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Calliteara pudibunda (Lepidoptera Lymantriidae) in Northwest Italy

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Abstract

During the years 1988-1992 an outbreak of the pale tussock moth, *Calliteara pudibunda* (L.), took place in northwest Italy (Piedmont and Liguria) in different sites of beech and mixed broadleaf woods in the western Alps, from 700 to 1,300 m of height. This outstanding outbreak (the first recorded below the 48th parallel) was monitored during 1990-1993, checking pupal densities and rearing parasitoids. In pupae, ichneumonids reached a maximum parasitization rate of 34% and tachinids accounted for up to 19%, whereas in larvae a rather low parasitization rate was equally divided between Diptera (Tachinidae) and Hymenoptera (Ichneumonidae, Braconidae, Eulophidae). Two cases of hyperparasitization were found of the ichneumonid *Goedartia alboguttata* (Gravenhorst) by *Euceros kiushuensis* Uchida in the beechwood of Calizzano in Liguria. Very few cases of oophagous parasitization by *Trichogramma* spp. could be detected. Insect, bird and mammal predators were rather ineffective on the number of larvae, pupae and adults of the pale tussock moth. Viral, microbial and fungal agents of larval and pupal mortality were determined. The end of the outbreak was caused by cytoplasmic and nuclear polyhedroses, at least in three of the four investigated areas. The presence of the pale tussock moth in the following years was limited to few larvae seen sporadically in the forests and no pupae could be found.

Key words: Pale tussock moth, outbreak, parasitoids, hyperparasitoid, entomopathogenic agents.

Introduction

Calliteara pudibunda (L.) is a tussock moth present in Europe between the 37th and the 60th parallels, but it causes outbreaks, as mentioned in the existing literature (Wellenstein, 1978), only in territories included between the 48th and the 57th parallels. In central Europe outbreaks in beechwoods have been reported since 1810 especially in Germany (Klimitzek, 1972; Wellenstein, 1978), while in northern Europe, massive infestations have been noted only on beech in southern Sweden (Sylvén, 1944; Heqvist, 1949; Nilsson, 1978), and Denmark (Meulengracht-Madsen and Nielsen, 2001), and on oak in eastern Europe (Poland, Rumania, and the Ukraine) (Paramonow, 1935; Wellenstein, 1978).

Regarding the southern half of the continent there have been records only of the presence of the insect (Garcia-Tejero, 1943; Zangheri, 1963); the only notable known outbreaks have been reported in northwestern Italy (Arzone *et al*., 1993, 1994).

In Italy, between the end of the 1980s and the first years of the 1990s, an outbreak had involved beechwoods between the 44th and the 45th parallels in Piedmont and Liguria. The main localities affected were situated in the territory of the municipalities of Cumiana, Bibiana, Lusernetta, and Luserna San Giovanni in the province of Turin, Brondello in the province of Cuneo, Calizzano and neighbouring municipalities in the province of Savona (figure 1).

The scientific literature does not report indications in the past of similar phenomena in Italy (Disconzi, 1865; Lessona, 1878; Soli, 1900; Cecconi, 1924; Grandi, 1951; Della Beffa, 1961). The exceptional nature of this event led to an investigation on the dynamics of the outbreak.

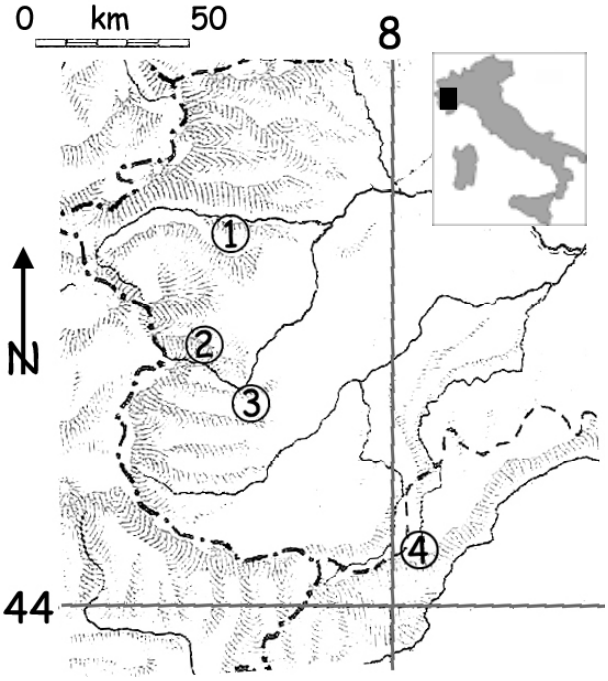

Figure 1. Sites where *C. pudibunda* outbreaks occurred in 1990-1992 in northwest Italy. 1: Cumiana; 2: Bibiana, Lusernetta, Luserna S. Giovanni; 3: Brondello; 4: Calizzano.

Materials and methods

In the years between 1990 and 1993, inspections were carried out in the various infested localities to monitor the outbreak and collect material.

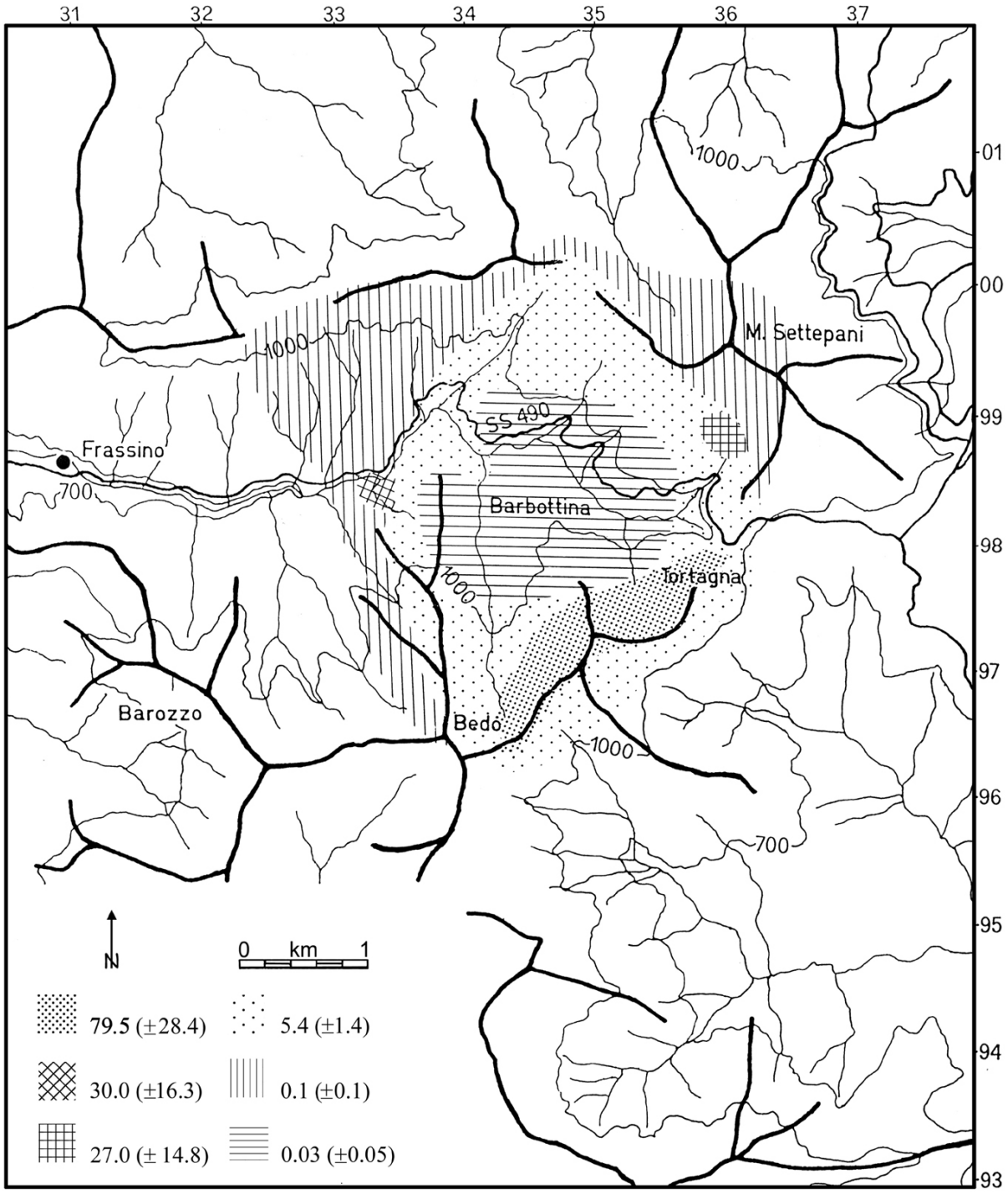

Figure 2. Results of pupal densities in the Calizzano beechwood after the 1990 outbreak (thick lines = ridges, thin lines = streams, contours = altitude levels, SS 490 = national road).

In autumn and winter, samplings of viable pupae were carried out on 10 randomly chosen areas of 1 m^2 per square kilometre of infestation so to draw out a map of pupal densities. A hierarchical cluster analysis was performed using the SPSS software, version 9 for Windows, then the clusters were split further, grouping the sampling sites having a geographical contiguity. Maps were drawn on the 1 square kilometre grid of the UTM maps of the Italian Istituto Geografico Militare.

The pupae collected and taken to the laboratory were isolated separately in test-tubes and kept in natural conditions. The specimens were checked weekly to monitor the emergence of adults or of natural enemies from the cocoon.

From June to September visits to the forests were intensified to collect eggs and larvae of different instars, which were then reared in the laboratory at a temperature of 23±2° C, a photoperiod of 16h, and a relative

humidity of 60±5%, to obtain their parasitoids. The latter were sent for determination to the International Institute of Entomology in London, to the Staatliches Museum für Naturkunde in Stuttgart, to the Hungarian Natural History Museum in Budapest, to the Department of Entomology and Agricultural Zoology of the University of Portici, and to the Regional Museum of Natural Sciences in Turin.

Dead larvae collected in the forests and sampled pupae that gave no emergences and were seen moulded or dead were sent to the former Istituto di Entomologia "Guido Grandi" of Bologna and to the Experimental Institute for Agricultural Zoology in Florence for the determination of fungal or bacterial pathogenic agents. The viral agents of mortality were determined in the Institute of Virology and Environmental Microbiology of Oxford, where three larvae per site were analysed.

In the years following the outbreak (1994-2004) further inspections were carried out in the infested areas and in other broadleaf woods of the western Alps with the aim to monitor the presence of pupae or larvae.

Results

Dynamics of the outbreak

The inspections carried out in September 1990 at Bibiana, Brondello, Calizzano, and Cumiana showed up a strong infestation with larvae in the penultimate and final instars and some pupae that had already appeared.

The infested areas were completely defoliated. Several larvae were roaming over the trees and on the ground, or were feeding on herbaceous plants or on the few conifers present; a great number of others were dead under the trees or on other supports, such as posts and guard-rails, with their bodies contracted and dried up. Samples of these larvae sent for the determination of probable pathogens revealed none of them, therefore the death was probably caused by starving.

On the edge of the defoliated areas, however, the larvae continued to feed on beech, chestnut and oak trees, still having leafy branches.

The cocoons were woven between the leaves on the ground, but in some sites, where leaves were lacking, the larvae had spun their cocoon in sheltered places, such as the cavities at the base of the trees or under rocks, or fixing the cocoon to other pre-existing ones.

The samplings carried out on the pupae in the Calizzano beechwood, where the infestation reached a considerable extension, highlighted a typical situation of concentric expansion of the infestation (figure 2). In the central area, where the number of larvae was such as to determine early defoliation and therefore the death from starvation of the larvae, the presence of pupae per square metre was insignificant (0.03/m^2). In the surrounding area, where the larvae had been able to complete their development, the number of viable pupae per square metre was 5.4, therefore over the threshold of 4/m^2 beyond which total defoliation can be expected in the subsequent year, as indicated by Zwölfer and Postner (1954). The situation in the external area, with a lower density of pupae (0.1/m^2), implied the presence outside the defoliated area (mount Settepani) of very few larvae, while in the defoliated area, exposed to the South, where the beeches were smaller in size, the death from starvation of the larvae was again noted.

In 1991, it was possible to follow the entire biological cycle of *C. pudibunda* in the various infested localities in Liguria and in Piedmont, with the exception of Brondello, where the outbreak was over.

In June at Calizzano, during the flight period, a considerable concentration of adults, almost all males, was noted around light sources near the wood; in particular, thousands of dead adults were found under the pylons supporting the floodlights on the top of mount Settepani (Savona) at 1,380 m above sea-level.

In the daytime, adults could be found often mating on tree-trunks and branches, generally up to a height of three metres from the ground, or on the understorey, where the eggs were then laid.

The newborn larvae began to feed by skeletonizing the leaves of the host-plants; hazel and brambles were the first to be defoliated.

To move around in search of food, the young larvae were wind-borne, hanging from a long silk thread; this behaviour was observed up to the fifth instar.

At the end of July in the Calizzano beechwood the local regional government commissioned a treatment on around 600 hectares, by means of a helicopter equipped with normal volume pumps, with a powder formula based on *Bacillus thuringiensis* Berliner var. *kurstaki*. This treatment gave no quantifiable results. At the end of September, over 3,700 hectares were defoliated.

At Cumiana, different situations were noted, depending on the locality. Defoliation reached its maximum extent, involving 390 hectares of beechwood including the two areas defoliated the previous year and the portion of forest included between these. In September in the locality Fontana Combalas (figure 3), the death of all the larvae was observed in about twenty days and a strong smell of rot covered all the area. The samples sent for the determination of the probable pathogens gave as a result the presence of viruses of cytoplasmic and nuclear polyhedrosis (table 1). The area was not completely defoliated, but a large part of the larvae

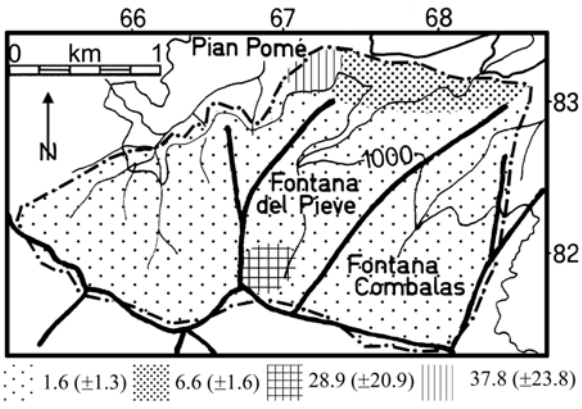

Figure 3. Results of pupal densities in the area of Cumiana infested by *C. pudibunda* in 1991 (thick lines = ridges, thin lines = streams, contours = altitude levels).

Table 1. Viruses of cytoplasmic polyhedrosis (CPV) and nuclear polyhedrosis (NPV) detected in larvae of *C. pudibunda* collected in the different localities in 1991 and 1992. In parentheses the virus found in a lower amount.

Locality	Year	Virus	No. samples
Calizzano	1991	CPV	6 (33.3 %)
		CPV (+NPV)	2 (10.1 %)
		CPV/NPV	2 (10.1 %)
		NPV (+CPV)	2 (10.1 %)
		Negative	6 (33.3 %)
	1992	CPV	4 (44.4 %)
		CPV (+NPV)	1 (11.1 %)
		NPV (+CPV)	1 (11.1 %)
		NPV	1 (11.1 %)
		Negative	2 (22.2 %)
Cumiana	1991	CPV	8 (66.6 %)
		NPV	2 (16.7 %)
		NPV (+CPV)	2 (16.7 %)
	1992	CPV	6 (100.0 %)
Luserna and Bibiana	1991	CPV	8 (66.6 %)
		NPV	2 (16.7 %)
		CPV (+NPV)	1 (8.3 %)
		NPV (+CPV)	1 (8.3 %)
	1992	CPV	3 (100.0 %)

was no longer feeding and roamed slowly along tree-trunks and on the ground. Dying, they remained hanging from their prolegs, while the front part of the body was bent downwards; the larvae were limp and their integument came apart easily. In this locality, very few pupae were found in winter searches (1.6/m^2).

In the Bibiana municipality the infestation affected the same area as the previous year. Divided into three parts of around 20 hectares each: one of tall beech trees and old coppices, one of oaks, and one of chestnut mixed with other broad-leaf plants. In autumn, a considerable number of larvae became pupae especially in the beechwood part.

The results of the sampling of viable pupae per square metre carried out in the beechwoods of Cumiana and Calizzano during the winter of 1991-92 are shown in figures 3 and 4.

The sampling of pupae in the Calizzano beechwood gave a picture similar to that of the previous year: a central zone with a low density of pupae per square metre (1.1/m^2) and a surrounding area with a density higher than the critical threshold (5.5 and 25.3/m^2). In particular, in the portions of beechwood situated at heights above the Frassino river with a North and West exposure, the highest density of pupae per square metre was found; while a very low density (0.4/m^2) was noted in the wide peripheral zone. In June 1992, an enormous number of adults was present above all in the central part of the beechwood. On the surface defoliated the previous year, a treatment based on *B. thuringiensis* var. *kurstaki*, fluid formula, was carried out by the local regional government in the second half of July, using a helicopter equipped with a micronair device. A non-quantifiable mortality of larvae in the second and third instars was noted, continuing by degrees in subsequent months. The larvae had the same appearance as those that had died the previous year at Cumiana. Everywhere, a high mortality rate was observed, caused by food shortage and by the action of *B. thuringiensis* and polyhedroses. In September almost 500 hectares were defoliated, where larvae were dying from polyhedrosis in the penultimate and final instar (table 1). The results of the autumn-winter sampling of viable pupae per square metre gave poor results (figure 5), both in the defoliated areas and in those not defoliated (0.5/m^2), except in one small zone near the southern slopes of mount Settepani, where the density was near to the critical one (3.2/m^2).

In 1992, in the Cumiana beechwood, the polyhedrosis epidemic spread to the whole infested area and the larvae died before completing their development (table 1). There were no more defoliations except in a few hectares in the Fontana del Pieve locality and above Pian Pomè where the larvae died gradually during September. Subsequent searches of pupae gave no results. In the other localities no larvae or pupae were found.

At Bibiana, in just 20 hectares of beechwood, the number of egg-laying females was very high and an extremely large number of egg masses was visible on tree-trunks and on the grass of the undergrowth; the larvae that developed from them had already completely defoliated the area in the second half of August, when the majority of them were in the fifth or sixth instar; before the end of the month they all died, showing an appearance similar to those that had died the previous year for polyhedroses at Cumiana (table 1). In the rest of the infested area, which included, besides the portions of the previous year, other 80 hectares of broadleaf plants mixed with beech in the territory of Bibiana and on the other side of the stream Traversero in the territory of the municipality of Luserna San Giovanni (figure 6), the larvae died in September for the same pathogenic agents. The sampling of pupae carried out in autumn gave negative results.

In 1993, during the inspections of the areas infested in the previous year, a very small number of larvae was found only in two localities of the Calizzano beechwood - to be precise, on the southern slopes of mount Settepani, where the previous year the pupal density was higher, and at the beginning of the Bric Tortagna road. There were no defoliations and in the autumn no pupae were found.

In the years 1994-2004 winter inspections to collect pupae on the soil gave no results in the previously infested areas and only few isolated larvae were seen in summer both in the formerly infested areas and in other broadleaf woods. In the latter woods the presence of this species appeared higher than usual, i.e. sightings in Piedmont of *C. pudibunda* larvae before the outbreak were much rarer. This presence was not quantified, but was rather steady throughout the years.

Parasitoids

Rearing the sampled pupae led to the emergence of *C. pudibunda*, of its natural enemies, and of *Euceros kiushuensis* Uchida (Ichneumonidae), a hyperparasitoid of

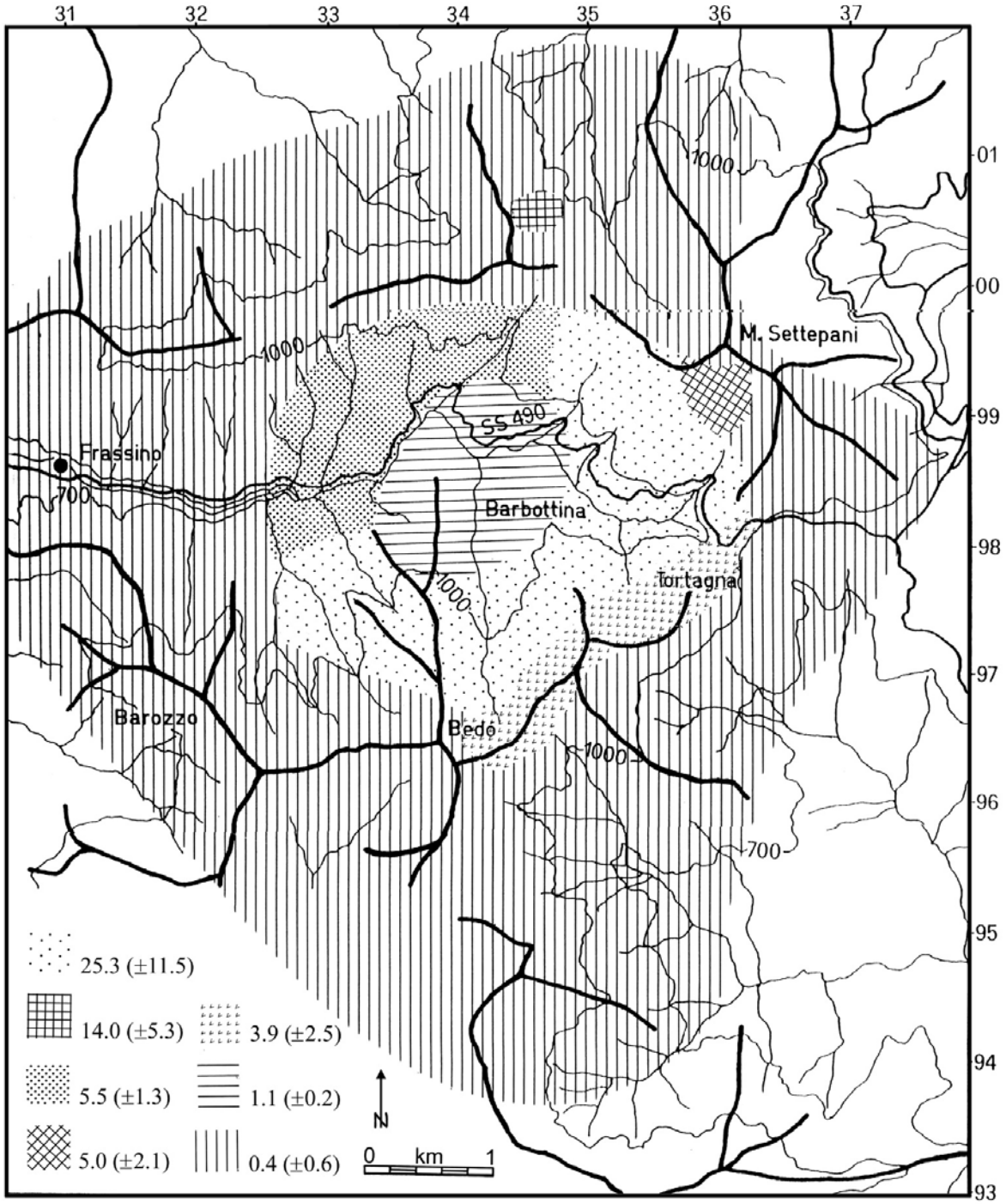

Figure 4. Results of pupal densities in the Calizzano beechwood after the 1991 outbreak.

Goedartia alboguttata (Gravenhorst) (Ichneumonidae) (table 2). The parasitization rate of pupae was between 10 and 34% with the exception of Brondello, where the majority of the pupae had died and *Beauveria bassiana* (Balsamo) Vuillemin was detected on them (table 3).

The parasitoids of the pupae belonged to Hymenoptera Ichneumonidae and Diptera Tachinidae represented by two and five species, respectively. The ichneumonids made up 80-95% of the parasitoids with a clear prevalence of *G. alboguttata* (75-92%). The tachinids, although always present, reached noteworthy percentages only in the Bibiana and Cumiana beechwoods (11-19%); among these, *Pales pavida* (Meigen) was almost always prevalent, especially in the final year of the outbreak, followed by *Carcelia rasa* (Macquart). There were only two cases of hyperparasitization in Calizzano by *E. kiushuensis*, which occurred in the final years of the outbreak.

The parasitoids listed in table 4 were reared from the larvae collected in the forests and raised in the laboratory. The death of *C. pudibunda* larvae caused by parasitoids affected all instars, with the exception of the first

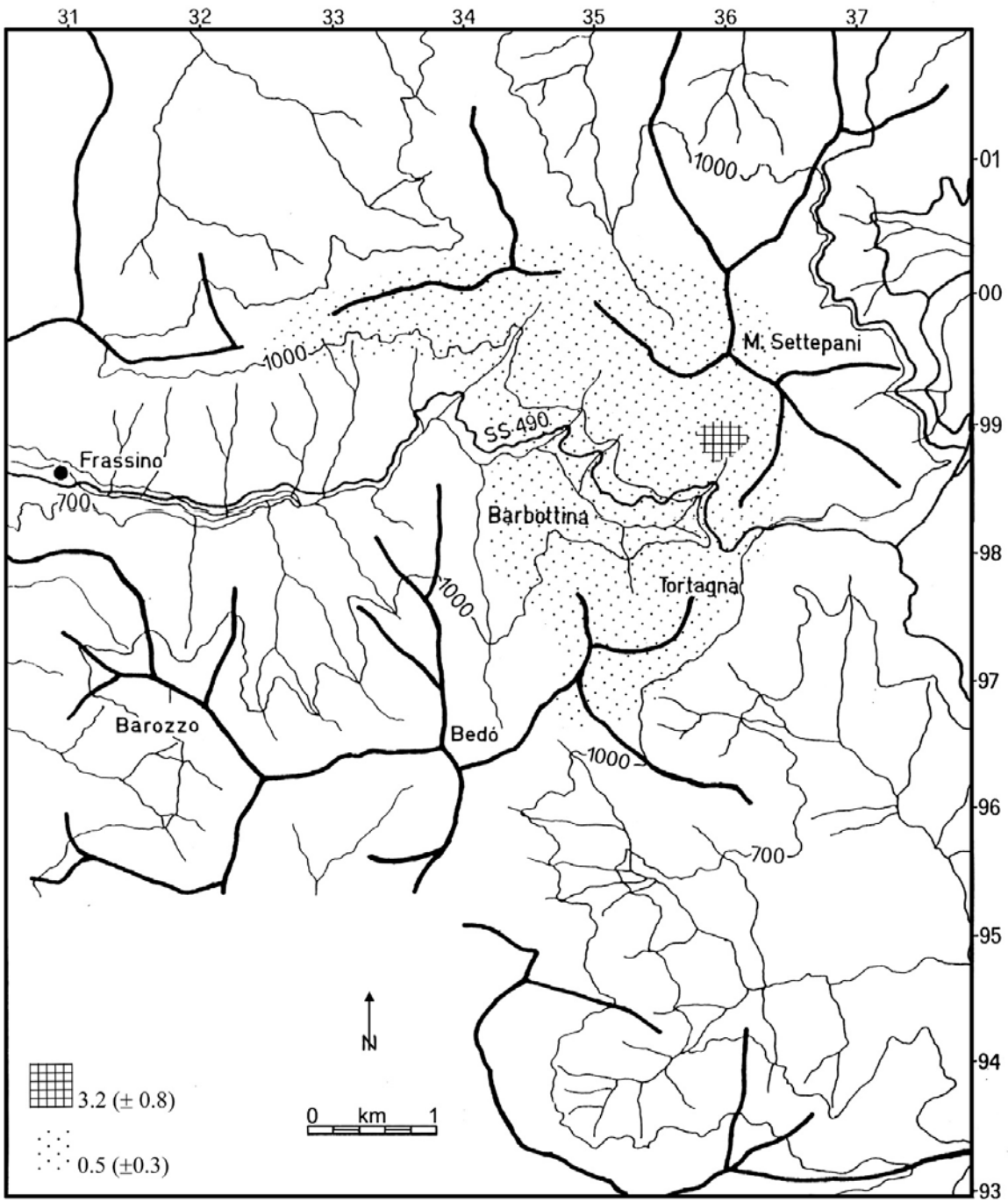

Figure 5. Results of pupal densities in the Calizzano beechwood after the 1992 outbreak.

one. The Hymenoptera first emerged from the cocoon in August, having developed at the expense of the first three larval instars of the pale tussock moth; in particular, specimens of *Eulophus ramicornis* (Fabricius) (Eulophidae) emerged from the cocoon at the end of July and the beginning of August; specimens of *Phobocampe unicincta* (Gravenhorst) (Ichneumonidae) and *Glyptapanteles liparidis* (Bouché) (Braconidae) also emerged in August and September from larvae of the fourth, fifth, and sixth instars; it should also be noted that in 1992-93, in Calizzano, the presence of a considerable number of *Ph. unicincta* cocoons was noted, and, on tree-trunks and leaves, single dead *C. pudibunda* larvae in the seventh and eighth instars were observed, surrounded by small cocoons, which were by then empty, similar to those of *G. liparidis*.

Among the tachinid flies, only *P. pavida* proved to be of some importance in terms of numeric prevalence, compared with the other tachinids and because of the high number of larval instars involved. Puparia of this

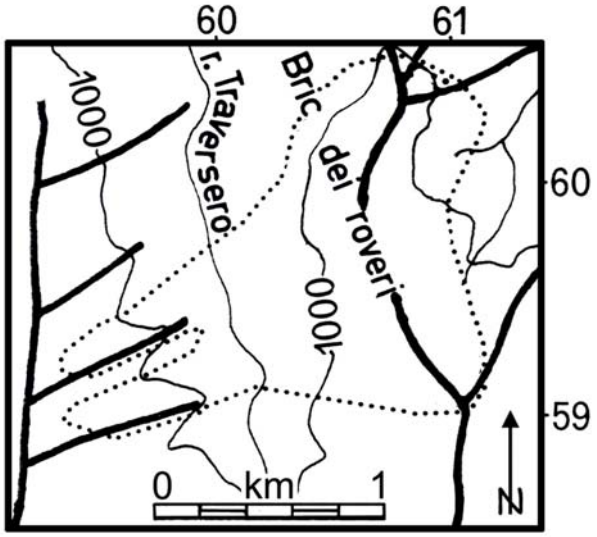

Figure 6. Area of Bibiana and Luserna S. Giovanni defoliated by *C. pudibunda* in 1992 (dotted contour).

species, of *C. rasa* and of a specimen of *Compsilura concinnata* (Meigen) were also found inside the cocoons of the pale tussock moth near the remains of the eopupa; only one specimen of *C. concinnata* came out from a sixth-instar larva. The two cases of emergence from the cocoon of *C. rasa* in February can probably be attributed to breeding conditions in the laboratory.

From the rearing of the sampled pupae, the emergence of *C. pudibunda* and its natural enemies took place, as shown in table 2; the parasitoids indicated in table 4 were obtained from the larvae collected in the forests and raised in the laboratory; few individuals of two undetermined species of *Trichogramma* (Chalcidoidea Trichogrammatidae) emerged in July from the 30,038 eggs collected in the three localities: one yellow-coloured and composed entirely of females at Calizzano (9 and 12 individuals from 2 egg masses) and Cumiana (5 individuals from 1 egg mass) in 1991 and at Bibiana (1, 6, 15 from 3 egg masses) and Calizzano (3, 5, 7, 11 from 4 egg masses) in 1992, and the species, black-coloured and composed of one defective male and twelve females, at Calizzano (Mount Settepani) in 1992.

The ichneumonid wasp *G. alboguttata* was still abundant in the Calizzano beech wood in 1993, as adults flying in the wood were observed in June-July. Their number decreased remarkably in the following years (1994-1995), and pupal samplings on 10 square metres in different parts of the wood gave no positive results.

Predators

In the three infested localities predatory insects were observed, both in the adult and young stages, in trophic activity on adults and larvae of *C. pudibunda*. They belonged to three species of Heteroptera Pentatomidae: *Pentatoma rufipes* (L.), *Pinthaeus sanguinipes* (F.), and *Troilus luridus* (F.). In addition, a considerable number of insectivorous vertebrates was noted: Paridae birds and arvicolid and murid mammals. Frequently, masses of *C. pudibunda* wings could be observed on the ground, that probably came from the predatory activity of bats.

Table 2. Parasitization rates of *C. pudibunda* pupae collected in the different sites and years (roman type: number of specimens, boldface: percentage on the total of pupae, italics: percentage within the category).

	Calizzano			Bibiana		Lusernetta and Luserna		Cumiana		Brondello
	1990	1991	1992	1990	1991	1990	1991	1990	1991	1990
No. pupae	885	2,587	96	175	261	84	128	180	1,226	165
Emerged moths	399	1,091	36	57	-	41	-	75	321	7
	45.08	**42.17**	**37.5**	**32.57**	-	**48.81**	-	**41.67**	**26.18**	**4.24**
Males	203	502	23	28	-	27	-	45	197	4
	50.88	*46.01*	*63.89*	*49.12*	-	*65.85*	-	*60*	*61.37*	*57.14*
Females	196	589	13	29	-	14	-	30	124	3
	49.12	*53.99*	*36.11*	*50.88*	-	*34.15*	-	*40*	*38.63*	*42.86*
Parasitized	99	245	25	37	89	13	13	51	397	8
	11.19	**9.47**	**26.04**	**21.14**	**34.1**	**15.48**	**10.16**	**28.33**	**32.38**	**4.85**
Pimpla sp.	5	6	0	2	0	2	1	0	15	1
	0.56	**0.23**	**0**	**1.14**	**0**	**2.38**	**0.78**	**0**	**1.22**	**0.61**
	5.05	*2.45*	*0*	*5.41*	*0*	*15.38*	*7.69*	*0*	*3.78*	*12.5*
Goedartia sp.	90	207	23	28	79	10	11	43	327	6
	10.17	**8**	**23.96**	**16**	**30.27**	**11.9**	**8.59**	**23.89**	**26.67**	**3.64**
	90.91	*84.49*	*92*	*75.68*	*88.76*	*76.92*	*84.62*	*84.31*	*82.37*	*75*
Tachinids	4	31	1	7	10	1	1	8	55	1
	0.46	**1.2**	**1.04**	**4**	**3.83**	**1.19**	**0.78**	**4.44**	**4.49**	**0.61**
	4.04	*12.65*	*4*	*18.92*	*11.24*	*7.69*	*7.69*	*15.69*	*13.85*	*12.5*
Hyperparasites	0	1	1	0	0	0	0	0	0	0
	0	**0.04**	**1.04**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	0	*0.41*	*4*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Dead for other reasons	387	1,251	35	81	-	30	-	54	508	150
	43.73	**48.36**	**36.46**	**46.29**	-	**35.71**	-	**30**	**41.44**	**90.91**

Table 3. Fungi and bacteria isolated from samples of *C. pudibunda* coming from the different localities in the different years of the outbreak.

Locality	Year	Isolates	No. Samples
Brondello	1990	***Beauveria bassiana***	6
Calizzano	1990	***Beauveria bassiana***	5
		Aspergillus sp.	1
	1991	***Alternaria alternata***	2
		Penicillium sp.	2
		Aspergillus niger	2
		Streptomyces sp.	1
		Micrococcus sp.	1
		Bacillus cereus	1
	1992	*Penicillium* sp.	4
		Acremonium sp.	1
		Alternaria sp.	1
Cumiana	1990	***Beauveria bassiana***	3
	1991	*Penicillium* sp.	13
		Streptomyces sp.	2
	1992	***Aspergillus niger***	11
		Beauveria bassiana	3
		Fusarium sp.	3
		Verticillium lecanii	1
Luserna and Bibiana	1990	***Beauveria bassiana***	4
		Aspergillus sp.	2
	1991	*Penicillium* sp.	2
		Fusarium sp.	1
		Acremonium sp.	1
		Serratia marcescens	1
		Streptomyces sp.	1
	1992	***Alternaria alternata***	3

Microbial agents and viruses

The fungi isolated and determined from dead *C. pudibunda* pupae collected in the field in the different years in the three localities include numerous saprophytic micro-organisms (table 3), among which the following species that may have also an entomopathogenic action: *B. bassiana* and *Verticillium lecanii* (Zimmermann) Viégas. In Calizzano, in the majority of dead larvae collected in the field, *B. thuringiensis* and viruses of cytoplasmic and nuclear polyhedrosis were detected. The viruses in particular were found in all the samples collected at Bibiana, Lusernetta, and Cumiana in 1991 and 1992 and in most of the samples collected in the Calizzano beechwood in the same years. The negative results in the virus assays were probably larvae killed by *B. thuringiensis*.

Discussion

C. pudibunda was found to be present in the whole Italian peninsula, with a greater frequency in the far past, at least in Piedmont (Lessona, 1878). The indications relating to the southern parts of Spain and Italy (Garcia-Tejera, 1943, Zangheri, 1963) move the southern limits of distribution of this species well beyond those indicated by Wellenstein (1978). In spite of a constant but rare presence of the pale tussock moth, only in the years 1990-1993 did it cause outbreaks in Piedmontese and Ligurian beechwoods, similar to those occurring in Europe between the 48th and 57th parallels. It must be kept in consideration that also in Trentino (Italian eastern Alps) in 1991 a greater presence of *C. pudibunda* was noted: in Val di Non at a height of 600-700 m apple trees were infested, and in the neighbouring woods, as well as locally in Valsugana, also beech and oaks were involved (Hellrigl, 1995).

A contemporaneous outbreak in Central Europe occurred in the Czech Republic (Urban and Šedivý, 1997). Another infestation took place at the same time in Rumania (Simionescu, 1994) at lower latitudes, close to the Italian ones, but has not seemed to be particularly outstanding, whereas in Italy this phenomenon has never taken place previously, and is the first that exists in the literature to occur outside the areas typical of outbreaks for this species in Europe.

A more recent outbreak, in Denmark in 1998 (Meulengracht-Madsen and Nielsen, 2001), seems an isolated phenomenon, not recorded elsewhere in Europe. In Italy, our observations gave no population increase in that year.

Our observations agree with the probability that the hot and dry summers of the 1980s were the underlying cause of the outbreaks, as indicated for other insect species by various authors (Currado *et al*., 1991; Ozenda, 1991; Baltensweiler, 1993; Battisti *et al*., 1994; Battisti, 2004).

Table 4. Parasitization of *C. pudibunda* larvae. A = Cumiana; B = Bibiana, Luserna and Lusernetta; C = Calizzano.

Instars	I	II	III	IV	V	VI	V–II	VIII	Eopupa	No. insects	Period	Site
Diptera Tachinidae												
Carcelia rasa									x	2	IX	C
									x	2	II	B-C
Pales pavida				x	x	x	x	x	x	24	IX-X	A-B-C
Compsilura concinnata									x	1	XI	C
						x				1	VIII	B
Hymenoptera Ichneumonidae												
Phobocampe unicincta			x	x	x	x				28	VIII-IX	A-B-C
Hymenoptera Braconidae												
Glyptapanteles liparidis			x	x	x	x				5	VIII-IX	C
Meteorus versicolor		x	x	x						6	VIII-IX	A-B-C
Hymenoptera Eulophidae												
Eulophus ramicornis		x	x							2	VII-VIII	C

The outbreaks occurring at the same time in the localities of the western Alpine chain showed the typical pattern of this species, with a population increase to be seen in the second half of the 1980s, a peak during the years 1990-1992, followed by a rapid collapse of the outbreak due to an epidemic of cytoplasmic and nuclear polyhedroses. The influence of naturally present *B. thuringiensis* cannot be evaluated, due to treatments made on the whole infested area of the Calizzano beechwood in 1991 and 1992, but a highly pathogenic strain was isolated from dead larvae collected in Ligura already in 1990 (Pelagatti and Roversi, 1994).

Few data exist in the literature on fungi affecting *C. pudibunda*. Remarkable seems the influence in the Czech Republic in 1992-1993 of *Paecilomyces farinosus* on 46.6% of the pupae (Urban and Šedivý, 1997). This fungus was not isolated from the Italian samples and the only fungus that had a strong action was *B. bassiana* on pupae at Brondello in 1990.

The population dynamics observed in Italy are in accordance with the works by Veldmann and Biehl (1986), Sylvén (1944), Peter (1986), and Wellenstein (1978) regarding outbreaks in central and northern Europe; in particular, the end of the infestations due to polyhedroses is reported by Jahn and Weber (1966), Urban (1967), Wellenstein (1978), Lobinger (1991), and Urban and Šedivý (1997).

The predatory activity of mammals, birds and insects against larvae, pupae and adults of *C. pudibunda* is not quantifiable and is seen in any case to be of low incidence, as already reported by Sylvén (1944) and by Wellenstein (1978).

For the parasitoids, the percentages reported in the literature refer to the outbreak of *C. pudibunda* at Longalund in Sweden in 1941-42, when the ichneumonids reached 7% and the tachinids 2-3% (Sylvén, 1944). Also on this occasion, the most represented species was the ichneumonid *G. alboguttata*, while among the tachinids *Carcelia gnava* Meigen was prevailing. Other data concerning parasitoids come from the Czech Republic (Urban and Šedivý, 1997), where in 1992-1993 *Phobocampe* sp. parasitized up to 3.3% of the larvae and *Pimpla hypochondriaca* (Retzius) killed up to 16.9% of the pupae. These percentages are not so far from the Italian ones and confirm the low impact of parasitoids during outbreaks. Unfortunately, data are missing on the effectiveness of parasitoids and predators during normal population densities of *C. pudibunda*, and also these densities are not quantified.

Of over 30,000 *C. pudibunda* eggs collected in the three localities sampled, few units were found to be parasitized by yellow-coloured females of *Trichogramma* sp.. Specimens of black-coloured *Trichogramma* sp. emerged only from a few of the eggs of one single laying collected on the slopes of the Mount Settepani in the Calizzano beechwood. Both *Trichogramma* species could not be identified owing to the lack of males in the former species and to the presence of only one defective male in the latter species; unfortunately molecular analyses were not possible because the specimens were preserved in 70% alcohol. In the literature, the only two sightings of *C. pudibunda* oophagous parasitoids refer to proctotrupids (Sylvèn, 1944) and *Trichogramma evanescens* (Lebedyanskaya *et al*., 1936). The first case relates to one single laying parasitized out of 50,000 eggs collected, confirming the rarity of *C. pudibunda* egg parasitoids in the forests; in the second case, instead, the trichogrammatid was multiplied in the laboratory on *C. pudibunda* eggs for use in the biological control of a lepidopteran pest of beet (Lebedyanskaya *et al*., 1936).

The results obtained during the outbreak of *C. pudibunda* in Northwest Italy confirm what has already been written by other authors, i.e. the incidence of the parasitoids never reaches levels which might represent an obstacle to the occurrence of the outbreak. In addition, defoliations caused by the pale tussock moth seem not to have relevant effects either on the wood growth or on the vitality of the plants affected, since they occur towards the end of the good season and are not repeated for more than two or three consecutive years, as has been noted on oak (Paramonow, 1936) and on beech (Schneider, 1954; Nilsson, 1978). It should therefore be emphasized that any insecticidal intervention against *C. pudibunda* is not necessary both because of the side-effects on the forest ecosystem and because of the cost of the treatment being higher than the economic damage caused by the pale tussock moth (Paramonow, 1935; König, 1954; Schneider, 1954, Nilsson, 1978).

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