

Quantifying travel behavior for infectious disease research: a comparison of data from surveys and mobile phones

Authors

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Supplementary Information

Travel survey derived travel results

Table S1: Responses from the travel surveys to the question ‘Have they made any overnight trips in the last 3 months?’.

	% (N)
Yes	7.4 (195)
No	90.1 (2388)
Don’t know	0 (2)
Missing	0.6 (15)

Table S2: The top five locations where travelers spent most of their time while traveling.

	% (N)
Homa Bay	6 (12)
Kisumu	15 (29)
Migori	13 (26)
Nairobi	9 (18)
Nyando	31 (60)

Table S3: The primary reason for traveling.

	% (N)
Work	8 (16)
Buying/Selling Market	4 (7)
School/University	2 (3)
Visit Family/Friends	54 (105)
Other	32 (63)
Missing	0 (1)

Table S4: The provided answers for ‘Other’ reasons for traveling.

	% (N)
Medical	11 (7)
Worship	8 (5)
Business	0 (0)
Funeral	73 (46)
Meeting	5 (3)
Music	1.5 (1)
Shopping	1.5 (1)

Table S5: Responses form both surveys to the question, ‘When did they come back (from an overnight trip)?’.

	% (N)
< 2 weeks	25 (48)
2-4 weeks	30 (59)
> 4 weeks	45 (88)

Table S6: The number of trips per traveler to other districts outside of the home location (from the survey data).

	% (N)
1	64 (126)
2	13 (26)
3 to 7	11 (21)
8 to 14	6 (12)
15 to 60	6 (11)

Table S7: The top five locations where adult men and women spent most of their time while traveling.

	Male: % (N)	Female: % (N)
Homa Bay	3 (2)	8 (7)
Kisumu	16 (11)	14 (12)
Migori	13 (9)	16 (13)
Nairobi	16 (11)	7 (6)
Nyando	27 (19)	33 (27)

Mobile phone data derived travel results

Table S8: The duration of travel by mobile phone subscribers including travel lasting at least 1 day.

Duration of Trip (days)	Number of Trips by MP Subscribers	Percentage
1	37038	46.46
2	15092	18.93
3	7446	9.34
4	4278	5.37
5	2940	3.69
6	2377	2.98
7	1634	2.05
8	1129	1.42
9	900	1.13
10	667	0.84
11	570	0.71
12	471	0.59
13	381	0.48
14	386	0.48
15	320	0.40
16	245	0.31
17	265	0.33
18	211	0.26
19	185	0.23
20	186	0.23
21	151	0.19
22	130	0.16
23	140	0.18
24	153	0.19
25	120	0.15
26	125	0.16
27	93	0.12
28	92	0.12
29	85	0.11
30	197	0.25
31	88	0.11
32	71	0.09
33	66	0.08
34	39	0.05
35	36	0.05
36	36	0.05

37	43	0.05
38	47	0.06
39	39	0.05
40	27	0.03
41	45	0.06
42	35	0.04
43	43	0.05
44	35	0.04
45	62	0.08
46	68	0.09
47	39	0.05
48	34	0.04
49	25	0.03
50	18	0.02
51	17	0.02
52	18	0.02
53	30	0.04
54	28	0.04
55	21	0.03
56	17	0.02
57	17	0.02
58	23	0.03
59	15	0.02
60	21	0.03
61	93	0.12
62	13	0.02
63	17	0.02
64	10	0.01
65	10	0.01
66	11	0.01
67	12	0.02
68	15	0.02
69	15	0.02
70	21	0.03
71	14	0.02
72	11	0.01
73	12	0.02
74	14	0.02
75	14	0.02
76	25	0.03
77	26	0.03

78	11	0.01
79	13	0.02
80	12	0.02
81	12	0.02
82	12	0.02
83	14	0.02
84	6	0.01
85	7	0.01
86	6	0.01
87	9	0.01
88	6	0.01
89	5	0.01
90	4	0.01
91	7	0.01
>=92	161	0.20

Comparison between the data sets

To compare between the mobile phone and survey data, we estimated the number of subscribers using the survey data and calculated a range for the number of trips taken by these subscribers.

Table S9: The number of trips to other districts from the mobile phone (MP) and survey data.

District	MP Data Number of Trips	Survey Data Number of Trips
Baringo	7	
Bomet	108	
Bondo	162	4
Bungoma	65	
Buret	200	1
Busia	55	
Butere/Mumias	30	1
Embu	3	
Garissa	1	
Gucha	2,114	1
Homa Bay	8,062	12
Isiolo	2	
Kajiado	68	
Kakamega	96	

Keiyo	8	
Kericho	888	6
Kiambu	323	
Kilifi	13	
Kirinyaga	5	
Kisumu	3,434	29
Kitui	4	
Koibatek	9	
Kuria	103	
Kwale	1	
Laikipia	16	
Lamu	2	
Lugari	1	
Machakos	32	
Makueni	8	
Malindi	4	
Mandera	2	
Maragua	2	
Marakwet	-	
Marsabit	1	
Mbeere	-	
Meru Central	12	
Meru North	3	
Meru South	4	
Migori	2,970	26
Mombasa	59	5
Moyale	-	
Mt. Elgon	3	
Muranga	-	
Mwingi	-	
Nairobi	2,091	18
Nakuru	71	
Nandi	175	
Narok	120	1
Nyamira	49,613	1
Nyandara	25	
Nyando	12,269	60
Nyeri	17	
Samburu	2	

Siaya	164	5
Suba	233	5
Taita Taveta	5	
Tana River	1	
Teso	14	
Tharaka	1	
Thika	72	
Trans Mara	78	
Trans Nzoia	79	
Turkana	3	
Uasin Gishu	203	2
Vihiga	113	
Wajir	1	
West Pokot	7	
Central Prov.	-	2
Coast Prov.	-	1
Rift Valley Prov.	-	1
Western Prov.	-	1
Outside Kenya		5
Missing		1
Kisii		7

Estimating the number of subscribers from the survey data

Table S10: The population estimates and mobile phone ownership in the study sites. We estimated a range for the number of mobile phone subscribers in the study sites using the number of individuals, households, percentage of households with a mobile phone, and an estimated number of subscribers per household.

Number of individuals in districts (census)	798,912
Number of individuals in study area	19,744
Number of HH in study area	776
Perc of HH w mobile phone (mp)	0.47
Number of individuals per HH	3.70
Subscribers per HH - min	1
Subscriber per HH - max	4
Number of total subscribers - min	2,508
Number of total subscribers - max	11,485

Table S11: The estimated number of subscribers who have traveled using the survey data. We calculated a range for the estimated number of subscribers who have traveled. We used the percentage of individuals who have traveled (8%) as well as the demographic (adult males who live in a HH with a MP) with the highest percentage (16%) of travelers. According to the survey data, between ~900-1,800 estimated subscribers have traveled.

Percentage of individuals who have travel	0.08
Number of estimated subscribers who have traveled - min	200.64
Number of estimated subscribers who have traveled - max	918.78
Percentage of adults within HH w MP who have travel	0.15
Number of estimated subscribers who have traveled - min	376.20
Number of estimated subscribers who have traveled - max	1,722.72
Percentage of adult males within HH w MP who have travel	0.16
Number of estimated subscribers who have traveled - min	401.28
Number of estimated subscribers who have traveled - max	1,837.57

Malaria exchange

In the main text, we used a malaria-travel metric, Pfm , that is based on travel between individuals from the study sites (i) to all other districts (j) is defined as:

$$Pfm_{i,j} = \frac{PfPR_i * PfPR_j}{PfPR_i + PfPR_j} m_{i,j}$$

where $m_{i,j}$ is the population weighted travel to other districts. The symmetric nature of this measure does not capture the directionality of travel and is used to describe the travel mediated malaria exchange between locations. Previously, in ¹⁵ this measure was developed to describe communities of countries that were clustered together based on travel and malaria endemicity. We are describing the exchange of malaria parasites using a less refined metric due to the coarseness of the travel survey data³⁰. In particular, the previously developed metrics require travel data on 1) the number of trips, 2) the destination of travel, and 3) the duration of the journey. From the questions asked during the travel survey, only a general understanding of two of these requirements is possible. Most importantly, respondents did not provide estimates on the durations of their journeys. Without an estimate on the duration of travel, we could not use our previously method and instead choose a simpler travel related malaria exchange metric that has been previously published.

Table S12: The malaria-travel metric. We calculated a malaria-travel metric using the parasite rate data for each district and travel from Kisii and Rachuonyo to all destination districts. The malaria-travel metric is shown (1e-4) for each destination district.

Destination	Survey,	Survey,	Mobile Phone,	Mobile Phone,
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District	Kisii	Rachuonyo	Kisii	Rachuonyo
Baringo	0.00	0.00	0.02	0.02
Bomet	0.00	0.00	0.41	0.22
Bondo	0.00	4.83	0.81	12.18
Bungoma	0.00	0.00	1.49	2.21
Buret	0.00	0.15	1.15	0.98
Busia	0.00	0.00	0.81	3.71
Butere/Mumias	0.57	0.00	0.43	1.77
Embu	0.00	0.00	0.01	0.00
Garissa	0.00	0.00	0.00	0.01
Gucha	0.00	0.45	48.83	7.17
Homa Bay	0.00	13.47	77.52	496.95
Isiolo	0.00	0.00	0.01	0.01
Kajiado	0.00	0.00	0.18	0.05
Kakamega	0.00	0.00	1.85	2.74
Keiyo	0.00	0.00	0.01	0.04
Kericho	0.00	1.55	2.83	12.94
Kiambu	0.00	0.00	0.24	0.08
Kilifi	0.00	0.00	0.22	0.08
Kirinyaga	0.00	0.00	0.00	0.00
Kisumu	0.55	31.48	31.31	214.87
Kitui	0.00	0.00	0.02	0.02
Koibatek	0.00	0.00	0.03	0.01
Kuria	0.00	0.00	2.80	1.69
Kwale	0.00	0.00	0.03	0.00
Laikipia	0.00	0.00	0.01	0.02
Lamu	0.00	0.00	0.02	0.00
Lugari	0.00	0.00	0.00	0.04
Machakos	0.00	0.00	0.05	0.04
Makueni	0.00	0.00	0.03	0.00
Malindi	0.00	0.00	0.03	0.04
Mandera	0.00	0.00	0.02	0.00
Maragua	0.00	0.00	0.00	0.00
Marakwet	0.00	0.00	0.00	0.00
Marsabit	0.00	0.00	0.02	0.00
Mbeere	0.00	0.00	0.00	0.00
Meru Central	0.00	0.00	0.04	0.02
Meru North	0.00	0.00	0.01	0.02
Meru South	0.00	0.00	0.03	0.00
Migori	0.00	26.40	82.25	76.19
Mombasa	0.00	1.39	0.65	0.45

Moyale	0.00	0.00	0.00	0.00
Mt. Elgon	0.00	0.00	0.00	0.15
Muranga	0.00	0.00	0.00	0.00
Mwingi	0.00	0.00	0.00	0.00
Nairobi	0.07	0.27	1.93	1.13
Nakuru	0.00	0.00	0.12	0.05
Nandi	0.00	0.00	1.03	2.67
Narok	0.04	0.00	0.30	0.10
Nyamira	0.00	0.35	279.79	887.51
Nyandarua	0.00	0.00	0.02	0.00
Nyando	0.00	51.15	4.90	716.73
Nyeri	0.00	0.00	0.00	0.00
Samburu	0.00	0.00	0.00	0.00
Siaya	0.00	6.44	1.91	11.19
Suba	0.00	6.05	2.43	15.30
Taita Taveta	0.00	0.00	0.07	0.02
Tana River	0.00	0.00	0.01	0.00
Teso	0.00	0.00	0.50	0.37
Tharaka	0.00	0.00	0.00	0.01
Thika	0.00	0.00	0.08	0.03
Trans Mara	0.00	0.00	1.21	0.31
Trans Nzoia	0.00	0.00	1.42	0.70
Turkana	0.00	0.00	0.03	0.06
Uasin Gishu	0.13	0.15	1.29	0.85
Vihiga	0.00	0.00	0.98	5.57
Wajir	0.00	0.00	0.01	0.00
West Pokot	0.00	0.00	0.03	0.09
TOTAL	1.36	144.14	552.22	2477.43