Balsa—*Production and Utilization*

Although not the lightest known wood, balsa is the lightest commercial timber, and as such has found utilization in the manufacture of airplanes, life preservers, insulating equipment and packing crates. During recent war years Ecuador supplied 95 percent of world production but must now meet competition from wild and cultivated sources in Central America and Ceylon.

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Introduction

Spanish Conquistadores under the leadership of Pizarro sailed along the northwest coast of South America from Panama to Ecuador and observed native Indians sailing a gigantic raft made of logs lashed together with vines. The mast carried a huge cotton lugsail, and in the center of the raft was a kitchen raised like a quarter-deck. As a seagoing craft it represented the highest development ever produced by any pre-Columbian people, and similar crafts are still in use on the Rio Guayas of Ecuador today. To this primitive contraption for navigation the Spaniards applied the name " balsa ", their equivalent for our word " raft ". This same term later came into use with reference to small boats made by other tribes of Indians and used by them on the high waters of Lake Titicaca. The latter craft, however, were not made of logs but of reeds that grow along the margin of Titicaca. They are still made and used by the Indians of that region and are still known in Spanish as well as English as " balsas ". The name was applied also to the logs of which the coastwise craft were made, so that today the word " balsa " has two applications, one to the kind of wood that was used in those coastal rafts, the other to canoe-like boats made from reeds that grow along the shore of Titicaca. It is only with respect to the first of these uses, that is, with regard to certain trees and the timber obtained from them, that we are concerned in this article.

Taxonomy and Nomenclature

The trees which furnished the material for those primitive coastwise rafts and which are today known as " balsa " have been placed in the genus *Ochroma*, of which, for all practical purposes, there is only one species, *O. lagopus* Sw. (*O. pyramidale* (Cav.) Urb.). As many as eleven species have been recognized, but they can well be regarded as varieties of one. These variations are found in the West Indies and from southern Mexico through Central America into Colombia and Ecuador. *Ochroma* is one of about 25 genera in the family Bombacaceae which includes *Ceiba*, the silk-cotton tree that is the source of kapok gathered as fibers attached to its seeds.

While generally referred to as " balsa " and in Jamaica as " corkwood ", " down-tree " or " dum ", these trees and the timber which they yield are known in

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various parts of Latin America by a variety of native names which are listed in Record and Hess' " Timbers of the New World ".

Description

Balsa trees are deciduous and attain heights up to 60 feet or more when given ample room on rich well-drained soil at low elevation. At maturity two-thirds to three-quarters of their trunks may be free of branches. Growth is usually rapid, exceeded perhaps only by that of papaya; in one year a height of 12 feet and a diameter of two inches or more may be attained, and trees five to eight years old may be 60 feet tall and 24 to 30 inches in diameter.

In Ecuador flowering occurs in August, and the large showy blossoms are succeeded by fawn-colored fruits not unlike huge cotton bolls about the size of a man's hand. The resemblance of the fruit when mature but not yet burst open to a rabbit's foot presumably accounts for the specific name *lagopus*. When the fruit bursts a mass of down emerges with grape-like seeds buried in it. The down consists of fibers attached to the seeds, but not permanently as in cotton. The seeds, 1000 to the ounce, are picked from the pods by hand when they are to be used for plantation plantings and for experimental purposes.

Wood

It is the wood of balsa trees that bestows upon them whatever value they possess in the trade of the world, for that wood, while not the lightest known, is the source of the lightest commercial timber. There are other woods lighter than balsa, but they lack its strength and are not available in sufficient size or quantity to be commercially important [1].

Wood, as ordinarily known, owes its properties of weight, hardness and other features to the fact that the walls of the cells which compose it become greatly thickened as they mature and undergo complicated chemical changes, including deposition of a substance known as " lignin " in them. This process of lignification results in the total or almost total eradication of cavities within the cells by virtue of those cavities becoming obliterated by the thickening walls. The result is that wood, generally speaking, is a mass of thick-walled cells, referred to as " fibers ", which give it strength and other qualities. In balsa and other extremely lightweight woods, however, this process of lignification takes place only to a very slight degree or not at all, and at maturity of the trees producing those woods the cells which compose them are still thin-walled and have air-filled cavities within them. Hence their lightness. It may be argued, therefore, that balsa should not be referred to as " wood ", since it has not undergone the lignification which is the essential feature of wood proper. Retention of the term is desirable, however, in distinguishing the material of the stem from the trees as a whole, and is used for that purpose in this article.

Balsa wood does not display annual rings but has uniform growth, as is generally characteristics of tropical trees. It is usually oyster-white, is simetimes tinged with shades ranging from pink to brown, has a silky luster and appears velvety to the touch. It is so soft that it can be dented easily with one's fingernail. Its uniform, spongy, almost parenchymatous texture, because of its very small percentage of actual wood fiber, is

[1] According to one report (5), in which three specimens of balsa are given the specific gravities .377, .120 and .116, the following specific gravities are assigned to five lighter woods: *Cavanillesia arborea* of Brazil, .106; *C. platanifolia* of Panama, .103; *Herminiera elaphroxylon* of the African Nile region, .065; *Alstonia spathulata* of Malaya, .058; *Aeschynomene hispida*, .044.

nine-tenths air by volume when dried and one-tenth thin-walled cells.

Well-seasoned commercial balsa has a specific gravity of 0.2, which is about half that of cork. Its strength is half that of spruce wood, the modulus of rupture being 2100 pounds per square inch, the crushing strength 2150 pounds per square inch. At present it is the lightest known wood having sufficient strength and stiffness to be commercially useful. However, Wm. T. Cox, forester-biologist of the Foreign Economic Administration in 1942–43, in studying Ecuador's forests felt that cuipo (*Cavanillesia platanifolia*) " a very large tree occurring in heavy stands may become important as a wood averaging as light or lighter than balsa " (4). He also points out that the weight of balsa is not uniform but varies from 5½ pounds to 25 pounds per cubic foot of dry lumber, which he believes is a wider range than for any other lumber known. Even the heaviest balsa—14 to 25 pounds—has uses, but they are not those for which balsa is ordinarily desired.

Locally natives have noted two types of trees which they call " hembra " (female) and " macho " (male) because of their different natures. The tree called " hembra " sounds squashy inside when the trunk is struck with a machete, much as though cutting into a thick piece of cactus. El macho, while similar in appearance, has a hard metallic ring when struck, and the machete penetrates only a fraction of an inch. This may be due to some change in structure which takes place with age.

In general, after they are twelve years old, there is a tendency for denser wood to form on the outside of trees. During this same period heart rot, called " water heart ", frequently occurs at the center of the trunk. For these reasons, wood from young trees is preferred for industrial uses, since it is extremely light.

Physical Requirements of Balsa

Climate. Balsa is a tree of the humid tropics where rainfall is great and temperatures have but small range and are constantly high. Quevedo, the center of balsa production in Ecuador, has an average annual rainfall of 100 inches. Rainfall varies with elevation, becoming heavier toward the mountains. Where elevations are over 100 feet above sea level, 100 inches is the general average. The tropical Guayas-Duale-Vincas basin, where 65 percent of Ecuador's balsa is cut, recognizes only two seasons—the rainy season or invierno, which extends from December to May or June, and the dry season called verano or summer, which extends from June to November. The wet season is broken by the veranillo, a short period of dry weather, which comes shortly after the December solstice. In like manner the dry season is broken by the inviernillo (little winter) or " cordonazo de San Francisco ", a short rainy period which follows the September equinox. In addition, the winter season may have cloudless skies at times. Likewise either the drizzling mist and light rains, locally called the " garüa ", or frequent dense morning fogs may break the drought of summer.

The mean summer temperature in this area is about 77° and the mean of winter 80° to 82° on the plain. These temperature and rainfall figures are comparable to those found in other tropical countries where balsa is produced.

Topography. Balsa trees thrive on tropical coastal lowlands from sea level to 2500 feet near mountains where there is plenty of moisture plus proper drainage which is essential. The littoral of Ecuador is not greatly handicapped by topographic conditions, since most of it is low-lying with few hills that can be considered serious obstacles.

Soils. The balsa tree does best on well-drained, moist, sandy soils of the jungle. These conditions, together with heavy rainfall, insure rapid growth which gives the wood its singular lightness. As a result of experimental work carried on in Ceylon (6), the curator of the Royal Botanical Gardens gives the ideal conditions and site for raising balsa as: *a*) light porous or sandy soil containing a small amount of humus; *b*) a location along the banks of rivers where sand may be washed up by floods; *c*) an elevation of not over 2000 feet; *d*) and rainfall of approximately 100 inches annually. Ceylon, which is in the monsoon tropics, experienced a severe drought in 1945 when the southwest monsoon failed. Though all other physical requirements were met, the rainfall that year did not permit balsa to maintain the normal rate of growth for marketable timber.

Distribution

Balsa is indigenous throughout Middle America and the northwestern part of South America. It grows in a dozen varieties from the southern part of Mexico to Peru. None grows naturally in the United States.

Ecuador. The tree has greater commercial significance in Ecuador than in any other country of tropical America. In 1943 Ecuador controlled 95 percent of the world's production, largely because the trees are found in the greatest amounts and best quality there.

There are four areas which produce balsa in quantity. All are in the littoral, with Guayaquil as the principal focus of activity. The Piedras area in the Province of El Oro (3° 10′ S.), southeast of Guayaquil, has not been exploited and will no doubt be a future source of supply. The Santo Domingo region (15′ S. 79° 10′ W.) in the Province of Pinchincha also has virgin forests that are untouched.

The main area of growth and production is between Quito and Guayaquil, in the Andean foothills surrounding Quevedo in the Province of Los Rios, where soil and climatic conditions are ideal for growth. At present 65 percent of the balsa cut in Ecuador comes from the Quevedo district. Because of plantation methods begun, as well as wild growth, it is expected that this will remain the principal producing area. It has easy access to the sawmills in Guayaquil via the many tributaries of the Guayas River.

Another 25 percent of Ecuador's commercial production comes from the area surrounding Esmeraldas in the extreme northwest of the country. Because of the great distances and operation difficulties there, it is customary to cut balsa of smaller diameter. This makes for a lighter finer grade lumber but causes far greater waste in sawing. Most of the logs are floated down the Esmeraldas to the mills at the port of the same name, but some find their way to mills at Rio Verde, Borbón and Limones.

The fourth area is in Manabi Province along the coast in a semicircle extending from Manta to Santa Ana and then north to the coast again. About ten percent of Ecuador's production comes from this region, making it the third most important production area. Due to seasonal rainfall which results in low water conditions at times, transportation by streams is not always possible, so that trucks and a railroad spur operate between Santa Ana and the port of Manta during the dry season. In the wet season logs go by river to Manta and Bahia de Caráquez. This has resulted in the cutting of trees before they have attained their greatest commercial value.

Peru, Colombia, Venezuela. Balsa occurs in the Amazon region of Peru, in the Magdalena River Region of Colombia, and in the tropical lowlands of Venezuela. All these countries exported small quantities to the United States

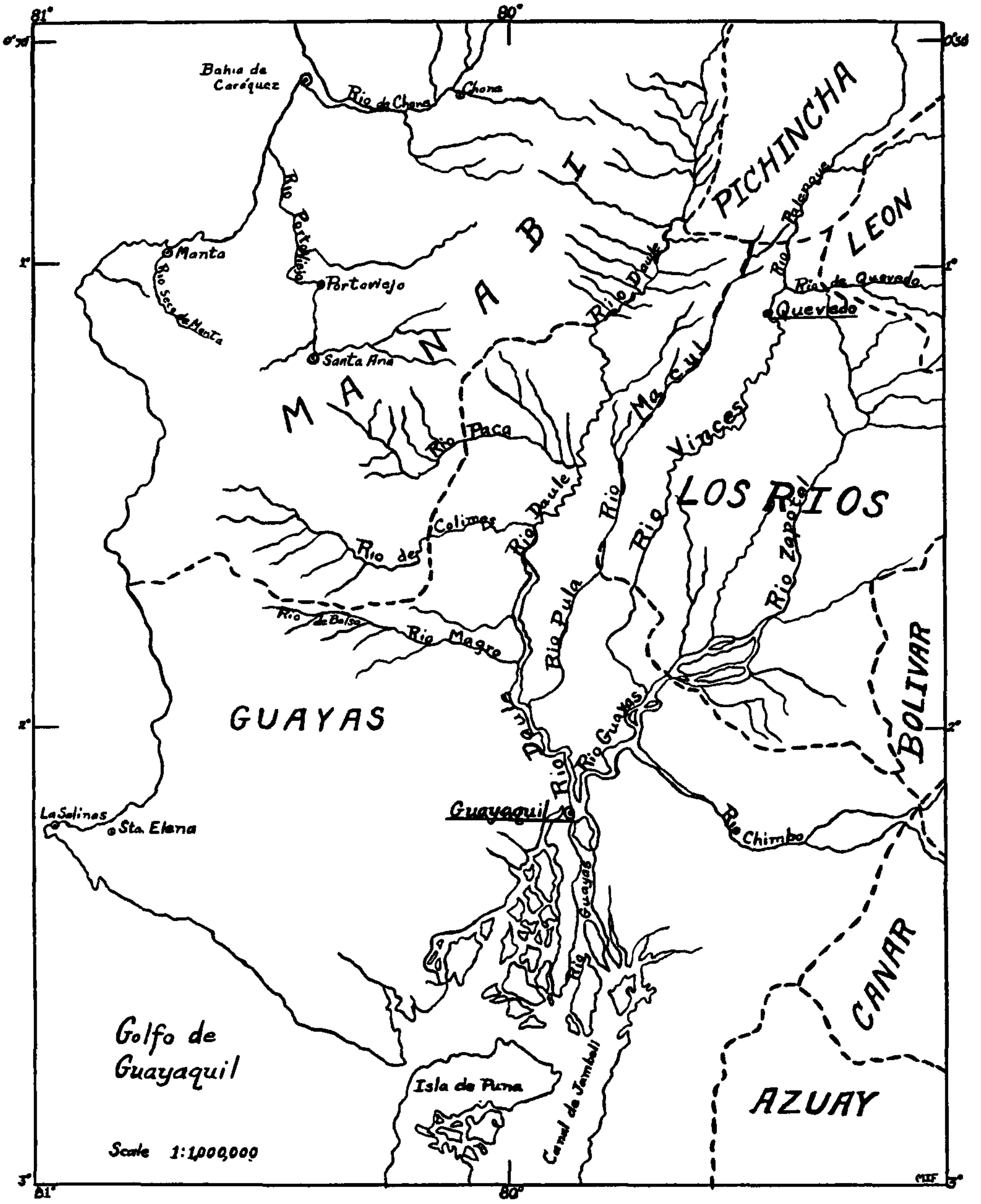


Fig. 1. Map of major balsa-producing areas in Ecuador.

from 1935 to 1941. From studies made in those countries, Mr. Cox (5) believes that while Ecuador is still the chief source of balsa lumber, the country has much less standing timber than either Peru or Colombia.

FIG. 2 (*Left*). Balsa tree being cut for lumber near Quevedo, Ecuador.
FIG. 3 (*Right*). Balsa tree about two years old. Estacion Experimental Agricola del Ecuador.

Costa Rica. Costa Rican production of balsa rose from the negligible cuttings of private individuals to substantial quantities by large-scale plantation operations in 1942–43. Balsa is found in the San Juan River area and along the forested boundary of Costa Rica and Nicaragua, but occurs most frequently on the west side of the country in the provinces of Limon, Guanacaste and Puntarenas. Much of it is grown on abandoned banana plantations of the Caribbean coast. Often the logs are transported to mills on the narrow gauge railroads formerly used for banana transport.

Four sawmills were in operation in Limon province in 1944—at Colorado Bar, Siquirres, Guápiles and Limón. The latter is a finishing plant completed by the International Balsa Company of Limón at a cost of $125,000. At least three other companies—Enrique Alvarado, Sociedad Alvarado Chacon and Iglesias-Phillips—were in operation at the end of 1944. All had leased portable sawmills.

In 1915 the United States imports of balsa were chiefly from Costa Rica. It was treated with paraffin before being used in life preservers.

Nicaragua. Considerable stands of balsa exist on the Caribbean coast and in southern Nicaragua. All export shipments from the country have been made from the Pacific coast port of Corinto. The balsa is from the southern end of Lake Nicaragua near the Costa Rica border.

Guatemala and Panama. Balsa is found in the dense evergreen tropical forests of northern Guatemala and along the Pacific belt. In Panama it is widely used. It grows along the forested Atlantic coast and on the Pacific side in the region southeast of the canal on the Veraguas and Los Santos peninsulas.

Honduras and British Honduras. Balsa is common in the Atlantic coastal belt of Honduras. British Honduras also has plentiful supplies. The tree grows exceptionally fast there. Both countries export small quantities to the United States.

Mexico. Balsa occurs in scattered tracts on the south coast of Mexico. It is also found southward from northern Vera Cruz on the Gulf Coast. On the west coast it grows in the dense tropical forests up to 2500 feet elevation as far north as central Sinaloa.

Puerto Rico and West Indies. Balsa, locally known also as "corcho" and "downtree", is one of the commonest trees in this area, where it grows very rapidly. It has been used here many years for rafts. Its soft white wood serves as a substitute for cork; its bark yields a rope fiber; and the down from the fruit is used to stuff pillows. Professor Gifford reports that in the West Indies natives use it for poles "somewhat as Chinese use bamboo for shoulder poles, tobacco poles, etc.; all uses where a light, rather strong pole is needed". Small boys use it for floats when swimming.

Ceylon. Ceylon is the only area in the Old World producing balsa commercially. A specimen was introduced to the Royal Botanical Gardens at Peradeniya near Kandy, Ceylon, in 1884. Experiments in growing balsa were not brought to public attention until 1931, and after that interest was dormant another ten years until at the beginning of the war Australian aircraft firms sent urgent inquiries to the curator of the Gardens. Since then Ceylon has turned attention to scientific production and today "can produce easily and economically, balsa which is second to none in the world for quality" (6).

Wild Trees vs. Plantations

Wild balsa is the principal source of the wood today, but the trend is toward controlled plantation culture. Like most tropical trees, balsa is seldom found in thick or dense stands, so it is often necessary to harvest from large areas to obtain any quantity. The trees are more abundant as second growth where clearings have been made by nature or by cultivation. Since the seed is scattered by winds, trees spring up singly and in patches, with many other trees, in clearings. This natural seeding produces so many young plants that the tree is sometimes called the "weed tree". Its prolific nature makes it hard to estimate accurately the volume of balsa that exists.

In 1937 the Ecuadoran government passed a law requiring the planting of two small balsas for every tree cut for commercial use; thus they are assured of a future supply, provided that law is enforced.

Plantations are a comparatively new development in Ecuador. Von Hagen (1) wrote of the Balsera Corporation in

Ecuador in 1940. Presumably there were only three plantations then. All were under German ownership, one of them under Herr Klinger. This plantation, like others, was started by cutting the virgin forest and firing it, much as the natives do when they plant their garden patches. Seeds were then placed in bamboo tubes, four inches in diameter, set upright in the ground. When the plants reached four or five inches in height, they were ready to be transplanted to the open field. In one year some trees planted in this manner reached heights three times that of an average man. After planting, the jungle growth was not cut again, to force the trees to fight for light; hemmed in on all sides they had to shoot up out of the dark and damp toward the sun.

Seeding in furrows has been tried more recently on a limited and experimental basis. The largest plantation in Ecuador is near Quevedo where plantation methods are becoming more common as a result of wartime stimulus.

Companies in Middle America during the war frequently contracted with the governments, as in Costa Rica, to plant specified acreages within a given period of years. Abandoned banana plantations served as ideal sites for the new experiment, since balsa trees thrive as second growth on clearings. Plantations provide trees of greater uniformity than the jungles and easier to exploit.

In Ceylon all balsa is grown scientifically on plantations. These were started as a result of experimental work of the curator of the Royal Botanical Gardens. By 1944 he had found that trees spaced 10′ × 10′ were too close; those spaced 12′ × 12′ had larger girth and were taller. Eventually 15′ × 15′ spacing proved the most successful. They also tried pruning two lateral shoots to leave one main stem from which to obtain a maximum straight trunk without knots. This experiment was a failure; crooked shapes resulted from the pruning attempt to produce one leader. They found it best to leave the tree to its natural selective processes. Normally there will be 10 to 12 feet of knotless trunk before it branches into the three stems.

The Royal Botanical Gardens determined that 5000 trees growing under suitable conditions will achieve five feet girth in four to six years and will provide 125,000 cubic feet of light trade balsa. Purchasers have contracted for 200,000 cubic feet annually. So the Royal Botanical Gardens advocate, for a beginning, the planting in Ceylon of at least 100 acres yearly, to yield a quarter of a million cubic feet at the end of five or six years. Seedlings would be furnished to the growers by the Gardens.

Logging Methods and Operations

At present logging methods used in Ecuador and elsewhere in most of tropical America are very primitive. Trees are cut by hand, the workmen using broad-bladed axes called machetes. The bark is slashed with the machete and removed at once by peeling off with sharp poles; then the end of the log is "sniped" or pointed. Just above the point a groove is cut into which a chain or rope is fitted to drag the log to the river. The bark-peeling reduces worm damage, makes skidding easier and hastens drying.

Logging by tractor is too expensive, since so much road must be cleared to get so little timber. Skidding from a cutting area to a log deck, either on a stream bank or a road, may be by mules, oxen or human labor. Oxen offer the maximum of extractive efficiency; they can skid logs on easily constructed trails and are generally used wherever pasture is available. In some areas where animals are not available, logs are dragged out by natives. Consequently it is not customary to cut trees very far from roadside or streams. Light as balsa is,

FIG. 4. Bark being removed from balsa log before shipment to sawmill. The bark is slashed with a machete, then peeled off with sharp poles. Near Quevedo, Ecuador.

logs 16 feet long and up to 20 inches in diameter are seldom cut where they will have to be skidded more than a mile and a half.

Under present conditions the methods are very wasteful. In addition to the waste that occurs in squaring and pointing the log for easy skidding, there is no attempt to make use of all timber of value in a cutting area. Balsa logs under ten inches or over 15 inches may even be left to rot in the forest after cutting and peeling. Smaller logs are considered uneconomical to move, while larger ones cannot always be handled by the facilities in some local mills.

Logging operations lack organization. Sawmill operators rarely own standing timber (Costa Rica, an exception) and so do not engage in combined logging and sawmill operations. Instead they depend on purchasing logs from native loggers, contractors or middlemen.

The type of logging operations employed have made forest operations costly. So, whenever adverse conditions of climate, topography or transportation are encountered, or whenever there are difficulties in obtaining suitable labor, costs are likely to become prohibitive.

Previous to the war natives were getting five sucres (sucre = five to seven cents) for a balsa log 20 feet long by two feet in diameter. At the same time a model airplane in the United States sold for fifty cents. It consisted of a piece of balsa approximately 8 × 10 inches. During the war, when cutting operations took place on privately owned land, the owner usually received from five to 20 sucres per stump, or between 30 cents and $1.48 in United States currency, depending on the number of logs cut from each. An average tree produces two or three logs 16 feet in length. If the land was government owned, the logger received for his labor the sale price of the logs.

When oxen are used to transport logs, the usual charge is one dollar per day for the use of the animals and 75 cents per day wages for the owner and driver.

Sometimes a broker may employ natives at 15 to 25 cents for each log cut, peeled and grooved for raft riding. Natives employed on balsa plantations as laborers receive an average of 65 cents per day in addition to food. If a laborer is not under contract or does not work on a plantation, he sells the logs he cuts to brokers in towns along the main rivers. The brokers also engage laborers to make up rafts for transporting the logs to the sawmill areas.

Logs are cut only a few weeks in advance of milling and shipping because exposure induces deterioration. Green balsa is highly perishable and may spoil quickly simply by exposure to the sun. Practically all logs are rafted down rivers to mills at river ports. From the loading decks the logs are pushed downstream to where there is sufficient water to handle rafts. Rafts are made up of ten to 50 sections, each section consisting of 15 to 20 logs. In many cases huts are built atop the rafts and raftsmen pick up agricultural products along the way to take to coastal markets. Rafts are covered with banana leaves or weighted down with hardwood logs, charcoal or salable articles to keep them shaded and nearly submerged. This greatly reduces insect and checking damage. Sometimes when rafts are weeks getting to mills there is a great loss of lumber and reduction of quality. If logs ride high in the water, pollia (larvae of the ambrosia beetle) work in the wood above water and the hot sun checks the logs badly, so that one-third to one-half the contents of the logs are worthless. If moisture content can be kept high enough until the logs reach the mill, it tends to prevent development of fungi also.

Fresh peeled logs contain a much greater percentage of water than older logs but are still quite buoyant. Once dried they do not take up much moisture. Logs lying in the Guayas River 12 years were only 65 percent submerged. Balsa rafts held in backwaters for years at Iquitos and along the upper Amazon are still buoyant and do not easily waterlog.

The Guayas River provides outlet for balsa from Quevedo to Guayaquil. The trip from Quevedo down to the milling area takes six or seven days in the rainy season and about two weeks in the dry season. In the northwest the Esmeraldas River is used to the port of the same name. When water is high enough to raft all the logs, the time required is about four days. Only smaller logs can be floated during the dry season, and the time in transit is longer because there is no other means of transport. In Manabi Province balsa goes by the Rio Seco de Manta to Manta and by the Rio de Chone and its tributaries to Bahia de Caráquez during the rainy season. When trucks and railroads have to be used during the dry season, the transit time to Manta is reduced to one day.

The comparative costs of shipping logs from the cuttings to Guayaquil, Esmeraldas and Manta are not appreciably different. However, there appears to be some basis for a higher price of logs at Esmeraldas and Manta because of the transportation difficulties during dry seasons. In 1946 the price of a delivered log at Guayaquil was estimated at 45 sucres or about $3.30 in American money. Broken down into various charges on a per log basis and given in terms of United States currency, the average price includes:

Felling, peeling and transporting to river bank	$0.55
Making up rafts (per section of 15 logs, one man making three sections per day)	2.00
Tax for river passage at Guayaquil	0.15
Tax payments at Vinces	0.06
Transportation to Guayaquil	0.18
Cost of labor and other transportation	0.40
Total	$3.14 (7)

No comparable information is available on logging operations and methods in other balsa-producing countries.

The Sawmill Industry

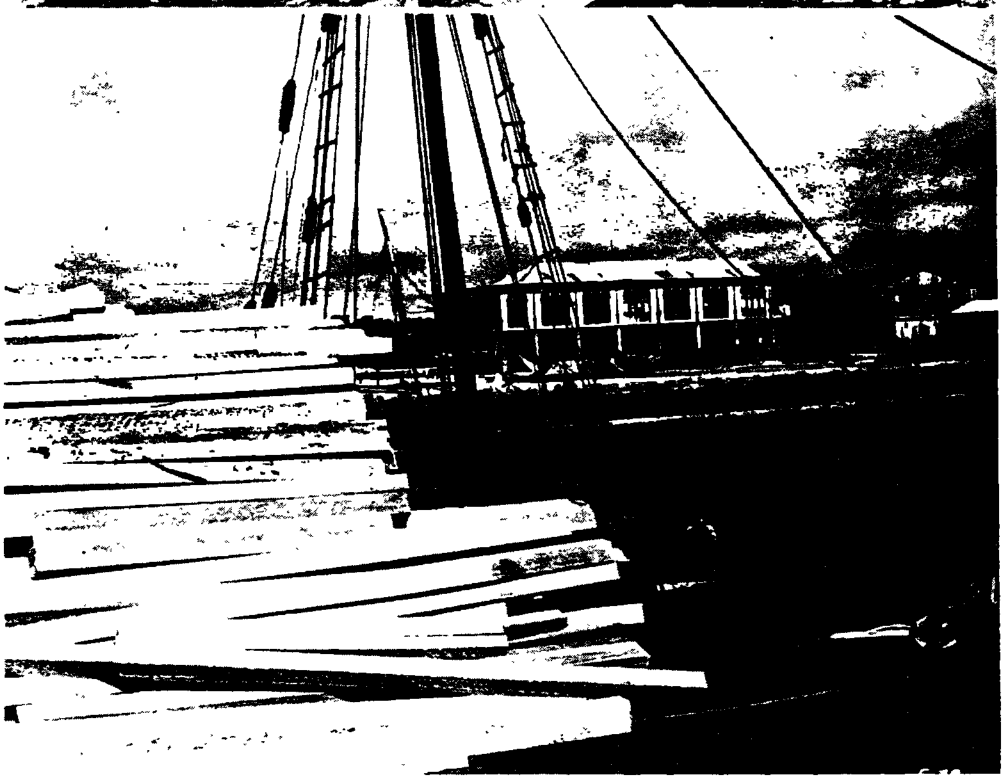
The principal sawmills of Costa Rica have been mentioned elsewhere as being under the management largely of United States companies.

Ecuador's primary sawmills are located at Guayaquil, with others at Esmeraldas, Manta, Rio Verde, Bahia de Caráquez, Borbón and Limones. In 1943 there were reportedly 33 sawmills in balsa production, with 22 of them located in the Guayaquil area, nine in the Esmeraldas area and the remainder in the Manabi district.

Before the war these mills had a motley assortment of equipment—gangsaws from England, American circular saws and planers, and German equipment to a smaller extent. Motive power was provided by German steam engines, French airplane motors and American automobile engines.

The demand for balsa during the war changed the apparatus in a majority of the mills. Considerable American equipment was imported, and, due to American efforts to assure adequate production, the balsa sawmills became fully equipped. Most mills now have circular saws to cut logs into boards and planks, some have frame saws, and one mill has a band saw. Electricity has displaced the steam and gasoline power in the Guayaquil area. Power is supplied by the Empresa Electrica del Ecuador in Guayaquil, and mill owners find it more economical. With decrease in balsa demands these mills can and have in some instances been converted to other hardwood production.

Most balsa mills receive logs at the



riverside where undivided logs are separated from sections of incoming rafts and then are drawn from the river by winches or powered cables. After sawing, the lumber must be thoroughly dried by kiln or sun to meet foreign market standards. Such practices, as we know them, were not customarily carried on by Ecuadorans, with the result that the wood was subject to checking, splitting, warping and shrinking.

The demand for balsa led to the introduction of standard air-seasoning and drying methods. Air- or sun-drying requires an average of 20 days in the dry season and about two months during the rainy season. It reduces moisture content to equilibrium at 15 to 18 percent. One common method of sun-drying is to end-stack the boards, resting them against a horizontal rack. Another method is to stack the lumber in alternate parallel layers so that succeeding boards are laid at right angles to the last placed layer. Air-seasoning and storage are out-of-doors but should be under roofs to protect from rain and sun. Balsa shavings are used to minimize the effects of the damp ground. A four-inch stock may be air-seasoned by end-racking during the dry season in as short a period as three weeks. The method takes longer but is much less expensive than kiln-drying.

Despite the rapid air-drying nature of balsa, the urgency of demand was so great during the war that kiln-driers were installed. This reduced drying time for a four-inch stock to five days and the moisture content to eight percent. However, moisture content goes up quickly to 14 or 15 percent when the wood is removed from the kiln. Often 25 percent moisture is absorbed on shipboard, so kiln-drying may have to be repeated at the shipping destination.

The war experience did prove that kiln-dried wood from Ecuador is more uniformly seasoned and so can command a higher price if the kilns are properly handled. Costa Rica found during the war that inadequate equipment and unskilled kiln operators resulted in as high as 40 to 50 percent waste in drying. Often it was heated too quickly or highly for such softwood, leaving a moist center surrounded by dry wood. Therefore Costa Rican operators concluded it would be more feasible and economical to air-dry in the country of origin and kiln-dry in the United States if the use to be made of the wood required it. Full utilization of the kiln and other industrial installations in Ecuador would require a higher level of production than the present decreased world demand for balsa.

Mill Production Costs

Mill production costs are hard to compute. Unpredictable losses through wastage are large. Approximately 25 percent of all logs delivered to the mills are defective, a condition which cannot be detected prior to cutting. The foremost reason for rejection is "water heart", caused by structural change of fiber during growth and most common in the larger trees. Again this cannot be detected until after the wood is cut and is being seasoned, at which time the fibers collapse or shrink excessively. Other logs contain worm holes, cracks or checks, or other defects developed en-route to the mills, which either reduce their classification and purchase price or make them unsuited to commercial use. Since most trees contain sweeps, curves or slight bends, it is exceptional to find 16-foot logs entirely straight the full length. The loss in sawing in this case could be avoided by cutting shorter logs.

FIG 5 (*Upper*). Balsa log rafts at the sawmill in Guayaquil.

FIG. 6 (*Lower*). Balsa lumber for export on the dock at Puerto Bolivar, El Oro Province, Ecuador.

The scale of wages paid in the sawmills customarily ranges from six to 15 sucres (44 cents to $1.08) for an eight-hour day. In Guayaquil and some other sawmill areas local regulations require double pay for overtime work. In general the workers are unskilled, unorganized and change employment frequently. All employment is subject to regulation under Ecuadoran labor laws which require: *a*) a certificate of identification; *b*) provision for adjustment of labor disputes—employee has recourse to a commission, employer considered at fault until proved otherwise; *c*) regulations for granting sickness and injury pay, and payment to discharged persons; *d*) payment of one month's salary to dismissed employee if he has worked with company a year, and higher payments for longer service.

Grading

Except in the establishment of rules for grading balsa, there is no similarity between the general policies and practices that govern the Ecuadoran lumber industry and that of the United States. A system of orderly grading was introduced by the United States Office of Economic Warfare to assure standard classification and quality of balsa for use in foreign markets. Each grade is identified by weight properties and degree of acceptable defectiveness.

Classification "AA" is known as " air-grade " lumber. Weight here is the greatest differential, but the wood must also be entirely free of defects. Grade "A", though heavier and containing slight defects not of structural importance, is considered almost equal to "AA". Much depends on inspection, where defects are judged in grades " B " and " C ". Grade " B " is commonly used in life rafts and industries other than aircraft manufacturing. Shorts have more defects than Grade " C " but are classified separately, more because they are not of standard dimensions in length or width (7).

Grading is done at the Ecuadoran sawmills to enable ships to load at Guayaquil with lumber for a United States destination without second sorting and consequent rejects. Ecuador also adopted the use of the United States standard lumber rule. One-fourth inch under is allowed for planing. The " Old Ecuadoran " method, in which the thickness and length are taken to the nearest lower full inch, is also commonly used and is an advantage to the buyer. When lumber is bundled a third method known as " cubing " is used, in which a single computation of length, width and total thickness of the bundle is made in measuring. The advantage here rests with the seller who gains as much as 15 percent in volume because of spaces between the bundled boards.

Ceylon has its own grading system—Light (first grade), Medium and Heavy. First grade lumber is so light that the trees from which it is cut add one foot to their girth in one year, and the wood when dried naturally scales only 7½ pounds per cubic foot. Even Medium balsa (nine to 11 pounds per cubic foot) and Heavy balsa (11 to 15 pounds per cubic foot) compare favorably with cork and are a suitable substitute for it. Wood graded on the Ceylon basis and sent to the Melbourne Aircraft Company of Australia in 1941 proved superior to Ecuadoran and Mexican balsa received at that time (6). One Ceylon tree yielded 155 cubic feet and had a nine-foot girth at its base.

Marketing Balsa

Very little balsa cut in Ecuador or the other producing countries is used domestically. Practically all is exported. Before the war 85 percent of Ecuador's balsa exports were to the United States, between three and five percent to Great Britain, and less than ten percent to all other countries. Other pre-war customers included France, Germany and Japan. From 1935 to 1941 Ecuador supplied 99 percent of the balsa needs of the United States and Great Britain. Costa Rica, Guatemala, Nicaragua, Colombia, Panama and Venezeula all produced small quantities during this period.

During the war the United States absorbed 90 percent of the total shipped, and the United Kingdom took practically all the rest for use in airplanes. Peru, Canada, Curaçao and Australia became markets for the remainder. Balsa obtained shipping priority and moved freely from all ports because of its strategic character.

According to the Pan-American Yearbook for 1945, Ecuador's balsa exports in 1943 were valued at 43,418,722 sucres, or about $3,000,000, which gave balsa the rank of third most valuable export of that country for that year.

In 1944 the United States imported balsa from the countries indicated and in the amounts shown in Table I, which is based on the report of the Foreign Commerce and Navigation of the United States for that year.

The enormous increase in demand for the wood for wartime uses began to decline soon after mid-1944. Balsa exports from Ecuador dropped 64 percent from October, 1945, to October, 1946. The United States continued to provide Ecuador's best market, taking 94 percent of the export. The decline continued during 1947 despite efforts of several United States importers to develop new uses for the wood. In the first ten months of 1949 balsa exports from Ecuador were valued at only slightly over two million sucres or about five percent of their all-time high in 1943.

Pre-war markets were negligible, probably due to lack of information. Between the two world wars Costa Rica and Ecuador supplied most of the United States demands for five million board feet a year, two-thirds of which was used in model airplanes. In reporting on Ecuador's forest resources in 1947, E. F. Horn, a professional forester, said balsa lumber is expected to be more in demand than at any time before the war.

TABLE I

UNITED STATES IMPORTS OF BALSA—1944

Country	Balsa (1,000 bd. ft.)	Dollars
Mexico	34 (sawed boards)	3,145
Nicaragua	52 " "	3,174
Guatemala	1,087 " "	93,545
Colombia	1,284 " "	100,411
Costa Rica	1,990 " "	194,642
Chile	132 " "	11,256
Ecuador (1)	3,438 " "	268,180
Ecuador	25,759 " "	2,023,120
Ecuador	52 (logs)	2,454
Total	33,776	2,697,475

(1) Free under Executive Order #9177.

Labor Supply

Of the 3,250,000 people in Ecuador, approximately two million live in the Sierra, one million in the coastal provinces and the remainder in the Oriente. Spanish and other whites make up eight percent of the total population; Indians, 27 percent; mestizos, 54 percent; negroes and mulattoes, eight percent; and the remaining three percent are from all other races.

Indians and mestizos, who occupy the Sierra highlands, are interested primarily in tilling the land. They are self-sufficient for the most part, so that the forest holds no interest except as a source of firewood. The peoples of the littoral—mestizos, negroes and others—are engaged in producing plantation crops for export. This creates a competition for labor. The primitive Indians who inhabit the Oriente are interested mainly in clearing the land for subsistence farming. They have had no experience in lumbering in any way comparable with that of the native labor in the littoral, or even that of the Sierras.

In the coastal region where rubber and balsa are collected, an area comprising 30,000 square miles, the population is estimated to be 550,000, an average of 18 per square mile, a high ratio as compared to the moist tropics elsewhere. It provides a fair quota of agricultural laborers. Nevertheless Ecuador has a labor problem. When the chief crops of this region—cacao, bananas, sugar, rice—are being harvested during March, April and May, shortage of laborers ensues. Then balsa enterprises must compete for workers. There is also severe competition with rubber tapping and cinchona bark gathering.

At the present time the balsa industry must compete with a deficient labor market. Although there are possibilities for recruiting labor among certain Indian tribes and other population groups, much work will be necessary before any significant additional labor force for balsa enterprises can be secured. However, certain districts in the Province of Manabi, which exports considerable balsa, are inhabited by descendants of industrious Cara tribes. Limited increase in numbers of laborers from these tribes is possible.

There is a common belief that the health of Andean laborers when transferred to the less invigorating climate of the coast is affected adversely, so that labor is not available to the coast. The Indian population of the coast is not large and cannot be depended on to furnish laborers in numbers.

In the Provinces of Guayas, Manabi and Esmeraldas there are estimated to be about 7,000 African Negroes who are drawn on to some extent to serve the balsa industry.

Uses and Future of Balsa

Nearly 500 years ago Indians under the rule of the Incas were using balsa rafts to transport armies and equipment up the Guayas river, and ever since then the natives of that region have been making almost identical rafts for more peaceful pursuits up and down the same and other streams of Ecuador. Other than such native primitive utilization, balsa found almost no employment until 1911 when a few thousand logs entered world commerce. Shortly thereafter World War I brought balsa out of the tropical jungle, both literally and figuratively, and put it to work in life preservers. The British used the wood at that time in 80,000 floats that supported their mine barrage in the North Sea.

It was not until 1936, however, that balsa became a significant item of peacetime trade. Prior to that year its chief uses were for toys and manual training schools where it served well for cutting into model airplanes, toys and other models. Other uses in minor quantities included loud speakers for radios, soundproof construction and movie props. By 1936 its suitability, because of its great buoyancy, for use in life preservers, life floats, swimming belts, pick-up buoys, submarine mine floats, pontoons and surfboards became appreciated, and with the advent of World War II its uses multiplied and the old ones were promoted. Because of its value at that

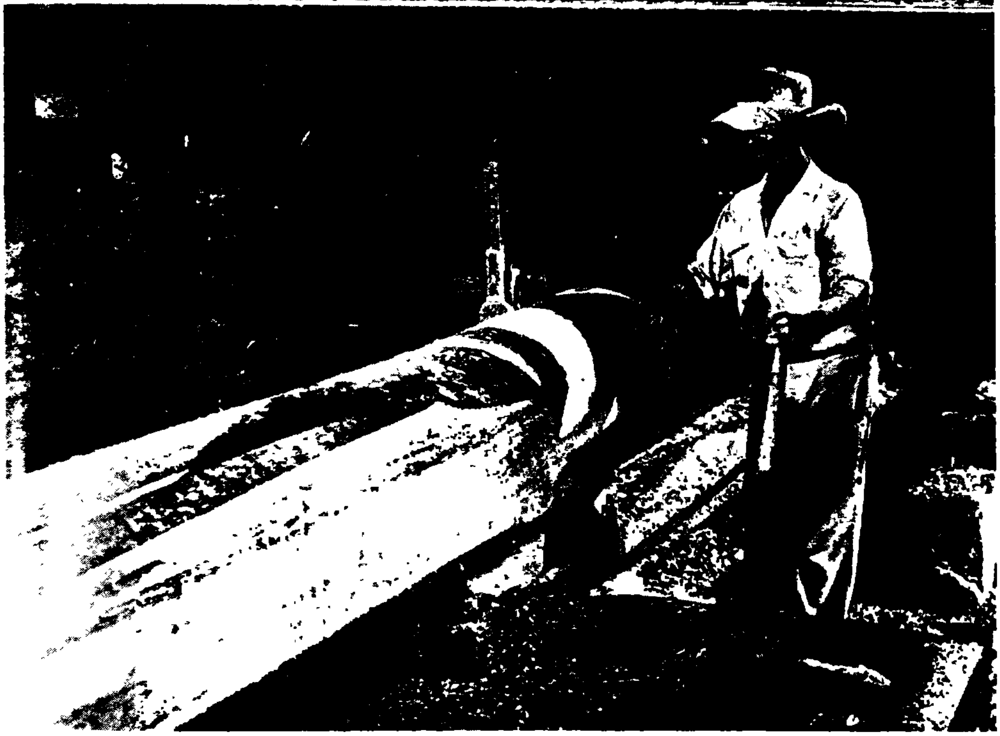


FIG. 7 (*Upper*). Balsa logs being transported by truck from Quevedo to the sawmill.

FIG. 8 (*Lower*). Sawing balsa logs is difficult because the wood is fibrous and the logs are usually wet.

time for plywood in the construction of the 400-mile per hour British Mosquito bombers, it was classified by the War Production Board as a strategic material of war, and efforts were made to cultivate the trees on plantations as a supplement to the wild supply. As noted under grading, the balsa utilized in airplane construction had to pass more stringent inspection than wood used for life-saving equipment, and toward the end of the war sheets of balsa were firmly bonded with sheets of aluminum alloy for extremely light airplane construction.

FIG. 9. Balsa drying in the sun. This lot is being inspected before shipment to England for wooden airplane construction.

Present-day uses of balsa fall into six categories: *a*) aircraft construction; *b*) buoyancy apparatus; *c*) toys and models; *d*) insulation; *e*) packing crates; *f*) house building. Each of these uses, broadly speaking, requires a specific grade of the material, and in some cases it must first be treated. Airplane manufacturers use it for fairings and for the inside walls of passenger compartments because of its lightness and strength, combined with its sound- and vibration-absorbing qualities. For use in naval rafts, life preservers and floats the wood must be covered with water-proof material to prevent it from becoming water-soaked. Toys and models are obvious outlets because of the lightness and workability of balsa. As an insulating material against both heat and cold in incubators, truck bodies, ship holds, refrigerators and cold storage rooms, it is ideal, since, in addition to being extremely light, it is odorless and when treated offers resistance to absorption of moisture. For these same reasons it is extremely valuable as a material for constructing various types of containers for transporting dry ice.

Its resiliency, combined with strength, and a smooth soft surface, makes balsa an excellent shock-absorbing material. Because of these qualities it has found a major use in pads as protective packing against damage when shipping pianos, finely finished furniture, high quality radios, sensitive instruments, fragile ceramics and similar articles. Factories, too, find use for it to absorb vibrations of machinery.

Though world markets for balsa have experienced a huge decline when compared with wartime demands, balsa is expected to remain in greater demand than at any time before the war. Its utilization for small gliders and planes as well as in life rafts will continue, and there is likely to be a demand for it in model plane construction. All the other fields already mentioned have prospects for growth, and additional ones undoubtedly will develop. Among the latter, one suggested outlet is as a new type of "fill" for an extremely lightweight tennis racket. The brightest future for balsa lumber, however, would seem to be in the box industry, particularly in relation to airplane freight where lightness of material combined with strength is so important. Development of this field should be a great boon to South American countries where air freight is often the only feasible means of transport to interior places.

House construction is the least developed field of balsa utilization, but it is reported that in Ceylon, where a lightweight wood for ceilings is needed, balsa may be used for that purpose, now that it is being produced in the island since its introduction from America during recent years.

Conclusion

Ecuador owes its leading position in the balsa industry to favorable natural growing conditions and inexpensive labor for cutting, collecting and shipping. As a result of the war and largely through United States efforts, many new methods of inspecting, grading, milling and handling balsa wood were introduced. Balsa plantations, although a new development, are very promising in outlook and certainly will assure a future balsa supply. Such plantations, taking advantage of abandoned banana lands where balsa thrives as second growth on old clearings, will also provide greater uniformity of product and other scientific controls over future production.

The world market shows a decline in demand for the one wood from Ecuador that has been the object of specialization for sale abroad. Nevertheless the future outlook for balsa, though the market be only a small part of the expanded wartime production, is more promising than for other tropical logs and lumber. The world's potential consumption of balsa remains a matter of speculation, but a continuing small world market does exist.

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