Researchers' perceptions of malaria eradication: findings from a mixed-methods analysis of a large online survey

Abstract

Quantifying an event's probability and time frame is essential for calculating its expected value. Uncertainty regarding feasibility makes it difficult for policymakers and public health practitioners to forecast the return on investment of malaria eradication. Since the opportunity cost of investments in eradication-specific interventions can be high - particularly in contexts with other urgent health priorities - understanding eradication's expected value is essential. In a large online survey of malaria researchers (n = 844), we query perceptions regarding the likelihood and time frame of eradication. We assess perceived years to and likelihood of eradication, and adjust for selection bias. We also carry out a qualitative analysis of the free-form comments provided by 61% of respondents. Our results show that researchers are skeptical of the feasibility of near-term malaria eradication, with most believing that eradication will not be achieved for 50 years or more.

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Research Highlights

- Employs a very large online survey of specialist researchers

- Assesses perceived time frame and likelihood of global malaria eradication among researchers

- Results suggest that most malaria researchers believe short-term global malaria eradication to be unlikely

- Identifies challenges pertaining to eradication through qualitative analysis

Keywords

Malaria; eradication; elimination; mixed methods; survey; crowdsourcing

Introduction

Background

Malaria is a parasitic disease transmitted among humans by mosquitoes. The *Plasmodium falciparum* species accounts for a large majority of the 200 million annual cases as well as the half million annual deaths worldwide (White et al., 2014) (WHO, 2016) (Ashley et al., 2018). Malaria "elimination", the "interruption of all local transmission of the infection in a country or region" (Tanner et al., 2015) is actively being pursued by dozens of countries around the world, leading to a renewed push for "eradication" ("the worldwide interruption of transmission") (Hopkins, 2013) (Rabinovich et al., 2017) (Lancet, 2011).

This is not the first time that eradication has been in the international spotlight. The scientific and public health communities have had eradication on their policy agenda since the World Health Organisation (WHO) established the Global Malaria Eradication Program in the 1950s (Nájera et al., 2011). In 1957, U.S. President Dwight Eisenhower told Congress that malaria could be expected to be eradicated in five years. Following the failure of the WHO's first attempt, the focus shifted away from global eradication towards local elimination and control strategies. In recent years, much of the discourse regarding malaria has shifted back to global eradication (Roberts and Enserink, 2007), with funders, researchers, and public health practitioners rallying to the cause (Tanner et al., 2015). The Bill and Melinda Gates Foundation has begun actively promoting eradication as feasible "within a generation" (Gates, 2014), and the WHO has set ambitious goals, stating the objective of eliminating malaria in 65 new endemic countries from 2015 through 2030 (Figure 1).
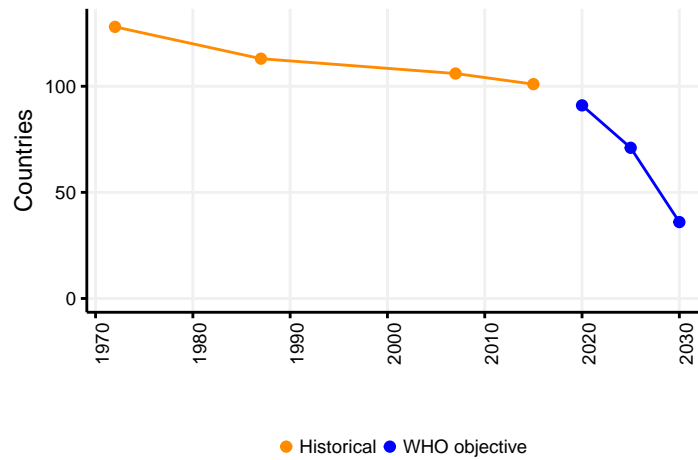

Figure 1: Countries with malaria: Observed and WHO objectives

Even in areas of high endemicity, advances in immunology, parasitology, modeling and vaccinology, along

with rapid economic development, have made eradication appear a more feasible goal, though not possible ⁴⁰ in the short term (Snow, 2015) (Eckhoff et al., 2014). From both administrative (Yamey, 2004) and scientific (Alonso et al., 2011) points of view, eradication has never before received so much attention.

Most of the current research on expert opinion regarding the feasibility of malaria eradication focuses on the *how* rather than the *if* and the *when* (Tanner et al., 2015). The participants in the Malaria Eradication Research Agenda (MalERA) process, in particular, have guided research goals and identified gaps in order ⁴⁵ for elmination to occur (Alonso et al., 2011) (Rabinovich et al., 2017). Though the MalERA authors firmly state that eradication is *not* feasible given the "current tools and state of knowledge", mentions to the time frame are vague ("within the lifetime of young scientists just embarking on their careers" (Alonso et al., 2011) and "in the longer term" (Rabinovich et al., 2017)) and no mention is made of the perception of the overall probability of achieving eradication. International programmes, such as the WHO Global Malaria ⁵⁰ Programme (GMP), have acknowledged the need "to take an official position on how and under what timeline malaria eradication could be achieved" ("Malaria policy advisory committee to the WHO," 2015). Clarity on timeline and likelihood of eradication could inform forecasting of disease transmission, and plays a crucial role in the economic analysis of the expected value of malaria eradication initiatives, ultimately informing health policy decisions. But achieving clarity is difficult, given the many complex and interacting variables ⁵⁵ which affect malaria transmission, research funding, and technological development. The question of *how* is complex enough, rendering questions of *if* and *when* even more difficult to answer.

Proponents of disease eradication point to the success of historical and current campaigns (smallpox and polio, respectively), and highlight the long term benefits in health and wealth to future generations (Barrett, 2013). One often cited figure is for smallpox eradication, in which the investment of each dollar led to a ⁶⁰ return of greater than 400 (Barrett, 2006); unlike smallpox (for which analysis was able to be retrospectively constructed based on observed costs and benefits), in the case of a prevalent disease, forecasting models have to be used in order to prospectively estimate the value of an investment. Additionally the estimated impact of malaria on economic indicators is heterogeneous, with singificant impact in areas of Sub-Saharan Africa - where the endemicity is high - and little to no impact in areas of low endemicity (Cutler et al., 2010) ⁶⁵ (Barofsky et al., 2015).

The general objective of eradication serves to inspire, rally funder support, motivate researchers, and focus the efforts of public health practitioners. The recently established Lancet Commission on malaria eradication states that "eradication is the only acceptable end goal" (while acknowledging that there exists "scepticism about [its] technical feasibility") (Chen et al., 2018). To the extent that malaria eradication (by definition) ⁷⁰ has never occurred, the parameters needed for a ex-post cost-benefit analysis are unknown. Nonetheless,

prospectively estimating eradication's return on investment is crucial to deciding when and how to pursue the goal, especially in light of the high direct and opportunity costs of eradication-specific interventions. One approach to economic evaluation is the use of mathematical and stochastic models. These have been applied to diseases which are closer to eradication than malaria, since the uncertainty around model input parameters is less, requiring fewer cascading assumptions in order to present possible comparative scenarios. For example, Kastner et al. were able to describe 4 relatively realistic pathways to Lympathic Filariasis eradication, as well as the pre-requisite role and magnitude of certain interventions (Kastner et al., 2015). A similar modeling framework was then used to estimate the cost of eradication (Kastner et al., 2017). A recent modeling analysis on onchocerciasis eradication, based on a disease transmission model, showed that the costs of elimination (relative to staying in "control mode") in Africa would be far lower even in the short term, thanks to the improvements it would lead to in both treatment times and prevented surveillance costs. Given the relative proximity of eradication, and the narrow geographic scope, the authors were also able to estimate the timeline to eradication (Kim et al., 2017).

This level of detail and specificity in the economic evaluation landscape of malaria eradication, unfortunately, is not possible (or at least not commonly undertaken), given its high prevalence and epidemiological complexity. In fact, there are no mathematical models (to the authors' knowledge) estimating the likelihood and time frame of eradication, or its derivative cost-benefit ratio. Globally, where mathematical modeling has been used for the purposes of forecasting the future epidemiology of malaria, the methods have generally been aimed at optimizing elimination methods (Slater et al., 2015), determining whether a strategy is scalable (Brady et al., 2017), guiding funding and drug development (Patouillard et al., 2017) (Slater et al., 2017), or comparing a range of hypothetical morbidity scenarios (Winskill et al., 2017), rather than assessing the likelihood of or time until the occurrence of those scenarios.

To the extent that (i) estimating eradication's likelihood and timeframe is essential to forecasting the cost-benefit ratio of eradication interventions, and (ii) mathematical models generally do not venture into areas of such high uncertainty, alternative methods are needed. Just as the stock market aggregates perceptions to provide a fairly accurate assessment of something as complex as a company's value, aggregating perceptions may be a useful tool for tackling the complexity of malaria eradication. Many studies have shown value in expert elicitation as a means to reduce uncertainty and inform decision making (Morgan, 2014). As Francis Galton demonstrated in his famous study in which he showed that the crowds' aggregated estimates of cow's weight formed a quasi-normal distribution centered around the true weight (Wallis, 2014) (Galton, 1907), averaging the perceptions of many can be more accurate than taking the opinion of any single expert, since the biases of diverse viewpoints can be complementary and symbiotic. Measuring consensus and discord

among disease-specific researchers from a variety of disciplines can serve as a barometer of (informed) opinion, both guiding resources and identifying areas of concern (Keenan et al., 2013).   105

The optimal assignment of resources for malaria eradication campaigns hinges on the expected value of those campaigns, the latter being a direct function of the discount rate applied to future benefits and the probability of "success" (ie, eradication). Holding constant factors such as the cost of eradication and the benefits of achieving it, the return on investment of malaria eradication initiatives is a function of eradication's timeframe (assuming a > 0 discount rate) and probability (assuming a $< 100\%$ likelihood of success). Given   110 this, estimating these parameters is crucial to evaluating if and when attempts at eradication should be undertaken.

Though the case-specific marginal cost of eradication can be expected to be high (relative to a simple control approach), successful eradication would mean massive recurring savings in the long-term (Barrett, 2013). However, to the extent that the case-specific marginal cost of prevention in an eradication campaign is high,   115 estimating the likelihood of success is fundamental to the correct distribution of resources, particularly in low-income environments.

We propose that the aggregation of malaria researchers' perceptions regarding the time frame and likelihood of eradication forms a probability distribution which can be used to estimate the expected value of eradication-specific investments. The objective of this study is to gauge (expert) opinion about, estimate the likelihood of,   120 and quantify the potential time frame to malaria eradication through a systematic online survey of malaria research professionals from a wide array of academic disciplines. In doing so, we aim to help guide the optimal distribution of health resources by informing estimations of the expected value of malaria eradication efforts.

Methods

Our study population included all first authors (with available email addresses) returned in a PubMed   125 search for the term "malaria" from January 1, 2010 through December 20, 2016. We used PubMed because it was the most comprehensive publication database for malaria-related research, and also exposed enough metadata about articles and authors so as to allow for relevant analysis. Personalized emails addressing the author by name and mentioning the relevant paper were sent to each of the 7680 authors during the period from December 20, 2016 through January 2, 2017. Researchers were invited to participate by clicking a link   130 to the survey form. The survey was simple, consisting of only name, email, and four content-related fields along with a "general comments" section. The survey was administered and data were collected through

Google Drive. The original survey is viewable at https://goo.gl/forms/IroAEooDuJ6KM5Ho2.

Content-related survey fields consisted of:

1. Area of expertise.

2. Perceived probability (%) of malaria eradication in 10, 20, 30, 40, and 50 years.

3. Free choice perceived number of years until malaria eradication.

The survey was intentionally as short as possible, so as to appeal to time-pressed participants. However, supplementary data on researchers is of value for the assessing of selection bias and determinants of perception. Accordingly, we estimated the likelihood of a participant being of one of two genders (male or female) based on first name. In order to do this, we used data from the North Atlantic Population Project, and U.S. government (Mullen, 2015). We also calculated the total number of citations which each author had received, as well as the total number of articles authored. We binned total citations into three categories: 0-5 (junior-level researchers, PhD students, etc.); 6-99 (most professional academics); and >99 (the most prolific researchers). The searching and retrieval of information pertaining to articles and citations from the PubMed database was carried out using the RISmed package (Kovalchik, 2015). Information retrieved about authors was used to de-bias paramaters in an ordinary least squares regression, analyzing the association between number of publications and perceived years to eradication.

Survey results were first analyzed descriptively. Following Francis Galton's example, we naively take the average of all responses as the likely point estimate for event probabilities, and the totality of the responses to each numeric question as the likely confidence interval of those likelihoods and time frames.

Quantitative analysis was carried out in R language (R Core Team, 2015). All analysis code, as well as the code used for the identification and contacting of participants, is publicly available at https://github.com/ joebrew/malaria_survey.

Qualitative analysis of free text comments was carried out using thematic content analysis, with inductive open coding (Markey et al., 2014). Participants were invited to provide "any general comments on the timeline and likelihood of global eradication". Thematic content analysis (Vaismoradi et al., 2016) was employed to code responses following the 6-phase approach laid out by Braun and Clarke (Braun and Clarke, 2006). The approach was inductive, used open-coding to identify latent themes, and underwent several iterations in which codes were modified, discarded and created. Using the RQDA software to assist in data management and theme coding (Huang, 2017), four subject themes were identified. Comments were additionally coded as either descriptive (comments pertaining to the "problem" of malaria eradication) or presciptive (pertaining to potential "solutions" for eradicating malaria). Finally, free-text comments were

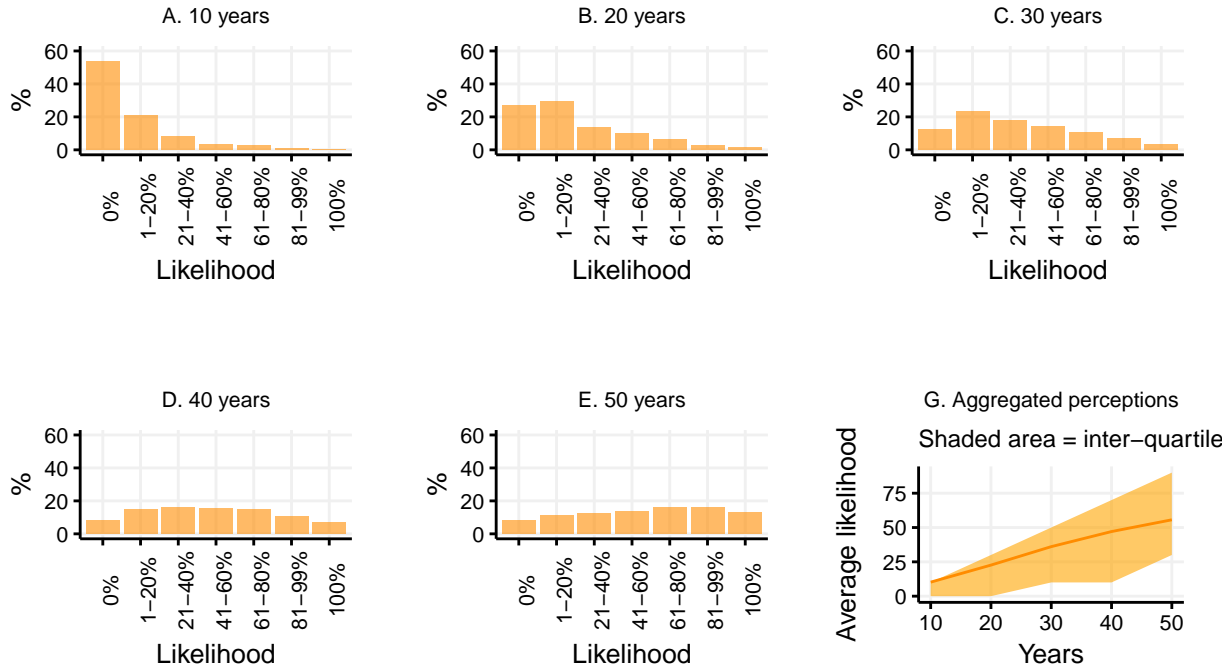scored for overall sentiment polarity (Rinker, 2017).

Results

Figure 2: Perceptions of likelihood of eradication

A total of 884 researchers participated in the survey from the 7918 invitations sent (participation rate of 11.16%). Areas of expertise were non-exclusive and self-described, with participants having the option to choose from up to 3 of 10 checkboxes, or to write in one or more "other" areas of expertise.* 604 (68.3%) participants declared three or fewer areas of expertise.

Participants had a total of 219 unique (self-described) areas of expertise. The five most popular were Epidemiology (357), Information Technology (344), Parasitology (319), Biology (277), Clinical medicine (207).

Quantitative results

Most participants saw eradication as extremely unlikely in the next 10-30 years, but increasingly likely thereafter. Figure 2 shows the distribution of year-specific likelihood perceptions (panels A-E), as well as

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*Response categories were Anthropology, Biochemistry, Bioinformatics, Biology, Chemistry, Clinical medicine, Drug discovery, Ecology, Economics, Entomology, Epidemiology, Geography, GIS, History, Immunology, Infectious disease, IT, Malaria, Medical entomology, Medicinal chemistry, Microbiology, Parasitology, Pharmacology, Pharmacy, Political science, Public health, Statistics, Vector biology, Vector control, and Virology.

an illustration of how both likelihood and uncertainty grow over time (panel F). At the 40 year mark, the distribution of perceived likelihood of eradication appears "normal", and by 50 years it is slightly shifted to the right (ie, consensus is towards eradication more probable than not).

In regards to responses to perceived years until eradication, 59 (0.7%) were either blank or uninteligible, whereas 825 participants responded. Among respondants, 616 (74.7 %) estimated that it would be 50 or more years until eradication.

Respondents were qualitatively different from non-respondents. Importantly, the average number of total author-specific citations was 40.91 among respondents, but 92.92 among non-respondents. This suggests a tendency for more senior or impactful researchers not to respond. When examining the number of average citations per article, the difference between respondents remained: 4.75 among respondents, and 8.95 among non-respondents, highlighting the greater impact of non-respondents relative to respondents. Males responded at a greater rate (12.18) than females (9.14).

Table 1: Response rate by author characteristics

Variable	Characteristic	Responded	Invited	Response rate
Sex	Female	209	2287	9.14 %
	Male	358	2939	12.18 %
	NA	317	2692	11.78 %
Citations	0-5	621	3299	18.82 %
	6-99	179	3270	5.47 %
	> 99	84	1349	6.23 %

Selection bias is not of concern in the case of differential response if the groups for whom there are differences are not different in terms of the outcome variable. This was the case for sex: males responded at a significantly greater rate than females ($p < 0.001$), but were not statistically significantly different in regards to pessimism/optimism (ie, time frame or likelihood of eradication). In the case of researcher impact (as measured by the total number of citations), selection bias plays an important role: being highly-cited was associated both with eradication "pessimism" as well as likelihood of non-response. In other words, our pool of respondents was less highly-cited than our pool of invitees, and among respondents, those who were highly-cited tended to be more pessimistic.

In order to de-bias sample selection, we employed Heckman's two-step correction method as well as simple

binomial logistic regression model to estimate the likelihood of response as a function of sex and (binned) number of citations. To the extent that the two methods presented nearly identical value, we present here the results of the latter. Having estimated the odds of survey participation, we then used the inverse of the selection model's predictions as weights in a simple linear model to adjust our estimates. We run a separate weighted model to estimate the likelihood of eradication at 10, 20, 30, 40, and 50 years. Figure 3 shows both the aggregated perceived likelihood of eradication over time before and after adjusting for sample selection based on binned number of publications. Our adjusted and unadjusted estimates coincide in the long-term, but diverge sharply in the near-term; adjustment suggests that had our pool of respondents been more representative, the average perceived likelihood of near-term eradcation would have been much lower.
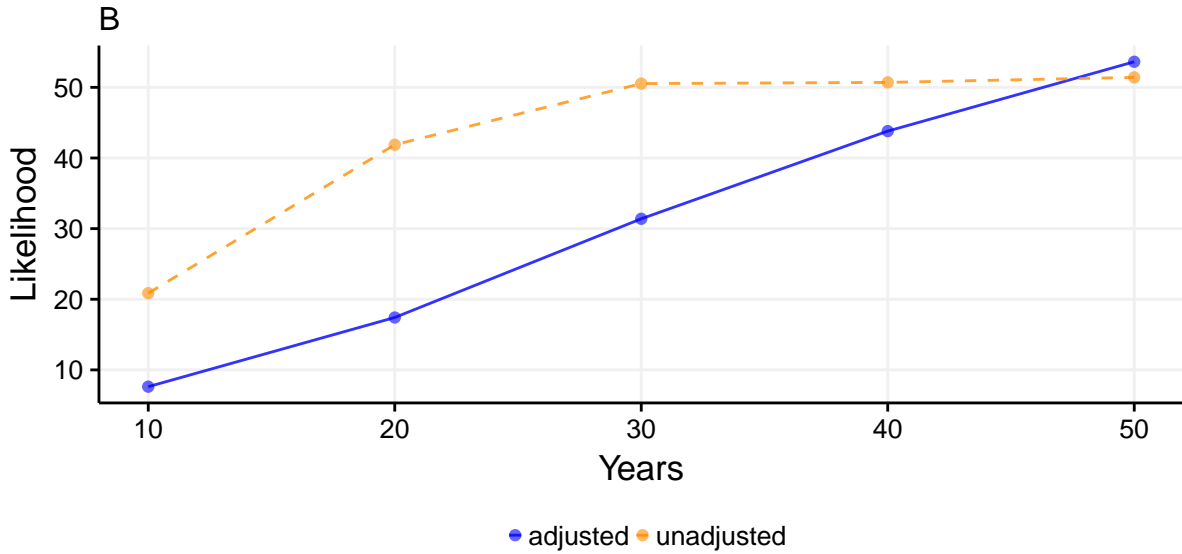

Figure 3: Aggregated perceived likelihood of eradication over time, adjusted for sample selection and unadjusted.

Qualitative analysis of comments

Of the 884 who responded to the survey, 540 (61.09%) provided a comment. Relative to non-commenters, commenters were more optimistic on average, but also more polarized in opinion. The three subject themes identified through iterative, open coding were:

1. *Solutions*: Comments pertaining to the innovations required to achieve eradication, priorities, and the desirability of certain approaches.

2. *Systemic challenges*: comments pertaining to political, social, environmental or logistical issues related to eradication.

3. *Complexity*: comments which focus on the multi-dimensional components of eradication.

Comments were also classified as descriptive or prescriptive. A majority (59.26%) were descriptive. Descriptive commenters were more pessimistic (in regards to perceived years until eradication) than prescriptive commenters, though this difference did not reach the level of statistical significance ($p = 0.21$ using Pearson's Chi-squared test). Descriptive comments also received sentiment polarity scores which were more negative than prescriptive comments, although again this difference did not reach the level of statistical significance ($p = 0.18$).

In regards to **solutions**, comments largely pertained to the necessity of further technological advances and innovations. One participant wrote that "currently available technology can't achieve [eradication], even if delivered optimally"; another argued that eradication could not be achieved without a "game-changing innovation", whereas multiple others referred to the need for "transformative" technologies:

> We can't achieve eradication with our current tools. We'd need new medicines, a better vaccine, and maybe other vector control tools.

Many noted the need to "overcome the challenge of drug resistance". More than 10% of commenters noted the need for an effective vaccine. Genetic engineering was mentioned by several commenters as a promising means to achieve eradication quickly. Most comments coded as "solutions" were prescriptive in nature, often suggesting the nature of the needed innovation, with a heavy slant towards pharmaceutical options and vaccination.

Systemic challenges to malaria eradication were noted by the majority of commenters. Comments in this category can be divided into four sub-themes: (i) lack of coordination, (ii) lack of good surveillance and health services delivery, (iii) lack of political will and (iv) poverty. In direct contrast to the previous comments, many emphasized that "we already have the tools to achieve eradication" and that the only piece lacking was "robust health systems". Many commenters noted problems of coordination, as illustrated in the below quote.

> It will be very difficult to eradicate malaria... not because we don't have the technologies, which we already have... the problem is politics. Malaria doesn't stop in (sic) borders of a country and it would take a joint effort of a lot of political leaders to get programs in place to fight malaria. Unfortunately I don't see this happening anytime soon.

Others echoed the sentiment, with many comments focusing on the need of strong surveillance and treatment delivery systems. Many commenters focused on other reasons for stagnating progress, such as "weak or failing

health systems...due to political unwillingness or conflict". Many noted that malaria is a "disease of poverty", with "social injustice" as the root cause. Some made the sequential argument that "eradication of poverty" must preceed disease eradication. Along the same lines, one commenter wrote:

> Eradication requires a full systems-wide approach, not a disease-specific approach. The eradication of smallpox was a triumph of management, not medicine or technology.

Another noted that the survey "left off the list the most important factor - economic development". Many echoed the sentiment, stating that "with no economic development, you cannot have eradication" and that poverty is the "cause" of malaria. Comments coded as "systemic" tended to be descriptive and more pessimistic than others.

Complexity was a relatively rare category (<20% of all comments), those whose comments were coded as the "complexity" category were more pessimistic than average in regards to the timeline and likelihood of eradication. Many commenters highlighted the inherent challenges in the epidemiology of malaria, such as the changing dynamics of malaria transmission, the resilience of the parasite and vector, climate change, and the inability to aim interventions accurately with an "ever-moving target". The potential for adaptation was highlighted in reference both to the mosquito as well as the parasite itself. Many comments addressed the fact that the conversation on eradication is largely taking place within the public health community, whereas the causes of malaria endemicity are largely orthogonal to public health interventions, "going beyond the health sector". Several commenters pointed out the multitude of prerequisite conditions for eradication to even be considered feasible:

> To my mind, this question is highly dependent on background context, e.g. global political and economic dynamics, as well as international conflict. Complete global eradication is an extremely singular goal that requires a vast array of necessary conditions - if any of these fail, eradication will not be achieved.

Many commenters thought that the terms "eradication" and "malaria" were so complex and nebulous that the public health practitioners should avoid the them all together, so as to not repeat the mistakes of the WHO GMP in the 1950s. For example, some highlighted that talking about "malaria" as one disease misses the mark, since the different species of parasite and contexts in which they live make elimination in each area very distinct from other areas. One commenter wrote that eradication is a "postwar" idea that developed from the "abandonment of a broad sociopolitical understanding of the causes of disease, and the emphasis on technological solutions." Many stated that global malaria eradication was simply not possible, and two argued that it may not be desirable or ethical. One stated that the concept was "absurd" and that "I'm not

even sure why people talk about it". Another questioned the utility of discussing "eradication" as a concept: 275

> Eradication is a different objective than elimination. Elimination means that the disease is not endemic but could reappear even in a country like Norway if infrastructure breaks down. Elimination may be possible in poor endemic countries, following socioeconomic development. Eradication means that the parasite disapears from the planet, which is not realistic...

Comments questioning the utility of eradication as a concept or goal tended to be skeptical of its feasibility. 280 Largely, they were prescriptive, advocating for a re-framing of the conversation so that the focus was not on an "arbitrary" goal like eradication, but rather on scaling up control and making region-specific progress.

Discussion

Approximately three-quarters of respondents believe that malaria will not be eradicated in the next 50 years. When adjusted for selection bias, the perceived likelihood of eradication in 50 years remains similarly low, 285 but estimates for shorter-term eradication are even lower.

Eradication of a disease is a "high stakes game", exposed to multiple competing - and at times contradictory - incentives from multiple stakeholders (Barrett, 2007). Understanding these incentives, and the factors which can alter them, is vital to understanding how eradication can succeed, and where it is most vulnerable to failure. The return on investment of eradication-specific interventions is affected by the fact that most 290 researchers agree that eradication will take a long time to achieve. This, in turn, reduces the expected value of future benefits, disincentivizing eradication-specific investment. Given this, it is important to quantify the positive externalities of "failed" eradication; in areas of high endemicity, even if the goal of elimination is not achieved, the reduction in burden or disease can still make interventions cost-effective.

However, areas of high malaria endemicity are often also those with high competing health costs. When 295 estimating the return on investment of malaria elimination initiatives, not only must one take into account the potential benefits (even in the case of failure), but also the opportunity costs (even in the case of success). After all, elimination is not a binary success/failure proposition - an initiative should be judged both on its epidemiological circumstances (Churcher et al., 2014) as well as the counterfactual improvements in health which could have been achieved via other paths. 300

Limitations

This paper has several limitations. Conceptually, academic researchers are specialists - their narrow, field-specific view of eradication's feasibility is of arguable reliability, given that they may be unfamiliar with the operational, cultural and "real-world" challenges of malaria eradication. Though crowds have been found to be more "wise" than individuals in many cases, the application of an approach similar to the "wisdom of crowds" is not suitable to all classes of problems (Mannes et al., 2014). Crowds can be susceptible to social biases (Lorenz et al., 2011) (although this survey's anonimity largely protects against this issue), and other biases may come in to play, especially given that our study was of a crowd of "specialists", rather than the population as a whole.

Four potential biases are worth mentioning specifically. (1) "Conjunction fallacy" suggests that the general goal of eradication may seem less likely than the sum of the goals of country-specific elimination. (2) A (reverse) variant of the "hot hand fallacy", in which researchers may mistakenly base their assessment of current chances of eradication on previous failures. (3) Parkinson's law of triviality suggests that researchers may disproportionately see the challenges of their own research (antimalarial drug resistance, etc.) as larger or more relevant to the global eradication campaign than they really are. (4) Finally, and ironically, "optimism bias" may play a perverse role in researchers' responses; though eradication is certainly a goal desired by all, one could argue that malaria research specialists subconciously realize that they actually stand to lose out profesionally in the case of eradication.

As with Keenan et al's survey of experts regarding the feasibility of eradication of neglected tropical diseases, our survey detected relatively high levels of eradication skepticism and did not delve into whether researchers had clinical or operational experience, nor did it assess opinions of program workers, nor did it explore complexities pertaining to different types of or forms of existence of malaria. Though our sample size was over twice Keenan's, this was largely due to having contacted more authors, as our response rate was only one fourth as large (Keenan et al., 2013).

This study included the first authors of indexed journals. Though certainly a group with important knowledge related to malaria, this misses malaria control program employees, health agency workers, and other stakeholders. Their experiences and viewpoints may be different from those of academics, and arguably more relevant. Our de-biasing method accounts for different response rates of "senior" vs. "junior" researchers, but does not take into account the fact that first authors are generally more junior than senior authors (ie, the pool from which we sampled may have been biased itself). To the extent that in our results suggests that those with less experience (as represented through publications) tended to be more "optimistic" regard-

ing eradication, it is reasonable to assume that the restriction of first authors may have lead to an overly optimistic sample, making the results of the survey even more striking.

Conclusion

The findings of our survey show researchers expressing hesitance about the likelihood of eradication and   335
suggesting a long time frame until it is achieved. The causes for scepticism are diverse, but common themes were the need for innovation, systemic challenges, and the complexity of the disease and its transmission.

The implication of these results are two-fold: (1) that those working or investing in eradication-specific campaigns, as well as those modeling these campaigns' hypothetical cost-effectiveness, should factor in researchers' perceived low likelihood and long time frame when calculating those campaigns' expected value;   340
(2) that champions of near-term eradication may need to make a more compelling case to malaria researchers of eradication's feasibility, in order to better focus and inspire the latter.

We have strived to present the results of our study without insinuation regarding the "true" feasibility and timeframe of eradication, as only time will tell whether the collective "wisdom" of researchers was worth adhering to or not. The actual cost-effectiveness of eradication interventions is not only a function   345
of eradication's success, but also of a number of other factors which are only knowable retrospectively. This study's primary contribution is the provision of a snapshot of perceptions of malaria researchers, whose opinions may be of value not only to other researchers, but also to the malaria and public health communities at large.

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