Urban Aquaculture

Water-sensitive transformation of cityscapes via blue-green infrastructures

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Dipl.-Ing.
Grit Bürgow
geb. in Berlin

von der Fakultät VI Planen Bauen Umwelt
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Vorsitzende: Prof. Undine Gisecke
Gutachter: Prof. Dr.-Ing. Stefan Heiland
Gutachterin: Prof. Dr.-Ing. Angela Million (Uttke)
Gutachterin: Prof. Dr. Ranka Junge

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Grit Bürgow

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“Water is a source of life, power, comfort, and delight,
a universal symbol of purification and renewal.
Like a primordial magnet, water pulls at a primitive and deeply rooted part of human nature.
More than any other single element besides trees and gardens,
water has the greatest potential
to forge an emotional link between man and nature in the city.”

Anne Whiston Spirn (1984)

Für meine Eltern
Doris und Kurt

For my parents
Doris and Kurt

ABSTRACT

Parallel growth and shrinkage challenges cities and their citizens globally regarding a sustainable transformation of infrastructures and life-styles. Facing local fresh water, food and everyday resource provision the question arises, how can human- and ecosystem-related livelihoods and life-qualities be regenerated in a multifunctional manner? Water as a universal medium of life, transport and creation plays a key role within this change process.

The present publication links natural and cultural questions relating to actual challenges of a water-sensitive city and landscape development. By starting with the relevance of water in its hybridity as a natural landscape element, cultural infrastructure, and the cradle of the city, the study researches characteristic facets of an urban aquaculture. It broadens the classic understanding of aquaculture by linking different perspectives from ecology, technology, design, history and future of the city and landscape. By supplementing the original meaning, the *water-farming culture* and part of agriculture, it integrates facets of *water-life culture* and *water-wellbeing culture* into an urban image of aquaculture.

Types of contemporary and traditional aquacultural infrastructures are the central research subject. Through their blue-green services (regeneration of freshwater, food, biodiversity) they are newly interpreted as specific blue-green infrastructures. In addition to the classic forms of water-farming (swimming gardens, fish ponds or water-farm greenhouses), the research investigates other types of urban water-wellbeing (bathing ships, urban river pools). Empirical case studies illuminate facets of an urban aquaculture at a citywide scale. The focus is on everyday life dealing with technical infrastructure and the accompanying, visible and invisible, physical landscape change. Furthermore, typological case studies investigate multifunctional design and service potentials of natural and cultural benefit at a project scale. These include characteristics such as effective use of space and resources through combined water and food production, the flexibility of design or possibilities of participation and applied learning along with infrastructural design and management processes. As a result, the types of blue-green infrastructure explored are highlighted as building-blocks and catalysts of water-sensitive urban development. The research concludes with an outlook on future challenges and fields of action and further research on a sustainable urban aquaculture. Possibilities of a further qualification at the design-built level of *aquatecture* and participative-communicative level of *aquapuncture* are addressed.

The study creates a practice-oriented knowledge base for integrated planning and design processes at the interface between urban design, multifunctional everyday infrastructures and landscape ecosystem services. It provides important impulses for cross-cultural dialogue in the sense of a learning-from by linking local knowledge and contemporary know-how.

ZUSAMMENFASSUNG

Paralleles Wachsen und Schrumpfen stellt Städte und ihre Bewohner weltweit vor Herausforderungen eines nachhaltigen Infrastruktur- und Lebensstilwandels. Im Hinblick auf die lokale Versorgung mit Frischwasser, Nahrung und alltäglichen Ressourcen stellt sich die Frage, wie menschliche und ökosystembezogene Lebensgrundlagen in multifunktionaler Weise regeneriert werden können. Wasser als universelles Lebens-, Transport- und Gestaltungsmedium übernimmt hierin eine Schlüsselrolle.

Die vorliegende Publikation verbindet natur- und kulturbezogene Fragestellungen angesichts aktueller Herausforderungen wassersensibler Stadt- und Landschaftsentwicklung. Ansetzend an der Bedeutung des Wassers in seiner Hybridität als natürliches Landschaftselement, kultureller Infrastruktur und Wiege der Stadt, erforscht die Arbeit charakteristische Facetten urbaner Aquakultur. Durch die Verknüpfung verschiedener Blickwinkel von Ökologie, Technologie, Design, Geschichte und Zukunft von Stadt und Landschaft erweitert sie dabei das klassische Verständnis von Aquakultur. Ergänzend zur originären Bedeutung, der „Wasser-Farmkultur" und Teil der Agrikultur, integriert sie die Facetten „Wasser-Lebenskultur" und „Wasser-Wohlfühlkultur" in das städtische Bild von Aquakultur.

Zentraler Untersuchungsgegenstand sind zeitgenössische und traditionelle Aquakultur-Typen. Durch ihre blau-grünen Leistungen (Regeneration von Frischwasser, Nahrung, Biodiversität) werden sie als spezifische blau-grüne Infrastrukturen neu interpretiert. Neben klassischen Formen des Water-Farmings (schwimmende Gärten, Fischteiche oder Wasserfarm-Gewächshäuser) werden weitere Typen eines urbanen Water-Wellbeings (Badeschiffe, Flussbäder) beforscht. Empirische Fallstudien beleuchten auf der gesamtstädtischen Ebene Facetten einer urbanen Aquakultur. Fokussiert wird der alltäglich lebensweltliche Umgang mit technischer Infrastruktur und der begleitende, sicht- und unsichtbare, physische Landschaftswandel. Ergänzend untersuchen typologische Fallstudien auf der Projektebene multifunktionale Design- und Servicepotenziale mit natur- und kulturbezogenem Mehrwert. Dazu zählen Eigenschaften wie die effektive Raum- und Ressourcennutzung durch die kombinierte Wasser- und Nahrungsmittelproduktion, die Flexibilität des Designs oder Möglichkeiten der Partizipation und des angewandten Lernens bei infrastrukturellen Gestaltungs- und Managementprozessen. Im Ergebnis werden die untersuchten Typen blau-grüner Infrastruktur als Bausteine und Katalysatoren wassersensibler Stadtentwicklung herausgestellt. Die Arbeit schließt mit einem Ausblick auf künftige Herausforderungen, Handlungs- und Forschungsfelder einer nachhaltigen urbanen Aquakultur. Addressiert werden Möglichkeiten der weiteren Qualifizierung auf baulich-gestalterischer Ebene einer "Aquatectur" und auf partizipativ-kommunikativer Ebene einer "Aquapunktur".

Die Arbeit schafft eine praxisorientierte Wissensbasis für integrierte Planungs- und Gestaltungsprozesse an der Schnittstelle zwischen Stadtgestaltung, multifunktionalen Alltagsinfrastrukturen und landschaftlichen Ökosystemdienstleistungen. Es liefert wichtige Impulse zum kulturübergreifenden Dialog im Sinne eines Voneinander-Lernens, in dem es lokales Wissen mit zeitgemäßem Know-How verknüpft.

PREFACE

URBAN AQUACULTURE IN LANDSCAPE PLANNING AND URBAN DESIGN

The adaption and reconstruction of infrastructure systems is a key area of action in post-industrial cities throughout the world. Decentralization approaches, the search for multifunctional infrastructure systems, globalized production and consumption patterns of national resources and nutrition are culturally and planning driven processes that have and will continue to shape our cities in the future. Within this, the future development of cities cannot be discussed without taking water as resource for households, agriculture and industry into account. Water is a basic and global resource for mankind, which cannot be replaced. With more people than ever living in cities, water is an urban issue. Challenges such as resource shortages, flooding, supply security, and conflicting land and water uses can be met via the creation of innovative water infrastructures to adapt to changing climate and demographics and sustainable use of (waste) water-related resources.

Within this context, the research work of Grit Bürgow offers an enriching perspective on water – not only as a basic resource and amenity for urban life, but also as a landscape and design element within technical and cultural infrastructures of cities. She puts local water resource management at the beginning of a rethinking of water usage and the redesign of urban water infrastructure. She aims to redefine an AQUACULTURE as a potential for future urban design and landscape planning, as well as community building.

The term aquaculture originally describes a farming process integrating the growing of aquatic flora and fauna species. AQUACULTURE in Bürgow's understanding means much more: It incorporates manifold ways of water usage in everyday city life, with a special focus on the historic use of water(ways) for fishing and shipping goods, urban bathing and swimming culture. She considers aspects of integrated water and natural resource management, as well as potential for the implementation of blue-green infrastructure to food and biomass production within the city. Here, she cites a number of international examples and reflects on their potential for implementation to the urban context.

Obviously, the history of cities throughout the world is linked to water supply. Waterways were key settings for the foundation and development of human settlements. They have shaped city morphologies, basic infrastructure and resources for transport, manufacturing, and food production. The research presented revives an integrated concept of water usage: as an energy source, for urban food production, and as an urban amenity. This could initiate a discussion on the future role of water in urban development. It is a discussion that goes beyond the well known waterfront development and rain water management initiatives. The role of behavioral patterns and knowledge is addressed. Water is still taken for granted in Western cities. Bürgow's research also aims to present ways in which a more conscious perception and resource-conserving use of water could be reached through an engaging and participatory implementation of water infrastructure. It makes clear that sustainable development of cities can only happen based on the everyday and enhanced knowledge and actions of people. Bottom-up initiatives can already be seen in Western cities, including Berlin. In some cases, this bottom-up activism and modus of the self-made city is backed up by scientific research and fostered by official city and landscape planning programs.

Bürgow not only analyzes approaches and ways towards an Urban AQUACULTURE, but she also identifies a number of challenges to overcome on the level of governance, implementation of relevant legal provisions, physical design, and stakeholder communication and participation. Potentials and challenges are the starting point for two strategic recommendations Bürgow entitles "Design-build strategy: Aquatecture" and "Participatory process strategy: Aquapuncture". The two strategies are at different levels: Aquatecture addresses architectural and urban design, while Aquapuncture highlights (temporary) spatial experiments and approaches to (built) environment participation and education.

Both approaches require a spectrum of skills and knowledge necessary for planners and designers. There is a need to be able to work and communicate across professional boundaries and with diverse groups. Urban aquaculture planning and design is a medium-sized multidisciplinary practice bringing together the skills of architects, planners and other types of designers and infrastructure engineers towards more dynamic, creative work that does not necessarily fit the definition of urban and landscape planning.

Bürgow's research offers a profound basis for this work, giving detailed information, drawing a thematic background and depicting case studies in text, quantitative data, and figures. She connects her knowledge as a researcher and her professional experiences in water infrastructure design and management. This book is a worthwhile read for the scientific community as well as for practitioners.

In the future, a number of stakeholders will be city builders of resource-efficient and livable neighborhoods. By debating Urban Aquaculture regarding its potentials and rich facets, a common and visionary understanding of water use, management, planning and design can be fostered.

Prof. Dr.-Ing. Angela Million, Department of Urban Design and Urban Development, TU Berlin
Prof. Dr.-Ing. Stefan Heiland, Department of Landscape Planning and Landscape Development, TU Berlin

ABBREVIATIONS

a	year
BOD	biological oxygen demand (amount of dissolved oxygen needed by aerobic organisms to mineralize organic compounds in a given wastewater stream at a temperature of 20°C over a five-day period)
CCB	Coalition Clean Baltic Initiative
CO_2	carbon dioxide
COD	chemical oxygen demand (amount of dissolved oxygen needed to mineralize all organic compounds, including persistent pollutants)
d	day
DW	dry weight
FW	fresh weight
GWP	Global Water Partnership
IWRM	integrated water and resource management
K	potassium
N	nitrogen
n. d.	no date
NFT	nutrient film technique
NH_3	ammonia
n. i.	no identification
NO_3	nitrate
O_2	oxygen
P	phosphorous
p.e.	person equivalent
PV	photovoltaics
R&D	research and development
STP	sewage treatment plant
UA	urban aquaculture
WSUD	water-sensitive urban design
WSUDM	water-sensitive urban design-management

INTRO

Citation format

The citation at the end of the block relates to the entire previous paragraph, whereas the citation before the end of the block relates to the previous statement or section.

Readability

All Latin names are written in italics.
Central conclusions and statements are highlighted with bullet points or indents.

Graphical representation

All layout plans and maps are oriented north, unless otherwise noted.

Editorial deadline

Since the development trends in the urban water context are very dynamic, for reasons of manageability, the editorial deadline of this research has been laid on 20 March 2013.

CHAPTER 1: INTRODUCTION – URBAN AQUACULTURE

1.1 Scope of research

1.1.1 Starting points

Cities are probably the most intriguing landscapes of the 21st century. Being highly transformative, they face both threatening extremes and creative potentials. Changing demographics, migration, climate and water patterns, peak oil, or the emerging scarcity of daily life resources challenge cityscapes. Water is increasingly recognized as a key concern in one of the defining 21st century issues: climate change.[1] A statement at the 2010 World Climate Change Conference in Cancún, Mexico, delivered by Dr. Letitia A. Obeng, Chair of the Global Water Partnership, gets right to the heart of it: "When world leaders speak about climate, they invariably speak of water – of floods, droughts and failed harvests and express their alarm. They are right to do so: because climate change is primarily about water."[2]

Water is known as the "largest import and export product of cities."[3] The fact that more than half of the world's population today live in cities and megacities with more than ten million inhabitants[4] reflects the diversity of the urban water challenge.[5] According to UNEP projections, the world population will reach ~9 billion in 2050,[6] whereas the number of people facing water stress conditions is predicted to increase fourfold up to 2 billion.[7] Growing megacities from Rio de Janeiro to Kolkata and declining metropolises in North America and former East Germany unveil the common social/cultural and ecological/natural water dimension.

The Istanbul Water Consensus[8] proposed strategies for local and regional authorities regarding urban climate change by particularly focusing on the necessary transformation of water infrastructures: "These changes require new infrastructure projects to anticipate the effects of climate change in the design of water, sanitation, rainwater and other urban infrastructure."[9] The latest *Greening EU Cities Report* complements the latter by suggesting the pilot embedding of the new infrastructures in "visible urban projects."[10] Furthermore, it recommends the setting-up of experimental pilot projects "(…) that break new ground and provide innovative ideas and ways of developing local areas, carried out on a trial basis."[11]

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[1] WWDR 3a (2009); WWF (2008a); WWF (2008b)
[2] GWP (2010)
[3] Wolman (1965) in: Spirn (2001, p. 483)
[4] UN-HABITAT (2008)
[5] GWP (eds.) and Rees (2006); GWP (eds.) and Bahri (2009); Camarsa *et al.* (2010); WWF (2011)
[6] UN (2004)
[7] Knight, P. (1998) in: Niemczynowicz (1999)
[8] WWC (2005)
[9] Ibid.: p. 3
[10] CEP (2011, p. 41)
[11] Ibid.: p. 46

Facing local water, food and energy provision as an integrated challenge, along with post-industrial urban transformations *beyond oil*, there is also a growing trend towards the active inclusion of *living* and more flexible infrastructures. When one thinks of vertical farms, rooftop gardens or floating structures, water is thus an essential key to livable cities. Along with similar *new* urban infrastructures, the question of how to provide and regenerate everyday resources within the increasingly urbanized spaces and landscapes arise. Questions of how to design and manage corresponding everyday life infrastructures for basic resource and wellbeing services (in short, *everyday infrastructures*) are also affiliated.

Consequently, the following three key challenges of sustainable urban redevelopment, including the redesign of everyday infrastructures in place-specific contexts, have to be investigated:

- Integrated use of space and design of everyday infrastructures striving for multifunctional service provision that might include recreational and educational services;
- regenerative production and consumption of daily life resources (prosumption: a portmanteau word encompassing both); and
- citizens' engagement in common everyday infrastructure designs and practices

By focusing on the growing relevance of a "regenerative design,"[12] challenges on the human scale are becoming central, in addition to eco-technical issues of solar drive, resource upcycling, etc. This relates to questions of usability, attractivity, affordability, multifunctionality, or adaptivity, and includes pragmatic features, such as balancing between low-cost and high-cost approaches, low-tech and high-tech efforts, or enhancing natural and cultural life qualities.
Facing the emerging need of integrative problem-solving, the initial assumption is that one of the new 21st century urban building-blocks comprises flexible, multifunctional and attractive everyday infrastructures for the regenerative provision of daily life resources and qualities. Accordingly, the *new* infrastructures need to become embedded into decentralized urban spaces and daily socio-ecological contexts.[13] Hence, besides basic resource services of water, food or energy provision, services of urban wellbeing, embracing recreation, art or applied learning, become indispensable to a *renewed*, thus more integrated, infrastructural design.
The second assumption is that the renewed urban infrastructures demand a renewed culture of using, and managing the related resource flows and life services. Therefore, new requirements emerge at the same time combined with the necessary conversion of the prevailingly centralized and largely inflexible energy and water infrastructures.

1.1.2 Central research issues

Today's centralized infrastructures for the provision of water or energy are prevailingly monofunctional in the Western world. Their design and performance depend on fossil fuel and

[12] Lyle (1994)
[13] Pizarro *et al.* (2010a)

relate predominantly to linear and long-distance resource flows.[14] Two key problems with this are in a nutshell, from a natural perspective, (1) a lack of landscape ecosystem service[15] support, and, from a cultural perspective, (2) a lack of everyday perception and participative interaction.

PROBLEMS OF WESTERN WATER INFRASTRUCTURES AND URBAN RESOURCE MANAGEMENT

(1) Lacking landscape ecosystem service support for common livability: Although contemporary urban water infrastructures make use of biological-natural processes (micro-organismic water purification via mineralization, nitrification or methanization, etc.), they do not actively regenerate landscape ecosystem services in watersheds. In fact, the majority of current water production and treatment technologies more or less undermine landscape processes as their basic ecosystem service providers. Collecting water from lakes, and wetlands often causes “landscape dehydration,”[16] and the release of sewage treatment plant outflow into natural water bodies causes eutrophication.[17] The current standards of drinking water and wastewater management are primarily based on fossil fuel. The operation of either the centralized pump network or treatment process designs aiming to quickly break down organic water compounds (e.g. converting ammonia (NH_3) into nitrate (NO_3) via nitrification) requires high amounts of energy. On the other hand, nitrate – the final product of artificial fertilizer production – is technically produced via the energy-intensive Haber-Bosch process. Guterstam stresses it as follows: “The production of ammonia-nitrogen by the Haber-Bosch technique uses 1.5 liters of oil for each kilogram of extracted nitrogen from the atmosphere.”[18]

(2) Lacking everyday perception and participative intervention (centralized vs. decentralized): The prevailing centralized water infrastructure technologies, comprising vast networks of pipes, pumps, transport lines, and treatment plants, integrate and rely on socio-cultural processes, such as proper maintenance and management. Nevertheless, they exclude experiences on a more human scale. This issue is linked to the current gap of the sensorial perception of water along with the missing relational experiences and interaction in open spaces and urbanized landscapes. The sociologist, Detlev Ipsen, stresses the phenomena of “hidden infrastructures”[19] and “the invisible city.”[20] He refers to the ideal of the “hygienic city” arising in the 19th century when “water disappears from the senses of urbanites and responsibility of the citizens.”[21] Beyond improved public health, however, the increasing lack of the everyday tangibility to water in urban space leads to the loss of aesthetic, emotional and recreational values. Hence, it limits the human experience of the natural water processes in the city. The German historian,

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[14] e.g. Guy *et al.* (2001); Monstadt and Naumann (2004); Hardwicke (2008); Moss *et al.* (2008); Newton (2008); Hao and Novotny (2010); WWF (2010)

[15] Costanza (1987); Costanza *et al.* (2001); Daily (1997); MEA (2005); TEEB (2008); Groot *et al.* (2010)

[16] e.g. Bernhardt (2005); Bernhardt (2009)

[17] e.g. Guterstam (1991, p. 38); Todd and Todd (1993, p. xvi)

[18] Guterstam (1997, p. 1213)

[19] Ipsen *et al.* (1998, p. 19)

[20] Ibid.: p. 17

[21] Ibid.: p. 19

Christoph Bernhardt, describes it as "gradual 'desensualization' of the public spaces."[22] The landscape architect and planner, Anne Whiston Spirn, referring to the urban designer, Kevin Lynch, and his book *A Theory of Good City Form* (1981), highlights the role of experiencing urban nature as follows: "City form that increases the visibility of natural processes (the passing of the seasons, the movement of water, the birth and death of living organisms), creates an environment that has both a sense of immediacy and evolution over time."[23] According to Lynch, "The mental sense of connection with nature is a basic human satisfaction, the most profound aspect of sensibility (…)."[24]

Contemporary German socio-cultural infrastructure research stresses that the global basis and abstract scientific-political debates in people's daily lives should become more bottom-up focused. The social psychologist, Harald Welzer,[25] claims a new "climate culture"[26] and the production of everyday knowledge (*Gebrauchswissen*) to motivate people to turn from knowledge to action. He highlights the need for "practice communication" vs. abstract "knowledge communication" that lacks everyday experience.[27]
Ipsen et al.[28] exemplarily point to the relevance of *water culture* creating meanings and, therefore, relationships and responsibilities. According to Ipsen and colleagues, the active use and handling of water in everyday life is closely intertwined with the "material production of meanings,"[29] thus making it a cultural affair.

By facing the urban challenges of climate-responsive strategies mentioned, the primary focus of this research is on water-sensitive design-management approaches in the city and landscape. Referring to the close interrelation between water and climatic extremes, as mentioned in the introduction, it thereby opens a door to a broader climate change debate. This integrates issues of sustainable water and resource management, and the design of related infrastructures as well as stressing obvious interrelations, e.g. regarding place-based water-centric *climate changes* and *climate chances* (3.3.3; 3.3.4). With this background, the next section introduces the central research approach of the dissertation to tackle the problems of prevailing Western water infrastructures and urban resource management.

1.1.3 Central research questions, objectives, limitations

The dissertation investigates so far underexposed facets of aquaculture – as a complementary part of agriculture – in the context of the city embracing an *urban aquaculture*. Accordingly, it explores water in its hybrid role as a *natural* landscape element and *cultural* human

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[22] German language version in: Bernhardt (2005, p. 72)
[23] Spirn (2001, p. 481)
[24] Lynch (1981) in: Ibid.
[25] Welzer (2011)
[26] Welzer *et al.* (2010)
[27] Welzer (2011)
[28] Ipsen (1998)
[29] Ibid.: p. 15

infrastructure from a global-local perspective. By widening the classic understanding of water-farming, it integrates other urban aquacultural practices of living and wellbeing such as those related to a city's shipping or swimming culture (1.3)
Aquacultural typologies ranging from swimming gardens and ponds-and-pools to types of water-farm greenhouse are the central subject of research (1.3.2). They are *newly* recognized and interpreted as specific types of blue-green infrastructure facing postindustrial urban challenges, such as fresh water and food provision, multifunctional infrastructure design at a human-scale or bathing quality in urban rivers.

In this regard, the three central questions within the normative framework of sustainability are:

1. What are the characteristic facets of urban aquaculture forming the water-based identities, morphologies and relationships of cities on a human scale?
2. What cross-cultural aquacultural types are there and what multifunctional (blue-green) design and service potentials can they fulfill as urban building-blocks and specific blue-green infrastructures?
3. How can similar multifunctional infrastructures catalyze a water-sensitive transformation of cityscapes and contribute to a sustainable urban aquaculture in the 21st century?

The research questions are explored through both theory (Chapters 2-3) and empirical case studies (Chapters 4-5), while bridging the following three main research spheres in a transdisciplinary manner:

- *Sustainable urban design:* The focus is on both urban morphologies (spatial pattern) and metabolisms (daily resource flows). Based on the pioneering work in regenerative design and ecological design[30] as well as ecological engineering,[31] the contemporary research embedded refers to sustainable urbanism[32] and landscape urbanism.[33] It stresses the approaches of a *water-sensitive urban design* (WSUD)[34] as applied design-research within water urbanism.[35]
- *Everyday life infrastructures:* The focus is on socio-cultural perspectives of everyday infrastructure practices and usability with an emphasis on water infrastructures in

[30] Spirn (1984); Todd and Todd (1984); Mc Harg (1992, p. 172); Todd and Todd (1993); Lyle (1994); van der Ryn and Cowan (1996); Meyer (1997); Thompson and Steiner (1997); Spirn (2001)

[31] Guterstam and Todd (1990); Etnier and Guterstam (1991); Todd (1991); Guterstam and Etnier (1996); Steinfeld and Del Porto (2004); Bohemen (2005a); Steinfeld and Del Porto (2007)

[32] Spirn (1984); Spirn (2001); Ellin (2006); Farr (2008)

[33] Corner (2003); Corner (2006); Waldheim (2006); Shannon (2006); Schäfer (2010)

[34] France (2002); Wong (2006); Novotny (2007); France (2008); IBA Hamburg (eds.) (2008); JSCWSC (2009, pp. 1.3); Hao and Novotny (2010); Wong *et al.* (2011); Howe (2012); Hoyer *et al.* (2011)

[35] e.g. Shannon and Meulder (2008); Hooimeijer *et al.* (2005); Dreiseitl (2001); Stokman (2008)

both public and private spheres.[36] It includes spatial and cultural research on traditional technologies and engineering practices as part of human water culture.[37]

- *Landscape ecosystem services:* The focus is on ecosystem services and products for basic life support, referring to sustainability concepts such as those developed in ecological economics and landscape research.[38] It emphasizes *ecohydrology*[39] as an integrative ecosystem science investigating both aquatic and terrestrial ecosystems in its dependency on water.[40]

RESEARCH GAPS AND OBJECTIVES

There is a relative scarcity of work that assesses and synthesizes existing knowledge related to regenerative and water-sensitive urban design, urban water culture or urban aquaculture.41 The literature that links both natural and cultural issues facing water-sensitive design and quality of life issues at the cutting-edge between urban, infrastructural and landscape ecosystem processes is limited. Although demanding integrative problem-solving, the three research spheres have been rather isolated and unconnected so far. To fill the current gap, this work falls between the three research spheres (Figure 1). Therefore and in favor of a broader perspective striving to synthesize existing knowledge and experiences, the focus is on the opportunities arising due to combining various themes, functions or purposes.

Furthermore, emerging trends of *self-made cities*[42] and *self-sustainable cities*[43] stress bottom-up-oriented action requirements, particularly valuing interactions, interrelations and the human scale. Along with these needs, the investigations address both small-scale technologies and small-scale urban and community projects in the past and present. They reflect on the growing relevance of creative city engagements and the paradigm shift in the urban design and planning field, which particularly becomes transparent with urban farming[44] and associated bottom-up initiatives.

[36] Kluge and Schramm (1988); Heidenreich and Glasauer (1997); Ipsen *et al.* (1998); Ipsen (1998); Heidenreich (2004); Auer (2004); Goodbody and Wanning (2008);

[37] Mishra (2001); Orlove (2002); Heidenreich (2004); Costa-Pierce *et al.* (2005); Shannon (2008); Laureano (2001); Ipsen *et al.* (1998)

[38] Costanza (1987); Daily (1997); Costanza *et al.* (2001); Farber *et al.* (2002); MEA (2005); TEEB (2008); Groot *et al.* (2010); Hermann *et al.* (2011)

[39] Caduto (1990); Ripl (1992); Ripl (1995); Savenije (1995); GWP and Falkenmark (2003); Falkenmark and Rockström (2005); Falkenmark and Rockström (2006); Kravčik *et al.* (2007)

[40] Falkenmark and Rockström (2005, p. xxi).

[41] e.g. Todd and Todd (1984); Todd and Todd (1993); Lyle (1994); Ipsen *et al.* (1998); Bunting and Little (2002); France (2002); Heidenreich (2004); Costa-Pierce *et al.* (2005); Novotny (2007); Shannon and Meulder (2008); Hao and Novotny (2010); Hoyer *et al.* (2011); Howe (2012); Dreiseitl (2001); Hooimeijer *et al.* (2005); France (2008)

[42] Ferguson (2006); Hou (2010)

[43] Gorgolewski *et al.* (2011); Klanten and Bolhöfer (2011); Taylor (2011); Müller (2011)

[44] Viljoen *et al.* (2005); Reynolds (2008); Despommier (2011); Gorgolewski *et al.* (2011); Klanten and Bolhöfer (2011); Taylor (2011); Müller (2011)

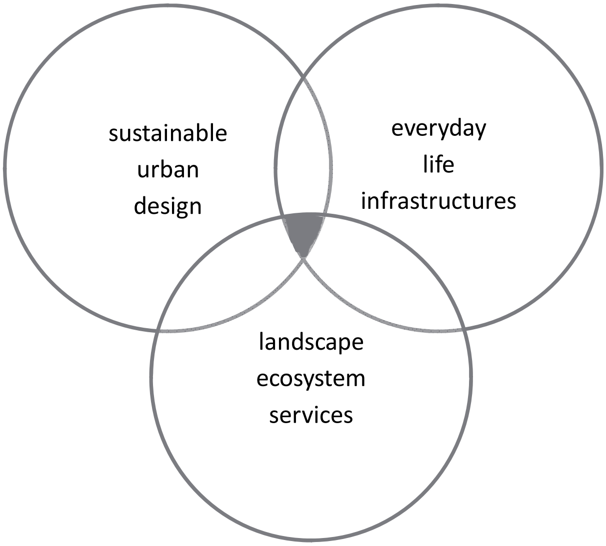

Figure 1: Central research spheres and placement of research

The main research objectives are thus:

- To understand urban spatial transformation from a hybrid (natural-cultural) perspective, stressing intertwined city, infrastructure and landscape ecosystem processes connected via water.
- To investigate characteristic facets of urban aquaculture and the service potentials of swimming gardens, ponds-and-pools and types of water-farm greenhouse infrastructure.
- To reimagine the roles of aquacultural blue-green infrastructures in everyday life context of 21st century post-industrial and post-fossil fuel cities.
- To propose water-sensitive urban design-management strategies, as well as participative communication and applied learning approaches as a contribution to a sustainable cityscape development.
- To discuss bottom-up driven, but professionally assisted creative city engagement strategies.
- To create *new* integrated knowledge at the interface between city, landscape, eco-technology and their users.

LIMITATIONS OF RESEARCH

The research is devoted to transdisciplinarity from the perspective of a landscape designer and planner. By its nature, this implies risks. Although *seeing beyond the end of one's nose* is

mostly more inspiring than *stewing in one's own juices*, it can lead to limited insights and sometimes raises the appearance of superficiality. However, the author is aware of that, in the same way she is conscious about the deficits of purely disciplinary tunnel vision, which can often entail even larger risks.
As the research ranges widely, the intention is to bridge as yet separated themes and fields. The emphasis is on the qualitative potentials and challenges of urban aquaculture and so far unconventional, yet emerging aquacultural blue-green infrastructures. The specific investigation of risks, such as along the decentralized integration of the *new* modular infrastructures referring particularly to implementation, economic feasibility or liability issues, is not the core. Furthermore, culturally specific differences or formal instruments of planning and politics are not the core. However, those points are at least touched on in the corresponding sections if relevant within the empirical research context.

1.2 Research Design

1.2.1 Methodology and content organization

This dissertation was performed as an explorative and qualitative study in a transdisciplinary context. Each chapter focused on specific research aspects, according to the three research spheres and the central research questions.

The research applied a phenomenological approach, which relates to empirical observations of phenomena compared to each other. The name is derived from the Greek *phenomenon* describing occurrences that are observable. Denscombe[45] summarizes the nature of this research strategy as follows:

> "(…) it is seen as an approach that emphasizes:
> - subjectivity (rather than objectivity);
> - description (more than analysis);
> - interpretation (rather than measurement);
> - agency (rather than structure).
>
> Its credentials as an alternative to positivism are further reinforced by the fact that phenomenological research generally deals with people's
>
> - perceptions or meanings;
> - attitudes and beliefs;
> - feelings and emotions."[46]

Furthermore, he refers to the role of "experience" and the "everyday world:"

[45] Denscombe (2007, p. 75)
[46] Ibid.

> "Phenomenology is concerned, first and foremost, with human experience – something denoted by the term 'phenomenology' itself. A phenomenon is a thing that is known to us through our senses. It is seen, heard, touched, smelled, tasted. It is experienced directly, rather than being conceived in the mind as some abstract concept or theory. (…)
>
> Phenomenology is also characterized by a particular interest in the basics of social existence. (…) In practice, this translates into special importance being attached to the routine and ordinary features of social life, and to question about how people manage to 'do' the everyday things on which social life depends."[47]

In line with the phenomenological approach, the incorporation of experiential knowledge from the author's research and design practice of more than ten years was important. The author's educational background in landscape design, ecology, biotechnology and ecological engineering as well as management and entrepreneurship, contributed previous theoretical and practical knowledge to this study. This included, for example, practical aquaculture greenhouse experience as a research intern and several work-research stays at the Stensund Wastewater Aquaculture – a European long-term pilot project run from 1989-2000 in Sweden (→ Chapter 3:; Chapter 5:). However, the previous experiences were complemented by new investigations during the core time of this study. This included case study field-trips to New York City and interviewing key people from the Swedish case study ten years after the closure of the pilot greenhouse during 2009-2011 (1.2.2). Furthermore, urban explorative design-research of a hands-on character was carried out in the place-based context of Berlin, particularly on mobile aquacultural infrastructures during urban festivals, public interventions or collaborative design studio experiments (e.g. Asia-Pacific Weeks, Berlin 2009, 2011,[48] borderlining workshop Rio-Berlin 2009,[49] summer studio urban design 2010,[50] Berlin Initiative and Festival Über Lebenskunst) (→ Chapter 3:; Chapter 4:; Chapter 6:).

Additionally, the dissertation applied integrative methods as practiced in transdisciplinary research (e.g. ecological economics, design-planning, landscape architecture, or social ecology).[51] According to Costanza,[52] transdisciplinary research questions are not divided into an "intellectual map."[53] Rather than protecting them with disciplinary borders (e.g. through disciplinary languages) or widening the disciplinary perspective to other disciplines by keeping the same language (interdisciplinary approach), the borders are "permeable and adaptable."[54]

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[47] Ibid.: p. 77

[48] APW (2009); APW (2011)

[49] Wieck *et al.* (2009)

[50] Pizarro *et al.* (2010b)

[51] Becker and Jahn (2006); Bergmann and Schramm (2008); Bergmann *et al.* (2010); http://www.bmbf.de/de/972.php (2012-01-11)

[52] Costanza *et al.* (2001)

[53] Ibid.: p. 94

[54] German language version in: Ibid. (English translation by C. Champlin and E. Leismer).

This interpretation is consistent with socio-ecological research in German-speaking countries.[55] The transdisciplinary field of *socioecology*, thereby, was introduced by the Frankfurt Institute for Social-Ecological Research (ISOE) coining the "societal relations to nature" and the hybrid character of intertwining natural-cultural processes.[56]
With this background, the novelty and benefit of this research is the production of *new* insights using knowledge integration and integrative conceptual model building. The author's own research contribution, thereby, lay in the unifying approach of exploring both *water-cultural* (everyday human) and *water-natural* (landscape ecosystem) blue-green infrastructure services in interrelation to a *new* extended understanding of urban aquaculture.

The main transdisciplinary methods following the phenomenological approach were:

- literature, documentary and cartographic research[57];
- term clarification and construction (1.3); conceptual model building (e.g. 2.2; 6.2);[58]
- empirical case study research in a place-based (Berlin) and mutual international context focusing pilot case references and *first mover projects* in a real-life community context and of personal research experience that included visiting research, project site visits and expert interviews performed as non-standardized oral interviews[59]); and
- explorative research in a place-based context (Berlin) for the generating and testing of new ideas, methods and practices relating to design-build and participatory process strategies, such as student workshops, studio projects (e.g. borderlining workshop Rio-Berlin 2009, summer studio urban design 2010, Technische Universität, Berlin) or collaborative experiments and interventions in urban space during festivals or public events (e.g. Swimming Marketplace and Swimposium during Asia-Pacific Weeks, Berlin 2009 and 2011; DAS NUMEN H2O – Spree River experiment during Festival Über Lebenskunst August 17-21, 2011)[60].

The dissertation comprises two major parts embracing theory and applied case study research Figure 2). After the general introduction (Chapter 1), the first part (Chapters 2-3) focuses on theoretical state-of-the-art research linking urban design with landscape ecosystems and blue-green infrastructure perspectives. The focal intention of Chapter 2 is to introduce an overview of how water, in its hybrid role as a natural landscape element and cultural infrastructure, formed the Western cities' water-based identities and morphologies. It depitcts characteristic

[55] e.g. Kanning (2005, p. 37); Becker and Jahn (2006); Bergmann *et al.* (2010)

[56] According to Becker (2006), socioecological systems are best characterized as "natural-cultural hybrids." With this background, the novelty and benefit of research derived from synthesizing existing knowledge and experiences from so far unconnected fields, themes or purposes, and focused on the opportunities arising from this.

[57] Due to the integrative character of research, a deep investigation of disciplinary courses was limited. Therefore, the literature used mainly refers to secondary sources providing overviews and basic integrative insights. Additionally, key literature and basic concepts were identified according to each research field.

[58] Bergmann *et al.* (2010)

[59] Friedrichs *et al.* (1990)

[60] e.g. APW (2009); Wieck *et al.* (2009); Pizarro *et al.* (2010b); APW (2011); ÜLK (2011)

aquacultural facets from the past to the present in the urban context. Complementarily, Chapter 3 investigates key features of blue-green services, which could be derived from state-of-the-art landscape ecosystem and green water infrastructure research. Additionally, it investigates cross-cultural aquacultural types of water-farming of low-tech/high-tech character – from swimming gardens and fishponds to water-farm greenhouses, integrating fish, aquatic animal and hydroponic plant production. Facing contemporary urban needs, such as space- and resource-efficient water and food provision, they are *newly* perceived and interpreted as specific blue-green infrastructures. The outcomes of chapter 2 and 3 provide the structure and basis of evaluation for the applied case study research that follows in the second part (Chapters 4-5).

Chapter 4 – the *Berlin case study* – is an in-depth research of urban aquaculture history in its three facets at a city-wide scale tracing everyday relationships with water and water infrastructure. It, furthermore, explores the place-based history of spatial-infrastructural transformation, literally from the waterscape to the cityscape. Moreover, it illustrates contemporary blue-green infrastructure projects, which contributed to the reemergence of a post-industrial urban aquaculture. Chapter 5 complements by looking at international pilot case studies in Nordic and moderate climates. It focuses on the integration of the new infrastructures into existing urban spaces (New York City) or living neighborhoods (Sweden) whereby creating a new tangibility of water processes in the everyday life context.

Chapter 6 summarizes the main conclusions and the lessons learnt. Based on and regarding the third central research question, it proposes water-sensitive design-planning tools concerning the design-build level – addressed as *aquatecture*, and the participatory process level – addressed as aquatecture. The chapter concludes with an outlook on future fields for design and research action.

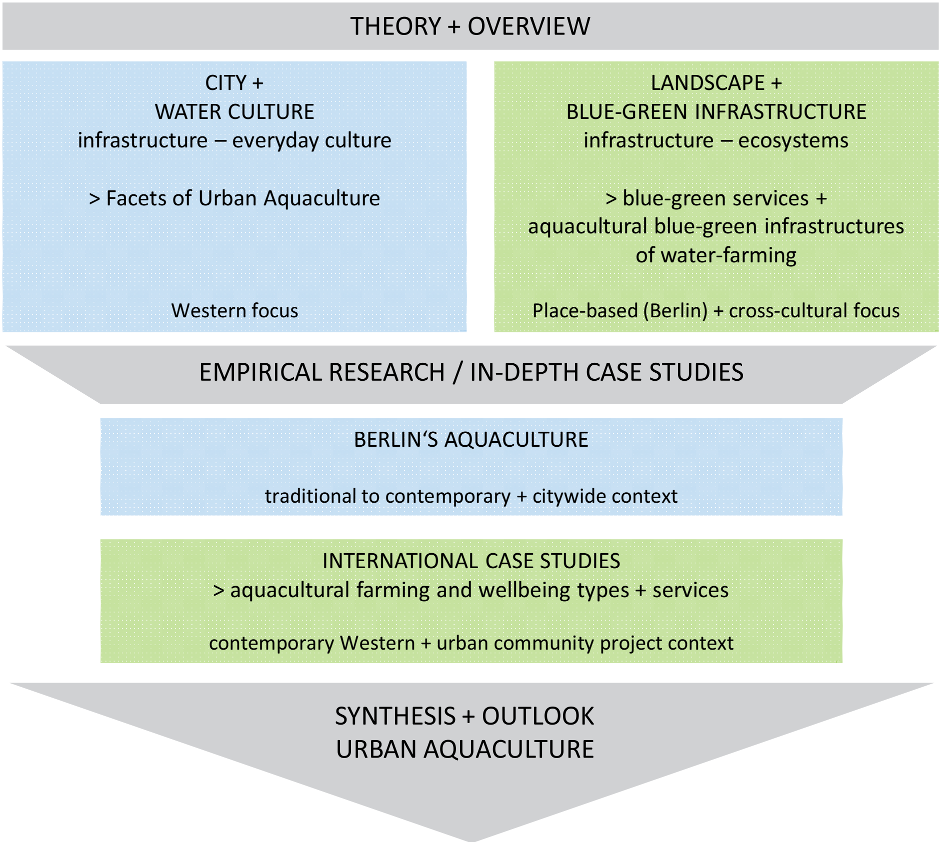

Figure 2: Research design

1.2.2 Case study selection and set of evaluation criteria

Spatial selection

The spatial selection of place-based and international research (→ Chapter 4:; Chapter 5:) focused on Nordic and moderate climate conditions. The project sites in Sweden, located in an archipellago south of Stockholm, and New York City were viewed as being of promising transferability potential to the city of Berlin regarding both natural and cultural circumstances.

(1) Berlin, as a traditional and contemporary water city with currently ~3.4 million inhabitants, was chosen as a local case study to explore in-depth characteristic facets of urban aquaculture in past and present waterscape history. Personal biographical knowledge combined with both the highly transformative character with regard to spaces and cultural lifestyles, and its *blue-green character* make it an appropriate Western water city reference case. Berlin has almost double the proportion of *urban green* and *urban blue*, with about 48% of the metropolitan area,

compared to New York City, with ~27%.[61] Coincidently or not, the length of Berlin's sewer network runs for more than 8,400 kilometers, which corresponds to the distance from Berlin to New York City.[62] Its postindustrial urban farming and river culture in particular have already initiated water-sensitive transformations. The cocreation of new blue-green infrastructures from *aquaponic* (fish aquaculture and hydroponic plant cultivation) and *hydroponic* (water-based plant cultivation) ponds and greenhouses to floating river pools reflect vividly and tangibly on an emerging postindustrial aquaculture in Berlin. Meanwhile, many of the new *aquacultural landscapes* have become lively and creative *spaces of possibility* integrated within decentralized urban spaces and socio-cultural contexts.

(2) The Swedish case study – the Stensund Wastewater Aquaculture cross-sectorally combining decentralized wastewater management with aquaponic greenhouse production – was located at a Folk College campus in the Trosa community south of Stockholm on the coastline of the Baltic Sea. It represented a small-scale settlement of about 100-150 inhabitants, as can also be found in decentralized Western urban contexts. Established in 1989[63] and run for ~10 years, it has become a unique European pilot project, inspirational source and role model of integrated resource management combining productive water-farming, wastewater treatment services and applied education in Ecological Engineering and Design. However, as it is no longer *alive*, the case is not widely known in the urban and landscape design research field or among technical water experts. Due to its unique long-term experience and broad variety of follow-up projects (5.2.5), it was regarded as a basic learning-from case.

(3) New York City was chosen as an inspirational Western reference city. Similar to Berlin, New York City has the international image of a creative and lively city. At the same time, it is a highly vulnerable waterfront city that is currently reinventing its waterfront relationship on multiple levels. The 2010 exhibition *Rising Currents* at MoMA stressed the urgent demands of climate and water-sensitive adaptations as follows: "New York City and its environs face several impending urgencies, challenges confronting coastal and river cities world-wide. Decaying infrastructure and rising sea levels caused by climate change are pressing issues, and they demand unconventional thought and action."[64] Many socio-entrepreneurial initiatives have been emerging to tackle the diverse challenges in site-specific contexts. Its innovative and creative bottom-up projects have contributed to New York City's meaning as an important 21st century urban lab to learn-from for future livable and lively water cities.

Criteria of case selection and evaluation

At the center of international pilot case research (→ Chapter 5:) were best practices of private- or community-driven bottom-up development having a strong interrelation with the public realm – the people and the living space. The pilot cases chosen focused on a variety of aquacultural

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[61] SENSTADT (eds.) (2012, p. 13)
[62] Reichert (1994, p. 9)
[63] Guterstam (1996, p. 74)
[64] MoMA (2010)

typologies covering greenhouse, floating pool and garden blue-green infrastructures. Regarding the specific case study selection, the primary criteria were not solely the novelty of technology, research insights or personal experiental knowledge. Moreover, the first mover character by the time of implementation and the currently *new* relevance for real-life urban community integration was of high priority. Furthermore, these pilot projects had existed for at least 18 months prior to the main time of empiric research, including site visits (2009-2010).

Accordingly and by linking the landscape ecosystem to an everyday human perspective, a set of *blue-green design criteria* was defined for the specific case selection and evaluation. It included the following six criteria to assess the multifunctionality of blue-green infrastructure design regarding natural and cultural life-support:

- Supporting blue-green services
- Flexibility of design
- Tangibility of processes and aesthetics
- Participative intervention and responsibility
- Community integration
- Applied learning, transforming spaces and mindscapes

The first two criteria, thereby, reacted to the first key problem detected for the current monofunctional (water) infrastructures (1.1.2). Due to they address eco-technical performance features. In addition to, the criteria three to six focused on aspects of the human-scale and user aspects of technical infrastructures by addressing so-far missing features of perception, attractiveness, participative learning, usability, and responsibility.

In line with these six criteria, four case studies were selected and evaluated qualitatively, supported by exemplary and quantitative data if available and useful. They represented urban aquacultural applications of a combined low-tech/high-tech infrastructural design within Western neighborhood contexts. These first mover projects comprised different typologies, services, spatial scales, and contexts. Besides physical and technological features, all the case studies embraced sociocultural features by serving applied learning, urban recreation and community building. Further details regarding the defined criteria are described in the project case study section (5.1).

The urban context was mainly addressed regarding its water-sensitive transformational potential. However, the Swedish case study was not urban and is not extant. Although no longer in operation today and representing a rather old European pilot study, it was regarded as still up-to-date and alive. The Stensund Wastewater Aquaculture represented a type of building-integrated water-farm greenhouse for combined water and resource management . With regard to its broad urban innovation potential for the postindustrial city, it functioned as a *key case study* and, consequently, attributed the largest share.

The selection of the New York City cases covered a broad range of blue-green infrastructures from water-farm greenhouse to swimming garden and types of floating pool. The first New York case study (*The Science Barge*) reflected the applied research approaches of building-integrated water-farming (soil-less farming). Functioning as a prototype farm, it was based on the water in New York's Hudson River. The main project objective was to demonstrate the urban potentials of self-sustenance with basic resources (water, food, energy). Water-based farming modules (mainly hydroponics for light-weight roof-top applications) were combined with eco-technologies for rain and river water purification and regenerative energy modules on a rather independent pontoon structure. The Barge was both a showcase and applied training center to learn and teach about flexible and decentralized technologies for potential building applications as low-tech and high-tech variants. Regarding the integration into real-life neighborhood contexts, it could be a rather fixed urban waterfront infrastructure or move to other parts of the city as a nomadic type of infrastructure.

The other two New York cases primarily featured urban water-wellbeing. Furthermore, they reflected on both trends of *renaturalizing waterscapes* through low-tech approaches of urban river remediation (*The Oyster Dock*) and of *reculturalizing waterscapes* through mobile and high-tech-oriented urban waterfront revitalization strategies (*The Floating Lady*).

Last but not least, it should be mentioned that, with the growing speed and emergence of creative urban bottom-up projects in the context of urban farming (4.5), the selection of cases could be, *per se*, *only* a glimpse. Some recent internationally relevant projects within Western city contexts, such as from Urban Farmers in Basel,[65] could be only marginally seen to be affiliated to Berlin projects (4.5.3) due to being launched after the core time of empiric research in this study.

1.3 Key terminology

1.3.1 Urban Aquaculture – Aquaculture

Urban aquaculture embracing urban fishing, shipping, swimming, and other aquatic activities of a city's and its citizens' everyday water culture integrates the following three characteristic facets: (1) water-farming culture – regarding water-based food and biomass production, (2) water-living culture – concerning living by and with the water, and (3) water-wellbeing culture – addressing water-centric human wellbeing, including psychological, spiritual and physical wellness aspects (2.1.2; 4.4). In this way, the reseach *newly* broadens the standard definition of *aquaculture* – according to FAO (1995), "the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants"[66] – forming an urban image of aquaculture.

Regarding the water-farming facets, sustainable forms of aquaculture are particularly addressed. This refers to the traditional meaning of aquaculture that originated ~4,000 years

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[65] http://urbanfarmers.com (2011-09-03)

[66] Bunting and Little (2002, p. 448)

ago in Asia as integrated polycultural water-farming practice, hence a complimentary element and branch of agriculture. It has been the sector of agriculture with the largest economic growth since the end of the 20th century. Contemporary industrialized aquaculture is associated with considerable risks or environmental impacts, such as eutrophication of natural water bodies, hormone loads or the clearing of mangrove woods. However, productive industrial aquaculture for “the controlled cultivation of aquatic plants and animals”[67], can be designed and managed for the multifunctional renewal of vital resources, processes and quality, consequently providing a sustainable added value.[68]

1.3.2 Aquacultural typologies – Aquaponics – Hydroponics – Water-Farms – River Pools

Aquacultural typologies, such as swimming gardens, ponds-and-pools, and types of water-farm greenhouses are newly interpreted and investigated as specific blue-green infrastructures (3.4; 5.1). Aquacultural blue-green infrastructures (in short, *aquacultural infrastructures* or *aquacultural typologies*) describe aquatic ecosystem technologies for natural-cultural life-support and the renewal of livelihoods. The term *water-farm* addresses water-based farming technologies and practices, such as *hydroponics* (soil-less plant cultivation), *aquaculture* (fish and aquatic animal cultivation, e.g. crayfish, mussels) or *aquaponics* (combination of *aqua*culture and hydro*ponics*).
Similar to the meaning of urban aquaculture, the adjective *aquacultural* intends to address more than solely water-farm productive contents. Corresponding aquacultural practices comprise everyday activities from shipping, fishing, drinking, washing and bathing, to swimming. Affiliated aquacultural infrastructures that are investigated and recognized in the past and contemporary urban landscape context comprised, for example, bathing ships or ecologically cleaned urban *river pools*. Thus, aquacultural blue-green infrastructures were recognized. Aquacultural services additionally correlate with water-cultural rituals, and individual or societal water use in place-specific contexts. Their close intertwining *water-natural* landscape ecosystem processes reflect the hybrid *natural-cultural* infrastructure character.

1.3.3 Blue-green infrastructures – Everyday life infrastructures – Regenerative infrastructures

The overarching term *blue-green infrastructures* stands for water ecosystem-based technologies for regenerative hybrid (natural-cultural) life-support, including integrated water, food, energy, and other quality of life services. The perception of food, thereby, is linked to the “Cradle-to-Cradle concept.”[69] Food consists of various *green* materials, including living biomass and biological waste, which can be food or soil substrate for other living beings. The attribute

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[67] Tilley *et al.* (2008, p. 141)

[68] Stewart and Serfling (1979); Todd and Todd (1984); Edwards and Pullin (1990); LI (1991); Guterstam and Todd (1990); Etnier and Guterstam (1991); LI (1991); Guterstam (1996); Prein (1996); Guterstam *et al.* (1998); Junge-Berberović *et al.* (1999); Bunting and Little (2002); Bohemen (2005a); Costa-Pierce *et al.* (2005); Graber and Junge-Berberović (2008); Graber and Junge-Berberović (2009); Gorgolewski *et al.* (2011); Despommier (2011)

[69] McDonough and Braungart (2002)

blue stands for daily fresh water flows, and *green* for everyday vegetative ecosystem services (e.g. biomass production, evaporative cooling). Thus, they specify key landscape elements and process drivers and are similarly used in the concept of “blue and green water.”[70] They, also refer to Anglo-Saxon spatial planning terminology, such as green infrastructures (vegetative spaces), blue infrastructures (water spaces) or grey infrastructures (roads, sealed surfaces, etc.). *Green infrastructure* is interpreted as follows: “all natural, semi-natural, and artificial networks of multifunctional ecological systems within, around, and between urban areas, at all spatial scales.”[71] The combined terminology *blue-green* is used to express the intertwined process character of serving natural-cultural life-support in a hybrid manner.[72] The notion of blue-green infrastructure in Germany is used, for example, within the regional landscape scale context of the Regionale 2010 in the Cologne region.[73]

Blue-green infrastructures could be built structures (e.g. constructed wetlands) or self-organized landscapes (e.g. natural wetlands). This is also addressed by the EU strategy on green infrastructure,[74] which refers to the different conceptual applications on an urban and landscape scale.[75] However, the research focus is on designed blue-green infrastructures in urban and suburban contexts. As *everyday life infrastructures* (in short, everyday infrastructures) they provide basic daily life resources and wellbeing services. As *regenerative* or *living* infrastructures, they mimic water and ecosystem-based processes while enhancing and regenerating their blue-green services of common life support (e.g. fresh water, biomass, biodiversity, moderate temperature). Regenerative infrastructure approaches refer to design-build strategies practiced in the transdisciplinary fields of ecological engineering and ecological design, respectively regenerative design. Those concepts highlight the inclusion of ecosystem-based principles, such as natural self-purification, natural cooling, fertile soil recreation, or regeneration of biodiversity and natural beauty into sustainable spatial design and engineering processes. Guterstam refers to the fundamental research of H. T. Odum in the 1960s, “who (…) has described ecological engineering as half science and half engineering: ‘techniques of designing and operating the economy with nature … Just as an engineer is asked to make a bridge that works and lasts, the ecological engineer should provide a pattern with nature that works and lasts.’”[76] Bohemen highlights the initial introduction of the term by Mitsch and Jørgensen (1989), who defined ecological engineering “as a combination of various disciplines: ecology and technology.”[77] Van der Ryn and Cowart define ecological design as: “the intentional shaping of matter, energy, and process to meet a perceived need or desire. Design is a hinge that inevitably connects culture and nature through exchanges of materials, flows of energy, and choices of land-use.”[78] This interpretation mutualizes with Lyle’s reflection of a regenerative

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[70] GWP and Falkenmark (2003); Falkenmark 2005 #410}; Falkenmark and Rockström (2006)

[71] Tzoulas (2007)

[72] Bürgow (Stockholm 22-25 May)

[73] http://www.regionale2010.de (2010-10-10)

[74] http://ec.europa.eu/environment/nature/ecosystems/index_en.htm (2010-10-10)

[75] EEA (2011, p. 30)

[76] Guterstam (1991, pp. 41–42)

[77] Bohemen (2005a, p. 11)

[78] van der Ryn and Cowan (1996, p. 8)

design: "By design I mean conceiving and shaping complex systems (...). Environmental design is where the earth and its processes join with human culture and behavior to create form."[79]

1.3.4 Water-based – water-centric – water-dependent – water-sensitive

The adjectives water-based, water-centric or water-dependent are used solely descriptively, whereas water-sensitive highlights a normative design-planning perspective. The latter is linked to approaches of a water-sensitive urban design (WSUD),[80] which is defined as follows:

> "In its broadest context, WSUD is the integrated design of the urban water cycle, incorporating water supply, wastewater, stormwater and groundwater management, urban design and environmental protection. It represents a fundamental shift in the way water and related environmental resources and water infrastructure are considered in the planning and design of cities and towns, at all scales and densities. WSUD aims to see all streams of water being managed as a resource, as they have quantitative and qualitative impacts on land, water and biodiversity, and the community's aesthetic and recreational enjoyment of waterways."[81]

According to Wong and Ashley:

> "WSUD brings 'sensitivity to water' into urban design, i.e. it aims to ensure that water is given due prominence within the urban design process. The words 'Water Sensitive' define a new paradigm in integrated urban water cycle management that integrates the various disciplines of engineering and environmental sciences associated with the provision of water services including the protection of aquatic environments in urban areas."[82]

1.3.5 Landscape – Landscape Ecosystems – Cityscape – Waterscape

The notion of "landscape" is used in both senses, as a physical (material) and a constructed or perceived (immaterial) reality. This harmonizes with the European Landscape Convention (ELC): "'Landscape' means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors."[83] Furthermore it embraces "man-made landscapes" by stating: "'Landscape is applied as a territorial concept equally addressing

[79] Lyle (1993, p. IX)

[80] France (2002); Hooimeijer *et al.* (2005); Wong (2006); Novotny (2007); France (2008); IBA Hamburg (eds.) (2008); JSCWSC (2009, pp. 1.3); Hao and Novotny (2010); Hoyer *et al.* (2011); Wong *et al.* (2011); Howe (2012); Hoyer *et al.* (2011)

[81] JSCWSC (2009, pp. 1.3)

[82] Wong and Ashley (2006), Cited in: Wong (2006, p. 2)

[83] Art. 1a In: EU (2010a)

rural areas, 'cityscapes' (urban and industrial areas), 'waterscapes', as well as high-quality, ordinary and degraded landscapes."[84]

The ELC offers an integrative perspective embracing the European historic conceptions of the cultural (or aesthetical) landscape and the natural (or functionalist) conception.[85] For a clearer distinction between urban (cultural) and landscape (natural) processes, in context of this research the term 'landscape' is primarily used for addressing the physical side to coin 'natural' landscape functions[86] or ecosystem services[87]. This is in line with contemporary regional landscape strategies[88] referring to the partly overlaps of both concepts (e.g. recognized by the EU biodiversity strategy[89]). Similar to, the extended notion "landscape ecosystem services" is used to stress the fact that the physical landscape is the living base of ecosystems.

If stressing the perceptional side such as different spatial qualities of the landscape, merging terms such as cityscape or waterscape are used. The notion "waterscape," for instance, has been introduced by Herbert Dreiseitl,[90] whose projects merge green open space, landscape design with water infrastructural design. Similar hybrid notions reflect the perception of the landscape as a "landscape-infrastructure," as discussed in contemporary sustainable urbanism research,[91] particularly landscape urbanism,[92] as an emerging field therein. It integrates transdisciplinary themes of architecture, infrastructure, landscape, art, planning, and design by stressing process-oriented approaches.
As a result of this "transforming landscape perception," contemporary discourses do not solely reflect the landscape as a more or less static pictorial space of the natural environment. Through integrating transformative features, a hybrid and fluid perception of everyday infrastructure, landscape and urban processes becomes dominant. It reflects on the natural-cultural intertwinedness from the scale of the human body to the larger urban metabolism[93] (2.1.2; 3.2). Hence, rather than excluding man-made spaces, such as the city and its infrastructures, as "landscape opposites," the dynamic and interrelated perception focuses on their inclusion. This broadened landscape perspective has been introduced into the contemporary German-speaking landscape discourse by cultural landscape studies.[94] It refers to the groundwork of the Anglo-American geographer, John Brinckerhoff Jackson, working in the 1950s.[95] Through observing dynamic patterns and phenomena of urbanization and

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[84] Ibid. Art. 2
[85] (Donadieu and Perigord 2007) In: Kirchhoff and Trepl (2009)
[86] A spatial planning concept with a long political tradition in Germany and the Netherlands Lohrberg *et al.* (2013).
[87] A spatial planning and economic concept of Anglo-American research tradition MEA (2005); TEEB (2008); Groot *et al.* (2010); Hermann *et al.* (2011).
[88] e.g. Lohrberg *et al.* (2013)
[89] EC (2011) In: Ibid.
[90] Dreiseitl (2001)
[91] Spirn (1984); Spirn (2001); Ellin (2006); Farr (2008)
[92] Angelil and Klingmann (1999); Corner (2003); Corner (2006); Waldheim (2006); Shannon (2006); Schäfer (2010)
[93] Heidenreich (2004)
[94] e.g. Franzen and Krebs (2005), Hauser (2005)
[95] Jackson (1984)

industrialization in the 20th century landscape, Jackson extended the then prevailing static landscape perception. He introduced a new concept called "landscape 3" which perceived contemporary landscapes as the "dynamic fabric of man-made spaces."[96]

Complementary and analogous to this paradigm shift in landscape perception, the German-speaking discussion on processes of suburbanization introduced the notion of "Zwischenstadt"[97] or "Landschaft 3"[98] (translated and directly linked to Jackson's cultural landscape studies). Last but not least, the condensed term "Scape," introduced by Rem Kolhaas and the Pearl-River student, affiliates to Jackson's landscape 3 concept. This notion addresses the phenomenon of dissoluting disciplinary borders if facing contemporary highly transformative urban processes. Kohlhaas argues: "SCAPE, neither city nor landscape is the new post-urban condition (...) the end of two disciplines, architecture and landscape architecture, and their future merger."[99] In this sense, the traditional dichotomy of city and land(scape) gradually gives way to a hybrid and dynamic reflection on landscape morphologies,[100] where mental opposites, such as city versus land or culture versus nature, dissappear. It is important to highlight that, in this sense, the perceptional change is primarily addressed. According to the physical appearance, the "natural" landscape or the "cultural" city, for instance, still can and still should be distinguished according to their distinctive material, aesthetic or ecological qualities.

NATURE – CULTURE

The interpretation of *nature* in this research context primarily addresses the landscape ecosystem dimension by referring to the life-supporting role of ecosystem services. The understanding of *culture*, first of all, stresses the everyday human dimension. It is affiliated with the interpretation of *water culture* by Ipsen et al.,[101] which is analogously used as culinary culture or living culture. Thus, the focus is on the everyday cultural dimension. It addresses various socio-cultural meanings of water as a natural element, technical infrastructure or aesthetic medium. Furthermore, it includes the design of using and handling water alongside the human-intentive production of meanings.[102]

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[96] Ibid. In: Prominski (2003, p. 55)
[97] Sieverts (1998)
[98] Prominski (2003); Eisel *et al.* (2009)
[99] Koolhaas *et al.* (2000)
[100] Angelil and Klingmann (1999); Angelil (2003)
[101] Ipsen *et al.* (1998, p. 15)
[102] Ibid.

PART I

THEORY

CHAPTER 2: OVERVIEW OF CITIES' WATER, INFRASTRUCTURE AND LANDSCAPE HISTORY

Chapter 2 explores the common patterns of cities' water and landscape history and infrastructural facets of urban aquaculture from the perspective of sustainable urbanism, focusing on landscape urbanism and water urbanism. These contemporary spatial strategies link with process-oriented notions, such as "performative urbanism,"[103] "fluid urbanism"[104] or "integral urbanism."[105] Corner stresses it as follows: "In conceptualizing a more organic, fluid urbanism, ecology itself becomes an extremely useful lens through which to analyze and project alternative urban futures. The lessons of ecology have aimed to show how all life on the planet is deeply bound."[106] Ellin complements Corner, and points out the difference to the current prevailing separated planning approaches by stating: "In contrast to the master-planned functionally-zoned city which separates, isolates, alienates, and retreats, Integral Urbanism emphasizes connection, communication, and celebration."[107]
Therefore, the research contents in this chapter are grounded on sustainable design-planning approaches as developed in an Anglo-Saxon context in the 1980s, particularly regenerative design and ecological design. Since that time, the field of landscape architecture and planning has expanded through placing their contents into the urban and landscape watershed context.[108]

The objective of this chapter is to unveil common patterns of water-centric infrastructural interventions from two complementary angles: (1) the urban morphogenesis in exemplary Western water cities by facing an everyday "human" water culture; and (2) visible and invisible morphological landscape transformation induced from and along with managing and altering the flows of water. The notion of *infrastructural intervention* is most often used in a financial context linked to investments in different economic sectors, such as transport, irrigation and electrification.[109] However, in light of this research, it relates to issues of physical transformation induced by technical (water) infrastructures. Therefore, the term points to technical infrastructural interventions in the watersheds, e.g. through the building of canals, weirs and sluices, or the pumping of water.

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[103] e.g. Shane (2006, p. 59); Stokman (2011)
[104] e.g. Corner (2006); Heidenreich (2004)
[105] e.g. Ellin (2006)
[106] Corner (2006, p. 29).
[107] Ellin (2006)
[108] Spirn (1998) sets out the early basis for a process-oriented spatial reflection and action approach by referring to the "landscape as stage (…) and play with many actors – flowers, people, trees, rocks Spirn (1998)."
[109] UNESCAP (p. 26)

2.1 Urban water histories

2.1.1 Water as the cradle of cities: water-based identities, morphologies and aquacultural practices

Water as the cradle of the city has always played a substantial role.[110] Most famous large cities are most commonly those that originated by the water: beside rivers, lakes or seashores. Water has shaped urban prosperity and morphologies, particularly along the waterfronts, by enabling urban trade and enterprise.

Waterways and natural water cycles have nourished the metabolism of the city. Spirn refers to the life-supporting role in the urban context by saying: “Water is the city’s life blood: it drives industry, heats and cools homes, nurtures food, quenches thirst, and carries waste.”[111] She further points out the role of urban water creating a specific urban geo-hydrological pattern: “Taken together, urban activities, the density of urban form and the impervious materials of which it is built, the pattern of settlement and its relation to the natural drainage network, and the design of the drainage and flood control system produce a characteristic urban water regime.”[112]

Furthermore, water sustains and facilitates the everyday infrastructure services of food and resource provision and, consequently, has shaped each city’s culinary culture closely intertwined to its water culture. Fish and food caught in local rivers and the sea served as typical local dishes, and urban aquacultural practices of fishing or shipping have also cocreated place-based waterscapes for many centuries. In the face of 21st century urban resource challenges, famous old cities can, thus, be *urban mirrors* which can be reflected upon and learnt from. In addition to unveiling a city’s cultural water history, the urban form reflects on the natural history of the water. Often similar in experience, it tells a common *hi-story* of natural-cultural changes in spaces and landscapes, of growth and shrinkage, of rise and fall, and of urban quality of life over time. Urban histories most often link to everyday stories of basic provision with common goods and services telling about people’s food and water culture. Consequently, they reflect on characteristic facets of urban aquaculture, as well as a city’s and its citizens’ individual water-based identity in the sense of a *waterscape biography* (→ Chapter 4:). Hooimeijer points out that the cultural issue of urban identity appeared during the 1970s, along with a revived attention to water as an important part of the city’s identity.[113]

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110 A significant part of this section refers to intermediate doctorate research results of the author. See, in particular: Bürgow (2012)

111 Spirn (1984, pp. 139–140)

112 Ibid.

113 Hooimeijer (2005, p. 172); Hooimeijer *et al.* (2005, p. 15)

Illustrations from Paris and Venice

The Latin saying *Nomen et omen* (*name is omen* – the name is fitting for the object or person) appears to be true for human beings and cities.[114] The names of most famous European water cities are based on their geographical waterscape biography. Paris, for example, in its etymological meaning, derives from the Gallo-Latin *Lutetia Parisiorum* – the name of a fortified town and capital of the Gaulish tribe of the *Parisii*. It literally means *Parisian swamps*. Although the tribal name is of unknown origin, it comes traditionally from Celtic *par* – boat (cf. Gk. *baris*; see *barge* as a flat-bottomed freight boat).[115] Paris's coat of arms shows a ship, which, interestingly, is also reflected in the urban morphology (Figure 3).

Water-based urban morphologies

In addition to names, everyday water practices and infrastructural interventions are literally footprinted in urban morphologies. Water, as a key element of natural and cultural life forming and transforming the "face of the landscape" (2.1.3), also shaped the "face of the city."[116] This description refers to Kostof's research on the urban morphogenesis (cf. Gk. *morphé* – form, shape, and *genesis*: literally meaning *the beginning of shape*).[117] The architectural historian reflects on the genesis of cities as an interactive process between structures (buildings, infrastructures) and living processes (human beings, socio-cultural life). "What greatly interests me is how and why cities have acquired their particular form. I do not deal with form as an abstraction or with the impact of form on human behaviour, but rather with form as a bearer of meaning. And, the meaning of architecture is ultimately always rooted within a given historical and cultural context."[118]

Ian McHarg, the landscape architect and regional planner, highlights that urban water culture is tangibly expressed in urban morphologies: "So, of course, the measure of cities is their culture, but this embraces the visible city as an expression of the given form and as an adaptation to it. This is a visible and manifest expression of the culture – the morphology of man-nature and man-city."[119] When one reads the urban morphology of Venice, the city's "amphibian" character[120] – transformed from a natural island into an urban lagoon – becomes tangible (Figure 3).
As the historic capital of an independent city-state, Venice's name is linked to the ancient tribe of the *Veneti* inhabiting the region in Roman times.[121] Various descriptions such as "Queen of

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[114] A significant part of this section refers to intermediate doctorate research results of the author. See, in particular: Bürgow (2012)

[115] http://www.etymonline.com/index.php?search=paris&searchmode=none (2010-10-01)

[116] English title: *The City Assembled*, German title: *Das Gesicht der Stadt* (direct translation: "The face of the city") Kostof (1992)

[117] http://www.etymonline.com/index.php?search=morphogenesis&searchmode=none (2010-10-01)

[118] German language version in: Kostof (1992, p. 9) (English translation by C. Champlin and E. Leismer).

[119] Mc Harg (1992, p. 172)

[120] Bevilacqua (2010, p. 155)

[121] Charnock (1859)

the Adriatic," "Serenissima," "City of Water," "City of Bridges," "The Floating City," or "City of Canals" refer to Venice's urban water-cultural biography.[122]

Figure 3: Water-based urban morphologies – Left: Paris (~1615). Right: Venice (~2010)

EARLY URBAN AQUACULTURAL PRACTICES

Regarding the intertwining of urban water and food culture, Venice has been shaped by place-based lagoon aquaculture (*valli*).[123] Because the shallow and warm brackish lagoons were full of fish and other water *poultry*, urban aquaculture, in its traditional sense of water-farming, provided the major food source.[124] Firstly developed in medieval times, it still operates in a modern form today. To produce the required quantity of fish, according to Bevilacqua, sustainable practices of urban aquaculture guaranteed the city's food sovereignty.[125] In addition to free fishing (*pesca vagantina*) practiced in the lagoon and the open sea beyond the beaches, strict legislation governed water-land uses in and outside the water city. Limited fishing seasons were introduced to prevent overfishing in the free fishing area. Keeping the surrounding water bodies clean has been another prerequisite for both the city's fisheries and salt industry.[126] The sustainable urban aquacultural practices were complemented by early forms of sustainable urban forestry. High-quality wood from the oak tree (*Quercus robur*) was needed in great quantities for the city's fleet of ships, as Venice became a leading maritime power.[127] In addition to military purposes, oak was used for building construction. Venice's famous palaces (*palladi*) – as Bevilacqua points out: "actually stand upon a forest of petrified tree trunks that had to be rammed into the mud, the caranto, to make a solid base for the island."[128] Similar to aquaculture

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[122] Ibid.
[123] Bevilacqua (2010, p. 153)
[124] Valentien (2010)
[125] Bevilacqua (2010)
[126] Ibid.
[127] Ibid.
[128] Ibid.: p. 155

regulations, a special law regulated the sustainable production of oak wood, including principles of rotation with regards to logging, or replanting after harvesting, as early as 1470.[129]

As the Western water cities' histories illustrate, they all have a *wet-land history* in common. As most prominently known from the Dutch pond-and-dike patterned waterscape morphologies,[130] other famous European water cities, such as Amsterdam, would never have been inhabited in the long-term without constantly managing the flows and courses of water above and below ground. Hence, the first glimpse of certain aspects of Western water cities' morphogenesis described needs a deeper understanding regarding an urban waterscape biography. Since Berlin's waterscape biography, following the transformation from a natural wetland into an urban waterscape, shows a similar pattern, it will be explored as a place-based in-depth case study focusing on characteristic urban aquacultural facets (→ Chapter 4:).

2.1.2 Water and human wellbeing: everyday psychological-physical relationship

A city's water-based identity, besides being closely intertwined with the landscape, is complementarily characterized by its people's daily relationship to water. There has been a psychological and physical relationship between men and water throughout human history. This can be perceived as both (1) *water nature* via water as a natural landscape element (e.g. river, ocean, lake), and 2) *water culture* via water as a cultural infrastructure (e.g. shower, bathtub, swimming pools). Bathing rituals, which became increasingly facilitated through building infrastructures along with industrial urbanization, reflect on this hybrid *nature-culture* of water infrastructures from an everyday human life perspective. Enhanced by the "material imagination" of "clear and transparent water," Heidenreich, the urban environmental and cultural sociologist, highlights the value of human body experience associated to feelings of refreshing or rejuvenating.[131] Due to this, a close relationship between humans and water is formed. Water as a "symbol of purity," becomes "psychologically and physically tangible."[132]

Bathing and drinking rituals or holy wells illustrate the deeper meaning of water for human wellbeing. Metaphors such as "the fountain of youth," "holy water" or "redeeming oneself"[133] are associated with water-cultural rituals known from early bathing cultures, such as those practiced in Roman bathhouses. Urban water culture after the fall of the Roman Empire and in medieval times experienced a severe setback in Europe. Due to the occurrence of syphilis, urban bathhouses disappeared from the late Middle Ages onwards.[134] Heidenreich refers to the cultural imagination of the "permeable" and "vulnerable" body next to plague epidemics, particularly if bathing in warm water, reflecting the Zeitgeist of the 16th century.[135] Hence, the

[129] Bevilacqua (2010)
[130] Hooimeijer *et al.* (2005)
[131] Heidenreich (2004, p. 254)
[132] Ibid.
[133] Kiby and Kramer (1993, pp. 58–59)
[134] Ibid.
[135] Heidenreich (2004, p. 244)

symbol of water as a *purging element* remains culturally valued, for example, being associated with metaphors such as the *magic of wells* or to the imagination of swimming in wild water.[136] Kiby refers to associated emotions and feelings if "bathing in nature, under the open sky," which became popular in medieval times.[137] He, furthermore, points to the contrast between public bathing in static water versus bathing in "living and flowing" water, fed either by warm springs or "well-tempered rivers."[138]

Cultural fears concerning pestilence were gradually replaced through reknitting the "fabric between men and water,"[139] only from the mid-19th century. The increase of private bathrooms and changing medical devotion from the body fluids towards its more solid parts reflect on a new body hygiene and the new trust in the self-forces of the human body. Heidenreich describes the water-cultural daily lifestyle arising at the beginning of the 19th century as follows: "For the first time cleanliness is at the center of the cultural concepts of body and water. So that humans do not lose their energy, their power, their physical and moral health, from now on they must expose themselves daily to the cleansing water."[140] Warm water treatments were regarded as symbols of an effeminate and artificial aristocratic culture, and the emerging civil society now valued the rising positive virtues of cold and clear water. This cultural and habitual transformation is related to a new way of thinking about water comprising health beliefs of physical, spiritual and mental strengthening, which illustrates the saying "being thrown in at the deep end."[141] Emerging showering and bathing practices generally reflect the new feeling of life experience containing erotic, relaxing or refreshing aspects (e.g. the feeling of rain while showering) in human water culture.[142] Heidenreich describes the new private bathrooms as "technical flow rooms"[143] or "flow spaces."[144] They are "transitional spaces" mediating between the socio-cultural, technical and natural spheres. As fluid (infra-)structures, they dissolve supposed borders between inside-outside, culture-nature, city and landscape, etc.[145] The increase in the number of public swimming pools beside rivers or lakes symbolize new concepts of healthy living as being closely related to sports and outdoor experiences. The philosopher Böhme also stresses the "emotional side of water." He refers to the strong appeal of water to the human soul, which, after being neglected by classical pragmatic science since 1800, has been rediscovered.[146] Similar to Spirn's reflections expressed in the introductory quote,[147] Böhme points out the strength of water to reform the societal relationship to water in general.[148]

[136] Kiby and Kramer (1993, p. 50)
[137] Ibid.
[138] Ibid.
[139] Heidenreich (2004, p. 247)
[140] German language version in: Heidenreich (2004, p. 247) (English translation by C. Champlin and E. Leismer).
[141] Similar to the German saying: "In's kalte Wasser springen." Heidenreich (2004, p. 245)
[142] Heidenreich (2004, pp. 251–266)
[143] Ibid.: p. 209
[144] Ibid.
[145] Ibid.
[146] Böhme (2004, pp. 18–22)
[147] Spirn (1984, p. 142)
[148] Böhme (2004, pp. 18–22)

To summarize, water remained as a symbol of everyday wellbeing throughout urban history from a human psychological and physical perspective. The transforming power and magic of water seems timeless, as reflected in a quote by Ninck in 1921: “It can bewitch and disenchant, and this happens even in the same way: by the leap into the water, swimming in a river or a lake, drinking from a well (...).”[149] Wellness rituals, health spas, drinking cures, and swimming and bathing are various forms of water-wellbeing representing a high diversity of cultural expressions and spiritual beliefs. Hence, facets of water-living, water-farming and water-wellbeing characterize urban aquaculture in its place-based context.

A city’s water history is always intertwined with the greater landscape. The natural landscape history often reflects alterations caused by large-scale infrastructure interventions in space over time. They are commonly accompanied by man-made regulations of water flows and courses in natural watersheds and its ecosystems.

2.1.3 Water and technical infrastructure processes: Hydro-morphological landscape transformation

The histories of Western water cities have a common biography of dehydrating the natural waterscapes from which they have emerged. Kostof describes the genesis of famous global cities by pointing out cross-cultural similarities. Large-scale water interventions influenced the genesis of the city from the first settlements on the swamp lands beside the Euphrates and Tigris rivers ~3500 BC, the urbanization of the Nile delta ~3000 BC, to the first Chinese cities along the Yellow River.[150]

Similarly, Spirn, in her farsighted book *The Granite Garden* published in 1984,[151] traces the natural-cultural landscape history of the city of Boston. She refers to the cross-cultural pattern in the city’s landscape history. The following quote reflects on common urban stories of rise and fall. They are linked to daily-life needs and activities in their interdependency to everyday landscape processes, particularly green production.

> “Despite their differences, all cities have transformed their environments in a similar fashion: certain urban natural features are as characteristic of ancient Babylon and Rome as they are of modern Boston and Chicago. The human activities that modify the natural environment are common to all cities: the need to provide security, shelter, food, water, and the energy to fuel human enterprises; the need to dispose of wastes, to permit movement within the city and into and out of it; and the ever-escalating demand for more space. The ancient cities of Asia and the Mediterranean and the old cities of Europe transformed nature into a characteristically urban environment many centuries ago. The younger cities of North America are equally urban, but the transition from wilderness to city took place more recently over the past three centuries. (…) The natural

[149] German language version in: Ninck (1921, p. 148) (English translation by C. Champlin and E. Leismer).
[150] Kostof (1992, p. 30).
[151] Spirn (1984)

> environments of London, Tokyo, and New York – all large cities with a temperate climate – have as much in common as each has with its own rural outskirts."[152]

Regarding common lessons learned, Spirn stresses the prerequisite role of landscape ecologies as an immanent part of urban nature. Therefore, the art of which and how infrastructural practices are applied relates directly to the art of transforming landscape morphologies and processes. How, when and where food, wood or fiber is grown on land or in water, for instance, defines the state of the landscape ranging from wilderness to urban.

Therefore, technical infrastructures and corresponding practices for providing basic daily-life resources and services of transport, water, food, or energy within human history have formed the *face of the landscape* both locally and globally. This description is used and understood similarly to Kostof's research on "the face of the city."[153]

The genesis and prosperity of famous cities are closely intertwined with technical infrastructure interventions in the greater watershed[154] as the city's (physical) landscape embedding. The way in which the water management was planned greatly influenced the process of landscape change over time. Wild landscapes were cultivated and urbanized through regulating water tables via pumps and canals, and rivers tamed by sluices, weirs and dykes. Drainage technologies and canalization engineering, as prevailing infrastructural interventions, enabled landscape dehydration for the cultivation of arable land. Similarly, morphological landscape transformations induced and catalyzed by water infrastructure interventions can be explored throughout Western cultural history (4.2.7). Pumping technology allowed basic infrastructural services of water supply and disposal. The new water infrastructure technologies thus provided both profits and losses simultaneously in the daily quality of life. Improved hygiene conditions and a blossoming bathing culture along with the growth of cities cultivated urban pleasures, as it influenced the aesthetic and atmospheric qualities in place-specific contexts (4.4). However, as urban infrastructure technologies and practices were exported to other cities, particularly with fast city growth, stress on the landscape water regime showed the drawbacks and the other side of the coin.[155] The loss of natural habitats, such as wetlands, and their provisioning or regulative ecosystem services led to water stress and deteriorating surface water qualities in the further process of infrastructural landscape cultivation and urbanization (3.3).

Hydro-morphological landscape interventions are particularly known regarding famous Dutch water cities, which were predominantly "cities in wetlands."[156] Large-scale infrastructural interventions were necessary in order to build settlements in former swampy riverscapes or drained lakes. These interventions were mostly facilitated by military engineers due to the high level of technology. According to Hooimeijer, this caused a problematic segregation between

[152] Ibid.: pp. 12-13
[153] Kostof (1992, p. 54)
[154] e.g. Bernhardt (2007); Bernhardt (2009); Bernhardt (2011)
[155] Ibid.
[156] Hooimeijer (2005); van de Ven (2005)

civil engineering and urban development in the long run. He points out in his book *Dutch Water Cities*,[157] the kind of water ignorance up to contemporary times, particularly in the context of modern city development. Referring to the landscape architect, Elizabeth Meyer (2005), he stresses the disregard of the urban water system by illustrative figures concerning the reduction of urban water surfaces: "Where in cities up to 1940 the total surface of the city contained 12-15 per cent of water, in post-war city expansions, this percentage was often reduced to less than 5 per cent."[158]

The large-scale and long-term landscape change processes described are profoundly explored in the German natural-cultural landscape history by the cultural historian Blackbourne.[159] He refers to the mutual mindscape of control over nature regarding "the wild to be tamed." Blackbourne tangibly describes the technical Zeitgeist of the landscape domination which arose during the history of infrastructural transformation in Berlin-Brandenburg's Oder rivershed from the 16th century on under the control of the Prussian kings.

Large-scale landscape engineering, predominantly facilitated by the U.S. Army Corps of Engineers, has also been part of North American cities' natural history up to modern times.[160] Boston and New York City are traceable examples. As far as the landscape history of Boston is concerned, Spirn describes the process of how Boston's former wetlands were changed into rural and urban settlements.[161] She illustrates the military-like efforts regarding the landfilling of Boston's Back Bay for purposes of reclamation: "But the most dramatic of these nineteenth-century fill operations, and certainly the largest, was the filling of the Back Bay, the tidal flats at the base of the Boston Commons. Landfill operations started in 1858 and continued for several decades. The Back Bay was filled with a combination of Boston's garbage and sand and gravel from Needham, nine miles away."[162] The speed of urban landscape engineering is illustrated by citing a publication of the Boston Museum of Fine Arts (1969): "Land fill progressed at the rate of almost two house lots per day, a train of thirty-five loaded gravel cars arriving in Back Bay on the average of once an hour, night and day, six days a week, for almost forty."[163]
Concerning the speed of morphological landscape transformation, Spirn states that: "Boston, Massachussetts, has evolved from wilderness over a mere three-and-a-half centuries. In that short span of time, the original natural environment has been transformed almost beyond recognition into a characteristically urban nature."[164]

157 Hooimeijer *et al.* (2005)
158 Hooimeijer (2005, p. 172)
159 Blackbourn (2008)
160 Sanderson (2009)
161 Spirn (1984)
162 Ibid.: p. 18
163 Ibid.: pp. 13-14
164 Ibid.

2.2 Conclusion

The following general insights can be derived ahead of further in-depth case study research on urban aquaculture (→ Chapter 4:) against the background of an overview of exemplary Western cities' waterscape histories from an interwoven water-natural and water-cultural perspective.

- Water as a *cradle of the city* has shaped urban identities and morphologies, which can also be traced in urban names referring to a city's and its citizens' close water relationship.
- Early water-based everyday life practices in the city, such as fishing, shipping or bathing rituals, are recognized as aquacultural practices that cocreated a place-based urban aquaculture with its characteristic facets. Daily use, handling and enjoyment of water constantly formed a psychological-physical water relationship on a human scale.
- Cities' water-based genesis and prosperity were accompanied by large-scale landscape dehydrations induced by technical infrastructure interventions, particularly the draining of the wetlands and watersheds from which the cities emerged.

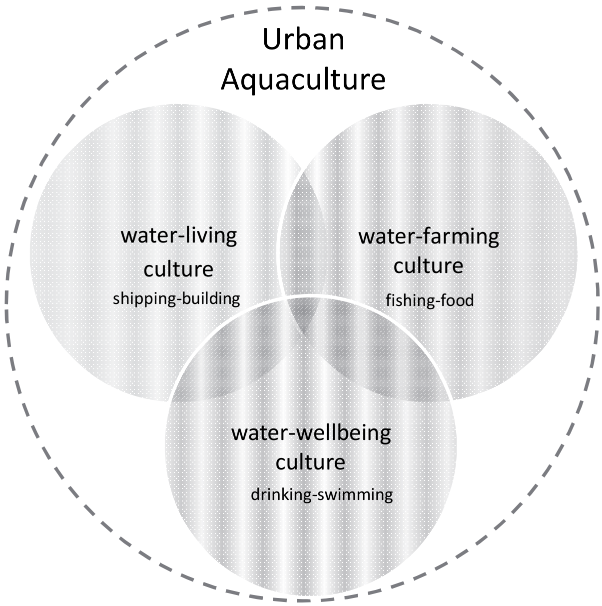

Figure 4: Scheme of characteristic facets of urban aquaculture

By including the *urban water-cultural dimension* an extended water-based image of the city – summarily addressed as *Urban Aquaculture* can be derived. Figure 4 summarizes the characteristics of place-based urban aquaculture explored so far. It highlights the following three facets: (1) water-living culture, referring to water-based transport and building practices, such as shipping and living at the water; (2) water-farming culture, affiliated to water-based food and biomass production; and (3) water-wellbeing culture, concerning everyday human psychological and physical aspects along with the daily use and handling of water as a cultural resource and an element of life. By their natures, the conceptual borders between the three facets are fluid and overlap (e.g. water-farming and water-living culture, since fishing is often linked to shipping).

In order to further ground and complement the urban water research results, the following Chapter 3 explores the natural-cultural process intertwining along water infrastructures. The focus is on landscape ecosystem and watershed processes and on cross-cultural aquacultural farming types mimicking blue and green landscape services.

CHAPTER 3: BLUE-GREEN SERVICES AND AQUACULTURAL BLUE-GREEN INFRASTRUCTURES OF WATER-FARMING

3.1 Introduction

Chapter 3 derives from the hybrid character of everyday water infrastructures. This becomes evident when focusing on daily interactions between human life and ecosystem processes mediated via water as a landscape element and urban infrastructure, which is highlighted by contemporary spatial-cultural and socioecological research.[165]

The first part introduces state-of-the-art landscape ecosystem research, particularly ecohydrological and watershed perspectives.[166] They refer to the role of small water cycles for regenerating ecosystems services, such as stressed by the blue and green water concepts.[167] Facing the status quo and prognoses of place-based climate change focusing on water issues, the transfer of the basic blue-green landscape principles is referred to as water-centric *climate chance* and is strongly water-related. Building-integrated vegetative rainwater strategies[168] are stressed as one promising approach mimicking similar blue-green services. The key benefits of such a decentralized green water management are illustrated based on research applied in the city of Berlin. However, in order to better understand the contemporary sustainable urban water strategies as a natural and cultural blue-green infrastructure challenge, the second part complements by exploring characteristic aquacultural types of water-farming. Facing future city needs of sustainable food and biomass resource provision, they become recognized and newly interpreted as specific multifunctional blue-green infrastructures.

3.2 Natural-cultural waters: hybrid everyday infrastructures between spheres of nature and culture

Cityscapes and their water infrastructures are increasingly perceived as both materialized and fluid structures. Heidenreich describes them as "fluid spaces."[169] The dynamic merging of *cultural* (e.g. technological) and *natural* (e.g. ecosystem) life processes becomes particularly apparent when rethinking daily water infrastructures and their flows along the various scales of urban watersheds: from *micro-watersheds* to *macro-watersheds*.

In general, a watershed is a morphological landscape entity or catchment which is bordered by watershed divides. Shepard describes it as follows: "They are ecosystems composed of different land patches that are drained by a network of streams and comprise our landscape."[170]

[165] Heidenreich and Glasauer (1997); Ipsen *et al.* (1998); Ipsen *et al.* (1998); Ipsen (1998); Guy *et al.* (2001); Heidenreich (2004); Kluge (2008); Moss *et al.* (2008); Monstadt and Naumann (2004); Wissen (2009, p. 146);

[166] Odum (1983); Caduto (1990); Ripl (1992); Ripl (1995); Savenije (1995); Niemczynowicz (1999); GWP and Falkenmark (2003); Falkenmark 2005 #410}; Falkenmark and Rockström (2006); Kravčik *et al.* (2007)

[167] Ripl (1992); Ripl (1995); Kravčik *et al.* (2007); GWP and Falkenmark (2003); Falkenmark and Rockström (2005); Falkenmark and Rockström (2006)

[168] SENSTADT and TUB (2010b); SENSTADT (2011)

[169] Heidenreich (2004)

[170] Shepard (1977)

Regarding rivers, a rivershed is the catchment area where all precipitation and related run-offs feed the same waterway system (Figure 5).

The use of the term micro-watershed is used similary to the term "microlandscape"[171] – introduced in the context of the spatial-dynamic perception of landscapes. Thus, it points to the micro perspective of an urban watershed, which might be a private bathroom or building-related pipe systems. A micro-watershed (e.g. at building-scale) covers spatial scales and life spheres of a building and related open spaces. The macro-watershed (e.g. at urban scale) covers larger areas, such as the catchment area of a settlement, water production and treatment facilities or drinking-water protection zones.

Figure 5: Watershed drainage basin including green *and* blue *water flows*

The fluid interplay of natural and cultural processes in technical infrastructures becomes particularly obvious when reflecting on urban waterflows through rivers or pipes. Landscape and infrastructure processes and flows permanently and dynamically merge with each other on a daily basis, particularly with regard to urban watersheds (e.g. river flows with water pipes). Monstadt refers to current large-scale technical infrastructures as creating "the central interface between nature and modern societies,"[172] whereby becoming transparent as hybrid structures.[173] The borders between the putatively opposed spheres of nature and culture – a perception dominant in hard sciences and technical engineering[174] – become permeable and dissolve (Figure 6).[175] Therefore, water infrastructures appear as place-based mediators, mediating the confluence between everyday *water nature* (e.g. natural ecosystems) and everyday *water culture* (e.g. technical infrastructures) at various watershed scales in both public and private spheres.

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[171] Franzen and Krebs (2005); Franzen (2006)
[172] Monstadt and Naumann (2004, p. 17)
[173] Monstadt and Naumann (2004)
[174] Bartels (2008)
[175] Latour (2007); Haarmann and Lemke (2008); Heidenreich (2004); Kluge (2008)

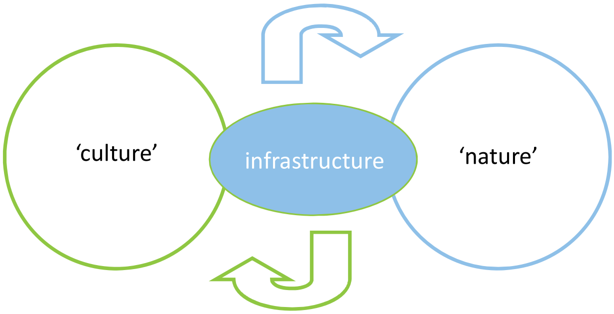

Figure 6: Fluid perception of urban water infrastructures mediating everyday natural and cultural life and landscape spheres

In sum, water infrastructures interact and interconnect with the landscape ecosystem services on which they actually depend.[176] To reflect and value the "landscape as infrastructure"[177] is revived in contemporary discourses on landscape urbanism. Furthermore, it links to actual debates on the issue of *green infrastructures*,[178] highlighting the natural-cultural intertwining of daily flows of goods and services (3.2). This becomes particularly transparent for networked infrastructures, such as water or energy. Brown, the architect and green designer, refers to technical infrastructures for daily urban resource provision as "transformed nature in essence"[179] and, consequently, claims to create "infrastructural ecologies."[180] Facing the post-fossil fuel city of the future, she envisions sustainable urban infrastructures as integrate (rather than separate) components of natural processes[181] becoming supportive to landscape ecosystem services.

3.3 Blue-green landscape services for everyday life-support facing Berlin's Spree watershed

Blue-green landscape services are performed and sustained by ecosystems; examples are natural water purification via wetlands and forests, or local temperature moderation via plant/water-based evaporation. Everyday water-based infrastructural services depend on common life-supporting landscape ecosystem services. The notion of common life-support, therefore, includes humans and other living beings. John T. Lyle introduced the notion of a "working landscape."[182] This interpretation stresses the key-role of the physical landscape and its ecosystems as a basic platform and provider of life-supporting urban ecosystem services.

[176] Brüll and Bürgow (2000); Brüll *et al.* (2001)
[177] e.g. Alfsen-Norodom and Walsh (2004); Hooimeijer (2005); Corner (2006); Gill *et al.* (2007); Shannon and Meulder (2008); Stokman (2008); Sanderson (2009)
[178] e.g. Gill *et al.* (2007); Camarsa *et al.* (2010); EU (2010b); CEP (2011)
[179] Brown (2010a)
[180] Ibid.
[181] Brown (2010b)
[182] Lyle (1993); Lyle (1994, p. 287)

The regeneration of freshwater, food, biomass, biodiversity, or natural cooling, for example, is essential to sustain human and city life.[183]

From a natural perspective, the primarily fossil fuel-driven technologies lack the active support of the physical landscape as a basic platform and provider of common life-supporting ecosystem services.[184] Whereas from a cultural perspective, the segregation of resource production, consumption and reproduction processes through fossil fuel-based transport lead to a lack of perception of the natural-cultural interdependency. Current processes of postindustrial transformation, including regenerative production and technologies, therefore, require an integrated understanding of how the *fluid interplay* between city, infrastructure and landscape ecosytem life works through daily metabolic processes. By focusing on sustainable and integrated water and resource management,[185] from urban micro-watershed to macro-watershed scale, an integrated understanding of how basic ecosystem processes work is required.

3.3.1 Small water cycles

The *small water cycle* is the conceptualized notion of various interwoven water cycling processes driven by terrestrial landscape ecosystems, such as rainforests, wetlands, lakes, or rivers. The small water cycle is part of and complements the *big water cycle*, which addresses global water cycling processes, such as from land to sea. It is called *small* scale-wise, as watersheds are smaller compared to the global or planetary scale. Unfortunately, the attribute *small* is misleading.[186] This is most evident when looking at figures of annual rainfall over the land stating an average of 720 mm, whereas the average input from the sea is 310 mm.[187] It shows that more than double the amount of fresh (rain)water amount is regenerated by ecosystems on land as the largest contributors to the global water cycle.

The small water cycle is a particular subject of sustainable watershed management referring to basic research in limnology.[188] Falkenmark and Rockström stress the new significance and wider relevance of the term “ecohydrology”[189] by stating: “The term 'ecohydrology' can no longer refer only to aquatic systems, since terrestrial ecosystems are equally water-dependent.” They further state:

“Consequently, what is now needed is a wider knowledge base that makes it possible to take an ecological approach to land and water resources. A basis was laid by the UNESCO book ‘Comparative Hydrology: An Ecological Approach to Land and Water Resources’ (Falkenmark and Chapman, 1989), which highlighted hydrological differences between different

[183] Brüll *et al.* (2001); Hermann *et al.* (2011)

[184] Brüll *et al.* (2001)

[185] GWP (eds.) and Rees (2002)

[186] e.g. Kravčik *et al.* (2007, p. 17)

[187] Ibid.

[188] Odum (1983); Caduto (1990); Ripl (1992); Ripl (1995); Savenije (1995)

[189] Falkenmark and Rockström (2005, p. xxi)

hydroclimates and between different landscape elements, in particular sloping lands and flatlands."[190]

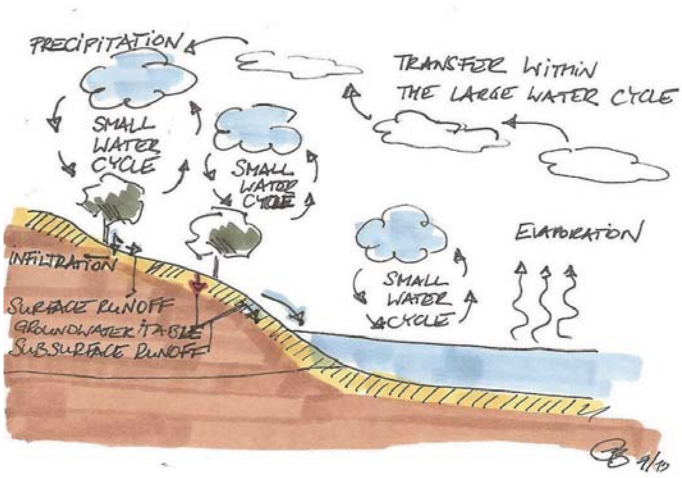

Figure 7: Small water cycles by green ecosystems minimize horizontal run-offs in favor of vertical loops of evaporation-condensation serving temperature moderation and freshwater provision

Small water cycles are sustained by photosynthetic processes, particularly by living plants and their water-storing tissues as tangibly known from highly evaporative and water-retentive *spongy* landscape ecosystems. Wetlands, deciduous forests and rainforests are major contributors of terrestrial evapotranspiration, and thus, precipitation (Figure 7). According to Kravĉik et al. (2007) up to two-thirds of water is returned to the land as a "repeated creation of precipitation over land."[191] Niemczynowicz (1999) particularly stresses rainwater as "a driving force of all hydrological landscape processes."[192] This is linked to findings, which Savenije (1995) made in the Sahel to prevent desertification and the occurrence of droughts, stating that: "The most important measure in this respect, is the feedback of moisture to the atmosphere through evaporation from vegetation."[193] Hydrological disturbances that occur within devastated landscapes are mainly caused by deforestation,[194] hence, land-use changes that eliminate green water performance.

Although there are contextual climatic and landscape differences, the ecohydrological research results commonly claim rainfall or the surface water cycle as the basic water loop. Falkenmark and Rockström refer to water as "the bloodstream of the biosphere."[195] They stress the relevance of atmospheric water (vapor, moisture) in the watersheds as follows:

[190] Ibid.
[191] Kravčik *et al.* (2007, p. 17)
[192] Niemczynowicz (1999, p. 2)
[193] Savenije (1995)
[194] e.g. Savenije (1995, p. 517)
[195] Falkenmark and Rockström (2005, p. 3)

> "It is, however, not widely known that about 60 per cent of rainfall stems from vapour produced from the land surface. This means that the hydrological "bloodstream" that supports the biosphere and the anthroposphere is, to a large extent, generated by the biosphere itself. This leads to the important conclusion that natural and manmade changes in the landscape can have significant impacts on the sustainability and reliability of rainfall."[196]

3.3.2 Blue water – Green water

Falkenmark and Rockström help to better differentiate small water cycle processes in the landscape watersheds through their qualitative conceptualization, particularly of the various interacting water-vegetative ecosystem processes. Whereby, all plant-based and soil-based water storage and evaporation are called *green water*, all recharge feeding aquifers and rivers available for human use are called *blue water*.[197] Vertical (green) water flows (e.g. via evaporation and precipitation) have an influential role in place-based freshwater regeneration. Horizontal *blue surface-water run-offs* (e.g. from land to open water bodies) are reduced due to the *green water loops (*Figure 8*).* Quantitatively, the authors refer to two-thirds of rainwater transformed into green water, whereas only one-third (or 40,000 km³/year) is blue water running towards the sea.[198]

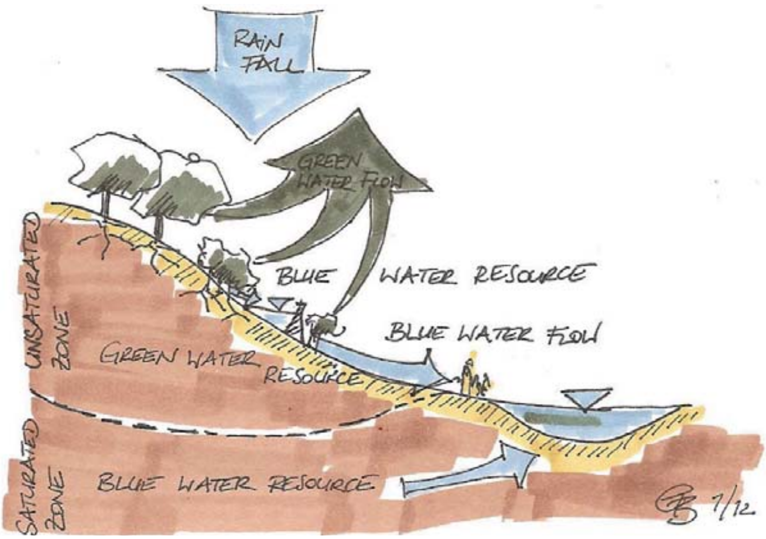

Figure 8: Green (vegetative) and blue (surface) water flows in landscape watersheds

[196] Ibid.: p. 11
[197] GWP and Falkenmark (2003); Falkenmark and Rockström (2005); Falkenmark and Rockström (2006)
[198] Falkenmark and Rockström (2005, p. xxii)

BIOLOGICAL – CHEMICAL – PHYSICAL WATER FEATURES

From a thermodynamical ecosystem perspective, Ripl stresses the following three "processor features" of water:[199] (1) biological capability (photosynthesis/respiration), (2) chemical capability (solution/dissolution), and (3) physical capability (evaporation/condensation), through which the solar energy pulse is gradually transformed and dissipated.[200] Consequently, water, interrelated with the spatial-temporal pattern of the pulsed solar energy input, induces life-creating and life-sustaining landscape conditions on Earth.[201] Without water, life conditions in the various terrestrial watersheds would be literally *desert-like*.

This appears very basic, and, according to its socio-political relevance, is rather innovative and fundamental. Falkenmark and Rockström highlight the fundamental relationship, which has been neglected for a long time, between water and ecosystem life-support. They remark that the issue became part of the global agenda only with the Second World Water Forum in 2000. The prominent Agenda 21 and outcome of the Rio Conference in 1992, "contains a long chapter on conventional water issues, but disregards the fundamental role of water in sustaining all ecological life forms on Earth."[202] Furthermore, they stress the "shift in thinking"[203] by stating: "To be successful, water management will not only have to incorporate straightforward technological efforts but must also respond to the problems and benefits caused by the evident links between land use and water, between upstream and downstream regions, and between water and ecosystems."[204]

Facing current discussions regarding water-sensitive and climate-responsive cityscape development, the key role of life-supporting small water cycles has been either underexposed or neglected so far, as prominent climate change reports on both a global[205] and regional[206] scale reflect. Concerning the Berlin's watershed situation, landscape-based green and blue water services have not yet been recognized as having priority nature in place-based water and climate change analyses of the status quo and prognoses.

The following two subchapters, therefore, stress the importance of local-regional perspectives of water-centric *climate changes and chances* in their interdependency. They focus on the key role of water as having a highly place-based character and quality. Two spatial perspectives are in the focus: (1) the macro-watershed perspective (landscape scale), taking into account the contemporary status quo, prognoses and trends of water and climate change in Berlin-Brandenburg's Spree rivershed, and (2) the micro-watershed perspective (building-scale), taking into account building-integrated rainwater pilot project illustrations stressing (vegetative) *green* water management to improve natural cooling and water purification services in Berlin.

[199] Ripl (1992); Ripl (1995)
[200] Ibid.
[201] Falkenmark and Rockström (2005, p. 3)
[202] Falkenmark and Rockström (2005, p. xix)
[203] Ibid.
[204] Ibid.
[205] Stern and Cabinet Office - HM Treasury (2006); Bates and Kundzewicz (2008)
[206] BWB (eds.) *et al.* (2008); SENGUV (2009a); Lotze-Campen *et al.* (2009)

3.3.3 Macro-watershed perspective: man-made water-centric *climate changes* at a landscape scale

The quality and availability of water are mainly place-based products of ecosystems performing blue and green water processes in watersheds. Additionally, they closely depend on the art of managing urban, industrial or agricultural watersheds and their flows.[207] Consequently, quality and availability of water refer to human value systems,[208] such as those reflected in regenerative design principles,[209] within a sustainable landscape quality management aiming to regenerate physical and psychological landscape qualities (fertile soil, clear water, balanced temperatures, biodiversity, place-based landscape patterns, and aesthetics, etc.).[210]

Currently discussed global problems of water and climate change, therefore, depend greatly on man-made influences in the greater watershed,[211] for example, various infrastructural interventions, such as groundwater withdrawals, rainwater management, dehydration, deforestation, and sealing of surfaces (2.1.3). The disregard of landscape ecosystem services, for example, in Berlin-Brandenburg, causes about 15.4 million m³ permanent loss of peat soil annually.[212] Similarly, influential changes to the small water cycle, therefore, should, firstly, be reflected on and tackled as a man-made and watershed-based challenge. They are most often land-use related rather than a result of global climate or global hydrological change. These insights, furthermore, refer to contemporary historic research results critically reflecting the *sanitary city concept* which emerged in the 19th century. With regard to the Berlin-Brandenburg region, the rising water consumption along the expansion of the water supply network in Berlin (4.3.2) led to the over-exploitation of water resources from the mid-20th century onward.[213] Therefore, historic figures state that: "In 1921 the water flow of the Spree fell to a critical rate of five to six cubic metres per second, far below the officially defined point of environmental damage (*Schadensgrenze*) of fifteen cubic metres per second."[214]

LOCAL-REGIONAL WATER AND CLIMATE CHANGE CHALLENGES

Recent studies on the Berlin-Brandenburg region predict dramatic climate change,[215] which is more precisely called *water(shed) change*. Although the northeastern part of Germany belongs to one of Europe's driest regions in a moderate climate context,[216] the greater rivershed of the Elbe (Figure 9), at only 680 m³, has the second lowest water availability per person in Europe.[217]

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207 Niemczynowicz (1999)
208 e.g. Farber *et al.* (2002); Hermann *et al.* (2011)
209 Lyle (1994)
210 Brüll and Bürgow (2000); Brüll *et al.* (2001); Brüll (2009); Brüll (2010)
211 Niemczynowicz (1999); Ripl and Scheer (2007)
212 Lotze-Campen *et al.* (2009, p. 34)
213 Bernhardt (2011, p. 163)
214 In: Ibid.: p. 163
215 e.g. BWB (eds.) *et al.* (2008); SENGUV (2009a); Lotze-Campen *et al.* (2009); LAWA (2010)
216 Knierim *et al.* (2009)
217 Lotze-Campen *et al.* (2009, p. 30)

Water forecasts for Berlin, with a ~3.2 million population, anticipate major decreases of urban flows to below minimum levels (8 m³/s) in the main tributary river Spree for 2035 to meet the current water demands of the city.[218] Currently, Berlin obtains about 70% of its drinking-water from the river basins of the Spree and Havel, using induced bank filtration as the place-based mode of drinking-water production.[219] The supplemental purchase of water from Poland and the Czech Republic is under political negotiation at a supraregional/supranational level.[220] At a local political level, options to enhance reclaimed water from sewage treatment plants are under study.[221]

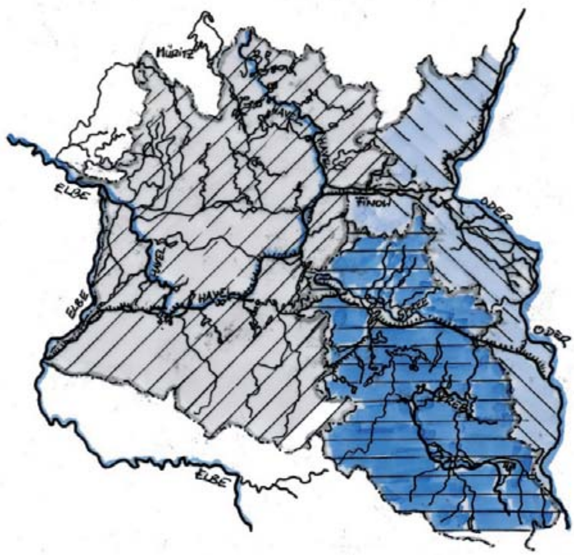

Figure 9: Berlin-Brandenburg's Spree and Havel watershed between the rivers Oder and Elbe

The Spree rivershed crosses the federal states of Saxony (well-head) and Brandenburg (mouth) with a total area of 10,100 km², whereby 7,155 km^2 are in Brandenburg.[222] As referred to in relevant local and regional water and climate change reports,[223] the expected decreases of tributaries and run-offs are mainly due to the closure of opencast mining in the state of Brandenburg's Lausitz region. They are associated with large-scale disturbances of the landscape's water regime upstream of Berlin's eastern river Spree towards its well-head in the Lausitz area. The broader Berlin rivershed, including *Spreewald*, the Lusatian alluvial forest, has been majorly impacted by surface mining from the late-20th century[224] until today.

[218] BMBF (2005, p. 22)
[219] Massmann *et al.* (2007, p. 41)
[220] BMBF (2005); Wechsung *et al.* (2005)
[221] BWB (eds.) *et al.* (2008); Lotze-Campen *et al.* (2009, pp. 34–36)
[222] MUGV (2011)
[223] BMBF (2005); Lotze-Campen *et al.* (2009); Grünewald (2010); Lischeid (2010); LAWA (2010)
[224] BMBF (2005, p. 21)

The three prevailing place-based forms of large-scale infrastructural interventions degenerating blue-green landscape services are:

- Groundwater withdrawals, which create large-scale draw-down funnels in the soil,[225] due to enforced soil mineralization and acidification processes.
- The redirection of rivers to refill mining holes, which causes severe hydrological disturbances in adjacent watershed areas and leads to the desiccation of forests and natural wetlands, particularly in the Spreewald area.[226]
- The discoloration and cloudiness of river waters due to iron hydroxide and sulfur washed out due to the naturally increasing groundwater refilling the lignite mines. It harms aquatic life (e.g. gills of fish become stuck together) and causes surface water acidification.[227]

The degeneration of blue-green landscape services becomes tangible in Berlin-Brandenburg's Spree rivershed. It particularly addresses the phenomenon of landscape dehydration, respectively man-made desertification, through opencast mining. The striking number of more than 70,000 ha/700 km² of post-mining landscape reflects a large-scale infrastructural intervention. It accounts for almost 10% of the total watershed area of the river Spree.[228] In addition to the closure of the last mines in upper Lusatia from 2030, dramatic changes in water quantity are predicted due to the anticipated water-flows dropping to below minimum. Some sources refer to inflows of 5 m³/s, which would bring the river literally to a standstill.[229] Regarding Berlin's surface water quality as the main condition of drinking-water production, a report by Berlin's water works refers to the danger of water acidification occurring particularly due to higher sulfur concentrations in the Spree.[230]

CRITICAL REVIEW OF LOCAL-REGIONAL WATER AND CLIMATE CHANGE STUDIES

When critically reviewing the rationales behind the prominent local-regional studies mentioned, the city's current water supply challenges are mainly argued with global climate change scenarios and global hydrological perspective in mind.[231] The latest *Water Supply Report 2040*[232] by Berlin's water utility (Berliner Wasserbetriebe), in compliance with prominent global climate change scenarios, neglects the influential role of the small water cycle. The *PIK-Report*,[233] released by the Berlin Senate, also solely considers the big water cycle from land to sea as the major cause of water stress. Regarding water prognoses within a global climate change scenario for 2050, it primarily stresses the decrease of river run-offs due to increased

[225] Grünewald (2010, p. 25); Lischeid (2010, pp. 39–41)
[226] BMBF (2005); Wechsung *et al.* (2005); Lotze-Campen *et al.* (2009); Lischeid (2010); Schuster (2011)
[227] Schuster (2011); http://www.klare-spree.de/ (2012-09-03)
[228] Schuster (2011)
[229] BMBF (2005, p. 22)
[230] BWB (eds.) *et al.* (2008, p. 61)
[231] e.g. SENGUV (2009a, pp. 14–15); Grünewald (2010)
[232] BWB (eds.) *et al.* (2008)
[233] Lotze-Campen *et al.* (2009)

evaporation.[234] The *dilemma* of corresponding hydrological studies, arguing from a global water cycle perspective, is that landbased evaporation counts as *loss*[235] in local-regional water balance calculations. The disregard of small water cycle-related blue-green services for re-creating working landscapes, which reflects, for example, the notion of a *rain-forest*, in its final consequence leads to *re-active* and *degenerative* watershed strategies. The political negotiations addressed earlier regarding the additional supranational purchase of water are an example of this.

However, place-based strategies to improve surface water quality towards bathing water quality,[236] have been demanded in recent years.[237] This objective harmonizes with the *European Water Framework Directive*[238]. A good ecological water quality is multi-beneficial to both economic and public health, since healthy water after bank filtration can be delivered to the customers.[239] In addition to quality, a seasonally balanced and sufficient water supply is crucial for shipping, fishing, industrial cooling purposes (e.g. energy infrastructures). The local production, particularly of healthy food and raw materials through agriculture, forestry, aquaculture, or fisheries, relies heavily on hydrologically balanced watersheds, in other words, working landscapes and their blue-green services.

To perform and sustain city life based on regenerative processes requires a landscape quality management, respectively watershed quality management, that includes urban watersheds.[240] Therefore, the main intention of the next subchapter is to illustrate the key-benefits of urban *watershed action* to be interpreted as water and climate *chance* in global and local contexts.

3.3.4 Micro-watershed perspective: Man-made water-centric *climate chances* at building scale

The local-regional climate and water prognoses forecasted for the Berlin and Brandenburg region have been rather forestalled in contemporary city life and are not yet a tangible reality in everyday contexts. Nevertheless, the latest urban development concepts stress the need to promote green infrastructures combined with decentralized water management.[241] The Berlin Senate Department for Urban Development published new guidelines for rainwater management in 2010, stressing decentralized and *green* water approaches at building scale.[242] They mutualize with the increasing formal-political recognition of the role of green infrastructures at an EU policy level, such as those addressed by the Greening EU Cities report (1.1).

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[234] Lotze-Campen *et al.* (2009, p. 30)
[235] e.g. Lischeid (2010, p. 41)
[236] EU (2006)
[237] SENGUV (2009a, pp. 14–15)
[238] EU (2000); SENGUV (2009b)
[239] BWB (eds.) *et al.* (2008)
[240] Brüll and Bürgow (2000); Brüll *et al.* (2001); Brüll (2009); Brüll (2010)
[241] SENSTADT (2011); TU Berlin (2011)
[242] SENSTADT and TUB (2010b)

If technical (water) infrastructures are respected as major drivers of spatial transformation,[243] the building-integrated redesign and management of water flows is a promising starting point for an anticipated reversal. Berlin's recent climate-responsive urban development plan (*STEP Klima*)[244] elaborated on the lead of the TU Department for Landscape Planning and Landscape Development, which also stresses green (vegetative) and mostly low-tech measures, such as the greening of buildings or vegetative storm-water management, in building-related open spaces as climate-responsive urban strategies.[245]
It, thus, refers to the city's long-term experiences of piloting building-integrated water strategies.[246] They highlight water-sensitive urban design measures and recognize the current lack of small water cycles, particularly green water performance in the city, as one of the main causes of *urban heat islands*. Green rainwater strategies are proposed, backed by place-based water balance data. They are argued as preferential to non-vegetative and solely technical infiltrative rainwater systems (e.g. vegetated open swales enhancing rainwater evaporation vs. technical swale-pipe infiltration, trough-trench or percolation systems enhancing fast rainwater infiltration). The benefits of the green rainwater management with regard to natural urban cooling and the buildings' energy consumption has been specifically investigated for green roofs and facades within the existing neighborhoods of Berlin.[247] Quantitative data of green water performance gained through urban hydrological measurements, particularly evaporation, agree with the results of ecohydrological landscape research.

KEY BENEFITS OF GREEN WATER MANAGEMENT

The key benefits of vegetative water management as a blue-green infrastructural design approach are summarized in the following, as they are extensively described in the guidelines. Based on the Berlin data, they illustrate potential man-made water and climate *chances* of promoting blue-green services in the city.

- *Green water management reproduces local freshwater sources, while balancing the pattern of local precipitation, and thus, preventing heavy rainfall events.* They are literally *rainwater-making systems* through enhancing local precipitation via vegetative evaporation. Based on Schmidt's lysimeter measurements, green roofs with 5-12 cm of growing media can evaporate 65-75% of the annual precipitation.[248] This urban moisture recycling potential mutualizes with landscape hydrological investigations described earlier and associated figures stating that two-thirds of terrestrial ecosystem-based evaporation is returned via rain onto the land.
- *Green water management supports soil nutrient conservation vs. soil nutrient mineralization.* According to Schmidt, the non-vegetative rainwater technologies

[243] e.g. Bernhardt (2005); Bernhardt (2011)
[244] TU Berlin (2011)
[245] Ibid.
[246] SENSTADT (eds.) *et al.* (1995); SENSTADT (2002); SENSTADT and TUB (2010a); SENSTADT and TUB (2010b); SENSTADT (2011)
[247] Ibid.: pp. 12-17
[248] Ibid.: pp. 12-13

favored so far provoke about 40-50 times more infiltration in one square meter when compared to natural groundwater recharge.[249] Hydrological figures tracing natural water and climate conditions in eastern Germany, thereby, represent only 10 to 20% of natural groundwater recharge and run-off. Whereas 80 to 90% of annual precipitation is looped via evaporation.[250] The fast technical groundwater recharge through decentralized storm-water management enforces soil mineralization due to the constant oxygen entry.

- *Green water management provides urban cooling.* The greening of buildings, integration of open water bodies and similar urban design measures reduce the surface temperature of buildings and other sealed surfaces. Temperature measurements show that non-green surfaces convert ~95% of the radiation balance into sensitive heat (tangible as extreme heat). Whereas already extensive forms of roof greening can reduce the proportion by 70% due to solar energy uptake in the process of evaporation.[251] The small water cycle in the form of vapor produces short-wave latent heat. The gaseous water thereby prevents the creation of long-wave sensitive heat, which is critical with regard to global warming and moderate living temperatures.[252]

In the light of these insights, the proactive and regenerative support of blue-green services, therefore, appears as one of the key measures. Understanding current post-industrial transformation processes as a natural and cultural challenge, the final subchapter, therefore, reimagines aquacultural typologies as specific blue-green infrastructures for everyday life support from the cross-cultural past to the present. It profiles characteristic types and exemplarily illustrates blue-green services, while highlighting their multiple benefits in rural and metropolitan contexts. The focus is on food and resource productive aspects.

3.4 Cross-cultural aquacultural farming types and multiple blue-green services

Aquacultural farming types and their blue-green service potential for everyday life-support are often overlooked in contemporary Western city contexts, despite their global heritage in place-based contexts. However, traditional forms and practices are emerging *in a new look* through post-industrial transformation processes. Trends of “self-made city”[253] development, such as those linked to urban farming, urban river culture and other citizen-based and entrepreneurial bottom-up projects, particularly provoke the reimagination of aquacultural practices and technologies (Chapter 4:; Chapter 5:).

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[249] Schmidt (2010, p. 104)
[250] Ibid.
[251] SENSTADT and TUB (2010b, pp. 16–19)
[252] Ibid.
[253] Ferguson (2006)

Water-farming and everyday resource management, for instance, have been practiced over many centuries. Place-based adaptations can be found globally in addition to countries in Asia, such as India, which typify such methods (Figure 10). Traditional low-tech applications range from the Japanese pearl oyster culture, the Egyptian Pharaohs' tilapia fish pools and the European castle moat aquaculture to the French oyster ropes. The United States "Farm pond program,"[254] which was launched by President Roosevelt in the 1930s to increase farmers' incomes,[255] is another example reflecting the younger aquacultural history. Contemporary more high-tech types of water-farming in a metropolitan context encompass aquaponic greenhouses for water-farming, floating gardens for surface water remediation and revitalized periurban fishponds for landscape water balancing (4.5).

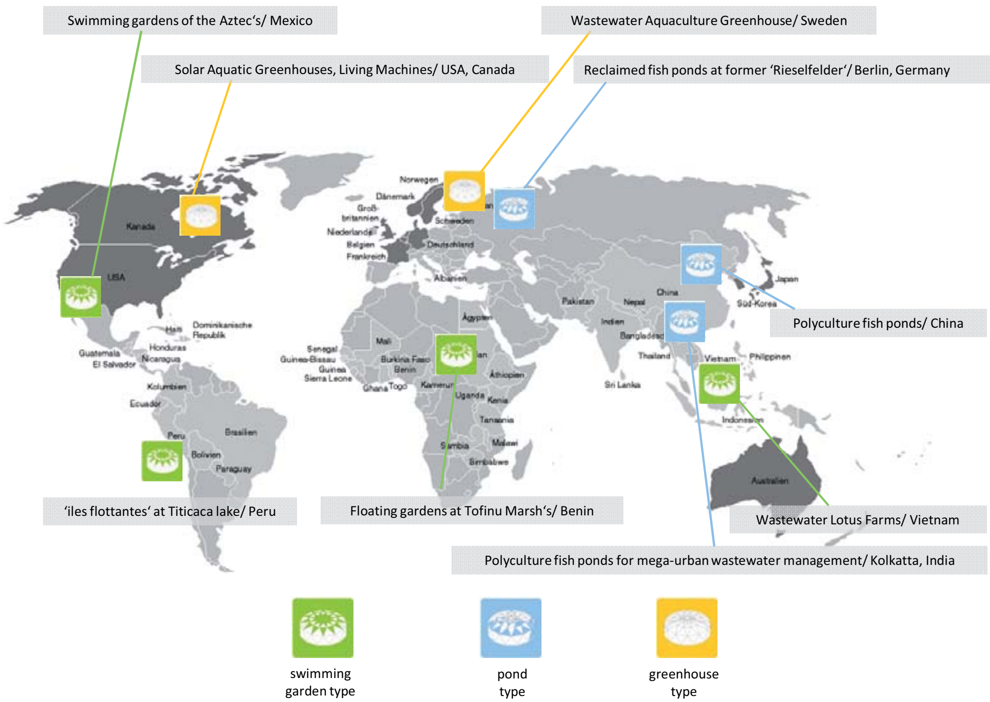

Figure 10: Examples of aquacultural farming types of low-tech/high-tech character from the global past to the present

The following subchapter portrays cross-cultural water-farming types – from swimming gardens and ponds to types of water-farm greenhouses – in past and present contexts. The variety and flexibility from low-tech to high-tech applications are of particular interest when illustrating the multiple blue-green service potentials of natural and cultural life-support.

[254] McVey (1993)
[255] Ibid.

3.4.1 Types of swimming gardens

Swimming gardens are found in almost all cultures. Their roots lie a long way back in human daily life and landscape history. Prominent examples are the swimming gardens of the Aztecs which can be traced in Mexico City's natural-cultural history (Figure 11).

AMERICA

The Aztecs developed a water-sensitive lake and resource management on the island of Xochimilco – *place of growing flowers* in the Nahuati language – in the middle of Lake Texcoco. It included the separation of brackish water from freshwater and crop cultivation on floating rafts, called *chinampas*, made from reeds. As the Spanish conquerors were not aware of these traditional practices which originally embraced five former lakes, they dried out the Mexican Basin at the beginning of the 17th century. Today, Mexico City has a population of 20 million people.[256]

Another example are the floating islands called *iles flottantes*, which were invented by the extinct Uros people at Lake Titicaca, in Peru. These floating structures were flexible so that they could be detached in case of an attack and, therefore, represent ancient forms of mobile water living. Today, they are maintained by their descendants.[257] Layers of *totora* reed (*Schoenoplectus californicus ssp. tatora*) are applied in alternate directions. The reed material is still an important economic resource today, and is used, for example, as a food source, for boat building and the construction of huts.[258]

Figure 11 Left: Chinampas, Mexico-City. Right: Floating gardens at Inle Lake, Myanmar

ASIA

South Asian cultures are also famous for their water-sensitive modes of living and production. Urban aquacultural roots, such as those known from Vietnam, include wastewater-based lotus

[256] Álvarez *et al.* (2008)
[257] Orlove (2002)
[258] Ibid.

floating farm traditions.[259] Similar to indigenous American examples, Asian indigenous water-cultural traditions embrace water-centric belief and value systems. Shannon stresses that man had “to work with nature,” and the first aim was “to harness its powers of survival.”[260] This included, for example, adaptive skills to work with natural patterns, such as monsoons and flood waters: “Low-tech means and rational logics led to the efficient use of water of seasonal watercourses, storage of monsoon rains for use in dry seasons and building methods which adapted to flood waters. Modes of production worked with the dynamics of erosion and sedimentation and inextricable links between irrigation and settlement are evident throughout the region.”[261]

In Burma, Myanmar today, the indigenous Intha people – meaning *the sons of the lake* – developed individual “lake fields” when they settled on Lake Inle right in the middle of the country.[262] Installed in the 18th century, they are still in use today. Thereby, water hyacinths (*Eichhornia crassipes*), sludge and grass bundles are used to create swimming plant beds. They are anchored to the lake bottom by bamboo poles.[263] Since the lake is rather shallow (3-4 m) and due to the warm water temperature, the mix of plants and sludge convert rather quickly into fertile humus (compared to land conditions). Therefore, it allows the highly productive farming of spices and vegetables, such as cabbage, aubergine and beans, as well as the horticultural gardening of flowers. Nowadays, the Intha people belong to the wealthy class in the poor country of Myanmar.[264] Nevertheless, problems occur because of the clearings cut out of the surrounding forests. They cause soil erosion and nutrients spills into the lake while causing fast siltation and eutrophication. This is partly halted by additional and regular harvesting, particularly of the fast growing water hyacinths which are used as biomass over a wide area.[265] Similarly, traditional water-based farming modes for crop cultivation in Southern Bangladesh have been reinvented to secure critical food and income. Cultivated on beds of the same type of water hyacinths, food can be grown above floodwater to protect it from increasingly intense and frequent flood risks (Figure 11).

AFRICA

Floating farm traditions are also still alive in the West African country of Benin. The Tofinu people from Lac Nokoué, a ~150 km^2 large lake lagoon close to Benin’s capital Cotonou, are called “water people.”[266] They have been literally living *in the swamps* since the 17th century, but today, many health and socioeconomic problems occur due to the cutting of clearings and incoming saltwater causing deterioration of water quality. Nevertheless, the Tofinu people are

[259] Costa-Pierce *et al.* (2005, pp. 84–93)
[260] Shannon (2008, p. 49)
[261] Shannon (2008, p. 49)
[262] Altmann (1995)
[263] Ibid.: p. 126
[264] Ibid.: pp. 127-128
[265] Ibid.: pp. 132-134
[266] Bauer (1991)

perfectly adapted to a water-sensitive *amphibian lifestyle*. The lake, encompassing 45,000 people in 15,000 ha, is more densely populated than any other area onshore.[267]

CONTEMPORARY WESTERN CITIES IN MODERATE AND NORDIC CLIMATES

In Western cityscapes of moderate or Nordic climate pattern today, swimming gardens are not primarily implemented for economic reasons, but for symbolic ones – becoming meaningful blue-green infrastructures in contemporary cities. The artist project DAS NUMEN H2O,[268] as one of the awarded and funded projects of the 2011 Berlin festival *Über Lebenskunst*,[269] aimed to turn Berlin's Spree river water into drinking water. The final test-plant was installed on the rooftop of the Haus der Kulturen der Welt (House of World Cultures) in Berlin. It consisted of modular treatment technologies, including a set of biological and technical modules comprising mussel, mushroom, plant, and micro-membrane filters (Figure 12).

Figure 12: DAS NUMEN H2O – Experimental river water to drinking-water *installation on the rooftop of the Berlin Haus der Kulturen der Welt (House of World Cultures)*

The installation, as a form of creative expression and adaptation, used only solar-driven ecological and mechanical self-cleansing processes while reflecting the appreciation of "biological phenomena" as "an equitable co-author."[270]

The experiment was realized as a transdisciplinary collaboration between the artists and engineers, water experts and landscape designers while bridging art, science and technology in everyday urban space.[271] The author was invited to contribute to the *urban river experiment* and integrate explorative research on aquacultural small-scale interventions in public space. A swimming plant filter "Spreewaschgarten" was introduced as a *green* purifcation step to improve surface water quality.[272] The intention of this small-scale intervention was to raise awareness and sensitivity to urban water qualites by tangible discussing it in public spaces (6.2.4).

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[267] Ibid.: p. 124

[268] http://www.dasnumen.com/H2O.htm (2011-09-03)

[269] http://www.ueber-lebenskunst.org (2011-09-03)

[270] http://www.dasnumen.com/H2O.htm (2011-09-03)

[271] http://www.traila.org (2011-09-03)

[272] The plant filter has been implemented during a PHD workgroup session together with Henning Guenther whom the author wants to acknowledge. Special thanks go to the team of DAS NUMEN H2O – Julian Charrière, Andreas Greiner, Markus Hoffmann, and Felix Kiessling.

Although not completely successful with the drinking-water test, which might be due to non-point sources from the pipe material used, filter media, etc., the purified water *almost met* drinking-water standards. Compared to the priority of conventional drinking-water production, no chemical additives were applied. However, the results gained are still promising, not least against the background of the Berlin Water Framework Directive inventory, which classifies the surface water quality of the inner-city Spree as “highly-polluted” (grade III-IV).[273]

3.4.2 Types of farming pond

Ponds for fish, aquatic plants and animal farming are further aquacultural types. Pond-based forms and practices of food and biomass production are particularly well-known from Asian traditions of integrated farming.[274]

Polyculture (vs. monoculture) is one distinctive principle applied within this oldest form of sustainable agriculture. It can comprise various forms of land-use from polycultural fish production and rice-paddy fish-farming[275] to pond and dyke systems. The combination of fishponds linked to other agricultural livestock and crop production makes polyculture very space, energy and resource efficient, e.g. via using manure for pond fertilization or pond water for irrigation. Therefore, this multi-beneficial form of *aqua-agri-culture* has a higher productivity compared to contemporary practices of space extensive organic farming, besides being an environmentally benign farming method.[276]

POLYCULTURAL WATER-FARMING

Polycultural water-farming, as one of the oldest aqua-agricultural practices, encompasses the “simultaneous culture of two or more species with different food habits.”[277] Polycultural fishponds originated in ancient China about 3,000 years ago.[278] The first document, entitled *Fan Li on Pisciculture*, dates back to 500 BC.[279] Different food niches are stocked with fish with individual food requirements, such as herbivorous (plant and green algae feeders), carnivorous (meat feeders) and omnivorous (mixed diet). The high trimming density of diverse fish species in minimal space has a long tradition. A Chinese carp polyculture raises seven to ten carp species occupying different niches within the water body. Therefore, the various foods, including biological waste resources, can be efficiently reused within the three-dimensional water space, which is also known as the *multi-layer principle* (Figure 13).

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[273] SENGUV (2009b)

[274] e.g. Guterstam (1991); Bocek (1996b); Hinge and Stewart (1991); Stewart *et al.* (1991); Jana (2003)

[275] Stewart *et al.* (1991)

[276] Hinge and Stewart (1991)

[277] Bocek (1996a, p. 8)

[278] Wang (1998)

[279] McVey (1993)

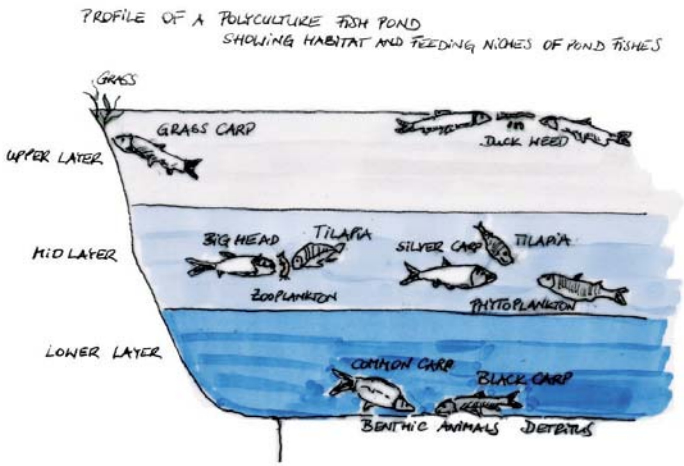

Figure 13: Chinese multi-layer farming principle in a fish polyculture

Wang refers to the following basic principles: “According to their different environmental requirements, the farming and livestock raising are arranged together to formulate a comprehensive production system with multi-layer in space and multi-sequence in time in order to make full use of solar energy, water and mineral nutrients so as to gain high economic benefit in given land and period.”[280]

The following fish species are raised in a Chinese carp polyculture within a surface area of 100 m^2:[281]

- Grass carp *(Ctenopharyngodon idella)* 2
- Silver carp *(Hypophtalmichthys molitrix)* 12
- Bighead carp (*Aristichthys nobilis*) 1
- Common carp (*Cyprinus carpio*) 17

Approximately 50-75% of the nutrients within a fish polyculture are constantly recirculated through the interdependent metabolic activities.[282] Up to 8,000 kg of fish per year and hectare may be produced in tropical latitudes.[283] By comparison, EU project results from Hungary stress that continental climate fish yields in traditional ponds are an average of 1,000 kg.[284] According to sustainable case study results, the harvest can be increased up to 20,000 kg fish if intensive and extensive pond culture producing Common carp, European catfish and Nile tilapia are combined.[285]

280 Wang (1998, p. 3)
281 Bocek (1996b, p. 10)
282 Rennert (2009)
283 Bocek (1996b, p. 2)
284 SUSTAINAQUA (2009, p. 37)
285 Ibid.

The data mentioned illustrate the high productivity and the multiple benefits created due to the various resource loops performed in the three-dimensional water space. They refer to basic blue-green principles, particularly plant-biofilm-based microbial activities and associated metabolic cycles, such as are sketched in the summarizing table of basic blue-green principles and services (Table 3).
Beside carp, various other fish species in most diverse *compositions* are kept worldwide. Regarding warm water fish polyculture, tilapia species are raised in tropical and subtropical inland waters, such as in Africa, and South and Central America. There is a broad variety of tilapia, similar to carp. In addition to their disease resistance, they are, like carp, particularly tolerant of low oxygen and poor water quality.[286] Tilapia species range from *vegetarians* eating water-plants (e.g. *Tilapia rendalli*) to bottom-feeding *water pigs* (e.g. *Oreochromis niloticus, Oreochromis aureus, Oreochromis mossambicus*).

Integrated fish farming in a moderate climate context is known from European pisciculture, particularly in medieval castle moats and village ponds. They often combined biological wastewater-reuse. Similar to Chinese polyculture, sustainable principles often include biological waste and wastewater recycling for pragmatic reasons of reusing local fertilizer and nutrient resources.[287] This links to a story from Chinese farmers and their understanding of sustainability: “It is told from the Chinese farm country that if you were invited for dinner, it was a matter of politeness and respect to the host not to leave the house before you went to the toilet in order to leave the fertilizer for the next growing season. Otherwise you might never be invited again.”[288]

INTEGRATED WATER AND RESOURCE MANAGEMENT

Polycultural water-farming practices, as described, were reinvigorated at the turn of the 21st century. The largest traditional urban application still in operation today is the Kolkata fishpond-wetland system.[289] Referring to the approach of Integrated Water and Resource Management (IWRM), which was introduced by the Global Water Partnership (GWP), it was evaluated as a “low-cost sanitation and resource recovery system”[290]. With a critical eye on both health risks for farmers and consumers, and also economic benefits with regard to jobs and food supply, the system is valued as a unique case study. It fulfills both ecosystem services and socioeconomic benefits in a contemporary mega-city context in the global south.[291]

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[286] Bocek (1996c, p. 2)
[287] Prein (1990, p. 13)
[288] Guterstam (2009a)
[289] GWP (eds.) and Rees (2002, p. 314)
[290] Ibid.: p. 23
[291] Ibid.

SPATIAL PRODUCTIVITY

Historic research by Edwards[292] and Gosh[293] stresses exemplary quantitative data of sewage-fed fish-farming as a distinctive form of urban aqua-agriculture which has been practiced in Kolkatta since 1930. They state as follows: “The fisheries developed into the largest single excreta-reuse aquaculture system in the world with around 7,000 ha in the 1940s, supplying the city markets with 10-12 tons of fish per day.”[294] Major parts of the Kolkatta wetlands were restored within the *Ganga Action Plan* in the 1980s, whereby today, ~12,000 ha of wetlands east of Kolkata still exist (Figure 14). Nevertheless, in recent years, due to fast urbanization, the fishpond area has decreased to approximately 2,500 ha. They produce daily yield rates of 20 tons of fish providing locally priced food and employment to approximately 17,000 poor people.[295] Fish-farmers earn on average more than three-times the minimum agricultural wage.[296] Today, about 30% of the daily wastewater from the megacity of 15.5 million people is reused.[297]

Figure 14: Kolkatta reclaimed wastewater fish ponds

RESOURCE UPCYCLING – URBAN SEWAGE MINING

According the reuse potential of urban nutrients, Jana refers to the striking figures of 1.1 million m³ of municipal sewage per day containing about 5.5 tons of nitrogen, 1.7 tons of phosphorus and 3.3 tons of potassium.[298] If scaled up to the whole country of India, it is estimated that 90 tons of nitrogen, 32 tons of phosphorus and 55 tons of potassium, with a market resource value of Rs. 61 million (~ 900,000 €),[299] could be recovered on a daily basis.[300] Regarding contemporary post-industrial resource management in a Western context, it relates to urban strategies of *sewage mining*. Steinfeld and Del Porto put it as follows: “Sewer mining is the

[292] Edwards and Pullin (1990)
[293] Gosh (1991)
[294] GWP (eds.) and Bahri (2009, pp. 23–24)
[295] Ibid.; Edwards (2000); Bunting (2007)
[296] Gosh (1991, p. 68)
[297] Guterstam (2009b)
[298] Jana (1999)
[299] conversion rate 2011
[300] Ibid.

process of tapping into a sewer line (either before or after the sewage treatment plant) and extracting sewage to be treated in a small on-site treatment plant for nearby use as recycled water."[301]

Other forms of pond-based waste resource upcycling are applied by industries, such as breweries and starch factories. The nutrients are often transformed into aquatic plants from which sugar or proteins are retrieved. The fresh biomass is used as animal feedstuff. Another example refers to the restoration of wastewater-affected lakes (e.g. Lake Tai, Lake Dian), where aquatic plants and aquacultural fish production are combined to absorb nutritious salts.[302]

HEALTH ISSUES

Regarding environmental health impact, particularly due to heavy metals from major industries, such as chromium from the Kolkatta industries, it is stated that a reduction through wetland-soil bonding takes place.[303] Thus, these substances are prevented from entering the food chain. The permanently water-saturated soils provide anoxic conditions. This leads to an immobilization of heavy metals and other toxic substances.[304]
According to the Western context, the IWRM examples mentioned appear exceptional to today's Global South. However, Berlin's former *Rieselfelder* (irrigated fields) represent a similar multi-beneficial landscape infrastructure. They provided urban food and water combined with urban *waste* resource management during industrial mega-city growth at the turn of the 20th century (4.3.3). Current urban water and climate challenges fostered their reactivation along revitalizing multiple blue-green services. It is a contemporary case example of a reemerging traditional aquacultural blue-green infrastructure in a periurban landscape context of the Global North (4.5.2).

3.4.3 Types of water-farm greenhouses

Aquacultural greenhouses that enclose constructed aquatic ecosystems embrace integrated water resource management principles. They usually combine *aquaculture* (breeding of fish and other water animals) and *hydroponics* (soilless cultivation of plants or algae), which is also known as *aquaponics*. Co-benefits are created through using wastewater from aquacultural fish cultivation as fertilizer for hydroponic vegetable, herb or water plant production (4.5.3; 5.2; 5.3).

Younger high-tech design concepts related to vertical farming, roof-top or building-integrated water-farm greenhouses, including building-integrated water, energy and resource management, are known particularly from North-America and Asia.[305] At a technological level,

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[301] Steinfeld and Del Porto (2007, p. 65)
[302] Wang (1998, p. 5)
[303] Biswas (2000); Jana *et al.* (2000)
[304] Böken and Hoffmann (2009); Ripl (1992); Ripl (1995)
[305] e.g. Despommier (2011); Gorgolewski *et al.* (2011); Germer *et al.* (2011)

similar concepts have been long-term field-tested as decentralized applications, serving domestic and industrial wastewater management.[306]

BIOSHELTERS – LIVING MACHINES – SOLAR AQUATICS

Pioneering research on ecologically engineered greenhouses started in the late-1960s/early-1970s in North-America, and is associated with the projects of John and Nancy Todd or David Del Porto.[307] Groundbreaking experiments explored the general functionality of aquatic ecosystems for solar-based ecological wastewater management within a tropical greenhouse mesocosm under colder climate conditions. Affiliated to the work of the New Alchemy Institute, which was founded in 1969 by Todd, Todd and McLarney on the island of Cape Cod in Massachusetts,[308] the motivation for renting a 12-acre (49,000 m²) farm and setting up a greenhouse research lab is described as follows:

> "Accepting the likelihood that there were no existing institutes that would allow us the freedom of crossing disciplines, setting different values and priorities as the basis of our work, and looking at biology and agriculture in a larger social and cultural context, we created our own fledgling institute, (…). Our logo read: 'The New Alchemy Institute. To restore the land, protect the seas, and inform the Earth's stewards.'"[309]

Since initial studies were carried out under Nordic climate conditions, they included the integration of aquaculture modules into a greenhouse mescosm, while attaching it to an architectural building site for co-beneficial energy. Ecologically engineered types of water-farm greenhouse called "Bioshelters," "Living Machines"[310] or "Solar Aquatic Systems"[311] ((Figure 15) were developed as alternatives to conventional wastewater infrastructures. The objective was to find sustainable alternatives to Western "one-way" wastewater treatment strategies (1.3), which were criticized as "major polluters."[312] By referring to Guterstam,[313] Todd and Todd mention at least three fronts of system design failure:

> "Technically it produces byproducts in the form of sludges that are difficult of dispose and often toxic. Chemically, it uses hazardous compounds in the treatment process, all of which end up in the environment. Chlorine, for example, is widely used and can combine with organic matter to produce chloramines, which are known carcinogens. Aluminium salts, also frequently used to precipitate out sludge and phosphorus, have been implicated in problems ranging from the weakening of the forests to Alzheimer's disease. Further the treatment industry is simply not cost effective economically.

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306 http://www.ecological-engineering.com/ (2010-10-02)

307 Todd and Todd (1984); Todd (1991); Guterson (1993); Todd and Todd (1993); Steinfeld and Del Porto (2004); Bohemen (2005b)

308 Todd and Todd (1993, p. 2)

309 Ibid.: p. 4

310 Todd and Todd (1984); Todd (1991)

311 Steinfeld and Del Porto (2004)

312 Todd and Todd (1993, p. xvi)

313 Guterstam and Todd (1990)

Advanced wastewater facilities cannot be built and operated without massive federal subsidies. Nor do conventional waste treatment technologies produce anything in the way of economic by-products to offset their operating costs."

Figure 15: Left: Solar Aquatic System (SAS) – Tropical greenhouse for industrial wastewater treatment. Right: Stensund Wastewater Aquaculture – European pilot project at a Folk College campus

The first European aquacultural pilot greenhouse was realized at a Folk College campus in the Swedish archipelago south of Stockholm (Figure 15). Stensund Wastewater Aquaculture[314] provided productive and decentralized wastewater management focusing on aquatic food-web-based resource recycling and greenhouse production strategy. The project was initiated by the marine biologist Björn Guterstam and the architect Bengt Warne. It conducted applied research, development and training of Ecological Engineering and Design from 1989-2000. The greenhouse was designed as intensive indoor technology based on Chinese integrated farm principles described earlier.[315] It successfully combined and tested hydroponic and aquaponic technologies for wastewater treatment based on a hygienically and toxicologically controlled process, while achieving bathing water quality in the outflow.[316] Scientific research focused on nutrient reuse via constructed aquatic food webs (microalgae, fish, plants) and aquaponic tomato production.[317] Besides economic aspects, research further explored issues of energy management under Nordic climate conditions, and heavy metal and pharmaceuticals in domestic wastewater.[318] Although out of operation today, it is a matter of contemporary case study research due to its unique learning-from potential (5.2). Based on the Swedish results, further research was conducted for central Europe, particularly regarding the reuse of nutrients and improving the value chain.[319] (5.5.5)

[314] Guterstam (1991); Chan and Guterstam (1995); Guterstam (1995); Guterstam (1996)

[315] Guterstam (1991); Warne (1991); Frederiksson and Warne (1993); Chan and Guterstam (1995); Guterstam (1995); Guterstam (1996)

[316] Bürgow (1998); Bürgow (Stockholm 22-25 May)

[317] Guterstam (1991); Warne (1991); Frederiksson and Warne (1993); Chan and Guterstam (1995); Guterstam (1995); Guterstam (1996)

[318] Adamsson (1999); Roggenbauer (2005);

[319] Junge-Berberović *et al.* (1999); Junge-Berberović (2001); Staudenmann and Junge-Berberović (2003); Graber and Junge-Berberović (2008); Graber and Junge-Berberović (2009)

Since initial studies were carried out under Nordic climate conditions, it included the integration of aquaculture modules into a greenhouse mesocosm, while attaching it to an architectural building site for co-beneficial energy. If it is building-integrated, in the form of a winter garden or a roof-top farm, this water-based production further offers structural advantages compared to soil-based production. Architectural structures developed, Todd and Todd describe, as “the fruitfulness of the marriage between biology and architecture.”[320] The new urban forms called “Bioshelters” – as the more overarching generic name for other notions such as “Ark,” “Solar Aquatics” or “Living Machines” – stress the common “issue of shelter.”[321] Todd states as follows: “(...) to try to create an integrative form of architecture that would incorporate renewable energies and biological systems in the form of growing areas for plants and fish. (...) a number of variations of small translucent structures that were both greenhouse and aquaculture facilities.”[322] He further points out:

> “Living machines can be designed to produce fuels or food, to treat wastes, to purify air, or to regulate climates, or even all of these simultaneously. They are engineered with the same principles used by nature to build and regulate its great ecologies in forests, lakes, prairies, or estuaries. Their primary energy source is sunlight. As the planet, they have hydrological and mineral cycles. They are, however, totally new contained environments. To create a living machine, organisms are reassembled in unique ways for specific purposes.”[323]

Todd stresses the prospective role in future cities becoming “basic building blocks.”[324]

To sum up, the greenhouse contained *solar aquacultural loop technologies* mimicking natural ecosystem processes via an integrated energy, water and food production offering the following key benefits:

- direct use of solar and other free energy sources (e.g. warm air from the building);
- direct building-integrated recirculation of daily water and nutrient resources (e.g. rainwater, organic wastewater) in addition to their upcycling due to green production; and
- direct production and consumption of food and biomass on-site (“prosuming”[325]) and associated energy and cost savings, particularly transport.

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[320] Todd and Todd (1993, p. 6)
[321] Ibid.: p. 5
[322] Ibid.
[323] Todd (1991, pp. 335–336)
[324] Todd and Todd (1993, p. 6)
[325] Bürgow *et al.* (2012)

3.4.4 Facts and figures of blue-green services and benefits

The aquacultural types explored so far focused primarily on water-farming facets closely linked to the place-based cultural and landscape context. As three-dimensional blue-green infrastructures, they offer multiple benefits due to the integrated production of fish and living biomass based on solar energy use without the additional need of artificial fertilizer or fodder (e.g. pellets). Regarding everyday life services, illustrative figures of productivity and energy, space and resources are compiled in the following, while selectively referring to aquacultural farming types and practices.

PRODUCTIVITY AND ENERGY

According to the productive and energy point of view, the aquaculture expert Bernhard Rennert,[326] from Berlin's Institute of Freshwater Ecology and Inland Fisheries (IGB), stresses the following benefits:

- Three-dimensional use of (water) space enables higher productivity per square meter.
- As fish are swarm animals, a high farming density is natural and advantageous with regard to animal welfare (e.g. due to prevention of stress and aggressive behavior depending on the particular species).
- Little energy is required to move in water.
- Due to poikilothermic living, no extra energy is required to regulate body heat. As opposed to terrestrial life, fish and other cold-blooded aquatic animals do not need to regulate their body heat according to ambient temperature.
- About 1 kg of feedstuff is required to produce 1 kg of high-quality fish (e.g. trout), whereas it requires 3 kg for 1 kg of poultry and 10 kg feedstuff for 1 kg of beef or pork.
- Land-based aquaculture production compared to a trawling fishery consumes less fossil fuel. A trawling fishery requires 1 kg of fuel to catch 1 kg of fish.

As opposed to the benefits mentioned, current industrial aquaculture production modes require high indirect amounts of fossil fuel energy. The largest portion of the fodder by far is covered by fish-flour and fish-oil, which, in the majority of cases, originate from fossil fuel driven marine fisheries.[327] It contributes ~80% of the food ration of carnivorous (meat consuming) fish production.[328] Therefore, political and consumer ethics discussions within the last few years have led to strategies and initiatives to promote more sustainable modes of aquaculture food production.[329]

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[326] Rennert (2009)
[327] Ibid.
[328] Ibid.
[329] e.g. MEA (2005, pp. 21, 81, 125); TEEB (2008); BMU (2008a); DBU (2009)

The solar-based upcycling of nutrients and the conversion into high-energy proteins via variously interwoven food webs is of high priority in sustainable aquaculture production, while offering multiple benefits. Stewart, Hang and Hinge, according to calculations for an exemplary integrated aqua-agri-cultural farm of 2 ha in Denmark (Table 1), state as follows: “Our calculations have shown that the projected system has not only a positive energy balance of almost 2:1, but also produces nutrients in excess of the system’s needs. There is no demand for artificial fertilizer or pesticides and fuel use is low due to the system’s compactness.”[330] Compared to figures of conventional fossil-fueled agriculture and organic farming, they point out that:

> “Conventional Danish agriculture operates with an on-farm deficit of more than 2:1. In other words, in energetic terms Danish agriculture consumes more than double the amount of resources it produces. Even with the most environmentally benign farming methods, such as organic dairy farming, the on-farm energy deficit is as much as 1.5:1. The deficit is due not only to the use of electricity in stables and diesel oil for machinery but also to importation to the farm of animal feed.”[331]

The authors recommend the enhanced use of solar and biogas technology in order to optimize local energy efficiency. It is particularly effective when combined with the raising of pigs and geese in an animal-friendly and healthy manner (~200 m²/pig and 10 m²/goose). An additional minimum area of 1.5 ha is recommended for self-sufficient organic farming.[332]

Table 1: Exemplary integrated 2-ha size farm design

Field I	**Area [m²]**
Greenhouse	760
Algae Ponds	270
Polyculture Ponds	6160
Aeroponics	1500
Hydroponics	500
Other	810
	10000
Field II	**Area [m²]**
Algae Ponds	540
Polyculture Ponds	6160
Aeroponics	1500
Hydroponics	500
Other	1300
	10000

330 Hinge and Stewart (1991, p. 182)
331 Ibid.: p. 181
332 Ibid.: p. 182

Complementing the integrated farm data, research data collected by Junge-Berberović[333] provide a general overview of the high productivity of aquaculture biomass (Table 2).

Table 2: Average biomass composition and growth rates of some organism groups in aquaculture

	Maximum growth /harvest rates	**Growth rate**	**Biomass composition**		**Elimination by harvesting**	
Organism	**kg FW/ha/a**	**g DW/m²/d**	**% N**	**% P**	**g N/m²/d**	**g P/m²/d**
Microalgae *	(240,000)	13.0	6.0	0.6	0.78	0.078
Macrophyta						
Macrophyta floating *	(150,000)	8.0	3.9	0.8	0.312	0.064
Macrophyta emerging *	(160,000)	9.0	1.7	0.3	0.153	0.027
Eichhornia sp. Otelfingen 1998		41.9			0.770	0.190
Crayfish		(DW ~ 20% FW)				
Semi-intensive (Australia)	2,000	→ 0.110	10	1	0.011	0.001
Extensive (unfed) (Australia)	200	→ 0.011	10	1	0.011	0.000
Calcutta Wetlands (Jana 1998)	750	→ 0.041				
Zooplankton						
Daphnia (**)		0.6-80.0 **	9.5	1.2	< 9.0	< 9.0
DePauw and Pruder (1986)	up to 48,000	→ 2.64	10	1	0.264	0.026
Otelfingen 1998					0.090	0.009
Fish	up to 9,350	→ 0.512	10	1	0.052	0.005
Fish (Hungary)		0.4	10	1	0.040	0.004

FW = Fresh Weight
DW = Dry Weight
values in italics are assumed or calculated using assumptions
* mean of several values cited in literature
** range of values calculated from Berberović (1990) and different sources

SPACE AND RESOURCES

As opposed to solely land-based household wastewater irrigation systems, which can handle loading rates equivalent to 200-300 people/ha/day, aquaculture ponds, due to their three-dimensionality, are 10 times more effective. Hygienically safe loading rates are equivalent to 2,000-3,000 people/ha/day.[334]

[333] Junge-Berberović (2001)
[334] Prein (1990, p. 39)

AQUAPONIC GREENHOUSE FIGURES

In addition to the productive reuse and purification of organic wastewater, the solely greenhouse-based production of food and other marketable biomass can be the main purpose of this system. It combines both aquaculture and hydroculture production modes, often applied as aquaponic greenhouse design. Aquaponic greenhouse production in temperate climates most often refers to the combination of fish and tomato production. Graber and Junge-Berberović address the objective as follows: "The primary goal of aquaponics is to reuse the nutrients released by fish to grow crop plants."[335]

The following aspects are stressed for hydroponic plant selection: "The selection of plant species adapted to hydroponic culture in aquaponic greenhouses is related to stocking density of fish tanks and subsequent nutrient concentration of aquacultural effluent. Lettuce, herbs, and specialty greens (spinach, chives, basil, and watercress) have low to medium nutritional requirements and are well adapted to aquaponic systems."[336] Due to combining hydroponic vegetable with aquaculture fish production (= aquaponics), the nutrient solution for fertilizing hydroponic plants does not need to be controlled precisely: "However, in aquaponics, nutrients are delivered via aquacultural effluent. Fish effluent contains sufficient levels of ammonia, nitrate, nitrite, phosphorus, potassium, and other secondary and micronutrients to produce hydroponic plants."[337]

Graber and Junge-Berberović, in their earlier greenhouse studies, highlighted the following figures, while investigating the combined growth of fish and the three hydroponically cultivated crop plants: aubergine, tomato and cucumber:[338]

- A total of 69% of nitrogen removed was recycled into tomato biomass
- Phosphorus recycling approached ~100% in hydroponic (as intended with suitable fertilizer) and 50% in aquaponic production.
- A lack of potassium due to low concentrations in fish-water leads to poorer tomato quality in aquaponic compared to other production methods.
- The yields of fish did not differ from typical conventional aquaculture with tilapia and perch.
- Nutrient recycling rates through harvesting above ground is 100-200 g N/m²*a and 10-20 g P/m²*a, achieving rates of 32-40% total N and 22-27% total P.

To sum up, the benefits of aquaponics are as follows:

- Hydroponic vegetable production can be optimized through aquaponics. Instead of using artificial fertilizer, nutrient-rich water from aquaculture production (e.g. fish) is

[335] Graber and Junge-Berberović (2009, p. 149)
[336] Diver (2006, p. 1)
[337] Ibid.
[338] Graber and Junge-Berberović (2009)

both a natural fertilizer and production base of vegetable production. In return and as a positive side-effect, the hydroponic plants naturally purify the water. The concentration of nutrients (N, P) and micronutrients (Zn, Mn, etc.) in wastewater from fish production is at an optimum for hydroponic tomato cultivation.[339]

- A rule of thumb is that wastewater from 1 kg fish can fertilize 5 kg of vegetables.[340]

By referring to early and similar simple recirculation systems of aquaponic fish-tomato production, Rennert highlights the following advantages:[341]

- saving of manure,
- twofold utilization of water,
- no costs related to denitrification,
- twofold utilization of heating energy, and
- no discharge of wastewater and, consequently, no land-based nutrient losses if the remaining fish manure is also recycled, e.g. via combined constructed wetland or productive soil systems.

3.5 Conclusion

The following insights can be derived from ecohydrological landscape research. They stress the common life-supporting role of small water cycles and corresponding blue-green services:

- The perception of borders between so far putatively opposed spheres of *nature* and *culture* dissolves when the fluid intertwining of everyday water-dependent infrastructural and landscape ecosystem processes are reflected.
- Urban water and resource management mediated through technical infrastructures depend on basic blue-green services provided and regenerated by landscape ecosystems, particularly due to their small water cycle performance.
- Qualitative and quantitative figures of the small water cycle highlight rainwater recreated via terrestrial moisture feedback loops[342] as the *basic water loop* on earth. Due to being sustained by land-based ecosystems, such as (rain-)forests or wetlands, the *green water cycle* contributes up to two-thirds of the terrestrial freshwater sources.
- A building-related green (vegetative) rainwater management offers place-based water-centric *climate chances* in the urban watershed. Besides favoring water-recirculative evaporation via plant technologies vs. water run-offs via technical infiltration, the *climate chance* lies particularly in local temperature moderation due to natural cooling.

[339] Graber and Junge-Berberović (2008)
[340] Graber (2011)
[341] Rennert (1992)
[342] Savenije (1995)

Table 3 summarizes basic blue-green principles and services. Literally called *Blue embraces green – Green embraces blue*, the *blue-green service matrix* provides a base for applied case study research, particularly to explore and evaluate blue-green service potentials of aquacultural infrastructure types (→ Chapter 4:; Chapter 5:).

Table 3: Basic blue-green principles and services: Blue embraces green – Green embraces blue.[343]

Blue embraces green principle and example	**Effect**	**Service**
Water as living space	Vital water	Vitality, diversity, recreation, spirituality
Water retention and filtration via evapotranspiration	Balanced landscape hydrology	Local fresh water cycle, water risk prevention (floods, droughts)
Plant vitality, ecosystem vitality	Enhanced biomass productivity	Vital food and biomass reproduction, aesthetics, joy, livability
Green embraces blue principle and example	**Effect**	**Service**
Plant- or biofilm-based metabolic cycles	Enhanced surface water quality	Drinking-water quality, bathing water quality, landbased retention and recirculation of vital nutrients and minerals
Decelerated and pulsed water-flows	Wider flow space and variety of living spaces	Habitat diversity, water risk prevention (floods, droughts)
Vegetative cooling processes due to evapotranspiration	Pulsed solar energy transformation (60-80%)	Temperature moderation, heat risk prevention

Exemplary references: (Caduto 1990); (Ripl 1992); (Savenije 1995); (Falkenmark, Rockström 2005); (Kravčik et al. 2007)

Complementing the results from landscape ecosystem research, the aquacultural types of water-farming mimic blue-green landscape principles and services as listed in Table 3. Consequently, they are recognized and interpreted as specific blue-green infrastructures. Facing contemporary urban needs, the following additional (natural-cultural) opportunities can be summarized:

- Aquacultural water-farm types as constructed aquatic ecosystems of cross-cultural heritage are specific blue-green infrastructures of everyday life-support fulfilling multifunctional blue-green services. They pro-actively regenerate daily-life resources (food, biomass, energy, freshwater, etc.) and other ecosystem services (natural cooling, nutrient and water retention, biodiversity, etc.). By mimicking blue-green landscape principles and services, they promote small water cycles from micro- to macroscale and regenerate everyday natural life qualities in urban watersheds. In addition, aquacultural blue-green infrastructures provide everyday cultural life qualities, since they enhance sensual, educational, artistic and aesthetically pleasing, recreational, and other services which are inevitable to overall human wellbeing.

343 The table has been elaborated to a great extent within PHD workgroup discussions with Henning Guenther in 2011, who the author wants to acknowledge.

- Swimming gardens, aquacultural ponds and greenhouses are flexible, space- and resource-efficient water-farm infrastructures at human-scale. They reflect on the wide range of aquacultural technologies from low-tech/high-nature to high-tech/high-nature applications. They enable an integrated everyday resource provision due to the three-dimensional bundling of space, energy, water, and other resources. Moreover, their modularity offers possibilities of decentralized adaptation to different urban settings from densely to sparsely populated areas.
- Compared to agricultural production, three-dimensional aquacultural or combined aqua-agricultural production enables higher productivity per square meter and a better utilization of energy and resources. Polycultural farm systems have no demand for artificial fertilizer, pesticides or fuel due to the circular design of water and resource flows and compactness of production. Regarding fish production, 1 kg of feedstuff is required to produce 1 kg fish, whereas ten times as much feedstuff is needed to produce 1 kg of beef or pork.

In light of these outcomes, aquacultural blue-green infrastructures create the common intersection between the key research areas of city, infrastructure and landscape transformation. Accordingly, they are recognized as a central subject of further empirical research.

The key blue-green service and infrastructure features explored and summarized so fa, create the particular framework for further in-depth case study exploration at a project scale (→ Chapter 4:).
However, the following Chapter 4 explores Berlin’s aquaculture at a citywide scale linked to the history of water-based transformation from the natural landscape to the cultural/urbanized landscape. By focusing on both urban aquaculture overarching to a city’s water-based identity and aquacultural infrastructures in the past and present daily life contexts, Chapter 4 serves as a bridge to further empirical research at an international project scale.

PART II

CASE STUDIES

CHAPTER 4: PLACE-BASED CASE STUDY – BERLIN'S AQUACULTURE AND WATERSCAPE BIOGRAPHY FROM NOMADISM TO URBANISM

4.1 Introduction

Chapter 4 centers on question how the city emerged from the landscape and how a place-based urban aquaculture with characteristic aquacultural practices and infrastructure types matured.

By linking the water- and landscape-centered view, the focus is on Berlin's individual aquacultural biography from preurban to urban times by looking at the needs of the contemporary and future city. Similar to a personal biography or curriculum vitae, the notion of *waterscape biography* is used and addressed in the urban context to particularly reflect on people's daily life culture by and with water.

The *Berlin case study* spans a range from the early roots of settlement via times of megacity development of industrialization at the beginning of the 20th century up to current post-industrial trends concerning creative city projects. The main intention is twofold: On the one hand, to reimagine place-based roots of everyday water-culture and traditional water practices of people living in Berlin; on the other hand, to reread the urban morphology as an intertwined natural-cultural history of interplaying landscape, infrastructure and urban processes.

Following the overarching conclusions of Chapter 2 on cities' waterscape history and place-based urban aquaculture, Chapter 4 is structured along the three characteristic urban aquacultural facets:

- water-living culture,
- water-farming culture, and
- water-wellbeing culture.

The literature reviewed comprises relevant place-based urban history[344] in addition to more recent thematically focused sources.[345] The rather rare literature to date on Berlin's water-farming traditions rely to a great extent on limnological research of Berlin's natural-cultural history of fish and fishery in the Spree river catchment area.[346] These sources are supplemented by various texts tracing the roots of urban agriculture and horticulture in Berlin,[347] and cartographic studies, including mapping studies to track physical-morphological changes such as those induced by infrastructural interventions over time. They are complemented by historic photos reflecting Berlin's daily water-culture and aquacultural practices.

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[344] e.g. Bauer (1988); Berliner Geschichtswerkstatt e.V. (1991); Materna *et al.* (1987); Ribbe and Schmädeke (1994); Uhlemann (1987)

[345] e.g. BWB (eds.) (1993); Conradt and Korte (2005); Klein and Seeliger (2010); Park (2010); Pawlowski (2004); Steinmann (2008); Strauß (2002)

[346] Arlinghaus *et al.* (2002)

[347] von Plessen (1985); Prein (1990); Prein (1996)

4.2 Berlin's water-living culture

4.2.1 Urban landscape metamorphosis: From preurban to urban waterscape morphologies

Aquacultural roots and milestones of living by and with the river refer to Berlin's place-based *water-living culture*. In addition, this notion includes a boatbuilding culture and traditions of floating urban transport. As anthropological phenomena, they relate to forms and practices of *water-living*, such as dwelling, living or trading by the water-shore and waterfronts.

The natural abundance of water in the Berlin landscape was the reason for the initial settlement by hunters during the middle of the Stone Age up to the city's official foundation by trading people in medieval times. The city's morphology was shaped by glaciers about 18,000 years ago in the so-called *Weichseleiszeit* (ice age of the Weichsel river). To track and perceive this long-term spatial-temporal *landscape metamorphosis*,[348] the mapping approach *back in time* in the sense of a "looking back for the future"[349] was used. It mutualizes with the research of the landscape ecologist Eric W. Sanderson. In his book *Manhatta*,[350] he traces the natural history of Manhattan Island before its Western exploration by Henry Hudson in 1609. He states that: "The goal of the Manhattan project has never been to return Manhattan to its primeval state. The goal of the project is to discover something new about a place we all know so well, whether we live in New York or see it on television, and, through that discovery, to alter our way of life."[351]

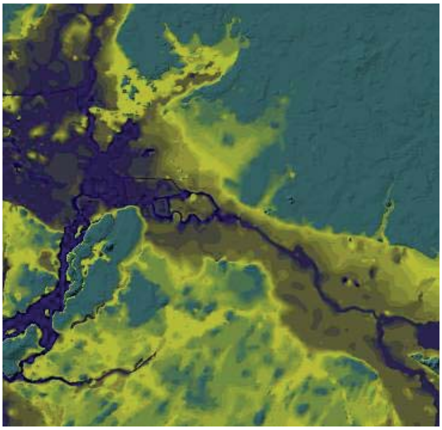

Figure 16: The course of the glacial valley in Berlin and Brandenburg with the island in the Spree

The GIS-based 2-D map illustrates Berlin's geohydrological setting within the Spree rivershed as part of the glacial meltwater channel (Figure 16). The river Spree runs into the city from the

[348] from Greek *metamorphoun* – to transform, *meta* – change and *morphe* – form, thus meaning the change of form and shape) http://www.etymonline.com/index.php?search=metamorphosis+&searchmode=none (2010-09-03)

[349] e.g. Yarinsky (2008)

[350] the native North American Indian word for "island of many hills" Sanderson (2009, p. 10)

[351] Sanderson (2009, p. 33)

south-east, soon passing the narrowest section of the valley with the island in the Spree – the heartland of the merchants' city foundation from 1237 near today's Hackescher Markt (4.2.5). A short distance beyond the parliament building (*Reichstag*), the River Spree is a tributary of the River Havel – a sub-rivershed of the River Elbe and Berlin's waterway connection to the North Sea and the Atlantic Ocean.

Formative geomorphological elements are the plateaus of Barnim, Teltow and Glien in the north, south and west, respectively. Below the glacial and fluvioglacial sediments, which are up to 170 meters thick consisting mainly of gravel and sand and serving as a natural filter and storage for the infiltrating rainwater, a 100-meter thick clay horizon called the *Septarienton* separates freshwater from saltwater.[352] Groundwater flows at a very slow velocity from the plateaus to the glacial meltwater channel. As a specific phenomenon, the groundwater level is naturally higher than adjacent river levels due to high frictional resistance when trickling though the gravel-sand layers. Thus, assuming there are no impacts such as groundwater drawings, a characteristic feature of Berlin's hydrologic pattern is the natural inflow of groundwater into the Spree.[353]

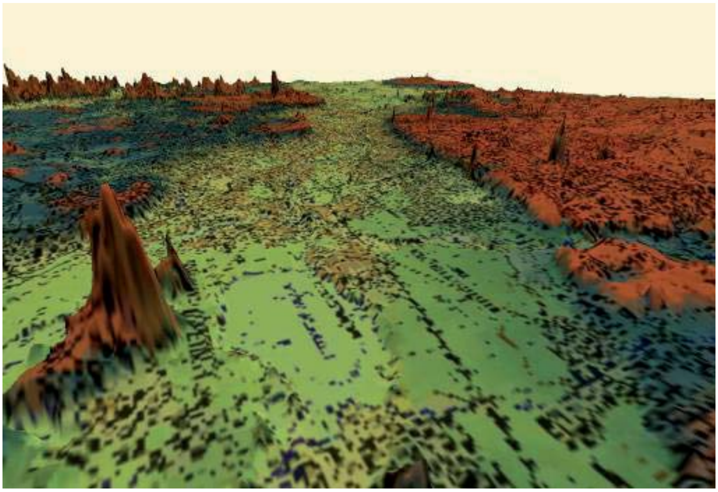

Figure 17: Preurban primeval landscape state of the Spree river valley in Berlin

The GIS-based 3-D maps illustrate two landscape morphological phases overlooking Berlin in an east-west direction: (1) The view follows the primeval glacial meltwater channel in preurban times (Figure 17), and (2) the flow of the major part of the Spree river – a relic of the melting ice – in urban times (Figure 18), flanked by the Barnim and Teltow plateaus at the northern and southern riverbanks, respectively.[354] The Barnim plateau to the north includes the rubble mountains in today's district of Prenzlauer Berg: *Mont Klamott* (height 78 m) at *Volkspark*

[352] BWB (eds.) *et al.* (2008, p. 22)
[353] BWB (eds.) (1993, p. 23)
[354] Bürgow and Dalchow (2009)

Friedrichshain (smaller peak in the front) and the *Oderbruchkippe* at the *Volkspark Prenzlauer* (height 91 m; higher peak in the back). The Teltow plateau to the south includes the former airport of Tempelhof, today's Tempelhofer Feld. The pronounced mountains on the edge of the Teltow are the Kreuzberg and the Hasenheide Park, both artificially heightened/elevated.

Figure 18: Urban landscape morphology of the Spree river valley with the Teltow Plateau (south) and Barnim Plateau (north)

4.2.2 First boats, first Berliners: Stone Age 9000-3000 BC

Berlin's characteristic landscape morphology during the Stone Age when the first human settlers occurred (about 11,000 years ago) is described as an "arctic water landscape."[355] The first permanent, though partly nomadic, inhabitants appeared in 9000 BC.[356] The *ancient Berliners* were reindeer hunters settling along Berlin's main rivers of the Spree, Havel and Panke. Whereas the daily life of people was determined by hunting on land and fishing from the riverbanks, the water-body itself was soon conquered by boats in favor of better fishing.[357]
The first boats were built using reindeer antlers for the framework. They represent the oldest middle-European boat type. Trading in the early Stone Age was mainly local and dominated by barter trade.[358]

From 8,000 BC (middle Stone Age), the local climate became warmer, which provided ideal conditions for the growth of forest. Consequently, hunting and the collection of edible and viable forest products, such as berries, mushrooms and wood logs used for log boats, improved in the middle Stone Age. Axes for cutting wood were produced from flints, rocks and deer antlers.

[355] Hatebur and Baumann (1982, p. 15)
[356] Bauer (1988, p. 10)
[357] Hatebur and Baumann (1982, p. 16)
[358] Materna *et al.* (1987, p. 27)

Fishing was carried out with spears, hooks, tridents, and cast nets[359] made out of bones, stones and antlers.[360]

Figure 19: Reconstruction of a middle Stone Age river dwelling

The Berliners of the middle Stone Age were still nomads. New resting and storage places either in the lower river valleys and on islands, or on sandy dunes and the higher lands of the Barnim and Teltow plateaus were chosen for temporary living.[361] Although no permanent dwellings existed, the inhabitants returned to their camps for hunting and fishing in close interplay with seasonal rhythms.[362] The construction material used for shelter reflected what could be harvested in the waterscape. Wetland plants, such as reeds, were used for hut and tent building (Figure 19).

4.2.3 From nomadic to domestic lifestyles: Climate extremes and migration of German tribes from recent Stone Age to late Bronze Age 3000-600 BC

Boat fishing and farming of livestock along rivers and creeks were in close coexistence until the beginning of Bronze Age in about 1800 BC, attesting to a prevailingly nomadic lifestyle. The density of people was relatively low as reflected in the vast woodlands growing along Berlin's riverbanks and on the plateaus of Barnim and Teltow.[363] The dominant boat type of the Bronze Age was the *sun ship* made from birch bark as the outer shell, wooden blocks for stabilization and hazel rods used as frames.[364]

Domestic lifestyle occur for the first time about 3000 BC accompanied by the adaptation of land-use practices performed in the drier climate of the south. Animal husbandry and cultivation of

[359] Hatebur and Baumann (1982, p. 14)
[360] Materna *et al.* (1987, p. 13)
[361] Bauer (1988, p. 10)
[362] Materna *et al.* (1987, p. 13)
[363] Ribbe and Schmädeke (1994, p. 14)
[364] Hatebur and Baumann (1982, p. 17)

land with wheat, barley and millet was introduced into the Berlin landscape.[365] The site in Schmöckwitz is one of the oldest dwelling places carrying the legacy of several thousand years of waterfront living in Berlin.[366]
The transition from a mobile to domestic lifestyle became more evident due to the rise in agricultural cults, such as burying or sacrificing animals. The rituals were meant to affect fertility and reproduction of land and domestic animals, and were also practiced during funeral and cult ceremonies.[367]

From the early towards the end of the Bronze Age, by about 700 BC, local climate change caused extreme events. Major floods induce migration of people to higher plateaus.[368] Due to the wet climate, forests re-spread and settlements became completely abandoned, additionally triggered by the growing pressure of migrating German tribes of the Semnonen or Sueben coming from South.[369] The Elb-Germans were permanent dwellers living in pole houses with clay walls and reed roofs. They practiced agriculture, mainly flax cultivation, cattle and pig husbandry, supplemented by horse, sheep and goat farming (Figure 20).

The population density rose constantly, particularly in the Havel-Spree estuary close to the water-shores (e.g. at Müggelsee), and also on the higher plateaus (e.g. at the hills of Müggelberge). Both exemplary sites are in today's south-eastern district of Berlin-Köpenick.[370] Local economy improved and reached its peak by about 100 BC.[371]

Figure 20: Reconstruction of a Bronze Age village, about 900-800 BC, with houses of the Berlin-Buch type

[365] Bauer (1988, p. 10)
[366] Hatebur and Baumann (1982); Materna *et al.* (1987, p. 13)
[367] Bauer (1988, p. 21)
[368] Ibid.: p. 14
[369] Ibid.
[370] Materna *et al.* (1987, p. 41)
[371] Ribbe and Schmädeke (1994, p. 15)

By 50 BC, a new climate decline had caused conflicts between the tribes, leading to migrations of Elb-German tribes towards the Western rivers Main and Rhine. The population started to recover only in this period. Along with the discovery of so-called iron ore in the Spree river meadow, the remaining Semnonen invented preindustrial handcrafts by running iron mills as well as producing limestone around 100 to 200 AD.[372] Boatbuilding improved mainly due to better woodworking, as in the case of carving log boats.[373]

4.2.4 River-people floating in: Slavic times 600-1200 AD

In addition to climatic changes, a big migration period throughout Europe – known as *Völkerwanderung* (mass migration) – was caused by the raids and conquests of the Huns from about 500 BC.[374] It lasted for about 200 years and led to a major migration of the German tribes from Berlin towards the south, and southwest to the rivers Main and Rhein by 450 AD.[375] At the same time, western Slavic tribes migrated further south and west.

RIVER NAMES

By the end of 600, the western Slavic tribes of the Wends, also called Elb-Wends (e.g. the tribes of Sorbs and Luticys),[376] had crossed the river Oder. They settled along the lakes and rivers, which provided both fishing grounds and sufficient water for livestock.[377] The two main Slavic tribes entering the Berlin-Brandenburg rivershed were the *Spreewanen* and the *Heveller*. They name their places of settlement after the biggest watercourses: *Hevelduni* (north-west) and *Spriauwane* (south-east), which later on became known as the rivers Havel and Spree.[378]

Being traditional nomads, the Wends were *river-fishing people*, naming the rivers they were settling at according their individual character. Although the name *Havel* originates from German *hab(u)la* (lagoon or harbor)[379] and the name *Spree* originates from German *sprew* (spray, sprinkle or seeding), local river names were inherited from Slavic vocabulary.[380] The Slavic names for Spree were, for example, *zpriav*, *zspriawa* or *spiawe*, meaning *the sparkling*.[381] The name of Berlin's third main river, the Panke, which rises close to Bernau north of Berlin and confluences with the Spree in central Berlin, originated from the Slavic *pankowe* meaning *river with vortices*.[382]

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[372] Ibid.

[373] Hatebur and Baumann (1982, p. 18)

[374] The Huns are middle and eastern Asian nomads known as "horse people."

[375] Bauer (1988, p. 16); Hatebur and Baumann (1982, p. 18)

[376] http://www.unterspreewald.de/cgi-bin/idx.pl?q1=1&q2=9&q3=0 (2010-08-01)

[377] Bauer (1988, p. 19)

[378] Hatebur and Baumann (1982, p. 18)

[379] Udolph (1992, p. 4)

[380] Materna *et al.* (1987, p. 45); Udolph (1992, pp. 3–4)

[381] Other sources refer to "sorbic river", which according to the German etymologist Udolph, seems to be a later translation Udolph (1992, pp. 3–4).

[382] Lemke (1955, p. 7)

FIRST CORES OF BERLIN SETTLEMENTS

The Slavic people most often chose former German dwellings in which to settle, whereby reusing the sites and their remaining infrastructures, such as water wells. In addition to fish and meat as their primary diet, they used slash-and-burn techniques on the forests to convert them to pastureland with direct access to river watering places.[383]

The political and economic centers of the Slavic settlers were the two moated castles of Köpenick and Spandau. Established before 800, both suburban headquarters at the southeastern and western fringes represent Berlin's oldest cores of urban settlement. The castle at Spandau – the second headquarters of the Heveller[384] and built on a former Havel island – was only accessible by boat at the beginning, until around 800 and the building of a wooden bridge[385] (Figure 21). Almost at the same time, Köpenick – the headquarters of the Spreewanen Prince Jaxa – was established. As an economically favorable site, it is situated right where the river Dahme confluences with the Spree. Spandau, which was mentioned for the first time in a document in 1197, thus 40 years before Berlin-Coelln, and officially privileged as town in 1232,[386] has similar locational advantages.[387]

Figure 21: Reconstruction of the fortress and settlement at Berlin-Spandau (~800)

After 1180 and by 1209 at the latest, the Saxonian Wettins had conquered Köpenick.[388] Battles for power between the principalities towards the end of 1200 led to the first settlement of people at the as yet unsettled Spree fort and smallest section in the glacial valley between the plateaus of Barnim and Teltow (Figure 22).

The settlers were probably merchants and craftsmen from the Lower Rhine, West-Ostphalia and Flanders.[389]

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[383] Bauer (1988, p. 17); Ribbe and Schmädeke (1994, p. 17)

[384] The main headquarters of the Heveller was the town of Havelberg, at the mouth of the river Havel with the Elbe northwest of Berlin.

[385] Hatebur and Baumann (1982, p. 18)

[386] Steinmann (2008, p. 135)

[387] Ribbe and Schmädeke (1994, p. 17)

[388] Ibid.

[389] Materna *et al.* (1987, pp. 95–96); Bauer (1988, p. 24)

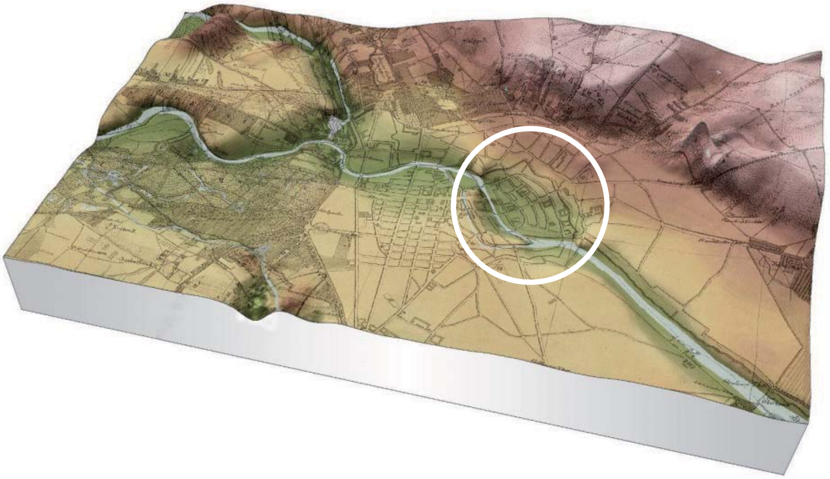

Figure 22: The medieval core of the city foundation at the smallest section within the glacial valley including the two arms of the Spree at the center

4.2.5 From *Berl* to Berlin: Founding a maritime market city in Hanseatic merchant times 1237−1518

CITY FOUNDING

The exact date of the city's foundation at the northern and southern Spree islands – the heart and cradle of Berlin – is unknown (Figure 23). Nevertheless, archaeological finds trace relicts of Roman-style churches (dated from 1220 and 1230) on both sides of the double-city Berlin-Coelln.[390] The first, at the southern side of Coelln, was the church of St. Petri – patron Saint of fishermen – and the one at the northern side, was the Church of St. Nikolai – patron Saint of merchants. The original written testimony was from October 28, 1237, which mentioned the city of Coelln for the first time. The city of Berlin is referred to seven years later in 1244. Hence, 1237 becomes the official date of the foundation of the double-city of Berlin and Coelln.[391]

The name *Coelln* very likely referred to the merchants from the river Rhine settling at the unsettled narrow Spree crossing. Historic sources referred to Coelln's name as given by the city's sheriff, Schulze Marsilius. The first time he was mentioned in 1247, he represented the interests of the merchants and entrepreneurs from the Rhine. Legends tell that Marsilius himself probably originated from either Cologne or Soest in Westphalia, but the city of Cologne on the river Rhine certainly gave the southern part of the double-city on the Spree River its name from the Latin *Colonia.*[392]

[390] Bauer (1988, p. 24)
[391] Ribbe and Schmädeke (1994, p. 23)
[392] Materna *et al.* (1987, pp. 80–89)

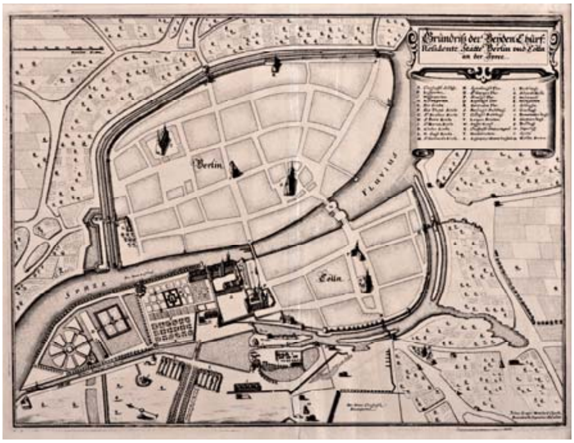

Figure 23: First map of Berlin, Memhardt Plan (1652) – a reconstruction of the double-city from 1237 with Coelln in the south and Berlin in the north.

In addition to the water-cultural associations, expressed by notions such as *Little Venice* or *New Amsterdam*, the city's natural water history is reflected in Slavic etymology. The name of the northern part, *Berlin*, refers to the Slavic word *Berl*. The etymological roots are *brlo* (Ukranian) meaning swamp or *brlja* (Croatian-Serbian) meaning puddle, while describing shallow, swampy waters. Thus, all names refer to the old city's location on low, marshy ground along the Spree River.[393]

Figure 24: Berlin's maritime network (~1500) with the main water route Berlin – Hamburg

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[393] Udolph (1992)

Located on two main trading routes, crossing east-west and north-south, Berlin soon emerged as an important trading center during the Middle Ages. The rivers Spree and Havel connect the Oder and the Elbe as the main rivers bridging south and north (Figure 24).

TRADING AND SHIPPING

The first city wall had been built from stone by 1250.[394] Due to the financial calamity of the territorial lords of Brandenburg, Berlin and Coelln purchased sovereign interests in real estate, land, property, and market space until 1298. Following this, feudal property was abandoned and replaced by common municipal property.[395] In 1307, Berlin and Coelln unified becoming the federal city of Berlin. A common city hall was built at the connecting bridge, the *Lange Brücke*.[396] Berlin had about 7,000 inhabitants at that time. By 1308/09, the first city association of both Berlin and Brandenburg had been founded in Berlin – the so-called *Märkischer Städtebund*. It elected Berlin as its administrative capital. From that time, Berlin developed as a free trading town independent of any dominion power or the protection of a sovereign fortress. Due to its trading network with other maritime cities and Flemish regions, Berlin's merchants organized global trade and majorly influenced urban agricultural production (4.3). It very likely paralleled the foundation of new villages and trading centers in those regions.[397] In 1344, a guild of skippers was founded – presumably an association of Berlin merchants who were also seafarers.[398]

During the Middle Ages, Berlin developed as an important transhipment point by transiting traded goods from water to land. Towards the end of the 13th century, the Mühlendamm was built for two reasons: Firstly, to dam the shallow Spree for better transport, and secondly, to make use of water power. Watermills at Mühlendamm were built and used as flour mills. The *Unterbaum* (the lower dam nearby today's Berliner Dom at Fischerbrücke northwest) and the *Oberbaum* (the upper dam *Mühlendamm* nearby today's *Märkisches Museum* southeast of the city) were installed to control the shipping trade better and mainly for toll collection. At night, this passage was locked by an underwater tree-trunk to block through traffic on the Spree River.[399] This was replaced by a bridge later in the 18th century. From Mühlendamm, non-stop shipping was interrupted due to the separation of the *Oberspree* (upper Spree) and the *Unterspree* (lower Spree). Additionally, Mühlendamm became the central toll collection point for all boats passing Berlin after purchasing the shipping-toll rights from Brandenburg's Margrave, Markgraf Otto IV. Therefore, the former main location at Köpenick, at the south-eastern entrance, moved to the center[400] and Berlin-Coelln developed as the collection point for traded imported and exported goods.[401]

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[394] Bauer (1988, p. 30)
[395] Materna *et al.* (1987, pp. 109–110)
[396] Ibid.
[397] Ibid.: p. 74
[398] Ibid.: p. 96
[399] Bauer (1988, p. 31)
[400] Uhlemann (1987, p. 95)
[401] Ribbe and Schmädeke (1994, p. 27)

Berlin became a member of the *Hanse* – an association of merchants from *Niederdeutschland* (lower Germany) – during the same period. The Hanse existed from the middle of the 12th until the middle of the 17th century to advocate common interests, as well as provide security of overseas transit. Berlin was a Hanseatic city partner from 1358 until 1518.[402] *Hanse goods* shipped in and out of Berlin are documented in a tariff-roll dated 1397 (Table 4). It reflects the natural resources, particularly wood, which Berlin-Brandenburg exported. Although reflecting economic wealth, it also paralleled with times of large-scale deforestation of natural forests in the region, leading to decreasing ecosystem services and the later implementation of a *controlled forestry*[403] (4.2.7).

Table 4: Imported and exported Hanse goods according to the tariff-roll from 1397

Imported Hanse goods	Exported Hanse goods
From Poland: wood, corn, animal skin, wax	From Berlin-Brandenburg: wood, hops and Maerkish wine (main trading routes: via Flanders, Rhine)
From Stettin: salted and smoked herring via the Oder	
From Hamburg: cloth coming from Flanders, herring, stick fish, pepper, ginger, saffron, figs, rice	

In addition to natural wood, other local export goods, such as limestone or bricks, were further valuable landscape products, which can be traced in the oldest accounts from Berlin's department of finances (*Kämmereirechnungen*), dated 1504-1508 (Table 5)[404]. According to the *townbook* of Berlin, wood and rye were the main export goods at the end of the 14th century. Contrary to this, all sea fish, as well as river fish from the Oder, were imported to Berlin from the harbors along the Baltic Sea. Skins and pelts from Russia were shipped into Stettin or transported over land via Frankfurt/Oder.[405]

Table 5: Imported local periurban goods according to the oldest accounts from Berlin's department of finances (1504-1508)

Berlin's locally resourced imports	Periurban resource-scapes
Limestone	Rüdersdorf
Brick-earth	Glindow
Firewood	Via the River Dahme
Plaster	Sperenberg

[402] Materna *et al.* (1987, pp. 95–96)

[403] Schott (1997); Brüll (1998, p. 35)

[404] Uhlemann (1987, p. 180)

[405] Ibid.

Marketplaces were opened close to the parish churches – the *Molkenmarkt* near St. Nikolai (Berlin) and the *Fischmarkt* near St. Petri (Coelln) – for local sales purposes.[406] They sold handcrafts and agrarian products from the periphery, particularly corn, vegetables, fruit, flax, hemp, hops, wool, livestock, poultry, butter, cheese, tallow, eggs, wax, and other vegetable or animal products. Long-distance goods (*Krämerwaren*), such as home appliances or accessories for textile and leather production, were sold by local grocers.[407] The seasonal market, the *Jahrmarkt*, was held in Berlin on May 1, September 14 and November 1 each year, and in Coelln on August 10 and November 11, and was specially opened for non-local merchants.[408]

4.2.6 Urban shipping: Floating goods and river barges in 16th-18th century

The history of the early city reflects the importance of water transportation to Berlin's water-based development. It became a maritime city due to its membership of the Hanseatic League. Traded goods were shipped mainly via waterways, which consequently expanded. Soon, the energetic benefits of water transport compared to land transport were realized. By 1550, the first sluice was built at the city moat in Coelln at the southern arm of the Spree. At the end of the 16th century, there were two sluices on the Havel, one at Spandau (from 1232) and one at Oranienburg (from 1349), while shipping was mainly on *free rivers*.[409]

Along with the introduction of the chapter sluice in Brandenburg (~1650), local shipping was extended in the 17th century. Spandau's first sluice was documented by 1550, whereas Berlin's sluice *Mühlendammschleuse* at today's *Spreekanal* was documented in 1578. It must have been built about 20-25 years earlier,[410] and its original wood construction was rebuilt in stone after its total demolition during the 30-years war under Frederick III in 1694 (Figure 25). The Margrave left a memorial stone with the Latin inscription: "Ligneam invent lapid relinquit," meaning "He found it in wood, but left it in stone."[411]

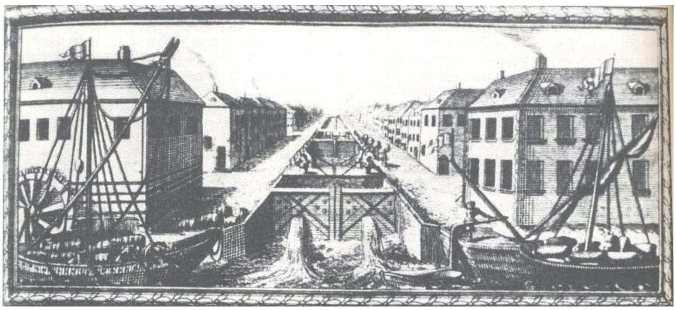

Figure 25: Berlin's new city sluice Mühlendammschleuse *by 1694 – new construction after the 30-years war*

[406] Bauer (1988, pp. 31–32)
[407] Ibid.
[408] Materna *et al.* (1987, pp. 100–102)
[409] Uhlemann (1987, p. 28)
[410] Ibid.: p. 95
[411] In: Uhlemann (1987, p. 97)

The rise of local shipping due to the reconstruction of sluices, respectively new chapter sluices, induced an emerging urban waterfront design, which was introduced by Dutch architects, along with stone reinforcement of the river banks. It led to an almost complete depletion of temporal flooding, which had been a regular *water event* since the Middle Ages. The associated geohydromorphological pattern determined site-specific urban development so far, which included housing on higher hilltops safe from flooding. Available technologies of dehydration and water control (312.1.3) allowed the urbanization of as yet undeveloped river shores along main streams and riparian zones, which are the *Wiesen* (meadows) on historic maps (Figure 26).

The mixture of gardens, pastures, scattered sheds, and stables from this time increasingly transformed into an urban waterfront.

Figure 26: Berlin's Wiesen *– flood-plain meadows along the Spree in the city center (map 1857)*

FROM WATERSCAPES TO WATERFRONTS

A new fortification was built along with the new canals. It included moats 50 m wide and associated impoundments to stabilize the water-table. Therefore, temporal and place-based seasonal flooding, as known from places near the bridges at *Waisenbrücke* and *Gertraudenbrücke* was restricted. As the city expanded, it incorporated former floodplains, transforming its natural waterscape into urban waterfronts. New waterfront quarters, such as *Friedrichswerder* and *Dorotheenstadt*, appeared in the 18th century[412]

The name of Berlin's street on the Spree, *Schiffbauerdamm* (boatbuilder's dam), north of the Spree in Berlin-Mitte and close to *Weidendammer Brücke*, refers to Berlin's place-based traditions of shipbuilding. It emerged along with the establishment of the Prussian Marine Corps in 1657 (Figure 27).

412 Hansen and Mauter (1993, p. 38)

Figure 27: Berlin-Schiffbauerdamm with private dockyard in the foreground and the pleasure boat of the first Prussian King, Friedrich I (1717)

Figure 28: Historic waterfront photo – one of the oldest photographs (1855)

New ships were designed along the new waterfronts (Figure 28). Whereas the wooden barrel, according to Hatebur and Baumann, had been the “container of the Middle Ages,”[413] the *Schute* (barge) gained the significance of a *floating container* subsequently. It provided the daily transport of goods and people. Additionally, it was a symbol of Berlin’s place-based boat architecture in the design tradition of the *Hanse cogge*, which originated in the Netherlands.[414] Whereas the *Havelkahn* was the dominant local fishing boat, the Schute represented Berlin’s dominant freighter ship. Also called a *Zille*, this old German word refers to Slavic influences and the origins of the Roman notion for boat – *Navicella*.[415]

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[413] Hatebur and Baumann (1982, p. 20)

[414] Ibid.

[415] Hatebur and Baumann (1982, p. 20).

URBAN PLEASURE BOATS

In addition to providing floating transport, the Schute became famously known as a symbol of pleasure, which is addressed in the German idea of a *Lustschiff* (pleasure boat).
The Margrave Frederick III (1688-1701), who later became King Friedrich I (1701-1713), had been famous for his maritime ambitions, setting-up a fleet of local ships for pleasure on the Prussian inland waters. As place-based versions of the Prussian Marine barges, they were initially meant for royal yard celebrations and receptions, such as royal guests sailing from one castle to the other.[416] A famous *royal water route* linked the castle of *Schloss Niederschönhausen* on the Panke River with the castle *Schloss Charlottenburg*. Thereby Berlin's third largest river, the Panke in the north – after confluencing with its "larger sister Spree"[417] near today's Invalidenstrasse (center) – was connected via the newly built ditch *Charitégraben* (today's *Spandauer Schiffahrtskanal* – built in 1704) in the west (4.3.2).

Figure 29: Left: Spree gondola *for public transport after crossing to Berlin-Moabit (~1820)*

Boatmen from Spandau introduced the first public water transport for the combined shipping of people and goods during the 17th century. It was followed by *Treckschutenfahrten* as a place-based form of water transport via towing barges. Special dams for towing, such as that at Schiffbauerdamm, needed to be built to accommodate the two drawing horses. Since public transport of the royal employees did not fully stretch the operation, ordinary Berliners could also use them by paying two silver pennies per person. Later, in the 18th century under Friedrich II – Frederick the Great (1712-1786), regular passenger shipping known as *Plaisir-Fahrten* were offered by the boatman A. Meyen in 1740. Gondolas steered by gondoliers were the local pleasure ships (Figure 29) Routes ran along "green water alleys," for example, connecting public gardens in front of Stralauer Tor and the preurban villages of Stralau and Treptow.[418]

[416] Hansen and Mauter (1993, pp. 28–29)
[417] Lemke (1955, p. 58)
[418] Hansen and Mauter (1993, pp. 29–31)

REGENERATIVE WATER TRANSPORT

Cargo shipping was mainly based on regenerative energy utilizing the benefits of water transport from the Middle Ages on (Table 6). Particularly in shallow waters, boats known as *Treidelboote*, initially drawn by people, were soon replaced by horse-power. Additionally, it was a common practice to move traded goods by using sailing barges, such as on the *Oder-Spree-Kanal* in Berlin-Brandenburg, until the beginning of the 20th century.

Table 6: Energetic benefits of water transport compared to land transport

Type of transport	Water transport <> land transport
Weight of goods drawn by one horse [kg]	~1,000
Via narrow channels	~30,000
Via wide channels	~75,000

In addition to energy-saving advantages, water-based transport is often more time efficient. Whereas during the Middle Ages the trading of goods between the Hanseatic cities of Danzig and Lübeck took fourteen days by land, water transport only took four days.[419]

Besides using wind as a natural energy source for shipping, rafting was a complementary form of regenerative water transport. It was, for example, known from timber rafting and described by contemporary witnesses in the mid-18th century. Wood logs for construction purposes were floated into the city leading to severe transformations of the Spree riverbanks.[420] Therefore, the rather wild appearing riparian zones were becoming increasingly claimed and adjusted for the heavy transshipment of urban goods providing daily basic needs, particularly firewood.

DEGENERATIVE SIDE-EFFECTS

Although water transport itself used regenerative power until the beginning of the 20th century, major wood clearances, due to the growing demand for urban firewood transported via waterways since the Middle Ages, showed opposite *degenerative* side-effects. Increasing timber exports from the Brandenburg landscape since Berlin's city founding as a merchants' trading base and emerging economy (4.2.5) were closely intertwined with the history of land degradation through clearance-cutting in the urban context. One example was the clearance-cutting of the *Kämmereiheide* by 1800. This urban municipal forest in Berlin-Wedding (north) became a major industrial site for leather tanners.[421] Once the urban trees were gone, urban windmills came. Wedding particularly developed into a real *mill district*, which is traceable in street names such as *Müllerstrasse*. Urban mills were encouraged and subsidized by the so-called *Prussian mill edict* of October 1810.[422] Previously, large urban soil depletion and wind erosion started, for example, from 1730 along with the construction of a new tariff and excise

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[419] Park (2010, p. 54)
[420] Eberhardt *et al.* (1995, pp. 12–13)
[421] Simon (2001, pp. 17–18)
[422] Ibid.: p. 22

wall for the northern suburbia. To provide construction material, periurban forest northwest of Berlin was clearance-cut and transformed into a wooden fortress.[423]

4.2.7 *Berlin is built from a boat*: Waterfronts and swimming marketplaces in 18th-20th century

FROM WILD TO TAMED RIVERS: URBAN WATER INFRASTRUCTURAL LANDSCAPE INTERVENTIONS

Berlin's landscape metamorphosis from *Berl to Berl-in*, transforming the previous *water-scape* into a *water-city* (4.2.5), became particularly tangible in those neighborhoods either close to the river or to the groundwater table. Pumps, channels and pipes replaced the natural geohydromorphological pattern. Former flood-plains, which existed during the Middle Ages when the Spree frequently overflowed its riverbanks, for example, near today's Hackescher Markt and Lustgarten,[424] were reclaimed for permanent settlement. Controlled by water engineering, damming, channelizing, and advanced hydroengineering techniques, the process of dehydration and colonization of the former *wild* riverscape morphologies, such as natural swamps or flood plains, was facilitated (2.1.3). In addition, natural urban water-flows were increasingly replaced by technically managed and controlled ones.

Table 7: Berlin's growth of population between 1740 and 1900

Year	Number of Berlin inhabitants
1740[425]	90,000
1797[426]	183,960
1810[427]	153,070 (reduced garrison)
1849[428]	328,692
1867[429]	702,437
1871[430]	913,000 (capital)
1900[431]	2,712, 000 (3rd biggest megacity)

Urban water infrastructural landscape transformation was then readable in shorter time spans. The continuing growth of population (Table 7) constantly required new quarters for new people. They were attracted by the Prussian settlement policies after the 30-years war, initiated under Friedrich Wilhelm, the Great Elector. In 1710, under the rule of King Friedrich Wilhelm I (1688-1740), Berlin became the *Royal capital and residential city*. Moreover, the previously

[423] Ibid.: pp. 17-18
[424] Bauer (1988, p. 31)
[425] Uhlemann (1987, p. 181)
[426] Bauer (1988)
[427] Uhlemann (1987, p. 183)
[428] Bauer (1988)
[429] Ibid.
[430] Ibid.
[431] Uhlemann (1987, p. 184)

autonomous cities of Berlin, Coelln, Friedrichswerder, Friedrichstadt, and Dorotheenstadt were becoming unified.[432]

URBAN CHANNELS AND FIRST STEAMBOATS

Urban growth was accompanied by the construction of new waterways and harbors. This reflected on the blooming hydroengineering era, which was associated with the prosperity of urban trade and construction in Berlin and Brandenburg from the mid-18th until the end of 19th century. The first channels for the transport of construction material had already been built in the 16th century, such as in Rüdersdorf (limestone) and along the river Notte (gypsum). Nevertheless, major construction occurred in the 18th century, such as the Storkower Kanal for wood transport (1746) and the Ruppiner Wasserstrasse for wood and peat (1788).[433] Within 120 years, the waterway network surrounding Berlin had been enlarged by 290 km to a total extension of more than 800 km. By the end of the 18th century, Brandenburg's waterway network had reached its general outline (Figure 30). The ships were able to carry up to 100 tons.[434]

Figure 30: The water transport network surrounding Berlin by 1790

New inner-city channels were built from the beginning of the 18th century along with the extension of existing system of urban ditches. They improved the faster transport of construction material right into the city, particularly of wood. In 1705, the extension of the former Landwehrgraben up to Hallesches Tor enabled timber rafting to the Royal wood storage depot. Almost contemporaneous, in 1704, the 2 km long Charitégraben was built branching from the Spree (today's Humboldthafen) and linking it to the Panke.[435] Initially serving Royal barge pleasure trips (4.2.6), it became part of the Berlin-Spandauer-Schiffahrtskanal in the 19th century for the transport of goods.[436]

[432] Ibid.: p. 142
[433] Ibid.: p. 181
[434] Ibid.: p. 182
[435] Uhlemann (1987, p. 97)
[436] Ibid.: pp. 101-112

ZEITGEIST OF MASTERY OVER NATURE

The first steamboat was launched on the Spree in 1816. It was named after the Prussian princess Charlotte of Prussia.[437] Sailing ships were increasingly replaced along with the rise of steam-shipping in the 19th century. Wind as a regenerative power was replaced by coal and diesel oil, and the rivers and channels were adjusted according to the increasing sizes of fossil fuel-powered freighter ships.[438] It was a reflection of the 19th century Zeitgeist and the strong human belief in *mastery*, respectively *conquest of nature*[439]. The cultural historian Blackbourne describes the domination and control of the German landscape. The taming of wild rivers was particularly forced under the rule of the Prussian military after the 30-years war under Friedrich Wilhelm (the Great Elector) and his son Friedrich II (Frederick the Great). It was accompanied by *hard* landscape engineering alongside large-scale dehydration of wetlands and rectification of rivers, as prominently known from the Oder watershed (*Oderbruch*) during the 17th and 18th centuries.[440] This landscape transformation can be physically traced via the morphological transformation of rivers. The riverscape, including its riparian zones, became increasingly adapted to fossil fuel technologies. Particularly in the urban landscape, steamboats literally *steam-drove* waterfront transformation according to the sizes and forms of ships and harbors as major marketplaces and transhipment points. Many rivers became entirely channelized, and new canals linked rivers to each other while further accelerating the water-based transport of goods.

NEW WATERFRONT-NEIGHBORHOODS: LUISENSTADT AND LUISENSTADTKANAL

Freighter-shipping in Berlin was already large by 1820. It was reflected in the waiting times at the city sluice, where the river skippers had to wait to go through the lock for up to six to eight days. The situation became worse about 1840. During peak-times, 65-70 ships had to pass through the locks, leading to waiting times up to several weeks. It impressed the urgent need to build a new by-pass of the city sluice.[441] Consequently, the *Landwehrkanal* was built according to the plans of the landscape architect and urban planner Peter Joseph Lenné. The canalization of the former *Landwehrgraben* (moat) took place along with the city extension of the new *Luisenstadt* at the former *Köpenicker Feld* close to the southern city wall (). Following the course of the Landwehrgraben for about 7.5 km, the channel still provided the discharge of Spree water during river floods and transported wood as far as Hallesches Tor.[442]
Along with Lenné’s plans, which combined infrastructural and aesthetically pleasing requirements, the Luisenstadtkanal became a new centerpiece as an urban waterscape connection between the Spree and the Landwehrkanal (Figure 31). After a construction time of five years, the Luisenstadtkanal was opened for shipping in 1850.[443]

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[437] Ibid.: p. 23
[438] Strauß (2002, p. 15); Park (2010, p. 62)
[439] Blackbourn (2008)
[440] Ibid.; Brose (1994, p. 156); Brüll (1998, p. 39)
[441] Uhlemann (1987, p. 98)
[442] Ibid.
[443] Ibid.: p. 100

Accompanying the canal construction, material was shipped into the Luisenstadt. The former urban garden and farmland grew into a neighborhood. It had become the most populous and largest neighborhood in Berlin by the end of the 19th century (4.3.2). However, the canal's value for shipping was soon limited. Due to the 90 degrees bend at the *Engelbecken* (Angel's basin), maneuvering was difficult. Additionally, both canal basins, the Engelbecke (Figure 31) and the *Wassertorbecken*, were too small to be fully used as docks. Furthermore, the width of the canal was sized according to smaller barges.[444] Thus, enlarging the massive retaining walls made from brick for larger-sized barges was impossible.

Figure 31: Michaelskirche with Engelbecken and Luisenstaedtischer Kanal (1905)

By the end of the 19th century, railway transport had become a strong competitor for cargo shipping. Therefore, after finishing construction at Luisenstadt, the canal lost its relevance for urban transport. Already by 1925, only two or three ships passed through the Luisenstadtkanal per month. The slow velocity (due to the low difference in the water-table between the canal and the Spree), use for wastewater run-off, odor complaints, and hygiene risks led to its closure. The canal was filled in between 1926 and 1929.[445]

SWIMMING MARKETPLACES: ENGELBECKEN AND HUMBOLDTHAFEN

However, before the closure of urban harbors and canals as central points of trade and transshipments of daily goods, Berlin's trading water-sites were literally *swimming marketplaces*, particularly during times of industrial growth.

BERLIN MEGA-CITY

When Berlin became the capital of the German Empire in 1871, the economy was booming. The number of new inhabitants tripled within 30 years, reaching 2,712,000 by 1900 (Table 7).[446] At that time, Berlin was the third largest global megacity population-wise (after New York and London), and the world's largest city area-wise.[447]

[444] Ibid.

[445] Löffler (1995b, pp. 68–71)

[446] Uhlemann (1987, p. 184)

[447] http://www.preussenweb.de/berlin3.htm (2009-12-03)

Although railway transportation competed with shipping, the place-based quote "Berlin is built from a boat"[448] remained typical for Berlin's water-based identity and water city genesis during mega-growth from the second half of the 19th century. Two additional inner-city channels, the *Berlin-Spandauer-Schiffahrtskanal* and the *Charlottenburger Verbindungskanal*, were built,[449] including new innercity harbors, between 1845 and 1875. The *Humboldthafen* was opened as a transshipment point on the Berlin-Spandauer-Schiffahrtskanal between 1847 and 1859, including parts of the former Charitégraben. Located at the site of a former vineyard, which had been owned by a Huguenot family, Menardie, running a restaurant there, it remained Berlin's most important harbor until 1920. The foundation excavation was used to reclaim the eastern Spree swamps,[450] presumably for the new Luisenstadt quarter.

In addition to Humboldthafen, the *Urbanhafen* at the Landwehrkanal was built between 1891 and 1896. Its name was devoted to and derived from the Latin word *urbs* (city) given by the Berlin city planner and head of municipal planning and building, James Hobrecht. Being another important urban water-marketplace, it facilitated the process of rapid urbanization along with the city's extension of land-use according to the Hobrecht Plan from 1862. Furthermore, complementing the Engelbecken, the Urbanhafen provided transhipment of construction material and storage of goods by the Landwehrkanal. It supplied the newly built districts south of the city until the beginning of the 20th century.

In this last phase of large-scale hydroengineering and water infrastructural landscape transformation in an urban and regional landscape context, Berlin announced a record result in the transhipment of goods reaching 10.4 million tons in 1906. The innercity water transport almost doubled between 1890 and 1905. Transported goods were mainly construction material, firewood, sugar beet, and potatoes.[451] About 3 billion bricks were imported to the city from brickyards in Brandenburg via the rivers Spree and Havel between 1900 and 1910; sometimes the production could not meet the demand.[452]

Regarding local prosperity, the harbors were important swimming marketplaces reflecting the close intertwining between the shipping of daily goods and their direct marketing through urban rivers and canals. Thus, the swimming marketplace tradition was closely interwoven with Berlin's local food supply and culinary culture. A contemporary witness described the atmosphere at Engelbecken shortly before the Landwehrkanal was closed and filled in by 1925:

> "Thirty or forty years ago (ca. 1890), the 'Engelbecken' was an officially permitted skating rink frequented by both young and old, situated conveniently at everyone's front door and where the wind was calm as it sat low below the protective sloped banks. During

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[448] German saying: *Berlin ist aus dem Kahn gebaut*. Steinmann (2008, p. 54)
[449] Uhlemann (1987, p. 183); Steinmann (2008, p. 54)
[450] Steinmann (2008, p. 100)
[451] Uhlemann (1987, pp. 183–185)
[452] Steinmann (2008, p. 54)

> Chistmas time, the Bohemian fruit barges would come bringing apples and nuts, docking on both sides of the 'Oranienbrücke' (Oranien Bridge)."[453]

The Engelbecken and the Humboldthafen remained important swimming marketplaces and urban harbors for the transhipment of goods until ~1925, when the majority of new constructions were finished and shipping of goods was replaced by railroad transport.

URBAN SAILING AND PLEASURE BOATS

Although water transport declined, losing its economic relevance with increasing fossil fuel-driven urban development from the early-20th century on, it remained attractive for private water mobility and pleasure. Sailing, pleasure boat trips or rowing were part of an increasing urban water leisure pastime and were illustrated through historic photographs (Figure 32).

Figure 32: Berlin sailing regatta (1895)

While the last few paragraphs reflected Berlin's waterscape biography through its water-living culture as the main facet of preurban and urban aquacultural lifestyle, the next subchapter explores the city's water-farming culture that imprinted Berlin's urban forms, landscape morphologies and culinary culture.

4.3 Berlin's water-farming culture

Apart from the saying "Berlin is built from a boat," one can add "Berlin is a fishing place." Although not quite correct, as the first Berliners were reindeer hunters (4.2.3), this statement contains a lot of truth. Fishing – as a mode of water-farming and a facet of urban aquaculture (2.2) – is traceable as a major form and practice of daily-food provision in Berlin from the middle of the Stone Age.[454]

[453] Paetel (1995) (English translation by C. Champlin and E. Leismer).
[454] http://www.berlin.de/sen/umwelt/fischerei/fischereiamt/de/fischereiaufsicht.shtml (2009-12-03)

In the following, the idea of water-farming culture refers to aquacultural roots from catching fish in rivers and streams to harvesting ponds. It relates to the productive sense of aquaculture. While fishing practices subtracted from Berlin's natural abundance of river fish, Berlin's water-farming culture is a mirror of the productive cultural landscape history. It most often includes integrated waste and water management practiced alongside sustainable periurban aqua-agriculture forms.

Three different types of practices are focused on to show the variety and better reflect on Berlin's place-based variations of urban water-farming:

- *river-fishing* focusing on place-based modes of sustainable fishery, such as practiced in the fishing village of Stralau (4.3.1);
- *riverside-farming* reflecting on urban horticulture and agriculture, particularly focusing on the morphological transformation of the former *Köpenicker Feld* into *Luisenstadt* – literally *from an urban farm into an urban form*, as one of the biggest working and living quarters in Berlin (4.3.2); and
- *periurban aqua-agriculture* accompanied by the introduction of the *Rieselfelder* – Berlin's former irrigated fields as elements of the central sewage system during fast urban industrial growth at the turn of the 20th century – reflecting the city's water-farming culture combined with integrated waste and water management practices (4.3.3).

4.3.1 Early fishermen, fishing rights and duties

Fishing on the Spree River, as one of the oldest local economies in Berlin, is typically authentic for the Slavic period of settlement.[455] Slavic fishing culture is reflected in the names of streets and districts, such as the *Fischerkiez* in Berlin-Köpenick as one of the two early permanent settlements and Slavic headquarters (4.2.4). First fishing practices are traceable through the transfer of fishing tariffs by Margrave Woldemar to the *Jungfrauenkloster* (virgins' abbey) in Spandau in 1318.[456]

Documented overfishing dates back to 1200.[457] Depletion of river fish reached such a state that the previously existing *everyman's right of fishery* had to be abandoned and was replaced by a new fishing policy – the *Fischereirecht*. Consequently, fishermen's guilds were founded, for example, at Tiefwerder near Spandau in 1349, or on the Stralau peninsula on the eastern upper Spree in 1407, strengthening their profession.[458] By 1375, the first fishing villages were officially mentioned in the land register *Landbuch Mark Brandenburg*, for example, Pichelsdorf near Spandau, and Rahnsdorf and Schmöckwitz near Köpenick.[459]

[455] Arlinghaus *et al.* (2002, p. 210)
[456] http://www.berlin.de/sen/umwelt/fischerei/fischereiamt/de/fischereiaufsicht.shtml (2010-08-08)
[457] Arlinghaus *et al.* (2002, p. 211)
[458] Ibid.
[459] Materna *et al.* (1987, pp. 120–121)

A fishery control called *Pritzstabel* (Wendish/Slavic *Pristaw* – steward) was founded in Spandau in 1407 and in Köpenick in 1487 to survey fishery rights. The *steward of fishery* was delegated by the Margrave. The Pritzstabel became a government position in 1639. By 1668, it was publically nominated for the first time as it was repeated in the fishery edict of 1682. As documented, it was a rather unsafe duty, since the fishermen do not want to be called to order, and there was risk of the Pristabel being assaulted.[460] The professional designation was renamed *Fischmeister* in 1907.[461]

Regarding urban fishery, sluice fishery, including fishing in weirs and water ditches, boomed during the Middle Ages. Similar to the aquacultural traditions known from Venice (2.1.1), sluice aquaculture was practiced, for example, near *Mühlendamm*, Berlin's oldest sluice.[462]

Although the Spree had abundant fish due to its extensive flood-plains as breeding and feeding grounds, the first regulations of sustainable river fishery were introduced in Medieval times as a reaction to overfishing. The regulations included, for example, the prohibition of night fishing in Stralau, which was documented for the first time in 1400, and they restricted the sizes of fishing nets up to two-fingerbreadths.[463]
Since waters were becoming further devastated in combination with urban growth, a regulatory law of fishery surveillance was released in 1574 under the Elector Kurfürst Johann Georg.[454] Berlin's first legal basis of surveying fisheries on urban riverscapes and water bodies officially introduced a fishing grace period, making the fishing village of Stralau locally well-known.[464]

Stralauer Fischzug – Local aquacultural ritual and festival

Although the village of Stralau (old German *Strala* or *Strela* – tongue of land) had been a settlement since the Stone Age, it was documented for the first time by Thidericus de Stralow in 1240. By 1398, Stralau was listed as a fishing village in the town register of Berlin encompassing 11 "fisher yards."[465]

Along with the fishery law of 1574, the Berlin peninsula obtained local prominence due to its aquacultural tradition known as *Stralauer Fischzug*. Introduced as an early sustainable fishing practice, it evolved as a local public ritual to ensure food sovereignty through, for example, seasonal restrictions of river fishing to safeguard the fish stock in the Spree. Every year from Holy Thursday to August 24th, St. Bartholomew's Day, the casting of fishing nets was restricted. After the termination of the grace period, on the first day of the new catching season, fishermen pulled in their nets five times, each of which was called a *Fischzug*. While the first four catches created the yearly income of the parson, the last catch benefited the community. The last

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[460] Ibid.
[461] Ibid.
[462] Arlinghaus *et al.* (2002, p. 211)
[463] Arlinghaus *et al.* (2002, pp. 210–211)
[464] Ibid.
[465] Steinmann (2008, pp. 45–46)

Fischzug was the prelude to a celebration of the fishing harvest, also naming the village festival accordingly (Figure 33).[466]

Figure 33: Stralauer Fischzug, St. Bartholomew's Day, August 24, 1888

What originated as a rural ritual, further evolved by becoming an urban folk festival along with urban growth and the termination of the river fishery after 1780. The Stralauer Fischzug gradually turned from a fishing event into a turbulent drinking event, which finally contributed to its cessation by the early-20th century.[467] Hence, the village of Stralau retained its tradition as well as its urban character as a fishing village.

Berlin's fast industrialization led to further decreases of local river water quality, particularly due to increasing wastewater inflows from the textile industry, dye-works and bleaches, such as on the upper Spree.

INDUSTRIAL RIVERSCAPE TRANSFORMATION – CHANGING HYDROMORPHOLOGY, FISH AND CULINARY CULTURE

Until the early Middle Ages, the so-called *king fish*, such as salmon *(Salmo salar)* or sturgeon *(Acipenser sturio)*, passed through the upper Spree. By the 18th/19th century, both species had been seen for the last time in the river. It has not been completely proven if increased industrialization with rising urban run-offs was the main reason for the disappearance, since spawning often failed due to sluices. Besides the depletion of migratory fish, a decrease in the number of crayfish became evident before the 19th century in Berlin-Brandenburg's Spree rivershed.[468]

However, a multiplicity of reasons effected the hydromorphology of fish species in quality and quantity, such as disproportional wastewater run-offs into natural surface waters, overfishing or large-scale water-infrastructural landscape interventions through dams, canals, sluices, dehydration of fens, and wetlands, etc. (→2.1.3; 4.2.6). As far as Brandenburg's fishery was concerned, the decrease of fish became evident and resulted in public indignation, known from the *Deichstiche* – a rebellion of Brandenburg's fishermen. They protested against the major

[466] Ibid.

[467] Hansen and Mauter (1993, p. 28); Steinmann (2008, p. 46)

[468] Köhler *et al.* (2002, pp. 211–212)

losses of fish in the *Oderbruch* by cutting the dikes. It led to a special Edict in 1754 restricting these kinds of civil disobedience.[469]

Regarding fish quantities – with relevance to urban food sovereignty – an urban fishery could feed ~30-40,000 people in preurban riverscape times. Contrary to this, by 1895, the fishery on the river Havel (from Spandau to the estuary) professionally fished by ~69 families could feed ~2,500 people.[470] Although those numbers might underestimate the relevance of local fish production, historic photos from the end of the 19th century of *Fischerinsel* (island of fishermen) near Mühlendammbrücke still give the impression of Berlin as a *fishing town*.

Figures of urban fishery recorded by Berlin's oldest fishery association *Spreeherren* reflect a growing number of fishermen from the 15th to the 18th centuries. In 1407, more than six professional fishermen were registered for the Spree (Stralauer Kiez). By the end of the 18th century, with already 183,960 Berlin inhabitants (Table 7), freshwater fishery provided incomes for a total of 170 people, including 67 Spree fishermen. Nevertheless, from the beginning of the 19th century, the importance of the fishing profession had changed rapidly. By 1867, only 11 fishermen were registered.

From the beginning of the 20th century onwards, industrial riverbank transformations, particularly by water-dependent industries, such as laundries, dye-works and tanneries, provoked further riverscape deterioration. Along with decreasing riverwater quality and fish species towards the turn of the 20th century, culinary cultural habits changed. Attractive fish delicacies such as eel (*Anguilla anguilla*), catfish (*Silirus glanis*), pike-perch (*Stizostedion lucioperca*), or sturgeon species, such as sterlet (*Acipenser ruthenus*), that disappeared from the river, also disappeared from the local menus. The last spawning sturgeons in the Spree were traced close to Lange Brücke in 1845.[471] Less culinary fish, such as Carp *(Cyprinus carpio)*, Carp Bream *(Abramis brama)* or other whiting, as a *new* dominant catch provoked fishermen to complain about the cooking qualities of their wives. An anonymous quote reflects that: "Many young housewives are not able to cook those tastily."[472] Less quality and quantity of river fish stimulated *new* man-made interventions, such as trimming the fish stocks, as reported in the *Oberspreewald* (upper Spree forest).[473]

There were similar hydromorphological changes alongside the construction of water mills, reduction of flood-plains, short cutting streams, or off-cutting old side streams known from the river Panke.[474] Nowadays, a side river of the Spree, in glacial times the Panke had been the main Berlin river, described as "rapid" or "wild."[475] Known for its "crystal-clear water"[476] probably

[469] Brose (1994, p. 156)
[470] Ibid.
[471] Ibid.
[472] In: Köhler *et al.* (2002, p. 212)
[473] Köhler *et al.* (2002, p. 212)
[474] Lemke (1955, p. 46)
[475] Ibid.
[476] Hansen and Mauter (1993, p. 24)

up to the first decades of the 19th century, tasty fish, such as trout, bream, perch-pike, as well as lampreys, had been living in the naturally overflowing Panke River.[477]

Processes of riverscape transformation are closely intertwined with the changing role of local freshwater fisheries. The status of a fisherman changed from a profession to a recreational affair which, consequently, led to subsistence fishery.[478] Due to depleting river quality and fish, Berlin's fishermen's craft became extinct at the turn of the 20th century.

4.3.2 Urban farms become urban forms: Köpenicker Feld/Luisenstadt in the 16th-19th centuries

Similar transformation processes as those described for river-fishing from medieval to pre-industrial times are traceable along Berlin's waterfront development. Whereas the riparian landscapes preciously remained open for *riverside-farming* until the first decades of the 19th century, so far unsettled patches were urbanized with Berlin's megacity growth period. The process of morphological landscape change, literally *from urban farms to urban forms*, can be particularly traced for the *Köpenicker Feld* adjacent to the Spree. The former agricultural field became an urban quarter – the *Luisenstadt*. It was the largest quarter at the turn of the 20th century, today's *Wrangel Kiez* in Berlin-Kreuzberg. The German idea of a *Kiez* thereby describes the place-based individual character and identity of a neighborhood district.

The urban landscape metamorphosis can be mapped back in time via 3-D GIS animations (4.2.1). The Köpenicker Feld gradually transformed from a traditional farmland with pastures, via a mixed landscape of urban gardens, wood storage, lime kilns, and limestone sheds during the 16th and 17th centuries into an urban quarter.[479] From the 18th and 19th centuries on, this urban landscape transformation was characterized by *people move in, farms and gardens move out.*
King Friedrich Wilhelm III (1797-1840) released the deployment of a land-use plan for the Luisenstadt, on the land of the former Köpenicker Feld, south of and close to the city wall, in 1836 (Figure 34). In contrast to other urban quarters that were master-planned from scratch, such as *Dorotheenstadt* (1673) or *Friedrichstadt* (1688), the Luisenstadt grew from its rural past. This was primarily due to the influence of Berlin's landscape architect Peter Joseph Lenné (4.2.7).[480]

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[477] Ibid.
[478] Arlinghaus *et al.* (2002, pp. 212–215)
[479] Eberhardt *et al.* (1995); Löffler (1995a)
[480] Eberhardt (1995, p. 79)

Figure 34: Köpenicker Feld/Luisenstadt shortly before and after the Masterplan (1840-1854)

To start the realization of the new urban design in 1845, large-scale meliorations of so far productively used urban farms and gardens at the lower Spree meadows were induced. Formerly abundant in water and fertile soils, the riverside farms of meadows, pastures and watering places became urbanized. An imaginative description of the former productive foodscape is given by the quote of a contemporary witness drawing a picture of the Spree riverbanks near the Köpenicker Feld south of the city wall ~1735:

> "To the right of the garden, one sees practically nothing other than buildings, stretching into the distance, with soil prime for cultivating. Turning towards the Spree to the left, one views the same: stretches of gardens, fine buildings and apartments and the lime kiln. Space on the bank of the Spree is taken up by rafts and firewood. And further on, one finds beautiful fields, meadows and wooded areas granting such a pleasant and amusing view. Rich fertilizing of the fields allows them to be sown year after year, and they are plusher than the others around Coelln and Berlin. They fill barns and storage rooms better and even produce a better tobacco. Stepping into the yards, the eye could never take in enough of the beautiful pleasure gardens, the most magnificent furnishings, the statues and countless flowers and the fruit-bearing trees and soil. And who would believe that these gardens bear their fruits and greens both naturally and artificially year-round? Go to the mountains and see the same in the beautiful vineyards that bear the savory wine grapes and other fruits."[481]

Bernhardt describes this process as "the expulsion of water from the city,"[482] which paralleled "the expulsion of livestock from the public spaces."[483] He refers to the close intertwining with the paradigm of "the sanitary city," which emerged in the 19th century and strongly influenced urban design and planning in Germany, particularly due to the Prussian policies.[484] Besides the

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[481] German language version In: Eberhardt and Löffler (1995, pp. 12–13) (English translation by C. Champlin and E. Leismer).

[482] Bernhardt (2005)

[483] Ibid.: p. 81

[484] The full consequences of this new cultural paradigm, such as in regard to urban politics, particularly public politics of hygiene in relation to urban and housing affairs, are beyond the scope of this research. Nevertheless, exemplary reference should be made to the profound research by Bernhardt in the context of the Berlin-Brandenburg region,

change of riverscape morphology, morphological landscape transformation from rural to urban pattern becomes readable if one temporal-spatially maps the urban grid. The street pattern of Luisenstadt was derived from rural land boundaries of Köpenicker Feld, traceable in maps of 1772 and 1811 (Figure 35).[485] The urban layout of trails or streets probably referred to the former land property situation documented in the land register, which, for example, detects the course of previous cattle and farm lanes.[486]

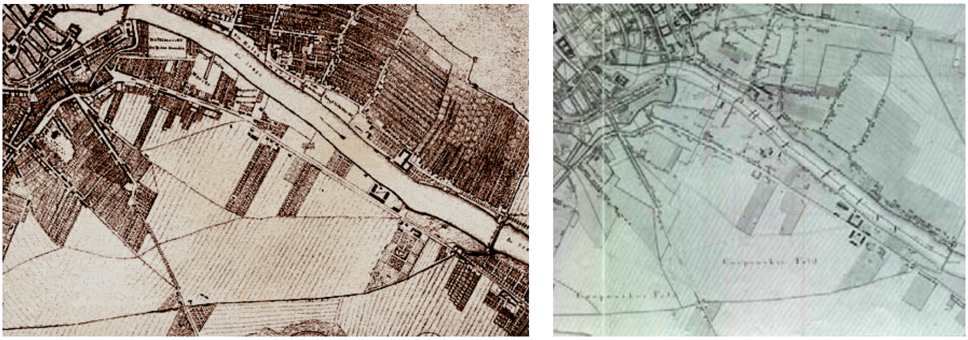

Figure 35: Köpenicker Feld becomes Luisenstadt (1772-1811)

The constant growth of Berlin's population, which for Luisenstadt increased from 13,000 (1802) up to more than 300,000 inhabitants (1900), prompted the tearing down of the city wall in 1867-69. Situated right in the newly settled area, the wall lost its meaning.[487] The Luisenstadt from the beginning of the 19th century gradually changed its economic status from providing urban food farming to being a center of urban handcrafts. Due to its diverse migrational and vocational history, which started with the Huguenots at the end of 17th century, the major shift from rural to industrial businesses happened within 300 years. Gardening, food production or pre-industrial handcrafts, such as tanning or cotton spinning, was replaced by industrial businesses along with the use of steam power. Triggered by the increasing use of fossil fuel energy (mainly pit coal), heavier industrial production and handcrafts became dominant. Metal processing, iron foundries, dye-works, tiled stove and lamp production, printing factories, and industrial ice production[488] were the prevailing urban industries from the 19th century on.[489] Berlin's successful entrepreneur Carl Bolle became famous for industrial ice production. He knew of the value of ice due to his trading business, first of all fresh fish and milk. Natural ice was harvested from frozen lakes, such as the *Rummelsburger See* (Figure 36). In cold winters, up to 500 tons were stored in wooden sheds that were enclosed by special double-insulation, which had also been invented by Bolle.

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stressing the controversial segmentation between sectoral and integrative land-use planning, as well as emerging patterns of social and regional injustice along the emerging policies of "sanitary welfare" Bernhardt (2005); Bernhardt (2009); Bernhardt (2011).

[485] Bürgow and Dalchow (2009)

[486] Eberhardt (1995, p. 79); Bürgow and Dalchow (2009)

[487] Eberhardt and Löffler (1995, p. 15)

[488] Steinmann (2008, p. 49)

[489] Eberhardt and Löffler (1995, pp. 12–14); Löffler (1995a); Schmelich (1995)

By 1900, Luisenstadt had turned into the largest and one of the most populous quarters of Berlin with almost 300,000 people living there.[490] The mix of people, handcrafts and buildings was reflected by a *front-house living* and *back-yard working* culture, which became typical. Nowadays known as *Kreuzberger Mischung* (Kreuzberg's mix), it still reflects the typical work and life culture in the Kreuzberger Kiez.[491]

As urban gardens and food production had to make space for housing for increasing numbers of immigrants during Berlin's industrial boom time, the demand for safe and sufficient water provision, waste management and appropriate infrastructures grew simultaneously.

Figure 36: Ice production at Rummelsburger See (1909)

4.3.3 Urban aqua-agriculture facing *mega-urbanization* and centralization of water infrastructures in the 19th-20th centuries

Berlin became the capital of the German empire in 1871. In addition to its megacity growth, the demand for a central sewage system also grew. The rapid economic development caused a sharp increase in the number of people. More than one million people lived in the city by 1876 and Berlin's population was increasing by more than 3% per year.[492]

Along with the accelerated industrialization from the mid-19th century, the urban water demand rapidly increased, not least due to the latest private fittings connected with water in the home being installed. The English *water closet* had become part of the standard water infrastructure at a building scale. Although a high-tech invention in its time, it needs large amounts of freshwater for flushing. Thus, the increasing amounts of wastewater and its release directly onto streets and into rivers led to insufficient sanitary conditions. A shocking total of 18,806 people

[490] Eberhardt (1995, pp. 77–82)
[491] Löffler (1995a)
[492] BWB (eds.) (1993, p. 28)

died from cholera between 1851 and 1867. This tragic matter compelled James Hobrecht, head of Berlin’s municipal planning, and Rudolf Virchow, well-known physician and city delegate, to initiate a public discussion by *connecting the dots* between sewage disposal and public health.[493] Virchow pointed out that the epidemic danger could only be prevented by installing an underground drainage system.[494]

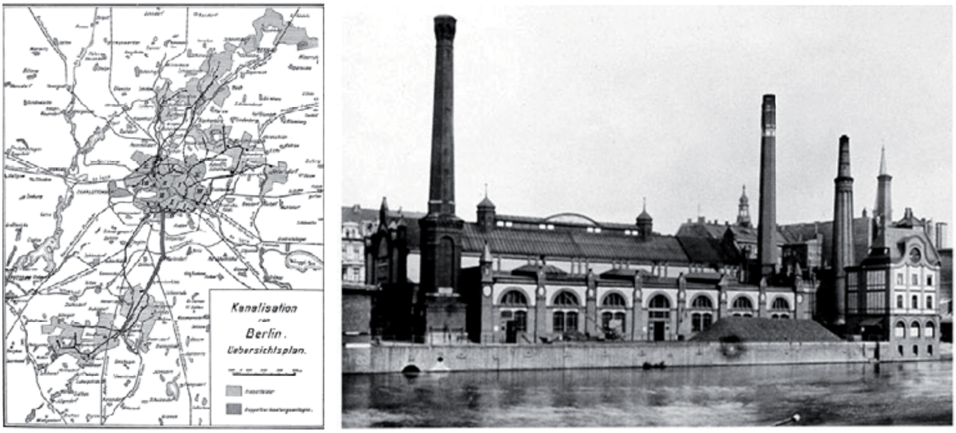

Figure 37: Left: Radialsystem V (start of operation April 1, 1881). Right: Berlin’s central sewage system (~1900)

Hobrecht received the order to conceive a central sewage system in 1869 by designing Berlin’s general wastewater infrastructure layout including the *Mischkanalisation* (mixed sewer for household water, stormwater and wastewater) (Figure 37).[495] The initial sewer system of 1876 was 30.5 km long and comprised 1,025 households.[496] By 1893, 22,250 properties were centrally connected.[497] Dividing Berlin’s waste-watersheds into twelve radial systems, Hobrecht suggests the pumping of wastewater flows to periurban aqua-agricultural farms (Table 8). The farm fields, called *Rieselfelder* or *Rieselgüter* (irrigated fields), provided pretreated wastewater irrigation and land-based water purification. The *Magistrat* (municipality of Berlin) purchased land on the urban fringes of the city for this purpose. The wastewater-based aqua-agricultural fields were connected to individual radial segments. The sewerage from each radial system was pumped via underground pipelines to the related Rieselfeld.[498] The Radialsystem V at Holzmarktstrasse (timber market road), close to today’s Ostbahnhof and nowadays a cultural center, was built as one of the first central wastewater pumping stations and connected to the Rieselfelder northeast of Berlin (Figure 37). It served about 400,000 people.[499]

[493] Ibid.: p. 93; Pawlowski (2004, p. 91)
[494] Bürgow (1998, p. 43)
[495] Mohajeri (2005)
[496] BWB (eds.) (1993, p. 16)
[497] Clemens (1998, p. 5)
[498] Bürgow (1998)
[499] RADIALSYSTEM -V- New Spaces for the Art (2007, p. 4)

Table 8: Berlin's radial systems and associated Rieselfelder

No.	Radialsystem	Rieselgüter
1	I, II, IV	Osdorf, Frederikendorf, Heinersdorf, Kleinbeeren, Großbeeren, Ruhlsdorf
2	III, VII	Vorwerk Schenkendorf, Sputendorf, Schenkendorf (Gütergotz)
3	IV	Wartenberg, Malchow, Blankenburg
4	V	Falkenberg and Bürknersfelde, Hohen-Schönhausen, Ahrensfelde
5	VIII, IX, X	Rosenthal and Blankenfelde, Möllersfelde, Lindenhof and Bauerländereien of Französisch-Buchholz
6	XII	Hellersdorf

In addition to designing the irrigation field layout, Hobrecht advised on the healthy management of periurban aqua-agricultural farms in close cooperation with the physicians Rudolf Virchow and Robert Koch. A quote from the Brandenburg *Hauptarchiv* (central archive) reflects on their hygienic safety when inaugurated: "The expectations for the first waste treatment facility in Berlin and its water purifying capability were high, as the case of Rudolf Virchow's first visit to the treatment facility demonstrates. He scooped up a glass of water filtered by the drainage discharge unit and drank it in front of the crowd, thereby challenging the visitors to test the water for themselves."[500]

DIVERSITY, ECONOMY AND MARKETING OF RIESELFELD PRODUCTS

The Rieselfeld management was linked to periurban farm production. Practiced as combined aqua-agriculture, it referred to traditional cultural forms of integrated water and resource management, such as those practiced in Asia for more than 3,000 years (3.4). Furthermore, they responded to European fishpond culture, having strong roots in Eastern European, particularly Slavic cultures, such as practiced by the Cistercian monks.[501]

The Rieselfeld layout consisted of irrigation ditches, orchards, vegetable patches, and fishponds (Figure 38). The size of the irrigation cells depended on the soil conditions, hence empirical values state that an area of ~100 ha was sufficient to provide for about 75,000 people (Table 9).[502]

[500] German language version In: Bürgow (1998, p. 43) from Brandenburgisches Landeshauptarchiv (n. d.) (English translation by C. Champlin and E. Leismer).

[501] Prein (1990, p. 13); Bürgow (1998, pp. 39–40)

[502] Erbs (1937, p. 585)

Figure 38: Pond and dyke layout of Rieselfeld Blankenburg–Malchow–Wartenberg (north of Berlin)

Table 9: Berlin's Rieselfelder (mainly north and south) by name and size (~1895)

Rieselfeld locations	Size [ha]
Osdorf and Frederikenhof	808
Heinersdorf and Teltower Parzellen	421
Großbeeren	959
Falkenberg and Bürknersfelde	701
Hohen-Schönhausen	100
Ahrensfelde	162
Wartenberg	458
Malchow	558
Blankenburg	280
Rosenthal and Blankenfelde	851
Möllersfelde	60
Lindenhof	164
Französisch-Buchholz-Bauerländereien	289
Blankenfelde-Bauerländereien	85
Hellersdorf	447
Schenkendorf	670
Kleinbeeren	473
Sputendorf	480
Ruhlsdorf	428
Gütergotz	686
TOTAL	9080

As far as the diversity of cultivated crops was concerned, various kinds of cabbage were grown, due to their appropriateness and high demands of water and nutrients. These included white and red cabbage, savoy cabbage, cauliflower, kale, and Brussels sprouts.[503] In addition, root vegetables, such as swedes, beet, fodder beet, sugar beet, carrots, horseradish, celery, onions, leeks, and potatoes, as well as other crops, such as melons, pumpkins, lettuce, spinach, artichokes, mustard, and corn were grown. Moreover, kitchen herbs, such as melissa, thyme, marjoram, rue, mint, sage, lavender, and wormwood were also cultivated. Other produce ranged from tobacco, willows and hemp to strawberries, raspberries, currants, and gooseberries.[504] Agricultural roads were planted on either side with fruit trees, such as pear or apple.[505]

According to Plessen, local food marketing was successful as long as the land cultivated was rather small and the way of irrigating was “something new.”[506] Although the fields provided fresh local urban food production and safe work, the managing of crop diversity required high labor. Additionally, sales in the later years became difficult, most probably due to marketing products as *Rieselfeld crops*. As public demand decreased, products were sold to local food merchants at relatively low prices since the quality of the food was comparably low. Their high water and nutrient contents decreased preservability.[507]

Regarding the marketing of fish, Prein states that, at the beginning, some sales resistance of the waste-fed fish was reported.[508] However, after an appropriate public campaign explaining the nature of nutrient upcycling, the fish marketing had been successful.[509] It primarily paid off by selling carp for the New Year, which is a culinary tradition on New Year’s Eve in certain regions of Germany and many Slavic countries. However, when the scheme started, there had been a threat that the market would be *flooded* with cheap wastewater-fish, but the local farmers’ fears soon disappeared. Saxony and Bavaria by that time had a total fishpond area of 22,000 ha with a production of 2,000-2,500 tons of carp/yr, while additionally importing 1,500 tons per year.[510] Prein refers to investigations by Miller (1914), who compared the economic profitability of different sewage systems. In summary, Miller stated, that although the initial costs for the fishpond system were twice as high (e.g. for trickling or sand filters), in the long run, they were the cheapest method due to producing an economic return.[511] Furthermore, he pointed out that the income achieved through fish sales reduced running costs, but the largest income was obtained through the production of electricity in the hydroelectric power plant downstream of the storage lake.[512]

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[503] Bürgow (1998, pp. 43–44)
[504] von Plessen (1985, p. 321)
[505] Bürgow (1998, p. 44)
[506] von Plessen (1985, p. 321)
[507] Ibid.
[508] Prein (1990, p. 39)
[509] Ibid.
[510] Prein (1990, p. 39)
[511] Ibid.
[512] Ibid.

Wastewater-fed fishponds – Reusing organic wastewater as a resource

Design and production performance

By the mid-19th century, Justus von Liebig (1803-1873), the agricultural chemist, had calculated that amounts of nutrients (mainly nitrogen and phosphorus) were becoming land-based losses if released into natural water bodies. Liebig referred to the agricultural risk of natural soil depletion. Ironically, nowadays, Liebig is better known as the "father of artificial fertilizing."[513]
Berlin's Rieselfeld management reused nitrogen and phosphorus as major daily urban nutrients. Moreover, valuable minerals such as calcium, magnesium, potassium, and sodium were *free* local fertilizers. They served as soil conditioners to regenerate the buffer capacity of the poor sandy clay soils (4.5.2).[514]

Complementing wastewater-based agricultural production, aquacultural production was tested by the engineers Oesten (1887) and Cronheim (1904) at the manors in Malchow and Blankenburg.[515] As Prein pointed out, Oesten's patented design proposal of 1897 was a "three-stage aquaculture system" comprising (1) a microorganism/algae pond, (2) a zooplankton pond, and (3) a fishpond.[516] Furthermore, Cronheim investigated the production performance of "wastewater-fed fishponds"[517] which received mechanically de-sludged wastewater together with larger amounts of freshwater for dilution.[518] They were also called "sewage field drain-fed fishponds"[519] since they were fed with drains from sewage fields. Nevertheless, in reality, the idea of *sewage-fed* was misleading, as there was always a pretreatment step of the primary sewage water. Consequently, the sludge was separated from the inflowing water.
In the sequel of successful results, polishing fishponds for final purification of the drained effluents were implemented at 12 locations (e.g. Blankenfelde, Französisch-Buchholz, Schoenerlinde, Falkenberg, Malchow, Osdorf, Spandau-Wansdorf). The still rather high amounts of nutrients were further utilized from the effluent. By 1924, Berlin had a population of 2.2 million, and ~11,000 ha of irrigation fields, including 114 fishponds with a total area of 84 ha.[520]

Production rates (~150 kg/ha/yr) were comparable to normal ponds. Compared to the channeling of fish into rivers, normal fish production was only about 15 kg/ha/yr.[521]
Regarding effluent quality, the primary aim was to produce low concentrations of bacteria and suspended solids in the water released into rivers and water bodies. A general quality standard is the survival of river trout (*Salmo trutta morpha faria*) and brook trout (*Salvelinus fontinalis*), which have the highest demands regarding pH and oxygen. Therefore, trout serve as living

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[513] Mahal (1994, p. 25); Bürgow (1998, p. 42)
[514] Bürgow (1998, p. 43)
[515] Prein (1996, p. 156)
[516] Prein (1990, p. 16).
[517] Ibid.
[518] Prein (1996, p. 156)
[519] Prein (1990, p. 15).
[520] Prein (1990, pp. 14–16)
[521] Ibid.: p. 15

indicators in a final control basin, reflecting the high water quality as well as utilization of nutrients.[522]

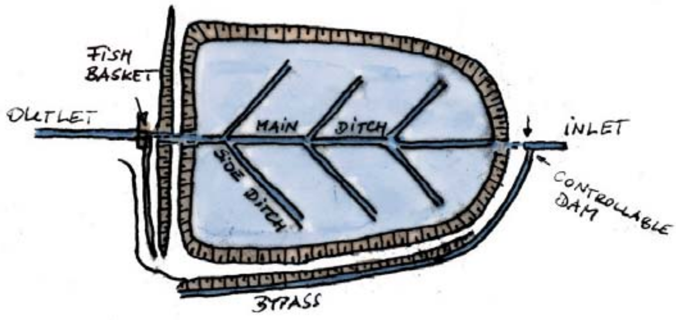

Figure 39: Regular pond layout: moat surrounding main drainage channel with fishbone-like side-ditches

High productivity, hygienic safety and space efficiency were positive results of the initial fishpond experiments by Oesten and Cronheim in Berlin. Simultaneously, a public debate opened about farming fish while safely reusing household wastewater nutrients, leading to an upscaling of Berlin's Rieselfelder.

Figure 40: Most common fish cultivated in wastewater-fed ponds. Left: common carp (Cyprinus carpio), Right: tench (Tinca tinca)

PUBLIC HEALTH, BIODIVERSITY AND RECREATION

Permanently checked by the commission for food safety, health risks were annotated "of no concern" by the "thorough German officials."[523] Regarding counts of bacteria, including coliforms, a proper functioning of the wastewater-fed fishponds revealed a 99% reduction compared to the input water.[524] According to Prein, no data on human pathogens in ponds and fish had been published, and citing Demoll (1926): "The fish (…) do not differ from any fish which are grown in well-kept fishponds."[525] Checked by governmental laboratories, human pathogens have been never found in fish muscle. However, increasing loads due to growing water consumption,

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[522] Prein (1990, pp. 14–16)
[523] Prein (1990, p. 36)
[524] Ibid.
[525] In: Prein (1990, p. 36)

as well as continuing industrialization and agricultural intensification caused rising health risks through soil and groundwater contamination by heavy metals and other chemical substances.[526]

Since winter temperatures were too low for substantial carp fish production coupled with wastewater polishing, the fishponds were run from March/April to October/November. The annual harvest was between 100 and 150 tons. The fish were sold to restaurants and large institutions, while being monitored on a regular basis by the health authorities. According to microbiological measurements, the total concentration of fecal coliform in the pond water was equivalent to 10^1-10^3/100 ml. These levels were considered safe for the fish flesh to remain free from pathogens. According to official reports, the fish quality complied with the standards of the German Federal Bureau of Health. Furthermore, heavy metals and aromatic hydrocarbon concentrations met governmental standards.[527] As far as heavy metals were concerned, it was stressed that, due to binding in the loamy soils[528] and pond sediments, they were not harmful to fish.[529] This insight also harmonized with results from the Kolkatta wetlands (3.4.2).

Wastewater-based fish production throughout Germany was rather widespread from the end of the 19th century until the 1950s. Around 90 schemes existed at that time, either fed with pre-treated wastewater diluted with freshwater or with secondary water (e.g. nutrient-rich effluents from sewage fields) to feed fish and finally polish the water.[530]

However, as Bernhardt points out: "(…) in the course of the 1920s, the new sanitary system showed its limits, not only in spatial, but also in technological and social regards. (…) To continue the established practices would have meant expanding the sewage farm system by investing large amounts of money."[531] Furthermore, the shift towards heavy urban industrialization led to the maximum irrigation capacities being exceeded from the mid-20th century onward. Therefore, the Berlin Rieselfelder were gradually closed down and replaced by mainly monofunctional and fossil fuel-based urban water infrastructures. The mixing of biodegradable household waters with non-biodegradable industrial sewerage containing harmful toxic substances increased technical treatment efforts. While the proportion of heavy industrial waters was 7.3% in 1926, it rose further with the intensification of irrigation. The increasing interference with ecosystem and public health concerns[532] led to the final closure of the last Rieselfelder in the mid-1980s. Last but not least, both rising land prices at the urban fringes and deteriorating surface water quality and quantity were further reasons for the termination of this unique aqua-agricultural landscape infrastructure.[533]

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[526] Strauss (1996, p. 84); Bernhardt (2011, pp. 162–163)
[527] Strauss (1996, pp. 83–84)
[528] Böken and Hoffmann (2009)
[529] Prein (1990, p. 36)
[530] Ibid.
[531] Bernhardt (2011, pp. 162–163)
[532] Prein (1996)
[533] Ibid.: p. 157; Bürgow (1998, pp. 46–48)

Facing contemporary issues of sustainable urban wastewater management while securing natural drinking-water quality and quantity, the following quote of Prein intriguingly reflects the challenges of a similar urban aqua-agricultural infrastructure: "The quality of effluent from the ponds was comparable to that of natural water."[534]
However, contemporary challenges of water and climate change adaptation provoked the revitalization of large parts of the Berlin Rieselfelder (4.5.2).

4.4 Berlin's water-wellbeing culture

Clear and fresh water as a daily symbol of leisure, human health and well-being is inevitably intertwined with an urban quality of life.[535] The final sub-paragraph explores characteristic aquacultural facets along with Berlin's water-wellbeing culture. These factors associate particularly with the everyday cultural production, use and handling of freshwater.

Two features of Berlin's water-wellbeing culture including public health issues are in focus to trace place-based traditions and practices:

- urban recreational bathing and swimming culture, and
- drinking and washing culture, which includes local drinking water production and beer-brewing traditions along the river.

4.4.1 Urban bathing and swimming culture from medieval to industrial times

Urban bathing culture has been part of everyday cultural life in Berlin since medieval times. The barber surgeons, who were organized into an individual guild outside the handicraft trade, received their own professional regulations in 1462.[536] This paralleled an emerging spa culture in famous water places throughout Europe,[537] including the city of Berlin.
However, due to the occurrence of syphilis, medieval bathhouses soon disappeared.[538] Berlin's last bathhouse *Am Kroegel* (behind the Molkenmarkt) closed in 1678. Thereafter, bathing went out of fashion until the beginning of the 19th century.[539] Nevertheless, an everyday water-culture remained alive as it was a meaningful part of the city's aquacultural biography. Berlin's bathing and swimming culture particularly can be traced through famous public bathhouses and lidos. They have been influential until today, particularly reemerging alongside a contemporary urban water-wellbeing culture in the light of post-industrial waterscape developments (4.5.1). However, natural wells also served public health and wellbeing in cities over centuries.

[534] Prein (1990, p. 36)
[535] Chapman and Larkham (1999)
[536] Materna *et al.* (1987, p. 96)
[537] Kiby and Kramer (1993); Auer (2004, pp. 28–31)
[538] Kiby and Kramer (1993, p. 57)
[539] Hansen and Mauter (1993, p. 32)

THE (HI)STORY OF GESUNDBRUNNEN – THE *HEALTHY WELL*

A mineral spring north of Berlin, on the River Panke, has become the titular saint for a central place within the quarter of Wedding known as *Gesundbrunnen* (healthy well).
The legend refers to the regent Friedrich I (1688-1740), who enthusiastically recounted that the spring water tasted like iron when he tried it during a rest on a hunting trip at the mill near the mineral spring.[540] Friedrich II (1712-1786) prompted the chemical examination of the water. Due to its special character, the well was exploited and acquired by the pharmacist Heinrich Wilhelm Behm by 1757. Sensing a lucrative business, Behm further extended the well and its surroundings by establishing a bathhouse, a well-house, stables, and a dairy farm, besides gastronomic facilities.[541] The *grand opening* of the initially named *Friedrichs-Gesundbrunnen* was in 1760, and a quote from a brochure published by Behm reflects on his business endeavor:

> "We keep a lifeguard on hand, who doubles as a surgeon. He makes preparations for the bathers and caters to his guests in an artful, if not scientific manner. There is a chef in an adjoining building who delights in the preparing of his delicious meals. Whether a nice glass of French wine or a German Moselle, or a healthy fermented beer, he always serves up the finest drinks."[542]

A *corp de logis*" – two side-wings with open arched hallways and a garden – were constructed by 1768, besides the well-house bearing the inscription: "In fonte Salus" (In the source lies health).[543] In addition to high-society and bourgeois spa guests, city strollers were soon using the space and a tavern opened beside the well.[544] In 1809, the Friedrichs-Gesundbrunnen was renamed *Luisenbad* in honor of Queen Luise (1776-1810). At this time, the *healthy well* became one of the great urban entertainment places, including more than 40 cabarets, coffeehouses, beer taverns, and dancing halls, and was nicknamed *Plumpe*.[545]

Berlin's industrial growth during the 19th century induced the establishment of other bathhouses in Berlin's typical block-units, for example, the *Marienbad* (today's Badstrasse 36).[546] Along with the emerging urban proletarian culture towards the turn of the 20th century, a public coffee kitchen opened in 1906.[547] As part of the public beer- and coffee-garden tradition, the guests only paid for hot water or corkage.[548] This reflects on the kind of *socially responsible price-making*. Due to the growing number of hard-working people, a new proletarian beer-garden culture in the neighborhood of Luisenbad emerged, such as at *Weimanns Volksgarten* with a

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540 Kuhrt and Gebhardt (2002, p. 8)
541 Ibid.
542 German language version in: Kuhrt and Gebhardt (2002, p. 8) (English translation by C. Champlin and E. Leismer).
543 Hansen and Mauter (1993, p. 27)
544 Ibid.
545 Kuhrt and Gebhardt (2002, p. 9)
546 Ibid.: p. 53
547 Gärtner and Mäder (2009)
548 Ibid.

capacity of 10,000 people. Theater was also performed in addition to the restaurant provided. Up to 60,000 Berliners spent their spare time here on special days, such as Whitsun.[549]

Unfortunately, public use of the *healthy well* compared with its neighboring River Panke was not the same. From 1850, 30 tanneries were established upstream of the well, releasing their wastewaters into the Panke, leading to its new nickname “Stinkepanke” (stinky Panke).[550] Until 1880, about 15 leather factories, 16 tanneries, one butchery, and two papermills were operating along the riverbanks between Soldiner Brücke and the Panke estuary on the southern Spree. Increasing housing construction in the 1860s damaged the well and ten years later, along with excavation works, the well disappeared. The well-house was torn down and a tenant house built on the property of Badstrasse 39 by 1890.[551]

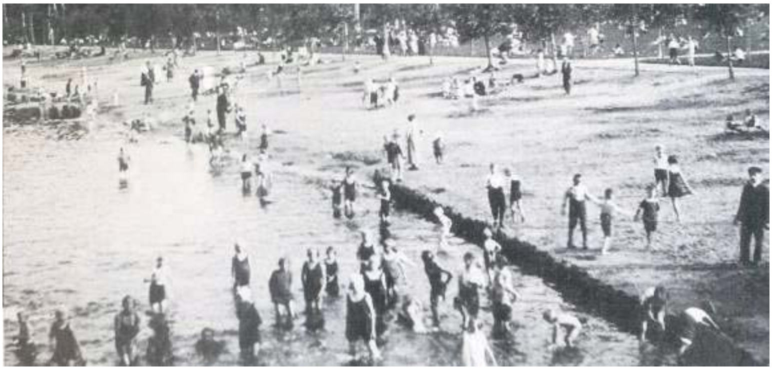

Figure 41: Swimming in the river (~1926)

Although the surface water quality deteriorated severely, the Panke itself became and remained a place of urban water-wellbeing at the beginning of the 20th century along with Berlin’s megacity growth and heavy industrialization. The Berliners longed for cool refreshment, particularly during hot summers. Urban waterscapes in general provided leisure in winter too, particularly through ice-skating on the frozen canals. These public uses reflect the social side of an urban aquaculture as closely related to water-wellbeing (Figure 41).

PUBLIC BATHHOUSES, BATHING SHIPS AND URBAN LIDOS

Water places, and public bathhouses in particular, have been central meeting places in cities providing urban communication and relaxation, such as were particularly known from Roman or Arabic culture.[552] A place-based example of Berlin’s 1920s bathhouses was the *Admiralsbad* (today’s Admiralspalast) in Berlin-Friedrichstrasse.

[549] Kuhrt and Gebhardt (2002, p. 53)
[550] Ibid.: p. 9
[551] Ibid.: p. 53
[552] Kiby and Kramer (1993, pp. 60–72)

Joseph Roth, a philosopher and journalist in Berlin during the *Golden Twenties* and known for his *flânerie stories*, portrayed the nightlife atmosphere at Admiralsbad as follows:

> "But, he (the traveler) thinks such an involuntary bath, because one cannot find a hotel, is not unpleasant at all. (…) Humans in their primitive state stroll through the hallways of the Admiral Palace. The country roads of the world must have looked like this when they were still completely young and the collection of ladies and gentlemen was still not a flowering branch of trade."[553]

The history of the Admiralsbad began in 1867.[554] During construction work on the location, a brine well was found, prompting the architects to build a small bathhouse, which was replaced by a new building in 1910. The new *Admiralsgartenbad* (admiral's garden bath), with its representative architecture, including a main swimming pool of 14 m length by 5 m width, soon became a popular place. According to Steinmann, the interior design was luxurious. It embraced numerous Roman-Russian baths, and individual men's and ladies' bathing rooms with classic mosaics and sculptures. They were supplemented by an "exclusive coffeehouse," a "two-storey cinema" and "an ice-rink 50 meters long by 23 meters width."[555] Providing both urban entertainment and water pleasure, the Admiralsbad was an authentic example of Berlin's water-wellbeing culture up to the first decades of the 20th century.

In addition to recreational bathing, swimming became popular from the end of 18th century. In light of a new Zeitgeist at the turn of the 19th century, as Heidenreich pointed out, a new "cultural body image" arose.[556] As swimming in cold water was popularized, a rising trust in natural body power to resist diseases emerged (2.1.2). On a similar basis, public pools and lidos emerged at urban water-shores.[557]

One of Berlin's first public swimming pools, after the closure of the last medieval bathhouses at the end of the 17th century, opened in 1802 at today's *Museumsinsel* (Museums Island). It was followed by the *Welpert'sche Badeschiff* (Welpert's bathing ship) at *Lange Brücke* close to today's city hall, the *Rote Rathaus*, in 1803.[558] The bathing ship consisted of a wooden pontoon and was roofed with a tent-structure creating a floating bathing-tent architecture (Figure 42). The physician Dr. Welpert offered various medical water treatments, such as bran, sulfur or saltwater baths, in addition to tropical droplet baths.[559]

The new public pools on the Spree River were not solely meant for medical treatments. In fact, they were also the cradle of water sports. Swimming sports, particularly, emerged along with the

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[553] German language version in: Roth (1999, p. 113) (English translation by C. Champlin and E. Leismer).
[554] Steinmann (2008, p. 91)
[555] Ibid.
[556] Heidenreich (2004, pp. 245–246)
[557] Ibid.
[558] Hansen and Mauter (1993, p. 32); Steinmann (2008, p. 83)
[559] Conradt and Korte (2005, p. 127)

sports movement directed by F.L. Jahn and K.F. Friesen.[560] Another key person in the development of swimming disciplines was the Prussian General von Pfuel, who taught at the Prussian General School. Pfuel set up a wooden river swimming barge (*Badeprahmen*) on the Spree at Köpenicker Str. 11. In addition to its military use, it was opened to the public becoming known as *Pfuel'sche Badeanstalt* (Pfuel's swimming pool).[561] Pfuel was motivated to test and teach his new swimming technique, which imitated the movements of frogs. Due to its success, his swimming classes became a model for other swimming schools as well as river swimming pools which emerged all over Germany afterwards.[562] The first swimming clubs were established during the same period. The first German swimming association *Tischysche Frösche* was founded in Berlin-Moabit in 1840. The name *frogs* presumably referred to Pfuel's swimming style.[563] The swimming training included three steps of learning: The first step was performed suspended from a fishing-rod, which was replaced by a retaining strap in the second stage, and finally, a loose rope.[564] This was the standard in swimming schools for more than 100 years, and his model was only replaced by learning techniques without any devices in 1920.

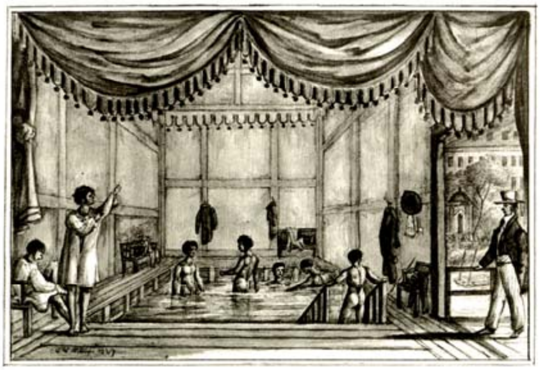

Figure 42: Bathing tent, watercolor, L.L. Mueller (1827)

Along with public bathing in designated pools, *wild bathing* became widespread. Although the police tried to stop it, there was no penalty that could really curtail the *free pleasure* of river bathing in the Spree and the Panke or in the city moats of *Kupfergraben*, *Schafgraben* or in the *Tiergarten*.[565] The growing demand for public bathing and urban lidos is illustrated in a letter drafted by the police department of Charlottenburg: "The need for recreational bathing seems to grow day by day. Each city seeks to assure that safe public swimming areas are procured and constructed."[566]

[560] Hansen and Mauter (1993, pp. 33–36)
[561] Ibid.
[562] Steinmann (2008, p. 58)
[563] Hansen and Mauter (1993, p. 36)
[564] Steinmann (2008, p. 58)
[565] Steinmann (2008, p. 83)
[566] German language version in: Steinmann (2008, p. 83) (English translation by C. Champlin and E. Leismer).

More bathing-ships opened over the following years, such as *Pochhammer'sche Badeanstalt* in 1828. The first public river swimming-pool began its operation at the *Waisenbrücke* in 1850. Fourteen additional river swimming barges were opened up to 1904. The most well-known ones were located behind the *Werdersche Mühlen* (Werder mills), for example, at *Nordhafen* (northern harbor), *Schillingbrücke* (Schilling bridge) below *Lessingbrücke*, behind Mühlenstrasse (Berlin-Wedding), and at Cuvrystrasse (Berlin-Kreuzberg).[567]
Since only men were allowed to use the bathing-ships at that time, eventually, almost 30 years after Welpert's bathing-ship had opened, the first bathing-ship for ladies was moored at *Moabiter Brücke*.[568] Opened in 1831, this location was run by a woman, Amalie Lutz, who further attracted female celebrities of that time, such as the composer Fanny Hensel, who was a sister of Felix Mendelssohn Bartholdy.[569]

In addition to the so-called *wooden boxes* emerging all along the river[570], a more natural and *truly* urban swimming culture developed at the turn of the 20th century. Public swimming pools and lidos in the city's green urban areas emerged, particularly at Wannsee (*see* means lake) in the western part, and Müggelsee in the eastern part. One of the most popular lidos due to its sandy beach and clear swimming water was the *Badeanstalt Rohrgarten* in the Grunewald forest close to Wannsee. After becoming the first municipally authorized lido in 1907, other public lidos followed, such as the *Strandbad Müggelsee* in 1912. Its guests in the first year numbered 177,000.[571]

Figure 43: Swimming festival at Kochsee in Charlottenburg (1910)

River bathing and public pools became essential to Berlin's place-based urban aquaculture. As part of its water-wellbeing facet, a drinking and washing culture emerged in parallel at the beginning of the industrial era.

567 Hansen and Mauter (1993, pp. 33–34)
568 Steinmann (2008, p. 83)
569 Ibid.: p. 107
570 Hansen and Mauter (1993, p. 35)
571 Ibid.: pp. 35-36

4.4.2 Drinking and washing along the rivers of Berlin until industrial times

Before introducing a central drinking-water supply in 1853 along with the initial groundbreaking of the first waterworks, the Berliners received their water for drinking and washing purposes either directly from the rivers or from local wells.
Presumably, the quantity and quality of drinking-water had been sufficient until the start of industrial urban development in the late-19th and early-20th centuries. As primarily bio-degradable (waste-)water fractions from domestic sources and workshops is released into surface waters, the natural self-purification capacity of water bodies can regenerate. However, after 1850, along with the constant growth of population towards the margin of a million, hygienic risks increased. Various waste and wastewaters overloaded the gutters, particularly effecting the water safety of the wells. The demand for safe public drinking-water supply was growing.

CENTRAL DRINKING-WATER AND DAILY WATER INFRASTRUCTURAL-CULTURAL PRACTICES

The foundation of a central water supply in cities was laid and introduced by English engineers in the 18th century.[572] Due to the invention of the steam engine, pumps could be run, and the process of cast-iron pipe production enabled the replacement of less durable materials, such as wood, brick or lead. New iron and ferroconcrete construction techniques in the 19th century allowed subterranean developments such as culverts. Modern English living quarters equipped with a central water supply soon became a model for other major European cities.[573]

Figure 44: Left: Berlin's first waterworks run by the private English Berlin Waterworks Company at Stralauer Tor (1856). Right: Water tank at windmill hill – today's Wasserturm *at Prenzlauer Berg (1856)*

Regarding the city of Berlin, von Hinkeldey, the chief of police, on behalf of the Prussian state government, contracted the private operators Charles Fox and Thomas Russel Crampton to install the city's central water supply in 1852. The initial contract commenced in 1856 and

[572] Kiby and Kramer (1993, p. 94)
[573] Ibid.

included a duration period of 25 years. It prompted the foundation of the stock corporation Berlin Water Works Company, London, with a stock capital of 1.5 million taler.[574]

The Berlin water strategy by the mid-19th century envisioned a rather complete urban water supply via surface water captured from the main river Spree. In 1853, the first waterworks at Stralauer Tor at the Stralau peninsular on the Spree was built by the English engineer Henry Gill, who later became the director (Figure 44).[575] Spree riverwater was pumped into high-level reservoirs, which simultaneously serve as settlement tanks. After the pretreatment, the water further passed through open sand filters and finally ran into a clean open water tank. Fresh drinking-water was pumped via the water tanks, which arose as new urban landmarks, into the supplying net. Due to additional high-level water tanks installed at the city's highest points (e.g. the former windmill hill and today's *Wasserturm* in Prenzlauer Berg), day-and-night water supply could be facilitated (Figure 44).[576]
Initially, public acceptance of the new water supply was low. The people resisted literally *drinking water from the river*. River-based drinking-water production thereby also included abstraction of water from major lakes fed by the Spree and Havel rivers (e.g. Müggelsee and Tegeler See). Berlin's river and surface water was losing a lot of its quality due to fast city and industrial growth from the mid-19th century onwards.

However, by realizing the benefits of a central supply, the number of houses with central drinking-water in 1864 was tenfold greater compared to 1857 with only 300 houses being initially connected to the central net.[577] Since water tax was a percental proportion of the rent, water consumption increased fast.[578] It was, furthermore, triggered by new building-related water infrastructures, such as the water-closet and bathtubs, which initially were only used by the upper classes. At the beginning of the second phase of industrialization at the turn of the 20th century, these assets increasingly became living standards. Working and middle class people could also allow themselves the luxury of private bathing. Whereas smaller middle-class apartments might have mobile bathrooms through installing flexible and space-efficient foldaway bathtubs, low-income households might indulge themselves in borrowing a bathtub, including or excluding warm bathing water, as a kind of *temporary water wellbeing* (Figure 45).

The increasing number of water-closets in private apartments led to an increasing amount of wastewater. However, the disposal of urban wastewater became tedious since it was mostly performed via horses and carts in the mid-19th century (Figure 45). Furthermore, town hygiene became an emerging issue as the growing amounts of wastewater were released into the gutter. The number of ~19,000 Cholera deaths which occurred between 1851 and 1867 became the main reason for installing Berlin's central sewer system from 1876 onwards (4.3.3).[579]

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[574] BWB (eds.) (1993, pp. 12–13)
[575] Ibid.
[576] Ibid.
[577] Ibid.: pp. 13-16
[578] Ibid.
[579] BWB (eds.) (1993, p. 16); Pawlowski (2004)

The industrial Zeitgeist at the beginning of the 20th century accelerated the installation of private water assets, which soon became a modern standard. As industrialization speeded up (~30,000 new inhabitants moved to Berlin between 1860 and 1870), there was an increasing need to expand the central public water and wastewater infrastructure network.[580] As the construction of urban water infrastructures and consumption of water accelerated, the need to build additional waterworks also grew. The English Berlin Water Works Company would only be willing to invest if the duration of the contract was extended for another 25 years. However, the city government refused, and in 1873, Berlin's central water infrastructure was re-transferred into public ownership, while Henry Gill still remained as a director.[581]

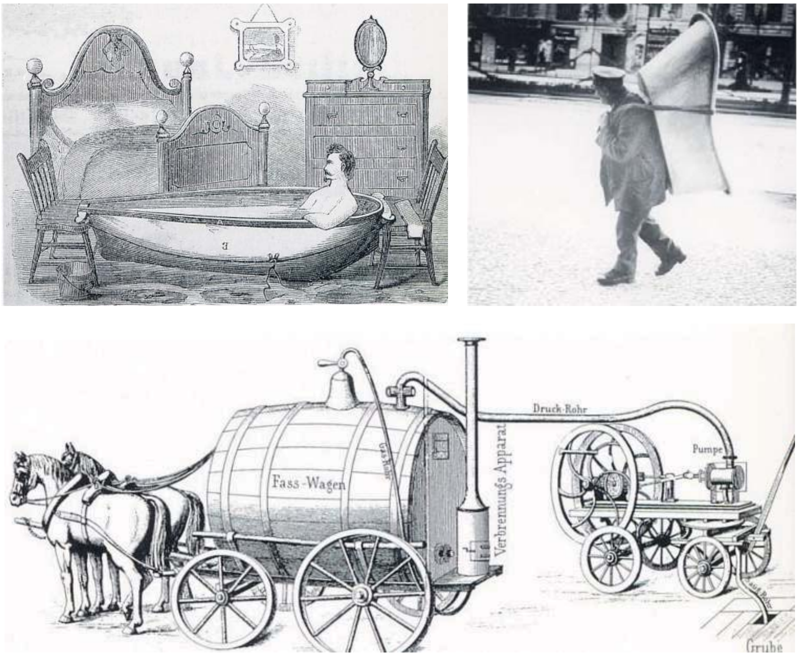

Figure 45: Top left: Foldaway bathtub. Top right: Borrowing bathtub.
Bottom: Urban wastewater disposal in the 19th century via horse-drawn vehicles

SWITCHING FROM SURFACE WATER TO GROUNDWATER USE

In the following years, improved hydromorphological investigations along with better cartographic and drilling techniques led to the expansion of the central drinking-water supply. The urban population rose by 3% between 1876 and 1885, and the existing waterworks at Stralauer Tor reached its limits in terms of capacity and space.[582] The civil engineer, Ludwig

[580] BWB (eds.) (1993, pp. 16–17)
[581] Ibid.
[582] BWB (eds.) *et al.* (2008, p. 28)

Alexander Veitmeyer, had already explored the water conditions of Tegeler See (northwest) and Müggelsee (southeast) on behalf of the municipality in 1868. Cushioned by this preliminary work, Henry Gill launched the new waterworks at Tegeler See with a daily capacity of 86,400 m³ in 1874.[583]

Nevertheless, the use of groundwater was soon recommended by the public authorities because of further deterioration in the quality of surface water, mainly due to increasing barge traffic and industrial wastewater released upstream of Stralauer Tor. Consequently, the Stralau waterworks finally had to close down 1893.[584] Although meant to improve hygiene and public health, problems occurred because of high iron content in the groundwater and a lack of adequate removal techniques. Public pressure to ensure safe water supply increased. As enlargement of the existing Tegel waterworks beside the river Havel nearby Spandau were limited because of both additional water withdrawal and further extensions along the downstream Havel lakes, Henry Gill decided to extend Berlin's drinking-water production on the Spree further upstream. Construction works started along the lakeshores of Müggelsee in 1888 (Figure 46). In the same year, about 1.3 million people were connected to the central water network. Piping was almost 640 km total in length and the highest daily usage per person was 92 liters, almost the same as today's figures with the difference that Berlin's sewer network nowadays is more than 8,400 km.[585] Gill's calculations were based on a population of 2.5 million people with a daily peak consumption of 100 liters per person, amounting to 250,000 m³ in total. If the productive capacity of Tegel (86,400 m³/d) were deducted, the Müggelsee plant needed to provide 163,300 m³ of freshwater per day, which amounted to a permanent lake water withdrawal of 2 m³/s.[586]

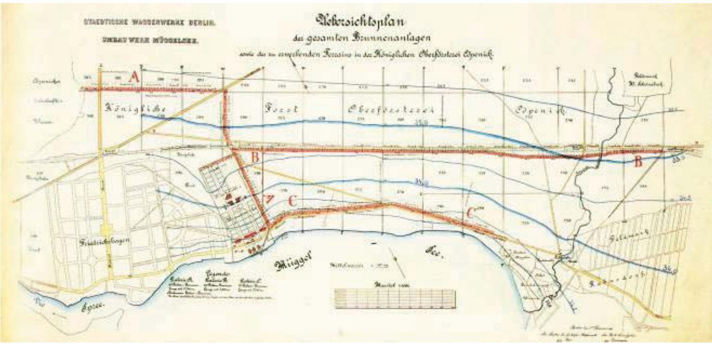

Figure 46: Layout of wells at Müggelsee (December 1, 1903)

In addition to the new Müggelsee waterworks, regular water quality controls were introduced and performed by the Hygienic Institute of Berlin. However, lake water quality decreased in the

583 Ibid.: p. 18
584 BWB (eds.) (1993, pp. 16-28; 45-47)
585 Reichert (1994, p. 9)
586 Ibid.: pp. 28-39

following years as more factories were built and operated upstream of the lake. Therefore, drinking-water production switched after a certain period from the predominant use of surface water to groundwater, similar to the Tegel waterworks. The public water supply in 1890 still used filtered river water from the Havel and Spree without any quality constraints. Hence, a municipal resolution to redesign the waterworks at Tegeler See and Müggelsee switching from surface to groundwater production was adopted ten years later. The withdrawal of lake water from Tegeler See stopped due to exceeding capacities in 1902, whereas the redesign of the Müggelsee waterworks, along with the construction of deep-well pumps adjacent to the lakeshore, started in 1904. The maximum capacity was increased up to 172,800 m³/d, which is similar to a maximum production rate of 2.5 m³/s.[587]

Three groundwater galleries including 350 wells for producing groundwater were built with eight to eleven comprising a group along the Müggelsee, which were connected to a collecting pipe ending in an 8 m wide by 10 m deep collection well (Figure 46). Each groundwater well was 40-50 m deep and had a maximum capacity of up to 6-8 l/s.[588]

Discussion of groundwater versus surface water use

The use of groundwater is problematic from the perspective of blue-green landscape services. Underground water-flows were accelerated, particularly pumping from deep groundwater tables. The high oxygen input into the soil led to the creation of extensive funnels along with drought and mineralizing (unsaturated) soil conditions (Figure 47). The disturbance of soil conserving conditions (saturated *sponge state*) provoked irreversible effluents of alkaline soil elements, such as calcium or potassium, via the rivers to the sea.[589] This loss of essential cations undermined the soil's buffer capacity and triggered acidification and mobilization of heavy metals.[590] In the long-run, groundwater interventions decreased the fertility of soil, as well as the physical sustainability of the whole watershed ecosystem.[591]

These problems were known from the Müggelsee-Dahme watershed in the *Müggelberge* (Müggel Hills).[592] In line with the increasing groundwater withdrawals, forestry had to change from deciduous to coniferous tree production as a drought-tolerant measure from the mid-20th century on.[593]

However, in sum and despite the groundwater-related problems described, Berlin's central drinking-water production can be evaluated as quite sustainable.[594] This is primarily due to its place-based production mode of partly using surface and groundwater as a drinking-water source,

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[587] Ibid.

[588] Ibid.: pp. 39-62

[589] Ripl (1992); Ripl (1995); Ripl *et al.* (1997)

[590] Böken and Hoffmann (2009); Ibid.

[591] Ripl (1992); Ripl (1995); Ripl *et al.* (1997)

[592] Bürgow (1998, pp. 57–64)

[593] Ibid.

[594] Massmann *et al.* (2007)

while utilizing biological-mechanical filter processes. Currently, about 70% of Berlin's drinking-water is captured from the river basins of the Spree and Havel and induced bank filtration[595].

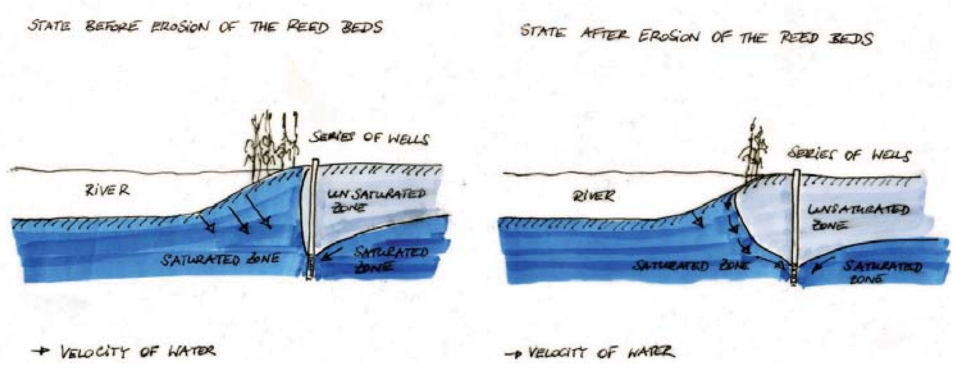

Figure 47: Creation of groundwater funnels by deep-well pumping inducing erosion of reed stocks

BEER-BREWING AND DRINKING CULTURE

The central drinking-water supply actually went back to the first water pipelines installed for beer-brewing. The brewery trade was already booming in the 16th century. In 1570, the former mayor Johannes von Blankenfelde was induced to lay wooden pipes, although only of short endurance, to supply the brewery trade and public bathhouses in Berlin.[596]

The beer-brewing industry has played a traditional role in the history of Berlin's drinking culture. In the early days, it was locally imported from the northern town of Bernau, which was famous for the cultivation of hops. Bernau, at that time, was known as the illustrious "beer city" as by 1570 it already had 146 brewhouses.[597] Besides local export, the beer from Bernau was exported to Hamburg, Denmark and Norway. Figures from 1564 refer to a yearly beer production of 24,400 tons, compared to 30,740 tons in 1613. During this period, ~47 craft breweries offered beer from Bernau, including the *Rathskeller* at Berlin's city hall. However, the last brewhouse closed in Bernau in 1909,[598] mainly due to the replacement of the hop gardens with vegetable farms, particularly for potatoes. Potatoes were introduced to Berlin by Margrave Friedrich Wilhelm after the 30-years war. They were also cultivated within the city, such as in the royal kitchen and herb garden (today's Lustgarten).[599]

However, beer-brewing never disappeared. Similar to the cultivation of wine on Berlin's Teltow and Barnim plateaus,[600] hydrogeomorphological landscape advantages were best utilized before industrial cooling became prevalent. Higher urban landscape elevations were chosen

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[595] Ibid.: p. 41
[596] BWB (eds.) *et al.* (2008, p. 13)
[597] Lemke (1955, pp. 18–19)
[598] Ibid.
[599] Steinmann (2008, p. 77).
[600] Schwartz (1983)

offering the advantage of installing basements for the cooling and storage of beer (Figure 48). In 1867, ~50 breweries existed, which had large vaults designed with massive walls and cooled by stored cold winter air.[601] The breweries only became morphologically independent from the beginning of the 20th century, along with the invention of the *Linde refrigerator*, due to the fossil fuel-driven use of steam power.[602]

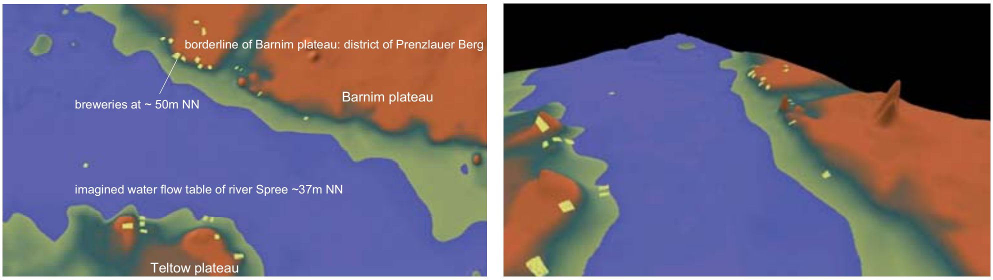

Figure 48: Morphological distribution of Berlin breweries during the times of city boom (1860-1870)

New sites for industrial breweries were developed directly along the waterfronts during the 20th century. Supposedly independent from morphological advantages, riversides were preferred locations due to the possibility of direct water-use for industrial beer production. Parallel to an urban washing culture, the growing laundry business greatly influenced Berlin's riverside development.

WASHING AT THE RIVER – WASHING THE RIVER?

Similar to the significance of wells, which according to Böhme are "centers of societal organization," urban washing places have a mutual cultural meaning.[603] Their role as centers of communication illustratively reflects the German saying *Gewäsch austauschen* (clap-trap).[604]
The expression *washerwoman* refers to the particular societal role of women who are responsible for this kind of daily business. Therefore, it is not surprising that a woman was the foundress of the first laundry in Berlin during early urban industrialization. Henriette Lustig opened the first laundry in 1835 in the south-eastern district of Köpenick.[605] She laid the foundation of the industrial laundry business which developed in Köpenick thereafter. Thirty years later, Wilhelm Spindler opened the first industrial laundry, which led to a boosting of industrial development on the left side of the Spree River (looking downstream). Previously, he ran a modest dye-works in Burgstrasse in the historic center of Berlin, and later, a steam dye-works in Wallstrasse. Since economic success was contrary to ecological and public health, Spindler's laundry business needed to be translocated to the outskirts. The major problems

[601] Arnold and Salm (2007, p. 26)
[602] Bürgow and Dalchow (2009)
[603] Böhme (2004, p. 22)
[604] Ibid.
[605] Steinmann (2008, pp. 23–24)

were due to the chemical wastewater containing a high amount of suds, as well as the waste heat released into urban waters and air in the densely populated center. Thus, in 1871, Spindler purchased ~200 acres on the left Spree riverside downstream of the district of Köpenick, which later became *Spindlersfeld*, also nicknamed “washhouse Berlin.”[606]

In concluding the historical review of Berlin’s waterscape biography, one overarching challenge touching all of the three facets of urban aquaculture can be derived and summarized by the objective to literally *wash the river*. It stresses the urban need and value of good and healthy surface water quality as it is envisioned by the EU Water Framework Directive.[607] As it has a timeless value, this objective also builds a bridge from the past to the present and future of water-sensitive cityscape development.

The concluding subchapter, therefore, gives glimpses of projects and trends of contemporary urban aquaculture and affiliated blue-green infrastructure development in Berlin which are still evolving.

4.5 Re-emerging aquacultural infrastructures in post-industrial times

Today, Berlin is a *blue-green city* if one reviews the proportion of urban *green* and *blue* areas. Whereby green spaces and landscapes cover about 44%, natural water bodies embrace 7% of the city area. Berlin, with its ~3.5 million residents, is one of the most populated European cities ranking after London, and, with its ~892 km², the largest urban area in Germany and Central Europe.[608]

After the closure of the of heavy industry and in addition to the reoccupation of abandoned industrial waterfront sites from the 1990s on, the former *fluid wall* – Berlin’s river Spree – transformed into a new cultural and lively urban waterscape. The renewed tangible access awakened a new devotion to Berlin’s major rivers and water bodies along with the reemerging and maturing of a contemporary post-industrial aquaculture. Thus, the aqua-cultural developments glimpsed in the last subchapter highlight innovative bottom-up projects of water-cultural and water-natural impetus from micro- to macroscale.

Typical Berlin water-cultural projects are linked to names such as the *Badeschiff*,[609] *Spree 2011*,[610] *Flussbad*,[611] or the former beach club *Bar 25*,[612] and its emulators, such as *Kater Holzig*[613] or the recent *Mörchenpark*[614] at the site of the former Bar 25. They reflect the variety of place-based waterfront projects symbolizing a new era of *post-industrial river culture*.[615]

[606] Ibid.
[607] EU (2000)
[608] e.g. SENSTADT (eds.) (2012)
[609] http://www.arena-berlin.de (2010-08-28)
[610] http://www.spree2011.de (2010-08-28)
[611] http://www.realities-united.de (2011-09-03)
[612] http://www.bar25.de (2010-08-28)
[613] http://www.katerholzig.de (2010-08-28)
[614] http://moerchenpark.de (2010-08-28)
[615] Stokman and Klaus (2006); Kruse and Steglich (2006)

However, most of Berlin's river projects have clearly passed their peak with regard to temporary waterfront developments. The uncontrolled and creative *spaces of possibility* are, similar to other everyday commons, highly contested. The current question is: How will the city's waterfronts further develop in the field of tensions between self-induced local and global market-driven real-estate redevelopment? The Mörchenpark, thereby, is one of the more unconventional follow-up projects. Launched as an *urban village project*, it features affordable community housing development, a diverse mix of cultural and new urban craftmanship-oriented[616] uses, urban farming, and socioecological lifestyle themes. By envisioning a *green riverbank development* at the site of the historic *Holzmarkt* adjacent to today's cultural area *Radialsystem V*, this project is placed somewhere between corporate real estate development and creative local entrepreneurship.

Complementary to the water-cultural developments mentioned, water-natural, thus primarily ecologically motivated, waterscape projects have evolved since the turn of the 21st century. A current issue of political discussion[617] and a matter of the local water framework action plan[618] is improving Berlin's surface water quality, for example, protecting surface water quality from spills of dirty water during heavy storm water events. Another example is the large-scale revitalization of the former Rieselfelder in Hobrechtsfelde due to the reuse of secondary wastewater sources from the nearby sewage treatment plant. Additionally, traditions of urban aqua-agriculture have reemerged in a contemporary form. The revitalized pond-and-dyke landscape today serves purposes of landscape water rebalancing, particularly to secure urban forestry, as well as reestablishing urban wetlands combined with recreation. Last but not least, regarding the global trend of sustainable and healthy urban food provision, there is an emerging trend of building-integrated water-farming projects that include aquacultural and hydroponic production modes. They are another category of contemporary Berlin aquaculture often combining building-integrated design and resource management approaches.

In light of the examples mentioned, the final paragraphs explore trends of post-industrial urban aquaculture along the following lines: (1) waterscape reculturalization, (2) waterscape renaturalization, and (3) building-integrated water-farming. The focus is on the new interpretation and integration of traditional, hence renewed, aqua-cultural blue-green infrastructures from floating pools, urban fishponds to roof-top water-farm greenhouses, while intending to reflect on the broad variety of actors.

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[616] Geldorf (2011)

[617] SENSTADT and TUB (2010b); TU Berlin (2011)

[618] SENGUV (2009a)

4.5.1 Waterscape reculturalization: From bathing-ships to river pools and solar ships

BADESCHIFF – FLOATING POOLS

Berlin's *Badeschiff*,[619] created by the artist Susanne Lorenz and the architects AMP Architectos with Gil Wilk, who converted an industrial river barge into a public pool, became one of Berlin's main new infrastructure symbols (Figure 49). As one of the first floating pool projects worldwide, it became an initiator and incubator for other cities. Implemented as an urban art project in 2004 near the former *Osthafen* (eastern harbor) at the *Kulturarena*,[620] the Badeschiff can, therefore, be interpreted as a *bottom-up catalyst* of water-sensitive urban transformation.
By envisioning surface water qualities to swim in, it communicates themes of urban quality of life, while physically creating a *new* place of water-wellbeing right in the city. At the same time, it reawakens memories of place-based traditions from the 19th and 20th century from Berlin to Paris or New York City (5.5). Called *Badeschiff*, *La piscine flottante sur la seine* or *Floating Lady*, respectively, floating pools are more than *just* infrastructures transforming urban landscapes and mindscapes. Floating pools contribute to the city's contemporary water-based identity and livability. The perception of urban rivers as more or less lifeless industrial transport infrastructures changes through creating special atmospheres and tangible connections between people and water in the city. Urban waterfronts become lively waterscapes.

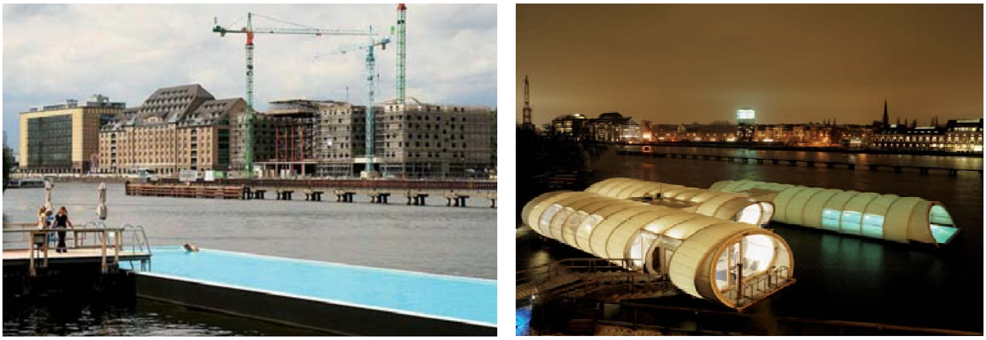

Figure 49: Floating pool Badeschiff *on Berlin's river Spree adapted to seasonal uses.*
Left: Summer use: public pool by AMP Arquitectos with Gil Wilk, Teneriffa, artist Susanne Lorenz.
Right: Winter use: sauna tent structure by Thomas Freiwald and Wilk-Salinas Architekten

FLUSSBAD – RIVER POOLS

A mutual and more recent waterscape project, which further reinvents a Berlin 21st century post-industrial river culture, is the *Flussbad*. It envisions an ecologically cleansed river pool at the Kupfergraben, at Berlin's Museums Island – the historic island in the Spree close to Berlin Cathedral (Figure 51). The idea of swimming right in the heart of Berlin has been developed by the architect-artist group realities:united, which won the gold prize of the 2011 Holcim Award for

[619] http://www.kulturarena-berlin.de (2010-08-28)
[620] http://vermietung.arena-berlin.de (2010-08-28)

sustainable construction and infrastructure plans.[621] The project objective is to make the more than one hundred years unused Kupfergraben re-accessible, while repurposing its meaning. The project developers state as follows:

> "Flussbad aims to diminish the mental division between 'everyday Berlin' and the public Berlin belonging exclusively to tourists and federal agencies. It will provide a badly needed recreational facility in this part of the city and return some 'authentic life' to Berlin's museum island, one of Berlin's most heavily-trafficked tourist destinations with over a million visitors a year. At the same time, Flussbad puts an end to the economic nonsense of a completely unused waterway – the Kupfergraben – transforming the river itself into a strong argument for the quality of living in the inner city again." [622]

The river pool encompasses one of Berlin's traditional floating pool locations. Its realization is envisioned for 2019. The developers state that:

> "The steps necessary to convert the river arm into a swimming pool are surprisingly simple and very cost-efficient. The upper course is used as a reed bed filter, which naturally purifies the water – a barrage at the lower end prevents unfiltered water to backflow. The quay wall along the Lustgarten is transformed into a generous stair providing access to the swimming pool and offers a place to sit, hang out, watch or dry. Limited practical necessities like locker rooms and footbridges complete the system."[623]

The value for the city of Berlin is described as follows: "With a length over 700 meters, Flussbad would not only be the world's longest swimming pool, but also would surely become an urban magnet for both tourists and Berliners, as well as a powerful yet charming vehicle for the city's global marketing."[624]

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[621] Schleutker-Franke (2012)

[622] http://www.realities-united.de/#AWARD,36,1 (2011-11-01)

[623] Ibid.

[624] Ibid.

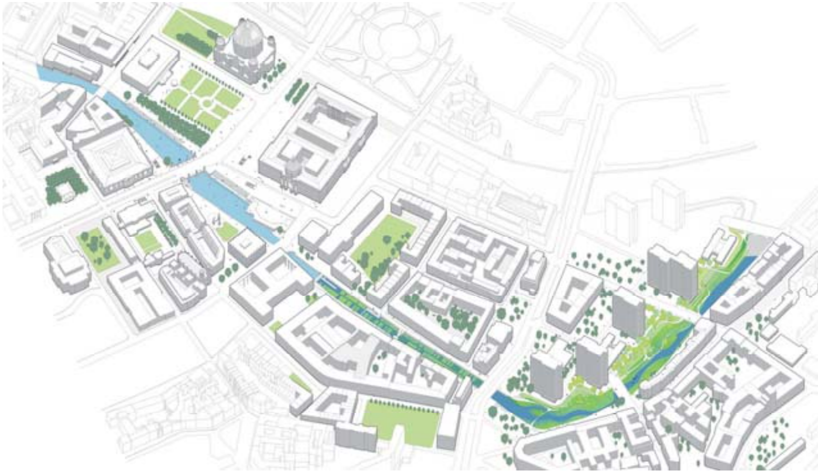

Figure 50: Flussbad by realities:united – making Berlin's inner-city Spree with the Kupfergraben swimmable

Figure 51: Flussbad – ecologically filtered urban river pool vision by realities:united

SOLAR SHIPPING

Remediating Berlins' rivershores and urban water surfaces towards bathing quality and a "good ecological status"[625] according to EU water framework standards is also envisioned by pioneering solar shipping initiatives. The "socioecological river charter,"[626] for example, proposed 11 corner-marks for Berlin's city parliament elections in 2011 as active citizenship. Among others, a strong focus is on improving the bathing quality in the innercity Spree, as well as making the riverbanks publicly accessible by keeping at least 50 meters free from building

[625] EU (2000)

[626] solarpolis (2010); Paulus (2011)

and traffic (vs. direct shoreline buildings). It claims an active shift to solar water transport as an emission-free, thus, clean shipping measure for better surface water quality. Regarding public transport, it stresses the support of solar water taxis and landing places as opposed to fossil-fueled water transport.[627] Additionally, it proposes renaturalization measures, such as constructed wetlands or floating plant filters[628] along the rivershores, and the redesigning of the mixed sewer system. Currently, a mixed sewer system is installed in most parts of the central city, where flows of rainwater, wastewater and slurry mix in the gutter confluence. The redesigning of the mixed sewer system in central urban areas of Berlin by, for example, building integrated rainwater concepts, has also been promoted by the Berlin Senate for urban development and environmental protection since the 1990s (3.3.4).[629]

The latest socioecological waterfront development facing solar shipping on the Spree is the extension and redesign of Berlin's historic Osthafen. Called *Osthafensteg 2.0*, the project developer SolarWaterWorld AG envisions both an "open-minded place about the future at the water" and "place of memory" of the former Berlin wall with parts right through the Spree River.[630] The site, furthermore, opts to create a "link between culture, urban nature, water sports and sustainability," including a solar energy station and other service stations for solar shipping.

Parallel to the cultural remediation of natural urban waterscapes, urban cultural waterscapes, such as the historic Rieselfelder, have been revitalized alongside natural watershed restoration. Although severe problems occurred alongside 20th century heavy industrialization, parts of Berlin's northern irrigation fields have lately been successfully reactivated to tackle contemporary place-based water-climate changes (3.3.3).

4.5.2 Waterscape renaturalization: From wastewater irrigation fields to revitalized urban nature

REMEDIATED *RIESELFELDER* IN BERLIN-HOBRECHTSFELDE

This periurban watershed revitalization project based on reclaimed water use has been run by the forestry department at Berlin-Buch in cooperation with the Berlin waterworks since 2004. A combination of periurban forestry and natural wetland habitat restoration, between 5,000 and 6,000 m³ out of the ~80,000 m³ total water volume released by the nearby sewage treatment plant at Schönerlinde is reused on the land.[631] After ~10 years of negotiations, the tertiary water, abbreviated to "re-water,"[632] has served as a valuable resource in an area of about 1000 ha of former irrigation fields in Berlin-Hobrechtsfelde since 2004. Instead of being directly recharged into receiving water bodies and, consequently, becoming lost for the small water cycles (3.3), it stabilizes place-based water hydrology. As a unique renaturalization measure in the former

[627] Ibid.
[628] Günther (2010a); Günther (2010b)
[629] SENSTADT (eds.) *et al.* (1995): SENSTADT and TUB (2010b); SENSTADT (2011)
[630] SolarWaterWorld AG (2012)
[631] Zeuschner (2005); NABU (2006, pp. 57–58)
[632] http://www.kompetenz-wasser.de (2010-10-08)

flood plains of the Panke River, a tributary of the Spree, it provides active water-stress and drought prevention on the larger landscape watershed scale (Figure 52). In addition to securing forestry recultivation and wood production in the former aqua-agricultural landscape, the Rieselfelder, nowadays, provide urban biodiversity and recreation along with the reestablishment of valuable wetland ecosystems.[633] Thus, they are revalued as a multibeneficial landscape infrastructure for the reproduction or regeneration of urban ecosystem services, such as soil fertility, local water balance, urban biodiversity, and recreation, as important to the everyday quality of life.

Meanwhile, the Rieselfelder are the subject of sustainable land management research. They are currently being further investigated by the transdisciplinary project *ELaN* – a joint initiative of research institutions and water providers funded by the German Federal Ministry of Education and Research (BMBF).[634] The aim is to explore multifunctional sustainable land and water management strategies, for example, for combined agriculture, forestry, ecohydrology, biodiversity, and climate services.

FLOATING VEGETATION FOR SURFACE WATER REMEDIATION

Regarding local surface water quality, floating vegetation mats have been proven to further improve the clarified water being recharged on land for landscape revitalization.[635] As representative swimming garden types and if constructed as a biodegradable structure, they support blue-green services in the watershed (→Table 3) combined with other low-cost/low-tech blue-green infrastructures (e.g. planted sand filters, constructed wetlands or ecologically restored pond shores). As the plants roots with their microbial ecosystem are in the water for up to one meter,[636] they retard flow velocity and remove dissolved substances, which has been proved for storm water pollutants.[637] If constructed from biodegradable material, they are, furthermore, appropriate to remediate heavily transformed rivers, as the first urban experiments at Berlin's *Stadtspree*, the inner-city river, show.[638] Due to being tolerant to fluctuating water levels, the floating vegetation can be a low-cost alternative to renaturate urban water bodies or become integrated into urban storm water management strategies alongside approaches of *aquatecture* and *aquapuncture* (6.2). Having either a more natural (e.g. floating vegetation)[639] or cultural (e.g. swimming garden) character, they can create aesthetic qualities, while improving both urban microclimates through evapotranspiration and surface water quality through the plant's root processes (3.4.1).

In light of contemporary issues of water-climate-change adaptation, the most striking benefit is probably the tolerance of fluctuating water levels. Hence, floating types can offer low-cost

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[633] NABU (2006); SENSTADT (eds.) *et al.* (2009)
[634] ZALF (2011)
[635] Barjenbruch *et al.* (2008)
[636] Kerr-Upal and Seasons (2000)
[637] Headley and Tanner (2006)
[638] SENSTADT (2004)
[639] Barjenbruch *et al.* (2008); Günther (2010a); Günther (2010b)

alternatives to *green-wise* purify *blue* surface waters and result in regenerated ecologically healthy swimming waters.

Figure 52: Renaturalized Hobrechtsfelder Rieselfelder *using reclaimed waters from a nearby sewage treatment plant for watershed revitalization (2005)*

4.5.3 Urban aquacultural farming: From container to building applications

Complementary to integrated land management approaches in periurban contexts, recent applied research and development projects are focusing on building-integrated urban farming as space- and resource-effective approaches within the urban landscape context.[640]

A low-cost application can be container farms. A test and showcase was installed in 2011 at the Malzfabrik[641] (a former malt factory and, today, a sustainable and cultural business location) to sound out the entrepreneurial opportunities of greenhouse-based commercial fish and vegetable farming. Meanwhile, the system is run by the Berlin-based start-up firm ECF (Efficient City Farming). It was bought from the Swiss start-up Urban Farmers and rebuild afterwards (Figure 53).[642] The modular structure consists of a two-storey modular construction with a standard size greenhouse on top of a cargo shipping container. The water-farm technology applied after a first rebuilding phase in 2012 uses a aquaponic greenhouse patent, called ASTAF-PRO. Based on earlier studies, it was developed by Dr. Rennert and partners[643] at the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB). The patented technology refers to a specific valve used within the aquaponic production. Hydroponically grown tomatoes in the upper storey greenhouse take up most of the nutrients provided by the fish tanks located in the container underneath, where the water is naturally purified.[644] After flowing through the NFT-based hydroponics (5.3.3), the greenhouse water flows back into the main water reservoir.

[640] e.g. http://www.zfarm.de (2011-10-01)
[641] http://www.malzfabrik.de (2011-09-03)
[642] http.//ecf-farmsystems.com; http://urbanfarmers.com (2011-09-03)
[643] Rennert (1992)
[644] Böckel vom (2011)

Figure 53: Container Farm aquaponics – mobile urban showcases with fish tank at ground level and greenhouse above. Left: Urban Farmers, Basel. Middle and Right: Rebuild model by ECF, Berlin

Basic features of the container farm at the Malzfabrik are:[645]

- Two uncoupled communicating loops with an overflow valve from the fish tank into the hydroponics, but no direct water flowing back from the hydroponic greenhouse into the fish tank to prevent potential fish toxicity due to high ammonia content (high pH);
- 75% reduction in water consumption due to multiple circular water use (~25% of water is evaporated); and
- about 200 kg vegetables (tomatoes, lettuce, herbs) and 150 kg fish (tilapia) per 8-month growing season in Berlin (March-October).

Depending on the indoor temperature, the evaporated water in the hydroponic greenhouse (~10-25% per day) is supplemented via a groundwater well. It would be an option in the future to replace the groundwater by collected rainwater. Future objectives envision the system's upscaling and adaptation to the factory's roof-top with available space of ~7000 m² from which ~1000 m² will be covered by a roof-top greenhouse.

Other cases applied in the greater Berlin region have been installed and tested by small and medium sized companies. An aquaponic greenhouse encompassing 280 m² for tropical fish and plant production was built in Beelitz-Elsholz, close to Potsdam, south-west of Berlin, in 2000 (Figure 54). It provides project-based research and development (R&D) and is run by the companies IBAU (Innovatives Büro für Aquakultur- und Umwelttechnik) and TERRA URBANA GmbH.

International R&D includes:[646]

- Demonstration of aquaponic systems in the Democratic Republic of Laos on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ);

[645] Hahlweg (2011)

[646] Ibid.

- circulation systems for intensive fish cultivation and aquaculture, e.g. SANSED – integrated water resource management Closing Nutrient Cycles in Decentralized Water Treatment Systems in the Mekong-Delta, Vietnam, on behalf of the German Federal Ministry of Education and Research (BMBF); and
- use of nutrients from intensive aquaculture for cultivation of microalgae and use of CO_2 from combustion processes to produce valuable microalgal biomass (tested in the space shuttle), on behalf of the German Environmental Foundation (DBU).

Figure 54: Aquaponic greenhouse for applied and experimental R&D including tropical plant and fish production

Applied and experimental R&D in the water-farm greenhouse focuses on:[647]

- African tilapia production with optional harvest rates of ~60-80 t/ha*a;
- Vietnamese climbing perch (*Anabas testudineus*) with optional ~80 t/ha*a or 400-500 t/ha*a (two growing cycles per year in tropical climate): and
- exotic plant production, e.g. papayas, figs, Moringa Oleifera.

4.6 Conclusion

Characteristic facets of urban aquaculture as traced for Berlin, linked to its place-based water-living, water-farming and water-wellbeing culture unveil the everyday character of urban water relations. The water-based connection between socio-cultural life and ecological landscape processes becomes tangible through the aquacultural practices of shipping, fishing or swimming in the city. The following main insights from the Berlin case study complement and further detail the more general research results of Chapter 2:

- Urban aquacultural infrastructure practices facilitate a tangible relationship of natural and cultural water processes within city spaces at an everyday human scale, from private to public life spheres. Swimming marketplaces at harbors and canals or Berlin's Rieselfelder as periurban pond-and-dyke landscapes refer to place-based aqua-agricultural traditions unveiling daily resource provisions in the city. The cocreation of urban waterscape

[647] Ibid.

morphologies sharpens the perception and encourages the accessibility of water as an everyday natural and cultural element. The aquacultural infrastructure-landscape types from fishponds and floating pools to water-farm greenhouses appear as both attractive and useful. Additionally, they tangibly reflect on potential problems and risks of public concern. Therefore, they can initiate and enable broader societal discourses, such as about human and environmental health.

- The way and quality of interaction between landscape and urban life processes mediated via aquacultural practices defines urban waterscape qualities. Large-scale shipping, for example, as associated to Berlin’s prosperous growth in the past, was primarily based on large-scale water infrastructural interventions of mastering the landscape. Natural water-scapes became technically adjusted according to the size of ships and distances of goods transported. This can be traced through river regulations, land drainage or deforestation. On the other hand, contemporary urban farming or river culture catalyzed bottom-up processes of renaturalizing-reculturalizing the different urban waterscapes. Ecologically filtered river pools or solar ships emerge as complementary regenerative infrastructures. The renewed aquacultural infrastructure types and practices reflect on post-industrial developments offering advantages of a regenerative reversal.
- Affiliated with the extended interpretation of urban aquaculture, aquacultual blue-green infrastructures embrace water-farming types (e.g. fish ponds, swimming gardens) as well as traditional and contemporary types of water-living (e.g. solar ships, swimming marketplaces) and well-being (e.g. bathing ships, ecologically filtered river pools). They are recognized as building-blocks and bottom-up catalysts of urban aquaculture. Figure 55 extends the characteristic facets of urban aquaculture *(*Figure 4) by integrating the new perception of aquacultural blue-green infrastructures as bottom-up catalysts of a citywide urban aquaculture.

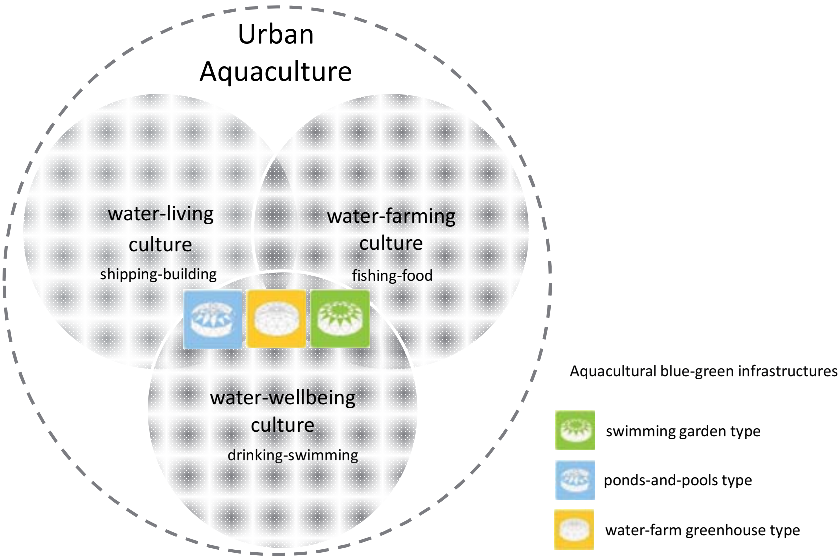

Figure 55: Extended scheme of urban aquaculture with aquacultural blue-green infrastructures as bottom-up catalysts

In order to tackle the reversal needed at an implemental level, the following Chapter 5 explores pilot case studies of aquacultural infrastructure types from low-tech to high-tech applications at the international project scale. Thereby two key questions guide the empirical research: (1) What are the multifunctional design and service potentials with regard to an everyday water-living, water-farming and water-wellbeing culture? (2) What are the learning-from experiences facing the urban integration within real-life community contexts?

CHAPTER 5: INTERNATIONAL PILOT CASES OF AQUACULTURAL BLUE-GREEN INFRASTRUCTURES IN MODERATE AND NORDIC CLIMATES

5.1 Introduction

The central motive of this chapter is to explore the multifunctionality of aquacultural technologies in contemporary Western lifestyle under moderate and Nordic climate conditions. The focus is on piloting international bottom-up developments of applied design-research impetus that have been integrated into existing neighborhoods embracing high-tech and low-tech applications (Figure 56). Furthermore blue-green infrastructure services of applied learning and other quality of life aspects are common to all cases in their individual socioecological contexts.

Figure 56: Overview of international aquacultural pilot case studies in a Nordic and moderate climates

Concerning the methodology of research and case selection described in 1.2, each typological case was evaluated according to the following six criteria:

- Supporting blue-green services
- Flexibility of design
- Tangibility of processes and aesthetics
- Participative intervention and responsibility
- Community integration
- Applied learning, transforming spaces and mindscapes

The evaluation criteria for the different aquacultural cases, first of all, responded to the problems of prevailing Western water infrastructures and resource management (1.1.3), integrating the outcomes explored so far regarding natural and cultural everyday life-support. Generally, both the eco-technical and the human psychological level were addressed in the context of spatial-infrastrural transformation. This linked to issues of place-based education by recognizing the value of a place for self-formation, as well as for the creation of identities and responsibilities. Anglo-Saxon research has stressed the individual interwovenness of people and places, as exemplarily stated by Ruth Wilson: "Knowledge of a place – where you are and where you come from – is intertwined with knowledge of who you are. Landscape, in other words, shapes mindscapes."[648] Michael Brody, furthermore, referring to the environmentalist Paul Shepard,[649] stressed the role of physical structures as follows: "Personal knowledge is a consequence of psyche and particular land forms, whereby terrain structure is a model for patterns of cognition."[650] In line with this interpretation, David Orr highlighted the concept that built structures – perceived as terrains, habitats or landscapes – are not only formed by mindscapes, but are also forming mindscapes.[651]

With this background, the first two case studies focused on greenhouse-based water-farm types, including integrated water and resource management principles. Complementarily, the third and fourth case studies stressed water-living and water-wellbeing facets.
Although each case study explored the most characteristic aquacultural infrastructure facet, there were overlapping features, such as between water-farming and water-wellbeing.

The following case study in the Nordic climate context represented a key case study due to its long-time experience in a small Western community context (1.2.2). It explored a decentralized wastewater management infrastructure reusing and upcycling everyday resources via a building-integrated aquaculture greenhouse ecosystem applying hydro- and aquaponic technologies.

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[648] Wilson (1997, p. 191)
[649] Shepard (1977)
[650] Brody (1997, p. 16)
[651] Orr (1994)

5.2 Case study 1: The Stensund Wastewater Aquaculture – Trosa community, Sweden

Figure 57: Stensund Wastewater Aquaculture – Trosa community, Sweden

5.2.1 Project Story

The Stensund Wastewater Aquaculture operated as a pilot test site from 1989-2000. Although it is no longer in operation, a broad variety of follow-up projects still make the Stensund project a valuable learning-from case today. It featured *high-end* integrated water and resource management through combining campus-based water-farming and wastewater treatment. As a decentralized resource infrastructure, it combined both safe and aesthetically pleasing communal wastewater upcycling in a tropical greenhouse under Nordic climate conditions. The Folk College community site, with about 100-150 permanent student residents, on the coastline of the Baltic Sea archipelago south of Stockholm, represented a decentralized urban settlement size. Therefore, it offered a suitable pilot test site with an assessable and rather transparent watershed.
Since this was the first European pilot plant primarily for testing decentralized aquaculture-based wastewater management, the fish and biomass produced were not used for food purposes. After four years of operation (1990-1994), results showed that the wastewater of about 34 p.e. (0.18 m^3/day*person) was reused, which differed from the intentional technical design of 100 p.e.[652]

The Stensund project was initiated by the marine biologist Björn Guterstam and the architect Bengt Warne. It embodied Europe's first aquacultural greenhouse providing communal off-grid wastewater management based on solar and aquatic ecosystem principles. Its state-of-the-art

[652] Ibid.: p. 73

ecological building style[653] and blue-green design features incorporating Chinese fish polyculture principles were particularly intriguing (3.4.2). According to similar intensive indoor technologies for the demonstration and applied research of food web-based wastewater nutrient upcycling, Guterstam referred to initial experimental studies in warmer climates in the USA by Dinges (1976) and Stewart et al. (1979).[654] Established under Northern European climate conditions, the project, furthermore, linked to pioneering research in the USA, particularly the solar aquatic greenhouse concept.[655]

By the end of the 1980s, the project started with exploring the potential of a community-based approach at a very practical and educational level. The project aims were embedded into the Coalition Clean Baltic Initiative (CCB) – a non-governmental initiative unifying environmental organizations, which was founded in Helsinki in 1990 as a cooperation for bundling activities enhancing maritime surface water quality of the Baltic Sea.[656] Guterstam (1991) referred to research by the ecologist Sten Selander from the Swedish Academy,[657] who stressed, as early as 1955, the great economic losses through untreated wastewater nutrients released into the sea, and "(…) predicted future starvation if the limited mineral phosphor wasn't recycled to agriculture."[658]

With this background, the Stensund Wastewater Aquaculture project opted to meet the CCB's objectives, first of all, through sustainable water management and land-use practices: "Stensund College was used as a model community, with 100 person equivalents (p.e.), for the purpose of developing a recycling concept for the wastewater resources of nitrogen, phosphorus and heat."[659] Based on early small-scale studies performed in 1987-1988, the full-scale plant was opened in October 1989.[660]

[653] Warne (1991); Frederiksson and Warne (1993, pp. 45–53)
[654] In: Guterstam (1991, p. 42)
[655] Guterstam (1996, p. 74)
[656] http://www.ccb.se/about.html (2012-02-02)
[657] Ibid.
[658] Selander (1955) in: Guterstam (1991, p. 39)
[659] Guterstam (1996, p. 73)
[660] Guterstam and Todd (1990) in: Guterstam (1991, p. 42)

5.2.2 Case study profile

BUILDING-INTEGRATED WASTEWATER RESOURCE MANAGEMENT VIA A BUILDING-INTEGRATED GREENHOUSE APPROACH

Table 10: Profile of the Stensund Wastewater Aquaculture

Features	Stensund Wastewater Aquaculture
Typological form and blue-green design features	Greenhouse aquaculture type embodying modular units including algae and zooplankton cultivation, fish polyculture combined with hydroponics (aquaponics) designed as nine-step wastewater upcycling purification system.
Nutshell description	European pilot aquaculture greenhouse serving as a community-based wastewater resource infrastructure and teach-and-research facility to practically cope with issues of increasing nutrient drainage from land to sea and decreasing natural surface water qualities.
Main infrastructure services	Wastewater treatment combined to nutrient recycling, solar and waste energy regeneration/reclamation Greenhouse production Education, R&D
Spatial setting	Campus of Stensund Folk College, Trosa, south of Stockholm, Sweden
Landscape setting	Archipelago on the Baltic Sea coast
Climate	Nordic climate (N Lat. 60°) Mean annual temperature: 6°C Precipitation: 539 mm*
Size	Residents: ~120 permanent students Greenhouse capacity: originally conceived for 100 person equivalent (p.e.), practically deployed for 34 p.e. Floor space: 180 m² Nine-step treatment surface area: 62 m² Total volume: 195 m³ Average daily inflow: ~6.2 m³ Hydraulic residence time: 32 days
Project initiators/developers	Dr. Björn Guterstam (marine biologist) and Bengt Warne (architect)
Operator/client	Stensund Ecological Center (SEC) c/o Stensund Folkhögskola
Development phases 1) Microscale test lab phase 2) Macroscale campus-based test and operation phase	 1987-1988 1989-2000 (from 1994 focusing on optimizing system's performance)
	Sources: *,http://www.climatetemp.info/sweden/stockholm.html (2012-02-02)

5.2.3 Multifunctional blue-green design and service potentials

The Stensund aquaculture greenhouse type represented a constructed aquatic ecosystem. It featured decentralized wastewater resource management combined with water-farming in a periurban communal and nonindustrial context. Due to mimicking natural processes, this special infrastructural mesocosm created tangible experiences of natural-cultural process intertwining. The term *mesocosm* (from ancient Greek *μέσος* – center; *κόσμος* – world, order)[661] describes the intermediary area between micro- and macrocosm. It is, an experimental tool that brings a small part of the natural environment under controlled conditions.[662]
In addition to eco-technical performance as reflected in building structural design, nutrient flows, detoxification, or effluent qualities, the blue-green infrastructure design encompassed new learning-teaching-researching modes in the emerging fields of Ecological Engineering and Design. An international transdisciplinary know-how exchange due to integration into the Folk College's curriculum, and the CCB course, was initiated and promoted through special scholarship and stipend programs.

The following basic blue-green design features were applied in the Stensund Aquaculture and are further detailed in the following:

- *using waste as a resource*,
- *turning waste into beauty*, and
- *making life-supporting processes tangible*.

USING WASTE AS A RESOURCE

Facing a decentralized ecological design-engineering approach, the intention was to test aquacultural options of healthy and safe recycling of communal nonindustrial wastewater resources, particularly phosphorous (P), nitrogen (N) and heat energy. Table 11 gives a general overview of nutrient resources contained in daily human wastewater flows, which are valuable plant fertilizers and soil ingredients.

Table 11: Select components found daily in human excreta per person

Elements (g/ppd)	Urine	Feces	Urine + Feces
Nitrogen	11.0	1.5	12.5
Phosphorous	1.0	0.5	1.5
Potassium	2.5	1.0	3.5
Organic carbon	6.6	21.4	30
Wet weight	1,200	70-140	1,200-1,400
Dry weight	60	35	95

[661] In: Liddell and Scott (1940)
[662] http://mesocosm.eu/node/16 (2011-09-03)

Sewage sludge contains ~90% phosphate, which agriculture currently loses via the production of food of animal and plant origin.[663] Towards the end of the 20th century, approaches of Ecological/Regenerative Design and Ecological Engineering[664] became increasingly popular, particularly sustainable sanitation strategies. Governmental and nongovernmental initiatives, called *ecosan* or *SuSanA*,[665] stressed the recycling of sludge from sewage treatment plants for fertilization and soil-rebuilding purposes in agriculture due to their economic relevance. In reference to actual phosphate debates, Jürgen Hahn, head of department at the German Environmental Protection Agency (EPA) – the *Umweltbundesamt* (UBA), highlighted the value of phosphorous as "(…) essential for all life."[666] As a major component of human DNA, it is "the fuel of life" of the catalyzed ATP-ADP "combustion process."[667] Phosphorous is a much scarcer resource than oil[668] and, nowadays, it is mined in Africa, to a great extent through socially and ecologically questionable methods. One side-product is radioactive uranium. According to Franz Stadelmann, Swiss agricultural researcher, the global phosphorous inventories will last for approximately 80 years.[669] He, furthermore, referred to figures of about 300,000 tons of mineral phosphate annually imported to Germany from countries such as Russia, China or Morocco, whereby better mineral deposits from the Guano islands, such as Nauru or Banaba, have already been depleted.[670] Last but not least, current debates are addressing quality and public health concerns due to an increasing proportion of heavy metals, such as uranium, in phosphate fertilizers. In Germany, uranium amounts to 283 g/kg in mineral fertilizer, which results in an average value of 15.5 g uranium/a*ha.[671] In light of these striking figures, sustainable sanitation strategies start at the source (vs. end-of-the-pipe). They focus particularly on biologically degradable communal sources alongside safe and promising decentralized wastewater concepts for new developments.

In the light of an *upcycling approach* within an assessable communal watershed, the three technical goals were:

- to utilize high aquatic reproduction rates with regard to renewable biomass, fish and other life-forms based on wastewater nutrients, while making use of the natural water self-purification capability;
- to focus primarily on photosynthetic food web-based wastewater treatment and nutrient upcyling,
- to improve energy efficiency through heat recovery technology.

[663] Stadelmann cited in: Schuh (2005)
[664] Guterstam (1991); Chan and Guterstam (1995); Bohemen (2005a)
[665] GTZ (2001); Tilley *et al.* (2008)
[666] Hahn in: Schuh (2005))
[667] Ibid.
[668] Gerling and Wellmer (2005)
[669] Stadelmann in: Schuh (2005, p. 2)
[670] Ibid.
[671] Bundesregierung (2005)

Regarding the third objective, the aquaculture contributed to the school's heating system with a small net export.[672]

TURNING WASTE INTO BEAUTY

Contrary to the basic concept of a sewage treatment plant (STP), the aquaculture greenhouse served a productive wastewater management to regenerate valuable biomass and freshwater resources. Rather than following a downcycling strategy, as performed in most 20th century STPs, the nutrients were used as a main fertilizer to create subtropical to tropical aquatic ecosystems in a Nordic Climate, thus, reclaiming the wastewater's heat energy.[673] In the Stensund case, the former wastewater achieved almost bathing water quality when released into the coastal landscape ecosystems outdoors.[674] Thus, swimming water and a green oasis were fortunate byproducts of the natural self-purification processes mimicked.[675]

In addition to eco-technical features, an attractive architectural and indoor-landscape design was envisioned from the beginning. The *issue of beauty* was of high priority in addition to the system's functionality, as visitors' feedback reflects:

> "Most of the Stensund visitors were astonished that it doesn't hum. They expected if visiting a sewage treatment plant, it must smell somehow. Thus, it is playing with expectations, and of course it is always nice if you can surprise people with something unexpected. And if a sewage treatment plant smells like a garden, what could be more surprising?"[676]

MAKING EVERYDAY LIFE-SUPPORT TANGIBLE

The greenhouse aquaculture comprised a nine-step controlled wastewater-based aquatic biomass production encompassing polycultural tropical fish cultivation, hydroponic vegetable production and a final outdoor polishing pond with noble crayfish (*Astacus astacus*) (Figure 58).[677]

REGENERATIVE AND BUILDING-INTEGRATED DESIGN

Regarding the building's structural beauty and special atmosphere, Bengt Warne, one of Sweden's first green architects, put the challenge as follows:

> "To design a building for ecological engineering such as the Stensund Aquaculture at Trosa was quite a challenge (…). From an architectural perspective, it must harmonize

[672] Guterstam (1996, p. 77)
[673] Bürgow (1998, p. 77)
[674] Guterstam (1996)
[675] Ibid.
[676] Guterstam (2010)
[677] Guterstam (1996)

with the Baltic Sea and its beautiful archipelago near Stockholm. It also has to suit the little castle and the classical park at Stensund. It should create a link to the forest and coastal wildlife nearby. It is meant to be a vital part of the extending Stensund Folk College, with its local, national and international network. Technically it was even a tougher challenge. The building construction ought to take as much advantage as possible of naturally driven systems in order to establish a tropical to subtropical climate for the biological processing of used water. Stensund has wind, rain, and plenty of sunshine – 2000 hours per year – but the winters are harsh, cold, dark, and long."[678]

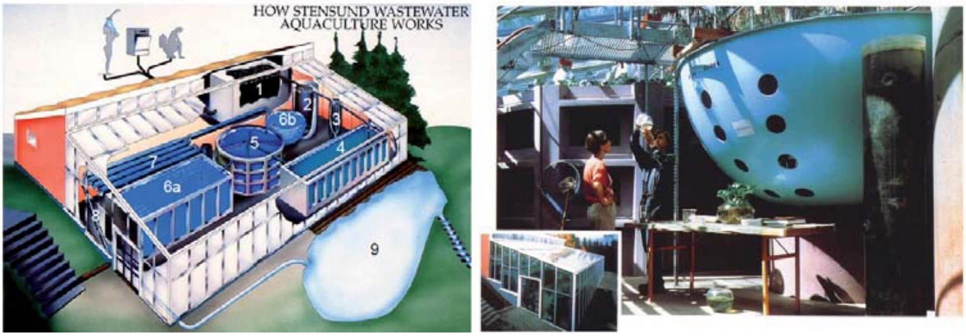

Figure 58: Left: Flow scheme design of Stensund Wastewater Aquaculture. Right: Atmospheric impression (indoor-outdoor)

The following building design features made essential daily-life processes tangible through architectural design:[679]

- Southern slope integration to reduce heat transmission;
- solar collector, which had a nearly doubled effect in winter due to the ice- and snow-covered coastal landscape of the Baltic Sea;
- construction of poison-free materials (wood, minerals) used as thermal storage for heat from day to night, and cold from night to day;
- foundation stored heat from week to week, whereby balancing climate extremes; masses of soil and rock under the building provided extra thermal storage; and
- the walls and roofs were superinsulated and all glazing was tripled.

Although running a greenhouse aquaculture under Nordic climate conditions was comparably unfavorable with regard to energy and light demands, the Stensund case worked through its integrated building design. As far as glazing was concerned, Guterstam, furthermore, pointed

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[678] Warne (1991, p. 176)
[679] Warne (1991)

out: "In order to adapt to a year-round subtropical climate, the greenhouse was built with three-layer glass and equipped with dark and shadow greenhouse curtains made of aluminum foil."[680]

NUTRIENT FLOWS

Percental nutrient reduction (inflow-outflow) during the first four-year test phase is stated as follows: "The average nutrient reduction for the Stensund Model community during 1990-93, with combined sludge separation, chemical precipitation, and aquaculture (including discharge from aquaculture to soil infiltration) was 72% of the phosphorous and 60% of the nitrogen."[681]

In general, nutrient upcycling within the first operational phase (1990-1993) achieved promising results, which reflected the lowering of nitrogen (N) and phosphorous (P) concentrations in the effluent water along each process step. Annual figures were calculated as follows: "The total amount of phosphorous in Stensund's sewage varies during this time from 53 to 78 kg, while corresponding levels of nitrogen are 415 to 572 kg. The largest part of the phosphorous and a sizeable part of the nitrogen have been separated in the sludge before treatment in the aquaculture or before discharge into the recipient."[682]

The original design of the nine-step process had been partly adjusted to optimize eco-technical performance, particularly the recycling of phosphorous and nitrogen in the form of plant and animal biomass (Table 12).[683] Hence, a particular focus was laid during the second phase (1994-1997) on optimizing the system's performance primarily through enhancing nitrification (conversion of ammonia into nitrate) as a key to successful microalgae and zooplankton cultivation (5.2.2).[684]

In addition to technical optimization, people were trained in basic source control, which implied the use of phosphor-free cleaning agents from beginning of the project. Annual figures of 0.66 kg/person were calculated in the Stensund micro-watershed, as opposed to the Swedish average of 1.0 kg/person. The 34% source reduction reached was primarily due to changing habits, such as the daily use of phosphate-free cleaning agents in the Folk College's kitchen and on campus by students and personnel.[685] Moreover, urine separation toilets were installed to showcase the potential of nitrogen reclamation; 90% of nitrogen originates from urine (Table 11).[686]

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[680] Guterstam (1996, p. 77)
[681] Ibid.: pp. 84-86
[682] Ibid.
[683] Guterstam (2009a)
[684] Guterstam (1996, p. 89); Guterstam *et al.* (1998)
[685] Guterstam (1996, pp. 86–89)
[686] Ibid.

Table 12: Nutrient concentrations of nitrogen and phosphorous (N, P) in the nine-step water purification process

Step	Module (and adjustments)	Notes/Functions	N total [mg/l]	P total [mg/l]
0	Inflowing water	Mixture of domestic wastewater from campus dormitories and the school's kitchen	8000 (plus 4000 in sludge)	1000 (plus 500 in sludge)
1	Storage tank (28 m³)	Water collection; adjusting the flow to the daily rhythm of higher life	40	5
2	Anaerobic tank (20 m³)	Degradation of organic compounds; detoxification/precipitation of heavy metals	40	5
3	Aerated biofilter	Continuation of microbiological mineralization and detoxification	38	4.8
4	Phytoplankton cultivation (modified through combining with plankton-feeding carp as controlled cultivation failed)	First step of primary production with eutrophic green algae as dominant species (*Ankistrodemus, Scenedemus, Chlorella*)	13-35	2.8-4.5
5	Zooplankton cultivation (modified through combining with plankton-feeding carp as controlled cultivation failed due to high ammonia concentration[687])	Secondary production: grazers and detritus (dead organic matter) feeders (*Daphnia, Ceriodaphnia, Copepoda, Rotifera, Ostracoda, Protozoa*)		
6	Basins for combined farming of fish, crayfish and tropical aquatic plants			
6a	Fish polyculture inspired by Chinese polyculture	Different tropical and temperate climate fish (*Tilapia spec., Carp spec.*)	20-36	3.5-4.6
6b	Fish globe (9 m³) for combined aquatic plants and fish cultivation	Tropical aquatic plant species (*Eichhornia crassipes, Pistia stratoites*); tropical ferns (*Azolla filiculoides*); temperate duckweed (*Lemna minor*)		
7	Hydroponic channels	Hydroponic cultivation of vegetables (tomatoes: *Lycopersicon*) and other plants (e.g. willows: *Salix spec.*)		
8	Water staircase of flow forms	Aeration of water released outdoors	5-15	1.4-1.6
9	Outdoor crayfish pond (40 m³)	Cultivation and hibernation of noble crayfish species (*Astacus astacus*)		

[687] Adamsson (1999, pp. 28–30)

DETOXIFICATION

Various studies investigated the performance of anaerobic precipitation as an effective detoxification method (step 2) to avoid the bioaccumulation of metals and persistent chemical substances in the food chain.[688] The following striking results were reached:[689]

- According to reference data from 1990, copper showed the best removal at 97%;[690] 46% of this took place in the anaerobic tank.
- In general, there was no bioaccumulation in the aquatic food chains constructed fed with secondary (desludged/pretreated) communal wastewater.[691] One exception was the heavy metal detected in green algae, whereas the following consumer's steps of zooplankton, daphnids and fish indicated a reverse situation (bioexclusion), which referred to research of Tarifeino-Silva et al. (1982).[692]

In addition to metals, further potential life-toxic fractions, such as ammonia (NH_4), pH and household chemicals, were explored during the second phase of testing and operation from 1994 on, focusing on optimizing the system's performance.[693] The following results were summarized:

- "Ammonia toxicity was found to be the causative agent for zooplankton dysfunction,"[694] stated Adamsson, referring to the fact that ammonia toxicity increased with rising pH and temperature since the amount of unionized NH_3 increases.[695] An optimized nitrification was suggested along with the increased performance of the biofilter (step 3) to prevent life-toxic circumstances.[696]
- It was recommended that "(…) low toxic and/or easily degradable detergents at minimum effective washing concentrations" were used at the campus to prevent potential risks of the toxicity of chemicals used in households (e.g. detergents).[697]

EFFLUENT QUALITIES

Regarding effluent qualities, circular process-based wastewater treatment, as exemplarily performed in the Stensund Wastewater Aquaculture, was compared with a conventional sewage treatment plant, primarily based on one-way flows (Table 13). The comparison faced a classical water treatment parameter, comprising public health standards of the EU Bathing Water Directive (particularly E. coli), in addition to the classical treatment parameters regarding biological oxygen demand (BOD) and chemical oxygen demand (COD), and nutrients (N, P) contained in the effluents released.

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[688] Ibid.: pp. 82-83
[689] Ibid.
[690] Ibid.
[691] Ibid.
[692] In: Ibid.
[693] Adamsson (1999, pp. 28–30)
[694] Ibid.: p. 29
[695] Ibid.
[696] Ibid.
[697] Ibid.: pp. 28-35

Table 13: Comparison of effluent qualities of representative Stensund Aquaculture and Berlin Sewage Treatment Plant (annual mean measures)

Wastewater management system	Effluent quality according to EU bathing water standards (Directive 2006/7/EC)	BOD/COD	N total [mg/l]	P total [mg/l]
Stensund Aquaculture (based on quantitative data)[698] Step eight (water staircase)	*almost met* e.g. E. coli 1,000/100 ml[699] (EU Standard coastal waters: E. coli 500/100 ml)[700]	6.7/38 (Ø of 36 measurements: 1990-1993 during first period of operation)[701]	5-15[701]	1.4-1.6[701]
Conventional STPs[702]	*not met* e.g. E. coli 100,000/100 ml[703]			
STPs in Berlin:	//	3/0	10.02	
Schönerlinde	//	3.8/42	12.29	0.41
Münchehofe	//	3.1/43	9.14	0.76
Ruhleben	//	4.3/55	9.74	0.33
Waßmannsdorf	//	3.62/41.91	11.08	0.45
Stahnsdorf	//	3.01/48.6	7.49	0.43
Wansdorf				0.45

5.2.4 Discussion: Outcomes and evaluation

Narrow focus: Classical technical evaluation

In general and as the exemplary wastewater treatment parameters have shown, the ecologically engineered wastewater aquaculture reached almost the same results as conventional sewage treatment plants. Phosphorous release was still higher in the aquaculture, which was due to advanced phosphate elimination in the STPs. By contrast, surface water qualities released by the aquaculture were almost of bathing quality. This hygienic standard could not be met by the conventional STPs in Berlin. Bathing quality measures and the elimination of E. coli were 100 times higher compared to conventional treatment plants.

The Stensund Aquaculture succeeded as an integrative blue-green infrastructure that, rather than downcycling wastewater, managed it as an upcyclable daily resource. When this solar water loop technology was compared to the annual means of Berlin's fossil-fueled sewage treatment plants concerning prevailing nutrients, the nitrogen measures were lower and

[698] Guterstam (1996)
[699] Guterstam (2010)
[700] EU (2006)
[701] Guterstam (1996, p. 81) In: Roggenbauer (2005)
[702] Referring to quantitative data in: BWB (eds.) *et al.* (2008, p. 28)
[703] Guterstam (2010)

phosphate was higher (reference period 1990-1993).[704] If not reused on land, both nutrients would be major threats to natural waterbodies causing eutrophication.[705] The uptake of nitrogen and phosphorous was increased due to optimizing the treatment performance within the second operational period (1994-1997).[706, 707] As reflected in the effluents, the reduction was ~69% for nitrogen and ~72% for phosphorous, compared to the first period with nitrogen reduction less than 60% and phosphorous ~45%.[708] Nevertheless, lower phosphate concentrations in the effluent of conventional sewage treatment plants resulted from costly phosphate elimination with chemical treatments, particularly the admixture of metal salts (e.g. iron sulfate).

The eco-technical wastewater management approach as realized in the Stensund Wastewater Aquaculture was more efficient from a sustainable resource management point of view. Life-essential nutrients, such as nitrogen and phosphorous, were incorporated into productive ecosystem resource cycles. Contrary to the latter, the objective of the conventional hard water infrastructure approach was to mineralize these resources. The *one-way philosophy*, thus, excluded an active ecosystem life-support accompanied by circular resource services on which the urban everyday infrastructures actually depended.

In conclusion, the most striking parameter in the comparison analysis of classic water treatment parameters was the swimming water quality finally released from the aquatic indoor ecosystem. It reflected that most of the nutrients had been incorporated into living biomass, producing oligotrophic (nutrient-deficient) water as a by-product. After being released from the outdoor crayfish pond, the naturally purified water could be further used for irrigation and fertilization of a short rotation plantation of willows. As an additional land-based infrastructure,[709] short rotation plantations (SRPs) combined agricultural and forestry practices (agroforestry) to grow woody biomass.[710] Most of the water was, therefore, evaporated in the outdoor SRP, while supporting small water cycles along with the enhanced green water performance in the adjacent Baltic Sea watershed (3.3).

WIDENED FOCUS: MULTIFUNCTIONAL EVALUATION – SUSTAINABLE PROCESS INDEX

Complementing the classical technical evaluation through relevant water measures, Roggenbauer extended the rather narrow set of criteria through applying a more integrative, thus multifunctional, perspective.[711] In his comparative study, he calculated the sustainability process index (SPI) while investigating the performance of Stensund aquaculture, and two conventional Swedish treatment plants within the Trosa commune. Similar to evaluating the ecological footprint,[712] the starting point of SPI calculations was the assumption that all

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[704] Roggenbauer (2005)
[705] The accumulation of nutrients leads to changes in an ecosystem or parts thereof.
[706] Ibid.
[707] Guterstam *et al.* (1998)
[708] Roggenbauer (2005, p. 137)
[709] e.g. Biopros Consortium: Heinsoo *et al.* (2008); Brüll and Bürgow (2009); Bürgow (2009)
[710] Brüll and Bürgow (2009, p. 46)
[711] Roggenbauer (2005)
[712] Krotscheck and Narodowlawsky (1995) in: Roggenbauer (2005, p. 135)

processes in a sustainable economy are solar-based and, therefore, area is the limiting factor: "Area in m² is the basic unit in all SPI calculations."[713] Thus, the lower the SPI value, the better the sustainable performance of the infrastructure. Besides space-efficiency, further key SPI measures were exemplarily aggregated (Table 14).

Table 14: Exemplary key measures for SPI evaluation comparing the Stensund aquaculture with two conventional treatment plants within the Trosa commune

Key measures for SPI evaluation	Stensund Aquaculture	Langnö Treatment Plant	Trosa Treatment Plant
Treated wastewater amount	1990-1993: 6 m³/d 1994-1997: 12 m³/d theoretical future: 20 m³/d	50 m³/d	1600 m³/d
N recovery	1990-1993: < 60% 1994-1997: 45% theoretical future: 90%	40%	40%
P recovery	1990-1993: 69% 1994-1997: 72% theoretical future: 95%	95%	97%
Chemical phosphorous precipitant (poli-aluminum-chloride)	1990-1993: 1000 kg/a 1994-1997: 1000 kg/a theoretical future: functioning natural precipitation	5400 kg/a	85,500 kg/a
Oil (for supplemental heating)	1990-1993: 200 l/a 1994-1997: No. theoretical future: No.	no information // no heat pumps	no information // heat pumps installed
Employees/Staff	1990-1993: 1 1994-1997: 0.5 theoretical future: 0.5	0.2	0.5
Multiple uses	Sewage treatment plant Greenhouse, school, research lab, guided tours	no information	no information
SPI value	1990-1993: **0.16** one person needs ~16% of their available living area to dissipate their annual amount of wastewater into the Baltic Sea 1994-1997: **0.06** one person needs ~6% of their available living area theoretical future: **0.03** one person needs ~3% of their available living area	0.29 one person needs ~29% of their available living area	0.36 one person needs ~36% of their available living area

The Stensund system, although not fully working, was evaluated as the most sustainable wastewater infrastructure according to the integrative SPI evaluation. This was primarily due to the high rates of nutrients recovered and its multifunctionality reducing spatial needs.[714]

[713] Roggenbauer (2005, p. 135)
[714] Roggenbauer (2005)

In sum, water resource infrastructures that embrace multiple services have a better SPI. In the case of the Stensund Wastewater Aquaculture, the blue-green infrastructure served as a sewage treatment plant, greenhouse and applied learning facility. In addition to technical and socioeconomical infrastructure criteria, as included in the SPI, the evaluation was further extended in the following.

INTERTWINED FOCUS: NATURAL-CULTURAL EVALUATION

According to central problems and questions addressed (1.1.3), the *intertwined focus* faces the blue-green infrastructure design and service evaluation regarding multifunctional natural and cultural life-support: The natural perspective, thus, focuses on blue and green water services and affiliated regenerative design issues, and the cultural one highlights usability and transformative features. It includes criteria such as flexibility, tangibility and aesthetics, or participation. Against the backdrop of currently prevailing Western technical infrastructure design and resource management (1.1.2), the Stensund case is qualitatively evaluated according to its multiple infrastructure benefits of mutual natural-cultural life-support (Table 15).

To conclude: In light of the long-term design-research experience of 13 years (1987-2000), the Stensund Aquaculture was a pertinent international pilot and reference project. It successfully demonstrated multifunctional options of aquacultural wastewater management embracing water purification, energy regeneration and living biomass production performed in a solar greenhouse under Nordic climate conditions. Besides serving as a multiple eco-technical water infrastructure in a real-life Western context, it was a unique educational infrastructure for both applied learning and researching. It became an important international hub – as a meeting point and network base – for people from different nations and cultures to mutually bring in and exchange ideas and experiences. Shortly before the project's closure, Stensund Aquaculture was selected out of 200 projects for a European award from the Altran Foundation encouraging technological innovations and recirculation systems for improved quality and access. Thus, after finishing the pilot test phase and closing the greenhouse aquaculture in 2000, the Stensund project continued to exist. The aim of raising interest and transforming mindsets in using and handling everyday basic resources was more than met. Its unique learning-from potential is exemplarily described in one out of 100 personal statements attached to the *Aquaculture Declaration*, which was initiated and supported by actual and former project participants in 1999: "(…) I could spend all day and night there as I used to running tests during nights, just because I loved it. Everybody knows that the best way to learn is just to touch things you are learning about."[715]

Due to its integrated socioecological design, the Stensund Wastewater Aquaculture became an inspirational source and role model for further adaptations under moderate climate conditions, particularly in Switzerland.

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[715] Brüll and Bürgow (1999, p. 14)

Table 15: Evaluation of multifunctional blue-green infrastructure design and services – The Stensund Wastewater Aquaculture

Evaluation criteria	++ (clearly achieved)	+ (partly achieved)	- (not achieved)
Supporting blue-green services	++		
	Referring to the *basic blue-green services* (Table 3), all criteria are met – indoor and outdoor landscape wise. Prevailing blue-green services comprise: 1) landbased retention and recirculation of vital nutrients and minerals; (2) regeneration of bathing water quality and local fresh water regeneration; (3) vital food and biomass reproduction; (4) increased diversity, vitality and livability; and (5) recreational functions due to enhancing the aspects of aesthetics, joy, etc.		
Flexibility of design			-
	Since both flow quantities and pathways were rather fixed, the overall system layout was only adjustable to a certain extent within the food web constructed. Infrastructural design and service limits occurred due to structural fixation.		
Tangibility of processes and aesthetics	++		
	The combined nine-step water purification and aquatic greenhouse production process has been fully perceivable and accessible by public visitors, and it was designated to a high aesthetic standard (visually, sensorially).		
Participative intervention and responsibility		+	
	The structural design and processes were 100% transparent, and researchers, students and public visitors were directly involved (mentally, physically), therefore, optional interventions (e.g. regarding technical or user-wise modifications) were rather high. Nevertheless, limits occurred due to structural inflexibilities. The possibility of becoming responsible, such as during courses or internships, was high.		
Community integration		+	
	Integration of local students was limited as the curriculum focused on Ecological Engineering in an international and Baltic Sea context. Therefore, Folk College students were able to join in on a free basis, which turned out to be a success.		
Applied learning, transforming spaces and mindscapes	++		
	Thousands of visitors and experts saw the aquaculture over 14 years – from the microscale test lab (1987-1988) to the macroscale campus-based operational test plant phase (1989-2000). Inspiring through its beauty and integrative approach embraced, it influenced the personal biographies of many visitors and project participants. As a global learning-from case, it became a driver of at least a dozen follow-up projects in their site-specific contexts.		

5.2.5 Learning-from and follow-up projects

AQUAPONIC GREENHOUSES, SWITZERLAND

The first follow-up wastewater aquaculture was built in 1995 in Waedenswil as a project of the Zurich University of Applied Science. It was followed by the second Swiss wastewater aquaculture project in Otelfingen, near Zurich, which was applied as an industrial application starting operation in 1998 (Figure 59). Linked to a methanization plant for municipal organic waste, the Otelfingen aquaculture processes bio-industrial wastewater through a partly indoor aquaculture plant. At the time of construction it encompassed 36 basins covering 360 m² in total area holding 420 m³ volume. The technical objective was to convert dissolved nutrients into valuable biomass while meeting Swiss wastewater standards.[716] The basic concept was developed by Junge-Berberović and Staudenmann in 1997.[717] Consisting of a one-step thermophilic biogas reactor, followed by an aerobic polishing unit, the eutrophic biogas effluent was used as a fertilizer for the wastewater-fed aquaculture.[718]

Based on the fact that the sole purpose of wastewater treatment via a greenhouse-based aquaculture production plant is unfeasible, the Otelfingen project aimed to further explore the efficient and safe production of renewable biomass, fish and other valuable products. Facing the pilot experiences from the Stensund and North-American wastewater aquaculture facilities, a twofold challenge was addressed:

- adaptation from tropical to temperate (indoor) climate (technically and biologically), and
- adaptation from non-industrialized to Western economy (adaptation of product palette and new marketing ideas).[719]

Figure 59: Indoor view of the Otelfingen aquaculture, and image of the company's biogas-driven vehicles

The Otelfingen project considered key-factors of optimization with regard to technical processes, e.g. nitrification and primary (microalgae) production.[720] In addition, economic

[716] Junge-Berberović *et al.* (1999); Junge-Berberović (2001); Staudenmann and Junge-Berberović (2003);
[717] Graber and Junge-Berberović (2008, p. 300)
[718] Ibid.
[719] Staudenmann and Junge-Berberović (2003, p. 69)

feasibility was enhanced due to offering marketable products and services (e.g. valuable non-food products, special educational courses).[721]

As opposed to cheaper and more efficient biological wastewater systems,[722] Junge-Berberović referred to the "greatest recycling potential"[723] as the main advantage of wastewater-fed aquacultures. "Therefore, a central issue in improving wastewater-fed aquaculture should be to increase the share of recycled nutrients."[724] In line with this, she listed a wide array of aquaculture products which could be safely and healthily produced in a controlled greenhouse environment while utilizing natural self-purification capacities at minimal space (Table 16).[725]

Table 16: Array of marketable products through wastewater-fed aquaculture

Category of products	Aquaculture species
Food for humans – Edible plants	High-protein algae (*Spirulina*) Water spinach (*Ipomea*) Water chestnut (*Elocharis dulcis, Cyperus esculentes*) Water nuts (*Trapa, Alternanthera*) Hydroponic vegetables and herbs (*Capsicum*, basil, lettuce)
Food for humans – Edible animals	Mussels Prawns (*Macrobrachium*) Crayfish (*Procambarus clarkii, Astacus, Cherax*) Fish (carp species, *tilapia, clarias, Channa striata, Micropterus salmonidae*)
Animal feed	Phytoplankton (*Microcystis, Scenedemus, Selenastrum, Anacystis, Phacus, Closterium*) High-protein floating plants (*Lemna, Azolla, Wolffia*) Zooplankton (*Asplanchna, Filina, Keratella, Brachionus, Moina, Daphnia, Cyclops*) Fish feed (earthworms)
Raw materials	Fibers for furniture, baskets (*Eichhornia*) Cellulose for paper (*Typha*) Isolation material (*Typha*) Fertilizer (algae suspension, plant biomass) Renewable energy sources
Luxury products	Pearls (*Hyriopsis, Cristaria*) Ornamental plants (*Eichhornia, Nuphar*) Ornamental fish (koi – *Cyprinus carpio*)

- In addition to successfully reaching Swiss standards in effluent quality, a wide palette of aquaculture products was harvested as biomass. Approximately 97% (~2,080 kg) were floating macrophytes. Out of a total 2,150 kg fresh weight (FW) aquatic biomass during the 16-week experimental period (137 kg/week), 67 kg Daphnia and 4.4 kg fish were harvested.[726] The macrophytes were either sold as ornamental

[720] Guterstam *et al.* (1998)
[721] Guterstam (1999)
[722] e.g. compared to much more cost-effective planted soil filters Graber and Junge-Berberović (2008, p. 308)
[723] Junge-Berberović (2001, p. 111)
[724] Ibid.
[725] Junge-Berberović (2001, p. 116)
[726] Staudenmann and Junge-Berberović (2003, pp. 81–87)

plants or reused for biogas production.[727] Water hyacinths (*Eichhornia crassipes*) reached the largest proportion in yield (Figure 60).

- During warm days, water hyacinths are able to reproduce by 15% of the total water surface, reaching 20-40 t/ha of fresh plant harvest per day.[728] Furthermore, water hyacinths can provide a promising raw material (Table 16). Due to their high fiber content, they are used in furniture and textile design. Lesser duckweed (*Lemna minor*) reaches similar growth rates. It is a perfect animal fodder (e.g. fish, ducks and pigs) due to providing higher protein (vs. fiber).[729]

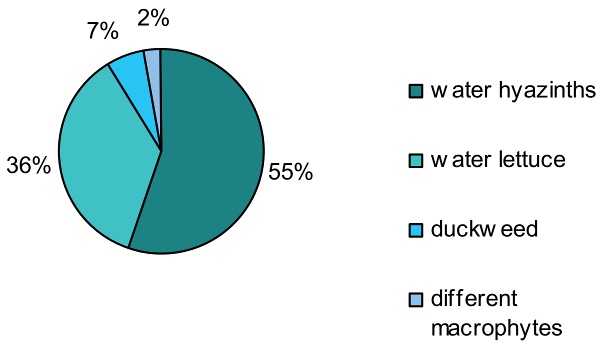

Figure 60: Proportional yields of macrophytes during 16-week experimental period in Otelfingen

The follow-up research focused on increasing the nutrient-recycling efficiency. Related results stated that it was possible to increase the fraction of nutrients eliminated via primary production up to 40%, which was significantly higher than reported in literature.[730] Although, biogas effluent loading was five times higher in 2000 compared to 1999, nitrogen elimination increased four-fold due to system and plant uptake. The system uptake for phosphorous was similar, but plant uptake doubled.[731] The probable reasons for better process performance mentioned were:

- more frequent harvesting, and
- a higher percentage of rooted plants that were able to extract phosphorous from sediment.[732]

Based on the Otelfingen experience, another successful Swiss pilot aquaculture project was initiated in 2000. The tropical greenhouse in Ruswil, nearby Luzerne successfully combined productive tropical fish aquaculture (*Tilapia spec.*) and soil-based fruit farming (e.g. papayas,

[727] Ibid.
[728] Bachofen *et al.* (1981, p. 88)
[729] Ibid.
[730] Graber and Junge-Berberović (2008, p. 299)
[731] Ibid.: pp. 304-305
[732] Ibid.

bananas, mangos), while reusing waste heat from a nearby gas densification plant and wastewater from fish production for irrigation and fertilization.[733] (Figure 61) After the closure of the piloting test system, further commercial models combining aquatic with soil-based tropical production were introduced and replicated. A recent follow-up project focusing on urban food production (no wastewater reuse) is the Urban Farmers' roof-top greenhouse in Basel, which is marginally glimpsed affiliated to contemporary Berlin examples (4.5.3).

Figure 61: The Tropehus *in Ruswil – a pilot greenhouse with tropical fish and plant production*

[733] Heeb (2005)

5.3 Case study 2: The Science Barge – New York City, USA

Against the backdrop of the successful project experiences in European decentralized and periurban contexts, aquacultural blue-green infrastructure case studies in the following focused on the 21st century mega-urban context of New York City. The empirical research explored aquacultural blue-green infrastructure approaches facing needs of urban food provision and wellbeing in the light of water- and climate-sensitive redevelopment at human-scale. Therefore, the impetus was on embedding within the urban neighborhood and a close relation to everyday life education. The case studies encompassed hands-on learning and integrative design projects that cocreated place-based forms of contemporary urban aquaculture alongside entrepreneurial bottom-up developments.

Figure 62: The Science Barge – Hudson River, New York City

5.3.1 Project Story

The Science Barge is a pilot floating greenhouse in New York City. As a solar off-grid infrastructure, it symbolizes self-sufficient 21st century lifestyle possibilities combining integrated urban farming, everyday life education and community rebuilding services in a metropolitan context.

The Science Barge was launched in 2007 as a *prototype sustainable urban farm* (Figure 63) on New York's Hudson River in central Manhattan by the environmental nonprofit organization *NY Sun Works Science Barge*. The project's *raison d'être* was centered on emerging questions tackling major global cities alongside postindustrial transformation processes, such as: How to provide healthy and fresh food within the city's boundaries on a daily basis, in a high-quality and climate-friendly manner? How to use local space, resource and regenerative energy flows effectively and mutually beneficially?

According to Benjamin Linsley, Managing Director of BrightFarm Systems – the commercial follow-up of the NY Sun Works Science Barge – two main purposes were targeted within the initial two-year period. The first purpose was rather technical and driven by applied research objectives. Linsley referred to it as follows:

> "Is it possible to take a greenhouse and put it into the city and run it in a carbon-neutral or low-low carbon fraction? (…) And the other purpose for us was to demonstrate, to be able to come and shout about and to challenge people to say: Look, this equipment worked very well. It is extremly efficient. You know, we can do this in cities. These greenhouses don't need to be in the countryside."[734]

The project has gone through two development and operation phases since 2007, loosely called: *Let it flow* (phase 1) and *Let it grow* (phase 2). The start-up prototype development phase from 2007-2009 focused on technological design-research, particularly on hydroponic farming culture, including suitability and profitability of production, water and energy needs. It was followed by a place-based adaptation and integration phase as an evolving process. The currently ongoing second phase is centered round applied education, social outreach and neighborhood integration along with community rebuilding services.

Figure 63: The Science Barge located at Yonkers, New York City

After the successful two-year test period with all initial purposes fulfilled, the project was handed over to the nonprofit organization *Groundwork Hudson Valley* in 2010. As the permit for central New York expired, the location of the Science Barge moved north of the city, to the district of Yonkers in the Hudson River valley. Its purpose switched from R&D combined with socioenvironmental education to issues of everyday usability including hands-on learning. Being embedded into a low-income neighborhood, the project's value-framework embraced socioecological responsibility, relationship building and well-being at communal and human-psychological levels.

[734] Linsley (2010)

5.3.2 Case-study profile

FLOATING GREENHOUSE TEST CASE FOR FLEXIBLE ROOF-TOP WATER-FARM APPLICATIONS

Table 17: Profile of the Science Barge

Features	The Science Barge
Typological form and blue-green design features	Floating greenhouse embodying lightweight urban farming installations that are particularly appropriate for urban roof-tops, e.g. hydroponics, window-farming assets; further features include a constructed wetland as zero-effluent water system for evaporative filtration of production wastewater.
Nutshell description	*Urban ark* as a prototype off-grid infrastructure installed as a sustainable urban farm showcase and education center for testing potential roof-top applications with zero net carbon emissions, zero chemicals and zero run-offs.
Main infrastructure services	Urban food production combined with nutrient recycling, solar and waste energy use Education, R&D Community rebuilding in low-income neighborhood
Spatial setting	District of Yonkers, north of New York City
Landscape setting	Waterfront on the Hudson River
Climate	Humid subtropical climate (N Lat. 40°) Mean annual temperature: 12.6°C Precipitation: 1,260 mm*
Size	Classes: ~15-20 students Total floor space (barge): 400 m² Greenhouse floor space: ~200 m² Wetland boxes: ~7 m²
Project initiators/developers	Ted Caplow/New York Sun Works & Bright Farm Systems
Operator/client	Groundwork Hudson Valley
Development phases 1) start-up R&D phase 2) operation and applied education phase	 2007-2009 – NY Sun Works (applied research, demonstration and public outreach) 2010-current – Groundwork Hudson Valley (community integration and applied learning)
	Sources: * http://en.wikipedia.org/wiki/Climate_of_New_York (2012-03-03)

5.3.3 Multifunctional blue-green design and service potentials

The Science Barge features water-farming technologies, particularly fresh urban vegetable produce encompassing solar greenhouse-based hydroponic plant production modes. As highly-productive and lightweight (compared to soil-based) urban farming strategies, they offer advantages for potential roof-top applications. Further blue-green design and service features are the fully regenerative energy supply and space- and water-effective ways of fresh and healthy urban protein food production as highly appropriate for dense settlements.

In light of the currently ongoing second phase of the operation focusing on usability, applied learning and community services, the following blue-green features were tested according to their transferability into real-life urban contexts:

- Potentials of small-scale urban water-farming options from window-gardens to indoor-farms along combined and modular water and food production modes, and
- potentials of clean and healthy production, such as zero-emission performance through clean energy-based and CO_2 neutral food production or zero additives along with the 100% ban of pesticides, hormones and other harmful substances within sustainable farm production

Other blue-green features of the Science Barge apply particularly to water-sensitive design-management principles in a place-based context:[735]

- Almost 100% rainwater-based production,
- complementary use of purified river water (conversion of small quantities of brackish water into freshwater through reverse osmosis), and
- water and nutrient reuse through recirculating hydroponics.

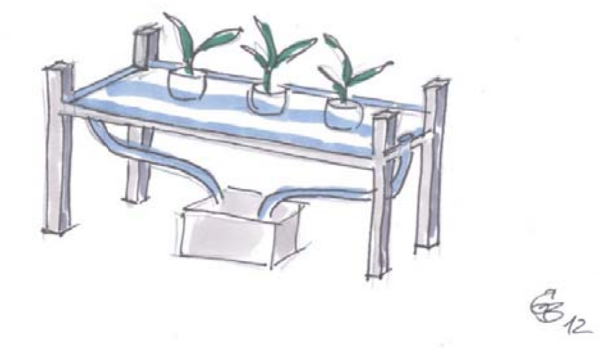

Figure 64: Circular nutrient and water pathway in an NFT system

According to its distinctive water-farming features, the prototype sustainable farm contained several recirculating hydroponic modules, partly tested and combined with aqua-horticultural cultivation including crayfish, mussels and small fish. Water could be re-harvested due to the circular flow design. The plants took up nutrients from the water that flowed by gravity through the growing channels, thus, purifying the water, which could be collected again in a tank for the next reuse (Figure 64).[736]

Based on the NFT system, various vegetables and fruit, from tomatoes, cucumbers, melons, lettuces, and beans to strawberries, grapes and herbs[737] were grown (Figure 65). NFT belongs

[735] Eder and Hill (2010)
[736] Ibid.
[737] Eder and Hill (2010)

to the category of liquid hydroponic systems, which also includes floating rafts (FR) or non-circulating aquaculture technologies.[738]

Figure 65: Left and Middle: Rainwater collection connected to recirculating hydroponics (NFT technology), Right: Hydroponic window-farming installation

To sum up, a selection of facts and figures highlighting the benefits of sustainable water-farming along with hydroponic food production were derived. They were a compilation of different research sources from urban farmers, practitioners and applied case-studies.

EXEMPLARY FACTS AND FIGURES OF HYDROPONIC FARMING

COMMON EVERYDAY RESOURCES

- Whereas today, up to 75% of freshwater is used to water crops,[739] hydroponics uses 2% less water that conventional farming.[740]
- Hydroponics uses 10% of the water amount compared to vegetables grown in soil.[741]
- Arable land is used effectively. Greenhouse hydroponic systems can reduce agricultural land and water use by a factor of five to ten.[742]
- Hydroponics produces eight to ten times more vegetable foodstuffs in the same area and time.[743]

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[738] Diver (2006)
[739] Jones (2002)
[740] Medina (2012)
[741] Ibid.
[742] NY Sun Works (2011)
[743] Ibid.

COSTS

- Reduction of costs can be achieved due to direct marketing of fresh products. No transportation or food preservation is needed due to producing and consuming in the city (*prosuming city*),[744] respectively "LoopCity"[745] (6.3.1).
- Further cost savings are made due to the absence of pesticides and the substitution of artificial fertilizer, particularly phosphorous through wastewater reuse (e.g. from fish aquaculture) (5.2.1).

BUILDING-INTEGRATED WATER-FARMING

- Lightweight water-farming modules offer structural building advantages.
- Resources which have been *wasted* up to now can be directly reused in a synergistic manner, e.g. waste heat (for greenhouse heating), waste air (optional greenhouse-based CO_2 conversion into O_2), and wastewater (optional nutrient reuse as *free fertilizer*).
- Co-beneficial socio-cultural values can be generated, e.g. within a neighborhood or coworking projects.

CLEAN ENERGY – ZERO EMISSION

The use of clean energy has been one major objective within the initial two-year test phase. Linsley mentioned that urban greenhouses as space- and water-efficient but high-energy systems had to be explored according to their potential to be operated on a carbon-free basis by using solely local regenerative energy.[746] The Wuppertal Institute stated as follows: "The term carbon-free refers primarily to the electricity and heat supply to the population as well as to the transportation infrastructure."[747]

The clean energy side of the Science Barge succeeded after the first two years of off-grid operation, reflected in the following figures:

- Today, almost 80% of the energy is provided by a set of solar PV panels as the base source.[748] The rest is complemented by a wind turbine, subsequently backed-up by a biodiesel and battery system.[749]
- Eder referred to the following figures concerning the biofuel potential for New York City: "New York City restaurants generate enough waste oil to supply 10 million gallons of biodiesel fuel annually."[750]

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744 Gorgolewski *et al.* (2011, pp. 164–167); Bürgow *et al.* (2012)
745 Uttke (2011)
746 Linsley (2010)
747 Wuppertal Institut (2010, p. 10)
748 Ibid.
749 Eder and Hill (2010)
750 Ibid.

- The regenerative energy features contribute to the Science Barge's clean energy profile due to zero (air) emissions, particularly carbon.[751]
- In addition to minimizing *the food-to-table-distance*, food transportation can be saved. Particulate emissions, such as nitrogen and sulfur oxide, from truck deliveries are reduced in addition to fossil fuel carbon emissions.[752]

HEALTHY PRODUCTION

Although using small amounts of additional fertilizer and fish fodder as industrial pellets, the Science Barge is a healthy production facility due to multiple reasons:

- No artificial additives such as hormones or pesticides are used.
- No wastewater effluents are generated due to the recirculative design in aquaponic and hydroponic food production. The remaining effluents are 100% evaporated through a zero-effluent wetland for biofiltration and evaporation (green-water performance) located on the deck of the barge.[753]
- Healthy water quality is regenerated due to preventing the use of chemical pesticides in addition to wastewater run-offs into natural surface waters.

5.3.4 Discussion: Outcomes and evaluation

PHASE 1: PROTOTYPING URBAN HYDROPONIC FARMING TECHNOLOGY

The two basic questions approached during the initial R&D phase were:

- Is it possible to run greenhouses in a carbon-neutral fraction?
- How many people could be served if the technology was up-scaled; basically using the vacant roof-space in New York City?[754]

Major results of applied design-research after the completion of test phase 1 were:

- Sustainable urban farming applying hydroponics or aquaponics is a very space- and water-efficient way to produce fresh food without using pesticides, hormones or other harmful substances, while being 100% local regenerative energy-based.[755]
- Hypothetical calculations made from the investigations applied state that 5,000 ha of available roof-space used for hydroponic food farming could serve ~20 million New Yorkers.[756] Thus, New York's roofscape has the potential to provide fresh produce for almost 100% of the current population of the whole metropolitan region. If one

[751] Linsley (2010)
[752] Ibid.
[753] Eder and Hill (2010)
[754] Linsley (2010)
[755] Ibid.
[756] Eder and Hill (2010)

calculates that New York City itself has about 8-9 million citizens, the city itself could actually export food to its greater metropolitan region.

After succeeding in the initial test phase, the two other project objectives of demonstration and environmental education became crucial within the second phase of the operation.

PHASE 2: APPLIED LEARNING AND COMMUNITY OUTREACH

With regard to the third main purpose of education, the focus switched from guided tours to various target groups ranging from press and commercial firms to schools and private visitors. A specific educational program was developed subsequent to handing the barge over to the British organization *Groundwork*. It created the basis for community-based work in the continuing second phase of the operation.[757]

The two central objectives during the second phase comprised the following issues:[758]

- Everyday life education, particularly due to hands-on learning (urban farming trainings, classes for kids, schools),
- socioecological communication embracing community outreach and rebuilding, urban quality of life and wellbeing.

The major insights gained were:

- There is a great demand among New York schools (primary schools, high schools, university classes) for learning skills in healthy urban food and water production.
- The Science Barge is a valuable sustainable community asset. It provides resources and attraction particularly to low-income neighborhoods, which get access to local fresh produce and know-how about related farming practices.

Scholarship assistance to poor schools in the area of Yonkers has been provided since then. It comprises support of daily field trips to and student internships in the evenings and on weekends at the Science Barge. Eder stated as follows:

> "The Barge is unique, giving Yonkers residents who are being trained on board a head-start in the fields of hydroponics, aquaponics, solar and wind power and urban farming. This area of Yonkers is also considered a 'food desert' meaning there is very limited access to fresh produce grown locally and without harmful pesticides. For this reason, the concepts of sustainable urban agriculture are very pertinent to the community. The educational program, run five days a week, introduces the importance of eating fresh, local produce to children, some of whom have a diet of primarily fast food."[759]

[757] Linsley (2010)
[758] Eder and Hill (2010)
[759] Eder (2010)

Against the backdrop of currently prevailing Western technical infrastructure design and resource management (1.1.2), the Science Barge case was qualitatively evaluated according to its blue-green infrastructure benefits of multifunctional natural-cultural life-support (Table 18).

Table 18: Evaluation of multifunctional blue-green infrastructure design and services – The Science Barge

Evaluation criteria	++ (clearly achieved)	+ (partly achieved)	- (not achieved)
Supporting blue-green services		+	
	Referring to the basic blue-green services (Table 3), almost all criteria are met – indoor and outdoor landscape wise. Prevailing blue-green services comprise: (1) vital food and biomass reproduction; (2) landbased retention and recirculation of vital nutrients and minerals; (3) local fresh water regeneration, (4) increased diversity, vitality and livability; and (5) recreational functions due to enhancing the aspects of aesthetics, joy, etc. Potentials of optimization particularly regard the substitution of industrial fish fodder and fertilizer through improved local nutrient cycles (e.g. vermicomposting, etc.).		
Flexibility of design	++		
	The overall design is quite modular. Flow quantities, pathways and the production layout are flexible to modify and adapt to a certain extent.		
Tangibility of processes and aesthetics		+	
	All components are fully tangible and accessible by public visitors. The flexible low-tech design includes a standard greenhouse of decent architectural quality (visually, sensorially).		
Participative intervention and responsibility	++		
	The structural design and processes are 100% transparent. This allows visitors, school children, students, and the interested public to participate easily. The possibility to influence due to technical or user-oriented modifications is high, and to become responsible by attending courses or internships.		
Community integration		+	
	There is a strong community link due to offering specific curricula as well as scholarship assistance to struggling schools in the area. Hence, there is still potential to integrate local people better at a daily-life level.		
Applied learning, transforming spaces and mindscapes	++		
	There has been wide public interest from the beginning, since public outreach has been a central issue. In addition to the diversity of course programs aimed at different target groups, thousands of international visitors learnt-from the project. Moreover, local entrepreneurs and companies have been inspired and initiated follow-up projects.		

Summing up, the Science Barge has been a pertinent international pilot and reference project. It proved that greenhouse-based sustainable and healthy food production was possible within the city. Technically, it successfully demonstrated the multiple benefits of urban water-farming due to hydroponic and aquaponic fish, fresh vegetable and protein produce on a clean energy basis. Socially, it served as a unique multiple blue-green infrastructure for hands-on learning and community purposes, catalyzing further educational and commercial aquaponic and hydroponic greenhouse projects.

5.3.5 Learning-from and follow-up projects

ROOF-TOP GREENHOUSE SCHOOLS

Inspired by both the educational program of the Science Barge and the idea of producing fresh healthy food right in the city, the Manhattan School for Children started the first follow-up project in 2010.[760] The 130-m^2 roof-top greenhouse stands on a three-story building in the Upper West Side. The project's objective was to create a more sustainable campus and curriculum, and "a school-based successor to the Science Barge (…), which is hoped to serve as a prototype that can be replicated at other schools throughout New York City."[761]

Linsley, from the project design-building team BrightFarm Systems, put the integrative goals of this public-private partnership as follows:

> "(…) food for the school, the ability to talk about where the food grows and connect it to kids' understanding of healthy eating. Particularly in the U.S. where in a lot of cities, urban kids only ever see packaged food. So it's very difficult to talk about nutrition, vitamins and, you know, a healthy balanced diet when all they ever see is packaged food. It is much easier when you go to a tomato plant growing and you can talk about nutrients that go into a tomato and the vitamins that come out. You know it is a very, very powerful way of talking about healthy eating. But it is also a very powerful way of talking about environmental science and then biology."[762]

The project currently serves about forty students in applied learning of scientific and environmental concepts on urban food production all year round. Furthermore, it provides teachers' education in collaboration with neighboring institutions, e.g. providing after-school and weekend workshops.[763]

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[760] Linsley (2010)
[761] Gorgolewski *et al.* (2011, p. 179)
[762] Linsley (2010)
[763] Ibid.

GROCERY GREENHOUSE AND COMMERCIAL URBAN FARM IN NEW YORK CITY

If commercial and marketing benefits meet, roof-top greenhouse farms are promising urban building-blocks. The 840-m² greenhouse of Eli Zabar in Manhattan's Upper East Side was an early commercial success story of urban roof-top farming established in 1993.[764] However, it became broadly known alongside the 21st century Zeitgeist of urban farming. Installed on the roof of a former vinegar factory, it co-benefitted the gourmet marketplace in the underlying floors selling fresh products directly where produced.[765] Thus, it was a pioneering entrepreneurial example contributing to the emerging *prosuming city* or *loop city* trends.

Dedicated to large-scale urban roof-top farming, Gotham Greens was the entrepreneurial producer's spin-off of the Science Barge. Jennifer Nelkin, the company's director of the 12,000-ft^2 commercial hydroponic roof-top farm greenhouse, summarized the mission of the recent project: "We are trying to demonstrate that sustainable urban agriculture can be economically viable in the city."[766]
In addition to monetary benefits due to saving transport, energy and other costs, the more Zeitgeist-related benefits addressed human ethical motives in light of socio-ecological responsibility and lifestyle. The company's Managing Director, Viraj Puri, stressed the great disadvantage of today's industrial agriculture, which "occupies 40% of the world's land surface, uses 60% of the freshwater withdrawals worldwide, and causes 15% of world greenhouse emissions, and is the largest source of water pollution."[767] To turn urgent global problems into commercial entrepreneurial opportunities was also envisioned by the first customer cooperation with the grocery store *Whole Foods*. It aimed as follows: "70% of the produce will go to its New York stores, but Gotham Greens also hopes to deliver produce to farmer's markets around the city."[768]

Linsley stressed in summary, that New York City, along with the variety of urban farming projects, has strengthened its first mover role as one important "center for urban farming, roof-top agriculture."[769] Moreover, trends of healthy and sustainable urban lifestyles became tangible along with the revitalization of New York's various waterfront spaces. They reflected particularly on aquacultural facets of a reemerging urban water-living and water-wellbeing culture.

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[764] Gorgolewski *et al.* (2011, pp. 164–167)
[765] Ibid.
[766] Stone (2009)
[767] Puri (2008)
[768] Stone (2009)
[769] Linsley (2010)

5.4 Case study 3: The Oyster Dock – The New York Harbor School at Governors Island, USA

Figure 66: The Oyster Dock – Governors Island, New York City

5.4.1 Project Story

Governors Island – a military outpost first named in 1698[770] – is located at the mouth of New York's East River, in the center of the harbor of South Manhattan. As a military installation, it was formerly owned by the State and Federal Government, and recently became the property of New York City.[771] Besides Battery Park, Gantry Plaza State Park, Hudson River Park, Riverside Park South, and Brooklyn Bridge Park it is recognized as: "One of the next major public landscapes at the water's edge."[772]

The Oyster Dock was launched on a low-tech and low-cost basis in the summer of 2009. The intention was to introduce a replicable *eco-dock* for the recultivation of the New York Harbor oyster, which had been almost erased due to overharvesting and pollution. The idea was spearheaded by Michael Fishman, Managing Director of Urban Answers, a New York City-based planning and consulting firm. The design consisted of a ~120 m² walking wooden platform with metal grates under which several oyster tanks were placed (Figure 67). With about 600,000 oysters, it is the largest concentrated oyster population in the New York Harbor area.[773] Along with a series of Harbor School projects at New York's waterfronts, the project serves nowadays as a catalyst of socioecological riverscape remediation. Based on the fact that New

[770] Davis (2011, pp. 1–2)
[771] Fishman (2010b)
[772] Davis (2011, pp. 1–2)
[773] Fishman (2010a); Kamp (2010)

York's shorelines have over ten times the linear feet of other global waterfront cities, such as Sidney, Dubai and Los Angeles,[774] Fishman summarized the broader project vision:

> "The oyster dock is a replicable model for any structures built in and around New York Harbor to find ways to repopulate it with oysters and clean the water. Specifically on Governors Island it sets a precedent as the first project in a series of water edge and Harbor School projects that will build on activating the health of the water as well as the quality of life and education for students and visitors to the Island."[775]

Figure 67: The Oyster Dock as a low-tech outdoor learning-teaching platform

The project started up in collaboration with the New York Harbor School. As a high school devoted to harbor-related activities, first of all, research, exploration and maritime training, its curriculum infuses at least one water day per week. Landlocked in Bushwick Brooklyn, the new island school was opened at the newly city-owned Governors Island.[776]

Before the new school opened, the Oyster Dock was the first project which allowed direct access to the water for educational teaching and research purposes. Initiated by a schoolteacher building oyster farms with students, the equipment was attached to the underside of the dock allowing ~600,000 oysters to mature and to become re-harvested within the broader harbor area. Besides enhancing marine wildlife and biodiversity, the Oyster Dock cleans surface water all year round and is used for small craft, swimming in summer, research of water quality, and the like.[777]

[774] Fishman (2012, p. 7)
[775] Fishman (2010b)
[776] Ibid.
[777] Ibid.

5.4.2 Case-study profile

SWIMMING UNDERWATER GARDEN FOR NATURAL WATERSCAPE REMEDIATION AS LOW-TECH APPROACH

Table 19: Profile of the Oyster Dock

Project name	The Oyster Dock
Typological form and blue-green design features	 Swimming underwater garden type for oyster cultivation as pontoon structure of low-tech/low-cost character.
Nutshell description	Replicable floating eco-dock prototype that cleans water by harvesting oysters below the deck year-round and acts as an outdoor classroom, boat launch, water testing, and swimming site.
Main infrastructure services	Riverscape restoration, including surface water quality, waterscape ecologies, particularly oysters combined with theme-based public school activities and socioecological engagement.
Spatial setting	Governors Island waterfront vis-à-vis New York Harbor
Landscape setting	Island in the Hudson River
Climate pattern	Humid subtropical climate (N Lat. 40°) Mean annual temperature: 12.6°C Precipitation: 1,260 mm*
Sizing	Total floor space: ~120 m² Complete with 600,000 oysters being farmed underneath
Project initiators/developers	Michael Fishman/Urban Answers, New York City Project partners include Governors Island Preservation and Education Corporation (the government body responsible), the New York Harbor School (an Urban Assembly school) and the New York State Department of Environmental Conservation
Operator/client	New York Harbor School
Development phases 1) start-up phase 2) operation phase	 1999-2007 2007-current
	Sources: * http://en.wikipedia.org/wiki/Climate_of_New_York (2012-03-03)

5.4.3 Multifunctional blue-green design and service potential

The Oyster Dock as a *low-tech/low-cost* approach stands out for following two pioneering blue-green design and service potentials:

- Creating a replicable underwater garden with the capacity of growing ~600,000 oysters "cleaning hundreds of gallons of water in New York Harbor annually."[778] Thereby "each oyster is a natural water-filtration system, pumping between 20 and

[778] Ibid: p. 7

50 gallons of seawater through its gills each day and extracting algae and phytoplankton for its food."[779]

- Linking an ecological approach of riverscape remediation with a socially engaged public school approach pushed by "an alliance with the Urban Assembly, a nonprofit organization that has created 22 small, theme-based public schools in low-income areas."[780]

Sanderson compared the diversity of "ecological neighborhoods" ranging from the ocean to freshwater and land with those of urban neighborhood communities.[781] In light of this, the Oyster Dock, firstly, captivated through its socioecological engagement striving to recreate relationships between humans and neighboring water ecologies. This has been enabled in a close partnership with the environmental organization NY/NJ Baykeeper, a partner organization of Riverkeeper, which is devoted to protecting the Hudson River.[782] In an interview with the New York Times journalist David Kamp, Murray Fisher, the program director of the Harbor School, stressed the role of the "restoration-based curriculum" in the low-income area's public school which: "(…) makes kids feel that they're valuable contributing members of society. (…) At the very least, it would give them a relationship with a marine environment, which hardly anyone has in New York City."[783] Furthermore, he expressed his hopes "that the Governors Island oysters would ultimately be the Adams and Eves of a marine-life renaissance in the harbor."[784]

According to the project's broader value, Fishman highlighted that ecological, economic and physical systems surrounding our waterways have been in crisis since the industrial revolution. Therefore, similar projects "can repair the damage done over generations of abuse."[785] The artificial oyster reef made best use of salvaged material (lumber, steel). Fishman summarized its multiple blue-green services as follows: "The dock serves as the New York Harbor School's first usable presence on Governors Island and will remain their (and the public's) waterfront access component into the future as they (and the island development) begin to evolve on the island. Acting as a classroom, boat launch and testing site for water quality and habitat restoration."[786] The school's director also added its relevance to create future careers and perspectives of young people by saying: "The oyster thing alone, it's not just about oysters. It's about policy, technology, permits, aquaculture. We need people to become scuba divers, boat drivers, photographers, scientists, lawyers, lawmakers, marine-policy experts."[787]

[779] Kamp (2010)
[780] Ibid.
[781] Sanderson (2009, pp. 137–169)
[782] Kamp (2010)
[783] Fisher in: Ibid.
[784] Kamp (2010)
[785] Fishman (2010b)
[786] Ibid.
[787] Fisher in: Kamp (2010)

5.4.4 Discussion: Outcomes and evaluation

Facing the rising needs of adapting urban life patterns and basic infrastructures to emerging crises and unpredictable futures, the Pacific Oyster became a symbol itself. As a tenant of the maritime neighborhood, it symbolized a “master of survival.”[788] Being a highly flexible and adaptive species, it can be cultivated in many climates.[789] The Oyster Dock approach, therefore, was of global relevance to a *learn-for* resilient city context. It mutually links natural ecosystem restoration with applied learning and socio-ecological engagement.

Against the backdrop of currently prevailing Western technical infrastructure design and resource management (1.1.2), the Oyster Dock case was evaluated according to the multiple infrastructure benefits of mutual natural-cultural life-support mentioned (Table 20).

In summary, the Oyster Dock is a replicable blue-green waterfront infrastructure. Technically, it successfully proves flexible low-tech options to enhance common water-living and wellbeing in New York’s harbor area. It supports the restoration of riverscape ecologies and consequent natural surface water quality as common good. In addition, it serves as a unique socioecological infrastructure for hands-on learning and community purposes reconnecting human and marine tenants such as the Pacific Oyster.

[788] Saffer and Englert (2011, p. 57)
[789] Ibid.

Table 20: Evaluation of multifunctional blue-green infrastructure design and services – The Oyster Dock

Evaluation criteria	**++ (clearly achieved)**	**+ (partly achieved)**	**0 (not achieved)**
Supporting blue-green services	+		
	Referring to the basic blue-green services (Table 3), all relevant criteria are met. Prevailing blue-green services comprise: (1) regeneration of bathing water quality and local fresh water regeneration, (2) vital food and biomass reproduction; (3) increased diversity, vitality and livability; and (4) recreational functions. The project is a reference for sustainable oyster-farming linked to natural water-scape and water quality remediation .		
Flexibility of design	++		
	As a floating structure, the overall design is quite flexible and, thus, adaptable to different water-scape contexts. The underwater oyster farm is particularly adjustable to a certain extent.		
Tangibility of processes and aesthetics		+	
	All components are fully perceivable and accessible to students and visitors. As it is composed in a very low-tech manner, overall aesthetics, particularly of the pontoon structure in visual terms, are individual, hence, sensorial qualities are not disputed.		
Participative intervention and responsibility	++		
	The structural design and processes are 100% transparent. This allows the school students and the interested public to participate easily. The possibility to influence due to technical or user-oriented modifications is high, as well as to become responsible, such as during classes.		
Community integration		+	
	As the Harbor School's first usable presence on Governors Island, the Oyster dock is a common public waterfront access component. Acting as a classroom, boat launch and testing site for water quality and habitat restoration, it contains a great potential of community integration in the future as the island's development begins to evolve.		
Applied learning, transforming spaces and mindscapes		+	
	Since the project is rather young, public interest and public outreach are constantly growing. As a permanent part of the high school curriculum devoted to harbor-related activities (research, exploration, maritime training), it infused the everyday water relationship of school students.		

5.4.5 Learning-from and follow-up projects

INSPIRATIONS AND VISIONS OF THE AQUEOUS CITY

The 2010 MoMA exhibition *Rising Currents*[790] reflected that there was a growing recognition of New York City's ecological neighborhoods[791] and their urban ecosystem services. Today's visionary concepts have been reality in the past and might be in the near future. This is particularly true for New York's oyster-farming visions. Whereas the Oyster Dock is already today's reality in a real-life human-scale context, the concept of a *New Aqueous City* by nArchitects set it in a broader and futuristic water urbanistic setting.[792]

The contribution to the *Rising Currents* project, which was sponsored by MoMA and P.S.1 Contemporary Art Center, envisioned most of Manhattan's basic infrastructures onto the water. The designers stated as follows: "Water becomes the new connective tissue between the city and the harbor."[793]
This kind of repurposing of the uses of urban water surfaces could include edible oyster-farm structures, which was complementarily proposed by SCAPE studio in their *Oyster-Tecture* approach (Figure 68). Analogously to the Oyster Dock, the focus was on revitalizing a long-lost natural oyster reef. It envisioned the "developing (of) an armature in the shallow waters of the Bay Ridge flats, just South of Red Hook, Brooklyn. The structure – a field of piles and a web of 'fuzzy rope' – will be seeded with native oysters, which then will begin their natural work of reef creation (hence the title oyster-tecture)."[794] The project site encompassed the Gowanus Canal, which had been the subject of several studies of decontamination and redevelopment, as well as Governors Island and the waters between.

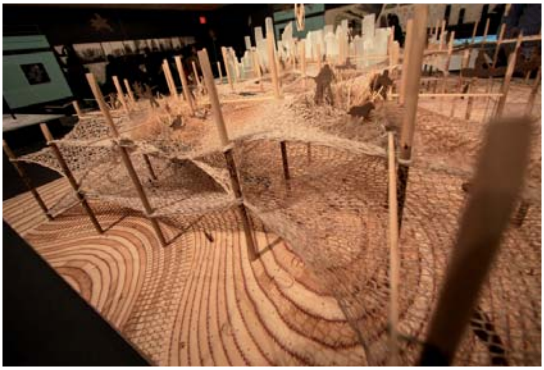

Figure 68: Oyster-Tecture infrastructure by SCAPE by team of Kate Orff

[790] MoMA (2010)
[791] Sanderson (2009)
[792] Rogers (2012)
[793] nArchitects cited in: Ibid.
[794] Ibid.

In the light of similar water- and climate-sensitive urban design proposals, the MoMA exhibition bridged to the global issue of developing resilient cities along soft infrastructure approaches. The exhibition text stated as follows: “According to a recent study by a New York City panel on climate change, even at current rates of global warming water levels will rise as much as two feet by 2080.”[795] According to these urgent place-based needs, the teams invited were asked “to consider a greater deployment of resilient, ‘soft’ infrastructure instead of relying solely on the traditional, defensive infrastructure of levies, seawalls, and storm-surge barriers built by the US Army Corps of Engineers.”[796]

To sum up, the multifunctional character of similar flexible infrastructures has become increasingly valued in tackling urban water and climate challenges. Their multiple blue-green service potentials from habitat restoration, water quality issues, storm water protection to community purposes have contributed to enhancing the everyday urban quality of life. A positive side-effect could be the recreation of literally *drinkable* and *swimmable* urban rivers.

[795] MoMA (2010)
[796] Ibid.

5.5 Case study 4: The Floating Lady – New York City, USA

Figure 69: The Floating Lady

5.5.1 Project Story

The idea of New York City's first floating pool called the *Floating Lady* was developed by former New York Parks Department official Ann L. Buttenwieser. More than two decades ago, she raised the question: "Why not put a swimming pool on a barge and moor it somewhere along the city's 578 miles of waterfront?"[797]

Parallel to research on her doctoral thesis on New York's urban bathing cultural history, in 1999, the newly founded Neptune Foundation hired the New York City-based architect Jonathan Kirschenfeld to initiate the design of a contemporary floating pool generation.[798] Buttenwieser, a former swimmer herself, launched this non-profit organization committed to re-establishing a 21st century urban river bathing culture through "commission(ing) the design and construction of a prototype for a new generation of movable waterfront pools for recreationally underserved communities."[799]

The *Floating Lady* thereby referred to five traditional floating pools around the Lower East Side in 1870[800] and 15 urban baths along the Hudson and East Rivers at the turn of the 19th century.

[797] Barron (2006)
[798] The Neptune Foundation (2012)
[799] Ibid.
[800] Chan (2007)

Buttenwieser described them as follows: “These floating saltwater baths, resembling giant houseboats with inner courtyards with seawater, offered their patrons exercise, relaxation – and coincidently – a place to wash. (…) By 1870, when New York's population had reached 1.4 million and an average of 2,000 new immigrants arrived each month, public baths came to be regarded as necessity rather than as a novelty.” Designed as wooden pontoon structures, the pools sat in the river whereby people swam directly in the river water protected by the structure around them.[801] The rivers in New York became increasingly polluted by raw sewerage,[802] and the remaining floating baths closed down in the 1940s due to the poor water quality and related public health reasons.

Figure 70: The Floating Lady at night

The reinvigoration of New York’s floating pool tradition started right after *9-11*, in 2001, challenging Kirschenfeld and the project developers concerning both funding and administration:

> “This is a seven-years-story though. And it went through every regulatory hurdle you can imagine. Is it a boat? Is it a building? (…) Building it down in Louisiana, half of it, and then bringing it to New York and then finishing it. (…) The fact that New York City never found a site until six months before we opened. So, we had only six months to compare a site. Just any obstacle you can imagine. We built it, before having a place, which is crazy, insane. We went ahead, spent 5 million dollars, brought it to New York and had no place to put it. It was like the ship of fools. We were really afraid that we would be homeless.”[803]

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[801] Kirschenfeld (2010)
[802] Buttenwieser (2002)
[803] Kirschenfeld (2010)

Site permission was given literally at the last minute. After retrofitting in Louisiana from 2003-2005, tugging up to New York in 2006, finally, on July 4, 2007, the C500 cargo barge-based *Floating Lady* was opened at Pier 4 near Brooklyn Bridge and northeast of Governors Island (Figure 70).[804]

5.5.2 Case study profile

FLOATING POOL FOR CULTURAL WATERSCAPE REMEDIATION AS HIGH-END APPROACH

Table 21: The Floating Lady Pool Profile

Project name	The Floating Lady
Typological form and blue-green design features	 Floating pool type made from a salvaged cargo barge of symbolic blue-green character, thus optional blue-green service integration.
Nutshell description	A moveable retrofitted C500 cargo barge transformed into a public swimming pool acting as a “migrating recreation pier.”*
Main infrastructure services	Urban recreation, community welfare
Spatial setting	Manhattan/Bronx – off Barretto Point Park, a five-acre stretch of Hunts Point with a view of North Brother Island**
Landscape setting	Waterfront on the Hudson River
Climate pattern	Humid subtropical climate (N Lat. 40°) Mean annual temperature: 12.6°C Precipitation: 1,260 mm***
Size	L x W: 80 ft x 260 ft; 25 m x 80 m Total floor space: 2,000 m² Volume: 100,000 gal; ~380 m³ Capacity: 170 swimmers at one time****
Project initiators/developers	Ann L. Buttenwieser/Neptune Foundation Jonathan Kirschenfeld/Architect NYC
Operator/client	Consortium of New York State, New York City agencies, Brooklyn Bridge Park
Development phases 1) start-up phase 2) operation	 1999-2007 2007-now
	* (Kirschenfeld 2012) ** http://floatingpool.org/index1.html (2010-05-05) *** http://en.wikipedia.org/wiki/Climate_of_New_York (2011-03-03) **** (Barron 2010)

[804] Ibid.

5.5.3 Multifunctional blue-green design and service potentials

Kirschenfeld referred to the blue-green infrastructure design objectives embraced as follows:

> "We always promote the floating pool as a green project not because it has a lot of green amenities, but basically because we converted a used cargo-barge into a floating swimming pool facility. That is repurposing in the most, I would say, significant sense of the term."[805] Being the first generic floating pool it is still a "plug-and-play version,"[806] since, by the time of implementation, it was economically not viable to make it completely self-sufficient. However, its symbolic value is of greater relevance: "Besides demonstrating that it is possible to create a fully sustainable off-the-grid structure, it indirectly communicates the future possibility of healthy and swimmable urban rivers."[807]

In sum, the two major blue-green objectives encompassed:

- Physical upcycling of a salvaged cargo boat into a floating public pool.
- Symbolic communication of full self-sufficiency and healthy swimmable urban rivers.

As mentioned earlier, besides design-build issues, the *Floating Lady* had to tackle some rather regulative challenges. According to Kirschenfeld:

> "The pool finally got site permission due to a last minute decision of the public client – a consortium of New York State and New York City agencies, as well as Brooklyn Bridge Park – which was the intention to get people to pay attention to this new project (…) called *Brooklyn Bridge Park*. And the best way to do it, was to bring something to it, because there was nothing, no construction. It was just piers, and industrial infrastructure. And nobody, no public was allowed to come here. So suddenly they said, here is a great idea to promote our idea of making a park. 'Let's bring the pool here, bring the press, bring TV, have these big public events for two months.'" (…).[808]

The biggest problem remaining, however, was to install a public pool in a publicly inaccessible site: "People had to walk probably half a mile from the subway station, down a hill, under a bridge, into a gate, across a parking lot and it's like the water's edge has nothing to do with the infrastructure of transportation."
Finally in 2008, the Neptune Foundation donated the park to the New York Department of Parks and Recreation, not least to fulfill its intrinsic requirement. The *Floating Lady* moved to the Bronx, off Barretto Point Park: "The only community in the five boroughs that has no public swimming pool. So there is an issue of social need and social justice."[809] Hence, the new location added a new infrastructural function to the *Floating Lady* – being more than *just a pool*.

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[805] Kirschenfeld (2012)
[806] Ibid.
[807] Ibid.
[808] Ibid.
[809] Ibid.

5.5.4 Discussion: Outcomes and evaluation

“Migrating recreation piers”[810] are, first of all, a symbol of a new generation of adaptive and movable infrastructures. The *Floating Pool* received numerous awards (e.g. the 2009 International Design Award) and was one of 15 projects exhibited in the American Pavilion during the 2008 Venice Biennale. As Kirschenfeld stressed, “peripatetic infrastructures” can also serve deprived neighborhoods without any direct access to public baths. To further evolve the “plug-and-play pool version,” the future challenge is to create an “off-the-grid, fully sustainable structure, that can go anywhere.”[811]

[810] Ibid.
[811] Ibid.

Table 22: Evaluation of multifunctional blue-green infrastructure design and services – The Floating Lady

Evaluation criteria	++ (clearly achieved)	+ (partly achieved)	- (not achieved)
Supporting blue-green services		+	
	Referring to the basic blue-green services (Table 3), the Floating Lady is a fully plug-in infrastructure. Ecological swimming water purification is not applied due to cost reasons. Nevertheless, the project contains a high symbolic value while particularly addressing social issues. Although envisioned from the beginning, ecological swimming water purification has not been applied so far due to cost reasons. Prevailing blue-green services comprise: (1) urban recreation by serving aquatic wellbeing along enhancing the aspects of aesthetics, joy, etc.; (2) increased vitality and livability; (3) local fresh water regeneration due to enhanced evaporation; and (4) temperature moderation and urban heat prevention due to enhanced evaporation Potentials of optimization particularly regard the transformation of the *Floating Lady* from a plug-in infrastructure into a more self-sufficient recreational pool.		
Flexibility of design		+	
	The overall design is rather fixed. Hence, certain parts are flexible to modify and adapt to a certain extent.		
Tangibility of processes and aesthetics		+	
	Nearly all components are accessible by public visitors and are of high aesthetic quality (visually, sensorially). Although sustainable performance is only partly perceivable.		
Participative intervention and responsibility			-
	As structural design and processes are rather fixed, the possibility and influence of human-scale intervention in regard to discussing, adjusting, optimizing, etc., the system is limited.		
Community integration	++		
	The new site in the Bronx offers a public pool facility in a neighborhood that had had no access to water-wellbeing services. Consequently, the pool is a tool to bridge social exclusion.		
Applied learning, transforming spaces and mindscapes	++		
	There has been a wide public interest from scratch, since public outreach has been a central issue. Although, at the beginning, mainly for marketing purposes of the Brooklyn Bridge Park, the project inspired through its urban waterfront transforming character as well as its social elements. Parallel and follow-up project developments were triggered locally and internationally.		

5.5.5 Learning-from and follow-up projects

ENVISIONING A FLOATING NEW YORK THEATRE

The project hosted over 50,000 swimmers during its initial eight-week season at the Brooklyn Height waterfront of the unbuilt Brooklyn Bridge Park in summer 2007.[812] However, not only exemplary numbers show the high appeal of urban water-wellbeing projects of this kind. As the sociocultural dimension is inevitable to the success of similar blue-green infrastructure projects, follow-ups need to consider issues of social justice, community building and place-based cultural qualities. Therefore, a follow-up and not yet realized project by Kirschenfeld architects is the Floating Theater. It concerns reusing a cargo barge and transforming it into a temporary cultural venue for film, performing arts and other events. The on-deck structure is modular, consisting of various seating boxes made from a steel scaffolding system.[813]

5.6 Conclusion

The pilot case studies in contemporary Western urban and community contexts illustrate various challenges that have been and still need to be tackled. The qualitative evaluations of multiple infrastructure features show the potential of the new blue-green infrastructure types to mutually link natural and cultural services of everyday life-support. The aquacultural infrastructures investigated, from urban greenhouses for productive wastewater and integrated farming services to swimming oyster gardens and floating pools for natural-cultural waterscape remediation, could encourage the water-sensitive renewal of 21st century Western cities. On the other hand, there are open fracture points alongside the prospective transfer of the pilot cases into the site-specific urban contexts.

To sum up, the following figures provide a comparative case study evaluation of the various learning-from experiences. They address (1) the multifunctionality of the aquacultural infrastructure cases investigated in regard to each of the six evaluation criteria (Figure 71 to Figure 76), and (2) a more general evaluation of the multifunctional blue-green infrastructure services outlining options of typological integration into urban spaces (Table 23)

[812] Kirschenfeld (2012)
[813] Kirschenfeld (1998)

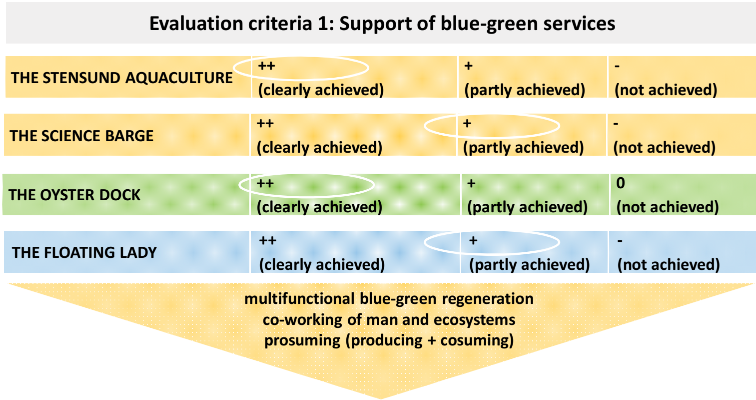

Figure 71: Comparative case study evaluation: Criteria 1 – Supporting blue-green services

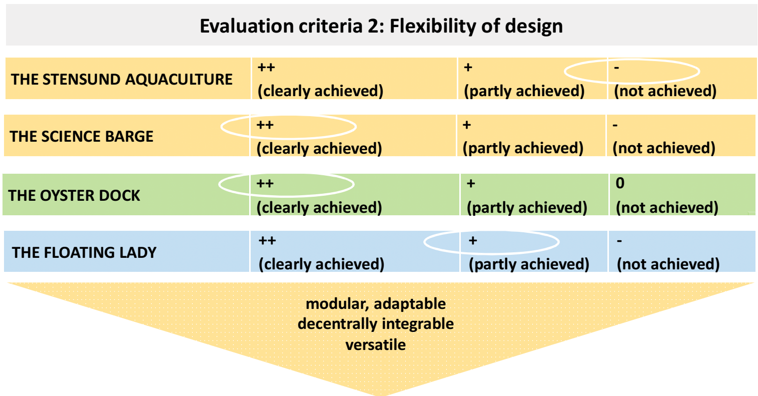

Figure 72: Comparative case study evaluation: Criteria 2 – Flexibility of Design

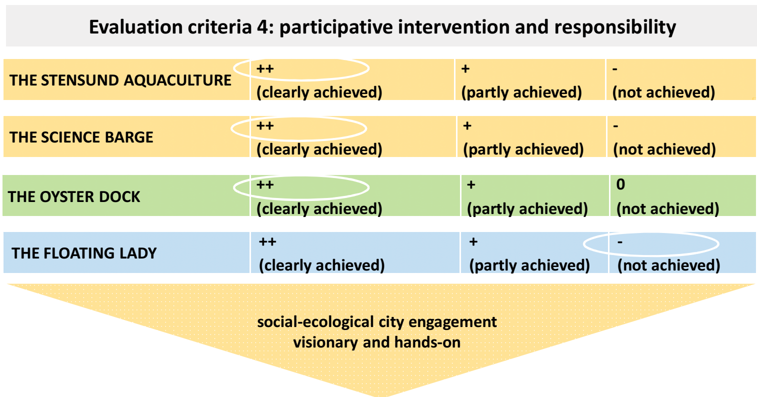

Figure 73: Comparative case study evaluation: Criteria 3 – Tangibility of processes and aesthetics

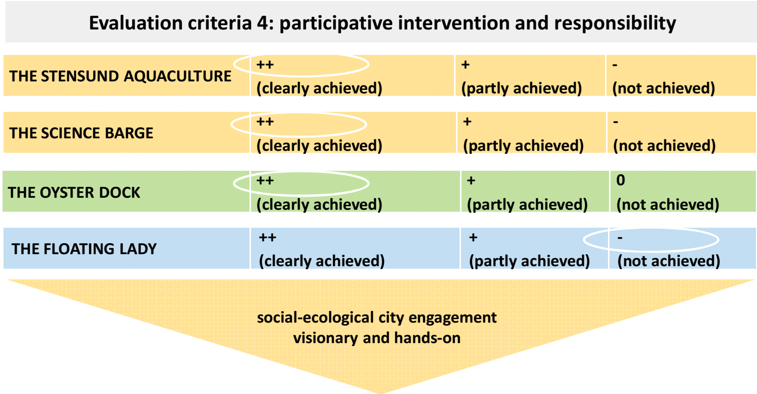

Figure 74: Comparative case study evaluation: Criteria 4 – Participative intervention and responsibility

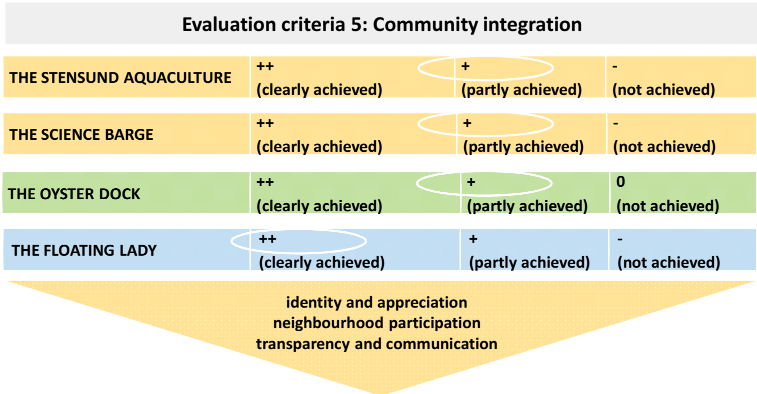

Figure 75: Comparative case study evaluation: Criteria 5 – Community integration

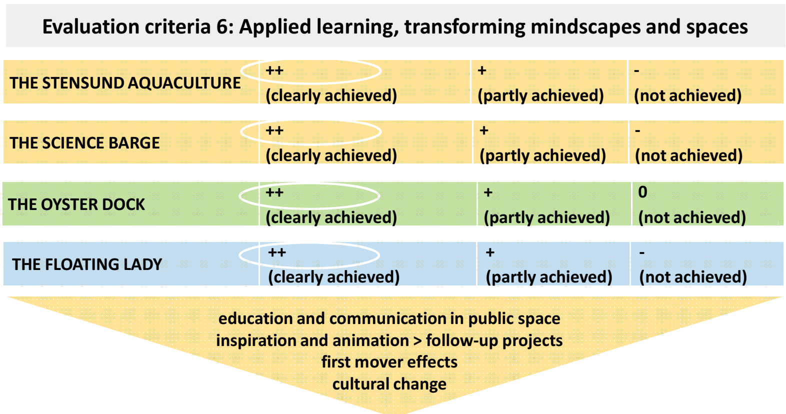

Figure 76: Comparative case study evaluation: Criteria 6 – Applied learning, transforming spaces and mindscapes

Table 23: Typological case evaluation of multifunctional infrastructure services and optional urban integration

	Aquacultural infrastructure type	Structural application	Multifunctional blue-green services	Optional urban integration
The Stensund Wastewater Aquaculture	Water-farm greenhouse	Building-integrated	1 Urban farming focusing on wastewater-based non-food and biomass production 2 Regenerative and self-sufficient resource provision (energy, water, biomass) 3 Applied education/ community learning and rebuilding	Roof water-farms Vertical water-farms Building expansions
The Science Barge	Water-farm greenhouse	Floating/ Pontoon	1 Urban food farming 2 Regenerative and self-sufficient resource provision (energy, water, biomass) 3 Applied education/ community learning and rebuilding	
The Oyster Dock	Swimming garden	Floating/ Pontoon	1 Surface water quality 2 Urban wildlife and biodiversity 3 Applied education/ community learning and rebuilding	Water spaces Waterfronts Waterscapes
The Floating Lady	Floating pool	Salvaged cargo barge	1 Urban recreation 2 Community rebuilding 3 Urban communication and marketing	

Based on the general potential, the following future roles of aquacultural infrastructures can be derived from the pilot case study research offering new opportunities within sustainable urban redevelopments:

- *Firstly, aquacultural blue-green infrastructures are meaningful bottom-up catalysts of the water-sensitive transformation, capable of creating a 21st century urban water identity in the sense of a post-industrial urban aquaculture.* The close relation to daily needs, rituals, lifestyles, and actions creates new meanings and responsibilities in urban spaces and place-based community contexts.
- *Secondly, they are multifunctional building-blocks of 21st century cityscapes combining utility and beauty.* As blue-green infrastructures for integrated food, water, energy and other daily resources and wellbeing services, they encourage everyday life-support and life qualities related to a post-industrial urban water-living, water-farming and water-wellbeing culture.
- *Thirdly, the different types of low- and high-tech aquaculture are useful hands-on learning and participation tools of socioecological city engagement including the communication and mediation of spatial conflicts.* The new blue-green infrastructures can be used for integrated problem-solving since they make the hybrid natural and cultural processes between human and ecosystem life spheres transparent. Due to the change of perception, they can encourage public dialogs between actors and stakeholders.

– *Finally, the new infrastructures can complement and pro-actively support existing centralized urban infrastructures by becoming attached to or integrated in the existing network.* Their modular design and recreational values can contribute to the necessary redesign of inflexible mono-technical infrastructures from housing to urban watershed scale. The emerging complementary infrastructural landscapes, such as swimming river gardens at public urban waterways or rooftop water-farms linked to building-integrated water and resource management applications, combine regenerative and recreational services in urban spaces.

Figure 77 illustrates an extended scheme of 21st century urban aquaculture integrating and valueing the catalyzing role of the new types of infrastructure and related practices.

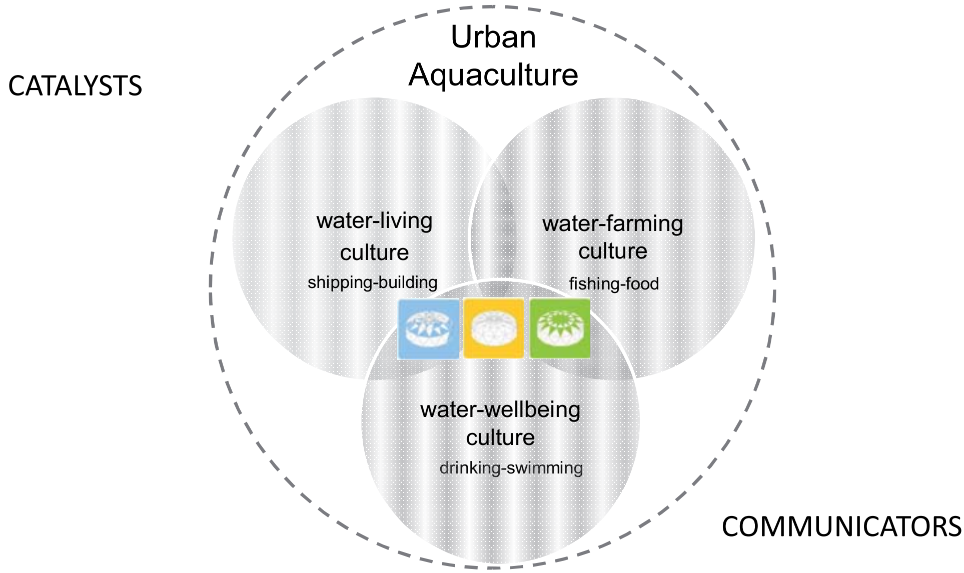

Figure 77: Prospective roles of aquacultural blue-green infrastructures

Although there are many benefits, the following list of remaining challenges regarding the place-based transfer and further implementation of aquacultural blue-green infrastructures can be summarized ahead of the final chapter:

- Site permission processes overcoming barriers of sectorized and decision-making processes
- Economic, technical and social feasibility
- Public acceptance, usability and safety (health risks regarding water-flows and products, etc.) in global and local contexts

- Accessibility and availability of space
- Combinability with existing urban infrastructure and other services
- Suitable operation models
- Balancing out potential co-uses and competing uses (solar, rainwater, etc.)

Considering and appreciating the new attraction and relevance, but also obstacles of so far unconventional aquacultural blue-green infrastructures, Chapter 6 summarizes the main conclusions and basic lessons learnt. In a proactive way, it proposes water-sensitive design strategies as a final summary and contribution to answer the third research question implying an open and outlooking character.

OUTRO

CHAPTER 6: SYNTHESIS AND OUTLOOK – WAYS TO FURTHER CATALYZE URBAN AQUACULTURE IN THE 21ST CENTURY

6.1 Summary of conclusions

The **Chapter 1** started with three central research questions:

1. What are the characteristic facets of urban aquaculture forming the water-based identities, morphologies and relationships of cities on the human scale?
2. Which cross-cultural aquacultural types are there and which multifunctional (blue-green) design and service potentials can they fulfill as urban building-blocks and specific blue-green infrastructures?
3. How can similar multifunctional infrastructures catalyze a water-sensitive transformation of cityscapes and contribute to a sustainable urban aquaculture in the 21st century?

The theoretical part (Chapters 1- 3) developed transdisciplinary relations from the three research spheres of the city (water-sensitive planning and building), the landscape (watersheds, ecosystem services, blue and green water principles) and infrastructures (multifunctional design and everyday cultural use). Characteristic types of aquaculture, such as in the context of urban farming and urban wellbeing created the intersection between these research areas and the central research subject. Regarding their multifunctional (blue-green) design and service potentials and by facing the challenges of water-sensitive urban design, they were newly interpreted as specific blue-green infrastructure.

Chapter 2 explored the relationship between water and the genesis and history of the city in the interplay between technical infrastructure, daily life culture and physical-morphological landscape transformation. The central result was the derivation of an extended understanding of aquaculture in the context of urban space. Besides the original water-farm culture (fishing and nutrition), it integrated facets of a water-living culture (living by the water, shipping) and a water-wellness culture (drinking culture, bathing culture). A threefold image of aquaculture was outlined as an answer to the first research question (Figure 4).

Chapter 3, in its first subchapter, highlighted the development of natural and cultural landscapes with regard to blue-green ecosystem services (e.g. small water cycles, temperature/climatic moderation, regeneration of fresh water, food, biomass, biodiversity). Along with local-regional examples of water-centric *climate changes* and *climate chances*, it outlined the relevance of a sustainable watershed management from the urban (micro) to the landscape (macro) watershed scale.
As a bridge between the landscape-ecosystem related and urban-everyday cultural perspective, the second subchapter portrayed cross-cultural traditional (low-tech) and contemporary (high-tech and low-tech) aquaculture typologies focusing on the original purpose of *water-farming*. The two central results were (1) the derivation of blue-green principles and services

(regeneration of ecosystem services, livelihoods and life-qualities as well as values such as aesthetics or recreation) and (2) the new perception, respectively reinterpretation, of the illustrated aquaculture types as specific blue-green infrastructures. The cross-cultural examples of aquacultural farming infrastructures (Figure 10) together with the *blue-green service matrix* (Table 3) delivered a first answer to the second research question. At the same time, Table 3 created a first reference frame regarding the evaluation criteria 1: *the support of blue-green services* along with further empirical research. On the basis of this, the empirical part of the research focused on the examination of theoretical results at at citywide scale in Berlin (→ Chapter 4:) and along with an international case study at a project scale in a real-life urban/community context (→ Chapter 5:).

Chapter 4 explored in-depth how the characteristic facets of urban aquaculture formed and transformed, which was exemplarily investigated for Berlin's biography of growth – from the landscape (Berl – Slavic for swamp) to the city (Berlin). In addition to physical-morphological processes, everyday cultural processes were traced in both the past and present. They illustrated visible and invisible water processes in the city. Furthermore, post-industrial urban aquaculture trends facing water-farming and water-wellbeing were outlined accompanied by blue-green infrastructure examples in the context of bottom-up city production (self-made city). The central result is the extension of the threefold image of urban aquaculture (Figure 4) through the integration of aquacultural blue-green infrastructures and their perception as bottom-up catalysts and building-blocks of urban aquaculture (Figure 55).

Chapter 5 focused on contemporary international pilot cases in Nordic and moderate climate zones in the Western city and community context. The focus of selection and evaluation was based on the integration of the projects into the urban neighborhood. In addition to the long-term experience of the case studies chosen (first of all the Swedish case), the connection of natural and cultural infrastructure potentials was central. It included regeneration of blue-green ecosystem services, functions of applied education or aspects of perception and aesthetics. The central results are (1) the comparative evaluation of the four cases regarding the six evaluation criteria of functional infrastructure (Figure 71 to Figure 76), and (2) the summarizing typological evaluation of the multifunctional (blue-green) design and service potentials (Table 23).

In the following, **Chapter 6** combines the main theoretical and empirical research results. Regarding the third research question of outlooking character, it transfers the lessons learnt proactively into water-sensitive design-management guidelines (Table 24) and summarizes those by formulating water-sensitive spatial strategies (Table 25). Thereby, it proposes the strategic tools of *aquatecture* – the design-built level and *aquapuncture* – at the participatory process level. They are meant to support the creative and professionally assisted urban design from bottom-up. In conclusion, the main themes and fields of action are derived to outline impulses and approaches of further research.

Facing the key question of what can be learnt with regard to the sustainable transformation of the cityscape and its everyday infrastructures, the following section summarizes general lessons learnt. It derives from an overarching summary of future potentials and challenges contributing to the third central research question addressing the water-sensitive future of cityscapes. Based on the theoretical and empirical research results, it derives conceptual and creative spatial design and participatory strategies. These are meant as tools and a starting-point for the further specification of a 21st century urban aquaculture according to contextual and usability requirements.

6.2 Lessons learnt and water-sensitive design-planning tools proposed

6.2.1 Summary of future potentials and challenges

The following research results highlight the general potential of urban aquaculture and related infrastructure developments:

- Current post-industrial urban transformations reflect on the emergence of *new* aquacultural infrastructures. Sustainable types of greenhouse for urban food and resource farming optionally linked with community-based wastewater resource management represent new 21st century building-blocks. When building-integrated, they can benefit a better utilization of heat and resource flows in a space-efficient way. Other applications comprise swimming gardens above and beneath the water, pond aquaculture for the cultivation of fish and water plants or floating swimming pools. As the cases from floating, mobile or landscape applications investigated show, similar flexible and multifunctional blue-green types of infrastructure can become integrated within existing urban spaces. Their modularity enables an active and continuous adaptation to changing conditions regarding sustainability. At the same time, they cocreate *new* infrastructural landscapes from micro- to macro-scale.
- The new aquacultural blue-green infrastructures catalyze new forms and qualities of 21st century urban aquaculture, while encouraging water-sensitive urban development processes. They respond to problems of fossil fuel energy-based central water infrastructures, particularly the lack of active landscape ecosystem support on which they depend. Besides enhancing *natural* blue-green services, such as the regeneration of freshwater, healthy food, biodiversity, moderate living climate, and other daily life essentials, the new infrastructures complementarily support sociocultural services in cities. Their decentralized integration within urban space enables both the flexible (physical) adaptation to different spatial conditions (e.g. growing, shrinking) and a change of perception and consciousness in daily life contexts. The close link to hands-on learning and participation combined with communicative and recreational services creates a *new* transparency and tangibility of everyday life-supporting and sustaining processes. Consequently, changes of lifestyles and routines towards a new *cultural handling of water* in post-industrial cities in the sense of an urban aquaculture become realistic.

The insights gained can help to bridge the gap between "global knowledge" and "everyday activities," as referred to by contemporary social and cultural research within the sustainability and climate change debates.[814] However, many obstacles have to be tackled in real-life contexts as the pitfalls are most often in the details. Considering the experiences from the case studies investigated, the following general challenges remain regarding the site-specific implementation and dissemination of the new aquacultural infrastructures within existing urban spaces and neighborhoods:

GOVERNANCE AND DECISION-MAKING LEVEL

- to raise acceptance at multiple levels of decision-making
- to support the integration of the renewed infrastructures at a more decentralized level
- to sound out opportunities to redevelop or repurpose existing centralized fossil infrastructures towards common life-support
- to critically reflect and adapt existing sectorized legal and political frameworks facing the future cross-sectoral implementation and dissemination of the renewed infrastructures
- to evaluate multiple chances and risks (economic, social, health concerns, etc.), as well as costs and benefits

IMPLEMENTATION LEVEL

- to match and critically adapt site-specific permission, technical and user-oriented requirements
- to meet public safety and liability issues, including public and environmental health and risk aspects
- to sound out the availability and accessibility of adequate space
- to apply appropriate operation models according to specific actor constellations and uses

PHYSICAL DESIGN LEVEL

- to balance tradition and modernity, while combining structural utility and beauty, low-tech and high-tech designs
- to sound out the opportunities of fixed and mobile designs
- to sound out the smooth merging of the renewed infrastructures within existing urban spaces and real-life contexts
- to balance out necessary transparency and opacity of life-supporting processes in public spheres

[814] Welzer (2011)

SOCIAL DESIGN AND COMMUNICATION LEVEL

- to raise awareness at multiple levels of decision-making and among the various stakeholder and actor groups
- to strive for transparent communication addressing potential chances and risks, particularly with regard to issues of public health and safety, and public and private financing
- to apply tailor-made strategies of participation and negotiation according to the specific stakeholder and interest groups
- to strive to balance the different power-relations regarding conflicting and competing uses of spaces and interests
- to develop project-specific communication forms and formats
- to strive for the co-beneficial share and exchange of know-how

Contemporary processes to sustainably transform urban spaces, infrastructures, lifestyles, and everyday actions face a permanent interplay of fast growth and shrinkage. The reiteration of local roots and the creative update of urban aquaculture and its modular infrastructures are both necessary to meet the challenges facing urban researchers, practitioners and engaged people.

6.2.2 Set of guidelines and strategic tools of water-sensitive urban transformation

The promotion of a respective building and participatory culture is a key to further qualify and raise the profile of urban aquaculture in the 21th century. Consequently, the following two levels of action are regarded as top-priority tasks:

- Design-build level: focusing on transformations of the physical structure and the design orientation, particularly the alteration of urban forms, infrastructures and related management processes;
- Participatory process level: focusing on transformations of perceptions and actions, particularly public awareness arising from applied communication and engagements in urban spaces and landscapes.

The spatial integration of new aquacultural infrastructures and practices for regenerating and sustaining water-dependent urban quality of life with reference to processes demands corresponding strategies of urban design and participation. *Aquatecture* and *aquapuncture* are proposed as promotional and complementary strategies. Aquatecture thereby addresses the design-build perspective, stressing the fluid design-resource management orientation. Complementarily, aquapuncture addresses the participatory process level; it, thus, focuses on collaborative intervention and communication aspects (Figure 78).

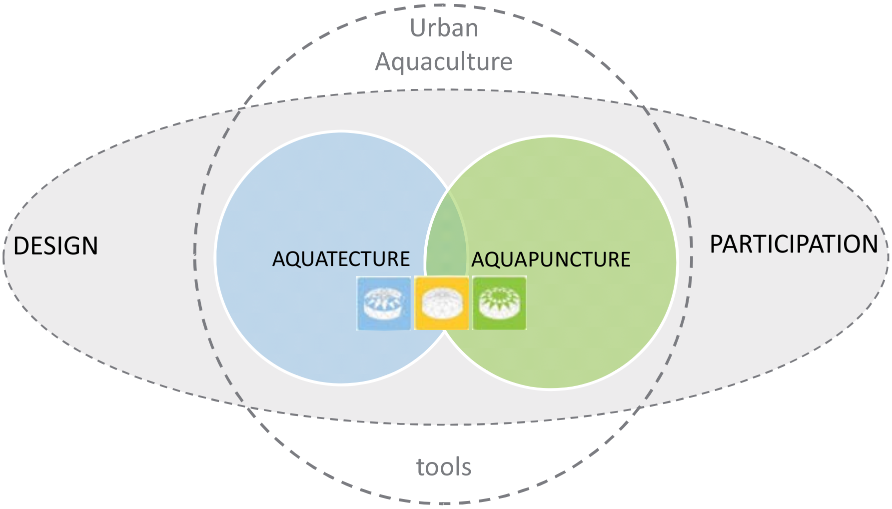

Figure 78: Aquatecture and aquapuncture as creative tools of water-sensitive urban design and participation to catalyze urban aquaculture

Aquatecture and aquapuncture serve as informal spatial strategies against the background of the pilot projects investigated, while facing emerging trends of both local self-induced and global real estate-driven urban development processes. They represent guidelines and offer professionally assisted bottom-up tools in the sense of a creative "catalogue of options."[815] The intention of similar visionary but pragmatic approaches of informal and bottom-up character is to inspire and broaden views by asking, "What if …,"[816] thus focusing potential strengths and benefits.

6.2.3 Design-build strategy: Aquatecture

The design-build approach of "aquatecture"[817] particularly asks: "What if we follow the flows and loops of water?" Similar to solar architecture, where the sun pulse defines the design of a building, aquatecture is a normative approach applying water-sensitive design-build principles. The notion of *aquatecture* thereby addresses both the creation and recreation of landscapes and living spaces of urban, industrial, rural, or wild character according to the flow and functions of water. As a *blue guideline*, it strives for the continuous regeneration of common basic services, such as fresh water and food, fertile soil, or a modest climate, besides human wellbeing, such as creation of identity, diversity, esthetics, joy, or recreation.[818]

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[815] It affiliates with the recent book entitled "Atlas of possibilities" Guiney and Crain (2012).

[816] Ibid.

[817] Brüll and Bürgow (2001); Bürgow (2012)

[818] Bürgow 2012, co-developed with Anja Brüll, aquatectura (2002)

RESOURCE FLOW LEVEL: WATER-SENSITIVE DESIGN-MANAGEMENT GUIDELINE

The following set of aquatecture principles offers an urban resource, flow-oriented, design-build guideline. Based on the currently prevailing major water flow types in Western city contexts, it focuses on water-sensitive urban design-management (WSUDM) for the support of basic blue-green services (Table 24).

The water-sensitive urban design-management principles derived from a landscape ecosystem point of view requires the inclusion of the urban cultural view, particularly with regard to a closer connection to everyday human life realities. In the context of climate change adaptation, contemporary sociocultural research, therefore, stresses the relevance of the human psychological focus to create a new "climate culture."[819] Moreover, spatial-infrastructural research claims the need for integrative design-planning in a people-engaging manner.[820] Thus, the implementation and testing of the proposed WSUDM principles within decentralized urban contexts requires further applied case research in contemporary Western real-life contexts in moderate and Nordic climates.

Sources:

* (SENSTADT (eds.) *et al.* 1995)
** N, P, K – Nitrogen, Phosphorous, Potassium
*** (TU Berlin 2011-2013)
**** (Schuh 2005)
***** (Guterstam 1997, p. 1213)
****** e.g. (Brüll et al. 2001)

[819] Welzer *et al.* (2010)
[820] Wissen (2009)

Table 24: Basic water-sensitive urban design-management principles for life-supporting blue-green services[821]

WSUDM principles supporting blue-green services	Details
Groundwater/drinking water	
Using renewable vs. fossil water sources	Production rate < reproduction rate No deep drilling and tapping of fossil groundwater to prevent soil mineralization and loss of natural water-scapes, such as wetlands, deciduous forests, etc. Slow artificial groundwater recharge
Valuable vs. costly water usage	Drinking-water quality for food and personal care uses Lower quality use via rainwater and greywater recycling for toilet flushing or irrigation
Rainwater/stormwater	
Local climate/temperature regulation	Enhancing green water performance via small water cycles Moderating temperature and water-flow extremes through evaporative blue-green surfaces (adiabatic cooling)
Preference for natural water retention, purification and detoxification vs. mono-technical solutions	Supporting landscape ecosystem-based water retention, flood risk prevention and phytoremediation (photosynthetic capabilities of plants for detoxification)
Preference of rainwater/storm water evaporation vs. drainage	Enhancing green water performance while preventing discharge into groundwater and soil mineralization along with diffuse substance discharges
On-site rainwater harvesting	Optional decentralized use for purposes of irrigation, toilet flushing
Wastewater/reclaimed water	
Valuing wastewater as a resource	Containing energy, carbon, nutrient, and water sources
Preventing mix of industrial and household sewage	Separating material flows at the source if possible and feasible (e.g. greywater, black water)
Separating and qualifying building-related wastewater flows as process water if feasible	Use of treated greywater as hygienically safe “bathing water quality” according to EU standards either for lower-quality water uses indoors (flushing water) or outdoors (irrigation water; other productive farming purposes, such as urban fish cultivation) Conversion of black water flows into hygienically safe fertilizer solutions and substrates for farm productive purposes, such as hydroponic plant and biomass cultivation***
Establishing nutrient loops, particularly N,P,K** as main plant nutrients	Prospective nutrient scarcity, e.g. phosphorous, potassium (P,K) not renewable (e.g. P available for ~50-150 years****) Nitrogen (N) fertilizer production as energy intense process (e.g. 1.5 liters of oil to extract 1 kg atmospheric nitrogen*****)
Recirculation of reclaimed water within local watersheds	Discharging water in the same or better quality as being withdrawn (“landscape quality requirement”)******

[821] The table refers to the long-term design-research practice of the author together with Anja Brüll since co-founding aquatectura – studios for regenerative landscapes Berlin-Aachen (2001).

URBAN DESIGN LEVEL: WATER-SENSITIVE PATTERN "UP- AND DOWNSTREAM OF THE CITY"

Complementing the resource flow focus, the urban design level highlights the spatial distribution of aquacultural types according to morphological patterns in the urban watersheds. Which services and benefits could aquacultural infrastructures generate within urban spaces and landscapes if managing the flows literally from urban rooftops down to the river?

Table 25 illustrates potential benefits of a prospective merging of various aquacultural infrastructure types in an optional urban "upstream-downstream aquatecture.[822]
Upstream water management might, therefore, start on rooftop, a road or an urban hill, while downstream water management might include the apartment downstairs, the bioswale[823] beside a pathway or a wetland park near the river.

[822] A significant part of this section refers to intermediate doctorate research results of the author. See, in particular: Bürgow (2012)

[823] "Bioswales are flat bottomed swales specially designed to infiltrate water and remove pollutants. Many bioswales have wetland plants intentionally planted in them in order to remove pollutants in the water at a higher rate." Delaware Department of Natural Resources and Environmental Control (2012)

Table 25: Aquatecture: Potential benefits of types of aquacultural blue-green infrastructure in an urban upstream-downstream relationship[824]

Type of aquaculture	Optional upstream application	Optional downstream application	Urban purposes and benefits
Swimming garden type 	– Roof water-gardens – Roadside bioswale gardens	– River gardens – Roadside bioswale gardens	Focus: water-living and water-wellbeing – Recreating surface water qualities – Remediating eutrophic water bodies – Revitalizing freshwater sources and waterscape ecologies – Urban biodiversity – Community rebuilding – Urban recreation and psychological wellbeing
Greenhouse type 	– Roof water-farms – Vertical water-farms	– Floating greenhouses	Focus: water-farming including resource management and water-living – Urban food and biomass production and consumption – Co-beneficial use of space and reuse of building-related resources (energy, water, nutrients) – Community rebuilding – Urban recreation and psychological wellbeing
Ponds-and-pools type 	– Recreational swimming pools with optional water-retention and natural purification – Fish and aquatic biomass ponds – Retention ponds (stormwater, pretreated wastewater, etc.) with optional aquatic production, recre-ation and renaturali-zation	– Floating pools – Polishing and buffer ponds – Constructed wetland ponds	Focus: water-farming including resource management and water-wellbeing – Revitalizing freshwater sources and waterscape ecologies – Urban recreational and psychological wellbeing – Community rebuilding – Rehabilitation of landscape watersheds incl. regulation of water balance – Risk prevention (droughts, floods, overflows from canalization) – Urban biodiversity – Urban fish and biomass production and consumption

[824] In: Bürgow (2012)

ARCHITECTURAL DESIGN SCALE: WATER-SENSITIVE BUILDINGS

Aquatecture can enhance blue-green services indoors and outdoors regarding the urban micro-scale of a building. The “biodome” is an exemplary prototype design combining low-tech and high-tech materials and construction principles. Building-related resource flows and regenerative design principles can be tangibly experienced. Separated and treated greywater from bathrooms is used instead of drinking-water for toilet flushing, whereas nutrient rich greywater from the cafeteria is used to fertilize and irrigate the tropical indoor landscape (Figure 79).

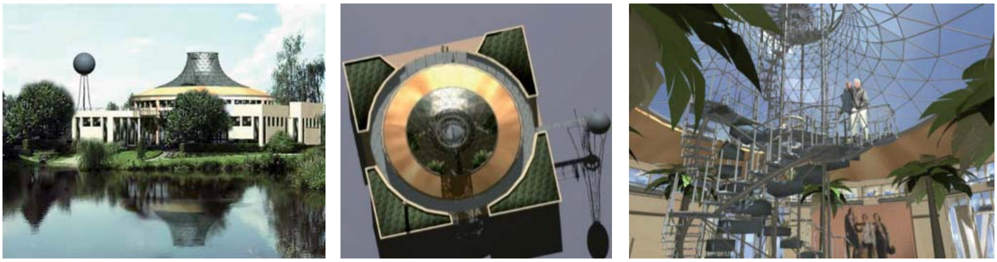

Figure 79: Prototype of building-integrated aquatecture: biodome®

Aquatecture on a housing scale can become a meaningful tool for showcasing, testing and evolving the new infrastructures, related technologies and usabilities within future city development. While focusing on water-sensitive transformations at a building, structural (architecture) and spatial (urban design) level, the approach of aquapuncture with its participatory process orientation is complementary. It focuses on transforming the user’s perceptions and everyday actions through water-sensitive learning and communication approaches, such as participative interventions and experiments in urban spaces and landscapes.

6.2.4 Participatory process strategy: Aquapuncture

Facing the broader urban social-political context, it is not always “love, peace and harmony.” Large sections of urban communities became more engaged either in an architectural context (e.g. cooperative building developments) or with regard to urban governance (e.g. emerging citizens’ involvement in the commons). Globally ongoing trends towards re-municipalization of urban water and energy services, as well as waterfront developments, between public and private interests are, meanwhile, contemporary realities calling for new forms of citizenship and stakeholder participation. In the place-based context of Berlin, social claims such as “Media-spree for all”[825] and citizen initiatives such as “Berliner Wassertisch”[826] or “Berliner Energietisch”[827] have received more attention due to succeeding people’s referendums. In the

[825] http://www.ms-versenken.org/ (2011-01-22)
[826] http://berliner-wassertisch.net/ (2011-01-22)
[827] http://www.berliner-energietisch.net/ (2012-05-01)

train of emerging global-local contests and conflicts concerning the commons,[828] these developments reflect on the rising need to develop a new public-private partnership culture at eye-level. It should balance power relations between corporate business interests and socio-cultural entrepreneurship and engagement, as well as informal and formal planning approaches. Given Berlin's contemporary "do-it-yourself culture,"[829] particularly concerning urban farming and water projects, infrastructural interventions in public spaces can work as appropriate and cheerful tools of applied learning, communication and participation.
Complementing the design-built approach of aquatecture that highlights water-sensitive design and management principles in an upstream-downstream relationship, the strategy of *aquapuncture* is recommended to facilitate the participatory process requirements. The notion of aquapuncture is introduced in line with the medical approach of acupuncture applied in traditional Chinese medicine.[830] Aquapuncture stands for a water-sensitive intervention strategy, similar to acupuncture, which intervenes at certain *spots* on the human body; it starts with water-sensitive interventions at specific places, alongside special occassions assumed to have a broader catalyzing effect. As a bottom-up process-oriented strategy, it can be useful for experimenting, networking or communicating new and existing projects in public spaces.

EXPERIMENTAL SCALE: WATER-SENSITIVE INTERVENTIONS

An illustrative example of aquapuncture facing issues of global and local water supply is the "river to drinking-water experiment" by DAS NUMEN H2O at the Berlin summer festival "Über Lebenskunst". As part of the author's explorative research with the artists and the interdisciplinary team (3.4.1), the intention was to make the ecological, social and urban water dimension tangible in public space. The festival's title thereby refers to the meaning of both the art of living and the art of survival, by particularly striving "to search for new ways and formats of communicating culture between art and daily life at the local and global level."[831] The experimental roof-top installation particularly intended to create a tangible connection to the city's major water supply, the river Spree. The water purification mechanisms applied, according to the artists, were "(…) aiming to provide free drinkable water from local water resources and an aesthetic moment in cooperation with nature triggering contemplation and reflection on water related issues like water pollution and water potability criteria, water preparation, water availability, water monopolism and water privatisation processes."[832]

Due to the great public interest, the project is a matter of further ongoing artistic-scientific research:

> "The modularity of the system aims to be adaptable to new site specific challenges, like the different climate conditions, the individual pollution cocktail of water and the energy resources found on the venues of its installation. This process of local adaptation offers

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[828] Ostrom and Helfrich (2011)
[829] SENSTADT (eds.) (2012)
[830] A significant part of this section refers to intermediate doctorate research results of the author. See, in particular: Bürgow (2012)
[831] http://www.ueber-lebenskunst.org (2011-09-03)
[832] http://www.dasnumen.com/H2O.htm (2011-09-03)

> invention potential for new filter steps to be developed. So to say the setup and design wants to change due to the site specific needs, the modular system is confronted with. Its feedback triggering further research and development."[833]

Accordingly, similar experimental *aquapunctural interventions* can trigger broader public perception and sensitivity to themes of healthy urban surface waters *as a mirror* of urban aquaculture.

Figure 80: DAS NUMEN H2O – river-to-drinking-water experiment – "water quality as mirror"

HANDS-ON SCALE: WATER-SENSITIVE PARTICIPATION

In addition to experiments, the mobile hands-on installations can be used to showcase new urban aquacultural practices (Figure 81).

). The new blue-green infrastructures can additionally become tools of participation and communication. Implemented not primarily for economic reasons but for symbolical ones, they can contribute to applied learning in public spheres raising questions of hands-on or perceptional character, such as: How can self-healing capacities, particularly self-cleansing processes and natural water remediation strategies, be reactivated in urban spaces and landscapes? Or, how can one make blue-green services of "Blue embraces green – Green embraces blue" vividly tangible?

Last but not least, similar participative design actions can be used for negotiation, networking or conflict mediation processes. They offer a platform for public dialogs to constructively discuss controversial topics on privatization of water, energy, public spaces, and such like in a more casual and hands-on manner. Reflecting this, hands-on workshops were performed during the Asia-Pacific Weeks Berlin 2009 and 2011 to initiate and facilitate business networks and collaboration in a cross-cultural context. A swimming marketplace was constructed through public engagement and temporarily installed at Berlin's historic Engelbecken, which was formerly a floating market.[834] A participatory designed bamboo raft "as a symbol for both renewability and mobility – the main topics of the APW 2009 – laid the trail for fruitful contacts

[833] Ibid.

[834] http://www.traila.org (2011-09-03)

towards the APW 2011 on themes of water, food and health."[835] The "Swimposium" in 2011 combined walks, raft-building and swimming garden team workshops to make water processes and uses tangible in urban space.[836]

Figure 81: Left: SWIMMING MARKETPLACE at Berlin's Engelbecken during the Asia-Pacific Weeks Berlin 2009 Middle: SWIMPOSIUM with floating raft-garden installations at Berlin's Spree during Asia-Pacific Weeks Berlin 2011 Right: FLOATING FOOD installation at the Berlin festival Über Lebenskunst

6.3 Outlook: Future fields for design and research action

The sustainable redevelopment of contemporary and future cities and infrastructures first of all demands the integration of multiple life values and qualities within decision-making and stakeholder processes to overcome solely economic considerations. The urban design journalist, John Thackara, puts it as follows: "The world needs a new kind of design based on an ethical framework in which life is the ultimate source of value; that re-conceives mainstream notions of 'development'; and that drives the transition from an extractive economy (minerals and hydrocarbons) to a restorative economy."[837]
The strategies of aquatecture and aquapuncture introduced have the potential to further catalyze a 21st century urban aquaculture within existing urban spaces and real-life contexts. As future fields for design and research action, they can become conceptual and creative spatial development tools and contribute to testing and evolving water-wise design-build and participatory process approaches. As spatial and communicative implementation strategies, they can assist negotiations between the various actors and spaces literally *from up on the roofs to down by the rivers*.

Design competency at different levels – from visionary concepts, strategic guidelines, multi-stakeholder processes to implementation and optimization – is needed to initiate the process. Aquatecture and aquapuncture can, thereby, mutually strengthen each other. The sole implementation of an innovative design-build project is not sufficient without accompanying research, monitoring and communication in the sense of a participatory learning-from process.

Based on the research results and the proposed water-sensitive strategies, the following three key fields of research and action towards future mutual urban and landscape development can

[835] Ibid.
[836] Ibid.
[837] Thackara (2011)

be derived: (1) prosuming infrastructures – prosuming cities, (2) socioecological city engagement – hands-on learning formats, and (3) urban partnership culture – aquacultural partnerships.

6.3.1 Prosuming infrastructures – prosuming cities

Prosuming describes a loop process. It refers to future cities where the regenerative production of everyday life resources is closely linked to their consumption.[838] It furthermore includes a paradigm shift from one-way resource flows and infrastructures towards multiple loops within the future *prosuming city*, respectively *LoopCity*. The reduction particularly of transport enables an effective use of space, time, energy, and other resources.

The recent book “My green city”[839] exemplarily illustrates various new infrastructure approaches in the sense of *prosuming infrastructures*. Embedded into urban farming projects, they reflect on people’s emerging care for everyday life-support and changing life values and lifestyles in future *prosuming cities*.
Research institutions and decision-makers in politics, government and business also in Germany increasingly recognize the innovative potential of urban farm approaches. In light of fast urban growth and shrinkage, building-integrated farm approaches become of particular relevance. In addition to the new *post-industrial Zeitgeist*, various new projects – from rooftop to vertical greenhouses and gardens – have been emerging within the past five years throughout the world showing different options of integrating this innovation. An interactive world map has been created by the ZFarm-project[840] – a project funded by the Ministry for Education and Research (BMBF).[841] According to intermediate research results, a limiting factor is the availability and accessibility of adequate space, particularly of urban roofs. Although the owners of buildings are generally interested in marketing, they often withdraw due to more lucrative and easier exploitation, such as solar energy production.[842]

Despite many remaining obstacles, prospective benefits are assumed to outweigh any disadvantages. Similar to the green city funding initiatives, the latest federal strategies in Germany, such as those released by the BMBF Ministry, stress research for smart and multifunctional water infrastructures as the key to sustainable future cities.[843] There is a growing need for applied research into acceptance building, user-oriented communication and dissemination of the new knowledge particularly facing building-integrated or city district-oriented approaches of a decentralized infrastructural redesign.[844]

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[838] A significant part of this section refers to collaborative research results affiliated to this research together with Anja Steglich and Caroline Paulick-Thiel, whom the author wishes to acknowledge. See, in particular, Bürgow *et al.* (2012)
[839] Klanten and Bolhöfer (2011)
[840] http://www.user.tu-berlin.de/wolfgang.straub/zfarm/svg/index_svg.html (2012-06-21)
[841] http://www.zfarm.de/ (2011-10-01)
[842] Dierich (2012)
[843] BMBF (2012); TU Berlin (2011-2013)
[844] TU Berlin (2011-2013)

A pragmatic way following multi-level steps is necessary and realistic to further promote the exploration and implementation of similar prosuming infrastructure and city approaches:

- at a funding policy level: To link to mutual funding programs and strategies (e.g. in the context of urban development funding, urban art and cultural projects); to qualify invitations to tender, particularly tending criteria towards qualitative and value-based aims reaching beyond a solely economic or technical emphasis as so far prevailing;
- at an implementation level: To link to and learn-from older pilot projects in a place-based context (e.g. building integrated rainwater management approaches as already proven technologies); and
- at a communicative level: To support the consolidation and dissemination of applied experiences alongside accompanying research, marketing and networking in a user-oriented and people-engaging manner, while bridging art and science, such as the approaches of aquapuncture illustrated previously.

6.3.2 Socioecological city engagement – Hands-on learning and education in urban space

In the context of climate change adaptation, contemporary socio-psychological research stresses the relevance of the human psychological focus to create a new "climate culture."[845] The development of practical everyday knowledge is the key in order to overcome the current "action gap."[846] At the same time, hands-on learning practices, such as those linked to urban farming or company gardening, become of growing importance in everyday life and work.
According to modern neuroscience, the human brain is a socially and culturally shaped construct to a much greater extent than assumed so far.[847] Hence, by cultivating intrinsic motives such as stressed by the rather young "science of happiness,"[848] various forms of socioecological city engagement can contribute to the proclaimed turn "from exploitation of resources towards development of potentials."[849] In addition to enhancing urban self-subsistence, they increasingly fullfill salubrious working and social-psychological needs.[850] Their tangible and applied character allows for an easier integration into contemporary everyday life culture[851].

In the light of this, socioecological city engagement needs to become part of applied design education to a greater extent than at present. It can contribute to the cultivation of new senses of responsibility combined with hands-on creativity and intrinsic wellbeing.[852] Co-benefits

[845] Welzer *et al.* (2010)
[846] Ibid.
[847] Bauer (2010); Hüther (2011a); Hüther (2011b)
[848] Diener (2000); Seligman (2002)
[849] In German: „von der Ressourcenausnutzung hin zur Potentialentfaltung" Hüther (2011b)
[850] Müller (2011); Rasper (2011)
[851] Welzer (2011)
[852] Edelhoff and Uttke (2010); Uttke (2010); Kurth and Uttke (2007)

besides applied learning and research face urban quality-of-life services along with healthy food and water engagements, esthetic and recreational upgrading and other meaningful endeavors in urban spaces and landscape. In this sense, it affiliates with the contemporary meaning of design education as stressed by the following quote: “Design education is an aesthetic and humanistic approach for teaching how to contribute to the improvement of the conditions that affect everyone’s lives.”[853]

Hands-on learning forms and formats, such as experiments, interventions, workshops, or installations embracing artistic and scientific methods, create cooperative learning and working atmospheres while producing new “educational landscapes” that materialize in space.[854] Last but not least, they can catalyze and facilitate new forms of corporate citizenship including new forms of urban partnerships.

6.3.3 Urban negotiation culture – urban aquacultural partnerships

The biggest challenge is probably to develop a mature urban negotiation culture in dealing with the commons. It needs common value-based rather than power-based relationships between the various players from active citizens, creative entrepreneurs to larger business corporations and public institutions. The dominating water service providers, either public or privately owned, particularly need to get closer to the citizens. Urban designers, planners and professionals can thereby take on a central role as independent mediators, coaches and experts. They can facilitate the set-up and consolidation of urban upstream-downstream partnerships as participatory design processes to negotiate an overall *water quality of life* in the sense of *aquacultural partnerships*.

The new professional value requires new competences, such as those related to regenerative design and management or community learning, in order to recreate and remediate urban life-support systems and qualities of life. While the approach of remediation particularly focuses on restoring or healing competences, the approach of recreation focuses on design-management competences from strategic planning to hands-on action embedded into a participatory learning culture.[855] This demands the shaping of various skills similar to the German meaning of “Gestaltungskompetenz.” It mutualizes with the objectives of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), stressing acquisition of learning skills in dealing with uncertainties within sustainable redevelopment and climate change processes.[856]

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[853] Zande Vande (2006, p. 205)
[854] Uttke *et al.* (2013)
[855] Bürgow *et al.* (2012)
[856] BMU (2008b, p. 98).

6.3.4 Summary of further design-research

Facing the aforementioned issues of future research and design action, Figure 82 summarizes the key-tools and key-fields addressed in theory and practice.

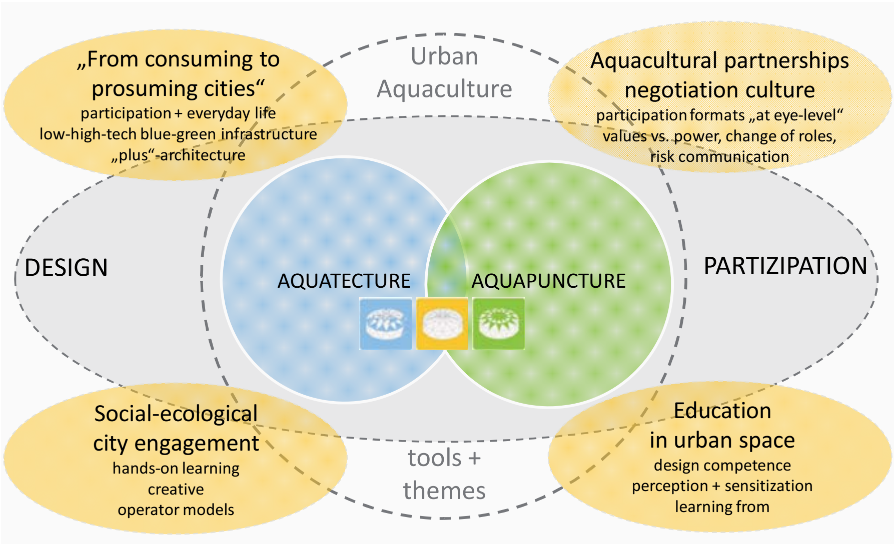

Figure 82: Future fields of design and research action

Courage and playfulness are needed to experiment with new ways of negotiation for the commons. Urban professionals need to be able to switch to different actor's roles within negotiation processes to understand the various interests and motivations. In addition, they can sound out innovative participation formats for balancing unequal power relations between the different interest groups and actors' constellations. In light of this, the following concluding thoughts are food for transdisciplinary discussions between design-planning professionals, infrastructure operators, users, and active citizens leading towards lively cities of the future.

6.3.5 Concluding thoughts

Urban designers, developers and committed individuals can incorporate water-sensitive knowledge into their actions. The research results enable the reflection of water-based urban life processes as a whole and not in isolation. The professionals and all those interested obtain an integrated understanding at the cutting edge between infrastructural resource practices, landscape ecosystem processes and sustainable urban redevelopment. This includes global and local perspectives and reaches beyond solely technical, ecological or social considerations. Consequently, a more holistic appreciation and consideration of water as a medium and mediator of various natural and cultural processes in the city becomes possible.
However, the biggest potential of urban aquaculture and its new infrastructures – from roof water-farm greenhouses, river gardens, floating pools to fishponds – is the capability to

reawaken dreams and longings. It may be the longing to farm on the roof with the soothing sound of bubbling water from the fish tank in the background or the thought of swimming right through the city. Besides the fun effect, unconventional visions of "drinking the river," "swimming through the city" or "fishing for fresh urban fish" can lend force and tangibility to stimulate individual and social responsibilities and actions towards the lively water cities of the future. They can become valuable attractors to broadly raise awareness within negotiations and contests of common life resources, spaces and services. Last but not least, building-integrated designs allow efficient use of space and resources, literally *making space* for new urban nature as well as *uncontrolled* wilderness and riverscapes inside and outside the city. In other words, new natural-cultural relationships might evolve in the context of a similar *build-wilderness*.

Every form of change starts with committed people. Facing the alarming privatization trends of the commons along with the globalization of markets, water and other quality-of-life essentials need to be reimagined as common amenities and human rights. They are a vivid result of landscape ecosystem and sociocultural processes in their place-based contexts. Therefore, and by their nature, they cannot be owned by a single player. Thus, the transformation towards multifunctional and more decentralized urban infrastructure systems is a collaborative change process. It pleads for a paradigm shift towards common humanistic values. The future challenge is to design, manage and sustain everyday resource services and qualities cooperatively, responsibly and respectfully either in urban, industrial, rural, or wilderness landscapes.

Figure 83: Impressions of a 21st century urban aquaculture from rooftops to rivers

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