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Spatiotemporal Dynamics in Bird Species Assembly in the Coastal Wetlands of Sicily (Italy): A Multilevel Analytical Approach to Promote More Satisfactory Conservation Planning

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Abstract: The Sicilian wetlands (Italy) are seriously threatened by human activities and ongoing climate change. The loss of these wetlands as migratory stepping stones could severely hamper the migratory flow of many bird species along the central Mediterranean. Targeted actions for the conservation of the avifauna require thorough knowledge of the utilization that waterbirds make of these habitats. Aiming to inform planning for more satisfactory bird habitat management and bird diversity preservation along the Mediterranean migratory bird flyway, in this study, we inventoried the avian metacommunity of the coastal wetlands in Sicily during the most critical period of the year (July–September) and used a multilevel analytical framework to explore the spatiotemporal dynamics in bird species assemblages. We recorded 73 bird species, of which almost 90% were migratory and 30 belonged to Annex I of the Birds Directive. At the metacommunity level, we found that all the biodiversity metrics were low in July and approximately doubled in the successive sampling sessions (August–September), where they showed little if any change. At the community level, we detected two main clusters of wetlands with regard to species richness, of which one (wetlands Baronello, Gela, Gornalunga, and Roveto) was characterized by higher levels of species richness in nearly all the sampling dates. The pattern of species richness in the Sicilian wetlands was most similar between the first and second half of August, while July was very dissimilar from all the other sampling dates. At the guild level, we found a significant increase during July–September in the number of the species belonging to the "Mediterranean" migration guild and the "divers from the surface" and "surface feeders" foraging guilds. At the species level, we detected a significant temporal sequence of the occurrence of waterbird species: two species were only early dwellers in July, ten species were only late dwellers in September, and twenty-six species made use of the Sicilian wetlands all summer long. The spatial distribution of the waterbird species differed significantly between any pair of sampling dates. Overall, the Little Grebe, the Spotted Redshank, and the Little Tern were the bird species with the highest site infidelity; by contrast, the Black Stork, the Broad-billed Sandpiper, the European Golden Plover, the Common Shelduck, and the Black-necked Grebe changed their spatial distribution among wetlands the least during July–September. Our study allowed us to detect (1) the wetlands and (2) the waterbird species to which the priority for conservation should be assigned, as well as (3) the exact time span during July–September when conservation measures should be mandatory, and not only advisable. These results provide a broader insight of the space–time patterns in bird species assembly in the coastal wetlands of Sicily during the critical summer period.

Keywords: avian diversity; Mediterranean bird flyway; Natura 2000 sites; procrustes analysis; seriation analysis; summer period; waterbird conservation

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1. Introduction

Wetlands are among the most diverse and productive ecosystems worldwide, and they provide a broad range of ecological and economic services and benefits, e.g., climate regulation, pollutant filtration services, soil melioration, flood hazard reduction, recreational and cultural services, and biodiversity maintenance [1–4]. The ecosystem service value provided by these ecosystems makes them the most valuable ecosystem per unit area [5]; in fact, it has been estimated that the global annual monetary value of wetland ecosystem services is approximately USD 47.4 trillion dollars, which represents 43.5% of the value of all natural resources [6]. Nonetheless, wetland loss due to natural and anthropogenic factors has been estimated at 64 to 71% since 1900 [7]. Pristine wetland ecosystems have been destroyed to gain land for urban development, agricultural cultivation, tourism and recreational activities, and industrial production [3,4]. In the near future, ongoing climate change, with warmer and dryer summer periods, will increase the risk of the complete drainage of wetlands in summer [8,9], while climate-induced sea level rises will boost the frequency of saltwater intrusions in coastal wetlands [10]. The increased evaporation caused by climate warming, jointly with saltwater intrusions, could drastically alter these ecosystems and decrease their species richness [11]. Accordingly, wetland-dependent species are declining at significantly higher rates than those of terrestrial ecosystems, and such evidence of declines is mounting for waterbirds as well [12].

The coastal wetlands of Sicily (Italy) belong to a migration route, namely the central–eastern Mediterranean bird flyway, of high importance for many avian species crossing the Mediterranean Sea. Because these wetlands serve as refueling areas for hundreds of thousands of waterbirds migrating between Africa and Europe every year [13,14], they are ranked among the most important natural sites at the European level [15]. In summer, these wetlands host many waterbird species, whose conservation interest is mainly at the European and global levels as almost 90% are migratory [9]. The summer period is also a bottleneck time for these waterbirds due to higher levels of tourism activities and human use (illegal dumpsites, camping sites, and so forth) and the concomitant decrease in water levels imputable to water diversions, evaporation, and low rainfall [16,17]. In fact, the coastal wetlands of Sicily are seriously impacted by human activities and climate warming. During 1990–2012, an increase in agricultural and artificial areas, and concomitant decrease in natural and semi-natural ones, occurred in the close surroundings of these wetlands, which caused severe threats like water diversion and discharges due to agricultural activities, the human use and degradation of the surroundings, and tourism pressure [18]. In addition, the increased evaporation has already boosted the frequency of complete wetland drainage in summer, and accelerated sea level rises are already causing frequent saltwater intrusions [9,17].

The conservation of suitable habitats for waterbirds has, thus, become a main objective of wetland management in Sicily. However, no studies so far have clarified the utilization that waterbirds make of these wetlands, in particular, during the critical summer period. Accordingly, in this study, we investigated the spatiotemporal dynamics in bird species assembly in the coastal wetlands of Sicily in summer, aiming to answer the following questions: (1) How much does the level of avian diversity change during July–September? (2) How similar/dissimilar are the studied wetlands with regard to species richness? (3) How does species richness vary by date? (4) Does the proportion of the different ecological guilds change during the summer period? (5) Can bird species be arranged into a temporal sequence so as to reveal statistically significant changes in species composition? (6) How much does the spatial distribution of the waterbird species change during July–September? (7) Which species exhibit the highest/lowest site fidelity? (8) How can we use these results to customize the conservation strategies for the avian diversity? In order to answer these questions, we employed a multilevel analytical approach involving the metacommunity, community, guild, and species levels. Our results can improve the conservation strategies of these waterbird species along the central–eastern Mediterranean bird flyway.

2. Materials and Methods

2.1. Study Area and Field Surveys

The study area (Figure 1) corresponded to the natural coastal wetlands larger than 10 hectares present in Sicily. The number of sampling points was proportional to the wetland extent, with a maximum of 12 points per wetland. Using regularly spaced sampling points with 200 m minimum distance to minimize spatial autocorrelation [19], we selected 58 sampling points in the wetlands under study (Table S1), where we carried out five sampling sessions of the avian diversity during the end of July to the end of September 2016, at regular intervals of 10–15 days between successive sessions. The sampling sessions corresponded to the second half of July (J2), the first (A1) and second (A2) half of August, and the first (S1) and second (S2) half of September. We applied the standard point count sampling method [20] that required a 100 m observation distance around each sampling point and a 15 min observation time with recording of all visual or vocal contacts. Following [21], we then assigned two functional traits to each bird species: foraging (divers from flight, divers from the surface, intermediate waders, large waders, small waders, and surface feeders) and migratory (Mediterranean, mixed, sedentary, and trans-Saharan) guilds. Our study did not require ethical approval, and we did not need permission for our fieldwork.

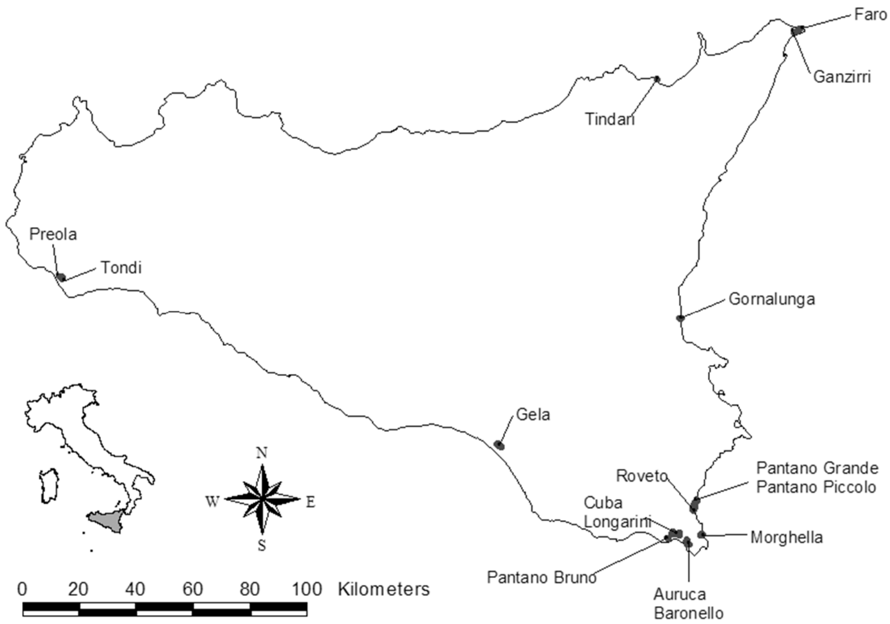

Figure 1. The sixteen coastal wetlands under study in Sicily (Italy). Faro and Ganzirri apart, all wetlands belong to the Natura 2000 network.

2.2. Data Analyses

2.2.1. Metacommunity Level

For each sampling date, we calculated the matrix fill (i.e., percent of 1 s in the presence–absence matrix), α diversity (mean number of bird species per wetland), γ diversity (total number of bird species in the wetlands under study), and β diversity. The latter was calculated with the standard equation in [22] (S1).

2.2.2. Community Level

We built the (16 rows $\times$ 5 columns) matrix **R** of species richness for the sixteen wetlands (rows) in the five sampling dates (columns; Table S2). We used two-way hierarchical cluster analysis with Ward's method (i.e., clusters were joined such that the increase in within-group variance was minimized; [23]) to allow simultaneous clustering in R-mode (i.e., wetlands) and Q-mode (i.e., sampling dates) of **R**.

2.2.3. Guild Level

We built the (5 rows × 6 columns) matrix **F** of the number of bird species belonging to the six foraging guilds (columns) in the five sampling dates (rows). We also calculated the (5 rows × 4 columns) matrix **M** of the number of bird species belonging to the four migratory guilds (columns) in the five sampling dates (rows).

We used the Mann–Kendall trend test [24,25] to detect consistently increasing or decreasing trends in the number of bird species belonging to the foraging (matrix **F**) and migratory (matrix **M**) guilds. The Mann–Kendall trend test is a non-parametric test that can be used to find trends for as few as four samples. The null hypothesis H_0 is that there is no monotonic trend in the series, while the alternate hypothesis H_1 is that a (positive or negative) trend exists. This test returned S that is negative for a negative trend, zero for no trend, and positive for an increasing trend. The Z statistic was used to calculate the p-value associated with S from the cumulative normal distribution; p-values < 0.05 were regarded as statistically significant.

2.2.4. Species Level

We created a (73 rows × 5 columns) matrix **P** of presences–absences of the seventy-three bird species (rows) recorded in the Sicilian wetlands in the five dates of sampling (columns; Table S3). We then used seriation analysis [26] to arrange bird species into a temporal sequence. Seriation analysis sought the best order of bird species such that the position of each species reflected its similarity to the others, thus revealing groupings or gradual changes in species composition during the study period. In doing so, the seriation routine operated a reordering of rows (taxa) and attempted to reorganize **P** such that the presences were concentrated along the diagonal. The amount of concentration of the presences along the diagonal of **P** was ascertained by the test criterion C proposed by [27], where a perfect seriation with all the presences along the diagonal of the matrix yields $C = 1$, while less-perfect seriations generate lower test criteria. We used constrained optimization (i.e., only taxa were free to move, while the dates of sampling were fixed) with Monte Carlo simulations that generated and seriated 10^3 random matrices with the same number of occurrences within each taxon and compared these to the original matrix to check if it was more informative (i.e., higher C) than a random one. The Z statistic was then used to calculate the p-value associated with the actual C from the cumulative normal distribution of the randomized C; p-values < 0.05 were considered statistically significant. Based on the results of the seriation analysis, we then grouped the waterbird species into several clusters representing the different temporal utilization of the Sicilian wetlands during July–September.

For each sampling date, we created the (73 rows × 16 columns) species-by-site incidence matrix **I** (Tables S4–S8). We then used procrustes analysis [28] to assess (a) the overall degree of pairwise concordance/discordance between sampling dates and (b) the waterbird species that were more responsible for such concordance/discordance. As otherwise stated, we sought to identify how much the spatial distribution of the waterbird species in the Sicilian wetlands differed (i.e., from species presence to absence, and vice versa) during July–September and which species showed high or low site fidelity. Procrustes analysis is a method of comparing two matrices of data, by attempting to transform them into a state of maximal superimposition. It does so by minimizing the sum of squared distances (termed m^2) between corresponding points in each matrix through translation, reflection, rigid rotation, and dilation of their coordinates. The null hypothesis H_0 was that the degree of concordance between species-by-site incidence matrices was no greater than expected given random inter-matrix associations. The significance of the m^2 statistic was tested by permutation [29], whereby the row assignments in one matrix were randomly permuted 9999 times to create the null distribution. The total length (L) of the residual vector gave, for each species, an assessment of its site fidelity/infidelity between any two sampling dates (the higher L, the higher the site infidelity). The sum of such residuals (S_L) quantified, for each species, its overall fidelity/infidelity to the wetlands under study during the summer period.

The methodological framework used in this study is depicted in Figure 2.

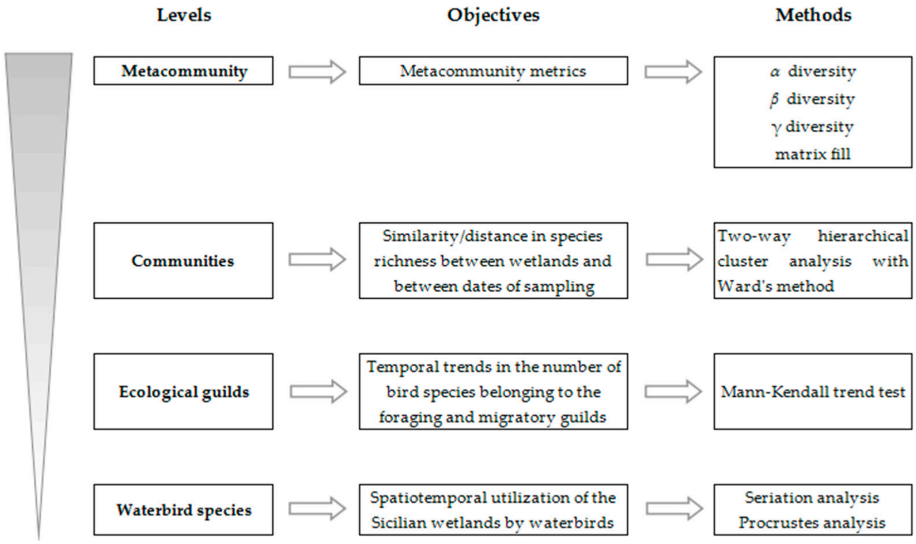

Figure 2. The methodological framework used in this study.

3. Results

We recorded 73 bird species, of which 68 were migratory (Table S9), 30 belonged to Annex I of the Birds Directive (Table S10), 8 belonged to SPEC category 1, 5 to SPEC category 2, and 15 to SPEC category 3 (Table S10).

With the exception of β diversity, all the metacommunity metrics were low in the second half of July (J2) and approximately doubled in the successive sampling sessions (A1, A2, S1, and S2), where they showed little if any change (Figure 3).

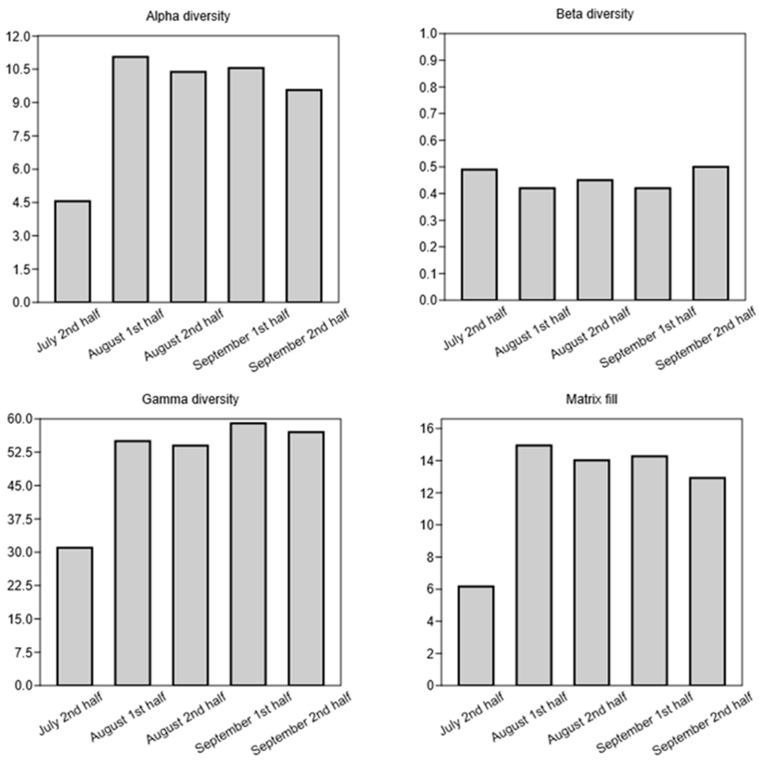

Figure 3. Metacommunity metrics relating to the five sampling sessions of the avian diversity.

At the community level, the highest species richness (40 waterbird species) was recorded at the wetland Roveto in the first half of September. The wetland Roveto registered the highest species richness in all the sampling dates, except for J2 when the wetland Cuba hosted 21 bird species. Two main clusters of wetlands emerged with regard to the bird richness (Figure 4). The first group (wetlands Baronello, Gela, Gornalunga, and Roveto) was characterized by higher levels of species richness in nearly all the sampling dates. Within this first cluster, the sub-group formed by the wetlands Gornalunga and Baronello had lower bird richness in all the sampling dates with respect to the second sub-group (Gela and Roveto). The second group (12 wetlands) was characterized by lower levels of species richness in almost all the sampling dates. Several sub-groups emerged, as well as the anomalous profiles of the wetlands Cuba (high bird richness in J2 and S2, both with very low values in A1, A2, and S1) and Pantano Bruno (high bird richness in A1 and A2, both with very low values in J2, S1, and S2). The sub-group formed by the wetlands Auruca, Morghella, and Longarini was characterized by the lowest levels of species richness in nearly all the sampling dates. The pattern of species richness in the wetlands under study was most similar between A1 and A2, with J2 being very dissimilar from the other sampling dates (Figure 4).

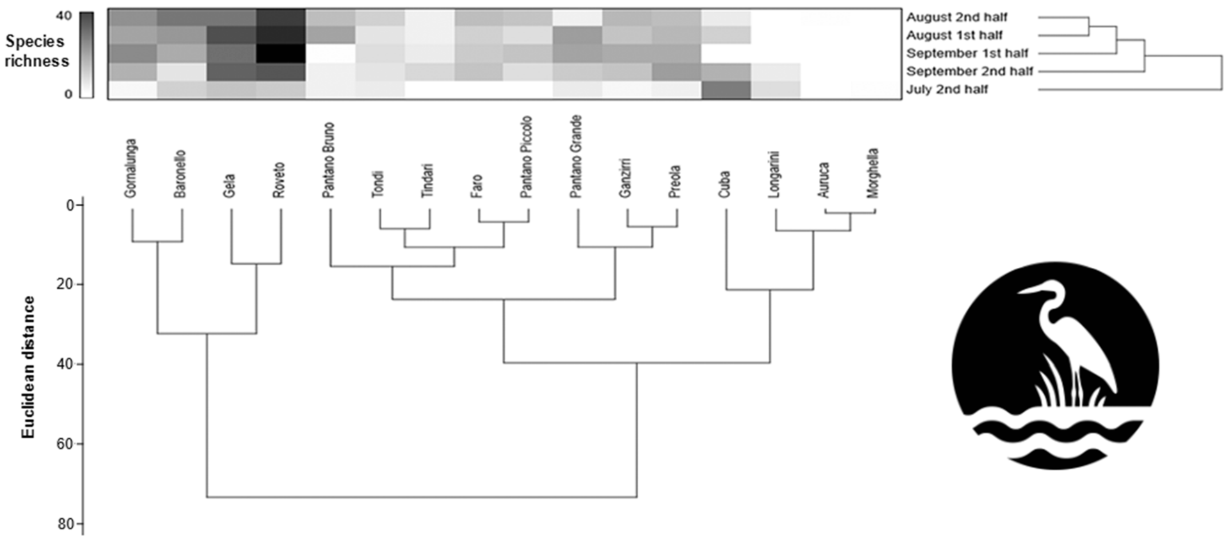

Figure 4. Results of the two-way hierarchical cluster analysis with Ward's method.

At the guild level, we found a significant increase in the number of the species belonging to the "Mediterranean" (S = 7; $p = 0.042$) migration guild during July–September (Table 1). We also found a significant increase in the species richness of the two foraging guilds "divers from the surface" (S = 7; $p = 0.042$) and "surface feeders" (S = 8; $p = 0.042$) (Table 2).

Table 1. Results of the Mann–Kendall trend test applied to matrix **M** of the number of bird species belonging to the four migratory guilds (columns) in the five sampling dates (rows).

Date of Sampling	Mediterranean	Mixed	Sedentary	Trans-Saharan
July (2nd half)	8	7	5	11
August (1st half)	13	18	5	19
August (2nd half)	13	17	5	19
September (1st half)	13	20	5	21
September (2nd half)	14	19	5	19
S:	7	6	0	5
p (no trend):	0.042	0.117	0.592	0.117
Statistically significant?	yes	no	no	no

Table 2. Results of the Mann–Kendall trend test applied to matrix **F** of the number of bird species belonging to the six foraging guilds (columns) in the five sampling dates (rows).

Date of Sampling	Divers from Flight	Divers from the Surface	Intermediate Waders	Large Waders	Small Waders	Surface Feeders
July (2nd half)	1	3	6	7	6	8
August (1st half)	7	5	9	9	9	16
August (2nd half)	7	5	8	8	10	16
September (1st half)	4	5	10	9	13	18
September (2nd half)	6	6	10	9	8	18
S:	1	7	6	5	4	8
p (no trend):	0.408	0.042	0.117	0.117	0.242	0.042
Statistically significant?	no	yes	no	no	no	yes

At the species level, we found a statistically significant ($C = 0.94$; $Z = -5.06$; $p < 0.01$) temporal sequence of the occurrence of waterbird species in the Sicilian wetlands during July–September (Figure 5). Two species (Great Egret and Black-tailed Godwit; group 1) were only early dwellers (J2 and A1). By contrast, ten species (groups 14, 15, and 16) were only late dwellers (S1 and S2). Twenty-six species made use of the Sicilian wetlands all summer long (group 2). Seven species were present intermittently from A1 to S2 (group 8), while a further 13 species were constantly present in the same period (group 9).

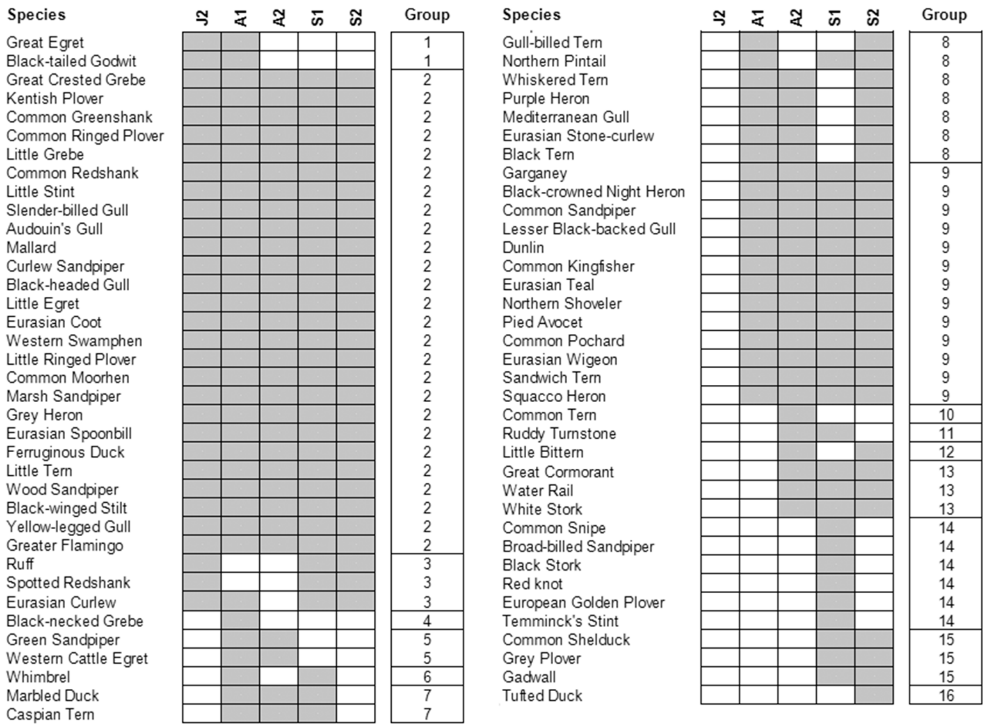

Figure 5. Results of the seriation analysis. The waterbird species are arranged into a statistically significant temporal sequence from early dwellers (group 1) to late dwellers (group 16). J2: second half of July. A1 and A2: first and second half of August. S1 and S2: first and second half of September.

The spatial distribution of the waterbird species in the Sicilian wetlands differed significantly between any pair of sampling dates, but differences decreased constantly from June to September (Table S11). Between J2 and A1 ($m^2 = 0.828$; $p < 0.01$), the species that most changed their spatial distribution were the Little Grebe ($L = 0.267$), the Western Swamphen ($L = 0.211$), and the Red knot ($L = 0.205$), while 13 species ($L = 0.057$) showed high site fidelity. Between A1 and A2 ($m^2 = 0.797$; $p < 0.01$), seven species (Spotted Redshank, Little Grebe, Red knot, Temminck's Stint, Lesser Black-backed Gull, Little Stint, and Audouin's Gull) markedly changed their spatial distribution in the Sicilian wetlands, while nine species ($L = 0.054$) demonstrated high site fidelity. Between A2 and S1 ($m^2 = 0.532$; $p < 0.01$), the Ruff (L = 0.174) was the species with the highest site infidelity, while many species kept their spatial distribution almost constant. Between S1 and S2 (m^2 = 0.494; $p < 0.01$), it was the Squacco Heron (L = 0.166) that most changed its spatial distribution in the Sicilian wetlands; by contrast, many species showed high site fidelity. Overall, the Little Grebe (S_L = 0.692), the Spotted Redshank (S_L = 0.611), and the Little Tern (S_L = 0.555) were the bird species with highest site infidelity during July–September (Figure 6); by contrast, the Black Stork (S_L = 0.223), the Broad-billed Sandpiper (S_L = 0.223), the European Golden Plover (S_L = 0.223), the Common Shelduck (S_L = 0.216), and the Black-necked Grebe (S_L = 0.201) changed their spatial distribution the least.

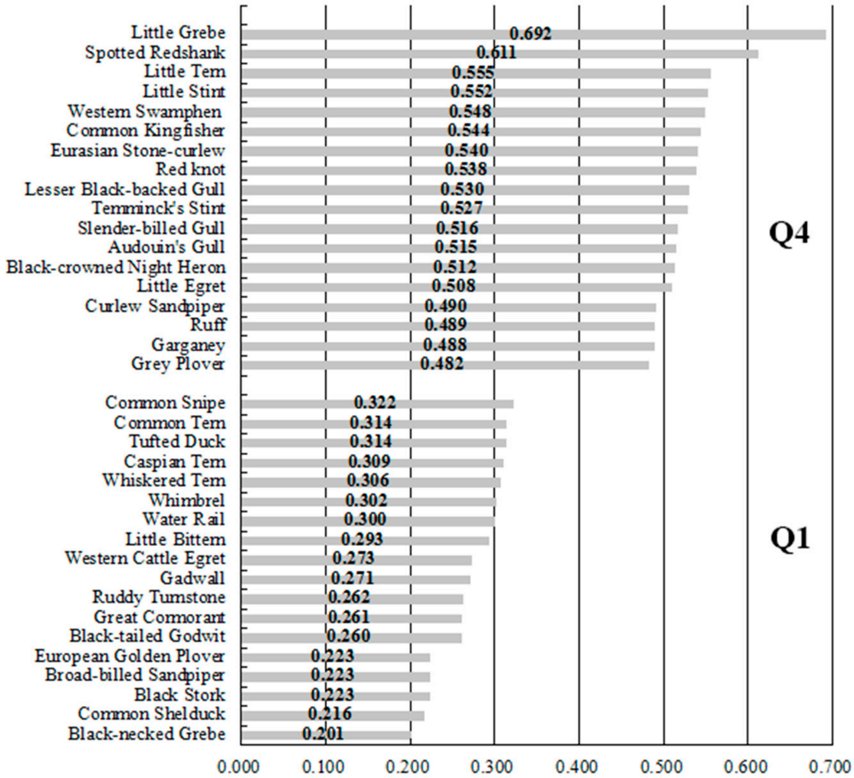

Figure 6. Results of the procrustes analysis. The numbers represent the sum of the residual vectors (S_L). Waterbird species are arranged downward from those exhibiting the highest site infidelity (i.e., lowest site fidelity) to those with the lowest one (i.e., highest site fidelity). Only the fourth (Q4; species with highest site infidelity) and first (Q1; species with highest site fidelity) quartiles are shown. The full list of species is given in Table S11.

4. Discussion

Many recent studies have clearly evidenced the unfavorable effects of human (e.g., water diversion for agricultural activities, water discharges, and tourist and recreational activities) and climate (e.g., saltwater intrusions due to climate-induced sea level rise and freshwater shortage due to warmer and dryer summer periods) threats on wetlands and the associated avifauna [30–37]. Waterbirds, especially migratory ones, are largely influenced by the climate conditions and human disturbance in wetlands, which can affect their migratory breeding and foraging [38]. Waterbirds are also particularly vulnerable to habitat changes caused by anthropogenic land conversions [39].

Targeted actions for the conservation of the avifauna require in-depth knowledge of the use that waterfowls make of wetlands. Accordingly, in this study, we investigated the spatiotemporal dynamics in waterbird species assembly in the coastal wetlands of Sicily (Italy) during the critical summer period by using a multilevel analytical approach involving the metacommunity, community, guild, and species levels. We found that (a) thirty waterbird species belonged to Annex I of the Birds Directive, and twenty-eight species belonged to SPEC category 1, 2, or 3 [40]; (b) all the metacommunity metrics were low in July and roughly doubled in the successive sampling sessions; (c) two main clusters of wetlands emerged with regard to species richness, of which one was characterized by high levels of species richness in nearly all the sampling dates; (d) the pattern of species richness in the Sicilian wetlands was most similar between the first and second half of August, with July being very dissimilar from all the other sampling dates; (e) there was a significant increase during July–September in the number of the species belonging to the "Mediterranean" migration guild and the "divers from the surface" and "surface feeders" foraging guilds; (f) there was a statistically significant temporal sequence of the occurrence of waterbird species; (g) some species were only early dwellers in July, some other species were only late dwellers in September, and twenty-six species made use of the Sicilian wetlands all summer long; (h) the spatial distribution of the waterbird species differed significantly between any pair of sampling dates; and (i) some bird species showed high site (i.e., wetland) fidelity, while some other species systematically changed their spatial distribution during July–September.

Implications for the Conservation of the Waterbird Species of the Sicilian Wetlands

Previous studies [9,16–18] have emphasized the critical condition of the avian metacommunity of the Sicilian wetlands during the summer period, with severe threats affecting most wetlands and significant negative effects on the associated avifauna. However, such studies have also evidenced that the peculiar structure of this avian metacommunity would facilitate the implementation of conservation policies that could mitigate and/or compensate for such effects. In fact, it has been demonstrated that, in summer, this avian metacommunity is significantly nested and presents random species assemblages [16,17]. In such a nested metacommunity, the species that exist on a few wetlands tend to be found also on those wetlands inhabited by many different species, which places special emphasis on the conservation of the most hospitable (i.e., with a larger number of species) wetlands. A random species assemblage indicates that species associations are weak and environmental control is predominant, which, in turn, suggests that proper interventions on wetland attributes will have substantial beneficial effects.

First, the support in terms of habitat and food provided by the Sicilian wetlands to the waterbird species, especially the migratory ones, is variable during the summer period. In July, the number of sedentary species was already at its maximum, while the number of migratory species was still very limited; in fact, we recorded only 31 waterbird species, and the matrix fill was only 6.2%. By contrast, the first half of August witnessed a large increase in the biodiversity metrics, with 55 waterbird species recorded, and the matrix fill rose to 14.9%. The second half of September showed a moderate decrease in the biodiversity metrics, which probably marked the decline in the importance of the Sicilian wetlands for the migratory waterbird species. The detected patterns of the biodiversity metrics suggest that the conservation strategies (prohibition of water diversions for agricultural activities; use of water delivery and water discharge structures to artificially raise and lower water levels; closure of all channels that connect these wetlands to the sea in order to limit saltwater intrusions; removal of illegal dumpsites present in the surroundings of some wetlands; and prohibition or limitation of tourist and recreational activities [16–18]) for these wetlands and the associated avifauna should be necessarily active in the period between early August (A1) and mid-September (S1), while they could be non-obligatory, although highly advisable, in the remaining part of summer. Because these conservation measures could be expensive and not easily accepted by locals, halving the period when they are mandatory is an important step towards their feasibility.

Second, four wetlands (Baronello, Gela, Gornalunga and Roveto) supported higher levels of species richness in nearly all the sampling dates in summer. Because these four wetlands cover the whole southeastern side of Sicily (Figure 1), which hosts most of the wetlands and waterbird species, they should be given the highest priority for interventions. As otherwise stated, these four wetlands should be considered the backbone of the preservation of the waterbird species in Sicily, where the priority for conservation measures should be concentrated. Because it is vital to act fast to put in place such measures, this result provides conservation managers a way to soundly limit their efforts to a restricted number of sites, thus increasing the feasibility of proactive conservation strategies.

Third, the significant increase during July–September in the number of the species belonging to the "Mediterranean" migration guild and the "divers from the surface" and "surface feeders" foraging guilds has important consequences for conservation planning. It has been demonstrated that the bird species belonging to the Mediterranean guild, as well as to the "divers from the surface" and "surface feeders" foraging guilds, are significantly favored by higher water levels and water-level fluctuations [16]. However, both the water levels and water-level fluctuations are reduced to the minimum in the Sicilian wetlands in August due to the increase in evaporation and the concomitant decrease in rainfalls [9]. This suggests that, at least in the four wetlands Baronello, Gela, Gornalunga, and Roveto in the period from early August up to mid-September, two solutions are highly advisable: a) the prohibition of water diversions for agricultural activities before and during the summer period and b) the use of water delivery and water discharge structures (e.g., hydraulic pumps) to artificially raise and lower water levels.

Fourth, waterbird species were shown to make diversified use of the Sicilian wetlands in summer. Thirty-nine species (groups 2 and 9; Figure 5) were present for at least 80% of time (i.e., at least four sampling sessions out of five) in summer. The remaining species made discontinuous use of the Sicilian wetlands, and the occurrence of nine species (Black-necked Grebe, Common Tern, Common Snipe, Broad-billed Sandpiper, Black Stork, Red knot, European Golden Plover, Temminck's Stint, and Tufted Duck) was only episodic. Conservation efforts should primarily address the waterbird species that were shown to be dependent on the Sicilian wetlands all summer long. With this view, the conjoint reading of the results of the seriation and procrustes analyses allowed us to detect the waterbird species at highest priority of conservation in these wetlands in summer. In fact, these thirty-nine species (groups 2 and 9) showed very different levels of site fidelity/infidelity during July–September (Figure 6, Table S11): some species were able to frequently change their spatial distribution, while others showed elevated site fidelity. The first group comprised the Little Grebe, the Little Tern, the Little Stint, the Western Swamphen, the Common Kingfisher, the Lesser Black-backed Gull, the Slender-billed Gull, the Audouin's Gull, and the Black-crowned Night Heron. The second group was composed of the Ferruginous Duck, the Eurasian Coot, the Kentish Plover, the Marsh Sandpiper, the Pied Avocet, the Common Ringed Plover, the Common Pochard, the Black-winged Stilt, the Eurasian Spoonbill, the Sandwich Tern, and the Common Greenshank. This latter group depended on the same wetlands for at least 80% of time in summer; thus, these species are at high risk of being impacted by the human alteration of wetlands and ongoing climate change and should be considered at highest priority of conservation. In addition, because waterbird species were highly sensitive to wetland traits in Sicily [9], the populations trends of the species of this second group could be used as proactive indicators of the ecological status of the Sicilian wetlands.

5. Conclusions

Every year, the coastal wetlands of Sicily witness the migration of hundreds of thousands of waterbirds migrating between Africa and Europe. However, the current levels of exploitation, combined with the exacerbation of climate-driven factors, could soon exclude many bird species from these wetlands and seriously hinder the migratory flow of many waterbirds along the central Mediterranean.

Accordingly, in this study, we used a multilevel analytical approach, involving the metacommunity, community, guild, and species levels, to detect the spatiotemporal dynamics in bird species assembly in these wetlands during the critical summer period. We found clear and sharp patterns in bird species assemblages at all the biodiversity levels investigated. Our study determined the wetlands and waterbird species to which the priority for conservation should be assigned, as well as the exact time span during the summer period when conservation measures should be mandatory, and not only advisable. Because human activities and climate change could induce fast changes to wetland traits, our results also suggest updating biodiversity data on a regular basis.

These results have implications for refining the conservation strategies of the waterbird species of the Sicilian wetlands. Because 14 out of 16 wetlands belong to the Natura 2000 ecological network of protected areas (i.e., the largest such network in the world, which requires management plans and conservation measures as the basis for the conservation of species and habitats in the Natura 2000 sites), these strategies should be highly feasible. Therefore, the present study added new valuable information for the proactive conservation of the waterbirds species of the Sicilian wetlands and, in general, of the migration routes along the central–eastern Mediterranean bird flyway.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13081333/s1, Table S1: List of the 58 sampling points used in the sixteen Sicilian wetlands under study; Text S1: Calculation of β diversity; Table S2: Matrix **R**: species richness (number of avian species) recorded in the coastal wetlands of Sicily during five sampling sessions; Table S3: Matrix **P**: presences–absences of waterbird species recorded in the Sicilian wetlands in five dates of sampling; Table S4: Species-by-site incidence matrix **I** in the second half of July; Table S5: Species-by-site incidence matrix **I** in the first half of August; Table S6: Species-by-site incidence matrix **I** in the second half of August; Table S7: Species-by-site incidence matrix **I** in the first half of September; Table S8: Species-by-site incidence matrix **I** in the second half of September; Table S9: Functional traits (foraging and migration) of the bird species recorded in the coastal wetlands of Sicily; Table S10: List of the avian species recorded in the coastal wetlands of Sicily; Table S11: Results of the procrustes analysis [22].

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