Dear Editor and anonymous reviewers,

The comments received from each reviewer (Reviewer Comment) and our responses (Reviewer Response) are listed below. We have also included the line numbers of the changes made in the responses. These line numbers correspond to the line numbers displayed in the revised draft file containing the track changes. In addition, the English wording and grammar in the revised manuscript has been reviewed and corrected by a specialized company. Following the response to Reviewer 2, we have included both the original text and the revised text (in bold).

Response to Reviewer1's comments

Introduction

(Comment 1)

Your introduction is very general and elaborate. The literature review adequately covers relevant studies but could not better highlight the novelty of this work. The rationale for focusing on small floodplain water bodies is not enough.

(Response 1)

In accordance with the reviewer's comments, we have streamlined the literature review and reorganized the description of the floodplains and floodplain waters in the study area, together with relevant previous studies. The text has also been revised to clarify the positioning and novelty of this study (Lines 37–111, Lines 111-122).

Materials and methods

(Comment 2)

Specify the number, depth, and spatial distribution of shallow groundwater wells relative to the backwaters. Clarify how these wells represent the aquifer's lateral and vertical heterogeneity, as this is critical for validating groundwater-endmember calculations.

(Response 2)

We agree with the reviewer's comment and have revised Figure 2 to more clearly illustrate the spatial distribution of shallow groundwater and its relationship with topography. In addition, based on previous studies, we have incorporated information on the stratigraphic distribution in the vicinity of the study area, as well as the flow direction of shallow groundwater (Figure 2, Lines 140-155).

(Comment 3)

Since CDOM was only measured in November 2022, justify why this single snapshot is sufficient to infer seasonal contributions of river water, groundwater, and sewage. Provide details on sensor calibration, analytical precision, and replicate measurements to support CDOM as a reliable mixing tracer.

(Response 3)

We agree with the reviewer's comment. To supplement the results based solely on data from November, we have added data from approximately 40 locations each for rivers and shallow groundwater, including the study site, collected during a different period (Lines 366-377). The additional data show that river CDOM concentrations are higher during periods of low flow (November in this study) than during the high-flow summer months (approximately July to September). In contrast, seasonal variations in CDOM concentrations in the surrounding shallow groundwater are minimal, and a clear difference in concentration between river water and shallow groundwater is maintained throughout the year. These results suggest that CDOM is an effective indicator for distinguishing backwater contributions. In addition, information on the basic performance of the CDOM sensor has been added (Lines 189-193).

Discussion

(Comment 4)

L327: The inference of denitrification in Backwater C relies on the 2:1 δ15N:δ18O enrichment ratio, but additional evidence (e.g., dissolved N_2 gas concentrations, sediment denitrification potential assays, or microbial marker genes) is needed to confirm this process. Explain why denitrification is prominent in Backwater C but not in other backwaters, considering factors like organic matter availability, hydrological residence time, and sediment properties.

(Response 4)

We were unable to obtain the additional evidence regarding denitrification suggested by the reviewer within the scope of this study. Therefore, we have clarified in the relevant section (Lines 416-434) that denitrification is presented as a possible explanation. Furthermore, as this study does not fully resolve the differences in the extent of denitrification inferred from NO_3 concentrations and $\delta^{15}N-NO_3$ and $\delta^{18}O-NO_3$ values among individual backwaters, we have cited relevant literature and emphasized the need for further detailed investigation.

(Comment 5)

Clarify the potential influence of the factory drainage (600 m upstream of Backwater A) on water chemistry. Provide data on the drainage's nutrient and tracer concentrations (e.g., CDOM, ions) to rule out or quantify its contribution to Backwater A's unique ion composition (high Na^+ and SO_4^{2-}).

(Response 5)

We agree with the reviewer's comment and, as a supplement, have added water quality data for industrial wastewater upstream of Backwater A, obtained by a different research organization, to the main text (Lines 359-365). Furthermore, water quality parameters in factory drainage, which are not included in the main text, have been compiled into a table in the supplementary materials (Table S8 Supplement).

Table S8 Water quality of the effluent in the upper reaches of Backwater A. The survey was conducted in February 2024.

parameters	
Electrical conductivity (mS m^{-1})	205
CDOM (ppb)	167
Alkalinity (ppb)	364
Na^+ (μmol L^{-1})	10768
K^+ (μmol L^{-1})	373
Mg^{2+} (μmol L^{-1})	509
Ca^{2+} (μmol L^{-1})	2401
Cl^- (μmol L^{-1})	1989
SO_4^{2-} (μmol L^{-1})	7124
NO_3^- (μmol L^{-1})	54
NH_4^+ (μmol L^{-1})	2.0
PO_4^{3-} (μmol L^{-1})	0.77
DSi (μmol L^{-1})	570

(Comment 6)

L389：Define "DIN" (Dissolved Inorganic Nitrogen) upon first use, as it includes NO_3^-, NH_4^+, and NO_2^-—a distinction critical for readers unfamiliar with aquatic biogeochemistry.

(Response 6)

We agree with the reviewer's comment. As this study measures only NO_3^- and NH_4^+, we have added a statement at their first occurrence defining $NO_3^- + NH_4^+$ as DIN (Line 22-31 and Lines 200-203).

(Comment 7)

There is no Conclusion.

(Response 7)

As suggested by the reviewer, we have added a corresponding statement to the conclusion (Lines 494-506).

Response to Reviewer2's comments

(Comment 1)

The abstract is generally well-structured and informative, providing clear ranges of nutrient concentrations. It is somewhat long and could be tightened.

(Response 1)

Thank you for your helpful comment. We have revised the abstract by simplifying several redundant sentences and reducing the overall length (Lines 8–12 and Lines 22–31).

(Comment 2)

L17: The claim that CDOM serves as "an effective indicator" might overstated given the singlecampaign measurement as you stated the measurement "only in November 2022" (L122).

(Response 2)

Thank you for your valuable comment. To supplement the results based solely on data from November, we have added data from approximately 40 locations each for rivers and shallow groundwater—including the survey site—from other periods (Lines 366-377). Since it was confirmed that river CDOM concentrations are higher during periods of low flow (November in this study) compared to the summer months (around July to September) when flow is high, we included a statement in the abstract regarding the universality of its effectiveness as an indicator.

(Comment 3)

L25: Subject–verb disagreement, "…the backwaters, which was…"

(Response 3)

Thank you for your helpful comment. We have deleted this sentence as part of the revision of the Abstract section.

(Reviewer 2_ Comment 4)

L27–28: The final sentence is vague and reads more like a future research direction than a conclusion.

(Response 4)

Thank you for your helpful comment. We have revised the final sentence to more clearly convey the main findings of this study. (Lines 31–35).

(Comment 5)

L60–62: The hypothesis statement is somewhat generic. The specific testable predictions could be sharpened, for example, what nutrient dynamics differences were expected, and why? The introduction would also benefit from briefly mentioning previous multi-tracer studies in floodplain contexts to better position the novelty of this work.

(Response 5)

Thank you for your valuable comment. Following the suggestion of Reviewer 1, we have revised and streamlined a concise overview of floodplain research. We have also added background information to introduce the hypothesis that environmental characteristics unique to Japanese rivers (i.e., short river lengths and steep gradients) influence small-scale floodplain systems, thereby clarifying the novelty of this study. Furthermore, we have incorporated, as you suggested, a description of the hypothesis for the study area as well as previous tracer-based studies in floodplains. (Lines 37-104, Lines 111-122).

(Comment 6)

L94: "Pond A" appears to refer to Backwater A?

(Response 6)

Thank you for pointing this out. The incorrect term has been corrected to "Backwater A" (Lines 159-160).

(Comment 7)

L109: Are the number of replicate samples (n=3) at each site likely refers to field replicates?

(Response 7)

Thank you for your question. We collected water samples in three separate bottles during field sampling. To avoid misunderstanding, the sentence has been revised for clarity (Lines 175-177).

(Comment 8)

L122–124: CDOM measurement is described only briefly, and calibration is not detailed sufficiently for reproducibility.

(Response 8)

Thank you for your helpful comment. We have added information on the basic specifications of the commercially available CDOM sensor and clarified that calibration was conducted only at the factory before shipment (Lines 189-193).

(Comment 9)

L138: "Standard materials USGS32, USGS34, and IAEA were used". Which IAEA standard?

IAEA-NO-3? Please specify the full standard details.

(Response 9)

Thank you for your comment. We have corrected the notation to IAEA-NO-3, as we used this standard reference material (Lines 208-209).

(Comment 10)

L236: DSi concentrations for Backwater C are reported as “14 to 40 μmol”, the unit L−1 appears to be missing. Additionally, these values are dramatically lower than those for Backwater A and B (175–276 μmol L−1), yet this large discrepancy is not discussed. Is this an artifact of diatom uptake, dilution by low-DSi rainwater, or a data entry error?

(Response 10)

Thank you for pointing this out. The value “14–40 μmol” was the difference in concentration between river water and backwater. We mistakenly left this value, which had been included in the first draft. The correct concentration range for Backwater C is 189–252 μmol L^{-1}. We have revised the text accordingly to avoid any misunderstanding (Lines 309-312).

(Comment 11)

L250: “corresponding” should be “corresponding”?

(Response 11)

Thank you for your helpful comment. The spelling has been corrected (Lines 324-326).

(Comment 12)

L268: “Ellins’ et al., 1990”, the apostrophe placement is unusual.

(Response 12)

Thank you for your comment. We have reviewed the cited reference and corrected the notation accordingly (Line 343).

Discussion

(Comment 13)

The discussion is structured around water origin estimation and nutrient dynamics, which is logical. However, the discussion remains largely qualitative and descriptive, it would be nice to have quantitative mixing estimates, but it seems out of the scope of this research.

(Response 13)

Thank you for your valuable comment. We attempted to estimate mixing ratios based on data from major ions, ^{222}Rn, and δ^2H & δ^{18}O–H_2O to support a quantitative discussion. However, due to the variability in shallow groundwater and the lack of data on discharge rates, these estimates involved substantial uncertainty. Therefore, determining mixing ratios at multiple sites remains a subject for future work.

(Comment 14)

L322: The δ15N range for river water is cited as "15–20‰, Kumazawa, 1999" but the authors' own data show a range of 12.7‰–18.1‰ (L240). Using the authors' measured values rather than a literature value would be more appropriate here.

(Response 14)

Thank you for your comment. The text has been revised so that the discussion is explicitly based on the $\delta^{15}N\text{-}NO_3$ measurements obtained in this study (Lines 408-410).

(Comment 15)

L364: "groudwater" should read "groundwater" and "compostion" should read "composition."

(Response 15)

Thank you for your helpful comment. The spelling has been corrected (Lines 460-462).

(Comment 16)

Conclusion?

The manuscript ends abruptly after Section 4.4 without a Conclusions section. For Biogeosciences, a concise synthesis of the main findings, their broader significance, and key limitations is expected. The current Discussion does not adequately summarize the study's contribution. A dedicated Conclusions section (approximately 150–250 words) should be added.

(Response 16)

Thank you for your comment. The conclusion has been revised to provide a concise summary of the study's findings, significance, and limitations based on the discussion (Lines 494-506).

(Comment 17)

Data availability

L395: The statement "Available from the corresponding author upon reasonable request" does not meet Biogeosciences' data policy. The data should be deposited in a public repository prior to acceptance.

(Response 17)

Thank you for your comment. In response, the data used in this study have been made publicly available through the Zenodo repository under the title "Water chemistry and geochemical tracers dataset from the Tama River Watershed, Japan (2022)" (DOI: 10.5281/zenodo.20115076). The corresponding information has been added to the revised manuscript (Lines 508-509).

The original text and the revised version are listed below. The revised text is shown in bold. The line numbers correspond to those displayed in the Author's track-changes file.

Lines 8–12

(Original text)

Within floodplains, semi-enclosed water bodies develop, among which those partially connected to the river are known as backwater (i.e., locally called Wando in Japanese). Although backwater serves as habitats for aquatic organisms, studies on the origin of spring water within backwater and the associated nutrient supplies remain limited.

(Revised version)

River floodplains contribute to river ecosystems by supporting high biological productivity and biodiversity. Backwaters, locally called Wando in Japanese, are semi-enclosed water bodies formed along rivers that serve as habitats for aquatic organisms. However, research on the origin of the seepage water supplied to backwater and the associated nutrient supply remains limited.

Lines 22–31

(Original text)

While no significant difference in DIN concentration was observed between rivers and groundwater, the increase in $\delta^{15}N$ & $\delta^{18}O–NO_3$ observed in one backwater site, coinciding with the decrease in nitrate concentration, suggested denitrification occurring in subsurface flow paths. As a result, in the backwaters, strongly influenced by the urban river, nutrient conditions reflected inputs from treated wastewater, leading to relatively stable N:P ratios in space and time. In contrast, the backwaters, which was primarily replenished by groundwater, showed pronounced seasonal fluctuations in N:P ratios due to variations in microbial activity, fertilizer inputs, and river inflow rates.

(Revised version)

Although no significant difference in DIN (NO_3^- + NH_4^+) concentrations was observed between river water and groundwater, the use of $\delta^{15}N$ & $\delta^{18}O–NO_3$ revealed differences in the sources of NO_3 between urban rivers and groundwater, as well as the possibility of denitrification in the floodplain subsurface of some backwaters. Furthermore, it was suggested that differences in the geology and topography of the floodplains surrounding each backwater, which influence seasonal changes in river flow and microbial activity, may also lead to variations in N:P ratios among individual backwaters.

Lines 31–35

(Original text)

Given the influence of nutrient environments on microbial communities and primary producers, the ecological functions of backwater can be better understood through intensive research focused on water-quality processes.

(Revised version)

This study, based on multiple geochemical tracer analyses, suggests that, in Japan's steep-gradient urban rivers, hydrological connectivity and microbial activity can vary even within short river sections, and that backwaters exhibit spatially and temporally diverse nutrient environments.

Lines 37-104, Lines 111-122

(Original text)

Rivers form distinctive landforms and landscapes in their surrounding areas through processes such as erosion, transportation, and deposition. Among these, floodplains, which are areas where water overflows from rivers during heavy rainfall, function as transition zones connecting terrestrial and aquatic ecosystems (i.e., an aquatic/terrestrial transitional zone) (Junk et al., 1989). Floodplains have diverse aquatic ecosystems, including secondary channels, stagnant waters, ponds, and lakes isolated from the main channel (Amoros and Bornette, 2002; Galat et al., 1997; Ward et al., 2002).These areas are referred to as floodplain water bodies (Nagayama et al., 2015), which function as a foundation for maintaining high biodiversity by creating diverse landscapes within rivers through spatiotemporal changes in physical and hydrological conditions in response to flood intensity and frequency (Amoros and Bornette, 2002; Junk et al., 1989; Keruzoré et al., 2013; Tockner et al., 2000; Ward et al., 2002).

Floodplain water bodies are affected by overflow and underflow from the main river channel, as well as by groundwater discharge from surrounding highlands (Hancock, 2002). Since underflow seeps into sediments from riverbeds and banks and reemerges through floodplains, the decomposition of organic matter in the underflow process induces changes in the aerobic-anaerobic environment (Lewandowski and Nützmann, 2010), thereby influencing nutrient dynamics (Boulton et al., 1998; Brunke and Gonser, 1997; Findlay, 1995; Hendricks and White, 1988).

Organic matter decomposition in underground streams also leads to high concentrations of nitrate (NO_3^-) and ammonium (NH_4^+) at the spring point, which serve as hotspots for algal production (Coleman and Dahm, 1990; Grimm and Fisher, 1984; Valett et al., 1994). On the other hand, the anaerobic condition during the underflow process causes denitrification (Gooddy et al., 2014; Haycock and Burt, 1993) and is also known to function as a system for removing excessive nitrogen loads in water bodies.

Floodplains are considered to have high productivity in river ecosystems (Lewis et al., 2001; Sparks, 1995; Spink et al., 1998), and studies on nutrient dynamics and biological production have been conducted in large floodplain water bodies extending several kilometers in length. Bondar-

Kunze et al. (2009) in their study of the Danube River, revealed that floodplain water bodies serve the function of supplying organic matter to the main river through primary production using nutrient inputs from the main river. In addition, the vast floodplain of the Mississippi River is reported to perform net primary production and exhibit autotrophic characteristics during certain seasons (Houser et al., 2015).

In Japan, river channel improvement has been actively carried out for a long time for flood control and water utilization. As a result, extensive natural floodplains are very rare in many rivers, and floodplains within channels restricted by embankments have formed (Nagayama et al., 2015). Such rivers form small floodplain water bodies (i.e., backwater) called Wando in Japanese that are several dozen to several hundred meters long, and many of these backwaters have springs (Figure 1). Previous studies have highlighted the ecological usefulness of river mainstems as evacuation sites during floods and as breeding grounds for juvenile fish (Denda et al., 2002, 2006; Dole-Olivier, 1998; Kimizuka, 1998; Minagawa et al., 2015; Nakajima et al., 2008). However, many other aspects, such as water quality and primary production, remain poorly understood. We hypothesized that, similar to large floodplains, the surrounding environment and water supply routes in backwater affect nutrient dynamics, which in turn may be related to phytoplankton communities and primary production in the floodplain.

The objectives of this study are comprehensively identifying the origin and pathways of spring water and associated nutrients (N, P, Si) in different backwater systems by measuring ion composition, ^{222}Rn concentration, stable hydrogen and oxygen isotope ratios (δ^2H & δ^{18}O–H_2O) in water, and chromophoric dissolved organic matter (CDOM) concentration at the spring. Finally, we will discuss nutrient dynamics that influence ecological systems, such as phytoplankton production and communities.

(Revised version)

Rivers form distinctive landforms and landscapes in their surrounding areas through processes such as erosion, transport, and deposition. In particular, floodplains—where water from rivers overflows during periods of high levels water caused by rainfall—function as transition zones connecting terrestrial and aquatic ecosystems (Junk et al., 1989). In floodplains, hydrological changes such as flooding and seasonal flow fluctuations result in the formation of diverse water bodies (floodplain water bodies; Galat et al., 1997; Tockner & Stanford, 2002; Ward, 1989; Ward et al., 1999) and affect nutrient cycling (Bondar-Kunze et al., 2009), primary production (Houser et al., 2015; Spink et al., 1998), and ecosystems (Amoros & Roux, 1988; Bornette & Amoros, 1991; Keruzoré et al., 2013). In particular, nutrient dynamics—which are closely linked to both productivity and algal communities—exhibit source-sink behavior within the complex interactions between floodplain waters and rivers (Gmitrowicz-Iwan et al., 2020; Pongsivapai et al., 2021; Zurbrügg et al., 2013).

The hydrological conditions (e.g., river discharge and groundwater levels) and geology (e.g., grain size and organic matter content) surrounding floodplains are complex, leading to variations in the distribution of river underflow (Texier et al., 2024) and fluctuations in the mixing state of river water and groundwater (Biehler et al., 2020). Furthermore, changes in redox conditions associated with hydrological conditions influence the behavior of phosphorus and nitrogen (e.g., phosphorus adsorption and desorption, nitrification, and denitrification). Environmental tracers and stable isotope ratios have often been used in hydrological and water quality surveys in such floodplains (Gooddy et al., 2014; Verstraeten et al., 2002). A study of 100 floodplain water bodies along the Rhine and Meuse rivers showed that the composition of nutrients and ions in each backwater varied with distance from the river and whether they were inside or outside levees (Van Den Brink et al., 1993; Van Den Brink & Van Der Velde, 1991), along with the composition of phytoplankton and small invertebrate communities (Brunke, 2002; Brunke et al., 2003; Van Den Brink et al., 1994). However, no studies have examined the relationship between nutrient dynamics and the origin (river water, groundwater, precipitation) and pathways (surface water, spring water) of water supplied to floodplains.

Because Japan is characterized by abundant rainfall and approximately 70% of the country is mountainous, many rivers have steep gradients and fast-flowing currents (Oguchi et al., 2001) (Figure S1). In addition, residential areas and farmland are concentrated on the alluvial fans, plains, and plateaus of the middle reaches of rivers and downstream areas. Consequently, urban rivers have undergone channel modifications for flood control and water resource management (Nakamura & Oki, 2018; Takahashi & Uitto, 2004), resulting in many floodplains whose extent is restricted by levees (Nagayama et al., 2015). Within the floodplain, semi-enclosed water bodies form, partially isolated from the river by developing sandbars (Kayaba et al., 1997). These are referred to as "Wando" in Japan (hereinafter, "Backwater") (Figure 1). It has been reported that these floodplain water bodies contribute to the aquatic ecosystem by creating a physically stable environment (Denda et al., 2002, 2006; Kimizuka, 1998; Minagawa et al., 2015; Nakajima et al., 2008). In the middle reaches of urban rivers, which are dotted with backwaters, water quality changes significantly over short distances due to agricultural runoff and wastewater treatment plant effluent. On the other hand, permeable alluvial fans and abundant rainfall provide the plains with large quantities of groundwater, creating recharge sources with varying water qualities in the vicinity of backwaters. There has been no research on the contribution of such river water and groundwater to the origin of backwater.

We hypothesized that the complex contribution of abundant unconfined groundwater and fast-flowing urban rivers to floodplain waters drives water-quality-forming mechanisms that differ from those in large continental rivers. Therefore, this study focused on the Tama River,

which flows through the suburbs of Tokyo, Japan, and examined the hydrological connectivity between river water and surrounding groundwater by using multiple geochemical tracers in several floodplain water bodies We examined the impact of backwaters on river ecosystems by investigating the dynamics of nutrients, including their sources and the supply processes influenced by biogeochemical processes, as well as the resulting concentrations and composition.

Lines 140–155

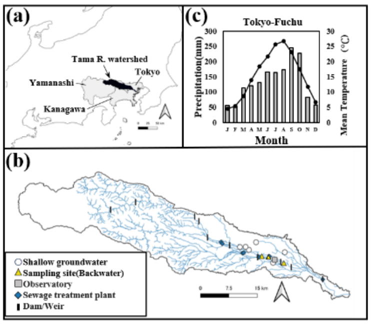
(Original text)

The Tama River forms river terraces from its middle to lower reaches. It was assumed that the numerous springs along the terraced cliffs would eventually flow into the Tama River and the floodplain as shallow groundwater.

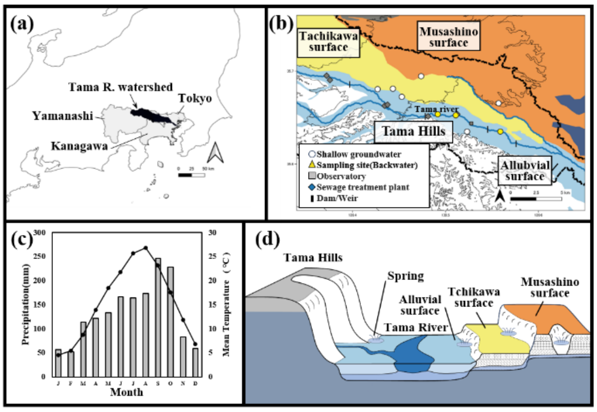
(Revised version)

The northern portion of the study area includes the central part of the alluvial fan formed by the Tama River. The alluvial fan area is characterized by a surface loam layer, with a highly permeable gravel layer beneath, resulting in abundant shallow groundwater. The shallow groundwater flows in a fan-shaped pattern from west to east, originating at the top of the alluvial fan (Shimano, 1994; Yamanaka, 2012). Groundwater levels in the area have been shown to flow southeastward and discharge into the Tama River (Hosono, 2003; Shindo, 1968). It has been established that these aquifers contribute to the replenishment of a deeper, confined aquifer. This assertion is supported by several lines of evidence, including groundwater contour lines (Shindo, 1968), tritium (Shimada et al., 1994a), and stable hydrogen and oxygen isotope ratios (Shimada et al., 1994b). The Tama River's flow has river terraces along the southern periphery of the alluvial fan. The intersection of the shallow groundwater's water table with the ground surface at the base of these terraces gives rise to numerous localized springs (Ohira et al., 2003; Shimano, 1994; Ueda et al., 2000) (Figure 2d). On the right bank of the Tama River, a hilly area rises several dozen meters above the alluvial plain; like the alluvial fan on the left bank, its surface is covered with a layer of loam. The subsurface comprises alternating layers of gravel, silt, and sand (Takano, 1994), and shallow groundwater flowing through highly permeable layers emerges at the boundary between the hilly terrain and the Tama River alluvial deposits.

Figure 2



Original figure 2



Revised version figure 2

Line 159-160

(Original text)

During the survey period, the drainage flowed into the floodplain, but no inflow was observed flowing into Pond A or the main river as surface water.

(Revised version)

During the survey period, the drainage flowed into the floodplain, seeped underground and no surface water inflow was observed into Backwater A or the main river.

Lines 175-177

(Original text)

Water samples (n=3) were collected at each of the backwaters and adjacent river mainstreams approximately once a month from February to November 2022.

(Revised version)

Water samples were collected at each backwater and adjacent river mainstream approximately once a month from February to November 2022. At each site and sampling occasion, water was collected and subsampled into three separate bottles.

Lines 189-193

(Original text)

Only in November 2022, we measured the concentration of chromophoric dissolved organic matter (CDOM) using a CDOM sensor (Cyclops-7-Logger, Tuner, USA) by immersing the sensor in water collected in a bucket for 10 minutes.

(Revised version)

In November 2022, the concentration of colorimetric dissolved organic matter (CDOM) was

measured using a CDOM sensor (Cyclops-7-Logger, Tuner Designs, USA), which had a resolution of 0.5 ppb and a detection limit of 3.0 ppb based on factory calibration (Khamis et al., 2015), by submerging the logger in water collected in a bucket for 10 minutes.

Line 200-203

(Original text)

Major anions (Cl^-, NO_3^-, SO_4^{2-}) and cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) were determined using an ion chromatography system (DIONEX ICS-1100 for cations and DIONEX DX-120 for anions, Dionex Corporation, USA).

(Revised version)

Major anions (Cl^-, NO_3^-, SO_4^{2-}) and cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) were determined using an ion chromatography system (DIONEX ICS-1100 for cations and DIONEX DX-120 for anions, Dionex Corporation, USA). The sum of NO_3^- and NH_4^+ was defined as dissolved inorganic nitrogen (DIN) concentration.

Lines 208-209

(Original text)

Standard materials USGS32, USGS34, and IAEA were used, and analytical precision for $\delta^{15}N$ and $\delta^{18}O$ was generally better than 0.2‰ and 0.6‰, respectively.

(Revised version)

Standard materials USGS32, USGS34, and IAEA-NO-3 were used, and analytical precision for $\delta^{15}N$ and $\delta^{18}O$ was generally better than 0.2‰ and 0.6‰, respectively.

Lines 309-312

(Original text)

In Backwater C, [DSi] were also higher than those in the adjacent rivers in most seasons, ranging from 14 to 40 μmol, but no statistically significant difference was observed.

(Revised version)

In Backwater C, [DSi] were also higher than those in the adjacent rivers in most seasons, ranging from 189 to 252 μmol L^{-1}, but no statistically significant difference was observed between each river and backwater.

Lines 324-326

(Original text)

The numbers shown on each symbol indicate the month of water sampling and its color indicate correspnding sampling site

(Revised version)

The numbers shown on each symbol indicate the month of water sampling and its color indicate corresponding sampling site

Line 343

(Original text)

(Dimova and Burnett, 2011; Ellins' et al., 1990).

(Revised version)

(Dimova and Burnett, 2011; Ellins et al., 1990).

Lines 359-365

(Original text)

In Backwater A, the inflow of factory effluent was observed upstream of the floodplain, and springs with high EC were observed as river flow increased. This suggests that the rising groundwater level in the floodplain due to increased river flow caused wastewater and groundwater to mix, forming the spring water.

(Revised version)

In Backwater A, spring water with high electrical conductivity (EC) and high concentrations of Na^+ and SO_4^{2-} was observed as river flow increased. Subsequent surveys revealed that in the upstream section of Backwater A, industrial effluent containing far higher concentrations of Na^+ and SO_4^{2-} (Na^+: approximately 11 mmol L^{-1}, SO_4^{2-}: approximately 7 mmol L^{-1} in Ueba unpublished data) (Figure 3a, Table S8 Supplement) and CDOM (167 ppb in Ueba unpublished data) were discharged into the floodplain. This suggests that seasonal increases in river flow caused the water level of underground riverwater in the floodplain to rise, resulting in a mixture of underground drainage and groundwater flowing into Backwater A.

Lines 366-377

(Original text)

In this study, CDOM concentrations showed clear differences in rivers, shallow groundwater, and treated sewage water (Figure 6). Dissolved organic matter (DOM) in urban rivers is suggested to be persistent (Dignac et al., 2000) because sewage treatment plants release refractory DOM after sewage treatment using microbial activity in the circulation tanks.

(Revised version)

In this study, CDOM concentrations showed clear differences between rivers, shallow groundwater, and treated sewage water (Figure 6). The effluent from the wastewater treatment plant undergoes multiple microbial treatment processes in the circulation tanks (Dignac et al.,

2000), resulting in extremely high CDOM levels, including refractory DOM. Therefore, the inflow of treated water would help maintain high CDOM concentrations in the river. CDOM concentrations being higher in river water than in groundwater was consistent with the results of our additional surveys conducted during the rainy and dry seasons, which have different river flow rates (i.e., 5.5 ppb and 5.9 ppb in shallow groundwater, and 9.4 ppb and 57.2 ppb in river water, during dry and wet seasons, respectively, R. Ueba unpublished data). Therefore, the relatively low CDOM concentrations observed in spring water at backwaters are thought to reflect dilution by shallow groundwater with lower CDOM concentrations.

Lines 408-410

(Original text)

In this study, [NO_3^-] in groundwater ranged from 130 to 350 µmol L^{-1}, as high as in river water, but δ^{15}N in NO_3 ($\delta^{15}N_{NO3}$) in groundwater (i.e., 1.7–6.9 ‰) was lower than that in river water (i.e., 15–20‰, Kumazawa, 1999) affected by treated sewage.

(Revised version)

Nitrate concentration ([NO_3^-]) in groundwater ranged from 130 to 350 µmol L^{-1}, as high as in river water, but δ^{15}N in NO_3 (δ^{15}N–NO_3) in groundwater (i.e., 1.7–6.9 ‰) was lower than that in river water (i.e., 12.7-18.1 ‰)

Lines 416-434

(Original text)

Especially in Backwater C, δ^{15}N–NO_3 and δ^{18}O–NO_3 increased in a ratio of approximately 2:1 (Figure 8), which is a typical phenomenon observed in the NO_3^- isotopes when denitrification occurs under anaerobic conditions (Kendall et al., 2008). The formation of anaerobic conditions and the activation of denitrification in the floodplain subsurface have been reported in many studies (Bernard-Jannin et al., 2017; Obana et al., 2011) . Denitrification in floodplains is not only caused by a decrease in dissolved oxygen (DO) but is also influenced by water quality parameters (such as organic matter content, water temperature, pH), groundwater level, soil particle size, and vegetation along the underflow path, among other factors (e.g., soil pH: Kaden et al., 2021; landscape and soil particle-size: Pinay et al., 2000; soil moisture: Pinay et al., 2007). The survey area is relatively narrow (i.e., within 5 km distance), and considering that there is little variation in the water quality of river water and shallow groundwater, the denitrification capacity of each backwaters may be influenced by localized transport and deposition processes in the meandering sections of the river and the resulting characteristic floodplain components such as grain size, vegetation, and organic matter content.

(Revised version)

(Figure. 7), while δ^{15}N–NO_3 and δ^{18}O–NO_3 increased at a ratio of approximately 2:1 (Figure. 8). These findings are consistent with phenomena observed during denitrification and suggest that significant denitrification likely occurred (Kendall et al., 2008). The formation of anaerobic conditions and the activation of denitrification in floodplain aquifers have been reported in numerous studies (Bernard-Jannin et al., 2017; Obana et al., 2011). Denitrification in floodplains is influenced not only by a decrease in DO but also by other factors such as water quality parameters (organic matter content, water temperature, pH, etc.), groundwater level, soil particle size, and vegetation along groundwater flow paths (e.g., soil pH: Kaden et al., 2021; topography and soil particle size: Pinay et al., 2000; soil moisture: Pinay et al., 2007; groundwater level: MaCarty et al., 2006). Previous studies of floodplains suggested that groundwater flow and water-level conditions contributed to locally elevated denitrification activity (McCklain et al., 2003; Vidon and Hill, 2004; Kollogg et al., 2005). [NO_3^-] in backwater springs varies by location within a relatively small study area (a 5-kilometer radius), despite the relatively stable [NO_3^-] in rivers and groundwater, suggesting that the sedimentary environments surrounding these backwaters differ due to factors such as river meandering. Therefore, to evaluate denitrification capacity at each site and identify its determining factors, it is necessary to understand the floodplain subsurface in three dimensions from the perspectives of hydrology and sediment composition.

Lines 460-462

(Original text)

DIN and DSi concentrations of spring water in each backwaters, river water, and shallow groudwater plotted with dotted lines indicating typical compostion ratios.

(Revised version)

DIN and DSi concentrations of spring water in each backwaters, river water, and shallow groundwater plotted with dotted lines indicating typical composition ratios.

Lines 494-506

(Revised version)

We hypothesized that water quality in backwaters within the mid-reaches of urban rivers varies due to complex contributions from river water and groundwater, influenced by surrounding land use, geology, and topography. Therefore, in this study, we used multiple geochemical tracers (ion balance, CDOM, ^{222}Rn, δ^2H & δ^{18}O–H_2O, δ^{15}N & δ^{18}O–NO_3) to estimate the origin and pathways of water and to examine the relationship between nutrient dynamics of growth-limiting nutrients such as N, P, and Si. The results from each tracer suggested that backwaters consist of mixtures of urban river water and groundwater, with

mixing ratios varying spatiotemporally, even within relatively short river sections. Phosphate and silicate concentrations in backwaters were influenced by inputs from urban rivers and shallow groundwater, which exhibited contrasting nutrient signatures (i.e., high phosphate and low silicate in urban rivers, and low phosphate and high silicate in groundwater). Although DIN concentrations were similar in urban rivers and shallow groundwater, analyses of $\delta^{15}N$ & $\delta^{18}O–NO_3$, together with seasonal variations in NO_3^- concentrations and dissolved oxygen (DO), suggested the sources of NO_3^- in backwaters and its removal via denitrification in floodplain groundwater. As a result, the use of multiple geochemical tracers revealed that nutrient dynamics in backwaters are controlled by the mixing of urban river water and shallow groundwater, as well as microbial activity in the floodplain, thereby contributing to water-quality diversification within the river ecosystem.

Lines 508-509

(Original text)

The datasets used in this study are available from the corresponding author upon reasonable request.

(Revised version)

The datasets generated and analyzed during this study are available in the Zenodo repository: https://doi.org/10.5281/zenodo.20115076.