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Integrated pest management strategies targeting the Florida kissing bug, *Triatoma sanguisuga*: Preventing this vector of Chagas disease from invading your home

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ABSTRACT

Triatomines (Hemiptera: Reduviidae: Triatominae), commonly called "kissing bugs", are blood-sucking pests and vectors of the protozoan parasite *Trypanosoma cruzi*, the causative agent of Chagas disease (CD). Eleven species of kissing bugs occur throughout the southern half of the USA, four of which are well known to invade human dwellings. Certain kissing bugs in the USA are known to transmit *T. cruzi* to humans and other animals and their bites can also lead to serious allergic reactions, including anaphylaxis. In Florida, the kissing bug *Triatoma sanguisuga* frequently invades homes, bites residents, and has been found infected with *T. cruzi*, placing humans and companion animals at risk for CD. This review outlines integrated pest management (IPM) strategies for minimizing human exposure to *T. sanguisuga* and CD. A comprehensive IPM plan for kissing bugs includes detailed inspections, removal of vertebrate host nesting areas, and kissing bug harborage, home improvements to exclude kissing bugs from entering structures, pest removal, and judicious use of pesticides. This approach can limit or eliminate kissing bug entry into residential structures, thereby preventing kissing bug bites, and CD infections in humans and companion animals.

1. Introduction

The kissing bug (Hemiptera: Reduviidae: Triatominae) species *Triatoma sanguisuga* (LeConte) can be found throughout the eastern USA, including some regions of the Midwest, eastern Texas, mid-Atlantic and southern states. It has been reported from 23 states, and dozens of counties in Florida (Bern et al., 2019; Beatty et al., 2022b). Kissing bugs that are naturally infected with the parasite *Trypanosoma cruzi*, the causative agent of Chagas disease (CD), have been found in the USA (Dorn et al., 2007; Klotz et al., 2014; Bern et al., 2019). Several species of wildlife, such as the Virginia opossum (*Didelphis virginiana*), have also been shown to be infected with *T. cruzi* in regions of Florida where *T. sanguisuga* occur (Torhorst et al., 2022, 2023). CD can lead to chronic cardiac and/or gastrointestinal manifestations that are often permanent and life-threatening (Pérez-Molina and Molina, 2018). During their growth and development kissing bugs pass through five nymphal stages prior to molting to the adult stage. Each nymphal instar must feed upon the blood of a vertebrate animal in order to molt and progress to the next (larger) stage. Triatomine nymphs cannot fly and therefore must reside in locations close enough to crawl to a host animal, such as a nesting mammal like an opossum or ground-dwelling rodent. The adult-stage kissing bug has wings, allowing it to fly, and disperse to find a mate and take a blood meal (Bern et al., 2019). In Florida, *T. sanguisuga* is the main kissing bug associated with human dwellings; this species has been collected throughout the state, including panhandle, north, central, and southern regions. Entomological surveys conducted over 50 years ago

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revealed that *T. sanguisuga* occurs in 32 counties (Thurman et al., 1948), but little work on the distribution of *T. sanguisuga* has been done since that early investigation. Recent research demonstrated that *T. sanguisuga* continues to be widespread in Florida, where it was found in at least 22 counties, in many cases invading homes, biting humans, and harboring *T. cruzi* (Beatty et al., 2022a). Florida *T. sanguisuga* infected with *T. cruzi* were first documented in 1988 from a bug found at a home in Gainesville, Florida (Beard et al., 1988) but new research is now showing that close to 30% of Florida *T. sanguisuga* harbor this protozoan parasite (Beatty & Bhosale; unpublished data). Additional ongoing research will help elucidate whether this vector is transmitting CD to domestic animals and humans in the state of Florida. In addition to transmitting *T. cruzi*, triatomine bites can cause significant allergic reactions and even anaphylaxis (Beatty et al., 2021).

In Florida, *T. sanguisuga* reside in the sylvatic and peridomestic environments, but frequently invade homes (Fig. 1) where they bite both humans and companion animals (Beatty et al., 2022b). Therefore, developing an integrated pest management (IPM) strategy will help mitigate their invasion into the home and concerns for bites and potential transmission of CD. In this review, we will discuss IPM as a strategy for tactics that can be used to prevent *T. sanguisuga* kissing bugs from invading homes in Florida.

2. The process of integrated pest management (IPM)

IPM is intended to be an evidence-based, sustainable programme of pest management. In general, IPM is a process designed to (i) prevent pests, (ii) inspect and monitor for pests, (iii) identify pests, (iv) implement tactics, and (v) evaluate the effectiveness of the plan. Tactics include some or all of the following (modified from Cooper, 2011; Oi, 2023).

- Inspection of areas for kissing bugs and activity, which requires recognizing evidence such as fecal spotting.
- Removal of host nesting areas close to structures.
- Harborage removal outside (i.e. wood or rock piles) and inside (i.e. wall hangings).
- Habitat modification that includes exclusion to prevent kissing bugs from entering (i.e. sealing cracks, keeping screens repaired). If you are standing inside a structure and can see light streaming in from structural cracks, that is enough space for many pests to enter.
- Pest removal, including the use of high-efficiency particulate air filter (HEPA) vacuums.
- Judicious use of pesticides.

General IPM strategies also include other physical modifications that may include modifying temperature and relative humidity and identifying the human behavior that caused the pest problem so that the behavior can be changed and prevent future pest problems. In the case of kissing bugs, a future research area may be to determine the suboptimal survival conditions in structures. The strength of IPM programmes is that they are evidence-based, and assembled in a time-tested process. The weakness is the necessary reliance on human behavior at many levels.

Developing and implementing an IPM plan are two separate processes. While developing an IPM plan is rather straightforward, implementing and having a community adopt IPM is more complex. Communication and education are the foundation of successful IPM implementation.

3. Communication and education

Bringing awareness of this potentially emerging threat requires a communication and education plan. Including communication and education as part of IPM programmes has been successful in changing human behaviors with another true bug, bed bugs (Bennett et al., 2016; Cooper et al., 2016). The continued challenge of IPM is sustainability which is rooted in education and communication and maintaining community trust. Both of these topics are outside the scope of this paper.

The communication strategy for vectors of pathogens must be clear, concise, and accurate. Artificial intelligence is a powerful tool that quickly generates content, but we must be vigilant in monitoring it accurately. Traditional and reliable methods of education and communication include vetted online resources and fact sheets (Capinera and Byron, 2023); teleconferences, in-person educational/outreach activities, and continuing education credits hosted by qualified, trustworthy sources. Social media also can be a powerful tool, but it is a double-edged sword. It enables influencers to spread both information and misinformation quickly, but falsehoods spread faster than truth (Ellis and Reichel, 2023). In one study of 126,000 stories tweeted by roughly 3 million people, Vosoughi et al. (2018) reported that falsehoods were 70% more likely to be retweeted and at a faster rate while accurate information took six times longer to reach social media users.

The key to effective communication is defining the audience. The audience for Chagas disease will be multi-leveled and extremely diverse from the general public to community leaders and government officials defining health care policies. One effective approach to education is bringing a *T. sanguisuga* insect in resin for people to hold and examine (Fig. 2A). This practice has been used in Texas for education and outreach (Bejcek et al., 2018). Educational activities could be targeted during *T. sanguisuga* adult dispersal periods (May through October) when humans are more likely to encounter *T. sanguisuga* adults (Fimbres-Macias et al., 2023).

Bringing awareness to the public can also be accomplished by working with Extension professionals and educating those in the pest

Fig. 1. A Adult female *Triatoma sanguisuga* found near a bed in a home in Alachua County, Florida. **B** Live adult *Triatoma sanguisuga* kissing bugs collected inside the home of a resident of Levy County, Florida, who was bitten by a kissing bug and then tested for Chagas disease.

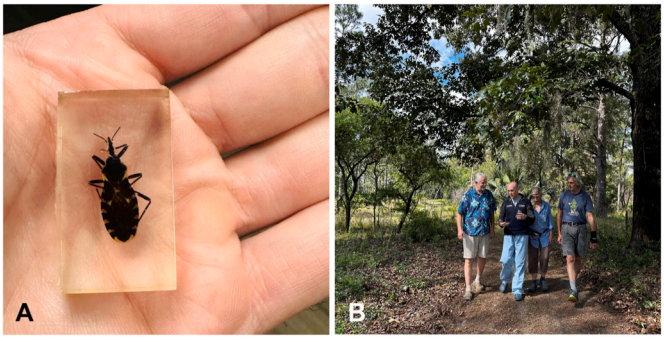

Fig. 2. A Clear resin cast of a *Triatoma sanguisuga* being held during an outreach activity to raise awareness about kissing bugs in Alachua County, Florida. **B** Dr Norman Beatty from the University of Florida discussing with and educating some community members who have had kissing bugs in their homes near Gainesville, Florida.

management industry. Many of the IPM recommendations, particularly regarding physical exclusion of kissing bugs, may be done directly by individuals instead of pest management companies.

In other regions of the USA, such as Texas, several initiatives have been successful in developing community science programmes to increase awareness of kissing bugs and CD (Curtis-Robles et al., 2015; Hamer et al., 2018). Similar initiatives in Central and South America have shown success with reducing vector-borne transmission of CD and exposure to triatomines which invade homes (Coura, 2013; Coura et al., 2014). Dr Norman Beatty at the University of Florida is developing a kissing bug community science programme to raise public awareness in Florida (Fig. 2B) and help researchers understand which regions have increased numbers of *T. sanguisuga* invading human dwellings (Beatty et al., 2022b).

4. Morphological identification of *Triatoma sanguisuga*

Several key morphological features exist to help differentiate *T. sanguisuga* from other species of the Reduviidae and the genus *Triatoma* which are found in Florida. Most adult *T. sanguisuga* are the size of a US quarter (approximately 1 inch or 25 mm) and have striking black and orange or yellow coloration (Fig. 3A). The compound eyes are black and located on the side(s) or lateral aspect of the head. The rostrum (proboscis) is straight and needle-like, used for biting and blood-sucking. When not feeding, the rostrum is held under the head, with the second segment extending down to the base of the neck (Fig. 3B). When the kissing bug prepares to bite, the rostrum is bent outward and forward like a long skewer. The body is mostly dark brown to black, with reddish to orange or yellowish marks on both sides of the neck, lateral aspect of pronotum, base of hemelytra, and connexivum. The neck collar has two anterolateral angle tubercles which are typically colored (Fig. 3A). The six legs are long and thin without the bulging parts that occur on some Hemiptera. The wings fold up over the middle of the anterior abdomen and do not extend past the distal margin of the abdomen. Utilizing the revised key in Lent and Wygodzinsky (1979), a Reduviidae specimen collected in Florida can be morphologically identified to the species *T. sanguisuga*. Maintaining a reference collection of *T. sanguisuga* and look-a-like species can aid in identification. Insects of the Reduviidae (Hempitera) which have similar morphological features (look-a-like) to *T. sanguisuga* and are found near human dwellings include the "milkweed assassin bug" *Zelus longipes*, "wheel bug" *Arilus cristatus*, *Apiomerus flaviventris*, *Rasahus biguttatus*, *Diaditus tejanus*, and *Reduvius personatus*.

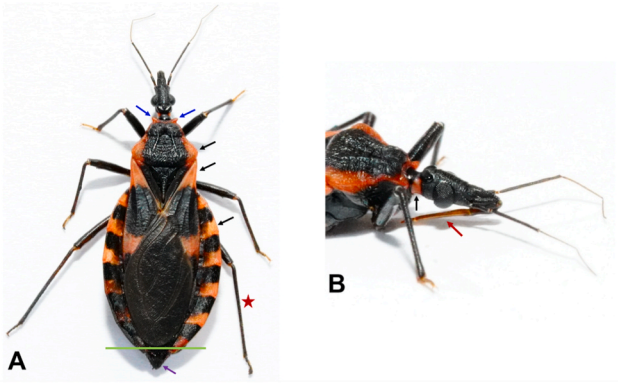

Fig. 3. **A** Adult *Triatoma sanguisuga* female in the dorsal view. Distinct orange markings occur on the lateral pronotum (*blue arrows*), base of hemelytra, and distal half of each connexivum of abdomen (*black arrows*). The wings do not extend past the abdomen when retracted (*green line*). Legs are dark in coloration, long and thin, without any appendages (*red star*). Females have exposed genitalia (*purple arrow*) seen in the dorsal view while males have a rounded abdomen in the dorsal view. **B** Lateral view of head showing black, compound eyes on each side with thin antennae. Rostrum (proboscis) is straight, needle-like and rests underneath the head, with a second segment (*red arrow*) that extends to base of neck. Orange markings are located laterally on the neck (*black arrow*) but typically do not wrap around.

5. Inspection and monitoring

Adult *T. sanguisuga* are most active at night and during their seasons of dispersal (May through October). They are attracted to artificial light, such as fluorescent outdoor lighting and can often be found on the outside of structures (Fig. 4A) between sunset and for 1.5–2 hours after (Fimbres-Macias et al., 2023). Homeowners and pest management professionals concerned about invading triatomines should inspect structures after sunset with active searching using a flashlight during the kissing bug active season. Developing an accurate map of the main structure, its surrounding vegetation, and other buildings (sheds, barns) can help determine a likely source of peridomestic *T. sanguisuga* and be a good starting point for developing a treatment plan. Detailed visual inspections should be performed of these areas and should also focus on locating features that support *T. sanguisuga* infestations, such as animal burrows (Fig. 4B), clutter (especially piles of lumber or firewood), hollow trees, crawl spaces (Fig. 4C), and other places where wild mammals (opossum or raccoon) and companion animals (dogs) may come in contact with kissing bugs. Dog houses/kennels (Fig. 4D) can provide a place for *T. sanguisuga* to hide and also feed upon companion animals (Klotz et al., 2016), contributing to large populations of kissing bugs. In general, passive traps have not been successful at capturing *T. sanguisuga* (Dye-Braumuller et al., 2019) and are not recommended for determining whether an infestation exists.

If insects suspected of being adults and/or nymph kissing bugs are encountered inside a home, identification of the bug should be confirmed by comparing the actual bug or a good-quality photograph of the bug with reference images. Photographs can be emailed to qualified entomologists for confirmation. After confirmation of identification, assessment for infestation and entry points into the home should be performed. If immature kissing bugs (nymphal stages 1–5) are found, this strongly suggests that a substantial breeding population of bugs exists on the premises (Dorn et al., 2007). Inspection of windows and doors for cracks and crevices, screens that are compromised or broken, and holes in floorboards can identify potential entry points for triatomines into homes (Klotz et al., 2016). Chimney flues can provide entry points for kissing bugs and should be assessed for breaches. Pet bedding and other areas where indoor pets spend time should be inspected for *T. sanguisuga* activity. Eggs and shed cuticle (exoskeleton) of nymphs are good indicators of kissing bug infestations. Blood-meal

Fig. 4. **A** An adult *Triatoma sanguisuga* collected at a home in Putnam County, Florida. **B** A fox den was found underneath this wood pile adjacent to a home in Alachua County, Florida, along with adult and nymph *Triatoma sanguisuga* kissing bugs. The homeowner had been bitten by a kissing bug several weeks earlier. **C** Florida home with a crawl space and front porch. **D** University of Florida graduate students, Chanakya Bhosale and Carson Torhorst, inspecting an outdoor dog kennel at a home where *Triatoma sanguisuga* were found.

fecal excreta (Fig. 5A) may be visible on bedsheets or other locations within the home where humans or animals are being bitten (Dorn et al., 2007).

6. Integrated prevention approaches

Decluttering around a home can help prevent *T. sanguisuga* from infesting a dwelling. Stacked firewood or lumber in close proximity to a home in Florida often attracts rodents and other wildlife, which in turn can support infestations of *T. sanguisuga* (Fig. 5B). Other types of clutter around the home that can provide nesting places for wild animals and attract *T. sanguisuga* include nonfunctioning automobiles, unused building and landscaping materials (bricks, blocks, pipes, etc.). Removal of clutter around the home or relocating it least 400–500 ft (approx. 120–150 m) away can reduce numbers of rodents and other mammals from the immediate vicinity of the main dwelling (Gardner-Santana et al., 2009). Excluding wildlife living within, under and near human dwellings is important, as this reduces the likelihood that infestations will establish close to the home. Rodent nests, fox dens, armadillo burrows and opossum latrines are particularly attractive to kissing bugs and should be removed by a wildlife- or pest control professional following State and Federal regulations. Prevention of animals from living within, underneath or directly around a man-made structure can help reduce triatomine infestations (Klotz et al., 2016). Pruning trees and shrubs so they do not touch the home can also prevent kissing bugs from crawling onto the dwelling. Cracks and crevices around windows, doors and other external entry points which can be utilized by kissing bugs to enter the home, should be sealed. Replacing damaged screens on windows (Fig. 5C) and doors can also prevent triatomines from entering through an open window or screened door. Door and window jambs that are weathered, cracked or do not seal completely when closed should be replaced since even small openings provide kissing bugs entry to the home from the surrounding environment.

The type of foundation can influence the likelihood of a kissing bug infestation. Homes that have a concrete slab foundation are at lower risk for *T. sanguisuga* entering through gaps in the floorboards. Many homes in Florida have crawl spaces or rest on piers or pilings in coastal areas. Crawl spaces should have well-maintained solid exteriors with latching doors to prevent rodents or other mammals (e.g. opossums and raccoons) from entering and residing/bivouacking. Manufactured and/or mobile homes often sit on cinderblocks that provide space underneath for wild animals to shelter. Lattice or other barriers should be installed on manufactured homes that sit above ground in order to prevent entry of wild or domestic mammals. Floorboards should have tight junctions (gaps less than 2 mm) to prevent *T. sanguisuga* from crawling through the spaces between the boards. Similarly, weep holes in brick and/or stone facades should be blocked with copper mesh to deter kissing bug entry. Stainless steel wire mesh can also be used to block access points in vents that connect to an attic. Citronella essential oils (obtained from the grass *Cymbopogon winterianus*), diethyltoluamide (DEET), picaridin, tee tree oil, and peppermint oil have shown little success at repelling some North American kissing bug species (*Triatoma rubida* (Uhler), *Triatoma protracta* (Uhler) and *Triatoma recurve* (Stal)) and deterring blood-feeding in a laboratory setting (Terriquez et al., 2013; Zamora et al., 2015). Among these testing products, only citronella essential oils have been shown to deter some probing *T. rubida* from feeding (Zamora et al., 2015), but it is unknown whether citronella essential oil could effectively repel *T. sanguisuga* from entering a home.

The placement, color, and type of lights used outside the home is an important consideration in kissing bug IPM (Schmidt et al., 2022). Lights should be placed away from structures, if possible. Standard fluorescent bulbs that emit "white light" attract kissing bugs and should be replaced with bulbs that emit light with a yellowish or orange hue (sodium vapor), particularly for porch lights. Blue light and UV (black light) are particularly attractive to kissing bugs and other biting insects and should not be used for outdoor lighting. During the months of May through October, external lights could be shut off from dusk to midnight, the period when dispersing *T. sanguisuga* adults are more active during dispersal season (Fimbres-Macias et al., 2023).

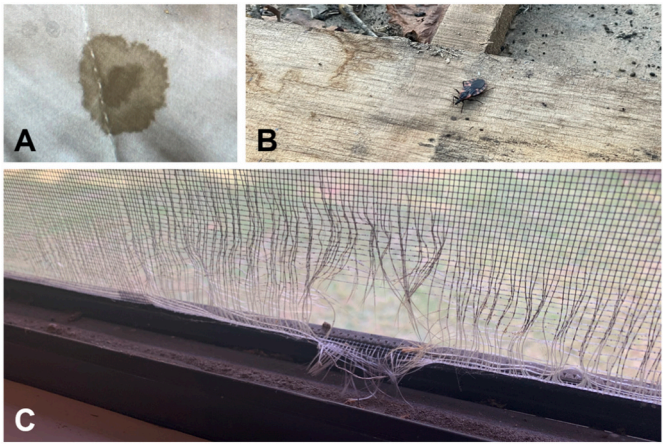

Fig. 5. **A** Fecal excreta found on the sheets of an individual who was confirmed to be bitten in their bed by *Triatoma sanguisuga*. **B** Adult *Triatoma sanguisuga* found in Alachua County, Florida, near a home with stacked lumber and rodent nests within the wood pile. **C** A potential entry point was found during an inspection of a home with a *Triatoma sanguisuga* infestation: a damaged window screen near the bedroom.

7. Integrated insecticide treatment approaches

In North America, kissing bugs, including *T. sanguisuga*, are not known to be resistant to commercially available insecticides, but research is needed to assess whether insecticide resistance is developing in this important group of vectors. Currently no insecticides are specifically labelled for controlling triatomines in the USA, but some insecticides are labelled for control of other blood-sucking Hemiptera, such as bed bugs. It is almost impossible to list every pest that a product is effective against on a pesticide label. In the USA, the Environmental Protection Agency (EPA) allows states to determine how to regulate pesticides as long as the regulation is not less stringent than the federal standard. States like Florida are "site states" meaning that even if triatomes are not specifically on the label, a product that could be used in cracks and crevices may also be used to control triatome bugs if the use pattern is on the product label. The use of targeted insecticides in areas where the bug could enter a home, and in other harborage areas can help kill invading adult and nymphal stages. Since kissing bugs are difficult to locate and/or observe and are typically nocturnal, applying insecticides directly to kissing bugs is challenging and unlikely to achieve control. The most likely effective treatments are residual insecticides that are applied as a spot treatment to cracks and crevices to where kissing bugs are likely to crawl, such as behind baseboards, corners, and toe kick spaces under cabinets. Residual insecticides persist for several days or weeks and can kill any insect that physically crawls or lands on the treated area. It is important to note that pesticides are temporary and not always guaranteed to control triatomine bugs (Grijalva et al., 2022). When applying a residual insecticide, always follow the label directions and ensure that the site of treatment is on the insecticide label. Additionally, any EPA-registered product that makes claims of efficacy against disease vectors must meet the requirements of Code of Federal Regulations Title 40, Chapter 1, Part 158, Subpart R.

8. Programme success and follow-up

Programme success would be determined by whether there was immediate relief from invading *T. sanguisuga*, followed by ongoing and lasting changes as directed in the IPM programme outlined in this

review. This would include prevention of harborages of triatomines near a human dwelling and other harborage areas, especially woodpiles, sheds, garages, and barns. Regular inspection (monthly) is advisable, especially during the dispersal season (May through October) and would permit timely prevention and control decisions. Monitoring for kissing bug bites and other evidence, such as fecal blood drops or smears on walls and furniture, can help determine whether a triatomine infestation is present in the home. Monitoring activities can be incorporated into community-based educational programs. If *T. sanguisuga* is found in the home after implementation of the IPM programme, the inspection stage should be reinitiated to assess for new or missed entry points or changes in the environment. Pest control professionals should inspect at least twice a year, with one inspection performed in the spring months prior to *T. sanguisuga* dispersal to assess if any new areas of a home or structure have new entry points or areas that need repair or targeted treatments, such as screens and window or door jambs.

9. Research needs

Triatoma sanguisuga is invading human dwellings in Florida (Beatty et al., 2022b) and has a broad geographical distribution throughout the state and much of the eastern USA (Bern et al., 2019). In the USA it has been estimated that approximately 10,000 persons are living with CD who have acquired the infection locally (Irish et al., 2022) but a national epidemiological assessment is needed to determine the incidence and true prevalence of autochthonous CD. Humans with confirmed exposure to *T. sanguisuga* should consider being tested for CD and a discussing CD with their primary care provider or an infectious diseases specialist (Forsyth et al., 2022).

Taking an IPM approach to prevent this triatomine from entering a home can help mitigate the risks of being bitten and also the spread of *T. cruzi*. Education and communication to diverse audiences are current major barriers to IPM for *T. sanguisuga*. Improvement in this domain would lead to greater awareness of this and other arthropod vectors in the USA, including ticks, mosquitoes, fleas and lice (Lizzi et al., 2014). Domiciliation of human dwellings by *T. sanguisuga* has been described in a case report from Louisiana where CD was transmitted to the human resident (Dorn et al., 2007) but robust study is needed to understand this triatomine is capable of this behavior. Entomological indicators of domiciliation among anthropic habitats include: (i) Domiciliary infestation index (DI) = No. of DU with adult triatomines/No. of DU inspected × 100; (ii) Domiciliary triatomine density (DTD) = No. of captured triatomines/No. of DU inspected; (iii) Domiciliary colonization index (DCI) = No. of DU with nymphs/No. of DU inspected × 100; (iv) Natural Infection index by *T. cruzi* (NI) = No. of infected triatomines/No. of examined triatomines × 100 (PAHO, 2003; Monsalve-Lara et al., 2021). Determining whether this triatomine is domiciliating (infesting) human dwelling needs attention and will aid in our understanding of autochthonous CD in the USA and Florida related to potential vector-borne transmission from *T. sanguisuga*.

Integrated Vector Management (IVM) carries very similar strategies to an IPM model but focuses on mitigation approaches and best practices to prevent vectored transmission of a pathogen. The overall concept of IVM relies heavily on reducing the vector population in the community, which will lead to a decreased or interrupted transmission of the pathogen, along with surveillance of disease transmission (Lizzi et al., 2014). Areas of focus for developing an IVM plan include: (i) Advocacy, social mobilization, and legislation; (ii) Collaboration within the health sector and with other sectors; (iii) Integrated approach; (iv) Evidence-based decision-making; and (v) Capacity-building as recommended by the World Health Organization (WHO, 2012). Currently we do not know the actual prevalence of autochthonous CD in the USA among regions where *T. sanguisuga* naturally resides. With more research to understand the ability for *T. sanguisuga* to act as a vector for the transmission of CD in the USA and Florida, an IVM can be developed to help mitigate transmission of *T. cruzi*.

Research is needed to better understand which treatments (non-insecticide and/or insecticide) can effectively control *T. sanguisuga*. Conducting dedicated studies to assess the efficacy of commonly used insecticides could help pest management professionals determine which insecticides to recommend when a home has an invasion or infestation of *T. sanguisuga*. The efficacy of insecticides which are known to have activity against other hemipteran pests, such as bed bugs (*Cimex* spp.), is unknown for kissing bugs in the USA. Non-insecticidal products, such as those that could act as a non-toxic repellent also need to be investigated. Citronella essential oils (obtained from the grass *Cymbopogon winterianus*) have been shown to prevent or deter several North American kissing bugs (*Triatoma rubida*, *Triatoma protracta* and *Triatoma recurva*) from blood-feeding in a laboratory setting (Zamora et al., 2015). It is unknown whether Citronella essential oil would repel *T. sanguisuga* from a home and more research is needed to understand which repellents would be effective. *Triatoma sanguisuga* is a blood-sucking pest which needs attention and developing IPM programmes can help reduce human and companion animal exposure to this vector in Florida and throughout its natural range in the USA.

10. Conclusions

Florida *T. sanguisuga* kissing bugs are blood-sucking insect vectors that transmit *T. cruzi*, the parasite that can cause CD. In sylvatic environments this triatomine can be found within or near hollow trees, wood debris (fallen trees or logs), brush piles with dry rotting logs and below-ground dens where nesting mammals may reside. They are commonly found near the dens of certain known reservoirs of *T. cruzi*, including the opossum, raccoon, and the nests of small rodents such as the woodrat (*Neotoma floridana*) (Irons and Butler, 1978; Lent and Wygodzinsky, 1979; Beatty et al., 2022b). This is a public health threat and prevention of *T. sanguisuga* from entering and invading human dwellings can mitigate unwanted bites and risk of CD infection. By employing the five steps of an IPM approach we can develop strategies for minimizing infestations by this pest. First, it is important to educate and communicate with community members who may have kissing bugs invading their homes. Working with public health officials and other community members, we can educate the general public through social media, events, and other venues. Community science programmes have also been useful for improving community engagement and also the importance of prevention (Curtis-Robles et al., 2015). Next, correct identification of *T. sanguisuga* at different maturation stages is important because several insects of the family Reduviidae that do not feed on blood can appear similar to kissing bugs. One challenge that exists is the correct identification of *T. sanguisuga* nymphs by a homeowner. Triatomines have five instars and a morphological key has been elaborated by Lent and Wygodzinsky (1979) which describes some features of *T. sanguisuga* nymphal stages. If a homeowner is concerned about nymphal stages of *T. sanguisuga* in their home they should contact a pest professional or entomologist with expertise in Triatominae for confirmation. Understanding the behavior of *T. sanguisuga* will also aid in correct identification, as kissing bugs are mainly active during dusk and early evening (Fimbres-Macias et al., 2023) and less likely to be active during the day or in gardens, which is when and where those Hemiptera that do not blood-feed are common. Correct identification of adult and nymphal stages is critical for homeowners and pest management professionals in order to make informed decisions regarding control strategies. Methodical inspection of a dwelling/home for evidence of invasion (bites, cast skins, blood fecal spots, active bugs) is a pivotal part of an IPM approach and could be integrated into community awareness and education activities. It is equally important to inspect the home for animals, particularly rodents or other mammals, that can serve as blood-meal sources which would attract kissing bugs to the dwelling and support their development and reproduction. A good IPM strategy can help prevent invasion of triatomines by integrating strategies to improve structural integrity of the home and rid the dwelling of attracting

features. Lastly, we can utilize diverse insecticide treatments, such as crack/crevice application, spot treatment, and other application methods allowable by the pesticide label to prevent both flying adults and crawling nymphs from entering the home or nearby structures. These concepts can help a homeowner or pest management specialist develop a site-specific IPM plan for preventing invasion of *T. sanguisuga* into homes in Florida.

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Norman L. Beatty: Conceptualization, Methodology, Investigation, Validation, Writing – original draft, Writing – review & editing. **Chanakya R. Bhosale:** Investigation, Validation, Writing – review & editing. **Carson W. Torhorst:** Investigation, Validation, Writing – review & editing. **Nathan D. Burkett-Cadena:** Methodology, Writing – review & editing. **Faith M. Oi:** Methodology, Writing – review & editing. **Colin J. Forsyth:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Samantha M. Wisely:** Methodology, Writing – review & editing.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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