International Perceptions of Urban Blue-Green Infrastructure: A Comparison across Four Cities

Supplementary Material

Case Study Cities

1. Newcastle-upon-Tyne, UK

Newcastle, with a population of 280,000, is situated on the north-western bank of the River Tyne in north-east England. A compact urban core is surrounded by residential areas and substantial green belt land to the north and west of the city. Newcastle faces a range of environmental challenges including flooding, poor air quality and an urban heat island effect (Newcastle City Council and Gateshead Council, 2015). In 2012, Newcastle experienced a severe rainfall event where 50 mm fell within a two-hour period, causing extensive flooding to approximately 1200 properties, predominantly due to surface water runoff (Environment Agency, 2012). Newcastle is also at risk of fluvial flooding; in December 2013 the River Tyne flooded parts of the Quayside after a tidal surge from the North Sea raised river levels (Newcastle City Council, 2016).

Following these events, Newcastle City Council (the Lead Local Flood Authority) and partners have invested in improving the city’s resilience to future flooding through a combination of blue, green and grey infrastructure. Several exemplar schemes showcase effective delivery of BGI (Blue-Green Infrastructure) through local and regional partnerships, e.g., sustainable drainage system (SuDS) ponds as part of the Newcastle Great Park development, and the Killingworth and Longbenton surface water management scheme that comprised a new underground overflow pipe, five surface attenuation basins and disconnected Longbenton Letch (stream) from the combined sewerage network and diverted into Forest Hall Letch (O’Donnell et al., 2018). A key component of the Newcastle City Strategic Surface Water Management Plan is a proposed network of ‘Blue-Green corridors’ to capture rainfall in the city center and transport it to the Tyne, with a goal of maximizing the social and environmental benefits of managing water above the ground in attractive blue-green systems (Amec Foster Wheeler, 2016). The signing of the Newcastle Declaration on Blue and Green infrastructure in 2019 by ten key stakeholder organisations (including Newcastle City Council, the Environment Agency, and Northumbrian Water) demonstrate the aspiration for BGI coupled with a change in attitudes and ways of working (UFR, n.d.).
2. Ningbo, China

Ningbo is a major port and industrial hub, situated southeast of the Yangtze River Delta in Zhejiang province. The 2020 population is c. 7.5 million and projected to reach 10 million by the 2030s. Ningbo is sensitive to seasonal climatic effects, particularly in the wet season when cyclonic storms (typhoons), tidal surges and intense rainstorms frequently visit the region (Chan et al., 2012). More than 44 typhoons are estimated to have impacted the city since the 1950s, causing 12 large floods and a total economic impact exceeding 93 billion RMB (Tong et al., 2007). Typhoon Fitow (October 2013), exhibiting a maximum 24-hr rainfall of 263mm, caused widespread pluvial flooding as runoff overloaded the city's drainage network (currently designed for 1-in-5 to 1-in-20 year events), affecting over 2.4 million people (Tang et al., 2015).

The outdated drainage systems in Ningbo (and many other Chinese cities) currently operate in exceedance of their design standards, and are unable to cope with the combination of rapid urbanization, reduction in permeable greenspace, and high intensity of cyclonic-enhanced rainstorms (Chan et al., 2018). The Sponge City Program (SCP) was initiated by the Chinese Government in 2013 to tackle these urban water challenges; mitigating flood risk while storing water to meet future demand by retrofitting existing cities with BGI to facilitate the absorption of rainwater and subsequent storage, purification and reuse (MHURD, 2014). The SCP is founded on pilot projects in demonstration zones within the 30 cities selected to trial this approach (Qiao et al., 2019). Participating cities must ensure that 20% of their urban land includes ‘sponge’ features (e.g. rain gardens, swales, wetlands, ponds, and permeable paving) by 2020, and 70-85% annual precipitation should be managed onsite. Strategies will improve stormwater management capacities from current low standards (1-in-1 to 1-in-5 year events) to 1-in-30 year events (ibid.). The SCP is being delivered within an urban governance framework that promotes development and urbanization in tandem with improving the natural environment and maintaining pre-development hydrological flow regimes (Jiang et al., 2017).

3. Rotterdam, the Netherlands

As a low-lying port city situated in the Rhine-Meuse Delta, Rotterdam has a close connection with water; approximately 85% of the city is up to 7m below sea level and the remaining 15% lies in unembanked areas (City of Rotterdam, 2013). Increasing the city’s resilience to the impacts of future climate change (notably rising sea levels and flooding from extreme rainfall events) is a key priority as outlined in the Rotterdam Climate Change Adaptation Strategy (City of Rotterdam, 2013) and subsequent Rotterdam Resilience Strategy (City of Rotterdam, 2016). A multi-layer-safety approach has been adopted and focuses on three key aspects: 1) maintaining and strengthening existing
infrastructure (dykes, barriers, sewers), 2) redesigning the city to create more space for water storage by promoting BGI, and 3) working with other city projects to link adaptation and spatial planning (Ministry of Infrastructure and the Environment, 2015). Multifunctional space, multiple beneficiaries, and multi-agency partnerships and funding are key, as is using urban water policy to help improve the quality of life of city residents (de Graaf and van der Brugge, 2010).

Over the last two decades, Rotterdam has produced numerous reports and guidance to support the transition to greater climate resilience, founded on the 2007 ambition to become 100% climate-proof by 2025 (maintaining functionality of the economic and social systems in the city with minimal disturbance during extreme weather events) (Municipality of Rotterdam, 2007). *Waterplan 2 - working on water for an attractive city*, progressed from the 2001 Waterplan by focussing on sustainability and adaptation at the scale of the Rotterdam Metropolitan Region. The 3rd edition of Rotterdam’s Waterplan (2013) comprises 13 sub-water plans in accordance with the urban typologies of the city (Municipality of Rotterdam, 2013).

Rotterdam Weather-Wise (Rotterdam Office of Climate Adaptation, 2019) can be considered the 4th edition of Rotterdam’s Waterplan. This promotes a bottom-up approach, involving both public and private actors, and focuses on small scale measures that will increase the city’s resilience to future climate change impacts while improving outdoor public spaces. This development is increasingly visible in the city, including several water squares, extensive BGI, depaving projects, 220,000 m² of green roofs, and a rooftop park functioning as flood defence (Buro Sant en Co, 2014).

4. Portland, Oregon, USA

Portland is located near the confluence of the Columbia and Willamette Rivers. The city of Portland, with a population of around 653,000 (United States Census Bureau, 2019), is the largest of the twenty-four cities in the region’s urban growth boundary (UGB). UGB’s are required around each city and metropolitan area in Oregon to protect farm and forest lands from development (Metro, 2014). This model of compact development has led to Portland being recognized as a world leader in smart growth (Mohammed et al., 2016).

Portland’s climate has two distinct seasons—a wet season from October-March when approximately 70% of precipitation falls, and a dry season from April-September (Fahy et al., 2019). Substantial investments have been made by government agencies, nonprofits, and private landowners to reduce nuisance flooding, improve water quality, and enhance fish habitat.
A $1.4 billion grey infrastructure project completed in 2011 has been complemented with an extensive system of green streets. These investments are expected to decrease discharges from the combined sewer system into the Willamette River from fifty times per year to an average of four times each winter and once every third summer (Netusil et al., 2014). The ‘Gray to Green’ initiative invested widely in BGI implementation to alleviate loadings on the piped infrastructure system and reduce adverse impacts on urban watercourses. These ongoing efforts have, to date, delivered over 900 green streets (bioswales), more than 400 ecoroofs, over 32,000 street trees, and invested in widespread culvert replacement or removal; purchasing of properties at high flood risk from willing sellers, and; reconnected and restored urban streams, floodplains and native vegetation (BES, n.d). In 2018, the City Council adopted one of the most aggressive green-roof policies in the United States that requires any new buildings with a net building area of 20,000 square feet or more to have a green roof. As of 2019, there were almost 1.4 million square feet of green roofs in the city of Portland (Netusil and Thomas, 2019).
Survey Questions

In several questions, respondents were asked to rank from ‘very significant’ to ‘very insignificant’. Here, we present the exact language used in the survey. However, for clarity, in the manuscript and the statistical analysis in Supplementary Material C, e.g., Table C.2., we use the term ‘significant’ in a statistical sense and report perceptions of significance from the survey as perceptions of relative ‘importance’.

1. What do you think are significant water challenges in your City? Please give each challenge a score from 1 (very significant) to 10 (not significant).

_____ Drought risk
_____ Fluvial (river, stream, creek) flood risk
_____ Coastal flood risk and storm surges
_____ Sea level rise
_____ Increasingly frequent extreme rainfall events
_____ Water quality deterioration and river health
_____ Aging/outdated water and wastewater infrastructure
_____ Combined sewer overflows
_____ Water supply
_____ Sanitation
_____ Saturated soils
_____ Low groundwater levels
2. How significant are the following benefits of Blue-Green infrastructure to you? Please select one option per line.

| Benefit                                                                 | Very significant | Significant | Neither significant or insignificant | Insignificant | Very insignificant | Don’t know |
|------------------------------------------------------------------------|------------------|-------------|---------------------------------------|---------------|--------------------|------------|
| Flood risk and stormwater management                                  |                  |             |                                       |               |                    |            |
| Water quality improvement                                              |                  |             |                                       |               |                    |            |
| Air quality improvement                                                |                  |             |                                       |               |                    |            |
| Carbon sequestration                                                   |                  |             |                                       |               |                    |            |
| Groundwater recharge and river base flows                              |                  |             |                                       |               |                    |            |
| Increased attractiveness/aesthetics                                    |                  |             |                                       |               |                    |            |
| Increase in property prices                                            |                  |             |                                       |               |                    |            |
| Reducing urban heat                                                    |                  |             |                                       |               |                    |            |
| Educational opportunities                                              |                  |             |                                       |               |                    |            |
| Enhanced biodiversity                                                  |                  |             |                                       |               |                    |            |
| Health and wellbeing improvement                                      |                  |             |                                       |               |                    |            |
| Rainwater use (e.g. rainwater harvesting)                              |                  |             |                                       |               |                    |            |
| Recreational opportunities                                             |                  |             |                                       |               |                    |            |
| Improved sense of place                                                |                  |             |                                       |               |                    |            |
| Noise reduction                                                        |                  |             |                                       |               |                    |            |
| Provision of jobs, e.g. building/maintenance                           |                  |             |                                       |               |                    |            |

3. Who are leading the way in implementing Blue-Green infrastructure in your City, and who should lead the way? Please select all options that apply.

| Organisation                                                                 | Are leading the way | Should lead the way |
|-----------------------------------------------------------------------------|---------------------|---------------------|
| Local Government (e.g. Local, Municipal or Provincial Authorities, City Agencies) |                     |                     |
| Elected Officials                                                           |                     |                     |
4. Which are the most effective factors for driving Blue-Green infrastructure implementation? Please select all options that apply.

☐ National Government legislation
☐ Local Government (e.g. Local, Municipal or Provincial Authorities, City Agencies) plans
☐ Local Planning Authority guidance
☐ Local Flood Authority guidance
☐ Multi-agency approaches
☐ Public-private partnerships
☐ Recognition of the multifunctionality of Blue-Green infrastructure
☐ Quantification and monetisation of the benefits and costs of Blue-Green infrastructure
☐ Lobbying from local communities, e.g. for agencies/organisations to reduce flood risk
☐ Other (please specify):
☐ Don’t know

5. What is needed to improve the uptake of Blue-Green infrastructure? Please select one option per line.

| Strategy                                      | Very significant | Significant | Neither significant or insignificant | Insignificant | Very insignificant | Don’t know |
|-----------------------------------------------|------------------|-------------|---------------------------------------|---------------|--------------------|------------|
| Clearer maintenance responsibilities           |                  |             |                                       |               |                    |            |
| Stronger national legislation                  |                  |             |                                       |               |                    |            |
| Stronger local legislation and regulations     |                  |             |                                       |               |                    |            |
| Requirement for Blue-Green infrastructure in all new developments |                  |             |                                       |               |                    |            |
| Increased awareness (developers)                                                                 |
| Increased awareness (policy-makers)                                                             |
| Mandatory standards, design and/or construction codes                                           |
| Increased local authority expertise and capacity                                                |
| Stronger enforcement from the planning system                                                    |
| Increased funding for Blue-Green infrastructure                                               |
| Wider range of funding resources                                                               |
| Better coordination at all levels of Government                                                 |
| More Blue-Green infrastructure champions                                                        |
| Best practice examples                                                                          |
| Improved valuation of the multiple benefits and costs                                           |
| Change in cultures and behaviours                                                               |
| Improved community engagement, education and outreach                                          |
| Post-project monitoring and evaluation                                                          |
| Continued research into processes and functionality                                             |
Responses to the free text option in questions 1, 3-4. NE = Newcastle, N = Ningbo, P = Portland and R = Rotterdam.

**Question 1.** What do you think are significant water challenges in your City?

| Respondent ID | ‘Other’ response |
|---------------|------------------|
| NE42          | Pluvial flood risk; Pinch points in the infrastructure network |
| P14           | Lack of affordability |
| P2            | Low stream flows and high water temperatures |
| P22           | Increased intensity of winter events and drought in summer, high water temps |
| P4            | Increase in portion of lots that are impervious in new development and redevelopment. |
| R22           | Extreme heat |
| R27           | Drought is very important, but in my opinion especially relevant in existing urban areas, not relevant in new build areas. |
| R34           | The challenges interrelate through already existing complex (infrastructure) networks. |
| R4            | Important is not the same as a substantial (big) risk... the above is filled in according to importance. |

**Question 3.** Who are leading the way in implementing Blue-Green infrastructure in your City, and who should lead the way?

| Respondent ID | ‘Other’ response – who are leading the way |
|---------------|------------------------------------------|
| N22           | Ministry of Housing and Construction Bureau |
| N29           | Some of the stakeholders listed should participate but not necessarily lead. |
| N7            | Government initiate legislation for the rewards and punishments measures to control the private developers to implement the Blue-Green infrastructure |
| NE2           | Landowners, land agents, surveyors, planning/engineering/landscaping consultants, |
| NE24          | no one organisation is leading the way - it is more via partnerships leading |
| P10           | We don’t have private water or sewer authorities so not ranked. |
| P11           | The City/Agencies were definitely leading but it’s become less of a priority. |
| P17           | marked for both in cases where some individuals are leading the way while others are not in the same grouping |
| R22           | Question is not entirely clear. |
| R24           | I think everyone should contribute, no distinctions. |
| R34           | Difficult, considering the complexity to differentiate. Area-orientated alliances and programming should be leading. |
| R7            | Housing corporations should be involved considering they own/manage large portion of properties. |

**Question 4.** Which are the most effective factors for driving Blue-Green infrastructure implementation?

| Respondent ID | ‘Other’ response – who are leading the way |
|---------------|------------------------------------------|
| N29           | I think these may be regional specific. In China, national initiative from the central government would still be the most influential factor to drive any infrastructure building while local government would have the knowledge and capital on the ground to implement it. PPP is now a fashion but it still needs to be driven from the government. This might not be true for other countries. |
| NE24          | Catchment plans |
| P10           | The original CWA lawsuit by local activist Nina Bell, spurred adoption of green infrastructure by the City of Portland BES. Without that I am not sure Portland would be leading the charge! |
| P14           | Local Design, Construction, and Maintenance guidance (In addition to Planning) |
| P2            | Methods for addressing long-term maintenance; clearer research on effectiveness to establish/update BMPs |
| P22           | NGOs |
| P8            | Commitment from community, i.e. community places value on blue-green infrastructure |
| R4            | Money. |
| R5            | Courage to deviate/ to think freely + sufficient resources for realisation and operation. |
**Statistical analysis**

**Table S1.** Ranking of the water challenges identified by the whole sample population and for each case study city. The values represent the median ranking for each water challenge. Lower rankings denote greater importance of the challenge. The most important challenges for each group are highlighted in grey. Water challenges that have (statistically) significantly different rankings between one or more cities are listed in the final column.

| Water challenge                        | All | Newcastle | Ningbo | Portland | Rotterdam | P-value (Kruskal-Wallis) | Sig. dif. and p-value (Dunn’s) |
|----------------------------------------|-----|-----------|--------|----------|-----------|-------------------------|-------------------------------|
| Fluvial flood risk                     | 3   | 4         | 3      | 4        | 3         | 0.871                   |                               |
| Increasingly frequent extreme rainfall events | 3   | 2         | 3      | 2        | 2         | 0.649                   |                               |
| Water quality deterioration and river health | 3   | 4         | 3      | 3        | 3         | 0.680                   |                               |
| Ageing water and wastewater infrastructure | 4   | 3         | 5      | 3        | 4         | 0.073                   |                               |
| Combined sewer overflows               | 4   | 3         | 4      | 5        | 4         | 0.634                   |                               |
| Coastal flood risk and storm surges    | 5   | 4         | 4      | 9        | 2         | 0.005 R — P (0.003) Ne — P (0.048) |                               |
| Sea level rise                         | 5   | 4         | 5      | 5        | 2         | 0.610                   |                               |
| Water supply                           | 5   | 7.5       | 5      | 5        | 4         | 0.010 R — Ne (0.007)    |                               |
| Saturated soils                        | 5   | 5.5       | 5      | 5        | 5         | 0.771                   |                               |
| Drought risk                           | 6   | 7         | 7      | 6        | 4         | 0.031 R — Ne (0.036)    |                               |
| Sanitation                             | 6   | 8         | 5      | 6        | 4         | 0.004 R — Ne (0.002)    |                               |
| Subsidence                             | 6   | 6.5       | 7      | 9        | 3         | 0.004 R — P (0.003)     |                               |
| Low groundwater levels                 | 7   | 8         | 7      | 7        | 4         | 0.004 R — Ne (0.002)    |                               |

*Significant differences at the $p = 0.05$ level are reported, based on Kruskal-Wallis Independent samples test and Dunn’s Post Hoc Non-Parametric Test, adjusted by the Bonferroni correction for multiple tests. Ne = Newcastle, N = Ningbo, P = Portland, R = Rotterdam.*
Table S2. Percentages of respondents in the whole sample population and each city that regarded the benefits of Blue-Green infrastructure (BGI) as very important or important. The highest percentages are highlighted in grey. The final column lists the cities where the percentage of respondents regarding the benefits as very important or important are (statistically) significantly different.

| BGI Benefits                                | All  | Newcastle | Ningbo | Portland | Rotterdam | P-value (Kruskal-Wallis) | Sig. dif. and p-value (Dunn’s) |
|---------------------------------------------|------|-----------|--------|----------|-----------|-------------------------|--------------------------------|
| Flood risk and stormwater management       | 97   | 94        | 94     | 100      | 100       | 0.591                   |                                 |
| Water quality improvement                  | 97   | 94        | 100    | 100      | 94        | 0.566                   |                                 |
| Health and wellbeing improvement           | 95   | 94        | 100    | 100      | 88        | 0.285                   |                                 |
| Enhanced biodiversity                      | 94   | 100       | 94     | 87       | 94        | 0.495                   |                                 |
| Increased attractiveness/aesthetics        | 92   | 100       | 94     | 87       | 88        | 0.470                   |                                 |
| Improved sense of place                    | 92   | 94        | 88     | 93       | 94        | 0.929                   |                                 |
| Rainwater use (e.g. RWH)                   | 84   | 81        | 88     | 73       | 94        | 0.444                   |                                 |
| Educational opportunities                  | 81   | 100       | 71     | 87       | 69        | 0.139                   |                                 |
| Air quality improvement                    | 80   | 81        | 82     | 87       | 69        | 0.698                   |                                 |
| Reducing urban heat                        | 78   | 50        | 94     | 87       | 81        | 0.037 N – Ne (0.033)    |                                 |
| Groundwater recharge and river base flows  | 73   | 56        | 82     | 80       | 75        | 0.317                   |                                 |
| Recreational opportunities                 | 72   | 100       | 76     | 47       | 63        | 0.008 Ne – P (0.006)    |                                 |
| Carbon sequestration                       | 66   | 63        | 65     | 100      | 38        | 0.003 P – R (0.001)     |                                 |
| Increase in property prices                | 56   | 44        | 76     | 60       | 44        | 0.167                   |                                 |
| Noise reduction                            | 56   | 56        | 76     | 47       | 44        | 0.166                   |                                 |
| Provision of jobs                          | 52   | 56        | 53     | 67       | 31        | 0.176                   |                                 |

Significant differences at the $p = 0.05$ level are reported, based on Kruskal-Wallis Independent samples test and Dunn’s Post Hoc Non-Parametric Test, adjusted by the Bonferroni correction for multiple tests. Ne = Newcastle, N = Ningbo, P = Portland, R = Rotterdam.
Table S3. Testing for statistically significant differences between respondents’ disciplinary backgrounds and perceptions of the very important benefits of Blue-Green Infrastructure (BGI). Disciplinary backgrounds include: Engineering, Environmental Management, Implementation, Landscape Architecture or Design, Planning, and Strategy and Policy/Finance (see Table 1).

| BGI benefits                              | P-value (Kruskal-Wallis) | Significantly different disciplines and p-value (Dunn’s) |
|-------------------------------------------|--------------------------|--------------------------------------------------------|
| Flood risk and stormwater management      | 0.131                    |                                                        |
| Water quality improvement                 | 0.021                    |                                                        |
| Increased attractiveness/aesthetics       | 0.268                    |                                                        |
| Health and wellbeing improvement          | 0.170                    |                                                        |
| Enhanced biodiversity                     | 0.727                    |                                                        |
| Improved sense of place                   | 0.958                    |                                                        |
| Rainwater use (e.g. rainwater harvesting) | 0.679                    |                                                        |
| Reducing urban heat                       | 0.775                    |                                                        |
| Recreational opportunities                | 0.888                    |                                                        |
| Groundwater recharge and river base flows | 0.033                    | Landscape Architecture or Design – Strategy and Policy/Finance (0.038) |
| Educational opportunities                 | 0.098                    |                                                        |
| Air quality improvement                   | 0.294                    |                                                        |
| Increase in property prices               | 0.342                    |                                                        |
| Provision of jobs                         | 0.232                    |                                                        |
| Carbon sequestration                       | 0.117                    |                                                        |
| Noise reduction                           | 0.305                    |                                                        |

Significant differences at the $p = 0.05$ level are reported, based on Kruskal-Wallis Independent samples test and Dunn’s Post Hoc Non-Parametric Test, adjusted by the Bonferroni correction for multiple tests.
**Table S4.** Effective socio-political and instrumental drivers for implementation of Blue-Green Infrastructure (BGI) in the four cities. The values show the percentage of respondents that selected each driver, for each city, and overall (respondents could select multiple options). The most effective drivers are highlighted in grey. Drivers that have (statistically) significantly different percentages between one or more cities are listed in the final column.

| Drivers                                                                 | All   | Newcastle | Ningbo | Portland | Rotterdam | P-value (Kruskal-Wallis) | Sig. dif. and p-value (Dunn’s) |
|------------------------------------------------------------------------|-------|-----------|--------|----------|-----------|-------------------------|---------------------------------|
| Local Government plans                                                 | 87    | 88        | 94     | 87       | 75        | 0.471                   |                                 |
| Recognition of the multifunctionality of BGI                           | 68    | 75        | 59     | 80       | 56        | 0.404                   |                                 |
| Local Planning Authority guidance                                      | 63    | 75        | 65     | 53       | 56        | 0.598                   |                                 |
| Multi-agency approaches                                                | 63    | 88        | 35     | 73       | 56        | 0.015                   | Ne – N (0.013)                  |
| Public-private partnerships                                            | 60    | 56        | 59     | 60       | 63        | 0.988                   |                                 |
| Quantification and monetisation of the benefits and costs of BGI       | 60    | 69        | 41     | 80       | 50        | 0.109                   |                                 |
| National Government legislation                                        | 52    | 69        | 88     | 47       | 0         | 0.000                   | R – Ne (0.001) R – N (0.000)   |
| Local Flood Authority guidance                                         | 43    | 63        | 35     | 27       | 44        | 0.215                   |                                 |
| Lobbying from local communities*                                       | 30    | 50        | 12     | 40       | 19        | 0.062                   |                                 |

Significant differences at the p = 0.05 level are reported, based on Kruskal-Wallis Independent samples test and Dunn’s Post Hoc Non-Parametric Test, adjusted by the Bonferroni correction for multiple tests. Ne = Newcastle, N = Ningbo, P = Portland, R = Rotterdam. *Lobbying for local communities, for example, for agencies/organisations to reduce flood risk.
Table S5. Perceptions of who are leading the way in Blue-Green Infrastructure (BGI) implementation in the case study cities, illustrated by the percentages of respondents that selected each category. The groups with the highest percentages in each city are shaded in grey. Statistically significant differences between the cities are listed in the ‘Sig. dif.’ column. WSC (Water and Sewerage Companies). *Environment Agency refers to the relevant national organisation in each country, e.g. the Environment Agency (UK), Environmental Protection Agency (USA), Ministry of Infrastructure and Water Management (Netherlands) or the Housing and Construction Bureau (China).

| Organisation / stakeholder | All | Newcastle | Ningbo | Portland | Rotterdam | P-value (Kruskal-Wallis) | Sig. dif. and p-value (Dunn’s) |
|----------------------------|-----|-----------|--------|----------|-----------|-------------------------|---------------------------------|
| Local Government           | 84  | 81        | 94     | 73       | 88        | 0.423                   |                                 |
| Individual champions       | 58  | 69        | 18     | 87       | 63        | 0.001                   | N – Ne (0.019)                 |
| Community                  | 53  | 38        | 6      | 87       | 88        | 0.000                   | N – P (0.000) Ne – P (0.019)   |
| Public WSC                 | 47  | 19        | 24     | 80       | 69        | 0.000                   | Ne – R (0.030) Ne – P (0.004) N – P (0.009) |
| Environment Agency*        | 42  | 69        | 47     | 27       | 25        | 0.044                   |                                 |
| Elected Officials          | 34  | 19        | 35     | 40       | 44        | 0.470                   |                                 |
| Not-for-profit             | 31  | 31        | 6      | 80       | 13        | 0.000                   | P – Ne (0.005) P – N (0.000) P – R (0.000) |
| Private WSC                | 31  | 88        | 12     | 20       | 6         | 0.000                   | Ne – R (0.000) Ne – N (0.000) Ne – P (0.000) |
| Consultants                | 28  | 38        | 6      | 53       | 19        | 0.018                   | N – P (0.019)                  |
| Developers                 | 25  | 6         | 6      | 33       | 56        | 0.002                   | R – N (0.006) R – Ne (0.007)   |

Significant differences at the p = 0.05 level are reported, based on Kruskal-Wallis Independent samples test and Dunn’s Post Hoc Non-Parametric Test, adjusted by the Bonferroni correction for multiple tests. Ne = Newcastle, N = Ningbo, P = Portland, R = Rotterdam.
Table S6. Perceptions of who should lead the way in Blue-Green Infrastructure (BGI) implementation in the case study cities, illustrated by the percentages of respondents that selected each category. The groups with the highest percentages in each city are shaded in grey. Statistically significant differences between the cities are listed in the ‘Sig. dif.’ column. WSC (Water and Sewerage Companies). *Environment Agency refers to the relevant national organisation in each country, e.g. the Environment Agency (UK), Environmental Protection Agency (USA), Ministry of Infrastructure and Water Management (Netherlands) or the Housing and Construction Bureau (China).

| Organisation / stakeholder | All | Newcastle | Ningbo | Portland | Rotterdam | P-value (Kruskal-Wallis) | Sig. dif. and p-value (Dunn’s) |
|----------------------------|-----|-----------|--------|----------|-----------|-------------------------|-------------------------------|
| Developers                 | 56  | 100       | 24     | 67       | 38        | 0.000                   | Ne – R (0.002), Ne – N (0.000) |
| Local Government           | 50  | 56        | 18     | 40       | 88        | 0.001                   | N – R (0.000)                 |
| Elected Officials          | 47  | 75        | 12     | 60       | 44        | 0.002                   | N – P (0.041), N – Ne (0.002) |
| Consultants                | 39  | 81        | 24     | 40       | 13        | 0.000                   | Ne – R (0.000), Ne – N (0.005) |
| Environment Agency*        | 39  | 50        | 18     | 73       | 19        | 0.003                   | P – R (0.012), P – N (0.008) |
| Public WSC                 | 36  | 38        | 24     | 27       | 56        | 0.211                   |                               |
| Individual champions       | 34  | 44        | 24     | 33       | 38        | 0.668                   |                               |
| Private WSC                | 31  | 50        | 29     | 40       | 6         | 0.052                   |                               |
| Community                  | 27  | 31        | 24     | 33       | 19        | 0.778                   |                               |
| Not-for-profit             | 19  | 25        | 24     | 20       | 6         | 0.515                   |                               |

Significant differences at the p = 0.05 level are reported, based on Kruskal-Wallis Independent samples test and Dunn’s Post Hoc Non-Parametric Test, adjusted by the Bonferroni correction for multiple tests. Ne = Newcastle, N = Ningbo, P = Portland, R = Rotterdam.
**Table S7.** The percentages of respondents from each city that regard different strategies for improving the uptake of Blue-Green infrastructure (BGI) as very important or important. Strategies with the highest percentages in each city are shaded in grey. Statistically significant differences between the cities are listed in the ‘Sig. dif.’ column.

| Improving BGI uptake | All | Newcastle | Ningbo | Portland | Rotterdam | P-value (Kruskal-Wallis) | Sig. dif. and p-value (Dunn’s) |
|----------------------|-----|-----------|--------|----------|-----------|-------------------------|-------------------------------|
| Increased awareness (policy-makers) | 94  | 94        | 94     | 93       | 94        | 1.000                   |                               |
| Wider range of funding | 94  | 100       | 100    | 86       | 88        | 0.277                   |                               |
| BGI in new developments | 92  | 100       | 88     | 100      | 81        | 0.128                   |                               |
| Increased funding for BGI | 91  | 94        | 94     | 87       | 88        | 0.832                   |                               |
| Clearer maintenance responsibilities | 89  | 88        | 100    | 73       | 94        | 0.110                   |                               |
| Increased local authority expertise and capacity | 86  | 81        | 94     | 93       | 81        | 0.508                   |                               |
| Increased awareness (developers) | 84  | 88        | 76     | 87       | 88        | 0.824                   |                               |
| Mandatory standards | 84  | 94        | 100    | 93       | 50        | 0.000                   | R – Ne (0.004) R – N (0.000) R – P (0.005) |
| Stronger local legislation and regulations | 84  | 88        | 100    | 87       | 60        | 0.006                   | R – N (0.005)                |
| Best practice examples | 84  | 81        | 100    | 71       | 81        | 0.083                   |                               |
| Improved community engagement, education and outreach | 84  | 100       | 76     | 87       | 73        | 0.106                   |                               |
| Improved valuation of multiple benefits/costs | 83  | 88        | 88     | 87       | 69        | 0.397                   |                               |
| Post-project monitoring and evaluation | 83  | 81        | 100    | 80       | 69        | 0.103                   |                               |
| Change in cultures and behaviours | 83  | 100       | 71     | 87       | 73        | 0.088                   |                               |
| Continued research into processes and functionality | 81  | 94        | 94     | 87       | 50        | 0.003                   | Ne – R (0.010) N – R (0.008) |
| Better coordination | 76  | 81        | 88     | 71       | 63        | 0.238                   |                               |
| Stronger enforcement from the planning system | 74  | 81        | 94     | 86       | 33        | 0.000                   | R – Ne (0.007) R – N (0.000) R – P (0.014) |
| More BGI champions | 73  | 88        | 71     | 80       | 53        | 0.097                   |                               |
| Stronger national legislation | 68  | 88        | 88     | 73       | 20        | 0.000                   | R – Ne (0.000) R – N (0.000) R – P (0.001) |

Significant differences at the p = 0.05 level are reported, based on Kruskal-Wallis Independent samples test and Dunn’s Post Hoc Non-Parametric Test, adjusted by the Bonferroni correction for multiple tests. Ne = Newcastle, N = Ningbo, P = Portland, R = Rotterdam.
References

Amec Foster Wheeler (2016) Newcastle City Strategic Surface Water Management Plan. Final Report. Report No 36634/F/001.

BES (n.d) Green Infrastructure. City of Portland, Bureau of Environmental Services (BES). Retrieved 7 February, 2020 from https://www.portlandoregon.gov/bes/34598.

Buro Sant en Co (2014) Four Harbour Roof Park. Retrieved on 10 March 2020 from http://landezine.com/index.php/2014/12/four-harbour-roof-park-by-buro-sant-en-co/.

Chan, F.K.S., Griffiths, J.A., Higgitt, D., Xu, S., Zhu, F., Tang, Y.-T., Xu, Y. and Thorne, C.R. (2018) “Sponge City” in China—A breakthrough of planning and flood risk management in the urban context. Land Use Policy 76, 772-778.

Chan, F.K.S., Mitchell, G., Adekola, O. and McDonald, A. (2012) Flood Risk in Asia’s Urban Mega-deltas Drivers, Impacts and Response. Environment and Urbanization Asia 3, 41-61.

City of Rotterdam (2013) Rotterdam Climate Change Adaptation Strategy. Retrieved on 25 February 2020 from http://www.urbanisten.nl/wp/wp-content/uploads/UB_RAS_EN_lr.pdf.

City of Rotterdam (2016) Rotterdam Resilience Strategy. Retrieved on 25 February 2020 from http://100resilientcities.org/wp-content/uploads/2017/06/strategy-resilient-rotterdam.pdf.

de Graaf, R. and van der Brugge, R. (2010) Transforming water infrastructure by linking water management and urban renewal in Rotterdam. Technological Forecasting and Social Change 77, 1282-1291.

Fahy, B., Brenneman, E., Chang, H. and Shandas, V. (2019) Spatial analysis of urban flooding and extreme heat hazard potential in Portland, OR. International Journal of Disaster Risk Reduction, 101117.

Jiang, Y., Zevenbergen, C. and Fu, D. (2017) Understanding the challenges for the governance of China’s “sponge cities” initiative to sustainably manage urban stormwater and flooding. Natural Hazards 89, 521-529.

Metro (2014) Urban Growth Boundary, Retrieved February 3, 2020 from https://www.oregonmetro.gov/urban-growth-boundary.

Ministry of Infrastructure and the Environment (2015) Dutch National Water Plan (2016-2021).

MHURD (2014) Technical Guide for constructing Sponge Cities (in Chinese). Ministry of Housing and Urban-Rural Development (MHURD), accessed 19 May 2020 at http://www.mohurd.gov.cn/wjfb/201411/W020141102041225.pdf.

Mohammed, I., Alshuwaikhat, H.M. and Adenle, Y.A. (2016) An approach to assess the effectiveness of smart growth in achieving sustainable development. Sustainability 8, 397.

Municipality of Rotterdam (2007) Waterplan 2 Rotterdam. Working on water for an attractive city. Rotterdam, The Netherlands. Municipality of Rotterdam, Water Authority of Hollandse Delta, Water Authority of Schieland and Krimpenerwaard, and Water Authority of Delfland. Retrieved from https://www.rotterdam.nl/wonen-leven/waterplan-2/Waterplan-2-samenvatting-Engels.pdf.
Municipality of Rotterdam (2013) Waterplan 3 Rotterdam. Recalibration Water Plan 2 - Working on Water for an Attractive and Climate-Proof City. Municipality of Rotterdam, Water Authority of Hollandse Delta, Water Authority of Schieland and Krimpenerwaard, and Water Authority of Delfland.

Netusil, N.R., Levin, Z., Shandas, V. and Hart, T. (2014) Valuing green infrastructure in Portland, Oregon. Landscape and Urban Planning 124, 14-21.

Netusil, N.R. and Thomas, B. (2019) Ecoroofs in Portland, Oregon, USA. Blue-Green Futures blog, retrieved February 3, 2020 from https://blogs.nottingham.ac.uk/bluegreenfutures/2019/11/19/ecoroofs-in-portland-oregon-usa/.

Newcastle City Council (2016) Local Flood Risk Management Plan. Retrieved February 25, 2020 from https://www.letstalknewcastle.co.uk/files/NCC_Flood_Risk_Management_Plan_-_March_2016.pdf.

Newcastle City Council and Gateshead Council (2015) Planning for the Future - Core Strategy and Urban Core Plan for Gateshead and Newcastle upon Tyne 2010-2030. https://www.newcastle.gov.uk/sites/default/files/2019-01/planning_for_the_future_core_strategy_and_urban_core_plan_2010-2030.pdf accessed 11.05.20.

O'Donnell, E., Woodhouse, R. and Thorne, C. (2018) Evaluating the multiple benefits of a Newcastle SuDS scheme. Proceedings of the ICE – Water Management 171, 191-202.

Qiao, X.-J., Liu, L., Kristoffersson, A. and Randrup, T.B. (2019) Governance factors of sustainable stormwater management: A study of case cities in China and Sweden. Journal of Environmental Management 248, 109249.

Rotterdam Office of Climate Adaptation (2019) Rotterdam Weather-Wise - urgency document. Retrieved March 10, 2020 from https://www.rotterdam.nl/wonen-leven/rotterdams-weerwoord/Urgentiedocument-2020_EN.pdf.

Tang, Y.-T., Chan, F.K.S. and Griffiths, J. (2015) City profile: Ningbo. Cities 42, 97-108.

Tong, Y., Zhang, D., Li, J. and Li, W. (2007) A study on drought and flood disasters and their regularity in Ningbo. Journal of Catastrophology 22 (2), 105-108 (in Chinese).

UFR (n.d.) Newcastle Blue and Green Declaration. Urban Flood Resilience (UFR) project website. Retrieved February 7, 2020 from http://www.urbanfloodresilience.ac.uk/newcastle-blue-and-green-declaration/newcastle-blue-green-declaration.aspx.

United States Census Bureau (2019) U.S. Census Bureau QuickFacts: Portland City, Oregon. Retrieved February 3, 2020 from https://www.census.gov/quickfacts/portlandcityoregon.