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日本城市生境营造前沿性案例研究

Case Studies on Pioneering Urban Habitat Projects in Japan

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摘要：从城市生境恢复的角度阐释日本 3 种不同的城市绿化开拓性项目。1）大阪万博纪念公园项目旨在恢复大阪城市核心绿地的自然景观（自我维持的森林）。为实现此目标，除实施相应的植物种植计划和种植方法外，待修复后的植被冠层高度郁闭后，模拟自然干扰的林窗再生的适应性管理是提高其物种多样性的关键。2）梅小路公园的“生命之森”生境花园是第一例实施 20 余年动态监测的生境修复项目。研究发现生境中物种的迁入定居和灭绝趋势因物种类别而异。3）平安神宫庭园是在城市基底中的濒危物种庇护所（隔离保护地）。庭园中丰富的生物多样性与日本园林造园特征有关，“缩景”（微缩自然）是其中之一；除此之外，还采用了适应性管理来替代自然干扰。最后，提出生境设计需充分考虑自然的 3 个属性：要素、格局与过程，其中过程属性是最具挑战的议题。

关键词：风景园林；自然修复；适应性管理；城市生境；生物多样性；濒危物种

Abstract: Three different kinds of pioneering projects of urban greenery in Japan were introduced from the viewpoint of urban habitat restoration. 1) EXPO'70 Commemoration Park project was a unique trial to restore natural landscapes, "Self-Sustaining Forest", as a core greenery of Osaka. It is impossible to realize the goal not only by the initial design of the plant communities and planting methods. After the forest canopy closing, the adaptive management of gap regeneration imitating the natural disturbance is a successful method to improve the species diversity. 2) "Inochi-no-mori" is the first case of a habitat restoration project that was monitored precisely for over 20 years. The monitoring group revealed that the trends of colonization and extinction of species in the habitat varied considerably by taxon. 3) The sacred garden of Heian Shrine is an isolated sanctuary of endangered species in the urban matrix. The reason for the rich biodiversity is related to Japanese landscape garden characteristics, such as "Shukkei" (miniaturizing nature). And, adaptive management needed as an alternative to natural disturbances. Habitat design needs to take into account the three properties of nature: "Elements", "Patterns", "Process"; and "Process" is the most challenging issue to deal with.

Keywords: landscape architecture; nature restoration; adaptive management; urban habitat; biodiversity; endangered species

理查德·瑞吉斯特（Richard Register）在 *Ecocity Berkeley*（1987）一书中写道：“庭园是自然的载体，城市是文化的载体……现如今，两者的功能都失去了均衡。”[1]

那么如何使城市建设与自然保护相得益彰？城市的发展势必破坏生物的基本栖息空间，然而某些物种仍然要在城市生存。有些物种已成功适应了城市环境，城市即已成为新的栖息地类型。这些情况都是在进行城市建设时所要面临的。日本有着人与自然和谐共生的文化，如水边的“花、鸟、风、月”景观，模仿自然的传统园林，以及由古树构成的神社圣林等。上述这些具有文化特质的自然可以作为建设城市的借鉴，使得城市中的原生动植物，在城市发展过程中得以继续栖息繁衍。

2012 年，日本政府颁布《2012—2020 生物多

样性国家战略》[2]，其中明确了 4 类生物多样性丧失危机。第 1 类：由人类活动和社会发展引起；第 2 类：由人为管理减少引起；第 3 类：由人为引进物种引起；第 4 类：由全球气候变化引起。该项国家战略的颁布，旨在促进形成自然丰富的城市，以实现“爱知生物多样性目标”。基于此，我们亟须找到创建“生物多样性丰富的城市”的解决途径和实现方法。

笔者从日本城市自然生境营造项目中选取了 3 个具有代表性的先进案例，分别展现不同场地尺度、营造方法和生境功能。3 个案例均已建成超过 20 年，笔者参与了建成后的动态监测和管理过程。因此，可以通过研究小组 20 多年的监测结果来讨论开创性的规划设计理念与自然过程之间的关系。1）大阪万博纪念公园：日本历史上最大尺度的城市森林自然恢复工程。其具有创新的规划理念，规划目标为创建“自我维持的城市森林”，形成自然植物群落。该项工程是在“生物多样性”概念出现之前的一个创新型项目。通过几十年的监测数据和管理成果的验证，可借鉴其为实现自然森林群落，采取的城市森林生境营造方法和独特的管理技术。2）梅小路公园“生命之森”：日本第一个位于城市中心公园中的生境营造项目。其设计理念是生物多样性保护和恢复。具体设计方法为通过地形塑造及乡土植被种植，模拟京都盆地自然生态系统。我们对场地建成后的生物群落进行了长达数十年的监测，可以清晰地验证其设计方法和管理成效。3）平安神宫生境花园：日本传统庭园中再现自然生境的项目。虽然平安神宫庭园是一种人工景观，但其在面临琵琶湖生物多样性危机时，作为生物多样性庇护所的生境功能近年却愈发凸显。基于此案例，探讨日本传统园林造园设计和管理的特点，以及如何实现生境功能。

以上 3 个案例在城市生态网络中发挥的重要作用均得到了广泛认可：1）日本国土交通省于 2006 年将大阪万博纪念公园列为“近畿地区城市环境基础设施规划”的重要组成部分；2）梅小路公园的重要性不仅经常在学术论文中被提及，而且京都市长在第一届全球城市和地方政府生物多样性峰会上介绍了“梅小路公园作为城市生物多样性核心”的作用；3）《京都府红皮书 2002》中高度评价了平安神宫庭园在琵琶湖流域生态网络中发挥的生境功能。

此外，几十年来，上述 3 个案例因其尺度和特征的不同分别采用了相应的管理方法，取得了丰硕成果，这些都可以从生物多样性监测结果中看出，因此上述 3 个案例也可以为城市生境适应性管理提供借鉴。

1 大阪万博纪念公园植物群落设计与人工林窗再生

1.1 自我维持的城市森林

为纪念 1970 年召开的世博会，在大阪北部千里山丘陵地区的世博会旧址上，建造了大阪万博纪念公园。纪念公园面积较大，达 340 hm²，公园建成后成为大阪北部地区快速城市化进程中保留下来的大型绿色核心。

自然文化区是公园的主要组成部分，占地约 100 hm²，其目标设定为“自我维持的森林”，以此恢复因举办世博会而受到大规模干扰的原生常绿阔叶林（地带性顶级群落）和半自然次生林（里山林）[3]。在城市区域内恢复包含地带性顶级群落的自然森林，是一个开创性的举措，甚至从全球角度来看，其理念也处于前沿。公园的总体规划由高山英华（Eika TAKAYAMA）负责，其中自然文化区由吉村元男（Motoo YOSHIMURA）设计，笔者作为项目组成员，负责种植设计工作。公园的历史沿革如图 1。

1.2 植物群落种植单元及种植方法

依照植物演替规律，在日本形成稳定的顶级群落可能需要数百年的时间。由于本项目计划在 2000 年之前建成能够自我维持的森林，所以设计团队的首要任务是尽快探明实现成熟森林生态系统的方法。

种植设计谨遵植物科学，以地带性成熟森林的植被组成为种植设计单元蓝本。然而，以场地现有生土的土壤条件、开敞性的立地环境来看，难于恢复森林植被。所以本项目在场地中央平坦地带（包括湖泊和设施）周围的山脊上修建了一条水道，湿润灌溉加速土壤熟化，以创造近成熟的森林环境。在种植计划实施过程中，利用混合种植先锋树种或肥料树种等各种独创性举措来促进森林生态系统的建立[4]303-321。

1.3 土壤改良促进森林形成

然而，在种植施工完成后的第 1 个 10 年，树木生长状态很差，依此情况，几乎难于在 2000 年形成一个成熟的森林生态系统。树木生长不良的原因是山体切割后暴露的海相黏土层形成了酸性硫酸盐土壤，而且在建设初期平整土地时重型机械又将土壤压实。笔者加入了由小桥澄治（Sumiji KOBASHI）领导的监测小组，并探明了土壤条件与树木生长状态之间的关系[5], [6]184-195，研究发现排水不良的土壤是限制树木生长的最重要因素，此结论促成了森林生长环境改良措施的实行。

然而，直至 20 世纪 80 年代末，笔者才意识到恢复自然森林生态系统的困难。恰逢此时，“生物多样性”一词出现，而另一创新概念“适应性管理”在 20 世纪 90 年代得到认可，用于管理过于复杂的生态系统。此外，笔者研究还发现对森林树种生长不利的排水不良场地，也是大阪市内残存的野生灌木和草本群落的生境[7]。

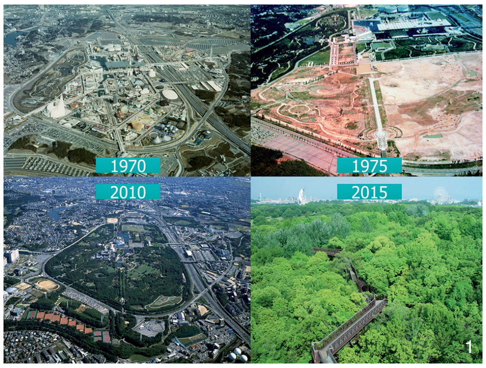
1.4 类似“萌生林”的结构状态，结构单一、树龄相同

20 世纪 90 年代，随着森林的逐渐形成，生物多样性问题变得严峻。因为森林植被没有长成多层复合结构，而是呈现出层次单一、密度过高的状态，即形成了由有限树种构成的类似“萌生林”的结构状态。尽管在制定种植计划和进行种植施工时选择了多样的树种，但是当年栽植的树苗几乎是同一世代的，这些树苗长大的结果是森林地被层消失、物种多样性和叶层高度多样性（foliage height diversity）降低。

1.5 人工林窗动态理论

基于维持自然成熟森林生物多样性的“林窗动态”理论，笔者提出启动“人工林窗动态”计划的建议，以实现形成“自我维持的森林”的种植设计初始目标。

该计划不仅需要创造约 15 m×15 m 的林窗，还需引入各种“林窗动态”举措，包括引入大阪市内与场地相邻的成熟森林表土等。大阪万博纪念公园是城市建成区中的一个孤



1 万博纪念公园的历史变迁
Changes of EXPO'70 Commemorative Park

2 人工林窗更新 1 年后，前景与背景中的森林状态
One year after the artificial gap regeneration; The front and back forest is a "sprout" forest

3 梅小路公园鸟瞰图
Aerial view of Umekoji park

岛，所以依靠自然力量，周边森林的物种很难自行迁移到公园内。鉴于此种情况，我们提取周边未开发区域森林的表土，引入到公园需修复的场地内，让表土种子库中蕴藏的种子自由萌发。

经过适应性管理指导委员会[8]的讨论，人工林窗项目于 2003 年开始实施，这也是在日本城市公园中进行的第 1 例林窗实验（图 2）。相关工作内容和实验成果已在名古屋举行的生物多样性条约第 10 次缔约国会议（COP10）[①]中发表。截至目前，已经形成由多样动植物共存、生态系统稳定的自然森林。

2 "生命之森"城市生境营造

2.1 基于提高城市生物多样性的生境花园

为庆祝京都建都 1 200 周年，京都市建成了第一个以恢复市区自然生境为目标的城市公园（0.66 hm^2）——梅小路公园。公园于日本城市绿化博览会召开之后开建，原址为京都车站附近的梅小路铁路货运站，经过更新设计后成了城市公共园林（图 3）。其中"生命之森"生境花园于 1996 年对外开放。笔者负责成立并协调由生态学家和景观设计师组成的研究小组。

公园对外开放后，在专家、学生和市民的合作下成立了志愿监测小组。此后，本研究团队带领监测小组持续 20 多年观测"生命之森"建成后的生物多样性情况，定期举办自然教育活动，每年发表 1 份调查报告[4]15-22。"生命之森"从货运站工业遗址成功地演变为城市中重要的动植物栖息地。研究小组甚至发现了超出预期的生物在此栖息，比如曾经在城市地区消失的翠鸟以及某种松露。在名古屋举办的生物多样性条约第 10 次缔约国会议（COP10）"城市生物多样性"分会（2010 年 10 月 24—26 日）中，京都市市长门川大作（Daisaku KADOKAWA）介绍了"生命之森"和研究小组的相关活动。日本政府在 2011 年发表的白皮书中也对研究小组的志愿活动有所阐述。

2.2 目的和宣言

建设"生命之森"的基本目的概述如下：1）为城市做出贡献，使市民能够享受大自然的季相变化；2）发挥 / 促进发挥生态系统服务功能，减少诸如热岛现象的城市环境问题；3）为市民提供康养景观，儿童可以体验、发现并向自然学习，促进健康成长；4）保护城市化进程前还未灭绝的本土物种，构建"山城荒野"（Yamashiro Wilderness）。尽管"生命之森"面积很小，但研究小组仍将其建设的基本目标设定为在京都市中心创造一个生物生境。

研究小组确保要建成一个生态系统[4]3-14，该生态系统必须：1）尽可能丰富本地物种多样性；2）尽可能具有发展性或可持续性；3）包含与京都密切相关并被市民熟悉的物种；4）包含未来会被喜爱的物种；5）具有较低数量的入侵物种。研究小组认为，对于公园的管理强度不应过大，而应控制在适中水平，并且要兼顾自然的发展进程。

2.3 设计

笔者认为，针对面积有限的"生命之森"生境设计，需有如下举措：1）以收费促进生境的保护，通过与日本庭园朱雀之庭（Suzaku-no-niwa）的联系实现；2）日常使用"树冠回廊"作为通行设施以减少地面步行系统对生境的干扰，以及设立封闭区域，该区域每年仅向游客开放几天；3）开发包括土崖在内的多样化地形，促进翠鸟筑巢；4）通过挖井抽取地下水以满足多类型池塘的用水需求；5）引入多种生态系统资源要素，如自然生态系统中的粗木碎屑（Coarse Woody Debris，简称 CWD）、乡村树篱、由河石垒成的石墙（Nozurazumi）、树桩、里山中出现的薪材堆等。

2.4 结果

令人惊讶的是：研究小组观察到了"生命之森"生境的动态演替进程，尤其在建成后的第 1 个 10 年[9-10]。栖息地中物种的迁入与灭绝动态变化显著。根据监测记载，"生命之森"中的显花植物种类在 1999 年到达峰值，随后逐渐减少。就鸟类而言，其种类在最初建成几年呈现出显著增加趋势，随后进入几乎稳定或稍微增加的阶段。而在真菌方面，地上真菌和菌根的种类也有所增加（表 1）。

2.5 "生命之森"城市生境营造的挑战

尽管建成后的"生命之森"在自然演替过程中呈现出积极的发展趋势，但随后还是出现了一些具有挑战性的问题。

第 1 个挑战是外来入侵物种。丰富的蜻

蜓种群数量因牛蛙的出现而大大减少（建造后第2年记录）；因小龙虾造成的损害，水生植物逐渐减少，随后灭绝；女贞（*Ligustrum lucidum*）在森林环境的边缘和内部都具有入侵性。第2个挑战是在有限的空间内，如何权衡生态系统演替与物种多样性之间的关系[11]。以草本先锋植物为主的干扰依赖物种，在建成第3年后开始减少。

2.6 展望与挑战

“生命之森”项目可以说是在工业遗产（如货运火车站）生态恢复后形成的城市孤立生境中，精确记录自然演替过程的第一个例子。这些监测记录也为未来采用新的科学技术提供了宝贵的信息。目前，环境DNA检测是用于环境监测的创新性方法。如研究小组对于真菌的监测数据，可以为环境DNA研究提供有价值的信息。但是对于实际存在的庞大的真菌种群来说，基于观察得来的监测数据只是其中非常有限的一部分。“生命之森”是一个孤立生境，其水源来自雨水和地下井水。环境DNA研究可以分析“生命之森”的水体，从而揭示多样的真菌类型（operational taxonomic unit，简称OTU），其数量远远超过我们肉眼监测的记录。

此外，当前项目面临的另一个重要问题是如何应对从具有较小树木和开放冠层的异质生境，向具有较高树木和封闭冠层的同质生境的自然演替。在此种演替趋势下，显花植物物种多样性正在逐渐减少。日本橡树枯萎事件也在演替进程中产生了负面效应。而自然生态系统中的有利干扰，例如洪水干扰、风力干扰都不会在“生命之森”这种城市公园中蕴藏的小规模生态系统内发生。

近年来，由于京都市周边森林中梅花鹿数量的增多，造成了森林生物多样性的严重破坏。所以，我们可以期待，未来城市建成区中的生物生境将有可能发挥巨大的作用，可以成为濒危物种的避难所。

综上，笔者认为需调整对于城市生境生态系统的管理策略，即从被动的管理（等待新物种的自然迁移定居）转为主动管理，如引入濒危物种，为其创建相应的栖息地环境等。这也是为实现“没有物种灭绝的城市”而进行的适应性管理举措之一。

表1 “生命之森”建成后生境恢复的典型生态事件（按时间顺序选定）
Tab. 1 Chronological selected ecological events in the “Inochi-no-mori” restored habitat after construction

时间	Year	典型生态事件	Selected ecological events
第1年	1st yr.	引入150种植物	Introduced 150 plant spp.
第2年	2nd yr.	蜻蜓15种，韧伞属的蘑菇在日本第3次被记录	15 dragonfly spp., 3rd record of mushroom, *Hypholoma*. spp., in Japan
第3年	3rd yr.	牛蛙破坏了蜻蜓种群	Bullfrogs damaged the dragonfly population
第4年	4th yr.	224种草本植物 里山的代表性蝴蝶（拟斑脉蛱蝶） 食肉动物（三齿胡蜂，翠鸟）	Colonized 224 herbaceous plant spp. Butterfly of Satoyama (*Hestina persimilis* japonica) Carnivores (*Vespa analis, Alcedo atthis*)
第5年	5th yr.	40种树木 小锹形虫	Tree colonized 40 spp. *Dorcus rectus*
第6年	6th yr.	蕨类植物：22种（种植5种） 蝉壳（蝉，熊蝉）	Fern: 22 spp. (5 spp. planted) Cicada shell (*Graptopsaltria nigrofuscata, Cryptotympana facialis*)
第7年	7th yr.	苔藓植物：23科39种	Bryophyte: 23 families, 39 spp.
第8年	8th yr.	树苗：59种（密度：32.5株/m^2，最大高度：8 m）	Seedlings of trees: 59 spp. (density: 32.5/m^2, max height: 8 m)
第9年	9th yr.	松露	Truffle (*Tuber* sp.) recorded
第10—22年	10th—22nd yr.	麻皮蝽（南方昆虫） 日本橡树枯萎，189种树木、411种草本植物、69种苔藓植物、72种包括乌拉尔猫头鹰在内的鸟类	*Erthesina fullo* (Southern insect) Wilting of the Japanese oak occurred, 189 woody, 411 herbaceous plant spp., 69 bryofytes, 72 spp. of avifauna including Ural owl recorded

3 平安神宫生境花园

3.1 概述

2019年，一项大规模、精心管理的污泥疏浚工程在平安神宫庭园中的池塘展开，这也是其40年来的首次疏浚。工程现场安设了大型污泥处理设施，共有1 000人参与疏浚，尽管污泥处理耗时3个月，但是池塘里的生物种群却得到很好的保护。因为工程时刻在监督委员会的监控下进行，该委员会成员包括生态学专家、景观和文化遗产方面的专家、京都市政府工作人员等。施行此种举措不仅源于平安神宫作为国立名胜的文化价值，还因为其是京都城市基底中一个重要的生物栖息地。

3.2 作为野生动植物生境的日本传统园林

平安神宫始建于1895年，是日本工业促进博览会的展馆，同时其建成也是为了纪念京都建都1 100年。这座面积3.3 hm^{2}的神社园林由著名的景观设计师第七代小川治兵卫（Jihei OGAMA，1860—1933）设计建造，人们也称他为第七代“植治”，其曾在日本京都市东山地区建造了许多优秀的现代园林作品，包括山县有朋的私产无邻庵庭园等。这些庭园的特点是广泛应用“借景”，以及创造溪流、池塘等自然式水体景观，水源全部来自琵琶湖疏水路（图4）。平安神宫庭园于1975年被认定为日本国立名胜，本研究主要强调其作为城市基底中生物生境的作用。

3.3 庭园中的生物多样性

翔实的调查报告[12]记录了平安神宫庭园中丰富的生物多样性：年间共发现约200种木本植物、300种草本植物、106种苔藓、40种蕨类植物、4种海龟和40种鸟类，足见该庭园作为城市基底中孤立生境的重要作用。

3.4 分形，形成自然生境多样性的重要因素

平安神宫庭园生物多样性丰富的原因可以在设计中找到，即“缩景”（微缩自然）[13]621-625, 14[375-388]。庭园中每个池塘的形态都可以看作是一个分形[15]615-618，这种现象在自然界景观中是广泛存在的（图5）。

简单地说，分形理论表示局部形态和整

体形态是相似的，且每一部分都（至少近似地）是整体缩小后的形状，称为自相似。我们分析了日本传统园林中池塘形态、种植设计、置石分布的特征，发现分形维数是日本传统园林形式和风格的一个重要量化特征[14]375-388。此外，分形现象可以为不同大小的生物提供多样的生境。综上，基于分形理论的“微缩自然”是日本园林的一个特征[15]615-618，使其能够作为野生生物的庇护所而存在。

3.5 城市基底中濒危物种的孤立保护区

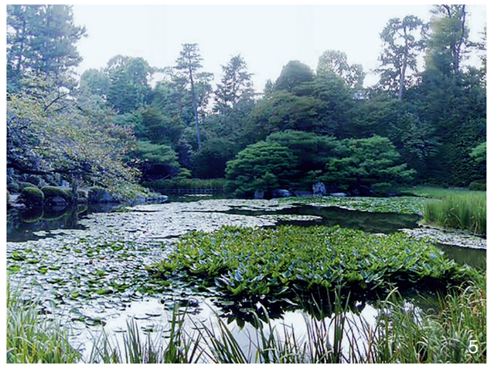
平安神宫庭园发挥生境功能的一个有意义的成果是濒危物种纵带鳑（*Acheilognathus cyanostigma*）的栖息[13]621-625。纵带鳑是一种广受欢迎的鱼类，原本生存在琵琶湖中。1996 年滋贺县立琵琶湖博物馆展出此鱼，但是发现博物馆里的纵带鳑种群是平安神宫池塘中种群的后代。那么为什么纵带鳑没有在琵琶湖中聚集，却能在平安神宫的池塘里存活下来？

纵带鳑很可能是一路顺着琵琶湖疏水路（连接琵琶湖和京都的运河）从平安神宫而来，但是如果平安神宫庭园里只有一个孤立的池塘，纵带鳑就不能繁殖。因为其繁殖需通过在大型双壳软体动物中插入一根长的输卵管产卵，发育后的幼鱼仍然要依靠埋藏在沙中的底栖贝类生存。而双壳软体动物的幼体则需要寄生在小的底栖鱼类上，如吻鰕虎鱼属（*Rhinogobius*）。从纵带鳑的生活史和生态习性来看，纵带鳑的存在即证明平安神宫庭园中的池塘已经形成了一个多生境的生态系统。此外，1983 年琵琶湖发生第一次淡水赤潮时，为防止污水进入，琵琶湖入水口安装了砂滤池，该过滤器有效防止了外来物种对池塘生境的入侵，如蓝鳃太阳鱼（*Lepomis macrochirus*）和大口黑鲈（*Micropterus salmoides*）等。

3.6 对于适应性管理的需求

在 2000 年左右，平安神宫庭园中的鲤鱼种群数量因锦鲤疱疹病毒（KHV）的流行而显著下降，湖底污泥堆积问题变得严峻，双壳软体动物栖息地恶化，纵带鳑种群急剧减少，被称为“微型琵琶湖”的平安神宫庭园池塘生态系统危机频现。

4 平安神宫庭园中的水体形态
Shape of the ponds of Heian Shrine



5 平安神宫庭园中的一个池塘
One of the ponds of the Heian Shrine

为了应对此问题，我们在第七代“植治”的日记中找到了对其建园理念的描述[16]，彼时他刚刚完成了京都清风荘（Seifuso）庭园（山县有朋的别墅）的建造工作。第七代“植治”亲自去鸭川捕捉小鱼，并将它们放进庭园中的池塘。这一描述清晰地表明了第七代“植治”恢复庭园自然的意图。因此，为了保持和传承设计者所期望的自然景观，必须对平安神宫庭园中的池塘进行人为清淤疏浚管理，而不是仅仅依靠几十年一遇的自然干扰。

4 讨论

城市生境对于维持和丰富城市生物多样性发挥着重要作用，是建设“防止物种灭绝的可持续城市”的基础。笔者重点介绍了经人为恢复和营造的城市生境，并没有讨论诸如自然保护区、神社森林、城市农业用地、河流、水库等各类已经存在的自然生境。这些生境都是维持城市生物多样性的基础。随着城市化进程的加快，城市生物多样性已经显著降低，城市生境的恢复和营造对于实现 2015 年联合国可持续发展峰会提出的可持续发展目标（Sustainable Development Goals，简称 SDG）就必不可少。

4.1 斑块面积

大型栖息地斑块能够栖息更多样的物种[17]，提供更多的生态系统服务。但是在城市中心地区建立新的大型生境以应对生物多样性危机，是昂贵和困难的，也是不现实的。本文中 3 个案例的建设都有特殊历史意义：亚洲举办的第一届世博会、京都建都 1 200 周年纪念和 1 100 周年纪念。我们需要从生物多样性的角度探讨栖息地斑块面积大小与城市孤立生境效能之间的关系。

根据我们以京都为对象的研究发现，约 1 hm^2 的孤立生境（如梅小路公园中的“生命之森”、平安神宫庭园）可以成为日本食虫山雀（*Parus minor*）的栖息地；3~10 hm^2 的栖息地可以为小型猛禽棕鹰（*Ninox scutulata*）提供生境；而苍鹰则需要 100 hm^2 的区域栖息（如大阪万博纪念公园）[18-20], [21]23-34。由此可见，大型栖息地比小型栖息地发挥更大的作用。但是，景观生态学领域的经典议题“单个大型栖息地或几个小型栖息地”（Single Large or Several Small，简称 SLOSS）：单个大型栖息地（Single Large，简称 SL）与几个小型栖息地（Several Small，简称 SS）相比，哪种方式更好？由以上研究可以发现，就稀有物种的数量和创建稀有物种的栖息地而言，SS 比 SL 更具优势。尽管 SS 的栖息地面积很小，但是栖息地的独特性非常重要。

虽然生境面积大小是决定物种多样性的非常重要的正向参数，但是该参数的实际影响力因物种而异。蕨类植物、草本植物[21]23-24、蚂蚁[22]和苔藓[23]更易受到小生境多样性的影响[24]。从此视角来看，日本园林作为生境的意义非常重要，尤其对于小型生物来说。

4.2 紧循自然过程的生境管理

城市生境作为城市生态网络，旨在保护和维持地区原生生物多样性。景观生态学中要素、格局、过程这 3 个自然的属性是解析城市孤立生境物种多样性的关键[25]。大阪万博纪念

表 2 自然的 3 个属性以及构建以自然为导向的城市[26]

Tab. 2 Three properties of nature and the goal of the nature-oriented city[26]

属性 Properties	基本组成 Basic contents	荒野 Wilderness	生物多样性导向的城市 Biodiversity-oriented city	退化的自然 Deteriorated nature
要素 Elements	植物、动物、地质、地形…… Flora, fauna, geology, topography…	原生动植物 Original flora and fauna	无物种灭绝前提下的土地利用，亲近自然 Land use without species extinction, close to nature	野生物种灭绝，入侵性外来物种 Species extinction in the wild, predominant invasive aliens
格局 Pattern	斑块、廊道、基质、景观…… Patch, corridor, matrix, landscape…	原生景观镶嵌体，连续的生态系统：山—川—里—海 Original shifting mosaics, connected ecosystems: mountain-river-floodplain-sea	完善的绿化系统，包括核心栖息地斑块和分散的重要小栖息地斑块，保护原生栖息地斑块前提下的土地利用 Optimized greenery including core habitats and scattered significant small habitats, land use considering original habitat	破碎化和彼此孤立的绿化系统，生态交错带消失 Fragmented and isolated greenery, disappearing ecotones
过程 Process	风、水流、沉积物移动、物种迁移…… Wind, water flow, sediment transportation, species colonization…	太阳耀斑、昼夜和季节更替、台风、地震灾害 Sun fleck, diurnal and seasonal change, yearly fluctuation, catastrophes by typhoon, earthquake	针对干扰依赖型生态系统，进行基于风险评估的灾害管理双赢设计，风险与生态系统服务联系 Disaster management with risk assessment considering disturbance-dependent ecosystems, Win-Win design, risk and ecosystem service communication	大坝和河岸过度控制，干扰依赖型物种灭绝 Excessive control by dams and banks, extinction of disturbance-dependent species

公园案例表明仅仅进行景观要素（生态系统类型、物种等）和格局（创建不同类型森林斑块、塑山造河）的设计，还不足以恢复自然森林，还需重点引入“干扰形成景观生态多样性”这一概念，作为自然过程（如“林窗动态”和洪水干扰）的替代对其进行适应性管理。同理，从景观要素和格局的角度来看，梅小路公园设计得当，然而随着森林的生长，会发现其生境由最初的异质镶嵌格局转变为均匀结构，并出现干扰依赖型植物物种多样性显著降低这个问题。平安神宫庭园作为微缩自然（见池塘的形状、材料、微生境分布以及与琵琶湖的连接等）发展出独特而丰富的生物多样性，但是目前面临缺乏洪水干扰等自然过程的问题。

人工修复或营造形成的生境的可持续性很大程度上取决于适应性管理水平，如池塘清淤疏浚即可以看作是自然洪水干扰的替代。对于大阪万博纪念公园这类大尺度的生境来说，一定程度的自然干扰可以发挥生态系统的自我调节作用。所以在自然的 3 个属性中，过程属性是最具挑战的议题（表 2）。

从景观要素和格局视角来看，本文 3 个项目都是成功案例。苍鹰被发现在大阪万博纪念公园这种大型斑块内筑巢，梅小路公园和平安神宫庭园也成为濒危物种的避难所。然而，最重要的是需通过人工干扰进行适应性管理，以代替自然干扰，即“过程”是维持生物多样性和场地生境功能的一个重要属性。

所以，在进行生境恢复设计时，不仅要针对场地进行景观要素、空间格局设计，还要对自然和人为管理制定相应程序。虽然自然干扰可能会造成灾害，但一定程度的自然干扰对生境的健康是必不可少的。生境的适应性管理与“绿色基础设施”和“生态灾害降低”（Ecosystem-based Disaster Risk Reduction，简称 Eco-DRR）密切相关[27]，如雨水花园不仅可以成为城市中的小型生境，还可以缓解热岛现象以及全球气候变暖导致的暴雨灾害[28]。

注释 (Note)：

①“生物多样性条约第 10 次缔约国会议（简称 COP10）于 2010 年 10 月 11—29 日在日本爱知县名古屋市举行，会议公布 2010 年濒危动物名单，通过遗传资源利益分配的相关议定书，提出 2010—2020 年保护生物多样性目标。

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图表来源：

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（编辑 / 刘昱霏）

Richard Register wrote in his book *Ecocity Berkeley* (1987): "The Garden is the paradise of nature, and the City is the paradise of culture. Or at least they could be…. Today, both are out of balance."[1]

How can we harmonize city construction with nature conservation? City development inevitably degrades the essential habitat of creatures; however, some species also live in urban areas. Moreover, some species successfully adapt to living in an urban environment as their new habitat. In Japan, we sometimes notice the traditional culture of living with nature and celebrating the "Flower, Bird, Wind, Moon" along the waterside, nature-oriented landscape gardens, and sacred shrine forests with old trees. It seems that such cultural nature could act as a clue to building cities where the species that originally lived will not be extinct.

The Cabinet of Japan approved the National Biodiversity Strategy of Japan 2012—2020 (Government of Japan 2012)[2], which takes into account four types of biodiversity loss: the first crisis (caused by human activities including development), second crisis (caused by a reduction in human activities), third crisis (caused by artificially introduced factors), and the fourth crisis (caused by changes in the global environment). The strategy aims to promote the development of urban areas that are rich in nature in order to achieve the Aichi Biodiversity Targets. We need to identify a better method for creating cities that are rich in biodiversity.

I selected three representative cases from the viewpoint of the history of the designed natural landscape in urban areas in Japan. The points of selection are the scale, design method and habitat function of the designed landscape. All selected three cases have been managed over 20 years since construction, and I am involved in the monitoring and management process; therefore, we can discuss the relationships between planning or design concept with natural processes through verifying outcomes and troubles. 1) EXPO'70 Commemorative Park is the largest scale of natural forest restoration on the disturbed urban site in Japan ever. And the innovative planning concept to set the goal as "self-sustaining forest" that means natural plant communities. The project was an innovative one before the concept of biodiversity was born. We can study the outcome of the initial plant community design method and unique forest management techniques to realize natural forest communities through the data of monitoring and management over decades. 2) "Inochi-no-mori" is the first urban habitat project in a city park in the city center, with the theme of biodiversity conservation and restoration in Japan. The design method is to mimic the remnant ecosystems of Kyoto basin introducing trees and plants with topography arrangement. Because of the intensive monitoring of the biota of the site, we can discuss the outcomes of the design method and the needed management through decades. 3) Garden of Heian Shrine is one of the famous traditional Japanese gardens that intend to reproduce natural landscapes. Although it is a man-made landscape, habitat function as a biodiversity refuge is highlighted recently, facing the biodiversity crises in the original nature, Lake Biwa. Habitat function of the Japanese landscape gardens could be discussed by considering characteristics of the design and management.

All three cases are widely recognized for their importance in urban ecological networks; 1) Ministry of Land, Infrastructure, Transport and Tourism of Japan nominated the EXPO park area as an element of "Urban Environmental Infrastructure Plan of Kinki District" in 2006, 2) the significance of 'Inochi-no-Mori' is not only discussed in papers, but also the Mayor of Kyoto introduced it as the core of biodiversity in the First Global Biodiversity Summit of Cities & Subnational Governments, 3) habitat function of the Garden of Heian Shrine in the ecological network of the Lake Biwa basin is highly valued in the *Red Data Book of Kyoto Prefecture* (2002).

Over the decades, these cases have been uniquely managed with different characteristics, while examining the monitoring results from a biodiversity perspective. These cases therefore provide meaningful insights into considering desirable adaptive management of urban habitat.

1 Plant Community Design and Artificial Gap Regeneration in EXPO'70 Commemorative Park

1.1 "Self-Sustaining Forests" in Urban Areas

EXPO'70 Commemorative Park is a large park (340 hm^2) that was the former site of the world EXPO held in 1970 at Senri hills in northern Osaka and now stands as a commemorative park to that event. It comprises a green core of open space that was preserved amidst the process of the urban development in northern Osaka that marked the beginning of the era of high economic growth in Japan.

The main part of the park is the Nature-Culture Zone, covering around 100 hm^2, the goal of which was set as "Self-Sustaining Forest" with the aim of restoring natural evergreen broad-leaved forests (climatic climax forests) and semi-natural secondary forest (Satoyama forests) to the ground that had seen large-scale disturbance resulting from the hosting of EXPO'70 (Commemorative Organization for the Japan World Exposition'70, 1972)[3]. It was a pioneering approach, even from a global perspective, to restore natural forests including climax forests in urban areas.

The master plan of the whole park was supervised by Dr. Eika TAKAYAMA (and the Nature-Culture Zone was designed by Mr. Motoo YOSHIMURA). I was involved in the project team as a member of planting design staff (Fig. 1).

1.2 Plant Community Design Unit and Planting Methods

Plant succession theories tell us that climax forests are likely to need several hundred years in order to become established in Japan. However, the target year for completion of the "Self-Sustaining Forest" was set as 2000. Therefore, the mission of the design team was to propose methods for realizing the mature forest ecosystem as rapidly as possible. The planting design was based on vegetation science, considering the species composition of existing forest vegetation as a design unit. However, the open environment and immature soils could have proved too tough for the forest vegetation. Therefore, in order to bring it closer to the mature forest environment, a unique attempt was made to construct a water channel along the ridge surrounding the central flat part that contains the lakes and facilities. The planting sought to mix pioneer species or fertilizer trees, and various other unique methods were designed to enhance the establishment of the forest ecosystem [4]303-321.

1.3 Edaphic Improvement for the Forest Growth

However, in the first decade after planting, the tree growth was so poor that it seemed difficult to establish a mature forest by the year 2000. The reasons for poor growth are acid sulfate soil that resulted from the layer of marine clay exposed by the cutting of the hills, and the compacting of soil by the heavy machines used in the land reclamation.

I joined the monitoring team led by Dr. Sumiji KOBASHI and clarified the relationship between the soil conditions and tree growth [5], [6]184-195. I contributed to enhancing the forest growth environment by providing the finding that the poorly drained soil was the most important factor in limiting normal tree growth.

However, it was in the late 1980s that I came to realize exactly how difficult it is to restore real natural forests. That was when the term "biodiversity" was born, while the concept of "adaptive management", which is an innovative concept for managing ecosystems that are too complex to understand in their entirety, became recognized in the 1990s.

I realized that the poor drainage sites that provided poor conditions for the growth of forest species were also unique sites of wild grassland and bush communities that were about to disappear from the Osaka city area as a result of rapid urbanization[7].

1.4 "Sprout Forests", Single Layer and Same Age

The next issue became serious in the 1990s. While forests are seemingly formed gradually, problems were detected from the viewpoint of biodiversity. Indeed, forests were not multi-layered but rather single-layered overcrowded forests, so-called "Sprout Forests" consisting of limited species. In spite of the diverse species selected, the trees planted were considered to be of almost the same generation. As such, the vegetation on the forest floor disappeared, while the diversity of species and range of foliage heights also decreased.

1.5 Artificial Gap Dynamics

Therefore, taking into account the "Gap Dynamics" theory, which explains the mechanism by which the biodiversity of a natural mature forest is maintained, I made a proposal to the decision-maker to launch an "artificial gap dynamics" project as a means of realizing the original theme of "Self-Sustaining Forest". This would entail not only creating a gap of around 15 m × 15 m but also introducing various types of gap dynamics, including spreading the surface soil from the surrounding forests of Osaka. We expected soil seed bank of various species to recruit. The soils could be taken from another, adjacent urban developing site, considering the EXPO'70 park is an isolated patch in the urban matrix, so that it is hard for new species to colonize from surrounding forests.

From 2003 onward, what was probably the first trial (Fig. 2) of applied gap dynamics in urban parks was carried out based on a discussion by the adaptive management steering committee[8]. Those activities and outcomes were also widely announced at a side event of the CBD COP10 in Nagoya.

2 Urban Habitat, "Inochi-no-mori"

2.1 Habitat Garden for Urban Biodiversity

The first project as a city park aimed at restoring natural habitat in urban areas (0.66 hm^2) in Kyoto took place on the occasion to celebrate 1 200 years since Kyoto became the capital. The site of the former Umekoji railway freight train yard, near Kyoto Station, was developed as a public park in Kyoto City following the National Urban Greening Fair (Fig. 3). "Inochi-no-mori" (Living Forest) was opened in 1996.

The author was in charge of coordinating the study group for the project alongside ecology and landscape design specialists. After the park opened, a volunteer monitoring group was set up with the cooperation of experts, students, and citizens. We have continued to conduct intensive monitoring with citizens and hold nature study tours, and have published a report every year[4]15-22. The forest grew into a significant habitat on the former freight train yard that was far from nature. Not only have unexpected creatures colonized the area, such as the kingfisher, once extinct from urban areas, and a kind of truffle, but the ongoing valuable monitoring has enabled several students to utilize the monitoring data and gain a doctoral degree. At the occasion of the City Biodiversity Summit 2010, held in the City of Nagoya, Aichi Prefecture, Japan (from 24 to 26 October 2010) as a side event for the 2010 Convention on Biological Diversity, COP10, Mr. Daisaku KADOKAWA, the mayor of Kyoto, introduced "Inochi-no-mori" and our activities in his presentation speech. Our voluntary activities were also introduced in a white paper by the Japanese Government in 2011.

2.2 Purpose and Declaration

The basic purposes of establishing "Inochi-no-mori" are summarized as follows: 1) to contribute to a city where you can enjoy the blessings of the four seasons of nature, 2) to enable/facilitate enjoyment of ecosystem services, reducing urban environmental problems such as the heat island phenomenon, 3) to provide a healing landscape for citizens where children can experience, discover, and learn from the abundant nature for their healthy growth, 4) to contribute to a city without extinction of native species before urbanization: "Yamashiro Wilderness" .

While the area of the habitat is very limited, we nevertheless summarized the basic goal as the creation of a habitat before the urbanization of the city of Kyoto.

So we pledged [4]3-14 to nurture an ecosystem that would 1) be as rich as possible in native species diversity, 2) be as developmental or sustainable as possible, 3) contain species that are closely related to Kyoto and are familiar to citizens, or 4) include species that would be loved in the future, and 5) have a low population of invasive species that may degrade the biodiversity.

We also agreed that the management should not be so intensive but instead kept to a moderate level and with regard for natural processes.

2.3 Designs

I suggest that successful design methods for the habitat of the limited area should have the following objectives: 1) to protect the area as a paid area connected to the Japanese garden "Suzaku-no-niwa", 2) to limit the footpaths used on a daily basis including "Canopy Corridor Bridge", and for closed areas to be opened to the public for guided tours on several days a year, 3) to develop a diverse topography, including soil cliffs, to encourage the kingfisher to nest, 4) for the several types of ponds to be supplied with water by digging a well, 5) to introduce diverse ecosystem resources including CWD (Coarse Woody Debris) in the natural ecosystems but also elements such as a country hedge, "Nozurazumi" (a dry-stone wall using river stones), tree stumps, and firewood deposit in the Satoyama ecosystems.

2.4 Outcomes

We were surprised to observe the dynamic ecological succession[9-10] of the "Inochi-no-mori" habitat, especially during the first decade. The trends of colonization and extinction of species in the habitat varied considerably by taxon.

The maximum number of flowering plant species in Inochi-no-mori was recorded in 1999; however, it then gradually decreased. In the case of avifauna, an increasing phase during the first several years was followed by an almost stable or slightly increasing phase, while in the case of fungi, there appeared to be an increase in the number of epigean and mycorrhiza species. Selected events are shown in Table 1.

2.5 Challenges in the Urban Habitat Project

In spite of the positive trends seen in the natural succession, a number of challenging issues subsequently arose, as described in the yearly reports, which are available on the website.

The first challenge was the invasive alien species. The very rich dragonfly fauna, which was recorded in the second year after construction, was drastically reduced by bullfrogs. The aquatic plants were gradually reduced and then died out due to damage caused by feeding crayfish. Glossy Privet (*Ligustrum lucidum*) was invasive both at the edge of and within the forest environment.

The second challenge is how to deal with the tradeoff between ecosystem succession and species diversity in the limited area[11]. Disturbance-dependent species, mostly herbaceous pioneer plants, began to decrease after the third year.

2.6 Further Challenges

"Inochi-no-mori" was almost the first example of the succession process to be precisely recorded in an urban isolated habitat restored from unnatural land use such as a freight train yard. Therefore, the monitoring records provide precious information for new science and technology. For example, the environmental DNA detection method has recently become an innovative technology for environmental monitoring; however, verification of the results presents a challenge in terms of the standardization of the method. Inochi-no-mori is an isolated habitat whose water source is rainwater and the water from the well on the site. Therefore, our monitoring data on fungi provides valuable information for environmental DNA research due to the fact that we are able to observe very limited fractions of the total rich biodiversity. The ongoing environmental DNA study using the water of Inochi-no-mori is now revealing the various taxonomic fungi (OTU), far more than the species recorded by the monitoring.

The current important issue is how to deal with natural succession from the heterogeneous habitat with smaller trees and open canopies to the homogeneous habitat with taller trees and closed canopies. And the species diversity of flowering plants is gradually decreasing. The Japanese oak wilt event created a slight counter process in the succession trends; however, none of the types of natural disturbances seen in a natural ecosystem, such as floods and windfall of large trees, occur in the limited area of the urban park.

Recently, considering the increasing loss of biodiversity owing to the severe damage caused by feeding sika deer in the surrounding forests of Kyoto city, we might expect a further significant event in the urban habitat, in that it could become a refuge for endangered species. As such, we amended the policy from a passive attitude, waiting for the natural colonization of new species, to one based on active management, which included introducing endangered species by preparing the condition of the habitat. This is one of the actions involved in adaptive management to realize "the city without species extinction."

3 Garden of Heian Shrine as a Habitat Garden

3.1 Introduction

This year, a large but carefully managed sludge dredging project was undertaken in the ponds of Heian Shrine for the first time in about 40 years. A large sludge treatment plant was installed, and a total of 1,000 people worked on it for 3 months while conserving the biota of the ponds. The project was conducted under the supervision of a committee that included specialists in ecology, Japanese gardens, and cultural properties, working alongside Kyoto city administration staff. The project was carried out because the garden is not only a cultural property in the form of a National Place of Scenic Beauty but also a significant patch of habitat in the urban matrix of the city of Kyoto.

3.2 Japanese Garden as a Wildlife Habitat

Heian Shrine (Heian-jing) was originally constructed in 1895 as a pavilion for the National Exposition for Promoting Industries held in Kyoto, commemorating 1,100 years of the transition of the capital to Kyoto. The 33,000 m^2 sacred garden was built by notable landscape artist OGAWA Jihei VII (1860—1933), also known as Ueji, who had previously built many excellent modern landscape gardens across the Higashiyama area (foot of the eastern mountains of Kyoto), including the Murin-an garden of Aritomo YAMAGATA. Those gardens are characterized by their borrowed sceneries and natural waterside landscapes of streams and ponds using water drawn from the epoch-making canal that leads from Lake Biwa. The sacred garden of Heian Shrine was registered as a National Place of Scenic Beauty in 1975 (Fig. 4). We should emphasize not only the aspect of its scenery but also its function as a habitat in the urban matrix.

3.3 Biodiversity of the Garden

The intensive research report[12] recorded the astonishing fact of the rich biodiversity: about 200 tree species, 300 herbaceous plant species, 106 moss species, 40 fern species, four turtle species, and 40 bird species in a year.

Thus, the garden functions as a significant isolated habitat within the urban matrix of the city of Kyoto.

3.4 Fractals as an Important Element of Natural Habitat Diversity

Important reasons for the rich biodiversity may be found in its design[13]621-625, [14]375-388: a kind of miniature nature, "Shukkei" (miniaturizing nature). The shape of each pond in the garden can be considered as a fractal[15]615-618, which is often observed in natural landscapes (Fig. 5).

Fractal intuitively means that the part and the whole are similar, and they exhibit similar patterns at increasingly small scales, called self-similarity. We analyzed the fractal dimensions of the pond shapes and tree and stone distributions of historical Japanese gardens. And we confirmed that the fractal dimensions of Japanese traditional gardens could be a significant quantitative property of their form and style[14]375-388. Furthermore, fractals can provide habitat diversity for various sizes of organisms; therefore, "miniaturizing nature" is an important concept within Japanese gardens[15]615-618 that enables them to function as a sanctuary for wildlife.

3.5 Isolated Sanctuary of Endangered Species in the Urban Matrix

The most interesting outcome is the surviving endangered fish species[13]621-625, striped bitterling (*Acheilognathus cyanostigma*), in Lake Biwa, the largest lake in Japan.

Originally a popular fish species, the striped bitterling has been displayed at the Lake Biwa Museum in Shiga prefecture, opened in 1996, as a species of Lake Biwa. But the population is the return of a descendant that survived at Heian Shrine. Why did it survive in this pond even though it was not collected in Lake Biwa? It is likely that the fish came from Lake Biwa through the canal that connects the lake to Kyoto; however, the fish cannot breed if there is only a pond. The striped bitterling lays its eggs by inserting a long oviduct into a large bivalve. Bitterling, as waterside fish, adapt to water level fluctuations and are characterized by a life cycle in which the juveniles survive on shellfish that are submerged in the sand, even during the drought season. The larvae of shellfish are also parasitic on small benthic fish species such as Yoshinobori (*Rhinogobius*), which is why the presence of the striped bittering indicates that an ecosystem of diverse habitats has been formed in the garden ponds. Moreover, when the first freshwater red tide occurred in Lake Biwa in 1983, a sand filter was installed at the inflow inlet from the canal, to prevent polluted water from entering the lake. It is important that the filter also prevented the invasion of the alien species Bluegill (*Lepomis macrochirus*)and Black Bass (*Micropterus salmoides*).

3.6 Need for Adaptive Management

In the early 2000s, however, following a remarkable decline in the carp population owing to a pandemic of koi herpes virus (KHV infection), the accumulation of sludge became prominent and the bivalve habitat deteriorated, which resulted in the crisis of a drastic decline in the striped bitterling population.

The garden ponds of Heian Shrine, also called mini Lake Biwa, have also suffered from sludge accumulations in recent years.

We found a description in the diary[16] of the landscape artist Ueji, from when he had just finished construction work on the garden of Seifuso (Aritomo YAMAGASTA's Kyoto villa); he went to the Kamo river to catch small fish and released them into the pond. This description clearly shows his intent to restore nature in the garden. Thus, in order to inherit the natural scenery he intended, it is essential to undertake dredging instead of relying on the natural disturbance caused by flooding that occurs after heavy rains once every several decades.

4 Discussion

Urban habitats play an important role in urban biodiversity, serving as the basis of a sustainable city without species extinction. Here, I have only discussed the ecological aspects of a restored urban habitat and have not discussed the current existing habitat including various kind of reserves, sacred shrine forests, agricultural land left in urban areas, rivers, reservoirs, and so on. These are the fundamentals of urban biodiversity. However, because urban biodiversity has deteriorated due to the development so far, the restoration of habitats is indispensable for realizing the Sustainable Development Goals (SDGs), which was adopted by the UN Sustainable Development Summit held in 2015.

4.1 Patch Size

Large habitats are capable of inhabiting a variety of species[17]; and can be expected to have large ecosystem services. On the other hand, creating and managing new large habitats in urban areas to respond to the biodiversity crisis is costly and difficult. All three cases are associated with special events: the first world EXPO held in Asia, 1,200 years, and 1,100 years anniversary of capital establishment in Kyoto. We need to consider the significance of the size of fragmented habitats from the viewpoint of biodiversity.

According to our research in the city of Kyoto[18-20], [21]23-24, an isolated habitat in an area covering around 1 hm^2 (such as the garden of Heian Shrine and Inochi-no-mori in Umekoji park) could become a habitat for an insect-eating Japanese tit (*Parus minor*), an area of 3-10 hm^2 could be a habitat for the small raptor Brown hawk-owl (*Ninox scutulata*), while a goshawk could live in an area covering 100 hm^2 (such as EXPO'70 Commemorative Park). Thus, large habitats are better than smaller ones; however, the famous proposition, SLOSS: Single Large (SL) or Several Small (SS) habitats, which is better, tells us that SS is more advantageous than SL in terms of the number of species and the establishment of a habitat for rare species. Yet even if it is small, the restoration of a unique habitat has great significance.

Of course, the size of a habitat is a very important positive parameter for determining the species diversity. However, the actual significance of the area varies greatly depending on the taxonomic group. Ferns, herbs[21]23-24, ants[22], and mosses[23] are greatly affected by the diversity of micro-habitats[24]. Japanese landscape gardens as a habitat, particularly for small organisms, are significant for this reason.

4.2 Habitat Management Considering Natural Process

Important significance of urban habitats is to ensure the original biodiversity of the area, as an ecological network. Landscape ecological discussion using the concepts of "Elements/ Pattern/Process" is the key issue[25]to understand the species diversity of fragmented patches in urban areas (Tab. 2)[26].

EXPO case showed us the consideration of elements (such as ecosystem types, species) and patterns (such as several types of forest patch and making hills and rivers) are not enough to restore natural forests. More concern on the landscape ecological diversity formed by disturbances needed; and the adaptive management as an alternative to natural processes (such as gap dynamics and flooding). Inochi-no-mori case was well designed to set up the initial stage from the viewpoint of the elements and patterns of nature, however, growth of the forests made the initial heterogeneous mosaic pattern to change into more homogeneous structure. And the significant degradation of species diversity of disturbance-dependent plants was observed. Heian Shrine case is characterized as miniaturized patterns of nature (such as shape, material, microhabitat distribution of ponds and the connection to Lake Biwa) that allowed to developing the unique and rich biodiversity of the garden. But lack of natural process such as flooding is the reason of the problem we faced recently.

However, the sustainability of restored habitats depends on adaptive management, such as mud dredging of pond bottoms as an alternative to natural flooding. In the case of a large habitat such as EXPO'70 park, it is possible to accept a certain degree of natural disturbance such as trees brought down in a typhoon. Among the three properties of nature shown in the Table, "Process" is the most challenging issue to deal with (Tab. 2).

All three cases originally had strong points in the construction; or in terms of "Elements"and 'Pattern', those were good practices. Goshawk successfully nested at the large patch, EXPO. Inochi-no-mori and the garden of Heian shrine are the refuge of endangered species. However, adaptive management of human disturbances as alternative to natural disturbances is the essential "Process" to maintain biodiversity and attractiveness of each site.

In a habitat restoration project, it is not only the design of the elements and patterns of the site that need to be studied carefully, but also the design of the management program in place for natural and human processes. Natural disturbances can cause disasters but are also essential for a healthy habitat. Therefore, adaptive management of habitat is closely related to "Green Infrastructure" and Eco-DRR "Ecological Disaster Reduction"[27]. The rain garden is very useful as a habitat in the city, as well as mitigating the heat island phenomenon and mitigating heavy rain disasters due to global warming[28].

Sources of Figures and Tables:

Fig. 1 Photo courtesy of Osaka Prefectural Government; Fig. 2, 4 Source of the author; Fig. 3 Photo courtesy of Kyoto City; Fig. 5 Photo courtesy of Mr. ITO Sosuke; Tab.1 drawn by the author; Tab. 2 Source of the paper written by reference [26].

(Editor / LIU Yufei)