

# 城市荒野景观营造： 以上海乡土生态科普示范基地为例

## Urban Wilderness Construction: An Example of Shanghai Urban Biodiversity Education Base

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摘要

恢复受损的城市生态系统是城市荒野景观的核心价值之一。通过城市荒野景观的营造，可在城市破碎化生境中恢复该地区原有生物群落的结构和功能，并在低人工干预的情况下，使乡土生物群落稳定地存在与演替。本文介绍了以生物多样性恢复为主要目的的“上海乡土生态科普示范基地”项目，项目探讨和研究了主动型城市再野化过程中应采取的设计原则与技术路径，并围绕这一目标进行了生境类型划分、乡土生物引种、生物群落构建、生态效益评估等一系列工作，以期丰富城市荒野景观营造及城市环境下基于自然的解决方案的技术积累与理论研究。在项目实施的一年半时间内，项目地共记录乡土植物260种、昆虫255种、两栖爬行动物7种、鸟类71种及哺乳动物6种，其生物多样性和动物的种群密度均远高于周边未改造的人工林地，并且植物群落已开始进行自发的正向演替，取得了较为理想的效果。该项目的技术方案在城市郊野公园、野生动物栖息地、生态廊道、科普教育基地等项目中有广阔的应用前景。

关键词

城市荒野景观；乡土物种；群落演替；城市生物多样性；生态修复；基于自然的解决方案

ABSTRACT

One of the core values of urban wilderness construction is to restore the structures and functions of biological communities in fragmented urban habitats, and enable the stability and ecological succession of native communities with low human intervention. The paper discusses the design principles and technical methodologies in active urban rewilding by the example of Shanghai Urban Biodiversity Education Base project. Aiming to restore urban biodiversity and enrich the technical and theoretical research of urban wilderness construction and Nature-based Solutions, this project conducted habitat division, native species introduction, natural community construction, ecological benefit assessment, etc. In a year and a half, 260 native plant species, 255 insect species, 7 amphibian and reptile species, 71 bird species, and 6 mammal species were recorded within the 1.7 hm<sup>2</sup> project site, showing higher biodiversity and density of animal populations than unrestored constructed forests surrounding. Along with the spontaneous progressive succession of the plant communities, the project has achieved good results. The technical approaches proposed in the project can be broadly applied in design and construction of country parks, wildlife habitats, ecological corridors / networks, and environmental education bases.

KEYWORDS

Urban Wilderness; Native Species; Community Succession; Urban Biodiversity; Ecosystem Restoration; Nature-based Solutions

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## 1 引言

根据联合国《生物多样性公约》，生物多样性是指地球上各个生态系统中所有具有生命的生物的多样性，包括生态系统多样性、物种多样性和遗传多样性三个层次<sup>[1]</sup>。目前对于生物多样性的保护与恢复措施大多集中在自然保护地，对于非自然保护地（尤其是城市地区）生态系统修复与保护的认知与关注尚显不足，将城市作为“生态系统”进行研究亟待更多理论与实践的积累<sup>[2]-[6]</sup>。已有研究表明，城市的生物多样性具有重要作用，且城市生态系统可支撑较高的生物多样性，其中涉及许多濒危物种与受胁物种<sup>[4][7][8]</sup>。更重要的是，城市生物多样性恢复与保护工作具有现实的迫切需求。城市地区承载了全球一半以上的人口<sup>[9]</sup>，而许多城市化进程发生在生物多样性的热点地区<sup>[10]</sup>，对生物多样性产生了深刻而不可逆的负面影响：直接表现为城市地表覆盖的改变导致自然生境的破坏、退化与破碎化，间接表现为加剧了气候变化，这些都造成了城市生物多样性的破坏与衰退<sup>[11]-[13]</sup>。

现有研究归纳了多种城市生物多样性保护的方法与策略<sup>[6]</sup>，如城市绿地管理中划定保护区<sup>[14][15]</sup>，协调城市土地利用与生物多样性保护<sup>[16]</sup>，将生物多样性融入城市设计<sup>[17]</sup>，以及促进城市荒野的发展<sup>[18][19]</sup>等。其中，城市荒野（urban wilderness）通常指城市中残留的自然保护地、修复过的自然生态系统、废弃荒地，以及人工设计的荒野景观<sup>[19]-[21]</sup>，其最突出的特征在于，虽处于人类活动密集区域中，却不受或较少受到人类干预、保留自然原貌并发生自然演替<sup>[22]-[24]</sup>。也有研究认为在城市范畴下，“城市野境”（urban wildscape）这一术语更适合描述城市中仍在进行自然演替且生态过程占主导的荒野景观，如城市内部或周边的自然林地、未利用或被遗弃的场地、河流廊道、棕地等<sup>[24]-[26]</sup>。曹越等人的研究将此语境下对城市荒野的保护与营造途径分为4种，即保护（在城市保护地中保护野性自然）、修复（再野化部分城市区域）、设计（在城市公园中营造类荒野景观）、融合（在城市空间中系统性融入野性自然）<sup>[24]</sup>。除了划定城市中及其边缘地带的自然保护地外，城市生物多样性的保护与恢复主要依赖于场地修复：一类是自然发生的被动型城市再野化，即城市废弃荒地经过自然演替形成野生动物栖息地；另一类是由人类介入引导的主动型城市再野化，即人类根据生态演替的规律对场地进行系统性生态修复。

由于被动型城市再野化历时长，对场地周围自然

连通性要求高，虽在国外有成功案例，但在国内大型城市中较难实现。我国城市建成区面积与人口规模远大于大多数国外城市，人类干扰更为频繁，且大多数城市的园林绿化并没有使用足够数量和种类的乡土物种，导致较难通过物种自然扩散的方式恢复生态系统结构和功能。在这种条件下，采取人为规划及引导的主动型城市再野化更具现实意义。目前，中国主动型城市再野化的成功案例尚不多见，仍处于研究探索阶段。本文以城市荒野工作室的“上海乡土生态科普示范基地”项目为例，介绍了以城市生物多样性恢复与保护为目的的主动型城市再野化技术路径与场地实践经验，以期丰富城市荒野景观营造及城市环境下基于自然的解决方案的理论研究与技术积累。

## 2 场地背景与修复设计

### 2.1 场地情况

该项目位于上海浦江郊野公园内。总面积1.7hm<sup>2</sup>，为国有林地；场地较为平整，无明显的地势变化；外围三面环水，内部无水系。在2019年7月实施改造前，工作室对现场进行了土质检测和植被调查。结果显示，场地内土壤较为粘重，有机物含量低，偏碱性（pH≥7.8）；种有香樟（*Cinnamomum camphora*）、女贞（*Ligustrum lucidum*）、意大利214杨（以下简称“意杨”，*Populus × canadensis* ‘I-214’）、梧桐（*Firmiana simplex*）等乔木和部分园艺品种的地被植物，植物种类较为单一。受土质与地形影响，排水不畅，植物生长状况不理想，女贞、梧桐等乔木已陆续出现死亡情况。外来物种入侵情况严重，在降雨多、气温高的6月，地表约60%的面积被喜旱莲子草（*Alternanthera philoxeroides*）与白车轴草（*Trifolium repens*）覆盖，约5%的面积被春飞蓬（*Erigeron philadelphicus*）、钻叶紫菀（*Symphotrichum subulatum*）、加拿大一枝黄花（*Solidago canadensis*）等菊科入侵物种覆盖（图1），乡土草本植物的生长受到明显抑制。

### 2.2 设计原则

项目旨在探索城市生物多样性恢复的技术路径，同时保育因城市发展而丧失栖息地的乡土生物。围绕生物多样性恢复的主要目标，工作室制定了如下设计原则：

1) 使用长三角地区乡土植物的苗木，在场地区

件受限、苗木短缺及无法满足生态功能的情况下，可酌情选择少量具有相似生态功能的非乡土物种进行替换，但其比例不得超过植物总量的5%；

2) 以接近自然群落的结构进行植物配置，推动自然演替；

3) 根据场地条件营造多样的生境类型，各生境类型之间借由植物种类的变化自然过渡，杜绝人工构筑物或绿篱分隔，以保证野生动物的活动不受限制；

4) 确定重点研究和保育的生物种类，并以特定野生动物的取食及栖息特点选择植物、营造生境；

5) 道路、护栏、解说牌、警示牌等设施以灰褐色、绿色为主色调，杜绝使用过于鲜艳的颜色，以免使野生动物受惊。

根据以上设计原则，工作室对场地进行了初步设计，而在实际施工过程中结合场地实际条件，进一步优化了地形、水系和植物等的设计。

### 2.3 技术流程

根据场地现状和项目目标，工作室结合群落演替规律制定了技术流程（图2）。

### 2.4 功能分区规划

该项目为生物多样性恢复技术的研究和展示基地，因此需要在有限的空间内营造尽可能多样的生境，最大限度提高可容纳物种的上限，方便未来的研

1. 改造前喜旱莲子草与白车轴草混生的草地，后方为死亡的女贞。

1. Before restoration, *Alternanthera philoxeroides* and *Trifolium repens* covered the site with dead *Ligustrum lucidum* behind.



### 3 项目实施

#### 3.1 基础环境改造

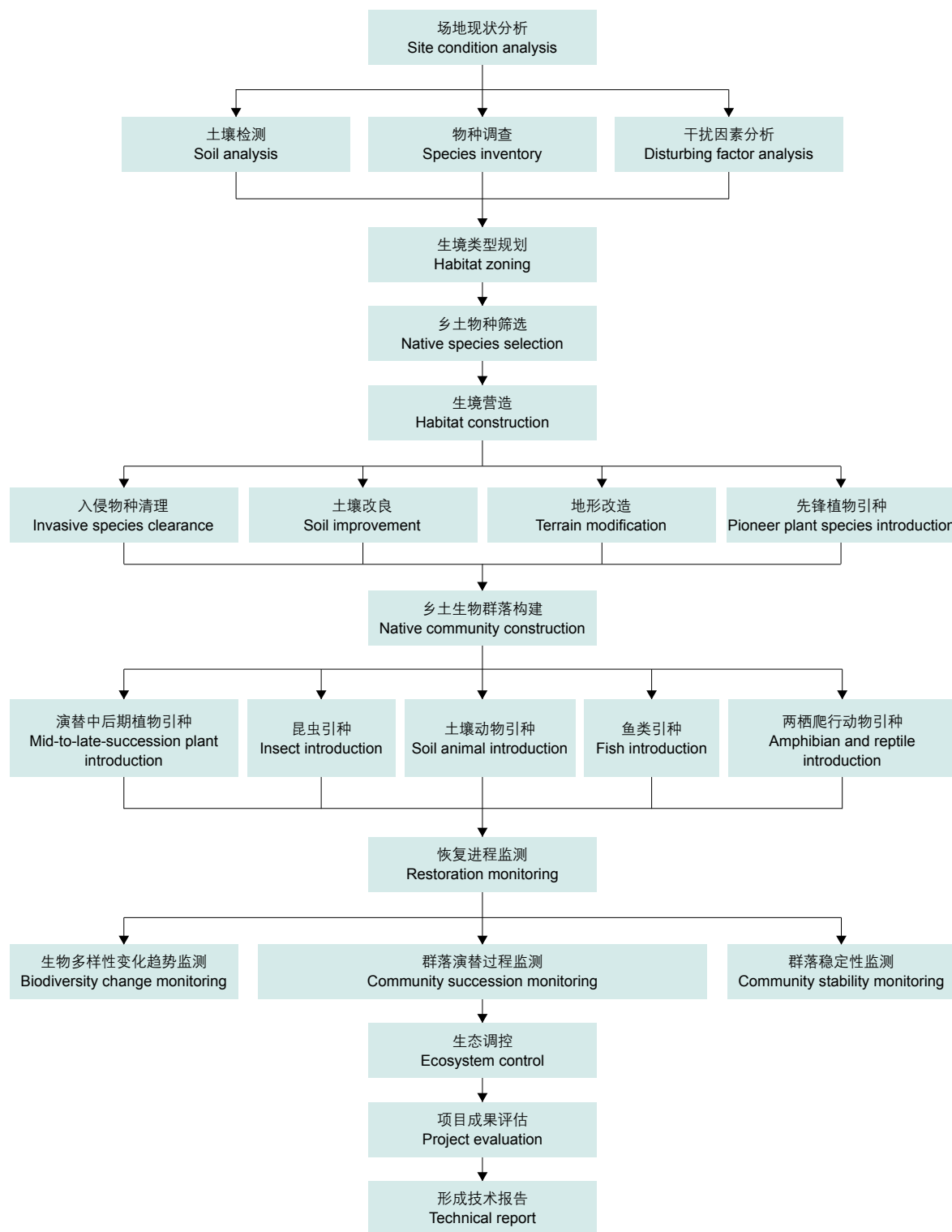
在施工阶段，工作室遇到了以下难点：1) 场地内部缺少水系，难以为水生生物和两栖动物提供栖息环境；2) 土质较差、排水不畅导致树木不断死亡；3) 入侵物种数量较多，无法通过人工拔除有效控制；4) 现有林地不能移栽或砍伐，地形无法完全按要求改造。

针对以上问题，工作室首先进行了地形调整和水系营造：在场地中央空旷处挖掘小型池塘，使用水泵抽取场地北侧外部河道水进入内部水系，流经池塘后沿人工小溪流入南侧外部河道；将场地内的排水沟与池塘连通，增强雨季排水能力。挖出的土方则在东侧落叶林中堆高形成缓坡，用于种植不耐水湿的乡土乔木（图3-2）。

地形改造完成后，采用人工和机械结合的方式对场地进行了整体翻耕，同时施加腐熟的园林垃圾，增加土壤有机质。根据工作室以往项目的经验，翻耕可以打破入侵物种目前的优势，给土壤种子库中的乡土植物种子创造萌发的机会，从而形成禾本科先锋植物与入侵物种相竞争的局面，辅以人工调控，逐渐扩大禾本科植物的竞争优势。这一方法能够显著降低入侵物种的盖度与发芽率，为接下来乡土植物的群落构建打下基础。此外，为满足未来科研需求，工作室在场地中增设了电路、无线网络、灌溉系统和监控系统。

#### 3.2 乡土生物群落构建

有别于人为干预强度较大的景观营造方式，城市荒野景观需要使用乡土物种构建合理的群落结构，使其自发演替。在土壤翻耕后，除原有乔木外，场地上的其他植物已经被人工清除（可将此时的场地视为生态学意义上的“次生裸地”），当新的植物开始生长，漫长的次生演替过程就此发生：喜光、耐贫瘠、种子萌发率高且生长迅速的先锋物种（如部分禾本科植物和由鸟类传播的速生木本植物）会最先出现，在演替初期覆盖地表的大部分面积。随着先锋物种的生长，树荫面积不断扩大，喜光的禾本科植物逐渐被耐阴植物取代；林下湿度增加，顶级群落建群种的幼苗开始萌发，经年累月逐渐取代先锋树种成为这片林地的优势种。在土壤种子库足够丰富的前提下，这一过程中会出现大量的演替中期植物，但总体趋势不变。



2. 技术流程示意图

3-1. 基于生物群落差异的生态功能分区

3-2. 改造后场地航拍图（摄于2020年6月）

2. Diagram of the technical roadmap

3-1. Ecological zoning based on community differences

3-2. Aerial photography of the optimized site (June, 2020)

究和教学。工作室根据现有场地条件，将其划分为7个不同的生态功能区：乡土蝶类招引区、乡土灌木展示区、乡土水生生物保育区、乡土常绿树种区、科普活动区、乡土常绿/落叶树种混交区，以及乡土落叶树种区（图3-1）。

该项目中的每一个功能分区实质上就相当于一种乡土生物群落，也都遵循着上述演替过程。物种的引入不是一蹴而就的，而是需要在3~5年的时间里，不断根据环境的变化引入不同的物种，在不违背演替规律的情况下增加群落内的生物多样性。除了增加植物的多样性外，对于具有重要生态功能但无法自然迁移至项目地的动物（如鱼类、两栖动物及扩散能力较差的昆虫等），还需在生境营造满足其生存需求后进行人为引种。下文将以乡土水生生物保育区、科普活动区、乡土常绿树种区和乡土落叶树种区为例，介绍对应生物群落的营造过程。

水生生物保育区位于项目的中轴线，其中心为一个人工挖掘的小型水塘（图4），水塘面积约100m<sup>2</sup>，最深处约1.5m，未进行防渗处理。水塘内种植刺苦草（*Vallisneria spirulosa*）、眼子菜（*Potamogeton distinctus*）等沉水植物（图5），并投放方形环棱螺（*Bellamya quadrata*）、圆顶珠蚌（*Unio douglasiae*）等底栖生物。二者均有助于水质净化，为其他生物的引入创造了条件。一个月后，逐渐引入高体鳊（*Rhodeus ocellatus*）、青鳉（*Oryzias latipes*）等十余种乡土鱼类。由于水塘面积较小，为保证水塘生态系统的平衡与稳定，不得引入乌鳢（*Channa argus*）等捕食能力过强的鱼类。2019年9月至2020年8月，陆续引种乡土水生、湿生植物30种，进一步增加了该区域的生物多样性，国家二级保护植物粗梗水蕨（*Ceratopteris pteroides*）已在水塘西北侧的浅滩上建立了稳定的种群。

位于水塘西侧的是科普活动区的草地，种有糠稷（*Panicum bisulcatum*）、荩草（*Arthraxon hispidus*）、狗牙根（*Cynodon dactylon*）、竹叶茅

（*Microstegium nudum*）等乡土草本植物（图6）。由于禾本科植物较多，短额负蝗（*Atractomorpha sinensis*）、中华稻蝗（*Oxya chinensis*）、迷卡斗蟋（*Velarifictorus micado*）等直翅目昆虫数量丰富，为蛙类提供了充足的食物。工作室观测到金线侧褶蛙（*Pelophylax plancyi*）、泽陆蛙（*Fejervarya multistriata*）、黑斑侧褶蛙（*Pelophylax nigromaculatus*）、饰纹姬蛙（*Microhyla ornata*）、中华蟾蜍（*Bufo gargarizans*）在此活动（图7）。

规划的常绿树种区原本为一片樟树林。由于郁闭度过高，喜阳植物无法存活，因此工作室在林下栽种了菜蕨（*Diplazium esculentum*）、双穗求米草（*Oplismenus undulatifolius var. binatus*）、紫金牛（*Ardisia japonica*）、朱砂根（*Ardisia crenata*）等本土阴生植物。在春夏季，斑驳的阳光照在林下低矮的阴生植物上，景观效果出色（图8）。此外由于林下光照较弱，适宜作为陆生萤火虫黄脉翅萤（*Curtos costipennis*）的栖息地。经过一年的引种和复育工作，已有少量萤火虫出现（图9）。

意杨林所在的落叶树种区位于场地东侧。由于意杨并非上海的乡土植物，且生长过速、病虫害较多、林木稀疏，工作室计划用乡土落叶树种逐渐取而代之。区域内已有较多构树（*Broussonetia papyrifera*）、桑（*Morus alba*）等先锋树种个体借助鸟类传播自发生长。在不进行疏伐的情况下栽种榔榆（*Ulmus parvifolia*）、朴（*Celtis sinensis*）、楝（*Melia azedarach*）、椿叶花椒（*Zanthoxylum ailanthoides*）、枳椇（*Hovenia acerba*）等十余种乡土落叶树种。随着意杨因病虫害、台风等自然因素死亡，该区域可逐渐恢复为以乡土落叶树种为主的群落。

## 4 生态效益评估

### 4.1 生态恢复进程监测

城市荒野景观产生的生态价值是高度人工化的园林所不可替代的，但尚未形成有效、合理的评估标准。在该项目的整个营造过程中，城市荒野工作室及华东师范大学生态与环境科学学院共同对植物、昆虫、两栖动物、鸟类和哺乳动物进行了持续监测，以初步评估该项目的生态价值。

植物调查通过普查整理植物名录，并结合样方法采集不同生境类型中的植物及林下环境数据。昆虫调查针对不同物种分别采用网捕法、巴氏罐诱法、灯诱法、扫集法、振落法和搜捕法，记录场地内昆虫物种及数量。两栖动物调查采用样线法，观察记录水边或周围草丛中的两栖动物种类及数量。鸟类调查同样采用样线法，记录其种类和数量。哺乳动物调查采用红外相机监测法，统计兽类活动时间、出现频率等数据。

自开始施工至2020年11月，场地内共记录到乡土植物260种、昆虫255种、两栖爬行动物7种、鸟类71种及哺乳动物6种，其多样性和动物的种群密度均远高于周边未改造的人工林地。昆虫的多样性对于病虫害防控十分重要，工作室还特别开展了对城市传粉昆虫种类及与植物对应关系的监测和研究（图10）。

在植物和昆虫的多样性足够高的情况下，鸟类会被食物吸引而来，监测中还发现鸟类在场地内的筑巢数量较多。2019年冬季，小太平鸟（*Bombycilla japonica*）等较为罕见的鸟类在这里成群越冬（图11）。在哺乳动物方面，经过一年以上的红外相机调查，可确定场地内东北刺猬（*Erinaceus amurensis*）、

- 1 乡土蝶类招引区  
Native Butterfly Attracting Zone
- 2 乡土灌木展示区  
Native Shrub Zone
- 3 乡土水生生物保育区  
Native Aquatic Species Conservation Zone
- 4 乡土常绿树种区  
Native Evergreen Tree Zone
- 5 科普活动区  
Environmental Education Activity Zone
- 6 乡土常绿/落叶树种混交区  
Mixed Native Evergreen/Deciduous Tree Zone
- 7 乡土落叶树种区  
Native Deciduous Tree Zone





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黄鼬 (*Mustela sibirica*)、黑线姬鼠 (*Apodemus agrarius*) 均有稳定的种群；并且自2020年9月开始，监测到有华南兔 (*Lepus sinensis*) 在场地内长期停留 (图12, 13)。但同时也发现，流浪猫对黑线姬鼠和鸟类的捕食情况十分严重，未来需要加强监测和管理。

理论上，本项目应在施工前一年对项目地的生物多样性开展调查，以便客观对比、评估改造前后的生物多样性变化情况。但由于施工前预留时间过短，改造前并未对场地进行充分调研。未来或可考虑通过以附近未改造林地参照的方式来研究其生物多样性的变化趋势。

#### 4.2 生态调控

一般而言，城市荒野景观具有较高的生物多样性，并且以自然演替为主，人为干预为辅，因此养护

工作量较小，但技术难度较高，需严禁使用任何化学杀虫剂，否则会对生物多样性造成显著负面影响。就实际情况而言，项目场地内螳螂、瓢虫、寄生蜂和蜘蛛等捕食性昆虫和节肢动物数量较多，对维持昆虫种群的平衡起到了显著作用，因此该项目从未也无需使用任何杀虫剂，就能保证植物健康生长 (图14)。

此外，项目未对自然死亡的树木和枯枝落叶等园林垃圾进行外运处理。死亡树木锯成数段后堆放在林下，任其自然腐朽 (图15)。随着真菌对树木的分解，拟步甲、锹甲等甲虫会在朽木中产卵，其幼虫以朽木为食，可加速分解过程。通常在3~5年内，大部分朽木会被分解为松软的有机质，可用于改善土壤。草本和树叶则任其自然凋落，在冬季形成落叶层，为土壤动物提供理想的栖息环境。

养护过程中最大的工作量在于对外来入侵植物的

防控。在项目实施前，场地内喜旱莲子草、春飞蓬、加拿大一枝黄花等入侵植物的数量十分庞大，若单纯依靠人工清理，工作量巨大，且效果不理想。项目大量应用乡土植物中糠稷、荇草、狗牙根等先锋草本植物，迅速挤占了入侵植物的生长空间，入侵植物的覆盖率在一年内从65%降低到5%。剩余入侵物种需要在开花前人工拔除以防再次扩散。这一步骤的工作量主要取决于场地内原有入侵物种数量，而入侵物种会随着乡土植物群落结构的稳定逐渐减少。相关案例可见工作室于2016年实施的建设项目，经过4年的自然演替和人工防控，截至2020年，入侵物种已无法构成威胁 (图16) [27]。

除上述内容外，其他养护工作主要为道路保洁、设备维护，以及处理台风等自然灾害带来的植物折断、死亡问题，养护成本远低于常规绿地。

## 5 城市荒野景观的科普功能

由于场地内生境类型多样、乡土生物群落结构较为完整，相比于常规的公园绿地，可开展的科普活动种类更加丰富，效果也更好。自2020年5月对外开放以来，场地中共开设自然教育课程18门，累计4 500人次参加；其中亲子夜间生物观察活动累计已有1 500人次参加，以项目生态修复过程为主题开展的职业体验课程“小小城市生态修复师”获评全国科普日优秀活动。随着场地中生物多样性的不断提升，未来将设计更具有本土特色的课程体系。为了配合课程的开展，项目还设计了一套基于生态学的解说系统。有别于常规的植物解说牌，解说内容并不着重于植物结构和分类的介绍，而是用通俗易懂的语言从生态学的角度阐释物种间的关系，更具有故事性和趣味性，解说牌的所有物种图均为手绘图，以便展示生物最典型的结构和形态（图17，18）。

## 6 结语

过去，主动型城市再野化的实践中常常存在以下误区：1）忽视群落结构与功能，将“生物多样性”简单地理解为“更多物种”，设计施工中欠缺参照本地生态系统生态演替规律进行设计与调控的思维；2）把重点仅放在“造林”上，将“生物多样性”简单地理解为“植物多样性”，或认为只要提高场地的植物多样性，动物多样性就“自然

而然”地恢复，因而忽视动植物之间生态过程的综合影响，无法使城市荒野的植物设计真正满足动物的需求；3）忽视植物的遗传多样性，将“生物多样性”局限于“物种多样性”，施工中并未对选用苗木的产地和繁育方式加以区别（相比扦插和组织培养，实生苗具有更高的遗传多样性），所营造的城市荒野缺乏完善的生物多样性优化功能；4）对于城市荒野的功能界定模糊，将城市再野化项目等同于类荒野景观的营造，在审美、游憩需求与生物多样性保护功能（如栖息地营造、生态廊道/生态网络构建）之间难以平衡，场地设计目的不明。而受限于前述设计施工的误区，后期运营上的更多功能（如相关科学研究监测以及生态科普教育活动等）难以实现。

生物多样性的恢复与维持是城市荒野景观的重要目的与功能之一。为实现其价值，设计施工应遵循生态学规律，充分考虑不同生物类群对栖息地和食物的需求，以乡土物种构建可自然演替的生物群落。本项目探讨和研究了主动型城市再野化过程中应采取的生物多样性恢复技术手段，并围绕这一目标进行了生境类型划分、乡土生物引种、生物群落构建、生态效益评估等一系列工作，取得了较为理想的效果。但作为一个半封闭状态的实验性项目，该项目并未对市民的游憩和景观审美需求做出积极回应。生物多样性恢复与人类活动需求有机结合是城市荒野景观营造期望实现的目标，但二者存在天然的矛盾，工作室仍在探索解决这一问题的适宜技术和设计方法。

目前，中国的城市荒野景观营造还处于探索阶段，其设计理念、技术路径、苗木采购乃至养护管理均缺

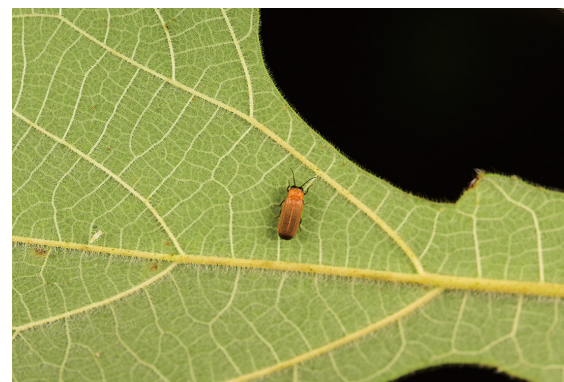
乏可供借鉴的成熟案例，还需要进行大量的基础研究才能推广应用，因此短期内实现难度较大。但随着生态文明建设的不断推进，城市荒野景观的生态功能将会受到前所未有的重视，在郊野公园、野生动物栖息地、生态廊道、科普教育基地等项目中有广阔的应用前景。此外，低廉的维护成本也是促进其发展的一大优势。随着人力成本不断上升，养护要求不高的部分城市林地更加适宜采用这一方式进行营造。LAF

### 项目信息

项目地址：中国上海市浦江郊野公园内  
项目面积：1.7hm<sup>2</sup>  
景观设计：城市荒野工作室  
首席设计师：郭陶然  
项目团队：谢惊华、山冰沁、魏羚峰、董佳、蒲川、马泽豪  
设计时间：2019年7月至今

4. 2020年8月的池塘
5. 水生生物保育区种的龙舌草 (*Ottelia alismoides*)
6. 场地中的小溪及草地
7. 场地中出现的金线侧褶蛙
8. 林下阴生植物群落
9. 场地中出现的黄脉翅萤

4. Pond in August, 2020
5. *Ottelia alismoides* in the Aquatic Species Conservation Zone
6. The creek and grassland on the site
7. *Pelophylax plancyi* on the site
8. Understory shade-tolerant plant communities
9. The *Curtos costipennis* on the site



## 1 Introduction

According to the United Nations Convention on Biological Diversity, “biological diversity” means the “variability among living organisms from all sources including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems”<sup>[1]</sup>. Currently, most of the measures for biodiversity conservation and restoration are implemented in protected areas, while those outside of protected areas, especially in urban areas, are still insufficient, indicating that studying urban areas as an “ecosystem” needs more theoretical and practical support<sup>[2]-[6]</sup>. Previous studies show that urban ecosystems are able to harbor relatively high urban biodiversity, including many endangered and threatened species<sup>[4][7][8]</sup>. More critically, the conservation and restoration of urban biodiversity are urgent at present, since over half of the global human population lives in urban areas<sup>[9]</sup>. However, urbanization sometimes occurs in biodiversity hotspots<sup>[10]</sup>, causing profound and irreversible negative effects on biodiversity: destruction, degradation, and fragmentation of natural habitats directly led by urban surface change, and indirect exacerbation of climate change, all of which have resulted in urban biodiversity loss<sup>[11]-[13]</sup>.

Previous studies conclude several approaches and strategies for urban biodiversity conservation<sup>[6]</sup>, including the designation of protected areas that are increasingly complemented by integrative approaches arguing for a biodiversity-friendly management of green spaces<sup>[14][15]</sup>, a reconciliation of urban land use and biodiversity conservation<sup>[16]</sup>, the integration of biodiversity in urban design<sup>[17]</sup>, and / or the promotion of urban wilderness<sup>[18][19]</sup>. Here, urban wilderness refers to remaining natural protected areas, restored natural ecosystems, abandoned wilderness areas, and wilderness landscape designed by humans<sup>[19]-[21]</sup>, with its feature of

being intact in ecological succession and free from human interventions though located in human settlements<sup>[22]-[24]</sup>. Other studies suggest that in the context of “urban areas,” the term “urban wilderness” suits better to describe urban wildscapes where succession occurs and ecological processes dominate in cities, such as natural forests, unused land, river corridors, abandoned sites, or brownfields inside or around the city<sup>[24]-[26]</sup>. In such context, Cao Yue et al. categorized the protection and construction of “urban wilderness” into 4 approaches: protection (of wild nature in urban protected areas), restoration (by rewilding specific urban areas), design (of wildscapes in urban parks), and integration (of wild nature into urban areas systematically)<sup>[24]</sup>. Besides identifying natural protected areas within cities and suburbs, conservation and restoration of urban biodiversity depend mainly on ecosystem restoration for certain sites through two paths: one is the natural succession from urban wastelands to wildlife habitats, i.e. the passive urban rewilding; and the other is the active urban rewilding guided by human intervention, meaning that humans conduct systematic ecosystem restoration based on the natural laws of ecological succession.

Although with successful cases abroad, passive urban rewilding is difficult to achieve in large Chinese cities as it takes a long time and requires high connectivity to nature around the sites. Due to the large built area and population size, human interference is more frequent in most Chinese cities. In addition, there are insufficient native species used in landscape architecture practices, resulting in obstacles in restoring the ecosystem structures and functions through the natural spread of native species. Thus, it is more practical to take an active urban rewilding approach with proper planning and guidance. Currently, with rare successful cases, active urban rewilding in China still needs more research and practices. This paper, taking Shanghai Urban Biodiversity Education Base project started in 2019 by Forest

City Studio as an example, introduces the field practices and technical methodologies in active urban rewilding to enrich the technical and theoretical research on urban wilderness construction and Nature-based Solutions in urban environments.

## 2 Site Background and Design

### 2.1 Site Conditions

The project site is located in Shanghai Pujiang Country Park, occupying a state-owned forest of 1.7 hm<sup>2</sup>, where there was a flat terrain without obvious topographical shifts. The site was surrounded by water on three sides, with no internal water system. Before the restoration by the project in July 2019, the project team conducted soil analyses and vegetation surveys. The results show that soils on the site were sticky and alkaline (pH ≥ 7.8) with low organic content, and plant species were limited, including merely *Cinnamomum camphora*, *Ligustrum lucidum*, *Populus × canadensis* ‘I-214’, and *Firmiana simplex* trees, and some horticultural ground covers. Trees such as *Ligustrum lucidum* and *Firmiana simplex* suffered mortality due to the poor drainage under certain soil texture and terrain conditions, while native herbaceous plant species were suppressed by invasive species—in humid and hot June, 60% of the site surface was covered by *Alternanthera philoxeroides* and *Trifolium repens*, and 5% by Asteraceae species such as *Erigeron philadelphicus*, *Symphotrichum subulatum*, and *Solidago canadensis* (Fig. 1).

### 2.2 Principles of Design

Aiming to explore the technical methodologies of urban biodiversity restoration and conserve native species losing habitats due to urban development, the project team established following 5 principles:

1) Use native nursery stocks of the Yangtze River Delta. In case that site conditions are

limited or stocks are insufficient that cannot satisfy the ecological functions, no more than 5% of the total plant species could be replaced with non-native species that have similar ecological functions;

2) Design quasi-natural plant communities to foster ecological succession;

3) Based on site conditions, create a variety of habitats where they transit naturally to others via the change of plant species composition, and eliminate any artificial structures or hedges to guarantee wildlife activities;

4) Identify significant species for research and conservation, and select plant species and / or create habitats based on the foraging and / or perching features of certain wild animals;

5) Set facilities of roads, guardrails, commentary signs, and warning signs mainly in gray, brown, or green tones, and eliminate the use of particularly bright colors that may frighten wild animals.

Based on the design principles above, the team made a preliminary design plan for the site, and further optimized the terrain, water system, and plant design considering the actual site conditions.

### 2.3 Technical Roadmap

In accordance with the site conditions and project goals, the team formulated the technical roadmap, shown in Figure 2, based on the law of community succession.

### 2.4 Function Zoning

As to providing a base for biodiversity restoration technology research and exhibition, it is necessary to create habitats as diverse as possible within the limited space, harboring maximal species to facilitate future research and public education. According to existing conditions, the site was divided into 7 ecological function zones, including Native Butterfly Attracting Zone, Native Shrub Zone, Native Aquatic Species Conservation Zone, Native Evergreen Tree Zone, Environmental Education Activity Zone, Mixed Native Evergreen / Deciduous Tree Zone, as well as Native Deciduous Tree Zone (Fig. 3-1).

## 3 Project Implementation

### 3.1 Basic Environmental Optimization

During the construction process, the project team confronted the following difficulties: 1) The site lacked an internal water system, failing to provide habitats for aquatic and amphibian species; 2) Increasing number of trees died due to the poor soil quality and drainage; 3) Too many invasive species to effectively control by manual pulling; 4) The state-owned forests were not allowed to move or cut, which restricted the terrain modification.

To address the above issues, the project team first carried out topographic modification and

water system construction. Small ponds were dug in open space in the center of the site, filled with water pumped from the outside river on the north side of the site, forming an internal water system that flows along the constructed creek into the outside river on the south. In addition, ditches were connected with the outside rivers to enhance drainage during the rainy season. All excavated soils formed a pile with gentle slopes in the eastern forests, where wet-intolerant native trees were planted (Fig. 3-2).

After modifying the terrain, the project team adopted a combination of manual and mechanical methods to conduct an overall plowing for the site and fertilized it with decomposed garden wastes to increase soil organic matter. The team's previous experiences have proved that plowing helps break the dominance of invasive species so that the native plants in the soil seed bank can germinate. In this manner, the pioneer species of Poaceae could gradually outcompete invasive species with proper human intervention and then dominate. This approach will significantly reduce the coverage and germination rates of invasive species, providing vantage for native plant community construction. Additionally, electric circuits, Wi-Fi, irrigation systems, and monitoring systems were set to support future research.

### 3.2 Native Community Construction

Different from intensively managed



10-1



10-2



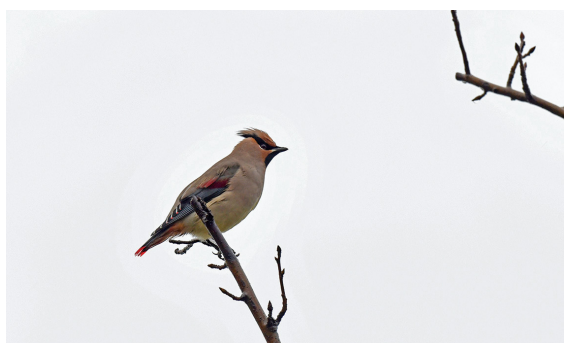
10-3



10-4

10. 独居蜂大多属于传粉昆虫，对植物多样性的维持具有重要意义。而和营社会性生活的蜜蜂 (*Apis* spp.) 不同，独居蜂营独居生活，偏好在植物空茎、树洞、石缝内营巢。本项目为研究独居蜂对筑巢生境和传粉植物的偏好，在7种生境类型中各搭建一组人工蜂巢（图10-1，内部为供独居蜂筑巢用的芦苇秆），成功吸引到切叶蜂 (*Megachilidae* spp.)，图10-2为切割过的叶片在此筑巢（图10-3，10-4）。

10. Most solitary bees, vital pollinators to maintain plant diversity, prefer nesting in hollow stems, tree holes, or gaps between rocks, rather than living socially in colonies as honeybees (*Apis* spp.) do. To investigate the preference of solitary bees regarding nesting habitat and plants, 7 bee hotels are set one per habitat (Fig. 10-1, the reed stalks for solitary bees to nest), successfully attracting *Megachilidae* spp. (Fig. 10-2 showing leaves that are cut) to nest (Fig. 10-3, 10-4).



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11. 小太平鸟 (摄于2019年12月)  
12. 红外相机拍摄到的黄鼬  
13. 红外相机拍到的华南兔

11. *Bombycilla japonica* (December, 2019)  
12. *Mustela sibirica* recorded by camera trap  
13. *Lepus sinensis* recorded by camera trap

landscapes, urban wilderness is constructed with reasonable community structures by utilizing native species to guarantee spontaneous succession. After plowing, all plants except trees are cleared manually, creating a “secondary bare area” in an ecological context, and an endless secondary succession takes place when new plants grow. At the beginning stage, most areas of the site will be covered by sun-loving, robust, highly-germinated, and fast-growing pioneer plant species such as some Poaceae plants and

woody plants spread by birds, who will bring expanding shade and increasing humidity under the canopy. Then the sun-loving grasses will be replaced by shade-tolerant plants while the climax species are germinating, gradually replacing the pioneer species and dominating the forests. If the soil seed bank is sufficiently abundant, a large number of mid-successional plants will appear in this process, but finally, they will reach similar climax communities.

Each function zone in this project is essentially a native community, following the above succession processes. Species will be introduced constantly during 3 to 5 years according to the changes in the environment and natural laws of succession to increase biodiversity. Animals with important ecological functions who cannot migrate to the site (e.g. fish, amphibians, and insects with poor dispersal ability) will also be introduced to the site after creating habitats that meet their survival needs. The following examples of the Native Aquatic Species Conservation Zone, Environmental Education Activity Zone, Native Evergreen Tree Zone, and Native Deciduous Tree Zone demonstrate the processes of community construction.

The Native Aquatic Species Conservation Zone is located at the central axis of the site with a 100-square-meter man-made pond in the middle (Fig. 4), whose deepest depth is about 1.5 meters without anti-seepage treatment. Submerged plants such as *Vallisneria spinulosa* and *Potamogeton distinctus* (Fig. 5), and benthos such as *Bellamya quadrata* and *Unio douglasiae* were introduced into the pond. A month after introduction when they began to help purify the water, a dozen of fish species such as *Rhodeus ocellatus* and *Oryzias latipes* were introduced gradually. Considering the limited pond size, the introduction of predators such as *Channa argus* will be restricted to maintain ecological equilibrium and ecosystem stability. From September 2019 to August 2020, 30 native

aquatic plant species were introduced to the site and further increased the biodiversity there: *Ceratopteris pteridoides*, a second-class protected plant species in China, has established a stable population on the northwest shoal of the pond.

The grassland west to the pond, i.e. the Environmental Education Activity Zone, is the place for native herbs such as *Panicum bisulcatum*, *Arthraxon hispidus*, *Cynodon dactylon*, and *Microstegium nudum* to grow (Fig. 6). Feeding on plentiful Poaceae plants, Orthoptera insect species, e.g. *Atractomorpha sinensis*, *Oxya chinensis*, and *Velarifictorus micado*, became abundant, thus attracting frogs including *Pelophylax plancyi*, *Fejervarya multistriata*, *Pelophylax nigromaculatus*, *Microhyla ornata*, and *Bufo gargarizans* to the grassland (Fig. 7).

The *Cinnamomum camphora* forest was restored as the Native Evergreen Tree Zone by planting native shade-tolerant plants, such as *Diplazium esculentum*, *Oplismenus undulatifolius* var. *binatus*, *Ardisia japonica*, and *Ardisia crenata*, under the forest due to high canopy density. In spring and summer, sunlight passes through the tree foliage, sparkling on the underbrush, which produces excellent landscape effects (Fig. 8). This weak light condition in the understory is also suitable for the terrestrial firefly *Curtos costipennis*. After one year of introduction and breeding, a small number of fireflies have appeared in this zone (Fig. 9).

The forest of *Populus × canadensis* ‘I-214’ in the Native Deciduous Tree Zone on the east side of the site was planned to be replaced by native deciduous trees due to their non-native origin, fast-growing, pests and diseases, and poor quality. Before restoration, pioneer trees spread by birds such as *Broussonetia papyrifera* and *Morus alba* have been growing spontaneously in the zone. A dozen of native deciduous trees including *Ulmus parvifolia*, *Celtis sinensis*, *Melia azedarach*, *Zanthoxylum ailanthoides*, and *Hovenia acerba* were planted without thinning

*Populus × canadensis* 'I-214' who will die out due to (a)biotic factors e.g. pests or typhoons. The zone then will gradually get restored with native deciduous tree domination.

## 4 Ecological Benefit Assessment

### 4.1 Monitoring of Ecosystem Restoration Process

The ecosystem services and their value provided by urban wilderness are irreplaceable by artificial gardens. However, effective or reasonable assessment criteria have not been developed yet. During the restoration of the site, the project team and the School of Ecological and Environmental Sciences at East China Normal University have cooperated to conduct continuous monitoring of plants, insects, amphibians, birds, and mammals to assess the ecosystem services of the project.

Plant surveys including general investigation and relevés were adopted to inventory the flora and (a)biotic data in various habitats. Insect surveys utilized aerial nets, Barber pitfall traps, light traps, sweep nets, beating sheets, and / or observation worksheets to collect insects and record their species and individual numbers on the site. Both richness and abundance of amphibians were observed and recorded via

the line-transect method, i.e. walking along the designed routes surrounding the water and tussocks. Birds were surveyed by the same method but along different routes.. Mammals are monitored by camera traps to record data, e.g., the time and frequency of animal activities.

Till November 2020, the project team has recorded 260 native plant species, 255 insect species, 7 amphibian and reptile species, 71 bird species, and 6 mammal species within the project site since restoration, showing higher biodiversity and animal population density than unrestored artificial forests surrounding. As insect diversity plays an important role in pest and disease control, monitoring and researching the particular linkage between urban pollinator insects and plant species were conducted (Fig. 10).

When plants and insects diversity are high enough, birds will be attracted by food. A high frequency of birds was found nesting on the site. In the winter of 2019, some rare bird species, e.g. *Bombycilla japonica*, migrated to the site for the winter (Fig. 11). Stable populations of mammals, such as *Erinaceus amurensis*, *Mustela sibirica*, and *Apodemus agrarius*, are found on the site after over-one-year monitoring. Meanwhile, the team also recorded *Lepus sinensis* staying on the site since September 2020 (Fig. 12, 13). However,

the threat to *Apodemus agrarius* and birds from stray cats is severe, which needs further monitoring and management in the future.

Theoretically, biodiversity surveys should be conducted within one year before the restoration to better compare and evaluate the changes of biodiversity before and after restoration. However, limited by the short preparation period of the project, biodiversity data before restoration are insufficient. In the future, a comparison between the project site and unrestored forests surrounding may be doable to reflect the trend of biodiversity changes on the project site.

### 4.2 Ecosystem Control

Generally, urban wilderness with high biodiversity is mainly under natural succession and supplemented by human intervention, thus requiring relatively lower but more technical maintenance. No chemical pesticides on the site are allowed so as to minimize negative impacts on biodiversity. In fact, the abundance of carnivorous arthropods such as mantises, ladybugs, parasitoid wasps, and spiders can help maintain the equilibrium of insect populations. Therefore, the project enabled the healthy growth of plants without any pesticide (Fig. 14).

Additionally, all green wastes, including leaf

14. 场地中出现的一种寄生性青蜂 (Chrysididae sp.)



14  
© 马萍

15. 场地中被真菌分解的朽木



15  
© 郭陶然

16. 建成于2016年的上海宜嘉苑生态保育区，这里生长有乡土植物260种，已形成稳定的群落结构。



16  
© 郭陶然



17  
© 郭晓然



18  
© 郭晓然

litter or naturally dead trees sawn and piled in the understory for natural decay, remain on the site (Fig. 15). As fungi decompose the wood, darkling beetles and stag beetles will lay eggs where decayed and their larvae feeding on the rotten part will accelerate the decomposition. Within 3 to 5 years, most wood will decompose into organic matter, which can be used to improve soil quality. Without human intervention, herbs and leaves wither naturally, creating a layer of litter in winter, which provides suitable habitats for soil animals.

The heaviest maintenance workload is invasive plant control as a large number of invasive plants such as *Alternanthera philoxeroides*, *Erigeron philadelphicus*, and *Solidago canadensis* existed on the site before restoration. Manual clearance is too heavy to be feasible or efficient. Therefore, a large number of pioneer plant species, such as *Panicum bisulcatum*, *Arthraxon hispidus*, *Cynodon dactylon*, are grown, which quickly occupied the space, and as a result, the coverage of invasive plants was reduced from 65% to 5% within one year. The remaining needs to be manually removed before they flower to prevent further expansion. The workload at this step mainly depends on the abundance of invasive species that gradually decrease as the native plant community becomes stable. Another similar project completed by the project team started in 2016, where invasive species were no longer a

threat after 4 years of ecological succession and manual control by 2020 (Fig. 16)<sup>[27]</sup>.

In addition to the above, other maintenance work mainly includes road cleaning, equipment maintenance, and management of plant breaking or death caused by natural disasters such as typhoons. The cost of maintenance is much lower than that of traditional green spaces.

## 5 Environmental Education Function of Urban Wilderness

Compared to traditional green spaces, the site has more diverse habitats and a relatively complete community structure, for which a larger variety of environmental education activities with better feedback can be organized. Since the open of the site in May 2020, 18 environmental education courses have been offered, with 4,500 participants attending, among which a parent-child activity about nocturnal species observation has attracted 1,500 person-times; a course about experiencing professional ecosystem restoration, called “Little Restoration Specialist,” was awarded the “Outstanding Activity on National Science Popularization Day.” The team plans to develop a curriculum system with more local characteristics in the future as the biodiversity of the site is being optimized. In addition, a set of explanatory signs based on ecological knowledge was designed to cooperate with the courses, which explain the relationships between

species with easy-to-understand and interesting words, instead of introducing plant structure or taxonomy. All species pictures are hand-drawn to better illustrate the most typical morphology of a creature (Fig. 17, 18).

## 6 Conclusion

Previous practices of active urban rewilding often have the following issues. First, they simply understood “biodiversity” as “more species,” resulting in ignorance of the community structures and functions, and fewer concerns on the law of ecological succession learning from the native ecosystems in designing and managing practices. Second, they often focused only on “tree planting,” understanding “biodiversity” as “plant diversity,” or deemed that animal diversity would be optimized “naturally” as long as plant diversity was increased, and therefore ignored the comprehensive interaction of ecological processes between animals and plants. As a result, those urban wilderness practices could not truly meet the needs of native animals. Third, they limited “biodiversity” to “species diversity,” ignoring genetic diversity, for which they did not distinguish the origins and breeding methods of the nursery stocks (plants growing from seed usually have higher genetic diversity than those by cuttings or tissue culture), resulting in urban wilderness without the capacity for biodiversity improvement. Fourth, they ambiguously defined

17. 隐藏在朽木中的解说牌，介绍了天牛蛀食导致树木死亡的过程。
  18. 乡土蝶类招引区长廊中的蝴蝶解说牌，便于儿童在活动过程中识别蝴蝶。
17. Information board hidden in decayed wood, introducing the process of longhorn beetles feeding on tree tissue and causing the death of a tree.
  18. Tour guide signs in the gallery of the Native Butterfly Attracting Zone help children identify butterflies during educational activities.

the urban wilderness construction as equivalent to wildscape design, without the clarification of urban wilderness functions, thus hardly balancing the aesthetic and recreational functions against biodiversity conservation (e.g., habitat creation and ecological corridor / network construction). Moreover, these issues further limited the future site management and operation (e.g., related scientific research, monitoring, and environmental education activities).

The restoration and maintenance of biodiversity are some of the important objectives and functions of urban wilderness. Thus, in both design and construction processes, the needs of different biological groups should be the main focus so as to create native communities with natural succession following ecological laws. The project explored the technical methodologies of

biodiversity restoration in active urban rewilding by conducting habitat division, native species introduction, natural community construction, ecological benefit assessment, etc., and has achieved positive results. However, citizens' recreational and aesthetic needs were to some extent ignored in this semi-enclosed experimental project. For future urban wilderness construction, integrating the seemingly contradictory biodiversity restoration and human activity needs should be an emphasis. Thus, the project team will continue exploring appropriate technology and design solutions to the problem.

Currently, urban wilderness construction in China still needs further research. Although mature design concepts, technical methodologies, seedling procurement, and even maintenance and management cannot be achieved overnight,

the ecological functions of urban wilderness are promising along with continuous and extensive basic research and advance of Ecological Civilization Construction in China. There are many application possibilities in country parks, wildlife habitats, ecological corridors, and environmental education bases. In addition, the low maintenance cost is a major advantage of urban wilderness which will be appreciated by urban forests requiring low maintenance, as labor costs continue to increase. **LAF**

#### PROJECT INFORMATION

**LOCATION:** Pujiang Country Park, Shanghai, China

**AREA (SIZE):** 1.7 hm<sup>2</sup>

**LANDSCAPE DESIGN:** Forest City Studio

**CHIEF DESIGNER:** Guo Taoran

**PROJECT TEAM:** Xie Jinghua, Shan Bingqin, Wei Lingfeng, Dong Jia, Pu Chuan, Ma Zehao

**DESIGN PERIOD:** July, 2019, on going

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