Population dynamics of *Stomoxys calcitrans* (L.) (Diptera: Muscidae) in southwestern France

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SUMMARY

The seasonal dynamics of a *Stomoxys calcitrans* population was evaluated, using Vavoua traps, in a semi-urban area located in southwestern France (National Veterinary School of Toulouse) where horse and cattle paddocks were available. A bimodal pattern of stable fly population dynamics was observed, both peaks occurring in early summer and fall. Outdoors stable fly activity was nonexistent in winter and very low during summer. Minimum daily temperature variations explained 38% of the variation of capture levels in the traps and a minimum value of 15°C is necessary to observe significant stable fly activity. In this study, it was not possible to demonstrate significant correlations between precipitations in the weeks before trapping, duration of sunshine, relative humidity and wind speed and the stable fly catches in the Vavoua traps. The long duration of outdoors stable fly activity in this area (a total of eight months during the year) does not facilitate the control of this pest.

Keywords: *Stomoxys calcitrans*, stable fly, population dynamics, climate.

RÉSUMÉ

Dynamique des populations de *Stomoxys calcitrans* (L.)(Diptera : Muscidae) dans le sud-ouest de la France.

La dynamique saisonnière d'une population de *Stomoxys calcitrans* a été évaluée à l'aide de pièges Vavoua dans une zone péri-urbaine du sud-ouest de la France (Ecole Nationale Vétérinaire de Toulouse) où des pâtures à chevaux et à bovins sont présentes. La dynamique saisonnière des populations de stomoxes était bimodale avec deux pics d'activité au début de l'été et en automne. L'activité des stomoxes était nulle en hiver et très faible au cœur de l'été. Les variations de la température minimale journalière ont permis d'expliquer 38% de la variation des captures et une valeur minimale de 15°C était nécessaire pour observer une activité significative avec les pièges Vavoua. En revanche, la pluviométrie dans les semaines qui précèdent les captures, la vitesse du vent, la durée d'ensoleillement et le pourcentage d'humidité ne semblent pas avoir d'effets majeurs sur la totalité de la période considérée. La longue période d'activité de *S. calcitrans* à l'extérieur des bâtiments (un total de huit mois sur l'année) ne facilite pas le contrôle de cet insecte.

Mots-clés : *Stomoxys calcitrans*, dynamique de population, saison, température, climat

Introduction

Stable flies, *Stomoxys calcitrans* (L.), are among the most important arthropod pests of livestock worldwide. Stable flies affect cattle and horses in a variety of ways. High levels of biting activity lead to substantial reductions in cattle weight gain and milk production [4, 23]. Furthermore, these flies may mechanically transmit various pathogens, such as *Besnoitia besnoiti* and West Nile Virus [1, 2, 15, 5], two emerging diseases in southern France affecting cattle and horses respectively [7, 6]. Limited data on stable fly population dynamics are available in Denmark [21], New Zealand [12], Brazil [19], Ethiopia [20] or Thailand [13, 17] whereas more detailed studies have been carried out in La Réunion Island in the Indian Ocean [9] or in the U.S [22, 23]. All these studies highlight the role of climatic factors such as temperatures, relative humidity and rainfalls in the dynamics of stable fly populations. In particular, the study of Taylor et al. [22] pointed out the effects of the mean temperatures and the total rainfalls during three and six weeks before a trapping session. In our knowledge, despite their economic importance, no specific study has been dedicated to the dynamics of *S. calcitrans* populations in southwestern Europe. In order to control vector populations and reduce their pathogenic and economic importance, knowledge of their ecology and biology is necessary. Threrefore, a research project has been set up in southwestern France (Toulouse, Midi-Pyrénées region) to : 1) evaluate the seasonal dynamics of stable fly populations in this region and 2) determine the most important climatic variable which influence this seasonal dynamics.

Materials and methods

STUDY AREA

A seasonal study of stable flies based upon adult trapping was conducted at the National Veterinary School of Toulouse (NVST), located in a semi-urban area, close to the Toulouse-Blagnac Airport, southwestern France (43°36'N; 1°26'E; 189 m a.s.l). In this area, the year can be divided into four seasons: winter from January to March, spring from April to June, summer from July to September and fall from October to December. Maximal rainfalls are usually observed in spring and autumn, while hot temperatures and limited rainfalls characterize the summer months in this area. Winter conditions are not severe in southwestern France as minimum temperatures below 0°C are rarely observed. Climate data were obtained from a French weather station (Toulouse-Blagnac Airport Station, located two kilometers from the study area). Mean, minimum and maximum daily temperatures, relative humidity, daily rainfall, duration of sunshine and wind speed were monitored throughout each trapping day over the study period. Appreciatively, one-quarter of the NVST property is composed of pasturelands, which are equally divided into horse and cattle paddocks (about ten horses on the one hand and twelve cattle on the other). Minimum distance between cattle and horses paddocks is 50 m. Cattle and horse paddocks contain feeding sites of hay in round bales which are considered as major developmental sites for *S. calcitrans* [3].

TRAPS AND EXPERIMENTAL DESIGN

Vavoua traps were used in this study to evaluate outside activity of stable flies. According to Gilles *et al.* [11], these phthalogen blue cloth traps are highly efficient for studying the dynamics of stable fly populations. From January to December 2009, five Vavoua traps were placed along the fence of two paddocks: two traps in front of a horse paddock (traps called H1 and H2) and three traps in front of a cattle paddock (traps called C1, C2 and C3). These traps were installed outside the paddocks one meter from the fence and at least 50 m from each other. Traps were placed grossly weekly from the beginning of January (W1: week 1) to the end of December (W52) with a total of 49 trapping sessions. Trapping days were strategically chosen so as to avoid wind and rains as Vavoua traps are known to catch very few stable flies under such climatic conditions. For each trapping day, traps were installed early in the morning (7: 30 am) and removed in the evening (6: 30 pm) since activity of *Stomoxys calcitrans* is known to be diurnal. All flies captured in the traps were killed (- 80°C, 10 minutes), and then identified according to Zumpt *et al.* [24] and counted trap by trap. Apparent densities per trap and per day were evaluated for each trap.

DATA ANALYSIS

xlSTAT (version 2014.1.01, Addinsoft) software was used for the statistical analysis. Climatic variables (mean, minimum and maximum daily temperatures, relative humidity, total rainfalls during 21 days before a trapping day, total rainfall during 42 days before a trapping day, duration of sunshine and wind speed) and the total numbers of stable flies trapped in the five Vavoua traps were used in principal component analysis. A Spearman correlation matrix was established between the different variables. The numbers of stable flies collected in the H (horse) and C (cattle) traps respectively were compared by variance analysis with repeated data.

Results

CLIMATIC VARIABLES

The main climatic parameters recorded at the Toulouse-Blagnac Airport during the year 2009 are summarized in Figures 1a and 1b. Minimum, maximum and mean daily temperatures during trapping days increased gradually from W1 to W37 then declined until W52. The mean of daily minimum temperatures in 2009 was 9.6°C whereas the mean of daily minimum temperatures for the three decades (1981-2010) was 9.1°C. In the same vein, the mean of daily maximum temperatures in 2009 was 19.2°C (18.5°C for the three decades mentioned above). Total rainfall in 2009 reached 586 mm, which is close to the annual mean of rainfalls calculated for the last three decades (638 mm). The rainfalls were irregularly distributed during that year with a peak in spring (April, W13 to W16) and in the late fall (November and December, W45 to W52). The summer of 2009 (W27 to W37) was marked by high temperatures (above 30**°C),** low relative humidity (less than 40%) and scarce rainfalls (below 40 mm per month). As windy days were avoided for trapping, the mean +/- SD of the wind speed recorded during the trapping days was 15 km/h +/- 7 and the maximum value was 30 km/h.

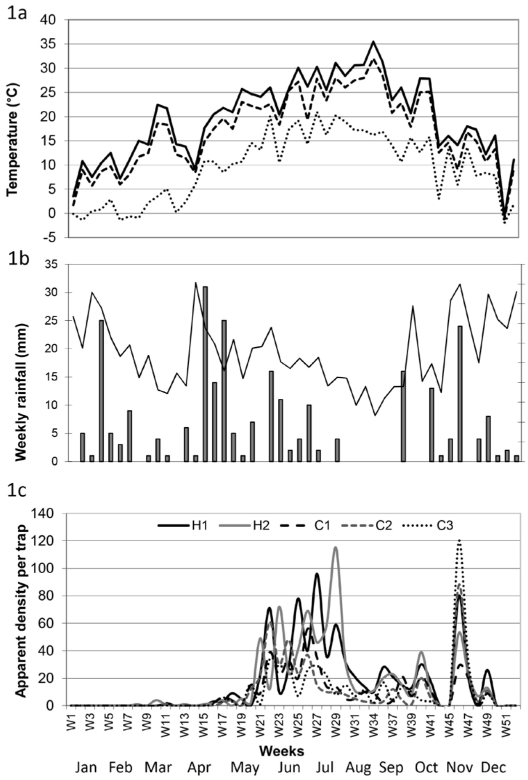

FIGURE 1:

1a: Minimum (….), maximum (solid line) and mean temperatures (----) in the study site during the year 2009 (source Toulouse-Blagnac Airport, Meteo France Station).

1b: Monthly total rainfalls (grey bars, in mm) and percentage of relative humidity (black line) in the study site during the year 2009 (source Toulouse-Blagnac Airport, Meteo France Station).

1c: Apparent densities (AD) per trap and per day according to the location of traps: two traps located along the horse pasture (H1 and H2) and three traps located along the cattle pasture (C1, C2 and C3). X axis is the period of the year (from week 1 in January to week 52 at the end of December).

POPULATION FLUCTUATIONS

The captures performed with Vavoua traps, located in proximity of horse and cattle paddocks respectively, are shown in Figure 1c. No significant captures were observed from week 1 to week 16 (late April) and during weeks 51 and 52 (late December). Populations increased rapidly in May to reach more than 30 stable flies per trap day at the end of May and between 30 and 117 stable flies per trap day until the end of July. During this period, apparent densities were similar in traps located close to horse and cattle paddocks; however captures were higher in horse traps between week 27 and week 30. Low numbers of captured stable flies were recorded in summer (from W30 to W45) in both cattle and horse traps. This period (W30 to W45) corresponded to high temperatures, low relative humidity and absence of rain. A second peak of high stable fly activity was observed in the fall (late November) in both kinds of traps. At the beginning of winter, very low captures (W49-W50) or no captures at all (W51-W52) succeeded the second peak. Finally, substantial stable fly activity was recorded during eight months in the campus of the Veterinary School of Toulouse. Apparent densities observed in cattle traps in one hand and in horse traps in the other hand were not significantly different. A graphical representation of the principal component analysis is shown in Figure 2. The plane determined by the two axes F1 and F2 represented 65.67% of the total variation. The captures of stable flies were positively related to temperature variables and duration of sunshine during the trapping day. However, no relation was detected between stable fly captures and wind speed or the total rainfall in the three or six weeks before a trapping day. The matrix of Spearman correlations is presented in Table I. The total number of stable flies in the Vavoua traps was positively correlated to minimal temperature (R^2 = 0.384, $p < 0.001$), mean temperature (R^2 = 0.248, $p < 0.001$) and maximal temperature (R^2 = 0.23, $p < 0.001$). Minimum temperatures seemed to be a determinant factor for stable flies' outdoors activity explaining about 40% of the variability of the total number of captured stable flies in Vavoua traps. However, no significant correlation was found between the number of stable flies and any other climatic variable.

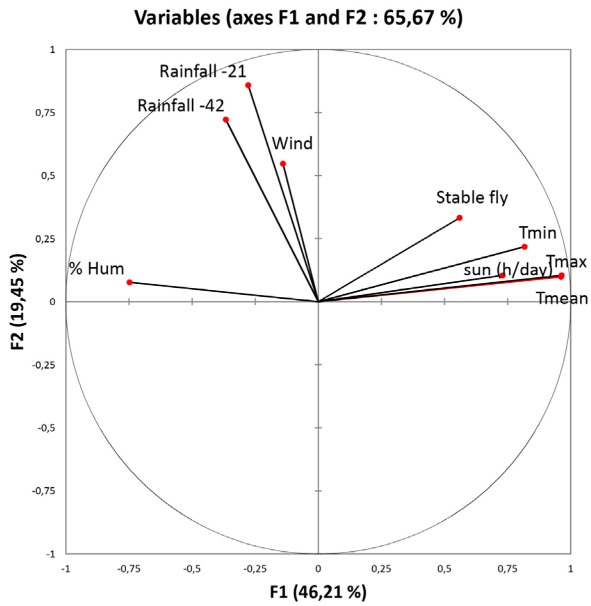

FIGURE 2: Principal component analysis performed on 49 trapping session from January to December 2009.
(Stable fly: total number of *Stomoxys calcitrans* trapped in five Vavoua traps; Tmin: minimal temperature; Tmax: maximal temperature, Tmean: mean temperature; sun (h/day): duration of sunshine; Wind; wind speed; % Hum: relative humidity; Rainfall-21: total rainfalls during the 21 days before the trapping day; Rainfall-42: total rainfalls during the 42 days before the trapping day)

Discussion

One of the most striking results of this study is the bimodal pattern of stable fly activity subject to the climatic conditions in southwestern France. A similar bimodal pattern has been observed in eastern Nebraska [22] whereas unimodal patterns have been recorded in tropical countries where a succession of rainy and dry seasons occur [17, 20]

Variables	Tmin	Tmax	Tmean	Wind	% Hum	Rainfall -21	Rainfall -42	Sun (h/day)	Stable fly
Tmin	**1**	0,868***	0,882***	-0,043	-0,291*	-0,087	-0,184	0,322*	0,620***
Tmax	0,868***	**1**	0,992***	-0,160	-0,634***	-0,153	-0,248*	0,649***	0,480***
Tmean	0,882***	0,992***	**1**	-0,121	-0,629***	-0,162	-0,263*	0,637***	0,498***
Wind	-0,043	-0,160	-0,121	**1**	0,101	0,367**	0,108	0,000	0,144
% Hum	-0,291*	-0,634	-0,629***	0,101	**1**	0,188	0,267*	-0,853***	-0,215
Rainfall -21	-0,087	-0,153	-0,162	0,367**	0,188	**1**	0,685***	-0,065	-0,022
Rainfall -42	-0,184	-0,248*	-0,263*	0,108	0,267*	0,685***	**1**	-0,096	-0,069
Sun (h/day)	0,322*	0,649***	0,637***	0,000	-0,853***	-0,065	-0,096	**1**	0,205
Stable fly	0,620***	0,480***	0,498***	0,144	-0,215	-0,022	-0,069	0,205	**1**

TABLE I: Spearman correlations' matrix between climatic parameters and the total number of *Stomoxys calcitrans* collected in five Vavoua traps (49 trapping sessions from January to December 2009) (*: p < 0.05; **: p < 0.01; ***: p < 0.001) and in the North of Europe [21] where long and harsh winters are likely to inhibit larval development and adult fly activity. Temperatures seem to account for most of the variations observed in stable fly activity measured by Vavoua traps. During winter, minimum temperatures are too low to permit adult fly activity. It is noteworthy that the minimum daily temperature should reach 15°C in order to observe significant captures in the traps. Furthermore, low stable fly activity was recorded in this study during the hot and dry summer. According to the experiments of Lysyk [16] and Gilles et al. [10], high temperatures (above 30°C) are associated with decreased survival of immature stages, female fecundity and median longevity of females and males. This could explain the low level of captures during this period. In this study, total rainfall during three or six weeks before a trapping day was not significantly correlated to the number of captures contrary to the study of Taylor [22] in the United States where these variables accounted for 12% of the overall variation. The reasons of this discrepancy are not known. Finally, two distinct periods of the year (late spring and fall) seem to provide adequate conditions for high outdoor activity of stable flies. However, stable fly activity in the fall was more variable than in spring and early summer, some peaks of activity in autumn being preceded and followed by periods without any captures. This was similarly observed in Nebraska [22] and in a previous and preliminary study in the Pyrenees mountains [14]. It seems that stable flies are highly adaptable, exploiting favorable climatic conditions between spring and late autumn for their outdoors activity.

Taking the total duration of the study into account, there was no significant difference of apparent densities between traps located in proximity of cattle and horses. However, a tendency was observed in summer, indicating that horses may be slightly more attractive than cattle. Nevertheless, our experiment was not designed to address this question and further investigations are required before coming to conclusions.

Finally, the long period of outside activity of stable flies (eight months in this study) makes control of this pest difficult. Moreover, high activity has been observed at the end of winter and in the beginning of spring (before the turnout of animals) inside cowsheds, extending the period of pathogen transmission such as bovine besnoitiosis in southwestern France [14]. It has proven difficult to protect cattle from fly bites during such a long period of time for obvious cost and environmental reasons; therefore, chemical measures of vector control should be a focus during high activity periods in late spring and fall. In addition, integrated pest control should be proposed to avoid large release of insecticides in the environment or on the animals.

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