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Polypores as indicators of conservation value in Corsican pine forests

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Abstract

The polypore flora was studied in mountain forests of *Pinus nigra* ssp. *laricio* in Corsica, France. Data on logs and species composition were collected in 17 sites with different stand characteristics in order to identify species indicating old-growth conditions. Thirty seven species were found, all of them occurring scarcely. More than 40% of the species were new to Corsica. The species composition varied much between sites, but there was no correlation with any of the stand variables. Fifty-seven percent of the species are in North Europe on Red Lists, or considered to be indicators of old-growth conditions. Their presence is probably a result of old stand age and existence of considerable amounts of dead wood. Also, three of the species found are otherwise confined to the boreal region and could be relicts from the latest glaciation.

Keywords: Polypores; *Pinus nigra* ssp. *laricio*; Dead wood; Forest conservation; Corsica

1. Introduction

The French island of Corsica is the fourth largest island of the Mediterranean. It is characterized by high and steep mountains and 25% is covered by forests. The dominant tree species in the higher mountains is the laricio pine (*Pinus nigra* ssp. *laricio*), whose natural occurrence is otherwise restricted to Sicily and the southern part of the Apennine peninsula. The laricio pine of Corsica is often considered distinct, var. *corsicana* (Said, 1996).

Mediterranean pine forest with endemic *Pinus nigra* is classified as a "natural habitat type of community interest whose conservation requires the designation of special areas of conservation" (European Communities' Council directive 92/43/EEC, annex I). To a large extent the forests of the steep Corsican mountains escaped the early exploitations which destroyed most of the forests in the western Mediterranean (Rota, 1991). Nowadays, the laricio pine in Corsica is generally subject to forestry through clear felling with a rotational period of 140–180 years (Said, 1996). Only one 50 ha biological reserve of laricio pine forest has so far been created (Varese, 1998).

One approach to selecting areas of laricio pine forests for conservation is to use indicator species, as is usually done in northern Europe (Karström, 1992; Nitare and Norén, 1992; Kotiranta and Niemelä, 1996). Most of the species used in northern Europe are included in the national Red Lists (Bratt et al., 1993; Karström, 1993; From and Delin, 1995; Norén et al., 1995). Polypores have turned out to be particularly suitable as indicators of old-growth conditions, as many species prefer large well decayed logs and become rarer with increased logging (Bader et al., 1995).

No previous study has been undertaken on the polypores of the corsican pine forests. The aim of the present study is to fill this gap, and to examine the correlation between species composition and a number of abiotic and biotic variables, in order to identify possible indicator species.

2. Study area

The study was performed in forests subject to the management of the state agency "Office National des Forêts" (ONF; Fig. 1). The stands were chosen in consultation

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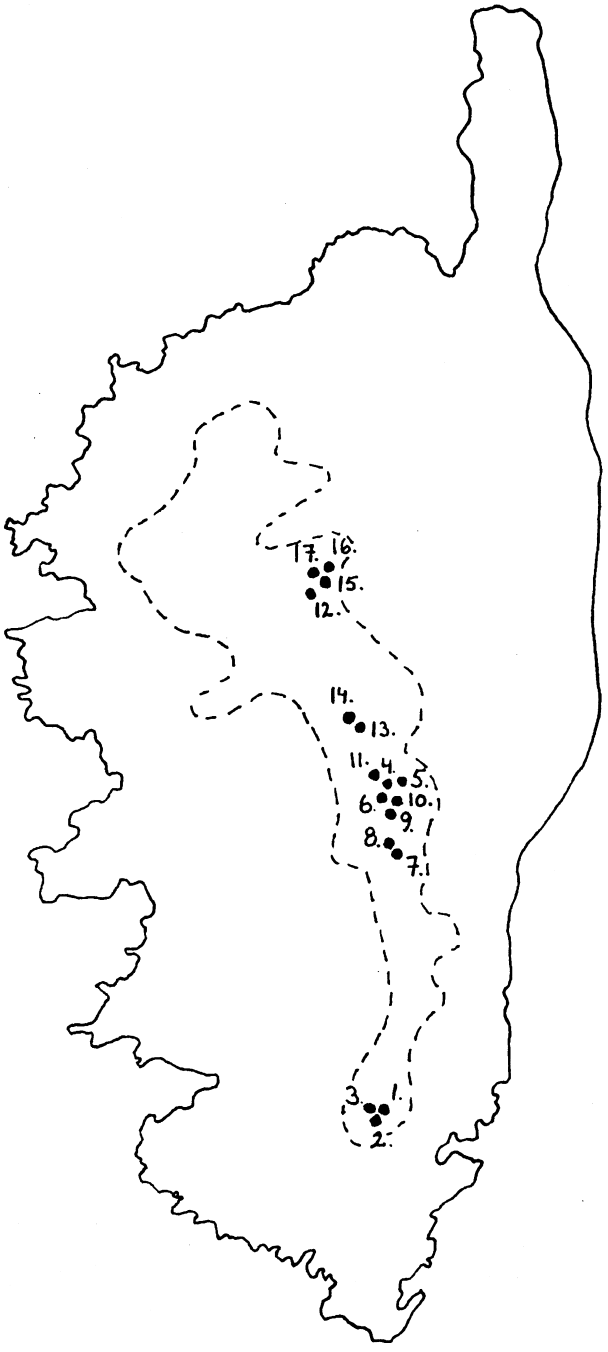

Fig. 1. Survey map showing the location of the 17 studied sites in Corsica. The approximate natural distribution of the laricio pine in Corsica, according to Debazac (1964), is marked with a broken line.

with the ONF foresters, according to the following criteria: (1) the dominant should be laricio pine; (2) the forest should be of "mature" age ("futaie adulte" or "vieille futaie" in the ONF classification); (3) there should be no or few traces of recent forestry activity; and (4) the density of logs on the ground should be as high as possible.

The stands were located between 1020 m and 1520 m a.s.l., sometimes near the timber line (Table 1), generally on very steep slopes. Boulders and blocks formed by nearby weathering were common. Below 1200 m, *Erica arborea* constituted a key element of the shrub layer, whereas low shrubs such as *Anthyllis hermanniae*, *Genista lobelii* and *Berberis aetnensis* dominated at higher altitudes. Low individuals of beech (*Fagus sylvatica*) were common. The vegetation in the field layer was generally scarce, often consisting of scattered *Pteridium aquilinum* and *Helleborus lividus* ssp. *corsicus*. The ground was covered by a thick mat of pine needles.

3. Methods

3.1. Species inventories and stand data

The study was performed in October and November 1997 at 17 sites (Table 1). Altitude and slope were recorded from maps, as well as the distance to the main village of the district — a possible indicator of the impact of early forestry.

In each site 20-m wide transects were laid out, starting and ending a few metres from the edge of a homogenous stand. The first was placed through the centre of the stand, and all naturally fallen laricio pine logs with a diameter $\geqslant 0.15$ m and a length $\geqslant 1.5$ m (including broken logs) were studied. Branches were excluded. Further transects were examined on alternative sides until at least 10 logs had been recorded, except for site No. 5, where only six logs could be found. Where density of logs was high, a few more transects were laid out and random sampling was continued in order to get a better measure of log density, number of species per log etc. All transects of a site were considered a plot. Site No. 8 was already marked into 50×50 m squares (for studies on the Corsican nuthatch *Sitta whiteheadi*), so we recorded logs in three of these squares. Site No. 10 was so small that we examined all logs and then measured the area.

The maximum diameter of each log was recorded. The decay stage was determined according to the following five-point scale (Renvall, 1995): (1) wood hard, bark more or less intact; (2) wood fairly hard, trunks usually decorticated; (3) wood fairly soft, with small area of wood already decomposed; (4) wood soft, large sections of the wood usually completely decomposed; and (5) wood very soft, almost completely decemposed. A sixth stage was added for logs where all of the sapwood had disappeared, leaving a bone-hard skeleton of resinous heartwood. Each log was classified as uprooted windthrow or broken stem, and the occurrence of fruiting bodies of polypores was noted.

We also noted all species of polypores seen inside the stand but outside the plot, or on other kinds of laricio pine wood, such as logs cut by man, standing trees, stumps, roots, or branches.

Table 1
Characteristics of the 17 study sites in Corsica

Stand variables	Site 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Plot size (ha)	2.4	1.0	0.2	1.5	1.4	0.4	0.3	0.6	0.2	1.6	0.6	0.2	0.8	0.6	0.1	0.3	0.3
Randomly sampled logs	11	12	17	13	6	10	14	13	14	11	11	11	10	13	11	18	16
Altitude (m a.s.l)	1060	1130	1100	1380	1030	1440	1250	1150	1120	1350	1450	1430	1020	1520	1500	1500	1490
Distance to main village (km)	11.0	11.2	11.0	7.6	7.0	6.5	3.1	3.3	2.2	6.7	5.0	7.5	7.0	5.6	5.7	5.3	4.9
Basal area (m^2 ha^{-1})	–	29.1	39.8	28.0	40.0	33.5	43.9	–	43.3	15.9	26.9	23.0	33.7	17.0	30.2	32.7	35.7
Average diameter of highest trees (m)	1.18	0.98	0.57	0.69	0.51	0.67	0.59	0.69	0.61	1.22	1.21	0.84	0.70	1.20	0.71	0.96	1.25
Stand age (minimum estimate)	–	–	151	196	131	170	163	176	191	260	–	181	184	337	209	122	111
Fire impact	2	2	0	3	3	2	3	3	1	2	2	3	2	2	3	3	3
Cut stumps ha^{-1}	5.3	0.0	0.0	8.0	67.9	23.7	3.7	12.0	15.0	0.6	26.7	0.0	2.4	8.9	0.0	17.6	10.0
Average log diameter	0.39	0.29	0.27	0.41	0.39	0.31	0.31	0.42	0.23	0.55	0.64	0.44	0.24	0.58	0.47	0.41	0.39
Logs >0.35 m (% of all logs)	38	33	12	67	33	30	23	69	14	64	100	73	10	69	75	69	38
Average decay stage of logs	3.6	2.8	2.8	4.1	2.8	3.4	4.1	3.5	3.3	2.3	2.6	3.9	3.0	3.2	3.8	4.1	2.9
Logs of decay stage 4–6 (% of all logs)	55	25	12	50	50	50	71	54	57	18	18	64	20	46	55	72	38
Logs ha^{-1} (windthrows and broken stems)	4.5	12.0	70.8	8.7	4.3	26.3	51.9	20.0	70.0	7.1	18.3	55.0	12.2	23.2	84.6	52.9	53.3
Broken stems ha^{-1}	2.0	4.0	45.8	6.0	3.6	18.4	40.7	18.5	60.0	5.1	13.3	45.0	12.2	7.1	69.2	44.1	46.7
Broken stems (% of all logs)	45	33	65	69	83	70	79	92	86	73	73	82	100	31	82	83	88

The nomenclature of fungi follows Ryvarden and Gilbertson (1993, 1994), except for *Skeletocutis vulgaris*, which has been dealt with by Niemelä and Dai (1997).

The basal area of the stand was approximated with relascope and corrected for slope (Anon., 1997). Diameter at breast height was measured on at least three of the highest trees. Approximate stand age was obtained for sites 6 and 10 from the ONF and in other cases by coring three of the highest trees in each stand. Since some of the trees were too large for the drills, these values should be considered minimum estimates. No samples were obtained from sites 1, 2 and 11.

All cut stumps were counted inside the plot to evaluate the impact of forestry. Traces of fire were classified according to a three-point scale supposed to express increasing fire impact: (1) burnt wood on the ground, e.g. logs; (2) burnt bark on standing trees, or occasional fire scars; and (3) abundant fire scars, burnt stumps, or trees killed by fire.

3.2. Statistical analysis

Species richness of each site was defined as the number of species occurring on 10 randomly selected logs (except for site No. 5, where only six logs were found). All logs were used to establish the proportion of logs with fruit bodies as well as the average number of species per log. The total number of species recorded in each site, regardless of sampling, was also counted. The correlation of these four variables (Table 3) to the stand variables (Table 1) was tested.

In order to test if the species composition of the plots was correlated to the stand variables (Table 1), processed data matrixes (presence/absence) for all species recorded three times or more (Table 2) were subjected to Detrended Correspondence Analysis (DCA; ter Braak and Prentice, 1988) Since most stands contained only one or two species per 10 randomly sampled logs, all observations made on laricio wood were included. The analysis was performed using the program PC-ORD (McCune and Mefford, 1997).

4. Results

4.1. Stand data

The minimum age of the stands varied from 111 to 337 years (Table 1); the oldest tree cored was at least 416 years (site No. 14). The highest trees were usually very large: the average diameter at breast height ranged from 0.51 to 1.25 m. The largest single tree was 1.64 m at breast height. The basal area of the stands ranged from 15.9 m^2 ha^{-1} to 43.9 m^2 ha^{-1} with an average value of 31.5 m^2 ha^{-1}.

Cut stumps were found in all plots but four. The highest density recorded was 67.9 stumps ha^{-1}, and the

Table 2
Frequency and characteristics of polypore species found on laricio pine in Corsica

Species	Frequency (% of randomly sampled logs)	Number of sites with species[a]	Red list category (Sweden)[b]	Red list category (Finland)[c]	Indicator of old or virgin forest conditions[d]
Skeletocutis lenis	1.9	5	VU	CD	Virgin
Oligoporus fragilis	1.9	4	–	–	–
Trichaptum fusco-violaceum	1.9	4	–	–	–
Skeletocutis vulgaris	1.4	6	*	–	–
Antrodia sordida	1.4	3	–	–	–
Heterobasidion annosum	1.4	3	–	–	–
Oligoporus lateritius	1.4	3	–	R	Old
Antrodia xantha	1.0	5	–	–	–
Leptoporus mollis	1.0	3	*	–	Old
Parmastomyces transmutans	1.0	3	–	–	–
Phaeolus schweinitzii	0.5	7	*	–	Old
Dichomitus squalens	0.5	3	EN	CD	Virgin
Ischnoderma benzoinum	0.5	3	–	–	–
Skeletocutis amorpha	0.5	3	–	–	–
Gloeoporus taxicola	0.5	2	*	–	Old
Hapalopilus salmonicolor	0.5	2	NT	–	–
Inonotus triqueter	0.5	2	EN	R	–
Oligoporus rennyii	0.5	2	–	–	–
Physisporinus rivulosus	0.5	1	–	–	–
Skeletocutis kuehneri	0.5	2	NT	–	–
Antrodia primaeva	0.5	1	EN	R	Virgin
Antrodia cf. sitchensis	0.5	1	–	R	–
Ceriporiopsis cf. mucida	0.5	1	*	–	–
Diplomitoporus lindbladii	0.5	1	–	–	–
Oligoporus cf. hibernicus	0.5	1	NT	R	Virgin
Oligoporus sericeomollis	0.5	1	–	–	Old
Phellinus pini	–	10	*	–	Old
Antrodia ramentacea	–	2	*	–	–
Fomitopsis pinicola	–	2	–	–	–
Antrodia crassa	–	1	EN	V	Virgin
Antrodia cf. gossypina	–	1	NT	–	–
Antrodiella semisupina	–	1	–	–	–
Hapalopilus nidulans	–	1	–	–	–
Oligoporus caesius	–	1	–	–	–
Skeletocutis carneogrisea	–	1	–	–	–
Skeletocutis ochroalba	–	1	VU	–	–
Skeletocutis odora	–	1	VU	R	Old

[a] Including species observed on all kinds of laricio pine wood, not randomly sampled.
[b] EN, endangered; VU, vulnerable; NT, near threatened (Gärdenfors, 2000). *, not on Red list, but indicating sites with high conservation values (Hallingbäck and Aronsson, 1998).
[c] V, vulnerable; R, rare; CD, care demanding (Kotiranta and Niemelä, 1996).
[d] Kotiranta and Niemelä (1996).

mean value 11.9 stumps ha^{-1} Traces of fire were found in all plots but one, mostly trees which had been damaged or killed by fire.

4.2. Log characteristics

A total of 211 logs were randomly sampled in study plots (ranging from 6 to 18 per site; Table 1). The basal diameter could be measured for 191 of these logs (Fig. 2a). The mean diameter was 39 cm (median value 32 cm) and the largest log measured 1.31 cm at the base. Twenty-three percent of the logs measured 50 cm or more at the base. The mean value for each study plot ranged from 23 to 64 cm.

The distribution of different stages of log decay was very close to normal (Fig. 2b) with a mean value of 3.3 and median value of 3. The mean decay stage of individual study plots varied from 2.3 to 4.1. The percentage of logs in late decay stages (4–6) ranged from 12 to 72% in the various plots.

The density of natural logs in the stands varied between 4.3 and 84.6 ha^{-1} with a mean value of 33.8 and a median value of 23.2. Seventy-three percent of the logs were broken stems whereas 27% were uprooted windthrows.

4.3. Species number and frequency

A total of 37 polypore species were found, most of them very rare: 14 species were recorded only once and eight species only twice (Table 2). The species frequency was equally low. The average number of species per log

Table 3
Variation in species richness

Site	Number of species on 10 randomly sampled logs	Mean number of species per log (all randomly sampled logs)	Proportion of logs with species (all randomly sampled logs)	Total number of species recorded in each site
1	2	0.18	0.18	5
2	1	0.17	0.17	3
3	3	0.35	0.29	8
4	1	0.08	0.08	4
5	2	0.33	0.33	7
6	3	0.30	0.20	7
7	2	0.14	0.14	8
8	3	0.30	0.30	11
9	2	0.21	0.21	7
10	4	0.55	0.45	9
11	3	0.36	0.27	4
12	1	0.18	0.18	5
13	2	0.20	0.20	2
14	2	0.23	0.15	5
15	1	0.09	0.09	1
16	2	0.17	0.11	3
17	2	0.31	0.31	6

was 0.23, the average of the different plots ranging from 0.08 to 0.55 (Table 3). In five of the sites, only one species was found per 10 logs. The highest number was four species per 10 logs, while the mean and median values were two species. Including non-random observations, the number of species per site ranged from one to 11.

Polypores were found on 20.9% of the logs. In most cases, there was one single species per log. Two species were found on six logs only (2.8%), all of them larger then the average log.

The number of species per log tended to be higher on large logs than on thin logs (Fig. 3a). It should be noted, however, that the highest class (diameter >1 m) consisted of only two logs. The number of species was higher on newly fallen logs than on more decayed ones (Fig. 3b). No species was found on logs of decay stage 6, which consisted of very hard heartwood. The frequency of species was higher on uprooted windthrows than on broken stems: an average of 0.26 species was found on each windthrow, compared to 0.19 species on each broken stem.

4.4. Species richness and composition

The stand variables were neither correlated with number of species, proportion of logs with polypores nor mean species number per log.

The DCA ordination revealed that the study plots were very different in terms of species composition. The length of the gradient in ordination axis 1 was 3.4 standard deviations, while the gradient in axis 2 was 4.3 standard deviations. These axes explained a great deal of the variation of the species composition (eigenvalue

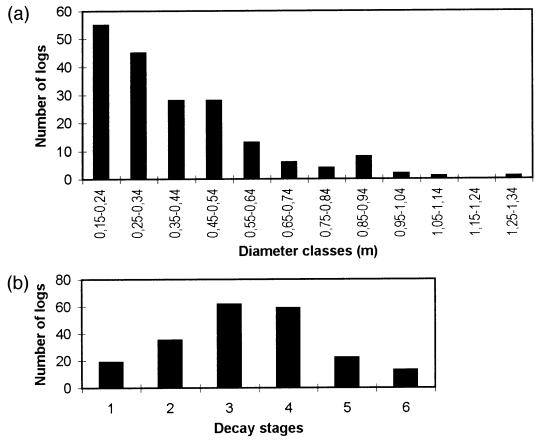

Fig. 2. Number of natural logs (a) in different diameter classes, $n=191$, and (b) decay stages, $n=210$.

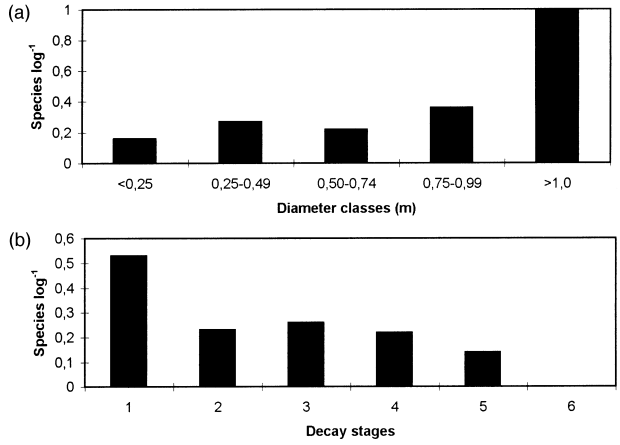

Fig. 3. Average number of species per natural log (a) in different diameter classes, $n=191$, and (b) decay stages, $n=210$.

0.496 and 0.305). However, the first and most important axis was only very weakly correlated to one of the stand variables, i.e. to mean decay stage of logs. The second axis was not correlated to any of the stand variables. The third axis, which explained only a small part of the variation (eigenvalue 0.146), was weakly correlated to density of cut stumps.

5. Discussion

5.1. Species number and frequency

An important contribution to the general knowledge of the Corsican forests was made through this study. More than 40% of the species were previously unrecorded from Corsica, according to published data (Milleliri, 1985; Neville et al., 1987; Neville, 1988; Michau, 1990; Pieri and Rivoire, 1992, 1994).

The total number of polypore species found on logs, 37, was about the same as the number found by Renvall (1995) on logs of Scots pine (*Pinus sylvestris*) in northern Finland, in spite of the fact that he examined almost twice as many logs. However, in Corsica, all species occurred very infrequently. The three most frequent species, *Skeletocutis lenis*, *Oligoporus fragilis* and *Trichaptum fusco-violaceum*, were only found on 1.9% of the logs, respectively. *Trichaptum fusco-violaceum* was more than three times as frequent in the mesic pine forest in northern Finland studied by Renvall. The most common species in Finland, *Antrodia xantha*, occurred on 14.1% of the Scots pine logs, but only on 1% of the logs in Corsica, where it was still one of the most common species (Table 2).

This striking difference might to some extent be due to annual variation, since 1997 was one of the poorest of the last 20 years for fungi in general, according to local mycologists (Jean Alesandri, pers. commun.). It could also be a result of more general climatic factors. Mean temperature is higher in Corsica than in northern Finland during all seasons, and precipitation is important in the area of laricio pine (800–1800 mm per year; Debazac, 1964). Decay ought to be much faster in Corsica. According to Renvall (1995), slow decomposition rate is an important factor in maintaining high species diversity of fungi on logs.

5.2. Indicator species

One of the aims of the study was to find species that could be used as indicators of conservation value. The first criterion of a good indicator species is that its occurrence shall be predictable, i.e. it should be found in most of the stands having such qualities as the species is thought to indicate (Karström, 1993). However, none of the species found during the study fulfilled this basic criterion. The only outcome of the DCA ordination was a weak correlation between the first axis and mean decay stage of logs. This was quite expected, since many polypore species show a marked preference for logs of a certain decay stage (Renvall, 1995). Neither species composition nor species richness was correlated to any other of the environmental variables of the stands, not even to the frequency of logs or man-made stumps, which in other studies have proven to be important (Bader et al., 1995; Berglund, 1997).

Nevertheless, the total list of species gives a clear indication of the conservation value of the laricio pine forest as a whole. Many of the polypores found are dependent on old-growth conditions, according to data from northern Europe (Table 2). Seven species are considered in Finland to be typical of old forests and five to be confined to virgin forests (Kotiranta and Niemelä, 1996). Thirteen of the species are included in either the Swedish or the Finnish Red List, seven of them in both (Kotiranta and Niemelä, 1996; Gärdenfors, 2000). Seven of the species not included in the Swedish Red List are still considered to be indicators of sites with high conservation values (Hallingbäck and Aronsson, 1998). In all, 57% of the species found (21 species) are red-listed in North Europe, are considered to be indicators of old-growth conditions, or both.

Ecological data from northern Europe cannot be directly transposed to the Mediterranean, and no Red List for fungi has yet been established for this part of France. However, there is barely any good reason to presume that the ecology of all these species should be completely different in Corsica. Also, although cut stumps can be found almost everywhere, the old-growth features of the laricio pine forests are evident. Stand age is high. Despite the low density of logs, the total volume of dead wood on the ground is often important, since logs can be huge. Most species of wood-inhabiting fungi have a clear preference for a certain log dimension, and species that are adapted to decomposing thick logs are generally confined to pristine or near-pristine forests (Renvall, 1995). Kruys et al. (1999) showed that red-listed species of wood-inhabiting fungi, hepatics, mosses, and lichens show a marked preference for utilizing large diameter logs, whereas more common species generally do not have such a preference. Therefore, the continuous presence of large amounts of dead wood is probably an important factor for the maintenance of species diversity in the laricio pine forests.

5.3. Boreal species in Corsica

In addition to species dependent on old-growth conditions, the Corsican forest contains at least three species whose distribution is nowadays predominantly boreal: *Antrodia primaeva*, *A. sordida*, and *Skeletocutis ochroalba* (Ryvarden and Gilbertson, 1993, 1994; Table 2). The main European distribution area of *Antrodia primaeva* is northern Sweden, Norway and Finland, about 2500 km from Corsica. *Antrodia sordida* had previously only been recorded once in Europe, in Sachsen in Germany, whereas *Skeletocutis ochroalba* was only known from two localities in Sweden (Ryvarden and Gilbertson, 1993, 1994; Leif Ryvarden pers. commun.). The prospects of spore dispersion from northern Europe to Corsica is probably poor. Thus, if these species were allowed to disappear, a spontaneous return would be unlikely.

The occurrence of boreal species in Corsica has an interesting parallel in the finding of *Piloporia sajanensis* in Sardinia, several thousand kilometres south of the nearest locality in Sweden (Bernicchia and Ryvarden, 1997). *P. sajanensis* is thought to have come to Sardinia during the latest glaciation, when boreal species were able to spread southwards. As the climate grew warmer, the vegetation changed, the coniferous forests of Sardinia disappeared and *P. sajanensis* survived as a relict on one

of the few available hosts, namely *Juniperus oxycedrus*. The presence of boreal species in Corsica may be a result of similar processes. Thus, these species can be seen as indicators of a forest continuity, dating back to the latest glaciation.

5.4. The need for conservation measures

Since the laricio pine forests are included in the European Communities directive on natural habitats, conservation measures are currently under discussion. There are a couple of projects aiming at the study and the protection of the bryophyte *Buxbaumia viridis*, the endemic Corsican nuthatch (*Sitta whiteheadi*), and a few rare vascular plants (Varese, 1998). So far, fungi have not been taken into account, and they are not included in the above-mentioned directive. The results of the present study suggest that fungi form an important and very particular part of the biodiversity of the laricio pine forest, in much the same way as in coniferous forests in Sweden and Finland (Kotiranta and Niemelä, 1996, Gärdenfors, 2000). Polypore species depending on old-growth conditions most likely would respond negatively to logging, especially through clear-felling. Since the frequency of polypore species is low, and since different sites vary considerably in species composition, the hitherto unique biological reserve of 50 ha (Varese, 1998) can hardly be sufficient to preserve biodiversity.

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