

# Oral history as a citizen science tool to understand biodiversity loss and environmental changes: a case study on firefly extinction in Morelia, Michoacán, Mexico (#105150)

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# Oral history as a citizen science tool to understand biodiversity loss and environmental changes: a case study on firefly extinction in Morelia, Michoacán, Mexico

Danna Betsabe Rivera Ramírez <sup>1</sup>, Cisteil X Pérez-Hernández <sup>Corresp., 2, 3</sup>, Yaayé Arellanes-Cancino <sup>4</sup>, Luis Mendoza-Cuenca <sup>Corresp. 2</sup>


<sup>1</sup> Unidad Lerma, Universidad Autónoma Metropolitana, Lerma de Villada, State of Mexico, Mexico

<sup>2</sup> Faculty of Biology, Behavioral Ecology Laboratory, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, Mexico

<sup>3</sup> IUCN SSC Firefly Specialist Group, Gland, Switzerland

<sup>4</sup> Facultad de Economía, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, Mexico

Corresponding Authors: Cisteil X Pérez-Hernández, Luis Mendoza-Cuenca  
Email address: cxinum@gmail.com, lfmendoza@umich.mx

**Background.**  Fireflies are nocturnal insects easily recognizable by their notable bioluminescence. They are also bioindicators of ecosystem health due to their sensitivity to environmental changes. In this study we employ oral history regarding fireflies and their habitats to compile the collective memory of the inhabitants of Morelia, in central-western Mexico, to analyze changes in biodiversity associated with urbanization. **Methods.** The main tools we used were interviews and surveys, in addition to data from scientific literature, entomological collections and citizen science platforms. We explored fireflies as useful elements both to collect oral histories from volunteers (experts or non-experts on the topic) and to serve as a source of biological data (e.g., current and past distribution of fireflies in the city, estimates of biodiversity loss, and threat factors), and even to analyze the potential loss of local ecological knowledge among human generations. **Results.** A total of 112 surveys and interviews were conducted with people of three different generations and from different parts of Morelia to collect human demographic data, and spatial, temporal, abundance, and perception data on fireflies. We found local recognition of fireflies by most Morelians, as well as reports of a decrease in both the frequency and abundance of fireflies, and even identified sites of local extinction, i.e., the disappearance of these insects from the environments where people used to see them. Morelians associated these phenomena with increased anthropogenic activities in the city, such as urban growth and a notable increase in pollution and deforestation. Most Morelians believe that the current conditions of the city are unsuitable for the existence of fireflies, and that it is important to conserve these insects because they play an important role in ecosystems and are of high environmental and aesthetic value. In contrast, the younger generation of Morelians showed lower interaction and recognition of these insects in

nature, which could be related to the loss of collective memory over generations and the shifting baseline syndrome. **Conclusions.** In contexts where historical scientific data are not available, we suggest that fireflies can be used to assess the history of natural environments and changes in the populations of these insects. Moreover, fireflies can be beneficial in terms of engaging people in conservation strategies, citizen science, and science communication.

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Danna Betsabe Rivera Ramírez<sup>1</sup>, Cisteil X. Pérez-Hernández<sup>2,3</sup>, Yaayé Arellanes-Cancino<sup>4</sup>, Luis Mendoza Cuenca<sup>2</sup>

<sup>1</sup> Universidad Autónoma Metropolitana, Unidad Lerma, Lerma de Villada, Estado de México, México

<sup>2</sup> Facultad de Biología, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, México

<sup>3</sup> IUCN SSC Firefly Specialist Group, Gland, Switzerland, Gland, Switzerland

<sup>4</sup> Facultad de Economía Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, México

Corresponding Authors:

Cisteil X. Pérez-Hernández<sup>2,3</sup>

Ciudad Universitaria, Av. Francisco J. Múgica S/N, Col Felicitas del Río, Morelia, Michoacán, 58030, México

Email address: cxinum@gmail.com

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<sup>1</sup> Universidad Autónoma Metropolitana, Unidad Lerma, Lerma de Villada, Estado de México, México

<sup>2</sup> Facultad de Biología, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, México

<sup>3</sup> IUCN SSC Firefly Specialist Group, Gland, Switzerland, Gland, Switzerland

<sup>4</sup> Facultad de Economía Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, México

Corresponding Author:

Cisteil X. Pérez-Hernández<sup>1</sup>

Ciudad Universitaria, Av. Francisco J. Múgica S/N, Col Felicitas del Río, Morelia, Michoacán, 58030, México

Email address: cxinum@gmail.com

## Abstract

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Key words: collective memory, oral history, urbanization, bioindicators

## Introduction

Fireflies (Coleoptera, Lampyridae) are beetles that are characterized by emitting their own light (*i.e.*, they are bioluminescent). This group of insects has a wide range of geographic distribution and high morphological and ecological diversity (Fausch, 2017). Fireflies contribute significantly to ecological networks and ecosystem stability and, due to their sensitivity to environmental change, they are also considered bioindicators of environmental integrity (Hagen et al., 2015; Idris et al., 2021). Their larvae are voracious predators of snails, slugs, and earthworms (Fallon et al., 2019), and some species are used as biological control agents for snails associated with crops (Fu and Meyer-Rochow, 2013). Adult fireflies are a food resource for birds, lizards, bats, and spiders (Lloyd, 1973; Moosman et al., 2009). From an anthropocentric point of view, these insects are also important because their bioluminescence is very striking to the human eye, and they have been integrated into human stories and culture for thousands of years as a result (Ineichen, 2016).

Adult fireflies typically exhibit annual life cycles and present higher species richness and abundance during the rainy season, coinciding thus with the fructification or harvesting of native and cultivated plants (Zaragoza-Caballero, 2004; Ineichen, 2016). In some firefly species, adult males and females congregate in large numbers at the same site and fly through vegetation or over open fields while performing their bioluminescent courtship dances. The glow or flashes they emit to send their courtship messages vary widely in color, intensity, and intermittency, and some species synchronize their flashes in large flickering clouds which creates a great visual impact for the observer (e.g., *Photinus palaciosi* in Tlaxcala, Mexico, and *Pteroptyx tener*, in Selangor, Malaysia; Owens et al., 2022). It is therefore common for these nocturnal displays of fireflies to create a lasting impression on their observers for decades.

Recent studies indicate that urbanization is one of the main factors that threatens the global insect fauna, especially fireflies, due to the loss of their habitats and other changes in the natural environment (Jusoh and Hashim, 2012; Lewis et al., 2020; Wagner et al., 2021). Moreover,



increasing water pollution, artificial night light pollution, and pesticides use in recent decades have significantly impacted firefly and other insect populations (Isenring, 2010; Ridgway, 2013; Vaz et al., 2021; Owens et al., 2022). This phenomenon has been a challenge to document at regional and local scales in countries such as Mexico, unlike other countries such as England, where monitoring and studies of insect diversity and abundance have been conducted for decades or even centuries (e.g., Gardiner and Didham, 2020; Tso et al., 2021). In most Latin American countries, data pertaining to a “zero” or “previous” state of nature are scarce. However, these approaches are vital to recover as much data as possible to facilitate the creation of conservation and restoration strategies for the future, particularly in regions with the highest animal (including firefly) diversity and abundance. Citizen or community science may be a useful tool to address this issue since it encompasses the activities of the non-expert public in scientific discovery and research, data collection, monitoring, and experimentation across a wide range of disciplines, including environmental and ecological science (Theobald et al., 2015; Fraisl et al., 2022). It could also be useful to document the environmental history of developing cities.

Drastic changes in ecosystems also seem to be related to the loss of collective memory in human communities regarding past conditions of natural environments and habituation to existing environmental degradation (Pauly, 1995; Soga and Gaston, 2018). This psychological and sociological phenomenon is known as the *Shifting Baseline Syndrome* and has been studied mainly in fisheries and in avian and tree communities (Pauly, 1995; Papworth et al., 2009; Jönsson et al., 2021; Soga and Gaston, 2018).

In the city of Morelia in Michoacán, central-western Mexico, the process of transformation and expansion of urban zones that has taken place since the 1960s decade is the main cause of land cover change and biodiversity loss in the region (López et al., 2001; MacGregor-Fors, 2010; Bollo et al., 2022). This urban growth has increased exponentially, due to the massive development of housing, commerce, industry, and tourism that has taken place at an accelerated rate and with little or no planning (López et al., 2001; López Núñez and Pedraza Marrón, 2012; Bucio-Mendoza et al., 2017; Bollo et al., 2022). Morelia is a medium-sized, mid-sized or intermediary city with a population of approximately 600,000 people living in the urban zone, which connects important rural and urban areas (United Cities and Local Governments, 2020; Bollo et al., 2022; IMPLAN, 2022; Ruíz-López et al., 2022). This category of city presents the fastest growing urban areas, usually with a lack of planning, and currently hosts 20% of the world’s population and more than a third of the total urban population (United Nations, 2018; United Cities and Local Governments, 2020).

Recently, Pérez-Hernández et al. (2023) found that urbanization in Morelia has affected firefly populations in the region since, although there are a high number of firefly species (26) in and around the city, there are also several areas where these insects are locally extinct. In their study, these authors utilized citizen science activities to obtain data on local extinctions in Morelia that were crucial to understanding the factors negatively impacting fireflies and biodiversity in the city.

In this study, we used different tools from oral history to compile information regarding different aspects of firefly populations from Morelia, and to create collective representations and knowledge about the past state of the firefly populations and their habitats, as well as to document the processes of change in the natural environment of the city, through the knowledge and experience of its citizens. From these data, we present an evaluation of the collective memory of different human generations about the fireflies in the current urbanized zone of Morelia. The main tools we used were interviews and surveys, in addition to data from scientific literature, entomological collections and citizen science platforms. We explored fireflies as useful elements both to collect oral histories from volunteers (experts or non-experts on the topic) and to serve as a source of biological data (e.g., current and past distribution of fireflies in the city, estimates of biodiversity loss, and threat factors), and even to analyze the potential loss of local ecological knowledge among human generations.

## Materials & Methods

### *Short history of urbanization in Morelia*

This study was conducted in the city of Morelia, Michoacán de Ocampo, in central-western Mexico, a medium-sized city with approximately 1 million inhabitants (60% of them living in the urban zone and the rest living in the rural zones) and a population density of 708.122 ind/km<sup>2</sup> (IMPLAN, 2022; INEGI 2022). During the pre-colonial era, swamps covered the area currently occupied by the city and the human population remained in the peripheral areas (López Núñez and Pedraza Marrón, 2012). Later, during the Spanish colonization (from the 16<sup>th</sup> to the 18<sup>th</sup> century), the swamp areas were replaced with homes and agricultural and livestock zones and the city expanded rapidly until the mid-20<sup>th</sup> century. More recently, from 1960 to 2020, the city expanded its size 15-fold, presenting an average urban expansion rate of 1.8 km<sup>2</sup> or 1.6% per year (Fig. 1; López *et al.*, 2001, López Núñez and Pedraza Marrón, 2012; INEGI, 2022; IMPLAN, 2022).

Figure 1. Growth of the urban area of the city of Morelia (Michoacán, Mexico) in 1960, 1990, and 2021. Based on López *et al.* (2001), López Núñez and Pedraza Marrón (2012), and IMPLAN (2022). The map also shows records of firefly populations observed in Morelia by the oldest generation (pink stars), the middle generation (orange rhombus) and the youngest generation (aqua blue circles), as well as the most frequently reported sighting sites (yellow triangles). Image ©2023 CNES/AIRBUS, Landsat/Copernicus, Image ©2023 Maxar Technologies. Map data ©2023 Google, INEGI.

### *Oral history compilation*

Oral histories were collected through individual interviews to reconstruct and transmit the history of Morelians (Fig. 2a). The use of surveys was also integrated as a more appropriate technique to facilitate the collection of information from participants with little time available and in very crowded sites (Zamorski and Kurkowska-Budzan, 2009). The interviews and surveys were

recorded in three formats: voice recording, video, and on paper, in order to facilitate the subsequent work of writing up and systematizing the data.

The interviewees were at least five years of age and from Morelia, or with at least five years of residence in the city (Fig. 2b). This served to assess the congruence of the oral history with the changes that had occurred in the environment. The interviews or surveys were conducted by three individuals between April and June 2022. The participants were interviewed in their homes, in locations with a high influx of people (e.g., urban parks, science fairs, bookstores, etc.; Fig. 2b-d), and in different areas of the city to ensure the greatest possible diversity of areas of the city and residents. The data were processed in a database to facilitate their classification. In the initial phase, the data were annotated verbatim and subsequently categorized for the purpose of analyzing the various documented narratives.

### *Ethical statement*

Ethical approval for this research was obtained from the Committee of Bioethics, Ethics in investigation, investigation, and Biosecurity, and by General Coordinator of the postgraduate programs of the Michoacana University of San Nicolás de Hidalgo Ethical to carry out this study. Consent for conducting the interviews and surveys was obtained verbally from all participants, who were fully informed about the purposes of our research and how their responses would be used and stored. Furthermore, no personal, biometric, or identity data was requested from those who voluntarily completed the survey.

Figure 2. Compilation of oral history on fireflies in Morelia city, A) first author Danna Rivera during an interview in 2021; B, C and D) map of Morelia city illustrating the expansion of the urban area over the last 60 years used during the interviews and surveys on fireflies in a science exhibition in the Michoacana University. Image credits: (A) Danna Rivera, (B, C, D) Cisteil X. Pérez-Hernández.

### *Interview structure*

To collect the oral history, we employed the methodology proposed by Lara and Antúnez (2014), which consists of triangulation among questions, dialogue, and perception. To achieve this, we used a guide comprising i) a brief presentation of the project, ii) a section on the demographic and residency data of the participants, and iii) questions on the spatial, temporal, abundance, and perception aspects of fireflies (Table 1). The presentation facilitated an atmosphere of trust and introduced the participants to the context of the project, without generating pressure or bias regarding the perceived importance of their testimony or responses.

The demographic data (age and sex) of the participants made it possible to recognize the participation of three generations. The first corresponds to those born in 1973 (now 51 years old) or before that year, the second to those born between 1974 and 2001 (21 to 50 years old) and the third to those born between 2002 and 2019 (5 to 20 years old). The categorization not only allowed us to analyze discrepancies in the knowledge of fireflies among different generations of

Morelians, but also to determine how each of these generations perceives the changes in the city and to evaluate the possible existence of a Shifting Baseline Syndrome (SBS) in the population of Morelia. The participant's place of residence allowed us to cover the greatest possible diversity of areas within the city, thus avoiding bias in the data based on the history of any particular area.

The third section comprised 14 questions pertaining to data on past and/or current observations, or the lack thereof, of fireflies by Morelians. The objective was to obtain spatial, temporal, abundance, and perception data related to these bioluminescent insects (Table 1).

Table 1. Questions applied to 112 inhabitants of the city of Morelia, in Michoacán, Mexico. The participants belonged three different generations, to evaluate their perception of fireflies and their natural environment, and to reconstruct the history of firefly populations in recent decades; n, number of participants who answered the question.

### *Analysis of change in firefly habitats and populations*

To estimate changes in the natural environment of the city of Morelia, we utilized the geographic location of sites reported as current or past habitats of fireflies in the city (e.g., locality and/or street) by participating citizens, as well as the time of sighting. To ensure the accuracy of the information collected, we used a map of the city that illustrated the expansion of the urban area over the last 60 years (Fig. 2b-d). We also used data from the citizen science platform Naturalista (2022), the entomological collection of the Universidad Michoacana de San Nicolás de Hidalgo, and entomological collections conducted in 2021 and 2022 (see the maps and data in Pérez-Hernández et al., 2023a, b). All data were georeferenced through photointerpretation and a historical comparison of satellite images from 1960, 1990, and 2021, as provided by the Instituto Municipal de Planeación de Morelia (IMPLAN, 2022) and the QGIS 3.22.1 software.

We tested for associations among Morelian generations and their i) observations of fireflies in nature, ii) experiences and emotions on firefly sightings, iii) perceptions of changes in sightings frequency and abundance of fireflies; iv) perceptions of changes in firefly habitats, and v) perceptions of firefly values for ecosystems and humans. All statistical analyses were performed using Pearson's Chi-squared tests with R 4.1.2 (R CoreTeam, 2021).

## **Results**

The 112 participants belonged to 84 (62.2%) of the total number of 135 neighborhoods registered in Morelia. Of the participants, 65 (58%) identified themselves as female, while the remaining 47 individuals (42%) identified as male. No participants identified with another gender category. The first generation of participants (individuals >51 years old) accounted for 32.1% (36 individuals) of the interviews, followed by the second generation (21-50 years old) at 36.6% (41), and the third generation (5-20 years old) at 31.3% (35) (Suppl. Mat. Table S1).

### *Local knowledge and perceptions about fireflies*

The highest frequency of firefly sightings was found in intra-urban and peri-urban areas (Fig. 1). A total of 97.3% of the participants (109 individuals) indicated that they could identify fireflies by their bioluminescence. Furthermore, 88.4% had observed them in their natural habitat (Fig. 3a). Of these, 85.7% (96 individuals) indicated that their experience with fireflies was positive in those encounters (e.g., excitement, admiration, awe), while the rest said it caused “fear” (Fig. 3b). Interestingly, of the total number of participants, only 2.7% (three individuals) said they did not recognize fireflies, while 8.9% (exclusively members of the second and third generations) indicated that they were aware of fireflies through other media (e.g., films, stories, photographs; Fig. 3a, b). There was a significant association regarding how different generations of Morelians knew about fireflies ( $\chi^2= 6.882$ ,  $df=2$ ,  $p=0.032$ ; Fig. 3a).

Figure 3. Local knowledge and perceptions about fireflies in Morelia city, Michoacán, Mexico; a) observations of fireflies in their natural habitat, other sources or have never been seen; and b) experiences and emotions on firefly sightings among three different Morelian generations, from a total of 112 interviewed people.

#### *Perspective of the inhabitants of Morelia regarding the loss of and threats to fireflies*

At least 72 of the 109 participants (66%, belonging to all three generations), who had previously observed fireflies in their natural habitat, recalled seeing them in Morelia at different times: >50 years ago (8.3%), >20 years ago (12.5%), >10 years ago (6.9%), 5 years ago (20.8%), and one year prior to the survey (51.4%) (Fig. 4a). In each of the three generations, the highest proportion of memories of firefly sightings was recorded in 2021; i.e., in the most recent season (Fig. 4a). The time of firefly sightings was significantly associated with the different Morelian generations ( $\chi^2= 22.553$ ,  $df=10$ ,  $p=0.012$ ).

The information obtained indicated a decline in firefly sightings in Morelia over the last decade. A total of 30.6% of the participants ( $n=72$ ) have ceased observing fireflies in their environment or have seen them only a few times (29.2%) or only once (13.8%). Only 19.3% of the participants continue to observe fireflies frequently (every rainy season over the past 10 years), while 7.1% do so occasionally (over the last decade) (Fig. 4b). Moreover, in the oldest generation, the perspective of firefly loss was significantly higher than in the other generations ( $\chi^2= 21.201$ ,  $df=8$ ,  $p=0.006$ ; Fig. 4b). A notable 20.8% of this generation reported a noticeable decline in firefly populations over time, compared to only 6.9% in the middle generation and 2.7% in the youngest generation (Fig. 4d).

Figure 4. Perceptions of Morelians regarding the changes in firefly populations; a) observations of fireflies in different times among Morelian generations; b) changes in frequency of their firefly observations during the last decade; c) perceived abundance (individual number) of fireflies seen at the time of the sighting; d) changes in the abundance seen in the last decade.

Regarding the abundance of fireflies historically observed by the participants in our study,

56.9% (n=72) observed few fireflies, 11.1% saw a normal number, and 32% indicated observing a high number. Of these, 32.7% belonged to the first generation, 34.4% to the second generation, and 32.7% to the third generation (Fig. 4c). No significant differences were found among generations in their perceptions of changes in firefly abundances through time. However, most participants recalled that, in 2021 (pre-survey year), they observed the lowest abundance of fireflies compared to previous years. At least 73.6% (53 individuals) perceived a diminution or disappearance of fireflies from their usual sighting sites, while only 2.7% (two individuals) observed an increase in the number of fireflies compared to previous years (Fig. 4d).

A total of 22.2% of the participants (16 individuals, n=72) indicated that there have been no changes in the site where they saw fireflies. Of these individuals, eight were from the third generation. In contrast, 85% of those over 20 years of age (from the first and second generations) reported local changes in firefly habitats, including the loss or diminution of natural areas due to increased anthropogenic activities. There was a significant association among Morelian generations and the perceived changes in firefly habitats ( $\chi^2=34.284$ ,  $df=14$ ,  $p=0.001$ ). Construction activities were identified as the main cause of the perceived environmental deterioration (61.1% of the participants, 40 individuals over 20 years old). Only 10.7% of the participants (12 individuals, n=112) indicated that there have been no changes in Morelia in recent years, with most of these individuals belonging to the third generation (eight individuals). The remaining 89.3% (100 individuals) did perceive important changes in the city in recent years. These changes corresponded to growth in the urban area (89%), pollution (4%), deforestation (4%), and other factors (3%) and the perception of those changes were significantly associated with the different generations of Morelians ( $\chi^2=31.997$ ,  $df=10$ ,  $p<0.0004$ ; Fig. 5a). Furthermore, 61.8% (55 individuals; n=89) considered that the presence of fireflies in their locality is unfeasible. The majority (69.5%, 38 individuals) attributed this to the unsuitable current conditions in the city for these insects.

Figure 5. Perceptions of Morelian people about habitat changes and value of fireflies; a) changes in firefly habitats in the last years; b) value of fireflies for ecosystems; c) value of fireflies for humans.

# *Environmental and personal value of the fireflies for humans*

The majority of participants who did recognize fireflies (78%, n=109) considered them an important component of ecosystems and are of high environmental value (Fig. 5b). Of these, 11.9% (13 individuals) attributed their importance to the role they play in food webs (e.g., as predators of other animals and pests), 56.8% (62 individuals) attributed an intrinsic value (e.g., “all living beings fulfill a function in the environment, and that is why they continue to exist”), and 9.3% (10 individuals) considered that they have an aesthetic value (e.g., they visually enrich the environment). The remaining 22% (24 individuals, n=109) demonstrated no particular interest in fireflies and did not consider them to have an environmental value (45.8% of the first generation, 25% of the second generation, and 29.2% of the third generation). A significant



association was found between generations and their perceptions of the importance of fireflies to ecosystems ( $\chi^2=20.953$ ,  $df=10$ ,  $p=0.021$ ).

A total of 9.2% of the participants (10 individuals,  $n=109$ ) did not consider fireflies to be important for humans, while 4.6% (five individuals) said they did not know (Fig. 5c). However, 86.2% of the participants (94 individuals) indicated that fireflies are important to humans for the following reasons: i) their emotional value (29.8%,  $n=94$ ), including the joy they bring when remembering and/or seeing them, or that they create greater empathy towards nature; (ii) their aesthetic value (47.9%,  $n=94$ ) because they are “a delight to behold” or “a real spectacle”; (iii) their cultural value (5.3%,  $n=94$ ) because these individuals consider that fireflies form an important part of the community and the identity of the people of Morelia; and iv) their environmental value (17%,  $n=94$ ) because fireflies are important for maintaining ecological balance and as a bioindicator species. There were no significant associations between generations and their perceptions of the importance of fireflies to humans.

### *Transmission of collective memory among the inhabitants of Morelia*

Most participants (82.6%,  $n=109$ ) had never heard stories about these bioluminescent insects, either from family members or other members of their community. Only 17.4% (all belonging to the first and second generations) related some anecdotes previously shared by family members. In total, 19 stories were obtained, dating back more than a decade, which described aspects of their lived experiences (42.1% of the stories) and the decline in the abundance and frequency of firefly populations (57.9% of the stories). For example, their ancestors told them that “there used to be more fireflies”, “before the constructions in the southern part of Morelia, there were a lot of fireflies”, and “in my childhood, I saw a lot of fireflies”. Furthermore, 34.4% of the participants ( $n=99$ ) indicated that they had never shared their experiences or anecdotes about fireflies with other individuals, while 65.6% had shared their stories with their family and friends.

### *Historic and current distribution of fireflies in Morelia*

A total of 116 firefly sighting sites were identified in Morelia. Of these, 84 (72.4%) were reported by the interviewed participants, two (1.7%) were from the entomological collection of the UMSNH, 15 (12.9%) from the *Naturalista* (2016-2022) platform, and 15 (12.9%) from the entomological collections of the “Luciérnagas de Michoacán” project (Pérez-Hernández *et al.* 2023 a,b). The most frequently referenced sites across the different information sources and time periods were the Bosque Cuauhtémoc, Tenencia Emiliano Zapata and Jesús del Monte. Only seven sites were identified from sources dating back over 50 years, 16 sites from 1994 to 2012, and 50 sites from 2016 to 2022 (Fig. 1). The sightings from the 1970s were concentrated in what was then the peri-urban zone (today the intra-urban zone) while, from 1994 onwards, there were more sightings in the intra- and peri-urban zones.

## **Discussion**

Our study is the first effort in Mexico to ascertain changes in biodiversity associated with urbanization over time, by employing citizen science and oral history data. The results covered a

wide range of residential areas and ages of inhabitants of Morelia and demonstrated the local recognition of fireflies among Morelians. The data collected through the oral histories of the local inhabitants enabled us to document a decline in the populations of these insects over recent decades and to identify the factors associated with this decline. This would not have been achievable by consulting scientific publications alone. The results also provide evidence of a decline in interactions between the inhabitants of Morelia and fireflies, which reflects the decrease in the general interaction of citizens with nature over generations. Although the Morelian citizens placed a high personal and ecosystem value on the fireflies, we found no evidence of community-level appreciation and a limited transmission of firefly-related stories across generations.

Our findings indicate that the inhabitants of Morelia readily identify fireflies by their bioluminescence and often associate positive emotions with these memories and experiences (e.g., Lewis *et al.*, 2021; Lloyd, 1983). In the case of individuals who indicated that they were unfamiliar with fireflies, it is possible that the interviewees use a different term for the insects than that mentioned during the interviews (“luciérnagas”). These could include terms such as “alumbrador”, “lucecitas” and *chpíri etetsi* (meaning fireflies, in Purépecha). For this reason, we recommend that future studies employ a greater range of expressions to obtain a more diverse set of testimonies.

All individuals in the first generation (the oldest) reported having observed fireflies in their natural habitat. This is in contrast to the second and third generations, where a proportion of the participants only gained their knowledge of fireflies through other media (e.g., films, photographs, social networks). Furthermore, the knowledge and experiences of the first generation of Morelians are strongly associated with the fact that these individuals had greater interaction with the natural environment. Guerrero-Martínez (2015) states that the manner in which people relate to their environment generates diverse notions regarding nature. Local views suggest that the rapid shift from a rural to an urban environment in Morelia over recent decades may be generating biases in the human-environment relationship, particularly among the second and third generations. In this sense, this study revealed that the observation sites of the older individuals were mainly in what had been the peri-urban and extra-urban areas at the time of observation, with a similar pattern evident for the second generation. In contrast, most of the observations of the younger individuals occurred in the current urbanized area, which may reflect the fact that they no longer directly “experience nature”.

In contrast, recent sightings (i.e., 2016-2022), reported mostly by the younger generation, were associated with green areas located within the current intra-urban zone (e.g., gardens, central reserves, parks, cemeteries). As evidenced in other studies, these areas help maintain insect populations in urbanized areas (Raupp *et al.*, 2010) and are also the areas to which people of the younger generation living in urbanized areas have greater access and are where these individuals can interact with nature. In particular, fireflies require sites with vegetation, high soil moisture levels, and low levels of light pollution (Fallon *et al.*, 2019; Idris *et al.*, 2021; Pérez-Hernández *et al.*, 2023a). However, in the current urbanized area of Morelia, public spaces that



meet these requirements are scarce (Bollo *et al.*, 2022). Only the peri-urban and extra-urban areas present the optimal conditions required for fireflies and other insects (Pérez-Hernández *et al.*, 2023a), as well as for interaction between humans and nature.

In the last five years, firefly sightings in Morelia and surrounding areas have been more numerous than in previous years, which we associate with the recent creation and dissemination of citizen science projects designed to record Mexican biodiversity (e.g., *Naturalista*, 2022; *Buscando Luciérnagas* project by del-Val *et al.*, 2024). However, Morelians also reported a notable decline in sightings compared to past seasons, with a continued reduction in frequency of sightings over recent years. This more recent decrease could be due to various factors associated with urbanization, including habitat loss, contamination of soils and water bodies, and light pollution (Lewis *et al.*, 2020; Fallon *et al.*, 2021; Owens *et al.*, 2022; Vaz *et al.*, 2023). These insects are also highly sensitive to variations in temperature and seasonality of rainfall, which have increased in recent years (Evans *et al.*, 2018).

In the city of Morelia, firefly extinction zones are associated with a low proportion of green spaces and high levels of light pollution (Pérez-Hernández *et al.*, 2023a), which can be added to the environmental deterioration of the city and particularly to the increase in urban area (Bollo *et al.*, 2022). The inhabitants of this city have perceived these changes in their surroundings as negative. In particular, construction activities were identified as the main cause of the environmental deterioration of their natural surroundings, which is also associated with the demographic growth recorded in the area since the 1960s (López *et al.*, 2001, López Núñez and Pedraza Marrón, 2012).

The responses of the citizens of Morelia indicate that, for them, fireflies are of considerable importance in ecosystems and possess high environmental, intrinsic, and emotional value. The intrinsic value can be leveraged to highlight the importance of conservation and to modify our interaction with the surrounding environment (Batavia and Nelson, 2017). The high emotional value that the citizens of Morelia ascribe to the fireflies could be linked to social issues, such as affectivity. This could facilitate a more complex and profound understanding of the importance of generating awareness about non-human fauna (Nghiem *et al.*, 2020; Mata *et al.*, 2021).

In this study, we compared the opinions and experiences of different generations regarding the observation of fireflies and nature to analyze the environmental, social, and cultural changes that have taken place in the city of Morelia over time. We found that changes in firefly sighting sites and the gradual loss of fireflies were perceived mainly by individuals of more than 20 years in age (from the first and second generations). This is possibly because these individuals possess more information, having experienced past conditions and being aware of the changes that their environment has undergone, compared to individuals of the third generation (Guerrero-Gatica, 2019). Furthermore, the third generation demonstrated greater disinterest in fireflies and their significance. This could be due to the lack of information about these insects or a general lack of engagement with their natural environment, and could act to generate biases in the collective memory and increase the detachment of the younger generations from their natural surroundings.

It has been suggested that the lack of intergenerational transmission of information,

particularly orally, can lead to generational amnesia regarding changes in the natural environment (Soga and Gaston, 2018). In the case of the inhabitants of Morelia, this lack of oral history transmission could lead to the development of the Shifting Baseline Syndrome. For example, the younger generations' perspective regarding their environment, which is severely degraded, as well as their minimal interaction with non-urbanized environments, could generate a lower expectation of what a healthy environment should look like (Pauly, 1995; Soga and Gaston, 2018). This situation could complicate the development of effective ecosystem conservation, restoration, and management strategies (Humphries and Winemiller, 2009; Bonebrake *et al.*, 2010; Bilney, 2014; Soga and Gaston, 2018; Guerrero-Gatica, 2019).

There has been considerable debate about the veracity and reliability of oral history as a source of academic information. This is due to the potential subjectivity of the information collected, and the impact of various factors (e.g., social class, gender, territory, generation, culture, the “memory illusion” phenomenon) (Ortíz, 2005; Papworth *et al.*, 2009). However, it has also been proposed that oral history, when transmitted by different people, can be shared and/or compatible with each other, such that the stories are related and serve to generate collective memories of the past (Kansteiner, 2002). Furthermore, distortions in the subjectivity of the stories can be reduced if they are analyzed according to the objectives, interests, and value system implicit in the research (Barbieri, 2007). In our study, we employed a variety of information sources to compare the testimonies and reinforce the data on local extinction sites of the firefly populations (e.g., databases and maps of urban growth in Morelia). The interviews were also structured and categorized in a manner designed to systematize the information obtained.

Other studies have suggested the possibility of employing anecdotal evidence about the absence of fireflies to demonstrate their local extinction (Wong and Yeap, 2012; Dawood and Saikim, 2016). Based on our findings, we also recommend the use of oral history about fireflies as a valuable tool for evaluating ecosystem integrity and the Shifting Baseline Syndrome (see also Pérez-Hernández and Rivera-Ramírez, 2024 *in press*). This is due to the following factors related to the fireflies: i) they are insects that are easily recognizable by people due to their bioluminescence, ii) they have a visual impact that can elicit diverse emotions and create a lasting impression in the memory (Ineichen, 2016), iii) they form aggregations that differ sufficiently from other bioluminescent organisms (e.g., Elateridae, Phengodidae), iv) they have populations that were previously very common and abundant, and changes in their presence and quantity are perceptible (e.g., Lewis, 2016; Faust, 2017; Lloyd, 2018; Lewis *et al.*, 2020), v) many species emerge at specific times of the year (e.g., rainy season, Zaragoza-Caballero 2004), and it is therefore possible to obtain information about people's attention to seasonal phenomena and their environment (e.g., Juárez Becerril, 2017, 2022; Takada, 2012; Ineichen, 2016), vi) people associate them with well-conserved habitats, so information about their perception of historic changes in their environments and their appreciation of nature can be compiled (Badillo, 2016), vii) the systematic and objective collection of oral histories regarding fireflies, and their comparison with other sources of information, can provide direct evidence of the intensity,

causes, and possible consequences of the local extinction of fireflies, viii) accessing the memories held by people regarding the fireflies can generate information about the transmission of oral stories across generations, which can be used to stimulate collective memory and reduce generational environmental amnesia, ix) information from oral stories could be used to assess the cultural impact of the extinction of insects such as fireflies, x) documenting and reporting the loss of these charismatic insects and its causes could serve as a catalyst for increased citizen participation in conservation and sustainable management strategies for ecosystems (Lewis et al., 2021).

## Conclusions

Our findings suggest that different generations of inhabitants of the city of Morelia have perceived a decline in firefly populations due to the loss of green areas and the expansion of urban infrastructure in the city. This information is invaluable for assessing and monitoring firefly diversity in Morelia, including identifying extinction sites. The compilation of oral history also allows us to preserve local knowledge and expand the research landscape in a context of scarce sources of historic scientific information. It also enables evaluation of the Baseline Change Syndrome present among the citizens of Morelia. This is an area of significant interest for conservation efforts, including those focused on fireflies and other species in Morelia, which are conducted by disseminating knowledge about the species and the threats they face. Despite the challenges involved in using oral histories, they can provide valuable insights into historical events that are often overlooked but still have a significant impact on current perceptions of different socio-environmental problems. The methodology and findings of our study could be applied to other medium-sized cities with a similar history of urban development. This will enable a deeper understanding of their history of environmental deterioration and its causes and its consequences. Finally, given the charisma ascribed to fireflies by humans, they could be utilized as a flagship species in citizen science projects for the study and monitoring of biodiversity, as well as in the generation and implementation of conservation and sustainable management projects for the natural environment.

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# References

- Badillo G. 2016. Matlatzinca. The Fireflies that Embellish the Trees. Animated Short film. Available at: <https://68voces.mx/matlatzinca-las-lucirnagas-que-embellecen-los-arboles>
- Barbieri M. 2007. Usos y metodología de los relatos de vida en la producción de conocimiento social. *Voces recuperadas, Revista de Historia Oral* 10 (23):46–50.
- Batavia C, Nelson MP. 2017. For goodness sake! What is intrinsic value and why should we care? *Biological Conservation* 209:366–376 DOI 10.1016/j.biocon.2017.03.003
- Bilney RJ. 2014. Poor historical data drive conservation complacency: The case of mammal decline in south-eastern Australian forests. *Austral Ecology* 39(8):875–886. DOI: 10.1111/aec.12145
- Bollo M, Martín G, Martínez A. 2022. Las áreas verdes de la ciudad de Morelia, Michoacán, México. *Investigaciones Geográficas* 107:e60494 DOI: 10.14350/ig.60494
- Bonebrake TC, Christensen J, Boggs CL, Ehrlich PR. 2010. Population decline assessment, historical baselines, and conservation. *Conservation Letters* 3(6):3715–378. DOI 0.1111/j.1755-263X.2010.00139.x
- Brühl CA, Zaller JG, 2019. Biodiversity decline as a consequence of an inappropriate environmental risk assessment of pesticides. *Frontiers in Environmental Science* 7:177. DOI 10.3389/fenvs.2019.00177.
- Bucio-Mendoza S, Vieyra A, Burgos A. 2017. Impactos del crecimiento urbano e industrial en el sur de Morelia, el caso del territorio de la Mintzita, Michoacán. In: Carrasco-Gallegos B, ed. *Megaproyectos urbanos y productivos. Impactos socioterritoriales*. Universidad Autónoma del Estado de México, 144–155.
- Dawood MM, Saikim FH. 2016. Studies on congregating fireflies (Coleoptera; Lampyridae; *Pteroptyx* sp.) in Sabah, Malaysia: a review. *Journal of Tropical Biology and Conservation* 13:13–25. DOI: 10.51200/jtbc.v13i.394
- del-Val E, Flores-Gutiérrez AM, González R, Calleros A. 2024. Buscando Luciérnagas: findings on Mexican fireflies from an 8-year virtual citizen science project. *PeerJ* 12:e18141 DOI: 10.7717/peerj.18141
- Evans TR, Salvatore D, Van de Pol M, Musters CJM. 2018. Adult firefly abundance is linked to weather during the larval stage in the previous year. *Ecological Entomology* 44(2):265–273 DOI: 10.1111/een.12702
- Fallon CE, Walker AC, Lewis S, Cicero J, Faust L, Heckscher CM, Pérez-Hernández CX, Pfeiffer B, Jepsen S. 2021. Evaluating firefly extinction risk: initial red list assessments for North America. *PLOS ONE* 16(11):e0259379 DOI 10.1371/journal.pone.0259379.
- Fallon CE, Hoyle S, Lewis S, Owens A, Lee-Mäder E, Hoffman Black S, Jepsen A. 2019. Conserving the jewels of the night: guidelines for protecting fireflies in the United States and Canada. Portland, OR. The Xerces Society for Invertebrate Conservation 48 (3).

- 556 Faust LF. 2017. *Fireflies, glow-worms, and lightning bugs: identification and natural history of*  
557 *the fireflies of the eastern and central United States and Canada*. University of Georgia Press,  
558 11, 376 p.
- 559 Fraisl D, Hager G, Bedessem B, Gold M, Hsing P-Y, Danielsen F, Hitchcock CB, Hulbert JM,  
560 Piera J, Spiers H, Thiel M, Haklay M. 2022. Citizen science in environmental and ecological  
561 sciences. *Nature Reviews Methods Primers* 2:64 DOI 10.1038/s43586-022-00144-4
- 562 Fu X, Meyer-Rochow VB. 2013. Larvae of the firefly *Pyrocoelia pectoralis* (Coleoptera:  
563 Lampyridae) as possible biological agents to control the land snail *Bradybaena ravida*.  
564 *Biological Control* 65(2):176–183. DOI 10.1016/j.biocontrol.2013.02.005
- 565 Gardiner T, Didham RK. 2020. Glowing, glowing, gone? Monitoring long-term trends in glow-  
566 worm numbers in south-east England. *Insect Conservation and Diversity* 13:162–174. DOI  
567 10.1111/icad.12407
- 568 Google Earth. 2021. Morelia city and surrounding areas. Coordinates 19.68329177, -  
569 101.24299184, INEGI Maxar Technologies CNES/Airbus. Available at  
570 <http://www.google.com/earth/index.html>.
- 571 Guerrero-Gatica M, Aliste E, Simonetti JA. 2019. Shifting gears for the use of the shifting  
572 baseline syndrome in ecological restoration. *Sustainability* 11(5): 1458. DOI:  
573 10.3390/su11051458
- 574 Guerrero-Martínez F. 2015. Concepciones sobre los animales en grupos mayas contemporáneos.  
575 *Revista Pueblos y Fronteras Digital* 10(20): 6–43.
- 576 Hagen O, Santos RM, Schlindwein MN, Viviani VR. 2015. Artificial night reduces firefly  
577 (Coleoptera: Lampyridae) occurrence in Sorocaba, Brazil. *Advances in Entomology* 3(01):  
578 24–32. DOI: 10.4236/ae.2015.31004
- 579 Humphries P, Winemiller KO. 2009. Historical impacts on river fauna, shifting baselines, and  
580 challenges for restoration. *BioScience* 59(8): 673–684. DOI 10.1525/bio.2009.59.8.9
- 581 Idris NS, Mustapha MA, Sulaiman N, Khamis S, Husin SM, Darbis NDA. 2021. The dynamics  
582 of landscape changes surrounding a firefly ecotourism area. *Global Ecology and*  
583 *Conservation* 29:e01749. DOI 10.1016/j.gecco.2021.e01741
- 584 IMPLAN. 2022. Instituto Municipal de Planeación de Morelia (IMPLAN). Available at:  
585 <https://implanmorelia.org> (Accessed 20 August 2024)
- 586 INEGI. 2022. Instituto Nacional de Estadística y Geografía. Available at:  
587 <http://en.www.inegi.org.mx/app/areasgeograficas/?ag=16053#collapse-Resumen> (Accessed  
588 20 August 2024)
- 589 Ineichen S. 2016. Light into Darkness: The Significance of Glowworms and Fireflies in Western  
590 Culture. *Advances in Zoology and Botany* 4(4):54–58. DOI: 10.13189/azb.2016.040402
- 591 Isenring R. 2010. Pesticides and the loss of biodiversity. *Pesticide Action Network Europe*,  
592 London 26:3–25.
- 593 Jönhsson J, Mårald E, Lundmark T. 2021. The shifting society syndrome: Values, baselines, and  
594 Swedish forest conservation in the 1930s and 2010s. *Conservation Science and Practice*  
595 3:e506. DOI 10.1111/csp2.506

- Juárez Becerril AM. 2017. De animales, plantas y lluvia: el uso de la fauna y la flora en la dinámica de la meteorología indígena. *Ulúa* 30:155–187. DOI 10.25009/urhsc.v0i30.2558
- Juárez Becerril AM. 2022. El estudio de los animales en la dinámica del tiempo meteorológico. Apuntes históricos y antropológicos. in: Juárez Becerril AM, coords. *Los animales del agua en la cosmovisión indígena, una perspectiva histórica y antropológica*. Publicaciones de la Casa Chata, México, 93–112.
- Jusoh WFA, Hashim NR. 2012. The effect of habitat modification on firefly populations at the Rembau-Linggi estuary, Peninsular Malaysia. *Lampyrid* 2:149–155.
- Kansteiner W. 2002. Finding meaning in memory: A methodological critique of collective memory studies. *History and Theory* 41(2):179–197. DOI 10.1111/0018-2656.00198
- Lara P, Antúnez Á. 2014. La historia oral como alternativa metodológica para las ciencias sociales. *Revista de Teoría y Didáctica de las Ciencias Sociales* 2014(20):45–62.
- Lewis SM. 2016. *Silent sparks: The wondrous world of fireflies*. NJ: Princeton University Press.
- Lewis SM, Thancharoen A, Wong CH, López-Palafox T, Santos PV, Wu C, Reed JM. 2021. Firefly tourism: Advancing a global phenomenon toward a brighter future. *Conservation Science and Practice* 3(5):e391.
- Lewis SM, Wong CH, Owens AC, Fallon C, Jepsen S, Thancharoen A, Wu C, De Cock R, Novák M, López-Palafox T, Khoo V, Reed M. 2020 A global perspective on firefly extinction threats. *BioScience* 70(2):157–167. DOI 10.1093/biosci/biz157.
- Lloyd JE. 1973 Firefly parasites and predators. *The Coleopterists' Bulletin* 91–106.
- Lloyd JE. 1983. Bioluminescence and communication in insects. *Annual Review of Entomology* 28:131–160. DOI 10.1146/annurev.en.28.010183.001023
- Lloyd JE. A naturalist's long walk among shadows of North American *Photuris*: Patterns, outlines, silhouettes. . . echoes. Bridgen Press; 2018.
- López E, Bocco G, Mendoza M, Duhau E. 2001. Predicting land-cover and land-use change in the urban fringe: a case in Morelia city, Mexico. *Landscape and Urban Planning* 55(4):271–285 DOI 10.1016/S0169-2046(01)00160-8.
- López Núñez MC, Pedraza Marrón HA. 2012. Territorio como patrimonio: el espacio periurbano de la ciudad de Morelia y el agotamiento de los recursos. *Revista Asuntos Económicos y Administrativos*, Facultad de Ciencias Contables, Económicas y Administrativas 22:267–283.
- MacGregor-Fors I. 2010. How to measure the urban-wildland ecotone: redefining 'peri-urban' areas. *Ecological Research* 25(4):883–887 DOI 10.1007/s11284-010-0717-z.
- Mata L, Andersen AN, Morán-Ordóñez A, Hahs AK, Backstrom A, Ives CD, Bickel D, Duncan D, Palma E, Thomas F, Cranney K, Walker K, Shears I, Semeraro L, Malipatil M, Moir ML, Plein M, Porch N, Vesik PA, Smith TR, Lynch Y. 2021. Indigenous plants promote insect biodiversity in urban greenspaces. *Ecological Applications* 31(4):e02309 DOI 10.1002/eap.2309
- Moosman JrPR, Cratsley CK, Lehto SD, Thomas HH. 2009. Do courtship flashes of fireflies (Coleoptera: Lampyridae) serve as aposematic signals to insectivorous bats?. *Animal Behaviour* 78(4):1019–1025.

- Naturalista. (2022). Lampyridae from:  
[https://www.naturalista.mx/observations?place\\_id=7447&taxon\\_id=47731](https://www.naturalista.mx/observations?place_id=7447&taxon_id=47731) (Accessed 21 December 2022).
- Nghiem TPL, Wong KL, Jeevanandam L, Chang CC, Tan LYC, Goh Y, Carrasco LR. 2021. Biodiverse urban forests, happy people: Experimental evidence linking perceived biodiversity, restoration, and emotional wellbeing. *Urban Forestry & Urban Greening* 59:127030. DOI 10.1016/j.ufug.2021.127030.
- Ortíz L. 2005. Historia Oral: reflexiones desde sus límites y problemas. *Revista Humanidades* 6:14–20.
- Owens ACS, Van den Broeck M, De Cock R, Lewis SM. 2022. Behavioral responses of bioluminescent fireflies to artificial light at night. *Frontiers in Ecology and Evolution* 10: 946640 DOI 10.3389/fevo.2022.946640.
- Papworth SK, Rist J, Coad L, Milner-Gulland EJ. 2009. Evidence for shifting baseline syndrome in conservation. *Conservation Letters* 2:93–100. DOI 10.1111/j.1755-263X.2009.00049.x
- Pauly D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology & Evolution* 10(10): 430.
- Pérez-Hernández CX, Gutiérrez Mancillas AM, del-Val E, Mendoza Cuenca LF. 2023a. Living on the edge: Living on the edge: urban fireflies (Coleoptera, Lampyridae) in Morelia, Michoacán, Mexico. *PeerJ* 11:e16622 DOI 10.7717/peerj.16622
- Pérez-Hernández CX, Mendoza-Cuenca LF, Romo-Galicia A. 2023b. Dataset of the Lampyridae (Coleoptera) from Morelia, Michoacán, México. Universidad Michoacana de San Nicolás de Hidalgo Facultad de Biología. Available at <https://doi.org/10.15468/3asucg>
- Pérez-Hernández CX, Rivera-Ramírez DB. 2024. *In press*. La historia oral sobre luciérnagas como fuente de información para analizar la pérdida de nuestra memoria colectiva. In: Castaño-Meneses G, Navarrete-Heredia JL, eds. *Los Artrópodos y el Hombre: Una Perspectiva desde México*. Universidad de Guadalajara
- R Core Team. 2021. R: A language and environment for statistical. computing. Vienna: R Foundation for Statistical Computing. Available at <https://www.r-project.or>
- Raupp M, Shrewsbury P, Herms D. 2010. Ecology of Herbivorous Arthropods in Urban Landscapes. *Annual Review of Entomology* 55:19–38 DOI 10.1146/annurev-ento-112408-085351
- Ruiz-López C, Méndez-Lemus Y, Vieyra A, Alvarado C. 2022. City-regions and socio-economic segregation in mid-sized cities in Mexico: the cases of Oaxaca and Morelia. *Town Planning Review* 93 (5):519–546. DOI 10.3828/tp.2021.45
- Soga M, Gaston KJ. 2018. Shifting baseline syndrome: causes, consequences, and implications. *Frontiers in Ecology and the Environment* 16(4):222–230. DOI 10.1002/fee.1794
- Takada K. 2012. Japanese interest in “Hotaru” (Fireflies) and “Kabuto-Mushi” (Japanese Rhinoceros Beetles) corresponds with seasonality in visible abundance. *Insects* 3: 424–431. DOI 10.3390/insects3020424

- 675 Theobald E, Ettinger A, Burgess H, DeBey L, Schmidt N, Froehlich H, Wagner C,  
676 HilleRisLambers J, Tewksbury J, Harsch MA, Parrish JK. 2015. Global change and local  
677 solutions: Tapping the unrealized potential of citizen science for biodiversity research.  
678 *Biological Conservation* 181:236–244. DOI 10.1016/j.biocon.2014.10.021
- 679 Tso C-HM, Lowther A, Monteith D, Banin LF, Simm W, Rennie S, Hollaway M, Henrys P,  
680 Killick R, Watkins J, Blair GS. 2021. Integration of long-term collocated ecological datasets:  
681 examples from the UK Environmental Change Network (ECN). [Abstract EGU21-2293] EGU  
682 General Assembly 2021. DOI 10.5194/egusphere-egu21-2293
- 683 United Cities and Local Governments, 2020. *United Cities and Local Governments, World*  
684 *Council 2020*. Available at: <https://www.old.uclg.org/en/agenda/intermediary-cities> (accessed  
685 20 August 2024).
- 686 United Nations. 2018. *Revision of world urbanization prospects. Department of Economic and*  
687 *Social Affairs*. New York, NY: Author
- 688 Vaz S, Manes S, Gama-Maia D, Silveira L, Mattos G, Paiva PC, Figueiredo M, Lorini ML.  
689 2021. Light pollution is the fastest growing potential threat to firefly conservation in the  
690 Atlantic Forest hotspot. *Insect Conservation and Diversity* 14(2):211–224 DOI  
691 10.1111/icad.12481.
- 692 Vaz S, Manes S, Khatrar G, Mendes M, Silveira L, Mendes E, Rodrigues EM, Gama-Maia D,  
693 Lorini ML, Macedo M, Paiva PC. 2023. Global meta-analysis of urbanization stressors on  
694 insect abundance, richness, and traits. *Science of the Total Environment* 903:165967. DOI  
695 10.1016/j.scitotenv.2023.165967
- 696 Wagner DL, Grames EM, Forister ML, Berenbaum MR, Stopak D. 2021. Insect decline in the  
697 Anthropocene: Death by a thousand cuts. *Proceedings of the National Academy of Sciences*.  
698 118(2):e2023989118. DOI 10.1073/pnas.2023989118
- 699 Wong CH, Yeap CA. 2012. Conservation of congregating firefly zones (CFZs) in Peninsular  
700 Malaysia. *Lampyrid* 2:174–187.
- 701 Zamorski K, Kurkowska-Budzan M. 2009. *Oral History: The Challenges of Dialogue*. John  
702 Benjamins Publishing Co. Vol. 10, 224 p.
- 703 Zaragoza-Caballero S. 2004. Lampyridae (Coleoptera). In: García-Aldrete AN, Ayala R, eds,  
704 *Artrópodos de Chamela*. Instituto de Biología, Universidad Nacional Autónoma de México,  
705 México, Mexico City, 139–150.



# **Table 1**(on next page)

Table 1. Questions applied to 112 inhabitants of the city of Morelia, in Michoacán, Mexico.

The participants belonged three different generations, to evaluate their perception of fireflies and their natural environment, and to reconstruct the history of firefly populations in recent decades; n, number of participants who answered the question.

**Table 1.** Questions applied to 112 inhabitants of the city of Morelia, in Michoacán, Mexico, belonging to three different generations, to evaluate their perception of fireflies and their natural environment, and to reconstruct the history of firefly populations in recent decades; n, number of participants who answered the question.

Question	Value Range	Justification	n
1. Do you know fireflies? 1.1 How do you recognize them?	a) Yes b) No c) Not sure 1.1 Open-ended question	The aim was to assess the general recognition of fireflies and to detect biases in the testimonies (e.g., observations referring to cockroaches, Elateridae, or to “dragonflies”, which are often confused with “fireflies” in Spanish).	112
2. Have you ever seen fireflies in nature? 2.1 How was your experience? (aesthetic, sensorial, emotional appreciation) 2.2 Do you know them through any other media?	a) Yes b) No 2.1 Open-ended question 2.2 a) Yes b) No c) Not sure	It is possible that the experiences between the interviewees and the fireflies may evoke a sense of rootedness, thereby imprinting themselves upon the memory. This question sought to elicit more detailed recollections of these experiences.	109
3. Have you seen fireflies in Morelia? Where?	a) Yes b) No	The aim was to geographically delimit the areas where fireflies have been present throughout the history of the city (since 1950).	99
4. When was the last time you saw them in Morelia? (approximate time)	a) Last season (2021) b) 5 years ago c) 10 years ago d) 15 years ago e) >20 years ago f) >50 years ago	By comparing the location and timing of sightings with environmental changes, we sought to document the history of possible environmental deterioration in the firefly habitats.	72
5. How many times have you been able to see them in Morelia in the last few years?	a) Never seen again b) Only once c) Only a few times d) Sometimes e) Frequently	The testimony on the recurrence of sightings allowed us to obtain information on temporal patterns of firefly presence, and to associate these patterns with the environmental changes evaluated.	72

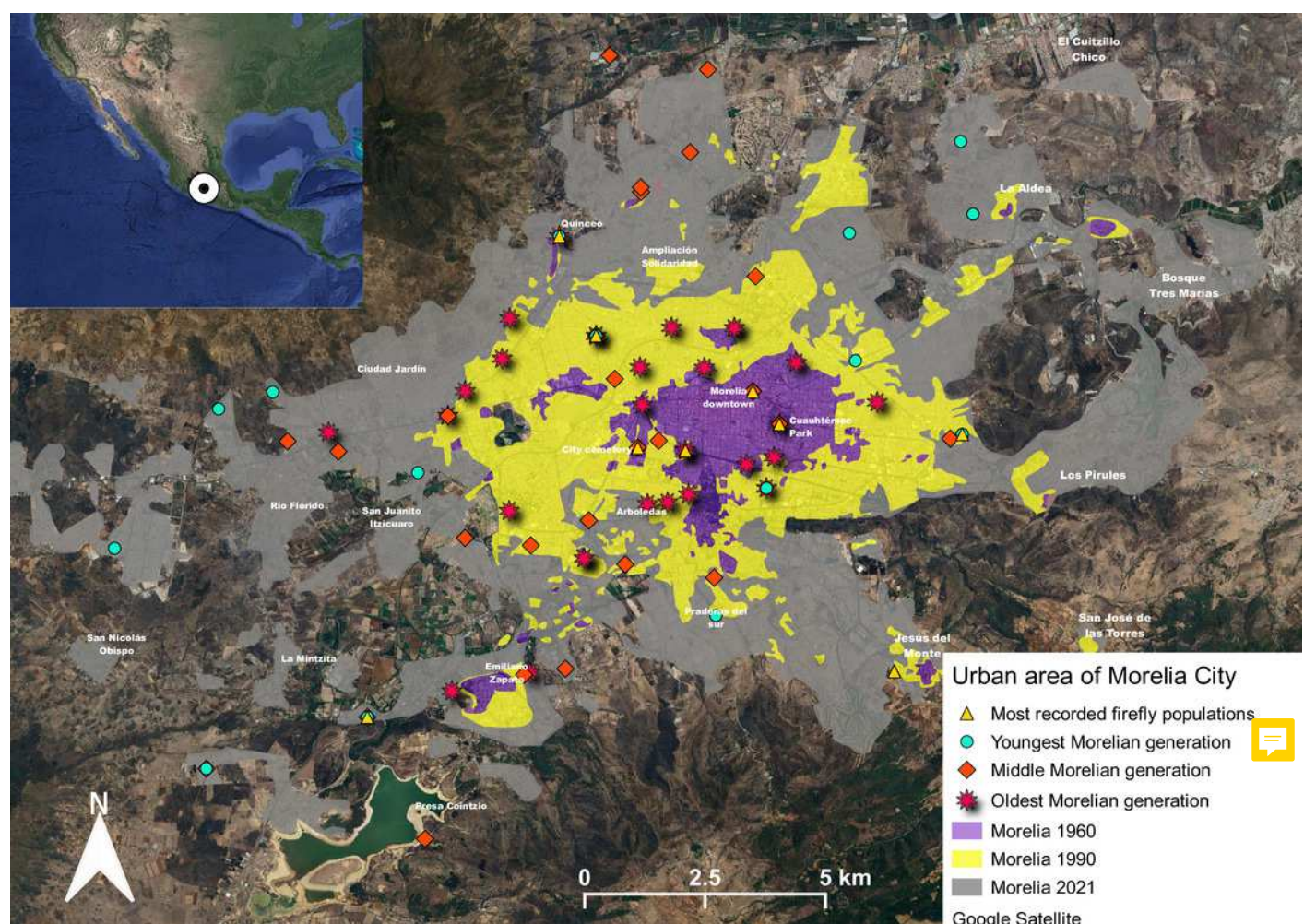
6. How many fireflies do you think you saw the last time (per year or season)?	a) Few (<10) b) Some (ca. 20-30) c) Many (>50)	This was used to estimate the change in the size of past and current firefly populations.	72
7. Do you think that there have been changes in the number of fireflies you have seen? 7.1 What are the changes?	a) Yes. 7.1 What are the changes? (Open response) b) No c) Doesn't know	This was used to document the perception of changes in the size of firefly populations. The objective was to document evidence of the gradual decline of firefly populations in the area. Knowledge about the historic and current status of fireflies was key to the interpretation of the Shifting Baseline Syndrome (SBS) (individual and collective memory).	62
8. Has anything changed in the places in Morelia where you once saw fireflies? 8.1 What changes?	a) Nothing has changed b) Plantations c) Constructions d) Crops e) Others	This information was used to detect the factors associated with the potential loss or diminution of the firefly distribution area, and to reconstruct the citizen perception of the increase in urbanization in Morelia.	72
9. Have you noticed changes in Morelia over recent years? 9.1 What changes?	a) Yes. 9.1 Open response b) No c) Don't know	The aim was to gather information on the perception of the processes of change that have occurred in different areas of the city of Morelia.	112
10. Do you think there should be fireflies in the town where you live? 10.1 Why?	Open-ended question	This allowed evaluation of the people's perception of the ecological requirements of fireflies as well as the characteristics of their natural environment.	89
11. Do you think fireflies are important for the environment/ecosystems? 11.1 Why?	Open-ended question	This perspective offered an insight into the perception of fireflies in the Morelia area and the extent of current knowledge about them.	109
12. Do you consider fireflies to be important for humans?	a) Yes. 12.1 Why? (Open response) b) No. 12.2 Why?	Perception at the individual level forms part of the manner in which information is transmitted for the	109

	(Open response) c) Don't know	construction of a collective memory.	
13. Where you live have you ever heard stories about firefly sightings? 13.1 What stories have you heard? 13.2 Who told them to you? 13.3 From how long ago are these stories?	13. a) Yes; then: 13.1 Open ended question 13.2 Open ended question 13.3 a) Approximately 5 years b) Approximately 10 years c) Approximately 15 years d) Approximately 20 years e) More than 20 years 13. b) No	Given that shared oral histories generate collective memory, this information was useful to estimate the manner and frequency of the transmission of oral histories regarding the past and current status of firefly populations. With this information, it was possible to evaluate the existence or loss of collective memory among generations.	109
14. Do you often tell your stories about fireflies to others in your family or community?	a) Yes b) No	This made it possible to evaluate the practice of oral history among the inhabitants of Morelia, and to establish the scope of oral histories in terms of generating a collective memory about the state of firefly populations and the natural environment.	99

# Figure 1

Figure 1. Growth of the urban area of the city of Morelia (Michoacán, Mexico) in 1960, 1990, and 2021.

Based on López *et al.* (2001), López Núñez and Pedraza Marrón (2012), and IMPLAN (2022). The map also shows records of firefly populations observed in Morelia by the oldest generation (pink stars), the middle generation (orange rhombus) and the youngest generation (aqua blue circles), as well as the most frequently reported sighting sites (yellow triangles). Image ©2023 CNES/AIRBUS, Landsat/Copernicus, Image ©2023 Maxar Technologies. Map data ©2023 Google, INEGI.

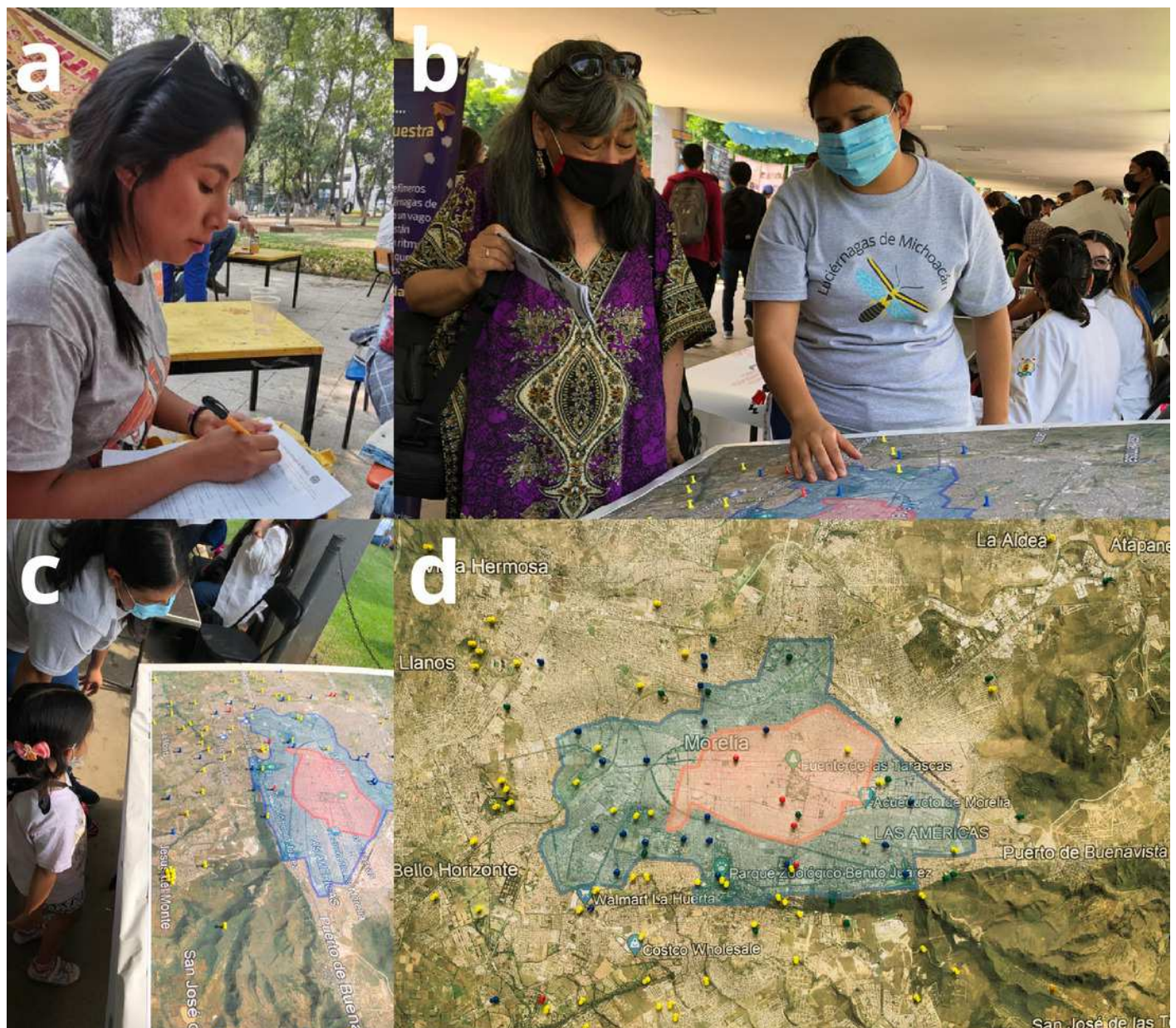




# Figure 2

Figure 2. Compilation of oral history on fireflies in Morelia city.

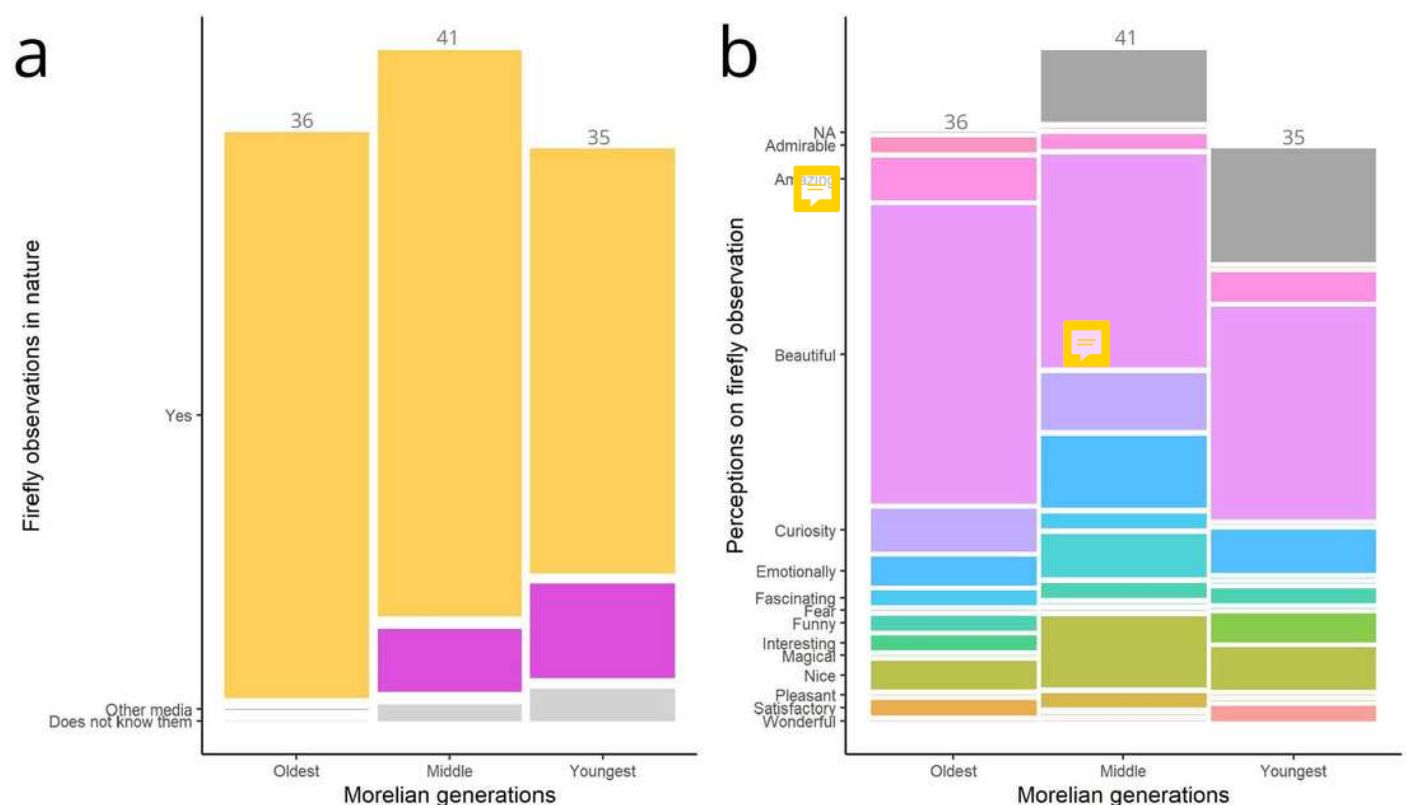
(A) first author Danna Rivera during an interview in 2021; (B), (C) and (D) map of Morelia city illustrating the expansion of the urban area over the last 60 years used during the interviews and surveys on fireflies in a science exhibition in the Michoacana University. Image credits: (A) Danna Rivera, (B, C, D) Cisteil X. Pérez-Hernández.



# Figure 3

Figure 3. Local knowledge and perceptions about fireflies in Morelia city, Michoacán, Mexico.

(A) observations of fireflies in their natural habitat, other sources or have never been seen; and (B) experiences and emotions on firefly sightings among three different Morelian generations, from a total of 112 interviewed people.

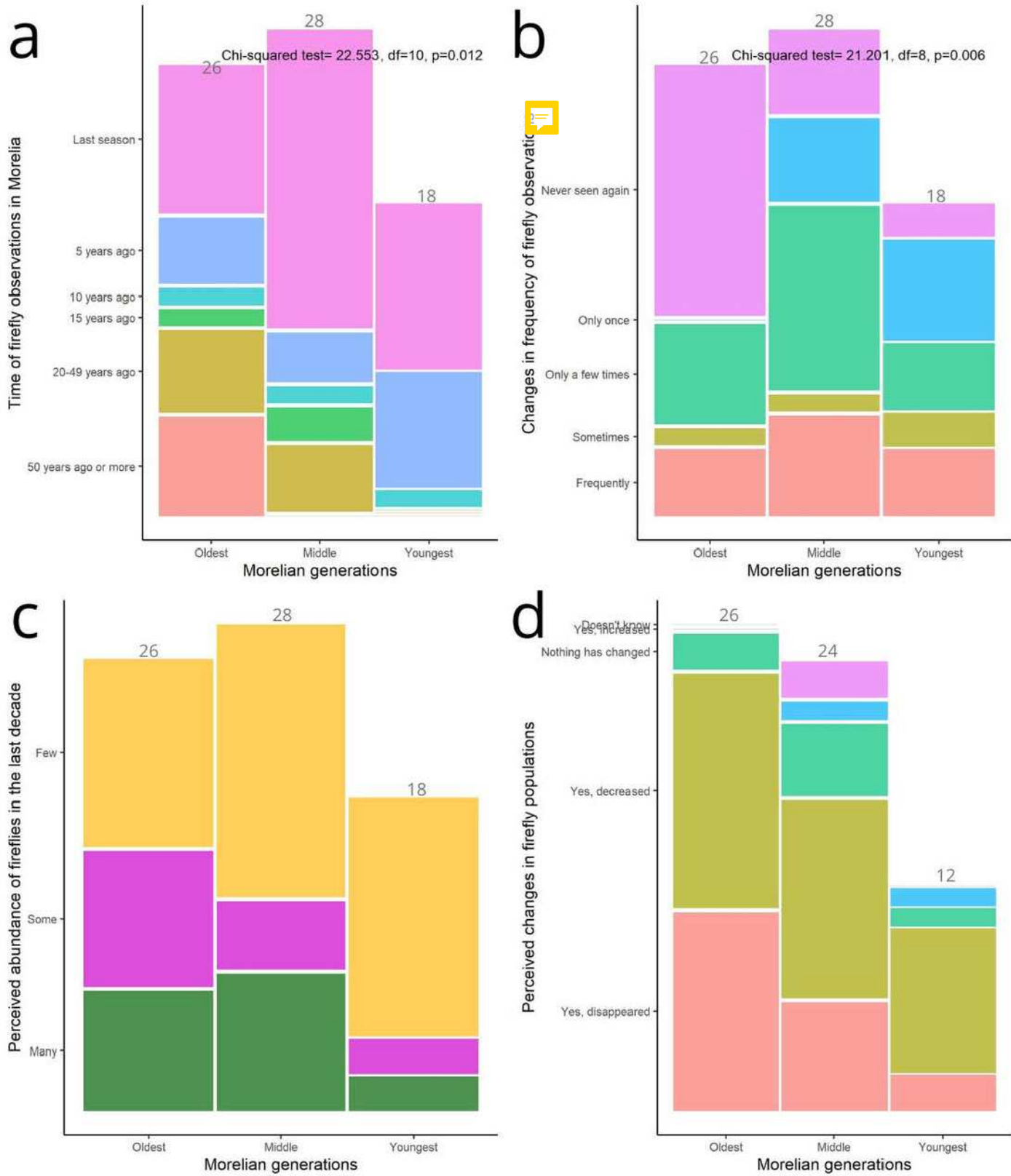


# Figure 4

Figure 4. Perceptions of Morelians regarding the changes in firefly populations.

(A) observations of fireflies in different times among Morelian generations; (B) changes in frequency of their firefly observations during the last decade; (C) perceived abundance (individual number) of fireflies seen at the time of the sighting; (D) changes in the abundance seen in the last decade





# Figure 5

Figure 5. Perceptions of Morelian people about habitat changes and value of fireflies

(A) changes in firefly habitats in the last years; (B) value of fireflies for ecosystems; (C) value of fireflies for humans.

