Ann Sci For (1995) 52, 477-487

Original article

Dating natural gaps in the holm oak forest (*Quercus ilex* L) in Fango MAB Reserve (Corsica) by reading rings of maquis components

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(Received 15 July1994; accepted 2 December 1994)

Summary — This work is related to the study of natural gaps in a *Quercus ilex* Mediterranean forest in Corsica, France. The aim was to find a way to precisely date the *volis* to obtain a chronological sample which corresponded to the time of vegetation opening due to the fall of a holm oak and up to complete vegetation closure. The best marker appeared to be *Phillyrea latifolia*, a typical maquis tree found in association with the holm oak, which has a high capacity to produce stem sprouts after the breakage. In order to date the *chablis*, rings from the stem sprouts must be counted and a careful observation of the other species must be made to confirm results.

Corsica / *Quercus ilex* / maquis / natural gap / dendrochronology

Résumé — Datation des trouées naturelles en forêt de chênes verts (*Quercus ilex* L) dans la réserve MAB du Fango (Corse) par la lecture des cernes des essences du maquis. *Ce travail a trait à l'étude des trouées naturelles dans une forêt méditerranéenne à* Quercus ilex *en Corse. Il s'agit de trouver un moyen de dater précisément les volis afin d'obtenir un échantillonnage chronologique, correspondant à l'ouverture de la végétation, par chute d'un vieux chêne vert, jusqu'à la fermeture complète du milieu. Le meilleur marqueur de ces événements se révèle être* Phillyrea latifolia, *arbre du maquis en association avec le chêne vert, qui présente une excellente capacité à rejeter de tige après cassure. Il suffit de compter les cernes de ces rejets pour dater les chablis, tout en prenant en compte les autres espèces du maquis pour confirmer les résultats.*

Corse* / Quercus ilex / *maquis / trouée naturelle / dendrochronologie

INTRODUCTION

Gaps from natural treefalls have already been studied: (i) in tropical forests (Oldeman, 1974; Florence, 1981; Huc and Rosalina, 1981; Rollet, 1983; Riéra and Alexandre, 1988; Hartshorn, 1989); and (ii) in temperate forests (Falinski, 1977; Walter, 1979a, 1979b; Faille *et al*, 1984a, 1984b; Collins and Pickett, 1987; Koop and Hilgen, 1987; Lemée *et al*, 1991). However, no work has yet been performed on Mediterranean forests, in particular holm oak forests (*Quercus ilex* L).

In the Mediterranean basin, the frequency and intensity of disturbances over the centuries (fires, firewood cutting, coal mining, grazing, *etc*) have made it impossible to study large modern forest areas, which have evolved naturally over a long period of time. Barbéro (1990) is the only author who noted the existence of *chablis* in southern France and regeneration in these natural openings.

Chablis is defined as (Oldeman, 1990) "the uprooting of a tree, the uprooted tree, the inaccessible heap of broken or surviving vegetation and the branches, the opening (gap) in the forest canopy." The author distinguishes it from the *volis* which is "the breaking of a tree trunk (most often by storm), the broken and fallen upper part of the tree, the mass of vegetation and branches and the gap».

This study focused on natural gaps. It is rarely possible to date gaps directly.

Faille *et al* (1984a, b) and Koop and Hilgen (1987) used a natural known disturbance (hurricane of 1967) as a base and dated their *chablis* before or after this event by comparing trunk decomposition on the ground.

In tropical forests, settling by opportunistic species creates lines of seeds along the trunks on the ground. Brokaw (1982) suggested that new tree age class then appears. Dating the event seems to cause problems, but no explanation was provided on the method used. Riéra (1986) stated that the estimation of the *chablis* age is quite difficult. Rollet (1983) considered 4 age classes for gaps: "very recent, recent, old and very old", without explaining his criteria for identifying these classes.

A synchronistic analysis of natural gaps at different ages (from vegetation opening to complete vegetation closure) was undertaken. The purpose of this work was to discover 1 or more markers which made it possible to precisely date the event, to study natural regeneration in holm oak forests in the meso-Mediterranean strata.

REGION AND STUDY AREA

This study was performed in the Fango Valley (Haute-Corse), an area classified as a man and biophere reserve since 1977 (Viale and Frontier, 1979) due to the ancient nature of the holm oak forests stands.

The valley extends from the Paglia Orba (altitude 2 525 m) to the sea (approximately 10 km). The climate is subhumid Mediterranean with an average annual rainfall of 720 mm (forest ranger lodge, altitude 192 m) and an average annual temperature of 14.6°C. On the shady side of the valley, the state forest covers an area of 4 318 ha (fig 1).

The forest lies essentially on rhyolites (Vellutini, 1973). The studied forest has not been exploited since 1827 (ONF, 1992), in the Perticato district. *Volis* are principally located in the lower part of the vale, on a 15 ha area with an altitude ranging from 300 to 450 m. The old holm oak forest is at least 150 years old and it grows on brown acid soil (Roche and Roux, 1976).

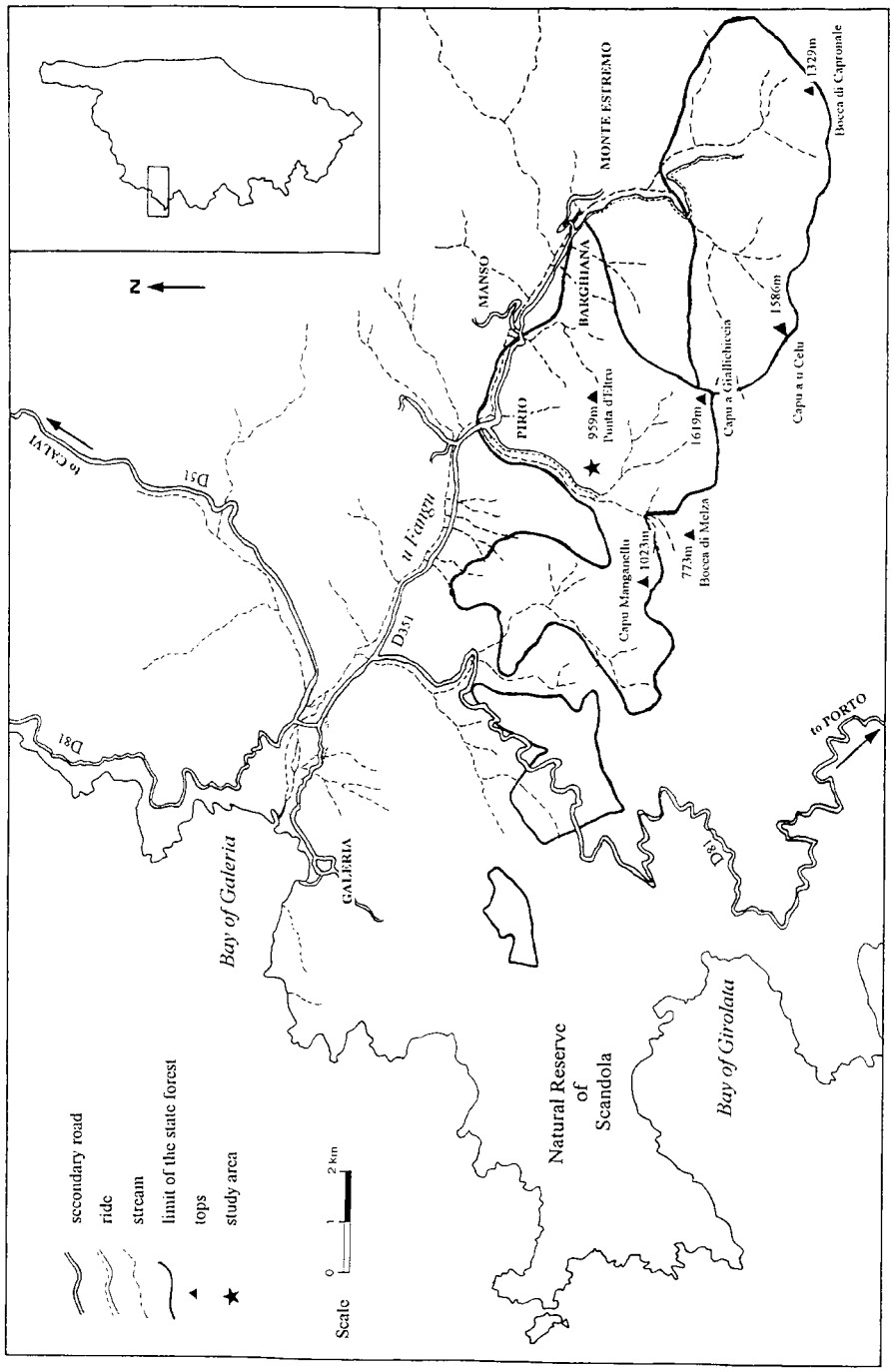

Fig 1. Localisation of the state forest of the Fango.

MATERIALS AND METHODS

The forest structure consists of a mosaic of large holm oaks (cover from 50 to 75%; dbh from 0.40 to 1 m; height from 15 to 20 m) and clumps (total density: 460 t/ha; g = 28 m^2/ha) with a high maquis below (height to 7 m) (M'hamedi, 1994; Panaïotis, 1994).

The age of these *Quercus ilex* causes *volis*, which are often single. Ten *volis* were selected, located in areas with relatively similar ecological conditions. Their dating was first determined by the decomposition state of the wood. We wanted to obtain the whole range of possible ages: from the gap of the 1st year to the period of complete vegetation closure, when trunks on the ground are entirely decomposed.

After localization of these differently aged gaps, we noticed the very high capacity of some maquis species to produce sprouts from a previous breakage. This "gap filling" can occur in different ways (figs 2, 3, 4).

In the forest, samples are cut at the base of these sprouts (figs 2, 3, 4: s is the collected stem section). The samples were cut again in the laboratory to obtain small 1 to 1.5 cm thick rounds. They were pumiced with very thin sandpaper to allow ring reading with a focusing glass.

RESULTS AND DISCUSSION

The number of rings in each sample makes it possible to estimate their age (table I) using classic dendrochronology techniques (Martin, 1974).

Before observing sprouting, *Fraxinus ornus* L was the intended age marker in these gaps. This hypothesis was based on the fact that this tree acts as an opportunistic species, and would thus take advantage of these natural clearings to root in large quantities due its anemophilous nature.

Nevertheless, the surface of these clearings was not large enough (120 m^2 at the largest) to permit real settling to occur. Furthermore, it was often present in the undergrowth (see table III, where plot 4C corresponds to the control forest plot without canopy opening). It characterizes a phytosociological subassociation with the holm oak: the *Quercetum ilicis gallo provinciale-*

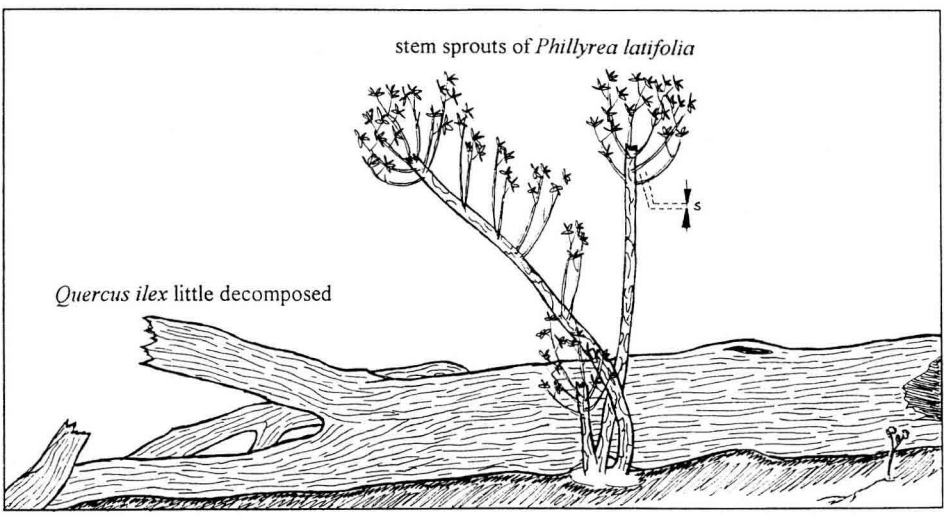

Fig 2. Recent *volis* (5 years). Holm oak fall has induced the breakage of *Phillyrea latifolia* stems. Lightning favors the emergence of sprouts at the break. Cuts are taken at the base of these sprouts. s is the section of the stems collected. The number of rings in this section yields *volis* age.

Table I. Age (years), diameter (cm) and height (cm) of the different stems harvested in the *volis*.

	Age	Diam	Height		Age	Diam	Height
Volis I				Volis V			
Fraxinus ornus 1	7	0.8	117	*Fraxinus ornus 1*	40	1.4	520
Fraxinus ornus 2	13	1.2	178	*Fraxinus ornus 2*	14	1.2	120
Fraxinus ornus 3	16	1.2	173	*Phillyrea latifolia 1*	16	3.1	450
Phillyrea latifolia 1	7	1.5	280	*Phillyrea latifolia 2*	16	3.7	410
Phillyrea latifolia 2	8	1.3	90	Volis VII			
Phillyrea latifolia 3	7	0.8	80	*Fraxinus ornus*	17	1.6	290
Phillyrea latifolia 4	8	2.2	90	*Phillyrea latifolia 1*	18	4.2	400
Volis II				*Phillyrea latifolia 2*	18	3.7	350
Fraxinus ornus 1	6	0.7	125	*Phillyrea latifolia 3*	18	3.5	450
Fraxinus ornus 2	5	0.8	70	*Quercus ilex*	17	1.8	250
Phillyrea latifolia 1	6	1.1	205	*Arbutus unedo*	18	2.8	310
Phillyrea latifolia 2	6	1.2	160	Volis VIII			
Arbutus unedo	6	1.6	70	*Fraxinus ornus 1*	13	1.1	230
Volis III				*Fraxinus ornus 2*	13	1.5	260
Fraxinus ornus	26	4.4	500	*Phillyrea latifolia 1*	6	1.4	230
Phillyrea latifolia 1	14	2.5	350	*Phillyrea latifolia 2*	18	3.1	440
Phillyrea latifolia 2	14	2.2	360	*Phillyrea latifolia 3*	6	1.6	210
Viburnum tinus	14	1.4	210	Volis IX			
Quercus ilex	14	1.1	120	*Phillyrea latifolia 1*	4	1.2	180
Volis IV				*Phillyrea latifolia 2*	2	0.4	45
Fraxinus ornus 1	12	1.3	140	*Phillyrea latifolia 3*	2	0.6	90
Fraxinus ornus 2	14	0.8	138	Volis X			
Phillyrea latifolia 1	12	2.8	400	*Phillyrea latifolia 1*	19	2.8	470
Phillyrea latifolia 2	12	2.2	330	*Phillyrea latifolia 2*	19	3.3	310
Phillyrea latifolia 3	11	3.1	390	*Phillyrea latifolia 3*	19	4.4	520

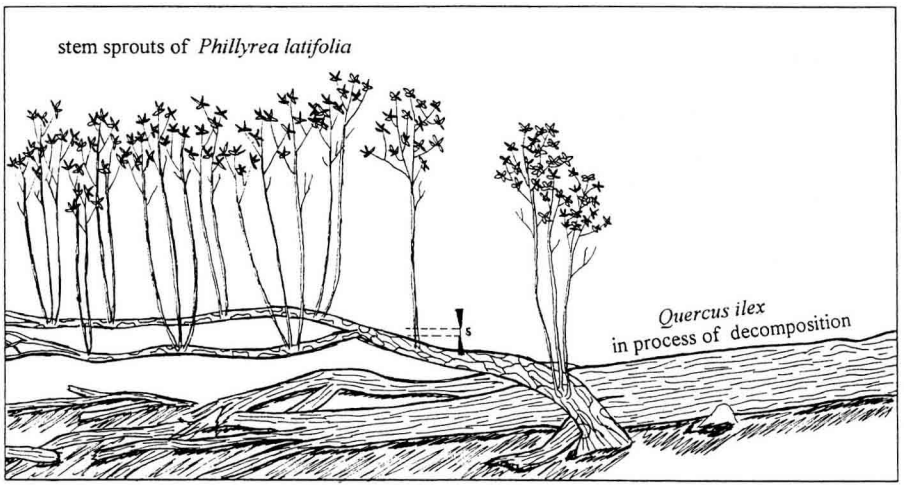

Fig 3. Middle-aged *volis* (12 years). Holm oak fall has induced the breakage of *Phillyrea latifolia* stems. Lightning favors the emergence of sprouts at the break. Cuts are taken at the base of these sprouts. s is the section of the stems collected. The number of rings in this section yields *volis* age.

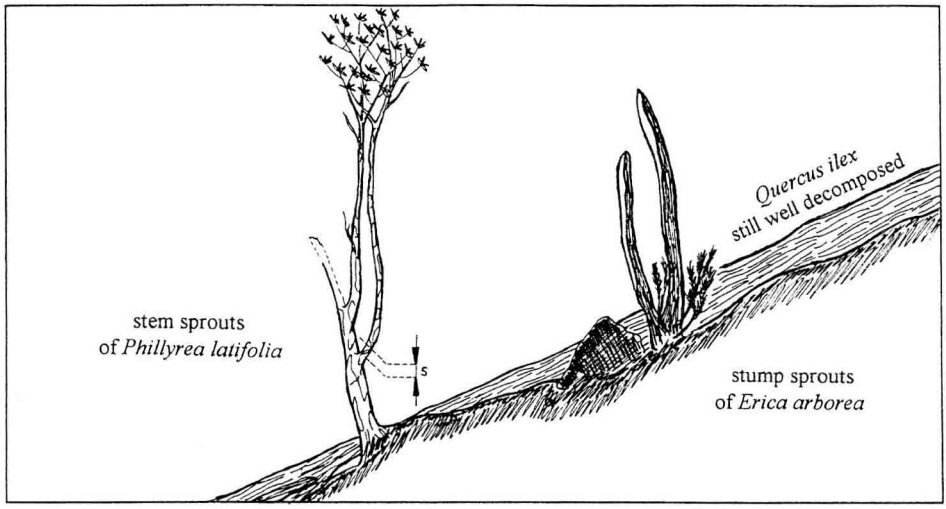

Fig 4. Old *volis* (16 years). Holm oak fall has induced the breakage of *Phillyrea latifolia* stems. Lightning favors the emergence of sprouts at the break. Cuts are taken at the base of these sprouts. s is the section of the stems collected. The number of rings in this section yields *volis* age.

ornetosum (Allier and Lacoste, 1980; Gamisans, 1991).

In spite of its deciduous nature, the ash tree presents some false and double rings. It can wait for a long time for a favorable moment for upward growth (an opening in the canopy). It sometimes infiltrates through the maquis to reach the sunlight (see table I, *volis V*, a 40-year-old shoot with a diameter of 1.4 cm). Consequently, the rings are very close together and hard to distinguish. Nevertheless, one can observe a clear increase in the 1st rings corresponding to a sudden outburst of sunlight (Lémée, 1985) (table I: *volis III*, the sample of *Fraxinus ornus* shows widely spaced rings at 14 years old). The dating of the gaps cannot only be performed by reading *Fraxinus ornus* rings; this tree could be used as an indirect temporal marker.

Dating based on sprouts from *Phillyrea latifolia* L stems yielded results which were consistent with the state of decomposition of the trees lying on the ground. Rings for *Phillyrea latifolia* stems are well-defined. The new sprout takes advantage of the whole shrub root system and of the intense lighting available through the gap. The diameter increase is important enough to localize the sequence corresponding to 1-year rings: this species presents double rings due to several annual growth periods.

Estimation of *volis* age was essentially based on *Phillyrea latifolia*, which seems to

Table II. Estimation of *volis* ages (in years).

Volis	VI	IX	II	I	IV	III	V	VII	VIII	X
Age	0	2	5	7	12	14	16	17	18	19

respond best to shoot breakage caused by holm oak fall (table II).

Volis VI corresponds to a holm oak fall in the spring 1993. The delay before *Phillyrea latifolia* emits a stem probably depends on the season during which the *volis* occurs. It can be estimated to within 1 year at the longest, when growth the following spring corresponds to the "naught point" of rings. The 1st visible ring corresponds to the 1st year of sprout growth. Initial *P latifolia* sprout rings are better defined than seedling rings (of *Quercus ilex*, for example) which are hard to date at 1 year. At *volis IX*, sample 1 in table I is 4 years old. The 2 other samples (2 and 3) are 2 years old. Thus, the opening is 2 years old, as further shown by the closing rate and the decomposition rate of the trunk compared to others. Sample 1 comes from a preexistant bough.

Volis V roughly indicates the closing period of these gaps. Sixteen years seem to be necessary for gap cicatrization in *volis* under 100 m^2, with a closing rate of 95% (the closing rate corresponds to the vertical crown projection of the forest strata [A1;A2] and of the higher shrub strata [a1]) (see table III).

Volis VII presents almost no evidence of decayed holm oak wood on the ground. Twenty years seem to be necessary for trunk decomposition in the biotic and abiotic conditions of the vale.

The other maquis species (with the exception of *Phillyrea latifolia*) occasionally yield complementary information to help estimate more precisely *volis* age.

– *Erica arborea* L always breaks in the stem. The sprouts are emitted from the stump. These sprouts are not good markers because they do not necessarily occur at the same time as opening. They can appear after the main stem droops due to insufficient light.

– *Arbutus unedo* L sprouts well from the stem but does not occur as frequently as *Phillyrea latifolia* (see table III). The probability for this species to be damaged by the oak fall is therefore low. Nevertheless, it is a good potential temporal marker (dating to be compared with the one provided by *Phillyrea*).

– *Viburnum tinus* L is rare in the undergrowth (table III). It is not a good marker: its stems bend down but do not break due to small diameter. Only 1 sample was collected in the 10 *volis.*

– *Quercus ilex* is often present in shrub from near the *volis*. Cutting it would certainly yield interesting information (increase in ring growth), but this would eliminate the only study element (sometimes 2 or 3 individuals).

Tree penetration with the increment borer is often very difficult and ring reading is increasingly difficult due to tannins (Zhang, 1987).

The seedlings, sometimes numerous, are anterior to the tree fall. The acorns present at the time of the event (seed bank), or posterior to the fall (mast coming from closely seed trees), probably benefit from the light to germinate or grow faster (currently under study). Consequently, they cannot provide precise information for *volis* dating.

CONCLUSION

Phillyrea latifolia is the best marker for natural gaps occurring after the fall of large holm oaks in the Fango forest. This species has numerous good features:

– It is the maquis species which skirts the holm oak in dense forests the longest, due to its forest behavior and its capacity to grow higher than *Arbutus unedo* and *Erica arborea*.

Table III. Phytosociological *relevés* of 10 *volis* (October 93) (*relevés* 1 to 10) and of the forest control plot (May 93) (*relevé* 11).

Relevés (table)		1	2	3	4	5	6	7	8	9	10	11
Relevés *(volis)*		VI	IX	Ii	I	IV	III	V	VII	VII	X	4C
Tree cover (+ 10 m)	A1 (%)	–	–	20	20	20	–	–	5	10	50	50
Tree cover (10–5 m)	A2 (%)	15	–	5	–	20	60	20	75	10	40	–
Shrub cover (5–1.5 m)	a1 (%)	10	30	20	10	30	30	80	10	40	10	60
Shrub cover (1.5–0.3 m)	a2 (%)	10	40	5	10	20	20	5	10	10	5	5
Herb cover (< 0.3 m)	h (%)	5	20	5	5	5	5	1	10	10	5	5
Moss cover	m (%)	10	25	5	5	30	10	20	40	40	60	10
Litter cover	l (%)	70	30	50	50	40	50	50	40	80	70	60
Rocky		*	*	–	–	*	–	–	–	–	**	*
Stony		**	*	**	**	**	**	**	*	**	**	**
Shingly		*	–	*	***	*	*	*	–	**	–	*
Area (m^2)		120	110	170	90	100	160	95	95	130	88	225
Slope (°)		35	20	30	35	35	35	35	35	35	30	40
Exposure		nw	nw	wnw	w	nw	w	nw	nw	nw	nw	wnw
Altitude (m)		345	310	315	410	355	320	315	345	395	380	315
Volis height (m)		0.8	0.2	1.5	1.5	0.2	1.5	2	0	1.3	0	–
Diameter of the trunk basis (m)		0.82	0.28	0.89	0.70	0.70	0.76	0.60	0.73	0.89	0.57	–
Closing rate (%)		10	20	25	10	50	70	95	95	75	100	–
Age of the *volis* (in years)		0	2	5	7	12	14	16	17	18	19	–
Max height (in m)		12	6	15	10	10	10	10	15	10	15	15
Mean shrub height (m)		0.5	5	3	1.2	3	5	5	5	3.5	8	5
Number of species		13	15	11	11	14	11	8	15	13	11	14
Trees												
Quercus ilex	A1	–	–	2.1	2.1	2.1	–	–	1.1	2.2	3.3	3.3
Quercus ilex	A2	2.3	–	1.1	–	1.1	1.2	2.1	1.1	2.1	–	–
Fraxinus ornus	A2	–	–	–	–	+	–	–	–	–	–	–
Phillyrea latifolia	A2	–	–	–	–	2.2	3.2	2.1	2.2	–	1.3	–
Arbutus unedo	A2	–	–	1.1	–	1.1	2.2	–	2.3	–	2.1	–
Erica arborea	A2	–	–	+	–	–	–	–	2.3	–	2.2	–
Shrubs												
Arbutus unedo	a1	–	–	2.2	–	2.2	+	3.2	–	2.2	–	2.2
Arbutus unedo	a2	–	1.1	1.1	+	1.1	–	–	–	1.2	–	1.1
Erica arborea	a1	–	1.2	–	–	1.1	+	2.2	+	1.1	–	2.3
Erica arborea	a2	+	+	+	2.1	+	–	+	+	+	–	1.1

Phillyrea latifolia	a1	1.1	2.3	2.3	1.1	1.2	2.3	2.2	1.1	2.3	2.2	2.1
Phillyrea latifolia	a2	1.1	2.2	1.1	–	2.1	2.3	–	+	1.2	1.1	+
Quercus ilex	a1	+	–	–	2.1	+	1.1	–	–	+	+	–
Quercus ilex	a2	+	+	–	–	1.2	1.1	1.1	1.1	+	1.3	–
Smilax aspera	a1	–	1.2	+	–	2.3	2.4	2.4	+	1.1	+	1.3
Smilax aspera	a2	1.1	1.3	+	–	2.2	2.2	–	+	1.1	–	+
Rubus ulmifolius	a1	–	1.3	1.2	–	–	–	–	2.2	–	–	1.2
Rubus ulmifolius	a2	–	3.3	1.1	+	1.1	–	–	1.1	–	–	+
Fraxinus ornus	a1	+	–	–	–	–	–	+	+	–	–	–
Fraxinus ornus	a2	+	1.1	+	1.1	1.1	1.1	1.1	–	+	–	1.1
Viburnum tinus	a2	+	–	–	–	+	+	–	–	–	–	–
Rubia peregrina	a2	–	–	–	–	–	+	–	–	–	–	–
Hedera helix	a1	–	–	–	–	–	–	–	+	–	–	–
Myrtus communis	a1	–	–	–	–	–	–	1.1	–	–	–	–
Herbs												
Quercus ilex		1.1	+	1.1	1.1	1.1	–	+	+	1.1	1.1	1.1
Fraxinus ornus		+	+	1.1	1.1	1.1	1.1	+	1.1	1.1	+	+
Phillyrea latifolia		+	+	+	+	+	–	+	+	+	+	1.1
Arbutus unedo		+	+	+	+	–	–	+	+	+	+	–
Erica arborea		+	+	–	+	–	+	+	+	+	+	+
Viburnum tinus		+	1.1	+	–	1.1	–	–	+	–	–	+
Juniperus oxycedrus		–	+	–	–	–	–	–	–	–	–	–
Rubia peregrina		–	1.2	+	+	+	+	+	1.2	+	–	1.1
Smilax aspera		+	1.2	+	–	+	1.1	+	1.1	+	–	+
Rubus ulmifolius		–	+	+	–	+	+	–	+	+	–	–
Hedera helix		–	–	–	–	–	–	–	+	–	–	–
Galium rotundifolium		+	–	–	–	+	1.2	–	1.2	1.2	+	+
Cyclamen repandum		–	–	–	–	–	–	–	–	–	–	1.2
Cyclamen hederifolium		–	–	–	+	–	–	–	–	–	–	–
Brachypodium retusum		–	1.2	–	1.1	–	–	–	–	–	–	–
Ruscus aculeatus		+	–	–	–	–	–	–	–	–	–	–
Hieracium gr *pilosella*		–	–	–	–	–	–	–	+	+	–	–
Selaginella denticulata		–	+	+	–	–	–	–	–	–	–	–
Polypodium cambricum		+	+	–	–	+	–	–	+	+	+	+
Asplenium adiantum-nigrum		+	+	+	+	+	+	–	+	+	+	+
Asplenium trichomanes		+	–	–	+	–	–	–	–	–	1.2	–
Moss		2.3	2.3	2.3	2.2	2.3	3.3	1.3	2.3	3.4	4.4	2.3

Abund-dominance: + rare; 1 < 5%; 2, 5 to 25%; 3, 25 to 50%; 4, 50 to 75%; 5, > 75%. Sociability: 1 individually; 2 in group; 3 in troop; 4 small colonies; 5 in crops. Stones : – none; * < 10%; ** 10 to 25%; *** 25 to 50%; **** > 50%.

– Its nearly systematic presence gives it more of a chance to be damaged.

– Its exceptional stem sprouting capacity yields the "naught point" of the gap.

– The smooth aspect of the sprout bark compared to the primary trunk makes them easy to recognize even 20 years after the event.

– Finally, its rings are very well-defined.

Nevertheless, more sampling and data from other species (*Arbutus unedo*, *Fraxinus ornus*, *Quercus ilex*) would be necessary to confirm these results.

The precise dating of the *volis* in the Mediterranean forest is possible due to the excellent sprouting capacity of its species, especially *Phillyrea latifolia*. The *volis* can be accurately dated to within approximately 1 year, which is in accordance with results obtained in other forests.

The study of natural gaps in the Fango MAB Reserve may make it possible for us to better understand the dynamics of holm oak forests, which have been disturbed over the centuries.

ACKNOWLEDGMENTS

This work is part of a global research program on the study of the potential regeneration of aging holm oak stands (*Quercus ilex* L) in Corsica (Fango Man & Biosphere Reserve) supported by the Ministery of Environment (SRETIE-EGPN).

Thanks are due to the Regional Natural Park of Corsica for their participation in this project. We are grateful to I Barros who improved the English.

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