Sirex noctilio

The pine-killing woodwasp

Detection, biology and control 2001

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Introduction

Up to 80% of trees in some forests were killed by sirex in some compartments of forest in the Green Triangle.

Sirex (*Sirex noctilio*) is a woodwasp that can devastate pine plantations. Originally from Europe, it was discovered in Hobart during the 1950s and in Melbourne in 1961. Since then it has spread throughout Victoria, South Australia, A.C.T. and New South Wales and by 2001 was within 140 km of the Queensland border. It has not yet reached Western Australia or the Northern Territory.

In 1987, a massive outbreak of sirex in the "Green Triangle" of south western Victoria and South Australia caused the death of millions of trees largely because parasitic nematodes were almost entirely absent .

Based on experiences from the Green Triangle it has been calculated that without control sirex could have cost the Australian forestry industry between $1 billion and $4 billion during each rotation of Australia's radiata pine forests.

Sirex signs and symptoms

At the beginning of a sirex infestation usually only suppressed, stressed or damaged trees can be killed because there are too few sirex attacking any one tree. As the sirex population builds up there are large numbers of sirex that can attack and kill almost any tree. However, fire or wind damage, delayed thinning, drought and other forms of stress can make trees particularly susceptible. Trees less than 12 years old tend not to be susceptible.

Characteristic resin beads and runs may occur on the tree trunk after oviposition by sirex

The needles of sirex-struck trees firstly wilt and become pale green in early summer and frequently turn red brown during winter.

Sirex biology

Sirex usually has a one year life cycle with adults emerging from late December to March and living for two or three weeks.

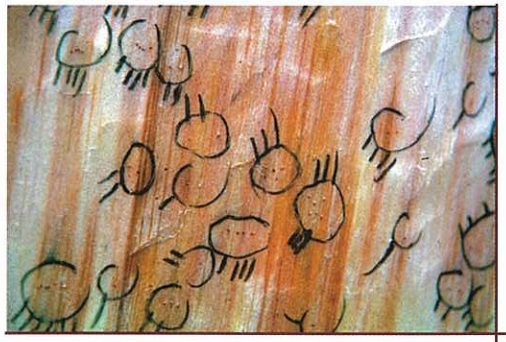
Female sirex drilling into pine tree.

The female sirex drills 10-20 mm into the wood and inserts a toxic mucous and spores of a pathogenic fungus (*Amylostereum areolatum*). If the tree is suitable, one or more eggs are also laid nearby.

The toxic mucus prevents sugar from being passed down from the leaves. Normally sugar is converted by the tree into fungal poisons (polyphenols) at the site of fungal infection thus stopping the fungus spreading but the mucus prevents this happening after a successful sirex attack.

Fungal spores, also injected by the sirex, can now grow into the wood and within a few weeks/months a successfully attacked tree will die as a result of the combination of mucous and fungus. The fungus then grows throughout the dead tree while the eggs laid by sirex hatch and the resulting sirex grubs bore into the wood feeding on the growing fungus.

Sirex larvae



Oviposition (egg-laying) usually occurs from late December to late March.

Removal of bark can reveal characteristic fungal streaking of the wood and oviposition holes (pin hole size) made by sirex marked to show numbers of ovipositions.

Usually single holes contain only mucous and fungus whereas multiple holes close together (that are made only when the wood is suitable) contain eggs.

Cylindrical sirex larvae each with a characteristic spike at the hind end bore into the tree leaving hard packed "frass" to fill the round tunnel behind them. (x 0.5)

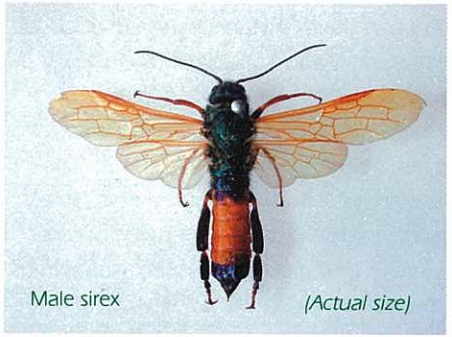
Larvae hatch from eggs soon after the tree dies and begins to dry. However this may be delayed for many months in cold wet areas. As they get bigger, the larvae move deeper and deeper into the tree sometimes growing to 5 cm in length and over 1 cm in diameter but often being only a fraction of this size before they pupate. Larvae usually pupate at the end of the first year but can delay pupation for a further year or more if the wood does not dry enough.

Sirex larvae (actual size)

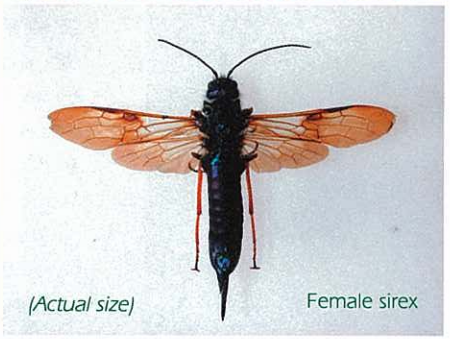
Sirex adults

A few weeks after pupation, the adult sirex wasp chews its way out of the tree leaving a perfectly round hole. This readily distinguishes it from most other pine tree borers in Australia which leave oval holes after emergence.

Perfectly round exit holes identify the presence of sirex



Male sirex *(Actual size)*



(Actual size) Female sirex

Natural enemies of sirex

Various insect parasitoids (parasitoids kill their host, parasites don't) and parasitic nematodes from around the world were collected, evaluated and in some case liberated by CSIRO for the control of sirex. The most successful organism for controlling sirex has been a parasitic nematode, although the early introduction of parasitoid wasps to sirex affected areas can place substantial pressure on the sirex population.

Parasitoid wasps

Of the insect parasitoids, *Ibalia leucospoides* has been the most successful. An *Ibalia* female seeks out the holes drilled by sirex and inserts its ovipositor into these and lays its own eggs into developing sirex eggs. The *Ibalia* larva then lives inside the sirex larva while the sirex larva grows over several months. It emerges from and kills the sirex just before the sirex larva would have pupated.

Ibalia females lay their eggs into developing sirex eggs.

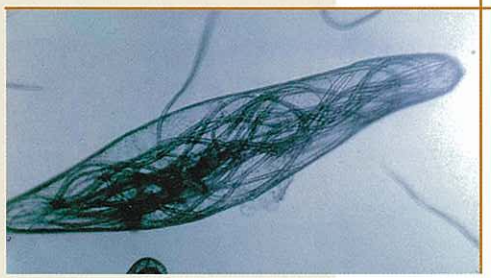
Initially, in Australia, levels of parasitism by *Ibalia* were usually not more than about 20% but during the late 1990s levels in some areas of Victoria have frequently exceeded 50%. *Ibalia* usually finds its own way into sirex populations soon after they establish.

Megarhyssa nortoni paralyses and lays its eggs on large sirex larvae.

Other insect parasitoids include *Rhyssa persuasoria*, *Megarhyssa nortoni* and *Schletterarius cinctipes*. *M. nortoni* drills deep into sirex infested trees after detecting large sirex larvae. It pierces the sirex larva and paralyses it before laying an egg on it. The *Megarhyssa* larva hatches and then grows rapidly over many days while it sucks the entire contents out of the sirex. This spectacular insect, sometimes reaching over 20cm in length, usually kills only a few percent of the sirex population and so contributes little to control.

Nematode parasites

Juvenile nematodes penetrate and eat the contents of sirex eggs while still inside the parent sirex thus effectively sterilising it.



A nematode parasite *Beddingia* (previously *Deladenus*) *siricidicola* was introduced into Australia mainly from Sopron in Hungary. This nematode sterilises female sirex by invading all her eggs before she oviposits them.

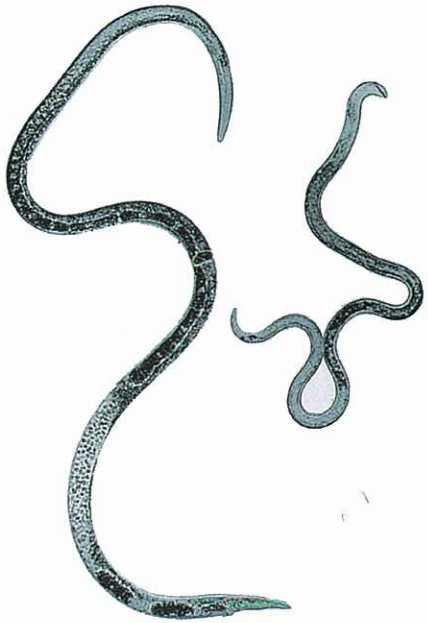
Large parent nematodes (up to 20 mm long and often green in colour) are found within the body cavity of sirex. Just before the adult sirex emerges from a tree the adult nematodes release thousands of juvenile nematodes into the sirex's blood. These juvenile nematodes now migrate into the sirex's reproductive system and then into the developing eggs.

The sirex female will still oviposit these eggs, now filled with nematodes into trees where unparasitised sirex lay viable eggs. The nematodes soon move out of the eggs into the tracheids (tubes) of the tree. However the nematode has a complicated life cycle before it can get back into sirex again. The juvenile nematodes feed on the fungus as it grows in the tree and develop into free living adult nematodes completely different from their parasitic parent.

Fungus feeding female nematode

Nematode parasites

This free living form of the nematode (less than 2mm long) lays eggs that hatch into juvenile nematodes that can again feed on fungus and develop into the same kind of adult. This fungal feeding cycle of nematodes can be repeated indefinitely without the intervention of a parasitic cycle. Within a sirex-killed tree, vast numbers of nematodes breed up for many generations throughout the tree feeding on the fungus as it grows. The nematodes thus reach all parts of the tree including places where there are sirex larvae derived from non-nematode-infected sirex.



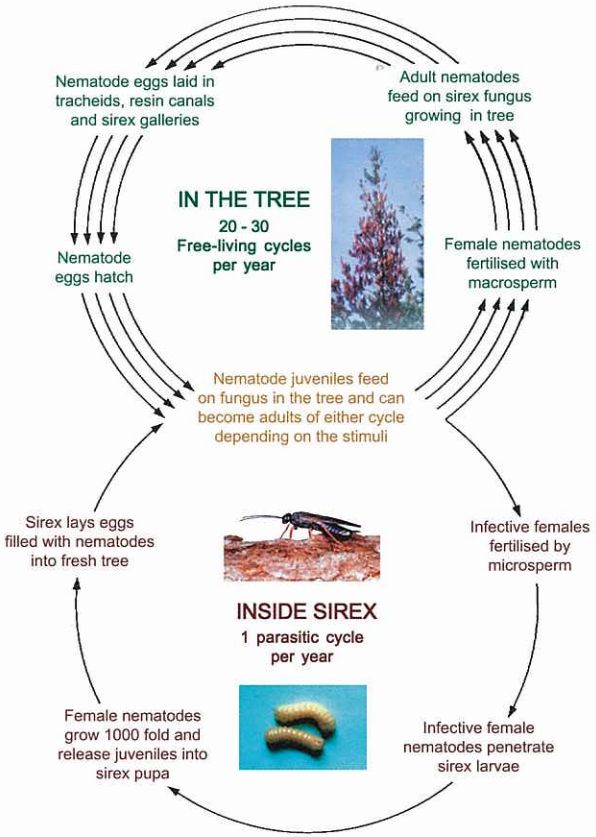
Nematode eggs developing near to sirex larvae are triggered by the extra carbon dioxide and acidity present to develop into a very different form of adult nematode. This form of adult nematode is adapted to penetrate sirex larvae and then grow up to a thousand fold in size in the sirex blood ready (as the sirex larva turns from pupa to adult) to produce the thousands of juvenile nematodes that enter sirex eggs and sterilise the sirex.

The two forms of adult female that are extraordinarily different from each other. The female on the left is the fungal feeding form.. That on the right is the infective form that must penetrate a sirex larva before becoming parasitic and growing up to a thousand fold in size

Nematode parasites

Because the nematode is density dependent, often approaching 100% parasitism when infestation levels of sirex are particularly high, it is considered to be the most important control agent. In addition the nematode is relatively easy to manipulate provided great care is taken to maintain its virulence.

BIOLOGY OF THE NEMATODE PARASITE OF SIREX *BEDDINGIA SIRICIDICOLA*



Biological control using nematodes

The principle behind using nematodes to control sirex is to have nematodes well distributed within sirex populations as soon as sirex infestations begin to establish. From then on nematode infection should spread and maintain itself naturally. This is initially achieved by inoculating sirex-killed trap trees with nematodes. Then sirex females emerging from these inoculated trees carry nematodes in their eggs to nearby trees that are being attacked by uninfected sirex.

Pure cultures of nematodes being transferred aseptically from agar plates to flasks.

In the laboratory the fungus feeding cycle is used to breed up large numbers of nematodes on sterilised wheat/rice in 500ml flasks.

Flasks are harvested about 6 weeks after inoculation by simply rinsing them out with water. The resulting nematodes are then washed and concentrated before being dispatched to forest managers.

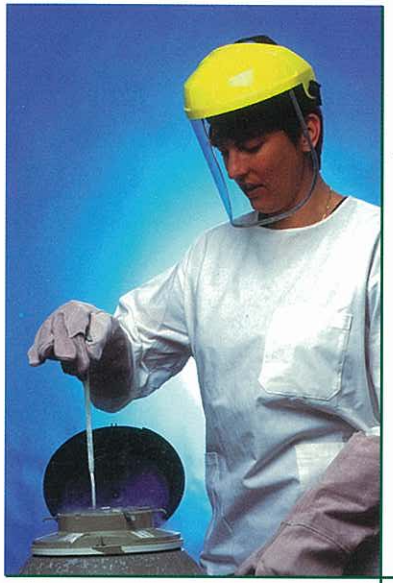
A flask freshly inoculated with nematodes and another ready to harvest.

Groups of five to ten trap trees are established, at easily accessible points (roadsides), several weeks before the sirex flight season. Trees are prepared by injecting enough weedkiller near the base of each to almost, but not quite kill the trees. During the following autumn successfully struck trap trees are felled and injected with nematodes at 60 cm intervals along the trunk.

A wad punch mounted in a hammer that enables clean cutting of the tree's tracheids (wood tubes) so that nematodes can enter.

Just prior to inoculation, the nematode suspension is diluted and mixed with fine polyacrylamide gel. Felled trap trees are inoculated by making clean cut holes through the tree bark and into the wood using a wad punch mounted in a hammer. The holes are then filled with the nematode/gel squeezed from a sauce bottle.

Nematode/gel is squeezed from a sauce bottle into each inoculation hole.



Vials of the Kamona strain of *Beddingia siricidicola* are stored in liquid nitrogen to avoid loss of infectivity.

A major problem

If handled correctly there is no reason why nematodes should not be used to successfully control sirex for many hundreds of years to come. However, a problem arose, when maintaining cultures over several decades. Although nematodes were intermitently re-isolated from the field, they were continually cultured and sub-cultured in the fungal feeding cycle. This led to an artificial selection against the nematodes' ability to form the infective stage. (Any infective females that developed in fungal culture could not reproduce and eventually died). The resulting nematodes (now called the "defective strain") were unwittingly used over many years for liberating into sirex infested pine forests. Luckily it was possible in the early 1990s, to isolate a strain (the Kamona strain) from a forest in Tasmania where the original strain had naturally perpetuated since shortly after the original nematode released in 1970. Hundreds of vials of the Kamona strain are now kept stored in liquid nitrogen and fresh cultures are made at the begining of each year so that there is little chance of adverse selection happening again. The task now is to replace the old defective strain, (where it is present in sirex-infested forests) with the Kamona strain as well as simply introducing the Kamona strain into all areas newly infested with sirex.

Other control measures

Thinning plantations on time can greatly reduce the incidence of Sirex. However thinning should not be conducted during spring or early summer since resulting damage to the remaining trees predisposes them to attack by Sirex. For small wood-lots, removing and burning infested trees during the winter, should keep sirex in check.

Further information

For further information on sirex control you should contact your state forestry agency (listed in the State Government section of the telephone directory) who will contact the chair of the National Sirex Co-ordination Committee and consult the following publications.

BEDDING, R.A. (1993) Biological Control of *Sirex noctilio* using the nematode *Deladenus siricidicola*. 20pp in *Nematodes and the biological control of insect pests* (Eds R.A. Bedding, R.J. Akhurst & H.K. Kaya) CSIRO Publications 11-20. (Available as a reprint from CSIRO Entomology)

HAUGEN, D.A., BEDDING, R.A., UNDERDOWN, M.G. AND NEUMANN, F.G. (1990) National strategy for control of *Sirex noctilio* in Australia. *Australian Forest Grower 13* No.2.

For detailed instructions on how to control sirex obtain a copy of:
NATIONAL SIREX COORDINATION COMMITTEE. (2000) *National Sirex Control Strategy-Operations Worksheets*. 2000 (from the National Sirex Coordination Committee)

A Warning

An area of pine forest in the 'Green Triangle' of South Australia and southwestern Victoria in 1988 where up to 80% of trees were killed by sirex in the absence of nematode control agents.

CSIRO

NSCC National Sirex Coordination Committtee

Produced by CSIRO and the National Sirex Coordination Committee