

Migratory connectivity analysis

by EURING Migration Atlas

Sitta europaea (EURING code 14790)

1.1 Connectivity between individuals

The analysis evaluated 2828 individuals (5656 encounters) filtered from a total of 101663 records in the EURING databank which were considered for the Atlas. The species shows a significant connectivity from clustering, with a number of first-level clusters = 9 (Table 14790-1; Figure 14790-1).

Table 14790-1. Results from the migratory connectivity analysis. For each cluster, the degree of connectivity (r_M), its statistical significance (p-value) and 95% confidence interval limits are shown. When the p-value is less than or equal to 0.1, the degree of clustering structure (oasw) and the best number of clusters identified are reported.

Cluster name	Level of clustering	N individuals	Migratory connectivity (r_M)	p-value	Lower 95% confidence limit	Upper 95% confidence limit	Best number of clusters	oasw
0	0	2828	0.999	0.001	0.998	0.999	9	0.512
1	1	196	1.000	0.001	0.999	1.000	8	0.687
2	1	527	0.977	0.001	0.951	0.994	4	0.602
3	1	334	0.922	0.001	0.845	0.981	8	0.749
4	1	260	0.996	0.001	0.989	0.999	5	0.596
5	1	469	0.992	0.001	0.987	0.996	2	0.598
6	1	102	0.967	0.001	0.901	0.999	9	0.620
7	1	197	0.997	0.001	0.993	0.999	2	0.649
8	1	35	0.999	0.001	0.998	1.000	9	0.827
9	1	708	0.998	0.001	0.996	1.000	8	0.511
11	2	2	-	-	-	-	-	-
12	2	27	1.000	0.001	0.999	1.000	8	0.842
13	2	7	-	-	-	-	-	-
14	2	17	-	-	-	-	-	-
15	2	74	0.992	0.001	0.979	0.999	4	0.849
16	2	31	1.000	0.001	0.999	1.000	5	0.945
17	2	37	1.000	0.001	0.999	1.000	2	0.832
18	2	1	-	-	-	-	-	-
21	2	113	0.962	0.001	0.926	0.987	9	0.667
22	2	74	0.971	0.001	0.947	0.997	6	0.647
23	2	318	0.846	0.001	0.702	0.966	7	0.703
24	2	22	0.994	0.001	0.987	1.000	8	0.761
31	2	5	-	-	-	-	-	-
32	2	13	-	-	-	-	-	-
33	2	15	-	-	-	-	-	-
34	2	20	0.932	0.001	0.778	0.999	6	0.733
35	2	81	0.608	0.001	0.351	0.873	6	0.580

Cluster name	Level of clustering	N individuals	Migratory connectivity (r_M)	p-value	Lower 95% confidence limit	Upper 95% confidence limit	Best number of clusters	oasw
36	2	7	-	-	-	-	-	-
37	2	17	-	-	-	-	-	-
38	2	176	0.750	0.001	0.445	0.993	8	0.874
41	2	22	0.685	0.001	0.346	1.000	9	0.565
42	2	68	0.995	0.001	0.978	1.000	9	0.572
43	2	62	1.000	0.001	0.999	1.000	9	0.817
44	2	94	0.984	0.001	0.956	0.996	3	0.776
45	2	14	-	-	-	-	-	-
51	2	375	0.979	0.001	0.967	0.988	9	0.625
52	2	94	0.993	0.001	0.986	0.998	9	0.724
61	2	26	0.995	0.001	0.983	0.999	9	0.770
62	2	3	-	-	-	-	-	-
63	2	23	0.822	0.001	0.677	0.969	8	0.570
64	2	6	-	-	-	-	-	-
65	2	14	-	-	-	-	-	-
66	2	11	-	-	-	-	-	-
67	2	6	-	-	-	-	-	-
68	2	7	-	-	-	-	-	-
69	2	6	-	-	-	-	-	-
71	2	180	0.990	0.001	0.980	0.998	7	0.601
72	2	17	-	-	-	-	-	-
81	2	7	-	-	-	-	-	-
82	2	4	-	-	-	-	-	-
83	2	4	-	-	-	-	-	-
84	2	7	-	-	-	-	-	-
85	2	3	-	-	-	-	-	-
86	2	5	-	-	-	-	-	-
87	2	3	-	-	-	-	-	-
88	2	1	-	-	-	-	-	-
89	2	1	-	-	-	-	-	-
91	2	160	0.999	0.001	0.998	1.000	6	0.531
92	2	74	0.919	0.001	0.806	0.998	9	0.556
93	2	115	0.998	0.001	0.995	1.000	9	0.706
94	2	42	1.000	0.001	1.000	1.000	7	0.738
95	2	74	0.985	0.001	0.968	0.998	9	0.618
96	2	81	0.996	0.001	0.987	1.000	8	0.678
97	2	79	0.998	0.001	0.996	1.000	8	0.822
98	2	83	0.999	0.001	0.997	1.000	3	0.718
121	3	1	-	-	-	-	-	-
122	3	10	-	-	-	-	-	-
123	3	5	-	-	-	-	-	-
124	3	4	-	-	-	-	-	-
125	3	2	-	-	-	-	-	-
126	3	2	-	-	-	-	-	-
127	3	2	-	-	-	-	-	-
128	3	1	-	-	-	-	-	-
151	3	6	-	-	-	-	-	-
152	3	2	-	-	-	-	-	-
153	3	63	0.981	0.001	0.936	0.994	2	0.796
154	3	3	-	-	-	-	-	-

Cluster name	Level of clustering	N individuals	Migratory connectivity (r_M)	p-value	Lower 95% confidence limit	Upper 95% confidence limit	Best number of clusters	oasw
161	3	4	-	-	-	-	-	-
162	3	2	-	-	-	-	-	-
163	3	5	-	-	-	-	-	-
164	3	19	-	-	-	-	-	-
165	3	1	-	-	-	-	-	-
171	3	34	0.999	0.001	0.997	1.000	9	0.792
172	3	3	-	-	-	-	-	-
211	3	49	0.475	0.001	0.233	0.714	3	0.493
212	3	17	-	-	-	-	-	-
213	3	5	-	-	-	-	-	-
214	3	6	-	-	-	-	-	-
215	3	15	-	-	-	-	-	-
216	3	8	-	-	-	-	-	-
217	3	3	-	-	-	-	-	-
218	3	3	-	-	-	-	-	-
219	3	7	-	-	-	-	-	-
221	3	24	0.718	0.001	0.459	0.983	5	0.492
222	3	7	-	-	-	-	-	-
223	3	6	-	-	-	-	-	-
224	3	26	0.899	0.001	0.726	1.000	9	0.846
225	3	5	-	-	-	-	-	-
226	3	6	-	-	-	-	-	-
231	3	20	0.833	0.001	0.718	1.000	8	0.650
232	3	25	0.772	0.001	0.341	0.969	2	0.744
233	3	36	0.801	0.001	0.638	0.958	2	0.798
234	3	172	0.855	0.001	0.708	0.974	2	0.792
235	3	28	0.335	0.007	0.157	0.908	8	0.726
236	3	32	0.789	0.001	0.550	0.998	7	0.723
237	3	5	-	-	-	-	-	-
241	3	4	-	-	-	-	-	-
242	3	2	-	-	-	-	-	-
243	3	3	-	-	-	-	-	-
244	3	3	-	-	-	-	-	-
245	3	3	-	-	-	-	-	-
246	3	4	-	-	-	-	-	-
247	3	2	-	-	-	-	-	-
248	3	1	-	-	-	-	-	-
341	3	13	-	-	-	-	-	-
342	3	2	-	-	-	-	-	-
343	3	1	-	-	-	-	-	-
344	3	1	-	-	-	-	-	-
345	3	2	-	-	-	-	-	-
346	3	1	-	-	-	-	-	-
351	3	2	-	-	-	-	-	-
352	3	31	0.670	0.021	0.473	0.998	8	0.803
353	3	3	-	-	-	-	-	-
354	3	38	0.408	0.006	0.202	0.715	9	0.672
355	3	4	-	-	-	-	-	-
356	3	3	-	-	-	-	-	-
381	3	1	-	-	-	-	-	-

Cluster name	Level of clustering	N individuals	Migratory connectivity (r_M)	p-value	Lower 95% confidence limit	Upper 95% confidence limit	Best number of clusters	oasw
382	3	1	-	-	-	-	-	-
383	3	70	0.518	0.001	0.179	0.827	4	1.000
384	3	7	-	-	-	-	-	-
385	3	86	0.170	0.031	0.065	0.567	6	0.977
386	3	5	-	-	-	-	-	-
387	3	5	-	-	-	-	-	-
388	3	1	-	-	-	-	-	-
411	3	2	-	-	-	-	-	-
412	3	3	-	-	-	-	-	-
413	3	5	-	-	-	-	-	-
414	3	2	-	-	-	-	-	-
415	3	3	-	-	-	-	-	-
416	3	1	-	-	-	-	-	-
417	3	3	-	-	-	-	-	-
418	3	1	-	-	-	-	-	-
419	3	2	-	-	-	-	-	-
421	3	10	-	-	-	-	-	-
422	3	4	-	-	-	-	-	-
423	3	7	-	-	-	-	-	-
424	3	19	-	-	-	-	-	-
425	3	2	-	-	-	-	-	-
426	3	5	-	-	-	-	-	-
427	3	9	-	-	-	-	-	-
428	3	7	-	-	-	-	-	-
429	3	5	-	-	-	-	-	-
431	3	2	-	-	-	-	-	-
432	3	8	-	-	-	-	-	-
433	3	25	0.957	0.001	0.561	1.000	6	0.803
434	3	7	-	-	-	-	-	-
435	3	9	-	-	-	-	-	-
436	3	2	-	-	-	-	-	-
437	3	4	-	-	-	-	-	-
438	3	2	-	-	-	-	-	-
439	3	3	-	-	-	-	-	-
441	3	73	0.836	0.001	0.517	0.966	9	0.599
442	3	17	-	-	-	-	-	-
443	3	4	-	-	-	-	-	-
511	3	115	0.927	0.001	0.875	0.954	9	0.728
512	3	36	0.919	0.001	0.758	0.999	9	0.718
513	3	54	0.807	0.001	0.620	0.996	7	0.771
514	3	16	-	-	-	-	-	-
515	3	50	0.988	0.001	0.973	0.997	7	0.837
516	3	12	-	-	-	-	-	-
517	3	34	0.883	0.001	0.508	0.981	7	0.644
518	3	23	0.983	0.001	0.957	0.999	6	0.721
519	3	35	0.765	0.001	0.510	0.894	2	0.667
521	3	38	0.437	0.059	0.196	1.000	3	0.965
522	3	11	-	-	-	-	-	-
523	3	7	-	-	-	-	-	-
524	3	9	-	-	-	-	-	-

Cluster name	Level of clustering	N individuals	Migratory connectivity (r_M)	p-value	Lower 95% confidence limit	Upper 95% confidence limit	Best number of clusters	oasw
525	3	3	-	-	-	-	-	-
526	3	15	-	-	-	-	-	-
527	3	5	-	-	-	-	-	-
528	3	2	-	-	-	-	-	-
529	3	4	-	-	-	-	-	-
611	3	4	-	-	-	-	-	-
612	3	9	-	-	-	-	-	-
613	3	5	-	-	-	-	-	-
614	3	1	-	-	-	-	-	-
615	3	1	-	-	-	-	-	-
616	3	1	-	-	-	-	-	-
617	3	1	-	-	-	-	-	-
618	3	3	-	-	-	-	-	-
619	3	1	-	-	-	-	-	-
631	3	3	-	-	-	-	-	-
632	3	2	-	-	-	-	-	-
633	3	2	-	-	-	-	-	-
634	3	3	-	-	-	-	-	-
635	3	1	-	-	-	-	-	-
636	3	6	-	-	-	-	-	-
637	3	3	-	-	-	-	-	-
638	3	3	-	-	-	-	-	-
711	3	10	-	-	-	-	-	-
712	3	45	0.856	0.001	0.664	0.974	9	0.621
713	3	62	0.957	0.001	0.859	0.999	5	0.590
714	3	17	-	-	-	-	-	-
715	3	11	-	-	-	-	-	-
716	3	20	0.990	0.001	0.968	1.000	2	0.829
717	3	15	-	-	-	-	-	-
911	3	48	0.985	0.001	0.932	1.000	9	0.726
912	3	23	0.999	0.001	0.998	1.000	8	0.826
913	3	19	-	-	-	-	-	-
914	3	46	0.995	0.001	0.989	0.999	8	0.719
915	3	14	-	-	-	-	-	-
916	3	10	-	-	-	-	-	-
921	3	7	-	-	-	-	-	-
922	3	7	-	-	-	-	-	-
923	3	5	-	-	-	-	-	-
924	3	8	-	-	-	-	-	-
925	3	3	-	-	-	-	-	-
926	3	14	-	-	-	-	-	-
927	3	18	-	-	-	-	-	-
928	3	8	-	-	-	-	-	-
929	3	4	-	-	-	-	-	-
931	3	30	-	-	-	-	-	-
932	3	13	-	-	-	-	-	-
933	3	13	-	-	-	-	-	-
934	3	18	-	-	-	-	-	-
935	3	10	-	-	-	-	-	-
936	3	7	-	-	-	-	-	-

Cluster name	Level of clustering	N individuals	Migratory connectivity (r_M)	p-value	Lower 95% confidence limit	Upper 95% confidence limit	Best number of clusters	oasw
937	3	9	-	-	-	-	-	-
938	3	13	-	-	-	-	-	-
939	3	2	-	-	-	-	-	-
941	3	9	-	-	-	-	-	-
942	3	12	-	-	-	-	-	-
943	3	4	-	-	-	-	-	-
944	3	2	-	-	-	-	-	-
945	3	9	-	-	-	-	-	-
946	3	4	-	-	-	-	-	-
947	3	2	-	-	-	-	-	-
951	3	10	-	-	-	-	-	-
952	3	5	-	-	-	-	-	-
953	3	11	-	-	-	-	-	-
954	3	11	-	-	-	-	-	-
955	3	3	-	-	-	-	-	-
956	3	9	-	-	-	-	-	-
957	3	10	-	-	-	-	-	-
958	3	11	-	-	-	-	-	-
959	3	4	-	-	-	-	-	-
961	3	16	-	-	-	-	-	-
962	3	2	-	-	-	-	-	-
963	3	7	-	-	-	-	-	-
964	3	31	0.850	0.001	0.721	1.000	8	0.916
965	3	7	-	-	-	-	-	-
966	3	7	-	-	-	-	-	-
967	3	9	-	-	-	-	-	-
968	3	2	-	-	-	-	-	-
971	3	31	0.942	0.001	0.540	0.987	2	0.840
972	3	20	0.786	0.006	0.491	1.000	2	0.859
973	3	2	-	-	-	-	-	-
974	3	3	-	-	-	-	-	-
975	3	6	-	-	-	-	-	-
976	3	5	-	-	-	-	-	-
977	3	3	-	-	-	-	-	-
978	3	9	-	-	-	-	-	-
981	3	25	0.992	0.001	0.982	1.000	3	0.901
982	3	39	1.000	0.001	0.999	1.000	9	0.903
983	3	19	-	-	-	-	-	-

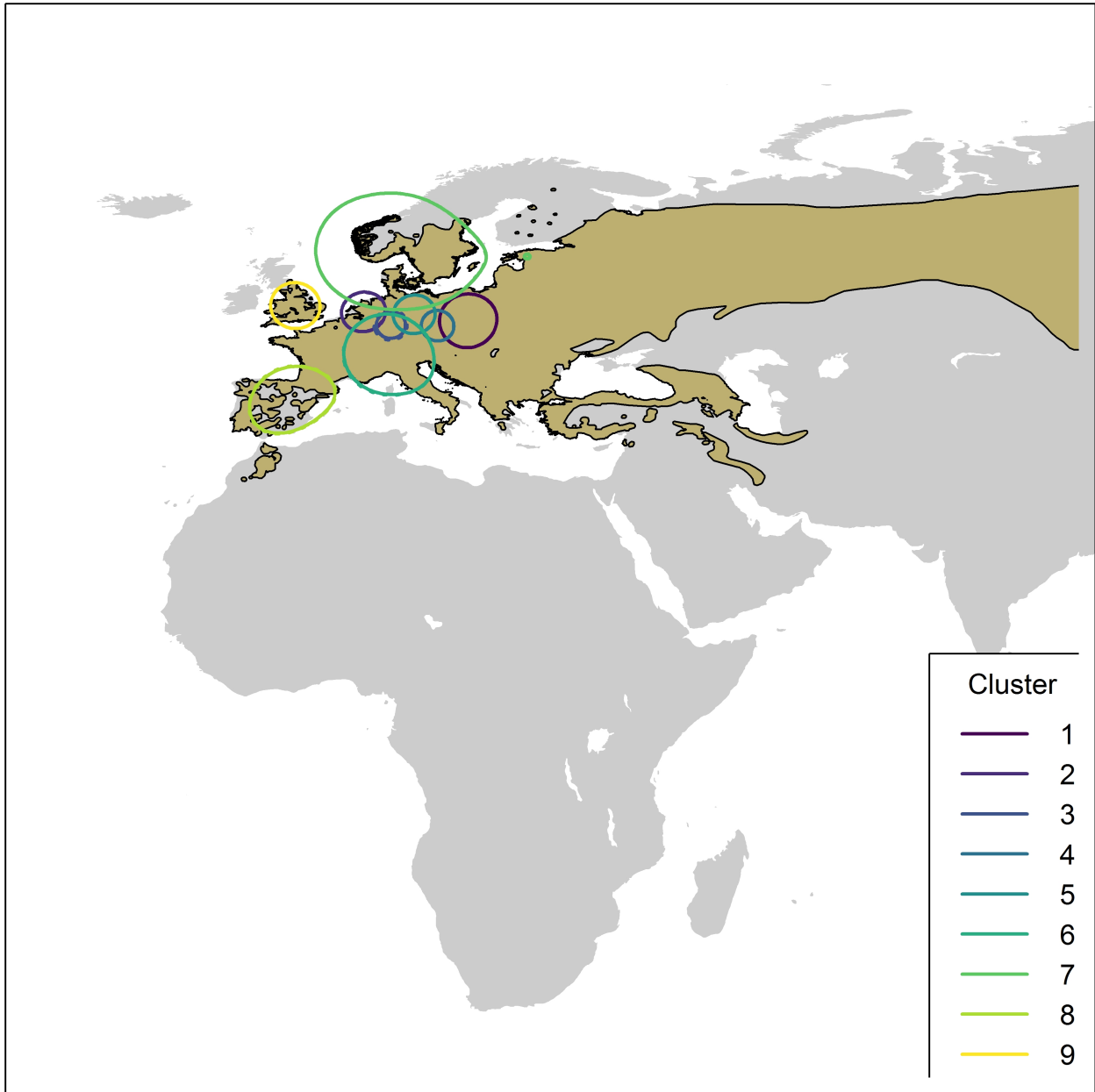


Figure 14790-1. Map showing 95% kernel contours of of first-level clusters identified by the migratory connectivity analysis, if any, or 95% kernel contours of all encounters, in case of no clustering structure. Solid lines indicate the clusters in the breeding range, dotted lines those in the non-breeding range. Different contour colours correspond to different clusters, as reported in legend. The species distribution range is also shown (breeding range: blue; non-breeding range: dark grey; resident range: beige; from BirdLife International, 2019).

1.2 Sensitivity analysis

Results of power analysis and validation. Analyses at the species level were re-run on subsamples of individuals of decreasing size (100 repetitions per subsample size), according to simple random sampling of individuals (Figure 14790-2) and stratified sampling of individuals within the breeding range (Figure 14790-3) and the non breeding range (Figure 14790-4). For stratified sampling, we selected individuals with a

probability inversely proportional to the number of observation in each country. Figures below report the results of the procedure.

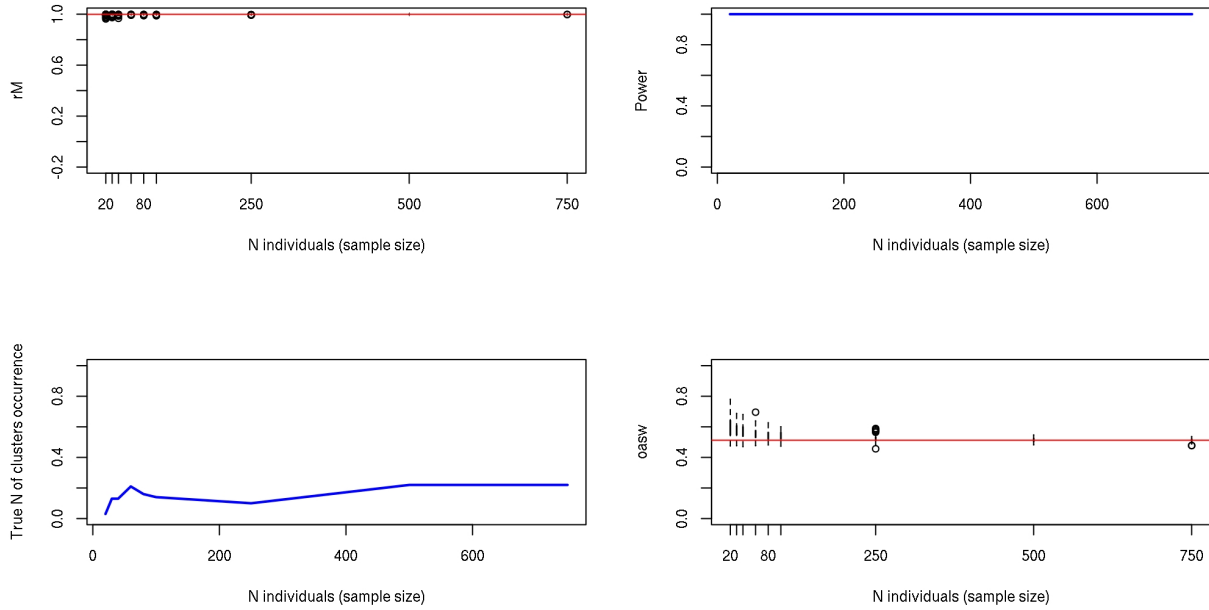


Figure 14790-2. Top left: simulated distribution (boxplots) and observed value (red line) of connectivity. Top right: Simulated power of the analysis (i.e. proportion of times the analyses on the subset of individuals was significant). Bottom left: Proportion of times the analysis provides the observed best number of cluster. Bottom right: simulated distribution (boxplots) and observed value (red line) of clustering intensity.

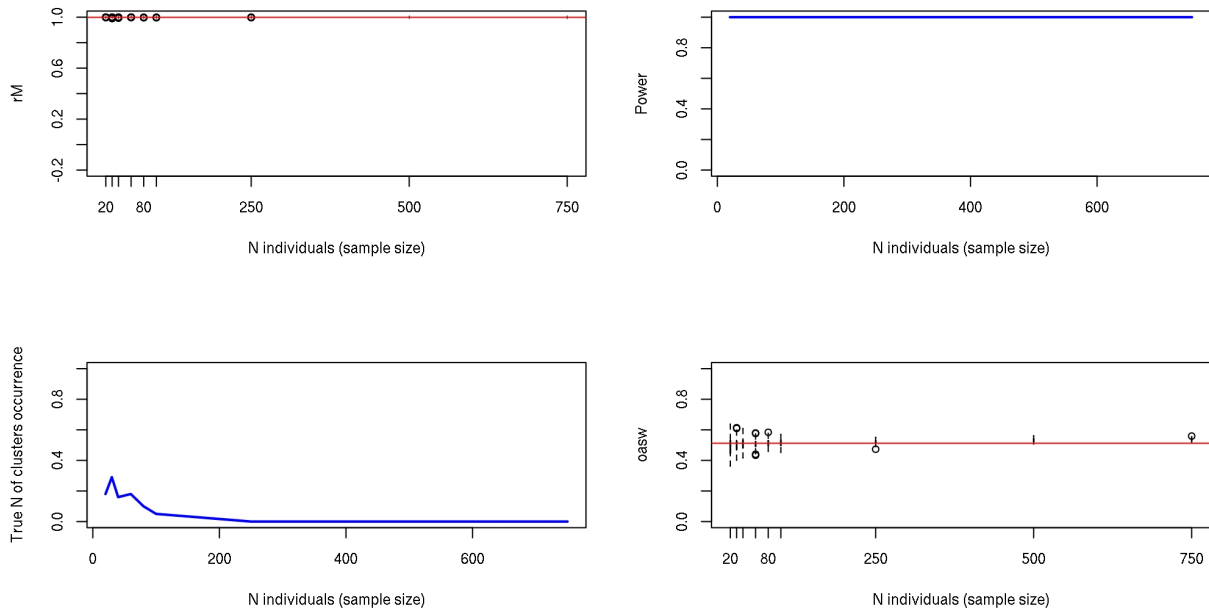


Figure 14790-3. Top left: simulated distribution (boxplots) and observed value (red line) of connectivity. Top right: Simulated power of the analysis. Bottom left: Proportion of times the analysis provides the

observed best number of cluster. Bottom right: simulated distribution (boxplots) and observed value (red line) of clustering intensity.

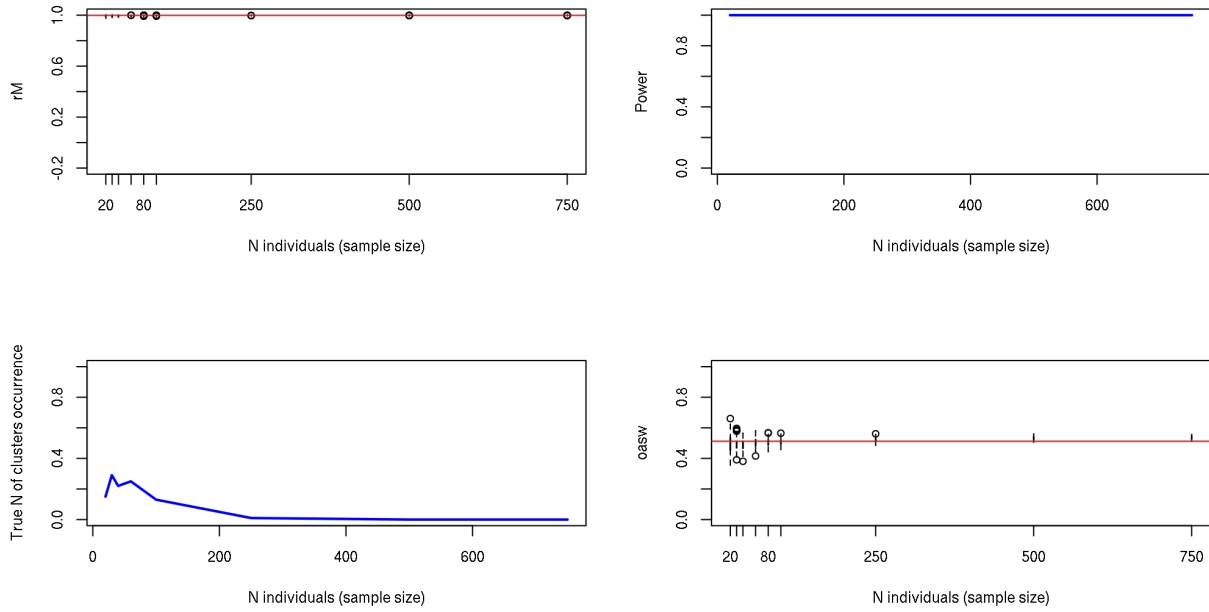


Figure 14790-4. Top left: simulated distribution (boxplots) and observed value (red line) of connectivity. Top right: Simulated power of the analysis. Bottom left: Proportion of times the analysis provides the observed best number of cluster. Bottom right: simulated distribution (boxplots) and observed value (red line) of clustering intensity.

The comparison between the bootstrapped distribution of r_M values from live recaptures and dead recoveries is not significant ($p = 1$); Figure 14790-5).

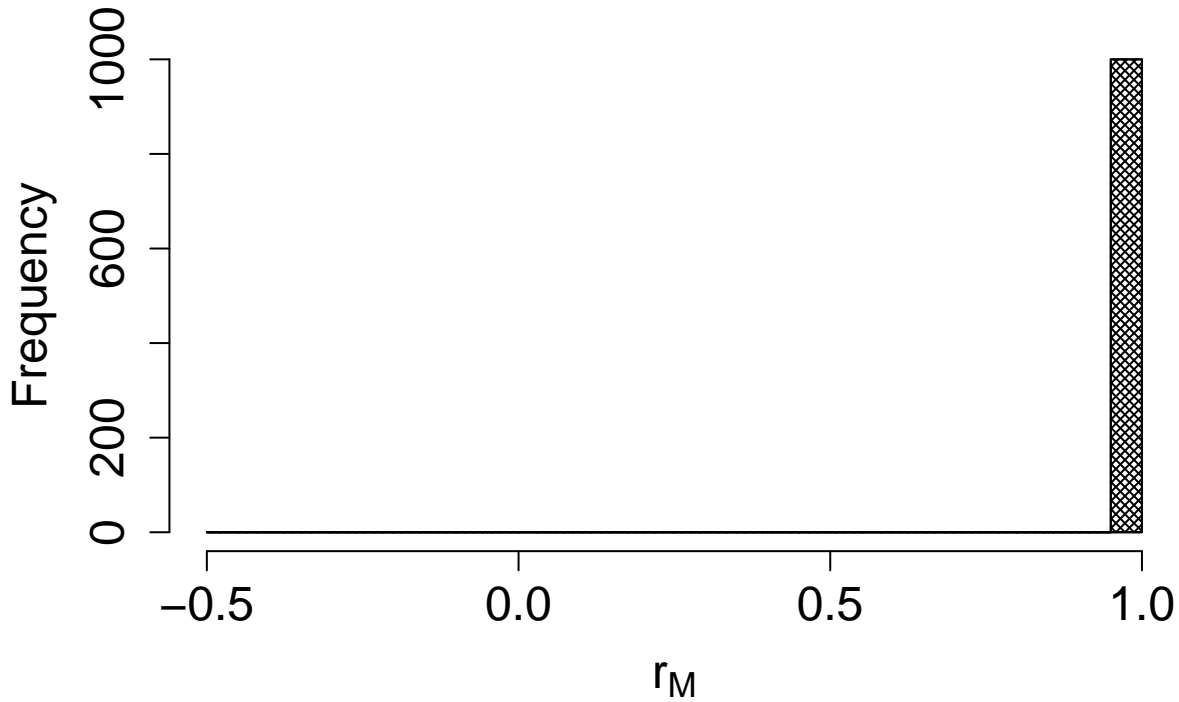


Figure 14790-5. Comparison between the bootstrapped distributions of connectivity value for alive recaptures (filling lines with angle=45°) and dead recoveries (filling lines with angle=375°).

2. Connectivity between pre-defined regions

The species shows high connectivity (MC = 0.999; MC = 0.999 when adjusted for absolute abundance) between 8 breeding regions and 8 non breeding regions (Table 14790-2; Figure 14790-6).

Table 14790-2. Transition probabilities between pre-defined regions. Estimated abundance (number of individuals) in each breeding region is also reported.

Breeding region	Abundance	Non breeding region	Transition probability
Central Europe	8379650	Central Europe	0.996
Central Europe	8379650	South-west Europe	0.001
Central Europe	8379650	West Europe	0.004
East Europe	11692328	East Europe	1.000
North Europe	469020	North Europe	1.000
North-west Europe	440000	North-west Europe	1.000
South-central Europe	2050000	South-central Europe	1.000
South-east Europe	4971000	South-east Europe	1.000
South-west Europe	2299363	South-west Europe	1.000
West Europe	1650914	Central Europe	0.002
West Europe	1650914	West Europe	0.998



Figure 14790-6. Map showing pre-defined regions in different colours, with black arrows linking centroids of individual encounters in different regions. Arrow width is proportional to transition probability.

Reference

BirdLife International and Handbook of the Birds of the World (2019). Bird species distribution maps of the world. Version 2019.1. Available at <http://datazone.birdlife.org/species/requestdis>.