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Public perceptions and behaviours related to the risk of infection with Aedes mosquito-borne diseases: a cross-sectional study in Southeastern France

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ABSTRACT

Objectives: To explore public perceptions and behaviours related to the risk of flavivirus and alphavirus infection in Southeastern regions of France following the recent colonisation of the Asian tiger mosquito, *Aedes albopictus*, and the identification of four autochthonous cases of dengue and chikungunya fever in these regions.

Design: Cross-sectional telephone survey using a proportional random digit dialling selection method.

Setting: Interviews were conducted from 28 November 2011 to 29 January 2012 using a computer-assisted telephone interviewing system.

Participants: 1506 French speaking adults aged 18 years or older residing in French Mediterranean regions.

Results: Protective health behaviours were found to be performed less frequently among men (AOR=0.65, 95% CI 0.52% to 0.80%), residents with lower educational status (AOR=0.61, 95% CI 0.43% to 0.85% for respondents with primary school education; AOR=0.69, 95% CI 0.53% to 0.90% for those with some secondary school education), and those living in regions where the Aedes mosquito is objectively rare (AOR=0.60, 95% CI 0.36% to 0.98% for Aude; AOR=0.63, 95% CI 0.44% to 0.89% for Hérault; AOR=0.56, 95% CI 0.34% to 0.93% for Eastern Pyrenees). Empirical results also suggest that behavioural responses to infection risk are greater shaped by the perceived exposure to Aedes, notably the perceived frequency of mosquito bites (AOR=2.07, 95% CI 1.84% to 2.32%) and visual identification of Aedes mosquitoes in one's immediate environment (AOR=1.98, 95% CI 1.45% to 2.71%) rather than by other common predictors of protective behaviours.

Conclusions: These findings may help with the development of innovative instruments designed to make more visible and personal the threat of flavivirus and alphavirus infections induced by the presence of *A. albopictus* in order to promote significant behavioural changes among populations at risk.

ARTICLE SUMMARY

Article focus

- This study examines public perceptions and behaviours related to the risk of flavivirus and alphavirus infections following the recent identification of autochthonous cases of dengue and chikungunya in Southeastern France.
- The aim of this research, which is one of the first empirical studies devoted to this issue within mainland Europe, is to inform the education and prevention efforts performed by public health authorities in the regions colonised by Aedes mosquitoes.

Key messages

- Despite the considerable media coverage concerning the health threats related to the proliferation of Aedes mosquitoes, the frequency with which people perform behaviours recommended by public health authorities to reduce the risk of flavivirus and alphavirus infections remains low in Southeastern France.
- Overall, perceived exposure to the vector appears to be one of the most significant predictors of self-reported engagement in health-protective behaviours.
- Innovative prevention instruments designed to make more visible and personal the exposure to the health threat, such as inexpensive mosquito traps, may help promote significant behavioural changes in these regions.

Strengths and limitations of this study

- This study relies on observational data about health behaviours collected from telephone interviews known to be subject to several systematic biases such as selection bias, social desirability bias or recall bias, which may lead to measurement errors.
- Nevertheless, this study permits the identification of amendable factors associated with the engagement of a variety of protective behaviours, those of which could be considered in future intervention studies designed to promote behavioural change.

Behavioural response to the risk of infection with mosquito-borne diseases

INTRODUCTION

During the last decade, *Aedes albopictus*, a tropical mosquito native to Southeast Asia, has successfully colonised the Mediterranean regions of Southeastern France. In 1999, the first sporadic identification of *A. albopictus* in metropolitan France was detected in the region of Lower Normandy.¹ From 2004 to 2007, the species has permanently established itself in the southern French departments of the Alpes-Maritimes (2004), Upper Corsica (2006), South Corsica and Var (2007). Most recently in 2010, *A. albopictus* has settled in the departments of the Alpes-de-Haute-Provence and Bouches-du-Rhône, specifically in certain districts in the city of Marseille. *A. albopictus* has also been observed and occasionally eliminated in a number of communes in the regions of Languedoc-Roussillon and Rhône-Alpes.² *A. albopictus* plays an important role in a range of human arboviral diseases, including yellow fever and chikungunya, and is generally considered within the biomedical community to be a secondary vector for the transmission of dengue and West Nile Virus.³ In 2010, 87 suspected cases of flavivirus infection were reported in the region of Provence-Alpes-Côte d'Azur. Among these cases, in September 2010, two indigenous cases of dengue were confirmed in the city of Nice, and two cases of chikungunya were confirmed in the city of Fréjus.⁴ Given the absence of effective antiviral drugs and vaccines to treat and prevent dengue and chikungunya, these initial cases have provoked intense regional and national media coverage and have triggered strong concerns within medical and political communities, turning *a bad dream into reality*.⁵

To date, reducing the presence of the vector in the environment remains the main strategy being used to prevent and control the transmission of arboviruses. In this aim, the WHO has promoted an Integrated Vector Management (IVM) approach to vector control. The key elements of IVM include source reduction, pesticide application, biological control, education, public awareness and the promotion of personal protection.⁶ The collaboration of local communities (community-based approach) is thus recognised as essential to long-term vector control, especially for the management of domestic breeding points,⁷ in spite of limited evidence for the effectiveness of these strategies.^{8–10} Individual behaviour changes that contribute to controlling dengue include personal protection against mosquitoes, the assessment of dengue symptoms and treatment-seeking that lead to early diagnosis and intervention. In Southeastern France, through the dissemination of regular prevention communications, public health authorities encourage populations at risk to practise health-protective behaviours, including the use of insect repellents, mosquito nets, indoor and outdoor insecticide sprays as well as the regular elimination of standing water around the home.¹

Nevertheless, several studies have shown that the success or failure of community collaboration and personal behaviour change rely to a large extent on lay perceptions of mosquito-borne diseases related to *Aedes* mosquitoes.^{11 12}

The main objective of this study was to examine how lay people perceive emerging health threats associated with the recent presence of *Aedes* mosquitoes in Southeastern regions of France, and to examine the association between public perceptions and protective behaviours aimed at reducing the risk of mosquito bites and mosquito-borne diseases. By characterising and assessing these lay perceptions and behaviours, and by identifying geographic and socioeconomic variations among populations exposed to *Aedes* mosquitoes, more effective public health services, programmes and policies related to the prevention and control of mosquito-borne diseases can be developed to prevent future sporadic arboviral outbreaks in the Southeastern regions of France, and elsewhere.

METHODS

Participants and procedures

Random digit dialling was used to select survey participants. To ensure regional representativeness of the sample, a stratified selection procedure based on administrative departments and communes was used. Participants were then selected based on a two-step probability sampling design, poststratified for age and gender so that the sample approximated the latest census data. An initial sample of households was randomly drawn from the telephone directory. Then, one eligible respondent per household was selected using the Kish method (also known as the 'next birthday method'). Survey professionals collected the data using computer-assisted telephone interviews. Survey participants had to be 18 years or older, as of January 2012, and residing in one of the three French Mediterranean regions (Languedoc-Roussillon, Provence-Alpes-Côte d'Azur and Corsica). There was a 46.7% response rate of households who agreed to take the interview. The survey was conducted according to the rules established by the National Data Protection Authority (Commission Nationale Informatique et Libertés), which is responsible for the ethical issue and protection of individual data collected in France. Informed consent of all participants was obtained verbally at the beginning of the interview. Questionnaire administration took an average of 19 min. In total, 1506 individuals completed the questionnaire, providing a maximum theoretical margin of error of $\pm 2.4\%$ with a CI of 95%.

Questionnaire and measures

The majority of the items found in the questionnaire were derived from existing literature devoted to protective health behaviours as well as from previous qualitative interviews conducted with potential survey participants

¹For a review of the interventions conducted by the mosquito control agencies in these regions, go to http://www.eid-med.org/FR/Missions/page_mission_e.htm

Behavioural response to the risk of infection with mosquito-borne diseases

as part of an exploratory study in the city of Nice.¹³ Following a pilot study conducted in December 2011, some questionnaire items were revised to improve comprehensiveness, validity and questionnaire administration time.

Demographic and exposure variables

The questionnaire included a wide range of items aimed at collecting socioeconomic and demographic information such as age, gender, education, family income, marital status, work status, occupational status, size of household and housing conditions. In addition, participants were asked if (1) they had ever seen 'tiger mosquitoes' in their immediate environments (response options: 'Yes', 'No', or 'Not sure') and (2) how frequently were they bitten by mosquitoes during the summer season (response options: 'Often', 'Sometimes', 'Seldom' or 'Never'). These two items were then used to measure subjective exposure to potential vectors of infectious diseases.

Cognitive and emotional variables

Using an adapted version for mosquito-borne diseases, health threat perceptions were first assessed with the Brief Illness Perception Questionnaire.¹⁴ The brief illness perception questionnaire (B-IPQ), consisting of eight items, is designed to rapidly and reliably identify a limited set of proximal cognitive determinants of particular behaviours related to health threats and illnesses in large-scale studies. The questionnaire measures the following dimensions: causes, identity, timeline, consequences, understanding, personal control, treatment control and feelings of fear/worry (see [table 1](#)). Three

items were adapted from the methodological literature¹⁵ as complementary questions, to assess perceived exposure (*How exposed do you think you are to the tiger mosquito?*), perceived severity (*How serious do you think are mosquito-borne diseases?*) and perceived vulnerability (*How vulnerable do you think you are to the risk of contracting mosquito-borne diseases?*) to mosquito-borne diseases. With the exception of the cause and identity items, each item was rated on an 11-point Likert scale ranging from 0 to 10, in which the meaning of the end-points was explicitly indicated.

Behavioural variables

Precautionary behaviours in relation to reducing exposure to mosquitoes and mosquito-borne diseases can be grouped as chemical, physical or ecological. Participant behaviour was first assessed by asking whether they habitually protected themselves from mosquito bites (*In summer, do you use the following means to protect yourself from mosquito bites?*) for which possible options were 'Yes, often', 'Yes, sometimes', 'No, seldom' or 'No, never' to seven behavioural recommendations from public health authorities. Of the seven recommendations, three were related to chemical interventions: using *insect repellent on skin*, *outdoor insecticide spray*, and *indoor insecticide spray*. Two were related to physical interventions: *sleeping under mosquito bed net* and *limiting outdoor activity during peak mosquito biting times*. Two were related to ecological interventions: *eliminating standing water containers*, and *covering water storage*.

Data analysis

Current perceptions and behaviours related to mosquitoes were compared among different subgroups of

Table 1 Questionnaire items for cognitive and emotional variables adapted from the brief illness perception questionnaire

Items	Questions	Options
Causes	Do you think that all mosquitoes can transmit diseases?	Yes, No, Not sure
	Do you think that tiger mosquitoes can transmit diseases?	Yes, No, Not sure
Identity	Do you believe that the following diseases can be transmitted by the tiger mosquito?	AIDS, chikungunya, dengue fever, influenza, malaria, meningitis & encephalitis
	Do you believe that the following symptoms can be related to a mosquito-borne disease?	Nausea/headaches, sudden fever, muscle/joint pains, fatigue/loss of strength, sleep difficulties, abdominal pain/diarrhea, difficulty breathing, skin rashes
Timeline	How long do you think mosquito-borne disease would last?	0=a very short time, 10=forever
Consequences	How much do mosquito-borne diseases affect the quality of life of infected people?	0=no affect at all, 10=severely affect the quality of life
Understanding	How well do you think you understand mosquito-borne diseases?	0=don't understand at all, 10=understand very clearly
Personal control	How much personal control do you think you have over risk of mosquito-borne diseases?	0=absolutely no control, 10=extreme amount of control
Treatment control	How much do you think treatment can help with mosquito-borne diseases?	0=not at all, 10=extremely helpful
Worry	How worried are you about the risk of contracting mosquito-borne diseases?	0=not worried at all, 10=extremely worried

Behavioural response to the risk of infection with mosquito-borne diseases

people by using descriptive statistics. The generalised linear model was used to explore the association between each of the aforementioned cognitive or sociocontextual variables and the number of protective behaviours reported by participants in reducing their exposure to mosquito bites and mosquito-borne diseases. The responses obtained from the behavioural variables were reduced to a nominal level by combining the positive options ('Yes, often', 'Yes, sometimes') into a 'Yes' category (coded as 1), and the negative options ('No, seldom', 'No, never' and 'Don't know') into a 'No' category (coded as 0). These values were then summed to generate a score (scale 0–7) that assessed self-reported frequency with which participants performed specific protective behaviours recommended by public health authorities. In our multivariate regression models, variables significant at p Value higher than 0.25 in the univariate analysis were excluded.

RESULTS

Perceived exposure to diseases transmitted by *Aedes* mosquitoes

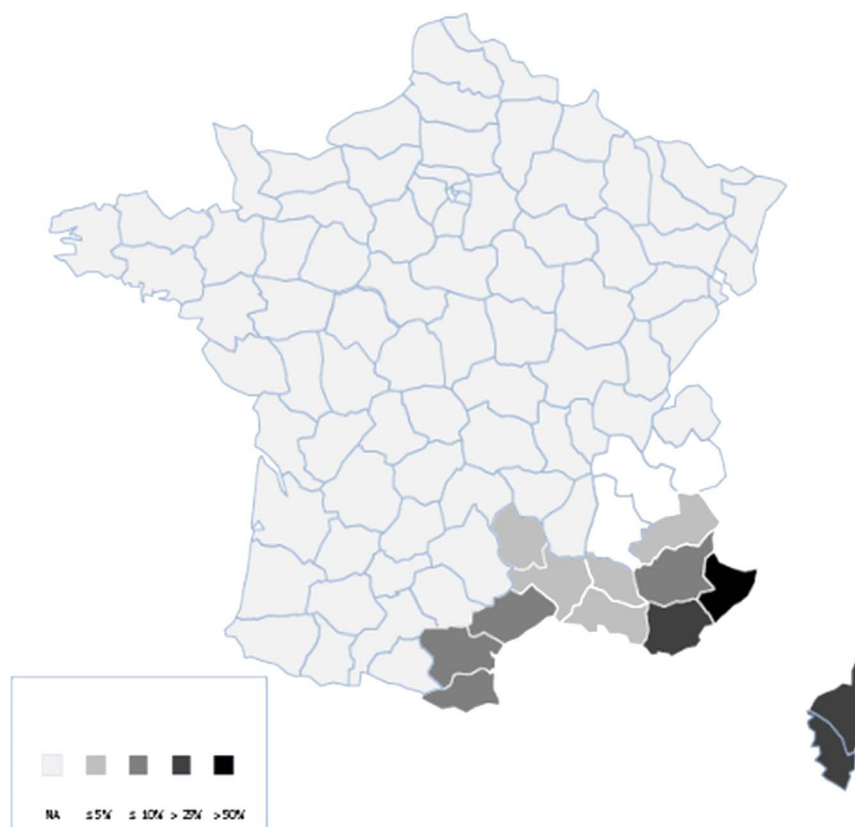
Among the 1506 individuals questioned during the winter 2011–2012, about 20% reported that they had seen 'tiger mosquitoes'. Of this 20%, 80% further indicated they had seen these mosquitoes in their immediate environment. With respect to perceived exposure to *Aedes* mosquitoes, important geographical disparities can be observed. Indeed, as demonstrated in [figure 1](#),

more than one quarter of the participants located in the departments of the Alpes-Maritimes, Corsica and Var reported to have seen *Aedes* mosquitoes in their immediate environments, while less than 10% of the participants in other areas reported having seen the mosquito. Moreover, a majority of participants (77%) believed that *Aedes* mosquitoes can transmit infectious diseases. More specifically, participants most frequently identified (properly) chikungunya and (incorrectly) malaria as *Aedes* mosquito-borne diseases (74% and 72%, respectively). Of concern is that only 8% of the respondents correctly believed that meningitis and encephalitis could be communicated by these mosquitoes, while 11% erroneously but unsurprisingly believed that mosquitoes could communicate AIDS and influenza.

Perceived symptoms of common mosquito-borne diseases

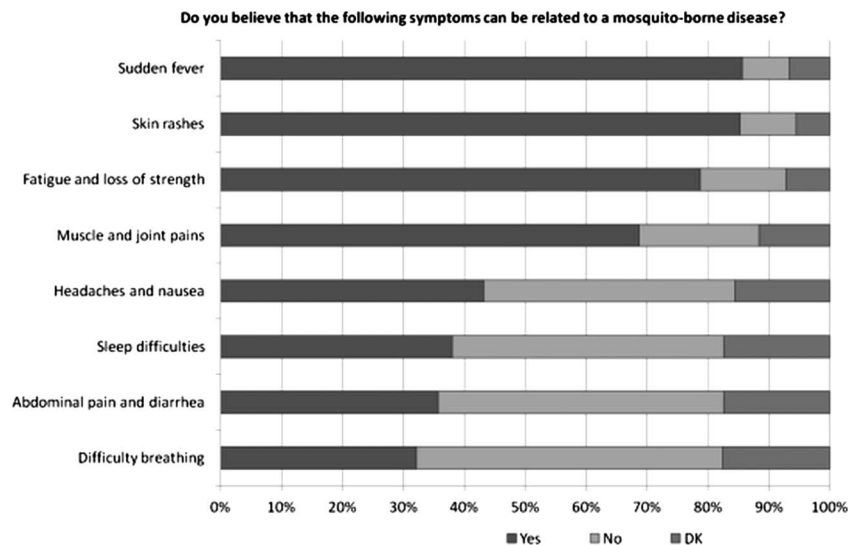
Participants identified the different symptoms that they believed were linked to mosquito-borne diseases. As demonstrated in [figure 2](#), more than two-thirds of participants reported that sudden fever, skin rashes, fatigue, muscle and joint pains could be attributed to an *Aedes* mosquito-borne disease, in accordance with the biomedical evidence on the clinical manifestation of these diseases.¹⁶ On the other hand, nausea and headache, which have long been recognised as typical symptoms, were only identified by 43% of participants. The remaining symptoms were identified as relevant *Aedes* mosquito-borne disease clinical manifestations by only about one-third of respondents, which suggests that the

Figure 1 Map of self-reported observations of *Aedes* mosquitoes in Southern France (%).



Behavioural response to the risk of infection with mosquito-borne diseases

Figure 2 Perceptions of symptoms related to common mosquitoes-borne diseases (%).



vast majority of the population is uncertain, unaware or does not understand the symptoms associated with mosquito-borne diseases.

Perceived threat associated with *Aedes* mosquitoes

Mean threat perception scores (total and by region), which include perceived vulnerability to and perceived severity of the diseases transmitted by *Aedes* mosquitoes are reported in [table 2](#). With the exception of feeling worried and perceived exposure to *Aedes* mosquitoes, the mean scores were all greater than the midpoint value on the response scale adapted from the B-IPQ. Significant differences were observed between regions. For example, participants living in the departments of Var and Corsica displayed significantly higher mean scores in relation to feeling worried, perceived vulnerability to, severity of mosquito-borne diseases and perceived exposure to the vector, than other participants.

Current protective behaviours related to mosquitoes

Although 56% of participants reported they were sometimes or often bitten during summer, only 40% of them were likely to take preventive measures aimed at reducing the risk of mosquito bites. Self-reported protective behaviours against mosquito bites are shown in [figure 3](#). Approximately one-half of participants reported not practising any of the seven recommended behaviours, compared with approximately one-third of participants who reported they practised three or more protective behaviours. The most frequent preventive measures were using indoor insecticide spray (20.2%), eliminating standing water containers (17.7%) and applying insect repellent to the skin (17.4%).

Predictors of protective behaviours related to mosquitoes

As aforementioned, univariate and multivariate ordinal regressions were used to examine the association between the number of self-reported protective behaviours (the dependent variable) and a range of

cognitive, personal and contextual characteristics. The results displayed in [table 2](#) demonstrate that most of the factors were significantly associated with the number of preventive measures taken by participants. However, in a simultaneous multiple regression analysis, only a small number of variables were found to directly influence self-reported health protective behaviours, accounting for 31% of the variance. Adjusting for all significant variables, mosquito bite pressure and identification of *Aedes* mosquitoes were highly associated with self-reported frequency of recommended protective behaviours (AOR=2.07 and 1.98 respectively, $p<0.001$). Among all participants, males, less educated people and inhabitants from areas located in Languedoc-Roussillon were less likely to report protective behaviours than other participants. Among the cognitive variables, perceived exposure, perceived behavioural control and the feeling of worry remained significantly associated with practising a range of recommended behaviours against mosquitoes ([table 3](#)).

DISCUSSION

To the best of our knowledge, this is one of the first surveys conducted in continental Europe exploring public behaviours in response to perceived health threats associated with the recent colonisation of *A. albopictus* among populations at risk of acquiring mosquito-borne diseases. One year following the first indigenous cases of dengue, this survey, which was conducted in the three Mediterranean regions of France, has allowed us to provide an estimate of the nature and scale of public health protective behaviours in avoiding mosquito bites and mosquito-borne diseases. Unsurprisingly, the frequency of the behaviours recommended by the public health authorities was found to vary considerably among different social groups and geographic areas. Residents in Southeastern departments of France such as the Alpes-Maritimes, Corsica and Var

Behavioural response to the risk of infection with mosquito-borne diseases

Table 2 Perceptions and behaviours related to Aedes mosquitoes by area (mean, SD and significance)

Geographic area	1. Consequences (0–10 scale)		2. Timeline (0–10 scale)		3. Personal control (0–10 scale)		4. Treatment control (0–10 scale)		5. Understanding (0–10 scale)		6. Worry (0–10 scale)		7. Exposure (0–10 scale)		8. Vulnerability (0–10 scale)		9. Severity (0–10 scale)		10. Protection (0–7 scale)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Corsica	7.33	(2.15)	6.33	(2.58)	7.28	(2.38)	7.28	(2.24)	5.52	(2.93)	5.29	(3.33)	4.87	(3.15)	5.42	(2.71)	7.27	(1.97)	2.15	(1.95)
Alpes Haute Provence	6.59	(2.29)	6.37	(2.81)	6.55	(2.57)	6.83	(2.12)	5.24	(3.00)	4.09	(2.95)	3.09	(2.93)	4.33	(2.63)	6.05	(2.32)	0.79	(1.38)
Hautes Alpes	7.50	(2.03)	6.93	(2.91)	7.77	(1.94)	7.20	(2.14)	5.24	(2.72)	4.03	(3.02)	2.29	(2.93)	4.03	(3.04)	6.47	(2.11)	0.91	(1.40)
Alpes Maritimes	7.62	(1.74)	6.62	(2.35)	7.11	(2.42)	6.86	(2.35)	6.17	(2.59)	5.25	(3.02)	5.60	(3.18)	6.02	(2.73)	7.02	(1.84)	2.29	(1.87)
Aude	7.17	(1.98)	6.74	(2.50)	7.33	(2.14)	7.24	(2.40)	5.59	(3.28)	4.84	(3.07)	4.12	(2.82)	5.14	(2.85)	6.77	(1.70)	1.08	(1.67)
Bouches du Rhône	7.43	(2.02)	6.56	(2.61)	6.86	(2.48)	6.87	(2.17)	5.56	(2.79)	5.11	(3.07)	3.82	(2.79)	5.05	(2.59)	7.27	(1.93)	1.44	(1.65)
Gard	7.22	(1.79)	6.55	(2.28)	6.89	(2.38)	6.58	(2.53)	5.03	(3.13)	4.66	(3.03)	3.65	(2.89)	5.00	(2.61)	7.15	(1.59)	1.69	(1.83)
Hérault	6.98	(2.19)	6.56	(2.43)	7.10	(2.48)	7.23	(2.14)	5.50	(2.67)	4.46	(2.78)	3.59	(2.89)	4.73	(2.82)	6.68	(2.11)	0.95	(1.43)
Lozère	7.42	(1.87)	6.47	(2.32)	6.16	(1.57)	7.11	(1.64)	4.58	(2.46)	3.21	(3.34)	2.32	(2.16)	3.42	(2.27)	7.05	(1.72)	0.63	(1.38)
Pyrénées Orientales	7.19	(1.76)	6.27	(2.59)	7.21	(2.09)	7.15	(1.96)	5.65	(2.65)	4.49	(2.94)	3.95	(3.37)	4.81	(2.60)	6.88	(1.92)	1.00	(1.54)
Var	7.62	(1.91)	6.69	(2.47)	7.40	(2.39)	7.06	(2.36)	5.59	(2.94)	5.06	(3.38)	4.55	(3.30)	5.41	(2.82)	7.45	(1.78)	1.91	(1.95)
Vaucluse	7.32	(2.17)	6.38	(2.62)	7.36	(2.38)	6.90	(2.10)	5.55	(2.86)	4.57	(3.19)	3.10	(2.60)	4.43	(2.50)	6.99	(2.01)	1.35	(1.69)
Total	7.33	(2.02)	6.51	(2.52)	7.12	(2.39)	7.01	(2.24)	5.56	(2.85)	4.89	(3.15)	4.13	(3.07)	5.10	(2.72)	7.07	(1.94)	1.49	(1.76)
F-value	1.56		0.38		1.51		1.07		11.25		2.23		9.94		4.59		2.99		10.53	
p Value	0.105		0.964		0.122		0.381		0.247		0.011		0.000		0.000	*	0.001		0.000	

1. How much do mosquito-borne diseases affect the quality of life of infected people? 2. How long do you think mosquito-borne disease would last? 3. How much personal control do you think you have over risk of mosquito-borne diseases? 4. How much do you think treatment can help with mosquito-borne diseases? 5. How well do you think you understand mosquito-borne diseases? 6. How worried are you about the risk of contracting mosquito-borne diseases? 7. How exposed do you think you are to the tiger mosquito? 8. How vulnerable do you think you are to the risk of contracting mosquito-borne diseases? 9. How serious do you think are mosquito-borne diseases? 10. Number of protective behaviours performed by the participants.

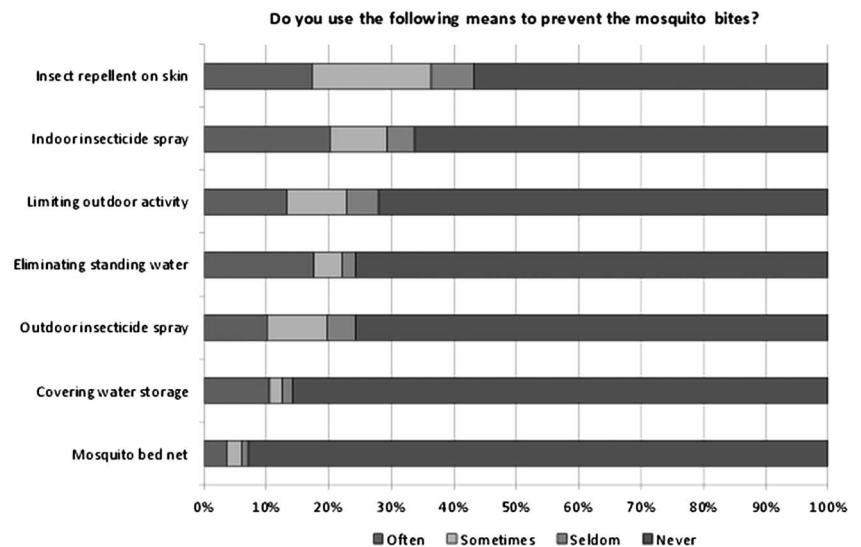
were significantly more likely to practise protective behaviours than residents in the Northern and Western departments of the country. This survey has also allowed us to identify a range of underlying factors leading to protective behaviours, those of which should be further examined and considered in the development and implementation of future large-scale mosquito-borne disease prevention programmes.

As discussed above, nearly all of the social and cognitive factors were significantly associated with self-reported frequency of protective behaviours aimed at reducing the risk of mosquito bites. In addition, previous studies analysing public responses to emerging infectious diseases demonstrate that these social and cognitive factors have consistently been found to influence health protective behaviours.^{17–19} These factors were all highly intercorrelated, and a simultaneous multiple regression analysis demonstrated that a small number of factors proved to have a direct influence on health protective behaviours in the context of progressive colonisation in these regions by *A. albopictus*. First, independent of personal experience with mosquito bites, it was found that people living in regions where *Aedes* mosquitoes are generally absent were less likely to perform a range of protective behaviours. Second, there is a social gradient in the behavioural response to the threat of mosquito-borne diseases; males and less advantaged participants were found to be significantly less likely to practice protective behaviours in avoiding mosquito bites. Third, the frequency of protective behaviours appears to vary as a function of both the perceived exposure to mosquitoes in general and more specifically to the *Aedes* mosquito. These three findings merit further discussion as each may have important implications on future prevention and control strategies related to mosquito-borne diseases.

The first finding regarding geographic location may be attributed to the fact that populations residing in these areas are objectively much less exposed to *Aedes* mosquitoes. Overall, with the noticeable exception of the area surrounding Marseille (~1 995 000 inhabitants) where the vector is more abundant, visual observations of *Aedes* mosquitoes reported by respondents fit relatively well with entomological data collected a few months prior by vector surveillance systems and on a variety of mosquito traps demonstrating the presence or absence of *Aedes* mosquitoes.²⁰ In line with previous empirical works, the geographic proximity of infectious diseases vectors appears to play a crucial role in the perceptions and behaviours related to an emerging health threat.^{12 21 22} Thus, the relative absence of *Aedes* mosquitoes in these areas might contribute to a less immediate and personal perceived health threat with respect to the spread of *Aedes* mosquitoes.

The second finding regarding the effects of sociodemographic variables on protective behaviours were strongly congruent with existing literature in the field of health promotion and on the prevention of emerging infectious diseases. Women were found to be more likely

Behavioural response to the risk of infection with mosquito-borne diseases

Figure 3 Self-reported protective behaviours aimed at reducing mosquito bites (%).**Table 3** Logistic ordinal regression models predicting recommended protective behaviours (OR, 95% CI and significance)

Factors	Univariate models		Multivariate model	
	Unadjusted OR	p Value	Adjusted OR	p Value
Geographic area				
Alpes de Haute Provence	0.49 (0.26 to 0.92)	0.013	0.54 (0.29 to 1.01)	0.054
Alpes Martimes	2.61 (1.76 to 3.85)	0.000	1.08 (0.76 to 1.53)	0.659
Aude	0.66 (0.38 to 1.14)	0.063	0.60 (0.36 to 0.98)	0.045
Corsica	2.25 (1.30 to 3.90)	0.000	1.30 (0.79 to 2.15)	0.289
Hérault	0.63 (0.41 to 0.96)	0.003	0.63 (0.44 to 0.89)	0.010
Pyrénées Orientales	0.66 (0.38 to 1.14)	0.059	0.56 (0.34 to 0.93)	0.025
Var	1.80 (1.18 to 2.73)	0.005	1.119 (0.78 to 1.59)	0.534
Bouches du Rhône	Referent		Referent	
Gender				
Male	0.52 (0.43 to 0.63)	0.000	0.65 (0.52 to 0.80)	0.000
Female	Referent		Referent	
Age group				
18–34	1.51 (1.10 to 2.07)	0.011	0.82 (0.57 to 1.17)	0.284
35–49	1.80 (1.38 to 2.34)	0.000	1.20 (0.89 to 1.61)	0.215
50–64	1.79 (1.41 to 2.28)	0.000	1.44 (1.11 to 1.88)	0.005
65 and older	Referent		Referent	
Education				
Primary school	0.62 (0.44 to 0.88)	0.008	0.61 (0.43 to 0.85)	0.004
Some secondary school	0.66 (0.51 to 0.85)	0.001	0.69 (0.53 to 0.90)	0.007
Completed high school	0.76 (0.59 to 0.96)	0.027	0.72 (0.55 to 0.94)	0.016
Some college and higher	Referent		Referent	
Observation of Aedes				
Yes	4.18 (3.26 to 5.38)	0.000	1.98 (1.45 to 2.71)	0.000
No/not sure	Referent		Referent	
Frequency of mosquito bites	2.57 (2.31 to 2.86)	0.000	2.07 (1.84 to 2.32)	0.000
Perceptions of the threat				
Perceived cause	1.61 (1.28 to 2.02)	0.000	1.28 (0.97 to 1.68)	0.072
Perceived symptoms	1.04 (0.99 to 1.09)	0.062	0.98 (0.93 to 1.03)	0.500
Perceived consequences	1.10 (1.04 to 1.15)	0.000	0.99 (0.92 to 1.06)	0.836
Perceived timeline	1.05 (1.00 to 1.09)	0.030	0.99 (0.95 to 1.05)	0.929
Perceived behavioural control	1.08 (1.03 to 1.12)	0.000	1.07 (1.02 to 1.12)	0.005
Perceived treatment control	1.04 (0.99 to 1.08)	0.092	1.01 (0.96 to 1.06)	0.637
Feeling of worry	1.16 (1.13 to 1.20)	0.000	1.11 (1.06 to 1.15)	0.000
Perceived exposure	1.24 (1.19 to 1.28)	0.000	1.07 (1.02 to 1.12)	0.005
Perceived vulnerability	1.16 (1.12 to 1.21)	0.000	0.97 (0.93 to 1.02)	0.318
Perceived severity	1.13 (1.07 to 1.19)	0.000	1.02 (0.95 to 1.09)	0.564

Behavioural response to the risk of infection with mosquito-borne diseases

to take protective actions aimed at reducing the risk of mosquito bites and infection related to the spread of *Aedes* mosquitoes. This is not surprising as the 'gender gap' is one of the most documented phenomena of social and cultural influences in the field of public health.^{23 24} Similarly, the level of formal education was significantly associated with the adoption of control and prevention measures, which may contribute to the development and maintenance of future novel socioeconomic inequalities in health. This corresponds with the growing public health evidence that the differences in the social pattern of health behaviours are a main cause of social gradients in most developed countries.^{25 26}

The third finding reveals that the perceived exposure to the threat plays a considerable role in the adoption of protective behaviours. After adjusting for other variables, self-reported protective behaviours were found to be directly and strongly influenced by participants' previous experiences with mosquitoes (being bitten, observing *Aedes* mosquitoes in the immediate environment). This suggests that the identification of *Aedes* mosquitoes may play a role in motivating people to engage in protective health behaviours, thus reducing risk of infection. From a psychological perspective, this finding can be interpreted as an effect of stimulus vividness on risk perception. There is growing evidence that vividness with which health threats can be imagined and mentally represented constitutes one of the most important determinants of actual behaviour change.^{27 28} Therefore, one can deduce that the vividness of the health threat mediates, at least in part, the relationship between the participants' visual detection of *Aedes* mosquitoes in their immediate environment and their behavioural reaction to the risk of mosquito-borne diseases.

To conclude, we believe that these findings hold important implications for the prevention of mosquito-borne diseases. Motivating individuals to modify their behaviours is generally very difficult; therefore, it is important to determine the variables that can help to activate a range of health protective behaviours in order to reduce health risks.^{29 30} The periodic assessment of perceptions and behaviours related to mosquito-borne diseases may play an important role in the design and implementation of future prevention programmes by providing useful information about individuals and subgroups that are most likely to benefit from conventional health communication campaigns.³¹ However, as perceived exposure to the threat was found to be one of the most critical factors in promoting protective behaviours, future interventions should be targeted at altering these perceptions in order to ultimately promote significant behavioural changes among populations at risk of mosquito-borne diseases. Perhaps more interestingly, future research should examine the efficacy of interventions aimed at modifying the perceived exposure to the vector. Notably, a large distribution of inexpensive mosquito traps can provide to the population at risk of mosquito-borne diseases a more visible and thus

personal indication of threat and exposure to *Aedes* mosquitoes.³² Intervention research is now needed to determine whether these instruments may be effective in improving the quality and quantity of health protective behaviours practised by individuals residing in areas currently colonised by *Aedes* mosquitoes.

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