Outbreaks of *Dendrolimus superans* (BUTLER) (Lepidoptera: Lasiocampidae) Related to Weather in Hokkaido¹

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Dendrolimus superans (BUTLER) occasionally causes serious damage to coniferous forests in Siberia, Sakhalin, the Kuriles, Hokkaido and Honshu. Four major outbreaks have been recorded in Hokkaido, all in the Kitami district, since 1942 (KAMIJO, 1977).

Many authors have demonstrated relationships between weather and outbreaks of defoliating forest insects. Some examples include *Hyphantria cunea* DRURY (MORRIS, 1964), *Malacosoma disstria* HÜBNER (IVES, 1973), and *Choristoneura occidentalis* FREEMAN (THOMSON et al., 1984). TABATA (1924) also showed that an outbreak of *D. superans* occurred after consecutive warm summers in Sakhalin. In this paper, weather conditions of the past 61 years were analyzed to elucidate weather factors related to the outbreaks of *D. superans* in Hokkaido.

In Hokkaido *D. superans* needs more than 1 year to complete a generation, spending 1 or 2 winters in the larval stage (FUKUYAMA, 1981). The average number of eggs in the ovary of a female is approximately 200 (INOUE and SHINOHARA, 1953). Density of overwintering larvae during an outbreak was over 1,000 per tree (FUKUYAMA, 1981), whereas the density level of innocuous populations ranges from 0.1 to 50 larvae per tree (unpublished). It thus appears that consecutive favorable years are necessary for the initiation of *D. superans* outbreaks.

METHODS

Larvae feed on leaves from May to October, and adults appear and eggs hatch from June to August. Monthly means of air temperature (monthly means of daily maxima and minima) from May to October

and monthly precipitation from June to August observed at the Tsubetsu climatological station, situated in the middle of the Kitami district, were therefore analyzed. Unavailable data (for the 17 years before 1950) and missed observations were estimated by using linear regression on data obtained at the Abashiri station, about 40 km east of the Tsubetsu station. The coefficient of determination (r^2) ranged from 0.65 to 0.86 except for the temperatures of May ($r^2=0.54$) and September (0.53) and the precipitation of July (0.40).

Normals, and standard deviations of weather factors, were calculated for the 61 years since 1929 (Table 1). For the 4 years preceding the 4 major outbreaks in 1941, 1952, 1962 and 1976 (KAMIJO, 1977), mean deviates from the normals were divided by the standard deviations to obtain mean standard deviates. If the absolute values of a weather factor were constantly large before outbreaks, the factor was considered to be related to the events.

RESULTS AND DISCUSSION

Figure 1 indicates that late summer temperatures were generally higher during the several years preceding the outbreaks than during the normals. Mean temperatures of August and September in the 3 years preceding the outbreaks were 21.7°C ($SD=1.3$, $n=12$) and 16.4°C ($SD=1.3$, $n=12$), respectively; they were both significantly different from the normals ($p<0.05$). Accordingly, the 3-year running averages of mean temperature of August and September were plotted over the 3rd

Table 1. Normals of the weather factors
at Tsubetsu, Hokkaido, 1929–1989
($n=61$)

Weather factor	Mean±SD
Mean temperature (°C)	
May	10.8±1.3
June	15.0±1.5
July	19.4±2.3
August	20.3±1.6
September	15.5±1.3
October	8.7±1.0
Precipitation (mm)	
June	64.3±33.1
July	75.8±34.1
August	99.9±44.7

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year (Fig. 2). All the recorded outbreaks occurred within or just after the periods of warm summers, when the 3-year average temperatures of August and September were about 1°C higher than the normal. It is apparent that outbreaks of *D. superans* follow years with warm, late summers. According to TABATA (1924), a 1919 outbreak in Sakhalin was also preceded by consecutive warm summers.

The nuclear polyhedrosis virus (NPV) played an

Fig. 1. Mean standard deviates (mean deviates from the normals/ SD , $n=4$) for the 4 years preceding the 4 major outbreaks in the Kitami district. T—Monthly mean temperature. P—Monthly precipitation.

important role in the collapse of the outbreak population in 1976 (HIGASHIURA, 1977). It can be speculated that the vigor of populations is reduced for several generations after the beginning of the population decline by prolonged activity of viral polyhedrosis in the environment (MYERS, 1988). The prolonged effects of the disease might have suppressed outbreaks in the warm period of the middle 1940's.

Figure 1 suggests also that heavy precipitation in June and July may be related to the outbreaks, but the precipitation means in June and July in the preceding 2 years, 78.0 mm ($SD=24.1$, $n=8$) and 98.5 mm ($SD=41.0$, $n=8$), respectively, were not significantly different from the normals ($p>0.05$). Detailed studies are required to confirm the suggested relationship.

From August to September, young hatched larvae feed on leaves. YAMAGUCHI (1977) reported that percent mortality of young larvae before overwintering was about 3 times higher at 10°C than at 15 and 20°C. It seems that high temperature in late summer moderates the mortality of young larvae. In the case of a congeneric species, *D. spectabilis* (BUTLER), the mortality during the early larval stage has a great influence upon population changes, and is mainly attributable to climatic conditions (KANAMITSU, 1962; KOKUBO, 1965, 1975). KOKUBO (1975) also suspected that rainfall is a main mortality factor in the early larval stage. Further studies are necessary to explain the effects of weather on the early larval mortality of *Dendrolimus* species.

Fig. 2. Three-year running averages plotted over the 3rd year showing mean temperature of August and September at Tsubetsu, 1929–1989. Transverse line indicates the mean temperature ($=17.9^{\circ}\text{C}$). Arrows indicate the outbreaks recorded in 1941, 1952, 1962 and 1976, in the Kitami district.

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