RESEARCH ARTICLE

# Preliminary Observation of Native *Glyptostrobus pensilis* (Taxodiaceae) Stands in Vietnam

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ABSTRACT: Results of preliminary studies of last remnants of *Glyptostrobus pensilis* native populations in Vietnam are presented in the paper in form of standard taxonomical treatment with comments on ecology, population structure and natural conditions of its habitats. Perspectives of conservation of this unique Tertiary relict are specially assessed and discussed.

KEY WORDS: Native populations, *Glyptostrobus pensilis*, Taxodiaceae, tertiary relict, Vietnam, eastern Indochina.

## INTRODUCTION

Taxodiaceae family closely related to Cupressaceae includes 9 genera - *Athrotaxis, Cryptomeria*, *Cunninghamia, Glyptostrobus, Metasequoia, Sequoia, Sequoiadendron, Taiwania* and *Taxodium* sporadically spreading in Asia, North America and Tasmania. Representatives of two monotype genera in this family – *Taxodium distichum* (L.) Rich. and *Glyptostrobus pensilis* (Staunton ex D. Don) K.Koch are ecological twin analogues forming similar mono-dominant permanently inundated damp swampy forests. At the same time, while native swamp forests with *Taxodium distichum* cover in our days endless coastal swampy territories on the south of North America, *Glyptostrobus pensilis* stands presently on the verge of full extinction in the nature. *Glyptostrobus pensilis* known also under the names – thông nước, thuỷ tùng (Vietnamese), shui song (Chinese), and "Water Pine" or "Chinese Swamp Cypress" (English), is typical Tertiary relict species formerly widespread prior to the Quaternary glaciations in vast areas of Northern Hemisphere, including the high Arctic, where it formed extensive swampy tropical and subtropical mono- and oligo-dominant forests. The species was reduced to its current range before and during the ice ages. Toward the years of our era, small sporadic relict stands of *G. pensilis* survived in lowland and hill damp swampy areas of southeastern China, central Vietnam and eastern Laos. The species vanished in nearly all these natural refugiums already during last centuries due to modern anthropogenic deforestation, land drainage, melioration and agricultural landscape transformation. Fortunately, in many areas of southern China *G. pensilis* observed now as a more or less common cultivated tree. It is reported presently in Fujian, S. Guangdong, S. Guangxi, Hainan, E. Jiangxi, E. Sichuan, SE. Yunnan and Zhejiang (Fu et al., 1999; Li and Xia, 2005). In our days, few miserable native stands of this unique relict species still survive only in central Vietnam known in Vietnamese literature as "Central Highlands" (Fig. 1) and in eastern Laos. These are alone places in the world where we still can see remnants of unique native relict coniferous forests widely spreading in Asia in Tertiary ages. Results of preliminary studies of last remnants of *G. pensilis* native populations in Vietnam are presented below in form of standard taxonomical treatment with comments on ecology, population structure and natural conditions of its habitats.

## TAXONOMIC TREATMENT

Taxodiaceae Warming
*Glyptostrobus* Endlicher, Syn. Conif.: 69 1847.

***Glyptostrobus pensilis*** (Staunton ex D. Don) K. Koch, Dendrologie 2, 2: 191, 1873; Le Kim Bien, Phan Ke Loc, Fl. Taynguyen. Enum.: 220, 1983; Phan Ke Loc, Journ. Biol. (Ha Noi), 6, 4: 10, 1984; Nguyen Tien Hiep, Vidal, Fl. Cambod. Laos Vietnam, 28: 60, 1996; Pham Hoang Ho, Ill. Fl. Viet Nam 1: 222, fig. 891, 1999; Nguyen Tien Hiep et al., Vietnam Conifers: 60, 2004. - *Thuja pensilis* Staunton ex D. Don in Lambert, Descr. Pinus, ed. 2, 2: 125, 129. Figs. 2 & 3, 1824.



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*Thuja lineata* Poiret, Encycl. (Lamarck) Suppl. 5: 303, 1817.
*Juniperus aquatica* Roxb., Fl. Indica 3: 838, 1832.
*Taxodium heterophyllum* Brongn., Ann. Sci. Nat. Sér. 1, 30: 184, 1833.
*Taxodium japonicum* (Thunb. ex L.f.) Brongn. var. *heterophyllum* Brongn., Ann. Sci. Nat. (Paris) 30: 184, 1833.
*Taxodium japonicum* Brongn., 1839, Ann. Sci. Nat. (Paris), Sér. 2, 12: 232, non Brongn., 1833.
*Taxodium sinense* J. Forbes, Pinetum Woburn.: 179, 1839.
*Glyptostrobus heterophyllus* (Brongn.) Endlicher, Syn. Conif.: 69, 70, 1847.
*Sabina aquatica* (Roxb.) Antoine, Cupress.-Gatt.: 70, 1857.
*Cupresopinnata heterophylla* (Brongn.) J. Nelson, Pinaceae: 62, 1866.
*Cupresopinnata sinensis* (Forbes) J. Nelson, Pinaceae: 62, 1866.
*Glyptostrobus sinensis* A.Henry ex Loder, Gard. Chron., Ser.3, 66: 259, 1919.
*Glyptostrobus aquaticus* (Roxb.) R. Parker, Indian Forest. 15: 61, 1925.
*Thuja lineata* auct. non Poir., 1817.
*Glyptostrobus lineatus* auct. non (Poir.) Druce, 1917.
*Thuja orientalis* auct. non L.: Lour., Fl. Cochinchin.: 580, 1790,; id., Flora Cochinchin. 2: 712, 1793.

Described from SE. China ("Province of Guangdong"). Type ("*G. L. Staunton s. n.*") – BM.

Description (species description is based solely on studied wild Vietnamese specimens): Tree evergreen, semi-deciduous, monoecious, to 25 m tall and to 1.5 m d.b.h. (diameter at breast high) with approximately estimated age to 400 years, markedly buttressed at the base. Trunk erect, straight, occasionally particulated from the base into 2-3 (-5), commonly unequal boles, formation of several stems in individual tree due to natural particulation gives superficial impression of separate specimens planted in cultivation closely together as was speculatively suggested by some authors (Farjon, 2005); main branches more or less whorled. Crown ovate to pyramidal, becoming broader with age, lower branches spreading, upper ones sub-erect. Air roots (pneumatophores) few, to 0.6 tall and 0.3 m thick, grow from lateral roots, and spread up to 0.5-5 m around tree base. Bark thick, soft, grey to brown, longitudinally fissured, exfoliating into long papery irregular ribbons. Branchlets dimorphic, perennial and annual. Perennial branchlets more or less long, usually remaining for several years, ridged and grooved, with whitish lines of stomatal dots and decurrent leaf bases, often fertile. Annual branchlets short, always sterile, deciduous as unit. Leaves spirally arranged, dimorphic; on perennial shoots leaves sessile, scale-like overlapping to subulate spreading, relatively thick, triangular to quadrangular in cross section, persistent for 2 or 3 years, cowered with numerous white stomatal dots; leaves on annual shoots, unclearly 2-ranked, flat, thin, oblong to linear, falcate, 5-20 mm long. Pollen (male) cones terminal on short, erect branchlets bearing scale-like leaves, solitary, globose to broadly-ovoid, 2-6 mm long, 2-4 mm wide,

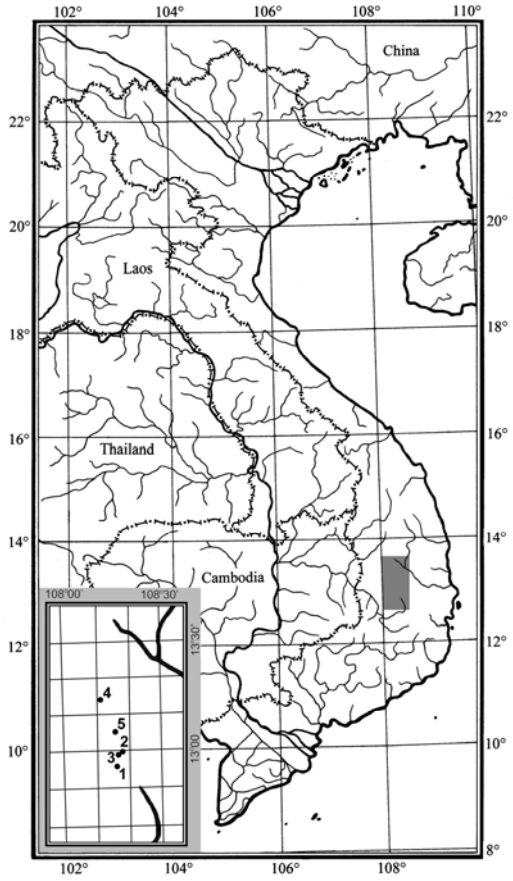



**Fig. 1. Map of modern distribution of *Glyptostrobus pensilis* in Vietnam.**

brown to dark brown. Microsporophylls 8-20, spirally arranged, sessile, broadly-ovate, 1.5-2 mm long, 1-1.5 mm wide, concave; pollen sacs 4-7, palmately clustered at the base of microsporophyll, green to yellowish-green, globose to broadly-obovate. Seed (female) cones terminal, globular to obovoid, pale green, glaucous, later brown, 1.2-22 mm long, 10-15 mm wide, on short erect broadening peduncle covered with triangular scale-like acute leaves, which become similar with seed cone scales toward the peduncle apex; sterile (cone) bract and seed bract completely connate into scale (seed-scale complex) with only free triangular, acute recurved apex of sterile bract. Seed cone scales 12-22, spirally arranged, sessile, thin woody, obovate to spatulate-triangular, recurved, 8-12 mm long, 3-5 mm wide; basal scales sterile; median scales 2-seeded, with rough warty teeth at apex and triangular mucro above their centre; apical scales ligulate, multiangular, sterile. Seeds dark brown, ellipsoid, slightly flattened, 5-6 mm long, 2.5-3.5 mm wide, with terminal thin, brownish, oblique attached, triangular, wing about 3 mm long, unequally bilobulate at the apex. Seed cones ripening and shedding mature seeds in November – December.



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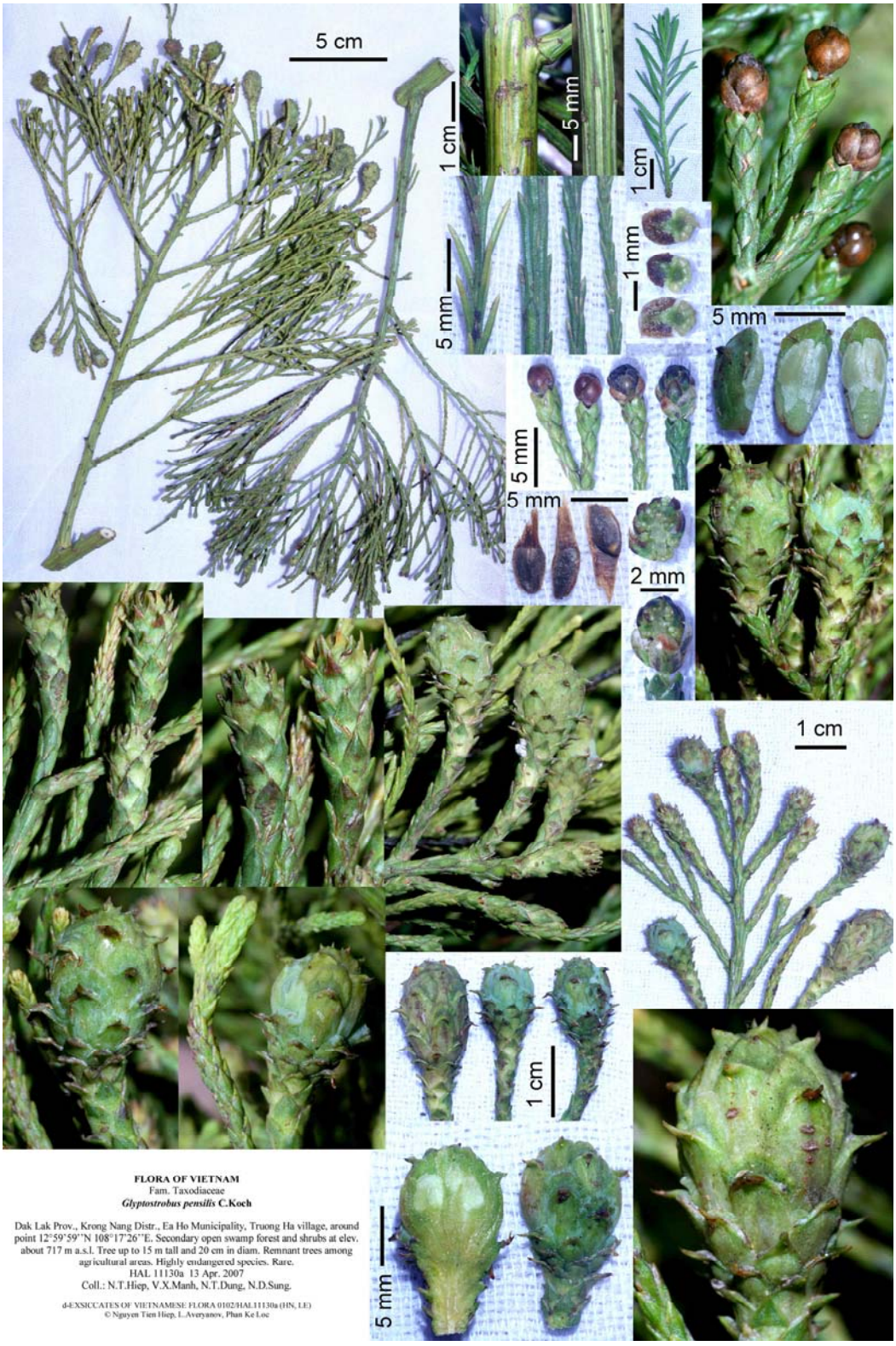



**Fig. 2. Digital herbarium specimens of *Glyptostrobus pensilis* from Vietnam, *HAL 11130a* (photographs of Leonid V. Averyanov).**



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Former distribution: Wide tropical and subtropical areas in Northern Hemisphere during Tertiary ages.

Present distribution: Central Vietnam, Dak Lak Province, only 5 close locations (Fig. 1), eastern Laos, Borikhamxai Province, about dozen small populations in very limited area allied to Vietnamese border. Also was reported from southern China, where no longer exist in the wild (Fu et al., 1999). In our days cultivated in many provinces of southern China, as well as in some countries outside it's primary area, commonly in lowland, damp, riparian lands, river deltas, sometimes along rice fields, on flooded or waterlogged soils, commonly near sea level (Dallimore et al., 1967; Vidakovic, 1991; Fu et al., 1999).

Specimens examined: Location 1: Dak Lak Prov., Krong Buk Distr., Buon Ho townlet, around point 12º56'07''N 108º16'57''E, open wet low slope of small river in the center of town among agricultural private vegetable fields, alone much decreased tree about 19 m tall with bole 66 cm in diameter (d.b.h.), 1 April 2008, *N.T.Hiep, L.Averyanov, P.K.Loc, N.T.Vinh, P.T.Duyen, HAL 11357* (HN). Location 2: Dak Lak Prov., Krong Nang Distr., Ea Ho Municipality, Truong Ha village, around point 12º59'59''N 108º17'26''E, secondary open swamp forest and shrubs at elevation about 717 m a.s.l., tree up to 15 m tall and 20 cm in diam, few remnant trees among agricultural areas, 13 Apr. 2007, *N.T.Hiep, V.X.Manh, N.T.Dung, N.D.Sung, HAL 11130a*, d-EXSICCATES OF VIETNAMESE FLORA *0102/HAL 11130a* (HN); Krong Nang Distr., Ea Ho Municipality, Truong Ha village, around point 12º59'59''N 108º17'26''E, secondary open swamp forest and shrubs at elevation about 717 m a.s.l., tree up to 15 m tall and 20 cm in diam., remnant trees among agricultural areas, 13 Apr. 2007, *N.T.Hiep, V.X.Manh, N.T.Dung, N.D.Sung, HAL 11130b*, d-EXSICCATES OF VIETNAMESE FLORA *0103/HAL 11130b* (HN). Location 3: Dak Lak Prov., Krong Nang Distr., Ea Ho Municipality, Trap K'Sor *Glyptostrobus pensilis* Species/Habitat Protected Area, 12º59'07''N 108º17'02''E, evergreen closed swamp forest on alluvial soils in flat swampy valley between hills at elevation about 706 m a.s.l., few decreased trees up to 15 m tall, 13 March 2008, *N.T.Hiep, Averyanov L., P.K.Loc, N.T.Vinh, N.S.Khang, T.H.Thai, HLF 7111* (HN); Krong Nang Distr., Ea Ho Municipality, Trap K'Sor *Glyptostrobus pensilis* Species/Habitat Protected Area, around point 12º59'12''N 108º16'50''E, secondary shrubs and grasslands on seasonally wet, swampy gray soils on the place of extinct primary swamp forest at elevation about 706 m a.s.l., tree 4-6 m tall, very rare, few much decreased relict trees scattered on the territory of reserve, 1 April 2008, *N.T.Hiep, L.Averyanov, P.K.Loc, N.T.Vinh, P.T.Duyen, HAL 11349* (HN); 2 April 2008, *N.T.Hiep, L.Averyanov, P.K.Loc, N.T.Vinh, P.T.Duyen, HAL 11358* (HN); Krong Nang Distr., Ea Ho Municipality, Trap K'Sor *Glyptostrobus pensilis* Species/Habitat Protected Area, evergreen closed swamp forest on alluvial soils in flat swampy valley between hills at elevation about 706 m a.s.l. around point 12º59'11''N 108º17'06''E, tree up to 24 m tall and 79 cm in diam., 27 November 2008, *P.K.Loc, N.H.Cuong HAL 11946* (HN); around point 12º59'11''N 108º17'04''E, tree up to 24 m tall and 90 cm in diam., 28 November 2008, *P.K.Loc, N.H.Cuong HAL 11947* (HN); around point 12º59'19''N 108º17'07''E, tree up to 24 m tall and 90 cm in diam., 28 November 2008, *P.K.Loc, N.H.Cuong HAL 11948* (HN); around point 12º59'16''N 108º16'47''E, tree up to 24 m tall and 90 cm in diam., 29 November 2008, *P.K.Loc, N.H.Cuong HAL 11949* (HN). Location 4: Dak Lak Prov., Ea H'Leo Distr., Ea Ral Municipality, *Glyptostrobus pensilis* Ea Ral Species/Habitat Protected Area, around point 13º13'54''N 108º11'03''E, primary swamp coniferous forest with *Glyptostrobus pensilis* at elevation about 570 m a.s.l., tree to 20 m tall, mono-dominant of coniferous forest, 4 April 2008, *N. T. Hiep, L. Averyanov, P. K. Loc, N. T. Vinh, P. T. Duyen, HAL 11406* (HN). Location 5: Dak Lak Prov., Krong Buk Distr., Chu Ne Municipality, Buon Rah Distr. protection site, around point 13º04'53" N 108º16'01" E, at elevation about 705 m, few relictual trees 20-25 m tall and 150 cm in diam., 2 December 2008. *P.K.Loc, N.H.Cuong, HAL 11950* (HN).

## METHODOLOGY

As a rule, in all observed localities more or less depressed specimens of *Glyptostrobus pensilis* dominate. Commonly largest part of trees in available populations has low vitality. The level of vitality was assessed by estimation of percentage of living part of tree canopy. It ranges from 100% (when all branches of canopy covered with normal healthy leaves) to 0% (when canopy have no leaves in recently died trees). Usual gradation of observed spectrum of tree vitality is illustrated on Fig. 4.

Approximate tree age was estimated on the base of calculation of a number of timber rings that are formed annually due to regularly alternating of dry and rainy seasons. In most cases, the age of individual trees was assessed by dividing of half tree bole thickness at d.b.h. by thickness of abstract timber ring calculated as average on the base of analysis of 10 model timber sections (Table 1, Fig. 5).

Average thickness of an individual timber rings in studied bole model radiuses varies from 0.83 to 3.85 mm (with minimal and maximal ring thickness - about 0.25 and 7.5 mm respectively). Total average thickness of an individual ring for all studied boles was calculated as 1.88 mm, which may be more or less typical for *G. pensilis* timber at d.b.h. in studied area. If this true, age of observed trees with boles 4-147 cm d.b.h. ranges between 11-391 years old respectively. Wide variation of individual timber rings in their thickness (0.25-7.5 mm) gives evidence that *G. pensilis* trees in some periods of their life grew fairly fast increasing bole thickness annually more than on 1.5 cm. In some other periods they grew much slowly, increasing timber diameter less than on 1 mm each year (Fig. 5).

All field observations, descriptions of plant communities and species identifications are based on herbarium collections, which are housed now at Herbaria of Institute of Ecology and Biological Resources of Vietnam Academy of Science and Technology (HN) and Komarov Botanical Institute of the Russian Academy of Science (LE).

Description of vegetation, species composition of plant community, horizontal and vertical structure of the forests were made by studies of model plots. Linear dimensions of bole/canopy diameter, high of trees etc., were made by standard measurement methodology.

## DATA OF FIELD EXPLORATIONS

Monsoon closed semi-deciduous and dry evergreen lowland rich forests were primarily typical on flat basalt



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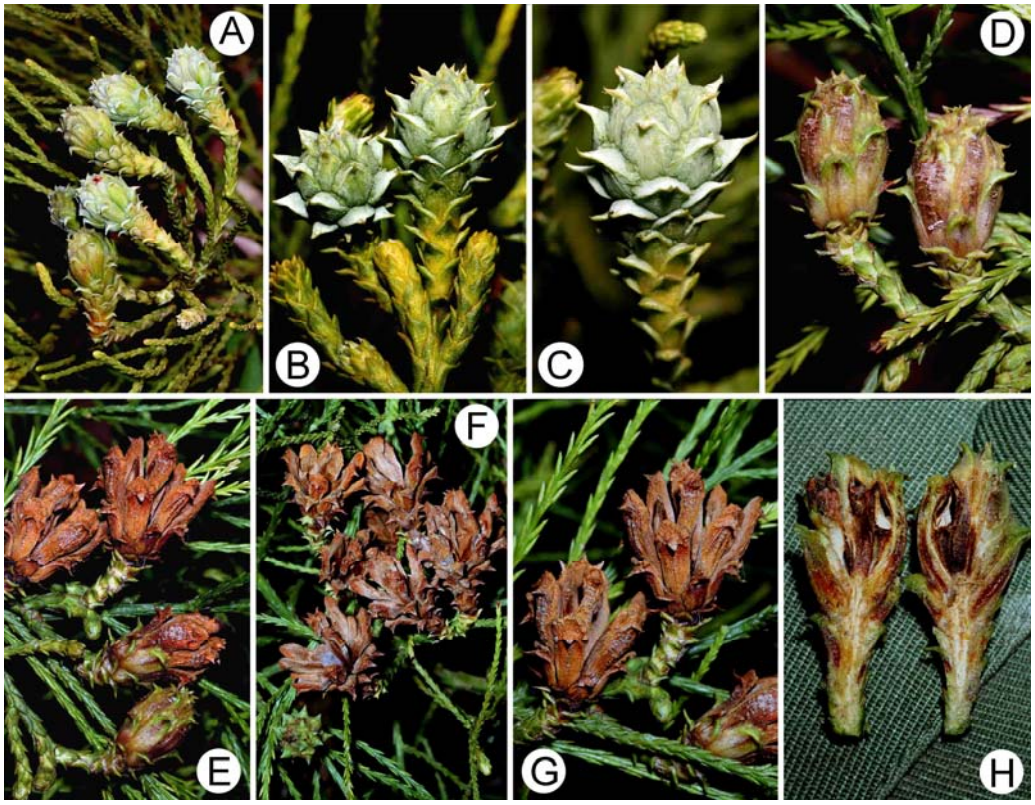



**Fig. 3. Seed cones of *Glyptostrobus pensilis* from native Vietnamese specimens (*HAL 11349*). A-D: Young and ripening seed cones. E-G: Ripe opening seed cones. H. Longitudinal section of seed cone damaged by fungal infection (photographs of Leonid V. Averyanov).**

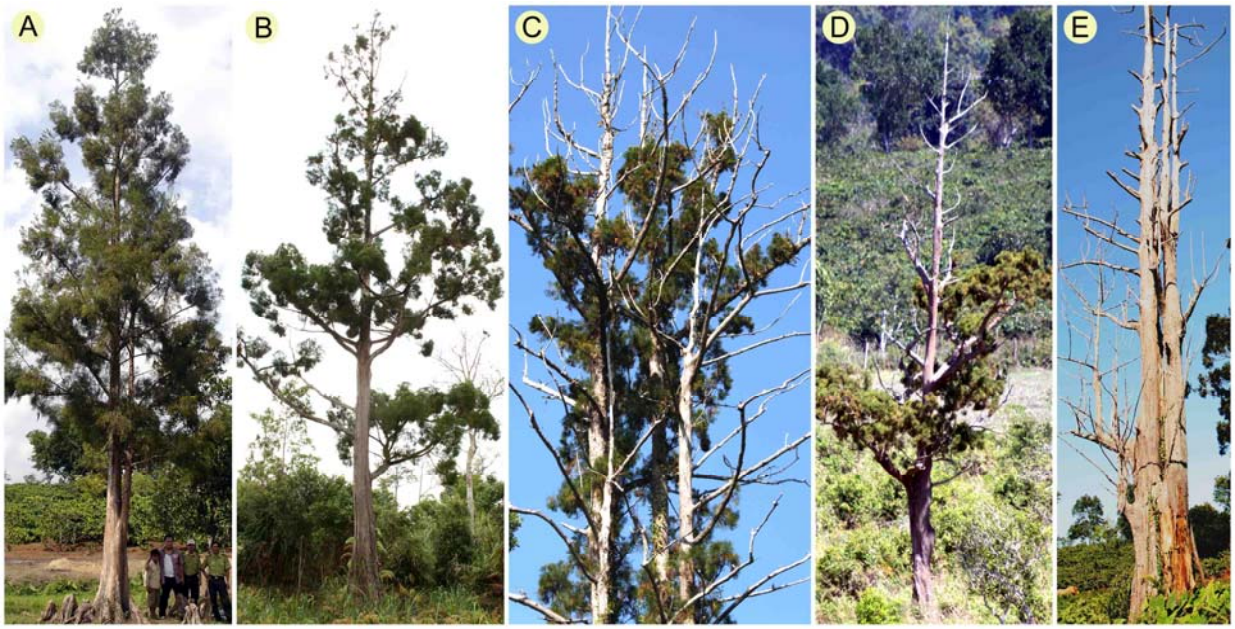



**Fig. 4. Illustrations of different levels of tree vitality in studied native stands of *Glyptostrobus pensilis*. Respectively: A – about 100%, B – 75%, C – 50%, D – 25% and E – 0% vitality (photographs of Leonid V. Averyanov).**



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**Table 1. Timber rings calculations in *Glyptostrobus pensilis* boles in extinct forest in Ea Ho Municipality of Krong Nang District (Trap K'Sor Species/Habitat Protected Area)**

| Studied radius No | Studied radius length in mm | The number of rings in studied radius | Average thickness of an individual ring in mm |
|---|---|---|---|
| 1 | 50 | 33 | 1.52 |
| 2 | 50 | 34 | 1.47 |
| 3 | 50 | 21 | 2.38 |
| 4 | 50 | 13 | 3.85 |
| 5 | 10 | 12 | 0.83 |
| 6 | 50 | 42 | 1.19 |
| 7 | 40 | 16 | 2.50 |
| 8 | 110 | 51 | 2.16 |
| 9 | 100 | 64 | 1.56 |
| 10 | 40 | 30 | 1.33 |
| Average thickness of an individual ring in mm for all studied radiuses | | | 1.88 |

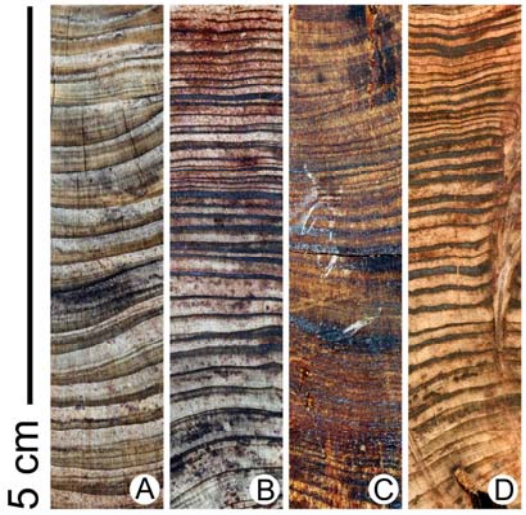



**Fig. 5. Typical annual timber rings of *Glyptostrobus pensilis* on 4 selected radial timber sections (A-D) used for approximate estimation of tree ages in studied populations. (photographs of Leonid V. Averyanov).**

plains and low hills of Dak Lak Province. These rich primary woods have been highly affected by human activities about a century ago and were replaced by secondary semi-deciduous and deciduous forests and savanna-like woodlands spreading on thin rather poor, usually ferralite highly degraded soils. As main dominants in these widespread plant formations appear numerous representatives of Dipterocarpaceae and Lythraceae families and some other broad-leaved fast growing trees (Averyanov et al., 2003). At the same time, some variants of relict primary lowland woods of specific habitats certainly included here a number of conifers. Most probably, numerous swampy leveled riverine depressions spreading on plains of Dak Lak Plateau provided ancient, very reliable refuge for relict coniferous forests with *G. pensilis* before human land reclamation. Now these forests and individual trees almost completely become extinct due to total agricultural transformation of landscapes, wide urbanization, forest fires and damage of hydrological regime of their habitats.

Our inventory field works implemented during 2007-2008 revealed 5 last localities of native *G. pensilis* stands in Vietnam (Fig. 1).

First discovered locality of *G. pensilis* includes alone native growing tree surprisingly remained on wet stream slope at the centre of Buon Ho Town (12º56'07''N 108º16'57''E). Old local stories say about numerous trees growing along wet stream valley in this place years ago, but any actual confirmations of this fact are not available. Observed tree (April 2008) was 19 m tall, 66 cm d.b.h., with estimated age about 176 years and vitality around 55% (Fig. 6A). This tree grows on private land, actually on backyard kitchen garden of local villagers. The survival of this specimen in coming years is highly problematic.

The second studied locality of *G. pensilis* was found near Truong Ha village (Krong Nang District, Ea Ho Municipality, around point 12°59'59''N 108°17'26'' E, April 2007 and April 2008). Here were found 5 extant scattered trees 6-15 m tall, with vitality ranging between 100 to 0% (in just recently died trees). Trees were observed in open flat swampy bottom of broad depression lying between low rolling basaltic hills covered with coffee plantations (Figs. 6B, C & G). Elevation of this habitat is 717 m above sea level. Wide present-day excavations of numerous underground stumps, roots and other remains of valuable fragrant *G. pensilis* timber (Figs. 6D-G) give certain picture of existence of majestic closed mono-dominant coniferous forest in this local area few decades ago. Some trees in this extinct wood reached more than 1.5 m d.b.h. and age at least 400 years old (Figs. 6D & E). Anthropogenic deforestation for rice paddies, forest fires and direct logging were clearly main factors of recent *G. pensilis* forest extinction in this region. The land here still has no any nature protection status and survival of observed remained extant trees during coming years looks very bleak. At the same time, swampy peaty soils and appropriate permanent aquatic regime of ground water-level create in observed depression rare unique conditions for attempts of *G. pensilis* cultivation and possible reforestation.



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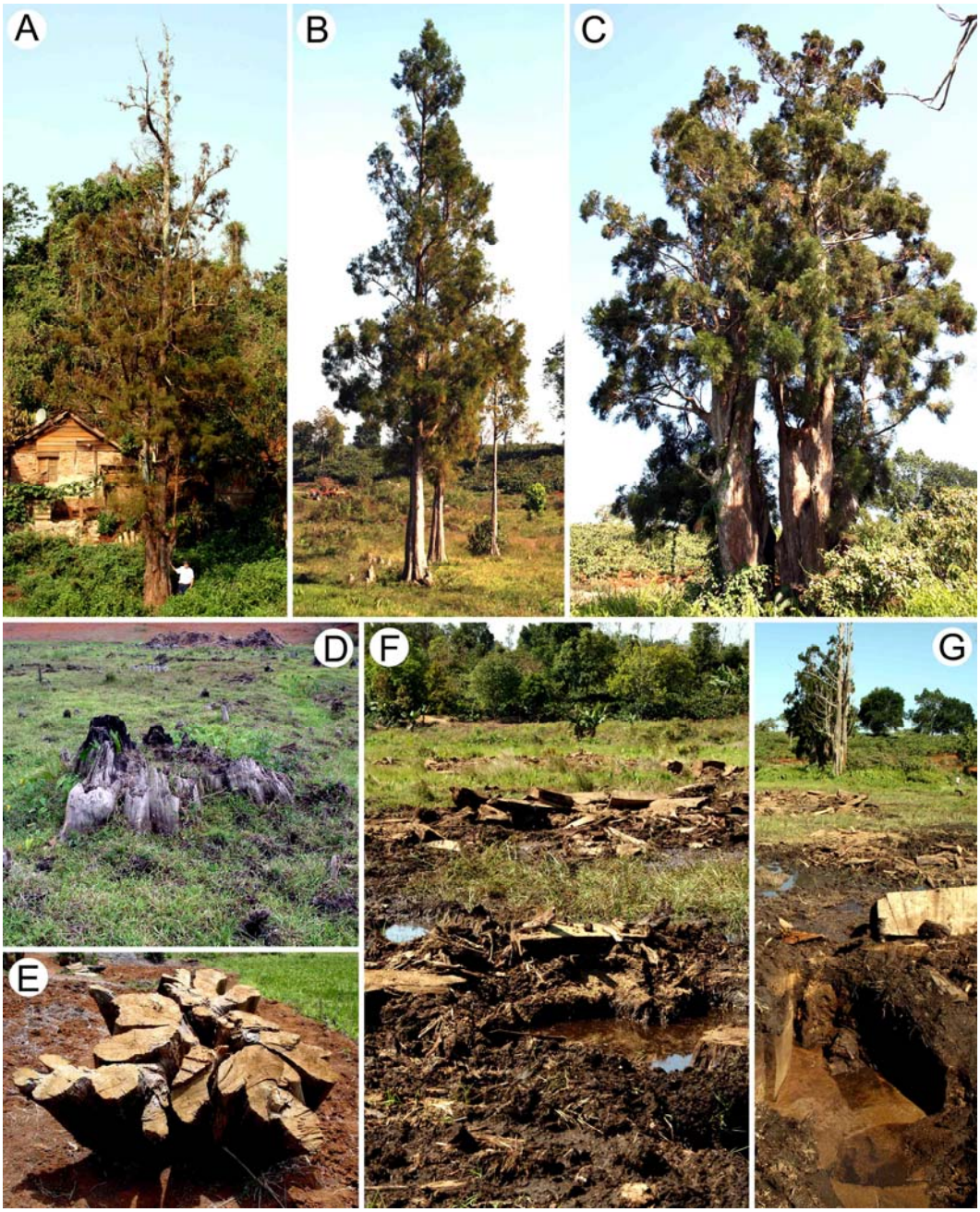



**Fig. 6. Localities of extant and extinct stands of *Glyptostrobus pensilis* in Dak Lak Province of southern Vietnam. A: Alone tree discovered on stream slope in Buon Ho town (*HAL 11357*). B & C: Trees (*HAL 11130b)* scattered on flat open swampy valley in vicinities of Truong Ha village (Krong Nang District, Ea Ho Municipality). D & E: Stumps of large trees in place of extinct primary mono-dominant coniferous forest in the same area. F & G: Excavation of *G. pensilis* stumps and roots for valuable timber in place of extinct primary coniferous forest in the same area (photographs of Leonid V. Averyanov and Tien Hiep Nguyen).**

Third *G. pensilis* locality represents earlier discovered stand that received status of nature protected area known as "Trap K'Sor *G. pensilis* species/habitat protected area" since 1984. It inhabits broad swampy depression associated with Ea Amuh River valley placed in flat area at elevations about 700 m a.s.l. around point 12º59'12''N 108º16'50''E (Fig. 7). Like previous locality, this area belongs to Ea Ho Municipality of Krong Nang District. Inventory fulfilled in April 2008 confirmed occurrence of 34 extant trees (Fig. 8) and indicated their



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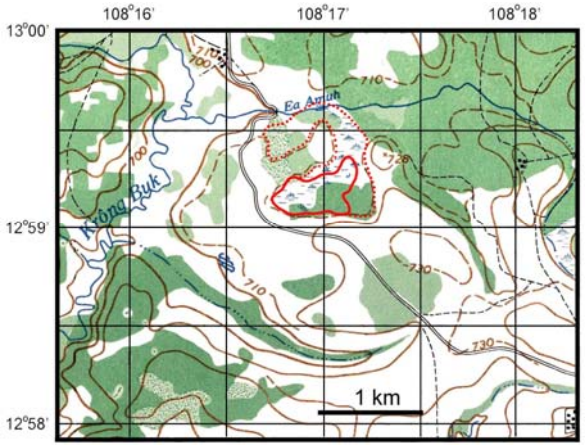



**Fig. 7. Map of former *Glyptostrobus pensilis* forest stand in Trap K'Sor Species/Habitat Protected Area (Dak Lak Province, Krong Nang District, Ea Ho Municipality). Expected area of extinct coniferous forest is marked on the map with red dotted line; solid red line outlines area of still extant sporadically scattered trees.**

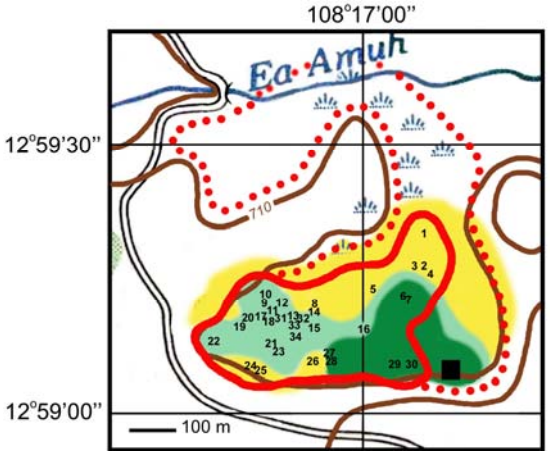



**Fig. 8. Scheme of disposition of extant *Glyptostrobus pensilis* trees in Trap K'Sor Species/Habitat Protected Area (Dak Lak Province, Krong Nang District, Ea Ho Municipality) according to inventory of April 2008. Expected area of extinct coniferous forest is marked on the scheme with red dotted line; solid red line outlines area of still extant sporadically scattered trees. Individual trees are marked with black figures; black quadrate designates position of model plot used for study of extinct coniferous forest. Different kinds of vegetation are marked on the scheme with different color: dark green – close evergreen forest, light green – secondary scrub, yellow – secondary high-tall grasslands, white – short-tall grasslands, pastures and agricultural lands.**

dimensions, approximate vitality, age, actual habits and threats. These data are presented in Table 2. Tree height in this stand of *G. pensilis* varies from 2.7 to 24 m, diameter of bole (d.b.h.) varies from 20 to 140 cm, specimen's vitality ranges in limits 5-95% and their approximate ages lie in limits 53-372 years. Average vitality of trees in this population is rather low and rates as about 65.8%.

Observed extant trees of this population scattered now on rather limited territory grow as a component of small fragment of remnant relict primary swamp forest, among secondary swampy shrubs and in open tall-high grasslands (Figs. 8 & 9A-C). Very few trees here have high vitality and form a number of massive air roots rising to 0.5 m tall distant from tree base in radius comparable with radius of tree crown (Figs. 9D & E). At the same time primary area of *G. pensilis* forest in this region was recently much wider. Numerous stumps and other timber remains of *G. pensilis* observed here distinctly outline primary area of presently extinct forest as at least three times wider than area of still extant scattered trees (Fig. 8). The study of *G. pensilis* remains conducted in April 2008 on square of model plot 40 x 40 m (1600 $m^2$) give bright evidence of full extinction of majestic closed full-blooded mono-dominant coniferous *G. pensilis* woods here few decades ago (point 12°59'10''N 108°17'11''E, at elevation 708 m a.s.l.). In many cases, these forests certainly formed closed dense stands with projective canopy coverage approaching to 100% (Figs. 9F & G). Largest trees in this area had boles up to 1.5 m in diameter and were probably as old as 400 years and even older (Figs. 9H & I).

Obtained data on approximate reconstruction of horizontal structure of canopy tier of extinct coniferous forest in limits of model plot are presented on Fig. 10 and Table 3. Canopy diameter of extinct trees was estimated on the base of extrapolation of observation of remnant extant trees found in conditions of primary forest. Diameter of canopy was approximately accepted with dependence of diameter of stumps as follow: trees with bole/stump 0.8-1.4 m d.b.h. might have canopy diameter about 6 m; trees with bole/stump 0.5-0.8 m d.b.h. might have canopy 5 m, and trees less than 0.5 m d.b.h. formed canopy about 4 m in diameter. At least 73 stumps were found on model plot square 1600 $m^2$ (40 x 40 m). Projective coverage of coniferous tier with *G. pensilis* was estimated here as at least 65-70%, but it might essentially higher.

Largest extant stand of *G. pensilis* in Vietnam is found presently in specially organized protected area officially called as "Ea Ral species/habitat protected area" situated in Ea H'Leo District, Ea Ral Municipality around point 13º13'54''N 108º11'03''E. This locality occupies flat swampy slightly inclined (from SE to NW) depression spreading along small streamlet running between low rolling basaltic hills at elevation about 570 m above sea level (Fig. 11). A dam erected about 25 years ago crossed the streamlet valley. This caused extinction of *G. pensilis* forest in largest territory of its primary distribution in this locality (Fig. 11). Presently remained *G. pensilis* stand occupied here square area 10 hectares and numbers about 220 trees (Nguyen Tien Hiep et al., 2004). Most probably,



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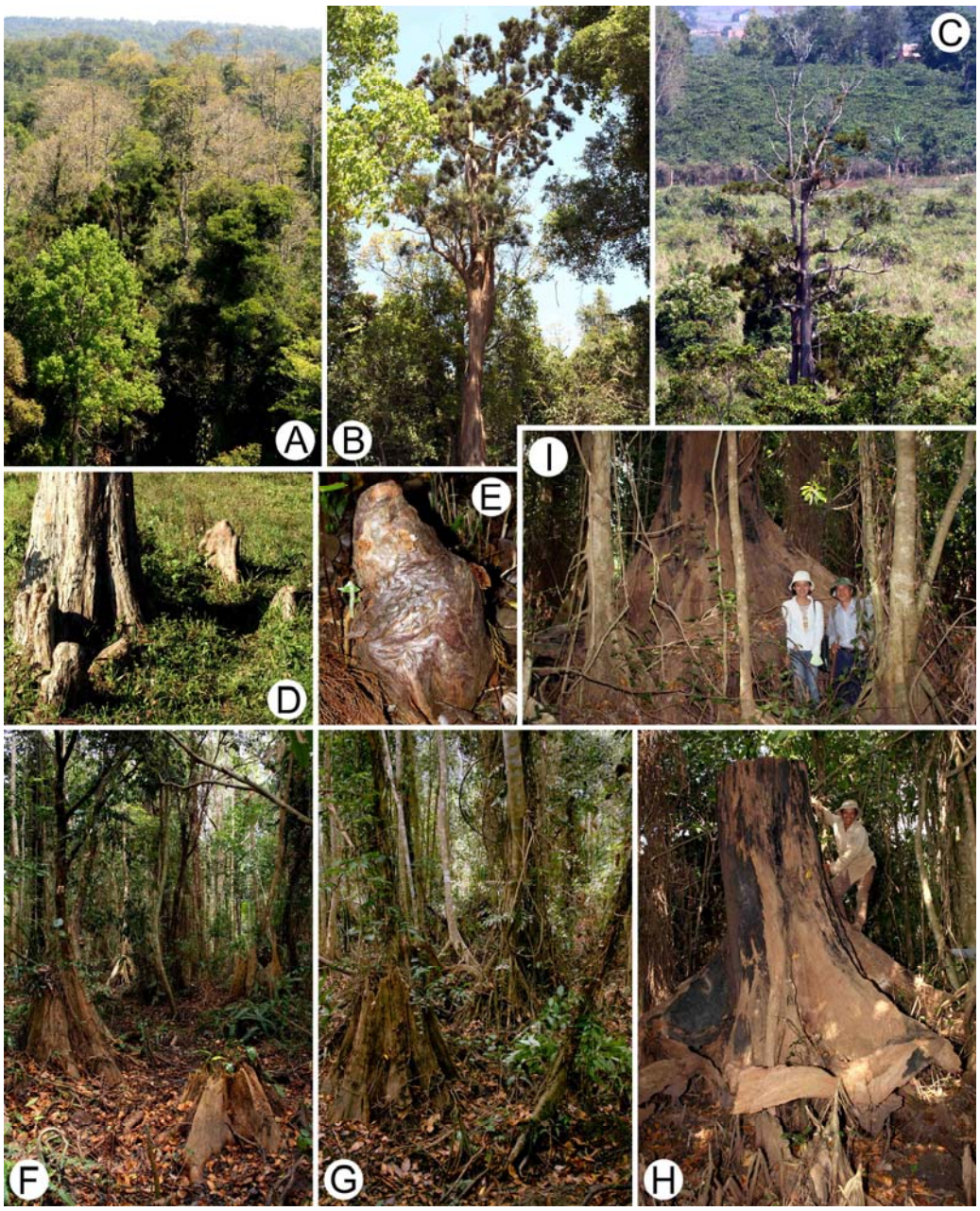



**Fig. 9. Localities of extant and extinct stands *Glyptostrobus pensilis* in Dak Lak Province of southern Vietnam. A: Primary mixed forest with *G. pensilis* in Trap K'Sor Species/Habitat Protected Area (Krong Nang District, Ea Ho Municipality). B & C: *G. pensilis* trees (*HLF 7111*) of different vitality in primary forest (B) and in secondary scrub (C) on periphery of the same protected area. D & E: Air roots (pneumatophores) typical for extant specimens of *G. pensilis* in all studied habitats. F & G: Numerous stamps of recently extinct mono-dominant *G. pensilis* coniferous forest (center of studied model plot) in Trap K'Sor Species/Habitat Protected Area. H & I: Largest stumps of *G. pensilis* 1.5-2 m d.b.h. with approximate age of extinct trees about 475-550 years old found in the same area (photographs of Leonid V. Averyanov).**

this stand represents last remnant of primary swamp coniferous *G. pensilis* forest with its original appearance and more or less intact structure (Figs. 12A-C). It was studied and described in April 2008 by assessment of representative model plot 1600 $m^2$ (40 x 40 m) placed at the centre of this relict woodland (Fig. 11). Like studied extinct forest in Trap K'Sor Species/Habitat Protected Area this still extant *G. pensilis* stand includes more than 70 trees on square 1600 $m^2$ forming rather closed growth with projective coverage of the first coniferous canopy



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**Table 2. Characteristic of extant *Glyptostrobus pensilis* trees in Ea Ho Municipality of Krong Nang District (Trap K'Sor Species/Habitat Protected Area).**

| Tree No | Approxi-mately estimated tree height in m | Bole diameter (d.b.h.) in cm | Approxi-mate vitality (in %) | Approxi-mately estimated tree age |
|---|---|---|---|---|
| 1 | 12 | 25 | 95 | 67 |
| 2 | 9 | 51 | 70 | 136 |
| 3 | 3.3 | 51 | 95 | 136 |
| 4 | 15 | 57 | 70 | 152 |
| 5 | 20 | 100 | 50 | 266 |
| 6 | 18 | 33 | 90 | 88 |
| 7 | 19 | 123 | 60 | 327 |
| 8 | 3.3 | 45 | 75 | 120 |
| 9 | 15 | 27 | 75 | 72 |
| 10 | 15 | 89 | 60 | 237 |
| 11 | 2.7 | 30 | 98 | 80 |
| 12 | 3.8 | 54 | 85 | 157 |
| 13 | 11 | 31 | 75 | 82 |
| 14 | 17 | 28 | 90 | 75 |
| 15 | 4.6 | 35 | 80 | 93 |
| 16 | 5.2 | 140 | 55 | 372 |
| 17 | 24 | 91 | 5 | 242 |
| 18 | 11 | 70 | 40 | 186 |
| 19 | 17 | 93 | 55 | 247 |
| 20 | 3.6 | 40 | 85 | 106 |
| 21 | 18 | 78 | 40 | 208 |
| 22 | 21 | 63 | 75 | 168 |
| 23 | 17 | 81 | 20 | 215 |
| 24 | 10 | 57 | 45 | 152 |
| 25 | 16 | 90 | 15 | 239 |
| 26 | 20 | 117 | 15 | 311 |
| 27 | 21 | 54 | 35 | 144 |
| 28 | 11 | 20 | 95 | 53 |
| 29 | 20 | 90 | 70 | 239 |
| 30 | 20 | 79 | 75 | 210 |
| 31 | 15 | 90 | 75 | 239 |
| 32 | 18 | 34 | 90 | 90 |
| 33 | 12 | 29 | 90 | 77 |
| 34 | 5.2 | 55 | 90 | 146 |

**Table 3. Characteristic of extinct *Glyptostrobus pensilis* forest in Ea Ho Municipality of Krong Nang District (Trap K'Sor Species/Habitat Protected Area) in model plot of 1600 $m^2$ (40 x 40 m).**

| Tree No | Approximately estimated tree bole diameter (d.b.h.) in cm | Approximately estimated tree canopy diameter in m | Approximately estimated tree age |
|---|---|---|---|
| 1 | 86 | 6 | 229 |
| 2 | 94 | 6 | 170 |
| 3 | 68 | 5 | 181 |
| 4 | 60 | 5 | 160 |
| 5 | 50 | 5 | 133 |
| 6 | 55 | 5 | 146 |
| 7 | 100 | 6 | 266 |
| 8 | 76 | 6 | 202 |
| 9 | 65 | 6 | 173 |
| 10 | 45 | 4 | 120 |
| 11 | 84 | 6 | 223 |
| 12 | 60 | 5 | 160 |
| 13 | 55 | 5 | 146 |
| 14 | 37 | 4 | 98 |
| 15 | 50 | 5 | 133 |

**Table 3. Continued.**

| Tree No | Approximately estimated tree bole diameter (d.b.h.) in cm | Approximately estimated tree canopy diameter in m | Approximately estimated tree age |
|---|---|---|---|
| 16 | 50 | 5 | 133 |
| 17 | 60 | 5 | 160 |
| 18 | 50 | 5 | 133 |
| 19 | 50 | 5 | 133 |
| 20 | 45 | 4 | 120 |
| 21 | 80 | 6 | 213 |
| 22 | 100 | 6 | 266 |
| 23 | 110 | 6 | 293 |
| 24 | 140 | 6 | 372 |
| 25 | 100 | 6 | 266 |
| 26 | 100 | 6 | 266 |
| 27 | 80 | 6 | 213 |
| 28 | 70 | 5 | 186 |
| 29 | 50 | 5 | 133 |
| 30 | 70 | 5 | 186 |
| 31 | 40 | 4 | 106 |
| 32 | 70 | 5 | 186 |
| 33 | 80 | 6 | 213 |
| 34 | 110 | 6 | 293 |
| 35 | 100 | 6 | 266 |
| 36 | 100 | 6 | 266 |
| 37 | 85 | 6 | 226 |
| 38 | 60 | 5 | 160 |
| 39 | 40 | 4 | 106 |
| 40 | 50 | 5 | 133 |
| 41 | 120 | 6 | 319 |
| 42 | 80 | 6 | 213 |
| 43 | 50 | 5 | 133 |
| 44 | 80 | 6 | 213 |
| 45 | 100 | 6 | 266 |
| 46 | 60 | 5 | 160 |
| 47 | 120 | 6 | 319 |
| 48 | 80 | 6 | 213 |
| 49 | 70 | 5 | 186 |
| 50 | 55 | 5 | 146 |
| 51 | 95 | 6 | 253 |
| 52 | 30 | 4 | 80 |
| 53 | 50 | 5 | 133 |
| 54 | 60 | 5 | 160 |
| 55 | 60 | 5 | 160 |
| 56 | 50 | 5 | 133 |
| 57 | 55 | 5 | 146 |
| 58 | 60 | 5 | 160 |
| 59 | 60 | 5 | 160 |
| 60 | 40 | 4 | 106 |
| 61 | 60 | 5 | 160 |
| 62 | 90 | 6 | 239 |
| 63 | 70 | 5 | 186 |
| 64 | 45 | 4 | 120 |
| 65 | 65 | 5 | 173 |
| 66 | 100 | 6 | 266 |
| 67 | 60 | 5 | 160 |
| 68 | 110 | 6 | 293 |
| 69 | 80 | 6 | 213 |
| 70 | 35 | 4 | 93 |
| 71 | 80 | 6 | 213 |
| 72 | 140 | 6 | 372 |
| 73 | 80 | 6 | 213 |



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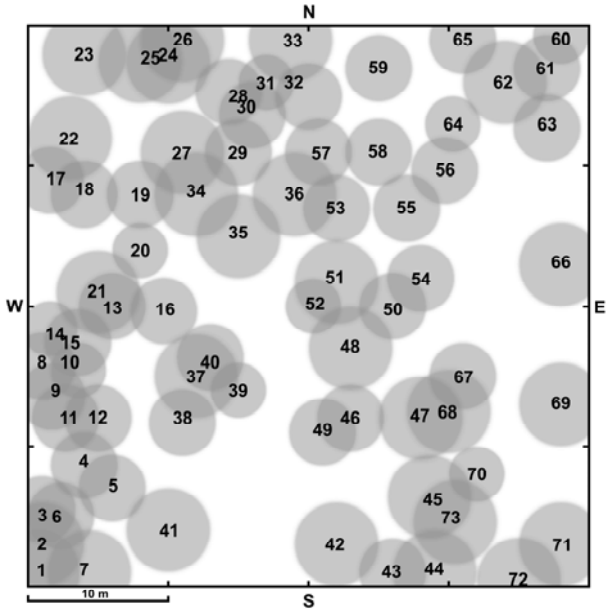



**Fig. 10. Scheme of reconstructed projective coverage of canopy storey in model plot placed in extinct coniferous *Glyptostrobus pensilis* forest in Trap K'Sor Species/Habitat Protected Area (Dak Lak Province, Krong Nang District, Ea Ho Municipality).**

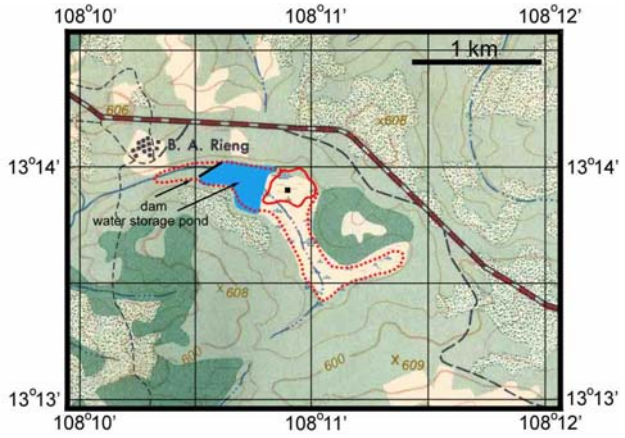



**Fig. 11. Map of former and extant *Glyptostrobus pensilis* forest stand in Ea Ral Species/Habitat Protected Area (Dak Lak Province, Ea H'Leo District, Ea Ral Municipality). Expected area of extinct coniferous forest is marked on the map with red dotted line; solid red line outlines area of remnant primary coniferous forest; black quadrate designates position of studied model plot.**

tier estimated as about 80% (Figs. 13-15). Tree height varies in this studied forest between 3.5-25 m tall with their d.b.h. ranging in limits 4-95 cm. Approximately estimated age of observed and studied trees lies between 11-253 years old (Table 4). However, some old stumps of logged trees occasionally scattered on *Glyptostrobus* forest territory in this area reach 110 m d.b.h. Age of such trees may be about 295 year. Average vitality of extant *G. pensilis* trees in this population approaches to 100%. Some trees form here two and even three main erect stems due to early stem particulation (Table 4).

Last locality of *G. pensilis* known in Vietnam designated here as point 5 (Fig. 1). This small population is situated in Chu Ne Municipality of Krong Buk District and includes few very old, highly depressed trees scattered on agricultural lands, secondary grasslands and pastures. The survival of *G. pensilis* trees in this site is highly problematic, besides this area was declared as "Buon Rah District protection site" being formally officially protected.

## STRUCTURE AND SPECIES ASSEMBLY OF GLYPTOSTROBUS PENSILIS STANDS

Horizontal structure of the first canopy stratum of extant primary *G. pensilis* forest is shown on scheme of studied model plot (Fig. 13). Continuous coniferous canopy matrix with projective coverage 80-85% includes also canopies of few angiosperm deciduous trees (*Sterculia pierrei*) that appear here as occasional emergents. Projective coverage of angiosperm tree canopies of first stratum in studied *G. pensilis* forest commonly does not exceed 5%. However, they become dominant in conditions of progressive conifers extinction.

Vertical structure of coniferous primary *G. pensilis* forest is shown by schematic drawings with indication of main dominants of the wood strata (Figs. 14 & 15). Both drawings were made on the base of field observations along transects A-B and C-D marked on studied model plot (Fig. 13). All field observations and species identifications are based on herbarium collections made during 2007 and 2008 years.

Remnants of relict primary coniferous forest with *G. pensilis* that remains in Trap K'Sor and Ea Ral Species/Habitat Protected Areas have similar structure and species composition in all wood strata.

Intact primary full-blooded coniferous *G. pensilis* forest forms mono-dominant first canopy stratum with projective coverage 70-100%. Angiosperm deciduous, semi-deciduous and evergreen trees that reach 20-25 m tall occasionally appear here as more or less common secondary emergents. Among species of this group most usual are deciduous - *Sterculia pierrei* and *Pterocymbium tinctorium*, and evergreen - *Litsea longipes*, *Michelia mollis*, and some species of *Ficus*. Similar data were also shortly reported for these forests about 30 years ago (Schmid, 1974).

Second forest storey (particularly on open, less inundated plots) includes mostly evergreen broad-leaved trees 7-20 m tall, such as *Elaeocarpus* sp., *Rhaphiolepis*



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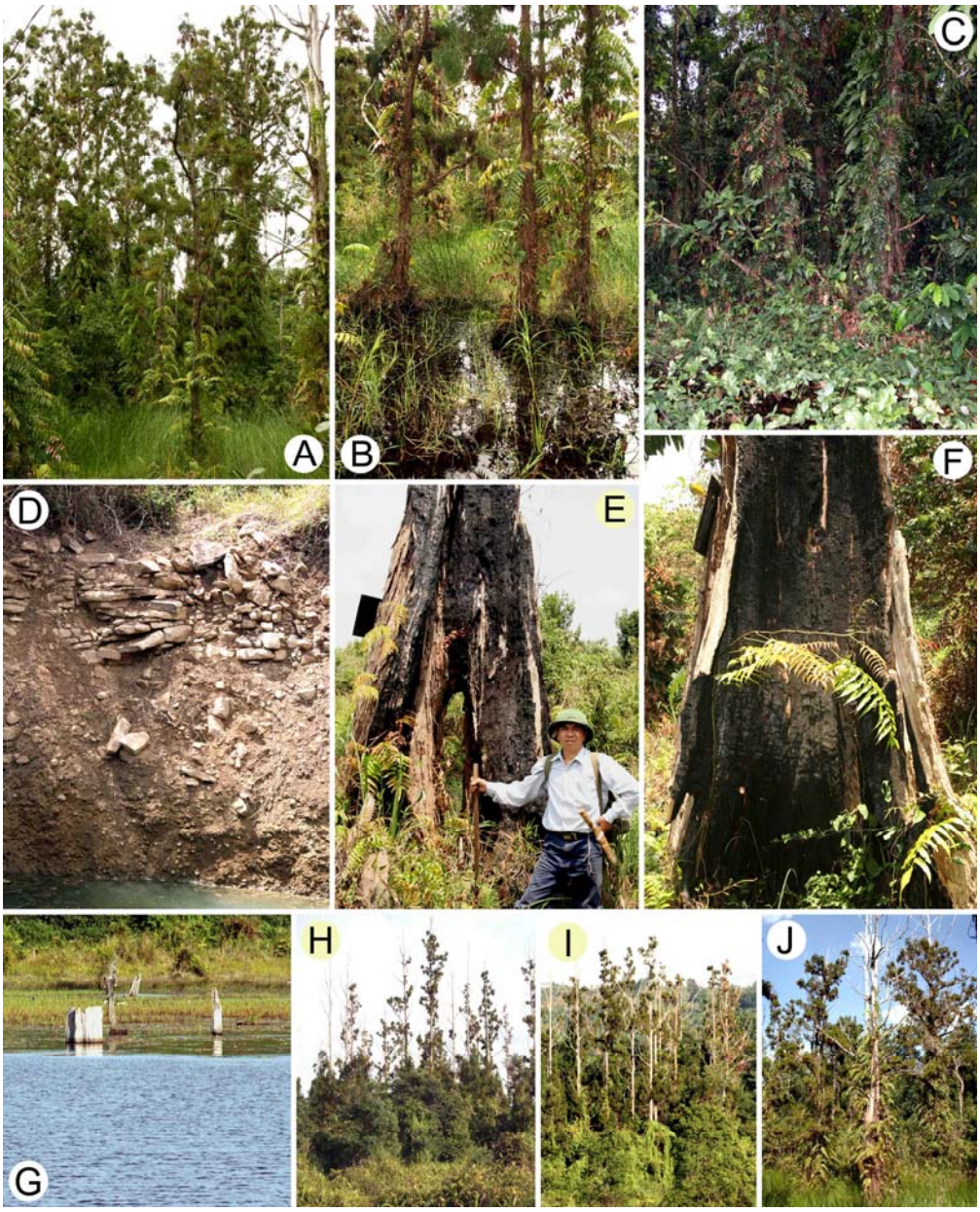



**Fig. 12. Localities of extant and extinct stands *Glyptostrobus pensilis* in Dak Lak Province of southern Vietnam. A-C: Primary mono-dominant coniferous swamp forest with *G. pensilis* (*HAL 11406*) in Ea Ral protected area (Ea H'Leo District, Ea Ral Municipality); D: One of the wells for the water intake on periphery of protected swampy valley with ground-water level down more than on 3 m below ground surface in Trap K'Sor Species/Habitat Protected Area (Krong Nang District, Ea Ho Municipality); E & F: Slowly regenerating *G. pensilis* trees highly damaged by fire in the same area; G: Stamps of died *G. pensilis* trees flooded by deep water of storage pond in Ea Ral Species/Habitat Protected Area; H-J: *G. pensilis* trees of low vitality depressed by over-inundation on periphery (H, I) and in central part of population (J) in the same area (photographs of Leonid V. Averyanov).**

*indica*, some species of *Ficus* and a number of *Syzygium* species, like - *Syzygium chanlos*, *S. syzygoides*, *S. tinctorium* and *S. tramnion* (Fig. 15). On drained depression slopes along swamp forest periphery were additionally observed evergreen *Dillenia ovata* and deciduous *Dillenia pentagyna*.

Shrub (third) storey of coniferous swamp forest do not exceed 7 m tall and includes a number of shrubs, which form fairly dense thickets in more or less open wet inundated places. Most common species in this group are - *Cleistocalyx nervosum*, *Ilex annamensis*, *Pandanus multidrupaceus*, *Rapanea linearis*, *Syzygium formosum*,



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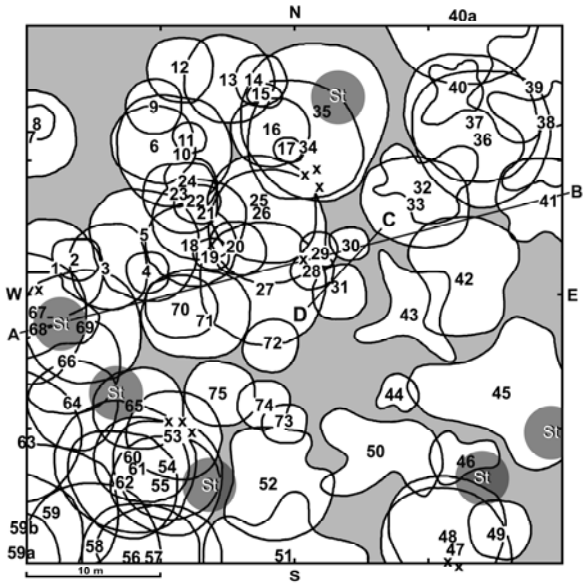



**Fig. 13. Scheme of projective coverage of canopy storey in model plot placed in primary coniferous *Glyptostrobus pensilis* forest in Ea Ral Species/Habitat Protected Area (Dak Lak Province, Ea H'Leo District, Ea Ral Municipality). White more or less round spots mean projective coverage of individual canopies of *G. pensilis* trees, marked with black figures, X – means died trees and stumps; symbol "St" indicates position of *Sterculia pierrei* trees. Lines A-B and C-D designate transects of studied profiles of vertical habitat structure.**

*Glochidion hirsutum,* as well as some species of *Ficus* and *Viburnum* (Fig. 15).

Herbaceous storey has height from few cm to 3-4 m tall and consists of many herbs, ferns, dwarf shrubs, as well as numerous wet loving riparian and sub-aquatic grasses (Poaceae) and sedges (Cyperaceae). Among most common herbaceous species were observed *Ardisia aciphylla*, *Asplenium longissimum, Catimbium speciosum, Donax cannaeformis*, *Ficus simplicipinna, F. subulata*, *Floscopa glomerulata*, *Nephrolepis biserrata, Ophiorrhiza sanguinea.* Swamp forest provides also home for a number of wet lowing orchids, like *Arundina graminifolia, Calanthe lyroglossa, Calanthe triplicata, Hetaeria* sp. and very rare, typical swampy orchid - *Dipodium paludosum.* More or less common immature seedlings of trees of highest strata additionally participate in formation of herbaceous storey. Vigorous growth of riparian, sub-aquatic and aquatic herbs may be seen everywhere in shallow water (commonly 0.5-1 m depth), particularly in open places. Usual species in this group are *Commelina paludosa*, *Eleocharis* sp., *Fuirena umbellata, Hydrocera triflora, Lasia spinosa, Ludwidgia perennis, Oenanthe javanica, Scirpus mucronatus, Scleria corymbifera* and *Utricularia* sp. (Figs. 14 & 15).

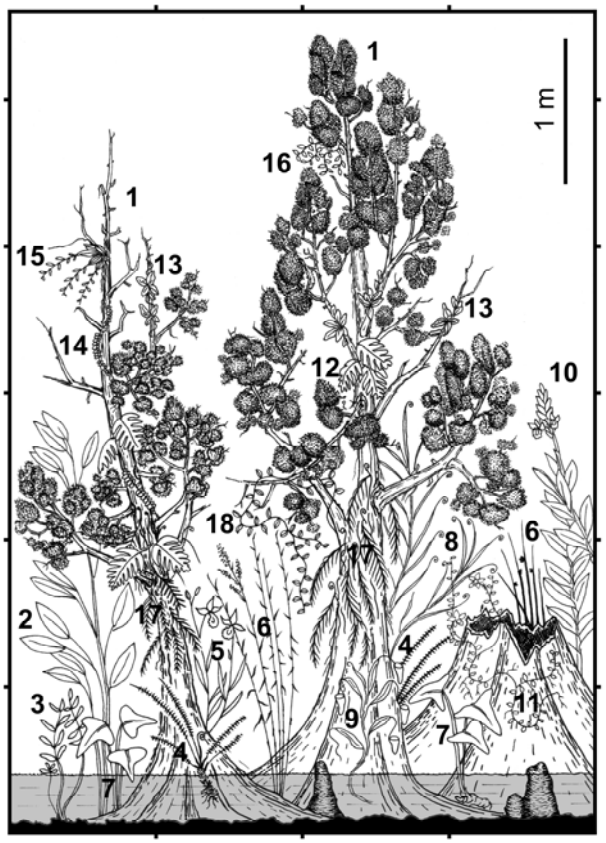



**Fig. 14. Vertical structure of *Glyptostrobus pensilis* swamp forest with emphasis to herbaceous plant species along transect C-D (view from NW to SE) demarcated on scheme of model plot (Fig. 13). Black figures on the drawing field designate usual co-dominants of plant community as follow: 1: *Glyptostrobus pensilis* (trees marked on scheme of model plot as № 30 & 31). 2: *Donax cannaeformis*. 3: *Ludwidgia perennis* (also *Ardisia aciphylla*, *Commelina paludosa*, *Ficus subulata*, *Floscopa glomerulata*, *Oenanthe javanica* and *Ophiorrhiza sanguinea*). 4: *Asplenium longissimum* (also *Nephrolepis biserrata*). 5: *Arundina graminifolia* (also *Calanthe lyroglossa*, *C. triplicata* and *Dipodium paludosum*). 6: *Scirpus mucronatus* (also *Eleocharis* sp., *Fuirena umbellata* and *Scleria corymbifera*). 7: *Lasia spinosa* (also *Hydrocera triflora*). 8: *Flagellaria indica*. 9: *Nepenthes mirabilis*. 10: *Catimbium speciosum*. 11: *Thrixspermum amplexicaule* (also *Zehneria indica*). 12: *Rhaphidophora hookeri* (also *Epipremnum giganteum* and *Rhaphidophora decursiva*). 13: *Dischidia major* (also *Dischidia imbricata*, *D. nummularia* and *Hoya diversifolia*). 14: *Psychotria serpens*. 15: *Dendrobium crumenatum* (also *Aerides odorata*, *Bulbophyllum odoratissimum*, *B. orientale*, *Eria pannea*, *Pholidota imbricata*, *Thrixspermum centipeda*). 16: *Taxillus chinensis*. 17: *Stenochlaena palustris* (also *Lygodium japonicum*, *L. microphyllum*). 18: *Smilax perfoliata*. On the drawing are schematically shown only herbaceous (semi-herbaceous) species and *G. pensilis* trees (drawing of Leonid V. Averyanov).**

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**Fig. 15. Vertical structure of *Glyptostrobus pensilis* swamp forest along transect A-B (view from SSE to NNW) demarcated on scheme of model plot (Fig. 13). Individual *Glyptostrobus* trees are marked at the bottom of drawing with white figures; died trees are marked with "X". Black figures on the drawing field designate main co-dominants of plant community as follow: 1: *Sterculia pierrei* (also *Litsea longipes*). 2: *Michelia mollis* (also *Pterocymbium tinctorium*, *Rhaphiolepis indica*, *Syzygium chanlos*, *S. tinctorium* and *S. tramnion*). 3: *Rapanea linearis* (also *Ilex annamensis* and *Ficus* sp.). 4: *Syzygium syzygoides* (also *Syzygium formosum*, *Cleistocalyx nervosum* and *Viburnum* sp.). 5: *Pandanus multidrupaceus*. 6: *Donax cannaeformis*. 7: *Catimbium speciosum*. 8: *Ficus laevis* (also *Poikilospermum suaveolens*). 9: *Calamus palustris*. 10: *Stenochlaena palustris*. 11: *Rhaphidophora hookeri* (also *Epipremnum giganteum*). On the drawing are schematically shown only species higher (longer) than 3 m (drawing of Leonid V. Averyanov).**

**Table 4. Characteristic of extant *Glyptostrobus pensilis* forest in Ea Ral Municipality of Ea H'Leo District (Ea Ral Species/Habitat Protected Area) in model plot of 1600 m$^2$ (40 x 40 m).**

| Tree No | Tree height in m | Tree d.b.h. in cm | Approximately estimated tree age | Tree vitality in % | Approximate canopy diameter in m |
|---|---|---|---|---|---|
| 1 | 18 | 35 | 93 | 100 | 5 |
| 2 | 8 | 35 | 93 | 100 | 3.2 |
| 3 | 16 | 25 | 67 | 100 | 4 |
| 4 | 8 | 25 | 67 | 100 | 3.2 |
| 5 | 20 | 35 | 93 | 100 | 4 |
| 6 | 14 | 30 | 80 | 100 | 4 |
| 7 | 16 | 38 | 101 | 100 | 5 |
| 8 | 6 | 15 | 40 | 100 | 2.4 |
| 9 | 9 | 18 | 48 | 100 | 3.6 |
| 10 | 22 | 32 | 85 | 100 | 7 |
| 11 | 4 | 11 | 29 | 100 | 1.6 |
| 12 | 10 | 25+20+8 | 67 | 100 | 4 |
| 13 | 16 | 28 | 75 | 100 | 4 |
| 14 | 8 | 16+9 | 43 | 100 | 3.2 |
| 15 | 5 | 17 | 45 | 100 | 2 |
| 16 | 13 | 28 | 75 | 100 | 5.2 |
| 17 | 4 | 11 | 29 | 100 | 1.6 |
| 18 | 14 | 18 | 48 | 100 | 5.6 |
| 19 | 6 | 15+4 | 40 | 100 | 2.4 |
| 20 | 10 | 19 | 51 | 100 | 4 |
| 21 | 15 | 21 | 56 | 100 | 6 |
| 22 | 3.5 | 4 | 11 | 100 | 1.4 |
| 23 | 10 | 17 | 45 | 100 | 4 |
| 24 | 8 | 22 | 59 | 100 | 3.2 |
| 25 | 22 | 27 | 72 | 100 | 5 |



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**Table 4. Continued.**

| Tree No | Tree height in m | Tree d.b.h. in cm | Approximately estimated tree age | Tree vitality in % | Approximate canopy diameter in m |
|---|---|---|---|---|---|
| 26 | 20 | 29 | 77 | 100 | 4 |
| 27 | 20 | 42 | 112 | 100 | 5.2 |
| 28 | 5 | 9 | 24 | 100 | 2 |
| 29 | 5 | 17 | 45 | 100 | 2 |
| 30 | 5 | 16 | 43 | 50 | 1.5 |
| 31 | 7 | 13 | 35 | 100 | 2.8 |
| 32 | 18 | 55 | 146 | 50 | 4.2 |
| 33 | 16 | 50 | 133 | 100 | 4.2 |
| 34 | 18 | 30 | 80 | 100 | 6 |
| 35 | 25 | 58 | 154 | 100 | 7 |
| 36 | 22 | 54 | 144 | 100 | 6.4 |
| 37 | 24 | 60 | 161 | 100 | 6.6 |
| 38 | 24 | 60 | 161 | 45 | 6.6 |
| 39 | 25 | 50 | 133 | 65 | 7 |
| 40 | 8 | 40+35 | 106 | 50 | 3.2+3 |
| 40a | 24 | 60+45+30 | 161 | 100 | 6.6 |
| 41 | 18 | 47 | 125 | 80 | 4.5 |
| 42 | 20 | 95 | 253 | 80 | 6.2 |
| 43 | 24 | 58 | 154 | 10 | 2.5 |
| 44 | 8 | 15 | 40 | 80 | 3.2 |
| 45 | 25 | 92 | 245 | 75 | 7 |
| 46 | 11 | 70+35 | 186 | 75 | 4.4 |
| 47 | 16 | 26+8 | 69 | 100 | 5.2 |
| 48 | 16 | 30 | 80 | 100 | 5.2 |
| 49 | 9 | 20 | 53 | 100 | 3.6 |
| 50 | 20 | 70 | 186 | 75 | 6.2 |
| 51 | 25 | 70+35 | 186 | 75 | 7 |
| 52 | 22 | 55+45 | 146 | 90 | 6.4 |
| 53 | 17 | 46 | 122 | 100 | 5.3 |
| 54 | 18 | 24 | 64 | 100 | 6 |
| 55 | 18 | 20 | 53 | 100 | 6 |
| 56 | 20 | 20 | 53 | 100 | 6.2 |
| 57 | 18 | 18 | 48 | 100 | 6 |
| 58 | 22 | 50 | 133 | 100 | 6.4 |
| 59 | 23 | 33 | 88 | 100 | 5 |
| 60 | 20 | 24 | 64 | 100 | 5.6 |
| 61 | 16 | 22 | 59 | 100 | 5 |
| 62 | 18 | 20+10 | 53 | 100 | 5.2 |
| 63 | 20 | 22 | 59 | 100 | 5.4 |
| 64 | 17 | 26 | 69 | 100 | 3.8 |
| 65 | 18 | 30 | 80 | 100 | 5.2 |
| 66 | 16 | 20 | 53 | 100 | 5 |
| 67 | 16 | 36 | 96 | 90 | 5 |
| 68 | 18 | 32 | 85 | 100 | 5.2 |
| 69 | 18 | 32 | 85 | 100 | 5.2 |
| 70 | 12 | 20+12 | 53 | 100 | 3.8 |
| 71 | 14 | 24+10+8 | 64 | 100 | 3.6 |
| 72 | 8 | 26+12 | 69 | 100 | 2.4 |
| 73 | 6 | 16+14 | 43 | 100 | 2.2 |
| 74 | 9 | 22 | 59 | 100 | 3 |
| 75 | 12 | 30 | 80 | 100 | 4.2 |

Extra-storey vegetation includes numerous vine and epiphytic plants. Among aboriginal woody lianas that reach 20-35 m long were observed *Calamus palustris*, *Ficus laevis*, *Mussaenda dinhensis*, *Spatholobus parviflorus* and *Poikilospermum suaveolens*. All they are not too much common in intact forest. As a main co-dominants in primary swamp forest appears such semi-woody vines as *Flagellaria indica*, *Lygodium japonicum*, *L. microphyllum* and especially *Stenochlaena palustris*. Last species reaches very high abundance and occasionally may be observed as alone mono-dominant fern-vine covered all tree boles with dense, reticulate cover coming from the ground to their canopies. Less significant, but also very typical here are some small herbaceous vines, like *Nepenthes mirabilis*, *Psychotria serpens*, *Raphistemma pulchellum*, *Spatholobus parviflorus* and *Zehneria indica* (Fig. 14).

Group of epiphytic creeping herbaceous vines commonly observed in canopies of trees includes such



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common species as *Dischidia imbricata, D. major, D. nummularia, Epipremnum giganteum, Hoya diversifolia, Piper* sp., *Rhaphidophora decursiva* and *R. hookeri.* Typical epiphytes are also very common here. They are mainly orchid species, like *Aerides odorata, Bulbophyllum odoratissimum, B. orientale, Dendrobium crumenatum, Eria pannea, Pholidota imbricata, Taeniophyllum* sp., *Thrixspermum amplexicaule* and *T. centipeda*. At the base of shady mossy conifer's boles may be often seen small epiphytic fern – Canopy branches on some old specimens provide home to colonies of small parasitic shrubs from Loranthaceae family, mainly - *Taxillus chinensis* (Fig. 14).

Extinction of conifers and logging of the second and third forest strata lead to formation of secondary scrub, which often degrades into high- and middle-tall secondary grasslands. In our days, such weedy plant communities replaced coniferous *G. pensilis* forests in nearly all localities of their primary distribution.

Seedlings, saplings and immature specimens of some aboriginal elements of primary wood, like *Elaeocarpus* sp., *Ficus simplicipinna, Ilex annamensis, Semecarpus cochinchinensis, Sterculia pierrei*, *Syzygium syzygoides* and *Viburnum* sp. may be still found in secondary shrub communities, which replace primary coniferous forests. However, invasive secondary woody species, such as *Melastoma candidum*, *Melicope triphylla, Semecarpus cochinchinensis* and many others, become dominant here and successively displace all species of primary plant communities. Many fast growing woody and shrubby species of the secondary dry *Dipterocarpus* forest (typical for surrounding hilly neighborhoods) actively migrate to peripheral parts of degraded swamp forest due to anthropogenic drainage. Among most usual species of this group in our studies were observed such trees as *Careya sphaerica, Dillenia ovata, D. pentagyna, Dipterocarpus obtusifolius, Pterocymbium tinctorium, Shorea obtusa* and dwarf xerophytic spiny palm - *Phoenix loureiri.*

Open secondary grasslands spreading now widely in places of former coniferous forest retain very few aboriginal species of extinct wood. Commonest of them may be only found in particularly wet open places. They are - *Asplenium longissimum, Catimbium speciosum, Commelina paludosa*, *Donax cannaeformis*, *Eleocharis* sp., *Floscopa glomerulata*, *Fuirena umbellata, Lasia spinosa, Ludwidgia perennis, Nephrolepis biserrata, Oenanthe javanica, Scirpus mucronatus* and *Scleria corymbifera*. Usual dominants here are tall and dense invasive grasses and sedges like *Leersia hexandra*, *Miscanthus* spp., *Paspalum conjugatum, Phragmites karka, Saccharum spontaneum, Scleria corymbifera* and *Setaria palmifolia*. Many herbaceous and hemi-herbaceous vines become very common in such open grassy plant communities. Among them most common are - *Argyreia capitata, Ipomoea* sp., *Lygodium microphyllum, Merremia pierrei, Paederia foetida, Smilax perfoliata* and *Stenochlaena palustris*. Tall sedges and grasses intermixed with numerous vines form very dense thickets that represent stable climax kind of secondary herbaceous vegetation, where natural regeneration of any native forest formations looks hardly possible.

## COMPARATIVE ANALYSIS OF EXTANT AND EXTINCT *GLYPTOSTROBUS PENSILIS* FORESTS

Structure and superficial appearance of studied extant *G. pensilis* populations are different in some details. Variation of extant trees according to their high in Trap K'Sor Species/Habitat Protected Area relatively is not too wide. The population is presented with rather short- and middle-high trees, mainly 3-20 m tall (Table 2 & 5, Fig. 16). Rather low trees in this population grow in more or less open environments, depressed by secondary shrubby and grassy vegetation. Most of these specimens besides their stunt habit are fairly old and seriously damaged by forest fire (Figs. 12E & F). Variation of tree height in Ea Ral Species/Habitat Protected Area population was assessed by study of representative model plot that included 75 trees. Their height varied here in a bit wider limits, mainly from 4 to 22 m tall (Tables 4 & 5, Fig. 16). Trees in this population have higher vitality and grow in closed forest that approximates to primary conditions. Comparative ratio of trees of different height in both studied populations is presented in Table 5 and Fig. 16.

Structure of extant and extinct *G. pensilis* forest according to bole diameter (d.b.h.) was studied in Trap K'Sor and Ea Ral Species/Habitat Protected Areas. Comparative ratio of trees of different bole thickness (and respectively age) in two extant and one extinct forest stands are presented in Table 6 and Fig. 18. As may be seen from these data, extant and extinct *G. pensilis* forest in Trap K'Sor Species/Habitat Protected Area have similar structure. Trees of 30-90 cm d.b.h., having approximate age about 80-240 years dominate in both cases. Some trees in these studied stands can reach 140 cm d.b.h. (with approximate age – 370-400 years), but young tree component here almost completely absent. Obviously, youngest trees extinct very fast under negative changing of environmental conditions. Young tree component is much better presented in Ea Ral Species/Habitat Protected Area. Trees 10-30 cm d.b.h. with approximate age 25-80 years form here more than 50% of population. At the same time, individual trees reach 100 cm d.b.h. (about 265 years).



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**Table 5. Proportion of different tree height categories in studied *Glyptostrobus pensilis* stands (in %). Numbers of trees are indicated in brackets.**

| Tree height categories in m | Trap K'Sor Species/Habitat Protected Area extant forest stand | Ea Ral Species/Habitat Protected Area model plot in extant forest |
|---|---|---|
| 2.1-4 | 17%(6) | 4%(3) |
| 4.1-6 | 9%(3) | 10%(7) |
| 6.1-8 | - | 11%(8) |
| 8.1-10 | 6%(2) | 8%(6) |
| 10.1-12 | 15%(5) | 4%(3) |
| 12.1-14 | - | 5%(4) |
| 14.1-16 | 15%(5) | 13%(10) |
| 16.1-18 | 17%(6) | 16%(13) |
| 18.1-20 | 15%(5) | 11%(8) |
| 20.1-22 | 3%(1) | 7%(5) |
| 22.1-24 | 3%(1) | 7%(5) |
| 24.1-26 | - | 5%(4) |

**Table 6. Proportion of bole diameter (d.b.h.) categories in studied *Glyptostrobus pensilis* extant and extinct stands (in %). Numbers of trees are indicated in brackets.**

| Tree diameter (d.b.h.) categories in cm | Trap K'Sor Species/Habitat Protected Area extant forest stand | Trap K'Sor Species/Habitat Protected Area extinct forest stand | Ea Ral Species/Habitat Protected Area model plot in extant forest |
|---|---|---|---|
| 4-10 | 0 | - | 2%(2) |
| 11-20 | 3%(1) | - | 29%(22) |
| 21-30 | 15%(5) | 1%(1) | 31%(23) |
| 31-40 | 15%(5) | 5%(4) | 13%(10) |
| 41-50 | 3%(1) | 19%(14) | 8%(6) |
| 51-60 | 20%(7) | 20%(15) | 11%(8) |
| 61-70 | 6%(2) | 11%(8) | 4%(3) |
| 77-80 | 6%(2) | 14%(10) | - |
| 81-90 | 15%(5) | 6%(4) | - |
| 91-100 | 8%(3) | 14%(10) | 2%(2) |
| 101-110 | 0 | 4%93) | - |
| 111-120 | 3%(1) | 3%(2) | - |
| 121-130 | 3%(1) | - | - |
| 131-140 | 3%(1) | 3%(2) | - |
| 141-150 | 0 | - | - |

**Table 7. Proportion of tree vitality categories in studied *Glyptostrobus pensilis* stands (in %). Numbers of trees are indicated in brackets. Tree vitality of 100% means full-blooded healthy tree, vitality of 0% means died tree; numerous old stumps here were not counted.**

| Tree vitality categories (in %) | Trap K'Sor Species/Habitat Protected Area extant forest stand | Ea Ral Species/Habitat Protected Area model plot in extant forest |
|---|---|---|
| 100-81% | 32% (11) | 84% (64) |
| 80-61% | 29% (10) | 11% (8) |
| 60-41% | 18% (6) | 4% (3) |
| 40-21% | 9% (3) | - |
| 20-0% | 12% (4) | 1% (1) |

Indirectly such data may indicate habitat conditions as more optimal for conifer growth. Forest structure in this case may be typical for ripe climax coniferous forest, which lived in former primary intact conditions years ago when natural regeneration of population was possible.

As may be seen from Table 7 and Fig. 17, vitality of *G. pensilis* trees obviously higher in population of Ea Ral than in population of Trap K'Sor Species/Habitat Protected Areas. However, proportion of decreased trees in both stands is very high, particularly in peripheral zone of population, which actually surrounded by more or less numerous more than half died and died trees (Figs. 12H-J). The rising ratio of highly decreased trees in whole populations indicates to obvious successive their degradation.

## NOTES ON CONSERVATION

*Glyptostrobus pensilis* is one of the most ancient extant conifers in the world, with a history that dates back at least more than 100 million years. Until recently, it was widespread in Northern Hemisphere, but after the last series of glaciations, its populations have been reduced to few small refugees in south-eastern China, central Vietnam and eastern Laos. Wide anthropogenic



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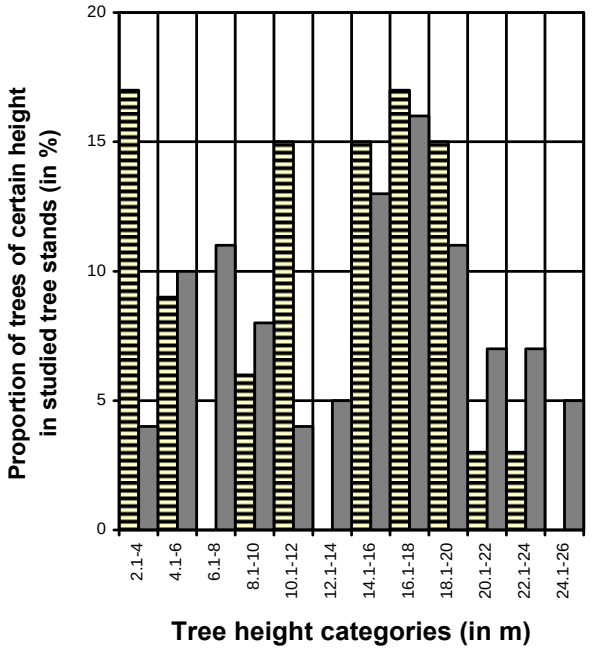



**Fig. 16. Proportion of trees of different height in studied *Glyptostrobus pensilis* stands (in %). Height categories are marked with columns of line (Trap K'Sor Species/Habitat Protected Area population) and solid gray shading (model plot in Ea Ral Species/Habitat Protected Area population).**

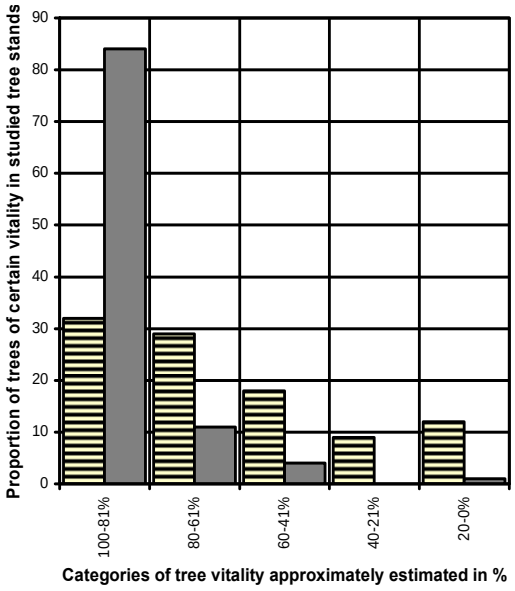



**Fig. 17. Proportion of trees of different vitality in studied *Glyptostrobus pensilis* stands (in %). Spectrum of vitality categories are marked with columns of line (Trap K'Sor Species/Habitat Protected Area population) and solid gray shading (model plot in Ea Ral Species/Habitat Protected Area population). Tree vitality of 100% means full-blooded healthy tree, vitality of 0% means died tree; numerous old stumps here were not counted.**

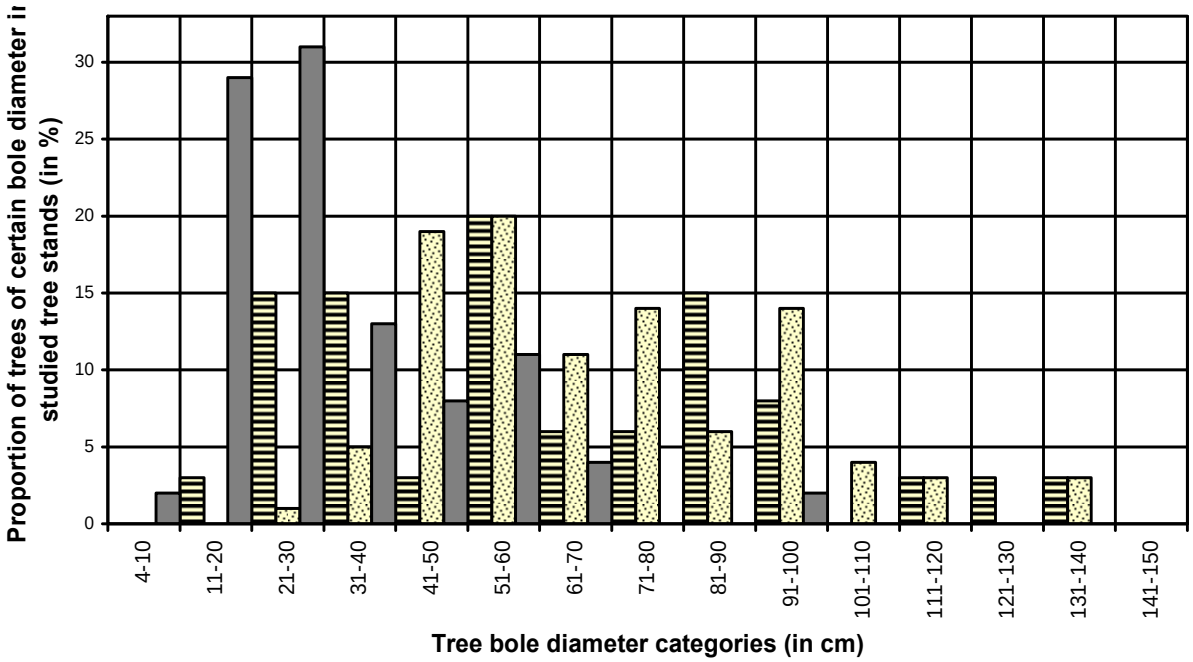



**Fig. 18. Proportion of trees of different bole diameter (d.b.h.) in studied *Glyptostrobus pensilis* extant and extinct stands (in %). Spectrum of bole diameter categories are marked with columns of line (Trap K'Sor Species/Habitat Protected Area extant population), dotted (model plot in Trap K'Sor Species/Habitat Protected Area extinct forest) and solid gray shading (model plot in Ea Ral Species/Habitat Protected Area population).**



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transformation of landscapes in mainland Southeast Asia during our ages leaded to extinction of last remnant native *G. pensilis* populations everywhere except 5 miserable close localities in Dak Lak Province at the center of Vietnam (Dallimore et al., 1967; Vidakovic, 1991; Fu et al., 1999; Luu and Thomas, 2004) and few close localities in eastern Laos near Vietnamese border. All present localities of *G. pensilis* in Vietnam are found at the center of Dak Lak Plateau that belongs to eastern part of South Indochinese floristic province (Takhtajan, 1978, 1986; Averyanov et al., 2003). The natural range of this floristic province with its rather uniform natural conditions includes also wide unexplored lowland and rolling hill areas of Laos (Averyanov et al., 2003). This unstudied basaltic area gives some hopes for future discovery of another unknown native populations of *G. pensilis*. Nevertheless, available reports on *G. pensilis* occurrence in Khammouan Province in Laos based on verbal reports of Vietnamese foresters (Luu and Thomas, 2004) never been confirmed by herbarium collections. At the some time, a number of closely allied native *G. pensilis* populations were recently found in Borikhamxai Province of eastern Laos near Vietnamese border around point 18°01'48"N 105°02'30"E (our personal unpublished data).

Formerly, *G. pensilis* had, undoubtedly, much wider distribution in central and southern Vietnam, at least in Dak Lak, Lam Dong and Gia Lai Provinces. Already first explorer of Indochina - Jao Loureiro recognized and reported this tree more than two hundred years ago under the name *Thuja orientalis* as a plant "*colitut rara in Cochinchina*" (Loureiro, 1793). Later the species was surprisingly missed in fundamental "Flore Générale de l'Indochine» (Lecomte and Humbert, 1907-1951), but was confirmed in a number of following succeeded publications on Vietnamese flora (Le and Phan, 1983; Phan, 1984; Nguyen and Vidal, 1996; Ho, 1999; Nguyen et al., 2004). Noticeable, that all these reports are based on very few collections made solely in two populations survived to our days and studied mainly in our investigation. Meanwhile, the tree was never been reported from northern Vietnam except few uncertain speculative data unconfirmed by any collections (Fu et al., 1999; Farjon, 2005).

The logging for excellent fragrant timber and transformation of almost all habitats into rice paddies were leading factors of *G. pensilis* extinction in the last decades. Up to now *G. pensilis* timber is highly valued for a fine fragrance and texture, as well as resistance to termites and water. In the past it used widely for cabinetwork, fine art articles, musical instruments and fine furniture. The aerial roots are soft and spongy and were sometimes used for making of different kinds of corks. Presently a number of governmental decrees effectively discontinue any logging of *G. pensilis* trees in its largest populations. *G. pensilis* is listed in Group I of the "Rare and Precious Flora and Fauna of Vietnam" (Council of Ministers Decree 18/1992/HDBT, dated 17/1/1992, on Providing a list of Rare and Precious Species of Flora and Fauna and Regulations for their Management and Protection). Under this legislation, reserves and management plants have been established, exploitation and use were forbidden. Further legal protection was given under Law on Environmental Protection (Government Decree 175/1994/CP, dated 18/10/1994 on Guiding the Implementation for the Environmental Protection Law) that was aimed at regulating developments in the surrounding areas. The Dak Lak Provincial People's Committee declared reserves for both largest *G. pensilis* populations as "Trap K'Sor and Ea Ral Species/Habitat Protected Areas" in 1994. Management boards and management plans along with guard stations and fences were established (Tordoff et al., 2004; Nguyen et al., 2004). The species was also listed as threatened in Vietnam by the World Conservation Monitoring Centre. Recently *G. pensilis* was listed in Group IA - Plant species or group of plant species prohibit of exploitation and uses for commercial purpose of the Governmental Decree No 32/2006/NĐ-CP, dated at 30/03/2006 on the Management of threatened, precious, rare native plants and animals. However, in our days negative successive changing of habitats becomes a main factor of decreasing of still remained *G. pensilis* populations.

Largest part of *G. pensilis* trees in all discovered and studied localities exhibits reduced vitality that indicates present ecological conditions as far from perfect. Permanent lotic inundation up to 1 m depth above swamp peat soils derived from basalt is living important requirement of normal development of coniferous forest with *G. pensilis*. Such water regime permanently characteristic for *Glyptostrobus* primary habitats is dramatically disturbed in all remained populations, which now are surrounded by coffee plantations and similar highly drained agricultural areas.

In this connection few native growing *Glyptostrobus* trees discovered outside protected areas in Buon Ho Town and near Truong Ha village (Figs. 1 & 6A-C) have probably no chance to survive for future. All they are located within densely inhabited area. Forest in this region has been cleared for cultivation and most of the surrounding lowlands deeply drained many decades ago. Predetermined extinction of these trees will be certainly very regrettable fact, as such isolated relict former population fragments often conceal very high specific genetic diversity (Li and Xia, 2005).

Main damage factor of *G. pensilis* habitat in Trap K'Sor Species/Habitat Protected Area is drawdown of



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ground-water in the swampy valley during rainless season due to wide consumption of water from numerous wells situated along periphery of protected swampy area. Regular irrigation of coffee plantations from November till April is living important for successful coffee planting on surrounding lands. Huge drain of water during this period leads to dropping of ground-water level on more than 3 m below ground surface (Fig. 12D) and strong drying of *Glyptostrobus* habitat substratum. Frequent forest fires during this time seriously destroy habitat burning away shrubs, grasses and fertile peat soil horizons. While fire is a rather frequent event brings no much harm to quite tolerant *Dipterocarpus* deciduous forests in surrounding lowland basaltic areas, it seriously damages swamp vegetation, which has no any adaptations to this factor. Some largest old *G. pensilis* trees can survive under swamp burning, but vitality of such specimens become strongly reduced (Figs. 12E & F) certainly moving them to coming extinction. Strong dramatic deficit of water during dry season is obvious and leading factor of *Glyptostrobus* population decreasing in this locality nevertheless official protection regime, fences and formal monitoring. As long as this factor remains its action, effective protection of the *G. pensilis* relict stand looks bleak. In such conditions, all remained 34 *G. pensilis* trees may extinct in this area before the conflict between protective efforts and agricultural industry water consumption will be solved.

Ironically, contrariwise to previous example, largest part of *G. pensilis* population protected in Ea Ral protected area extinct due to raise of ground-water level in its swamp habitat. Dam crossed swampy valley few years ago leaded to formation of water storage pond, which simply flushed half of the forest territory (Fig. 11). Some remnants of largest *G. pensilis* boles may be seen above water surface of this man-made lake up to now (Fig. 12G). Numerous trees adjoining to the lake did not die, but were strongly depressed by over-inundation (Figs. 12H & I). Unfavorable seasonal over-inundation dynamics, probably, also provide negative influence and even kill trees growing in places of deep water all over the population area (Fig. 12J). Nevertheless, foundation of dam and water storage lake partially can solve principal conflict between *G. pensilis* population conservation and deficit of water necessary for watering of surrounding agricultural lands. The monitoring and maintenance of optimal ground-water level throughout habitat of *G. pensilis,* undoubtedly, are first-important actions for effective forest protection. Such action looks quite realistic in this area, why conservation of *G. pensilis* stand here has certainly better perspectives for future. Effective protection of *G. pensilis* also needs detailed inventory of all extant specimens in this population. Different reports estimate their number from 100 (Vu, 1996) to 220 trees (Nguyen et al., 2004). However, accurate detailed inventory of all *Glyptostrobus* trees including small immature specimens depressed in deep shade of lowest forest strata was hardly ever been done. According to our preliminary observation, number of extant trees including small specimens certainly exceeds reported figures.

It is remarkable, that reproductive potentials of *G. pensilis* in all studied localities in Vietnam is very low. Numerous ripening cones observed in spring 2007 and 2008 were damaged with fungal (or bacterial) infection and form no normal seeds (Fig. 3H). In further special study, we find no one normally developed seed, fact that was also reported in earlier papers (Luu and Thomas, 2004). Additionally, no one seedling or saplings were found in all known *G. pensilis* localities during detailed field works. Youngest found trees were estimated as about 53-98 years old in Trap K'Sor and about 11-40 years old in Ea Ral protected area populations (Tables 2 & 4). Average tree age in both populations was assessed as 194 and 88 years old respectively. Obviously natural regeneration in all studied populations absent at least during last decade, which also was reported by other authors (Luu and Thomas, 2004). It is highly probable that all known populations of *G. pensilis* extinct in one generation without special measurements and propagation *in situ*. Accordingly, IUCN (2001) criteria classify *G. pensilis* as "Critically Endangered" (CR) species (under all mentioned categories: A-E), which certainly approaches to category – "Extinct in the Wild" (EW). It is important to underline that highly fragmented and declined populations of *G. pensilis* in Vietnam represent last remnants of native swamp coniferous forests, which no more exist outside the country. This globally endangered species approaches now to the verge of full extinction in the wild. It is one of the brightest examples of global floristic treasure and object for conservation of highest priority. Despite all connected problems, the efforts at *in situ* conservation should be strongly maintained because the swamp *G. pensilis* community represent assemblage that no longer occur anywhere else (Nguyen et al., 2004).

Propagation of *G. pensilis ex-* and *in-situ* is probably alone way to save globally significant genetic material of Vietnamese populations for future. The Vietnamese Forest Science Institute has undertaken some positive scientific approaches to this problem (Luu and Thomas, 2004; Nguyen et al., 2004). A major problem here is the lack of viable seeds and the difficulty of rooting of cuttings. Seed collections have been made from remaining Vietnamese trees repeatedly but no germination has been recorded. However, these reports are still based on limited materials. Investigation of all still available mature trees for viable seeds may bring certain success on this matter. Seed cones mature in November - January. In other countries, cones are usually collected when brown, dried and seed stored until



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spring when they are planted. Successful germination commonly takes about 20 days.

Attempts at vegetative propagation have also been largely unsuccessful. A limited number of clones have been successively rooted and are being grown at the Forest Science Institute of Vietnam Research Centre in Dalat City situated at the center of Vietnam (Nguyen et al., 2004). If these clones can be established, then other techniques could be used to produce material for further *ex-situ* works. It was additionally reported that semi-hardwood cuttings, preferably with a heel from juvenile trees are able root under mist, after treatment with hormones. It is possible to propagate the species from mature trees by cuttings, but rooting percentages are low (about 2% after 10 weeks). Rooted cuttings should be kept shaded. Planting should be done on raised mounds, rather than directly into water logged areas (Luu and Thomas, 2004). Tissue culture is another potential option for species propagation. Special scientific program for propagation of *G. pensilis* for repatriation and cultivation in appropriate habitats can save this unique conifer at least in culture. Such program will have not only scientific, but also high applied significance. Besides excellent fragrant timber, this tree has a very attractive ornamental habit, healthy odor of leaves and is suitable for wide planting near water for dam ground stabilization.

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# 越南原生杉科植物水松之初步觀察

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摘要：本文報導殘存於越南水松原生族群初步研究結果。本研究以包括生態學、族群結構、自然生境條件等角度的分類學處理，對於這自第三紀子遺至今的稀有物種保育遠景提出特別的評價與討論。

關鍵詞：原生族群、水松、杉科、第三紀子遺、越南、東印度支那。



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