

= Sirex woodwasp =

The Sirex woodwasp ( *Sirex noctilio* ) is a species of horntail , native to Europe , Asia , and northern Africa . Adults vary in length from 9 to 36 mm ( 0 @. @ 35 to 1 @. @ 42 in ) .

This woodwasp is an invasive species in many parts of the world , including Australia , New Zealand , North America , South America , and South Africa , where it has become a significant economic pest of pine trees . The wasp can attack a wide variety of pine species , although some species seem to be more susceptible than others , and stressed trees often are attacked .

During oviposition , the female wasp lays two eggs with or without a mucoid substance and a symbiotic fungus for the larvae to feed on once they hatch . The mucoid substance is toxic to trees and aids in tree decline . The ascospores from the symbiotic fungus , *Amylostereum areolatum* , are also pathogenic .

= = Characteristics = =

= = = Adult = = =

The Sirex woodwasp has a sturdy , cylindrical body without a waist , but with a pointed abdomen . The female body is 15 ? 36 mm ( 0 @. @ 59 ? 1 @. @ 42 in ) , and the male is 9 ? 32 mm ( 0 @. @ 35 ? 1 @. @ 26 in ) long . Both sexes have long , black , bristle @-@ shaped antennae , which are rather close together .

The body of the male is black , except for the orange middle part of the abdomen . The wings are yellowish @-@ translucent and the antennae are black . The front pair of legs have a yellowish @-@ orange colour , the back pair is heavily thickened and is coloured black on the posterior splint and tarsus , while the femur is orange .

The females are iron blue , and have orange legs and black antennae . This is a notable distinction from *Sirex juvencus* , which has red antennae . The females also have yellowish wings . The ovipositor is below the tapering tip of the abdomen . The sting is connected with the mycetangia , which are special organs on the abdomen , where the female stores the oidiae ( asexual fungus spores ) , from broken segments of hyphae . These spores are deposited , together with the eggs , in the host tree wood to germinate . Both larvae and adults have strong mandibles and can drill through lead plates .

= = = Larva = = =

The larvae of the Sirex woodwasp are almost colourless and only have three stub @-@ shaped pairs of sterna . They cut through host wood with their powerful mandibles . They have a pointed , dark tip at their rear end , which presses the drilling dust on the walls of the borehole . They closely resemble other larvae in the genus *Sirex* .

= = Native and introduced range = =

The native habitat of the Sirex woodwasp is the temperate Palaearctic , ranging from Maghreb over Europe , Siberia , and Mongolia , to the Kamchatka peninsula . They live in deep pine @-@ rich forests .

The species has reached other continents , such as Australia , South Africa and North America , through the export of timber and firewood . While invasion was prevented in North America for a long time , the Sirex woodwasp established itself in New Zealand around 1900 . There , it contributed to massive pine declines in the first half of the 19th century , spreading to Tasmania in the 1950s and then to the Australian mainland . Since 1980 , it has reached pine plantations in Uruguay , and later also Argentina , Brazil and Chile ; it was found in South Africa in 1994 . The population increased in the Great Lakes area from 2004 on ; the species had reached Vermont ,

New York , Pennsylvania , Ohio , and Michigan by 2009 . The wasps can swarm between 20 and 50 km ( 12 and 31 mi ) , and will take until about 2050 to spread to the far southeast of the USA at the current spreading rate .

Subsequently , forestry authorities intensified their pest control methods and additionally started education campaigns , such as warning not to transport firewood over large distances or to store it too long . Through wood export , the wasp can spread to East Asia , West Australia and parts of Africa . Remote locations , such as the Horn of Africa , may be spared from the *Sirex* woodwasp , providing the area is controlled . The Invasive Species Specialist Group ( ISSG ) of the IUCN has graded the wasp as heavily invasive .

= = Ecology = =

= = = Phenology = = =

The flight time of the adults or imagines begins in the late summer to early autumn , but the date depends on the region and climate . The males hatch out earlier than females and create swarms which gather around the treetops . The females seek out leks and couple with the males on the uppermost shoots . Then the females search for suitable host trees , if possible choosing weak and dry wood . They orient on monoterpene hydrocarbon compounds , which weakened trees produce . When a tree is stressed through dryness or exterior injuries , the compounds pervade osmotic barriers and escape from the bark .

The female drills several holes through the bark down to the xylem to place one egg in each . At the same time , she inserts spores of *Amylostereum areolatum* and a phytotoxic secretion . The holes branch out into several tubes , which lead away radially . The eggs are white , sausage @-@ shaped , and 1 @. @ 0 ? 1 @. @ 5 mm ( 0 @. @ 039 ? 0 @. @ 059 in ) by 0 @. @ 2 ? 0 @. @ 3 mm ( 0 @. @ 0079 ? 0 @. @ 0118 in ) in size . Small females may lay 20 eggs , while the largest can lay up to 500 . Sometimes , eggs are not placed in every tube . In the last tube , the female injects only the secretion and the fungal spores . The females often die after just three or four days , sometimes even during oviposition ( egg @-@ laying ) , through overexertion .

= = = Development of larvae = = =

Larvae of *Sirex* woodwasp develop through arrhenotoky : male larvae develop only from unfertilized eggs , the females only from fertilized ones . Usually , 10 males are produced per female , but the ratio varies between 20 : 1 and 1 : 1 . The larvae hatch after eight days at the earliest , but in some exterior conditions , they may remain in the egg for several months . At the optimal temperature of around 25 ° C ( 77 ° F ) , they hatch out after 10 to 12 days . Although the larvae hatch at 30 ° C ( 86 ° F ) two to three days earlier , they are 20 % more likely to die . Such extreme temperatures result in slower development , and below 6 @. @ 2 ° C ( 43 ° F ) , the larvae die . A sufficient interspersation of the wood with the mycelium of the woodwasp is crucial for its hatching , as the fungus prevents the wood from drying out . Without these prerequisites , hatching is not possible . The tree can only ward off the infestation if it floods the boreholes with resin or halts the fungus by producing a wall of polyphenols .

Six to 12 larval stages occur . During the first two stages , the larvae live off surrounding fungal tissue , until they reach the inner wood . Up to the fourth stage , they eat through the final summer wood along the tracheids , and finally towards the heartwood . After the seventh stage , they usually reach their maximum size . While penetrating further , they normally turn either up or down , but they turn back if they meet a foreign borehole , encounter bubbles of resin , or dry out . The larvae only live off the fungal mycelium , which they digest through a secretion . They pupate several centimeters under the bark . Before this , female larvae sequester a secretion containing fungal oidia , which adult females incorporate in their mycetangia above their ovipositors . The adults eat through the bark , but , depending on the weather , they remain in the hatch hole for up to three

weeks before they leave the wood in warm and sunny weather .

The period from hatching to pupation lasts 10 days to two years , exceptionally up to six years . Climate is a major factor , because development is slower in colder regions .

#### = = = Symbiosis = = =

The *Sirex* woodwasp and *Amylostereum areolatum* have a mutualistic symbiotic relationship . The *Sirex* woodwasp is , together with *Sirex juvencus* and *S. nitobei* from eastern Asia , one of three symbionts of the fungus that in the first instance benefits from its vector function . Additionally , the wasp creates the optimal conditions for the infestation through the fungus by drilling into the underlying wood layers and weakening the host tree . The fungus adapted to this process in the course of the years and has created fruit bodies only rarely or in the crop .

Conversely , the woodwasp is fully dependent on the symbionts . Decomposition enables the larvae to unlock the wood by producing white rot . The mycetangia of this and other wasps from the family Siricidae support a close relationship with saprobiontic fungi . Without the process of decomposition of the host tree and weakening of the infested tree , the development of larvae is arrested . If the tree can recover from the consequences of the wasp secretion , it blocks the boreholes with resin , thus killing the larvae .

#### = = = Host spectrum = = =

The *Sirex* woodwasp only attacks conifers , especially pines . In its usual habitat , these are mainly *Pinus sylvestris* , *Pinus pinaster* and *Pinus nigra* . In the Southern Hemisphere and in North America , the wasp attacks exotic and domestic pine species , generally in plantations . Examples include *Pinus radiata* and *Pinus taeda* in the United States .

Unlike any other species of Siricidae , the *Sirex* woodwasp can damage relatively healthy trees so heavily , they die back . However , the wasp mainly infests weakened trees ; only when the population is high does the insect also attack intact and healthy trees . Because the wasp larvae and the fungus need healthy wood , the *Sirex* woodwasp does not infest dry or dead timber . However , wasps may hatch from processed wood which was already infested .

By the spring of 2011 , *S. noctilio* had been found in Michigan , Pennsylvania , New York , and Vermont . Pines in North America that have been attacked or confirmed as hosts are : Scots ( *Pinus sylvestris* ) , Monterey ( *P. radiata* ) , loblolly ( *P. taeda* ) , slash ( *P. elliotii* ) , shortleaf ( *P. echinata* ) , ponderosa ( *P. ponderosa* ) , lodgepole ( *P. contorta* ) , and jack ( *P. banksiana* ) ( Haugen 1999 ) .

#### = = = Symptoms of infestation = = =

Infestation damage can be divided into four categories or phases , depending on whether it is caused by the imago , fungus , larvae or secondary parasites .

The first reaction of the host tree is traced to the adult wasp and occurs after 10 to 14 days . A phytotoxic secretion of the wasp impairs metabolism in the shoots and needles , causing loss of water balance . The result is brown coloration of the needles and leaf drop . As with many other wood pests , fine resin drops in wasp boreholes are found in the central trunk . Attacked pines tend to develop flagging . Tip dieback begins with the needles becoming chlorotic and changing from green to yellowish @-@ red , finally turning completely brown over a three- to six @-@ month period . The wasp bores 1 / 8- to 3 / 8 @-@ inch @-@ diameter holes in the tree . Unstressed trees may be attacked uniformly along the main stem , while trees with low osmotic phloem pressure are preferentially attacked , with denser clusters of boreholes .

During this process , fungal spores germinate in the boreholes , a reaction caused by the dryness of the tree , creating an appropriate environment and an entry for air . The fungus breaks down the lignin , causing white rot . It moves towards the vertically aligned xylem . The vertical profile shows reddish and white streaks which run in the direction of growth .

In the third stage , the larva begins to bore into the wood . By doing this , it eats the path , which at first proceeds towards the trunk center , before turning and running back to the bark . The paths are not visible in cross @-@ section , because they are heavily blocked with wood flour ; they may also be unobserved during wood processing . The lengths of the paths vary , depending on the wood , between 5 and 20 cm ( 2 @. @ 0 and 7 @. @ 9 in ) in diameter , which depends on the size of the larvae . The exit holes are circular and of very small diameter .

Stressing of the host tree and visible larval boreholes appear in the fourth stage . The infestation is reinforced by further insects or fungi , which in turn may cause more symptoms . Imago , fungus , and larvae together can cause tree death in a period ranging from two weeks to eight months .

= = = Natural enemies and parasites = = =

Birds are the primary natural enemies of the *Sirex* woodwasp . The adults are frequently hunted by swallows ( *Hirundidae* ) and swifts ( *Apodidae* ) , both of which prefer males . The black woodpecker ( *Dryocopus martius* ) and great spotted woodpecker ( *Dendrocopus major* ) consume some larvae , but do not specialize on the *Sirex* woodwasp .

Several parasites have a larger impact on woodwasp populations . These include *Ibalia leucospoides* ( *Ibaliidae* ) ; *Schletterius cinctipes* , *Megarhyssa nortoni* ( *Ichneumonidae* ) ; and *Rhyssa persuasoria* . While *I. leucospoides* lay its eggs into the woodwasp 's egg and the hatching period is therefore similar to its host 's , the ichneumons mentioned lay their eggs on larvae or adult woodwasps ; they hatch out later in the springtime . The parasites locate host larvae hidden in the wood using their antennae to detect cues , including the smell of leaking drill dust or fungus mycelium , weak vibrations , or differences in temperature . The majority of these insect hyperparasites feed on honeydew and nectar , both of which affect the woodwasps ' sensitivity .

Another parasite is the nematode *Beddingia* ( *Deladenus* ) *siricidicola* , which was suggested in the New World in the 1970s as a possible biological control . *B. siricidicola* causes infertility in female wasps , but does not impair the fertility of males . Inside the host tree , the nematodes primarily feed on fungal mycelium . If they get near the wasp larvae , they infect females , which then couple with males and finally infest the wasp larvae . These eventually exit the tree carrying the nematodes with them . Competition for food between *B. siricidicola* and the wasp larvae also occurs , resulting in slower growth and possible starvation of the woodwasp larvae . The population of the *Sirex* woodwasp is very prone to infestation by *B. siricidicola* ; infestation rates of up to 90 % have been recorded . The nematodes are often used to combat the wasps by combining them with the symbiosis partner *Amylostereum* . The related species *B. wilsoni* has a similar effect , but as it also lives parasitically with the genus *Rhyssa* , it is not used for pest control .

= = Management options = =

Several biological control agents have been employed to try to limit populations of the *Sirex* woodwasp . *B. siricidicola* has been shown to infect up to 70 % of the wasps , but delivery and inoculation have been an issue when delivering the organism to the tree . The introductions of parasitic wasps . *Megarhyssa nortoni nortoni* , *Rhyssa persuasoria persuasoria* and *Ibalia leucospoides leucospoides* have been successful at hyperparasitism , but do not reduce wasp populations below 40 % of the local population . Although some success in slowing the population growth of the wasp has been observed , these measures are not stopping the spread of the wasp .

As a consequence of forest damage in Australia and New Zealand , wood imports to those countries have been required to be certified free from living *Sirex* larvae .

Treatment has also been attempted with bromomethane (  $\text{CH}_3\text{Br}$  ) , through heat , or by removing the bark .