

Supplementary Materials

# Prioritizing Birds' Habitats for Conservation to Mitigate Urbanization Impacts Using Field Survey-Based Integrated Models in the Yangtze River Estuary

Meihua Gao <sup>1</sup>, Shubo Fang <sup>1,2,\*</sup>, Matthew J. Deitch <sup>2</sup>, Yang Hu <sup>1,3</sup>, Dongsheng Zhang <sup>4,5</sup>, Zhongrong Wan <sup>5</sup>, Peimin He <sup>1</sup>, Yanlin Pan <sup>1</sup> and Tesfay G. Gebremicael <sup>2</sup>

<sup>1</sup> College of Marine Ecology and Environment, Shanghai Ocean University, Shanghai 201306, China; m200401148@st.shou.edu.cn (M.G.); 52263904022@stu.ecnu.edu.cn (Y.H.); pmhe@shou.edu.cn (P.H.); m220501209@st.shou.edu.cn (Y.P.)

<sup>2</sup> Soil, Water, and Ecosystem Sciences Department, University of Florida, IFAS West Florida Research and Education Center, Milton, FL 32583, USA; mdeitch@ufl.edu (M.J.D.); t.gebremicael@ufl.edu (T.G.G.)

<sup>3</sup> State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200241, China

<sup>4</sup> College of Fisheries and Life Science, Shanghai Ocean University, Shanghai 201306, China; dszhang@shou.edu.cn

<sup>5</sup> Shanghai Eco-Nanhui Voluntary Society, Shanghai 201306, China; 13061782760@wo.cn

\* Correspondence: sfang1@ufl.edu

**Table S1.** The Digital Object Identifier (DOI) of various bird species in Global Biodiversity Information Facility (GBIF).

Ecological Group	Species	The DOI of GBIF
Terrestores	<i>Columba livia domestica</i>	10.15468/dl.52m5sz
	<i>Streptopelia orientalis</i>	
	<i>Streptopelia chinensis</i>	
Raptatores	<i>Circus spilonotus</i>	10.15468/dl.5chzsr
	<i>Elanus caeruleus</i>	
Passeres	<i>Garrulax canorus</i>	10.15468/dl.xfa5g9
	<i>Paradoxornis heudei</i>	
	<i>Acridotheres cristatellus</i>	
	<i>Motacilla alba</i>	
	<i>Pycnonotus sinensis</i>	
	<i>Lonchura punctulata</i>	
	<i>Muscicapa dauurica</i>	
	<i>Prinia inornata</i>	
	<i>Acrocephalus orientalis</i>	
	<i>Dicrurus macrocercus</i>	
	<i>Gracupica nigricollis</i>	
	<i>Eophona migratoria</i>	
	<i>Motacilla tschutschensis</i>	
	<i>Spinus spinus</i>	
	<i>Motacilla cinerea</i>	
	<i>Spodiopsar cineraceus</i>	
	<i>Acridotheres tristis</i>	
	<i>Hirundo rustica</i>	
	<i>Chloris sinica</i>	
	<i>Cecropis daurica</i>	

Ecological Group	Species	The DOI of GBIF
Scansores	<i>Anthus novaeseelandiae</i>	10.15468/dl.6xep3c
	<i>Passer montanus</i>	
	<i>Spodiopsar sericeus</i>	
	<i>Turdus mandarinus</i>	
	<i>Coccothraustes coccothraustes</i>	
	<i>Pica pica</i>	
	<i>Alauda gulgula</i>	
	<i>Horornis canturians</i>	
	<i>Lanius schach</i>	
	<i>Cisticola juncidis</i>	
	<i>Sinosuthora webbiana</i>	
	<i>Upupa epops</i>	
	<i>Alcedo atthis</i>	
Grallatores	<i>Caprimulgus indicus</i>	10.15468/dl.d7qb3x
	<i>Cuculus canorus</i>	
	<i>Egretta garzetta</i>	
	<i>Ardea cinerea</i>	
	<i>Ardeola bacchus</i>	
	<i>Ardea alba</i>	
	<i>Bubulcus ibis</i>	
	<i>Nycticorax nycticorax</i>	
	<i>Ardea intermedia</i>	
	<i>Numenius madagascariensis</i>	
	<i>Chlidonias leucopterus</i>	
	<i>Amaurornis phoenicurus</i>	
	<i>Tringa ochropus</i>	
	<i>Recurvirostra avosetta</i>	
	<i>Tringa erythropus</i>	
	<i>Himantopus himantopus</i>	
	<i>Calidris alpina</i>	
	<i>Gallinula chloropus</i>	
	<i>Limosa limosa</i>	
	<i>Tringa totanus</i>	
	<i>Calidris ruficollis</i>	
	<i>Charadrius alexandrinus</i>	
	<i>Pluvialis squatarola</i>	
	<i>Vanellus cinereus</i>	
	<i>Actitis hypoleucos</i>	
	<i>Calidris acuminata</i>	
	<i>Pluvialis fulva</i>	
	<i>Charadrius dubius</i>	
	<i>Tringa glareola</i>	
	<i>Glareola maldivarum</i>	
	<i>Sterna hirundo</i>	
	<i>Xenus cinereus</i>	
	<i>Calidris temminckii</i>	
	<i>Tringa nebularia</i>	

Ecological Group	Species	The DOI of GBIF
	<i>Calidris alba</i>	10.15468/dl.ahcshv
	<i>Gallinago gallinago</i>	
	<i>Chlidonias hybrida</i>	
	<i>Tringa stagnatilis</i>	
	<i>Calidris subminuta</i>	
	<i>Numenius phaeopus</i>	
Natatores	<i>Tachybaptus ruficollis</i>	

**Table S2.** The related parameters of PLUS model. The Pearson product-moment correlation coefficient and VIF of environmental variables.

Environmental Layer	Pearson Product-Moment Correlation Coefficient								VIF
	Gdp	Population	Residence	Highway	Mainway	Water	Stream	Precipitation	
gdp	1								2.168
population	0.466 **	1							1.379
residence	−0.609 **	−0.290 **	1						3.679
highway	−0.595 **	−0.347 **	0.746 **	1					3.370
mainway	−0.264 **	−0.306 **	0.548 **	0.608 **	1				11.626
water	0.307 **	0.029 **	−0.334 **	−0.317 **	−0.041 **	1			1.259
stream	−0.321 **	−0.310 **	0.622 **	0.590 **	0.925 **	−0.050 **	1		9.354
precipitation	0.0001	0.164 **	−0.059 **	−0.365 **	−0.585 **	0.048 **	−0.400 **	1	2.353

\*\* . Correlation is significant at the 0.01 level (1-tailed)

**Table S3.** The explains, contribution and *p* value of the important environmental data in ordination biplots.

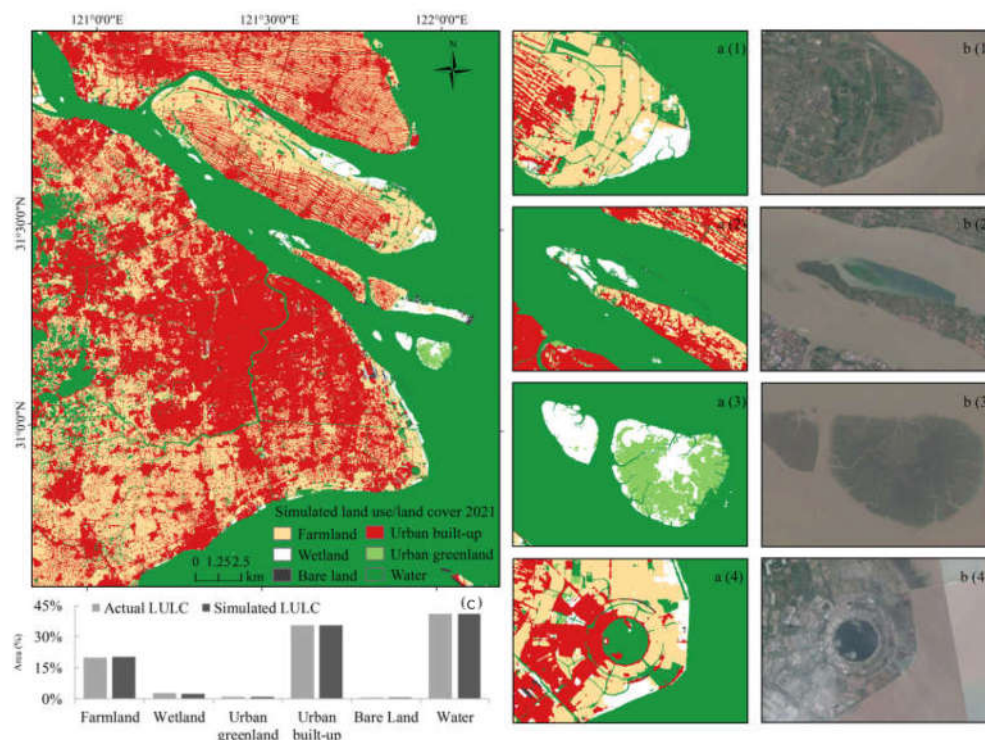
Environmental Data	Explains %	Contribution %	P
Dist_greenland	0.7	35.6	0.002
Dist_water	0.4	17.8	0.002
Dist_built_up	0.3	14.9	0.002
Dist_wetland	0.2	10	0.002
Dist_bareland	0.2	8.3	0.002
Dist_farmland	0.2	7.4	0.004

**Table S4.** Landscape pattern index of LULC landscape level in Yangtze estuary.

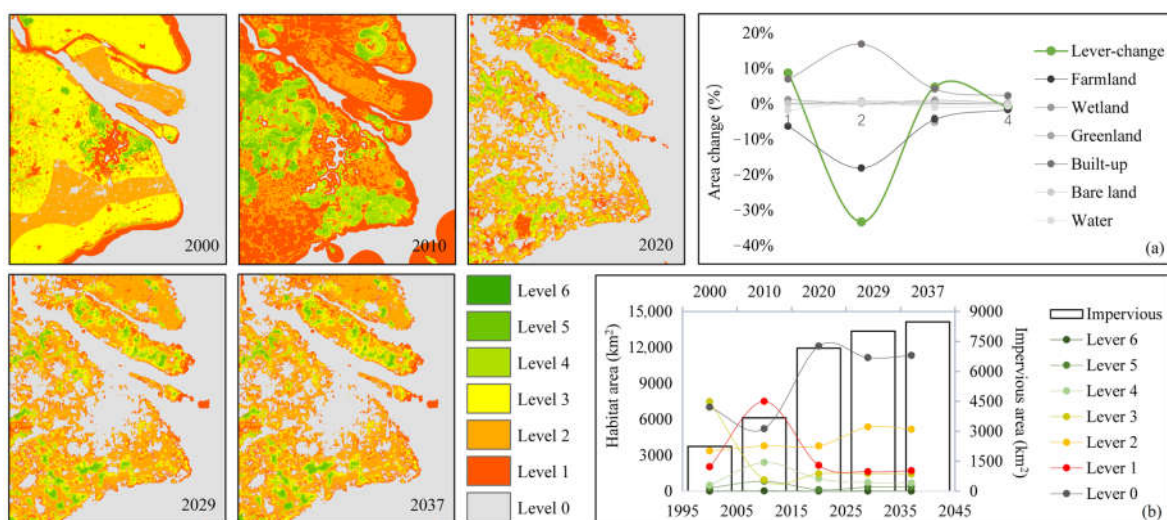
YEAR	NP	LSI
2000	14,796	63
2010	11,345	59
2020	73,386	116
2029	596,182	211
2037	589,290	204

**Table S5.** Landscape pattern index of LULC class level in Yangtze estuary.

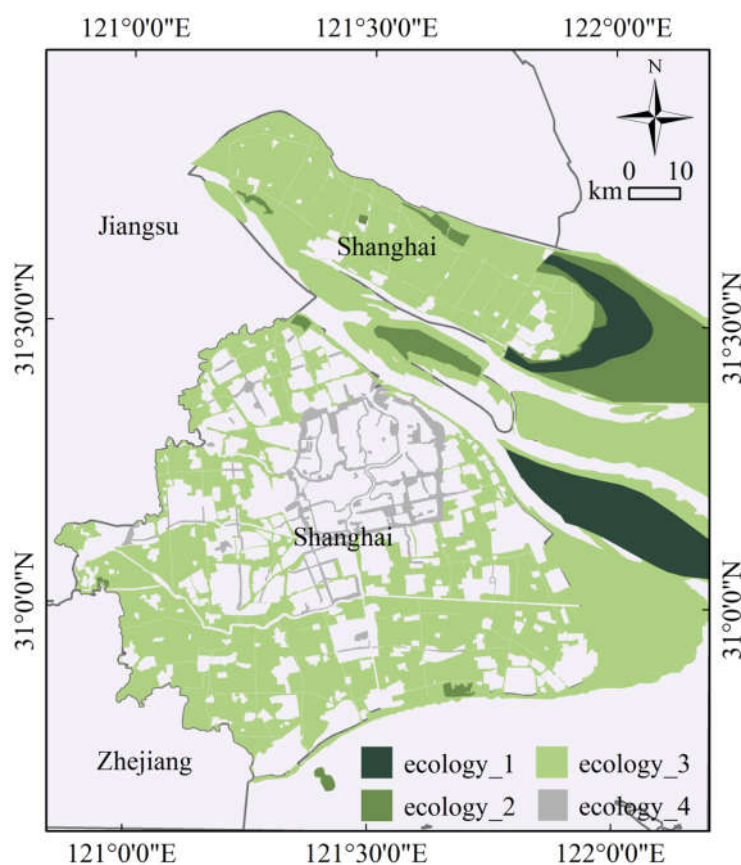
YEAR	Farmland		Wetland		Bare Land		Water		Greenland		Build-Up	
	NP	LSI	NP	LSI	NP	LSI	NP	LSI	NP	LSI	NP	LSI
2000	2849	86	163	17	31	6	8133	37	886	19	2734	122
2010	3192	85	91	15	164	14	3960	30	1576	32	2362	98
2020	22,593	189	11,519	89	1185	40	14,248	57	7882	91	15,959	144
2029	510,422	423	17,487	114	1676	35	39,338	87	9361	119	17,898	25
2037	511,218	427	15,699	109	1139	32	36,481	84	9875	116	14,878	244



**Figure S1. Simulated LULC 2021.** The simulated LULC in 2021 (a(1–4)) was compared with the 2021 Google map (b(1–4)). (c) The simulated 2021 LULC generated based on the actual LULC of 2017 and 2021 was validated with the actual 2021 LULC interpreted by Sentinel-2 satellite images.



**Figure S2. The level of bird habitats from 2000–2037.** Level 0 indicated a non-bird habitat. Level 1 indicated a bird habitat suitable for an ecological group. The higher the level represented the more overlapping the habitat of different ecological groups. (a) The perArea changes (%) of bird suitable habitat and each LULC type in the four periods (2000–2010, 2010–2020, 2020–2029, and 2029–2037). (b) Change in the proportion of area to total area from 2000–2037.



**Figure S3.** Shanghai Ecological Spatial Planning Map. **Ecology\_1** refers to the first-class ecological space, which includes the core areas of Chongming Dongtan Bird National Nature Reserve and Jiuduansha Wetland National Nature Reserve. **Ecology\_2** refers to the second-class ecological space, which includes the edge areas of national-level nature reserves, natural reserves located within cities, primary protected areas of drinking water sources, core areas of forest parks, core areas of geoparks, mountains, and important wetlands. **Ecology\_3** refers to the third-class ecological space, which includes permanent basic farmland, forest land, wetlands, rivers, lakes, wildlife habitats, and other ecological protection areas. Finally, **Ecology\_4** refers to the fourth-class ecological space, which includes the outer ring green belt, urban park green space, water systems, wedge-shaped green spaces, and more.