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Supplementary material

Appendix S1

This appendix includes a) additional details on parameter settings for utilized software and b) effects of effective samples size and proportional sampling on the power and accuracy of genetic surfacing.

Appendix S1a. Additional information on parameters settings for utilized software

EasyPop: we simulated populations in EasyPop with the following universal parameter settings: diploid organisms, two sexes, equal sex ratio, random mating, free recombination between loci, mutation rate of 0.0005 (Dallas 1992), stepwise mutation with Kam events (0.05 probability), and 30 loci (see Table 1 for varied simulation conditions). All simulations began with each locus fixed at one allele and 5000 generations for burn-in under complete admixture; all populations reached equilibrium in fewer than 3000 generations.

STRUCTURE: STRUCTURE analysis was executed under the following conditions with no a priori definition of clusters or cluster number: 100 000 generation burn-in followed by 50 000 Markov Chain Monte Carlo (MCMC) iterations, equal alpha (starting value 1.0), uniform priors, correlated allele frequencies, admixture of populations, population number (K) 1–11, and lambda inferred from the data.

Appendix S1b. Effect of unequal population sizes and proportional sampling

Not all extant populations are of equal size, therefore we simulated uneven effective populations with two migration probabilities (0.01 and 0): 500/500 (UN1, UN7, control), 600/400 (simulations UN2, UN8), 700/300 (simulations UN3, UN9), 800/200 (simulations UN4, UN10), 900/100 (simulations UN5, UN11) and 950/50 (simulations UN6, UN11) (Table S1). We subsampled these data at both absolute levels (n=200, 100, and 50) and proportion of the data (100%, 20%, 10%, and 5%). This was done to both provide a comparison among all simulation conditions, as well as to evaluate the relative power of detecting landscape genetic structure by sampling a percent of effective population size versus an absolute number of samples.

Overall small effective population size or unequal effective population size by suitable habitat patch had little impact on the power to detect significant landscape genetic structure (54/60 significant; Table S1). In the absence of migration, the genetic surfacing approach was extremely powerful (0.90 – 1) even with an effective population size of 100. In the presence of migration (0.01 migration probability), the genetic surfacing approach had >0.50 power at an effective population size as small as 100 (Appendix S2). In the absence of migration across the unsuitable habitat, all correlations were significant, while in the presence of low migration (probability = 0.01) landscape genetic structure was not detected when one effective population size was ≤ 100 or less (UN5, UN6; Table S1). However, statistical power to detect landscape genetic structure increases with equal numbers of samples per population relative to a random draw of genotypes from the entire landscape (Appendix S2).

Table S1. Simulation parameters and power to detect landscape genetic structure with full dataset

Table S1 displays EasyPop (Balloux 2001) simulation conditions as follows: simulation identification (Simulation), the number of generations populations post vicariance (Gen), probability of migration per individual per generation across the unsuitable habitat (Fig. 1) (M Between), probability of migration between adjacent subpatches within populations (Fig. 1) (M Within), total effective population size for the entire landscape (Total N_e), number of simulated (not genetically identified) populations or subpopulations (Pops), and effective population size per habitat patch (N_e/Patch). We held all other parameters constant across simulations (see main text). All simulations for effective population size and unequal population size were conducted in landscape A. The table displays number significant correlations (Sig, X/5), mean correlation coefficient (μR), and standard deviation (SD) for correlations between the patch model of landscape genetic structure and genetic surface.

Simulation	Gen	M(B)	M(WI)	Total N_e	Pops	N_e/Patch	Sig	μR	SD
N1	500	0.01	Na	1000	2	500, 500	5	0.976	0.003
N2	500	0.01	Na	500	2	250, 250	5	0.944	0.010
N3	500	0.01	Na	200	2	100, 100	5	0.951	0.019
N4	500	0.01	Na	100	2	50, 50	5	0.928	0.012
N5	500	0.01	Na	50	2	25, 25	3	0.716	0.105
N6	500	0	Na	1000	2	500, 500	5	0.976	0.001
N7	500	0	Na	500	2	250, 250	5	0.985	0.003
N8	500	0	Na	200	2	100, 100	5	0.977	0.002
N9	500	0	Na	100	2	50, 50	5	0.968	0.003
N10	500	0	Na	50	2	25, 25	5	0.886	0.105
UN1	500	0.01	Na	1000	2	500, 500	5	0.976	0.003
UN2	500	0.01	Na	1000	2	600, 400	5	0.949	0.009
UN3	500	0.01	Na	1000	2	700, 300	5	0.911	0.025
UN4	500	0.01	Na	1000	2	800, 200	5	0.867	0.040
UN5	500	0.01	Na	1000	2	900, 100	3	0.458	0.376
UN6	500	0.01	Na	1000	2	950, 50	1	0.235	0.174
UN7	500	0	Na	1000	2	500, 500	5	0.991	0.001
UN8	500	0	Na	1000	2	600, 400	5	0.989	0.002
UN9	500	0	Na	1000	2	700, 300	5	0.985	0.003
UN10	500	0	Na	1000	2	800, 200	5	0.971	0.009
UN11	500	0	Na	1000	2	900, 100	5	0.928	0.033
UN12	500	0	Na	1000	2	950, 50	5	0.878	0.012

Appendix S2

Simulation data summarized by sample size (N, on left) and number of loci (Loci, on right). Headings are as follows: Simulation (Sim): Simulation (conditions defined in Table 1, Appendix S1b), Model: landscape model used to simulate data (habitat patch (Patch), distance (Dist), patch–distance interaction (PXD); see text for definitions), Power (P): statistical power (1–β (Type II error)) to detect landscape genetic structure with the genetic surface, Model Choice (MC): the proportion of times the correct landscape model was selected out of the total number of significant simulations, F_{st}: average F_{st} between population clusters and A (allelic divergence): average allelic divergence between population clusters as estimated in Structure.

Sim	Model	N	P	MC	Fst	A	Loci	P	MC	Fst	A
T1	Patch	1000	na	na	0.073	0.081	30	na	na	0.069	0.085
(0 gen)	Patch	200	na	na	0.042	0.040	20	na	na	0.055	0.064
	Patch	100	na	na	0.064	0.085	10	na	na	0.062	0.086
	Patch	50	na	na	0.040	0.043	5	na	na	0.033	0.015
T2	Patch	1000	na	na	0.103	0.110	30	na	na	0.091	0.130
(1 gen)	Patch	200	na	na	0.064	0.081	20	na	na	0.087	0.088
	Patch	100	na	na	0.056	0.067	10	na	na	0.051	0.047
	Patch	50	na	na	0.059	0.063	5	na	na	0.053	0.057
T3	Patch	1000	0.60	0.80	0.069	0.111	30	0.30	1.00	0.047	0.071
(5 gen)	Patch	200	0.10	1.00	0.043	0.045	20	0.20	0.80	0.056	0.092
	Patch	100	0.00	na	0.054	0.059	10	0.15	0.75	0.047	0.055
	Patch	50	0.05	1.00	0.025	0.020	5	0.10	0.67	0.041	0.018
T4	Patch	1000	0.95	0.86	0.064	0.095	30	0.35	1.00	0.058	0.083
(10 gen)	Patch	200	0.20	0.80	0.047	0.061	20	0.45	0.82	0.053	0.070
	Patch	100	0.10	0.67	0.037	0.035	10	0.30	0.86	0.043	0.053
	Patch	50	0.15	1.00	0.047	0.049	5	0.30	0.75	0.040	0.032
T5	Patch	1000	1.00	1.00	0.093	0.238	30	1.00	1.00	0.076	0.188
(50 gen)	Patch	200	0.90	0.95	0.075	0.183	20	0.85	1.00	0.068	0.166
	Patch	100	0.85	0.94	0.067	0.138	10	0.75	1.00	0.076	0.167
	Patch	50	0.40	0.89	0.046	0.057	5	0.55	0.79	0.062	0.094
T6	Patch	1000	1.00	1.00	0.147	0.411	30	0.95	1.00	0.113	0.294
(100 gen)	Patch	200	1.00	0.91	0.121	0.342	20	1.00	1.00	0.118	0.304
	Patch	100	0.95	0.90	0.104	0.270	10	0.90	0.90	0.114	0.310
	Patch	50	0.65	0.87	0.077	0.153	5	0.75	0.79	0.103	0.268
T7	Patch	1000	1.00	1.00	0.236	1.087	30	1.00	0.95	0.199	0.787
(250 gen)	Patch	200	1.00	1.00	0.205	0.863	20	0.95	1.00	0.198	0.823
	Patch	100	1.00	1.00	0.196	0.780	10	1.00	1.00	0.211	0.875
	Patch	50	0.95	0.86	0.159	0.572	5	1.00	0.91	0.188	0.817
T8	Patch	1000	1.00	1.00	0.311	1.608	30	0.95	0.95	0.275	1.172
(500 gen)	Patch	200	1.00	1.00	0.277	1.320	20	0.95	1.00	0.273	1.228
	Patch	100	1.00	1.00	0.268	1.197	10	0.95	1.00	0.277	1.382
	Patch	50	0.80	0.94	0.238	0.954	5	0.95	1.00	0.270	1.308
T9	Patch	1000	1.00	1.00	0.387	2.697	30	1.00	1.00	0.359	2.112
(1000 gen)	Patch	200	1.00	1.00	0.355	2.204	20	1.00	1.00	0.360	2.132
	Patch	100	1.00	1.00	0.341	1.972	10	1.00	1.00	0.349	2.111
	Patch	50	1.00	1.00	0.324	1.676	5	1.00	1.00	0.340	2.190
M1	Patch	1000	1	1.00	0.311	1.608	30	1	0.95	0.275	1.172
(0 mp)	Patch	200	1	1.00	0.277	1.320	20	1	1.00	0.273	1.228
	Patch	100	1	1.00	0.268	1.197	10	1	1.00	0.277	1.382
	Patch	50	1	0.94	0.238	0.954	5	1	1.00	0.270	1.308

M2	Patch	1000	1	0.80	0.213	0.912	30	1	0.85	0.195	0.733
(0.001 mp)	Patch	200	1	0.90	0.195	0.764	20	1	0.90	0.197	0.732
	Patch	100	1	1.00	0.185	0.689	10	1	0.89	0.191	0.757
	Patch	50	1	0.75	0.178	0.627	5	0.95	0.78	0.188	0.769
M3	Patch	1000	1	1.00	0.306	1.534	30	1	1.00	0.271	1.162
(0.005 mp)	Patch	200	1	1.00	0.280	1.300	20	1	0.95	0.281	1.307
	Patch	100	1	1.00	0.263	1.134	10	1	1.00	0.267	1.148
	Patch	50	1	0.90	0.248	0.973	5	1	0.95	0.278	1.325
M4	Patch	1000	1	0.90	0.077	0.205	30	0.9	1.00	0.063	0.151
(0.01 mp)	Patch	200	0.9	0.88	0.070	0.169	20	0.9	0.94	0.068	0.158
	Patch	100	0.7	0.79	0.057	0.101	10	0.65	0.77	0.062	0.123
	Patch	50	0.3	1.00	0.046	0.053	5	0.4	0.63	0.058	0.097
M5	Patch	1000	0.9	0.83	0.057	0.129	30	0.8	1.00	0.043	0.084
(0.05 mp)	Patch	200	0.6	0.92	0.048	0.070	20	0.8	0.88	0.062	0.125
	Patch	100	0.7	0.77	0.061	0.083	10	0.4	0.88	0.058	0.084
	Patch	50	0.1	0.50	0.052	0.065	5	0.25	0.00	0.056	0.054
M6	Patch	1000	0.6	0.82	0.062	0.083	30	0.3	0.83	0.075	0.112
(0.1 mp)	Patch	200	0.1	1.00	0.051	0.053	20	0.2	0.75	0.057	0.086
	Patch	100	0	na	0.062	0.066	10	0.1	na	0.056	0.029
	Patch	50	0.1	1.00	0.045	0.044	5	0.15	1.00	0.032	0.019
M7	Patch	1000	na	na	0.045	0.122	30	na	na	0.060	0.078
(0.2 mp)	Patch	200	na	na	0.044	0.063	20	na	na	0.056	0.088
	Patch	100	na	na	0.042	0.035	10	na	na	0.049	0.055
	Patch	50	na	na	0.028	0.029	5	na	na	0.044	0.028
N1	Patch	500	0.90	0.90	0.311	1.608	30	0.90	0.63	0.275	1.172
1000	Patch	200	0.90	0.88	0.277	1.320	20	0.90	0.77	0.273	1.228
	Patch	100	0.65	0.79	0.268	1.197	10	0.65	0.94	0.277	1.382
	Patch	50	0.40	1.00	0.238	0.954	5	0.40	1.00	0.270	1.308
N2	Patch	500	0.72	0.95	0.084	0.133	30	0.72	0.90	0.052	0.088
500	Patch	200	0.64	0.88	0.087	0.133	20	0.64	0.86	0.078	0.080
	Patch	100	0.56	1.00	0.077	0.087	10	0.56	0.88	0.066	0.089
	Patch	50	0.40	0.80	0.063	0.041	5	0.40	1.00	0.065	0.057
	Patch	10	0.70	1.00	0.015	0.001					
N3	Patch	200	0.73	0.84	0.155	0.169	30	0.70	0.56	0.052	0.120
200	Patch	100	0.47	0.88	0.134	0.151	20	0.73	0.86	0.091	0.119
	Patch	50	0.30	0.77	0.116	0.108	10	0.47	0.86	0.131	0.088
	Patch	40	0.52	0.82	0.107	0.108	5	0.30	0.86	0.133	0.054
	Patch	20	0.52	0.80	0.075	0.034					
	Patch	10	0.40	0.50	0.024	0.000					
N4	Patch	100	0.08	0.93	0.162	0.117	30	0.52	na	0.028	0.079
100	Patch	50	0.50	0.86	0.155	0.095	20	0.52	0.80	0.093	0.057
	Patch	20	0.30	0.67	0.064	0.024	10	0.40	0.85	0.106	0.053
	Patch	10	0.30	0.00	0.041	0.001	5	0.08	1.00	0.132	0.000
N5	Patch	40	0.00	1.00	0.214	0.146	30	0.50	na	0.047	0.053
50	Patch	8	1.00	0.33	0.067	0.019	20	0.30	0.67	0.060	0.058
	Patch						10	0.30	1.00	0.109	0.028
	Patch						5	0.00	0.80	0.118	0.027
N6	Patch	1000	1.00	1.00	0.311	0.205	30	1.00	0.95	0.063	0.151
1000	Patch	200	1.00	1.00	0.277	0.169	20	1.00	1.00	0.068	0.158

	Patch	100	0.95	1.00	0.268	0.101	10	1.00	1.00	0.062	0.123
	Patch	50	0.73	0.94	0.238	0.053	5	0.95	1.00	0.058	0.097
N7	Patch	500	0.83	1.00	0.566	5.137	30	0.73	1.00	0.490	3.980
500	Patch	200	0.83	1.00	0.545	4.540	20	0.83	0.96	0.538	4.014
	Patch	100	0.83	1.00	0.537	3.964	10	0.83	1.00	0.550	3.919
	Patch	50	0.93	1.00	0.519	3.424	5	0.83	0.95	0.555	3.643
	Patch	20	0.77	0.88	0.511	2.719					
N8	Patch	200	0.87	1.00	0.690	5.571	30	0.93	0.85	0.559	4.200
200	Patch	100	0.90	1.00	0.684	5.046	20	0.77	0.73	0.658	4.418
	Patch	50	0.68	0.95	0.671	4.436	10	0.87	0.91	0.703	4.120
	Patch	40	0.60	0.90	0.672	4.261	5	0.90	0.86	0.700	3.963
	Patch	20	0.68	0.60	0.655	3.580					
	Patch	10	0.64	0.00	0.557	2.427					
N9	Patch	100	0.60	1.00	0.767	5.574	30	0.68	0.94	0.580	4.063
100	Patch	50	0.60	1.00	0.752	4.898	20	0.60	0.88	0.705	4.087
	Patch	20	0.90	0.88	0.733	4.012	10	0.68	0.87	0.751	3.890
	Patch	10	0.50	0.57	0.657	2.832	5	0.64	0.94	0.753	3.431
N10	Patch	40	0.50	0.60	0.817	4.638	30	0.60	0.60	0.390	2.745
50	Patch	8	0.90	0.00	0.730	2.850	20	0.60	0.33	0.562	2.536
	Patch						10	0.90	0.50	0.570	2.196
	Patch						5	0.50	0.50	0.612	1.621
UN1	Patch	1000	1	0.90	0.077	0.205	30	0.9	1.00	0.063	0.151
500	Patch	200	0.9	0.88	0.070	0.169	20	0.9	0.94	0.068	0.158
	Patch	100	0.7	0.79	0.057	0.101	10	0.65	0.77	0.062	0.123
	Patch	50	0.3	1.00	0.046	0.053	5	0.4	0.63	0.058	0.097
UN2	Patch	1000	0.9	1.00	0.038	0.136	30	0.75	0.93	0.051	0.094
400	Patch	200	0.7	0.93	0.057	0.088	20	0.65	1.00	0.044	0.112
	Patch	100	0.5	1.00	0.056	0.083	10	0.5	1.00	0.057	0.059
	Patch	50	0.1	1.00	0.056	0.026	5	0.25	1.00	0.055	0.067
UN3	Patch	1000	0.9	1.00	0.066	0.116	30	0.6	1.00	0.061	0.080
300	Patch	200	0.6	1.00	0.062	0.068	20	0.45	1.00	0.068	0.123
	Patch	100	0.2	0.80	0.062	0.066	10	0.4	1.00	0.076	0.072
	Patch	50	0	Na	0.068	0.079	5	0.15	0.67	0.055	0.055
UN4	Patch	1000	0.9	1.00	0.039	0.107	30	0.5	1.00	0.046	0.110
200	Patch	200	0.4	0.88	0.062	0.050	20	0.35	0.86	0.058	0.076
	Patch	100	0.2	1.00	0.054	0.074	10	0.3	1.00	0.048	0.053
	Patch	50	0.1	0.00	0.063	0.049	5	0.25	0.80	0.067	0.041
UN5	Patch	1000	0.6	1.00	0.047	0.090	30	0.2	1.00	0.060	0.137
100	Patch	200	0.2	0.80	0.052	0.097	20	0.3	0.83	0.040	0.065
	Patch	100	0.1	na	0.063	0.067	10	0.1	1.00	0.049	0.033
	Patch	50	0	na	0.073	0.058	5	0.2	1.00	0.087	0.076
UN6	Patch	1000	0.2	1.00	0.033	0.063	30	0.05	1.00	0.042	0.064
50	Patch	200	0	na	0.056	0.058	20	0.05	1.00	0.045	0.086
	Patch	100	0	na	0.049	0.067	10	0.05	1.00	0.077	0.037
	Patch	50	0	na	0.083	0.021	5	0.05	1.00	0.058	0.024
UN7	Patch	1000	1	1.00	0.311	1.608	30	0.95	0.95	0.275	1.172
500	Patch	200	1	1.00	0.277	1.320	20	0.95	1.00	0.273	1.228
	Patch	100	1	1.00	0.268	1.197	10	0.95	1.00	0.277	1.382
	Patch	50	0.8	0.94	0.238	0.954	5	0.95	1.00	0.270	1.308

UN8	Patch	1000	1	0.91	0.268	1.770	30	1	0.95	0.282	1.415
400	Patch	200	1	1.00	0.282	1.455	20	1	1.00	0.295	1.446
	Patch	100	1	1.00	0.298	1.293	10	1	1.00	0.305	1.409
	Patch	50	1	1.00	0.331	1.130	5	1	0.95	0.297	1.378
UN9	Patch	1000	1	0.80	0.254	1.779	30	0.95	1.00	0.270	1.320
300	Patch	200	1	1.00	0.273	1.423	20	1	0.90	0.289	1.355
	Patch	100	1	1.00	0.287	1.263	10	1	0.95	0.287	1.472
	Patch	50	1	1.00	0.318	1.059	5	1	0.90	0.286	1.375
UN10	Patch	1000	1	0.83	0.277	1.961	30	1	0.85	0.275	1.623
200	Patch	200	1	0.80	0.305	1.541	20	1	0.95	0.326	1.613
	Patch	100	1	1.00	0.326	1.315	10	0.9	0.83	0.331	1.537
	Patch	50	0.8	1.00	0.359	1.049	5	0.9	0.89	0.336	1.093
UN11	Patch	1000	1	0.91	0.257	2.580	30	0.75	0.47	0.307	1.805
100	Patch	200	1	0.44	0.309	2.054	20	0.65	0.62	0.343	1.642
	Patch	100	0.6	0.15	0.374	1.492	10	0.7	0.57	0.326	1.752
	Patch	50	0.2	1.00	0.402	1.001	5	0.65	0.69	0.366	1.927
UN12	Patch	1000	1	0.95	0.127	1.426	30	0.5	0.70	0.094	1.207
50	Patch	200	0.5	0.67	0.197	0.855	20	0.5	0.60	0.188	1.087
	Patch	100	0.3	0.42	0.215	0.688	10	0.5	0.90	0.260	0.736
	Patch	50	0.3	1.00	0.288	0.370	5	0.55	0.91	0.285	0.309
HM1	PXD	1000	1	1.00	0.264	1.225	30	1	1.00	0.245	1.033
0.05	PXD	200	1	1.00	0.242	1.054	20	1	1.00	0.242	1.041
0.001	PXD	100	1	1.00	0.225	0.923	10	0.95	1.00	0.248	1.107
	PXD	50	0.9	0.95	0.203	0.767	5	0.9	0.95	0.200	0.790
HM2	PXD	1000	1	1.00	0.270	1.380	30	1	0.95	0.250	1.146
0.1	PXD	200	1	1.00	0.246	1.185	20	1	0.95	0.254	1.158
0.001	PXD	100	1	0.95	0.240	1.084	10	0.95	1.00	0.238	1.148
	PXD	50	0.9	0.89	0.225	0.907	5	0.95	0.95	0.238	1.104
HM3	Patch	1000	0.8	1.00	0.328	2.171	30	0.8	0.94	0.296	1.718
0.2	Patch	200	0.8	1.00	0.306	1.851	20	0.8	1.00	0.296	1.689
0.001	Patch	100	0.8	1.00	0.300	1.721	10	0.8	1.00	0.323	1.963
	Patch	50	0.8	0.93	0.274	1.423	5	0.75	1.00	0.293	1.795
HM4	Dist	1000	0.8	0.42	0.268	2.034	30	0.8	0.43	0.264	1.693
0.01	Dist	200	0.8	0.25	0.247	1.594	20	0.75	0.38	0.249	1.684
0.01	Dist	100	0.8	0.33	0.235	1.435	10	0.75	0.33	0.231	1.435
	Dist	50	0.8	0.50	0.210	1.138	5	0.8	0.30	0.216	1.390
HM5	PXD	1000	0.8	1.00	0.179	0.625	30	0.75	0.92	0.150	0.491
0.05	PXD	200	0.8	1.00	0.159	0.545	20	0.8	0.88	0.154	0.514
0.01	PXD	100	0.7	0.67	0.144	0.449	10	0.65	0.80	0.158	0.516
	PXD	50	0.6	0.88	0.131	0.366	5	0.6	1.00	0.152	0.464
HM6	PXD	1000	1	1.00	0.164	0.652	30	1	1.00	0.138	0.530
0.1	PXD	200	1	0.85	0.141	0.555	20	1	0.85	0.140	0.507
0.01	PXD	100	1	0.70	0.135	0.492	10	0.9	0.74	0.140	0.505
	PXD	50	0.9	0.76	0.118	0.393	5	0.95	0.72	0.140	0.549
HM7	Patch	1000	1	1.00	0.161	0.545	30	1	0.90	0.131	0.450
0.2	Patch	200	1	1.00	0.143	0.472	20	1	1.00	0.130	0.423
0.01	Patch	100	1	0.79	0.129	0.404	10	0.95	0.95	0.151	0.450
	Patch	50	0.9	0.76	0.124	0.359	5	0.85	0.71	0.143	0.458
HM8	Dist	1000	0.9	0.47	0.076	0.197	30	0.95	0.53	0.057	0.130

0.1	Dist	200	0.8	0.54	0.075	0.158	20	0.85	0.50	0.087	0.186
0.1	Dist	100	0.6	0.17	0.062	0.103	10	0.5	0.18	0.061	0.116
	Dist	50	0.5	0.25	0.061	0.069	5	0.3	0.50	0.069	0.096

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