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Policy Forums

The Native Vegetation Protection Law of Brazil and the challenge for first-order stream conservation

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A B S T R A C T

First-order streams in Brazil are protected by the Native Vegetation Protection Law of Brazil (NVPL), which regulates the land-use in rural properties and is linked with aquatic conservation. We investigated the importance of the data-set resolution to identify first-order streams (State of São Paulo, Brazil) and estimated its length compared to other water bodies. We found that first-order streams represent around 58% of the total length of the drainage system. In addition, we compared this database with that of the Environmental Rural Registry (CAR in Portuguese). Compared with the lower resolution data-set, the length of first-order streams self-declared in CAR was 80% lower. We also found a concerning number of small dams in first-order streams, which severely changes their dynamics. Therefore, we recommend the use of finer resolution data-sets in order to create tools to support legal compliance that goes beyond the limited information provided by CAR.

Introduction

First-order streams are defined as intermittent or perennial water bodies with no temporary or perennial tributaries (Freeman et al., 2007). They are the smallest water bodies in a catchment but, cumulatively, account for most of the total channel length in a watershed (Downing et al., 2012; Lowe and Likens, 2005; Taniwaki et al., 2017b). Because they connect upland and riparian systems with the rest of the river network, first-order streams control the water quality, biodiversity, and ecological health of entire drainage networks and waterways (Lowe and Likens, 2005). Consequently, the degradation or loss of first-order streams by anthropogenic activities can cause serious environmental impacts and alter the structure and function of downstream receiving water bodies (Covich et al., 2006; Lorion and Kennedy, 2009; Taniwaki et al., 2017a). Increasingly, social-economic impacts such as increased risk of water scarcity, as observed recently in the city of São Paulo, one of the largest water crises in the history of Brazil are being considered as well (Dobrovolski and Rattis, 2015).

Depending of the land-use, first-order streams can disappear from the landscape if the erosion rates are greater than the sediment transport capacity of the channels (Faria, 2014). Therefore, first-order streams are highly vulnerable to human-mediated disturbances and require effective protection from legislation. The highest water quality in a watershed is usually found in springheads and in first-order streams (Cantonati et al., 2012; von Fumetti et al., 2007). However, agricultural activities and urbanization can dramatically change their streamflow and nutrient dynamics, reducing water quality and water availability due to the high connectivity of these ecosystems to adjacent landscapes (Alexander et al., 2007; Arango and Tank, 2008; Recha et al., 2012; Taniwaki et al., 2017a).

An event that drew greater attention to first-order streams in Brazil and to the modifications of water streams protection and restoration resulted from the enactment of the Native Vegetation

Abbreviations: CAR, Environmental Rural Registry; NVPL, Native Vegetation Protection Law of Brazil; GIS, Geographic Information System; APP, Permanent Protection Areas.

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Protection Law of Brazil (Law #12,651/2012, hereafter – NVPL), which replaced the 1965 Forest Code. This is the major law for water streams conservation, since it establishes mandatory protection and, in some cases, restoration of native vegetation around water springs and along riparian buffers, which are legally considered Permanent Protection Areas (APP) (Brancalion et al., 2016). The width of the dual riparian buffers that must be protected along both sides of a water course is defined by the width of the water course (Brancalion et al., 2016). For first-order streams (<10 m width), APP width is 30 m. If native vegetation was already converted to alternative land-uses, native vegetation cover has to be recovered in a portion of the APP or in their total extend, depending of the size of the landholding (Brancalion et al., 2016). A riparian buffer of only five meters should be recovered in small farms, while in large farms their width varies from 20 to 100 m. Since most of the first-order streams are less than 10 m wide, restoration demands have been severely reduced (Soares-Filho et al., 2014). This is a key negative aspect of the NVPL against first-order streams since riparian buffers are known to help protect water bodies from a wide range of anthropogenic impacts, such as land-use and climate change, eutrophication and excess of sediment (Ferreira et al., 2012; Peñuelas et al., 2013; Souza et al., 2013; Taniwaki et al., 2017b).

Another controversial aspect of the recent modifications in the NVPL is related to ephemeral streams and springs. In the Forest Code of 1965, ephemeral and intermittent streams were not defined as different water bodies; they were considered to be like any other part of the drainage network and protected accordingly. In the NVPL, the protection or restoration of riparian vegetation is no longer mandatory for the protection of ephemeral aquatic ecosystems; however, the protection of these ecosystems is probably more relevant than ever as predictions suggest that ephemeral streams will become more abundant as the frequency and magnitude of droughts increase with climate change (Gomez-Gener et al., 2016; Taniwaki et al., 2017b). Ephemeral streams represent an important source of carbon dioxide emissions by aquatic environments (Gomez-Gener et al., 2016; Hotchkiss et al., 2015), so increasing their abundance can create a positive feedback to climate change by increasing emissions of greenhouse gases.

Due to these limitations of NVPL, several studies have contested the rationale for reducing the width of riparian buffers protection, given the potential negative consequences for biodiversity and human wellbeing (Brancalion et al., 2016; Ferraz et al., 2014; Soares-Filho et al., 2014). In the discussions, a topic that has gained attention from scientists and policymakers is how to properly identify these water bodies in the landscape. Presently, the methods used may not be appropriate but there is no scientific assessment to affirm otherwise.

A positive aspect of the NVPL was the establishment of a system to identify water bodies and other environmental aspects in rural properties. The Environmental Rural Registry (Cadastro Ambiental Rural – CAR in Portuguese) is a mandatory but free self-declaratory registry of rural properties and rural landholdings that produces a diagnosis of environmental compliances and non-compliances to legal rules (Brancalion et al., 2016). This system integrates environmental information of APPs, legal reserve areas, forest and native vegetation remnants, restricted use areas and consolidated areas from rural proprieties in Brazil. CAR could be a key feature to identify first-order streams, because it is conducted through high-resolution images and by the landholders who know their properties. However, despite high efficacy (408 million hectares included), the quality of this dataset has never been assessed.

Given the challenges for the conservation of ephemeral and first-order streams in Brazil and especially in fast-changing regions like the state of São Paulo, the objectives of this study were two-folds: (1) To determine the length of first-order streams in different geomorphological regions of the state of São Paulo using GIS database with resolution 1:10,000 and 1:50,000; (2) to compare the outcome from the GIS database with the different resolutions and also with the dataset provided by landholders through the CAR electronic system SICAR (resolution 1:10,000). Failing to identify first-order streams because datasets available to landholders are inappropriate can potentially result in further reductions to the NVPL, and consequently, hinder conservation efforts in one of the most biodiverse regions of the world (Gaston, 2000). Assessing the magnitude of the mismatch is of utter importance.

Length of first-order streams in São Paulo State

The total length of the fluvial system in the state of São Paulo was estimated in 150 sample units (1257 ha each) in five different geomorphological regions on a regional scale (1:50,000) and the lengths of first-order streams at the local (1:10,000) and regional scales (1:50,000) were further compared to detect differences between the databases (Fig. 1). The sample units were analyzed in five different geomorphological regions because of differences in geomorphology and topographic relief and because they represent the major conditions where riparian buffer restoration will be required in Brazil, as consequence of the historical large-scale conversion of native ecosystems to agricultural lands. The process involved analyzing the dataset (drainage network) provided by the Instituto Brasileiro de Geografia e Estatística (IBGE, 2013) for regional and local scales, and then analyzing the topographic dataset provided by the Instituto Geográfico e Cartográfico do Estado de São Paulo (IGC, 2009). Our results show that the state of São Paulo has approximately 332,000 km of streams and rivers at the regional scale, of which 194,000 km are first-order streams, which collectively represent around 58% of the total fluvial system in the state.

At the local scale, first-order streams have approximately 255 thousand kilometers in length, represented by approximately 33 thousand kilometers by perennial streams and 222 thousand kilometers by intermittent streams. These results are around 25% higher than the results at the regional scale, indicating that if the database is not appropriate, the length of these ecosystems could be underestimated, as well conservation and restoration requirements. Therefore, we highlight the importance in using the more refined dataset available for identifying first-order streams; otherwise these waterbodies could be neglected, with negative consequences for the entire fluvial system.

Implications for riparian forest restoration

Riparian forest restoration is an important intervention for protection of first-order streams, providing better conditions for biota and for maintaining ecological flows and water quality (Aarons and Gourley, 2012; Alexander et al., 2007; Stanfield and Jackson, 2011). However, the most commonly used database for restoration programs is at regional scale (1:50,000), because it is the most complete available database for water resources in São Paulo. As we highlighted above, this database underestimates around 25% of first-order streams and therefore, restoration programs might underestimate or neglect these important ecosystems for restoration. A more serious consequence would be the ongoing conversion of native ecosystems covering riparian buffers to agricultural lands. If water courses are not identified, they do not receive the legal status of APP, and could be more vulnerable to degradation. In addition, we found that at the local scale, only a small portion of the mapped streams is perennial. This means that according to the NVPL, intermittent streams could migrate to ephemeral dynamics,

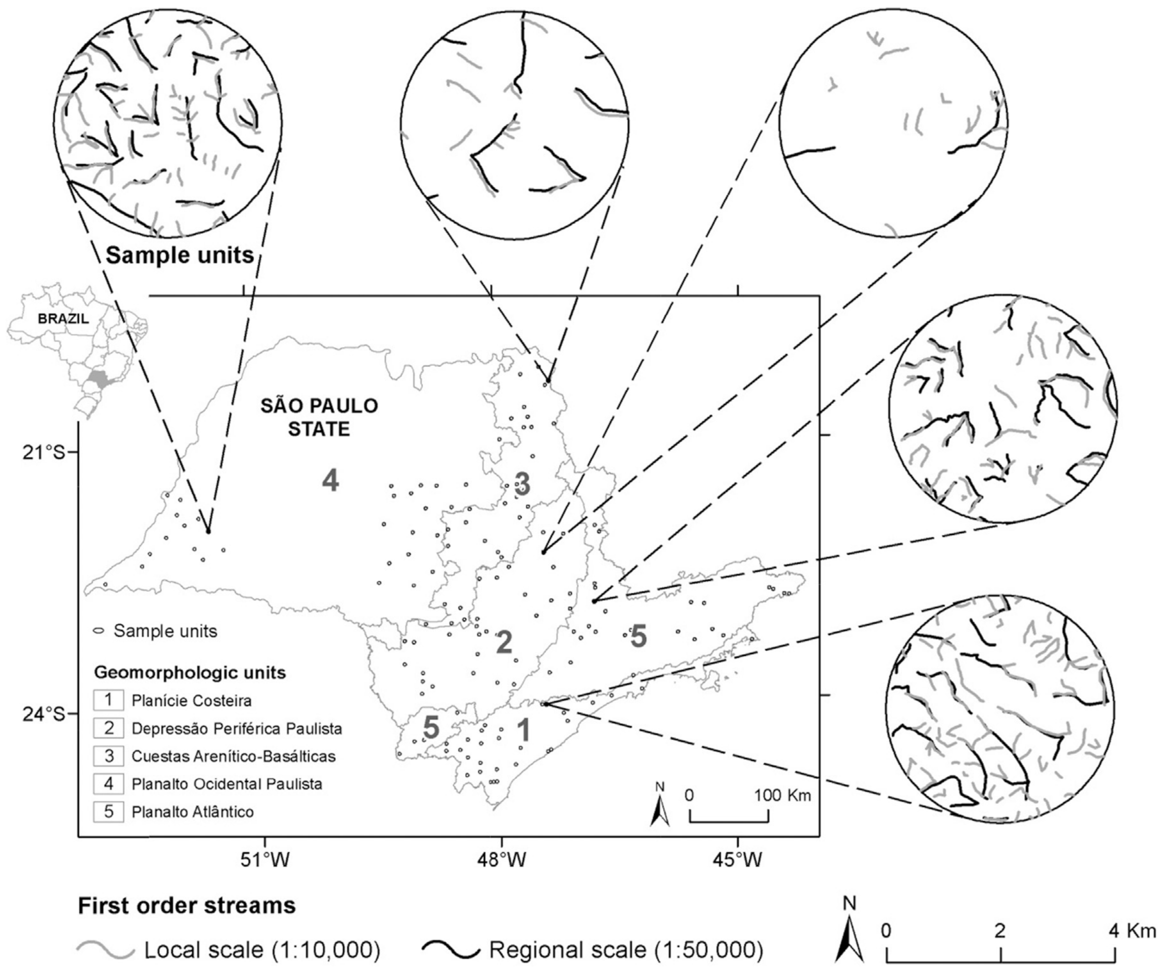

Fig. 1. Spatially explicit distribution of sample units by each geomorphologic region in São Paulo State. In detail, the sample unit shows the overlap of first-order streams mapped on the local (1:10,000) and regional (1:50,000) scale.

as consequence of stronger and more frequent droughts mediated by climate change, misplacing their legal protection coverage.

Environmental Rural Registry (CAR) – data crossing

The information denoted as SICAR was provided by the Secretariat of Environment of the State of São Paulo (April 2016) for comparison with the other databases generated using GIS tools. The SICAR database (resolution of 1:10,000) was analyzed using the same sample units that were used to estimate the length of first-order streams. Subsequently, we compared the databases (overlapping) to determine potential errors in the SICAR database. When the SICAR database was analyzed, around 80% of the total amount of self-declarations was declared. We found that the length of first-order streams declared in the SICAR was around 51 thousand kilometers, which is around 73% lower than the estimation at the regional scale (1:50,000) and around 80% lower than the estimation at the local scale (1:10,000) (Fig. 2). These findings are enormously important for conservation strategies and restoration programs, because the difference accounts for 143 thousand kilometers of riparian buffers that could be neglected with the use of this database (length at regional scale discounted by the values of first-order streams declared in CAR). It is important to mention that the CAR declaration from landowners was not complete when this study was conducted. However, the difference seems inconsistent to be explained by the lack of information of the 20% of the rural properties that were not yet registered.

Small dams in first-order streams: implications for riparian buffer restoration and stream ecology

By analyzing the datasets at the local scale, we were also able to detect a remarkable number of small dams in first-order streams. While damming streams is a common practice in the study region and elsewhere to support irrigation, fishery, recreation and cattle hydration, the intervention fundamentally change the dynamics of nutrient retention, carbon flows, streamflow and also creates barriers for the movement of aquatic organisms across the landscape (Leal et al., 2016). In total, we found that around 15% of first-order streams in our study samples were impacted by small dams, which were usually smaller than 1 ha. The consequences go beyond the potential impacts on the structure, function and diversity of lotic ecosystems since the protection and restoration of riparian buffers is not mandatory for small dams (up to 1 ha), by NVPL. The removal of these small dams and protection of first-order streams should be incorporated into the new Brazilian environmental laws to prevent the construction of these anthropogenic ecosystems, as well as the protection of riparian buffers in dams further downstream.

Conclusions and implications

This study emphasizes the importance of the quality and scale of cartographic databases on conservation and restoration planning. The CAR system, for example, has demonstrated to be inefficient in detecting first-order streams in São Paulo State. Considering

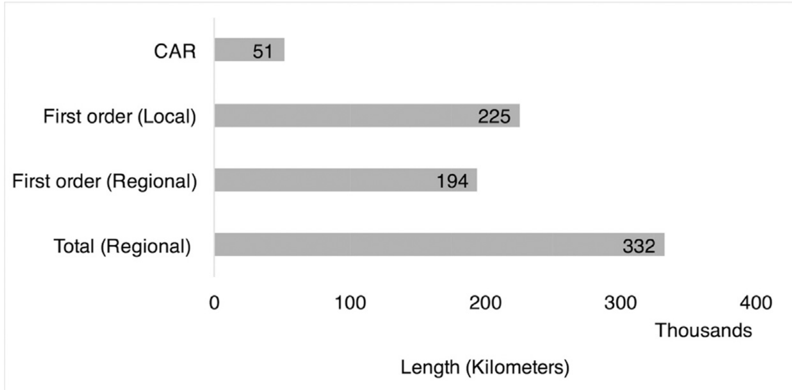

Fig. 2. Comparison of the total fluvial system length in São Paulo State with first-order streams mapped at the regional and local scales and with the length declared by landholders in the CAR system.

such failures in detecting first-order streams, which constitute the largest length of water bodies in a watershed, the requirements of ecosystem restoration are likely to be underestimated. Therefore, we recommend the use of finer resolution datasets (below 1:10,000) to detect first-order streams in São Paulo State and other regions of Brazil. This approach will help to include several water bodies that would not be possible to detect using maps at coarser resolution. Restoring these environments will help to provide better water quality (Cunha et al., 2016; Taniwaki et al., 2017a, 2017b), and to reduce the risks of habitat loss and stream narrowing (Sweeney et al., 2004).

It is important to mention that only São Paulo State and a few other states in Brazil have fine resolution images available (1:10,000). Places that are enormously important for the conservation of freshwater ecosystems, for example, the Amazonian states of Amazonas and Pará have only 1:50,000 resolution images. This implies that stream conservation programs in these states are severely affected, with several water bodies not represented in databases and out of the radar of protective environmental laws. Even first-order streams included in the present databases may no longer be protected in the future due to the conversion of intermittent to ephemeral streams, as consequence of land degradation and climate change.

The elevated number of intermittent streams in São Paulo State is evidence of the emerging risks that deficient databases and legislation changes without scientific support bring to the conservation of freshwater ecosystems and water security to people.

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References

Aarons, S.R., Gourley, C.J.P., 2012. The role of riparian buffer management in reducing off-site impacts from grazed dairy systems. Renew. Agric. Food Syst. 28, 1–16, http://dx.doi.org/10.1017/s1742170511000548.

Alexander, R.B., Boyer, E.W., Smith, R.A., Schwarz, G.E., Moore, R.B., 2007. The role of headwater streams in downstream water quality. J. Am. Water Resour. Assoc. 43, 41–59, http://dx.doi.org/10.1111/j.1752-1688.2007.00005.x.

Arango, C.P., Tank, J.L., 2008. Land use influences the spatiotemporal controls on nitrification and denitrification in headwater streams. J. North Am. Benthol. Soc. 27, 90–107, http://dx.doi.org/10.1899/07-024.1.

Brancalion, P.H.S., Garcia, L.C., Loyola, R., Rodrigues, R.R., Pillar, V.D., Lewinsohn, T.M., 2016. A critical analysis of the Native Vegetation Protection Law of Brazil (2012): updates and ongoing initiatives. Nat. Conserv. 14, 1–15, http://dx.doi.org/10.1016/j.ncon.2016.03.003.

Cantonati, M., Fuereder, L., Gerecke, R., Juettner, I., Cox, E.J., 2012. Crenic habitats, hotspots for freshwater biodiversity conservation: toward an understanding of their ecology. Freshw. Sci. 31, 463–480, http://dx.doi.org/10.1899/11-111.1.

Covich, A.P., Crowl, T.A., Heartsill-Scalley, T., 2006. Effects of drought and hurricane disturbances on headwater distributions of palaemonid river shrimp (Macrobrachium spp.) in the Luquillo Mountains, Puerto Rico. J. North Am. Benthol. Soc. 25, 99–107, http://dx.doi.org/10.1899/0887-3593(2006)25[99:eodahd]2.0.co;2.

Cunha, D.G.F., Sabogal-Paz, L.P., Dodds, W.K., 2016. Land use influence on raw surface water quality and treatment costs for drinking supply in São Paulo State (Brazil). Ecol. Eng. 94, 516–524, http://dx.doi.org/10.1016/j.ecoleng.2016.06.063.

Dobrovolski, R., Rattis, L., 2015. Water collapse in Brazil: the danger of relying on what you neglect. Nat. Conserv. 13, 80–83, http://dx.doi.org/10.1016/j.ncon.2015.03.006.

Downing, J.A., Cole, J.J., Duarte, C.M., Middelburg, J.J., Melack, J.M., Prairie, Y.T., Kortelainen, P., Striegl, R.G., McDowell, W.H., Tranvik, L.J., 2012. Global abundance and size distribution of streams and rivers. Inl. Waters 2, http://dx.doi.org/10.5268/IW-2.4.502.

Faria, A.P., 2014. Transporte de sedimentos em canais fluviais de primeira ordem: respostas geomorfológicas. Rev. Bras. Geomorfol. 2, 191–202, http://dx.doi.org/10.20502/rbg.v15i2.410.

Ferraz, S.F.B., Ferraz, K.M.P.M.B., Cassiano, C.C., Brancalion, P.H.S., da Luz, D.T.A., Azevedo, T.N., Tambosi, L.R., Metzger, J.P., 2014. How good are tropical forest patches for ecosystem services provisioning? Landsc. Ecol. 29, 187–200, http://dx.doi.org/10.1007/s10980-014-9988-z.

Ferreira, A., Cyrino, J.E.P., Duarte-Neto, P.J., Martinelli, L.A., 2012. Permeability of riparian forest strips in agricultural, small subtropical watersheds in south-eastern Brazil. Mar. Freshw. Res. 63, 1272–1282, http://dx.doi.org/10.1071/mf12092.

Freeman, M.C., Pringle, C.M., Jackson, C.R., 2007. Hydrologic connectivity and the contribution of stream headwaters to ecological integrity at regional scales. JAWRA J. Am. Water Resour. Assoc. 43, 5–14, http://dx.doi.org/10.1111/j.1752-1688.2007.00002.x.

Gaston, K.J., 2000. Global patterns in biodiversity. Nature 405, 220–227.

Gomez-Gener, L., Obrador, B., Marce, R., Acuna, V., Catalan, N., Casas-Ruiz, J.P., Sabater, S., Munoz, I., von Schiller, D., 2016. When water vanishes: magnitude and regulation of carbon dioxide emissions from dry temporary streams. Ecosystems 19, 710–723, http://dx.doi.org/10.1007/s10021-016-9963-4.

Hotchkiss, E.R., Hall Jr., R.O., Sponseller, R.A., Butman, D., Klaminder, J., Laudon, H., Rosvall, M., Karlsson, J., 2015. Sources of and processes controlling CO_2 emissions change with the size of streams and rivers. Nat. Geosci., http://dx.doi.org/10.1038/ngeo2507, http://www.nature.com/ngeo/journal/vaop/ncurrent/abs/ngeo2507.html#supplementary-information.

IBGE, 2013. IBGE Downloads [WWW Document]. Inst. Bras. Geogr. e Estatística, http://downloads.ibge.gov.br/downloads_geociencias.htm (accessed 06.07.17).

IGC, 2009. Mapeamento Topográfico Escala 1:10,000 [WWW Document]. Inst. Geográfico e Cart, http://www.igc.sp.gov.br/produtos/mapeamento.html (accessed 06.06.16).

Leal, C.G., Pompeu, P.S., Gardner, T.A., Leitão, R.P., Hughes, R.M., Kaufmann, P.R., Zuanon, J., de Paula, F.R., Ferraz, S.F.B., Thomson, J.R., Mac Nally, R., Ferreira, J., Barlow, J., 2016. Multi-scale assessment of human-induced changes to Amazonian instream habitats. Landsc. Ecol. 31, 1725–1745, http://dx.doi.org/10.1007/s10980-016-0358-x.

Lorion, C.M., Kennedy, B.P., 2009. Relationships between deforestation, riparian forest buffers and benthic macroinvertebrates in neotropical headwater streams. Freshw. Biol. 54, 165–180, http://dx.doi.org/10.1111/j.1365-2427.2008.02092.x.

Lowe, W.H., Likens, G.E., 2005. Moving headwater streams to the head of the class. Bioscience 55.

Peñuelas, J., Sardans, J., Estiarte, M., Ogaya, R., Carnicer, J., Coll, M., Barbeta, A., Rivas-Ubach, A., Llusià, J., Garbulsky, M., Filella, I., Jump, A.S., 2013. Evidence of current impact of climate change on life: a walk from genes to the biosphere. Glob. Change Biol. 19, 2303–2338, http://dx.doi.org/10.1111/gcb.12143.

Recha, J.W., Lehmann, J., Walter, M.T., Pell, A., Verchot, L., Johnson, M., 2012. Stream discharge in tropical headwater catchments as a result of forest clearing and soil degradation. Earth Interact. 16, http://dx.doi.org/10.1175/2012ei000439.1.

Soares-Filho, B., Rajão, R., Macedo, M., Carneiro, A., Costa, W., Coe, M., Rodrigues, H., Alencar, A., 2014. Cracking Brazil's Forest Code. Science (80-) 344, 363–364.

Souza, A.L.T., Fonseca, D.G., Liborio, R.A., Tanaka, M.O., 2013. Influence of riparian vegetation and forest structure on the water quality of rural low-order streams in SE Brazil. For. Ecol. Manag. 298, 12–18, http://dx.doi.org/10.1016/j.foreco.2013.02.022.

Stanfield, L.W., Jackson, D.A., 2011. Understanding the factors that influence headwater stream flows in response to storm events. J. Am. Water Resour. Assoc. 47, 315–336, http://dx.doi.org/10.1111/j.1752-1688.2010.00518.x.

Sweeney, B.W., Bott, T.L., Jackson, J.K., Kaplan, L.A., Newbold, J.D., Standley, L.J., Hession, W.C., Horwitz, R.J., 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. Proc. Natl. Acad. Sci. U. S. A. 101, 14132–14137, http://dx.doi.org/10.1073/pnas.0405895101.

Taniwaki, R.H., Cassiano, C.C., Filoso, S., Ferraz, S.F.B., Camargo, P.B., Martinelli, L.A., 2017a. Impacts of converting low-intensity pastureland to high-intensity bioenergy cropland on the water quality of tropical streams in Brazil. Sci. Total Environ. 584–585, 339–347, http://dx.doi.org/10.1016/j.scitotenv.2016.12.150.

Taniwaki, R.H., Piggott, J.J., Ferraz, S.F.B., Matthaei, C.D., 2017b. Climate change and multiple stressors in small tropical streams. Hydrobiologia, http://dx.doi.org/10.1007/s10750-016-2907-3.

von Fumetti, S., Nagel, P., Baltes, B., 2007. Where a springhead becomes a springbrook – a regional zonation of springs. Fundam. Appl. Limnol. 169, 37–48, http://dx.doi.org/10.1127/1863-9135/2007/0169-0037.