birds

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Article

New evidence on the linkage of population trends and species traits to long-term niche changes

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SUPPLEMENTARY MATERIALS

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Table S1. Land-cover variables used in PCA (E-space). "DUSAF code" and "description" represent the classification according to the 3rd level of DUSAF digital map [59], while "Variable code" and "name" indicate the corresponding land covers used in the analysis after merging of some variables.

Land-cover variables			
DUSAF code	**DUSAF description**	**Variable code**	**Variable name**
111	Continuous urban matrix (e.g., dense residential areas)	C110	Continuous urban matrix
121	Industrial areas and large production plants		
122	Road and rail networks		
123	Harbours		
124	Airports		
131	Quarries		
132	Dumps		
133	Building sites		
134	Degraded areas		
141	Green urban areas		
142	Recreational areas		
112	Discontinuous urban matrix (e.g., farmsteads, scattered residential areas)	C112	Discontinuous urban matrix
211	Arable lands (e.g., maize, wheat, horticulture)	C211	Arable lands
213	Paddy fields	C213	Paddy fields
221	Vineyards	C220	Permanent orchard plantations
222	Orchards		
223	Olive groves		
224	Wood plantations	C224	Wood plantations
231	Meadows and pastures	C231	Meadows and pastures
311	Broadleaved forests	C311	Broadleaved forests
312	Coniferous forests	C312	Coniferous forests
313	Mixed forests	C313	Mixed forests
321	Grasslands	C321	Grasslands
322	Shrublands	C322	Shrublands
324	Shrub and grass vegetation under evolution	C324	Shrub and grass vegetation under evolution
331	Areas around waterbodies without vegetation	C330	Areas with sparse or absent vegetation
332	Debris deposits and rocks		
333	Rock areas with sparse vegetation		
334	Glaciers and perennial snow		
411	Wetland vegetation	C410	Wetland vegetation
511	Rivers and streams	C511	Rivers and streams
512	Natural and artificial lakes	C512	Natural and artificial lakes

Table S2. List of species traits and referencing literature.

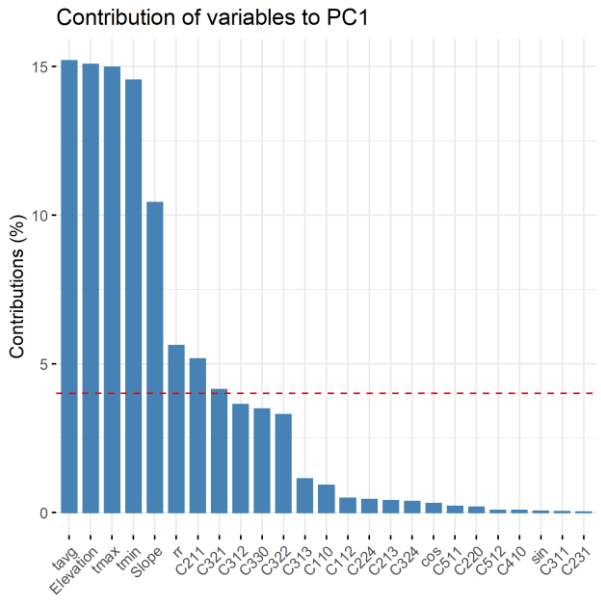
Species traits		Abbreviation	References
Continuous			
Mean length of the body		len	[87]
Mean length of the wing		wing	[87]
Mean length of the tail		tail	[87]
Mean length of the bill		bil	[87]
Mean length of tarsus		tar	[87]
Mean weight in breeding season		wei	[87]
Mean clutch size		clu	[87]
Mean number of broods per breeding season		bro	[53,87]
Annual fecundity (clu x bro)		fec	[88]
Incubation period		inc	[87]
Fledging period		fle	[87]
Dispersal ratio (len/cube root[wei])		disr	[89,90]
Specialization index for the foraging habitat		SSI.fh	[53,91,92]
Specialization index for the acquisition behavior		SSI.acq	[53,91,92]
Specialization index for the nesting habitat		SSI.nes	[53,91,92]
Specialization index for the foraging substrate		SSI.fs	[53,91,92]
Specialization index for the diet		SSI.tr	[53,91,92]
Overall specialization index (mean[SSi.fh, SSi.acq, SSI.nes, SSI.fs, SSI.tr])		SSI.ov	[53]
Categorical			
Migration strategy		-	[53]
Groups	Long-distance migrants		
	Short-distance migrant		
	Sedentary		
Landscape type		-	[53]
Groups	Farmland		
	Woodland		
	Natural-open habitat		
	Several		
Nest type		-	[53,87]
Group	Elevated-nester		
	Ground-nester		
	Hole-nester		
Diet		-	[53,93]
Group	Vertebrates		
	Plant-eaters		
	Invertebrates		
	Omnivores		

Table S3. Coordinates of each variable respect to the first two PCA-axes (E-space). See Table S1 and Section 2.2 in the main text for variables' abbreviations.

Variable	PC1	PC2
C110	0.23	0.05
C112	0.17	0.11
C211	0.56	−0.41
C213	0.15	−0.20
C220	0.10	0.04
C224	0.16	−0.21
C231	0.02	0.35
C311	−0.04	0.56
C312	−0.47	−0.12
C313	−0.26	0.36
C321	−0.50	−0.35
C322	−0.45	−0.41
C324	−0.15	0.06
C330	−0.46	−0.39
C410	0.06	−0.03
C511	0.11	−0.17
C512	−0.06	−0.03
Elevation	−0.95	−0.10
sin	0.05	−0.17
cos	−0.13	0.08
Slope	−0.79	0.37
rr	−0.58	0.49
tmax	0.95	0.10
tavg	0.96	0.10
tmin	0.94	0.13

Figure S1. Contribution of each variable (%) to PC1 (a) and PC2 (b) (E-space). The red-dashed line represents the expected average contribution. If the contribution of the variables were uniform, the expected value would be the reciprocal of the number of variables (4%).

a)



b)

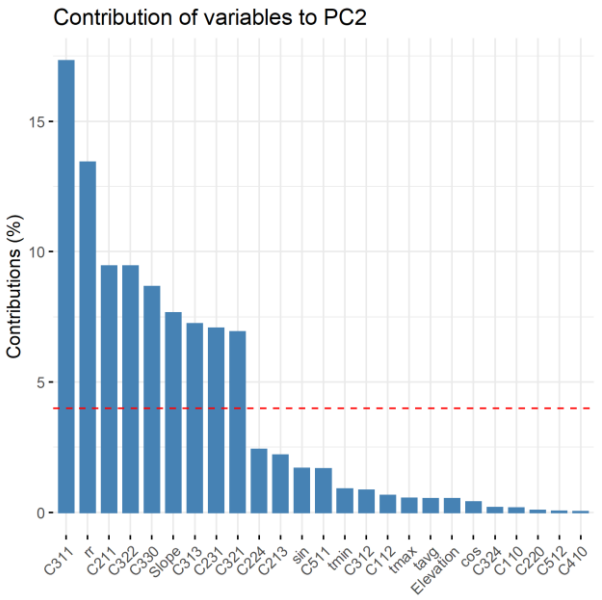


Table S4. Niche breadth and centroid for each species along the PCA-axes (E-space) in T1 and T2. T_1 = 1992–95–96; T_2 = 2015–16–17; PC1 = PCA-axis 1; PC2 = PCA-axis 2. Species are presented with the common name [97] and following the taxonomic order.

Species	Breadth				Centroid			
	T_1		T_2		T_1		T_2	
	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
Black-crowned Night Heron	0.18	0.40	0.06	0.33	1.59	–1.17	1.92	–0.94
Little Egret	0.09	0.33	0.12	0.38	1.53	–1.27	2.09	–1.03
Grey Heron	0.13	0.48	0.42	0.56	1.63	–1.06	2.03	–0.76
Mallard	1.26	1.69	0.41	0.68	1.35	–0.56	2.03	–0.85
Black Kite	1.49	1.12	1.47	1.36	0.15	0.70	0.50	1.18
Common Buzzard	2.05	1.20	2.39	1.44	–0.70	1.71	1.38	0.46
Common Kestrel	5.86	2.16	2.64	0.85	0.46	0.31	2.09	–0.67
Common Quail	0.42	0.57	0.16	0.59	1.63	–0.21	2.22	–0.91
Common Pheasant	0.58	1.26	0.39	0.75	1.56	–0.29	2.08	–0.73
Common Moohren	0.31	0.79	0.19	0.44	1.60	–0.66	2.02	–0.73
Feral Pigeon	0.38	0.75	0.36	0.63	1.62	–0.22	1.99	–0.20
Common Wood Pigeon	0.68	1.28	0.92	1.04	1.39	0.06	1.91	–0.22
Eurasian Collared Dove	0.50	0.90	0.57	0.77	1.55	–0.26	1.99	–0.24
European Turtle Dove	0.82	1.04	0.47	0.82	1.43	–0.03	1.89	–0.43
Common Cuckoo	4.19	1.72	4.76	1.89	1.03	–0.07	–0.65	0.83
Common Swift	2.39	1.27	3.10	1.22	1.45	–0.16	1.85	–0.04
Eurasian Wryneck	2.08	1.12	1.26	0.81	1.35	0.11	1.36	0.49
European Green Woodpecker	1.87	0.78	3.22	1.44	–0.61	1.26	0.83	0.38
Great Spotted Woodpecker	2.09	2.44	3.82	1.49	0.49	0.90	1.20	0.43
Eurasian Skylark	0.69	0.47	9.40	0.84	1.77	–0.70	2.03	–0.98
Eurasian Crag Martin	3.76	2.60	4.17	2.05	–1.74	1.55	–1.50	0.47
Barn Swallow	1.43	1.19	0.63	0.70	1.54	–0.07	2.02	–0.26
Common House Martin	2.05	1.27	4.61	1.24	1.13	0.33	1.48	0.07
Tree Pipit	2.74	1.86	1.74	2.31	–3.77	0.01	–3.55	–0.31
Water Pipit	0.44	0.78	1.40	1.09	–5.63	–2.52	–4.86	–2.50
Western Yellow Wagtail	0.17	0.44	0.06	0.34	1.79	–0.72	2.26	–1.03
Grey Wagtail	7.49	1.96	4.72	2.25	–2.75	0.23	–2.22	0.25
White Wagtail	5.20	1.57	6.43	1.73	–0.02	0.59	–0.91	0.31
Eurasian Wren	6.29	2.35	3.76	2.41	–1.59	1.07	–1.97	1.07
Dunnock	0.44	0.80	1.82	2.91	–5.49	–1.07	–4.54	–1.28
European Robin	3.90	1.32	3.57	2.22	–1.90	1.52	–1.97	1.26
Common Nigthingale	0.68	1.05	0.37	0.70	1.60	–0.38	2.06	–0.62
Black Redstart	6.09	3.11	7.03	2.72	–5.66	–2.02	–3.89	–0.36

Table S4 (cont.)

Common Redstart	3.45	1.10	4.11	1.21	–1.02	1.47	–0.66	0.72
African Stonechat	0.86	0.72	1.17	0.72	1.73	–0.44	1.92	0.02
Northern Wheatear	1.92	2.13	1.09	1.22	–5.49	–2.52	–4.73	–2.14
Common Blackbird	3.68	1.39	5.31	1.47	1.34	–0.01	1.76	–0.16
Song Thrush	3.59	1.19	3.06	3.23	–3.95	–0.02	–2.30	0.91
Mistle Trush	4.30	3.27	2.27	3.44	–3.08	0.38	–4.22	–0.58
Cetti's Warbler	0.33	0.67	0.23	0.51	1.71	–0.53	1.87	–0.53
Melodius Warbler	1.12	1.47	0.34	0.78	1.27	0.11	1.89	–0.42
Lesser Whitethroat	2.89	2.73	1.59	2.09	–5.75	–0.80	–4.69	–1.89
Eurasian Blackcap	3.85	1.20	4.57	1.33	0.93	0.25	1.01	0.32
Western Bonelli's Warbler	3.21	1.14	2.26	1.77	–1.47	1.76	–1.46	1.60
Common Chiffchaff	4.40	1.77	3.61	2.94	–1.91	1.53	–2.11	0.89
Goldcrest	2.83	1.77	2.12	1.57	–3.11	0.58	–2.88	0.57
Common Firecrest	5.19	0.85	3.47	0.80	–4.48	–0.44	–1.71	0.89
Spotted Flycatcher	2.13	1.28	2.63	1.08	0.86	0.83	0.54	0.78
Long-tailed Tit	2.66	0.75	2.58	1.13	–0.84	1.63	0.63	0.95
Marsh Tit	2.20	0.95	1.62	0.45	–1.97	1.57	–1.23	1.83
Willow Tit	1.79	1.85	1.57	3.11	–4.96	–0.73	–5.08	–1.60
European Crested Tit	3.47	2.05	3.19	3.55	–3.30	0.26	–3.34	–0.22
Coal Tit	5.04	1.90	3.24	3.16	–3.41	0.49	–2.58	0.72
Eurasian Blue Tit	2.58	0.88	1.93	0.90	–0.77	1.48	–0.39	1.34
Great Tit	2.90	1.41	2.97	1.26	0.44	0.59	1.36	0.25
Eurasian Nuthatch	1.56	0.23	2.59	0.99	–0.31	1.62	–1.38	1.66
Eurasian Golden Oriole	0.61	1.05	0.39	0.89	1.52	–0.19	1.90	–0.30
Red-backed Shrike	2.46	1.43	2.42	0.76	0.59	0.44	0.83	0.51
Eurasian Jay	4.37	1.34	3.53	1.53	–1.24	1.17	–0.84	1.36
Eurasian Magpie	0.34	0.65	0.32	0.66	1.53	–0.26	2.07	–0.43
Carrion Crow	5.44	2.81	3.77	2.70	–1.89	1.42	–4.42	–0.47
Hooded Crow	2.49	1.29	2.94	1.19	1.45	–0.15	1.68	0.08
Common Starling	0.71	0.95	0.34	0.64	1.60	–0.26	2.01	–0.34
Italian Sparrow	1.30	1.20	1.33	0.81	1.55	–0.16	1.97	–0.19
Eurasian Tree Sparrow	0.72	0.81	0.76	0.62	1.61	–0.32	2.04	–0.46
Common Chaffinch	5.58	1.36	6.15	1.98	–0.41	0.89	–0.95	0.69
European Serin	1.13	0.72	2.06	0.63	1.27	0.41	1.47	0.23
European Greenfinch	1.05	1.06	1.25	0.60	1.45	0.02	1.86	0.09
European Goldfinch	1.25	1.28	2.70	0.71	1.54	–0.11	1.85	0.05
Common Redpoll	0.74	1.51	1.22	1.67	–6.18	–2.16	–5.13	–2.11
Eurasian Bullfinch	2.57	1.22	2.04	2.78	–4.60	–0.20	–2.56	0.17

Figure S2. Notched box plots of niche breadth and centroid for each PCA-axis (E-space) in T_1 and T_2. From T_1 to T_2, the median of the niche breadth varied from 2.05 (range = 0.09-7.49) to 2.06 (range = 0.06-9.40) along PC1, and from 1.20 (range = 0.23-3.27) to 1.13 (range = 0.33-3.55) along PC2. From T_1 to T_2, the median of the niche centroid varied from 0.49 (range = − 6.18-1.79) to 1.01 (range = − 5.13-2.26) along PC1, and from − 0.02 (range = − 2.52-1.76) to − 0.04 (range = − 2.50-1.83) along PC2. In each box plot, the sample dimension is equal to the total number of the species (n=71). Whiskers are 1.5 x IQR. Black dots represent outliers. T1 = 1992–95–96; T2 = 2015–16–17; PC1 = PCA-axis 1; PC2 = PCA-axis 2. Nothces give a roughly 95% confidence interval for medians. Wilcoxon rank sum test detected differences only for centroids' comparison along PC1 (niche breadth PC1: W = 2550, p-value = 0.906; niche breadth PC2: W = 2625, p-value = 0.671; niche centroid PC1: W = 1991 , p-value = 0.031; niche centroid PC2: W = 2727, p-value = 0.401).

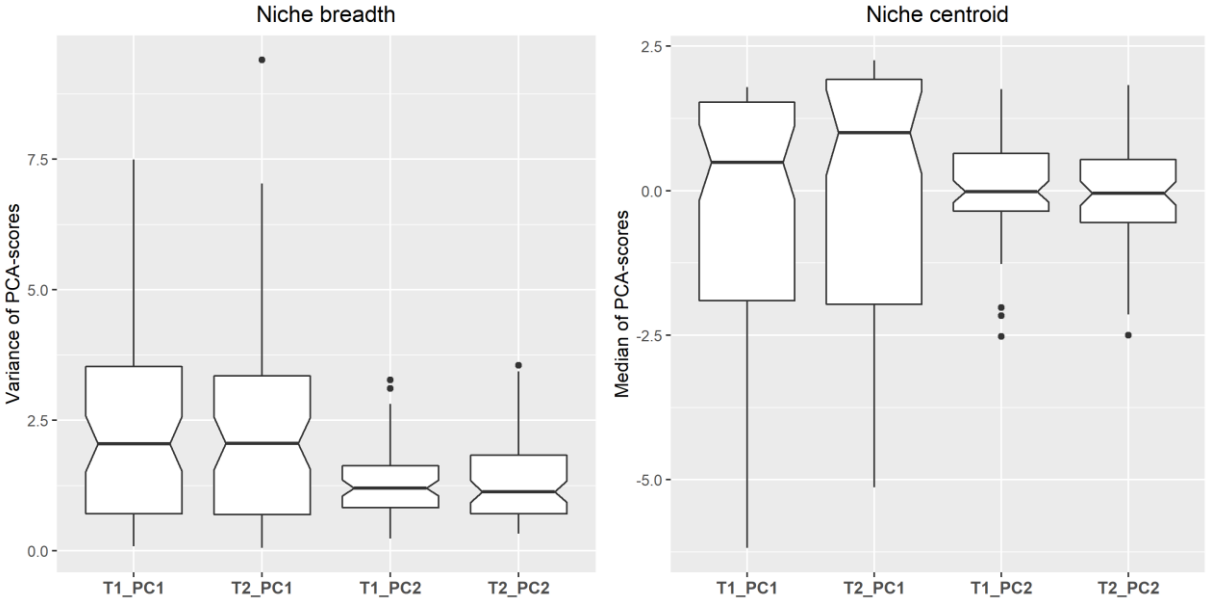
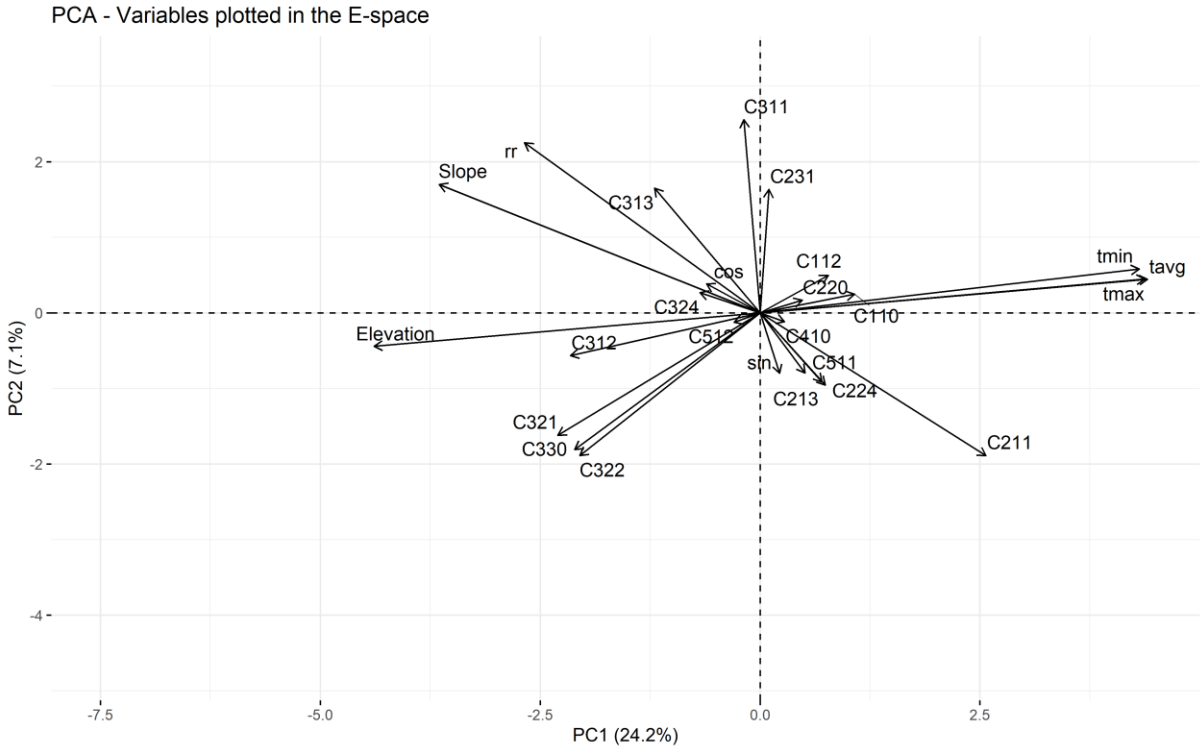
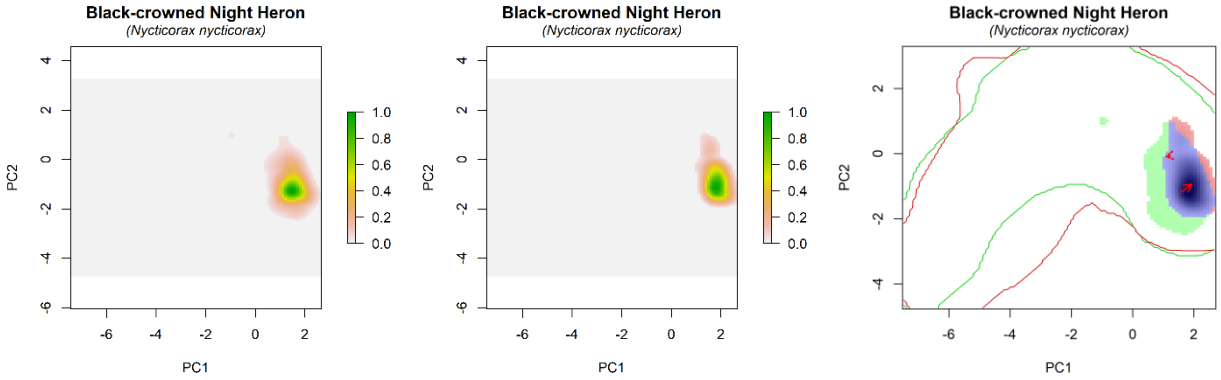


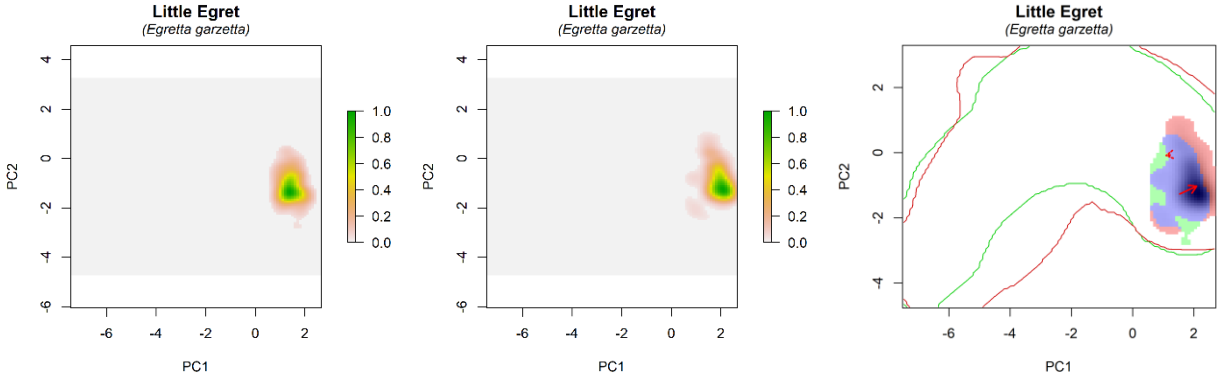
Figure S3. Niche quantification in the E-space for each species in T_1 (1992-95-96) and T_2 (2015-16-17) and niche changes between the two periods. The first plot represent the coordinates of the variables in the E-space to ease the interpretation of the niche respect to the PCA-axes. Niche in T_1 is shown in the left column, in T_2 in the middle column, and the overlap in the right column. In each row is represented a single species with its common and scientific name [97]. In the graphs of niche in T_1 and T_2 separately, the density of occurrence of species is depicted through a colored gradient from light grey (0) to green (1). In the graphs representing niche changes between T_1 and T_2, the red area indicates the E-space exclusively occupied in T_2, the green area the E-space exclusively occupied in T_1, and the blue area the E-space occupied in both T_1 and T_2. Color intensity of the filled area represents the density of occurrence of species in T_2. The green and red solid lines represent the whole extent of the available E-space in T_1 and T_2, respectively. Arrows indicate the centroids' shift from T_1 to T_2 for the available E-space (dashed arrow) and for the occupied E-space (solid arrow).




Black-crowned Night Heron
(Nycticorax nycticorax)
PC1
PC2

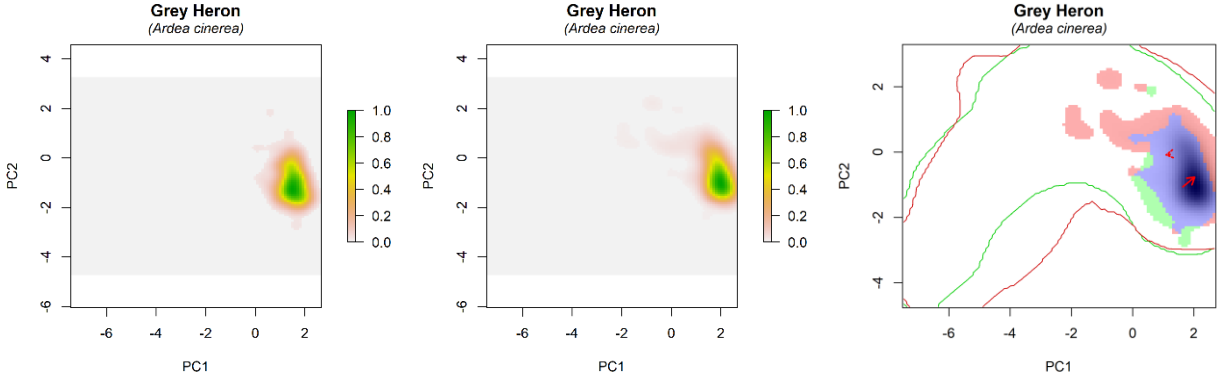
Black-crowned Night Heron
(Nycticorax nycticorax)
PC1
PC2

Black-crowned Night Heron
(Nycticorax nycticorax)
PC1
PC2


Little Egret
(Egretta garzetta)
PC1
PC2

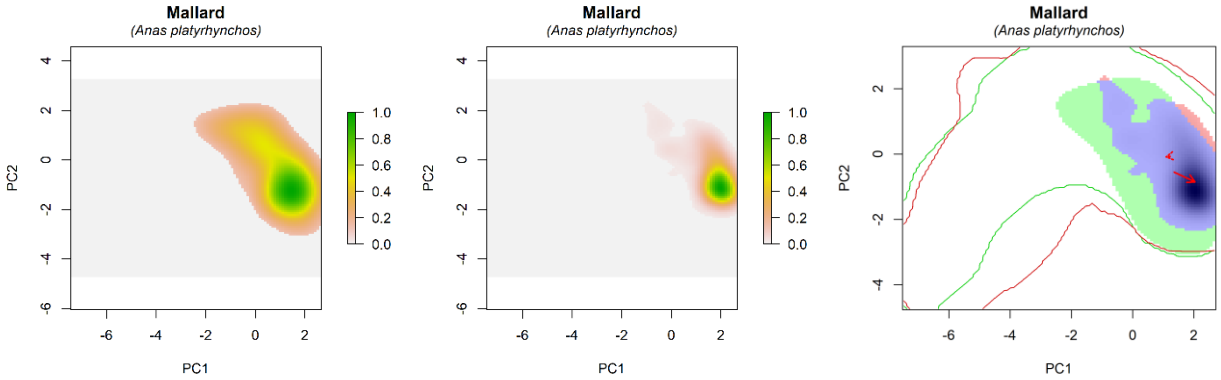
Little Egret
(Egretta garzetta)
PC1
PC2

Little Egret
(Egretta garzetta)
PC1
PC2


Grey Heron
(Ardea cinerea)
PC1
PC2

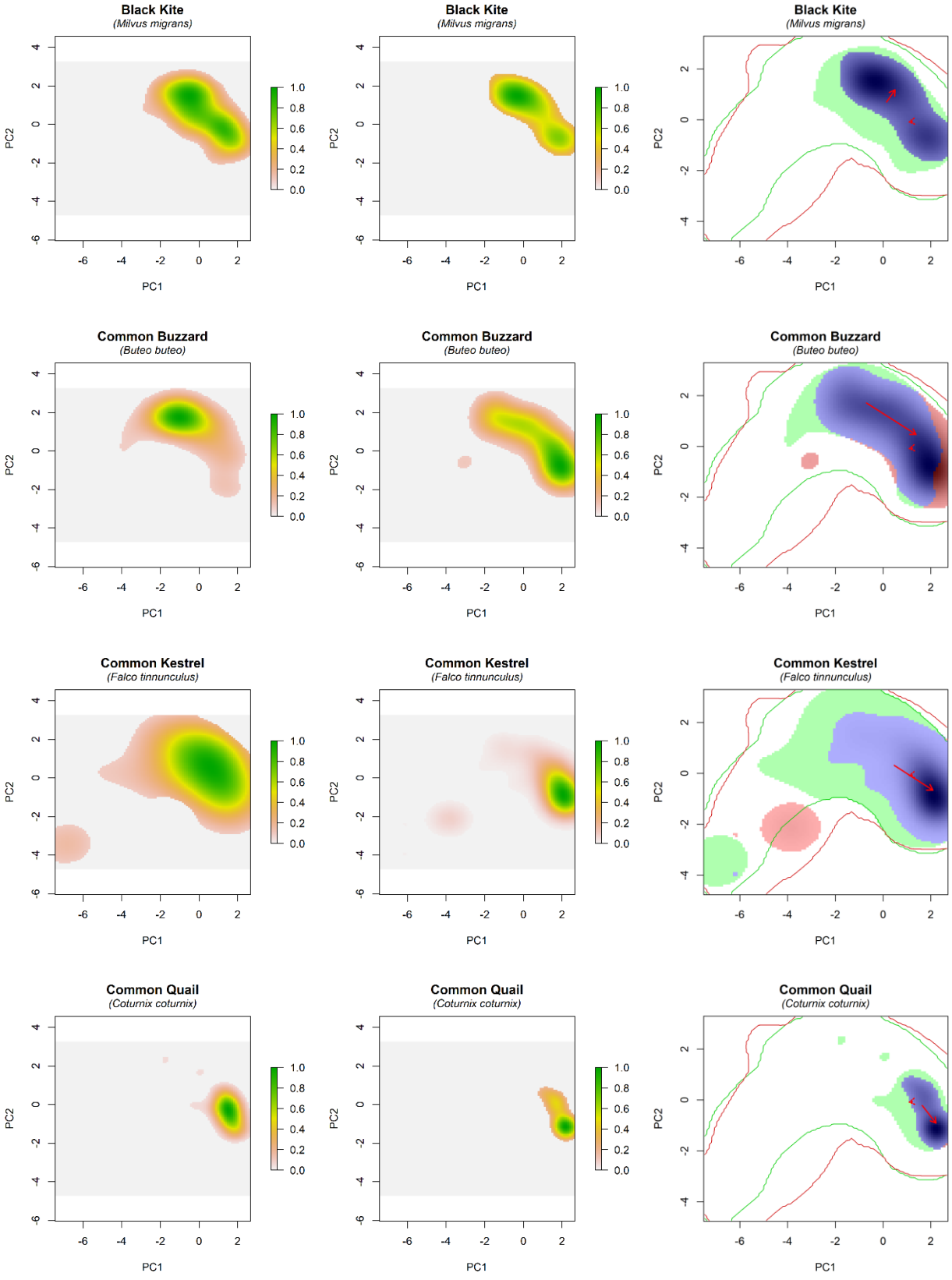
Grey Heron
(Ardea cinerea)
PC1
PC2

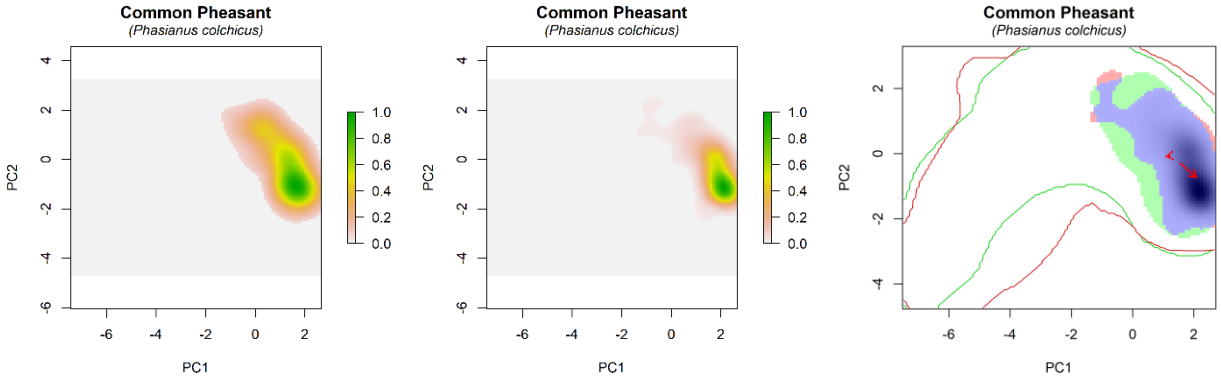
Grey Heron
(Ardea cinerea)
PC1
PC2


Mallard
(Anas platyrhynchos)
PC1
PC2

Mallard
(Anas platyrhynchos)
PC1
PC2

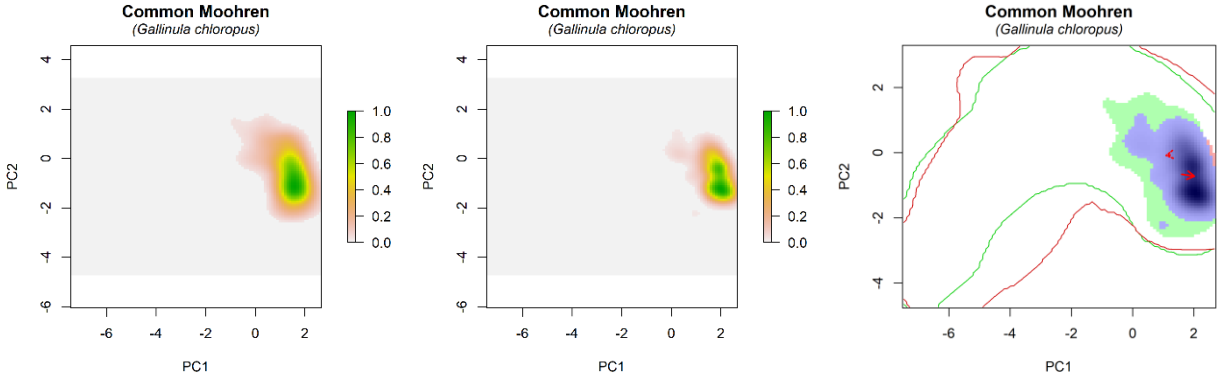
Mallard
(Anas platyrhynchos)
PC1
PC2


Black Kite
(Milvus migrans)
Black Kite
(Milvus migrans)
Black Kite
(Milvus migrans)
Common Buzzard
(Buteo buteo)
Common Buzzard
(Buteo buteo)
Common Buzzard
(Buteo buteo)
Common Kestrel
(Falco tinnunculus)
Common Kestrel
(Falco tinnunculus)
Common Kestrel
(Falco tinnunculus)
Common Quail
(Coturnix coturnix)
Common Quail
(Coturnix coturnix)
Common Quail
(Coturnix coturnix)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0


Common Pheasant
(Phasianus colchicus)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

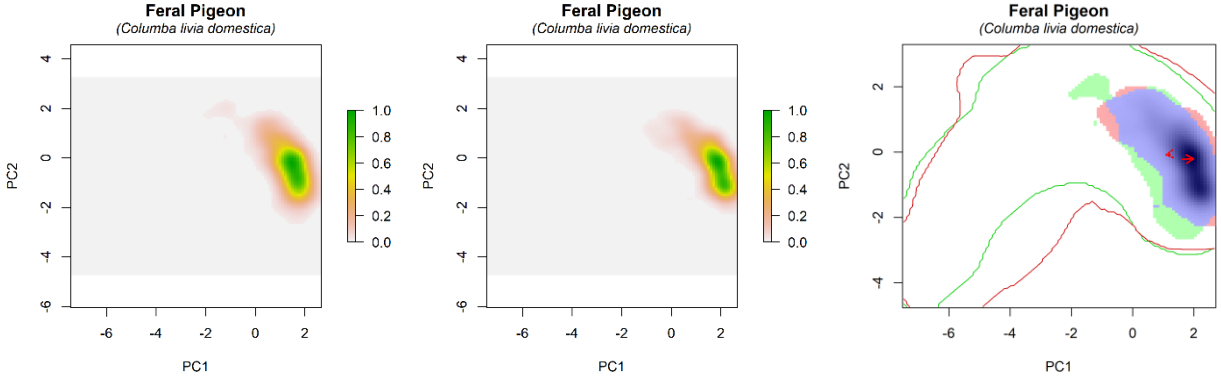
Common Pheasant
(Phasianus colchicus)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

Common Pheasant
(Phasianus colchicus)
PC2
PC1


Common Moohren
(Gallinula chloropus)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

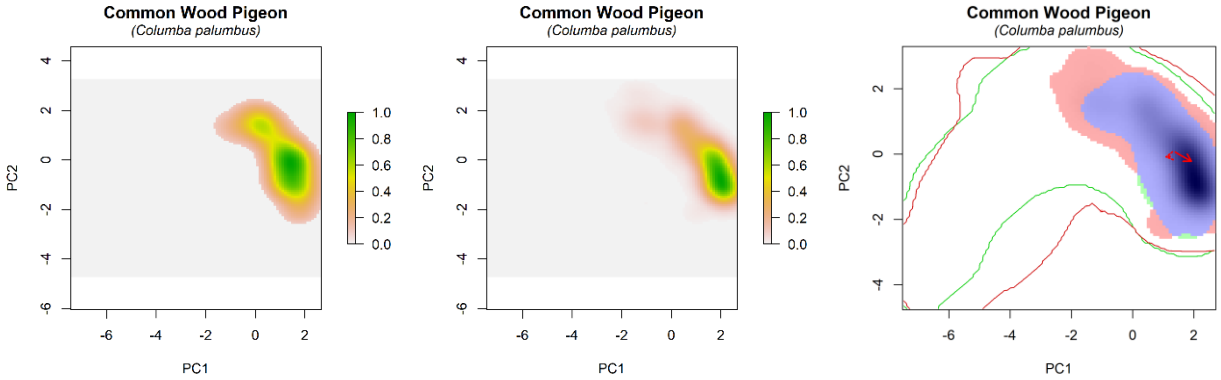
Common Moohren
(Gallinula chloropus)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

Common Moohren
(Gallinula chloropus)
PC2
PC1


Feral Pigeon
(Columba livia domestica)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

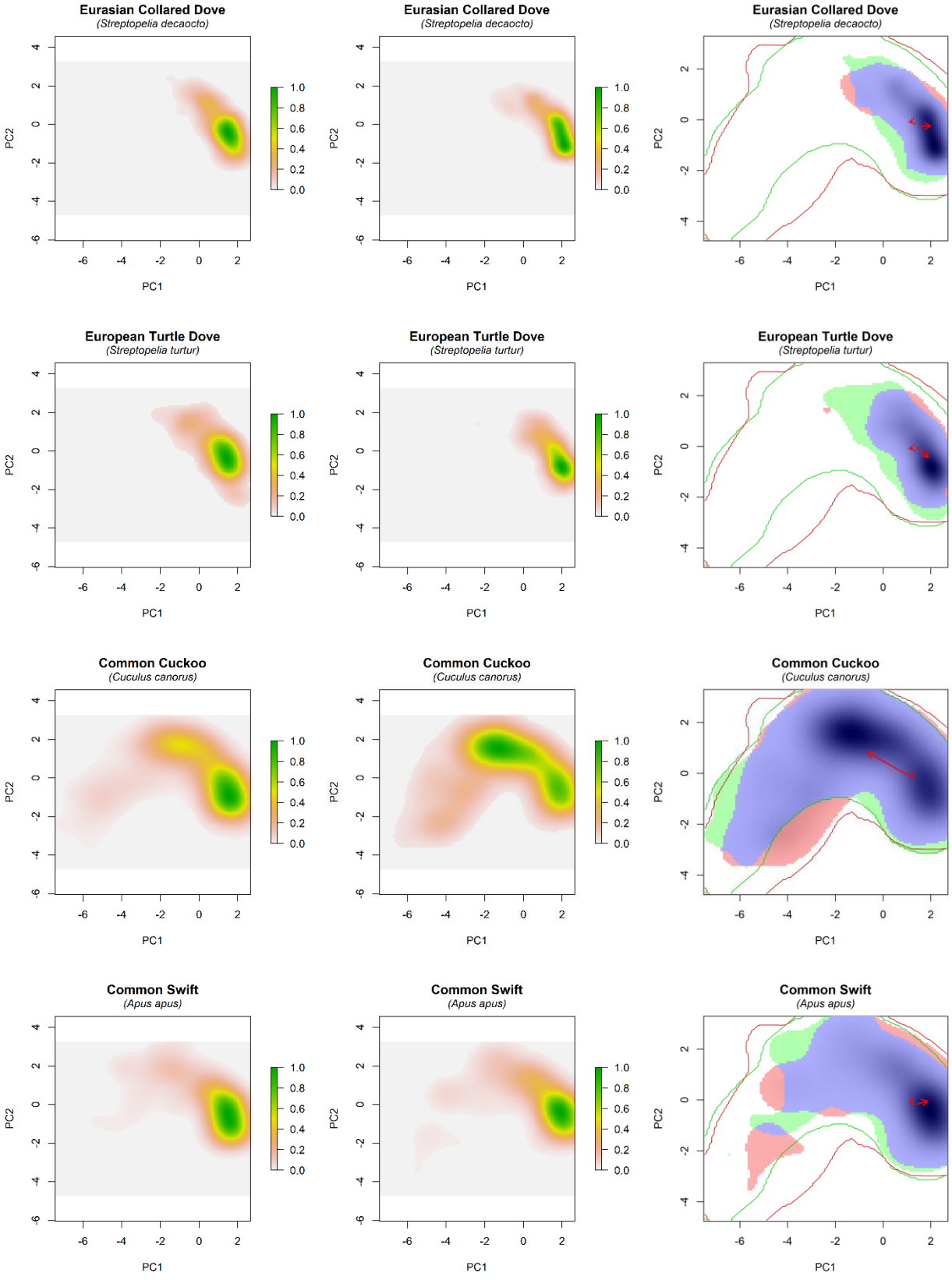
Feral Pigeon
(Columba livia domestica)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

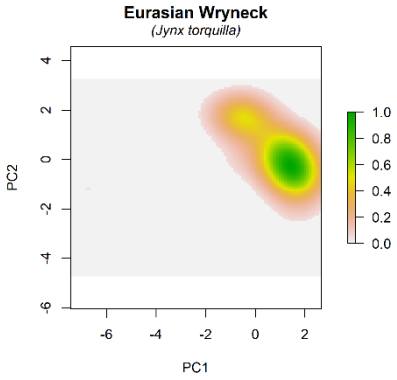
Feral Pigeon
(Columba livia domestica)
PC2
PC1

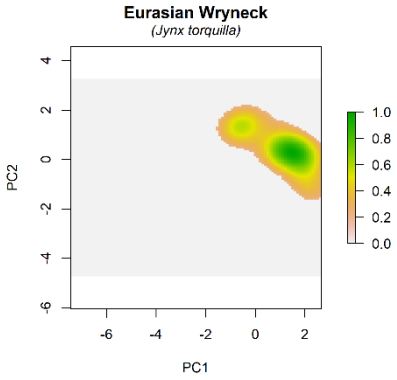

Common Wood Pigeon
(Columba palumbus)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

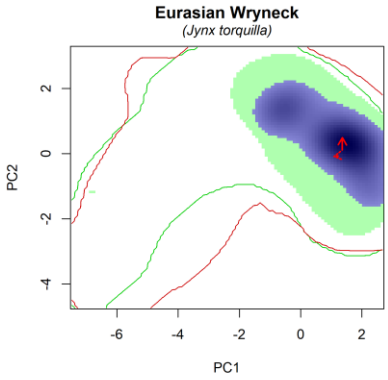
Common Wood Pigeon
(Columba palumbus)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

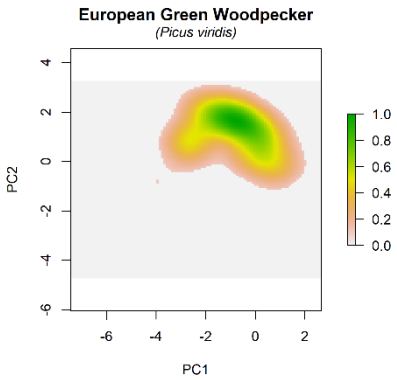
Common Wood Pigeon
(Columba palumbus)
PC2
PC1

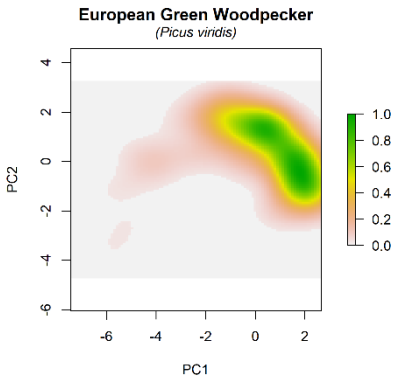

Eurasian Collared Dove
(Streptopelia decaocto)
Eurasian Collared Dove
(Streptopelia decaocto)
Eurasian Collared Dove
(Streptopelia decaocto)
European Turtle Dove
(Streptopelia turtur)
European Turtle Dove
(Streptopelia turtur)
European Turtle Dove
(Streptopelia turtur)
Common Cuckoo
(Cuculus canorus)
Common Cuckoo
(Cuculus canorus)
Common Cuckoo
(Cuculus canorus)
Common Swift
(Apus apus)
Common Swift
(Apus apus)
Common Swift
(Apus apus)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0

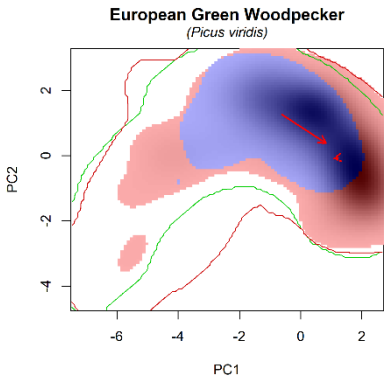

Eurasian Wryneck
(Jynx torquilla)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

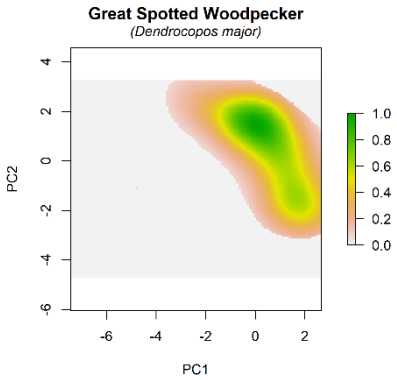

Eurasian Wryneck
(Jynx torquilla)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

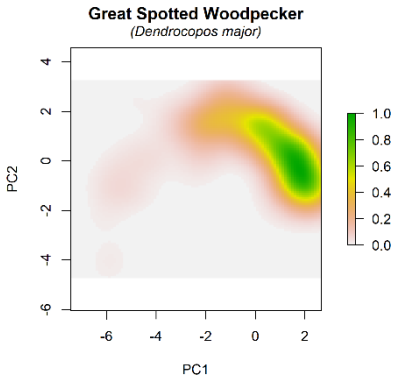

Eurasian Wryneck
(Jynx torquilla)
PC2
PC1

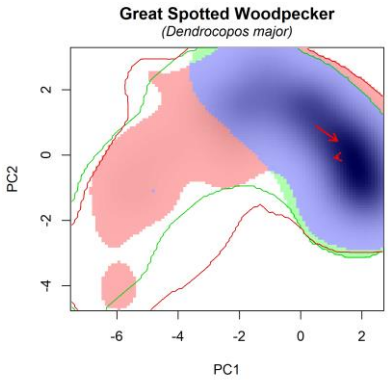

European Green Woodpecker
(Picus viridis)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

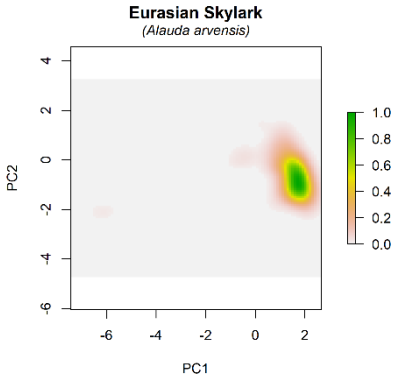

European Green Woodpecker
(Picus viridis)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

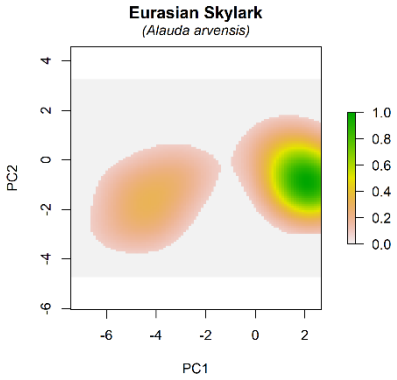

European Green Woodpecker
(Picus viridis)
PC2
PC1

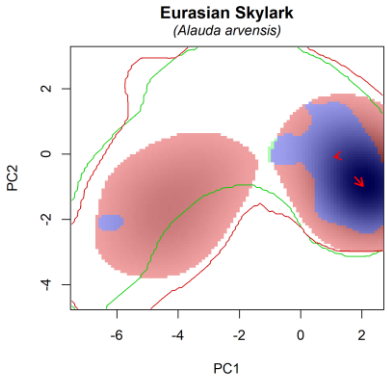

Great Spotted Woodpecker
(Dendrocopos major)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

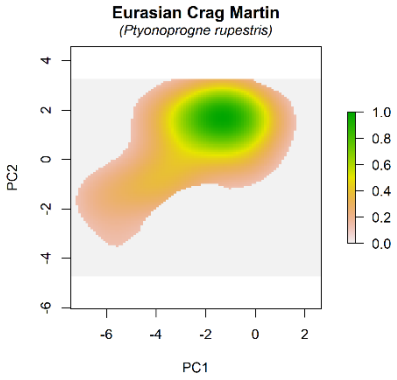

Great Spotted Woodpecker
(Dendrocopos major)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

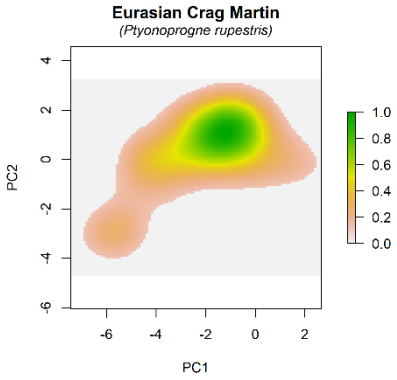

Great Spotted Woodpecker
(Dendrocopos major)
PC2
PC1

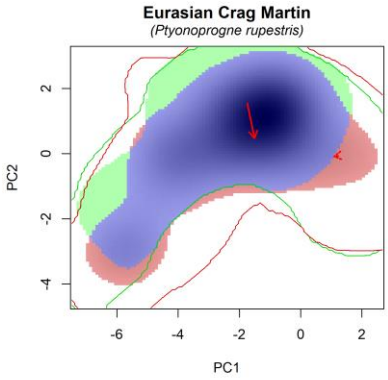

Eurasian Skylark
(Alauda arvensis)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

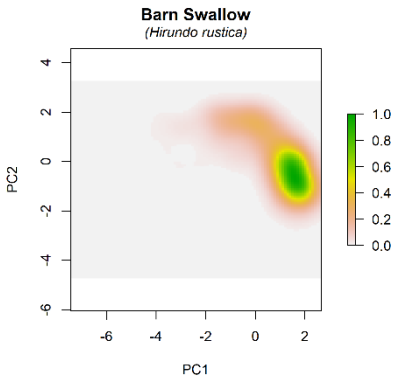

Eurasian Skylark
(Alauda arvensis)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

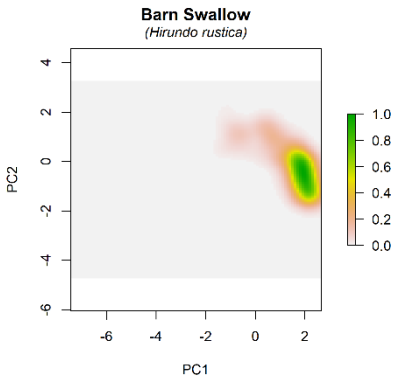

Eurasian Skylark
(Alauda arvensis)
PC2
PC1

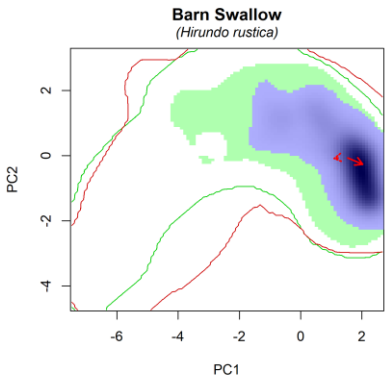

Eurasian Crag Martin
(Ptyonoprogne rupestris)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

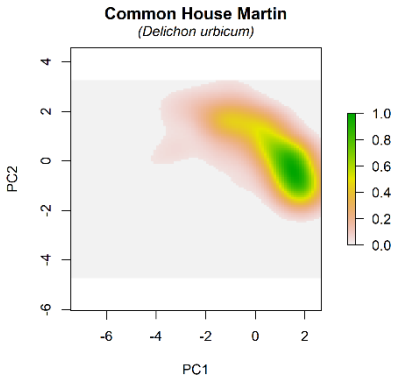

Eurasian Crag Martin
(Ptyonoprogne rupestris)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

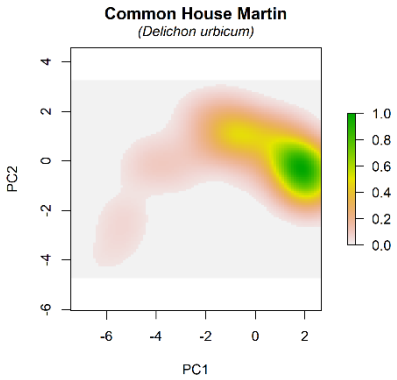

Eurasian Crag Martin
(Ptyonoprogne rupestris)
PC2
PC1

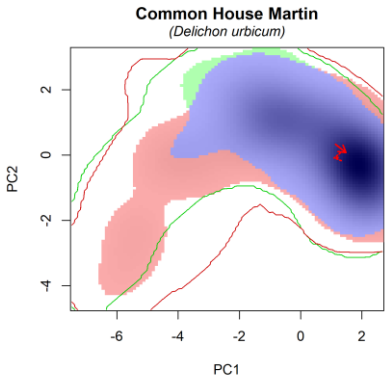

Barn Swallow
(Hirundo rustica)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

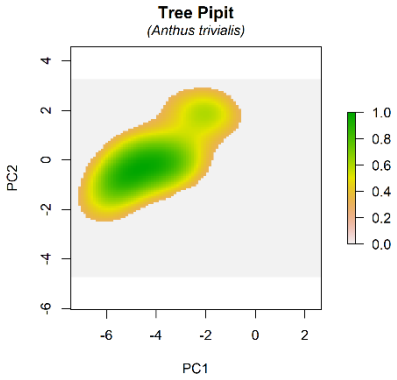

Barn Swallow
(Hirundo rustica)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

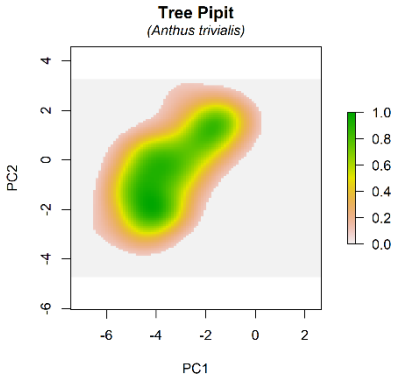

Barn Swallow
(Hirundo rustica)
PC2
PC1

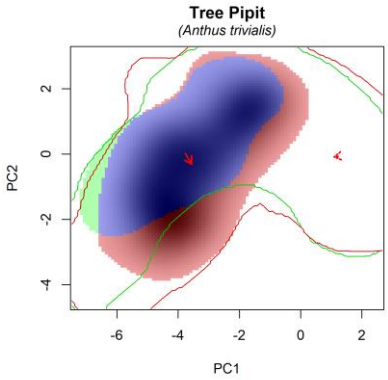

Common House Martin
(Delichon urbicum)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

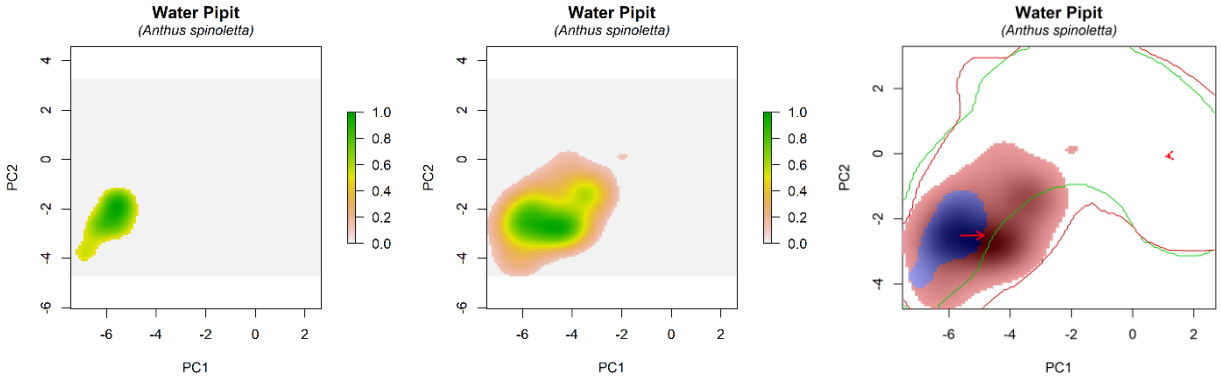

Common House Martin
(Delichon urbicum)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0


Common House Martin
(Delichon urbicum)
PC2
PC1


Tree Pipit
(Anthus trivialis)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

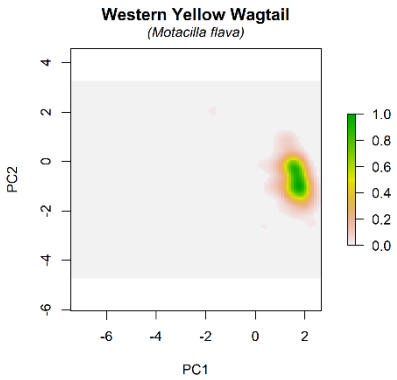

Tree Pipit
(Anthus trivialis)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

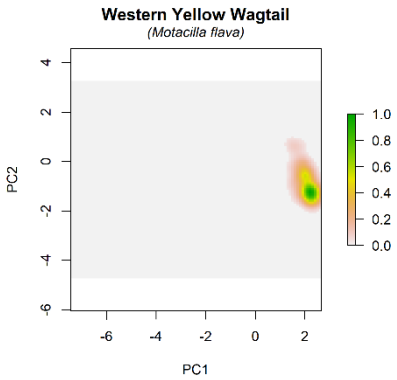

Tree Pipit
(Anthus trivialis)
PC2
PC1

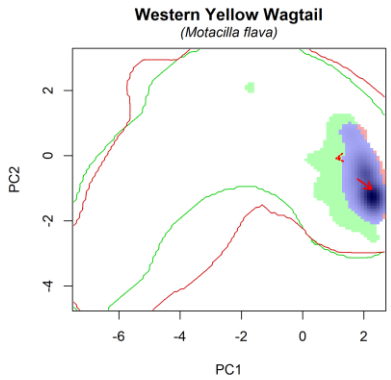

Water Pipit
(Anthus spinoletta)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

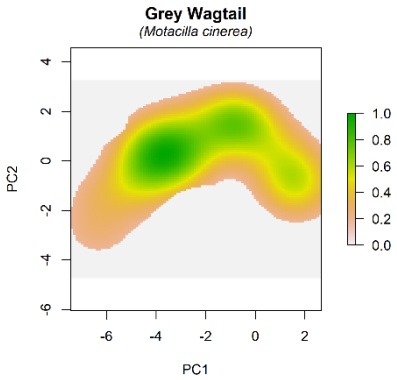
Water Pipit
(Anthus spinoletta)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

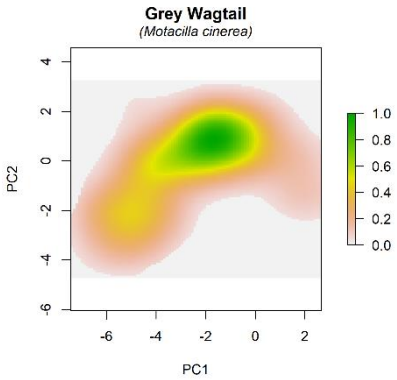
Water Pipit
(Anthus spinoletta)
PC2
PC1

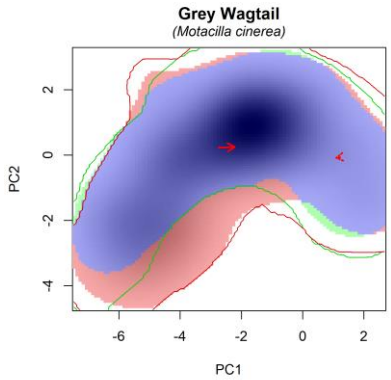

Western Yellow Wagtail
(Motacilla flava)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

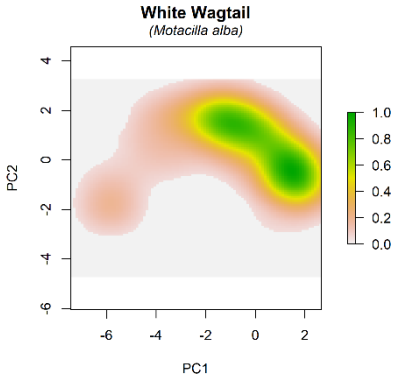

Western Yellow Wagtail
(Motacilla flava)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

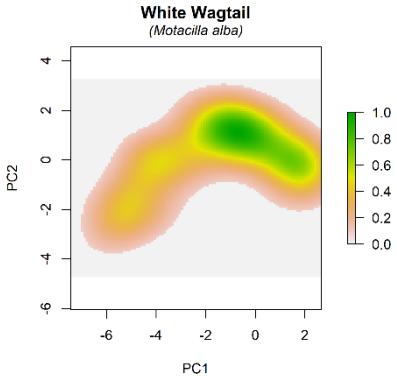

Western Yellow Wagtail
(Motacilla flava)
PC2
PC1

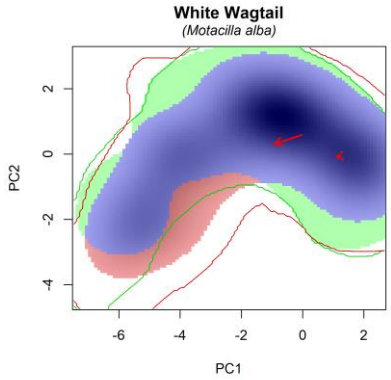

Grey Wagtail
(Motacilla cinerea)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

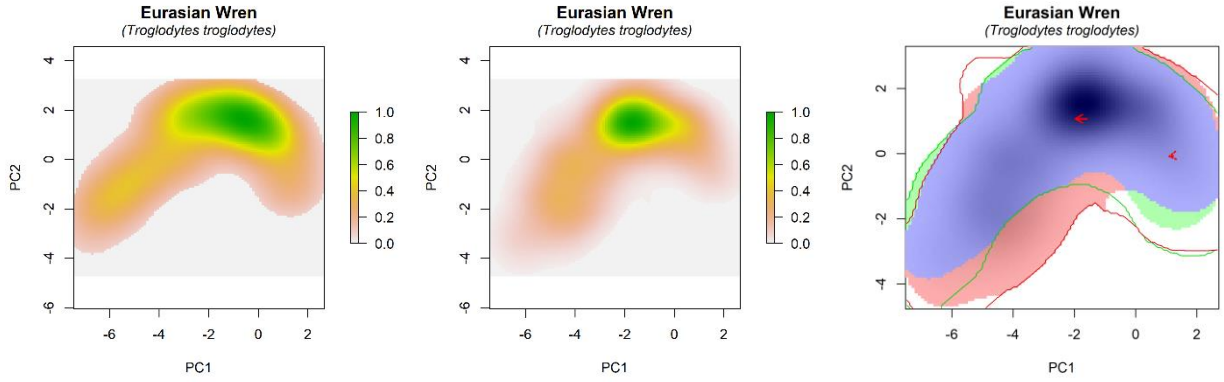

Grey Wagtail
(Motacilla cinerea)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0


Grey Wagtail
(Motacilla cinerea)
PC2
PC1


White Wagtail
(Motacilla alba)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

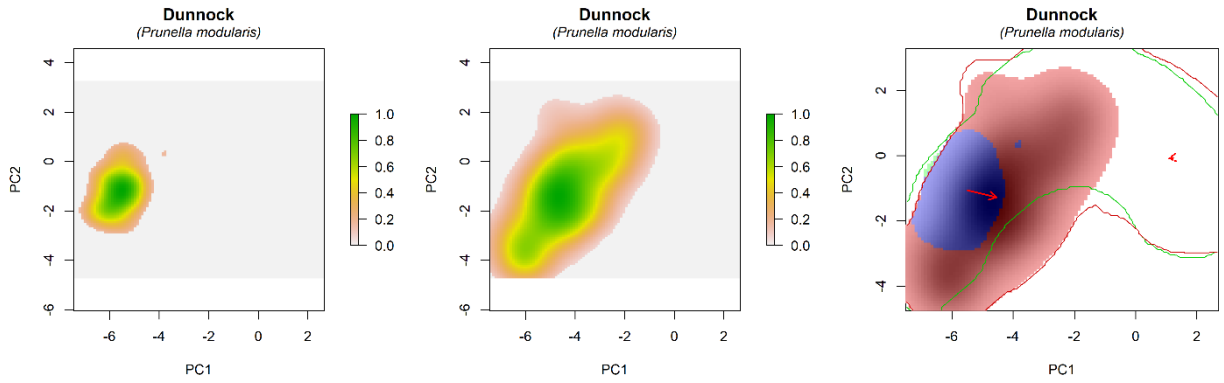

White Wagtail
(Motacilla alba)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0


White Wagtail
(Motacilla alba)
PC2
PC1


Eurasian Wren
(Troglodytes troglodytes)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

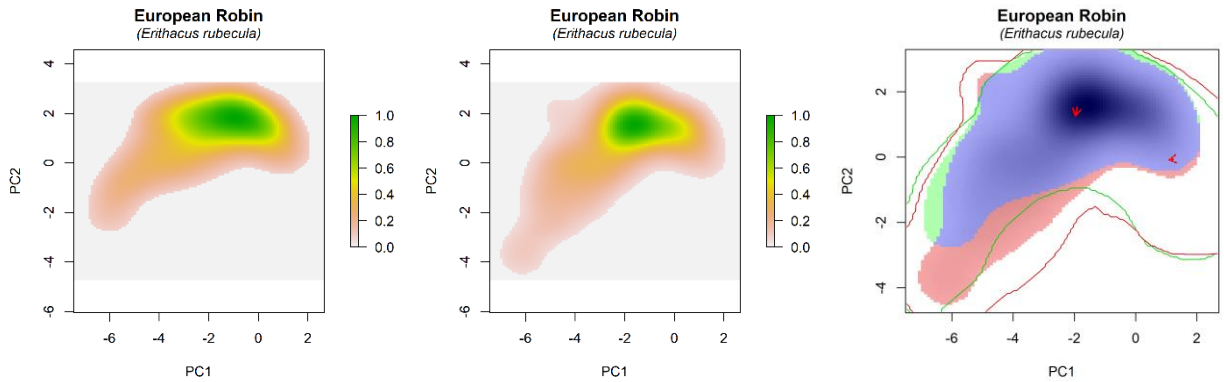
Eurasian Wren
(Troglodytes troglodytes)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

Eurasian Wren
(Troglodytes troglodytes)
PC2
PC1


Dunnock
(Prunella modularis)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

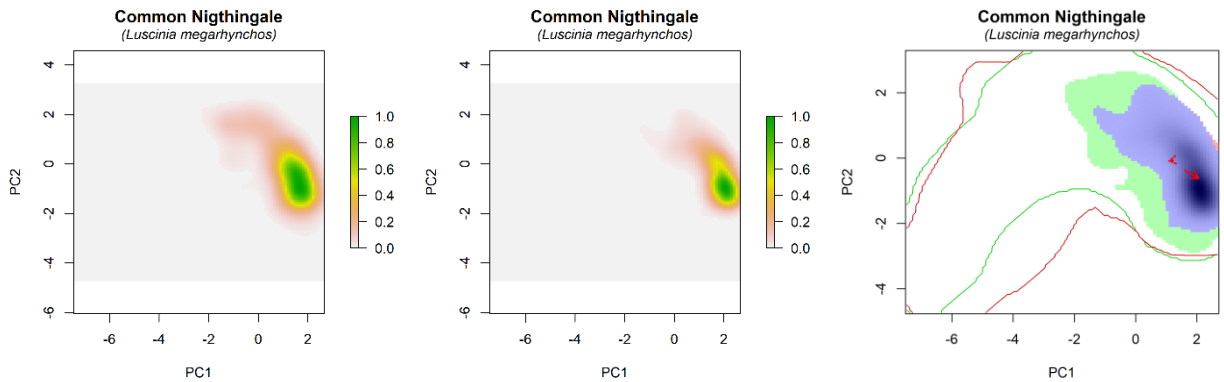
Dunnock
(Prunella modularis)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

Dunnock
(Prunella modularis)
PC2
PC1


European Robin
(Erithacus rubecula)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

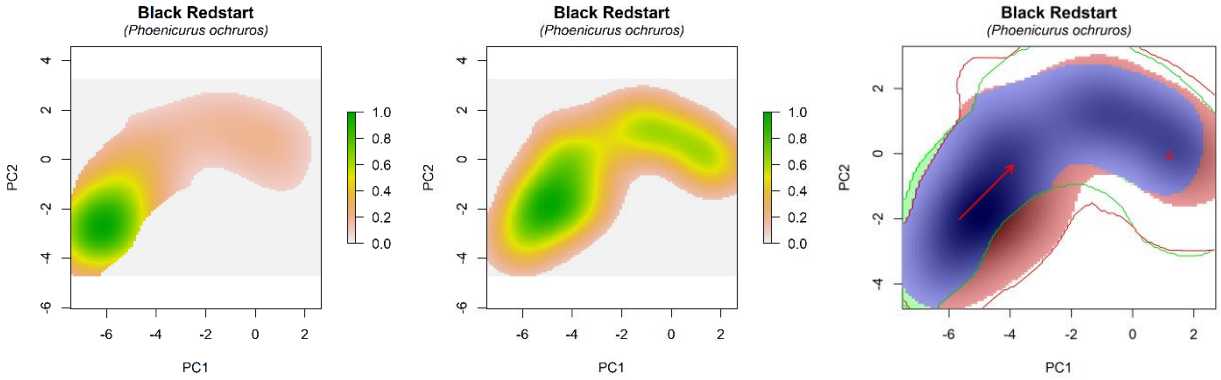
European Robin
(Erithacus rubecula)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

European Robin
(Erithacus rubecula)
PC2
PC1


Common Nigthingale
(Luscinia megarhynchos)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

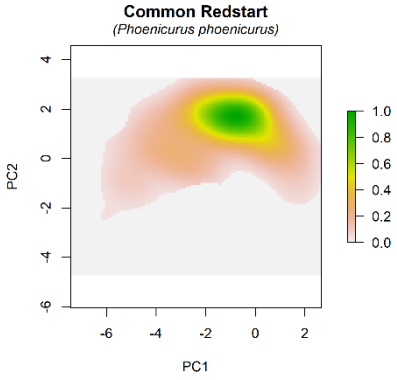
Common Nigthingale
(Luscinia megarhynchos)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

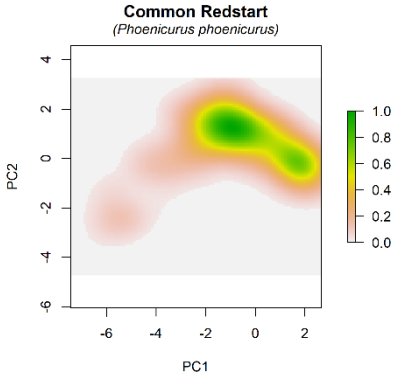
Common Nigthingale
(Luscinia megarhynchos)
PC2
PC1

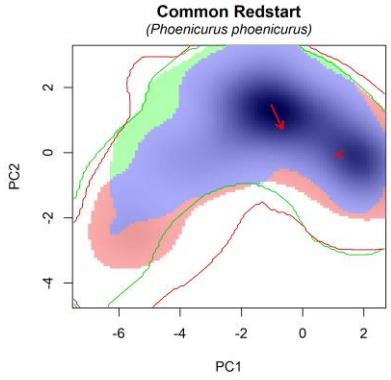

Black Redstart
(Phoenicurus ochruros)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

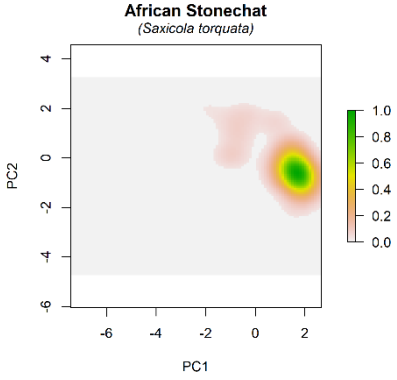
Black Redstart
(Phoenicurus ochruros)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

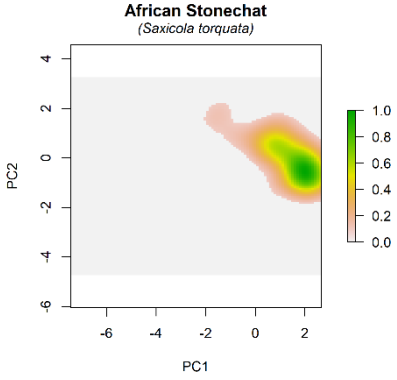
Black Redstart
(Phoenicurus ochruros)
PC2
PC1

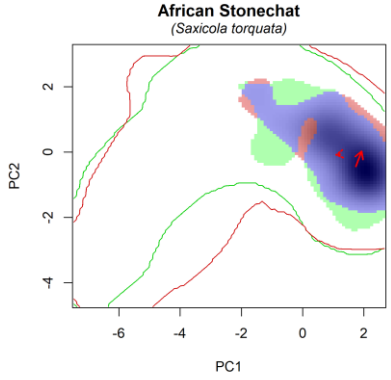

Common Redstart
(Phoenicurus phoenicurus)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

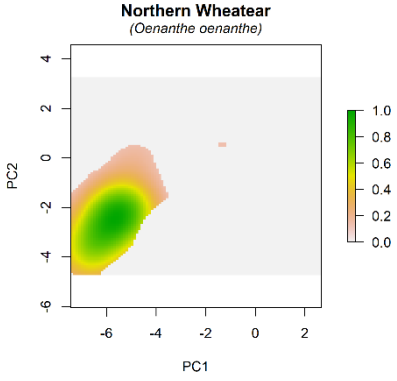

Common Redstart
(Phoenicurus phoenicurus)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

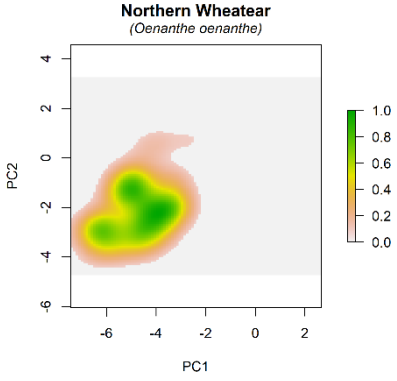

Common Redstart
(Phoenicurus phoenicurus)
PC2
PC1

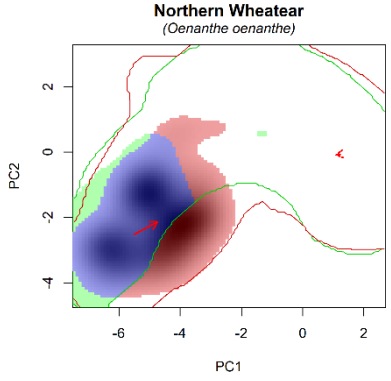

African Stonechat
(Saxicola torquata)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

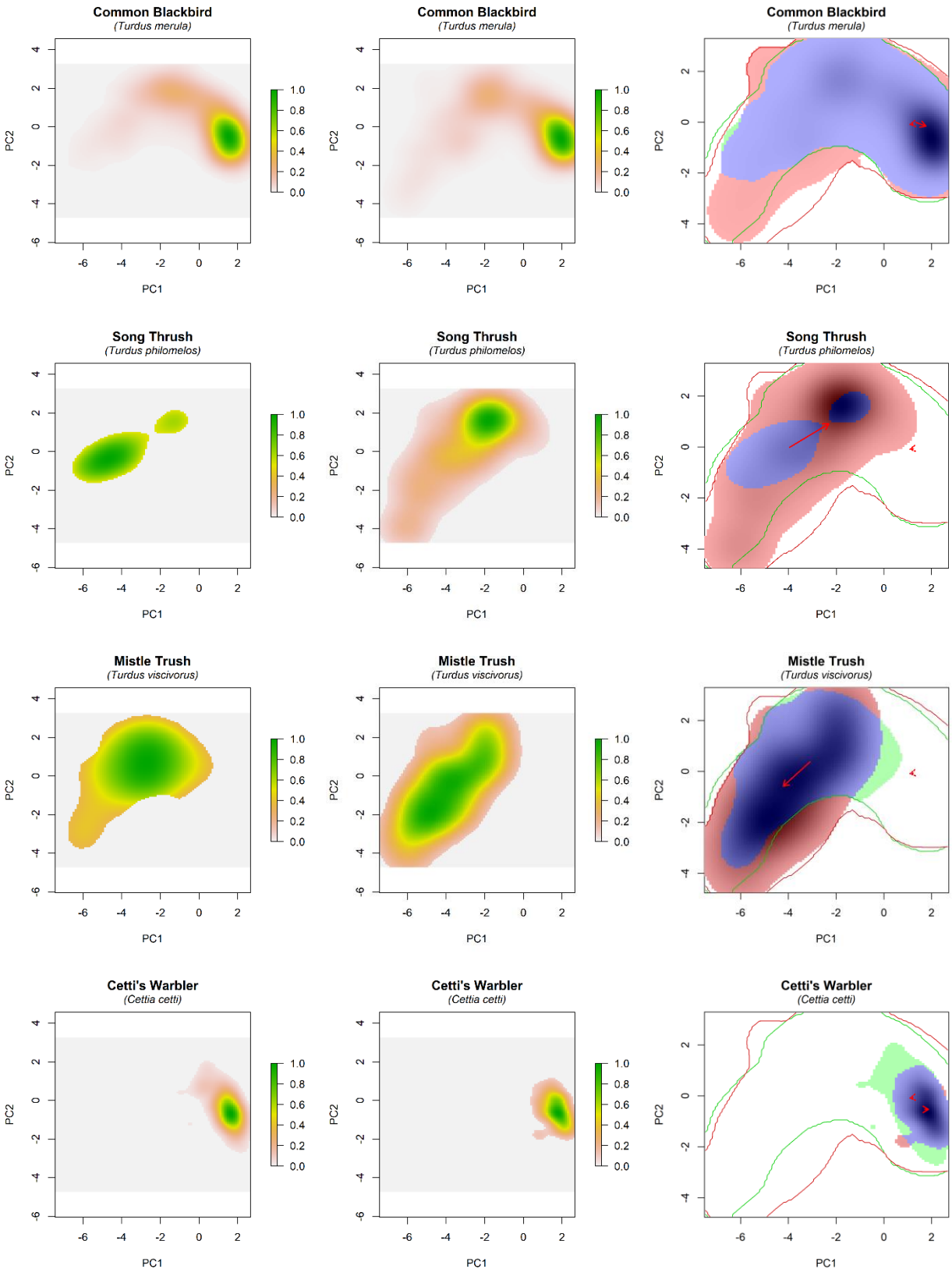

African Stonechat
(Saxicola torquata)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

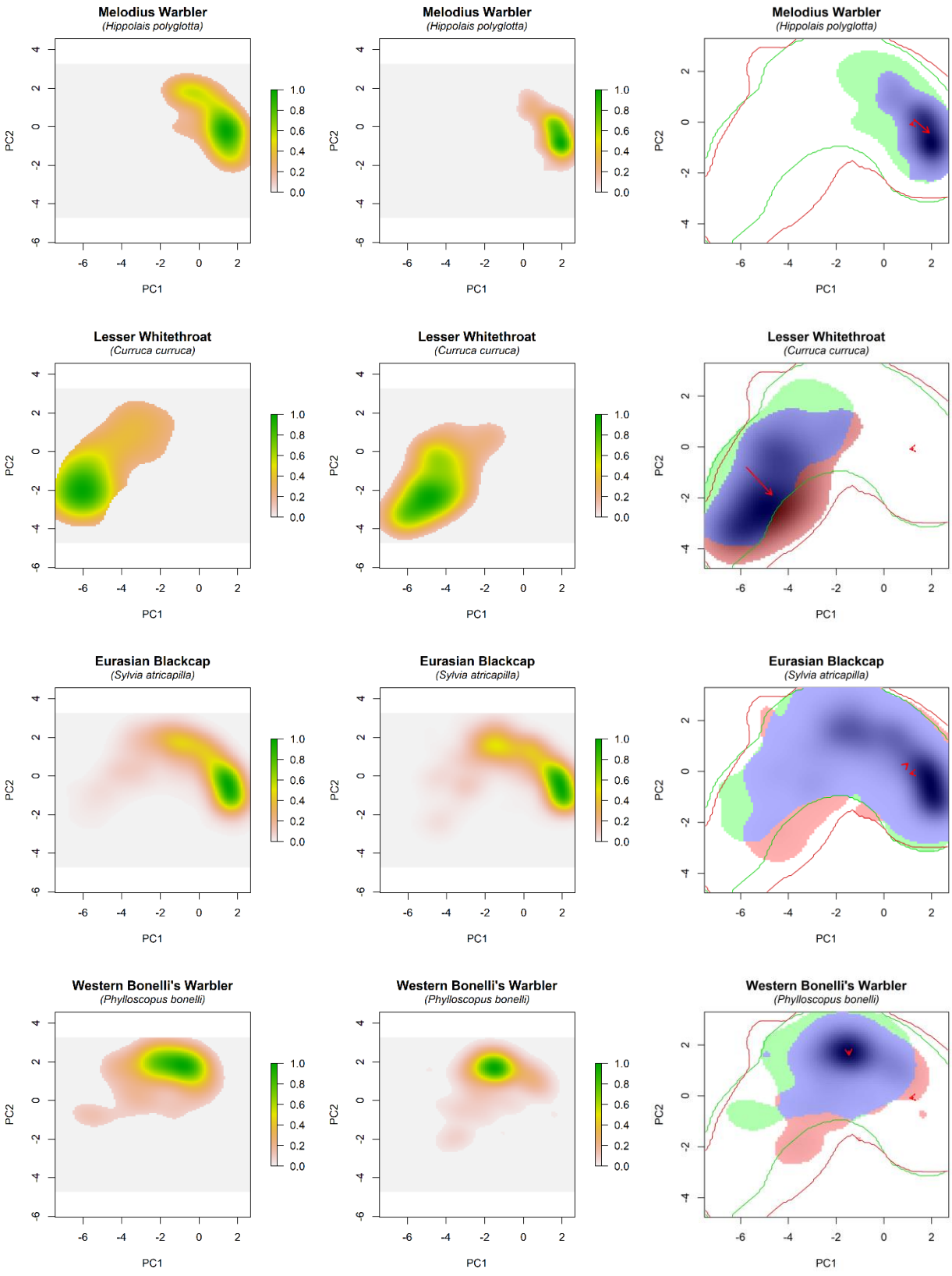

African Stonechat
(Saxicola torquata)
PC2
PC1

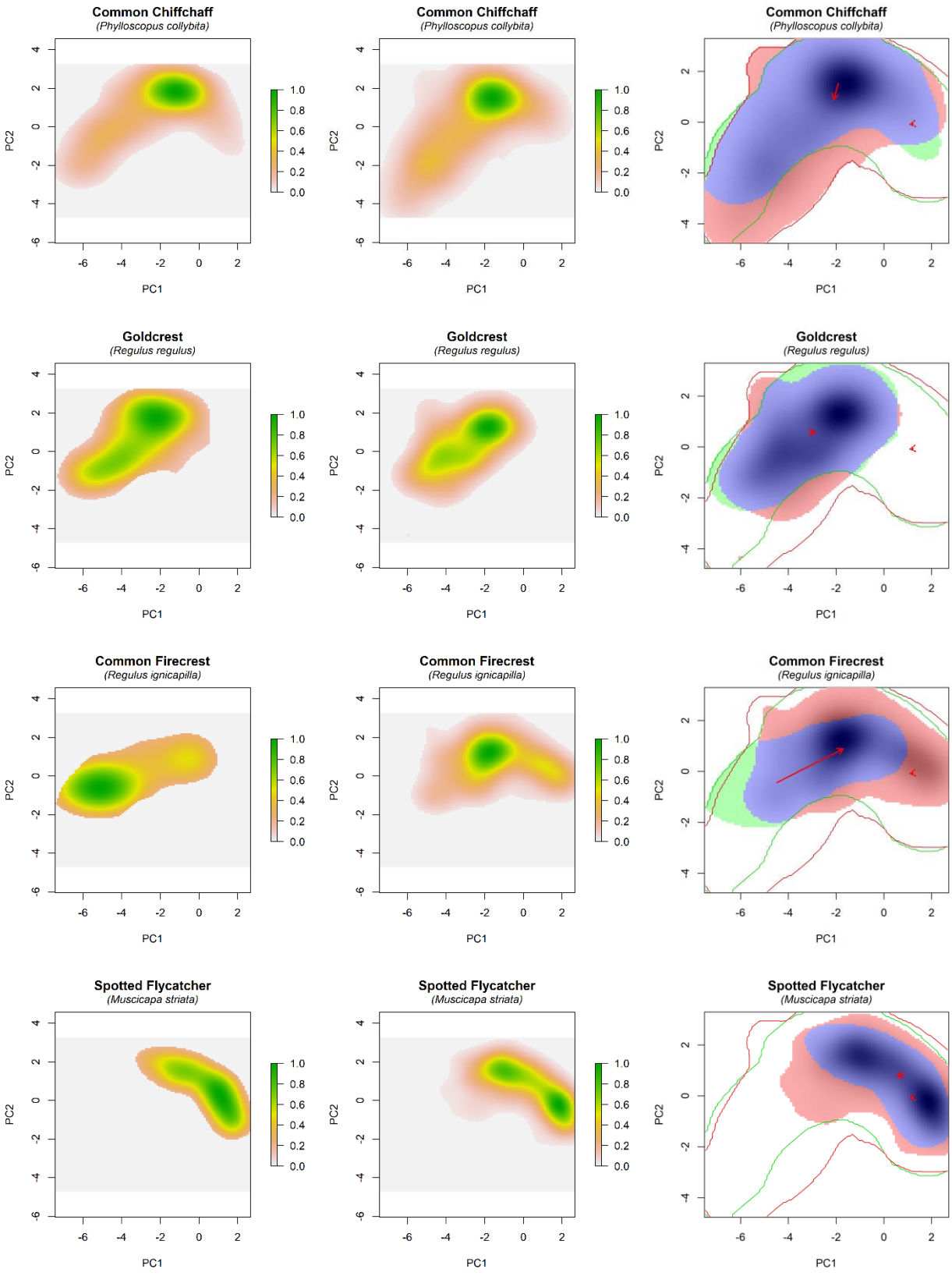

Northern Wheatear
(Oenanthe oenanthe)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

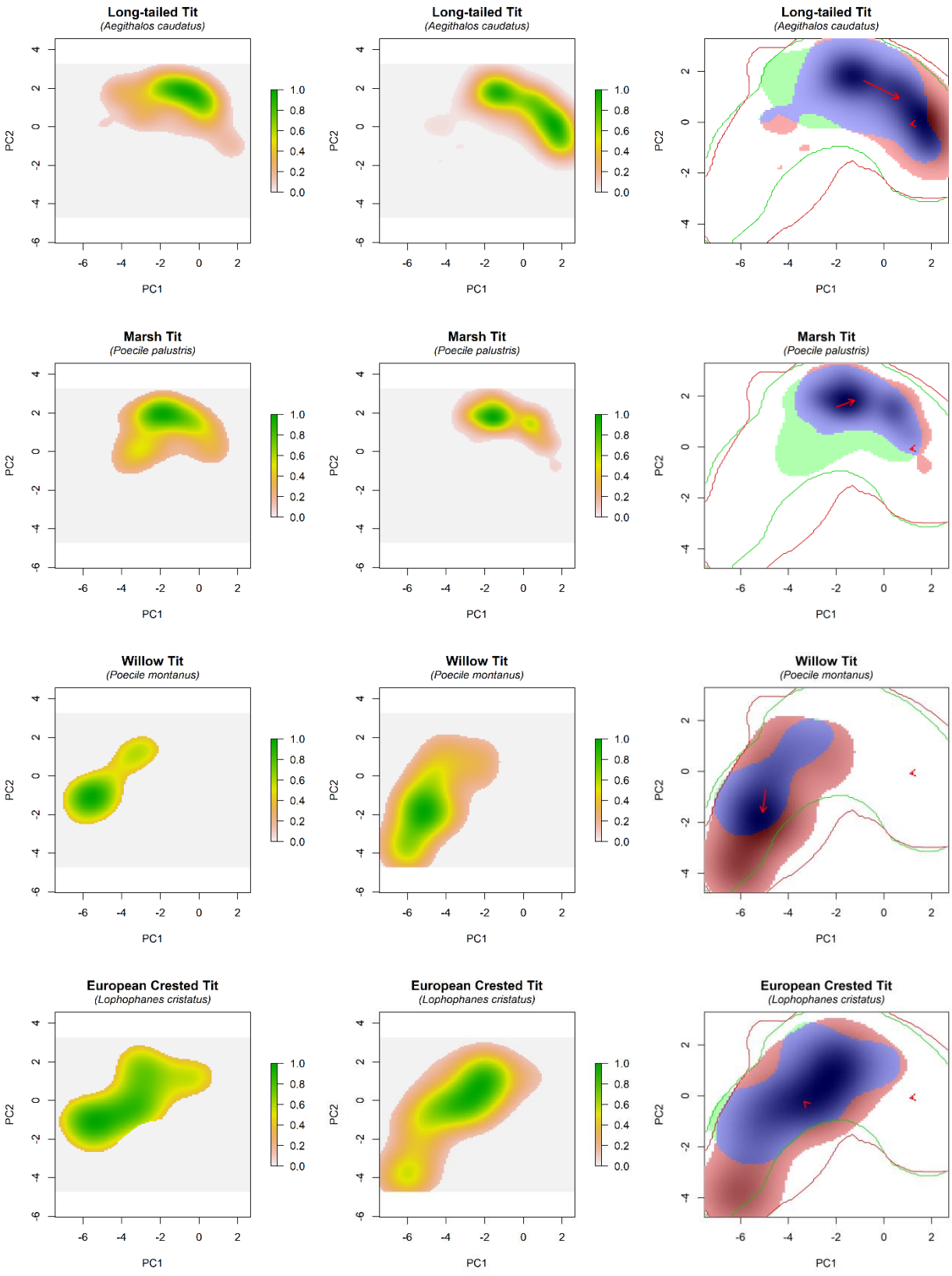

Northern Wheatear
(Oenanthe oenanthe)
PC2
PC1
1.0
0.8
0.6
0.4
0.2
0.0

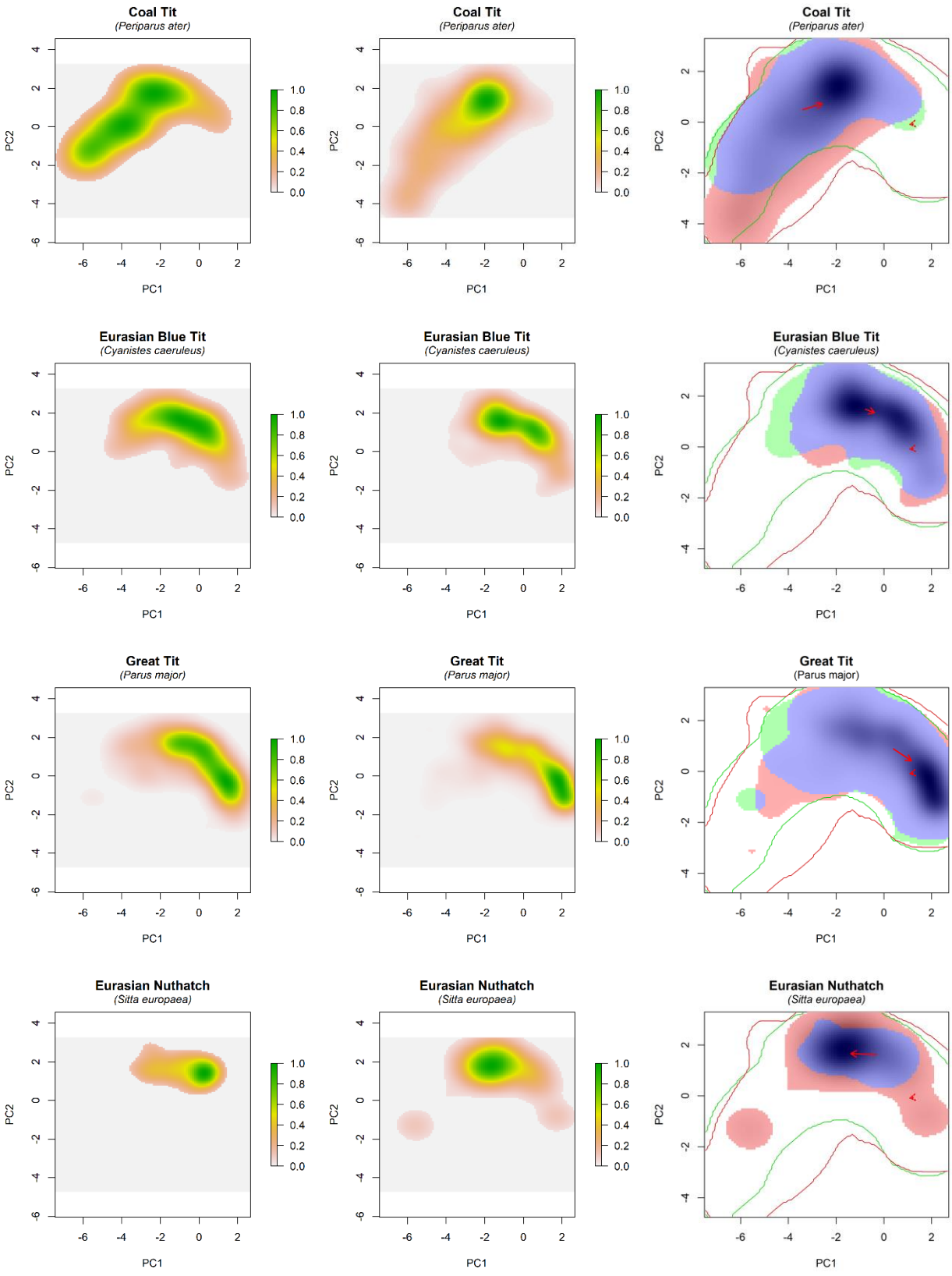

Northern Wheatear
(Oenanthe oenanthe)
PC2
PC1

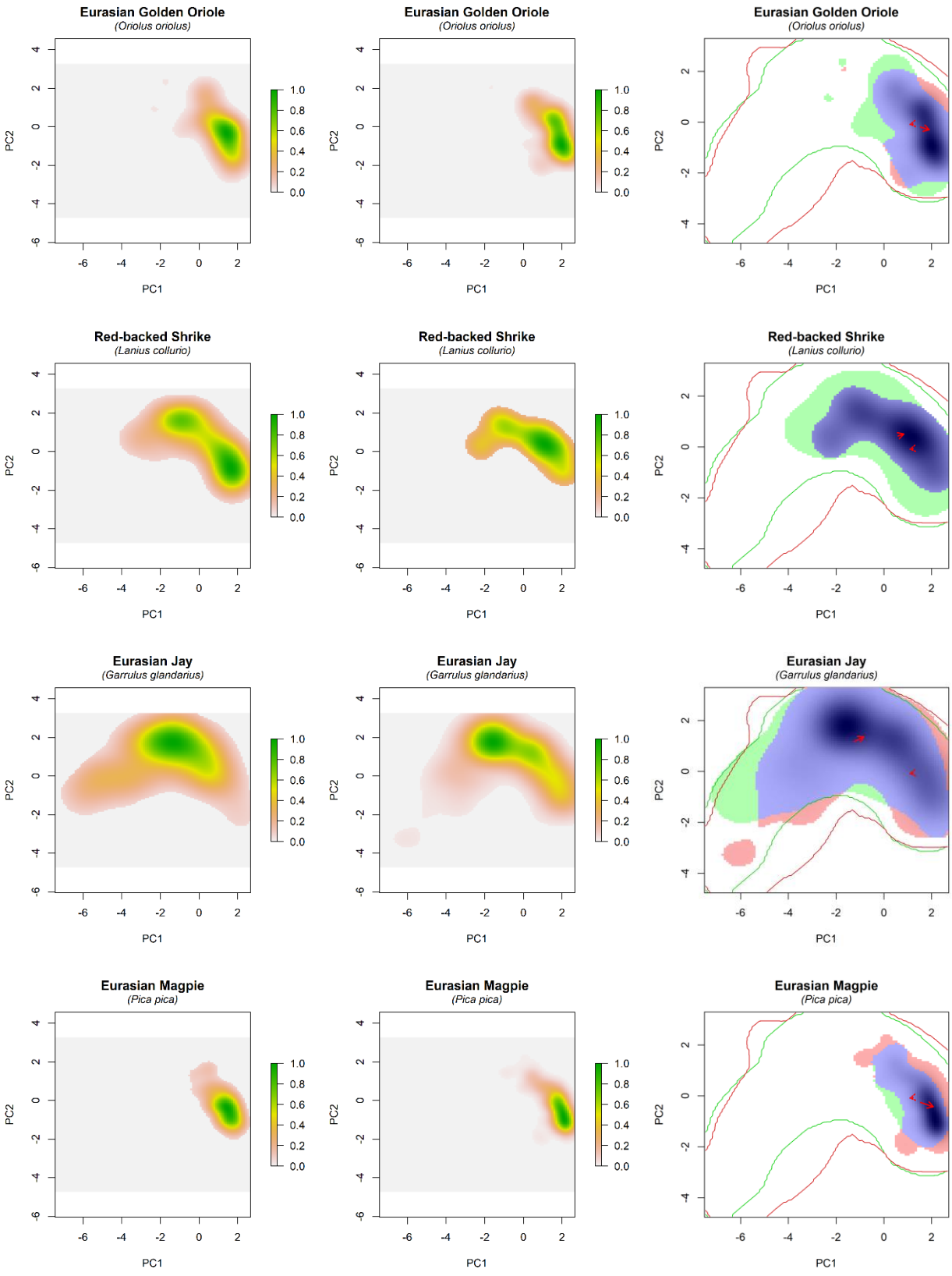

Common Blackbird
(Turdus merula)
Common Blackbird
(Turdus merula)
Common Blackbird
(Turdus merula)
Song Thrush
(Turdus philomelos)
Song Thrush
(Turdus philomelos)
Song Thrush
(Turdus philomelos)
Mistle Trush
(Turdus viscivorus)
Mistle Trush
(Turdus viscivorus)
Mistle Trush
(Turdus viscivorus)
Cetti's Warbler
(Cettia cetti)
Cetti's Warbler
(Cettia cetti)
Cetti's Warbler
(Cettia cetti)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0

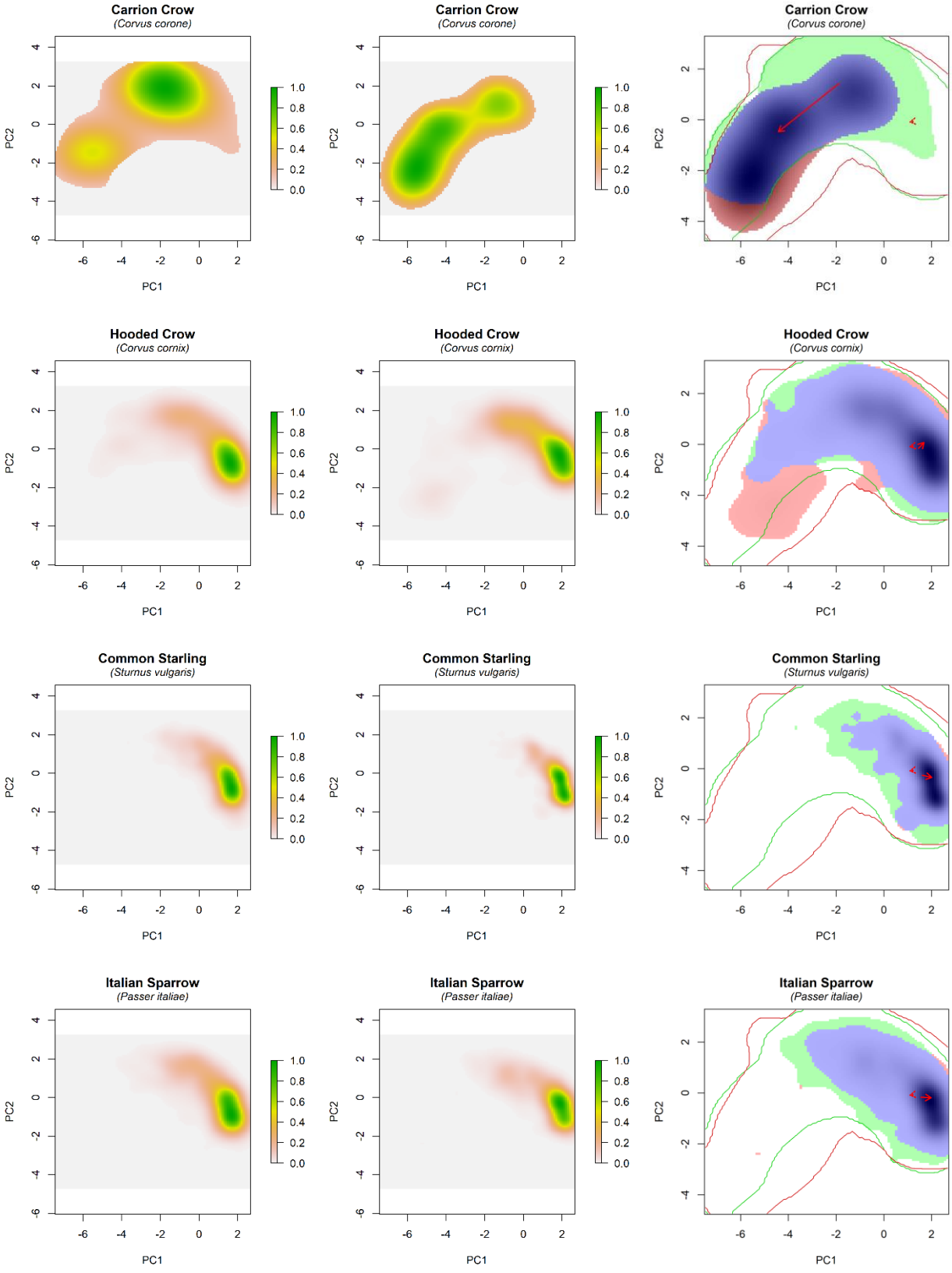

Melodius Warbler
(Hippolais polyglotta)
Melodius Warbler
(Hippolais polyglotta)
Melodius Warbler
(Hippolais polyglotta)
Lesser Whitethroat
(Curruca curruca)
Lesser Whitethroat
(Curruca curruca)
Lesser Whitethroat
(Curruca curruca)
Eurasian Blackcap
(Sylvia atricapilla)
Eurasian Blackcap
(Sylvia atricapilla)
Eurasian Blackcap
(Sylvia atricapilla)
Western Bonelli's Warbler
(Phylloscopus bonelli)
Western Bonelli's Warbler
(Phylloscopus bonelli)
Western Bonelli's Warbler
(Phylloscopus bonelli)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0

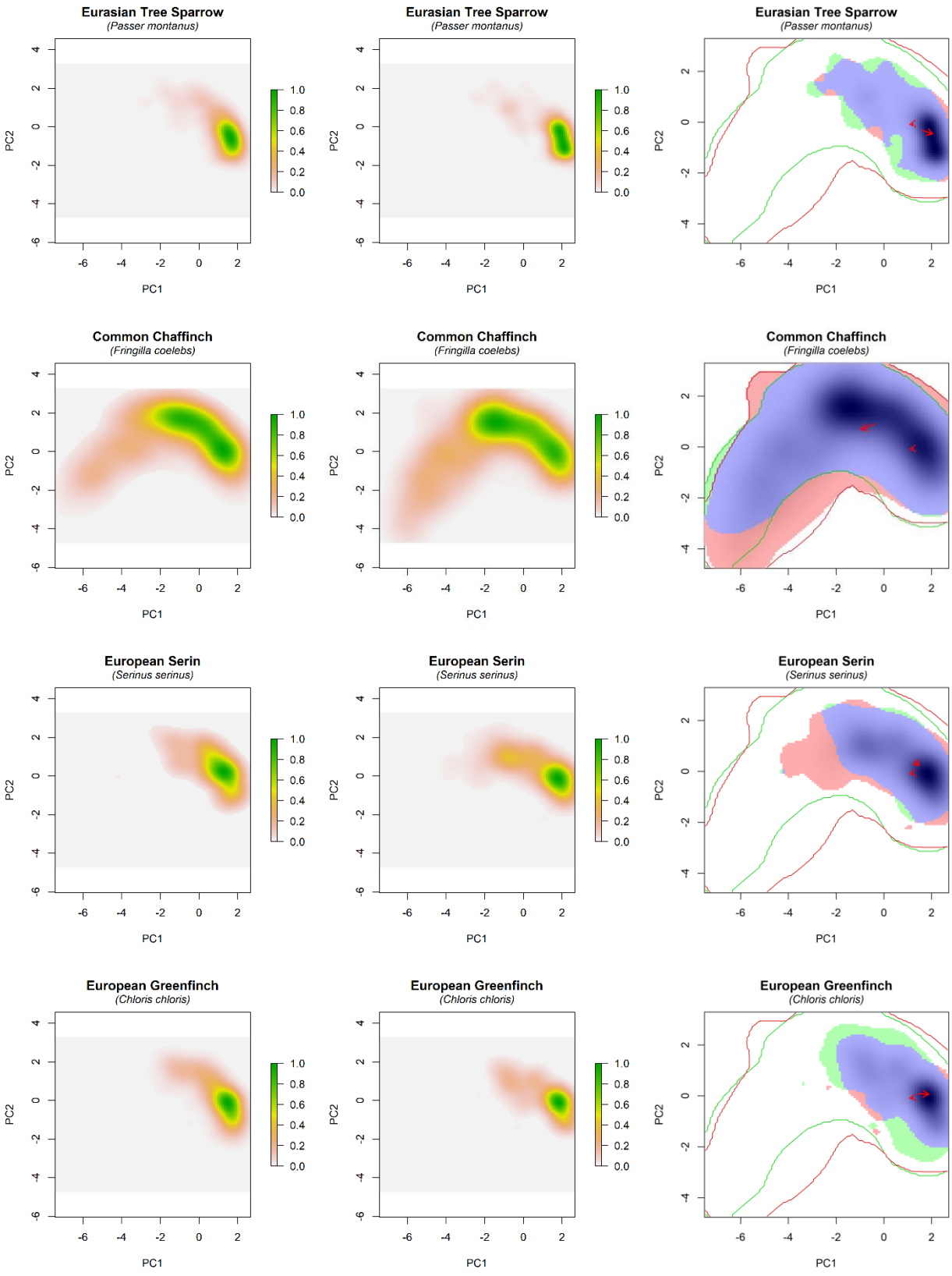

Common Chiffchaff
(Phylloscopus collybita)
Common Chiffchaff
(Phylloscopus collybita)
Common Chiffchaff
(Phylloscopus collybita)
Goldcrest
(Regulus regulus)
Goldcrest
(Regulus regulus)
Goldcrest
(Regulus regulus)
Common Firecrest
(Regulus ignicapilla)
Common Firecrest
(Regulus ignicapilla)
Common Firecrest
(Regulus ignicapilla)
Spotted Flycatcher
(Muscicapa striata)
Spotted Flycatcher
(Muscicapa striata)
Spotted Flycatcher
(Muscicapa striata)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0


Long-tailed Tit
(Aegithalos caudatus)
Long-tailed Tit
(Aegithalos caudatus)
Long-tailed Tit
(Aegithalos caudatus)
Marsh Tit
(Poecile palustris)
Marsh Tit
(Poecile palustris)
Marsh Tit
(Poecile palustris)
Willow Tit
(Poecile montanus)
Willow Tit
(Poecile montanus)
Willow Tit
(Poecile montanus)
European Crested Tit
(Lophophanes cristatus)
European Crested Tit
(Lophophanes cristatus)
European Crested Tit
(Lophophanes cristatus)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0


Coal Tit
(Periparus ater)
Coal Tit
(Periparus ater)
Coal Tit
(Periparus ater)
Eurasian Blue Tit
(Cyanistes caeruleus)
Eurasian Blue Tit
(Cyanistes caeruleus)
Eurasian Blue Tit
(Cyanistes caeruleus)
Great Tit
(Parus major)
Great Tit
(Parus major)
Great Tit
(Parus major)
Eurasian Nuthatch
(Sitta europaea)
Eurasian Nuthatch
(Sitta europaea)
Eurasian Nuthatch
(Sitta europaea)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0


Eurasian Golden Oriole
(Oriolus oriolus)
Eurasian Golden Oriole
(Oriolus oriolus)
Eurasian Golden Oriole
(Oriolus oriolus)
Red-backed Shrike
(Lanius collurio)
Red-backed Shrike
(Lanius collurio)
Red-backed Shrike
(Lanius collurio)
Eurasian Jay
(Garrulus glandarius)
Eurasian Jay
(Garrulus glandarius)
Eurasian Jay
(Garrulus glandarius)
Eurasian Magpie
(Pica pica)
Eurasian Magpie
(Pica pica)
Eurasian Magpie
(Pica pica)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0


Carrion Crow
(Corvus corone)
Carrion Crow
(Corvus corone)
Carrion Crow
(Corvus corone)
Hooded Crow
(Corvus cornix)
Hooded Crow
(Corvus cornix)
Hooded Crow
(Corvus cornix)
Common Starling
(Sturnus vulgaris)
Common Starling
(Sturnus vulgaris)
Common Starling
(Sturnus vulgaris)
Italian Sparrow
(Passer italiae)
Italian Sparrow
(Passer italiae)
Italian Sparrow
(Passer italiae)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0


Eurasian Tree Sparrow
(Passer montanus)
Eurasian Tree Sparrow
(Passer montanus)
Eurasian Tree Sparrow
(Passer montanus)
Common Chaffinch
(Fringilla coelebs)
Common Chaffinch
(Fringilla coelebs)
Common Chaffinch
(Fringilla coelebs)
European Serin
(Serinus serinus)
European Serin
(Serinus serinus)
European Serin
(Serinus serinus)
European Greenfinch
(Chloris chloris)
European Greenfinch
(Chloris chloris)
European Greenfinch
(Chloris chloris)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0

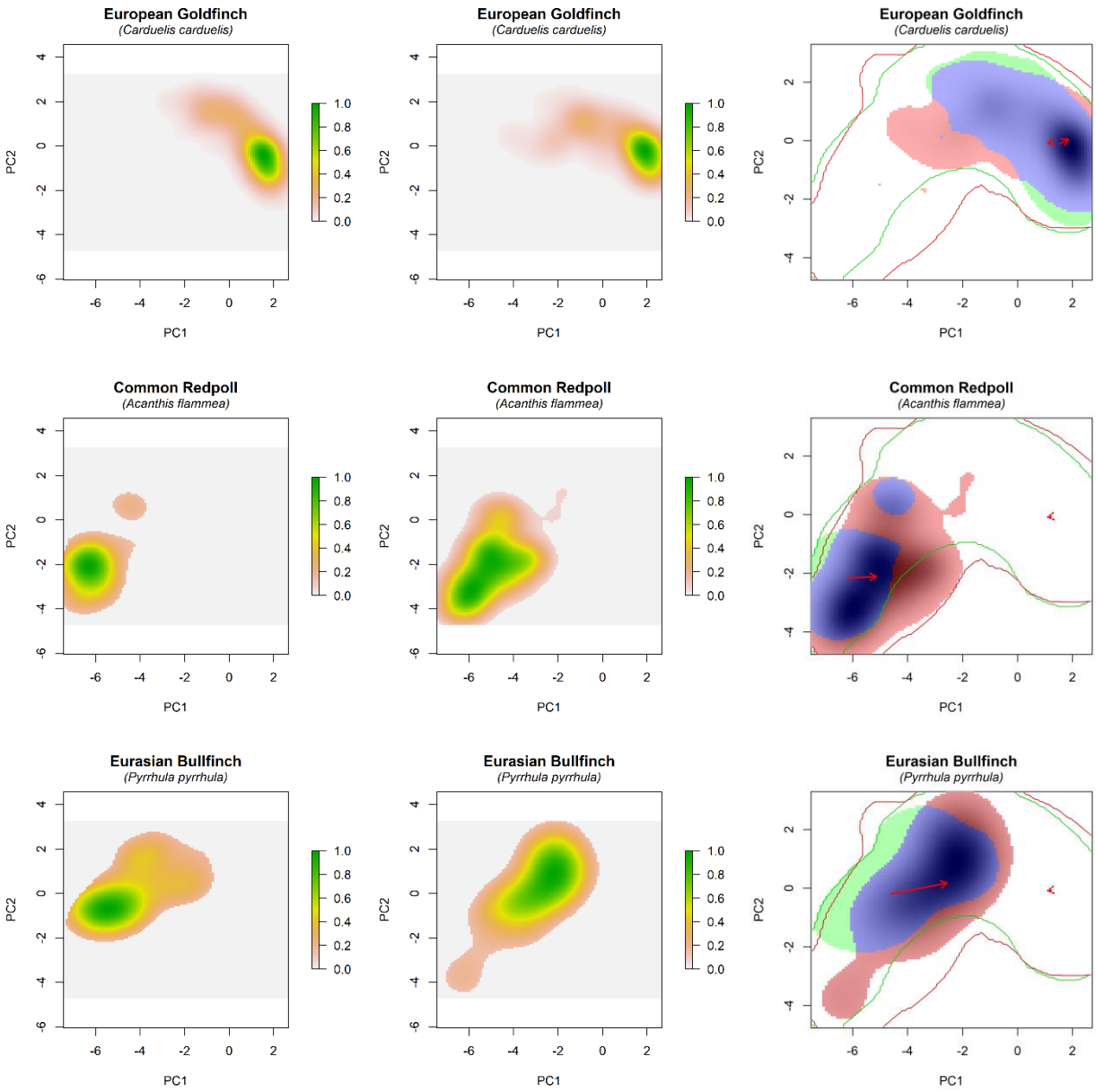

European Goldfinch
(Carduelis carduelis)
European Goldfinch
(Carduelis carduelis)
European Goldfinch
(Carduelis carduelis)
Common Redpoll
(Acanthis flammea)
Common Redpoll
(Acanthis flammea)
Common Redpoll
(Acanthis flammea)
Eurasian Bullfinch
(Pyrrhula pyrrhula)
Eurasian Bullfinch
(Pyrrhula pyrrhula)
Eurasian Bullfinch
(Pyrrhula pyrrhula)
PC1
PC2
1.0
0.8
0.6
0.4
0.2
0.0

Table S5. Schoener's D, expansion and unfilling index for each species. Species are presented with the common name [97] and following the taxonomic order**.**

Species	Schoener's D	Expansion	Unfilling
Black-crowned Night Heron	0.52	0.05	0.22
Little Egret	0.48	0.18	0.09
Grey Heron	0.54	0.10	0.05
Mallard	0.29	0.01	0.30
Black Kite	0.50	0.00	0.23
Common Buzzard	0.60	0.12	0.08
Common Kestrel	0.25	0.02	0.28
Common Quail	0.61	0.00	0.26
Common Pheasant	0.60	0.01	0.13
Common Moohren	0.56	0.00	0.15
Feral Pigeon	0.72	0.01	0.05
Common Wood Pigeon	0.71	0.04	0.01
Eurasian Collared Dove	0.73	0.01	0.05
European Turtle Dove	0.62	0.01	0.12
Common Cuckoo	0.74	0.00	0.01
Common Swift	0.71	0.03	0.02
Eurasian Wryneck	0.49	0.00	0.26
European Green Woodpecker	0.41	0.31	0.00
Great Spotted Woodpecker	0.59	0.07	0.01
Eurasian Skylark	0.14	0.41	0.00
Eurasian Crag Martin	0.60	0.06	0.11
Barn Swallow	0.59	0.00	0.12
Common House Martin	0.66	0.08	0.01
Tree Pipit	0.57	0.17	0.05
Water Pipit	0.23	0.54	0.00
Western Yellow Wagtail	0.49	0.01	0.22
Grey Wagtail	0.61	0.03	0.01
White Wagtail	0.63	0.05	0.07
Eurasian Wren	0.71	0.01	0.01
Dunnock	0.27	0.65	0.00
European Robin	0.81	0.06	0.02
Common Nigthingale	0.61	0.00	0.12
Black Redstart	0.54	0.05	0.01
Common Redstart	0.63	0.04	0.04
African Stonechat	0.58	0.06	0.08
Northern Wheatear	0.44	0.09	0.09
Common Blackbird	0.76	0.02	0.00

Table S5 (cont.)

Song Thrush	0.21	0.66	0.00
Mistle Trush	0.51	0.10	0.06
Cetti's Warbler	0.68	0.01	0.12
Melodius Warbler	0.40	0.00	0.32
Lesser Whitethroat	0.56	0.09	0.17
Eurasian Blackcap	0.79	0.01	0.01
Western Bonelli's Warbler	0.47	0.14	0.15
Common Chiffchaff	0.63	0.06	0.01
Goldcrest	0.71	0.00	0.04
Common Firecrest	0.33	0.29	0.19
Spotted Flycatcher	0.65	0.11	0.00
Long-tailed Tit	0.59	0.14	0.08
Marsh Tit	0.45	0.04	0.28
Willow Tit	0.38	0.47	0.00
European Crested Tit	0.46	0.26	0.08
Coal Tit	0.61	0.09	0.06
Eurasian Blue Tit	0.68	0.02	0.06
Great Tit	0.75	0.01	0.02
Eurasian Nuthatch	0.46	0.25	0.00
Eurasian Golden Oriole	0.57	0.02	0.08
Red-backed Shrike	0.57	0.00	0.23
Eurasian Jay	0.60	0.02	0.07
Eurasian Magpie	0.61	0.08	0.05
Carrion Crow	0.47	0.06	0.30
Hooded Crow	0.69	0.02	0.01
Common Starling	0.63	0.00	0.06
Italian Sparrow	0.70	0.00	0.03
Eurasian Tree Sparrow	0.67	0.01	0.03
Common Chaffinch	0.70	0.02	0.00
European Serin	0.73	0.05	0.01
European Greenfinch	0.65	0.01	0.08
European Goldfinch	0.60	0.06	0.02
Common Redpoll	0.48	0.27	0.03
Eurasian Bullfinch	0.40	0.21	0.23

Table S6. Coordinates of the 18 continuous species traits and of niche metrics respect to the four retained PCA-axes (trait space). See Table S2 for traits' abbreviations.

Traits	**Dim1**	**Dim2**	**Dim3**	**Dim4**
len	0.97	0.06	0.13	0.10
wing	0.97	0.09	–0.08	–0.04
tail	0.76	0.03	0.05	0.04
bil	0.81	–0.10	0.16	0.05
tar	0.90	–0.01	0.17	0.10
wei	0.92	0.08	0.25	0.12
clu	–0.19	–0.15	0.89	–0.11
bro	–0.27	0.43	–0.29	0.71
fec	–0.49	0.19	0.58	0.43
inc	0.83	0.17	0.20	–0.11
fle	0.75	0.24	0.11	–0.11
disr	0.42	0.24	–0.44	–0.55
SSI.fh	–0.25	0.75	0.34	–0.12
SSI.acq	0.14	0.58	–0.32	0.27
SSI.nes	–0.16	0.85	0.13	–0.25
SSI.fs	0.24	0.77	–0.09	0.11
SSI.tr	–0.70	0.08	0.11	–0.39
SSI.ov	–0.29	0.92	0.08	–0.16
Niche metrics	**Dim1**	**Dim2**	**Dim3**	**Dim4**
Schoener's D	–0.08	0.10	–0.12	0.07
Expansion	–0.13	–0.06	–0.04	0.10
Unfilling	0.23	–0.04	0.19	–0.17

Figure S4. Biplots between niche metrics and PCA-axes (trait space). (a) Dim1-Dim4. (b) Dim3-Dim4. For traits' abbreviations see Table S2. Dashed red arrows indicate the intensity of correlation for the niche metrics in the PCA space. D = Schoener's D; exp = expansion index; unf = unfilling index.