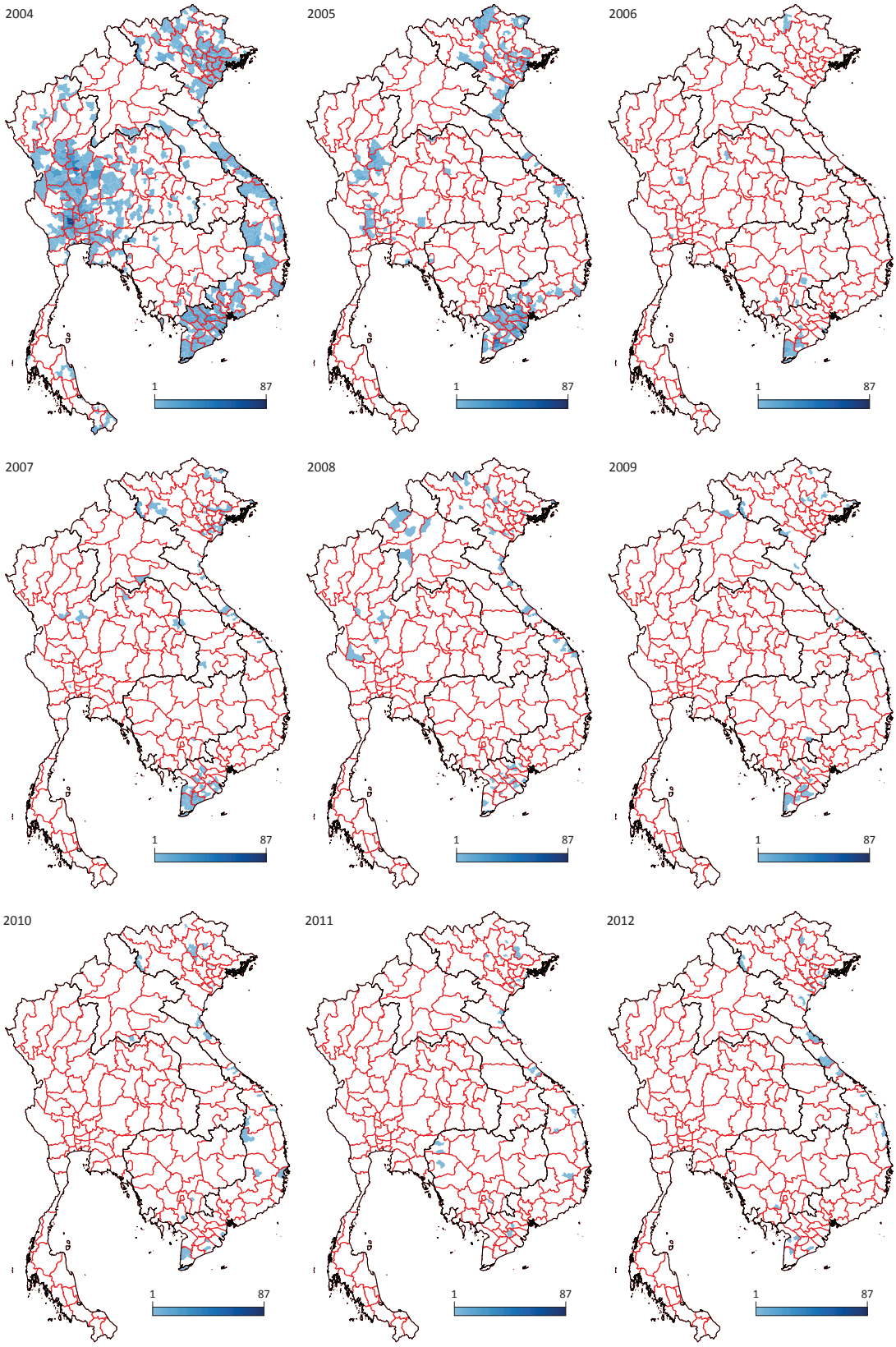

Figure S1. Maps of annual outbreak records. In each map, outbreak records are assigned to and reported by admin-2 polygons.

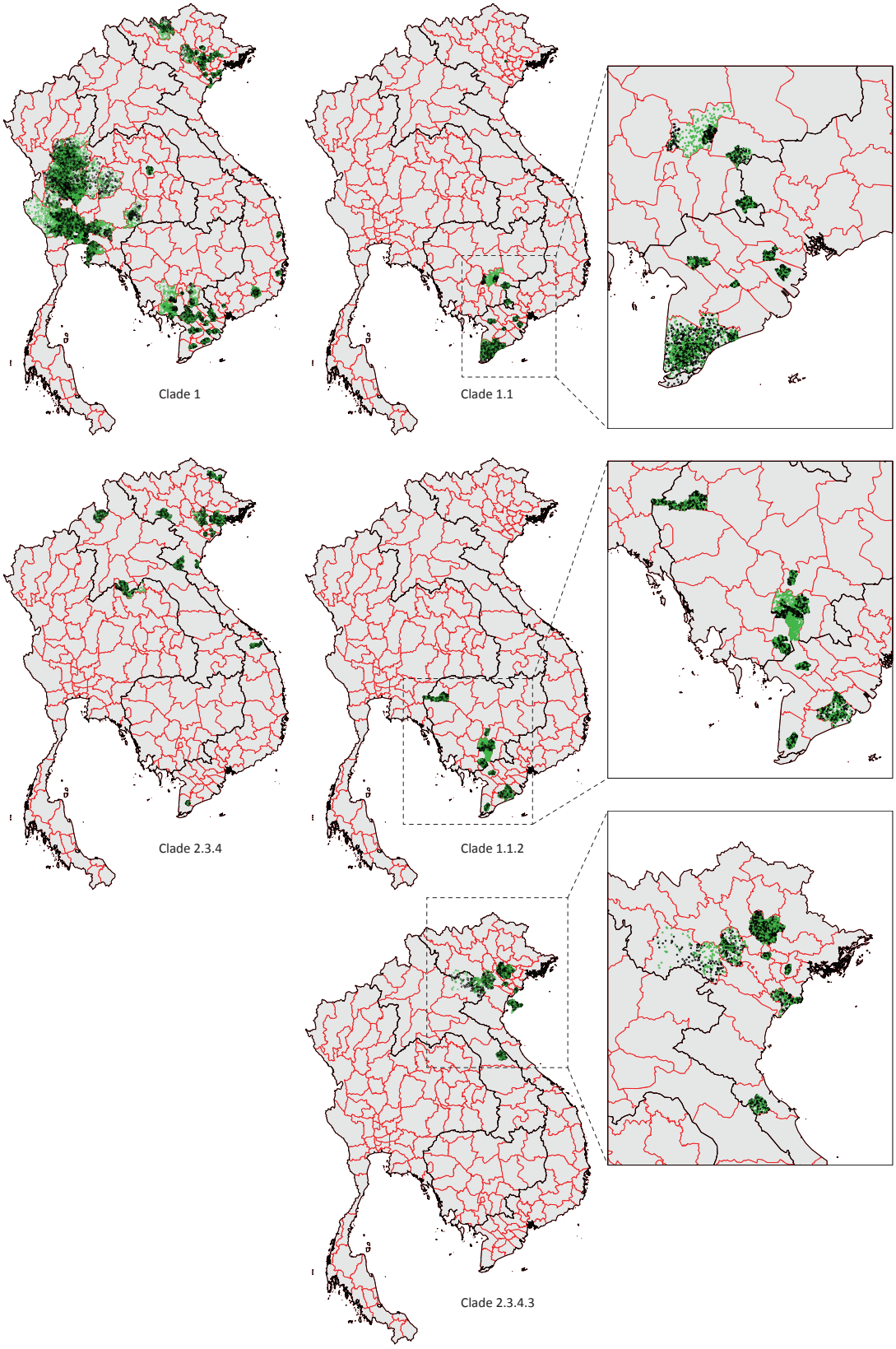

Figure S2. Comparison between unconstrained and constrained sampling location priors used for each clade-specific continuous phylogeographic analysis. Sampling locations drawn from unconstrained and constrained priors are represented by green and black dots, respectively. Similar to the other maps, international (admin-0) borders are in black and admin-1 borders in red. As detailed in the text, external information assigned to admin-2 polygons can be used to constrain sampling position priors for sequences originally assigned to a broad admin-1 polygon. While in the case of unconstrained priors, the entire admin-1 polygon is used to define the sampling position prior for these admin-1 sequences.

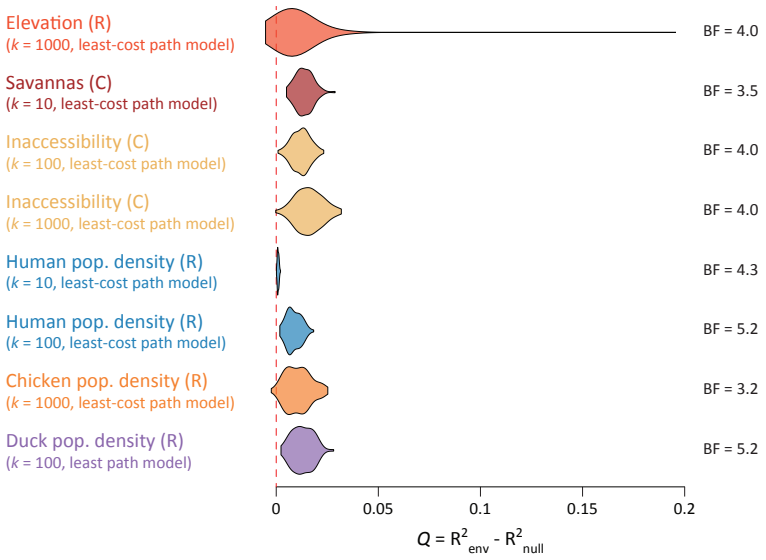

Figure S3. Analysis of the impact of several environmental factors on lineage dispersal velocity. These violin plots report the increase Q of the determination coefficient R^2 when performing a linear regression between dispersal durations and environmental distances computed on the environmental raster rather than on the "null" raster. Reported distributions of Q values are based on 100 posterior trees. Here, results are only reported for the combinations of environmental factor, parameter Q value and path model leading to a Q distribution significantly higher than 0 and associated with a Bayes factor value >3 (see the text for further details and Table S1 for the complete results).

Table S1. impact of several environmental factors on H5N1 dispersion velocity. The results are based on 100 trees sampled in each posterior distribution. "C" and "R" indicate if the considered environmental raster was considered as a conductance ("C") or resistance factor ("R"), and *k* is the rescaling parameter used to transform the initial raster (see the Appendix S1 for further details). For regression coefficients and *Q* values we report both the median estimate and the 95% HPD interval. The Bayes factor (BF) supports based on the randomisation procedure is only reported when $p(Q > 0)$ is at least 90%. Following Kass & Raftery (1995) we consider Bayes factors (BF) >3 and >20 as "positive" and "strong" supports for a significant correlation between the environmental distances and dispersal durations.

Path model	Environmental factor	*k*	Regression coefficient	*Q* statistic	$p(Q > 0)$	BF
least-cost	elevation (C)	10	0.005 [0.003, 0.009]	0.006 [0.002, 0.011]	0.99	1.1
		100	0.020 [0.013, 0.038]	0.032 [0.013, 0.056]	1.00	2.3
		1000	0.048 [0.030, 0.104]	0.030 [0.011, 0.074]	1.00	2.4
	elevation (R)	10	0.001 [0.001, 0.003]	0.000 [-0.002, 0.003]	0.58	-
		100	0.001 [0.000, 0.001]	0.004 [-0.001, 0.019]	0.89	-
		1000	0.000 [0.000, 0.000]	0.008 [-0.001, 0.030]	0.94	4.0
	croplands (C)	10	0.010 [0.006, 0.017]	-0.001 [-0.004, 0.004]	0.32	-
		100	0.076 [0.041, 0.138]	0.003 [-0.004, 0.021]	0.82	-
		1000	0.189 [0.001, 0.532]	0.000 [-0.008, 0.028]	0.50	-
	croplands (R)	10	0.001 [0.001, 0.002]	0.020 [0.009, 0.035]	1.00	2.2
		100	0.000 [0.000, 0.000]	0.037 [0.014, 0.064]	1.00	1.6
		1000	0.000 [0.000, 0.000]	0.039 [0.015, 0.069]	1.00	1.5
	forests (C)	10	0.013 [0.009, 0.020]	0.020 [0.007, 0.033]	1.00	1.9
		100	0.029 [0.021, 0.048]	0.033 [0.011, 0.066]	1.00	1.4
		1000	0.042 [0.030, 0.068]	0.033 [0.009, 0.068]	1.00	2.0
	forests (R)	10	0.001 [0.000, 0.001]	-0.001 [-0.005, 0.003]	0.17	-
		100	0.000 [0.000, 0.000]	-0.001 [-0.006, 0.010]	0.41	-
		1000	0.000 [0.000, 0.000]	0.000 [-0.006, 0.013]	0.46	-
	savannas (C)	10	0.008 [0.006, 0.013]	0.013 [0.006, 0.022]	1.00	3.5
		100	0.019 [0.014, 0.033]	0.030 [0.013, 0.057]	1.00	2.2
		1000	0.029 [0.020, 0.049]	0.037 [0.013, 0.068]	1.00	2.8
	savannas (R)	10	0.001 [0.001, 0.002]	-0.002 [-0.004, -0.001]	0.01	-
		100	0.001 [0.000, 0.002]	-0.001 [-0.005, 0.014]	0.29	-
		1000	0.000 [0.000, 0.000]	-0.003 [-0.009, 0.018]	0.25	-
	inaccessibility (C)	10	0.006 [0.003, 0.009]	0.003 [0.001, 0.006]	1.00	2.8
		100	0.041 [0.029, 0.061]	0.013 [0.004, 0.020]	1.00	4.0
		1000	0.380 [0.263, 0.575]	0.016 [0.005, 0.029]	0.99	4.0
	inaccessibility (R)	10	0.001 [0.001, 0.002]	-0.001 [-0.003, 0.000]	0.03	-
		100	0.000 [0.000, 0.001]	-0.001 [-0.003, 0.002]	0.27	-
		1000	0.000 [0.000, 0.000]	0.000 [-0.002, 0.004]	0.45	-
	human pop. density (C)	10	0.002 [0.001, 0.004]	-0.001 [-0.002, 0.000]	0.00	-
		100	0.003 [0.001, 0.005]	-0.002 [-0.005, -0.001]	0.01	-
		1000	0.018 [0.011, 0.029]	0.001 [-0.002, 0.009]	0.8	-
	human pop. density (R)	10	0.002 [0.001, 0.003]	0.001 [0.000, 0.002]	1.00	4.3
		100	0.002 [0.001, 0.003]	0.008 [0.002, 0.015]	1.00	5.2
		1000	0.001 [0.000, 0.001]	0.028 [0.009, 0.052]	1.00	1.9
	chicken pop. density (C)	10	0.002 [0.001, 0.004]	0.000 [-0.001, 0.000]	0.20	-
		100	0.002 [0.001, 0.004]	-0.001 [-0.003, 0.000]	0.06	-
		1000	0.004 [0.002, 0.007]	-0.002 [-0.006, 0.000]	0.02	-
	chicken pop. density (R)	10	0.002 [0.001, 0.003]	0.000 [-0.001, 0.001]	0.83	-
		100	0.002 [0.001, 0.003]	0.001 [-0.001, 0.003]	0.93	2.4
		1000	0.002 [0.001, 0.002]	0.011 [0.002, 0.023]	0.99	3.2
	duck pop. density (C)	10	0.002 [0.001, 0.004]	-0.001 [-0.003, 0.000]	0.00	-
		100	0.003 [0.001, 0.005]	-0.003 [-0.006, 0.000]	0.02	-
		1000	0.013 [0.008, 0.025]	0.000 [-0.004, 0.008]	0.53	-
	duck pop. density (R)	10	0.002 [0.001, 0.003]	0.001 [0.000, 0.002]	0.98	2.4
		100	0.002 [0.001, 0.004]	0.012 [0.004, 0.021]	1.00	5.2
		1000	0.001 [0.000, 0.001]	0.033 [0.010, 0.056]	1.00	2.4
Circuitscape	elevation (C)	10	0.251 [0.194, 0.414]	0.010 [0.001, 0.021]	0.97	1.4
		100	0.313 [0.225, 0.593]	0.009 [-0.012, 0.037]	0.77	-
		1000	0.432 [0.276, 0.916]	-0.012 [-0.037, 0.037]	0.32	-
	elevation (R)	10	0.092 [0.072, 0.146]	-0.017 [-0.026, -0.005]	0.01	-
		100	0.014 [0.008, 0.022]	-0.035 [-0.054, -0.017]	0.01	-
		1000	0.001 [0.001, 0.002]	-0.038 [-0.059, -0.019]	0.01	-
	croplands (C)	10	0.362 [0.211, 0.690]	-0.030 [-0.051, -0.008]	0.02	-
		100	0.567 [0.157, 1.307]	-0.038 [-0.064, -0.008]	0.02	-
		1000	0.600 [-0.018, 2.078]	-0.044 [-0.070, -0.009]	0.01	-
	croplands (R)	10	0.029 [0.023, 0.044]	0.012 [-0.012, 0.031]	0.88	-
		100	0.003 [0.003, 0.005]	0.013 [-0.014, 0.036]	0.85	-
		1000	0.000 [0.000, 0.001]	0.013 [-0.014, 0.037]	0.85	-
	forests (C)	10	0.293 [0.234, 0.475]	0.017 [-0.001, 0.035]	0.96	1.9
		100	0.328 [0.249, 0.518]	0.007 [-0.015, 0.036]	0.66	-
		1000	0.325 [0.229, 0.529]	-0.005 [-0.034, 0.021]	0.30	-
	forests (R)	10	0.034 [0.024, 0.060]	-0.034 [-0.054, -0.015]	0.01	-

	100	0.003 [0.001, 0.007]	-0.043 [-0.068, -0.021]	0.01	-
	1000	0.000 [0.000, 0.001]	-0.044 [-0.070, -0.021]	0.01	-
savannas (C)	10	0.245 [0.183, 0.389]	0.009 [-0.002, 0.019]	0.94	1.9
	100	0.292 [0.208, 0.497]	0.012 [-0.008, 0.034]	0.87	-
	1000	0.312 [0.219, 0.548]	0.008 [-0.016, 0.034]	0.73	-
savannas (R)	10	0.077 [0.052, 0.130]	-0.025 [-0.039, -0.010]	0.00	-
	100	0.005 [0.001, 0.012]	-0.045 [-0.066, -0.022]	0.00	-
	1000	0.000 [0.000, 0.001]	-0.048 [-0.071, -0.023]	0.00	-
inaccessibility (C)	10	0.307 [0.239, 0.425]	0.006 [-0.003, 0.015]	0.90	-
	100	0.942 [0.699, 1.265]	0.002 [-0.017, 0.029]	0.56	-
	1000	5.291 [3.737, 7.261]	-0.006 [-0.028, 0.026]	0.32	-
inaccessibility (R)	10	0.098 [0.073, 0.162]	-0.008 [-0.016, 0.003]	0.06	-
	100	0.019 [0.013, 0.034]	-0.018 [-0.032, 0.005]	0.04	-
	1000	0.002 [0.001, 0.004]	-0.020 [-0.036, 0.006]	0.04	-
human pop. density (C)	10	0.189 [0.146, 0.303]	-0.007 [-0.013, -0.002]	0.01	-
	100	0.242 [0.177, 0.410]	-0.021 [-0.032, -0.007]	0.01	-
	1000	0.625 [0.423, 1.002]	-0.029 [-0.045, -0.010]	0.01	-
human pop. density (R)	10	0.162 [0.126, 0.239]	0.006 [-0.003, 0.021]	0.92	1.1
	100	0.048 [0.032, 0.069]	-0.005 [-0.025, 0.031]	0.32	-
	1000	0.005 [0.003, 0.007]	-0.016 [-0.038, 0.019]	0.16	-
chicken pop. density (C)	10	0.178 [0.135, 0.284]	-0.002 [-0.008, 0.003]	0.13	-
	100	0.191 [0.140, 0.319]	-0.010 [-0.021, 0.002]	0.04	-
	1000	0.272 [0.186, 0.529]	-0.024 [-0.043, -0.004]	0.01	-
chicken pop. density (R)	10	0.170 [0.132, 0.268]	0.000 [-0.005, 0.005]	0.55	-
	100	0.130 [0.102, 0.182]	0.002 [-0.012, 0.017]	0.62	-
	1000	0.024 [0.016, 0.036]	-0.016 [-0.039, 0.019]	0.21	-
duck pop. density (C)	10	0.188 [0.142, 0.291]	-0.009 [-0.016, -0.002]	0.01	-
	100	0.213 [0.149, 0.396]	-0.025 [-0.040, -0.006]	0.02	-
	1000	0.379 [0.217, 0.778]	-0.032 [-0.052, -0.009]	0.02	-
duck pop. density (R)	10	0.152 [0.118, 0.228]	0.005 [-0.003, 0.015]	0.85	-
	100	0.051 [0.036, 0.076]	0.002 [-0.017, 0.033]	0.55	-
	1000	0.006 [0.004, 0.009]	-0.007 [-0.028, 0.028]	0.29	-