



**UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO**  
**POSGRADO EN CIENCIAS BIOLÓGICAS**  
INSTITUTO DE ECOLOGÍA  
**BIOLOGÍA EVOLUTIVA**

**COSTOS EVOLUTIVOS DE UNA TRAMPA ECOLÓGICA EN LIBÉLULAS**

**TESIS**

**POR ARTÍCULO CIENTÍFICO**

**Ecological traps in dragonflies and damselflies: the role of condition, visual capacity and a discussion of susceptible species world-wide**

QUE PARA OPTAR POR EL GRADO DE:

**MAESTRA EN CIENCIAS BIOLÓGICAS**

PRESENTA:

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**DICIEMBRE, 2019**



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COORDINACIÓN DEL POSGRADO EN CIENCIAS BIOLÓGICAS

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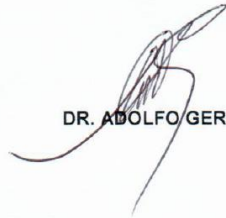
Me permito informar a usted que en la reunión ordinaria del Comité Académico del Posgrado en Ciencias Biológicas, celebrada el día 7 de octubre de 2019, se aprobó el siguiente jurado para el examen de grado de **MAESTRA EN CIENCIAS BIOLÓGICAS** en el campo de conocimiento de **Biología Evolutiva** de la alumna **ENSALDO CÁRDENAS ANGÉLICA SELENE** con número de cuenta 309173146 por la modalidad de graduación de **tesis por artículo científico** titulado: **"Ecological traps in dragonflies and damselflies: the role of condition, visual capacity and a discussion of susceptible species world-wide"**, que es producto del proyecto realizado en la maestría que lleva por título: **"COSTOS EVOLUTIVOS DE UNA TRAMPA ECOLÓGICA EN LIBÉLULAS"**, ambos realizados bajo la dirección del **DR. ALEJANDRO CÓRDOBA AGUILAR**, quedando integrado de la siguiente manera:

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Sin otro particular, me es grato enviarle un cordial saludo.

**ATENTAMENTE**  
**"POR MI RAZA HABLARA EL ESPÍRITU"**  
Ciudad Universitaria, Cd. Mx., a 7 de noviembre de 2019

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## Agradecimientos

- Al posgrado de Ciencias Biológicas, UNAM.
- A CONACYT por la beca otorgada para realizar mis estudios de Maestría en el periodo 2017-2 – 2019-1 (CVU: 815395/ BECARIO: 620154).
- A los apoyos PAEP por el apoyo económico para presentar los resultados de este trabajo en el European Congress on Odonatology 2018.
- Al Proyecto PAPIIT-DGAPA IN206618 “Insectos mexicanos en peligro de extinción: patrones, causas y consecuencias”.
- A los miembros del comité tutor: Dr. Alejandro Córdoba Aguilar, Dr. Roberto Munguía-Steyer and Hugh Drummond.

Cuando pienso en todo lo que ha implicado este proceso, lo primero que llega a mi mente en la lista de las personas a las que tengo que agradecer por hacer esto posible, empiezo por mi amada familia quien ha sido mi soporte y apoyo para cumplir este sueño.

A mi mamá que ha estado conmigo en los momentos más duros y a Sr. Papá que siempre ha creído en mí. A mis hermanos: Isaac, Hugo, Carlitos y Paco quien hacen de mi mundo un lugar mejor. A mi abuelita Amalia quien se preocupa de mi bienestar y salud como nadie más. A Koko y Nao son la mejor compañía no humana que alguien podría desear.

A mis mejores amigos Alicia y Ricardo, no tengo suficientes palabras para decirles todo lo que su amistad significa para mí, gracias por todo lo que hacen por mi cada día desde que llegaron a mi vida, sin ustedes esto no sería posible.

Un agradecimiento especial a las personas que han contribuido en este trabajo empezando con mi director de tesis el Dr. Alex, quien me ha guiado con paciencia infinita, gran esfuerzo y dedicación desde que llegue al laboratorio hace ya algunos ayeres, preocupándose siempre por mi desarrollo profesional y personal. A Maya Rocha y a David Schneider cuyo talento y paciencia y conocimientos sirvieron de pilar para este trabajo.

A mis sinodales, el Dr. Carlos Córdero, Dr. Rodolfo Novelo, Dr. Atilano Contreras y la Dr. María del Coro quienes han tenido la mejor disposición para guiarme y ayudarme en todo momento.

A mis compañeros de laboratorio y amigos, Ulises, Anita, Iván, Cata, Edday, Aldo, Angelita, Monse, Joshua, Xavier, Tania, Jaime y por supuesto al M. en C. Raúl Martínez quienes siempre ofrecen con la mejor disposición su ayuda y soporte.

Por supuesto a la licenciada Erika Rodríguez, quien con su infinita paciencia siempre brinda su apoyo y ayuda.

A mis muy queridos amigos Romy, Sam, Pactli, Helen, Mely y Abril, les doy las gracias por su infinito apoyo, por sus consejos y por sus palabras de aliento.

Finalmente, a la UNAM, que ha sido mi segundo hogar desde hace tanto tiempo, que ha sido el escenario donde todas las metas y sueños se cumplen.

Leonardo da Vinci dijo “No da paso atrás quien está atado a una estrella” Eso es cierto, yo los tengo a todos ustedes.

¡Gracias!



A María del Carmen Segura, ojalá estuvieras aquí.

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## Resumen

Aun cuando conocemos que existe una amplia gama de organismos que son susceptibles de caer en una trampa ecológica, sabemos poco de si la condición y/o capacidad visual de un animal puede afectar esta susceptibilidad. Las libélulas y caballitos del diablo (Odonata) utilizan superficies artificiales para sus actividades sexuales, ya que reflejan la luz polarizada de manera semejante a sus hábitats acuáticos. En este estudio nos preguntamos las preferencias por estos sitios artificiales, sus costos, su vínculo con la condición individual (basado en el tamaño, lípidos y proteínas) y capacidad visual (basado en el ancho de los ojos). Para esto usamos tres especies de odonatos, *Enallagma praevarum*, *Ischnura denticollis* y *Sympetrum illotum*, las cuales se expusieron a una trampa ecológica vs un control. Registramos el tiempo que pasaron las tres especies, así como las conductas en ambos tratamientos. También, medimos el tamaño corporal y ancho de ojos, proteínas y lípidos de los animales que usaron la trampa ecológica vs animales que no la usaron. Además, mostramos una lista de especies observadas en varias regiones del mundo, que caen en trampas ecológicas. Encontramos que las tres especies confundieron y usaron la trampa ecológica, aunque dos especies (*I. denticollis* and *S. illotum*) las usaron más intensamente. Los individuos de *I. denticollis* que usaron la trampa, tuvieron menor cantidad de lípidos, tamaño y sus ojos fueron más grandes en comparación con los individuos de la misma especie que no usaron la trampa. Estos resultados sugieren variación intra e interespecifica en función del uso de trampas. Nuestra lista indica que predominantemente son libélulas más que caballitos del diablo, los que usan superficies artificiales y que hay cierta inercia filogenética. Esto sugiere una propiedad relacionada con la ascendencia en la propensión a caer.

## Summary

Even though we know that a wide range of organisms are susceptible to falling into an ecological trap, we know little about whether condition and/or visual capacity of an animal affects this susceptibility. Dragonflies and damselflies use artificial surfaces for their sexual activities, since they reflect polarized light similarly to their aquatic habitats. We investigated within- and between-species preferences for these artificial sites, their costs and link with individual condition (based on lipid and protein content and body size) and visual capacity (based on eye width). For this we used *Enallagma praevarum*, *Ischnura denticollis* and *Sympetrum illotum* which were exposed to an ecological trap against a control. We recorded the time and behavior in both treatments, and wing length, eye width, protein and lipid contents of animals that used the ecological trap against animals that did not use it. We also provide species observed world-wide, which have been observed to use artificial surfaces. All three species used the ecological trap, although two species (*I. denticollis* and *S. illotum*) used it more frequently. *I. denticollis* individuals that used the trap had a lower lipid quantity, smaller size and larger eyes than the individuals that did not use the trap of the same species. These results suggest intra and interspecific variation in susceptibility to falling into traps, related to individual condition. Our world-wide list indicates that dragonflies rather than damselflies use artificial surfaces, and that there is some phylogenetic inertia. This suggests an ancestry-related property in the propensity to fall into traps.

## Introducción

Una trampa ecológica es un hábitat o recurso de baja calidad o subóptimo, que asemeja las características de otros hábitats de mejor calidad disponibles. Estas trampas pueden engañar y sesgar las preferencias de los individuos por estos sitios (Robertson, Rehage & Sih, 2013). Los hábitats de mala calidad son en su mayoría, resultado del cambio abrupto en el ambiente generado por la actividad antropocéntrica. Estos cambios modifican uno o varios componentes de las señales auditivas, olfativas o visuales que los organismos usan naturalmente para seleccionar un hábitat adecuado (Gallaway, Olsen & Mitchell, 2010; Robertson & Chalfaun, 2016). La integración de estos componentes a nivel neuronal y cognoscitivo por un animal lo hacen más susceptible de reconocer erróneamente un componente ambiental como un hábitat o recursos de calidad (Gallaway, Olsen & Mitchell, 2010; Robertson & Chalfaun, 2016).

La ocurrencia de las trampas ecológicas es ubicua y tiene consecuencias negativas a distintos niveles (Hale & Swearer, 2016). Estos niveles pueden ir desde reducción de la adecuación de un individuo, provocar una baja en la densidad poblacional o incluso extinción local (Schlaepfer, Runge & Sherman, 2002; Robertson & Chalfaun, 2016). Sin embargo, se admite que no todos los animales son susceptibles de ser engañados. Si bien se cree que la selección que actuó en el pasado ya no es adaptativa en el presente, también es cierto que algunos animales escapan a los dilemas de usar una trampa o no mediante a sus capacidades de reconocimiento o de dispersión (Robertson et al. 2013). Una forma de entender por qué puede haber variación individual de caer en una trampa es la condición fisiológica, aunque esta última ha sido muy poco evaluada (Robertson et al. 2013; Hale and Swearer, 2018). Puede ser el caso, por ejemplo, que un individuo que ha recibido poco alimento y, por lo tanto, tiene una condición empobrecida, sea más susceptible de ser engañado parte porque su umbral de detección de la calidad de un ambiente (o la trampa) es más bajo (Robertson et al. 2013). Aunque esta variación individual ya ha sido discutida como algo importante en el entendimiento de los predictores de preferencias de hábitats basado en una desviación de una selección de hábitat ideal (Pärt et al. 2007), esta variación se ha abordado poco. En caso de que la condición sea importante, entonces uno podría esperar que sean los animales de mala

condición sean los más susceptibles de caer en una trampa. De lo contrario, la condición no importará en la toma de decisiones y, por lo tanto, animales tanto de buena como mala condición serán igualmente susceptibles de caer en una trampa. Sobre los predictores, también poco se ha explorado si la capacidad sensorial es un atributo importante en la preferencia por las trampas. Por ejemplo, se esperaría que los animales cuyas decisiones de uso de trampas están basadas en la capacidad visual, la probabilidad de caer en un engaño está relacionada con el tamaño de los ojos. En este caso, y si la propiedad de caer en la trampa es un atributo de toda la especie, el tamaño del ojo (y de aquí, su capacidad visual) no estaría relacionado con la propensión de caer en una trampa.

Un caso que ha llamado la atención en términos de trampas ecológicas es la confusión de hábitats por sus emisiones de patrones de luz polarizada en insectos acuáticos (Horváth & Kriska, 2008; Horváth et al. 2009). Los insectos, en general, detectan señales ambientales abióticas y bióticas a partir de tales patrones usando fotoreceptores ubicados en el margen del ojo (von Phillisborn, 2018). Dado que la polarización de la luz es constante a pesar de diferencias de color e intensidad, funciona como una señal confiable (O'Hanlon et al. 2018). En particular, los odonatos (libélulas y caballitos del diablo), son ejemplos de insectos acuáticos sensibles y atraídos a la luz polarizada visible en los intervalos del espectro ultravioleta. Esta sensibilidad es utilizada en el reconocimiento del hábitat acuático que aprovechan tanto machos como hembras para identificar un sitio idóneo para las actividades sexuales, por ejemplo, la defensa de un territorio, la búsqueda de pareja y la puesta de huevos (Bernáth et al., 2001). Sin embargo, existen otros materiales como las carrocerías de los autos, láminas o paneles de plástico, o los reservorios de petróleo que reflejan la luz polarizada igual que un cuerpo de agua. Estas superficies funcionan como trampas ecológicas para las libélulas, las cuales son atraídas por estas superficies brillantes para las actividades sexuales (Bernáth et al., 2001; Wildermuth & Horvéth, 2005; Horváth et al., 2007; Harabiš & Dolný, 2012; Villalobos-Jiménez et al. 2018). El uso de estos sitios no aptos para sus despliegues conductuales puede afectar el desempeño de las libélulas en la búsqueda de pareja, la reproducción y la supervivencia de la descendencia (Schlaepfer, Runge & Sherman, 2002; Navara & Nelson, 2007). La mayor parte de la investigación se ha basado en pocas especies y ha buscado entender cuáles son las características del hábitat que estos organismos

reconocen y cuáles son los mecanismos que influyen en la selección de hábitat. Sin embargo, no existen estudios que se enfoquen en explorar qué tan común son otras especies de caer en las trampas, los costos en la adecuación de la mala elección del hábitat en libélulas, y los predictores de condición fisiológica y/o capacidad visual en la selección del hábitat erróneo.

En este estudio hemos utilizado tres especies de odonatos ubicados en un ambiente urbano, para averiguar de forma experimental los representantes de: a) costos en adecuación que surgen de una elección errónea del hábitat; b) predictores de condición del animal y capacidad visual. Para los costos de adecuación hemos usado componentes conductuales relacionado con el tiempo que invierten defendiendo o usando una trampa. Para el proxy de condición, hemos usado tanto el tamaño corporal como el contenido de lípidos y proteínas corporales en individuos que caen y no en la trampa. Tanto los lípidos como proteínas son componentes esenciales de la condición en odonatos (Van Praet et al. 2014; revisado por Stoks & Córdoba-Aguilar, 2012) e insectos (Kouřimská & Adámková, 2016) en general. Para el proxy de capacidad visual, hemos usado el ancho de los ojos donde razonamos que a mayor el tamaño de estos, mayor será la capacidad visual. Más allá de las especies que han servido como sujetos de estudio, hemos incluido también otras especies de odonatos que son susceptibles de caer en trampas ecológicas.

Ecological traps in dragonflies and damselflies: the role of condition, visual capacity and a discussion of susceptible species world-wide

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Running head: Ecological traps and dragonflies

Keywords: ecological traps, Odonata, fitness, size, physiology



## Summary

Even though we know that a wide range of organisms are susceptible to falling into an ecological trap, we know little about whether condition and/or visual capacity of an animal affects this susceptibility. Dragonflies and damselflies use artificial surfaces for their sexual activities, since they reflect polarized light similarly to their aquatic habitats. We investigated within- and between-species preferences for these artificial sites, their costs and link with individual condition (based on lipid and protein content and body size) and visual capacity (based on eye width). For this we used *Enallagma praevarum*, *Ischnura denticollis* and *Sympetrum illotum* which were exposed to an ecological trap against a control. We recorded the time and behavior in both treatments, and wing length, eye width, protein and lipid contents of animals that used the ecological trap against animals that did not use it. We also provide species observed world-wide, which have been observed to use artificial surfaces. All three species used the ecological trap, although two species (*I. denticollis* and *S. illotum*) used it more frequently. *I. denticollis* individuals that used the trap had a lower lipid quantity, smaller size and larger eyes than the individuals that did not use the trap of the same species. These results suggest intra and interspecific variation in susceptibility to falling into traps, related to individual condition. Our world-wide list indicates that dragonflies rather than damselflies use artificial surfaces, and that there is some phylogenetic inertia. This suggests an ancestry-related property in the propensity to fall into traps.

## Introduction

An ecological trap is a habitat or resource of low or null quality that resembles the characteristics of other available habitats of better quality. These traps can deceive and skew the preferences of individuals (Robertson, Rehage, & Sih, 2013). Poor quality habitats are mostly the result of an abrupt environmental change generated by anthropocentric activity. These changes may cause the auditory, olfactory or visual cues that organisms use naturally to select an adequate habitat to be made inefficient (Robertson & Chalfoun, 2016). Thus, animals may erroneously recognize an environmental component as a high-quality habitat or resource (Gallaway, Olsen, & Mitchell, 2010).

The occurrence of ecological traps is ubiquitous and has negative effects at different biological levels (Hale & Swearer, 2016), which can range from a fitness reduction at the individual level to negative effects on population density or even local extinction (Robertson & Chalfoun, 2016; Schlaepfer, Runge, & Sherman, 2002). While it is believed that the selection that acted in the past is no longer adaptive in the present, it is also true that some individuals and species identify and avoid these traps successfully (Robertson et al., 2013). This difference in their response may be explained by intra and interspecific variation in their susceptibility to being deceived given by some specific character (Powney, Cham, Smallshire, & Isaac, 2015). One way to understand this variation is that susceptibility may depend on animal's physiological condition, although this rationale has been very scarcely considered (Hale & Swearer, 2016; Robertson et al., 2013). For example, it may be the case that an individual who has received little food and, therefore, has a poor condition, is more likely to be deceived. It may be that the capability to detect the quality of an environment (or the trap) by a poor-condition individual is lower (Robertson et al., 2013). This individual variation has been discussed as an important part in the predictors for habitat preferences based on a deviation from an ideal habitat selection (Pärt, Arlt, & Villard, 2007). In case the condition is important, then one could expect that animals in worst condition are the most susceptible to fall into a trap. Otherwise, the condition will not matter in decision-making and, therefore, animals of both good and bad condition will be equally susceptible to falling into a trap (Robertson & Chalfoun, 2016). On the predictors, little has been explored about

the sensory capacity as an important attribute in the preference for traps. For example, organisms whose light attraction is affected by visual capability would be expected to fall into deception based on the size of their eyes: the larger the eye, the stronger the attraction. This prediction and its test have been corroborated in moths (van Langevelde, Ettema, Donners, WallisDeVries, & Groenendijk, 2011) and the explaining mechanism is that vision ability and sensitivity is size-related in insects (Moser et al., 2004; Yack, Johnson, Brown, & Warrant, 2007).

The pattern of reflection of the polarized light is an important signal to detect suitable habitats for aquatic insects (Horváth & Kriska, 2008; Horváth, Kriska, Malik, & Robertson, 2009). Opposite to white light whereby electromagnetic waves vibrate at all likely planes perpendicular to the direction of propagation, polarized light waves are completely reflected in one plane (Horváth et al., 2009). Given that bodies of water always reflect polarized light regardless of the surrounding vegetation and water movement, this principle works as a reliable cue for habitat discrimination (O'Hanlon, White, & Umbers, 2018). In particular, the Odonata (dragonflies and damselflies) are examples of sensitive aquatic insects, that are attracted to the polarized light visible along the ultraviolet spectrum (Corbet, 1999). This sensitivity is used in the recognition of aquatic habitat by both males and females to choose a suitable site for sexual activities, such as the defense of a territory, the search for a mate and/or oviposition (Bernáth, Szedenics, Molnár, Kriska, & Horváth, 2001). However, there are other artificial materials, such as car components, plastic sheets, and/or oil reservoirs, that show polarized light patterns similar to those of water (Horváth, Malik, Kriska, & Wildermuth, 2007). These function as ecological traps for odonates, which are attracted to shiny surfaces for sexual activities (Bernáth et al., 2001; Harabiš & Dolný, 2012; Horváth et al., 2007; Villalobos-Jimenez, Meah, & Hassall, 2018; Wildermuth & Horvéth, 2005). The use of these non-suitable sites for their behavioral displays negatively affects the performance of odonates in the search for a mate, reproduction, and offspring survival (Navara & Nelson, 2007; Schlaepfer et al., 2002). Odonata have the largest eyes amongst insects with the higher amount of ommatidia, which allows them a visual field of 360° and the ability to detect color, movement, ultraviolet light, and the plane of polarization of light

(see (Corbet, 1999)). For these reasons, sight is a very important attribute in habitat recognition and, thus, falling in ecological traps in these animals.

Work related to ecological traps in odonates has been based on a few species and has sought to understand which are the habitat characteristics that these organisms recognize as well as the mechanisms that influence habitat selection. There are no studies that focus on exploring which species fall into traps, the fitness costs of poor habitat selection in dragonflies, nor the predictors for physiological condition and/or visual ability in the wrong habitat selection. In this study we have used three odonate species, located in an urban environment, to experimentally document fitness-related costs that arise from a wrong choice of habitat. We also linked the individual condition and visual capability to determine if these characteristics were associated with such choice. As a proxy of a fitness cost, we have used the time they invested defending or using the trap as in (Horváth et al., 2007) considering that the time spent in cannot be used for other vital functions such as feeding. This time proxy has been already used by other authors and is based on the time budget that adults devote to different activities (reviewed by Corbet, 1999). For condition, we used body size and lipid and protein contents in individuals that do and do not fall in the trap. Both lipids and proteins are essential components of odonate condition (Stoks & Córdoba-Aguilar, 2012; Van Praet et al., 2014), and insects in general (Kouřimská & Adámková, 2016). As a visual capacity proxy, we used eye width, where we assume that the bigger the size of the eyes, the greater the visual capacity (for the reasoning of this relationship see (Moser et al., 2004; van Langevelde et al., 2011; Yack et al., 2007)). Finally, we have included a list of species of odonata that are susceptible to falling into ecological traps, gathered from records from distinct observers in different world regions. The idea with this list is to provide the first multi-species analysis and to discuss emerging patterns.

## Methods

### Study área

We carried out our study in the Cantera Oriente, which is part of the “Pedregal de San Ángel” Ecological Reserve of Ciudad Universitaria in Mexico City, Mexico (19° 19' 1.54” N, 99° 10' 21.59” O) (Lot, 2007) (Fig. 1). The reserve has partial access to the public and has preserved some of the original flora and fauna in the form of lake, wetland, garden and forest landscapes (Lot, 2007). The reserve has three large ponds connected by several canals. The observation experiment was carried out between May and November of 2018, and the individuals for lipid and protein measurements were collected in January and February of 2019.

### Observation sites

For trap installation, three sites were chosen which are normally used by all studied species (Fig. 1). The first site is a lentic water canal of 5x40 mts approximately. The second site is a patch of grassland of 20x20 m approximately, next to a lotic water canal. The third site is a 30x40 m lentic water pond surrounded by abundant shrub vegetation but far from trees. All three sites are naturally exposed to sun rays during daytime, and had a separation of 200 m. The order in which the sites were visited was given at random by the site [www.random.org](http://www.random.org).

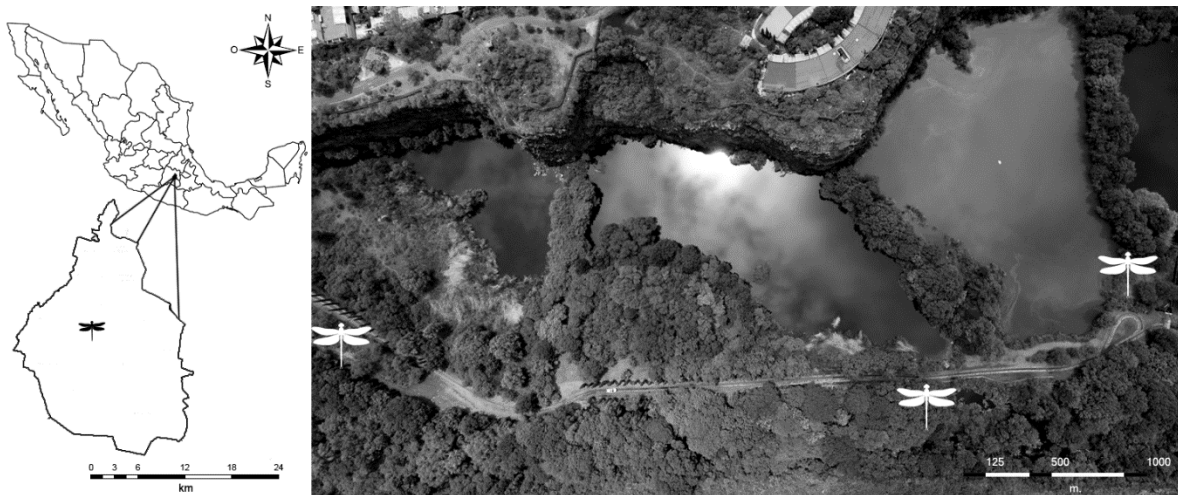


Fig. 1 Location of the Cantera Oriente reserve with respect to Mexico City (left panel), and an aerial view of where time and behavioral recordings were made (as depicted by the dragonfly icon) inside the reserve (right panel).

## Study animals

*E. praevarum* is a small (26-35 mm length), blue damselfly. It is moderately abundant and uses areas of submerged vegetation, lentic waters, and high grasses throughout the year. *I. denticollis* is also a small damselfly (22-26 mm length), highly abundant in both lentic and lotic water canals during most of the year except for the months of January and February. Both *E. praevarum* and *I. denticollis* are non-territorial species whose males search for females in a scramble competition fashion (for *E. praevarum*, all authors' unpublished observations, for *I. denticollis* see (Córdoba-Aguilar, 1992)). *S. illotum* is a fairly large dragonfly (38-40 mm length), very common and that occurs all year round (González-Soriano & Barba-Medina, 2009). Males of this species defend a fixed area by repelling conspecific males by means of rapid and directed flights (all authors' unpublished observations). Males of *S. illotum* allow the females they have copulated with, to use their territories for oviposition (all authors' unpublished observations).

## Experimental setting

We used two aluminum trays of 50 x 100 cm and 8 cm deep (0.38 mm thick). Both trays had five pine wood sticks of 30 cm high and 1 cm in diameter, which were placed vertically along one of the 100 cm edges (one stick every 20 cm) to be used as perches (Suppl. Mat. Fig. 1). The trays were painted green "pastizal" (Vinimex, CDMX, México, Cat.#217-06) in their entirety to simulate their surroundings. One tray was filled with water from the nearest water body, to a depth of 7 cm so that for water quality inside the trap matched the surrounding environment. The other tray was fitted with a thin stainless-steel sheet attached 7 cm from the bottom, making up our trap. The idea was for the ecological trap to simulate car pieces which are commonly found in the surroundings of lakes and ponds that are used by odonates as part of their reproduction habitat. Both trays were placed next to each other but separated by 20 cm distance. The arrangement of both trays was such that both were equally close to the body of water.

### Polarimetry

The relative reflection-polarization patterns of both trails were measured using photopolarimetric methodologies. We adapted a videopolarimetry technique, developed to understand polarized light detection by aquatic insects (Horváth & Varjú, 1997). Using a rotating multilayer polarizing filter (CLP circular polarizer filter, VIV-FK3-58, Vivitar Inc., Edison New Jersey) mounted on a Canon 5D mark II DSLR (Digital Single-Lens Reflex) camera (Canon Inc., Ōta, Japan), polarization patterns were observed in the blue (B), green (G) and red (R) parts of the spectrum at  $\lambda_B = 450\text{nm}$  (wavelength of maximal sensitivity bandwidth of the camera's complementary metal-oxide-semiconductor sensor),  $\lambda_G = 520\text{nm}$  and  $\lambda_R = 615\text{nm}$  (Prasad, Nguyen, & Brown, 2013).

Each picture recorded the light polarization at three different angles ( $0^\circ$ ,  $45^\circ$  and  $90^\circ$ ) to detect patterns of light polarization of all three observation sites. All pixel digital values from each picture were extracted for the three-color spectra (R, G, B) and processed using the Raster (Hijmans, 2015) package in R (R Development Core Team, (2013). Brightness, intensity and direction of polarized light were calculated using the same methods proposed by Horváth & Varjú, (1997).

### Behavioral observations

Each site was observed for 50 min between 11:00 AM and 14:00 PM (which is when odonate adults show the peak activity). The days for observations were chosen with the criteria that weather had to be warm and sunny. Animals may be active when it is cloudy and fairly cold, but such activity is less common. The observations were made one meter away from the traps, and the insects were followed inside a 3 m radius. All subjects who fell in either treatment were captured and marked after leaving the observation area by placing a dot in their thorax using permanent black Ink (Sharpie, Atlanta, Georgia, USA) (Hagler & Jackson, 2001) This ink usually lasts until the animal dies (Anderson, Cordoba-Aguilar, Drury, & Grether, 2011). We recorded species and animal identity, the tray (water or stainless steel) it used, as well as the time spent displaying each of the following typical odonate behaviors (Corbet, 1999): 1) patrolling, in which the male flies over the water body, usually to find females; 2) perching,

which is when the animal stop on one of the sticks, which allows both rest and better observe the arrival of females or other males; 3) activity in pairs, which can be either tandem (when the male uses his abdominal appendages to hold the female's neck) or copulation (the couple adopts a heart shape, where both make genital contact); and, 4) aggression, which is when the male interacts with another with persecutions and/or direct confrontations. It should be noted that agonistic behavior can occur with males of the same or other species, so we recorded both types as the same. The observations were recorded considering the animal number, the species it belonged to, in which tray it was observed, which behavior it displayed and for how long. Each behavior was recorded as an independent event and was timed with a smartphone's stopwatch with a minimum display time of one second. The counting was done using M Stopwatch (version 2.2.5) which allows recording the time spent according to each behavioral category by each individual. However, the time spent displaying all behaviors was added up by each category and for each tray. In case there was more than one subject in the traps, all available individuals were registered simultaneously to a maximum of five individuals, after which new subjects were ignored.

#### Condition: size and physiology

We collected 140 adult males (60 of *I. denticollis*, 60 of *E. praevarum* and 20 of *S. illotum*) from January to February of 2019 between 10:00 AM and 12:00 PM. This daily time interval and chosen months were selected based on the peak in reproductive activity shown by all species, and when animals were more abundant respectively (all authors' unpublished observations.). Half of the individuals of each species was collected while using the stainless steel tray. The other half was collected 300 meters away from the areas where the traps were placed. All individuals were photographed with a Canon 5D mark II DSLR (Digital Single-Lens Reflex) camera (Canon Inc., Ōta, Japan), placed on a tripod, using a millimetric paper to know the scale (1 mm). We used the ImageJ program (v. 1.52) (Schneider, Rasband, & Eliceiri, 2012) to measure the following structures in triplicate: anterior wing length, head width, right eye width and body length. The person who took the measurements did not know if the individuals were caught far from or in the traps.



Using the (Foray et al., 2012) method, we determined total protein and lipid concentrations with the collected animals. However, we only used the thorax per individual (i. e. we removed head, abdomen, legs and wings) because it contains the necessary muscles and biochemical reserves for exhaustive activities such as flying (Marden, 2008). Each thorax was put in a 2 ml centrifuge tube and crushed with 180  $\mu$ l of saline phosphate buffer (PBS) to a hyaline solution using a TissueLyser II bead mill (QIAGEN, Valencia, California). Subsequently, 180  $\mu$ l were taken from the tube and put in a new tube to be centrifuged at 180 RFC for 5 min at 4°C. Next, 2.5  $\mu$ l of the supernatant were taken in duplicate and placed in a 96-well microplate. Finally, we added 250  $\mu$ l of Bradford reagent. The plates were incubated for 20 minutes and read spectrophotometrically at 595 nm using an ELx800 spectrophotometer (BioTek, Vermont, USA). A curve was made using bovine serum albumin dilution series as standard for calibration.

The method of van Handel (1985) modified by (Foray et al., 2012) was used for lipid determination. From the remaining 175  $\mu$ l after taking the aliquots for the protein assay, 5  $\mu$ l of PBS were added. 1500  $\mu$ l of Methanol: Chloroform solution (2:1) were added and shaken for two min. The samples were then centrifuged for 15 min at 180 RFC. Next, a 100  $\mu$ l aliquot per sample was taken and placed in a microplate to be dried in a water bath. Then, 10  $\mu$ l of sulfuric acid (98%) were added, and the plate was returned to the water bath for 2 min. Finally, the plate was cooled on ice and 190  $\mu$ l of vanilline reagent was added, which was prepared the same day of its use, with vanilline and phosphoric acid (68%), at a concentration of 1.2 g/L. The plate was read on a spectrophotometer at 515 nm with a glyceryl trioleate lipid dilution series as standard for calibration.

#### Odonata list of species attracted to ecological traps

We used a mailing list (<https://mailweb.pugetsound.edu/mailman/listinfo/odonata-1>) to ask users to submit data on dragonfly and damselfly species that they had seen using artificially shiny surfaces and performing activities such as patrol, perch, tandem, copulation or

oviposition. This mailing list reaches different odonate professionals and amateurs around the world, and is probably the most used of other odonate email world-wide lists. We sent three messages, one per year from 2016 to 2018. We asked people to record the species and the location of observations. We complemented this information with data already published.

### Statistical analyses

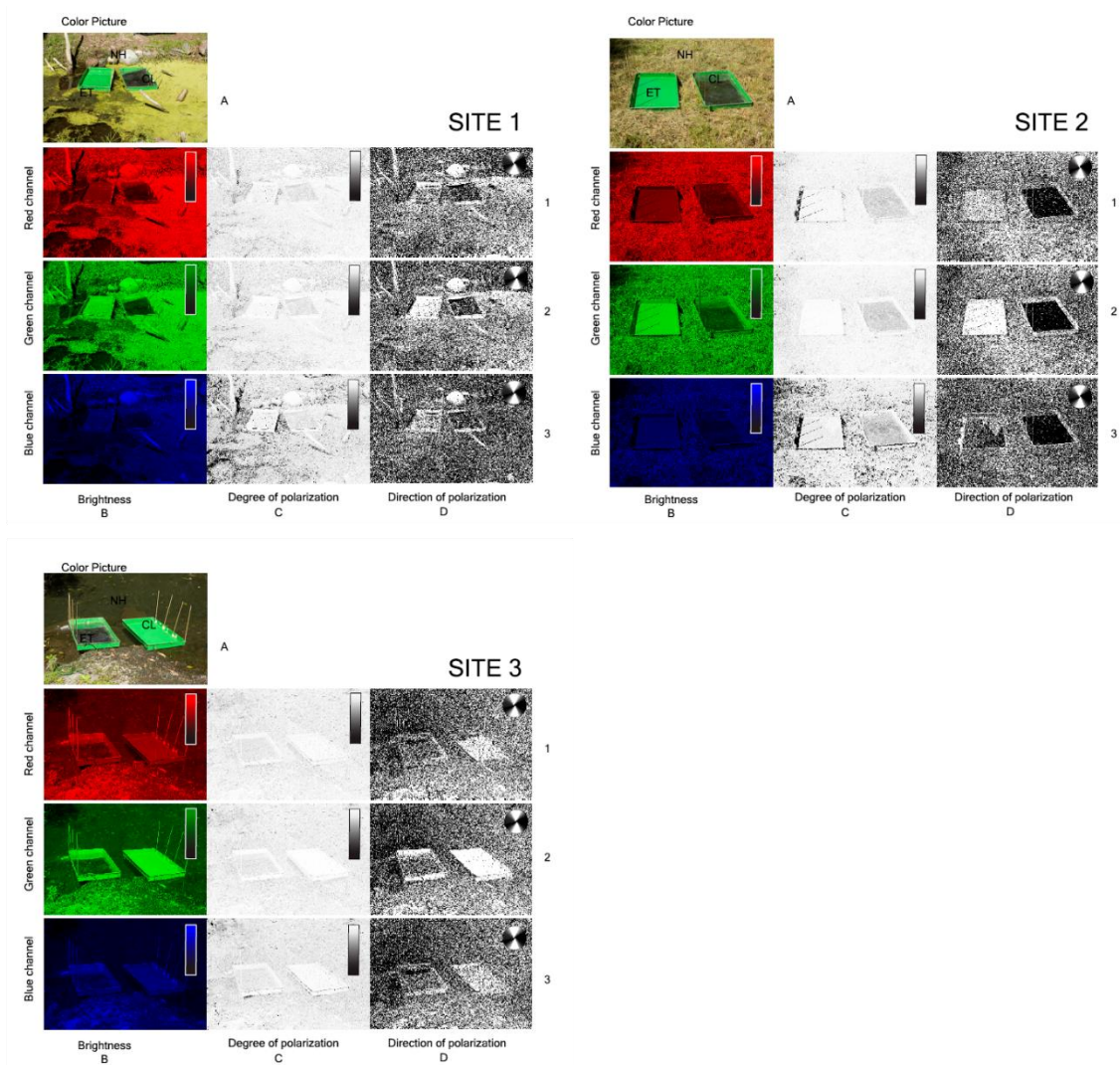
We evaluated the differences between the time spent (in seconds) by each individual in either the trap or the control. This is, how long animals spent using the trap vs the control. For this, we used a generalized linear mixed model (GLMM) with normal distribution using seconds as a response variable and trap type as explicative variable, and individuals as a random factor because each individual could display multiple behaviors. Then, we evaluated the number of all recorded behaviors per individual carried out on each trap (ecological trap and control) using a GLMM using counts of behaviors as response variable, type of behavior and tray as explicative variables with individuals as a random factor with a Poisson distribution

To determine whether some traits explained the incidence of individuals in the ecological trap and the control, we calculated the variation coefficient for each morphological trait that was measured in the photographs. Subsequently, we computed a correlation analysis among traits. Then, we used the raw measures of morphological traits of uncorrelated traits which were transformed in proportional traits values (e.g. eyes size/head size). These proportional traits were evaluated using mixed ordinal general linear models with Monte Carlo and Markovian chains. We used an independent model for each proportional trait as an explanatory variable and the type of trap as a response variable. To measure the differences in the content of energy reserves (lipids and proteins) between the individuals that fell in the stainless-steel trap and the individuals not exposed to any traps, we used a GLMM with normal distribution with the individuals as a random factor. All statistical analyzes were performed for each species using R i386 3.4.0 (Team, 2013) with the "lme4" package.

### Results

## Polarimetry

Our visual analysis of the images suggested differences between the ecological trap, the control and the natural habitat. The ecological trap shows a higher degree and angle of polarization than the control or the natural habitat, which have similar characteristics (Suppl. Mat. Fig. 1).



Suppl. Mat. Fig. 1. (A) Color image of the three different study sites (Site 1, 2 y 3). (B – D), brightness (light intensity) (column B), degree (column C) and direction (column D) of the polarization pattern of the different sites as measured by photo polarimetry through red (row 1), green (row 2) and blue (row 3). The three different numeric values are coded by the different color tones: the larger the brightness, the higher the color intensity. As for polarization degree, the darkest is that of the grey tone (white = 0%; black = 100%).

Direction: 0° = white, 45°= grey, 90°= black. CL: control, TR, ecological trap, and NH: natural habitat.

### Behavioral preferences

All three species used both the ecological trap and control treatments (Figs. 2 and 3). In *E. praevarum*, there were no differences in time spent in both (Table 1, Fig. 2). However, while the individuals of *I. denticollis* spent less time in the ecological trap than in the control, those of *S. illotum* used the ecological trap longer than the control (Table 1, Fig. 2).

Table 1. Results of a general linear mixed model comparing total behavioral types and time spent in animals of three odonate species that used an ecological trap vs a control treatment.

Behavior				
Species	Predictors	df	Z	P
<i>Ischnura denticollis</i>	Treatment	1	-6.84	<0.0001
	Residuals	109		
<i>Enallagma praevarum</i>	Treatment	1	-3.11	<0.001
	Residuals	59		
<i>Sympetrum illotum</i>	Treatment	1	4.1	<0.0001
	Residuals	34		
Time spent				
Species	Predictors	df	F	P
<i>I. denticollis</i>	Treatment	1	12.79	<0.005
	Residuals	109		
<i>E. praevarum</i>	Treatment	1	1.03	0.31
	Residuals	59		
<i>S. illotum</i>	Treatment	1	4.14	<0.05
	Residuals	34		

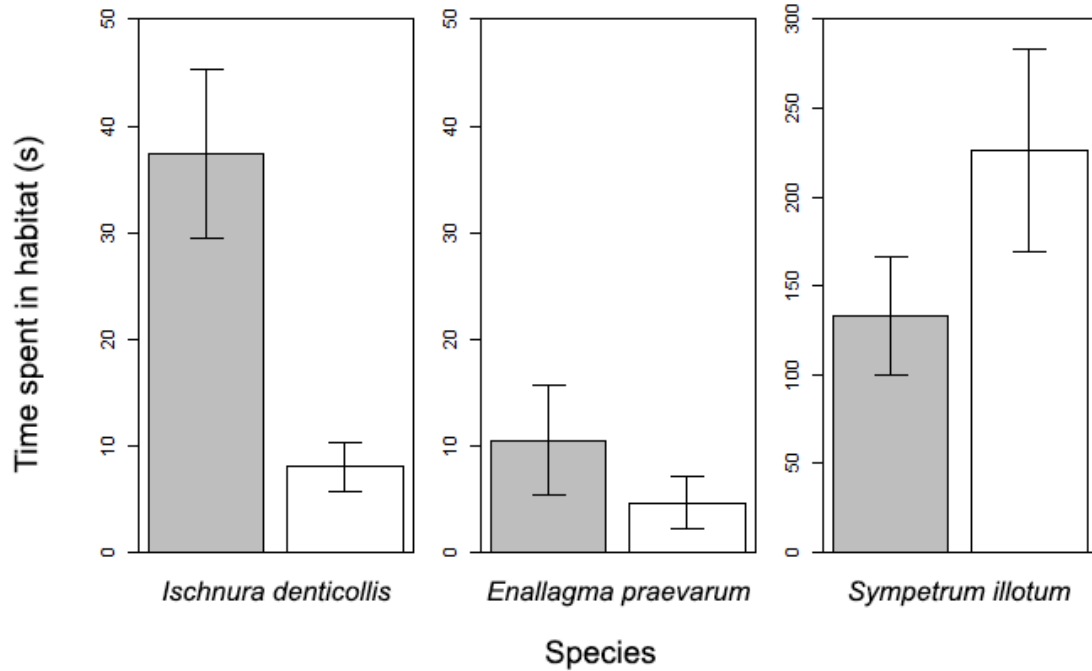


Figure 2. Occupation time of three odonate species exposed to an ecological trap (white bars) vs control (grey bars) treatments. Values are mean and standard errors.

In terms of behavior, *E. praevarum* and *I. denticollis* carried out more activities in the control than in the ecological trap (Table 1, Fig. 3). *S. illotum* showed more behaviors in the ecological trap than in the control (Table 1, Fig. 3).

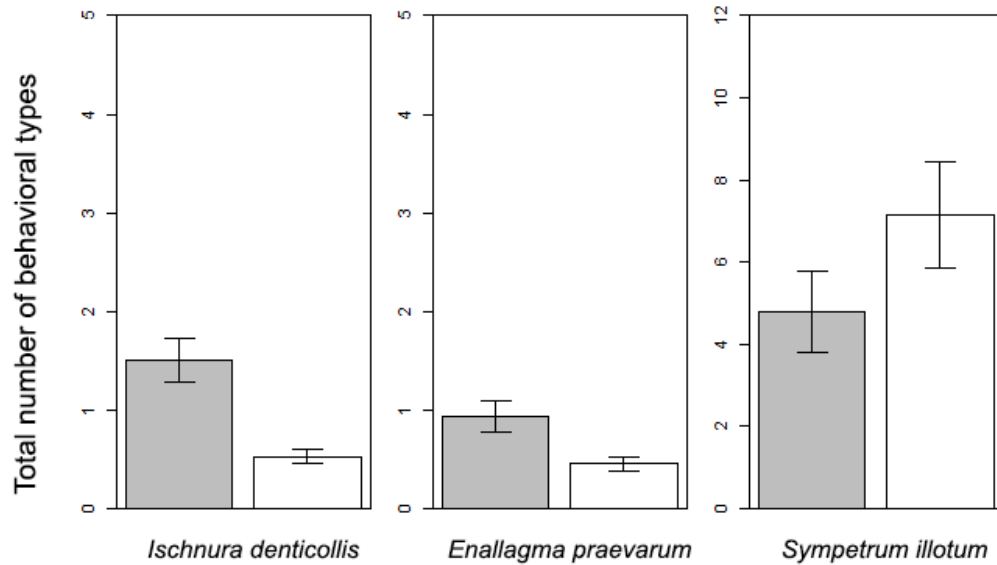


Figure 3. Number of behaviors of three odonate species exposed to an ecological trap (white bars) vs control (grey bars) treatments. Values are means and standard errors.

### Condition and visual capacity

In terms of size, we only found significant values in *I. denticollis*: individuals with smaller bodies but larger eyes were more likely to use the traps (Table 2, Fig. 4). As for the proteins and lipids, only *I. denticollis* showed differences: animals that used the ecological trap had a lower amount of lipids than those that did not use it (Table 3, Fig. 5).

Table 2. Results of using mixed ordinal general linear models with Monte Carlo and Markovian chains to determine the relation between body components and the probability of being captured in an ecological trap in three odonate species.

Species		Mean	l-95% CI	u-95% CI	P
<i>Ischnura denticollis</i>	Wings length/Body size	-79.86	-97.33	-63.94	<0.001
	Eye width/ Head length	108676.32	21057.42	226056.19	<0.05
	Wings length/Body size	-38506	-183665	107264	0.59
	Eye width/ Head length	-3554	-195292	180937	0.97
<i>Sympetrum illotum</i>	Wings length/Body size	2556	-189050	195406	0.99
	Eye width/ Head length	-8742	-220609	152079	0.96

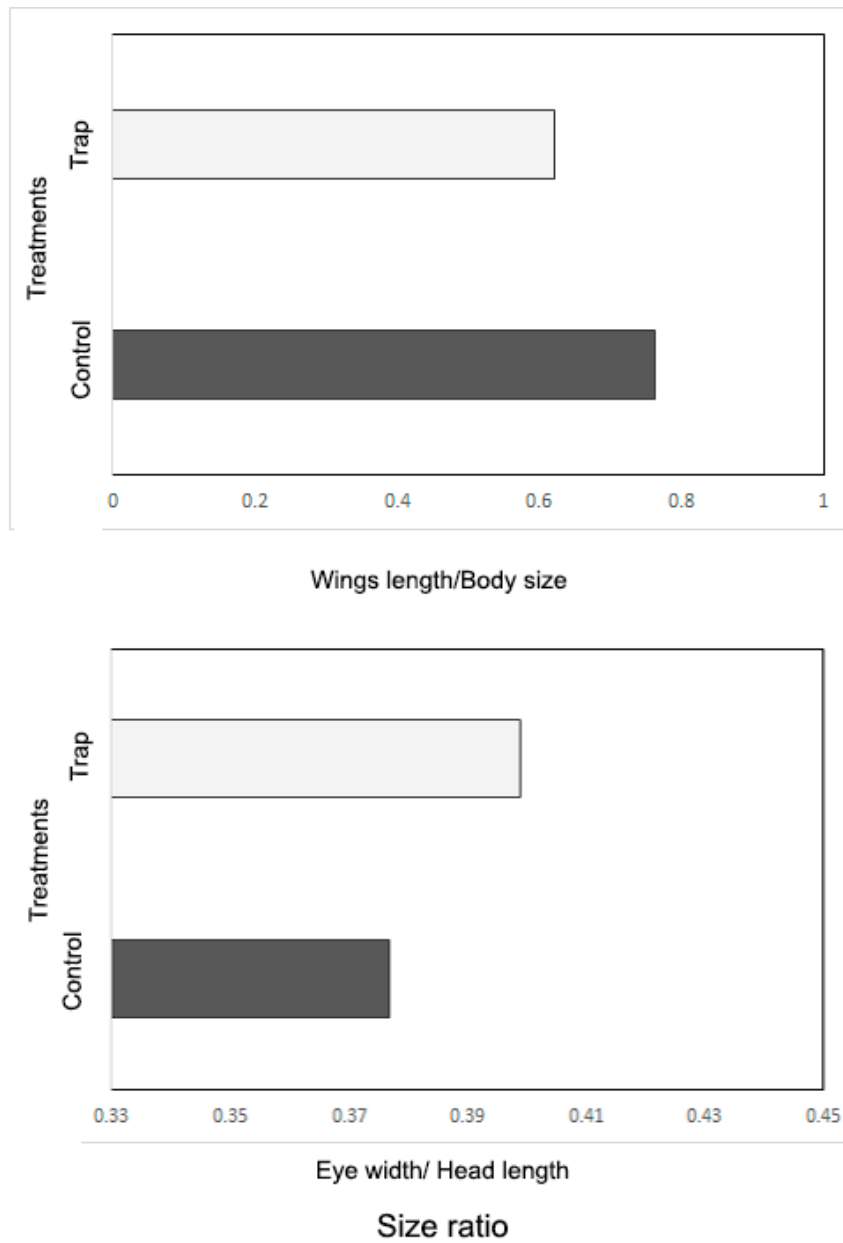


Figure 4. Relation between two different body traits of *Ischnura denticollis* animals that were captured on an ecological trap (white bars) or far from the trap (grey bars). Values are means and standard errors.



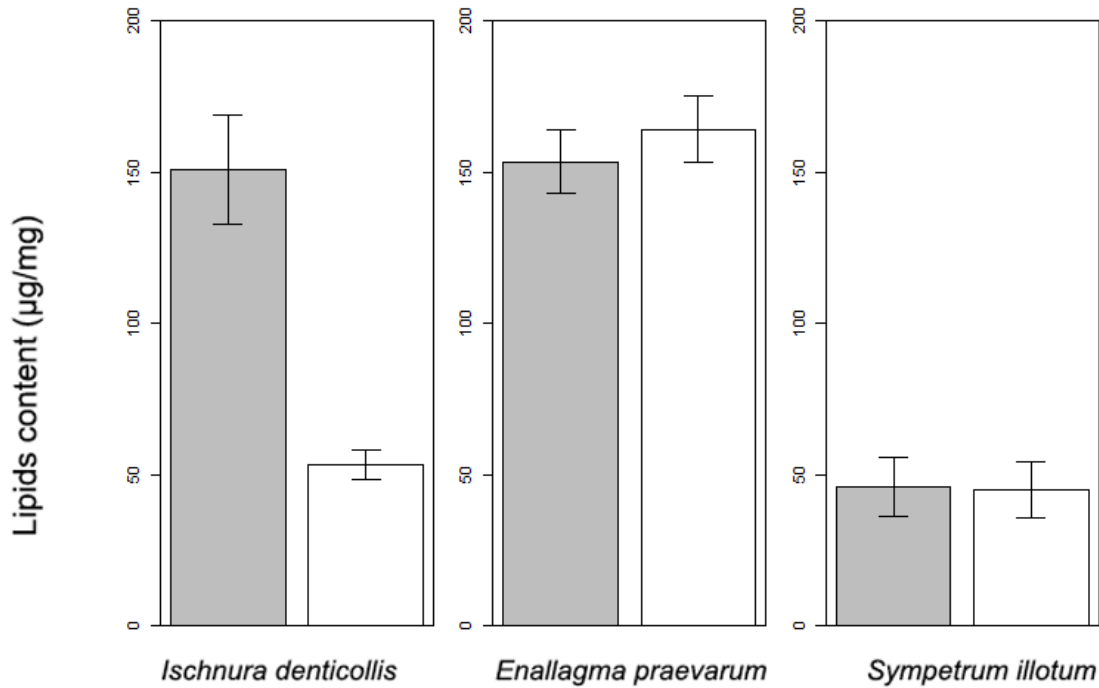


Figure 5. Lipid content of three odonate species exposed to an ecological trap (white bars) vs control (grey bars) treatments. Values are means and standard errors.

#### Odonates using artificial habitats world-wide

Our email-based questionnaire resulted in 25 species where 20 species were dragonflies and 5 damselflies (suppl. Mat. Table 1).

Suppl. Mat. Table 1. A list of odonate species recorded in different world areas, that were seen using artificial habitats. The source where such information was gathered is provided.

Family	Species	Trap	Location	Source
Aeshnidae	<i>Aeshna juncea</i>	Perspex	Canton Graubünden, Swiss	Wildermuth, 1998
Aeshnidae	<i>Anax imperator</i>	Crude oil, aluminium	Budapest, Hungary	Personal observation, Horváth
Corduliidae	<i>Cordulia aenea</i>	Perspex	Canton Graubünden, Swiss	Wildermuth, 1998

Libellulidae	<i>Crocothemis erythraea</i>	Car body	Huesca, Spain	Torralba Burrial & Ocharán, 2003
Coenagrionidae	<i>Enallagma cyathigerum</i>	Crude oil, aluminium, asphalt roads	Kunfehértó, Hungary	Horváth et al., 1998, 2012
Coenagrionidae	<i>Erythromma viridulum</i>	Crude oil, aluminium, asphalt roads.	Kunfehértó, Hungary	Horváth et al., 1998; Horváth et al., 2010
Coenagrionidae	<i>Ischnura elegans</i>	Crude oil, aluminium, asphalt roads	Kunfehértó, Hungary; several urbanized locations, UK	Horváth et al., 1998; Horváth et al., 2009
Coenagrionidae	<i>I. pumilio</i>	Crude oil, aluminium, asphalt roads	Kunfehértó, Hungary	Horváth et al., 1998.
Lestidae	<i>Lestes macrostigma</i>	Crude oil, aluminium, asphalt roads	Kunfehértó, Hungary	Horváth et al., 1998; Horváth et al., 2011
Libellulidae	<i>Libellula depressa</i>	Car body	Vipava river, Slovenia; Puymeras, France	Personal observation, Damjan Vinko; Wildermuth & Horveth, 2005
Libellulidae	<i>L. fulva</i>	Car body	Slovenia	Personal observation, Damjan Vinko
Libellulidae	<i>L. quadrimaculata</i>	Perspex, Aluminium foil, crude oil, asphalt	Canton Graubünden, Swiss; Kunfehértó, Hungary	Wildermuth, 1998; Horváth et al., 1998; Horváth et al., 2014
Libellulidae	<i>Macrothemis pseudimitans</i>	Car body	Cuernavaca, Mexico; Popotla, Mexico	Personal observation
Libellulidae	<i>Orthetrum albistylum</i>	Plastic	Vipava river, Slovenia	Personal observation, Damjan Vinko
Libellulidae	<i>O. cancellatum</i>	Crude oil, aluminium, asphalt roads	Kunfehértó, Hungary	Horváth et al., 1998; Horváth et al., 2013
Libellulidae	<i>Pantala flavescens</i>	Car body	Jonesboro, Arkansas, USA; Nueva York USA; Cuernavaca, Pachuca and Mexico City, Mexico; Sri Lanka	Personal observation, George L. Harp; John Greoquire; Alex Córdoba-Aguilar; Nancy van der Poorten
Libellulidae	<i>P. hymenaea</i>	Car body	Cardel, Mexico ; East Virginia, USA; Oklahoma, USA	Personal observation, M. May; Personal observation B. Grimes; Personal observation, B. Smith-Patten
Libellulidae	<i>Perithemis domitia</i>	Car body	Santa Cruz and Arizona, USA	Personal observation, D. Paulson

Coenagrionidae	<i>Pyrrhosoma nymphula</i>	Perspex, Aluminium foil	Canton Graubünden, Swiss	Wildermuth, 1998
Corduliidae	<i>Somatochlora alpestris</i>	Perspex, Aluminium foil	Canton Graubünden, Swiss	Wildermuth, 1998
Corduliidae	<i>Somatochlora arctica</i>	Rubbish bag	Pohorje, Slovenia	Personal observation, Damjan Vinko
Libellulidae	<i>Sympetrum corruptum</i>	Car body	Mexico City, Mexico	Personal observation
Libellulidae	<i>S. danae</i>	Polished black gravestones	Kiskunhalas, Hungary	Horváth et al., 2007.
Libellulidae	<i>S. flaveolum</i>	Polished black gravestones	Kiskunhalas, Hungary	Horváth et al., 2007.
Libellulidae	<i>S. illotum</i>	Car body, Stainless steal,	Cuernavaca, and Mexico City, Mexico	Personal observation
Libellulidae	<i>S. meridionale</i>	Polished black gravestones	Kiskunhalas, Hungary	Horváth et al., 2007.
Libellulidae	<i>S. sanguineum</i>	Car body	Budapest and Kiskunhalas, Hungary	Personal observation, Horváth; Horváth et al., 2007.
Libellulidae	<i>S. striolatum</i>	Car body, Window	Mala Vovcha, Ukraine; Kiskunhalas, Hungary; Ljubljana, Slovenia	Personal observation E. Karolinskiy; Horváth et al., 2007; Personal observation, Damjan Vinko
Libellulidae	<i>S. vulgatum</i>	Crude oil	Kunfehértó, Hungary	Horváth et al., 1998.

## Discussion

Odonates are able to see in a broad light spectrum, from ultraviolet to long wavelength (Yang & Osorio, 1991) reviewed by Bybee, Johnson, Gering, Whiting, & Crandall, (2012). Although a finer study of the optical properties of our study subjects would be adequate for example, analyzing opsins; (Bybee et al., 2012), our approach with the polarimetry of the different sites is equally convenient. In our case, the trap showed a higher degree and angle of polarization which would make them more attractive to odonates. With this experimental design, we found that all species used the trap yet there was interspecific variation in such

use. Although *E. praevarum* performed fewer behaviors in the trap, it spent the same time in both treatments, suggesting that it also used the trap as a potential habitat. *I. denticollis* seemed efficient when discriminating between the two trays as it preferred the control. However, the use of either treatment was not at random as it was related to the animal condition and visual capacity (see below). Finally, *S. illotum* preferred the ecological trap over the control, both in time and behavior. In general terms, this comparison between the three species indicates that *S. illotum* could be more ecologically impacted by artificial objects that reflect polarized light in a similar fashion to natural habitats. However, more accurate measurements at a demographic level are required to see the real impact of the traps (Hale & Swearer, 2016). For example, if traps are not so common in an environment, population viability will not be affected (Donovan & Thompson III, 2001; Harabiš & Dolný, 2012).

It could be suggested that the use of ecological traps can be explained according to a density dependent context (Battin, 2004). For example, that the most abundant species is the one that is more likely to use a trap. Although we do not measure the density or abundance of the three species, *I. denticollis* seems to be the most abundant species followed by *E. praevarum* and *S. illotum* in an approximate ratio of 50:40:1 (see also González-Soriano & Barba-Medina, 2009). In fact, *I. denticollis* is a very common species in central Mexico, often surpassing other species with which it occurs (Córdoba-Aguilar's unpublished data). Despite this, *I. denticollis* was less likely to use the trap. Related to this, a recent study indicated that in another species of *Ischnura* (*I. elegans*) that inhabits urban environments and that are also exposed to traps, the animals were able to reject their use, which was interpreted as a selection against erroneous habitats (Villalobos-Jimenez et al., 2018). Although this could be expected for species whose populations persist in urban environments (Villalobos-Jimenez et al., 2018) the results with *E. praevarum* and *S. illotum* are not consistent with this hypothesis. The fact that we have found interspecific differences suggests cognitive properties inherent to each species. Although we know that species of the genus *Ischnura* and *Enallagma* are capable of learning and recognizing co-specifics (Fincke, Fargevieille, & Schultz, 2007; Ting, Bots, Jvostov, van Gossum, & Sherratt, 2009), we do not know if this is the case of *Sympetrum*. The relationship between learning and their propensity to fall into the trap could be an interesting topic to develop using our study species.

Another result is the link between animal condition and the use of traps. On one hand, our findings indicate that, regardless of condition, *E. praevarum* and *S. illotum* are equally likely to use the traps. This suggests that filter processes at the individual level can affect both individuals with varying condition in terms of the body parameters we use. This pattern shows that the traps do not affect some specific phenotypes (Hale, Morrongiello, & Swearer, 2016). However, the case of *I. denticollis* is different since individuals with worse condition (less lipids and small) are selectively more affected. Note that individuals with these characteristics are usually less successful as lipid content is an important factor in fitness-related attributes such as the success of finding a partner (Marden & Cobb, 2004), immune capacity (González-Tokman, Córdoba-Aguilar, González-Santoyo, & Lanz-Mendoza, 2011) and/or survival (Córdoba-Aguilar & Munguia-Steyer, 2013). In the case of *I. denticollis*, natural selection via traps would remove the less successful phenotypes, a situation that has not been examined in detail in the theory behind the ecological traps (Hale & Swearer, 2016). Broadly speaking, the ideas surrounding ecological traps have focused on the detection of environmental cues (Robertson & Chalfoun, 2016), demographic effects (Donovan & Thompson III, 2001; Harabiš & Dolný, 2012), environmental improvement and/or conservation biology in general (Battin, 2004; Hale et al., 2016; Hale & Swearer, 2016; Robertson et al., 2013; Schlaepfer et al., 2002). However, the cues could selectively remove certain phenotypes, although in our case they may be the least successful. This would mean that the effects of this selection would be less severe for *I. denticollis* than for *E. praevarum* or *S. illotum*, although this would have to be tested with fitness measurements.

Another topic that has received little attention surrounding ecological traps is that of trap detection and variation in sensory capacity. Contrary to what we expected, we found that individuals with more developed visual capabilities were more likely to fall into traps, as was the case with *I. denticollis*. Perhaps, larger eyes allow individuals to show greater polarotaxia (van Langevelde et al., 2011). However, it is interesting that this is the same species where small size is related to the propensity to fall into traps. This complex link - small size and large eyes - had not been examined in odonates as far as we know. In any case, this suggests that individuals in worse condition, but with better visual ability, are selected against. This would be counter-intuitive with the idea that individuals with a bad condition would be selected against as one would expect large eyes on a predator to be favored (Buschbeck &

Friedrich, 2008; Veilleux & Kirk, 2014). If this is the case, then the traps would affect those animals with a greater visual capacity in *I. denticollis*.

Finally, our list of odonate species seen on bright surfaces is not extensive, but several emerging patterns deserved to be discussed. First, there were considerably more species of dragonflies than damselflies recorded. Perhaps the fact that dragonflies have a greater mobility (Angelibert & Giani, 2003) grants them a greater likelihood to advance to urban areas. Second, since most of the sightings were in shiny surfaces, perhaps the structure of the habitats required by the dragonflies is much simpler than that of the damselflies. For example, we do not know if, in general, damselflies require the reflection of water plus other components of the environment (e. g. presence of macrophytes; (Butler & Demaynadier, 2008). In fact, dragonflies spend more time in flight, so they do not require perching sites as much (Corbet, 1999). Third, since dragonflies are larger, they are more easily detected by observers. However, most observers are experienced amateurs or professionals, which would reduce this bias. Fourth, there were certain genera that were repeated across observations, as is the case of *Orthetrum*, *Pantala* and *Sympetrum*. These coincidences suggest that the propensity to fall into traps is a phylogenetic property. One way to test such phylogenetic inertia is to test species of these genera for which we do not know whether they use traps. If these species respond positively to traps, it can be said that there is a pattern of ancestry in the propensity to use traps. This would also indicate that there is a sensory bias that predisposes these species in a manner analogous to how species recognize new patterns in their conspecifics (Fuller & Endler, 2018).

## Acknowledgements

This article is a requirement to obtain the Master's degree in Biological Sciences, in the field of Evolutionary Biology, of the Posgrado en Ciencias Biológicas at Universidad Nacional Autónoma de México (UNAM). Authors thank the Posgrado en Ciencias Biológicas (UNAM) as well as CONACYT for scholarship number 620154. To R. Munguía-Steyer and H. Drummond for their comments during the development our research. A PAPIIT-DGAPA IN206618 grant provided funds for this work.

## Data Availability Statement

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

## Conflict of interest

The authors have no conflict of interest to declare.

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## Discusión y conclusiones

El análisis de polarimetría indicó que nuestro diseño experimental es, a los ojos humanos y probablemente de los odonatos, similar. Los odonatos son capaces de ver en un espectro de luz muy amplio, desde el ultravioleta (UV) hasta longitud de onda larga (LWV) (e.g. Yang & Osorio, 1991; revisado por Bybee et al. 2012). Aunque un estudio más fino de las propiedades ópticas de nuestros sujetos de estudio sería adecuado (por ejemplo, analizando opsinas), nuestro acercamiento con la polarimetría de los diferentes sitios es igualmente conveniente.

Con este diseño experimental, encontramos que hay variación interespecífica en el uso de las trampas ecológicas. De inicio, hay que aclarar que las tres especies usaron las trampas. Aunque *E. praevarum* realizó menos conductas en la trampa, pasó el mismo tiempo en los dos tratamientos lo cual sugiere que igualmente usaba las trampas como un hábitat potencial. *I. denticollis*, sin embargo, parecía eficiente al discriminar entre los dos hábitats aunque el uso de ambos no es al azar y está relacionado con la condición y capacidad visual (ver abajo). Finalmente, destaca que *S. illotum* prefirió las trampas sobre el control tanto en tiempo como en conductas desplegadas. En términos generales, esta comparación entre 3 especies indica que *S. illotum* podría ser más impactada ecológicamente por objetos artificiales de propiedades de reflejo polarimétrico similares a los hábitats naturales. Sin embargo, se requieren mediciones más precisas a nivel demográfico que permitan ver el impacto real de las trampas (e.g. Hale & Swearer, 2016). Por ejemplo, si las trampas no son tan comunes en un ambiente, la viabilidad de las poblaciones puede seguir adelante (Donovan & Thompson, 2001; Harabiš & Dolný, 2012).

Se podría sugerir que el uso de las trampas ecológicas pueden explicarse según un contexto denso-dependiente (Battin, 2004). Por ejemplo, que la especie más abundante sea la que sea más propensa a usar un hábitat erróneo. Si bien no medimos la densidad o abundancia de las tres especies, *I. denticollis* parece ser la especie más abundante seguida de *E. praevarum* y *S. illotum* en una relación aproximada de 50:40:1 (ver también González-Soriano & Barba-Medina, 2009). De hecho, *I. denticollis* es una especie muy común en ambientes del centro de México con frecuencia superando a otras especies con las que co-ocurre (A. Córdoba-Aguilar, datos no publicados). A pesar de estas diferencias en La Cantera, *I. denticollis* fue menos propensa a usar la trampa. Relacionado con esto, un estudio

reciente indicó que en otra especie de *Ischnura (elegans)* de ambientes urbanos y que también usa trampas, los animales fueron capaces de rechazar su uso, lo cual se interpretó como selección en contra de hábitats erróneos (Villalobos-Jiménez et al. 2018). Aunque esto se podría esperar, en general, para especies cuyas poblaciones persisten en ambientes urbanos (Villalobos-Jiménez et al. 2018), los resultados con *E. praevarum* y *S. illotum* no son coherentes con esta hipótesis. El hecho que hayamos encontrado diferencias interespecíficas sugiere propiedades cognitivas inherentes a cada especie. Si bien sabemos que especies del género *Ischnura* (e.g. Ting et al. 2009) y *Enallagma* (Fincke et al. 2007) son capaces de aprender (reconociendo coespecíficos), no sabemos si este es el caso de *Sympetrum*. La relación aprendizaje y propensión de caer en las trampas podría ser un tópico interesante en libélulas, como el caso de la comunidad de odonatos de La Cantera.

Otro resultado interesante es el vínculo de la condición animal con el uso de las trampas. Por un lado, nuestros hallazgos indican que, sin importar la condición, los animales de *E. praevarum* y *S. illotum* son igualmente propensos a usar las trampas. Esto sugiere que los procesos de filtro a nivel individual pueden afectar tanto a individuos de buena como de mala condición en términos de los parámetros corporales que nosotros usamos. Este patrón quiere decir que las trampas no actúan afectando sólo a algunos fenotipos (e.g. Hale et al. 2016). Sin embargo, el caso de *I. denticollis* es distinto ya que los individuos con peor condición (menos lípidos y más pequeños) son selectivamente más afectados. Estos individuos en general son menos exitosos ya que, como ocurre en odonatos, la cantidad de lípidos es un factor importante en atributos vinculados con la adecuación como son el éxito de conseguir pareja (e.g. Marden & Cobb, 2004), capacidad inmune (González-Tokman et al. 2001) y/o supervivencia (e.g. Córdoba-Aguilar & Munguía-Steyer, 2013). En el caso de *I. denticollis*, la selección a través de las trampas removería los fenotipos menos exitosos, una situación que no ha sido examinada a detalle en la teoría detrás de las trampas ecológicas (Hale et al. 2016). A grandes rasgos, las ideas alrededor de las trampas ecológicas se han enfocado en la detección de pistas ambientales (e.g. Robertson & Chalfoun, 2016), efectos demográficos (e.g. Donovan & Thompson, 2001; Harabiš & Dolný, 2012), mejoramiento del ambiente y/o biología de la conservación en general (e.g. Battin, 2004; Schlaepfer et al. 2002; Hale & Swearer, 2016; Hale et al. 2016; Robertson et al. 2013). Sin embargo, las pistas podrían remover selectivamente ciertos fenotipos aunque en nuestro caso pueden ser los

menos exitosos. En comparación, los efectos de esta selectividad serían menos graves para *I. denticollis* que para *E. praevarum* o *S. illotum* aunque, nuevamente, habría que poner a prueba esto con mediciones finas de adecuación de las tres especies.

Otro punto soslayado en las discusiones alrededor de las trampas ecológicas es el de la detección de las trampas y la variación en la capacidad sensorial. Contrario a lo que esperábamos, encontramos que los individuos con capacidad visual más desarrollada fueron más susceptibles de caer en las trampas, como fue el caso de *I. denticollis*. Quizás en este caso, ojos más grandes permitan que los individuos muestren mayor polarotaxia. Sin embargo, es interesante que esta es la misma especie donde el tamaño menor se relaciona con la propensión de usar las trampas. Este vínculo complejo, menor tamaño-ojos más grandes, no había sido examinada en odonatos hasta donde sabemos. De cualquier modo, esto sugiere que los individuos en peor condición, pero mejor capacidad visual, sean removidos. Esto sería contra-intuitivo con la idea de que los individuos con mala condición serían seleccionados en contra ya que uno esperaría que los ojos grandes en un depredador serían favorecidos (e.g. Buschbeck & Friedrich, 2008; Veilleux & Kirk, 2014). De ser este el caso, entonces las trampas afectarían a aquellos animales con mayor capacidad visual en *I. denticollis*. Habría que estudiar el balance que resulta de efectos negativos de las trampas sobre individuos de menor tamaño y menos lípidos, pero mayor agudeza visual en la población.

Finalmente, nuestra lista de especies de odonatos vistas en superficies brillantes no es extensa pero varios patrones emergentes merecen ser discutidos. En primer lugar, es el hecho de que hubo considerablemente más especies de libélulas que caballitos del diablo. Quizás el hecho de que las libélulas tienen mayor capacidad de desplazamiento (Angelibert & Giani, 2003) les permite avanzar a las áreas urbanas con mayor probabilidad. En segundo lugar, como la mayoría de los avistamientos fueron en superficies tipo cristales de auto, quizás la estructura de los hábitats requerida por las libélulas sea mucho más simple que la de los caballitos del diablo. Por ejemplo, no sabemos si en general los caballitos del diablo requieren el reflejo del agua más otros componentes del ambiente, como plantas para percharse. De hecho, las libélulas pasan más tiempo en vuelo por lo que no requieren perchas (Corbet, 1999). En tercer lugar, dado que las libélulas son más grandes, son más fácilmente detectadas por los observadores. Sin embargo, la mayor parte de los observadores son amateurs

experimentados o profesionales lo cual reduciría este sesgo. En cuarto lugar, es el hecho de que hay ciertos géneros que se repiten en las observaciones como es el caso de *Orthetrum*, *Pantala* y *Sympetrum*. Estas coincidencias sugieren que la propensión de caer en las trampas es una propiedad filogenética. Una manera de averiguar esto es poniendo a prueba especies de estos géneros de los cuales no se tiene documentado si usan superficies brillantes. Si estas especies son igualmente atraídas, se puede decir que hay un patrón de ancestría en la propensión de caer en las trampas. Esto también indicaría que hay un sesgo sensorial que predispone a esas especies de una manera análoga a como las especies reconocen patrones nuevos en sus coespecíficos (Fuller & Endler, 2018).