

Supplementary Table 1. Protected areas studied. Location according to Finnish uniform coordinate system (epsg: 2393). Local temperature variation ($\sigma TAM_{J_{local}}$) is the small-scale variation in April-June mean temperature (°C, standard deviation) in each protected area (i.e. temperature variation at 50 m x 50 m spatial resolution, see text). Broad-scale air temperature ($TAM_{J_{broad}}$) in 1981–1999 and in 2000–2017 show the mean April-June temperature (°C) of the corresponding periods based on climate data at 10 km x 10 km resolution. Transect km and combined density of northern forest bird species (pairs/km²) in each area in 1981–1999 and in 2000–2017 are presented.

Area	Location, northern coordinate	Location, eastern coordinate	Land area, km ²	Forest proportion	$\sigma TAM_{J_{local}}$	$TAM_{J_{broad}}$ 1981– 1999	$TAM_{J_{broad}}$ 2000– 2017	Transect km, 1981–99	Transect km, 2000–17	Combined density, pairs/km ² , 1981–99	Combined density, pairs/km ² , 2000–17
Aneenvaara	7317	3542	8.2	0.97	0.153	5.4	6.3	6.0	12.0	13.27	30.29
Asmuntinsuo	7302	3477	11.3	0.36	0.016	6.1	6.9	8.4	12.0	7.37	6.04
Auttiköngäs	7354	3509	3.7	0.98	0.112	5.6	6.5	3.6	5.0	30.34	9.68
Elimyssalo	7122	3661	79.1	0.81	0.085	6.5	7.3	117.2	71.3	20.10	21.92
Eteläneva	7081	3345	28.4	0.69	0.029	7.4	7.9	4.1	37.2	2.78	0.46
Etelä-Sydänmaa	7044	3402	5.6	0.84	0.027	7.6	8.0	10.1	8.7	23.42	3.59
Haapaveden suot	7128	3429	21.3	0.44	0.115	7.2	8.1	15.4	24.6	8.50	2.17
Haarasuo	7187	3407	6.8	0.43	0.014	7.4	8.1	5.8	5.5	3.93	3.17
Harjuntakanen	7040	3406	10.8	0.75	0.041	7.6	8.0	5.2	11.1	27.06	6.09
Hiidenportti	7085	3599	49.4	0.91	0.127	7.0	7.8	120.6	50.2	15.92	3.59
Hirvisuo	7234	3466	42.1	0.31	0.032	6.8	7.5	23.7	29.8	6.76	3.05
Hoikkasuo	7289	3422	7.7	0.32	0.034	6.5	7.4	8.6	9.0	7.11	0.35
Huhtaneva	7193	3403	6.8	0.61	0.017	7.0	7.8	6.2	7.0	6.22	0.52
Hurunvaara	7244	3567	23.7	0.83	0.130	5.8	6.5	18.8	11.2	16.19	15.05
Iivaara	7297	3629	23.6	0.94	0.251	5.1	6.0	24.2	26.1	31.49	14.30
Iso Tilansuo	7204	3522	34.6	0.44	0.050	6.6	7.4	25.3	13.1	6.10	6.08
Isokangas	7212	3448	3.3	0.81	0.036	7.2	7.9	22.0	49.9	2.78	1.21
Iso-Palonen	7136	3662	33.8	0.75	0.068	6.5	7.3	74.8	11.4	16.54	12.14
Isosuo	7292	3579	25.0	0.67	0.150	5.3	6.2	29.1	26.2	23.58	9.01
Iso-Syöte	7278	3527	11.4	0.83	0.282	6.0	6.8	5.7	7.3	31.95	6.65
Itämäki	7111	3485	10.6	0.93	0.102	7.1	7.8	4.4	25.2	14.06	3.48

Jaurakkavaara	7223	3532	4.3	0.97	0.189	6.3	7.0	17.1	8.2	10.10	1.78
Jonkerinsalo	7081	3632	35.8	0.89	0.167	6.9	7.6	51.5	53.6	14.18	10.52
Juortanansalo	7162	3636	53.2	0.77	0.081	6.3	7.0	89.4	61.1	29.48	18.65
Jäkäläkangas	7024	3687	2.3	0.94	0.166	7.1	7.9	6.0	6.8	8.48	3.96
Jänessuo	7293	3448	10.9	0.57	0.029	6.3	7.1	15.4	12.3	13.09	6.82
Kansanneva	7108	3473	18.7	0.77	0.042	7.3	8.0	12.2	16.3	2.31	2.12
Karsikkovaara	7198	3625	11.3	0.80	0.073	6.1	6.8	11.6	12.6	16.93	20.24
Kaunislampi	7298	3523	1.9	1.00	0.117	6.0	6.8	4.0	3.8	24.62	2.32
Kiimingin letot	7222	3452	10.7	0.65	0.028	7.2	7.8	28.9	15.2	11.37	3.56
Kilsiaapa	7357	3401	94.0	0.63	0.104	6.1	7.0	27.5	77.6	15.08	12.79
Kinnussuo	7151	3591	6.5	0.45	0.053	6.5	7.2	4.2	3.8	19.55	18.41
Kissansuo	7003	3693	24.6	0.51	0.036	7.4	8.1	14.1	18.0	5.57	3.29
Korouoma	7332	3535	67.9	0.77	0.340	5.2	6.1	27.8	29.2	25.74	17.71
Koutusjärvi	7393	3378	20.7	0.93	0.328	5.9	6.7	8.5	24.0	39.78	12.26
Kummunlammet	7224	3433	2.8	0.48	0.045	7.1	7.7	3.8	3.9	20.53	0.81
Kusisuo	7261	3440	4.1	0.15	0.012	6.7	7.5	3.3	7.6	12.37	2.42
Kuusikärri	7288	3538	2.4	1.00	0.155	5.7	6.4	3.5	12.9	24.43	6.07
Kuusisuo	7229	3476	41.0	0.36	0.061	6.9	7.6	20.6	22.2	7.15	6.50
Kärppäsuo	7255	3470	15.9	0.37	0.028	6.7	7.4	11.8	10.3	10.34	3.05
Kärsämäenjärvet	7088	3464	5.1	0.70	0.021	7.5	8.1	8.7	10.9	6.33	9.66
Käärmeaapa	7296	3446	11.1	0.32	0.026	6.3	7.1	16.2	12.8	19.43	6.95
Linjalamminkangas	7031	3374	4.5	0.53	0.025	7.6	8.0	4.5	8.8	8.34	1.53
Litokaira	7274	3466	295.5	0.50	0.087	6.5	7.3	230.0	180.6	19.85	7.46
Louevaara	7368	3419	18.7	0.91	0.258	6.0	7.0	9.8	20.7	41.37	7.58
Loukkuneva	7162	3444	8.1	0.69	0.012	7.2	8.1	9.8	7.7	2.91	1.31
Malahviansalo	7188	3626	22.4	0.85	0.086	6.2	6.9	47.0	18.2	14.25	16.20
Martimoaapa	7300	3413	137.3	0.50	0.136	6.2	7.1	102.0	114.2	9.64	4.22
Martinselkonen	7230	3629	60.4	0.68	0.114	5.7	6.5	60.7	18.5	27.59	21.82
Mesiönvaara	7203	3616	5.1	0.65	0.048	6.0	6.7	5.0	5.7	11.77	17.44
Miekojärvi	7390	3386	13.0	1.00	0.177	6.0	6.7	1.2	7.9	16.87	3.98
Mujejärvi	7076	3624	17.5	0.90	0.056	6.9	7.7	3.0	15.7	9.40	3.43

Murhisalo	7175	3644	57.9	0.72	0.054	6.1	6.9	130.2	18.0	26.48	20.38
Murtovaara	7079	3587	6.6	0.97	0.173	7.2	8.0	6.4	1.5	8.02	3.55
Mustanrinnantunturi	7350	3527	85.9	0.87	0.156	5.2	6.1	57.0	44.9	19.53	17.13
Mustiaapa	7369	3407	58.0	0.66	0.064	6.0	7.0	35.1	56.0	23.99	16.14
Mustosensuo	7174	3598	20.1	0.70	0.050	6.4	7.1	25.3	17.8	15.07	11.18
Mämmisuo	7307	3513	13.1	0.58	0.081	5.9	6.8	4.8	13.7	32.84	12.01
Niittysuo	7211	3493	24.3	0.36	0.017	6.8	7.6	15.3	3.1	3.22	2.73
Nikkilänaapa	7287	3417	3.5	0.23	0.021	6.5	7.4	7.9	1.1	10.02	17.27
Närängänvaara	7283	3623	51.9	0.61	0.142	5.3	6.2	47.9	51.0	28.76	27.59
Ohtosensuo	7264	3511	21.1	0.46	0.047	6.5	7.2	16.7	21.6	7.88	16.23
Oijusluoma	7303	3590	11.8	0.86	0.156	5.1	6.0	8.0	18.6	20.11	21.46
Olvassuo	7213	3506	268.9	0.45	0.119	6.7	7.4	142.6	275.8	11.95	3.92
Oravisuo	7353	3617	4.4	0.80	0.106	5.0	5.9	5.0	4.5	16.99	19.42
Oulanka N	7365	3616	138.3	0.60	0.173	4.8	5.8	96.3	40.4	30.40	19.96
Oulanka S	7354	3609	135.9	0.92	0.313	4.9	5.8	251.0	222.5	22.75	22.28
Pajupuronsuo	7288	3593	30.9	0.66	0.085	5.4	6.2	26.1	25.7	32.08	16.02
Paljakka	7176	3550	31.1	0.92	0.249	6.3	7.1	50.3	29.8	35.28	20.45
Patanajärvenkangas	7014	3361	2.7	0.55	0.043	7.7	8.1	3.4	13.3	15.62	3.95
Patvinsuo	7000	3686	96.6	0.54	0.102	7.4	8.1	102.7	173.9	7.64	4.73
Pesäneva	7080	3394	1.6	0.14	0.009	7.6	8.0	2.8	3.5	3.53	5.22
Piilopirtinaho	7073	3573	5.5	0.93	0.303	7.0	7.7	5.0	3.7	10.41	1.77
Pilpasuo	7208	3442	3.7	0.54	0.029	7.5	8.2	19.6	50.7	3.55	2.00
Pisavaara	7350	3414	48.7	0.88	0.343	6.1	7.1	62.6	48.9	17.62	8.51
Pohjoisneva	6998	3365	22.1	0.50	0.035	7.7	8.2	10.0	24.4	3.15	0.34
Poikainlammet	7239	3452	10.1	0.48	0.019	7.1	7.7	11.6	11.7	6.12	1.46
Pumpulikirkko	7058	3574	3.1	0.94	0.096	7.1	7.9	5.1	22.7	28.26	7.85
Pönttövaara	7012	3701	4.0	0.82	0.077	7.2	8.0	5.0	7.1	15.92	5.46
Pötkönsuo	7314	3590	6.3	0.61	0.068	5.0	5.9	6.3	6.3	19.67	14.10
Rasvasuo	7061	3650	18.4	0.75	0.033	7.1	8.0	20.5	28.4	8.50	5.69
Reposuo	7029	3659	8.9	0.33	0.048	7.4	8.1	8.8	9.2	5.27	0.19
Revonneva	7175	3415	38.1	0.34	0.044	7.3	8.1	6.0	39.0	1.00	1.71

Riisitunturi	7338	3558	123.8	0.81	0.280	5.2	6.0	102.9	83.5	29.00	26.64
Rimpijärvi	7291	3430	13.7	0.25	0.018	6.4	7.2	24.8	11.8	7.13	6.04
Rimpineva	7086	3395	6.5	0.49	0.024	7.6	8.0	5.0	8.2	2.84	2.53
Ritaneva	7075	3353	22.0	0.57	0.022	7.4	8.0	8.0	20.5	6.32	1.16
Riuskanselkonen	7240	3583	41.3	0.64	0.083	5.7	6.4	14.5	29.9	17.03	17.24
Rokua	7162	3475	13.4	0.98	0.087	6.9	7.7	25.4	23.9	6.44	1.87
Romevaara	7274	3613	32.9	0.75	0.150	5.3	6.2	30.1	26.3	32.74	20.07
Rumala	7133	3481	47.8	0.39	0.048	7.1	7.9	20.0	47.1	1.19	1.79
Runkaus	7322	3432	69.8	0.60	0.097	6.1	7.0	77.7	32.6	21.29	11.11
Ruunaa (nature reserve)	7033	3683	68.8	0.82	0.105	7.2	8.0	73.3	250.9	7.57	4.38
Ruunaa (hiking area)	7031	3674	26.1	0.83	0.091	7.2	8.0	30.0	66.4	4.02	0.71
Räkäsuo	7196	3466	26.3	0.30	0.033	7.1	7.9	363.0	128.7	7.11	4.16
Rääpysjärvi	7286	3559	4.2	0.82	0.060	5.6	6.5	10.6	15.1	24.64	9.15
Saariaapa	7326	3437	20.0	0.45	0.037	6.0	7.0	17.7	14.3	19.15	3.56
Saarijärvi	7188	3525	12.6	0.75	0.063	6.5	7.2	5.6	14.8	12.16	9.66
Salamajärvi	7010	3391	72.4	0.63	0.058	7.7	8.1	68.8	52.6	19.92	3.49
Salamanperä	7012	3388	12.2	0.61	0.043	7.7	8.1	78.8	58.5	7.15	2.60
Sammakkoaho	7266	3594	6.5	0.88	0.050	5.5	6.3	4.6	5.9	46.06	20.33
Siikavaara	7221	3543	28.4	0.95	0.502	6.3	6.9	47.9	8.6	16.66	9.26
Siprunvaara	7314	3587	6.5	0.85	0.134	5.0	5.9	6.3	3.9	21.88	31.00
Soininsuo	7273	3494	24.6	0.25	0.033	6.4	7.2	15.3	11.7	3.91	9.26
Sukerijärvi	7363	3584	31.9	0.54	0.029	4.9	5.9	29.7	20.1	25.66	20.57
Suoniemensuo	7161	3618	9.3	0.72	0.043	6.4	7.1	9.4	5.5	20.00	5.96
Suuripää	7320	3404	41.7	0.52	0.023	6.2	7.1	23.5	37.8	6.04	2.66
Syöte	7274	3536	300.3	0.81	0.274	5.8	6.7	121.6	210.1	27.19	12.05
Säippäsuo	7178	3487	45.9	0.40	0.043	6.9	7.7	34.1	43.2	5.64	1.44
Särkipera	7339	3603	7.3	0.63	0.133	4.8	5.8	2.0	10.4	14.95	13.08
Säynäjäsuu	7188	3598	9.8	0.22	0.028	6.3	6.9	55.7	9.1	8.54	11.85
Talaskangas	7094	3507	48.2	0.75	0.076	7.2	7.9	76.1	102.5	15.91	6.08

Teerisuo	7086	3613	30.2	0.77	0.087	7.0	7.8	88.5	40.8	17.63	10.77
Tervajärvi	7258	3565	13.8	0.64	0.051	5.8	6.5	14.8	12.1	37.77	19.94
Tiilikka	7056	3564	44.0	0.72	0.111	7.2	8.0	58.1	94.1	16.28	3.01
Tolkansuo	7171	3489	20.6	0.28	0.029	6.9	7.7	9.4	19.0	1.01	0.45
Torvensuo	7204	3488	14.4	0.38	0.036	6.9	7.6	8.9	5.7	2.73	8.21
Tulisuo	7163	3614	31.5	0.61	0.077	6.4	7.1	40.6	12.3	17.12	23.28
Tuuliaapa	7276	3426	12.8	0.41	0.047	6.6	7.4	12.3	8.9	15.23	5.48
Tyräsuo	7261	3482	7.1	0.07	0.022	6.6	7.4	5.1	5.2	3.05	1.12
Törmäsenrimpi	7121	3483	20.6	0.36	0.040	7.2	7.9	9.9	18.9	7.01	2.00
Ulvinsalo	7095	3663	39.2	0.93	0.109	6.7	7.5	100.8	8.2	18.50	10.51
Valtavaara	7339	3597	9.7	0.87	0.312	4.8	5.8	217.3	214.5	25.53	21.25
Varpusuo	7308	3505	10.1	0.13	0.024	5.9	6.8	4.2	5.8	11.30	8.42
Veittiaapa	7295	3428	28.6	0.44	0.039	6.4	7.2	51.2	41.0	8.61	4.31
Veneneva	7143	3462	120.0	0.52	0.049	7.1	8.0	38.4	121.0	7.41	5.84
Vieremänsuo	7252	3622	28.8	0.65	0.071	5.6	6.4	8.1	24.0	36.30	17.18
Viisiriihinen	7195	3627	3.2	0.84	0.050	6.1	6.8	6.2	6.2	10.26	22.00
Virmajoki	7290	3644	29.5	0.60	0.070	5.1	6.1	28.0	30.6	35.42	39.96

Supplementary Fig. 1. The agreement between observed and interpolated monthly (1–12, 1 = January, 12 = December) average air temperatures (1981–2010, in °C) based on a leave-one-out cross-validation of 318 meteorological stations, in terms of the adjusted r-squared, mean error (Bias) and root mean squared error (RMSE). The red dashed line depicts the 1:1 line.

