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REVIEW

A critical review of the effect of water storage reservoirs on organic matter decomposition in rivers

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Abstract: Organic matter decomposition is vital in sustaining river food webs. However, little is known about the effect of water storage reservoirs on organic matter decomposition in rivers. In this paper, we reviewed and analyzed 37 studies that investigated the effect of man-made reservoirs on organic matter decomposition in rivers. Most studies focused on decomposition of tree leaf litter (54.1%) and macrophytes litter (43.2%), while fewer studies evaluated decomposition of wood (2.7%). Based on qualitative analysis, the effect of small weirs on organic matter decomposition is local and the effect on most habitat variables is minimal. Mean effect sizes (Hedges' *g*) for organic matter decomposition were –1.98 for small weirs, –1.31 for small reservoirs, and –0.66 for large reservoirs. This review demonstrates that, in general, reservoirs have a negative effect on litter decomposition. Litter decomposition, an important ecosystem process, is sensitive to impacts of reservoirs in different types of rivers.

Key words: dam, organic matter decomposition, energy source, ecological integrity, environment.

Résumé : La décomposition de matière organique est essentielle au maintien des réseaux trophiques fluviaux. Cependant, on en sait très peu à propos de l'effet des réservoirs de retenue sur la décomposition de matière organique dans les rivières. Dans le cadre de cette étude, nous avons passé en revue et avons analysé 37 études au sujet de l'effet des réservoirs artificiels sur la décomposition de matière organique dans les rivières. La plupart des études ont porté sur la décomposition des litières de feuilles d'arbres (54,1 %) et des litières de macrophytes (43,2 %), tandis que moins d'études ont évalué la décomposition de bois (2,7 %). D'après l'analyse qualitative, l'effet de petits déversoirs sur la décomposition de matière organique est local et l'effet sur la plupart des variables d'habitat est minimal. Les ampleurs moyennes de l'effet (*g* de Hedges) de la décomposition de matière organique étaient –1,98 pour les petits déversoirs, –1,31 pour les petits réservoirs et –0,66 pour les grands réservoirs. Cet examen démontre qu'en général les réservoirs ont un effet négatif sur la décomposition de litière. La décomposition de litière, un processus écosystémique important, est sensible aux impacts des réservoirs situés dans différents types de rivières. [Traduit par la Rédaction]

Mots-clés : barrage, décomposition de matière organique, source d'énergie, intégrité écologique, environnement.

1. Introduction

Reservoirs are one of the most common human impacts on rivers worldwide (Nilsson et al. 2005). Reservoirs are constructed to supply water for purposes such as agriculture, domestic use, hydroelectric power generation, and recreation. As a result of increased demand for water, the number of reservoirs has increased dramatically in the last 100 years (WCD 2000). This has resulted in regulation of flow for more than half of all rivers globally (WCD 2000). Despite the various benefits that are provided by reservoirs, they may increase abiotic factors such as water temperature and nutrients and decrease biotic factors such as fungi and invertebrates, and functional ecosystem processes (e.g., litter decomposition) (Elosegi and Sabater 2013; Mbaka and Mwaniki 2015; von Schiller et al. 2015).

Most studies on the effect of reservoirs on rivers focused on habitat factors and biotic communities, such as invertebrates, fish, and algae (Rosenberg et al. 1997; Ellis and Jones 2013; Mbaka and Mwaniki 2015). However, depending on the impact of reservoirs on river habitat factors and biotic communities, reservoirs also have negative or positive effects on riparian vegetation and fundamental ecosystem processes, such as organic matter decomposition—an important source of energy in rivers and greenhouse gases in the environment (Fisher and Likens 1973; Jansson et al. 2000; Abril et al. 2013). Allochthonous organic matter can contribute more than 90% carbon in headwater streams (Fisher and Likens 1973). This observation led to conceptualization of ecosystem processes, where organic matter is initially decomposed by microorganisms (e.g., fungi), and subsequently by macroinvertebrate shredders, that breakdown coarse particulate organic matter into fine organic particles (Vannote et al. 1980; Graça 2001; Pascoal and Cássio 2004). The fine organic matter becomes a crucial food source for primary consumers, such as filtering-collectors, that are consumed by predators. Therefore, any alteration of organic matter transfer and decomposition in rivers would modify the food web structure and energy flow (Muehlbauer et al. 2009; Mendoza-Lera et al. 2012).

Given that reservoirs may cause habitat factors (e.g., nutrients, flow) to increase or decrease, their effect on biotic communities (e.g., fungi, bacteria, and invertebrates) and organic matter decomposition process may be either positive or negative (Menéndez et al. 2012). Depending on study design (e.g., longitudinal location of study sites), type of organic matter, litter bags mesh size, and characteristics related to reservoirs, such as trophic status, water

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release mechanism, size, and water residence time, reservoirs may have varied effects on biotic and abiotic factors and organic matter decomposition process (Nelson and Roline 2000; Menéndez et al. 2012; Quintão et al. 2013; Mbaka and Mwaniki 2015). Differences in response of biotic and abiotic factors among rivers may increase or decrease organic matter decomposition rates in reservoirs, upstream sites flooded by reservoirs or downstream sites (Short and Ward 1980; Casas et al. 2000; Menéndez et al. 2012). For example, Quintão et al. (2013) evaluated the effect of two large reservoirs (i.e., reservoirs with water storage capacity greater than 3 000 000 m^3, WCD 2000), with different trophic status, on aquatic macrophytes (*Eichhornia* sp., *Typha* sp.) leaves decomposition rates using 10 mm mesh size litter bags. The authors found the highest decomposition rates in the eutrophic reservoir. Leaf litter decomposition was mainly influenced by microorganisms (i.e., fungi and bacteria), than invertebrate shredders, and water temperature, oxygen, and nutrient concentrations influenced microbial development. Short and Ward (1980) assessed the effect of a reservoir that released deep water on alder tree leaf (*Alnus* sp.) packs decomposition rate and found that although the mean abundance of invertebrate shredders was reduced at the downstream site, high temperature increased leaf packs breakdown rate, through increased microbial processing. Mendoza-Lera et al. (2012) evaluated the effect of small reservoirs (14 000–64 000 m^3) on decomposition rates of alder tree leaves, using 5 mm mesh size bags, and they found that although the reservoirs had minor effects on factors such as temperature, nutrients, flow, and fungi abundance, leaf litter decomposition rates were reduced at the downstream sites of reservoirs owing to low abundance of invertebrate shredders. In contrast, Mbaka and Schäfer (2016), using 8 mm mesh size bags, reported that small weirs (80–720 m^3) that released surface water caused a reduction in the abundance of invertebrate shredders and alder tree leaf litter decomposition rates at the sites located immediately upstream of the area flooded by the weirs, although factors such as temperature and nutrients did not differ significantly among sites.

The organic matter decomposition process is useful in evaluation of the effect of disturbance on ecological integrity of lotic ecosystems (Castela et al. 2008; Young et al. 2008). Moreover, organic matter decomposition can help to disentangle the ecological effect of reservoirs in the presence of multiple stressors (Colas et al. 2013). However, little is known about the effect of reservoirs on organic matter decomposition in rivers (Menéndez et al. 2012). This review paper, therefore, aimed to conduct a synthesis of case studies, by qualitative and quantitative analysis, to gain further insights on the effect of different types of reservoirs on organic matter decomposition in rivers. We hypothesized that reservoirs would have a negative effect on litter decomposition rate by decreasing habitat variables, such as water flow rate, and densities of invertebrate shredders and microorganisms (e.g., fungi).

2. Literature survey and data analysis

The databases Web of Knowledge, Pubmed, Google Scholar, and Scopus were searched for publications on the effect of man-made water storage reservoirs on organic matter decomposition in rivers. The search was limited to papers published between 1980 and 2016. Papers were searched using the following terms: (dam OR impoundment OR reservoir OR pond OR weir) AND (decomposition OR decay OR processing OR breakdown) AND (leaf litter OR wood OR organic matter) AND (stream OR river). Moreover, the searches were enhanced by scanning reference lists of identified papers for additional literature. A total of 47 papers based on this criteria were found. Out of these papers, 10 papers were excluded from further analysis because the research was conducted in dammed rivers, but focused on other stressors (e.g., metals or green house gases, e.g., Abril et al. 2013), or involved laboratory mesocosm studies (e.g., Bonanomi et al. 2015) and lakes. The remaining 37 papers were read thoroughly and qualitative information such as study design, type of organic matter (e.g., leaf litter), mesh size of litter bags, and reservoir details (e.g., volume) was obtained (see supplementary data, Table S1[1]) . The biotic and abiotic factors (e.g., invertebrates, fungi, temperature, nutrients, and flow velocity), as well as organic matter decomposition, were divided into three groups based on significant increase and decrease, or no significant effect of reservoirs (Table S2[1])—although non-significance may sometimes be as a result of low statistical power (Lieber 1990). The longitudinal location of study sites was coded as FU (further upstream), for study sites not impacted (control) by reservoirs; IU (immediate upstream), for study sites located less than 50 m from the area flooded by reservoirs; RES (reservoir), for study sites located within reservoirs; ID (immediate downstream), for study sites located within 50 m from the dam wall; and FD (further downstream), for study sites potentially impacted by reservoirs, but located further downstream (Table S2[1]). Reservoirs were categorised into (*i*) large reservoirs (volume greater than 3 000 000 m^3, WCD 2000), (*ii*) small reservoirs (volume between 50 000 and 3 000 000 m^3), and (*iii*) small weirs (volume less than 50 000 m^3).

The effect of water storage reservoirs on habitat variables and organic matter decomposition was quantified by calculating standardised mean differences, Hedges' g (Gurevitch and Hedges 1993)—using means and standard errors and means and standard deviations. A 95% confidence interval (CI) was used to evaluate whether g was statistically significantly different from zero, with significant results having a CI without a zero (Gurevitch and Hedges 1993). Data analysis was performed using MetaWin statistical software package version 2.0 (Rosenberg et al. 2000).

3. Literature survey findings

3.1. Database description

Our survey of the literature resulted in 37 papers that satisfied our search criteria (Table S1[1]) on the effect of reservoirs on organic matter decomposition in rivers. The majority of studies assessed large reservoirs (51.5%) and small reservoirs (39.4%), with fewer studies focusing on small weirs (9.1%). Most of the studies targeted decomposition of tree leaf litter (54.1%) and macrophytes (43.2%), whereas fewer studies (2.7%) dealt with decomposition of wood. Litter was mainly collected after natural abscission (44.8%) and before abscission (44.8%) than during abscission (10.4%). Coarse mesh litter bags (68.8%) were more frequently used than leaf packs (18.7%) or fine mesh litter bags (12.5%); and decomposition was mainly evaluated using the negative exponential model (63.3%) than the linear model (26.7%), or both models (10%). Evaluation of the effect of reservoirs on rivers was primarily conducted through comparison of reference conditions to further downstream (27.5%) and reservoir reaches (27.5%), while fewer studies assessed immediate upstream (5.3%) and immediate downstream (12.2%) reaches.

3.2. Qualitative review

Generally, small weirs had no significant effect on most habitat variables, compared with large reservoirs (Table 1). For example, studies on small weirs found that they had no significant effect on chemical variables, whereas large reservoirs were reported to significantly increase conductivity, nitrates, phosphates, and ammonium. Additionally, small weirs were primarily reported to significantly decrease the densities of invertebrate shredders and organic matter decomposition rates at study sites located within

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[1] Supplementary data are available with the article through the journal Web site at http://nrcresearchpress.com/doi/suppl/10.1139/er-2016-0041.

Table 1. Number of studies that reported effect of reservoirs on biotic and abiotic factors and organic matter decomposition in rivers.

	Small weir			Small reservoir			Large reservoir		
Variable	Increase	Decrease	No change	Increase	Decrease	No change	Increase	Decrease	No change
Width	—	1_{ID}	—	—	—	4	—	—	—
Velocity	—	2_{ID}	1	—	2_{FD}	3	—	—	2
Temperature	—	—	3	1_{FD}	1_{FD}	4	—	—	2
pH	—	—	3	1_{FD}	—	2	—	—	3
Canopy cover	—	—	1	—	—	3	—	1_{FD}	—
Fine sediment	—	—	—	—	—	4	—	—	—
Oxygen	—	—	3	1_{FD}	—	5	—	—	2
Conductivity	—	—	2	—	1_{FD}	6	$2_{\text{FD,ID}}$	—	1
Alkalinity	—	—	—	—	—	3	—	—	2
Nitrates	—	—	3	—	—	5	$2_{\text{FD,ID}}$	—	—
Phosphates	—	—	2	—	—	4	1_{FD}	—	—
Ammonium	—	—	1	—	—	2	1_{ID}	—	—
Fungi diversity	—	—	—	1_{FD}	—	3	—	—	—
Fungi abundance	—	—	—	1_{FD}	1_{FD}	3	—	—	—
Invertebrate diversity	—	—	—	—	3_{FD}	2	—	—	1
Invertebrate density	—	—	1	—	—	5	—	—	2
Invertebrate shredders density	—	$2_{\text{IU,ID}}$	—	1_{FD}	1_{FD}	3	—	1_{ID}	1
Decomposition rate	—	$3_{\text{IU,RES,ID}}$	—	1_{FD}	$5_{\text{FD,RES}}$	—	—	$3_{\text{ID,RES}}$	1

Note: IU, immediate upstream; RES, reservoir; ID, immediate downstream; FD, further downstream.

the vicinity of reservoirs (IU, RES, ID), whereas small reservoirs were reported to increase or decrease the two variables at study sites located in reservoirs (RES) and further downstream (FD) (Table 1).

3.3. Quantitative analysis

Results of analysis of the effect sizes of physico-chemical variables, biotic communities (e.g., invertebrates), and litter decomposition are presented in Table 2. With regard to chemical variables, large reservoirs caused a significant increase in conductivity (g = 3.34, CI = 1.05 to 5.62) at the immediate and further downstream reaches. However, large reservoirs had a negative and non-significant effect on pH (g = –1.27, CI = –3.08 to 0.54). Small reservoirs had negative and non-significant effects on phosphates (g = –0.18, CI = –1.28 to 0.91), conductivity (g = –0.04, CI = –1.14 to 1.06), and oxygen (g = –0.09, CI = –1.23 to 1.04). A similarly negative trend was observed for chemical variables such as phosphates, oxygen, nitrates, and pH at the immediate upstream, reservoir, and immediate downstream sites of small weirs. With regard to physical variables, small weirs had a non-significant effect on water velocity (g = –1.82, CI = –3.85 to 0.21). Large reservoirs had a larger positive effect on water temperature (g = 0.49) than small weirs (g = 0.04). Small reservoirs had a negative effect on invertebrate density (g = –0.55), shredders density (g = –0.65), and fungi density (g = –0.34). Small weirs had the largest negative effect on litter decomposition rate (g = –1.98), followed by small reservoirs (g = –1.31) and large reservoirs (g = –0.66). In general, the effect of small weirs and reservoirs on most habitat variables was smaller than that of large reservoirs. Small weirs primarily had an effect on variables at the reaches located in close proximity to the reservoirs, whereas small reservoirs affected sites located further downstream.

4. Impact of reservoirs on organic matter decomposition in rivers

Based on qualitative review, small weirs had no significant effect on most water variables and affected organic matter decomposition process at the study sites located near the reservoirs. On the other hand, small and large reservoirs caused many variables to significantly increase or decrease at the reservoir, immediate downstream, and further downstream (Table 1). Large reservoirs have bigger effects on river physico-chemical conditions than small weirs, owing to their greater volume and water retention time (Poff and Hart 2002; Maxted et al. 2005). Consequently, this will affect the spatial extent to which habitat variables are affected (Poff and Hart 2002).

Quantitative analysis showed that small weirs (g = –1.98, CI = –3.82 to –0.14) and small reservoirs (g = –1.31, CI = –1.82 to –0.79) had significant negative effects on leaf litter decomposition rate. Large reservoirs had a non-significant effect (g = –0.66, CI = –1.65 to 0.34) on leaf litter decomposition rate (Table 2). This suggests that water storage reservoirs have varied effects on litter decomposition process. For example, Tuch and Gasith (1989) evaluated the effect of a large reservoir (4 000 000 m^3) on macrophyte (*Typha* sp.) leaf litter decomposition rate and found that study sites located further downstream (1.5 km) had significantly slower decomposition rates than reference sites. In contrast, Casas et al. (2000) investigated the effect of a large reservoir (70 000 000 m^3) that released deep water on tree leaf litter decomposition rate and found that the reservoir did not have a significant effect. The authors suggested that although high nutrient concentrations (up to 14 fold) at the downstream side could have accelerated decomposition rates (Suberkropp and Chauvet 1995), high hydrological variability at the upstream side may have caused greater physical breakdown of leaf litter (Rueda-Delgado et al. 2006). González et al. (2013) investigated the effect of a small reservoir (90 000 000–710 000 000 m^3) on alder tree leaf litter decomposition process and found that the decomposition rate was significantly reduced at the downstream side. The authors suggested that modification in the structure of invertebrate (e.g., shredders) and fungi communities could be responsible for the observed differences. The strong negative effect (g = –1.98) of small weirs on leaf litter decomposition rate can be attributed to the negative effect of weirs on water velocity (g = –1.82), nitrates (g = –0.11), phosphates (g = –0.02), or fine sediment deposition (Belančić et al. 2009; Avilés and Niell 2007; Sanpera-Calbet et al. 2012; Ágoston-Szabó et al. 2016).

Other factors that influence organic matter decomposition in regulated rivers include reservoir typology (e.g., water release mechanism), activities in the catchment area, season of investigation, and size of river (Menéndez et al. 2012; Colas et al. 2013; Arroita et al. 2015; Abril et al. 2015). For example, Menéndez et al. (2012) investigated the effect of four small surface and deep release reservoirs on alder tree leaf litter decomposition rates

Table 2. Effect size (Hedges' *g*) mean values and associated 95% confidence intervals (CI) for the effect of water storage reservoirs on habitat variables, biotic communities (e.g.invertebrates), and organic matter decomposition in rivers.

	Small weir		Small reservoir		Large reservoir	
Variable	*n*	*g* (95% CI)	*n*	*g* (95% CI)	*n*	*g* (95% CI)
Width	—	—	3	0.34 (–1.4 to 2.0)$_{\mathrm{FD}}$	—	—
Velocity	3	–1.82 (–3.85 to 0.21)$_{\mathrm{IU,RES,ID}}$	4	–0.27 (–1.38 to 0.83)$_{\mathrm{FD}}$	3	–0.02 (–1.96 to 1.92)$_{\mathrm{ID,FD}}$
Temperature	3	0.04 (–1.43 to 1.52)$_{\mathrm{IU,RES,ID}}$	4	–0.13 (–1.24 to 0.98)$_{\mathrm{FD}}$	3	0.49 (–1.25 to 2.24)$_{\mathrm{ID,FD}}$
pH	3	–0.20 (–1.69 to 1.28)$_{\mathrm{IU,RES,ID}}$	3	0.29 (–1.29 to 1.87)$_{\mathrm{FD}}$	3	–1.27 (–3.08 to 0.54)$_{\mathrm{RES,ID,FD}}$
Fine sediment	—	—	3	0.58 (–1.08 to 2.25)$_{\mathrm{FD}}$	—	—
Oxygen	3	–0.34 (–1.86 to 1.16)$_{\mathrm{IU,RES,ID}}$	4	–0.09 (–1.23 to 1.04)$_{\mathrm{FD}}$	3	0.83 (–0.77 to 2.44)$_{\mathrm{ID,FD}}$
Conductivity	3	0.04 (–1.43 to 1.52)$_{\mathrm{IU,RES,ID}}$	4	–0.04 (–1.14 to 1.06)$_{\mathrm{FD}}$	3	3.34 (1.05 to 5.62)$_{\mathrm{ID,FD}}$
Alkalinity	—	—	3	0.28 (–1.35 to 1.93)$_{\mathrm{FD}}$	—	—
Nitrates	3	–0.11 (–1.68 to 1.46)$_{\mathrm{IU,RES,ID}}$	4	0.18 (–0.91 to 1.28)$_{\mathrm{FD}}$	—	—
Phosphates	3	–0.02 (–1.78 to 1.73)$_{\mathrm{IU,RES,ID}}$	4	–0.18 (–1.28 to 0.91)$_{\mathrm{FD}}$	—	—
Invertebrate density	—	—	4	–0.55 (–1.21 to 0.11)$_{\mathrm{FD}}$	—	—
Invertebrate shredders density	—	—	4	–0.65 (–1.32 to 0.01)$_{\mathrm{FD}}$	—	—
Fungi density	—	—	4	–0.34 (–1.0 to 0.33)$_{\mathrm{FD}}$	—	—
Fungi diversity	—	—	3	0.21 (–0.71 to 1.13)$_{\mathrm{FD}}$	—	—
Leaf litter decomposition rate	3	–1.98 (–3.82 to –0.14)$_{\mathrm{IU,ID,RES,CMB}}$	6	–1.31 (–1.82 to –0.79)$_{\mathrm{FD,CMB}}$	3	–0.66 (–1.65 to 0.34)$_{\mathrm{RES,ID,FD,CMB}}$

Note: *n*, number of studies; IU, immediate upstream; RES, reservoir; ID, immediate downstream; FD, further downstream; CMB, coarse mesh bag.

and found that the reservoir that released deep water caused decomposition rate to significantly increase at the downstream site, as a result of increase in water temperature, concentration of dissolved inorganic nitrogen, and density of macroinvertebrate shredders. However, the reservoirs that released surface water caused decomposition rates to decrease at the downstream sites, as a result of reduction in densities of shredding invertebrates. The activities (e.g., metal contamination) taking place in an area also influence organic matter decomposition rates in reservoirs. For example, Colas et al. (2013) investigated tree leaf litter decomposition rates in small reservoirs located in areas that received different levels of metal contamination and found that decomposition rates were reduced in contaminated reservoirs. With regard to size of river, Abril et al. (2015) evaluated the effect of small weirs and reservoirs, located on low- and high-order (Strahler 1957) streams, on commercial wood sticks (*Populus* sp.) decomposition rates and found that decomposition rates were only significantly different between lotic and lentic reaches in high-order streams. Seasonal differences in decomposition rates were also more pronounced in high-order streams. The discrepancies between streams in decomposition rates were attributed to variability in factors such as water temperature, nutrient concentrations, and water residence time. Similarly, Arroita et al. (2015) investigated the effect of small weirs on leaf litter decomposition rates, during different seasons, and found that decomposition rates were only significantly different between impact and reference reaches in winter. The authors also found that damming significantly reduced water discharge, width, and water depth, but did not affect water quality. These effects on wetted river width and hydraulic depth are termed ecosystem contraction, and they have been reported to significantly influence biotic communities and lotic ecosystem functions (Dewson et al. 2007; Elosegi and Sabater 2013; Mbaka and Schäfer 2016). In summary, studies assessing the effect of water storage reservoirs should take into account the different factors that affect organic matter decomposition in rivers.

Most studies (80%) evaluated decomposition of tree leaf litter. This finding could be due to studies selectively focusing on the most common and abundant riparian vegetation type in a study area (Quintão et al. 2013; Mbaka and Schäfer 2016). Nevertheless, decomposition of plant detritus is affected differently by reservoirs (Carpenter et al. 1983; Quintão et al. 2013). For example, Pinna et al. (2003) evaluated decomposition rates of reed (*Phragmites* sp.) and alder tree leaves in streams affected by reservoirs. The authors reported that alder tree leaves decomposed significantly faster than reed leaves, and decomposition rates for both plants were slower at the study sites affected by reservoirs. Pomeroy et al. (2000) compared leaf litter decomposition rates of native willow (*Salix* sp.) and cottonwood (*Populus* sp.) to those of non-native cedar (*Tamarix* sp.) at the downstream side of a large reservoir. The study showed that leaf litter decomposition rates were slower than in non-regulated river systems, and that there were significant differences in the decomposition rates of different plant leaves, with cottonwood having the fastest decay rate.

The leaf litter used in the reviewed studies was primarily (44.8%) collected before or after natural abscission. Given that plant leaves greatly change their constituents (e.g., secondary compounds and nutrients) and quality during abscission (Sanger 1971; Lee and Gould 2002), collection of leaf litter during different times can have varied effects on breakdown of leaves by biotic communities, and affect comparability of decomposition rates across different dammed river systems. Ideally, leaf litter for assessment of decomposition process in dammed river systems should be collected when litter falls naturally, by using methods such as traps (Muehlbauer et al. 2009).

The negative exponential decay model was more frequently (63.3%) applied in organic matter decomposition studies. This finding could be due to the reviewed studies mainly focusing on parameters reflecting the speed of litter breakdown, although models based on such parameters may not take into account other aspects that influence the decomposition process (e.g., temperature) (Gessner and Chauvet 2002; Menéndez et al. 2012). Use of different models may be more useful because decomposition rates may be better adjusted to certain models (Pozo et al. 2011; Menéndez et al. 2012; González et al. 2013). For example, Menéndez et al. (2012) evaluated the effect of four small reservoirs on alder tree leaf litter decomposition rate and found that the decomposition dynamics between control and impacted sites were better explained by a linear than by an exponential model. Cho and Kong (1998) evaluated the effect of reservoirs on 10 emergent macrophyte species decomposition rates using four decay models. The authors found that an asymptotic decay model provided a better estimate of the litter decomposition process in the littoral zone of a reservoir.

Coarse mesh litter bags were more frequently (68.8%) used in organic matter decomposition studies than fine mesh bags. This finding may be due to studies primarily focusing on the decomposition process mediated by invertebrate shredders. Nevertheless, use of fine mesh bags help to identify organic matter breakdown by microorganisms (Nelson and Roline 2000). For example, Nelson and Roline (2000) evaluated the decomposition rate of aspen (*Populus* sp.) in a stream impacted by a large reservoir using fine and coarse mesh litter bags. The authors found that the leaves protected from macroinvertebrates with fine mesh litter bags did not demonstrate differences in decomposition rates between study sites, suggesting that decomposition by microorganisms was not significantly different. However, there were significant differences in leaf litter decomposition rates in coarse mesh litter bags between sites, suggesting that differences in macroinvertebrate communities played a vital role in the decomposition process.

Organic matter decomposition is an important source of energy for river food webs and has been proposed as a tool for assessing ecosystem health (Gessner and Chauvet 2002). Therefore, for studies to comprehensively investigate the effect of water storage reservoirs on rivers, they should take into consideration the effect on habitat conditions, composition of organisms, and functional processes, such as ecosystem metabolism and organic matter decomposition (Rosenberg et al. 1997; Death et al. 2009; Aristi et al. 2014). Importantly, the effect of small reservoirs on river health may be better revealed by assessing organic matter decomposition because effects on water quality may be limited (e.g., Mendoza-Lera et al. 2012; González et al. 2013; Mbaka and Schäfer 2016). In conclusion, it is vital to assess the effect of water storage reservoirs on ecosystem function, and structure, to better the detection of ecological impacts, and conservation of different types of regulated river systems.

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