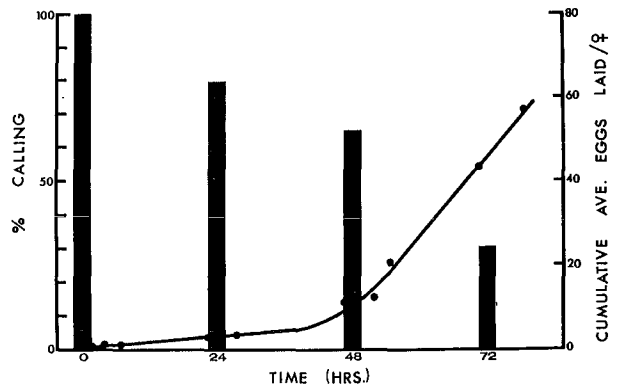

Figure 1. Comparison of calling behavior and egg deposition of 23 virgin *O. leucostigma* females over a 3 1/2-day period. Vertical bars represent female calling and continuous line represents oviposition.

usually ovipositing and only rarely were behaviorally inactive. This relationship between calling and oviposition is not surprising because in moths these behaviors are mutually exclusive although some pheromone may be released during oviposition (Grant, 1975).

Figure 1 also demonstrates that by the time females are more than 2 days old they have deposited a considerable number of unfertilized eggs. As a consequence these females are noticeably smaller than newly emerged females. Undoubtedly this accounts for the smaller masses of fertilized eggs laid by older females.

Thus the consequences of aging for whitemarked tussock moth females are reduced fecundity because of spewing and a decreased frequency of calling behavior which ultimately reduces the chances of mating. Concomitantly, pheromone production declines further decreasing the attractiveness of females. Clearly it is advantageous for whitemarked females to mate as soon as possible after eclosion. In field populations, the emergence of males before females may be one mechanism to ensure such early mating, but other mechanisms, perhaps related to pheromones and mating behavior, should also be looked for.—G. G. Grant and L. McCarty, Insect Pathology Research Institute, Sault Ste. Marie, Ont.

Weather and Outbreaks of the Eastern Hemlock Looper in Newfoundland.—The eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), is a native pest of the coniferous forests of eastern North America, and periodic outbreaks, at 5-7-year intervals, have been reported from Newfoundland Island since 1912. The outbreaks usually lasted from 4 to 6 years but individual infestations collapsed in about 2 years (Otvos *et al.*, Inf. Rep. N-X-68, 1971).

Weather is generally believed to be a major factor affecting fluctuations of insect populations. This paper examines the population changes of the eastern hemlock looper in Newfoundland in relation to temperature and precipitation during the period of 1947-1971 with the utlimate goal of using this relationship to facilitate forecasting the course of future outbreaks.

Information on looper population levels on balsam fir, *Abies balsamea* (L.) Mill., black spruce, *Picea mariana* (Mill.) B. S. P. and white spruce, *P. glauca* (Moench) Voss, was obtained from Island wide surveys conducted annually by the Forest Insect and Disease Survey. The average number of larvae per tree was calculated for the Island and plotted for each year from 1951 to 1971. Earlier records on insect numbers were incomplete and were not included in the analysis.

Temperature and precipitation data during the larval and pupal stages of the looper (May-August) recorded at three weather stations across the Island (St. John's, Gander and Stephenville) were obtained from the Monthly Record (Atmospheric Environment Service, Environment Canada). The average difference from the 30-year (1941-1970) normal for temperature and precipitation during May to August was computed and plotted for each year.

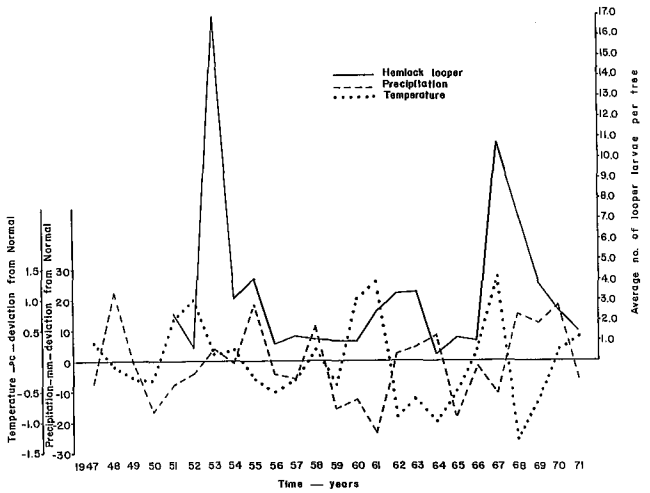

Figure 1. Average number of hemlock looper larvae per tree and deviations of temperature and precipitation from their 30-year normals (1941-1970).

Three peaks in looper numbers shown in Figure 1 represent the outbreaks during the period of 1951 to 1971: the first from 1947 to 1954 (Carroll, Can. Ent. 88:587-599, 1956) and the second and third from 1959 to 1963 and from 1966 to 1971, respectively (Otvos *et al.*, Inf. Rep. N-X-68, 1971). The increase in looper numbers to epidemic levels was preceded by about 2 years of warmer than normal temperatures for two of the three outbreaks and above-normal temperatures occurred for 2 years during the third outbreak. Precipitation generally was less than normal during the three outbreaks. Similarly a number of spruce budworm epidemics in different parts of Canada were preceded by a period of 3 to 4 years of warm, dry weather (Wellington *et al.*, Can. J. Res. (D) 28: 308-111, 1950; Ives, Inf. Rep. NOR-X-118, 1974; and Pilon and Blais, Can. Ent. 93: 118-123, 1961). Thomson (Bi-mon. Progr. Rep. 8(3):3, 1952) working on the western hemlock looper in British Columbia reported that weather was usually extremely dry in September (when mating of this insect occurs in B.C.) for 3 years prior to a major increase in adult numbers.

In Newfoundland, the decline of the eastern hemlock looper numbers was generally preceded by a period of lower than normal temperatures. Precipitation usually was above the normal during the decreasing phase of the outbreaks. Silver (Can. Ent. 95:58-61, 1963) reported that epidemic blackheaded budworm populations decreased or collapsed during or following periods of above average precipitation.

The results of this preliminary investigation suggest that deviation of temperature and precipitation from the normal was correlated with fluctuations of looper population levels. These and possibly other weather parameters affect looper populations, in part directly, by influencing larval development and in part indirectly, through their affect on biotic control factors such as parasites and diseases. A more detailed analysis of the patterns between weather and looper population levels will be conducted to develop a system for forecasting the development and decline of hemlock looper outbreaks.—Imre S. Otvos, Newfoundland Forest Research Centre, St. John's, Nfld.

Mortality of Overwintering Eggs of the Eastern Hemlock Looper in Newfoundland.—The eastern hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.) is an important pest of balsam fir, *Abies balsamea* (L.) Mill., forests. The eggs of the looper are about 1 mm in length and are laid from late August to October, usually singly or in groups of two or three on a variety of substrates including bark and lichens on trees and moss on the forest floor (Otvos, Clark and Clarke, Nfld. For. Res. Centre, Inf. Rep. N-X-68, 1971). The insect overwinters in the egg stage and hatches in June of the following year (Carroll, Can. Ent. 88: 587-599, 1956). This note presents data on the mortality of overwintering looper eggs in four generations.

One square foot (929 cm²) of birch bark (*Betula* spp.) and sphagnum moss (*Sphagnum* spp.) or samples of the lichen, old man's beard (*Usnea* sp.) were collected twice in looper infested stands near Robinson's River in western Newfoundland and at Salmonier River and Bellevue Beach in eastern Newfoundland. The first collection was made between late October and mid-November after egg laying was completed and the second collection during the following spring before larval hatching had begun. The samples collected in the fall were stored for about two months at 90% R. H. and 2°C to break diapause and those collected in the spring were processed without storage.

The eggs were extracted by soaking the samples in 2% aqueous bleach solution which releases the looper eggs without affecting hatching of the larvae or the emergence of egg parasites (Otvos and Bryant, Can. Ent. 104: 1511-1514, 1972). The extracted eggs were classed as fertile or sterile (Otvos and Bryant, 1972) and the fertile eggs were reared in petri dishes (85 mm x 10 mm); 25 eggs/dish, at 21 ± 20.0°C and 70% R. H., under 12-hour light regime. The emergence of looper larvae and adult parasites was recorded daily until both larval and parasite emergence was completed. Hatching and parasitism were calculated as percentages based on the number of fertile eggs. The difference in hatching between the fall and spring samples collected at the same location was considered to be due to mortality of overwintering eggs. The total monthly precipitation and the mean monthly temperature during the winter (from October to May) and their deviations from the 30-year average (1941-1970) were analysed to determine if these parameters were related to mortality of overwintering eggs. Precipitation and temperature data were obtained from Monthly Records (Atmospheric Env. Serv., Environ. Can.) for two stations near the study areas (Colinet and Port aux Basques).

Percent hatch from eggs collected in the fall varied between 66% and 86% in the four generations (Table 1). This range of hatching success agrees closely with the average of 70% based on rearings of 5,000 looper eggs collected at 11 widely separated locations in Newfoundland (Otvos, unpublished data). Less than 5% of the unhatched eggs contained pharate larvae or partly developed embryos, in the remainder the content of the eggs appeared to be desiccated. The highest percentage of hatch occurred at Bellevue where the infestation was the youngest. Infestations at the other locations were older but still in the increasing phase. Proportionately more larvae hatch from eggs at the beginning of an infestation than during the latter stages (Otvos, unpublished data).

Percent hatch from eggs collected in the spring ranged between 10% and 25% in the first three generations (Table 1). The percentage of eggs killed by parasites was about the same for eggs collected in the fall and spring, therefore, parasitism cannot be the cause of the decrease in hatching success.

The difference between the hatching of the eggs collected in the fall and spring (i.e., mortality of overwintering eggs) in the four generations was 45.4%, 58.3%, 65.3% and 1.9%. The difference of 1.9% in the fourth generation is so small that it can be ignored. The sum of the differences of the monthly mean temperatures from their respective normals during the overwintering period of the eggs in the four generations was -9.1°C, -13.5°C, -8.9°C and -2.3°C suggesting that mortality of over-wintering hemlock looper eggs is inversely related to the difference between the mean temperature and the normal. The exceptionally high survival of the eggs at Bellevue is considered to be the result of the relatively early stage of the infestation and the higher winter temperatures at this location.

The average hatchings from the four fall and spring collections, regardless of substrates, were 73.0% and 31.4% respectively (Table 1) showing a 41.6% egg mortality over the winter. Although the lethal low temperature for overwintering looper eggs is not known, it could be assumed that low winter temperature was mainly responsible for the mortality of overwintering eggs. Snow is generally considered as an excellent insulation and it should have provided good protection from

TABLE 1

Percent hatching of hemlock looper larvae and parasitism of eggs collected in the fall and spring in four generations

Sample				No. eggs reared	Percent	
date	location	substrate	size[d]		hatching	parasitism
Fall 72	Salmonier River	B.B.[a]	29	319	66.1	2.5
		Moss[b]	26	77	70.1	1.3
		Total		396	66.9	2.3
Spring 73	Salmonier River	B.B.	30	162	25.9	0
		Moss	20	108	14.8	0
		Total		270	21.5	0
Fall 73	Salmonier River	B.B.	25	57	77.2	1.8
		Moss	20	10	70.0	0
		Total		67	76.1	1.5
Spring 74	Salmonier River	B.B.	30	137	21.9	1.5
		Moss	20	71	9.9	0
		Total		208	17.8	1.0
Fall 74	Robinson's River	B.B.	20	64	75.0	9.4
		Moss	10	11	81.8	9.1
		Total		75	76.0	9.3
Spring 75	Robinsons's River	B.B.	20	48	8.3	12.5
		Moss	10	8	25.0	0
		Total		56	10.7	10.7
Fall 75	Bellevue Beach	O.M.B.	45	152	84.9	0
		Moss	10	7	100.0	0
		Total		159	85.5	0
Spring 76	Bellevue Beach	O.M.B.	48	111	88.3	0
		Moss	10	8	87.5	0
		Total		119	87.4	0
Fall		B.B.		440	68.9	3.4
		B.B. & O.M.B.		592	73.0	2.5
		Moss		105	73.3	1.9
		Total		697	73.0	2.4
Spring		B.B.		347	21.9	2.3
		B.B. & O.M.B.		458	38.0	1.8
		Moss		195	16.4	0
		Total		653	31.4	1.2

[a]B.B. = Birch bark; [b]Moss = Sphagnum moss; [c]O.M.B. = Old man's beard

[d]Sample size are in ft² except for O.M.B., where samples were 'moderately' packed in wire baskets (25 cm x 15 cm x 10 cm) before processing.

temperature extremes for eggs in the sphagnum moss and partial protection for eggs on the trees, yet mortality among the eggs was similar even during the winter of 1974-75 when about 45% of the total winter precipitation (958.90 mm) was snow. The form of precipitation during the winter does not appear to influence the mortality of the overwintering hemlock looper eggs.—Imre S. Otvos, Newfoundland Forest Research Centre, St. John's, Nfld.

PATHOLOGY

Transmission of *Entomophthora egressa* MacLeod and Tyrrell to *Malacosoma disstria* (Hbn.), a Non-host Species.—It is difficult to assess the real effect of supplementing a pathogen present in an insect population at a low level. One approach is to introduce a pathogen to which the host is susceptible but which does not occur naturally on the particular insect under study.

Entomophthora egressa MacLeod and Tyrrell was first isolated in 1972 (Tyrrell and MacLeod, J. Invertebr. Pathol. 19: 354-360, 1972) from the eastern hemlock looper *Lambdina fiscellaria fiscellaria* (Guen.). Other strains of *E. egressa* have since been isolated from several other lepidopterous species. The forest tent caterpillar larvae (*Malacosoma disstria* Hbn.) proved readily susceptible to the fungus by injection of the protoplast state (Tyrrell and MacLeod, 1972), but it has never been observed in natural populations of this insect. Furthermore, the pear shaped conidia of *E. egressa* can be readily distinguished from the oblong to ellipsoidal conidia of the natural *Entomophthora* pathogen of the forest tent caterpillar.

Preliminary tests under greenhouse conditions showed that fourth instar forest tent caterpillar larvae could readily be infected with *E. egressa* via the conidial stage of the fungus. The conidia came from forest tent caterpillar larvae which had been injected with *E. egressa* protoplasts. A small scale field test was therefore set up to determine whether an *E. egressa* infection could be established in a natural population of forest tent caterpillar.

Twelve hundred fourth instar laboratory-reared forest tent caterpillar larvae were injected with protoplasts of *E. egressa* strain 519 on 3-4 June, 1974, and groups of 100 were placed in 1-quart cardboard containers and held in the laboratory until 6 June, when they were transported to a field location near Alban, Ont. One container was fastened to each of 12 separate poplar trees (*Populus tremuloides* Michaux) about 4 ft above the ground and the top was left open to allow the larvae to crawl out of the container. The trees, already partially defoliated, were about 15-20 ft in height and supported a population of forest tent caterpillars visually estimated to be at least 10^4 per tree. The population was sampled on this date (about 15-25 insects per tree) and subsequently at 3-4 day intervals. The sample insects were pooled and reared in the laboratory on poplar foliage for 7 days. Any which died were examined microscopically for the presence of fungus. Injected larvae retained in the laboratory died approximately 4-7 days after injection and mortality was greater than 90%.

Table 1 presents a summary of the results. The dates are those on which the sample was collected; the associated mortality is that recorded over the next 7 days. Observations on 10 June revealed that many of the injected larvae had died withour leaving the cups in which they were placed on the tree. This number could not be estimated due to decomposition of the larvae, but dead, sporulating larvae were observed on the tree trunks in the vicinity of the cups. It is reasonable to assume that most, if not all, artificially-infected insects had died before the sample was taken on 10 June, and certainly by 13 June. As a further check, 50 additional laboratory-infected insects had been placed on a small (4 ft) tree adjacent to the sample trees and enclosed in a wire mesh screen. These insects were recovered on 10 June, and mortality was 100%. The results therefore show that the fungus was successfully transmitted to insects in the natural population. Despite the fact that the fungus on all infected insects in the laboratory-reared samples produced conidia, the disease failed to maintain itself in the field population. However, complete defoliation of the trees occurred about the 13-17 June and the insects entered the wandering phase which precedes pupation.

TABLE 1

Date	Sample size	Total mortality in laboratory rearing	Diagnosis		
			E. egressa	E. spp.	Other
6/6/74[a]	N.R.[b]	0	-	-	-
10/6	187	54	54(28.5%)	0	0
13/6	280	71	70(25.0%)	1(0.4%)	0
17/6	186	4	1(0.5%)	0	3
20/6	265	29	1(0.4%)	6(2.3%)	22
24/6	316	36	0	17(5.4%)	19
27/6	159	38	0	10(6.3%)	28

[a] Date on which laboratory-infected insects were introduced into field populations.
[b] N.R. = not recorded.

Interestingly, the natural pathogen did not appear in the population until this time, although our results show that the insects are susceptible to *Entomophthora* infection prior to this time.

In summary, it was shown that the fungus *E. egressa* can be transmitted from laboratory-infected insect larvae to field populations of another host insect, and with suitable modifications to the experimental procedure may provide an alternative method of studying the dynamics of fungus epizootics.—David Tyrrell, Insect Pathology Institute, Sault Ste. Marie, Ont.

Comparison of Field-propagated Nuclear Polyhedrosis Virus from Douglas-fir Tussock Moth with Laboratory-produced Virus.—The virus used in the trials was a strain of white-marked tussock moth, *Orgyia leucostigma* (J. E. Smith), nuclear polyhedrosis virus (NPV) originally isolated in Nova Scotia. To propagate it in the field, 36 Douglas-fir trees (mean weight 4.5 m) with a population of 30-150 Douglas-fir tussock moth, *Orgyia pseudotsugata* (McD.), larvae per 46 cm branch tip were sprayed in the Kamloops area in British Columbia on June 7th, 1975 using a mist blower. The larvae were mainly in the fourth and fifth instar and 7.6 *l* of aqueous spray containing 10^8 polyhedra/ml were applied.

First deaths due to virus were recorded 10 days after the application. Larvae were harvested by shaking each tree and collecting them on a beating sheet after 14 days. They were removed from the debris, lyophilized and ground to a fine powder. This operation yielded about 7,000 larvae which in turn gave 188 g of powder with 4 billion polyhedra/g. Approximately 20 man-hours were utilized in this field propagation experiment and there was sufficient virus to spray 3 ha at the operationally recommended dosage of 250 billion polyhedra/ha (Stelzer *et. al.*, J. Econ. Entomol., in press).

To compare the efficacy of this field-produced virus with laboratory-produced virus, a sample of the latter, propagated in white-marked tussock moth larve, was supplied by the Insect Pathology Research Institute (IPRI). This lyophilized material contained 10 billion polyhedra/g. Both virus samples were formulated in water to give 25 billion polyhedra per 9.4 *l* and 25% (v/v) molasses was added as an anti-evaporant and UV protectant.

Three 2 ha plots were selected in the Kamloops area, one for each virus treatment and one as a check. Pre-treatment counts were made on first and second instar larvae and are shown in Table 1. The applications were made the following day on June 2nd, 1976 using a Cessna *Agtruck A188* equipped with 22 1810 "Tee Jet" nozzles set at 45° to the airflow. With a boom pressure of 2.8 kg/cm^2 and a swathe width of 30 m the delivery rate was 9.4 *l*/ha. The plots were sprayed twice in order to obtain an application of 125 billion polyhedra/ha at 18.8 *l*/ha which is half the operationally recommended dosage. This was selected to avoid overkill and make the comparison of the two treatments more meaningful.

Larval population density estimates were made 17, 24 and 31 days following the spray and the mortality due to the treatment was calculated by Abbott's formula (Abbott, J. Econ. Entomol. 18: 265-267, 1925). These results are shown in Table 1. Larvae sent to IPRI for virus identification 33 days after the application showed 30% NPV infection from the field-produced virus plot, 30% NPV from the laboratory-