Logging of *Virola surinamensis* in the Amazon Floodplain: Impacts and Alternatives

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Abstract

This paper summarizes the results of a 3-year study of virola (*Virola surinamensis* (Rol.) Warb.), an important timber resource that illustrates the problems and opportunities of wood extraction in the Amazon region. Abundant in the floodplain of the Amazon River and its major tributaries, virola is used by plywood industries to make a high-quality veneer and by sawmills to make moldings for house construction. These activities provide thousands of jobs and generated gross revenues of ca. $50 million in 1989, but they also exert high pressure on natural stands of virola that will ultimately undermine future supplies. Based on an analysis of the ecological impacts of logging, the flow of wood through regional industries and the effectiveness of current forest sector policies, we recommend policy alternatives that could promote sustained use of this resource. But lack of public awareness and political will makes adoption of such alternatives unlikely over the near term. As a

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result, the virola economy will probably repeat the boom-and-bust cycles that have characterized resource use in the Amazon region.

Introduction

Logging is the fastest growing land use in Brazil's Amazon region and, with the possible exception of mining, the most lucrative. Since the 1980s, the spread of this land use has been fueled by construction of a network of roads in the region and by declining stocks of native forest resources in southern Brazil--which induced wood-processing industries to relocate to Amazonia. As major sources in Southeast Asia dry up by the early 21st century, the region is likely to assume paramount importance in the international tropical timber trade.

Despite its growing importance, logging is a relatively recent phenomenon in much of the Amazon region. Prior to the 1980s, it was largely confined to bottomlands adjacent to major rivers, which facilitated transport and permitted extraction of the bulk of Amazonian timber during 300 years (Rankin 1985). As a result, floodplain logging has a historical dimension that is largely missing from the uplands, and this dimension provides a basis for discerning the future of logging in the region as a whole.

This paper focuses on virola (*Virola surinamensis* (Rol.) Warb.), the most economically important wood in the Amazonian floodplain and, until 1989, the second most important wood export (after mahogany) in the Brazilian Amazon. A source of raw material for hundreds of sawmills in the Amazon estuary, virola is a crucial element in the regional economy. In addition, it shows excellent potential for sustained management in plantations and in natural stands. Despite its potential for sustained use, however, current harvesting practices and associated policies are leading to the rapid exhaustion of this resource.

Virola's economic importance, unsustainable exploitation and potential for sustained use make it an appropriate case for understanding the problems and opportunities associated with wood extraction in the Amazon region. Summarizing the results of a 3-year study (Anderson et al. 1994, Macedo and Anderson 1993), this paper begins with an analysis of current logging practices and their environmental impacts. Then we look at the dimensions and economic efficiency of the diverse industrial sectors that utilize virola. Next, we investigate the effectiveness of current policies designed to regulate supply and demand of virola. Finally, based on our findings, we propose alternative policies that could lead to sustained use of this resource. Although these alternatives are technically feasible, their adoption requires a degree of public awareness and political will that is currently lacking. The case of virola--one of the most promising cases for sustainable use of a tropical timber species--thus provides sobering insight concerning the future of logging in the Amazon region.

Logging

The regional context

Logging of virola is concentrated in and around Marajó, a 49,606 km^2 island in the Amazon River estuary (Figure 1). This region--and especially the western portions of Marajó and adjacent areas--is covered by a complex web of water courses, and much of its area is subject to periodic floods generated by tides. Historically, the estuarine region has served primarily as a source of forest and riverine products, while agriculture has played a secondary--and usually subsistence--role. This dependence on wild products has led to repeated boom-and-bust cycles, which have become more pronounced over the past century due to the increasing penetration of international markets in the Amazon region. In the late 19th century, the estuary provided an important source of fuelwood for steamships that plied the Amazon River and its tributaries, and also of natural rubber for the world market. By the early 20th century, however, the decline of steamships reduced demand for fuelwood, and the market for local sources of rubber also dwindled with the initiation of plantation production in Southeast Asia. Rising international prices produced a brief boom in rubber production during the Second World War, which ended abruptly with the restoration of plantation sources in the late 1940s. Large-scale extraction of timber for export began in the 1950s and now--together with the harvesting of palm heart from the *açaí* palm (*Euterpe oleracea* Mart.)--constitutes the major market-oriented activity in the Amazon estuary.

The rise of virola

The estuary's current logging boom traces its origins to 1956, when Georgia Pacific established a plywood plant in the town of Portel (Figure 1). Today a total of six plywood industries operate in the region, although most have diversified their raw material sources and only two continue to rely primarily on virola. Through the 1970s, local plywood industries concentrated almost exclusively on virola due to its unique combination of ecological, physical and mechanical characteristics: the species is abundant in bottomlands, and its easily peeled wood is low in density (0.45 g/cm^3), light in color and highly porous--ideal qualities for production of plywood veneer. Plywood industries favor large-girthed trees (>45 cm in diameter), which are more appropriate for peeling. Because such large-girthed trees are relatively rare, extraction of virola expanded beyond the estuarine region during the 1970s, and by 1987 had reached the vicinity of Benjamin Constant on the Colombian frontier--more than 3,000 km distant. After nearly 40 years of exploitation, natural stands of virola no longer furnish the needs of most local plywood industries, which have substituted it with inferior floodplain species such as *sumaúma* (*Ceiba pentandra* Gaertn.) and *ventosa* (*Hernandia* spp.).

Virola wood is also highly prized by sawmills. Light in color and lacking well-defined growth rings, its wood is ideal for production of moldings used in house construction. The first sawmill specializing in virola was established during the 1960s near the town of Breves (Figure 1), and today hundreds of sawmills operate in the Amazon estuary, focusing most of their production on virola. In contrast to plywood industries, sawmills utilize wood obtained from small-girthed trees (<30 cm in diameter), which greatly increases the intensity of forest exploitation. As a result, extraction of virola for sawnwood is still largely concentrated in the estuarine region.

although growing scarcity is leading sawmills to seek more distant sources.

Ecological impacts

Logging of virola follows the distribution of the species, which proliferates in inundated forests from the mouth of the Amazon River to its headwaters, including principal tributaries such as the Madeira and Purus Rivers (Rodrigues 1972). In the Amazon estuary, logging of virola is exclusively manual and takes place primarily during the rainy season (January-June), when high flood waters facilitate removal of logs. During the dry season (July-December), when wood extraction is much more difficult, loggers generally dedicate themselves to other activities such as fishing, rubber tapping, harvesting fruits of the *açaí* palm and clearing plots for subsistence agriculture. Cutting trees and sectioning logs is carried out manually (Figure 2A), and the logs are removed by dragging them over the ground (Figure 2B) or floating them along natural or man-made canals (Figure 2C). Upon arriving at major water courses, the logs are cabled together along their lengths to form an extensive, raft-like platform (Figure 2D). This platform is generally sold to an agent or middleman and subsequently floated to a wood-processing plant.

The intensity of virola extraction varies according to the type of forest. Virola occurs in seasonally inundated floodplain forest (*mata de várzea*) and permanently inundated swamp forest (*mata de igapó*, cf. Prance 1980). In the Amazon estuary, these two vegetation types cover an estimated area of 25,000 km^2 (Calzavara

1972). While floodplain forest is far more extensive, it generally contains a much lower concentration of virola than does swamp forest (Figure 3). As a result, logging of virola tends to be extensive in floodplain forest and intensive in swamp forest. Two case studies reveal the ecological impacts of these contrasting types of logging.

In a floodplain forest site on the Mocoões River in central Marajó (Figure 1), Uhl (1990) found that extensive logging for plywood industries concentrates on large trees (averaging 52 cm in dbh), removes a low volume per unit area (ca. 5 m^3/ha) and damages only 10% of the remaining trees. Forest regeneration after such a low level of disturbance is probably rapid, especially on relatively fertile floodplain soils. Furthermore, as virola grows well on disturbed sites, the highly selective logging carried out on the Mocoões River may actually enhance growth of the remnant stand. Yet the long-term effects on the stand are less certain, as selective logging targets genetically superior trees and consequently leaves behind less desirable germplasm (Kageyama 1981).

In contrast, in a virola-dominated swamp forest on the Preto River 50 km W of Marajó island (Figure 1), we found that logging targets relatively small trees (averaging 35 cm in dbh, with a minimum dbh of 26 cm) and consequently removes a high volume per unit area (145 m^3)--representing 90% of the original virola stand and 56% of the entire swamp forest (Macedo and Anderson 1993). After a 5-year period, we also found that such intensive logging results in the complete elimination of virola seedlings from the understory. This elimination appears to be due to the presence of a thick surface layer of organic matter, which impedes root penetration by seedlings and causes them to desiccate during the dry season. As a result, intensive logging leads to the eventual demise of virola in swamp forest--an ecosystem that, prior to logging, is frequently dominated by this species.

Industrial Use

Demand

In the Amazon estuary, the main types of industries that utilize virola include approximately 350 small sawmills (annual production ≤ 1,000 m^3), 24 large sawmills (annual production > 1,000 m^3) and two plywood industries. Based on analysis of a questionnaire applied to a sample of these industries (Mousasticoshvily 1991), we estimate that in 1989 they provided 5,045 direct jobs and indirect employment for thousands, and generated ca. $50 million in gross receipts. Using the questionnaire data, we constructed a flowchart illustrating the movement of virola wood during 1989 (Figure 4). The flowchart shows that wood processing industries in the estuarine region purchased approximately 722,000 m^3 of virola logs. Large sawmills were far and away the largest consumers (435,000 m^3), followed by small sawmills (242,000 m^3) and plywood industries (45,000 m^3). The share of large sawmills was in fact greater, since they purchased all of the sawnwood produced by small sawmills. As a result, we estimate that 86% of virola wood passed directly or indirectly through 24 large sawmills located in the Amazon estuary. This finding has important policy implications, which we discuss below.

Processing and marketing

According to our estimates (Figure 4), the 722,000 m^3 in virola logs purchased in 1989 generated roughly 287,000 m^3 in final products--a yield of about 40%, which is extremely low by modern wood processing standards. Most (91%) of the sawnwood produced was exported, primarily to the United States; in contrast, the plywood produced from virola (including a mix of other species) was split fairly evenly between domestic (52%) and international (48%) markets. Interestingly, we found that our 1989 estimate of virola sawnwood exported by local industries (222,919 m^3) was 2.3 times the official government figure (93,860 m^3; cf. Figure 5), which suggests that considerable quantities of virola wood are marketed informally. The policy implications of this finding are discussed below.

Performance

A comparative analysis reveals the performance of the three major types of industries that process virola (Table 1). In environmental terms, as plywood industries consume a lower volume of virola logs and convert a higher proportion into finished product, they exert less pressure on the stands of virola than do large or small sawmills. In financial terms, the profit margin of plywood industries is much higher than that of large or small sawmills. And in social terms, while plywood employ fewer people than do small sawmills, they provide higher salaries and job security than both large and small sawmills, and they pay far higher taxes.

Current Policies and Patterns of Resource Use

Logging

The office of Brazil's environmental agency (IBAMA) responsible for the Amazon estuary employs only one forest guard and lacks necessary infrastructure and financial resources for effective monitoring of the virola market. To investigate that effectiveness, we analyzed two legal parameters designed to regulate logging of virola.

First, IBAMA stipulates a minimum diameter limit of 29 cm (or 90 cm in circumference) for marketed virola logs. In a random sample of logs present on the Preto River during 2-day periods in the rainy and dry seasons, we found that a substantial proportion (22%) was below this limit (Macedo and Anderson 1993). Most illegal logs are extracted during the dry season: we found that 82% of the logs sampled in this period were below the legal limit.

Second, the Brazilian government also defines a limit based on tree size: 45 cm in dbh for logging operations in native forest (Brazilian Forestry Code, Law No. 4771/65). To illustrate the effectiveness of both tree- and log-size limits in regulating extraction of virola, we calculated the volume of uncut, residual and extracted wood in a hypothetical, intensive logging operation at our swamp forest study site near the Preto River (Table 2). Of the total volume of virola wood extracted per ha (145 m^3), only 33% would be below the legal minimum log size, while fully 70% would be derived from diameter classes below the minimum tree size. Although it greatly diminishes the impacts of logging, the minimum tree size is virtually impossible to enforce. On the other hand, our field observations suggest that strict enforcement of the log-size limit would probably induce loggers to extract fewer legal-sized logs per tree rather than cut fewer trees. In short, the tree-size limit would reduce the impacts of current extraction but is impossible to enforce, while the log-size limit is enforceable but would probably not reduce ecological impacts. We conclude that current policies to regulate the logging of virola are not only poorly enforced but ill-conceived.

Reforestation

The Brazilian Forestry Code establishes levels of reforestation according to the amount of wood consumed. For each cubic meter utilized by wood-processing industries, six seedlings of forest species must be planted (Regulation Number 441 of August 9, 1989). Planting costs are borne by the industries, which can pay IBAMA a tax to support reforestation by third parties or, with IBAMA approval, implement their own reforestation projects. Payment of the tax or direct involvement in reforestation is required to obtain official permits for transporting logs, which determine the amount of wood that industries can legally purchase.

Ten reforestation projects involving virola are currently underway in Brazil, encompassing a total area of approximately 4,800 ha (Kanashiro and Yared 1991). We examined in detail two projects in the Amazon estuary, carried out by the major plywood industries utilizing virola (cf. Anderson et al. 1994): an 80-ha plantation established by EIDAI near the town of Portel; and a 2,666-ha plantation established by TREVO along the Amazon River, downstream from the town of Gurupá (Figure 1). For comparative purposes, we utilized data from a 2,450-ha plantation of virola in floodplain forest in Surinam (Schulz and Rodriguez 1966).

The plantation of EIDAI (Table 3A) was established on a cleared upland site that was periodically weeded. In plantings established 4-12 years previously, we found that 37% of the trees were dead and an additional 19% were defective in form, probably due to virola's poor adaptation to upland soils. Furthermore, under the high light conditions characteristic of this plantation, virola trees tend to branch and bifurcate at low heights, thus reducing the volume of trunk available for log extraction. As a result, after 10 years the plantation had only attained a mean total height of 4.2 m and an exploitable volume of 56.1 m^3/ha.

The plantation of TREVO (Table 3B) was established in the understory of a floodplain forest previously logged for virola. Other than occasional thinning of understory vegetation, no silvicultural treatments were carried out in the forest. We found that the form of the trees was, in general, superior to that of the plantation established by EIDAI in full sun. Yet, due to the low levels of light in the untreated forest understory, yields of the TREVO plantation were negligible: after 10 years the plantation had attained a mean total height of 2.2 m and an exploitable volume of <10 m^3/ha.

The plantation in Surinam (Table 3C) was also established in the understory of a floodplain forest that had been logged for virola. But in contrast to the previous case, this forest was selectively thinned to increase luminosity to 65-80% of full sun, and was subsequently weeded twice per year to reduce competition. This combination of treatments resulted in a relatively high yield: after 10 years the plantation had attained a mean total height of 16.0 m and an exploitable volume of 208 m^3/ha.

The yields of the Surinam plantation are relatively high for a native species not yet subjected to genetic improvement. Based on the results obtained after 12 years (Table 3C), Schulz and Rodrigues (1966) estimated that this plantation would yield 440 m^3/ha under a 40-year rotation--equivalent to a mean productivity of 11 m^3/ha/yr. By comparison, plantations of improved strains of *Pinus caribea* on cleared sites in Surinam attained a mean productivity of 17 m^3/ha/yr. Through simple selection of seeds from high-quality trees, we believe that virola could attain similar yields.

The experiences summarized above indicate the best strategy for obtaining productive plantations of virola. This species grows best on moist, bottomland soils under intermediate light levels maintained by periodic silvicultural interventions. In the Amazon estuary, such conditions are found in extensive areas of floodplain forest currently logged for virola, where establishment of understory plantations could guarantee future supplies. Yet this strategy has not been adopted by the industries that are most dependent on virola. Despite 12 to 20 years of experience in reforestation, the two industries investigated in our study continue to maintain plantations under inadequate ecological conditions and without appropriate silvicultural treatments. This situation appears to reflect the general absence of forest policy enforcement noted above. Due to non-enforcement, the taxes for reforestation actually paid are well below the levels specified by law, which weakens incentives for direct investment in reforestation projects. Together with weak economic incentives, the risks of long-term investment in a historically inflationary economy and insufficient technical orientation probably explain the disappointing results of reforestation projects involving virola in the Amazon estuary.

Forest management

Virola has several qualities that would facilitate management of natural stands. The species is widely distributed in the floodplain of the Amazon River and its major tributaries (Rodrigues 1972), where it regenerates profusely. In the Amazon estuary, the fruiting period of virola (January through March) coincides with peak floods, which assures dissemination of seeds over extensive areas. In addition to water, birds such as toucans (*Ramphastos sulfuratus* Lesson and *R. swainsonii* Gould) serve as important dispersal agents (Howe and Schupp 1985). The seeds of virola exhibit up to 90% germination in nurseries, and while its seedlings do not tolerate the deep shade of the forest understory, they grow well in small gaps. Virola's strong apical dominance permits development of a straight, cylindrical stem, with minimal branching and a small crown--ideal characteristics for a timber species. In contrast with mahogany, virola appears to be free of serious phytosanitary problems. Its natural abundance, which has promoted exploitation to-date, could also facilitate management. Virola is common in floodplain forest and achieves extremely high densities and volumes in swamp forest. In this latter ecosystem, selective logging of large-girthed trees (dbh ≥ 45 cm) could probably be sustained if carried out under sufficiently long rotations (≥10 years).

Despite this potential, however, there are currently no efforts to manage natural stands of virola on a commercial scale. As in the case of plantations, managing natural stands represents another lost opportunity to increase the supply of virola for local industries.

Current prospects

Although it is impossible to determine precisely how long current stocks of virola will last, evidence suggests that--after nearly 40 years of exploitation and with growing demand by hundreds of sawmills in the estuary--most of the marketable sources of this species are already exhausted, and the collapse of the virola market is imminent. The abrupt decline in export of sawnwood since 1989 (Figure 5), the difficulties in obtaining logs reported by all industrial sectors, the substitution by lower-quality timber species and the lack of effective measures to augment supplies are clear signs of the demise of the virola market, which threatens to undermine locally-based industries dependent on this resource, increasing the estuarine region's already high rates of unemployment and urban migration.

Alternative Policies and Patterns of Resource Use

Changing the above scenario requires alternative policies and resource-use patterns to decrease present demand and increase future supplies of virola. In this final section, we explore possible strategies to achieve each of these goals.

Demand

The combined demand of plywood industries and large and small sawmills has placed unprecedented pressure on natural stands of virola. Furthermore, our study shows that existing plywood industries absorb lower quantities of virola wood--and make slightly more efficient use of that wood--than do either large or small sawmills. Consequently, we would recommend a series of policies that reduce the overall flow of virola to wood-processing industries and, in addition, favor those industries that make more efficient use of this resource.

To reduce overall demand, we would first recommend *concentrating monitoring efforts on large sawmills*. As our study shows, the large sawmills in the Amazon estuary consume 60% of virola logs (by volume) and purchase all of the sawnwood produced by small sawmills, thus absorbing over 80% of the total flow of virola wood through regional industries. More effective monitoring of large sawmills would be relatively easy, as these industries are few in number (24) and are mostly concentrated in or near major towns and cities. Effective monitoring would also enable governmental authorities to obtain more accurate measures of wood consumption and production--which are essential for regulating the virola market and exacting realistic taxation. The latter, in turn, could help support stepped-up monitoring by IBAMA and induce industries to engage more seriously in reforestation.

As a second and complementary measure, we would recommend *limiting the purchase of virola timber by sawmills to a 6-month period during the rainy season (January through June).* This limitation would discourage extraction of small-girthed logs--a practice that occurs primarily during the dry season and greatly increases the impact of logging on natural stands. As above, this measure could be carried out by monitoring large sawmills and would be far more effective and easier to implement than the log-size limitation currently utilized.

Third, our study indicates the need for polices to *induce more efficient raw material use by industries involved with virola.* Specifically, fiscal incentives could be provided to wood-processing industries investing in technologies that (1) increase final product value and (2) reduce raw material waste. This measure could have critical implications not only for virola, but for all forest resources currently utilized by wood-processing industries in the Amazon region.

Supply

We would also recommend measures to increase supplies of virola. The most important measure is *to impose realistic taxation on virola consumption, which would provide a stronger fiscal incentive for reforestation.* As discussed above, we believe this policy could be effectively implemented by concentrating monitoring efforts on large sawmills.

To promote the development and dissemination of appropriate management techniques for reforestation, we would recommend *establishment of a research program on virola.* This program could involve joint collaboration between regional research institutions and local industries engaged in reforestation projects, and it could be supported by revenues derived from realistic taxation of those industries.

And finally, we would recommend *promoting alternative markets for virola timber produced from sustainable sources.* Such markets offer higher prices, which could discourage the currently wasteful use of virola. This measure would require labeling to distinguish timber derived from sustainable sources. Industries and non-profit groups have begun efforts to establish such labeling in Brazil.

Prospects for change

The above recommendations are technically feasible and, if implemented, would promote dramatic transformations in the current exploitation of virola by regional industries in the Amazon. Indeed, similar recommendations could be developed to govern the use of most native timber resources in the Amazon region.

Despite the need for policy change, however, three factors are likely to impede their implementation over the near term. First, there is little awareness among local inhabitants in the Amazon estuary of the impending demise of the virola market, and much less of the possible social and economic impacts of that demise. Yet broad public awareness of these issues is an essential prelude to adopting appropriate solutions. Second, while representatives of wood-processing industries are acutely aware of virola's shrinking supply, they generally view substitution by other species as the most appropriate solution. This solution does not take into account the lower quality of virola's substitutes, which could undermine final product competitiveness--especially in international markets.

Finally, implementation of the above recommendations would require substantial changes in the present structure and operation of governmental agencies involved in regulating the virola market, especially IBAMA. In addition to increased human and financial resources for monitoring local industries, IBAMA's regional offices need greater autonomy to administer funds and hire qualified personnel--both in the estuary and elsewhere in the Amazon region. As mentioned above, realistic taxing of wood-processing industries would probably cover most or all of these additional costs. The need for increased autonomy, however, runs counter to a long tradition of centralized administration that is a hallmark of federal agencies in Brazil. This tradition is derived, in part, from efforts to stem corruption and control government spending, and abandoning it would require a degree of political will that virola's demise is unlikely to muster.

Based on these considerations, the most probable scenario is that supplies of virola will continue to diminish and regional industries will increasingly substitute it with inferior species. This substitution, in turn, will lead to increased pressures on a wide range of forest resources, thus exacerbating the ecological impacts of current logging practices in the region. And as those resources are in turn depleted, wood-processing industries in the Amazon estuary--which employ thousands and in 1989 generated $50 million in revenues from virola alone--will eventually relocate to new areas where forest resources are more abundant. This scenario is a recurring historic pattern in Brazil, and it is destined to continue without policies that take into account the full value of those resources. In the absence of such policies, the boom-and-bust cycles that have characterized Amazonia's past are likely to continue in the future.

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Table 1. Comparison of small sawmills, large sawmills and plywood industries. Source: Mousasticoshvily, Jr. (1991).

	Small Sawmills (n=46)	Large Sawmills (n=22)	Plywood Industries (n=2)
A. Raw Material			
1. Demand for raw material - m^3 of logs	242,088	434,447	45,000
2. Efficiency of industrial use of raw material - m^3 utilized per m^3 of logs	40%,	43.1%	46.1%
B. Labor			
1. Mean monthly salary - US$	55.44	97.35	344.90
2. Number of employees per sector	1,936	1,434	1,675
3. Stability of employment - % of jobs maintained throughout the year	14	70	100
C. Financial Aspects			
1. Value of investment - US$ per factory	1,500	1,600,000	3,000,000
2. Operational costs - US$/$m^3$	79.92	97.09	58.30
3. Final Price - US$/$m^3$	84.11	124.7	371.3
4. Net profit - % of final price	5.0	22.1	84.3
D. Governmental Issues			
1. Legality - % of licensed firms per sector	50	100	100
2. Contribution in taxes - US$/yr	0	355,000	9,000,000

Table 2. Volumes of uncut wood, residual wood, illegal logs, and legal logs as a function of tree diameter in a hypothetical logging operation in mature swamp forest in Rio Preto.

Tree diameter class (cm)	Uncut wood	Residual wood	Illegal logs	Legal logs	Total volume
			m^3/ha		
15.0-19.9	5.5	0.0	0.0	0.0	5.5
20.0-24.9	12.5	0.0	0.0	0.0	12.5
25.0-29.9	4.3	7.2	17.1	0.0	28.5
30.0-34.9	0.0	10.2	14.2	8.3	32.7
35.0-39.9	0.0	18.5	12.9	20.5	52.0
40.9-44.9	0.0	13.3	4.1	23.6	41.1
45.0-49.9	0.0	14.8	0.0	24.5	39.3
50.0-54.9	0.0	5.2	0.0	8.4	13.6
55.0-59.9	0.0	2.7	0.0	6.8	9.5
≥60.0	0.0	0.5	0.0	4.2	4.7
Total	22.3	72.4	48.3	96.3	239.4

Table 3. Responses of virola in plantations: (A) in full sun, (B) in shade without silvicultural treatment, and (C) in shade with silvicultural treatment.

A. Plantations in full sun.

Locale	Age (yr)	Trees (n/ha)	Mean Height (m)	Max. Height (m)	DBH (cm)	Basal Area (m^2/ha)	Volume (m^3/ha)
Portel-PA	4	1,899	4.5	6,2	7.0	7.0	23.2
	6	1,910	6.7	9.1	8.2	10.6	46.1
	7	1,019	6.6	8.7	11.1	9.9	40.6
	8	1,019	6.0	7.1	11.6	11.0	40.5
	9	1,324	5.3	7.5	10.5	11.4	39.9
	10	1,798	4.2	7.4	10.7	18.2	56.1
	11	997	9.0	12.1	14.2	16.4	93.9
	12	477	9.5	12.5	16.3	10.4	66.4

Source: Anderson, Mousasticoshvily and Macedo (1994).

B. Plantations in shade without silvicultural treatment.

Locale	Age (yr)	Trees (n/ha)	Mean Height (m)	Max. Height (m)	DBH (cm)	Basal Area (m^2/ha)	Volume (m^3/ha)
Macapá-AP	3	986	0.6	2.0	-	-	-
	8	1,134	1.4	6.0	2.0	-	-
	10	902	2.2	8.9	2.2	-	-
	15	1,245	3.6	18.0	5.3	4.9	19.7
	20	839	7.8	21.0	13.6	21.7	143.9

Source: Macedo, unpublished data (1990).

C. Plantations in shade with silvicultural treatment.

Locale	Age (yr)	Trees (n/ha)	Mean Height (m)	Max. Height (m)	DBH (cm)	Basal Area (m^2/ha)	Volume (m^3/ha)
Suriname	8	550	15.0	16.0	19.0	16.0	135.0
	9	550	15.0	17.0	22.0	21.0	175.0
	10	550	16.0	18.0	24.0	25.0	208.0
	11	450	18.0	19.0	26.0	23.0	179.0
	12	450	19.0	19.0	28.0	26.0	210.0

Source: Schultz & Rodriguez (1966).

Figure Legends

(Anderson et al.)

Figure 1. Map of the Amazon estuary. Triangle represents study site on the Preto River.

Figure 2. Logging of virola in the Amazon estuary. A - sectioning a virola bole into logs, Mocoões River; B - manual removal of a virola log from the forest, Mocoões River; C - transport of a virola log along a logging canal, Preto River; and D - transport of virola logs in a raft-like platform (*jangada*), Preto River. Photographs by I. Mousasticoshvily, Jr.

Figure 3. Abundance of virola according to diameter class in two inundated forest types in the Amazon estuary. Data from the floodplain forest sites courtesy of H. Knowles.

Figure 4. Flowchart illustrating the movement of virola wood through industries based in the Amazon estuary region during 1989. Source: Mousasticoshvily, Jr. 1991.

Figure 5. Sawnwood exports from Pará state, 1987-1993. Source: Pará State Association of Wood Industries for Export (AIMEX), unpublished.

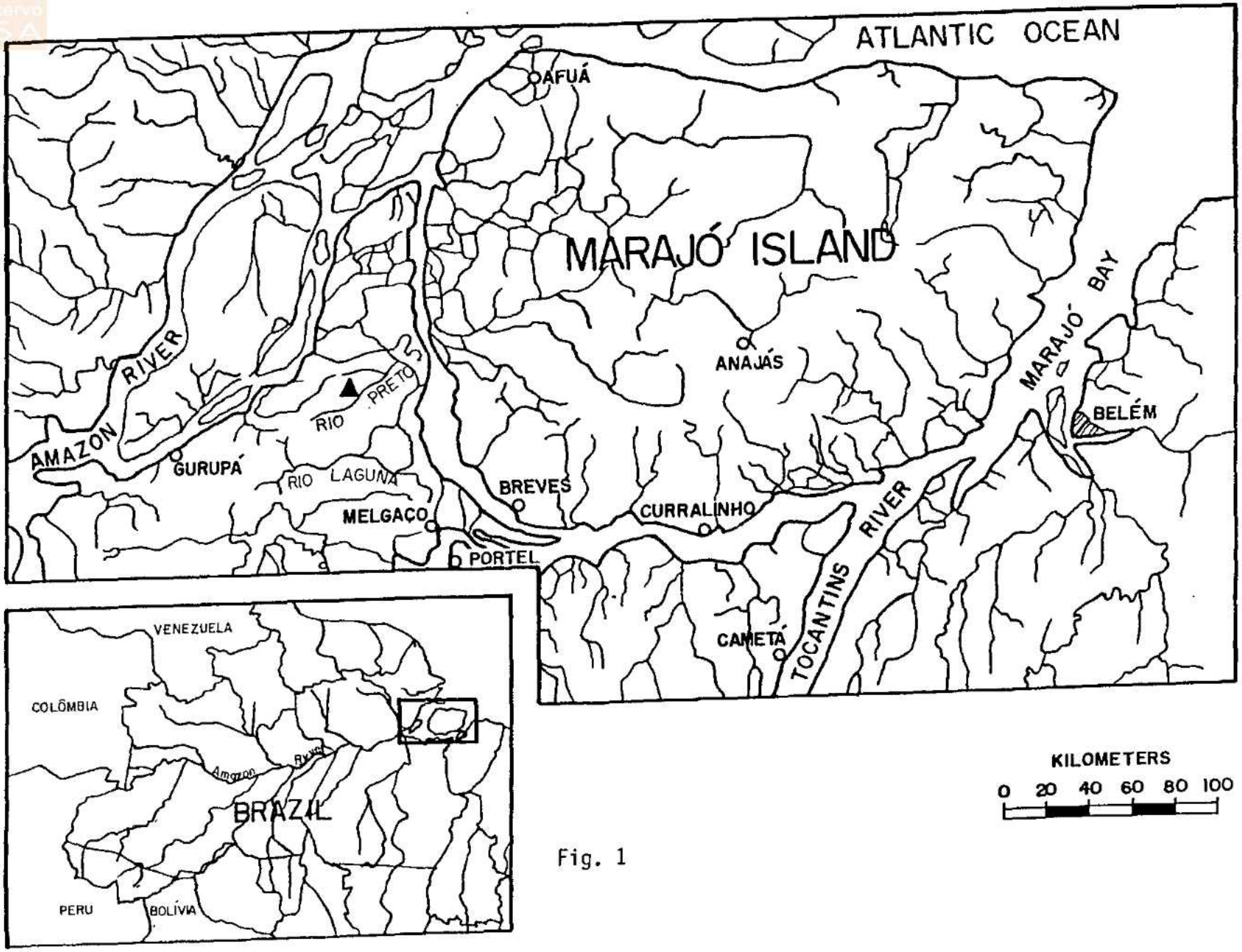

ATLANTIC OCEAN
AFUÁ
MARAJÓ ISLAND
MARAJÓ BAY
ANAJÁS
BELÉM
AMAZON RIVER
RIO PRETO
GURUPÁ
RIO LAGUNA
BREVES
MELGAÇO
PORTEL
CURRALINHO
TOCANTINS RIVER
CAMETÁ
VENEZUELA
COLÔMBIA
Amazon River
BRAZIL
PERU
BOLÍVIA
KILOMETERS
0 20 40 60 80 100

Fig. 1

Fig. 2

25(1)
Macedo & Anderson 2

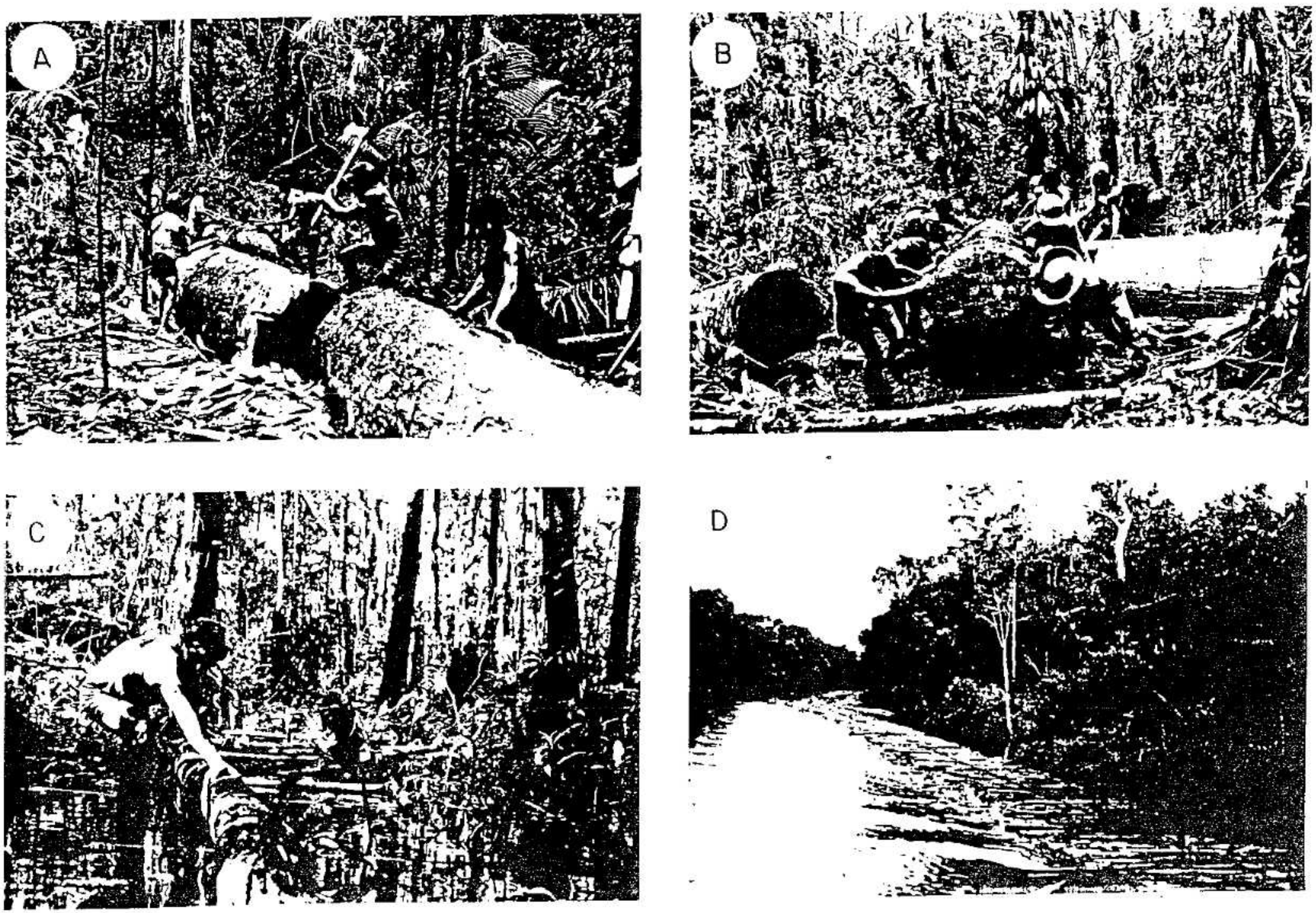


Fig. 3

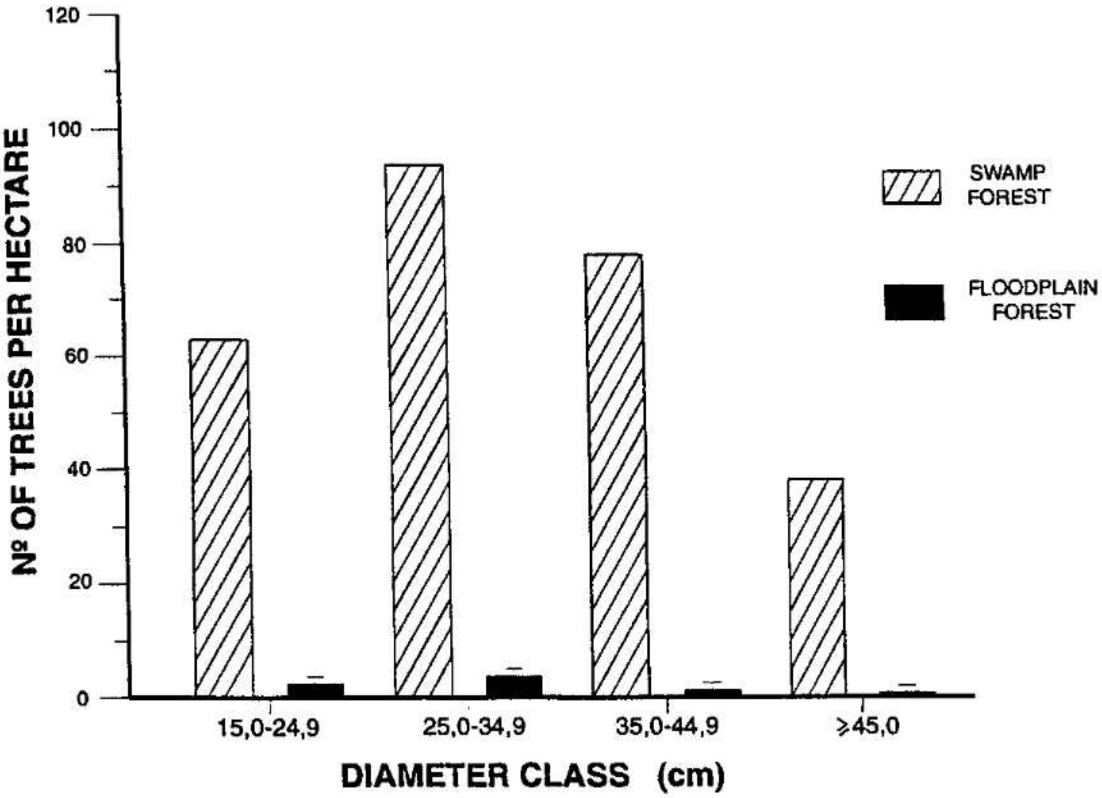

120
100
80
60
40
20
0
Nº OF TREES PER HECTARE
SWAMP FOREST
FLOODPLAIN FOREST
15,0-24,9
25,0-34,9
35,0-44,9
≥45,0
DIAMETER CLASS (cm)

Fig. 4

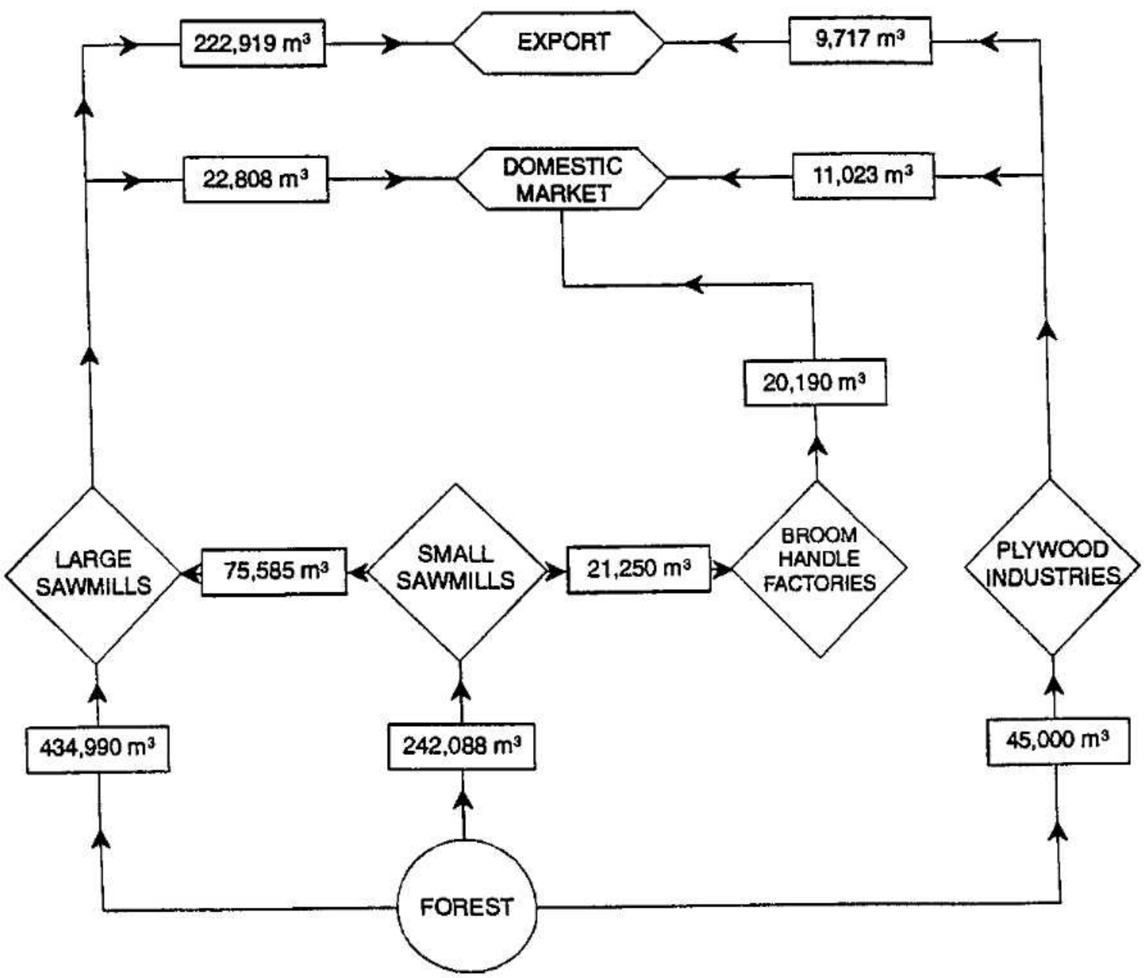
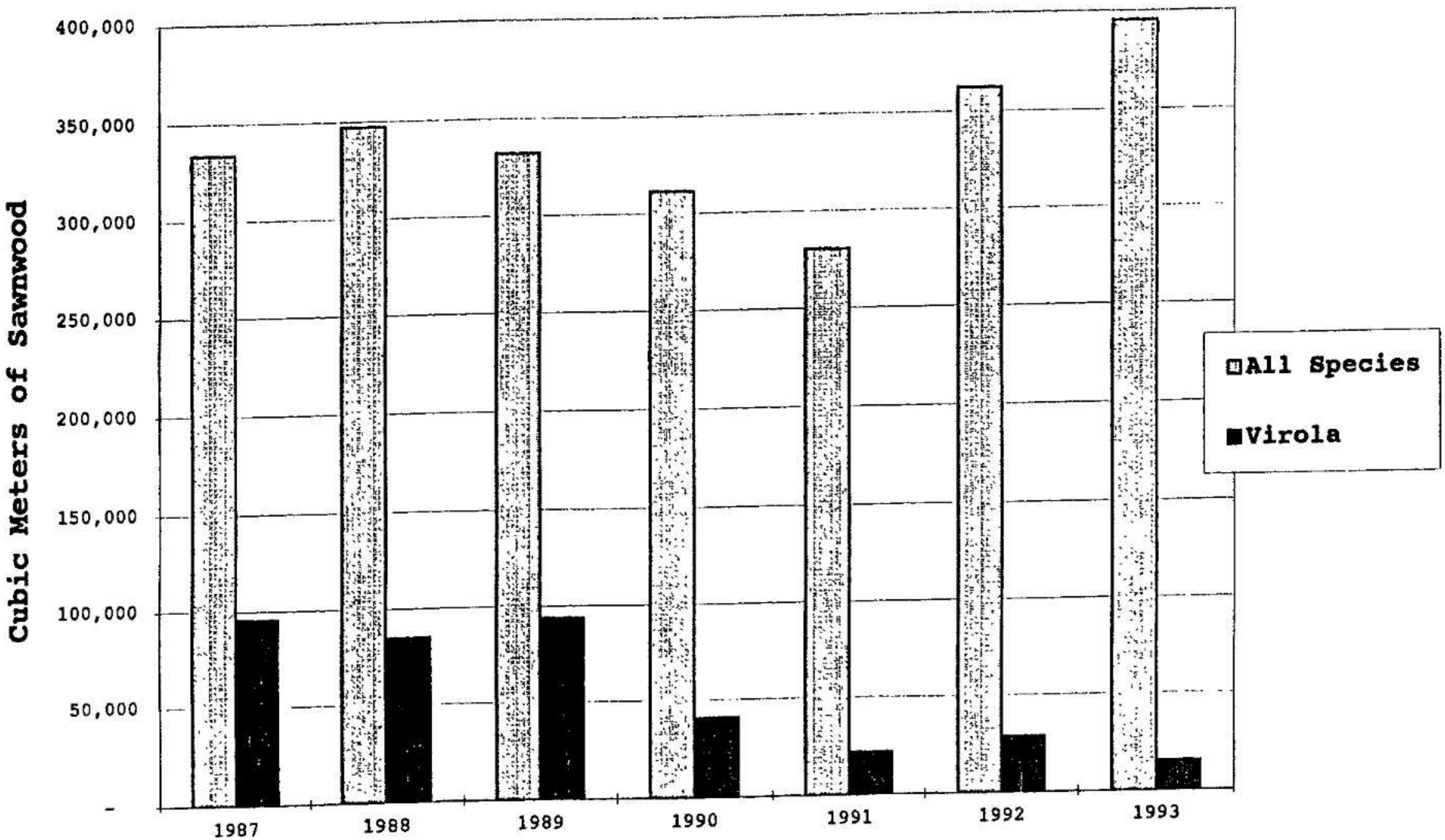

222,919 m³
EXPORT
9,717 m³
22,808 m³
DOMESTIC MARKET
11,023 m³
20,190 m³
LARGE SAWMILLS
75,585 m³
SMALL SAWMILLS
21,250 m³
BROOM HANDLE FACTORIES
PLYWOOD INDUSTRIES
434,990 m³
242,088 m³
45,000 m³
FOREST

Fig. 5


400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
-
Cubic Meters of Sawnwood
1987
1988
1989
1990
1991
1992
1993
All Species
Virola