



Lessons from a major pest invasion: The polyphagous shot hole borer in South Africa

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The arrival and establishment of invasive forest pests can cause devastating environmental damage and great economic impact. For example, the cost over the past decade of dealing with the arrival of a single invasive beetle in the USA, the emerald ash borer (*Agrilus planipennis*), is estimated at more than USD10 billion.¹ Originating from Asia, this beetle has killed hundreds of millions of native ash trees since it became established in the USA. However, this beetle is but one of hundreds of invasive insect pests that impact forests in the USA, and that contribute to a global tree health crisis caused by invasive insects and pathogenic microorganisms.²⁻⁴

South Africa is no different from other countries and is experiencing an increasing rate of introductions of damaging forest pests.^{5,6} These invasions are largely unintentional and are a by-product of globalisation and increasing global trade.^{7,8} The movement of living plants and plant products, including untreated wood packaging materials (i.e. pallets, dunnage and crating), is known to be a major pathway for these pests.^{9,10} For clarification, in this commentary we use the terms 'insect' and 'pathogen' to distinguish between the two types of organisms, although we also use the general term 'pest' to refer to both groups. The term 'invasive pest' is used for introduced species that, in addition to maintaining a self-sustaining population, show evidence of spread and impact.

Millions of years of co-evolution between plants and their pests has led to close ecological dependencies. Damaging outbreaks of native pests in their natural environments are rare; instead, pests play a vital role in shaping the dynamics and diversity of natural ecosystems.¹¹ For this reason, forest pests are often not known to be problematic, or not even known to science, prior to their arrival and establishment in a non-native environment. However, on their arrival, alien pests may encounter suitable native hosts that lack co-evolved resistance, with the potential for devastating consequences. Well-known examples in addition to that of the emerald ash borer in the USA, include chestnut blight (caused by *Cryphonectria parasitica*) in the USA and Europe, and *Phytophthora cinnamomi* in southwest Australia.^{1,12,13} These pests and others have fundamentally altered ecosystems, with entire tree species being practically eliminated from invaded landscapes. In addition to these dramatic changes in forest canopy composition, wide-ranging ecological impacts may result following these invasions. These impacts include significantly altered species richness and abundance, and the loss of important ecosystem services.¹⁴

The International Plant Protection Convention provides for the protection against invasive pests through the International Standards for Phytosanitary Measures. These measures are acknowledged by the Agreement on the Application of Sanitary and Phytosanitary Measures of the World Trade Organisation.¹⁵ Under current protocols, Pest Risk Analysis is the mechanism by which an organism can be recognised as a potential threat that requires regulation. An important issue arises: in order for an organism to be subject to regulation, it must be named and known to be harmful. In addition, phytosanitary inspections (by both exporting and importing countries) are typically visual, and therefore inadequate for detecting asymptomatic infections or infestations.¹⁶ Consequently, these pests have the potential to avoid interception at check points.¹⁷

Given the shortfalls in current biosecurity regulations, there has been a move to use sentinel trees (trees planted outside of their natural range) to identify new and emerging pest risks.¹⁸ As hubs of human movement and traded goods, urban areas are frequently the first point of contact for alien pests.^{19,20} Therefore, when located in urban environments, monitoring of sentinel trees also provides an opportunity for early detection of recently arrived pests.¹⁷

A sentinel project supported by the South African National Biodiversity Institute was initiated in 2016. In 2017, this project led to the discovery of the polyphagous shot hole borer (PSHB, *Euwallacea fornicatus*) in a national botanical garden in the country.²¹ A tiny ambrosia beetle, 2 mm in length and native to Southeast Asia²², the PSHB has a symbiotic relationship with three species of fungi, including the tree pathogen *Fusarium euwallaceae*. This fungus provides a food source for the beetle and its larvae, but, in susceptible trees, it kills the vascular tissue, causing branch die-back and tree death.

Since its initial discovery, the PSHB has spread rapidly. The beetle is now well established in South Africa, with its presence currently confirmed in all provinces except Limpopo. Worryingly, its host list also continues to grow. Over 100 tree species have been attacked in South Africa.²³ Not all of these are threatened with rapid death. Usually only trees in which the beetle is able to breed – so-called 'reproductive hosts' – are in immediate danger. To date, 36 host species (including exotic and indigenous trees) have been found to support PSHB reproduction in South Africa. This number will continue to grow as the beetle spreads to new areas and encounters new hosts. Importantly, some 'non-reproductive' hosts may become reproductive under certain environmental conditions. This makes compiling host lists problematic and the outcome of infestation difficult to predict.

The greatest impact of the PSHB invasion observed to date has been in urban environments. These, for example, include the outbreaks in Johannesburg, George and Knysna. A similar situation has been observed in two other countries invaded by the PSHB – the USA (California) and Israel^{24,25} – where the PSHB went on to emerge as a damaging pest to the avocado industry and trees in natural ecosystems. For this reason, there is concern regarding the possible impacts that the PSHB will have on economically important tree crops including avocados and plantation acacias in South Africa. But the threat to natural ecosystems is the most worrying. There are already indications that indigenous tree species at the fringes of infested urbanised areas are susceptible to PSHB infestation.



Shot hole borer beetles can be seen in the gallery of this tree.

Nearly three years have passed since the detection and reporting of what is arguably the most damaging tree pest to ever arrive in South Africa. An invasion of this magnitude should have elicited a rapid response and the development of a strategic action plan. However, South Africa has never before had to deal with a tree-killing pest of this importance. Moreover, with limited resources available and confusion regarding which government department should take responsibility, a coordinated response has failed to emerge.

In South Africa, the management of agricultural pests falls under the Department of Agriculture, Land Reform and Rural Development (DALRRD), specifically Plant Health Early Warning Systems. Where a pest is deemed an 'emergency plant pest' (EPP), the South African EPP Response Plan provides for a rapid response to prevent establishment and spread, and coordination of communication between government agencies, academia and plant industry professionals.²⁶ A second piece of legislation, the *South African National Environmental Management: Biodiversity Act (NEMBA, Act 10 of 2004)* Alien and Invasive Species Regulations, provides for the listing of invasive alien species that threaten biodiversity.²⁷ This Act is overseen by the Department of Environment, Forestry and Fisheries (DEFF), and contains explicit guidelines for the development of monitoring, control and eradication plans.

The PSHB presents a unique challenge in that it crosses boundaries between agriculture, commercial forestry, natural forests and urban trees.²⁸ It has been detected on backyard avocado trees and roadside weedy acacias, but not yet in commercial avocado orchards or plantation forests. The only commercial crop on which PSHB has been detected to date is pecan, although early indications suggest the impact to this tree species may not be high. The PSHB has not yet been declared an agricultural EPP and no formal response has been triggered. This may be a consequence of the PSHB not yet appearing as a pest in commercial settings.

Similar challenges have been encountered in regard to listing PSHB under NEMBA. Despite submission (in November 2018) of a detailed pest risk analysis, the process by which listing is facilitated, its addition to the NEMBA list is yet to be finalised. Perhaps the lack of empirical evidence for the impact of the PSHB in natural ecosystems resulted in a reluctance on the part of the then Department of Environment Affairs to take full responsibility for the management of this pest. The recent relocation of the Forestry portfolio from the previous Department of Agriculture, Forestry and Fisheries to the now combined Department of Environment, Forestry and Fisheries may resolve this matter, as two portfolios which are threatened by this pest, now reside in the one department.

The major impact of the PSHB has been in urban environments, which leads to the question of where the responsibility for management of urban forests lies. In terms of government policy, urban forestry is mentioned briefly in the Forestry White Paper, prepared in 1996 by the then Department of Water Affairs and Forestry.²⁹ The National Forestry Action Programme³⁰ also provides for some recognition of urban forestry. Despite the existence of these policies, it seems urban forestry is poorly represented in South Africa, and a dedicated research and advocacy focus is lacking.³¹ Consequently, in the absence of a national strategy and with no clear structure in place to guide their response, most municipalities have understandably struggled to adequately manage this threat to the urban forest.

There is also the complication of understanding the extent to which local governments are responsible for urban forests within their municipalities. For example, a Public Road and Miscellaneous By-law gazetted by the City of Johannesburg Metropolitan Municipality forbids any damage to trees on any public road within the municipality (no lop, top, trim, cut down or removal of such trees) without prior written permission of the Council.³² Realistically, however, urban forestry is likely a low priority for local government in urban areas, where issues such as the provision of housing, potable water, sanitation and other services remain priorities.³¹ Given the limited financial resources available to local government to manage urban forest issues, there is a clear need for leadership and support from national government.

Dealing with the arrival of damaging invasive forest pests is challenging anywhere in the world. Australia, a country associated with a strong stance on biosecurity, is still grappling to provide a coordinated government response to the myrtle rust incursion, 7 years later.³³ It is perhaps not surprising, given the challenging nature of dealing with such incursions, that the listing of the PSHB and the development of a national strategy for response to this pest has not yet occurred. But this delay has not been without consequence.

In the absence of a nationally coordinated strategy, and without strong stakeholder and public engagement, a vacuum has been allowed to develop. This vacuum has provided a space in which opportunists could appear, ready to tout expensive and unproven treatments as the solution. It has also resulted in the public being exposed to conflicting messages, leading to confusion as to the most appropriate action to take in response to infestations. In the meantime, the beetle has continued to multiply and spread unchecked across the country.

Experiences from California, Israel, and South Africa indicate that the management of the PSHB is particularly challenging. This is largely due to its inbreeding mating system, wide host range, and ability to survive in felled wood for many months. Heavily infested reproductive hosts become 'reservoirs' of beetles, threatening the health of adjacent trees. Therefore, current best practice recommends removal of heavily infested trees in which beetles are breeding. Infested wood should be disposed of appropriately at designated dumping sites. Applying sanitation treatments such as chipping, composting, solarising or kiln-drying infested wood will greatly reduce the risk of further spread of the PSHB to new environments.³⁴

Treatment trials conducted in California suggest chemical control may have an application in protecting individual high-value trees. But this should not be seen as a 'silver bullet' for the problem. Ambrosia beetles (such as the PSHB) have cryptic habits and are notoriously difficult to control using pesticides. They spend little time on the tree surface and only ingest small amounts of wood, limiting their contact with pesticides.³⁵ In addition, research from California suggests treatments may only be effective when applied either as a preventative measure or during the very early stages of infestation.^{35,36} The duration of therapeutic effects following pesticide application are finite, with repeated applications required over time. Therefore, cultural practices such as removing dead and dying trees and the sanitation of infested wood remain the most important management tools.

The development of a consolidated national management strategy and action plan for the PSHB is crucially important. This strategy should be prepared in conjunction with strong stakeholder engagement, and intergovernmental coordination between the relevant government departments (DALRRD and DEFF) must be ensured. A well-coordinated public awareness campaign informing local government, residents and stakeholder groups about the beetle and its impact must be an essential component of this strategy. Municipalities should be encouraged and supported to remove and destroy heavily infested reproductive host trees. Staff from affected sectors (including private, municipal, provincial and national parks and gardens, and landscaping, nursery, tree felling, farming and forestry industries) need to be trained to identify and appropriately handle PSHB-infested material. There should be a strong emphasis on the dangers of moving untreated infested wood, and best



management practices for disposal of infested wood must be developed and promoted.

In the USA, campaigns such as 'Buy it where you burn it' have been strongly promoted to educate the public about the risk of movement of invasive forest pests by long distance transport of wood. The campaign promotes the local buying and burning of wood to limit the movement of firewood. While this campaign has been effective to some degree in the USA, managing the movement of wood in South Africa may prove more challenging. Within South Africa, the informal urban firewood trade is widespread and provides an important energy source and income security for many poorer urban residents.³⁷ The movement of infested wood through informal trade will be an important pathway of internal spread of the PSHB. However, managing this pathway has the potential to impact traders directly (through loss of access to harvestable wood), as well as to impact those who rely on this wood for cooking and heating. Careful consideration will need to be given to this issue.

The Forestry and Agricultural Biotechnology Institute of the University of Pretoria, where the PSHB invasion was first recognised, has initiated numerous baseline studies on the pest. But these have largely been restricted to surveillance and monitoring. Importantly, a multidisciplinary and multi-institutional Polyphagous Shot Hole Borer Research Network has recently been established to extend work on the pest. The network will coordinate research efforts undertaken by researchers from various institutions across the country. Current projects are investigating invasions in urban, agriculture and natural areas, and the search for a biological control agent will soon be initiated. Key to this network is a cross-sector collaborative approach. Now with funding made available by DEFF, further studies can be conducted under the framework of this network to underpin science and knowledge-based advice and policy processes.

While we hope that South Africa will never again have to see the arrival of a pest as damaging as the PSHB, the reality is that there seems to be no end to the accumulation of alien species worldwide.^{38,39} Of note is that we find ourselves in this, the International Year of Plant Health, facing a global threat to human health due to the COVID-19 pandemic. Many parallels can be drawn between the emergence of novel diseases of humans and invasions by forest pests. Not least of these is that they are both largely a consequence of human activities. There is strong evidence linking the role of anthropogenic disturbance as a major driver of emerging infectious diseases of both humans and forests. Moreover, the unprecedented level of global connectedness via trade and travel networks, facilitates the rapid spread of pathogens responsible for human and tree disease pandemics more than ever before.^{40,41} There is a very strong economic case for investing in strategies to reduce the threat posed by future pandemics to both human and forest health. It is clear that we require a greater capacity to predict, prevent and respond to emerging infectious diseases and forest pest invasions, and cross-disciplinary and global collaboration will enhance our ability to achieve this goal.⁴⁰⁻⁴²

We would do well to seriously reflect on the shortcomings of how we as a country have responded to the arrival of the PSHB and learn from them. Importantly, South Africa needs to be able to deal with new invasions more effectively in the future.

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