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Estimating Biomass and Carbon Content of Saplings in Puerto Rican Secondary Forests

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Saplings are here defined as trees having at least 1.37 m of height and no more than 5.0 cm in diameter at breast height (DBH). Saplings may contribute less than 5 percent to nearly 100 percent of the tree biomass, depending on the successional stage of a forest. Many equations to predict the biomass for small-diameter trees in plantations and natural stands have been published (e.g., Buech and Rugg, 1989; Chaturvedi et al., 1991; Dudley, 1992; Grundy, 1995; Kahn and Pathak, 1986; Kushalapa, 1988; Ku et al., 1981; Lövenstein and Berliner, 1993; Pande et al., 1988; Parrotta, 1989, 1999; Tandon et al., 1988a; Tandon et al., 1988b), but prediction equations for biomass in Caribbean tree species of sapling size are few. The information available consists of equations for tree species across diameter ranges extending into sapling sizes

(Ovington and Olson, 1970; Parrotta, 1989; 1999, Scatena et al., 1993; Weaver and Gillespie, 1992). Because more than 200 tree species may occur in Puerto Rican and other secondary Caribbean forests, broadly applicable models are needed. Models of biomass distribution in secondary forest can be constructed, using allometric equations. Although such equations can be used to predict reserves of wood products, fuel, and other products from sapling-size woody vegetation, these models find limited use in the region. Models of carbon sequestering in tropical secondary forests are needed to help understand the contribution of carbon sequestering to the total carbon cycle. General estimates of carbon concentration in biological materials, such as C = 50 percent of biomass (Odum, 1971), can be used but actual concentrations vary by a few percent between tissues and between species and better estimates are needed. This study was undertaken to develop allometric equations to predict dry biomass and carbon in sapling-size trees of secondary forests in Puerto Rico.

Twenty species of trees (or single-stem shrubs that often become small trees) common in secondary forests in Puerto Rico were selected for study (table 1). Thirty saplings were harvested from each species. Sampling was done in subtropical moist forest (Holdridge, 1967) except for a few samples taken from subtropical wet-transition-to-moist and subtropical dry-transition-to-moist forest. Samples were collected from the following forests in Puerto Rico: La Condesa sector of the Caribbean National Forest, the Woodlot of the Puerto Rico Botanical Garden, the campus of the International Institute of Tropical Forestry, Cañon Cristobal Natural Area, Camp Santiago military reservation, and Piñones State Forest.

Samples for each species were collected from at least two sites. Saplings to be sampled were severed at 2 cm above the ground line. Diameters were measured at 5 cm, 30 cm, 75 cm, and 137 cm above the ground line and total stem length was measured. In addition, 30 saplings from a mix of 25 species (only 3 of which were from the original 20 species) were harvested for later testing of general equations. The harvested trees were cut into pieces, placed in paper bags, air-dried in a solar drier (reaching about 38 °C during the day) for one month, oven-dried for 24 hours at 105 °C in a forced-air oven, and finally weighed. Molding of samples did not occur. After weighing, sub-samples of wood, bark, and leaves of five randomly selected saplings per species were collected. Also, samples were collected from five saplings per species (of the original 20 study species) to determine the specific gravity of wood from the interior of the lower stem.

Carbon contents in dried and ground samples of wood, bark, and leaves were determined by the dry combustion method (Leco Corporation 1994, 1995). Wood specific gravity (dry weight/green volume) was determined by water immersion of small sawn samples (American Society of Testing and Materials 1968). Allometric equations were generated by simple and multiple linear regression with a significance level of $p = 0.05$.

Summary data for ranges of stem lengths and diameters at various heights of sample saplings are given in Table 1. Mean wood specific gravity values and tissue carbon contents for bark, leaves and wood for the 20 species are given in Table 2. Scatter diagrams of total sapling dry weight versus DBH squared multiplied by total stem length (D^2L) for all the species were examined and found to be linear. *Eugenia mon-*

TABLE 1. Size ranges of saplings of 20 species sampled from secondary forests in Puerto Rico.

Species	Stem length	Diameter		
		5 cm	30 cm	75 cm
Albizia procera	1.8-7.7	1.3-7.6	1.1-6.8	1.0-6.6
Ardisia elliptica	1.6-6.5	1.6-5.8	1.4-4.5	1.1-4.4
Bucida buceras	1.4-5.4	1.0-6.8	1.0-4.8	0.6-4.3
Calophyllum calaba	1.6-7.7	1.4-6.6	1.1-5.6	0.8-5.3
Casearia decandra	1.6-6.3	1.5-6.3	0.8-5.9	0.8-5.3
Casiaria guianensis	1.6-8.1	1.3-7.2	1.1-6.0	0.9-5.7
Eugenia monticola	1.4-8.5	0.8-5.5	0.7-4.9	0.4-4.7
Faramea occidentalis	1.6-7.1	1.5-6.2	1.2-5.7	1.1-5.7
Guarea guidonia	1.3-6.0	1.6-6.9	1.2-5.9	0.8-5.0
Inga laurina	1.8-7.0	1.8-7.2	1.4-6.7	1.0-7.4
Leucaena leucocephala	1.6-8.4	1.0-6.3	0.7-5.8	0.4-5.4
Miconia prasina	1.5-5.7	0.9-6.7	0.9-5.8	0.7-5.3
Myrcia splendens	2.2-6.5	1.3-6.4	1.1-6.4	0.9-5.8
Ocotea leucoxylon	1.7-6.0	1.4-5.6	1.2-4.5	1.1-4.2
Pimenta racemosa	1.6-8.6	1.1-6.2	1.1-6.0	0.6-5.8
Schefflera morototoni	1.7-6.2	1.6-8.5	1.5-6.9	1.3-6.5
Spathodea campanulata	1.8-6.9	1.8-8.6	1.2-6.6	0.9-5.4
Sysygium jambos	1.8-6.6	1.7-7.1	1.6-6.8	0.9-5.0
Tabebuia heterophylla	1.5-5.6	2.2-7.1	1.6-6.4	1.0-5.7
Thespesia grandiflora	1.5-5.8	1.5-7.0	1.4-6.3	1.0-5.9

TABLE 2. Means and standard errors of specific gravity of wood in the interior of the lower stem and carbon concentrations of tissues of saplings of 20 species of secondary forests in Puerto Rico.

Species	Specific gravity	Carbon content			
		Wood	Bark	Leaves	W.A.[1]
Albizia procera	0.404 ± 0.050	0.502 ± 0.001	0.477 ± 0.010	0.516 ± 0.003	0.500
Ardisia elliptica	0.480 ± 0.013	0.506 ± 0.001	0.492 ± 0.007	0.489 ± 0.003	0.502
Bucida buceras	0.656 ± 0.015	0.509 ± 0.000	0.433 ± 0.003	0.450 ± 0.002	0.489
Calophyllum calaba	0.528 ± 0.022	0.518 ± 0.001	0.537 ± 0.008	0.548 ± 0.002	0.525
Casearia decandra	0.630 ± 0.031	0.518 ± 0.003	0.457 ± 0.009	0.520 ± 0.002	0.508
Casiaria guianensis	0.602 ± 0.033	0.515 ± 0.000	0.452 ± 0.007	0.500 ± 0.003	0.503
Eugenia monticola	0.710 ± 0.016	0.521 ± 0.002	0.513 ± 0.005	0.537 ± 0.000	0.522
Faramea occidentalis	0.620 ± 0.036	0.509 ± 0.002	0.489 ± 0.005	0.487 ± 0.002	0.503
Guarea guidonia	0.520 ± 0.038	0.526 ± 0.003	0.515 ± 0.008	0.545 ± 0.003	0.527
Inga laurina	0.608 ± 0.022	0.530 ± 0.002	0.522 ± 0.005	0.535 ± 0.002	0.529
Leucaena leucocephala	0.700 ± 0.035	0.517 ± 0.003	0.513 ± 0.007	0.511 ± 0.002	0.516
Miconia prasina	0.630 ± 0.021	0.503 ± 0.002	0.464 ± 0.013	0.502 ± 0.004	0.500
Myrcia splendens	0.614 ± 0.033	0.526 ± 0.001	0.523 ± 0.004	0.515 ± 0.001	0.524
Ocotea leucoxylon	0.340 ± 0.017	0.534 ± 0.002	0.489 ± 0.005	0.536 ± 0.007	0.527
Pimenta racemosa	0.666 ± 0.031	0.539 ± 0.004	0.514 ± 0.010	0.526 ± 0.004	0.533
Schefflera morototoni	0.162 ± 0.014	0.517 ± 0.001	0.480 ± 0.002	0.512 ± 0.002	0.511
Spathodea campanulata	0.234 ± 0.026	0.504 ± 0.001	0.461 ± 0.004	0.511 ± 0.002	0.498
Sysygium jambos	0.556 ± 0.020	0.519 ± 0.002	0.525 ± 0.002	0.536 ± 0.002	0.522
Tabebuia heterophylla	0.514 ± 0.005	0.554 ± 0.001	0.545 ± 0.002	0.526 ± 0.001	0.549
Thespesia grandiflora	0.488 ± 0.018	0.548 ± 0.002	0.526 ± 0.009	0.532 ± 0.001	0.543

[1]Weighted Average.

ticola is shown as an example (Fig. 1). Although several forms were tried, simple linear regression forced through the origin with D^2L as the independent variable was the most efficient and easiest to use for predictive purposes. The coefficients and R-squared values for the 20 species and diameter measurements at 5 cm, 30 cm, and 75 cm are given in Table 3. Regression equations using measurements of diameter at 137 cm above ground line were somewhat erratic and were not considered. R-squared values for regression equations ranged from 0.913 to 0.991. Diameter measured at 30 cm was slightly more efficient than lower or higher positions on the stem and had an average R-squared value of 0.971.

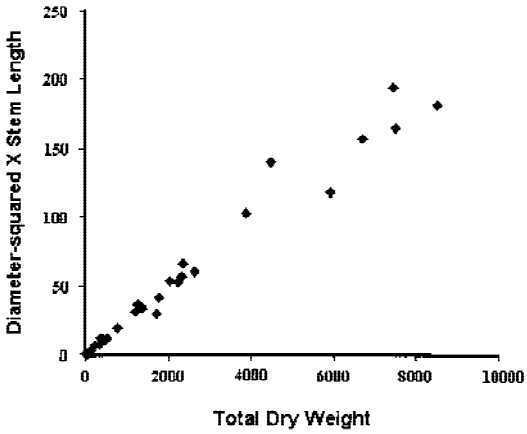

FIG. 1. Example of scatter diagram, total dry weight of saplings of *Eugenia monticola* plotted against diameter at 30 cm squared multiplied by stem length.

Because more than 200 species occur in local secondary forests, equations for only 20 common species can be inadequate. To accommodate additional species that might occur, and for simplicity of use, a general-purpose equation was calculated using all 600 samples of the 20 species in the study. Because the species differ particularly in wood specific gravity, this factor was introduced as an additional independent variable. Simple linear regression forced through the origin resulted in the following models:

$$\text{Total dry weight} = 42.019SL(D_{5\ cm})^2 \quad \text{R-squared} = 0.945$$
$$\text{Total dry weight} = 52.896SL(D_{30\ cm})^2 \quad \text{R-squared} = 0.954$$
$$\text{Total dry weight} = 61.309SL(D_{75\ cm})^2 \quad \text{R-squared} = 0.949$$

Where S = specific gravity of species to be predicted, L = stem length, and D = diameter measured at 5, 30, and 75 cm, respectively. Regression models in multiple and polynomial forms resulted in lower R-squared values.

The mixed-species group of 30 saplings, not used in preparing the general formulas, was tested by Pearson's correlation of predicted versus actual dry weights. Correlation coefficients (r values) of 0.937, 0.942, and 0.948 were obtained for the models for diameters at 5, 30, and 75 cm. Probably any measurement point between 20 and 60 would give nearly

TABLE 3. Coefficients and adjusted R-squared values for prediction models for total dry weight of saplings of 20 species of secondary forests of Puerto Rico.

	5 cm		30 cm		75 cm	
Species	Coeff[1]	ARS[2]	Coeff	ARS	Coeff	ARS
Albizia procera	14.698	0.991	18.653	0.987	21.723	0.970
Ardisia elliptica	14.766	0.936	22.010	0.981	23.891	0.966
Bucida buceras	20.299	0.930	42.410	0.972	33.433	0.986
Calophyllum calaba	21.587	0.971	27.040	0.983	31.510	0.983
Casearia decandra	28.965	0.967	34.359	0.980	41.135	0.977
Casearia guianensis	24.887	0.984	32.818	0.971	38.394	0.982
Eugenia monticola	33.963	0.985	41.888	0.984	45.375	0.988
Faramea occidentalis	23.62	0.951	30.045	0.962	35.792	0.976
Guarea guidonia	15.981	0.983	21.818	0.982	28.369	0.962
Inga laurina	26.742	0.983	31.123	0.983	31.488	0.950
Leucaena leucocephala	22.019	0.985	27.509	0.965	32.104	0.970
Miconia prasina	29.036	0.976	38.344	0.981	49.358	0.990
Myrcia splendens	26.004	0.960	31.900	0.980	38.242	0.982
Ocotea leucoxylon	17.339	0.967	21.645	0.973	25.222	0.976
Pimenta racemosa	33.039	0.964	38.094	0.935	44.820	0.945
Schefflera morototoni	9.909	0.939	13.604	0.960	16.761	0.940
Spathodea campanulata	9.022	0.964	13.477	0.971	19.22	0.968
Syzygium jambos	29.715	0.946	35.105	0.948	40.375	0.953
Tabebuia heterophylla	19.427	0.982	23.370	0.981	28.359	0.971
Thespesia grandiflora	25.911	0.913	31.788	0.933	36.719	0.931
Mean		0.964		0.971		0.968

[1]Coefficient.
[2]Adjusted r-squared.

the same results, were the equations prepared using them.

Total weight of carbon in saplings can be predicted by simply multiplying carbon content values by the weights obtained using one of the models. For species not listed in Table 1, mean values of 0.521, 0.496, and 0.517 can be used for wood, bark, and leaves respectively. Because these tissues do not occur in equal quantities in saplings, a ratio of 0.72 to 0.16 to 0.12, derived as an average of a large number of species was used (Buech and Rugg, 1989; Francis and Baker, 1981; Ku et al., 1981; Kushalapa, 1988; Pande et al., 1988; Tandon et al., 1988a; Tandon et al., 1988b). This ratio and the above-cited means yield a weighted average for whole-sapling carbon of 0.516.

Many studies have produced allometric equations for dry weight biomass of trees with diameter ranges extending into the sapling range, and in other areas of the world, equations for small trees, saplings and shrubs have been produced for a large number of species (see earlier citations). Using mostly log-log transformations, these authors have been able to achieve adjusted r-squared values in the range of 0.95. However, these complicated equations often daunt foresters and the less mathematically inclined researchers. DBH approaches 0 at the lower limit of sapling size. Although representing a lesser portion of the total biomass of saplings in stands, their numbers increase almost exponentially as diameter decreases. The equations presented in this note offer the advantage of representing a broad range of species from the largest life zone (moist) and most extensive forest type (secondary). Diameter ranges are represented down to the lower limit of sapling size. The equations are very easy to use and give the same accuracy as more sophisticated models. A draw-back is that inventory data for trees are normally measured in terms of DBH. If sapling sizes are to be included, a different measurement height (such as 30 cm) would have to be used.

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LITERATURE CITED

American Society for Testing and Materials. 1968. 1968 book of ASTM standards. Part 16. American Society for Testing and Materials, Philadelphia, Pennsylvania. 930 pp.

Buech, R.R. and D.J. Rugg. 1989. Biomass relations of shrub components and their generality. For. Ecol. Manag. 26: 257-264.

Chaturvedi, A.N., Shubhra Bhatia, and H.M. Behl. 1991. Biomass assessment for shrubs. Indian Forest. 117: 1032-1035.

Dudley, N.S. 1992. Preliminary biomass equations for

eight species of fast-growing trees. J. Trop. For. Sci. 5: 68-73.
Francis, J.K. and J.B. Baker. 1981. Biomass and nutrient accumulation in cottonwood plantation-the first four years. USDA Forest Service Res. Note SO-278. 4 p.
Grundy, I.M. 1995. Wood biomass estimation in dry miombo woodland in Zimbabwe. For. Ecol. Manag. 72: 109-117.
Holdridge, L. R. 1967. Life zone ecology. Tropical Science Center, San Jose, Costa Rica. 206 pp.
Khan, T.A. and P.S. Pathak. 1986. Biomass prediction models in *Leucaena leucocephala* (Lam.) De Wit plantations. Leucaena Res. Notes 7: 53-54.
Ku, T.T., J.K. Francis and C.R. Blinn. 1981. Fertilizer response and biomass accumulation of a 5-year-old sweetgum plantation. *In* J.P. Barnett (ed.), First Biennial Southern Silviculture Research Conference, pp. 195-198. Southern Forest Research Station, New Orleans, Lousiana.
Kushalapa, K.A. 1988. Biomass predictions in *Eucalyptus* plantations using Furnival Index. J. Trop. For. 4: 58-67.
Lövenstein, H.M. and P.R. Berliner. 1993. Biometric relationships for non-distructive above ground biomass estimations in young plantations of *Acacia salicina* Lindl. and *Eucalyptus occidentalis* Endl. New Forests 7: 255-273.
Odum, E.P. 1971. Principles of ecology. Saunders, Philadelphia, Pennsylvania. 574 pp.
Ovington, J.D. and J.S. Olson. 1970. Biomass and chemical content of El Verde lower montane rain forest plants. *In* H.T. Odum and R. Pigeon (eds.): A tropical rain forest, a study of irradiation and ecology at El Verde, Puerto Rico, pp H53-H61. U.S. Atomic Energy Commission, Division of Technical Information, Oak Ridge, Tennessee.
Pande, M.C., V.N. Tandon and M. Negi. 1988. Biomass production in plantation ecosystem of *Ailanthus excelsa* at five different ages in Utter Pradesh. Indian Forest. 114: 362-371.
Parrotta, J.A. 1989. The influence of management practices on the biogeochemical stability of tropical fuelwood plantations. Trop. Ecol. 30: 1-12.
Parrotta, J.A. 1999. Productivity, nutrient cycling, and succession in single- and mixed-species plantations of *Casuarina equisetifolia, Eucalyptus robusta*, and *Leucaena leucocephala* in Puerto Rico. For. Ecol. Manag. 124: 45-77.
Scatena, F.N., W. Silver, T. Siccama, A. Johnson and M.J. Sánchez. 1993. Biomass and nutrient content of the Bisley experimental watersheds, Luquillo Experimental Forest, Puerto Rico, before and after Hurricane Hugo, 1989. Biotropica 25: 15-27.
Tandon, V.N., M.C. Pande, R. Lajpat and H.S. Rawat. 1988a. Biomass production and its distribution by *Acacia nilotica* plantations at five different ages in Haryana. Indian Forest. 114: 770-775.
Tandon, V.N., M.C. Pande and R. Singh. 1988b. Biomass estimation and distrubution of nutrients in five different aged *Eucalyptus grandis* plantation ecosystems in Karala State. Indian Forest. 114: 184-199.
Weaver, P.L. and A.J.R. Gillespie. 1992. Tree biomass equations for the forests of the Luquillo Mountains, Puerto Rico. Comm. Forest. Rev. 71: 35-39.

in PC as having zonate tetrasporangia, suggested that these algae may be taxonomically identical.

Two authentic specimens of *Halymenia pennata* have been included in this study, one in PC and the other in BM. The former (in the Thuret-Bornet Herbarium of PC) was examined and photographed, and a sketch with notes on an accompanying herbarium sheet was also photographed. The BM specimen was photographed by W. R. Taylor and the photograph is at MICH. A photograph by Dr. Taylor of the Crouans' specimen of "*Chrysymenia ramosissima*" (in BM) from Guadeloupe is in MICH and was included in this study. Many collections of *Agardhiella ramosissima* from the tropical western Atlantic were available in MICH for comparison. The herbarium abbreviations follow Holmgren et al. (1990).

In their original account of *Halymenia pennata*, Crouan and Crouan (in Schramm and Mazé, 1865) stated that the collection was made in March from the port of Moule (Guadeloupe, French West Indies). The specimen with this name in the Thuret-Bornet Herbarium in PC (Fig. 1) indicates in the label data that it is from "Moule, Mars, 1862, M. Schramm". It also bears the number "278". The branching of this specimen is primarily pinnate and planar, although some branches arise at angles out of the usual plane of branching. The main axis is flattened, up to 8 mm wide, and is branched to three orders (assuming that the blade is a primary axis). The numerous secondary branches are also flattened and not as wide as the primary axis. The branches are narrowly attenuated at their basal attachment to the bearing blade. The basal part of the frond is missing. This specimen bears an annotation that it has zonately divided tetrasporangia, a characteristic in conflict with an assignment to *Halymenia* and the Halymeniaceae—a family characterized by cruciately divided tetrasporangia (Guiry, 1990). An accompanying herbarium sheet bears a sketch and notes (Fig. 2) of the base of an apparently different specimen but with the same no. 278. The specimen appears to have three orders of branches from the reduced primary axis. The notes indicate that this sketch is of the base of a large specimen, that the base is not as fibrous as that of *Gracilaria cervicornis*, and that the fronds are thick, gelatinous, and translucent. Several of these words are also in the protologue. This specimen in PC (Fig. 1) conforms with all critical elements of the protologue and is therefore designated the lectotype of *Halymenia pennata*.

A photograph [in MICH] of a second authentic specimen of *Halymenia pennata* in BM was made by Dr. W. R. Taylor. That specimen (Fig. 3) is not as large or densely branched as the PC specimen, but it shares the same pinnate branching from a broad (6 mm) primary axis. The primary axis is 9 cm long but it is obviously incomplete. The main axis is branched to three orders, the branches are also borne along the margins, and they are narrowly constricted at their bases. This specimen also bears no. 278, like the designated lectotype, and thus this specimen in BM is treated here as an isolectotype.

Knowing the provenance of the French West Indies for *Halymenia pennata* and recognizing that the tetrasporangia are zonately divided, it became obvious that *H. pennata* and *Agardhiella ramosissima* (Harvey) Kylin, a species of Solieriaceae that is widespread throughout the tropical western Atlantic, are synonyms. Some collections in MICH identified as *A. ramosissima* have conspicuously broad primary axes, well developed planar, pinnate branching, and other attributes that agree with the features outlined above for *H. pennata*. Littler and Littler (2000) described the thallus of *A. ramosissima* as fleshy, slippery but firm, repeatedly pinnately branched, alternate to opposite, with flattened main axes, and producing zonately divided tetrasporangia scattered in surface patches.

It should be noted that the Crouans also reported the occurrence of *A. ramosissima* from Guadeloupe (in Schramm and Mazé, 1878, as *Chrysymenia ramosissima*). Figure 4 is a photograph taken by Dr. Taylor [in MICH] of a Guadeloupe specimen in the BM (Crouans no. 1331). The close resemblance to *H. pennata* is evident in the flattened primary axes, the dense pinnate branching, and the narrowly constricted bases of the lateral branches. The Crouans (in Mazé and Schramm, 1878) also referred to a "*Chrysymenia ramosissima* var. *latifrons* Crn. mscr.," indicating the presence of a broad-bladed form.

Agardhiella ramosissima was described by Harvey [1853, as "*Chrysymenia* (*Cryptarachne*) *ramosissima*"] cast up from deep water at Key West, Florida, and considered rare. The alga was described as having compressed axes below, terete above, and distichously much branched. The main axis was provided throughout its length with very patent, distichously arranged lateral branches that arose at very obtuse angles. Harvey noted the presence of female plants, referring to immersed conceptacles, and depicted a vertical section through a conceptacle. He did not observe tetrasporangia. Agardh (1876) transferred the species to *Rhabdonia* and later (1885) recognized two varieties, var. *harveyana* [presumably the nominate variety, i.e., var. *ramosissima*] and var. *dilatata* (differentiated by the flattened nature of its axes). Børgesen (1919) added observations on the occurrence of this species in the Danish West Indies and pointed out the similarity of the vegetative and reproductive development with that of *Agardhiella*. He referred to the specimens as f. *dilatata* and being compressed with branches "given off from the edges and mostly regularly opposite, now and then also alternating or unilaterally." He found fragments of a nearly terete plant, which he treated as f. *harveyana* (that is, f. *ramosissima*). Taylor (1928) reported *Rhabdonia ramosissima* var. *dilatata* J. Agardh from Florida on the basis of Collins et al.'s *Phycotheca Boreali-Americana No. 1397* (1907), but admitted that this taxon was otherwise unknown to him. Kylin (1932) transferred the species to *Agardhiella*, where it remains, and mentioned the possibility that the two varieties described by J. Agardh could represent distinct species.

Taylor (1942) extended the range of *Agardhiella ramosissima* to Venezuela. His collection (Taylor no. 39-371 in MICH) from Punta Arenas at the western end of Tortuga Island shows a strong resemblance to *H. pennata* in size (to 43 cm long) and its broad, flattened, percurrent main axis (7-11 mm wide) that gives rise to distichously arranged compressed laterals, which are

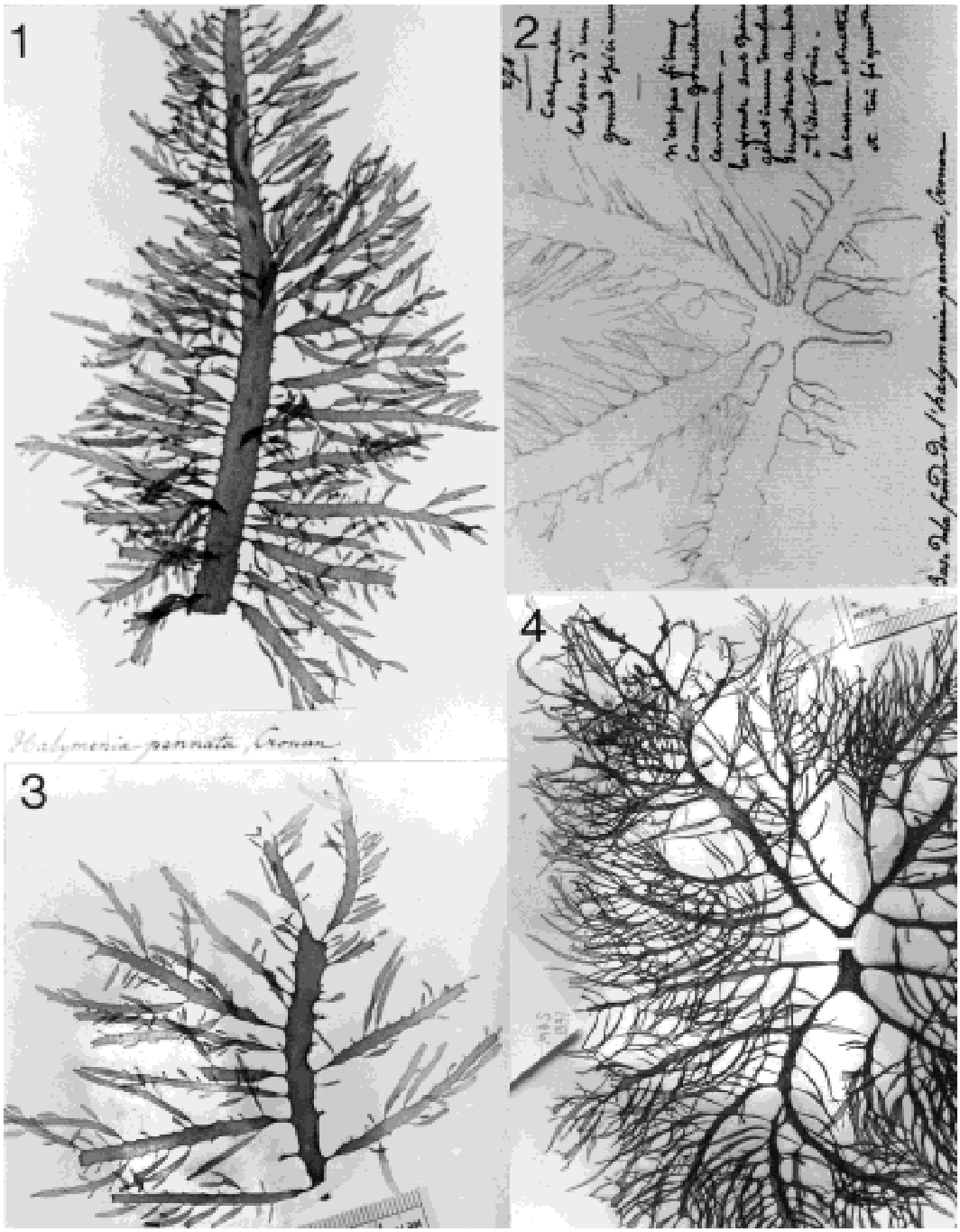

FIG. 1-4. Lectotype of *Halymenia pennata* (Crouan 278, Moule, Guadeloupe) in Thuret-Bornet Herbarium, PC FIG. 2. Sketch of base of *Halymenia pennata* with notes, Crouan 278, in Thuret-Bornet Herbarium, PC. FIG. 3. Isolectotype of *Halymenia pennata*, Guadeloupe specimen, Crouan 278, BM. FIG. 4. Guadeloupe specimen of *Chrysymenia* [*Agardhiella*] *ramosissima*, Crouan 1331, BM.

themselves branched to two additional orders. The occurrence of *Agardhiella ramosissima* in deep water offshore of North Carolina was verified by Schneider and Searles (1973, 1991).

Pedrini (1984) made the first report of *Agardhiella ramosissima* from as far south as Rio de Janeiro, Brazil. In their study of flattened Solieriaceae, Guimarães and Oliveira (1996) recognized two genera occurring in Brazil—*Agardhiella* and *Meristiella*. They depicted *A. ramosissima* as being comprised of percurrent flattened or compressed axes up to 70 cm long and 0.5-2.0 cm wide, with 2-4 orders of subopposite, distichously arranged flattened lateral branches. These branches are said to be constricted at the point of insertion on the main branch and attenuated at the apex. The specimen depicted in their Fig. 20 (from Itaipava, Brazil) shows a strong resemblance to *Halymenia pennata*. The analysis of the morphological variation in the Brazilian populations of A. *ramosissima* led Guimarães and Oliveira (1996) to conclude that the recognition of varieties (e.g., the broad var. *dilatata*) was not justified. Thus, they would not support Kylin's (1932) suggestion that var. *dilatata* and *A. ramosissima* var. *ramosissima* could be separate species. Should Kylin's idea gain acceptance, the epithet *pennata* (from *Halymenia pennata* of the Crouans) would be a valid and available name for this species with the broad, flattened main axis. The current taxonomic treatment is as follows:

Agardhiella ramosissima (Harvey) Kylin, 1932: 17.

Basionym: *Chrysymenia* (*Cryptarachne*) *ramosissima* Harvey, 1853: 190.

Homotypic synonym: *Rhabdonia ramosissima* (Harvey) J. Agardh, 1876: 593.

Rhabdonia ramosissima var. *ramosissima* = var. *Harveyana* J. Agardh, 1885: 85.

R. ramosissima var. *dilatata* J. Agardh, 1885: 85.

Homotypic synonym: *Neoagardhiella ramosissima* (Harvey) M.J. Wynne et W.R.Taylor, 1973: 103.

Heterotypic synonym: *Halymenia pennata* H. Crouan & H. Crouan in Mazé and Schramm, 1865: 9.

Literature Cited

Agardh, J. G. 1876. Species, genera et ordines algarum. . ., Vol. 3, Pt. 1. Epicrisis systematis floridearum. Weigel, Leipzig, vii + 724 p.

Agardh, J. G. 1885. Till algernes systematik. VII. Florideae. Lunds Universitets Års-Skrift, Afdelningen för Mathgematik och Naturvetenskap 21(8): 1-117 + 1 pl.

Børgesen, F. 1919. The marine algae of the Danish West Indies. Part 3: Rhodophyceae (5). Dansk Bot. Ark. 3: 305-368.

Collins, F. S., I. Holden and W. A. Setchell. 1907. Phycotheca Boreali-Americana. Fasc. XXVIII. (Exsicc.). Malden, Mass.

DeToni, G. B. 1924. Sylloge algarum. . .Vol. VI. Florideae. Sectio V. Addimenta. Patavii, xi + 767 p.

Dixon, P. S., 1967. Notes on important algal herbaria, V. The herbaria of Bonnemaison and the brothers Crouan. British Phycological Bulletin 3: 213-218.

Guimarães, S. M. P. B. and E. C. Oliveira. 1996. Taxonomy of the flattened Solieriaceae (Rhodophyta) in Brazil: *Agardhiella* and *Meristiella*. Journal of Phycology 32: 656-668.

Guiry, M. D. 1990. Sporangia and spores. *In*: Cole, K.M. & Sheath, R.G. (eds.) Biology of the Red Algae, pp. 347-376. Cambridge University Press, Cambridge.

Harvey, W. H. 1853. Nereis Boreali-Americana. . .Part II. Rhodospermeae. Smithsonian Contributions to Knowledge 5(5):1-258, pls. XIII-XXXXVI.

Holmgren, P. K., N. H. Holmgren and L. C. Barnett. 1990. Index Herbariorum, I. The Herbaria of the World, 8th ed. New York Botanical Garden, New York, × +693 pp. [Regnum Vegetabile, vol.120]

Kylin, H. 1932. Die Florideenordnung Gigartinales. Lunds Univ. Årsskr., N.F., Avd. 2, 28(8). 88 pp.

Littler, D. S. and M. M. Littler. 2000. Caribbean Reef Plants. An identification guide to the reef plants of the Caribbean, Bahamas, Florida and Gulf of Mexico. Off-shore Graphics, Inc. Washington, D.C. 542 pp.

Mazé, H. and A. Schramm. 1878 (dated 1870-1877). Essai de classification des algues de la Guadeloupe. 2nd edn. Basse-Terre, Guadeloupe, Imprimerie du Gouvernement, xix + iii [= errata] + 283 pp.

Murray, G. 1888-1889. Catalogue of the marine algae of the West Indies region. Journal of Botany, British and Foreign 26: 193-196; 237-243; 303-307; 331-338; 358-363. [1889] 27: 237-242; 257-262; 298-305.

Pedrini, A. 1984. Algas marinhas bentônicas do litoral Norte-Fluminense. I-Lista preliminar das algas "Arribadas" da Praia de Manguinhos (Guaxindiba - São João da Barra - Rio de Janeiro). Atas da Sociedade Botanica do Brasil, secção Rio de Janeiro 2: 133-142.

Schneider, C. W. and R. B. Searles. 1973. North Carolina marine algae. II. New records and observations of the benthic offshore flora. Phycologia 12: 201-211.

Schneider, C. W. and R. B. Searles. 1991. Seaweeds of the Southeastern United States: Cape Hatteras to Cape Canaveral. Duke University Press, Durham, xiv + 553 pp.

Schramm, A. and H. Mazé. 1865. Essai de classification des algues de la Guadeloupe. Edn. 1. Basse-Terre, Guadeloupe, Imprimerie du Gouvernement, 52 = [1] [= errata] p.

Schramm, A. and H. Mazé. 1866. Essai de classification des algues de la Guadeloupe. Edn. 1a. Cayenne, Guyane française, Imprimerie du Gouvernement, 144 = [iii] p.

Silva P. C., P. W. Basson and R. L. Moe. 1996. Catalogue of the benthic marine algae of the Indian Ocean. University of California Publications in Botany 79: xiv + 1,259.

Taylor, W. R. 1928. The marine algae of Florida, with special reference to the Dry Tortugas. Publications of the Carnegie Institution of Washington 379, v + 219 pp., 37 pls.

Taylor, W. R. 1942. Caribbean marine algae of the Allan Hancock Expedition, 1939. Allan Hancock Atlantic Expedition Report Number 2. 193 p.

Taylor, W. R. 1960. Marine algae of the eastern tropical and subtropical coasts of the Americas. University of Michigan Press, Ann Arbor, Michigan, ix + [1] + 870 pp.

Wynne, M. J., 1986. A checklist of benthic marine algae of the tropical and subtropical western Atlantic. Canadian Journal of Botany 64: 2239-2281.

Wynne, M. J., 1998. A checklist of benthic marine algae of the tropical and subtropical western Atlantic: first revision. Nova Hedwigia Beiheft 116, iii + 155 p.

Wynne, M. J. and W. R. Taylor. 1973. The status of *Agardhiella tenera* and *Agardhiella baileyi* (Rhodophyta, Gigartinales). Hydrobiologia 43: 93-107.