

1 **Micro-epidemiology and spatial heterogeneity of *P. vivax* parasitaemia in** 2 **riverine communities of the Peruvian Amazon: A multilevel analysis**

3
4 Carrasco-Escobar Gabriel^{1,2,0}, Gamboa Dionicia^{1,3,4}, Castro Marcia C.⁵, Bangdiwala Shrikant I.^{6,7},
5 Rodriguez Hugo⁸, Contreras-Mancilla Juan¹, Alava Freddy⁸, Speybroeck Niko⁹, Lescano Andres
6 G.², Vinetz Joseph M.^{3,4,10}, Rosas-Aguirre Angel^{3,9,*}, Llanos-Cuentas Alejandro^{2,3,0,*}

- 7
8 1. Laboratorio ICEMR-Amazonia, Laboratorios de Investigación y Desarrollo, Facultad de Ciencias y
9 Filosofía, Universidad Peruana Cayetano Heredia, Lima 31, Peru;
10 2. Facultad de Salud Pública y Administración, Universidad Peruana Cayetano Heredia, Lima 31, Perú;
11 3. Instituto de Medicina Tropical "Alexander von Humboldt", Universidad Peruana Cayetano Heredia, Lima
12 31, Perú;
13 4. Departamento de Ciencias Celulares y Moleculares, Facultad de Ciencias y Filosofía, Universidad
14 Peruana Cayetano Heredia, Lima 31, Peru;
15 5. Department of Global Health and Population, Harvard T.H. Chan School of Public Health, 665 Huntington
16 Avenue, Building I, Room 1113, Boston, MA, USA;
17 6. Department of Biostatistics, University of North Carolina Gillings School of Global Public Health, Chapel
18 Hill, NC, USA;
19 7. Department of Health Research Methods, Evidence and Impact, McMaster University, Hamilton, ON,
20 Canada;
21 8. Región de Salud Loreto, Iquitos, Loreto 160, Peru;
22 9. Research Institute of Health and Society (IRSS), Université Catholique de Louvain, Brussels 1200,
23 Belgium;
24 10. Division of Infectious Diseases, Department of Medicine, University of California San Diego School of
25 Medicine, La Jolla, California, USA;

30 ⁰ **Corresponding Authors**

31 Alejandro Llanos-Cuentas

32 E-mail: alejandro.llanos.c@upch.pe

34 Gabriel Carrasco-Escobar

35 E-mail: Gabriel.carrasco@upch.pe

37 *** These authors contributed equally to this work.**

38 **Key Words:** Malaria, *Plasmodium vivax*, molecular epidemiology, sub-microscopic infections,
39 spatial analysis, multilevel model, high-risk clusters, human mobility, human population movement.

40 **SUPPLEMENTARY TABLES AND FIGURES**

41 **Supplementary Table S1.** Common destinations of travel records self-reported by inhabitants from
 42 Gamitanacocha (GC), Libertad (LI), Primero de Enero (PE), and Urco Miraño (UM).

43

Communities	GC	LI	PE	UM	Total
Individuals	N=18	N=33	N=20	N=25	N=96
Travels	n=36 (%)	n=84 (%)	n=59 (%)	n=82 (%)	n=261 (%)
Destinations:					
Iquitos	2 (5.56)	7 (8.33)	5 (8.47)	47 (57.32)	61 (23.37)
Mazan	3 (8.33)	13 (15.48)	1 (1.69)	12 (14.63)	29 (11.11)
Quebradas ^	10 (27.78)	60 (71.43)	38 (64.41)		108 (41.38)
Yurimaguas		1 (1.19)		4 (4.88)	5 (1.92)
Maucallacta	18 (50.00)				18 (6.90)
Paucarillo	2 (5.56)				2 (0.77)
Pebas	1 (2.78)				1 (0.38)
14 de Julio		2 (2.38)			2 (0.77)
Inganoyata		1 (1.19)			1 (0.38)
Santa Cruz			14 (23.73)		14 (5.36)
Orosa River			1 (1.69)		1 (0.38)
Sucusari				2 (2.44)	2 (0.77)
Indiana				3 (3.66)	3 (1.15)
Palmeras				6 (7.32)	6 (2.30)
Pampa Hermoza				4 (4.88)	4 (1.53)
Santa Teresa				4 (4.88)	4 (1.53)

^ Reported by parker

44 **Supplementary Table S2.** Random effects of multi-community null and multivariate model for
45 *P. vivax* parasitaemia.

	Var	95% CI
Null Model		
Household	0.0151	(0.00005 - 4.46881)
Individual	0	(-)
Multi-community Model		
Household	0	(-)
Individual	0	(-)

Mixed-effect Poisson Models with only random intercepts; Var= Variance estimate by mixed-effects model.

46

47

48 **Supplementary Table S3.** Random effects of community-specific null and multivariate models for *P. vivax* parasitaemia.

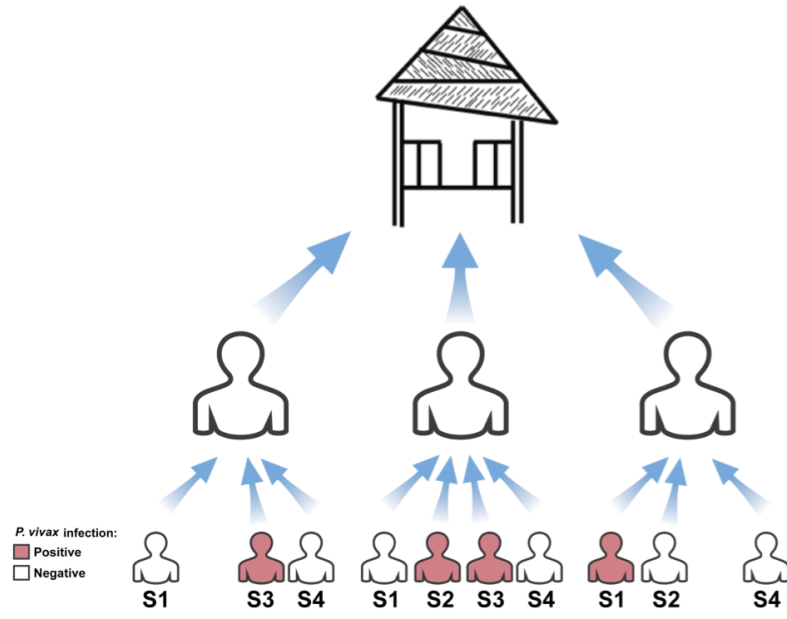
	Gamitanacocho		Libertad		Primero de Enero		Urco Mirañó	
	Var	95% CI	Var	95% CI	Var	95% CI	Var	95% CI
Null models								
Household	0	(-)	0	(-)	0	(-)	0.0362	(0.153 - 0.2142)
Individual	0	(-)	0	(-)	0	(-)	0	(-)
Community-Specific models								
Household	0	(-)	0	(-)	0	(-)	0.0219	(0.0001 - 5.0111)
Individual	0	(-)	0	(-)	0	(-)	0.0000	(-)

Mixed-effect Poisson Models with only random intercepts; Var= Variance estimate by mixed-effects model.

49
50

51
52
53

Supplementary Figure S1. Multilevel structure of data collected in the study.



Name of Level	Subscript to index level	Variables measured on each member of the level
Household [154 Households]	k	HH structure, walls material, roof material, HH sprayed, electricity supply, livestock and high-risk cluster location.
Individual [820 individuals]	j	Gender, age, education, outdoor occupation.
Repeated observations in time [up to 4 surveys (S)]	i	Travel history, fever symptom, <i>P. vivax</i> parasitaemia by PCR.

HH=Household

54