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RESEARCH ARTICLE

# Dynamics and composition of breeding bird communities on Kitay Island, Central Sivash region

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## Abstract

The Central Sivash region, a unique ecosystem of saline lakes and reed-beds, hosts important colonial waterbird communities. This study analyzes long-term changes (1949–2024) in the breeding bird population on Kitay Island, one of the area's key islands. Our results reveal a significant ecological restructuring, marked by a pronounced increase in Great Cormorants (*Phalacrocorax carbo*), which became the dominant species, and a concurrent decline in Yellow-legged Gulls (*Larus cachinnans*). Total nest numbers peaked in the late 20th century before declining to a lower, stable level. Community analyses identified three distinct succession phases: a gull/tern-dominated assemblage (1950–1980), a cormorant-dominated phase (1990–2010), and a more mixed and diverse recent community. These shifts are interpreted in the context of environmental drivers including habitat change, interspecific competition, predation pressure, and reduced human disturbance. This most recent phase is characterized by a slight reduction in species dominance and an increase in diversity, driven by the arrival of new species. These findings demonstrate profound community turnover and highlight the dynamic response of avian populations to environmental change, providing critical insights for the conservation management of this sensitive habitat.

## Keywords

Colonial waterbirds, community ecology, long-term ecological monitoring, Great Cormorant (*Phalacrocorax carbo*), ecological succession, Sivash lagoon, Azov Sea wetlands, species turnover, interspecific competition, biodiversity dynamics

## Introduction

The Central Sivash region, located on the border of Kherson Oblast and the Autonomous Republic of Crimea, is a former bay of the Azov Sea now isolated by dams, forming a hypersaline lake system with varied freshwater and brackish habitats. Covering approximately 80,000 hectares, this region supports unique wetland ecosystems that are vital for aquatic biodiversity. Kitay Island, a continental-type island within this system, provides critical breeding grounds for colonial waterbirds such as the Great Cormorant (*Phalacrocorax carbo*), Palas's Gull (*Larus ichthyaetus*), and Yellow-legged Gull (*Larus cachinnans*) (Siokhin et al. 1988; Andriushchenko et al. 2000). Islands in such lacustrine and coastal environments are known to be especially important for breeding waterbirds, yet are highly sensitive to habitat alteration, predation, and anthropogenic disturbance (Whittaker et al. 2008; MacArthur and Wilson 2001).

Long-term ornithological monitoring in the Sivash has documented dynamic colonial nesting assemblages, with populations fluctuating in response to environmental change, predation, and human activity (Siokhin 2000; Matsyura 2000). Recent trends suggest an increase in cormorant numbers alongside shifts in gull colonies, consistent with broader patterns in temperate wetlands (Siokhin and Matsyura 2025). Furthermore, the region's mosaic of habitats – shaped by salinity gradients, vegetation succession, and nutrient inputs from bird colonies – creates a heterogeneous landscape that supports diverse avian and plant communities. This dual ecological significance underscores the need for integrated conservation approaches.

Despite these valuable insights, comprehensive multidecadal analyses of species composition, abundance trends, and community structure metrics remain scarce for the Central Sivash islands. Most existing studies focus on individual species or short-term population assessments, leaving a gap in understanding long-term community turnover, functional shifts, and the drivers of such change in this unique saline wetland (Anderson et al. 2011). This gap limits the ability to predict community responses to ongoing environmental pressures, including climate change, habitat modification, and human encroachment.

This study aims to address this knowledge gap by analyzing a 75-year dataset (1949–2024) of breeding bird colonies on Kitay Island. Through an integrated examination of population trends, diversity indices, species turnover, and community ordination, we seek to (1) quantify long-term changes in the avian community, (2) identify key phases of ecological succession, and (3) elucidate the potential drivers, including environmental change and interspecific interactions, underlying observed dynamics. The findings are intended to inform effective conservation strategies for maintaining avian biodiversity in the Central Sivash and similar wetland ecosystems under increasing environmental change.

## Materials and methods

### Study Area and Data Collection

The study was conducted on Kitay Island, a continental-type island in the Central Sivash lagoon system (46°03′44″ N, 34°20′23″ E). The area is characterized by saline lake conditions, variable shoreline erosion, and meadow-steppe vegetation dominated mainly by Bromus, Elytrigia, and Atriplex species (Fig. 1). Kitay Island serves as a critical breeding site for several colonial waterbird species, including Great Cormorant (*Phalacrocorax carbo*), Yellow-legged Gull (*Larus cachinnans*), and Palas's Gull (*Larus ichthyaetus*), see Fig. 2.

Long-term data on bird nest counts were compiled from archival ornithological surveys, reserve monitoring records, and recent field observations spanning 1949 to 2024. Historical sources (Siokhin et al. 1988) provided early-stage data, complemented by local reserve monitoring results and recent field surveys conducted as part of long-term regional monitoring programs (Siokhin 2000; Siokhin et al. 2021).

**Figure 1.** Kitay Island (Central Sivash area). Photo by V. Siokhin.

### Data Standardization and Integration

To ensure comparability across decades, data were carefully cross-referenced and validated. Historical surveys (1949–1980s) primarily used total colony counts and nest mapping from fixed observation points – methods consistent with the standardized protocols later adopted by the regional monitoring program. From 1990 onward, annual surveys followed a consistent protocol: direct nest counts within defined colony boundaries during the peak breeding period (May–June), conducted by experienced ornithologists. Where methodological differences existed (e.g., estimated vs. direct counts in early years), data were harmonized by referring to original notes and applying conservative adjustments only when supported by explicit metadata. Despite these efforts, some inter-decadal variability in detection probability remains a known limitation of long-term retrospective datasets.

**Figure 2.** Kitay Island coastline. Photo by V. Siokhin.

## Data Preparation

All species recorded breeding on Kitay Island during the study period were included in the community matrix. The full species list comprised: Great Cormorant (*Phalacrocorax carbo*), Palas's Gull (*Larus ichthyaetus*), Yellow-legged Gull (*Larus cachinnans*), Caspian Tern (*Hydroprogne caspia*), Shelduck (*Tadorna tadorna*), Common Starling (*Sturnus vulgaris*), Sand Martin (*Riparia riparia*), Jackdaw (*Corvus monedula*), Steppe Crane (*Anthropoides virgo*), Eurasian Oystercatcher (*Haematopus ostralegus*), and Barn Swallow (*Hirundo rustica*). Annual nest counts (or breeding pair equivalents) were organized into a community matrix with years as rows and species as columns. Zero values indicate years in which a species was not recorded breeding.

### Statistical and Community Analyses

All statistical analyses were performed using R software (version 4.3.1) and relevant ecological packages including vegan (v2.6-4), ggplot2 (v3.4.4), ggrepel (v0.9.3), and tidyr (v1.3.0).

We calculated annual species diversity using Shannon's diversity index (H') to capture species richness and evenness, and the Berger-Parker dominance index (d) to quantify the proportional abundance of the most abundant species (Kadmon and Allouche 2007). Indices were computed using the vegan::diversity() function. To assess temporal trends, indices were also aggregated by decade for visualization.

Linear regressions of nest counts against year were performed per species to detect significant long-term population trends. Slope coefficients, coefficients of determination ($R^2$), and p-values were calculated using the lm() function in R.

For multivariate analysis of community composition, we calculated a Bray–Curtis dissimilarity matrix between all year-pairs using the vegan::vegdist() function. The Bray–Curtis index was selected because it is widely recommended for ecological community data, being sensitive to compositional differences while ignoring joint absences, and it performs well with the abundance data and moderate number of species in this study (Anderson et al. 2011). Principal Coordinates Analysis (PCoA) was then applied to this matrix using the cmdscale() function to ordinate years in reduced space. PCoA was chosen over Non-metric Multidimensional Scaling (NMDS) because the limited number of species (n=11) and the high proportion of zeroes in the matrix can lead to instability and zero-stress warnings in NMDS; PCoA provides a stable, eigenvalue-based ordination suitable for this dataset.

Species turnover between sequential decades was quantified as the proportion of species gained or lost relative to the total species pool across periods ($\beta_t$). This metric was calculated as $\beta_t = (b + c)/(S_1 + S_2)$, where b and c are the numbers of species unique to the first and second period, respectively, and $S_1$ and $S_2$ are the species richness values for each period.

Spatial data for Kitay Island's geographic location were visualized with base maps from the maps package and layered with geospatial points indicating the island's precise coordinates. The map was rendered using ggplot2 with coordinate correction to maintain accurate aspect ratios.

## Results

### Species Composition and Population Trends

The breeding bird community on Kitay Island (Fig. 2) was dominated by several key colonial waterbird species during the study period (1949–2024). The most abundant species were the Great Cormorant, Yellow-legged Gull, Palas's Gull, and a suite of others including Shelduck (*Tadorna tadorna*), Common Starling (*Sturnus vulgaris*), and Steppe Crane (*Anthropoides virgo*).

Long-term monitoring revealed significant shifts in the avian community structure, marked by pronounced population trends, species turnover, and distinct temporal phases. Population trends, analyzed using untransformed nest count data, varied considerably among the key species (Fig. 3). The Great Cormorant exhibited a very significant population increase (slope = +60.1 pairs/year; 95% CI: 53.2 to 67.0; $R^2 = 0.77$, $p < 0.001$), becoming the dominant species in recent decades. In contrast, Yellow-legged Gulls experienced a significant decline (slope = -3.7 pairs/year; 95% CI: -7.1 to -0.3; $R^2 = 0.18$, $p = 0.03$). The Palas's Gull population remained stable (slope = +0.1 pairs/year; 95% CI: -0.5 to 0.7; $R^2 = 0.01$, $p = 0.72$), characterized by an episodic presence at the site.

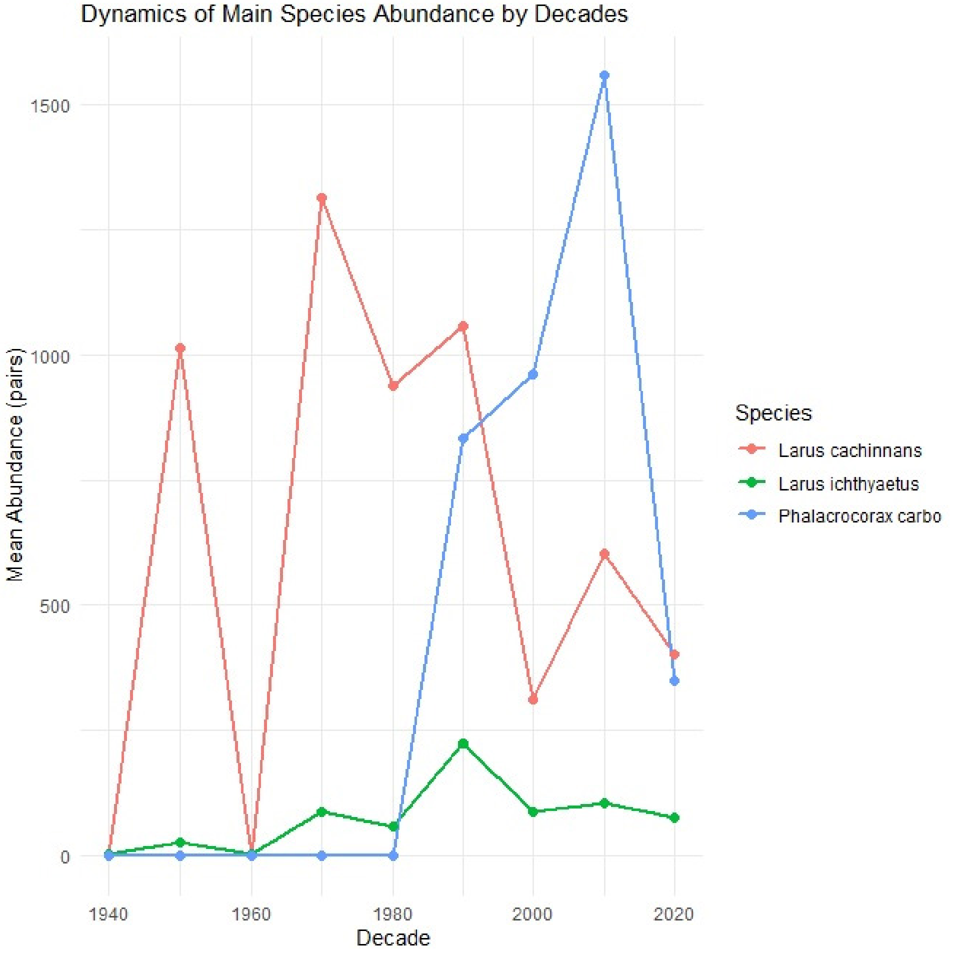


**Figure 3.** Temporal trends of nest counts for key breeding species (1949–2024). Regression lines with 95% confidence intervals are shown for species with significant trends ($p < 0.05$).

The total number of nests across all species peaked between 1990 and 2000, after which it declined to a lower, stable level. This pattern was reflected in the species turnover rate.

## Diversity and Dominance Patterns

Analysis of community diversity revealed significant temporal shifts in species richness and evenness. A linear regression of the annual Shannon diversity index (H') against year showed a significant negative trend from 1949 to 2010 (slope = -0.011 per year, $R^2 = 0.32$, $p < 0.001$), indicating a long-term decline in diversity during this period. This decline correlated with increasing dominance by a few prolific species, notably the Great Cormorant and Palas's Gull. However, from 2010 onwards, the trend reversed. A separate regression for the period 2010–2024 indicated a significant positive trend (slope = +0.026 per year, $R^2 = 0.45$, $p = 0.006$), confirming a recovery of diversity associated with the arrival of new species (e.g., Barn Swallow, Steppe Crane) and a partial recovery of community evenness (Fig. 4).

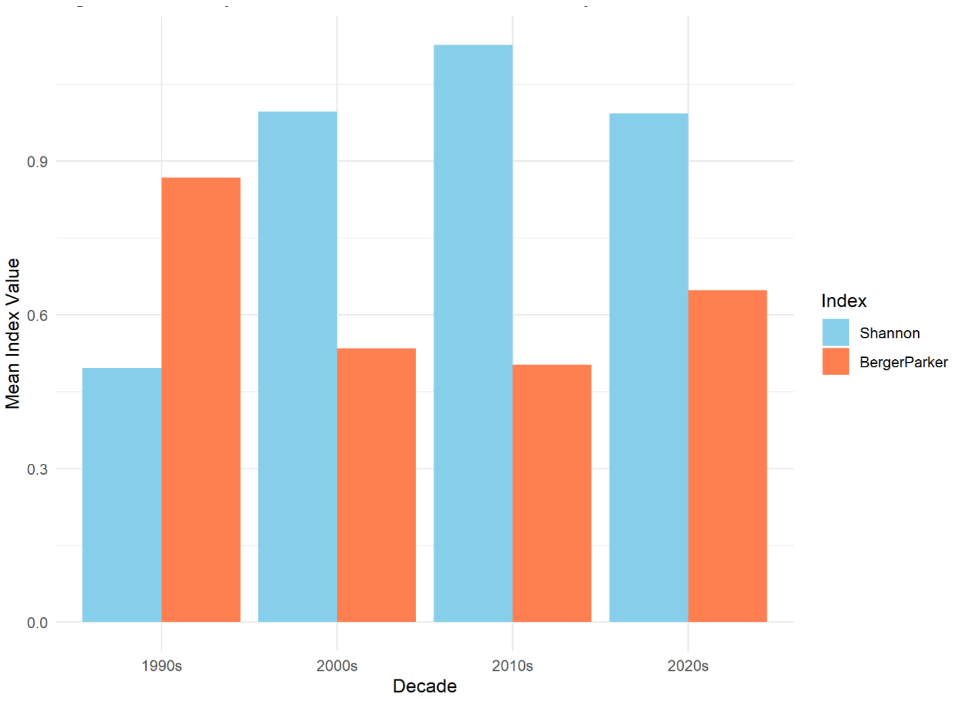


**Figure 4.** Decadal trends in community diversity and dominance. A) Shannon diversity index (H') with a fitted loess smoother (blue line) and significant trend segments indicated (dashed red lines). B) Berger-Parker dominance index (d) by decade (mean ± SD).

The Berger-Parker dominance index (d) mirrored this pattern, with values peaking during 1990–2010 (mean d = 0.82 ± 0.04 SD), indicative of a strong monopoly by the most abundant species. The index showed a significant decrease towards the most recent decade (mean d for 2015–2024 = 0.65 ± 0.05; t-test, $p < 0.01$), signaling an increase in species coexistence.

## Community Structure and Ordination Analyses

Multivariate analyses of community composition identified three main temporal phases. Both cluster and Non-metric Multidimensional Scaling (NMDS) analyses consistently revealed a gull/tern-dominated community from 1950 to 1980, followed by a cormorant-dominated phase from 1990 to 2010, and a more mixed and diverse community in recent years. The NMDS ordination (stress = 0.12) clearly visualizes this segregation and the temporal trajectory of the community (Fig. 5).

These ordination results highlight significant compositional turnover and community restructuring over the 75-year period.

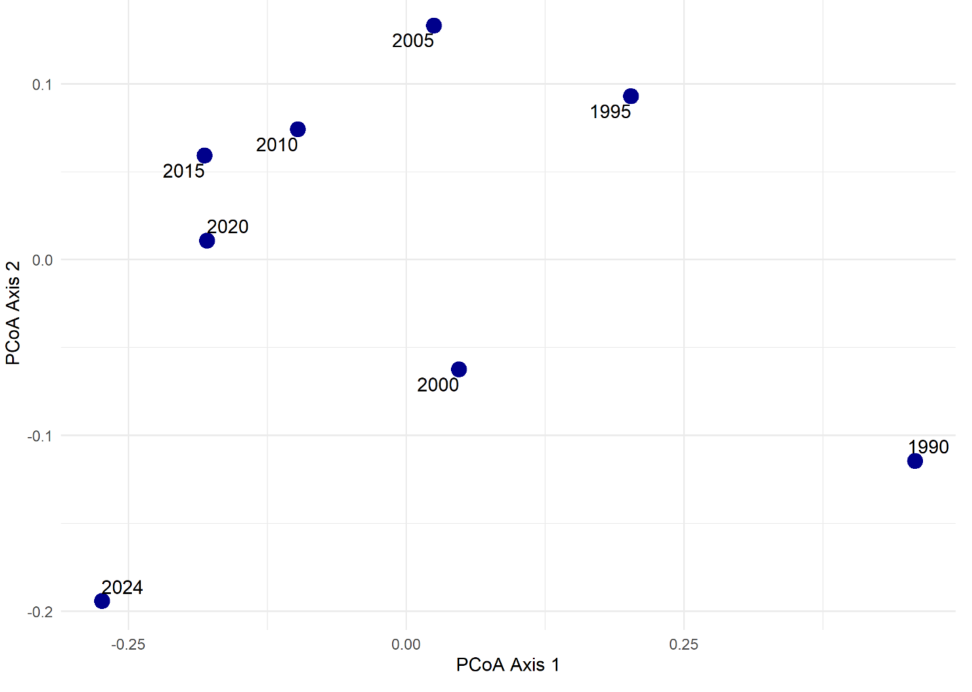


**Figure 5.** Non-metric multidimensional scaling (NMDS) plot of community structure changes (1949–2024). Points represent annual community composition, colored by decade. The temporal trajectory (arrow) illustrates the shift from gull/tern-dominated (1950s-70s) to cormorant-dominated (1990s-2000s) and finally to a mixed community (2010s-20s).

### Species Turnover and Functional Composition

Species turnover was highest between 1950–1980 ($\beta_t$ = 0.50–0.57), indicating a highly dynamic community during a period of likely environmental disturbance or habitat change. Subsequent turnover declined to approximately 0.29 during the cormorant-dominated phase (1990–2010), and further to $\beta_t \approx 0.22$ in the last decade (2015–2024), suggesting a trend toward greater community stability.

A summary of turnover rates and the associated shifts in functional group composition is presented in Table 1.

**Table 1.** Species turnover ($\beta_t$) and functional group composition by period

| Period | Species Turnover ($\beta_t$) | Dominant Functional Groups | Functional Diversity Notes |
|---|---|---|---|
| 1950–1980 | 0.50–0.57 | Gulls, Caspian Tern colonies | High turnover, dominance by few species |
| 1990–2010 | ~0.29 | Increasing Great Cormorant dominance | Decreasing diversity, high dominance |
| 2015–2024 | ~0.22 | Mixed colonies, new species arrivals | Increasing diversity, reduced dominance |

Functional diversity patterns correspond with these results. The community transitioned from gull- and tern-dominated functional groups to cormorant dominance, followed by a more functionally diverse assemblage including insectivores (e.g., Barn Swallow), waders (e.g., Eurasian Oystercatcher), and other ecological guilds.

## Discussion

The long-term data from Kitay Island reveal substantial shifts in breeding colonial waterbird communities over the past seven decades. The pronounced increase of the Great Cormorant aligns with regional patterns observed in other temperate wetland systems (Somers et al. 2011). While this increase strongly correlates with the overall breeding population trend on the island, the underlying drivers are likely multifaceted. We interpret this trend as a consequence of interacting factors, including reduced human disturbance, potential increases in food supply due to regional fisheries dynamics, and broader habitat changes favorable to cormorants. It is important to note that the correlative nature of our study limits definitive causal inference; the cormorant expansion may be a response to these environmental changes rather than the sole cause of subsequent community shifts.

In contrast, the decline of the Yellow-legged Gull suggests potential competitive pressure from the expanding cormorant population. Interspecific interactions, such as predation on gull eggs or chicks by more aggressive species and competition for nesting space, are plausible mechanisms documented in similar colonial assemblages (Mierauskas and Buzun 1991; Kharitonov 1999). However, this hypothesis of direct displacement requires validation with behavioral and spatial data on nest-site overlap and aggression rates. Alternative drivers for the gull decline must also be considered, including changes in local food resources, increased predation from other sources, or broader climatic influences on reproductive success (Ławicki 2012).

The observed community restructuring occurred within a dynamic local environment. Specific environmental changes in the Central Sivash, such as fluctuating salinity regimes following dam construction, episodes of shoreline erosion altering nesting habitat, and varying levels of anthropogenic disturbance (e.g., fishing, tourism), likely acted as key drivers of the documented succession phases. The high species turnover during the mid-20th century coincides with significant anthropogenic modification of the Sivash hydrology, suggesting habitat instability as a primary driver of early community dynamics. Unfortunately, the lack of continuous, quantitative data on these local abiotic and anthropogenic factors precludes a formal statistical link to avian trends in this study, highlighting an important avenue for future interdisciplinary research.

The recent phase (post-2010) is characterized as a "mixed" community, defined by an increase in species richness, a reduction in the dominance index, and a more even distribution of abundance among species. This shift is driven by both the arrival of new species (e.g., Barn Swallow, Steppe Crane) not previously recorded as breeders and the persistence or modest recovery of some existing species, leading to greater functional diversity. The emergence of insectivores and waders alongside the dominant piscivores indicates increased niche diversification and potentially more complex trophic interactions within the island ecosystem (Panov 2009).

The high dominance indices observed during 1990–2010 highlight the spatial limitations of nesting habitat on the small island, which can allow a single species to monopolize optimal sites (Stephens et al. 2004). The subsequent slight decline in dominance and increase in evenness correspond with increased species richness and suggest a degree of niche partitioning, possibly signaling a maturing community structure (Kadmon and Allouche 2007). Species turnover analyses demonstrate that the colony underwent its most considerable reorganization in the mid-20th century. The recent lower turnover, coupled with rising diversity indices, suggests the community may be approaching a new dynamic equilibrium, though it remains susceptible to ongoing environmental pressures (Hubbell 2001; Sax and Gaines 2008).

These findings emphasize the critical importance of continuous long-term monitoring to detect and interpret ecological trends in sensitive coastal habitats (Anderson et al. 2011). Maintaining such refugia is vital for supporting regional biodiversity, especially under accelerating anthropogenic and climatic pressures.

Future research should prioritize integrating detailed habitat quality assessments (e.g., vegetation cover, salinity metrics) with avian population data to better disentangle environmental drivers. Direct studies of predator-prey dynamics and interspecific competition within colonies are needed to test the mechanisms suggested here. Furthermore, consideration of landscape-scale processes and connectivity with mainland populations would provide a broader context for interpreting local changes (Matsyura and Siokhin 2025; Andreenkov et al. 2020). Experimental approaches, such as nest-site manipulation, could help test hypotheses on competitive interactions and resource limitation, further elucidating the mechanisms driving the profound community turnover documented in this study.

## Conclusions

The analysis of long-term data reveals significant transformations in the breeding bird communities on Kitay Island, highlighting the rise of Great Cormorant as a key dominant species, fluctuating gull populations, and an overall community undergoing ongoing restructuring. The study demonstrates the value of integrative long-term monitoring for understanding ecological dynamics and guiding biodiversity conservation in sensitive wetland ecosystems.

Great Cormorants showed a very significant population increase (slope +60.1 pairs/year; $R^2$=0.77; p<0.001), becoming dominant in recent decades. Palas's Gulls declined significantly (slope -3.7 pairs/year; $R^2$=0.18; p=0.03). Caspian Terns characterized by episodic presence with total nests peaked in 1950–1955, then totally declined. Species turnover was highest in 1950–1980 (~0.5) indicating dynamic changes, but declined recently (~0.22). Diversity indices showed a decrease in late 20th century with renewal trends post 2010 through new species arrival (e.g., Barn Swallow, Steppe Crane). Cluster and NMDS analyses revealed three main community phases: gull/tern dominated (1950–80), cormorant dominated (1990–2010), and mixed diverse community recently. Dominance of a few species was high but reduced slightly recently, with functional diversity shifting due to species losses and gains.

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## References

Anderson MJ, Crist TO, Chase JM, Vellend M, Inouye BD, Freestone AL, Sanders NJ, Cornell HV, Comita LS, Davies KF, Harrison SP, Kraft NJ, Stegen JC, Swenson NG (2011) Navigating the multiple meanings of β diversity: a roadmap for the practicing ecologist. Ecology Letters 14(1): 19–28. https://doi.org/10.1111/j.1461-0248.2010.01552.x

Andreenkov OV, Andreenkova NG, Zhimulev IF, Tsybulin SM (2020) Nesting of the Black-headed Gull and other gulls on the islands of the Novosibirsk Reservoir. Fauna of the Urals and Siberia 2: 16–22 [In Russian]

Andriushchenko YuA, Siokhin VD, Chernichko II, Chernichko RN, Matsyura AV (2000) Central Sivash: abundance and distribution of nesting waterbirds in the wetlands of the Azov-Black Sea coast of Ukraine. In: Abundance and Distribution of Nesting Waterbirds in the Wetlands of the Azov–Black Sea Coast of Ukraine. Melitopol, Kyiv, 217–250. [In Russian]

Barbazyuk EV (2020) On the ecology of the Great Black-headed Gull, Gull-billed Tern and Caspian Tern in the Orenburg region. Steppe Science 1(XVI): 37–51. https://doi.org/10.24411/9999-006A-2020-10005 [In Russian]

Fink DT, Auer AJ, Strimas-Mackey M, Ligocki S, Robinson O, Hochachka W, Jaromczyk L, Crowley C, Dunham K, Stillman A, Davies I, Rodewald A, Ruiz-Gutierrez V, Wood C (2023) eBird Status and Trends. Data Version: 2022. Cornell Lab of Ornithology, Ithaca, New York. https://doi.org/10.2173/ebirdst.2022

Hubbell SP (2001) The unified neutral theory of biodiversity and biogeography. Princeton University Press, Princeton, 375 pp.

Kadmon R, Allouche O (2007) Integrating the effects of area, isolation, and habitat heterogeneity on species diversity: a unification of island biogeography and niche theory. The American Naturalist 170(3): 443–454. https://doi.org/10.1086/519853

Kharitonov S (1999) Breeding-site fidelity and colony formation in the great black-headed gull. Branta 2: 64–75.

Laurance WF (2008) Theory meets reality: How habitat fragmentation research has transcended island biogeographic theory. Biological Conservation 141(7): 1731–1744. https://doi.org/10.1016/j.biocon.2008.05.011

Ławicki Ł (2012) Great Black-headed Gull: why is it still so rare in northern and western Europe? Birding World 25: 380–389.

MacArthur RH, Wilson EO (2001). The theory of island biogeography. Princeton University Press, Princeton, NJ, 203 pp.

Matsyura A (2000) Interactions between the Yellow-legged gull (*Larus cachinnans*), the Great black-headed gull (*Larus ichthyaetus*), and the Great cormorant (*Phalacrocorax carbo*) breeding on Kitay Island (Central Sivash). Vestnik Zoologii 14(2): 76–79. [In Russian]

Matsyura AV, Siokhin VD (2025) Spatial patterns of breeding colonies of Great Cormorant (*Phalacrocorax carbo*) and Palas's Gull (*Larus ichthyaetus*) on Kitay Island in the Central Sivash lagoon system. Acta Biologica Sibirica 11: 1137–1151. https://doi.org/10.5281/zenodo.17432470

Mierauskas P, Buzun V (1991) Competitive interactions between the Herring Gull *L.* a. *cachinnans* and the Great Black-Headed Gull *L. ichthyaetus* at Sivash Lake

(South Ukraine). Seevögel-Zeitschrift des Vereins Jordsand zum Schutz der Seevögel und der Nature 12(2): 33–35.

Panov EN (2009) The social and communication behaviour of the Great Black-headed Gull. British Birds 102: 72–83.

Sax DF, Gaines SD (2008) Species invasions and extinction: the future of native biodiversity on islands. Proceedings of the National Academy of Sciences of the United States of America 105(suppl 1): 11490–11497. https://doi.org/10.1073/pnas.0802290105

Siokhin VD (2000) Characteristics of the distribution and abundance of nesting birds in the wetlands of the Azov-Black Sea coast. Branta 3: 412–444. [In Russian]

Siokhin VD, Chernichko II, Adamatskaia TB et al (1988) Colonial Hydrophilic Birds of the South of Ukraine: Charadriiformes. Naukova Dumka, Kyiv, 174 pp. [In Russian]

Siokhin VD, Gorlov PI, Kostiushyn VA (2021) Long-term population dynamics of birds on the islands of Sivash and Dzharylgach Bay during the nesting period. Collection of Scientific Works Dedicated to the 35th Anniversary of the Interdepartmental Azov-Black Sea Ornithological Station. Melitopol, 160–165. [In Russian]

Siokhin VD, Matsyura AV (2025) Current state of colonial birds in the island complexes of the Sivash region. Russian Ornithological Journal 34(2520): 1678–1683. [In Russian]

Somers Ch, Doucette J, Weseloh D, Kjoss V (2011) Interactions between Double-crested Cormorants and other ground-nesting species. Waterbirds 34: 168–176. https://doi.org/10.1675/063.034.0205

Stephens SC, Koons DN, Rotella JJ, Willey DW (2004) Effects of habitat fragmentation on avian nesting success: a review of the evidence at multiple spatial scales. Biological Conservation 115(1): 101–110. https://doi.org/10.1016/S0006-3207(03)00098-3

Whittaker RJ, Fernández-Palacios JM, Matthews TJ (2008) Island Biogeography: Ecology, Evolution, and Conservation. 2nd ed. Oxford University Press, 416 pp.