Chapter 17
Surveillance and Control of the Sirex Woodwasp: The Chilean Experience

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Abstract *Sirex noctilio* was first detected in Chile in the Valparaíso Region in 2001. This led to an intensive attempt to eradicate the pest. The same year and after the detection of the pest in Los Lagos Region and its expansion to other regions north to Los Lagos, actions to deal with the pest were focussed on its containment and suppression. With this goal, Chile implemented quarantine and biocontrol measures with the parasitic nematode *Deladenus* (=*Beddingia*) *siricidicola* and the insect parasitoids, *Megarhyssa nortoni* and *Rhyssa persuasoria. Ibalia leucospoides* had been independently introduced earlier. Research and technical programs financed mainly by the Chilean Government in collaboration with private forestry companies and the regulations and measures implemented by the Servicio Agrícola y Ganadero made it possible to maintain the Sirex populations at tolerable limits. An important result of the control programs have been the successful establishment of various biological control agents and growing levels of parasitism of *D. siricidicola*.

17.1 Introduction

Continental Chile is approximately 4,300 km long and 427 km wide at its widest point. Chile is 75.5 million ha in size; approximately 11% of this area is forested. This forested area is comprised of about 4.75 million ha of unprotected native forest,

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1.4 million ha of protected native forest and approximately 7.5 million ha of commercially productive native forest. The south-central part of Chile (35° S–42° S) is considered the most important area for commercial forestry because it provides the most suitable conditions for the growth of *Pinus radiata* and other *Pinus* species. Extensive establishment of commercial pine plantations began in the 1970s with the implementation of government incentives for plantation development. These incentives promoted the expansion of the forest products industry and subsidized the majority of costs for reforestation and plantation establishment. The forest sector in Chile currently comprises 2.2 million ha of plantations lying between 32° and 42° latitude south (the south-central region), 65% of which are planted to *P. radiata*. Plantations of *P. ponderosa* and *P. contorta* have also recently been established in Chile mainly south of the 45th parallel (INFOR 2007).

Forestry in Chile has experienced marked growth in the last few decades and has evolved both in technological and economic terms. This growth is reflected in the strong presence of the Chilean forest sector in the world's most demanding markets, which require high quality products and increasingly strict environmental standards of production. Large companies met this challenge early by adopting environmental management systems. They currently use the Chilean System for Sustainable Forest Management Certification, which grants a seal of approval required mainly by European and North American markets (Comisión Nacional de Buenas Prácticas Agrícolas 2006).

In light of the detection of *Sirex noctilio* in various South American countries (Argentina, Uruguay and Brazil) during the 1980s, a National Program for the Early Detection of *S. noctilio* in Chile was implemented in 1990 under the national coordination of Servicio Agrícola y Ganadero (SAG). The program included the full participation of the primary Chilean forestry companies through an agreement of understanding, which included surveillance and control under the standardization of work protocols which are still in operation.

The National Programme for the Early Detection of *S. noctilio* involved specific forest health surveys, the establishment of a network of trap trees and a monitoring program using funnel traps to detect the pest and initiate early control measures. As a result, the first outbreak of *S. noctilio* was detected in Chile in January 2001 in a trap baited with alpha-pinene and ethanol located near Guardia Vieja, Valparaíso Region. This outbreak was associated with a nearby hydroelectric facility that had imported large quantities of equipment from Europe in wood packaging materials. In March of the same year, a *S. noctilio* female was captured in Ensenada, Los Lagos Region, about 1,000 km south of the first outbreak. In both cases the presence of immature individuals of the pest in *P. radiata* trees was confirmed. The most recent discovery is believed to have been a result of migration of the pest from southern Argentina.

As a consequence of the first detections of *Sirex* in 2001, an Official Control Program for *S. noctilio* in Chile was developed and implemented in the same year. The chief objective was to avoid damage to commercial *P. radiata* plantations in the country. The program includes a strategy for containment and suppression of outbreaks of the pest, including surveillance, outbreak control and quarantine measures in Chile. It also includes cooperative measures with neighbouring countries to reduce the infestation of new areas in accordance with the phytosanitary guidelines set by the International Plant Protection Convention (IPPC).

Given the importance of the approximately 1.5 million ha of commercial *P. radiata* plantations and the damage that *S. noctilio* can potentially cause to the Chilean forest industry, the pest was declared under official control as a part of the national strategy for its detection and control. This strategy includes: eradicating or suppressing new outbreaks to reduce infestations to protect commercial pine plantations; increasing the surveillance in pest risk areas for the quick detection of the pest; and developing a biological control program. Chilean forestry companies have taken part in the program from the beginning by applying technical surveillance and control protocols in their forested lands. They have also participated in pest control activities in neighbouring countries to reduce the risk of introduction into new areas.

This review outlines the Chilean experience relating to the surveillance and control of *S. noctilio*. We begin by briefly providing some background on the biology of *S. noctilio* and the history of forest health practices in Chile.

17.2 Forest Health in Chile

Countries such as Australia, New Zealand and Chile have established extensive, continuous plantations of exotic species of the genus *Pinus*, particularly *P. radiata*. These plantations are homogenous not only in terms of species but also in terms of age, density and management. A similar situation exists in Brazil, Argentina, Uruguay and South Africa with species such as *P. taeda*, *P. elliotti* and *P. patula*. However, in those areas, the size and diversity requirements of plantations are standard. All of these countries try to maximize production by planting the species best suited to the forest soil types in their geographic region. The motivation for this approach is decidedly economic, and it seems that there has been no real concern for risks such as pests and fire that are inherent in the establishment of extensive monoculture plantations. However, increased international trade during the past decades, particularly involving wood products used as packaging material for the transportation of goods, have increased the risk of new pests being introduced. These new pests can cause serious damage because they normally arrive without their natural enemies.

Sirex noctilio is an economically important pest in areas dominated by plantations of *P. radiata, P. taeda, P. elliotti* and *P. caribaea.* Plantations are more susceptible when established on poor sites, at high densities, in extensive stands of the same age and without adequate silvicultural planning and management. *Sirex noctilio* seems to prefer codominant or suppressed trees with a diameter at breast height of greater than 12 cm. Abiotic factors such as prolonged drought, wind and snow can also greatly influence the establishment and dispersal of the pest.

Frequent monitoring during the rotation of a forest crop will ensure that infestations are discovered. Abiotic factors can also influence the establishment of a pest, and must be considered. The predictability of these factors increases with the availability of long-term data, facilitating decision-making and simulation modelling of different disturbance parameters. The importance of forest health information should not be underestimated because its absence can lead to huge losses. The Green Triangle outbreak in Australia is a good example, where use of the nematode *Deladenus siricidicola* failed after some years of mass rearing, losing its effectiveness as a control method. Thus, the lack of sufficient surveillance allowed a new and serious outbreak to occur (Haugen 1990; Haugen and Underdown 1990).

Many of the factors that favour the arrival of a pest can be avoided through effective forestry practices and the maintenance of forest health. In terms of silviculture, preventive actions can include quarantine, sanitary thinning and wood waste management, such as is practiced in Chile and Argentina. These practices are effective for the control of *S. noctilio* at the local level (Villacide and Corley 2006, 2007).

17.3 *Sirex noctilio*: A Remarkable Taxon

Anyone who has studied *S. noctilio* must recognise that they are dealing with a remarkable taxon and this is especially true for the female wasps. From the biological point of view, various characteristics are fundamental to the life history strategy of *S. noctlio*. These insects have mycangia that have evolved with the fungus *Amylostereum areolatum* and whose hyphae provide food for the larvae during their first stages of development. They also have reservoirs for the phytotoxic mucus that prepares the tree for oviposition. The presence of pro-ovigenic females with a haplodiploid reproductive system is remarkable as is the ovipositor adapted to drill into the bark and deposit its eggs and the insect has is able to disperse very effectively. Their reproductive strategy is perfectly synchronized between the pest, the fungi and the susceptible trees.

For effective *S. noctilio* infestation, the quality or quantity of susceptible trees is important, depending on population levels. Under low population levels of the pest, high density stands and suppressed, codominant trees, broken by wind are most susceptible, while at high population levels all trees are susceptible. Sex ratio has been considered a good indicator of population age of *S. noctilio*. When *Sirex* first arrives in a new area, there are more males than females, while in areas where the pest is well established the sex ratio tends to be closer to 1:1. Pest management decisions were made based on this knowledge of the biology and ecology of this pest in areas of southern Chile where it has been established since 2001. For example, the population level and sex ratio may help to explain the time of the infestation, its probable origin and allow forest managers to make the best decision in a specific area (e.g., sanitation versus biological control, declaration of a new quarantine area or selected areas for intensive surveillance).

The symbiotic fungus, *A. areolatum* has recently received special attention. Molecular techniques have provided news tools for identification, understanding the mutualistic associations of *Amylostereum* species with different species of siricids, and the phylogenetic relationships among its species. Advances have also been made in the understanding of the ecology, biology, behaviour and functions of these species (Slippers et al. 2000, 2002, 2003). A collaborative project between the University of Pretoria (South Africa) and Uppsala University (Sweden) investigated the evolutionary biology of the mutualistic symbiosis of siricids and fungi, as well as the monitoring and control of forest pests (Slippers et al. 2006).

The phytotoxic mucus of *S. noctilio* has received less attention apart from the mention of its mode of action in weakening attacked trees and causing their eventual mortality. In general, little research has been done on the mucus (Wong and Crowden 1976). Its effect is a key factor in successful establishment of *Sirex* and it is deposited before the process of oviposition. It is clear that the fungus and the mucus together are responsible for the phytotoxicity and subsequent mortality of living trees (Spradbery and Kirk 1978) (see Chap. 3 for further discussion).

17.4 Surveillance of *Sirex noctilio* in Chile

17.4.1 Surveillance Program

The objective of the surveillance program for *S. noctilio* is to detect outbreaks in endangered areas and to determine its distribution throughout the country during each season. This program allows for control of the outbreaks, the collection of information to define quarantine areas in the country, and the assessment of the pest's status in the area, according to International Standards for Phytosanitary Measures (ISPM) No. 6: Guidelines for Surveillance (IPPC/FAO 1997).

The program first assesses the risk of pest introduction into endangered areas so that the distribution of available resources can be prioritized. The intensity of surveillance activities to be carried out annually is then determined, with emphasis placed on areas of greatest risk. The specific phytosanitary surveillance program for the detection of *S. noctilio* in endangered areas includes three different detection strategies applied in a complementary manner: (1) detection via ground surveys; (2) trap trees, and (3) monitoring via funnel traps.

17.4.1.1 Ground Surveys

An annual ground survey is carried out in Chile in *Pinus* spp. plantations in *S. noctilio* endangered areas. Teams of surveyors search for suspect trees that present signs and/or symptoms of attack by the pest and then trees are cut and sawn into logs. Log samples are sent for laboratory analysis to determine the presence or absence of the pest through a search for immature *S. noctilio* or adults close to emergence that may be present in the wood. Approximately 10,000 survey stations throughout the country are set up each year.

Table 17.1 Number of locations where *Sirex noctilio* was detected in Chile from 2001–2009

Region	2001	2002	2003	2004	2005	2006	2007	2008	2009
Valparaíso[a]	13	0	0	0	0	0	0	0	0
Bio-Bio	0	0	0	0	0	0	0	0	12
La Araucanía	0	11	12	96	18	70	72	14	8
Los Ríos and Los Lagos	2	19	11	70	234	152	8	12	17
Total	15	30	23	166	252	222	80	26	37

[a]Outbreak eradicated

17.4.1.2 Trap Trees

A network of trap trees treated with herbicides is set up in *Pinus* spp. plantations in *S. noctilio* endangered areas, according to the basic methodology developed by Neumann et al. (1982). The purpose of this activity is to artificially predispose trees to attack by the pest. Detection plots each consist of five trees. The trees are cut, sawn into logs and analyzed during the spring according to specified procedures. Samples of wood are then extracted and sent to the laboratory for analysis to determine the presence or absence of the pest. A network of approximately 1,000 trap tree detection plots is set up annually according to a specific work plan involving SAG and forestry companies.

17.4.1.3 Funnel Traps

A country-wide network of 8–12 unit funnel traps baited with the attractants alpha-pinene and ethanol is set up and checked every 10–15 days. This phytosanitary surveillance activity is oriented towards the capture of *S. noctilio* adult females during the flight of the insect in *S. noctilio* endangered areas of the country where plantations, woodlots or isolated trees of *Pinus* spp., *Abies* spp., *Picea* spp., and *Larix* spp. are present. Special emphasis is given to areas close to international border access roads where goods in wood packaging materials arrive from abroad.

17.4.2 Distribution of Sirex noctilio *in Chile*

After the outbreak in the Valparaíso Region was eradicated, the distribution of the pine woodwasp in Chile has been restricted to the Regions of Bio Bio, La Araucanía, Los Ríos and Los Lagos (SAG 2005a). The majority of commercial *P. radiata* plantations located in endangered areas are currently Sirex free. *Sirex noctilio* was detected at 37 points in 2009, including the detection of the pest in a new region; the wasp was detected in *P. radiata* plantations in the Alto Bio Bio area (Table 17.1).

17.5 Control of *Sirex noctilio* in Chile

Control of *S. noctilio* in Chile is carried out using a combination of quarantine measures, sanitation and biological control. The aim of these measures is to reduce the possibility of infestation in susceptible areas throughout the country that are still pest free, which make up close to 95% of the area occupied by *P. radiata* plantations in Chile, and to reduce the prevalence of this pest in quarantine areas where its presence has been reported.

17.5.1 Quarantine Control

The Official control program for the Sirex woodwasp includes the application of internal and external quarantine phytosanitary measures. These are aimed at reducing the possibility of pest spread in endangered areas. They also seek to lower the chances of reintroduction of *S. noctilio* from abroad, which could broaden the genetic diversity of the pest.

17.5.1.1 Internal Quarantine

The main purpose of this activity is to reduce the risk of spread of the pest in Chile when it is detected within the country. The application of this quarantine measure is based on Resolution No. 2.758 (SAG 2009). This resolution defines the area under quarantine as the entire area where *S. noctilio* is detected plus a 20 km radius around this area. The endangered area is defined as the zone surrounding the area under quarantine where host species of the pest are present (Fig. 17.1).

The phytosanitary procedures of the internal quarantine prohibit the movement of timber from *S. noctilio* host species from quarantine and endangered areas, unless this timber has been subjected to heat treatment, chipping or fumigation with methyl bromide. The movement of timber is controlled through supervision of the harvest and highway inspections of lumber transport trucks. Companies that do not comply with these internal phytosanitary regulations are penalized and the timber is confiscated, destroyed, or returned to the place of origin (Fig. 17.2).

17.5.1.2 External Quarantine

This activity is carried out mainly through the application of the ISPM No.15: Guidelines for regulating wood packaging material in international trade (IPPC/FAO 2009) as well as Resolution No. 133 (SAG 2005b). This establishes specific phytosanitary requirements for the entry of wood materials used to package goods imported from abroad.

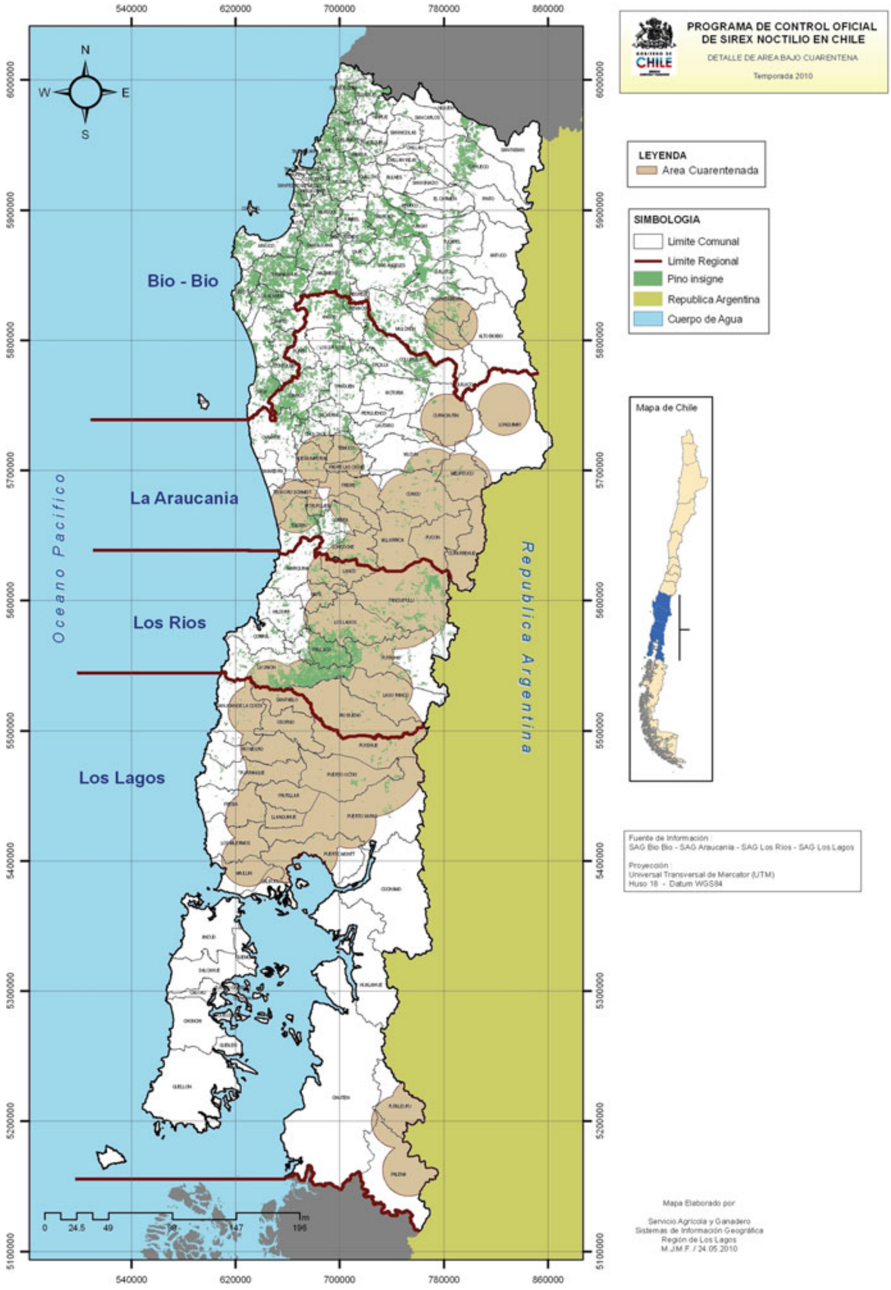

Fig. 17.1 Quarantine areas (light brown) for *Sirex noctilio* in Bio Bio, La Araucanía, Los Ríos and Los Lagos Regions of Chile (2009)

Fig. 17.2 Quarantine control of transportation of pine logs in Chile

In practice, the fulfilment of these regulations is verified through the inspection of 7–10% of shipments of foreign goods packaged in wood material. These materials must be heat-treated or subjected to fumigation with methyl bromide in the country of origin and must come with the mark specified by ISPM No.15. Inspections are carried out at international border controls in Chile and at the good's final destination, mainly industrial sites where machinery is imported. Wood packaging that does not comply with the phytosanitary regulations is destroyed, returned to the country of origin or subjected to quarantine, while any detected pests are sent to a SAG laboratory for taxonomic analysis. As a result of the above procedures, *S. noctilio* has been intercepted in wood packaging material from abroad 40 times between 1995 and 2009, highlighting the risk of spread of this pest via international trade of goods in wood materials.

17.5.2 Sanitation

Between 2001 and 2006, the control of *S. noctilio* was carried out through the phytosanitary treatment of all pest outbreaks. The pest was detected 708 times during this period. Affected trees were cut down and either burned, buried, fumigated or

Table 17.2 Parasitism levels of *Deladenus siricidicola* in adult females of *Sirex noctilio* in the provinces of Río Negro, Neuquén and Chubut (República Argentina), evaluated during the periods 2002–2003 to 2006–2007

	Parasitism in females (%) by year				
Province	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007
Río Negro	13.8	48.7	64.1	81.8	60.1
Neuquén	30.2	38.8	32.5	53.4	90.7
Chubut	–	–	–	70.5	85.3

heat-treated to eliminate immature or adult pests that could be present in the timber. The primary objective was local eradication. However, because eradication is not always possible, sanitation reduces the pest populations thus decreasing the risk of spread to endangered areas, and allowing sufficient time for the parallel development and implementation of a biological control program.

17.5.3 Biological Control

The aim of the biological control program is to suppress the pest with the nematode *D. siricidicola*, and insect parasitoids *I. leucospoides*, *M. nortoni* and *R. persuasoria*. The program strategy involves obtaining these biological control organisms, placing them under quarantine in the SAG laboratories, mass rearing them in Chile and then releasing them in the area under quarantine.

Chile and Argentina have a bilateral agreement, Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA)/Argentina and SAG/Chile for the biological control of *S. noctilio*. The objective of this bilateral plan is to use biological control methods to reduce the populations of *S. noctilio* in the Patagonian provinces of Neuquén, Río Negro and Chubut in southern Argentina, close to the Chilean border. The plan involved the production of *D. siricidicola* in two laboratories (one in Chile and one in Argentina) for release in those provinces during the period 2001–2007, and the quarantine and breeding of the parasitoid wasps *M. nortoni* and *R. persuasoria* in the SAG/laboratories for release during the period 2004–2009 using the biosecurity protocols of SAG/Chile and SENASA/Argentina.

In Argentina from 2001 to 2007, 13,877 pine trees were inoculated with *D. siricidicola* with 3,918 dosages of the nematode. The evaluation of parasitism levels showed that this organism is established in the three provinces of Argentina, with parasitism levels in adult females between 60.1% and 90.7% (Table 17.2). From 2004 to 2009, 93 females and 97 males of *M. nortoni* were released in Neuquén and Río Negro provinces of Argentina, where the parasitoid has been established successfully in both Argentinean areas. *Rhyssa persuasoria* has been released at the same places (23 females and 59 males), without recovery from field until recently (2009).

Fig. 17.3 Inoculation of *Deladenus siricidicola* in radiata pine trap trees in Chile. (**a**) Pruning and cleaning of the trap tree; (**b**) Gel inoculation

17.5.3.1 Quarantine, Rearing and Inoculation of *Deladenus siricidicola*

Two strains of *D. siricidicola* are currently available in Chile: Encruziliada do Sul, from Brazil; and Tangoio, from New Zealand. Both of these strains have been subjected to quarantine protocols according to Chilean legislation; the Encruziliada do Sul strain has been authorized for field release. After quarantine, the nematode is produced in two Chilean laboratories: SAG laboratory in Osorno and Controladora de Plagas Forestales (CPF S.A.) laboratory located in Los Angeles. The production at both laboratories assures the sufficient supply of *D. siricidicola* for each season. The nematodes are reared on *A. areolatum* grown on wheat grain using established techniques (Bedding and Iede 2005). They are released in the field only within the quarantine area, and are applied in gel form to inoculate groups of five *P. radiata* trap trees previously treated with herbicide (Fig. 17.3).

Inoculations with *D. siricidicola* were first carried out in Chile in 2006. That year, 2,307 groups of trap trees were inoculated. Almost 50% of the trees were on the property of small forest owners and the remaining trees were on land belonging to forestry companies (Table 17.3).

Table 17.3 Inoculations of *Deladenus siricidicola* in Chile in Bio Bio, La Araucanía, Los Ríos and Los Lagos Regions from 2006 to 2009

Year of inoculation	Number of trap trees inoculated in groups	Number of inoculated trees	Number of dosages of *D. siricidicola* used
2006	847	5,464	1,116
2007	1,460	8,810	1,606
2008	1,329	8,120	1,245
2009	999	5,005	1,015
Total	4,635	27,399	4,972

Table 17.4 Releases of *Megarhyssa nortoni* in Chile from 2005 to 2009

Region	Year of release	Number of places	Number of females	Number of males	Total
Bio Bio	2009	1	29	30	59
La Araucanía	2005	1	23	39	62
	2007	4	124	132	256
	2008	4	136	135	271
	2009	1	0	95	95
Los Ríos	2007	2	60	60	120
	2008	4	120	113	233
Los Lagos	2006	1	32	32	64
	2007	3	74	155	229
	2008	2	54	70	124
	2009	2	53	58	111
Total		**25**	**705**	**919**	**1,624**

17.5.3.2 Collection, Quarantine, Rearing and Release of *Megarhyssa nortoni* and *Rhyssa persuasoria*

These species were collected during the years 2004–2008 in different localities on the North and South Islands of New Zealand in *P. radiata* forests where *S. noctilio* is present. Their post-entry quarantine was carried out in the Quarantine Laboratory for Wood Insects SAG Lo Aguirre in the city of Santiago. The rearing of these insects in quarantine was achieved using *Pinus* spp. logs infested with *S. noctilio* from Argentina. This was because Chile's has a very low *S. noctilio* population and thus, logs sufficiently infested for the rearing of this insect were not available.

The logs were placed in a quarantine room under controlled temperature, relative humidity and photoperiod in an effort to generate the environmental conditions of a forest to allow the development and mating of the insects. After two generations under quarantine, the insects obtained were examined individually, sexed, and released in authorized quarantine areas in *P. radiata* forests where *S. noctilio* existed or was suspected to be present. Between 2005 and 2009, a total of 1,624 adult individuals of *M. nortoni* were released in quarantine areas (Table 17.4). Adult parasitoid releases are carried out in the mornings on sunny days in the Spring. Standardized

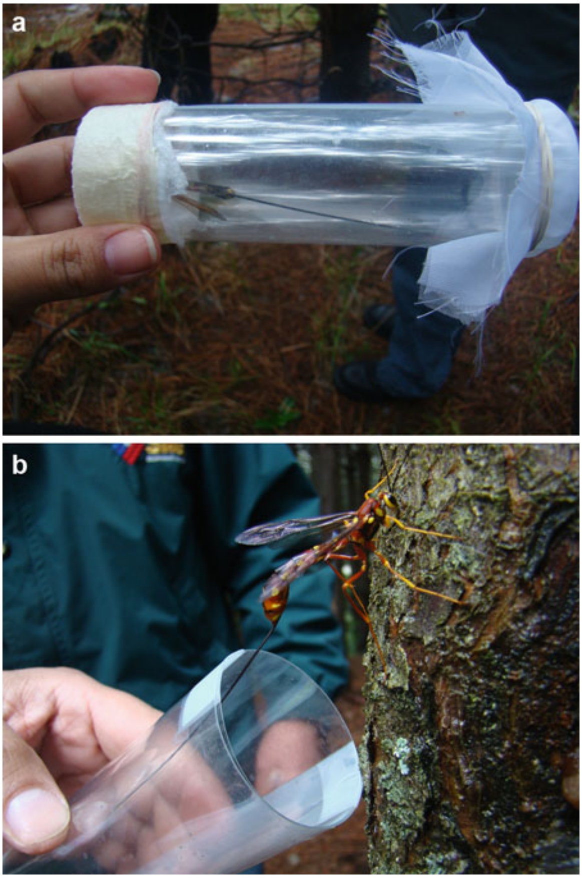

Fig. 17.4 Release of *Megarhyssa nortoni* in Chile. (**a**) Transport cages; (**b**) Liberation of an adult female

protocols are followed for every step of the process. The infested *P. radiata* stands where the releases are carried out have previously been evaluated to ensure that releases are carried out where they have a high probability of succeeding (Fig. 17.4).

17.5.3.3 Evaluation of Biological Control Programs

The biological control program for *S. noctilio* is evaluated based on the presence and incidence of both the parasite and the parasitoids released in the country. The establishment, parasitism and dispersion of parasites and parasitoids associated with *S. noctilio* is evaluated through combined systematic and random sampling of previously numbered 50 × 50 km grids in each of the La Araucanía, Los Ríos and Los Lagos Regions where the pest is present. Stands that are infested or suspected to be infested with *S. noctilio* are selected at random from each grid. Standardized samples of pieces of pine are taken from each stand and are placed in an insectarium

Table 17.5 Parasitism levels of *Deladenus siricidicola* in adult females of *Sirex noctilio* in Chile in Bio Bio, La Araucanía, Los Ríos and Los Lagos Regions from 2007 to 2009

	Parasitism (%)		
Region	2007	2008	2009
Bio-Bio			0
Araucanía	10.5	38.6	41
Los Rios	14.8	13.2	30.8
Los Lagos	40.0	22.2	64.5
Total	13.6	29.9	44.0

under field conditions to rear the insects. For a period of a year, all insects that emerge, including both the pest and its parasitoids, are removed from the insectarium, counted and sexed daily. *Sirex noctilio* females are dissected to determine the presence or absence of *D. siricidicola*.

As a result of these studies, it has been shown that *D. siricidicola* has become established in Chile and is present in areas infested by the pest in the La Araucanía, Los Ríos and Los Lagos Regions. The level of parasitism observed in *S. noctilio* females to December 2007 is 13.6%; however, the nematode's distribution is irregular because in some of the areas evaluated no establishment has been observed, while in others present levels of parasitism are close to 80%. During 2009, the national parasitism level was 44%; the Los Lagos Region has the highest parasitism level (Table 17.5).

Ibalia leucospoides introduced into Chile by SAG in 1997 has shown an acceptable level of parasitism (25–30%), close to that observed for the same species in other areas where this organism is present (Ruiz 2006). *Ibalia leucospoides* has dispersed to almost half of the areas infested with *S. noctilio* and, due to its long history of presence in the country, is not expected to significantly increase its level of biological control. *Megarhyssa nortoni* has been observed as established at two localities in Chile, thus rearing and release activities must be continued for this parasitoid.

17.6 Summary and Conclusions

The management of *S. noctilio* in Chile has been an integrated effort that has maintained the populations at low levels for several years. Currently the quarantine areas for *S. noctilio* are between 37.6° and 43.8° south latitude and the control measures are diminishing the points of detection and the population levels. Just recently, the pest was detected in the Bio Bio Region where the main *Pinus* plantations in Chile occur. Here with different sites, climatic conditions and large areas of plantations, it will be important to examine any changes in insect behaviour and the use of biocontrol methods must be closely monitored.

Deladenus siricidicola is the key species used in the control of *S. noctilio*. Chile adopted its use and developed modifications for rearing, preservation, viability, inoculation and final evaluation of this nematode. Some aspects, such as loss of viability after cryopreservation or parasitic capacity after generations of repetitive mass rearing under laboratory conditions using the same strains are currently under investigation. From 2007 the SAG and CPF-S.A. laboratories, located in Los Lagos and Bio Bio Regions, have produced sufficient nematodes to treat the areas under quarantine for *S. noctilio* in southern Chile. Because the procedures for mass rearing nematodes are already well-established probably just a few innovations can be developed; however, the cryopreservation of nematodes to reduce the loss of virulence has been considered a very important issue to maintain the nematode vitality. The levels of biological control by *D. siricidicola* in Chile are considered suitable.

Parasitoids recognized to be effective for *S. noctilio* control have been introduced into some infested localities that have a high enough population of the pest to support the introduction of the parasitoids. *Ibalia leucospoides*, a koinobiont endoparasitoid of eggs, first and second instars, averages control levels between 25% and 30% of parasitism. This parasitoid displays a Type III functional response, which is considered desirable because biological control agents must work well even with variable pest population levels (Fernández-Arhex and Corley 2003; Ruiz 2006). Apart from its effectiveness, its searching behaviour and association with *Amylostereum* have been studied (Villacide and Corley 2002; Fernández-Arhex and Corley 2003; Martínez et al. 2006). Other parasitoid species such as *M. nortoni* and *R. persuasoria*, both idiobiont ectoparasitoids, have been released in Chile from material collected in New Zealand, with the objective of reducing the population levels of the pest and to complement control realized with *Ibalia* and *D. siricidicola. Megarhyssa nortoni* was established in southern Chile, which implies correct release techniques in the field. At this time, the Official Program of *S. noctilio* in Chile includes the production of this wasp in insectaries located close to the infested areas to increase the production and distribution of the parasitoids. The techniques for breeding, quarantine and release of parasitoids have been successfully developed in Chile by SAG and CPF-S.A.

There are still many unanswered questions as to how and where *S. noctilio* mate, the number of males, survival rates and more. These questions do not seem to have engaged research interest despite their importance in population monitoring, creating predictive models of dispersal, and generating data to simulate population growth and predict the incidence of the haplodiploid condition in the following season. Unfortunately, quite a few observations are not generally available because they are unpublished or appear in media with limited circulation. Nonetheless important contributions from Argentina, Chile, Uruguay and Brazil regarding the understanding the life cycle and behaviour of *S. noctilio* include Aguilar and Lanfranco (1988); Corley et al. (2002); Villacide et al. (2004) and Corley and Villacide (2005), and are summarized in Chaps. 4, 15–17.

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