OUTBREAK OF ZEIRAPHERA RUFIMITRANA ON SILVER FIR HITHERTO UNKNOWN IN SOUTHWEST GERMANY

HERMANN BOGENSCHÜTZ

Forest Research Station
D-7800 Freiburg, Germany

INTRODUCTION

The most important defoliator of the silver fir, *Abies alba*, is *Choristoneura murinana* (Lepidoptera: Tortricidae) (Bogenschütz 1978). The fact that *Zeiraphera rufimitrana* H.-S. (Lepidoptera: Olethreutidae) (Bovey 1978) often occurs simultaneously with *C. murinana* has, in practice, frequently led to misidentification. The larvae of both species feed exclusively on juvenile needles in the upper, sun-exposed tree crowns and cause an identical type of defoliation. Foraged needles discolor reddish-brown in the early summer and are later shed. Once the brown needles have been shed, one can assess the severity of the infestation, over the course of previous years as well as more recently. Damage inflicted by the two species can be distinguished on the basis of morphological and behavioral differences between them. In this paper I present the results obtained from studies pursued since an outbreak of *Z. rufimitrana* in the Black Forest in 1986. It represents the first outbreak of this particular pest observed in southwest Germany to date.

METHODS

The population dynamics of *Z. rufimitrana* can be determined in two ways: 1) indirectly, by appraisal of needle loss on yearly shoot orders, and 2) directly, by studies of population densities of various developmental stages. Both procedures have advantages and disadvantages. The indirect method is universally applicable, allowing a relatively large area to be surveyed quickly. The direct method can be applied only during a very short, specified time period and is highly work intensive. It is used to determine not only changes in population density but also the factors influencing population dynamics.

Using the indirect method, we examined a stand on the western slopes of the Black Forest which had been severely damaged in 1988. The age of the trees in the stand ranges from 95 to 115 years. The stand is comprised of 85 percent silver fir, the remainder divided between beech and oak and has an average height of 23 m. Sloping to the southeast, it lies at roughly 550 m above sea level.

In the winter of 1988-89, two field assistants using binoculars appraised the degree of defoliation in the discernible portions of the crown. Damage estimates based on yearly growth were rated in three categories: 1) low, up to a maximum of 1/3 defoliation, 2) medium, up to a maximum of 2/3 defoliation, and 3) high, up to complete defoliation. In addition to the stand thus assessed, a heavily infested selection forest with a high proportion of silver fir was singled out in the upper Black Forest

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BARANCHIKOV, Y.N., MATTSON, W.J., HAIN, F.P., and PAYNE, T.L., eds. 1991. Forest Insect Guilds: Patterns of Interaction with Host Trees. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-153.

region, at about 850 m above sea level. In both of the stands, direct methods were used to collect data on population dynamics. To determine the density of the hibernating eggs, it is necessary to fell the sample tree. Sample branches from the upper crown area were then searched for eggs under the microscope. To determine the density of the descending larvae, a procedure was used whereby funnel traps (0.25 m^2), whose containers were filled with litter and humus, were placed directly under the tree crowns. In 1989, the year our data were collected, the feeding period was completed in the first half of June. Larvae were collected from the crown on different dates during the feeding period to determine the degree of parasitism, either by dissection or by rearing.

RESULTS

In the forest district of Staufen the outbreak of *Z. rufimitrana* began in 1986. The years following showed a steady increase in the number of trees attacked, the area of infested stands approximately 600 ha in 1988, and the intensity of defoliation (Fig. 1). The eggs were found singly or in small groups between the bud scales of the year's shoots and to a lesser degree, between the scales at the base of the male flowers. Shoots located in the upper half of the crown were favored. In the initial phase of the study, we removed branches from the uppermost eight to 12 branch whorls of four dominant or codominant trees and sampled 10 shoots, both middle and secondary, from each whorl.

The number of eggs found on each branch whorl sampled fluctuated greatly (Fig. 2), especially in the two uppermost whorls. Below the eighth branch whorl a clear reduction in egg numbers was found. As a result, the survey of fir stands will be limited to the third through seventh whorls, thereby yielding a sample of 5 x 10 = 50 shoots per tree. Table 1 shows that the rather consistent results obtained from four sample trees in the forest district of Staufen. In contrast, the results obtained from the forest district of St. Blasien showed greater variability. It must be noted that in the latter area, the old sampling method, examining the full upper crown, was still used. However, the order of magnitude of the results coincided in both regions.

Less than half of the eggs found during the winter were intact and consequently developed to young larvae in the spring. On the average 8 or 11 percent respectively had a black discoloration. These eggs had been parasitized. The remaining eggs were empty (Table 2).

Table 1. Egg density.

Forest district	Number of sample trees	Eggs/shoot			
		Min.	Max.	$\bar{x}$	s
Staufen	4	10.2	13.7	12.3	1.6
St. Blasien	9	4.0	13.3	7.4	3.6

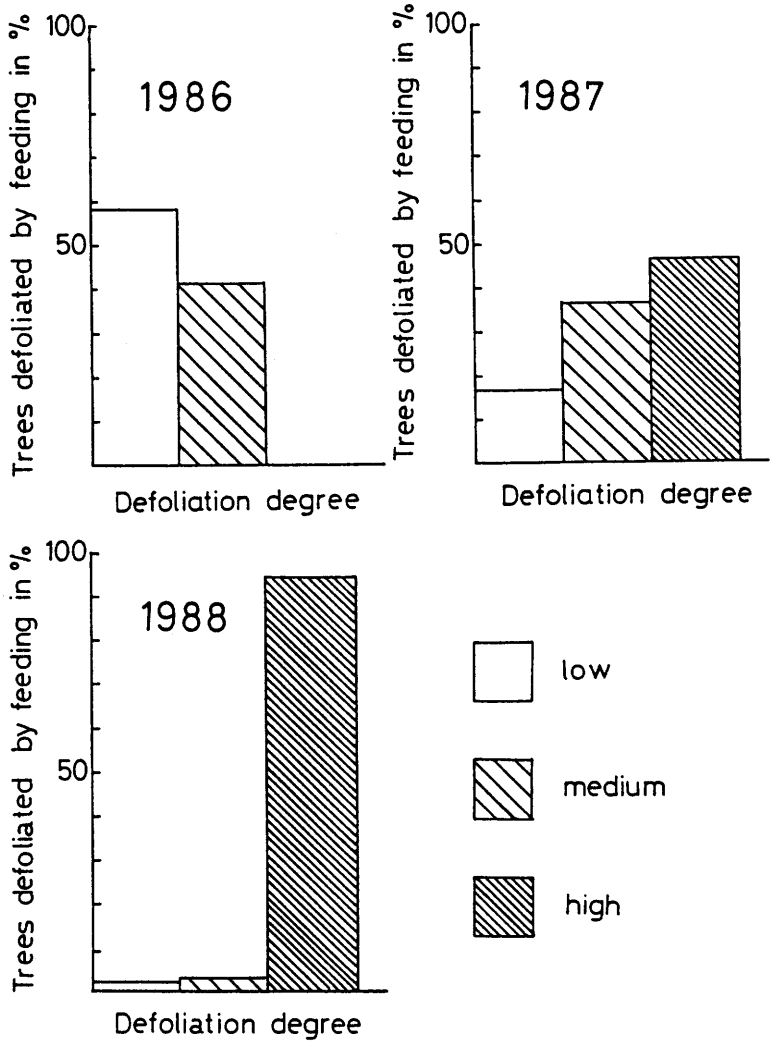

Figure 1. Increasing defoliation by *Zeiraphera rufimitrana* in the forest district of Staufen.

Table 2. Condition of the eggs.

Forest district	Number of eggs	Ratio (%)		
		Healthy	Paras.	Empty
Staufen	4085	29.8	8.4	61.4
St. Blasien	3514	42.7	10.9	46.4

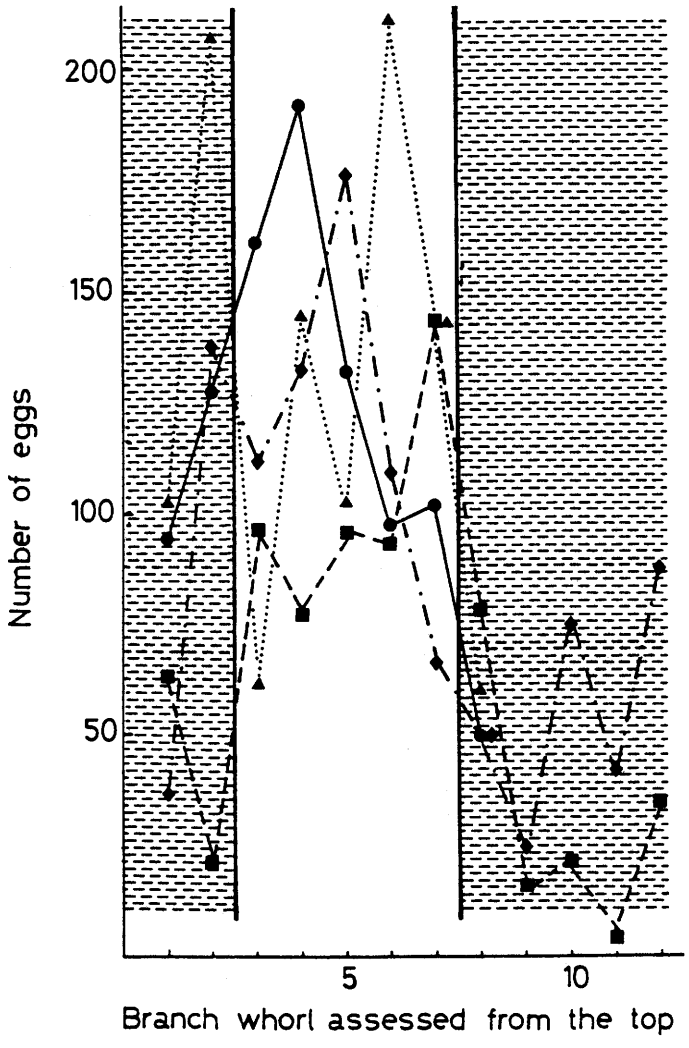

Figure 2. Distribution of the egg density (eggs/shoot) of *Zeiraphera rufimitrana* within the crown of four individual silver fir trees (whorl 1 was uppermost).

Table 3. Density of the descending larvae.

Forest district	Number of funnel traps	Larvae/m^2
Staufen	45	15
St. Blasien	9	110

Although egg density did not differ much in the two study areas, the number of descending larvae per m^2 sampled at Staufen was only 14 percent of the amount sampled at St. Blasien (Table 3).

Although parasitoids have been found to be important factors in the mortality of the larvae, they are not responsible for the different population declines. At least two hymenopterous species produced notable degrees of parasitization, reaching almost 60 percent (Table 4), but they have yet not been identified. Species 1 is a parasitoid originating from former larval instars. It leaves the host during or prior to the fourth instar to spin a cocoon in the crown. Species 2 to 4 were found relatively seldom. Species 5--an ectoparasite of late larvae--had a degree of parasitization of up to 50 percent. Parasitoids of pupae were also found.

Table 4. Parasitization of the larvae (estimated by dissection).

Forest district	Sampling date	Larval instar (%)					Total paras. (%)	Frequency per species in % of the total parasitization				
		L1	L2	L3	L4	L5		1	2	3	4	5
Staufen	08/05/89	77	9	12	2	0	32	100	0	0	0	0
	24/05/89	0	0	13	74	13	43	92	0	0	8	0
	08/06/89	0	0	1	8	91	59	16	0	0	0	84
St. Blasien	19/05/89	3	19	29	47	2	39	95	2	3	0	0
	29/05/89	0	0	17	61	22	40	93	0	7	0	0
	20/06/89	0	0	0	3	97	43	5	0	3	0	92

DISCUSSION

As with *C. murinana*, the regional distribution of *Z. rufimitrana* corresponds with the distribution of its host *Abies alba*. Since 1945 five outbreaks have been documented, occurring both within and outside the natural habitat of the silver fir (Fig. 3). These outbreaks have a noticeably broad elevational range, from sea level to 1400 m, and occupy an area extending from northern Germany to northern Italy, a fact which indicates that outbreaks of *Z. rufimitrana* are not site specific. That is further verified by the current outbreak in southwest Germany, where numerous isolated populations have been discovered, occurring in different growth zones each in turn possessing a broad range of site conditions (Fig. 4). The type of stand management applied, furthermore, had no influence on the outbreaks, which were detected both in even-aged monocultures and in mixed forests. Outbreaks can usually be found on mature and overmature trees. Defoliation occurs exclusively on the sun-exposed portions of the tree crowns. Because of its obvious attraction to warmth, we can assume that climatic conditions are a factor in outbreaks of *Z. rufimitrana*. Tests are currently being conducted to determine whether a positive correlation exists between extraordinary weather conditions and outbreaks of *Z. rufimitrana*.

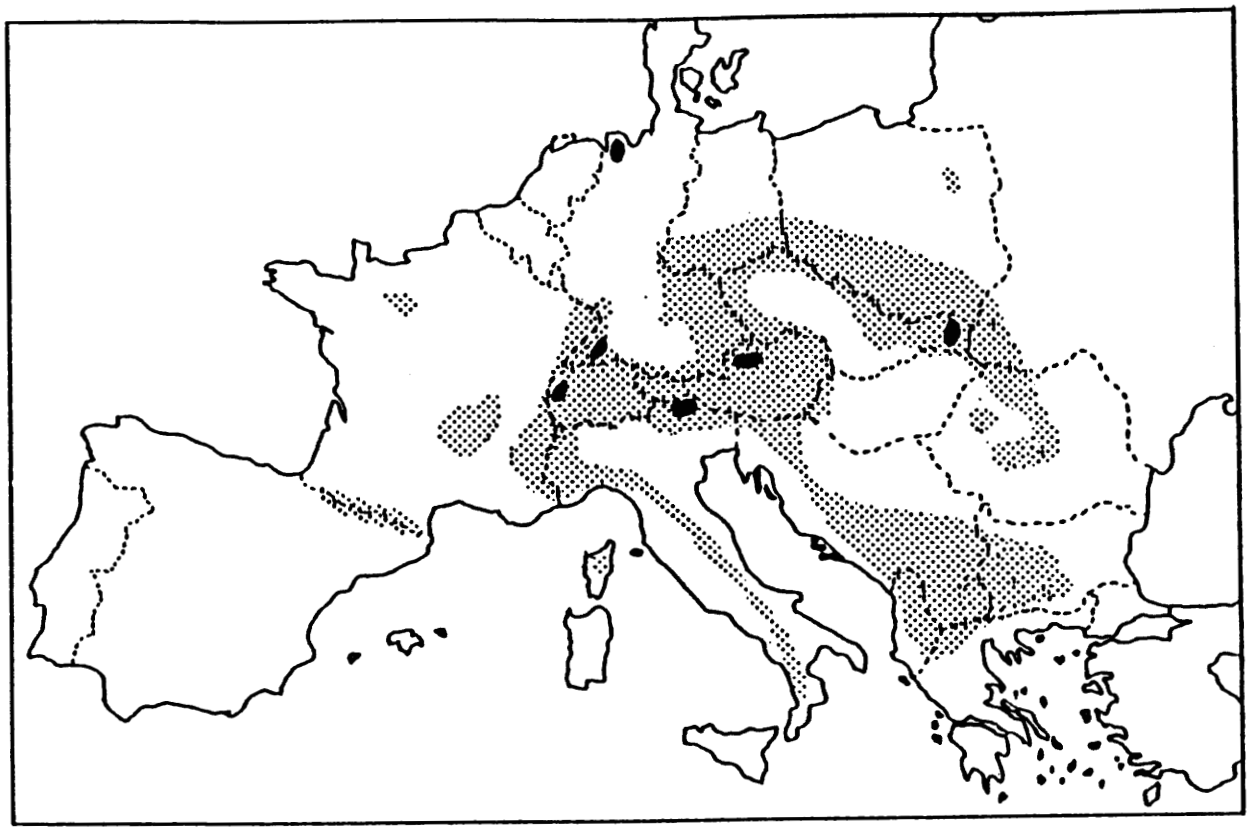

Figure 3. Natural habitat of *Abies alba* (dotted area) and zones of outbreaks of *Zeiraphera rufimitrana* since 1945 (shaded black).

The outbreak of *Z. rufimitrana* in the forest district of Staufen began in 1986, and a noticeable decline in the damage was observed in 1989. That means that the culmination of the defoliation in 1987 and 1988 was followed by a collapse of the population in the fourth year of the outbreak. A clear population decline has been shown in the differences between the densities of the eggs and the larvae. Effective parasitism is one reason for this decline. Other factors may be the lack of synchrony of the larval hatching and the budding of silver fir, or the influence of predators, especially on the stages descending to or living on or in the ground. Future studies should concentrate on these factors about which we know little as yet.

Another question to be studied arises from the empty eggs found in winter. Had the larvae already hatched in summer or fall, or had they been emptied by a predator? The fate of eggs prior to the winter is currently being researched.

SUMMARY

The first observed outbreak of *Zeiraphera rufimitrana* was recorded within the natural habitat of the silver fir in southwest Germany in 1986. The larvae feed exclusively on needles of May shoots. By assessing needle loss from preceding shoot orders, it is possible to reconstruct the course of the outbreak. The peak of the outbreak was observed in two districts within the Black Forest in 1988. Although egg counts reached 12.3 and 7.4 eggs per shoot respectively in the two districts, only 15 and

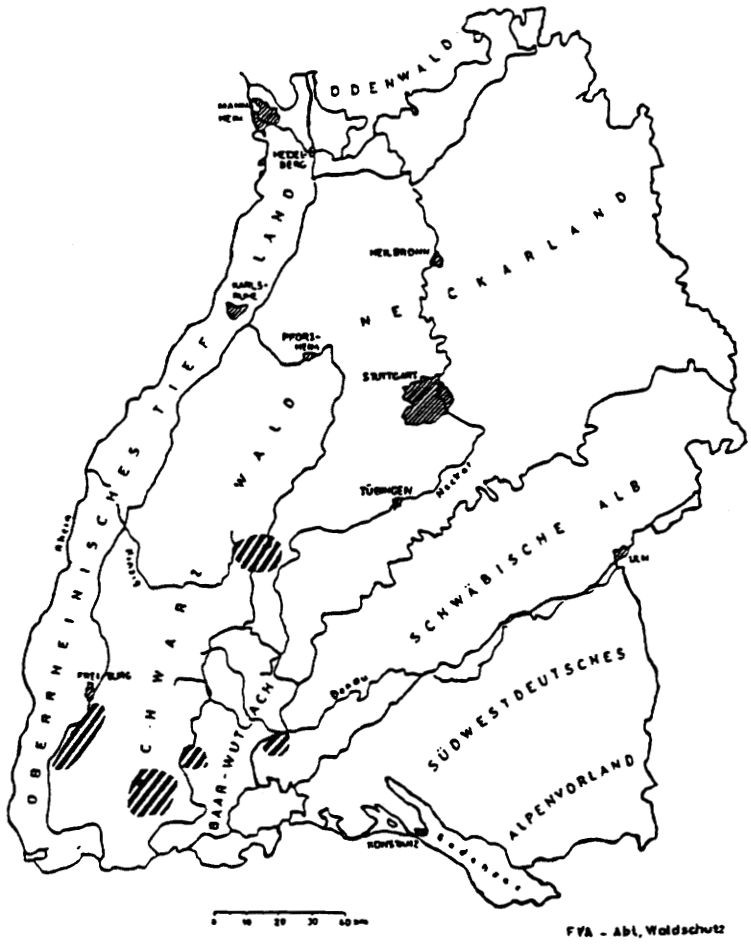

Figure 4. Growth zones of Baden-Württemberg and a real distribution of *Zeiraphera rufimitrana* outbreaks (hatched area) since 1987.

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110 larvae per m^2, respectively, reached the pupal stage. Parasitoids accounted for a substantial portion of the decrease in population density, with a mortality rate of 8 to 11 percent of the eggs and 43 to 59 percent of the larvae parasitized. Additional factors relating to mortality are discussed.

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