Urban-Act
Integrated Urban Climate Action
for Low-Carbon & Resilient Cities

Technical Research on Urban Biodiversity Conservation Planning

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Project description
Integrated Urban Climate Action for Low-Carbon and Resilient Cities (Urban-Act)

The Urban-Act project is implemented on behalf of the International Climate Initiative (IKI) of the Federal Government of Germany. Within the Federal Government, the IKI is anchored in the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN).

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Abstract

Urban biodiversity forms the foundation of healthy and stable urban ecosystems. Under rapid urbanization, unprecedented pressures—such as habitat fragmentation, invasion by non-native species, and loss of native species—are being exerted on urban biodiversity, thereby undermining ecological balance and threatening sustainable urban development and human well-being. Consequently, the importance of planning for urban biodiversity conservation has steadily increased. Science-based and well-designed planning represents a key strategy for addressing biodiversity loss, enhancing urban resilience, and promoting harmonious coexistence between people and nature; such planning should be integrated as an essential component of urban planning and management.

I. Research Objectives

The present study aims to examine the objectives, scope and role, primary tasks, and the necessary contents for preparing urban biodiversity conservation plans, and to specify the spatial-planning technical methods applicable to those plans. A pilot application in Xiamen is presented to demonstrate the practical effectiveness of the proposed approach and technical methods and to extract lessons for wider application.

II. Technical Roadmap

Based on interdisciplinary theories and methods from urban–rural planning and conservation ecology, the research **first synthesizes requirements for urban biodiversity conservation and the technical elements related to spatial planning; this synthesis clarifies conservation objectives, the plan's positioning within the broader planning system, and the specific planning tasks, thus forming a technical framework for biodiversity conservation planning; Subsequently,** based on the review and interpretation of theoretical knowledge and technical methods for urban biodiversity conservation planning, stakeholder surveys and semi-structured interviews were conducted with representatives from government departments, research institutions, universities, international organizations, and industry enterprises to collect cross-sectoral perspectives. On this basis, a three-stage planning framework was developed: **(1) analysis of biodiversity resources and the current conservation status; (2) construction of a spatial layout for biodiversity conservation; and (3) formulation of implementation recommendations for biodiversity conservation; for each stage, the required technical procedures and methods were explicitly defined. Finally, a pilot project in Xiamen implemented the framework and produced an integrated technical system composed of multi-source data integration and analysis, habitat-quality assessment, species distribution mapping, construction of a biodiversity habitat-protection network, and concrete implementation recommendations.**

III. Main Conclusions

(I) Goals and institutional positioning of urban biodiversity conservation planning

1. The primary goals of urban biodiversity conservation planning are to translate relevant policy requirements into concrete spatial and management measures; to delineate conservation zoning and management areas; to specify requirements for activity controls, infrastructure avoidance (setback) and ecological restoration; to establish an effective spatial conservation configuration; and to guide the preparation of sectoral and specialized plans so that biodiversity considerations are explicitly embedded across other planning instruments.

2. Urban biodiversity conservation plans are positioned as a specialized element within the broader territorial spatial-planning system and are expected to align with the system's institutional requirements. Vertical alignment with national and provincial strategies and their municipal-level implementation is required, while horizontal coordination with the city's comprehensive (master) urban spatial plan and with detailed plans is essential. Promotion of the integration of biodiversity assessment into formal plan evaluation and appraisal procedures (for example, the "Double Evaluation" framework in the domestic context) and alignment of conservation planning with related sectoral plans are also necessary.

(II) Technical methodologies for urban biodiversity conservation planning

A technical methodology was developed, comprising five interrelated elements: multi-source data integration and analysis; assessment of habitat quality; species distribution mapping; establishment of a habitat protection network (habitat/ecological network); and formulation of conservation management and implementation

recommendations. Method steps included: first, the compilation, harmonization and supplementation of historical and current biodiversity datasets and supporting spatial data; second, GIS-based evaluation of the functional roles and relative importance of habitat patches within the study area; third, identification of the spatial distribution of core (source) habitats, buffer zones and ecological corridors that together constitute the habitat network; and finally, derivation of conservation and management recommendations from the identified network to construct a multi-level, spatially connected system for biodiversity protection.

Implementation of the methodology was piloted in Xiamen. The pilot comprised an analysis of the city's ecological setting, its biodiversity resource base and the status of ongoing conservation efforts. **The analysis clarified Xiamen's biodiversity assets and values, the existing conservation baseline conditions and constraints, and the principal development pressures and sources of conflict affecting biodiversity.** Species selection and data compilation were undertaken on the basis of the baseline review and with consideration of habitat representativeness, legal protection status, rarity and threat classification, special ecological and cultural values, and local cultural significance. **Six representative bird species were selected as focal taxa—Chinese Egret, Saunders's Gull, Blue-tailed Bee-eater, Purple Swamphen, Great Cormorant, and Greater Coucal—and their distribution records were compiled.** Habitat classification for Xiamen was produced through interpretation of high-resolution remote-sensing imagery, with resulting habitat-patch delineations supplemented and cross-checked against current land-use maps, resource surveys and other spatial datasets. On that basis, expert interviews were conducted with government managers, researchers, academics, NGO representatives and practitioners from environmental-sector enterprises to define the calculation principles for a Species Disturbance Index (as applied in this study). The Species Disturbance Index was calculated for each habitat patch using metrics such as patch area and perimeter, habitat type, and the spatial distribution of human-induced disturbances. Combination of focal-species distribution records with the Species Disturbance Index enabled evaluation of the functional roles and relative importance of habitat patches and identification of the network's core (source) habitats, buffer zones and ecological corridors. Based on the identified habitat network, biodiversity conservation recommendations were proposed in four areas: optimization of ecological spatial patterns; enhancement of ecological restoration efforts; inclusion of additional biodiversity indicators in performance evaluation systems; and promotion of synergies between biodiversity conservation and climate-change adaptation to realize co-benefits.

At present, the proposed methodology is primarily applicable at the city scale; analyses at smaller scales (such as site- or sub-district level) may draw on the same conceptual approach but will require scale-specific adjustments. Further research will focus on deepening and refining the assessment of anthropogenic impacts and on elaborating implementation recommendations for biodiversity conservation planning.

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1 Overview of the Study

1.1 Research objectives and significance

Biodiversity underpins human survival and development and is critical to climate regulation and to efforts to mitigate climate change. Humanity currently faces a critical juncture requiring coordinated action to conserve biodiversity and to deliver global sustainable development. The *Kunming–Montreal Global Biodiversity Framework (GBF), adopted at COP15 in December 2022, established a set of targets for the decade to 2030 — including a goal to conserve at least 30% of global terrestrial and marine areas by 2030 — and calls for biodiversity and its multiple values to be mainstreamed into policies, regulations, planning processes and development decisions.*

Mainstreaming of biodiversity into sectoral and spatial planning is also emphasized in international guidance and in China's national strategies. Under the GBF, **the inclusion of biodiversity in urban planning is urged** to strengthen native biodiversity, ecological connectivity and integrity, improve human health and well-being and people's connection to nature, promote inclusive and sustainable urbanization, and secure the provision of ecosystem functions and services. In China's position paper for the United Nations Summit on Biodiversity — "*Building a Shared Future for All Life on Earth: China in Action*" — a clear commitment is made **to incorporate biodiversity conservation into economic and social development plans, ecological protection and restoration plans, territorial spatial planning, and related specialized plans**. The policy document **"*Opinions on Further Strengthening Biodiversity Conservation*"** requires that biodiversity conservation be integrated into medium- and long-term plans across regions and relevant sectors, and calls for the continuous optimization of the spatial pattern for biodiversity conservation. The *National Biodiversity Conservation Strategy and Action Plan (2023–2030)* further proposes **optimizing the national development-and-conservation pattern and making biodiversity protection an important component of Territorial Spatial Planning**.

Territorial Spatial Planning (TSP), as the national framework for spatial development and the spatial blueprint for sustainable development, provides an essential governance instrument for ensuring that biodiversity conservation objectives are reflected in decision-making and action at multiple levels. A number of municipal and county authorities across China have begun to integrate biodiversity considerations into their TSPs; several provincial and municipal authorities, including Shanghai, have initiated pilot demonstration projects for urban biodiversity conservation and reported early positive outcomes, although the practice overall remains at an exploratory stage. Drawing on a pilot application in Xiamen, **this study examines the content and technical methodologies required for preparing urban biodiversity conservation plans,** with the objective of providing practicable pathways and a scientific basis for implementing biodiversity requirements within Territorial Spatial Planning under the strategic frameworks of "Ecological Civilization" and "Beautiful China." Where relevant, the study also seeks to provide technical support for enhancing urban ecosystem services and for supporting a Chinese-style modernization that emphasizes harmonious human–nature relations, thereby assisting the natural-resources sector in fulfilling its responsibilities in climate-change response.

1.2 Research scope

(1) To clarify the goals and institutional positioning of urban biodiversity conservation planning: To identify biodiversity-related requirements across relevant departments; to specify the technical contents that connect biodiversity conservation with spatial planning; to define the role and positioning of urban biodiversity conservation within the Territorial Spatial Planning (TSP) system; and to determine the specific tasks and components to be included in urban biodiversity conservation plans.

(2) To develop technical methodologies for spatial planning of urban biodiversity conservation: To integrate case-study evidence with pathway analysis in order to articulate the planning logic; and to construct a methodological framework and associated toolset for plan preparation and implementation that is appropriate to the urban context.

(3) To carry out an empirical application in the Xiamen pilot: To analyze local biodiversity characteristics and the potential impacts of urban–rural development on biodiversity using available species-distribution data; to explore and test methods for establishing an urban biodiversity conservation spatial network; and to formulate spatial-management recommendations and nature-based solutions (NbS) strategies that generate co-benefits for climate-change response.

1.3 Research methodology

(1) Establishment of a planning–cross-sector linkage framework. A comprehensive review and interpretation of interdisciplinary theories and methods from urban–rural (territorial) planning and conservation ecology were undertaken, followed by stakeholder surveys and semi-structured interviews with government departments, research institutions, universities, international organizations, and industry enterprises. Strengthening communication and collaboration among these actors was emphasized, and the results informed the development of a technical framework for urban biodiversity conservation planning that links planning processes with cross-sector implementation.

(2) Integration of multi-source data with species-distribution modelling. A multi-source dataset was compiled from documentary and bibliographic sources (including documents and reports provided by relevant agencies, academic monographs, and literature retrieved from CNKI and Web of Science) and from online biodiversity and spatial data repositories (for example, Harvard Dataverse, AutoNavi/Gaode mapping datasets, and records from the China Bird-watching Records Center). Species distribution model(s) (SDMs) were applied together with GIS-based spatial analysis (implemented in ArcGIS) to derive and test candidate spatial layouts for biodiversity conservation.

1.4 Technical roadmap

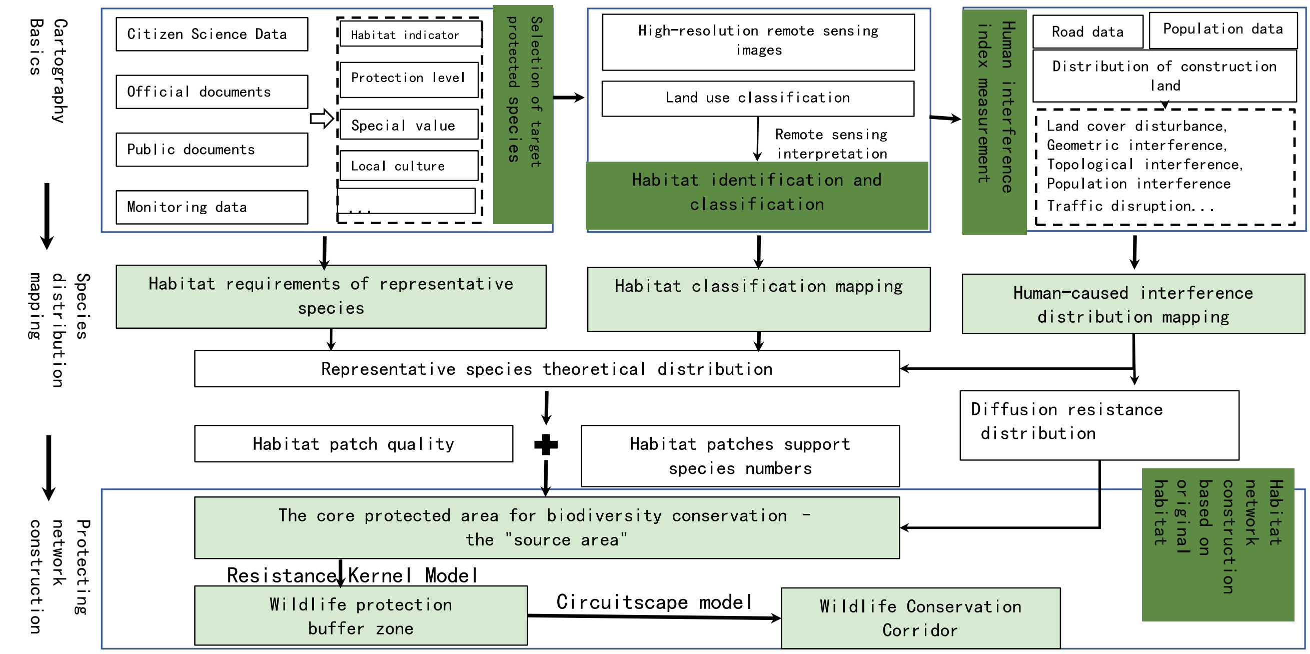

Figure 1-1: Technical Roadmap
Source: author's illustration

The technical roadmap (Figure 1-1) comprises the following components: multi-source data integration and analysis; selection of focal (target) species; habitat identification and classification; computation of an anthropogenic-disturbance index for habitat patches; species distribution mapping; and construction of a habitat protection (ecological) network for biodiversity conservation.

2 Review of Research and Practice (Domestic and International)

2.1 Research on urban biodiversity conservation planning

2.1.1 Research on constructing urban ecological security patterns based on sources–corridors–nodes

The Ecological Security Pattern (ESP), as a comprehensive analytical framework, aims to systematically identify and analyze landscape ecological elements and their spatial configuration that are critical for maintaining the health and security of ecological processes, and plays an indispensable role in safeguarding the stability and security of regional ecosystems. The ESP not only provides a strong quantitative research basis for the scientific delineation of Ecological Protection Redlines and for the fine-scale zoning of ecological functional areas, but also provides an important technical paradigm for the construction of urban habitat networks.

Structurally, the ESP follows the basic framework of "source–corridor–node": by identifying key ecological source areas, constructing ecological connectivity corridors, and strengthening the functional roles of ecological nodes, it achieves optimization and protection of the overall structure and function of the ecosystem.

(1) Ecological source areas

As regions that sustain long-term species populations and serve as starting points for dispersal, ecological source areas generally have strong biodiversity-maintaining functions and high ecological sensitivity, and they play an important role in maintaining ecosystem stability. Results of biodiversity conservation importance assessments can be used to identify ecological source areas that target biodiversity conservation objectives [1]. In addition, landscape connectivity must be considered, commonly represented by indices such as the Integral Index of Connectivity, the Probability of Connectivity, and patch-importance indices [2–3]. Ecological source areas targeted for biodiversity conservation are preliminarily determined by overlaying these areas with source areas identified for other ecosystem services and ecological sensitivity. Because ecological source areas need to reach a certain scale to be effective, fragmented small patches should be merged according to regional characteristics, and contiguous patches exceeding a given threshold area should be extracted as ecological source areas; different studies adopt different thresholds — Wu Zhilong et al. used 0.8 km² as a threshold, while Xu Jia et al. used 3 km² [4–5]. Identification of ecological source areas typically references the Ecological Protection Redline, and some studies directly take the Ecological Protection Redline area as the ecological source area [6].

(2) Ecological corridors

As carriers of energy and material cycles, ecological corridors are important ecological land that enable ecological processes and energy flows to be connected across the region. On the basis of source identification, constructing a resistance surface and then extracting ecological corridors is the main paradigm for building an ecological security pattern. A resistance surface denotes the minimum resistance value for dispersal from source areas to other spatial units and represents the resistance that species must overcome when moving between regions, thereby indicating connectivity and accessibility from source areas to each spatial unit [7]. Resistance factors used to build the resistance surface include natural factors (such as elevation, slope, and vegetation cover) and socio-economic factors (such as land-use type, distance to roads, distance to water bodies, and intensity of anthropogenic disturbance); these factors decisively influence species movement and habitat suitability [8–10]. Fei Fan et al., for example, used birds as indicator species and constructed a resistance-surface model based on their life-history traits to represent resistance affecting their "habitat–migration" processes [11]. The Minimum Cumulative Resistance (MCR) model is currently the most commonly used method for calculating ecological corridors [12–13]; in addition, circuit-theory approaches and ecological-connectivity screening are also major methods for simulating potential ecological corridors [14–16].

(3) Ecological nodes

As important stepping stones for species movement, ecological nodes can reduce distances between patches and increase the frequency and success rate of species migration. Ecological nodes are typically selected from corridor intersections, intersections of corridors and water systems, and important turning points along long-distance corridors [17], or by selecting the geometric center of important regional ecosystem-service areas as ecological nodes [18].

2.1.2 Research on biodiversity conservation importance assessment in municipal territorial spatial planning

The "Double Evaluation" process within Territorial Spatial Planning (TSP) requires a Biodiversity Conservation Importance Assessment to assist in delineating Ecological Protection Redlines and in identifying an Ecological Security Pattern (ESP). In the planning process, this assessment must identify and evaluate the current status, conservation potential, and threats to biodiversity across different areas, so as to ensure that proposed planning schemes will not destroy important biological habitats, will not threaten the survival of rare or endangered species, and will not negatively affect the overall stability and integrity of ecosystems.

The "Double Evaluation," as the premise and foundation of Territorial Spatial Planning, comprises evaluations of soil and water conservation, water-source protection, biodiversity conservation, soil-erosion risk, and waterlogging risk. The Biodiversity Conservation Importance Assessment is a key component of the "Double Evaluation" and serves as the foundational basis for biodiversity conservation planning under the TSP system. Biodiversity is considered at three levels—ecosystem diversity, species diversity, and genetic diversity—and, correspondingly, the biodiversity-importance assessment is divided into ecosystem-level, species-level, and genetic-resource–level evaluations [19]. The *Guidance on Assessment of Resource and Environmental Carrying Capacity and Territorial Spatial Development Suitability (Trial), issued by the Ministry of Natural Resources in January 2020, regulates the work and technical approach for ecological-importance assessments.* **The guidance requires that municipal- and county-level evaluations, based on the results of provincial assessments, use higher-resolution data and field surveys to validate, revise, or supplement those results.** As an important intermediary level within the planning system, municipal Territorial Spatial Planning should validate and, where necessary, refine provincial biodiversity assessment results across the three levels (ecosystem, species, genetic) and provide guidance for micro-level biodiversity design.

Table 2-1: Main Indicators for Biodiversity Assessment

Biodiversity Type	Key Assessment Indicators
Ecosystem diversity	Habitat quality; ecosystem-type diversity; ecosystem connectivity and fragmentation; ecosystem stability
Species diversity	Species richness; species endemism; species threat/endangerment status; population dynamics
Genetic diversity	Genetic (genotypic) diversity

Source: WANG Haiyang, WANG Haoqi, CHEN Xiyue, et al. 2023. Review on evaluation and enhancement of urban biodiversity [J]. Acta Ecologica Sinica, 43(08): 2995–3006.

(1) Ecosystem level

A habitat is the spatial environment in which organisms live; it provides all necessary biotic and abiotic resources for completing life-history processes and thus forms the fundamental basis for species persistence and reproduction. Consequently, at the ecosystem level, **habitat-quality assessment serves as a principal basis for evaluating the importance of biodiversity-maintenance functions.** In the context of the "Double Evaluation," a commonly used composite indicator for characterizing biodiversity-conservation importance is **the Biodiversity Conservation Service-Capacity Index, which comprises climate, terrain, vegetation and water-body parameters — for example, temperature, precipitation, elevation, slope, vegetation net primary productivity (NPP), vegetation cover, and distance to water sources** [21–25]. Building on this approach, some studies further incorporate **anthropogenic factors (such as land-use type and distance to roads) to produce more comprehensive habitat-quality evaluations** [26–27]. Municipal-level biodiversity assessments commonly adopt administrative units (municipality, county, township, etc.) as the spatial assessment units.

Table 2-2: Indicators for Biodiversity Conservation Importance Assessment at the Ecosystem Level

Indicator Category	Assessment Indicator
Climate	Temperature, precipitation
Terrain	Elevation, slope
Vegetation and Water Bodies	Vegetation net primary productivity (NPP); Normalized Difference Vegetation Index (NDVI); forest type; stand age; canopy closure; distance to nearest water body
Anthropogenic Impact	Land-use type; distance to roads

Source: Planners, 37(02): 28–33. Acta Ecologica Sinica, 41(07): 2596–2608. Journal of Ecology and Environmental Sciences, 30(03): 631–643. Proceedings of the 2021 China Urban Planning Annual Conference (08 Urban Ecological Planning): 32–45. China Metal Bulletin, (02): 165–166. Chinese Landscape Architecture, 37(09): 95–100. Chinese Landscape Architecture, 38(06): 97–102.

(2) Species level

Indicator species are frequently used to evaluate biodiversity's support functions because of their ecological importance or sensitivity within a regional ecosystem. With conservation status taken into account, indicator species may include nationally protected species listed as Category I and II, species classified as threatened on the IUCN Red List [28], and commonly applied focal types such as flagship species, umbrella species, and endemic species. Birds are a commonly selected indicator group owing to their relative ease of observation and identification, their high mobility, and their sensitivity to environmental change.

Species-level importance for biodiversity conservation can be divided into current support capacity and potential support capacity. Current support capacity is typically quantified using diversity indices (for example, species richness, Shannon diversity, and evenness) [27]. However, because baseline biodiversity surveys are often incomplete, species-level measures may lack sufficient empirical support in some regions; consequently, species-level assessments are commonly integrated with ecosystem-level indicators. For example, Cai Haisheng et al. [29] constructed a biodiversity assessment model that combined ecosystem-type diversity with indicators including the richness and endemism of wild fauna and flora, the richness of threatened species, and the degree of invasion by non-native species.

Species Distribution Models (SDMs) employ existing occurrence records to simulate and predict potential habitats and distribution ranges (examples include MaxEnt, GARP and Bioclim), thereby representing the potential support capacity for species diversity. The Maximum Entropy (MaxEnt) model, in particular, estimates habitat suitability based on species' environmental preferences and is widely used for modelling potential ecological space — including cases with limited presence records — and has seen growing application in conservation planning [30]. For instance, Ma Xing et al. [31] used MaxEnt to map bird-diversity distribution patterns and conservation gaps in Guangdong Province, informing "Three-Lines" coordination and zoned biodiversity protection. Predicting species distributions is important for protecting indicator-species habitats. Ma Mengxiao et al. [32] applied MaxEnt to simulate bird distribution ranges in Panjin and to evaluate biodiversity-maintenance importance, providing evidence for delineating Ecological Protection Redlines.

(3) Genetic resource level

The genetic-resource level constitutes a key layer of biodiversity and is frequently referenced in the "Double Evaluation." Nevertheless, evaluation frameworks and methods for genetic resources remain relatively underdeveloped; as a result, existing research has predominantly emphasized ecosystem-level and species-level assessments, with relatively few studies conducting comprehensive genetic-level evaluations. In several studies, assessments at the genetic level have relied upon previously delineated primary natural distribution areas of germplasm or genetic resources — for example, designated germplasm-conservation zones or genetic-resource protection areas [27].

2.2 Urban biodiversity conservation planning practice

2.2.1 Local Biodiversity Action Plans (LAPs)

The Local Biodiversity Action Plan (LAP) is a pilot local biodiversity action initiative launched by ICLEI — Local Governments for

Sustainability in 2006. Acting as a local implementation guide within the national biodiversity-planning objectives framework, the LAP has drawn attention from many cities internationally.

In the United Kingdom, LAPs are formulated jointly by local authorities and stakeholders to identify specific habitats and species that should be prioritized for local conservation. To reflect priorities established at the national level, LAPs typically focus on the protection of important habitats and species at risk of extinction, while also providing measures to conserve more widespread habitats and local species [33].

In Ireland, the County Development Plan identifies designated sites, legally protected species and sensitive landscapes, and sets policies and objectives to conserve and strengthen biodiversity within semi-natural or less intensively managed landscapes; it thus safeguards broader elements such as rivers, small woodlands and species-rich grasslands. The LAP functions as a core component of the County Development Plan: its principal tasks include conducting habitat inventories and county-level biodiversity assessments to identify habitats, species and sites of local significance, and this information is used to delineate sensitive areas. As a statutory planning instrument, the LAP integrates biodiversity considerations into the overall framework for land-development assessment and decision-making [34].

In high-density Singapore, LAP practice emphasizes the transition from a "Garden City" concept towards a "City in a Garden," articulated under the goal of being "A Haven for Biodiversity." The approach treats biodiversity as a national natural heritage, adopts integrated approaches to nature conservation, and seeks to build an ecological spatial network that fosters harmonious coexistence between people and nature; biodiversity and ecosystem considerations are embedded in national planning processes [35].

During the implementation period of China's previous *National Biodiversity Conservation Strategy and Action Plan (2011–2030)*, eighteen provinces completed and published provincial Biodiversity Conservation Strategies and Action Plans. Cities such as Chengdu, Shenzhen and Jinan issued local biodiversity conservation strategies and action plans. Most of these local strategies and action plans are primarily text-based, although some include schematic maps for delineated biodiversity-priority areas. Typical plan contents include the delineation of protected areas, the identification of priority conservation fields and actions, and the specification of future investment projects and lead implementing agencies. Plan chapters generally cover the current status of biodiversity; achievements, problems and challenges in conservation work; biodiversity conservation strategies; biodiversity-priority areas; priority fields and actions; safeguarding measures; and priority conservation projects, with some plans appending figures or tables.

2.2.2 Biodiversity conservation planning

In earlier years, specialist biodiversity conservation planning at the urban scale was often undertaken in response to urban development needs—particularly to fulfil requirements for National (Ecological) Garden City applications—and was principally incorporated into green-space system planning during the master-plan stage, following the provisions set out in the *Outline for Green Space System Planning (Trial).* Many such biodiversity provisions did not exist as standalone plans but instead appeared as dedicated chapters within green-space plans; these chapters tended to emphasize plant resources and gave comparatively less attention to urban wildlife. Correspondingly, indicator systems commonly focused on plant-oriented metrics, such as the "Native Plant Index," reflecting a plant-centered habitat system [36]. For example, the *Chengdu City Plant Diversity Conservation Plan* prepared and published by the Chengdu Gardening and Landscaping Bureau in 2001 was produced to satisfy National Garden City application requirements. Other cities—including Shijiazhuang, Kunming, Haimen, Wuzhou, Fuzhou, Huangshan, Anshun and Lishui—have prepared urban biodiversity conservation planning at the master-planning level. In recent years, dedicated biodiversity conservation plans have increasingly been prepared by, or jointly prepared among, ecological-environment, forestry, parks/landscaping, and natural-resources and planning departments. These newer plans typically cover a broader scope and contain more substantive content, thereby offering better guidance for urban biodiversity conservation practice. Representative recent examples include the *Shenzhen Biodiversity Conservation Plan (2015–2030), the Huizhou Biodiversity Conservation Plan (2021–2030), and the draft Shenzhen Wildlife Protection Plan (2024–2035)*, which is currently undergoing public consultation.

2.3 Summary of research and practice

China currently lacks nationally established standards and guidelines for urban biodiversity conservation planning. Consequently, local authorities often do not have a uniform set of guidance documents to follow when preparing plans, which leads to inconsistency in plan content and variation in planning standards across regions. Some local biodiversity conservation plans remain narrowly focused—primarily on green-space development and ecological restoration—and give insufficient consideration to the comprehensive protection and management of urban biodiversity. These plans frequently fail to address the full spectrum of urban ecosystems and biological communities. **From a methodological perspective, a preliminary workflow has formed that is based on the selection of focal species, the identification of habitat patches, and the construction of habitat networks** [37–38]**. By conducting habitat-suitability assessments and constructing resistance surfaces to calculate ecological connectivity, practitioners identify priority conservation patches and ecological corridors. These results provide scientific evidence for delineating Ecological Protection Redlines and key ecological-security areas, for prioritizing protected-area designation and management, and for building biodiversity-protection spatial networks within an Ecological Security Pattern framework** [39–40]**. Nevertheless, research on the behavioral traits and spatial requirements of priority protected species remains insufficient.**

At the same time, the lack of concrete implementation guidance and operational measures has made it difficult to translate plans into action. Urban biodiversity conservation involves multiple departments and sectors, yet effective cross-departmental coordination mechanisms are currently lacking; poor inter-departmental information exchange and limited resource sharing constrain the practical implementation of plans.

3 Guiding Concepts and Framework (Methodology)

3.1 Objectives and positioning of urban biodiversity conservation planning

3.1.1 Objectives of biodiversity conservation planning

As a specialized plan, biodiversity conservation planning should implement the requirements set out in regional and local *Biodiversity Conservation Strategies and Action Plans* (and in other relevant policy instruments). The plan should define territory-wide conservation spatial requirements — including spatial zoning, regulatory controls, and priority habitat restoration — establish the spatial configuration for biodiversity conservation, set avoidance requirements for major infrastructure development, and guide the preparation of related specialized plans (for example, ecological-restoration plans and ecological-space plans).

3.1.2 Positioning of biodiversity conservation planning within the planning system

Biodiversity conservation planning should align with the linkage and coordination requirements of the five-level, three-category Territorial Spatial Planning (TSP) system. Vertically, the plan must ensure strategic alignment with national and provincial strategies and strengthen measures to translate those strategies into municipal-level implementation, thereby forming a coherent vertical pathway from national strategy through provincial zoning to municipal execution. Horizontally, the plan must secure strategic integration and spatial control of biodiversity within the comprehensive (master) urban spatial plan and detailed plans, promote the incorporation of biodiversity assessment into the municipal "Double Evaluation" process, and enhance coordination with other specialized plans related to natural-resource protection and use (see Figure 3-1).

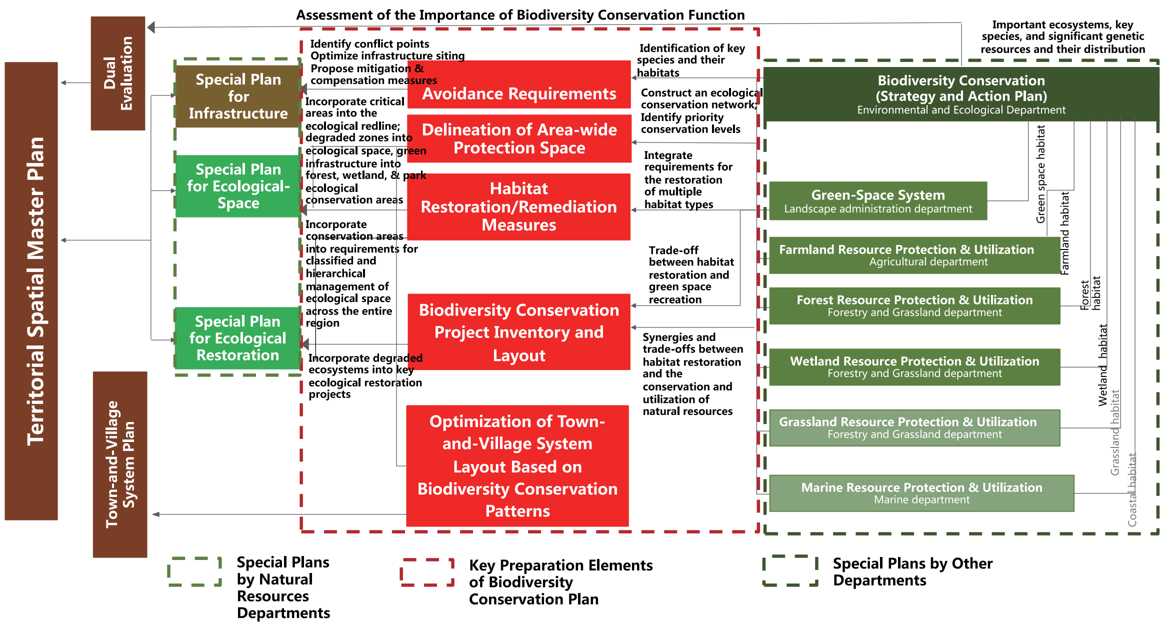

Figure 3-1: Key Preparation Elements of Specialized Biodiversity Conservation Plans and Their Linkages with Other Planning Instruments
Source: author's illustration

3.2 Technical methodology for urban biodiversity conservation planning

3.2.1 Analysis of biodiversity resources and conservation status

(1) Ecological-location analysis

Ecological-location analysis is conducted by compiling and reviewing materials that reflect the regional importance of biodiversity conservation, including but not limited to Conservation International's Global Biodiversity Hotspots, global migratory-bird flyway maps, the *National Ecological Function Zoning*, the *Scope* *of China's Priority Areas for Biodiversity Conservation*, the *National Biodiversity Conservation Strategy and Action Plan*, the *Overall Planning for Major Projects on National Important Ecosystem Protection and Restoration (2021–2035)*, and other higher-level territorial spatial planning and biodiversity policy documents. Based on these sources, the analysis inventories important ecological-protection spaces (such as nature reserves and natural-heritage sites), identifies major regional ecosystems and the distribution ranges of key species within and around the planning area, and clarifies the city/county's ecological-location characteristics and its significance in national and regional biodiversity conservation.

(2) Biodiversity resources survey

1) Compilation of existing biodiversity data

Existing biodiversity datasets and documentary records are assembled from multiple institutions and sources, including local ecology and environment bureaus, natural-resources authorities, forestry and greening departments, universities and research institutes, NGOs, and citizen-science initiatives. Relevant materials include monitoring and survey reports, species checklists, field guides and atlases, journal articles and theses, news reports, and database records from specialist repositories (for example, bird-recording databases). For planning areas that contain national- or provincial-level nature reserves, natural-heritage sites or forest parks, priority retrieval of scientific-survey and monitoring reports is recommended; for localities that have applied for National Garden City or Forest City status, application dossiers held by greening and forestry authorities should be consulted to obtain supplementary biodiversity information.

2) Field surveys of biodiversity

Subject to available time and funding, supplementary field surveys of species diversity should be conducted within the larger ecological patches in the city/county. Survey methods and technical standards should follow the relevant taxon-specific volumes of the industry standard *Technical Guidelines for Biodiversity Observation*.

3) Analysis of biodiversity resources

The current status of biodiversity resources within the planning area is analyzed at three hierarchical levels—species diversity, ecosystem diversity, and genetic diversity—on the basis of compiled documentary data and field-survey results. At the species-diversity level, plant- and animal-diversity resources should be assessed by quantifying indicators such as the number of plant species, the number and composition of key protected wild plants (including nationally protected species listed at first and second levels), and the number and composition of medicinal and ornamental plant species. For fauna, the total number of animal species, the composition of principal taxonomic groups, and the number and composition of endangered and protected species should be documented (referring to national first- and second-level protected animals, species listed on the *IUCN Red List of Threatened Species*, and species included in the CITES Appendices — using Chinese translations of these lists where appropriate). Species that hold particular local significance should be identified. Using available geospatial occurrence records, distribution maps should be produced for the major taxonomic groups.

At the ecosystem-diversity level, the distribution patterns of vegetation types across the principal ecosystem categories present in the planning area (for example, forest, wetland, farmland and grassland) should be characterized. At the genetic-diversity level, the quantity, composition and spatial distribution characteristics of principal germplasm and genetic-resource holdings within the planning area should be assessed.

(3) Analysis of current biodiversity conservation efforts and status

The planning area's natural-resource strengths and conservation value should be evaluated in light of its biodiversity characteristics. Local government documents (such as local Biodiversity Conservation Strategies and Action Plans and local implementation schemes) should be reviewed, and these documentary sources should be combined with interviews of relevant administrative departments (including ecology and environment, forestry and grassland, natural resources, and agriculture and rural affairs). On this basis, the protected-area network, the conservation status of key protected species, and the development of eco-tourism and nature-education initiatives should be analyzed to clarify the conservation foundations and principal challenges. Finally, conflicts between conservation and development should be assessed by analyzing the extent to which urban and rural development and construction activities disturb biodiversity.

3.2.2 Spatial framework for biodiversity conservation

(1) Selection of target conservation species

The selection of conservation targets is the primary step in protection planning. Conservation targets are the biodiversity elements that require protection; because resources are limited, it is not feasible to design separate conservation interventions for every element, so a representative subset of biodiversity must be selected. The commonly adopted strategy is the coarse–filter / fine–filter approach: the coarse filter selects representative ecosystems within the region as conservation targets, thereby protecting most species associated with those habitats; the fine filter then identifies important species that may be missed by the coarse filter—typically rare, threatened and endemic species [41].

Within biodiversity-priority areas, conservation targets should be screened according to species protection status (for example, national first- and second-level protected species, species listed on the IUCN Red List, and species included in the CITES Appendices) and by special attributes (for example, national or endemic status; ecological role such as umbrella species; and social influence or recognition such as flagship species). Outside priority areas, indicator taxa (for example, bird species) can be used, with emphasis on threatened or legally protected species.

(2) Habitat identification and classification

Habitat identification and classification constitute fundamental preparatory work for biodiversity conservation, enabling a deeper understanding of species' habitat requirements and adaptive strategies and providing a scientific basis for designing conservation measures. Habitat classification should reference the land-use categories adopted by territorial natural-resource authorities to ensure compatibility with Territorial Spatial Planning, since land-use classes partly reflect habitat elements. Dividing the complex natural environment into distinct habitat types (for example, forest, grassland, wetland, and marine) facilitates the development of targeted conservation interventions, such as establishing nature reserves in key habitats or implementing site-appropriate ecological restoration.

This study adopts the principles and methods of the "Green Map" concept for habitat identification and implements a selective habitat-mapping method [42]. Habitat units are delineated primarily according to habitat spaces suitable for target species, with the unit level and type determined by the mapping extent and spatial scale. Referring to the *Technical Guidelines for Biodiversity Observation and the Classification and Coding Table for the Third National Land Survey, and based on the habitat characteristics and spatial scale of the study area, ten first-level habitat units are defined according to land-use and avian habitat requirements:* **forest, grassland, bare land, water bodies, wetlands, marine areas, farmland, gardens/orchards, urban and rural green space, and built-up land.** Secondary-level units subdivide first-level categories according to habitat horizontal-structure characteristics; because secondary classification applies at detailed-control-plan (DCP) scale, this study implements first-level classification only. **First-level classes are derived by interpreting high-resolution remote-sensing imagery and are then adjusted and refined using current land-use maps, resource-survey datasets and other spatial data.** Habitat mapping is implemented on the ArcGIS platform.

(3) Calculation of anthropogenic disturbance index

Human activities are a central factor affecting species and their habitats. Anthropogenic disturbances may be classified as direct disturbances—activities that directly alter habitat extent or composition (for example, conversion of natural wetlands to farmland or of farmland to industrial land)—and indirect disturbances—secondary impacts on habitat quality arising from human activities, such as noise, air emissions, and wastewater. The ecological effects of these disturbances depend on both their intensity and spatial distribution [43]. Fragmentation produced by development of given area and intensity can increase edge effects and reduce habitat quality more severely than equivalent development concentrated at the periphery [44].

Anthropogenic disturbance originates primarily from three sources: (a) human production and residential activities; (b) pollution of environmental media (for example, water, air and soil contamination and noise); and (c) land-cover change. To represent these pressures at the habitat-patch scale, the following indicators are proposed: population density; distance to roads; distance to built-up (construction) land; and the impervious-surface ratio of habitat patches. Patch susceptibility to edge effects is evaluated using geometric metrics. Accordingly, a set of disturbance sub-indices is constructed: **population disturbance, traffic disturbance, topological disturbance, geometric (shape) disturbance, and land-cover disturbance.** Sub-index computation is based on patch attributes and anthropogenic-pressure distributions: **population disturbance is derived from population-density data; traffic disturbance and topological disturbance are calculated from straight-line distances between habitat patches and roads or built-up land; geometric disturbance is quantified using patch area and shape metrics (for example, shape index); and land-cover disturbance is estimated as the proportion of impervious surface (the fraction of patch area not covered by tree canopy or vegetation). Influence ranges and thresholds for each sub-index are determined through literature review and expert consultation. The sub-indices are normalized and integrated to produce a composite Species Disturbance Index, which, when combined with habitat-suitability information,** indicates patch quality for focal species.

(4) Construction of the habitat protection network

Building on the "Source–Corridor–Node" structure of the

Ecological Security Pattern, the study establishes a "Source–Buffer–Corridor" paradigm for habitat-protection networks in urbanizing landscapes. Using available species-distribution data, the function and conservation importance of habitat patches across the study area are assessed to identify Source (core) habitats, Buffer zones, and Corridors that are critical for maintaining animal diversity; these identifications form the basis for targeted conservation management recommendations. **A Source habitat is defined as a patch of primary conservation significance. A Buffer zone is an adjacent ecological area that either currently provides relatively favorable habitat conditions or possesses restoration potential sufficient to become high-quality habitat. A Corridor is a spatial linkage that can provide the necessary habitat conditions to support movement and migration of focal species between Source patches.** Buffers and Corridors connect dispersed Sources into an integrated habitat network, providing space for population dispersal and migration and thereby supporting the long-term viability of wildlife populations in urban contexts. Although habitat patches within Buffers and Corridors are generally inferior to Source patches with respect to habitat elements, levels of anthropogenic disturbance and species suitability, they typically satisfy one or more basic resource or shelter requirements and thus act as stepping stones or stopover sites during movement.

For each focal species, a survival-suitability threshold is defined as the difference between the species' probability of occupancy and its Species Disturbance Index (a value scaled to the 0–1 range, where values near 0 indicate effectively no possibility of occupancy and values near 1 indicate potential suitability). This threshold is used as the index for assessing habitat suitability. **The Habitat Suitability Index (based on the threshold) is applied** to quantify the suitability of habitat patches and to identify combinations of Source habitats that are both of high conservation value and practicable to manage. **A resistance surface is constructed by mapping the target species' Species Disturbance Index across the landscape. Buffer zones are identified from that resistance surface as areas outside Source habitats that exhibit relative suitability and connectivity potential. The Minimum Cumulative Resistance (MCR) model [45-46] is then applied to analyze movement resistance between Source habitats and to delineate Corridors, with particular attention to (a) unique or limited passageways between two key Sources and (b) corridors that link multiple dispersed Sources.**

3.2.3 Recommendations for implementing biodiversity conservation planning

(1) Recommendations for optimizing the ecological spatial pattern

Core biodiversity conservation patches should be delineated based on the modeled spatial distributions of focal species and by integrating anthropogenic-disturbance factors. A regional protection network should then be proposed to strengthen ecosystem stability and resilience through a scientifically informed spatial layout. Protected-area boundaries and extents should be adjusted and optimized according to the identification of important habitats. A zonal (ring-based) protection strategy should be adopted for core conservation areas and their ecological buffers. Within the urban matrix, conservation sub-zones should be delineated and additional green spaces provided to mitigate the pressures of urban development on biodiversity.

(2) Recommendations for enhancing ecological restoration efforts

A comprehensive ecological-restoration project inventory should be established that is linked to the optimized ecological spatial pattern and to on-the-ground conditions. Differentiated restoration strategies should be proposed that correspond to the specific degradation conditions of different areas. Restoration and management measures should be planned across project phases (pre-project, implementation and post-implementation) to accommodate temporal dynamics. An ecological-restoration monitoring system, adapted to available technologies and local conditions, should be established. Public-engagement and outreach strategies should be developed to encourage community participation and to enhance environmental awareness and stewardship.

(3) Recommendations for additional indicators in performance (health) assessment

Additional indicators should be proposed for multi-dimensional ecological health and performance assessment. Suggested indicator categories include: biodiversity status, focal/indicator species metrics, ecosystem-service provision, extent and impact of invasive alien species, ecological-spatial pattern metrics, intensity of anthropogenic disturbance, and effectiveness of social outreach. These indicators should generate dynamic data to support policy and management decisions and enable fine-grained, near-real-time management responses to emerging challenges under climate change.

(4) Recommendations for synergistic enhancement under climate change

In view of climate-change impacts, the plan should propose a series of biodiversity-conservation measures that deliver co-benefits for climate-change adaptation and mitigation.

4 Case Study: Xiamen Biodiversity Conservation Planning

4.1 Analysis of Xiamen's biodiversity resources and conservation status

4.1.1 Ecological-location analysis

Xiamen is located on China's southeast coast at the mouth of the Jiulong River and has a South subtropical maritime monsoon climate. The terrain generally slopes from northwest to southeast, while Xiamen Island slopes from south to north. The city's landscape is characterized by mountains to the rear and the sea to the front, a diversity of landforms, an extensive maritime area and a long, indented coastline with varied coastal types; these natural conditions are favorable. **Xiamen occupies an important regional ecological location and performs significant ecological functions: it serves as an important international "stopover" and wintering area for migratory waterbirds and is an important habitat for the small population of the Chinese white dolphin.**

At the regional scale, Xiamen adjoins the Zhangjiangkou Mangrove — an internationally important wetland in Fujian Province (see Figure 4-1). It lies between Quanzhou Bay and Dongshan Bay, areas recognized as China's Marine Key Biodiversity Area (see Figure 4-2), and it borders terrestrial priority conservation areas such as the Wuyi Mountains and the Nanling region. The eastern coastal zone of Xiamen (including the whole of Xiamen Island) falls within the Priority Areas for Marine Biodiversity Conservation for the East China Sea and the Taiwan Strait (see Figure 4-3); rare and threatened species are concentrated in these areas, which therefore possess substantial ecological functions and high conservation value.

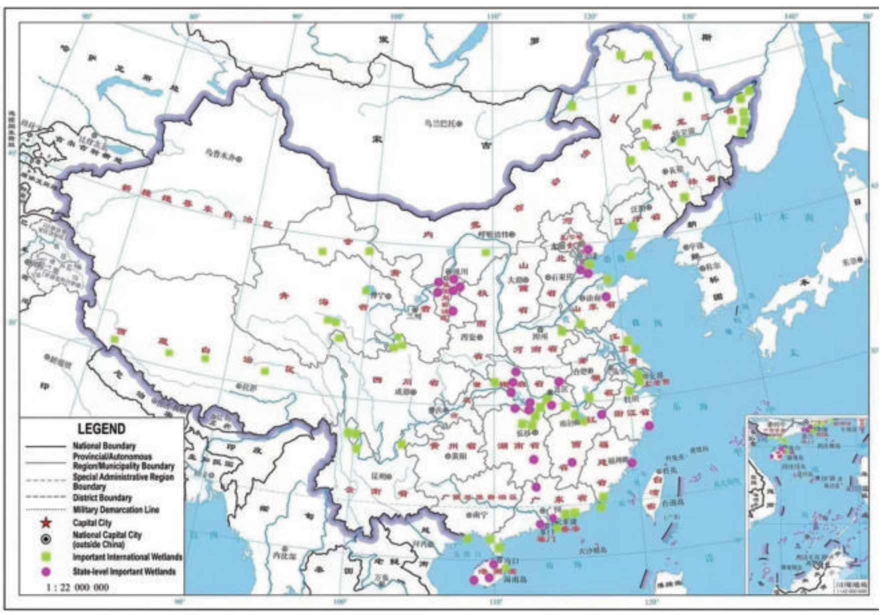

Figure 4-1: Schematic Diagram of the Distribution of China's Wetlands of International and National Importance
Source: National Wetland Protection Plan (2022–2030). State Forestry and Grassland Administration. 2022

Figure 4-2: Distribution Map of China's Marine Key Biodiversity Areas
Source: Report on the Identification of China's Marine Key Biodiversity Areas. SEE Marine Conservation. 2023

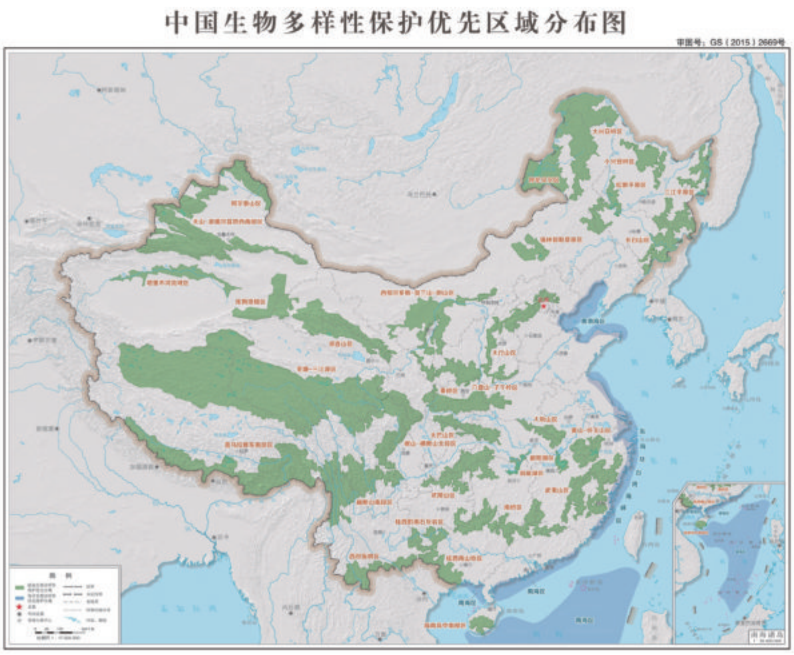

Figure 4-3: Scope of China's Priority Areas for Biodiversity Conservation
Source: China's Priority Areas for Biodiversity Conservation. Ministry of Environmental Protection, 2015

Xiamen lies on a major global migratory-bird flyway and functions as an important coastal stopover and habitat for numerous bird species (Figures 4-4 and 4-5). Although Xiamen has not been formally designated as a Key Bird Area at the national level, it faces the Important Bird Area of the Kinmen National Park across the sea (Figure 4-6), and regular bird movements occur between the two areas. The city is located on a national migratory-bird flyway and serves as a breeding ground for the Blue-tailed Bee-eater (*Merops philippinus),* a national second-class protected bird and summer migrant; a municipal nature reserve and monitoring stations for this species have been established within the high-density urban area (Figure 4-7).

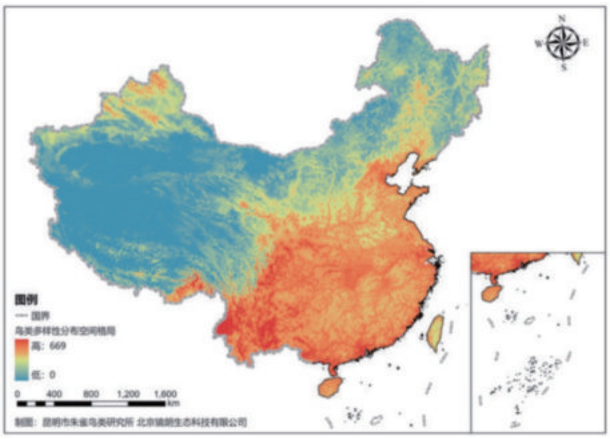

Figure 4-4: Spatial Pattern of Avian Diversity Distribution in China
Source: China Bird Observation Annual Report 2022. China Bird Watching Joint Action Platform. 2023

Figure 4-5: Schematic Diagram of China's Migratory Bird Flyways
Source: China Action Plan for the Protection and Restoration of Migratory Bird Flyways (2024-2030). National Development and Reform Commission. 2024

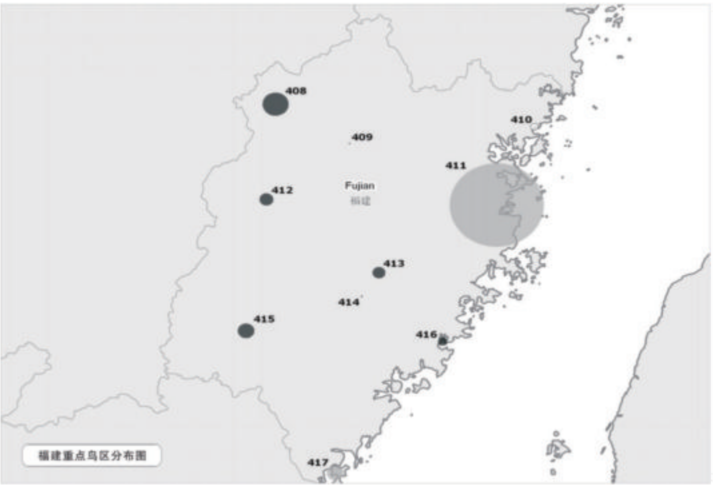

Figure 4-6: Distribution Map of Key Bird Areas in Fujian Province
Source: Directory of Important Bird Areas in China (Mainland). BirdLife International. 2009

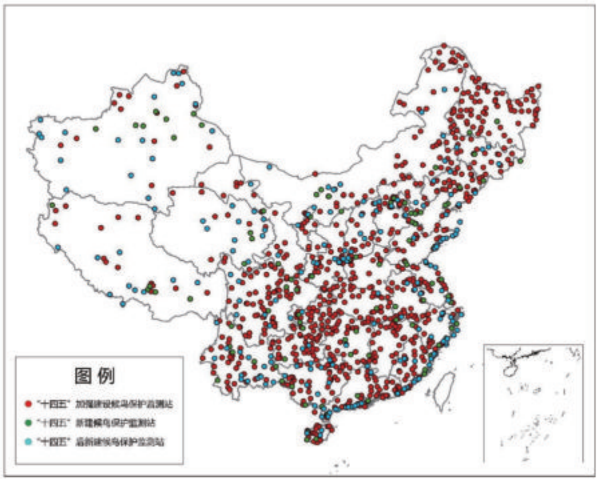

Figure 4-7: Layout Map of National Migratory Bird Conservation and Monitoring Stations
Source: National Action Plan for the Protection of Migratory Bird Flyways (2021–2035). National Forestry and Grassland Administration. 2022

Xiamen's coastal waters are among the key habitats for the Indo-Pacific humpback dolphin, commonly referred to in China as the Chinese white dolphin. The Chinese white dolphin (*Sousa chinensis)* is designated as a National First-Class Key Protected Aquatic Mammal and was listed as Vulnerable on the IUCN Red List of Threatened Species in 2018. Commonly known as the "panda of the sea," it has very stringent water-quality requirements and serves as both a flagship species and an indicator species of nearshore marine ecosystems. According to the literature [47], approximately 83% (4,730 individuals) of the global population of Chinese white dolphins inhabit China's southeastern coast, and China currently hosts at least nine geographic populations of the species (see Figure 4-8). Xiamen's coastal waters are one of the important habitats for the Chinese white dolphin in China, and research on Chinese white dolphins in Chinese waters was first conducted by the Fujian Fisheries Research Institute at Xiamen Port. Xiamen has established the Xiamen Nature Reserve for Rare Marine Species and implements protection measures for the Chinese white dolphin; the population in the Xiamen area was estimated at about 72 individuals as of 2018, and Chinese white dolphins are observed there year-round (see Figure 4-9).

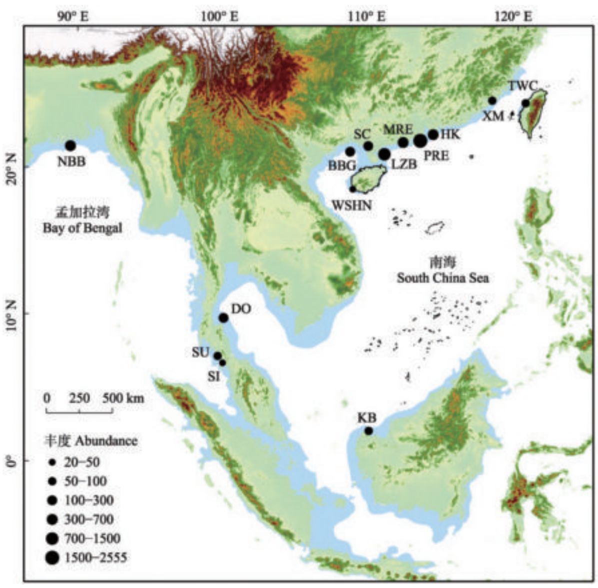

Figure 4-8: Distribution and Population of Major Geographical Populations of the Chinese White Dolphin Worldwide
Source: Biodiversity Science, 31(5): 145–160

Figure 4-9: Multiple Chinese white dolphins sighted near Gulangyu Island, Xiamen
Source: "Chinese White Dolphins 'Patrol' Xiamen's Gulangyu Island." People's Daily Online. 2023

Xiamen possesses a rich local biodiversity culture. Locally, Xiamen Island is nicknamed "Egret Island" (Lù Dǎo) and "Egret River" (Lù Jiāng); two traditional explanations exist for the name "Egret Island" [48]: one attributes the name to the island's planform resemblance to a bird with outstretched wings, and the other traces the name to an ancient legend of egrets settling on the island (Figures 4-10 and 4-11). The city's historical association with egrets is long established: following a public vote, the Egret was formally designated as the city bird by the Standing Committee of the Eighth Xiamen Municipal People's Congress in October 1986. According to the *Xiamen Bird Checklist (2023),* Xiamen hosts 18 of the 26 Ardeidae (egret and heron) species recorded in China, indicating substantial local diversity in this group. The city's "Egret" identity is visible across place names and public art (for example, Bailuzhou Park and the Egret Goddess sculpture) (Figure 4-12).

Xiamen has cultivated a strong urban bird-appreciation culture, and an increasing number of residents actively support and protect local birdlife (Figure 4-13). In an interview with the research team, President Peng of the Xiamen Bird Watching Society noted that the Society—established in March 2002 as the first social organization in China dedicated to birdwatching and habitat conservation—has, over two decades, conducted extensive bird surveys, public outreach and habitat-protection activities, and has contributed to the establishment of local conservation sites such as the Wuyuan Bay Wetland Park, the Xiamen Blue-tailed Bee-eater Reserve, and the Xiamen Purple Swamphen Conservation Base.

Figure 4-10: Xiamen Island's planform resembles a flying egret
Source: Map of Fujian Coastal Defense (partial). Qing dynasty, Qianlong period

鷺江名勝詩鈔
海澄江 煦編
鷺江
同安縣志廈門一名鷺江
讀史方輿紀要廈門作夏門一名鷺嶼
薛起鳳撰鷺江志 煦按據廈門父老傳嘗廈門未開闢時有白鷺甚多棲止江上故有鷺孔之名廈門志云廈門亦號爲桃源明紀石青題詩云花源今可得此亦一桃源又有句云玄髮青衫漢代口桃花流水豈秦人 廈門自宋時名爲嘉禾嶼屬泉州府同安縣以產嘉禾得名 鷺江志宋太平興國時產嘉禾一莖數穗故名 明江夏侯周德興城廈門 是廈門二字之始見 爲中左所 洪武元年定自京師至郡縣皆立衛指揮使領左右中前後五千戶所隸福建都指揮司二十年江夏侯周德興經略福建抽

Figure 4-11: The name "Egret River" deriving from the egret
Source: Anthology of Scenic Poetry of Egret River

Figure 4-12: Egret Goddess Sculpture
Source: Internet
(Xiamen Bailuzhou Park)

Figure 4-13: Xiamen Bird-Loving Week Activities
Source: "Experiencing the True Meaning of Harmonious Coexistence Between Humans and Birds." Jimei Daily. 2024

4.1.2 Analysis of biodiversity resources

(1) Plant diversity

Xiamen lies within the Fujian–Guangdong coastal vegetation region. The zonal vegetation is dominated by South subtropical monsoon evergreen broad-leaved forest, and coastal plant assemblages are also present. Xiamen's warm temperatures, ample heat accumulation and long growing season provide favorable overwintering conditions, making the area highly suitable for plant growth, reproduction, and for the introduction and acclimatization of species. According to the 2024 urban biodiversity baseline survey conducted by the Xiamen Natural Resources and Planning Bureau, **the city's vegetation includes 7 vegetation groups, 14 vegetation types, 19 vegetation subtypes, 54 alliances (associations) and 99 plant communities.** The city's vascular-plant resources comprise 190 families, 776 genera and 1,442 taxa (including subspecies, varieties and cultivars): lycopods and ferns number 117 species (24 families, 51 genera); gymnosperms total 18 species (7 families, 13 genera); and angiosperms comprise 1,307 species (159 families, 712 genera). **Eleven wild plant species have been identified as priorities for protection.** Ten of these are listed as national second-class key protected wild plants: Fujian Mules-foot Fern (*Angiopteris fokiensis* Hieron.), Lamb of Tartary (*Cibotium barometz* (L.) J. Sm.), Cyathea (*Alsophila spinulosa* (Hook.) Tryon), Black Tree fern (*Gymnosphaera podophylla* (Hook.) Copel.), Fujian Cypress (*Fokienia hodginsii* (Dunn) A. Henry & Thomas), Ormosia henryi (*Ormosia henryi* Prain), wild soybean (*Ormosia xylocarpa* Chun ex H. Y. Chen), woolly glycine (*Glycine tomentella* Hayata), riverweed (*Cladopus nymanii*), and kumquat (*Citrus japonica*). One species, Lim's Crape Myrtle (*Lagerstroemia limii Merr.*), is listed as a Fujian Provincial Key Protected Wild Plant. In addition, mangrove species such as Water-pencil Mangrove (*Kandelia obovata* Sheue, Liu & Yong), Large-leafed Mangrove *(Bruguiera gymnorhiza* (L.) Lam.), Grey Mangrove *(Avicennia marina* (Forssk.) Vierh.), and River Mangrove *(Aegiceras corniculatum* (L.) Blanco) form mangrove ecosystems that play an important role in maintaining local coastal biodiversity and in ensuring coastal ecological security [49].

(2) Animal diversity

Xiamen supports relatively rich animal diversity, with aquatic fauna being particularly diverse compared with terrestrial fauna. Long-term human activities have severely reduced the city's original forest cover and substantially altered plant communities and associated terrestrial animal assemblages. Coupled with the insular nature of Xiamen Island, these factors have resulted in comparatively greater richness of aquatic taxa than terrestrial taxa. According to biodiversity surveys, Xiamen hosts: **448 bird species (21 orders, 79 families); 12 terrestrial wild mammal species (5 orders, 8 families); 300 fish species (4 classes, 36 orders, 81 families); 21 amphibian species (2 orders, 7 families); and 28 reptile species (2 orders, 11 families).** (Data sources: birds — *Xiamen Bird Checklist (2023),* Xiamen Bird Watching Society; terrestrial mammals — Xiamen Natural Resources and Planning Bureau, 2024; other taxa — *Xiamen Urban Biodiversity Conservation Planning Report,* 2013.)

Xiamen is home to a number of rare and protected species. National First-Class protected species recorded in the area include the Chinese white dolphin (*Sousa chinensis*), the Chinese pangolin (*Manis pentadactyla*), the small Indian civet (*Viverricula indica*), and the Chinese egret (*Egretta eulophotes*). National Second-Class protected species include the Burmese python (also called the Asiatic rock python, *Python molurus bivittatus*), the lancelet (*Branchiostoma belcheri*), the leopard cat (*Prionailurus bengalensis*), and the Blue-tailed Bee-eater (*Merops philippinus*). The region also supports Fujian Provincial Key Protected Species such as the greater pipefish (*Syngnathus acus*), the heptagon pipefish (*Syngnathus heptagonus*), the spotted (three-spot) seahorse (*Hippocampus trimaculatus*), the spiny seahorse (*Hippocampus histrix*), Kellogg's seahorse (*Hippocampus kelloggi*), the Japanese (Mohnike's) seahorse (*Hippocampus mohnikei*), ayu (sweetfish, *Plecoglossus altivelis*), the dark-spotted frog (*Pelophylax nigromaculatus*), the yellow-bellied weasel (*Mustela kathiah*), and the Siberian weasel (*Mustela sibirica*) (Data sources: birds — Xiamen Bird Checklist (2023), Xiamen Bird Watching Society; terrestrial mammals — Xiamen Natural Resources and Planning Bureau, 2024; other taxa — Xiamen Urban Biodiversity Conservation Planning Report, 2013) (see Table 4-1). Current observations indicate a declining trend in populations of some nationally protected species in Xiamen—most notably the Chinese white dolphin—largely attributable to human development activities; these taxa therefore face substantial conservation pressure.

Table 4-1: Key Protected Wild Fauna in Xiamen

Taxonomic Group	Name in English	Latin Name	Protection Class
Mammals	Chinese White Dolphin	Sousa chirrensis	I
	Chinese Pangolin	Manis pentadactyla	I
	Small Indian Civet	Viverricula indica	I
	Leopard Cat	Prionailurus bengalensis	II
	Common Dolphin*	Delphinus delphis	II
	Risso's Dolphin*	Grampus griseus	II
	Pacific White-Sided Dolphin*	Laenorhynchus obliquidens	II
	Common Bottlenose Dolphin*	Tursiops truncatus	II
	Indo-Pacific Bottlenose Dolphin*	Neophocaena phocaenoides	II
	False Killer Whale*	Pseudorca crassidens	II
Reptiles	Asiatic Rock Python	Python molurus bivittatus	II
	Big-headed Turtle*	Platysternon megacephalum	II
Amphibians	East Asian Bullfrog / Edible Frog*	Hoplobatrachus rugulosus	II
Fish	Chinese Sturgeon*	Acipenser sinensis	I
	Lancelet	Branchiostoma belcheri	II
	Giant Mottled Eel*	Anguilla marmorata	II

Source: Xiamen Natural Resources and Planning Bureau, 2024; Xiamen Urban Biodiversity Conservation Planning Report, Xiamen University & Xiamen Municipal Landscape and Forestry Bureau, 2013

Note: The 2024 baseline resource survey did not include targeted investigations of aquatic mammals, amphibians, or fish; entries marked with an asterisk (*) or otherwise noted are therefore drawn from the 2013 Municipal Landscape and Forestry Bureau report.

Xiamen supports a rich avifauna and hosts a substantial number of rare and conservation-relevant bird species. According to the *Xiamen Bird Checklist (2023)* compiled by the Xiamen Bird Watching Society, 448 wild bird species (21 orders, 79 families) were recorded in Xiamen as of December 2023, representing 29.77% of the 1,505 bird species listed for China (448/1,505). Compared with the 2022 checklist, ten species were newly recorded for the city in 2023. An analysis of submissions to the China Bird-watching Records Center (https://www.birdreport.cn/) for 2014–2023 identified 5,019 birdwatching reports (submissions) and 95,019 individual observation records, covering 422 species across 21 orders and 71 families. Observation hotspots—measured by the number of submissions per site—are concentrated in the city's southern coastal zone; Xiamen Island in particular exhibits a high density of reports (Figure 4-14). Recorded species in Xiamen fall into six avian ecological guilds. The species composition is dominated by passerines, followed by waders/shorebirds and waterbirds (Figure 4-15). Spatially, records of waders and waterbirds are concentrated in coastal and riparian habitats, while passerines, arboreal species, terrestrial ground-dwelling birds and raptors are recorded more broadly across urban green spaces, suburban woodlots and inland habitats (Figures 4-16 through 4-21).

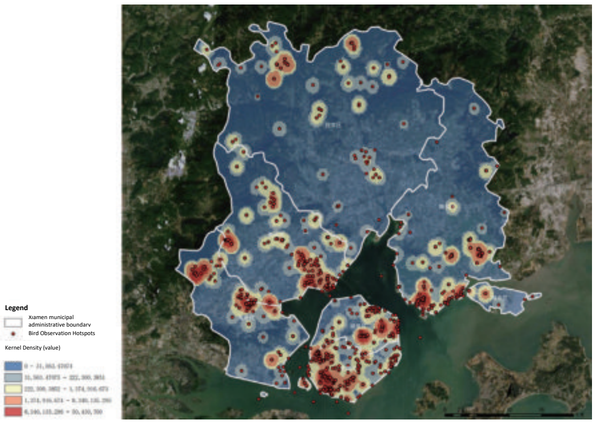

Figure 4-14: Distribution of Bird Observation Hotspots in Xiamen, 2014–2023 (by number of submissions)
Source: author's illustration

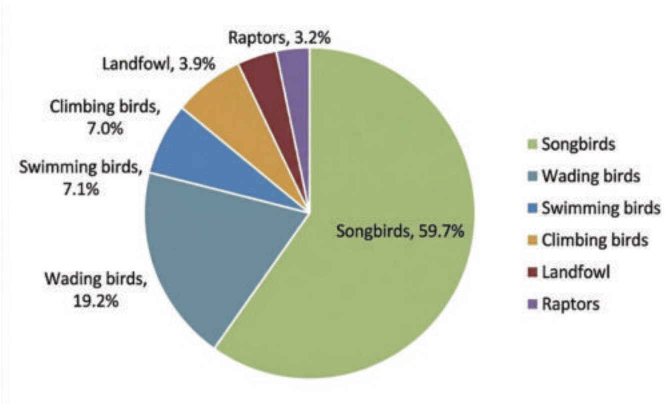

Figure 4-15: Proportion of Bird Observation Submissions by Avian Guild in Xiamen, 2014–2023 (by number of submissions)
Source: author's illustration

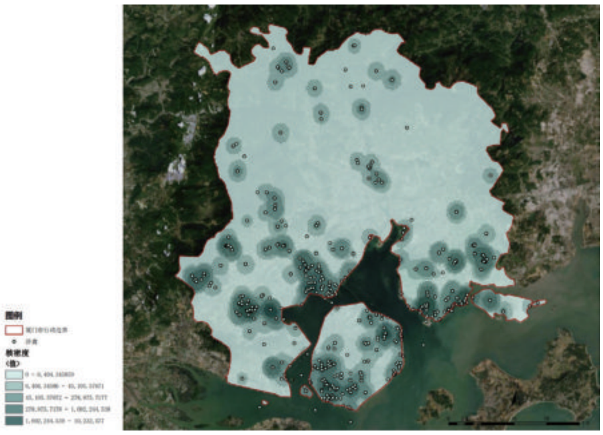

Figure 4-16: Distribution of Wader (Shorebird) Observation Hotspots in Xiamen, 2014–2023 (by number of submissions)
Source: author's illustration

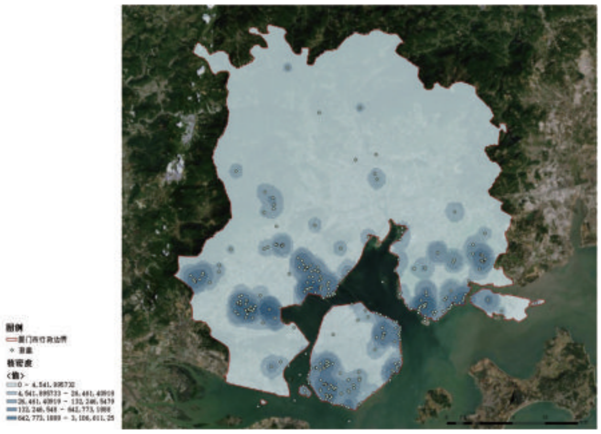

Figure 4-17: Distribution of Waterbird (Aquatic Bird) Observation Hotspots in Xiamen, 2014–2023 (by number of submissions)
Source: author's illustration

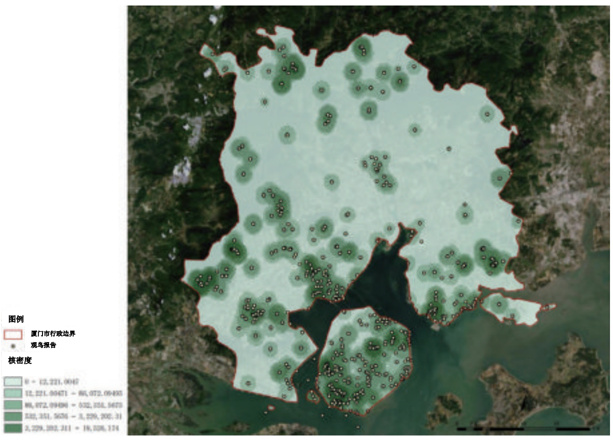

Figure 4-18: Distribution of Passerine (Songbird) Observation Hotspots in Xiamen, 2014–2023 (by number of submissions)
Source: author's illustration

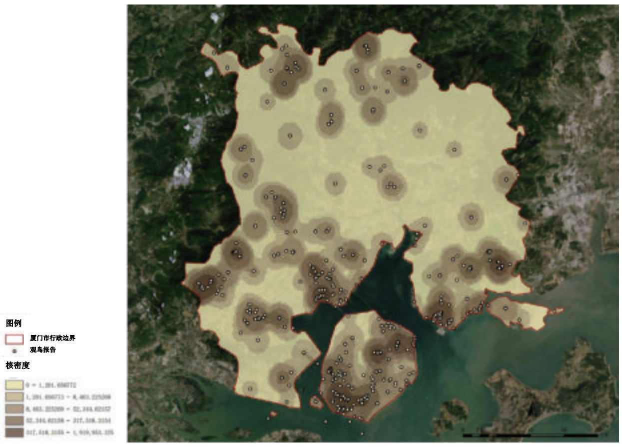

Figure 4-19: Distribution of Arboreal/Climbing Bird Observation Hotspots in Xiamen, 2014–2023 (by number of submissions)
Source: author's illustration

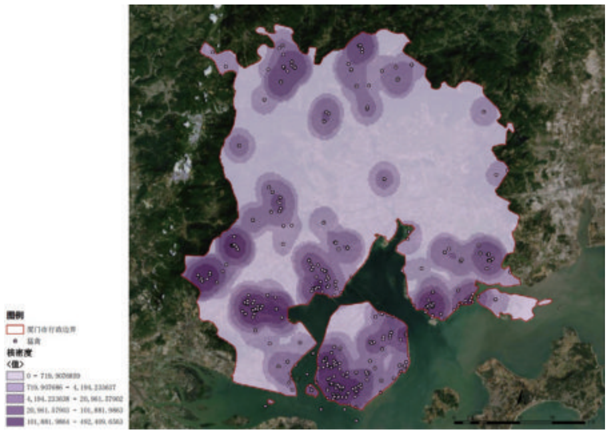

Figure 4-20: Distribution of Raptor Observation Hotspots in Xiamen, 2014–2023 (by number of submissions)
Source: author's illustration

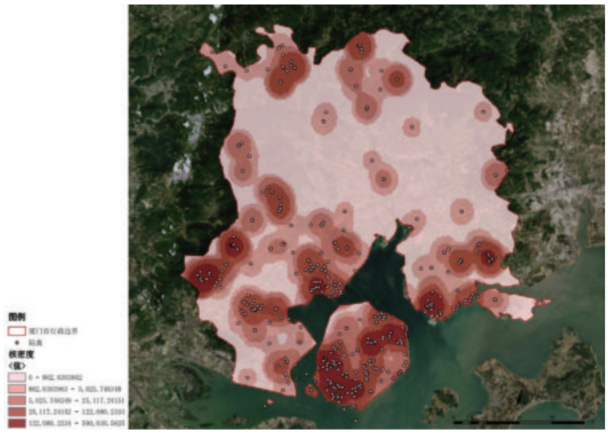

Figure 4-21: Distribution of Terrestrial Ground-Dwelling Bird Observation Hotspots in Xiamen, 2014–2023 (by number of submissions)
Source: author's illustration

Xiamen hosts a rich assemblage of rare avian species. According to the *Xiamen Bird Checklist (2023),* the city contains 13 national Class I protected bird species and 78 national Class II protected bird species (see Table 4-2). Data obtained from the China Bird-watching Records Center include observations of 10 of the nationally Class I species (589 observation records) and 70 of the nationally Class II species (7,694 observation records). The spatial distribution of these records closely corresponds to the city's overall bird-observation hotspots (Figure 4-22). Under the *IUCN Red List of Threatened Species*, Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) categories are regarded as threatened. According to the *Xiamen Bird Checklist (2023)*, Xiamen hosts 22 threatened bird species in total. Records for 17 of those threatened species are present in the China Bird-watching Records Center database; these are distributed across IUCN threat categories as follows: CR (Critically Endangered) — 2 species: Yellow-breasted Bunting (*Emberiza aureola*); Spoon-billed Sandpiper (*Eurynorhynchus pygmeus*) — total of 76 observation records; EN (Endangered) — 6 species: Siberian Sand Plover (*Anarhynchus mongolus*); Black-faced Spoonbill (*Platalea minor*); Oriental Stork (*Ciconia boyciana*); Great Knot (*Calidris tenuirostris*); Far Eastern Curlew (*Numenius madagascariensis*); Nordmann's Greenshank (*Tringa guttifer*) — total of 494 observation records; VU (Vulnerable) — 9 species: Collared Crow (*Corvus torquatus*); Chinese Egret (*Egretta eulophotes*); Saunders's Gull (*Chroicocephalus saundersi*); Sharp-tailed Sandpiper (*Calidris acuminata*); Rustic Bunting (*Emberiza rustica*); Relict Gull (*Ichthyaetus relictus*); Common Pochard (*Aythya ferina*); Black-capped Kingfisher (*Halcyon pileata*); White-gorgetted Jungle Flycatcher (*Rhinomyias brunneatus*) — total of 658 observation records. Observation reports for these threatened species are concentrated primarily in Xiamen's southern coastal zone (see Figure 4-23).

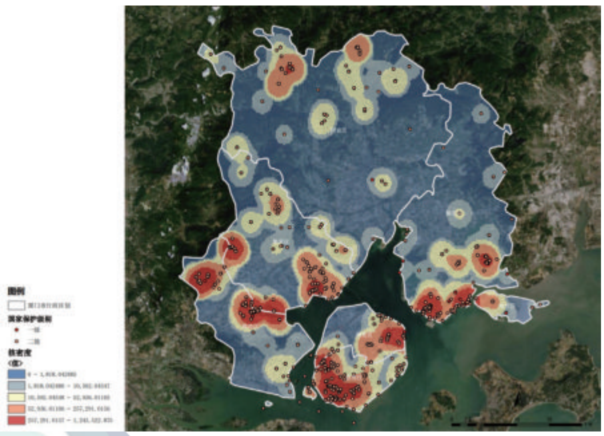

Figure 4-22: Distribution of Observation Hotspots for Nationally Protected Bird Species in Xiamen, 2014–2023 (by number of observation records)
Source: author's illustration

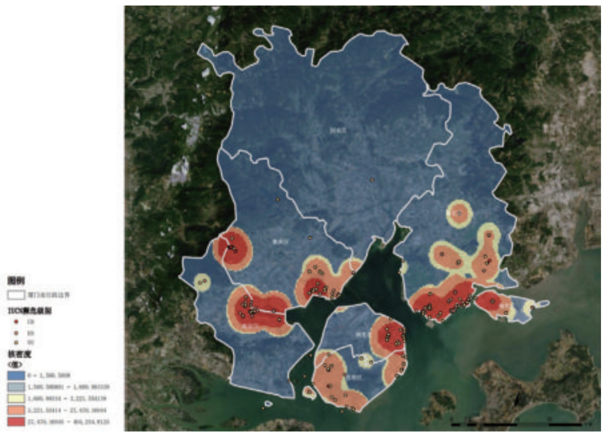

Figure 4-23: Distribution of Observation Hotspots for Threatened Bird Species in Xiamen, 2014–2023 (by number of observation records)
Source: author's illustration

Table 4-2: Key Protected Avifauna in Xiamen

Name in English	Latin Name	Protection Class
Black Stork	Ciconia nigra	I
Oriental Stork	Ciconia boyciana	I
Black-faced Spoonbill	Platalea minor	I
Chinese Egret	Egretta eulophotes	I
Cinereous Vulture	Aegypius monachus	I
Nordmann's Greenshank	Tringa guttifer	I
Eastern Imperial Eagle	Aquila heliaca	I
White-bellied Sea Eagle	Haliaeetus leucogaster	I
Spoon-billed Sandpiper	Eurynorhynchus pygmeus	I
Nordmann's Greenshank	Tringa guttifer	I
Saunders's Gull	Chroicocephalus saundersi	I
Relict Gull	Ichthyaetus relictus	I
Yellow-breasted Bunting	Emberiza aureola	I
Lesser Whistling Duck	Dendrocygna javanica	II
White-necklaced Partridge	Arborophila gingica	II
Swan Goose	Anser cygnoides	II
Silver Pheasant	Lophura nycthemera	II
Greater White-fronted Goose	Anser albifrons	II
Tundra Swan	Cygnus columbianus	II
Mandarin Duck	Aix galericulata	II
Cotton Pygmy-Goose	Nettapus coromandelianus	II
Baikal Teal	Sibirionetta formosa	II
Black-necked Grebe	Podiceps nigricollis	II
Eurasian Spoonbill	Platalea leucorodia	II
Japanese Night-Heron	Gorsachius goisagi	II
Malayan Night-Heron	Gorsachius melanolophus	II
Pacific Reef Heron	Egretta sacra	II
Lesser Frigatebird	Fregata ariel	II
Red-footed Booby	Sula sula	II
Osprey	Pandion haliaetus	II
Black-winged Kite	Elanus caeruleus	II
Crested Honey Buzzard	Pernis ptilorhynchus	II

Name in English	Latin Name	Protection Class
Black Baza	Aviceda leuphotes	II
Crested Serpent Eagle	Spilornis cheela	II
Mountain Hawk-Eagle	Nisaetus nipalensis	II
Black Eagle	Ictinaetus malaiensis	II
Bonelli's Eagle	Aquila fasciata	II
Crested Goshawk	Accipiter trivirgatus	II
Chinese Goshawk	Accipiter soloensis	II
Japanese Sparrowhawk	Accipiter gularis	II
Besra	Accipiter virgatus	II
Eurasian Sparrowhawk	Accipiter nisus	II
Northern Goshawk	Accipiter gentilis	II
Eastern Marsh Harrier	Circus spilonotus	II
Hen Harrier	Circus cyaneus	II
Pied Harrier	Circus melanoleucos	II
Black Kite	Milvus migrans	II
Grey-faced Buzzard	Butastur indicus	II
Eastern Buzzard	Buteo japonicus	II
Purple Swamphen	Porphyrio poliocephalus	II
Band-bellied Crake	Porzana paykullii	II
Pheasant-tailed Jacana	Hydrophasianus chirurgus	II
Asian Dowitcher	Limnodromus semipalmatus	II
Little Curlew	Numenius minutus	II
Eurasian Curlew	Numenius arquata	II
Far Eastern Curlew	Numenius madagascariensis	II
Ruddy Turnstone	Arenaria interpres	II
Great Knot	Calidris tenuirostris	II
Broad-billed Sandpiper	Limicola falcinellus	II
Greater Crested Tern	Thalasseus bergii	II
Barred Cuckoo-Dove	Macropygia unchall	II
White-bellied Green Pigeon	Treron sieboldii	II
Greater Coucal	Centropus sinensis	II
Lesser Coucal	Centropus bengalensis	II
Eastern Grass Owl	Tyto longimembris	II

Name in English	Latin Name	Protection Class
Mountain Scops Owl	Otus spilocephalus	II
Collared Scops Owl	Otus lettia	II
Oriental Scops Owl	Otus sunia	II
Eurasian Eagle-Owl	Bubo bubo	II
Collared Owlet	Glaucidium brodiei	II
Asian Barred Owlet	Glaucidium cuculoides	II
Northern Boobook	Ninox japonica	II
Long-eared Owl	Asio otus	II
Short-eared Owl	Asio flammeus	II
Red-headed Trogon	Harpactes erythrocephalus	II
White-throated Kingfisher	Halcyon smyrnensis	II
Blue-tailed Bee-eater	Merops philippinus	II
Blue-throated Bee-eater	Merops viridis	II
Common Kestrel	Falco tinnunculus	II
Amur Falcon	Falco amurensis	II
Eurasian Hobby	Falco subbuteo	II
Peregrine Falcon	Falco peregrinus	II
Fairy Pitta	Pitta nympha	II
Eurasian Skylark	Alauda arvensis	II
Chinese Hwamei	Garrulax canorus	II
Red-billed Leiothrix	Leiothrix lutea	II
Short-tailed Parrotbill	Neosuthora davidiana	II
Bluethroat	Luscinia svecica	II
Siberian Rubythroat	Luscinia calliope	II
White-gorgetted Jungle Flycatcher	Rhinomyias brunneatus	II
Fujian Niltava	Niltava davidi	II

Source: Xiamen Bird Checklist (2023). Xiamen Bird Watching Society. 2024

(3) Ecosystem diversity

Xiamen is located at the terrestrial–marine interface and supports a diverse suite of ecosystem types, including forest ecosystems, wetland ecosystems (subdivided into freshwater wetlands and coastal/tidal wetlands), urban green-space systems, marine ecosystems, and farmland/agricultural ecosystems (Figure 4-24).

Forest ecosystems: Forests in Xiamen are mainly distributed off the principal urban island, on adjacent mainland and peripheral islands. Native (primary) forest has been extensively degraded over historical time, and present-day forest ecosystems are therefore predominantly secondary in character. These secondary forests—comprising semi-natural stands and planted forests—are concentrated on mountains, hills and coastal sandy areas. They typically exhibit simplified community structure and well-defined vertical stratification. Canopy heights in mature stands generally range from about 15 to 20 m. Many stands are monospecific (dominated by a single tree species), while others are mixed, typically comprising two to three co-dominant canopy species.

Wetland ecosystems: Xiamen's freshwater wetlands occur principally around reservoirs, ponds and along river corridors off the main island. Coastal wetlands include subtidal areas, intertidal flats (mudflats and sandflats), aquaculture zones, and smaller extents of salt pans, estuarine waters, sandy beaches and mangrove stands. These coastal wetland types are integral components of Xiamen's bay-city landscape and are priority areas for biodiversity conservation and ecosystem-service provision.

Urban green-space systems: Urban green-space provision in Xiamen has expanded steadily. As of the end of 2022, the built-up area's green-space ratio was 41.5% and vegetation (green) cover within the built-up area reached 45.65%. The built-up area contains a total of 16,830.74 hectares (ha) of green space, of which approximately 5,789 ha are classified as parkland. The city has developed 180 parks of various types (comprehensive, specialized and community parks). (Source: Xiamen Municipal Landscape and Forestry Bureau. Accessed at http://szyl.xm.gov.cn/js/csjswlx/202204/t20220402_2651717.htm).

Marine ecosystems: Xiamen Bay is a subtropical estuarine embayment characterized by a marked salinity gradient—from higher-salinity waters at the bay mouth to lower-salinity and brackish conditions toward the Jiulong River estuary—creating a mosaic of aquatic habitats that support high marine and coastal biodiversity. These habitats serve as important breeding, feeding and nursery areas for numerous aquatic and seabird species and therefore possess high conservation value [50].

Figure 4-24: Types and Distribution of Key Protected Ecosystems in Xiamen
Source: Xiamen Urban Biodiversity Conservation Planning Report. Xiamen University & Xiamen Municipal Landscape and Forestry Bureau (2013).

In response to global climate change and rapid coastal socio-economic development, Xiamen has implemented context-specific measures for mangrove conservation, restoration and sustainable utilization. Mangrove ecosystems—woody plant communities occupying intertidal mudflats in tropical and subtropical zones—deliver multiple ecosystem services, including high biodiversity value, considerable carbon sequestration capacity and important climate-regulating functions. As of December 2023, the cumulative area of established (restored and planted) mangroves in Xiamen reached 173.9 ha. Major restoration and greening components and their approximate restored/planting areas include: Yundang Lake mangrove stand (3.0 ha); Haicang Aoguan shoreline protection and ecological remediation (36.2 ha); Huandong (Romantic Line) greening (Jimei Bridgehead: 17.0 ha; Tongan Coastal Romantic Line: 8.5 ha); Xinglin Bridge–Xinyang Bridge shoreline remediation (5.2 ha); Xiatanwei Mangrove Park (85.0 ha); and the Jiuxikou–Dadeng Bridge marine ecological protection and restoration project (19.0 ha) [51]. Among these, Xiatanwei, the Binhai West Romantic Line, Fenglin Bay and Dongyu are identified as four representative mangrove restoration areas (Table 4-3; see spatial distribution in Figure 4-25).

Table 4-3: Summary of Mangrove Restoration Projects in Xiamen's Coastal Zone

Area Name	Location	Restoration Year	Primary Tree Species	Restored Area (hm^2)
Xiatanwei	Xiatanwei Coastal Wetland Park, Xiang'an District	2012	Grey Mangrove (Avicennia marina); River Mangrove (Aegiceras corniculatum); Water-pencil Mangrove (Kandelia obovata Sheue, Liu & Yong); Sonneratia (Sonneratia apetala); White Mangrove (Laguncularia racemosa); Red Mangrove (Rhizophora stylosa).	85 (Source: Xiamen Natural Resources and Planning Bureau)
Binhai West Romantic Line	Huandong Coastal/Tongan District (Huandong Sea Area – Coastal Tourism Romantic Line)	2017	Sonneratia (Sonneratia apetala); Water-pencil Mangrove (Kandelia obovata Sheue, Liu & Yong); Large-leafed Mangrove (Bruguiera gymnorrhiza)	28
Fenglin Bay	Xunjiang Road, Jimei District	2003	Sonneratia (Sonneratia apetala); Water-pencil Mangrove (Kandelia obovata Sheue, Liu & Yong)	2.7
Dongyu	Dongyu Village, Haicang District	1997	Water-pencil Mangrove (Kandelia obovata Sheue, Liu & Yong)	0.14

Source: Chinese Journal of Ecology, 42(10): 2419–2424.

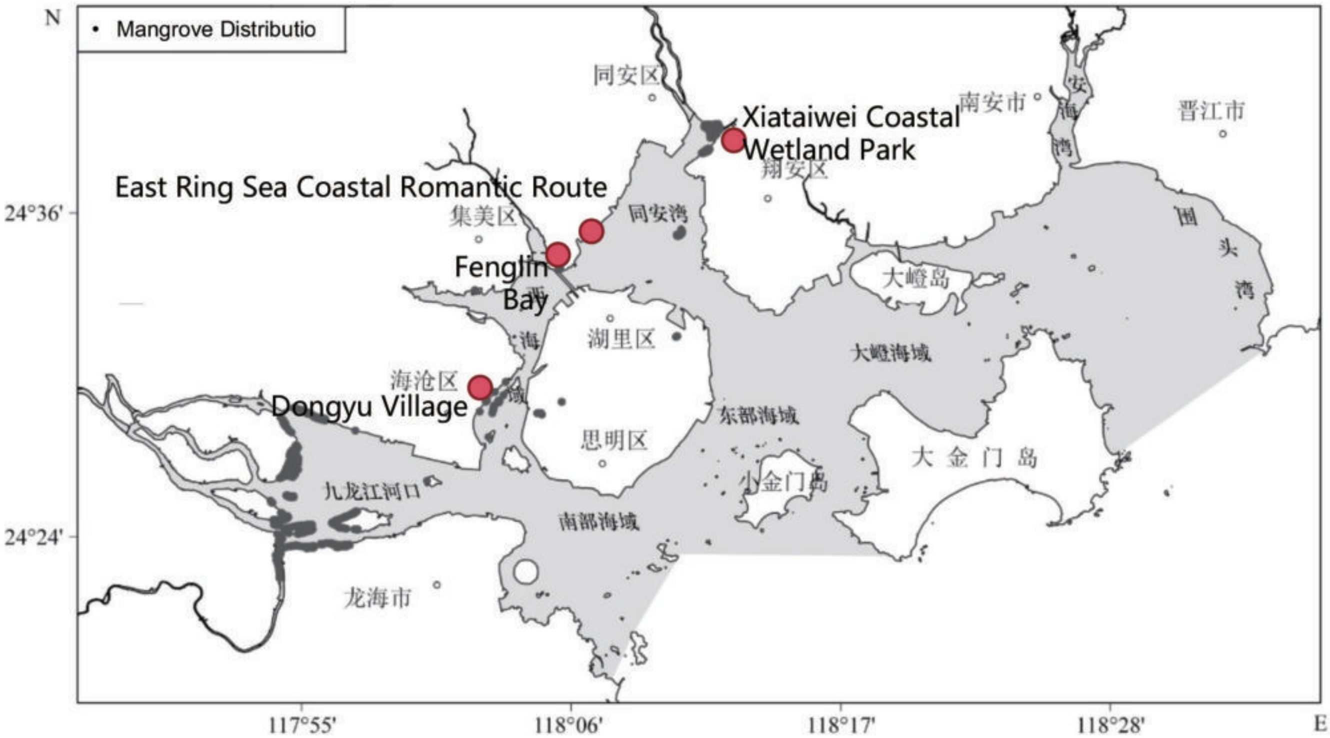

Figure 4-25: Overview of Mangrove Distribution in Xiamen Bay (as of 2018)
Source: redrawn from Journal of Applied Oceanography, 40(1): 43–55.

(4) Genetic diversity

Xiamen's horticultural germplasm resources have been largely introduced from other regions; these include a wide range of species used in urban landscaping, such as diverse members of the genus Ficus, representatives of the palm family *(Arecaceae)*, and taxa of the arum family *(Araceae)*. Through measures such as germplasm introduction, acclimatization trials, and ex-situ conservation, the Xiamen Botanical Garden has assembled a collection of 2,296 plant taxa and maintains 5,417 accessions of native plant material within its living collections. The Garden has also implemented multiple research projects aimed at conserving plant genetic resources and developing improved cultivars; notable projects include *Research on Germplasm Collection and New Cultivar Breeding Techniques for Fujian Mountain Cherry, Innovation and Application of Hedychium Germplasm Resources, and Screening of Bougainvillea Breeding Resources and the Development of New Superior Varieties* [54]. In addition to ornamental germplasm, Xiamen possesses rich crop genetic resources, including rice, vegetables, fruits, ornamental flowers and medicinal plants. Leveraging its geographic and institutional advantages for cross-Strait exchanges — together with favorable technological and transport infrastructure — the city has actively promoted a "Seed Project" that has fostered four pillar seed-and-seedling sectors: crop seed production, forestry seedling production, livestock breeding stock, and aquaculture seedling production. This development has positioned Xiamen as a nationally significant distribution and marketing hub for agricultural and aquacultural seeds and seedlings. (Source: *Xiamen Urban Biodiversity Conservation Planning Report, 2013.)*

4.1.3 Current biodiversity conservation efforts and status

Over recent years, Xiamen has drawn extensively on the experience summarized as the "Xiamen Practice" and has vigorously promoted the construction of ecological civilization; as a result, biodiversity conservation work in the city has achieved notable progress.

(1) Planning documents and regulatory measures relating to biodiversity conservation

Biodiversity considerations have been systematically integrated into a wide range of spatial-planning and policy instruments in Xiamen, including the Territorial Spatial Master Plan, sectoral and specialized plans, action programs, the 14th Five-Year Plan, and relevant regulatory measures (see Table 4-4).

Table 4-4: Summary Table of Planning Documents and Regulatory Measures Related to Biodiversity Conservation in Xiamen

Type	Document Title
Territorial Spatial Plan	Draft of the Xiamen Territorial Spatial Master Plan (2020–2035)
Specialized Plans	Xiamen Specialized Plan for Territorial Spatial Ecological Restoration (2021–2035)
	Xiamen Green Space System Plan (2021–2035)
	Xiamen Yundang Lake Area Special Protection Plan
	Xiamen Integrated Transportation Plan (2021–2035)
	Xiamen Water Resources Allocation Plan (2019–2035)
	Xiamen Urban Rail Transit Network Plan (2021–2035)
	Xiamen Master Plan for the National Nature Reserve of Rare Marine Species
	Xiamen Marine Environmental Protection Plan (2016–2020)
	Beautiful Xiamen Master Plan for Environmental Protection (2014–2030)
Plans for the 14th Five-Year Period	Xiamen 14th Five-Year Specialized Plan for Ecological and Environmental Protection
	Xiamen 14th Five-Year Plan for Ecological Civilization Development
	Xiamen 14th Five-Year Specialized Plan for Forestry Development
	Xiamen 14th Five-Year Plan for Marine Economic Development
	Xiamen 14th Five-Year Integrated Transportation Plan
Management Regulations	Xiamen Regulations on Urban and Rural Planning
	Xiamen Regulations on Ecological Civilization Construction in the Special Economic Zone
	Xiamen Administrative Measures for the Ecological Blue Line for Water Systems
	Xiamen Administrative Measures for the Protection and Utilization of Uninhabited Islands
	Xiamen Provisions on Multi-Plan Integration Management in the Special Economic Zone
	Xiamen Administrative Measures for Urban Green Lines
	Administrative Measures for the Xiamen Dayu Island Egret Nature Reserve
	Xiamen Implementation Provisions for the Management of Ecological Control Lines
	Xiamen Regulations on Sea Area Use Management
	Xiamen Administrative Measures for Cultivated Land Protection (Abolished)
Other Documents	Xiamen Urban Biodiversity Conservation Planning Report (2013)
	Xiamen Three-Year Action Plan for Territorial Spatial Ecological Restoration (2020–2022)

Source: compiled by the author

The draft *Xiamen Territorial Spatial Master Plan (2020–2035)* reports that Xiamen was among the first Chinese cities to implement the "Multi-Plan Integration" reform, creating a single master blueprint for city-wide spatial planning and incorporating environmental spatial-control requirements within that integrated planning platform. The draft delineates the following ecological boundaries: an Ecological Control Line covering 981 km² (approximately 58% of the municipality's terrestrial area); an Ecological Protection Redline of 288 km² (approximately 17% of the terrestrial area); and a Marine Ecological Protection Redline of 84 km² (approximately 25% of the municipality's marine jurisdiction).

Specialized planning instruments — for example, the *Xiamen Municipal 14th Five-Year Plan for Ecological and Environmental Protection* and related sectoral plans — include dedicated chapters or sections on strengthening biodiversity conservation, and set out specific targets and measures. A number of targeted action programs have been implemented, including a marine biodiversity census, mangrove ecosystem restoration projects, and species-specific measures for the conservation of the Chinese white dolphin (*Sousa chinensis*) and the lancelet (*Branchiostoma belcheri*).

At the regulatory level, Xiamen has promulgated and enforced specific management measures designed to protect key sites and species. For example, the city has adopted the *Administrative Measures for the Xiamen Dayu Island Egret Nature Reserve*, which provide legal and operational safeguards for the reserve and underpin local conservation actions.

(2) Nature protected-area system

Xiamen has developed a preliminary yet functionally comprehensive network of protected areas. As of 2021 the municipal protected-area system comprised one national nature reserve, one municipal nature reserve, three national nature parks and five provincial nature parks (see Table 4-5 and Figure 4-26 for details and spatial distribution).

Table 4-5: Summary of Protected Areas in Xiamen (as of 2021)

Name of Protected Area	Designation Level	Category	Approval Year	Approved Area (ha)
Nature Reserves				
Xiamen National Nature Reserve of Rare Marine Species	National	Nature Reserves	2000	7,588
Xiamen Wuyuan Bay Blue-tailed Bee-eater Nature Reserve	Municipal	Nature Reserves	2011	40
Nature Parks				
Xiamen National Marine Park	National	Marine Park	2011	2,487
Xiamen Lianhua National Forest Park	National	Forest Park	2003	3,824
Xiamen Bantou Provincial Forest Park	Provincial	Forest Park	-	4,816
Tongan Tingxi Provincial Forest Park	Provincial	Forest Park	-	3,892
Xiamen Tianzhu Mountain Provincial Forest Park	Provincial	Forest Park	-	2,651
Gulangyu-Wanshi Mountain Scenic Spot	National	Scenic Spot	2015	24,688
Beichen Mountain Scenic Spot	Provincial	Scenic Spot	-	1,220
Xiangshan Mountain Scenic Spot	Provincial	Scenic Spot	-	848

Source: Fujian Provincial Master Plan for Protected Areas (2022–2035), official website of Xiamen Municipal People's Government

Figure 4-26: Distribution of Protected Areas in Xiamen (as of 2021)
Source: author's illustration

(3) The "Xiamen Practice": experience in ecological protection and restoration

Xiamen is an important place where Xi Jinping's Thought on Ecological Civilization was nurtured and first put into practice. For many years, comprehensive lake governance has served as the city's guiding approach, and coordinated land–sea planning together with river–sea linkage has been maintained. The "Xiamen Practice" refers to the following valuable experience: **adherence to ecological priority and green development; insistence on protection before development; creation of a sound ecological foundation for urban development through environmental governance, ecosystem restoration, and ecological-network construction; continuous enhancement of the greening of the economy; continuous cultivation of new development drivers and new development patterns; and strengthening of the potential and resilience for high-quality development.**

Over the past 36 years, municipal authorities derived lessons from the remediation of Yundang Lake and the recovery of Junying Village, and translated these lessons into scalable policy and planning reforms. As an early pilot of institutional innovation, Xiamen advanced the "Multi-Plan Integration" reform and took an early lead in drafting and implementing the *Xiamen Territorial Spatial Master Plan (2021–2035).* Major infrastructure and restoration initiatives under this programme included comprehensive remediation and development projects for five bay areas (Haicang Bay / West Sea Area, Wuyuan Bay, Xinglin Bay, Tongan Bay, and Maluan Bay) and extensive mangrove restoration schemes. Key outcomes and flagship achievements include the Wuyuan Bay Blue-tailed Bee-eater Nature Reserve, the Coastal "Romantic Line" along Xiamen's eastern shoreline, the Xiamen Science City, a more than 200-km "Mountain-to-Sea Health Trail," and the establishment of the Xiamen World Ocean Week as a platform for national and international exchange.

In biodiversity conservation specifically, Xiamen has implemented a suite of wetland restoration and protected-area projects. The Yundang Lake ecological-restoration project has re-established critical habitat for egrets and other rare waterbirds and provided high-quality breeding habitat for migratory species. The Wuyuan Bay wetland restoration and integrated development project has been recognized as an early model for realizing the value of ecosystem services. The Blue-tailed Bee-eater Nature Reserve exemplifies successful urban wildlife protection within a dense urban setting. The Xiatanwei mangrove restoration, supported by sustained artificial propagation and release programs, has helped to reconstruct a near-natural wetland system—comprising mangroves, bare tidal flats, tidal creeks and shallow waters—and was highlighted as a "carbon-neutral forest" in the context of the BRICS Xiamen Summit. **Xiamen has also implemented targeted conservation measures for rare marine species such as the Chinese white dolphin (*Sousa chinensis*) and the lancelet (*Branchiostoma belcheri*),** and has established the Xiamen National Nature Reserve for Rare Marine Species.

Yundang Lake experience:

The Yundang Lake restoration experience is a successful model of Xiamen's ecological-environment governance, and provides referenceable experience and lessons for urban water-environment management in other cities.

At the outset of the restoration, clear objectives and strategic direction for Yundang Lake were defined. In 1988, Comrade Xi Jinping, then a member of the Standing Committee of the Xiamen Municipal Party Committee and Executive Vice Mayor, presided over a special meeting and creatively proposed the 20-character (in Chinese) guiding principle: "manage the lake according to law; cut off pollution sources; dredge and build embankments; revitalize the water body; beautify the environment." This principle concentrated the concepts of systematic governance and integrated measures, and laid a solid foundation for subsequent restoration work. During the restoration process, Xiamen adopted multiple coordinated measures and developed a model of comprehensive and systemic governance. First, intensive control of pollution sources in the lake basin was implemented: polluting enterprises within the watershed were closed or relocated, sewage-lifting pumping stations and seawater-pumping stations were constructed, and rain–sewage separation works were carried out; Second, continuous dredging of the lake and reservoirs was undertaken to enhance the stormwater regulation and storage capacity of the lake area; Third, ecological water-replenishment projects were implemented: the natural tidal range was used to drive tidal intake and discharge, and measures to introduce clear, living water were constructed; Fourth, scientific research and technical innovation were strengthened to develop new methods for aquatic ecological restoration, including the use of ecological floating beds and mangrove planting to improve water quality. At the same time, governance was promoted toward institutionalization and standardization. Following the comprehensive restoration, the Yundang Lake was developed into Xiamen's first nationally designated key open park. Ecological indicators have continued to improve and biodiversity has recovered: a total of 95 bird species and nearly 200 species of plankton and aquatic plants have been recorded. Rare and protected animals that have reappeared include the Chinese horseshoe crab (*Tachypleus tridentatus*), the filefish *Rudarius ercodes* (a filefish species historically recorded in local waters), the Blue-tailed Bee-eater (*Merops philippinus*), and the Rustic Bunting (*Emberiza rustica*).

Figure 4-27: Aerial View of Yundang Lake

Source: reports by the Ministry of Ecology and Environment of the People's Republic of China. Accessed at https://www.mee.gov.cn/home/ztbd/2023/mlhh2/yxal2/fj/202311/t20231113_1055780.shtml

Management experience of the Wuyuan Bay Blue-tailed Bee-eater Nature Reserve:

The Wuyuan Bay Blue-tailed Bee-eater Nature Reserve in Wuyuan Bay, Xiamen, was established in 2011 with the approval of the Xiamen Municipal Government under the *Notice of the Xiamen Municipal People's Government on Establishing the Wuyuan Bay Blue-tailed Bee-eater Nature Reserve* (Xia Fu [2011] No. 508). The reserve covers an area of approximately 40 ha. The reserve's boundary includes the area inside the planned roads surrounding Qimashan, the Tongyu Wetland north of Wuyuan Bay Road, the area west of the Island Ring Road and the northwest branch roads of Wuyuan Bay, and the zone east of the lake's western shore. It is the first nature reserve established within the central urban area of Xiamen Island. Qimashan functions as the Blue-tailed Bee-eater's nesting and breeding locality, while Wuyuan Bay serves not only as a breeding area but also as an important foraging ground.

As Qimashan constitutes core habitat for the species, nest-site maintenance and the construction of artificial nesting faces have been carried out in accordance with the Blue-tailed Bee-eater's reproductive characteristics, thereby expanding available breeding habitat and securing successful reproduction. Infrastructure upgrades have been implemented to strengthen management capacity; these include the replacement and upgrading of power lines, repair and maintenance of timber management cabins and bird-watching fences, and fire-ant control measures. On the management side, the reserve implements fully enclosed management, retains native vegetation and wildlife assemblages, maintains 24-hour on-duty staffing, and enforces strict oversight of any construction projects affecting the reserve. During the breeding season (April–August), primary breeding-area access routes are continuously closed and full enclosure management is enforced.

The reserve also places emphasis on collaboration with universities and research institutes to conduct scientific surveys and monitoring activities, and it continuously refines reserve construction and management measures based on expert advice. Following ornithological guidance, the Qimashan cliff face is maintained annually: existing nest cavities are washed, backfilled and reformed; cliff-like earthen nesting faces are constructed using a sand-to-soil mixture at an 8:2 ratio to create new nest faces; and, on the basis of existing nest faces, the nesting area has been substantially expanded to accommodate a larger number of Blue-tailed Bee-eaters nesting concurrently.

Figure 4-28: Aerial Photograph of the Xiamen Wuyuan Bay Blue-tailed Bee-eater Nature Reserve
Source: People's Daily Online. Accessed at http://fj.people.com.cn/n2/2024/0122/c181466-40722755.html

Figure 4-29: Artificial Nesting Faces Constructed within the Xiamen Wuyuan Bay Blue-tailed Bee-eater Nature Reserve
Source: People's Daily Online. Accessed at http://fj.people.com.cn/n2/2024/0122/c181466-40722755.html

4.1.4 Challenges facing biodiversity conservation

(1) Resource advantages and values

High forest cover and ecosystem diversity. The relatively high forest cover in Xiamen provides a solid foundation for the city's biodiversity. As of 2022, forest cover in Xiamen reached 29.30%, and the city's built-up area had a green-space ratio of 41.5%, green coverage of 45.65%, and per-capita park green area of 14.84 m^2 (sources: Xiamen Municipal People's Government; Xiamen Municipal Bureau of Landscape and Forestry. Accessed at https://www.xm.gov.cn/xmyw/202407/t20240730_2881520.htm， https://szyl.xm.gov.cn/dtxx/bjdt/202204/t20220427_2658262.htm). Under the *Xiamen 14th Five-Year Specialized Plan for Forestry Development*, the city aims to stabilize forest cover at 30% and to reach a standing timber volume of 3.49 million m^3 by 2025, reflecting Xiamen's commitment and progress in forest protection. Xiamen's ecosystem types are diverse—principally forest, marine and wetland systems—which together supply a broad suite of suitable habitats and thus support high species richness and ongoing biodiversity development. In the process of urban development, the city has increasingly emphasized the harmonious coexistence of nature and the urban environment. Through the implementation of bay-oriented ecological-protection projects, landscape-greening works, and modern municipal infrastructure, Xiamen has integrated ecological protection into urban construction—commonly expressed as "a city on the sea, with the sea woven into the city"— thereby beautifying the urban environment while protecting existing natural ecosystems and contributing to Xiamen's emergence as a highly scenic ecological garden city.

Xiamen is home to a rich diversity of flora and fauna, including highly valuable and endangered flagship species such as the Chinese white dolphin. Xiamen's subtropical maritime climate—characterized by long warm seasons, low temperature variability, effective seasonality of heat and water, and generally humid conditions—creates favorable conditions for wild plants and animals. The Xiamen National Nature Reserve of Rare Marine Species is an important conservation base for biodiversity in Xiamen. It was formed by merging the former provincial-level Xiamen Chinese White Dolphin Reserve, the provincial-level Dayu Island Egret Reserve, and the municipal-level Lancelet Reserve, and it covers an area of 75.88 km^2. The reserve protects 18 rare and endangered marine and coastal taxa, including the Chinese white dolphin — widely acclaimed as a "marine national treasure," designated as a national first-class protected species and of very high scientific and conservation significance — and lancelets, which are of important scientific value as transitional taxa in the evolutionary shift from invertebrates to vertebrates, together with multiple egret species.

Location on a major migratory flyway supports abundant populations of coastal waterbirds. Xiamen lies on an important global migratory flyway, and each year large numbers of migratory birds use the city as stopover and/or wintering habitat. These assemblages include various egrets (including the Chinese Egret, *Egretta eulophotes,* Saunders's Gull *Chroicocephalus saundersi*, and the Spoon-billed Sandpiper *Eurynorhynchus pygmeus*), among other rare species. The presence of these waterbirds not only enriches local biodiversity but also provides valuable field data and study sites for ornithological research and conservation. Local sites such as Dongyu (East Islet) and Fenglin are well known for their abundant waterbird populations; these areas supply food resources and essential roosting and foraging habitat and attract large numbers of researchers and birdwatchers for monitoring and study.

(2) Conservation foundations and challenges

Xiamen has established a relatively complete system of ecological spatial planning and regulatory instruments, but it needs to further advance the construction of "a single integrated master blueprint." The city's planning framework encompasses multiple levels from top-level strategic plans to instruments for concrete implementation, including the *Xiamen Territorial Spatial Master Plan* and the *Xiamen Implementation Provisions for the Management of Ecological Control Lines.* These documents define key spatial elements such as Ecological Protection Redlines, permanent basic farmland, and urban development boundaries, and they prescribe zoned management of ecological functions. Nevertheless, coordination and integration among these various plans remain a work in progress. The city therefore needs to accelerate the development of a single integrated master blueprint and explicitly incorporate biodiversity conservation planning into that unified framework.

A system of protected areas has been established, including nature reserves, forest parks, marine parks and scenic areas, and Xiamen also features small, distinctive nature reserves embedded within high-density urban areas; nevertheless, the construction of a territory-wide conservation spatial network linking protected areas and surrounding lands requires further exploration. Xiamen has established a protected-area system, covering nature reserves, forest parks, marine parks and scenic areas, which provides an important safeguard for biodiversity. It is particularly worth noting that Xiamen has established a small municipal-level Blue-tailed Bee-eater Nature Reserve within a high-density urban area; the reserve is managed under full enclosure and was established specifically to protect a single rare bird species. However, with the deepening of Territorial Spatial Planning, connectivity between protected areas needs to be strengthened. It is necessary to explore the construction of a territory-wide conservation spatial network that includes Protected Areas (PAs) and Other Effective area-based Conservation Measures (OECMs), and to link this network with the Territorial Spatial Master Plan, thereby laying the foundation for further enhancing protection.

Although targeted monitoring of flagship species such as the Chinese white dolphin has been carried out and baseline biodiversity surveys have been initiated, a comprehensive, sustained monitoring and tracking system is still lacking, which may compromise evidence-based management decisions. Multiple rounds of baseline surveys have been completed, but not all taxonomic groups have been fully covered, and there is not yet an established long-term programme for continuous observation of temporal and spatial changes in species distributions. This gap increases the risk that some ecologically important areas will be overlooked in planning and decision-making.

Xiamen has implemented localized protection sub-zones and species-focused restoration projects (for example, for leopard cat and python habitats, and for mangrove restoration), and the Yundang Lake remediation and related "Xiamen Practice" are nationally recognized examples of ecological restoration.

(3) Development pressure and conflict

Xiamen's urban vegetation is characterized by a diverse and abundant non-native flora; further investigation is required into frequently occurring species, dominant taxa, and plants originating from principal source regions. According to Li Jing et al., in their study *Species Composition of Urban Alien Plants in Xiamen,* the city's non-native flora comprises 223 species in 174 genera and 67 families, and in most green-space types exotic species constitute more than 50% of the flora, indicating a prominent role for non-native taxa in Xiamen's urban vegetation. Systematic research remains insufficient regarding the environmental impacts of these non-native plants within the urban context, and published reports addressing the ecological effects of the widely distributed exotic species are scarce. For example, Xiamen's designated city tree, the Flame Tree (*Delonix regia*), and its designated city flower, the Paper Flower (*Bougainvillea glabra Choisy*), are both non-native and are now widely cultivated in the city. Although these species contribute substantially to urban greening and aesthetic enhancement, their local ecological effects remain poorly documented; the potential for future invasiveness therefore warrants careful attention, and large-scale promotion should be preceded by rigorous ecological assessment.

Estuarine and port habitats constitute important and suitable environments for rare species such as the Chinese white dolphin, while simultaneously representing key areas for Xiamen's urban and economic development. Construction, commercial shipping and fishing activities within harbors and estuaries can interfere with conservation of such key species, creating a need to balance development and protection. As a rapidly developing coastal city, Xiamen relies heavily on its port and estuarine zones as pillars of the local economy. Long-term disturbances associated with port and navigation-channel expansion and large-scale land reclamation may lead to degradation of dolphin habitat, manifested as declines in water quality, reductions in prey availability, and habitat fragmentation. These factors adversely affect the survival and reproduction of the Chinese white dolphin. Increased shipping traffic raises the risk of vessel–dolphin collisions; when foraging or socializing, dolphins may enter navigation lanes and collide with fast-moving vessels, with potential outcomes including serious injury or mortality. In promoting the development of port and estuarine areas, therefore, priority should be given to the conservation of rare species such as the Chinese white dolphin, with efforts made to reconcile development objectives and effective protection measures.

The breeding period and suitable habitat of the Chinese white dolphin are temporally dynamic; enhanced research into temporal changes in habitat suitability for this and other co-occurring rare or endangered species is required to inform adaptive and sustainable conservation approaches. The dolphins' breeding period is not fixed and may shift in response to environmental and climatic drivers. Chinese white dolphins are typically active in waters shallower than 30 m in depth; however, activity areas vary with seasonality and tidal cycles as water depths fluctuate. Consequently, conservation and management planning should incorporate spatial habitat distribution, temporal variation in water depth and distance from shore, and species-specific ecological requirements, so as to develop scientifically justified protection strategies and management measures.

4.2 Spatial framework for biodiversity conservation in Xiamen

4.2.1 Selection of target conservation species

Based on data available for that year and expert consultation, six bird species were tentatively designated as target conservation species. The selection criteria included (1) representativeness of habitat types, (2) protection and rarity/endangerment status, (3) special ecological or other values, and (4) local cultural significance. The selected species include taxa listed at the national Class I and Class II protection levels and represent important habitat types in Xiamen, including wetlands and marine areas (see Table 4-6).

Table 4-6: Key Attributes of Target Bird Species

Name in Chinese	Latin Name	English Name	Order	Family	Number of Reports (China Bird-watching Records Center Database)	Number of Locations (China Bird-watching Records Center Database)	Total Individuals (China Bird-watching Records Center Database)	IUCN Red List Status	National Protection Level	Residency Status	Diet	Ecological Type	Habitat Type	Behavior	Disturbance Tolerance	Mobility	Habitat / Nesting Area
Huang Zui Bai Lu	Egretta eulophotes	Chinese Egret	Pelecaniformes	Ardeidae	139	35	394	VU	Class I	S	Carnivorous, Insectivorous	Wading Bird	Forages in intertidal zones of coastal estuaries, mudflats, and salt fields, occasionally moving to freshwater wetlands near the coast. Nests on uninhabited sea islands, choosing cliff shrubs, low bushes, or coastal woodland areas.	Usually solitary, in pairs, or in small groups; may form flocks of dozens during migration. Typically nests in colonies, breeding sympatrically in coastal areas with Little Egrets, Great Egrets, Black-crowned Night Herons, and Cattle Egrets, or on islands with Little Egrets, Intermediate Egrets, or Black-faced Spoonbills. Forages elegantly while wading on shallow water or mudflats.	Exhibits the longest flight initiation distance, prefers open habitats, and is sensitive to noise.	10km	250-400m²
Hei Zui Ou	Chroicocephalus saundersi	Saunders's Gull	Charadriiformes	Laridae	71	28	693	VU	Class I	W	Carnivorous, Insectivorous	Swimming Bird (Marine)	Highly dependent on the coast, rarely venturing inland; breeds in relatively dry, sparsely vegetated short grasslands near the coastline.	Flies gracefully, capable of sudden descents, with noticeably long, pointed wings. Rarely swims on the sea surface; nests and breeds among coastal vegetation such as Suaeda species (saltwort).	Relevant studies define the unilateral distance of habitat fragmentation impact on Saunders's Gull breeding grounds as: roads at 200 m, abandoned oil wells at 50 m, operational oil wells at 300 m, and residential areas at 750 m.	10km	Highly sensitive to fragmentation; nests are primarily located in sparsely populated Suaeda and reed marshes, ensuring no significant obstacles within 1,000 m.
Li Hou Hu Feng	Merops philippinus	Blue-tailed Bee-eater	Coraciiformes	Meropidae	465	82	4,265	LC	Class II	S	Insectivorous	Climbing Bird	Active on the edges of sparse forests, open farmlands, and riverbanks.	Gathers in flocks in open, arid areas, capturing insects in flight. The breeding season is from April to June. Nests are excavated into steep earthen banks and small mounds in wide, open wastelands.	Long flight initiation distance (approximately 80 m), prefers open habitats, and is sensitive to noise.	10km	(Qimashan area approximately 30,000 m²; nesting area approximately 800 m²)

Name in Chinese	Latin Name	English Name	Order	Family	Number of Reports (China Bird-watching Records Center Database)	Number of Locations (China Bird-watching Records Center Database)	Total Individuals (China Bird-watching Records Center Database)	IUCN Red List Status	National Protection Level	Residency Status	Diet	Ecological Type	Habitat Type	Behavior	Disturbance Tolerance	Mobility	Habitat / Nesting Area
Zi Shui Ji	Porphyrio porphyrio	Purple Swamphen	Gruiformes	Rallidae	492	59	1204	NR	Class II	R	Omnivorous	Wading Bird	Found in eutrophic wetlands at altitudes below 2,500 m, occupying open water bodies with slow or calm currents and dense vegetation cover.	Typically moves in pairs or family groups. Gentle in temperament, with foraging activity peaking at dawn and dusk. Often walks deliberately on floating vegetation and can climb reed stems. Poor flyer, usually covering only short distances when forced into flight; wing beats are slow, legs dangle, giving a clumsy appearance.	Exhibits a moderate flight initiation distance, prefers open habitats, and is sensitive to noise.	10km	250-400m^2
Pu Tong Lu Si	Phalacrocorax carbo	Great Cormorant	Suliformes	Phalacrocoracidae	780	159	125274	LC	-	W	Carnivorous	Swimming Bird	Inhabits a variety of aquatic environments including estuarine reservoirs, rivers, lakes, ponds, and marshes, and is occasionally observed in coastal areas.	Often active in groups, frequently resting on rocks or branches in the water. Highly skilled at swimming and diving; upon spotting prey, dives to catch fish, sometimes remaining submerged for nearly one minute. During migration, individuals form V-shaped or linear formations.	/	10km	/
He Chi Ya Juan	Centropus sinensis	Greater Coucal	Cuculiformes	Cuculidae	1,231	223	1,800	LC	Class II	R	Insectivorous, Carnivorous	Climbing Bird	Typically active below 1,200 m altitude in secondary forests, tall grasslands, scrub, bamboo groves, grass piles at the edges of cultivated land, mangroves, rice paddies, and gardens.	Often walks, hops, and pursues prey on the ground or within scrub. It is non-brood-parasitic, constructing its own nests in tall grass, bushes, or bamboo groves.	Prefers ecotones between forest and farmland; highly susceptible to human capture and disturbance due to intensive human activity.	/	/

Source: ZHENG Guangmei (ed.). 2017. A Checklist on the Classification and Distribution of the Birds of China (Third Edition) [M]. Beijing: Science Press. WANG Yanping, SONG Yunfeng, ZHONG Yuqian, et al. 2021. A dataset on the life-history and ecological traits of Chinese birds [J]. Biodiversity Science, 29(9): 1149–1153. DU Yucheng, QIAO Qing. 2013. Landscape Approaches in Avian Habitat Conservation of Dongying [J]. Agricultural Science-Technology and Information (Modern Gardens), 10(4): 35–40. JIANG Huaping, WANG Wei, ZHANG Mengzhen. 2022. Natural Education Site Design for Wuyuan River Bee-eater Reserve in Haikou [J]. Guangdong Landscape Architecture, 44(1): 11–15. YANG J, HUANG X. 2021. The 30 m annual land-cover dataset and its dynamics in China from 1990 to 2019 [J/OL]. Earth System Science Data, 13(8): 3907–3925.

(1) Chinese Egret (*Egretta eulophotes*)

The Chinese Egret is a wetland-dependent wader that can serve as an ecological indicator and is afforded a high level of legal protection. It is commonly observed in Xiamen from April through June. As a member of the *Ardeidae* family, it represents Xiamen's "Egret Island" culture and is much appreciated by local residents and bird-watchers. In Xiamen, its occurrences are concentrated in the eastern coastal zone of Xiang'an District, with scattered records across other waterside areas. Overall, its distribution is relatively broad (see Figure 4-30).

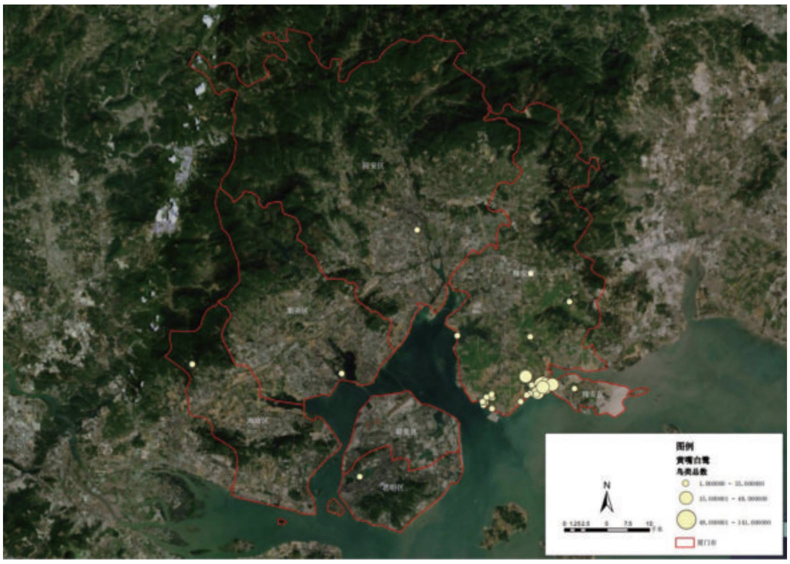

Figure 4-30: Reported Occurrences of Chinese Egret in Xiamen (2014–2023; total counts)
Source: author's illustration

(2) Saunders's Gull (*Chroicocephalus saundersi*)

The Saunders's Gull is a coastal seabird dependent on coastal zone habitats; it is highly protected and constitutes an important winter migrant in Xiamen. The species has a long history of depiction in Chinese painting and literature. It was first recorded in Xiamen by British ornithologist Robert Swinhoe in 1871 and has been referred to locally as the "Strolling Gull." In Xiamen, its distribution is predominantly coastal, mainly in the eastern coastal sector of Xiang'an District, with scattered records in adjacent coastal areas (see Figure 4-31).

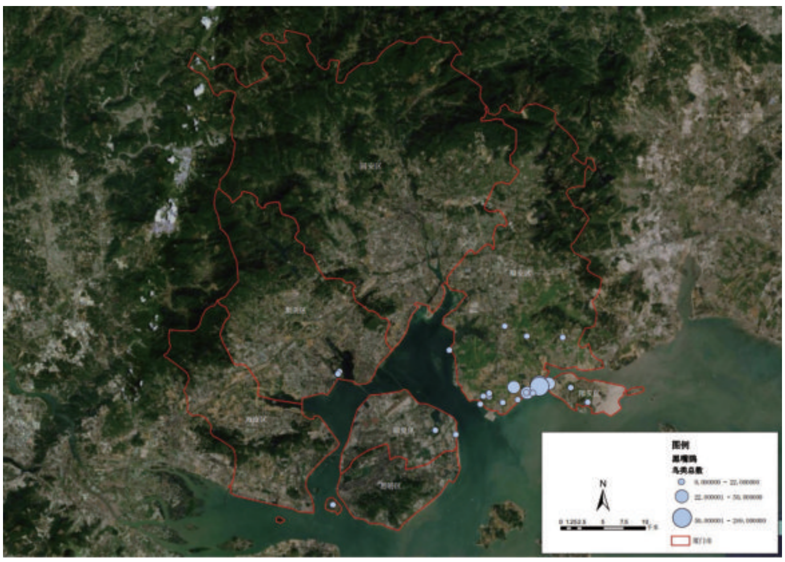

Figure 4-31: Reported Occurrences of Saunders's Gull in Xiamen (2014–2023; total counts)
Source: author's illustration

(3) Blue-tailed Bee-eater (*Merops philippinus*)

The Blue-tailed Bee-eater typically arrives in Xiamen around April to breed in suitable sandy soil walls and departs around October. Celebrated as "China's most beautiful small bird" and a flagship species of Xiamen, it is charismatic and locally emblematic. Its nesting habitat closely overlaps with urban residential areas; the Xiamen Wuyuan Bay Blue-tailed Bee-eater Nature Reserve, comprising sites in the city center together with Wuyuan Bay Wetland Park, provides formal protection. Currently, the species is mainly found in Xiamen's coastal zones, with particularly dense occurrences on Xiamen Island adjacent to high-density urban construction (see Figure 4-32).

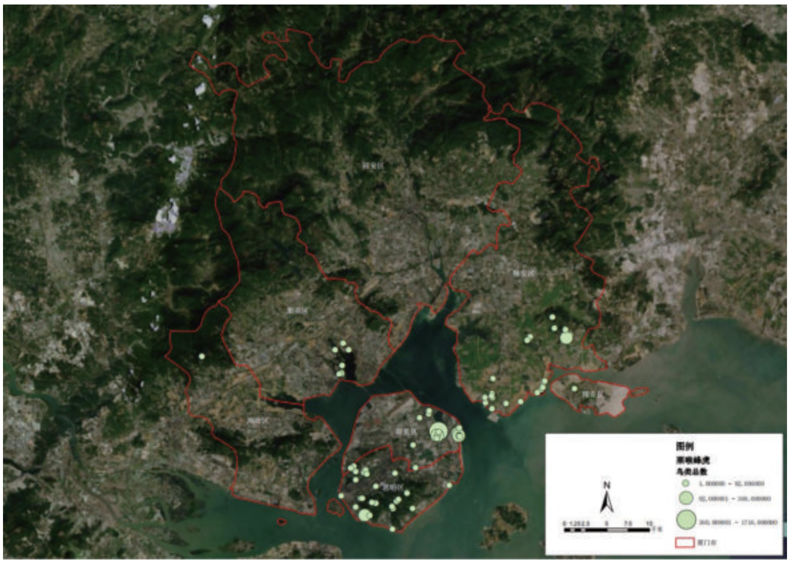

Figure 4-32: Reported Occurrences of Blue-tailed Bee-eater in Xiamen (2014–2023; total counts)
Source: author's illustration

(4) Purple Swamphen (*Porphyrio poliocephalus*)

The Purple Swamphen is a wetland-dependent wader notable for its striking appearance. Xiamen is the type locality for the South China subspecies. In 1866 and 1868, British ornithologist Robert Swinhoe collected two specimens in Xiamen and first formally published them internationally in the journal *Ibis*. Once locally extirpated, the species was rediscovered in Xinglin Bay in 2012 by a member of the Xiamen Bird Watching Society, prompting ongoing local protection. Currently, populations are concentrated in two coastal wetlands—Maluan Bay and the Zhangdaiqiao River—with smaller numbers in Xinglin Bay and scattered occurrences elsewhere (see Figure 4-33).

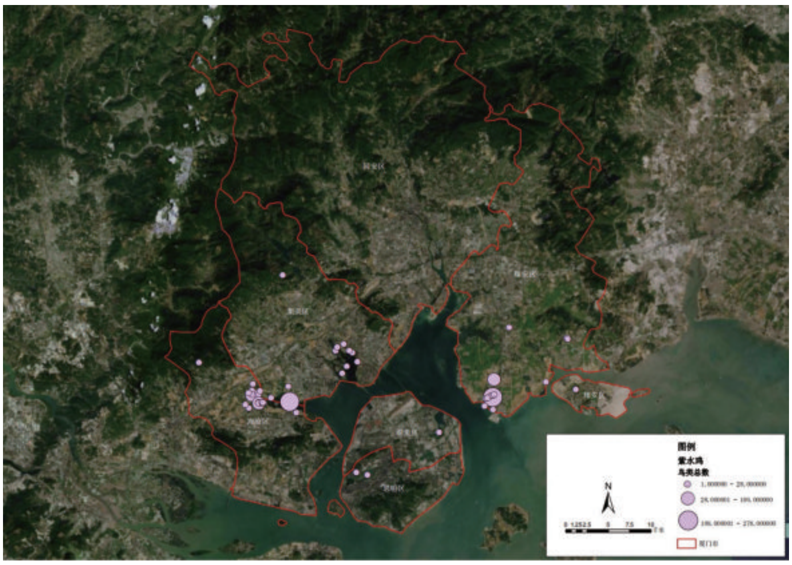

Figure 4-33: Reported Occurrences of Purple Swamphen in Xiamen (2014–2023; total counts)
Source: author's illustration

(5) Great Cormorant (*Phalacrocorax carbo*)

The Great Cormorant is a waterbird dependent on aquatic habitats. Xiamen supports a large population, primarily foraging along its coastal zones. These birds travel daily between Xiamen and Kinmen (Quemoy) at dawn and dusk, creating a spectacular scene. This event, known locally in Kinmen as "Cormorants Returning at Night," is promoted as a key bird-watching attraction. According to birdwatching records, populations in Xinglin Bay and Maluan Bay can exceed 10,000 individuals, with additional birds distributed across other riparian and coastal areas (see Figure 4-34).

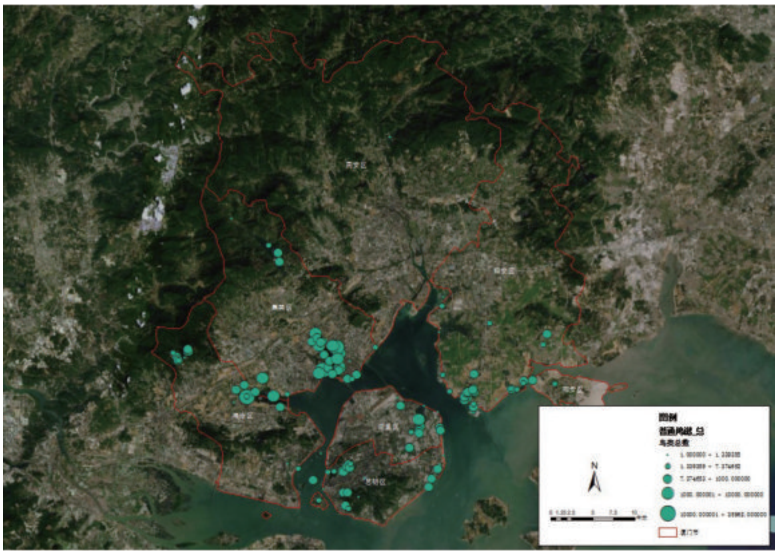

Figure 4-34: Reported Occurrences of Great Cormorant in Xiamen (2014–2023; total counts)
Source: author's illustration

(6) Greater Coucal (*Centropus sinensis*)

The Greater Coucal is a National Class II Protected Species. In Xiamen, it is concentrated in southern wetlands and mountainous areas, with some scattered populations in the northern mountains (see Figure 4-35). The species favors forest edges, secondary scrub, reed-lined riverbanks, and mangroves. It commonly moves on the ground but also hops between bushes and low trees. As an integral component of the ecosystem, the Greater Coucal plays an important role in the food chain. Its diet is primarily carnivorous, including insects such as caterpillars, locusts, grasshoppers, weevils, cockroaches, ants, and bees; invertebrates including centipedes, crabs, snails, earthworms, crustaceans, and mollusks; and small vertebrates, such as snakes, lizards, rodents, bird eggs, and nestlings. This diverse diet enables the species to help control pests and maintain ecological balance.

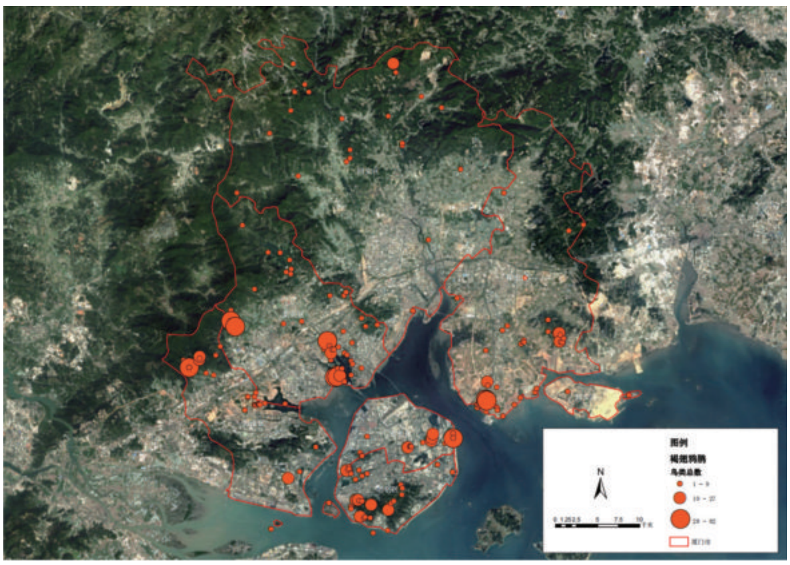

Figure 4-35: Reported Occurrences of Greater Coucal in Xiamen (2014–2023; total counts)
Source: author's illustration

4.2.2 Habitat identification and classification

Based on Xiamen's natural geographic conditions and with reference to the *Classification Guide for Territorial Spatial Survey, Planning, and Use Control,* Xiamen's land use was classified **into ten key habitat types: forest, grassland, bare land, water bodies, wetlands, sea areas, farmland, garden plots, urban/rural green spaces, and construction land, using differences among ecosystem types as the main classification criterion.**

Landsat 8 satellite imagery from 2023 served as the primary data source for remote sensing interpretation and was corrected based on relevant planning maps and previous interpretation products. This process extracted Xiamen's habitat distribution and characteristics, reflecting the quality of its natural ecological components. Remote sensing interpretation was conducted using eCognition 9 software, applying a multi-stage, object-based classification method. The 2023 land use data (Reference [60]water and carbon cycle between Earth's spheres. Accurate LC information is a fundamental parameter for the environment and climate studies. Considering that the LC in China has been altered dramatically with the economic development in the past few decades, sequential and fine-scale LC monitoring is in urgent need. However, currently, fine-resolution annual LC dataset produced by the observational images is generally unavailable for China due to the lack of sufficient training samples and computational capabilities. To deal with this issue, we produced the first Landsat-derived annual China land cover dataset (CLCD) and high-resolution remote sensing imagery were used to validate the results. Sample-based validation yielded a Kappa coefficient of 0.8581, indicating a high accuracy of habitat identification. The outcome was the 2023 Xiamen Habitat Classification Map (Figure 4-36).

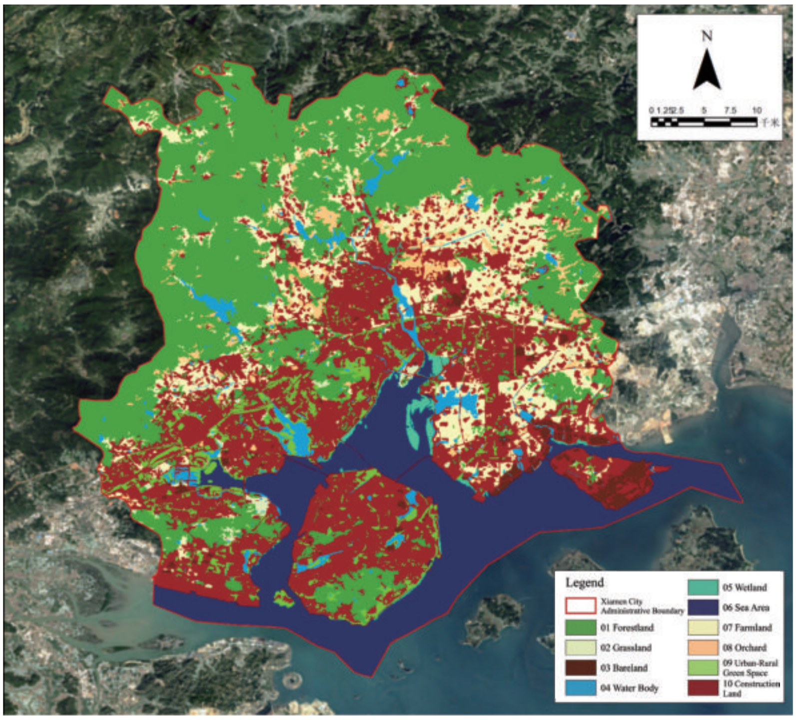

Figure 4-36: Habitat Classification Map of Xiamen, 2023
Source: author's illustration

4.2.3 Calculation of anthropogenic disturbance index

This study considered the intensity of direct and indirect disturbances, as well as the influence of edge effects, for each habitat patch. Five anthropogenic disturbance indices—population, traffic, topological, geometric, and land cover disturbances—were used to quantitatively analyze the impacts of human activities on Xiamen's ecological space, forming the basis for evaluating the suitability of habitat patches for target species. The calculation rules for these indices were established based on literature review and expert consultation (Table 4-7). Calculations and visualization were performed using ArcGIS software. Disturbance indices for each species within a habitat patch were derived by overlaying the layers of traffic, population, geometric, topological, and land cover disturbances.

Given that species differ in their sensitivity to human disturbance, a questionnaire was distributed to a panel of experts—including scholars, bird-watching enthusiasts, reserve staff, and government administrators—to obtain species-specific weights (Table 4-8). These weights were then applied to calculate the disturbance index for each target species. The calculated disturbance indices are presented in Figures 4-37 through 4-42.

Table 4-7: Principles for Calculating the Anthropogenic Disturbance Index

Disturbance Type	Calculation Principle
Traffic disturbance	Using buffer analysis, multi-ring buffers were generated around Class I and Class II roads with the following species-specific base units (unit interval widths): Chinese Egret – 40 m; Saunders's Gull – 30 m; Blue-tailed Bee-eater – 20 m; Purple Swamphen – 20 m; Great Cormorant – 20 m; Greater Coucal – 10 m; Disturbance intensity was assigned by Euclidean distance to the road in these unit intervals: the closer the distance, the greater the disturbance. A distance of 0 m is assigned a value of 10; for each successive unit interval outward the disturbance value decreases by 1. Traffic disturbance intensity therefore ranges from 0 to 10.
Topological disturbance	Using buffer analysis, multi-ring buffers were generated around areas classified as built-up/construction land with the following species-specific base units (unit interval widths): Chinese Egret – 50 m; Saunders's Gull – 30 m; Blue-tailed Bee-eater – 20 m; Purple Swamphen – 50 m; Great Cormorant – 20 m; Greater Coucal – 20 m; Disturbance intensity was assigned by unit intervals of proximity to built-up land: the closer a habitat patch is to built-up land, the greater the disturbance. Distances below 20 m are assigned a value of 10; for each additional unit interval of distance the disturbance value decreases by 1. Topological disturbance intensity therefore ranges from 0 to 10.
Geometric disturbance	Intensity is assigned from geometric characteristics; the overall geometric disturbance score is the arithmetic mean of the Area Disturbance Intensity and the Shape Disturbance Intensity. Area disturbance: unit interval areas (hm^2) are species-specific: Chinese Egret – 3 hm^2; Saunders's Gull – 0.5 hm^2; Blue-tailed Bee-eater – 0.5 hm^2; Purple Swamphen – 1 hm^2; Great Cormorant – 1 hm^2; Greater Coucal – 0.5 hm^2. Larger patch area corresponds to lower disturbance. Patches smaller than 1.5 hm^2 are assigned a value of 10; for each additional species-specific unit interval of area the disturbance value decreases by 1. Area disturbance intensity ranges from 0 to 10. Shape disturbance: values are assigned from the Shape Index (defined as patch perimeter divided by the perimeter of a square with the same area). Species-specific Shape Index unit intervals are: Chinese Egret – 1.0; Saunders's Gull – 1.5; Blue-tailed Bee-eater – 2.5; Purple Swamphen – 0.5; Great Cormorant – 1.0; Greater Coucal – 2.0. A smaller Shape Index indicates lower disturbance. A Shape Index greater than 5.5 is assigned a value of 10; for each decrease by one unit interval in the Shape Index, the disturbance value is decreased by 1. Shape disturbance intensity ranges from 0 to 10.
Population disturbance	Xiamen's population density was calculated from gridded (per-kilometer) population data; Using population density, species-specific unit intervals (persons / hm^2) are applied as follows: Chinese Egret – 15 persons/hm^2; Saunders's Gull – 20 persons/hm^2; Blue-tailed Bee-eater – 20 persons/hm^2; Purple Swamphen – 10 persons/hm^2; Great Cormorant – 15 persons/hm^2; Greater Coucal – 20 persons/hm^2. Higher population density corresponds to greater disturbance. Densities below 1 person/hm^2 are assigned a value of 0; for each increase by one unit interval the disturbance value increases by 1. Population disturbance intensity ranges from 0 to 10.
Land-cover disturbance	The proportion of impervious surface within each patch was derived from ground vegetation and canopy cover data and used to assess land-cover disturbance; Using impervious surface proportion, species-specific unit intervals (%) are applied as follows: Chinese Egret – 4%; Saunders's Gull – 6%; Blue-tailed Bee-eater – 4%; Purple Swamphen – 4%; Great Cormorant – 5%; Greater Coucal – 5%. A higher impervious proportion corresponds to greater disturbance. Values below 1% are assigned a value of 10; for each increase by one unit interval the disturbance value decreases by 1. Land-cover disturbance intensity therefore ranges from 0 to 10.

Source: author's compilation based on References [61–75] and expert consultations

Table 4-8: Disturbance Index Weights for Target Species Habitat Suitability

Representative Species	Traffic disturbance	Topological disturbance	Geometric disturbance	Population disturbance	Land-cover disturbance
Chinese Egret	0.29	0.25	0.19	0.14	0.14
Saunders's Gull	0.26	0.26	0.18	0.15	0.15
Blue-tailed Bee-eater	0.26	0.17	0.17	0.20	0.20
Purple Swamphen	0.27	0.3	0.17	0.13	0.13
Great Cormorant	0.28	0.22	0.17	0.17	0.16
Greater Coucal	0.20	0.20	0.16	0.32	0.12

Source: Developed based on expert interviews

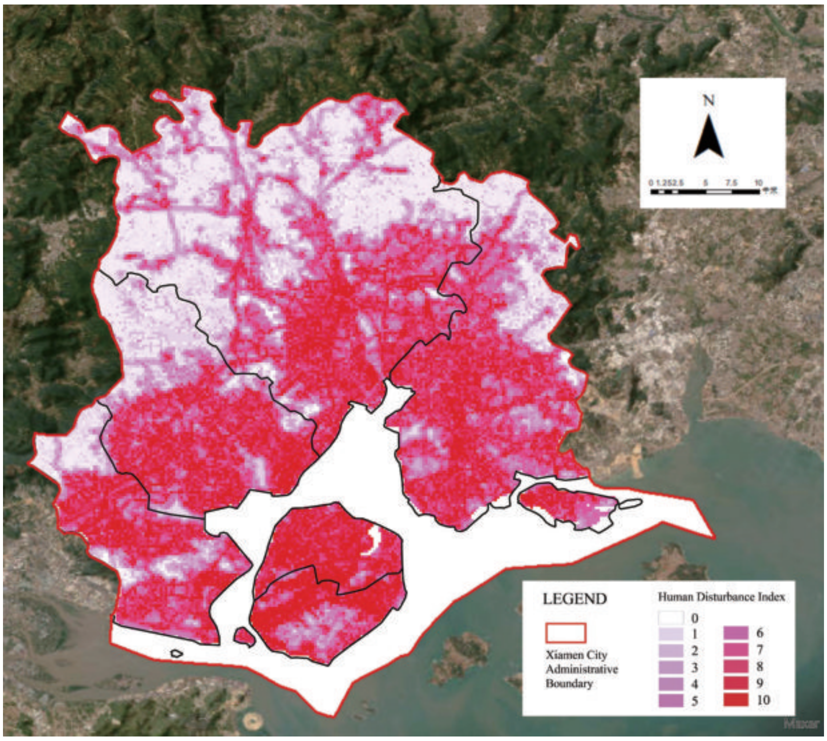

Figure 4-37: Chinese Egret Disturbance Index
Source: author's illustration

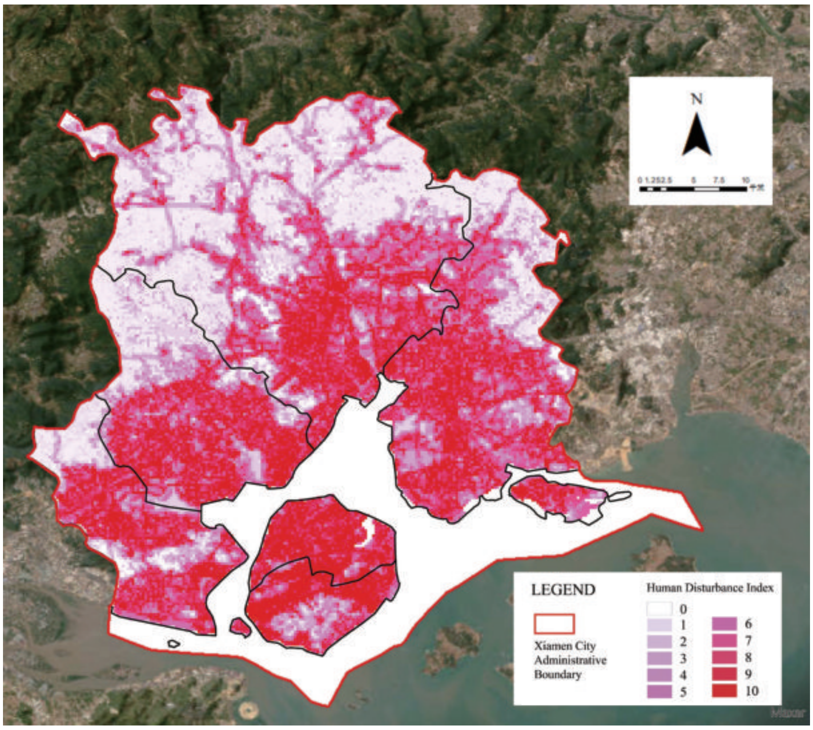

Figure 4-38: Saunders's Gull Disturbance Index
Source: author's illustration

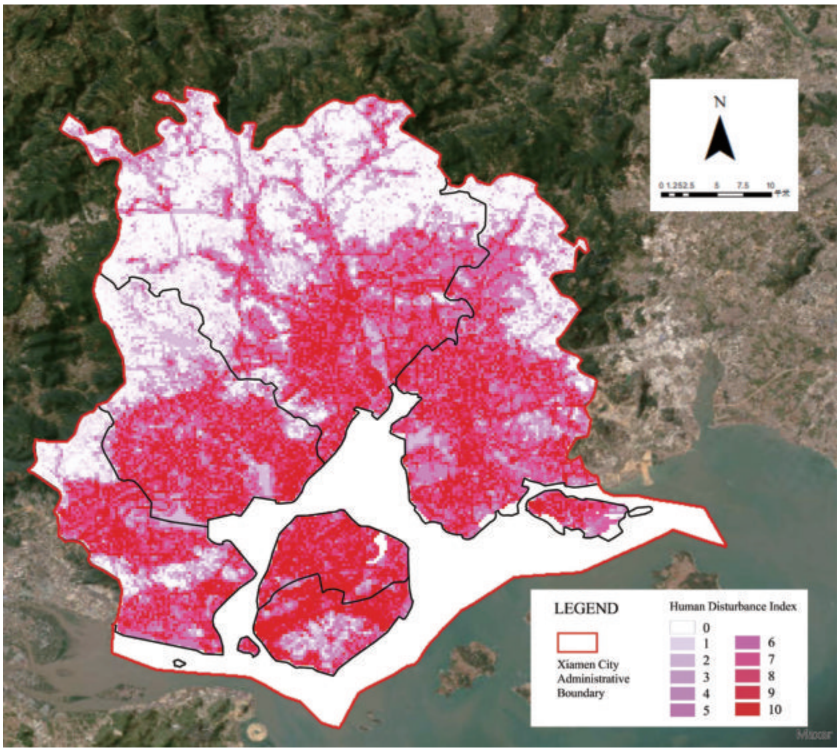

Figure 4-39: Blue-tailed Bee-eater Disturbance Index
Source: author's illustration

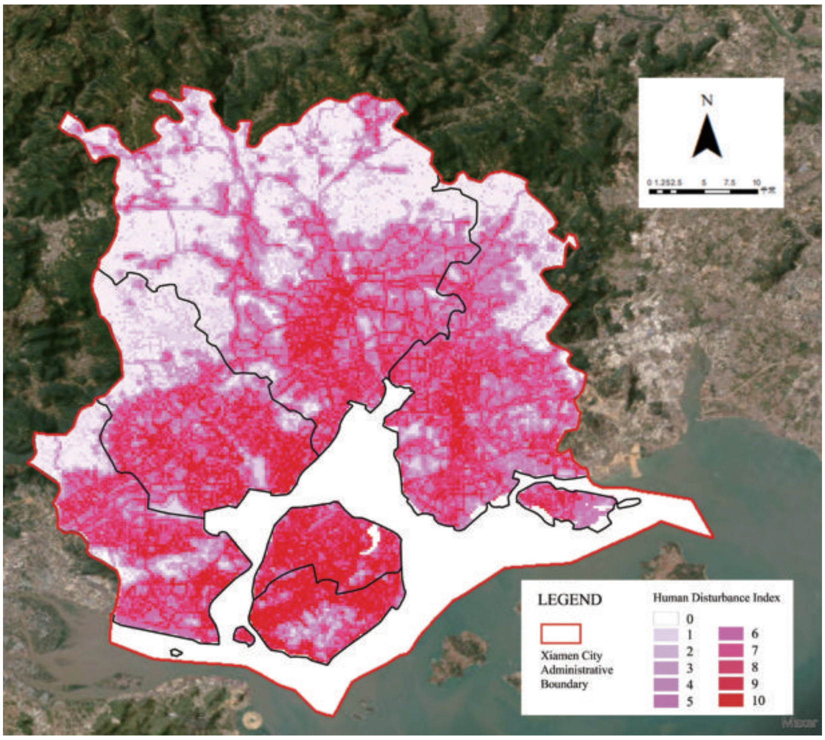

Figure 4-40: Purple Swamphen Disturbance Index
Source: author's illustration

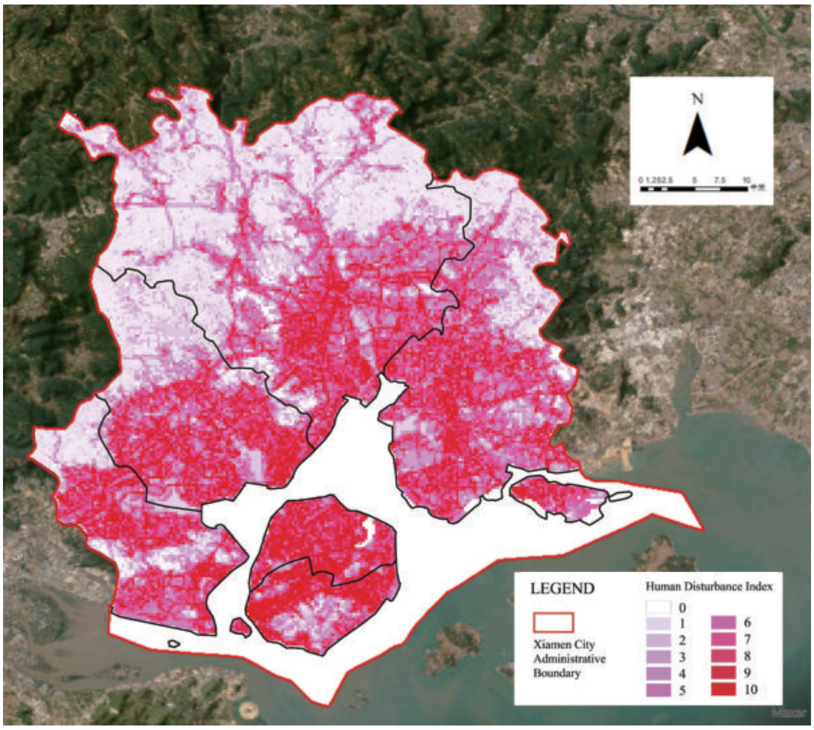

Figure 4-41: Great Cormorant Disturbance Index
Source: author's illustration

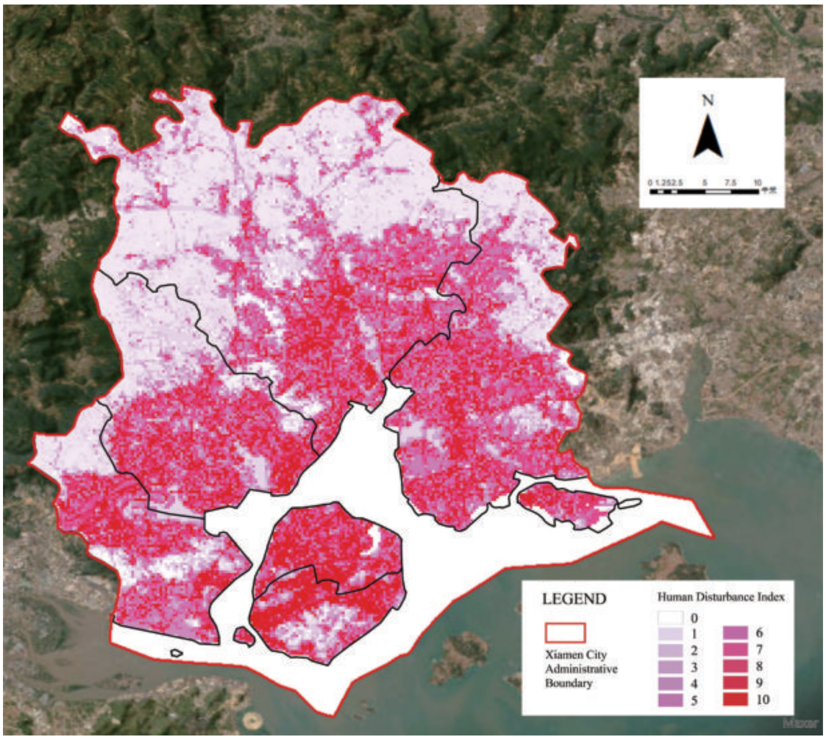

Figure 4-42: Greater Coucal Disturbance Index
Source: author's illustration

4.2.4 Construction of the habitat protection network

(1) Identification of source habitats

Establishing a biodiversity conservation network in an urban context involves using available species-distribution data to evaluate the ecological functions and relative importance of habitat patches. From this evaluation, habitat "Source" areas of particular significance for biodiversity conservation are identified, serving as the foundation for targeted conservation and management recommendations. Source habitats are defined as patches of particular conservation significance. Given that the habitat of the Chinese White Dolphin is highly dynamic, influenced by variations in water quality and depth, this report first conducts an empirical study to construct a terrestrial habitat-protection network based on six target bird species.

The procedure for identifying Source habitats comprises: **1. Mapping the predicted potential distribution for each target species; 2. Deriving species-specific habitat suitability maps that incorporate the anthropogenic-disturbance indices; 3. Calculating a Habitat Importance Index for each patch and identifying Source habitats accordingly.**

Species-specific suitability thresholds are used to evaluate the suitability of habitat patches for terrestrial target species. Based on the Habitat Suitability Index, patches of high conservation value are identified as Source habitats (Figure 4-49). The calculation formula is as follows:

(1) Suitability Threshold = Habitat Characteristic Value – Species Disturbance Index

Habitat Characteristic Value: Each habitat patch is assigned 0 or 1 based on the species' potential distribution probability. Patches with high-probability potential distribution areas (probability > 0.65, as determined by expert consultation) are assigned a value of 1; all others are assigned 0.

Potential terrestrial distribution: A habitat patch is considered a potential distribution area for a given target species when all ecological attributes of the patch meet that species' habitat requirements. Distribution modeling was conducted individually for the six target species: Chinese Egret, Saunders's Gull, Blue-tailed Bee-eater, Purple Swamphen, Great Cormorant, and Greater Coucal. (To reduce bias from spatial clustering and prevent model overfitting, occurrence records for each species were spatially filtered using SDMs tools, applying a 1-km threshold to retain only one record per grid cell. Based on habitat mapping and informed by species' ecological preferences, six environmental predictors were selected: habitat type, distance to inland water bodies, distance to the sea, distance to forest, distance to wetlands, and elevation. All predictors were resampled to a uniform 30 m × 30 m grid resolution. Occurrence and environmental data were input into MaxEnt, using a 75%/25% training/testing split. Models were resampled with the bootstrap method, each repeated ten times; the mean output across runs was taken. The Area Under the ROC Curve (AUC) values ranged from 0.795 to 0.923. The composite species-distribution probability for each grid cell was defined as the maximum predicted probability among the six species (Figures 4-43 through 4-48).

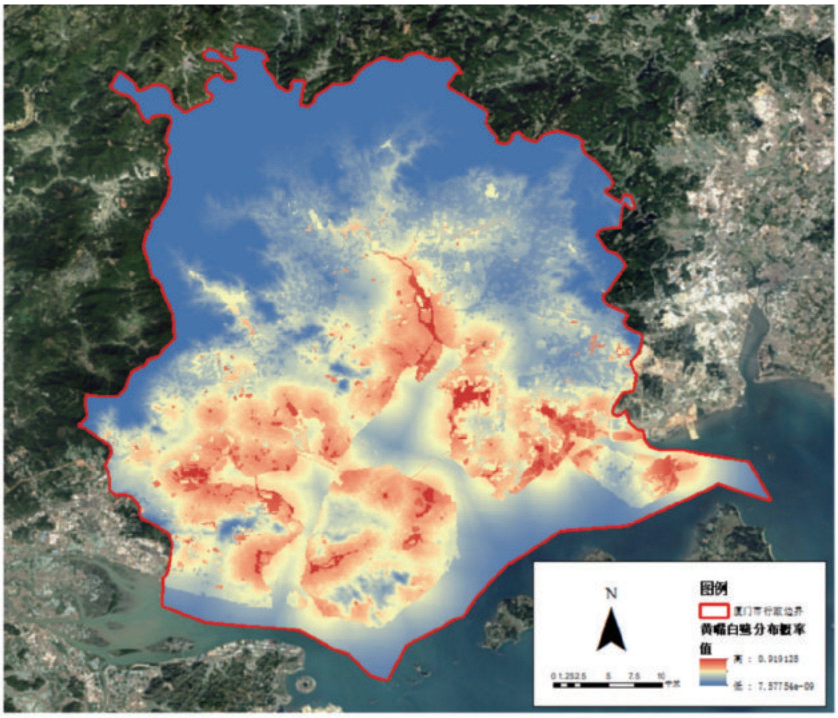

Figure 4-43: Potential Distribution Map of the Chinese Egret
Source: author's illustration

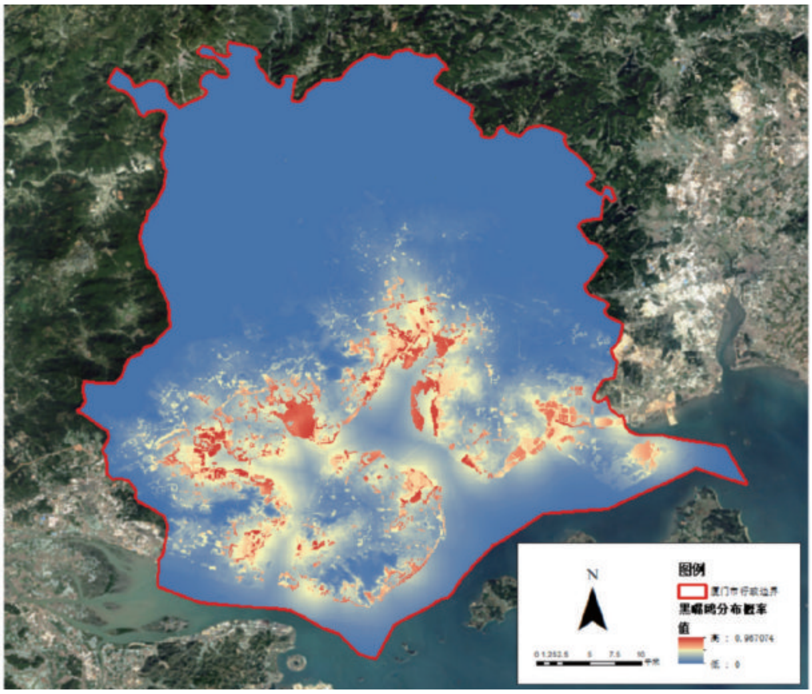

Figure 4-44: Potential Distribution Map of the Saunders's Gull
Source: author's illustration

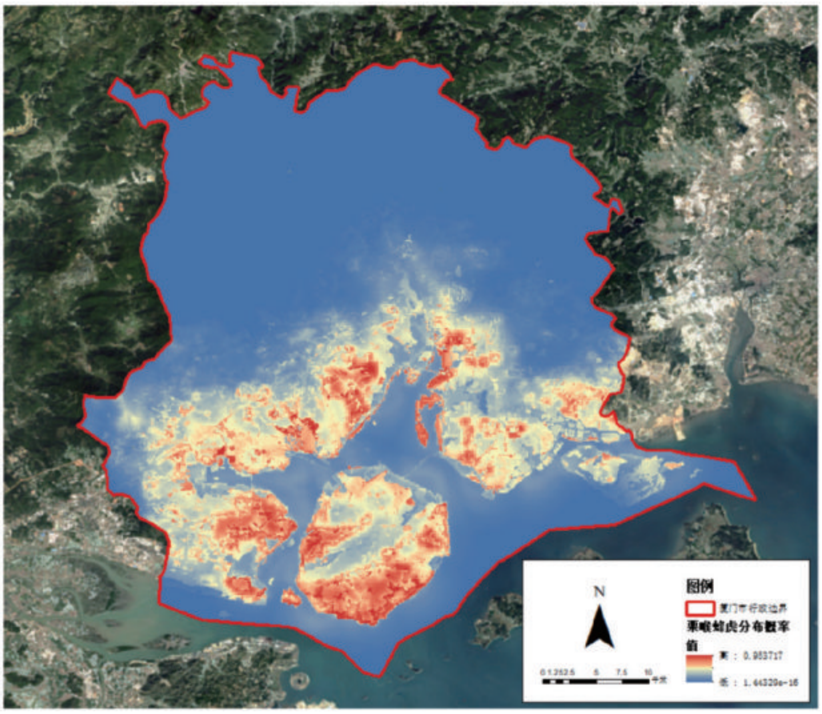

Figure 4-45: Potential Distribution Map of the Blue-tailed Bee-eater
Source: author's illustration

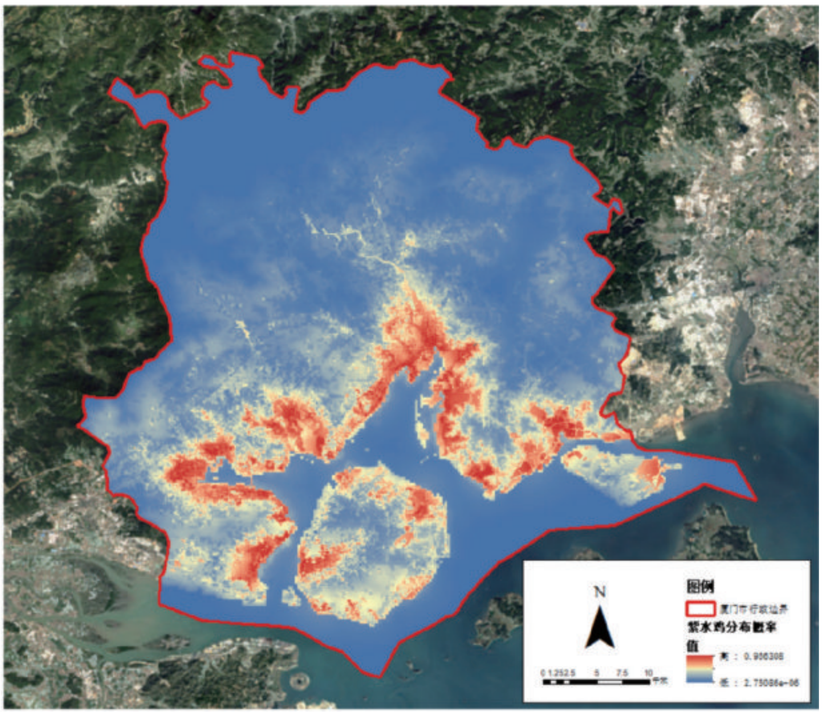

Figure 4-46: Potential Distribution Map of the Purple Swamphen
Source: author's illustration

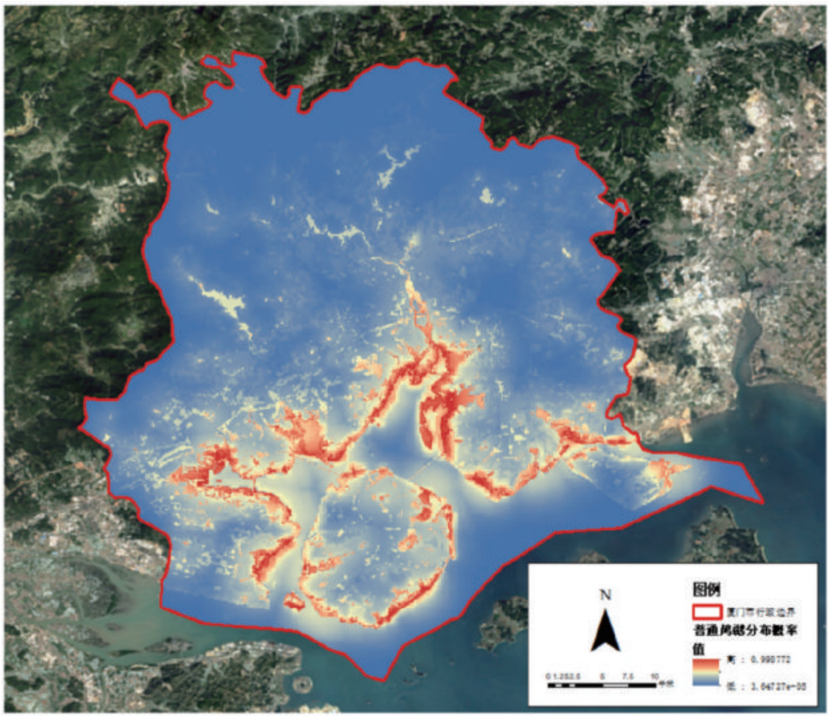

Figure 4-47: Potential Distribution Map of the Great Cormorant
Source: author's illustration

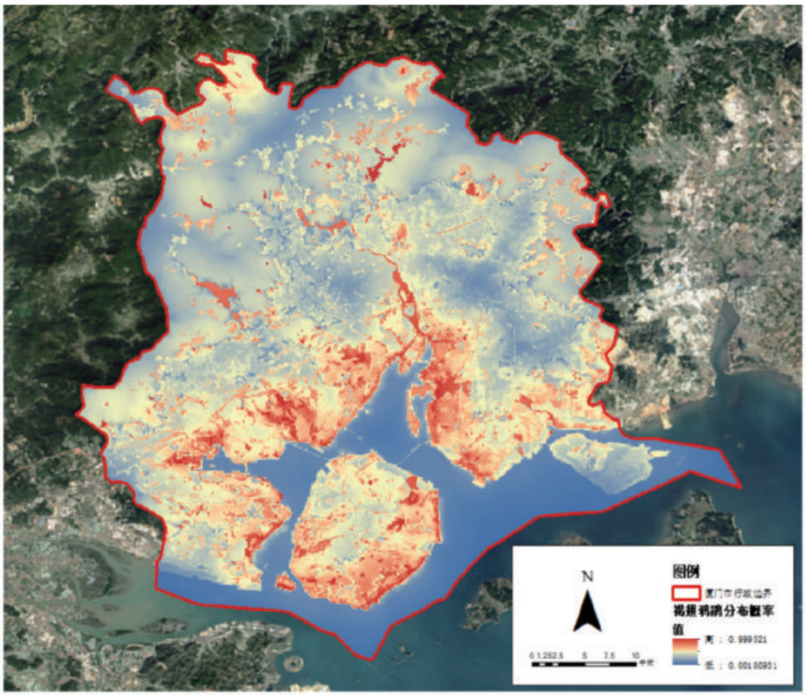

Figure 4-48: Potential Distribution Map of the Greater Coucal
Source: author's illustration

The anthropogenic-disturbance indices computed in Section 4.2.3 were normalized, and Formula (1) was applied to calculate species-specific habitat suitability thresholds. Threshold maps for the six target species were then overlaid to generate the Species Suitability Threshold Map (Figure 4-49).

Considering the role of protected areas in urban biodiversity, **existing protected areas were combined with high-suitability patches to define Source habitats** (Figure 4-50).

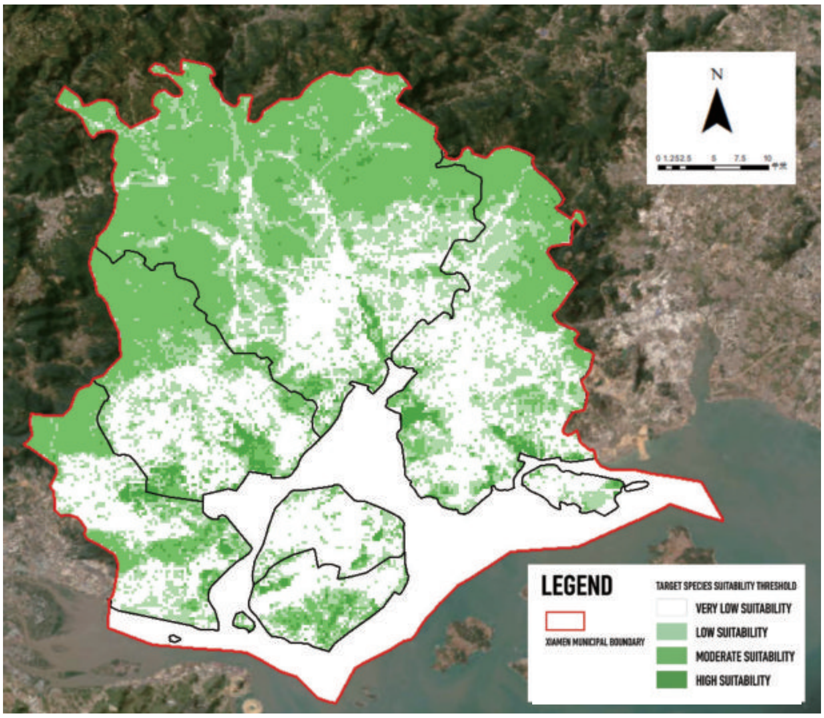

Figure 4-49: Results of Suitability-Threshold Calculations
Source: author's illustration

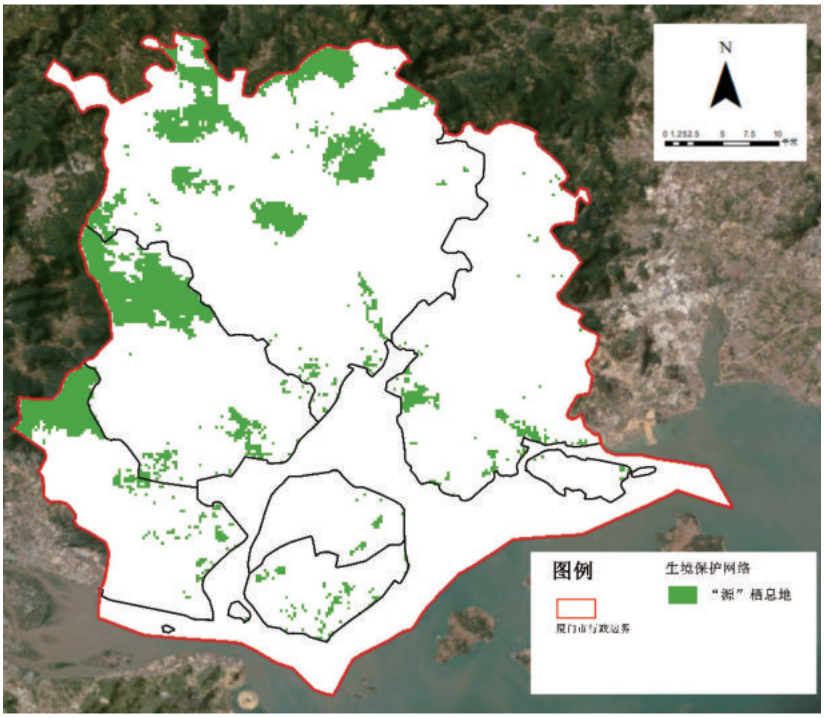

Figure 4-50: Identification of "Source" Habitats
Source: author's illustration

(2) Identification of buffer zones

Buffer zones are habitat patches surrounding Source areas that provide basic habitat or possess restoration potential. These patches are generally less optimal than Source habitats regarding habitat attributes, anthropogenic disturbance, and species suitability. Nevertheless, they satisfy one or more basic ecological needs of target species, serving as stopover sites or stepping stones during movement. **Anthropogenic-disturbance indices for the six target species were overlaid to create a species-migration resistance surface (Figure 4-51). Based on this surface, buffer habitats minimally impacted by human disturbance were identified as critical connectivity areas (Figure 4-52).**

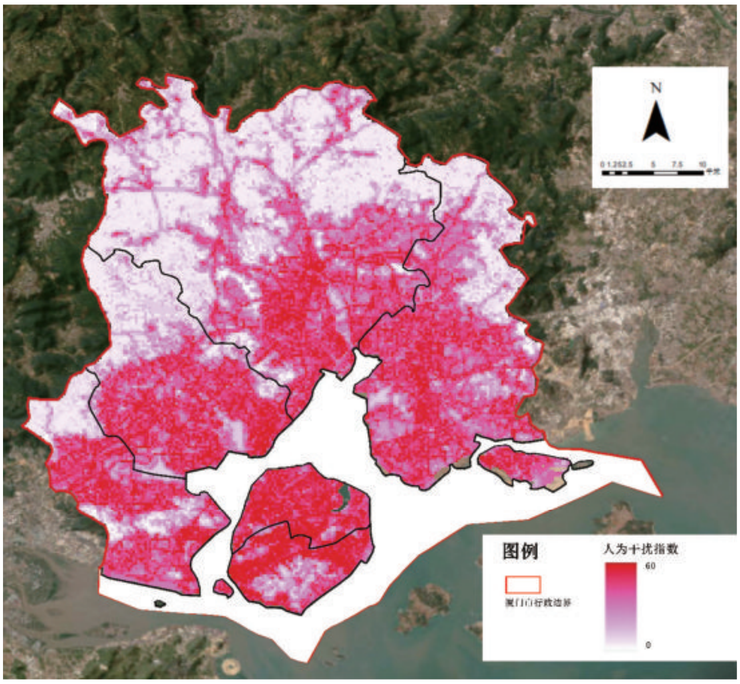

Figure 4-51: Resistance Surface
Source: author's illustration

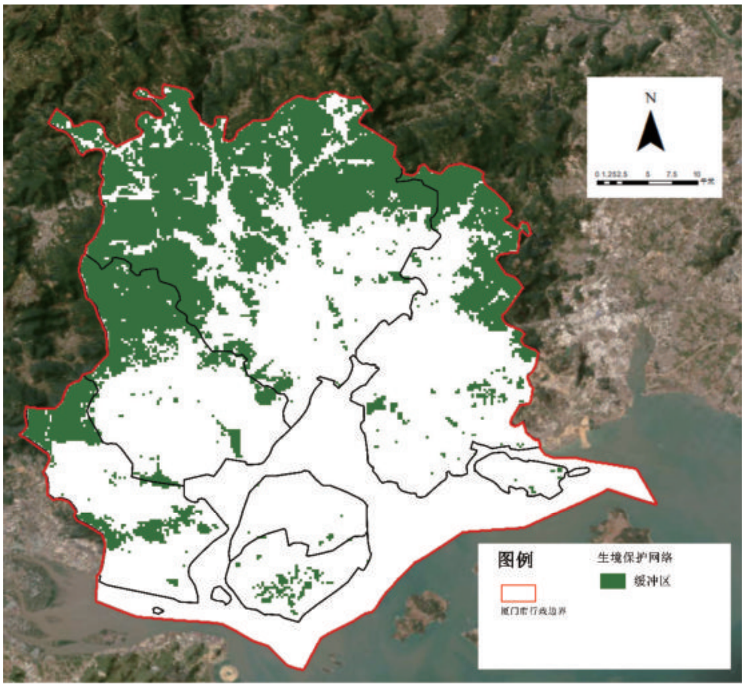

Figure 4-52: Buffer Zones
Source: author's illustration

(3) Corridor construction

Corridors are spatial links connecting Source areas, providing essential habitat elements for species during long-distance movements. Minimum Cumulative Resistance (MCR) modeling was implemented in ArcGIS using cost-distance and least-cost-path analyses to identify corridors (Figure 4-53).

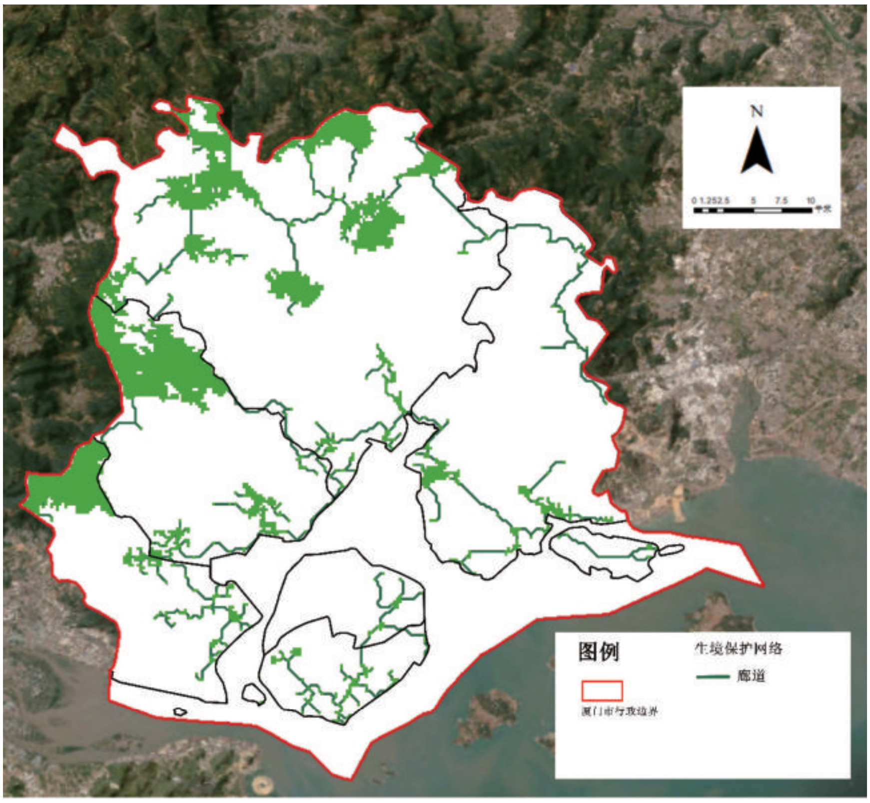

Figure 4-53: Corridors
Source: author's illustration

4.3 Recommendations for implementing Xiamen's biodiversity conservation plan

(1) Recommendations for optimizing the ecological spatial pattern

Analysis of Xiamen's Habitat Protection Network (Figure 4-54) indicates that **Source habitats on Xiamen Island are concentrated around Yundang Lake, Dongpingshan, Xiamen University, and Wuyuan Bay Park, whereas Source habitats off the island are mainly located in coastal wetlands and protected areas in the northern mountains. Compared with cities in biodiversity hotspot regions (e.g., some cities in Yunnan Province), Xiamen's urban Source habitats are smaller in total area and fewer in number. Buffer zones are primarily found in the northern mountains, while existing built-up areas hinder the formation of ecological corridors**.

To optimize the city's ecological spatial pattern, planning must be conducted at a city-wide scale, integrating island and offshore systems as well as terrestrial and marine ecosystems. Based on the current status of the Habitat Protection Network, the following recommendations are proposed:

- Protect and enhance Source habitats and other ecological core areas, and leverage these sites for ecological education and public outreach;
- Improve the quality and increase the extent of buffer zones, using ecological restoration projects to strengthen their function as ecological barriers;
- Promote coordination between ecological spatial planning, urban development, and economic growth. Reserve ecological space within urban master plans and integrate ecological principles throughout all phases of urban development. In urban renewal projects, adopt eco-city design approaches and

increase the number of internal ecological "stepping stones" (small habitat patches), forming the basis for additional internal ecological corridors and supporting concurrent ecological, economic, and social benefits;

- Institutional arrangements: establish a coordination mechanism for ecological spatial planning to enhance inter-departmental communication and cooperation, ensuring consistency in ecological protection policies and measures.

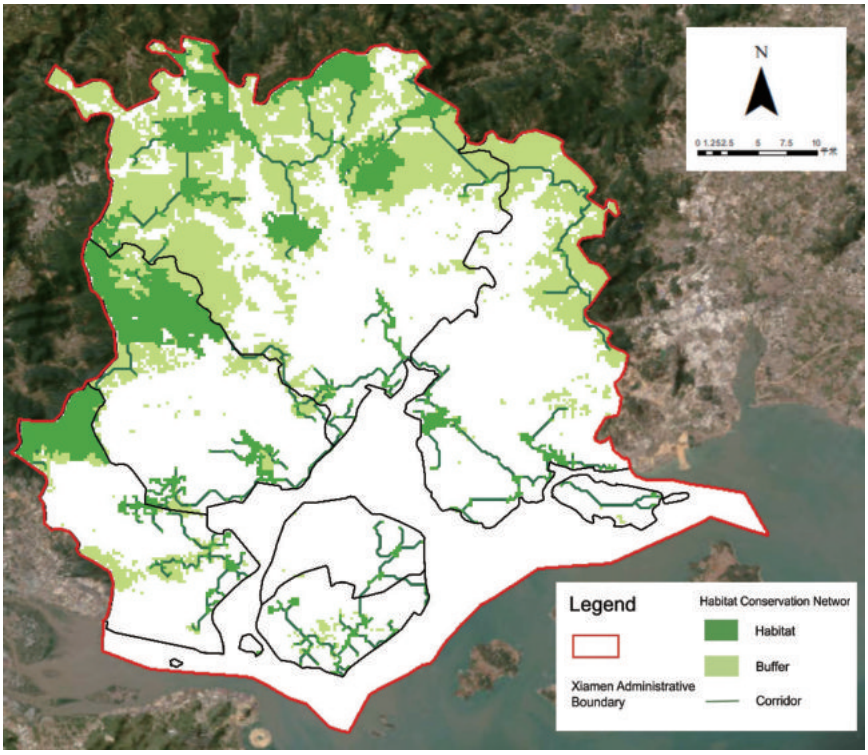

Figure 4-54: Habitat Protection Network Map
Source: author's illustration

(2) Recommendations for enhancing ecological restoration efforts

- The Habitat Protection Network results should be incorporated into ecological restoration planning, with targeted restoration measures proposed for Source habitats, Buffer zones, and Corridors.
- **On Xiamen Island, Source habitats** such as Yundang Lake, Dongpingshan, Xiamen University, and Wuyuan Bay Park function as the city's green lungs and major recreational areas. For urban water bodies like Yundang Lake, ongoing water-quality management and ecological restoration are recommended. Measures include establishing lakeshore/riparian wetland treatment strips, planting aquatic vegetation to improve water quality and restore aquatic communities (e.g., fish), enhancing the lakeside greenway system, and installing interpretive signage so residents can learn about the ecosystem while using the trails. Urban forests such as Dongpingshan should be strictly protected. Illegal structures should be removed, vegetation restored, and landscapes replanted primarily with native species. Multi-functional trails for hiking and fire prevention should be created, with suitable buffer zones maintained between forests and adjacent residential areas to preserve ecological integrity. Green-campus initiatives should be promoted at Xiamen University and nearby campuses, with underutilized spaces converted into small ecological gardens, maintained for vegetation health, and selectively opened to the public for environmental education and hands-on conservation practice. Urban ecological parks such as the Wuyuan Bay Park should further enhance wetland landscapes, provide bird-watching platforms or hides, and offer environmental-education programs in ways that do not disturb bird habitats.
- **Coastal wetlands and protected areas off the island** are critical ecological resources. Enforcement of wetland-protection regulations should be strengthened to prevent destructive activities such as land reclamation and illegal fishing. A routine ecological-monitoring system should track wetland indicators in near real-time where possible. Restoration outcomes should

be continuously evaluated, including monitoring growth of salt-tolerant vegetation such as mangroves to provide suitable breeding and foraging spaces for migratory birds and marine organisms. Controlled eco-tourism, including designated viewing routes, can allow visitors to enjoy the landscape while fostering environmental awareness.

- In **northern mountain buffer zones**, active forest management should be prioritized. This includes planned thinning of diseased or dead trees and replanting with native broadleaf species to enhance ecosystem stability and reduce wildfire risk. Ecological buffer belts should prevent agricultural and industrial pollution from encroaching on core areas, and all development projects must be strictly regulated to maintain ecological barrier functionality.
- To address the scarcity of urban Source habitats, underutilized urban spaces—such as areas under overpasses and vacant lots—should be ecologically redesigned as micro-habitats. Planting nectar- and pollen-producing plants and installing insect hotels can attract pollinators and other wildlife. Vertical greening on rooftops and building façades should be promoted **to create functional substitutes for natural stepping stones within ecological corridors**. Fragmented habitat patches should be connected using green bridges and vegetated corridors to facilitate species movement, enhance urban biodiversity, and make Xiamen's ecological space more cohesive and resilient.

(3) Recommendations for additional indicators in performance (health) assessment

- According to the Notice issued by the *Notice Issued by the General Office of the Xiamen Municipal People's Government on the Work Plan for Urban Health Examination and Evaluation of Territorial Spatial Planning*, only one mandatory indicator in Xiamen's territorial spatial-planning evaluation—the area of newly established ecological restoration—directly relates to biodiversity conservation. Based on relevant case studies and considering Xiamen's ecological context and biodiversity resources, the following additional indicators are recommended:
- Net change in bird species number: defined as the number of newly recorded bird species in the target year minus the number of bird species that have become locally extinct during the same period. The assessment should be based on the 2024 baseline biodiversity survey, combined with historical observation records from the Xiamen Bird Watching Society. The target is no net loss, or a slight increase in species number.
- Proportion of habitat area restored to good ecological function (%): calculated as (area of restored habitat) ÷ (area of originally degraded habitat) × 100%. This indicator measures efforts to restore fragmented habitats and to enable species within existing habitats to regain good ecological function.
- Proportion of invasive alien species (%): calculated for each taxonomic group as (number of invasive alien species) ÷ (total number of species in the group, including both native and invasive species) × 100%. This indicator reflects the threat posed by invasive alien species.
- Proportion of permeable area (%): calculated as (total permeable area, including natural areas, parks, and other pervious urban surfaces) ÷ (total urban area) × 100%. This indicator evaluates the city's capacity for rainwater infiltration and stormwater regulation.
- Urban tree canopy cover (%): calculated as (area of tree canopy cover) ÷ (total urban green space area) × 100%. This indicator assesses the capacity of urban greening to provide climate regulation services.

5 Conclusions and Future Plan

5.1 Preliminary conclusions

5.1.1 Objectives and positioning of urban biodiversity conservation planning

As a specialized planning instrument, urban biodiversity conservation planning should implement the requirements of regional and local *Biodiversity Conservation Strategies and Action Plans,* as well as other relevant policy documents. The plan should clearly define territory-wide biodiversity conservation requirements, including spatial zoning, regulatory controls, and priority habitat restoration. It should establish a coherent spatial configuration for biodiversity conservation, set avoidance requirements for major infrastructure projects, and guide the development of related specialized plans such as ecological restoration plans and ecological-space plans.

The planning framework must align with the five-level, three-category Territorial Spatial Planning (TSP) system. Vertically, it should ensure strategic consistency with national and provincial priorities, and provide actionable guidance for municipal-level planning, forming a clear pathway from national strategy through provincial zoning to municipal implementation. Horizontally, the plan should embed biodiversity considerations strategically within urban master and detailed plans, incorporate biodiversity assessment into the municipal "Double Evaluation" system, and strengthen coordination with other specialized plans addressing natural resource protection and utilization.

5.1.2 Technical methodology for urban biodiversity conservation planning

A comprehensive technical methodology has been developed, comprising five key components: multi-source data integration and analysis, habitat quality assessment, species distribution mapping, construction of a habitat-protection network, and formulation of conservation management recommendations. This methodology has been applied in a pilot study in Xiamen. The implementation steps are as follows:

Step 1: Compilation and integration of biodiversity information: Comprehensive surveys and data mining were used to collect and consolidate urban biodiversity information, including historical records and recent monitoring data.

Step 2: Assessment of habitat patch function and importance: Using Geographic Information Systems (GIS) and species distribution data, detailed analyses were conducted to evaluate each habitat patch's capacity to meet species' ecological requirements and its exposure to anthropogenic pressures.

Step 3: Identification of key habitats, buffer zones, and corridors: Spatial distributions of habitats, buffer areas, and ecological corridors critical for wildlife biodiversity were identified by combining assessments of habitat quality, patch support for species, and species dispersal potential. This approach highlights patches of high conservation significance.

Step 4: Formulation of conservation and management recommendations: Based on the habitat network, targeted recommendations were developed, including ecological restoration, habitat protection, construction of migration corridors, and sustainable-use planning. The objective is to establish a multi-level, interconnected biodiversity conservation system.

5.2 Future work plan

Future work will focus on improving the scientific rigor and spatial precision of the biodiversity-conservation habitat network and providing actionable recommendations for implementing Xiamen's biodiversity conservation plan. Additional data will be collected to refine species-specific weights for anthropogenic-disturbance factors, enabling a more robust and effective evaluation of human impacts on biodiversity. Expert consultation meetings will be convened to incorporate specialist input into refining recommendations for ecological spatial pattern optimization, enhancement of ecological restoration efforts, and implementation of additional indicators in urban health assessment. In addition, priority climate-change areas and actions will be integrated to propose measures that achieve co-benefits and synergies between biodiversity conservation and climate-change response initiatives.

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