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Review article

Current status of the small hive beetle *Aethina tumida* in Latin America

N. Bulacio Cagnolo[1,2], P. Aldea-Sánchez[2,3], B. Branchiccela[2,4], R. A. Calderón-Fallas[2,5], L. A. Medina-Medina[2,6], M. A. Palacio[2,7], R. Velarde[2], E. W. Teixeira[2,8], and K. Antúnez[2,9]

[1] Instituto de Investigación de La Cadena Láctea (INTA-CONICET), Ruta 34, Km 227, Rafaela, Santa Fe, Argentina
[2] Sociedad Latinoamericana de Investigación en Abejas (SOLATINA), Montevideo, Uruguay
[3] Facultad de Ciencias de La Salud, Universidad SEK, Instituto de Investigación Interdisciplinar en Ciencias Biomédicas SEK, Santiago, Chile
[4] Sección Apicultura. Instituto Nacional de Investigación Agropecuaria, Colonia Uruguay
[5] Centro de Investigaciones Apícolas Tropicales, Programa Integrado de Patología Apícola, Universidad Nacional, Heredia, Costa Rica
[6] Departamento de Apicultura, Universidad Autónoma de Yucatán, Campus de Ciencias Biológicas Y Agropecuarias, Mérida, Yucatán, Mexico
[7] Fac. de Ciencias Agrarias, Instituto Nacional de Tecnología Agropecuaria INTA- PROAPI. EEA Balcarce Universidad Nacional de Mar del Plata. Balcarce, Buenos Aires, Argentina
[8] Laboratório Regional de Pesquisa Em Sanidade Apícola (LASA), Secretaria de Agricultura E Abastecimento, Instituto Biológico, Agência Paulista de Tecnologia Dos Agronegócios (APTA), São Paulo, Brazil
[9] Laboratorio de Microbiología y Salud de Las Abejas, Departamento de Microbiología, Instituto de Investigaciones Biológicas Clemente Estable, Montevideo, Uruguay

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Abstract – The small hive beetle (SHB), *Aethina tumida*, is a parasitic pest and scavenger of social bees native to sub-Saharan Africa. It is a generalist species which can also reproduce in association with nests of stingless bees, fruits, and even rotten meat. Although in its native range, it usually does not cause severe damage to strong colonies and nests; it has invaded new areas worldwide, causing significant economic losses to social bees in some locations. Here, we present an overview of the current situation of SHB invasion into Latin America by describing its distribution, its impact on beekeeping and the commercialization of bee products, and its potential risk to native bees. In addition, we discuss the strategies carried out in different countries to manage or prevent its entrance and spread. Our findings highlight the need for further research efforts aimed at filling gaps in our understanding of the dynamics of SHB invasions in Latin America, their sources, and trajectories. By contrasting the experiences in countries in which preemptive and preventive measures were taken with countries in which they were not, we conclude that taking such measures has a positive impact on managing SHB invasions. Late notifications of SHB presence in some countries made it difficult to identify SHB dispersal routes and enabling factors. Interactions of SHB with different honey bee and native bee populations remain under-studied, and research on these interactions will determine the severity of SHB as a pest in the region. Latin America offers a dynamic and diverse environment for studying SHB and its interaction with bees.

***Aethina tumida* / invasive pest / honey bee / Latin America**

Corresponding author: N. Bulacio Cagnolo,
bulacio.natalia@inta.gob.ar
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1. INTRODUCTION

International trade of honey bees and their products has negatively impacted honey bee health due to the introduction of exotic pests and parasites, which spread rapidly within a region or country. Exotic pests and parasites often have the capability to switch hosts, thus posing new threats to native species. An example of such an invasive species is the small hive beetle (SHB) *Aethina tumida* Murray 1867 (Coleoptera: Nitidulidae), a parasite and scavenger of Western honey bees, *Apis mellifera*, originally described as endemic to sub-Saharan Africa (Lundie 1940; Neumann and Elzen 2004). Besides honey bees, SHBs can also parasitize other groups of bees, such as stingless bees (Apidae: Meliponini) (Lóriga Peña et al. 2014; Nacko et al. 2020; Pereira et al. 2021), bumblebees (*Bombus* spp.) (Hoffmann et al. 2008), and solitary bees (Gonthier et al. 2019). Furthermore, the beetle can feed and complete its life cycle on alternate plant hosts, including fruit crops such as melon, avocado, mango, and orange (Neumann and Elzen 2004; Buchholz et al. 2008; Arbogast et al. 2010). A recent study showed that SHBs could also feed on flowers (Gonthier et al. 2019).

The SHB has spread to new locations worldwide, aided by the global honey bee trade. In particular, the wax trade has been shown to be a major driving force behind its spread (Idrissou et al. 2019). Currently, SHB is colonizing territories outside its native range on almost every continent (Neumann et al. 2016). The SHB has been reported in the USA (Elzen et al. 1999), Egypt (Mostafa and Williams 2002), Canada (Lounsberry et al. 2010), Portugal (Da Silva 2014), Italy (Mutinelli et al. 2014; Granato et al. 2017), The Philippines (Cleofas et al. 2016), Korea (Lee et al. 2017), Mauritius (Muli et al. 2018), Australia (Animal Health Australia 2003), China (Zhao et al. 2020; Liu et al. 2021), and La Reunion (Arrêté préfectoral N° SALIMPSPAE-2022–965-D-2). The SHB was first reported in Latin America (LA) in 2005, and has since invaded several countries in the region (Genaro 2008; Calderón et al. 2015; Neumann et al. 2016; Toufailia et al. 2017; Ramirez and Calderón 2018). Here, we present the first comprehensive account of SHB invasion into Latin American countries, its current distribution in honey bees in the region, its impact on beekeeping and the commercialization of hive products, and its potential as a threat to native bees including bumble bees, stingless bees and solitary bees. Finally, we describe the strategies carried out in different LA countries to prevent SHB entry and spread.

2. CURRENT SITUATION OF *A. TUMIDA* IN LATIN AMERICA

Timely reports of *A. tumida* in different countries are important to alert sanitary authorities and beekeepers, and to establish monitoring programs aimed at preventing dispersal into neighboring areas or countries. Using World Organization for Animal Health (OIE) reports, communications with national sanitary authorities, local reports, and regional and country level published studies, we describe here chronologically, and by country, the approximate trajectories of SHB invasions. Finally, we use all this information to provide a map that outlines the current distribution of *A. tumida* in Latin America (Figure 1).

2.1. SHB in Jamaica

The first report of SHB in LA dates from 2005 in Jamaica (Food and Environment Research Agency (FERA) 2010; OIE 2016a). There is no information about the extent and characteristics of this outbreak or if any containment measures were taken, probably because the pest only became a notifiable disease to the OIE a year later, in 2006. Semestral reports submitted to OIE from 2016 to 2018 indicated the presence of the scavenger in managed bees, and between 2017 and 2018 its presence was also reported in feral bees (i.e., OIE 2016b). The only measures taken as described in those reports were "restrictions of movement, border precautions and routine surveillance." However, there is no information regarding to what extent those measures are implemented today on the ground.

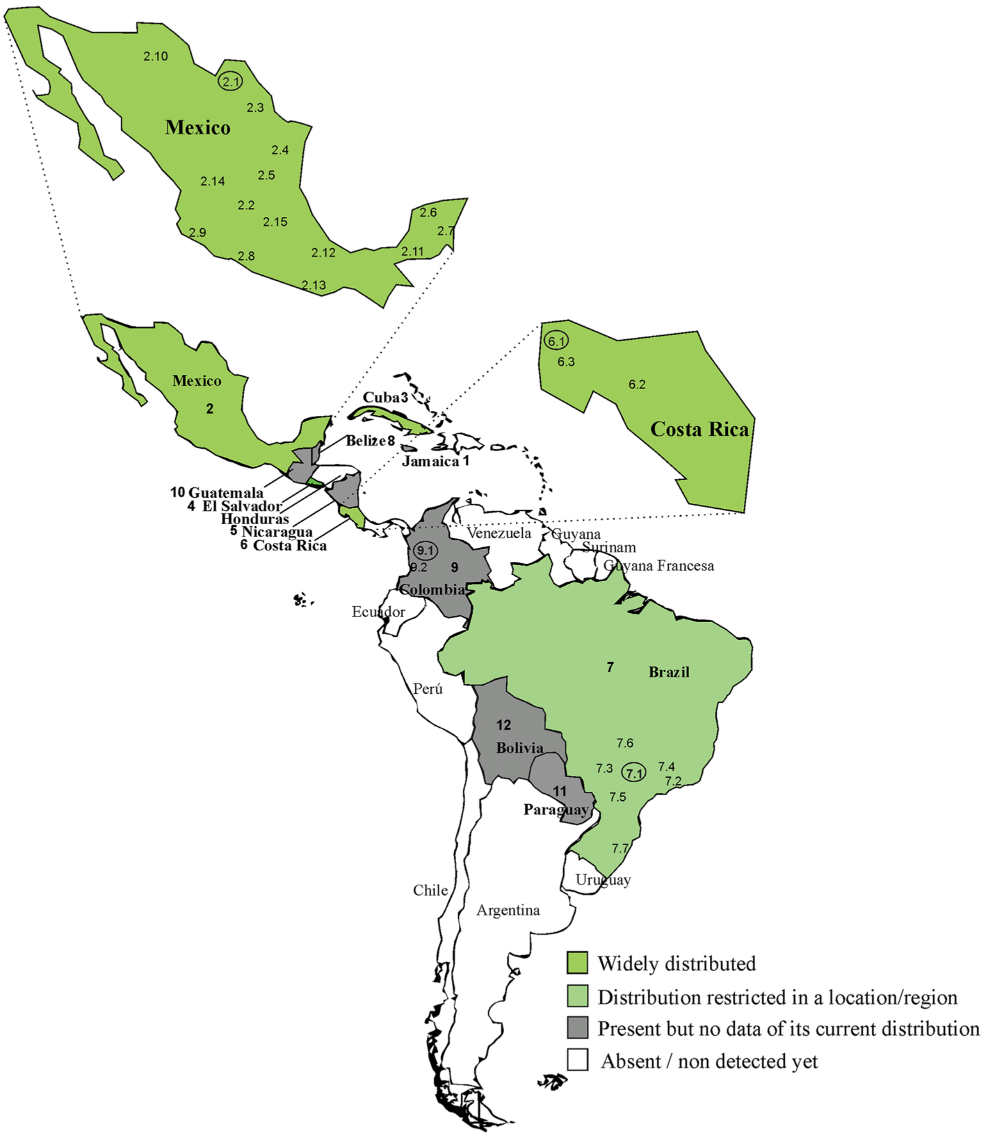

Figure 1. Political map showing the distribution of *Aethina tumida* in Latin America up to November 2022. The SHB introductions in each country are shown in chronological order: (1) Jamaica (2005) (FERA 2010; OIE 2016a); (2) Mexico (2007) (OIE 2007); (3) Cuba (2012) (OIE 2012); (4) El Salvador (2013) (OIE 2013); (5) Nicaragua (2014) (Calderón et al. 2015; OIE 2014b; c); (6) Costa Rica (2015) (OIE 2015b); (7) Brazil (2015) (OIE 2016c); (8) Belize (2016) (OIE 2016b); (9) Colombia (2020) (OIE 2020a); (10) Guatemala (2020) (García-Ochaeta 2020); (11) Paraguay (2022) (OIE 2022a, b, c); (12) Bolivia (2022) (OIE 2022c). The countries in bold refers to those where the SHB has been reported. The circled numbers refers to the first location where the SHB was reported in the country, and the following reports are indicated in chronological order. An amplification of Mexico and Costa Rica are shown to follow its dispersal in detail.

2.2. SHB in Mexico

In 2007, the SHB was detected in Africanized honey bee (AHB) colonies in Coahuila, Mexico, in an apiary near the border with the USA (OIE 2007). This apiary was immediately eliminated, and the beetle was assumed to have been eradicated. However, it was later detected in 2008 in Guanajuato and in 2010 in Nuevo Leon and Tamaulipas. Considering the containment measures taken at the focal point of detection, the low colony density of this region (≤ 0.1 colonies/km^2) (SIAP-SADER 2022) and that migratory beekeeping is not practiced in this area; local authorities hypothesize that later reports of SHB detection (2008, and 2010) were due to independent entry events from the USA. However, considering that the beetle was detected in the middle of the country (Guanajuato) one year after the first report, it cannot be ruled out that SHB was not completely eradicated from Coahuila in 2007 and it spread southwards unnoticed. In 2012, it was detected in San Luis Potosí, close to Guanajuato. During the same year, it was also reported in Yucatan and Quintana Roo, both southern states located in the Yucatan peninsula (Medina-Medina et al. 2013). Because the report in the central region (San Luis Potosí) and the Yucatan peninsula occurred at the same time, and because of the distance involved, the reports from Yucatan most certainly correspond to an independent arrival, directly into the port, as probably occurred in the USA and Italy (Hood 2000; Neumann and Elzen 2004; Granato et al. 2017). Due to the high density of managed colonies (3.3 to 9.8 managed hives/km^2) and wild swarms (12.5 to 37.5 feral nests/km^2) in the Yucatan peninsula (Quezada-Euán and May-Itzá 1996), an eradication plan based on the elimination of infested apiaries was not feasible. Consequently, containment measures taken for the Eastern and Southern part of the country corresponded only to restrictions on the movement of colonies. From 2007 to 2015, *A. tumida* was reported in at least 15 of the 32 Mexican states, with the most significant incidence of positive reports registered for the states of the Yucatan Peninsula (Yucatan, Campeche, and Quintana Roo), where 37% of the country's managed colonies are concentrated (Medina-Valdez 2015; SIAP-SADER 2022). Under the tropical conditions of this area, the numbers of SHB adults present in AHB showed a marked seasonal fluctuation, with the highest numbers detected during the warm and humid months of the rainy season (October and November, with a total of 111 and 120 SHBs, respectively), and a much lower number at the beginning of the dry season (February, with a total of 21 adults) (Tucuch-Haas et al. 2020). Increased soil temperature and moisture during rainy seasons have a favorable impact on the survival and development time of SHB pupae (Cornelissen et al. 2019) helping to explain why more SHB adults are registered within honey bee colonies during these periods. Similar seasonal fluctuations in SHB population sizes have been reported for European honey bee colonies (EHB) in the Southeastern USA (De Guzman et al. 2010), in Australia (Annand 2011), and for African honey bees in Kenya (Torto et al. 2010). The low number of larvae found inside colonies and the absence of important economic losses would suggest that the reproductive potential of SHB in AHB colonies in Mexico is low (García-Martinez et al. 2013; Medina-Medina et al. 2013; Carrillo-Rodriguez and Medina-Medina 2016).

In 2018, SHB was declared endemic to the entire Mexican territory, as it was considered to be a low-risk pest, from the epidemiological, economic, and public health point of view, and can be controlled through good management practices (SAGARPA–SENASICA 2018). This declaration implies that it is no longer mandatory to report the presence of the pest, rendering official information regarding its dispersal and current distribution unavailable, hindering a further understanding of the beetle's dispersal, the factors influencing this dispersal, and the evaluation of the efficacy of confinement measurements, if any were taken at a given location.

2.3. SHB in Cuba

Five years after its arrival into Mexico, in July of 2012, SHB was reported in Villa Clara, Cuba (OIE 2012). During the following years, several outbreaks were reported throughout the country, including reports from Artemisa, Mayabeque, La

Habana, Sancti Spiritus, Ciego de Avila, Matanzas, Pinar del Río, and Cienfuegos (OIE 2014a). Therefore, SHB is expected to have successfully invaded the entire island. Although in Cuba, only EHB are reported to be present (Yadró-García et al. 2020), no severe cases of SHB infestation have been reported to date. In addition, the SHB larvae have never been found inside colonies, and only adult beetles were detected. This may be associated with a low level of reproduction (Spiewok and Neumann 2006), or to the reproduction in feral colonies, being unnoticed by beekeepers. Anyway, no significant damages to colony integrity, like the destruction of honey and pollen chambers, brood combs, or colony losses due to SHB infestation, have been reported yet in colonies maintained with good management practices (OIE 2014a).

2.4. SHB in El Salvador

In Central America, the presence of SHB was first reported in December of 2013 in AHBs from Sonsonate, El Salvador (OIE 2013), in 11 out of 47 colonies from an apiary. During the following weeks, SHBs were detected in other locations in the country, including Las Victorias, Las Delicias, La Ceiba, El Botoncillal, El Corozo, Cara Sucia, Montano, El Cimarrón, Juan Higinio, Las Flores, El Tunal, Tecoluca, Tenancingo, and Santa Cruz Minchapa (OIE 2014b). SHB positive colonies were not eliminated, quarantined, and restricted of movement as containment measures were applied (OIE 2014b).

2.5. SHB in Nicaragua

A few months later, in March 2014, SHB was reported in AHB in Nicaragua (OIE 2014b; Calderón et al. 2015), in the locality of San Juan del Sur, Department of Rivas (southern part of the country), about 8 km north of the border with Costa Rica. Adult beetles and larvae were found in a commercial apiary during an inspection with instructional purposes that was being conducted by honey bee researchers, and were later officially reported as SHBs by the Official Veterinary Service. Seventeen from a total of eighteen colonies resulted positive (OIE 2014c). Inspections carried out in perifocal areas found two new outbreaks in neighboring communities, where adult beetles and larvae were detected (OIE 2014d). Epidemiological control measures included the disinfection of work equipment, monitoring of the affected colonies, and training of beekeepers in the area were performed, but affected colonies were not eliminated. In 2015, sampling schemes were carried out in the affected zones and in the rest of the municipalities of the department of Rivas, without finding newly infested apiaries; therefore, the outbreak was considered resolved (OIE 2014e). In parallel to these activities, treatments with lime (calcium oxide) and the placement of contact traps for SHB were carried out. Despite these efforts, new outbreaks were later reported in Managua (2016), Estelí, Lechecuagos, and Madriz (OIE 2014f). Although no other outbreaks have been reported to OIE since then, the beetle most certainly is still present in the country.

2.6. SHB in Costa Rica

After the Tropical Beekeeping Research Center-National University (CINAT-UNA), Calderón et al. (2015) confirmed the presence of the SHB in Nicaragua; the National Animal Health Service (SENASA) of Costa Rica placed a "sentinel apiary" with four AHB colonies in Santa Cecilia-La Cruz, Guanacaste, close to the border. These colonies were visually monitored by examining individual frames, hive covers, and bottom boards for each colony (Cornelissen and Neumann 2018). Sentinel apiaries are established in different contexts as early warning systems to alert of sanitary problems, in this case to perform periodical SHB surveillance and maximize the likelihood of detection in an area close to a potential point of entry (SENASA 2020). In August 2015, SHB adults were detected in the sentinel apiary (OIE 2015a). Those colonies were immediately eliminated, and movement was restricted to and from this region.

Months later, the apiary was reinstalled, and SHB specimens reappeared shortly (OIE 2015b). Simultaneously, a nationwide monitoring program carried out between 2014 and 2017 by the Bee Pathology Program of CINAT-UNA confirmed that SHB remained restricted to the original detection site.

The Nicaragua to Costa Rica trajectory, as described, allows us to underline two important points: first, once the beetle spreads within a country (as it was the case in Nicaragua), the invasion to border countries is a recurrent threat, and carefully positioned sentinel apiaries are a useful means to achieve early detection of the invader; second, the adoption of timely confinement measures such as restricting colony movement in areas with low colony densities (as was the case in North-West Costa Rica) are effective to prevent or slow down SHB dispersal (SENASA 2017a, b; Ramirez and Calderón 2018).

Nevertheless, in September 2018, adult specimens were found in a wild honey bee swarm located in Heredia-Central Valley in the middle of the country (about 265 km south from the first detection site). Since (i) no reports prior to this event occurred at nearby locations, (ii) no intensive beekeeping is practiced at the focal point of detection in the Central Valley, and (iii) this point is located nearby an important fruit distribution center that receives fruits from all over Costa Rica, including Guanacaste. Calderón and Ramirez (2019) hypothesized that the beetles found in the Central Valley could have arrived in fruit transported into the facility from Guanacaste. No other reports of the beetle in central parts of the country have occurred since then. However, in October 2019, *A. tumida* was confirmed in a commercial apiary in Liberia, Guanacaste, approximately 25 km south from the initial point of detection in the country (Arguedas et al. 2020). In addition, 10 colonies of the stingless bee *Melipona beecheii* located near the first point of detection in La Cruz, Guanacaste, were visually inspected by checking inside the colonies, and no SHBs or signs of infestation were found (Calderón and Sanchez 2021).

Currently, the monitoring program of SENASA involves 12 commercial apiaries that have been designated as sentinel apiaries for epidemiological surveillance and are located in a south-east direction from the two previous points of detection within the Guanacaste Province, from Liberia to Santa Cruz (Ana Cubero Murillo, unpubl. data). Colonies were monitored monthly and visually by checking frames, hive covers, and bottom boards for each colony (Cornelissen and Neumann 2018). *Aethina tumida* has so far been detected in seven of these apiaries (Guisela Cháves Guevara, unpubl. data).

2.7. SHB in Brazil

The first report of SHB in South America dates to March 2015 in Brazil, probably as an independent introduction. SHB was detected in a small apiary from the Laboratory of Useful Insects of the University of São Paulo, located in Piracicaba, state of São Paulo, in the southeastern part of the country. This finding occurred presumably due to the intensive colony inspections typically carried out at a university research and teaching apiary, and only adult specimens were found (Toufailia et al. 2017). In the experimental apiary where the beetle was first detected, the colonies were not eliminated, and no containment measures were taken (Toufailia et al. 2017). The final confirmation of SHB's identity and official notification occurred in February 2016 (OIE 2016c), 11 months after the initial report. A regional evaluation was done within a radius of 20 km from the focal point, and several meetings with authorities of beekeeping associations and related industries took place in order to guide in the detection, notification, and implementation of measures to prevent and control the spread of the beetle (OIE 2016c). In addition, in 2018 and 2020, the Department of Animal Health published recommendations which include: the periodic inspection and immediate "disinfestation" of affected colonies, limitation of the movement of infected colonies, procedures for the extraction and processing of honey and other bee products, and an epidemiological surveillance plan (SEI/MAPA 2019). However, several outbreaks were detected in the same region during 2016–2017 (OIE 2016d), where adult SHBs and larvae (possibly *A. tumida*) were found. At the same time, new outbreaks were reported in the neighboring state of

Rio de Janeiro (OIE 2016d; Pereira et al. 2019). In the Rio de Janeiro cases, larvae were only found in depopulated (abandoned) hives which contained remaining food (honey and pollen), suggesting SHB reproduction within these colonies (Hood 2000; Neumann and Elzen 2004).

In January 2019, SHB was reported in the Center-West Region (state of Mato Grosso do Sul) (IAGRO 2019), in the Southeast Region (state of Minas Gerais) (IMA-01 2019), and the South Region (state of Paraná) (Agencia de Defesa Agropecuaria do Parana (ADAPAR-GSA 01) 2019), being declared in this state as a "disease limited to one or more areas" (personal comm. Abrego, L.G./MAPA, 2021). It was later notified in the state of Goiás, in the Center-West Region of the country (GESAN 2020).

The rapid spread of SHB to several Brazilian states could be attributed to migratory beekeeping and the lack of early detection strategies. Brazil, with more than 8.5 million square kilometers of surface area, is a Federal Republic, organized in states which exercise autonomy regarding their sanitary institutions, inside their federative units, and whose level of interaction in this respect varies widely. In other words, local responses regarding animal health policies might differ from one state to the next, but only if more restrictive than what is established by the most federal level (that is disciplined by the Ministry of Agriculture, Livestock and Food Supply). This scenario has made it challenging to implement a national strategy for early detection of this pest that could have effectively prevented its spread through the country, as clearly illustrated by the pattern of reports described above. This means that at present, there is a high risk of persistent and continued SHB dispersal into other northern and southern states within the country and ultimately to neighboring countries.

2.8. SHB in Belize

In 2016, SHB was reported in Belize (OIE 2016e), in Consejo, Corozal district, a coastal town near the border with Mexico, where adult specimens were detected. In July 2017, the Ministry of Agriculture carried out a national SHB survey and inspected 95% of the apiaries in the country. SHB infestation was only confirmed in Corozal, where all 277 hives were infested, and 67% were categorized as heavily infested. In March 2018, new outbreaks were confirmed in three apiaries of the neighboring Orange Walk district (OIE 2018).

After the management of infested hives and containment measures were taken (control of hive movements in and out of the infested districts to the rest of the country), the outbreaks were considered as solved (OIE 2018).

2.9. SHB in Colombia

In October 2020, SHB was reported in AHB in Colombia, in the state Risaralda (in the Pereira municipality) (OIE 2020a). Two weeks later, two new outbreaks were reported at about 200 km, in Valle del Cauca (Palmira municipality) (OIE 2020a; OIE 2020b; Numa-Vergel et al. 2021). Only adult specimens and one larva were recovered, and no damage to the colonies was reported. Following inspections that confirmed SHB was present in areas adjacent to where the pest was first identified; it was decided to declare *A. tumida* as an endemic pest in the country (Technical Direction of Animal Health-Agricultural Colombian Institute- ICA 2022, pers. comm).

The containment protocol in Colombia requires the complete elimination of larvae and adults, as well as removing contaminated combs; but incineration of the hive is not mandatory. Currently, the reported events cannot be considered as resolved and the situation is considered as stable, meaning there is no evidence of colony deaths solely caused by SHB (Technical Direction of Animal Health-Agricultural Colombian Institute- ICA 2022, pers. comm).

2.10. SHB in Guatemala

The first report of *A. tumida* at Peten Department Guatemala in AHB was published in

August 2020, when adult specimens were detected feeding on honey and pollen (García-Ochaeta 2020; OIE 2021). Authorities hypothesized that the entrance was associated with the mobilization of colonies in border areas. Peten borders Belize in the east and México in the west and north. A monitoring program carried out in different areas of Peten confirmed the presence of adult beetles in six different municipalities and larvae in only one (García-Ochaeta 2020).

Containment measures included placement of traps to capture and eliminate beetles, prohibiting the mobilization of hives and their products within the department of Peten and to other departments, and continuous training for local and national beekeepers on good beekeeping production practices and trapping (OIE 2021).

2.11. SHB in Paraguay

The first detection of SHB in Paraguay was confirmed in May 2022 in 21 colonies from an apiary located in the District of Pedro Juan Caballero, Amambay province, a province bordering Matto Grosso do Sul, Brazil. The colonies with high numbers of beetles, detected immediately after opening the hive, were incinerated. The remaining colonies were transferred to new hives and maintained in the same place. The inert material was disinfected by submerging it in containers with boiling water for a few minutes, and the floor was covered with lime. A perifocal area was established, about 100 km around the initial report, and apiaries within this area were inspected once a month. Beetle blaster traps were used for monitoring. Sanitary authorities held meetings with local beekeepers to discuss monitoring and management methods, and recommended the restriction of colony movements (OIE 2022a).

Authorities of SENACSA (Paraguay) are in contact with SENASA (Argentina) to discuss the evolving situation, and the procedures carried out by the Paraguayan service to contain the disease. Their plan is to carry out a nationwide surveillance and training program. Until Novembre 2022, no other outbreaks have been detected in this country (OIE 2022b).

2.12. SHB in Bolivia

In the case of Bolivia, SHB was first reported in June 2022. SHB adults were found in one of three newly established colonies in Machaj Marca, Vinto, Department of Cochabamba, in the central part of the country (OIE 2022c), a location distant to any border: at about 670 km from the border with Brazil and 550 km from the border with Paraguay. These colonies had been established from nucleus colonies that had been brought in from Santa Cruz de la Sierra, Department of Santa Cruz. The infested colony was destroyed, and an epidemiological study was carried out within a radius of 13 km^2 (OIE 2022c). The presence of SHB was soon confirmed in a second apiary out of 16 apiaries located within the peripheral surveillance area to the point of first detection.

As a result of this initial report, and in response to beekeeper demands, SENASAG started traceability efforts to determine if beetles were present in the Department of Santa Cruz, and at other locations known to commonly receive nucleus colonies from sources located there. The presence of SHB was almost immediately confirmed in three apiaries located in areas peripheral to the city of Santa Cruz de la Sierra, and in a single location further south in the Department of Chuquisaca (OIE 2022c). Based on this succession of events, the most likely scenario is that SHB was present in Bolivia much earlier and remained below the detection threshold or was noticed by beekeepers but not perceived as a threat to their operations. This situation may have presumably occurred because of SHB cryptic low-level reproduction (Spiewok and Neumann 2006) when associated with AHB colonies in the lowlands of Bolivia (corresponding to the Department of Santa Cruz, 400 masl), where continuous beekeeping in large-scale operations is practiced and nucleus colonies are produced. In addition, warnings or training sessions to familiarize Bolivian beekeepers with the incoming threat were not implemented, and it is likely that most beekeepers remained unfamiliar with SHB until the first report was issued. SHBs may have caused more evident damage when associated with weaker colonies at the inter-Andean valley of Cochabamba, where honey bees are exposed to thermal and nutritional stressors characteristic of more marked seasonal cycles at much higher altitudes (2500 masl).

The Bolivian case of SHB invasion and reporting may illustrate to a great extent a pattern common to countries where no preemptive measures (surveillance strategies, educational campaigns, and projects aimed at early detection) are implemented before the arrival of the invasive pest. This context may have detrimental effects, when the invading pest can evade detection or extend its range while maintaining itself below a detection threshold, until outbreaks are triggered by constraining conditions for honey bee colonies. However, this pattern may be the rule, rather than the exception, for many of the above described cases in other countries in Latin America. Furthermore, this case also highlights the limitation of report dates as indicators of SHB arrival into a region, as in many cases, those dates may correspond to outbreak events after the invader has become established. In any case, it remains elusive to determine to what extent the lag in reporting can be attributed to the beetles passing completely undetected or due to their detection but not reporting due to lack of beekeeper training or them not being perceived as a threat.

3. TRACING SMALL HIVE BEETLE INVASIONS IN LATIN AMERICA

There is no conclusive information on whether this parasite's entry and dispersion routes into the different Latin American countries has been through natural dispersal or the result of human activities such as commercialization of bee colonies (legal or illegally), fruit transportation between countries, or carried over with other goods. Following the dates and locations of SHB reports throughout Latin America, it is possible, but not conclusive, that the beetle was first introduced into Jamaica probably via beeswax trade from the USA (Idrissou et al. 2019). Next, the beetle most likely entered Mexico through natural dispersal from the USA (Figure 1). Genetic analysis does support these two hypotheses since beetle populations from both countries have haplotype Hap 11 which is characteristic of USA and Tanzanian SHB populations (Idrissou et al. 2019). Following its entry into Mexico, either from the north or through an independent arrival into the Yucatan peninsula, or both, SHB dispersed southward following the continental route through the Central American isthmus, arriving in Colombia in 2020 (Figure 1). Based on the absence of earlier reports of SHB in countries bordering Brazil, the presence of the beetle in this country may be due to a separate isolated introduction event into Sao Paulo, followed by dispersal within the country, as strongly suggested by the pattern of the Brazilian reports. Based on molecular analysis, the source of this Brazilian invasion is probably the USA (Cordeiro et al. 2019; Idrissou et al. 2019). In this hypothetical scenario, the later reports of SHB in Belize and Guatemala might reflect a lag in reporting the parasite rather than its actual absence (Figure 1).

Setting aside the differences in geographic scale, location, and country size, we can draw some conclusions about the outcomes of SHB invasion in a country that had put in place preemptive measures versus countries in which those were absent altogether. The Costa Rica case strongly supports the notion that by implementing sentinel apiaries de nuovo or designating commercial apiaries as sentinels for continued monitoring, a degree of containment and deceleration of the invasion could be attained. Most importantly, the detection of SHB at the purposefully established sentinel apiary near the border with Nicaragua most likely provided a better grasp of the dynamics at the early stages of the invasion process. The later placement of other sentinel apiaries following the putative trajectory of the invasion, and the confirmation that SHB was indeed following this route, accompanied with measures to restrict the movement of colonies in and out of the region, may pay off in terms of slowing down SHB spread and allow for the tracking of the invasion, anticipating SHB movements. Yet, the fact that SHBs were found associated with a swarm in the Central Valley three years after the first report illustrates that this approach is not devoid of gaps, and that we may be underestimating the potential of SHB to be transported by alternative means, such as other bee species, or associated with other types of incoming freight, originating in or nearby the areas of early detection.

As a contrasting case, if we observe the latest country in which SHB has been reported, Bolivia, where absolutely no preemptive measures were taken, as was the case for most of the countries in the region, the first thing we notice is that the date of the first OIE report becomes uninformative in terms of the dynamics of the early stages of the invasion. On the contrary, the report in these cases most likely corresponds to an outbreak induced in an already established population that was released from the constraints that kept it in check, motivating a report based on the perceived potential economic damage; or alternatively, by the fortuitous encounter with informed bee researchers, as it was the case for the first reports from Nicaragua and Brazil. Indeed, the first proposition may have also been the case for SHB invasions into the Yucatan peninsula, Guatemala, El Salvador, and Colombia. Another striking point accompanying this pattern is that once sampling strategies are extended to a larger geographic region within a country, following the initial report, SHB presence is shortly confirmed at multiple locations. In most cases, i.e., when SHB has affected the wild populations, it seems certainly too late to implement countrywide eradication measures, since not all wild bee nests can be found. In the short to middle term, sanitary authorities opt for declaring SHB as endemic, as it was the case in Mexico and Colombia.

Colony density and the migratory beekeeping practices in the first detection play an important role in the success of early eradication measures, as illustrated by the cases in northern México and Costa Rica. The reports from northern Mexican states bordering the USA (Coahuila, Nuevo Leon, and Tamaulipas) with an incipient beekeeping industry (≤ 0.1 colonies/km^2) and no migratory beekeeping are thought to correspond to independent arrivals. Eradication measures taken in those states may have slowed down the southward movement of the pest, which only appeared three years later in central Mexico. The conditions and outcome were similar in northern Costa Rica (Guanacaste). In contrast, after the introduction in Yucatan peninsula (Mexico), an area with very high colony densities, SHB quickly spread to multiple apiaries, making eradication simply impractical.

When interpreting these patterns solely based on the dates of the reports, it is important to consider that one of the most striking characteristics of the region is its great diversity, not only in terms of habitats that might serve as corridors for the scavenger dispersal, but also its socioeconomic diversity, which is linked to the uneven distribution of beekeeping operations. Furthermore, we must consider its political diversity, which impacts each country's differential priorities in terms of sanitary programs, often guided by which commodities are more tied to their economic needs and growth. All of these have a profound impact on the surveillance strategies, if any, that different countries carry out at any given time and consequently impact the chance to properly and timely report the presence of the beetle and subsequently implement or not contingency strategies.

Considering the above-described regional context, genetic studies of SHB populations in the continent will enlighten our understanding of the biogeography and the epidemiological factors associated with the beetle's success. The speculative pathways of invasion we have outlined here require its confirmation by molecular approaches, and further contextualize the distribution and extent of SHB invasion in greater detail. Moreover, the diversity of the region in terms of honey bee populations, degrees of africanization, alternative bee and non-bee hosts, as well as beekeeping practices provide a unique scenario where to analyze which factors are shaping SHB distribution and adaptation in this region; a region where the beekeeping industry has a preponderant role in some countries and an emerging status in others. Altogether, this background and the basic summary of SHB reports we have gathered here, clearly underline the need for the countries in the region to implement joint research strategies, beyond surveillance efforts, with committed economic and political support to structure meaningful programs to mitigate the negative impacts of SHB for apiculture, meliponiculture, and the local bee fauna.

4. SMALL HIVE BEETLE THREATS TO NATIVE BEE SPECIES IN LATIN AMERICA

In addition to the threats that SHB represents for honey bee colonies, it remains a potential hazard to native stingless bees and bumblebees (Ambrose et al. 2000; Hoffmann et al. 2008; Bobadoye et al. 2018; Nacko et al. 2020; Pereira et al. 2021; Toledo-Hernandez et al. 2021), as well as other native solitary bees in Latin America. SHB can complete their entire life cycle in a species of the family Megachilidae, *Megachile rotundata* (Gonthier et al. 2019). Therefore, the impact of this pest for native bees should be evaluated considering whether it represents a real threat or danger for the survival of their populations, which is yet to be done.

Currently, ≈426 species (in 31 genera) of native stingless bees are reported in the Neotropics (Grüter 2020), and several of them are widely used in meliponiculture, an ancestral practice that has been maintained in rural communities due to its cultural and economic value (Quezada-Euán et al. 2018). For example, for the Maya ethnic groups, the stingless bee *Melipona beecheii* Bennett is one of Mesoamerica's most important managed species (Quezada-Euán et al. 2018).

In Cuba (Matanzas and Mayabeque provinces), Lóriga-Peña et al. (2014) reported the presence of adults and larvae of *A. tumida* in managed colonies of *M. beecheii*. Of 258 managed *M. beecheii* colonies that were inspected, seven (2.72% of the total colonies) were infested with SHBs. Two of these colonies were transferred from wild nests into artificial hives. One week after the transfer, larvae were observed in the pollen pots and hive floor; in the other five colonies, only SHB adults were observed, ranging in number from 6 to 21 individuals.

In Mexico (Yucatán), SHB adults have also been observed inside *M. beecheii* nests; nevertheless, few individuals (12 individuals in total) were collected during an inspection carried out in 50 managed nests and no damage such as the destruction of pollen and honey pots, or the loss of stingless bee colonies due to this pest have yet been reported (Hernandez-Torres et al. 2021).

These results are like those observed by Pereira et al. (2021) in Brazil (Rio de Janeiro), where the presence of SHB was reported inside the nests of the stingless bee *Melipona rufiventris* from two different locations, where colonies were recently split or were very weak, with low bee populations.

These observations show that SHBs can infest managed *Melipona* spp. colonies and disturb them. Newly transferred and recently divided colonies may be at special risk when stingless beekeepers do not adopt good and appropriate management practices.

Although the volatiles of the whole colony, mainly pollen, stored honey, and brood, from stingless bees (Bobadoye et al. 2018) and bumblebees (Graham et al. 2011) are attractants for SHB adults, and females can quickly invade their colonies, these bees displayed a repertoire of behaviors to avoid the presence of this pest inside their nests. For example, *Bombus impatiens* can defend their nest by eliminating SHB eggs and larvae and the latter are finally stung (Hoffmann et al. 2008). In the stingless bee species *Austroplebeia australis* and *Trigona carbonaria*, it has been observed that the workers are efficient in rapidly removing SHB eggs and young larvae (<3 days old), and adults are immediately mummified and entombed alive inside the nests (Greco et al. 2009; Halcroft et al. 2011).

The use of resins in stingless bee nests is fundamental for the function of the colonies. Resins are important materials for the construction of their brood combs, pots for the storage of honey and pollen, and involucrum, as well as for the protection of their nests against certain predators and pests. In the case of SHB, studies carried out in a few species determined that stingless bees apply resinous substances on the body of the invaders, which confers these stingless bees an advantage for counteracting the presence of SHBs within their nests (Shanahan and Spivak 2021). In *A. mellifera*, different behaviors displayed by the workers toward SHB adults and immatures have been described (Neumann and Elzen 2004; Neumann et al. 2016); similar studies should be extended to other stingless bee species, mainly those that are managed by meliponiculturists throughout Latin America, to determine if they exhibit avoidance or resistance mechanisms to invasions by this pest. The degree of the effectiveness of such mechanisms should be determined.

5. IMPACT OF SMALL HIVE BEETLE ON BEEKEEPING IN LATIN AMERICA

There are no specific studies or reports regarding the impact of SHB on European or Africanized honey bee colonies in Latin America. However, as reported in other geographic areas, some stress factors can increase the vulnerability of colonies to *A. tumida* infestations, including poor beekeeping practices (mismanagement of space within colonies) and queen-related problems (queen losses, queen supersedure or drone-laying queens) (Spiewok and Neumann 2006). These factors seem to be especially important in our continent since the detection of SHB in Latin American bees has been associated with weak colonies (Toufailia et al. 2017; Pereira et al. 2021). Mustafa et al. (2014) reported that honey bee colonies with a large number of worker bees did not show any damage related to SHB infestation. In contrast, colonies with lower bee numbers showed the presence of larvae or colonies collapsing, indicating that weak colonies are unlikely to prevent SHBs from reproducing by killing or removing eggs and larvae. Consequently, beekeeping management practices should aim at preventing the emergence of weakened colonies, which implies that beekeeper education and training activities are key tools to attain this objective.

Considering the resistance mechanisms displayed by African honey bees (Neumann and Hartel 2004; Neumann et al. 2016) and that the africanization process is widely extended in Latin America (Whitfield et al. 2007), the reproductive success of SHB in AHB is expected to be limited. However, the presence of large areas where EHB populations are prevalent in countries and regions within countries with a beekeeping industry already focused on the international trade of biological material (queens, nucleus colonies, etc.) such as Chile and Argentina, actually free, could have two main consequences: first, areas with high EHB populations may serve as reservoirs for subsequent invasions (Araneda et al. 2021); second, SHB invasion into those areas could have an indirect negative impact for the beekeeping industry, because losing the "free of *A. tumida* status" may bring out the possibility of denied access to some markets where queens and nucleus colonies are currently exported. Additionally, Mexico, Argentina, and Uruguay are three of the main honey exporters worldwide (FAOSTAT 2022). Considering the increased risk for honey fermentation associated with SHB presence, it is possible, but not certain, that some honey trade problems could arise, which might call for the implementation of additional quality control measures and/or certification requirements.

6. ACTIONS CARRIED OUT BY LATIN AMERICAN COUNTRIES TO PREVENT SMALL HIVE BEETLE ESTABLISHMENT OR DISPERSAL

Considering the potential damage of SHB to honey bees and native bee species and their biological, cultural, and economic relevance, the prevention of SHB spread throughout the continent should be a regional priority. Although there are some bilateral cooperation strategies addressing the issue, there is no regional contingency plan currently agreed upon by all Latin American countries.

Different countries have implemented different and disjoint strategies for SHB early detection or to prevent its spread (Tables I and II), mainly:

- Interactions between national sanitary agencies, authorities, and researchers to design joint actions.
- Epidemiological surveillance: establishing networks of sentinel apiaries with periodic inspections, with or without traps. Sentinel apiaries are purposefully located in areas with a high probability of SHB entrance, mainly close to international borders.
- Training programs directed to technicians and beekeepers focused on SHB recognition

Table I Actions carried out in different Latin American countries where SHB has not been reported (indicated as yes or no when were taken), for early diagnosis, or prevention of SHB entrance or dispersal

Actions	Argentina	Chile	Uruguay
Declaration of SHB-free	Yes	Yes	No
Epidemiological surveillance (networks of sentinel apiaries with periodic inspections, close to international borders)	Yes (59 apiaries in 20/23 provinces, with traps)	No	YES (Inspection of commercial colonies closed to the borders)
Training programs directed to technicians and beekeepers focusing on SHB recognition, identification, importance of early diagnosis, potential impact on beekeeping and method for colony inspections. Distribution of flyers and brochures	Yes	Yes	Yes
Implementation of border control protocols or restrictions for products representing a high risk for SHB introduction from countries with reported cases (inc. honey bees or bee products)	Yes	Yes	No
Requirement of complementary phytosanitary certification for imported fruit from a country with SHB	Yes	No	No
Interaction between sanitary agencies, authorities, beekeepers, and researchers, to design actions	Yes	No	Yes
Design of a mobile phone application to recover information from beekeepers and technicians regarding suspicious specimens and their localization	Yes (Mobile phone application name: SIG-APP)	No	No
References	SENASA 2017a, b, health alert (No. 302/2016), Bulacio Cagnolo et al. 2017; Bulacio Cagnolo 2018	Araneda et al. 2021	Juan Campá, DILAVE, personal comm

Table II Actions proposed by different Latin American countries with SHB (indicated as yes or no when were taken), to prevent its dispersal

Actions	Mexico	Brazil	Bolivia	Costa Rica	Dominican Republic	Paraguay	Colombia
Declaration of SHB as endemic	Yes	No	No	No	No	No	Yes
Epidemiological surveillance (networks of sentinel apiaries with periodic inspections, close to international borders, with/without traps)	Yes (Apiaries close to the initial outbreak)	Yes (In some states)	No	Yes	Yes (11 apiaries with 40 colonies each, with traps)	Yes (Planned the for medium term)	No
Training programs directed to technicians and beekeepers focusing on SHB recognition, identification, importance of early diagnosis, potential impact on beekeeping and method for colony inspections. Distribution of flyers and brochures	Yes	Yes	No	Yes	Yes	Yes	No
Interaction between national sanitary agencies, authorities, beekeepers and researchers to design actions	Yes	Yes	Yes	No	No	Yes	No
References	SAGARPA-SENASICA 2018	Teixeira,E.W. personal comm	Mendizabal, N.H. personal comm	Calderón and Ramirez 2019; Arguedas et al. 2020	Niyra Castillo Ramirez personal comm	Escobar Martínez and Boggino Santacruz personal comm	ICA 2022 personal comm

and identification, the importance of early detection, the potential impact on beekeeping and methods for colony inspection. These programs should include the distribution of training materials (flyers and brochures with images illustrating different stages of the beetle life cycle) directed to beekeepers and personnel from honey extraction rooms to facilitate SHB recognition and identification.

7. FINAL CONSIDERATIONS

The small hive beetle in Latin America was first reported in 2005 in Jamaica; since then, eleven LA countries have officially reported its presence (OIE 2007; FERA 2010; OIE 2012, 2013, 2014b, c; Calderón et al. 2015; OIE 2015b, c, 2016a, b, 2020a, García Ochaeta 2020; OIE 2022a, b, c). Though limited information is available concerning its impact on honey bees and native bees in LA countries, it could negatively impact colony strength, honey quality (associated to honey fermentation), and international trade of bees and hive products. Implementing strategies for the early detection of this pest as it spreads to new countries or areas requires the development of epidemiological surveillance programs, the development of training programs for technicians and beekeepers to aid in beetle recognition (adults/larvae), the implementation of adequate management protocols in apiaries and honey extraction rooms, proper identification of the damage caused by the pest, and generating greater awareness in the beekeeping sector and authorities. Taken together, the described strategies would provide an integrative approach to minimize the impacts of this parasitic pest on the region.

Finally, we provide a snapshot of what is known about the distribution and status of SHB in the region. We currently lack enough information to reconstruct the complete and detailed trajectory of SHB invasions and its dispersal patterns in LA, including the possible sources of introduction or the variability in the degree of damage to AHB, EHB, native bee colonies, or solitary bees. Therefore, the precise nature and extent of the invasions of this pest, and its dispersal trajectories within Latin America and the Caribbean remain to be studied. Because of the extent of the geographic area and the multiplicity of factors that may impact the patterns of spread, in part due to the diversity of ecoregions and management practices, such studies would require the participation of a network of researchers and sanitary authorities from the entire region and the use of up-to-date sampling and genetic analysis tools. Nevertheless, this review may constitute the basis for designing future transnational studies to answer the remaining questions regarding SHB invasion and its impacts for LA and will contribute to the implementation of effective monitoring and containment strategies in LA countries where the pest has not yet arrived. In this regard, it is essential to generate a surveillance protocol agreed upon at a regional level to monitor the dispersion of SHB in LA and to create a regional platform of relevant information to promote the continued interaction between researchers, beekeepers, and sanitary authorities.

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NBC, MAP, and KA conceived the idea of the review, NBC, PAS, BB, RACF, LAMM, MAP, RV, EWT, and KA wrote the paper, revised, and approved the final document.

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REFERENCES

ADAPAR (Agência de Defesa Agropecuária do Paraná) (2019) Primeira ocorrência de *Aethina tumida* em apiário no Paraná. Nota tecnica GSA01/2019. https://ciram.epagri.sc.gov.br/ciram_arquivos/apicultura/alertas/aethina_tumida_pr.pdf. (Accessed 06 July 2022)

Ambrose JT, Stanghellini MS, Hopkins DI (2000) A scientific note on the threat of small hive beetles (*Aethina tumida* Murray) to bumble bees (*Bombus* sp.) colonies in the United States. Apidologie 31:455–456

Annand N (2011) Investigations on small hive beetle biology to develop better control options. Thesis presented in fulfilment of the requirement for the degree of Master of Science. University of western Sydney. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.915.672&rep=rep1&type=pdf. (Accessed 26 June 2022)

Animal Health Australia (2003) Small hive beetle national management plan. Deakin, Australia: Animal Health Australia Council Ltd, 17. Available at https://honeybee.org.au/pdf/SHB_FINAL_Mgt_Plan_AHA%20_31-10-03_.pdf. (Accessed 27 June 2022)

Araneda X, Aldea P, Freire X (2021) Small hive beetle (*Aethina tumida* Murray), a potential threat to beekeeping in Chile. Chilean J Agric Anim Sci ex Agro-Ciencia 37(1), 3–10. ISSN 0719–3882 print ISSN 0719–3890. https://doi.org/10.29393/CHJAAS37-1SHXA30001

Arbogast RT, Torto B, Teal PE (2010) Potential for population growth of the small hive beetle *Aethina tumida* (Coleoptera: Nitidulidae) on diets of pollen dough and oranges. Fla Entomol 93(2):224–230

Arguedas M, Soto JF, Ramírez M, Calderón RA (2020) Distribución del Pequeño Escarabajo de la Colmena, *Aethina tumida*, en abejas africanizadas (*Apis mellifera*) en diferentes zonas apícolas de Costa Rica. Revista Ciencias Veterinarias 38(2):13–29

Bobadoye BO, Fombong AT, Kiatoko N, Suresh R, Teal PE, Salifu D, Torto B (2018) Behavioral responses of the small hive beetle, *Aethina tumida*, to odors of three meliponine bee species and honey bees, *Apis mellifera scutellata*. Entomol Exp Appl 166(7):528–534

Buchholz S, Schiffer M, Spiewok S, Pettis J, Duncan M, Ritter W, Spooner-Hart R, Neumann P (2008) Alternative food sources of *Aethina tumida* (Coleoptera: Nitidulidae). Journal of Apicultural Research and Bee World 47:202–209. https://doi.org/10.1080/00218839.2008.11101460

Bulacio Cagnolo N, Lorenzo A, Rabinovich M, Rodriguez G, Palacio MA (2017) El PEC: Argentina se preparó para detectar el ingreso de esta plaga exótica. [online] https://inta.gob.ar/noticias/el-pec-argentina-se-preparo-para-detectar-el-ingreso-de-esta-plaga-exotica. (Accessed 08 Sept 2022)

Bulacio Cagnolo N (2018) Monitoreando el pequeño escarabajo de la colmena. [online]. https://inta.gob.ar/videos/monitoreando-el-pequeno-escarabajo-de-las-colmenas-pec [online] https://www.youtube.com/watch?v=JqS-ZaSv0k8. (Accessed 08 Sept 2022)

Calderón RA, Ramírez M, Ramírez F, Villagra W (2015) Primer reporte de la presencia del pequeño escarabajo de la colmena *Aethina tumida*, en colmenas de abejas africanizadas en Nicaragua. Revista Ciencias Veterinarias 32(1):29–33

Calderón RA, Ramírez M (2019) New record of the small hive beetle, *Aethina tumida*, in Africanized Honey Bee Colonies in Costa Rica. Bee World 96(3):87–89

Calderón RA, Sánchez L (2021) Reportes sobre la presencia del Pequeño Escarabajo, *Aethina tumida* (Coleoptera: Nitidulidae), en colonias de abejas nativas sin aguijón. Libro de Resúmenes: XII Congreso Mesoamericano de Abejas Nativas. 56 p

Carrillo Rodríguez A, Medina Medina LA (2016) Medidas para el control del pequeño escarabajo de la colmena *Aethina tumida* M. en colonias de abejas *Apis mellifera* en Yucatán. 23° Congreso Internacional de Actualización Apícola. 105–108 p

Cleofas RC, de Guzman LI, Polintan EA, Dupo BAL, Locsin AA (2016) Current status of small hive beetle infestation in the Philippines. J Apic Res 55(1):74–77. https://doi.org/10.1080/00218839.2016.1194053

Cordeiro EMG, Soares PL, Alves DA, Soares Correa A (2019) Updating the saga of the small hive beetle (*Aethina tumida*): molecular inference of the origin of the South American invasion.

Apidologie 50:273–276. https://doi.org/10.1007/s13592-019-00636-5

Cornelissen B, Neumann P, Schweiger O (2019) Global warming promotes biological invasion of a honey bee pest. Global Change Biology 25: 3642–3655. https://doi.org/10.1111/gcb.14791

Cornelissen B, Neumann P (2018) How to catch a small beetle: top tips for visually screening honey bee colonies for small hive beetles. Bee World 95(3):99–102. https://doi.org/10.1080/0005772X.2018.1465374

Da Silva V (2014) The first report of *Aethina tumida* in the European Union, Portugal 2004. Bee World 91(4):90–91

De Guzman LI, Frake AM, Rinderer TE (2010) Seasonal population dynamics of small hive beetles, *Aethina tumida* Murray, in the south-eastern USA. J Apic Res 49(2):186–191

Elzen PJ, Baxter JR, Westervelt D, Randall C, Delaplane KS, Cutts L, Wilson WT (1999) Field control and biology studies of a new pest species, *Aethina tumida* Murray (Coleoptera, Nitidulidae), attacking European honeybees in the Western Hemisphere. Apidologie 30:361–366

FAOSTAT (2022). Production database from the Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/faostat/

FERA (Food and Environment Research Agency) (2010) The small hive beetle: a serious threat to European apiculture. Sand Hutton, UK: Food and Environment Research Agency, 23 pp. [online] https://secure.fera.defra.gov.uk/beebase/downloadDocument.cfm?id=17. (Accessed 26 June 2022)

García-Martínez O, Saldaña-Ortiz T, Hernández-Lopez AM, Santana García P, Hernández-Torres A (2013) Comportamiento del pequeño escarabajo de las colmenas *Aethina tumida* Murray (Coleoptera: Nitidulidae) en el noreste de México. Memorias 21ª Reunión Anual CONASA, 6-8 noviembre, Monterrey, N.L., México, 6 pp

García-Ochaeta JF (2020) Primer registro del pequeño escarabajo de la colmena *Aethina tumida* Murray (Coleoptera: Nitidulidae) en colmenas de abejas africanizadas en Guatemala. Insecta Mundi 0826:1–4

GESAN (GERÊNCIA DE SANIDADE ANIMAL) (2020) Primeiro registro de ocorrência do Pequeno Besouro das Colmeias (PBC), *Aethina tumida*, no Estado de Goiás. Nota Técnica nº: 3/2020 - GESAN- 06233. https://www.agrodefesa.go.gov.br/files/Setembro2020/notatecnica.pdf. (Accessed 06 July 2022)

Genaro JA (2008) Origins, composition, and distribution of the bees of Cuba (Hymenoptera: Apoidea: Anthophila). Insecta Mundi 1:583

Gonthier J, Papach A, Straub L, Campbell JW, Williams G, Neumann P (2019) Bees and flowers: how to feed an invasive beetle species. Ecol Evol 9:6422–6432. https://doi.org/10.1002/ece3.5217

Graham J, Ellis JD, Carroll MJ, Teal PE (2011) *Aethina tumida* (Coleoptera: Nitidulidae) attraction to volatiles produced by *Apis mellifera* (Hymenoptera: Apidae) and *Bombus impatiens* (Hymenoptera: Apidae) colonies. Apidologie 42(3):326–336

Granato A, Zecchin B, Baratto Ch, Duquesne V, Negrisolo E, Chauzat MP, Ribiére-Chabert M, Cattoli G, Mutinelli F (2017) Introduction of *Aethina tumida* (Coleoptera: Nitidulidae) in the regions of Calabria and Sicily (southern Italy). Apidologie 48:194–203. https://doi.org/10.1007/s13592-016-0465-3

Greco MK, Hoffmann D, Dollin A, Duncan M, Spooner-Hart R, Neumann P (2009) The alternative Pharaoh approach: stingless bees mummify beetle parasites alive. Naturwissenschaften 97(3):319–323. https://doi.org/10.1007/s00114-009-0631-9

Grüter C (2020) Stingless bees: their behavior, ecology and evolution; Springer International Publishing, ISBN 978–3–030–60089–1. 385 pp

Halcroft M, Spooner-Hart R, Neumann P (2011) Behavioral defense strategies of the stingless bee, *Austroplebeia australis*, against the small hive beetle. Aethina tumida Insect Soc 58(2):245–253

Hernández-Torres H, Kirejtshuk AG, Núñez VC, García MO (2021) On *Aethina tumida* Murray (Coleoptera: Nitidulidae: Nitidulinae) in hives of *Apis mellifera* Linnaeus (Hymenoptera: Apidae) in Campeche, México. J Apicul Res 1–4. https://doi.org/10.1080/00218839.2021.1889223

Hood WM (2000) Overview of the small hive beetle, *Aethina tumida*, in North America. Bee World 81:129–137. https://doi.org/10.1080/0005772X.2000.11099483

Hoffmann D, Pettis JS, Neumann P (2008) Potential host shift of the small hive beetle (*Aethina tumida*) to bumblebee colonies (*Bombus impatiens*). Insect Soc 55:153–162. https://doi.org/10.1007/s00040-008-0982-9

IAGRO (Agência Estadual de Defesa Sanitária Animal e Vegetal) – (2019) Ocorrência da *Aethina tumida* em Mato Grosso do Sul e medidas que serão adotadas. NOTA TÉCNICA/GAB/DDSA/IAGRO Nº 001/2019

Idrissou FO, Huang Q, Yañez O, Neumann P (2019) International Beeswax Trade Facilitates Small Hive Beetle Invasions. Sci Rep 9:10665. https://doi.org/10.1038/s41598-019-47107-6

IMA-01 (2019) Lage, Eduardo., IMA coordinator (Mining Agriculture) of Pesab-MG pers. comm

Lee S, Hong KJ, Cho YS, Choi YS, Yoo MS, Lee S (2017) Review of the subgenus *Aethina* Erichson s. str. (Coleoptera: Nitidulidae: Nitidulinae) in Korea, reporting recent invasion of small hive beetle. Aethina Tumida J Asia-Pac Entomol 20:553–558. https://doi.org/10.1016/j.aspen

Liu Y, Han W, Gao J, Su S, Beaurepaire A, Yañez O, Neumann P (2021) Out of Africa: novel source of small hive beetles infesting Eastern and Western honey bee colonies in China. J Apic Res 60(1):108–110. https://doi.org/10.1080/00218839.2020.1816686

Lóriga-Peña W, Fonte L, Demedio J (2014) Reporte de *Aethina tumida* Murray (Coleoptera, Nitidulidae) en colonias de la abeja sin aguijón *Melipona beecheii* Bennett de Matanzas y Mayabeque. Rev Salud Anim 36(3):201–204

Lounsberry Z, Spiewok S, Pernal SF, Sonstegard TS, Hood WM, Pettis J, Neumann P, Evans JD (2010) Worldwide diaspora of *Aethina tumida* (Coleoptera: Nitidulidae), a nest parasite of honey bees 103(4):671–677. https://doi.org/10.1603/AN10027

Lundie AE (1940) The small hive beetle *Aethina tumida*, Science Bulletin, vol 220. Department of Agriculture and Forestry, Government Printer, Pretoria

Medina-Medina LA, Medina Zaldívar JM, Galván-Hernández G, Peral-Rodríguez JJ, Várguez-Soberanis EU, Carrillo-Rodríguez A (2013) Comportamiento del pequeño escarabajo de la colmena (*Aethina tumida*) en la Península de Yucatán. Memorias 21ª Reunión Anual CONASA, 6-8 noviembre, Monterrey, N.L., México, 5 pp

Medina-Valdez R (2015) Vigilancia Epidemiológica de las Enfermedades en Abejas. 23ra Reunión Anual del Consejo Técnico Consultivo Nacional de Sanidad Animal (CONASA). Noviembre 2015, Zacatecas, Mexico

Mostafa AM, Williams RN (2002) New record of the small hive beetle in Egypt and notes on its distribution and control. Bee World 83(3):99–108. https://doi.org/10.1080/0005772X.2002.11099549

Muli E, Kilonzo J, Sookar P (2018) Small hive beetle infestations in *Apis mellifera* unicolor colonies in Mauritius island. Mauritius Bee World 95(2):44–45

Mustafa SG, Spiewok S, Duncan M, Spooner-Hart R, Rosenkranz P (2014) Susceptibility of small honey bee colonies to invasion by the small hive beetle, *Aethina tumida* (Coleoptera, Nitidulidae). Short Comm J Appl Entomol 138:547–550

Mutinelli F, Montarsi F, Federico G, Granato A, Ponti AM, Grandinetti G, Chauzat MP (2014) Detection of *Aethina tumida* Murray (Coleoptera: Nitidulidae.) in Italy: outbreaks and early reaction measures. J Apicul Res 53(5):569–575

Nacko S, Hall M, Duncan M, Cook J, Riegler M, Spooner-Hart M (2020) Scientific note on small hive beetle infestation of stingless bee (*Tetragonula carbonaria*) colony following a heat wave. Apidologie 51:1199–2120. https://doi.org/10.1007/s13592-020-00799-6

Neumann P, Elzen PJ (2004) The biology of the small hive beetle (*Aethina tumida*, Coleoptera: Nitidulidae): gaps in our knowledge of an invasive species. Apidologie 35:229–247

Neumann P, Hartel S (2004) Removal of small hive beetle (*Aethina tumida*) eggs and larvae by African honeybee colonies (*Apis mellifera scutellata*). Apidologie 35(2004):31–36

Neumann P, Pettis JS, Schafer MO (2016) Quo vadis *Aethina tumida*? Biology and control of small hive beetles. Apidologie 1–40. https://doi.org/10.1007/s13592-016-0426-x

Numa-Vergel SJ, Sandoval-Cáceres YP, Vergara-Navarro EV (2021) First Record of *Aethina tumida* Murray (Coleoptera: Nitidulidae) in Colombia Journal of Agricultural and Urban Entomology 37:33–37

OIE (2007) Immediate notification of small hive beetle infestation in México, IN_6397 [online] https://wahis.oie.int/#/report-info?reportId=1079. (Accessed 05 July 2022)

OIE (2012) Immediate notification of small hive beetle infestation in Cuba, IN_12277 [online] https://wahis.woah.org/#/report-info?reportId=24449. (Accessed 06 July 2022)

OIE (2013) Immediate notification of small hive beetle infestation in El Salvador IN_14498 [online] https://wahis.woah.org/#/report-info?reportId=21716. (Accessed 06 July 2022)

OIE (2014a) Follow-up report of small hive beetle infestation in Cuba. FUR_15673 [online] https://wahis.woah.org/#/report-info?reportId=24533. (Accessed 06 July 2022)

OIE (2014b) Follow-up report of small hive beetle infestation in El Salvador. FUR_14907 [online] https://wahis.woah.org/#/report-info?reportId=21725(Accessed 06 July 2022)

OIE (2014c) Immediate notification of small hive beetle infestation in Nicaragua. IN_14888 [online] https://wahis.woah.org/#/report-info?reportId=27546(Accessed 06 July 2022)

OIE (2014d) Follow-up report of small hive beetle infestation in Nicaragua. FUR_15280 [online] https://wahis.woah.org/#/report-info?reportId=27559. (Accessed 06 July 2022)

OIE (2014e) Follow-up report of small hive beetle infestation in Nicaragua. FUR_20270 [online] https://wahis.woah.org/#/report-info?reportId=27664. (Accessed 06 July 2022)

OIE (2014f) Follow-up report of small hive beetle infestation in Nicaragua. FUR_21804 [online] https://wahis.woah.org/#/report-info?reportId=27707. (Accessed 06 July 2022)

OIE (2015a) Immediate notification of small hive beetle infestation in Costa Rica IN_18506 [online] https://wahis.woah.org/#/report-info?reportId=24599. (Accessed 06 July 2022)

OIE (2015b) Follow-up report of small hive beetle infestation in Costa Rica. FUR_20368 [online] https://wahis.woah.org/#/report-info?reportId=24636. (Accessed 06 July 2022)

OIE (2016a) 23rd Conference of the OIE Regional Commission for the Americas Santa Cruz de la Sierra, Bolivia, 14 - 18 November 2016a. [online]https://rr-americas.oie.int/wp-content/uploads/2019/11/23_cr_finalreport_eng.pdf. (Accessed 06 07 2022)

OIE (2016b) Six-monthly report on the notification of OIE-listed diseases, infections and infestations. Report 146150 [online] https://wahis.woah.org/#/report-smr/view?reportId=26214&period=SEM01&areaId=117&isAquatic=false. (Accessed 06 07 2022)

OIE (2016c) Immediate notification of small hive beetle infestation in Brasil IN_19529 [online] https://wahis.woah.org/#/report-info?reportId=7426. (Accessed 06 July 2022)

OIE (2016d) Follow-up report of small hive beetle infestation in Brasil. FUR_21456 [online] https://wahis.woah.org/#/report-info?reportId=8268. (Accessed 06 July 2022)

OIE (2016e) Immediate notification of small hive beetle infestation in Belize. IN_22898 [online] https://wahis.oie.int/#/report-info?reportId=8930. (Accessed 06 July 2022)

OIE (2018) Follow-up report of small hive beetle infestation in Belize FUR_26186. [online] https://wahis.oie.int/#/report-info?reportId=10778. (Accessed 06 July 2022)

OIE (2020a) Immediate notification of small hive beetle infestation in Colombia. IN_34680 [online] https://wahis.woah.org/#/report-info?reportId=25003. (Accessed 06 July 2022)

OIE (2020b) Follow-up report of small hive beetle infestation in Colombia. FUR35101 [online] https://wahis.woah.org/#/report-info?reportId=25010. (Accessed 06 July 2022)

OIE (2021) Immediate notification of small hive beetle infestation in Guatemala. IN_151829 [online] https://wahis.woah.org/#/report-info?reportId=40272. (Accessed 06 July 2022)

OIE (2022a) Immediate notification of small hive beetle infestation in Paraguay. IN_155272 [online] https://wahis.woah.org/#/report-info?reportId=53548. (Accessed 06 July 2022a)

OIE (2022b) Follow-up report of small hive beetle infestation in Paraguay. FUR_155985 [online] https://wahis.woah.org/#/report-info?reportId=56306. (Accessed 06 July 2022b)

OIE (2022c) Immediate notification of small hive beetle infestation in Bolivia. IN_155778 [online] https://wahis.woah.org/#/report-info?reportId=55534. (Accessed 06 July 2022c)

Pereira SN, Gottschalk S, Palmeira JL, Paulino J, Antunes MR, Boechat R, Pereira da Silva Junior VP, de Moraes P, Soares Alves LH, Prezoto F (2019) Notes on *Aethina tumida* Murray (Coleoptera: Nitidulidae) in an apiary in the state of Rio de Janeiro. EntomoBrasilis 12(2):88–90. https://doi.org/10.12741/ebrasilis.v12i2.824

Pereira SN, Alves LHS, da Costa RF, Prezoto F, Teixeira EW (2021) Occurrence of the small hive beetle (*Aethina tumida*) in *Melipona rufiventris* colonies in Brazil. Sociobiology 68(1):e-6021. https://doi.org/10.13102/sociobiology.v68i1.6021

Quezada-Euán JJG, May-Itza WDJ (1996) Características morfométricas, poblacionales y parasitosis de colonias silvestres de *Apis mellifera* (Hymenoptera: Apidae) en Yucatan. México Folia Entom Mex 97:1–19

Quezada-Euán JJG, Nates-Parra G, Maués MM, Roubik DW, Imperatriz-Fonseca VL (2018) The economic and cultural values of stingless bees (Hymenoptera: Meliponini) among ethnic groups of tropical America. Sociobiology 65(4):534–557

Ramírez M, Calderón RA (2018) Situación del Pequeño Escarabajo, *Aethina tumida*, en colmenas de abejas Africanizadas (*Apis mellifera*) en Costa Rica: Muestreo de apiarios 2014–2017. Revista Ciencias Veterinarias 36(1):19–26

SAGARPA-SENASICA (2018) Acuerdo mediante el cual se dan a conocer en los Estados Unidos Mexicanos las enfermedades y plagas exóticas y endémicas de notificación obligatoria de los animales terrestres y acuáticos. 16 pp. [online] https://dof.gob.mx/nota_detalle.php?codigo=5545304&fecha=29/11/2018#gsc.tab=0. (Accessed 28 June 2022)

SENASA (2017a) RESOLUCIÓN-302–2016-SENASA. Alerta sanitario. http://www.senasa.gob.ar/normativas/resolucion-302-2016-senasa-servicio-nacional-de-sanidad-y-calidad-agroalimentaria. (Accessed July 6 07 20220)

SENASA (2017b) Plan de emergencia para brote del Pequeño escarabajo de la Colmena. Costa Rica. [online] https://www.senasa.go.cr/informacion/centro-de-informacion/informacion/estado-sanitario/planes-de-contingencia. (Accessed 16 Oct 2021)

SENASA (2020) API-PV-001 v06. Protocolo de Vigilancia Epidemiológica para el Pequeño Escarabajo de la Colmena. Costa Rica. Available at http://www.senasa.go.cr › sgc › pnapi › file (Accessed 28 June 2022)

Shanahan M, Spivak M (2021) Resin use by stingless Bees: a review. InSects 12:719

SEI, MAPA. Nota Técnica 9/2019/DSE/CAT/CGSA/DSAIP_2/SDA/MAPA. Infestação de colmeias pelo *Aethina tumida*. Available at http://www.iagro.ms.gov.br/wp-content/uploads/2019/09/Nota-Te%CC%81cnica-9-2019.pdf. (Accessed 4 07 2022)

SIAP-SADER (2022) Población apícola: número de colmenas de 2011 a 2020. [online] https://www.gob.

mx/cms/uploads/attachment/file/655396/Inventario_2020_abeja.pdf. (Accessed 26 June 2022)

Spiewok S, Neumann N (2006) Cryptic low-level reproduction of small hive beetles in honey bee colonies. Journal of Apicultural Research and Bee World 45(1):47–48

Toledo-Hernández E, Moraga-Cáceres EU, Lormendez CC, Alvear-García A, Peña-Chora G (2021) First report in North America of the parasitic small hive beetle, *Aethina tumida*, Infesting a Hive of Stingless Bee. Plebeia Frontalis Southwestern Entomologist 46(4):1037–1040

Torto B, Fombong A, Arbogast RT, Teal PEA (2010) Monitoring *Aethina tumida* (Coleoptera: Nitidulidae) with baited bottom board traps: occurrence and seasonal abundance in honey bee colonies in Kenya. Environ Entomol 39(6):1731–1736

Toufailia HA, Alves DA, Bená DC, Bento JMS, Iwanicki NSA, Cline AR, Ellis JD, Ratnieks FLW (2017) First record of small hive beetle, *Aethina tumida* Murray. South America Journal of Apicultural Reserach 56(1):76–80

Tucuch-Haas JI, Rangel-Fajardo MA, Basulto-Graniel JA, Yam-Herrera F, del R, Burgos-Diaz JA, Tucuch-Haas CJ (2020) Fluctuación poblacional de *Varroa destructor* (Anderson & Trueman) y *Aethina tumida* (Murray) en colonias de abejas. Revista del Centro de Graduados e Investigación – ITM 35(82):41–45

Whitfield CW, Behura SK, Berlocher SH, Clark AG, Johnston JS, Sheppard WS, Smith DR, Suarez AV, Weaver D, Tsutsui ND (2007) Thrice out of Africa: ancient and recent expansions of the honey bee. Apis mellifera Science 314:642. https://doi.org/10.1126/science.1132772

Yadró García C, Rodríguez LA, Pérez Piñeiro A, Pérez Morfi A, Invernizzi C, Tomasco I (2020) Cuban honey bees: significant differentiation from European honey bees in incomplete isolation. J Apic Res 60(3):375–384. https://doi.org/10.1080/00218839.2020.1841460

Zhao H, Yang S, Liu J, Huang W, Ji C, Ren Q, Xia X, Hou C (2020) First detection of small hive beetle *Aethina tumida* Murray (Coleoptera: Nitidulidae) infesting eastern honeybee, *Apis cerana* Fabricius (Hymenoptera: Apidae). China Sociobiology 67(1):126–128. https://doi.org/10.13102/sociobiology.v67i1.4381