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A Door-to-Door Strategy for *Aedes albopictus* Control in Northern Italy: Efficacy, Cost-Analysis and Public Perception

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Abstract

Objective: The aim of the study was to evaluate in several Northern Italy urban localities the cost-effectiveness and the public perception of an intensive *Ae. albopictus* control strategy by integrating accurate inspection and treatment of private areas with the standard disinfestations of catch basins in public areas.

Methods: The applied door-to-door strategy (DtoD) includes periodical inspections of private properties with larval treatment of permanent breeding sites and removal or inactivation of occasional breeding sites, together with direct information to the residents. The effectiveness of the service was assessed in the period 2013-2015 by means of ovitraps and in the period 2015-2017 by human landing collections (HLC). Public perception was evaluated by a survey questionnaire at the end of the season.

Results: In the period 2013-2017, 94.7% of the 41,827planned inspections were managed according to the program, while 5.3% were not made due to detected specific reasons.

The reduction in the *Ae. albopictus'* density, when compared to similar urban areas managed with the standard mosquito control plan (regular larval treatment of breeding sites in public areas and community engagement), resulted in the range 36-62% when using ovitraps and 69-72% when using HLC. Simple questionnaires distributed to citizens' to evaluate their perception showed that 59.3-89.2% declared the DtoD service highly effective or effective, while 3.2-13.1% declared DtoD poorly effective or ineffective.

The average cost of the DtoD package was in the range 5-9 Euro/inhabitant/year, depending on the local condition, while the average cost of the standard plan at the Emilia-Romagna regional level was calculated in 1.3 Euro/inhabitant/year.

Conclusion: The tested DtoD strategy resulted very effective in the reduction of the *Ae. albopictus* population in urban context and has been favorably received by the resident population. On the other hand, the strategy requires a remarkable organizational effort.

Keywords: Mosquito control; Larval treatment; Source reduction; Private properties; Urban mosquitoes; Breeding sites; Efficacy evaluation; Cost-Efficacy

Introduction

Ae. albopictus is currently widespread in Italian urban areas where it causes impressive nuisance as well as sanitary concerns [1-3].

In some cases, Public Administrations (PAs) responsible for mosquito control, mainly Municipalities, Public Health Agencies and Regional Bureaux, have implemented monitoring and control programs specifically targeted at this species [4], including larval control in public areas, information campaigns, Mayor Ordinance and focal adult control. In situations where imported cases of Chikungunya, Dengue and Zika are detected, emergency measures are adopted to prevent possible outbreaks [5].

Nevertheless, even in the best organized programs, the results are unsatisfactory; mainly because of the insufficient rate of community participation and the lack of political will to fine citizens who disregard the Mayor Ordinance [6].

The Emilia-Romagna *Ae. albopictus* management plan is considered one of the best organized plan in Italy and it includes larval control in public road drains, monitoring by ovitraps, the Mayor Ordinance and the use of citizens' information to obtain community participation [4,5].

In order to make available to the PAs a more effective and feasible *Ae. albopictus* control strategy, and following the experiences developed in other situations [7-9], we organized and pilot-tested in real operational conditions a door-to-door strategy (DtoD). In this paper, we present the DtoD strategy, the results achieved, and the cost-effective evaluation.

Materials and Methods

Pilot trials were conducted in operational conditions involving six small towns in the period 2013-2017 (Table 1), with the support of the Emilia-Romagna Region, the six Municipalities and the Life Conops EU project (www.conops.gr).When possible, the DtoD strategy was applied to the whole target urban area to minimize mosquito immigration from external areas.

Please refer to the Table 1 which clearly explains the urban areas surface extension (ha), Access Unit (AU) (no.), ovitraps (no.) and HLC sessions (no.) under door-to-door trial in the period 2012-2017.

The applied DtoD strategy consists of the following actions:

- six larval control treatments in public road drains in the period April-September, using manual pump spraying Diflubenzuron (Arysta LifeScience France) or Vectomax®FG (and , Sumitomo Chemical Italia) or Aquatain AMF™ (polydimethylsiloxane, Bleu Line Italia);
- six DtoD interventions in the period April-September, including source removal, larval treatment of permanent breeding sites using the same products as in public areas and direct information to the residents;

- the introduction of predatory copepods in the large permanent containers[10];
- the activation of a green phone line to support citizen contact;
- organization of a database to store the contact phone number of each resident, the most appropriate timing for the visits and the number and exact locations of permanent breeding sites in each property;
- communication campaigns including on-site meetings, web news, notes on the major local aggregation points, a personal letter sent by the Municipality to each resident, the notice of the next date of the visit by the Alert System (this is a system some Municipalities have put in place to directly communicate with citizens through SMS if need be).

Municipality		2013	2014	2015	2016	2017
DtoD areas	S.Giovanni P.to	ha 80.45 no. AU 398 no. ovitraps 11	ha 139.91 no. AU 806 no. ovitraps 15	ha 240.25 no. AU 1,120 no. ovitraps 25 no. HLCs 20	ha 225.96 no. AU 1,205 no. HLCs 130	//
	S.Agata B.se	ha 10.08 no. AU 45	//	//	//	//
	Castello d'Argile	ha 51.71 no. AU 388 no. ovitraps 10	ha 51.71 no. AU 394 no. ovitraps 10	//	//	//
	S.Pietro in C.le	//	//	ha 26.27 no. AU 208 no. ovitraps 10 no. HLCs 15	//	//
	Bentivoglio	//	//	ha 39.72 no. AU 281 no. ovitraps 10 no. HLCs 14	ha 146.46 no. AU 983 no. HLCs 96	ha 146.46 no. AU 1,004 no. HLCs 80
	Galliera	//	//	//	ha 45.09 no. AU 392 no. HLCs 35	ha 115.45 no. AU 812 no. HLCs 45
Control areas		no. ovitraps 31	no. ovitraps 30	no. ovitraps 31 no. HLCs 10	no. HLCs 123	no. HLCs 80

Table 1: Urban areas surface extension (ha), private properties (no.), ovitraps (no.) and HLC sessions (no.) under door-to-door trial in the period 2012-2017.

Because of the high *Ae. albopictus* carrying-capacity of the urban areas in Northern Italy [11], it became necessary to develop an intensive DtoD strategy fixing a minimum threshold of properties to be visited in each turn to 95%.

In order to achieve this, the work was organized to take place during late afternoon hours and on Saturdays, when the probability of finding the residents at home was higher.

On few occasions, the operators were supported by the Local Police service in a bid to ensure they were allowed entrance into the properties of residents refusing to let them in.

Properties that, at the first highly accurate inspection conducted at the beginning of the season, had no breeding sites were excluded from successive visits within the season.

The effectiveness of the DtoD in reducing the *Ae. Albopictus* population density was evaluated by two methods:

- In the period 2013-2015, ovitraps checked biweekly [12] were used in DtoD treated areas in comparison with similar areas where only public road drains were treated;
- While in the period 2015-2017, human landing collection (HLC) sessions were conducted in parallel on the same days and at the same time in DtoD treated vs control areas (Table 1).

HLC session of 15 min each in late afternoons was performed in fixed positions by single operators equipped with manual battery-operated aspirators during the peak of female *Ae. albopictus* activities (data not published).

Operators rotated around sampling stations to avoid bias due to difference in personal attraction to mosquitoes.

The residents' perception was evaluated by multiple choice questionnaires kept anonymous and distributed door-to-door at the end of the season in DtoD treated areas, in the period 2012-2017.

The cost analysis was based on real cost of hiring personnel, products, equipment and information campaign.

Results

The reach of the DtoD service application has been monitored during the whole period by collecting data on the property access rate and the breeding sites number (Table 2).

Efficacy evaluation by ovitraps

Ovitraps were positioned in the urban areas, in DtoD treated as well as in control areas, from May to the beginning of October, at densities in the range of 0.03-0.3 ovitrap/ha (Table 3).

Year	No. planned inspections in subsequent rounds	% inspections managed (± SD)	Mean no. permanent breeding sites/property (± SD)	Mean operational time/property in minutes (± SD)
2013	4,030	90.4 (± 3.8)	4.3 (± 3.7)	5.7 (± 1.4)
2014	5,935	93.0 (± 1.7)	5.0 (± 5.2)	4.8 (± 2.6)
2015	7,884	93.7 (± 3.8)	5.1 (± 4.6)	5.9 (± 1.8)
2016	13,071	95.1 (± 3.1)	4.9 (± 4.4)	5.4 (± 6.9)
2017	10,867	96.2 (± 3.7)	4.4 (± 3.5)	5.4 (± 2.3)

Table 2: Number and rate of door-to-door application (including properties without breeding sites), average number of breeding sites treated and average time spent.

	Door-to-Door areas				Control areas			
Year	**No. ovitraps**	**No. masonite strips**	**Total no. eggs**	**No. eggs/ovitrap/ 14days (±SD)**	**No. ovitraps**	**No. masonite strips**	**Total no. eggs**	**No. eggs/ovitrap/ 14days (±SD)**
2013	21	155	38,021	248.7 (± 134.4)	31	273	116,864	408.3 (± 201.6)
2014	25	198	28,309	133.3 (± 81.1)	30	261	94,966	355.5 (± 197.1)
2015	45	363	144,165	384.0 (± 212.5)	31	272	138,323	597.2 (± 410.7)
Total	91	716	210,495	274.9 (± 191.2)	92	806	350,153	454.4 (± 304.4)
	SS	**D. of F.**	**MS**	**F**	**p**			
Intercept	21036684	1	21036684	334.62	<0.0001			
Area	1354120	1	1354120	21.54	<0.0001			
Month	1623408	3	541136	8.61	<0.0001			
Area*Month	398570	3	132857	2.11	0.10			
Error	11567512	184	62867					

Table 3: Data collected by ovitraps positioned in door-to-door vs control urban areas and ANOVA.

Two way Anova and block Anova (Area*Month $F_{1,3}$=10.19 and $p<0.05$) showed a significant effect of DtoD when compared to control areas (where only breeding sites present in public areas were treated) (Table 3).

Egg density reduction rate was about 39% in 2013, 62% in 2014 and 36% in 2015 (global average reduction rate in the three years period was 39%).

Efficacy evaluation by HLC

Data collected by HLC sessions are presented in Table 4.

Two way Anova and block Anova (area*month $F_{1,3}$=22.55 and $p<0.02$) showed a significant effect of DtoD when compared to control areas (Table 4).

The average rate of reduction was about 69% in 2015, 72% in 2016 and 69% in 2017(global average reduction in the three years period was 71%).

Citizens' perception as evaluated by questionnaires

Three main questions were presented to residents at the end of the season:

What are their opinions on the efficacy of DtoD, expressed by ticking one of the five possible answers: highly effective, effective, not completely effective, poorly effective, and ineffective?

What are their opinions on the efficacy compared to the previous year when DtoD was not applied (question proposed in the first year of DtoD application only): less mosquitoes, same mosquitoes, more mosquitoes?

What is their willingness to have the DtoD service in the next year: yes or no?

In the period 2012-2017, 11,609 questionnaires were distributed to residents in the DtoD treated villages, obtaining a recovery rate of 35.2% (range 20.7-42.1%).

The percentage of citizens declaring the DtoD service highly effective or effective was in the range 59.3-89.2%, while the percentage declaring DtoD poorly effective or ineffective fell in the range 3.2-13.1% (Figure 1).

	Door-to-Door areas			Control areas		
Year	**No. HLC session**	**Total no. females collected**	**No. females/session (±SD)**	**No. HLC session**	**Total no. females collected**	**No. females/session (±SD)**
2015	49	186	3.8 (± 4.2)	10	124	12.4 (± 8.8)
2016	261	929	3.6 (± 4.9)	123	1,607	13.1 (± 14.8)
2017	125	364	2.9 (± 3.4)	80	758	9.5 (± 9.0)
Total	435	1,479	3.4 (± 4.5)	213	2,489	11.7 (± 12.8)
	SS	**D. of F.**	**MS**	**F**	**p**	
Intercept	29250.48	1	29250.48	463.08	<0.00001	
Area	9113.51	1	9113.51	144.28	<0.00001	
Month	2489.00	3	829.67	13.14	<0.00001	
Area*Month	1212.31	3	404.10	6.40	<0.0003	
Error	40425.45	640	63.16			

Table 4: Data collected by HLC sessions in door-to-door vs control urban areas and ANOVA.

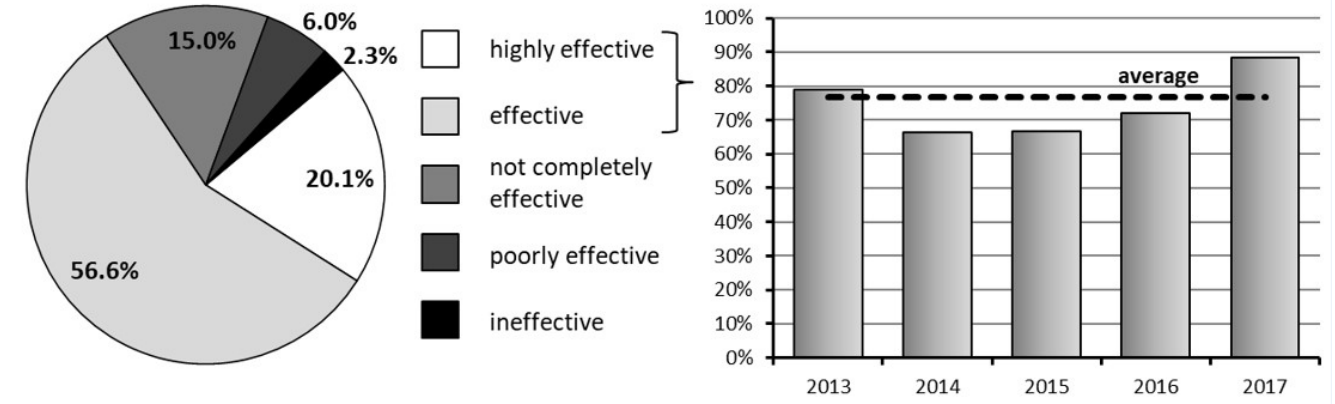

Figure 1: Citizen Perception as declared in questionnaires.

The second question was presented to residents in villages where the DtoD was being conducted for the first time; in the period 2014-2017.The answers on the perception of the presence of mosquitoes compared to the previous year are reported in Figure 2.

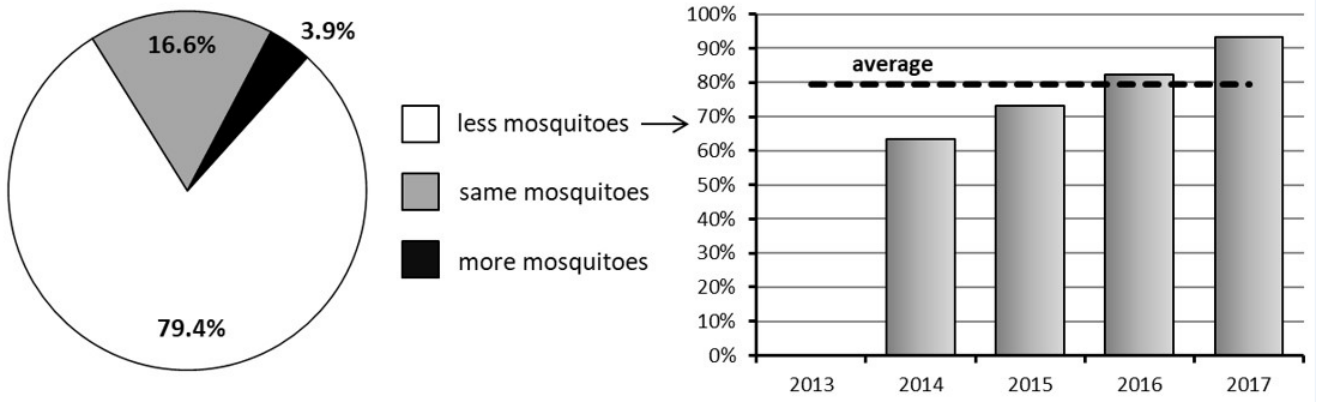

Figure 2: Effectiveness of door-to-door service compared to the year before without door-to-door.

About 80% of the respondents declared fewer mosquitos in the year of DtoD application, about 16% declared same or more mosquitoes, and about 4% declared more mosquitoes than the previous year.

The third question had a large majority of the citizens declaring in favour of having the DtoD service in the next year (Figure 3).

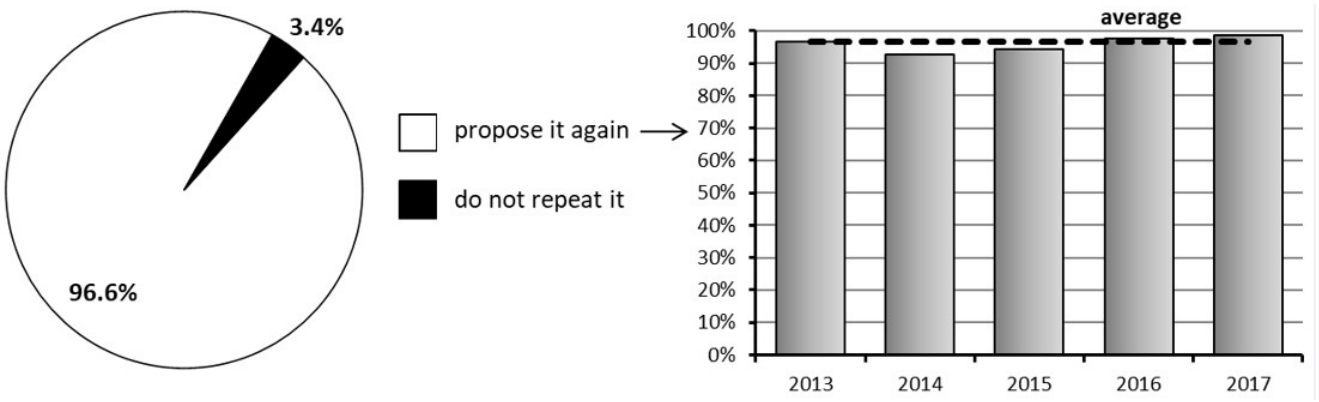

Figure 3: Willingness to have the door-to-door service in the next year.

Discussion

The experience gained from the implementation of the DtoD service in small villages in Northern Italy raised several important issues to be considered when planning an intervention of this type.

A close collaboration with the involved Municipalities in order to inform and ask for active participation of the citizens is essential to achieving the required high rate of properties coverage.

In our case, residents were largely welcoming to the operators, with a very low rate of refusal in the range of 1-2%. The mean rates of refusal showed a tendency to increase slightly with the prolongation of the service: 0.9% in the first year, 1.1% in the second year, and 1.4% in the following years.

The Local Police was involved in few occasions only, to enforce access to properties where the conditions of the backyards were considered possible important breeding sites for *Ae. albopictus* but the owner would not allow access.

The rate of DtoD coverage tended to increase with the year of application (Table 2) because of the collection of comprehensive contact information allowing the planning of personalized timing of the visits.

In Municipalities where the Alert System was available, the citizens were informed few days before each visit, and the service proceeded smoothly.

The mean operational time per property tended to decrease with the year of application and in the course of the same season, because of the more proficient planning of the visit allowed by the organization of a database with specific information on each resident (Table 5).

Because of the high *Ae. albopictus* carrying-capacity of the villages in Northern Italy, the rate of coverage was planned in such a way as to reach 95% of the entire properties to be treated in each turn.

Year	First turn	Second turn	Third turn	Fourth turn	Fifth turn	Sixth turn	Seasonal average
2013	12.0	8.6	8.6	7.7	6.4	//	8.6
2014	9.6	9.1	6.5	4.8	6.1	//	7.2
2015	12.2	7.3	6.1	5.7	6.4	//	7.6
2016	9.8	8.0	6.5	5.7	5.7	5.7	7.1
2017	11.7	7.9	5.9	5.8	5.0	5.2	6.9

Table 5: Mean operational time (min) per property in door-to-door service (full package service included).

The mean rate of coverage achieved in the whole period was not far from the planned target (94.7 ± 3.8% SD against 95.00% planned), while the efficacy in the reduction of *Ae. albopictus* population density as estimated by ovitraps and HLC was lower than expected. Ovitraps showed a reduction in the mean number of eggs/ovitrap collected by 39%, 62% and 36% in 2013, 2014 and 2015 respectively (Table 3).

HLC showed a reduction in the mean number of females/session collected by 69%, 72% and 69% in 2015, 2016 and 2017 respectively (Table 4).

In 2015, the only year when we employed the two efficacy evaluation methods, the ovitraps estimated egg reduction by 35%, while HLC estimated female reduction by 69%.

Previous studies comparing ovitraps and HLC data in Italy found a significant correlation between the two methods [6,13], but this was not the case in our situation. The reason might be due to the probable increase in the number of females laying eggs in ovitraps as a result of the important reduction in the availability of oviposition sites in the DtoD areas, thus influencing the correlation between the two monitoring methods.

Both ovitrap and HLC indicate effectiveness in the reduction of the *Ae. albopictus* population density well below the 95% corresponding rate of treated properties. We hypothesized that cryptic breeding sites and incomplete larval mortality in treated breeding sites, together with the immigration of females from external areas, might have played a significant role.

The residents' perception as derived from the survey show a high rate of satisfaction, with 70-80% of the citizens responding positively on the effectiveness of the service (Figures 1-3).

The real costs paid for the DtoD service are shown in the Table 6. The main costs are for personnel and for the management and quality assurance, while the cost for larvicidal products is low. The management costs show a tendency to decrease in successive years, thanks to the acquired detailed information on each property organized in a database.

Municipality	Year	Cost for field workers (%)	Cost for other activities (%)*	Cost for larvicidal product (%)	Total cost (€)	No. Inhabitants in the DtoD areas	Cost per capita (€)
S.Giovanni P.to	2013	49.8	49.5	0.8	11,035.00	1,247	8.85
Castello d'Argile	2013	49.1	50.3	0.6	9,600.00	1,419	6.77
S.Giovanni P.to	2014	61.0	38.3	0.7	20,672.50	3,262	6.34
Castello d'Argile	2014	55.8	43.1	1.1	7,525.00	1,468	5.12
S.Giovanni P.to	2015	72.7	26.3	1.0	26,567.50	4,212	6.31
Bentivoglio	2015	49.1	50.3	0.5	7,630.00	1,036	7.36
S.Pietro in Casale	2015	47.3	52.2	0.5	5,460.00	615	8.88
S.Giovanni P.to	2016	49.9	45.1	5.1	30,861.00	4,354	7.05
Bentivoglio	2016	50.9	46.2	2.9	31,721.50	3,876	8.18
Galliera	2016	57.6	40.1	2.3	16,352.50	1,950	8.39
Bentivoglio	2017	62.1	34.9	3.0	28,636.00	3,952	7.25
Galliera	2017	60.0	36.7	3.3	25,907.00	4,018	6.45

Table 6: Breakdown of costs and unit cost paid for the door-to-door service. (*) including programming, coordination, operator training, support, copepod distribution, evaluation of effectiveness of services.

The average real costs paid annually by Emilia-Romagna Public Administrations to support the standard *Ae. albopictus* control plan was 1.3 euros per inhabitant with significant variation at the municipality level [14]. The DtoD service, with the modalities described and based on the general conditions in the Italian villages, will require a cost in the range of 5-9 euros/inhabitant/year, depending on the population density and the urban condition (Table 6).

Conclusion

We envisage three main obstacles to the large-scale application of the DtoD service in Italy: the economic sustainability, the legislation regarding the provision of a public service in private properties due to public health emergencies, and the high risk of resistance due to the intensive selective pressure to which the local mosquito population may be submitted [15].

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