Supporting Information

Common birds combine pest control and seed dispersal in apple orchards through a hybrid interaction network.

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Table S1. Number of individual birds of different species sampled at field censuses, mist-netting, dropping content visual analysis, dropping content analysis after DNA extraction, and DNA-metabarcoding analysis. DNA extraction and metabarcoding subsamples were chosen to represent as many as possible bird species (with a minimum sample size of 3 individuals) according to their capture frequency and aiming to cover the different capture sites and dates across the whole year. The consideration of bird species as legitimate seed disperser (LSD) is also shown.

Species	Sp. acronym	Census	Mist-netting	Dropping content	DNA extraction	DNA metabarcoding	LSD[a]
Acrocephalus scirpaceus	Acr sci	0	1	1	1	0	-
Aegithalos caudatus	Aeg cau	16	51	49	37	35	-
Anthus pratensis	Ant pra	0	1	1	0	0	-
Anthus trivialis	Ant tri	0	1	1	0	0	-
Carduelis carduelis	Car car	28	35	35	14	13	-
Certhia brachydactyla	Cer bra	10	13	10	10	9	-[b]
Cettia cetti	Cet cet	2	0	0	0	0	-
Chloris chloris	Chl chl	12	11	11	11	11	-
Cisticola juncidis	Cis jun	7	0	0	0	0	-
Columba palumbus	Col pal	2	0	0	0	0	+
Cyanistes caeruleus	Cya cae	61	46	45	37	31	-
Curruca communis	Cur com	0	2	2	2	0	+
Dendrocopos major	Den maj	12	4	3	3	3	+
Emberiza cirlus	Emb cir	0	3	3	1	0	-
Erithacus rubecula	Eri rub	143	203	199	106	76	+
Ficedula hypoleuca	Fic hyp	9	14	14	14	12	+
Fringilla coelebs	Fri coe	35	36	35	22	20	+[c]
Garrulus glandarius	Gar glan	23	2	2	1	0	+
Hippolais polyglotta	Hip pol	3	1	1	0	0	-
Hirundo rustica	Hir rus	0	1	1	0	0	-
Lanius collurio	Lan col	4	8	7	7	7	+
Motacilla cinérea	Mot cin	1	3	3	1	0	-
Muscicapa striata	Mus str	2	4	4	4	3	+
Nannus troglodytes	Nan tro	56	11	11	11	11	-[d]
Oriolus oriolus	Ori ori	6	3	3	4	3	+
Parus major	Par maj	61	136	116	79	60	-
Passer domesticus	Pas dom	1	1	1	0	0	-

Table S1 (cont.).

Species	Sp. acronym	Census	Mist-netting	Dropping content	DNA extraction	DNA metabarcoding	LSD[a]
Periparus ater	Per ate	2	7	7	7	7	-
Phoenicurus ochruros	Pho och	0	1	1	0	0	+
Phoenicurus phoenicurus	Pho pho	0	1	1	1	0	+
Phylloscopus collybita	Phy col	2	36	32	27	26	+
Phylloscopus ibericus	Phy ibe	3	1	1	-	0	+
Phylloscopus trochilus	Phy tro	0	6	6	6	5	+
Picus sharpei	Pic sha	3	4	4	4	4	+
Pyrrhula pyrrhula	Pyr pyr	8	19	14	11	10	-
Regulus ignicapilla	Reg ign	17	17	15	15	15	-[e]
Saxicola rubicola	Sax rub	0	2	2	0	0	-
Serinus serinus	Ser ser	17	30	29	16	17	-
Sturnus vulgaris	Stu vul	47	0	0	0	0	+
Sylvia atricapilla	Syl atr	124	197	195	128	75	+
Sylvia borin	Syl bor	1	4	4	4	4	+
Turdus iliacus	Tur ili	50	3	3	3	3	+
Turdus merula	Tur mer	95	102	95	68	57	+
Turdus philomelos	Tur phi	47	48	48	35	33	+
Turdus pilaris	Tur pil	0	1	1	0	0	+
Totals		**910**	**1070**	**1016**	**690**	**550**	

a- Status by Simmons, B. I., Sutherland, W. J., Dicks, L. V., Albrecht, J., Farwig, N., García, D., ... & González-Varo, J. P. (2018). Moving from frugivory to seed dispersal: Incorporating the functional outcomes of interactions in plant–frugivore networks. *Journal of Animal Ecology*, *87*(4), 995-1007

b- Status checked after Harrap, S. (2020). Short-toed Treecreeper (*Certhia brachydactyla*), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA.

c- Considered LSD of ivy *Hedera helix* given the occurrence of intact seeds in the fecal analysis.

d- Status checked after Kroodsma, D. E., D. Brewer, D. A. Christie, and J. S. Marks (2020). Eurasian Wren (*Troglodytes troglodytes*), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA.

e- Status checked after Martens, J. and M. Päckert (2020). Common Firecrest (*Regulus ignicapilla*), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA

Table S2. Relative abundance of ripe fruits of different plant species sampled across the three study sites and the whole year.

Species	No. fruiting plants	No. fruits	Relative abundance (prop.)
Arum maculatum	1	35	1.49E-05
Bryonia dioica	8	2436	1.04E-03
Cornus sanguinea	159	154684	6.60E-02
Crataegus monogyna	5	143	6.10E-05
Euonymus europaeus	100	55757	2.38E-02
Hedera helix	132	873410	3.73E-01
Ilex aquifolium	8	13963	5.96E-03
*Iris foetidissima**	3	620	1.75E-05
Laurus nobilis	75	316842	1.35E-01
Ligustrum vulgare	4	108	4.61E-05
Lonicera periclymenum	15	784	3.34E-04
Phytolacca americana	5	47	2.01E-05
Prunus spinosa	65	20730	8.84E-03
Rhamnus alaternus	12	4668	1.99E-03
Rosa canina	225	45589	1.94E-02
Rubia peregrina	108	7842	3.35E-03
*Rubus fruticosus***	230	207282	8.84E-02
Ruscus aculeatus	488	24687	1.05E-02
Sambucus nigra	83	263679	1.12E-01
Smilax aspera	299	345475	1.47E-01
Solanum dulcamara	9	283	1.21E-04
Solanum nigrum	1	41	1.49E-05
Tamus communis	42	3402	1.45E-03
Viscum album	20	2181	9.30E-04

* *Iris foetidisima* fruit unit considered here is the capsule that contains, on average, 25 red fleshy-like mimetic seeds

** *Rubus fruticosus* fruit unit considered here is the bramble (i.e. polydrupe), composed, on average, by 30 one-seeded drupes.

Table S3. Results of Gamma-family (log link) Generalized Linear Mixed Models evaluating the effects of bird species relative abundance (percentage of individuals), body mass (g) and diet diversity (inverse Simpson Index) on bird species centrality measures on the hybrid (pest control and seed dispersal) interaction network. All predictors were standardized prior to analysis. Models included the variance (±SD) estimate for taxonomic identity factors included as random effects. Marginal and conditional (in parentheses) R2 values are also given.

Response variables	**Weighted degree** (Gamma, log)				**Harmonic closeness** (Gamma, log)				**Betweenness** (Gamma, log)			
	R^2 = 0.560 (0.681)				R^2 = 0.653 (0.814)				R^2 = 0.608 (0.608)			
Predictors	Estimate	SE/SD	t	P	Estimate	SE/SD	t	P	Estimate	SE/SD	t	P
Intercept	-3.242	0.235	-13.77	<0.001	-0.879	0.041	-21.64	<0.001	4.610	0.215	21.43	<0.001
Relative abundance	0.976	0.198	4.91	<0.001	0.186	0.027	6.81	<0.001	1.178	0.298	3.94	<0.001
Body mass	-0.097	0.208	-0.46	0.640	0.011	0.032	0.33	0.740	-0.378	0.207	-1.83	0.068
Diet diversity	-0.075	0.241	-0.31	0.754	-0.041	0.033	-1.22	0.223	0.0172	0.299	0.06	0.953
Genus [Family] (random)	0.151	0.389			0.004	0.067			0.000	0.000		
Family (random)	0.041	0.203			0.003	0.052			0.000	0.000		

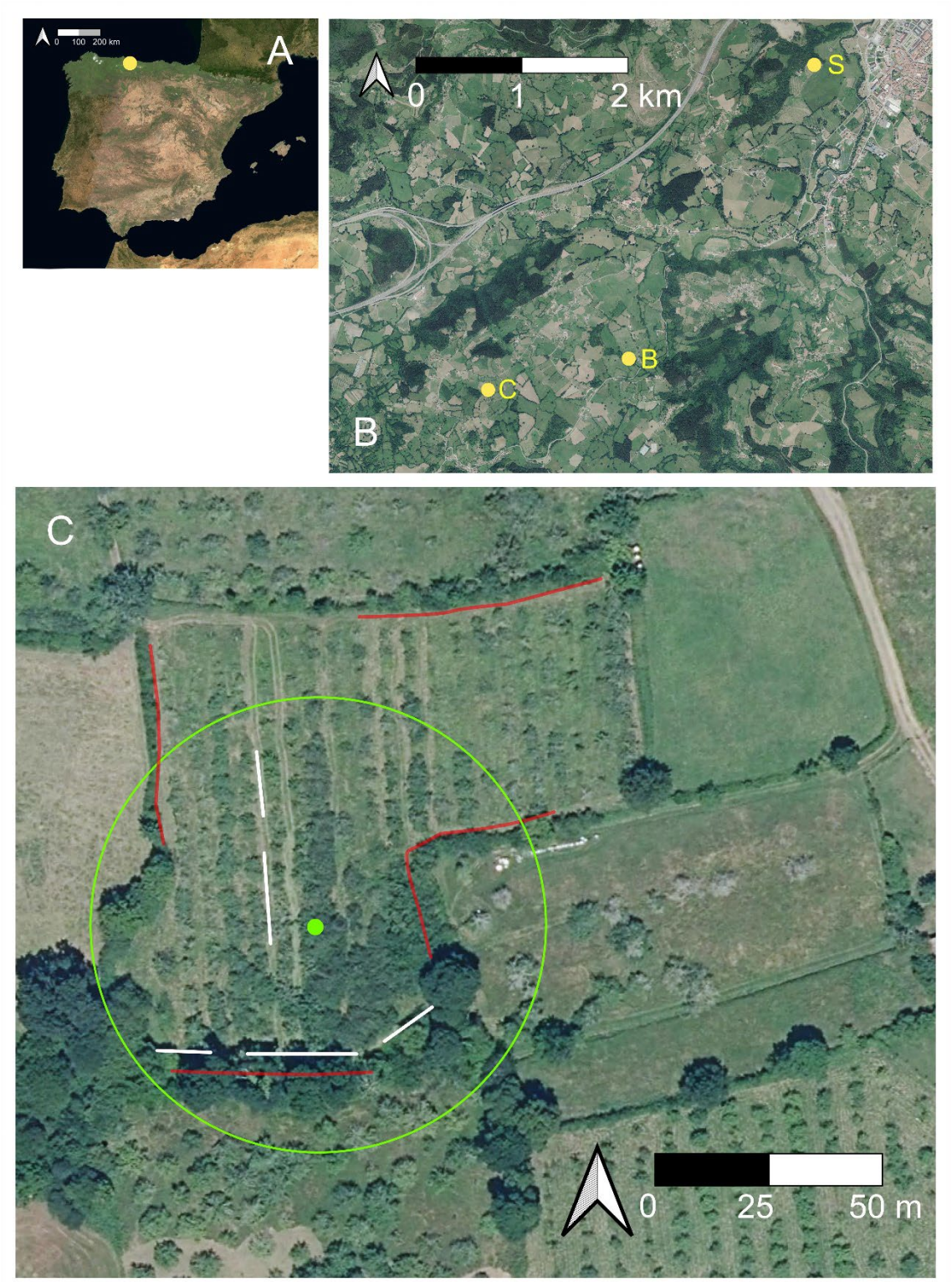

Figure S1. A) Location of the study sites in northern Spain. B) View of study sites (S: Sorribes, 43º 28' 44'' N, 5º 26' 54'' W, 25 m asl; B: Bustariega, 43º 27' 22'' N, 5º27'69'' W, 97 m asl; and C: Camoca, 43º 27' 10'' N, 5º 28' 58'' W, 85 m asl) in the region, highlighting the variegated landscape composed of a fine-grain mosaic with anthropogenic patches (pasture meadows, timber plantations, apple orchards, other crops and urban settlements) and seminatural-woody habitats (like hedgerows and native forest patches). C) Aerial view of Camoca site representing the 50-m radius point-count plot for bird censuses (green circle), location of settlement of mist-nets for bird capture (white lines) and transects for counts of fleshy-fruits along woody hedgerows and forest patches surrounding apple orchard (red lines).

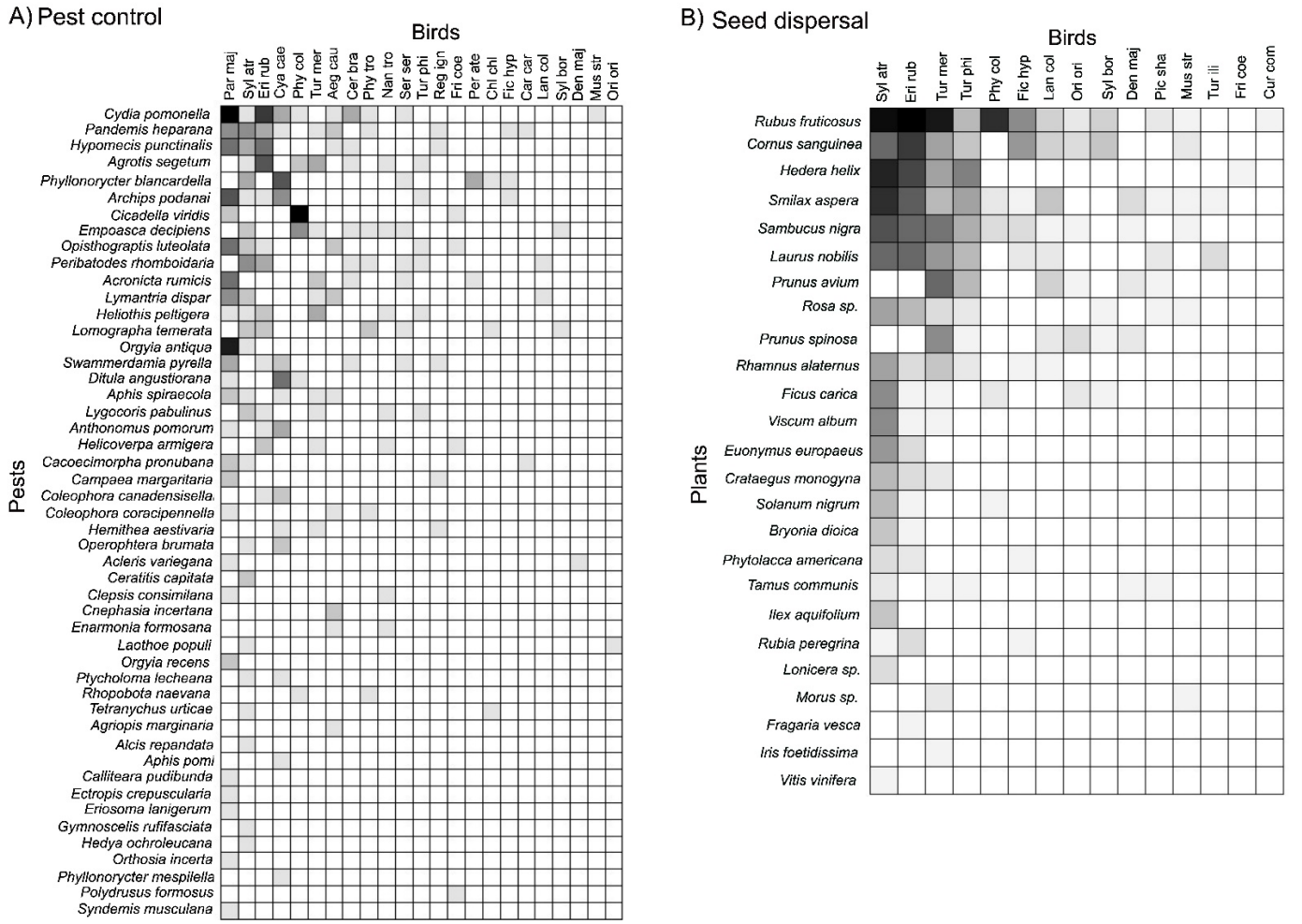

Figure S2. Representation of bird-pest (A) and bird-plant (B) interaction matrix underpinning, respectively, pest-control and seed dispersal networks. Actual interactions between species pairs are depicted in grey-to-black squares, with darkness proportional to the frequency of occurrence. See Table S1 for bird species acronyms.

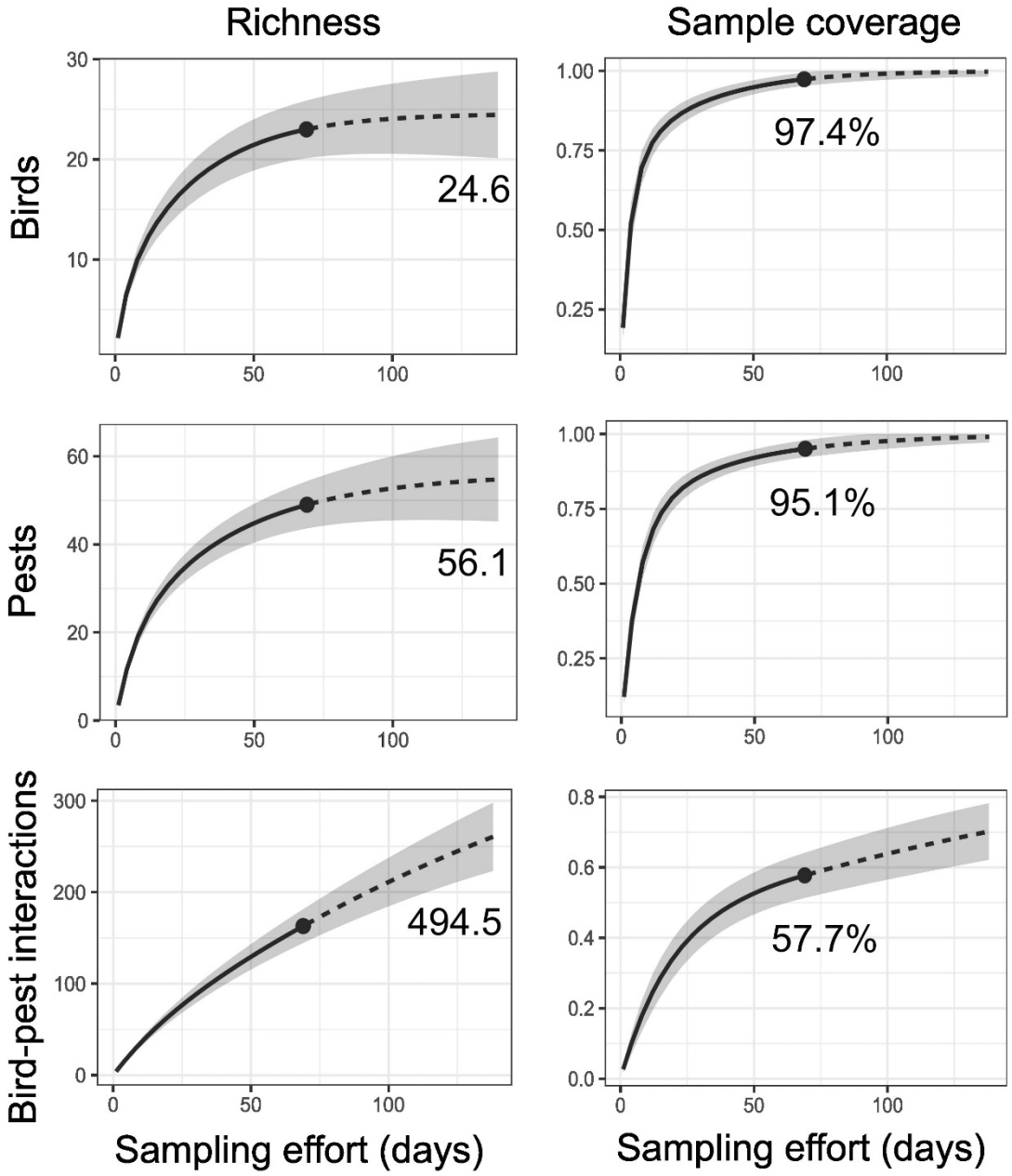

Figure S3. Cumulative curves of birds, apple pest arthropods, and bird-pest interactions richness and sample coverage, per sampling effort unit (mist-netting days). Dot symbol represents the observed value and the dashed line the extrapolated values expected with higher sampling effort. Shaded area represents 95% confidence intervals. Asymptotic values are shown for richness. Sample coverage values indicate the percentages of the total number of observations belonging to the set of species (or interactions) detected in the sample, and it is interpreted as an estimate of sample completeness.

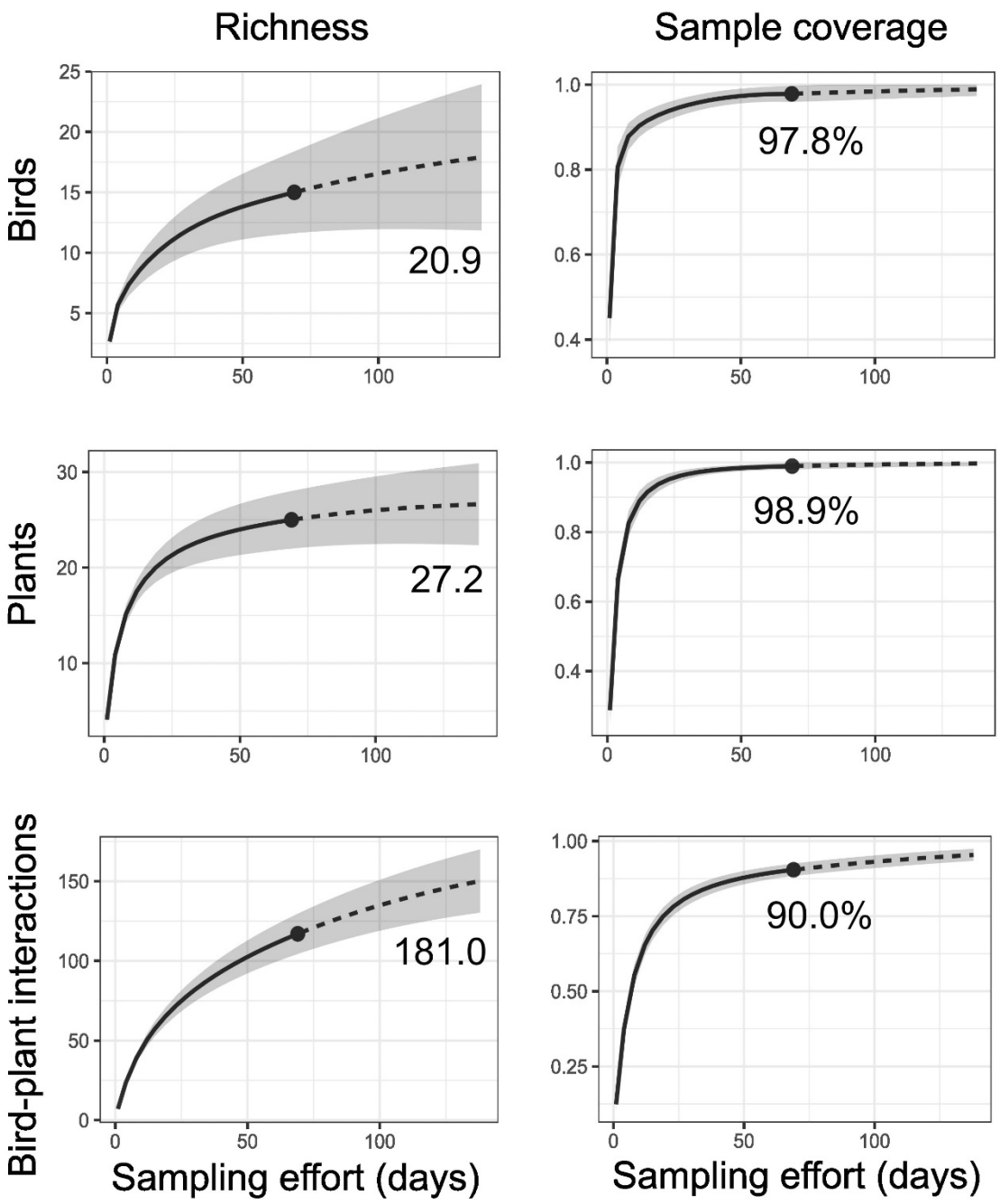

Figure S4. Cumulative curves of birds, fleshy-fruited plants, and bird-plant interactions richness and sample coverage, per sampling effort unit (mist-netting days). Dot symbol represents the observed value and the dashed line the extrapolated values expected with higher sampling effort. Shaded area represents 95% confidence intervals. Asymptotic values are shown for richness. Sample coverage values indicate the percentages of the total number of observations belonging to the set of species (or interactions) detected in the sample, and it is interpreted as an estimate of sample completeness.

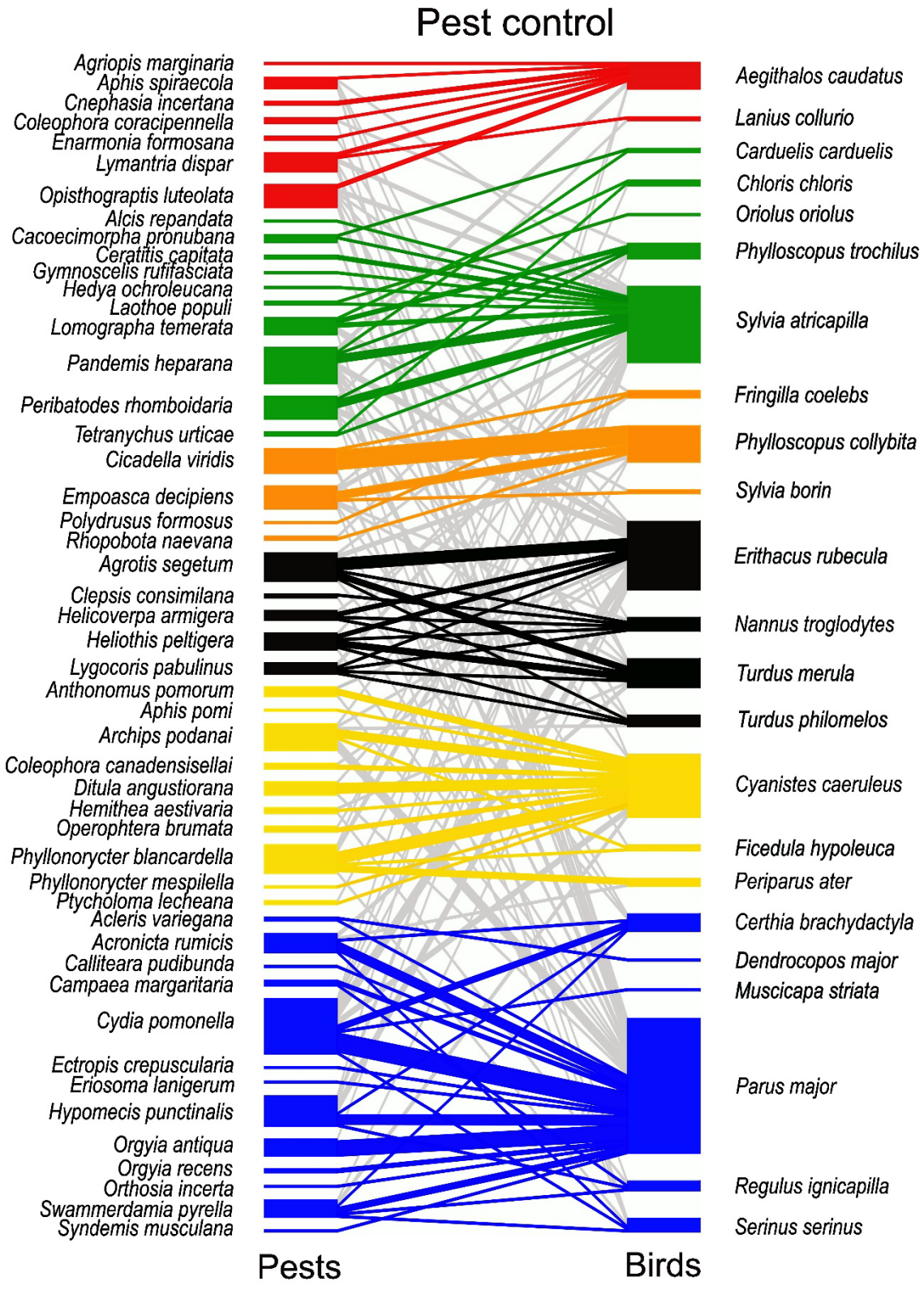

Figure S5. Detailed representation of bipartite networks between pests and birds (pest control). Rectangles in columns correspond to different species, with rectangle height being proportional to species interaction frequencies. Links between rectangles represent paired interactions between species, with link width being proportional to the proportion of interactions. Species and interactions are ordered to highlight modularity (different colors indicate species and links conforming different modules.

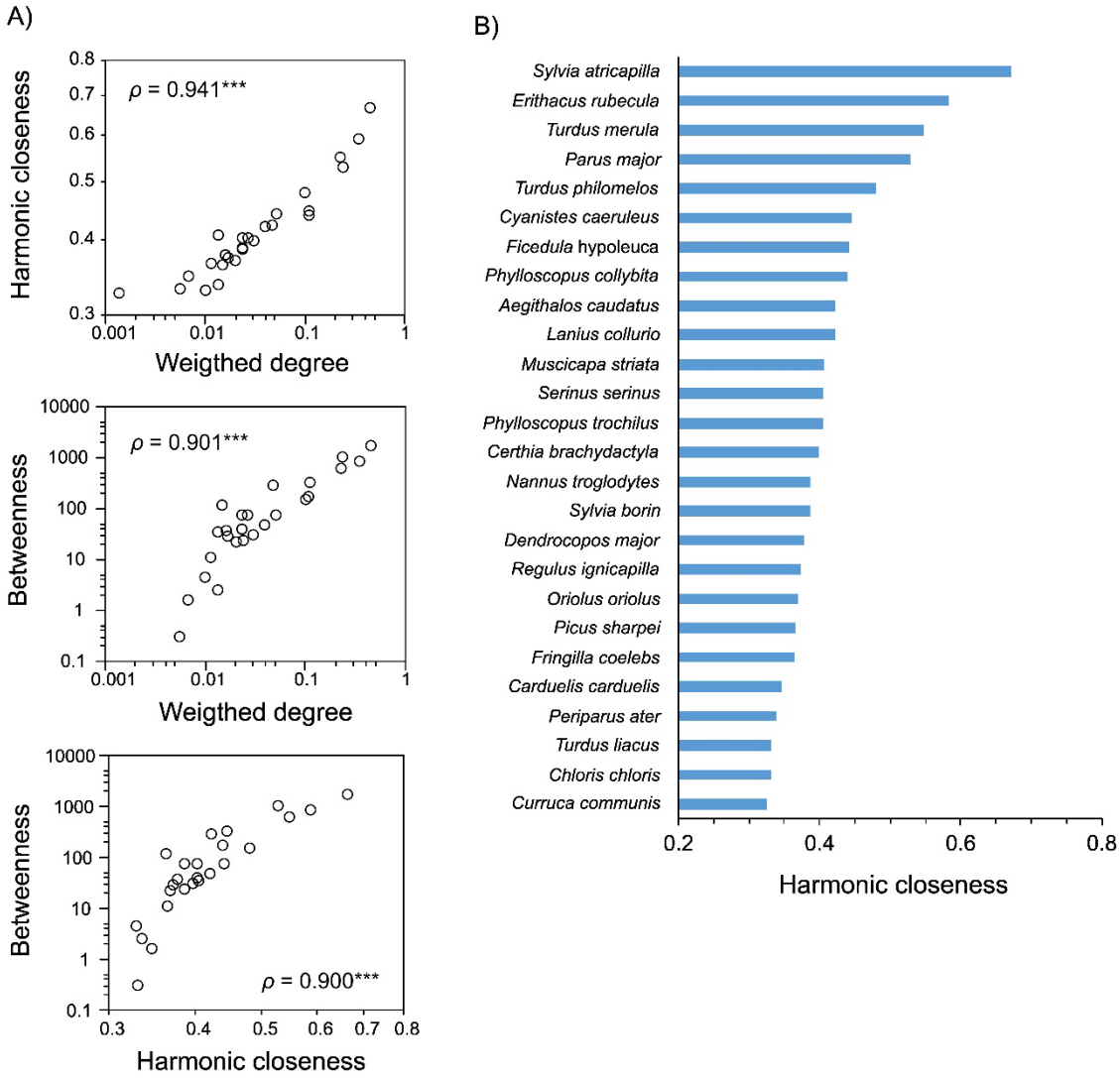

Figure S6. A) Bivariate representations of centrality measures (weighted degree, harmonic closeness and betweenness, in logarithmic scale) of different bird species. Values of Spearman's correlation coefficient between measures (ρ) and their degrees of significance (***: $P < 0.001$) are shown. B) Example of distribution of centrality values (harmonic closeness) across bird species.

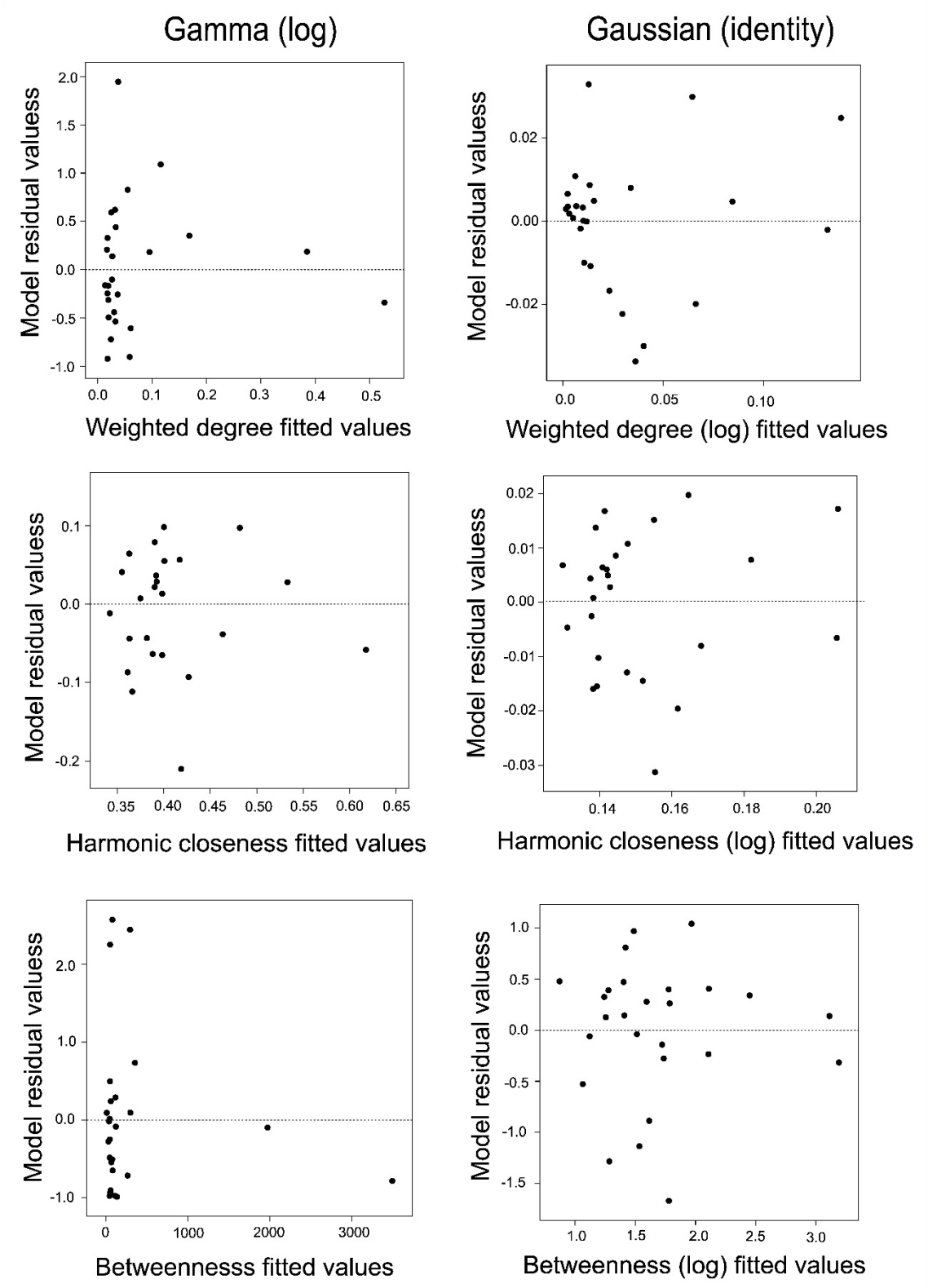

Figure S7. Plots of residual vs fitted values corresponding to different centrality measures (weighted degree, harmonic closeness and betweenness) used as response variables in different Generalized Linear Mixed Models considering Gamma (log link) or Gaussian (identity link, log-transformed data) as distribution family, and bird species relative abundance (percentage of individuals), body mass (g) and diet diversity (inverse Simpson Index) as fixed predictors (see also Table 2 in the main text and Table S3).