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Landscape Planning and Design in the Century of the City

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城市时代下的风景园林规划与设计
Landscape Planning and Design in the Century of the City

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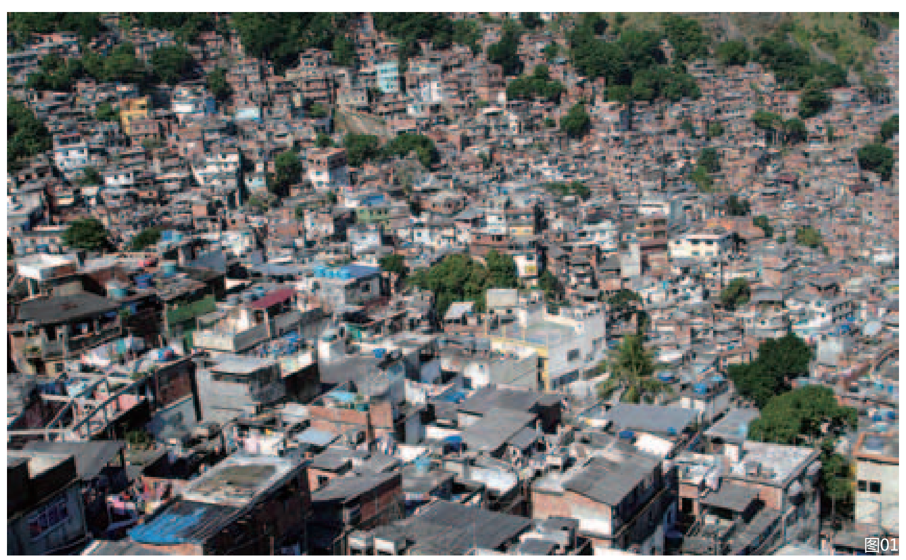
摘要：城市化进程会在世界各个领域以不同的速度发生，但主要将发生在发展中国家。在对全球化城市进程给城市发展所带来的机遇和挑战的分析基础上，就城市动态类型学、生态系统服务与功能、绿道与绿色基础设施等展开了论述，并以上海为例对蔓生城市的实验价值做了分析，展望了风景园林对于城市可持续发展的意义与趋势。
关键词：城市时代；城市动态类型学；生态系统服务；风景园林

Abstract: Urbanization is expected to occur at different rates around the world but will mostly occur in the developing countries. Based on the analysis of the opportunities and challenges that global urbanization has brought to the cities, the author discusses about the urban dynamics typology, ecosystem services and functions, greenways and green infrastructure, and so on. Taking Shanghai as example, the author also analyzes the experiment values of urban sprawl, and lays expectation on the significance and trends of landscape architecture to urban sustainable development.
Key words: Urban Age; Urban Dynamics Typology; Ecosystem Service; Landscape Architecture

图01 21世纪大部分城市化进程的扩张将会发生在非正式发展地区，比如图片所示的巴西里约热内卢的贫民窟
Fig.01 Much of the world's expanding 21st Century urbanization will occur in informal development as this favela in Rio de Janeiro, Brazil.



本文是作者在举办于马萨诸塞大学阿莫斯特分校的2013年法布士风景园林与绿道规划国际会议上发表的演讲的要点概述。

1 全球城市化进程的趋势及挑战

在20世纪初，大约百分之十的世界人口居住在城市中。而21世纪之所以被人们称为城市的时代，是因为在2007年，城市人口在历史上第一次达到了世界人口的50%。在接下来的数十年中，世界总人口将从70亿增加到100亿，其中大部分增长都将在城市中发生[1]。重要的是，城市人口增长的趋势将在本世纪持续，并预计在2050年达到63亿，在2100年则达85亿[2]。城市化进程会在世界各个领域以不同的速度发生，但主要将发生在发展中国家。城市人口增长这一现象将主要发生在当代大学生以及规划与设计专业的应届毕业生的职业生涯中。如果这个拥有超级城市的新世界想要实现可持续发展，那么它的城市就必须实现可持续——这是一个巨大的挑战，尤其是对城市与风景园林规划和设计领域的挑战。

到2100年，亚洲地区将发生城镇人口的最大增幅：从2010年的18亿，到2050年的33亿，最后增加到38亿（联合国人类发展报告，2012）。通过大众媒体的传播，中国被广泛误解为一个超级城市国家。事实上，在2011年，中国的城市人口比例（50.6%）远低于美国（82%）和荷兰（83%）[3]。然而，中国目前正在经历一个巨大的、前所未有的城市迁移过程。在未来的25年里，中国将会建造更多人口超百万的城市，甚至超过美国目前百万人口城市数目的总和。在中国，这种农村向城市的人口迁移正在有条不紊地进行，仅仅在接下来的12年中，就有2.5亿人口涌入中国现有的或者新建的城市[4]。从这一点来说，中国将可以成为一个实验室，让世界其他国家学习如何以可持续发展的方式来规划和设计城市，适应新的城市人口。

此前，联合国千年生态系统评估提出了一个基本论点，那就是："实现千年发展目标的奋斗将是'城市的成功或是失败'"[5]。这一主张是基于城市化和社会经济发展之间的联系，包括城市发展对于城市周边农村环境的影响、提供为农村发展和支持农村经济的源动力。这个大胆的论点，在全球范围内掀起了对于城市规划者和设计者的基本挑战，即"如何以可持续的方式，扩张现有城市规模、建设新城市，以满足新城市人口的巨大需求，并同时管理景观和生态，让城市和居民赖以生存的生态系统正常服务？"

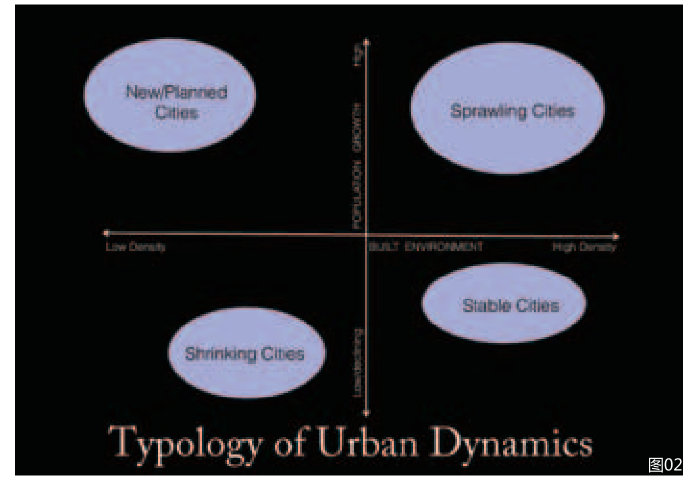


图02 城市动态的类型学
Fig.02 A typology of Urban Dynamics

图03 上海是一个拥有快速增长的人口和高密度建成环境的经典案例
Fig.03 Shanghai is a classic example of a sprawling city with high rates of population growth and a high density of built environment.

2 城市动态的类型学

城市化的动态可以理解为基于人口增长和建成城市环境的密度水平的类型学（图02）。蔓生的城市会在人造环境密度高，人口增长迅速的情况下出现。随着城市的持续发展，它们会从城市中心开始，通常沿着交通干线，向外扩张。在蔓生的城市，由于城市空间的激烈经济竞争，城市开放空间变得格外稀缺。规划的有效性也往往由于紧急的新发展以及现有的难以更改的密度而受到限制。然而，实践和实验创新的城市发展和绿色基础设施的动力和机会是巨大显著的。人们对于城市扩张的普遍反应是遏制，或者精明增长——让城市在一个可以提供生态系统功能的、相互链接的网络开放空间结构下，从容发展。

稳定的城市拥有中度到高度的建成环境，并且有一个稳定的人口。这些城市往往已经建立了城市开放空间系统。而这些建成的城市开放空间，在城市空间竞争激烈的背景下，与新的或者重新开发的绿地相链接的概率，比正在增长的城市要低。在稳定的城市中，城市规划会是目的性与机会性并存，而对于常规二次开发的建筑和基础设施的需求，为推行绿色建筑和绿色基础设施提供了机会。因为城市每隔几十年都要更新和重建，这样的重建提供了可持续改造的机会。比如说主要的道路一般在每20年需要重铺/重建。而在这一过程中，重建的道路可改造成一条绿色街道，适当地添加可渗透性、高反照率的铺装，配上自行车道、绿化带以及野生动物地下通道。

新的/计划的城市发生在人口增长速度快，但建成环境密度低的国家或区域范围内。新的城市通常建立在农业区域，需要重新安置时，将现有的建设少、环境相对干净的区域设为"绿地"，而将之前经济活动留下来的污染土地但拥有较少人口的地方设为"棕地"。新的/计划的城市为大胆的、富有远见的规划和设计提供了最大机会——在落实高效的土地利用和交通的同时，包含了人为设计的、可提供生态系统服务的城市开放/绿地空间系统。"生态城市"运动展现了探索创新模式和城市化概念的新型城镇化的潜力。

萎缩的城市有以下特征：人口不断下降，最终形成密度越来越低的建成环境。城市萎缩发生在宏观经济变化和缺乏就业和公共收入的背景下。在萎缩的城市中蕴含着独特的更新和重建机会，通过谨慎"编辑"未被利用/未被充分利用城市发展——引入可持续的填充式发展，结合城市交通和开放空间资源。萎缩的城市具有重塑自己的身份、经济以及物理形态——包括其城市/绿地结构——的潜力，这同时也是一种挑战。

城市动态的类型学提供了一个结构化的系统，根据城市地区的人口增长和城市形态密度进行分类。类型学暗示了内在的一种特定类型的城市动态的特定的机会和挑战。在这个"城市的时代"，最具挑战性和最重要的类型也许是蔓生的城市。

3 蔓生的城市作为城市实验室

上海是一个典型的无限蔓延的城市。它有着悠久的城市历史，目前正处于开发热潮之中。这个包含上海和长三角在内的特大型区域为研究提供了难得的机会。上海市城市化生态过程与生态恢复重点实验室（以下简称为SHUES）已经由华东师范大学建立，以期解决共生的挑战和机遇问题。

SHUES是由包括中国国家自然科学基金委员会在内的多源资助的一个跨学科研究小组。它在以下3个方面开展研究：1）复杂的城市和农村生态系统；2）规划管理和设计城市与区域生态系统；3）生态工程设计。SHUES运用其研究来解决城市环境和生态问题。在象伟宁教授的领导下，SHUES已成为一个使用城市区域作为实验室的典范，他们监测和管理数据库，随时间的推移记录城市状况。在许多方面上，SHUES都类似于美国亚利桑那州凤凰城和马里兰州巴尔的摩的城市长期研究中心。但是，因为上海是世界上最大的城市之一，并有望在未来继续扩张，因此SHUES可以使用"从实践中学习"的方法来理解复杂的城市生态环境问题，并设计和监测创新和实验性的解决方案①。

4 衡量城市生态系统服务

生态系统服务的概念在千年生态系统评估报告中被广泛推广。它有4类服务类型：支持、供应、监管和文化。这些都是为人类利益而提供的自然生态系统的服务和功能。为便于阐述，可以将它们分为三大类：非生物

图04

类，生物类以及文化类[6]。非生物类型是无生命体的服务，它们来自于物理环境，例如水文学，这也许是在城市生态规划与设计中最重要的一环。

生物生态系统则是与生活和生命系统相关。生态系统为野生动物物种提供栖息地和行动走廊。空气污染减排及污染防治可以通过城市森林实现。伟大的哲学家和科学家，比如利奥波德（Aldo Leopold）提醒我们，保护生物多样性是明智的，因为我们无法知道在未来，哪一些物种将会被证明有多么重要。马萨诸塞大学教授德里克·洛夫利发现了生活在华盛顿特区波托马克河的沉积物中的地杆菌。这种细菌能代谢和稳定有毒废物。这就是一个表面看似毫无价值，但最终被证明价值非凡的生物体的例子。如果我们想要实现城市的可持续发展，我们就要使它们成为生物多样性的中心——而不是生物多样性的沙漠！

文化和社会生态系统服务在城市可持续发展中同样重要。公园是重要的，当然有对人类娱乐的方面，但它也支持着人类健康，为健康的社会交往提供场所。我们正在创造21世纪城市的新的性质，以提供一整套的生态系统服务：非生物类，生物类以及文化类。上述以及其他概念共同定义和肯定着一项，那就是，生态系统服务对人类健康和福祉的各个方面都至关重要。生态系统功能是人类赖以生存在一个可持续发展的世界的保障。可持续性的挑战在21世纪的城市中成功与否，就取决于城市所提供的生态系统服务。因此，我们可以认为，生态系统服务是城市可持续发展的指标。

生态系统服务可以作为联系城市形态（模式）和城市过程（生态系统服务）的考核指标。一旦对其进行了了解、测量和映射，生态系统服务便可成为城市可持续发展规划的目标和基准。在规划和设计可持续发展的城市中，风景园林师已经从生态学家那里学习到保护及恢复城市绿地和生境的大、小斑块之间连通性的重要性。绿道具有提供广阔的城市区域生态系统服务套件的潜能。绿色基础设施是另一种为城市提供生态系统服务的现代的理念[6]。生态设计的概念，包括绿道和绿色基础设施，得到人们的日益理解和重视。随着全球城市化进程推进，设计师在测量和记录其所设计的项目所能提供的生态系统服务时，将面临更大的挑战。

5 绿道和绿色基础设施中的生态系统功能监测

生态系统功能的概念被越来越多地理解为城市可持续性的重要目标和指标。设计领域的下一个挑战将会是提倡以提供特定生态系统功能为目标的项目，并对其实施监测。在设计领域中，并没有支持监测系统的传统。如果监测可以在小尺度的、安全失败的设计实验中实施，那么失败的风险将能被降到最低，而创造成功的潜力将达到最大化[7]。

城市森林的其中一项预期效益是增加生物多样性。测量鸟类的多样性可以用“点测法”实现，通过一个或多个专业培训的/专家观测者进入一个城市森林，并记录下在特定时间段所观察到的或听到的鸟类数量和种类，然后对不同观测者的结果，包括观测时间、观测的地点进行比较和计算。这一方法在生物领域被广泛认知，却很少在设计领域中运用。这些数据将用于记录特定城市森林的种植和组态所产生的生物多样性效益。如果风景园林师可以增加生物多样性的监测，他们就可以与“设计实验”科学家们合作，学习如何提供城市所需的生态系统服务。

屋顶绿化能提供多元的生态系统服务：能源节约、雨水蓄洪、改善水质、延长建筑物屋顶的更换，并对生物多样性——尤其是益虫的支持。在高度城市化的环境下，绿色空间和栖息地有限，屋顶绿化可以成为传粉昆虫宝贵的栖息地。为城市蔬菜、树木和花卉授粉的蜜蜂可以在绿色屋顶中找到栖息地。而蜂种的存在性和多样性可以通过多种陷阱装置来测量。“陷阱锅”是用黄色的平底锅，装满肥皂水，吸引和捕捉蜜蜂的装置。通过定期收集和调度监测陷阱装置，我们可以了解蜜蜂的种类有多少，哪些是存在于绿色屋顶——为周围社区提供授粉服务。“马莱兹陷阱”是更大一些的帐篷状装置，可以捕捉更广泛多样的飞虫。和“陷阱锅”一样，“马莱兹陷阱”可以进行定期采样和记录，从而了解哪些昆虫存在于绿色屋顶。

人造湿地通常被广泛用于提供生态系统功能。浮动湿地一种独特的绿色基础设施，它可以在城市水域建设人工浮动栖息地，以提供栖息地并改善水质。由于浮动湿地可以在大型水面移动，因此很难用常规方法对其进行监测。图8描述了传统的监测方法，它采用GPS相联的传感器将湿地位置、水温以及水质等参数数据报告到卫星上。因为这个系统与遥感相连，它可以在已知坐标的不同位置，连续地报告水质的数据。

雨水花园是较常见的一种绿色基础设施，它可以提供与水有关的生态系统服务，包括雨水滞留、渗透以及水质改善。不幸的是我们很少对雨水花园进行监测。但是，如果在建造雨水花园前就决定对其进行监测，那么安装一个简易的监测井就十分容易，所需成本也十分低廉。监测井可以用来收集于雨水花园下不同深度穿过的水样品，并通过实验室对样品进行分析，以测量选定样本的水质参数（即硝酸盐，磷）的效果。如果在建设雨水花园时没有安装监测井，那么后期再进行安装的将会变得非常具有破坏性，而且成本昂贵。

这些示例演示了绿道和绿色基础设施的未来生态系统服务，并如何对其进行准确的监测。如果以标准认可的方法进行数据收集，就可以科学地对数据进行分析，并了解不同的绿道或绿色基础设施的配置或整改对生态系统服务的不同影响。当监测成为一种惯例，每个城市建设都可以看成一个实验，在一个自适应的设计过程中，计划和设计都可被视为一种机会去探索和开发新研究，并对这些想法进行测试。这是一种不同于采用标准解决方案的专业规划和设计实践的新的方式。

6 总结

在这个城市的世纪，可持续发展将在现有和未来的城市中成功或失败。城市可持续发展可以被理解为，甚至计量为，城市中特定的支持人口增长的生态系统功能，和人类赖以生存的生物多样性。设计专业领域可以通过在城市规划和设计整合生态系统服务，纳入基础设施、环境和绿色系统来促进城市可持续发展。由于这是一个全新的、具体的挑战，且在每个城市都不尽相同，设计师们必须找到和测试新的想法，以“从实践中学习”的方式，测试这些想法在特定条件和位置下是如何随时间推移而作用的。如果规划者和设计者可以有效地实践适应性设计，他们会意识到从城市化的过程中学习与获益的可能性。这样的话，城市化进程将能够从一个已察觉的人类问题开始转变——转变成新思路和新实践的源头，而这个源头将可能会对城市可持续发展的解决方案产生重大意义。

图05

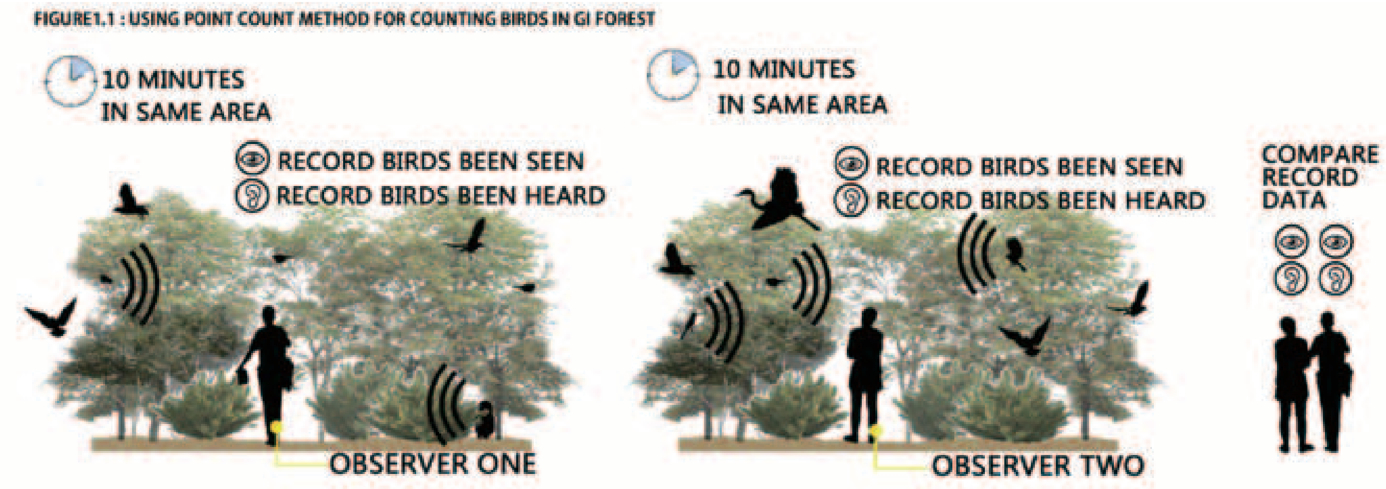


图06

This article is a summary of the keynote presentation given by the author at the 2013 F á bos Landscape Planning and Greenway Conference, University of Massachusetts Amherst

1 Trends and Challenges of Global Urbanization

At the start of the 20th Century approximately 10 percent of the world's population lived in cities. The 21st Century has already been called the century of the city because, in 2007 for the first time in history, the world's population became more than 50% urban. In the coming decades the world's total population is expected to rise from 7 billion to 10 billion, with much of that increase occurring in the world's cities (Urban Age Project, 2007). Importantly, this trend towards an urban population is expected to continue throughout the century, reaching 6.3 billion urban inhabitants by 2050 and 8.5 billion by 2100 (UN ESA, 2012). This urbanization is expected to occur at different rates around the world but will mostly occur in the developing countries. Much of this increase in urban population will occur during the professional careers of the current generation of university students and recent graduates in planning and design. If this new hyper-urban world is to be

图04 中国广东省绿道深圳地段游客中心/观景台。
Fig.04 Visitor center/observation structure on the Guangdong Province Greenway Shenzen, PRC.
图05 建立湿地雨水管理，水质缓解和野生动物栖息地。位于加拿大不列颠哥伦比亚省温哥华市福溪。
Fig.05 Created wetland for storm water management, water quality mitigation and wildlife habitat. Southwest False Creek, Vancouver, British Columbia, Canada.
图06 在绿色基础设施/城市森林中实施鸟类测量点测法 图片来源：刘姝
Fig.06 The point count method for Counting Birds in a Green Infrastructure/Urban Forest. Credit: Shu Liu.

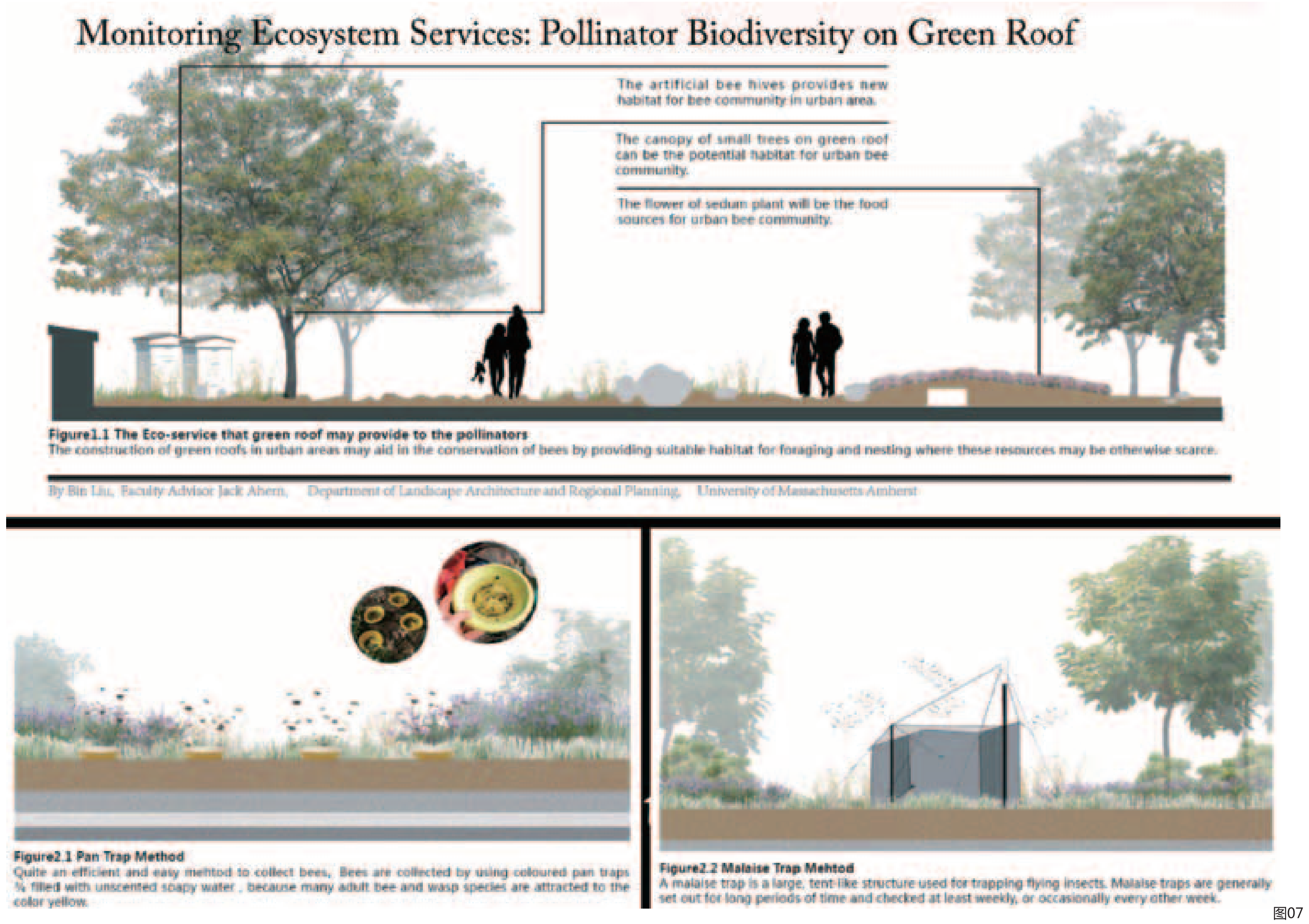


图07

图07 监测生态系统功能：绿色屋顶上的授粉昆虫 图片来源：刘斌
Fig.07 Monitoring Ecosystem Services: pollinators on green roofs. Credit: Bin Liu

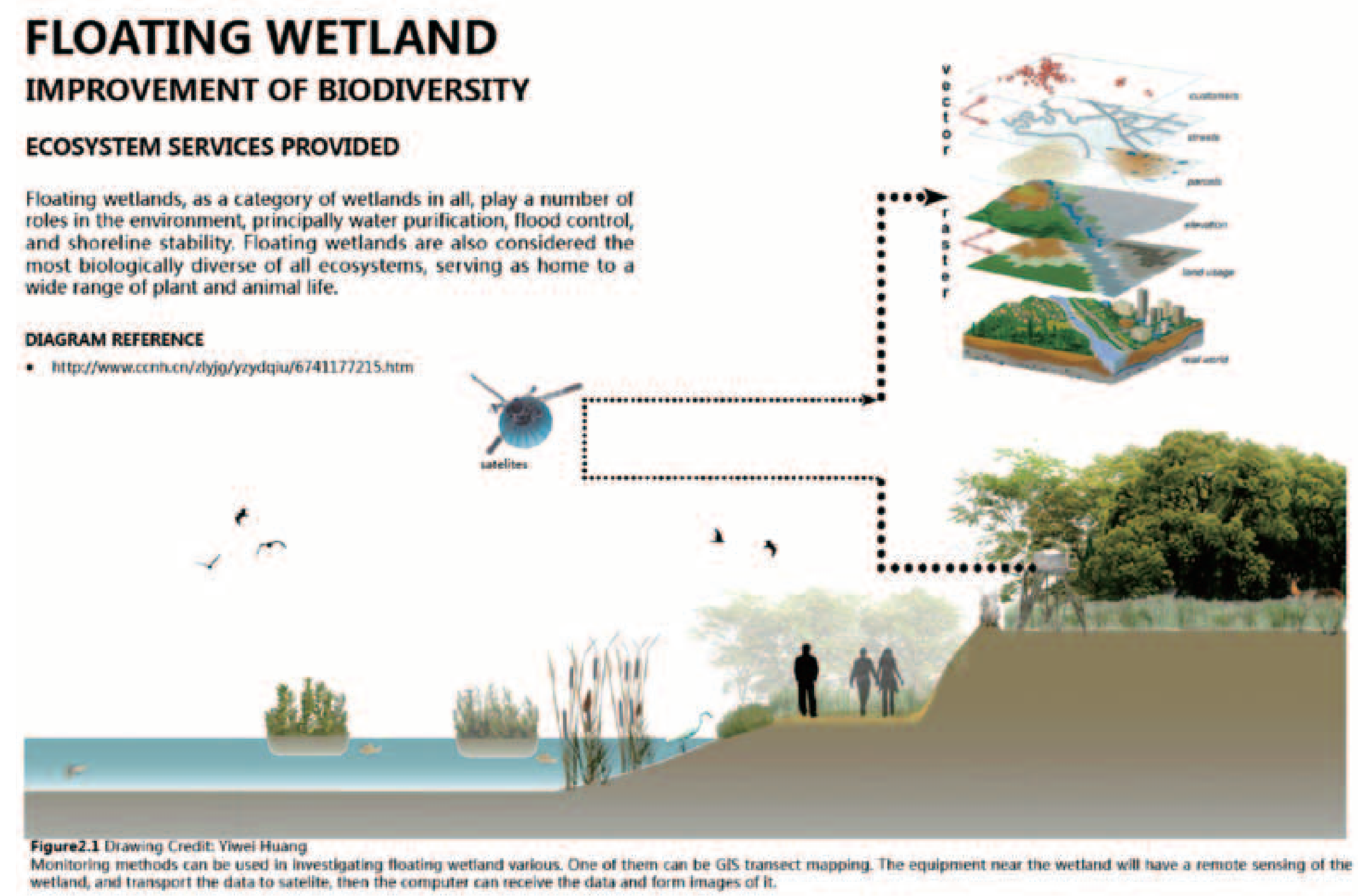


图08

图08 浮动湿地生态系统功能的远程监测 图片来源：黄伊伟
Fig.8 Remote monitoring of ecosystem services for floating wetlands. Credit: Yiwei Huang.

sustainable, its cities must be sustainable - and that represents a profound challenge, especially for urban and landscape planning and design professions.

By the year 2100, the Asian region will see the world's largest increase in urban population from 1.8 billion in 2010 to 3.3 billion in 2050 to 3.8 billion (UN ESA 2012). Through the popular media, China is widely misunderstood as a hyper-urban country. In 2011 China's population was far less urban (50.6%) than the United States (82%), or The Netherlands 83% (CIA). However, China is in the process of a massive, unprecedented urban migration. In the next 25 years, China will build more cities with more than one million people than total of current cities with over one million population in United States. In China, this rural-to-urban migration is well underway, with 250 million additional Chinese planned to move into new and existing cities in the next 12 years alone! (New York Times, 2013) In this respect China has the potential to become a laboratory from which the rest of the world can learn how to plan and design cities to accommodate this new urban population in a sustainable manner.

The United Nation's Millennium Assessment raised the radical proposition that "the struggle to achieve the Millennium Development Goals will be "won or lost in cities" (UN 2006). This proposition is based on the link between urbanization and socio-economic development including the effect of urban development on the rural environments around cities, providing engines for rural development and supporting the rural economy. This bold proposition, in a global context, raises a basic challenge for urban planners and designers "How can existing cities be expanded, and new cities created - in a sustainable manner, to meet the crushing demands of the new urban population while managing landscapes and ecosystems to provide the ecosystem services that the cities, and their residents depend on?

2 A Typology of Urban Dynamics

The dynamics of urbanization can be understood with a typology based on the level of population growth and the density of the built urban environment (Fig.02). Sprawling Cities occur where high rates of population growth occur in the context of a high-density built environment. Because these cities continue to grow they expand from the center, typically along transportation routes. In sprawling cities, urban open space becomes scarce due to the intense economic competition for urban space. The effectiveness of planning is often limited by the exigency for new development, and the existing density that limits change through planning. However, the motivation and opportunity to implement and test innovative urban development and green infrastructure is substantial. The common response to sprawl is containment, or smart growth - allowing the city grow in a more deliberate way crafting a connected, networked open space structure to provide ecosystem services.

Stable cities have a moderate to high density of built environment, but a stable population. These cities often have established urban open space systems, and the opportunity to include new green space in conjunction with new or re-development because the competition for urban space is moderate to low in comparison with sprawling cities. In stable cities urban planning can be intentional and opportunistic, and the need for routine re-development of buildings and infrastructure provides opportunity to implement green building and infrastructure. Because cities need to be rebuilt every few decades, that rebuilding creates the opportunity for sustainability retrofits. Take the example of major roads that generally need repaving/rebuilding every 20 years. During rebuilding a road can become a green street with permeable, high-albedo paving materials, bicycle lanes, tree planting belts, and wildlife underpasses added where appropriate.

New/Planned cities occur in national or regional contexts where population growth is high, but the existing density of the built environment is low. New cities are often located in agricultural regions, requiring resettlement, in "greenfields" where existing development is minimal and the environment is relatively clean, and "brownfields" where prior economic activity left a contaminated environment, but existing population is low. New/Planned cities provide the greatest opportunity for bold, visionary planning and design – employing the best practices for efficient land use and transportation while including an intentional urban open/green space system to deliver ecosystem services. The "eco-city" movement demonstrates the potential for new urbanization to explore innovative models and urbanization concepts.

Shrinking cities are defined by a declining population and eventually produce a low, or lower density of built environment. Shrinking cities occur because of macroeconomic changes and suffer from lack of employment and public revenues. Shrinking cities provide unique opportunities to renew and rebuild through deliberate "editing" of un/underused urban development – by introducing sustainable infill developments, integrated with urban transportation and open space resources. Shrinking cities hold the potential and the challenge to reinvent their identity and economy, and physical form – including their urban/green space structure.

The typology of urban dynamics offers a structured system to classify urban regions based on their population growth and density of urban form. The typology suggests the particular opportunities and challenges that are inherent in a particular type of urban dynamic. In this "Century of the City" perhaps the most challenging and important type are the sprawling cities.

3 Sprawling Cities as Urban Laboratories

Shanghai is a quintessential sprawling city. It has a long urban history and is currently in the midst of a development boom. This mega-regional context of Shanghai and the Yangtze River Delta provides a unique opportunity for research. The Shanghai Key Lab for Urban Ecological Processes and Eco-restoration (SHUES) at East China Normal University has been organized to address the simultaneous challenge and opportunity.

SHUES is an interdisciplinary research group funded by the Natural Science Foundation of China, among other sources. SHUES conducts research in three areas: 1) complex urban and rural ecosystems, 2) planning managing and design of the urban and regional ecosystem and 3) ecological engineering. SHUES applies its research to solve urban environmental and ecological problems. Under the Direction of Xiang, Wei-ning, SHUES has become a model for using an urban region as a laboratory where monitoring and data base management can document urban conditions over time. In many respects SHUES is similar to the Urban Long Term Research Centers in Phoenix Arizona and Baltimore Maryland in the US. However, because Shanghai is one of the world's largest cities, and is expected to expand into the future, SHUES has a unique opportunity to "learn-by-doing" in understanding complex urban ecological issues, and designing and monitoring innovative and experimental solutions (SHUES 2013).

4 Measuring Urban Ecosystem Services

The concept of ecosystem services was popularized in the Millennium Ecosystem Assessment. There are four categories of services, supporting, provisioning, regulatory and cultural. These are the services and functions provided by natural ecosystems to the benefit of humans. I've organized them into three broad categories for the sake of illustration: Abiotic, Biotic and Cultural (Novotny et al 2010). The abiotic are the non-living services that come from the physical environment, for example hydrology, which is perhaps the most important process in the urban ecology planning and design.

The biotic ecosystem services are related to life and living systems. Ecosystems provide habitat and movement corridors for wildlife species. Air pollution mitigation and remediation can be provided by urban forests. Great philosophers and scientists like Aldo Leopold remind us that it is wise to protect biodiversity, because we don't know how important any species may prove to be in the future. A professor at the University of Massachusetts, Derek Lovley, discovered the geobacter bacteria living in the sediment of the Potomac River in Washington. This bacteria can metabolize and stabilize toxic waste. Here is an example of an organism with no apparent value that has proven to be highly valuable. If our cities are to be sustainable, we need them to be centers of biodiversity – not biodiversity deserts!

Cultural and social ecosystem services are equally important for urban sustainability. Parks are important, of course for human recreation, but also to support human health and to provide places for healthy social interaction. We are creating a new nature in 21st Century cities and we need this new nature to provide a broad suite of ecosystem services, abiotic, biotic and cultural. These, and other concepts both define the term and affirm that ecosystem services are essential for all aspects of human health and well-being. Ecosystem services are what humans depend on for survival in a sustainable world. If the challenge for sustainability will be won or lost in 21st Century cities, it will depend on the ecosystem services that cities provide. Ecosystem services can therefore be understood as the metrics of urban sustainability.

Ecosystem services can serve as assessment metrics to link urban form (pattern) with urban process (ecosystem services). Once understood, measured, and mapped, ecosystem services can become the goals and benchmarks of planning for urban sustainability. In planning and designing sustainable cities, landscape architects have learned from ecologists of the importance of protecting and restoring connectivity between large, and small patches of urban green spaces and habitats. Greenways are understood for their potential to provide a broad suite of ecosystem services in urban areas. Green infrastructure is another contemporary concept for providing urban ecosystem services (Novotny et al 2010). Ecological design concepts including greenways and green infrastructure are increasingly understood and valued. As urbanization advances globally, designers will be increasingly challenged to measure and document the ecosystem services that their plans actually provide.

5 Monitoring Ecosystem Services in Greenways and Green Infrastructure

The concept of ecosystem services is increasingly understood as a useful goal and metric for urban sustainability. The next challenge for design professionals is to advocate for and practice monitoring of projects that aim to provide particular ecosystem services. Design professions do not have a tradition of supporting monitoring. If monitoring can be conducted on small-scale, safe-to-fail design experiments, the risk of failure can be minimized and the potential to earn success can be maximized (Ahern 2011).

I have developed methods for monitoring specific ecosystem services associated with greenways and green infrastructure with landscape architecture students at the University of Massachusetts Amherst. We developed a "toolbox" of methods that landscape architects and planners can readily build into projects that intend to provide ecosystem services.

One of the expected benefits of urban forests is to increase biodiversity. Measuring of bird diversity can be conducted with the "point count" method where one or more trained/expert observers visit an urban forest or neighborhood and record the number and type(s) of birds seen and heard in a specific observation time. The results between multiple observers, observation dates, and locations can be compared and averaged. This method is well-known in biology but is rarely practiced by design professionals. These data serve to document the biodiversity benefits of particular types of urban forest plantings and configurations. If landscape architects can learn to promote biodiversity monitoring they can become partners with scientists in "design experiments" to learn how to provide ecosystem services in cities.

Green roofs are advocated for the multiple ecosystem services they provide: energy savings, stormwater retention, water quality improvement, extending building roof replacement, and supporting biodiversity – particularly of beneficial insects. In highly urbanized environments where green space and habitat is limited, green roofs may become valuable habitats for pollinating insects. The bees that pollinate urban vegetables, trees and flowers can find habitat on green roofs. The presence and diversity of bee species can be measured by several types of traps. The "pan-trap" deploys yellow pans filled with soapy water that attracts and captures the bees. The traps can be collected and monitored on a regular schedule to learn how many individuals and which species of bees are present on the green roof – and providing pollination services to the surrounding neighborhood. Malaise traps are larger tent-like structures that can capture a wide diversity of flying insects. As with pan traps, malaise traps can be sampled and recorded on a regular basis to learn which insects are present on the green roof.

Created wetlands are commonly used to provide ecosystem services. Floating wetlands are a unique type of green infrastructure that constructs artificial floating habitats on urban waters to provide habitat and water quality improvements. Because floating wetlands can move across large water surfaces, they are difficult to monitor by conventional methods. Figure 8 illustrates a monitoring method that employs GPS-linked sensors to report data to satellites on the floating wetland location, water temperature and water quality parameters. Because this system works with remote sensing it can report data continuously on water quality at different locations with known coordinates.

Rain gardens are one of the more common types of green infrastructure to provide water-related ecosystem services including stormwater retention, infiltration and water quality improvement. Unfortunately monitoring is rarely conducted in rain gardens. However, if a commitment to monitoring is made before the rain garden is constructed, simple monitoring wells can be easily installed at low cost. The wells can be used to gather water samples at multiple depths beneath the rain garden to measure the effect of the substrate on selected water quality parameters (i.e. Nitrate, Phosphorous) through laboratory analysis of the samples. If these wells are not installed during installation they become very disruptive and expensive to install.

These examples demonstrate how the ecosystem services intended and expected from greenways and green infrastructure can be accurately monitored. If the data are collected with standard accepted methods, it can be scientifically analyzed to learn the differential effects of alternative greenway or green infrastructure configurations or treatments on ecosystem services. When monitoring becomes a regular practice, every urban construction can be understood as an experiment, in an adaptive design process where plans and designs are conceived as opportunities to explore and develop new research, and to test ideas. It's a different way of thinking about professional planning and design practice than conventional work that tends to apply standard solutions.

6 Summary

In this century of the city, sustainability will be won-or-lost in existing and future cities. Urban sustainability can be understood, and measured, as the specific ecosystem services provided in cities to support human populations and the biodiversity on which humans depend. Design professionals can contribute to urban sustainability by integrating ecosystem services into plans and designs for infrastructure, settlements and green systems in cities. Because this is a new challenge, and is specific and different in every city, designers must develop and test new ideas and "learn-by-doing" how these ideas perform over time under specific conditions and locations. If planners and designers can effectively practice adaptive design, they may realize the possibility to learn from, and benefit by the process of urbanization. In this way urbanization can change from a perceived human problem – to the source of new ideas and practices that can be important to the solution for urban sustainability.

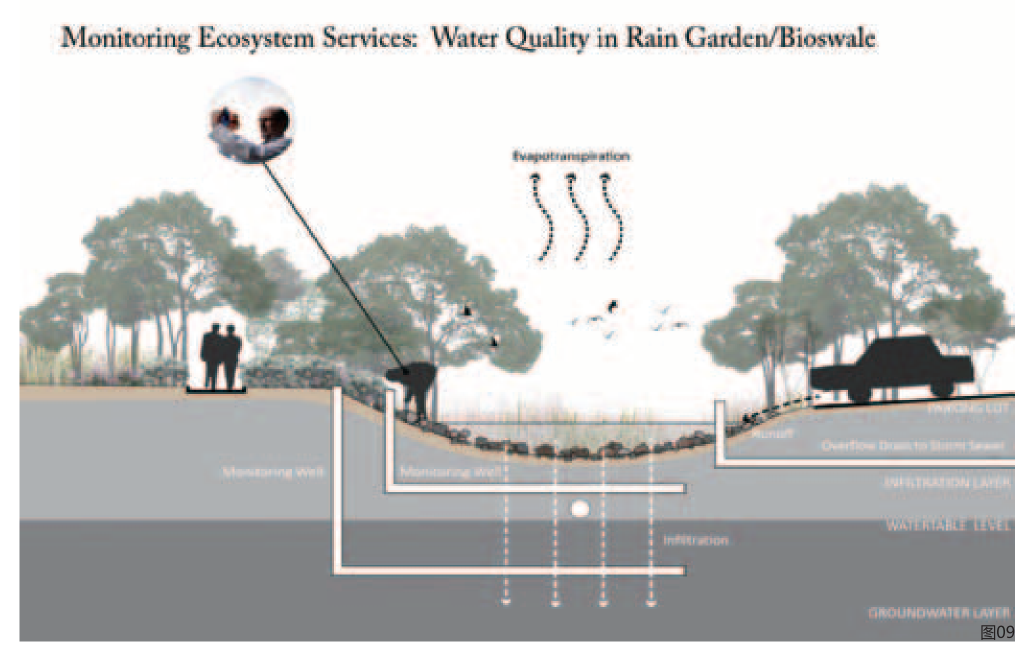


图09 监测生态系统功能：雨水花园和生态种植沟中的水质测量 图片来源：周张侃

Fig.09 Monitoring Ecosystem Services: Water quality in rain gardens and bioswales. Credit: Zhangkan Zhou

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注释:

①资料参考自上海市城市化生态过程与生态恢复重点实验室网站：http://www.shues.org/

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