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Folk songs and the regional geographic environment: the influence and inspiration of biodiversity and ecosystems on Chinese folk songs in the Yangtze River Delta

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The geographical environment forms the foundation for human existence and cultural development and serves as a vital source of inspiration within cultural ecosystem services (CES). In China, numerous folk songs reference ecosystems and biodiversity, providing a unique data source to quantify the inspirational impacts of these songs. This study examines the relationship between folk songs and the regional geographic environment and evaluates how ecosystems and biodiversity inspire the creation of folk songs on the basis of Chinese folk songs from the Yangtze River Delta region. The species names and ecosystem types referenced in the lyrics to 4072 Chinese folk songs were studied, categorized into distinct groups, and examined with multiple regression analysis. Among the analyzed songs, 52.58% referenced biodiversity and 19.43% mentioned specific ecosystems. The most prevalent ecosystems mentioned were wetlands and farmlands, whereas plants, mammals, and birds were the most commonly mentioned taxonomic groups. The primary sources of inspiration included the plant families Rosaceae, Poaceae, and Nelumbonaceae, and the animal families Bombycidae, Cyprinidae, Anatidae, and Phasianidae, all of which are closely related to the lives of the local populace. The degree to which biodiversity and ecosystems impact folk songs varies across different regions. These findings underscore the crucial role of wildlife in inspiring Chinese folk songs and reveal the profound connection between these songs and the unique geography and local culture of the Yangtze River Delta region.

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Introduction

In recent decades, music has emerged as a significant subject within geographic analysis (Johansson et al., 2023), giving rise to the subfield of music geography. Initially, music geography explored the role of music in local, national, and global contexts, the relationship between soundscapes and specific locations, the spread and distribution of musical styles, and geographical imagery in lyrics (Leyshon et al., 1995; Nash et al., 1996). The relevance of geography to the comprehension of music has become clear (Doughty, 2023); however, this field remains largely unexplored (Altaweel, 2020).

As an expression of cultural life, music is connected to the natural environment more intimately than many other cultural expressions (Qiao, 2023). Musical styles often spread along mountains, rivers, and coastlines and are maintained and integrated into plateaus, basins, peninsulas, and islands (Bence, 1965). Geographic and spatial analyses reveal that music possesses significant spatial properties that impact not only where it is played but also where venues may develop (Altaweel, 2020). A romanticized interconnectedness is evident between the natural environment and the local cultural identity, as exemplified by Alpine yodeling (Sweers, 2019). Owing to differences in backgrounds, methods of creation, communication channels, and value orientations, various types of music (such as professional and folk genres) exhibit differing degrees of connection with the natural environment as well as varying depths and intensities of their relationship with geography (Qiao, 1998).

Folk songs are not only a form of music but also a carrier of regional culture, reflecting the natural conditions, social history and cultural traditions of a region. They vary in genre, style, and function and are shaped by geographical conditions such as river systems, terrain, mountain ranges, and climate (Miao and Qiao, 1985; Qiao, 1998; Qiao, 2023). In China, the vast territory gives rise to diverse regional human and natural environments, each with its own unique characteristics. Using the methods of cultural geography and integrated models, seven cultural areas of Chinese folk songs have been defined (Wu et al., 2005). Their terrain and climate differences contribute to the distinct styles of folk songs across these regions.

Inspiration is a way of "providing intellectual motivation and humanity" (Daily et al., 2009), "cultural and artistic information" (de Groot et al., 2002), "heritage, spirit, and emotion" (Boyd and Banzhaf, 2007), "philosophical satisfaction" (Wallace, 2007), "regional landscape inspiration" (Burkhard and Gee, 2012), "inspiration to music and art" (Sagie et al., 2013), and "design inspiration" (Fletcher et al., 2014). Indeed, inspiration is not a product of a single kind of experience but rather is produced by all types of experiences associated with ecosystems (Chan et al., 2012). Previous studies have measured the inspirational value of an ecosystem using qualitative analysis of the design inspiration provided by aquatic insects to artists (Eidelberg et al., 2007), creative inspiration to musicians (Macadam and Stockan, 2015), or landscape inspiration for the creation of short stories (Bieling, 2014). The lyrics of numerous folk songs vividly encapsulate the relationship between music and the geographical environment, frequently employing direct and evocative language that emphasizes local species and ecosystems to illuminate the inspirational significance of cultural ecosystem services (CES). By using web-accessible databases of artistic works, the relative inspirational value drawn from ecosystems and biodiversity in the environment of a specific cultural context can be quantified. A previous study used geo-tagged digital photographs uploaded to social media resources to conduct a spatial analysis of the covariation between ecosystem services to identify the perceived aesthetic value of different ecosystem sites (Casalegno et al., 2013). On the basis of an online repository of popular music containing 30 million tracks, a quantitative estimation was conducted to study the inspirational value of types of ecosystems (Coscieme, 2015). According to the prevalence of bird species in the accessible online database Peomhunter, the species-specific contributions of farmland birds to poetry has been calculated (Hiron et al., 2018). Recently, an ecological approach was adopted to quantify the artistic inspiration drawn from ecosystems and biodiversity on the basis of Japanese children's songs (Katayama and Baha, 2020), and the inspirational value of cultural ecosystem services was assessed on the basis of Chinese poetry (Dai et al., 2022).

Although the role of music in expressing local identity and reflecting spatial experience has been acknowledged in the field of music geography (Leyshon et al., 1995; Nash et al., 1996; Doughty, 2023), the integration of ecological frameworks into musical analysis remains relatively limited. Scholars have emphasized the importance of place, landscape, and soundscape in shaping musical forms, but few have examined how ecosystems themselves function as material and symbolic foundations for music creation. In the field of CES studies, an emerging body of literature has begun to quantify the aesthetic and inspirational value of biodiversity, particularly through poetry, photography, and visual arts (Katayama and Baha, 2020; Dai et al., 2022; Coscieme, 2015). These studies highlight how species and landscapes inspire emotional, symbolic, and spiritual responses in cultural expression. However, musical traditions—especially orally transmitted folk songs—have been largely overlooked in this research trajectory despite their strong connection to local environments and ecological rhythms.

Chinese folk songs are a treasure trove of cultural resources characterized by distinctive local traits and national styles. Since the beginning of the twenty-first century, there has been burgeoning enthusiasm for "original ecology folksongs" throughout China. Performed by village-born singers in local dialects and obviously traditional styles, these songs and the related discourse emphasize ties to place, cultural authenticity, and the relationship between the physical environment and human culture (Rees, 2016). Many folk songs depict nature and wildlife, offering a valuable repository of information to explore the connection between folk music and the regional environment. By combining ecological modeling with regional folk song data from the Yangtze River Delta (YRD), the present study addresses this interdisciplinary gap. It combines methods from biogeography, ethnomusicology, and CES research to explore how biodiversity and ecosystems are embedded in the lyrical and structural features of traditional songs. We thoroughly analyzed the environmental elements within the lyrics of folk songs in the Yangtze River Delta region and identified the ecosystem types (e.g., wetland, forest, farmland) and taxonomic groups (e.g., plants, insects, fishes, birds) that were mentioned. We subsequently determined the number of subgroups (families) for each taxonomic group and the most frequently mentioned habitat groups and assessed their contributions to Chinese folk songs. Finally, we explored the correlation between types of habitats and the number of folk songs associated with each taxonomic family using a multiple linear regression model and identified regional variations in the influence of biodiversity and ecosystems on folk songs in the Yangtze River Delta region. This approach expands the methodological toolkit for evaluating CES in musical contexts and contributes to a more holistic understanding of how ecological knowledge is culturally encoded and transmitted through traditional folk songs.

Methods

Background information on the Yangtze River delta. The Yangtze River Delta (YRD) region, which includes the cities within Shanghai Municipality and the provinces of Jiangsu,

Zhejiang, and Anhui, comprises 41 cities in the lower Yangtze River Basin in China. Owing to its rich historical background, the YRD has transformed into a major urban cluster since the Ming and Qing Dynasties. This area spans approximately 358,000 square kilometers of alluvial plain and experiences a subtropical monsoon climate marked by warm, humid, and rainy summers and cold, dry winters. The primary land uses include farmland, woodland, grassland, wetland, and construction land, which account for 47.76%, 28.42%, 3.19%, 7.65%, and 12.98% of the total area, respectively (Hu et al., 2023). The region's diverse climate and habitats are believed to have historically supported its high biodiversity.

Data collection. The names of species (e.g., plants, insects, birds) and ecosystem types (e.g., farmland, grass land, wetland) were thoroughly extracted from the lyrics of folk songs recorded in the *Compilation of Chinese Folk Songs* (CCFS), which includes volumes from Shanghai (Jiang et al., 1998), Jiangsu (Shi et al., 1998), Zhejiang (Ma et al., 1998) and Anhui (Chen et al., 1998). These compilations were meticulously collected and assembled by local experts with support from the Ministry of Culture of the People's Republic of China, the State Ethnic Affairs Commission, and the Chinese Musicians Association.

Biodiversity was classified into six taxonomic groups: plants, insects, fish, herpetofauna, birds, and mammals. Many of the organisms mentioned in the folk songs, particularly animals, could be identified only at the family level. Therefore, the total number of songs was calculated for each family to determine how many songs were inspired by biodiversity, excluding organisms not identified at the family level. Ecosystem types were identified through the lyrics of folk songs. Although a grassland habitat is present in the Yangtze River Delta, the grasslands mentioned in these songs usually refer to farmland or urban green spaces. Consequently, in this study, ecosystems were categorized into four types: farmland (arable land), woodland (forestland), wetland (including rivers, lakes, ponds, and oceans), and urban areas (comprising cities and settlements with construction).

Data analysis. Family richness is a good predictor of species richness in both temperate and tropical areas (Williams and Gaston, 1994; Balmford et al., 1996). In this study, the number of families (family richness) was used as a surrogate for the number of species (species richness) in each taxonomic group, and Venn diagrams (Chen, 2022) were constructed to illustrate the number of families across the four regions where the six taxonomic groups were identified as well as the number of families shared among these regions.

We constructed family accumulation curves, which can provide insight into how each taxonomic group is structured with respect to the provision of cultural services (Hiron et al., 2018). The number of families needed to achieve 80% and 95% of the total contributions to folk songs within each taxon was calculated to determine how many families are needed to sustain these levels of biodiversity benefits.

The relationships between the number of songs inspired by families and their habitat types were examined using multiple linear regression models. The dependent variable was the total number of songs related to each family, and the predictor variables were the dummy variables representing the use of habitat types (0 = not used, 1 = used). Specifically, we included four habitat types as predictors: farmland, woodland, wetland, and urban area. To ensure the robustness of the multiple linear regression model, we conducted a normality test on the regression residuals. An information theoretic approach was used for model selection and inference (Burnham and Anderson, 2002). We computed an Akaike information criterion corrected for small sample size (AICc) and Akaike weights (wi) for all possible parameter subsets. The models were ranked with the value of AICc, and variables from models with ΔAICc <2 were selected to reconstruct the model. The Akaike weight (w_i) reflects the probability that a given model is the true model. If no single model was clearly superior to the others (i.e., w_i of the best model <0.9), we adopted multimodel inference approaches (Burnham and Anderson, 2002; Grueber et al., 2011) and calculated the average of the estimate parameter and standard error of the variables. We computed the sum of w_i (SW_j) as a measure of the relative importance of each predictor j. The larger SW is, the more important the variable j is relative to other variables (Burnham and Anderson, 2002).

Statistical analyses were performed using the packages 'VennDiagram' (Chen, 2022), "ggplot2" (Wickham et al., 2024) and 'MuMIn' (Bartoń, 2024) in R version 4.4.0 (R Development Core Team, 2024).

Results

General results. A total of 4072 folk songs were analyzed: 831 from Shanghai, 1399 from Jiangsu, 835 from Zhejiang, and 1007 from Anhui Province. We found that 2141 songs (52.58%) referenced six taxonomic groups, whereas 791 songs (19.43%) alluded to four ecosystems within the YRD region. The proportions of each ecosystem and taxonomic group referenced in the folk songs are illustrated in Fig. 1. Wetlands constituted the main

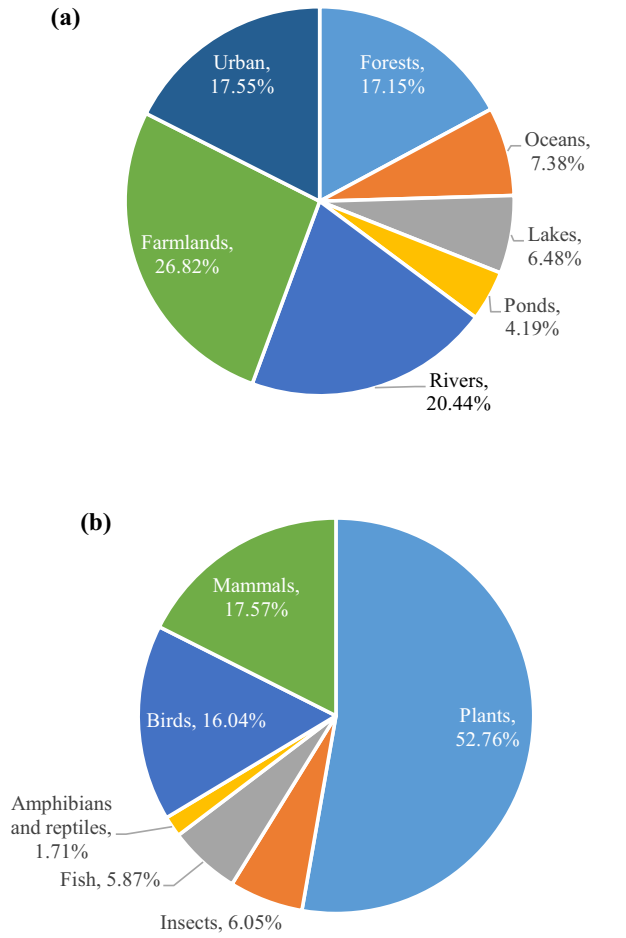

Fig. 1 Proportions of folk songs inspired by ecosystems and biodiversity in the YRD region. a Proportion of folk songs inspired by different ecosystem types. Wetlands include rivers, lakes, ponds, and oceans; **b** Proportion of folk songs inspired by different taxonomic groups.

type of ecosystem and accounted for 9.48% of all folk songs in the Yangtze River Delta region, among which rivers, lakes, ponds and oceans accounted for 5.03%, 1.60%, 1.03% and 1.82%, respectively. Taxonomic groups were dominated by plants, which were mentioned in 36.42% of all songs. The patterns of influence of ecosystems and taxonomic groups on folk songs in the YRD varied across regions. For example, in Jiangsu Province, farmland dominated wetlands, whereas in Anhui Province, mammals were less prevalent than birds (Figs. S1 and S2).

Family richness and accumulation curve. Family richness included 83 families for plants ($n = 1483$ songs), 28 for insects ($n = 170$), 32 for fishes ($n = 165$), 9 for herpetofauna ($n = 48$), 29 for birds ($n = 451$), and 12 for mammals ($n = 494$). A Venn diagram of the families mentioned in the folk songs of the four areas revealed that 21, 3, 20, and 26 separate families were mentioned in Jiangsu, Anhui, Zhejiang and Shanghai, respectively (Figs. 2 and S3).

The family accumulation curves revealed that 80% and 95% of the total contributions were associated with 15 and 37 families for plants, 9 and 16 families for insects, 16 and 23 families for fishes, 5 and 6 families for herpetofauna, 11 and 16 families for birds, and 5 and 6 families for mammals, respectively (Fig. 3). For plants, the Rosaceae family (e.g., cherry blossoms, roses, and apricots) was the greatest contributor, followed by Poaceae (e.g., barley, wheat, and reeds) and Nelumbonaceae (e.g., lotus) (Table 1). For animals, most of the top-ranking families were closely related to human life, including Bombycidae (e.g., silkworm) and Culicidae (e.g., mosquitoes) for insects; Cyprinidae (most freshwater species) for fishes; Anatidae (ducks and geese); Phasianidae (chickens); Corvidae (magpie and crows); Hirundinidae (swallows) for birds; Bovidae (cattle and buffaloes); Equidae (horses); Felidae (cats and tigers); and Canidae (dogs) (Table 2). For insects, generic names representing 'butterfly' for several families of Lepidoptera also appeared in many folk songs.

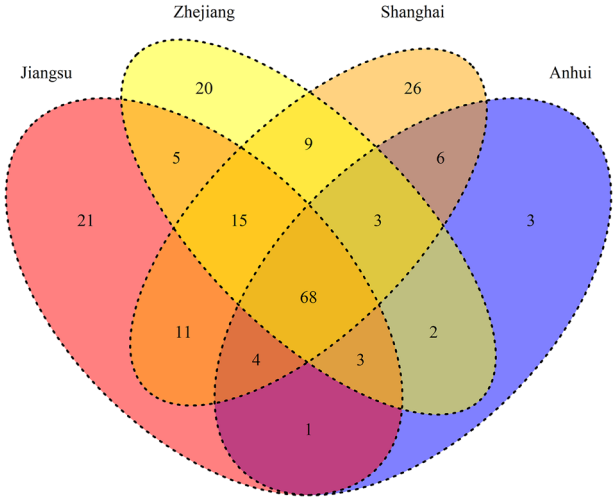

Fig. 2 Venn diagram of families mentioned in folk songs in the YRD Region. The number of unique and shared families were illustrated among Jiangsu, Anhui, Zhejiang, and Shanghai for all taxonomic groups.

Model selection of families with relationships to habitat types. The model selection table indicated that no single model demonstrated a significant advantage over the others in explaining the number of folk songs related to each family, i.e., the best model had a w_i of <0.9 (Table 2). The results of the multimodel inference approach revealed that the habitats with a large SW (SW = 1) with positive model-averaged coefficients were farmland, woodland and urban habitats in Shanghai, Zhejiang and Anhui Provinces, whereas those in Jiangsu Province were farmland and woodland (Table 3).

The family structure revealed a variety of patterns across different habitats in the YRD region (Fig. 4). For example, frequently cited families within farmlands included Poaceae, Rosaceae, Malvaceae, and Magnoliaceae in Jiangsu; Poaceae, Rosaceae, Malvaceae, Phasianidae, and Asteraceae in Anhui; Poaceae, Bovidae, Equidae, and Fabaceae in Zhejiang; and Poaceae, Rosaceae, Phasianidae, Fabaceae, and Cucurbitaceae in Shanghai. In contrast, woodland habitats were characterized by Rosaceae, Poaceae, Phasianidae, and Nelumbonaceae in Jiangsu; Theaceae, Poaceae, Bovidae, and Rosaceae in Anhui; and Theaceae and Nelumbonaceae in Zhejiang.

Discussion

Regional biodiversity and ecosystem contributions to the Chinese folk songs. Despite being a crucial component of CES, inspirational services have often been overlooked by researchers because of the scarcity of data sources and evaluation methods

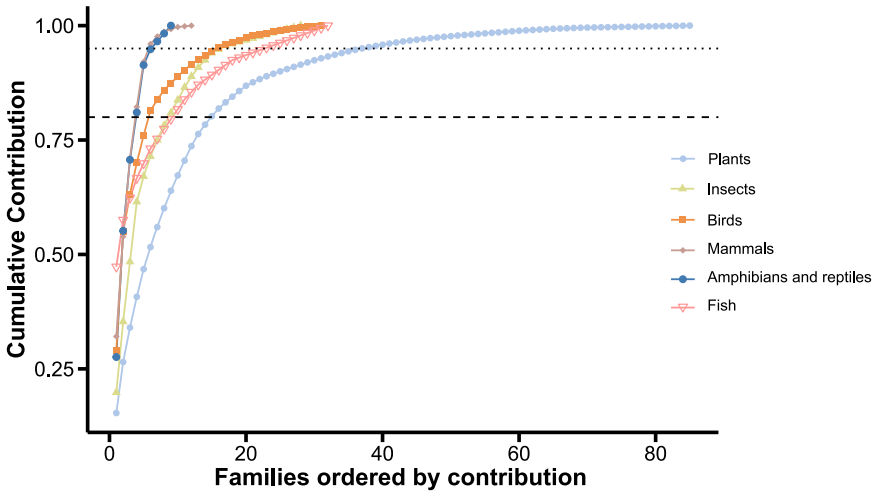

Fig. 3 Family accumulation curves for the six taxonomic groups. The dashed and dotted lines indicate 80% and 95% of cumulative contributions, respectively. See Table 1 for the family ID.

Table 1 List of families appearing in Chinese folk songs in the YRD for the six taxonomic groups compared. The list of families in each area is shown in Tables S1–S4.

ID	Family	No. songs	ID	Family	No. songs	ID	Family	No. songs	ID	Family	No. songs
	Plants		24	Rhamnaceae	19	48	Dipterocarpaceae	5	72	Bromeliaceae	1
1	Rosaceae	533	25	Rutaceae	18	49	Meliaceae	5	73	Caryophyllaceae	1
2	Poaceae	387	26	Magnoliaceae	17	50	Asphodelaceae	5	74	Cabombaceae	1
3	Nelumbonaceae	261	27	Orchidaceae	17	51	Aceraceae	5	75	Chloranthaceae	1
4	Salicaceae	233	28	Liliaceae	17	52	Sapindaceae	5	76	Campanulaceae	1
5	Calycanthaceae	210	29	Vitaceae	17	53	Leguminosae	4	77	Dioscoreaceae	1
6	Asteraceae	167	30	Onagraceae	16	54	Cycadaceae	4	78	Hamamelidaceae	1
7	Fabaceae/ Leguminosae	152	31	Araceae	15	55	Euphorbiaceae	4	79	Taxaceae	1
8	Malvaceae	143	32	Ginkgoaceae	14	56	Alismataceae	4	80	Oxalidaceae	1
9	Oleaceae	133	33	Zingiberaceae	13	57	Ericaceae	4	81	Verbenaceae	1
10	Lythraceae	116	34	Cupressaceae	13	58	Fagaceae	4	82	Scrophulariaceae	1
11	Theaceae	112	35	Cyperaceae	13	59	Musaceae	4	83	Schisandraceae	1
12	Paeoniaceae	110	36	Burseraceae	11	60	Piperaceae	4			
13	Cucurbitaceae	92	37	Buxaceae	11	61	Hydrangeaceae	3		***Insects***	
14	Brassicaceae	71	38	Convolvulaceae	10	62	Iridaceae	3	1	Papilionoidea	50
15	Amaryllidaceae	64	39	Ranunculaceae	9	63	Apiaceae	3	2	Culicidae	39
16	Solanaceae	58	40	Ebenaceae	9	64	Juglandaceae	3	3	Bombycidae	33
17	Balsaminaceae	47	41	Thymelaeaceae	9	65	Aquifoliaceae	3	4	Apoidea	33
18	Moraceae	43	42	Araliaceae	8	66	Anacardiaceae	2	5	Libelluloidea/ Aeshnoidea	14
19	Rubiaceae	43	43	Caprifoliaceae	8	67	Urticaceae	2	6	Acrididae	11
20	Trapaceae	40	44	Myricaceae	7	68	Arecaceae	2	7	Cicadidae	9
21	Pinaceae	26	45	Lamiaceae	7	69	Nymphaeaceae	2	8	Muscidae	8
22	Pedaliaceae	24	46	Juncaceae	6	70	Alliaceae	1	9	Formicidae	7
23	Amaranthaceae	22	47	Polygonaceae	6	71	Potamogetonaceae	1	10	Lampyridae	7
11	Mantidae	7	9	Percichthyidae	4		***Herpetofauna***		16	Fringillidae	6
12	Gryllidae	6	10	Anguillidae	4		(***Amphibians and reptiles***)		17	Alcedinidae	4
13	Vespidae	5	11	Stromateidae	4	1	Bufonidae	16	18	Laridae	4
14	Blattidae	4	12	Mugilidae	3	2	Ranidae	16	19	Pycnonotidae	3
15	Corydidae	4	13	Synbranchidae	3	3	Emydidae	9	20	Sylviidae	3
16	Pediculidae	2	14	Bagridae	2	4	Serpentes	6	21	Paradoxornithidae	3
17	Sphingidae	2	15	Cynoglossidae	2	5	Trionychidae	6	22	Paridae	2
18	Araneoidea	1	16	Gobiidae	2	6	Gekkonidae	2	23	Sturnidae	2
19	Aleyrodidae	1	17	Engraulidae	2	7	Colubridae	1	24	Rallidae	2
20	Ceratopogonidae	1	18	Muraenesocidae	2	8	Dicroglossidae	1	25	Upupidae	2
21	Lasiocampidae	1	19	Platycephalidae	1	9	Cheloniidae	1	26	Bombycillidae	1
22	Pieridae	1	20	Cottidae	1				27	Ciconiidae	1
23	Termitidae	1	21	Platyrhinidae	1		***Birds***		28	Laniidae	1
24	Curculionidae	1	22	Salangidae	1	1	Phasianidae	194	29	Ploceidea	1
25	Limacodidae	1	23	Adrianichthyidae	1	2	Anatidae	173			
26	Pulicoidea	1	24	Scombridae	1	3	Corvidae	54		***Mammals***	
27	Sarcophagidae	1	25	Sphyraenidae	1	4	Hirundinidae	46	1	Bovidae	215
28	Tettigoniidae	1	26	Periophthalmidae	1	5	Accipitridae	40	2	Equidae	146
			27	Psettodidae	1	6	Passeridae	36	3	Felidae	115
	Fish		28	Scorpaenidae	1	7	Columbidae	16	4	Canidae	75
1	Cyprinidae	88	29	Serranidae	1	8	Leiothrichidae	14	5	Suidae	66
2	Sciaenidae	19	30	Synodontidae	1	9	Oriolidae	10	6	Muridae	26
3	Trichiuridae	9	31	Tetraodontidae	1	10	Cuculidae	10	7	Leporidae	11
4	Clupeidae	8	32	Soleidae	1	11	Gruidae	10	8	Mustelidae	7
5	Channidae	6				12	Cacatuidae	9	9	Cercopithecidae	4
6	Siluridae	6				13	Ardeidae	6	10	Sciuridae	3
7	Cobitidae	4				14	Phalacrocoracidae	6	11	Hylobatidae	1
8	Elasmobranchii	4				15	Alaudidae	6	12	Vespertilionidae	1

(Dai et al., 2022). In this study, we found a strong link between the regional geographic environment and music. Various groups of organisms and different ecosystems served as sources of inspiration for folk songs, although their relative contributions differed among and within taxonomic groups, demonstrating their significant contribution to Chinese folk songs. This conclusion seems plausible considering that the area is situated in the alluvial plain of the lower Yangtze River near the Yellow Sea and East China Sea and is marked by a complex internal water network and thriving agricultural practices.

Several families contributed to the majority of the biodiversity mentioned in folk songs, with the top-ranking families predominantly comprising common species. Among them, some were closely linked to human life, such as the families Poaceae

Table 2 Model selection table showing the top ten models ranked by AICc to explain the number of songs related to each taxonomic family in different areas of the YRD region.

Area	No.	Farmland	Urban area	Wetland	Woodland	df	logLik	AICc	ΔAICc	w_i
Jiangsu	1	+	+		+	5.0	−546.6	1103.7	0.0	0.2
	2	+	+		+	5.0	−546.6	1103.7	0.0	0.2
	3	+	+	+	+	6.0	−545.9	1104.5	0.8	0.1
	4	+	+	+	+	6.0	−545.9	1104.5	0.8	0.1
	5	+		+	+	5.0	−547.1	1104.6	0.9	0.1
	6	+		+	+	5.0	−547.1	1104.6	0.9	0.1
	7	+			+	4.0	−549.7	1107.6	3.9	0.0
	8	+			+	4.0	−549.7	1107.6	3.9	0.0
	9	+	+	+		5.0	−551.3	1113.1	9.4	0.0
	10	+	+	+		5.0	−551.3	1113.1	9.4	0.0
Anhui	1	+	+		+	5.0	−343.4	697.5	0.0	0.7
	2	+	+	+	+	6.0	−343.3	699.7	2.2	0.3
	3		+		+	4.0	−349.8	708.0	10.5	0.0
	4		+	+	+	5.0	−348.8	708.2	10.7	0.0
	5	+		+	+	5.0	−350.9	712.5	15.0	0.0
	6	+	+			4.0	−352.1	712.7	15.2	0.0
	7	+	+	+		5.0	−351.7	714.2	16.6	0.0
	8	+			+	4.0	−354.3	717.0	19.5	0.0
	9			+	+	4.0	−356.1	720.6	23.1	0.0
	10		+	+		4.0	−359.3	727.1	29.6	0.0
Zhejiang	1	+	+	+	+	6.0	−492.3	997.2	0.0	0.4
	2	+	+	+	+	6.0	−492.3	997.2	0.0	0.4
	3	+	+		+	5.0	−495.3	1001.1	3.9	0.1
	4	+	+		+	5.0	−495.3	1001.1	3.9	0.1
	5	+		+	+	5.0	−497.3	1005.1	7.9	0.0
	6	+		+	+	5.0	−497.3	1005.1	7.9	0.0
	7	+	+	+		5.0	−497.4	1005.3	8.1	0.0
	8	+	+	+		5.0	−497.4	1005.3	8.1	0.0
	9	+			+	4.0	−503.1	1014.6	17.4	0.0
	10	+			+	4.0	−503.1	1014.6	17.4	0.0
Shanghai	1	+	+		+	5.0	−554.7	1119.7	0.0	0.2
	2	+	+		+	5.0	−554.7	1119.7	0.0	0.2
	3	+	+	+	+	6.0	−554.2	1120.9	1.2	0.1
	4	+	+	+	+	6.0	−554.2	1120.9	1.2	0.1
	5	+			+	4.0	−556.7	1121.7	2.0	0.1
	6	+			+	4.0	−556.7	1121.7	2.0	0.1
	7	+		+	+	5.0	−556.2	1122.9	3.2	0.0
	8	+		+	+	5.0	−556.2	1122.9	3.2	0.0
	9		+	+	+	5.0	−559.2	1128.8	9.0	0.0
	10		+	+	+	5.0	−559.2	1128.8	9.0	0.0

Table 3 Multimodel inference results showing sums of the Akaike weights (SWs), model-averaged coefficients and adjusted standard errors of the predictor groups for the number of songs related to family.

Area	Variables	SW	Estimate coefficients	SE	*Z* value
Jiangsu	(Intercept)	-	−0.12	1.64	0.07
	Farmland	1.00	19.25	3.54	5.44***
	Urban area	0.72	5.23	4.56	1.15
	Woodland	1.00	12.29	3.57	3.44***
	Wetland	0.57	3.21	3.97	0.81
Anhui	(Intercept)	-	0.45	1.18	0.38
	Farmland	1.00	6.33	1.84	3.43***
	Urban area	1.00	4.14	2.07	2.00*
	Woodland	1.00	13.86	2.28	6.07***
	Wetland	0.35	0.61	1.34	0.45
Zhejiang	(Intercept)	-	−0.88	1.09	0.80
	Farmland	1.00	13.03	2.13	6.11***
	Urban area	1.00	6.89	2.19	3.14**
	Woodland	1.00	7.57	2.38	0.80**
	Wetland	1.00	5.23	2.16	2.42*
Shanghai	(Intercept)	-	0.45	1.18	0.38
	Farmland	1.00	6.33	1.84	3.43***
	Urban area	1.00	4.14	2.07	2.00*
	Woodland	1.00	13.86	2.28	6.07***
	Wetland	0.35	0.61	1.34	0.45

*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$

and Fabaceae in plants; Bovidae, Equidae, and Felidae in mammals; Phasianidae and Anatidae in birds; and Bombycidae in insects. Dai et al. (2022) also reported that ecological elements such as rivers, mountains, and flowers are often utilized in Chinese poetry to express the writer's emotions and usually symbolize a distinct spirit, character, or ideology. In contrast to poetry, Chinese folk songs arise predominantly from the people; these songs are created and transmitted orally and exhibit notable improvisational traits. The melodies encompass various stylistic forms and are often marked by simple structures that facilitate communal performance and transmission. The language is direct and natural and frequently incorporates local dialects and colloquialisms, enabling these folk songs to draw profound inspiration from the region's abundant biodiversity and ecosystems.

Plants have the greatest inspirational benefits in the YRD region, followed by mammals, birds, insects, and other groups. These songs are slightly different from old children's songs that have been studied in Japan (Katayama and Baha, 2020). In Japanese children's songs, plants are the most significant source of inspiration, accounting for 54.7% of songs, followed by birds, insects, mammals, and other categories. These differences can be attributed not only to variations in environmental and natural habitats but also to the unique cultural backgrounds of the two nations. Birds are frequently mentioned in English poetry (Hiron et al., 2018) and Chinese poetry (Dai et al., 2022), indicating their potential significance as a pivotal species that provides a source of inspiration in temperate regions. However, the proportion of

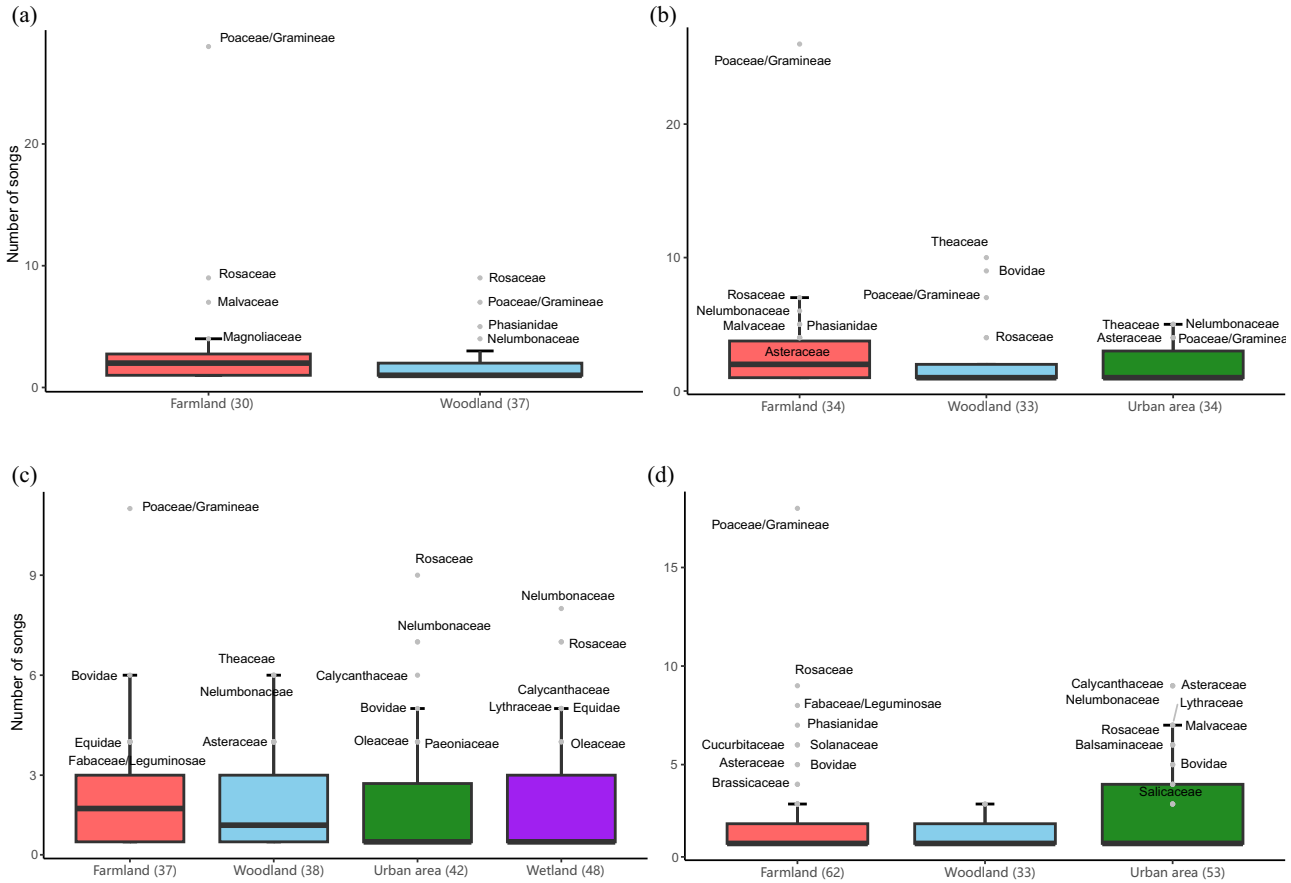

Fig. 4 Relationships between habitat types and the number of songs associated with each family. a Jiangsu; **b** Anhui; **c** Zhejiang; **d** Shanghai. The numbers in parentheses indicate the sample sizes. Jittered points (with scientific names of the families referenced in more than four songs) are also shown.

songs inspired by birds in the YRD region is smaller than the proportion of Japanese children's songs. These comparisons highlight the universality of ecological inspiration for artistic expression while underscoring the unique regional characteristics of Chinese folk music.

Nonetheless, we recognize that folk songs may not accurately represent the present distribution or abundance of species, as ecosystems may have evolved over time due to factors such as urbanization, agricultural expansion, and climate change. As oral cultural artifacts, these songs often preserve ecological memories and symbolic meanings, rather than offering precise, time-bound ecological data. Although this limits their use for temporal ecological monitoring, it highlights their value as cultural records of biodiversity perception.

Regional variation in biodiversity and ecosystems found in folk songs. The study of music geography includes the role of spatiality in the formation and creation of music and how it reflects the "mutually generative relations of music and place" (Leyshon et al., 1995). In China, the natural barriers created by mountains and rivers significantly influence the diverse ecological environments across regions. With regard to the influence of biodiversity on folk songs in the Yangtze River Delta region, plants constitute the primary taxonomic group across all four areas, mammals form the secondary group in Jiangsu, Zhejiang, and Shanghai, whereas birds take this position in Anhui (Figs. S1, S2). This focus is closely tied to the geographical environment of Anhui, which is characterized by intricate terrain-rolling hills in the central region and predominantly mountainous areas in the southern region as well as a rich diversity of bird species.

Similar observations emerge in ecosystem studies (Fig. 4) of the geographical environment. Jiangsu is characterized by a low, flat terrain and a dense water network. In addition to a few low mountains and hills, plains make up 68.8% of the total area, and rice cultivation is highly developed in these paddy field areas. The landscape of Zhejiang is characterized by hills and mountains as well as an extensive coastline and numerous coastal islands. The agricultural economy is categorized into three types: the plain economy focuses on rice, silkworms, cotton, hemp, and freshwater fish; the mountain economy is primarily based on forestry and tea; and the coastal economy relies on marine fisheries and aquaculture. Songs about silkworms are a distinctive feature of folk music in Zhejiang Province. In Shanghai, the lyrics of local songs often reflect the role of water in village life and agricultural labor, frequently featuring words such as river, pond, bridge, water, fish, and lotus root. These expressions are deeply connected to the environment and to settings such as farmland, rice, cotton, flowers, and birds, all of which are imbued with a distinct local flavor. These elements are intricately woven into the tapestry of Shanghai's folk culture and find concentrated expression in its folk songs.

In the 1980s, the scholar Qiao Jianzhong introduced the concept of "land and songs" in the study of music geography in China. He proposed that the spatial distribution of folk music should be analyzed from multiple perspectives and examined in relation to the geographical contexts of its origin and dissemination, thereby uncovering the intricate connections between folk music and geography (Qiao, 2009). After years of enrichment and development, this concept was reinterpreted, reconstructed, and extended to the academic level and was used to explore the

relationships among "music, geography and humanity" (Qiao, 2012). Our findings indicate that the folk songs of the YRD region are deeply rooted in specific geographical environments and cultural backgrounds, potentially reflecting the local populace's understanding of and reverence for regional biodiversity and ecosystems. The geographical landscape and its changes provided the essential conditions for the creation and development of folk songs, and the integration of the social and natural environments enriched the content and depth of musical composition. Therefore, it is imperative to consider biodiversity and ecosystems when examining the complex interrelationships among music, geography, and humanity.

The ecological themes of representative folk songs highlight the value of CES. Inspiration is not a product of a single type of experience but rather of all types of experiences associated with ecosystems (Chan et al., 2012). The cultural meanings that link biodiversity to regional identity can be found in many folk songs from the YRD. The ecological elements of folk songs are not only decorative but also serve symbolic and emotional functions rooted in local cultural values. For example, a folk song from southern Jiangsu contains the lyric, "the little boat drifts into the river, the water surface echoes with my sister's song, the lotus flowers vibrant as flames; which one is my sister?" Here, the lotus (*Nelumbo nucifera*) not only reflects the natural beauty of the wetland ecology but also symbolizes the romantic feelings of the characters and the harmony between people and nature. Indeed, the lotus usually symbolizes purity, beauty, and good fortune in folk songs and holds a prominent position in the cultures of Jiangsu and Zhejiang. Similarly, waterfowl such as Mandarin ducks (*Aix galericulata*) frequently symbolize love, particularly the steadfast and harmonious bond between husbands and wives.

In the YRD region, certain lyrics within folk songs poignantly highlight regional biodiversity while advocating for its preservation. For example, the folk song "Fresh Fishes in Twelve Months" is popular in Rudong County, Jiangsu province, which is located along the Yellow Sea coast. Lyrical records represent a regional "fish calendar," illustrating the seasonal availability of species and their role in culinary tradition. In southern Jiangsu Province along the banks of the Yangtze River, another folk song titled "Seasonal Fishery Culture" features a different selection of fish species. The former focuses primarily on marine species, including *Coilia nasus* from Engraulidae, *Ilisha elongata* from Clupeidae, *Collichthus bindus* from Sciaenidae, *Mugil cephalus* from Mugilidae, and *Trichiurus japonicus* from Trichiuridae. In contrast, the latter emphasizes freshwater or migratory species such as *Carassius auratus*, *Ctenopharyngodon idellus*, *Mylopharyngodon piceus*, *Hypophthalmichthys molitrix* from Cyprinidae, *Tenualosa reevesii* from Clupeidae, and *Siniperca chuatsi* from Serranidae. However, some lyrics encapsulate practical ecological knowledge either directly or through metaphorical subtleties. In Anhui Province, there is a notable folk song titled "Do Not Mistake Barnyard Grass for Rice," which includes the following lines: "jumping into the rice field to pull weeds, struggling to distinguish between barnyard grass and rice; Seeking my elder sister's guidance, she remarked, 'My dear brother, you are such a goof; Barnyard grass has a bare stalk, while rice is adorned with fine hairs.'" The folk song not only conveys the affection between two characters but also highlights the distinctions between the two plants.

These examples indicate that Chinese folk songs in the YRD are intricately intertwined with ecological symbolism and traditional ecological wisdom and have profound cultural and ecological significance. A comparable phenomenon is evident in the mid-twentieth century songs of the renowned singer Luiz Gonzaga, whose lyrics encapsulate the traditional ecological knowledge of northeastern Brazil. Cultural history and lyrical and musical analysis suggest that Gonzaga's voice is a vehicle for the transmission of knowledge about the weather, and this music, produced by a profit-driven industry, plays a role in the maintenance of local ecological knowledge (Silvers, 2015). By understanding rain and drought using natural indicators, Gonzaga's music offers credibility, clarity, and resonance within the region's semiarid backlands. Consequently, the depiction of biodiversity and ecosystems in folk songs functions not merely as a backdrop but also as an essential cultural component of everyday life, thereby enriching the inspirational aspects of CES.

Conclusion

This study reveals the strong relationships between folk songs and various types of habitats and reveals distinct patterns across different regions of the YRD. It emphasizes the inspiring influence of ecosystems and biodiversity on these cultural expressions. The results demonstrate that ecosystems, taxonomic groups, and certain families are closely linked to Chinese folk songs. Our study of the relationships among music, geography, and people offer valuable insight into how ecosystems and biodiversity serve as sources of artistic inspiration. These methodologies can be extended to other artistic works that include content descriptions, such as poetry, paintings, literature, photography, and films.

The present study provides valuable insights for environmental management. By creating visually appealing and desirable scenery, heterogeneous landscapes can directly offer high CES (van Berkel and Verburg, 2014) and indirectly support high biodiversity (Benton et al., 2003). The loss of these diverse landscapes due to urbanization and agricultural intensification since the mid-20th century may contribute to a decline in CES and human well-being (Katayama and Baha, 2020). Our research indicates that the inspirational benefits of ecosystems originate predominantly from wetlands and farmlands in the YRD region, whereas the biodiversity benefits are derived from terrestrial flora and fauna. Therefore, it is imperative to conserve a wide array of ecosystems and their associated flora and fauna in the YRD region to sustain artistic inspiration for folk songs. Maintaining ecosystem diversity and landscape heterogeneity is essential during China's rapid urbanization in the future.

Future research can extend this study by comparing folk songs from different ecological regions in China. A larger dataset may reveal concealed patterns in the interplay between geographic environments and cultural expressions, thereby advancing the field of CES. Folk songs in China can be broadly categorized into three genres: Haozi, Shange and Xiaodiao (Qiao, 2009). A more in-depth analysis is needed to elucidate the melodic characteristics and social functions of the three genres as well as their ecological and environmental contexts and to investigate the impact of geography on musical forms and expressions.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Author contributions

Wang C and Chang Q wrote the manuscript text, Liu Y and Wang P conducted the data analysis, and Liu Y prepared figures 1–4. All authors reviewed the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants or their data.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

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