochemical quenching values when compared to seedlings growing under an artificial gap (Fig 4).

DISCUSSION

Area Trends

The model GIS and output show the rapid invasion and establishment of mangroves into the He'eia Meadowlands area. Mangrove expansion in the area is calculated to increase by an order of magnitude between the years 1928 and 1949 and doubles between the years 1949 and 1971. From 1971 to 1991 there is a net area decrease, yet comparisons of each year theme reveal some clearing of mangrove for agricultural purposes and the development and expansion of mangrove adjacent to the State Park parking area. These subtleties in area trends for different time years can be further explored using the existing GIS (with a few additional modifications) by investigating state and location changes. More refined estimates of the rate of mangrove spread can also be achieved by increasing the number of year themes, increasing the number of data samples.

The project GIS and the methods used to create it proved to be a reasonably accurate and efficient means of mapping mangrove coverage, calculating mangrove area and estimating area trends based on net coverage changes. Previous

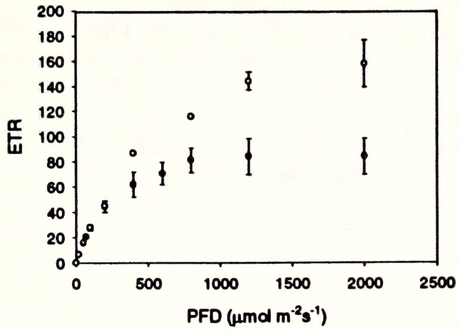

Fig. 3. Relation between electron transport rate (ETR) and photon flux density (PFD) for seedlings of *Rhizophora mangle* growing in shade and gap in He'eia State Park, Hawai'i. Closed dots represent understory plants; open dots are plants in gaps.

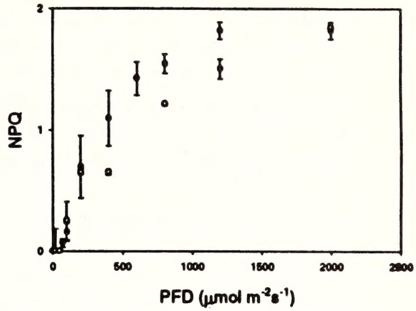

Fig. 4. Relation between nonphotochemical quenching (NPQ) and phton flux density (PFD) for seedlings of *Rhizophora mangle* growing in shade and a gap in He'eia State Park, Hawai'i. Closed dots represent understory plants; open dots are plants in gaps.

studies (Walsh, 1967) cite the mangroves coverage at He'eia State Park at approximately 14 ha, 2 hectares larger than the respective estimate from the GIS output. However, potential differences in the reference bounds of these two estimates may offset any computational differences. Accuracy of alignment was tested for the four mangrove coverage themes and found to be sufficiently congruent (with variances of +/- 25m at points ~700m from the mid-point of the line of transformation). Registration problems associated with sources of error (ie. photograph distortion, angle differences, alignment variation) could be improved by using a more sophisticated 'rubber sheeting' transformation process that includes three or more points. Yet, this transformation was not performed because the ArcView version used to create this particular GIS file does not support this feature.

Population structure

The high proportion of seedlings compared to other size classes is disproportionate for the values that have been reported in places were mangroves grow natively. Steele reported a proportion of 2:1 when comparing seedlings vs. adults of *R. mangle* in a Samoan swamp (Steele, 1998) and similar values have been found in the New World. The high amount of seedlings can be attributed to the lack of predation and competition that mangroves encountered in Hawai'i. On the other hand, the fact that saplings showed a clear preference for open canopies suggests a positive influence of light on the growing ability of the already established seedlings.

Physiological measurements

The results of this study are consistent with data found by Cheeseman et al. (1997) who confirmed effective protection of mangrove photosynthetic systems from photoinhibition, when analyzing canopy mangrove leaves. The ability to tolerate large and sudden changes in PFD can be a major selective pressure in determining seedling performance (Scholes et al., 1997). An example of such a case is the high mortality (up to 30%) of dipterocarp rain forest seedlings reported by Brown and Whitmore, following the creation of a gap (1992). Our results suggest, by the contrary, that *R. mangle* seedlings have a high potential to acclimate to new light conditions which is evident from the different pattern observed in seedlings growing under contrasting light environments. Nevertheless, the fact that non-photochemical quenching for a PFD of 2000 μmol m^{-2} s^{-1} was the same for seedlings in the gap and understory suggests that above such value even light adapted seedlings will dissipate a high proportion of light energy. According to Clough (1992), the minimum light flux density required for gross photosynthesis to balance the daily respiratory losses for mangrove seedlings is likely to be 200 µmol m^{-2} s^{-1}, which is similar to the PFD encounter in the shaded understory. In our experiments, seedlings growing in the understory achieved a maximum electron transport rate at about 800 µmol m^{-2} s^{-1}, which suggest that under such shaded environments a seedling's performance must be at its working limit.

Implications for conservation

The results of this study have meaningful implications for the understanding of mangrove dynamics in Hawai'i. An efficient means of mangrove inventorying and an area expansion is demonstrated. In addition, GIS products of this study can be adapted for use in further scientific analysis and modeling, for example analyzing limiting environmental factors of mangrove expansion or modeling the production and dispersal of propagules for use in mangrove control programs (Allen, pers. com.). Furthermore, *R. mangle* seedlings may be limited by light underneath closed understory, maintaining sub-optimal photosynthetic rates. They may be "released" from this slow growth stage following the formation of a gap in response to an increase in light. As this study suggests, gap formation favors growth of already established mangrove seedlings. Since mangrove control in Hawaii inevitably involves the creation of artificial gaps and established seedlings have the potential to respond favorably to these conditions, control of propagule dispersal and additional seedling establishment will also be a necessary component of any effective management efforts.

Literature Cited

Allen, J. A. 1998. Mangroves as alien species: the case of Hawai'i. Global Ecology and Biogeography Letters 7: 61-71.

Brown N. D. and T. C. Whitmore. 1992. Do dipterocarp seedlings really partition tropical rain forest gaps? Philos. Trans. R. Soc. B335: 369-378.

Bigelow, K.A., K. Alspach, R. Lohle. T. McDonough, C. Ravetto, G. Stender and C. Wong. 1989. *Assesment of mangrove ecosystem of west Molokai, Hawai'i, with additional site surveys of Moauni Beach Park and Ualapu'e Fishpond.* Marine Option Program, University of Hawai'i, Honolulu, HI.

Chazdon, R.L. and N. Fletcher. 1984. Light environments of tropical forests. In Medina E., H.A. Mooney, and C. Vazquez-Yanes (eds.). *Physiological ecology of plants in the wet tropics.* Junk, The Hague, pp 553-564.

Cheeseman, L. J., L. B. Herendeen, A. T. Cheeseman and B. F. Clough. 1997. Photosynthesis and photoprotection in mangroves under field conditions. Plant, Cell and Environment 20: 579-588.

Clough, B. F. 1992. Primary productivity and growth of mangrove forest. In: *Tropical Mangrove Ecosystems.* A. I. Robertson and D. M. Alongi (Eds.). pp. 225-249. American Geophysical Union. Washington, D.C.

Cox, E.F. and P.L. Jokiel. 1996. *An environmental study of Nu'upia Ponds Wildlife Management Area,* Marine Corps Base Hawaiian, Kane'ohe. Final Report.

Devaney, D.M., M. Kelly, P.J. Lee, & L.S. Motteler. 1982. *Kan'ohe: a history of change.* Bess Press, Honolulu, HI, USA.

Ewel, J.J. & S.W. Bigelow. 1996. Plant life-forms and tropical ecosystem functioning. Biodiversity and ecosystem processes in tropical forests (ed. by G. Orians, R. Dirzo, and J.H. Cushman), pp. 101-126. *Ecological Studies*, Vol. 122. Springer-Verlag, Berlin.

Scholes, J. D., M. C. Press and S. W. Zipperlen. 1997. Differences in light energy utilization and dissipation between dipterocarp rain forest seedlings. Oecologia 109: 41-48.

Steele, O. C. 1998. *The influence of predation and herbivory on the establishment of mangrove seedlings.* M.Sc. thesis, University of Hawai'i-Manoa, Honolulu, Hawai'i.

Walsh, G. 1967. An ecological study of a Hawaiian mangrove swamp. In: *Estuaries.* G. H. Lauff (Ed.). pp. 420-431. American Association for the Advancement of Science Publication 83, Washington, D.C.

Wester L. 1981. *Introduction and spread of mangroves in the Hawaiian Islands.* Assoc. Pacific Coast Geographers Yearbook 43: 125-137.

Growing Native
A Regular Feature on Native Plant Horticulture

Sulfur Paste: An Effective Treatment for a Fungal Disease That Attacks *Lama* (*Diospyros sandwicensis*) Seedlings

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Wai'anae, Hawai'i 96792

Lama (*Diospyros sandwicensis*) seedlings are occasionally attacked by a fungal disease that can kill them in just a few days. The first indications of the disease are dark patches on the hypocotyl of the seedling. (Often, the patches appear first near the hypocotyl bend, the region most likely to be damaged as the seedling pushes its way up through the soil.) The patches are rapidly followed by wrinkling and constriction (i.e., wilting) of the infected region. When the region can no longer support the weight of the seedling's leaves, the hypocotyl folds downward. Two or three days later the seedling is dead. A postmortem examination of the seedling with a microscope revealed that the fungal hyphae are concentrated in the vascular tissue of the seedling.

If noticed early, before folding, the seedling can be treated and cured. Use a clean cotton swab to liberally apply a 12% sulfur paste to the hypocotyl. I normally use Safer®Brand Garden Fungicide Concentrate directly from the bottle. Less concentrated sulfur sprays were ineffective at stopping the disease. Let the sulfur dry on the hypocotyl. Repeat the application every couple of days and do not wash away the sulfur during your normal watering. If successful, progression of the disease will halt. Continue treatment for one to two weeks and then let the sulfur gradually wash away during your normal watering. Recovered seedlings have a visible and persistent swelling at the original infected site; this is a consequence of replacement tissue and is nothing to worry about. Compared to uninfected seedlings, those attacked and cured of the disease grow slightly more slowly. However, I have never seen a reoccurrence of the disease or lost a cured plant.

John Culliney (personal communication) has treated a similar disease of *kauila* (*Alphitonia ponderosa* and *Colubrina oppositifolia*) seedlings using powdered sulfur applied with a toothpick. Readers that have seen the disease attack other species are encouraged to contact the author and try the sulfur paste treatment.

Palikea Trail Native Plant List

John B. Hall
5326 Keikilani Circle, Honolulu, HI 96821

Survey Date(s): December 12, 1998 and many earlier trips.

Reason for Trail Selection: The Palikea trail passes through the most easily accessible segment of native forest remaining on the crest of the Wai'anae Range. A number of rare endemic species of plants are found along this trail.

Location Reference: O'ahu Sectional Maps #103 and 110; USGS Map: Schofield Barracks Quadrangle.

Access: By conducted tour only, arranged through the Nature Conservancy of Hawai'i, 1116 Smith Street, #201, Honolulu, HI 96817. Phone (808) 537©4508. There is a limit of 15 people per party, including two docents. For a botanically oriented docent, call John Hall, 377-5442, and ask him to arrange a date for your trip.

Elevations: 2,776-3,098 ft. (Summit of Mauna Kapu to summit of Palikea, a short distance beyond the terminus of the trip described here.)

Native Plants: Drive to Trail Head and Mauna Kapu

Erythrina sandwicensis (wiliwili)
Hibiscus arnottianus (koki'o ke'oke'o)
Mariscus sp.
Pisonia brunoniana (papala kepau, papala)
Rumex albescens (hu'ahu'ako)
Santalum ellipticum ('iliahialo'e, or lowland sandalwood)
Sicyos pachycarpus (kupala)

Ferns and fern allies:
Lepisorus thunbergianus (syn.=*Pleopeltis thunbergiana*, pakahakaha)
Sphenomeris chinensis (syn.=*Odontosoria chinensis*, pala'a)

Side Trails Taken: None. The primary mission of the Nature Conservancy is to conserve the biological resources of this area. It therefore asks all parties to stay on established trails and not to make side trips off of them.

Other Notes:

A. *Santalum ellipticum* is on the 2nd curve past the first gate on the drive up. *Erythrina sandwicensis* is seen in the nearby gulches.

B. Lamoureux (1963) reported the presence of Phyllanthus sandwicensis (now P. distichus) on Mauna Kapu, but we did not observe it there.

C. Significant introduced plants, Mauna Kapu: *Acacia mearnsii*, *Ageratina riparia*, bamboo, *Eucalyptus robusta*, *Kalanchoe pinnata*, *Lantana camara*, *Oplismenus hirtellus*, *Paspalum conjugatum*, *Passiflora suberosa*, *Physalis peruviana*, *Rubus rosifolius*, and *Schinus terebinthifolius*. Ferns: *Phlebodium aureum*, *Thelypteris* (*Christella*) *dentata*, and *Thelypteris* (*Christella*) *parasitica*.

D. This section ends where the shelf trail along the back of Mauna Kapu regains the crest of the ridge. Elevation at this point is about 2660 ft

Native Plants: Ridge Crest—Ironwood (*Casuarina*) Section

Acacia koa (koa)
Alyxia oliviformis (maile)
Bidens torta (ko'oko'olau)
Carex wahuensis (endemic sedge)
Chamaesyce multiformis ('akoko)
Cocculus trilobus (huehue)
Coprosma foliosa (pilo)
Dianella sandwicensis ('uki'uki)
Dodonaea viscosa (a'ali'i)
Eragrostis variabilis (kawelu)
Hedyotis schlectendahliana (kopa)
Hedyotis terminalis (manono)
Mariscus sp. (endemic sedge)
Metrosideros polymorpha ('ohi'a lehua
Myrsine emarginata (kolea)
Peperomia tetraphylla ('ala'ala wai nui)
Pouteria sandwicensis ('ala'a)
Santalum freycinetianum ('iliahi, mountain sandalwood)
Scaevola gaudichaudiana' (naupaka kuahiwi)
Styphelia tameiameiae (pukiawe)

Viola chamissoniana (pamakani, tree violet)

Ferns, fern allies, and other:
Dicranopteris linearis (uluhe)
Lepisorus thunbergianus (syn.=*Pleopeltis thunbergianus*; pakahakaha)
Sphenomeris chinensis (syn.=*Odontosoria chinensis*; pala'a)
Trentepohlia aurea (green alga-red patches on rocks)

Side Trails Taken: None.

Other Notes:
A. This section of the ridge is dominated by *Casuarina equisetifolia* (ironwood).
B. Lamoureux also reported the presence of *Myrsine sandwicensis* and *Leptospermum laevigatum* in this section.
C. Significant introduced plants: *Casuarina equisetifolia, Clidemia hirta, Ehrharta stipioides, Fraxinum uhdei, Grevillea robusta, Lantana camara, Melaleuca quinquenervia, Melinis minutiflora,* Monterey Cypress, *Myrica faya, Oplismenus hirtellus, Opuntia ficus-indica, Paspalum conjugatum, Passiflora suberosa, Psidium cattleianum,* and *Schinus terebinthifolius.* Ferns: *Phlebodium aureum, Thelypteris (Christella) dentata, Thelypteris (Christella) parasitica.*
D. A convenient landmark for the end of this section of the trail and the beginning of the last section is the tunnel where the trail passes through some large boulders. Elevation at this point, about 2740 ft.

Native Plants: Ridge Crest— Native Forest Section

Acacia koa (koa)
Antidesma platyphyllum (hame, mehame)
Alyxia oliviformis (maile)
Bidens torta (ko'oko'olau)
Broussaisia arguta (kanawao or pu'ahanui)
Carex meyenii (indigenous sedge)
Carex wahuensis (endemic sedge)
Chamaesyce multiformis ('akoko)
Cheirodendron trigynum ('olapa)
Clermontia oblongifolia ('oha wai)
Cocculus trilobus (huehue)
Coprosma foliosa (pilo)
Coprosma longifolia (pilo)
Cyrtandra waianaeensis (hahala)
Dianella sandwicensis' ('uki'uki)
Dodonaea viscosa (a'ali'i)
Dubautia laxa (na'ena'e or pua melemele)
Dubautia plantaginea (na'ena'e or kupaoa)
Exocarpos gaudichaudii (hulumoa, kaumahana)
Freycinetia arborea ('ie'ie, 'ie)
Gahnia beecheyi (endemic sedge)
Hedyotis schlechtendahliana (kopa)
Hedyotis terminalis (manono)
Hibiscus arnottianus (koki'o Ke'oke'o)
Korthalsella cylindrica (hulumoa, kaumahana)
Ilex anomala (kawa'u, Hawaiian Holly)
Labordia kaalae (kamakahala)
Labordia waiolani (kamakahala)
Lobelia yuccoides (panaunau)
Melicope clusiifolia (kukaemoa, kolokolo mokihana)
Melicope kaalaensis (alani, alani kuahiwi)
Melicope oahuensis (alani, alani kuahiwi)
Metrosideros polymorpha ('ohi'a lehua)
Myrsine lessertiana (kolea lau nui)
Panicum nephelophilum (konakona)
Peperomia membranacea ('ala'ala wai nui)
Peperomia tetraphylla ('ala'ala wai nui)
Perrottetia sandwicensis (olomea)
Phyllanthus distichus (pamakani mahu, pamakani)
Pipturus albidus (mamaki)
Pittosporum confertiflorum (ho'awa)
Psychotria mariniana (kopiko)
Psychotria hathewayi (kopiko)
Rumex albescens (hu'ahu'ako)
Scaevola gaudichaudiana (naupaka kuahiwi)
Scaevola mollis (naupaka kuahiwi)
Schiedea pubescens var. *purpurascens*
Smilax melastomifolia (hoi kuahiwi, aka'awa, or pi'oi)
Stenogyne kaalae (ma'ohi'ohi)
Styphelia tameiameiae (pukiawe)
Vaccinium calycinum ('ohelo, 'ohelo kau la'au)
Vaccinium dentatum ('ohelo)
Viola chamissoniana (pamakani, tree violet)
Wikstroemia oahuensis ('akia, kauhi)
Zanthoxylum kauaense (a'e)

Ferns and fern allies:
Asplenium contiguum
Asplenium cookii
Asplenium horridum ('iwa, 'alae)

Asplenium macraei (ʻiʻiwa lau liʻi)
Adenophorus tamariscinus (wahine noho mauna)
Athyrium microphyllum (ʻakolea)
Cibotium chamissoi (hapuʻu, hapuʻu ʻiʻiʻi)
Dicranopteris linearis (uluhe)
Diplazium arnottii
Diplazium sandwichianum (hoʻiʻo)
Diplopterygium pinnatum (uluhe lau nui)
Doodia kunthiana (ʻokupukupu lauʻiʻi)
Dryopteris fusco-atra (hapuʻu ʻiʻi)
Dryopteris nuda
Dryopteris sandwicensis
Elaphoglossum aemulum (laukahi nunui, stag's tongue fern)
Elaphoglossum alatum (ʻekaha ʻula)
Elaphoglossum crassifolium (ʻekaha, stag's tongue fern)
Elaphoglossum paleaceum (*E. hirtum*, makuʻe, hairy stag's tongue fern)
Grammitis tenella (mahinalua)
Lepisorus thunbergianus (syn.=*Pleopeltis thunbergiana*; pakahakaha)
Microlepia speluncae
Microlepia strigosa (palapalai)
Nephrolepis exaltata ssp. *hawaiiensis* (kupukupu, ʻokupukupu, common sword fern)
Oligadenus pinnatifidus (*Adenophorus pinnatifidus*, palai laʻau)
Phlegmariurus phyllanthus (*Huperzia phyllantha*, wawaeʻiole)
Polypodium pellucidum (ʻae)
Psilotum complanatum (moa)
Psilotum nudum (moa)
Pteridium aquilinum var. *decompositum* (*P. decompositum*, kilau)
Sadleria cyatheoides (ʻamaʻu)
Selaginella arbuscula (lepelepeamoa, branched spikemoss)
Sphenomeris chinensis (syn.=*Odontosoria chinensis*; palaʻa, lace fern)
Vandenboschia davallioides (palai hihi)

Side Trails Taken: At the summit at which the hike ends, there is a small grassy alcove to the left. Native plants seen on side trail: *Pipturus albidus*, *Cheirodendron trigynum*, and *Myrsine lessertiana*.

Other Notes:

A. Lamoureux reported the following additional plants in this section: *Cladium angustifolium* (=*Machaerina angustifolia*), *Rollandia waianaeensis* (=*Cyanea lanceolata*) *Charpentiera* sp., *Syzygium sandwicensis*, and *Microsorum spectrum* (fern).

B. Significant introduced plants: *Ageratina adenophora*, *Buddleia asiatica*, *Casuarina equisetifolia*, *Clidemia hirta*, Cook Pines, *Crocosmia* × *crocosmiiflora*, *Desmodium incanum*, *Drymaria cordata*, *Eucalyptus* sp., *Gnaphalium purpureum*, *Lantana camara*, *Melinis minutiflora*, *Myrica faya*, *Paspalum conjugatum*, *Passiflora suberosa*, *Rubus rosifolius*, *Schinus terebinthifolius*, *Setaria gracilis*, *Setaria palmifolia*, *Sporobolus indicus*, *Stachytarpheta* sp., Sugi pine, turpentine tree, and *Verbena litoralis*. Ferns: *Blechnum occidentale*, *Cyathea cooperi*, *Deparia petersenii*, *Phlebodium aureum*, *Thelypteris* (*Christella*) *dentata*, *Thelypteris* (*Christella*) *parasitica*.

C. There is a small colony of endangered *Achatinella* snails found on this section of the trail. ***Please be particularly careful not to brush against or shake the vegetation as you may dislodge these small animals.*** Use extra caution on the steep and slippery slopes near the end of the trail, as there are likely to be snails in this vicinity, and the temptation to grab the plants here is especially strong.

D. Elevation, about 3060 ft.

Acknowledgements

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Literature Cited

Lamoureux, C. H. 1963. Field Guide to the Maunakapu-Palikea Trail, Newsletter of the Hawaiian Botanical Society 2:81-83.

Valier, K. 1995. Ferns of Hawaii, University of Hawaiʻi Press, Honolulu, Hawaii.

Wagner, W. L., Herbst, Derral R., and Sohmer, S. H., 1990. *Manual of the Flowering Plants of Hawaii*. vols 1and 2, University of Hawaiʻi Press and the Bishop Museum Press, Honolulu, Hawaii.

Bamboo and Polynesian Voyaging

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Abstract. Bamboo (*Schizostachyum glaucifolium*) was one of the major Polynesian plants carried by early settlers in their micration eastward from Indonesia to the far reaches of Polynesia. The genera *Bambusa, Dendrocalamus*, and *Gigantochloa*, with their straight, thick-walled, and durable stems, became an edeal material for use in the construction of outrigger canoes. The Mandar seafarers of the Celebes Islands of Indonesia, for example are know as peoples with a "bamboo culture." They continue to use bamboo for the mast, sail boom and float of their "*Sande*" outrigger canoe, as they have for thousands of years. A comparative study is made to correlate the employment of bamboo in the ancient outrigger canoes of Mandar, the Society islands, the Marquesas, and Hawai'i. Preliminary findings show that in the Society Islands, bamboo was used as a base section into which a wooden mast was inserted, and it was also used as a sail boom to which a sprit was lashed. The use of bamboo in the construction of the Marquesan outrigger canoe was substantially reduced. It was used only for narrow covering strips to secure the washstrakes, underbody, and end pieces on the inner and outer portion of the hull. No bamboo was used in building the Hawaiian outrigger canoe. However, Bamboo culms were consistently used during voyaging to transport fresh water. In Hawai'i, bamboo symbolized the god Kane—the procreator.

The people who became Malayo-Polynesians migrated to Taiwan and thence to the Philippines and Indonesia by means of rafts and canoes from South China some 4,500 to 5,000 years ago. They spoke ancestral forms of Austronesian languages, eventually diversifying into many ethnic groups throughout insular Southeast Asia and the Indonesian archipelago. Some of them still retain their maritime cultural orientation. Examples include the Bajau of Sulu (north of the Celebes Islands), the Buginese from the gulf of Bone (south of Celebes), the Makassarese in south Celebes, the Mandarese in south-west Celebes, the Butungese in south-east Celebes, and the Madurese to the east of Java (Horridge, 1986). Among these seafarers, the Mandarese are known as people with a "bamboo culture," extensively using bamboo in the construction of their houses, rafts, outrigger canoes, and fishing and cooking implements (Masrury et al. 1996).

The seafaring Malayo-Polynesians spread further eastward into Melanesia by 3,000 BC, arriving in Fiji by 2,000 BC, in the Society Islands around 600 BC (Irwin 1992), the Marquesas by 200 BC, and the Hawai'i Islands before 400 AD (Sutton 1994). These ancient Polynesian migrants had developed suitable outrigger canoes, and used sophisticated navigational methods allowing long distance voyages (Badger 1974). Bamboo was one of the many plants carried by them for planting in the new lands. Bamboo culms were used in the construction of their sea craft, and in many different ways during sea voyages (Holmes, 1983).

This paper reviews the important roles of bamboo in Polynesian voyaging. Discussion is divided into three areas. The initial step considers the distribution and the anatomical, morphological, and physical aspects of four bamboo genera that were commonly used in the construction of outrigger canoes and rafts. Secondly, a comparative study is made to correlate the employment of bamboo in the ancient outrigger canoes of Mandar, the Society Islands, Marquesas, and Hawai'i. Thirdly, ethnomedicinal, navigational and other voyage-related uses of bamboo are explored. The study will attempt to answer the following questions: Was bamboo persistently used as building material for Polynesian outrigger canoes as they disseminated throughout the Pacific? Was the bamboo raft a popular sea craft in Polynesia? How extensive was the usage of bamboo during their sea voyages?

The Four Bamboo Genera

In mountainous areas of the Celebes Islands of Indonesia where the temperatures ranges between 72-86°F, and the annual rainfall is about 80 inches, bamboo grows very rapidly. The culms can grow as much as 47.6 inches in a 24 hour period.

The giant bamboo *Gigantochloa* reaches a state of maturity within three growing seasons, by which time its fiber cell wall around the periphery of the culm wall has completely thickened and lignified. In addition, polylamellation of fiber walls has taken place around the circumference of the fiber bundles. The well-developed fiber cells influence the ability of the culm to resist compression, bending, tensile stress, thermal expansion, and elasticity (Murphy and Alvin, 1996).

There are over 60 native bamboos (Poaceae subfamily Bambusoideae, tribe Bambuseae) in Indonesia. Four bamboo genera (*Bambusa*, *Dendrocalamus*, *Gigantochloa*, and *Schizostachyum*) have always been popular commodities used as construction materials for outrigger canoes and rafts (Piper 1992).

Bambusa (subtribe Bambusinae)

Bambusa reaches 60 feet in height and 4 inches in diameter, with a moderately thick-walled culm. Having a sympodial rhizome, it produces upright dense clumps of culms (Wong 1995). It flowers once in 20 to 60 years, and then dies (gregarious flowering habit). *Bambusa blumeana* is commonly used for masts, outrigger floats, and rafts in Indonesia. *Bambusa vulgaris* is also used for outrigger floats despite being relatively susceptible to beetle attack due to its high starch content (Sharma 1980). Wallis reported in 1767 seeing rafts made of *Bambusa* in the Society Islands (Barrau 1971). (Fig. 1).

Dendrocalamus (subtribe Bambusinae)

Dendrocalamus is distributed largely in the Moluccas Islands of Indonesia. Species grow up to 100 feet tall from a pachymorph rhizome. It has a very thick-walled culm, 10 inches in diameter, and a gregarious flowering habit (Dransfield 1980). *Dendrocalamus giganteus* has been know to have the largest culm among bamboos. It was split longitudinally into halves to make a two-man craft (Piper 1992). *Dendrocalamus brandisi* is also utilized for masts (Sharma 1980). (Fig. 2)

Gigantochloa (subtribe Bambusinae)

Gigantochloa is distributed throughout Thailand, Malaysia, and Indonesia. Its dense culms grow from pachymorph rhizomes, and reach up to 65 feet tall and 8 inches in diameter. Dransfield (1980) states that sometimes all the culms of one or more clumps produce flowers, but it is not known whether all these clumps would die after flowering or only the culms that produce flowers. It has a relatively thick-walled culm and is very durable. *Gigantochloa maxima* was split longitudinally into halves for making small canoes (Farrelly 1984). *Gigantochloa levis* is used for masts in Indonesia (Sharma 1980). (Fig. 3).

Schizostachyum (Subtribe Melocanninae)

The center of distribution of *Schizostachyum* is Southeast Asia. The slender culms, 2-3 inches diameter, grows from a pachymorph rhizome up to 40 feet tall. Flowers are produced year round. This genus has a very think walled culm, is light weight, and durable. *Schizostachyum zollingeri* is made into rafts in the Celebes Islands (Dransfield 1980). *Schizostachyum glaucifolium* grows throughout the islands of the Pacific (Ohrnberger and Goerrings 1984). Handy reported in 1932 the traditional use of this species for rafts in the Society Islands, while Porter cited in 1822 its similar use in the Marquesas (Barrau 1971). (Fig. 4).

Bamboo as Material for Sea Craft

A long curved section of a bamboo culm containing two nodes is depicted in an ancient Chinese pictogram to denote the Chinese word for "boat." The pictogram suggests a bamboo raft, which was probably the earliest water craft in East Asia (Farrelly 1984).

Equipped with a sail, a much stronger raft was refined in Southeast Asia. It was used to transport timber and other goods across the ocean (Piper 1992). In the Society Islands, bamboo rafts loaded with coral blocks were towed between islands (Haddon and Hornell 1975).

Bamboo was instrumental in the making of outrigger canoes. Attached to a narrow, unstable craft, the outrigger prevents a tiny canoe from capsizing. Piper (1992) claims that a hollow, straight and light-weight bamboo pole floats on the ocean more effectively than an outrigger made of solid wood. Masrury et al. (1996) note the high resistance of bamboo floats to absorptions of seawater. Futhermore, due to its strength, elasticity and durability, bamboo is favored for

Fig. 1. *Bambusa vulgaris* Schrader ex Wendland. Culm sheath and inflorescence.

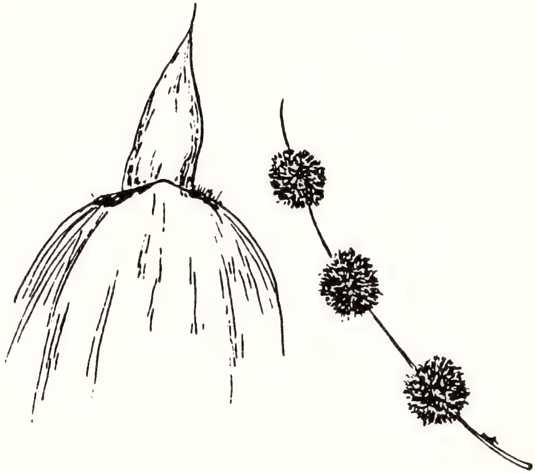

Fig. 2. *Dendrocalamus giganteus* Munro. Culm sheath and inflorescence.

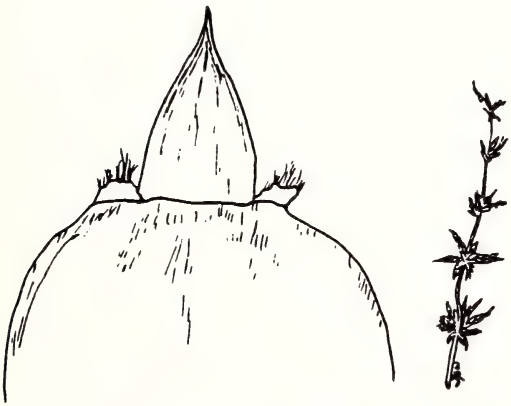

Fig. 3. *Gigantochloa levis* Merrill. Culm sheath and inflorescence.

Fig. 4. *Schizostachyum glaucifolium* Munro. Culm sheath and inflorescence.

masts and booms.

For thousands of years the Malayo-Polynesian seafarers, such as the Mandarese, the Makassarese, and the Madurese, had perfected boat-making techniques. Their boom-lashing technique and their types of rudders and rigs became a prototype for later Polynesian styles (Horridge 1986). Early Oceanic migration presupposes a slow diffusion of Malayo-Polynesians carried by small outrigger canoes eastward through the Malacca Straits (Goldman 1970). Although not as effective, large-sailed bamboo rafts would also have been able to carry them abroad (Horridge 1987).

Outrigger Canoes in Mandar. The Mandarese occupy many small islands in the Java sea, the Straits of Makassar, and the southwestern Celebes Islands. Their fishing boats are known as "*Sande*" (meaning "pointed" or "sharp"). These craft are fast double outrigger canoes that are also used for interisland transportation. The dugout hull is about 33 feet long with vertical sides 3 feet deep, and an upturned prow of additional 3 feet. A single triangular sail is attached to a 60 foot tall bamboo mast. A bamboo boom is attached to the mast (Horridge 1981).

A long, straight bamboo culm is used as a float on both outriggers. The culm protrudes 3 feet beyond the stern and 1.5 feet beyond the prow. The hollow forward and aft sections of the float are fitted with plugs of jack fruit would (*Artocarpus heterophyllus*).

A series of religious ceremonies are performed by a priest from the time the log is selected, through the process of canoe building, and its launching into the sea (Masrury et al. 1996). This ceremonial aspect of canoe building is to be seen all through Polynesia.

Outrigger Canoes in the Society Islands. The Society Islands are located in central East Polynesia. Having a moderate rainfall at sea level, precipitation increases rapidly at higher altitudes on the windward sides of the high islands, allowing dense patches of bamboo groves of the genus *Bambusa* and *Schizostachyum* (Mueller-Dombois and Fosberg 1998).

Here ancient single outrigger canoes were made of breadfruit wood (*Artocarpus incisus*). A washstrake in the form of a plank about 13 inches wide was sewn vertically upon the edges of the dugout hull. With a sail, this canoe traveled far beyond the sight of land to other islands (Best 1977).

Bamboo was employed for the sail boom, to which a sprit was lashed. A hollow bamboo culm was affixed to the hull and used as a base for securing the upper portion of the mast.

Two slightly-curved outrigger booms were attached to a long cylindrical float. The fore end of the float extends much farther beyond the fore boom. Haddon and Hornell (1975) report that no bamboo was utilized as outrigger float material in Polynesia.

Outrigger Canoes in the Marquesas Islands. Located at the northeastern edge of Eastern Polynesia, the Marquesas Islands have a mesic tropical climate. The high islands are incised by deep valleys that run right down to high sea cliffs, giving no coastal plains. Whistler (1991) reports that only small patches of *Schizostachyum glaucifolium* are found in the generally wet uplands.

Haddon and Hornell (1975) describe a 40 foot long single outrigger canoe of the marquesas. The hull was formed of a dugout underbody to which ornamental bow and stern pieces were attached. About 12 to 18-inch deep washstrakes were furnished with a narrow flange projecting outward along its upper edge, forming a narrow gunwale. Long pads of rough sennit were placed within the seam between the underbody, the washstrakes, and the end pieces of the hull. The joints were then protected by narrow covering strips of bamboo sewn over them on both inner and outer sides of the canoe.

The outrigger booms appear to have been either curved or straight. The end section of the booms were connected with stanchions to the float. One or both ends of the float were pointed.

The Marquesan rig was triangular in shape with the apex in a downward position. It was attached to a short movable mast, almost identical to that used in Hawai'i.

Outrigger Canoes in Hawai'i. The Hawaiian Islands are the most isolated archipelago in the world. The nearest archipelago of high islands are the Marquesas, about 3,350 km away. Emory (1963) states that the earliest Hawaiian settlers came from the Marquesas. A later influx of

Polynesian migrants arrived from the Society Islands around the twelfth century.

Admiral F. E. Paris reported that bamboo was very rare in Hawai'i during his visit in 1839 (Haddon and Hornell 1975). Due to its durability and strength, *koa* (*Acacia koa*) was favored for hulls. Its ideal density for canoes was between 40-60 pounds per cubic foot (Holmes 1983). Breadfruit wood was selected for washstrakes. The curved outrigger booms made from *'ohi'a lehua* (*Metrosideros polymorpha*) were polished and octagonal in cross section (Haddon and Hornell 1975). Wood from *wiliwili* (*Erythrina sandwicensis*) was preferred for floats (Banack 1991).

Various Uses of Bamboo During Sea Voyages

The importance of bamboo in Polynesian voyaging surpasses that of any other plant. Not only were young shoots of bamboo dried or made into sweets for consumption, but the culms were used for storing food and water. Banack (1991) reports that the culm was made into an aquarium to keep freshly caught fish and shell fish on board. The culm was also utilized as a cooking container, fire blower, canoe bailer, and torch, and was also burned for charcoal.

To supplement food supplies, fish were caught using implements made of bamboo such as fishing rods, fish traps, fishing nets, spears, net floats, net shuttles, cordage, and anchors. The sharp, freshly split edge of bamboo stems were used as knives (Piper 1992).

In an emergency situation, the ashes of *Schizostachyum glaucifolium* leaves were mixed with coconut oil and rubbed onto burns (Whistler 1992). Bamboo nodes were boiled to make medicine for chest pain and urino-genital disorders. The shoot or the rhizome was boiled to be used for kidney trouble. The oil and silicaceous materials (*tabashir*) found in bamboo stems have curative properties. An egg was cooked slowly in the culm to absorb these essential substances and eaten as a tonic to cure asthma. *Bambusa vulgaris* cv. *vittata* was believed to cure jaundice (Piper 1992).

Also of great importance was a navigational device called "*mattang*" (stick chart)—a web of bamboo strips representing possible wave patterns. Using the *mattang*, along with other visual, astronomical, and sensory information, a skilled navigator could deduce his position. These navigational tools were developed into a highly refined science-art by the Malayo-Polynesian migrants some three thousand years ago in the course of colonizing the islands across the Pacific (Davenport 1960; Farrelly 1984).

Not to be overlooked is the spiritual importance of bamboo as one of the primary plant manifestations of the major male deity, Kane, the god of procreation (Johnson 1981).

Conclusions

Bambusa, *Dendrocalamus*, and *Giganto-chloa* are superior in quality and always near at hand in the Celebes Islands. Therefore, their employment for mats, sail booms, and outrigger floats is favored by the Mandares canoe builders. However, their gregarious flowering characteristic and sensitivity to drying during transport prevented them from being successfully propagated in the new lands in the Pacific.

Schizostachyum glaucifolium was distributerd throughout the Society Islands, the Marquesas, and Hawai'i due to its readily available seeds. However, its slender, thin-walled culms were only suitable for raft-making.

Although bamboo was not employed in the construction of Hawaiian outrigger canoes, it had great importance as a symbol of the godу of the god Kane—the procreator and provider of fresh water, sunlight, and life subtances in nature.

Schizostachyum glaucifolium remained highly important as a medicine and for making various implements used during Polynesian voyages. This ancient ethnobotanical knowledge clearly demonstrates strong cultural links between the Polynesians and their predecessors in Southeast Asia.

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Literature Cited

Badger, G. 1774. The Explorers of the Pacific. Kangaroo Press.

Banack, S. A. 1991. Plants and Polynesian Voyaging. *In* Islands, Plants, and Polynesians—An Introduction to Polynesian Ethnobotany (P. A. Cox and S. A. Banack, eds.) Proceedings of a symposium, Brigham Young University, Hawaii.

Barrau, J. 1971. Useful Plants of Tahiti. Societe des Oceanistes, Paris.

Best, E. 1977. The Maori Canoe and Polynesian Voyagers. AMS press Inc. New York, NY.

Davenport, W. W. 1960. Marshal Islands Navigational Charts. The Bobbs-Merrill Company Inc., Indianapolis.

Emory, K. P. 1963. East Polynesian relationship. J. Polynsian Soc. 72: 78-100.

Farrelly, D. 1984. The Book of Bamboo. Sierra Club Books, San Francisco.

Goldman, I. 1970. Ancient Polyniesian Society. The University of Chicago Press, Chicago.

Haddon, A. C. and J. Hornell. 1975. Canoes of Oceania. Bernice P. Bishop Museum Special Publications 27, 28, 29. Bishop Museum Press, Honolulu.

Holmes, T. 1981. The Hawaiian Canoe. Editions Limited, Kauai.

Horridge, A. 1981. The Prahu-Traditional Sailing Boat of Indonesia. Oxford University Press, Oxford.

Horridge, A. 1986. Sailing Craft of Indonesia. Oxford University Press Tte. Ltd., Singapore.

Horridge, A. 1987. Outrigger Canoes of Bali and Madura, Indonesia. Bishop Museum Special Publication 77. Bishop Museum Press, Honolulu.

Irwin, G. 1992. The Prehistoric Exploration and Colonization of the Pacific. Cambridge University Press.

Johnson, R. K. 1981. Kumulipo—The Hawaiian Hymn of Creation. Vol. 1. Topgallant Publishing Co., Ltd., Honolulu.

Masrury, M., St. Arifah, and Hariyani. 1996. Sande—Perahu Khas Daerah Mandar. Bagian Proyek Pembinaan Permuseuman, Sulawesi Selatan.

Mueller-Dombois, D. and F. R. Fosberg. 1998. Vegetation of the Tropical Pacific Islands. Springer-Verlag, New York.

Murphy, R. J. and K. L. Alvin. 1996. Fibre maturation in bamboos. *In* The Bamboos (G. P. Chapman, ed.) Linnean Society Symposium Series no. 19. Academic Press, London.

Ohrnberger, D. and J. Goerrings. 1984. The bamboos of the World—Genus *Schizostachyum*. Odenthal, Federal Republic of Germany.

Piper, J. M. 1992. Bamboo and Rattan—Traditional Uses and Beliefs. Oxford University Press, Inc., New York.

Sharma, Y. M. L. 1980. Bamboo in the Asia-Pacific region. *In* Bamboo Research in Asia (G. Lessard and A. Chovinard, eds.) Proceedings of a Workshop held in Singapore.

Sutton, D. G. 1994. The Origins of the First New Zealanders. Auckland University Press.

Whistler, W. A. 1991. Polynesian Plant Introductions. *In* Islands, Plants, and Polynesians—An Introduction to Polynesian Ethnobotany (P. A. Cox and S. A. Banack, eds.) Proceedings of a symposium, Brigham Young University, Hawaii.

Wong, K. M. 1995. The Bamboos of Meninsular Malaysia. Forest Research Institute, Malaysia.

This paper was presented in the VIth International Congress of Ethnobiology, Whakatane, New Zealand, November 23-28, 1998.

Minutes of the Hawaiian Botanical Society

December Meeting

• The December 7 meeting of the Hawaiian Botanical Society was called to order by the President.

• Minutes of the November 2, 1998 meetings were approved as read.

• No guests were announced.

• **Treasurer's Report.** Ron Fenstemacher reported that the ending balance in our account was $4330.00. The report was read and approved.

• **Committee Reports**

  • The conservation Committee announced that it needed more members.

• **Old Business**

  • A letter written to the manager of Wal Mart to ask them to stop selling *Sphaeropteris cooperi* on the Big Island was read. Discussion ensued. Membership approved the letter.

• **New Business**

  • A letter was read in support of the reappointment of Mike Wilson as the head of the DLNR for the membership to approve. Supportive comments from the membership were heard, and a letter in favor of his reappointment was approved by the membership.

  • A field trip was announced, but there was limited space and the trip was already full.

• **Plant of the Month** was "Kokia cookei, *saving Hawai'i's Rarest Plant*" by Winston Morton, Office of Hawaiian Affairs Ho Olu Mea Kanu Project.

• **Guest Speaker.** The speakers for December were Jane N. Gemma and Richard E. Koske, Dept. of Biological Science, University of Rhode Island. Their talk was entitled "*Mycorrhizae in Endemic Hawaiian Plants: Implications for Cultivation and Habitat Restoration.*"

January Meeting

• The January 11 meeting of the Hawaiian Botanical Society was called to order by Leilani Durand, President.

• No guests were introduced.

• The minutes of the December 7th meeting were read and approved.

• **Treasurer's Report.** Ron Fenstemacher reported that the ending balance in our account was $9654.14. The report was read and approved.

• **Membership report.** The membership report stated that *HBS* had 2 new life members.

• **Old Business**

  • A letter was sent to the Governer regarding the reappointment of Mike Wilson as the head of the DLNR.

• **New Business**

  • Betsy Gagne of the DLNR announced that the state botanist had retired.

  • A Hawaiian native plant sale at Wally's Garden shop was announced.

  • An announcement about a botanical excursion to Australia was made inviting people to join.

• **Plant of the Month** speaker was our treasurer, Ron Fenstemacher, his talk was entitled, "*Rediscovered Extinct Plants:* Cyanea/Rollandia purpurellifolia *and* Lobelia monostachya."

• **Guest Speaker.** The speaker for January was Dr. Allison Kay of the University of Hawai'i, Department of Zoology. Her talk was entitled "*Early Naturalists in Hawai'i - What Darwin Didn't Know.*"

February Meeting

• The February 1, 1999 meeting of the Hawaiian Botanical Society was called to order by President Leilani Durand.

• The minutes of the January 11th meeting were approved as read.

• All guests were welcomed.

• **Membership Report**: The membership report stated that there were 232 current members that inclued 1 new member and 19 renewals.

• **Treasurer's Report**: Ron Fenstemacher read the treasurer's report stating that the ending balance was $3756.13.

• **Old Business**

• Earth Justice Legal Fund won the lawsuit against U.S. Fish and Wildlife thereby enabling the designation of areas as critical habitats to protect endangered plants.

• **New Business**

• The Hawaiian Botanical Society received 3 letters by an anonymous person on the Big island. These letters are to urge the Hawaii State Capitol to include funds for *Miconia* control in Department of Land and Natural Resources budget for 1999.

• An announcement was made about a talk to be held at the McCoy Pavilion on February 10 by NTBG's president, Dr Paul Cox.

• **Plant of the Month** was *Bidens asymmetrica* by our Vice-President, Alvin Yoshinaga.

• **Guest Speakers:** Our guest speakers were nature photographers David Littschwager and Susan Middleton. Their slide show was entitled: "*America's Endangered Species: Don't Say Goodbye*" with a special focus on Hawaii.

March Meeting

• The March 1, 1999 meeting of the Hawaiian Botanical Society was called to order by Leilani Durand, President.

• The minutes of the February 1st meeting were approved as read.

• No new guests were announced.

• **Membership Report:** The membership report stated that there were 233 members that included 5 renewals.

• **Treasurer's Report:** Ron Fenstemacher read the treasurer's report stating that the ending balance was $3817.52.

• **Old Business**

• The letter from an anonymous person on the Big Island urging the Hawaii State Capitol to include funds for Miconia control in DLNR's budget for 1999 was read. A motion was made and approved to forward this letter from the Hawaiian Botanical Society to the state Senate.

• **New Business:**

• Suggestions were invited on how to celebrate the Hawaiian Botanical Society's 75th anniversary.

• The trail side plant protection program was discussed to flag plants that should not be cut down and to form a group that could do the flagging and later remove it.

• Summary of a letter from the Invasive Exotic Species Program to *HBS* was presented. This letter requests *HBS* to endorse a letter to Vice President Al Gore to ensure that the Department of Agriculture has sufficient flexibility under international trade rules to adopt phytosanitary measures that are as effective as possible to prevent the entry of alien organisms into Unites States.

• An announcement was made to sign up for the field trip to Mt. Ka'ala on March 27th.

• **Plant of the Month** was *'ilima, Sida fallax*, and was presented by given by Michelle Stephens of the Department of Botany, University of Hawai'i.

• **Guest Speaker:** The guest speaker was Dr S. H. Sohmer. His talk was entitled "*Building a Botanical Institute from the Ground up: The Botanical Research Institute of Texas (BRIT).*"

April Meeting

• The April 5, 1999 meeting of the Hawaiian Botanical Society was brought to order by President Leilani Durand.

• No new guests were announced.

• The minutes of the March 1st meeting were approved as read.

• **Membership report** was not presented.

• **Treasurer's report:** Ron Fenstemacher read the treasurer's report stating that the ending balance was $4259.96

• **Committee Reports:**

• Vickie Caraway outlined the program for the celebration of the Hawaiian Botanical Society's 75th anniversary to be held on May 8th. Motion was made and approved to spend $400 towards celebration expences.

• The Science fair committee announced that the 42nd State Science fair was conducted from March 29 to April 1 and three prizes were awarded.

• **Old Business**

• The *Miconia* letters were sent out and no reply has been received as yet.

• Earth Justice Legal Fund sent a follow up letter to the USFWS regarding support of critical habitat designation.

• The letter to Al Gore about preventing the entry of alein organisms into United States was sent.

• **New Business**

• Conservation Council for Hawaii requested *HBS* to contribute funds for the Earth Day poster. A motion was made and approved to contribute $300 towards the printing of this poster.

• An announcement was made about the display of Kapa in the East West Center.

• Trail side plant protection committee announced that the group was going to be in the field on May 8 in an effort to flag the plants.

• Betsy Gagne announced that there would a talk by Rebecca Randell and Elizabeth Stampe at DLNR.

• **Plant of the Month** talk was given by Mick Castillo of the U. S. Fish and Wildlife Service on the "*Big Island Tetramolopiums*".

• **Guest Speaker**: The guest speaker was Dr. Charles Lamourex, Director of the Lyon Arboretum, University of Hawaii. His talk was entitled "*A Botanical Safari to South Africa*".

Erratum

The announcement of the Hawaiian Botanical Society Awardees at the 41st Hawaii State Science and Engineering Fair in the last issue of the *Newsletter of the Hawaiian Botanical Society* (vol. 37 no.3: p. 50) erroneously mentioned that the event was held at the Neal Blaisdale Exhibition Center. No text was given with the list of recipients and the editor, with no malicious intent, misspelled Neal Blaisdell in a paragraph prepared to state when and where the event took place. The event was therefore held at the Neal Blaisdell Exhibition Center.

As many of you know, Neil Blaisdell was an important civic leader in Honolulu for many years and served as Mayor of the City and County of Honolulu from January 1955 through December 1968.

No disrespect was intended to the family and friends of our past Mayor by this misprint, and certainly this should not be a reflection of the outstanding work that the Science Fair Committee (chaired by Karen Shigematsu and assisted by Winona Char) does each year in evaluating the numerous projects present at the HSSEF.

Announcement

Specialists Discuss the Future of Botanical Information at the IBC

During the final symposium session of the XVI International Botanical Congress in St. Louis on Saturday, 7 August 1999, a group of botanists, librarians and archivists will speak about the critical need to preserve the record of botanical science, both past and present. The symposium is sponsored by the Council on Botanical and Horticultural Libraries (CBHL), and co-sponsored by the Historical Section of the Botanical Society of America.

If you are reading this article, it is in a journal considered important for botanists and other users of botanical information. Such information in all of its forms is often taken for granted. The symposium will address the provision and preservation of the literature and information on which botanists depend and to which they and others may expect to have indefinite access.

The complex issues involved in the preservation of the past and ongoing record of botanical science cannot be resolved by librarians and archivists alone, so this symposium is seen as a timely way to bring these issues to botanists, particularly now that the current botanical record is moving towards electronic formats. The problem of an endangered botanical documentary record is global and pressing, but fortunately changes in communications technology can make collaborative and coordinated efforts increasingly more feasible.

Speakers will address such issues as the changing documentary record of botany; the increasing use of electronic information; the need for botanical documentation; and the physical limitations of books, artwork, manuscripts, maps, computer files, and other materials found in botanical libraries and archives. They will view availability and access, both in the short term and in the future. They will also discuss large-scale preservation strategies that have been recently pursued in several other scientific disciplines, so that botanists can assess the suitability of such strategies for the plant sciences.

Botany as a discipline has less than 400 years of publishing to call upon, although the study of plants dates back to ancient times. Modern paper unfortunately does not last very long, and neither do digital documents or the technologies that produce them. Unless something is begun to counter their inevitable deterioration and obsolescence, with the resulting lost of information, the work that botanists do will itself become endangered. If we look ahead 100 years, what will be left of the botanical record? What should be left? Clearly not everything needs to be preserved, but how do we determine what does need to be safeguarded for future use, and how do we ensure its preservation?

Following the symposium the papers will be published, and a future meeting may be convened so that the matters raised can be given a fuller analysis in all botanical disciplines. Such analysis could lead to development of a global preservation strategy for botanical literature and information. The scale of these matters is daunting, as considerable expertise and resources will be required to begin to address the overall need for preservation and continuing access to what is so easily taken for granted today.

Please support this initiative to help set a new course in botanical history by preserving its accomplishments for the future. Delegates to the IBC are urged to consider attending these talks. Further information is available at <http://huntbot.andrew.cmu.edu/CBHL/symposium.html>, or by contacting Malcolm Beasely <M.Beasely@nhm.ac.uk>, telephone +44 (0) 171 938 8928 (England), or Charlotte Tancin <ct0u@andrew.cmu.edu>, telephone 412-268-7301 (U.S.).