Bekämpfungsmaßnahmen. Erfolgreich eingesetzt wurden vor allem Pyrethroide verschiedener Herkunft. Die Ausbringung erfolgte überwiegend mit Luftfahrzeugen. Auf dem Höhepunkt der Kalamität 1982 waren 159 Flugzeuge und 23 Hubschrauber im Einsatz.

Schließlich werden einige Beobachtungen über die Erholung geschädigter Bestände mitgeteilt. Totalverluste — vor allem an Fichte — beschränkten sich auf den erstaunlich geringen Anteil von rd. 0,5 % der Gesamtschadfläche.

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Outbreaks of Nun Moth (*Lymantria monacha* L.) in Denmark with remarks on their control

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With 5 figures and 2 tables

Abstract

Outbreaks of the Nun Moth (*Lymantria monacha* L.) are known from 11 Danish localities. Three started in 1971—72, and 5 in the period 1979—81. Several insecticides were used controlling the outbreaks. Very efficient was endosulfan — and immediate — but it inflicted some bird losses. Very efficient was also difluron, but its slow action could not be accepted at the higher population levels. Less efficient was trichlorfon and *Bacillus thuringiensis* (Dipel). The latter failed completely in one year presumably due to a temperature fall.

Prognosis and especially the need for a two-year prognosis are discussed.

1 Introduction

The localization of all known outbreaks of the Nun Moth in Denmark is shown on fig. 1. Some of them were only small. The first year of damage was as follows: 1 Bromme 1848, 2 Lystrup 1856, 3 Sonnerup 1902, 4—5—6 Ellet, Silkeborg, Grindsted 1971—72 and 7—11 Gludsted-Hjöllund, Nörlund, Læsö, Söbjerg and Bordrup 1979—81. Table 1 gives an impression of the areas involved in the period 1971—1982.

Mainly Norway Spruce (*Picea abies* [L.] Karst.) was implicated, but also several other conifers, e. g. Sitka Spruce (*P. sitchensis* [Bong.] Carr.), Scots Pine (*Pinus silvestris* L.) and Lodgepole Pine (*P. concorta* Loud.). It should be noted here that the three localities which were latest in the 1979—81 series concerned Pine stands — with a possibly slower *Lymantria* expansion. All Danish outbreaks took place on rather meagre soils, which were also sensitive to drought. The conifer plantations on such soils are generally rather uniform but outbreaks did, however, also occur in small isolated forests with very mixed stands, which in no way corresponded to the "concept of monocultures" often applied to the *Lymantria* outbreaks.

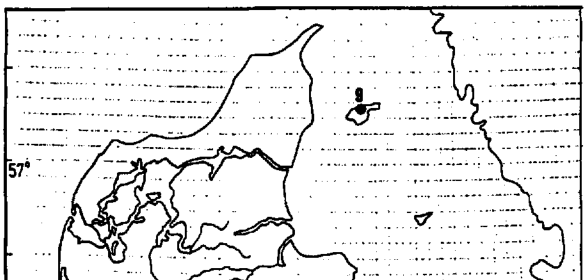

Fig. 1. Localities with Nun Moth outbreaks in Denmark. The signatures refer to initiation in the periods: ■ before 1903; ⋆ 1971—1972; ● 1979—81

The relation of the Danish outbreaks to climate is rather clear, but has been reported elsewhere (BEJER, 1984).

Table 1. Recent outbreaks of *Lymantria monacha* in Denmark

	Approximate areas (ha) threatened from severe defoliation	Controlled ha
1971	20	0
1972	100	30
1973	310	300
1974	180	170
1979	380	320
1980	1060	1060
1981	120	80
1982	210	210

In this paper mainly the practical aspects of control will be discussed. Some of the control operations in the period 1971—74 were planned and evaluated in Nordic cooperation especially with Dr. H. EIDMANN, Sweden, which is gladly acknowledged. Some data from the 1971—74 period have partly been reported earlier (BEJER-PETERSEN, 1974) and, especially concerning biological control, by ZETHNER (1976).

2 General prognosis

While at some places the first Nun Moth defoliation was a surprise, it was followed up in the following years of the outbreak by a one-year-prognosis for extent and severeness. This was made by counting moth females on the stems. About one stem per 2.5—3.0 ha was chosen arbitrarily. A critical limit of 12 females per tree below 3 m height was used. The figure was accumulated by summation of countings every third day during the flight period like WELLENSTEIN (1942). In several cases the forest districts involved wanted a critical level somewhat lower than 12, e.g. 8, used. As a possible short term correction of the one-year-prognosis eggmasses were in the spring incubated to ensure the level of hatching. This was mostly 90—95 % and only occasionally down to 60 %.

3 Control measures and their effect

Control operations were in the period 1971—82 carried out with different insecticides, a *Bacillus thuringiensis* preparation (Dipel) and virus, always from helicopter, and on spruce as soon after the bursting of the new foliage as possible. The new shoots did, however, need to have some size "to carry" the insecticide and thus protect them.

The effect of the control operations was followed by countings of dead larvae on sheets and of dead larvae and frass droppings on glued plates. Especially the frass countings proved useful as even a large effect judged from counting of dead larvae might prove too small because very high numbers of larvae might still be present in the crowns. Examples of treatment and their effect are given in figs. 2—5 and in tables 1 and 2. When in table 2 a control efficiency has been given without a question mark it is based on frass dropping counts. With a question mark it is a rough estimate.

The frass dropping counts did in some cases reveal the necessity of respraying immediately (after a few days). Larval numbers in such spruce crowns came up to 20—30,000 per 80 years old tree on meagre soil. The number of needles in this crown would normally be about 2—4 million (MØLLER, 1945). But after the drought years in the mid-1970'es and after some preceding defoliation the number was estimated to only about 0.5—1 million. This might again correspond to food for only 500—1,000 Nun Moth larvae (SCHWERDTFEGER, 1970) and very little defoliation could then be tolerated even if the new foliage was protected.

At the highest larval populations and on the weakest trees therefore a very high and absolutely immediate effect of the sprayings was necessary to save the trees. In other situations lower efficiency or slower action was acceptable. This again might mean that less toxic insecticides could be used here.

Table 2 and figures 2—5 show the effect of the different control agents. Endosulfan and difluron reached high degrees of effect, but quickly and slowly respectively. They could be applied together. Trichlorfon and *Bacillus thuringiensis* reached lower levels and the latter failed completely in one year (fig. 3). This was probably due to a cold spell after the application.

It is seen that a very effective control (and immediate) can be reached with endosulfan. In fact no stands were lost after treatment with endosulfan, while some 30—40 ha were lost with inefficient insecticides (e.g. lindane). Another about 80 ha were lost because of too late recognition of the outbreak.

Table 2. Countermeasures against *Lymantria monacha* and their effect

Measure used	Year	Dosage a.i. g/ha	Spray l/ha	% Effect	Comments
fenitrothion	1972	1000	45	65–75?	
lindane	1972	500	45	< 50?	Larger larvae
lindane	1979	400	100	<50?	
endosulfane	1973	700	80	80	Tit nestling mortality
endosulfane	1973	700	80	60	Larger larvae
endosulfane	1974	700	80	90	Tit nestling mortality
endosulfane	1974	700	160	96	Mortality in adult chaffinches
endosulfane	1979–81	700	150	93–97	Tit nestling mortality
trichlorfon	1974	1250	80	77	
Difluron (Dimilin)	1979–80	66–99	100–150	→ 100?	slow acting
Bac. thuringiensis (Dipel)	1973	35	80	76	(Pine)
Bac. thuringiensis (Dipel)	1974	35	80	0?	colder (?)
Virus	1973, 74	10^7 pol./ml	80	?	effect mainly next year, evaluation difficult

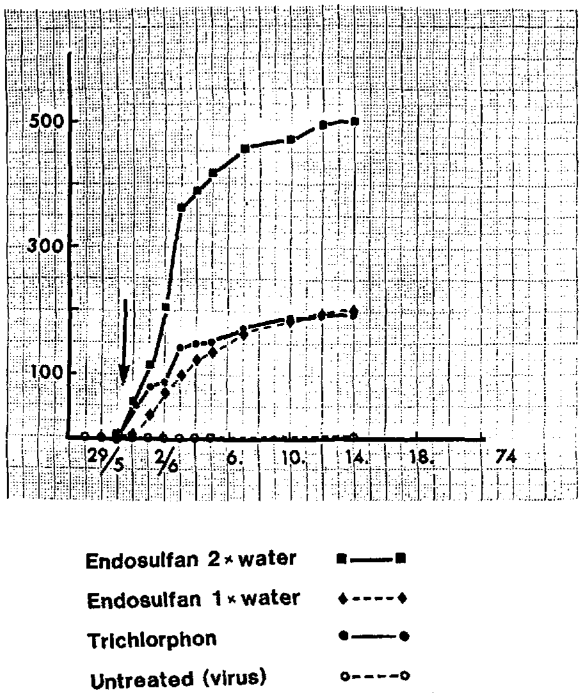

Fig. 2. Larval mortality, Grindsted 1974, accumulated per square metre. The arrow indicates time of spraying. Mortality on the *Bacillus thuringiensis* (Dipel) plot is not shown but the total was less than 10 larvae. Water: 1 × = 80 l/ha, 2 × = 160 l/ha. See also Fig. 3

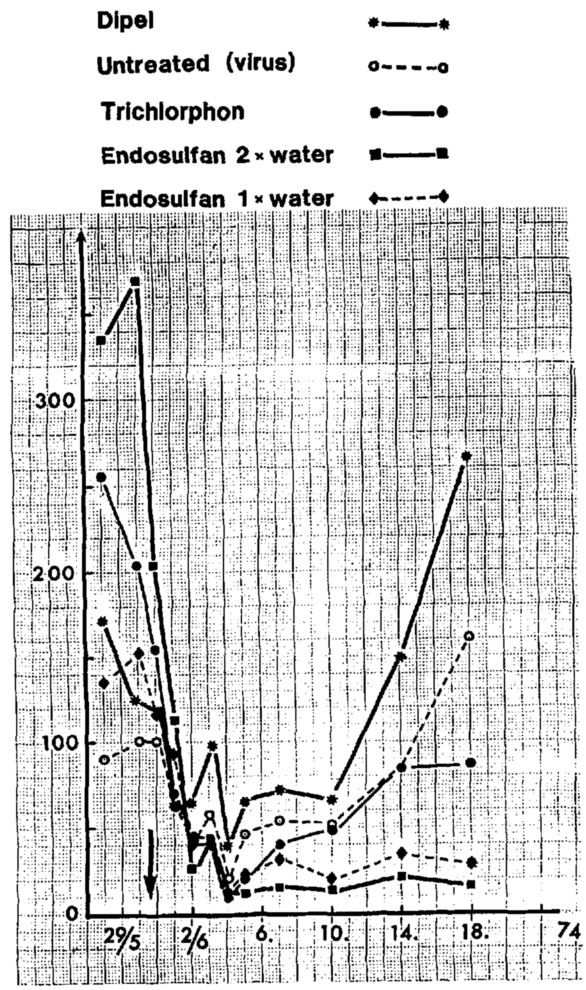

Fig. 3. Frass droppings, Grindsted 1974, daily fall per square metre and per hour. The figure corresponds to Fig. 2. The depression from June 2nd till June 10th was due to maximum temperatures of only 12—15 °C, before and after they were 15—17 °C and 21—24 °C respectively

Protected by the sprayings were appr. 1,500 ha, some of this area 2 to 3 times.

Endosulfan in the standard dosis, however, inflicted strong tit *(Parus sp.)* nestling losses and in one occasion (1974) the high water dosis combined probably with some overlapping of spray killed several chaffinches (*Fringilla coelebs* L.) on the two first days after spraying. These birds were mainly near roads where it was easy to pick up killed Nun Moth larvae. Bird song continued, though, unchanged in most other endosulfan areas. Endosulfan is therefore a remedy only appropriate in the most severe situations. In these it was accepted even by "green groups" because it did not accumulate and because it secured the existence of the old stands of forest. At a potential future outbreak of the Nun Moth endosulfan would probably be sought replaced by a synthetic pyrethroid. There was no bird mortality with the treatments including difluron, *Bac. thuringiensis* and virus. Other insecticides have been investigated earlier as to nestling losses, which were most often negligible (BEJER-PETERSEN et al., 1972).

4 Comments on control strategy

The intention of the Danish control operations was to protect those forest stands which were clearly threatened in the particular year and only those. They did not include surrounding areas with lower Moth populations. This was a reasonable strategy with the insecticides available in the early 1970'es and also in the last end of the gradations when the outbreaks were losing momentum. But it was a drawback that some defoliation would invariably take place both in- and outside the sprayed areas. These stands were therefore year by year less vigorous and might again next year need an "emergency insecticide". An insecticide like difluron makes it tempting to try a preventive control because it is relatively harmless to higher fauna, because it is effective and because it is so slow-acting that it is best used on smaller, not yet dangerous larval populations, which would develop above the critical level next year. Similar considerations would by the way apply to virus — if it was available.

Difluron did — taking its time — indeed clean up the treated areas very thoroughly. Such a preventive procedure would allow the major areas to be treated with milder countermeasures. On the contrary the restrictive area spraying, which was actually followed, might instead rather lead to larger areas becoming treated with strong insecticides, because outer zone trees always lost some foliage in the first phase of the outbreak period. It was therefore in later years, if the outbreak expanded,

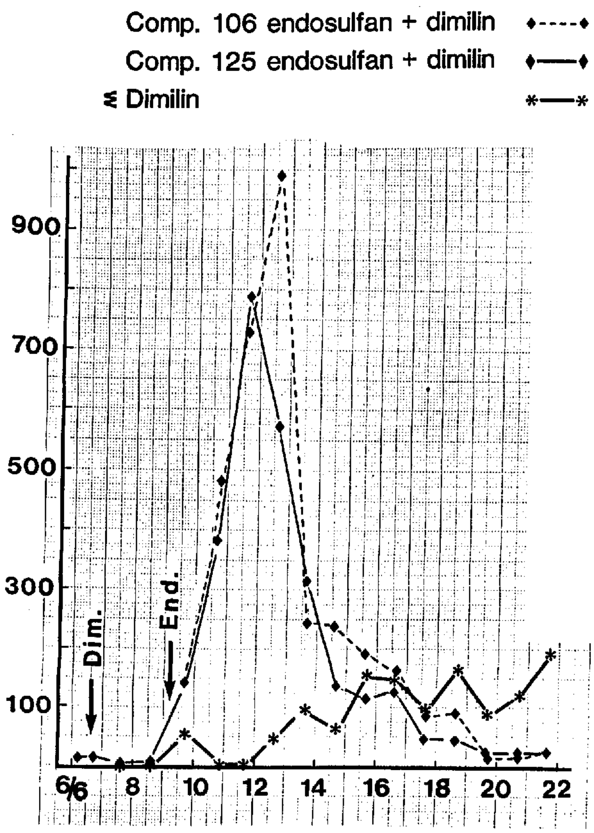

Fig. 4. Larval mortality in different treatments and compartments of Gludsted, 1979, daily fall per square metre. Arrows indicate time of spraying. Σ = total for five plots sprayed solely with difluron (Dimilin). The fall of dead larvae on unsprayed plots was negligible and not shown.

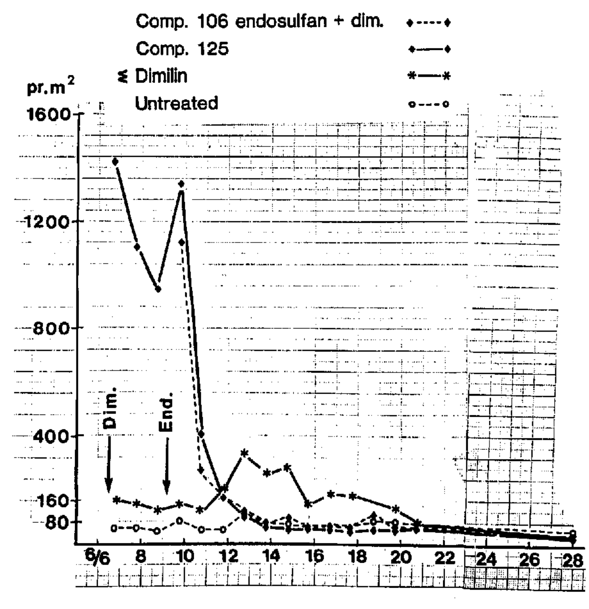

Fig. 5. Frass droppings in different treatments and compartments, Gludsted 1979, daily fall per square metre and per hour. The figure corresponds to Fig. 3. Untreated represents a low population level with no control necessary. See also Fig. 4

necessary to stop the defoliation immediately (with endosulfan).

The relevance of these considerations would, however, strongly depend upon a reliable 2-year-prognosis for the expansion trend. Maybe pheromone traps alongside with some index (e. g. larval or pupal weight or the size of trapped males) might help to provide such information.

Pilot experiments on a pheromone prognosis are at the time being carried out in Denmark, they are coordinated with a similar German work by Dr. H. BOGENSCHÜTZ, and initiated for Denmark by T. SECHER JENSEN who also worked on the disruption method.

Zusammenfassung

Massenvermehrungen der Nonne (*Lymantria monacha* L.) in Dänemark und ihre Bekämpfung

Massenvermehrungen der Nonne (*Lymantria monacha* L.) sind in Dänemark von insgesamt 11 Lokalitäten bekannt, drei davon im Zeitraum 1971/72 und fünf 1979/81. Zur Bekämpfung wurden verschiedene Insektizide eingesetzt. Gut und schnell wirksam war Endosulfan, verursachte allerdings einige Verluste an Vögeln. Sehr wirksam war auch Dimilin, seine langsame Wirkung konnte allerdings bei den hohen Populationsdichten der Nonne nicht akzeptiert werden. Weniger wirksam war Trichlorfon und *Bac. thuringiensis* (Dipel). Dipel erwies sich in einem Jahr als völlig unwirksam, vermutlich infolge eines Temperatursturzes. Die Bedeutung der Prognose und vor allem die Notwendigkeit einer Voraussage der Dichteentwicklung über zwei Jahre werden diskutiert.

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