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Analysis of a 7-year abundance dataset of *Culex pipiens* s. L.

M C Proença
Senior Researcher, Department of Physics, Faculty of Sciences, University of Lisbon, Lisbon, Portugal

Abstract
This is a preliminary analysis of a *Culex pipiens* s.l. data set captured during seven years over Portugal mainland in a long-term surveillance program that include also other mosquitoes; we focus on *Culex pipiens* females' abundance because is the most frequent species in Portugal and due to its medical importance, acting as a vector for more than 20 viruses. We quantify the methods used, the type of bait in the traps and the places of capture for 37.094 females *Culex pipiens* at national level and compare regional health administrations with further detail using the captures above 25 individuals. A first overall analysis show that the options with better efficacity were CDC traps without bait, although the CO2 bait option follows closely. A second look using a subset containing 84% of all females in the dataset shows more detail on the performance of the two main bait options - dry ice and without bait, both used in all regions. We were able to conclude that the dry ice option led to larger catches in all but the southernmost region, with milder weather, where a higher density of mosquitoes seems to justify the irrelevance of the bait. These results will help to shape the surveillance program in next years, eventually reducing costs and enabling better planning.

Keywords: *Culex pipiens* s. L., mosquito abundance, mosquito surveillance, mosquito traps

Introduction

In this preliminary analysis of a 7-year data set of *Culex pipiens* s.l. we quantify the use of several methods of capture, the type of bait and the places of capture, comparing the results both at national and regional level, using as spatial reference the 5 regional health administrations, shown in Figure 1. The focus is on *Culex pipiens* females because of its medical importance [1], acting as competent vectors in the transmission of many pathogens to humans [2], namely West Nile virus [3], iridoviruses, rheoviruses, and parvoviruses [4].

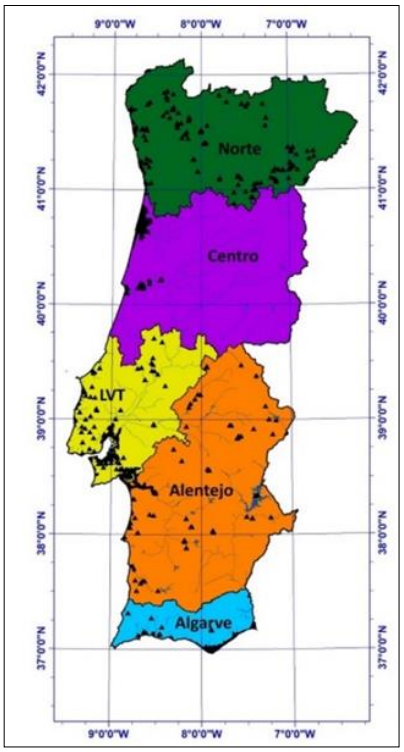

Fig 1: Portugal mainland and the five regional health administrations – Norte (green), Centro (purple), Lisboa e Vale do Tejo (LVT) (yellow), Alentejo (orange) and Algarve (blue). All contribute to the long-term mosquito's surveillance program.

The data set contains 2.057 records, concerning 2.181 traps where a total of 37.094 *Culex pipiens* females were captured, to which refers all the observations hereafter. The captures have different dimensions: 45% register zero captures and 25% captures between 1 and 5 individuals; 88% of all captures are under 25 individuals.
The unit used for comparison through the data set is the Capture Efficacity (CE), the ratio between the number of females caught and the number of traps per site. We compare the records of inside versus outside captures, five methods of capture (CDC and BG traps, inside and outside vacuum and mosquitaire) and the bait options used, which were CO2, dry ice, BG attractant and no bait at all. This preliminary exploitation of the data was done in Excel and Statistical Package for the Social Sciences (SPSS from IBM).

Results
We analyze the data globally at national level considering all the captures in Portugal mainland, and at regional scale, using the regional health administrations as spatial reference. Both conclusions are presented.

National level
Local of capture
Most of the mosquitoes were captured outside (77%) versus only 2% of captures inside dwellings, with 21% of records unspecified. Comparing the yield of the traps placed inside and outside using the average capture of females per trap, we can see that outside traps have more than 4 times the yield of inside traps, as we could expect from vector known habits [5], although there is a considerable number of unspecified situations among the records (Table I).

Table 1: Average yield of traps in different locations

Local	Number of traps	Cx pipiens females captured	Cx pipiens fem / N. of traps
Inside	45	165	3.7
Outside	1671	27592	16.5
Unknown	465	9337	20.1

Method
The CDC trap was the method most frequently used, present in 81% of all traps and in all regions; the outside vacuum (used in 12% of the traps), was used in three regions, Alentejo, LVT and Norte, with significant use only in the last one. Six traps in the total of 2.181 (0.3%) do not report the method.
The yield of CDC traps is 25 times larger than any other method, justifying its use at national and regional levels (Table II).

Table 2: Average yield of different traps

Method	Number of traps	Cx pipiens females captured	Cx pipiens fem / N. of traps
CDC trap	1768	36819	20.8
BG trap	20	1	0.1
Inside vacuum	43	16	0.4
Outside vacuum	266	197	0.7
Mosquitaire	78	61	0.8
Unknown	6	0	0.0

Bait
The type of bait most frequently used was dry ice, present in 46% of all traps and used in all regions. The CO2 and the option no-bait were used approximately in the same proportions (17% and 16%); the less used bait was BG attractant, actually only applied in 10% of the traps in Norte region (Fig. 2).

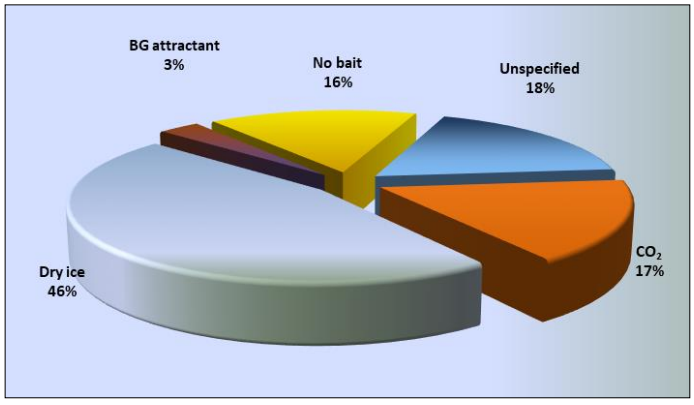

Fig 2: Distribution of bait types by all traps.

Overall, the average trap yield is almost the same for two of the three most used bait options, CO2 and no-bait, being even superior for the last option (Table III).

Table 3: Average yield of different baits

Bait	Number of traps	Cx pipiens females captured	Cx pipiens fem / N. of traps
CO2	369	8282	22.4
Dry ice	1007	18634	18.5
BG attractant	68	25	0.4
No-bait	347	8546	24.6
Unknown	390	1607	4.1

Conclusions

At national level, the larger efficacity in the capture of *Culex pipiens* females came from the location outside with CDC traps without bait.

To compare the two options on the bait that had the best results, a T-test was performed considering independent samples: the result showed that the difference between the average capture using CO2 (average (□)=22.4, standard deviation (□) =86.8) and the no-bait option (□=24.6, □=87.8) is not statistically significant (t(714)=-0.334, p=0.738) at 0.05 significance level. So, considering overall captures of any dimensions, we can say with 95% of confidence that there is no difference in use Co2 or use the traps without bait.

If we look at the captures larger than 25 females of *Culex pipiens*, that were just 267 (12%) of the 2.181 traps, almost all took place outside, mainly with CDC traps and several bait options. It should be noted that these 12% of all traps placed over 7 years captured a total of 31.018 individuals, representing 84% of all captures taken in the same period.

In this context - considering only catches ≥ 25 individuals - the option no-bait presented an average yield per trap that seems manifestly higher than the CO2 option (Table IV); statistically, the difference is not significant, due the large standard deviations of the samples (without bait: □= 187.5, CO2: □=192.0).

Table 4: Average yield of captures ≥ 25 according to bait options

Bait	Number of traps	Cx pipiens females captured	Cx pipiens fem / N. of traps
CO2	56	7175	128.1
Dry ice	154	15154	98.4
BG attractant	0	-	-
No-bait	42	7744	184.4
Unknown	15	945	63.0

Regional level

Analyzing the results at each health region from North to South (Fig. 1), we can see the evolution of captures with latitude, independently of the quantity of traps; the Norte region is an example, because despite having contributed almost a third of all traps (Fig. 3-a), these traps captured only 5% of all *Culex pipiens* females in the dataset (Fig. 3-b).

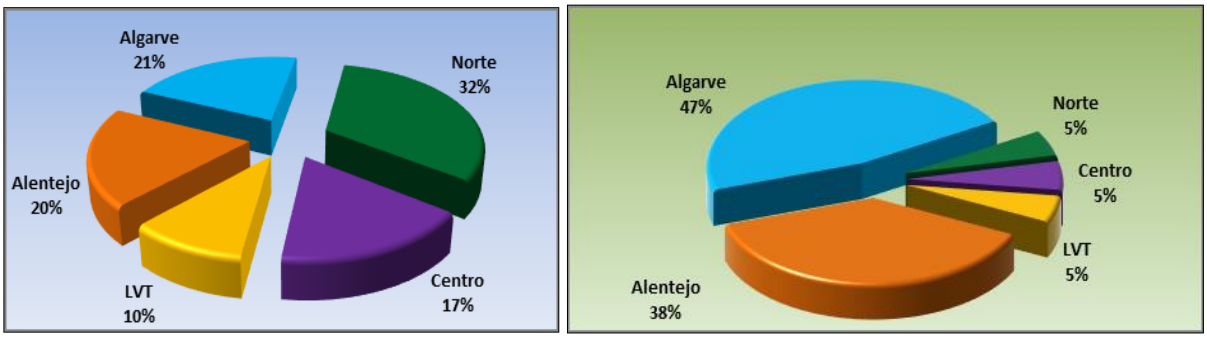

Fig 3: a) Distribution of traps by regional health administrations in Portugal mainland and b) percentual of captures by region. The region Norte, although contributing with near one third of the traps, only catch 5% of all females of *Culex pipiens* in the 7-year dataset.

To look in more detail to the five regions and try to identify the set of parameters that led to more substantial captures, we separated and processed captures with 25 or more individuals. All the options in study were analyzed and compared for each region in this meaningful subset of data. The average yield of traps is different in the five regions, and increases as latitude decreases, as can be seen in Fig.4.

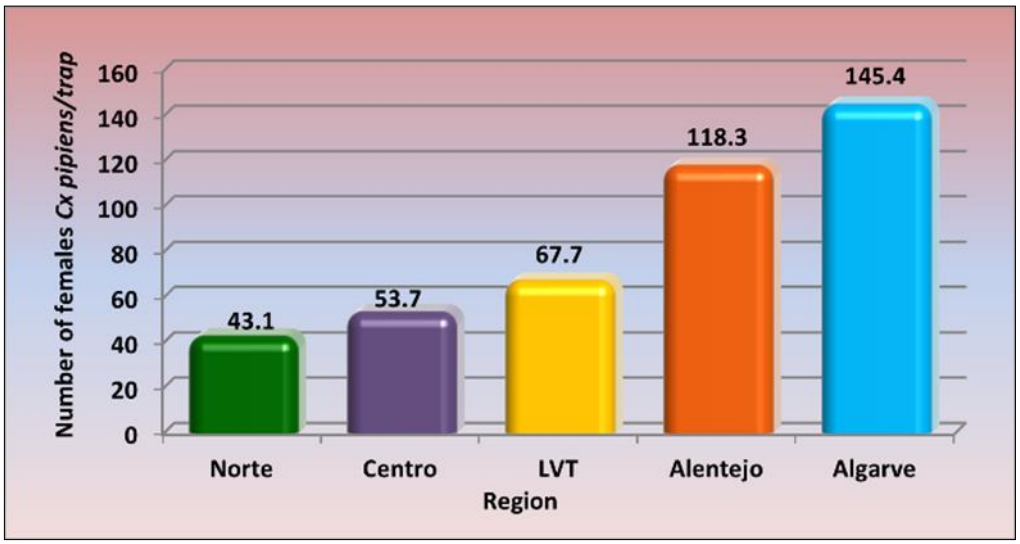

Fig 4: The average yield of the traps (number of *Culex pipiens* females per trap) for the subset of captures with 25 or more individuals increases as latitude decreases. This subset includes 84% of all individuals in the dataset.

Local of capture

Regarding the capture site, only region Centro and southernmost Algarve had a higher yield on inside catches (Table V); in the central region Alentejo the location of the traps seems indifferent, while Norte and LVT had better results with traps placed outside.

Table 5: Average yield of traps in different locations by region

Local	Norte	Centro	LVT	Alentejo	Algarve
Inside	39.45	55.95	52.57	117.16	159.06
Outside	56.33	41.00	76.58	120.50	102.35
Unknown	-	35.0	-	-	-

Method

Region Norte was the only region that captured more than 25 individuals with other method than CDC trap, using vacuum outside with a result in the same order as obtained with CDC traps. In the remaining regions, these captures have always occurred with CDC traps, and its yield increases to south: the average yield in Algarve is more than 3 times the average in Centro (Table VI), with a difference of 3 degree of latitude between the two regions (Fig. 1).

Table 6: Average yield of traps by method and region

Method	Norte	Centro	LVT	Alentejo	Algarve
CDC trap	43.38	53.74	67.74	118.33	145.41
Outside vacuum	39.00	-	-	-	-

Bait

The bait option BG attractant is not present in the captures leading to larger numbers of individuals. Region Norte, which was the only one exploiting all the bait options, only have catches of 25 or more females with the options dry ice and without bait, the first having a better performance (Table VII) if we don't account for the captures with unspecified bait. Dry ice is also the most effective option in the Centre, LVT and Alentejo. In region Centro the options Co2 and no bait have nearly the same yield, and dry ice performs better. In LVT dry ice also has a better yield than the no bait option, and sadly there is many records without specification of bait. This is also the case for Alentejo, where the dry ice continues to be the most effective option, followed by CO2 and no bait.

Table 7: Average yield of traps according to bait and region

Bait	Norte	Centro	LVT	Alentejo	Algarve
CO2	-	35.0	-	86.4	205.8
Dry ice	43.3	57.2	60.8	152.9	77.1
No bait	33.0	38.0	46.5	52.0	222.7
Unknown	47.0	-	100.8	49.8	-

The southern Algarve is the only region where dry ice didn't lead to the higher average capture, that role being assigned to no bait and CO2. presents an average yield of 107.1, which we can attribute to its mild weather 5, providing optimized conditions for mosquitos' survival and abundance.

Conclusions

Considering the captures of 25 individuals or above, the use of dry ice as bait gives the bigger average captures in all regions except for Algarve, where the option no-bait performs better. A possible explanation is that, with the highest mosquito density, the additional attraction of a bait seems to be irrelevant.

The results at national level were distorted by the large quantity of mosquitoes captured at Algarve (47% of the dataset total), where the option no-bait is viable, but from all the other regions where this is not the case, the best options are CDC traps placed outside, with dry ice. CO2 cost seems to be avoidable, as it doesn't capture more individuals than dry ice at Centro and Alentejo, and its yield at Algarve is surpassed by the no bait option, obviously less expensive.

CDC traps performs very well and seem superior to other methods whenever they can be compared.

We hope this preliminary analysis could help shape the next years of the long-term surveillance program, contributing to reduce costs and targeting the most advantageous situation for capture of *Culex pipiens* females.

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