Asian gypsy moth: the risk to New Zealand

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The gypsy moth, *Lymantria dispar* L., is a native of both Asia and Europe. Until recently, it was believed that all gypsy moths on the North American continent originated from Europe. During 1990 and 1991 a new 'strain' of gypsy moth was found in British Columbia and in Oregon and Washington States. This strain exhibits differences in reproduction, dispersal and host range. The European gypsy moth (EGM) has been present in North America for over 100 years, originating, it is believed, from a single introduction. Because of its biology it has been predictable in dispersal pattern. The Asian gypsy moth (AGM), however, exhibits traits which will make its distribution much more difficult to predict. Table 1 compares the two 'strains'.

AGM is found north of 30°N latitude until it reaches the far northern latitudes where taiga begins. In its natural habitat eruptive populations are recorded as occurring every six-seven years (Schaefer *et al.* 1984). It has one generation per year where it is indigenous. Schaefer *et al.* (1984) recorded differences in the phenology of AGM with latitude. Although it remained univoltine (one generation per year) in the lower latitudes the time of egg hatch and adult flight became progressively earlier. This indicates that the AGM has great plasticity in its response to environmental cues. If it entered New Zealand, in the absence of natural enemies and the presence of a mild oceanic climate, it may become multivoltine (several generations per year).

The phenology of the eggs may also be a cause for concern. EGM demonstrate a skewed distribution in egg hatch (Waggoner 1984) but all of the eggs are usually hatched or unviable after the first year. They also require a cold shock before development can be completed. The information on AGM is mainly anecdotal but what we do know is that 25% of the egg mass can hatch during the first year without a cold shock. If the eggs survive to a second year, which is quite possible, then a further 25% of the original egg mass can hatch; after that egg hatch becomes continuous (D. Bridgwater pers. comm. 10/1992, Humble pers. comm. 4/1992). It is obvious from this that the AGM eggs can survive for extended periods of time.

Monitoring AGM can be difficult in areas where EGM is also present. The most effective monitoring technique is pheromone trapping. Gypsy moth sex pheromones only attract males of the species. The males of both 'strains' are identical; no rapid method of differentiating them morphologically has yet been developed. Specimens collected in North America have to be differentiated using mitochondrial DNA (mtDNA) analysis. Since mtDNA is only passed through the female, any males identified using this technique can be guaranteed to belong to one 'strain'. This is an expensive and time-consuming method of analysis. In the US only Cornell University has the skill and equipment to complete mtDNA analysis. Fortunately, in New Zealand, EGM is not present and has not arrived from Europe or North America. This is mainly due to its mode of dispersal which is not as effective as AGM for covering long distances. AGM's preference for lighted areas makes it more likely to 'hitchhike' on modern modes of transport such as planes and ships. In the event of AGM entering New Zealand, by egg masses or young larvae ballooning to shore on silken threads, pheromone trapping without mtDNA analysis would be sufficient for monitoring populations and dispersal, as EGM is not present. All actions would be on the assumption that it is AGM.

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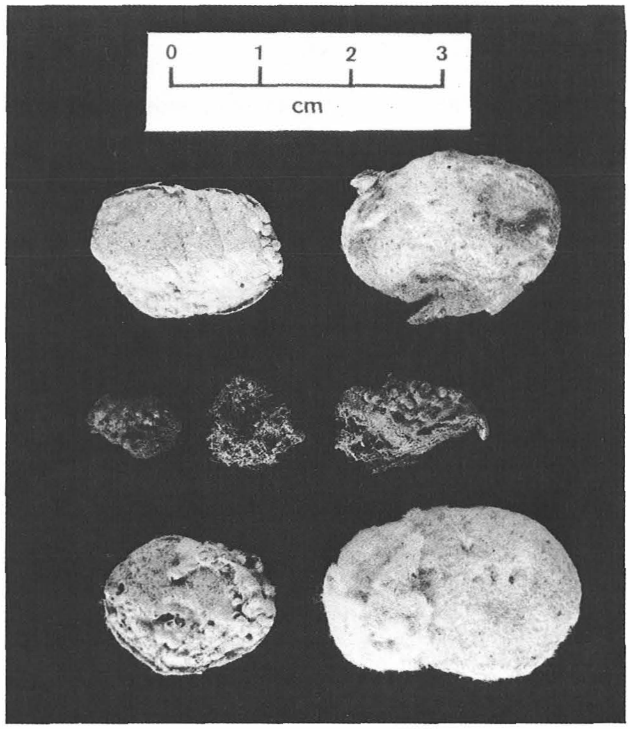

Lymantria dispar (Lymantriidae). **Gypsy moth egg masses from Russian ship Khudozhnik N Rerikh at Wellington May 26, 1993.**

New Problem

The AGM has been around for as long as the EGM. Why then did it become a problem?

It has already been observed that indigenous forests in China and eastern Commonwealth of Independent States (CIS) are subject to cyclic eruptive populations of AGM. During 1990 and 1991 the populations of AGM around the ports of Vladivostok, Vostochny and Nakhodkha were very high. Increased trade between the CIS and Northwest America presented an opportunity for the pest species to be transported into areas where it could become established. New floodlights were installed in these ports to allow ships to be loaded and unloaded at night. Because AGM is positively attracted to light many of the ships in port were oviposited on by female AGM attracted to the area. It is postulated that this is the reason AGM was transported to the US during this time of high population. One ship entering an American port yielded enough eggs to "fill an oil drum". Merely having egg masses transported into port is not enough to allow the moth to become established. Eggs must also hatch at the appropriate time during transportation to allow the possibility of young larvae ballooning to shore on silk threads. If the eggs have been on board for an extended period of time then continuous hatching may occur.

Risk Assessment

It was originally thought by forest health staff that the risk of AGM entering the Southern Hemisphere by ship was low. The fact that shipping passed through the tropics led us to believe that all eggs would hatch before they arrived here or die because of high temperatures. Recent information from the US indicates that our assessment was incorrect. A ship examined off the coast of Florida was found to have three egg masses on it. This ship would have to spend an extended period of time in tropical waters to get to Florida from an infested area. Max Ollieu (Forest Pest Management, Pacific North West) informed us that ships have spent more than one year in the tropics and arrived in northern ports with viable egg masses. Extrapolating from this information, we must regard any ship that has been in port near the infested area during the last two years as a potential risk.

There was also the problem of port inspectors in the CIS. The level of training was not as high as in many western countries and ship hygiene was not perceived as a priority for vessels leaving port, so the possibility of egg masses being observed before departure was much reduced in these areas. Even ships which had been inspected and passed by the CIS authorities were found to be infested by US Inspectors (Gypsy Moth Exotica 1992). However, recent experience indicates that CIS inspection may have improved. The New Zealand National Institute of Water and Atmospheric Research (NIWAR) has leased a CIS research vessel to carry out surveys around the New Zealand coast. This vessel had been in the port of Vladivostok for a period of eight months and the Ministry of Forestry expressed some concern about it. On March 23, 1993 this vessel was requested to heave to 5-8 km off the coast near Tauranga. In the company of MOF staff the author carried out an inspection of the ship. The ship had been inspected twice before leaving Vladivostok and the crew were aware of the problem and had carried out further inspections en route to New Zealand. No egg masses were found. This increased awareness combined with the fact that the cyclic eruption of AGM around eastern Siberian ports is on the wane reduces our risk rating for these areas if the ship has been inspected. A watching brief was recommended and targeted ships, i.e. ships which have been in port in the infested area up to two years ago, will continue to be inspected before landfall. However, a recent event caused considerable alarm in New Zealand. During a routine inspection of a Russian container vessel an egg mass was found. The ship had left the port of Auckland on May 24 and was en route to Wellington before the eggs were positively identified as being from Asian Gypsy Moth. Under new powers recently written into the Forests Act (section 71c) MOF can hold a ship suspected of carrying a potential pest 8 km offshore for inspection. This ship, the K. N. Rerikh, was ordered to heave-to at the required distance off the coast near Wellington. The crew had attempted to clean the ship before it was inspected. A further seven egg masses were found and as a consequence of this the ship was banned from New Zealand ports until it received a certificate of cleanliness and a subsequent inspection by quarantine authorities.

The threat of infestation from North America is ambiguous. If the AGM is established there then the risk of it entering the Southern Hemisphere is greatly increased. The information being conveyed to us after the control measures were implemented in infested areas is contradictory. Pheromone trapping and analysis (mtDNA) of the specimens indicate that AGM is no longer present. These data must be tempered by the caveat that only 20% of the individuals captured have been analysed. Unsubstantiated reports from Vancouver report AGM flying around the port. This last report is not verifiable at this time. We have requested that our colleagues in Canada investigate these reports for us and they will report back to us as soon as they can be either substantiated or refuted.

Greater trade links with this part of the world increase the opportunity for accidental AGM introductions. The ability of the AGM egg masses to withstand very low temperatures would allow the moth to be transported here by plane. This is an area of risk which did not have to be considered by the Americans when dealing with the CIS, as aerial links are very rare between these areas.

AGM in Japan has been mentioned in several enquiries to Forest Health staff. This is not considered a high risk at this time. Defoliating outbreaks of gypsy moth have been recorded for many years (mainly in Hokkaido). The Japanese moth is considered an indigenous sub-species, *Lymantria dispar praeterea*

TABLE 1

Life Stage	EGM North America	AGM USSR
Adult Male	Strong Flier Attracted to pheromone	Strong Flier Attracted to pheromone
Adult Female	Flightless	Strong Flier (> 30 km) Attracted to light
Larvae	1st Instars disperse Uniform colour	1st and 2nd Instars disperse Highly variable colour
	Larvae feed in canopy at night, move to resting sites during day	*Larvae feed at night, remain on* host during day
	Late instars use artificial resting locations when they are provided.	Late instars use artificial resting locations when they are provided.
Hosts	Oak, Birch, Poplar, Willow, Alder	In excess of 500 species identified including conifers and hardwoods.
Egg Masses	On tree boles, rocks, litter.	On foliage, tree bole, rocks, virtually any object associated with lights.
Egg Phenology	<5% premature eclosion[1]	25% premature eclosion
	Full eclosion usually completed in one season. Vernalisation required.	Full eclosion may take several years if eggs survive. Vernalisation not required.
Mortality	NPV[2], Bt[3], Fungus[4], 11 parasites (mostly univoltine*), and various predators.	NPV, Bt, Fungus, Microsporidia numerous parasites and predators

KEY TO TABLE 1

1 Eclosion = egg hatch.

2 NPV = Nuclear polyhedrosis virus (Baculoviridae). Many pest species are susceptible to species specific baculoviruses. Under natural conditions these viruses are 'density-dependent', that is, when populations reach high levels the caterpillars become more likely to contract and transmit the disease. It has been postulated that the retention of flight in AGM allows the female to escape from these crowded/diseased areas and establish in areas where the population is present in low numbers.

NPVs have been used in pest control programmes in some countries with variable success. In Canada the sawfly *(Neodiprion sertifer)* was successfully controlled using an NPV. In Britain the results have been variable against Pine Beauty Moth *(Panolis flammea)* and the crop type *(Pinus contorta)* could not justify the more expensive application methods associated with NPVs.

3 Bt = *Bacillus thuringiensis* is the primary bacterium commercially available for control of insect pests. These bacterial preparations available as wettable powders typically contain about a thousand resistant parasporal bodies per milligram. The powders are wetted and sprayed and the pest may then ingest vegetative bodies while feeding. Each vegetative body contains two structures, a spore and a protein crystal. Although the spore often releases some toxins, the important insecticidal element is the protein of the crystal. When the parasporal body reaches the high pH of the gut, the protein crystal dissolves. This is what kills the pest; the spore itself does not germinate and propagate vegetatively until pH conditions change when the gut ruptures and the insect becomes a corpse. As the cadaver dries out, the bacterium resporulates to form parasporal bodies.

4 Fungus = Invasion of insects by fungi results from a spore landing on the cuticle of the insect, and the germ tube then penetrates the cuticle directly. Examples of these would be *Beauveria bassiana* used against cabbage white caterpillars or *Isara farinosa* which infects Pine Beauty Moth and the Larch Sawfly. They are seldom effective as biocontrol agents because they depend on moisture to sporulate and very high humidity to be successful.

5 Univoltine = One generation per year.

6 An aspect of the insect's biology, which should be considered in evaluating risk, is that of the many *Pinus* spp. AGM is capable of attacking. *Pinus radiata* is a favoured species for oviposition and eucalypts in Asia have been defoliated by large populations (R. Wylie, Queensland Forest Service, pers. comm.).

Kardakoff (Inoue 1982), and appears to have a more restricted host range (Schaefer *et al.* 1986). Gypsy moth in Japan is also subject to destruction of egg masses by a fungus *Entomophaga maimaiga*. This fungus has been tested for efficacy in the US and during periods of high humidity caused very high mortality of egg masses (News Briefs, Journal of Forestry 1993). This part of the world, along with Korea, Taiwan and mainland China, is placed in the low risk category. Until an eruptive population event is reported or egg masses begin to arrive on ships from ports in these countries we cannot justifiably place them in the high-risk category. Given all of the above information our assessment of the risk to New Zealand from AGM is the same as any of the pestiferous species, e.g. *Hylobius abietis* from Europe, entering our ports. We should concentrate our scarce resources on ships coming from areas where we know the risk of infestation is high but not to the exclusion of surveying transport which could bring in pests just as damaging to New Zealand forestry as Asian gypsy moth.

Action

The actions initiated to date are:

- MAF have already been alerted and briefed. They are checking containers carried by aircraft (air cans) and aircraft wheel ports for AGM egg masses. MAF also inspect ship containers for other species of insect pests and have been useful in covering this area of surveillance.
- Ships known to have been in infested areas are targeted for inspection.
- The Ministry of Forestry in collaboration with Customs and MAF now have the power to order a ship to heave-to 8 km from the New Zealand coastline. This includes offshore islands.
- If a ship is found to be infested it will not be allowed into New Zealand ports for a period of two years or until it can demonstrate it has been cleared and certified by inspectors before leaving port.
- Prior to an infested ship being expelled from port, the egg masses should be examined for signs of hatching and live larvae. Records of wind direction/speed during the period of the ship's approach to New Zealand should be taken to ascertain the most likely area of landfall for ballooning larvae. A predictive model using wind speed, direction and landform is available for this purpose.

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