Trip Report

Name: Andrew Liebhold, NRS, Morgantown, WV aliebhold@fs.fed.us 304-285-1512

Purpose: (Project, name of meeting, etc) "Spread of *Sirex* in Argentina"

Dates: March 18-24, 2007

I traveled to Bariloche, Argentina for a working visit with Dr. Juan Corley, Instituto Nacional de Tecnología Agropecuaria (National Agricultural Technology Institute). Dr. Corley is one of the most prominent South American scientists working on the ecology and management of *Sirex noctilio*. My trip was primarily designed to help me gain familiarity with the *Sirex* system and to initiate collaborative projects with Argentine entomologists.

Figure 1. Map of Argentina

About half of my time with Dr. Corley was spent in the field, observing *Sirex* damage. The first discovery of *Sirex* in South America was in Uraguay in the early 1980's and soon thereafter it was discovered in Southern Brazil and Northern Argentina. These are subtropical regions where pines are grown on short-rotations and *Sirex* can have multiple generations per year. In the 1990's a secondary *Sirex* population was discovered in northern Patagonia and it has continued to spread to the south over the last 10 years

In Patagonia, pine growing conditions are much poorer. In particular, total annual precipitation is low and the growing season is short. Nevertheless, there have been many pine plantations initiated over the last 30 years as part of efforts to diversify the local economy. Some of these have been planted in the steppe area of eastern Patagonia, while others have been planted in the slightly more mesic portions of the foothills of the Andes. Many of the latter plantations occupy sites previously hosting native forest tree species.

The two conifer species that are most commonly planted in Patagonia are *Pinus contorta* and *P. ponderosa*. *Pinus contorta* appears to receive much many more *Sirex* attacks. Douglas-fir is also planted though it is not a suitable host for *Sirex*. Many of these stands are heavily managed (i.e., thinned, pruned, etc) (Fig. 2).

Fig. 2. Pruned *P. ponderosa* plantation in the steppe regions of Patagonia

I visited several stands that had received heavy damage caused by *Sirex* (Fig. 3). Many of these were plantations with a mix of species and *P. con*torta always exhibited much greater damage. While many of the attacked trees were suppressed or otherwise in poor condition, many appeared healthy. Much of the mortality exhibited a distinct amount of aggregation.

Fig. 3. Tree mortality caused by *Sirex*.

In most damaged stands, there appeared to be active salvage of newly-killed trees. I also saw several sites where the nematode had been introduced as part of their biological control efforts carried out by the Argentine quarantine agency. This practice appeared to closely follow the practices carried out in Australia in which infested trees are felled and inoculated with nematode via plugs that are pounded into holes drilled along the tree bole.

In Patagonia populations, *Sirex* larvae require 1, 2 or 3 years to complete development. In infested stands, it was possible to observe emerge emergence holes from both from the current year (hole was light brown on the inside) and previous year (emergence hole was distinguishably weathered) (Fig. 4). Dr. Corley's *Sirex* rearings confirm that within all populations, about 50% of the population emerges after 1 year but part of the population requires either 2 or 3 years to complete development

Figure 4. *Sirex* emergence holes.

During my trip, Dr. Corley and I made plans for future collaboration. We began to assemble data on the historical spread of *Sirex* in South America and elsewhere in the southern hemisphere, with the intention of writing a paper comparing rates of spread among the various infested areas. We also discussed plans to accelerate Dr. Corley's research on *Sirex* dispersal. Growing out of these discussions, we developed a proposal that Dr. Corley submitted to the US Forest Service Northern Research Station for a joint project on studying *Sirex* dispersal (proposal is attached as Appendix 1). We both agreed that more information on *Sirex* dispersal is of critical importance in formulating future management of Sirex in both South and North America. We also discussed that it would be useful for Dr. Corley to attend the USDA Interagency Research Forum on Invasive Forest Pests in Annapolis, MD in 2008. We are currently exploring possibilities to obtain funding for his travel. It should be noted that the Argentine research program was severely damaged by the Argentine economic crisis of 2000 and even though much of the research underway at the National Agricultural Technology Institute was scientifically sound, their funding levels appear to be low.

APPENDIX 1 – PROPOSAL SUBMITED TO USDA FS NRS

"Dispersal of *Sirex Noctilio* and its role in invasion dynamics"

Principal Investigator: Juan C.Corley, Laboratorio de Ecología de Insectos, INTA EEA Bariloche, CC 277 - (8400) Bariloche, Argentina +54(0)2944-422731, FAX +54(0)2944-424991 jcorley@bariloche.inta.gov.ar

Cooperators and Other Participating Institutions: Andrew Liebhold, USDA Forest Service Northern Research Station, Morgantown, WV

Amount requested: $13,600

Project Goals and Supporting Objectives:
Project goal: Quantify flight dispersal of *Sirex noctilio* and incorporate this information to clarify the potential for spread of this insect in relation to infection by the parasitic nematode, *Beddingia siricidicola*.
Supporting objectives:

1. Quantify the distribution of dispersal distances for adult female and male *Sirex noctilio*
2. Determine the effect of mating status on female dispersal
3. Determine the effect of nematode infection on female dispersal

Project Justification:

Sirex noctilio is a woodwasp native to Europe, Asia and northern Africa where it is considered a minor secondary pest attacking pines (Spadberry and Kirk 1978). The species has been inadvertently introduced into a number of countries in the southern hemisphere including: New Zealand, Australia, Uruguay, Argentina, Brazil, Chile and South Africa (Carnegie et al. 2006). In these areas the insect has caused upwards of 80 percent mortality in plantations of North American pines especially Monterey pine (*P. radiata*) and loblolly pine (*P. taeda*). However, there has also been considerable success in reducing the intensity of outbreaks via silviculture and introduction of a parasitic nematode, *Beddingia siricidicola*, as well as several parasitoid species (Haugen et al. 1990). Nevertheless, there has long been concern that introduction of *S. noctilio* to N. America could potentially result in a significant forest pest problem (Ciesla 2003).

The discovery of *S. noctilio* populations in North America began in September, 2004 when a single adult was discovered in a trap placed in Fulton, NY (Hoebeke et al. 2005). Subsequently, infested trees were discovered in nearby Oswego, NY and Oswego is believed to be the initial point of introduction (it is a port city) in the USA from which populations have spread. Surveys conducted with attractant traps in 2006 indicate the presence of populations in 24 counties in NY and 2 counties in PA.

The spread of *S. noctilio* is expected to continue through most of North America and both climatic conditions and presence of host species appears suitable for establishment and

population growth (Carnegie 2006, USDA 2006). There is particular concern that this species could develop into a serious pest problem both in plantations (primarily southeastern US) and natural forests (e.g., pine dominated ecosystems in the western and Midwestern US). While there are many factors that may potentially affect whether this species ultimately becomes a pest in the US (e.g., role of competing Siricids and native parasitoids), the question of how quickly this species is likely to spread is a subject of utmost importance. Reports from the southern hemisphere indicate historical expansion rates ranging from 20-60 km/yr (Tribe and Cillie 2004, Carnegie et al. 2006). While there is considerable evidence that long-range dispersal of *S. noctilio* can occur via the accidental movement of infested wood, little is known about localized spread. This information may be of particular importance in considering strategies to eradicate isolated populations. While eradication is not considered an option for the core population, eradication is being considered for any distant secondary populations that may be detected in the future (USDA 2006).

Little quantitative information exists on dispersal of *S. noctilio*. Qualitative descriptions (e.g., Morgan and Stewart 1966) indicate that males and females take flight both before and after mating; however dispersal distances have not been measured. The relative extent of movement by mated females, unmated females and males is of considerable significance to spread of this species. If females disperse long distances before mating, such movement may not immediately result in spread of established populations. But either movement of unmated females in the previous generation or movement of males in the current generation could result in a 'cloud' of males that elevate mating success at the range margin and thereby elevate rates of spread.

The parasitic nematode, *Beddingia siricidicola,* has been deployed both in the southern hemisphere and in the US as a biological control agent against *S. noctilio*. If *B. siricidicola* infection debilitates the dispersal capabilities of *S. noctilio* then this could affect the ability of this parasite to control populations. It may result in the escape of uninfected *S. noctilio* populations at the expanding front (wasp spread would surpass spread of the nematode). Thus it is important to understand the effect of nematode infection on dispersal.

Current *S. noctilio* populations in Patagonia are moderately dense. In contrast, populations in the infested portion of New York State are quite low and this would make it virtually impossible to conduct the dispersal studies outlined in this proposal in the US. Considering both the availability of *S. noctilio* populations as well as the experience our laboratory has with this insect, we believe that we are ideally situated to conduct this research. Furthermore, we have already begun preliminary studies of dispersal described here.

Preliminary results

To study *S. noctilio* flight, we constructed a set of 5 flight mills, based on the model of (Schumacher et al., 1997). These flight mills consists of a tubular structure mounted in a square box with a Perspex transparent roof, within which individual wasps are glued to

one end of a balanced wooden rod through an entomological pin. The rod is held in place through a metal axle by two powerful magnets allowing the wasp to fly in circles within the device (Fig. 1). An external circuit board that has two inputs allows connecting optical sensors, and outputting data into the computer. A specialized program collects data from the interface board, recording each rotation of the wooden rod, each time the beam of light generated between both sensors is interrupted by the end opposite to the one where the insect is held. From these data we calculate flight speed, accumulated flight distance and total flight time.

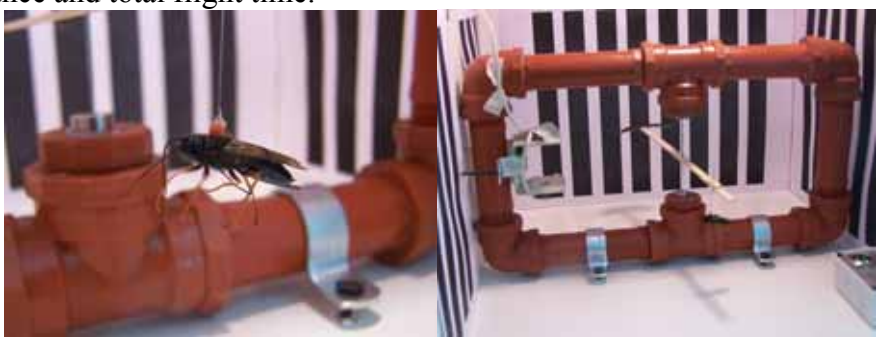

Figure 1. Flight mill apparatus designed after Schumacher et al. (1997)

Preliminary results from these flight mills indicated that *S. noctilio* is capable of performing long flights. The maximum distance flown for a single individual in a one day-long trial was 49 km with an average speed of 0.37 m/s, however most of the time individuals remained resting, and during flight, speed was highly variable. Using wavelet analysis, we were able to identify three different patterns of flight closely related to wasp body size (Bruzzone *et al*, in prep.).

In addition, preliminary results comparing nematode bearing female *S. noctilio* versus healthy individuals, suggest that infected wasps fly significantly less and that this may me explained by the smaller size adult infected wasps reach (Fig. 2).

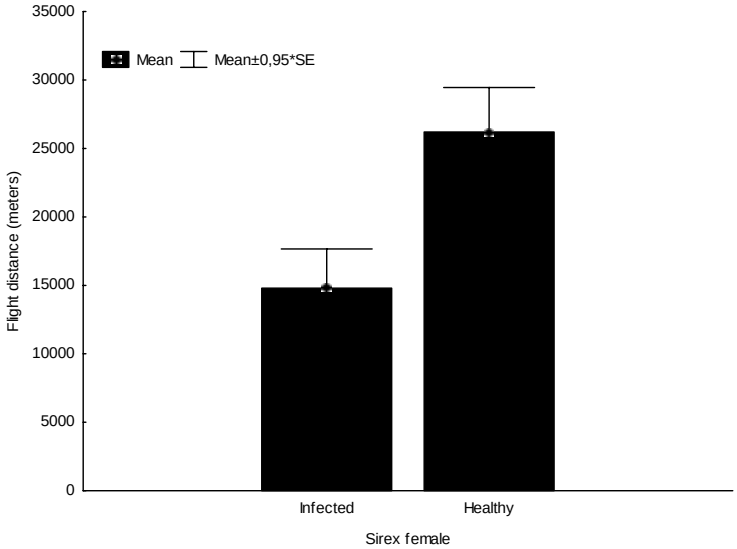

Fig. 2. Flight distance of *Sirex noctilio* healthy (n=24) and *Beddingia siricidicola* infected (n=28) females. (F(1|50) = 6,06610562| p = 0,0173) (Unpublished data).

In a separate study we obtained data from which information about dispersal distances can be inferred (Corley *et al*. in review). In this study, we performed an inspection of 100% of all trees in an isolated 80 ha stand of *Pinus contorta* and *P. ponderosa* in which the location of all trees under attack by *S. noctilio* were recorded using a GPS. These surveys were conducted over 3 consecutive years and all data were imported to a GIS. Using the GIS, we were able to calculate the distance that each tree was from a tree that was attacked in the previous generation. These data (Fig. 3) indicate a distribution a distribution of dispersal distances over which most dispersal distances are less than 100 m though a few disperse much further.

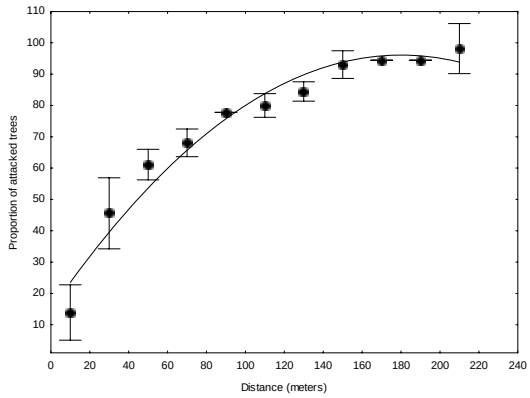

Fig.3: Dispersal of *Sirex noctilio* within a pine plantation, estimated by the redistribution of attacked trees in 3 successive years. Maxim distance observed was 21 m (Corley *et al*, in review).

Research Approach:

Dispersal is a notoriously difficult process to quantify. Many of these problems arise because of the inherent difficulty of quantifying dispersal over both long and short distances. Our approach to the problem utilizes three experimental approaches that focus on dispersal over varying distances.

<u>Experiment 1- Short-range dispersal (0-75 m)</u>. In this mark-recapture experiment, approximately 200 adults will be liberated at the center of a selected plantation. Adults will be marked using a fluorescent powder prior to release. They will be recaptured using a network of interception traps (unbaited so as to not affect behavior) arranged in a radial fashion about the release point at distances of 12, 24, 48 and 72m. Traps will be constructed as large black cloth panels, deployed between adjacent trees and coated with sticky glue. Traps at each radius will be partially displaced from the previous radius so as to minimize interference. Traps will be regularly inspected and all trapped insects tallied, measured (length) and returned to the laboratory where they will be dissected to determine the presence of nematode infection. This experiment will be replicated 5 times using unmated females, mated females and males. Adults released in this experiment will be obtained via rearing from field-collected logs. We expect to obtain a mixture of both

infected and uninfected individuals from field collections. Mating will be controlled via daily collection of adults from rearing chambers.

Experiment 2- Medium-range dispersal (50-1000 m). This experiment focuses on emigration dispersal of a naturally occurring population. An array of funnel traps will be set out in a radial design at varying distances (50, 150, 300 and 1000 m) from the edge of selected plantations. Our previous work (Bruzzone *et al*, in prep. and Corley *et al* submitted) indicates that this scale of 50-1000 m encompasses the distances observed during the localized expansion of invading *S. noctilio* attacks. Stands utilized here will be isolated from the nearest pine stand by at least 4 km and they will be surrounded by non-host tree (e.g., *Austrocedrus* spp.) forests over distances of at least 2 km. Traps, will be baited with α/β -pinnene and deployed at the beginning of the flight season (December) and checked every 15 days until the termination of flight (typically May). Male and females individuals caught at each trap will be tallied, measured (length) and dissected in the laboratory to check for infection *Beddingia siricidicola*.

Experiment 3 – Long-range dispersal (> 1 km). This is a flight mill experiment designed to provide information on long distance flight potential of male and female wasps.
In each experiment we will monitor flight of individual tethered wasps for 23 consecutive hours using our previously developed flight mill apparatus with computer interface. Wasps will be obtained from laboratory rearing facilities, which consist of locker-type cages with field-collected logs from attacked hosts. For each treatment of unmated females, mated females and males we will perform 100 replicate tests. As in experiment 1, we expect that sample of adults will contain both infected and uninfected individuals. Nematode infection will be determined after flight through dissection under a binocular lens, while mated will be controlled by collecting insects daily and kept in individual cages(unmated) or in communal cages where mating may occur. Mating will be confirmed after flight by either dissection or oviposition assays.

Analysis of variance will be used to test for effects of sex, mating status and nematode infection on dispersal distance. We will also test these effects on maximum minimum distance flown, and maximum and mean flight speed using data from experiment 3. A variety of kernel-fitting methods will be utilized for estimation of dispersal kernels based upon experimental data (Turchin 1998, Strand and Cain 2003).

Expected Products and Outcomes:

We anticipate estimation of dispersal kernels for female *S. noctilio* based upon the field experiment. We may lack adequate data to estimate the tail of this dispersal distribution but flight mill experiments will provide an estimate of maximum dispersal distances. This information may be of critical importance in designing efforts to either slow, contain or eradicate isolated *S. noctilio* populations in the US that may be detected in the future.

Information on the relative dispersal capabilities of males vs. females as well as mated vs. unmated females will provide new insight into the mechanisms driving spread of this

species. Because unmated females produce viable male offspring, populations at the population front may not be critically limited by the availability of males for mating.

Information on the effect of nematode infection on spread will also provide critical information about the spatial dynamics of this host/parasite interaction. Preliminary results indicate that parasitized hosts have decreased dispersal capabilities and this could profoundly affect the spread and persistence of this important natural enemy.

Timetable of research activities

Dates	Activity
July-Nov., 2007	Locate field sites
Nov., 2007 – Apr., 2008	Experiment 3
Feb.,– Mar., 2008	Experiment 2
Jan.- April, 2008	Experiment 1
May-Oct., 2008	Data analysis
Nov., 2008 – Mar., 2009	Experiment 3
Feb.,– Mar., 2009	Experiment 2
Jan.- April, 2009	Experiment 1
May-Oct., 2009	Data analysis and preparation of manuscripts

Literature Cited

Allan E. Strand, Michael L. Cain (2003) Methods for estimating long-distance dispersal Oikos 103 (2), 261–273

Bruzzone OA. JM Villacide & Corley,JC. Flight polymorphism in the woodwasp *Sirex noctilio* (Hymenoptera: Siricidae): an analysis of tethered flight data using wavelets. In preparation.

Carnegie, A. J., Matsuki, M. Haugen, D.A., Hurley, B.P., Ahumada R., Klasmer, P., Sun, J., Iede, E.T., 2006. Predicting the potential distribution of *Sirex noctilio* (Hymenoptera: Siricidae), a significant exotic pest of *Pinus* plantations. Ann. For. Sci. 63 119-128.

Ciesla, W.M. 2003. European Woodwasp: A Potential Threat to North America's Conifer Forests. Journal of Forestry 101: 18-23

Corley, J.C., JM Villacide & OA Bruzzone. Spatial dynamics of woodwasp (*Sirex noctilio* F., Hymenoptera:Siricidae) attacks within a pine plantation of Patagonia (Argentina). Entomología Experiemntalis et Applicata *(in review).*

Haugen, D.A., R.A. Bedding, M.G. Underdown, F.G. Neumann. 1990. National Strategy for Control of Sirex Noctilio in Australia. Special Liftout Section No. 13.

Hoebeke, E.R., D.A. Haugen, and R.A. Haack 2005. Sirex noctilio: Discovery of a Palearctic siricid woodwasp in New York. Newsletter of the Michigan Entomological Society 50(1&2):24-25.

Morgan, F.D. and N.C. Stewart. 1966. The biology and behavior of the woodwasp Sirex noctilio F. in New Zealand. Trans. roy. Soc. N. Z. Zool., Vol. 7 No 14. pp 195- 204.

Schumacher, P., A. Weyeneth, D. C. Weber and S. Dorn (1997) Long flights in Cydia pomonella L. (Lepidoptera: Tortricidae) measured by a flight mill: influence of sex, mated status and age. Physiol. Entomol. 22: 149–160.

Spadberry, J.P., and A.A. Kirk. 1978. Aspects of the ecology of siricid woodwasps (Hymenoptera: Siricidae) in Europe, North Africa and Turkey with special reference to the biological control of Sirex noctillio F. in Australia. Bull. Ent. Res. 68, 341-359.

Tribe, G.D., Cillie, J.J. 2004. The spread of Sirex noctilio Fabricius in South Africa pine plantations and the introduction and establishment of its biological control agents, African Entomology, v. 12(1), Entomological Society of Southern Africa, Pretoria. p. 9-17.

Turchin, P. 1998. Quantitative Analysis of Movement: measuring and modeling population redistribution in plants and animals. Sinauer Associates, Sunderland, MA.

USDA Animal and Plant Health Inspection Service. 2006. Organism Pest Risk Analysis: Risks to the Conterminous United States Associated with the Woodwasp, Sirex noctilio Fabricius, and the Symbiotic Fungus, Amylostereum areolatum (Fries: Fries) Boidin. July, 2006.

Currículum vitae
Corley, Juan Carlos
March 2007

1. Personal information.

*Date and place of birth**: Buenos Aires (Argentina), 29 August 1963.***
Address: San Martín 432 - (8400) Bariloche- ARGENTINA.
TE:+54(02)944-4-48761 - FAX:+54(02)944-4-24875; jcorley@bariloche.inta.gov.ar;
URL: http://www.inta.gov.ar/bariloche/investiga/insectos.htm

2. Current position

-**Adjunct Researcher** – CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas)
- **Principal Researcher** at the Insect Ecology Laboratory, INTA (National Institute for Agricultural and Livestock Technology), Bariloche Experimental Station
-**Assistant Editor (The Americas)** – *International Journal of Pest Management*.
-**Assistant Editor**- *Revista de la Sociedad Entomológica Argentina*.

3. Studies

* *M.Sc*. in Ecology. 1993. School of Biological Sciences, University of Wales, Bangor.
* *Ph.D in Biologys.* 2001. Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires.

4. **Student supervisión** Total 11

5. Publication record

In peer-reviewed journal, total 35.
Technical reports, total 33.
Book chapters, total 2.

Selected 5 recent publicactions:

1. Castelo M, Ney-Nifle M, **Corley, JC** and Bernstein C (2006). Ovipostion height increases parasitism by *Mallophora ruficauda*. ***Behavioural Ecology and Sociobiology*** 61: 231-243.
2. Martínez A, Fernández-Arhex V, and **Corley JC.** (2006). Chemical information from the fungus *Amylostereum aerolatum* and host foraging behaviour in the parasitoid *Ibalia leucospoides* ***Physiological Entomology*** *31(4):1-5*.
3. Fernández-Arhex V. & **Corley JC** (2005). The functional response of *Ibalia leucospoides*, a parasitoid of *Sirex noctilio*. ***Biocontrol Science and Technology*** 15(1):1-6. ISI 2004, *0.87.*
4. Fernández - Arhex, V & **JC Corley** (2003). The functional response of parasitoids and its implications for biological control. ***Biocontrol Science and Technology*** *13(4): 403-413.*
5. **Corley, JC**; AF Capurro & C. Bernstein (2004). Prolonged diapause and the stability of host-parasitoid interactions. ***Theoretical Population Biology*** 65 (2): 193-203.