Silent pessimists - researchers' perceptions of malaria eradication and implications for health spending

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Abstract

Quantifying an event's probability and time frame is essential for calculating its expected value. In the case of global malaria eradication, uncertainty regarding feasibility makes it difficult for policymakers and public health practitioners to make fully informed decisions. The opportunity cost of investments in eradication-specific interventions can be high, particularly in contexts with other urgent health priorities. In a systematic survey of malaria researchers, we query perceptions regarding the likelihood and time frame of eradication, as well as the perceived chief areas needed for improvement in order for eradication to be achieved. We assess pessimism/optimism (via the proxy of years-to-eradication), broken down by area of expertise. Our results, which suggest a disconnect between public institutional discourse and private opinion, serve as a barometer of professional perspectives, and serve to highlight areas where attention is most needed for eradication to be achieved.

Introduction

Background

The scientific and public health communities have had eradication on their long-term agenda since the WHO established the Global Malaria Eradication Program in the 1950s (Nájera, González-Silva, and Alonso 2011). Following the failure of the WHO's first attempt, the focus shifted away from global eradication and 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 leadership of the World Health Organization (WHO) has supported this goal. 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, even if not possible 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, nor appeared so within grasp.

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

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Agenda (MalERA) process, in particular, have positioned themselves as thought leaders in the field of guiding research goals and identifying gaps in order for elmination to occur (Alonso et al. 2011). 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") and no mention is made of the perception of the probability of achieving eradication.

The problem

The WHO Global Malaria Programme (GMP) has acknowledged that it "needs to take an official position on how and under what timeline malaria eradication could be achieved" ("Malaria Policy Advisory Committee to the WHO: Conclusions and Recommendations of Seventh Biannual Meeting" 2015). Such a position could inform policy, and plays a crucial role in the economic analysis of the expected value of malaria control inteventions.

However, no such position has been taken. This omission is likely intentional, and certainly understadable, given that MalERA's and the WHO GMP's goals are to guide research and technology in the direction of eradication, and not necessarily address the larger and much more subjective questions of *if* and *when*.

But just how close are we to eradication? The objective serves to inspire, rally funder support, motivate researchers, and focus the efforts of public health practitioners. Proponents of disease eradication point to the success of historical and current campaigns (smallpox and polio, respectively), and highlight the benefits in health and wealth to future generations. However, the opportunity cost of investments in eradication-specific interventions can be high. And the "expected value" of an investment in a binary scenario (eradication or not) is a function of the probability of the scenario's occurrence, and the temporal lag of that occurrence. Therefore, knowing the likelihood and time frame of eradication of malaria is essential for making sound investments in health.

The need for the wisdom of crowds

Patients often ask for a "second opinion", a request which implicitly recognizes two important truths: (1) that an expert can sometimes be wrong and (2) that the combined opinions of multiple people can better approximate the truth than the opinion of only one. As Sir Francis Galton demonstrated in his famous ox-weight experiment (Wallis 2014), averaging the opinions 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.

Additionally, one could argue that assessing likelihood and time frame of eradication is too important, subjective and complex a task to be left to only powerful individuals or small panels and committees. It requires the "wisdom of crowds." 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).

Rationale

A great deal of previous research already covers the the cost per case prevented (E. Sicuri et al. 2011, Silumbe et al. (2015), Bôtto-Menezes et al. (2016), Ilunga-Ilunga et al. (2014), Dalaba et al. (2015)). Likewise, a literature exists which could serve as a model for quantifying the location-specific opportunity costs associated with funneling funds towards malaria eradication (Stuckey et al. 2014, White et al. (2011), Korenromp (2012)). The correct discount rate for estimating the value of future lives saved is more of a philosphical question than an economic one. This leaves only the probability and time-frame to eradication, questions which have been addressed anecdotally, but never answered quantitatively.

The economic case for striving to achieve malaria eradication is compelling (Barofsky, Anekwe, and Chase 2015). 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, estimating the likelihood of success is fundamental to the correct distribution of resources, particularly in low-income environments.

In other words, the rational assignment of resources for malaria eradication campaigns hinges on the expected value of those campaigns. We can describe this relationship formulaically below:

$$I_T = P(x)\ \frac{B(m)}{m}(1+\delta)^{-T} \text{ - } P(x)\ \frac{C(m)}{m}\ (1+\delta)^{-T}$$

- I is the return on investment
- m is the number of malaria cases
- x is the cut-off for a "successful campaign", ie the portion of eradication achieved
- T is the time-frame (to both costs and benefits)
- P is the probability of success
- B is the benefit of preventing malaria
- C is the cost of preventing malaria
- δ is the discount rate and opportunity cost

(I) is the return on investment at time (T) (the "end of malaria"). We take the present value of the benefits multiplied by the probability of succcess minus the value of costs times the probability of success, and multiplyboth terms by the discount rate traised to T to arrive at the return on investment.

Objective

The objective of this study is simple: to help guide the optimal distribution of health resources by gauging (expert) opinion about, estimating the likelihood of, and quantifying the time frame to malaria eradication through a systematic survey of malaria research professionals from a wide array of academic disciplines.

Methods

Ethics

This research followed the principles of the Declaration of Helsinki. The study's protocol was approved by the Scientific Committee of the Barcelona Institute for Global Health.

Participants

Our study population included all first authors (with available email addresses) returned in a PubMed search for the term "malaria" from January 1, 2010 through December 20, 2016. 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 to the survey form. Participants were informed directly on the survey form of the study's purpose, that responses were not guarnteed to be anonymous, and where to find further details on the study.

Survey

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.
4. Ranking of the WHO's "health system building blocks" in regards to attention needed in order to achieve eradication.

Data generation

The survey was intentionally as short as possible, so as to appeal to time-pressed participants. However, supplementary data on researchers' demographics is of value. Accordingly, we estimated the likelihood of a participant being of one of two genders (male or female) based on first name, and the likelihood of a participant being of one of five ethnicities (White, Black, Hispanic, Asian, Other) based on the provided last name.

Analysis

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.

Ordinary least squares regression was employed to estimate the effect of area of expertise on the eradication pessimism-optimism (through the proxy of perceived years to eradication).

Content analysis of free text comments was carried out using frequency analyses. Comments were categorized and coded according to (more details needed here).

All 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.

The searching and retrieval of information from the PubMed database was carried out using the RISmed package (Kovalchik 2015). Qualitative analysis relied on the RQDA package (citation needed here).

The estimation of gender and ethnicity likelihoods for each participant relied on Mullen's implementation of US Social Security Administration names' analysis (Mullen 2015) and Khanna et al's bayesian prediction algorithm for the estimation of racial categories (Khanna, Imai, and Jin 2017).

De-biasing of sample selection was carried out using Heckman's 2 step approach (citation needed), as implemented by Toomet (Toomet and Henningsen 2008).

Results

A total of 7919 researchers participated in the survey.

Sample selection and de-biasing of results

This section is unfinished. Below are regression outputs for both OLS and Heckman's 2 step model. I will update this soon.

```
Call:
lm(formula = years ~ sentiment + area_epidemiology + area_anthropology,
    data = df[df$responded, ])

Residuals:
    Min      1Q  Median      3Q     Max
-45.735   0.214   4.581   4.981   8.376

Coefficients:
                      Estimate Std. Error t value            Pr(>|t|)
(Intercept)            45.0193     0.4467 100.791 <0.0000000000000002 ***
sentiment              -0.3162     0.1727  -1.831              0.0675 .
area_epidemiologyTRUE   0.3996     0.6834   0.585              0.5589
area_anthropologyTRUE   2.0347     2.1851   0.931              0.3520
```

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 9.646 on 821 degrees of freedom
  (59 observations deleted due to missingness)
Multiple R-squared:  0.005405,	Adjusted R-squared:  0.001771 
F-statistic: 1.487 on 3 and 821 DF,  p-value: 0.2166

--------------------------------------------
Tobit 2 model (sample selection model)
2-step Heckman / heckit estimation
5197 observations (4659 censored and 538 observed)
13 free parameters (df = 5185)
Probit selection equation:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)        -1.6524        Inf       0        1
gendermale          0.1730        Inf       0        1
ethnicityblack      0.2148        Inf       0        1
ethnicityhispanic   0.5511        Inf       0        1
ethnicityother      0.0000        Inf       0        1
ethnicitywhite      0.3003        Inf       0        1
Outcome equation:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)            43.4920         NA      NA       NA
sentiment              -0.1394         NA      NA       NA
area_epidemiologyTRUE  -0.0908         NA      NA       NA
area_anthropologyTRUE   1.7344         NA      NA       NA
Multiple R-Squared:0.0019,	Adjusted R-Squared:-0.0056
   Error terms:
              Estimate Std. Error t value Pr(>|t|)
invMillsRatio   1.2001         NA      NA       NA
sigma           9.2245         NA      NA       NA
rho             0.1301         NA      NA       NA
--------------------------------------------
```

Expertise profile

Areas of expertise were non-exclusive and self-described, with participants having the option to choose from up to 3 of 10 checkboxes[1], or to write in one or more "other" areas of expertise. 1 participants (0%) declared only one area of expertise, with 604 (7.6%) declaring three or fewer.

Participants had a total of 222 unique (self-described) areas of expertise, of which 32 areas of expertise had 5 or more participants.

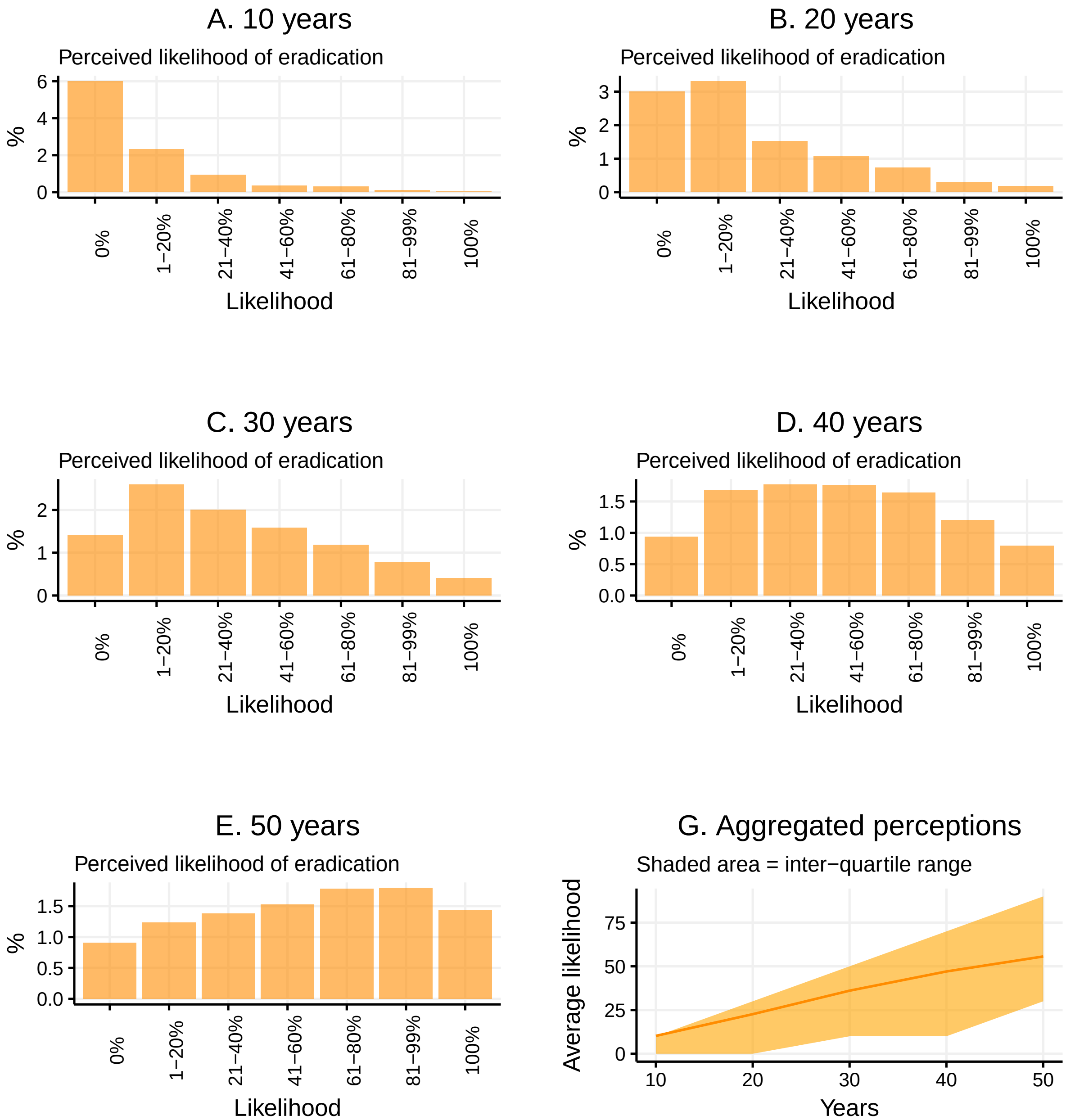
Area	Researchers
Epidemiology	357
It	344
Parasitology	319
Biology	277
Clinical medicine	207

[1]Checkbox categories were anthropology, biology, clinical medicine, economics, epidemiology, immunology, parasitology, political science, statistics, and virology.

Area	Researchers
Immunology	103
Statistics	86
Entomology	58
Economics	34
Public health	29
Chemistry	27
Chemistry	27
Virology	23
Anthropology	20
Political science	14
Medical entomology	12
Pharmacology	9
Vector control	9
Ecology	8
Malaria	8
Infectious disease	7
Medicinal chemistry	7
History	6
Biochemistry	5
Bioinformatics	5
Drug discovery	5
Drug discovery	5
Geography	5
Gis	5
Microbiology	5
Pharmacy	5
Vector biology	5

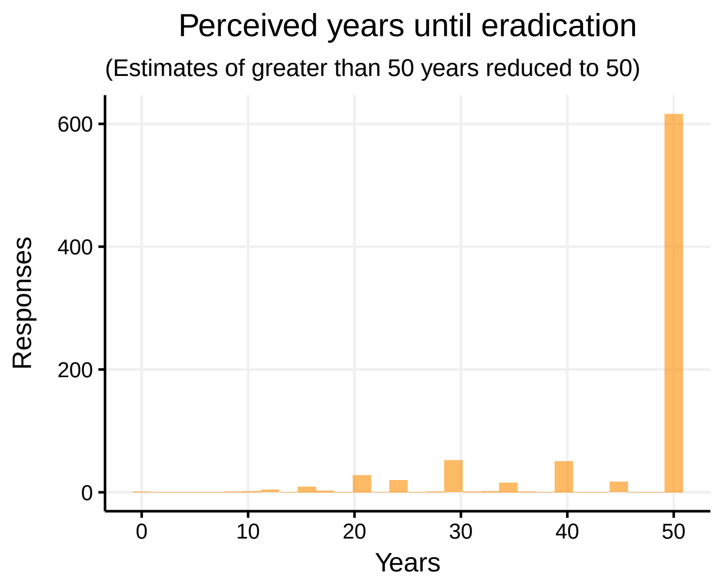
Likelihood of eradication

Participants were asked to quantify (as a percentage) the likelihood of eradication in the next 10, 20, 30, 40, and 50 years. Most participants saw eradication as extremely unlikely in the next 10-30 years, but increasingly likely thereafter. The following figure shows the distribution of year-specific likelihood perceptions (panels A-E), as well as an illustration of how both likelihood and uncertainty grow over time (panel F).



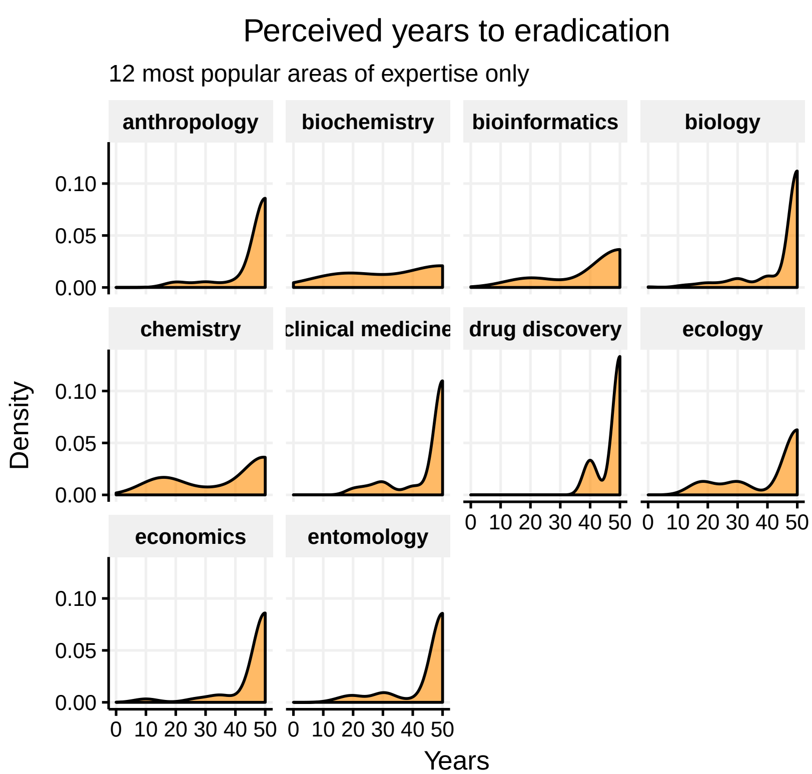
Time frame to eradication

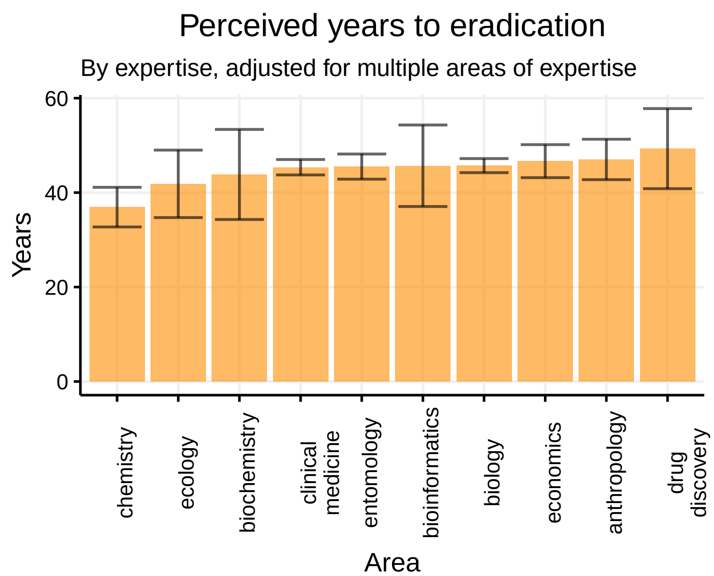
Participants were asked to provide the number of years they believe it will take until eradication can be achieved. 7094 (89.6%) were either blank or uninteligible, whereas 825 participants responded. Among respondants, 616 (74.7 %) estimated that it would be 50 or more years until eradication. The below histogram shows the distribution of responses, appended at 50.



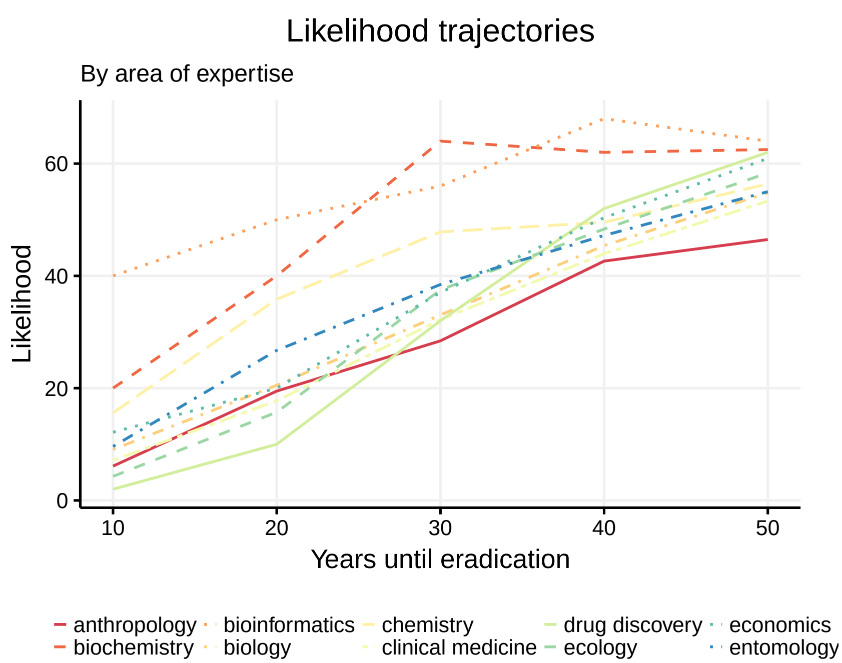
Difference in perceptions by expertise

Participants were heterogenous in their perceptions, with all of the 5 pre-determined cut-offs containing the whole range of likelihoods (0-100%), and the free-form time frame responses suggesting that eradication would be achieved in as little as 0 to as many as "never". Heterogeneity can be partly explained by area of expertise, as evidenced by significant differences in the perceived years to eradication by area of expertise.



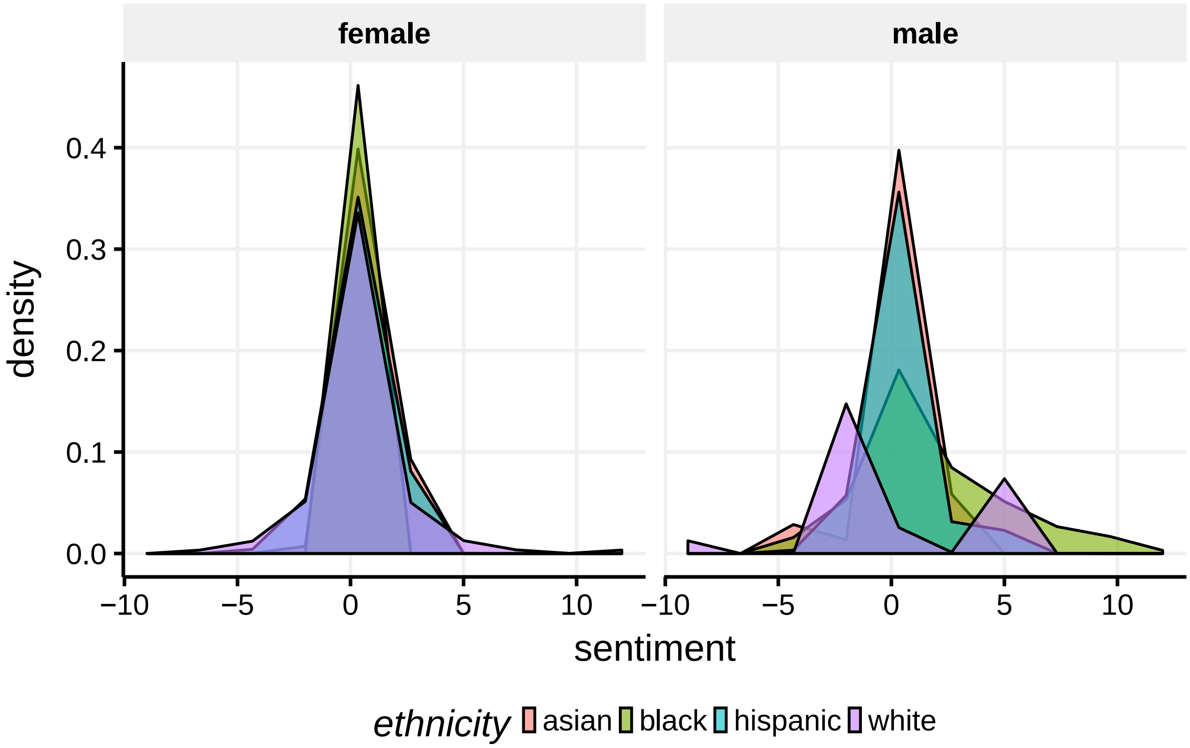


Heterogeneity by area of expertise is also apparent in perceived likelihood of eradication over the pre-defined five time-points, as seen below.



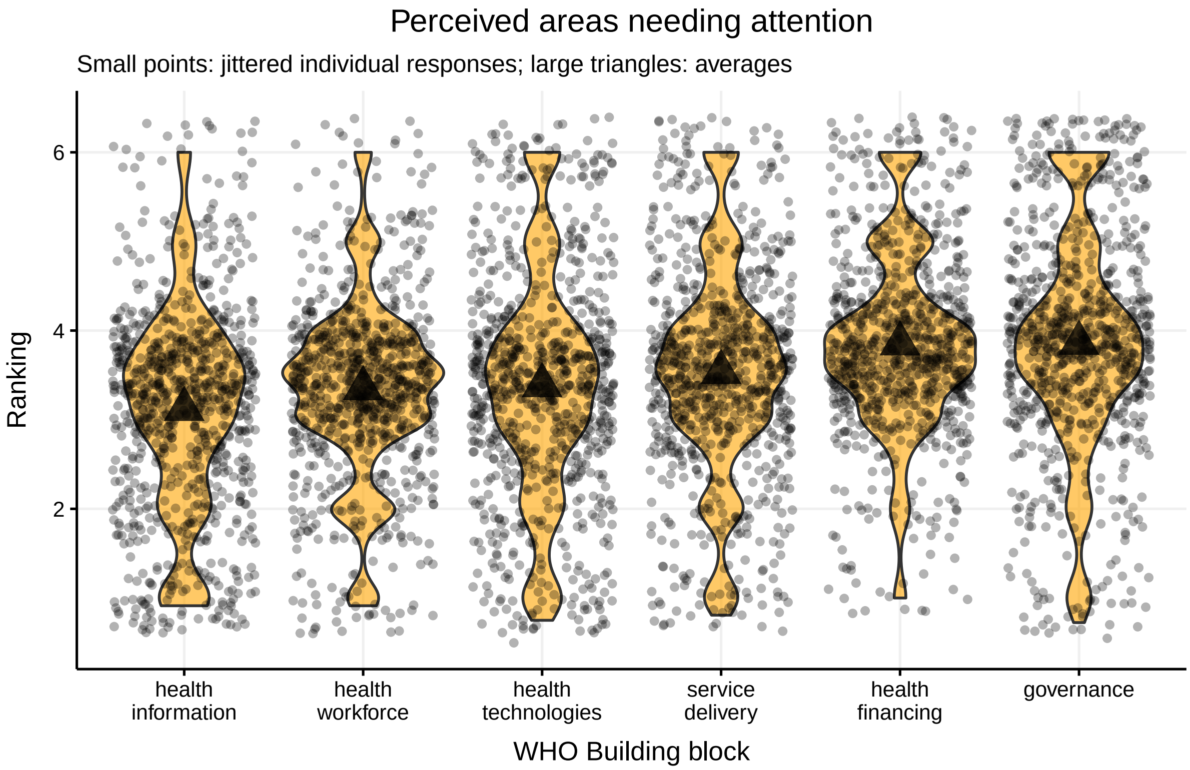
Sentiment analysis of free-text commentary

This section is unfinished. Below is the distribution of "sentiment" among the responses (0 is neutral, below 0 is negative, above 0 is positive), but this is preliminary. The chart is colored by ethnicity, and faceted by gender.



Health system building blocks

Finally, researchers were asked to rank the WHO's 6 health system building blocks as needing the most to least attention (6-1 scale) in order for eradication to be achieved. Disagreement was high, as evidenced by the variance in responses in the below point and violin chart. However, the general tendency was that governance was recognized as the most important area requiring attention, with health information thought to be the area least requiring attention.



Discussion

Collective pessimism

Our study reveals a striking gap between the public discourse on malaria eradication, and those views held (largely privately) by malaria researchers. Approximately three-quarters of respondents believe that malaria will not be eradicated in the next 50 years; in other words, assuming our pool of respondents is of typical post-PhD age, most believe they will not live to see eradication.

If we take the pooled opinions of researchers, as revealed through this survey, as the best approximation of truth available, then the disconnect between public discourse on malaria eradication and private opinion is troubling. It suggests that the goals set by the Bill and Melinda Gates Foundation (eradication "within a generation") and the WHO GMP (eradication "within the lifetime of young scientists just embarking on their careers") are unrealistic at best, and misleading at worst. This has important implications for spending in public health, since the attention and resources of funders, researchers and government agencies are directed to those areas where a result is expected.

On the other hand, there are many reasons to be skeptical that the combined "wisdom of crowds" of malaria researchers is a reliable indicator of truth. First, academic researchers are specialists - their narrow, field-specific view of eradication's feasibility is arguably less reliable than the more "global" views of the WHO, or Bill Gates. Second, a number of biases may come in to play in this study.

Among these biases, 4 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.

Whether the collective "wisdom" of researchers is worth adhering to or not is arguable. That said, to the extent that researchers' private opinions differ so greatly from those of global health leaders is itself a noteworthy result. If leaders' high levels of optimism are well-placed, this suggests that researchers are unduly pessimistic, and efforts should be made to convince them that eradication is more feasible than they realize. If, on the other hand, collective wisdom is a better forecasting agent than the proclamations and objectives of global health leaders, then it is important to recognize the sad truth that we are likely further from eradication than we would like to be. In this case, though the discourse on eradication can be motivating and inspiring, resources should be directed in a manner that reflects an intended outcome's likelihood of occurrence.

Building blocks to eradication

It is noteworthy that there was so much discord among researchers in regards to which WHO building blocks required the most attention in order for eradication to be achieved. All six possible categories received votes for both the lowest and highest levels of importance, as well as every level in between. And the difference between "health information" (the building block deemed as least important) and "governance" (the most important) was less than 0.5 on a 1-6 scale.

This discord suggests that the path to implementing strategies for eradication is not clear, at least from the perspective of this study's participants. This could mean that further work is needed in order to prioritize which areas require the most investment and attention in order for eradication to occur. On the other hand, one could interpret this result as reflecting the fact that previous work on priorities (ie, MalERA) has not been fully accessed or understood by the larger malaria research community.

Areas of expertise

It is noteworthy that among the most "optimistic" experts were from the field of bioinformatics. This could be explained by the fact that, relative to other more "traditional" areas of science, informatics regularly sees paradigm shifts, and changes in technology and breakthroughs occur at a more rapid rate. That said, the high degree of optimism among chemists would seem to contradict this hypothesis. At any rate... (more details will go here).

Limitations

In addition to the biases mentioned above, this study has many limitations. First, though results are not disclosed at the individual level, this survey was not entirely anonymous, suggesting that social desirability bias may have influenced responses, and that selection bias likely meant our pool of participants were substantially different from those who choose not to participate.

Second, we made no distinguishment between quality of research, years of experience, academic achievements, geographical area, etc. Our inclusion criteria were simple and rudimentary, allowing us to access many diverse viewpoints, but (perhaps inappropriately) weighting all viewpoints as equal.

Third, this study included the corresponding 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 are most likely vastly different from those of academecians.

Implications

Our survey attempted to quantify the likelihood of and time frame to malaria eradication by gauging the collective opinion of malaria researchers. Our results suggest that eradication is unlikely in the short and medium terms, and that there exists a great deal of disagreement among researchers in regards to which areas require the most attention in order for eradication to occur. The implication of these results are three-fold: (1) that those working or investing in eradication-specific campaigns should factor in the low likelihood and long time frame when calculating those campaigns' expected value; (2) that champions of near-term eradication need to make a more compelling case to malaria researchers of eradication's feasibility, in order to better focus and inspire the latter;

and (3) that discord among malaria researchers as to which areas need the most attention in order for eradication to occur suggests a need for open discussion and concensus-making, so that resources and focus are directed appropriately.

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