ORIGINAL ARTICLE

Consequences of riparian forest invasions by alien plants for litter decomposition in small streams and ponds

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ABSTRACT

Riparian forests play a crucial role in aquatic ecosystems by regulating light, temperature, channel stability and nutrient cycling. However, these forests are highly vulnerable to invasion by alien plant species, which can alter leaf litter inputs and decomposition dynamics, thereby impacting freshwater ecosystem functions. This study explores the decomposition rates of native black alder (*Alnus glutinosa*) and two riparian invaders, Japanese knotweed (*Fallopia japonica*) and Canada goldenrod (*Solidago canadensis*), in both headwater streams and pond mesocosms in Central Europe. We conducted experiments with 169 litter bags to assess decomposition rates and test the home-field advantage hypothesis. The hypothesis assumes that native litter decomposes faster due to the evolutionary adaptation of local decomposer communities. We found that invasive *S. canadensis* decomposed significantly faster than native *A. glutinosa* in both lotic and lentic environments. On the other hand, invasive *F. japonica* decomposed at a comparable rate (streams) or at a slower rate (ponds) than the native species. These findings contradict the home-field advantage hypothesis, suggesting that decomposition rates are primarily driven by litter nutrient content rather than geographic origin. The rapid breakdown of *S. canadensis* is likely driven by the low C:P ratio of its litter. The rapid decomposition of this litter may lead to short-term nutrient boosts that are quickly lost due to microbial activity, whereas the slow decomposition of *F. japonica* may limit immediate nutrient availability but extend their accessibility over longer periods. Overall, the invasion of riparian zones by species with litter traits distinct from those of native species can disrupt ecosystem processes, leading to cascading effects on aquatic food webs and nutrient cycling. Understanding the effects of riparian forest invasions on organic matter processing is essential for managing biodiversity and maintaining ecosystem integrity in freshwater environments.

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INTRODUCTION

The riparian forests are essential for aquatic ecosystems as they affect the light and temperature conditions of the water (Baxter *et al.*, 2005), channel stability (Naiman and Décamps, 1997) and nutrient supply (Harner *et al.*, 2009). The decomposition of leaf litter from riparian vegetation is a fundamental ecological process in freshwater ecosystems, particularly in small headwater streams (Vannote *et al.*, 1980), supporting energy transfer from plant litter to higher trophic levels (Cummins *et al.*, 1989; Gessner *et al.*, 1999; Graça, 2001). Although less studied in standing waters, allochthonous organic matter may play an important role in lake ecosystem metabolism, particularly by fueling microbial processes (Jansson *et al.*, 2007; Brett *et al.*, 2017). For example, allochthonous organic material can substantially influence energy transfer and community structure in unproductive lakes by promoting microbial dominance in energy mobilization pathways. This can lead to decreased primary production, lower energy mobilization efficiency and shifts in community composition, potentially altering trophic interactions (Jansson *et al.*, 2007). Since wetland size inversely correlates with the amount of litter inputs per unit area (Stoler and Relyea, 2020; Dekanová *et al.*, 2023), the metabolism of small lakes and ponds may be considerably influenced by allochthonous organic matter inputs.

Riparian forests are highly susceptible to invasions by alien plants due to the high content of nutrients and moisture in soils, light availability, frequent occurrence of disturbances as well as easy dispersal of seeds and plant fragments along the streams (Daehler, 2003; Richardson *et al.*, 2007; Boyero *et al.*, 2012; Kominoski *et al.*, 2013; Svitková *et al.*, 2024). Invasive alien plants often dominate the riparian zones they invade due to their high competitive ability (Coleman and Levine, 2007; Pfeifer-Meister *et al.*, 2008), potentially resulting in the complete replacement of native species (Naiman and Décamps, 1997; Ringold *et al.*, 2008). Changes in native riparian vegetation and the associated shifts in plant functional traits can extend across ecosystem boundaries and impact food webs, organic matter processing and nutrient cycling in aquatic ecosystems (Kominoski *et al.*, 2013; García *et al.*, 2014). These effects on food webs occur through changes in the quantity and quality of basal resources, which alter colonization patterns and affect the density and composition of communities, ultimately leading to changes in the rate of organic matter decomposition. For instance, the shedding of low-quality leaf litter by some invasive plants can reduce the abundance of aquatic decomposers, potentially lowering decomposition rates (Davies and Boulton, 2009; Kominoski *et al*., 2013), as well as the growth and taxonomic richness of these organisms (Boyero *et al.*, 2012), which may negatively affect aquatic ecosystem functioning (Richardson *et al*., 2007). On the other hand, the highly attractive leaves of some invasive species may cause a rapid depletion of resources, leading to a subsequent lack of supply (McNeish *et al.*, 2012; Dekanová *et al.*, 2021).

The differences in attractivity of native and alien leaf litter to decomposers are often explained by the home-field advantage hypothesis, which assumes that decomposers prefer to colonize substrates they frequently encounter and, therefore, the origin of the plant litter is the driving force behind the decomposition rate (Ayres *et al.*, 2009). Thus, we may expect that native vegetation is the most suitable source for local decomposers adapted to the nutrient content of the native leaf litter, meaning that the native leaf litter should decompose faster than other leaf litter types (Gholz *et al.*, 2000). The home-field advantage hypothesis was confirmed by some studies that observed slower decomposition of alien species litter compared to native species (García *et al.*, 2012, 2014; Serra *et al.*, 2013). However, there are also contradictory results, since several studies have shown that the leaf litter decomposition rate either did not differ between native and alien plant species (Reinhart and VandeVoort, 2006; Lecerf *et al.*, 2007; Bottollier-Curtet *et al.*, 2015; Kennedy and El-Sabaawi, 2017) or was even faster in alien species (McNeish *et al.*, 2012; Kuglerová *et al.*, 2017; Dekanová *et al.*, 2021).

Another explanation for differences in decomposition rates between native and invasive litter may be interspecific variability in nutrient content (Tibbets and Molles, 2005; Cornwell *et al*., 2008), meaning that the attractiveness of leaf litter to microbial decomposers is driven by its elemental quality, with decomposers favoring litter rich in labile compounds and readily available nutrients (Graca, 2001; Gessner *et al*., 2007; Hladyz *et al.*, 2009; Bottollier-Curter *et al*., 2015). Carbon, nitrogen and phosphorus content, along with their elemental ratios, are considered key predictors of leaf litter decomposition rates (Frost *et al*., 2006; Bottollier-Curter *et al*., 2015). Because decomposers face stoichiometric constraints when processing nutrient-poor litter, the mismatch between their nutritional requirements and the elemental composition of the resources represents a stoichiometric limitation that ultimately drives decomposition rates (Danger *et al*., 2021).

Our preliminary research revealed that the rapid decomposition of invasive litter in a pond environment was dominated by microbial processes (Dekanová *et al*., 2021). Here, we extended the experiment to replicated headwater streams and pond mesocosms to test whether the observed differences in microbial decomposition between invasive and native litter are consistent across freshwater ecosystems. Regarding differences between aquatic habitats, slower microbial decomposition in ponds than in streams can be reasonably expected due to variations in water flow, nutrient and oxygen concentrations, all of which influence microbial communities (Langhans *et al*., 2008; da Silva *et al*., 2019; Hill *et al*., 2022). However, interspecific differences in decomposition rates are expected to remain consistent across habitat types.

To evaluate the hypotheses, we conducted litter bag experiments in 10 headwater streams and 32 pond mesocosms and compared the rate of leaf litter decomposition of the native species black alder (*Alnus glutinosa* (L.) Gaertn.), a typical riparian and floodplain forest species in Central Europe (Hrivnák *et al.*, 2020; Hrivnák *et al.*, 2024), with that of two alien invasive species: Japanese knotweed (*Fallopia japonica* (Houtt.) Ronse Decraene) and Canada goldenrod (*Solidago canadensis* L.). These invasive species pose serious threats to both natural ecosystems through biodiversity loss and habitat alteration, as well as significant economic burdens related to property damage and management costs (Shaw and Seiger, 2002; Fennel *et al.*, 2018). The ecological and economic consequences of *S. canadensis* invasions are less studied but the species is known to reduce local biodiversity by displacing native plant species (Dong *et al.*, 2015), altering soil properties and homogenizing habitats, leading to degraded soil quality and ecosystem functions (Bielecka *et al.*, 2020; Zhu *et al.*, 2022). Both *F. japonica* and *S. canadensis* are widely distributed along riparian zones in Central Europe, with a strong ability to form dense, monospecific stands (Fig. 1 e-g) that disrupt native plant communities (Slezák *et al.*, 2020; Zelnik *et al.*, 2020; Simon *et al.*, 2023; Skokanová *et al.*, 2024). However, their influence on the biodiversity and ecosystem functioning of adjacent freshwater systems remains less understood.

METHODS

Experimental sites

We conducted the litter bag experiments in 32 pond mesocosms and 10 headwater streams in the central part of Slovakia (Fig. 1a) during the autumn and winter of 2020 (pond mesocosms) and 2021 (streams), respectively.

The pond mesocosms consisted of 110-L polyethylene barrels with a depth of 1 m. The mesocosms were filled with 100 L of stream water (pH = 8.4±0.1, conductivity = 165±3.5 µS cm^{-1}, dissolved oxygen = 2.4±3.5 mg L^{-1}) on 25 August 2020 and set outdoors at the Technical University in Zvolen, Slovakia (Fig. 1d). On 3 September, we added 1.5 L of homogenized pond substrate and 0.8 L of pond water, obtained from the nearby pond Červená studňa (*Tab. S1*), to inoculate the mesocosms.

Specimens of *Potamogeton natans* from the same pond were planted in each mesocosm (27±4 g of plant wet weight per mesocosm).

The studied streams were low-order (2nd–3rd), shallow (mean depth ± SD: 0.2±0.06 m), slightly alkaline (pH: 7.7±0.2), well-oxygenated (11.4±0.6 mg O_2 L^{-1}) and with low conductivity (104±30 µS/cm^{-1}) and showed no direct anthropogenic impact (Fig. 1 b,c; *Tab. S1*). Streams were shaded by riparian canopies (cover: 72±15%) dominated by black alder, with co-occurring willows, and no invasive species were observed in the studied reaches.

Leaf litter decomposition experiments

The litter bag experiments were conducted to compare microbial leaf litter decomposition rates of the invasive plant species *Fallopia japonica* and *Solidago canadensis* with the native species *Alnus glutinosa*. Leaves were collected from plants before abscission in autumn and air-dried in the laboratory (~ 25°C) until a constant weight was achieved (~ 7 days). The carbon, nitrogen and phosphorus content of the leaf litter for each species was measured (EA-TCD, AES-ICP) prior to the experiment (*Tab. S2*).

To assess decomposition attributable to microbial activity, we prepared single-species litter bags using nylon mesh with a 0.5 mm mesh size, which permits colonization by microbial decomposers while effectively excluding macroinvertebrates (Bärlocher, 2020). We weighed 6.1±0.23 g of dried leaves from a single species for each litter bag in streams and 3.9±0.25 g for each litter bag in pond mesocosms. More litter was used in streams to compensate for potentially higher losses. A total of 70 litter bags were exposed in streams, and 99 litter bags were exposed in pond mesocosms.

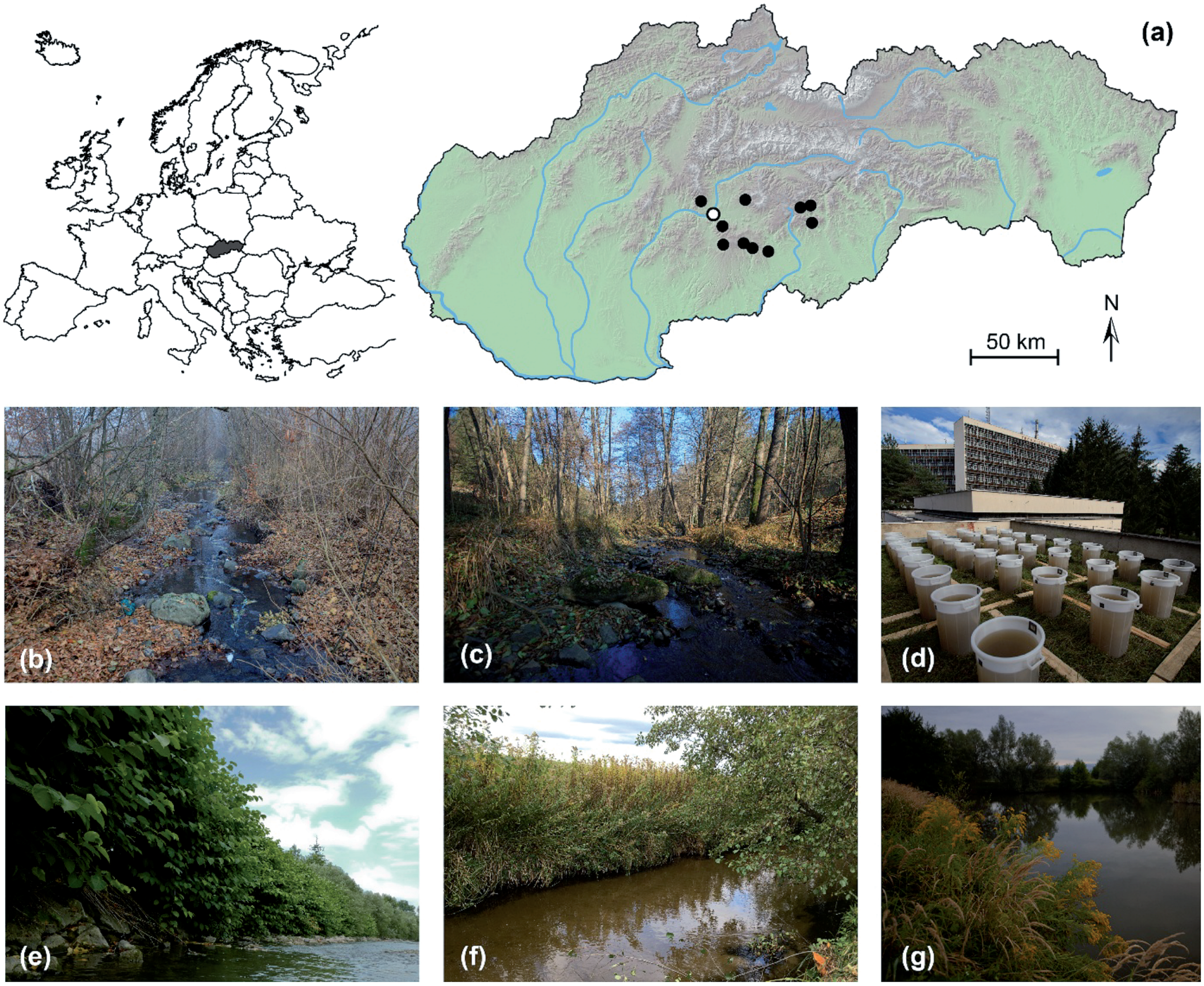

Fig. 1. Location of the 10 studied streams (black dots) and 32 mesocosms (white dot) in Slovakia (a), where the litter bag experiments were conducted. The insets show two of the studied headwater streams (b,c), the mesocosm facility at the Technical University in Zvolen (d) and examples of stream and pond riparian zones invaded by Japanese knotweed (*Fallopia japonica* (Houtt.) Ronse Decraene) (e) and Canada goldenrod (*Solidago canadensis* L.) (f,g). Note the placement of litter bags attached to a metal chain in one of the streams (b).

Three single-species litter bags (one per species) were placed equidistantly along the perimeter at the bottom of each mesocosm on 11 September 2020, arranged in a triangular layout to maximize separation and minimize potential interspecific interactions. Three additional bags were deployed to mesocosms on the same day and collected 24 h later to estimate the correction factor for handling losses and leaching. Each mesocosm was supplied with a temperature data logger (Minilog II-T; Vemco, Bedford, Nova Scotia, Canada) recording the water temperature every hour throughout the experiment. The remaining 96 bags were retrieved after eight weeks.

In streams, the litter bags were attached to metal chains anchored into the streambed sediment with iron bars on 15 November 2021. Each chain was equipped with a Minilog II-T data logger, which recorded water temperature hourly throughout the experiment. To account for handling losses and leaching, one bag was collected from each stream 24 hours after deployment (Benfield *et al.*, 2017; Zukswert and Prescott, 2017). These bags were used to adjust the initial weights of the leaf litter for mass losses unrelated to biological decomposition. The remaining 60 bags were retrieved after four weeks, with six bags per stream - two replicate bags for each of the three leaf species.

All litter bags were stored in plastic zip-locks immediately after collection, frozen in the field and transported to the laboratory. The bags were stored in a freezer at -18°C till laboratory processing. Before processing, the bags were defrosted at laboratory temperature for a few hours. The remaining leaves were gently rinsed using tap water to remove fine sediment. The leaves were oven-dried in marked paper bags at 45°C for 24 h. Immediately after drying, the litter was placed in a desiccator until reaching laboratory temperature. Subsequently, the litter was weighed on analytical balances to the nearest 0.01 mg.

Data analysis

To quantify the decomposition rates of invasive and native species, we used the exponential decay model to estimate the rate coefficients (Petersen and Cummins, 1974). The coefficients were calculated based on the proportion of mass remaining relative to the initial dry mass, ensuring that decomposition rates are standardized regardless of differences in initial litter amounts. The coefficients were quantified as mass loss per degree-day (k_{dd}), with degree-days determined by the cumulative sum of daily mean water temperatures, accounting for potential confounding effects of temperature differences among sites. We also report the coefficients calculated as mass loss per day (k_d) to facilitate comparisons among studies.

Linear mixed-effects models (LMMs) (Pinheiro and Bates, 2000) were used to evaluate differences in decomposition rates among different species using the lme4 package (Bates *et al.*, 2015). The models included the fixed effect of litter species, while the identity of streams and mesocosms was treated as a random intercept to account for repeated measurements at the same sites. We screened residuals of the LMMs in diagnostic plots using the DHARMa package (Hartig, 2022). In the LMM for streams, the rate coefficients were logarithmically transformed to meet distributional assumptions. The statistical significance of the fixed effects was assessed using F tests with Kenward-Roger approximation for denominator degrees of freedom, implemented via the lmerTest package (Kuznetsova *et al.*, 2017). When a significant effect was revealed, we performed post hoc tests with Tukey-adjusted probabilities to compare the estimated marginal means, using the emmeans package (Lenth, 2016). Marginal (R^2_m) and conditional (R^2_c) pseudo-determination coefficients were calculated for each model to quantify the proportion of total variance explained by interspecific differences in decomposition rates and the total variance explained, respectively (Nakagawa *et al.*, 2017), using the performance package (Lüdecke *et al.*, 2021).

The analyses were performed in R (R Core Team, 2022), and the plots were created using the ggplot2 package (Wickham, 2016).

RESULTS

The observed decomposition rates varied widely and ranged from $-k_{dd}$ <0.0001 degree-days^{-1} for *F. japonica* (lentic environment) to 0.014 degree-days^{-1} for *S. canadensis* (lotic environment) (Tab. 1). In general, decomposition rates were higher in the headwater streams [average (SD) $-k_{dd}$ = 0.005 (0.002) degree-days^{-1}] than in pond mesocosms [0.002 (0.001) degree-days^{-1}]. The mixed-effect models revealed significant differences in decomposition rates among the studied species in headwater streams ($F_{(2, 46.3)} = 26.8$, $p<0.0001$, $R^2_m = 0.27$, $R^2_c = 0.73$) and pond mesocosms ($F_{(2, 62.0)} = 142.7$, $p<0.0001$, $R^2_m = 0.66$, $R^2_c = 0.78$). *S. canadensis* decomposed significantly faster than native *A. glutinosa* in both streams (*post-hoc* test: $t_{(46.3)} = -6.7$, $p<0.0001$) and ponds ($t_{(62)} = -12.1$, $p<0.0001$). The rate of decomposition for *S. canadensis* was 1.5±0.8 (SD) times higher

Tab. 1. Summary characteristics of leaf litter decomposition rates of native (*A. glutinosa*) and invasive (*F. japonica*, *S. canadensis*) plant species in headwater streams and pond mesocosms expressed per degree-day (k_{dd}) and day (k_d).

Environment/ litter species	$-k_{dd}$ (degree-days^{-1})				$-k_d$ (days^{-1})			
	mean	SD	min	max	mean	SD	min	max
Headwater streams								
A. glutinosa	0.00460	0.00174	0.00321	0.01089	0.00993	0.00242	0.00634	0.01532
F. japonica	0.00467	0.00112	0.00309	0.00669	0.01038	0.00233	0.00664	0.01814
S. canadensis	0.00695	0.00272	0.00264	0.01432	0.01425	0.00322	0.00715	0.02108
Pond mesocosms								
A. glutinosa	0.00140	0.00035	0.00072	0.00208	0.00893	0.00214	0.00467	0.01349
F. japonica	0.00095	0.00048	<0.00001	0.00239	0.00616	0.00321	<0.00001	0.01593
S. canadensis	0.00271	0.00072	0.00087	0.00380	0.01722	0.00426	0.00563	0.02466

than that of native species in streams and 1.9±0.7 times higher in pond mesocosms (Fig. 2). In contrast, the decomposition rate of invasive *F. japonica* litter did not differ significantly from that of native species in streams ($t_{(46.0)} = 0.66$, $p=0.787$) but was significantly slower than that of native species within ponds ($t_{(62.0)} = 4.2$, $p=0.0003$).

DISCUSSION

Our study demonstrates that invasive species do not exhibit uniform litter decomposition patterns across different environments, with *S. canadensis* displaying a pronounced tendency for faster decomposition than native *A. glutinosa*, whereas *F. japonica* decomposes at a comparable or slower rate than native species depending on the habitat. These findings contradict the home-field advantage hypothesis, assuming that the origin of a plant species should be a driving force of the decomposition process (Ayres *et al.*, 2009). This hypothesis was supported by several studies that reported slower decomposition of alien species litter compared to native species (Abelho and Graça, 1996; Bailey *et al.*, 2001; García *et al.*, 2012, 2014; Serra *et al.*, 2013; Ferreira *et al.*, 2015). However, the general validity of the home-field advantage hypothesis has been questioned by multiple studies (Braatne *et al.*, 2007; Lecerf *et al.*, 2007; Kuglerová *et al.*, 2017; Fogelman *et al.*, 2018; Dekanová *et al.*, 2021; Yang *et al.*, 2021). Based on our results, invasive species leaf litter appears to be rapidly utilized by decomposers, even if they are not adapted to this type of resource.

Rather than being determined by geographic origin, differences in decomposition rates between leaf species may be explained by interspecific variability in the physical characteristics of leaf litter and its nutrient content (Tibbets and Molles, 2005; Leishman *et al.*, 2007; Cornwell *et al.*, 2008). Thin and soft leaves with a higher specific leaf area (SLA) can be more easily processed by decomposers than tougher leaves with a lower SLA (Cornelissen *et al.*, 1999; Cornwell *et al.*, 2008). Regarding the species involved in our study, the SLA of the fastest-decomposing *S. canadensis* leaves was expectedly higher than that reported for the tougher leaves of the native *A. glutinosa* (*Tab. S2*). However, *F. japonica*, despite having thinner leaves, exhibited a significantly slower decomposition rate, suggesting that leaf physical structure alone does not fully explain interspecific differences in litter decomposition.

Beyond the physical characteristics of litter, carbon, nitrogen and phosphorus content, along with their elemental ratios, are often identified as crucial predictors of leaf litter decomposition rates (Frost *et al.*, 2006; Bottollier-Curtet *et al.*, 2015). Decomposers processing nutrient-depleted substrates tend to prefer litter with a higher content of labile compounds and readily available nutrients (Graça, 2001; Gessner *et al.*, 2007). The mismatch between decomposer requirements and the elements available in their resources constitutes a stoichiometric constraint that ultimately controls litter decomposition rates (Danger *et al.*, 2021). Therefore, elemental ratios, especially the C:N and C:P, can greatly influence the attractiveness of leaf litter (Mooshammer *et al.*, 2012; Yang *et al.*, 2021). The faster decomposition of *S. canadensis* is likely driven by its favourably low C:P ratio, while the slower rates in *F. japonica* and, to a lesser extent, *A. glutinosa* are likely due to their higher C:P ratios and the associated phosphorus limitation (*Tab. S2*). Although the decomposition of both *A. glutinosa* and *F. japonica* is presum-

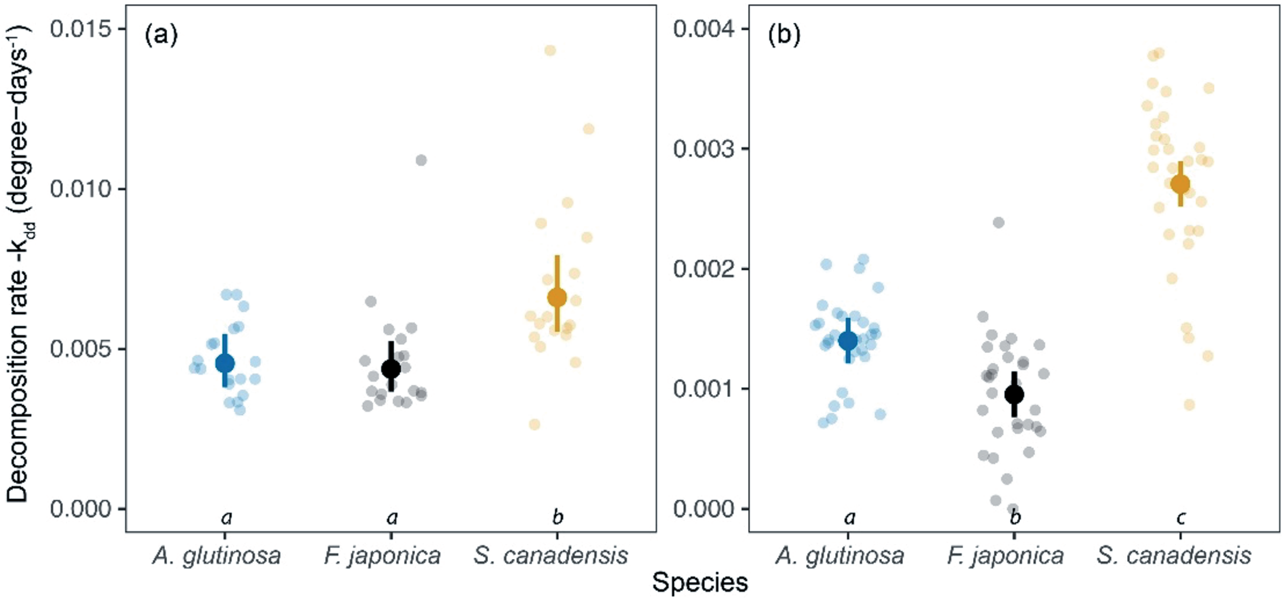

Fig. 2. Differences in leaf litter decomposition rates of the native species (*Alnus glutinosa*) and invasive species (*Fallopia japonica*, *Solidago canadensis*) in headwater streams (a) and pond mesocosms (b). Observed values (small dots) are shown alongside estimated population means (large dots) and 95% confidence intervals (error bars). Statistically significant differences between litter types, revealed by pairwise *post-hoc* tests ($p<0.05$), are indicated by different italicized lowercase letters.

ably P-limited, the lower C:N ratio in *A. glutinosa* may help boost its decomposition relative to *F. japonica*. Bottollier-Curtet *et al.* (2011) also considered nutrient content, rather than geographic origin, as the primary driver of decomposition, evaluating the decomposition rates of five native and five invasive species. The fastest decomposing was the leaf litter of *Impatiens glandulifera*, which, like *S. canadensis* in our study, contained the highest amount of phosphorus among studied plant species.

The rapid decomposition of *S. canadensis* in a lentic environment was recently reported in other studies (Dekanová *et al.*, 2021; Anda *et al.*, 2023). Our study confirmed high decomposition rates in standing waters and revealed even faster decomposition of this species in running waters. When calculated on a per-day basis, the rates of *S. canadensis* leaf litter decomposition observed in the studied streams ($-k_d = 0.007\text{-}0.021$ day^{-1}) and pond mesocosms (0.006-0.025 day^{-1}) are roughly comparable to those observed by Dekanová *et al.* (2021) in an artificial pond (0.011 day^{-1}) and by Anda *et al.* (2023) in wetlands (0.018-0.028 day^{-1}). Although the decomposition rates reported for *F. japonica* are not directly comparable due to the use of different mesh sizes of litter bags, the relatively slow decomposition of this species observed in our research corresponds with the findings of some other studies conducted in ponds (Bottollier-Curtet *et al.*, 2011) and headwater streams (Dangles *et al.*, 2002; Braatne *et al.*, 2007; Lecerf *et al.*, 2007).

We observed that microbial leaf litter decomposition proceeds 2.6 to 5 times faster in forest streams than in pond mesocosms. This is consistent with the findings of Langhans *et al.* (2008) and Hill *et al.* (2022), who found significantly faster microbial decomposition in streams compared to ponds. The contrasting decomposition rates between lentic and lotic waters are likely caused by different physico-chemical and biological conditions in these environments. In contrast to well-oxygenated streams (11.4 mg O_2 L^{-1}, on average), low oxygen content in pond mesocosms (2.4 mg O_2 L^{-1}) may hinder the decomposition process. For example, Pattee and Chergui (1994) reported that decomposition in an oxbow lake nearly ceases after an initial phase of litter weight loss, a pattern they also confirmed under hypoxic conditions in the laboratory. Low oxygen concentrations can severely impair key decomposers - aquatic fungal communities - which typically dominate microbial decomposition (Hieber and Gessner, 2002; Pascoal *et al.*, 2021). Low oxygen conditions reduce diversity, decrease biomass and inhibit sporulation of fungal communities (Medeiros *et al.*, 2009). Consequently, fungal biomass on litter exposed to lentic environments is often lower than in lotic water bodies (Baldy *et al.*, 2002; Langhans *et al.*, 2008; da Silva *et al.*, 2019). Moreover, higher concentrations of nutrients and potentially toxic leachates in standing waters can significantly impact microbial communities and the processes they mediate (Canhoto *et al.*, 2013; Foulquier *et al.*, 2014; Arroita *et al.*, 2018), ultimately leading to slower litter decomposition in ponds.

The replacement of native riparian vegetation with monocultures of rapidly decomposing invasive plants, such as *S. canadensis*, may initially introduce a pulse of high-quality allochthonous litter into aquatic ecosystems. However, litter that is rapidly decomposed by microbes is less available to aquatic invertebrates and a large amount of carbon from these resources may be lost to microbial respiration (Siders *et al.*, 2018). Consequently, although initially abundant, this resource may become unavailable to aquatic detritivores before it can be effectively assimilated. In contrast, the slow microbial decomposition of invasive leaf litter such as *F. japonica* in ponds can limit nutrient release and delay the microbial conditioning process, which is critical for enhancing litter palatability through the breakdown of complex organic compounds and the accumulation of microbial biomass (Bärlocher and Kendrick, 1975; Graça *et al.*, 2001; Danger *et al.*, 2021). However, such recalcitrant leaves might serve as longer stored potential resources over multi-month intervals and stabilize fluctuations in the rates of leaf litter integration into aquatic food webs (Cereghetti *et al*., 2025). Overall, the formation of monospecific stands of invasive riparian plants with markedly different leaf litter traits than native species can impair the functioning of adjacent aquatic ecosystems. These shifts in litter decomposition dynamics underscore the potential for invasive species to disrupt ecosystem processes, with cascading consequences for aquatic food webs and nutrient cycling.

CONCLUSIONS

Our experiments revealed pronounced differences in decomposition rates among the three riparian species. The dominance of phosphorus-rich litter of *S. canadensis* could shift food webs toward a highly pulsed, microbially-driven regime, whereas stands of *F. japonica* might create slow-release nutrient stores and qualitatively different habitats. Both outcomes represent departures from the dynamics under native alder-dominated riparian vegetation, with unknown consequences for primary producers, invertebrates, fishes, amphibians and ecosystem processes.

While our experiments captured initial decomposition dynamics, field studies of invaded sites might help to assess how long-term dominance by *S. canadensis* or *F. japonica* shapes local aquatic communities and ecosystem functions. Moreover, it remains unclear how mixtures of invasive and native leaves decompose together. Since riparian zones often have mixed-species leaf litter, future experiments should test whether the presence of *A. glutinosa* or other native leaves might slow down or alter the breakdown of *S. canadensis* litter or *vice versa*. Addressing these gaps will improve our understanding of how invasive riparian plants reshape freshwater ecosystem dynamics and will inform management strategies aimed at preserving native biodiversity and ecosystem functions.

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Online supplementary material:

Tab. S1. Characteristics of the studied streams and a pond used as a source for the mesocosm experiment.

*Tab. S2. Characteristics of native (*A. glutinosa*) and invasive (*F. japonica, S. canadensis*) leaf litter species used in the experiments.*