NRL Report 5673

NATURAL RESISTANCE OF WOODS TO BIOLOGICAL DETERIORATION IN TROPICAL ENVIRONMENTS

PART 1- SCREENING TESTS OF A LARGE NUMBER OF WOOD SPECIES

C.R. Southwell, C.W. Hummer, Jr.,
B.W. Forgeson, T.R. Price,
T.R. Sweeney, and A.L. Alexander

Organic and Biological Chemistry Branch
Chemistry Division

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1. Figure 11, reproduced below, is issued to replace Fig. 11 which now appears on page 19 of NRL Report 5673.

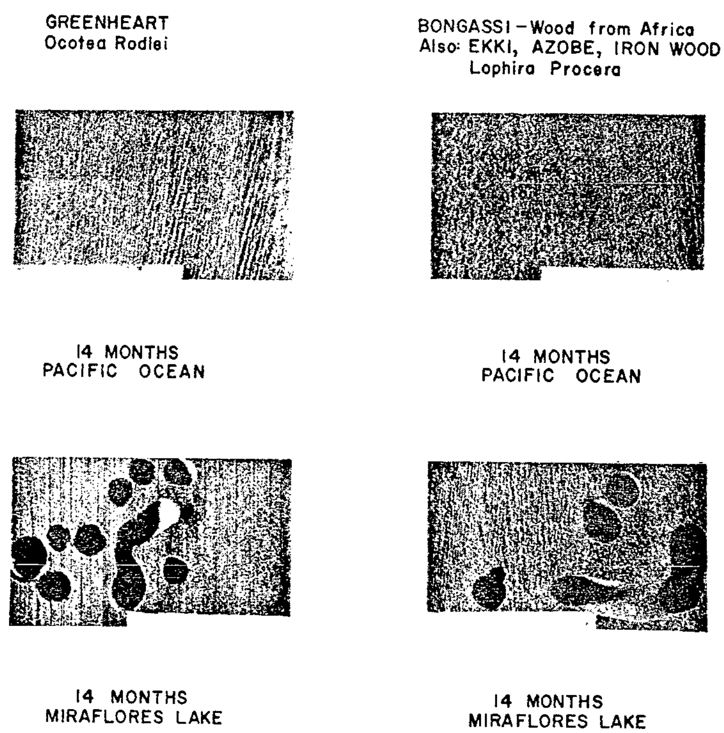

Fig. 11 - Cross sections of exposed samples (14 months) of two well known resistant wood species showing the more destructive effects from brackish water borers

M. E. Jansson
M. E. JANSSON
By direction

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ABSTRACT

In four different tropical environments, heavily infested with wood-destroying organisms, 114 species of scientifically identified woods have been undergoing a screening test for periods up to an 18-month exposure. Many of the woods were selected because of their reputed resistance to biological attack.

Results of marine borer resistance studies have revealed 21 woods to be highly resistant to borers in Pacific Ocean water for the first 14 months of exposure. In tropical brackish water only 3 woods studied were highly resistant and very heavy damage was observed on 69 during the 14-month period.

Stake tests in tropical jungle soil on both the Atlantic and Pacific Coasts of Panama showed 26 woods to be very durable to both subterranean termites and fungal decay for the first 18 months of exposure. A number of these resistant woods had not been studied previously.

From the results of these studies, each wood included has been assigned resistance ratings of high, moderate, or low in respect to marine borer attack in sea water, teredo attack in brackish water, subterranean termites in tropical soil, and fungal decay in contact with jungle soil. Detailed descriptions of wood species which are considered to be of special interest are included.

PROBLEM STATUS

This is an interim report; work on this problem is continuing.

AUTHORIZATION

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NATURAL RESISTANCE OF WOODS TO BIOLOGICAL DETERIORATION IN TROPICAL ENVIRONMENTS

PART 1 - SCREENING TESTS OF A LARGE NUMBER OF WOOD SPECIES

PREFACE

The destruction of wooden structures by marine borers always has been a serious and almost insolvable problem in temperate and tropical seas. Inland too, especially in tropical regions, wood is subject to the ravages of biological attack; here the many varieties of fungi in the soil and air cause extensive damage in the form of decay, and subterranean termites cause even more rapid and wide-spread destruction when they invade wooden structures. Chemical treatments are sometimes used to mitigate these biological attacks on wood. Such preventive measures as pressure treatment with coal tar creosote or with other preservatives in oil or water solutions, fungicidal dips and paints, and soil poisoning have been effective, albeit expensive.

The Panama Canal Company and other U.S. Government Agencies in the Canal Zone use a large volume of timber annually. Much of the timber imported from the United States has low resistance to biological attack unless treated, and even then it is sometimes unsatisfactory, especially in waterfront structures. An example of deterioration of treated timbers in Canal Zone waters can be seen in Fig. 1.

Many of the timbers growing in Panama are reputed to have resistance to one or more forms of biological attack, but the lack of specific knowledge of their suitability, coupled with difficulty in identifying species, has led to many costly misapplications. Therefore, the Panama Canal Company decided that an investigation of some of these woods should be undertaken to establish their relative resistance to biological attack in tropical environments. The Canal Zone Corrosion Laboratory, operated by the U.S. Naval Research Laboratory, has various exposure sites in the Canal Zone area and is engaged in studies of deterioration of construction materials in the tropics. This Laboratory was the logical choice to carry out this study and was requested to undertake the program. The U.S. Naval Research Laboratory, cognizant of the value of the information sought, especially if resistant species were found that could be analyzed for their source of resistance, agreed to conduct the investigation at the Corrosion Laboratory.

Initially the Panama Canal Company requested only a study of marine borer resistance of the various woods; this was and still is the major purpose of the investigation. But as the work of procurement progressed and the collection of scientifically identified wood species contained to grow in magnitude and value, with an increasingly large number of previously untested species included, the research potential reached a point where it became obviously desirable to obtain all the usable information possible from this collection of wood samples. Consequently the Naval Research Laboratory scientists in conference with the Office of Naval Research decided to expand the program to include above- and below-ground termite and decay resistance studies on all the woods, and to include for evaluation and comparison a number of standard and newly developed wood treatments. Normally 42 separate samples were exposed throughout the five exposure sites for each species represented. The entire program, with the numerous controls, included the exposure and evaluation of more than 5000 separate pieces.

Fig. 1 - Examples of marine borer damage to wooden structures in Canal Zone waters. Creosoted piling, Balboa Harbor of the Pacific entrance of Panama Canal, low tide view.

PROCUREMENT OF SAMPLES

The tropical rain forests of the world contain a countless variety of trees, a great number of which yield durable timbers unmatched by most of those found in the temperate zones. Many of these fine woods are known only in very restricted localities and some still may be botanically unclassified. In Panama, where the North and South American species meet and mingle and where the Atlantic and Pacific watershed forests merge, there probably is a greater number of species present than in any comparable area in the world. According to native lore, old Indian tales, and the experience of local builders and lumber dealers, some of the tropical woods available in Panama have inherent natural resistance to one or more of the wood-destroying organisms. Scientific investigations (1-3) have demonstrated that this is indeed the case for at least a few of them.

The original plan was to investigate only those woods which were well known and suitable for structural purposes, or any that had a reputation for natural durability. However, in discussions with operators of lumber companies and sawmills, boatbuilders, and backwoods lumbermen, many more species were suggested to be potentially as useful and plentiful as those presently on the market. As collection of specimens progressed, the number of species included was practically tripled over the original list of about 40 until finally 114 species native to Panama and 10 imported from other parts of the world were included. The imported woods were from Africa, Asia, and North and South America, most of them being of known high resistance to biological attack. Southern pine, a relatively nonresistant species, was included as a control to evaluate the distribution and intensity of attack in the exposure areas. A complete list of the scientific and common names of the species included in the investigation is given in Appendix B.

Some of the woods in the study had been evaluated previously for marine borer resistance in other waters, e.g., Edmondson's studies in Hawaii (1), tests by the Yale School of Forestry (4), and tests by Clapp Laboratories at Duxbury, Mass. (3). Five species endemic to Panama had been studied in Canal Zone waters by Zetek (2). For most of the woods on which some reliable scientific information was available, samples from only one tree were included in this investigation. For each species that had not been investigated previously, samples were taken from two trees whenever possible.

Woods were obtained from many sources. The lumber dealers of Panama donated many of the samples. The Panama Canal Company Storehouse, Locks, and Industrial Divisions were other sources of commercially available timbers. The local boatyard operators were very helpful in suggesting species and donating samples for the program. When all these sources of supply had been exhausted, the U.S. Naval Research Laboratory used its own forces and equipment in the field to select and cut trees needed for the program. Expeditions were organized to go as far as the Colombian and Costa Rican borders to obtain as many of the suitable timbers from these wilderness areas as possible.

IDENTIFICATION OF WOOD SPECIES

It was realized from the start that positive scientific identification of genera and species of the woods included was a necessity, and unless this could be accomplished the studies should not be carried out. The woods were identified either by the examination of herbarium material or by study of the anatomy of the wood and comparison with previously classified material. The identifications based on herbarium materials were the more positive and were used whenever possible. Dr. W.L. Stern and Dr. K.L. Chambers of the Yale School of Forestry, under the auspices of the Office of Naval Research, made a field trip to Panama, and in company with a representative of the Naval Research Laboratory traveled to all parts of the country and personally collected herbarium and wood samples for many of the species studied. The majority of the wood identifications were made by Stern et al. (5,6) at Yale University. Most of the woods for which no herbarium material was available were relatively well known and were readily matched to previously identified specimens in the Yale collection. In some instances, however, all identification efforts were unsuccessful, and Appendix B includes several woods for which only the genus could be determined and four for which no identification could be made. Where these unidentified woods have been found to possess good natural resistance, additional efforts are being made to determine the correct scientific classification.

In the course of the identification work, one new species of tree was discovered by Stern and Chambers and the description added to the botanical literature (7). This tree has been named *Paramachaerium gruberi* and is known as sangrillo negro in the Puerto Armuelles area of Panama, where it is esteemed as a durable heavy construction timber. Several other species were reported from Panama for the first time.

EXPOSURE SITES

Marine borer studies were conducted at two locations in the Canal Zone, one in the Pacific Ocean and the other in Miraflores Lake. The ocean samples were suspended from the Naval Research Laboratory's test pier on the Fort Amador causeway about 1-1/2 miles out from the natural shoreline, shown in Fig. 2a. In Miraflores Lake the samples were hung from a floating lock gate anchored approximately in the center of the lake, shown in Fig. 2b.

The Fort Amador site is a normal open tropical ocean water exposure with chloride concentration of the water approximately 17,000 parts per million. The incidence of teredo activity at this location for the five years prior to start of this study has been rated as very heavy by Clapp Laboratories (8). The Limnoria activity, however, was reported to be only moderate compared to other locations in the world.

Miraflóres Lake is about one square mile in area and is located on the Pacific side of the canal between the second and third Pacific side Locks. The average elevation of the lake is 58 feet above sea level. The water is brackish (approximately one-fiftieth the salinity of sea water), and the salinity varies with the season, rainfall, and number of lockages in the canal. Salinity at this site is reported for various seasons of the year during the exposure period in Table 1. The Locks Division of the Panama Canal Company has reported intense teredo activity in this lake, causing some of the most costly damage suffered locally from these organisms. Limnoria have not been reported in this brackish water.

Samples intended for exposure to fungus and termite attack were placed at three jungle locations. One is sheltered from sunlight and rainfall and is on the Atlantic side of the Isthmus at Fort Sherman (Fig. 2e), another is in an unsheltered jungle area near Galeta Point, also on the Atlantic side of the Isthmus (Fig. 2d), and the third is in an unsheltered area on the Pacific side of the Isthmus at Fort Clayton in the Albrook Field Fuel Annex (Fig. 2c). Climatic conditions relative to these exposure sites are shown in Fig. 3.

TEST PROCEDURES

The investigation was set up as a two-part program. In the first part it was planned to screen a large number of species by short term exposure to eliminate all those that were nonresistant; in the second part it is planned to continue long term studies on all species that possess above average durability, and finally to select the best of these for testing as large specimens in and near the areas of proposed commercial use in the Canal Zone. The first part is the subject of this report.

Samples exposed at the Fort Amador and Miraflores Lake sites were 1-1/2 × 3 × 18 inches. At Fort Amador all of the specimens were exposed at a depth of 3 to 5 ft below mean low tide. Each rack contained 32 samples, two of which were untreated southern pine controls. Figure 4 shows a rack of samples being lowered into the water from the Fort Amador pier. At Miraflores Lake the specimens were hung from a floating platform, the top specimen on the rack being 8 ft. below the surface and the bottom specimen 12 ft below the surface. Each lake rack contained 10 samples plus one untreated southern pine control. The exposure elevations selected had proved to be the areas of heaviest marine borer attack during pilot tests conducted at each of the locations. The variation of incidence of attack with water depth for Fort Amador can be seen in Fig. 5. Four replicates from each log of each species were distributed throughout the exposure areas. However, when samples from two different trees of the same species were available, they were exposed in adjacent positions on the same rack to determine whether significant variations existed between trees of the same species.

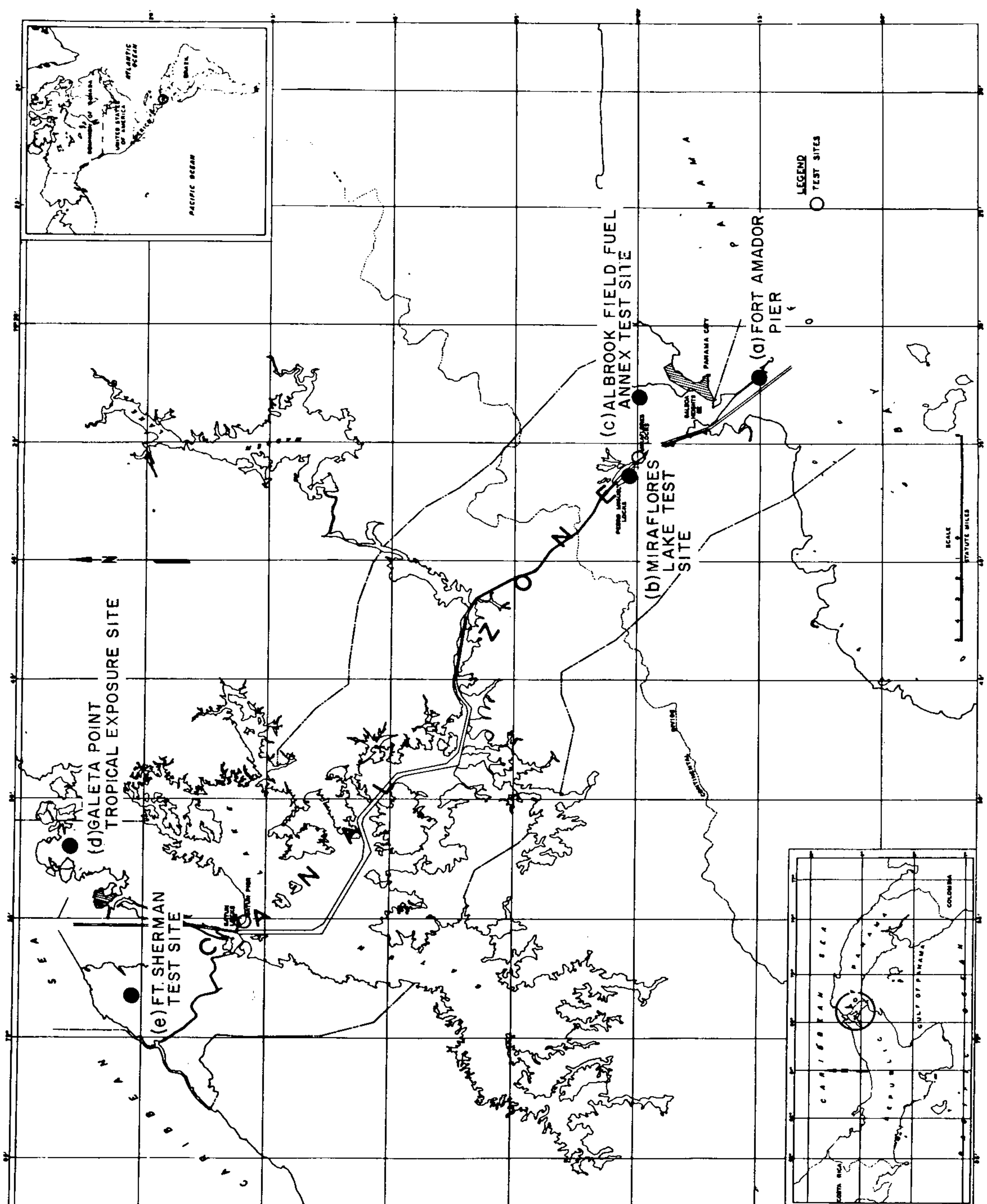


Fig. 2 - Location of tropical wood exposure sites in the Panama Canal Zone

Table 1
Salinity of Miraflores Lake
Record of 2-1/2 Years Sampling at Mid-Lake Test Site

Date of Sample	Chloride Concentration - ppm*		
	Surface	10-ft Depth	25-ft Depth
1958			
3-26	-	486	-
4-11	-	483	-
5-14	-	453	-
6-2	-	413	-
6-18	-	432	-
7-17	-	437	-
8-7	-	457	-
9-5	-	450	-
10-2	-	278	-
11-20	226	227	261
12-8	320	321	318
1959			
2-3	-	568	600
3-2	639	662	-
5-11	582	597	674
7-2	458	460	500
8-6	365	388	455
9-11	342	340	341
10-16	277	275	293
12-1	261	261	262
1960			
1-6	-	314	-
2-11	375	370	431
3-23	-	522	-
4-24	479	476	502
6-9	319	337	316
8-2	-	347	-
8-31	-	273	-
9-21	-	277	-
10-24	211	213	232
Average 1958-1960	-	392†	-

*Total chlorides by Silver Chromate Method – Scotts Standard Methods of Chemical Analysis.
†Pacific Ocean water at Fort Amador, C.Z. averages 17,400 ppm

Samples exposed to termite and fungus attack at Galeta Point on the Atlantic side of the Isthmus and at Albrook Field Fuel Annex on the Pacific side were 1-1/2 × 1-1/2 × 18 inches and were exposed vertically with half the length of the stakes underground. Three replicates from one log of each species of wood were exposed in each of the stake test plots. One hundred and thirty six stakes of untreated southern pine were distributed throughout these two test areas as controls.

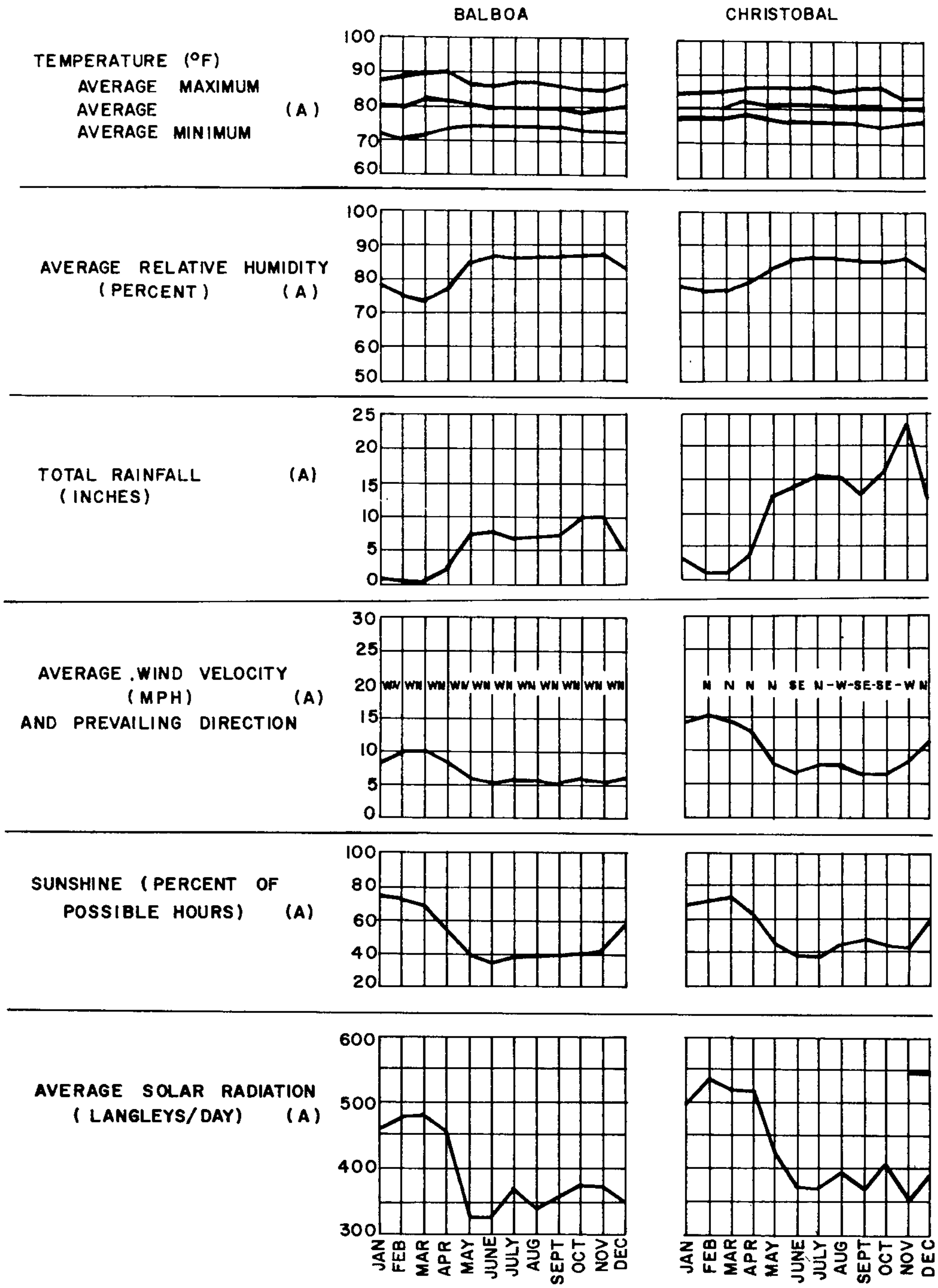


Fig. 3 - Canal Zone climatic conditions. Note: (a) Average records, 20 years minimum (b) Average records, 2-1/2 years.

Prior to installation of samples in the Albrook site the soil in the test plot was excavated to a depth of one foot and thoroughly dry-mixed in a mechanical mixer with DDT powder to effect a concentration of 100 parts per million of DDT in the soil. The DDT

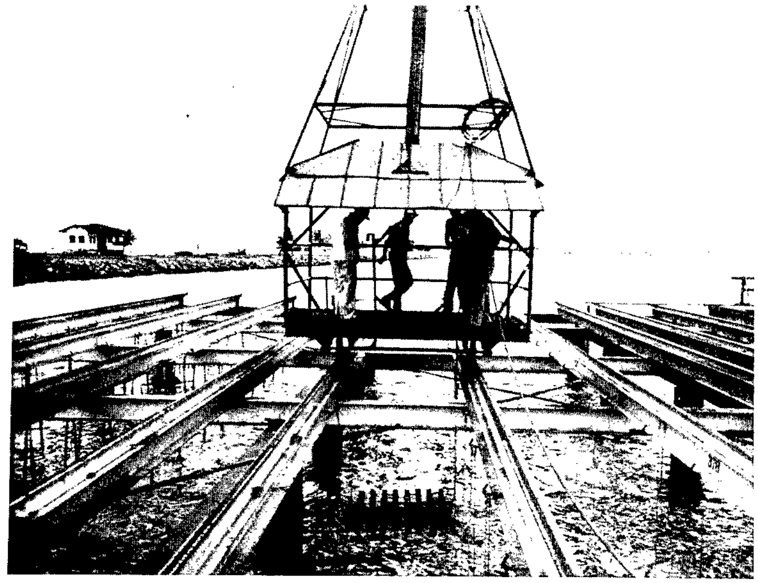


Fig. 4 - Exposure rack containing thirty-two samples being lowered into position in the Pacific Ocean at Fort Amador test pier, Canal Zone

was added in an attempt to prevent the entry of termites and thereby limit the biological attack to fungi.*

At the Fort Sherman site, on the Atlantic side of the Isthmus, samples were 1/2 × 2 × 5 inch panels attached to 1 × 2 × 16 inch oak splines. Five samples and an untreated southern pine control panel were attached to each spline and spaced at intervals of 1/2 inch. Six replicates from each log were dispersed throughout the test area. The spline was placed in contact with the soil and the test panels were then about one inch above the ground. The purpose of this type of exposure was to minimize the effect of ground line fungal attack, while permitting free access to subterranean termites. The complete exposure area at this site was sheltered from rain and sun.

The chemical treatment of common woods to give them increased resistance to biological attack is a well known and effective method of imparting reliable durability to structural timbers. Hunt and Garratt (9) list about 30 major preservatives that have been or are used in commercial treatment of wood. Many of these are effective under certain conditions and a number of them are currently used for protection from fungal or termite attack. For protection from marine borer attack coal tar creosote or a combination of coal tar and coal tar creosote are the only preservatives in general use and rather high dosages, which can be obtained only with effective pressure treatments, are required.

In the present studies no attempt was made to make a full scale investigation of a large number of wood preservatives, but it was decided that southern pine pressure-treated with creosote and with creosote coal tar solution should be included as a standard of comparison for the durable tropical woods. Pentachlorophenol treated specimens were included in the termite and decay studies. Table 2 lists the treated controls included

*The treatment proved to be ineffective in excluding subterranean termites. The rate and intensity of attack on pine controls in this area was practically the same as in adjacent untreated soil.

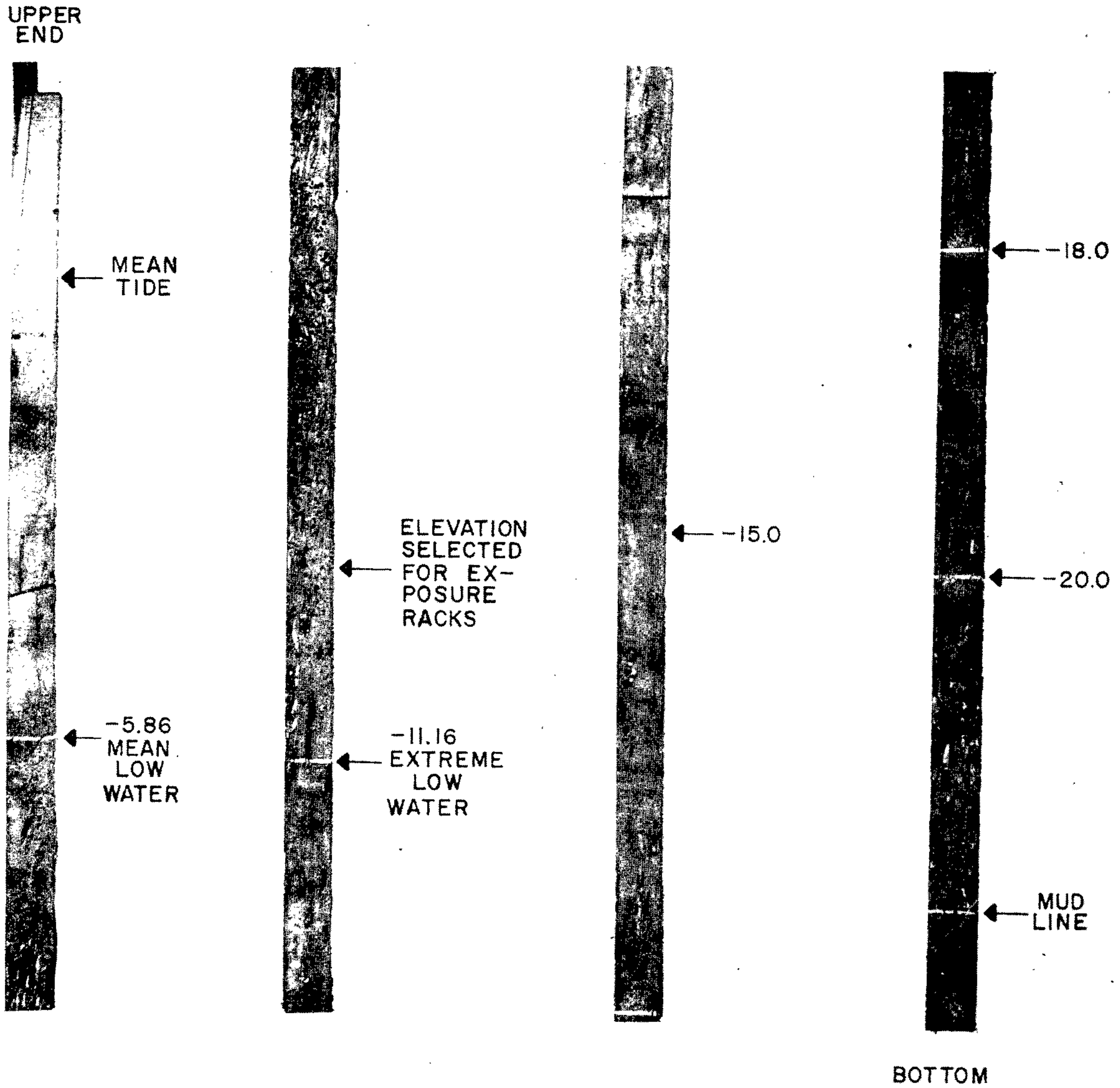


Fig. 5 - Variation in incidence of marine borer attack with depth of exposure at Fort Amador test pier. Section view through center of 30 ft by 4 × 4 inch fir column exposed six months from mud line to mean tide.

in the study. Exposure procedures for each type of treated wood were the same as used for each species of untreated wood. A number of other chemical treatments were also studied and the results will be published separately.

All specimens exposed to marine borer attack at Fort Amador and at Miraflores Lake were inspected seven months and 14 months after installation. At Fort Amador one replicate of each species was removed at each inspection period. In addition all samples that were obviously heavily attacked at seven and 14 months were removed. No removals were made at Miraflores Lake after seven months of exposure, since none of the samples seemed to be heavily attacked. Two of the southern pine control panels were removed at this time and found to be slightly damaged. At the end of the 14-month exposure, the attack at Miraflores Lake exceeded that at Fort Amador in severity, and the same removal procedures were then employed.

Table 2
Treated Controls Used in Natural Deterioration Studies

Marine Borer Studies (Ocean and Brackish Water)	Av. Retention (lb/cu ft)	Attack After 14 Months
Creosote	33.9	None
70/30 Creosote-Coal tar solution	23.5	None
Termite and Fungus Studies	Av. Retention (lb/cu ft)	Attack After 18 Months
Creosote		
Stakes*	8.9	None
Panels†	10.9	None
Pentachlorophenol		
Stakes*	0.48	None
Panels†	0.56	None

*Stakes exposed at Galeta Point, C.Z. and Albrook Fuel Annex, C.Z.
†Panels exposed at Fort Sherman, C.Z.

Since it is sometimes difficult to ascertain the extent of damage by inspection of the exterior surfaces, each of the marine borer test pieces removed was sectioned longitudinally before inspection. For comparison of interior and exterior views of a heavily attacked panel see Fig. 6.

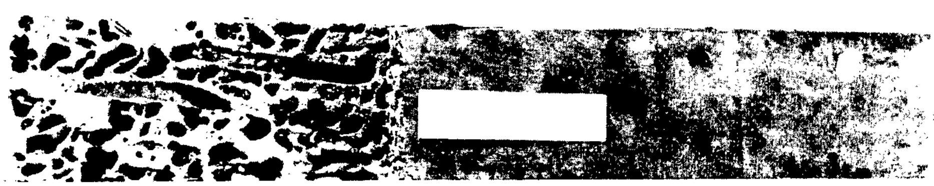


Fig. 6 - Partially cutaway view of a hard wood that has been heavily attacked by teredinidae borers. Interior damage is much greater than outward appearance signifies.

Upon inspection of sectioned samples a degree of attack rating was assigned. The six descriptive adjectives used to designate attack levels were: None, trace, slight, moderate, heavy, and very heavy. This rating system was based on that developed by William F. Clapp Laboratories for rating marine borer damage (8). The method used in these Canal Zone studies differed slightly from Clapp's in that heavy and very heavy ratings were combined and called very heavy; the moderately heavy rating then was considered to be heavy. All remaining ratings were identical.

The samples exposed to attack by termites and fungus were inspected at 6, 12, and 18 month intervals at each of the exposure sites. Inspection consisted of lifting the stake or panel, examining visually, and scraping and probing with a knife blade or other suitable instrument to determine the extent of damage. During the 18-month inspection one stake of each species of wood remaining was removed from exposure and sectioned to determine more accurately the extent of internal deterioration.

At each inspection stakes and panels were graded for both decay and termite damage. The rating methods used closely parallel those described in AWPA Standard Method for Field Testing with Stakes (10). Intensity of attack was rated by grading with one of six adjective ratings: None, trace, slight, moderate, heavy, and very heavy. Stakes were rated separately on both above and below ground damage.

RESULTS OF SCREENING TESTS

Comprehensive Summary

A summarized evaluation of results of all exposures for periods of 14 and 18 months is presented in Table 3. The last four columns (resistance rating) of this table give condensed results of durability of the individual wood species to each of the biological wood destroyers. Sea water and brackish water borer results are reported separately, since different species of Teredinidae were involved at these two sites, and since the results showed that there was a difference in amount and intensity of attack. The stake test plots on the Atlantic and Pacific sides of the Isthmus gave very similar results, with variations between sites in almost all cases being practically no greater than variations observed for replicate stakes in a single plot. Therefore the ground durability ratings for both termites and fungus are composited from both stake exposure sites. The panel tests at Fort Sherman, because of the slower attack of termites and fungus on this type specimen, had much less significance in these short time tests and were referred to only when needed to classify the termite resistance of a few woods that were rapidly destroyed by decay in the stake tests.

When all replicates of all exposures for two or more inspection periods are considered, quite a voluminous amount of data has been collected; all of this evidence was sifted, weighed, and evaluated to establish in which resistance group each wood species should be assigned in Table 3. The three-category system of low, medium, and high resistance was used to simplify the table.

1. Highly resistant woods given the No. 1 rating were only slightly attacked or completely unattacked for all specimens exposed for the 14- or 18-month exposure periods.

2. Moderately resistant woods are those which were attacked to some extent but probably not sufficiently to seriously impair structural qualities.

3. Low resistance woods have little or no natural resistance, with heavy or very heavy attack being noted on most or all of the samples.

It is believed that additional grading subdivisions for these initial short term results would be superfluous and tend to imply fictitious accuracy. Photographic examples of typical attack levels represented by the three rating categories are shown for termites and marine borers in Figs. 7 and 8.

In the first column of Table 3 the scientific names of the woods are listed alphabetically, with both genus and species shown if known. The most used common name from the region where the sample was obtained is given in column 2. The large number of common names used for some of these woods is quite confusing, and no attempt has been made to give more than one or two of the best known. With the genus identified, it is possible to refer to works on tropical forestry and botany to obtain many other common names for most of the woods.* The area from which each sample was procured is shown in column 3.

*"Timbers of the New World" (11) is especially recommended. "Flora of the Canal Zone" (12) and "Rain Forests of Golfo Dulce" (13) also have excellent lists of common names.

Table 3
Comprehensive Summary of Results of
Woods Exposed to Biological Deterioration in the Tropics

Alphabetical Listing of Woods by Generic Names	Common Names from Area of Procurement	Geographical Area of Procurement	Density of Wood A - Heaviest B, C, D, E, F - Lightest (*)	Resistance Rating (1 - High, 2 - Moderate, 3 - Low)			
				Marine Borers (14 months)		Subterranean Termites (18 months)	Terrestrial Decay (18 months)
				Ocean Water	Brackish Water		
Anacardium excelsum	Espavé	Panamá, R.P.	E	3	3	2	3
Andira inermis	Cocú	Canal Zone	D	3	3	2	3
Aspidosperma megalocarpon (prob.)	Carreto, Alcarreto	Panamá, R.P.	B	2	3	2	2
Astronium graveolens	Zorro, Zorrillo, Ron-Ron	Panamá, R.P. Chiriqui, R.P.	C	3	2	2	2
Avicennia nitida	Mangle Salada	Canal Zone	B	3	3	3	3
Bombacopsis quinata	Cedro Espino	Panamá, R.P.	E	2	2	1	1
Bombacopsis sessilis	Ceibo	Canal Zone	F	3	2	3	3
Brosimum sp. (prob.)	Berba, Guayabo Blanco	Panamá, R.P.	D	3	3	3	2
Bursera simaruba	Almacigo, Indio Desnudo	Canal Zone	F	3	3	3	3
Brysonima crassifolia	Nance	Canal Zone	D	3	3	3	2
Callitris glauca	Australian Cypress Pine	Australia	D	1	2	1	2
Calophyllum brasiliense	María	Panamá, R.P.	E	2	3	2	2
Calycophyllum candidissium	Alazano, Lemonwood, Lancewood	Canal Zone	C	2	2	2	3
Carapa slateri	Cedro Macho, Bateo, Tangaré	Bocas del Toro, R.P. Darien, R.P.	E	3	3	3	3
Carapa sp.	Cedro Vino	Panamá, R.P.	E	2	3	3	3
Cariniana pyriformis	Chibugá, Albarco	Darien, R.P.	E	2	2	1	2
Caryocar costaricense	Henené	Darien, R.P.	B	3	3	1	1
Caryocar sp.	Ajo	Darien, R.P.	E	3	3	1	2
Cassia, moschata	Bronze Shower	Canal Zone	C	2	2	1	1
Cedrela mexicana	Cedro Amargo	Panamá, R.P.	F	2	2	1	2
Cedrela sp.	Cedro Granadino	Chiriqui, R.P.	F	2	3	3	3
Centrolobium orinocense	Amarillo de Guayaquil	Darien, R.P.	D	2	3	1	1
Chlorophora tinctoria	Mora	Panama, R.P.	E	1	2	1	1
Chrysophyllum cainito	Caimito, Star Apple	Canal Zone	B	1	2	1	3
Colubrina glandulosa	Carbonero de Amunicion	Canal Zone	B	3	3	1	1
Conocarpus erectus	Zarragosa	Canal Zone	B	1	2	1	1
Copaifera aromatica	Cabimo	Panamá, R.P.	D	3	3	1	1
Cordia alliodora	Laurel Negro	Bocas del Toro, R.P.	F	1	2	1	3
Cornus disciflora	Mata Hombro	Chiriqui, R.P.	D	3	3	3	3
Coumarouna oleifera	Almendro	Panamá, R.P.	B	2	3	1	1
Croton panamensis	Sangre	Canal Zone	E	3	3	3	-
Dalbergia retusa	Cocobolo	Panamá, R.P.	A	1	1	1	1
Dialium guianense	Tamarindo	Panama, R.P.	A	1	2	1	-
Dialyanthera otoba	Miguelario	Bocas del Toro, R.P.	F	3	3	3	-
Dicorynia paraensis	Angelique, Basra Locus	Surinam	C	1	1	1	2
Diphysa robinioides	Macano	Canal Zone	B	2	3	1	1
Enterolobium cyclocarpum	Corotú	Canal Zone	E	2	3	1	1
Erythrina glauca	Gallito	Canal Zone	F	3	3	3	3
Eschweilera (prob.)	Guayabo Macho	Panamá, R.P.	D	2	2	2	2
Genipa americana	Jagua	Canal Zone	D	3	3	3	3
Gliricidia sepium	Bala, Mata Ratón	Canal Zone	A	2	2	1	1
Guaiacum officinale	Lignum Vitae	Central America	A	2	2	1	1
Guarea longipetiolata	Chuchupate	Chiriqui, R.P.	E	2	3	1	2
Guarea trichilioides	Guaragao	Panamá, R.P.	C	2	2	1	1
Hieronyma alchorneoides	Pantano	Chiriqui, R.P.	B	1	2	1	3
Hippomane mancinella	Manzanillo	Canal Zone	E	2	2	-	-
Hura crepitans	Nuno	Canal Zone	F	3	3	3	3
Hymenaea courbaril	Algarrobo	Canal Zone	C	3	3	2	2
Lafoensia punicifolia	Amarillo Negro	Canal Zone	C	3	3	1	2
Laguncularia racemosa	Mangle Blanco	Canal Zone	D	3	3	3	3
Lecythis ampla	Coco	Darien, R.P.	C	3	3	1	2
Lecythis or Manilkara	Coco	Darien, R.P.	A	2	3	1	2
Licania arborea	Raspa	Panamá, R.P.	D	1	2	-	3
Licaria pittieri	Jigua Negro	Darien, R.P.	E	2	3	2	3

(*) A - Extremely heavy, air dry specific gravity > 1.0; B - Very heavy, 0.9 - 1.0 air dry specific gravity; C - Heavy, 0.8 - 0.9 a.d.s.g.; D - Moderately heavy, 0.7 - 0.8 a.d.s.g.; E - Medium density, 0.5 - 0.7 a.d.s.g.; F - Light, a.d.s.g. < 0.5.

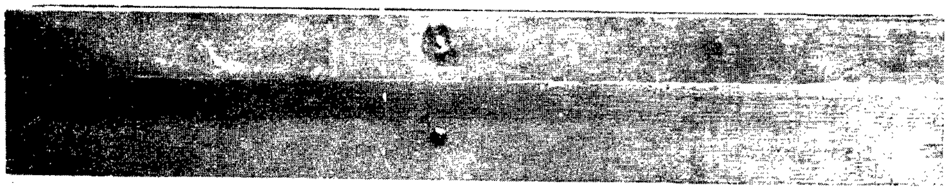
Table 3 (Cont'd)
Comprehensive Summary of Results of
Woods Exposed to Biological Deterioration in the Tropics

Alphabetical Listing of Woods by Generic Names	Common Names from Area of Procurement	Geographical Area of Procurement	Density of Wood A - Heaviest B, C, D, E, F - Lightest (*)	Resistance Rating (1 - High, 2 - Moderate, 3 - Low)			
				Marine Borers (14 months)		Subterranean Termites (18 months)	Terrestrial Decay (18 months)
				Ocean Water	Brackish Water		
Lophira procera	Bongassi, Ekki, Azobe, Iron Wood	Africa	A	1	2	1	1
Lonchocarpus sp.	Iguanillo	Canal Zone	B	3	3	2	3
Luehea seemanii	Guácimo	Canal Zone	E	2	2	3	3
Magnolia sororum	Vaco, Baco	Chiriqui, R.P.	E	3	3	2	3
Manilkara bidentata	Níspero Balata	Darien, R.P.	B	3	3	1	1
Manilkara chicle	Níspero Zapote	Canal Zone	A	3	3	1	2
Manilkara sp.	Rasca	Panamá, R.P.	A	2	2	1	1
Minquartia guianensis	Crillo, Manwood	Bocas del Toro, R.P.	C	2	2	1	1
Mora oleifera	Alcornoque	Darien, R.P.	D	3	3	3	3
Myroxylon balsamum	Bálsamo	Darien, R.P.	A	3	3	1	1
Nectandra whitei	Bambito	Panamá, R.P.	D	3	3	3	2
Ocotea dendrodaphne	Ensiva, Insiba	Darien, R.P.	C	2	2	1	1
Ocotea rodiei	Greenheart	British Guiana	B	1	2	1	1
Paramachaerium gruberi	Sangrillo Negro	Chiriqui, R.P.	C	2	3	1	1
Pelliciera rhizophorae	Palo de Sal	Canal Zone	D	2	3	3	3
Peltogyne purpurea	Nazareno	Panamá, R.P.	B	3	3	1	2
Pentaclethra macroloba	Gavilán	Bocas del Toro, R.P.	C	2	3	1	2
Phoebe johnstonii	Aguacatillo	Canal Zone	E	3	3	3	3
Pinus caribaea	Nicaraguan Pine	Nicaragua	E	3	3	3	-
Pinus sp.	Southern Yellow Pine	U.S.A.	F	3	3	3	-
Pithecellobium mangense	Uña de Gato	Canal Zone	E	1	2	1	2
Pithecellobium saman	Rain tree	Canal Zone	E	3	3	2	3
Platymiscium pinnatum	Quirá	Panamá, R.P.	B	1	2	1	1
Pouteria campechiana	Mamecillo	Canal Zone	A	1	1	1	3
Pouteria chiricana	Níspero de Monte	Canal Zone	B	1	2	2	3
Prioria copaifera	Cativo	Canal Zone	E	3	3	3	3
Pseudotsuga taxifolia	Douglas Fir	U.S.A.	E	3	3	3	-
Quercus sp.	Native Oak, Roble	Chiriqui, R.P.	B	3	3	3	-
Rizophora brevistyla	Mangle Rojo - Pacific	Panamá, R.P.	A	3	3	3	3
Rizophora mangle	Mangle Rojo - Atlantic	Canal Zone	B	3	3	-	3
Sterculia apetala	Panama	Canal Zone	F	3	2	3	3
Swartzia panamensis	Cutarro	Darien, R.P.	B	2	3	1	1
Swartzia simplex	Naranjito	Canal Zone, R.P.	B	3	2	2	3
Sweetia panamensis	Malvecino	Panama, R.P.	B	2	3	1	2
Swietenia macrophylla	Mahogany, Caoba	Panamá, R.P.	E	2	3	1	2
Symphonia globulifera	Sambogum, Cerillo	Bocas del Toro, R.P.	E	3	3	3	3
Tabebuia chrysantha	Guayacán Negro	Panamá, R.P.	A	2	3	1	1
Tabebuia guayacan	Guayacán	Chiriqui, R.P.	A	1	2	1	1
Tabebuia pentaphylla	Roble de Sabana	Panamá, R.P.	E	2	2	2	2
Tectona grandis	Canal Zone Teak	Canal Zone	E	2	2	1	2
Tectona grandis	Burma Teak	Burma	E	1	2	1	3
Terminalia amazonia	Amarillo	Panamá, R.P.	C	2	3	1	2
Terminalia catappa	Almond	Canal Zone	E	1	2	2	3
Terminalia myriocarpa	Dalienze	Canal Zone	E	2	2	3	3
Ternstroemia seemanii	Manglillo	Canal Zone	E	2	3	3	3
Tetragastris panamensis	Animé	Darien, R.P.	B	3	3	1	2
Tetrathylacium johnsenii	Macho	Canal Zone	D	3	3	3	3
Trattinickia aspera	Caraño	Canal Zone	F	3	3	3	-
Trichilia tuberculata	Alfaje	Canal Zone	C	2	2	3	3
Vatairea sp.	Amargo-Amargo	Panamá, R.P.	E	3	3	2	3
Virola koschnyi	Bogamaní, Gorogán	Chiriqui, R.P.	F	3	3	3	-
Virola sebifera	Mancha	Chiriqui, R.P.	E	3	3	3	-
Vitex floridula	Cuajado	Canal Zone	D	3	3	3	3
Vochysia ferruginea	Mayo	Canal Zone	F	2	3	3	3
Vouacapoua americana	Acapú	Brazil	B	1	2	1	1
Zanthoxylum belizenge	Acabú, Arcabú	Panamá, R.P.	F	3	3	2	3
Unknown	Macana Blanco	Panamá, R.P.	A	2	2	1	1
Unknown	Vasca	Darien, R.P.	E	1	2	3	3
Unknown	Sigua	Panamá, R.P.	E	2	3	2	3
Unknown	Naranjillo	Chiriqui, R.P.	D	2	2	2	2

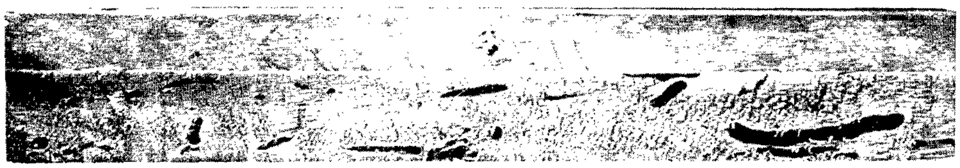
Fig. 7 - Exterior and interior sectional views of stakes selected as typical of a high, medium, and low resistance to subterranean termites

The great majority of the woods collected came from the Republic of Panama, and these have been broken down to show from which province of Panama the sample was obtained, such as Darien, R.P., or Panama, R.P., etc. Figure 9 is a map of Panama showing location of provinces and timber resources as reported by Garver (14). The woods coming from other countries are known to the export market and only the general area of procurement is given, e.g., southern pine, U.S.A.

Approximate densities of the samples tested are given in column 4 of Table 3. Exact specific gravities have not been determined, since variations in density of wood from different trees and even different pieces from the same tree did not warrant the effort of precise determinations on the large number of samples. Sufficiently accurate results to classify the samples into five groups were obtained by float or no-float tests in four different liquids having specific gravities of 1.0, 0.9, 0.8, and 0.7. Specific gravities of woods lighter than 0.7 were obtained by pycnometer methods. All specific gravity samples were small pieces of representative material that had been thoroughly air-dried for two years at an average relative humidity of 35 percent.



(A) HIGH RESISTANCE – POUTERIA (NISPERO DE MONTE)



(B) MODERATE RESISTANCE – CALOPHYLLUM (MARIA)

(C) LOW RESISTANCE – PELTOGYNE (NAZARENO)

Fig. 8 - Examples of high, moderate, and low resistance to marine borers in tropical sea water, Fort Amador, Canal Zone

Marine Borer Resistance

Marine borer damage to wooden structures is almost invariably caused by the combined or separate attack of three principal types of organisms. Limnoria, isopod crustaceans usually not over 1/8 inch in length, damage wood essentially by surface attack. Shallow, interlocking burrows are drilled by the organism's mandibles and natural erosion usually rapidly washes away the interstices between burrows, thereby reducing the diameter of the timber attacked. Heavy Limnoria infestation can cause a reduction in the diameter of a pile of 1/2 to 1 inch per year. Of the marine wood borers, Limnoria are least affected by coal tar creosote treatment of wood, the most common treatment for the preservation of wood marine structures.

Possibly the most familiar wood-boring marine organisms are those in the teredine borers of the phylum Mollusca. These borers, commonly called "shipworms," are relatives of the common bivalves, such as the clams and oysters. The teredine borers enter wood in the embryonic state and spend the rest of their lives imprisoned therein. Their burrows are continually enlarged to accommodate their growth, and extensive damage can result with few traces visible on the surface.

The pholads, also molluscan, frequently burrow in rocks along the sea coast but sometimes enter wood. Normally the pholads are not a very serious problem, since the population level is usually low.

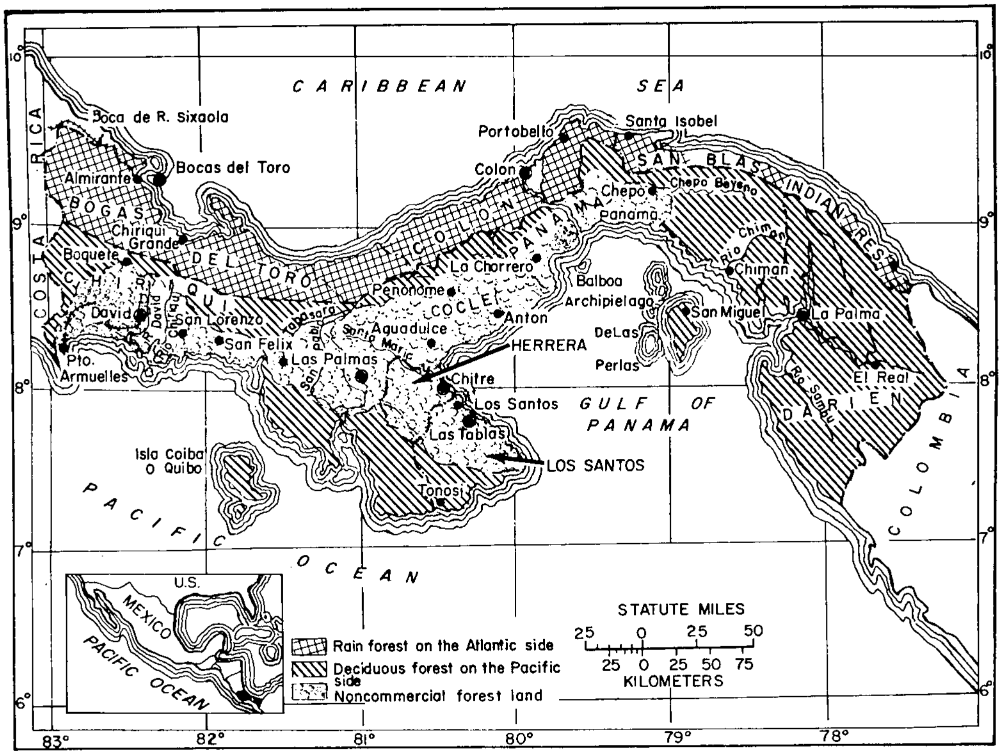


Fig. 9 - Map of the Republic of Panama showing location of Provinces and type of forests

In this, the screening phase of the investigation, determination of resistance to teredine borers was the primary objective of the studies. The site at Fort Amador had been evaluated by Clapp Laboratories (8) and was reported to be very heavily infested with teredine borers. The test site in Miraflores Lake was not as well classified, but engineers of the Panama Canal Company were aware that in this brackish water heavy damage was caused by marine borer attack, and Clapp Laboratories test panels at the Pacific end of the lake showed very heavy attack by Teredo. A section through an untreated pine fender timber used in the Panama Canal on the Pacific end of Miraflores Lake can be seen in Fig. 10.

During the 14-month exposure period covered by this report similar results in these waters were observed. The first inspection, after a seven-month exposure, revealed that all the pine control panels in the ocean at Fort Amador were very heavily attacked by teredine borers, and after 14 months only small pieces of the controls remained. Control pieces installed at Fort Amador for the second seven-month period showed that intensity of attack during this exposure interval was about the same as for the first seven months.

The first seven-month inspection of pine control pieces from Miraflores Lake indicated that the initial rate of attack was lower than in the ocean; however, in the second seven-month period destruction in the lake was very rapid and equaled or exceeded that observed at Fort Amador. It is assumed that the borer population had to build up to this newly available food supply in the mid-lake area.

Classification of the borer species was performed by William F. Clapp Laboratories, Duxbury, Massachusetts. Mr. Albert P. Richards, President of that laboratory, was

Fig. 10 - Marine borer damage to Panama Canal fender timbers, Miraflares Locks, untreated pipe

present and acted as consultant in the inspection and rating for seven-month and 14-month removals. Some of the Teredinidae species identified in the wood samples at Fort Amador were: Bankia caribbea, B. zeteki, B. cieba, B. katherinae, B. gouldi, B. destructa, Teredo trulliformis, T. panamensis, T. diegensis.

Only one species of marine boring organism has been identified at the Miraflores Lake site. This is Teredo healdi, well known in the brackish waters of Lake Maracaibo, Venezuela, and one of the few species of the teredine borers able to live in waters of such low salinity. No Limnoria or pholads were found in the lake.

The single species found at Miraflores Lake was more destructive to most woods than the combined borer species found in the Pacific Ocean samples. Twenty-one woods were rated as highly resistant to ocean borers for 14-month exposure, while only three were found highly resistant to the Teredo healdi for the same period. Table 4 lists the wood species found to have high resistance to marine borers at each of the locations. Many of the reputedly high-resistance woods, such as: Ocotea rodiei (greenheart), Lophira procera (bongassi), Vouacapoua americana (acapu), and Gallitris glauca (Australian cypress pine) were practically unattacked by ocean borers but were only moderately resistant to Teredo healdi in the lake. Examples of this difference can be seen in Fig. 11, which shows sections of greenheart and bongassi after exposure in the ocean and lake for 14 months. The fact that a wood is not resistant to the lake borers does not necessarily condemn the material for use in ocean exposure, but it does show that its natural resistance is not effective under all conditions.

Table 4
Woods Found Highly Resistant to Marine Borers for 14 Months (Generic Names)

A. Sea water - Pacific Ocean (Fort Amador)	
Callitris glauca	Lophira procera
Chloraphora tinctoria	Ocotea rodiei
Chrysophyllum cainito	Pithecellobium magense
Conocarpus erectus	Platymiscium pinnatum
Cordia alliodora	Pouteria campehiana
Dalbergia retusa	Pouteria chiricana
Dialium guianense	Tabebuia guayacan
Dicornia paraensis	Tectona grandis (Burma)
Hieronyma alchorneoides	Terminalia catappa
Licania arborea	Vouacapoua americana
B. Brackish water (Miraflores Lake)	
Dalbergia retusa	
Dicornia paraensis	
Pouteria campechiana	

Only three of the 114 species studied were rated highly resistant in both environments for the full 14-month exposure period. These three outstanding woods were: Dalbergia retusa (cocobolo), Pouteria campechiana (mamecillo), and Dicorynia paraensis (angelique).

In the brackish lake water at Miraflores only the three species named above of the 114 studied were rated highly resistant after 14-month exposure, while 69 species were in the low or nonresistant category. The remaining 42 were found to be moderately resistant. All species that were rated moderately or highly resistant in the lake for 14 months were equally good or better in the ocean, indicating that the brackish water exposure was a more severe criterion of overall resistance to Teredinidae than ocean exposure.

In the 14-month Pacific Ocean exposure at Fort Amador 21 species were found to be highly resistant; 51 were nonresistant, and 42 were considered moderately resistant.

The few species that possess all-around high resistance will undoubtedly draw more attention, but the large number of low resistant woods found are also significant, as the negative results obtained can prevent costly misapplication of the nonresistant tropical timbers.

Species resistant to marine borers were generally of high density. The three woods found to be highly resistant in the brackish water were all hard and heavy, specific gravities ranging from 0.88 for angelique to 1.05 for cocobolo. In Pacific sea water, too, most of the resistant species were hard, heavy woods, but not invariably so. One of the major exceptions was Cordia alliodora (laurel negro), a wood of only 0.42 specific gravity, which was found to have high resistance to Teredinidae. A few of the medium density woods also were revealed to have better than average resistance to borers.

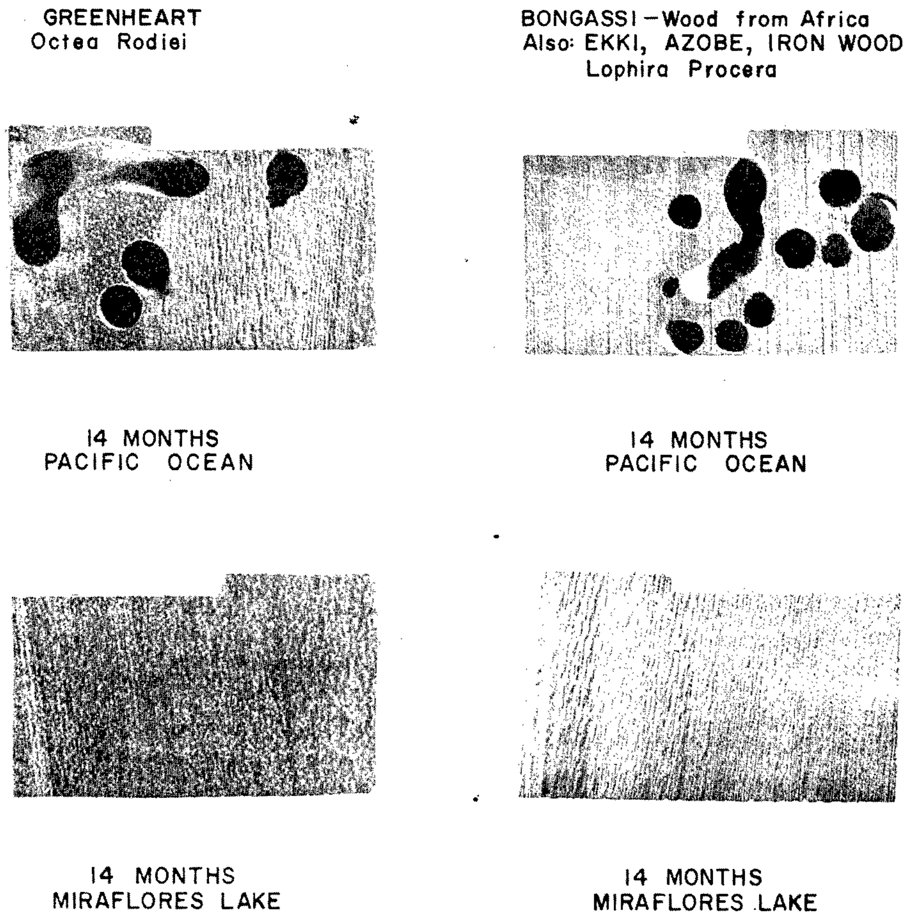


Fig. 11 - Cross sections of exposed samples (14 months) of two well known resistant wood species showing the more destructive effects from brackish water borers

However, some of the heaviest woods, such as Rizophora (red mangrove), Manilkara (nispero), and Myroxolyon (balsamo) were rapidly and heavily attacked by Teredinidae. Seven-month damage on two species of Rizophora, specific gravity 1.0, can be seen in Fig. 12. Even Guaiacum officinale (lignum vitae), the densest wood included in the present investigation, specific gravity 1.23, was no more than moderately resistant for 14 months.

It is recognized that any given species of wood growing under various sylvicultural conditions can have very different properties in its resistance to destructive organisms. However, in these marine borer exposure studies duplication of results for replicate panels in the same exposure were, in general, very good; and samples from different logs of the same species usually were similar in resistance rating. This effect was most apparent when all panels that had been exposed for 14 months had been removed from exposure and sectioned, with replicates from different logs juxtaposed.

As shown in Table 2 none of the creosote or creosote-coal tar treated southern pine control specimens were attacked in either environment during this period. No exact comparison between the life of these treated specimens and the more resistant species can be made yet but it would not be surprising if the treated specimens proved to have a much longer life.

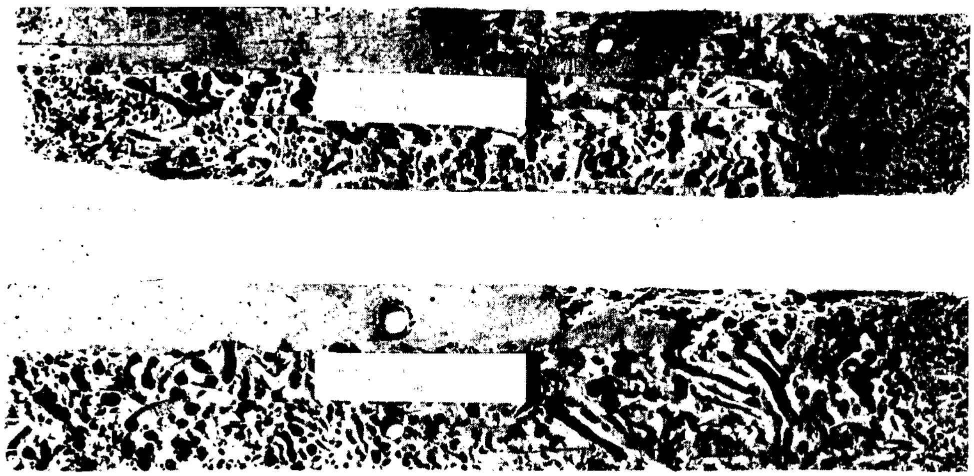


Fig. 12 - Heavy marine borer damage obtained on two different species of red mangrove (Rizophora) after only seven months under tropical sea water, Fort Amador, Canal Zone

Resistance to Termites

Termites are social insects found throughout the tropics and much of the temperate zone. In spite of the common name "white ants," they are not related to the ants but are actually distantly related to the roaches. They are usually divided into two groups, the drywood termites (including the damp wood termites) and the subterranean termites. The drywood termites live solely in the wood but the colonies are relatively small and they are a serious problem in only a few places. The subterranean termites must maintain a contact with the earth, hence the frequent observation of tunnels over walls or foundations between infested wood and the ground. The termites of this type are capable of forming large colonies which can cause serious damage to unprotected wooden structures in a short period of time.

Hunt and Garratt (9) report that in the United States termites have assumed a position of major importance among the organisms responsible for the destruction of wood in service. An accurate appraisal of the damage caused by termites is impossible, but damage to buildings alone amounts to millions of dollars annually. Most of this damage is due to subterranean termites. In Panama the destruction of unprotected nonresistant wooden structures can be spectacularly rapid, principally because of the abundance of the subterranean species Coptotermes niger. Other important species found in Panama are: Heterotermes convexionetatus, Heterotermes tenuis, and Masutitermes cornigera.

Wolcott (15) in studies made in Puerto Rico rated a large number of wood species with respect to their resistance to the West Indian dry wood termite, Cryptotermes brevis. Many of the wood species evaluated are among the woods included in the present studies. In 1958 the Navy Caribbean Area Public Works Office compiled the latest information on the resistance of different woods to biological attack including Wolcott's work. However, concerning resistance of tropical woods to the more destructive subterranean termites, very little data on controlled exposure tests of a large number of species could be found.

A summary of the termite resistance determined for each species of wood tested can be found in Table 3. In addition to this specific information for each wood, some interesting general results were obtained from the termite studies. Fifty-three of the 114 tropical wood species tested were found highly resistant to termites, 38 species were rated

Table 5
Woods Found Highly Resistant to Subterranean Termites for an 18-Month Exposure in both the Atlantic and Pacific Side Stake Tests (Generic Names)

Bombacopsis quinata	Cedrela mexicana
Callitris glauca	Centrolobium orinocense
Cariniana pyriformis	Chrysophyllum tinctoria
Caryocar sp.	Chrysophyllum cainito
Cassia moschata	Colubrina glandulosa
Conocarpus erectus	Minquartia guianensis
Copaifera aromatica	Myroxylon balsarmum
Cordia alliodora	Ocotea dendrodaphne
Coumarouna oleifera	Ocotea rodiei
Dalbergia retusa	Paramachaerium gruberi
Dialium guianense	Peltogyne pupurea
Dicornia paraensis	Pentaclethra macroloba
Diphysa robinioides	Pithecellobium mangense
Enterolobium cyclocarpum	Platymiscium pinnatum
Gliricidia sepium	Pouteria campechiana
Guaiacum officinale	Swartia panamensis
Guarea longipetiolata	Sweetia panamensis
Guarea trichilioides	Swietenia macrophylla
Hieronyma alchorneoides	Tabebuia chrysantha
Lafoensia punicifolia	Tabebuia guayacan
Lecythis or Manilkara	Tectona grandis (Burma)
Lophira procera	Tectona grandis (Panama)
Manilkara bidenta	Terminalia amazonia
Manilkara chicle	Tetragastris panamensis
Manilkara sp.	Vouacapoua americana

nonresistant and the remaining 20 are considered moderately resistant. The 53 woods found to have high resistance to subterranean termites for 18-month exposure on both the Atlantic and Pacific sides of the Isthmus of Panama are listed in Table 5.

A few species of soft woods appeared to be particularly attractive to termites; stakes of Bursera simaruba (almacigo) and Dialyanthera otoba (miguelario) were completely destroyed before any of the other woods were attacked to any significant extent. All the dispersed replicate samples of these two species were consistently attacked at each of the three different exposure sites. Southern pipe, the control wood, was only slightly more resistant; almost invariably the pine control stakes which were distributed generously throughout the test areas were attacked very quickly. Only in the panel tests where pine was attached to oak holders was there some inconsistency of attack on pine controls. Since the North American white oak is also a favorite of these termites, they occasionally preferred to stay in the oak; and as a result a few of the pine controls in this type exposure were unattacked for 18 months.

Stake tests seemed to give much more rapid and reliable results for the termite resistance investigation than the sheltered panel specimens. Although with more exposure time the panels appear to be following the same patterns of resistance as the stakes, correlation between replicates, with the exception of the highly attractive woods for which all samples were heavily attacked, is generally not as good with the panels as with the stakes. The masking effect of decay which was expected to be a problem with the stakes was not a serious one. Apparently the termite attack was not deterred by the presence of fungus activity in the wood; but whether it was accelerated by the presence of fungus in some woods is undetermined.

Forty-one of the 65 hard, heavy woods tested, specific gravity greater than 0.7, were found to have high resistance to subterranean termites for 18 months. A longer exposure period will be required before the best of these can be screened out. Of greater general interest, because of their more usable weight, are the medium and light density woods with high termite resistance. Ten species of the 32 medium density woods and two of the 14 light woods showed exceptionally high resistance, considering their low density.

These woods of medium and light weight found to have high termite resistance for the first 18 months of exposure were *Bombacopsis quinata* (cedro espino), *Cariniana pyriformis* (chibuga, albarco), *Caryocar sp.* (ajo), *Chlorophora tinctoria* (mora), *Enterolobium cyclocarpum* (corotu), *Guarea longipetiolata* (chuchupate), *Pithecellobium mangense* (una de gato), *Swietenia macrophylla* (mahogany), *Tectona grandis* (Canal Zone teak), *Tectona grandis* (Burma teak), *Cedrela mexicanna* (cedro amargo) and *Cordia alliodora* (laurel negro).

No termite attack was observed on either creosote or pentachlorophenol treated control specimens during this period as shown in Table 2. No comparison can be made yet between the effectiveness of the chemical treatments and the natural resistance of the resistant species.

Resistance to Jungle Decay

Decay of wood is the result of activities of low forms of plants known as wood-destroying fungi. Under favorable conditions the fungi spread through the wood in all directions from the point of inception, usually passing from cell to cell through bore holes which they form in cell walls. Favorable conditions for decay are an optimum moisture range, suitable temperature, food, and air (9).

Few of the decay-producing fungi are able to attack all kinds of wood, and some woods seem to be practically immune to most of the varieties. In the jungle soil there are a great number of fungi available and conditions of temperature and moisture are ideal for their activities. Stake samples in this soil provide a very severe test of a wood's resistance to decay. In the stake tests in which half of the specimen is underground the wood is exposed with a moisture gradient from air dry at the top to saturation at the bottom. At various elevations optimum moisture conditions occur for growth of different fungi. The heaviest attack usually occurred close to the ground-line; often the wood above and below ground appeared completely unaffected, while that close to the ground had lost most of its strength.

Although fungal decay damage usually developed more slowly than termite damage, the number of species possessing high resistance to decay was considerably less than the 53 with high termite resistance. The specific results given in Table 3 show that thirty of the woods were rated highly resistant to decay after 18-month exposure, while for the same period 46 were classed as having low resistance. Twenty-eight were considered moderately resistant, and ten could not be rated because of the masking effect of rapid termite attack. A list of the wood species found to have high decay resistance in both the Atlantic and Pacific side stake tests is given in Table 6.

Table 6
Woods Found Highly Resistant to Decay for an 18-Month Exposure in both the Atlantic Side and Pacific Side Stake Tests (Generic Names)

Bombacopsis quinata	Lophira procera
Caryocar costaricense	Manilkara bidentata
Cassia moschata	Manilkara sp.
Centrolobium orinocense	Minquartia guianensis
Chlorophora tinctoria	Myroxylon balsamum
Colubrina glandulosa	Ocotea dendrodaphne
Conocarpus erectus	Paramachaerium gruberi
Copaifera aromatica	Platymiscium pinnatum
Coumarouna oleifera	Pseudotsuga taxifolia
Dalbergia retusa	Swartzia panamensis
Diphysa robinioides	Tabebuia chrysantha
Enterolobium cyclocarpum	Tabebuia guayacan
Gliricidia sepium	Vouacapoua americana
Guaiacum officinale	
Guarea trichilioides	

As with other wood-destroying organisms, fungi showed a preference for light soft woods; of the 30 woods that were highly resistant 26 were hard and heavy, with specific gravity greater than 0.7. Only three medium density species, Bombacopsis quinata (cedro espino), Enterolobium cyclocarpum (corotu), and Chlorophora tinctoria (mora) received high resistance ratings for an 18-month exposure. Because of the importance of decay resistance in wood for any type of service, all three of these woods will be discussed in the next section under "Woods of Special Interest."

No fungus attack was found on the creosote or pentachlorophenol treated control specimens during this period and no comparisons can be made yet between the effectiveness of the treatment and the resistance of the best species of untreated wood.

Several times during the course of these studies attention was directed to Gatun Lake. In this lake there has been a screening test of tropical woods on a grand scale. When the lake was filled 50 years ago, a large area of tropical forest was partially submerged. Now, at times of low water level, the profusion of stumps gives evidence of the thick forests that once stood on this ground. The underwater portions of the trees have remained apparently free from any biological deterioration. This is not surprising, since this is fresh water and there are no marine borers, and the moisture content of the submerged wood would be too high for fungus or termites. The upper portions, however, were evidently vulnerable to air-borne spores of wood-destroying fungi. These dead trees protruding from the lake offered a complete moisture gradient in a warm tropical atmosphere, and fungus attack was probably severe. Tree-nesting and drywood termites also must have contributed their share to the downfall of these forests.

In spite of many years of exposure to these extreme conditions some of the trees have not been felled, either by attack from the biological organisms or from the effects of natural weathering for half a century. Some even stand with their branches, almost down

Fig. 13 - A few of the surviving trees in Gatun Lake after 50 years of partial inundation by fresh water. Pictures made during period of extreme low water show stump of some of the nonsurvivors.

to twig size, still intact. Figure 13 shows a few views of these lonely trees that have outlasted the forest that once surrounded them.

Twenty-five standing trees from various parts of the lake have been sampled. Of these, twenty-two were Tabebuia guayacan (guayacan), one was Swartzia panamensis (cutarro), one was Manilkara dariensis (nispero), and one has not been definitely classified. The woods were all extremely hard and heavy and very sound. Guayacan seems to be the predominant species remaining in the lake, and it appears to be the best preserved of those examined.

Only a relatively small portion of the accessible areas of the lake has been surveyed and from this type of evidence it cannot be determined which species were not durable. For example, mahogany may not be represented because of selective logging before the flooding, or perhaps none grew in the area sampled. There is no doubt, however, about the excellent durability of those still standing; and reference to ratings shown in Table 3 reveal that all three of the identified woods, Tabebuia guayacan (guayacan), Swartiza panamensis (cutarro), and Manilkara dariensis (nispero) were highly resistant to termites and decay in the 18-month stake tests.

Wood Species of Special Interest

In the quest for resistant woods, an ideal discovery would be a timber that would be highly resistant to all biological deterioration, and of sufficient size and quantity to be worthwhile commercially. A glance down the list in Table 3 will show the small number of woods rated highly resistant in all categories. Only Dalbergia retusa (cocobolo) can be considered highly resistant in all the environments. Unfortunately this is not a commercially useful timber because of its extremely high density and relative scarcity. Any woods that were moderately resistant in Miraflores Lake and highly resistant in all other environments should certainly be considered exceptional. In this high all-around resistance category were Chlorophora tinctoria (mora), Conocarpus erectus (zarragosa), Gliricidia sepium (bala), Ocotea rodiei (greenheart), Platymiscium pinnatum (quira), Tabebuia guayacan (guayacan), and Vouacapoura americana (acapu). Two other woods were highly resistant to everything except jungle decay at the ground line and are also worthy of note. These two were Dicorynia paraensis (angelique) and Pouteria campechiana (mamecillo).

Practically, high resistance to all environments is not a necessity, since it is improbable that a wood would be subjected to all types of attack in the same structure. Any species that possesses high resistance to the borers in the sea and moderate to high resistance in the brackish lake water should be of considerable interest for its underwater durability, and those exhibiting high durability to both termites and decay in the stake tests are worthwhile considering for their above water durability. Woods described in Appendix A possessed a high degree of resistance to one or more of the exposures, and either because of this resistance or because of other features are considered to be of special interest.

Of special local interest in the Canal Zone and Panama are the woods of common usage or occurrence in the area. Most of these will not be found among those listed in Appendix A because not many of them were found to have high resistance properties, and a surprising facet of this investigation was the discovery of the number of common woods that had low resistance to all of the tropical biological wood destroyers. Such woods as Prioria copaifera (cativo), Anacardium excelsum (espave), Rizophora mangle (red mangle), Mora oleifera (alcornoque), Vatairea sp. (amargo-amargo), and Carapa slateri (tangare) showed no notable resistance in any environment in these studies. This does not mean that none of these are good structural timbers, but it does indicate that they should not be used unless protected against biological deterioration. It is unfortunate that the low resistance of these commonly used woods has had a detrimental effect on the reputation of all tropical woods in the area.

CONCLUSIONS

1. The large number of wood species showed great variability in their natural resistance to biological wood destroyers. For the 14-month exposure period marine borer resistance of the 114 different woods varied over a complete range from very heavy attack to no attack. Likewise, for the 18-month exposures to termite and decay, a complete range of resistance for the various woods was indicated. Thus for each environment studied some species of woods were discovered that were immune to the wood-destroying organisms present.

2. The hard, heavy wood group included a proportionally larger number of the resistant species in each environment, but there were many nonresistant heavy woods and some very resistant light woods, indicating that properties other than density contribute to the natural resistance of wood.

3. Nonresistance in all tropical environments was found for about 1/3 of the 114 species investigated. These nonresistant woods should not be used in permanent structures in any tropical environment without proper preservative treatment.

4. Some of the woods that were relatively unknown were found to have high resistance in one or more environments and these species may have considerable potential as special purpose construction timbers.

5. The perfect timber, resistant to everything, occurring in large size and plentifully was not found. Only one species, Dalbergia retusa (cocobolo), was highly resistant in all environments but its potential as a commercial timber appears to be limited.

6. Teredo healdi, in the brackish water of Miraflores Lake, were found to be more destructive than the marine borers in the ocean and many of the well-known borer resistant woods such as ekki, greenheart, and acapu were practically unattacked in the tropical ocean, but were damaged in the brackish water environment.

7. Several of the relatively unknown Panamanian woods such as Chrysophyllum cainito, Dalbergia retusa, and Pouteria campechiana seem to be resistant to marine borers for the period tested, and the source of their high resistance should be worth investigating.

8. The ocean marine borer resistance of at least one low density wood was outstanding. This was laurel negro (Cordia alliodora) a plentiful and fast growing species in Panama.

9. Subterranean termites attack certain woods very rapidly, but they are very selective and 53 of the 114 woods tested were resistant to termites for the 18 months. Longer exposure periods are expected to disclose more information on the relative termite resistance of these woods.

10. Thirty-two of the 114 tropical woods tested as stakes in jungle soil were excellent in resistance to decay for the 18-month exposure. Longer exposure periods will probably establish more precise decay ratings of these woods.

11. Woods that were high in decay resistance were generally very resistant to termites also. Some of these woods such as Bombacopsis quinata, Copaifera aromatica, Chlorophora tinctoria and Paramachaerium gruberi seem to have excellent properties for use as durable construction timbers.

12. A few hard, heavy woods are able to resist tropical fungi for a great number of years. Sound trees still standing after 50 years of partial inundation in Gatun Lake were identified as Tabebuia guayacan, Swartzia panamensis, and Manilkara dariensis.

13. Longer term exposures on treated samples and the exceptionally durable tropical woods are needed to establish their relative potential.

RECOMMENDATIONS FOR ADDITIONAL STUDIES

It is anticipated that two more reports concerning these tropical wood studies will be forthcoming. One will cover the second phase of this investigation which will evaluate the long term results of the more durable woods with respect to marine borers and will include exposure studies made with large timber sections of two or three of the most promising woods selected from the screening tests results reported herein. These exposures are to be made in the Panama Canal Locks in close proximity to other timber now in use in the canal. The second report will cover three and five year exposure results in all environments of the more durable tropical woods compared to the southern pine treated with various wood preservatives.

On this latter subject it would also seem very desirable to examine the possibilities of combining some of the better chemical treatments with a selected few of the tropical woods. Apparently very little work has been done on chemical treatment of tropical wood species. A combination of a good preservative with a naturally resistant wood should give an extremely useful wood for underwater construction, with the possibility of an appreciably longer life than obtainable from creosote pressure treated pine or fir.

The Limnoria resistance of many of these tropical woods seems very high in these exposures and Edmondson has reported similar results in Hawaiian waters. Unfortunately the Pacific Ocean waters in which these screening studies were made are not heavily infested with Limnoria. Additional exposures are now under way with selected woods to establish Limnoria ratings. These samples are being exposed in the Caribbean Sea where the Limnoria activity is known to be very severe.

ACKNOWLEDGMENTS

The collection phase of the program could not have been accomplished without the cooperation of many people in both the Canal Zone and Panama, especially Mr. Walter Lindsay, Agronomist of the Grounds Maintenance Division of the Panama Canal Company, who served as guide and advisor on many of the collection trips made with laboratory forces. Mr. August Adrian, lumberman of the Pinas Bay area near the Panama-Colombian border, supplied many of the samples used in the test and gave generously of his time and supplied native helpers and guides while the collecting expedition was in his area. Mr. Louis Martinz, businessman of Panama, donated many of the samples from his lumber yards and supplied guides and quarters for the collecting expedition in the northern highlands. The United Fruit Company donated samples of wood and supplied quarters and guides around Almirante and Puerto Armuelles; Richard and Edward Kandler, lumbermen in the vicinity of Bocas del Toro, donated samples, transportation, and guides for collecting in that region; John Duncan and other local boatbuilders gave advice and samples for use in the investigation. Robert Novey, Terrence Ford, Camilo Quelquejeu, Hernand Behn, and other lumber dealers in Panama City and Colon contributed information and samples.

Scientific identification of the wood species required considerable research and effort on the part of expert botanists and wood anatomists. Dr. William L. Stern, Curator of Woods at the Smithsonian Institution and formerly Curator of the Samuel James Record Memorial Collection at Yale University and Dr. K.L. Chambers and Dr. G.K. Brizicky of Yale University, supplied the scientific knowledge and ability that made possible the wood identifications.

The cooperation of William F. Clapp Laboratories and particularly of Mr. Albert P. Richards, president of that organization, who made two trips to Panama as consultant during field inspections of marine borer samples, is gratefully acknowledged. Mrs. Dorothy J. Wallour, also of Clapp Laboratories gave valuable assistance in the identification of borer species.

The authors are grateful to the Koppers Company for performing the creosote treatment of controls for the marine borer resistance tests and to Mr. S.M. Miller, of the Marine Laboratory, University of Miami, for treating the controls for the stake tests.

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APPENDIX A

NOTES ON SOME RESISTANT WOOD SPECIES

The woods described in this Appendix were among those found to have high resistance in one or more of the test environments. They have been selected for discussion because they are considered to be of special interest, either for their high resistance or for a combination of resistance and commercial usability.

Photographs on these pages show some of the special interest woods compared to other well known or reputedly resistant species of similar density.

Bombacopsis quinata - cedro espino

The heartwood of this species was very durable in the ground, showing high resistance to termites and decay. In addition, the heartwood was moderately resistant to both ocean and Miraflores Lake marine borers. For a medium density wood such all around resistance is exceptional. Ten Panamanian woods have been tested previously for resistance to termites and decay in the Canal Zone by the U.S. Forestry Service (A1); of the ten woods only cedro espino was reported to have any long term resistance. This should not give the impression that this is the only durable wood in the ground. In these current studies, where 114 species were tested, 26 woods were found to be durable for 18 months. Cedro espino, however, was the only one of the 26 included in the Forestry Service exposures.

This is a large tree of common occurrence in Panama and is well known to the local lumbermen by whom it is considered a good general purpose construction timber although it is reported to cause corrosion of iron fasteners. Figure A-1 compares samples of cedro espino with southern pine after a 14-month exposure in the sea water at Fort Amador, C.Z.

(A)

(B)

Fig. A1 - Cutaway view of marine borer exposure specimens after 14 months in the ocean. Cedro espino (A) compared to the control, southern pine (B).

Cariniana pyriformis - chibuga, albarco

Chibuga had high resistance to subterranean termites and moderate resistance to terrestrial decay and to marine borers in both exposures. Wolcott (A2) reports moderate resistance to termites and Edmondson found only light teredo attack after 18 months on samples from Colombia. The wood is known to occur near the Panama-Colombia border where it is reported to be of frequent occurrence and in good timber stands. It has a reputation for difficulty in working due to silica deposits. When cut and polished it has a beautiful finish resembling that of bleached mahogany and was for a time marketed as "Colombian mahogany."

Centrolobium orinocense - amarillo de guayaquil

In Panama not much is known about the occurrence of this wood as to either frequency or size, but the timber is esteemed by local boatbuilders, and it is reported to be of frequent occurrence in the province of Darien. It is of interest because it seems to be a fine, moderately heavy wood of good properties and in the stake tests was highly durable to both subterranean termites and terrestrial decay.

Chlorophora tinctoria - mora

In these Canal Zone studies mora was one of the all around resistant woods. It was highly resistant to decay and subterranean termites for the 18-month exposure and to marine borers in the ocean for 14 months. It was moderately resistant to the destructive teredo inhabiting the brackish water of Miraflores Lake. The wood is well known in the Panama lumber market and highly esteemed by boatbuilders, but apparently is not very plentiful. However, it is reported by Allen (A3) to be a common species near the Panama-Costa Rican border, and is considered by United Fruit Company Engineers to be their best all-purpose heavy construction timber. It is known in that area for its high resistance to insect attack and decay in contact with the ground, and the wood is considered hard and strong, with a somewhat interwoven grain that does not crack, check, or warp; it works easily and takes a high polish. Yale (A4, A5) reports physical properties similar to Black Locust and exceptionally low shrinkage, comparable to teak. They report high durability in contact with the ground. Wolcott (A2) rates it as having high resistance to dry wood termites. Edmondson found samples from Puerto Rico to be moderately resistant to teredo, but Clapp (A6) found high resistance for a 10-month exposure at Kure Beach, North Carolina. Photographs of mora compared with Burma teak after 14-month exposure in ocean and brackish water are shown in Fig. A2.

Chrysophyllum cainito - caimito, star apple

This species was one of the two Panamanian woods most resistant to marine borers for the first 14-month period. Considering both ocean and lake exposures, it was superior to most of the imported woods of reputed high resistance (Vouacapoua americana, Lophira procera, Callitris glauca, and Ocotea rodiei), but caimito was poorly resistant to terrestrial decay. Photographs in Fig. A3 show comparisons of marine borer samples of caimito and Lophira procera (bongassi).

Trees are of medium size and fairly common throughout Panama. The wood is hard, heavy and strong but its poor decay resistance seriously reduces the commercial possibilities. The unknown constituent that repels marine borers makes this wood particularly interesting.

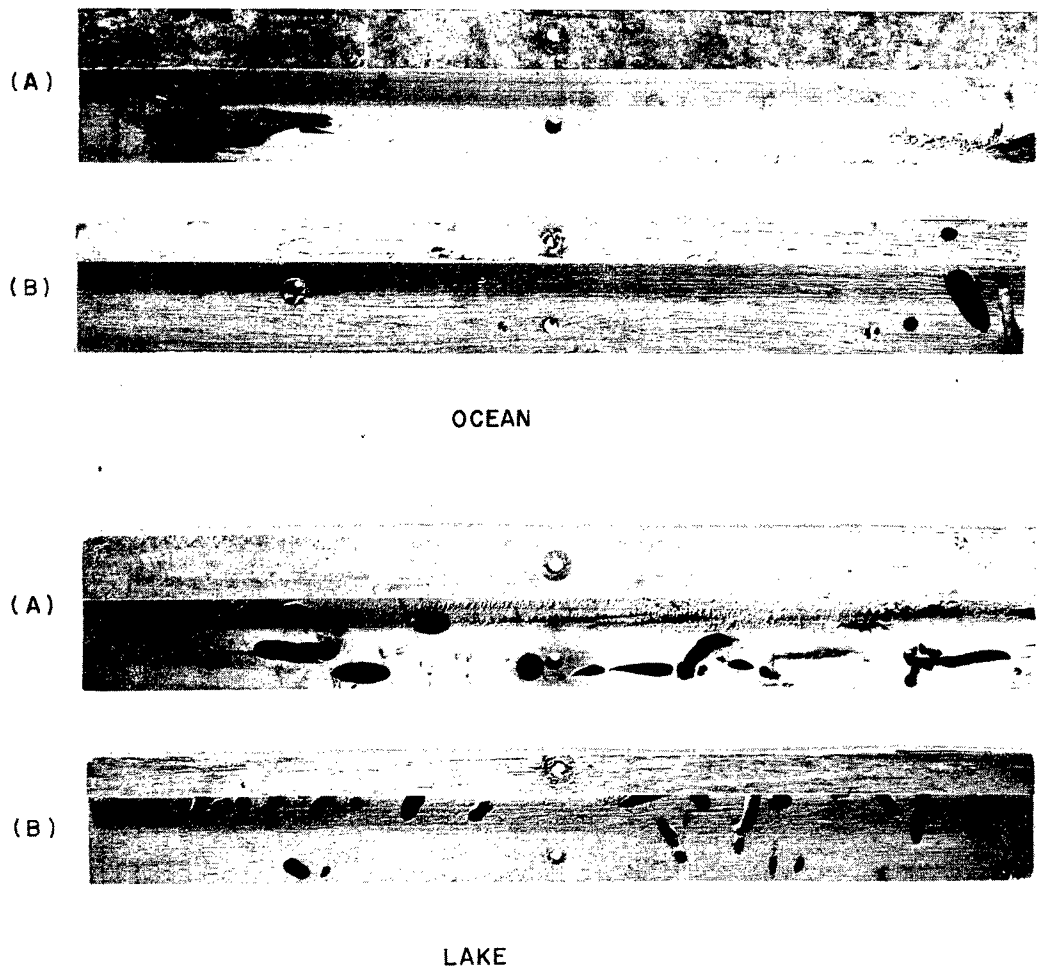

Fig. A2 - Cutaway view of marine borer exposure specimens after 14 months in the ocean. Mora (A) compared to Burma teak (B) for both ocean and lake exposures.

Conocarpus erectus - zarragosa

This tree is known in English as the "button mangrove" and is the only one of the five mangle swamp trees tested that was naturally resistant. Mangle woods, probably because they have resistant bark and grow in salt water tidal marshes, have a reputation for resistance to marine borers. Zarragosa wood actually is resistant. It had high resistance to ocean borers and moderate resistance to the brackish water borer in Miraflores Lake. Figure A4 compares samples of exposed wood of zarragosa with white mangrove, a typical nonresistant mangle. In addition the studies indicated zarragosa has high resistance to subterranean termites and decay. All four other mangles, red (Rizophora), white (Laguncularia), salada (Avicennia), and palo de sal (Pelliciera) were nonresistant in all environments.

Zarragosa wood is hard, heavy, and strong. Wood of this species from Puerto Rico was tested by Edmondson (A7) and found resistant to marine borers in Hawaiian waters.

The trees seem to be plentiful in mangrove swamps on the coasts of Panama, but they are small in size (the two tested were both 10 inches in diameter) and reported to be of poor form.

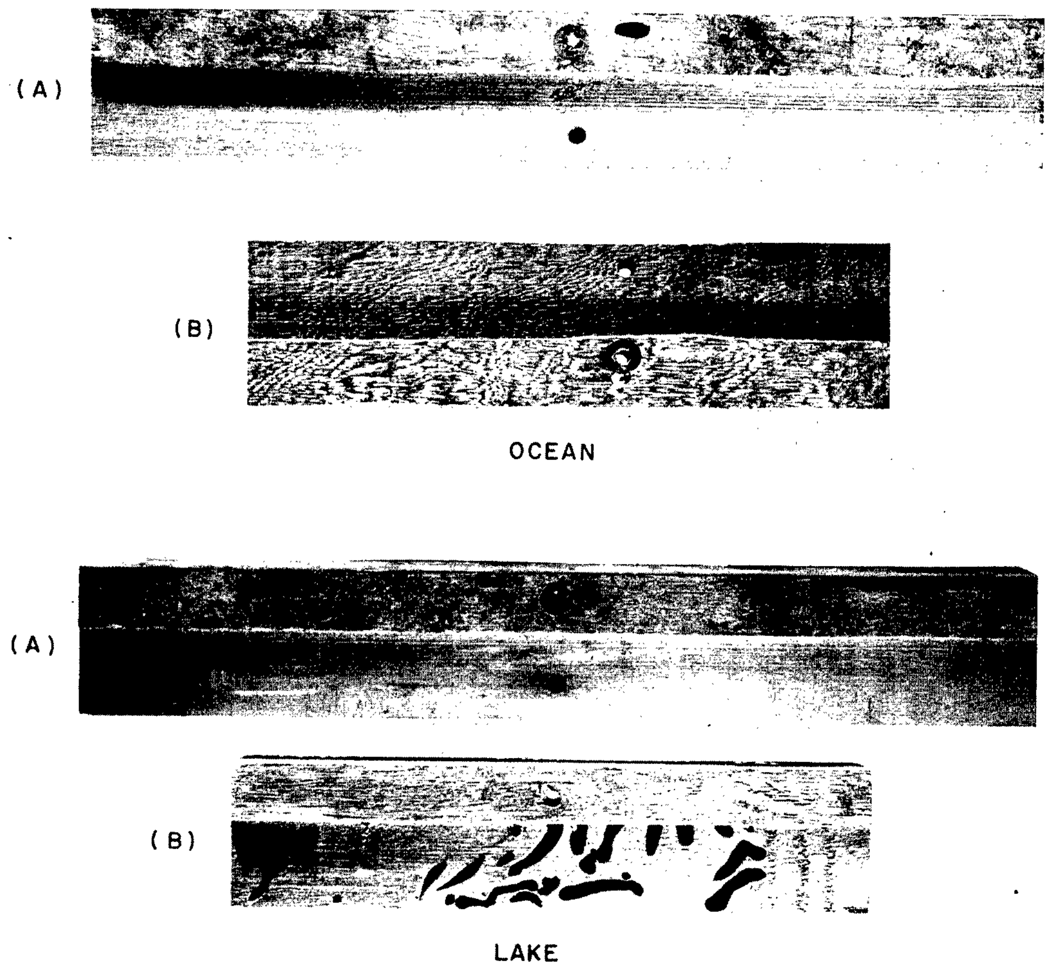

Fig. A3 - Cutaway view of marine borer exposure specimens after 14 months in the ocean and lake. Caimito (A) compared to Bongassi (B).

Copaifera aromatica - cabimo

An interesting species because of its excellent durability in the termite and decay studies and the beauty and usefulness of the wood. It was not, however, resistant to marine borers. This lumber is well known in Panama and highly esteemed for its high strength, easy working and smooth finishing properties. Reported as large forest trees and of frequent occurrence in Panama forests. Record and Hess (A8) state that all species of Copaifera contain gum or oil which are the source of the commercial product known as copabia balsam. Cabimo is considered a good general construction, flooring, and furniture wood in Panama and has been used for exterior facing in local plywood. Except possibly as plywood facing, it is not known to have been exported either commercially or in trial lots.

Cordia alliodora - laurel negro

One of the most interesting species in the investigation. Cordia alliodora wood is light weight, 0.42 air-dry specific gravity, and strong for its weight. It is of very common occurrence in all parts of Panama, but is logged only on a limited scale in Bocas del Toro

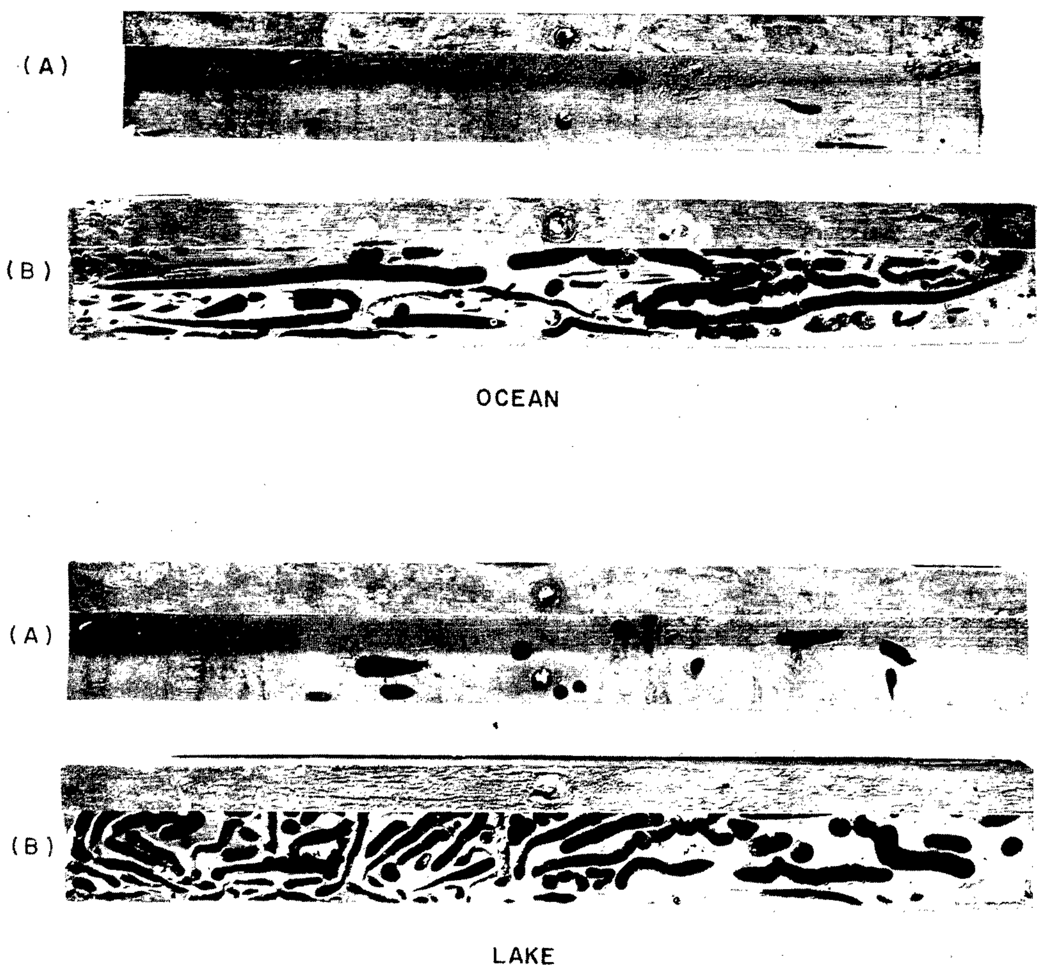

Fig. A4 - Cutaway view of marine borer exposure specimens after 14 months in the ocean and lake. Zarragosa (A) compared to white mangle (B).

Province. Lumbermen distinguish two types of lumber of this tree which are called laurel negro and laurel blanco (negro is considered to be the more desirable wood); however, botanically, only one species is recognized and any differences are attributed to growing conditions or age of trees. In these exposures laurel negro from Bocas del Toro was used.

Allen (A3) reports <u>Cordia alliodora</u> to be one of the most useful general purpose construction woods in the Golfo Dulce area of Costa Rica and lists it as being suitable for many purposes, including such varied uses as beams and girders, boat planking and oars, bridge boards, railroad ties, and interior construction. He also thinks this would be one of the finest native trees for reforestation since growth rate is rapid and remarkably uniform on cleared land. Record and Hess (A8) say <u>Cordia alliodora</u> is a medium size to large tree occurring throughout the American tropics, with useful and attractive wood, worthy of greater consideration by consumers everywhere. Extensive tests at Yale School of Forestry on <u>Cordia alliodora</u> from several Central American countries, with Panamanian wood having the best physical properties show the wood to be highly resistant to brown and white rot. It is easily worked, finishes smoothly, glues readily, holds its place remarkably well when manufactured, and has excellent characteristics. Edmondson (A7) tested <u>Cordia alliodora</u> from Puerto Rico in Hawaiian waters and found it nonresistant to marine borers.

In these exposure tests in the Canal Zone logs from three trees of Cordia alliodora were tested. Resistance to teredine borers and Limnoria in the ocean for 14 months was very high for all three; practically the only damage was from occasional pholad attack. This was exceptional resistance for a wood of this low density. In Miraflores Lake the resistance to teredo was moderate on two logs and low on one. Photographs of samples after a 14-month exposure in the ocean are compared to mahogany in Fig. A5. In the termite tests no attack occurred on any samples for 18 months in heavily infested ground. In decay resistance studies the wood appeared very durable for 12 months, but loss of strength near the ground line was observed on most of the samples after 18 months. Since Burma teak was somewhat similarly affected by the jungle exposure, the commercial possibilities of laurel should not be ignored because of this result. All in all laurel seems to be an exceptionally worthwhile wood that has been only slightly exploited. The heartwood of laurel negro is reported to be specially scented, and the constituents affording this light wood such high repellency to biological attack should be of great interest to wood chemists.

Coumarouna oleifera - almendro

Almendro was moderately resistant to marine borers in the ocean but severely attacked in brackish water. Termites and decay were totally repelled making it a very durable wood for other than underwater use. Wangaard (A9) reports extremely high

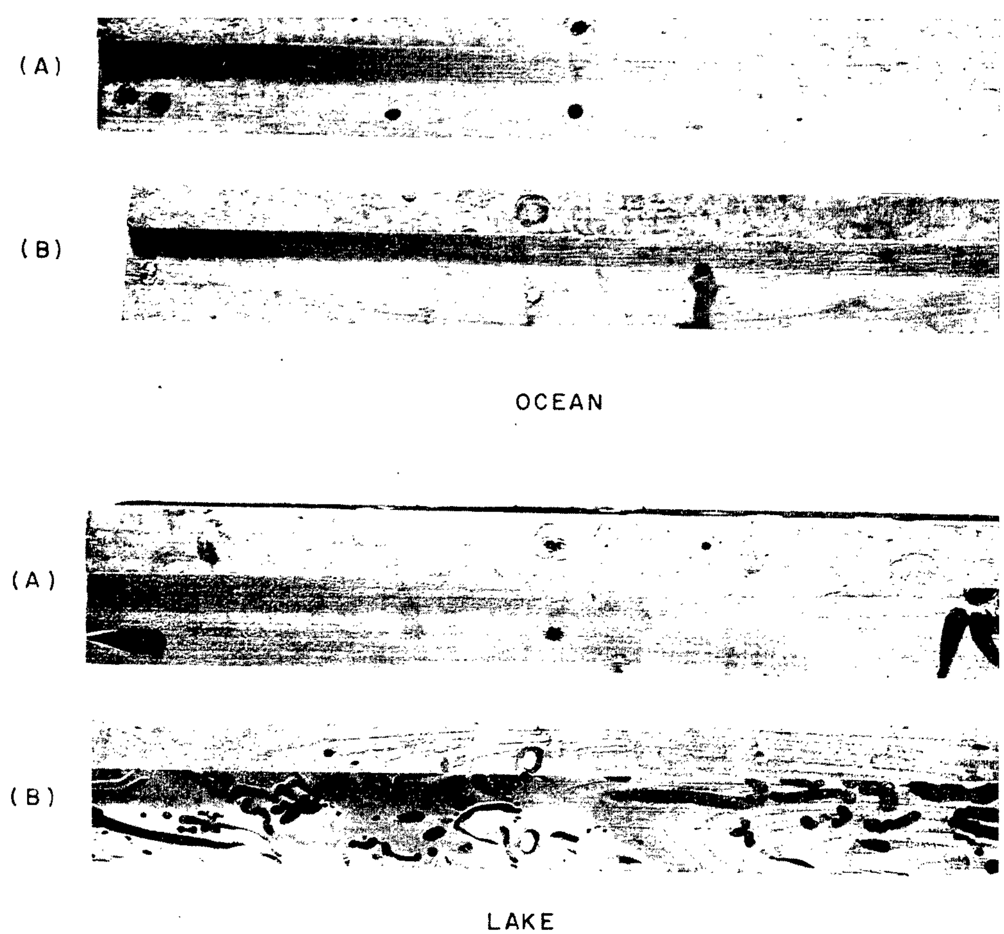

Fig. A5 - Cutaway view of marine borer exposure specimens after 14 months in the ocean. Three specimens of laurel negro (A) representing the three logs sampled are compared to mahogany (B).

mechanical properties and lists it as one of the best species for durable above water construction. Yale School of Forestry found it to resist both brown rot (Poria moticola) and white rot (Polyporus versicolor) in pure culture tests, further attesting to its durability. An extremely hard, heavy, roe-grained wood that has high resistance to splitting and cracking; it compares favorably with greenheart (Ocotea rodiei) in mechanical properties. Plentiful in the lowlands it grows to heights of 150 feet and reaches three feet in diameter. Its toughness, high shock-resistance, and other superb mechanical properties lend it to uses such as farm implements, heavy duty flooring, construction timbers, and crossties. To date this wood has not been extensively exploited.

Dalbergia retusa - cocobolo

Cocobolo is a well known hard wood and has been exported to the United States from Central America for many years for use as knife and tool handles, articles of turning, etc. Apparently it is not very plentiful or of good timber form in Panama. The wood contains an unusually heavy concentration of natural oils. It was highly resistant to all biological wood destroyers in these studies and was the only wood that showed high resistance in all exposures, although it was not completely unattacked by marine borers as was Pouteria campechiana.

Dicornia paraensis - angelique, basra locus

This wood is known for its high silica content and resistance to marine borers (A10). This high resistance was borne out in the present tests. Figure A6 shows angelique compared to guayacan after a 14-month exposure in both the ocean and lake. In the ground termites did not attack it but it showed only moderate resistance to decay. The Panama Canal Company imports this wood for special purpose use under salt, brackish, and fresh water. Good service has been reported for periods up to seven years.

Considering both the brackish and sea water exposures this wood was the most resistant to marine borers of any of the five woods of known high resistance included in the study (greenheart, angelique, bongassi, acapu, and Australian cypress pine). All of the above were excellent in sea water, but only angelique was highly resistant in brackish water. However, angelique and Australian cypress pine were only moderately resistant to jungle decay while the other four were highly resistant.

Enterolobium cyclocarpum - corotu

Edmondson (A7) reports that both green and seasoned wood was heavily attacked by teredine borers after six months but it proved slightly better in the present Canal Zone studies. After 14 months it was found to be poor in the brackish water exposure but moderately resistant in the ocean. The heartwood was very durable in the ground being highly resistant to termites and decay. Both Edmondson (A7) and Record and Hess (A8) report it as moderately durable, however, Allen (A3) states it is not termite resistant. The fact that the sapwood is very poor in most respects perhaps adds to the conflicting reports. A medium density wood it resembles walnut in appearance. The trees grow to large proportions, 6 - 8 ft in diameter and 85 ft high. Although plentiful in Panama it has not been commercially exploited. It is used elsewhere for dugouts, furniture, and general inside carpentry.

Guarea trichilioides - guaragao

This wood is mentioned by Record and Hess (A8) as being the most widely distributed of the genus. However, it is not well known by the local lumbermen, and its occurrence

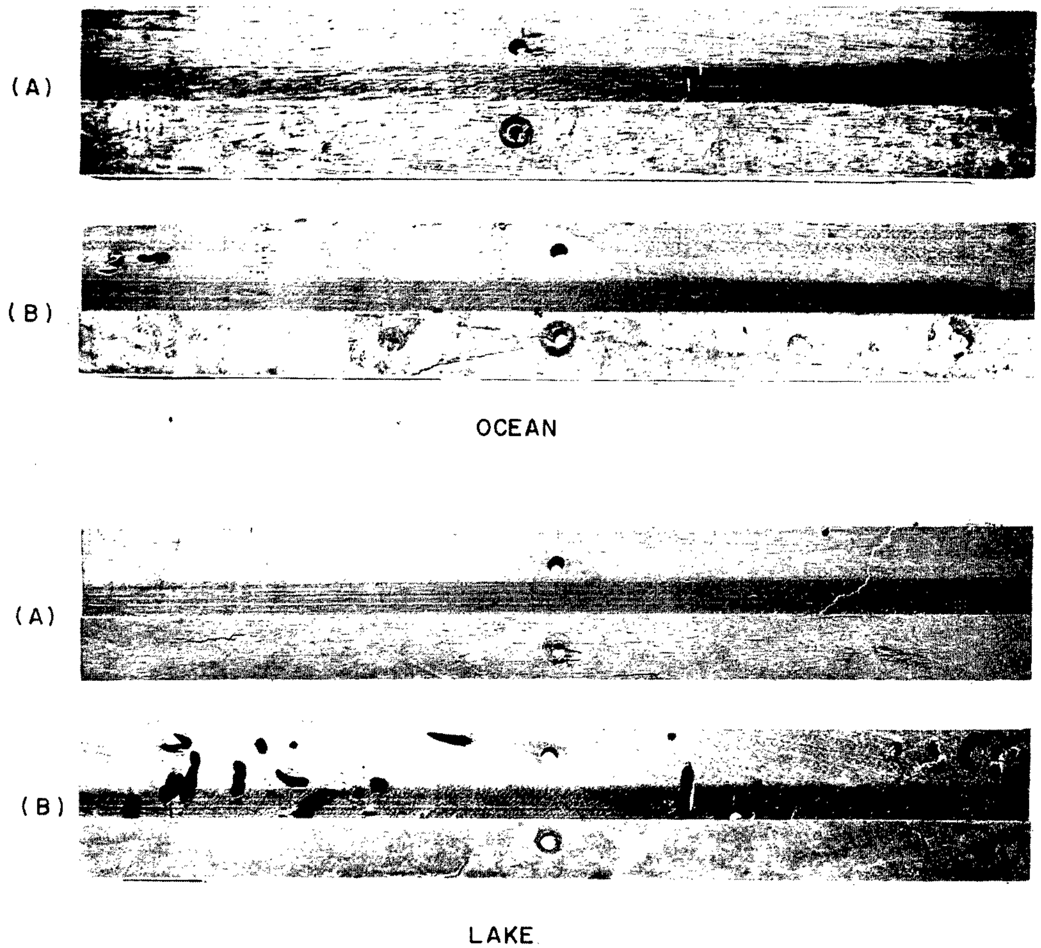

Fig. A6 - Cutaway view of marine borer exposure specimens after 14 months in the ocean and lake. Angelique (A) compared to guayacan (B).

in this area is undetermined as to size and quantity. Edmondson (A7) found that seasoned heartwood of this species from Puerto Rico was riddled by teredos after seven months. Wolcott rates this wood as moderately resistant to dry wood termites.

It is of interest because of its durability in contact with the ground, where it was found in this study to have high resistance to both subterranean termites and decay. It proved to be moderately resistant to marine borers in both exposures.

Hieronyma alchorneoides - pantano

This hard, heavy wood was found to have high resistance to ocean borers and subterranean termites and moderate resistance to Teredo healdi in Miraflores Lake, but has low decay resistance in contact with the ground.

It is a large forest free apparently quite common in Northern Panama and the Canal Zone, but not known, at least by this name, in Darien. The wood is available commercially in Panama City. Allen reports it common around Golfo Dulce, Costa Rica, but says it must be protected when in contact with the ground. Record and Hess (A8) report rather high durability, but say warping is a problem.

Ocotea dendrodaphne - ensiva, insiba

This wood, of the same genus as greenheart (Ocotea rodiei), showed moderate resistance to teredine borers in both exposures. It completely resisted decay and termite attack after 18-month exposure. Little can be found in the literature on this species and there is some question that the common name is representative. Samples were obtained in Darien Province where it is reported to be plentiful. The wood is moderately heavy and of very attractive appearance. The fragrant odor evident when sawing is a distinctive characteristic.

Paramachaerium gruberi - sangrillo negro

A hitherto unclassified species, this wood has been confused with tamarindo (Dialium guianense). While poorly resistant to marine borers in the ocean and moderately resistant in Miraflores Lake it was found highly resistant to both terrestrial decay and termites. The main point of interest is its excellent durability in contact with the ground. The United Fruit Company in Puerto Armuelles, Chiriqui, uses it satisfactorily in construction and it is reported to be fairly plentiful in that area. Its distribution and abundance in other areas is uncertain.

Platymiscium pinnatum - quira

A wood of very high all around resistance in these Canal Zone exposure studies, it was highly resistant to ocean borers, fungi, and subterranean termites, and moderately resistant to Miraflores Lake borers. Figure A7 shows cross sections of underwater samples of quira compared to greenheart.

The wood is hard, strong and handsome, and has been exported in the past as Panama redwood for use as tool and knife handles and articles of turnery. It is reported to make high quality flooring, paneling, cabinet work and furniture. It is well known by Panamanian boatbuilders and esteemed for keels, stems, and other heavy pieces and has a local reputation for resistance to marine borers. Trees are medium to large, 75 to 100 ft tall, and up to 3 ft in diameter. It occurs in Canal Zone forests but apparently is not very common. Reportedly it is of frequent occurrence in Chiriqui.

Pouteria campechiana - mamecillo

Mamecillo was one of the woods most resistant to marine borers in this study. Although the one tree tested was small (10 inches in diameter), after a 14-month exposure there was no damage to any of the 12 replicate samples either in the ocean or lake. Figure A8 shows comparisons of pieces of this wood with Acapu after a 14-month exposure. Little is known about the abundance or size of trees of mamecillo. They are reported to be of frequent occurrence in Darien and to grow tall and slender. They are also said to occur fairly commonly in the Canal Zone. The wood is hard, heavy, and strong but not durable in the ground. It is of particular interest because of the very high resistance to marine borers.

Pouteria chiricana - nispero de monte

This, another species of Pouteria, also has very high resistance to marine borers. Edmondson (A7) found still another species, P. demerarae, to have good resistance. Nispero de monte is reported to reach great size (the two tested were not large, 10- and 15-inch diameters) and to be quite common in the Canal Zone area. It is reported to be well known and fairly frequent in Darien and said to grow tall and slender there, suitable for piling. As with mamecillo it was susceptible to fungal decay in the ground. The principal interest was its high resistance to marine borers.

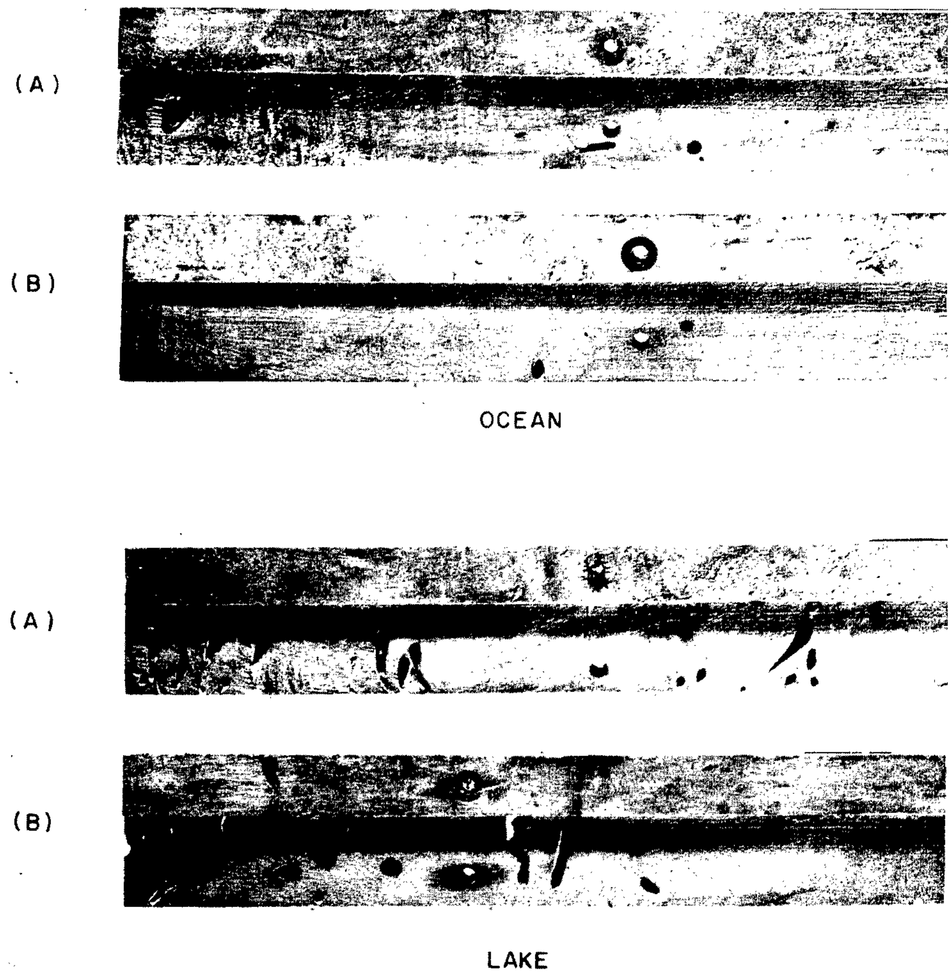

Fig. A7 - Cutaway view of marine borer exposure specimens after 14 months in the ocean and lake. Quira (A) compared to greenheart.

Tabebuia guayacan - guayacan

Of the three species of Tabebuia tested, guayacan was in all respects superior. It proved to have high resistance to termites and decay. It was also highly resistant to marine borers in the ocean, but to the brackish water borers it was only moderately resistant. Yale School of Forestry reported this wood very durable to both white rot and brown rot in pure culture tests. An outstanding example of the durability is the number of trees still standing in Gatun Lake (fresh water) some 50 years after the lake was flooded (Fig. 12). Several churches in Panama, approximately 300 years old are believed to still have the original guayacan beams.

Guayacan is a hard, heavy wood, and is found as large trees, fairly common in Darien Province. The wood was suggested by Yale to be suitable for construction timbers, flooring, furniture, and marine piling. It is moderately difficult to season.

Tabebuia pentaphylla - roble de sabana

In appearance this wood resembles oak (Quercus), therefore its Spanish name of roble. It was more durable than the true oak from the mountains of Chiriqui Province. Roble de

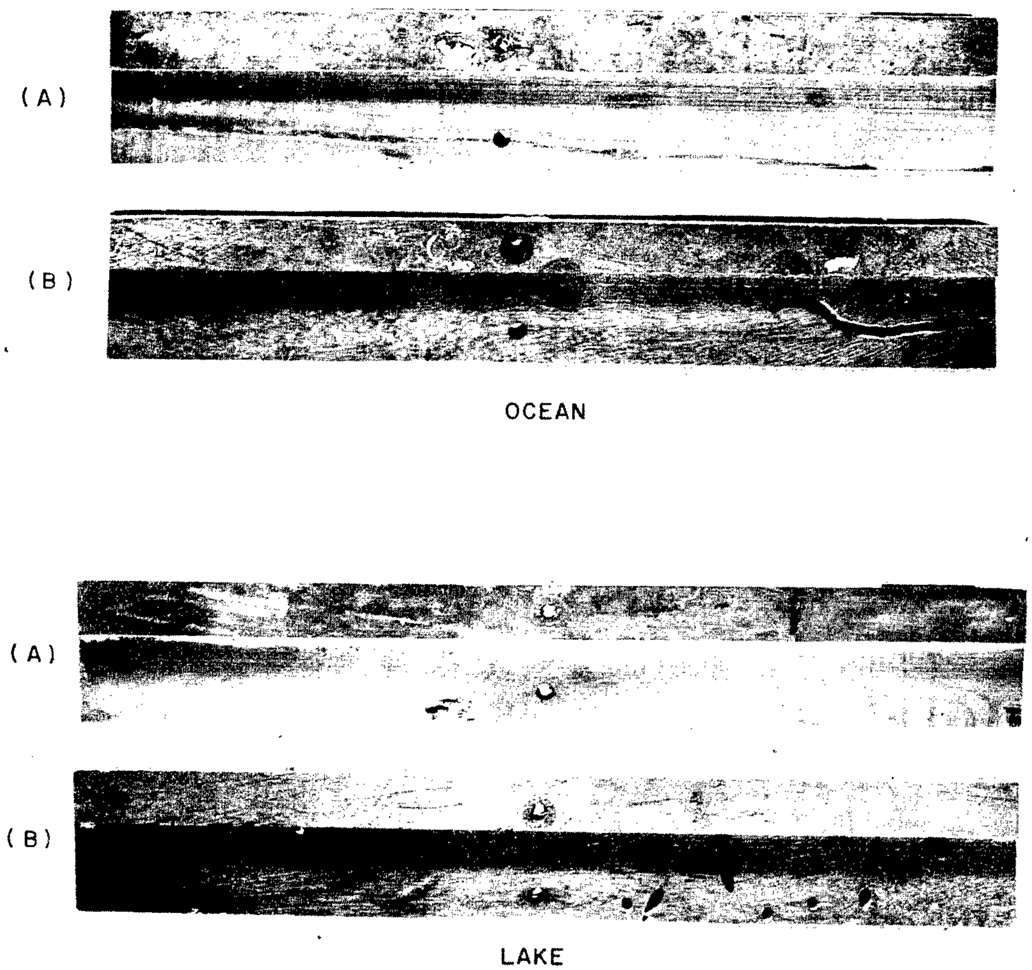

Fig. A8 - Cutaway view of marine borer exposure specimens after 14 months in the ocean and lake. Mamecillo (A) compared to acapu (B).

sabana was found to be moderately resistant to decay, termites, and marine borers. Yale School of Forestry in pure culture tests also observed moderate durability to white and brown rot. The trees attain large size and are plentiful. Since it seasons easily and works well this close grained, hard, medium density wood is used frequently for construction, carpentry, and furniture.

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APPENDIX B

ALPHABETICAL LISTING OF WOODS STUDIED SCIENTIFIC AND COMMON NAMES

Acabú - see Zanthoxylum belizense

Acapú - see Vouacapoua americana

Aguacatillo - see Phoebe johnstonii

Ajo - see Caryocar sp.

Alazano - see Calycophyllum candidissium

Albarco - see Cariniana pyriformis

Alcarreto - see Aspidosperma megalocarpon

Alcornoque - see Mora oleifera

Alfaje - see Trichilia tuberculata

Algarrobo - see Hymenaea courbaril

Almacigo - see Bursera simaruba

Almendro - see Coumarouna oleifera

Almond - see Terminalia catappa

Amargo-amargo - see Vatairea sp.

Amarillo - see Terminalia amazonia

Amarillo de guayaquil - see Centrolobium orinocense

Amarillo negro - see Lafoensia punicifolia

Anacardium excelsum - espavé

Andira inermis - cocú

Angelique - see Dicorynia paraensis

Animé - see Tetragastris panamensis

Arcabú - see Zanthoxylum belizense

Aspidosperma megalocarpon (probably) - carreto, alcarreto

Astronium graveolens - zorro, zorillo, or ron-ron

Australian cypress pine - see Callitris glauca

Avicennia nitida - mangle salada

Azobe - see Lophira procera

Baco - see Magnolia sororum

Bala - see Lophira procera

Bálsamo - see Myroxylon balsamum

Bambito - see Nectandra whitei

Basra locus - see Dicorynia paraensis

Bateo - see Carapa slateri

Berba - see Brosimum sp.

Bogamani - see Virola koschnyi

Bombacopsis quinata - cedro espino

Bombacopsis sessilis - ceibo

Bongassi - see Lophira procera

Bronze shower - see Cassia moschata

Brosimum sp. - berba, guayabo blanco

Bursera simaruba - almacigo, indio desnudo

Byrsonima crassifolia - nance

Cabimo - see Copaifera aromatica

Caimito - see Chrysophyllum cainito

Callitris glauca - Australian cypress pine

Calophyllum brasiliense - maría

Calycophyllum candidissium - alazano, lemonwood, lancewood

Caoba - see Swietenia macrophylla

Caraño - see Trattinickia aspera

Carapa slateri - cedro macho, bateo, tangaré

Carapa sp. - cedro vino

Carbonero de amunicion - see Colubrina glandulosa

Cariniana pyriformis - chibugá, albarco

Carreto - see Aspidosperma megalocarpon

Caryocar costaricense - henene

Caryocar sp. - ajo

Cassia moschata - bronze shower

Cativo - see Prioria copaifera

Cedrela mexicana - cedro amargo

Cedrela sp. - cedro granadino

Cedro amargo - see Cedrela mexicana

Cedro espino - see Bombacopsis quinata

Cedro granadino - see Cedrela sp.

Cedro macho - see Carapa slateri

Cedro vino - see Carapa sp.

Ceibo - see Bombacopsis sessilis

Centrolobium orinocense - amarillo de guayaquil

Cerillo - see Symphonia globulifera

Chibugá - see Cariniana pyriformis

Chlorophora tinctoria - mora

Chrysophyllum cainito - caimito, star apple

Chuchupate - see Guarea longipetiolata

Coco - see Lecythis ampla
Coco - see Lecythis or Manilkara
Cocobolo - see Dalbergia retusa
Cocú - see Andira inermis
Colubrina glandulosa - carbonero de amunicion
Conocarpus erectus - zarragosa
Copaifera aromatica - cabimo
Cordia alliodora - laurel negro
Cornus disciflora - mata hombro
Corotú - see Enterolobium cyclocarpum
Coumarouna oleifera - almendro
Crillo - see Minquartia guianensis
Croton panamensis - sangre
Cuajado - see Vitex floridula
Cutarro - see Swartzia panamensis
Dalbergia retusa - cocobolo
Dalienze - see Terminalia myriocarpa
Dialium guianense - tamarindo
Dialyanthera otoba - miguelario
Dicorynia paraensis - angelique, basra locus
Diphysa robinioides - macano
Douglas fir - see Pseudotsuga taxifolia
Ekki - see Lophira procera
Ensiva - see Ocotea dendrodaphne
Enterolobium cyclocarpum - corotú
Eschweilera (probably) - guayabo macho
Espavé - see Anacardium excelsum
Erythrina glauca - gallito
Gallito - see Erythrina glauca
Gavilán - see Pentaclethra macroloba
Genipa americana - jagua
Gliricidia sepium - bala, mata ratón
Gorogán - see Virola koschnyi
Greenheart - see Ocotea rodiei
Guácimo - see Luehea seemannii
Guaragao - see Guarea trichilioides
Guaiacum officinale - lignum vitae
Guarea longipetiolata - chuchupate
Guarea trichilioides - guaragao
Guayabo blanco - see Brosimum sp.
Guayabo macho - see Eschweilera
Guayacán - see Tabebuia guayacan
Guayacán negro - see Tabebuia chrysantha
Henéné - see Caryocar costaricense
Hieronyma alchorneoides - pantano
Hippomane mancinella - manzanillo
Hura crepitans - nuno
Hymenaea courbaril - algarrobo
Iguanillo - see Lonchocarpus sp.
Indio desnudo - see Bursera simaruba
Insiba - see Ocotea dendrodaphne
Iron wood - see Lophira procera
Jagua - see Genipa americana
Jigua negro - see Licaria pittieri
Lafoensia punicifolia - amarillo negro
Laguncularia racemosa - mangle blanco
Lancewood - see Calycophyllum candidissium
Laurel negro - see Cordia alliodora
Lecythis sp. - coco
Lecythis ampla - coco
Lemonwood - see Calycophyllum candidissium
Licania arborea - raspa
Licaria pittieri - jigua negro
Lignum vitae - see Guaiacum officinale
Lonchocarpus sp. - iguanillo
Lophira procera - bongassi, ekki, azobe, iron wood
Luehea seemannii - guácimo
Macano - see Diphysa robinioides
Macano blanco - Unknown genus
Macho - see Tetrathylacium johansenii
Magnolia sororum - vaco, baco
Mahogany - see Swietenia macrophylla
Malvecino - see Sweetia panamensis
Mamecillo - see Pouteria campechiana
Mancha - see Virola sebifera
Mangle blanco - see Laguncularia racemosa
Mangle rojo (Atlantic) - see Rizophora mangle
Mangle rojo (Pacific) - see Rizophora brevistyla
Mangle salada - see Avicennia nitida
Manglillo - see Ternstroemia seemanii
Manilkara - coco
Manilkara bidentata - níspero balata
Manilkara chicle - níspero zapote
Manilkara sp. - rasca
Manwood - see Minquartia guianensis
Manzanillo - see Hippomane mancinella
Maria - see Calophyllum brasiliense
Mata hombro - see Cornus disciflora
Mata ratón - see Gliricidia sepium
Mayo - see Vochysia ferruginea
Miguelario - see Dialyanthera otoba
Minquartia guianensis - crillo, manwood

Mora - see Chlorophora tinctoria
Mora oleifera - alcornoque
Myroxylon balsamum - bálsamo
Nance - see Byrsonima crassifolia
Naranjillo - Unknown genus
Naranjito - see Swartzia simplex
Native oak - see Quercus sp.
Nazareño - see Peltogyne purpurea
Nectandra whitei - bambito
Nicaraguan pine - see Pinus caribaea
Níspero balata - see Manilkara bidentata
Níspero de monte - see Pouteria chiricana
Níspero zapote - see Manilkara chicle
Nuno - see Hura crepitans
Ocotea dendrodaphne - ensiva or insiba
Ocotea rodiei - greenheart
Palo de sal - see Pelliciera rhizophorae
Panamá - see Sterculia apetala
Pantano - see Hieronyma alchorneoides
Paramachaerium gruberi - sangrillo negro
Pelliciera rhizophorae - palo de sal
Peltogyne purpurea - nazareño
Pentaclethra macroloba - gávilan
Phoebe johnstonii - aguacatillo
Pinus caribaea - nicaraguan pine
Pinus sp. - southern yellow pine
Pithecellobium mangense - uña de gato
Pithecellobium saman - rain tree
Platymiscium pinnatum - quirá
Pouteria chiricana - níspero de monte
Pouteria campechiana - mamecillo
Prioria copaifera - cativo
Pseudotsuga taxifolia - Douglas fir
Quercus sp. - roble de monte, native oak
Quirá - see Platymiscium pinnatum
Rain tree - see Pithecellobium saman
Rasca - see Manilkara sp.
Raspa - see Licania arborea
Rizophora brevistyla - mangle rojo (Pacific)
Rizophora mangle - mangle rojo (Atlantic)
Roble de monte - see Quercus sp.
Roble de sabana - see Tabebuia pentaphylla
Ron-ron - see Astronium graveolens
Sambogum - see Symphonia globulifera
Sangre - see Croton panamensis
Sangrillo negro - see Paramachaerium gruberi
Sigua - Unknown genus
Southern yellow pine - see Pinus sp.
Star apple - see Chrysophyllum cainito
Sterculia apetala - Panama
Swartzia panamensis - cutarro
Swartzia simplex - naranjito
Sweetia panamensis - malvecino
Swietenia macrophylla - mahogany, caoba
Symphonia globulifera - sambogum, cerillo
Tabebuia chrysantha - guayacán negro
Tabebuia guayacan - guayacán
Tabebuia pentaphylla - roble de sabana
Tamarindo - see Dialium guianense
Tangaré - see Carapa slateri
Teak (Burma) - see Tectona grandis
Teak (Canal Zone grown) - see Tectona grandis
Tectona grandis - teak (Burma)
Tectona grandis - teak (Canal Zone grown)
Terminalia amazonia - amarillo
Terminalia catappa - almond
Terminalia myriocarpa - dalienze (Panamanian grown)
Ternstroemia seemanii - manglillo
Tetragastris panamensis - animé
Tetrathylacium johansenii - macho
Trattinickia aspera - caraño
Trichilia tuberculata - alfaje
Uña de gato - see Pithecellobium mangense
Vaco - see Magnolia sororum
Vasca - Unknown genus
Vatairea sp. (probably) - amargo-amargo
Virola koschnyi - bogamaní, gorogán
Virola sebifera - mancha
Vitex floridula - cuajado
Vochysia ferruginea - mayo
Vouacapoua americana - acapú
Zanthoxylum belizense - acabú, arcabú
Zarragosa - see Conocarpus erectus
Zorillo - see Astronium graveolens
Zorro - see Astronium graveolens
UNIDENTIFIED - macano blanco
UNIDENTIFIED - naranjillo
UNIDENTIFIED - sigua
UNIDENTIFIED - vasca