Dr Anne Schiffer (a.schiffer@leedsbeckett.ac.uk) is a Senior Lecturer at the School of Art, Architecture and Design, Leeds Beckett University, UK; Dr Andrew Swan (a.d.swan@leedsbeckett.ac.uk) is a Reader at the School of Built Environment and Engineering, Leeds Beckett University, UK; Professor Dr Ronaldo Lopes R. Mendes (rmendes@ufpa.br) is a Professor at the Centre of Environment (NUMA), Federal University of Pará, Brazil and Professor Dr Mário Vasconcellos Sobrinho (mariovasc@ufpa.br) is a Professor at the Centre of Environment (NUMA), Federal University of Pará, Brazil

This study has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013/ under IRSES grant agreement No 612633, known as AguaSociAL. The lead author would like to thank Leandro Barbosa Mergulhão at the Federal University of Pará and Joelma Moraes Costa dos Anjos and Paulo Selmo Alves dos Anjos for hosting.

http://dx.doi.org/10.3362/1756-3488.18-00010, ISSN: 0262-8104 (print) 1756-3488 (online)

[CH]Looking to peripheral river islands in Brazil to develop an urban island water metabolism perspective

[AU]ANNE SCHIFFER, ANDREW SWAN, RONALDO LOPES R. MENDES, and MÁRIO VASCONCELLOS SOBRINHO

[ABS]Across Brazil, including the water rich Amazon region, access to safe drinking water remains a challenge and rainwater harvesting has gained credibility as a technological solution. Complementing a more techno-centric approach, this practice paper analyses initial findings from an 'immersion' that was undertaken in August 2017 on Paquetá and surrounding islands located on the periphery of Belém (Schiffer and Swan, 2018), through the proposed urban island water metabolism framework. As such, the research draws on the 'urban metabolism' concept which can be described as socio-technical, socio-economic, socio-political, and socio-ecological flows including water resources, people, and information in, out, and within the urban environment. Here, this has been adapted to 'urban island water metabolisms'. The research highlights the value of more holistic and situated understanding of water systems in urban island contexts including: the role of intra-island networks that operate beyond municipal borders; accessibility in the contexts of ever changing water levels; and seasonal dimensions. The paper recommends longer-term and comparative research to further the understanding of the specific needs and challenges for water management in these peripheral contexts and to strengthen the urban island water metabolism concept.

[KEY]**Keywords**: river islands, urban water metabolism, water management, urban island water metabolism, immersion

APPROXIMATELY 35 MILLION BRAZILIANS, in both rural and urban areas, live without access to clean drinking water (Ministry of Cities, National Secretariat of Environmental Sanitation and National Sanitation Information System, 2013; Grojec, 2017). As part of its commitment to the United Nations Sustainable Development Goals, the Brazilian government aims to ensure equitable access to safely managed drinking water for all by 2030 (WASHwatch, 2017). In this context, rainwater harvesting is promoted by different stakeholders and initiatives including the One Million Cisterns programme which galvanized civil society at the beginning of this century to benefit the semi-arid north-east (Doss-Gollin et al., 2016; Gomes

et al., 2014). Paradoxically, an estimated 45 per cent of households in the Amazon region lack access to safe drinking water, despite the mighty rivers that surround them (Bordalo, 2016. Many of the Amazon's island communities are not served by mains water supplies or sewer networks. This is partially due to their remote locations but also a lack of enforcement and enactment of Federal Government guidelines for domestic supplies (Ministry of Health, 2011). This is exacerbated firstly by low public or private financial and technological investment (Bordalo, 2017); secondly, poor public water management (Siqueira, 2005); and thirdly, in the view of political ecology, the commodification of water services with market resource focused on profit generation (Ribeiro, 2008).

Staff and students at the Federal University of Pará (UFPA) in Belém have been conducting practical experiments with rainwater harvesting both within the institution and on nearby river islands (e.g. Do Nascimento et al., 2016; Veloso and Mendes, 2014; Andrade, 2012). The university has also been an integral part of AguaSociAL, a four-year exchange programme aiming to strengthen research cooperation and knowledge sharing between Brazil and Europe within the water-related sciences. This includes on-site training related to the rationale and benefits of water treatment techniques and technologies such as rainwater harvesting.

There are a number of previous studies that have investigated the technical aspects of rainwater harvesting in Brazil (Doss-Gollin et al., 2016; Ghisi, 2006) and the AguaSociAL project continues to contribute to this growing body of technical literature (Cardoso-Castro et al., 2017). However, AguaSociAL has also sought to investigate community-driven development techniques for improving water access and has facilitated collaboration with social science- and humanities-based disciplines that complement the more technical learning. Specifically, this practice paper examines how the particular challenges of access and water technologies on a small group of river islands on the edge of Belém (Figure 1) can be more holistically understood through the proposed framework of the 'urban island water metabolism' (UIWM). This includes the interface between everyday practice and environmental, technological, economic, and political dimensions.

[CAP]*Figure 1 Islands studied in this research*

[A]Conceptual framework

River islands on the periphery of the urban mainland are both places in their own right and an organ of the city. They are part of the city's resource hunger as well as the hinterland that feeds it. They are split up by water into geographically separate entities while they remain politically, socially, and materially networked with the mainland and surrounding islands. However, water supply challenges are in many ways greater or distinct from those of the urban mainland and therefore require a distinct conceptual framework for analysis – UIWM.

Conceptually, this research draws on the 'urban metabolism' framework, which can be described as socio-ecological, socio-economic, socio-political, and socio-technical resource flows such as water in, out, and within the urban environment (Currie and Musango, 2016; Kennedy et al., 2007; Schiffer and Swan, 2018). Here, a circular or zero-waste metabolism is seen as sustainable and resilient (Agudelo-Vera et al., 2012) in contrast to a linear metabolism which is unsustainable and vulnerable (Klindworth et al., 2017; European Development Agency, 2015: 26). This research builds on previous studies that have adapted the urban metabolism concept to that of the urban water metabolism. This includes early adaptations (Hermanowicz and Takashi, 1999) and more recent studies of Los Angeles (Cousins and Newell, 2015) and Rome (Paolini and Cecere, 2015). In particular, the research adopts Serrao-Neumann et al.'s (2017) definition of urban water metabolisms as 'diverse sources and

functions of water in urban systems' to specifically explore the UIWM of Brazilian river islands.

[A]Methodology

Human-centred and situated research can provide a more holistic perspective on the complex dynamics and factors that shape everyday practice at the local level. In the wider context of AguaSociAL, qualitative research complemented the dominant techno-centric approach associated with engineering rainwater-harvesting systems, though it should be acknowledged that researchers at UFPA's Environment Centre carry out socio-economic diagnosis, placing the user and other stakeholders at the centre of technology developments (Veloso, 2012). Researchers as UFPA have been exploring the use of rainwater harvesting, especially for drinking purposes aimed at residents in the Amazon region since 2006. They have established the Rainwater Harvesting in the Amazon (GPAC Amazônia) research group which acts in the development and diffusion of social technologies that aim to provide robust alternatives to people residing in areas where access drinking water is difficult. To date, academic, technical, social, and political interventions have already been carried out (Rosa, 2011; Andrade, 2012; Veloso, 2012; Dias, 2013; Vieira, 2017; Belém 2014; Mendes et al., 2016).

The lead author gathered human insight into local practice during a five-day immersion on Paquetá Island in August 2017 (Schiffer and Swan, 2018). Methodologically, this builds on previous immersive research carried out with a community in West Africa (Schiffer, 2016; Greene and Schiffer, 2018) and was enabled through an established link between UFPA staff and a family that hosted the researcher. The research received ethical approval and was conducted to comply with the Leeds Beckett University ethics policy. Immersion was supported by a range of ethnographic methods including two semi-structured interviews with the host family and a group of NGO representatives as well as observations and informal conversations with members of five households on three islands located on both shores and interior water ways. Verbal exchange was conducted with the help of a translator who accompanied the researcher for several days. The immersion enabled the researcher to participate and closely observe family life and how everyday activities and water practices play out. This included visits to households, cultural, social, and income-generating activities on the neighbouring islands of Jutuba and Arapiranga. In addition, a drawing based on Google satellite images enabled co-mapping of infrastructure distribution as the researcher joined her hosts on their travels across the islands.

Following the period of immersion, subsequent insights were shared and discussed with staff at the Federal University of Pará. These discussions served to: develop the authors' awareness of the context of Belém and its islands; enable a comparison of technical and non-technical perspectives; and triangulate findings.

Fieldwork was based on a single, relatively short immersion. This is a key limitation that provided the researcher with insights from only the time of year visited. Therefore, there is the potential of 'seasonal blindness', a biased understanding of local life based on the limited insights gained from one season (Chambers, 2012: 38). Furthermore, the lead author's positionality as a female 'outsider' should also be acknowledged (Merriam et al., 2001). During visits to households, some men seemed noticeably distant, compared with women in the same households. In particular, the researcher's limited ability to freely converse in Portuguese provided a barrier, though translation and participation in practical day-to-day activities helped bridge this gap. Her association with the host family was key in enabling wider access to island life, though at times, the combination of outsider status and gender appeared to provide easier access to other women in the local community.

[A]Analysis of key findings through an urban island water metabolism perspective

Key findings have been adapted from Schiffer and Swan (2018) to explore the UIWM in the context of understanding the particular challenges and opportunities faced by peripheral river islands located in the Marajó Bay, which receives direct influence mainly from the Tocantins, Pará, and Guamá rivers (Silva, 2010; Lopes et al., 2017). As such, the following analysis provides a first step towards developing the UIWM within the aforementioned limitations of this research.

[B]*Seasonal dimensions of the water metabolism*

While oceanic islands and archipelagos are at the mercy of ocean tides and rising sea levels in the context of climate change, the consideration of water metabolisms of river islands usually starts up-river. Costa et al. (2003) analysed a 50-year time period and found that the discharge rate of the Tocantins River had increased substantially due to increased agriculture along its banks. They subsequently also suggested regional changes in the hydrological response as a result of reduced vegetation cover. However, more recently Monteiro et al. (2016) show that 'green water' flow and storage increases towards the river mouth 'following a gradient of decreasing anthropogenic land use and the transition […] to the Amazon Forest'.

From a rainwater harvesting point of view this is promising for Paquetá and neighbouring islands which are located approximately 100 km before the river empties into the Atlantic Ocean to the north. Yet, during fieldwork: 'local people across households on several islands described that there was insufficient rainfall to benefit from their rainwater harvesting installations' (Schiffer and Swan, 2018: 858). Interestingly a socio-economic factor emerged to off-set the shortfall in rain and subsequent supply of drinking water, as this period, which also 'coincided with the beginning of the açaí season which runs from August to January [… and the selling of which] constitutes a major economic activity for people on Paquetá and neighbouring islands' (Schiffer and Swan, 2018: 858). (Figure 2). The income enables people to buy in bottled water instead, though this is of questionable quality that may often exhibit high levels of turbidity (Goncalves, 2012: 126). In turn, this renders 'what could be a potentially circular system to provide clean drinking water into a linear system which depends on resources shipped in from the mainland'.

[CAP]*Figure 2 Access to drinking water on Paquetá in August 2017*

Due to their location in the areas of Marajó and Guajará bays, Paquetá and neighbouring islands are part of a river region with marine influence (Silva, 2010; Gregório and Mendes, 2009). During periods of low flow (September to December) the waters become brackish (Paiva et al., 2006), which is even worse for those families that usually use river instead of rainwater.

[B]*Socio-technical and socio-political dimensions in the context of changing water levels*

With the exception of Cotijuba island which has significantly more infrastructure development and is supplied by a borehole, households in the cluster of islands have access to either river and/or rain water systems. Water tanks for both systems are generally raised above the ground from where water is distributed using gravitational force. Tanks are located in close proximity to main buildings which are also raised on stilts to accommodate changing water levels (Photo 1). Studies suggest that the discharge of the Tocantins River peaks during

February at which point it increases by as much as 28 per cent and the water level rises (Salisbury et al., 2011; Costa et al., 2003). However, water levels also change by several metres throughout the day because the river is tidal due to its close proximity to the Atlantic Ocean.

[CAP]*Photo 1 House on stilts located on a waterway along the interior of Paquetá with a raised water tank in the front*

River water systems can be found across the islands but depending on which administrative authority these fall under they may or may not have benefitted from additional government subsidized rainwater harvesting systems, which are seen to provide better quality drinking water despite the seasonal shortage mentioned above. Those living on the islands belonging to the municipal area of Bacarena and not Belém therefore have no access to rainwater harvesting (Figure 3) (Lima da Silva and Tourinho, 2017). This includes residents on the island of Arapiranga who complained of common health problems such as vomiting and diarrhoea, likely to be associated with drinking river water. It should however be noted that people across the islands 'regularly come into contact with river water when they bathe in it' and so may still be at risk. In fact, the research highlighted healthcare as a major challenge, also in terms of accessing facilities. Therefore, the link between UIWM and island healthcare provision may in itself deserve further attention.

[CAP]*Figure 3 Administrative areas of Bacarena (grey) and Belém (black)*
[S]*Source: adapted from Schiffer and Swan (2018)*

The respective influences of local authorities and other key stakeholders over the implementation of water infrastructure in this region has been explored within a recent study (Cardoso-Castro et al., 2017): In Belém's water supply system local authorities are responsible to provide water access. However, they impose a system that is not culturally accepted by local communities, exacerbated by the fact that communities are excluded from the development of these.

Accessing healthcare, selling açaí, buying bottled water, going to school, attending church or visiting friends or family on different parts of the island network or the mainland all depend on access by boat (Photo 2). In turn, this access relies on the tidal waters in the Marajó Bay to sustain 'the intra-island, inter-island and island-[mainland] networks which are the basis for economic and social activities'. Here, administrative borders do not reflect the inter-island social networks that underpin island life. However, the dispersed location of households along the shores and waterways that run deep inside of some of the islands, can make it difficult to provide access to external goods and services that are brought in from the mainland. This is exacerbated by the constantly changing water levels, potential storms and the cost of diesel to power boat engines. Therefore, 'off-grid technologies are likely to be the most appropriate solution for the provision of drinking water' as well as other services such as electricity.

[CAP]*Photo 2 Boats on the shores of Arapiranga with Mucura in the background*

[A]Conclusions and scope for future research

This practice paper has highlighted that the UIWM consists of interrelating socio-economic, socio-political, socio-technical, and socio-ecological dimensions that impact on the availability and access to water resources on Paquetá and surrounding islands. Limited rainfall coupled with relatively higher income generated from the sale of açaí enables some households with rainwater harvesting systems to make up the shortfall with bottled water of questionable quality. Arguably, priority to develop additional schemes should be given to households that are less accessible due to their location on inner-island waterways and relative distance from mainland ports.

The supply of decentralized rainwater harvesting systems clearly has the potential to support clean water access on Paquetá and surrounding islands. However, the social networks that support island life in general need to be considered, particularly in relation to maintenance, which could not be observed due to the lack of rainfall, as well as finance. Here, in-depth research into how islanders organize across islands and administrative borders could lead to locally appropriate business models to support the long-term sustainability of regional infrastructure development. As such, the resilience of the water metabolism of one island cannot be seen in isolation from the others and the mainland.

Repeated immersions and ethnographic research will provide a longer-term perspective of the challenges and opportunities for delivery of clean water access including their relationship to health and well-being. Particular emphasis should be placed on research during different seasons to help establish a holistic understanding of the relationship between household practice and water levels of the river.

In addition to longer term studies on Paquetá and surrounding islands, a comparison with other urban river islands or island groups, would help inform the UIWM concept and further the understanding of the specific needs and challenges for water management in these peripheral contexts.

,

[A]References

Agudelo-Vera, C.M., Leduc, W.R.W.A., Mels, A.R. and Rijnaarts, H.H.M. (2012) ‘Harvesting urban resources towards more resilient cities’, *Resources, Conservation and Recycling* 64: 3–12 <http://dx.doi.org/10.1016/j.resconrec.2012.01.014>.

Andrade, C.G. (2012) *Aproveitamento de água da chuva para abastecimento em área rural na Amazônia. Estudo de caso: ilhas Grande e Murutucu, Belém-Pará* [online], Masters dissertation, UFPA, Belém <https://www.dropbox.com/s/rokvaezd29k0br1/Andrade%202012.pdf?dl=0> [accessed 30 July 2018].

Belém (2014) *Plano Municipal de Saneamento Básico de Abastecimento de Água e Esgotamento Sanitário de Belém – Pará, Vol.2, Concepções Técnicas e Proposições* [pdf] <http://ww3.belem.pa.gov.br/www/wp-content/uploads/PMSB-Bel%C3%A9m-PA_Volume-II2.pdf> [accessed 25 July 2018].

Bordalo, C.A.L. (2016) 'La paradoja del agua en la Amazonia brasileña. El pueblo sin agua en la región de las aguas' [The paradox of water in the Brazilian Amazon: people without water in the region of waters], *América Latina Hoy* 74: 81–95 <https://doi.org/10.14201/alh2016748195>.

Bordalo, C.A. (2017). 'O paradoxo da água na região das águas: o caso da Amazônia brasileira', *Geo-USP Espaço e Tempo* 21(1): 120–37 [online] <https://www.researchgate.net/publication/319132827_O_paradoxo_da_agua_na_regiao_das_aguas_o_caso_da_Amazonia_brasileira> [accessed 20 July 2018]. https://doi.org/10.11606/issn.2179-0892.geousp.2017.107531

Cardoso-Castro, P., Swan, A. and Mendes, R. (2017) 'Stakeholders' structural factors affecting the implementation of rainwater systems in the Amazon: the case of Belém', *International Sustainable Ecological Engineering Design for Society (SEEDS) Conference, 13–14 September 2017, Leeds, UK*.

Chambers, R. (2012) *Provocations for Development,* Rugby, UK: Practical Action Publishing.

Costa, H.C., Botta, A. and Cardille, J.A. (2003) 'Effects of large-scale changes in land cover on the discharge of the Tocantins River, Southeastern Amazonia', *Journal of Hydrology* 283(1–4): 206–17 <https://doi.org/10.1016/S0022-1694(03)00267-1>.

Cousins, J.J. and Newell, J.P. (2015) 'A political-industrial ecology of water supply infrastructure for Los Angeles', *Geoform* 58: 38–50 <https://doi.org/10.1016/j.geoforum.2014.10.011>.

Currie, P.K. and Musango, J.K. (2016) 'African urbanization: assimilating urban metabolism into sustainability discourse and practice', *Journal of Industrial Ecology* 21(5): 1262–76 <http://dx.doi.org/10.1111/jiec.12517>.

Dias, A.D. (2013) *A Sustentabilidade de Tecnologias Sociais de Abastecimento de Água da Chuva: O Caso de Comunidades Insulares de Belém-PA* [pdf], Master's dissertation, Belém, UFPA <http://repositorio.ufpa.br/jspui/bitstream/2011/5256/1/Dissertacao_SustentabilidadeTecnologiasSociais.pdf> [accessed 25 July 2018].

Do Nascimento, T.V., Fernandes, L.L., and Yoshino, G.H. (2016) 'Potencial de aproveitamento de água de chuva na Universidade Federal do Pará – Belém/PA' [Potential

of rainwater harvesting in the Federal University of Pará – Belém/PA], *Revista Monografias Ambientais* 15(1): 105–16 <http://dx.doi.org/10.5902/22361308>.

Doss-Gollin, J., De Souza Filho, F., and Da Silva, F.O.E. (2016) 'Analytic modeling of rainwater harvesting in the Brazilian semiarid northeast', *Journal of the American Water Resources Association* 52(1): 129–37 <http://dx.doi.org/10.1111/1752-1688.12376>.

European Development Agency (2015) *Urban Sustainability Issues: What Is a Resource-Efficient City?* Copenhagen: European Development Agency.

Ghisi, E. (2006) 'Potential for potable water savings by using rainwater in the residential sector of Brazil', *Building and Environment* 41: 1544–50 <https://doi.org/10.1016/j.buildenv.2005.03.018>.

Gomes, U.A.F., Heller, L., Cairncross, S., Domenèch, L. and Pena, J.L. (2014) 'Subsidizing the sustainability of rural water supply: the experience of the Brazilian rural rainwater-harvesting programme', *Water International* 39(5): 606–19 <http://dx.doi.org/10.1080/02508060.2014.951255>.

Goncalves, C. (2012) *Aproveitamento De Agua Da Chuva Para Abastecimento Em Area Rural Da Amazonia*, Estudo De Caso: Ilhas Grande e Murutucu, Belem-Para, NUMA.

Greene, M. and Schiffer, A. (2018) 'Learning from past and current energy transitions to build sustainable and resilient energy futures: from Ireland and The Gambia', in P. Sumpf and C. Buscher (eds), *SHAPE ENERGY Research Design Challenge: Control, Change and Capacity-Building in Energy Systems*, Cambridge: SHAPE ENERGY.

Gregório, A.M.S. and Mendes, A.C. (2009) 'Bathymetry and sedimentology of Guajará Bay, Belém, State of Pará, Brazil', *Amazônia Ciência e Desenvolvimento* 5(9) <http://repositorio.museu-goeldi.br/bitstream/mgoeldi/369/1/Amaz%C3%B4nia%20Ci%C3%AAncia%20e%20Desenvolvimento%205%289%29%202009%20GREGORIO.pdf> [accessed 21 July 2018].

Grojec, A. (2017) *Progress on Drinking Water, Sanitation and Hygiene – 2017: Update and SDG Baselines*, New York: World Health Organization and the United Nations Children's Fund.

Hermanowicz, W.S. and Takashi, A. (1999) 'Abel Wolman's "The Metabolism of Cities" revisited: a case for water recycling and reuse', *Water Science and Technology* 40(4–5): 29–36.

Kennedy, C., Cuddihy, J., and Engel-Yan, J. (2007) 'The changing metabolism of cities', *Journal of Industrial Ecology* 2(11): 43–59 <http://dx.doi.org/10.1162/jie.2007.1107>.

Klindworth, K., Djurasovic, A., Knieling, J. Säwert, K. (2017) 'From linear to circular: challenges for changing urban metabolism?! An analysis of local energy transition activities in four European cities', in S. Deppisch (ed.), *Urban Regions Now and Tomorrow*, Wiesbaden: Springer.

Lima da Silva, M. and Tourinho, H.L.Z. (2017) 'Território, territorialidade e fronteira: o problema dos limites municipais e seus desdobramentos em Belém/PA' [Territory, territoriality and border: the problem of municipal limits and its unfolding in Belém – PA], *Urbe. Revista Brasileira de Gestão Urbana (Brazilian Journal of Urban Management)* 9(1): 96–109 <http://dx.doi.org/10.1590/2175-3369.009.001.AO09>.

Lopes, R.M., Mesquita, K.F.C., Santos, M.L.S., and Pereira, J.A.R. (2017) 'Quality of water consumed in Mosqueiro Island, Belém-PA', *Revista DAE* <http://dx.doi.org/10.4322/dae.2016.024>.

Mendes, R.L.R., Cohim, E., Andrade Neto, C.O., Gavazza, S. Gnadlinger, J., Orrico, S.R.M., Brito, L.T. de L., and Rocha, A. (2016) *10o. Simpósio Brasileiro de Captação e Manejo de Água de Chuva, 2016* [online] <http://10sbcmac.ufpa.br/> [accessed 25 July 2018].

Merriam, S.B., Johnson-Bailey, J., Lee, M.Y., Kee, Y., Ntseane, G. and Muhamad, M. (2001) 'Power and positionality: negotiating insider/outsider status with and across cultures', *International Journal of Lifelong Education* 20(5): 405–16 <http://dx.doi.org/10.1080/02601370120490>.

Ministry of Cities, National Secretariat of Environmental Sanitation and National Sanitation Information System (2013) *Diagnóstico dos serviços de água e esgotos 2011* [*Diagnosis of Water and Sewage Services*], Brasília: SNSA/MCidades.

Ministry of Health Brazil (2011) Portaria Nº 2.914, de 12 de Dezembro de 2011 *Dispõe sobre os procedimentos de controle e de vigilância da qualidade da água para consume humano e seu padrão de potabilidade* [online] <http://bvsms.saude.gov.br/bvs/saudelegis/gm/2011/prt2914_12_12_2011.html> [accessed 23 July 2018].

Monteiro, J.A.F., Strauch, M., Srinivasan, R., Abbaspour, K., and Gücker, B. (2016) 'Accuracy of grid precipitation data for Brazil: application in river discharge modelling of the

Tocantins catchment', *Hydrological Processes* 30: 1419–30 <http://dx.doi.org/10.1002/hyp.10708>.

Paiva, R.S., Leça, E.E., Passavante, J.Z.O., Cunha, M.G.V.S., and Melo, N.F.A.C. (2006) 'Ecological considerations on phytoplankton from the Guajará bay and from the Guamá river estuary in Pará, Brazil', *Boletim do Museu Paraense Emilio Goeldi Ciencias Naturais* 1(2) [online] <http://scielo.iec.gov.br/scielo.php?script=sci_arttext&pid=S1981-81142006000200010> [accessed 23 July 2018].

Paolini, F. and Cecere, C. (2015) 'Improvement of urban water metabolism at the district level for a Mediterranean compact city', in J.-L. Scartezzini (ed.), *Proceedings of CISBAT 2015 International Conference on Future Building Districts: Sustainability from Nano to Urban Scale – Vol. I, 9–11 September 2015, Lausanne*, pp. 481–6, Lausanne: EPFL Solar Energy and Building Physics Laboratory.

Ribeiro, W.C. (2008) *Geografia Política da Água.* São Paulo: Annablume.

Rosa, R.G.R. (2011) *Aproveitamento de águas pluviais para consumo potável - estudo de caso: município de Belém-PA*, Master's dissertation, Belém: UFPA.

Salisbury, J., Vandemark, D., Campbell, J., Hunt, C., Wisser, D., Reul, N. and Chapron, B. (2011) 'Spatial and temporal coherence between Amazon River discharge, salinity, and light absorption by colored organic carbon in western tropical Atlantic surface waters', *Journal of Geographical Research* 116, C00H02: 1–14 <http://dx.doi.org/10.1029/2011JC006989>.

Schiffer, A. (2016) 'Empowered, excited, or disenfranchised? Unveiling issues of energy access inequality and resource dependency in The Gambia', *Energy Research & Social Science* 18: 50–61 <https://doi.org/10.1016/j.erss.2016.04.011>.

Schiffer, A. and Swan, A. (2018) 'Water security: a summary of key findings exploring islands in Brazil', *Journal of Security and Sustainability Issues* 7(4): 855–60 <https://doi.org/10.9770/jssi.2018.7.4(20)>.

Serrao-Neumann, S., Renouf, M., Kenway, S.J. and Low Choy, D. (2017) 'Connecting land-use and water planning: prospects for an urban water metabolism approach', *Cities* 60(Part A): 13–7 <https://doi.org/10.1016/j.cities.2016.07.003>.

Silva, J.P. (2010) *Avaliação da Qualidade da Água Superficial Utilizada no Sistema de Abastecimento Público do Município de Belém (PA)*, Master's dissertation, Belém: UFPA <http://www.ufpa.br/ppgec/data/producaocientifica/Jaqueline%20Portal.pdf> [accessed 21 July 2018].

Siqueira, J.E de Campos. (2005) Ideologia da água e privatização dos serviços de saneamento. In: Dowbor, L. and Tagnin, R.A. (2005) Administrando a água como se fosse importante. Gestão ambiental é sustantabilidade. São Paulo: Senac, pp. 37-46.

Veloso, N.S.L. (2012) *Água da chuva e desenvolvimento local: o caso do abastecimento das ilhas Belém* [pdf], Belém: UFPA <http://repositorio.ufpa.br/jspui/bitstream/2011/4494/1/Dissertacao_AguaChuvaDesenvolvimento.pdf> [accessed 24 July 2018].

Veloso, N.S.L. and Mendes, R.L.R. (2014) 'Aproveitamento da água da chuva na Amazônia: experiências nas ilhas de Belém/PA', *Revista Brasileira de Recursos Hídricos* 19(1): 229–42 <http://dx.doi.org/10.21168>.

Vieira, A.G.R. (2017) *Análise de custo efetividade de soluções alternativas de abastecimento de água em comunidades rurais do município de Belém e Acará* [pdf], Master's dissertation, Belém: UFPA <http://repositorio.ufpa.br/jspui/bitstream/2011/9533/1/Dissertacao_ProposicaoIndicadoresCusto.pdf> [accessed 25 July 2018].

WASHWatch (2017) 'Brazil: declarations and commitments' [online], <https://washwatch.org/en/countries/brazil/summary/> [accessed 6 July 2018].