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Towards a quantitative assessment of public attitudes to transgenic mosquitoes: Questions based on a qualitative survey in Mali

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Abstract. Genetically modified (GM) mosquitoes have been proposed as part of an integrated strategy for the control of dengue fever, chikungunya and malaria. Public consultation is essential prior to field trials. Despite this, very little data is available on perspectives to GM mosquitoes in disease endemic countries (DECs). We conducted a qualitative survey of perspectives to GM mosquitoes for malaria control in Mali, West Africa between the months of October 2008 and June 2009. The results of this survey suggest that mosquitoes are seen as one of several causes of malaria, people possess a strong practical knowledge of heredity through selective breeding, and there is a general desire to see evidence that GM mosquitoes can reduce malaria prevalence without negative consequences before approving a release. This suggests a series of themes that can be investigated with a quantitative survey capable of representing a larger population. We propose a series of closed questions designed to measure the attitudes of people in Mali to GM mosquitoes for malaria control. Furthermore, we discuss how these questions may be adapted to measure attitudes in other DECs, for other diseases, and for other types of GM mosquitoes. Ultimately, any quantitative study should be preceded by qualitative interviews, careful design and extensive pilot work. We detail each of these steps as required for a quantitative assessment of public attitudes to GM mosquitoes.

Keywords: *Anopheles gambiae*; Attitude statements; Closed questions; Malaria; Population replacement; Questionnaire.

INTRODUCTION

Mosquito-borne diseases such as dengue fever, chikungunya and malaria continue to pose a major health problem through much of the world. The Roll Back Malaria Initiative, which aimed to halve malaria deaths by 2010, was barely even successful in reducing malaria deaths (Shiff, 2000; WHO, 2009) and treatments for dengue fever and chikungunya remain elusive. The failure or lack of existing methods to control these diseases has sparked interest in new approaches, some of which involve the use of genetically modified (GM) mosquitoes (Alphey *et al.*, 2002; Vasan, 2009). A variety of initiatives are currently underway to assess the biosafety, risk assessment and management, and ethical-social-cultural issues related to a release of GM mosquitoes for disease control (Beech *et al.* 2009; Mumford *et al.* 2009). Public consultation is essential prior to field trials of GM mosquitoes, particularly since mosquitoes are a vector of human disease and GM crops, at least, face strong skepticism in both developed and developing nations (Bohannon, 2002; Heller, 2003). Public consultation also results in information exchange with community members and contributes to how disease control strategies are implemented (Lavery *et al.*, 2008; El Zahabi-Bekdash and Lavery, 2010). Several surveys have been conducted on public attitudes to genetically modified organisms (GMOs) in Western nations (Macer *et al.*, 1997; Ng *et al.*, 2000; Gaskell *et al.*, 2003; Pew Initiative, 2006), and at least one has asked people their views towards GM mosquitoes (Masakazu and Macer, 2003); however, from disease endemic countries (DECs), very little data is available.

With this in mind, we conducted a qualitative survey of perspectives to GM mosquitoes for malaria control in Mali, West Africa (Marshall *et al.*, 2010). We chose Mali because it is the site of extensive research on the ecology of malaria vectors of relevance to GM mosquito projects (Tripet *et al.*, 2005), and because it is home to a range of ethnic groups, including the Bambara, Dogon, Peul, Songhai and Taureg. We focused on malaria, because it is the most devastating vector-borne disease in sub-Saharan Africa; and on population replacement, because it is generally considered to be a strategy that holds great promise for malaria control (Mar-

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shall and Taylor, 2009). In this strategy, a disease-refractory gene is linked to a gene drive system capable of spreading genes to fixation in one or many populations (James, 2005). Our survey consisted of semi-structured interviews that lasted on average 45 minutes. Semi-structured interviews consist of a set of open questions, for which response options are not provided; and allow new questions to be brought up as a result of interviewee responses.

Qualitative surveys are interesting in their own right – they allow for freedom and spontaneity in responses, and provide a deep understanding of how respondents think about a topic (Banaka, 1971). They are also time-consuming and costly, and only a small number of respondents can be interviewed. Quantitative surveys are, in a sense, complementary – they consist predominantly of closed questions, for which a limited set of response options are provided. They are faster and less costly, and therefore allow a large number of respondents to be interviewed. They are well-suited for group comparisons and representing large populations; however they lack the spontaneity and freedom of qualitative surveys (Oppenheim, 1992). A successful quantitative survey will always be preceded by a qualitative one. This allows researchers to identify general themes, formulate meaningful questions, and enumerate a near-complete range of responses to these questions among the population of interest.

In this paper, we build on our preliminary qualitative survey (Marshall *et al.*, 2010) and propose a series of closed questions designed to measure the attitudes of people in Mali to GM mosquitoes for malaria control (Appendix 1). Among these are questions on disease causation, heredity, pest-resistant GM corn and GM mosquitoes. We discuss how these questions may be adapted to measure attitudes in other DECs, for other diseases, and for other types of GM mosquitoes. Our survey is provided in both Demographic and Health Surveys (DHS) format (DHS, 2010; Appendix 1A) and written format (Appendix 1B). DHS format is most suitable for populations with significant levels of illiteracy because interviewers can read out questions themselves and fill out respondents' answers in a coded manner. Written format, on the other hand, is more efficient when administering a survey among a highly literate population. Any quantitative study should be preceded by qualitative interviews, careful design and extensive pilot work; however, it is hoped that the following case study will provide a useful starting point.

Sample Population The first step in any study is to identify the population of interest. This is the full set of individuals whose attitudes we wish to quantify. For illustrative purposes, let our population be all Malian citizens 18 years or older living in Mali at the time of the survey. It is not possible to interview our entire population, so we must choose a sample. A completely random sample in which every individual is randomly selected is not feasible in Mali because respondents must be visited individually, and sampling from the entire country would be prohibitively expensive. The best alternative is cluster sampling, which takes advantage of the geographical structure of a population and applies the principle of probability sampling to each stratum sequentially (Henry, 1990). Attitudes to biotechnology have been measured in this manner in Europe (Gaskell *et al.* 2003). In Mali, a random sample may be difficult to achieve at the community level because random sampling is inconsistent with the village hierarchy; however, a careful explanation of its purpose may make it acceptable to the chief and elders. The aim should be to achieve as random a sample as possible while being respectful of local cultural etiquette.

In other settings, different sampling methods may be appropriate. In countries where almost everybody owns a telephone or is accessible by mail, random sampling is possible. Attitudes to biotechnology have been measured in this manner by telephone in Japan, New Zealand and the United States (Macer *et al.*, 1997; Pew Initiative 2006) and by postal questionnaires in Japan (Ng *et al.*, 2000; Masakazu and Macer, 2003). An electoral register or telephone book may be used as a sampling frame. Another option, if random sampling doesn't work, is quota sampling. In this case, a sample can be artificially engineered to have the same demographic qualities as its parent population. In general, the demographic qualities of a sample and parent population can be compared to check for sampling errors.

Preliminary Studies Any quantitative survey should be preceded by a preliminary study to understand how people think about a topic. The aim of such a study is to identify themes and formulate meaningful questions and response options (Banaka, 1971). The best sample is a judgment sample, the goal of which is not to be representative, but to obtain as diverse a range of responses as possible. Depending on the population, a sample of 30 to 40 people may be sufficient; but as a general rule, sampling should continue until no new ideas are obtained.

Our qualitative survey in Mali satisfies these criteria (Marshall *et al.*, 2010). Our judgment sample consisted of 80 people – 30 of various ethnicity in the district of Bamako, 20 predominantly Bambara in ethnicity in the region of Koulikoro, ten predominantly Dogon in ethnicity in the district of Mopti, and 20 traditional and Western-trained health professionals in Bamako and the region of Mopti. In each group, men and women of a variety of ages and social statures were interviewed. The urban sample consisted of teachers, hairdressers, cooks, vendors and taxi drivers, among other professions. Ten of the Bambara villagers had past experience with entomological research. Topics of conversation included malaria, heredity, genetic alteration, and acceptable conditions for a release of GM corn and malaria-refractory GM mosquitoes. Participants answered questions in a common setting with friends and relatives surrounding them. A number of general themes were identified and are referred to in the section on questionnaire design.

If one wished to attempt a quantitative survey encompassing all of Mali, the same open questions should be posed to communities that are predominantly Peul, Songhai and

Taureg in ethnicity and among some of the other six regions of Mali. The same procedure should be followed prior to designing quantitative surveys in other countries. A judgment sample should be chosen and a series of topics prepared depending on national cultural beliefs, the disease of interest and the nature, scale and scope of the applicable GM mosquito strategy. In some countries, group interviews may be more efficient. These are guided discussions led by a trained moderator who ensures the participation of all group members (Krueger, 1988). A combination of individual and group interviews may also be used.

Questionnaire Design Once preliminary studies have been completed and general themes identified, the first step in the design of a questionnaire is to decide on its aims. The purpose of our study is primarily descriptive – to quantify the proportions of Malians that hold particular views toward GM mosquitoes – however a number of secondary hypotheses may also be investigated. For example, what are the social determinants of these attitudes? Are there differences between males and females, parents and non-parents, rural and urban dwellers, or decision-makers and ordinary citizens? Do attitudes correlate with age group, religious affiliation or level of education? Does a better understanding of malaria, heredity or genetic engineering lead to more positive attitudes to GM mosquitoes? Do attitudes to GM corn correlate with attitudes to GM mosquitoes, and which of these two are viewed more positively? Every question should have a clear reason for being included, and we should know how we are going to analyze the results.

We divide our questionnaire into four modules – i) factual questions on malaria, heredity and GMOs; ii) attitude questions on GM corn; iii) attitude questions on GM mosquitoes; and iv) demographic information. We chose this order based on the internal logic of the inquiry; however piloting will reveal the optimal question order. For a spoken interview, as appropriate in Malian villages, the interviewer has some leniency in reading factual questions in order to offer explanations or correct misunderstandings. Attitude questions, however, must be read precisely due to their strong dependence on question wording. We include a preliminary module on GM crops because our qualitative interviews found that this provides a gradual introduction to questions on GM mosquitoes. Pilot studies will reveal whether this is necessary for a quantitative format. In other countries, these questions may be left out or substituted for questions on other GM crops. Demographic questions are best placed towards the end of a questionnaire so that respondents know what they are linking their information to (Oppenheim, 1992). For these questions, interviewers may probe respondents to make sure they have obtained the correct information.

The first module – background questions on malaria, heredity and GMOs – is closely based on the results of our preliminary study (Marshall *et al.*, 2010). In this study, most respondents cited mosquitoes as one of the main causes of malaria; however other causes were often cited in conjunction with mosquitoes, such as cold weather, oily foods, sweet foods, poor hygiene, eggs and mangoes. Respondents cited God and sharing the same blood as the main reasons why offspring resemble their parents, while a few educated people made reference to genes. Most respondents were familiar with selective breeding, citing its use in raising more desirable pigs, goats, cereal crops and fruit trees. Several respondents were familiar with grafted mangoes, and a few were aware of GM corn and rice abroad and the GM cotton controversy in Burkina Faso. Despite this, some of the organisms perceived as GMOs were not genetically modified, such as chickens and horses. These results were used to form response options for questions 1-4 in the questionnaire (Appendix 1).

The module on GM corn is based on the results of our preliminary study, taking into account the structure of opinion and attitude-based questions (Oppenheim, 1992). In our preliminary study, participants were told to imagine that an organization from a foreign country gifts them a GM corn that is resistant to insect pests and therefore produces a higher yield, but could have unknown consequences. In rural areas, most respondents wanted to try the crop in an isolated part of their community before approving a large-scale release. A number of other requirements were mentioned, such as the ability to preserve excess yields, and educational classes on how to grow GM corn. In question 5 of the questionnaire, respondents are asked to rate these requirements on a scale of three (very important) to one (not important). Combining the responses of several people allows us to scale the relative importance of each requirement and to see whether different groups of people tend to have different sets of requirements. In question 6, respondents are asked whether they would accept to grow GM corn in their community if some of these requirements are satisfied. Affirmative responses to the first six options may be added to obtain a crude "acceptability score" for each respondent. Factor analysis may also be used to see whether certain requirements tend to be grouped together (Gorsuch, 1983).

A series of six attitude statements about GM corn are listed in question 7. Attitude statements are single sentences that express a belief or point of view and are phrased so that respondents can either agree or disagree with varying intensity (Oppenheim, 1992). By using a pool of statements, it is hoped that people can be placed on an attitudinal scale, in relative terms. Half of this pool should be positive and half should be negative, in order to compensate for the tendency of people to give affirmative responses. Before use, attitude statements should be placed in random order. We read through our preliminary interview transcripts and chose six statements – three favorable and three unfavorable – about GM corn. We then randomized these statements and provided a Likert response scale (Likert 1932). Here, favorable statements are scored from five (strongly agree) to one (strongly disagree) and unfavorable statements are scored from one (strongly agree) to five (strongly disagree). Total scores can serve as a crude measure of favorability towards GM corn. This can then be compared between groups of

respondents and analyzed to see how it relates to other variables.

The same opinion and attitude-based question structures are used in the module on GM mosquitoes. Participants in the preliminary study were told to imagine that a foreign organization claims to be able to provide them with GM mosquitoes that are able to reduce malaria prevalence, but could have unknown consequences. In rural areas, there was widespread desire to see evidence that GM mosquitoes can reduce malaria prevalence, preferably through the performance of a trial in another community. The main concerns were that the project may not work, and that GM mosquitoes may transmit other diseases. The Malian government was the most-trusted organization in rural areas, while United Nations organizations were most-trusted overall.

These results were used in the formulation of questions 8-12. In question 8, respondents are asked to rate their requirements for a release of GM mosquitoes in their community; and in question 11, they are asked whether they would accept a release if some of these requirements are satisfied. In question 9, a number of concerns about GM mosquitoes are listed and respondents are asked to rate these on a scale of three (very worried) to one (not worried). This allows us to scale the relative strength of each concern and to see whether different groups of people are worried about different things. In question 10, respondents are asked how much they trust a number of organizations for information on GM mosquitoes. Finally, in question 12, a series of six attitude statements – three favorable and three unfavorable – on GM mosquitoes are listed. Likert scaling (Likert, 1932) can be used to provide a crude measure of favorability towards GM mosquitoes. This can then be compared between groups and related to other variables.

At the end of the questionnaire, a series of questions are asked to group respondents into demographic categories. These questions were selected with our secondary hypotheses in mind – for example, do attitudes to GM mosquitoes correlate with age group, gender or parenthood? Hypothetically, mothers may support a release to protect their children against malaria, or oppose a release to protect their children from the risks of an unknown technology. Finally, the respondent is thanked for their participation.

Questionnaire design depends highly on the results of preliminary qualitative interviews. For surveys in other DECs, it would be necessary to conduct these before design begins; however, the internal logic of the inquiry should be relatively general. A general progression from factual questions on disease, heredity and GMOs, to opinion and attitude questions on GM mosquitoes, to demographic questions should remain appropriate.

Questionnaire Piloting Questionnaires do not emerge out of the design phase in their final form – they must be tested, improved and tested again, possibly several times over. This process is referred to as "piloting" (Oppenheim, 1992). Every aspect of the questionnaire should be piloted, from the wording of questions to the relative positions of answer categories in a list, from the interview setting to the amount of space allocated for a "please specify" option. Expert advice can help to point out aspects of a questionnaire that might be problematic, but this is no substitute for actual pilot work. Respondents in a pilot study should be drawn from the population of interest and should be as diverse as possible, essentially forming a judgment sample.

Several aspects of the questionnaire in Appendix 1 need to be piloted. The questionnaire is quite long, which leads us to ask whether respondent fatigue might be a problem. If it is, then which questions should be left out? Are there particular questions that respondents have trouble with? Is the module on GM corn informative and useful, or would the questionnaire be more efficient without it? Do respondents make regular use of "please specify" options, and if so, should more response options be included? Are response options to some questions redundant? We should also be aware of contextual effects relating to question order – for example, do earlier questions on GM mosquitoes affect levels of agreement with subsequent attitude statements? Other questions relate to the method of questionnaire delivery. Does the gender, ethnicity or nationality of the interviewer affect the responses? Do female respondents feel more comfortable with female interviewers? And should the interviewer read out the questions and response options every time, or should literate respondents be allowed to complete the questionnaire in writing? This consideration is important because spoken interviews are more susceptible to social desirability bias, which could disproportionately influence the responses of illiterate respondents. For this reason, surveys of populations with significant levels of illiteracy may be advised to be spoken to all respondents regardless of the individual's literacy and recorded in DHS format (DHS, 2010; Appendix 1A); however, surveys of populations with very high literacy may be more efficient in written form (Appendix 1B).

Some questions require particular attention. In question 4, for example, there are other ways that we could measure awareness of GMOs. Would it be appropriate to add the number of true GMOs ticked (grafted mangoes, GM corn, GM rice and GM cotton) and then subtract the number of false GMOs ticked (GM chickens, GM horses, GM millet and GM plantains), or would another question provide a more accurate measure? Would it be possible to ask a question on GMOs preceding the definition of "genetic modification" to distinguish between aided and spontaneous awareness? How do responses to questions on GM corn and GM mosquitoes differ when this definition is changed? The wording of the introductory sections to questions on GM corn and GM mosquitoes should also be experimented with. In question 10 on trusted organizations, should a distinction be made between Arabic and public schools? What about Malian institutions at the local, regional and national levels? In questions 5, 8, 9 and 10, are three-level rating scales optimal, or should more or less levels be provided? Are show cards helpful for these questions?

Finally, the attitude statements in questions 7 and 12 must go through several stages of testing and improve-

ment. Unfavorable statements can be spotted if respondents quibble, if there are many "don't know" responses, or if the statements are skipped or crossed out. An item analysis can be used to determine which statements are most informative. This is done by calculating the correlation coefficient of each statement with the total statement pool and keeping the statements with the highest correlation coefficients. It should be checked whether a training session on Likert scales leads to more informative responses. One possibility is to have respondents fill out a brief survey on how much they like the taste of different foods in order to familiarize them with the use of linear scales.

DISCUSSION

Public consultation is essential prior to field trials of GM mosquitoes; however very little data is available on views towards GM mosquitoes from DECs. In this paper, we have described the main steps required to conduct a quantitative survey on this technology in a DEC. These steps include: i) sampling from the population of interest; ii) conducting a preliminary qualitative study; iii) designing the questionnaire; and iv) piloting the questionnaire to enhance its efficacy. Following a recent qualitative survey in Mali (Marshall *et al*., 2010), we have focused on the population replacement strategy for malaria control (James, 2005), although the methodology can easily be adapted for other DECs, diseases and transgenic strategies. A GM strain ('OX513A') of *Aedes aegypti* is undergoing open field trials in Cayman Islands (Wilson, 2009), and Malaysia is likely to follow suit in 2010 (TropIKA, 2010; Lee *et al*., 2008), while several countries are considering the use of transgenic mosquitoes to suppress the local vector population (Vasan, 2009). Questions on disease causation and GM mosquitoes would need to be altered accordingly. For a country such as Singapore with 96% adult literacy (Department of Statistics Singapore, 2010), written surveys may be adequate; however, for countries where literacy is not as high, spoken surveys utilizing the DHS format (DHS, 2010) may be more appropriate. Quantitative surveys should be used when we want an accurate description of the views of a large population, or when we seek a rigorous understanding of the determinants of these views.

For researchers interested in conducting these surveys, a number of caveats should be kept in mind. First, initial views on GM mosquitoes are expected to be obtained before field trials have been conducted. Hypothetical questions are known to have poor predictive reliability (Oppenheim, 1992), which should be kept in mind when interpreting the results of early surveys. Second, describing GM mosquitoes requires several essential words, such as "gene" and "genetic engineering," which are difficult to explain in local dialects. It is therefore important to understand what respondents understand of these terms and the context in which they give their responses. Third, in many DECs, including Mali, there are a number of local dialects into which the questionnaire must be translated. Translation leads to subtle changes in meanings and overtones, which should be acknowledged because attitude statements can be very sensitive to these changes. This concern also applies to factual questions, since the word for malaria, for example, has different connotations depending on the respondent and their local dialect (Giles-Vernick, 2008).

Sources of bias should be identified and minimized, particularly for opinion and attitude-based questions. Some of the main types of bias in quantitative surveys are non-response bias, interviewer bias, social desirability bias and questionnaire bias. The number of non-respondents is less of a problem than the possibility that non-respondents hold distinct attitudes. If a chief who disapproves the survey is less likely to approve of GM mosquitoes, and this view is reflected in his community, this could lead to bias. This bias can be minimized by building rapport and providing incentives. Interviewer bias can be caused, for example, when interviewers become careless at some point during their repetitive task. This can be managed by providing encouragement, reducing shift lengths, and following up with quality control. Social desirability bias occurs when questions are loaded with prestige. For example, people like to appear knowledgeable so they may claim to have heard of more GMOs than they really have. One solution is to ask questions in an indirect way so that respondents don't know the purpose behind the question. Attempts can also be made to verify factual questions. Finally, questionnaire bias was dealt with during the discussion on questionnaire design.

We encourage work on the assessment of public attitudes to GM mosquitoes in all DECs where these strategies are being considered. The disease of interest, strategy of control and local cultural beliefs may all differ; but the underlying methodology will remain the same. In all cases, new preliminary studies will be required and piloting will be necessary, but we hope that the case study in Appendix 1 will provide a useful template for questionnaire design. The field of GM mosquito research has been dominated by biologists to date; however, social science is becoming increasingly relevant as the technology moves from laboratory to field. We hope that the recent studies described and cited by this paper will stimulate further work by trained sociologists and medical anthropologists on this important topic, and provide useful information on the level of public support for novel genetic strategies in the fight against dengue fever, chikungunya and malaria.

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