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# HOST-FEEDING PREFERENCE OF *CULEX QUINQUEFASCIATUS* IN MONTERREY, NORTHEASTERN MEXICO

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ABSTRACT. Studies were conducted to determine the host selection patterns of *Culex quinquefasciatus* in the municipalities of Guadalupe and Escobedo near Monterrey, northeastern Mexico. Mosquitoes were captured inside and outside houses. Chickens and humans were the most common blood sources for all *Cx. quinquefasciatus* females, accounting for nearby 70% of blood meals. Human blood was detected by enzyme-linked immunosorbent assay in 36.4% and 28.4% of engorged females resting inside houses in Guadalupe and Escobedo, respectively. The proportions of indoor resting females fed on chicken blood were 38.7% and 56.7%, respectively. The weighted and unweighted human blood index (HBI) values were calculated, by using indoor and outdoor data, from the proportions of humanfed mosquitoes. Weighted means (HBI) estimates for Guadalupe and Escobedo were 23.0% and 15.4%, respectively. The forage ratios (FRs) for humans were <1.0 (with or without chicken populations); consequently, it seems that these mosquitoes feed on humans with less frequency in comparison with chickens, horses, and pigs. The FRs for chickens were the highest of all available hosts (1.7 and 3.2), and they were the most abundant hosts in Escobedo, and the second most abundant in Guadalupe, indicating a selective bias of *Cx. quinquefasciatus* for chickens (i.e. ornithophagic).

**KEY WORDS** *Culex quinquefasciatus*, blood meal identification, human blood index, Mexico

## INTRODUCTION

The source of blood meals is a critical determinant of the potential of a species to be a vector of diseases (Vinogradova 2000), and it is important to medical entomologists and epidemiologists for understanding host–vector relationships and the dynamics of disease transmission (Tempelis 1975, Fernandez-Salas et al.1993). *Culex quinquefasciatus* Say, 1823 (Knight and Stone 1977, WRBU 2001) is one of the vectors of West Nile Virus (WNV) in the United States and Mexico (Reisen et al., 2004). Host-feeding patterns of this species have been quantified by the relative frequency of blood from different host types in samples of engorged mosquitoes in Florida, and it was determined to be a general feeder, mostly on domestic birds, mammals, and passerines (Edman 1974). Within this framework, the human blood index (HBI) is defined as the proportion of freshly engorged mosquitoes found to contain human blood (Garrett-Jones 1964, Fleming 1986, Service 1993). This index is a component of vectorial capacity (Fleming 1986).

Vector competence studies indicate that *Cx. quinquefasciatus* is a relatively efficient laboratory vector of WNV (Goddard et al. 2002), and this virus was detected during 2003 in pools of this mosquitoes in California, Arizona, and Baja California, Mexico (Reisen et al. 2004), and also in horses and birds during 2002–2003 in Mexico (Blitvich et al. 2003, 2004; Fernandez-Salas et al. 2003). This report presents results of studies in two localities in northeastern Mexico (border to Monterrey) on the host-feeding patterns of *Cx. quinquefasciatus*.

## MATERIALS AND METHODS

### Description of study sites

Mosquito collections were made in the municipalities of Guadalupe (25°44′N and 100°16′W) and Escobedo (27°14′N and 101°24′W) in the metropolitan area of Monterrey. The climate in both localities is semiarid hot, with limited rainfall, except for occasional heavy rainstorms. The annual mean rainfall is approximately 600 mm, and annual mean temperature is 22°C. The elevation ranges from 450 to 530 m above sea level. Guadalupe and Escobedo have 670,162 and 233,445 inhabitants, respectively. These municipalities are industrial areas, but cereal crops such as corn, wheat, barley, oats, and beans also are grown in these areas. The

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Pesqueria and Santa Catarina rivers pass through this region, and the study sites are located near the rivers. Dogs, cats, pigs, and chickens are common in both municipalities, whereas horses are scarce.

### Mosquito collections

Diurnal indoor and outdoor resting mosquito collections were conducted in October and November 2003 (wet season), months when outbreaks of mosquito-borne diseases increase. In each locality, two field workers spent 4 h searching 15 houses each day each month. A thorough examination was made of wall, ceiling, and furniture by using flashlights, and indoor resting mosquitoes were collected using a modified CDC backpack aspirator (model 1412; John W. Hock Co. Gainesville, FL). Outdoor collections were made in the backyards of the houses. Captured specimens were held in plastic containers and transported to the laboratory where they were sorted by sex and classified as engorged, unfed, or gravid. Humans and domestic animals (dogs, cats, chickens, pigs, and horses) were censused at each location.

### Blood meal identification

The abdomens of freshly fed females were smeared onto Whatman no. 2 filter paper. The papers were then dried, wrapped with waxed paper, and stored at 4°C until processed for blood meal identification. A direct enzyme-linked immunosorbent assay (ELISA) described by Beier et al. (1988) and modified by Loyola et al. (1990) was used to identify the blood meals smears. Samples were eluted overnight at 4°C with 200 μl of a phosphate-buffered saline (PBS, pH 7.2) solution. Five microliters of each eluted sample was placed with 45 μl of coating buffer (35 mM sodium bicarbonate and 15 mM sodium carbonate, pH 9.6) in 6 wells of a polystyrene microtiter plate (Dynex Technologies, Chantilly, VA) and incubated for 1 h at room temperature. After blocking unreacted sites with 2.5% dry skimmed milk in PBS (pH 7.2) for 1 h, the wells were treated with anti-human, -cat, -dog, -chicken, -pig, or -horse IgG (H+L) peroxidase-labeled antibodies produced in goat (Kirkegaard and Perry Laboratories, Gaithersburg, MD). Color was developed using 2,2′-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) (Kirkegaard and Perry Laboratories) as a substrate. Blood samples of the same host species were dried on filter paper and used during tests as positive controls. A test was considered positive when its absorbance value was at least 2-fold higher than the mean of 5 negative controls (consisting of unfed female *Cx. quinquefasciatus* mosquitoes). Mixed blood meals represented 2 or more different hosts. The microplates were read in the microplate reader (Benchmark microplate reader, catalog no. 170-6850; Bio-Rad, Hercules, CA) at a wavelength of 405 nm.

### Data analysis

Two measurements of *Cx. quiquefasciatus* bloodfeeding habits were calculated from blood meal identification data. Estimates of HBIs were calculated from specimens collected inside houses and from outdoor sites (backyards). An HBI was calculated as the unweighted mean of the proportion of specimens with human blood (HBP) that were collected from indoor and outdoor locations (unweighted HBI = [% indoor human bloodfed + % outdoor human bloodfed]/2). This index is considered an unbiased estimate, because it uses percentages instead of raw numbers; it also was computed to account for bias introduced by disparities in the spatial distribution of resting females. The weighted HBI or crude mean also was computed; it is the sum of indoor and outdoor numbers containing a specific host blood meal divided by the total numbers of indoor and outdoor bloodfed mosquitoes (Garrett-Jones 1964).

The forage ratio (FR), which quantifies vector selection of a particular vertebrate host rather than other available hosts, also was measured (Boreham and Garrett-Jones 1973). The FRs were calculated by determining the percentage of *Cx. quinquefasciatus* females containing blood of a particular host, divided by the percentage of the total available host population represented by that particular host (Hess et al. 1968). An FR of 1.0 indicates neither a selective bias nor avoidance of a particular host animal; FRs significantly $>1.0$ indicate a selective bias, and values $<1.0$ indicate avoidance of a host in favor of other available hosts. Homogeneity chi-square tests were computed to analyze sample relative frequency comparisons (SPSS 10.0.1; SPSS Inc. 1999).

## RESULTS

### Mosquito collections

Overall, 985 *Cx. quinquefasciatus* were captured in this study (Table 1). Of this number, 782 (79.3%) were females and 203 (20.6%) were males. There were 287 (36.7%) females captured in Escobedo and 495 (63.2%) captured in Guadalupe. In total, 379 (48.4%) females were classified as engorged, 131 (16.7%) as gravid, and 272 (34.7%) did not contain blood. Of the engorged females, 256 (67.5%) were from Guadalupe, and 123 (32.4%) were from Escobedo (Table 2). One hundred and ninety-six (51.7%) engorged females were captured indoors, and 183 (48.2%) were captured outdoors (Table 1). There

Table 1. *Culex quinquefasciatus* mosquitoes captured indoors and outdoors. Resting collections were conducted in the municipalities of Guadalupe and Escobedo, northeastern Mexico, during October–November 2003. Data are presented on numbers captured, blood identification (host type), fed, unfed, gravid, and male.

| Locality | | Guadalupe | Escobedo | Total |
|---|---|---|---|---|
| Indoor resting | No. caught | 208 | 114 | 322 |
| | % tested | 62.0 | 58.7 | 60.8 |
| | Fed | 129 | 67 | 196 |
| | Unfed | 57 | 34 | 91 |
| | Gravid | 22 | 13 | 35 |
| | Males | 33 | 21 | 54 |
| Outdoor resting | No. caught | 287 | 173 | 460 |
| | % tested | 44.2 | 32.3 | 39.7 |
| | Fed | 127 | 56 | 183 |
| | Unfed | 106 | 75 | 181 |
| | Gravid | 54 | 42 | 96 |
| | Males | 82 | 67 | 149 |

were no significant differences in the proportion of females captured indoors and outdoors between the 2 localities ($\chi^2 = 11.3$, $P < 0.01$).

### Host feeding preferences

At each site, mosquitoes captured indoors and outdoors had a preference for avian blood, although mosquitoes captured indoors also fed frequently on humans (Table 2). Chickens were the sole source of blood for 38.8% and 56.7% of engorged mosquitoes captured inside houses in Guadalupe and Escobedo, respectively. In contrast, human blood was only detected in 36.4% and 28.4% of engorged mosquitoes captured inside houses in Guadalupe and Escobedo, respectively. Both chicken and human blood was detected in 9.3% of engorged mosquitoes captured inside houses in Guadalupe, whereas mixed chicken-human blood meals were not detected in indoor mosquitoes in Escobedo. Of the engorged mosquitoes captured outdoors, 44.1% and 73.2% from Guadalupe and Escobedo, respectively, contained chicken blood only. Only 9.4% of engorged mosquitoes captured outdoors in Guadalupe and none from Escobedo had human blood only. A small proportion of mosquitoes in each municipality had fed on horses, dogs, cats, and pigs.

### Human blood index

Females captured inside houses in both localities showed higher HBPs than those resting outdoors. HBPs of 36.4% and 28.4% were obtained for indoor samples from Guadalupe and Escobedo, respectively (Table 2). In contrast HBPs of 9.4% and 0.0% were reported for mosquitoes collected in backyards in Guadalupe and Escobedo, respectively. The total HBP (indoor and outdoor combined) in mosquitoes in Guadalupe was 23.0%; in Escobedo, it was 15.5% (Table 2). The differences between the 2 sites were not significant ($\chi^2 = 6.63$, $P < 0.01$).

The weighted and unweighted HBI values were calculated using indoor and outdoor data from the proportions of humanfed mosquitoes. Weighted mean HBI estimates for Guadalupe and Escobedo were 23.0% and 15.4%, respectively (Tables 3 and 4). The HBI values for the 2 sites were not significantly different ($\chi^2 = 3.84$, $P < 0.05$). The unweighted HBI values were slightly lower than the weighted values, 22.9% for Guadalupe and 14.2% for Escobedo. Again, the differences between these values were not significant ($\chi^2 = 6.63$, $P < 0.01$).

Of all available hosts, chickens were the most common blood source for *Cx. quinquefasciatus* mosquitoes followed by humans (Table 2). In the two places of collection, chickens were the blood source for 22.4–30.6% of all engorged *Cx. quinquefasciatus* females collected from outside resting sites. Chickens were the blood source for 25.2% and 19.3% of the engorged females collected indoors in Guadalupe and Escobedo, respectively. These rates resulted in host blood indices, weighted or unweighted, of 41.4% and 41.5% in Guadalupe and 64.2% and 65.0% in Escobedo, respectively (Tables 3 and 4). Mixed human–chicken were the third most common class of blood meal samples. The human–chicken blood indices were 10.9% (weighted) and 11.0% (unweighted) in Guadalupe, whereas, in Escobedo they were 0.8% and 0.9%, respectively (Tables 3 and 4). Weighted dog blood indices were 5.9% and 2.4% in Guadalupe and Escobedo, respectively. The unweighted indices for dog blood were 5.9% and 2.3% for the two sites, respectively. Blood meals from pigs were rarely found. Only 17.9% (68/379) of samples contained blood from more than one type of host (Tables 3 and 4).

Table 2. Blood meal identifications from *Culex quinquefasciatus* mosquitoes captured indoors and outdoors. Resting collections were conducted in the municipalities of Guadalupe and Escobedo, an urban area of Monterrey, northeastern Mexico, during October–November 2003.

| Host | Mosquitoes captured | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Guadalupe | | | | Escobedo | | | |
| | Indoors | Outdoors | Total | HBP[2] | Indoors | Outdoors | Total | HBP[2] |
| Human | 47 (36.4)[1] | 12 (9.4) | 59 | 23.0 | 19 (28.4)[1] | 0 (0.0)[1] | 19 | 15.5 |
| Chicken | 50 | 56 | 106 | | 38 | 41 | 79 | |
| Human–chicken | 12 | 16 | 28 | | 0 | 1 | 1 | |
| Horse | 0 | 2 | 2 | | 0 | 3 | 3 | |
| Dog | 2 | 13 | 15 | | 3 | 0 | 3 | |
| Cat | 2 | 3 | 5 | | 2 | 0 | 2 | |
| Pig | 0 | 1 | 1 | | 0 | 1 | 1 | |
| Other mixed | 11 | 16 | 27 | | 4 | 8 | 12 | |
| Not identified | 5 | 8 | 13 | | 1 | 2 | 3 | |
| Total | 129 | 127 | 256 | | 67 | 56 | 123 | |

[1] Human blood proportion or engorged females containing human blood.

### Forage ratios

Numbers of humans residing at each house sampled in this study as well as domestic vertebrates were counted. The patterns of host densities within the 2 study sites were distinct. In Guadalupe, 74.8% of vertebrates at the study sites were human, 12.9% were chicken, and 12.3% were other domestic animals. Regardless, chickens accounted for more than 48.8% of all the identified blood meals (Tables 5 and 6).

Humans were 3 times more abundant (74.8%) in Guadalupe than domestic animals (including chickens). However, the FR for humans was <1.0 in this locality, with 0.3 with and without chickens, which indicates that *Cx. quinquefasciatus* females fed more frequently on hosts other than humans. A similar situation is seen in Escobedo, when FRs for humans was 0.4 with chickens and 0.3 without chickens. Forage ratios >1.0 were calculated for other available hosts: chickens, pigs, and horses. The FRs for chicken in Guadalupe and Escobedo were 3.2 and 1.7, respectively (Tables 5 and 6). The FRs for pigs in Guadalupe were 1.3; although pigs represented less than 1% of all available hosts, they were fed on frequently by *Cx. quinquefasciatus* females. The second most frequently selected hosts in Escobedo were horses, with FRs of 2.7 and 1.7 with the chicken population included and excluded, respectively. An FR >1.0 indicates a selective bias. Forage ratio values for dogs and cats were <1.0, indicating avoidance of these hosts in favor of other available hosts (Tables 5 and 6).

Table 3. Weighted and unweighted HBIs human, avian, human–avian, and other host blood meals of *Culex quinquefasciatus* from indoor and outdoors resting collections. Resting collections were conducted in the municipality of Guadalupe, an urban area of Monterrey, northeastern Mexico, during October–November 2003.

| Host | % blood meal[1] | | Weighted mean[2] | Unweighted mean[3] |
|---|---|---|---|---|
| | Indoor | Outdoor | | |
| Human | 36.4 | 9.4 | 23.0[4] | 22.9 |
| Chicken | 38.8 | 44.1 | 41.4 | 41.5 |
| Human–chicken | 9.3 | 12.6 | 10.9 | 11.0 |
| Other animal | 15.5 | 33.9 | 24.6 | 24.7 |
| Total | 100 (129) | 100 (127) | 100 (256) | 100 (256) |
| Horse | 0.0 | 1.6 | 0.8 | 0.8 |
| Dog | 1.6 | 10.2 | 5.9 | 5.9 |
| Cat | 1.6 | 2.4 | 2.0 | 2.0 |
| Pig | 0.0 | 0.8 | 0.4 | 0.4 |
| Other mixed | 8.5 | 12.6 | 10.5 | 10.6 |
| Not identified | 3.9 | 6.3 | 5.1 | 5.1 |

[1] Percentage of blood meal by type of host. Blood meals were identified by ELISA.
[2] Weighted or crude mean: (numbers with human blood indoors + numbers with human blood outdoors)/(total numbers engorged indoors + total numbers engorged outdoors).
[3] Unweighted mean: (indoor % with human blood + outdoor % with human blood)/2.
[4] Human blood index (HBI).

Table 4. Weighted and unweighted HBIs, human, avian, human–avian, and other host blood meals of *Culex quinquefasciatus* from indoor and outdoors resting collections. Resting collections were conducted in the municipality of Escobedo, an urban area of Monterrey, northeastern Mexico, during October–November 2003.

| Host | % blood meal[1] | | Weighted mean[2] | Unweighted mean[3] |
|---|---|---|---|---|
| | Indoor | Outdoor | | |
| Human | 28.4 | 0.0 | 15.4[4] | 14.2 |
| Chicken | 56.7 | 73.2 | 64.2 | 65.0 |
| Human–chicken | 0.0 | 1.8 | 0.8 | 0.9 |
| Other animal | 14.9 | 25.0 | 19.5 | 20.0 |
| Total | 100 (67) | 100 (56) | 100 (123) | 100 (123) |
| Horse | 0.0 | 5.4 | 2.4 | 2.7 |
| Dog | 4.5 | 0.0 | 2.4 | 2.3 |
| Cat | 3.0 | 0.0 | 1.6 | 1.5 |
| Pig | 0.0 | 1.8 | 0.8 | 0.9 |
| Other mixed | 6.0 | 14.3 | 9.8 | 10.2 |
| Not identified | 1.5 | 3.6 | 2.4 | 2.6 |

[1] Percentage of blood meal by type of host. Blood meals were identified by ELISA.
[2] Weighted or crude mean: (numbers with human blood indoors + numbers with human blood outdoors)/(total numbers engorged indoors + total numbers engorged outdoors).
[3] Unweighted mean: (indoor % with human blood + outdoor % with human blood)/2.
[4] Human blood index (HBI).

Table 5. Forage ratio (FR)[1] estimates for *Culex quinquefasciatus* female resting collections were conducted in the municipality of Guadalupe, an urban area of Monterrey, northeastern Mexico, during October–November 2003.

| Host | % host population[2] | % host population[3] | % blood meals[4] | FR[1,2] | FR[1,3] |
|---|---|---|---|---|---|
| Human | 74.8 | 85.9 | 23.0 | 0.3 | 0.3 |
| Chicken | 12.9 | | 41.4 | 3.2 | |
| Animal[5] | 12.3 | 14.1 | 35.6 | 2.9 | 2.5 |
| Total | 100 | 100 | 100 | | |
| Horse | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 |
| Dog | 7.0 | 8.0 | 5.9 | 0.8 | 0.7 |
| Cat | 5.0 | 5.7 | 2.0 | 0.4 | 0.4 |
| Pig | 0.3 | 0.3 | 0.4 | 1.3 | 1.3 |
| Sample size | 699 | 609 | 256 | | |

[1] Forage ratio = % host blood meals/% host population.
[2] Chicken population included.
[3] Chicken population deleted.
[4] Weighted HBI; see Table 1.
[5] All animals other than humans plus not identified meal combined.

Table 6. Forage ratio (FR)[1] estimates for *Culex quinquefasciatus* females resting collections were conducted in the municipality of Escobedo, an urban area of Monterrey, northeastern Mexico, during October–November 2003.

| Host | % host population[2] | % host population[3] | % blood meals[4] | FR[1,2] | FR[1,3] |
|---|---|---|---|---|---|
| Human | 36.3 | 58.3 | 15.4 | 0.4 | 0.3 |
| Chicken | 38.0 | | 64.2 | 1.7 | |
| Animal[5] | 25.7 | 41.7 | 20.4 | 0.8 | 0.5 |
| Total | 100 | 100 | 100 | | |
| Horse | 0.9 | 1.4 | 2.4 | 2.7 | 1.7 |
| Dog | 8.8 | 14.1 | 2.4 | 0.3 | 0.2 |
| Cat | 6.3 | 10.1 | 1.6 | 0.3 | 0.2 |
| Pig | 9.9 | 16.0 | 0.8 | 0.1 | 0.1 |
| Sample size | 443 | 276 | | | |

[1] Forage ratio = % host blood meals/% host population.
[2] Chicken population included.
[3] Chicken population deleted.
[4] Weighted HBI; see Table 2.
[5] All animals other than humans plus not identified meal combined.

## DISCUSSION

### Resting populations

The determination of host-feeding patterns of *Cx. quinquefasciatus* in Monterrey is complicated by the use of insecticides in this area. Indeed, insecticides (ultra-low volume [ULV]) are continuously applied to houses to control mosquito-transmitted viruses such as dengue and WNV. Some changes in feeding patterns and densities of mosquitoes are expected in these conditions. The patterns of capture densities in the indoor and outdoor resting populations of *Cx. quinquefasciatus* in the 2 study sites were different (Table 1). The differences might be explained by Aquareslin® or Biphenthrin (ULV) being used in 1 of these communities within the study period. Adulticiding is one component of integrated pest management; Aquareslin (permethrin, esbiol, and piperonyl butoxide) and Biphenthrin 1.5% (ULV) are insecticides used in northeastern Mexico for disease control of dengue and WNV vectors (Norma Oficial Mexicana 2003).

*Culex quinquefasciatus* has been implicated as an important vector for WNV in the United States, although the vectorial competence of *Cx. quinquefasciatus* populations in Mexico has not been determined. However, WNV activity has been reported in Mexico (Blitvich et al. 2003, 2004; Fernandez-Salas et al. 2003). Vector competence studies are urgently required.

In Nuevo Leon, population densities of *Cx. quinquefasciatus* begin to increase during the rainy season (September–November), which is why the study was conducted at this time. Overall, the intensive collections of *Cx. quinquefasciatus* adults from indoors and outdoors from Escobedo were relatively less productive than those in Guadalupe, producing only 32.4% of the total number of engorged females processed for blood meal identification, whereas 67.6% were obtained in Guadalupe (Table 1).

The stream margins of Santa Catarina and Pesqueria rivers are good larval habitats for *Cx. quinquefasciatus* mosquitoes (Elizondo-Quiroga 2002), and the 2 study sites are located close to the streams. The study site in Escobedo is situated closer to the Pesqueria River than Guadalupe study site is to the Santa Catarina River; however, Guadalupe provided most of the engorged females (67.6%).

### Human blood index

In samples from the 2 study sites, both the weighted and unweighted blood indices for *Cx. quinquefasciatus* indicate a relatively ornithophilic vector. The unweighted mean was always slightly higher than the weighted blood index (BI) in the 2 localities (41.5% and 65.0% versus 41.4% and 64.2%) (Tables 3 and 4). The reason for the relationship between weighted and unweighted BIs probably relates to the effect of percentages of chicken bloodfed specimens in outdoor collections on the unweighted BI. For example, in Guadalupe, 44.1% of outdoor resting females contained chicken blood, whereas 73.2% had chicken blood meals in Escobedo, but indoor values were 38.8% and 56.7% in the same cities, respectively (Tables 3 and 4). Some studies found higher proportions of resting *Cx. quinquefasciatus* females with chicken blood in other areas. Hess et al. (1968) found 99% were blood meals of birds in Oahu Hawaii. Irby and Apperson (1988) reported 95% with avian blood (39% of galliform birds) in North Carolina. However, Niebylski and Meek (1992) found that *Cx. quinquefasciatus* populations in Louisiana fed most frequently (69.2%) on dogs, followed by birds (16.3%) and humans (11.1%). In Arizona, *Cx. quinquefasciatus* fed principally on humans (50%), birds (32%), and dogs (12%) (Zinser et al. 2004). Our data reveal a high degree of ornithophagy in total resting populations. Also, indications of endophily were provided by indoor resting mosquitoes containing blood meals from animal hosts other than humans; i.e., 38.8% chicken (50), 36.4% human (47), and 3.2% dog and cat (4) in Guadalupe, whereas the indoor blood meals were similar between chicken and human (Table 3). Outdoors blood meals from humans were much reduced (9.4% in Guadalupe).

Humans were 2nd after chickens as a source of blood meals for *Cx. quinquefasciatus* populations (Table 2). Furthermore, humans were most common host (chickens excluded) in both localities (Tables 5 and 6). Chickens and humans accounted for 64.4–79.6% of the *Cx. quinquefasciatus* blood meals. This pattern in host selection reveals a strong association of this mosquito with the domestic environment. Such an association clearly defines the human domicile as a high-risk biotope for the transmission of WNV. Mixed blood meals were present in nearly 1/5 of all engorged females (18%), represented by human–chicken (5%), human–dog, human–cat, human–pig, horse–chicken, and dog–chicken, and these findings have epidemiological importance for risk of disease transmission, in this case, WNV, posed by a vector that takes multiple partial meals (Boreham and Garrett-Jones 1973).

### Forage ratios

The HBIs were indicative of regular human–vector contact under the specific conditions of host availability at the study sites. In contrast, FRs, which are measures of host selection patterns, clearly defined *Cx. quinquefasciatus* as a zoophilic species, i.e. chicken, pig, and horse (Tables 5 and 6). The FRs for humans were $<1.0$ (with or without chicken populations);

consequently, it seems that these mosquitoes feed on humans at low frequency in comparison with chickens, horses, and pigs. Although horse and pig blood was rarely encountered in the mosquitoes, the availability of these hosts was minimal; host selection was consistently demonstrated for the larger mammals, such as horses (FR > 2.7) and pigs (FR > 1.3), which were less abundant than humans in the 2 cities. These animals present larger surface areas for host-seeking mosquitoes. Larger hosts are known to attract more bites of *Anopheles* mosquitoes (Fernandez-Salas et al. 1993). The FRs for chickens were the highest of all available hosts (1.7 and 3.2), and they were the most abundant hosts in Escobedo, and the 2nd most abundant hosts in Guadalupe, which indicates a selective bias of *Cx. quinquefasciatus* for chickens (ornithophagic).

In summary, *Cx. quinquefasciatus* populations in Monterrey fed most frequently on chickens, followed by humans. Some mosquitoes had multiple blood meals, from avian and mammalian species; thus, we assume that this species might be capable of transmitting WNV.

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