

Perception and knowledge of the *Sirex* woodwasp and other forest pests in South Africa

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- Abstract**
- 1 *Sirex noctilio* F. (Siricidae: Hymenoptera) is one of the most serious invasive pests of pine. In South Africa, there has been a national effort to control *S. noctilio*, including a campaign to increase awareness of the pest amongst the local forestry community.
 - 2 We considered the impacts that the arrival of the pest and the awareness campaign have had on perceptions and knowledge of *S. noctilio*, as well as other forestry pests, amongst members of the forestry community.
 - 3 For data collection, a survey questionnaire was developed and used in telephone interviews.
 - 4 The results obtained in the present study showed that the *Sirex* awareness campaign had increased knowledge of forestry pests in general but basic knowledge regarding the identification and symptoms of specific pests, such as *S. noctilio*, was poor. This will negatively influence monitoring efficacy.
 - 5 Traditional paper-based media and personal contact contributed most to enhanced awareness. Electronic media were less effective and improvement would require a more focused effort. It was of concern that private farmers and contractors, as well as non-European first language speakers, were less well informed about forestry pests.
 - 6 Clearly, a fragmented landscape in terms of ownership and language, presents challenges for effective communication of forestry pest threats.

Keywords Awareness media, forest pest management, human dimension, survey.

Introduction

Pests and pathogens pose a serious threat to forestry worldwide. This threat includes both environmental disturbance by altering natural forest habitat, and economic losses, including direct losses to the crop and indirect losses as a result of the required management interventions (FAO, 2009; Holmes *et al.*, 2009). The increase in global trade and travel has added to this threat by the consequential increase in invasive pests and pathogens (Haack, 2001; Wingfield *et al.*, 2008). These invasions are particularly threatening when pests and pathogens from the native range of the host tree are introduced

to environments where these trees are planted as non-natives in plantations. In such cases, the presence of a host monoculture for the pest or pathogen and a lack of their natural enemies provide favourable conditions for their rapid expansion.

In South Africa, a small natural forest resource led to the introduction of non-native tree species in the 18th and 19th Centuries. Species of *Pinus*, *Eucalyptus* and *Acacia* were thus used to establish plantations aiming to service the demand for wood and wood products (Owen & van der Zel, 2000). This led to a forestry industry based on non-native trees that occupies approximately 1% of the land surface (approximately 1.3 million ha), produces almost 18 million tons of roundwood per annum and is a major contributor to the South African economy (Godsmark, 2008). Subsequent to its establishment, the

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South African forestry industry has been increasingly plagued by invasive pests and pathogens (Wingfield *et al.*, 2008). Of these, the most serious invasive insect of pine has been the Sirex woodwasp *Sirex noctilio* F. (Siricidae: Hymenoptera).

Sirex noctilio is native to Eurasia (Spradbery & Kirk, 1978) but was accidentally introduced to the southern hemisphere, where it has become a serious pest of pine species (Hurley *et al.*, 2007) and, more recently, in the U.S.A. and Canada (Hoebeke *et al.*, 2005; de Groot *et al.*, 2007). Subsequent to its detection in South Africa in 1994, *S. noctilio* spread through three of the main forestry growing provinces. Together with its fungal symbiont *Amylostereum areolatum* (Basidiomycota), *S. noctilio* has caused extensive losses to pine, mainly in highly stocked *Pinus patula* (Pinaceae) stands planted for pulpwood (Hurley *et al.*, 2007).

In 2002, as a result of increasing infestations of *S. noctilio* in South Africa, a national committee was established with the aim of identifying and implementing appropriate control strategies for *S. noctilio*. This committee included representatives from government, private companies and landowners, as well as research organizations. An important component of the committee's strategy was to increase awareness of *S. noctilio* within the forestry community. The human dimension of forest pest disturbance, particularly how the perception and knowledge of stakeholders can influence management success, had been demonstrated in various studies (Nyeko *et al.*, 2002; McFarlane & Watson, 2008; Flint *et al.*, 2009), and a high level of awareness of *S. noctilio* was viewed as being crucially important to ensure the early detection of the pest and to obtain support for the management operations, such as the introduction of biological control agents. Efforts to promote the awareness of *S. noctilio* included information presented at conferences and field days, various forms of paper-based media, and information on the Internet. However, the impact that these initiatives have had on the knowledge and perception of *S. noctilio* (and other forestry pests) amongst members of the forestry community is unknown.

In the present study, we conducted a questionnaire using telephone interviews to examine the current perception and knowledge of *S. noctilio* and other forest pests, amongst members of the South African forestry community. Furthermore, we considered how these perceptions were influenced by the socio-demographic characteristics of the respondents. Perception in the present study was defined as 'a way of understanding or regarding something', and knowledge was defined as 'information or skills gained through experience or education; awareness gained by experience of a fact or situation' (Oxford Dictionary of Current English, 2001). We considered four key hypotheses, including: (i) knowledge of *S. noctilio* is positively correlated with knowledge of other forestry pests; (ii) perception of the importance of pests influences the basic knowledge of these pests; (iii) exposure to elements of the *S. noctilio* awareness campaign increases knowledge of *S. noctilio*; and (iv) socio-demographic characteristics of the respondents, such as job position, work experience, location, mother tongue and importance of major tree genera, influence the knowledge and perception of *S. noctilio* and forestry pests in general, as well as with respect to the *S. noctilio* awareness media that the respondents were exposed to.

Materials and methods

Survey methods and questionnaire design

The target population for the survey comprised those people involved with forestry in South Africa who, by the nature of their work, should be aware of forestry pests. This included private timber growers, contractors, plantation management, researchers and senior management. Administrative staff, nursery staff and those working in paper, pulp and saw-timber mills were excluded. The sampling framework for the target population was a list of the relevant employees supplied by companies, government and a co-operative that deals with private farmers. In addition, relevant people in the existing lists of contacts of the Institute for Commercial Forestry Research (ICFR) and the Forestry and Agricultural Biotechnology Institute were included. The complete list of people who could be contacted was not entirely comprehensive, although it provided sufficient numbers for the sample required.

After the contact list had been assembled, it was refined to exclude invalid numbers and duplicates. The final list amounted to 561 contacts. These contacts were from the main forestry provinces in South Africa, including the Western Cape, Eastern Cape, KwaZulu-Natal, Mpumalanga and Limpopo (Fig. 1). The desired sample size was a minimum of 232 (based on a desired 95% confidence limit and 5% margin of error). Sampling from the list of available contacts was random, although a minimum number of respondents were set for the provinces, namely Western Cape (9), Eastern Cape (9), KwaZulu-Natal (34), Mpumalanga (42) and Limpopo (3). This was based on the proportion of the given contacts living in that province and the importance of the province to forestry.

A questionnaire was prepared to assess the knowledge and perception regarding *S. noctilio* as well as forestry pests in general (Table 1). The questionnaire comprised six main sections: (i) questions to obtain socio-demographic information, namely job position, work experience, location, mother tongue, importance of major forestry species and presence of *S. noctilio* in the working environment; (ii) questions pertaining to general pest perception regarding importance of the impact, research and monitoring of forestry pests; (iii) questions pertaining to knowledge of some of the major forestry pests (scientific and common names were given); (iv) questions pertaining to the exposure of the respondent to different media channels that had been used to increase the awareness of *S. noctilio*; (v) questions pertaining to knowledge of *S. noctilio* (Table A1); and (vi) questions pertaining to the perception of *S. noctilio* regarding its control, impact and time required to manage the pest. The questions were preceded by a short introduction that explained the nature and importance of the survey.

The questionnaire consisted of closed questions that were either dichotomous, categorical, multiple choice or scale questions (Table 1). An exception was for the questions that called for the number of years work experience, where the actual number of years was given. Responses to scale questions were in the range from 1 to 10, where a response of one indicated the lowest and 10 the highest level of importance. Where appropriate, an option for 'Don't know' was given. The last question in the section dealing with knowledge of general forestry pests asked whether the respondent was aware of or



Figure 1 Map of South Africa, showing provinces and pine plantation distribution (in black).

had heard of *S. noctilio*. Where the response was negative, the questionnaire was terminated as the respondent would not be able to answer questions regarding their knowledge and perception of *S. noctilio*. However, the information collected concerning their knowledge and perception of forestry pests in general was still used. Thus, this question served as a qualifier to complete the remainder of the interview.

The questionnaire survey was conducted by means of telephone interviews provided by Consulta Research (South Africa). Telephone interviews offer some advantages, in that the study can be completed over a short period, substantial information can be collected within 15–30 min, there is effective sample control, ambiguities in the responses can be resolved and there is a high response rate (Churchill & Lacobucci, 2002; Proctor, 2005). Because a pre-testing of any questionnaire is vital (Churchill & Lacobucci, 2002), this was performed for five individuals who were not part of the target population. The pre-testing stage made it possible to determine the clarity of the questions, particularly concerning the pronunciation of scientific names and the length of the interview, and it ensured that the respondents had a clear understanding of the questions. The interviews were carried out from 15 to 26 June 2009.

Data editing and analysis

The data arising from the interviews were edited for errors and incomplete interviews were discarded. Interviews that contained missing fields were not considered. This excluded the interviews that terminated as a result of the qualifier question (see ‘Survey methods and questionnaire design’). Two variables were derived from the dataset. The first derived

variable indicated the number of general forestry pests known by the respondent (score out of five; considered as a categorical variable) and the other derived variable indicated the number of correct answers the respondent gave to the questions pertaining to their knowledge of *S. noctilio* (score out of 17; considered as a continuous variable). These derived variables were used in subsequent analyses to represent knowledge for general forestry pests and knowledge of *S. noctilio*, respectively.

Statistical analyses were performed using SAS, version 8.2 (SAS Institute, 2001). An analysis of variance using a generalized linear model procedure was used to examine factors that influence knowledge of *S. noctilio*, specifically socio-demographic characteristics and exposure to different awareness media, where the derived variable (knowledge of *S. noctilio*) was continuous. Logistic regression was used to examine influencing factors where the derived variable was not continuous. This included an examination of how socio-demographic characteristics influenced the response to questions pertaining to the perception of *S. noctilio*, exposure to awareness media and knowledge and perception of general forestry pests. A Kendall Tau correlation was used to examine the correlation between knowledge of *S. noctilio* and knowledge and perception of general forestry pests. Descriptive statistics (including mean, SD, SE and 95% confidence levels) were calculated to show the perception of general forestry pests and *S. noctilio*.

Variables were re-categorized for their use in the logistic regression analysis. This was based on an examination of frequency tables, where categories with low frequencies were grouped together. For the job description variable, contractors and private farmers were grouped together and those who responded as ‘other’ were categorized into an existing group,

Table 1 Summary of survey questions

Questions	Scale/categories
Socio-demographic information	
Which one of the following describes your position the best?	Six categories ^a
How many years have you been involved in forestry?	Continuous
In which province do you work or are based in for the majority of time?	Nine provinces
What is your mother tongue?	11 official languages
Indicate the importance of the following exotic tree species for your work: pine, eucalypts, wattle	Scale (1–10) ^b
Do you have <i>Sirex</i> in the area that you work in or are responsible for?	Yes/no
General pest perception	
How important do you consider the impact of forestry pests on plantation productivity in South Africa?	Scale (1–10) ^b
How important do you consider research on forestry pests for their control?	Scale (1–10) ^b
How important do you consider monitoring for the presence of forestry pests for their control?	Scale (1–10) ^b
General pest knowledge	
Which of the following forestry pests in South Africa are you aware of or have heard of: <i>Thaumastocoris peregrinus</i> , <i>Leptocybe invasa</i> , <i>Gonipterus scutellatus</i> , whitegrubs, <i>Sirex noctilio</i> ? (common names were also given)	Yes/no
Exposure to awareness media	
Were you informed of <i>Sirex</i> through: posters; pamphlets or pest cards; articles in ICFR/TPCP newsletters; internet or website; magazines or newspapers; field days; conferences; other?	Yes/no ^b
Sirex knowledge	
(Seventeen questions relating to knowledge on the identification, symptoms of attack, distribution and means of spread and control)	Multiple choice, Yes/no ^b
Sirex perception	
How important are the control measures: parasitic nematodes; parasitic wasps; plantation management?	Scale (1–10) ^b
How serious a problem is <i>Sirex</i> for forest productivity in South Africa (current and future)?	Scale (1–10) ^b
How long will it take to manage <i>Sirex</i> below economically important levels in South Africa?	Five categories ^c

^aContractor, private farmer, plantation management, researcher, senior management, other.

^bRespondants were also given the option 'Don't know'.

^cWithin the next year; within the next 5 years; more than 5 years; never; don't know.

ICFR, Institute for Commercial Forestry Research; TPCP, Tree Protection Cooperative Programme.

where appropriate, or they were discarded. Work experience was categorized as ≤ 5 years, >5 years but <20 years, and ≥ 20 years. Location was defined based on provinces where *S. noctilio* had been detected and provinces where *S. noctilio* had not been detected. For mother tongue, all languages besides English and Afrikaans were grouped together. All scale questions (1–10) were changed to a binary response, where a score of 1–7 was considered as being not very important and a score of 8–10 was considered as being very important. For the question 'How long will it take to manage *Sirex* below economically important levels', the responses were placed in two categories representing ≤ 5 years and >5 years, the later of which included the 'never' responses. Where the respondents provided a 'Don't know' response, for this as well as other questions, these responses were not included in the analyses.

Results

Socio-demographic characteristics

A total of 240 completed interviews were obtained, which gave an error level of 4.8% at a confidence level of 95%. In terms of demographic characteristics of the respondents, over half (53%) of the respondents were involved in plantation management, which included foresters, district foresters and area managers (Table 2). The remaining respondents were divided almost equally between senior management, researchers, and

private farmers and contractors. Most of the respondents had been involved in forestry for more than 5 years. Just over half (55%) of the respondents were located in a province where *S. noctilio* was present, although only 43% had *S. noctilio* in the plantation, farm or area in which they worked or for which they had responsibility. This was probably because some of the respondents residing in areas where *S. noctilio* was present were not involved in pine forestry. Afrikaans (Germanic language most closely related to Flemish and Dutch, spoken in South Africa and Namibia) was the most common language indicated as mother tongue by the respondents (46%), followed by English (32%). In total, nine of the 11 official languages of South Africa were represented as mother tongue languages of the respondents, with only isiNdebele and Setswana not being represented. Other languages included Shona (Zimbabwe and southern Mozambique), Luganda (Uganda) and German. The majority of respondents considered pine and eucalypts as being very important, and wattle as being not very important, to their work.

Knowledge and perception of general forestry pests

There was a high knowledge of general forestry pests. In this case, 94% of the respondents knew of at least three of the main forestry pests mentioned, 75% knew at least four and 45% knew all of them. *Sirex noctilio* and *Gonipterus scutellatus* (Curculionidae, Coleoptera) were the pests that were best

Table 2 Socio-demographic characteristics of sample population

Socio-demographic characteristic	Category	Percent of sample population
Job position	Private farmers/contractors ^a	15
	Plantation management	53
	Researcher	14
	Senior management	18
Work experience ^b	Five or less years	15
	More than 5 years	47
	More than 20 years	38
Location	In Sirex-infested area ^c	55
	Not in Sirex-infested area ^d	45
Mother tongue	English	32
	Afrikaans	46
	Other ^e	22
Importance of pine	Very important ^f	79
	Not very important ^g	21
Importance of eucalypts	Very important ^f	70
	Not very important ^g	30
Importance of wattle	Very important ^f	21
	Not very important ^g	79
Presence of Sirex in working area	Yes	43
	No	57

^aPrivate farmers and contractors were combined for analyses.

^bYears of work experience grouped into three categories for analyses.

^cWestern Cape, Eastern Cape, KwaZulu-Natal.

^dMpumalanga, Limpopo, Gauteng, Free State.

^eisiXhosa, isiZulu, Sepedi, Sesotho, Siswathi, Tshivenda, Xitsonga, Shona, Luganda, German.

^fScore of 1–7.

^gScore of 8–10.

known by the respondents, with 98% and 93%, respectively, of the respondents being aware of or having heard of them. Only four of the respondents (2%) had never heard of *S. noctilio* and they were therefore unable to continue with the questions pertaining to their knowledge and perception of *S. noctilio*. Whitegrubs (larvae of native Scarabaeidae, Coleoptera), *Leptocybe invasa* (Eulophidae, Hymenoptera) and *Thaumastocoris peregrinus* (Thaumastocoridae, Hemiptera) were not as well known as *S. noctilio* and *G. scutellatus*, with 77%, 74% and 70%, respectively, of the respondents being aware of or having heard of them. How important the respondents considered eucalypts for their work significantly influenced their knowledge of general forestry pests ($P = 0.02$, d.f. = 1). Thus, those respondents who considered eucalypts to be very important in their work were more likely to have a greater knowledge of general forest pests. This is probably because most of the pests mentioned in the survey were pests of eucalypts. None of the other socio-demographic characteristics significantly influenced knowledge of general forestry pests (Table 3).

The majority of respondents considered the impact of forestry pests on plantation forestry in South Africa to be very important (mean \pm SD = 8.3 ± 1.7). Research on forestry pests and monitoring for forestry pests were perceived to be very important for their control (mean \pm SD score = 9.0 ± 1.3 and 9.0 ± 1.4 , respectively). The level to which

respondents considered pine and eucalypts important to their work significantly influenced their perception of the importance of the impact of forestry pests (Table 3). Here, those who considered pine and eucalypts to be very important to their work were more likely to consider the impact of forestry pests as being very important.

The mother tongue of the respondent significantly influenced their perception on the importance of research on forestry pests (Table 3). Those whose mother tongue was Afrikaans or English were more likely to consider research on forestry pests as being very important. None of the other socio-demographic characteristics significantly influenced the perception of general forestry pests. Those who perceived research on forestry pests to be very important were more likely to have a greater knowledge of general forestry pests than those that did not consider research on forestry pests as being very important ($P = 0.04$, d.f. = 1).

Sirex awareness media

The results showed that most of the media avenues used to increase awareness of *S. noctilio* had provided a high degree of exposure (Table 4). All the different media tools, except conferences and the Internet/websites, had reached over 80% of the respondents. Only 67% of the respondents had heard of *S. noctilio* at a conference and only 51% of the respondents were informed of *S. noctilio* through the Internet/websites. Respondents also indicated they had been exposed to *S. noctilio* via e-mail, 'word of mouth', personal communication with staff of the ICFR and Tree Protection Cooperative Programme (TPCP), internal meetings/communications, studies at tertiary institutions or that they had seen *S. noctilio* themselves.

Certain socio-demographic characteristics significantly influenced whether respondents had been exposed to some of the awareness media (Table 3). Job position significantly influenced whether the respondent was exposed to *S. noctilio* through posters, pamphlets or pests identification cards and conferences. Work experience significantly influenced whether a respondent had been exposed to knowledge of *S. noctilio* through pamphlets or pest identification cards. Furthermore, the geographical location of the respondents significantly influenced whether they had been exposed to *S. noctilio* through magazines or newspapers and field days. Those involved in plantation management were more likely to have been made aware of *S. noctilio* through posters, followed by senior management, researchers, and private farmers and contractors. Private farmers and contractors, and those with the least work experience, were the least likely to have been exposed to *S. noctilio* through pamphlets or pest identification cards. Researchers were the most likely to have been exposed to *S. noctilio* at conferences and by other types of media (listed above), followed by senior management, plantation management, and private farmers and contractors. Those living in a province where *S. noctilio* was present were more likely to have been exposed to knowledge of *S. noctilio* through magazines and newspapers or at field days. The mother tongue of the respondent did not significantly influence their exposure to any of the media (Table 3).

Table 3 Influence of socio-demographic characters on perception of *Sirex noctilio*, exposure to awareness media, general pest knowledge and general pest perception

	Socio-demographic character							Presence of <i>Sirex</i> woodwasp in working area
	Job position	Work experience	Location	Home language	Importance of pine	Importance of eucalypts	Importance of wattle	
General pest knowledge	0.1	0.9	0.06	0.5	0.8	0.02*	0.1	0.8
General pest perception								
Impact of forestry pests	0.5	0.7	0.7	0.8	0.03*	0.03*	0.6	0.1
Research on forestry pests	0.6	0.2	0.4	0.04*	0.3	0.6	0.1	0.4
Monitoring of forestry pests	0.5	0.6	0.5	0.07	0.3	0.2	0.1	0.7
Exposure to awareness media								
Posters	0.003**	0.7	0.9	0.1	NA	NA	NA	NA
Pamphlets or pest cards	0.008**	0.0001***	0.8	0.1	NA	NA	NA	NA
Articles in TPCP/ICFR newsletters	0.1	0.3	0.8	0.1	NA	NA	NA	NA
Internet or website	0.2	0.4	0.9	0.9	NA	NA	NA	NA
Magazines or newspapers	0.2	0.1	0.03*	0.5	NA	NA	NA	NA
Field days	0.3	0.9	0.02*	0.3	NA	NA	NA	NA
Conferences	0.0002***	0.9	0.7	0.8	NA	NA	NA	NA
Other	0.05*	0.9	0.8	0.4	NA	NA	NA	NA
<i>Sirex</i> perception								
Importance of nematodes for control	0.4	0.4	0.4	0.9	0.02*	0.6	0.8	NA
Importance of wasps for control	0.3	0.6	0.7	0.5	0.8	0.1	0.2	NA
Importance of plantation management for control	0.01**	0.9	0.6	0.1	0.3	0.3	0.2	NA
Current threat of <i>Sirex</i>	0.2	0.9	0.08	0.3	0.004**	0.07	0.2	NA
Future threat of <i>Sirex</i>	0.05*	0.06	0.7	0.7	0.0004***	0.01**	0.2	NA
Time needed to control <i>Sirex</i>	0.03*	0.7	0.7	0.3	0.8	0.3	0.3	NA

*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

***Significant at $P < 0.001$.

Results are from logistic regression analysis, where the dependant variables were categorical.

NA, not available; ICFR, Institute for Commercial Forestry Research; TPCP, Tree Protection Cooperative Programme.

Table 4 Exposure of respondents to *Sirex noctilio* awareness media

Awareness media	Percent of sample population
Conferences	67
Field days	90
Magazines/newspapers	86
Internet/websties	51
ICFR/TPCP newsletters	89
Pamphlets/pest cards	86
Posters	84

ICFR, Institute for Commercial Forestry Research; TPCP, Tree Protection Cooperative Programme.

Knowledge and perception of *S. noctilio*

Of the 17 questions asked to assess knowledge of *S. noctilio*, the mean \pm SD number of correct answers from the respondent was 12.1 ± 3.1 (71%) (range 3–17). Most of the respondents had a basic knowledge of the trees infested by *S. noctilio* (pine) and the age of trees infested (generally above 7 years old), although knowledge regarding the identification of *S. noctilio*

and symptoms of infestation was poor (below 50% of the respondents) (Table 5). Regarding the distribution of *S. noctilio*, most respondents answered correctly that *S. noctilio* had been detected in the Western Cape, Eastern Cape and KwaZulu-Natal, and had not yet reached Limpopo. However, only 40% of the respondents answered correctly that *S. noctilio* had not been detected in Mpumalanga at the time that the survey was conducted (Table 5). Most of the respondents knew that *S. noctilio* could spread by natural flight, round wood and on wooden pallets, although only 60% of respondents knew that *S. noctilio* could not spread via the movement of bark (Table 5). Most of the respondents were aware that parasitic nematodes and plantation management were being used to control *S. noctilio* in South Africa, although less (65%) knew that parasitic wasps are also used (Table 5).

Knowledge of *S. noctilio* was significantly influenced by the job position and the mother tongue of the respondent (Table 6). Private farmers and contractors and those whose mother tongue was not Afrikaans or English had significantly less knowledge of *S. noctilio*. Exposure to *S. noctilio* awareness media significantly influenced knowledge of *S. noctilio* for all the media

Table 5 Knowledge of respondents on questions pertaining to the identification, symptoms, distribution, and means of spread and control of *Sirex noctilio*

Category	Subcategory	Percent of sample population
Control of <i>Sirex noctilio</i> by:	Plantation management	80
	Parasitic wasps	65
	Parasitic nematodes	90
Spread of <i>Sirex noctilio</i> by:	Bark	60
	Pallets	79
	Roundwood	93
	Flight	89
Presence of <i>Sirex noctilio</i> in:	Limpopo	72
	Mpumalanga	40
	KwaZulu-Natal	95
	Eastern Cape	77
	Western Cape	79
Recognizing <i>Sirex noctilio</i> infestation by:	Tree symptom	47
	Larval characteristic	42
	Wasp colour	31
	Tree age	78
	Tree species	97

except articles in ICFR/TPCP newsletters and Internet/websites, where those exposed to these media had a greater knowledge of *S. noctilio* than those who were not (Table 6). There was a significant positive correlation, although weak, between knowledge of *S. noctilio* and knowledge of general forestry pests ($r_k = 0.32$, $P < 0.0001$) (Table 7). There was no correlation between knowledge of *S. noctilio* and the perception of general forestry pests, relating to the importance of their impact, importance of research and importance of monitoring (Table 7).

Perception regarding the importance of using parasitic nematodes, parasitic wasps and plantation management to control *S. noctilio* was very high (score >8 on a scale of 1–10) (Fig. 2). The use of parasitic nematodes was, on average, perceived to be most important and the use of parasitic wasps the least important, although these differences were not significant. *Sirex noctilio* was perceived as a very serious problem for both current and future forest productivity in South Africa (score >8 on a scale of 1–10) (Fig. 2). The perceived threat to future productivity was slightly higher, although this difference was not significant. The majority of the respondents considered that *S. noctilio* would be managed below economically important levels within the next 5 years (42%) or in more than 5 years (48%). Only 3% considered that *S. noctilio* would be managed below economically important levels within the next year and only 2% considered that *S. noctilio* would never be managed below economically important levels. The remaining 5% did not know when *S. noctilio* would be managed below economically important levels.

The perception of *S. noctilio* was influenced by certain socio-demographic characteristics of the respondents (Table 3). Job position significantly influenced the perception of how important plantation management was to control *S. noctilio*, as well as the threat of *S. noctilio* to future forest productivity and the time needed to control *S. noctilio* below economically important levels. The perceived importance of plantation management was highest for plantation managers, and then for

Table 6 Factors affecting knowledge of *Sirex noctilio*

Variable	d.f.	F	P
Socio-demographic characteristics			
Job position	3	10.03	$<0.0001^{***}$
Work experience	2	2.29	0.1
Location	1	0.98	0.32
Home language	2	8.45	0.0003^{***}
Importance of pine	1	1.46	0.23
Importance of eucalypts	1	0	0.96
Importance of wattle	1	0.46	0.5
Presence of <i>Sirex</i> woodwasp in working area	1	1.48	0.23
<i>S. noctilio</i> awareness media			
Posters	1	4.18	0.042*
Pamphlets or pest cards	1	4.9	0.028*
Articles in TPCP/ICFR newsletters	1	3.72	0.055
Internet or website	1	1.05	0.31
Magazines or newspapers	1	9.89	0.0019**
Field days	1	12.25	0.0006**
Conferences	1	10.87	0.0011**
Other	1	8.33	0.0043**

*Significant $P < 0.05$.

**Significant at $P < 0.01$.

***Significant at $P < 0.001$.

Results from analysis of variance using a generalized linear model, where dependant variable was continuous.

ICFR, Institute for Commercial Forestry Research; TPCP, Tree Protection Cooperative Programme.

Table 7 Correlation between knowledge and perception of general forestry pests and knowledge of *Sirex noctilio*

	r_k	P	n
General pest knowledge	0.32	<0.0001	236
Importance of impact of forestry pests	-0.028	0.57	236
Importance of research on forestry pests	0.079	0.12	236
Importance of monitoring for presence of forestry pests	0.023	0.66	236

r_k , Kendall Tau correlation coefficient.

researchers, private farmers and contractors, and was lowest for senior management. Plantation managers were more likely to consider the threat of *S. noctilio* to future forest productivity as being very high, and this level of importance was perceived as progressively lower by private farmers and contractors, researchers and senior management. Researchers were most likely to consider that *S. noctilio* would be controlled below economically important levels in 5 years or less (68% of researchers), followed by senior management (50%), plantation management (46%), and private farmers and contractors (28%). The importance of pine in their work significantly influenced the perception of the threat of *S. noctilio* to current and future forest productivity. Those respondents who considered pine very important in their work were more likely to consider the threat of *S. noctilio* to current and future forest productivity as being very high. The importance of eucalypts in their work also significantly influenced the perception of the threat of *S.*

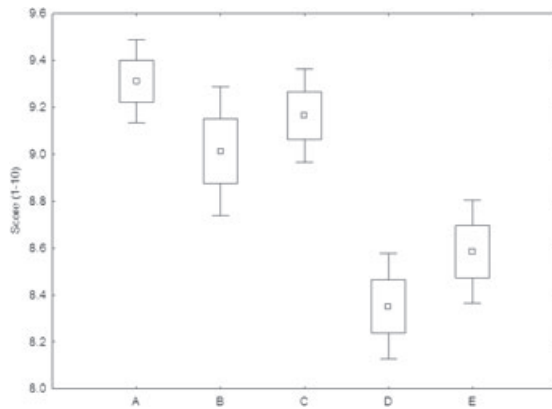


Figure 2 Perception of *Sirex noctilio*, as scored on a scale of 1–10, with one being not important and 10 being very important. (A) Importance of nematodes to control *S. noctilio*. (B) Importance of parasitic wasps to control *S. noctilio*. (C) Importance of plantation management to control *S. noctilio*. (D) Seriousness of *S. noctilio* for current forest productivity. (E) Seriousness of *S. noctilio* for future forest productivity. Small squares indicate the mean; large squares indicate the SE. Error bars show 95% confidence levels.

noctilio to future forest productivity. Thus, those respondents who considered eucalypts very important in their work were more likely to consider the threat of *S. noctilio* to future forest productivity as being very important.

Discussion

The present study examined perception and awareness (knowledge) of *S. noctilio* and general forest pests in South African forestry, as well as how these are influenced by various socio-demographic factors relevant to this community. The results obtained showed that: (i) knowledge of *S. noctilio* was positively correlated with knowledge of pests in general; (ii) perception regarding pests in general influenced knowledge of these pests; (iii) exposure to *S. noctilio* awareness media increased knowledge of *S. noctilio*; and (iv) socio-demographic characteristics influenced the knowledge and perception of *S. noctilio* and forestry pests in general, as well as the exposure to *S. noctilio* awareness media. A closer examination of the results revealed various successes and failures in efforts aiming to increase awareness of *S. noctilio* in the forestry community. They also provided useful information on how a serious pest threat and efforts to control it can influence knowledge and perception amongst members of the affected community.

Knowledge of general forestry pests and *S. noctilio*

Awareness of the most important forestry pests was relatively high, although it should have been more acute considering that the pests listed can cause serious losses. Besides *S. noctilio*, *G. scutellatus* was the pest about which most respondents were aware. *Gonipterus scutellatus* is an invasive pest of *Eucalyptus*, native to Australia, which was first detected in South Africa in 1916 (Tooke, 1955). Its presence as a serious pest of various *Eucalyptus* species for almost 100 years in South Africa

explains why this insect was very well known. *Thaumastocoris peregrinus* and *L. invasa* are also serious invasive pests of *Eucalyptus* spp., although their appearance in South Africa is much more recent, which probably explains why these pests were not as well known as *G. scutellatus*. *Thaumastocoris peregrinus* was first detected in South Africa in 2003, and on plantation *Eucalyptus* in 2005 (Jacobs & Nesser, 2005; Nadel *et al.*, 2010), and *L. invasa* was first detected in 2007, and on plantation *Eucalyptus* in 2009 (B.P. Hurley, personal communication). Whitegrubs are larvae of native Scarabaeidae beetles and are pests of various plants, including forestry species (Govender, 2007). Insecticides can be used to control whitegrubs, which has possibly reduced the pest status and awareness of these insects.

Almost all respondents were aware of *S. noctilio*. This included people from different geographical locations, with differing work experience and home languages, as well as different attitudes regarding the importance of pine in their work environment. This can probably be attributed to the major economic threat that *S. noctilio* poses for forestry in South Africa (Hurley *et al.*, 2007). Consequently, the publicity that it has received in media, such as those forms considered in the present study, including posters and pamphlets, field days, as well as word of mouth and other media, has been a vehicle for disseminating information.

Although awareness of *S. noctilio* was very high, there was a low basic knowledge regarding the characteristics needed to identify the insect and symptoms associated with its damage. It is important that those involved in forestry are able to identify *S. noctilio* and its symptoms to ensure the early detection of *S. noctilio* in new areas of infestation. This will ensure that management strategies can be established when the population of the insect is still low (Haugen *et al.*, 1990). Clearly, future efforts to disseminate information regarding *S. noctilio* will need to focus on the identification of the insect and symptoms associated with infestation.

Parasitic wasps have been used to a lesser extent than parasitic nematodes to manage *S. noctilio* populations. This probably explains why control based on the use of these parasitoids was less well known. The confusion surrounding the current distribution of *S. noctilio* was to be expected because *S. noctilio* had been detected on the border of Mpumalanga at the time of the survey. This explains why many of the respondents assumed that *S. noctilio* was already in that Province. A lack of accurate knowledge regarding the distribution of the insect can, however, affect the spread of the insect if people move infested wood because they perceive the insect to already be present in an area. This is a matter that will require attention in the future.

Perception of forestry pests and how this influences general pest knowledge

The impact that forestry pests have on plantation productivity, as well as the importance of research and monitoring aimed at their control, was perceived as being very important. This reflects the seriousness of pest infestations in South African plantation forestry. *Sirex noctilio* alone was estimated to result in approximately R300 million losses per annum to the forestry

industry during its peak in the KwaZulu-Natal province (Hurley *et al.*, 2007). Infestations of *G. scutellatus* are increasing. *Thaumastocoris peregrinus* has spread rapidly through South Africa and is now considered one of the main pests of *Eucalyptus* (Nadel *et al.*, 2010). Similarly, *L. invasa*, although only recently detected in plantations, poses a serious threat to *Eucalyptus* forestry. Three of these invasive pests have been detected in the last 15 years and there is evidence that the rate of appearance of new invasive pests is increasing with time (Wingfield *et al.*, 2008). The seriousness of native pest infestations is also increasing with the cossid moth *Coryphodema tristis* (Cossidae, Lepidoptera) causing extensive losses of *E. nitens* (Gebeyehu *et al.*, 2005; Boreham, 2006). Infestations of these pests are particularly serious because, in most cases, effective control measures are not available.

The perception that people have of pests can influence their knowledge of pests in general. The present study has shown that those respondents who perceived research on forestry pests and their control to be very important had a better knowledge of forestry pests. This influence was, however, only marginally significant and the perception of the impact of forestry pests and monitoring aimed at controlling them did not significantly influence general pest knowledge.

Exposure to S. noctilio awareness media

Awareness campaigns provide an effective means of supporting the management of pests and sharing information regarding their impact (García-Llorente *et al.*, 2008). For example, Heong *et al.* (1998, 2008) showed how different forms of communication, including radio broadcasts, information posters and leaflets, can be used effectively to alter management practices. The results of the present study suggest that the media used to increase awareness of *S. noctilio* has largely been effective in reaching members of the forestry community and also significantly increased knowledge of the pest. In particular, posters, pamphlets/pest identification cards, ICFR/TPCP newsletters, and magazines and newspaper articles have all had a high level of penetration into the forestry community and effectively increased knowledge of *S. noctilio*.

Conferences and the Internet or websites were the least effective media for informing people about *S. noctilio*. Conferences are generally not attended by members of all sectors of the forestry community and only a limited number of people can attend these meetings as a result of restricted costs and time constraints. The poor reach of the Internet or websites in promoting awareness of *S. noctilio* is possibly a result of many members of the forestry community not having frequent access to the Internet. Furthermore, at the time of the survey, there was no website that provided a good source of information on *S. noctilio*. Although online advertising in South Africa recorded the fastest growth rate from all English-language countries in 2008, there is still a very slow growth in Internet access, with only 8% of the population estimated to have Internet connection in 2007 (<http://www.worldwideworx.com>). An informative website on *S. noctilio* has recently been developed that is specifically targeted at the forestry community in South Africa (<http://www.icfr.ukzn.ac.za/collaboration/sirex>). This is expected to increase knowledge of *S. noctilio* among those that

have Internet connections, although it will not assist those people without access to the Internet.

A medium to promote knowledge of *S. noctilio* that could be very successful is the mobile phone. The use of mobile phones is increasing globally, including in Africa, and they are replacing land lines as the preferred means of communication (Hodge, 2005). Most people in South Africa have a mobile phone (Esselaar & Stork, 2005), and penetration using this medium will be high. Forms of communication will be much more limited, although potentially simple alerts with attached images could be dispatched, with the recipient directed to a contact number or website for more information should they suspect the presence of the pest in their area. This could be particularly useful in monitoring the spread of newly-discovered pests.

Influence of socio-demographic characteristics

The influence of socio-demographic characteristics on the knowledge and perception of pests and other invasive species has been clearly shown in various studies (Nyeko *et al.*, 2002; McFarlane *et al.*, 2006; García-Llorente *et al.*, 2008; Obopile *et al.*, 2008; Chang *et al.*, 2009). The influence of socio-demographic characteristics on the exposure to awareness media is also important because such media make it possible to develop the knowledge and perception of a problem amongst members of a given community. This survey exposed the negative issue of private farmers and contractors having the least exposure to awareness media and the lowest knowledge of *S. noctilio*. This was not a result of the importance of pine to these farmers and contractors because this variable was not found to significantly influence exposure to awareness media or knowledge of *S. noctilio*. Rather, it appears that the media used to promote awareness regarding *S. noctilio* have not penetrated this sector of the forestry community as successfully as others, and this has resulted in the lower level of knowledge regarding *S. noctilio*.

Posters, pamphlets/pest identification cards and conferences were the particular media that failed to reach private farmers and contractors effectively. This weakness will need to be addressed in the future. The forestry sector in South Africa is currently undergoing significant and government-supported transformation (<http://www2.dwaf.gov.za/webapp/ProjectsBBBEE.aspx>), which will continue to increase private ownership. The lack of awareness in this sector evident from this survey is consequently of particular concern.

Respondents to this survey whose mother tongue was neither English nor Afrikaans had a lower level of knowledge concerning *S. noctilio*. Furthermore, they considered the importance of research for the control of forestry pests as being less important than those whose mother tongue was English or Afrikaans. The lower level of knowledge regarding *S. noctilio* was not a result of the awareness media having been in English or Afrikaans because the mother tongue did not significantly influence exposure to awareness media. This result might at least partially be explained by the higher percentage of private farmers and contractors who were included in this group of respondents (Table 8). Furthermore, the surveys were conducted in English with an option for Afrikaans but not for the other languages spoken in South Africa, and this could have

Table 8 Division of mother tongue groups by percentage of different job opportunities represented in each group

	Contractor/ private (%)	Plantation management (%)	Researcher (%)	Senior management (%)	All (%)
Afrikaans	10	63	8	19	100
English	17	36	26	21	100
Other	23	60	8	9	100

influenced how well the questions pertaining to knowledge of *S. noctilio* were understood. The reason why this group considered research for the control of forestry pests to be less important is unclear, and this difference was only marginally significant. The future transformation of ownership in the South African forestry industry will increase the number of non-English and non-Afrikaans speaking people owning plantations. Thus, home language will need to be more carefully considered in future awareness campaigns.

Four of the five pests mentioned in the general pest knowledge section of the questionnaire were pests of *Eucalyptus*. This explains why those respondents who considered *Eucalyptus* as being very important in their work scored a higher knowledge of general forestry pests. These four pests and *S. noctilio*, which attack pine, have a serious impact on forest productivity (see 'Perception of forestry pests and how this influences general pest knowledge'). This then explains why the impact of forestry pests was perceived as higher by those who considered eucalypts and pine as being very important in their work. The importance of wattle did not influence the perception of forestry pests in general. This was possibly because insect pests on wattle do not currently pose as serious a threat as those on pine and eucalypts. Not unexpectedly, those respondents who considered pine as being very important also perceived the use of parasitic nematodes as biological control agents and the threat of *S. noctilio* as being very important.

Interestingly, geographical location of respondents did not influence perception or knowledge of forestry pests in general or *S. noctilio*. It was anticipated that the perception and knowledge of *S. noctilio* would differ between areas where *S. noctilio* is present and those where the pest is absent, although this was not the case. This is in contrast to the study of McFarlane *et al.* (2006), where members of the public living near the mountain pine beetle [*Dendroctonus ponderosae* (Curculionidae, Coleoptera)] outbreaks had a more informed view of the pest and were also more likely to support efforts to control it. The lack of a location effect on the knowledge and perception of *S. noctilio* is probably a result of it being a national threat to forestry, as well as efforts having been made to distribute information to all forestry areas.

Conclusions

The South African forestry community regards the threat of *S. noctilio* and other forestry pests, as well as the need to control them, as being extremely important. The national programme to increase the awareness of *S. noctilio* amongst members of the forestry community has largely been effective in increasing knowledge of the pest. This will consequently increase chances of early detection of *S. noctilio* in new areas of infestation and increase the support for management operations. This result

demonstrates the value of a nationally co-ordinated awareness campaign.

Where the awareness campaign failed was in its ability to reach private farmers and contractors. This demonstrates the affect that a fragmented and diverse forestry community poses for communication, and therefore pest management. Pest management in the future will need to consider more effective means of communication aiming to effectively reach all the sectors of the forestry community. The diversity of languages spoken amongst the target group also needs to be considered and there could be value in conducting research to better understand this and other aspects of the target group.

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Appendix

Table A1 Questions on *Sirex* knowledge

Questions	Scale/categories
Which tree is attacked by the <i>Sirex</i> woodwasp in South Africa?	Multiple choice
What age trees are attacked by the <i>Sirex</i> woodwasp in South Africa?	Multiple choice
What colour is the body of the <i>Sirex</i> female wasp?	Multiple choice
What is the distinguishing characteristic of the <i>Sirex</i> larva?	Multiple choice
Which one of the following is not correct? A tree attacked by the <i>Sirex</i> woodwasp can show the following symptoms?	Yes/no
Indicate with a yes or no, in which pine-growing provinces the <i>Sirex</i> woodwasp has been detected.	Yes/no (five options/questions)
Indicate with a yes or no, in what ways can <i>Sirex</i> spread to other areas.	Yes/no (four options/questions)
Are you aware of parasitic nematodes used to control the <i>Sirex</i> woodwasp in South Africa?	Yes/no
Are you aware of plantation management used to control the <i>Sirex</i> woodwasp in South Africa?	Yes/no
Are you aware of parasitic wasps used to control the <i>Sirex</i> woodwasp in South Africa?	Yes/no