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Biogeography

New geographic distribution of *Chrysomya megacephala*, the Oriental latrine blow fly (Diptera: Calliphoridae), in Mexico using citizen science and social media

Nueva distribución geográfica de *Chrysomya megacephala*, la mosca oriental de las letrinas (Diptera: Calliphoridae), en México usando ciencia ciudadana y redes sociales

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Abstract

In the present study we discuss the distribution of the exotic species *Chrysomya megacephala* (Fabricius, 1794) in Mexico, combining data from natural history collections, social media and citizen science. The oriental latrine blow fly is recorded for the first time in 16 Mexican states. Additionally, we provide an easy-to-follow guide to compare this species with similar looking species recorded from Mexico to help with its identification.

Keywords: *Chrysomya*; Neotropical region; Synanthropy; Integrative methods; Biological invasions

Resumen

En el presente estudio se ofrece una actualización de la distribución de la especie exótica *Chrysomya megacephala* (Fabricius, 1794) en México, con una metodología que combina datos de colecciones biológicas, redes sociales y ciencia ciudadana. La mosca oriental de las letrinas es registrada por primera vez en 16 estados. Adicionalmente, para facilitar su correcta identificación, proveemos una guía fácil de seguir para comparar esta especie con otras de apariencia similar reportadas en México.

Palabras clave: *Chrysomya*; Región neotropical; Sinantropía; Métodos integrativos; Invasiones biológicas

Introduction

Citizen science involves non-professionals with scientific activities, ranging from volunteers at museums helping in sample sorting, to bird migration counting, taking data, specimen collecting and recently by taking pictures for social media or nature apps (Aceves-Bueno et al., 2017; Eisen & Eisen, 2021; van Achterberg et al., 2020). The latter is more and more common nowadays, with online social media platforms like Instagram (www.instagram.com) and Facebook (www.facebook.com), online image depositories like Flickr (www.flickr.com) and online databases such as BugGuide (www.bugguide.net) and iNaturalist (www.inaturalist.org). For instance, the iNaturalist app doubled its observations from 25 million to 50 million in 2019-2020 (iNaturalist, 2021). The phenomenon of social media and nature enthusiasts' apps has prompted the description of new species of spiders, flies, millepedes, grasshoppers and plants (Edwards, 2020; Gonella et al., 2015; Jaume-Schinkel et al., 2020; Santamaria et al., 2020; Skejo & Caballero, 2016; Winterton, 2020), new locality records (Álvarez-Fidalgo et al., 2018; Mengual & de Soto Molinari, 2020), and new observations of species not recorded for decades (Wilson et al., 2020). Moreover, these platforms can also be very helpful in adding *in natura* information for museum specimens (Heberling & Isaac, 2018) and in monitoring pest species (Hadjiconstantis & Zoumides, 2021) or exotic species (Kaldari, 2019) distribution over time, which make them of particular interest for ecologists and conservation biologists.

The Calliphoridae (Insecta, Diptera), commonly known as blow flies or carrion flies, have ecological, veterinarian, economical and medico-legal importance, mainly because they cause myiasis in animals, including humans (Vargas & Wood, 2010). As an example, the eradication of the common screwworm *Cochliomyia hominivorax* (Coquerel, 1858) in Central and North America between the late 50s and the decade of 2000s reported substantial annual economic benefits to producers (more than US\$40 billion; Wyss, 2000). Most of calliphorids are attracted to decaying matter (Vargas & Wood, 2010), a biological feature that make them useful in forensic entomology (Byrd & Castner, 2009; Hall & Wall, 1995). In addition, some species are highly synanthropic and are vectors of bacteria, protozoans and helminths that can affect human health (Greenberg, 1973).

The blow flies have an almost cosmopolitan distribution and, in the last decades, some species distribution rapidly changed due to human activities, such as *Chrysomya*

megacephala (Fabricius, 1794), *C. rufifacies* (Macquart, 1843) and *C. albiceps* (Wiedemann, 1819) (Rognes, 1991), which were introduced in the American continent around 1970 (Baumgartner & Greenberg, 1985). These species present a strong larval competition with native species of the genera *Cochliomyia* Townsend, 1915 and *Comptosomyiops* Townsend, 1918, and this interaction can decrease the populations of the latter genera in the wild when competing for the same resources (Baumgartner & Greenberg, 1985; Faria & Godoy, 2001; Faria et al., 1999; Olea et al., 2012).

The original distribution of the oriental latrine blow fly, *Chrysomya megacephala*, was in south-east Asia (Pont, 1980). This species was introduced to South Africa and to South America via Brazil in the late 1970s (Laurence, 1981, 1986; Prins, 1979), presumably by a ship when Angolan refugees traveled to Brazil in 1975-1976 (Peris, 1987). By the 1980s it was already found in Argentina and Paraguay, in 1985 was reported in Venezuela and Peru, and later it was observed in Mexico in 1987. The first report of *C. megacephala* for the USA was in 1988 (Baumgartner & Greenberg, 1984; Banderhorst & Villet, 2018; Dear, 1985; Greenberg, 1988; Laurence, 1986). In recent years this species has been reported on the northern part of the USA and in the Iberian Peninsula, showing that this species could potentially extend its distribution worldwide and making it one of the globally most important species in forensic entomology (Banderhorst & Villet, 2018).

Despite having a potential world-wide distribution (see Banderhorst & Villet, 2018: Fig. 1), the current knowledge on *C. megacephala* distribution is mostly restricted to several local records in some countries based on published material from small study areas. Countries with records of *C. megacephala* are frequently listed as if the species occurs through the entire country, giving a false perception of the current distribution of the species. Citizen science and social media can overcome this problem and provide a more accurate picture of the real distribution of species with economical and medico-legal importance like *C. megacephala* and help in their monitoring (Alaniz et al., 2018; Barahona-Segovia & Barceló, 2021; Dörler et al., 2018; Maistrello et al., 2016). The aim of this study is to update the distribution of *C. megacephala* in Mexico using an integrative approach for its distribution based on literature, collections and social media records and to provide an easy-to-use visual guide to differentiate this species from other Calliphoridae in Mexico. We hope the present work helps improving the knowledge on blow flies in Mexico.

Materials and methods

The family Calliphoridae in Mexico is represented by 3 subfamilies and a total of 30 species (Jaume-Schinkel & Ibáñez-Bernal, 2020). Calliphorinae has 3 genera in Mexico: *Calliphora* Robineau-Desvoidy, 1830 with 6 species, *Cynomya* Robineau-Desvoidy, 1830 with 1 species, and *Protocalliphora* Hough, 1899 with 3 species. The subfamily Luciliinae is represented with a single genus, *Lucilia* Robineau-Desvoidy, 1830, with 8 species. Lastly Chrysomyinae has 7 genera in Mexico, namely *Cochliomyia* Townsend, 1915 with 2 species, *Compsomyiops* Townsend, 1918 with 3 species, *Chloroprocta* Wulp, 1896 with 1 species, *Chrysomya* Robineau-Desvoidy, 1830 with 2 species, *Hemilucilia* Brauer, 1895 with 2 species, *Paralucilia* Brauer & Bergenstamm, 1891 with 1 species, and *Phormia* Robineau-Desvoidy, 1830 with a single species.

The general morphological terminology follows Cumming and Wood (2017). To help with the taxonomical identification of *Chrysomya megacephala* and to avoid the confusion with other species of similar appearance of the genera *Lucilia*, *Cochliomyia*, *Compsomyiops* and *Paralucilia*, we compared each photography with a series of taxonomical characters based on the keys of Irish et al. (2014) and Jones et al. (2019), summarized on Table 1.

Literature search was conducted by tracking references from known literature with the help of the search engine Google Scholar (<https://scholar.google.com/>). To ensure the coverage of the most recently published literature we conducted a search in the scientific databases JSTOR (<https://jstor.org>), Web of Science (<https://www.webofscience.com/wos/woscc/basic-search>) and Scopus (<https://www.scopus.com>). Literature used for the study starts since the species was first reported in America in 1981 up to February 2021, focusing on studies involving blow flies (Calliphoridae) in America, and particularly Mexico. The studies included catalogues, species reports, ecological studies and taxonomical works with identification keys. All studies with occurrence data were recorded and mapped. Data from biological collections was obtained during visits of SJS to the Colección Instituto de Ecología, Xalapa (IEXA) and the Colección Nacional de Insectos- Instituto de Biología Universidad Autónoma de México (CNIN-IBUNAM), and from online databases with information of entomological collections such as the Global Biodiversity Information Facility (gbif.org) and the National Museum of Natural History, Smithsonian Institution (NMNH) (<https://collections.nmnh.si.edu/search/ento/>). Multiple specimens from the same locality were annotated as a single record.

Social media and online databases records

The platform www.naturalista.mx (the Mexican website for iNaturalist) and the Facebook groups “Insectos en México” and “Insectos y otros artrópodos de México”, together with the Facebook page “Zayulin: Moscas de México” were searched for *Chrysomya megacephala* records. All the available data (Supplementary material 1), including date of observation, locality with coordinates and name (or username) of the person who made the observation, were databased and used to map the species distribution.

Results

After an exhaustive literature review, we only found 9 published records of *Chrysomya megacephala* in Mexico (Castañeda-Vildózola et al., 1999; Greenberg, 1988; Huerta-Jiménez, 2015, 2021; Jaume-Schinkel & Ibáñez-Bernal, 2020; Jones et al., 2019; Kosmann et al., 2013; Munguía-Ortega et al., 2021; Pérez-Balam et al., 2012; Sánchez-Álvarez & Cupul-Magaña, 2012; Wolff & Kosmann, 2016). In addition, we obtained 19 records from the Global Biodiversity Information Facility (GBIF) as part of the digitalization process of the Colección de Artrópodos con importancia médica (CAIM), Laboratorio de Entomología, InDRE, in Mexico City, Mexico. The search on other online available collections such as National Museum of Natural History (NMNH) concluded without records of this species from the country. The entomological collections IEXA and CNIN-IBUNAM hosted some specimens from localities already known from the literature review. Since they did not include new localities, these records were not used to map the distribution. In this dataset we included one personal observation by SJS in the State of Puebla as this locality it is not reported in the literature. The compiled observations from literature and collections provide evidence for the presence of *C. megacephala* in 8 out of the 32 states of Mexico: Baja California, Baja California Sur, Estado de Mexico, Jalisco, Ciudad de Mexico, Morelos, Puebla, Veracruz, and Yucatan.

A total of 270 records were under the name of *Chrysomya megacephala* in iNaturalist (www.naturalista.mx) (Supplementary material 1). However, 53 records (19.62%) were pictures of other genera like *Lucilia* and *Compsomyiops*, of other families such as Sarcophagidae, Muscidae, or Syrphidae, or even from another order (Hymenoptera). Ten records (3.7%) belonged to the species *C. rufifacies* and 9 additional records are likely to be *C. rufifacies*, but due to the low picture quality and the lack of visible features we could not confirm their

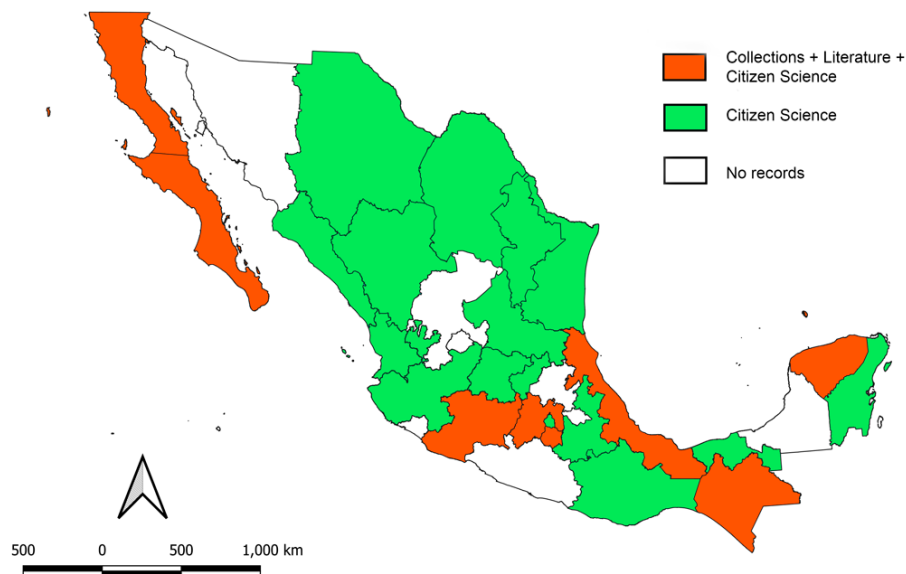


Figure 1. Map of Mexico with the updated distribution of *Chrysomya megacephala*.

identity. Moreover, 43 records (15.9%) were identified as *Chrysomya*, but no species-level identification was possible. Likewise, 146 records (57.4 %) were confirmed as *C. megacephala*, and another 9 records (3.33 %) seems to be *C. megacephala*, but we could not confirm the identity. Altogether, 146 out of 270 records (54 %) were used to map the distribution of *C. megacephala* in Mexico (Fig. 1). These data provide records for the 8 states that previously have literature records and 16 additional states without previous information or records of the species *C. megacephala*.

Using the combined data from citizen science, social media and literature records we reported the Oriental latrine blow fly for 25 out of the 32 federal states of Mexico: Baja California, Baja California Sur, Chiapas, Chihuahua, Coahuila, Ciudad de México, Durango, Estado de México, Guanajuato, Jalisco, Michoacán, Morelos, Nayarit, Nuevo León, Oaxaca, Puebla, Querétaro, Quintana Roo, San Luis Potosí, Sinaloa, Sonora, Tabasco, Tamaulipas, Veracruz and Yucatán. In other words, *C. megacephala* has at least 1 record in the 75% of the Mexican states, contrary to the previously 25% reported from literature and entomological collections.

In Mexico only 2 *Chrysomya* species are present to date (Jaume-Schinkel & Ibáñez-Bernal, 2020; Kosmann, et al., 2013), namely *C. megacephala* and *C. rufifacies*. Based on Irish et al. (2014) and Jones et al. (2019), they can be distinguished by some external morphological characters (Table 1).

Species of the genus *Chrysomya* are similar-looking to other species of the family Calliphoridae, but they can be differentiated from the species of *Cochliomyia* and *Comptosyiops* by lacking the darkened longitudinal vittae on the scutum (Fig. 2D) (present in *Cochliomyia* and *Comptosyiops*; Fig. 2A). *Chrysomya* species can be distinguished from *Lucilia* species by having a black fascia or black band alongside the posterior margin of each abdominal tergite (Fig. 2C, D) (posterior margin of tergites entirely shiny in *Lucilia* species; Fig. 2B). *Paralucilia fulvinota* (Bigot, 1877) also presents dark bands on the posterior margin of the abdominal tergites, but this taxon can be separated from *Chrysomya* species by the yellow-cream coloration of the gena (orange in *Chrysomya megacephala*, silver/white in *C. rufifacies*), infuscated wings (hyaline in *Chrysomya megacephala* and *C. rufifacies*) and the brownish-yellowish anterior thoracic spiracle (black in *Chrysomya megacephala*, white in *C. rufifacies*) (Table 1).

We provide an easy-to-follow guide to identify *Chrysomya megacephala* in pictures and to differentiate this species from other Calliphoridae species commonly found in Mexico (Fig. 2, Table 1).

Discussion

Along the northern portion, Mexico borders with the USA states of Arizona, California, New Mexico and Texas. *Chrysomya megacephala* was reported for California in

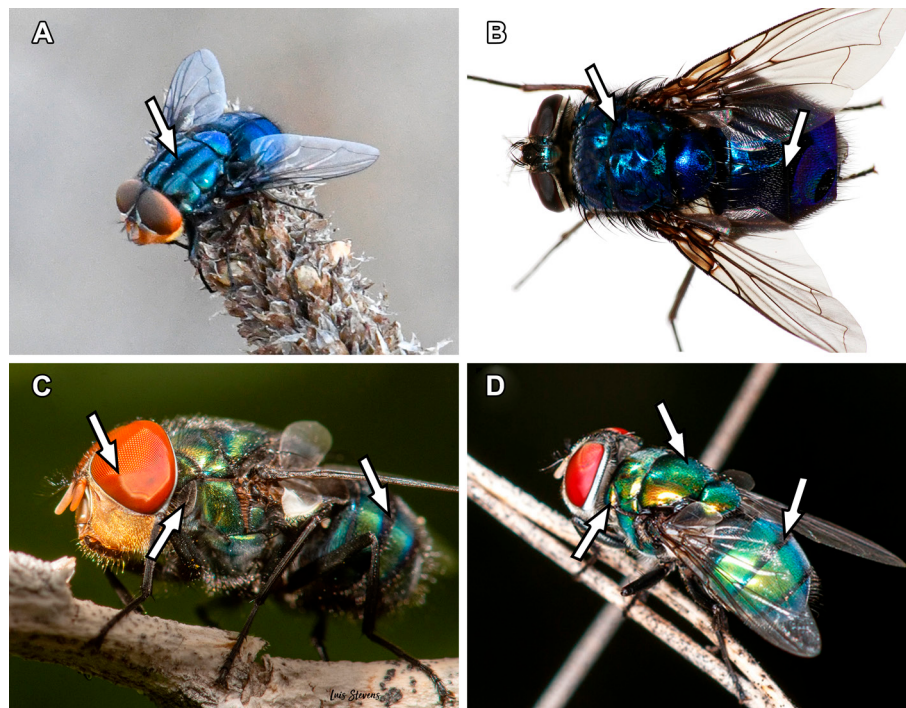


Figure 2. A, *Compsomyiops* sp., arrow indicating dark vittae on thorax. Photo by Chloe and Trevor van Loon. B, *Lucilia* sp., arrows from left to right pointing out the absence of dark vittae on thorax and the absence of a dark band on abdominal tergites. Photo by SJS. C, *Chrysomya megacephala*, arrows from left to right indicating contrast between enlarged upper facets of eye, the dark anterior thoracic spiracle, and the dark bands on abdominal tergites. Photo by Luis Stevens. D, *Chrysomya rufifacies*, arrows from left to right showing the white anterior thoracic spiracle, the lack of dark vittae on thorax, and the dark bands on abdominal tergites. Photo by Felix Fleck.

Table 1

Characters states to compare *Chrysomya megacephala* with similar species distributed in Mexico

Body part	Character	Species					
		<i>C. megacephala</i>	<i>C. rufifacies</i>	<i>Lucilia</i> spp.	<i>Cochliomyia</i> spp.	<i>Compsomyiops</i> spp.	<i>Paralucilia fulvinota</i>
		State of character					
Head	Gena coloration	orange	silver	variable	variable	variable	Yellow-cream
	Genal setae coloration	orange	silver/white	variable	variable	variable	usually dark orange
	Eyes	upper facets enlarged	upper facets not enlarged	not enlarged	not enlarged	not enlarged	not enlarged
Thorax	Anterior thoracic spiracle	brown, black or dark orange	white	variable	variable	variable	brown-yellowish
	Thoracic vittae	absent	absent	absent	present	present	absent
	Abdominal tergites 1+2	black	metallic	metallic	metallic	metallic	metallic
Abdomen	Posterior margin of abdominal tergites 3+4	black	black	metallic	black in some specimens	black (inconspicuous) in some specimens	black

1988, for Texas in 1991 and for New Mexico in 1995 (DeJong, 1995; Greenberg, 1988; Tomberlin et al., 2001; Wells, 1991). More recently, Jones et al. (2019) stated that the species is present from California to Alabama, covering Arizona. Thus, we assume that the species is present alongside the northern border of Mexico and extends its distribution through some states inside USA. On the contrary, we could not find any reports stating the presence of *C. megacephala* in Guatemala and Belize, the 2 border countries with Mexico to the south. On iNaturalist, we found a single record identified as *C. megacephala* for Guatemala (<https://www.inaturalist.org/observations/67867145>), but the picture quality is not the best to corroborate the identification. We contacted Dr. Enio Cano, Curator of the entomological collection of Escuela de Biología, Facultad de Ciencias Químicas y Farmacia, Universidad de San Carlos de Guatemala, M. Sc. Zabdi Moises Lopez Urizar curator of the entomological collection of Departamento de Biología, Universidad del Valle de Guatemala and the entomologist Ing. Filadelfio Guevara Chávez, all of them confirmed the presence of *C. megacephala* specimens in their collections from Guatemala. Dr. Enio Cano was kindly enough to provide coordinates from where he has collected some specimens (14°39'49.4" N, 90°27'41.0" W; 1,484 m asl). However, due to the SARS-CoV-2 pandemic, the access to these collections was restricted and no further data could be provided, making it difficult to accurately state this as the first record of *C. megacephala* for Guatemala. We were unable to get information from collections in Belize, consequently the status of the presence of this species for the country remains unknown.

Although there is no evidence on how *Chrysomya megacephala* was introduced in Mexico, it was reported for the first time in northern Mexico, in Baja California Sur (Greenberg, 1988). The next chronological record was in 1996 from the Yucatán Peninsula, southern Mexico, on the opposite side of the country. Then, in 1999, it was reported in central Mexico, in Estado de México (Castañeda-Vildózola et al., 1999). More recently (2012-2021), the species was reported for other localities (Jaume-Schinkel & Ibáñez-Bernal, 2020; Jones et al., 2019; Munguía-Ortega et al., 2021; Sánchez-Álvarez & Cupul-Magaña, 2012). All these previous literature records corroborate the presence of the Oriental latrine blow fly in 8 out of the 32 federal Mexican states. In the present study, using data from citizen science, social media and collection records, we reported the species in 25 Mexican states.

The absence of records in the remaining 7 states (namely Aguascalientes, Campeche, Colima, Guerrero, Hidalgo, Tlaxcala and Zacatecas) could be due to the lack of biodiversity monitoring programs for the introduced

species, combined with the lack of entomological surveys or ecological studies on blow flies in these states. Regarding the absence of *C. megacephala* in iNaturalist and other online resources there may be several reasons and further explanation might just be speculative. *Chrysomya megacephala* is a highly synanthropic species, which makes it rather easy to be observed in cities and urban areas; however, flies are not always considered photogenic and there is a general idea that flies are associated with filth. Therefore, citizen science and online platforms tend to register more records of different organisms, like butterflies or beetles (Barahona-Segovia & Barcelo, 2021). We suspect that the above-mentioned reasons contribute to the lack of general interest for blow flies from citizens and nature enthusiasts. Despite the low coverage in social media in comparison with other groups, the available data confirmed the presence of *C. megacephala* in 25 Mexican states, 3 times more states than those reported in the literature (Fig. 1). The presence of the Oriental latrine blow fly in the remaining 8 states is very likely, but further sampling effort should take place to have a complete distribution range of this species in Mexico.

The Oriental latrine blow fly can be easily differentiated from other Calliphoridae species present in Mexico if the diagnostic characters are visible (Fig. 2, Table 1). We encourage collecting some specimens always, particularly in localities where it is previously unknown to occur. *Chrysomya megacephala* is considered an important species in forensic entomology, and it is one of the most common world-wide mentioned species in studies in this field (Badenhorst & Villet, 2018). Consequently, a correct identification is crucial because it facilitates the exchange of information between experts and helps to contextualize the new findings (Badenhorst & Villet, 2018). Forensic entomology often relies on information about species distribution, and despite that the Oriental latrine blow fly is present in several countries, there are some gaps in its distribution. Citizen science has been recommended by several authors to fulfill these gaps in other species (Alaniz et al. 2018; Barahona-Segovia & Barcelo, 2021; Barahona-Segovia et al. 2018; Cardoso et al., 2011; Montalva et al., 2017). As shown in the present study, using available data from citizen science platforms and online databases proved to be an effective methodology to have a more comprehensive and updated distribution of *C. megacephala* in Mexico.

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