FACULTY OF BIOLOGY AND
ENVIRONMENTAL PROTECTION
University of Lodz

University of Lodz, Doctoral School of Exact and Natural Sciences

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ALBUM NUMBER: 6243

Assessment of the invasion potential of two genetically distinct populations of the Ponto-Caspian amphipod - *Dikerogammarus villosus*

Ocena potencjału inwazyjnego dwóch genetycznie zróżnicowanych populacji pontokaspijskiego obunoga – *Dikerogammarus villosus*

PhD Thesis

performed in the Department of Invertebrate Zoology and Hydrobiology in the Institute of Ecology and Environmental Protection at the Faculty of Biology and Environmental Protection of the University of Lodz

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Lodz, 2024

Acknowledgements

First of all, I would like to express my sincere thanks to my supervisor, prof. **Karolina Bącela-Spychalska** for her support, unlimited willingness to help and the kindness she has shown me through all this time. Her knowledge and dedication to science led me to the point at which I am.

I would also like to thank my auxiliary supervisor, dr **Tomasz Rewicz** in whose project I had the honour of carrying out my dissertation. His patience, support and understanding helped me to achieve my goals.

I am grateful to dr **Andrea Desiderato**, who has always cared about my progress. His support and friendship motivated me to improve myself and my work every day.

I would especially like to thank my colleagues at the Nicolaus Copernicus University in Toruń for their invaluable help, in particular prof. **Jarosław Kobak** and dr hab. **Łukasz Jermacz**.

I also thank my colleagues at the Nature Research Centre in Vilnius, especially dr **Denis Copilaș-Ciocianu** for his support and hospitality shown to me in Vilnius.

I would like to sincerely thank dr **Eliza Szczerkowska-Majchrzak**. Her invaluable help and the unlimited kindness she has shown me have been a huge support to me.

I would like to express my sincere thanks to the Vice-Rector of the University of Lodz and co-supervisor of my master's thesis – prof. **Krzysztof Pabis**, who has brought me to where I am today.

I would like to thank dr **Serena Mucciolo** for the friendship shown to me, which gave me the strength to work every day.

I would like to thank dr hab. **Agnieszka Rewicz** for huge mental support, which I often needed.

Many thanks to my colleagues in the Department of Invertebrate Zoology and Hydrobiology who have always been there to advise and help me and have always treated me well, especially prof. **Michał Grabowski**, dr **Piotr Jóźwiak**, dr **Iwona Słowińska**, dr hab. **Tomasz Mamos**, dr **Grzegorz Tończyk**, mgr **Monika Kuna-Majewska**.

I would like to thank my bachelor's and master's thesis supervisor - prof. **Magdalena Błażewicz**.

I would like to thank dr hab. **Katarzyna Popłońska** prof. UŁ and dr hab. **Agnieszka Wojtczak**, who first inspired me to do science.

I would like to give special thanks to my closest **family** and **friends** for their patience and support in my scientific work.

I dedicate this dissertation to my grandparents of blessed memory – **Łucja** and **Michał Podwysocki**, **Barbara** and **Jerzy Borczyński**. They have always shown me support in my goals and have always been proud of me. What a pity that you are no longer with me.

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Abstract

This PhD thesis aimed to test the intraspecific variation in invasive potential in freshwater ecosystems. As a model for my research, I have chosen *Dikerogammarus villosus* (Sowinsky, 1894) – an invasive Ponto-Caspian amphipod that spread in European aquatic environments from two geographically isolated and genetically distinct source populations – the Danube and the Dnieper deltas, forming the Western and the Eastern invasive groups, respectively. The wide distribution of both genetic units in various ecosystems of Europe, a high voracity and predatory pressure, successful competition for the habitat and resources, a high fecundity and fast maturation as well as large body size make this species a perfect model to study the invasion potential at the population level.

My first aim was to test if the Eastern Group of *D. villosus* could spread in lakes using boating as an invasion vector. My analyses revealed that the introduction of this species was promoted by high tourist pressure, especially sailing activities. *Dikerogammarus villosus* rapidly increases its abundance and range in new environments and contributes to the eradication of native and other invasive species.

My next aim was to assess the morphological variation of this species across populations of different origins, from native and invaded ranges as well as inhabiting various types of water bodies (i.e., freshwater lakes, freshwater river sections, brackish waters). My findings displayed a high morphological variation of *D. villosus*. I observed the adaptations in the mouthparts of the Eastern Group to be more herbivorous. I noticed the adaptations in the gnathopods of the Western Group for higher predatory capacity and in walking legs to enhance their locomotion abilities. The morphospace change between native and invaded ranges indicates the high phenotypic plasticity of the Eastern Group.

My third aim was to test if the groups differ in food preference as shown in the morphological study. The results revealed that the Western Group choose more often the food of animal origin than the plant tissue. Meanwhile, the Eastern Group reaches for meat and plant food with a similar frequency. I assume that the Western populations may display higher

predatory pressure, affecting the benthic communities, while the Eastern populations may use food resources more efficiently in case of their limitation.

My last aim was to test if these two groups differ in their ability to spread. I noticed that the Eastern Group can be bolder in exploring new environments. On the other hand, this group successfully competes for the preferred habitat forcing the weaker Western Group to spread more. In case of the future meeting of both groups, I assume that the Western Group will be promoted to spread to new environments.

In summary, I showed that the two groups, differing in genetic composition, also differ in certain biological traits which may promote their invasion in slightly different conditions. My results revealed the significance of the local conditions and genetic origin of populations in shaping their invasive traits that promote their dispersion and impact the environment. I stress the importance of integrating data from multiple populations to better assess the biology of the invasive species and try to predict its further spread in the environment and its potential consequences.

Streszczenie

Niniejsza praca doktorska miała na celu zbadanie wewnątrzgatunkowej zmienności potencjału inwazyjnego w ekosystemach słodkowodnych. Jako model do moich badań wybrałem *Dikerogammarus villosus* (Sowinsky, 1894) - inwazyjnego pontokaspijskiego obunoga, który rozprzestrzenił się w europejskich środowiskach wodnych z dwóch geograficznie izolowanych i genetycznie odrębnych populacji źródłowych - delt Dunaju i Dniepru, tworząc odpowiednio Zachodnią i Wschodnią grupę inwazyjną. Szeroki zasięg występowania obu jednostek genetycznych w różnych ekosystemach Europy, wysoka żarłoczność i presja drapieżnicza, skuteczna konkurencja o siedlisko i pokarm, wysoka płodność i szybkie dojrzewanie, a także duże rozmiary ciała sprawiają, że gatunek ten jest doskonałym modelem do badania potencjału inwazyjnego na poziomie populacji.

Moim pierwszym celem było sprawdzenie, czy Wschodnia Grupa *D. villosus* może rozprzestrzeniać się w jeziorach, wykorzystując żeglarstwo jako wektor inwazji. Moje analizy wykazały, że wprowadzeniu tego gatunku sprzyjała wysoka presja turystyczna, zwłaszcza żeglarstwo. *Dikerogammarus villosus* szybko zwiększa swoją liczebność i zasięg w nowych środowiskach i przyczynia się do eliminacji rodzimych i innych gatunków inwazyjnych.

Moim kolejnym celem była ocena zmienności morfologicznej tego gatunku w populacjach o różnym pochodzeniu, z obszarów rodzimych i inwazyjnych, a także zamieszkujących różne typy zbiorników wodnych (tj. jeziora słodkowodne, słodkowodne odcinki rzek, wody słonawe). Wyniki moich badań wykazały dużą zmienność morfologiczną *D. villosus*. Zaobserwowałem adaptacje w aparatach gębowych Grupy Wschodniej, aby były bardziej roślinożerne. Zauważyłem adaptacje w gnatopodach Grupy Zachodniej w celu zwiększenia zdolności drapieżnych i w odnóżach w celu zwiększenia ich zdolności lokomotorycznych. Zmiany niszy morfologicznej między obszarami rodzimymi i inwazyjnymi wskazują na wysoką plastyczność fenotypową Grupy Wschodniej.

Moim trzecim celem było sprawdzenie, czy grupy różnią się preferencjami żywieniowymi, jak wykazano w badaniu morfologicznym. Wyniki ujawniły, że Grupa Zachodnia częściej wybiera pokarm pochodzenia zwierzęcego niż roślinnego. Tymczasem grupa Wschodnia sięga po pokarm mięsny i roślinny z podobną częstotliwością. Zakładam, że populacje Zachodnie mogą wykazywać

większą presję drapieżniczą, wpływając na zbiorowiska bentosowe, podczas gdy populacje Wschodnie mogą efektywniej wykorzystywać zasoby pokarmowe w przypadku ich ograniczenia.

Moim ostatnim celem było sprawdzenie, czy te dwie grupy różnią się pod względem zdolności do rozprzestrzeniania się. Zauważyłem, że Grupa Wschodnia może być odważniejsza w nowych środowiskach. Z drugiej strony, grupa ta skutecznie konkuruje o preferowane siedliska, zmuszając słabszą Grupę Zachodnią do większego rozprzestrzeniania się. W przypadku przyszłego spotkania obu grup zakładam, że Grupa Zachodnia będzie promowana do rozprzestrzeniania się w nowych środowiskach.

Podsumowując, wykazałem, że obie grupy, różniące się składem genetycznym, różnią się również pewnymi cechami biologicznymi, które mogą promować ich inwazję w nieco innych warunkach. Moje wyniki ujawniły znaczenie lokalnych warunków i pochodzenia genetycznego populacji w kształtowaniu ich cech inwazyjnych, które promują ich dyspersję i wpływ na środowisko. Podkreślam znaczenie integracji danych z wielu populacji w celu lepszej oceny biologii gatunków inwazyjnych i próby przewidzenia ich dalszego rozprzestrzeniania się w środowisku i jego potencjalnych konsekwencji.

List of publications included in the doctoral thesis

I. **Podwysocki** K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K (2024c) Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161-192.

IF: 3.8; points of the Ministry of Education and Science: 140

II. **Podwysocki** K, Bącela-Spychalska K, Desiderato A, Rewicz T, Copilaș-Ciocianu D (2024a) Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe. Hydrobiologia. https://doi.org/10.1007/s10750-024-05565-8.

IF: 2.2; points of the Ministry of Education and Science: 100

III. **Podwysocki** K, Szczerkowska-Majchrzak E, Jermacz Ł, Kobak J, Bącela-Spychalska K, Rewicz T, Desiderato A (2024b) Predation or omnivory – two different feeding patterns displayed by two intraspecific lineages of the invasive Ponto-Caspian amphipod - *Dikerogammarus villosus*. Under review in Freshwater Biology.

IV. **Podwysocki** K, Desiderato A, Szczerkowska-Majchrzak E, Jermacz Ł, Kobak J, Bącela-Spychalska K, Rewicz T (2024d) The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). Under review in Animal Behaviour.

Total IF value: 6.0; points of the Ministry of Education and Science: 240

General introduction

Biological invasions are recognized as one of the strongest threats to biodiversity, right after habitat loss and landscape fragmentation (Walker and Steffen 1997). Particularly in freshwater ecosystems, invasive alien species (IAS[1]) cause a decline in the diversity and abundance of native species and may lead to an extinction of native biota (Ricciardi and Kipp 2008, Bellard et al. 2016), primarily due to predation and effective competition for resources (Crowder and Snyder 2010). Invasive alien species can transmit pathogens, disrupt the provision of ecosystem services, modify environments as ecosystem engineers and finally generate high economic costs due to compensation for their impact and invasion management (Bradshaw et al. 2016). Therefore, it is important to have a good overview of the biological invasion dynamics and directions to better predict the course and effects of future invasions to prevent them more effectively.

Despite the enormous amount of research on biological invasions that focuses on the species level (Lowry et al. 2013), the biology and impact of invasive species at the population level is increasingly being analysed (Simberloff et al. 2013, Sousa et al. 2024a). Studies on biological invasions at the species level usually ignore local context (e.g., habitat heterogeneity) that shapes invasion dynamics (Haubrock et al. 2024). While broader studies offer valuable insights, focusing on the population level allows for consideration of local environmental conditions that can influence the invasive potential[2] of specific populations (Sousa et al. 2024a). For instance, variations in benthic community structure across different water bodies, nutrient availability and environmental productivity result in diverse food resources available to invasive predators, influencing their trophic positions (Arbačiauskas et al. 2013, Hellmann et al. 2015, 2017). Additionally, the trophic position of invaders can be determined by individual size and abundance within specific populations (Jackson et al. 2017). Local conditions can shape also the fecundity in the population (Sakai et al. 2001, Sousa et al. 2024a). Due to favourable conditions and a specific set of life-history traits of individuals, some populations may be promoted to

[1] Invasive alien species (invasive non-native; invasive non-indigenous) – species intentionally or accidentally introduced by humans into areas where the species does not occur naturally, posing a threat to native species (Pyšek et al. 2020).

[2] Invasive potential (invasiveness) – the species capacity to spread from the site of primary introduction, to establish the populations in the environment and to negatively affect biodiversity and cause socioeconomic consequences (van Kleunen et al. 2010).

further spreading, while others may stagnate or even face extinction (Haubrock et al. 2024). Finally, dispersion capacity, so important for the invasions, can differ locally, mainly due to spatial transmission of propagules[3] and population growth (Clark et al. 2001). The regions can differ in human pressure, which impacts the probability of long-distance spread (Buchan and Padilla 1999). Moreover, the populations of invasive species may differ in invasive potential as a result of different stages of invasion. Populations from the front of invasions achieve larger body size, higher aggressiveness, higher dispersion capacity, broader trophic niches, higher fecundity and faster female maturation compared with long-established populations (Brandner et al. 2013, Masson et al. 2016, Sousa et al. 2024b). Furthermore, the population-level approach in biological invasion studies allows us to account for genetic diversity (Sousa et al. 2024a). Population invasiveness can vary depending on the genetic origin and diversity of the source populations (Valiente et al. 2010). Multiple introductions from a high diversity of source populations can lead to higher invasive potential due to gene admixture[4] (Rius and Darling 2014), though, some invasive lineages do not necessarily have to interbreed (Galipaud et al. 2015, Bystřický et al. 2022). Therefore, it is important to consider the origin of invasive species, their invasion history and the local environmental characteristics that can differentiate invasive potential, even if such studies require more data and can be more complex to interpret (Haubrock et al. 2024).

The invasion process consists of transport and introduction, establishment[5], lag stage, spread and impact (Darrigran and Damborenea 2015). Alien species[6] can be introduced to new environments via the artificial canals that connect previously isolated water bodies (Galil et al. 2008). However, many freshwater macroinvertebrates spread even to isolated water bodies (e.g., lakes) by biofouling on the vessels or attached to biofouling periphyton (Nehring 2005). Some species have been intentionally introduced for economic purposes (Grudule et al. 2007) or

[3] Propagule pressure (propagule size) – a measure of the number of viable individuals of an alien species introduced to a recipient environment, equal to the number of propagules released with a single introduction event and number of such events (Roman and Darling 2007).
[4] Admixture – the occurrence of individuals in the same population from multiple genetically distinct sources (Roman and Darling 2007).
[5] Established (colonist; naturalized) – self-sustaining population in a new area after the introduction. Population may spread in the future (Gormley et al. 2011).
[6] Alien species (introduced; non-indigenous; non-native) – species introduced to an area in which it does not occur naturally (Pyšek et al. 2020).

have been released by aquarists (Jabłońska et al. 2018). Invasive species can be transferred at short distances attached to water birds (Rachalewski et al. 2013) or at longer distances in ballast waters (Zhulidov et al. 2018).

Despite numerous possible vectors[7] and ways of transport and introduction, the arrival of non-native species to new areas does not necessarily mean their establishment. Successful establishment and probability of further spreading of alien species are possible if the environment serves favourable conditions and the species has several biological traits promoting its invasion (Moyle and Light 1996), such as wide environmental tolerance (Hoffmann and Hercus 2000, Lenz et al. 2011); the high dispersal capacity (Hänfling et al. 2011); the high fecundity, long reproduction period, fast growth and maturation (Sakai et al. 2001, Roman and Darling 2007). Numerous invasive species are effective generalist predators with a wide range of feeding modes (Machovsky-Capuska et al. 2016). Their broader trophic niches compared to native species allow them to use more efficiently food resources and occupy free ecological niches in new environments (Kostrzewa and Grabowski 2003, Feiner et al. 2013, Šidagytė et al. 2017b).

One of the donors of numerous freshwater IAS in Europe is the Ponto-Caspian region that consists of the Azov, the Black and the Caspian seas and the lower river sections flowing into them (Jażdżewski 1980). Since the beginning of the Pleistocene (~2.5 million BP), rapid climatic and geological changes have led to the reformation of the basin, its long isolation and fluctuating environmental conditions including salinity (Yanina 2014). Such climatic and geological history promoted diversification and a high level of endemism of the Ponto-Caspian biota, mainly among fishes, molluscs and crustaceans (Neilson and Stepien 2009, Wesselingh et al. 2019, Copilaş-Ciocianu et al. 2022). Therefore, many of these organisms exhibit significant genetic and phenotypic plasticity, as well as a wide ecological tolerance (Pauli and Briski 2018).

Among them, *Dikerogammarus villosus* (Sowinsky, 1894) (Figure 1) is a widely distributed IAS and belongs to the group of the 100 worst alien species in Europe (DAISIE 2009). The species has been recorded for the first time outside its native range in Hungary in 1926 (Nesemann and

[7] Vector – specific human or natural carrier transporting alien species to the recipient ecosystem (Roman and Darling 2007).

Pöckl 1995). In a few decades, the species has colonised most European waterways and successfully eradicated or reduced native biota as well as other invasive amphipod species (Bącela et al. 2008, Koester et al. 2016, Borza et al. 2018a). Several traits favour its invasion (Grabowski et al. 2007). First of all, *D. villosus* is a voracious omnivorous species, displaying a broad range of feeding modes (Platvoet et al. 2009, Richter et al. 2018). This species has an exceptional predatory capability preying on a wide range of varying body-size macroinvertebrate species from different trophic groups, leading to species eradication and ecosystem functioning (Dick et al. 2002). Moreover, *D. villosus* successfully competes for food resources (Van der Velde et al. 2000) and preferred habitat – stones and gravel (Hesselschwerdt et al. 2008, Boets et al. 2010). Consequently, this amphipod leads to spatial segregation forcing weaker competitors to inhabit less favourable habitats (Borza et al. 2018b). *Dikerogammarus villosus* has a large dispersal capacity and can actively drift as well as be transferred attached to the vessels, ropes and diving equipment (van Riel et al. 2011, Bącela-Spychalska et al. 2013). Known to be effectively introduced to isolated waterbodies by overland transport, it can colonise even remote ecosystems (Rewicz et al. 2017). *Dikerogammarus villosus* is euthermic and euryhaline (Bruijs et al. 2001, Wijnhoven et al. 2003) and spreads in large and polluted waters (Grabowski et al. 2009, Boets et al. 2010). Broad tolerance to salinity promotes the dispersion of this species in coastal waters (Šidagytė et al. 2017a), while temperature preference may promote its expansion according to future climatic scenarios (Gallardo and Aldridge 2013). This is all the more possible due to the high fecundity, fast growth and maturation and long reproductive period (Pöckl 2009).

Figure 1. Body habitus of *D. villosus*
(photographed by Prof. Michał Grabowski,
University of Lodz)

Thereby, *Dikerogammarus villosus* is a perfect model to study the invasive potential at the population level. The species invaded Europe from two geographically isolated and genetically differentiated source populations in the native range – the Danube and the Dnieper deltas (non-mentioning invasion in the River Volga from the populations in the Sea of Azov) (Rewicz et al. 2014). They formed two genetic units (Rewicz et al. 2015b) called here the Western and the Eastern Groups (Lineages, populations), respectively (Figure 2). Both groups arrived at the main rivers in Poland – the River Oder (the Western Group) and the River Vistula (the Eastern Group) (Jażdżewski et al. 2005, Bącela et al. 2008).

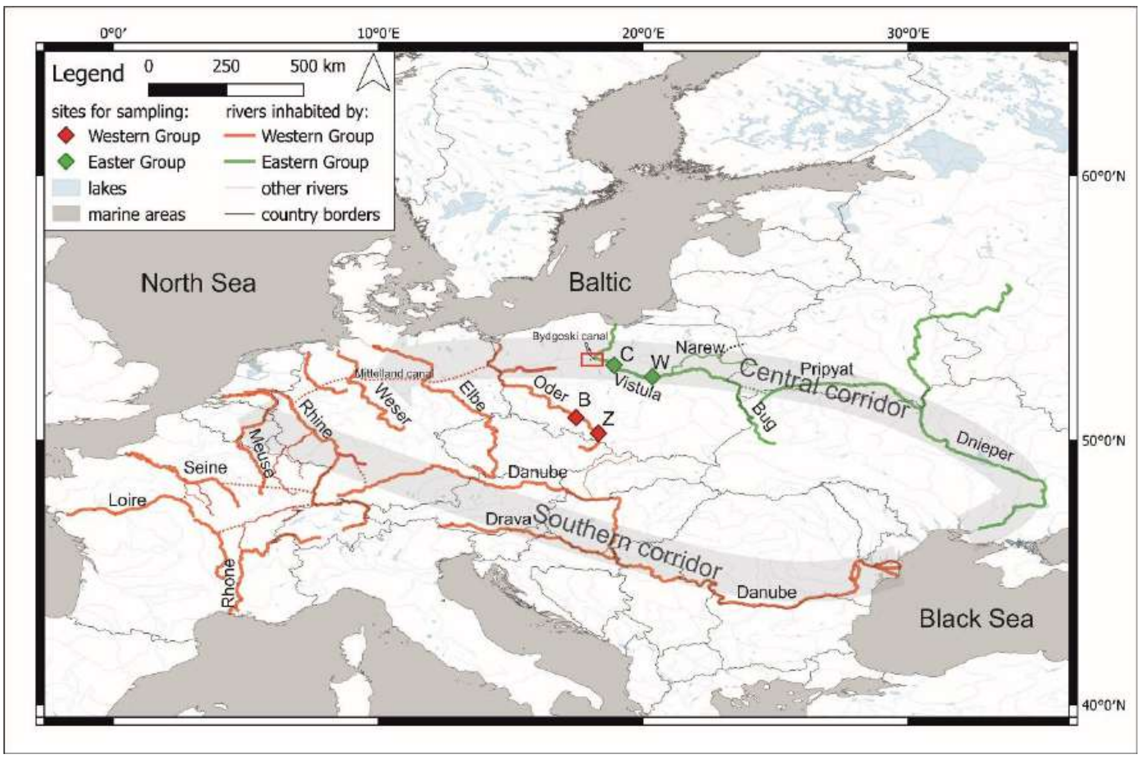


Figure 2. Distribution of the two invasive groups of *D. villosus* in Europe on the background of the migration corridors (grey transparent vector) according to the Bij de Vaate et al. (2002). Sampling sites representing populations of each group are designated by the letters as follows: B – Brzeg; C – Ciechocinek; W – Wyszogród; Z – Zdzieszowice.

Although many studies have been dedicated to the biology and invasion impact of *D. villosus* (Rewicz et al. 2014), the vast majority of studies on this species involve only populations from the Western Group, while the studies on the Eastern Group are much rarer (e.g., Dedyu

(1967); Lipinskaya and Makarenko (2019); Minchin et al. (2019)). The comparisons of both groups are even rarer, with one work published showing the differences in the expression of the heat shock proteins between these two groups, promoting higher heat tolerance across the Western Group (Hupało et al. 2018). Currently, these two groups are separated by a very short distance, less than 50 km – which is the Bydgoski Canal connecting the Oder and the Vistula River catchments. We may expect that in a scenario of co-occurrence of these two groups, they interact with each other, competing for the same resources and also modulating their invasiveness. What is more, as the genetic variation observed in the two invasive groups has an intraspecific character, it can be expected that they can interbreed and hybridize[8] in case of future contact (Rewicz et al. 2015a). If these two groups differ in certain traits, the genetic admixture may lead to the emergence of hybrids with a higher phenotypic variation compared to the parental populations (Hegarty 2012). Consequently, populations established as a result of interbreeding of front populations may have a higher invasive potential than parental populations. Therefore, it is crucial to study the biological traits that promote the invasion of the species on the intraspecies level, to better predict the future consequences of the invasion by different populations and their interbreeding.

[8] Hybridization – the breeding of individuals from genetically distinct populations (intra- or interspecific). Consequently, a new genotype with novel combination of alleles is created (Roman and Darling 2007).

Objectives

I aimed to assess the population effect on the differential invasive potential at the intraspecific level. I focused on selected traits that promote the invasion of the alien species: diet and dispersal capacity, to answer the following research questions:

I. Whether a high touristic pressure (boating) is reflected in a high dispersal rate of the Eastern Group in aquatic environments?

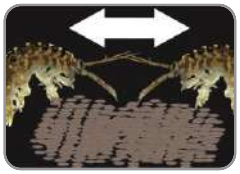
•Aim of Publication I

II. Whether this widely distributed invader, comming from two geneticly distinct source populations, and inhabiting different aquatic environments in Europe (rivers, lakes, brackish waters) display morphological variation potentially linked to the diet and locomotion?

•Aim of Publication II

III. Whether invasive populations of this species differ in food consumption rate and food preference?

•Aim of Manuscript III



IV. Whether invasive populations of this species differ in habitat competition leading to dispersion rate disparities?

•Aim of Manuscript IV

Choosing *Dikerogammarus villosus* as a model species will help answer my research questions. The results of my PhD thesis may contribute to a better comprehension of the biology, ecology and morphology of one of the most invasive freshwater species, being an example of population-level phenomena. My findings will help to predict future scenarios and consequences of the progressive expansion of aquatic invasive species. My work is one of the still rare analyses of invasiveness at the intraspecific level, highlighting the significance of such an approach in biological invasion studies.

Thesis overview

Most of the studies focusing on *Dikerogammarus villosus* biology and ecology in terms of its invasion are based on the populations of the Western Group, while the Eastern Group is much less studied (Kobak et al. 2015, Copilaş-Ciocianu and Šidagytė-Copilaş 2022). Therefore, in the **first publication** of my thesis (Podwysocki et al. 2024c) I aimed to 1) analyse the dynamics of Masurian Lakeland colonization by the Eastern Group of this invader; 2) test, if tourist pressure promotes the invasion of this group, and 3) confirm that the expansion of this species contributes to the eradication of other amphipod species (both native and invasive).

Therefore, I analysed the historical distribution and new records of amphipod species in the Masurian Lakeland – the area significantly impacted by touristic pressure, with a set of lakes with different isolation levels. This publication reports on the invasion history of this species and serves as a kind of introduction to the other parts of my thesis. My results show that invasive amphipods spread to new lakes through human activity and restrict native species – *Gammarus lacustris* G.O. Sars, 1863 – only to isolated lakes. Two older invaders – *Dikerogammarus haemobaphes* (Eichwald, 1841) and *Pontogammarus robustoides* (Sars, 1894) – began to reduce their abundance in favour of a rapidly spreading two new invaders – *Cheatogammarus ischnus* (Stebbing, 1899) and *D. villosus*.

Dikerogammarus villosus rapidly became a dominant amphipod. The invasion of this species in the lakes is associated with a higher density of boats and a shorter distance from town, where many marinas are located. Thereby, I proved an important role of the touristic pressure in the lake invasion by *D. villosus* of Dnieper origin, as already shown for the Western Group in the Alpine Lakes (Bącela-Spychalska et al. 2013). The invasion of the Eastern Group causes the eradication of native and other invasive gammarid species. As *D. villosus* is broadly distributed in Europe in various environments, and it is known to utilise variable resources as food, I assumed that the species may display a high morphological variability differentiating the feeding habits at the population level. Hence, in the **second publication** of my thesis (Podwysocki et al. 2024a), I compared the morphology of feeding-related body traits of amphipods between populations from native and invaded ranges, different environments, including freshwater lakes, freshwater river sections and brackish waters, and genetic units from a broad area in Europe. I also analysed the traits that are involved in movement, looking for differences in the locomotion abilities.

My results revealed the high morphological diversity of *D. villosus* in Europe across populations from different ranges, environments and genetic groups. The two groups (Western and Eastern) differ in the traits responsible for food processing and digestion, food capturing and locomotion. Amphipods of the Eastern Group are adapted to less specialised feeding and a higher share of plant material in their diet while individuals of the Western Group have adaptations to more specialised feeding and being more predatory. Moreover, I showed that traits reflecting locomotion ability are better developed in amphipods of the Western populations compared with the other populations. Both groups display unique morphospace changes in the invaded range compared with the native, but only the Eastern Group exhibits morphospace expansion, suggesting the higher plasticity of this group.

I concluded that the Eastern populations, due to higher plasticity and more omnivorous feeding, may have a higher invasion success in new environments, while the Western populations, due to higher feeding specialisation and enhanced predatory may pose a greater threat to local benthic communities. Moreover, the Western Group may have a higher spreading capacity. I decided to verify these patterns in two experiments described in the following two manuscripts of my thesis. If the experiments show similar patterns as the morphological data, I can assume that the morphological analyses can be successfully used to assess selected invasive traits in the population-level approach.

The differences in feeding habits shown by the morphology of feeding-related traits were then tested experimentally and the results of this work are presented in the **third manuscript** of my thesis (Podwysocki et al. 2024b)**.** I tested the consumption rate of three different food items (leaves, fish tissue, alive chironomid larvae), representing three different feeding modes (herbivory/grazing, necrophagy and predation, respectively) and food preferences of the Western and Eastern groups in two seasonally repeated experiments.

Both groups have similar consumption rates with a gentle tendency for the higher voracity exhibited by the Western populations. Although both groups consume the highest amount of chironomid larvae out of all the served food, the Western populations consume significantly more fish tissue than plant tissue, while the Eastern populations consume a similar level of these food items. These results prove that the Eastern Group is less specialised in feeding (is more omnivorous) than the Western one and maybe more flexible in feeding in the environment in case of limited resources. An important contribution of plant material in the diet of this group and high phenotypic plasticity has been presented in my second publication (Podwysocki et al. 2024a). On the contrary, the Western populations are more specialised in feeding, as their diet contains more food of animal origin. This is in agreement with the results of morphological analyses, suggesting the higher predatory ability of this group (Podwysocki et al. 2024a). Thus, I conclude that the Western populations may display higher predatory pressure on the local macroinvertebrate communities than the Eastern Group.

Thereby, morphological analyses on feeding-related traits may serve as a proxy for feeding habits in amphipods. In summary, both morphological and experimental approaches showed that the Western Group may pose a higher threat to benthic assemblages and the Eastern Group may be more successful in the establishment and further spread in new environments, especially those with limited food resources.

Although, both genetic groups of *D. villosus* are widely distributed across a range of waterbodies and their spread is also highly associated with touristic activity (Bącela-Spychalska et al. 2013, Podwysocki et al. 2024c), natural spread abilities may differ between them, what has been suggested by morphological variation in locomotion-related appendages (Podwysocki et al. 2024a). Therefore, in the **fourth manuscript** of my thesis (Podwysocki et al. 2024d), I aimed to compare the dispersion capacity between the groups, as well as to assess the impact of the groups on each other in the scenario when the two populations meet.

In the laboratory experiment, I tested how both groups spread when they compete for the preferred habitat and when they are separately in the environment. I observed that individuals from the Eastern populations move more in new environments. I expect that this group, displaying higher phenotypic plasticity and inhabiting more heterogenous environments, is bolder in exploring new habitats. When both groups are together exposed to spatial competition, the Eastern Group stays in the preferred habitat and the weaker competitor – the Western Group – spreads more. I assume that better-developed locomotion appendages of the Western populations allow these amphipods to escape from the direct competition for shelter.

In practice, this may mean that in the contact of both groups, the Eastern Group will settle in the preferred habitat while the Western Group will be forced to move more. It may allow the Western populations to increase the dispersion in Europe but can also mean migration to new types of environments like small tributaries and river brooks. Consequently, the Western Group may pose a threat to native biota so far safe from invasive species. Such a scenario demands further analyses supplemented with comparisons of more traits. Still, it is crucial to study biological invasions at the population level, especially since my results revealed a high contribution of the population effect in shaping the dispersion of amphipods.

Summarising, I have tested two important invasive traits of amphipods – the diet and the dispersion using experimental and morphological analyses (Table 1). Although both groups achieved invasive success in Europe and both of them pose a threat to benthic communities, my results revealed that the Western Group is more diet-specialised and spread more accompanied by the Eastern populations. Meanwhile, the Eastern Group may be a stronger competitor and more efficiently utilise the limited food resources. As both groups can spread aided by tourism, regular monitoring is crucial to prevent further spread. The population-level approach is pivotal to better comprehending the biology of invasive species.

Table 1. Comparison of invasive groups of *D. villosus* in several traits shaping the invasive potential

Trait		Western Group	Eastern Group	Publication/ Manuscript
Invasion process	Touristic pressure promotes the invasion	Yes (Bącela-Spychalska et al. 2013)	Yes	I
	Eradication of native and invasive amphipods	Yes (Borza et al. 2018a)	Yes	
Morphology	Phenotypic plasticity	lower	higher	II
	Food processing and digestion	more predatory	more herbivorous	
	Food capturing and handling	more predatory	more herbivorous	
	Mobility	higher	lower	
Food consumption		slightly higher	slightly lower	III
Food preference		more carnivorous	more omnivorous	
Dispersion capacity	Dispersion rate in a new environment	lower	higher	IV
	Dispersion when accompanied by the counterparts from the second group	higher	lower	
	Competition for preferred habitat	weaker	stronger	

General discussion

My findings revealed that *Dikerogammarus villosus* exhibit a substantial morphological variation across different populations in Europe, especially in the invaded range, promoting the adaptations of certain populations for higher predatory and dispersion abilities. Populations of this species differ in invasive potential depending on the source population. Individuals from the Dnieper Delta (the Eastern Group) are less specialised in their diet, more efficiently compete for the preferred habitat and display higher phenotypic plasticity compared with their Western counterparts (individuals that spread from the Danube Delta). Below, I discuss the main findings of my PhD thesis and their importance for the studies on biological invasions.

Many species can disperse using vessels as a human vector (Nehring 2005). Similarly, *Dikerogammarus villosus* can attach to the biofouling organisms covering submerged parts of vessels and can spread even to isolated water bodies. I showed that the Eastern Group of *D. villosus* spreads to those of the Masurian lakes that are characterised by high touristic pressure, and in the areas close to towns (Podwysocki et al. 2024c) as it was evidenced for the Western Group in the Alpine Lakes (Bącela-Spychalska et al. 2013). The lakes localised closer to the urban area have more dense touristic infrastructure, including the ports and marinas that are the entry points for numerous invaders (Minchin et al. 2019). It is further supported by my observations that the only Masurian lakes free of *D. villosus* (and other alien amphipods) are the ones where no touristic activity, such as sailing, or boating, was notified. In those waterbodies, the only recorded species was the native amphipod – *Gammarus lacustris*. I, therefore, stress the importance not only of regular monitoring of marinas and boat traffic between lakes (Cole et al. 2019), as well as the effectiveness of boat cleaning (Mohit et al. 2021) but also of educating the public to protect the habitats of native species.

Apart from the introduction of human vectors, the dispersion of numerous species in the environment results from avoiding competition with other species (Ronce 2007). If the environment provides a heterogenous habitat structure, the coexistence of invasive species with native ones may be possible (Chesson 2000). I observed that lakes with better-developed shorelines, and therefore providing more diverse environments, may allow the native species to escape from the competition with invasive species (Podwysocki et al. 2024c). However, if the environment is rather homogenous, the spatial partitioning forces weaker species or populations to disperse (Latli et al. 2019). I have observed that the Eastern populations, although actively exploring a new environment, better compete for the preferred habitat than their Western counterparts. I expect two implications of such a result. Firstly, in case of the meeting of both groups, the Western populations may be forced to spread more. Their higher spreading capacity may be also determined by the development of locomotion-related traits (Podwysocki et al. 2024a). In practice, this could mean the colonisation of smaller rivers and tributaries by the Western populations. Currently, these watercourses are the refuge for native species (Grabowski et al. 2009), therefore, the colonisation of invasive amphipods in these ecosystems may pose a threat to native biota. Consequently, the Western populations may achieve a higher impact on the native communities than the Eastern Group. Moreover, the Eastern populations, which are bolder in exploring new environments, may be more vulnerable to attacks by predators (Jermacz et al. 2015). Finally, the Eastern Group may be less successful in further colonisation. However, the final result may be quite the opposite in the context of a warming climate. I have observed that the Eastern Group prefers higher temperatures which may favour its spread in the future (Hupało et al. 2018, Podwysocki et al. 2024e).

The impact of invasive species is the result of multiple traits, including predatory pressure. I have observed that both groups can have slightly different impacts due to differences in food preferences (Podwysocki et al. 2024b). The Western Group has better-developed traits playing the role in preying (Podwysocki et al. 2024a) and consequently is more specialised in feeding and consumes more food of animal origin than plants. This group can pose a higher threat to benthic communities due to enhanced predatory pressure. Contrary, the Eastern Group is less specialized in its diet and may consume a similar level of animal and plant material. Mouthparts and stomach development indicate a high proportion of plant material in their diet (Podwysocki et al. 2024a). This strategy may determine the success of this group, especially during the invasion of new environments and when establishing in a situation of limited food resources (Machovsky-Capuska et al. 2016). Although, the predatory pressure of this group on macroinvertebrates may be weaker, consuming high amounts of plant material may affect the leaf processing in the environment, replacing native herbivorous species and impacting the food webs in the ecosystem (MacNeil et al. 2011, Truhlar et al. 2013).

Summarizing, the wide dispersal of invasive species in diverse environments makes it possible to study variations in invasive potential between populations. Populations derived from genetically different source populations and inhabiting environments with different conditions may have a different invasive potential and consequently threaten the ecosystem to different degrees. Although both groups have successfully colonised most of the European major rivers, effectively threatening native species, intra-species variability may result in different further invasion pathways for that species and the environmental consequences of this process. Although the ultimate course of further invasion is difficult to predict, studies of many populations provide a closer picture of invasion dynamics, especially when different genetic variants interact with each other. When hybridization between variants is enabled, the subsequent course of invasion may depend on the current invasion potential of pure groups. Therefore, it is crucial to study the biology of invasive species using the population-level approach. Then, such results can apply to other invasive aquatic species.

Conclusions

1. Waters with more intensive boat traffic are more vulnerable to biological invasions.
2. Widely distributed genetic variants of aquatic invaders inhabiting various environments exhibit a high morphological variability being the adaptations to environmental novelty.
3. Amphipods that spread from the Danube Delta (Western Group) have morphological adaptations for predation and they are more specialised in feeding habits posing a higher predatory pressure on benthic organisms.
4. Amphipods that spread from the Dnieper Delta (Eastern Group) have morphological adaptations for herbivory and are less specialised in their diet, therefore, they are more adapted to cope with limited food resources and can affect leaf processing in the ecosystem.
5. Amphipods of different origins can compete for the preferred habitat with the Eastern Group having a higher competition capacity and forcing the Western Group, having additionally better developed locomotion traits, to spread more to new environments.
6. Morphological analyses are a good proxy of some behavioural traits determining the invasive potential.
7. Biological invasions should be more studied at the population level to better predict the invasive potential and better estimate the impact of invasive species.

References

Arbačiauskas K, Lesutiene J rate, Gasiu-naite ZR (2013) Feeding strategies and elemental composition in Ponto-Caspian peracaridans from contrasting environments: Can stoichiometric plasticity promote invasion success? Freshwater Biology 58: 1052–1068. https://doi.org/10.1111/fwb.12108

Bącela-Spychalska K, Grabowski M, Rewicz T, Konopacka A, Wattier R (2013) The "killer shrimp" *Dikerogammarus villosus* (Crustacea, Amphipoda) invading alpine lakes: Overland transport by recreational boats and scuba-diving gear as potential entry vectors? Aquatic Conservation: Marine and Freshwater Ecosystems 23: 606–618. https://doi.org/10.1002/aqc.2329

Bącela K, Grabowski M, Konopacka A (2008) *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda) enters Vistula – the biggest river in the Baltic basin. Aquatic Invasions 3: 95–98. https://doi.org/10.3391/ai.2008.3.1.16

Bellard C, Cassey P, Blackburn TM (2016) Alien species as a driver of recent extinctions. Biology Letters 12: 20150623. https://doi.org/10.1098/rsbl.2015.0623

Bij de Vaate A, Jażdzewski K, Ketelaars HAM, Gollasch S, Van der Velde G (2002) Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. Canadian Journal of Fisheries and Aquatic Sciences 59: 1159–1174. https://doi.org/10.1139/f02-098

Boets P, Lock K, Messiaen M, Goethals PLM (2010) Combining data-driven methods and lab studies to analyse the ecology of *Dikerogammarus villosus*. Ecological Informatics 5: 133–139. https://doi.org/10.1016/j.ecoinf.2009.12.005

Borza P, Huber T, Leitner P, Remund N, Graf W (2018a) How to coexist with the 'killer shrimp' *Dikerogammarus villosus*? Lessons from other invasive Ponto-Caspian peracarids. Aquatic Conservation: Marine and Freshwater Ecosystems 28: 1441–1450. https://doi.org/10.1002/aqc.2985

Borza P, Huber T, Leitner P, Remund N, Graf W (2018b) Niche differentiation among invasive Ponto-Caspian *Chelicorophium* species (Crustacea, Amphipoda, Corophiidae) by food particle size. Aquatic Ecology 52: 179–190. https://doi.org/10.1007/s10452-018-9653-8

Bradshaw CJA, Leroy B, Bellard C, Roiz D, Albert C, Fournier A, Barbet-Massin M, Salles JM, Simard F, Courchamp F (2016) Massive yet grossly underestimated global costs of invasive insects. Nature Communications 7: 12986. https://doi.org/10.1038/ncomms12986

Brandner J, Cerwenka AF, Schliewen UK, Geist J (2013) Bigger Is Better: Characteristics of Round Gobies Forming an Invasion Front in the Danube River. PLoS ONE 8: e73036. https://doi.org/10.1371/journal.pone.0073036

Bruijs MCM, Kelleher B, Van Der Velde G, De Vaate AB (2001) Oxygen consumption, temperature and salinity tolerance of the invasive amphipod *Dikerogammarus villosus*: Indicators of further dispersal via ballast water transport. Archiv fur Hydrobiologie 152: 633–646. https://doi.org/10.1127/archiv-hydrobiol/152/2001/633

Buchan LAJ, Padilla DK (1999) Estimating the probability of long-distance dispersal overland dispersal of invading aquatic species. Ecological Applications 9: 254–265.

Bystřický PK, Rutová T, Brož V, Gajdošová M, Juračka PJ, Copilaş-Ciocianu D, Petrusek A (2022) Distribution patterns at different spatial scales reveal reproductive isolation and frequent syntopy among divergent lineages of an amphipod species complex in Western Carpathian streams. Limnology and Oceanography 67: 2796–2808. https://doi.org/10.1002/lno.12239

Chesson P (2000) General theory of competitive coexistence in spatially-varying environments. Theoretical Population Biology 58: 211–237. https://doi.org/10.1006/tpbi.2000.1486

Clark JS, Lewis M, Horvath L (2001) Invasion by extremes: Population spread with variation in dispersal and reproduction. American Naturalist 157: 537–554.

Cole E, Keller RP, Garbach K (2019) Risk of invasive species spread by recreational boaters remains high despite widespread adoption of conservation behaviors. Journal of Environmental Management 229: 112–119.

Copilaş-Ciocianu D, Šidagytė-Copilaş E (2022) A substantial range expansion of alien Ponto-Caspian amphipods along the eastern Baltic Sea coast. Oceanologia 64: 227–232. https://doi.org/10.1016/j.oceano.2021.09.005

Copilaş-Ciocianu D, Rewicz T, Sands AF, Palatov D, Marin I, Arbačiauskas K, Hebert PDN, Grabowski M, Audzijonyte A (2022) A DNA barcode reference library for endemic Ponto-Caspian amphipods. Scientific Reports 12: 1–14. https://doi.org/10.1038/s41598-022-15442-w

Crowder DW, Snyder WE (2010) Eating their way to the top? Mechanisms underlying the success of invasive insect generalist predators. Biological Invasions 12: 2857–2876. https://doi.org/10.1007/s10530-010-9733-8

DAISIE (2009) Handbook of Alien Species in Europe. Springer, Dordrecht, The Netherlands.

Darrigran G, Damborenea C (2015) Strategies and measures to prevent spread of invasive species. In: Boltovskoy D (Ed.), Limnoperna Fortunei. Invading Nature - Springer Series in Invasion Ecology,. Springer, Cham. https://doi.org/https://doi.org/10.1007/978-3-319-13494-9_20

Dedyu II (1967) Amfipody i mizidy basseinov rek Dnestra i Pruta (Amphipods and Mysids in the Dniester and Prut River Basins) [in Russian].

Dick JTA, Platvoet D, Kelly DW (2002) Predatory impact of the freshwater invader *Dikerogammarus villosus* (Crustacea: Amphipoda). Canadian Journal of Fisheries and Aquatic Sciences 59: 1078–1084. https://doi.org/10.1139/f02-074

Feiner ZS, Rice JA, Aday DD (2013) Trophic niche of invasive white perch and potential interactions with representative reservoir species. Transactions of the American Fisheries Society 142: 628–641. https://doi.org/10.1080/00028487.2013.763854

Galil BS, Nehring S, Panov V (2008) Waterways as Invasion Highways – Impact of Climate Change and Globalization. In: Nentwig W (Ed.), Biological Invasions. Springer, Berlin, Heidelberg.

Galipaud M, Gauthey Z, Turlin J, Bollache L, Lagrue C (2015) Mate choice and male–male competition among morphologically cryptic but genetically divergent amphipod lineages. Behavioral Ecology and Sociobiology 69: 1907–1916. https://doi.org/10.1007/s00265-015-2003-0

Gallardo B, Aldridge DC (2013) The “dirty dozen”: Socio-economic factors amplify the invasion potential of 12 high-risk aquatic invasive species in Great Britain and Ireland. Journal of Applied Ecology: 1–10. https://doi.org/10.1111/1365-2664.12079

Gormley AM, Forsyth DM, Griffioen P, Lindeman M, Ramsey DS, Scroggie MP, Woodford L (2011) Using presence-only and presence–absence data to estimate the current and potential distributions of established invasive species. Journal of Applied Ecology 48: 25–34.

Grabowski M, Bącela K, Konopacka A (2007) How to be an invasive gammarid (Amphipoda: Gammaroidea) - Comparison of life history traits. Hydrobiologia 590: 75–84. https://doi.org/10.1007/s10750-007-0759-6

Grabowski M, Bącela K, Konopacka A, Jażdżewski K (2009) Salinity-related distribution of alien amphipods in rivers provides refugia for native species. Biological Invasions 11: 2107–2117. https://doi.org/10.1007/s10530-009-9502-8

Grudule N, Parele E, Arbačiauskas K (2007) Distribution of Ponto-Caspian amphipod *Pontogammarus robustoides* in Latvian waters. Acta Zoologica Lituanica 17: 28–32. https://doi.org/10.1080/13921657.2007.10512812

Hänfling B, Edwards F, Gherardi F (2011) Invasive alien Crustacea: Dispersal, establishment, impact and control. BioControl 56: 573–595. https://doi.org/10.1007/s10526-011-9380-8

Haubrock PJ, Soto I, Ahmed DA, Ansari AR, Tarkan AS, Kurtul I, Macêdo RL, Lázaro-Lobo A, Toutain M, Parker B, Błońska D, Guareschi S, Cano-Barbacil C, Dominguez Almela V, Andreou D, Moyano J, Akalın S, Kaya C, Bayçelebi E, Yoğurtçuoğlu B, Briski E, Aksu S, Emiroğlu Ö, Mammola S, De Santis V, Kourantidou M, Pincheira-Donoso D, Britton JR, Kouba A, Dolan EJ, Kirichenko NI, García-Berthou E, Renault D, Fernandez RD, Yapıcı S, Giannetto D, Nuñez MA, Hudgins EJ, Pergl J, Milardi M, Musolin DL, Cuthbert RN (2024) Biological invasions are a population-level rather than a species-level phenomenon. Global Change Biology 30: 1–20. https://doi.org/10.1111/gcb.17312

Hegarty MJ (2012) Invasion of the hybrids. Molecular Ecology 21: 4669–4671. https://doi.org/10.1111/j.1365-294X.2012.05720.x

Hellmann C, Schöll F, Worischka S, Becker J, Winkelmann C (2017) River-specific effects of the invasive amphipod *Dikerogammarus villosus* (Crustacea: Amphipoda) on benthic communities. Biological Invasions 19: 381–398. https://doi.org/10.1007/s10530-016-1286-z

Hellmann C, Worischka S, Mehler E, Becker J, Gergs R, Winkelmann C (2015) The trophic function of *Dikerogammarus villosus* (Sowinsky, 1894) in invaded rivers: A case study in the Elbe and Rhine. Aquatic Invasions 10: 385–397. https://doi.org/10.3391/ai.2015.10.4.03

Hesselschwerdt J, Meeker J, Wantzen KM (2008) Gammarids in Lake Constance: Habitat segregation between the invasive *Dikerogammarus villosus* and the indigenous *Gammarus roeselii*. Fundamental and Applied Limnology 173: 177–186. https://doi.org/10.1127/1863-9135/2008/0173-0177

Hoffmann AA, Hercus MJ (2000) Environmental stress as an evolutionary force. BioScience 50: 217–226. https://doi.org/10.1641/0006-3568(2000)050[0217:ESAAEF]2.3.CO;2

Hupało K, Riss HW, Grabowski M, Thiel J, Bącela-Spychalska K, Meyer EI (2018) Climate change as a possible driver of invasion and differential in HSP70 expression in two genetically distinct populations of the invasive killer shrimp, *Dikerogammarus villosus*. Biological Invasions 20: 2047–2059. https://doi.org/10.1007/s10530-018-1679-2

Jabłońska A, Mamos T, Gruszka P, Szlauer-łUkaszewska A, Grabowski M (2018) First record and DNA barcodes of the aquarium shrimp, *Neocaridina davidi*, in Central Europe from thermally polluted River Oder canal, Poland. Knowledge and Management of Aquatic Ecosystems 419. https://doi.org/10.1051/kmae/2018004

Jackson MC, Evangelista C, Zhao T, Lecerf A, Britton JR, Cucherousset J (2017) Between-lake variation in the trophic ecology of an invasive crayfish. Freshwater Biology 62: 1501–1510. https://doi.org/10.1111/fwb.12957

Jażdżewski K (1980) Range Extensions of Some Gammaridean Species in European Inland Waters Caused by Human Activity. Crustaceana: 84–107.

Jażdżewski K, Konopacka A, Grabowski M (2005) Native and alien Malacostracan Crustacea along the Polish

Baltic Sea coast in the twentieth century Oceanological and Hydrobiological Studies Vol . XXXIV , Supplement 1. Oceanobiological and Hydrobiological Studies 34: 175–193.

Jermacz Ł, Dzierzyńska A, Kakareko T, Poznańska M, Kobak J (2015) The art of choice: Predation risk changes interspecific competition between freshwater amphipods. Behavioral Ecology 26: 656–664. https://doi.org/10.1093/beheco/arv009

van Kleunen M, Dawson W, Schlaepfer D, Jeschke JM, Fischer M (2010) Are invaders different? A conceptual framework of comparative approaches for assessing determinants of invasiveness. Ecology Letters 13: 947–958.

Kobak J, Jermacz Ł, Dzierzyńska-Białończyk A (2015) Substratum preferences of the invasive killer shrimp *Dikerogammarus villosus*. Journal of Zoology 297: 66–76. https://doi.org/10.1111/jzo.12252

Koester M, Bayer B, Gergs R (2016) Is *Dikerogammarus villosus* (Crustacea, Gammaridae) a 'killer shrimp' in the River Rhine system? Hydrobiologia 768: 299–313. https://doi.org/10.1007/s10750-015-2558-9

Kostrzewa J, Grabowski M (2003) Opportunistic feeding strategy as a factor promoting the expansion of racer goby (*Neogobius gymnotrachelus* Kessler, 1857) in the Vistula basin. Lauterbornia 48: 91–100.

Latli A, Michel LN, Lepoint G, Kestemont P (2019) River habitat homogenisation enhances trophic competition and promotes individual specialisation among young of the year fish. Freshwater Biology 64: 520–531. Available from: https://doi.org/10.1111/fwb.13239.

Lenz M, da Gama BAP, Gerner N V., Gobin J, Gröner F, Harry A, Jenkins SR, Kraufvelin P, Mummelthei C, Sareyka J, Xavier EA, Wahl M (2011) Non-native marine invertebrates are more tolerant towards environmental stress than taxonomically related native species: Results from a globally replicated study. Environmental Research 111: 943–952. https://doi.org/10.1016/j.envres.2011.05.001

Lipinskaya TP, Makarenko AI (2019) Comparative Analysis of Predatory Behavior of Invasive Alien *Dikerogammarus villosus* (Sowinsky, 1894) and Native *Gammarus varsoviensis* Jazdzewski, 1975 Amphipods. Russian Journal of Biological Invasions 10: 349–357.

Lowry E, Rollinson EJ, Laybourn AJ, Scott TE, Aiello-Lammens ME, Gray SM, Mickley J, Gurevitch J (2013) Biological invasions: a field synopsis, systematic review, and database of the literature. Ecology and Evolution 3: 182–196.

Machovsky-Capuska GE, Senior AM, Simpson SJ, Raubenheimer D (2016) The Multidimensional Nutritional Niche. Trends in Ecology and Evolution 31: 355–365. https://doi.org/10.1016/j.tree.2016.02.009

MacNeil C, Dick JTA, Platvoet D, Briffa M (2011) Direct and indirect effects of species displacements: an invading freshwater amphipod can disrupt leaf-litter processing and shredder efficiency. Journal of the North American Benthological Society 30: 38–48.

Masson L, Brownscombe JW, Fox MG (2016) Fine scale spatio-temporal life history shifts in an invasive species at its expansion front. Biological Invasions 18: 775–792. https://doi.org/10.1007/s10530-015-1047-4

Minchin D, Arbačiauskas K, Daunys D, Ezhova E, Grudule N, Kotta J, Molchanova N, Olenin S, Višinskienė G, Strake S (2019) Rapid expansion and facilitating factors of the Ponto-Caspian invader *Dikerogammarus villosus* within the Eastern Baltic sea. Aquatic Invasions 14: 165–181. https://doi.org/10.3391/ai.2019.14.2.02

Mohit S, Johnson T, Arnott S (2021) Recreational watercraft decontamination: can current recommendations reduce aquatic invasive species spread? Management of Biological Invasions 12: 148–164. https://doi.org/10.3391/mbi.2021.12.1.10

Moyle PB, Light T (1996) Biological invasions of fresh water: Empirical rules and assembly theory. Biological Conservation 78: 149–161. https://doi.org/10.1016/0006-3207(96)00024-9

Nehring S (2005) International shipping - a risk for aquatic biodiversity in Germany. NeoBiota 6: 125–143.

Neilson ME, Stepien CA (2009) Escape from the Ponto-Caspian: Evolution and biogeography of an endemic goby species flock (Benthophilinae: Gobiidae: Teleostei). Molecular Phylogenetics and Evolution 52: 84–102. https://doi.org/10.1016/j.ympev.2008.12.023

Nesemann H, Pöckl M (1995) Distribution of epigean Malacostraca in the middle and upper Danube (Hungary, Austria, Germany). Miscellanea Zoologica Hungaricaoologica hungaria: 49–68.

Pauli NC, Briski E (2018) Euryhalinity of ponto-caspian invaders in their native and introduced regions. Aquatic Invasions 13: 439–447. https://doi.org/10.3391/ai.2018.13.4.02

Platvoet D, Van Der Velde G, Dick JTA, Li S (2009) Flexible omnivory in *Dikerogammarus villosus* (Sowinsky, 1894) (Amphipoda) - Amphipod Pilot Species Project (AMPIS) Report 5. Crustaceana 82: 703–720. https://doi.org/10.1163/156854009X423201

Pöckl M (2009) Success of the invasive Ponto-caspian amphipod *Dikerogammarus villosus* by life history traits and reproductive capacity. Biological Invasions 11: 2021–2041. https://doi.org/10.1007/s10530-009-9485-5

Podwysocki K, Bącela-Spychalska K, Desiderato A, Rewicz T, Copilaş-Ciocianu D (2024a) Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe. Hydrobiologia. https://doi.org/10.1007/s10750-024-05565-8

Podwysocki K, Szczerkowska-Majchrzak E, Jermacz Ł, Kobak J, Bącela-Spychalska K, Rewicz T, Desiderato A (2024b) Predation or omnivory – two different feeding patterns displayed by two intraspecific lineages of the invasive Ponto-Caspian amphipod - *Dikerogammarus villosus* . Freshwater Biology Preprint.

Podwysocki K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K (2024c) Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161–192. https://doi.org/10.3897/neobiota.90.109221

Podwysocki K, Szczerkowska-Majchrzak E, Desiderato A, Jermacz Ł, Kobak J, Bącela-Spychalska K, Rewicz T (2024d) The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). Animal Behaviour Preprint.

Podwysocki K, Desiderato A, Szczerkowska-Majchrzak E, Copilaș-Ciocianu D, Jermacz Ł, Kobak J, Bącela-Spychalska K, Rewicz T (2024e) Experimental assessment of the invasive potential of the two intraspecific lineages of the Ponto-Caspian amphipod - *Dikerogammarus villosus* (Crustacea: Amphipoda): Does hybridization increase invasive potential? In: 13th International Conference on Biological Invasions. , 163.

Pyšek P, Hulme PE, Simberloff D, Bacher S, Blackburn TM, Carlton JT, Dawson W, Essl F, Foxcroft LC, Genovesi P, Jeschke JM, Kühn I, Liebhold AM, Mandrak NE, Meyerson LA, Pauchard A, Pergl J, Roy HE, Seebens H, van Kleunen M, Vilà M, Wingfield MJ, Richardson DM (2020) Scientists' warning on invasive alien species. Biological Reviews 95: 1–24. https://doi.org/10.1111/brv.12627

Rachalewski M, Banha F, Grabowski M, Anastácio PM (2013) Ectozoochory as a possible vector enhancing the spread of an alien amphipod *Crangonyx pseudogracilis*. Hydrobiologia 717: 109–117. https://doi.org/10.1007/s10750-013-1577-7

Rewicz T, Grabowski M, Macneil C, Bącela-Spychalska K (2014) The profile of a ' perfect ' invader – the case of killer shrimp, *Dikerogammarus villosus*. Aquatic Invasions 9: 267–288. https://doi.org/10.3391/ai.2014.9.3.04

Rewicz T, Wattier RA, Rigaud T, Bącela-Spychalska K, Grabowski M (2015a) Isolation and characterization of 8 microsatellite loci for the "killer shrimp'', an invasive Ponto-Caspian amphipod *Dikerogammarus villosus* (Crustacea: Amphipoda). Molecular Biology Reports 42: 13–17. https://doi.org/10.1007/s11033-014-3742-0

Rewicz T, Wattier R, Grabowski M, Rigaud T, Bącela-Spychalska K (2015b) Out of the Black Sea: Phylogeography of the Invasive Killer Shrimp *Dikerogammarus villosus* across Europe. Heath D (Ed.). PLOS ONE 10: e0118121. https://doi.org/10.1371/journal.pone.0118121

Rewicz T, Wattier R, Rigaud T, Grabowski M, Mamos T, Bącela-Spychalska K (2017) The killer shrimp, *Dikerogammarus villosus*, invading European Alpine Lakes: A single main source but independent founder events with an overall loss of genetic diversity. Freshwater Biology 62: 1036–1051. https://doi.org/10.1111/fwb.12923

Ricciardi A, Kipp R (2008) Predicting the number of ecologically harmful exotic species in an aquatic system. Diversity and Distributions 14: 374–380. https://doi.org/10.1111/j.1472-4642.2007.00451.x

Richter L, Schwenkmezger L, Becker J, Winkelmann C, Hellmann C, Worischka S (2018) The very hungry amphipod: the invasive Dikerogammarus villosus shows high consumption rates for two food sources and independent of predator cues. Biological Invasions 20: 1321–1335. https://doi.org/10.1007/s10530-017-1629-4

van Riel MC, van der Velde G, de Vaate AB (2011) Dispersal of invasive species by drifting. Current Zoology 57: 818–827. https://doi.org/10.1093/czoolo/57.6.818

Rius M, Darling JA (2014) How important is intraspecific genetic admixture to the success of colonising populations? Trends in Ecology and Evolution 29: 233–242.

Roman J, Darling JA (2007) Paradox lost: genetic diversity and the success of aquatic invasions. Trends in Ecology and Evolution 22: 454–464. https://doi.org/10.1016/j.tree.2007.07.002

Ronce O (2007) How does it feel to be like a rolling stone? Ten questions about dispersal evolution. Annual Review of Ecology, Evolution, and Systematics 38: 231–253. https://doi.org/10.1146/annurev.ecolsys.38.091206.095611

Sakai AK, Allendorf FW, Holt JS, Lodge M, Molofsky J, With KA, Cabin RJ, Cohen JE, Norman C, Mccauley DE, Neil PO, Parker M, Thompson JN, Weller SG (2001) The population biology of invasive species. Annual Review of Ecology, Evolution, and Systematics 32: 305–332.

Šidagytė E, Solovjova S, Šniaukštaitė V, Šiaulys A, Olenin S, Arbačiauskas K (2017a) The killer shrimp *Dikerogammarus villosus* (Crustacea, Amphipoda) invades Lithuanian waters, South-Eastern Baltic Sea. Oceanologia 59: 85–91. https://doi.org/10.1016/j.oceano.2016.08.004

Šidagytė E, Razlutskij V, Alekhnovich A, Rybakovas A, Moroz M, Šniaukštaitė V, Vaitonis G, Arbačiauskas K (2017b) Predatory diet and potential effects of *Orconectes limosus* on river macroinvertebrate assemblages of the southeastern baltic sea basin: Implications for ecological assessment. Aquatic Invasions 12: 523–540. https://doi.org/10.3391/ai.2017.12.4.09

Simberloff D, Martin JL, Genovesi P, Maris V, Wardle DA, Aronson J, Courchamp F, Galil B, García-Berthou E, Pascal M, Pyšek P, Sousa R, Tabacchi E, Vilà M (2013) Impacts of biological invasions: What's what and the way forward. Trends in Ecology and Evolution 28: 58–66. https://doi.org/10.1016/j.tree.2012.07.013

Sousa R, Nogueira JG, Padilha J (2024a) Moving from the species to the population level in biological invasions. Global Change Biology 30: 1–4. https://doi.org/10.1111/gcb.17396

Sousa R, Alves H, Gonçalves D, Padilha J, Teixeria A (2024b) The hidden side of the intrapopulation level in biological invasions. Preprint.

Truhlar AM, Dodd JA, Aldridge DC (2013) Differential leaf-litter processing by native (*Gammarus pulex*) and invasive (*Dikerogammarus villosus*) freshwater crustaceans under environmental extremes. Aquatic Conservation: Marine and Freshwater Ecosystems 24: 56–65. https://doi.org/10.1002/aqc.2375

Valiente AG, Ayllon F, Nuñez P, Juanes F, Garcia-Vazquez E (2010) Not all lineages are equally invasive: Genetic origin and life-history in Atlantic salmon and brown trout acclimated to the Southern Hemisphere. Biological Invasions 12: 3485–3495. https://doi.org/10.1007/s10530-010-9746-3

Van der Velde G, Rajagopal S, Kelleher B, Muskó IB, De Vaate AB (2000) Ecological impact of crustacean invaders: General considerations and examples from the Rhine River. Biodiversity Crisis and Crustacea.

Walker B, Steffen W (1997) An overview of the implications of global change for natural and managed terrestrial ecosystems. Ecology and Society 1. https://doi.org/10.5751/es-00028-010202

Wesselingh FP, Neubauer TA, Anistratenko V V., Vinarski M V., Yanina T, ter Poorten JJ, Kijashko P, Albrecht C, Anistratenko OY, D'Hont A, Frolov P, Gándara AM, Gittenberger A, Gogaladze A, Karpinsky M, Lattuada M, Popa L, Sands AF, van de Velde S, Vandendorpe J, Wilke T (2019) Mollusc species from the Pontocaspian region - an expert opinion list. ZooKeys 2019: 31–124. https://doi.org/10.3897/zookeys.827.31365

Wijnhoven S, van Riel MC, van der Velde G (2003) Exotic and indigenous freshwater gammarid species: physiological tolerance to water temperature in relation to ionic content of the water. Aquatic Ecology 37: 151–158. https://doi.org/10.1023/A

Yanina TA (2014) The Ponto-Caspian region: Environmental consequences of climate change during the Late Pleistocene. Quaternary International. https://doi.org/10.1016/j.quaint.2014.01.045

Zhulidov A V., Kozhara A V., van der Velde G, Leuven RSEW, Son MO, Gurtovaya TY, Zhulidov DA, Nalepa TF, Santiago-Fandino VJR, Chuikov YS (2018) Status of the invasive brackish water bivalve *Mytilopsis leucophaeata* (Conrad, 1831) (Dreissenidae) in the Ponto-Caspian region. BioInvasions Records 7: 111–120. https://doi.org/10.3391/bir.2018.7.2.02

Copies of publications included in the PhD thesis

Publication I.

Podwysocki K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K (2024c) Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161–192. https://doi.org/10.3897/neobiota.90.109221

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- **IF: 3.8**
- **Points of the Ministry of Education and Science: 140 pkt.**

NeoBiota 90: 161–192 (2024)
doi: 10.3897/neobiota.90.109221
https://neobiota.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
NeoBiota
Advancing research on alien species and biological invasions

Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities

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Academic editor: Eric Larson | Received 8 July 2023 | Accepted 14 December 2023 | Published 29 January 2024

Citation: Podwysocki K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K (2024) Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161–192. https://doi.org/10.3897/neobiota.90.109221

Abstract

Non-indigenous species (NIS) contribute to the decrease of native species' diversity on a local and global scale. One of Europe's most significant donors of freshwater invasions is the Ponto-Caspian Region. Following the construction of artificial canals connecting isolated waterbodies and the resulting heavy boat traffic, the Ponto-Caspian Amphipoda started to spread in Europe. Four amphipod species: *Dikerogammarus haemobaphes*, *Dikerogammarus villosus*, *Pontogammarus robustoides* and *Chaetogammarus ischnus* have invaded the Masurian Lakeland (North-eastern Poland). Based on literature and our data, we studied their distribution in 22 lakes in the region during the years 2001–2016. We analysed their distribution against several water quality parameters and levels of anthropogenic pressure. Our results also present the first records of two new invaders, *D. villosus* and *C. ischnus*, in the studied area. We show that the relative abundance and frequency of these two species rapidly increase and, simultaneously, the populations of the earlier invaders, i.e. *D. haemobaphes* and *P. robustoides*, decrease. The native species – *Gammarus lacustris* – seems to be negatively affected by NIS richness, as well as by the proximity of towns. The spread of NIS in the lakes appears to be facilitated by boating and the lower complexity of the shoreline. Our study shows how anthropogenic pressure, especially tourism, can facilitate bioinvasion, jeopardising native biodiversity unless appropriate regulations are implemented.

Keywords

assemblage succession, biological invasions, lakes, propagule pressure, recreational boating, time series, tourist pressure

Introduction

Biological invasions are perceived as the second strongest threat to biodiversity on a local and global scale, right after habitat degradation (e.g. CBD (2000); Sala et al. (2000); Dudgeon et al. (2006); Kettunen et al. (2009); Strayer and Dudgeon (2010); Lambertini et al. (2011); Mačić et al. (2018); Lipták et al. (2019); Iqbal et al. (2021); Yang et al. (2021); Vantarová et al. (2023)). Many non-indigenous species (NIS) cause declines in abundance and diversity of native species, which is particularly apparent in Europe and the USA (e.g. Pinkster et al. (1992); Dick and Platvoet (1996, 2000); Ricciardi and MacIsaac (2000); Ricciardi (2006); Bellard et al. (2016); Panlasigui et al. (2018); Albano et al. (2021); Haubrock et al. (2021); Yang et al. (2021)) and is more prominent in freshwater ecosystems than in marine and terrestrial ones (Strayer and Dudgeon 2010). Many studies show high economic costs incurred by biological invasions on a global scale (Pyšek and Richardson 2010; Cuthbert et al. 2021a, b; Kouba et al. 2022). The average annual costs of preventing biological invasions and reversing their effects globally reach $76 billion (Bradshaw et al. 2016); however, the costs of prevention of invasion are much lower than post-invasion management (Cuthbert et al. 2021a). Globally, the economic costs of aquatic bioinvasions have been estimated at $23 billion (Cuthbert et al. 2021b). The costs of amphipod invasions constitute a small part of the global costs of aquatic crustacean invasions ($180,000 out of an estimated $271 million); however, these costs are underestimated (Kouba et al. 2022).

Even though surface freshwaters represent only 0.01% of the Earth's water resources and constitute 0.80% of the Earth's surface, they are inhabited by ca. 6% of the world's species (Dudgeon et al. 2006; Strayer and Dudgeon 2010). Therefore, freshwater ecosystems are precious from environmental, economic, sanitary, cultural and scientific perspectives and also constitute a valuable spot for tourism (Dudgeon et al. 2006; Hall and Härkönen 2006). Unfortunately, these ecosystems are in crisis, as indicated by stronger biodiversity loss than in terrestrial ecosystems (Dudgeon et al. 2006). According to the Water Framework Directive (European Environment Agency 2000), every waterbody in the EU should have achieved a high or at least good ecological and chemical status by 2015. However, the latest reports indicate that only 40% of such waters have achieved a satisfactory, healthy status (European Environment Agency 2018). Land use and agriculture are amongst the most important factors in aquatic ecosystems' declining conditions globally (Foley et al. 2005; Feld et al. 2016). Thus, although freshwater ecosystems constitute only a tiny fraction of the Earth's surface, high anthropogenic pressure results in a more pronounced negative impact of invaders on native species than in marine ecosystems (Ricciardi and Kipp 2008).

One of the richest European sources of species invading inland waters is the Ponto-Caspian Region (Ricciardi and MacIsaac 2000; Bij de Vaate et al. 2002; Galil et al. 2008; Panov et al. 2009; Copilaș-Ciocianu et al. 2023a). This region covers the coastal area of the Caspian, Black, Aral and Azov Seas, with their brackish limans and deltas of rivers discharging into these seas (Jażdżewski 1980). The Ponto-Caspian basin constitutes a hotspot of crustacean diversity, particularly in the case of amphipod crustaceans (Cristescu and Hebert 2005; Väinölä et al. 2008; Copilaș-Ciocianu and Sidorov 2022; Copilaș-Ciocianu et al. 2022). Ponto-Caspian amphipods comprise around 10% of European freshwater invasive species (Pöckl et al. 2011). One of the main significant causes fuelling the bioinvasions of Ponto-Caspian species is the construction of canals that connect previously isolated watersheds (e.g. Jażdżewski (1980); Bij de Vaate et al. (2002); Nehring (2005); Galil et al. (2008); Arbačiauskas et al. (2010); Minchin et al. (2019); Jażdżewska et al. (2020)). Another important factor is translocations of species in ballast waters (Jażdżewski 1980; Pinkster et al. 1992; Bij de Vaate et al. 2002; Zhulidov et al. 2018). However, a more important vector of bioinvasions in freshwater ecosystems is transporting on biofouled hulls, filters and other submerged parts of vessels (Nehring 2005; Hewitt et al. 2009; Bącela-Spychalska et al. 2013; Anderson et al. 2014, 2015; De Ventura et al. 2016; Rewicz et al. 2017; Rodríguez-Rey et al. 2021). Biofouling of vessels by species resistant to desiccation enables their subsequent overland transport and the colonisation of isolated waterbodies (Bącela-Spychalska et al. 2013; Rachalewski et al. 2013; De Ventura et al. 2016). Fishing and diving equipment can also be an effective vector of invasions (Bącela-Spychalska et al. 2013; Anderson et al. 2014; Smith et al. 2020). Moreover, many species are also intentionally introduced into freshwater ecosystems (Grigorovich et al. 2002; Nehring 2005).

Seven species of Ponto-Caspian gammarids (Amphipoda, Gammaroidea) have already been recorded from Polish freshwaters: *Chaetogammarus ischnus* (Stebbing, 1899), *Dikerogammarus haemobaphes* (Eichwald, 1841), *Dikerogammarus villosus* (Sowinsky, 1894), *Obesogammarus crassus* (G.O. Sars, 1894), *Pontogammarus robustoides* (Sars, 1894), *Spirogammarus major* (Cărăușu, 1943) (former European population of *Echinogammarus trichiatus*) and *Chelicorophium curvispinum* (G.O. Sars, 1895) (Konopacka 1998; Gruszka 1999; Jażdżewski and Konopacka 2000; Konopacka and Jażdżewski 2002; Jażdżewski et al. 2005; Grabowski et al. 2007; Rachalewski et al. 2013; Copilaș-Ciocianu et al. 2023b). These species are already widely distributed in European inland waters, where they arrived through well-defined migration corridors: northern, central and southern (Bij de Vaate et al. 2002; Panov et al. 2009). Not only have they colonised the major rivers and canals constituting the invasions corridors, but also spread to the watersheds of these rivers, as well as many European lakes, for example, the Alpine Lakes (Rewicz et al. 2017) and the Great Masurian Lakes in Poland (Jażdżewski 2003; Jażdżewska and Jażdżewski 2008). An extensive up-to-date description of the distribution of alien freshwater amphipods in Europe can be found in Copilaș-Ciocianu et al. (2023a). As the dynamics of invasion in terms of species and ecosystem vulnerability varies and the impact of NIS depends on their invasion process (i.e. propagule pressure, species interactions), there is a constant need for monitoring and estimating trends and threats regarding invasions. The impact of invasive species on aquatic ecosystems is profound (Kurashov et al. 2012). Their introduction may lead to drastic changes in the macroinvertebrate community structure and affect the functioning of whole ecosystems (Jones et al. 1994; Jones et al. 1997; Lambertini et al. 2011). NIS can modify habitats as well as food chains and contribute to changes in energy flows – benthic communities can be transformed from being energy suppliers to upper trophic levels becoming major consumers of ecosystem energy (Nalepa et al. 2009; Kurashov et al. 2012).

Lakes seem to be particularly susceptible to biological invasions, as many of them are under high tourist pressure, resulting in a higher probability of alien species introduction, even if the lakes are not directly connected with the invasion corridor (Bącela-Spychalska et al. 2013; Bącela-Spychalska 2016; De Ventura et al. 2016; Rewicz et al. 2017). One such region is the Masurian Lakeland. It is the most popular area for yachting in Poland and one of central Europe's main inland yachting regions. The region is extensively used for associated recreational activities, particularly angling and camping (Kistowski and Śleszyński 2010; Ulikowski et al. 2021). Unfortunately, the level of knowledge about the risks of spreading invasive Amphipoda in this region is poor and out of date (Jażdżewski 2003; Jażdżewska and Jażdżewski 2008). Previous studies were based on sampling from only a few lakes, provided mainly presence/absence data and predated the effect of increased recreational pressure. Knowledge about the role of tourism, shipping and other factors in biological invasions in the Masurian Lakeland is poor and demands study. Given the significance of these factors in other regions, it is likely that their influence in the Masurian Lakeland is also considerable. The intensity of shipping and, therefore, its effect on biological invasions will increase with time (Sardain et al. 2019). Thus, it is crucial to understand these mechanisms in the study area. We also do not know how the invasion of amphipods affected native amphipods in the region. With regards to the faunistic data about the native amphipod species in the Lakeland, Jażdżewski and Konopacka (1995) mention two widely distributed lacustrine species, namely *Gammarus lacustris* G.O. Sars, 1863 and *Pallasiola quadrispinosa* (G.O. Sars, 1867). However, these data are old and require updating.

The aims of our study were: i) to update the knowledge on the distribution and expansion of the Ponto-Caspian amphipod fauna in the Masurian Lakeland; ii) to assess the distribution of native vs. invasive Ponto-Caspian amphipods in the context of biotic and abiotic characteristics of the lakes and anthropogenic pressure in this region, using both historical and newly-obtained data. Based on observed trends in other regions (e.g. Dick and Platvoet (2000); Grabowski et al. (2006); Van der Velde et al. (2009); Meßner and Zettler (2021)), we assumed that some invasive amphipods are replaced by stronger competitors and that native species are not able to co-exist with the invasive species. We hypothesise that high tourist pressure contributes to the dispersion of invasive amphipods, while the occurrence of the native species is linked to isolated lakes.

We tracked the distribution of invasive Amphipoda in the Masurian Lakeland since 2001, based on literature and our data. To explore the relationship between the structure of amphipod assemblages and lake characteristics, including human tourist pressure in the years 2014 and 2016, we collected data on the relative abundance of amphipods, measured basic water parameters, implemented hydromorphological data and estimated the tourist pressure.

Materials and methods

Study area

The Masurian Lakeland (Pojezierze Mazurskie in Polish) is a lake district (macroregion) in North-eastern Poland with a surface area of 52,000 km^2 including seven mesoregions, amongst others, the Land of the Great Masurian Lakes (Kraina Wielkich Jezior Mazurskich in Polish) and the Ełckie Lakeland (Pojezierze Ełckie in Polish) (Kondracki 2002). The landscape was formed between 16,000 and 11,000 BP (at the end of the last glaciation) and is characterised by strong latitude differentiation, dominantly with moraine hills (Hillbricht-Ilkowska et al. 2000; Ulikowski et al. 2021) and with glacial tills as a dominant component of the soil substratum (Hillbricht-Ilkowska et al. 2000). The lakes are mainly surrounded by a mosaic of agricultural areas and forests giving similar input of allochthonous organic and mineral matter to each lake (Chróst and Siuda 2006; Ejsmont-Karabin et al. 2020). Most lakes of this region are dimictic with summer thermal stratification (Ulikowski et al. 2021). They are connected with main European watersheds via artificial canals and small rivers: the River Pisa (flowing into the River Narew and then into the River Vistula) and the River Węgorapa (flowing into the River Pregolya and then into the Vistula Lagoon) (Bajkiewicz-Grabowska 2008; Jażdżewska and Jażdżewski 2008; Ulikowski et al. 2021). This connectivity increases the probability of invasive amphipods spreading in the region. For this study, we selected lakes with historical faunistic data, based on Jażdżewski and Konopacka (1995), as well as along a gradient of tourist pressure, including more natural and isolated lakes. We also selected sampling points on the rivers, i.e. the River Węgorapa, the River Pisa and the River Narew, which connect the Masurian Lakeland with major rivers, for example, the River Vistula and the River Neman (Fig. 1; see also Suppl. material 1).

Sampling and data collection

Our dataset consists of two types of data: (*i*) published, including the years between 2001 and 2007 (Jażdżewski 2003; Jażdżewska and Jażdżewski 2008) and (*ii*) new data coming from field surveys in 2008, 2009, 2014 and 2016. Additionally, to facilitate the monitoring of the amphipod expansion and to model the distribution of native *Gammarus lacustris*, we incorporated records from several lakes and the River Narew, which are situated outside of the study area (see Suppl. material 1). The studies that were conducted between 2001 and 2009 only have a qualitative character (i.e. presence/absence of amphipod species), while for 2014 and 2016, the species abundances are available. Generally, sampling was done through "kick-sampling" with a benthic hand-net with a mesh size of 0.5 mm, used for 45 min at each station, performed by two people with equal effort, from all available littoral habitats (sand, mud, gravel, stones and submerged macrophytes) at depths from 0.05 to 0.5 m. Such a semi-quantitative method gives reliable and comparable results for all sampling points and all study years/periods (Jażdżewski et al. 2002; Grabowski et al. 2006). The amphipods

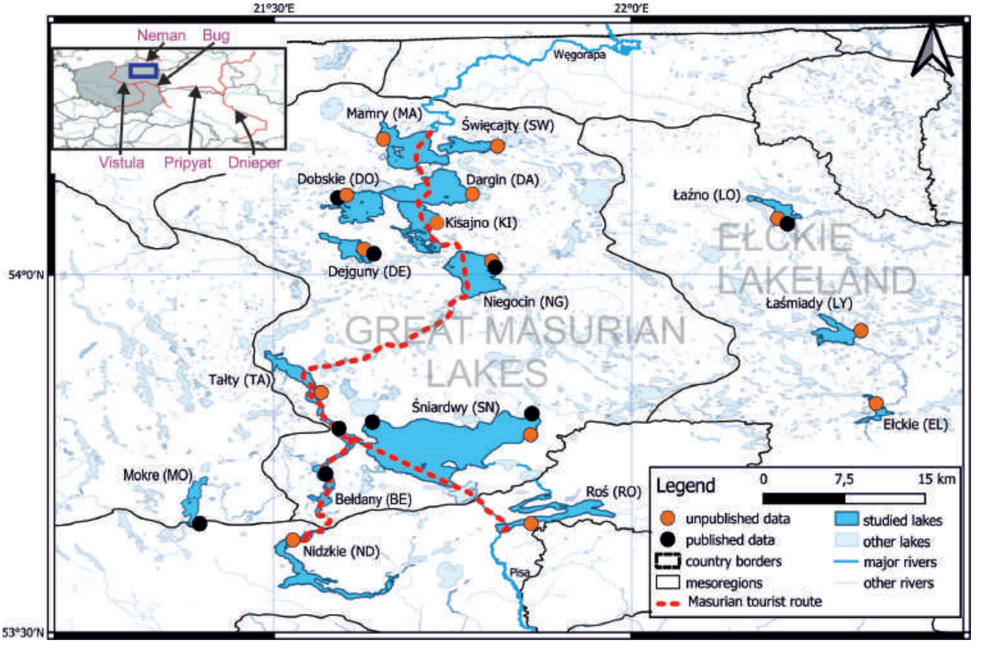


Figure 1. The sites in the Masurian Lakeland. Sites were divided into previously unpublished (records of this study) and published (Jażdżewski 2003; Jażdżewska and Jażdżewski 2008). Mesoregions are delimited according to Kondracki (2002). The two-letter acronyms for particular lakes were used in further Figures and Suppl. material 1.

were preserved in 96% ethanol and then identified in the laboratory to the species level, based on the available literature (Mordukhai-Boltovskoi 1964; Eggers and Martens 2001). This collection and preservation protocol was used at all studied sites and in all study years.

To detect the potential role of biotic and abiotic factors, as well as human pressure on the presence of invasive amphipods in the lakes sampled in 2014 and 2016, we used topological and anthropogenic variables, such as the surface-volume ratio or the distance from town. As a proxy of the level of anthropogenic pressure, we used the water quality status (water QS) from Soszka et al. (2016). This index categorises the waterbodies into six water quality categories (ranging from excellent – class I, to very poor – class VI), based on species assemblages and chemical and physical parameters of water according to the Water Framework Directive (European Environment Agency 2000). We presume that lower values of this variable (lower water class), indicating increased species diversity and reduced levels of nutrients and heavy metals in the water (better water quality), correspond to lower levels of anthropogenic pressure on the lake (European Environment Agency 2000; Sánchez et al. 2007; Lobato et al. 2015). Environmental heterogeneity creates more niches that can be occupied by co-occurring species (Chesson 2000). Thus, we used two indices: shoreline development (shoreline length to surface area ratio) from mojemazury.pl and surface area to volume ratio (A/V ratio) from Soszka et al. (2016). The shoreline development index is the ratio of the actual shoreline length of a lake to the circumference of a perfectly circular lake with the same area (Aronow 1982). High values indicate a more complex shoreline, retaining a higher load of nutrients from land (Cole 1975) and providing more niches for the biota (Chesson 2000). The surface area to volume ratio combines information about the depth and size of the lake and can be positively correlated with the productivity of the lake (Fee 1979). Smaller waterbodies (lower A/V ratio) may play the role of refugia for native species (Grabowski et al. 2009). The density of boats (i.e. the number of boats divided by the lake surface in ha), was obtained as the maximum possible number of moored boats in marinas (Johnson and Padilla 1996; Vander Zanden and Olden 2008; Ros et al. 2013). We assumed that the higher the density of boats in the lakes, the higher the tourist pressure and the higher the probability of transport of invasive species by vessels (Johnson and Padilla 1996; Vander Zanden and Olden 2008; Bącela-Spychalska et al. 2013; Ros et al. 2013). The maximum capacity of marinas was obtained from websites: mazury24.eu and skorupki.mazury.info.pl. Tourist infrastructure is mainly localised in urban areas (Kulczyk et al. 2016). Thus, we used the distance between the sampling point and towns (i.e. centroid) as an estimation of anthropogenic pressure. Moreover, land use in the vicinity of water-bodies can impact the temporal variations in amphipod assemblages (Cereghetti 2023). The distance was measured as a linear distance in km from the centroid of the closest town to the sampling point using QGIS software. Towns were designated according to the ESRI shapefile "UIA World Countries Boundaries", available at: https://hub.arcgis.com/datasets/UIA::uia-world-countries-boundaries. All spatial analyses and their visualisation were conducted using QGIS 3.10.13 (QGIS Development Team 2020).

Data analysis

Using all unpublished records since 2008 from the lakes and the rivers, including sites outside the study area (see Suppl. material 1), we modelled the presence of the only native gammarid (i.e. *Gammarus lacustris*) according to the number of NIS and the relative distance of each sampling site from town. We included this variable as a proxy of the anthropogenic propagule pressure (i.e. the introduction of NIS by human activities) of NIS at each site (i.e. inversely correlated). We used generalised linear mixed models (GLMMs) to include the random variable of the sampling year. Given the presence/absence nature of the data, we used a Bernoulli distribution fitted with glmmTMB (link = logit) with the homonymous package (Brooks et al. 2017). The possible inclusion of the interaction between NIS richness (i.e. number of species) and the distance from the closest town was also tested using the Akaike Information Criterion (AIC; Bozdogan (1987)). After fitting the model, we validated it by simulating its residuals using the package DHARMa (Hartig 2022). We also confirmed the absence of spatial autocorrelation of the residuals using the Spatial Autocorrelation function of the DHARMa package.

Using samples collected in 2014 and 2016, we first explored the variability of the environmental parameters of the sites and lakes, grouping them according to their geographical position and connectivity (i.e. I: northern, II: southern, III: eastern; Fig. 2B, see also Suppl. material 1). We hypothesised that nearby and interconnected lakes would exhibit comparable gammarid assemblages. This assumption is supported by findings from the Great Lakes in the USA, where the likelihood of species invasion was found to be the highest near the mouth of canals connecting the lakes (Grigorovich et al. 2005). To explore and visualise the environmental variability of the study area, we used a principal component analysis (PCA) with standardised values with *prcomp* of the package vegan (Oksanen et al. 2022). We analysed the gammarid assemblage using a permutational multivariate analysis of the covariance (PERMANCOVA) with an orthogonal design with two fixed factors (i.e. lake groups with three levels – I, II, III; time with two levels – 2014 and 2016) and five covariates: water QS, A/V ratio, shoreline development, density of boats and distance from the town. To control the possible sampling differences (i.e. being semi-quantitative), Hellinger distances were used to compare the abundances of the different species. To account for the excess of zero values, a dummy variable of 0.0001 was added to the whole dataset. We used first adonis2 of the package vegan with 9999 permutations and pairwise.adonis of the package pairwiseAdonis, with Holm correction and 9999 permutations, for the post hoc analysis between levels of the significant factors (Martinez Arbizu 2020). To visualise and corroborate the results of the PERMANCOVA, we finally used a constrained ordination using distance-based redundancy analysis (dbRDA), based on Legendre and Anderson (1999), with capscale (package vegan) and Hellinger distances, as for Permancova, including the covariates of the PERMANCOVA as constraining variables. All the analyses were performed in the R environment 4.3.0 version (R Core Team 2023).

Results

Temporal and spatial distribution of invasive species

We recorded four invasive gammarid species from 12 lakes and the Rivers Węgorapa and Pisa and one native species (*Gammarus lacustris*) from 16 lakes (Fig. 2A, Suppl. material 1). The first recorded invasive species was *Dikerogammarus haemobaphes* found in 2001 (Jażdżewski 2003) and the second was *Pontogammarus robustoides*, which was first observed in 2007 (Jażdżewska and Jażdżewski 2008). The spread of invasive species can be observed over time (Fig. 2B). Between 2014 and 2016, *D. haemobaphes* spread to one more lake and is observed now in nine of them. *Pontogammarus robustoides* did not colonise new lakes in 2016, compared to 2014. In 2014, we noticed the first appearance of the other two invaders: *C. ischnus* and *D. villosus* (Fig. 2A). The previous species was found in two lakes in 2014 and expanded to five further lakes in 2016, while the latter one was already found in five lakes in 2014 and expanded to two further lakes in 2016 (Fig. 2A). Although *Chaetogammarus ischnus* was recorded in the River Pisa in 2014 and 2016, *D. villosus* was not found in any of the studied rivers

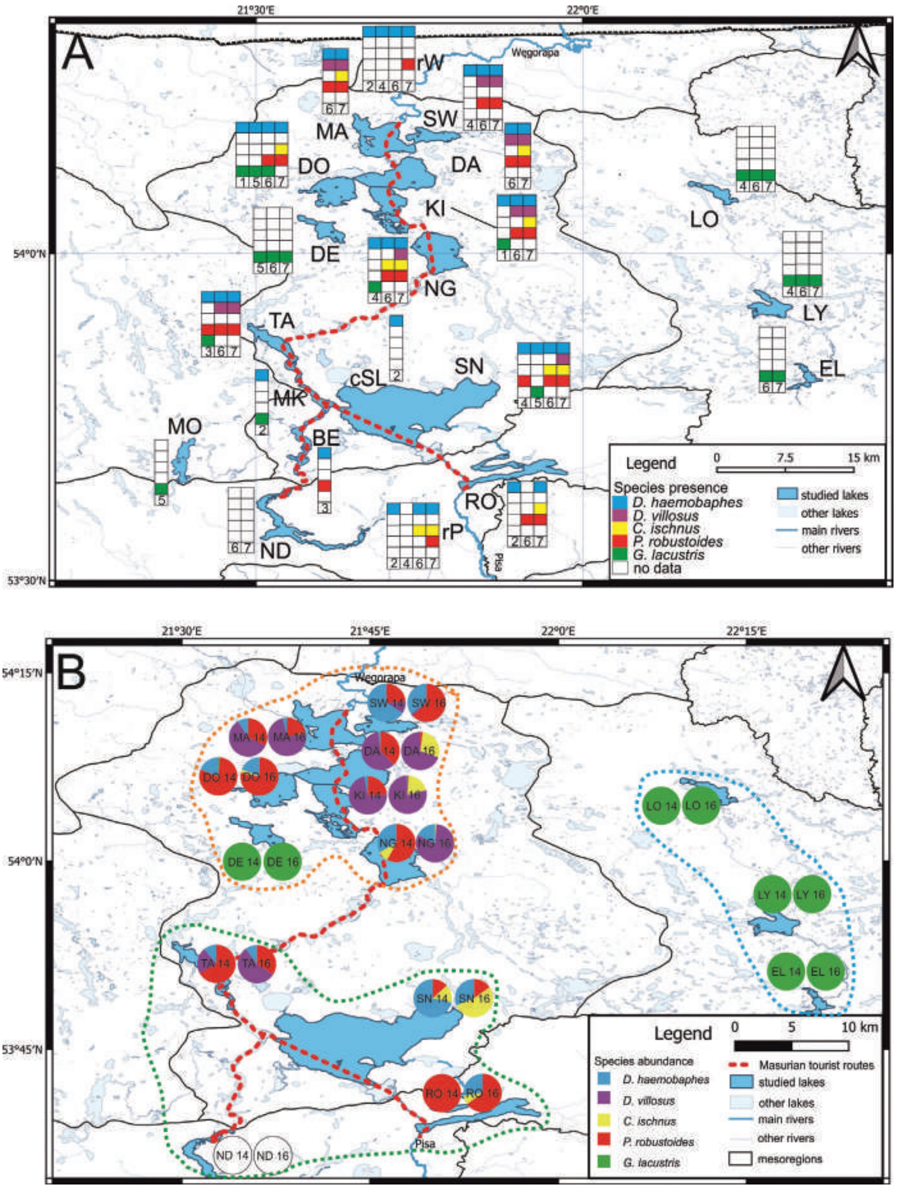


Figure 2. A the distribution of invasive and native amphipod species in studied lakes since 2001, based on published and new data (locality codes according to Suppl. material 1). Table at each lake showing the assemblage (colours in rectangles according to different species, see legend) variation in time (symbols for sampling years: 1 – 2001; 2 – 2002; 3 – 2007; 4 – 2008; 5 – 2009; 6 – 2014; 7 – 2016). Only years of samplings from each lake and river are shown. Colourless rectangles indicate that no amphipods were recorded during the sampling. The dashed black line indicates country borders; the dashed red line indicates the Masurian tourist boat route. Black lines delimit mesoregions according to Kondracki (2002) **B** the assemblage composition of the amphipod fauna in studied lakes in the years 2014 and 2016 (locality codes according to Suppl. material 1). Pie charts show the relative abundances of each species. An empty circle means no amphipods were recorded. Black lines delimit mesoregions according to Kondracki (2002). Coloured dotted lines around the pie charts correspond to the lake groups: orange – I, green – II, blue – III.

(Fig. 2A) The relative abundance of new invaders (*D. villosus* and *C. ischnus*) increased with time, while it decreased for *D. haemobaphes* and *P. robustoides* (Fig. 2B). In Lake Nidzkie, we did not record any amphipod species (Fig. 2A, B).

The modelled occurrence of native *Gammarus lacustris*

Generally, the native species – *Gammarus lacustris* – was not found in lakes inhabited by invasive species, apart from Lake Dobskie, where the native and invasive gammarids co-occurred in 2014 with a low number of *G. lacustris* (two individuals vs. 194 individuals of invasive species) (Fig. 2A, B; Suppl. material 1). The GLMM for the presence of *G. lacustris* showed the significant negative effect of NIS richness (p-value = 0.002) and the positive effect of the distance from town (p-value = 0.024), but not their interaction (Fig. 3). The inclusion of the year as a random effect barely increased the R^2 (Marginal 0.733 – Conditional 0.808), supporting the effectiveness in sampling efforts (Suppl. materials 2, 4).

Environmental factors and amphipod assemblage

The first three components of the PCA explained 85.5% of the variance amongst the environmental variables (Fig. 4A, B). According to PC1 and PC3 (~ 57% variance explained), the lakes further from the tourist route (i.e. group III) are, indeed, characterised by a lower number of boats, higher complexity of the shore and a greater distance from town. The PC2 was more related to the water quality status (water class) and the surface-volume ratio showing a general trend of better water quality (lower class of water quality status) and deeper waters for group I (highest class of water status – lowest water quality for group II). The PERMANCOVA results showed significant effects (p-values < 0.05) of shoreline development (F = 22.096, p < 0.001), the number of boats (F = 10.788, p < 0.001) and water quality status – water class (F = 3.794, p = 0.035) on the assemblage of amphipods (Suppl. material 3). Even though the relative abundance of species changed with time, i.e. increased in *D. villosus* and *C. ischnus* and decreased

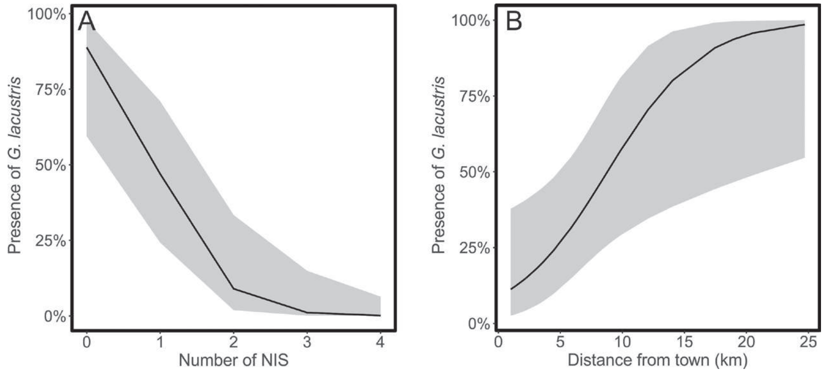
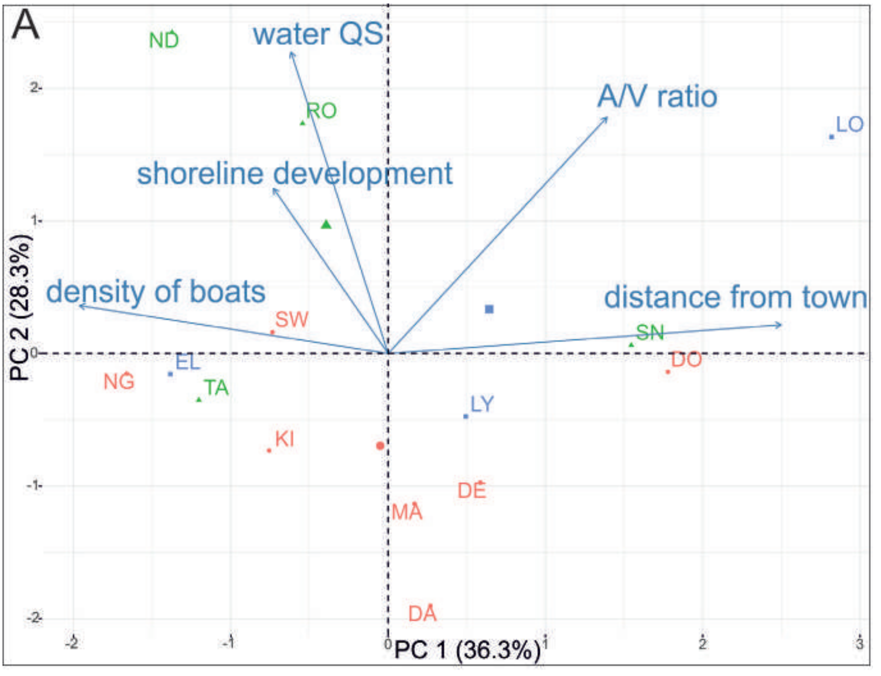


Figure 3. The predicted probability of occurrence of *G. lacustris* dependent on the richness of NIS (A) and the distance of the sampling point from town (B). The grey area delimits the 95% confidence intervals.



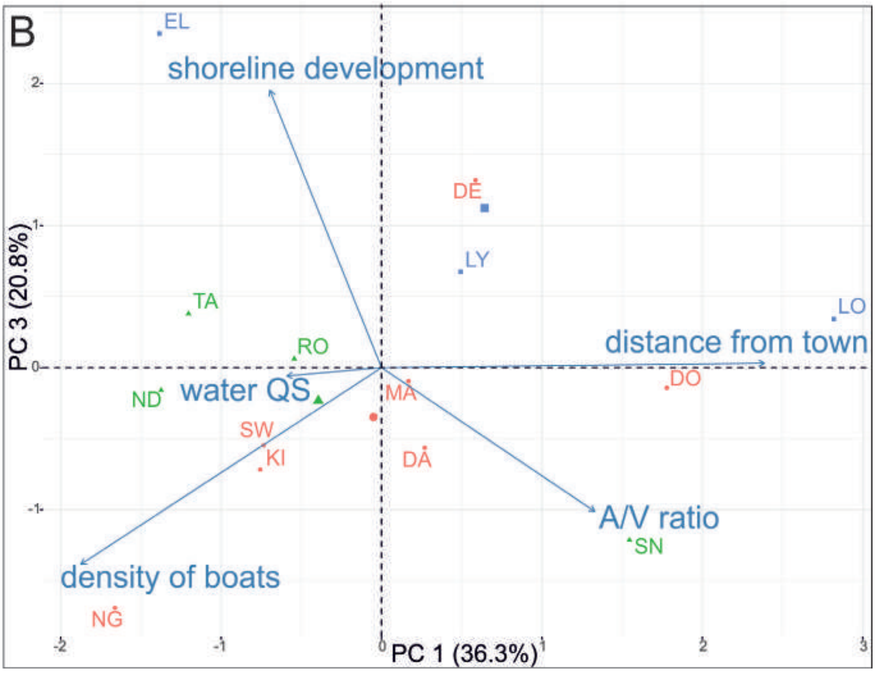


Figure 4. Biplots displaying the first three axes of the PCA of the environmental variables of the lakes sampled in 2014 and 2016 (**A** PC1-2 **B** PC1-3). The colours refer to the different lake groups: orange circles (I), green triangles (II) and blue squares (III). The lengths of the arrows are proportional to the loading of each variable, dashed lines = 0. The acronyms of lakes are according to Fig. 1 and Suppl. material 1.

in *D. haemobaphes*, *P. robustoides* and *G. lacustris*, the time factor was not significant. The differences in amphipod assemblages between lake groups (determined, based on the geographical position and interconnections between the lakes) were marginally significant, i.e. F = 2.680, p = 0.057) and the post hoc analysis showed a significant difference (p.adjusted < 0.001) between the group III (i.e. eastern group) and the others, but not between the first two (p.adjusted > 0.4).

The first two axes of the dbRDA fitted 90.1% of 52.1% of the total variation explained (Fig. 5). The presence of the native *G. lacustris* appeared more correlated to lakes with more complex shorelines. The occurrence of *D. villosus* was mainly explained by the increasing number of boats and proximity to town. The other three species (i.e. *P. robustoides*, *D. haemobaphes* and *C. ischnus*) seemed to be related to simpler shorelines and average values for the other variables, which was generally the opposite to *D. villosus*.

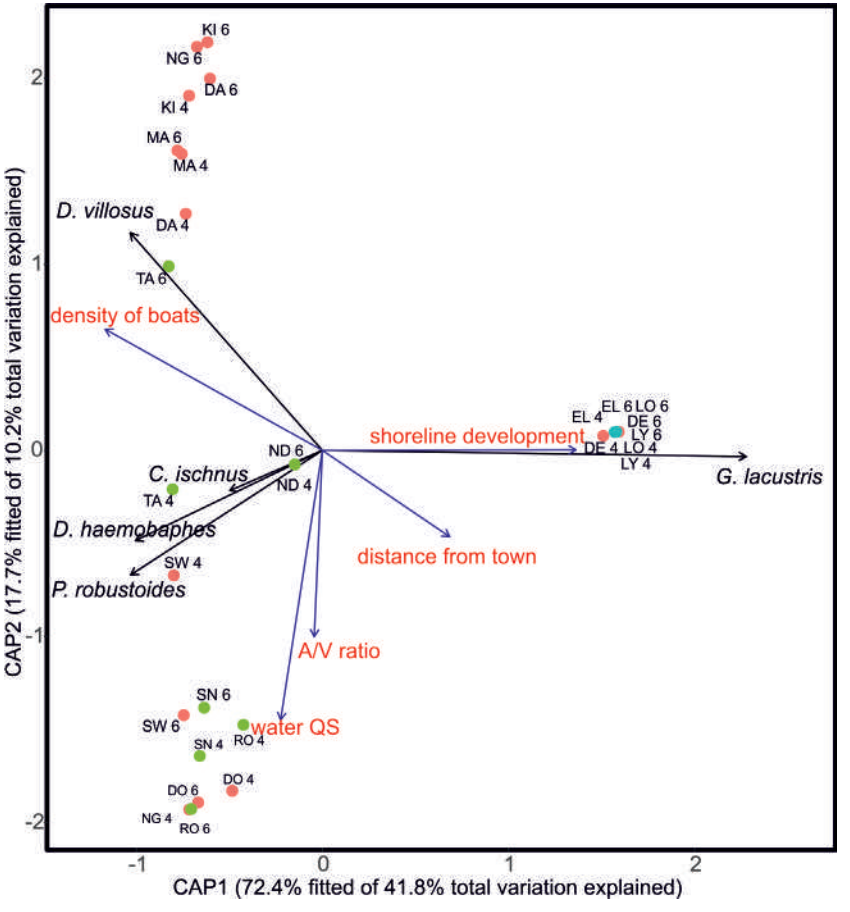


Figure 5. Canonical analysis of principal coordinates (CAPSCALE) derived from the Bray-Curtis dissimilarities of the gammarid assemblages and the environmental variables of the studied lakes in the years 2014 and 2016. The colours of the dots refer to the different lake groups: orange circles (I), green circles (II) and blue circles (III).

Discussion

Our study shows that, between 2001 and 2016, the number of invasive amphipod species in the study area increased drastically from one (*D. haemobaphes*) to four (three more species recorded: *D. villosus*, *P. robustoides*, *C. ischnus*). Simultaneously, a continuous decrease in the occurrence of native *Gammarus lacustris* was recorded. Our study reveals that the presence of NIS in lakes is primarily facilitated by three key factors: recreational boating activities, proximity to urban areas and simplified lake shorelines.

Distribution of *Gammarus lacustris*

According to our results, the presence of more than one NIS significantly affects the presence of the native *G. lacustris*, bringing the probability of its presence almost to zero already with three NIS (Fig. 3A). The species disappeared several years after the expansion of invasive amphipod species in several lakes (Fig. 2A, Suppl. material 1). For instance, the species was widely distributed until the last record in 2001 in Lake Kisajno (Jażdżewski 2003), in 2007 in Lake Tałty (Jażdżewska and Jażdżewski 2008), in 2008 in Lake Niegocin and in 2009 in Lake Śniardwy. Older data mention the presence of *Gammarus lacustris* in Lake Mamry (Jażdżewski 1975). In these lakes, the disappearance of *G. lacustris* coincided with the invasion of alien species. In 2014, *G. lacustris* was co-occurring with invasive species in only one lake (Lake Dobskie). One potential explanation could be the limited tourist activity in Lake Dobskie, as well as low species introduction probabilities, resulting from the absence of direct connections between this lake and other lakes situated along the Masurian tourist routes. Moreover, in 2014, the invasion of *C. ischnus* and *P. robustoides* in Lake Dobskie was still in its early stage. However, in 2014 the abundance of *G. lacustris* in this lake was very low and we did not record this species in 2016. Additionally, in 2002, we recorded the species co-occurring with *D. haemobaphes* in Lake Mikołajskie, but the presence of *G. lacustris* in this lake in subsequent years is unknown. In general, most of the records of *G. lacustris* in the Masurian Lakeland come from isolated lakes where invasive amphipods did not spread. In 2016, we found this species only in four isolated lakes, i.e. Dejguny, Ełckie, Łaśmiady and Łaźno (Fig. 2A; Suppl. material 1).

These four lakes (three of them in the eastern group of lakes) are characterised by low tourist pressure (low number of boats, long distance from the tourist routes) (Fig. 5). The low level of tourist pressure in these lakes and lack of direct connections with the Great Masurian Lakes (central part of the Masurian Lakeland), where all the invasive amphipods are present, may create a refuge for native species. Furthermore, we found that *G. lacustris* is associated with lakes distanced from towns (Figs 3B, 5). The proximity of the lakes to the urban areas results in their pollution and declining quality of water (Mishra et al. 2023). Although *G. lacustris* has a broad tolerance to environmental factors (Matafonov and Bazova 2014), its populations decline in polluted water, for example, with high acidity (Okland 1969) and pesticides (Gerhardt et al. 2011). Hence, it can be anticipated that *G. lacustris* will primarily be distributed in lakes with low anthropogenic pressure. Our results of CAPSCALE analysis show that higher classes of water quality status (lower water quality) characterise mainly lakes inhabited by *C. ischnus*, *D. haemobaphes* and *P. robustoides* (e.g. Lake Śniardwy, Lake Roś, Lake Święcajty), where we did not record *G. lacustris* (apart from Lake Śniardwy in 2009) (Fig. 5).

Instead, we recorded *G. lacustris* in lakes characterised by a high level of shoreline development. Lakes with higher shoreline complexity may provide higher habitat diversity, resulting in lower competition rates between species on environmental resources and, consequently, promoting the possible co-existence of many species, both native and invasive amphipods (Chesson 2000; Amarasekare 2003). While in the lakes with the lower value of this index, native amphipods may be unable to compete with invasive species and could become extinct. However, our results do not confirm this assumption. We found *G. lacustris* in lakes with high shoreline development (e.g. Lake Ełckie), but no invasive amphipods were found there. Isolation of these lakes and low tourist pressure could result in the lack of conditions for their invasion. Nonetheless, in the event of their invasion, we can suppose that the high shoreline complexity of these lakes would promote the co-existence of native and invasive amphipods.

The declining populations of *G. lacustris* in our studies are similar to the general tendency observed in Europe. This species seems to be one of the weakest competitors amongst European freshwater amphipods giving way to the Ponto-Caspian species of genera: *Chaetogammarus*, *Dikerogammarus* and *Pontogammarus* (Meßner and Zettler 2021). *Gammarus lacustris* occurs in a wide range of habitats; nevertheless, in the last few decades, the species has been pushed to the relict range of occurrence (Hesselschwerdt et al. 2008; Meßner and Zettler 2021). Nowadays, the species is present almost exclusively in isolated waterbodies and continues to decline (Meßner and Zettler 2021). The population decline is also attributed to the hydromorphological and hydrochemical changes that occur in aquatic ecosystems (Okland 1969; Matafonov and Bazova 2014).

Similarly, we did not record another native amphipod, *Pallasiola quadrispinosa*, also recorded as declining in the freshwater ecosystems due to invasive amphipods (Żmudziński 1995; Jażdżewski et al. 2004). According to Jażdżewski and Konopacka (1995), this species was found in several lakes of the Masurian Lakeland, i.e. Dargin, Dobskie, Ełckie, Kisajno, Łaśmiady, Mamry, Mikołajskie, Mokre, Niegocin, Śniardwy and Tałty. In some of these lakes, we collected *G. lacustris* without invasive species which suggests also the possible presence of *P. quadrispinosa* in these lakes. *Pallasiola quadrispinosa* thrives in colder temperatures and typically resides in deeper waters during the summer months, which may explain why the species was not recorded during our summer samplings.

Our findings report the set of lake features promoting the distribution of native amphipod species in the studied lakes. As the study area is highly impacted by tourist activities, our results can be useful for better comprehension of the threats to native amphipods in other regions with similar levels of anthropogenic pressure and biological invasions. Our conclusions may highlight the need to protect isolated lakes from tourism and urban area development.

Distribution of invasive amphipods

Freshwater NIS can easily spread with tourist activities, including yachting and angling in particular. Our results show that the number of boats is one of the factors which best explains the distribution of *D. villosus* (Fig. 5). The main part of the Masurian Lakeland with a high abundance of this species covers the area of high tourist activities, i.e. lakes from group I in the northern part of the Lakeland (Figs 2, 4). Yachting is a very significant component of tourism in the Masurian Lakeland, reaching 37% of total tourist activities in the region (Kulczyk et al. 2016). Masurian tourist routes run through these lakes, thus, tourist boat activity supplements yachting. In 2016, we recorded *D. villosus* in all these lakes. A good example is Lake Niegocin, which has a high level of tourist pressure and a rapid invasion of *D. villosus* was observed in 2016. In 2014, the species was absent in this Lake, while in 2016, it constituted 81% of all sampled amphipods. Lake Niegocin is located between the other lakes with high tourist pressure and the Masurian tourist route runs through this lake. The evidence of high tourist activity in this lake can be the high number of car parks per km of shoreline and one of the highest, amongst the Masurian lakes, number of beds in accommodation establishments in 2014 (Kulczyk et al. 2016).

Similar findings were done in other tourist lakes. In Alpine lakes, with higher yachting activity than in the Masurian Lakeland, the expansion of *D. villosus* was caused by yachting and using diving equipment (Bącela-Spychalska et al. 2013; Rewicz et al. 2017). Many species using boat biofouling to invade new waterbodies have broad tolerance to desiccation (Bącela-Spychalska et al. 2013; Glisson et al. 2020). Likewise, *D. villosus* has a high tolerance to air exposure (Rewicz et al. 2014). Moreover, the species is usually associated with another invasive species – zebra mussel (*Dreissena polymorpha*) and can survive up to six days out of the water between mussels fouling the boats (Martens and Grabow 2008). Similarly, the species can be transported with algae and macrophytes (Minchin et al. 2019). It enables them to expand rapidly in new waterbodies, including those isolated from others, by overland transport of boats and yachting equipment.

Overland transport of boats may explain the invasion of *D. villosus* in our study area. Although *D. villosus* was found in most of the recently studied lakes, the species was not found in the River Pisa and the River Węgorapa. These rivers connect the Masurian Lakeland with large rivers, where *D. villosus* is present. It suggests the possible expansion of this species in the Masurian Lakeland by overland transport apart from these rivers. In certain lakes, we did not record *D. villosus*. These lakes have no direct contact with the invaded lakes and low tourist activity almost excludes the possibility of overland boat transport. In contrast to the Alpine lakes, we did not expect diving and angling (using waders) equipment to play a significant role in invading isolated waterbodies by *D. villosus* in the studied area.

Another strong factor explaining the distribution of *D. villosus* is the distance from town. Our results show that this species occurs mainly in the lakes with towns nearby. Proximity to the town and tourist activities are correlated with each other. Most of the marinas are located in towns with well-developed tourist facilities. Indeed, the proximity to the ports and marinas is an important factor in promoting the expansion of *D. villosus* (Minchin et al. 2019). Higher tourist activities in proximity to urban areas may explain the distribution of *D. villosus* in the study area.

Distribution of other invasive species in the Masurian Lakeland, i.e. *P. robustoides*, *D. haemobaphes* and *C. ischnus*, concerns mainly the lakes with less developed shoreline and rather low water quality (higher class of water status). Predominantly, they are present in lakes with different conditions compared to those where *D. villosus* was found (Figs 4, 5). *Dikerogammarus haemobaphes* is the first Ponto-Caspian invasive amphipod recorded in the Masurian Lakeland (Jażdżewski 2003). This species was recorded in most of the studied lakes, as well as in the Rivers Węgorapa and Pisa. The presence of this species in the Rivers Bug and Narew suggests its invasion in the Masurian Lakeland from the east – from the River Dnieper. Despite the broad distribution of *D. haemobaphes* in the lakeland, this species was quickly over-dominated by *P. robustoides*. The latter species was first recorded in the study area in 2007 (Jażdżewska and Jażdżewski 2008). Three hypothetical routes of *P. robustoides* invasion to this region were proposed – from Kaliningrad (Russia) via the Pregel and the Węgorapa Rivers; from Lithuania via the Augustów Canal; from the Baltic Sea via the River Vistula and its tributaries (Jażdżewska and Jażdżewski 2008). However, since the first record of *D. villosus* in the region in 2014, the abundance of both species – *D. haemobaphes* and *P. robustoides* – drastically decreased until 2016. In 2016, *D. villosus* became the most abundant species in the lakes studied. These results are not surprising as the latter species is a strong competitor and successfully eliminates other invasive and native amphipods (Dick and Platvoet 2000; Platvoet et al. 2007; Bącela-Spychalska et al. 2012; Rewicz et al. 2014; Mathers et al. 2023). Especially, two of them – *D. haemobaphes* and *P. robustoides* – are weaker competitors than *D. villosus*, occurring in different habitats and occupying different niches (Bącela-Spychalska et al. 2012; Kobak et al. 2016; Poznańska-Kakareko et al. 2021; Copilaș-Ciocianu and Sidorov 2022). PCA and CAPSCALE results did not show a strong pattern in the distribution of these species, contrary to *D. villosus*, which suggests that *D. haemobaphes* and *P. robustoides* avoid niches occupied by *D. villosus* (Figs 4, 5). *Dikerogammarus haemobaphes* and *Pontogammarus robustoides* have high desiccation resistance, enabling their overland transport with vessels (Poznańska et al. 2013). Although sailing and angling activities may play an important role in their spreading (Bącela-Spychalska 2016; Csabai et al. 2020), tourist activities probably play a minor role in their distribution in the Masurian Lakeland (Fig. 5).

Another species rapidly spreading in the Masurian Lakeland is *Chaetogammarus ischnus*. In the study area, this species was recorded for the first time in 2014 (Fig. 2A; Suppl. material 1). In two years, its increasing abundance coincided with the decline of the abundance of *D. haemobaphes* and *P. robustoides* (Fig. 2B). In 2016, *C. ischnus* constituted more than half of the collected individuals in Lake Śniardwy. An especially high abundance of this species was observed in the southern group of lakes (group II), contrary to *D. villosus* occurring mainly in the northern group (group I). Moreover, we recorded *Chaetogammarus ischnus* in the River Pisa and did not record this species in the River Węgorapa. These results may suggest that *C. ischnus* invaded the Masurian

Lakeland from the southern direction, i.e. from the River Narew and then via the River Pisa. However, in the lakes where we recorded *D. villosus* and *C. ischnus* co-occurring, the abundance of both species increased. *Chaetogammarus ischnus* usually occupies similar habitats to *D. villosus*, i.e. sites with hard substrate, particularly covered by *D. polymorpha* (Żytkowicz and Kobak 2008; Copilaș-Ciocianu and Sidorov 2022). The coexistence of both species may be attributed to the small body size of *C. ischnus*, which enables this species to occupy microhabitats without interfering with *D. villosus* (Borza et al. 2018). This microhabitat-scale differentiation allows for both species to exist within the same habitat. Between *C. ischnus* and *P. robustoides*, the habitats also overlap, but usually *P. robustoides* limits the occurrence of *C. ischnus* because of its larger body size and more predatory diet (Żytkowicz and Kobak 2008). Therefore, we can hypothesise that *D. villosus* eliminates *P. robustoides* in the lakes studied and then *C. ischnus* refills the empty niche. In several lakes, for example, Dargin and Kisajno, we observed that *C. ischnus* reached a similar abundance in 2016 as *P. robustoides* had in 2014 (Fig. 2B; Suppl. material 1). Similar rapid invasion of *C. ischnus* and elimination of native species was observed in the Great Lakes in the USA (Dermott et al. 1998) and River Rhine in Europe (Van der Velde et al. 2000), where rapid range extension of *D. villosus* was observed as well (Bollache et al. 2004). *Chaetogammarus ischnus* can disperse over great distances (Witt et al. 1997). This species is capable of utilising natural water connections between different water-bodies, but it can also be transported through shipping (Nalepa et al. 2001). Witt et al. (1997) noted that the euryhaline nature of the species enables it to be transported even via ballast waters. However, the understanding of the invasion process of *C. ischnus* is limited and demands further studies.

Our results constitute an important contribution to the long-term observation of expansion dynamics of Ponto-Caspian amphipods and can be part of global databases monitoring invasive species. Rapid expansions underline the importance of regular, annual samplings in lakes and watersheds connecting them with invasion corridors. We show the very important role of tourist activities in lakes in the expansion of alien amphipods, in particular of *D. villosus*. These findings underline the important role of permanent monitoring of yachting and shipping vessels. Our predictions can be applicable in other tourist freshwater areas and help designate protection zones limiting boating. Our results can be also valuable to studies on other biofouling taxa. The significance of the town's proximity for the amphipod invasion is due to well-developed tourist facilities in urban areas and possibly water pollution; thus, lakes shorelines and marinas should be controlled as well. Water connections between lakes also should be regularly monitored. Our records of *Chelicorophium curvispinum* in the River Narew in 2014 and 2016 suggest that this species may be the next recorded invasive amphipod in the Masurian Lakeland (see Suppl. material 1). Some studies show a rapid expansion of *C. curvispinum* in freshwater ecosystems with the presence of *Dreissena polymorpha* and shipping (Van den Brink et al. 1993; Jażdżewski and Konopacka 2002). The current distribution of other invasive amphipods, for example, *Obesogammarus crassus* and *Gammarus tigrinus*, suggest no direct risk of their expansion in the Masurian Lakeland soon, but permanent monitoring of their expansion is necessary.

Limitations of our study

Although our data come from several years, it is important to indicate that the most recent data come from 2016; thus, the current invasion status in the study area can be worse than what we present here. The lack of lakes where native and invasive amphipods co-occur makes some of our findings difficult to interpret and partially speculative.

One of the crucial findings of our study is the impact of boating on the invasions. However, we need to remember that the methods we used have some limitations. We used the maximum capacity of marinas as the number of boats in use. Although on busy days the percentage of used boats in the total number of moored boats is high, as shown in Ros et al. (2013), these data are not precise and might be an under-representation of reality. We need to remember that, the association between boat density and the propagation of invasive amphipods has not been established through direct observation of vessel biofouling communities.

Lakes, especially those with high shoreline complexity, provide many habitats which various species can occupy. Therefore, analysing the data based on one sampling per lake may not depict the real diversity of the amphipod communities. Especially, the lack of records of amphipods in Lake Nidzkie, which has a connection with other lakes and Masurian tourist routes, suggests not enough efficient sampling. We need to be aware that the absence of a species in one sample does not exclude the possible occurrence of this species in other habitats of the same lake. Thus, our results, showing the replacement of native species by invasive species, present interesting trends, but are insufficient to conclude the extinction of certain species. Therefore, our findings should be perceived as predictions, not postulates.

Future directions

Future studies would benefit from utilising a more thorough and systematic sampling to provide a more accurate and reliable picture of the invasion process.

Our results show the importance of the proximity of sampling points to towns for invasions. Although we assume that this correlation is connected with tourist facilities and pollution, implementation of more data is needed in the future. Particularly, the distance between sampling points or lake centroid and marinas should be implemented in the analyses (Cole et al. 2019; Minchin et al. 2019). A significant effect of distance to marinas on invasions was noted by Minchin et al. (2019). Marinas are critical entry points for many invasive species and may play the role of reservoirs for newly-introduced invaders (Glasby et al. 2007; Ros et al. 2013; Fernández-Rodríguez et al. 2022).

Additionally, using the actual number of boats in use in the area would be advisable as was done in studies by Bącela-Spychalska et al. (2013) and Keramidas et al. (2018). Moreover, our knowledge about what part of the vessels are fouled by amphipods, which particular species can be transported and on what maximum distance is still scarce. Future studies would also benefit from including inspections of boats and ropes to identify potential vectors for amphipods, such as algae and mussels.

Dikerogammarus villosus, *Chaetogammarus ischnus* and *Chelicorophium curvispinum* can be transported with zebra mussels. Therefore, it is advisable to incorporate data on the occurrence of *D. polymorpha* in lakes and on vessels for future research. The type of vessel can also be an important factor. For instance, motorboats can be vectors of invasions, while canoeing does not play this role (Venohr et al. 2018). In this context, the presence/absence of silent zones, i.e. lakes or their parts where using boats with motors is forbidden, should complete the analyses. Knowledge about the success of the "check, clean and dry" strategy in the study area is missing. We expect that none of these methods is implemented as the local law does not demand their respecting. The method to prevent transporting invasive species on boats, as described in Mohit et al. (2021), should be tested in the Masurian Lakeland. Surveys amongst fishermen and tourists are worth collecting and analysing (Cole et al. 2019). To gain deeper insights into these dynamics, we recommend the establishment of an inter-lakes traffic registry. This registry would provide crucial data regarding boat traffic and potential pathways for the introduction of invasive species. Prevention measures and facilities for anglers should also be studied (Smith et al. 2023). To better understand which species can be transported by vessels, it is important to experimentally test the resistance of different invasive species like *C. ischnus* and *C. curvispinum* to desiccation.

As far as the financial and technical situation allows, samples should be collected from a large number of points on each lake. Additionally, studying a greater set-up of lakes would allow better tracking of invasions and more accurate detection of all amphipod species in the lakes. Finally, tracking of the invasion process can be supported by molecular studies (e.g. Mamos et al. (2021)).

Conclusions

The rapid expansion of the invasive Ponto-Caspian amphipods observed in this study aligns with a general trend along European freshwater basins. The contraction of the range and niche of native species when faced with more aggressive (e.g. *D. villosus*) and/or generalist (e.g. *C. ischnus*) species is something expected and confirmed by our findings. Even though many lakes seem to be still free from amphipod invaders, this may be for a short time considering the abrupt increase we have registered in just two years.

Our study emphasises the need for a comprehensive approach to understanding and addressing the dispersal of alien species through human activity. Our findings highlight the important role of boats in the spread of invasive amphipods within lake systems. The invasion process of *Dikerogammarus villosus* especially suggests the possible impact of overland boat transport in spreading this species in new lakes.

Furthermore, it is essential to raise awareness amongst lake users about the negative consequences of biological invasions and the necessity of implementing a "check, clean and dry" policy. By educating and engaging lake users, we can foster a sense of responsibility and cooperation in preventing the spread of invasive species. Implementing these measures collectively will contribute to better biosecurity practices and safeguard the ecological integrity of lakes against invasive species.

Acknowledgements

We would like to thank Krzysztof Jażdżewski, Ewa Janowska, Mariusz Surlejewski, Olga Antczak-Orlewska, Paula Krzywoźniak, Remi Wattier, Aleksandra Jabłońska and Anna Jażdżewska for help during sampling and their valuable suggestions. We would like to thank Stephen Venn for linguistic corrections and for providing valuable suggestions that improved the overall quality of the manuscript. We are grateful to Denis Copilaş-Ciocianu for the suggestions concerning the taxonomic status of *Spirogammarus major*.

References

Albano PG, Steger J, Bakker PAJ, Bogi C, Bošnjak M, Guy-Haim T, Huseyinoglu MF, LaFollette PI, Lubinevsky H, Mulas M, Stockinger M, Azzarone M, Sabelli B (2021) Numerous new records of tropical non-indigenous species in the Eastern Mediterranean highlight the challenges of their recognition and identification. ZooKeys 1010: 1–95. https://doi.org/10.3897/zookeys.1010.58759

Amarasekare P (2003) Competitive coexistence in spatially structured environments: A synthesis. Ecology Letters 6(12): 1109–1122. https://doi.org/10.1046/j.1461-0248.2003.00530.x

Anderson LG, White PCL, Stebbing PD, Stentiford GD, Dunn AM (2014) Biosecurity and vector behaviour: Evaluating the potential threat posed by anglers and canoeists as pathways for the spread of invasive non-native species and pathogens. PLOS ONE 9(4): 1–10. https://doi.org/10.1371/journal.pone.0092788

Anderson LG, Rocliffe S, Haddaway NR, Dunn AM (2015) The Role of tourism and recreation in the spread of non-native species: A systematic review and meta-analysis. PLOS ONE 10(10): e0140833. https://doi.org/10.1371/journal.pone.0140833

Arbačiauskas K, Rakauskas V, Virbickas T (2010) Initial and long-term consequences of attempts to improve fish-food resources in Lithuanian waters by introducing alien peracaridan species: A retrospective overview. Journal of Applied Ichthyology 26: 28–37. https://doi.org/10.1111/j.1439-0426.2010.01492.x

Aronow S (1982) Shoreline development ratio. Beaches and Coastal Geology. Encyclopedia of Earth Sciences Series. Springer, New York, 754–755. https://doi.org/10.1007/0-387-30843-1_417

Bącela-Spychalska K (2016) Attachment ability of two invasive amphipod species may promote their spread by overland transport. Aquatic Conservation 26(1): 196–201. https://doi.org/10.1002/aqc.2565

Bącela-Spychalska K, Wattier RA, Genton C, Rigaud T (2012) Microsporidian disease of the invasive amphipod *Dikerogammarus villosus* and the potential for its transfer to local invertebrate fauna. Biological Invasions 14(9): 1831–1842. https://doi.org/10.1007/s10530-012-0193-1

Bącela-Spychalska K, Grabowski M, Rewicz T, Konopacka A, Wattier R (2013) The 'killer Shrimp' *Dikerogammarus villosus* (Crustacea, Amphipoda) invading Alpine lakes: Overland transport by recreational boats and scuba-diving gear as potential entry vectors? Aquatic Conservation 23(4): 606–618. https://doi.org/10.1002/aqc.2329

Bajkiewicz-Grabowska E (2008) Obieg wody w systemie Wielkich Jezior Mazurskich [Water circulation in the Great Masurian Lake System]. In: Jasser I, Robak S, Zdanowski B (Eds) Ochrona i Rekultywacja wód Wielkich Jezior Mazurskich Narzędziem Rozwoju Naukowego, Gospodarczego, Społecznego i Kulturowego Regionu [Protection and Reclamation of Water in the Great Masurian Lakes as a Tool of Scientific, Economic Social and Cultural Development of the Region]. IRS, Olsztyn, 19–29. [In Polish]

Bellard C, Cassey P, Blackburn M (2016) Alien species as a driver of recent extinctions. Biology Letters 12(2): e20150623. https://doi.org/10.1098/rsbl.2015.0623

Bij de Vaate A, Jażdżewski K, Ketelaars HAM, Gollasch S, Van der Velde G (2002) Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. Canadian Journal of Fisheries and Aquatic Sciences 59(7): 1159–1174. https://doi.org/10.1139/f02-098

Bollache L, Devin S, Wattier R, Chovet M, Beisel JN, Moreteau JC, Rigaud T (2004) Rapid range extension of the Ponto-Caspian amphipod *Dikerogammarus villosus* in France: Potential consequences. Archiv für Hydrobiologie 160(1): 57–66. https://doi.org/10.1127/0003-9136/2004/0160-0057

Borza P, Huber T, Leitner P, Remund N, Graf W (2018) How to coexist with the 'killer shrimp' *Dikerogammarus villosus*? Lessons from other invasive Ponto-Caspian peracarids. Aquatic Conservation 28(6): 1441–1450. https://doi.org/10.1002/aqc.2985

Bozdogan H (1987) Model selection and Akaik"s Information Criterion (AIC): The general theory and its analytical extensions. Psychometrika 52(3): 345–370. https://doi.org/10.1007/BF02294361

Bradshaw C, Leroy B, Bellard C, Roiz D, Albert C, Fournier A, Barbet-Massin M, Salles J-M, Simard F, Courchamp F (2016) Massive yet grossly underestimated global costs of invasive insects. Nature Communications 7(1): e12986. https://doi.org/10.1038/ncomms12986

Brooks ME, Kristensen K, van Benthem KJ, Magnusson A, Berg CW, Nielsen A, Skaug HJ, Maechler M, Bolker BM (2017) glmmTMB Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling. The R Journal 9(2): 378–400. https://doi.org/10.32614/RJ-2017-066

CBD (2000) Global strategy on invasive alien species. – Convention on Biological Diversity, UNEP/CBD/SBSTTA/6/INF/9: 1–52.

Cereghetti E (2023) Stream ecosystems and terrestrial resources: a temporal perspective on detritus cycling and keystone shredders. PHD Thesis. Universität Zürich.

Chesson P (2000) General theory of competitive coexistence in spatially-varying environments. Theoretical Population Biology 58(3): 211–237. https://doi.org/10.1006/tpbi.2000.1486

Chróst RJ, Siuda W (2006) Microbial production, utilization, and enzymatic degradation of organic matter in the upper trophogenic layer in the pelagial zone of lakes along a eutrophication gradient. Limnology and Oceanography 51(1part2): 749–762. https://doi.org/10.4319/lo.2006.51.1_part_2.0749

Cole GA (1975) Textbook of Limnology. C. V. Mosby Co.,St. Louis, 283 pp.

Cole E, Keller RP, Garbach K (2019) Risk of invasive species spread by recreational boaters remains high despite widespread adoption of conservation behaviors. Journal of Environmental Management 229: 112–119. https://doi.org/10.1016/j.jenvman.2018.06.078

Copilaș-Ciocianu D, Sidorov D (2022) Taxonomic, ecological and morphological diversity of Ponto-Caspian gammaroidean amphipods: A review. Organisms, Diversity & Evolution 22(2): 285–315. https://doi.org/10.1007/s13127-021-00536-6

Copilaș-Ciocianu D, Rewicz T, Sands AF, Palatov D, Marin I, Arbačiauskas K, Hebert PDN, Grabowski M, Audzijonyte A (2022) A DNA barcode reference library for endemic Ponto-Caspian amphipods. Scientific Reports 12(1): e11332. https://doi.org/10.1038/s41598-022-15442-w

Copilaș-Ciocianu D, Sidorov D, Šidagytė-Copilas E (2023a) Global distribution and diversity of alien Ponto-Caspian amphipods. Biological Invasions 25(1): 179–195. https://doi.org/10.1007/s10530-022-02908-1

Copilaș-Ciocianu D, Palatov D, Rewicz T, Sands AF, Arbačiauskas K, van Haaren T, Hebert PN, Grabowski M, Marin I (2023b) A widespread Ponto-Caspian invader with a mistaken identity: integrative taxonomy elucidates the confusing taxonomy of *Trichogammarus trichiatus* (= *Echinogammarus*) (Crustacea: Amphipoda). Zoological Journal of the Linnean Society 198(3): 821–846. https://doi.org/10.1093/zoolinnean/zlad010

Cristescu MEA, Hebert PDN (2005) The "Crustacean Seas"– An evolutionary perspective on the Ponto-Caspian peracarids. Canadian Journal of Fisheries and Aquatic Sciences 62(3): 505–517. https://doi.org/10.1139/f04-210

Csabai Z, Borza P, Rewicz T, Pernecker B, Berta BJ, Móra A (2020) Mass appearance of the Ponto-Caspian invader *Pontogammarus robustoides* in the River Tisza catchment: Bypass in the southern invasion corridor? Knowledge and Management of Aquatic Ecosystems 421(421): 1–9. https://doi.org/10.1051/kmae/2020003

Cuthbert RN, Diagne C, Hudgins EJ, Turbelin A, Ahmed DA, Albert C, Bodey TW, Briski E, Essl F, Haubrock PJ, Gozlan RE, Kirichenko N, Kourantidou M, Kramer AM, Courchamp F (2021a) Biological invasion costs reveal insufficient proactive management worldwide. The Science of the Total Environment 819: e153404. https://doi.org/10.1016/j.scitotenv.2022.153404

Cuthbert RN, Pattison Z, Taylor NG, Verbrugge I, Diagne C, Ahmed DA, Leroy B, Angulo E, Briski E, Capinha C, Catford JA, Dalu T, Ells F, Gozlan RE, Haubrock PJ, Kourantidou M, Kramer AM, Renault D, Wasserman RJ, Courchamp F (2021b) Global economic costs of aquatic invasive species. The Science of the Total Environment 775: e145238. https://doi.org/10.1016/j.scitotenv.2021.145238

De Ventura L, Wissert N, Tobias R, Kopp K, Jokela J (2016) Overland transport of recreational boats as a spreading vector of zebra mussel *Dreissena polymorpha*. Biological Invasions 18(5): 1451–1466. https://doi.org/10.1007/s10530-016-1094-5

Dermott R, Witt J, Um YM, González M (1998) Distribution of the Ponto-Caspian Amphipod *Echinogammarus ischnus* in the Great Lakes and Replacement of Native *Gammarus fasciatus*. Journal of Great Lakes Research 24(2): 442–452. https://doi.org/10.1016/S0380-1330(98)70834-2

Dick JTA, Platvoet D (1996) Intraguild predation and species exclusions in amphipods: The interaction of behaviour, physiology and environment. Freshwater Biology 36(2): 375–383. https://doi.org/10.1046/j.1365-2427.1996.00106.x

Dick JTA, Platvoet D (2000) Invading predatory crustacean *Dikerogammarus villosus* eliminates both native and exotic species. Proceedings of the Royal Society B, Biological Sciences 267(1447): 977–983. https://doi.org/10.1098/rspb.2000.1099

Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Lévêque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ, Sullivan CA (2006) Freshwater biodiversity: Importance, threats, status and conservation challenges. Biological Reviews of the Cambridge Philosophical Society 81(2): 163–182. https://doi.org/10.1017/S1464793105006950

Eggers TO, Martens A (2001) Bestimmungsschlüssel der Süßwasser-Amphipoda (Crustacea) Deutschlands. Lauterbornia 42: 1–68. [In German]

Ejsmont-Karabin J, Kalinowska K, Karpowicz M (2020) Structure of Ciliate, Rotifer, and Crustacean Communities in Lake Systems of Northeastern Poland. In: Korzeniewska E, Harnisz M (Eds) Polish River Basins and Lakes – Part II. The Handbook of Environmental Chemistry 87. Springer, Cham, 77–101. https://doi.org/10.1007/978-3-030-12139-6_4

European Environment Agency (2000) Water Framework Directive (WFD) 2000. https://www.eea.europa.eu/policy-documents/water-framework-directive-wfd-2000

European Environment Agency (2018) State of Water report 7/2018. https://www.eea.europa.eu/publications/state-of-water

Fee EJ (1979) A relation between lake morphometry and primary productivity and its use in interpreting whole-lake eutrophication experiments. Limnology and Oceanography 24(3): 401–416. https://doi.org/10.4319/lo.1979.24.3.0401

Feld CK, Birk S, Eme D, Gerisch M, Hering D, Kernan M, Maileht K, Mischke U, Ott I, Pletterbauer F, Poikane S, Salgado J, Sayer CD, Van Wichelen J, Malard F (2016) Disentangling the effects of land use and geo-climatic factors on diversity in European freshwater ecosystems. Ecological Indicators 60: 71–83. https://doi.org/10.1016/j.ecolind.2015.06.024

Fernández-Rodríguez I, López-Alonso R, Sánchez O, Suárez-Turienzo I, Gutiérrez-Martínez R, Arias A (2022) Detection and prevention of biological invasions in marinas and ports: Epibionts and associated fauna of *Mytilus galloprovincialis* revisited. Estuarine, Coastal and Shelf Science 274: e107943. https://doi.org/10.1016/j.ecss.2022.107943

Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice IC, Ramankutty N, Snyder PK (2005) Global consequences of land use. Science 309(5734): 570–574. https://doi.org/10.1126/science.1111772

Galil BS, Nehring S, Panov V (2008) Waterways as Invasion Highways – Impact of Climate Change and Globalization. In: Nentwig W (Ed.) Biological Invasions. Ecological Studies (Vol. 193). Springer, Berlin. https://doi.org/10.1007/978-3-540-36920-2_5

Gerhardt A, Bloor M, Lloyd Mills C (2011) *Gammarus*: Important Taxon in Freshwater and Marine Changing Environments. International Journal of Zoology 2011: 524276. https://doi.org/10.1155/2011/524276

Glasby TM, Connell SD, Holloway MG, Hewitt CL (2007) Nonindigenous biota on artificial structures: Could habitat creation facilitate biological invasions? Marine Biology 151(3): 887–895. https://doi.org/10.1007/s00227-006-0552-5

Glisson WJ, Wagner CK, Verhoeven R, Muthukrishnan R, Contreras-Rangel R, Larkin DJ (2020) Desiccation tolerance of the invasive alga starry stonewort (*Nitellopsis obtusa*) as an indicator of overland spread risk. Journal of Aquatic Plant Management 58: 7–18.

Grabowski M, Konopacka A, Jażdżewski K, Janowska E (2006) Invasions of alien gammarid species and retreat of natives in the Vistula Lagoon (Baltic Sea, Poland). Helgoland Marine Research 60(2): 90–97. https://doi.org/10.1007/s10152-006-0025-8

Grabowski M, Jażdzewski K, Konopacka A (2007) Alien crustacea in Polish waters–Amphipoda. Aquatic Invasions 2(1): 25–38. https://doi.org/10.3391/ai.2007.2.1.3

Grabowski M, Bącela K, Konopacka A, Jażdżewski K (2009) Salinity-related distribution of alien amphipods in rivers provides refugia for native species. Biological Invasions 11(9): 2107–2117. https://doi.org/10.1007/s10530-009-9502-8

Grigorovich IA, MacIsaac HJ, Shadrin NV, Mills EL (2002) Patterns and mechanisms of aquatic invertebrate introductions in the Ponto-Caspian region. Canadian Journal of Fisheries and Aquatic Sciences 59(7): 1189–1208. https://doi.org/10.1139/f02-088

Grigorovich IA, Kang M, Ciborowski JJH (2005) Colonization of the Laurentian Great Lakes by the amphipod *Gammarus tigrinus*, a native of the North American Atlantic Coast. Journal of Great Lakes Research 31(3): 333–342. https://doi.org/10.1016/S0380-1330(05)70264-1

Gruszka P (1999) The river Odra Estuary as a gateway for alien species immigration to the Baltic Sea basin. Acta Hydrochimica et Hydrobiologica 27(5): 374–382. https://doi.org/10.1002/(SICI)1521-401X(199911)27:5<374::AID-AHEH374>3.0.CO;2-V

Hall MC, Härkönen T (2006) Lake Tourism: An Integrated Approach to Lacustrine Tourism Systems. Channel View Publications, Bristol, 256 pp. https://doi.org/10.21832/9781845410421

Hartig F (2022) DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models. R package version 0.4.6.

Haubrock PJ, Pilotto F, Innocenti G, Cianfanelli S, Haase P (2021) Two centuries for an almost complete community turnover from native to non-native species in a riverine ecosystem. Global Change Biology 27(3): 606–623. https://doi.org/10.1111/gcb.15442

Hesselschwerdt J, Meeker J, Wantzen KM (2008) Gammarids in Lake Constance: Habitat segregation between the invasive *Dikerogammarus villosus* and the indigenous *Gammarus roeselii*. Fundamental and Applied Limnology 173(3): 177–186. https://doi.org/10.1127/1863-9135/2008/0173-0177

Hewitt CL, Gollasch S, Minchin D (2009) The vessel as a vector – Biofouling, ballast water and sediments. In: Rilov G, Crooks JA (Eds) Biological Invasions in Marine Ecosystems. Ecological Studies (Vol. 204). Springer, Berlin, 117–131. https://doi.org/10.1007/978-3-540-79236-9_6

Hillbricht-Ilkowska A, Rybak J, Rzepecki M (2000) Ecohydrological research of lake – watershed relations in diversified landscape (Masurian Lakeland, Poland). Ecological Engineering 16(1): 91–98. https://doi.org/10.1016/S0925-8574(00)00093-8

Iqbal MF, Feng Y-L, Feng W-W, Liu M-C, Lu X-R (2021) Ecological impacts of the invasive plant *Xanthium strumarium* and the impacts of three aboveground herbivores on the invader. Ecological Indicators 131: e108140. https://doi.org/10.1016/j.ecolind.2021.108140

Jażdżewska A, Jażdżewski K (2008) *Pontogammarus robustoides* (G.O. Sars, 1894) (Crustacea, Amphipoda), a new Ponto-Caspian invader in Great Masurian Lakes (NE Poland). Fragmenta Faunistica 51(1): 1–7. https://doi.org/10.3161/00159301FF2008.51.1.001

Jażdżewska AM, Rewicz T, Mamos T, Wattier R, Bącela-Spychalska K, Grabowski M (2020) Cryptic diversity and mtDNA phylogeography of the invasive demon shrimp, *Dikerogammarus haemobaphes* (Eichwald, 1841), in Europe. NeoBiota 57: 53–86. https://doi.org/10.3897/neobiota.57.46699

Jażdżewski K (1975) Morfologia, Taksonomia i Występowanie w Polsce Kiełży z Rodzajów *Gammarus* Fabr. i *Chaetogammarus* MART. (Crustacea, Amphipoda). Acta Universitatis Lodziensis, Łódź, 185 pp. [In Polish]

Jażdżewski K (1980) Range Extensions of Some Gammaridean Species in European Inland Waters Caused by Human Activity. Crustaceana 6: 84–107.

Jażdżewski K (2003) An invasive Ponto-Caspian amphipod – *Dikerogammarus haemobaphes* (Eichwald, 1841)–conquers Great Masurian Lakes, north-eastern Poland. Fragmenta Faunistica 46(1): 19–25. https://doi.org/10.3161/00159301FF2003.46.1.019

Jażdżewski K, Konopacka A (1995) Malacostraca prócz Oniscoidea. In: Mroczkowski M (Ed.) Katalog Fauny Polskiej 13(1): 1–165. [In Polish]

Jażdżewski K, Konopacka A (2000) Immigration history and present distribution of alien crustaceans in Polish waters. In: von Vaupel Klein JC, Schram FR (Eds) The Biodiversity Crisis and Crustacea, Proceedings of 4th International Crustacean Congress, Brill, Leiden. Crustacean Issues 12: 55–64.

Jażdżewski K, Konopacka A (2002) Invasive ponto-caspian species in waters of the vistula and oder basins and the Southern Baltic Sea. In: Leppäkoski E, Gollasch S, Olenin S (Eds) Invasive Aquatic Species of Europe. Distribution, Impacts and Management. Springer, Dordrecht, 384–398. https://doi.org/10.1007/978-94-015-9956-6_39

Jażdżewski K, Konopacka A, Grabowski M (2002) Four Ponto-Caspian and one American gammarid species (Crustacea, Amphipoda) recently invading Polish waters. Contributions to Zoology 71(4): 115–122. https://doi.org/10.1163/18759866-07104001

Jażdżewski K, Konopacka A, Grabowski M (2004) Recent drastic changes in the gammarid fauna (Crustacea, Amphipoda) of the Vistula River deltaic system in Poland caused by alien invaders. Diversity & Distributions 10(2): 81–87. https://doi.org/10.1111/j.1366-9516.2004.00062.x

Jażdżewski K, Konopacka A, Grabowski M (2005) Native and alien Malacostracan Crustacea along the Polish Baltic Sea coast in the twentieth century Oceanological and Hydrobiological Studies (Vol. XXXIV, Supplement 1). Oceanological and Hydrobiological Studies 34: 175–193.

Johnson LE, Padilla DK (1996) Geographic spread of exotic species: Ecological lessons and opportunities from the invasion of the zebra mussel *Dreissena polymorpha*. Biological Conservation 78(1–2): 23–33. https://doi.org/10.1016/0006-3207(96)00015-8

Jones CG, Lawton JH, Shachak M (1994) Organisms as ecosystem engineers. Oikos 69(3): 373–386. https://doi.org/10.2307/3545850

Jones CG, Lawton JH, Shachak M (1997) Positive and negative effects of organisms as physical ecosystem engineers. Ecology 78(7): 1946–1957. https://doi.org/10.1890/0012-9658(1997)078[1946:PANEOO]2.0.CO;2

Keramidas I, Dimarchopoulou D, Pardalou A, Tsikliras AC (2018) Estimating recreational fishing fleet using satellite data in the Aegean and Ionian Seas (Mediterranean Sea). Fisheries Research 208: 1–6. https://doi.org/10.1016/j.fishres.2018.07.001

Kettunen M, Genovesi P, Gollasch S, Pagad S, Starfinger U, Ten Brink P, Shine C (2009) Technical support to EU strategy on invasive species (IAS)– Assessment of the impacts of IAS in Europe and the EU (final module report for the European Commission). Institute for European Environmental Policy (IEEP), Brussels, Belgium. 44 pp. [+ Annexes]

Kistowski M, Śleszyński P (2010) Presja turystyczna na tle walorów turystycznych Polski. Prace Komisji Krajobrazu Kulturowego Nr 14. [In Polish]

Kobak J, Rachalewski M, Bącela-Spychalska K (2016) Conquerors or exiles? Impact of interference competition among invasive Ponto-Caspian gammarideans on their dispersal rates. Biological Invasions 18(7): 1953–1965. https://doi.org/10.1007/s10530-016-1140-3

Kondracki J (2002) Geografia regionalna Polski, Warszawa, PWN, [ISBN 83-01-13897-1]. [In Polish]

Konopacka A (1998) Nowy dla Polski gatunek kiełża, *Dikerogammarus haemobaphes* (EICHWALD, 1841) (Crustacea, Amphipoda) oraz dwa inne rzadkie gatunki skorupiaków obunogich w Wiśle. Przegląd Zoologiczny 3–4: 211–218. [in Polish]

Konopacka A, Jażdżewski K (2002) *Obesogammarus crassus* (G.O. Sars, 1894) – one more Ponto-Caspian gammarid species in Polish waters. Fragmenta Faunistica 45(1): 19–26. https://doi.org/10.3161/00159301FF2002.45.1.019

Kouba A, Oficialdegui FJ, Cuthbert RN, Kourantidou M, South J, Tricarico E, Gozlan RE, Courchamp F, Haubrock PJ (2022) Identifying economic costs and knowledge gaps of invasive aquatic crustaceans. The Science of the Total Environment 813: e152325. https://doi.org/10.1016/j.scitotenv.2021.152325

Kulczyk S, Derek M, Woźniak E (2016) Zagospodarowanie turystyczne strefy brzegowej jezior na potrzeby żeglarstwa–przykład wielkich jezior mazurskich. Prace i Studia Geograficzne 61(3): 27–49. [In Polish]

Kurashov EA, Barbashova MA, Barkov DV, Rusanov AG, Lavrova MS (2012) Invasive amphipods as a factor of transformation of Lake Ladoga ecosystems. Russian Journal of Biological Invasions 3(3): 202–212. https://doi.org/10.1134/S2075111712030058

Lambertini M, Leape J, Marton-Lefevre J, Mittermeier R, Rose M, Robinson J, Stuart S, Waldman B, Genovesi P (2011) Invasives: A major conservation threat. Science 333(6041): 404–405. https://doi.org/10.1126/science.333.6041.404-b

Legendre P, Anderson MJ (1999) Distance-based redundancy analysis: Testing multispecies responses in multifactorial ecological experiments. Ecological Monographs 69(1): 1–24. https://doi.org/10.1890/0012-9615(1999)069[0001:DBRATM]2.0.CO;2

Lipták B, Veselý L, Ercoli F, Bláha M, Buřič M, Ruokonen T, Kouba A (2019) Trophic role of marbled crayfish in a lentic freshwater ecosystem. Aquatic Invasions 14(2): 299–309. https://doi.org/10.3391/ai.2019.14.2.09

Lobato TC, Hauser-Davis RA, Oliveira TF, Silveira AM, Silva HAN, Tavares MRM, Saraiva ACF (2015) Construction of a novel water quality index and quality indicator for reservoir water quality evaluation: A case study in the Amazon region. Journal of Hydrology 522: 674–683. https://doi.org/10.1016/j.jhydrol.2015.01.021

Mačić V, Albano PG, Almpanidou V, Claudet J, Corrales X, Essl F, Evagelopoulos A, Giovos I, Jimenez C, Kark S, Marković O, Mazaris AD, Ólafsdóttir G, Panayotova M, Petović S, Rabitsch W, Ramdani M, Rilov G, Tricarico E, Fernández TV, Sini M, Trygonis V, Katsanevakis S (2018) Biological invasions in conservation planning: A global systematic review. Frontiers in Marine Science 5: e178. https://doi.org/10.3389/fmars.2018.00178

Mamos T, Grabowski M, Rewicz T, Bojko J, Strapagiel D, Burzyński A (2021) Mitochondrial genomes, phylogenetic associations, and SNP recovery for the key invasive Ponto-Caspian amphipods in Europe. International Journal of Molecular Sciences 22(19): e10300. https://doi.org/10.3390/ijms221910300

Martens A, Grabow K (2008) Das risiko der verschleppung neozoischer Amphipoda beim überlandtransport von yachten. Lauterbornia 62: 41–44. https://doi.org/10.3391/ai.2007.2.1.4 [in German]

Martinez Arbizu P (2020) pairwiseAdonis: Pairwise multilevel comparison using adonis. R package version 0.4 mazury24.eu. https://mazury24.eu [in Polish]

Matafonov D, Bazova N (2014) Decline of *Gammarus lacustris* Sars (Crustacea: Amphipoda) population in the delta of the Selenga River. Biology Bulletin of the Russian Academy of Sciences 41(2): 168–175. https://doi.org/10.1134/S1062359014020071

Mathers KL, Clinton K, Constable D, Gerrard C, Patel C, Wood PJ (2023) Invasion dynamics of Ponto-Caspian amphipods leads to changes in invertebrate community structure and function. Freshwater ecology 14: 1–14. https://doi.org/10.1002/ecs2.4593

Meßner U, Zettler MB (2021) Drastic changes of the amphipod fauna in northern Germany and the displacement of *Gammarus lacustris* G.O. Sars, 1864 to relict habitats/status. Knowledge and Management of Aquatic Ecosystems 422(17): 1–8. https://doi.org/10.1051/kmae/2021016

Minchin D, Arbačiauskas K, Daunys D, Ezhova E, Grudule N, Kotta J, Molchanova N, Olenin S, Višinskienė G, Strake S (2019) Rapid expansion and facilitating factors of the Ponto-Caspian invader *Dikerogammarus villosus* within the Eastern Baltic sea. Aquatic Invasions 14(2): 165–181. https://doi.org/10.3391/ai.2019.14.2.02

Mishra M, Singhal A, Srinivas R (2023) Effect of urbanization on the urban lake water quality by using water quality index (WQI). Materials Today: Proceedings: 1–9. https://doi.org/10.1016/j.matpr.2023.06.357

Mohit S, Johnson TB, Arnott SE (2021) Recreational watercraft decontamination: Can current recommendations reduce aquatic invasive species spread? Management of Biological Invasions : International Journal of Applied Research on Biological Invasions 12(1): 148–164. https://doi.org/10.3391/mbi.2021.12.1.10

Mordukhai-Boltovskoi FD (1964) Caspian fauna beyond the Caspian Sea. Internationale Revue der Gesamten Hydrobiologie 49(1): 139–176. https://doi.org/10.1002/iroh.19640490105

Nalepa TF, Schloesser DW, Pothoven SA, Hondorp DW, Fanslow DL, Tuchman ML, Fleisher GW (2001) First finding of the amphipod *Echinogammarus ischnus* and the mussel *Dreissena bugensis* in Lake Michigan. Journal of Great Lakes Research 27(3): 384–391. https://doi.org/10.1016/S0380-1330(01)70653-3

Nalepa TF, Fanslow DL, Lang GA (2009) Transformation of the offshore benthic community in Lake Michigan: Recent shift from the native amphipod *Diporeia* spp. to the invasive mussel *Dreissena rostriformis bugensis*. Freshwater Biology 54(3): 466–479. https://doi.org/10.1111/j.1365-2427.2008.02123.x

Nehring S (2005) International shipping–a risk for aquatic biodiversity in Germany. Biological invasions–from ecology to control. NeoBiota 6: 125–143.

Okland KA (1969) On the distribution and ecology of *Gammarus lacustris* G.O. Sars in Norway, with notes on its morphology and biology. Norvegian journal of zoology 17: 111–152.

Oksanen J, Simpson G, Blanchet F, Kindt R, Legendre P, Minchin P, Hara R, Solymos P, Stevens M, Szoecs E, Wagner H, Barbour M, Bedward M, Bolker B, Borcard D, Carvalho G, Chirico M, De Caceres M, Durand S, Evangelista H, FitzJohn R, Friendly M, Furneaux B, Hannigan G, Hill M, Lahti L, McGlinn D, Ouellette M, Ribeiro Cunha E, Smith T, Stier A, Ter Braak C, Weedon J (2022) vegan: Community Ecology Package. R package version 2.6-4. https://CRAN.R-project.org/package=vegan

Panlasigui S, Davis AJS, Mangiante MJ, Darling JA (2018) Assessing threats of non-native species to native freshwater biodiversity: Conservation priorities for the United States. Biological Conservation 224: 199–208. https://doi.org/10.1016/j.biocon.2018.05.019

Panov VE, Alexandrov B, Arbačiauskas K, Binimelis R, Copp GH, Grabowski M, Lucy F, Leuven RS, Nehring S, Paunović M, Semenchenko V, Son MO (2009) Assessing the risks of aquatic species invasions via European inland waterways: From concepts to environmental indicators. Integrated Environmental Assessment and Management 5(1): 110–126. https://doi.org/10.1897/IEAM_2008-034.1

Pinkster S, Scheepmaker M, Platvoet D, Broodbakker N (1992) Drastic changes in the amphipod fauna (Crustacea) of Dutch inland waters during the last 25 years. Bijdragen tot de Dierkunde 61(4): 193–204. https://doi.org/10.1163/26660644-06104001

Platvoet D, Song Y, Shuqiang L, Van der Velde G (2007) Description of the lateral line organ of *Dikerogammarus villosus* (Sowinsky, 1894), with discussion on its function (Peracarida, Amphipoda). Crustaceana 80(11): 1373–1392. https://doi.org/10.1163/156854007782605619

Pöckl M, Grabowski M, Grabowska J, Bącela-Spychalska K, Wittmann KJ (2011) Large European rivers as biological invasion highways. In: Habersack H, Schober B, Walling D (Eds) International Conference on the Status and Future of the World's Large Rivers, 11–14 April 2011. Conference Abstract Book, Vienna, 215 pp.

Poznańska M, Kakareko T, Krzyżyński M, Kobak J (2013) Effect of substratum drying on the survival and migrations of Ponto-Caspian and native gammarids (Crustacea: Amphipoda). Hydrobiologia 700(1): 47–59. https://doi.org/10.1007/s10750-012-1218-6

Poznańska-Kakareko M, Lis M, Kakareko T, Augustyniak M, Kłosiński P, Kobak J (2021) Nearshore distribution of alien Ponto-Caspian amphipods in a European dam reservoir in relations to substratum type and occurrence of macroinvertebrate taxa. Knowledge and Management of Aquatic Ecosystems 422(5): 1–12. https://doi.org/10.1051/kmae/2021005

Pyšek P, Richardson DM (2010) Invasive species, environmental change and management, and health. Annual Review of Environment and Resources 35(1): 25–55. https://doi.org/10.1146/annurev-environ-033009-095548

QGIS Development Team (2020) QGIS Geographic Information System. Open Source Geospatial Foundation Project. https://qgis.org/en/site/about/index.html

R Core Team (2023) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. https://www.R-project.org/

Rachalewski M, Grabowski M, Konopacka A, Bącela-Spychalska K (2013) *Echinogammarus trichiatus* (Martynov, 1932)' A new Ponto-Caspian amphipod invader in Poland with remarks on other alien amphipods from the Oder river. Crustaceana 86(10): 1224–1233. https://doi.org/10.1163/15685403-00003228

Rewicz T, Grabowski M, Macneil C, Bącela-Spychalska K (2014) The profile of a 'perfect' invader – the case of killer shrimp, *Dikerogammarus villosus*. Aquatic Invasions 9(3): 267–288. https://doi.org/10.3391/ai.2014.9.3.04

Rewicz T, Wattier R, Rigaud T, Grabowski M, Mamos T, Bącela-Spychalska K (2017) The killer shrimp, *Dikerogammarus villosus*, invading European Alpine Lakes: A single main source but independent founder events with an overall loss of genetic diversity. Freshwater Biology 62(6): 1036–1051. https://doi.org/10.1111/fwb.12923

Ricciardi A (2006) Patterns of Invasion in the Laurentian Great Lakes in Relation to Changes in Vector Activity. Diversity & Distributions 12(4): 425–433. https://doi.org/10.1111/j.1366-9516.2006.00262.x

Ricciardi A, Kipp R (2008) Predicting the number of ecologically harmful exotic species in an aquatic system. Diversity & Distributions 14(2): 374–380. https://doi.org/10.1111/j.1472-4642.2007.00451.x

Ricciardi A, MacIsaac HJ (2000) Recent mass invasion of the North American Great lakes by Ponto-Caspian species. Trends in Ecology & Evolution 15(2): 62–65. https://doi.org/10.1016/S0169-5347(99)01745-0

Rodríguez-Rey M, Consuegra S, Börger L, Garcia de Leaniz C (2021) Boat ramps facilitate the dispersal of the highly invasive zebra mussel (*Dreissena polymorpha*). Biological Invasions 23(5): 1487–1496. https://doi.org/10.1007/s10530-020-02453-9

Ros M, Vázquez-Luis M, Guerra-García JM (2013) The role of marinas and recreational boating in the occurrence and distribution of exotic caprellids (Crustacea: Amphipoda) in the Western Mediterranean: Mallorca Island as a case study. Journal of Sea Research 83: 94–103. https://doi.org/10.1016/j.seares.2013.04.004

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH (2000) Global biodiversity scenarios for the year 2100. Science 287(5459): 1770–1774. https://doi.org/10.1126/science.287.5459.1770

Sánchez E, Colmenarejo MF, Vicente J, Rubio A, García MG, Travieso L, Borja R (2007) Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. Ecological Indicators 7(2): 315–328. https://doi.org/10.1016/j.ecolind.2006.02.005

Sardain A, Sardain E, Leung B (2019) Global forecasts of shipping traffic and biological invasions to 2050. Nature Sustainability 2(4): 274–282. https://doi.org/10.1038/s41893-019-0245-y

Smith ERC, Bennion H, Sayer CD, Aldridge DC, Owen M (2020) Recreational angling as a pathway for invasive non-native species spread: Awareness of biosecurity and the risk of long distance movement into Great Britain. Biological Invasions 22(3): 1135–1159. https://doi.org/10.1007/s10530-019-02169-5

Smith ERC, Heal R, Wood LE (2023) Understanding and improving biosecurity among recreational anglers in Great Britain. Journal of Fish Biology 102(5): 1177–1190. https://doi.org/10.1111/jfb.15345

Soszka H, Kolada A, Pasztaleniec A, Ochocka A, Kutyła S, Bielczyńska A (2016) Opracowanie zbiorczej oceny stanu jezior. Institute of Environmental Protection – National Research Institute. [In Polish]

Strayer DL, Dudgeon D (2010) Freshwater biodiversity conservation: Recent progress and future challenges. Journal of the North American Benthological Society 29(1): 344–358. https://doi.org/10.1899/08-171.1

UIA World Countries Boundaries (2023) UIA World Countries Boundaries. https://hub.arcgis.com/datasets/UIA::uia-world-countries-boundaries

Ulikowski D, Traczuk P, Kapusta A, Kalinowska K (2021) New records of alien monkey goby, *Neogobius fluviatilis* (Pallas, 1814), in the waters of the Great Masurian Lakes system (northeastern Poland). BioInvasions Records 10(4): 924–933. https://doi.org/10.3391/bir.2021.10.4.17

Väinölä R, Witt JDS, Grabowski M, Bradbury JH, Jażdżewski K, Sket B (2008) Freshwater Animal Diversity Assessment. Hydrobiologia 595: 241–255.

Van den Brink FWB, Van der Velde G, Bij de Vaate A (1993) Ecological aspects, explosive range extension and impact of a mass invader, *Corophium curvispinum* Sars, 1895 (Crustacea: Amphipoda), in the Lower Rhine (The Netherlands). Oecologia 93(2): 224–232. https://doi.org/10.1007/BF00317675

Van der Velde G, Rajagopal S, Musko I, Bij de Vaate A (2000) Ecological impact of crustacean invaders. General considerations and examples from the Rhine River. In: von Vaupel Klein JC, Schram FR (Eds) The biodiversity crisis and Crustacea, Proceedings of 4th International Crustacean Congress, Brill, Leiden, Crustacean Issues 12: 3–33.

Van der Velde G, Leuven RSEW, Platvoet D, Bącela K, Huijbregts MAJ, Hendriks HWM, Kruijt D (2009) Environmental and morphological factors influencing predatory behaviour by invasive non-indigenous gammaridean species. Biological Invasions 11(9): 2043–2054. https://doi.org/10.1007/s10530-009-9500-x

Vander Zanden MJ, Olden JD (2008) A management framework for preventing the secondary spread of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences 65(7): 1512–1522. https://doi.org/10.1139/F08-099

Vantarová KH, Eliáš Jr P, Jiménez-Ruiz J, Tokarska-Guzik B, Cires E (2023) Biological invasions in the twenty-first century: A global risk. Biologia 78(5): 1211–1218. https://doi.org/10.1007/s11756-023-01394-7

Venohr M, Langhans SD, Peters O, Hölker F, Arlinghaus R, Mitchell L, Wolter C (2018) The underestimated dynamics and impacts of water-based recreational activities on freshwater ecosystems. Environmental Reviews 26(2): 199–213. https://doi.org/10.1139/er-2017-0024

Witt JDS, Hebert PDN, Morton WB (1997) *Echinogammarus ischnus*: Another crustacean invader in the Laurentian Great Lakes basin. Canadian Journal of Fisheries and Aquatic Sciences 54(2): 264–268. https://doi.org/10.1139/f96-292

Yang Q, Weigelt P, Fristoe TS, Zhang Z, Kreft H, Stein A, Seebens H, Dawson W, Essl F, König C, Lenzner B, Pergl J, Pouteau R, Pyšek P, Winter M, Ebel AL, Fuentes N, Giehl ELH, Kartesz J, Krestov P, Kukk T, Nishino M, Kupriyanov A, Villaseñor JL, Wieringa JJ, Zeddam A, Zykova E, van Kleunen M (2021) The global loss of floristic uniqueness. Nature Communications 12(1): e7290. https://doi.org/10.1038/s41467-021-27603-y

Zhulidov AV, Kozhara AV, van der Velde G, Leuven RSEW, Son MO, Gurtovaya TY, Zhulidov DA, Nalepa TF, Santiago-Fandino VJR, Chuikov YS (2018) Status of the invasive brackish water bivalve *Mytilopsis leucophaeata* (Conrad, 1831) (Dreissenidae) in the Ponto-Caspian region. BioInvasions Records 7(2): 111–120. https://doi.org/10.3391/bir.2018.7.2.02

Żmudziński L (1995) Retreat of *Pallasiola quadrispinosa* [G.O.Sars] and *Monoporeia affinis* [Lindstrom] from the Polish lakes. Polskie Archiwum Hydrobiologii 42(4): 401–407.

Żytkowicz J, Kobak J (2008) Relationships between the occurrence of *Chaetogammarus ischnus* (Stebbing, 1898) and *Pontogammarus robustoides* (G. O. Sars, 1894) (Crustacea, Amphipoda) in a lowland Polish dam reservoir. Oceanological and Hydrobiological Studies 37(2): 39–50. https://doi.org/10.2478/v10009-007-0050-1

Supplementary material 1

Metadata for each sampling site and date

Authors: Krzysztof Podwysocki, Andrea Desiderato, Tomasz Mamos, Tomasz Rewicz, Michał Grabowski, Alicja Konopacka, Karolina Bącela-Spychalska

Data type: xlsx

Explanation note: Sampling sites between the years 2001–2016 with a number of individuals (or +/-) for the presence/absence) of each recorded Amphipoda species (names of invasive species have been underlined). Symbols for lakes provide two-letter acronyms used on the figures. Symbols for rivers and canals provide three-letter acronyms used on the figures. Water QS: Water quality status (Soszka et al. 2016); A/V ratio: Surface area to volume ratio (Soszka et al. 2016); Shoreline development: Shoreline length to surface area ratio (https://mojemazury.pl); Density of boats: number of boats per ha of lake surface (https://mazury24.eu; https://skorupki.mazury.info.pl).

Link: https://doi.org/10.3897/neobiota.90.109221.suppl1

Supplementary material 2

Summary of the best-fitting Bernoulli GLMM for the presence of native gammarid – *Gammarus lacustris*

Authors: Krzysztof Podwysocki, Andrea Desiderato, Tomasz Mamos, Tomasz Rewicz, Michał Grabowski, Alicja Konopacka, Karolina Bącela-Spychalska

Data type: docx

Link: https://doi.org/10.3897/neobiota.90.109221.suppl2

Supplementary material 3

Results of PERMANCOVA test using 9999 permutations

Authors: Krzysztof Podwysocki, Andrea Desiderato, Tomasz Mamos, Tomasz Rewicz, Michał Grabowski, Alicja Konopacka, Karolina Bącela-Spychalska

Data type: docx

Link: https://doi.org/10.3897/neobiota.90.109221.suppl3

Supplementary material 4

Supplementary image

Authors: Krzysztof Podwysocki, Andrea Desiderato, Tomasz Mamos, Tomasz Rewicz, Michał Grabowski, Alicja Konopacka, Karolina Bącela-Spychalska

Data type: jpeg

Link: https://doi.org/10.3897/neobiota.90.109221.suppl4

Supplementary material 1

Sampling sites between the years 2001–2016 with a number of individuals (or +/-) for the (presence/absence) of each recorded Amphipoda species (names of invasive species have been underlined). Symbols for lakes provide two letter acronyms used on the figures. Symbols for rivers and canals provide three letter acronyms used on the figures. Water QS: Water quality status (Soszka et al. 2016); A/V ratio: Surface area to volume ratio (Soszka et al. 2016); Shoreline development: Shoreline length to surface area ratio (https://mojemazury.pl); Density of boats: number of boats per ha of lake surface (https://mazury24.eu; https:// skorupki.mazury.info.pl).

Locality	Symbol	Reference	Analyses for which the data was used	Date	Latitude	Longitude	Lake group	Water QS (number and name of class)	A/V ratio	Shoreline development	Density of boats	Distance from town (km)	*D. haemobaphes*	*D. villosus*	*C. ischnus*	*P. robustoides*	*C. curvispinum*	*G. lacustris*
Lake Kisajno	KI	Jażdżewski 2003	tracking of expansion	19.08.2001	54.067 N	21.714 E	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	+	-	-	-	-	+
Lake Dobskie	DO	Jażdżewski 2003	tracking of expansion	16.08.2001	54.087 N	21.654 E	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	+	-	-	-	-	+
Lake Mikołajskie	MK	Jażdżewski 2003	tracking of expansion	11.09.2002	53.786 N	21.583 E	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	+	-	-	-	-	+
River Węgorapa	rW	Jażdżewski 2003	tracking of expansion	11.09.2002	54.243 N	21.718 E	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	+	-	-	-	-	-
connection Śniardwy-Łuknajno	cSL	Jażdżewski 2003	tracking of expansion	11.09.2002	53.799 N	21.636 E	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	+	-	-	-	-	-
Lake Roś	RO	Jażdżewski 2003	tracking of expansion	05.08.2002	53.665 N	21.932 E	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	+	-	-	-	-	-
River Pisa	rP	Jażdżewski 2003	tracking of expansion	12.09.2002	53.488 N	21.867 E	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	+	-	-	-	-	-
Lake Tałty	TA	Jażdżewska and Jażdżewski 2008	tracking of expansion	16.08.2007	53.839 N	21.564 E	n.d.	n.d.	n.d.	n.d.	n.d.	4.47	+	-	-	+	-	+
Lake Bełdany	BE	Jażdżewska and Jażdżewski 2008	tracking of expansion	17.08.2007	53.719 N	21.572 E	n.d.	n.d.	n.d.	n.d.	n.d.	7.07	+	-	-	+	-	-
River Pisa	rP	this study	tracking of expansion	11.06.2008	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-	-	-	-	-	-

Locality	Symbol	Reference	Analyses for which the data was used	Date	Latitude	Longitude	Lake group	Water QS (number and name of class)	A/V ratio	Shoreline development	Density of boats	Distance from town (km)	*D. haemobaphes*	*D. villosus*	*C. ischnus*	*P. robustoides*	*C. curvispinum*	*G. lacustris*
Lake Niegocin	NG	this study	tracking of expansion; GLMM	12.06.2008	54.014 N	21.808 E	n.d.	n.d.	n.d.	n.d.	n.d.	3.61	+	-	-	-	-	+
Lake Śniardwy	SN	this study	tracking of expansion; GLMM	12.06.2008	53.805 N	21.861 E	n.d.	n.d.	n.d.	n.d.	n.d.	9.06	+	-	-	+	-	-
Lake Święcajty	SW	this study	tracking of expansion; GLMM	12.06.2008	54.184 N	21.802 E	n.d.	n.d.	n.d.	n.d.	n.d.	7.2	+	-	-	-	-	-
River Węgorapa	rW	this study	tracking of expansion; GLMM	12.06.2008	54.245 N	21.721 E	n.d.	n.d.	n.d.	n.d.	n.d.	3.16	+	-	-	-	-	-
Lake Łaźno in Rogajny	LO	this study	tracking of expansion; GLMM	13.06.2008	54.074 N	22.216 E	n.d.	n.d.	n.d.	n.d.	n.d.	24.7	-	-	-	-	-	+
Lake Wiżajny in Wiżajny	WZ	this study	tracking of expansion; GLMM	13.06.2008	54.366 N	22.862 E	n.d.	n.d.	n.d.	n.d.	n.d.	2.24	-	-	-	-	-	+
Lake Łaśmiady in Sajzy	LY	this study	tracking of expansion; GLMM	13.06.2008	53.932 N	22.289 E	n.d.	n.d.	n.d.	n.d.	n.d.	12.08	-	-	-	-	-	+
Lake Dejguny	DE	this study	tracking of expansion; GLMM	24.09.2009	54.030 N	21.634 E	n.d.	n.d.	n.d.	n.d.	n.d.	12.04	-	-	-	-	-	+
Lake Drwęckie in Ostróda	DR	this study	tracking of expansion; GLMM	24.09.2009	53.702 N	19.957 E	n.d.	n.d.	n.d.	n.d.	n.d.	2.24	+	-	-	-	-	+
Lake Dobskie	DO	this study	tracking of expansion; GLMM	24.09.2009	54.108 N	21.595 E	n.d.	n.d.	n.d.	n.d.	n.d.	17.46	+	-	-	-	-	+
Lake Mokre in Zgon	MO	this study	tracking of expansion; GLMM	24.09.2009	53.650 N	21.395 E	n.d.	n.d.	n.d.	n.d.	n.d.	19	-	-	-	-	-	+
Lake Kalwa in Pasym	KL	this study	tracking of expansion; GLMM	24.09.2009	53.655 N	20.791 E	n.d.	n.d.	n.d.	n.d.	n.d.	20.59	-	-	-	-	-	+
Lake Bachotek	BC	this study	tracking of expansion	25.09.2009	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-	-	-	-	-	+
Lake Jeziorak in Siemiany	JZ	this study	tracking of expansion; GLMM	25.09.2009	53.738 N	19.587 E	n.d.	n.d.	n.d.	n.d.	n.d.	14.04	-	-	-	-	-	+

Locality	Symbol	Reference	Analyses for which the data was used	Date	Latitude	Longitude	Lake group	Water QS (number and name of class)	A/V ratio	Shoreline development	Density of boats	Distance from town (km)	*D. haemobaphes*	*D. villosus*	*C. ischnus*	*P. robustoides*	*C. curvispinum*	*G. lacustris*
Lake Śniardwy	SN	this study	tracking of expansion; GLMM	2009	53.805 N	21.861 E	n.d.	n.d.	n.d.	n.d.	n.d.	9.06	+	-	-	-	-	+
Lake Dargin	DA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	01.06.2014	54.113 N	21.775 E	A	I - Excellent	0.009	10.830	11.220	8.06	8	508	0	332	0	0
Lake Ełckie	EL	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	01.06.2014	53.819 N	22.342 E	C	III - Good	0.007	48.770	5.490	1	0	0	0	0	0	59
Lake Kisajno	KI	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	01.06.2014	54.072 N	21.729 E	A	I - Excellent	0.012	26.420	33.280	6.4	10	309	0	65	0	0
Lake Łaśmiady	LY	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	01.06.2014	53.917 N	22.321 E	C	III - Good	0.010	24.880	0.000	9.22	0	0	0	0	0	91
Lake Łaźno	LO	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	01.06.2014	54.074 N	22.215 E	C	IV - Fair	0.018	32.580	0.000	24.7	0	0	0	0	0	68
Lake Święcajty	SW	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	01.06.2014	54.179 N	21.813 E	A	IV - Fair	0.011	21.810	22.770	5.83	148	23	0	53	0	0
Lake Dejguny	DE	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	02.06.2014	54.030 N	21.634 E	A	II - Very good	0.008	31.060	0.000	12.04	0	0	0	0	0	70
Lake Dobskie	DO	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	02.06.2014	54.107 N	21.592 E	A	III - Good	0.013	18.190	1.690	17.46	37	0	0	157	0	2

Locality	Symbol	Reference	Analyses for which the data was used	Date	Latitude	Longitude	Lake group	Water QS (number and name of class)	A/V ratio	Shoreline development	Density of boats	Distance from town (km)	*D. haemobaphes*	*D. villosus*	*C. ischnus*	*P. robustoides*	*C. curvispinum*	*G. lacustris*
Lake Mamry	MA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	02.06.2014	54.190 N	21.653 E	A	III - Good	0.008	13.580	5.990	8.54	49	304	0	163	0	0
Lake Nidzkie	ND	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	02.06.2014	53.645 N	21.567 E	B	V - Poor/VI - Very poor	0.016	39.550	28.330	2	0	0	0	0	0	0
Lake Niegocin	NG	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	02.06.2014	54.019 N	21.808 E	A	IV - Fair	0.010	13.620	40.770	3.61	325	0	85	571	0	0
Lake Śniardwy	SN	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	02.06.2014	53.776 N	21.859 E	B	III - Good	0.017	8.570	1.410	9.85	605	0	131	111	0	0
Lake Tałty	TA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	02.06.2014	53.838 N	21.565 E	B	IV - Fair	0.007	26.490	17.950	4.47	91	188	0	574	0	0
Lake Roś	RO	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	03.06.2014	53.652 N	21.861 E	B	VI - Very poor	0.012	27.330	12.820	6.71	0	0	0	648	0	0
Lake Kisajno	KI	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	17.08.2014	54.050 N	21.693 E	A	I - Excellent	0.012	26.420	33.280	9.06	1	0	0	38	0	0
Lake Dargin	DA	this study	tracking of expansion	2014	54.1 N	21.761 E	A	I - Excellent	0.009	10.830	11.220	n.d.	9	53	0	15	0	0
Lake Mamry in Kietlice	MA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	19.08.2014	54.158 N	21.659 E	A	III - Good	0.008	13.580	5.990	9.22	12	139	0	8	0	0

Locality	Symbol	Reference	Analyses for which the data was used	Date	Latitude	Longitude	Lake group	Water QS (number and name of class)	A/V ratio	Shoreline development	Density of boats	Distance from town (km)	*D. haemobaphes*	*D. villosus*	*C. ischnus*	*P. robustoides*	*C. curvispinum*	*G. lacustris*
Lake Mamry in Węgorzewo	MA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	19.08.2014	54.210 N	21.739 E	A	III - Good	0.008	13.580	5.990	1.41	61	0	0	0	0	0
Lake Mamry	MA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	19.08.2014	54.191 N	21.675 E	A	III - Good	0.008	13.580	5.990	6.32	0	6	0	162	0	0
Lake Święcajty	SW	this study	tracking of expansion	2014	54.184 N	21.75 E	A	IV - Fair	0.011	21.810	22.770	n.d.	6	23	0	11	0	0
River Narew in Pułtusk		this study	tracking of expansion	2014	52.700 N	21.094 E	n.d.	n.d.	n.d.	n.d.	n.d.	1.41	9	453	360	0	287	0
River Narew in Łomża		this study	tracking of expansion	2014	53.195 N	22.092 E	n.d.	n.d.	n.d.	n.d.	n.d.	3.61	221	0	0	0	0	0
River Pisa in Jeże	rP	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	2014	53.487 N	21.868 E	n.d.	n.d.	n.d.	n.d.	n.d.	9.43	0	0	0	0	0	0
River Pisa in Niedźwiedzie near Szparki	rP	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	2014	53.590 N	21.824 E	n.d.	n.d.	n.d.	n.d.	n.d.	4.47	21	0	13	0	0	0
River Węgorapa near Maćków	rW	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	2014	54.244 N	21.721 E	n.d.	n.d.	n.d.	n.d.	n.d.	3.16	69	0	0	0	0	0
Lake Ełckie	EL	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	23.08.2016	53.819 N	22.342 E	C	III - Good	0.007	48.770	5.490	1	0	0	0	0	0	150
Lake Łaśmiady	LY	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	23.08.2016	53.917 N	22.321 E	C	III - Good	0.010	24.880	0.000	9.22	0	0	0	0	0	521
Lake Łaźno	LO	this study	tracking of expansion;	23.08.2016	54.074 N	22.215 E	C	IV - Fair	0.018	32.580	0.000	24.7	0	0	0	0	0	312

Locality	Symbol	Reference	Analyses for which the data was used	Date	Latitude	Longitude	Lake group	Water QS (number and name of class)	A/V ratio	Shoreline development	Density of boats	Distance from town (km)	*D. haemobaphes*	*D. villosus*	*C. ischnus*	*P. robustoides*	*C. curvispinum*	*G. lacustris*
			GLMM; Permancova, dbRDA, PCA															
Lake Niegocin	NG	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	23.08.2016	54.019 N	21.808 E	A	IV - Fair	0.010	13.620	40.770	3.61	198	903	9	2	0	0
Lake Roś	RO	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	23.08.2016	53.652 N	21.861 E	B	VI - Very poor	0.012	27.330	12.820	6.71	31	0	9	73	0	0
Lake Śniardwy	SN	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	23.08.2016	53.776 N	21.859 E	B	III - Good	0.017	8.570	1.410	9.85	246	2	422	122	0	0
Lake Dargin	DA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	24.08.2016	54.113 N	21.775 E	A	I - Excellent	0.009	10.830	11.220	8.06	2	649	266	22	0	0
Lake Dobskie	DO	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	24.08.2016	54.107 N	21.592 E	A	III - Good	0.013	18.190	1.690	17.46	6	0	1	25	0	0
Lake Kisajno	KI	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	24.08.2016	54.072 N	21.729 E	A	I - Excellent	0.012	26.420	33.280	6.4	6	335	87	4	0	0
Lake Mamry	MA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	24.08.2016	54.190 N	21.653 E	A	III - Good	0.008	13.580	5.990	8.54	36	616	8	175	0	0
Lake Święcajty	SW	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	24.08.2016	54.179 N	21.813 E	A	IV - Fair	0.011	21.810	22.770	5.83	66	4	0	120	0	0

Locality	Symbol	Reference	Analyses for which the data was used	Date	Latitude	Longitude	Lake group	Water QS (number and name of class)	A/V ratio	Shoreline development	Density of boats	Distance from town (km)	*D. haemobaphes*	*D. villosus*	*C. ischnus*	*P. robustoides*	*C. curvispinum*	*G. lacustris*
Lake Dejguny	DE	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	25.08.2016	54.030 N	21.634 E	A	II - Very good	0.008	31.060	0.000	12.04	0	0	0	0	0	588
Lake Nidzkie	ND	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	25.08.2016	53.645 N	21.567 E	B	V - Poor/VI - Very poor	0.016	39.550	28.330	2	0	0	0	0	0	0
Lake Tałty	TA	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	25.08.2016	53.838 N	21.565 E	B	IV - Fair	0.007	26.490	17.950	4.47	40	220	0	136	0	0
River Narew in Pułtusk		this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	2016	52.700 N	21.094 E	n.d.	n.d.	n.d.	n.d.	n.d.	1.41	29	99	175	0	19	0
River Narew in Łomża		this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	2016	53.195 N	22.092 E	n.d.	n.d.	n.d.	n.d.	n.d.	3.61	241	0	0	0	0	0
River Pisa in Jeże	rP	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	2016	53.487 N	21.868 E	n.d.	n.d.	n.d.	n.d.	n.d.	9.43	1	0	2	0	0	0
River Pisa in Niedźwiedzie near Szparki	rP	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	2016	53.590 N	21.824 E	n.d.	n.d.	n.d.	n.d.	n.d.	4.47	225	0	108	7	0	0
River Węgorapa near Maćków	rW	this study	tracking of expansion; GLMM; Permancova, dbRDA, PCA	2016	54.244 N	21.721 E	n.d.	n.d.	n.d.	n.d.	n.d.	3.16	39	0	0	1	0	0

Supplementary material 2

Table 2. Summary of the best-fitting Bernoulli GLMM for the presence of native gammarid - *Gammarus lacustris*. Distance from town in km, number of NIS as integer (i.e., 0-4) and year of sampling fitted as a random effect.

	Bernoulli GLMM (Presence of *G. lacustris*)		
Coefficient	*Log-Odds*	*Conf. Int (95%)*	*P-value*
(Intercept)	0.02	-1.86 – 1.90	0.985
Distance from town	0.27	0.04 – 0.51	**0.024**
Number of NIS	-2.27	-3.72 – -0.82	**0.002**
Random Effects			
σ^2	3.29		
$\tau_{00\ \mathrm{Year}}$	0.43		
ICC	0.11		
N_{Year}	4		
Observations	56		
Marginal R^2 / Conditional R^2	0.821 / 0.841		

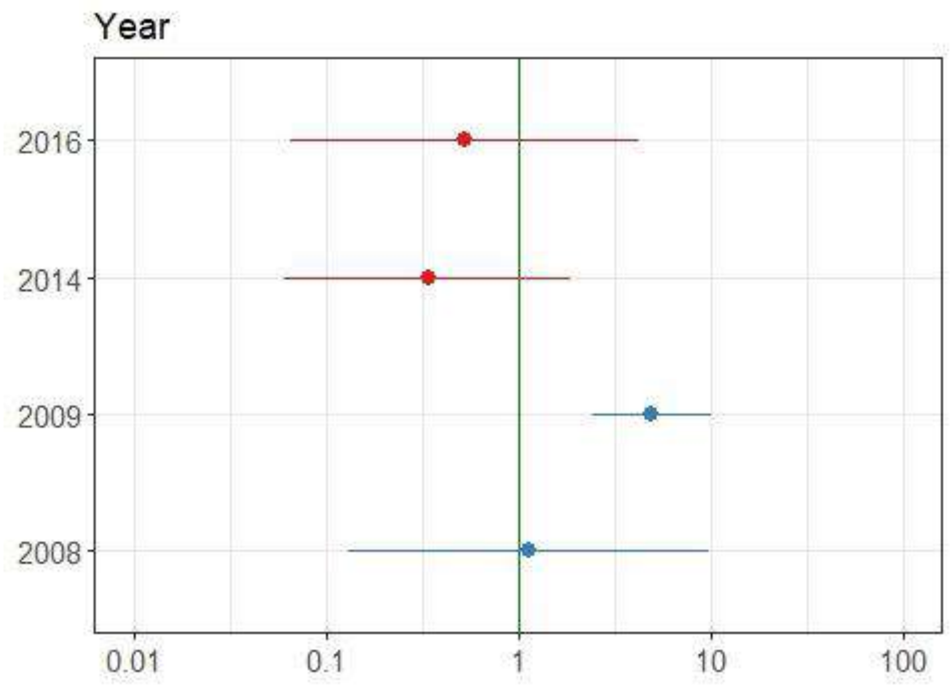
Supplementary material 3

Table 3. Results of PERMANCOVA test using 9999 permutations. The two fixed factors are: lake group (lake: three levels) and time (year: two levels), and their interaction (time: lake). Five covariates are: water quality status (water QS), lake surface-volume ratio (A/V ratio), the complexity of the shoreline (shoreline development), density of boats and distance from town. Significant p-values (< 0.05) are in **bold**.

Predictor	Df	Sum of Sqs	R2	F	Pr(>F)
water QS	1	0.408	0.059	3.794	**0.035**
A/V ratio	1	0.179	0.026	1.661	0.195
shoreline development	1	2.376	0.346	22.096	<**0.001**
number of boats	1	1.16	0.1699	10.788	<**0.001**
distance from town	1	0.22	0.032	2.047	0.133
time	1	0.11	0.016	1.024	0.318
lake group	2	0.575	0.084	2.675	0.057
time: lake	2	0.016	0.002	0.075	0.991
residual	17	1.828	0.266		
total	27	6.871	1		

Supplementary material 4

Figure 1. Random effects (year of sampling) plot



Załącznik nr 2

Krzysztof Podwysocki Łódź, 21.08.2024 r.

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OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K. 2024. Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161-192.

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji artykułu; opracowaniu metodyki zbierania informacji o presji turystycznej; zgromadzeniu danych fizyko-chemicznych, hydromorfologicznych oraz antropogenicznych potrzebnych do analiz; przygotowaniu danych do analiz statystycznych; przygotowaniu przeglądu literatury i przygotowaniu wstępu do artykułu; opisaniu części materiału i metod użytych w artykule; opisaniu części wyników w artykule; przygotowaniu dyskusji i wniosków w artykule; przygotowaniu tabel i grafik; korekcie artykułu zgodnie z uwagami współautorów; wysłaniu artykułu do czasopisma naukowego; korekcie artykułu zgodnie z uwagami recenzentów; koordynowaniu prac zespołu; organizowaniu spotkań celem dyskusji nad analizami oraz manuskryptem.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

K. Podwysocki
....
podpis

Appendix 2

Andrea Desiderato Lodz, 21.08.2024

name and surname *place and date*

Department of Invertebrate Zoology and Hydrobiology, University of Lodz, Lodz, Poland

affiliation

DECLARATION

I declare that in the work: Podwysocki K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K. 2024. Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161-192.

(authors, year of publication, title, journal or publisher, volume, pages)

my contribution consisted of:

contributing to the conceptualization of the study; collecting some spatial data; conducting the statistical analyses; describing statistical methods; describing part of the results; reviewing and editing the manuscript; providing feedback to the first author; and participating in meetings to discuss analyses and the manuscript.

(*the applicant for a doctoral degree should provide a detailed description of their contribution to the thesis)*

....

signature

Załącznik nr 2

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OŚWIADCZENIE

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mój udział polegał na:

współtworzeniu koncepcji badań; pobraniu części prób w terenie; przeprowadzeniu części analiz statystycznych; edycji manuskryptu oraz przesłaniu uwag do artykułu pierwszemu autorowi; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

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podpis

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OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K. 2024. Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161-192.

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(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

Tomasz Rewicz

podpis

Załącznik nr 2

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OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K. 2024. Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161-192.

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji badań; pobraniu części prób w terenie; przesłaniu uwag do artykułu pierwszemu autorowi; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem; zapewnieniu finansowania badań.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

....

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Załącznik nr 2

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OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K, Desiderato A, Mamos T, Rewicz T, Grabowski M, Konopacka A, Bącela-Spychalska K. 2024. Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161-192.

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mój udział polegał na:

współtworzeniu koncepcji badań; pobraniu części prób w terenie; przesłaniu uwag do artykułu pierwszemu autorowi; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem; opieką nad pracą doktoranta; zapewnieniu finansowania badań; byciu autorem korespondencyjnym.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

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Publication II.

Podwysocki K, Bącela-Spychalska K, Desiderato A, Rewicz T, Copilaș-Ciocianu D (2024a) Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe. Hydrobiologia. https://doi.org/10.1007/s10750-024-05565-8

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- **IF: 2.2**
- **Points of the Ministry of Education and Science: 100 pkt.**

Hydrobiologia
https://doi.org/10.1007/s10750-024-05565-8

Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe

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Received: 15 February 2024 / Revised: 16 April 2024 / Accepted: 23 April 2024

Abstract Phenotypic variability is a key factor promoting the establishment and spread of invasive populations in new environments. The Ponto-Caspian region contains a diverse endemic fauna known for its exceptional environmental plasticity, with many species invading European waters. However, the extent to which the environment shapes the phenotypic variability of these successful invaders remains poorly understood. We test to what extent the environment, intraspecific lineage affinity and geographic range interact and shape the variability of ecologically relevant functional morphological traits of the amphipod, *Dikerogammarus villosus*. Our results show the highest differentiation among environments, with an enhancement of predation-related traits in brackish waters relative to freshwaters. Differentiation among lineages and ranges (native/invaded) was smaller, occurring in traits related to locomotion and food processing. Although we uncovered an overall increase in variability outside the native range, the dynamics of morphological change were lineage-specific: the Western Lineage (invading via the River Danube) underwent a shift towards increased appendage length, while the Eastern Lineage (invading via the River Dnieper) underwent a significant overall morphospace expansion. We conclude that *D. villosus* exhibits a remarkable morphological variability across Europe that is influenced by the interplay between the environment as well as its evolutionary and invasion history.

Keywords Functional morphology · Phenotypic variability · Native range · Invaded range · Hypervolume · Genetic admixture · Ponto-Caspian

Handling editor: Katya E. Kovalenko

Guest editors: Sidinei M. Thomaz, Cécile Fauvelot, Lee B. Kats, Jonne Kotta & Fernando M. Pelicice / Aquatic Invasive Species IV

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10750-024-05565-8.

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Introduction

Non-native organisms often encounter various novel selection pressures that drive their evolutionary adaptation in the invaded range (Suarez & Tsutsui, 2008; Atwood & Meyerson, 2011). Invasive species in recently colonised habitats need to adapt to new competitive and predatory pressures (Milchunas et al.,

Published online: 09 May 2024

1988; Bossdorf et al., 2004) and various ecosystem conditions (Willi et al., 2006) compared to the native range. These selective pressures are highlighted by studies that found significant phenotypic and ecological differences between individuals from native vs invaded ranges (Gallardo et al., 2013; Cerwenka et al., 2014; Courant et al., 2017; Kosmala et al., 2017; Sotka et al., 2018; Dashinov & Uzunova, 2020; Dashinov et al., 2020; Balzani et al., 2021; Phillips & Hagey, 2022; Copilaş-Ciocianu et al., 2023a).

Phenotypic variation is the primary substrate onto which natural selection acts and is therefore of major importance for the establishment of populations in new environments (Fox et al., 2019). Widespread invasive species are likely to exhibit considerable phenotypic variation across their distribution (Evangelista et al., 2019), which facilitates their fitness maintenance both in favourable (opportunistic species) and stressful (robust species) environments (Knop & Reusser, 2012). The high phenotypic diversity of invasive species outside the native range can result from bypassing the bottleneck effect due to multiple introductions (Wattier et al., 2007; Gillis et al., 2009). Phenotypic diversity can also be shaped by the genetic disparities between the source populations in the native area (Hermisson & Wagner, 2004).

Generally, many invasive species are omnivorous, which increases their chances of successful establishment in new environments (Machovsky-Capuska et al., 2016). Usually, the trophic niches of non-native species are broader than those of native species (Feiner et al., 2013; Šidagyte et al., 2017a). Moreover, invasive species can exhibit significant trophic niche and morphological variability across geographic ranges and populations (Jourdan et al., 2019; Copilaş-Ciocianu et al., 2023a). However, the extent to which the evolutionary history in the native range and environmental plasticity can influence the phenotypic differentiation of invasive populations remain poorly investigated.

Functional morphology often reflects an organism's ecological niche since phenotypes interact with the environment primarily via external morphology (Bock & von Wahlert, 1965; Valen, 1965; Evangelista et al., 2019). As such, functional morphology shapes a species' spatial distribution and its role in the ecosystem (Ferry-Graham et al., 2002; Dehling et al., 2016), especially from a trophic perspective (Ferry-Graham et al., 2002; Pigot et al., 2020; Copilaş-Ciocianu et al., 2021). Some non-native species undergo morphological and associated dietary changes while colonising new environments (Klepaker, 1993; Adachi et al., 2012; Evangelista et al., 2019). However, the significance of environmental factors in shaping the phenotypic variability of invasive species is still poorly understood (Arbačiauskas et al., 2013).

The Ponto-Caspian region consists of the Black, the Caspian and the Azov Seas and their adjacent lagoons and river deltas (Jażdżewski, 1980). The dynamic geological history and long isolation of the basin promoted diversification and high endemism of various groups of Ponto-Caspian fauna, including crustaceans, molluscs and fish (Cristescu & Hebert, 2005; Griffiths, 2006; Neilson & Stepien, 2009; Wesselingh et al., 2019). Many of them display high phenotypic and environmental plasticity in newly colonised environments (Kostrzewa & Grabowski, 2003; Grabowska et al., 2009; Cerwenka et al., 2014; Copilaş-Ciocianu & Sidorov, 2022). Especially diverse and widely distributed group of Ponto-Caspian fauna are amphipod crustaceans (Väinölä et al., 2008; Copilaş-Ciocianu et al., 2020; Copilaş-Ciocianu et al., 2023b). Among them, particularly widespread are gammarids for which the Ponto-Caspian region constitutes a biodiversity hotspot (Väinölä et al., 2008; Rewicz et al., 2016; Copilaş-Ciocianu & Sidorov, 2022). Almost 40% of these species are invasive and rapidly colonised freshwater ecosystems in Europe (Jażdżewski, 1980; Bij de Vaate et al., 2002; Copilaş-Ciocianu et al., 2023b). Their invasive success is attributed to many biological traits, including diet plasticity, accompanied by a higher predatory ability (Van der Velde et al., 2000; Bącela-Spychalska & Van Der Velde, 2013; Dehedin et al., 2013). However, the morphological variation of traits responsible for feeding across populations from different environments and invasive history is poorly studied.

A good model species for such comparisons is *Dikerogammarus villosus* (Sowinsky, 1894). It is an invasive amphipod of Ponto-Caspian origin which has broadly spread in Europe (Grabowski et al., 2007; Rewicz et al., 2014; Copilaş-Ciocianu et al., 2023b). Phylogeographic analyses uncovered four genetically distinct native populations along the northwest shore of the Black Sea: the Dnieper Delta, the Dniester Delta, the Danube Delta and the Durungol liman (Rewicz et al., 2015b). Two of these genetically distinct lineages i.e., the Western (the Danube origin) and the Eastern (the Dnieper origin) colonised many European lentic and lotic waters (Rewicz et al., 2015a, b, 2017). The wide distribution of this species in Europe in various lentic and lotic environments could influence its morphological variability, similar to patterns observed in certain fish species (Dürrani et al., 2023; Záhorská et al., 2023). Moreover, this species also experienced one of the strongest climatic niche expansions in the invaded range among invasive Ponto-Caspian amphipods (Šidagytė-Copilas & Copilaş-Ciocianu, 2024). *Dikerogammarus villosus* is described as a crawler ecomorph (Copilaş-Ciocianu & Sidorov, 2022). Amphipods of this ecomorph generally have a slender body and long appendages and hide in coarse substrates such as gravel and stones (Copilaş-Ciocianu & Sidorov, 2022). *Dikerogammarus villosus* is an omnivorous species demonstrating a broad range of feeding habits (Platvoet et al., 2009; Worischka et al., 2018), which is confirmed by behavioural experiments (Pellan et al., 2015), stable isotopes studies (van Riel et al., 2006; Hellmann et al., 2015) and morphological comparisons of mouthparts (Mayer et al., 2008, 2009; Platvoet et al., 2009; Pellan et al., 2015; Richter et al., 2018). However, some differences in diet and trophic position were observed between certain populations of this species in the River Elbe and the River Rhine (Hellmann et al., 2015), suggesting that some morphological variation might be expected among populations. A recent study by Copilaş-Ciocianu et al. (2023a) has indeed shown that the diet and associated morphological traits of this species differ between the native range in the Black Sea and the invaded range in the Baltic Sea. However, it remains unknown to what extent the environment can influence phenotypic variability and if this variability differs among the two invading lineages. Examining this variability is essential due to its potential to reflect dietary plasticity — a key factor in the invasion process.

Therefore, the goal of our study was to test at the continental scale the effect of environment (brackish waters, freshwater lakes and freshwater river sections), intraspecific lineage (Western, Dniester and Eastern) and range (native and invaded) in shaping the variability of functional morphological traits that directly (gnathopods, mouthparts, stomach) or indirectly (antennae, walking legs) reflect the diet of *Dikerogammarus villosus*. Given its broad geographical occurrence in different types of waterbodies (freshwater river sections, brackish waters and freshwater lakes) and its trophic plasticity, we hypothesise that *D. villosus* exhibits a considerable amount of functional morphological variation. We further hypothesise that due to greater environmental heterogeneity in the invaded range, *D. villosus* experiences a significant morphospace expansion outside the native range. Understanding this variation is important for better comprehension of the invasive potential of this species.

Materials and methods

Sampling and laboratory procedures

The examined material consisted of male specimens of *Dikerogammarus villosus* collected from 35 sampling points across three different environments i.e., freshwater river sections, freshwater lakes and brackish waters, in both native and invaded ranges in Europe (as illustrated in Fig. 1 and detailed in Supplementary Table 1). We considered all of the native sampling sites as belonging to the brackish water category as they are located either in brackish coastal lagoons or in deltaic regions, which are regularly subjected to saline water intrusions. Some environmental factors may be unique to each environment type but multiple may be shared. Therefore, our division of environments is based mainly on salinity (brackish waters vs freshwater river sections and lakes) and water current (brackish waters and rivers vs lakes). These two main environmental factors were used in the discussion of our results. Based on Rewicz et al. (2015b), we divided our dataset into Western, Eastern and Dniester intraspecific genetic lineages. Specimens were collected at a depth of up to 0.5 m through "kick-sampling" with a benthic hand-net with a mesh size of 0.5 mm according to established protocols of Jażdżewski et al. (2002) and Grabowski et al. (2006). The amphipods were preserved in 96% ethanol and then identified in the laboratory to the species level based on the literature (Mordukhay-Boltovskoy, 1964; Eggers & Martens, 2001).

From most localities, 10 mature, well-preserved individuals, without visible damage to the body and appendages, were chosen for the dissection. In the case of five sampling points, a smaller number of

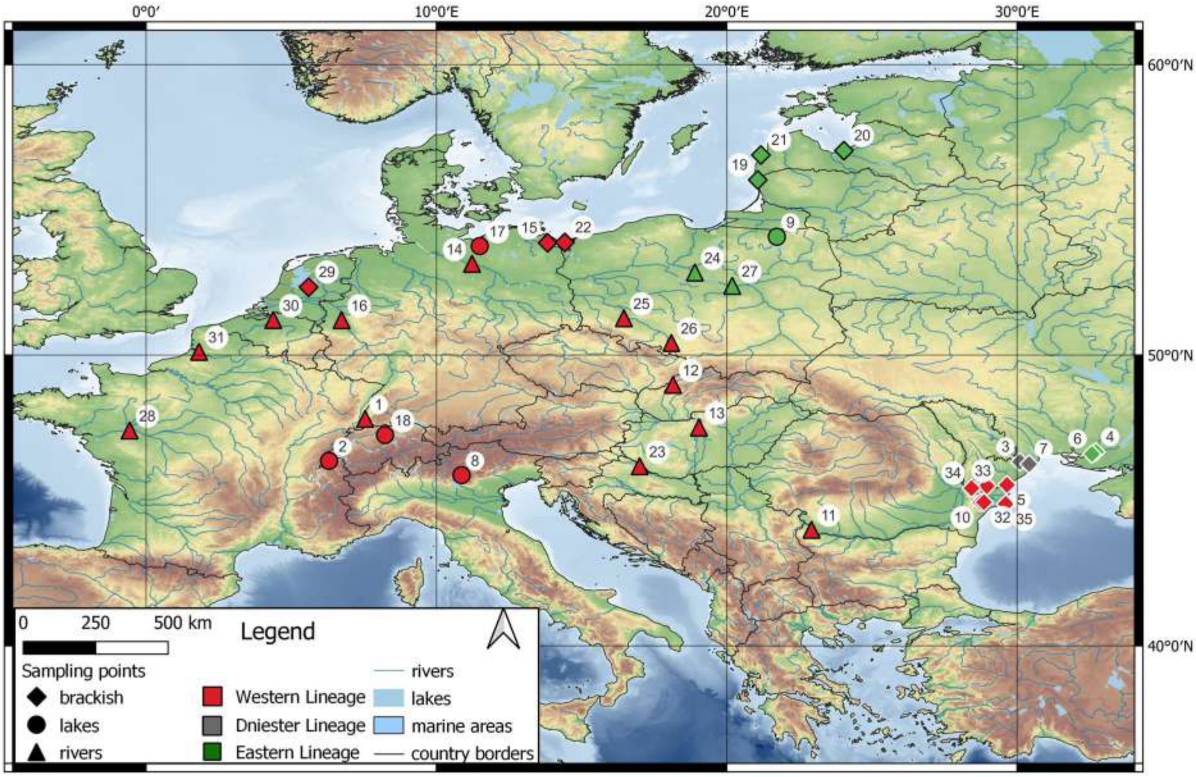

Fig. 1 Sampling sites in Europe are numbered according to Supplementary Table 1. Symbols with white and black outlines show sites from the native and invaded ranges, respectively

specimens (six specimens from each of two localities and nine individuals from each of three localities) was used, depending on material availability. In total, we used 339 individuals (9.7 ind./locality on average) for the dissection. Only male specimens were chosen as we wanted to exclude sexual dimorphism as a confounding factor (Conlan, 1991). Before the dissection, the cuticle was softened by immersing the specimens overnight in 1.5% lactic acid solution as in Zhao et al. (2021) and subsequently stored for a few hours in 1:3 glycerol-ethanol mix as in Copilaş-Ciocianu et al. (2021).

For assessing functional morphological differentiation, we chose 29 traits involved in sensory functions (both antennae), food processing and digestion (stomach, mandibles, maxillipeds), food capturing and handling (the first pair of gnathopods) and locomotion (the third and the seventh pair of pereiopods, the first pair of pleopods and the third pair of uropods) (see Supplementary Table 2). All traits were chosen according to Copilaş-Ciocianu et al. (2021). For comparative purposes, always the right body side was dissected as in Copilaş-Ciocianu et al. (2021). The left side was used for the dissection only when the appendages on the right body side were damaged. Always the right-side mandibles were dissected to take into account their asymmetry (Mayer et al., 2012). The dissections were conducted under the stereomicroscope using needles, fine tweezers and microsurgical scissors according to Copilaş-Ciocianu et al. (2021) and Zhao et al. (2021). Dissected appendages were mounted on microscope slides in glycerol and photographed under a Nikon SMZ1000 stereomicroscope with a Pixelink M15C-CYL camera. Afterwards, the measurements were conducted based on photographs in Digimizer 4 software. The landmarks were chosen according to Fišer et al. (2009) and Copilaş-Ciocianu et al. (2021).

Statistical analysis

Measurements (except the gnathopod palmar angle) were regressed against body length to remove the effect of body size. In the subsequent analyses, we used regression residuals. Specimens that showed outlying values (mean $\pm 2 \times$ SD) were excluded from further analysis. Morphological traits were either analysed altogether or separated into four functional groups of traits i.e., sensory functions (antennae, six measurements), food processing and digestion (mouthparts and stomach, four measurements), food capturing and handling (gnathopods, seven measurements) and locomotion (pereiopods, pleopods and uropods, 10 measurements). Body and head lengths can be a proxy of multiple ecological functions (Allen et al., 2006), therefore, were not assigned to any functional group and analysed only in the set of all traits altogether. A Permutational Multivariate Analysis of Variance (PERMANOVA) with 999 permutations was used to test for morphological differences (either all traits or split among the four functional groups) between three grouping factors i.e., geographic range (two levels: native and invaded ranges), lineage (three levels: Western, Dniester and Eastern) and environment (three levels: rivers (freshwater sections), lakes (freshwater), brackish waters). Populations were assigned an invasion range based on Copilaş-Ciocianu et al. (2023a), and lineage assignment followed Rewicz et al. (2017). Both the effects of factors as well as all the possible interactions between them were tested. However, because the native range in our study contains only one type of environment (brackish waters, see above), the range: environment interaction as well as the full lineage: environment: range interaction could not be tested. To avoid pseudoreplication, due to measurements of multiple specimens per locality, the population factor was included in the analysis as strata during the permutations. The Euclidean distance metric was used to measure dissimilarity between data points. Pairwise comparisons were conducted under the Bonferroni correction. All PERMANOVA tests were performed in R 4.3.0 (R Core Team, 2023) using *adonis2* function of the package *vegan* and *pairwise.adonis* of the package *pairwiseAdonis* for the post hoc analysis between levels of the significant factors (Martinez Arbizu, 2020). To visually explore the patterns of differentiation, Principal Component Analysis (PCA) using a Pearson Correlation matrix was performed in PAST 4 (Hammer et al., 2001).

To estimate the magnitude and patterns of morphological differentiation between lineages, environments and geographic ranges, the n-dimensional hypervolume approach was applied to the first two PCA dimensions (PC1, PC2) as in Copilaş-Ciocianu et al. (2023b). Due to the sake of comparability among functional trait groups only the first two PCA dimensions were included. Hypervolumes for native and invaded ranges were constructed by pooling all individuals from the Western and Eastern Lineages as well as separately for each of the two lineages. Individuals from the Dniester Lineage were excluded from the range hypervolume analysis as this lineage is currently not known to occur outside its native range. Additionally, we also tested which of the environments had the greatest effect on morphospace change in the invaded range compared with the native. For this, we conducted a pairwise hypervolume comparison among the native brackish environment with each of the three environments in the invaded range separately (i.e., native brackish waters vs invaded freshwater river sections; native brackish waters vs invaded freshwater lakes and native brackish waters vs invaded brackish waters) by accounting for each of the two invading lineages separately (the Western and the Eastern). All hypervolume pairs were constructed using the *hypervolume* v. 3.1.0. R package (Blonder et al., 2014, 2018, 2023). For each hypervolume pair, we calculated total and unique volumes, distances between centroids and the Jaccard index. Furthermore, we estimated morphological change dynamics (i.e., expansion, contraction and shift) among geographic ranges with the R package *BAT* v.2.9.2. (Cardoso et al., 2015). The change was assessed with the β_{total} diversity index (= 1 − a value of Jaccard similarity), ranging from 0 for fully overlapping morphospaces, and 1 for completely non-overlapping morphospaces. Subsequently, this index was decomposed into the $\beta_{replacement}$ index, indicating morphospace shift, and the $\beta_{richness}$ index, indicating morphospace contraction or expansion (Carvalho & Cardoso, 2020). We highlight that this terminology should not be confounded with the sequence of the invasion process. Therefore, it should be only considered as a change of morphospace between geographic ranges and not as changes with time.

Results

The PERMANOVA test showed that environment type has the most significant effect on the total (all traits combined) morphological differentiation ($F = 16.20$, $P = 0.001$), followed by lineage ($F = 5.35$, $P = 0.003$) and range ($F = 4.17$, $P = 0.023$) (Table 1). Pairwise comparisons (see Supplementary File 3) indicate significant differences between the Western and the Eastern Lineages ($P = 0.002$) and between the Eastern and the Dniester Lineages ($P = 0.020$). Regarding environments, significant differences were observed between brackish waters and rivers/lakes ($P < 0.001$/$P = 0.002$, respectively) but not between lakes and rivers. Significant differences between the Western and the Eastern Lineages were observed in lakes ($P = 0.025$) and in brackish waters between the Eastern and the Dniester Lineages ($P < 0.001$). Within the Western and Eastern Lineages, brackish waters differ

Table 1 Results of PERMANOVA testing the effect of range, lineage and environment and their interaction on all analysed morphometric traits and on four functional morphological groups

Traits	Factor	df	SS	R2	*F*	*P*
All	**Range**	1	150.40	0.01	4.17	**0.023**
	Lineage	2	385.80	0.03	5.35	**0.003**
	Environment	2	1169.60	0.09	16.20	**0.001**
	Lineage: Range	1	63.70	0.00	1.76	0.250
	Lineage: Environment	2	257.90	0.02	3.57	*0.070*
	Residuals	324	11,692.40	0.85		
	Total	332	13,719.80	1.00		
Sensory functions	Range	1	1.93	0.00	0.96	0.458
	Lineage	2	3.70	0.01	0.92	0.396
	Environment	2	17.00	0.02	4.21	**0.003**
	Lineage: Range	1	5.52	0.01	2.73	0.104
	Lineage: Environment	2	28.63	0.04	7.09	**0.001**
	Res	324	654.05	0.92		
	Total	332	710.83	1.00		
Food processing and digestion	Range	1	0.19	0.00	0.71	0.432
	Lineage	2	1.50	0.01	2.83	**0.046**
	Environment	2	7.89	0.08	14.84	**0.001**
	Lineage: Range	1	0.22	0.00	0.83	0.393
	Lineage: Environment	2	4.63	0.05	8.70	**0.001**
	Res	324	86.10	0.86		
	Total	332	100.53	1.00		
Food capturing and handling	Range	1	63.30	0.01	2.56	0.132
	Lineage	2	220.10	0.02	4.45	**0.011**
	Environment	2	1087.50	0.11	22.00	**0.001**
	Lineage: Range	1	0.40	0.00	0.02	0.930
	Lineage: Environment	2	150.90	0.02	3.05	0.215
	Res	324	8009.20	0.84		
	Total	332	9531.40	1.00		
Locomotion	**Range**	1	8.57	0.02	8.37	**0.001**
	Lineage	2	10.91	0.03	5.33	**0.002**
	Environment	2	2.96	0.01	1.45	0.29
	Lineage: Range	1	1.02	0.00	0.99	0.475
	Lineage: Environment	2	5.78	0.02	2.82	*0.053*
	Res	324	331.74	0.92		
	Total	332	360.97	1.00		

Interactions that lacked sufficient data were not considered. The significant effects ($P \leq 0.05$) are in **bold**. Marginally significant effects ($0.05 < P$ value ≤ 0.1) are in *Italic*.

Df degrees of freedom, *SS* sum of squares, *R2* R-squared, *F* F-statistic compared to the rivers (both $P < 0.001$) and lakes ($P = 0.017$, $P = 0.005$, respectively).

Sensory traits (antennae) differ between environments ($F = 4.21$, $P = 0.003$) and in the interaction between environments and lineages ($F = 7.09$, $P = 0.001$) (Table 1). Significant differences were detected between lakes and rivers ($P = 0.019$) as well as between lakes and brackish waters ($P = 0.001$). The Western and the Eastern Lineages differ in lakes ($P < 0.001$). Within the Eastern Lineage lakes differ significantly from brackish waters and rivers (both $P < 0.001$) (Supplementary File 3).

Food processing and digestion traits (mouthparts and stomach) differ significantly between environments ($F = 14.84$, $P = 0.001$), lineages ($F = 2.83$, $P = 0.046$) and in the interaction between lineages and environments ($F = 8.70$, $P = 0.001$) (Table 1). All environments differ from each other ($P < 0.05$), while the differences between lineages were observed between the Dniester and two other lineages ($P = 0.020$, $P = 0.036$ for comparison with the Western and the Eastern, respectively). Within the Eastern Lineage, all environments differ from each other ($P < 0.05$), while for the Western Lineage, brackish waters significantly differ from lakes and rivers ($P = 0.013$, $P = 0.034$, respectively). All the lineages differ from each other in brackish waters ($P < 0.05$). Additionally, the Western and the Eastern Lineages differ in lakes ($P = 0.010$) (Supplementary File 3).

Food capturing and handling traits (gnathopods) differ significantly between environments ($F = 22.00$, $P = 0.001$) and lineages ($F = 4.45$, $P = 0.011$) (Table 1). These traits differ between the Western and the Eastern Lineages ($P = 0.008$) and between populations from brackish waters and other environments ($P < 0.05$). Within the Eastern Lineage, populations from brackish waters significantly differ from other environments ($P < 0.001$ and $P = 0.006$ for comparisons with rivers and lakes, respectively). Within the Western Lineage, populations from brackish waters also differ from rivers and lakes ($P < 0.001$, $P = 0.019$, respectively). Brackish populations differ between the Eastern Lineage and two other lineages ($P < 0.05$) (Supplementary File 3).

Locomotion traits (pereiopods, pleopods and uropods) significantly differ between native and invaded ranges ($F = 8.37$, $P = 0.001$) and between lineages ($F = 5.33$, $P = 0.002$) (Table 1). Pairwise comparisons for lineages showed a significant difference between the Western and two other lineages ($P < 0.05$). Within the Eastern lineage, significant differences were observed between lakes and rivers ($P = 0.001$) as well as between lakes and brackish waters ($P = 0.002$). Populations from brackish waters differ between the Dniester and the Eastern Lineages ($P = 0.042$) as well as between river populations from the Western and the Eastern Lineages ($P < 0.001$) (Supplementary File 3).

In the PCA analysis, the first two axes explain 47.8% of the morphological variation. The first axis (39.8% of variation explained) reflects the length of pereiopods, mandible palps and peduncles of antennae, while the second axis (8.0% of variation explained) reflects the molar surface, palmar angle, and length of stomach, head, gnathopod palm, spines and setae of gnathopods as well as maxilliped palps (Fig. 2). Overall, populations from brackish waters are characterised by a tendency towards a narrower palmar angle, smaller molar surface and stomach length and have an increased body size and head length as well as palmar spines (Fig. 2b). Morphological variation increases in the invaded range, with populations being characterised by generally longer antennae and pereiopods compared to native populations (Fig. 2c).

PCAs for separate groups of traits (see Fig. 3a) increased the percentage of variation explained. PCA for sensory traits (86.2% of variation explained) indicates that populations from rivers and brackish waters have generally shorter antennae (Fig. 3b). PCA for food processing and digestion traits (69.7% of variation explained) indicates a trend towards decreasing stomach length and molar surface in populations from brackish waters (Fig. 3c) and from the Western Lineage (Fig. 3d). PCA for food capturing traits (66.8% of variation explained) indicates that populations from brackish waters have generally smaller palmar angles and longer palms, spines and setae of gnathopods relative to freshwater populations (Fig. 3e). A trend towards increasing gnathopod size was observed in the Western Lineage (Fig. 3f). PCA for locomotion traits (67% of variation explained) indicated a trend towards decreasing the length of the 7th pair of pereiopods in the native area (Fig. 3g) and for the Dniester Lineage (Fig. 3h).

Hypervolumes indicate that the highest morphospace overlap is found among the Western and the Eastern Lineages when ranges are disregarded

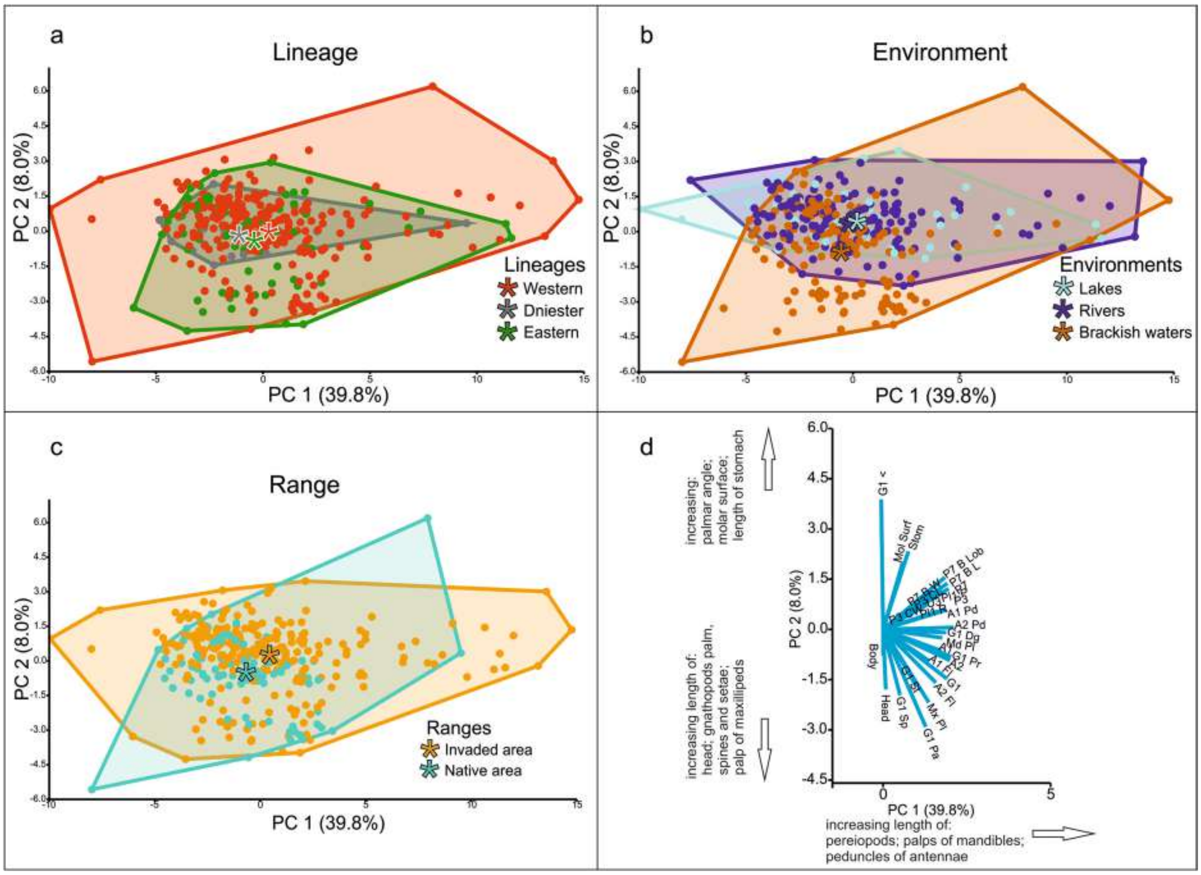

Fig. 2 PCA scatterplots of the overall morphological differentiation of *D. villosus* among lineages (**a**), environments (**b**) and ranges (**c**). For clarity, the biplot with 29 traits is shown on a separate plot (**d**). Abbreviations of the traits according to Supplementary Table 2

(Jaccard = 0.74) (Table 2, Fig. 4d). Considering only ranges, the amount of overlap decreases (Jaccard = 0.52) (Table 2, Fig. 4a). When both lineage and range are factored in, the amount of overlap decreases even more, with a moderate overlap among ranges within the Western Lineage (Jaccard = 0.48) (Fig. 4b), and a small overlap among ranges within the Eastern Lineage (Jaccard = 0.27) (Fig. 4c). Morphospace overlap among environments mirrors the PERMANOVA and PCA results, with the lowest overlap being observed among brackish and river/lake populations (Jaccard = 0.51 and 0.41, respectively) and the highest between rivers and lakes (Jaccard = 0.64) (Table 2, Fig. 4e).

Analysis of niche change dynamics reveals a morphospace expansion in the invaded range when lineages are pooled together (native volume = 67.36; invaded volume = 109.43) with the $\beta_{richness}$ explaining 75% of the total (β_{total}) differentiation (Table 2). When lineages are considered, niche change dynamics among ranges become more refined and lineage-specific, with the Western Lineage being characterised more by a shift accompanied by an expansion (native volume = 81.25; invaded volume = 103.20; $\beta_{replacement}$ = 66% of β_{total}) while the Eastern Lineage underwent a significant overall morphospace expansion (native volume = 36.94; invaded volume = 129.98; $\beta_{richness}$ = 96% of β_{total}).

Morphospace change dynamics among ranges differ according to the environment. The Western Lineage can be characterised by an expansion in brackish waters (native volume = 80.69; invaded volume = 137.21; $\beta_{richness}$ = 76% of β_{total}), a shift with a slight contraction in lakes (native volume = 80.69;

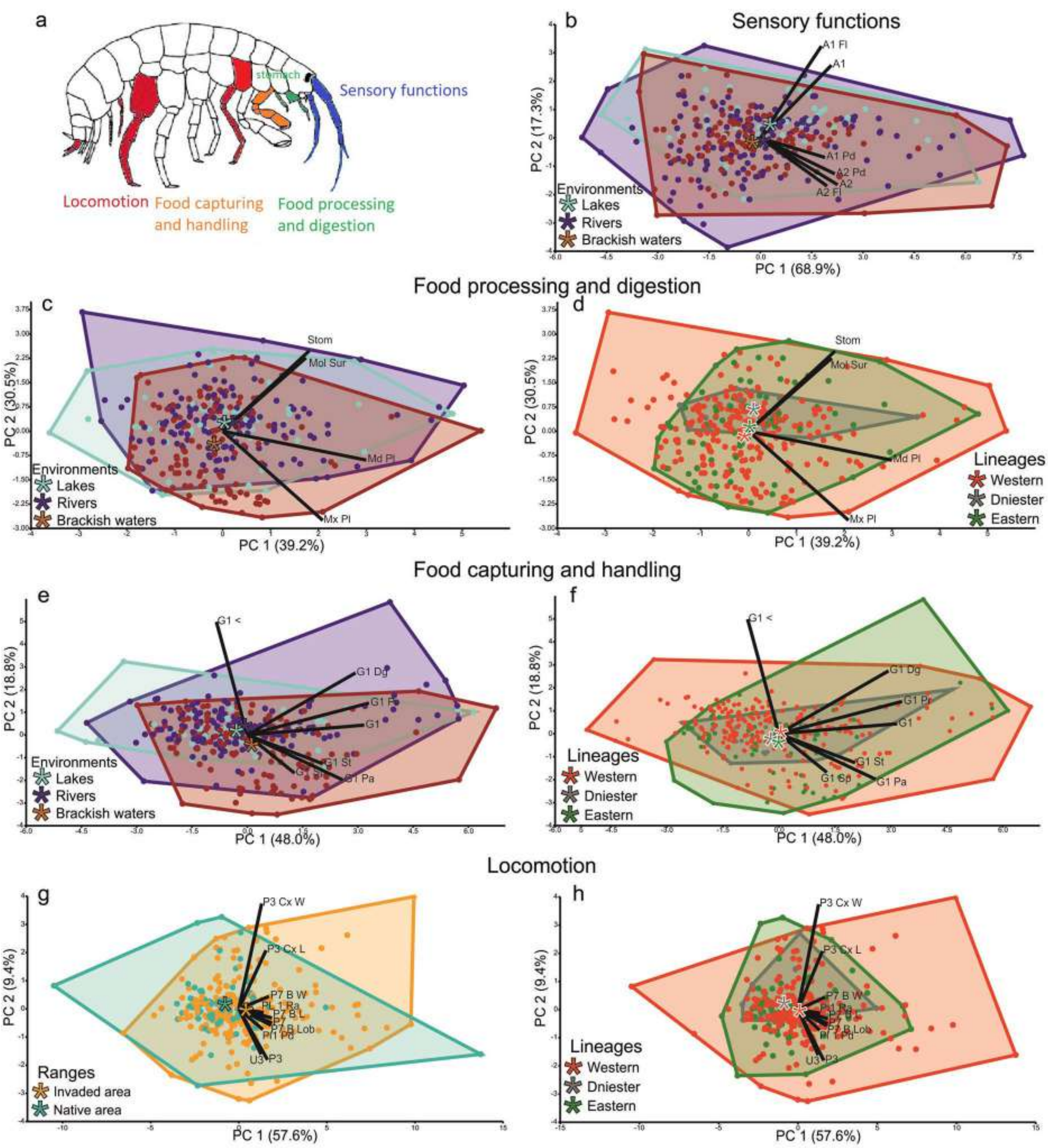

Fig. 3 PCA scatterplots of morphological differentiation among populations of *D. villosus* across environment types, ranges and lineages concerning functional groups of traits. Scheme highlighting the location and composition of functional groups (**a**). Only statistically significant combinations from PERMANOVA analysis for each group of traits are illustrated (**b**–**h**). Abbreviations of the traits according to Supplementary Table 2

invaded volume = 67.07; $\beta_{\text{replacement}} = 82\%$ of β_{total}) and a shift in rivers (native volume = 80.69; invaded volume = 82.99; $\beta_{\text{replacement}} = 97\%$ of β_{total}) (Table 2, Fig. 5a–c). While the Eastern Lineage can be characterised by an expansion in all environments in the invaded range i.e., in brackish waters (native volume = 37.07; invaded volume = 90.81; $\beta_{\text{richness}} = 89\%$ of β_{total}), in lakes (native volume = 37.07; invaded

Table 2 Results of hypervolume analysis of morphospace change patterns between lineages, environments and native and invaded ranges of *D. villosus*

Comparison	Volume (1)	Volume (2)	Volume (1) Unique	Volume Overlap	Volume (2) Unique	Jaccard index	Unique (1)	Unique (2)	Centroid distance	β Total	β Replacement	β Richness	Inferred morphospace change
Western(1)/ Eastern(2)	106.91	108.61	15.51	91.39	17.22	0.74	0.15	0.16	0.95	0.26			
Western(1)/ Dniester(2)	106.91	52.32	58.47	48.44	3.88	0.44	0.55	0.07	1.60	0.56			
Dniester(1)/ Eastern(2)	52.32	108.61	3.65	48.68	59.93	0.43	0.07	0.55	0.99	0.57			
River(1)/ Lake(2)	80.28	84.50	15.72	64.56	19.94	0.64	0.20	0.24	0.54	0.36			
River(1)/ Brackish(2)	80.28	91.72	22.36	57.92	33.80	0.51	0.28	0.37	2.22	0.50			
Lake(1)/ Brackish(2)	84.50	91.72	33.24	51.27	40.46	0.41	0.39	0.44	2.10	0.59			
Native(1)/ Invasive(2)	67.36	109.43	7.23	60.13	49.30	0.52	0.11	0.45	2.18	0.48	0.12 (25%)	0.36 (75%)	Expansion
Western Lineage: Native(1)/ Invasive(2)	81.25	103.20	21.60	59.65	43.55	0.48	0.27	0.42	2.35	0.52	0.34 (66%)	0.18 (34%)	Shift
Eastern Lineage: Native(1)/ Invasive(2)	36.94	129.98	1.71	35.23	94.75	0.27	0.05	0.73	1.53	0.73	0.03 (4%)	0.71 (96%)	Expansion
Western Lineage: Native(1)/ Invaded brackish(2)	80.69	137.21	9.10	71.58	65.63	0.49	0.11	0.48	3.03	0.51	0.12 (24%)	0.39 (76%)	Expansion
Western Lineage: Native(1)/ Invaded river(2)	80.69	82.99	33.17	47.51	35.48	0.41	0.41	0.43	2.78	0.59	0.57 (97%)	0.02 (3%)	Shift

Table 2 (continued)

Comparison	Volume (1)	Volume (2)	Volume (1) Unique	Volume Overlap	Volume (2) Unique	Jaccard index	Unique (1)	Unique (2)	Centroid distance	β Total	β Replacement	β Richness	Inferred morphospace change
Western Lineage: Native(1)/ Invaded lake(2)	80.69	67.07	42.38	38.30	28.76	0.35	0.53	0.43	1.88	0.65	0.53 (82%)	0.12 (18%)	Shift
Eastern Lineage: Native(1)/ Invaded brackish(2)	37.07	90.81	3.34	33.73	57.08	0.36	0.09	0.63	1.45	0.64	0.07 (11%)	0.57 (89%)	Expansion
Eastern Lineage: Native(1)/ Invaded river(2)	37.07	60.78	5.05	32.01	28.77	0.49	0.14	0.47	0.85	0.52	0.16 (31%)	0.36 (69%)	Expansion
Eastern Lineage: Native(1)/ Invaded lake(2)	37.07	81.98	7.45	29.62	52.36	0.33	0.20	0.64	3.97	0.67	0.17 (25%)	0.50 (75%)	Expansion

the table volume sizes, unique (unaffected by the overlap) parts of each relative to the volume size of each, and distance between centroids were presented for all comparisons. For comparisons of native and invaded ranges, total dissimilarity and its partitioning into replacement and richness indices were also presented to evaluate morphospace shift or expansion

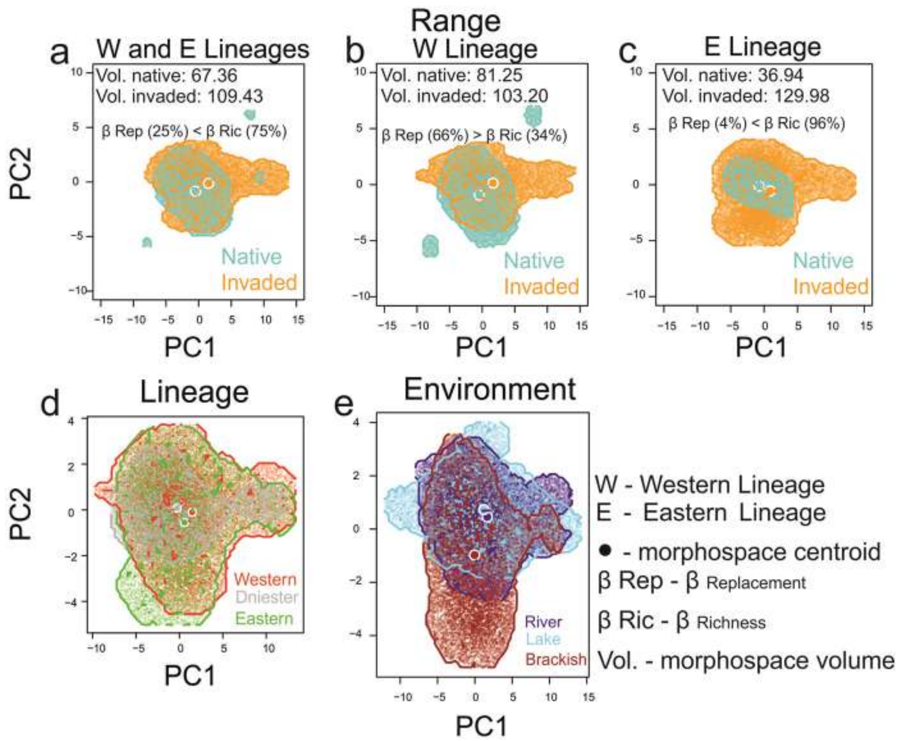

Fig. 4 Morphospace hypervolume for comparisons among ranges (**a**–**c**), lineages (**d**) and environments (**e**)

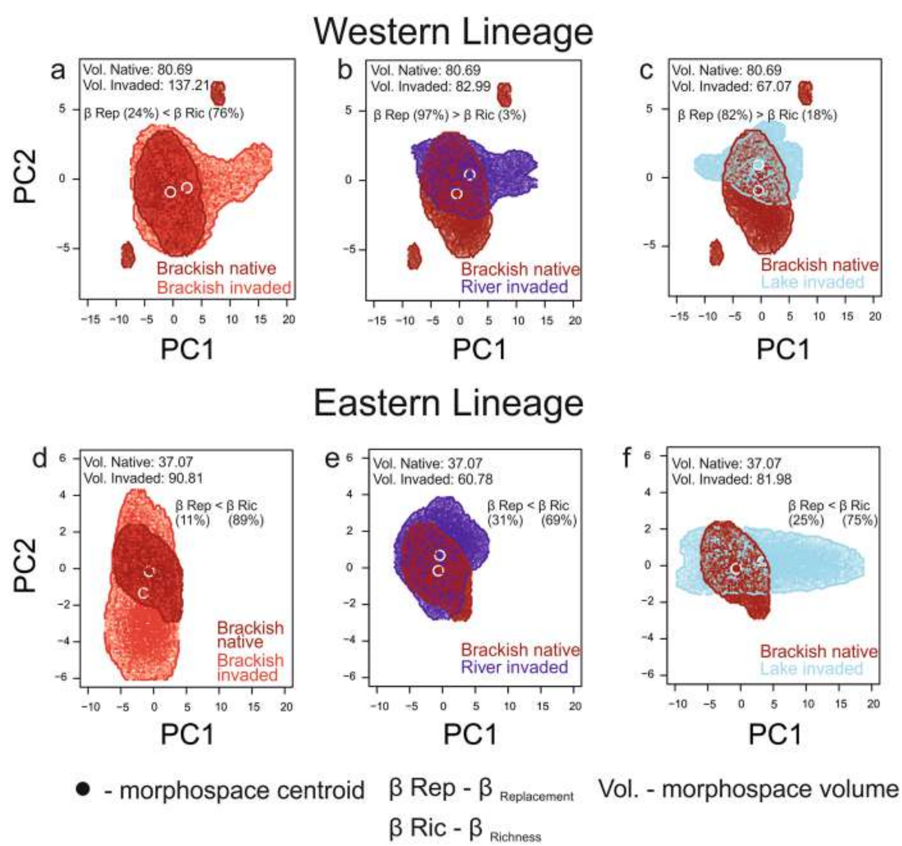

Fig. 5 Morphospace hypervolume for comparisons between the native range and each environment in the invaded range within the Western (**a**–**c**) and the Eastern Lineages (**d**–**f**)

volume = 81.98; $\beta_{richness}$ = 75% of β_{total}) and in rivers (native volume = 37.07; invaded volume = 60.78; $\beta_{richness}$ = 69% of β_{total}) (Table 2, Fig. 5d–f).

Discussion

Our results reveal that *Dikerogammarus villosus* exhibits a substantial amount of morphological variability across Europe. The main driver for this variation seems to be environment type as we uncovered that brackish water populations differ the most from populations inhabiting rivers and lakes. Differentiation between intraspecific lineages and among geographic ranges (native and invaded) is significant, but not as strong. Furthermore, we found that the two invading lineages (Western and Eastern) exhibit unique patterns of increasing morphological disparity in the invaded range, especially in brackish waters. Below we discuss the implications of these findings and their significance for the ongoing invasion of this species.

Individuals from brackish waters are characterised by longer setae on gnathopods propodi. This setation plays a role in filtering food particles, grooming and transferring to the mouthparts (Platvoet et al., 2006; Mayer et al., 2012). We also observed that the specimens from brackish waters have longer palms and narrower palmar angles. This increases the size of the opening between the dactylus and propodus, thus favouring the capture and handling of larger prey (Loxton & Nicholls, 1979; Fišer et al. (2019); Premate et al., 2021). These observations together with generally longer gnathopods of amphipods in brackish waters suggest that individuals from these populations can handle larger prey items, and as such could be more predatory.

The possibly higher predatory nature of brackish populations of *D. villosus* can be also evidenced by the modification of food processing and digestion traits. Plant material is less nutritious and energy efficient (Pellan et al., 2015). Therefore, herbivorous organisms need to consume a high amount of plant material to compensate for their energetic needs. Consequently, herbivorous amphipods have a larger stomach and a broader molar surface than carnivorous species (Coleman, 1991; Mayer et al. (2015), Watling (1993); Copilaş-Ciocianu et al., 2021). Indeed, we observed that *D. villosus* specimens from brackish waters have shorter stomachs and smaller molar surfaces than specimens from other populations, suggesting a possibly higher tendency towards carnivory (higher specialisation). This again indicates that brackish waters individuals may be more predatory than those in freshwater environments.

Amphipods detect prey using their antennae, hence relatively long antennae are thought to be more common in predatory species or populations (Copilaş-Ciocianu et al., 2021). We observed longer antennae among lake populations compared to brackish environments, which stands in contrast to the suggested higher carnivory of brackish populations. However, we can assume that their length is related to environmental conditions. Studies on hermit crabs show that chemical cues detection can be disturbed by water pH (De la Haye et al., 2012). In the case of amphipods, it is known that the environment can have an impact on the morphology of antennae (Jones & Culver, 1989; Delić et al., 2016). Indeed, we can speculate that lower pH in eutrophic lakes favours longer antennae for more efficient chemical detection. Furthermore, the length of the antennae may be also determined by the water current (Delić et al., 2016), and therefore, we may expect that specimens inhabiting lakes need longer antennae to orientate efficiently in a habitat with lower water currents compared with rivers and river mouths. Moreover, antennae are also responsible for filter feeding (Platvoet et al., 2006; Fišer et al., 2009), thus, standing in congruence with our observations. Namely, our previous conclusions claiming more herbivory and detritus feeding of freshwater populations may be an explanation for the observed trend. However, these observations need to be further studied and completed with experimental testing.

Considering the above, we can generally assume that brackish populations are more carnivorous than freshwater populations. Indeed, stable isotope analysis on the closely related *Pontogammarus robustoides* showed a higher trophic position (reflecting higher predation) of populations from brackish waters than freshwater environments (Arbačiauskas et al., 2013). It has been hypothesised that the higher phosphorus and lower nitrogen contents in brackish waters promote predation and faster growth rates (Arbačiauskas et al., 2013). Our results suggest that the putatively increased carnivory of brackish populations of *D. villosus* may cause a more severe impact on macrobenthic communities and more rapidly spread in coastal areas of the Baltic Sea (Šidagytė et al., 2017b; Copilaş-Ciocianu & Šidagytė-Copilaş, 2022).

We also observed morphological differences between ranges (i.e., native vs invaded). Specimens in the native range have a slightly narrower palmar angle of gnathopods of the 1st pair compared to the invaded range. It suggests more predatory habits of *D. villosus* in the native range and higher omnivory in the invaded range. Indeed, omnivorous habits are an important trait promoting the successful invasion of this species (Van der Velde et al., 2000; van Riel et al., 2006; Platvoet et al., 2009). Our findings are supported by a recent study that indicated a niche contraction in the invaded range with a shift towards decreased carnivory (Copilaş-Ciocianu et al., 2023a). However, the differences observed in our study are driven mainly by the environment. For instance, the palmar angle of gnathopods of the 1st pair differs between individuals of the Eastern Lineage from brackish waters in native and invaded ranges. A narrower palmar angle in the case of amphipods from Baltic populations (invaded range of the Eastern Lineage) underline their higher level of predatory and possible threat to the macrofauna of the Eastern coast of the Baltic Sea.

At the lineage level, we observed a significant differentiation with respect to the locomotor apparatus and food processing traits. Individuals from the Western populations have longer pereiopods, compared to those from the Eastern populations. The same can be observed for individuals from the invaded range in comparison to the native range. These appendages are responsible for locomotion, and their length positively influences locomotion speed (Kralj-Fišer et al., 2020; Boudrias (2002), Dahl (1978)). An enhancement of the spreading speed in the invaded range was observed for instance in cane toads (Kosmala et al., 2017). It can be assumed that predatory specimens might have longer pereiopods (Copilaş-Ciocianu et al., 2021), suggesting a higher predatory ability of *D. villosus* individuals from the Western Lineage and invaded range. The higher predatory ability of the Western Lineage can be also evidenced by bigger gnathopods. In contrast, we show that the populations from the Eastern Lineage have longer stomachs and broader molar surfaces, which might reflect a higher amount of plant material in their diet. We also find that the morphology of the Dniester Lineage, which is restricted only to the native Dniester lagoon, overlaps significantly with the Western and Eastern Lineages. This indicates that it has an intermediate morphology, which reflects its genetically intermediate position between the Western and Eastern Lineages (Rewicz et al., 2015b).

Each of the two invasive lineages displays a unique pattern of morphological change in the invaded range compared with the native area. We observed a morphospace shift in the invaded range within the Western Lineage and a morphospace expansion within the Eastern Lineage. Although the morphospace of the Eastern Lineage in the native range is smaller than that of the Western Lineage, it is larger in the invaded range. However, the factors behind this disparity could be multiple. One reason could be due to the possibly higher heterogeneity of the invaded environments in Eastern Europe, where there are fewer artificial channels and waters are less modified (Bij de Vaate et al., 2002). The Eastern Lineage also experienced a significant morphospace expansion in all three environment types in the invaded range which may suggest an intrinsically higher developmental plasticity than the Western Lineage. Regardless, one could assume that the more variable Eastern Lineage may be more successful in invading new habitats. Although fewer studies were done on the Eastern Lineage, they show a progressive expansion of *D. villosus* in the coastal areas of the Baltic Sea (Šidagytė et al., 2017b; Copilaş-Ciocianu & Šidagytė-Copilaş, 2022) but also in freshwaters of the Masurian Lakeland (Podwysocki et al., 2024).

Our results constitute an important contribution to the study of morphological variability and plasticity of invasive aquatic species. The high morphological disparity observed between populations of *D. villosus* from different environments, as well as among ranges and evolutionary lineages underlines the importance of incorporating environmental and evolutionary factors across a wide geographical area and not limiting these comparisons among the native and invaded ranges. Although the environment is the main driver of the observed variance, the differentiation among lineages and ranges suggests differences in plasticity between lineages. In particular, variation of traits responsible for food processing and digestion, can be an important driver of trophic niche expansion or shift in the newly colonised environments. However, experimental studies are critical for gaining a better comprehension of how morphological plasticity is reflected ecologically. Furthermore, experimental findings would also need to be validated with a complementary analysis of the diet (stable isotopes and gut content) of wild populations. Possible dietary differences between populations could also result from the chemical composition and ultrastructure of mouthparts, warranting further research in this direction (Mekhanikova et al., 2012).

Conclusion

Our study revealed that *Dikerogammarus villosus*, one of the most prominent invaders in Europe, exhibits a remarkable amount of morphological variability at the continental scale, especially in functional traits related to diet. Although the environment is the main driver of morphological divergence, intraspecific lineages and invasion history also play an important role. Moreover, the two invading lineages exhibit unique dynamics of morphological change in the invaded range relative to the native range, suggesting a lineage-specific invasion potential. The high morphological variability suggests a high level of plasticity, which likely reflects its high genetic diversity in the invaded range. This indicates a fast adaptive potential that promotes expansion and successful establishment in new habitats.

Acknowledgements We would like to thank Eglė Šidagytė-Copilaş (Nature Research Centre in Vilnius) for help and advice in the statistical analyses. We are grateful to Carl Smith, Richard Bailey, Stephen Venn, Krzysztof Pabis and Tomasz Mamos (University of Lodz) for constructive discussion that enhanced the quality of this manuscript. We would like to thank Jarosław Kobak and Łukasz Jermacz (Nicolaus Copernicus University in Torun) for help in the project proposal preparation and implementation of interesting conceptions. We are grateful to Michał Grabowski (University of Lodz) for advice during project proposal preparation and suggestions during the project implementation. Thanks are also due to two anonymous reviewers for their invaluable contributions to the improvement of this manuscript.

Author contributions KP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Funding acquisition, Project administration, Visualization, Writing—original draft. KBS: Conceptualization, Funding acquisition, Project administration, Supervision, Writing—review & editing. AD: Conceptualization, Methodology, Writing—review & editing, TR: Conceptualization, Resources, Supervision, Writing—review & editing. DCC: Conceptualization, Investigation, Methodology, Resources, Supervision, Validation, Writing—review & editing.

Funding The fellowship for the KP allowing for the study performance was founded by the University of Lodz within internal funds (IDUB Grant). The samples were collected within Projects 2018/31/D/NZ8/03061 and 2011/03/D/NZ8/03012 funded by Polish National Science Centre, N N304 350139 and N N304 081535 funded by Polish Ministry of Science and Education; Ponto-Caspian amphipods in the Baltic region: niche changes and functional comparison with local species (AMPHIBALT) funded by Research Council of Lithuania as well as field expeditions covered by internal funds of the University of Lodz.

Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Adachi, T., A. Ishikawa, S. Mori, W. Makino, M. Kume, M. Kawata & J. Kitano, 2012. Shifts in morphology and diet of non-native sticklebacks introduced into Japanese crater lakes. Ecology and Evolution 2: 1083–1098.

Allen, C. R., A. S. Garmestani, T. D. Havlicek, P. A. Marquet, G. D. Peterson, C. Restrepo, C. A. Stow & B. E. Weeks, 2006. Patterns in body mass distributions: sifting among alternative hypotheses. Ecology Letters 9: 630–643. https://doi.org/10.1111/j.1461-0248.2006.00902.x.

Arbačiauskas, K., J. Lesutienė & Z. R. Gasiūnaite, 2013. Feeding strategies and elemental composition in Ponto-Caspian peracaridans from contrasting environments: can stoichiometric plasticity promote invasion success? Freshwater Biology 58: 1052–1068.

Atwood, J. & L. Meyerson, 2011. Beyond EICA: understanding post-establishment evolution requires a broader evaluation of potential selection pressures. NeoBiota 10: 7–25.

Bącela-Spychalska, K. & G. Van Der Velde, 2013. There is more than one "killer shrimp": trophic positions and predatory abilities of invasive amphipods of Ponto-Caspian origin. Freshwater Biology 58: 730–741.

Balzani, P., S. Vizzini, F. Frizzi, A. Masoni, J. P. Lessard, C. Bernasconi, A. Francoeur, J. Ibarra-Isassi, F. Brassard, D. Cherix & G. Santini, 2021. Plasticity in the trophic niche of an invasive ant explains establishment success and long-term coexistence. Oikos 130: 691–696.

Bij de Vaate, A., K. Jażdzewski, H. A. M. Ketelaars, S. Gollasch & G. Van der Velde, 2002. Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. Canadian Journal of Fisheries and Aquatic Sciences 59: 1159–1174.

Blonder, B., C. Lamanna, C. Violle & B. J. Enquist, 2014. The n-dimensional hypervolume. Global Ecology and Biogeography 23: 595–609.

Blonder, B., C. B. Morrow, B. Maitner, D. J. Harris, C. Lamanna, C. Violle, B. J. Enquist & A. J. Kerkhoff, 2018. New approaches for delineating n-dimensional hypervolumes. Methods in Ecology and Evolution 9: 305–319.

Blonder, B., C. B. Morrow, S. Brown, G. Butruille, D. Chen, A. Laini, & D. J. Harris, 2023. Package ' hypervolume .' 92.

Bock, W. J. & G. von Wahlert, 1965. Adaptation and the form-function complex. International Journal of Ogranic Evolution 19: 1965.

Bossdorf, O., D. Prati, H. Auge & B. Schmid, 2004. Reduced competitive ability in an invasive plant. Ecology Letters 7: 346–353.

Boudrias, M. A., 2002. Are pleopods just "more legs"? The functional morphology of swimming limbs in *Eurythenes gryllus* (Amphipoda). Journal of Crustacean Biology 22: 581–594.

Cardoso, P., F. Rigal & J. C. Carvalho, 2015. BAT—biodiversity assessment tools, an R package for the measurement and estimation of alpha and beta taxon, phylogenetic and functional diversity. Methods in Ecology and Evolution 6: 232–236.

Carvalho, J. C. & P. Cardoso, 2020. Decomposing the causes for niche differentiation between species using hypervolumes. Frontiers in Ecology and Evolution 8: 1–7.

Cerwenka, A. F., P. Alibert, J. Brandner, J. Geist & U. K. Schliewen, 2014. Phenotypic differentiation of Ponto-Caspian gobies during a contemporary invasion of the upper Danube River. Hydrobiologia 721: 269–284.

Coleman, C. O., 1991. Comparative fore-gut morphology of Antarctic Amphipoda (Crustacea) adapted to different food sources. Hydrobiologia 223: 1–9.

Conlan, K. E., 1991. Precopulatory mating behavior and sexual dimorphism in the amphipod Crustacea. Hydrobiologia 223: 255–282.

Copilaş-Ciocianu, D. & E. Šidagytė-Copilaş, 2022. A substantial range expansion of alien Ponto-Caspian amphipods along the eastern Baltic Sea coast. Oceanologia 64: 227–232.

Copilaş-Ciocianu, D. & D. Sidorov, 2022. Taxonomic, ecological and morphological diversity of Ponto-Caspian gammaroidean amphipods: a review. Organisms Diversity and Evolution 22: 285–315. https://doi.org/10.1007/s13127-021-00536-6.

Copilaş-Ciocianu, D., Š Borko & C. Fišer, 2020. The late blooming amphipods: global change promoted post-Jurassic ecological radiation despite Palaeozoic origin. Molecular Phylogenetics and Evolution 143: 106664.

Copilaş-Ciocianu, D., B. V. Boros & E. Šidagytė-Copilas, 2021. Morphology mirrors trophic niche in a freshwater amphipod community. Freshwater Biology 66: 1968–1979.

Copilaş-Ciocianu, D., A. Garbaras & E. Šidagytė-Copilas, 2023a. Invasion is accompanied by dietary contraction in Ponto-Caspian amphipods. bioRxiv. https://doi.org/10.1101/2023.08.08.552405.

Copilaş-Ciocianu, D., D. Sidorov & E. Šidagytė-Copilas, 2023b. Global distribution and diversity of alien Ponto-Caspian amphipods. Biological Invasions 25: 179–195. https://doi.org/10.1007/s10530-022-02908-1.

Courant, J., S. Vogt, R. Marques, J. Measey, J. Secondi, R. Rebelo, A. De Villiers, F. Ihlow, C. De Busschere, T. Backeljau, D. Rödder & A. Herrel, 2017. Are invasive populations characterized by a broader diet than native populations? PeerJ 5: e3250.

Cristescu, M. E. A. & P. D. N. Hebert, 2005. The "Crustacean Seas"—an evolutionary perspective on the Ponto-Caspian peracarids. Canadian Journal of Fisheries and Aquatic Sciences 62: 505–517.

Dahl, E., 1978. The amphipod functional model and its bearing upon systematics and phylogeny. Zoologica Scripta 6: 221–228. https://doi.org/10.1111/j.1463-6409.1978.tb00773.x.

Dashinov, D. & E. Uzunova, 2020. Diet and feeding strategies of round goby, *Neogobius melanostomus* (Pallas, 1814) from the invasion front in the Danube River tributaries (Bulgaria): ontogenetic shift and seasonal variation. Limnologica 83: 125796. https://doi.org/10.1016/j.limno.2020.125796.

Dashinov, D., P. Czerniejewski, S. Balshine, C. Synyshyn, E. Tasheva-Terzieva, T. Stefanov, P. Ivanova, N. Mandrak & E. Uzunova, 2020. Variation in external morphology between the native and invasive populations of the round goby, *Neogobius melanostomus* (Actinopterygii: Gobiidae). Zoomorphology 139: 361–371. https://doi.org/10.1007/s00435-020-00480-7.

De la Haye, K. L., J. I. Spicer, S. Widdicombe & M. Briffa, 2012. Reduced pH sea water disrupts chemo-responsive behaviour in an intertidal crustacean. Journal of Experimental Marine Biology and Ecology 412: 134–140. https://doi.org/10.1016/j.jembe.2011.11.013.

Dehedin, A., C. Maazouzi, S. Puijalon, P. Marmonier & C. Piscart, 2013. The combined effects of water level reduction and an increase in ammonia concentration on organic matter processing by key freshwater shredders in alluvial wetlands. Global Change Biology 19: 763–774.

Dehling, D. M., P. Jordano, H. M. Schaefer, K. Böhning-Gaese & M. Schleuning, 2016. Morphology predicts species' functional roles and their degree of specialization in plant–frugivore interactions. Proceedings of the Royal Society b: Biological Sciences 283: 20152444.

Delić, T., P. Trontelj, V. Zakšek & C. Fišer, 2016. Biotic and abiotic determinants of appendage length evolution in a cave amphipod. Journal of Zoology 299: 42–50.

Dürrani, Ö., T. Ateşşahin, M. Eroğlu & M. Düşükcan, 2023. Morphological variations of an invasive cyprinid fish (*Carassius gibelio*) in lentic and lotic environments inferred from the body, otolith, and scale shapes. Acta Zoologica 104: 458–472.

Eggers, T. O. & A. Martens, 2001. Bestimmungsschlüssel der Süßwasser-Amphipoda (Crustacea) Deutschlands. A key to the freshwater Amphipoda (Crustacea) of Germany. Lauterbornia 42: 1–68.

Evangelista, C., J. D. Olden, A. Lecerf & J. Cucherousset, 2019. Scale-dependent patterns of intraspecific trait variations in two globally invasive species. Oecologia 189: 1083–1094. https://doi.org/10.1007/s00442-019-04374-4.

Feiner, Z. S., J. A. Rice & D. D. Aday, 2013. Trophic niche of invasive white perch and potential interactions with representative reservoir species. Transactions of the American Fisheries Society 142: 628–641.

Ferry-Graham, L. A., D. I. Bolnick & P. C. Wainwright, 2002. Using functional morphology to examine the ecology and evolution of specialization. Integrative and Comparative Biology 42: 265–277.

Fišer, C., P. Trontelj, R. Luštrik & B. Sket, 2009. Toward a unified taxonomy of *Niphargus* (Crustacea: Amphipoda): a review of morphological variability. Zootaxa 2061: 1–22.

Fišer, C., T. Delić, R. Luštrik, M. Zagmajster & F. Altermatt, 2019. Niches within a niche: Ecological differentiation of subterranean amphipods across Europe's interstitial waters. Ecography 42: 1212–1223. https://doi.org/10.1111/ecog.03983.

Fox, R. J., J. M. Donelson, C. Schunter, T. Ravasi & J. D. Galtan-Espitia, 2019. Beyond buying time: the role of plasticity in phenotypic adaptation to rapid environmental change. Philosophical Transactions of the Royal Society B 374: 20180174. https://doi.org/10.1098/rstb.2018.0174.

Gallardozu Ermgassen, B. P. S. E. & D. C. Aldridge, 2013. Invasion ratcheting in the zebra mussel (*Dreissena polymorpha*) and the ability of native and invaded ranges to predict its global distribution. Journal of Biogeography 40: 2274–2284.

Gillis, N. K., L. J. Walters, F. C. Fernandes & E. A. Hoffman, 2009. Higher genetic diversity in introduced than in native populations of the mussel *Mytella charruana*: evidence of population admixture at introduction sites. Diversity and Distributions 15(5): 784–795. https://doi.org/10.1111/j.1472-4642.2009.00591.x.

Grabowska, J., M. Grabowski & A. Kostecka, 2009. Diet and feeding habits of monkey goby (*Neogobius fluviatilis*) in a newly invaded area. Biological Invasions 11: 2161–2170.

Grabowski, M., A. Konopacka, K. Jażdżewski & E. Janowska, 2006. Invasions of alien gammarid species and retreat of natives in the Vistula Lagoon (Baltic Sea, Poland). Helgoland Marine Research 60: 90–97.

Grabowski, M., K. Bącela & A. Konopacka, 2007. How to be an invasive gammarid (Amphipoda: Gammaroidea)—comparison of life history traits. Hydrobiologia 590: 75–84.

Griffiths, A., 2006. Pattern and process in the ecological biogeography of European freshwater fish. Journal of Animal Ecology 75: 734–751.

Hammer, Ø., D. A. T. Harper & P. D. Ryan, 2001. Past: paleontological statistics software package for education. Palaeontologia Electronica 4: 1–9.

Hellmann, C., S. Worischka, E. Mehler, J. Becker, R. Gergs & C. Winkelmann, 2015. The trophic function of *Dikerogammarus villosus* (Sowinsky, 1894) in invaded rivers: a case study in the Elbe and Rhine. Aquatic Invasions 10: 385–397.

Hermisson, J. & P. Wagner, 2004. The population genetic theory of hidden variation and genetic robustness. Genetics 168: 2271–2284. https://doi.org/10.1534/genetics.104.029173.

Jażdżewski, K., 1980. Range extensions of some Gammaridean species in European inland waters caused by human activity. Crustaceana 84–107.

Jażdżewski, K., A. Konopacka & M. Grabowski, 2002. Four Ponto-Caspian and one American gammarid species (Crustacea, Amphipoda) recently invading Polish waters. Contributions to Zoology 71: 115–122.

Jones, R. & D. C. Culver, 1989. Evidence for selection on sensory structures in a cave population of *Gammarus minus* (Amphipoda). Evolution 43: 688–693.

Jourdan, J., K. Piro, A. Weigand & M. Plath, 2019. Small-scale phenotypic differentiation along complex stream gradients in a non-native amphipod. Frontiers in Zoology Frontiers in Zoology 16: 1–20.

Klepaker, T., 1993. Morphological changes in a marine population of threespined stickleback, *Gasterosteus aculeatus*, recently isolated in fresh water. Canadian Journal of Zoology 71: 1251–1258.

Knop, E. & N. Reusser, 2012. Jack-of-all-trades: phenotypic plasticity facilitates the invasion of an alien slug species. Proceedings of the Royal Society b: Biological Sciences 279: 4668–4676.

Kosmala, G., K. Christian, G. Brown & R. Shine, 2017. Locomotor performance of cane toads differs between native-range and invasive populations. Royal Society Open Science 4: 170517. https://doi.org/10.1098/rsos.170517.

Kostrzewa, J. & M. Grabowski, 2003. Opportunistic feeding strategy as a factor promoting the expansion of racer goby (*Neogobius gymnotrachelus* Kessler, 1857) in the Vistula basin. Lauterbornia 48: 91–100.

Kralj-Fišer, S., E. Premate, D. Copilaş-Ciocianu, T. Volk, Ž Fišer, G. Balázs, G. Herczeg, T. Delić & C. Fišer, 2020. The interplay between habitat use, morphology and locomotion in subterranean crustaceans of the genus *Niphargus*. Zoology 139: 125742. https://doi.org/10.1016/j.zool.2020.125742.

Loxton, R. G. & I. Nicholls, 1979. The functional morphology of the praying mantis forelimb (Dictyoptera: Mantodea). Zoological Journal of the Linnean Society 66: 185–203.

Machovsky-Capuska, G. E., A. M. Senior, S. J. Simpson & D. Raubenheimer, 2016. The multidimensional nutritional niche. Trends in Ecology and Evolution 31: 355–365. https://doi.org/10.1016/j.tree.2016.02.009.

Martinez Arbizu, P., 2020. pairwiseAdonis: pairwise multilevel comparison using adonis. R package version 0.4

Mayer, G., G. Maier, A. Maas & D. Waloszek, 2008. Mouthparts of the Ponto-Caspian invader *Dikerogammarus villosus* (Amphipoda: Pontogammaridae). Journal of Crustacean Biology 28: 1–15.

Mayer, G., G. Maier, A. Maas & D. Waloszek, 2009. Mouthpart morphology of *Gammarus roeselli* compared to a successful invader, *Dikerogammarus villosus* (Amphipoda). Journal of Crustacean Biology 29: 161–174.

Mayer, G., A. Maas & D. Waloszek, 2012. Mouthpart morphology of three sympatric native and nonnative gammaridean species: *Gammarus pulex*, *G. fossarum*, and *Echinogammarus berilloni* (Crustacea: Amphipoda). International Journal of Zoology 2012: 1–23.

Mayer, G., A. Maas & D. Waloszek, 2015. Mouthpart morphology of *Synurella ambulans* (F. Müller, 1846). Spixiana 38: 219–229.

Mekhanikova, I. V., D. S. Andreev, O. Y. Belozerova, Y. L. Mikhlin, S. V. Lipko, I. V. Klimenkov, V. V. Akimov, V. F. Kargin, Y. V. Mazurova, V. L. Tauson & Y. V. Likhoshway, 2012. Specific features of mandible structure and elemental composition in the polyphagous amphipod *Acanthogammarus grewingkii* endemic to lake Baikal. PLoS ONE 7: 1–9.

Milchunas, D. G., O. E. Sala & W. K. Lauenroth, 1988. A generalized model of the effects of grazing by large herbivores on grassland community structure. American Naturalist 132: 87–106.

Mordukhay-Boltovskoy, F., 1964. Caspian Fauna in Fresh Waters outside the Ponto-Caspian Basin. Hydrobiologia 23: 159–164.

Neilson, M. E. & C. A. Stepien, 2009. Escape from the Ponto-Caspian: evolution and biogeography of an endemic goby species flock (Benthophilinae: Gobiidae: Teleostei). Molecular Phylogenetics and Evolution. 52: 84–102. https://doi.org/10.1016/j.ympev.2008.12.023.

Pellan, L., V. Médoc, D. Renault, T. Spataro, & C. Piscart, 2015. Feeding choice and predation pressure of two invasive gammarids, *Gammarus tigrinus* and *Dikerogammarus villosus*, under increasing temperature. Hydrobiologia.

Phillips, J. G., & T. J. Hagey, 2022. Rapid morphological shifts in a co-invaded assemblage of lizards. Research Square Preprint: 1–19.

Pigot, A. L., C. Sheard, E. T. Miller, T. P. Bregman, B. G. Freeman, U. Roll, N. Seddon, C. H. Trisos, B. C. Weeks & J. A. Tobias, 2020. Macroevolutionary convergence connects morphological form to ecological function in birds. Nature Ecology and Evolution 4: 230–239. https://doi.org/10.1038/s41559-019-1070-4.

Platvoet, D., J. T. A. Dick, N. Konijnendijk & G. Van Der Velde, 2006. Feeding on micro-algae in the invasive Ponto-Caspian amphipod *Dikerogammarus villosus* (Sowinsky, 1894). Aquatic Ecology 40: 237–245.

Platvoet, D., G. Van Der Velde, J. T. A. Dick & S. Li, 2009. Flexible omnivory in *Dikerogammarus villosus* (Sowinsky, 1894) (Amphipoda)—Amphipod Pilot Species Project (AMPIS) Report 5. Crustaceana 82: 703–720.

Podwysocki, K., A. Desiderato, T. Mamos, T. Rewicz, M. Grabowski, A. Konopacka & K. Bącela-Spychalska, 2024. Recent invasion of Ponto-Caspian amphipods in the Masurian Lakeland associated with human leisure activities. NeoBiota 90: 161–192.

Premate, E., Š Borko, T. Delić, F. Malard, L. Simon & C. Fišer, 2021. Cave amphipods reveal co-variation between morphology and trophic niche in a low-productivity environment. Freshwater Biology 66: 1876–1888.

R Core Team, 2023. R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna.

Rewicz, T., M. Grabowski, C. Macneil & K. Bącela-Spychalska, 2014. The profile of a ’ perfect ’ invader—the case of killer shrimp, *Dikerogammarus villosus*. Aquatic Invasions 9: 267–288.

Rewicz, T., R. A. Wattier, T. Rigaud, K. Bącela-Spychalska & M. Grabowski, 2015a. Isolation and characterization of 8 microsatellite loci for the “killer shrimp’’, an invasive Ponto-Caspian amphipod *Dikerogammarus villosus* (Crustacea: Amphipoda). Molecular Biology Reports 42: 13–17.

Rewicz, T., R. Wattier, M. Grabowski, T. Rigaud & K. Bącela-Spychalska, 2015b. Out of the Black Sea: phylogeography of the invasive killer shrimp *Dikerogammarus villosus* across Europe. PLoS ONE 10: e0118121. https://doi.org/10.1371/journal.pone.0118121.

Rewicz, T., A. Konopacka, K. Bącela-Spychalska, M. Özbek & M. Grabowski, 2016. First records of two formerly overlooked Ponto-Caspian amphipods from Turkey: *Echinogammarus trichiatus* (Martynov, 1932) and *Dikerogammarus villosus* (Sovinsky, 1894). Turkish Journal of Zoology 40: 328–335.

Rewicz, T., R. Wattier, T. Rigaud, M. Grabowski, T. Mamos & K. Bącela-Spychalska, 2017. The killer shrimp, *Dikerogammarus villosus*, invading European Alpine Lakes: a single main source but independent founder events with an overall loss of genetic diversity. Freshwater Biology 62: 1036–1051.

Richter, L., L. Schwenkmezger, J. Becker, C. Winkelmann, C. Hellmann & S. Worischka, 2018. The very hungry amphipod: the invasive *Dikerogammarus villosus* shows high consumption rates for two food sources and independent of predator cues. Biological Invasions 20: 1321–1335.

Šidagytė-Copilaş, E., & D. Copilaş-Ciocianu, 2024. Climatic niche differentiation between native and non-native ranges is widespread in Ponto-Caspian amphipods. Freshwater Biology 277–287.

Šidagyte, E., V. Razlutskij, A. Alekhnovich, A. Rybakovas, M. Moroz, V. Šniaukštaitė, G. Vaitonis & K. Arbačiauskas, 2017a. Predatory diet and potential effects of *Orconectes limosus* on river macroinvertebrate assemblages of the southeastern Baltic Sea basin: Implications for ecological assessment. Aquatic Invasions 12: 523–540.

Šidagytė, E., S. Solovjova, V. Šniaukštaitė, A. Šiaulys, S. Olenin & K. Arbačiauskas, 2017b. The killer shrimp *Dikerogammarus villosus* (Crustacea, Amphipoda) invades Lithuanian waters, South-Eastern Baltic Sea. Oceanologia 59: 85–91.

Sotka, E. E., A. W. Baumgardner, P. M. Bippus, C. Destombe, E. A. Duermit, H. Endo, B. A. Flanagan, M. Kamiya, L. E. Lees, C. J. Murren, M. Nakaoka, S. J. Shainker,

A. E. Strand, R. Terada, M. Valero, F. Weinberger & S. A. Krueger-Hadfield, 2018. Combining niche shift and population genetic analyses predicts rapid phenotypic evolution during invasion. Evolutionary Applications 11: 781–793.

Suarez, A. V. & N. D. Tsutsui, 2008. The evolutionary consequences of biological invasions. Molecular Ecology 17: 351–360.

Väinölä, R., J. D. S. Witt, M. Grabowski, J. H. Bradbury, K. Jażdżewski & B. Sket, 2008. Freshwater Animal Diversity Assessment. Hydobiologia 595: 241–255.

Valen, L. V., 1965. Morphological variation and width of ecological niche. The American Naturalist 99: 377–390.

Van der Velde, G., S. Rajagopal, B. Kelleher, I. B. Muskó & A. B. De Vaate, 2000. Ecological impact of crustacean invaders: general considerations and examples from the Rhine River. Biodiversity Crisis and Crustacea 12: 3–34.

van Riel, M. C., G. Van Der Velde, S. Rajagopal, S. Marguillier, F. Dehairs & A. Bij de Vaate, 2006. Trophic relationships in the Rhine food web during invasion and after establishment of the Ponto-Caspian invader *Dikerogammarus villosus*. Hydrobiologia 565: 39–58.

Watling, L., 1993. Functional morphology of the amphipod mandible. Journal of Natural History 27: 837–849. https://doi.org/10.1080/00222939300770511.

Wattier, R. A., E. R. Haine, J. Beguet, G. Martin, L. Bollache, I. B. Muskó, D. Platvoet & T. Rigaud, 2007. No genetic bottleneck or associated microparasite loss in invasive populations of a freshwater amphipod. Oikos 116(11): 1941–1953.

Wesselingh, F. P., T. A. Neubauer, V. V. Anistratenko, M. V. Vinarski, T. Yanina, J. J. ter Poorten, P. Kijashko, C. Albrecht, O. Y. Anistratenko, A. D'Hont, P. Frolov, A. M. Gándara, A. Gittenberger, A. Gogaladze, M. Karpinsky, M. Lattuada, L. Popa, A. F. Sands, S. van de Velde, J. Vandendorpe & T. Wilke, 2019. Mollusc species from the Pontocaspian region—an expert opinion list. ZooKeys 2019: 31–124.

Willi, Y., J. Van Buskirk & A. A. Hoffmann, 2006. Limits to the adaptive potential of small populations. Annual Review of Ecology, Evolution, and Systematics 37: 433–458.

Worischka, S., L. Richter, A. Hänig, C. Hellmann, J. Becker, P. Kratina & C. Winkelmann, 2018. Food consumption of the invasive amphipod *Dikerogammarus villosus* in field mesocosms and its effects on leaf decomposition and periphyton. Aquatic Invasions 13: 261–275.

Záhorská, E., M. Šúrová & M. Balážová, 2023. Morphological variability in a successful invasive species originating from habitats experiencing different levels of disturbance. Journal of Vertebrate Biology 72: 23031.

Zhao, Y., C. Galvão & W. Cai, 2021. *Rhodnius micki*, a new species of Triatominae (Hemiptera, Reduviidae) from Bolivia. ZooKeys 1012: 71–93.

Supplementary File 1

Table 1. The measurements (raw data) on the dissected individuals (mm). The symbols for the body traits according to the Supplementary File 2. With the yellow colour are presented the individuals excluded from the analyses.

station number	station name	locality	individual code	status	lineage	ecosystem	Latitude	Longitude	date of sampling	Body	Head	A1	A1 Pd	A1 Fl	A2	A2 Pd	A2 Fl	G1	G1 Pr	G1 Pa	G1 Dg	G1 St
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_1	Invasive	Western	river	47.814	7.54597	19.11.2011	15.35	2.30	8.51	2.96	5.56	6.26	3.25	3.02	4.10	1.30	0.73	0.94	0.18
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_2	Invasive	Western	river	47.814	7.54597	19.11.2011	17.17	1.98	8.59	3.00	5.59	6.26	3.31	2.96	4.36	1.37	0.83	0.96	0.15
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_3	Invasive	Western	river	47.814	7.54597	19.11.2011	15.83	1.84	7.44	2.82	4.62	6.00	3.18	2.82	4.41	1.51	0.99	0.96	0.17
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_4	Invasive	Western	river	47.814	7.54597	19.11.2011	13.88	1.66	6.72	2.41	4.31	4.48	2.41	2.07	3.78	1.06	0.64	0.84	0.17
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_5	Invasive	Western	river	47.814	7.54597	19.11.2011	18.13	1.19	7.80	3.22	4.58	6.59	3.65	2.95	5.45	1.52	0.87	1.00	0.18
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_6	Invasive	Western	river	47.814	7.54597	19.11.2011	17.88	1.94	6.24	2.80	3.43	5.36	2.83	2.52	4.19	1.41	0.71	1.01	0.11
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_7	Invasive	Western	river	47.814	7.54597	19.11.2011	15.89	1.73	8.10	3.17	4.93	6.40	3.52	2.89	4.65	1.42	0.80	1.03	0.15
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_8	Invasive	Western	river	47.814	7.54597	19.11.2011	16.98	2.30	6.50	3.12	3.37	4.96	2.99	1.97	4.54	1.58	0.83	1.08	0.17
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_9	Invasive	Western	river	47.814	7.54597	19.11.2011	17.32	2.24	7.08	3.24	3.84	6.11	3.45	2.66	4.68	1.49	0.83	1.03	0.19
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_10	Invasive	Western	river	47.814	7.54597	19.11.2011	15.51	1.59	8.64	2.93	5.72	6.34	3.29	3.05	4.85	1.56	0.76	1.12	0.18
2	ALP60	Leman lake in Nernier, France	ALP60_1	Invasive	Western	lake	46.366	6.303497	26.11.2011	11.20	1.19	5.52	1.97	3.55	3.61	1.90	1.71	2.30	0.83	0.56	0.60	0.16
2	ALP60	Leman lake in Nernier, France	ALP60_2	Invasive	Western	lake	46.366	6.303497	26.11.2011	9.13	1.03	4.76	1.79	2.97	3.41	1.81	1.60	2.58	0.79	0.52	0.54	0.14
2	ALP60	Leman lake in Nernier, France	ALP60_3	Invasive	Western	lake	46.366	6.303497	26.11.2011	9.35	1.06	4.48	1.70	2.78	3.06	1.59	1.48	2.44	0.73	0.39	0.55	0.11
2	ALP60	Leman lake in Nernier, France	ALP60_4	Invasive	Western	lake	46.366	6.303497	26.11.2011	10.34	1.30	4.80	1.79	3.01	3.61	1.85	1.76	2.88	0.81	0.51	0.65	0.12
2	ALP60	Leman lake in Nernier, France	ALP60_5	Invasive	Western	lake	46.366	6.303497	26.11.2011	10.09	1.14	5.36	1.89	3.47	3.71	1.98	1.73	2.88	0.92	0.52	0.65	0.13
2	ALP60	Leman lake in Nernier, France	ALP60_6	Invasive	Western	lake	46.366	6.303497	26.11.2011	13.14	1.63	6.52	2.32	4.21	3.01	1.74	1.27	3.16	1.01	0.52	0.71	0.13
2	ALP60	Leman lake in Nernier, France	ALP60_7	Invasive	Western	lake	46.366	6.303497	26.11.2011	11.69	1.42	5.79	1.87	3.92	3.96	2.00	1.96	2.97	0.86	0.59	0.59	0.14
2	ALP60	Leman lake in Nernier, France	ALP60_8	Invasive	Western	lake	46.366	6.303497	26.11.2011	12.05	1.36	6.32	2.17	4.15	4.39	2.33	2.06	3.27	1.08	0.64	0.74	0.17
2	ALP60	Leman lake in Nernier, France	ALP60_9	Invasive	Western	lake	46.366	6.303497	26.11.2011	12.24	1.33	5.47	2.03	3.43	4.37	2.25	2.13	2.68	1.05	0.58	0.72	0.14
2	ALP60	Leman lake in Nernier, France	ALP60_10	Invasive	Western	lake	46.366	6.303497	26.11.2011	10.51	1.29	5.51	2.00	3.51	3.73	2.05	1.68	2.97	0.93	0.53	0.64	0.13
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_1	Native	Dniester	brackish	46.332	30.10121	13.07.2011	12.04	1.56	5.71	2.09	3.62	4.53	2.28	2.25	2.98	0.98	0.60	0.68	0.23
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_2	Native	Dniester	brackish	46.332	30.10121	13.07.2011	8.41	1.18	3.81	1.43	2.37	2.90	1.52	1.38	2.15	0.69	0.45	0.48	0.08
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_4	Native	Dniester	brackish	46.332	30.10121	13.07.2011	9.35	1.28	4.25	1.69	2.55	3.36	1.79	1.57	2.41	0.80	0.55	0.51	0.11

station number	station name	locality	individual code	status	lineage	ecosystem	Latitude	Longitude	date of sampling	Body	Head	A1	A1 Pd	A1 Fl	A2	A2 Pd	A2 Fl	G1	G1 Pr	G1 Pa	G1 Dg	G1 St
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_5	Native	Dniester	brackish	46.332	30.10121	13.07.2011	12.60	1.12	6.42	2.15	4.27	4.34	2.36	1.98	3.26	1.03	0.64	0.67	0.13
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_6	Native	Dniester	brackish	46.332	30.10121	13.07.2011	12.63	1.60	5.91	2.07	3.84	3.61	2.02	1.59	3.12	0.90	0.53	0.65	0.10
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_7	Native	Dniester	brackish	46.332	30.10121	13.07.2011	14.10	1.47	9.20	3.06	6.14	6.55	3.52	3.03	4.65	1.51	0.74	1.09	0.13
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_8	Native	Dniester	brackish	46.332	30.10121	13.07.2011	14.18	1.65	6.57	2.35	4.23	5.19	2.77	2.42	3.80	1.18	0.70	0.83	0.13
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_9	Native	Dniester	brackish	46.332	30.10121	13.07.2011	14.03	1.77	6.69	2.47	4.22	4.92	2.61	2.31	3.57	1.12	0.66	0.77	0.12
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_10	Native	Dniester	brackish	46.332	30.10121	13.07.2011	13.84	1.92	6.87	2.66	4.21	5.50	2.98	2.51	3.82	1.24	0.76	0.86	0.09
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_1	Native	Eastern	brackish	46.675	32.72008	11.07.2011	17.89	1.77	9.58	3.77	5.81	6.94	3.66	3.28	4.92	1.65	0.88	1.10	0.19
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_2	Native	Eastern	brackish	46.675	32.72008	11.07.2011	20.22	2.22	8.23	3.69	4.55	7.59	4.15	3.45	5.43	1.69	0.99	1.09	0.17
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_3	Native	Eastern	brackish	46.675	32.72008	11.07.2011	22.69	2.32	10.28	3.59	6.69	8.48	4.33	4.15	5.67	1.84	0.90	1.24	0.17
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_4	Native	Eastern	brackish	46.675	32.72008	11.07.2011	17.45	1.98	7.06	2.97	4.09	6.15	3.30	2.85	4.32	1.43	0.76	0.97	0.15
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_5	Native	Eastern	brackish	46.675	32.72008	11.07.2011	22.45	2.21	9.86	3.79	6.07	7.63	4.05	3.58	5.21	1.76	0.93	1.18	0.15
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_6	Native	Eastern	brackish	46.675	32.72008	11.07.2011	17.96	1.89	7.58	3.17	4.41	6.69	3.48	3.21	4.40	1.47	0.75	1.10	0.16
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_7	Native	Eastern	brackish	46.675	32.72008	11.07.2011	19.04	2.19	9.23	3.50	5.73	7.32	4.14	3.18	5.13	1.67	0.92	1.11	0.16
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_8	Native	Eastern	brackish	46.675	32.72008	11.07.2011	18.90	2.12	8.73	3.07	5.66	6.45	3.29	3.17	4.51	1.44	0.78	1.01	0.15
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_9	Native	Eastern	brackish	46.675	32.72008	11.07.2011	17.38	1.52	8.79	3.10	5.69	6.74	3.56	3.17	4.62	1.54	0.84	1.04	0.12
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_10	Native	Eastern	brackish	46.675	32.72008	11.07.2011	18.98	1.72	9.99	3.45	6.55	7.60	3.75	3.85	5.01	1.66	1.00	1.09	0.17
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_1	Native	Western	brackish	45.54	29.65501	14.07.2011	13.37	1.41	6.00	2.45	3.55	4.47	2.57	1.90	3.63	1.19	0.64	0.83	0.15
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_2	Native	Western	brackish	45.54	29.65501	14.07.2011	12.16	1.40	6.09	2.19	3.89	4.41	2.34	2.07	3.16	1.02	0.59	0.75	0.17
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_3	Native	Western	brackish	45.54	29.65501	14.07.2011	11.64	1.34	4.66	1.92	2.74	3.82	2.00	1.82	3.00	0.93	0.63	0.60	0.09
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_4	Native	Western	brackish	45.54	29.65501	14.07.2011	13.84	1.47	5.45	2.22	3.24	4.12	2.35	1.77	3.40	1.09	0.63	0.75	0.13
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_5	Native	Western	brackish	45.54	29.65501	14.07.2011	13.53	1.83	5.79	2.37	3.42	4.67	2.51	2.16	3.55	1.05	0.73	0.58	0.05
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_6	Native	Western	brackish	45.54	29.65501	14.07.2011	15.75	1.70	6.87	2.78	4.09	5.52	2.99	2.53	3.84	1.20	0.65	0.83	0.11
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_7	Native	Western	brackish	45.54	29.65501	14.07.2011	20.21	1.81	5.95	2.09	3.86	4.51	2.26	2.25	4.64	1.51	0.78	1.11	0.18
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_8	Native	Western	brackish	45.54	29.65501	14.07.2011	11.90	1.45	4.17	1.95	2.22	4.34	2.23	2.11	3.33	1.03	0.62	0.74	0.13
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_9	Native	Western	brackish	45.54	29.65501	14.07.2011	13.29	1.51	5.81	2.31	3.49	4.70	2.41	2.29	3.55	1.07	0.52	0.75	0.14
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_10	Native	Western	brackish	45.54	29.65501	14.07.2011	13.33	1.51	6.13	2.24	3.89	4.73	2.35	2.38	3.50	1.08	0.54	0.74	0.10
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_1	Native	Eastern	brackish	46.603	32.58279	16.08.2009	8.15	1.14	3.40	1.42	1.98	2.83	1.44	1.39	2.04	0.65	0.36	0.46	0.08
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_2	Native	Eastern	brackish	46.603	32.58279	16.08.2009	10.97	1.46	5.13	1.91	3.22	4.06	2.09	1.97	2.97	0.98	0.51	0.66	0.08
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_3	Native	Eastern	brackish	46.603	32.58279	16.08.2009	8.62	1.38	4.42	1.59	2.83	3.21	1.61	1.60	2.34	0.72	0.44	0.49	0.11

station number	station name	locality	individual code	status	lineage	ecosystem	Latitude	Longitude	date of sampling	Body	Head	A1	A1 Pd	A1 Fl	A2	A2 Pd	A2 Fl	G1	G1 Pr	G1 Pa	G1 Dg	G1 St
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_4	Native	Eastern	brackish	46.603	32.58279	16.08.2009	7.49	0.93	4.21	1.42	2.79	2.74	1.40	1.34	2.07	0.66	0.35	0.48	0.10
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_5	Native	Eastern	brackish	46.603	32.58279	16.08.2009	9.51	1.03	4.16	1.63	2.53	3.27	1.72	1.54	2.37	0.76	0.45	0.54	0.07
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_6	Native	Eastern	brackish	46.603	32.58279	16.08.2009	11.73	1.28	5.56	2.07	3.50	4.36	2.20	2.16	3.12	1.04	0.55	0.70	0.11
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_7	Native	Eastern	brackish	46.603	32.58279	16.08.2009	8.96	1.07	5.10	1.77	3.33	3.65	1.89	1.76	2.15	0.88	0.45	0.61	0.10
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_8	Native	Eastern	brackish	46.603	32.58279	16.08.2009	12.68	1.15	5.61	2.14	3.47	4.78	2.35	2.43	3.60	1.16	0.62	0.80	0.13
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_9	Native	Eastern	brackish	46.603	32.58279	16.08.2009	13.24	1.38	4.43	2.37	2.06	4.77	2.51	2.27	3.77	1.18	0.60	0.82	0.09
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_10	Native	Eastern	brackish	46.603	32.58279	16.08.2009	13.17	1.57	6.27	2.21	4.06	4.04	2.07	1.96	3.03	0.90	0.53	0.65	0.14
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_1	Native	Dniester	brackish	46.257	30.41911	22.08.2009	13.87	1.43	5.53	2.19	3.33	4.50	2.37	2.13	3.32	1.08	0.61	0.71	0.19
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_2	Native	Dniester	brackish	46.257	30.41911	22.08.2009	13.84	1.45	6.46	2.39	4.07	4.91	2.60	2.32	3.49	1.18	0.69	0.78	0.18
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_3	Native	Dniester	brackish	46.257	30.41911	22.08.2009	12.48	1.35	5.68	2.05	3.63	4.15	2.23	1.92	3.08	1.02	0.55	0.69	0.16
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_4	Native	Dniester	brackish	46.257	30.41911	22.08.2009	13.57	1.72	5.68	2.22	3.46	4.42	2.45	1.97	3.57	1.10	0.56	0.75	0.15
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_5	Native	Dniester	brackish	46.257	30.41911	22.08.2009	12.23	1.51	5.16	2.32	2.83	4.66	2.34	2.32	3.30	1.13	0.57	0.78	0.11
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_6	Native	Dniester	brackish	46.257	30.41911	22.08.2009	11.03	1.03	4.85	2.06	2.79	4.29	2.16	2.13	3.17	1.09	0.56	0.76	0.11
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_7	Native	Dniester	brackish	46.257	30.41911	22.08.2009	11.54	1.40	5.50	2.05	3.45	3.82	2.15	1.67	3.12	0.99	0.51	0.68	0.12
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_8	Native	Dniester	brackish	46.257	30.41911	22.08.2009	12.77	1.25	4.59	2.08	2.51	4.11	2.18	1.93	2.92	1.03	0.50	0.74	0.11
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_9	Native	Dniester	brackish	46.257	30.41911	22.08.2009	13.69	1.63	5.47	2.21	3.26	4.12	2.38	1.75	3.32	1.07	0.57	0.75	0.17
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_10	Native	Dniester	brackish	46.257	30.41911	22.08.2009	14.67	1.72	5.37	2.61	2.76	5.37	2.81	2.56	3.94	1.31	0.77	0.82	0.16
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_1	Invasive	Western	lake	45.874	10.86729	18.05.2011	12.40	1.43	6.28	2.22	4.06	4.98	2.60	2.38	3.58	1.18	0.60	0.82	0.16
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_2	Invasive	Western	lake	45.874	10.86729	18.05.2011	15.73	1.33	6.43	2.72	3.72	5.70	3.02	2.69	3.76	1.24	0.64	0.86	0.15
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_3	Invasive	Western	lake	45.874	10.86729	18.05.2011	14.09	1.52	5.74	2.31	3.43	5.08	2.72	2.37	3.45	1.18	0.56	0.83	0.18
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_4	Invasive	Western	lake	45.874	10.86729	18.05.2011	10.77	1.11	5.16	2.21	2.95	4.58	2.51	2.08	3.25	1.08	0.56	0.76	0.16
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_5	Invasive	Western	lake	45.874	10.86729	18.05.2011	11.87	1.24	5.28	2.07	3.21	3.99	2.13	1.86	3.00	1.06	0.48	0.76	0.15
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_6	Invasive	Western	lake	45.874	10.86729	18.05.2011	11.34	1.30	5.55	1.98	3.58	4.06	2.22	1.85	2.83	0.97	0.62	0.64	0.12
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_7	Invasive	Western	lake	45.874	10.86729	18.05.2011	10.90	0.95	6.23	2.23	4.00	4.43	2.38	2.05	3.18	1.09	0.76	0.65	0.15
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_8	Invasive	Western	lake	45.874	10.86729	18.05.2011	16.28	1.80	6.12	2.32	3.79	4.58	2.55	2.03	3.10	1.08	0.56	0.79	0.16
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_9	Invasive	Western	lake	45.874	10.86729	18.05.2011	19.79	2.12	6.48	2.71	3.77	5.14	2.75	2.39	3.44	1.17	0.69	0.83	0.13
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_10	Invasive	Western	lake	45.874	10.86729	18.05.2011	12.12	1.08	5.60	2.19	3.41	4.41	2.26	2.15	3.11	1.09	0.58	0.71	0.11
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_1	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	12.50	1.32	7.65	2.94	4.71	6.61	3.33	3.28	4.39	1.42	0.70	1.02	0.19
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_2	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	14.59	1.63	8.91	3.06	5.85	6.46	3.31	3.14	4.29	1.47	0.79	1.01	0.12

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9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_3	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	16.20	1.82	8.69	3.07	5.61	5.69	3.33	2.37	4.22	1.46	0.70	1.02	0.18
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_4	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	15.26	1.83	8.98	3.12	5.86	7.01	3.52	3.49	4.52	1.52	0.72	1.08	0.14
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_5	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	18.33	2.01	7.59	3.10	4.49	6.00	3.45	2.55	4.40	1.51	0.78	1.06	0.15
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_6	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	17.39	1.87	9.31	3.00	6.31	6.48	3.25	3.23	4.12	1.40	0.69	0.96	0.14
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_7	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	16.69	1.63	9.43	3.35	6.08	6.67	3.71	2.96	4.56	1.55	0.73	1.10	0.20
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_8	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	17.72	1.15	9.33	3.25	6.09	6.85	3.53	3.32	4.32	1.46	0.74	1.01	0.15
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_9	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	18.46	1.95	9.03	3.05	5.98	5.82	3.38	2.44	4.50	1.47	0.71	1.00	0.14
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_10	Invasive	Eastern	lake	54.072	21.7289	01.06.2014	13.87	1.63	9.22	3.40	5.82	6.09	3.34	2.75	4.72	1.58	0.81	1.09	0.15
10	MD26	Lake Babadag near Zebil, Romania	MD26_1	Native	Western	brackish	44.941	28.75104	14.08.2012	15.29	1.71	4.26	2.49	1.77	5.22	2.68	2.54	5.37	1.83	0.97	1.23	0.23
10	MD26	Lake Babadag near Zebil, Romania	MD26_2	Native	Western	brackish	44.941	28.75104	14.08.2012	15.13	1.54	6.57	2.21	4.36	5.09	2.58	2.51	5.37	1.57	0.92	0.98	0.20
10	MD26	Lake Babadag near Zebil, Romania	MD26_3	Native	Western	brackish	44.941	28.75104	14.08.2012	18.42	2.03	7.30	2.73	4.57	5.54	3.01	2.53	6.14	2.06	1.01	1.38	0.18
10	MD26	Lake Babadag near Zebil, Romania	MD26_4	Native	Western	brackish	44.941	28.75104	14.08.2012	17.74	2.07	7.80	2.97	4.83	6.99	3.70	3.29	4.22	1.45	0.73	0.96	0.11
10	MD26	Lake Babadag near Zebil, Romania	MD26_5	Native	Western	brackish	44.941	28.75104	14.08.2012	15.22	1.53	7.92	3.85	4.06	4.94	2.62	2.32	4.26	1.45	0.76	0.93	0.15
10	MD26	Lake Babadag near Zebil, Romania	MD26_6	Native	Western	brackish	44.941	28.75104	14.08.2012	15.32	1.43	7.76	2.93	4.84	5.99	3.17	2.82	4.03	1.36	0.75	0.90	0.09
10	MD26	Lake Babadag near Zebil, Romania	MD26_7	Native	Western	brackish	44.941	28.75104	14.08.2012	14.35	1.29	6.68	2.56	4.12	5.52	3.04	2.47	3.86	1.36	0.65	0.92	0.13
10	MD26	Lake Babadag near Zebil, Romania	MD26_8	Native	Western	brackish	44.941	28.75104	14.08.2012	16.18	1.60	6.63	2.47	4.16	5.43	2.82	2.61	3.85	1.27	0.64	0.86	0.12
10	MD26	Lake Babadag near Zebil, Romania	MD26_9	Native	Western	brackish	44.941	28.75104	14.08.2012	17.15	1.61	8.26	2.99	5.28	5.16	2.78	2.37	4.18	1.49	0.75	0.99	0.12
10	MD26	Lake Babadag near Zebil, Romania	MD26_10	Native	Western	brackish	44.941	28.75104	14.08.2012	16.10	1.64	8.27	2.98	5.29	5.02	2.74	2.28	4.12	1.48	0.77	0.97	0.11
11	ROCAL	River Danube in Calafat, Romania	ROCAL_1	Invasive	Western	river	43.995	22.92242	23.09.2011	10.46	1.21	5.40	1.82	3.58	3.94	2.12	1.82	2.74	0.94	0.52	0.63	0.11
11	ROCAL	River Danube in Calafat, Romania	ROCAL_2	Invasive	Western	river	43.995	22.92242	23.09.2011	11.11	1.12	5.07	1.87	3.19	3.88	2.11	1.77	2.79	0.94	0.48	0.66	0.12
11	ROCAL	River Danube in Calafat, Romania	ROCAL_3	Invasive	Western	river	43.995	22.92242	23.09.2011	12.79	1.08	5.76	2.02	3.74	3.83	2.12	1.71	2.84	1.00	0.51	0.72	0.12
11	ROCAL	River Danube in Calafat, Romania	ROCAL_4	Invasive	Western	river	43.995	22.92242	23.09.2011	12.81	1.25	4.90	2.15	2.75	4.24	2.29	1.95	3.14	1.09	0.55	0.73	0.16
11	ROCAL	River Danube in Calafat, Romania	ROCAL_5	Invasive	Western	river	43.995	22.92242	23.09.2011	12.58	1.39	6.05	2.22	3.83	4.42	2.40	2.02	3.10	1.12	0.62	0.74	0.12
11	ROCAL	River Danube in Calafat, Romania	ROCAL_6	Invasive	Western	river	43.995	22.92242	23.09.2011	11.20	1.28	5.73	1.96	3.77	4.17	2.24	1.93	2.81	1.00	0.50	0.70	0.09
11	ROCAL	River Danube in Calafat, Romania	ROCAL_7	Invasive	Western	river	43.995	22.92242	23.09.2011	11.09	1.28	6.17	2.11	4.05	4.35	2.18	2.17	2.85	0.98	0.49	0.73	0.08
11	ROCAL	River Danube in Calafat, Romania	ROCAL_8	Invasive	Western	river	43.995	22.92242	23.09.2011	11.22	0.95	5.29	2.07	3.22	3.95	2.14	1.81	2.83	0.93	0.47	0.65	0.11
11	ROCAL	River Danube in Calafat, Romania	ROCAL_9	Invasive	Western	river	43.995	22.92242	23.09.2011	10.73	1.18	5.18	1.81	3.37	3.52	1.83	1.70	2.78	0.86	0.49	0.58	0.08
11	ROCAL	River Danube in Calafat, Romania	ROCAL_10	Invasive	Western	river	43.995	22.92242	23.09.2011	10.87	1.16	5.01	1.80	3.20	3.64	1.88	1.76	2.65	0.89	0.46	0.66	0.11
12	ALP57	River Vah in Borcice, Slovakia	ALP57_1	Invasive	Western	river	48.976	18.15061	27.05.2011	13.23	1.40	5.69	2.26	3.43	4.36	2.48	1.88	3.36	1.11	0.60	0.77	0.09

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12	ALP57	River Vah in Borcice, Slovakia	ALP57_2	Invasive	Western	river	48.976	18.15061	27.05.2011	11.00	1.33	4.59	2.14	2.45	3.48	2.21	1.27	2.90	0.96	0.55	0.71	0.09
12	ALP57	River Vah in Borcice, Slovakia	ALP57_3	Invasive	Western	river	48.976	18.15061	27.05.2011	8.78	0.82	3.54	1.64	1.91	2.94	1.55	1.38	2.25	0.77	0.41	0.54	0.09
12	ALP57	River Vah in Borcice, Slovakia	ALP57_4	Invasive	Western	river	48.976	18.15061	27.05.2011	9.30	1.02	3.63	2.25	1.38	2.21	1.23	0.98	2.37	0.78	0.45	0.57	0.09
12	ALP57	River Vah in Borcice, Slovakia	ALP57_5	Invasive	Western	river	48.976	18.15061	27.05.2011	8.41	0.94	3.11	1.58	1.52	2.67	1.53	1.14	2.04	0.72	0.36	0.53	0.10
12	ALP57	River Vah in Borcice, Slovakia	ALP57_6	Invasive	Western	river	48.976	18.15061	27.05.2011	13.06	1.21	4.41	2.19	2.22	4.23	2.32	1.91	2.99	1.00	0.57	0.71	0.15
12	ALP57	River Vah in Borcice, Slovakia	ALP57_7	Invasive	Western	river	48.976	18.15061	27.05.2011	9.95	1.06	3.53	1.66	1.87	3.05	1.68	1.37	2.31	0.76	0.41	0.56	0.09
12	ALP57	River Vah in Borcice, Slovakia	ALP57_8	Invasive	Western	river	48.976	18.15061	27.05.2011	11.84	1.33	4.82	1.97	2.84	3.93	2.20	1.73	2.99	1.02	0.55	0.73	0.11
12	ALP57	River Vah in Borcice, Slovakia	ALP57_9	Invasive	Western	river	48.976	18.15061	27.05.2011	11.99	1.08	5.22	2.22	3.00	4.83	2.60	2.23	3.30	1.19	0.62	0.86	0.12
12	ALP57	River Vah in Borcice, Slovakia	ALP57_10	Invasive	Western	river	48.976	18.15061	27.05.2011	10.77	0.98	4.46	2.09	2.37	4.07	2.26	1.80	2.95	0.98	0.41	0.73	0.11
13	HDUN	River Danube in Budapest, Hungary	HDUN_1	Invasive	Western	river	47.515	19.04343	10.11.2018	14.00	1.47	6.39	2.68	3.71	5.26	2.79	2.47	3.70	1.32	0.67	0.82	0.16
13	HDUN	River Danube in Budapest, Hungary	HDUN_2	Invasive	Western	river	47.515	19.04343	10.11.2018	13.85	1.57	6.90	2.51	4.39	5.00	2.81	2.19	3.24	1.15	0.59	0.80	0.16
13	HDUN	River Danube in Budapest, Hungary	HDUN_3	Invasive	Western	river	47.515	19.04343	10.11.2018	10.12	1.16	4.76	2.19	2.57	4.25	2.13	2.12	2.71	0.98	0.52	0.70	0.11
13	HDUN	River Danube in Budapest, Hungary	HDUN_4	Invasive	Western	river	47.515	19.04343	10.11.2018	13.23	1.41	6.69	2.30	4.39	4.80	2.43	2.36	3.10	1.10	0.76	0.58	0.08
13	HDUN	River Danube in Budapest, Hungary	HDUN_5	Invasive	Western	river	47.515	19.04343	10.11.2018	13.50	1.56	7.24	3.02	4.22	5.76	3.11	2.65	3.59	1.24	0.62	0.83	0.13
13	HDUN	River Danube in Budapest, Hungary	HDUN_6	Invasive	Western	river	47.515	19.04343	10.11.2018	13.08	1.47	6.38	2.48	3.90	4.64	2.51	2.14	3.55	1.18	0.62	0.82	0.17
13	HDUN	River Danube in Budapest, Hungary	HDUN_7	Invasive	Western	river	47.515	19.04343	10.11.2018	12.33	1.42	6.20	2.39	3.82	4.68	2.39	2.28	3.13	1.15	0.59	0.78	0.11
13	HDUN	River Danube in Budapest, Hungary	HDUN_8	Invasive	Western	river	47.515	19.04343	10.11.2018	13.19	1.32	7.42	2.57	4.85	5.40	2.83	2.57	3.54	1.18	0.61	0.81	0.13
13	HDUN	River Danube in Budapest, Hungary	HDUN_9	Invasive	Western	river	47.515	19.04343	10.11.2018	12.71	1.21	5.05	2.49	2.56	4.41	2.51	1.90	3.09	1.08	0.54	0.79	0.11
13	HDUN	River Danube in Budapest, Hungary	HDUN_10	Invasive	Western	river	47.515	19.04343	10.11.2018	13.56	1.29	6.98	2.47	4.52	5.06	2.74	2.31	3.21	1.18	0.64	0.82	0.14
14	GPH16	River Elbe near Donitz, Germany	GPH16_1	Invasive	Western	river	53.144	11.22798	21.04.2018	18.39	1.52	9.93	3.84	6.09	7.12	4.04	3.08	5.13	1.68	0.86	1.12	0.16
14	GPH16	River Elbe near Donitz, Germany	GPH16_2	Invasive	Western	river	53.144	11.22798	21.04.2018	14.76	1.91	7.37	2.69	4.68	5.73	3.12	2.61	3.82	1.31	0.66	0.89	0.17
14	GPH16	River Elbe near Donitz, Germany	GPH16_3	Invasive	Western	river	53.144	11.22798	21.04.2018	12.39	1.21	6.13	2.28	3.85	4.25	2.17	2.07	2.85	0.95	0.52	0.70	0.13
14	GPH16	River Elbe near Donitz, Germany	GPH16_4	Invasive	Western	river	53.144	11.22798	21.04.2018	15.92	1.72	7.28	3.28	4.00	6.80	3.57	3.23	4.32	1.47	0.68	1.01	0.16
14	GPH16	River Elbe near Donitz, Germany	GPH16_5	Invasive	Western	river	53.144	11.22798	21.04.2018	17.53	1.69	9.01	3.07	5.94	6.48	3.43	3.05	4.19	1.45	0.67	1.00	0.13
14	GPH16	River Elbe near Donitz, Germany	GPH16_6	Invasive	Western	river	53.144	11.22798	21.04.2018	9.82	1.33	6.31	2.13	4.18	4.65	2.42	2.23	3.14	1.17	0.53	0.87	0.14
14	GPH16	River Elbe near Donitz, Germany	GPH16_7	Invasive	Western	river	53.144	11.22798	21.04.2018	11.32	1.04	5.92	2.13	3.79	4.05	2.17	1.89	3.11	1.17	0.61	0.77	0.14
14	GPH16	River Elbe near Donitz, Germany	GPH16_8	Invasive	Western	river	53.144	11.22798	21.04.2018	12.42	1.33	7.58	2.73	4.84	5.20	2.94	2.26	3.70	1.24	0.64	0.82	0.14
14	GPH16	River Elbe near Donitz, Germany	GPH16_9	Invasive	Western	river	53.144	11.22798	21.04.2018	14.01	1.36	7.01	2.53	4.48	4.75	2.76	1.99	3.43	1.17	0.63	0.81	0.12
15	GPH01	Usedom in Zecherin, Germany	GPH01_1	Invasive	Western	brackish	53.865	13.8313	19.04.2018	15.59	2.09	7.18	3.28	3.90	7.00	3.72	3.28	4.51	1.54	0.78	1.06	0.14

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15	GPH01	Usedom in Zecherin, Germany	GPH01_2	Invasive	Western	brackish	53.865	13.8313	19.04.2018	16.56	2.00	8.55	3.04	5.51	6.36	3.16	3.20	4.27	1.44	0.73	0.96	0.15
15	GPH01	Usedom in Zecherin, Germany	GPH01_3	Invasive	Western	brackish	53.865	13.8313	19.04.2018	19.22	2.12	8.32	3.32	5.01	6.41	3.78	2.63	4.56	1.49	0.72	1.01	0.12
15	GPH01	Usedom in Zecherin, Germany	GPH01_4	Invasive	Western	brackish	53.865	13.8313	19.04.2018	16.96	1.85	6.36	2.92	3.44	5.93	3.22	2.71	4.09	1.36	0.72	0.95	0.13
15	GPH01	Usedom in Zecherin, Germany	GPH01_5	Invasive	Western	brackish	53.865	13.8313	19.04.2018	11.89	1.05	8.36	3.09	5.27	6.20	3.27	2.93	4.11	1.32	0.69	0.87	0.13
15	GPH01	Usedom in Zecherin, Germany	GPH01_6	Invasive	Western	brackish	53.865	13.8313	19.04.2018	14.45	1.26	8.30	3.71	4.59	7.34	4.05	3.30	4.98	1.70	0.85	1.18	0.20
15	GPH01	Usedom in Zecherin, Germany	GPH01_7	Invasive	Western	brackish	53.865	13.8313	19.04.2018	16.53	2.03	8.22	3.03	5.19	5.94	3.08	2.86	4.47	1.47	0.76	0.98	0.15
15	GPH01	Usedom in Zecherin, Germany	GPH01_8	Invasive	Western	brackish	53.865	13.8313	19.04.2018	15.84	1.65	8.46	3.09	5.38	6.71	3.34	3.37	4.25	1.37	0.69	0.94	0.13
15	GPH01	Usedom in Zecherin, Germany	GPH01_9	Invasive	Western	brackish	53.865	13.8313	19.04.2018	19.61	1.56	8.33	3.29	5.03	6.87	3.64	3.23	4.78	1.61	0.77	1.13	0.15
15	GPH01	Usedom in Zecherin, Germany	GPH01_10	Invasive	Western	brackish	53.865	13.8313	19.04.2018	16.10	1.57	9.06	3.23	5.83	7.30	3.81	3.50	4.25	1.52	0.80	1.01	0.18
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_1	Invasive	Western	river	51.202	6.7343	27.04.2019	17.72	1.64	8.78	3.28	5.50	7.13	3.81	3.32	4.20	1.50	0.73	1.03	0.14
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_2	Invasive	Western	river	51.202	6.7343	27.04.2019	18.15	1.83	9.29	3.37	5.92	6.98	3.60	3.38	4.18	1.50	0.72	1.08	0.14
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_3	Invasive	Western	river	51.202	6.7343	27.04.2019	16.11	1.51	7.52	2.97	4.55	6.04	3.24	2.80	3.95	1.40	0.63	1.03	0.11
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_4	Invasive	Western	river	51.202	6.7343	27.04.2019	15.73	1.77	8.00	2.97	5.03	5.94	3.38	2.55	4.05	1.34	0.68	0.92	0.11
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_5	Invasive	Western	river	51.202	6.7343	27.04.2019	16.59	1.56	8.38	3.11	5.27	6.37	3.40	2.97	4.12	1.36	0.69	0.93	0.16
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_6	Invasive	Western	river	51.202	6.7343	27.04.2019	18.04	1.59	7.38	3.33	4.05	6.07	3.51	2.56	4.21	1.34	0.73	0.92	0.10
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_7	Invasive	Western	river	51.202	6.7343	27.04.2019	17.80	1.72	9.55	3.59	5.96	7.11	3.58	3.53	4.37	1.51	0.70	0.99	0.20
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_8	Invasive	Western	river	51.202	6.7343	27.04.2019	17.19	1.65	8.83	3.37	5.46	6.39	3.64	2.75	4.07	1.45	0.74	0.99	0.14
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_9	Invasive	Western	river	51.202	6.7343	27.04.2019	18.75	1.44	8.81	3.34	5.47	5.59	3.59	2.00	4.66	1.51	0.78	1.03	0.18
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_10	Invasive	Western	river	51.202	6.7343	27.04.2019	11.16	0.96	8.08	3.09	4.99	6.08	3.29	2.79	3.72	1.33	0.69	0.92	0.15
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_1	Invasive	Western	lake	53.754	11.49365	20.04.2018	14.65	1.42	8.16	2.90	5.26	5.85	3.34	2.51	4.05	1.41	0.72	0.99	0.20
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_2	Invasive	Western	lake	53.754	11.49365	20.04.2018	16.02	1.80	8.08	2.96	5.12	5.84	3.04	2.81	3.80	1.27	0.67	0.82	0.16
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_3	Invasive	Western	lake	53.754	11.49365	20.04.2018	15.48	1.49	5.96	2.98	2.98	5.60	3.05	2.55	3.56	1.32	0.68	0.89	0.12
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_4	Invasive	Western	lake	53.754	11.49365	20.04.2018	17.06	1.71	8.51	3.26	5.25	6.25	3.45	2.79	4.20	1.42	0.72	0.93	0.11
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_5	Invasive	Western	lake	53.754	11.49365	20.04.2018	12.82	1.36	7.41	3.23	4.18	4.40	2.47	1.93	3.08	0.92	0.30	0.78	0.09
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_6	Invasive	Western	lake	53.754	11.49365	20.04.2018	17.38	1.56	6.76	2.43	4.34	5.34	2.98	2.35	3.58	1.21	0.61	0.82	0.17
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_7	Invasive	Western	lake	53.754	11.49365	20.04.2018	14.26	1.47	6.41	2.25	4.15	4.71	2.49	2.22	2.98	1.00	0.50	0.68	0.13
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_8	Invasive	Western	lake	53.754	11.49365	20.04.2018	13.43	1.32	6.79	2.45	4.34	4.92	2.65	2.26	3.33	1.13	0.67	0.71	0.12
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_9	Invasive	Western	lake	53.754	11.49365	20.04.2018	13.84	1.32	7.02	2.62	4.40	4.68	2.62	2.06	3.14	1.07	0.58	0.74	0.13
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_10	Invasive	Western	lake	53.754	11.49365	20.04.2018	12.08	1.64	6.95	2.45	4.50	4.61	2.67	1.94	3.53	1.15	0.62	0.78	0.16

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18	ALP27	Hallwillersee, Switzerland	ALP27_1	Invasive	Western	lake	47.258	8.23137	21.05.2011	14.21	1.48	6.75	2.02	4.73	4.61	2.53	2.07	4.00	1.22	0.68	0.77	0.13
18	ALP27	Hallwillersee, Switzerland	ALP27_2	Invasive	Western	lake	47.258	8.23137	21.05.2011	15.87	1.61	8.33	2.62	5.72	6.33	3.29	3.04	4.76	1.46	0.78	0.98	0.07
18	ALP27	Hallwillersee, Switzerland	ALP27_3	Invasive	Western	lake	47.258	8.23137	21.05.2011	17.01	1.56	7.83	2.75	5.07	6.36	3.34	3.02	4.55	1.45	0.75	0.97	0.12
18	ALP27	Hallwillersee, Switzerland	ALP27_4	Invasive	Western	lake	47.258	8.23137	21.05.2011	13.64	1.38	6.83	2.00	4.83	4.55	2.52	2.03	3.78	1.22	0.67	0.76	0.12
18	ALP27	Hallwillersee, Switzerland	ALP27_5	Invasive	Western	lake	47.258	8.23137	21.05.2011	16.67	1.50	8.50	2.77	5.73	6.59	3.37	3.22	4.58	1.42	0.77	0.89	0.09
18	ALP27	Hallwillersee, Switzerland	ALP27_6	Invasive	Western	lake	47.258	8.23137	21.05.2011	15.83	1.79	6.89	2.46	4.43	5.40	2.94	2.45	4.28	1.31	0.81	0.83	0.06
18	ALP27	Hallwillersee, Switzerland	ALP27_7	Invasive	Western	lake	47.258	8.23137	21.05.2011	16.54	1.54	6.38	2.76	3.62	6.49	3.40	3.09	4.12	1.33	0.85	0.89	0.06
18	ALP27	Hallwillersee, Switzerland	ALP27_8	Invasive	Western	lake	47.258	8.23137	21.05.2011	16.06	1.66	8.70	2.79	5.91	6.05	3.35	2.70	4.80	1.47	0.79	0.95	0.12
18	ALP27	Hallwillersee, Switzerland	ALP27_9	Invasive	Western	lake	47.258	8.23137	21.05.2011	15.40	1.87	7.81	2.60	5.21	6.05	3.00	3.05	4.46	1.36	0.74	0.87	0.07
18	ALP27	Hallwillersee, Switzerland	ALP27_10	Invasive	Western	lake	47.258	8.23137	21.05.2011	15.26	1.24	5.97	2.21	3.76	4.99	2.87	2.12	4.29	1.36	0.68	0.91	0.05
19	Cu	Curonian Lagoon in Allesnyne, Lithuania	Cu_1	Invasive	Eastern	brackish	56.03	21.0713	2020	13.52	1.11	6.32	2.43	3.89	5.41	2.74	2.67	3.61	1.18	0.64	0.82	0.13
19	Cu	Curonian Lagoon in Allesnyne, Lithuania	Cu_2	Invasive	Eastern	brackish	56.03	21.0713	2020	14.65	1.58	6.21	3.01	3.20	5.26	2.91	2.35	3.84	1.27	0.66	0.89	0.11
19	Cu	Curonian Lagoon in Vente, Lithuania	Cu_3	Invasive	Eastern	brackish	56.03	21.0713	2020	15.92	1.33	5.30	2.48	2.82	5.42	2.87	2.55	3.81	1.27	0.60	0.95	0.16
19	Cu	Curonian Lagoon in Vente, Lithuania	Cu_4	Invasive	Eastern	brackish	56.03	21.0713	2020	13.73	1.34	5.48	2.28	3.20	4.70	2.44	2.26	3.27	1.11	0.58	0.78	0.11
19	Cu	Curonian Lagoon in Vente, Lithuania	Cu_5	Invasive	Eastern	brackish	56.03	21.0713	2020	12.56	1.34	5.97	2.35	3.62	4.66	2.51	2.16	3.07	1.07	0.59	0.71	0.12
19	Cu	Curonian Lagoon in Vente, Lithuania	Cu_6	Invasive	Eastern	brackish	56.03	21.0713	2020	12.97	1.30	5.67	2.21	3.46	4.36	2.41	1.95	3.08	0.99	0.57	0.65	0.08
19	Cu	Curonian Lagoon in Juodkante, Lithuania	Cu_7	Invasive	Eastern	brackish	56.03	21.0713	2020	15.98	2.11	4.96	2.65	2.31	5.57	2.89	2.68	3.78	1.25	0.66	0.82	0.09
19	Cu	Curonian Lagoon in Juodkante, Lithuania	Cu_8	Invasive	Eastern	brackish	56.03	21.0713	2020	15.06	1.33	6.98	2.75	4.22	5.02	2.98	2.04	3.82	1.28	0.66	0.86	0.13
19	Cu	Curonian Lagoon in Juodkante, Lithuania	Cu_9	Invasive	Eastern	brackish	56.03	21.0713	2020	16.53	1.60	7.40	2.66	4.75	5.36	2.99	2.36	3.80	1.31	0.69	0.88	0.13
19	Cu	Curonian Lagoon in Juodkante, Lithuania	Cu_10	Invasive	Eastern	brackish	56.03	21.0713	2020	13.26	1.39	5.54	2.41	3.13	4.65	2.45	2.20	3.13	1.00	0.54	0.70	0.14
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_1	Invasive	Eastern	brackish	57.038	24.03968	12.08.2020	20.87	1.79	10.02	3.70	6.32	7.95	4.17	3.78	5.41	1.72	1.05	1.20	0.14
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_2	Invasive	Eastern	brackish	57.038	24.03968	12.08.2020	16.87	1.78	6.85	2.92	3.93	6.13	3.15	2.98	4.39	1.44	0.82	0.95	0.19
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_3	Invasive	Eastern	brackish	57.038	24.03968	12.08.2020	15.30	1.63	6.62	2.44	4.18	5.29	2.75	2.53	3.72	1.24	0.75	0.80	0.16
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_4	Invasive	Eastern	brackish	57.038	24.03968	12.08.2020	16.00	1.62	6.29	2.60	3.69	5.51	2.89	2.61	3.97	1.32	0.75	0.89	0.18
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_5	Invasive	Eastern	brackish	57.038	24.03968	12.08.2020	14.05	1.41	7.11	2.44	4.67	5.56	2.84	2.71	3.94	1.14	0.71	0.78	0.10
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_6	Invasive	Eastern	brackish	57.038	24.03968	12.08.2020	14.41	1.56	6.69	2.63	4.06	5.28	2.80	2.48	3.71	1.26	0.70	0.84	0.16
21	LV20-7	Pavilosta, Latvia	LV20-7_1	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	19.73	2.16	9.67	3.57	6.10	7.91	4.04	3.88	5.38	1.66	1.02	1.13	0.19
21	LV20-7	Pavilosta, Latvia	LV20-7_2	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	21.37	2.14	10.36	3.94	6.42	8.24	4.31	3.92	5.48	1.74	1.09	1.20	0.22
21	LV20-7	Pavilosta, Latvia	LV20-7_3	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	14.14	1.60	6.98	2.45	4.53	5.02	2.56	2.46	3.65	1.17	0.75	0.78	0.16

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21	LV20-7	Pavilosta, Latvia	LV20-7_4	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	15.07	1.64	7.06	2.50	4.56	5.42	2.80	2.62	4.11	1.32	0.84	0.85	0.18
21	LV20-7	Pavilosta, Latvia	LV20-7_5	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	15.03	1.72	7.18	2.51	4.67	5.36	2.72	2.64	3.84	1.21	0.76	0.78	0.19
21	LV20-7	Pavilosta, Latvia	LV20-7_6	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	15.84	1.80	7.64	2.54	5.11	5.69	2.85	2.84	4.05	1.32	0.79	0.88	0.19
21	LV20-7	Pavilosta, Latvia	LV20-7_7	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	15.95	1.63	6.68	2.36	4.32	5.20	2.64	2.56	3.63	1.18	0.69	0.81	0.15
21	LV20-7	Pavilosta, Latvia	LV20-7_8	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	16.21	1.81	6.99	2.47	4.52	5.53	2.80	2.73	4.06	1.34	0.83	0.92	0.17
21	LV20-7	Pavilosta, Latvia	LV20-7_9	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	14.21	1.64	6.78	2.15	4.63	4.94	2.46	2.47	3.54	1.13	0.77	0.77	0.15
21	LV20-7	Pavilosta, Latvia	LV20-7_10	Invasive	Eastern	brackish	56.888	21.17796	13.08.2020	13.69	1.59	6.29	2.36	3.93	4.90	2.55	2.35	3.69	1.22	0.76	0.79	0.16
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_1	Invasive	Western	brackish	53.879	14.42522	22.09.2020	17.82	2.02	7.75	2.78	4.97	6.44	3.34	3.10	4.79	1.45	0.89	1.02	0.19
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_2	Invasive	Western	brackish	53.879	14.42522	22.09.2020	17.76	1.92	8.92	3.24	5.67	7.08	3.58	3.49	4.75	1.38	0.91	0.93	0.20
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_3	Invasive	Western	brackish	53.879	14.42522	22.09.2020	17.61	2.00	7.88	3.02	4.86	6.49	3.42	3.07	4.41	1.42	0.88	1.00	0.18
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_4	Invasive	Western	brackish	53.879	14.42522	22.09.2020	20.78	2.37	9.85	3.85	6.00	7.85	4.38	3.47	5.83	1.75	1.04	1.32	0.24
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_5	Invasive	Western	brackish	53.879	14.42522	22.09.2020	16.47	1.85	7.92	2.97	4.95	6.31	3.12	3.19	4.42	1.39	0.85	1.01	0.18
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_6	Invasive	Western	brackish	53.879	14.42522	22.09.2020	19.28	2.05	8.93	3.55	5.38	7.84	4.01	3.84	5.06	1.63	0.94	1.17	0.17
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_7	Invasive	Western	brackish	53.879	14.42522	22.09.2020	15.29	1.77	6.70	2.57	4.14	5.17	2.69	2.49	3.97	1.28	0.73	0.84	0.16
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_8	Invasive	Western	brackish	53.879	14.42522	22.09.2020	17.31	1.96	7.44	3.19	4.24	6.55	3.49	3.06	4.76	1.54	0.93	1.06	0.13
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_9	Invasive	Western	brackish	53.879	14.42522	22.09.2020	13.90	1.54	5.39	2.22	3.17	4.69	2.43	2.27	3.56	1.12	0.66	0.82	0.15
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_10	Invasive	Western	brackish	53.879	14.42522	22.09.2020	17.28	1.90	6.75	2.93	3.82	5.87	3.08	2.79	4.40	1.34	0.81	0.93	0.17
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_1	Invasive	Western	river	46.182	17.00371	2011	16.89	1.83	9.27	3.68	5.59	7.82	4.06	3.76	5.19	1.68	0.86	1.14	0.14
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_2	Invasive	Western	river	46.182	17.00371	2011	16.88	1.83	9.23	3.69	5.54	7.34	4.10	3.24	4.93	1.74	0.81	1.20	0.15
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_3	Invasive	Western	river	46.182	17.00371	2011	14.68	1.54	8.75	3.25	5.50	6.80	3.64	3.16	4.32	1.54	0.79	1.00	0.15
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_6	Invasive	Western	river	46.182	17.00371	2011	19.16	2.12	9.50	3.91	5.60	8.37	4.21	4.16	5.42	1.74	0.94	1.16	0.12
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_8	Invasive	Western	river	46.182	17.00371	2011	14.03	1.46	9.08	3.49	5.59	6.44	3.92	2.53	4.76	1.64	0.54	1.16	0.10
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_9	Invasive	Western	river	46.182	17.00371	2011	16.17	1.74	8.72	4.00	4.71	8.07	4.72	3.35	5.67	1.81	0.88	1.25	0.09
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_10	Invasive	Western	river	46.182	17.00371	2011	14.79	1.56	8.41	3.16	5.25	6.20	3.43	2.77	4.44	1.53	0.73	1.10	0.14
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_12	Invasive	Western	river	46.182	17.00371	2011	14.71	1.55	9.96	3.35	6.62	7.21	4.01	3.19	4.83	1.63	0.82	1.09	0.17
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_13	Invasive	Western	river	46.182	17.00371	2011	14.45	1.51	9.76	3.66	6.10	7.62	4.05	3.57	5.22	1.75	0.89	1.21	0.14
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_19	Invasive	Western	river	46.182	17.00371	2011	19.35	2.15	8.02	3.43	4.59	7.15	3.96	3.19	4.53	1.54	0.83	0.98	0.12
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_1	Invasive	Eastern	river	52.844	18.90484	5.2021	12.00	1.18	6.36	2.28	4.08	4.54	2.40	2.15	3.20	1.12	0.59	0.76	0.15
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_2	Invasive	Eastern	river	52.844	18.90484	5.2021	9.89	0.92	6.20	2.13	4.07	4.48	2.43	2.06	2.74	1.03	0.56	0.72	0.07

station number	station name	locality	individual code	status	lineage	ecosystem	Latitude	Longitude	date of sampling	Body	Head	A1	A1 Pd	A1 Fl	A2	A2 Pd	A2 Fl	G1	G1 Pr	G1 Pa	G1 Dg	G1 St
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_3	Invasive	Eastern	river	52.844	18.90484	5.2021	11.69	1.19	5.86	2.10	3.77	4.07	2.19	1.88	3.56	1.35	0.71	1.01	0.12
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_4	Invasive	Eastern	river	52.844	18.90484	5.2021	10.69	1.09	4.98	1.76	3.21	2.86	1.56	1.29	2.25	0.89	0.51	0.58	0.06
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_6	Invasive	Eastern	river	52.844	18.90484	5.2021	10.78	0.95	5.43	1.82	3.61	3.84	2.09	1.75	2.63	0.84	0.47	0.51	0.09
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_7	Invasive	Eastern	river	52.844	18.90484	5.2021	12.91	1.39	6.16	2.19	3.97	4.45	2.31	2.14	3.15	1.09	0.56	0.72	0.19
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_8	Invasive	Eastern	river	52.844	18.90484	5.2021	11.89	1.28	6.41	2.25	4.16	4.53	2.50	2.03	2.98	1.02	0.57	0.70	0.12
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_9	Invasive	Eastern	river	52.844	18.90484	5.2021	11.88	1.24	5.72	2.01	3.72	3.98	2.25	1.73	3.02	1.01	0.56	0.66	0.12
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_10	Invasive	Eastern	river	52.844	18.90484	5.2021	11.29	1.22	4.85	1.71	3.14	3.60	1.85	1.75	2.67	0.88	0.48	0.66	0.15
25	O21-9	River Oder in Lubiąż, Poland	O21-9_1	Invasive	Western	river	51.27	16.45971	5.2021	9.26	1.09	4.57	1.91	2.66	3.56	1.99	1.57	2.53	0.93	0.48	0.65	0.09
25	O21-9	River Oder in Lubiąż, Poland	O21-9_2	Invasive	Western	river	51.27	16.45971	5.2021	9.99	1.14	5.08	2.01	3.07	3.51	2.00	1.52	2.56	0.86	0.53	0.56	0.03
25	O21-9	River Oder in Lubiąż, Poland	O21-9_3	Invasive	Western	river	51.27	16.45971	5.2021	8.29	1.14	4.47	1.64	2.83	3.15	1.75	1.39	2.37	0.80	0.43	0.57	0.11
25	O21-9	River Oder in Lubiąż, Poland	O21-9_4	Invasive	Western	river	51.27	16.45971	5.2021	8.14	1.15	3.49	1.64	1.84	3.11	1.70	1.41	2.65	1.02	0.53	0.81	0.12
25	O21-9	River Oder in Lubiąż, Poland	O21-9_5	Invasive	Western	river	51.27	16.45971	5.2021	10.52	1.22	5.07	1.87	3.20	3.59	1.93	1.66	2.63	0.92	0.51	0.60	0.10
25	O21-9	River Oder in Lubiąż, Poland	O21-9_6	Invasive	Western	river	51.27	16.45971	5.2021	11.30	1.26	4.90	1.77	3.12	3.70	2.06	1.64	2.55	0.83	0.47	0.61	0.03
25	O21-9	River Oder in Lubiąż, Poland	O21-9_7	Invasive	Western	river	51.27	16.45971	5.2021	9.94	1.30	3.32	1.79	1.53	3.41	1.76	1.65	2.44	0.77	0.44	0.53	0.10
25	O21-9	River Oder in Lubiąż, Poland	O21-9_8	Invasive	Western	river	51.27	16.45971	5.2021	8.85	1.08	4.05	1.65	2.41	3.37	1.79	1.59	2.22	0.72	0.42	0.48	0.08
25	O21-9	River Oder in Lubiąż, Poland	O21-9_9	Invasive	Western	river	51.27	16.45971	5.2021	7.90	0.91	4.37	1.63	2.74	2.80	1.59	1.22	2.32	0.76	0.42	0.54	0.11
25	O21-9	River Oder in Lubiąż, Poland	O21-9_10	Invasive	Western	river	51.27	16.45971	5.2021	8.67	1.10	4.46	1.64	2.82	3.09	1.69	1.40	2.16	0.75	0.39	0.48	0.07
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_1	Invasive	Western	river	50.416	18.09396	5.2021	20.10	1.84	10.21	3.66	6.55	7.25	4.03	3.22	4.79	1.63	0.87	1.04	0.15
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_2	Invasive	Western	river	50.416	18.09396	5.2021	17.01	1.39	8.55	2.90	5.65	6.60	3.48	3.12	4.27	1.43	0.69	1.04	0.21
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_3	Invasive	Western	river	50.416	18.09396	5.2021	19.65	1.54	8.86	3.43	5.43	7.76	3.84	3.92	4.52	1.58	0.74	1.12	0.08
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_4	Invasive	Western	river	50.416	18.09396	5.2021	18.56	1.53	9.86	3.38	6.48	6.97	3.85	3.12	4.35	1.62	0.82	1.14	0.16
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_5	Invasive	Western	river	50.416	18.09396	5.2021	19.22	1.88	8.70	3.44	5.26	7.16	4.01	3.15	4.63	1.55	0.81	1.13	0.16
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_6	Invasive	Western	river	50.416	18.09396	5.2021	19.02	1.51	8.72	3.51	5.22	7.27	3.97	3.30	4.65	1.58	0.83	1.08	0.17
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_7	Invasive	Western	river	50.416	18.09396	5.2021	14.38	1.38	8.93	3.18	5.76	6.73	3.67	3.06	4.67	1.62	0.80	1.11	0.11
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_8	Invasive	Western	river	50.416	18.09396	5.2021	17.67	1.52	5.99	3.41	2.58	6.84	3.69	3.15	4.35	1.46	0.69	1.01	0.13
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_9	Invasive	Western	river	50.416	18.09396	5.2021	18.99	1.40	8.76	3.55	5.21	7.16	3.77	3.39	4.84	1.68	0.94	1.21	0.15
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_10	Invasive	Western	river	50.416	18.09396	5.2021	17.58	1.65	8.48	3.09	5.39	5.84	3.23	2.61	3.90	1.55	0.72	1.10	0.16
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_1	Invasive	Eastern	river	52.385	20.192	5.2021	19.78	1.93	8.92	3.39	5.53	6.24	3.77	2.47	4.64	1.48	0.74	0.96	0.16
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_2	Invasive	Eastern	river	52.385	20.192	5.2021	20.70	2.04	8.96	3.57	5.39	6.71	3.85	2.86	4.80	1.60	0.77	1.13	0.19

station number	station name	locality	individual code	status	lineage	ecosystem	Latitude	Longitude	date of sampling	Body	Head	A1	A1 Pd	A1 Fl	A2	A2 Pd	A2 Fl	G1	G1 Pr	G1 Pa	G1 Dg	G1 St
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_3	Invasive	Eastern	river	52.385	20.192	5.2021	20.43	1.98	9.92	3.69	6.23	7.57	4.03	3.54	4.81	1.79	0.84	1.23	0.17
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_4	Invasive	Eastern	river	52.385	20.192	5.2021	16.97	1.89	6.46	3.06	3.40	5.91	3.35	2.56	4.20	1.37	0.72	0.91	0.16
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_5	Invasive	Eastern	river	52.385	20.192	5.2021	15.86	1.83	8.94	2.99	5.95	5.63	3.25	2.38	5.58	1.70	0.62	1.31	0.10
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_6	Invasive	Eastern	river	52.385	20.192	5.2021	19.00	2.23	9.69	3.41	6.28	5.64	3.64	2.00	4.31	1.47	0.77	1.04	0.15
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_7	Invasive	Eastern	river	52.385	20.192	5.2021	16.37	1.62	8.17	3.10	5.07	5.63	3.26	2.38	4.12	1.44	0.75	0.99	0.16
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_8	Invasive	Eastern	river	52.385	20.192	5.2021	18.97	1.50	7.12	3.43	3.69	6.43	3.72	2.71	4.48	1.62	0.88	1.08	0.18
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_9	Invasive	Eastern	river	52.385	20.192	5.2021	20.10	1.83	8.37	3.35	5.03	5.64	3.38	2.27	4.58	1.60	0.82	1.05	0.14
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_10	Invasive	Eastern	river	52.385	20.192	5.2021	17.17	1.67	7.42	3.35	4.07	6.16	3.59	2.57	4.23	1.57	0.81	1.06	0.15
28	Ar31	River Loara in Bertignolles, France	Ar31_1	Invasive	Western	river	47.413	-0.56536	08.2022	17.50	1.86	5.98	3.27	2.71	6.41	3.77	2.64	4.21	1.39	0.73	0.99	0.15
28	Ar31	River Loara in Bertignolles, France	Ar31_2	Invasive	Western	river	47.413	-0.56536	08.2022	16.69	1.69	6.55	3.04	3.51	6.43	3.53	2.90	4.34	1.53	0.73	1.04	0.17
28	Ar31	River Loara in Bertignolles, France	Ar31_3	Invasive	Western	river	47.413	-0.56536	08.2022	16.41	1.64	5.54	2.96	2.58	5.57	3.28	2.29	3.86	1.40	0.66	1.01	0.16
28	Ar31	River Loara in Bertignolles, France	Ar31_4	Invasive	Western	river	47.413	-0.56536	08.2022	16.39	1.46	6.25	2.42	3.82	4.96	2.96	2.00	3.85	1.39	0.70	0.98	0.11
28	Ar31	River Loara in Bertignolles, France	Ar31_5	Invasive	Western	river	47.413	-0.56536	08.2022	12.99	1.19	5.40	2.35	3.04	3.82	2.31	1.50	3.04	1.05	0.53	0.76	0.10
28	Ar31	River Loara in Bertignolles, France	Ar31_6	Invasive	Western	river	47.413	-0.56536	08.2022	14.49	1.51	5.32	2.47	2.85	4.66	2.81	1.85	3.57	1.23	0.64	0.84	0.12
28	Ar31	River Loara in Bertignolles, France	Ar31_7	Invasive	Western	river	47.413	-0.56536	08.2022	13.31	1.34	5.76	2.27	3.49	4.90	2.61	2.29	3.23	1.15	0.51	0.83	0.16
28	Ar31	River Loara in Bertignolles, France	Ar31_8	Invasive	Western	river	47.413	-0.56536	08.2022	12.03	1.29	4.70	2.27	2.43	4.50	2.44	2.06	3.20	1.09	0.56	0.75	0.12
28	Ar31	River Loara in Bertignolles, France	Ar31_9	Invasive	Western	river	47.413	-0.56536	08.2022	13.92	1.41	5.59	2.37	3.23	5.32	2.85	2.47	3.54	1.20	0.64	0.81	0.16
28	Ar31	River Loara in Bertignolles, France	Ar31_10	Invasive	Western	river	47.413	-0.56536	08.2022	10.18	1.33	5.39	1.86	3.54	3.39	1.88	1.52	2.56	0.84	0.45	0.55	0.10
29	Ar15	Wolderwijd, Netherlands	Ar15_1	Invasive	Western	brackish	52.337	5.59871	08.2022	17.74	1.63	7.10	3.13	3.97	6.60	3.48	3.12	4.19	1.46	0.72	1.04	0.15
29	Ar15	Wolderwijd, Netherlands	Ar15_2	Invasive	Western	brackish	52.337	5.59871	08.2022	14.36	1.32	6.08	2.38	3.71	5.53	2.87	2.66	3.35	1.15	0.57	0.82	0.15
29	Ar15	Wolderwijd, Netherlands	Ar15_3	Invasive	Western	brackish	52.337	5.59871	08.2022	16.15	1.50	7.32	2.77	4.54	5.95	2.98	2.97	3.62	1.28	0.61	0.94	0.14
29	Ar15	Wolderwijd, Netherlands	Ar15_4	Invasive	Western	brackish	52.337	5.59871	08.2022	17.26	1.53	8.28	2.77	5.51	6.53	3.26	3.27	4.19	1.47	0.74	1.08	0.14
29	Ar15	Wolderwijd, Netherlands	Ar15_5	Invasive	Western	brackish	52.337	5.59871	08.2022	14.72	1.57	6.13	2.41	3.72	5.36	2.74	2.61	3.72	1.23	0.69	0.85	0.13
29	Ar15	Wolderwijd, Netherlands	Ar15_6	Invasive	Western	brackish	52.337	5.59871	08.2022	14.96	1.38	6.79	2.76	4.03	5.92	3.03	2.89	3.93	1.35	0.72	0.93	0.12
29	Ar15	Wolderwijd, Netherlands	Ar15_7	Invasive	Western	brackish	52.337	5.59871	08.2022	16.09	1.58	7.08	2.38	4.70	5.70	2.79	2.91	3.79	1.25	0.69	0.86	0.09
29	Ar15	Wolderwijd, Netherlands	Ar15_8	Invasive	Western	brackish	52.337	5.59871	08.2022	15.14	1.52	7.03	2.65	4.38	5.71	2.96	2.75	4.02	1.32	0.69	0.85	0.15
29	Ar15	Wolderwijd, Netherlands	Ar15_9	Invasive	Western	brackish	52.337	5.59871	08.2022	15.03	1.53	6.51	2.70	3.80	5.35	2.93	2.42	3.83	1.28	0.67	0.91	0.13
29	Ar15	Wolderwijd, Netherlands	Ar15_10	Invasive	Western	brackish	52.337	5.59871	08.2022	15.35	1.65	6.87	2.62	4.25	5.74	2.84	2.90	3.70	1.22	0.62	0.89	0.10
30	Ar21	River Leie, Belgium	Ar21_1	Invasive	Western	river	51.208	4.379102	08.2022	14.97	1.80	6.43	2.79	3.64	5.73	2.87	2.86	3.95	1.30	0.66	0.89	0.11

station number	station name	locality	individual code	status	lineage	ecosystem	Latitude	Longitude	date of sampling	Body	Head	A1	A1 Pd	A1 Fl	A2	A2 Pd	A2 Fl	G1	G1 Pr	G1 Pa	G1 Dg	G1 St
30	Ar21	River Leie, Belgium	Ar21_2	Invasive	Western	river	51.208	4.379102	08.2022	17.68	1.59	8.27	3.13	5.15	6.99	3.45	3.54	4.29	1.41	0.78	1.00	0.14
30	Ar21	River Leie, Belgium	Ar21_3	Invasive	Western	river	51.208	4.379102	08.2022	15.68	1.40	6.03	2.50	3.53	5.44	2.90	2.54	3.69	1.24	0.60	0.83	0.13
30	Ar21	River Leie, Belgium	Ar21_4	Invasive	Western	river	51.208	4.379102	08.2022	13.64	1.49	5.81	2.40	3.40	4.71	2.51	2.20	3.32	1.12	0.59	0.76	0.11
30	Ar21	River Leie, Belgium	Ar21_5	Invasive	Western	river	51.208	4.379102	08.2022	14.55	1.52	4.62	2.74	1.88	5.14	2.69	2.45	3.73	1.18	0.63	0.78	0.12
30	Ar21	River Leie, Belgium	Ar21_6	Invasive	Western	river	51.208	4.379102	08.2022	13.94	1.62	5.11	2.30	2.81	4.96	2.53	2.43	3.58	1.18	0.55	0.81	0.10
30	Ar21	River Leie, Belgium	Ar21_7	Invasive	Western	river	51.208	4.379102	08.2022	13.53	1.05	5.21	2.17	3.03	4.39	2.45	1.94	3.25	1.05	0.57	0.73	0.11
30	Ar21	River Leie, Belgium	Ar21_8	Invasive	Western	river	51.208	4.379102	08.2022	13.70	1.66	4.54	2.26	2.27	4.71	2.39	2.32	3.34	1.09	0.56	0.75	0.11
30	Ar21	River Leie, Belgium	Ar21_9	Invasive	Western	river	51.208	4.379102	08.2022	13.85	1.28	4.51	2.03	2.49	3.59	1.97	1.63	3.04	0.89	0.47	0.63	0.15
30	Ar21	River Leie, Belgium	Ar21_10	Invasive	Western	river	51.208	4.379102	08.2022	11.72	1.35	4.44	2.06	2.39	4.01	2.09	1.93	2.81	0.96	0.48	0.64	0.09
31	Ar23	River Somma in Abeville, France	Ar23_1	Invasive	Western	river	50.112	1.824287	08.2022	13.92	1.66	6.54	2.29	4.26	4.62	2.53	2.09	3.43	1.15	0.67	0.74	0.14
31	Ar23	River Somma in Abeville, France	Ar23_2	Invasive	Western	river	50.112	1.824287	08.2022	14.45	1.17	6.81	2.43	4.37	5.15	2.77	2.38	3.61	1.21	0.71	0.79	0.10
31	Ar23	River Somma in Abeville, France	Ar23_3	Invasive	Western	river	50.112	1.824287	08.2022	12.66	1.05	6.94	2.48	4.46	4.86	2.79	2.07	3.39	1.16	0.61	0.81	0.12
31	Ar23	River Somma in Abeville, France	Ar23_4	Invasive	Western	river	50.112	1.824287	08.2022	13.33	1.40	7.62	2.56	5.05	4.95	2.58	2.37	3.77	1.26	0.63	0.88	0.16
31	Ar23	River Somma in Abeville, France	Ar23_5	Invasive	Western	river	50.112	1.824287	08.2022	13.36	1.43	5.97	2.29	3.67	4.25	2.55	1.71	3.08	1.04	0.56	0.75	0.09
31	Ar23	River Somma in Abeville, France	Ar23_6	Invasive	Western	river	50.112	1.824287	08.2022	12.71	1.26	6.18	2.11	4.07	4.31	2.26	2.05	3.16	1.07	0.59	0.75	0.10
32	RO21-1	Sarichioi, Romania	RO21-1	Native	Western	brackish	44.942	28.86101	30.08.2021	12.81	1.64	6.62	2.46	4.16	5.08	2.68	2.41	3.66	1.13	0.66	0.78	0.16
32	RO21-1	Sarichioi, Romania	RO21-2	Native	Western	brackish	44.942	28.86101	30.08.2021	13.29	1.68	6.47	2.56	3.91	5.82	2.98	2.83	3.88	1.28	0.74	0.88	0.15
32	RO21-1	Sarichioi, Romania	RO21-3	Native	Western	brackish	44.942	28.86101	30.08.2021	12.52	1.48	6.65	2.39	4.26	5.16	2.72	2.45	3.70	1.16	0.71	0.77	0.14
32	RO21-1	Sarichioi, Romania	RO21-4	Native	Western	brackish	44.942	28.86101	30.08.2021	15.42	1.90	7.31	2.73	4.58	6.10	3.16	2.95	4.22	1.34	0.78	0.94	0.15
32	RO21-1	Sarichioi, Romania	RO21-5	Native	Western	brackish	44.942	28.86101	30.08.2021	13.79	1.72	7.45	2.53	4.91	5.56	2.93	2.63	3.87	1.24	0.72	0.86	0.16
32	RO21-1	Sarichioi, Romania	RO21-6	Native	Western	brackish	44.942	28.86101	30.08.2021	14.00	1.63	7.43	2.46	4.97	5.83	3.00	2.83	3.94	1.29	0.76	0.83	0.12
32	RO21-1	Sarichioi, Romania	RO21-7	Native	Western	brackish	44.942	28.86101	30.08.2021	13.07	1.64	7.34	2.63	4.71	5.18	2.89	2.29	3.70	1.24	0.70	0.84	0.12
32	RO21-1	Sarichioi, Romania	RO21-8	Native	Western	brackish	44.942	28.86101	30.08.2021	15.21	1.75	7.02	2.39	4.62	5.87	2.88	3.00	4.08	1.29	0.71	0.92	0.14
32	RO21-1	Sarichioi, Romania	RO21-9	Native	Western	brackish	44.942	28.86101	30.08.2021	11.75	1.54	6.11	2.03	4.08	4.63	2.27	2.36	3.33	1.01	0.57	0.72	0.12
32	RO21-1	Sarichioi, Romania	RO21-10	Native	Western	brackish	44.942	28.86101	30.08.2021	13.13	1.62	6.37	2.46	3.91	5.06	2.67	2.39	3.70	1.24	0.70	0.83	0.13
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-1	Native	Western	brackish	45.498	28.96451	24.08.2021	10.52	1.23	4.87	1.72	3.14	3.85	2.05	1.81	2.89	0.89	0.53	0.65	0.12
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-2	Native	Western	brackish	45.498	28.96451	24.08.2021	14.57	1.64	6.48	2.66	3.83	5.84	2.90	2.94	3.92	1.29	0.81	0.85	0.15
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-3	Native	Western	brackish	45.498	28.96451	24.08.2021	11.97	1.26	5.57	1.83	3.74	4.20	2.10	2.10	2.88	0.94	0.52	0.66	0.12
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-4	Native	Western	brackish	45.498	28.96451	24.08.2021	8.92	1.07	4.04	1.55	2.49	3.19	1.62	1.57	2.45	0.69	0.40	0.53	0.10

station number	station name	locality	individual code	status	lineage	ecosystem	Latitude	Longitude	date of sampling	Body	Head	A1	A1 Pd	A1 Fl	A2	A2 Pd	A2 Fl	G1	G1 Pr	G1 Pa	G1 Dg	G1 St
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-5	Native	Western	brackish	45.498	28.96451	24.08.2021	10.21	1.15	4.11	1.66	2.44	3.40	1.74	1.67	2.58	0.83	0.48	0.57	0.12
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-6	Native	Western	brackish	45.498	28.96451	24.08.2021	11.80	1.25	5.05	1.93	3.12	4.12	2.18	1.94	2.95	0.98	0.56	0.69	0.13
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-7	Native	Western	brackish	45.498	28.96451	24.08.2021	11.08	1.42	4.77	1.87	2.90	3.92	2.09	1.83	3.06	0.96	0.58	0.64	0.12
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-8	Native	Western	brackish	45.498	28.96451	24.08.2021	11.42	1.32	4.89	1.86	3.04	2.72	1.66	1.06	2.79	0.90	0.56	0.59	0.13
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-9	Native	Western	brackish	45.498	28.96451	24.08.2021	11.03	1.29	4.76	1.78	2.98	3.79	1.85	1.94	2.85	0.97	0.61	0.65	0.15
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-10	Native	Western	brackish	45.498	28.96451	24.08.2021	10.98	1.28	4.52	1.88	2.64	3.96	1.98	1.98	2.81	0.91	0.50	0.62	0.12
34	UA21-9	Kahul Lake, Ukraine	UA21-9_1	Native	Western	brackish	45.426	28.43682	28.08.2021	16.21	1.32	8.61	3.03	5.58	6.71	3.32	3.39	4.28	1.49	0.76	1.02	0.15
34	UA21-9	Kahul Lake, Ukraine	UA21-9_2	Native	Western	brackish	45.426	28.43682	28.08.2021	14.15	1.19	5.92	2.46	3.46	5.11	2.69	2.43	3.54	1.20	0.60	0.88	0.12
34	UA21-9	Kahul Lake, Ukraine	UA21-9_3	Native	Western	brackish	45.426	28.43682	28.08.2021	14.56	1.66	7.01	2.44	4.57	3.64	2.05	1.59	3.65	1.31	0.83	0.79	0.05
34	UA21-9	Kahul Lake, Ukraine	UA21-9_4	Native	Western	brackish	45.426	28.43682	28.08.2021	15.48	1.69	6.86	2.52	4.34	5.69	2.95	2.75	3.78	1.30	0.65	0.89	0.13
34	UA21-9	Kahul Lake, Ukraine	UA21-9_5	Native	Western	brackish	45.426	28.43682	28.08.2021	12.44	1.33	4.50	2.01	2.50	3.99	2.30	1.70	3.10	1.12	0.54	0.83	0.13
34	UA21-9	Kahul Lake, Ukraine	UA21-9_6	Native	Western	brackish	45.426	28.43682	28.08.2021	12.60	1.33	7.07	2.39	4.68	5.30	2.80	2.50	3.35	1.23	0.68	0.87	0.07
34	UA21-9	Kahul Lake, Ukraine	UA21-9_7	Native	Western	brackish	45.426	28.43682	28.08.2021	14.10	1.56	6.83	2.50	4.33	5.54	2.86	2.68	3.62	1.26	0.62	0.92	0.14
34	UA21-9	Kahul Lake, Ukraine	UA21-9_8	Native	Western	brackish	45.426	28.43682	28.08.2021	11.62	1.27	6.07	2.22	3.85	4.64	2.45	2.19	3.14	1.09	0.57	0.77	0.12
34	UA21-9	Kahul Lake, Ukraine	UA21-9_9	Native	Western	brackish	45.426	28.43682	28.08.2021	14.35	1.45	6.91	2.61	4.30	5.43	2.81	2.62	3.58	1.29	0.63	0.91	0.13
34	UA21-9	Kahul Lake, Ukraine	UA21-9_10	Native	Western	brackish	45.426	28.43682	28.08.2021	14.80	1.66	7.22	2.60	4.63	5.71	3.10	2.61	3.41	1.35	0.72	0.96	0.14
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_1	Native	Western	brackish	44.885	29.61313	25.07.2023	10.31	1.19	3.61	1.79	1.82	3.88	2.00	1.88	2.69	0.90	0.51	0.61	0.09
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_2	Native	Western	brackish	44.885	29.61313	25.07.2023	9.45	1.18	5.06	1.79	3.27	3.02	1.71	1.31	2.38	0.79	0.42	0.60	0.09
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_3	Native	Western	brackish	44.885	29.61313	25.07.2023	9.21	1.05	4.35	1.28	3.07	3.01	1.68	1.32	2.38	0.76	0.50	0.54	0.06
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_4	Native	Western	brackish	44.885	29.61313	25.07.2023	8.46	1.19	4.24	1.43	2.80	2.37	1.34	1.03	2.05	0.63	0.44	0.40	0.07
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_5	Native	Western	brackish	44.885	29.61313	25.07.2023	12.56	1.32	6.37	2.17	4.20	3.94	2.36	1.58	3.10	1.05	0.69	0.71	0.12
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_6	Native	Western	brackish	44.885	29.61313	25.07.2023	9.89	0.91	5.20	1.75	3.44	3.47	1.79	1.68	3.28	1.14	0.64	0.57	0.09
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_7	Native	Western	brackish	44.885	29.61313	25.07.2023	14.45	1.40	5.37	2.22	3.15	4.74	2.56	2.19	3.34	1.16	0.60	0.84	0.11
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_8	Native	Western	brackish	44.885	29.61313	25.07.2023	9.51	1.03	4.66	1.61	3.06	3.31	1.72	1.59	2.25	0.77	0.39	0.56	0.09
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_9	Native	Western	brackish	44.885	29.61313	25.07.2023	12.80	1.39	6.30	2.17	4.13	4.76	2.46	2.30	3.08	1.07	0.64	0.75	0.11
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_10	Native	Western	brackish	44.885	29.61313	25.07.2023	10.17	0.96	4.88	1.67	3.21	3.48	1.77	1.71	2.41	0.84	0.51	0.61	0.04

continued

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_1	Invasive	Western	river	0.80	43.95	4.78	1.60	1.33	6.47	1.84	1.42	2.09	1.57	3.05	1.54	1.74	1.76	0.04	1.33
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_2	Invasive	Western	river	0.66	42.35	5.08	1.67	1.39	6.45	2.07	1.52	2.03	1.59	3.11	1.46	2.64	1.74	0.04	1.36
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_3	Invasive	Western	river	0.54	38.69	5.94	1.78	0.98	6.29	1.99	1.54	1.93	1.62	2.56	1.66	2.08	1.78	0.04	1.50
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_4	Invasive	Western	river	0.37	52.13	5.51	1.81	1.04	5.89	2.03	1.46	2.04	1.50	3.01	1.40	2.39	1.76	0.04	1.41
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_5	Invasive	Western	river	0.65	23.37	6.54	1.83	1.32	7.23	2.46	1.46	2.43	1.76	3.24	1.81	2.25	1.93	0.07	1.72
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_6	Invasive	Western	river	0.56	43.34	4.91	1.76	1.38	6.47	2.12	1.45	2.18	1.68	2.78	1.48	2.13	1.83	0.03	1.49
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_7	Invasive	Western	river	0.49	45.96	6.14	1.90	1.10	6.75	2.31	1.49	2.30	1.67	3.14	1.62	2.44	1.92	0.11	1.42
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_8	Invasive	Western	river	0.61	38.68	6.23	1.76	1.17	6.86	2.12	1.47	2.02	1.77	3.63	1.69	2.19	2.00	0.05	1.44
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_9	Invasive	Western	river	0.65	24.45	6.68	1.87	1.27	7.06	2.14	1.65	2.20	2.07	3.27	1.66	2.26	2.15	0.05	1.65
1	FRRC2011_Rhine	River Rhine in Chalampe, France	FRRC2011_Rhine_10	Invasive	Western	river	0.70	43.47	6.21	1.67	1.09	6.45	2.09	1.42	1.99	1.78	2.85	1.54	2.41	1.76	0.04	1.40
2	ALP60	Leman lake in Nernier, France	ALP60_1	Invasive	Western	lake	0.27	45.69	3.75	1.07	0.89	4.34	1.21	1.08	1.08	1.28	1.96	1.05	1.53	1.05	0.03	0.92
2	ALP60	Leman lake in Nernier, France	ALP60_2	Invasive	Western	lake	0.28	41.76	3.53	1.01	0.65	4.16	1.20	0.99	1.25	1.07	1.91	0.99	2.21	1.10	0.02	0.98
2	ALP60	Leman lake in Nernier, France	ALP60_3	Invasive	Western	lake	0.27	46.39	3.41	0.99	0.72	3.19	0.85	0.71	0.83	0.78	1.54	0.79	1.88	1.09	0.02	0.76
2	ALP60	Leman lake in Nernier, France	ALP60_4	Invasive	Western	lake	0.34	48.97	3.95	1.18	0.75	4.35	1.32	1.10	1.37	0.94	1.88	0.87	2.23	1.21	0.02	0.78
2	ALP60	Leman lake in Nernier, France	ALP60_5	Invasive	Western	lake	0.31	43.73	3.14	1.17	1.03	3.51	1.31	1.00	1.21	1.16	1.87	0.94	1.90	1.30	0.02	0.96
2	ALP60	Leman lake in Nernier, France	ALP60_6	Invasive	Western	lake	0.34	41.82	4.54	1.30	0.86	5.13	1.50	1.21	1.49	1.25	2.17	1.20	1.75	1.40	0.05	1.05
2	ALP60	Leman lake in Nernier, France	ALP60_7	Invasive	Western	lake	0.31	44.02	3.73	1.36	1.13	4.46	1.35	1.09	0.97	1.22	2.12	1.00	2.13	1.32	0.01	0.97
2	ALP60	Leman lake in Nernier, France	ALP60_8	Invasive	Western	lake	0.34	42.02	4.24	1.01	0.91	4.98	1.56	1.14	1.50	1.27	2.17	1.22	2.52	1.39	0.04	1.16
2	ALP60	Leman lake in Nernier, France	ALP60_9	Invasive	Western	lake	0.32	42.59	4.55	1.26	0.83	4.58	1.55	1.17	1.58	1.35	2.24	1.26	1.76	1.34	0.01	1.27
2	ALP60	Leman lake in Nernier, France	ALP60_10	Invasive	Western	lake	0.33	40.73	4.06	1.13	0.69	4.58	1.38	1.06	1.48	1.23	2.10	1.11	2.08	1.32	0.03	0.86
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_1	Native	Dniester	brackish	0.33	43.05	4.10	1.67	0.85	4.54	1.41	1.12	1.41	1.07	2.11	1.11	2.06	1.28	0.03	0.96
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_2	Native	Dniester	brackish	0.22	43.30	3.56	0.84	0.62	3.41	1.04	0.83	1.07	0.81	1.52	0.83	2.01	1.00	0.03	0.85
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_4	Native	Dniester	brackish	0.27	39.08	3.27	0.93	0.62	3.66	1.17	0.86	1.12	0.90	1.97	0.92	1.90	1.10	0.03	0.95
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_5	Native	Dniester	brackish	0.50	39.08	4.40	1.24	0.84	4.78	1.59	1.03	1.60	1.14	2.01	0.96	2.21	1.33	0.05	1.00
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_6	Native	Dniester	brackish	0.30	44.58	3.42	1.45	1.11	4.60	1.58	1.30	1.65	1.09	2.63	0.95	2.38	1.38	0.06	1.12
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_7	Native	Dniester	brackish	0.66	43.29	6.28	1.87	1.08	6.41	2.28	1.40	2.16	1.67	2.94	1.35	3.29	1.95	0.08	1.45

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_8	Native	Dniester	brackish	0.42	42.91	5.05	1.36	0.86	3.57	1.26	1.20	1.21	1.23	2.46	1.33	2.84	1.58	0.04	1.24
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_9	Native	Dniester	brackish	0.39	40.97	4.54	1.38	0.80	5.23	1.62	1.25	1.64	1.22	2.15	1.15	3.00	1.49	0.05	1.16
3	TBQ30	Dniester liman in Krasna Kosa vilage, Ukraine	TBQ30_10	Native	Dniester	brackish	0.50	41.97	5.29	1.52	0.98	5.83	1.97	1.36	1.93	1.27	2.36	1.34	2.35	1.60	0.06	1.20
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_1	Native	Eastern	brackish	0.64	37.71	6.56	1.92	1.23	5.25	2.14	1.30	2.19	1.76	3.15	1.92	2.63	2.19	0.08	1.88
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_2	Native	Eastern	brackish	0.56	36.09	5.72	2.17	1.68	5.82	2.64	1.61	2.61	1.58	3.03	1.93	3.50	2.28	0.12	1.96
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_3	Native	Eastern	brackish	0.43	37.16	7.45	2.26	1.30	7.45	2.70	1.77	2.62	1.62	3.34	1.71	3.72	2.39	0.10	1.48
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_4	Native	Eastern	brackish	0.40	39.01	5.55	1.68	1.02	6.10	1.91	1.50	1.88	1.51	3.04	1.43	2.32	1.73	0.07	1.39
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_5	Native	Eastern	brackish	0.55	38.80	7.35	2.21	1.31	7.59	2.57	1.74	2.50	1.65	3.76	1.81	3.62	2.30	0.18	1.71
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_6	Native	Eastern	brackish	0.41	46.52	6.16	1.73	1.14	6.52	1.90	1.48	2.04	1.69	2.45	1.31	3.32	1.91	0.07	1.46
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_7	Native	Eastern	brackish	0.57	38.15	6.40	1.88	1.42	7.38	2.43	1.69	2.38	1.05	3.36	2.01	3.60	2.09	0.10	1.84
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_8	Native	Eastern	brackish	0.48	41.59	6.11	1.74	1.07	6.49	2.16	1.53	2.14	1.19	2.93	1.68	2.81	1.88	0.09	1.53
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_9	Native	Eastern	brackish	0.57	39.14	6.12	1.64	1.19	6.36	2.13	1.50	2.11	1.53	3.07	1.52	3.20	2.04	0.08	1.50
4	TBQ22	River Dniepr in Cherson, Ukraine	TBQ22_10	Native	Eastern	brackish	0.50	39.37	6.62	1.95	1.41	7.03	2.18	1.73	2.35	1.75	3.34	1.83	2.48	2.04	0.13	1.63
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_1	Native	Western	brackish	0.48	41.62	4.52	1.40	0.91	5.50	1.88	1.28	1.90	1.49	2.17	0.91	2.71	1.57	0.04	1.06
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_2	Native	Western	brackish	0.48	46.23	4.07	1.20	0.86	4.51	1.49	1.08	1.43	1.23	2.29	1.07	2.25	1.33	0.05	1.06
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_3	Native	Western	brackish	0.36	39.02	3.89	1.15	0.69	4.17	1.39	1.05	1.46	0.50	1.68	1.06	1.96	1.23	0.03	0.86
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_4	Native	Western	brackish	0.37	42.40	4.66	1.39	0.85	4.88	1.54	1.21	1.54	1.15	2.10	1.16	2.38	1.39	0.08	1.23
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_5	Native	Western	brackish	0.63	31.09	4.78	1.52	0.92	5.54	1.73	1.13	1.68	1.07	2.01	1.27	2.75	1.08	0.05	1.10
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_6	Native	Western	brackish	0.45	42.35	5.43	1.53	0.97	5.98	1.75	1.36	1.81	1.17	2.53	1.32	2.63	1.71	0.10	1.12
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_7	Native	Western	brackish	0.59	43.50	4.19	1.20	0.90	4.60	1.43	1.12	1.48	1.34	2.04	1.12	3.18	1.38	0.06	1.16
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_8	Native	Western	brackish	0.40	45.18	4.50	1.28	0.79	4.81	1.53	1.06	1.50	1.21	2.00	1.11	2.20	1.36	0.02	1.04
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_9	Native	Western	brackish	0.40	41.51	4.48	1.27	0.78	4.86	1.57	1.07	1.62	1.18	2.43	1.16	3.52	1.40	0.05	1.05
5	TBQ33	Sasik lake near Primorskoje village, Ukraine	TBQ33_10	Native	Western	brackish	0.34	36.98	4.54	1.38	0.99	4.87	1.73	1.10	1.67	1.17	2.25	1.14	3.32	1.40	0.06	1.23
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_1	Native	Eastern	brackish	0.17	44.40	2.82	0.77	0.46	3.20	0.95	0.75	1.02	0.85	1.24	0.84	1.77	0.89	0.04	0.77
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_2	Native	Eastern	brackish	0.45	38.70	3.88	1.11	0.69	4.03	1.29	0.97	1.30	1.18	1.73	1.02	1.78	1.22	0.03	1.10
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_3	Native	Eastern	brackish	0.26	41.91	3.32	0.70	0.39	3.35	1.07	0.76	1.11	0.90	1.58	0.77	1.51	0.98	0.02	0.75
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_4	Native	Eastern	brackish	0.17	44.44	2.92	0.93	0.55	3.21	0.98	0.77	0.94	0.80	1.62	0.77	2.02	0.91	0.01	0.86
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_5	Native	Eastern	brackish	0.21	44.24	3.21	0.91	0.60	2.99	1.06	0.87	1.08	0.86	1.60	0.89	2.63	1.03	0.05	0.91
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_6	Native	Eastern	brackish	0.43	38.55	4.22	1.15	0.82	4.21	1.40	1.01	1.43	1.21	2.19	1.21	1.57	1.28	0.02	1.01

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_7	Native	Eastern	brackish	0.26	40.00	3.16	1.12	0.83	3.39	1.28	0.87	1.29	0.94	1.62	1.03	1.72	0.94	0.02	1.02
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_8	Native	Eastern	brackish	0.52	39.80	4.56	1.28	0.79	4.57	1.42	1.08	1.17	1.44	2.16	1.18	2.65	1.46	0.03	1.17
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_9	Native	Eastern	brackish	0.52	38.56	5.29	1.30	0.78	5.31	1.64	1.16	1.56	1.22	1.90	1.31	2.51	1.47	0.06	1.27
6	UAO11	delta of River Dnieper in Cherson, Ukraine	UAO11_10	Native	Eastern	brackish	0.34	42.35	3.56	1.54	1.10	4.56	1.44	1.12	1.41	0.78	2.22	0.95	2.44	1.43	0.05	1.12
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_1	Native	Dniester	brackish	0.44	38.10	4.49	1.24	0.79	4.76	1.44	1.16	1.46	1.30	2.11	1.20	2.59	1.90	0.03	1.14
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_2	Native	Dniester	brackish	0.54	39.32	5.09	1.35	0.83	5.02	1.49	1.19	1.54	1.15	2.16	1.25	2.47	1.43	0.05	1.16
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_3	Native	Dniester	brackish	0.40	40.71	3.94	1.14	0.70	4.46	1.41	1.04	1.44	1.08	2.17	0.97	2.76	1.31	0.04	1.00
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_4	Native	Dniester	brackish	0.56	38.91	4.40	1.37	0.79	4.90	1.55	1.21	1.53	1.30	2.09	1.09	1.99	1.45	0.04	1.11
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_5	Native	Dniester	brackish	0.55	38.82	4.19	1.27	0.76	4.67	1.48	1.14	1.48	1.05	1.85	1.15	2.46	1.38	0.05	1.15
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_6	Native	Dniester	brackish	0.39	29.23	4.20	1.25	0.72	4.03	1.24	0.94	1.11	1.10	2.18	1.09	3.01	1.11	0.02	1.01
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_7	Native	Dniester	brackish	0.39	40.72	4.02	1.16	0.80	4.52	1.41	1.12	1.38	1.23	1.90	0.87	2.16	1.27	0.05	0.93
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_8	Native	Dniester	brackish	0.44	40.20	4.03	1.18	0.65	3.96	1.36	1.01	1.35	1.00	1.94	1.11	2.00	1.31	0.04	0.90
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_9	Native	Dniester	brackish	0.55	41.78	4.13	1.31	0.92	4.78	1.40	1.13	1.44	1.22	1.99	1.09	1.87	1.42	0.04	1.09
7	UAO29A	Dniestrovskij Liman in Owidiopol, Ukraine	UAO29A_10	Native	Dniester	brackish	0.51	35.62	5.27	1.50	0.83	5.15	1.60	1.34	1.74	1.47	2.43	1.21	2.71	1.59	0.08	1.31
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_1	Invasive	Western	lake	0.46	38.93	4.71	1.21	0.58	5.04	1.50	1.12	1.56	1.30	2.24	1.43	3.11	1.57	0.03	1.12
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_2	Invasive	Western	lake	0.39	39.00	5.24	1.52	0.85	5.29	1.88	1.29	1.88	1.41	2.26	1.55	2.69	1.58	0.12	1.14
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_3	Invasive	Western	lake	0.47	38.89	4.65	1.32	0.87	5.09	1.70	1.19	1.68	1.28	2.36	1.25	2.59	1.48	0.08	1.00
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_4	Invasive	Western	lake	0.35	42.01	4.29	1.34	0.84	4.97	1.53	1.19	1.57	1.27	2.07	1.35	2.25	1.40	0.04	1.05
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_5	Invasive	Western	lake	0.36	41.13	3.96	1.10	0.72	4.63	1.46	1.01	1.51	1.16	1.84	1.17	2.35	1.33	0.02	1.19
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_6	Invasive	Western	lake	0.24	41.35	4.10	1.18	0.74	4.73	1.49	1.07	1.47	1.13	1.86	1.16	2.14	1.34	0.02	0.95
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_7	Invasive	Western	lake	0.31	36.02	4.29	1.18	0.77	4.78	1.55	1.11	1.55	1.22	2.08	1.03	2.42	1.45	0.03	1.15
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_8	Invasive	Western	lake	0.32	44.44	4.42	1.27	0.67	4.57	1.56	1.00	1.58	1.31	2.15	1.26	2.62	1.49	0.04	0.92
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_9	Invasive	Western	lake	0.48	40.92	5.29	1.48	0.84	5.31	1.77	1.21	1.68	1.21	2.40	1.43	2.94	1.54	0.05	0.93
8	ALP11	Lago di Garda lake in Nago di Torbola, Italy	ALP11_10	Invasive	Western	lake	0.38	36.71	4.06	1.29	0.71	4.69	1.37	1.14	1.53	1.30	1.99	1.27	2.37	1.36	0.02	0.88
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_1	Invasive	Eastern	lake	0.62	41.70	5.86	1.76	1.04	6.41	2.15	1.45	2.15	1.71	2.78	1.79	3.02	1.73	0.03	1.45
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_2	Invasive	Eastern	lake	0.52	41.48	5.97	1.78	1.27	6.31	2.09	1.53	1.84	1.63	2.81	1.31	3.65	1.73	0.08	1.58
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_3	Invasive	Eastern	lake	0.47	39.32	5.56	1.80	1.05	5.77	2.02	1.48	1.95	1.58	2.53	1.66	2.10	1.79	0.04	1.11
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_4	Invasive	Eastern	lake	0.50	38.34	5.89	1.79	1.28	6.68	2.24	1.53	2.29	1.78	3.09	1.66	3.42	1.60	0.15	1.63
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_5	Invasive	Eastern	lake	0.70	41.13	5.99	1.78	1.06	6.53	2.10	1.52	2.11	1.81	2.97	1.59	3.71	1.86	0.09	1.29

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_6	Invasive	Eastern	lake	0.51	38.04	5.92	1.65	1.01	6.37	2.14	1.43	2.12	1.52	2.71	1.62	3.90	1.95	0.06	1.40
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_7	Invasive	Eastern	lake	0.68	40.18	6.23	1.98	1.14	6.82	2.23	1.57	2.17	1.73	3.36	1.81	2.57	1.87	0.03	1.73
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_8	Invasive	Eastern	lake	0.63	39.81	6.00	1.84	1.07	6.52	2.29	1.37	2.29	1.96	2.86	1.75	3.48	1.99	0.04	1.49
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_9	Invasive	Eastern	lake	0.51	36.82	5.81	1.73	1.04	6.28	2.04	1.46	2.14	1.59	2.70	1.79	2.19	1.86	0.04	1.72
9	12MW/14	Kisajno Lake in Pierkunowo, Poland	12MW/14_10	Invasive	Eastern	lake	0.78	39.76	6.52	2.00	1.22	6.89	2.36	1.57	2.41	1.70	1.71	1.84	3.00	2.00	0.13	1.58
10	MD26	Lake Babadag near Zebil, Romania	MD26_1	Native	Western	brackish	0.90	35.76	4.85	1.46	0.98	5.45	1.94	1.26	1.78	1.93	3.60	1.73	2.87	1.58	0.06	1.31
10	MD26	Lake Babadag near Zebil, Romania	MD26_2	Native	Western	brackish	0.65	27.95	4.69	1.26	0.67	5.05	1.43	1.03	1.60	1.36	3.26	2.34	3.05	1.35	0.04	1.16
10	MD26	Lake Babadag near Zebil, Romania	MD26_3	Native	Western	brackish	1.12	36.04	5.68	1.05	0.93	5.98	1.87	1.29	2.00	1.33	2.54	1.37	3.11	2.31	0.07	1.92
10	MD26	Lake Babadag near Zebil, Romania	MD26_4	Native	Western	brackish	0.35	31.30	6.01	1.73	1.09	6.50	1.86	1.30	1.84	1.36	2.81	1.49	2.16	1.82	0.03	1.34
10	MD26	Lake Babadag near Zebil, Romania	MD26_5	Native	Western	brackish	0.65	39.69	6.65	1.95	1.02	3.92	1.46	0.96	1.46	1.40	2.86	1.32	3.13	1.35	0.03	1.11
10	MD26	Lake Babadag near Zebil, Romania	MD26_6	Native	Western	brackish	0.59	37.52	5.34	1.59	1.03	5.89	1.81	1.31	1.70	1.43	2.59	1.43	2.85	1.65	0.03	1.35
10	MD26	Lake Babadag near Zebil, Romania	MD26_7	Native	Western	brackish	0.50	36.47	5.12	1.58	0.94	5.55	1.74	1.26	1.77	1.31	2.43	1.45	2.38	1.67	0.04	1.35
10	MD26	Lake Babadag near Zebil, Romania	MD26_8	Native	Western	brackish	0.60	38.69	5.09	1.39	0.92	5.62	1.76	1.27	1.78	0.97	2.64	1.44	2.42	1.61	0.02	1.38
10	MD26	Lake Babadag near Zebil, Romania	MD26_9	Native	Western	brackish	0.51	35.99	5.80	1.60	1.13	6.26	2.00	1.32	1.92	1.58	2.69	1.44	2.36	1.65	0.04	1.66
10	MD26	Lake Babadag near Zebil, Romania	MD26_10	Native	Western	brackish	0.54	35.71	6.05	1.74	1.07	6.38	2.08	1.43	2.22	1.45	2.73	1.05	3.56	1.62	0.03	1.45
11	ROCAL	River Danube in Calafat, Romania	ROCAL_1	Invasive	Western	river	0.31	39.68	3.87	1.10	0.73	4.41	1.41	1.05	1.50	1.04	1.77	1.12	2.22	1.23	0.02	0.92
11	ROCAL	River Danube in Calafat, Romania	ROCAL_2	Invasive	Western	river	0.37	41.35	3.16	1.13	1.08	4.28	1.39	1.07	1.48	1.13	1.72	1.14	2.24	1.28	0.03	0.92
11	ROCAL	River Danube in Calafat, Romania	ROCAL_3	Invasive	Western	river	0.34	43.20	4.06	1.23	0.81	4.61	1.34	0.95	1.24	0.84	1.98	1.17	2.28	1.27	0.03	1.14
11	ROCAL	River Danube in Calafat, Romania	ROCAL_4	Invasive	Western	river	0.39	36.73	4.13	1.25	0.79	3.52	1.58	1.04	1.61	1.14	2.00	0.98	1.70	1.34	0.02	1.03
11	ROCAL	River Danube in Calafat, Romania	ROCAL_5	Invasive	Western	river	0.48	40.00	4.43	1.26	0.78	4.93	1.63	1.18	1.61	1.11	1.90	1.24	2.96	1.41	0.04	1.14
11	ROCAL	River Danube in Calafat, Romania	ROCAL_6	Invasive	Western	river	0.31	43.01	3.97	1.15	0.70	4.84	1.39	1.02	1.54	1.11	1.77	1.08	2.22	1.24	0.01	1.16
11	ROCAL	River Danube in Calafat, Romania	ROCAL_7	Invasive	Western	river	0.25	51.41	4.11	1.22	0.68	4.47	1.32	1.10	1.56	1.14	1.94	1.12	2.58	1.30	0.02	1.06
11	ROCAL	River Danube in Calafat, Romania	ROCAL_8	Invasive	Western	river	0.29	37.74	3.22	1.17	1.02	4.33	1.44	0.96	1.53	0.94	1.82	0.77	2.21	1.34	0.03	1.21
11	ROCAL	River Danube in Calafat, Romania	ROCAL_9	Invasive	Western	river	0.21	41.05	3.76	1.41	0.79	4.21	1.34	1.08	1.48	0.68	1.84	1.05	2.05	1.23	0.01	1.17
11	ROCAL	River Danube in Calafat, Romania	ROCAL_10	Invasive	Western	river	0.25	46.52	3.52	1.09	0.69	4.12	1.33	1.01	1.45	1.19	1.82	0.96	1.84	1.19	0.04	0.97
12	ALP57	River Vah in Borcice, Slovakia	ALP57_1	Invasive	Western	river	0.40	40.79	4.29	1.29	0.78	4.95	1.66	1.21	1.73	1.30	1.97	1.20	2.19	1.40	0.04	0.98
12	ALP57	River Vah in Borcice, Slovakia	ALP57_2	Invasive	Western	river	0.21	45.53	3.99	1.23	0.76	4.72	1.52	1.10	1.54	1.10	1.74	1.02	2.30	1.25	0.04	0.99
12	ALP57	River Vah in Borcice, Slovakia	ALP57_3	Invasive	Western	river	0.22	42.48	3.02	0.95	0.61	4.02	1.14	0.89	1.20	0.68	1.32	0.87	1.15	0.99	0.03	0.80
12	ALP57	River Vah in Borcice, Slovakia	ALP57_4	Invasive	Western	river	0.23	45.58	3.39	1.02	0.68	3.89	1.23	0.94	1.29	1.00	1.53	1.01	1.43	1.18	0.03	0.83

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
12	ALP57	River Vah in Borcice, Slovakia	ALP57_5	Invasive	Western	river	0.22	45.15	2.87	0.84	0.57	3.90	1.15	0.86	1.18	0.93	1.36	0.84	1.42	0.91	0.01	0.68
12	ALP57	River Vah in Borcice, Slovakia	ALP57_6	Invasive	Western	river	0.30	44.63	3.30	1.30	1.20	4.82	1.63	1.12	1.62	1.26	1.93	1.10	2.08	1.26	0.06	0.98
12	ALP57	River Vah in Borcice, Slovakia	ALP57_7	Invasive	Western	river	0.19	49.38	3.20	1.03	0.65	3.66	1.17	0.91	1.23	1.00	1.34	0.90	1.55	1.10	0.04	0.91
12	ALP57	River Vah in Borcice, Slovakia	ALP57_8	Invasive	Western	river	0.25	43.88	3.97	1.20	0.79	4.60	1.44	1.12	1.51	1.19	1.65	1.09	1.99	1.24	0.05	0.89
12	ALP57	River Vah in Borcice, Slovakia	ALP57_9	Invasive	Western	river	0.44	43.22	3.66	1.43	1.27	5.23	1.58	1.31	1.62	1.20	1.91	1.25	2.34	1.40	0.04	1.63
12	ALP57	River Vah in Borcice, Slovakia	ALP57_10	Invasive	Western	river	0.35	46.29	3.34	1.01	0.65	4.28	1.49	1.08	1.58	0.97	1.68	1.07	2.15	1.32	0.06	1.20
13	HDUN	River Danube in Budapest, Hungary	HDUN_1	Invasive	Western	river	0.54	36.67	5.23	1.48	0.82	5.92	1.83	1.21	1.93	1.42	2.53	1.51	2.48	1.53	0.11	1.45
13	HDUN	River Danube in Budapest, Hungary	HDUN_2	Invasive	Western	river	0.37	39.83	4.84	1.30	0.91	5.68	1.83	1.16	1.97	1.68	2.59	2.60	2.16	1.52	0.02	1.08
13	HDUN	River Danube in Budapest, Hungary	HDUN_3	Invasive	Western	river	0.34	43.90	4.04	1.27	0.82	4.75	1.48	1.02	1.48	1.26	1.93	1.44	1.75	1.42	0.02	1.09
13	HDUN	River Danube in Budapest, Hungary	HDUN_4	Invasive	Western	river	0.62	34.30	4.46	0.85	0.71	4.58	1.59	1.08	1.59	1.29	2.01	1.26	2.14	1.41	0.02	1.00
13	HDUN	River Danube in Budapest, Hungary	HDUN_5	Invasive	Western	river	0.48	37.52	4.68	1.12	0.61	6.08	1.87	0.90	1.82	1.46	2.43	1.85	2.32	1.63	0.02	1.19
13	HDUN	River Danube in Budapest, Hungary	HDUN_6	Invasive	Western	river	0.45	39.99	4.80	1.47	0.92	5.48	1.84	1.21	1.89	1.49	2.57	1.91	2.51	1.42	0.06	1.08
13	HDUN	River Danube in Budapest, Hungary	HDUN_7	Invasive	Western	river	0.40	38.96	4.46	1.34	0.79	5.10	1.62	1.02	1.71	1.32	2.13	1.52	2.82	1.41	0.03	1.19
13	HDUN	River Danube in Budapest, Hungary	HDUN_8	Invasive	Western	river	0.14	40.39	4.98	0.84	0.62	5.80	1.79	1.24	1.90	1.35	2.54	1.57	2.84	1.61	0.06	1.48
13	HDUN	River Danube in Budapest, Hungary	HDUN_9	Invasive	Western	river	0.46	41.85	4.32	1.35	0.82	5.30	1.66	0.85	1.61	1.34	2.00	1.66	1.80	1.48	0.03	1.21
13	HDUN	River Danube in Budapest, Hungary	HDUN_10	Invasive	Western	river	0.36	45.11	4.01	1.45	1.11	5.41	1.64	1.25	1.68	1.44	2.32	1.31	2.81	1.54	0.06	1.39
14	GPH16	River Elbe near Donitz, Germany	GPH16_1	Invasive	Western	river	0.49	36.66	7.08	2.13	1.13	7.70	2.42	1.74	2.45	2.25	3.96	1.55	3.57	2.18	0.04	1.63
14	GPH16	River Elbe near Donitz, Germany	GPH16_2	Invasive	Western	river	0.88	39.56	5.37	1.55	1.01	5.88	1.89	1.31	1.89	1.69	3.46	1.51	3.30	1.81	0.04	1.49
14	GPH16	River Elbe near Donitz, Germany	GPH16_3	Invasive	Western	river	0.25	48.13	4.17	1.50	0.98	4.73	1.58	1.23	1.67	1.42	2.11	0.95	2.43	1.43	0.05	1.13
14	GPH16	River Elbe near Donitz, Germany	GPH16_4	Invasive	Western	river	0.84	40.03	6.01	1.74	1.03	6.55	2.14	1.47	2.15	1.88	3.25	1.81	3.56	1.80	0.03	1.35
14	GPH16	River Elbe near Donitz, Germany	GPH16_5	Invasive	Western	river	0.59	35.01	5.71	1.75	0.97	6.54	2.07	1.50	2.11	1.73	2.83	1.88	1.84	1.91	0.08	1.54
14	GPH16	River Elbe near Donitz, Germany	GPH16_6	Invasive	Western	river	0.52	43.86	3.66	1.34	1.23	4.98	1.56	1.21	1.65	1.47	2.21	1.15	2.18	1.51	0.03	1.25
14	GPH16	River Elbe near Donitz, Germany	GPH16_7	Invasive	Western	river	0.38	38.05	3.81	1.33	0.79	4.57	1.61	1.14	1.62	1.26	1.89	1.03	1.96	1.59	0.03	1.19
14	GPH16	River Elbe near Donitz, Germany	GPH16_8	Invasive	Western	river	0.50	37.27	4.89	1.43	0.97	5.65	1.70	1.33	1.76	1.41	2.34	0.79	2.66	1.62	0.04	1.29
14	GPH16	River Elbe near Donitz, Germany	GPH16_9	Invasive	Western	river	0.28	40.36	4.74	1.41	1.01	5.56	1.75	1.30	1.83	1.56	2.40	1.41	2.56	1.59	0.05	1.28
15	GPH01	Usedom in Zecherin, Germany	GPH01_1	Invasive	Western	brackish	0.64	42.18	6.35	1.78	1.10	7.16	2.39	1.46	2.57	1.76	3.00	1.63	2.89	1.98	0.05	1.65
15	GPH01	Usedom in Zecherin, Germany	GPH01_2	Invasive	Western	brackish	0.94	36.87	6.06	1.70	1.02	6.78	2.22	1.52	2.34	1.57	2.77	1.56	2.61	1.92	0.05	2.06
15	GPH01	Usedom in Zecherin, Germany	GPH01_3	Invasive	Western	brackish	0.49	45.06	6.83	1.86	1.01	7.07	2.44	1.51	2.48	1.78	2.98	1.68	3.01	1.99	0.10	1.46
15	GPH01	Usedom in Zecherin, Germany	GPH01_4	Invasive	Western	brackish	0.60	40.47	4.93	1.75	1.49	6.48	2.02	1.58	2.12	1.66	3.19	1.36	2.55	1.80	0.03	1.45

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
15	GPH01	Usedom in Zecherin, Germany	GPH01_5	Invasive	Western	brackish	0.61	36.55	5.59	1.72	1.15	6.21	1.91	1.32	2.10	1.67	2.74	1.63	2.06	1.54	0.06	1.48
15	GPH01	Usedom in Zecherin, Germany	GPH01_6	Invasive	Western	brackish	0.53	38.50	7.07	2.12	1.19	7.89	2.69	1.70	2.73	1.87	3.31	1.77	4.09	2.15	0.07	1.72
15	GPH01	Usedom in Zecherin, Germany	GPH01_7	Invasive	Western	brackish	0.50	36.04	5.95	1.74	1.10	6.58	2.12	1.47	2.17	1.66	3.16	1.63	2.87	1.94	0.03	1.58
15	GPH01	Usedom in Zecherin, Germany	GPH01_8	Invasive	Western	brackish	0.42	38.50	6.14	1.74	1.15	6.71	2.26	1.54	2.24	1.69	2.73	1.57	2.46	1.81	0.02	1.59
15	GPH01	Usedom in Zecherin, Germany	GPH01_9	Invasive	Western	brackish	0.64	40.12	6.73	1.89	1.04	7.26	2.43	1.55	2.36	1.68	3.39	1.75	3.24	1.99	0.03	1.68
15	GPH01	Usedom in Zecherin, Germany	GPH01_10	Invasive	Western	brackish	0.66	41.22	5.27	1.63	1.19	7.00	2.30	1.44	2.33	1.29	2.87	1.74	2.91	1.98	0.07	1.46
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_1	Invasive	Western	river	0.65	39.28	6.19	1.80	1.28	7.12	2.35	1.52	2.35	1.16	2.93	1.86	2.71	1.76	0.06	1.75
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_2	Invasive	Western	river	0.54	42.64	6.21	1.79	1.18	7.17	2.57	1.48	2.63	2.03	2.89	1.70	2.00	1.87	0.03	1.63
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_3	Invasive	Western	river	0.66	42.03	5.42	1.61	1.01	6.23	2.01	1.27	2.19	1.11	2.66	1.68	2.35	1.73	0.07	1.48
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_4	Invasive	Western	river	0.50	38.52	5.77	1.37	0.97	6.62	2.22	1.46	2.32	1.02	3.17	1.75	2.93	2.02	0.03	1.27
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_5	Invasive	Western	river	0.71	39.29	5.79	1.70	0.95	6.20	2.16	1.38	2.25	1.17	2.49	1.71	2.80	1.84	0.12	1.22
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_6	Invasive	Western	river	0.59	40.33	6.14	1.78	1.09	6.95	2.71	1.59	2.71	1.01	2.70	1.75	2.98	1.93	0.09	1.39
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_7	Invasive	Western	river	0.85	32.14	6.44	1.86	1.18	7.08	2.36	1.49	2.36	1.73	3.16	1.77	2.87	1.92	0.08	1.34
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_8	Invasive	Western	river	0.67	36.99	6.32	1.80	1.13	6.93	2.12	1.45	2.25	1.55	2.92	1.49	2.54	1.82	0.08	1.39
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_9	Invasive	Western	river	0.98	40.07	6.47	1.71	1.29	7.29	2.43	1.52	2.43	1.82	2.93	1.73	3.29	1.94	0.02	1.60
16	BNG25	River Ren in Dusseldorf, Germany	BNG25_10	Invasive	Western	river	0.58	40.72	5.42	1.52	0.90	6.20	1.94	1.33	2.03	1.62	1.90	1.78	3.56	1.68	0.10	1.37
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_1	Invasive	Western	lake	0.47	41.65	5.75	1.67	0.98	6.49	2.07	1.48	2.10	1.53	2.61	1.79	2.82	1.72	0.07	1.37
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_2	Invasive	Western	lake	0.58	36.61	5.51	1.60	1.00	5.96	1.74	1.34	1.81	1.79	2.52	1.40	3.08	1.62	0.04	1.35
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_3	Invasive	Western	lake	0.44	37.41	5.70	1.69	0.87	6.10	2.13	1.24	2.15	1.55	2.75	1.47	2.91	1.69	0.05	1.33
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_4	Invasive	Western	lake	0.53	35.20	5.84	1.77	1.03	6.53	2.14	1.42	2.24	1.71	3.19	1.76	3.14	1.83	0.03	1.38
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_5	Invasive	Western	lake	0.40	53.23	4.77	1.46	0.88	5.39	1.77	1.11	1.81	1.36	1.96	1.24	2.26	1.26	0.04	1.77
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_6	Invasive	Western	lake	0.49	42.48	5.06	1.49	0.99	5.71	1.82	1.22	1.86	1.33	2.28	1.55	1.93	1.57	0.02	1.14
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_7	Invasive	Western	lake	0.32	40.67	4.46	1.35	0.85	4.50	1.58	1.16	1.71	1.30	2.13	1.17	2.45	1.41	0.03	0.99
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_8	Invasive	Western	lake	0.51	39.91	4.73	1.36	0.97	5.08	1.56	1.21	1.64	1.50	2.26	1.37	2.68	1.44	0.03	1.15
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_9	Invasive	Western	lake	0.25	43.23	4.38	1.37	0.75	5.74	2.14	1.18	2.20	1.30	2.13	1.24	1.91	1.20	0.02	1.00
17	GPH10	Schweriner See in Flessenow, Germany	GPH10_10	Invasive	Western	lake	0.53	35.61	4.68	1.34	0.84	5.36	1.71	1.27	1.83	1.31	2.37	1.46	1.84	1.45	0.05	1.11
18	ALP27	Hallwillersee, Switzerland	ALP27_1	Invasive	Western	lake	0.48	36.42	4.43	1.69	1.39	6.41	1.76	1.26	1.78	1.22	1.91	1.72	2.43	1.33	0.02	1.23
18	ALP27	Hallwillersee, Switzerland	ALP27_2	Invasive	Western	lake	0.34	37.70	6.52	2.13	1.21	7.82	2.31	1.46	2.18	0.89	2.80	2.28	2.11	1.70	0.03	1.62
18	ALP27	Hallwillersee, Switzerland	ALP27_3	Invasive	Western	lake	0.41	40.34	6.32	1.96	1.15	8.02	2.29	1.38	2.22	1.39	2.35	2.16	2.96	1.62	0.05	1.57

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
18	ALP27	Hallwillersee, Switzerland	ALP27_4	Invasive	Western	lake	0.36	32.88	4.39	1.62	0.88	6.22	2.14	1.36	2.08	1.28	1.78	1.50	2.15	1.34	0.02	1.24
18	ALP27	Hallwillersee, Switzerland	ALP27_5	Invasive	Western	lake	0.36	37.90	6.69	2.10	1.18	6.00	2.20	1.41	2.11	1.37	2.53	1.47	2.80	1.42	0.04	1.51
18	ALP27	Hallwillersee, Switzerland	ALP27_6	Invasive	Western	lake	0.16	38.28	6.02	1.99	1.12	4.99	2.19	1.38	2.20	1.46	2.30	1.95	1.56	1.59	0.03	1.56
18	ALP27	Hallwillersee, Switzerland	ALP27_7	Invasive	Western	lake	0.41	41.70	6.86	2.22	1.20	6.94	2.38	1.45	2.27	1.80	2.48	2.22	3.70	1.66	0.13	1.68
18	ALP27	Hallwillersee, Switzerland	ALP27_8	Invasive	Western	lake	0.42	37.62	6.02	2.15	1.86	8.40	2.43	1.42	2.36	1.47	2.69	2.51	3.32	1.67	0.04	1.41
18	ALP27	Hallwillersee, Switzerland	ALP27_9	Invasive	Western	lake	0.30	34.11	6.18	1.95	1.12	5.63	2.08	1.29	1.86	1.29	2.69	1.90	2.28	1.74	0.06	1.62
18	ALP27	Hallwillersee, Switzerland	ALP27_10	Invasive	Western	lake	0.40	36.01	5.52	1.44	0.99	6.14	2.01	1.33	2.03	1.34	2.32	1.93	2.41	1.54	0.06	1.41
19	Cu	Curonian Lagoon in Allesnyne, Lithuania	Cu_1	Invasive	Eastern	brackish	0.80	41.73	5.12	1.46	0.89	5.83	1.74	1.23	1.80	1.48	2.08	1.28	2.01	1.53	0.05	1.22
19	Cu	Curonian Lagoon in Allesnyne, Lithuania	Cu_2	Invasive	Eastern	brackish	0.47	38.94	5.36	1.61	0.83	6.24	2.15	1.32	2.15	1.47	2.45	1.43	2.10	1.65	0.10	1.29
19	Cu	Curonian Lagoon in Vente, Lithuania	Cu_3	Invasive	Eastern	brackish	0.31	42.35	5.45	1.53	0.81	5.92	1.95	1.36	1.83	1.48	2.58	1.29	2.87	1.68	0.05	1.27
19	Cu	Curonian Lagoon in Vente, Lithuania	Cu_4	Invasive	Eastern	brackish	0.42	43.19	3.69	1.40	1.15	4.89	1.78	1.03	1.79	1.27	2.24	1.25	2.03	1.48	0.05	1.08
19	Cu	Curonian Lagoon in Vente, Lithuania	Cu_5	Invasive	Eastern	brackish	0.44	38.01	4.82	1.37	0.94	5.03	1.61	1.23	1.75	1.27	2.04	1.14	1.97	1.17	0.03	1.04
19	Cu	Curonian Lagoon in Vente, Lithuania	Cu_6	Invasive	Eastern	brackish	0.36	42.07	4.27	1.36	0.81	4.88	1.80	1.00	1.84	1.19	2.10	1.13	2.45	1.32	0.11	1.02
19	Cu	Curonian Lagoon in Juodkante, Lithuania	Cu_7	Invasive	Eastern	brackish	0.55	35.53	5.31	1.39	0.88	5.60	1.87	1.26	1.89	1.46	1.85	1.34	1.80	1.64	0.08	1.14
19	Cu	Curonian Lagoon in Juodkante, Lithuania	Cu_8	Invasive	Eastern	brackish	0.68	39.69	5.41	1.55	0.93	5.49	1.89	1.17	1.90	1.47	2.55	1.30	2.38	1.59	0.05	1.43
19	Cu	Curonian Lagoon in Juodkante, Lithuania	Cu_9	Invasive	Eastern	brackish	0.58	40.86	5.48	1.55	0.90	6.12	1.88	1.32	1.93	1.48	2.61	1.42	2.72	1.69	0.10	1.47
19	Cu	Curonian Lagoon in Juodkante, Lithuania	Cu_10	Invasive	Eastern	brackish	0.47	41.35	4.39	1.41	0.72	5.08	1.61	1.11	1.58	1.31	2.05	1.22	2.11	1.51	0.06	0.95
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_1	Invasive	Eastern	brackish	0.85	35.86	7.82	1.58	1.20	7.91	2.81	1.72	2.75	2.05	3.36	1.97	2.36	2.27	0.07	2.13
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_2	Invasive	Eastern	brackish	0.72	25.50	5.92	2.07	1.14	6.36	2.20	1.39	2.20	1.62	2.81	1.38	1.85	1.66	0.05	1.78
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_3	Invasive	Eastern	brackish	0.57	26.15	5.23	1.48	0.98	5.79	1.96	1.36	2.06	0.96	2.27	1.25	1.79	1.59	0.04	1.55
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_4	Invasive	Eastern	brackish	0.54	19.83	5.54	1.12	0.89	5.93	1.98	1.33	2.07	1.25	2.46	1.24	1.69	1.60	0.04	1.58
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_5	Invasive	Eastern	brackish	0.66	25.02	5.11	1.45	0.91	5.92	1.90	1.34	1.89	1.56	2.15	1.34	1.76	1.62	0.04	1.55
20	LV20-3	Daugava-Bullupe, Latvia	LV20-3_6	Invasive	Eastern	brackish	0.60	24.46	5.04	1.41	0.93	5.73	1.94	1.34	2.02	1.33	2.30	1.28	1.80	1.51	0.05	1.46
21	LV20-7	Pavilosta, Latvia	LV20-7_1	Invasive	Eastern	brackish	0.91	30.39	6.77	2.06	1.25	7.52	2.47	1.70	2.56	1.74	2.68	1.86	2.13	2.10	0.05	1.93
21	LV20-7	Pavilosta, Latvia	LV20-7_2	Invasive	Eastern	brackish	0.87	29.15	7.31	1.92	1.07	7.88	2.74	1.81	2.61	1.87	3.56	1.94	2.35	2.27	0.07	2.11
21	LV20-7	Pavilosta, Latvia	LV20-7_3	Invasive	Eastern	brackish	0.62	34.39	4.74	1.53	0.92	5.07	1.68	1.20	1.69	1.20	1.89	1.16	1.68	1.43	0.03	1.35
21	LV20-7	Pavilosta, Latvia	LV20-7_4	Invasive	Eastern	brackish	0.60	33.80	5.20	1.49	0.96	5.77	1.91	1.35	1.94	1.13	2.22	1.28	1.89	1.53	0.05	1.44
21	LV20-7	Pavilosta, Latvia	LV20-7_5	Invasive	Eastern	brackish	0.50	31.59	4.95	1.41	0.86	5.59	1.82	1.20	1.85	1.16	2.62	1.37	1.84	1.57	0.04	1.46
21	LV20-7	Pavilosta, Latvia	LV20-7_6	Invasive	Eastern	brackish	0.66	30.89	5.16	1.47	0.95	5.52	1.86	1.36	1.94	1.60	2.25	1.32	1.84	1.56	0.04	1.51

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
21	LV20-7	Pavilosta, Latvia	LV20-7_7	Invasive	Eastern	brackish	0.57	24.66	4.80	1.34	0.80	5.16	1.63	1.24	1.59	1.15	1.92	1.26	1.64	1.55	0.03	1.38
21	LV20-7	Pavilosta, Latvia	LV20-7_8	Invasive	Eastern	brackish	0.66	28.78	5.33	1.05	0.68	5.63	1.87	1.27	1.83	1.31	2.14	1.43	1.67	1.64	0.04	1.59
21	LV20-7	Pavilosta, Latvia	LV20-7_9	Invasive	Eastern	brackish	0.52	35.24	4.60	1.36	0.83	4.81	1.59	1.15	1.61	1.12	1.77	1.26	1.41	1.37	0.04	1.31
21	LV20-7	Pavilosta, Latvia	LV20-7_10	Invasive	Eastern	brackish	0.66	27.65	4.65	1.61	0.93	4.95	1.72	1.19	1.75	1.10	1.56	1.24	1.62	1.51	0.03	1.38
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_1	Invasive	Western	brackish	0.74	29.96	5.97	1.77	1.08	6.49	2.13	1.55	2.09	1.59	3.05	1.72	2.11	1.89	0.05	1.85
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_2	Invasive	Western	brackish	0.76	25.94	5.13	2.17	1.48	6.96	2.31	1.54	2.34	1.64	3.24	1.72	2.27	1.92	0.05	1.85
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_3	Invasive	Western	brackish	0.72	33.54	5.82	1.48	1.29	6.51	2.04	1.39	2.15	1.86	2.72	1.61	2.12	1.87	0.05	1.84
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_4	Invasive	Western	brackish	0.85	37.09	7.39	1.80	1.17	8.14	2.71	1.91	2.77	1.60	2.98	1.92	2.47	2.33	0.06	2.15
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_5	Invasive	Western	brackish	0.65	32.67	5.92	2.02	1.29	6.22	2.08	1.39	2.12	1.57	2.89	1.46	2.17	1.84	0.05	1.84
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_6	Invasive	Western	brackish	0.75	31.14	6.54	2.10	1.17	7.42	2.41	1.52	2.43	1.29	2.94	1.73	2.37	2.15	0.06	1.99
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_7	Invasive	Western	brackish	0.57	27.18	4.83	1.47	0.96	5.67	1.88	1.31	1.94	1.34	2.36	1.20	1.79	1.70	0.04	1.54
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_8	Invasive	Western	brackish	0.83	34.96	5.99	2.00	1.14	6.99	2.46	1.37	2.26	1.49	2.64	1.68	2.14	1.90	0.05	1.75
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_9	Invasive	Western	brackish	0.59	28.60	4.52	1.32	0.90	5.04	1.54	1.19	1.66	0.87	2.16	1.25	1.68	1.43	0.03	1.37
22	PL20-1	Szczecin Lagoon Bay in Wicko Wielkie, Poland	PL20-1_10	Invasive	Western	brackish	0.68	27.91	5.75	1.77	1.22	6.25	2.15	1.44	2.17	1.46	3.02	1.50	2.03	1.77	0.04	1.69
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_1	Invasive	Western	river	0.46	39.35	7.05	2.02	1.23	7.95	2.68	1.38	2.70	1.98	3.40	1.83	2.36	2.12	0.05	1.47
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_2	Invasive	Western	river	1.04	37.79	7.13	2.05	1.11	7.91	2.68	1.72	2.70	1.93	3.18	1.77	3.45	1.97	0.04	1.49
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_3	Invasive	Western	river	0.72	41.03	6.12	1.85	1.02	7.72	2.46	1.58	2.53	1.85	3.64	1.93	3.33	1.99	0.12	1.65
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_6	Invasive	Western	river	0.92	37.06	7.65	2.33	1.49	8.28	2.54	1.60	2.64	1.95	4.14	1.86	3.43	2.30	0.17	1.60
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_8	Invasive	Western	river	0.96	37.65	5.25	2.03	1.94	7.89	2.59	1.67	2.53	1.95	3.43	1.73	2.84	2.01	0.12	1.54
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_9	Invasive	Western	river	0.49	43.50	7.99	2.30	1.39	8.99	3.09	1.70	2.92	2.20	3.85	1.96	4.21	1.59	0.15	1.60
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_10	Invasive	Western	river	0.77	39.80	6.35	1.80	1.17	7.17	2.48	1.70	2.64	1.83	2.96	1.51	2.60	2.04	0.12	1.49
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_12	Invasive	Western	river	0.79	39.45	7.25	2.03	1.21	7.43	2.62	1.57	2.64	1.69	3.43	1.81	2.16	2.08	0.12	1.68
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_13	Invasive	Western	river	0.85	40.26	7.72	2.33	1.33	8.63	2.95	1.68	2.91	2.04	3.96	2.11	1.00	2.38	0.12	1.85
23	HR32	River Drava, mouth of the stream Gliboki, Croatia	HR32_19	Invasive	Western	river	0.64	39.85	6.90	1.57	1.01	7.39	2.31	1.55	2.39	1.87	3.39	1.84	1.92	1.96	0.11	1.56
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_1	Invasive	Eastern	river	0.36	39.69	4.53	1.23	0.80	4.12	1.20	0.94	1.20	0.99	1.85	1.12	1.47	1.42	0.03	1.09
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_2	Invasive	Eastern	river	0.43	41.75	4.32	1.46	0.76	4.62	1.51	1.00	1.66	1.30	1.84	1.29	1.91	1.33	0.04	0.95
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_3	Invasive	Eastern	river	0.71	47.60	3.79	1.23	0.71	4.28	1.36	1.02	1.39	1.13	1.71	1.05	1.57	1.08	0.04	1.01
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_4	Invasive	Eastern	river	0.32	39.57	3.60	1.04	0.62	3.56	1.19	0.84	1.24	0.95	1.46	0.94	1.82	1.20	0.03	0.82
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_6	Invasive	Eastern	river	0.35	41.67	3.82	1.13	0.73	4.40	1.29	1.02	1.42	0.95	1.63	1.14	1.23	1.18	0.03	0.89

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_7	Invasive	Eastern	river	0.41	38.99	4.23	1.07	0.76	4.92	1.53	1.07	1.57	1.15	2.02	1.11	2.67	1.42	0.03	1.19
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_8	Invasive	Eastern	river	0.41	37.91	4.26	1.25	0.77	4.63	1.55	1.13	1.72	1.18	2.04	1.24	1.55	1.34	0.05	1.05
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_9	Invasive	Eastern	river	0.38	36.32	3.97	1.14	0.74	4.70	1.45	1.06	1.52	1.11	1.79	1.13	1.55	1.30	0.04	0.95
24	W21-5	River Vistula in Nieszawa, Poland	W21-5_10	Invasive	Eastern	river	0.21	48.67	3.33	1.13	0.69	4.17	1.29	0.96	1.37	1.07	1.55	0.93	1.63	1.04	0.01	0.98
25	O21-9	River Oder in Lubiąż, Poland	O21-9_1	Invasive	Western	river	0.24	42.70	3.53	1.04	0.70	4.24	1.32	1.00	1.39	1.05	1.67	0.89	1.56	1.13	0.02	0.94
25	O21-9	River Oder in Lubiąż, Poland	O21-9_2	Invasive	Western	river	0.17	42.98	3.34	1.08	0.60	3.89	1.30	1.04	1.40	0.96	1.50	0.91	1.19	1.05	0.02	0.82
25	O21-9	River Oder in Lubiąż, Poland	O21-9_3	Invasive	Western	river	0.18	40.15	3.26	0.95	0.58	3.53	1.20	0.81	1.25	0.92	1.40	0.87	1.31	1.06	0.03	0.92
25	O21-9	River Oder in Lubiąż, Poland	O21-9_4	Invasive	Western	river	0.38	52.09	3.20	0.93	0.58	3.93	1.18	0.88	1.24	1.13	1.39	0.90	1.83	1.06	0.02	0.74
25	O21-9	River Oder in Lubiąż, Poland	O21-9_5	Invasive	Western	river	0.29	37.60	3.56	1.00	0.67	4.27	1.34	0.99	1.44	1.25	1.53	0.85	1.95	1.18	0.02	0.83
25	O21-9	River Oder in Lubiąż, Poland	O21-9_6	Invasive	Western	river	0.26	46.48	3.65	1.07	0.65	4.35	1.34	1.02	1.41	0.79	1.65	1.04	2.14	0.88	0.03	0.97
25	O21-9	River Oder in Lubiąż, Poland	O21-9_7	Invasive	Western	river	0.20	40.60	3.46	1.01	0.62	4.17	1.30	0.99	1.38	1.00	1.55	0.83	1.63	0.73	0.03	0.80
25	O21-9	River Oder in Lubiąż, Poland	O21-9_8	Invasive	Western	river	0.27	39.54	3.30	0.91	0.56	4.02	1.28	0.95	1.35	0.91	1.42	0.92	2.29	0.96	0.02	0.76
25	O21-9	River Oder in Lubiąż, Poland	O21-9_9	Invasive	Western	river	0.28	43.41	3.12	0.88	0.61	3.86	1.25	0.92	1.32	1.05	1.48	0.86	1.37	0.95	0.02	0.74
25	O21-9	River Oder in Lubiąż, Poland	O21-9_10	Invasive	Western	river	0.26	37.02	3.20	0.93	0.51	3.94	1.26	0.94	1.34	0.93	1.41	0.87	1.62	1.17	0.02	0.93
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_1	Invasive	Western	river	0.79	41.86	6.77	1.57	0.94	7.09	2.44	1.59	2.38	1.11	3.34	1.87	3.39	1.38	0.14	1.42
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_2	Invasive	Western	river	0.82	42.82	6.03	1.78	1.09	6.53	2.14	1.44	2.24	1.59	2.88	1.71	2.25	1.77	0.12	1.28
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_3	Invasive	Western	river	0.90	40.90	5.95	1.76	1.06	6.40	2.18	1.39	2.20	1.74	3.12	1.70	3.32	1.90	0.12	1.45
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_4	Invasive	Western	river	0.68	39.24	6.72	1.77	0.93	7.05	1.84	1.31	1.87	1.70	3.18	1.86	3.53	2.01	0.05	1.63
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_5	Invasive	Western	river	0.48	46.09	6.55	1.84	1.25	6.93	2.27	1.51	2.31	1.78	3.14	1.75	3.21	2.03	0.04	1.69
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_6	Invasive	Western	river	0.86	38.52	7.01	2.05	1.11	7.24	2.40	1.48	2.49	1.92	3.38	1.68	2.65	1.91	0.03	1.47
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_7	Invasive	Western	river	0.88	39.44	6.09	1.79	1.10	6.60	2.29	1.59	2.27	1.57	3.14	1.46	2.91	1.90	0.03	1.47
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_8	Invasive	Western	river	0.68	36.11	5.41	1.54	0.98	6.10	2.08	1.45	2.11	1.60	2.60	1.72	2.67	1.80	0.11	1.27
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_9	Invasive	Western	river	0.91	49.10	7.05	1.91	1.15	7.22	2.55	1.59	2.75	1.70	2.50	1.94	2.27	2.15	0.16	1.73
26	O21-12	River Oder in Zdzieszowice, Poland	O21-12_10	Invasive	Western	river	0.64	39.09	6.18	1.91	1.10	6.94	2.20	1.67	2.33	1.80	2.92	1.81	2.59	1.78	0.06	1.74
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_1	Invasive	Eastern	river	0.63	28.72	6.85	1.93	1.21	7.17	2.44	1.61	2.43	1.87	3.19	1.44	3.10	2.02	0.12	1.55
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_2	Invasive	Eastern	river	0.56	40.13	6.73	2.04	1.31	7.29	2.50	1.63	2.57	2.17	3.14	1.95	3.70	2.04	0.06	1.56
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_3	Invasive	Eastern	river	0.85	38.77	7.11	1.99	1.33	7.97	2.69	1.72	2.76	1.84	3.47	1.90	3.47	2.14	0.15	1.75
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_4	Invasive	Eastern	river	0.71	36.71	5.45	1.63	0.92	6.56	2.10	1.34	2.10	1.80	2.86	1.67	2.32	1.82	0.10	1.52
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_5	Invasive	Eastern	river	0.33	53.81	5.36	1.37	0.91	6.11	1.87	1.30	1.98	1.47	2.49	1.45	2.65	1.70	0.07	1.31

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_6	Invasive	Eastern	river	0.69	39.11	6.28	1.78	1.14	7.08	2.15	1.67	2.34	1.62	2.85	1.67	3.25	1.92	0.11	1.38
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_7	Invasive	Eastern	river	0.59	38.36	6.10	1.83	1.16	6.48	1.97	1.58	2.15	1.73	2.88	1.59	3.33	1.69	0.11	1.33
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_8	Invasive	Eastern	river	0.68	42.08	5.69	2.07	1.59	7.75	2.82	1.56	2.84	1.70	3.15	1.58	3.05	2.00	0.16	1.74
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_9	Invasive	Eastern	river	1.08	37.59	5.97	1.85	1.04	6.92	2.49	1.47	2.52	1.81	3.39	1.36	3.42	2.04	0.08	1.82
27	W21-7	River Vistula in Wyszogród, Poland	W21-7_10	Invasive	Eastern	river	0.97	41.71	6.14	2.20	1.17	6.75	2.41	1.48	2.42	1.76	2.72	1.74	3.56	1.78	0.06	1.32
28	Ar31	River Loara in Bertignolles, France	Ar31_1	Invasive	Western	river	0.63	43.87	6.00	1.72	1.10	6.37	2.08	1.48	2.17	1.57	2.84	1.33	2.08	1.86	0.10	1.33
28	Ar31	River Loara in Bertignolles, France	Ar31_2	Invasive	Western	river	0.82	42.78	6.14	1.73	1.05	6.92	2.35	1.45	2.26	1.52	3.03	1.66	2.57	1.86	0.06	1.50
28	Ar31	River Loara in Bertignolles, France	Ar31_3	Invasive	Western	river	0.69	41.10	6.54	1.53	0.95	6.55	2.10	1.46	2.17	1.47	2.67	1.45	2.81	1.71	0.10	1.35
28	Ar31	River Loara in Bertignolles, France	Ar31_4	Invasive	Western	river	0.53	39.47	5.18	1.37	0.89	5.98	1.93	1.38	1.93	1.38	2.54	1.43	2.66	1.66	0.04	1.46
28	Ar31	River Loara in Bertignolles, France	Ar31_5	Invasive	Western	river	0.47	46.48	4.03	1.31	0.72	4.16	1.53	1.08	1.63	0.99	1.98	1.14	2.44	1.36	0.02	0.96
28	Ar31	River Loara in Bertignolles, France	Ar31_6	Invasive	Western	river	0.62	37.87	4.90	1.31	0.88	5.36	1.89	1.19	1.90	1.36	2.27	1.20	2.55	1.65	0.04	1.20
28	Ar31	River Loara in Bertignolles, France	Ar31_7	Invasive	Western	river	0.46	45.11	4.46	1.23	1.07	5.16	1.63	1.12	1.60	0.91	2.07	1.17	2.60	1.46	0.03	1.30
28	Ar31	River Loara in Bertignolles, France	Ar31_8	Invasive	Western	river	0.64	39.81	4.22	1.28	0.84	4.83	1.52	1.13	1.60	1.08	2.23	1.08	1.92	1.35	0.06	1.18
28	Ar31	River Loara in Bertignolles, France	Ar31_9	Invasive	Western	river	0.42	45.09	4.94	1.55	0.76	5.52	1.80	1.17	1.83	1.30	2.19	1.31	2.46	1.51	0.06	1.38
28	Ar31	River Loara in Bertignolles, France	Ar31_10	Invasive	Western	river	0.35	38.81	3.58	1.02	0.62	3.79	1.53	0.92	1.38	0.69	1.31	0.86	2.32	1.15	0.02	0.99
29	Ar15	Wolderwijd, Netherlands	Ar15_1	Invasive	Western	brackish	0.62	46.27	6.08	1.77	1.04	6.72	2.16	1.43	2.20	1.30	2.73	1.64	2.93	1.75	0.06	1.40
29	Ar15	Wolderwijd, Netherlands	Ar15_2	Invasive	Western	brackish	0.56	44.60	4.78	1.37	0.89	5.32	1.76	1.19	1.85	0.80	2.37	1.23	2.29	1.50	0.07	1.13
29	Ar15	Wolderwijd, Netherlands	Ar15_3	Invasive	Western	brackish	0.62	45.96	5.51	1.75	1.05	6.11	1.90	1.45	1.92	1.31	2.48	1.37	2.55	1.77	0.09	1.55
29	Ar15	Wolderwijd, Netherlands	Ar15_4	Invasive	Western	brackish	0.58	43.48	5.83	1.95	1.20	6.45	1.81	1.37	1.82	1.64	2.64	1.61	2.98	1.82	0.06	1.51
29	Ar15	Wolderwijd, Netherlands	Ar15_5	Invasive	Western	brackish	0.79	42.08	5.21	1.45	0.98	5.59	1.82	1.43	1.84	0.97	2.59	1.22	2.64	1.48	0.03	1.14
29	Ar15	Wolderwijd, Netherlands	Ar15_6	Invasive	Western	brackish	0.50	42.24	5.16	1.48	1.04	5.96	1.94	1.25	1.86	0.98	2.80	1.46	2.77	1.44	0.06	1.42
29	Ar15	Wolderwijd, Netherlands	Ar15_7	Invasive	Western	brackish	0.65	41.86	4.94	1.55	0.80	5.47	1.81	1.32	1.86	1.35	2.05	1.37	2.67	1.66	0.06	1.23
29	Ar15	Wolderwijd, Netherlands	Ar15_8	Invasive	Western	brackish	0.53	39.37	5.51	1.57	0.91	5.76	1.90	1.33	2.06	1.12	2.65	1.34	2.84	1.73	0.04	1.46
29	Ar15	Wolderwijd, Netherlands	Ar15_9	Invasive	Western	brackish	0.50	43.59	5.82	1.63	0.97	5.83	1.95	1.29	2.01	1.24	2.58	1.23	2.64	1.65	0.06	1.33
29	Ar15	Wolderwijd, Netherlands	Ar15_10	Invasive	Western	brackish	0.54	47.12	5.10	1.46	0.83	5.58	1.84	1.35	1.91	1.85	2.47	2.65	2.11	1.58	0.03	1.21
30	Ar21	River Leie, Belgium	Ar21_1	Invasive	Western	river	0.49	40.40	4.59	1.40	1.05	5.90	1.93	1.22	1.90	1.29	2.19	1.27	2.18	1.60	0.07	1.53
30	Ar21	River Leie, Belgium	Ar21_2	Invasive	Western	river	0.48	44.01	6.23	1.76	1.16	6.96	2.30	1.50	2.32	1.23	2.65	1.44	2.13	1.74	0.04	1.54
30	Ar21	River Leie, Belgium	Ar21_3	Invasive	Western	river	0.73	35.24	5.41	1.42	0.82	5.89	1.86	1.39	2.00	1.34	2.26	1.23	2.51	1.47	0.03	1.39
30	Ar21	River Leie, Belgium	Ar21_4	Invasive	Western	river	0.44	41.69	4.50	1.43	0.81	5.29	1.64	1.22	1.72	1.49	2.21	1.15	2.41	1.52	0.08	1.07

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
30	Ar21	River Leie, Belgium	Ar21_5	Invasive	Western	river	0.58	38.68	4.87	1.41	0.84	5.38	1.71	1.16	1.95	1.32	2.64	1.21	2.33	1.52	0.07	1.24
30	Ar21	River Leie, Belgium	Ar21_6	Invasive	Western	river	0.52	38.79	4.63	1.44	0.86	5.38	1.66	1.19	1.82	0.84	2.26	1.31	2.14	1.42	0.04	1.22
30	Ar21	River Leie, Belgium	Ar21_7	Invasive	Western	river	0.62	43.05	4.69	1.33	0.82	5.04	1.67	1.15	1.63	0.75	1.94	1.13	2.39	1.38	0.05	1.22
30	Ar21	River Leie, Belgium	Ar21_8	Invasive	Western	river	0.53	36.12	3.33	1.34	0.99	4.85	1.62	1.17	1.59	1.08	2.06	1.07	1.99	1.44	0.05	1.03
30	Ar21	River Leie, Belgium	Ar21_9	Invasive	Western	river	0.37	49.04	4.07	1.56	0.83	4.33	1.52	1.05	1.65	0.94	1.77	1.16	1.63	1.28	0.04	0.99
30	Ar21	River Leie, Belgium	Ar21_10	Invasive	Western	river	0.50	35.91	3.99	1.09	0.71	4.88	1.49	1.02	1.52	0.73	1.86	0.99	1.40	1.22	0.06	0.94
31	Ar23	River Somma in Abeville, France	Ar23_1	Invasive	Western	river	0.63	34.80	4.60	1.29	0.86	5.29	1.70	1.20	1.67	1.41	2.12	1.30	2.23	1.49	0.03	1.11
31	Ar23	River Somma in Abeville, France	Ar23_2	Invasive	Western	river	0.66	39.46	4.75	1.49	0.78	5.58	1.95	1.31	1.93	0.74	2.16	1.28	2.13	1.40	0.03	0.99
31	Ar23	River Somma in Abeville, France	Ar23_3	Invasive	Western	river	0.67	41.80	4.70	1.23	0.90	5.54	1.80	1.25	1.80	1.24	2.15	1.23	1.99	1.34	0.07	1.09
31	Ar23	River Somma in Abeville, France	Ar23_4	Invasive	Western	river	0.52	39.52	4.78	1.50	0.92	5.66	1.68	1.29	1.75	1.26	2.43	1.50	2.48	1.48	0.09	1.28
31	Ar23	River Somma in Abeville, France	Ar23_5	Invasive	Western	river	0.33	48.37	4.14	1.21	0.78	5.05	1.61	1.22	1.77	1.29	1.41	1.16	1.94	1.41	0.07	1.19
31	Ar23	River Somma in Abeville, France	Ar23_6	Invasive	Western	river	0.47	43.80	3.86	1.18	0.67	4.22	1.45	1.09	1.54	0.85	1.71	1.09	1.88	1.26	0.05	1.08
32	RO21-1	Sarichioi, Romania	RO21-1	Native	Western	brackish	0.60	33.34	4.73	1.50	0.86	5.08	1.65	1.15	1.63	1.32	2.11	1.08	1.48	1.38	0.03	1.46
32	RO21-1	Sarichioi, Romania	RO21-2	Native	Western	brackish	0.57	34.04	5.08	1.52	0.83	5.49	1.78	1.17	1.75	1.44	2.42	1.23	1.73	1.57	0.04	1.58
32	RO21-1	Sarichioi, Romania	RO21-3	Native	Western	brackish	0.62	33.13	4.70	1.39	0.93	5.24	1.72	1.07	1.66	1.22	2.35	1.18	1.62	1.53	0.03	1.49
32	RO21-1	Sarichioi, Romania	RO21-4	Native	Western	brackish	0.68	31.37	5.40	1.52	1.05	5.93	1.97	1.32	1.95	1.55	2.73	1.32	1.91	1.72	0.04	1.62
32	RO21-1	Sarichioi, Romania	RO21-5	Native	Western	brackish	0.57	29.11	4.98	1.32	0.96	5.51	1.90	1.17	1.84	1.21	2.42	1.29	1.77	1.50	0.04	1.55
32	RO21-1	Sarichioi, Romania	RO21-6	Native	Western	brackish	0.62	32.71	4.95	1.12	0.88	5.61	1.81	1.23	1.92	1.32	2.62	1.23	1.75	1.54	0.03	1.56
32	RO21-1	Sarichioi, Romania	RO21-7	Native	Western	brackish	0.57	30.41	5.01	1.35	0.94	5.44	1.69	1.21	1.76	1.30	1.90	1.26	1.75	1.53	0.03	1.54
32	RO21-1	Sarichioi, Romania	RO21-8	Native	Western	brackish	0.59	33.49	5.13	1.46	1.01	5.65	1.73	1.27	1.88	1.32	2.44	1.37	1.83	1.59	0.04	1.57
32	RO21-1	Sarichioi, Romania	RO21-9	Native	Western	brackish	0.50	34.95	4.21	1.09	0.84	4.62	1.46	1.07	1.47	0.80	2.08	1.09	1.56	1.35	0.02	1.40
32	RO21-1	Sarichioi, Romania	RO21-10	Native	Western	brackish	0.61	27.42	3.81	1.43	1.12	5.43	1.70	1.18	1.73	1.14	2.20	1.26	1.73	1.57	0.03	1.50
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-1	Native	Western	brackish	0.35	39.70	3.93	1.29	0.75	4.31	1.46	0.93	1.50	0.95	1.73	0.94	1.27	1.17	0.02	1.12
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-2	Native	Western	brackish	0.59	24.60	5.53	1.37	0.95	6.04	1.98	1.27	1.88	1.15	2.74	1.37	1.81	1.64	0.04	1.53
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-3	Native	Western	brackish	0.44	37.82	3.78	1.19	0.69	4.17	1.50	0.93	1.37	1.05	1.75	0.68	1.28	1.12	0.02	1.17
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-4	Native	Western	brackish	0.33	46.15	6.27	1.50	1.05	6.97	2.35	1.63	2.49	1.91	2.46	1.56	1.06	0.97	0.02	0.90
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-5	Native	Western	brackish	0.33	37.22	3.52	1.14	0.63	3.93	1.33	0.87	1.33	0.64	1.53	0.87	1.24	1.08	0.02	1.05
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-6	Native	Western	brackish	0.40	25.55	2.02	0.88	0.44	2.24	0.72	0.51	0.76	0.58	0.83	0.54	1.39	1.17	0.02	1.12
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-7	Native	Western	brackish	0.52	26.84	4.01	1.21	0.71	4.30	1.42	1.06	1.49	1.02	1.47	0.91	1.36	1.32	0.02	1.17

station number	station name	locality	individual code	status	lineage	ecosystem	G1 Sp	G1 <	P3	P3 CL	P3 CW	P7	P7 BL	P7 BW	P7 B Lob	Pl1 Pd	Pl1 Ra	U3	St	Md Pl	Mol Sur	Mx Pl
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-8	Native	Western	brackish	0.42	35.49	3.76	1.00	0.66	4.17	1.34	0.94	1.39	0.84	1.93	0.95	1.22	1.22	0.02	1.13
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-9	Native	Western	brackish	0.44	32.11	3.97	1.07	0.69	4.22	1.42	0.91	1.42	0.81	1.80	0.89	1.30	1.23	0.02	1.17
33	UA21-1	Kahul lake in Utkonosivka, Ukraine	UA21-10	Native	Western	brackish	0.40	39.41	3.78	1.11	0.76	4.23	1.40	0.99	1.47	0.92	1.66	0.90	1.40	1.15	0.02	1.08
34	UA21-9	Kahul Lake, Ukraine	UA21-9_1	Native	Western	brackish	0.67	38.73	5.94	1.72	1.15	6.64	2.13	1.37	2.22	1.44	2.56	1.42	1.94	1.84	0.03	1.33
34	UA21-9	Kahul Lake, Ukraine	UA21-9_2	Native	Western	brackish	0.61	46.07	4.73	1.38	0.83	5.24	1.62	1.19	1.73	1.26	2.08	1.37	2.97	1.47	0.02	1.09
34	UA21-9	Kahul Lake, Ukraine	UA21-9_3	Native	Western	brackish	0.73	34.46	4.96	1.41	1.12	5.78	1.90	1.22	1.85	1.38	2.19	1.22	2.40	1.58	0.02	1.29
34	UA21-9	Kahul Lake, Ukraine	UA21-9_4	Native	Western	brackish	0.53	37.65	5.43	1.45	0.98	6.13	1.97	1.35	2.03	1.39	2.69	1.32	2.82	1.70	0.02	1.34
34	UA21-9	Kahul Lake, Ukraine	UA21-9_5	Native	Western	brackish	0.51	45.82	4.35	1.14	0.79	4.82	1.55	1.09	1.58	1.06	1.93	1.20	2.13	1.37	0.04	1.15
34	UA21-9	Kahul Lake, Ukraine	UA21-9_6	Native	Western	brackish	0.56	41.55	4.90	0.99	0.80	5.51	1.77	1.26	1.82	1.27	2.12	1.20	1.72	1.49	0.02	1.24
34	UA21-9	Kahul Lake, Ukraine	UA21-9_7	Native	Western	brackish	0.55	41.43	5.05	1.33	0.87	5.62	1.75	1.09	1.80	0.91	2.35	1.36	2.90	1.50	0.04	1.35
34	UA21-9	Kahul Lake, Ukraine	UA21-9_8	Native	Western	brackish	0.50	42.46	4.51	1.20	0.78	5.00	1.61	1.10	1.68	1.12	2.03	1.22	2.50	1.29	0.02	1.25
34	UA21-9	Kahul Lake, Ukraine	UA21-9_9	Native	Western	brackish	0.50	42.63	5.10	1.48	0.99	5.88	1.87	1.24	1.95	1.36	2.37	1.11	1.97	1.49	0.02	1.34
34	UA21-9	Kahul Lake, Ukraine	UA21-9_10	Native	Western	brackish	0.60	41.82	5.26	1.66	0.92	6.08	1.81	1.31	1.98	1.35	2.42	1.36	2.57	1.68	0.01	1.33
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_1	Native	Western	brackish	0.28	38.13	3.76	1.10	0.65	4.15	1.29	1.01	1.41	0.99	1.68	1.01	2.17	1.16	0.03	0.75
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_2	Native	Western	brackish	0.30	46.98	3.31	0.96	0.64	3.75	1.20	0.91	1.24	0.93	1.41	0.84	1.56	1.01	0.02	0.77
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_3	Native	Western	brackish	0.24	45.89	3.29	0.98	0.64	3.99	1.29	0.95	1.35	0.93	1.40	0.89	2.27	1.05	0.01	0.79
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_4	Native	Western	brackish	0.25	38.30	2.72	0.79	0.42	3.16	1.08	0.80	1.11	0.81	1.21	0.72	1.92	0.93	0.02	0.80
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_5	Native	Western	brackish	0.41	44.25	4.47	1.31	0.86	5.09	1.59	1.23	1.66	1.15	2.05	1.21	2.23	1.35	0.02	1.04
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_6	Native	Western	brackish	0.31	42.23	3.62	1.09	0.73	4.04	1.32	0.99	1.41	0.97	1.71	0.99	2.00	1.21	0.02	0.87
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_7	Native	Western	brackish	0.41	41.45	4.40	1.26	0.86	4.94	1.58	1.22	1.66	1.20	2.11	1.22	1.46	1.52	0.02	1.11
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_8	Native	Western	brackish	0.25	46.34	3.14	0.88	0.61	3.64	1.18	0.86	1.23	0.83	1.46	0.87	1.42	1.03	0.02	0.93
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_9	Native	Western	brackish	0.41	41.66	4.53	1.27	0.84	4.95	1.61	1.19	1.70	0.86	2.14	1.28	2.09	1.43	0.04	1.31
35	RO23-15	Sf. Gheorghe, Romania	RO23-15_10	Native	Western	brackish	0.25	44.71	2.84	1.07	0.96	3.90	1.24	1.01	1.35	0.69	1.62	0.87	1.41	1.11	0.02	0.97

Supplementary File 2

Table 1. The chosen body traits with their function and the abbreviations used in the figures in the body text of the paper and in Supplementary File 1.

Trait	Abbrevation	Function	References
Body length	BL	Related to feeding behaviour and metabolic rate	Allen et al., 2006
Antennae (sensory functions)			
Antenna length I	A1	Detection of movement, chemical cues and mates; Filter feeding	Fišer et al., 2009; Platvoet et al., 2006
Antenna length II	A2		
Mouthparts (food processing and digestion)			
Stomach length	St	Digestion	Coleman 1991, 1992
Mandibular palp length	Md Pl	Grasping and manipulating food particles; cleaning	Caine, 1974; Mayer et al., 2012; Mayer et al., 2015; Watling, 1993
Molar processus surface	Mol Sur	Crushing food particles; abrasion of plant material	
Maxilla I palp length	Mx Pl	Grasping and manipulating food particles	Mayer et al., 2012, 2015
Gnathopods (food capturing and handling)			
Gnathopod I length	G1	Capturing food items	Copilaș- Ciocianu et al., 2017; Fišer et al., 2009
Gnathopod I propodus length	G1 Pr	Grasping food items	Copilaș- Ciocianu et al., 2017; Fišer et al., 2009, 2019
Gnathopod I palm length	G1 Pa	Grasping food items	Copilaș- Ciocianu et al., 2017; Fišer et al., 2009, 2019
Gnathopod I diagonal length	G1 Dg	Grasping food items	Copilaș- Ciocianu et al., 2017; Fišer et al., 2009, 2019
Gnathopod I propodus setae length	G1 St	Grooming, filter feeding	Mayer et al., 2012; Platvoet et al., 2006

Trait	Abbrevation	Function	References
Gnathopod I palmar spine length	G1 Sp	Avoiding prey escape	Loxton & Nicholls, 1979
Gnathopod I palmar angle	G1 <	Avoiding prey escape	Loxton & Nicholls, 1979
Pereiopods (locomotion)			
Pereiopod III length	P3	Crawling, walking, cleaning	Fišer et al., 2009; Platvoet et al., 2006
Pereiopod VII length	P7	Crawling, walking	Fišer et al., 2009
Pleopod I ramus length	Pl1 Ra	Swimming, jet propulsion	
Pleopod I peduncle length	Pl1 Pd	Swimming, jet propulsion	
Uropod III length	U3	Swimming, jet propulsion	Boudrias, 2002; Dahl, 1978

Supplementary material 3

Table 1. Post hoc pairwise comparisons for the effect of the **lineage** in the PERMANOVA analysis for **all traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western vs Dniester	1	41.78	1.13	0.00	0.294
2	**Western vs Eastern**	1	318.74	7.64	0.02	**0.002**
3	**Dniester vs Eastern**	1	187.33	4.15	0.04	**0.020**

Table 2. Post hoc pairwise comparisons for the effect of the **environment** in the PERMANOVA analysis for **all traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	river vs lake	1	30.37	0.93	0.00	0.383
2	**river vs brackish**	1	883.57	21.49	0.07	**0.000**
3	**lake vs brackish**	1	330.46	7.96	0.04	**0.002**

Table 3. Post hoc pairwise comparisons for the effect of the **lineage:range** interaction in the PERMANOVA analysis for **all traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western:invasive vs Dniester:native	1	58.48	1.72	0.01	0.164
2	Western:invasive vs Eastern:native	1	17.54	0.49	0.00	0.625
3	**Western:invasive vs Western:native**	1	363.47	9.77	0.04	**0.001**
4	**Western:invasive vs Eastern:invasive**	1	560.22	13.93	0.06	**0.000**
5	Dniester:native vs Eastern:native	1	49.03	1.86	0.05	0.149
6	Dniester:native vs Western:native	1	78.02	2.15	0.03	0.123
7	**Dniester:native vs Eastern:invasive**	1	258.14	5.62	0.07	**0.010**
8	**Eastern:native vs Western:native**	1	148.77	3.69	0.05	**0.032**
9	**Eastern:native vs Eastern:invasive**	1	179.25	3.58	0.05	**0.035**
10	**Western:native vs Eastern:invasive**	1	200.16	4.11	0.04	**0.029**

Table 4. Post hoc pairwise comparisons for the effect of the **lineage:environment** interaction in the PERMANOVA analysis for **all traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Marginally significant effects (0.05 < p.value ≤ 0.1) are in *Italic*. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western:river vs Western:lake	1	23.74	0.75	0.00	0.470
2	Western:river vs Dniester:brackish	1	53.25	1.69	0.01	0.171
3	Western:river vs Eastern:river	1	52.85	1.50	0.01	0.210
4	**Western:river vs Western:brackish**	1	475.53	12.23	0.06	**0.000**
5	*Western:river vs Eastern:lake*	1	93.72	2.91	0.02	*0.051*
6	**Western:river vs Eastern:brackish**	1	1299.13	34.74	0.20	**0.000**
7	Western:lake vs Dniester:brackish	1	19.11	0.83	0.01	0.429
8	Western:lake vs Eastern:river	1	47.98	1.47	0.02	0.221
9	**Western:lake vs Western:brackish**	1	183.12	4.64	0.04	**0.017**
10	**Western:lake vs Eastern:lake**	1	83.93	3.62	0.07	**0.025**
11	**Western:lake vs Eastern:brackish**	1	847.71	23.03	0.27	**0.000**
12	*Dniester:brackish vs Eastern:river*	1	73.64	2.27	0.04	*0.093*
13	*Dniester:brackish vs Western:brackish*	1	116.25	2.86	0.03	*0.067*
14	**Dniester:brackish vs Eastern:lake**	1	116.10	7.36	0.21	**0.000**
15	**Dniester:brackish vs Eastern:brackish**	1	594.45	15.45	0.26	**0.000**
16	**Eastern:river vs Western:brackish**	1	194.51	4.46	0.03	**0.017**
17	Eastern:river vs Eastern:lake	1	52.49	1.53	0.03	0.206
18	**Eastern:river vs Eastern:brackish**	1	789.73	17.52	0.22	**0.000**
19	Western:brackish vs Eastern:lake	1	100.33	2.37	0.02	0.101
20	**Western:brackish vs Eastern:brackish**	1	460.50	9.73	0.08	**0.001**
21	**Eastern:lake vs Eastern:brackish**	1	342.52	8.03	0.19	**0.005**

Table 5. Post hoc pairwise comparisons for the effect of the **lineage** in the PERMANOVA analysis for **sensory traits**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western vs Dniester	1	1.88	0.89	0.00	0.370
2	Western vs Eastern	1	1.74	0.81	0.00	0.407
3	Dniester vs Eastern	1	2.12	0.98	0.01	0.332

Table 6. Post hoc pairwise comparisons for the effect of the **environment** in the PERMANOVA analysis for **sensory traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	**river vs lake**	1	11.76	4.82	0.02	**0.019**
2	river vs brackish	1	3.50	1.69	0.01	0.178
3	**lake vs brackish**	1	15.89	9.07	0.05	**0.001**

Table 7. Post hoc pairwise comparisons for the effect of the **lineage:range** interaction in the PERMANOVA analysis for **sensory traits**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western:invasive vs Dniester:native	1	2.33	0.99	0.00	0.339
2	Western:invasive vs Eastern:native	1	0.61	0.26	0.00	0.746
3	Western:invasive vs Western:native	1	2.15	1.01	0.00	0.328
4	Western:invasive vs Eastern:invasive	1	3.14	1.28	0.01	0.263
5	Dniester:native vs Eastern:native	1	0.81	0.52	0.01	0.550
6	Dniester:native vs Western:native	1	0.78	0.56	0.01	0.549
7	Dniester:native vs Eastern:invasive	1	2.65	1.11	0.02	0.295
8	Eastern:native vs Western:native	1	0.29	0.23	0.00	0.821
9	Eastern:native vs Eastern:invasive	1	1.49	0.66	0.01	0.478
10	Western:native vs Eastern:invasive	1	1.56	0.82	0.01	0.410

Table 8. Post hoc pairwise comparisons for the effect of the **lineage:environment** interaction in the PERMANOVA analysis for **sensory traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western:river vs Western:lake	1	4.68	1.92	0.01	0.155
2	Western:river vs Dniester:brackish	1	2.17	0.83	0.01	0.376
3	Western:river vs Eastern:river	1	3.17	1.27	0.01	0.256
4	Western:river vs Western:brackish	1	2.17	0.96	0.00	0.337
5	**Western:river vs Eastern:lake**	1	31.31	11.26	0.09	**0.000**
6	Western:river vs Eastern:brackish	1	5.23	2.09	0.02	0.134
7	Western:lake vs Dniester:brackish	1	2.81	1.77	0.03	0.171
8	Western:lake vs Eastern:river	1	0.94	0.58	0.01	0.545
9	Western:lake vs Western:brackish	1	3.16	2.03	0.02	0.129
10	**Western:lake vs Eastern:lake**	1	23.12	12.97	0.22	**0.000**
11	**Western:lake vs Eastern:brackish**	1	5.71	4.00	0.06	**0.029**
12	Dniester:brackish vs Eastern:river	1	1.11	0.63	0.01	0.502
13	Dniester:brackish vs Western:brackish	1	1.50	0.93	0.01	0.368
14	**Dniester:brackish vs Eastern:lake**	1	29.72	13.47	0.33	**0.001**
15	Dniester:brackish vs Eastern:brackish	1	0.32	0.21	0.00	0.787
16	Eastern:river vs Western:brackish	1	2.60	1.59	0.01	0.193
17	**Eastern:river vs Eastern:lake**	1	28.54	14.30	0.23	**0.000**
18	Eastern:river vs Eastern:brackish	1	3.14	1.98	0.03	0.143
19	**Western:brackish vs Eastern:lake**	1	31.08	17.99	0.16	**0.000**
20	Western:brackish vs Eastern:brackish	1	3.31	2.15	0.02	0.120
21	**Eastern:lake vs Eastern:brackish**	1	36.74	20.49	0.38	**0.000**

Table 9. Post hoc pairwise comparisons for the effect of the **lineage** in the PERMANOVA analysis for **food processing and digestion traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	**Western vs Dniester**	1	1.30	4.70	0.02	**0.020**
2	Western vs Eastern	1	0.10	0.33	0.00	0.676
3	**Dniester vs Eastern**	1	1.43	4.16	0.04	**0.036**

Table 10. Post hoc pairwise comparisons for the effect of the **environment** in the PERMANOVA analysis for **food processing and digestion traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	**river vs lake**	1	1.03	3.85	0.02	**0.036**
2	**river vs brackish**	1	2.48	8.81	0.03	**0.001**
3	**lake vs brackish**	1	4.16	12.77	0.07	**0.000**

Table 11. Post hoc pairwise comparisons for the effect of the **lineage:range** interaction in the PERMANOVA analysis for **food processing and digestion traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Marginally significant effects (0.05 < p.value ≤ 0.1) are in *Italic*. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	**Western:invasive vs Dniester:native**	1	0.94	3.65	0.02	**0.038**
2	Western:invasive vs Eastern:native	1	0.36	1.41	0.01	0.226
3	**Western:invasive vs Western:native**	1	1.27	4.53	0.02	**0.017**
4	**Western:invasive vs Eastern:invasive**	1	1.06	3.51	0.01	**0.045**
5	Dniester:native vs Eastern:native	1	0.10	0.51	0.01	0.555
6	**Dniester:native vs Western:native**	1	2.24	7.72	0.09	**0.005**
7	**Dniester:native vs Eastern:invasive**	1	2.10	5.68	0.07	**0.014**
8	**Eastern:native vs Western:native**	1	1.41	4.80	0.06	**0.024**
9	*Eastern:native vs Eastern:invasive*	1	1.30	3.50	0.05	*0.056*
10	Western:native vs Eastern:invasive	1	0.02	0.07	0.00	0.929

Table 12. Post hoc pairwise comparisons for the effect of the **lineage:environment** interaction in the PERMANOVA analysis for **food processing and digestion traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Marginally significant effects (0.05 < p.value ≤ 0.1) are in *Italic.* Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western:river vs Western:lake	1	0.44	1.78	0.01	0.162
2	**Western:river vs Dniester:brackish**	1	0.91	3.81	0.03	**0.041**
3	Western:river vs Eastern:river	1	0.28	1.14	0.01	0.291
4	**Western:river vs Western:brackish**	1	1.11	3.92	0.02	**0.034**
5	**Western:river vs Eastern:lake**	1	2.67	9.76	0.07	**0.002**
6	**Western:river vs Eastern:brackish**	1	5.97	25.28	0.16	**0.000**
7	Western:lake vs Dniester:brackish	1	0.27	1.24	0.02	0.260

no.	pairs	Df	SS	F	R2	p.value
8	Western:lake vs Eastern:river	1	0.03	0.14	0.00	0.870
9	**Western:lake vs Western:brackish**	1	1.63	5.41	0.04	**0.013**
10	**Western:lake vs Eastern:lake**	1	1.75	5.75	0.11	**0.010**
11	**Western:lake vs Eastern:brackish**	1	6.09	28.31	0.31	**0.000**
12	Dniester:brackish vs Eastern:river	1	0.29	1.36	0.02	0.242
13	**Dniester:brackish vs Western:brackish**	1	2.24	7.43	0.07	**0.004**
14	*Dniester:brackish vs Eastern:lake*	1	0.78	2.55	0.09	*0.099*
15	**Dniester:brackish vs Eastern:brackish**	1	6.39	36.62	0.46	**0.000**
16	**Eastern:river vs Western:brackish**	1	1.49	5.01	0.04	**0.019**
17	**Eastern:river vs Eastern:lake**	1	1.80	6.10	0.11	**0.010**
18	**Eastern:river vs Eastern:brackish**	1	5.86	28.11	0.31	**0.000**
19	**Western:brackish vs Eastern:lake**	1	3.93	11.24	0.11	**0.001**
20	**Western:brackish vs Eastern:brackish**	1	3.17	10.84	0.09	**0.000**
21	**Eastern:lake vs Eastern:brackish**	1	8.10	29.38	0.46	**0.000**

Table 13. Post hoc pairwise comparisons for the effect of the **lineage** in the PERMANOVA analysis for **food capturing and handling traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western vs Dniester	1	1.78	0.07	0.00	0.799
2	**Western vs Eastern**	1	209.39	7.18	0.02	**0.008**
3	Dniester vs Eastern	1	75.40	2.41	0.03	0.117

Table 14. Post hoc pairwise comparisons for the effect of the **environment** in the PERMANOVA analysis for **food capturing and handling traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	river vs lake	1	13.83	0.76	0.00	0.386
2	**river vs brackish**	1	873.83	31.07	0.10	**0.000**
3	**lake vs brackish**	1	304.11	9.57	0.05	**0.003**

Table 15. Post hoc pairwise comparisons for the effect of the **lineage:range** interaction in the PERMANOVA analysis for **food capturing and handling traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Marginally significant effects (0.05 < p.value ≤ 0.1) are in *Italic.* Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western:invasive vs Dniester:native	1	1.48	0.07	0.00	0.807
2	Western:invasive vs Eastern:native	1	0.27	0.01	0.00	0.941
3	**Western:invasive vs Western:native**	1	278.49	10.72	0.04	**0.001**
4	**Western:invasive vs Eastern:invasive**	1	492.97	17.67	0.07	**0.000**
5	Dniester:native vs Eastern:native	1	0.66	0.07	0.00	0.825

no.	pairs	Df	SS	F	R2	p.value
6	Dniester:native vs Western:native	1	71.75	2.46	0.03	0.115
7	**Dniester:native vs Eastern:invasive**	1	138.12	3.89	0.05	**0.049**
8	*Eastern:native vs Western:native*	1	91.38	3.27	0.04	*0.073*
9	**Eastern:native vs Eastern:invasive**	1	166.30	4.86	0.06	**0.029**
10	Western:native vs Eastern:invasive	1	21.92	0.56	0.01	0.459

Table 16. Post hoc pairwise comparisons for the effect of the **lineage:environment** interaction in the PERMANOVA analysis for **food capturing and handling traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	Western:river vs Western:lake	1	11.17	0.58	0.00	0.448
2	Western:river vs Dniester:brackish	1	13.44	0.71	0.01	0.392
3	Western:river vs Eastern:river	1	10.36	0.53	0.00	0.469
4	**Western:river vs Western:brackish**	1	467.55	17.48	0.08	**0.000**
5	Western:river vs Eastern:lake	1	17.34	0.92	0.01	0.338
6	**Western:river vs Eastern:brackish**	1	1235.43	49.46	0.27	**0.000**
7	Western:lake vs Dniester:brackish	1	1.32	0.09	0.00	0.784
8	Western:lake vs Eastern:river	1	0.11	0.01	0.00	0.980
9	**Western:lake vs Western:brackish**	1	166.18	5.59	0.04	**0.019**
10	Western:lake vs Eastern:lake	1	5.41	0.38	0.01	0.550
11	**Western:lake vs Eastern:brackish**	1	773.57	26.85	0.30	**0.000**
12	Dniester:brackish vs Eastern:river	1	1.34	0.09	0.00	0.785
13	Dniester:brackish vs Western:brackish	1	73.99	2.37	0.02	0.129
14	Dniester:brackish vs Eastern:lake	1	1.94	0.22	0.01	0.670
15	**Dniester:brackish vs Eastern:brackish**	1	498.53	15.54	0.27	**0.001**
16	**Eastern:river vs Western:brackish**	1	167.53	5.62	0.04	**0.019**
17	Eastern:river vs Eastern:lake	1	5.51	0.38	0.01	0.550
18	**Eastern:river vs Eastern:brackish**	1	776.01	26.82	0.30	**0.000**
19	Western:brackish vs Eastern:lake	1	28.14	0.87	0.01	0.356
20	**Western:brackish vs Eastern:brackish**	1	416.82	11.01	0.09	**0.002**
21	**Eastern:lake vs Eastern:brackish**	1	288.82	8.25	0.20	**0.006**

Table 17. Post hoc pairwise comparisons for the effect of the **lineage** in the PERMANOVA analysis for **locomotion traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	**Western vs Dniester**	1	5.78	5.12	0.02	**0.011**
2	**Western vs Eastern**	1	6.38	5.93	0.02	**0.005**
3	Dniester vs Eastern	1	1.47	1.79	0.02	0.140

Table 18. Post hoc pairwise comparisons for the effect of the **environment** in the PERMANOVA analysis for **locomotion traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	river vs lake	1	2.31	2.10	0.01	0.112
2	**river vs brackish**	1	3.22	3.13	0.01	**0.047**
3	**lake vs brackish**	1	5.41	4.87	0.03	**0.013**

Table 19. Post hoc pairwise comparisons for the effect of the **lineage:range** interaction in the PERMANOVA analysis for **locomotion traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Marginally significant effects (0.05 < p.value ≤ 0.1) are in *Italic.* Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SS	F	R2	p.value
1	**Western:invasive vs Dniester:native**	1	7.26	6.62	0.03	**0.004**
2	**Western:invasive vs Eastern:native**	1	10.51	9.74	0.05	**0.001**
3	**Western:invasive vs Western:native**	1	5.43	4.78	0.02	**0.009**
4	**Western:invasive vs Eastern:invasive**	1	4.12	3.90	0.02	**0.023**
5	Dniester:native vs Eastern:native	1	0.35	0.49	0.01	0.728
6	Dniester:native vs Western:native	1	1.77	1.64	0.02	0.195
7	**Dniester:native vs Eastern:invasive**	1	2.82	3.43	0.05	**0.033**
8	*Eastern:native vs Western:native*	1	3.20	3.11	0.04	*0.051*
9	**Eastern:native vs Eastern:invasive**	1	4.43	5.70	0.07	**0.004**
10	Western:native vs Eastern:invasive	1	1.09	1.09	0.01	0.305

Table 20. Post hoc pairwise comparisons for the effect of the **lineage:environment** interaction in the PERMANOVA analysis for **locomotion traits**. Significant effects (p.value ≤ 0.05) are in **bold**. Marginally significant effects (0.05 < p.value ≤ 0.1) are in *Italic*. Df: degrees of freedom; SS: Sum of Squares; R2: R-squared; F: F-statistic.

no.	pairs	Df	SumsOfSqs	F.Model	R2	p.value
1	Western:river vs Western:lake	1	1.38	1.23	0.01	0.258
2	**Western:river vs Dniester:brackish**	1	7.29	6.98	0.05	**0.002**
3	**Western:river vs Eastern:river**	1	9.51	9.79	0.06	**0.000**
4	*Western:river vs Western:brackish*	1	3.05	2.69	0.01	*0.072*
5	Western:river vs Eastern:lake	1	2.34	2.07	0.02	0.120
6	**Western:river vs Eastern:brackish**	1	6.01	6.17	0.04	**0.005**
7	**Western:lake vs Dniester:brackish**	1	4.59	4.23	0.07	**0.024**
8	**Western:lake vs Eastern:river**	1	5.00	5.38	0.07	**0.004**
9	Western:lake vs Western:brackish	1	1.60	1.33	0.01	0.238
10	Western:lake vs Eastern:lake	1	2.09	1.59	0.03	0.188
11	**Western:lake vs Eastern:brackish**	1	3.64	3.92	0.06	**0.021**
12	Dniester:brackish vs Eastern:river	1	0.48	0.68	0.01	0.562
13	*Dniester:brackish vs Western:brackish*	1	3.25	2.88	0.03	*0.063*
14	**Dniester:brackish vs Eastern:lake**	1	6.78	6.09	0.18	**0.009**
15	**Dniester:brackish vs Eastern:brackish**	1	1.82	2.92	0.06	**0.042**
16	**Eastern:river vs Western:brackish**	1	3.72	3.62	0.03	**0.031**

no.	pairs	Df	SumsOfSqs	F.Model	R2	p.value
17	**Eastern:river vs Eastern:lake**	1	7.37	8.64	0.16	**0.001**
18	*Eastern:river vs Eastern:brackish*	1	1.21	2.07	0.03	*0.090*
19	*Western:brackish vs Eastern:lake*	1	4.04	3.25	0.03	*0.056*
20	*Western:brackish vs Eastern:brackish*	1	2.45	2.37	0.02	*0.093*
21	**Eastern:lake vs Eastern:brackish**	1	6.22	7.59	0.18	**0.002**

Załącznik nr 2

Krzysztof Podwysocki Łódź, 21.08.2024 r.

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OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Bącela-Spychalska K., Desiderato A., Rewicz T., Copilaş-Ciocianu D. (2024). Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe. Hydrobiologia. https://doi.org/10.1007/s10750-024-05565-8

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji artykułu; przeprowadzeniu sekcji oraz pomiarów morfometrycznych; zaplanowaniu metod analiz statystycznych; przeprowadzeniu analiz statystycznych; przygotowaniu przeglądu literatury i przygotowaniu wstępu do artykułu; opisaniu materiału i metod użytych w artykule; opisaniu wyników w artykule; przygotowaniu dyskusji i wniosków w artykule; przygotowaniu tabel i grafik; korekcie artykułu zgodnie z uwagami współautorów; wysłaniu artykułu do czasopisma naukowego; byciu autorem korespondencyjnym; korekcie artykułu zgodnie z uwagami recenzentów; koordynowaniu prac zespołu; organizowaniu spotkań celem dyskusji nad analizami oraz manuskryptem; zapewnieniu finansowania badań; zarządzaniu i koordynacji planowania i realizacji działań badawczych w ramach projektu.

(osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy).

K. Podwysocki

....
podpis

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OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Bącela-Spychalska K., Desiderato A., Rewicz T., Copilaş-Ciocianu D. (2024). Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe. Hydrobiologia. https://doi.org/10.1007/s10750-024-05565-8

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji badań; pozyskaniu wsparcia finansowego dla projektu prowadzącego do niniejszej publikacji; zarządzaniu i koordynacji planowania i realizacji działań badawczych w projekcie, prowadzącego do niniejszej publikacji; opiece nad pracą doktoranta; przesłaniu uwag do artykułu pierwszemu autorowi; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

....

podpis

Appendix 2

Andrea Desiderato Lodz, 21.08.2024

name and surname *place and date*

Department of Invertebrate Zoology and Hydrobiology, University of Lodz, Lodz, Poland

affiliation

DECLARATION

I declare that in the work: Podwysocki K., Bącela-Spychalska K., Desiderato A., Rewicz T., Copilaș-Ciocianu D. (2024). Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe. Hydrobiologia. https://doi.org/10.1007/s10750-024-05565-8

(authors, year of publication, title, journal or publisher, volume, pages)

my contribution consisted of:

contributing to the conceptualization of the study; co-designing methodology; reviewing and editing the manuscript; providing feedback to the first author; and participating in meetings to discuss analyses and the manuscript.

(the applicant for a doctoral degree should provide a detailed description of their contribution to the thesis)

....

signature

Załącznik nr 2

Tomasz Rewicz Łódź, 21.08.2024 r.

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afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Bącela-Spychalska K., Desiderato A., Rewicz T., Copilaș-Ciocianu D. (2024). Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe. Hydrobiologia. https://doi.org/10.1007/s10750-024-05565-8

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji badań; udostępnieniu próbek; opiece nad pracą doktoranta; przesłaniu uwag do artykułu pierwszemu autorowi; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

Tomasz Rewicz

podpis

Appendix 2

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DECLARATION

I declare that in the work: Podwysocki K., Bącela-Spychalska K., Desiderato A., Rewicz T., Copilaș-Ciocianu D. (2024). Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda): a successful aquatic invader across Europe. Hydrobiologia. https://doi.org/10.1007/s10750-024-05565-8

(authors, year of publication, title, journal or publisher, volume, pages)

my contribution consisted of:

contributing to the conceptualization of the article; helping with the lab work (dissections); co-designing methodology; providing samples; supervising the PhD candidate; validating the results; reviewing and editing the manuscript; providing feedback to the first author; and participating in meetings to discuss analyses and the manuscript.

(the applicant for a doctoral degree should provide a detailed description of their contribution to the thesis)

....

Signature

Manuscript III.

Podwysocki K, Szczerkowska-Majchrzak E, Jermacz Ł, Kobak J, Bącela-Spychalska K, Rewicz T, Desiderato A (2024b) Predation or omnivory – two different feeding patterns displayed by two intraspecific lineages of the invasive Ponto-Caspian amphipod - *Dikerogammarus villosus*. Under review in Freshwater Biology.

Corresponding author: Krzysztof Podwysocki

Predation or omnivory – two different feeding patterns displayed by two intraspecific lineages of the invasive Ponto-Caspian amphipod - *Dikerogammarus villosus*

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Keywords: biological invasions; generalist predators; feeding habits; subspecies variation; seasonality; invasion potential; food preference; food consumption

Abstract

1. *Dikerogammarus villosus* (Sowinsky, 1894) is a Ponto-Caspian amphipod expanding in European freshwaters and posing a threat to biological diversity through several biological and behavioural traits, including high carnivory and voracity. The species spreads in Europe through two major corridors from two geographically and genetically different sources: the Danube and the Dnieper deltas. The two intraspecific lineages, the Western and the Eastern, respectively, differ also phenotypically. The goal of our study was to compare the food consumption and food preference of the lineages depending on season and amphipod size.
2. In the food consumption experiment, amphipods were provided with one of the three food types: willow leaves, dead fish tissue or alive chironomid larvae. In the food preference experiment, they were provided with all three food types together. All tests

were conducted in five different seasons. We analysed consumption rate and food preference after 24 h of exposure.

3. Amphipods of both lineages preferred consumption of the chironomid larvae in all seasons. However, those from the Western Lineage consumed less plant tissue than animal tissue while the preferences for dead fish tissue and plant tissue were similar for the Eastern Lineage. The amphipod size positively affected the consumption of specimens from the Western but not those from the Eastern Lineage. Both lineages responded similarly to the succession of the seasons, namely, the consumption rate was higher in warmer months (May-September).
4. Based on our results, we can assume that *Dikerogammarus villosus* from the Western Lineage is a voracious predator more specialised in consuming animal tissue. Although amphipods from the Eastern Lineage also prefer chironomid larvae, their consumption of all kinds of food is more uniform, suggesting their more omnivorous diet. As a consequence, the Western lineage of *D. villosus* (which came from the Danube Delta) may pose a higher threat to macroinvertebrate communities, but their counterparts from the Eastern Lineage (which came from the Dnieper Delta) may be more successful invaders due to their higher diet plasticity.
5. Our study is an important contribution to the assessment of invasive dynamics of *Dikerogammarus villosus* and may help predict the course and consequences of its further expansion. Our results show intraspecific variability of invasive pressure and highlight the importance of examining species invasiveness on the population level.

Introduction

Biological invasions pose a significant threat to biodiversity on a local and global scale (e.g., Pyšek & Richardson, 2010; Mačic et al., 2018; Pyšek et al., 2020; Vantarová et al., 2023). Invasive species may cause biodiversity loss of native species, alter food chains and modify whole ecosystems as habitat engineers (e.g., Vitousek et al., 1996; Dudgeon et al., 2006; David et al., 2017; Kuparinen et al. 2023). Successful invasions of many species can be attributed to their flexible dietary habits and food opportunism (e.g., Kostrzewa & Grabowski, 2003; Navarro et al., 2010; Borcherding et al., 2013; Galiana et al., 2014). Anthropogenic pressure may lead to an increase in food availability in the environment, promoting the invasion success of food opportunists (e.g., Tomczak et al., 2013; Iacarella et al., 2018). They tend to outcompete native species which are often more specialised in their feeding habits (Schmitt et al., 2019). Therefore, analyses of animal diets and food webs are crucial to assess the impact of invasive species (Park, 2004).

Invasive generalist predators have a profound negative impact on invaded communities as they connect multiple trophic levels (Snyder & Evans, 2006; Crowder & Snyder, 2010; Doherty et al., 2016). They directly impact local communities through interference effects such as intraguild predation or due to successful competition for resources (e.g., Polis & Holt 1992; Rosenheim et al. 1995; Crowder & Snyder, 2010). Indirectly, they may alter food webs by cascading effects, impact plant biomass (Schmitz, Hamback, & Beckerman, 2000; Halaj & Wise 2001) and affect predator-prey dynamics (Ives, Cardinale & Snyder, 2005; Pelikan et al. 2024). The magnitude of the impact of generalist predators can also be attributed to changes in environmental conditions (Snyder & Evans, 2006). For instance, the temperature increase is directly proportional to the energetic costs of biological processes (e.g., Brown et al., 2004; Ohlberger, Staaks & Hölker, 2007). Ectothermic animals compensate for these costs through dietary changes i.e., increasing food intake and/or shifting to energy-rich food sources, such as animal tissue (Parmenter, 1980; van der Velde et al., 2009; Woodward, Perkins & Brown, 2010). On the other hand, an increase in water temperature may accelerate leaf decomposition and promote food scarcity for leaf consumers (Gonçalves, Graça & Canhoto 2013). The consumption rate and prey size can also increase with an increase in the body size of the consumer (Brose et al. 2006). The ecological role of aquatic invasive generalist predators is still rarely studied. Their effect on local communities is complex and difficult to predict (Snyder & Evans, 2006).

Lately, biological invasion studies have been pointing out the importance of population-level assessments, suggesting that general assumptions may be misleading (Haubrock et al., 2024; Sousa et al., 2024). Accordingly, the feeding behaviour of an invasive species and, in consequence, its impact on invaded communities may depend on intraspecific differences among various populations of the invader, originating from different sources. While the genetic variation in invasive populations is usually lower than in the source population, lack of bottleneck effect, multiple introductions, population mixing and/or low enemy pressure (e.g., parasites) in newly colonised environments may lead to a similar or even higher level of genetic diversity compared to the native range (Wattier et al. 2007; Gillis et al. 2009, Zhan et al. 2012; Bock et al., 2016). The phenotypic effects of local populations can vary depending on the genetic distinctness of the source populations (Hermisson & Wagner 2004; Galipaud et al., 2015). Different intraspecific lineages of the same species often exhibit variations in invasive traits such as growth rate (Parker 2000; Diamantidis et al., 2011), morphology (Copilaș-Ciocianu & Sidorov, 2022; Podwysocki et al., 2024), temperature and salinity tolerance (Folino-Rorem, Darling & D'Ausilio, 2009; Nyamukondiwa, Kleynhans & Terblanche, 2010), fecundity (Benvenuto et al., 2012), habitat preference (Pfenninger & Nowak, 2008) and diet (Peake et al., 2018; Piria et al., 2022). These disparities can influence their invasion potential (Diamantidis et al., 2011; Dlugosch et al., 2015). Therefore, the predictions of the impact of invasive species can be biased if only single populations are tested. Moreover, genetic variation on the intraspecies level (i.e., populations and lineages) may increase through hybridization resulting in higher hybrid vigour (Facon et al., 2005). Therefore, populations and lineages can differ from one to another in their invasiveness. Among multiple traits worth studying, understanding the differences in feeding behaviour among invasive populations is vital for assessing their invasion potential and impact at the intraspecies levels.

Amphipods (Crustacea, Amphipoda) of Ponto-Caspian origin are a great model group for inter- and intraspecies comparisons. The Ponto-Caspian region is one of the hotspots of amphipod biodiversity (Väinölä et al. 2007). The specific geological history, variable salinity in the basin caused by numerous transgressions and regressions of the sea as well as a long isolation of the basin have resulted in high diversity and endemism of the local amphipod fauna (Reid & Orlova 2002; Cristescu & Hebert 2005). Some of them colonised Western and Central Europe, mainly via three invasion corridors being a net of major European rivers connected with man-made canals (Jażdżewski 1980; Bij de Vaate et al., 2002). These species achieved their invasive success due to their physiological tolerance to wide ranges of environmental conditions (e.g., salinity), high fecundity and early maturation (Grabowski, Bącela & Konopacka, 2007), as well as diet plasticity and feeding opportunism (Platvoet et al., 2009; Piscart et al., 2011; Dehedin et al., 2013).

One of the most successful invasive amphipod species of Ponto-Caspian origin is *Dikerogammarus villosus* (Sowinsky, 1894) (Gammaridae). This species has rapidly colonised and spread throughout numerous water bodies in Western and Central Europe (Rewicz et al., 2014). *Dikerogammarus villosus* invaded European rivers from two independent sources: the Western Lineage spread in the southern corridor from the Danube Delta via the River Danube to Western Europe, and then eastward in the central corridor via the Mittelland Canal in Germany to the River Oder in Poland, while the Eastern Lineage started the colonisation process from the Dnieper Delta and spread in Eastern and Central Europe (Ukraine, Belarus, Poland) through the Dnieper, Bug and Vistula Rivers as part of the central corridor (Rewicz et al., 2015 a, b). Due to their geographic isolation, already in the native range (the Danube and the Dnieper deltas), these two source populations show a significant genetic differentiation (Rewicz et al., 2015 a). As a consequence, they may exhibit variations in behavioural and physiological traits. For instance, these lineages of *D. villosus* present different levels of expressions of the Hsp70 protein in response to thermal stress, suggesting possible disparities in thermal tolerance (Hupało *et al.*, 2018). Therefore, it is reasonable to anticipate other behavioural and physiological differences between these lineages, including variations in feeding habits. Especially given the recently shown differences in feeding-related morphometric traits between the lineages (Podwysocki et al., 2024).

Dikerogammarus villosus is a voracious omnivore displaying a broad range of feeding habits, including detritivory, coprophagy, herbivory and carnivory (Platvoet *et al.*, 2009; Worischka et al., 2018). Behavioural experiments and mouthpart morphology suggest that *D. villosus* does not specialise in any particular feeding mode (Mayer *et al.*, 2008). The species is known to prey on various macroinvertebrates, such as chironomid and odonate larvae, isopods, amphipods, leeches, juvenile crayfish, and even vertebrates, such as fish eggs, fry, and tadpoles (Rewicz et al. 2014; Taylor & Dunn 2016; Warren, Brabeer & Dunn, 2021). Nevertheless, it has a tendency to predate and consume food of animal origin. As a consequence, the presence of *D. villosus* results in the extirpation of numerous taxa engaged in leaf shredding, leading to the disruption of leaf-litter processing and subsequent impacts on energy cycling within the ecosystem (MacNeil et al. 2011). The species itself may also be responsible for the leaf processing, replacing, at least partially, the role of native species (Truhlar et al. 2013). Hence local environmental variations and lineage origin can lead to different feeding habits of this species. Moreover, different populations and intraspecific lineages can vary in trophic position and display different feeding behaviour (Hellmann et al., 2015).

Therefore, this study is the first experimental comparison of food preferences of the two intraspecific lineages of *D. villosus* in the context of season and individual body weight. We aimed to investigate whether the two intraspecific lineages differ in food consumption and food preference throughout the year, taking into account amphipod size. The main hypotheses were: i) the lineages differ in food consumption rate and food preference; ii) food consumption rate and food preference vary between individuals sampled in different seasons; iii) food consumption rate and food preference depends on amphipod size (measured as body weight). We tested these hypotheses in the setup of two experiments - food consumption and food preference - during a year. The high invasiveness of *D. villosus* and lack of similar studies make our study an important contribution to the knowledge about invasion success on a population level and can be crucial for the predictions of further expansion of this species and its consequences for local communities.

Material and methods

Field study and experimental design

To analyse both lineages – the Western and the Eastern – as in Rewicz et al. (2015a), two large rivers leading to the Baltic Sea were chosen for the sampling, i.e., the River Oder, inhabited by the Western Lineage, and the River Vistula, occupied by the Eastern Lineage. Specimens for experiments were collected for two days, every two months from each of the rivers from two sites in the following order: first day on the River Oder (the Western Lineage): Brzeg (50° 51' 37.8'' N, 17° 27' 59.399''E), Zdzieszowice (50° 24' 42.12'' N, 18° 6' 25.559'' E) and second day on the River Vistula (the Eastern Lineage): Wyszogród (52° 23’ 4.56’’ N, 20° 11' 31.2'' E), Ciechocinek (52° 52' 52.68'' N, 18° 50' 0.6'' E) in 2022 (Figure 1). The animals were collected by “kick-sampling” and “sweep sampling” with a benthic hand-net with 500 µm-mesh size, at depths up to 1.5 m according to the protocol of Jażdżewski, Konopacka & Grabowski (2002) and Correa-Araneda et al., (2021), from stones and gravel around groynes, which are known as a preferred habitat for *D. villosus* (Bącela, Grabowski & Konopacka, 2008; Maazouzi et al. 2009; Boets et al. 2010; Copilaș-Ciocianu & Sidorov, 2022). To reduce the risk of biocontamination, after the sampling at each side, we visually inspected, rinsed with river and then distilled water, and air-dried all the equipment having contact with river water (i.e., waders, nets, trays, probes) according to the modified protocol used by U.S. Fish and Wildlife Service (2018). Experimental animals were collected every two months between March and November to cover five of six thermal seasons in Poland – typical climatic variability in areas with a transitional warm temperate climate (in the transitional zone of the temperate climate between maritime and continental ones) (Romer 1949; Marszelewski & Pius, 2016). Each of the months corresponded to one of the seasons. Within this period, water temperature, water resistivity, pH, conductivity, total dissolved solids (TDS) and water flow were measured monthly (see Supplementary File 1). Each time, from each site, 120 medium-sized specimens (10-15 mm) without visible signs of any infections or injuries were sampled. The amphipods were transported to the laboratory in 3.5 L buckets (40 individuals per bucket, filled with river water (~0.3 L) and decomposing leaves on the bottom), and placed in styro boxes with ice coolers. In the laboratory, the specimens were moved to white opaque plastic tanks (60 specimens per tank), 60 x 40 x 10 cm (length x width x height), opened from the top, and filled with a mixture of conditioned aerated water (7 L; mean pH=9.02; mean salinity: 0.1; mean conductivity: 400 μS/cm; mean oxygen concentration: 101.1%) with water from sampling sites in a proportion of 4:1, and containing 20 washed stones of an average diameter of 5 cm to serve as shelters for the animals. The temperature in the lab was kept at a stable level of 19±1 ^{o}C. Subsequently, amphipods were divided per sex according to the morphology of gnathopods (more robust gnathopods in males), and antennae (dense brush-like bunches of setae in males) (Zettler & Zettler, 2017) and then acclimatised for 24 hours. They were provided with a diet consisting of *Salix alba* leaves and alive chironomid larvae. Then, amphipods were starved for another 24 hours to equalise hunger levels among specimens before the experiment (Pellan et al. 2016). During the starvation period, each specimen was isolated in a 60 mL vial closed by a 1 mm mesh size net to avoid cannibalism and migration of faeces and other particles between vials. One drop-like black glass stone of a diameter of 1 cm was put into each vial to serve as a shelter. All vials were then placed horizontally into the tanks used previously for acclimatisation. As amphipods are known to be more active during the night (Dudley & Moore 1982; Lynn et al., 2021; Czarnecka et al., 2022), a longer night period was used to enhance amphipod activity and better emphasise potential differences in food consumption. Therefore, the specimens during acclimatisation and starvation (48 hours in total) were kept under a 10:14 h light : dark regime. Directly after the starvation period, the animals were used in the experiments.

Experiment 1: Food consumption

The food consumption of amphipods was tested every two months. The experiment (Figure 1) was conducted in circular, transparent, plastic pots, 7 cm in diameter and 4 cm in height. Each pot was filled with 60 mL of the same water as that used for acclimatisation and then randomly assigned to one of the three experimental treatments (food types): decomposing leaves of *Salix alba*, a piece of fish muscle tissue (*Cyprinus carpio*), and alive chironomid larvae. These food types represented three modes of feeding: shredding/grazing, scavenging and predation, respectively. The chosen food types are common food sources available to amphipods in the environment (Kownacki, 2000; Zambrano et al., 2006; Truhlar et al., 2013; Taylor & Dunn 2016). Leaves of *S. alba* had been immersed in oxygenated water for several weeks to start the decomposing process of plant material and to promote the formation of biofilm. The frozen fish tissue, obtained from a fish shop, was defrosted 12 hours before the experiment in water at laboratory temperature. A day before the experiment, alive chironomid larvae were bought from a pet shop and kept in a fridge (+4^{o}C).

The food was dried on the filter paper for 5 seconds, weighed with a balance with an accuracy of up to 0.001 g, and put into each pot right before the experiment. Weighing was performed by two operators using two balances. To control for the instrumental error, each operator processed four replicates of each food treatment and four control replicates (food without amphipods) i.e., eight in total per season. The mean weight of food in the treatments and controls was: 0.038 g (SD=0.019 g) and 0.037 g (SD=0.018 g) for leaf; 0.148 g (SD=0.105 g) and 0.144 g (SD=0.102 g) for dead fish tissue; 0.038 g (SD=0.010 g) and 0.038 g (SD=0.009 g) for alive chironomid larvae (eight individuals used according to Krisp & Maier (2005)).

Then, individual amphipods with an equal representation of both sexes (previously separated) from each of the four populations (Brzeg, Zdzieszowice, Wyszogród, Ciechocinek) were randomly placed separately in the pots with the same stone shelters from the prior starvation period to reduce the stress caused by the lack of shelter (Jermacz & Kobak, 2017). The experiment was conducted under the same photoperiod as that used during the acclimatisation. On each date (five in total), a total of 24 treatments (two sexes x three food types x four populations), each replicated eight times, were conducted, resulting in a total of

192 individuals being tested each time. After 24 h, the remaining food was weighed as described previously. Amphipods were preserved in ethanol 96% and weighed afterwards. Ovigerous females (with eggs or juveniles), as well as dead specimens or those that moulted during the experiment, were excluded from further analyses (see Supplementary File 2).

Experiment 2: Food preference

Food preference (Figure 1) was tested in a modified experimental setup according to Pellan *et al.* (2016). The two experiments (1 and 2) were conducted simultaneously with the same setup. The only difference was that in Experiment 2, a mixture of the three food items (i.e., all of them together) was provided to each specimen (mean weights: 0.036 g (SD=0.021 g) of leaf, 0.142 g (SD=0.101 g) of dead fish tissue and 0.038 g (SD=0.012 g) of eight alive chironomid larvae). On each date (five in total), a total of eight treatments (two sexes x four populations), each replicated eight times, were conducted. In total 64 specimens were tested. To control for the instrumental error and take into account the possible loss of leaf weight through the chironomid consumption, each operator processed four control replicates (mixed food without amphipods). The mean weight of food in the control treatments was: 0.038 g (SD=0.021 g) for leaf, 0.144 g (SD=0.095 g) for dead fish tissue, 0.037 g (SD=0.008 g) for alive chironomid larvae.

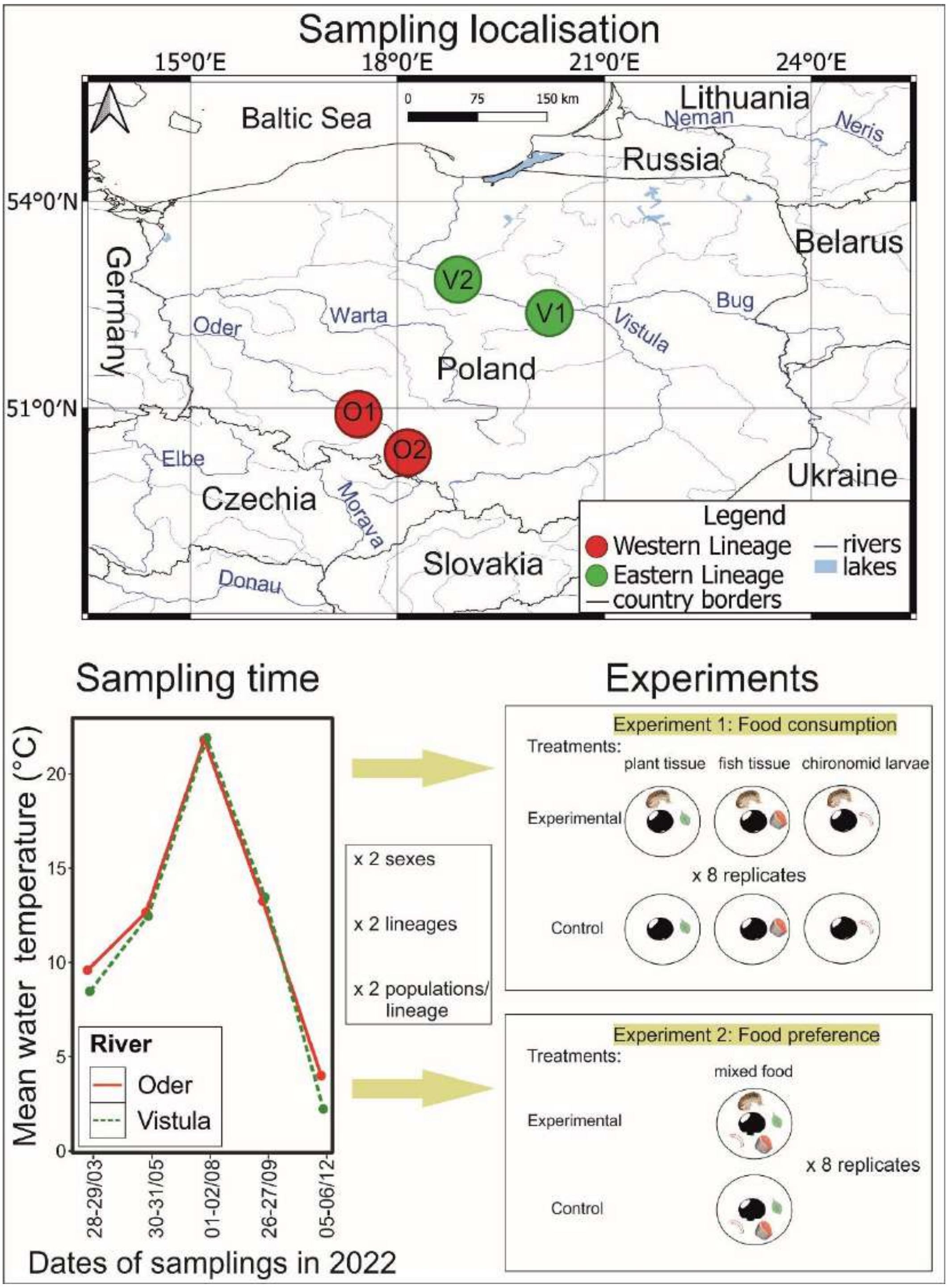

Figure 1. Study area and experimental design. Sampling points are numbered in the map as follows: O1 - Brzeg, O2 - Zdzieszowice, V1 - Wyszogród, V2 - Ciechocinek. The map was prepared in QGIS 3.10.13 (QGIS Development Team 2020).

Statistical analysis

All statistical analyses were performed using R software 4.3.0 (R Core Team 2023).

Food consumption (Experiment 1)

Food consumption was tested using GLMMs separately for each food type (a single model testing all food types together showed high overdispersion). The response variable was obtained from the formula below:

*food consumption = (Q1 - Q2) * (C1/C2)*

where (*Q*) is the amount of food (g) before and after the experiment (*1* and *2,* respectively); (C) is the mean amount of food (g) in control treatment before and after the experiment (*1* and *2,* respectively).

The obtained response variable was modelled in a GLMM with Tweedie distribution as we could not use a Gaussian model due to the non-normal distribution of the data. The basic model contained the full interaction between all fixed explanatory variables (lineage, season, sex, amphipod weight) (Table 1). Sex was used to control for the possible bias associated with different food consumption by males and females. The site was used as a random effect to control the variability within lineages and to account for the possible sampling bias. Extreme outliers were omitted from the analyses after visual inspection (a priori exclusion; see Supplementary File 2). Furthermore, based on AICc (Akaike Information Criterion with a correction for small sample sizes) (Akaike 1974), we compared the models by reducing step by step the particular interactions as well as random effects. However, the interaction between lineage and weight was always present in all tested models. Final models (Table 2) were validated by simulating their residuals using the package *DHARMa* (Hartig 2022). For every model, the Wald chi-square test was computed through analysis of deviance with the *Anova* function in the “car” package (Fox & Weisberg, 2019). When necessary, pairwise comparisons were generated with the emmeans function and Bonferroni adjustments via the “emmeans” package (Lenth 2022). GLMM marginal effects were predicted using the sjPlot package.

Food preference (Experiment 2)

To evaluate the food preference in Experiment 2, only positive values of the response variable (calculated as for Experiment 1) were used, excluding the animals that did not consume any food (i.e., did not show any food choice). The food consumption from mixed food treatments was then analysed as for Experiment 1. The basic model contained the interaction between lineage, season and food and between lineage, weight, food and sex (Table 1). Similarly to experiment 1, the site was used as a random effect, however, to take into account repeated measurements in the model, replicates (i.e., each specimen) were used as a random effect. The food consumption for each specimen was reported separately for each food type. Extreme outliers were omitted from the analyses after visual inspection (a priori exclusion; see Supplementary File 2). Then, based on AICc, we compared the models reducing step by step the particular interactions as well as random effects, however, the interaction between lineage and food and between lineage and weight as well as replicate was always present in all tested models. Final models (Table 2) were validated and pairwise comparisons were generated similarly to analyses in Experiment 1. GLMM marginal effects were predicted as in Experiment 1.

Table 1. Full models used in the analyses. Interactions between the variables were marked with an asterisk. Variables added to the model without interaction were marked with a plus sign. (1|variable) means random intercepts. In the column: Factors and levels, factor names are in **bold** with the number of levels in the brackets.

Analysis	Response variable	Full model	Factors and levels
Food consumption	leaf consumption fish consumption chironomid larvae consumption	lineage * weight * season * sex + (1|lineage:site), tweedie(link = "log")	**lineage** (2): Western, Eastern**;** **season** (5): March, May, July, September, November; **sex** (2): males, females; **site** (2): A (Brzeg/Wyszogród), B (Zdzieszowice/Ciechocinek)
Food preference	food consumption in mixed treatment	lineage * food * season + lineage * weight * food * sex + (1|lineage:site) + (1|season:site:sex:replicate), tweedie(link = "log")	**lineage** (2): Western, Eastern; **food** (3): leaf, fish, chironomid larvae; **season** (5): March, May, July, September, November; **sex** (2): males, females; **site** (2): A (Brzeg/Wyszogród), B (Zdzieszowice/Ciechocinek)

Results

Leaf consumption

Leaf consumption in Experiment 1 (Table 2, Figure 2A) was significantly different among seasons (Chisq=11.11, df=4, p=0.03). Maximum consumption was observed in May significantly higher than in November (p=0.05) and marginally significantly higher than in March (p=0.08; for pairwise comparisons, see Supplementary File 3). The consumption tended to increase with amphipod weight (Chisq=3.11, df=1, p=0.08). The proportion of variance explained by the fixed effects in this model was 0.030 (R^2 marginal).

Table 2. Results of GLMM models for food consumption (results of Experiment 1) and food preference (results of Experiment 2). (1|variable) means random intercepts. Significant effects (p≤0.05) are in **bold**. Marginally significant effects (0.05<p<0.1) are in *Italic*. Chisq: the chi-square statistic; Df: the degrees of freedom; Pr: p-value.

Model	Response variable	Final model	Factor	GLMM Chisq	Df	Pr (>Chisq)
Food consumption	leaf consumption	lineage * weight + season + sex, tweedie(link = "log")	lineage	0.38	1	0.54
			weight	3.11	1	*0.08*
			lineage:weight	1.22	1	0.27
			season	11.11	4	**0.03**
			sex	1.91	1	0.17
	fish consumption	lineage * weight + season + sex, tweedie(link = "log")	lineage	0.03	1	0.87
			weight	0.69	1	0.41
			lineage:weight	0.14	1	0.71
			season	22.86	4	**<0.01**
			sex	1.54	1	0.22
	chironomid larvae consumption	lineage * weight + season + sex + (1|lineage:site), tweedie(link = "log")	lineage	1.22	1	0.27
			weight	4.33	1	**0.04**
			lineage:weight	1.99	4	0.16
			season	44.44	1	**<0.01**
			sex	0.05	1	0.82
Food preference	food consumption in mixed treatment	lineage * food + season + lineage * weight + food + sex + (1|month:site:sex:replicate), tweedie(link = "log")	lineage	0.03	1	0.86
			food	142.36	2	**<0.01**
			lineage:food	5.54	2	*0.06*
			season	65.15	4	**<0.01**
			weight	0.55	1	0.46
			lineage:weight	6.64	1	**<0.01**
			sex	0.35	1	0.55

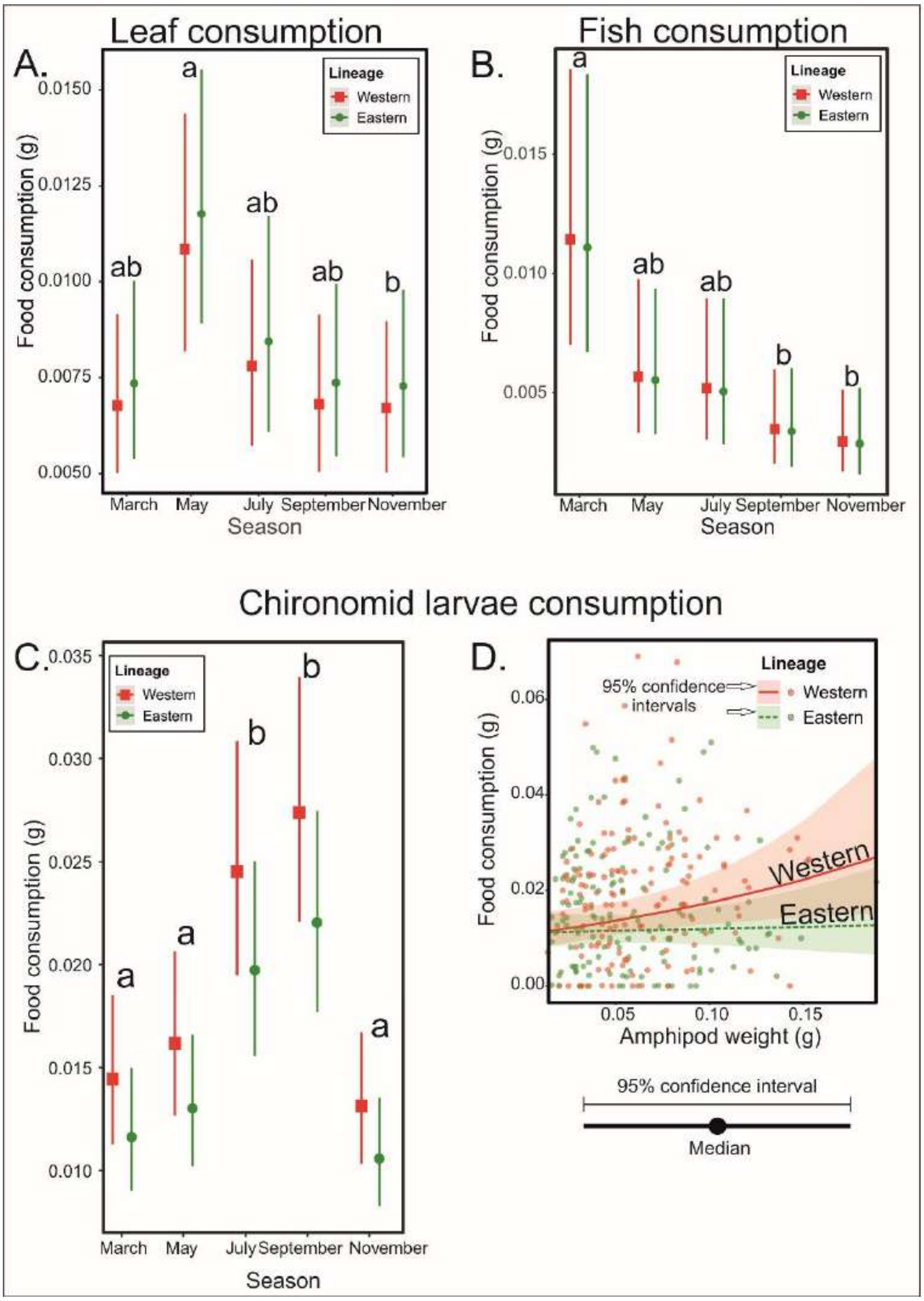

Figure 2. Leaf (A), dead fish tissue (B) and alive chironomid larvae (C) consumption by different amphipod lineages in various seasons, predicted by the GLMM (marginal effects). The interaction lineage * season was not tested but it is shown to display a similar response of both lineages to the sequence of seasons. Chironomid larvae consumption (D) depending on the amphipod weight predicted by the GLMM (marginal effects). Statistically significant differences are indicated by using distinct letters (p≤0.05; for every pairwise comparison, see Supplementary File 3).

Fish consumption

Similarly to leaf consumption, dead fish tissue consumption varied significantly only among seasons (Chisq=22.86, df=4, p<0.01). The highest consumption rate was observed in March while the lowest in September and November (Table 2; Figure 2B; for pairwise comparisons, see Supplementary File 3). The consumption rate was similar for both lineages. The proportion of variance explained by the fixed effects in this model was 0.075 (R^2 marginal).

Chironomid larvae consumption

Chironomid larvae consumption varied among seasons (Chisq=44.44, df=1, p<0.01). The highest consumption rate was noted in July and September (Table 2; Figure 2C; for pairwise comparisons, see Supplementary File 3). Amphipod weight and food consumption appeared positively correlated (Chisq=4.33, df=1, p=0.04), however, the tendency was not lineage-specific (Figure 2D). The site had a significant contribution to the variability observed (Marginal R^2/Conditional R^2: 0.186/0.247).

Food preference

The preferred food type (Table 2; Figure 3A) for both lineages was alive chironomid larvae and the least preferred was leaf (effect of food: Chisq=142.36, df=2, p<0.01). Though the consumption of alive chironomid larvae was similar for both lineages, amphipods from the Western Lineage tended to consume significantly more dead fish tissue than leaf, while consumption of these kinds of food was similar for amphipods from the Eastern Lineage (for pairwise comparisons, see Supplementary File 3). The lowest total consumption of food was observed in November (effect of season: Chisq=65.15, df=4, p<0.01). The total consumption was positively correlated with amphipod weight for individuals of the Western Lineage and negatively in the case of specimens from the Eastern Lineage (i.e., the effect of the interaction between lineages and weight: Chisq=6.64, df=1, p<0.01) (Table 2; Figure 3B). The replicate had a very low contribution to the variability observed (Marginal R^2/Conditional R^2: 0.364/0.368).

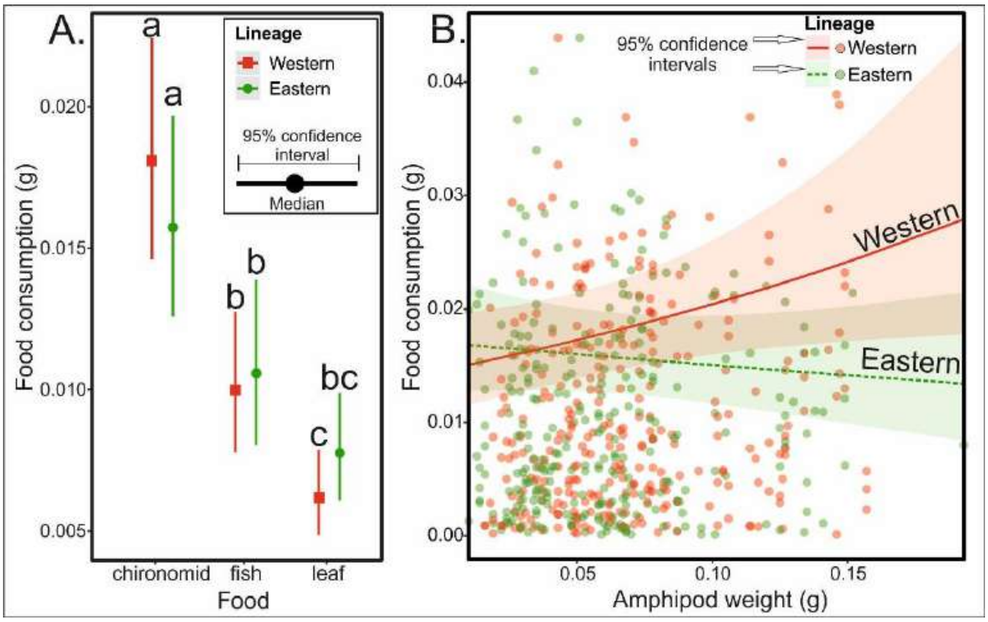

Figure 3. Consumption of three food types in the food preference experiment predicted by the GLMM (marginal effects) in the interaction with lineages (A). Total food consumption in the food preference experiment predicted by the GLMM (marginal effects) in the interaction with lineages and amphipod weight (B).

Discussion

This study shows that in general, the food consumption rate of *Dikerogammarus villosus* is similar for both lineages depending mostly on season and amphipod body weight. However, our investigation revealed that larger amphipods belonging to the Western Lineage exhibit a higher consumption rate compared to those from the Eastern Lineage of similar size. In instances when amphipods were provided with food choices, alive chironomid larvae were always the preferred food for both lineages and across all seasons. However, amphipods from the Western Lineage choose significantly more animal tissue than plant tissue, while amphipods from the Eastern Lineage tended to consume a similar amount of plant and dead fish tissue.

The consumption rate of alive chironomid larvae was the highest among all tested food types for both lineages. This supports the findings in other studies that showed alive prey as a preferred food item of other invasive gammarid species (Bącela-Spychalska & van der Velde 2013). The choice of this kind of food can be explained by the high energetic value of chironomid larvae, thus, feeding on this food best compensates for energetic costs (Pellan et al., 2016). *Dikerogammarus villosus* is an effective opportunistic predator with a sit-and-wait predatory strategy (Maazouzi et al. 2011). Thus, preying on slightly moving chironomid larvae is profitable for this species (Pellan et al., 2016). Preference for this kind of food underlines the strong carnivory and predatory behaviour of *D. villosus* (Bącela-Spychalska & van Der Velde 2013). However, the extent of chironomid larvae consumption was strongly determined by amphipod weight. Namely, the chironomid consumption rate grew with an increase in amphipod body weight. Increasing food consumption with an increase in body weight is connected with growing energy costs. Larger specimens need to consume more food to compensate for their energy needs. Moreover, the predatory efficiency is higher in the case of larger amphipods and consequently, they can catch and consume more larvae (Iltis et al. 2018).

The Western Lineage seems to be more carnivorous than the Eastern Lineage, especially in the case of bigger specimens. In the food preference experiment, amphipods from the Western Lineage consumed more chironomid larvae and dead fish tissue than leaf while specimens from the Eastern Lineage consumed similar levels of dead fish and plant tissue. These findings highlight the lower feeding specialisation of individuals from the Eastern Lineage and their probable higher diet plasticity. A possible reason for such disparities can be a higher habitat heterogeneity in the range of the Eastern Lineage. Eastern Europe is characterised by a lower amount of artificial canals and a lower level of modification of waterbodies (Bij de Vaate et al. 2002). Environmental heterogeneity creates more trophic niches that enable species to use a high spectrum of food resources (Grabowska, Grabowski & Kostecka 2009). Based on these findings we may expect that more diverse habitats in Eastern Europe promote higher plasticity of amphipods of the Eastern Lineage leading to their more omnivorous diet. These assumptions are partially supported by the morphological disparities between lineages. It was observed that amphipods of the Eastern Lineage have a larger molar surface in mandibles (Podwysocki et al., 2024). The molar surface of mandibles plays a role in crushing food particles, mainly of plant origin (Copilaş-Ciocianu, Boros & Šidagytė-Copilaș 2021). Therefore, it results from a greater contribution of amphipods of the Eastern Lineage to shredding/grazing. At the same time, amphipods from the Western Lineage have longer pereiopods and bigger gnathopods (Podwysocki et al., 2024). Pereiopods are responsible for locomotion, thus, their form may explain the higher predatory and carnivory of amphipods of the Western Lineage (Copilaş-Ciocianu, Boros & Šidagytė-Copilaș 2021). Similarly, bigger gnathopods may be evidence of higher predatory of individuals from this lineage.

Our findings enable us to diversify the invasive potential of the lineages. It seems like *D. villosus* from the Western Lineage, compared to the counterparts from the Eastern Lineage, is more feeding specialised, is more voracious and predatory. These are important traits that determine their invasive potential and threat to macroinvertebrate communities as invasive predators may accelerate biodiversity loss (Doherty et al. 2015). *Dikerogammarus villosus* in the range of the Western Lineage is known to successfully eliminate native species of amphipods and other indigenous invertebrate taxa as well as fish fry (Kley & Maier 2003, MacNeil & Platvoet 2005, van der Velde et al. 2009). At the same time, *Dikerogammarus villosus* from the Eastern Lineage seems to be less specialised and more omnivorous than their counterparts from the Western Lineage. We may expect that amphipods in the range of the Eastern Lineage can be more plastic in their foraging strategies. *Dikerogammarus villosus*, generally known for its intense leaf-littering processing, can have a more severe impact on energy cycling in the environments inhabited by the Eastern Lineage (Truhlar et al. 2013). Moreover, it can outcompete native predators and modify trophic webs by cascading effects, strongly impacting plant biomass (Kuparinen et al. 2023). Omnivory is an important trait that aids invasive species in spreading successfully in new environments (Machovsky-Capuska et al. 2016; Worischka et al., 2018; Pelikan et al. 2024; Warren et al. 2024). Therefore, the Eastern Lineage may be more successful in the establishment in newly invaded habitats. Consequently, this lineage may spread in the Western direction and a potential meeting with the Western Lineage may result in the hybridization between lineages.

Our results show also an important role of seasonality in shaping the food consumption and preferences exhibited by the invasive species over the year. The diet of amphipods varies among seasons (Platvoet et al. 2005; Pellan et al., 2016). When temperature increases, the energetic costs of metabolism of ectothermic organisms increase as well. These increased energy needs are compensated by a higher food intake or choosing more energetic food. Although chironomids were always the preferred food item for *D. villosus* in all seasons, their consumption was the highest in warmer months, i.e., July and September. Accordingly, also leaf consumption was higher in the warmer months, despite the generally lower energy value of plant tissue compared with other tested food types. Consumption of dead fish tissue was the lowest in autumn when energy needs were lower than in summer. Notwithstanding that the lineages show similar feeding responses to seasonality, the differences in food consumption between seasons over the year underline the significance of long-term studies on the feeding habits of invasive amphipods.

Our study is one the first that compares the intraspecific lineages of invasive species in terms of feeding habits. Our findings constitute an important contribution to the knowledge about the variability of invasive traits between the lineages. We show that the two genetically distinct lineages of a single species differ in consumption rate. Namely, the Western Lineage is more voracious and more carnivorous. It can use more caloric food. As a consequence, this lineage may strongly affect local macroinvertebrate communities. On the other hand, the Eastern Lineage can be a more successful invader due to using a higher variety of food resources. The strong positive effect of amphipod weight from the Western Lineage on the consumption rate underlines the threat of this lineage to the environment. Though the differences between lineages are rather small, taking into account the high abundance of this species in the environment, the impact of populations of different origins on the local macroinvertebrate communities may highly vary. As both lineages similarly react to seasonal variability, the differences between lineages are rather the effect of their origin and functional plasticity than the influence of the local abiotic conditions, which is also confirmed by the low contribution of the site in the variance explained by our models.

Laboratory experiments on food preference and consumption tend to overestimate predation rate and animal tissue consumption and underestimate herbivory compared to natural conditions (Koester, Bayer & Gergs, 2016; Worischka et al., 2018). Having a choice, *Dikerogammarus villosus* will more likely choose the most energy-rich food item provided. Access to energy-rich food in natural conditions is more challenging compared to experimental settings, leading to a reduced significance of such food in the amphipod diet. Even if the results of experiments should be supplemented with field data and/or morphological studies (Bącela-Spychalska & van Der Velde 2013; Copilaș-Ciocianu et al. 2023) because they cannot completely reflect the natural choices in the environment, experimentally it is possible to reduce the variables involved in the feeding behaviour by equalising biotic and abiotic conditions. Therefore, our study gives an insight into the differences in the potential invasion impact that can be exhibited by the two genetically distinct lineages of an important invasive species colonising European waterbodies, and being expected to spread further (Cancellario et al. 2023).

These results can be an important source of studies monitoring invasive potential and predicting further expansion of this and other invasive species. It is crucial to conduct in-depth research on the invasion potential of both lineages, as the potential meeting and breeding between lineages in the future may result in the emergence of intraspecific hybrids. The prediction of the invasiveness of these hybrids will be more effective if the invasion potential of both parental lineages is thoroughly understood.

Acknowledgements

Work was supported by the National Science Centre in Poland (grant: 2018/31/D/NZ8/03061). KP was funded by the University of Lodz. The authors are thankful to Sylwia Holak and Serena Mucciolo (both from the University of Lodz), who helped during the experiments. Moreover, the authors are grateful to Łukasz Trębicki and Jakub Bienias (both from the University of Lodz) for helping during field sampling. The authors' thanks also go to Julita Nawrocka (University of Lodz) who helped with amphipod weighting. The authors are grateful to Monika Kuna-Majewska (University of Lodz) for her help in the administration of the project that funded samplings and experiments. The authors are grateful to two anonymous reviewers. Their valuable suggestions improved the quality of the manuscript.

Author contribution statement:

Conceptualisation: KP, ŁJ, JK, KBS, TR, AD. Developing methods: KP, AD. Conducting the research: KP, ESM, AD. Data analysis: KP, JK, AD, data interpretation: KP, JK, AD. Preparation figures & tables: KP, ESM. Writing: KP, ESM, ŁJ, JK, KBS, TR, AD.

Conflict of Interest Statement:

The authors declare that they have no conflict of interest.

Data Availability Statement:

Data are available in the supplementary materials.

References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, 19(6), 716-723.

Bącela-Spychalska, K., & van Der Velde, G. (2013). There is more than one “killer shrimp”: Trophic positions and predatory abilities of invasive amphipods of Ponto-Caspian origin. *Freshwater Biology,* 58, 730–741. https://doi.org/10.1111/fwb.12078

Bącela, K., Grabowski, M., & Konopacka, A. (2008). *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Amphipoda) enters Vistula – the biggest river in the Baltic basin. *Aquatic Invasions,* 3, 95–98. https://doi.org/10.3391/ai.2008.3.1.16

Benvenuto, C., Cheyppe-Buchmann, S., Bermond, G., Ris, N., & Fauvergue, X. (2012). Intraspecific hybridization, life history strategies and potential invasion success in a parasitoid wasp. *Ecological Entomology*, 26, 1311–1329. https://doi.org/10.1007/s10682-011-9553-z

Bij de Vaate, A., Jazdzewski, K., Ketelaars, H. A. M., Gollasch, S., & van der Velde, G. (2002). Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. *Canadian Journal of Fisheries and Aquatic Sciences,* 59, 1159–1174. https://doi.org/10.1139/f02-098

Boets, P., Lock, K., Messiaen, M., Goethals, & Peter, L. M. (2010). Combining data-driven methods and lab studies to analyse the ecology of *Dikerogammarus villosus*. *Ecological Informatics,* 5, 133-139. doi: 10.1016/j.ecoinf.2009.12.005

Bock, D. G., Caseys, C., Cousens, R. D., Hahn, M. A., Heredia, S. M., Hübner, S., … Rieseberg, L. H. (2016). What we still don’t know about invasion genetics. *Invasion Genetics,* 346–370. doi:10.1002/9781119072799.ch20

Borcherding, J., Dolina, M., Heermann, L., Knutzen, P., Krüger, S., Matern, S., … Gertzen, S. (2013). Feeding and niche differentiation in three invasive gobies in the Lower

Rhine, Germany. *Limnologica*, 43, (1), 49–58, https://doi.org/10.1016/j.limno.2012.08.003

Brose, U., Jonsson, T., Berlow, E. L., Warren, P., Banasek-Richter, C., Bersier, L. F., … Cohen J. E. (2006). Consumer–resource body-size relationships in natural food webs. *Ecology,* 87(10), 2411-2417. https://doi.org/10.1890/0012-9658(2006)87[2411:CBRINF]2.0.CO;2

Brown, J. H., Gillooly, J. F., Allen, A. P., Savage, V. M., & West, G. B. (2004). Toward a metabolic theory of ecology. *Ecology*, 85(7), 1771–1789. doi:10.1890/03-9000

Cancellario, T., Laini, A., Wood, P.J., Guareschi, S. (2023). Among demons and killers: current and future potential distribution of two hyper successful invasive gammarids. *Biological Invasions* 25, 1627–1642. https://doi.org/10.1007/s10530-023-03000-y

Copilaș-Ciocianu, D., & Sidorov, D. (2022). Taxonomic, ecological and morphological diversity of Ponto-Caspian gammaroidean amphipods: a review. *Organisms Diversity & Evolution,* (22), 285–315.

Copilaș-Ciocianu, D., Boros, B. V., & Šidagytė-Copilas, E. (2021). Morphology mirrors trophic niche in a freshwater amphipod community. *Freshwater Biology,* 66, 1968–1979. https://doi.org/10.1111/fwb.13804

Copilaș-Ciocianu, D., Garbaras, A., Šidagytė-Copilas, E. (2023). Invasion is accompanied by dietary contraction in Ponto-Caspian amphipods. *BioRxiv preprint*, doi: https://doi.org/10.1101/2023.08.08.552405

Correa-Araneda, F., Núñez, D., Díaz, M. E., Gómez-Capponi, F., Figueroa, R., Acuna, J., ... & Esse, C. (2021). Comparison of sampling methods for benthic macroinvertebrates in forested wetlands. *Ecological indicators*, 125, 107551.

Czarnecka, M, Jermacz, Ł, Glazińska, P, Kulasek, M, & Kobak, J. (2022). Artificial light at night (ALAN) affects behaviour, but does not change oxidative status in freshwater shredders. *Environmental Pollution*, 306,119476. doi: 10.1016/j.envpol.2022.119476. Epub 2022 May 14. PMID: 35580711

Crowder, D. W., & Snyder, W. E. (2010). Eating their way to the top? Mechanisms underlying the success of invasive insect generalist predators. Biol Invasions 12, 2857– 2876. https://doi.org/10.1007/s10530-010-9733-8

Cristescu, M. E. A., & Hebert, P. D. N. (2005). The "Crustacean Seas" — an evolutionary perspective on the Ponto–Caspian peracarids. *Canadian Journal of Fisheries and Aquatic Sciences,* 62, 505–517.

David, P., Thébault, E., Anneville, O., Duyck, P.-F., Chapuis, E., & Loeuille, N. (2017). Impacts of Invasive Species on Food Webs. *Advances in Ecological Research*, 1– 60. doi:10.1016/bs.aecr.2016.10.00110.1016/bs.aecr.2016.10.001

Dehedin, A., Maazouzi, C., Puijalon, S., Marmonier, P., & Piscart, C. (2013). The combined effects of water level reduction and an increase in ammonia concentration on organic matter processing by key freshwater shredders in alluvial wetlands. *Global Change Biology,* 19, 763–774. https://doi.org/10.1111/gcb.12084

Diamantidis, A. D., Carey, J. R., Nakas, C. T. & Papadopoulos, N. T. (2011). Population-specific demography and invasion potential in medfly. *Ecology and Evolution,* 1, 479–488. https://doi.org/10.1002/ece3.33

Dlugosch, K. M., Anderson, S. R., Braasch, J., Cang, F. A., & Gillette, H. D. (2015). The devil is in the details: genetic variation in introduced populations and its contributions to invasion. *Molecular Ecology*, 24(9), 2095–2111. doi:10.1111/mec.13183

Doherty, T. S., Dickman, C. R., Nimmo, D. L., & Ritchie, E. G. (2015). Multiple threats, or multiplying the threats? Interactions between invasive predators and other ecological disturbances. Biological Conservation, 190, 60-68. https://doi.org/10.1016/j.biocon.2015.05.013

Doherty, T. S., Glen, A. S., Nimmo, D. G., Ritchie, E. G., & Dickman, C. R. (2016). Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences U S A*, 113 (40), 11261–11265. doi: 10.1073/pnas.1602480113. Epub 2016 Sep 16. PMID: 27638204; PMCID: PMC5056110

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., … Sullivan, C. A. (2006). Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Society*, 81, 163–182, https://doi.org/10.1017/S1464793105006950

Dudley, W. D., & Moore, K. A. (1982). The effect of environmental factors on the activity of *Gammarus pseudolimnaeus* (Amphipoda). *Hydrobiologia,* 96, 137–147 https://doi.org/10.1007/BF02185429

Facon, B., Jarne, P., Pointie,r J. P., &David, P. (2005). Hybridization and invasiveness in the freshwater snail *Melanoides tuberculata*: hybrid vigour is more important than increase in genetic variance. *Journal of Evolutionary Biology,* 18, 524–535. PMID: 15842482

Folino-Rorem, N. C., Darling, J. A. & D'Ausilio, C. A. (2009). Genetic analysis reveals multiple cryptic invasive species of the hydrozoan genus Cordylophora. *Biological Invasions,* 11, 1869–1882 https://doi.org/10.1007/s10530-008-9365-4

Fox, J., & Weisberg S. (2019). An {R} Companion to Applied Regression, Third Edition. Thousand Oaks CA.

Galiana, N., Lurgi, M., Montoya, J. M., & López, B. C. (2014). Invasions cause biodiversity loss and community simplification in vertebrate food webs. *Oikos,* 123(6), 721–728. doi:10.1111/j.1600-0706.2013.00859.x

Galipaud, M., Gauthey, Z., Turlin, J., Bollache, L., & Lagrue, C. (2015). Mate choice and male–male competition among morphologically cryptic but genetically divergent amphipod lineages. *Behavioral Ecology and Sociobiology*, 69, 1907–1916. https://doi.org/10.1007/s00265-015-2003-0

Gillis, N. K., Walters, L. J., Fernandes, F. C., & Hoffman, E. A. (2009). Higher genetic diversity in introduced than in native populations of the mussel *Mytella charruana*: evidence of population admixture at introduction sites. *Diversity and Distributions,* 15, (5), 784-795. https://doi.org/10.1111/j.1472-4642.2009.00591.x

Gonçalves, A. L., Graça, M. A. S., & Canhoto, C. (2013). The effect of temperature on leaf decomposition and diversity of associated aquatic hyphomycetes depends on the substrate. *Fungal Ecology*, 6 (6), 546–553. doi:10.1016/j.funeco.2013.07.002.Grabowska, J., Grabowski, M., & Kostecka, A. (2009). Diet and feeding habits of monkey goby (*Neogobius fluviatilis*) in a newly invaded area. Biological Invasions, 11, 2161-2170. DOI 10.1007/s10530-009-9499-z.

Grabowski, M., Bącela, K., & Konopacka, A. (2007). How to be an invasive gammarid (Amphipoda: Gammaroidea) - Comparison of life history traits. *Hydrobiologia,* 590, 75–84. https://doi.org/10.1007/s10750-007-0759-6

Hartig, F. (2022). DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models. R package version 0.4.6.

Halaj, J., & Wise, D. H. (2001). Terrestrial trophic cascades: how much do they trickle? *The American Naturalist*, 157(3), 262-281.

Haubrock, P. J., Soto, I., Ahmed, D. A., Ansari, A. R., Tarkan, A. S., Kurtul, I., ... & Cuthbert, R. N. (2024). Biological invasions are a population-level rather than a species-level phenomenon. *Global Change Biology*, 30(5), e17312.

Hellmann, C., Worischka, S., Mehler, E., Becker, J., Gergs, R., & Winkelmann, C. (2015). The trophic function of *Dikerogammarus villosus* (Sowinsky, 1894) in invaded rivers: A case study in the Elbe and Rhine. *Aquatic Invasions,* 10, 385–397. https://doi.org/10.3391/ai.2015.10.4.03

Hermisson, J., & Wagner, P. (2004). The Population Genetic Theory of Hidden Variation and Genetic Robustness. Genetics, 168, 2271–2284. DOI: 10.1534/genetics.104.029173

Hupało, K., Riss, H. W., Grabowski, M., Thiel, J., Bącela-Spychalska, K., & Meyer, E. I. (2018). Climate change as a possible driver of invasion and differential in HSP70 expression in two genetically distinct populations of the invasive killer shrimp, *Dikerogammarus villosus*. *Biological Invasions,* 20, 2047–2059. https://doi.org/10.1007/s10530-018-1679-2

Iacarella, J.C.,Adamczyk, E., Bowen, D., Chalifour, L., Eger, A., Heath, W., & Helms, S., … Baum, J.K. (2018). Anthropogenic disturbance homogenizes seagrass fish communities. *Global Change Biology*, 24, 1904–1918.

Iltis, C., Spataro, T., Wattier, R., & Médoc V. (2018). Parasitism may alter functional response comparisons: a case study on the killer shrimp *Dikerogammarus villosus* and two non-invasive gammarids. *Biological Invasions*, 20, 619–632. https://doi.org/10.1007/s10530-017-1563-5

Ives, A. R., Cardinale, B. J., & Snyder, W. E. (2005). A synthesis of subdisciplines: predator–prey interactions, and biodiversity and ecosystem functioning. *Ecology Letters,* 8:102–116. doi: 10.1111/j.1461-0248.2004.00698.x

Jażdżewski, K., 1980. Range Extensions of Some Gammaridean Species in European Inland Waters Caused by Human Activity. *Crustaceana* 6, 84-107.

Jażdżewski, K., Konopacka, A., & Grabowski, M. (2002). Four Ponto-Caspian and one American gammarid species (Crustacea, Amphipoda) recently invading Polish waters. *Contributions to Zoology,* 71, 115–122

Jermacz, Ł., & Kobak, J. (2017). Keep calm and don't stop growing: Nonconsumptive effects of a sympatric predator on two invasive Ponto-Caspian gammarids *Dikerogammarus villosus* and *Pontogammarus robustoides*. *PLoS One,* 12, 1–15. https://doi.org/10.1371/journal.pone.0182481

Kley, A., & Maier, G. (2003). Life history characteristics of the invasive freshwater gammarids *Dikerogammarus villosus* and *Echinogammarus ischnus* in the river Main and the Main-Donau canal. *Archiv für Hydrobiologie*, 156 (4), 457– 470.

Koester, M., Bayer, B., & Gergs, R. (2016). Is *Dikerogammarus villosus* (Crustacea, Gammaridae) a 'killer shrimp' in the River Rhine system? *Hydrobiologia,* 768, 299–313. https://doi.org/10.1007/s10750-015-2558-9

Kostrzewa, J., & Grabowski, M. (2003). Opportunistic feeding strategy as a factor promoting the expansion of racer goby (*Neogobius gymnotrachelus* Kessler, 1857) in the Vistula basin. *Lauterbornia,* 48, 91–100.

Kownacki, A. (2000). Diversity of benthic macroinvertebrates as a monitoring method for polluted rivers. *Acta Hydrobiologica,* 42, 207–214.

Krisp, H., & Maier, G. (2005). Consumption of macroinvertebrates by invasive and native gammarids: A comparison. *Journal of Limnology,* 64, 55–59. https://doi.org/10.4081/jlimnol.2005.55

Kuparinen, A., Uusi-Heikkilä, S., Perälä, T., Ercoli, F., Eloranta, A. P., Cremona, F., … Nõges, T. (2023). Generalist invasion in a complex lake food web. *Conservation Science and Practice*, 5 (6), Article e12931. https://doi.org/10.1111/csp2.12931

Lenth, R (2022). emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.8.1-1,<https://CRAN.R-project.org/package=emmeans>.

Lynn, K. D., Quintanilla-Ahumada, D., Anguita, C., Widdicombe, S., Pulgar, J., Manríquez, P. H., … Duarte, C. (2021). Artificial light at night alters the activity and feeding behaviour of sandy beach amphipods and pose a threat to their ecological role in Atlantic Canada. *Science of The Total Environment*, 780, 146568. doi:10.1016/j.scitotenv.2021.1465

Maazouzi, C., Piscart, C., Legier, F., Hervant, F. (2011). Ecophysiological responses to temperature of the “killer shrimp” *Dikerogammarus villosus*: Is the invader really stronger than the native *Gammarus pulex*? *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 159 (3), 268-274. https://doi.org/10.1016/j.cbpa.2011.03.019.

Maazouzi, C., Piscart, C., Pihan, J. C., & Masson, G. (2009). Effect of habitat-related resources on fatty acid composition and body weight of the invasive *Dikerogammarus villosus* in an artificial reservoir. *Fundamental and Applied Limnology/Archiv für Hydrobiologie,* 175, 327-338, Stuttgart

Machovsky-Capuska, G. E., Senior, A. M., Simpson, S. J.,& Raubenheimer, D. (2016). The Multidimensional Nutritional Niche. Trends in Ecology and Evolution, 31, 355–365. https://doi.org/10.1016/j.tree.2016.02.009

Mačic, V., Albano, P. G., Almpanidou, V., Claudet, J., Corrales, X., Essl, F., … Katsanevakis S. (2018). Biological invasions in conservation planning: A global systematic review. *Frontiers in Marine Science,* 5, 178. https://doi.org/10.3389/fmars.2018.00178

MacNeil, C., & Platvoet, D. (2005). The predatory impact of the freshwater invader *Dikerogammarus villosus* on native *Gammarus pulex* (Crustacea: Amphipoda); influences of differential microdistribution and food resources. *Journal of Zoology,* 267, 31–38. https://doi.org/10.1017/S0952836905007351

MacNeil, C., Dick, J. T. A., Platvoet, D., & Briffa, M. (2011). Direct and indirect effects of species displacements: an invading freshwater amphipod can disrupt leaf-litter processing and shredder efficiency. *Journal of the North American Benthological Society*, 30 (1), 38–48. doi:10.1899/10-056.1.

Marszelewski, W., & Pius, B. (2016). Long-term changes in temperature of river waters in the transitional zone of the temperate climate: a case study of Polish rivers. *Hydrological Sciences Journal*, *61*(8), 1430-1442.

Mayer, G., Maier, G., Maas, A., & Waloszek, D. (2008). Mouthparts of the Ponto-Caspian invader *Dikerogammarus villosus* (Amphipoda: Pontogammaridae). *Journal of Crustacean Biology,* 28, 1–15. https://doi.org/10.1651/07-2867R.1

Navarro, J., Oro, D., Bertolero, A. Genovart, M., Delgado, C. A., & Forero, M. G. (2010). Age and sexual differences in the exploitation of two anthropogenic food resources for an opportunistic seabird. *Marine Biology*, 157, 2453–2459. https://doi.org/10.1007/s00227-010-1509-2

Nyamukondiwa, C., Kleynhans, E., & Terblanche, J. S. (2010). Phenotypic plasticity of thermal tolerance contributes to theinvasion potential of Mediterranean fruit flies (*Ceratitis capitata*). *Ecological Entomology,* 35, 565–575.

Ohlberger, J., Staaks, G., & Hölker, F. (2007). Effects of temperature, swimming speed and body mass on standard and active metabolic rate in vendace (C*oregonus albula*). *Journal of Comparative Physiology B*, 177(8), 905–916. doi:10.1007/s00360-007-0189-9.

Park K. 2004. Assessment and Management of Invasive Alien Predators. *Ecology and Society*, 9 (2), 12. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art12/

Parker, I. M. (2000). Invasion dynamics of cytisus scoparius: a matrix model approach. *Ecological Applications,* 10: 726-743. https://doi.org/10.1890/1051-0761(2000)010[0726:IDOCSA]2.0.CO;2

Parmenter, R. R. (1980). Effects of Food Availability and Water Temperature on the Feeding Ecology of Pond Sliders (*Chrysemys s. scripta*). *Copeia*, 503–514. https://doi.org/10.2307/1444528

Peake, J., Bogdanoff, A. K., Layman, C. A., Castillo, B., Reale-Munroe, K., Chapman, J., … Morris Jr. J. A. (2018). Feeding ecology of invasive lionfish (*Pterois volitans* and *Pterois miles*) in the temperate and tropical western Atlantic. *Biological Invasions*, 20, 2567–2597. https://doi.org/10.1007/s10530-018-1720-5

Pelikan, L., Šidagytė-Copilas, E., Garbaras, A., Jourdan, J., & Copilaș-Ciocianu, D. (2024). Competitive interaction in headwaters: slow upstream migration leads to trophic competition between native and non-native amphipods. *NeoBiota,* 90, 193–216. https://doi.org/10.3897/neobiota.90.112383

Pellan, L., Médoc, V., Renault, D., Spataro, T. & Piscart, C. (2016). Feeding choice and predation pressure of two invasive gammarids, *Gammarus tigrinus* and *Dikerogammarus villosus*, under increasing temperature. *Hydrobiologia*, 781, 43–54. https://doi.org/10.1007/s10750-015-2312-3

Pfenninger, M., & Nowak, C. (2008). Reproductive isolation and ecological niche partition among larvae of the morphologically cryptic sister species *Chironomus riparius* and *C. piger. PLoS ONE* 3(5), e2157. https://doi.org/10.1371/journal.pone.0002157

Piria, M., Špeli´c, I., Velagi´c, L., Lisica, I., Kanjuh, T., Mari´c, A., Maguire, I., Radoˇcaj, T., Simonovi´c, P. (2022). Feeding habits and diet overlap between Brown trout lineages from the Danube Basin of Croatia. *Fishes*, 7, 179. https://doi.org/10.3390/fishes7040179

Piscart, C., Mermillod-Blondin, F., Maazouzi, C., Merigoux, S., & Marmonier, P. (2011). Potential impact of invasive amphipods on leaf litter recycling in aquatic ecosystems. *Biological Invasions,* 13, 2861–2868. https://doi.org/10.1007/s10530-011-9969-y

Platvoet, D. (2005). Temperature dependent feeding in *Dikerogammarus villosus* Sowinsky. Abstracts for Biological Invasions in Inland Waters (INWAT) Workshop, Firenze, Italy, May 5–7, 2005, p. 60.

Platvoet, D., van Der Velde, G., Dick, J. T. A., & Li, S. (2009). Flexible omnivory in *Dikerogammarus villosus* (Sowinsky, 1894) (Amphipoda) - Amphipod Pilot Species Project (AMPIS) Report 5. *Crustaceana,* 82, 703–720. https://doi.org/10.1163/156854009X423201

Polis, G. A., & Holt, R. D. (1992). Intraguild predation: the dynamics of complex trophic interactions. *Trends in Ecology & Evolution,* 7, 151–155.

Podwysocki, K., Bącela-Spychalska, K., Desiderato, A., Rewicz, T., & Copilaş-Ciocianu, D. (2024). Environment, intraspecific lineages and geographic range jointly shape the high morphological variability of *Dikerogammarus villosus* (Sowinsky, 1894)(Crustacea, Amphipoda): a successful aquatic invader across Europe. *Hydrobiologia*, 1-19.

Pyšek, P., & Richardson, D. M. (2010). Invasive species, environmental change and management, and health. *Annual Review of Environment and Resources,* 35, 25– 55. https://doi.org/10.1146/annurev-environ-033009-095548

Pyšek, P., Hulme, P. E., Simberloff, D., Bacher, S., Blackburn, T. M., Carlton, J.,T., … Richardson D. M. (2020). Scientists' warning on invasive alien species. *Biological Reviews,* 95, 1– 24. https://doi.org/10.1111/brv.12627

QGIS Development Team (2020) QGIS Geographic Information System. Open Source Geospatial Foundation Project. https://qgis.org/en/site/about/index.html

R Core Team (2023) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. https://www.R-project.org/

Reid, D. F., & Orlova, M. I. (2002). Geological and evolutionary underpinnings for the success of Ponto-Caspian species invasions in the Baltic Sea and North American Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, 59 (7), 1144-1158. https://doi.org/10.1139/f02-099.

Rewicz, T., Grabowski, M., Macneil, C., & Bącela-Spychalska, K. (2014). The profile of a ' perfect ' invader – the case of killer shrimp, *Dikerogammarus villosus*. *Aquatic Invasions,* 9, 267–288. https://doi.org/10.3391/ai.2014.9.3.04

Rewicz, T., Wattier, R., Grabowski, M., Rigaud, T., & Bącela-Spychalska, K. (2015a). Out of the Black Sea: Phylogeography of the Invasive Killer Shrimp *Dikerogammarus villosus* across Europe. *PLoS One,* 10, e0118121. https://doi.org/10.1371/journal.pone.0118121

Rewicz, T., Wattier, R. A., Rigaud, T., Bącela-Spychalska, K., & Grabowski, M. (2015b). Isolation and characterization of 8 microsatellite loci for the "killer shrimp'', an invasive Ponto-Caspian amphipod *Dikerogammarus villosus* (Crustacea: Amphipoda). *Molecular Biology Reports,* 42, 13–17. https://doi.org/10.1007/s11033-014-3742-0

Romer, E. (1949). Regiony klimatyczne Polski. *Prace Wrocławskiego Towarzystwa Naukowego Seria B*, 16. [in Polish]

Rosenheim, J. A., Kaya, H. K., Ehler, L. E., Marois, J. J., & Jaffee, B. A. (1995). Intraguild predation among biological-control agents: theory and evidence. *Biological Control,* 5, 303–335.

Schmitt, J.D., Peoples, B.K., Castello, L. & Orth, Donald. (2019). Feeding ecology of generalist consumers: a case study of invasive blue catfish Ictalurus furcatus in Chesapeake Bay, Virginia, USA. *Environmental Biology of Fishes*, 102, (1), 443–465. https://doi.org/10.1007/s10641-018-0783-6

Schmitz, O. J., Hamback, P. A., & Beckerman, A. P. (2000). Trophic cascades in terrestrial systems: a review of the effect of carnivore removals on plants. *The American Naturalist,* 155, 41–153.

Snyder, W. E., & Evans, E. W. (2006). Ecological Effects of Invasive Arthropod Generalist Predators. *Annual Review of Ecology, Evolution, and Systematic*s, 37, 95–122. http://www.jstor.org/stable/30033828

Sousa, R., Alves, H., Gonçalves, D., Padilha, J., & Teixeira, A. (2024). The hidden side of the intrapopulation level in biological invasions. *ARPHA Preprints*, *5*, e127932.

Taylor, N. G., & Dunn, A. M. (2016). Size matters: predation of fish eggs and larvae by native and invasive amphipods. *Biological Invasions*, 19, 89–107.

Tomczak, M. T., Dinesen, G. E., Hoffmann, E., Maar, M., & Støttrup, J. G. (2013). Integrated trend assessment of ecosystem changes in the Limfjord (Denmark): evidence of a recent regime shift? *Estuarine, Coastal and Shelf Science*, 117, 178–187.

Truhlar, A. M., Dodd, J. A., & Aldridge, D. C. (2013). Differential leaf-litter processing by native (Gammarus pulex) and invasive (Dikerogammarus villosus) freshwater crustaceans under environmental extremes. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 24, 56– 65. https://doi.org/10.1002/aqc.2375

U.S. Fish and Wildlife Service (2018). Guidelines for preventing the spread of aquatic invasive species. Region 7, Anchorage, https://www.fws.gov/sites/default/files/documents/Aquatic%20Invasive%20Species%20Prevention%20Guidelines%20508.pdf

Väinölä, R., Witt, J. D. S., Grabowski, M., Bradbury, J. H., Jazdzewski, K., & Sket, B. (2007) Global diversity of amphipods (Amphipoda; Crustacea) in freshwater. In: Freshwater Animal Diversity Assessment. Developments in Hydrobiology (Eds: E.V. Balian, C. Lévêque, H. Segers, K. Martens), vol 198. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-8259-7_27

van der Velde, G., Leuven, R. S. E. W., Platvoet, D., Bącela, K., Huijbregts, M. A. J., Hendriks, H. W. M., & Kruijt D. (2009). Environmental and morphological factors influencing predatory behaviour by invasive non-indigenous gammaridean species. *Biological Invasions,* 11, 2043– 2054. https://doi.org/10.1007/s10530-009-9500-x

Vantarová, K. H., Eliáš, P., Jiménez-Ruiz, J., Tokarska-Guzik, B., Cires, E. (2023). Biological invasions in the twenty-first century: a global risk. *Biologia*, 78, 1211– 1218. https://doi.org/10.1007/s11756-023-01394-7.

Vitousek, P. M., D'Antonio, C. M., Loope, L. L., & Westbrooks, R. (1996). Biological invasions as global environmental change. *American Scientist,* 84,468– 478.

Warren, D. A., Bradbeer, S. J., & Dunn, A. M. (2021). Superior predatory ability and abundance predicts potential ecological impact towards early-stage anurans by invasive 'Killer Shrimp' (*Dikerogammarus villosus*). *Scientific Report,* 11, 4570 https://doi.org/10.1038/s41598-021-82630-5

Warren, B. I. C., Pinder, A. C., Parker, B. Tarkan A. S., & Britton, J. R. (2024). Trophic relationships of translocated and indigenous chub *Squalius cephalus* populations with trophically analogous fishes. *Hydrobiologia,* 851, 1291–1303. https://doi.org/10.1007/s10750-023-05389-y

Wattier, R. A., Haine, E. R., Beguet, J., Martin, G., Bollache, L., Muskó, I. B., … Rigaud, T. (2007). No genetic bottleneck or associated microparasite loss in invasive populations of a freshwater amphipod. *Oikos,* 116(11), 1941–1953.

Woodward, G., Perkins, D. M., & Brown, L. E. (2010). Climate change and freshwater ecosystems: Impacts across multiple levels of organization. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 365, 2093–2106. https://doi.org/10.1098/rstb.2010.0055

Worischka, S., Richter, L., Hänig, A., Hellmann, C., Becker, J., Kratina, P., & Winkelmann, C. (2018). Food consumption of the invasive amphipod *Dikerogammarus villosus* in field mesocosms and its effects on leaf decomposition and periphyton. *Aquatic Invasions,* 13, 261–275. https://doi.org/10.3391/ai.2018.13.2.07

Zambrano, L., Martínez-Meyer, E., Menezes, N., & Peterson, A. T. (2006). Invasive potential of exotic aquaculture fish in American freshwater systems Invasive potential of common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) in American freshwater systems. *Canadian Journal of Fisheries and Aquatic Sciences,* 63, 1903–1910. https://doi.org/10.1139/F06-088

Zettler, M. L., & Zettler, A. (2017). Marine and freshwater Amphipoda from the Baltic Sea and adjacent territories. ISBN: 9783939767749 Hardback

Zhan, A., Perepelizin, P., Ghabooli, S., Paolucci, E., Sylvester, F., Sardiña, P., … MacIsaac, H. (2012). Scale-dependent post-establishment spread and genetic diversity in an invading mollusc in South America. *Diversity and Distributions,* 18(10), 1042–1055. DOI:10.2307/23326739.

Supplementary file 1

Table 1. Environmental data collected each month from sites. Averaged value from all observations during the year together with the standard deviation (SD), minimum (Min) and maximum (Max) value.

					Temperature (oC)			Salinity			Conductivity (µS)			pH			Water level (cm)		
Site	Latitude	Longitude	River	Lineage	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Brzeg	50° 51' 37.8'' N	17° 27' 59.399'' E	Oder	Western	13.23 ± 6.88	4.1	21.7	0.74 ± 0.25	0.4	1	1512.20 ± 396.23	899	1933	7.32 ± 0.38	6.99	7.84	174.60 ± 19.94	144	190
Zdzieszowice	50° 24' 42.12'' N	18° 6' 25.559'' E	Oder	Western	12.99 ± 6.25	3.9	19.9	1.10 ± 0.16	0.9	1.3	2237.6 ± 339.80	1864	2690	7.23 ± 0.32	6.98	7.69	248.3 ± 32.09	215	284
Wyszogród	52° 23’ 4.56’’ N	20° 11' 31.2'' E	Vistula	Eastern	12.76 ± 7.63	2.2	22.2	0.26 ± 0.05	0.2	0.3	666.80 ± 78.01	581	743	7.50 ± 0.80	6.57	8.68	299.00 ± 27.15	272	342
Ciechocinek	52° 52' 52.68'' N	18° 50' 0.6'' E	Vistula	Eastern	13.28 ± 8.14	2.3	23.2	0.30 ± 0.00	0.3	0.3	764.4 ± 70.15	692	862	7.46 ± 0.80	6.67	8.59	176.60 ± 42.10	132	242

Supplementary file 2

Table 1. The measurements from food consumption experiment. Measurements are displayed only for specimens used for the analyses (ovigerous females, dead specimens or those that moulted during the experiment were excluded). Q1 - the amount of food (g) before the experiment; Q2 - the amount of food (g) after the experiment; consumption - the response variable used in the analyses. Initials for operator: AD - Andrea Desiderato, ESM - Eliza Szczerkowska-Majchrzak, KP - Krzysztof Podwysocki, SH - Sylwia Holak.

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Eastern	A (Wyszogród)	Female	chironomid	1	KP	0.032	0.027	3	0.095	0.0035
March	Eastern	A (Wyszogród)	Male	chironomid	2	AD	0.041	0.037	1.5	0.136	0.002
March	Eastern	A (Wyszogród)	Male	chironomid	1	AD	0.04	0.04	0	0.062	0
March	Eastern	A (Wyszogród)	Female	chironomid	4	KP	0.053	0.041	1.5	0.079	0.0098
March	Eastern	A (Wyszogród)	Male	chironomid	4	KP	0.047	0.038	2	0.075	0.0069
March	Eastern	A (Wyszogród)	Female	chironomid	8	AD	0.046	0.023	3.5	0.049	0.0217
March	Eastern	A (Wyszogród)	Male	chironomid	8	AD	0.043	0.038	1	0.021	0.0029
March	Eastern	A (Wyszogród)	Male	chironomid	7	AD	0.036	0.031	1.5	0.101	0.0033
March	Eastern	A (Wyszogród)	Female	chironomid	7	AD	0.038	0.025	1	0.096	0.0116
March	Eastern	A (Wyszogród)	Female	chironomid	3	KP	0.056	0.051	0.5	0.036	0.0022
March	Eastern	A (Wyszogród)	Female	chironomid	5	KP	0.031	0.02	3.5	0.057	0.0099
March	Eastern	A (Wyszogród)	Male	chironomid	6	KP	0.038	0.029	2	0.104	0.0074
March	Eastern	A (Wyszogród)	Female	chironomid	6	AD	0.041	0.025	3	0.09	0.0146
March	Eastern	A (Wyszogród)	Male	chironomid	5	AD	0.04	0.04	0	0.08	0
May	Eastern	A (Wyszogród)	Female	chironomid	2	KP	0.031	0.014	4	0.084	0.0155
May	Eastern	A (Wyszogród)	Female	chironomid	1	AD	0.037	0.022	1	0.024	0.0127
May	Eastern	A (Wyszogród)	Male	chironomid	2	AD	0.036	0.029	1	0.113	0.004
May	Eastern	A (Wyszogród)	Female	chironomid	8	KP	0.053	0.028	3.5	0.053	0.0221
May	Eastern	A (Wyszogród)	Male	chironomid	4	KP	0.028	0.028	0	0.054	0
May	Eastern	A (Wyszogród)	Female	chironomid	4	AD	0.03	0.02	2.5	0.065	0.0079

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	A (Wyszogród)	Male	chironomid	8	AD	0.032	0.013	3.5	0.121	0.0176
May	Eastern	A (Wyszogród)	Male	chironomid	3	KP	0.033	0.015	4	0.037	0.0164
May	Eastern	A (Wyszogród)	Male	chironomid	7	AD	0.035	0.035	0	0.031	0
May	Eastern	A (Wyszogród)	Male	chironomid	6	KP	0.036	0.005	6.5	0.127	0.0305
May	Eastern	A (Wyszogród)	Male	chironomid	5	KP	0.033	0.032	0	0.078	0
May	Eastern	A (Wyszogród)	Female	chironomid	5	AD	0.038	0.014	4	0.022	0.0225
May	Eastern	A (Wyszogród)	Female	chironomid	6	AD	0.029	0.024	7	0.047	0.0025
July	Eastern	A (Wyszogród)	Female	chironomid	2	KP	0.032	0.013	4	0.016	0.0144
July	Eastern	A (Wyszogród)	Female	chironomid	1	KP	0.033	0.014	4	0.043	0.014
July	Eastern	A (Wyszogród)	Male	chironomid	1	SH	0.03	0.022	1	0.016	0.0002
July	Eastern	A (Wyszogród)	Male	chironomid	2	SH	0.035	0.005	6	0.035	0.0282
July	Eastern	A (Wyszogród)	Female	chironomid	8	KP	0.034	0.007	6	0.028	0.0245
July	Eastern	A (Wyszogród)	Male	chironomid	4	KP	0.027	0	7.5	0.043	0.027
July	Eastern	A (Wyszogród)	Female	chironomid	4	SH	0.034	0.005	5	0.029	0.0272
July	Eastern	A (Wyszogród)	Male	chironomid	8	SH	0.035	0.019	2	0.016	0.0093
July	Eastern	A (Wyszogród)	Female	chironomid	3	KP	0.034	0.008	5	0.024	0.0232
July	Eastern	A (Wyszogród)	Male	chironomid	3	KP	0.033	0.017	3.5	0.047	0.01
July	Eastern	A (Wyszogród)	Male	chironomid	7	SH	0.029	0.011	5	0.047	0.0141
July	Eastern	A (Wyszogród)	Female	chironomid	7	SH	0.031	0.01	3	0.029	0.0175
July	Eastern	A (Wyszogród)	Male	chironomid	6	KP	0.04	0.013	5	0.018	0.0224
July	Eastern	A (Wyszogród)	Male	chironomid	5	KP	0.03	0	8	0.055	0.03
July	Eastern	A (Wyszogród)	Female	chironomid	5	SH	0.024	0.014	4	0.036	0.005
July	Eastern	A (Wyszogród)	Female	chironomid	6	SH	0.031	0.02	0	0.028	0.0039
September	Eastern	A (Wyszogród)	Male	chironomid	1	ESM	0.028	0.024	1	0.095	0.0027
September	Eastern	A (Wyszogród)	Female	chironomid	2	KP	0.043	0.033	3	0.044	0.0082
September	Eastern	A (Wyszogród)	Male	chironomid	2	KP	0.043	0	8	0.084	0.043
September	Eastern	A (Wyszogród)	Female	chironomid	1	KP	0.039	0.025	3	0.019	0.0127
September	Eastern	A (Wyszogród)	Male	chironomid	8	ESM	0.038	0.006	7	0.068	0.0317
September	Eastern	A (Wyszogród)	Female	chironomid	8	ESM	0.047	0.046	0	0.032	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Eastern	A (Wyszogród)	Female	chironomid	4	ESM	0.047	0.028	3	0.031	0.0175
September	Eastern	A (Wyszogród)	Male	chironomid	4	KP	0.051	0.039	1.5	0.078	0.0099
September	Eastern	A (Wyszogród)	Female	chironomid	3	ESM	0.048	0.024	5	0.028	0.0227
September	Eastern	A (Wyszogród)	Male	chironomid	7	ESM	0.049	0	8	0.097	0.049
September	Eastern	A (Wyszogród)	Female	chironomid	7	KP	0.055	0.007	6.5	0.05	0.0476
September	Eastern	A (Wyszogród)	Male	chironomid	3	KP	0.044	0.04	2.5	0.064	0.0019
September	Eastern	A (Wyszogród)	Female	chironomid	6	ESM	0.048	0.032	1	0.024	0.0143
September	Eastern	A (Wyszogród)	Female	chironomid	5	ESM	0.049	0.028	3	0.054	0.0195
September	Eastern	A (Wyszogród)	Male	chironomid	5	ESM	0.054	0.034	3	0.098	0.0182
September	Eastern	A (Wyszogród)	Male	chironomid	6	ESM	0.054	0.016	6	0.087	0.0371
November	Eastern	A (Wyszogród)	Female	chironomid	1	KP	0.036	0.025	2	0.018	0.0111
November	Eastern	A (Wyszogród)	Male	chironomid	1	KP	0.032	0.022	2.5	0.149	0.01
November	Eastern	A (Wyszogród)	Male	chironomid	2	KP	0.034	0.028	1.5	0.041	0.0061
November	Eastern	A (Wyszogród)	Female	chironomid	8	ESM	0.03	0.022	3	0.052	0.008
November	Eastern	A (Wyszogród)	Male	chironomid	4	KP	0.037	0.035	1	0.054	0.0021
November	Eastern	A (Wyszogród)	Female	chironomid	4	KP	0.031	0.02	3	0.03	0.011
November	Eastern	A (Wyszogród)	Male	chironomid	8	KP	0.031	0.031	0	0.073	0.0001
November	Eastern	A (Wyszogród)	Female	chironomid	3	KP	0.039	0.03	1.5	0.051	0.0091
November	Eastern	A (Wyszogród)	Male	chironomid	3	KP	0.037	0.028	1	0.117	0.0091
November	Eastern	A (Wyszogród)	Male	chironomid	7	KP	0.024	0.026	1.5	0.071	0
November	Eastern	A (Wyszogród)	Female	chironomid	7	KP	0.03	0.027	1	0.029	0.0031
November	Eastern	A (Wyszogród)	Male	chironomid	6	ESM	0.023	0.012	4	0.132	0.011
November	Eastern	A (Wyszogród)	Male	chironomid	5	ESM	0.028	0.012	4	0.105	0.016
November	Eastern	A (Wyszogród)	Female	chironomid	5	KP	0.033	0.025	2	0.026	0.0081
November	Eastern	A (Wyszogród)	Female	chironomid	6	KP	0.041	0.037	1	0.029	0.0041
March	Eastern	B (Ciechocinek)	Female	chironomid	2	KP	0.05	0.024	3	0.054	0.0247
March	Eastern	B (Ciechocinek)	Female	chironomid	1	KP	0.045	0.037	2	0.092	0.006
March	Eastern	B (Ciechocinek)	Male	chironomid	1	AD	0.043	0.026	2	0.06	0.0156
March	Eastern	B (Ciechocinek)	Female	chironomid	8	KP	0.049	0.029	4	0.032	0.0184

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Eastern	B (Ciechocinek)	Male	chironomid	4	AD	0.041	0.26	3	0.052	0
March	Eastern	B (Ciechocinek)	Male	chironomid	8	AD	0.043	0.029	1.5	0.074	0.0124
March	Eastern	B (Ciechocinek)	Female	chironomid	4	AD	0.036	0.036	0	0.036	0
March	Eastern	B (Ciechocinek)	Female	chironomid	3	AD	0.041	0.025	2	0.059	0.0146
March	Eastern	B (Ciechocinek)	Male	chironomid	7	AD	0.04	0.04	0	0.093	0
March	Eastern	B (Ciechocinek)	Female	chironomid	7	KP	0.034	0.004	7.5	0.064	0.0298
March	Eastern	B (Ciechocinek)	Male	chironomid	6	AD	0.043	0.031	1	0.038	0.0103
March	Eastern	B (Ciechocinek)	Male	chironomid	5	AD	0.041	0.02	4	0.041	0.0199
May	Eastern	B (Ciechocinek)	Male	chironomid	2	KP	0.044	0.013	4	0.08	0.0296
May	Eastern	B (Ciechocinek)	Male	chironomid	1	KP	0.03	0.02	3	0.125	0.0079
May	Eastern	B (Ciechocinek)	Female	chironomid	2	KP	0.025	0.011	4.5	0.11	0.0129
May	Eastern	B (Ciechocinek)	Female	chironomid	1	AD	0.035	0.03	0	0.056	0.0019
May	Eastern	B (Ciechocinek)	Male	chironomid	4	KP	0.038	0.024	3	0.068	0.0115
May	Eastern	B (Ciechocinek)	Male	chironomid	8	KP	0.031	0.021	2	0.121	0.0078
May	Eastern	B (Ciechocinek)	Male	chironomid	3	KP	0.035	0.022	2	0.131	0.0107
May	Eastern	B (Ciechocinek)	Female	chironomid	7	KP	0.039	0.025	2	0.101	0.0114
May	Eastern	B (Ciechocinek)	Female	chironomid	3	KP	0.038	0.018	4.5	0.098	0.0181
May	Eastern	B (Ciechocinek)	Male	chironomid	7	AD	0.032	0	7.5	0.079	0.032
May	Eastern	B (Ciechocinek)	Male	chironomid	6	KP	0.029	0	8	0.099	0.029
May	Eastern	B (Ciechocinek)	Female	chironomid	6	KP	0.034	0.022	7	0.116	0.0097
May	Eastern	B (Ciechocinek)	Male	chironomid	5	AD	0.034	0.01	6	0.036	0.023
May	Eastern	B (Ciechocinek)	Female	chironomid	5	AD	0.032	0.031	0	0.09	0
July	Eastern	B (Ciechocinek)	Male	chironomid	2	KP	0.03	0	8	0.038	0.03
July	Eastern	B (Ciechocinek)	Male	chironomid	1	KP	0.039	0.014	6	0.054	0.02
July	Eastern	B (Ciechocinek)	Female	chironomid	2	KP	0.035	0	8	0.026	0.035
July	Eastern	B (Ciechocinek)	Female	chironomid	1	SH	0.036	0.006	4	0.023	0.0279
July	Eastern	B (Ciechocinek)	Male	chironomid	4	KP	0.034	0.008	5.5	0.048	0.0232
July	Eastern	B (Ciechocinek)	Female	chironomid	4	KP	0.054	0.003	7	0.038	0.0499
July	Eastern	B (Ciechocinek)	Male	chironomid	8	KP	0.049	0.007	5.5	0.044	0.0395

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Eastern	B (Ciechocinek)	Female	chironomid	8	SH	0.036	0.016	5	0.039	0.0143
July	Eastern	B (Ciechocinek)	Male	chironomid	3	KP	0.037	0.012	5	0.038	0.0207
July	Eastern	B (Ciechocinek)	Female	chironomid	7	KP	0.034	0.004	7	0.026	0.0286
July	Eastern	B (Ciechocinek)	Female	chironomid	3	KP	0.03	0.012	4	0.022	0.0137
July	Eastern	B (Ciechocinek)	Male	chironomid	7	SH	0.035	0.008	5	0.077	0.0242
July	Eastern	B (Ciechocinek)	Male	chironomid	6	KP	0.038	0.025	2.5	0.033	0.0041
July	Eastern	B (Ciechocinek)	Female	chironomid	6	KP	0.037	0.013	5	0.026	0.0194
July	Eastern	B (Ciechocinek)	Male	chironomid	5	SH	0.032	0.008	4	0.048	0.0212
July	Eastern	B (Ciechocinek)	Female	chironomid	5	SH	0.031	0.01	2	0.022	0.0175
September	Eastern	B (Ciechocinek)	Male	chironomid	1	ESM	0.031	0.01	6	0.065	0.0205
September	Eastern	B (Ciechocinek)	Female	chironomid	1	ESM	0.042	0.013	5	0.036	0.0283
September	Eastern	B (Ciechocinek)	Male	chironomid	2	KP	0.051	0.007	6	0.055	0.0436
September	Eastern	B (Ciechocinek)	Female	chironomid	2	KP	0.045	0.04	1	0.029	0.0029
September	Eastern	B (Ciechocinek)	Male	chironomid	4	ESM	0.04	0.025	4	0.062	0.0137
September	Eastern	B (Ciechocinek)	Female	chironomid	8	KP	0.041	0.025	4	0.038	0.0147
September	Eastern	B (Ciechocinek)	Male	chironomid	8	KP	0.033	0.004	7	0.073	0.0288
September	Eastern	B (Ciechocinek)	Female	chironomid	3	ESM	0.042	0.011	4.5	0.03	0.0304
September	Eastern	B (Ciechocinek)	Male	chironomid	7	ESM	0.048	0.012	5	0.066	0.0354
September	Eastern	B (Ciechocinek)	Male	chironomid	3	KP	0.051	0	8	0.101	0.051
September	Eastern	B (Ciechocinek)	Female	chironomid	7	KP	0.056	0.018	4	0.029	0.037
September	Eastern	B (Ciechocinek)	Male	chironomid	6	ESM	0.053	0.027	4	0.031	0.0246
September	Eastern	B (Ciechocinek)	Female	chironomid	5	ESM	0.06	0.049	1	0.032	0.0084
September	Eastern	B (Ciechocinek)	Male	chironomid	5	KP	0.049	0	8	0.04	0.049
September	Eastern	B (Ciechocinek)	Female	chironomid	6	KP	0.051	0.011	5	0.037	0.0394
November	Eastern	B (Ciechocinek)	Male	chironomid	2	ESM	0.038	0.035	0	0.058	0.0031
November	Eastern	B (Ciechocinek)	Male	chironomid	1	ESM	0.036	0.006	6	0.075	0.03
November	Eastern	B (Ciechocinek)	Female	chironomid	1	KP	0.052	0.025	1.5	0.022	0.0271
November	Eastern	B (Ciechocinek)	Male	chironomid	4	ESM	0.029	0.025	1	0.027	0.0041
November	Eastern	B (Ciechocinek)	Female	chironomid	4	ESM	0.034	0.032	0.5	0.02	0.0021

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Eastern	B (Ciechocinek)	Male	chironomid	8	ESM	0.034	0.029	2	0.076	0.0051
November	Eastern	B (Ciechocinek)	Female	chironomid	8	KP	0.03	0.008	6.5	0.027	0.022
November	Eastern	B (Ciechocinek)	Male	chironomid	3	ESM	0.029	0.012	5	0.085	0.017
November	Eastern	B (Ciechocinek)	Female	chironomid	7	ESM	0.035	0.023	3	0.032	0.0121
November	Eastern	B (Ciechocinek)	Female	chironomid	3	ESM	0.024	0.012	3	0.029	0.012
November	Eastern	B (Ciechocinek)	Male	chironomid	7	KP	0.037	0.02	4	0.025	0.017
November	Eastern	B (Ciechocinek)	Male	chironomid	6	ESM	0.025	0.025	0	0.02	0.0001
November	Eastern	B (Ciechocinek)	Female	chironomid	6	ESM	0.034	0.019	3	0.047	0.015
November	Eastern	B (Ciechocinek)	Male	chironomid	5	KP	0.025	0.019	3	0.057	0.006
November	Eastern	B (Ciechocinek)	Female	chironomid	5	KP	0.037	0.006	7	0.057	0.031
March	Western	A (Brzeg)	Male	chironomid	2	AD	0.038	0.005	6.5	0.057	0.0327
March	Western	A (Brzeg)	Female	chironomid	1	AD	0.038	0.032	2.5	0.054	0.0043
March	Western	A (Brzeg)	Male	chironomid	1	AD	0.042	0.024	4	0.072	0.0167
March	Western	A (Brzeg)	Female	chironomid	4	KP	0.038	0.036		0.048	0
March	Western	A (Brzeg)	Female	chironomid	8	KP	0.039	0.029	2.5	0.04	0.0084
March	Western	A (Brzeg)	Male	chironomid	4	KP	0.06	0.016	5	0.055	0.0431
March	Western	A (Brzeg)	Male	chironomid	8	AD	0.048	0.025	3.5	0.088	0.0216
March	Western	A (Brzeg)	Male	chironomid	7	KP	0.042	0.017	3.5	0.048	0.0241
March	Western	A (Brzeg)	Female	chironomid	3	KP	0.03	0.018	2.5	0.087	0.011
March	Western	A (Brzeg)	Female	chironomid	6	KP	0.037	0.032	1	0.067	0.0033
March	Western	A (Brzeg)	Male	chironomid	6	KP	0.039	0.029	2	0.046	0.0084
March	Western	A (Brzeg)	Male	chironomid	5	AD	0.042	0.011	5.5	0.057	0.0304
May	Western	A (Brzeg)	Female	chironomid	2	KP	0.026	0.006	5.5	0.048	0.0194
May	Western	A (Brzeg)	Male	chironomid	2	KP	0.025	0.011	4.5	0.043	0.0129
May	Western	A (Brzeg)	Male	chironomid	1	KP	0.029	0.009	6	0.031	0.0191
May	Western	A (Brzeg)	Female	chironomid	1	AD	0.031	0	8	0.079	0.031
May	Western	A (Brzeg)	Male	chironomid	4	KP	0.035	0.033	0.5	0.143	0
May	Western	A (Brzeg)	Male	chironomid	8	AD	0.04	0.019	4.5	0.049	0.019
May	Western	A (Brzeg)	Female	chironomid	4	AD	0.034	0.016	4	0.115	0.0163

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Western	A (Brzeg)	Male	chironomid	3	KP	0.035	0.013	4	0.121	0.0206
May	Western	A (Brzeg)	Female	chironomid	7	KP	0.037	0.023	8	0.082	0.0116
May	Western	A (Brzeg)	Male	chironomid	7	AD	0.035	0.001	5.5	0.031	0.0339
May	Western	A (Brzeg)	Male	chironomid	5	KP	0.02	0.015	4	0.041	0.0034
May	Western	A (Brzeg)	Male	chironomid	6	KP	0.036	0.021	3	0.055	0.0128
May	Western	A (Brzeg)	Female	chironomid	6	AD	0.031	0.008	6.5	0.025	0.0222
July	Western	A (Brzeg)	Female	chironomid	2	KP	0.043	0.003	7	0.095	0.0389
July	Western	A (Brzeg)	Male	chironomid	2	KP	0.035	0.01	5	0.069	0.0215
July	Western	A (Brzeg)	Male	chironomid	1	KP	0.103	0.026	2	0.083	0.0678
July	Western	A (Brzeg)	Female	chironomid	1	KP	0.038	0.015	3.5	0.024	0.0177
July	Western	A (Brzeg)	Male	chironomid	4	KP	0.041	0.009	6	0.027	0.0288
July	Western	A (Brzeg)	Female	chironomid	8	KP	0.079	0.015	3	0.055	0.0587
July	Western	A (Brzeg)	Male	chironomid	8	SH	0.035	0.028	2	0.035	0
July	Western	A (Brzeg)	Female	chironomid	4	SH	0.032	0.008	5	0.032	0.0212
July	Western	A (Brzeg)	Male	chironomid	3	KP	0.036	0.003	6	0.048	0.0319
July	Western	A (Brzeg)	Female	chironomid	7	KP	0.032	0	8	0.044	0.032
July	Western	A (Brzeg)	Male	chironomid	7	SH	0.03	0.002	7	0.087	0.0273
July	Western	A (Brzeg)	Male	chironomid	5	KP	0.045	0.013	4	0.044	0.0274
July	Western	A (Brzeg)	Male	chironomid	6	KP	0.032	0.011	5	0.055	0.0171
July	Western	A (Brzeg)	Female	chironomid	6	SH	0.03	0.017	2	0.014	0.007
July	Western	A (Brzeg)	Female	chironomid	5	SH	0.025	0.006	6	0.034	0.0169
September	Western	A (Brzeg)	Male	chironomid	1	ESM	0.062	0.01	6	0.08	0.0515
September	Western	A (Brzeg)	Female	chironomid	2	ESM	0.076	0.02	4	0.034	0.0549
September	Western	A (Brzeg)	Male	chironomid	2	ESM	0.031	0	8	0.06	0.031
September	Western	A (Brzeg)	Female	chironomid	1	KP	0.048	0.039	2	0.052	0.0069
September	Western	A (Brzeg)	Female	chironomid	8	ESM	0.034	0.005	7	0.049	0.0287
September	Western	A (Brzeg)	Male	chironomid	8	ESM	0.037	0.006	7	0.087	0.0307
September	Western	A (Brzeg)	Female	chironomid	4	KP	0.043	0	8	0.05	0.043
September	Western	A (Brzeg)	Male	chironomid	4	KP	0.043	0.005	7	0.073	0.0377

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Western	A (Brzeg)	Male	chironomid	3	ESM	0.04	0.031	1	0.077	0.0074
September	Western	A (Brzeg)	Male	chironomid	7	KP	0.059	0.032	3	0.078	0.0253
September	Western	A (Brzeg)	Female	chironomid	7	KP	0.055	0.03	4	0.036	0.0234
September	Western	A (Brzeg)	Female	chironomid	3	KP	0.046	0.022	4	0.044	0.0228
September	Western	A (Brzeg)	Female	chironomid	6	ESM	0.042	0.034	3.5	0.032	0.0062
September	Western	A (Brzeg)	Female	chironomid	5	ESM	0.041	0.04	0	0.025	0
September	Western	A (Brzeg)	Male	chironomid	6	ESM	0.036	0.03	1	0.048	0.0044
September	Western	A (Brzeg)	Male	chironomid	5	ESM	0.052	0.005	7	0.074	0.0467
November	Western	A (Brzeg)	Female	chironomid	2	ESM	0.041	0.029	1.5	0.047	0.0121
November	Western	A (Brzeg)	Male	chironomid	2	ESM	0.042	0.011	5	0.104	0.031
November	Western	A (Brzeg)	Male	chironomid	1	ESM	0.025	0.022	2	0.088	0.003
November	Western	A (Brzeg)	Female	chironomid	1	KP	0.033	0.033	0	0.064	0.0001
November	Western	A (Brzeg)	Male	chironomid	4	ESM	0.043	0.026	3	0.086	0.0171
November	Western	A (Brzeg)	Female	chironomid	8	ESM	0.037	0.017	5	0.103	0.02
November	Western	A (Brzeg)	Male	chironomid	8	KP	0.03	0.016	4	0.091	0.014
November	Western	A (Brzeg)	Male	chironomid	3	ESM	0.028	0.017	2	0.098	0.011
November	Western	A (Brzeg)	Female	chironomid	3	KP	0.033	0.01	5	0.023	0.023
November	Western	A (Brzeg)	Male	chironomid	7	KP	0.039	0.022	3.5	0.073	0.017
November	Western	A (Brzeg)	Male	chironomid	5	ESM	0.026	0.023	1	0.122	0.0031
November	Western	A (Brzeg)	Male	chironomid	6	ESM	0.034	0.017	3	0.037	0.017
November	Western	A (Brzeg)	Female	chironomid	6	KP	0.024	0.024	0	0.043	0.0001
November	Western	A (Brzeg)	Female	chironomid	5	KP	0.035	0.018	3	0.045	0.017
March	Western	B (Zdzieszowice)	Female	chironomid	1	KP	0.039	0.025	2	0.064	0.0126
March	Western	B (Zdzieszowice)	Male	chironomid	1	KP	0.034	0.029		0.091	0.0034
March	Western	B (Zdzieszowice)	Male	chironomid	2	AD	0.04	0.024	3	0.086	0.0147
March	Western	B (Zdzieszowice)	Male	chironomid	8	KP	0.037	0.019	4.5	0.087	0.017
March	Western	B (Zdzieszowice)	Male	chironomid	4	KP	0.032	0.013	5	0.076	0.0183
March	Western	B (Zdzieszowice)	Female	chironomid	4	KP	0.061	0.035	3	0.051	0.0241
March	Western	B (Zdzieszowice)	Female	chironomid	8	AD	0.035	0.01	6	0.069	0.0245

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Western	B (Zdzieszowice)	Male	chironomid	7	AD	0.042	0.005	7	0.12	0.0367
March	Western	B (Zdzieszowice)	Male	chironomid	3	KP	0.033	0.007	6	0.079	0.0256
March	Western	B (Zdzieszowice)	Male	chironomid	6	KP	0.036	0.029	0.5	0.056	0.0054
March	Western	B (Zdzieszowice)	Female	chironomid	5	KP	0.04	0.026	4	0.063	0.0126
March	Western	B (Zdzieszowice)	Female	chironomid	6	KP	0.059	0.015	5.5	0.054	0.0432
March	Western	B (Zdzieszowice)	Male	chironomid	5	AD	0.036	0.026	3	0.092	0.0086
May	Western	B (Zdzieszowice)	Male	chironomid	1	KP	0.024	0.002	7	0.189	0.0218
May	Western	B (Zdzieszowice)	Male	chironomid	2	KP	0.031	0	8	0.147	0.031
May	Western	B (Zdzieszowice)	Female	chironomid	2	KP	0.043	0.008	5	0.077	0.0342
May	Western	B (Zdzieszowice)	Female	chironomid	1	KP	0.024	0.018	2	0.078	0.0041
May	Western	B (Zdzieszowice)	Female	chironomid	8	KP	0.022	0	8	0.119	0.022
May	Western	B (Zdzieszowice)	Male	chironomid	8	AD	0.042	0.036	0.5	0.059	0.0022
May	Western	B (Zdzieszowice)	Male	chironomid	4	AD	0.031	0	7.5	0.115	0.031
May	Western	B (Zdzieszowice)	Male	chironomid	3	AD	0.04	0.023	3	0.116	0.0146
May	Western	B (Zdzieszowice)	Male	chironomid	7	AD	0.031	0.005	7	0.108	0.0255
May	Western	B (Zdzieszowice)	Female	chironomid	5	KP	0.023	0	8	0.089	0.023
May	Western	B (Zdzieszowice)	Male	chironomid	6	AD	0.032	0.005	7	0.153	0.0265
May	Western	B (Zdzieszowice)	Female	chironomid	6	AD	0.031	0.01	4.5	0.066	0.02
May	Western	B (Zdzieszowice)	Male	chironomid	5	AD	0.034	0.005	0	0.143	0.0285
July	Western	B (Zdzieszowice)	Male	chironomid	1	KP	0.039	0.005	7	0.084	0.0322
July	Western	B (Zdzieszowice)	Male	chironomid	2	KP	0.036	0.019	1	0.043	0.0103
July	Western	B (Zdzieszowice)	Female	chironomid	1	KP	0.037	0.018	3	0.033	0.0126
July	Western	B (Zdzieszowice)	Female	chironomid	8	KP	0.029	0	8	0.078	0.029
July	Western	B (Zdzieszowice)	Male	chironomid	8	SH	0.025	0.003	7	0.034	0.0209
July	Western	B (Zdzieszowice)	Female	chironomid	4	SH	0.03	0.005	5	0.031	0.0232
July	Western	B (Zdzieszowice)	Male	chironomid	4	SH	0.029	0.003	7	0.09	0.0249
July	Western	B (Zdzieszowice)	Female	chironomid	7	KP	0.034	0.008	6	0.038	0.0232
July	Western	B (Zdzieszowice)	Male	chironomid	3	SH	0.026	0.01	5	0.05	0.0125
July	Western	B (Zdzieszowice)	Female	chironomid	3	SH	0.028	0.006	5	0.054	0.0199

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Western	B (Zdzieszowice)	Male	chironomid	7	SH	0.038	0.007	4	0.046	0.0285
July	Western	B (Zdzieszowice)	Female	chironomid	5	KP	0.033	0.004	5.5	0.037	0.0276
July	Western	B (Zdzieszowice)	Male	chironomid	6	SH	0.026	0.022	2	0.059	0
July	Western	B (Zdzieszowice)	Female	chironomid	6	SH	0.023	0.017	2	0.032	0
July	Western	B (Zdzieszowice)	Male	chironomid	5	SH	0.032	0.017	4	0.041	0.009
September	Western	B (Zdzieszowice)	Male	chironomid	2	ESM	0.029	0.005	7	0.055	0.0237
September	Western	B (Zdzieszowice)	Male	chironomid	1	ESM	0.024	0	8	0.06	0.024
September	Western	B (Zdzieszowice)	Female	chironomid	2	KP	0.045	0.018	4	0.024	0.026
September	Western	B (Zdzieszowice)	Male	chironomid	4	ESM	0.049	0.01	7	0.041	0.0385
September	Western	B (Zdzieszowice)	Female	chironomid	8	ESM	0.038	0.031	0.5	0.055	0.0054
September	Western	B (Zdzieszowice)	Male	chironomid	8	ESM	0.037	0.037	0	0.078	0
September	Western	B (Zdzieszowice)	Female	chironomid	4	KP	0.045	0.045	0	0.02	0
September	Western	B (Zdzieszowice)	Male	chironomid	3	ESM	0.052	0.024	3.5	0.08	0.0267
September	Western	B (Zdzieszowice)	Male	chironomid	7	ESM	0.044	0.005	7	0.055	0.0387
September	Western	B (Zdzieszowice)	Female	chironomid	7	ESM	0.05	0.029	4	0.04	0.0195
September	Western	B (Zdzieszowice)	Female	chironomid	3	KP	0.041	0.031	3	0.037	0.0084
September	Western	B (Zdzieszowice)	Female	chironomid	5	ESM	0.043	0.018	4	0.052	0.024
September	Western	B (Zdzieszowice)	Female	chironomid	6	ESM	0.054	0.048	0	0.046	0.0034
September	Western	B (Zdzieszowice)	Male	chironomid	6	KP	0.05	0.011	6	0.054	0.0384
September	Western	B (Zdzieszowice)	Male	chironomid	5	KP	0.069	0	8	0.062	0.069
November	Western	B (Zdzieszowice)	Male	chironomid	1	ESM	0.037	0.012	5	0.108	0.025
November	Western	B (Zdzieszowice)	Male	chironomid	2	ESM	0.042	0.016	5	0.152	0.026
November	Western	B (Zdzieszowice)	Female	chironomid	2	ESM	0.036	0.028	1	0.029	0.0081
November	Western	B (Zdzieszowice)	Female	chironomid	1	ESM	0.047	0.023	3	0.029	0.0241
November	Western	B (Zdzieszowice)	Female	chironomid	8	ESM	0.036	0.08	7	0.031	0
November	Western	B (Zdzieszowice)	Male	chironomid	8	KP	0.03	0.02	3	0.079	0.01
November	Western	B (Zdzieszowice)	Female	chironomid	4	KP	0.034	0.025	0.5	0.047	0.0091
November	Western	B (Zdzieszowice)	Male	chironomid	4	KP	0.037	0.026	1	0.114	0.0111
November	Western	B (Zdzieszowice)	Female	chironomid	7	ESM	0.036	0.02	2	0.034	0.016

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Western	B (Zdzieszowice)	Male	chironomid	3	KP	0.029	0.002	7	0.095	0.027
November	Western	B (Zdzieszowice)	Female	chironomid	3	ESM	0.036	0.016	3	0.022	0.02
November	Western	B (Zdzieszowice)	Male	chironomid	7	ESM	0.022	0.005	6	0.048	0.017
November	Western	B (Zdzieszowice)	Female	chironomid	5	ESM	0.026	0.011	3.5	0.022	0.015
November	Western	B (Zdzieszowice)	Male	chironomid	6	KP	0.027	0.017	4	0.137	0.01
November	Western	B (Zdzieszowice)	Female	chironomid	6	KP	0.026	0.016	2.5	0.07	0.01
November	Western	B (Zdzieszowice)	Male	chironomid	5	KP	0.032	0.01	6	0.086	0.022
March	Eastern	A (Wyszogród)	Male	fish	1	KP	0.449	0.403		0.129	0
March	Eastern	A (Wyszogród)	Female	fish	2	AD	0.266	0.197		0.035	0.0263
March	Eastern	A (Wyszogród)	Female	fish	1	AD	0.325	0.265		0.068	0.0026
March	Eastern	A (Wyszogród)	Male	fish	8	KP	0.273	0.196		0.145	0.0345
March	Eastern	A (Wyszogród)	Male	fish	4	KP	0.208	0.207		0.058	0
March	Eastern	A (Wyszogród)	Female	fish	7	AD	0.364	0.29		0.036	0.0111
March	Eastern	A (Wyszogród)	Male	fish	7	AD	0.294	0.199		0.086	0.0519
March	Eastern	A (Wyszogród)	Female	fish	3	KP	0.304	0.252		0.069	0
March	Eastern	A (Wyszogród)	Male	fish	3	KP	0.257	0.215		0.095	0
March	Eastern	A (Wyszogród)	Male	fish	6	AD	0.35	0.267		0.089	0.0251
March	Eastern	A (Wyszogród)	Female	fish	6	AD	0.342	0.246		0.05	0.0427
May	Eastern	A (Wyszogród)	Male	fish	2	KP	0.12	0.086		0.052	0.0103
May	Eastern	A (Wyszogród)	Female	fish	1	KP	0.163	0.13		0.034	0
May	Eastern	A (Wyszogród)	Female	fish	2	KP	0.117	0.075		0.121	0.0213
May	Eastern	A (Wyszogród)	Male	fish	1	KP	0.252	0.194		0.04	0.0045
May	Eastern	A (Wyszogród)	Male	fish	8	KP	0.133	0.076		0.043	0.036
May	Eastern	A (Wyszogród)	Female	fish	8	KP	0.171	0.154		0.073	0
May	Eastern	A (Wyszogród)	Male	fish	4	AD	0.162	0.135		0.132	0
May	Eastern	A (Wyszogród)	Female	fish	3	KP	0.164	0.128		0.03	0.0007
May	Eastern	A (Wyszogród)	Male	fish	7	KP	0.234	0.164		0.04	0.0248
May	Eastern	A (Wyszogród)	Female	fish	7	AD	0.11	0.072		0.038	0.0181
May	Eastern	A (Wyszogród)	Male	fish	3	AD	0.211	0.149		0.019	0.0209

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	A (Wyszogród)	Female	fish	6	KP	0.216	0.202		0.049	0
May	Eastern	A (Wyszogród)	Male	fish	6	AD	0.193	0.173		0.139	0
May	Eastern	A (Wyszogród)	Female	fish	5	AD	0.17	0.141		0.084	0
May	Eastern	A (Wyszogród)	Male	fish	5	AD	0.143	0.129		0.04	0
July	Eastern	A (Wyszogród)	Male	fish	2	KP	0.16	0.134		0.023	0
July	Eastern	A (Wyszogród)	Female	fish	1	KP	0.146	0.113		0.022	0.0082
July	Eastern	A (Wyszogród)	Male	fish	1	KP	0.106	0.086		0.032	0.0011
July	Eastern	A (Wyszogród)	Male	fish	8	KP	0.085	0.061		0.017	0.0106
July	Eastern	A (Wyszogród)	Female	fish	8	KP	0.113	0.093		0.013	0
July	Eastern	A (Wyszogród)	Female	fish	4	KP	0.104	0.093		0.018	0
July	Eastern	A (Wyszogród)	Male	fish	4	SH	0.169	0.163		0.072	0
July	Eastern	A (Wyszogród)	Female	fish	3	KP	0.098	0.086		0.022	0
July	Eastern	A (Wyszogród)	Male	fish	7	KP	0.073	0.053		0.07	0.0084
July	Eastern	A (Wyszogród)	Female	fish	7	SH	0.165	0.128		0.023	0.0089
July	Eastern	A (Wyszogród)	Male	fish	3	SH	0.162	0.135		0.083	0
July	Eastern	A (Wyszogród)	Female	fish	6	KP	0.042	0.029		0.02	0.0066
July	Eastern	A (Wyszogród)	Male	fish	6	SH	0.156	0.149		0.02	0
July	Eastern	A (Wyszogród)	Female	fish	5	SH	0.167	0.152		0.034	0
July	Eastern	A (Wyszogród)	Male	fish	5	SH	0.182	0.181		0.024	0
September	Eastern	A (Wyszogród)	Female	fish	1	ESM	0.083	0.078		0.03	0
September	Eastern	A (Wyszogród)	Female	fish	2	KP	0.077	0.076		0.047	0
September	Eastern	A (Wyszogród)	Male	fish	2	KP	0.079	0.066		0.068	0.0086
September	Eastern	A (Wyszogród)	Male	fish	1	KP	0.097	0.084		0.062	0.0073
September	Eastern	A (Wyszogród)	Male	fish	4	ESM	0.087	0.087		0.056	0
September	Eastern	A (Wyszogród)	Female	fish	8	ESM	0.044	0.041		0.042	0.0002
September	Eastern	A (Wyszogród)	Female	fish	4	ESM	0.052	0.044		0.034	0.005
September	Eastern	A (Wyszogród)	Male	fish	8	KP	0.037	0.028		0.089	0.0071
September	Eastern	A (Wyszogród)	Female	fish	7	ESM	0.0127	0.124		0.041	0
September	Eastern	A (Wyszogród)	Male	fish	7	KP	0.042	0.042		0.059	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Eastern	A (Wyszogród)	Male	fish	3	KP	0.055	0.039		0.09	0.0134
September	Eastern	A (Wyszogród)	Male	fish	5	ESM	0.084	0.08		0.076	0
September	Eastern	A (Wyszogród)	Female	fish	5	ESM	0.073	0.064		0.04	0.0047
September	Eastern	A (Wyszogród)	Male	fish	6	KP	0.023	0.011		0.07	0.0113
September	Eastern	A (Wyszogród)	Female	fish	6	KP	0.058	0.052		0.038	0.0025
November	Eastern	A (Wyszogród)	Male	fish	2	ESM	0.056	0.05		0.128	0.0009
November	Eastern	A (Wyszogród)	Female	fish	1	ESM	0.05	0.047		0.062	0
November	Eastern	A (Wyszogród)	Female	fish	2	ESM	0.086	0.079		0.032	0
November	Eastern	A (Wyszogród)	Male	fish	1	ESM	0.052	0.046		0.099	0.0013
November	Eastern	A (Wyszogród)	Male	fish	8	ESM	0.08	0.07		0.036	0.0029
November	Eastern	A (Wyszogród)	Female	fish	8	ESM	0.067	0.053		0.07	0.0086
November	Eastern	A (Wyszogród)	Female	fish	4	KP	0.03	0.03		0.068	0
November	Eastern	A (Wyszogród)	Male	fish	4	KP	0.042	0.037		0.068	0.0012
November	Eastern	A (Wyszogród)	Female	fish	3	ESM	0.035	0.034		0.057	0
November	Eastern	A (Wyszogród)	Male	fish	7	ESM	0.079	0.072		0.147	0
November	Eastern	A (Wyszogród)	Female	fish	7	KP	0.036	0.032		0.048	0.0007
November	Eastern	A (Wyszogród)	Male	fish	3	ESM	0.064	0.062		0.07	0
November	Eastern	A (Wyszogród)	Female	fish	6	ESM	0.042	0.04		0.024	0
November	Eastern	A (Wyszogród)	Male	fish	6	KP	0.038	0.032		0.042	0.0027
November	Eastern	A (Wyszogród)	Female	fish	5	KP	0.039	0.035		0.028	0.0004
November	Eastern	A (Wyszogród)	Male	fish	5	KP	0.035	0.027		0.038	0.0053
March	Eastern	B (Ciechocinek)	Male	fish	2	KP	0.41	0.397		0.112	0
March	Eastern	B (Ciechocinek)	Female	fish	1	AD	0.381	0.278	5	0.052	0.0427
March	Eastern	B (Ciechocinek)	Male	fish	1	AD	0.357	0.318		0.099	0
March	Eastern	B (Ciechocinek)	Female	fish	4	KP	0.33	0.291		0.077	0
March	Eastern	B (Ciechocinek)	Male	fish	8	KP	0.361	0.326		0.045	0
March	Eastern	B (Ciechocinek)	Female	fish	8	AD	0.358	0.28		0.041	0.0173
March	Eastern	B (Ciechocinek)	Male	fish	4	AD	0.234	0.203		0.039	0
March	Eastern	B (Ciechocinek)	Female	fish	3	AD	0.321	0.278		0.045	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Eastern	B (Ciechocinek)	Male	fish	7	KP	0.238	0.203		0.075	0
March	Eastern	B (Ciechocinek)	Female	fish	7	KP	0.336	0.287		0.046	0
March	Eastern	B (Ciechocinek)	Female	fish	5	KP	0.252	0.197		0.054	0.0123
March	Eastern	B (Ciechocinek)	Male	fish	5	AD	0.298	0.234		0.059	0.0133
May	Eastern	B (Ciechocinek)	Male	fish	2	KP	0.279	0.228		0.034	0
May	Eastern	B (Ciechocinek)	Female	fish	2	KP	0.14	0.089		0.068	0.0265
May	Eastern	B (Ciechocinek)	Female	fish	1	AD	0.17	0.152		0.068	0
May	Eastern	B (Ciechocinek)	Male	fish	8	KP	0.186	0.156		0.141	0
May	Eastern	B (Ciechocinek)	Female	fish	8	KP	0.196	0.16		0.087	0
May	Eastern	B (Ciechocinek)	Male	fish	4	KP	0.161	0.124		0.155	0.0028
May	Eastern	B (Ciechocinek)	Female	fish	3	KP	0.173	0.133		0.074	0.0033
May	Eastern	B (Ciechocinek)	Male	fish	3	KP	0.181	0.137		0.019	0.0062
May	Eastern	B (Ciechocinek)	Male	fish	7	AD	0.168	0.107		0.036	0.0315
May	Eastern	B (Ciechocinek)	Male	fish	5	KP	0.115	0.1		0.073	0
May	Eastern	B (Ciechocinek)	Female	fish	5	KP	0.084	0.084		0.143	0
May	Eastern	B (Ciechocinek)	Male	fish	6	KP	0.16	0.137		0.134	0
May	Eastern	B (Ciechocinek)	Female	fish	6	KP	0.154	0.147		0.028	0
July	Eastern	B (Ciechocinek)	Female	fish	2	KP	0.117	0.105		0.033	0
July	Eastern	B (Ciechocinek)	Male	fish	1	KP	0.113	0.072		0.024	0.0252
July	Eastern	B (Ciechocinek)	Female	fish	1	KP	0.13	0.11		0.029	0
July	Eastern	B (Ciechocinek)	Female	fish	4	KP	0.075	0.075		0.011	0
July	Eastern	B (Ciechocinek)	Male	fish	8	KP	0.122	0.103		0.107	0
July	Eastern	B (Ciechocinek)	Female	fish	8	KP	0.128	0.085		0.029	0.0243
July	Eastern	B (Ciechocinek)	Male	fish	4	KP	0.047	0.038		0.033	0.0006
July	Eastern	B (Ciechocinek)	Female	fish	3	KP	0.068	0.045		0.028	0.0131
July	Eastern	B (Ciechocinek)	Male	fish	3	KP	0.156	0.115		0.046	0.0157
July	Eastern	B (Ciechocinek)	Female	fish	7	SH	0.162	0.155		0.025	0
July	Eastern	B (Ciechocinek)	Male	fish	7	SH	0.193	0.117		0.072	0.0503
July	Eastern	B (Ciechocinek)	Male	fish	5	KP	0.049	0.034		0.039	0.0075

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Eastern	B (Ciechocinek)	Female	fish	5	KP	0.074	0.066		0.016	0
July	Eastern	B (Ciechocinek)	Male	fish	6	KP	0.083	0.041		0.076	0.033
July	Eastern	B (Ciechocinek)	Female	fish	6	KP	0.067	0.042		0.031	0.0158
September	Eastern	B (Ciechocinek)	Female	fish	2	ESM	0.054	0.053		0.052	0
September	Eastern	B (Ciechocinek)	Male	fish	2	ESM	0.048	0.041		0.062	0.0042
September	Eastern	B (Ciechocinek)	Male	fish	1	KP	0.035	0.029		0.044	0.004
September	Eastern	B (Ciechocinek)	Female	fish	1	KP	0.075	0.075		0.012	0
September	Eastern	B (Ciechocinek)	Female	fish	8	ESM	0.038	0.031		0.028	0.0049
September	Eastern	B (Ciechocinek)	Male	fish	8	ESM	0.11	0.111		0.054	0
September	Eastern	B (Ciechocinek)	Male	fish	4	KP	0.027	0.027		0.078	0
September	Eastern	B (Ciechocinek)	Female	fish	4	KP	0.04	0.04		0.036	0
September	Eastern	B (Ciechocinek)	Male	fish	7	ESM	0.085	0.084		0.049	0
September	Eastern	B (Ciechocinek)	Female	fish	7	ESM	0.066	0.056		0.023	0.0062
September	Eastern	B (Ciechocinek)	Female	fish	3	KP	0.035	0.029		0.034	0.004
September	Eastern	B (Ciechocinek)	Male	fish	3	KP	0.042	0.033		0.058	0.0068
September	Eastern	B (Ciechocinek)	Female	fish	6	ESM	0.095	0.051		0.028	0.0406
September	Eastern	B (Ciechocinek)	Female	fish	5	ESM	0.076	0.077		0.022	0
September	Eastern	B (Ciechocinek)	Male	fish	5	ESM	0.086	0.082		0.052	0
September	Eastern	B (Ciechocinek)	Male	fish	6	KP	0.12	0.104		0.043	0.009
November	Eastern	B (Ciechocinek)	Male	fish	2	ESM	0.056	0.055		0.044	0
November	Eastern	B (Ciechocinek)	Female	fish	2	ESM	0.059	0.055		0.022	0
November	Eastern	B (Ciechocinek)	Male	fish	1	KP	0.104	0.101		0.07	0
November	Eastern	B (Ciechocinek)	Female	fish	1	KP	0.091	0.086		0.039	0
November	Eastern	B (Ciechocinek)	Male	fish	8	ESM	0.091	0.092		0.018	0
November	Eastern	B (Ciechocinek)	Female	fish	8	ESM	0.05	0.05		0.041	0
November	Eastern	B (Ciechocinek)	Male	fish	4	ESM	0.073	0.076		0.042	0
November	Eastern	B (Ciechocinek)	Female	fish	3	ESM	0.055	0.053		0.053	0
November	Eastern	B (Ciechocinek)	Male	fish	3	KP	0.064	0.046		0.059	0.0133
November	Eastern	B (Ciechocinek)	Female	fish	7	KP	0.051	0.038		0.02	0.0091

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Eastern	B (Ciechocinek)	Male	fish	7	KP	0.044	0.033		0.057	0.0076
November	Eastern	B (Ciechocinek)	Male	fish	5	ESM	0.038	0.038		0.026	0
November	Eastern	B (Ciechocinek)	Female	fish	5	ESM	0.092	0.094		0.018	0
November	Eastern	B (Ciechocinek)	Male	fish	6	ESM	0.082	0.082		0.082	0
March	Western	A (Brzeg)	Female	fish	2	KP	0.203	0.181		0.082	0
March	Western	A (Brzeg)	Male	fish	1	AD	0.339	0.225	4	0.073	0.0652
March	Western	A (Brzeg)	Female	fish	1	AD	0.312	0.247		0.083	0.0115
March	Western	A (Brzeg)	Male	fish	4	KP	0.377	0.295		0.061	0.0181
March	Western	A (Brzeg)	Male	fish	8	AD	0.298	0.241		0.102	0.0048
March	Western	A (Brzeg)	Female	fish	4	AD	0.363	0.338		0.055	0
March	Western	A (Brzeg)	Male	fish	3	AD	0.372	0.308		0.071	0
March	Western	A (Brzeg)	Male	fish	7	KP	0.439	0.378		0.083	0
March	Western	A (Brzeg)	Female	fish	6	KP	0.313	0.256		0.072	0.0015
March	Western	A (Brzeg)	Male	fish	6	KP	0.342	0.265		0.092	0.0196
March	Western	A (Brzeg)	Male	fish	5	AD	0.29	0.216		0.076	0.0272
March	Western	A (Brzeg)	Female	fish	5	AD	0.32	0.241		0.049	0.0268
May	Western	A (Brzeg)	Male	fish	2	AD	0.147	0.129		0.074	0
May	Western	A (Brzeg)	Female	fish	2	AD	0.128	0.11		0.04	0
May	Western	A (Brzeg)	Male	fish	8	KP	0.222	0.169		0.15	0.0064
May	Western	A (Brzeg)	Female	fish	8	AD	0.163	0.117		0.071	0.0137
May	Western	A (Brzeg)	Male	fish	4	AD	0.159	0.108		0.139	0.0212
May	Western	A (Brzeg)	Female	fish	4	AD	0.181	0.169		0.072	0
May	Western	A (Brzeg)	Female	fish	3	KP	0.241	0.214		0.078	0
May	Western	A (Brzeg)	Female	fish	7	KP	0.178	0.165		0.036	0
May	Western	A (Brzeg)	Male	fish	3	AD	0.118	0.127		0.139	0
May	Western	A (Brzeg)	Male	fish	7	AD	0.137	0.096		0.054	0.0145
May	Western	A (Brzeg)	Male	fish	6	KP	0.07	0.059		0.06	0
May	Western	A (Brzeg)	Female	fish	6	KP	0.148	0.127		0.098	0
May	Western	A (Brzeg)	Female	fish	5	AD	0.161	0.131		0.079	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Western	A (Brzeg)	Male	fish	5	AD	0.144	0.122		0.086	0
July	Western	A (Brzeg)	Male	fish	1	KP	0.165	0.127		0.041	0.0101
July	Western	A (Brzeg)	Female	fish	1	KP	0.232	0.187		0.032	0.0039
July	Western	A (Brzeg)	Male	fish	2	SH	0.191	0.167		0.076	0
July	Western	A (Brzeg)	Female	fish	8	SH	0.167	0.158		0.053	0
July	Western	A (Brzeg)	Male	fish	4	SH	0.181	0.158		0.065	0
July	Western	A (Brzeg)	Female	fish	4	SH	0.179	0.141		0.053	0.007
July	Western	A (Brzeg)	Female	fish	3	KP	0.067	0.057		0.045	0
July	Western	A (Brzeg)	Female	fish	7	KP	0.081	0.064		0.026	0.0029
July	Western	A (Brzeg)	Male	fish	3	SH	0.173	0.131		0.06	0.0132
July	Western	A (Brzeg)	Male	fish	7	SH	0.185	0.15		0.028	0.002
July	Western	A (Brzeg)	Male	fish	6	KP	0.085	0.044		0.042	0.0313
July	Western	A (Brzeg)	Female	fish	6	KP	0.052	0.034		0.024	0.0105
July	Western	A (Brzeg)	Female	fish	5	SH	0.156	0.127		0.048	0.0011
July	Western	A (Brzeg)	Male	fish	5	SH	0.161	0.137		0.084	0
September	Western	A (Brzeg)	Female	fish	2	ESM	0.072	0.062		0.023	0.0058
September	Western	A (Brzeg)	Male	fish	2	ESM	0.085	0.055		0.082	0.0263
September	Western	A (Brzeg)	Female	fish	1	ESM	0.024	0.062		0.023	0
September	Western	A (Brzeg)	Male	fish	1	KP	0.073	0.067		0.049	0.0015
September	Western	A (Brzeg)	Male	fish	8	ESM	0.08	0.077		0.076	0
September	Western	A (Brzeg)	Female	fish	8	ESM	0.087	0.082		0.025	0
September	Western	A (Brzeg)	Male	fish	4	ESM	0.041	0.041		0.103	0
September	Western	A (Brzeg)	Female	fish	4	KP	0.032	0.028		0.049	0.0021
September	Western	A (Brzeg)	Male	fish	3	ESM	0.071	0.069		0.091	0
September	Western	A (Brzeg)	Male	fish	7	KP	0.052	0.044		0.053	0.005
September	Western	A (Brzeg)	Female	fish	3	KP	0.028	0.026		0.064	0.0002
September	Western	A (Brzeg)	Female	fish	7	KP	0.054	0.044		0.06	0.007
September	Western	A (Brzeg)	Female	fish	5	ESM	0.079	0.071		0.025	0.0032
September	Western	A (Brzeg)	Male	fish	6	ESM	0.078	0.072		0.082	0.0011

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Western	A (Brzeg)	Female	fish	6	KP	0.077	0.049		0.04	0.0247
November	Western	A (Brzeg)	Male	fish	1	ESM	0.041	0.035		0.124	0.0024
November	Western	A (Brzeg)	Female	fish	1	ESM	0.049	0.035		0.022	0.0104
November	Western	A (Brzeg)	Male	fish	2	KP	0.032	0.028		0.08	0.0012
November	Western	A (Brzeg)	Female	fish	2	KP	0.054	0.051		0.068	0
November	Western	A (Brzeg)	Male	fish	8	ESM	0.065	0.062	0	0.092	0
November	Western	A (Brzeg)	Female	fish	8	KP	0.101	0.071		0.057	0.0228
November	Western	A (Brzeg)	Male	fish	4	KP	0.093	0.079		0.125	0.006
November	Western	A (Brzeg)	Female	fish	4	KP	0.025	0.022		0.066	0.0008
November	Western	A (Brzeg)	Female	fish	3	ESM	0.091	0.08		0.023	0.0029
November	Western	A (Brzeg)	Female	fish	7	ESM	0.058	0.057		0.067	0
November	Western	A (Brzeg)	Male	fish	3	KP	0.056	0.051		0.068	0
November	Western	A (Brzeg)	Male	fish	7	KP	0.029	0.024		0.085	0.0026
November	Western	A (Brzeg)	Male	fish	6	ESM	0.037	0.035		0.072	0
November	Western	A (Brzeg)	Female	fish	5	KP	0.053	0.043		0.044	0.0056
November	Western	A (Brzeg)	Male	fish	5	KP	0.056	0.052		0.127	0
March	Western	B (Zdzieszowice)	Male	fish	1	KP	0.293	0.263		0.124	0
March	Western	B (Zdzieszowice)	Female	fish	1	KP	0.267	0.235		0.074	0
March	Western	B (Zdzieszowice)	Male	fish	2	AD	0.314	0.216	5.5	0.104	0.0512
March	Western	B (Zdzieszowice)	Female	fish	2	AD	0.3	0.227		0.061	0.0238
March	Western	B (Zdzieszowice)	Female	fish	4	KP	0.407	0.366		0.085	0
March	Western	B (Zdzieszowice)	Female	fish	8	KP	0.272	0.221		0.067	0.0031
March	Western	B (Zdzieszowice)	Male	fish	8	KP	0.254	0.194		0.099	0.018
March	Western	B (Zdzieszowice)	Male	fish	3	KP	0.298	0.255		0.091	0
March	Western	B (Zdzieszowice)	Female	fish	7	KP	0.357	0.322		0.094	0
March	Western	B (Zdzieszowice)	Female	fish	5	KP	0.354	0.303		0.039	0
March	Western	B (Zdzieszowice)	Female	fish	6	KP	0.344	0.286		0.087	0
March	Western	B (Zdzieszowice)	Male	fish	5	KP	0.376	0.289		0.074	0.0244
March	Western	B (Zdzieszowice)	Male	fish	6	AD	0.345	0.25		0.075	0.0408

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Western	B (Zdzieszowice)	Male	fish	1	AD	0.169	0.149		0.134	0
May	Western	B (Zdzieszowice)	Male	fish	2	AD	0.141	0.114		0.134	0
May	Western	B (Zdzieszowice)	Female	fish	2	AD	0.198	0.15		0.085	0.0066
May	Western	B (Zdzieszowice)	Male	fish	4	AD	0.138	0.093		0.086	0.0194
May	Western	B (Zdzieszowice)	Female	fish	8	AD	0.186	0.119		0.067	0.0342
May	Western	B (Zdzieszowice)	Male	fish	3	KP	0.159	0.117		0.111	0.0097
May	Western	B (Zdzieszowice)	Female	fish	3	AD	0.15	0.117		0.076	0.0007
May	Western	B (Zdzieszowice)	Female	fish	7	AD	0.21	0.155		0.066	0.0123
May	Western	B (Zdzieszowice)	Female	fish	6	KP	0.231	0.206		0.079	0
May	Western	B (Zdzieszowice)	Male	fish	5	AD	0.169	0.132		0.08	0.0006
May	Western	B (Zdzieszowice)	Female	fish	5	AD	0.129	0.105		0.076	0
May	Western	B (Zdzieszowice)	Male	fish	6	AD	0.186	0.145		0.114	0.001
July	Western	B (Zdzieszowice)	Male	fish	1	KP	0.106	0.079		0.066	0.0096
July	Western	B (Zdzieszowice)	Female	fish	1	SH	0.195	0.17		0.042	0
July	Western	B (Zdzieszowice)	Male	fish	2	SH	0.182	0.169		0.038	0
July	Western	B (Zdzieszowice)	Female	fish	2	SH	0.182	0.164		0.021	0
July	Western	B (Zdzieszowice)	Male	fish	4	SH	0.182	0.167		0.067	0
July	Western	B (Zdzieszowice)	Female	fish	8	SH	0.171	0.145		0.049	0
July	Western	B (Zdzieszowice)	Male	fish	8	SH	0.176	0.153		0.066	0
July	Western	B (Zdzieszowice)	Male	fish	7	KP	0.069	0.063		0.079	0
July	Western	B (Zdzieszowice)	Male	fish	3	KP	0.052	0.05		0.041	0
July	Western	B (Zdzieszowice)	Female	fish	3	SH	0.18	0.14		0.09	0.0092
July	Western	B (Zdzieszowice)	Female	fish	6	KP	0.129	0.076		0.074	0.0363
July	Western	B (Zdzieszowice)	Male	fish	5	SH	0.159	0.144		0.08	0
July	Western	B (Zdzieszowice)	Female	fish	5	SH	0.187	0.161		0.07	0
July	Western	B (Zdzieszowice)	Male	fish	6	SH	0.187	0.167		0.066	0
September	Western	B (Zdzieszowice)	Male	fish	1	ESM	0.038	0.068		0.046	0
September	Western	B (Zdzieszowice)	Female	fish	2	ESM	0.034	0.068		0.042	0
September	Western	B (Zdzieszowice)	Female	fish	1	KP	0.054	0.048		0.02	0.0028

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Western	B (Zdzieszowice)	Male	fish	2	KP	0.068	0.063		0.078	0.0008
September	Western	B (Zdzieszowice)	Male	fish	8	ESM	0.056	0.056		0.071	0
September	Western	B (Zdzieszowice)	Female	fish	8	ESM	0.078	0.074		0.053	0
September	Western	B (Zdzieszowice)	Male	fish	4	ESM	0.058	0.054		0.048	0.0004
September	Western	B (Zdzieszowice)	Female	fish	4	KP	0.038	0.036		0.019	0
September	Western	B (Zdzieszowice)	Male	fish	7	ESM	0.087	0.084		0.054	0
September	Western	B (Zdzieszowice)	Female	fish	3	ESM	0.084	0.084		0.044	0
September	Western	B (Zdzieszowice)	Male	fish	3	ESM	0.061	0.053		0.09	0.0044
September	Western	B (Zdzieszowice)	Female	fish	7	KP	0.047	0.022		0.028	0.0235
September	Western	B (Zdzieszowice)	Male	fish	5	ESM	0.097	0.095		0.065	0
September	Western	B (Zdzieszowice)	Female	fish	5	ESM	0.055	0.05		0.025	0.0016
September	Western	B (Zdzieszowice)	Male	fish	6	ESM	0.066	0.064		0.084	0
September	Western	B (Zdzieszowice)	Female	fish	6	KP	0.086	0.079		0.025	0.0017
November	Western	B (Zdzieszowice)	Male	fish	1	KP	0.044	0.038		0.137	0.0021
November	Western	B (Zdzieszowice)	Female	fish	1	KP	0.061	0.053		0.054	0.0026
November	Western	B (Zdzieszowice)	Male	fish	2	KP	0.077	0.059		0.125	0.012
November	Western	B (Zdzieszowice)	Female	fish	4	ESM	0.046	0.035		0.054	0.0074
November	Western	B (Zdzieszowice)	Male	fish	4	KP	0.042	0.029		0.127	0.0101
November	Western	B (Zdzieszowice)	Female	fish	8	KP	0.032	0.025		0.06	0.0045
November	Western	B (Zdzieszowice)	Male	fish	7	ESM	0.049	0.041		0.111	0.0038
November	Western	B (Zdzieszowice)	Male	fish	3	ESM	0.038	0.029		0.068	0.0061
November	Western	B (Zdzieszowice)	Female	fish	3	KP	0.05	0.036		0.057	0.0103
November	Western	B (Zdzieszowice)	Female	fish	7	KP	0.035	0.026		0.037	0.0064
November	Western	B (Zdzieszowice)	Female	fish	6	ESM	0.058	0.056		0.033	0
November	Western	B (Zdzieszowice)	Male	fish	5	KP	0.025	0.013		0.146	0.0107
November	Western	B (Zdzieszowice)	Female	fish	5	KP	0.028	0.022		0.063	0.0038
November	Western	B (Zdzieszowice)	Male	fish	6	KP	0.034	0.022		0.091	0.0098
March	Eastern	A (Wyszogród)	Female	leaf	2	KP	0.057	0.052		0.079	0
March	Eastern	A (Wyszogród)	Male	leaf	2	AD	0.068	0.042		0.09	0.0214

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Eastern	A (Wyszogród)	Male	leaf	4	KP	0.026	0.023		0.081	0.0005
March	Eastern	A (Wyszogród)	Male	leaf	8	KP	0.098	0.08		0.072	0.0093
March	Eastern	A (Wyszogród)	Female	leaf	4	AD	0.065	0.056		0.057	0.0029
March	Eastern	A (Wyszogród)	Female	leaf	3	AD	0.07	0.056		0.073	0.0079
March	Eastern	A (Wyszogród)	Male	leaf	7	AD	0.066	0.044		0.05	0.0172
March	Eastern	A (Wyszogród)	Female	leaf	7	AD	0.061	0.04		0.047	0.0167
March	Eastern	A (Wyszogród)	Male	leaf	6	KP	0.038	0.035		0.101	0
March	Eastern	A (Wyszogród)	Female	leaf	5	KP	0.067	0.05		0.036	0.0116
March	Eastern	A (Wyszogród)	Female	leaf	6	KP	0.035	0.024		0.038	0.0084
March	Eastern	A (Wyszogród)	Male	leaf	5	AD	0.067	0.052		0.038	0.0094
May	Eastern	A (Wyszogród)	Male	leaf	2	AD	0.048	0.044		0.071	0
May	Eastern	A (Wyszogród)	Female	leaf	2	AD	0.059	0.042		0.067	0.0121
May	Eastern	A (Wyszogród)	Male	leaf	1	AD	0.067	0.047		0.041	0.0145
May	Eastern	A (Wyszogród)	Female	leaf	4	KP	0.029	0.022		0.041	0.0044
May	Eastern	A (Wyszogród)	Female	leaf	8	KP	0.023	0.017		0.061	0.004
May	Eastern	A (Wyszogród)	Male	leaf	4	AD	0.059	0.047		0.038	0.0065
May	Eastern	A (Wyszogród)	Male	leaf	8	AD	0.089	0.048		0.032	0.0354
May	Eastern	A (Wyszogród)	Male	leaf	7	KP	0.037	0.016		0.128	0.0191
May	Eastern	A (Wyszogród)	Male	leaf	3	AD	0.053	0.043		0.029	0.005
May	Eastern	A (Wyszogród)	Female	leaf	3	AD	0.059	0.025		0.092	0.0311
May	Eastern	A (Wyszogród)	Female	leaf	5	KP	0.031	0.009		0.079	0.0209
May	Eastern	A (Wyszogród)	Male	leaf	5	AD	0.055	0.042		0.041	0.0081
May	Eastern	A (Wyszogród)	Female	leaf	6	AD	0.06	0.041		0.036	0.0142
May	Eastern	A (Wyszogród)	Male	leaf	6	AD	0.058	0.032		0.174	0.0223
July	Eastern	A (Wyszogród)	Female	leaf	1	KP	0.043	0.024		0.042	0.0164
July	Eastern	A (Wyszogród)	Male	leaf	2	SH	0.03	0.025		0.033	0.0023
July	Eastern	A (Wyszogród)	Female	leaf	2	SH	0.03	0.019		0.014	0.0089
July	Eastern	A (Wyszogród)	Male	leaf	1	SH	0.034	0.031		0.027	0
July	Eastern	A (Wyszogród)	Female	leaf	4	KP	0.032	0.023		0.019	0.0065

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Eastern	A (Wyszogród)	Female	leaf	8	KP	0.013	0.004		0.021	0.0086
July	Eastern	A (Wyszogród)	Male	leaf	4	SH	0.032	0.014		0.026	0.0165
July	Eastern	A (Wyszogród)	Male	leaf	8	SH	0.035	0.029		0.032	0.0028
July	Eastern	A (Wyszogród)	Male	leaf	7	KP	0.03	0.024		0.019	0.0034
July	Eastern	A (Wyszogród)	Female	leaf	7	SH	0.034	0.014		0.028	0.0185
July	Eastern	A (Wyszogród)	Male	leaf	3	SH	0.035	0.014		0.068	0.0195
July	Eastern	A (Wyszogród)	Female	leaf	3	SH	0.032	0.028		0.019	0.0009
July	Eastern	A (Wyszogród)	Female	leaf	5	KP	0.052	0.033		0.032	0.0154
July	Eastern	A (Wyszogród)	Male	leaf	5	SH	0.035	0.022		0.064	0.0106
July	Eastern	A (Wyszogród)	Female	leaf	6	SH	0.034	0.03		0.034	0.0007
September	Eastern	A (Wyszogród)	Male	leaf	2	ESM	0.043	0.014		0.087	0.0278
September	Eastern	A (Wyszogród)	Female	leaf	1	ESM	0.035	0.032		0.037	0.0003
September	Eastern	A (Wyszogród)	Female	leaf	2	ESM	0.043	0.032		0.042	0.0083
September	Eastern	A (Wyszogród)	Male	leaf	1	KP	0.013	0.012		0.06	0
September	Eastern	A (Wyszogród)	Male	leaf	4	ESM	0.024	0.016		0.084	0.0067
September	Eastern	A (Wyszogród)	Female	leaf	8	ESM	0.032	0.025		0.041	0.0049
September	Eastern	A (Wyszogród)	Male	leaf	8	KP	0.014	0.008		0.098	0.0053
September	Eastern	A (Wyszogród)	Female	leaf	4	KP	0.021	0.016		0.04	0.0037
September	Eastern	A (Wyszogród)	Male	leaf	3	ESM	0.028	0.026		0.103	0
September	Eastern	A (Wyszogród)	Male	leaf	7	ESM	0.066	0.043		0.15	0.0194
September	Eastern	A (Wyszogród)	Female	leaf	3	KP	0.03	0.028		0.024	0
September	Eastern	A (Wyszogród)	Female	leaf	7	KP	0.052	0.025		0.029	0.0249
September	Eastern	A (Wyszogród)	Female	leaf	5	ESM	0.055	0.036		0.034	0.016
September	Eastern	A (Wyszogród)	Male	leaf	5	KP	0.014	0.005		0.098	0.0086
September	Eastern	A (Wyszogród)	Male	leaf	6	KP	0.015	0.01		0.097	0.0042
November	Eastern	A (Wyszogród)	Female	leaf	1	ESM	0.04	0.028		0.055	0.0102
November	Eastern	A (Wyszogród)	Male	leaf	2	KP	0.026	0.021		0.082	0.0036
November	Eastern	A (Wyszogród)	Female	leaf	2	KP	0.027	0.014		0.08	0.0121
November	Eastern	A (Wyszogród)	Male	leaf	1	KP	0.018	0.016		0.158	0.001

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Eastern	A (Wyszogród)	Female	leaf	4	ESM	0.026	0.022		0.054	0.0026
November	Eastern	A (Wyszogród)	Female	leaf	8	KP	0.041	0.027		0.047	0.0122
November	Eastern	A (Wyszogród)	Male	leaf	4	KP	0.022	0.009		0.04	0.0124
November	Eastern	A (Wyszogród)	Male	leaf	8	KP	0.03	0.025		0.111	0.0034
November	Eastern	A (Wyszogród)	Male	leaf	7	ESM	0.04	0.038		0.098	0
November	Eastern	A (Wyszogród)	Female	leaf	7	KP	0.01	0.01		0.029	0
November	Eastern	A (Wyszogród)	Male	leaf	3	KP	0.026	0.013		0.033	0.0122
November	Eastern	A (Wyszogród)	Female	leaf	3	KP	0.025	0.018		0.021	0.0058
November	Eastern	A (Wyszogród)	Female	leaf	5	ESM	0.072	0.066		0.056	0.0017
November	Eastern	A (Wyszogród)	Male	leaf	5	KP	0.024	0.011		0.05	0.0123
November	Eastern	A (Wyszogród)	Male	leaf	6	KP	0.015	0.006		0.14	0.0086
March	Eastern	B (Ciechocinek)	Female	leaf	2	KP	0.057	0.053		0.028	0
March	Eastern	B (Ciechocinek)	Male	leaf	1	KP	0.053	0.038		0.056	0.0109
March	Eastern	B (Ciechocinek)	Female	leaf	1	AD	0.06	0.055		0.053	0
March	Eastern	B (Ciechocinek)	Male	leaf	2	AD	0.059	0.049		0.048	0.0047
March	Eastern	B (Ciechocinek)	Male	leaf	8	KP	0.085	0.044		0.065	0.0362
March	Eastern	B (Ciechocinek)	Male	leaf	4	AD	0.062	0.036		0.058	0.0221
March	Eastern	B (Ciechocinek)	Female	leaf	4	AD	0.061	0.054		0.054	0.0011
March	Eastern	B (Ciechocinek)	Female	leaf	3	KP	0.048	0.037		0.042	0.007
March	Eastern	B (Ciechocinek)	Male	leaf	3	KP	0.059	0.048		0.066	0.0058
March	Eastern	B (Ciechocinek)	Female	leaf	7	KP	0.062	0.051		0.079	0.0055
March	Eastern	B (Ciechocinek)	Male	leaf	5	KP	0.075	0.06		0.101	0.0085
March	Eastern	B (Ciechocinek)	Male	leaf	6	AD	0.074	0.055		0.056	0.013
May	Eastern	B (Ciechocinek)	Female	leaf	1	KP	0.023	0.01		0.076	0.0118
May	Eastern	B (Ciechocinek)	Female	leaf	2	KP	0.024	0.016		0.059	0.0061
May	Eastern	B (Ciechocinek)	Male	leaf	2	KP	0.026	0.019		0.115	0.0048
May	Eastern	B (Ciechocinek)	Male	leaf	1	KP	0.02	0.012		0.022	0.0066
May	Eastern	B (Ciechocinek)	Male	leaf	8	KP	0.027	0.027		0.034	0
May	Eastern	B (Ciechocinek)	Female	leaf	8	AD	0.048	0.034		0.067	0.01

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	B (Ciechocinek)	Female	leaf	4	AD	0.067	0.059		0.093	0.0011
May	Eastern	B (Ciechocinek)	Female	leaf	7	AD	0.066	0.054		0.07	0.0057
May	Eastern	B (Ciechocinek)	Male	leaf	3	AD	0.052	0.026		0.105	0.023
May	Eastern	B (Ciechocinek)	Male	leaf	7	AD	0.061	0.048		0.127	0.0074
May	Eastern	B (Ciechocinek)	Female	leaf	3	AD	0.04	0.035		0.056	0.0009
May	Eastern	B (Ciechocinek)	Female	leaf	5	KP	0.03	0.018		0.037	0.0099
May	Eastern	B (Ciechocinek)	Male	leaf	5	KP	0.035	0.006		0.048	0.0283
May	Eastern	B (Ciechocinek)	Female	leaf	6	AD	0.046	0.041		0.06	0.0002
July	Eastern	B (Ciechocinek)	Female	leaf	1	KP	0.022	0.022		0.03	0
July	Eastern	B (Ciechocinek)	Female	leaf	2	KP	0.051	0.051		0.032	0
July	Eastern	B (Ciechocinek)	Male	leaf	2	KP	0.041	0.032		0.031	0.0055
July	Eastern	B (Ciechocinek)	Male	leaf	1	KP	0.018	0.018		0.026	0
July	Eastern	B (Ciechocinek)	Male	leaf	4	KP	0.023	0.019		0.032	0.0019
July	Eastern	B (Ciechocinek)	Male	leaf	8	KP	0.021	0.012		0.02	0.0077
July	Eastern	B (Ciechocinek)	Female	leaf	8	SH	0.03	0.022		0.024	0.0056
July	Eastern	B (Ciechocinek)	Female	leaf	4	SH	0.03	0.026		0.03	0.0011
July	Eastern	B (Ciechocinek)	Female	leaf	7	SH	0.037	0.028		0.029	0.0059
July	Eastern	B (Ciechocinek)	Male	leaf	3	SH	0.034	0.011		0.038	0.0218
July	Eastern	B (Ciechocinek)	Male	leaf	7	SH	0.031	0.013		0.067	0.0166
July	Eastern	B (Ciechocinek)	Female	leaf	3	SH	0.036	0.02		0.036	0.0138
July	Eastern	B (Ciechocinek)	Female	leaf	5	KP	0.032	0.022		0.041	0.0076
July	Eastern	B (Ciechocinek)	Male	leaf	5	KP	0.032	0.024		0.049	0.0054
July	Eastern	B (Ciechocinek)	Male	leaf	6	KP	0.029	0.027		0.029	0
July	Eastern	B (Ciechocinek)	Female	leaf	6	SH	0.032	0.01		0.023	0.0209
September	Eastern	B (Ciechocinek)	Female	leaf	2	ESM	0.032	0.02		0.016	0.0103
September	Eastern	B (Ciechocinek)	Male	leaf	1	ESM	0.02	0.014		0.044	0.0048
September	Eastern	B (Ciechocinek)	Male	leaf	2	ESM	0.072	0.025		0.078	0.0449
September	Eastern	B (Ciechocinek)	Female	leaf	1	KP	0.013	0.004		0.028	0.0087
September	Eastern	B (Ciechocinek)	Female	leaf	4	ESM	0.041	0.028		0.037	0.0106

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Eastern	B (Ciechocinek)	Male	leaf	4	ESM	0.042	0.042		0.042	0
September	Eastern	B (Ciechocinek)	Male	leaf	8	KP	0.019	0.001		0.046	0.0179
September	Eastern	B (Ciechocinek)	Female	leaf	7	ESM	0.052	0.018		0.026	0.0325
September	Eastern	B (Ciechocinek)	Female	leaf	3	ESM	0.036	0.031		0.024	0.0024
September	Eastern	B (Ciechocinek)	Male	leaf	7	KP	0.025	0.015		0.049	0.0087
September	Eastern	B (Ciechocinek)	Male	leaf	3	KP	0.016	0.01		0.044	0.0052
September	Eastern	B (Ciechocinek)	Female	leaf	5	ESM	0.011	0.006		0.02	0.0045
September	Eastern	B (Ciechocinek)	Male	leaf	5	KP	0.018	0.014		0.052	0.0028
September	Eastern	B (Ciechocinek)	Female	leaf	6	KP	0.022	0.013		0.029	0.0079
September	Eastern	B (Ciechocinek)	Male	leaf	6	KP	0.014	0.007		0.05	0.0064
November	Eastern	B (Ciechocinek)	Female	leaf	1	ESM	0.064	0.05		0.037	0.0107
November	Eastern	B (Ciechocinek)	Female	leaf	2	ESM	0.038	0.035		0.034	0.0007
November	Eastern	B (Ciechocinek)	Male	leaf	2	ESM	0.061	0.053		0.05	0.0045
November	Eastern	B (Ciechocinek)	Male	leaf	1	ESM	0.064	0.055		0.061	0.0054
November	Eastern	B (Ciechocinek)	Male	leaf	4	ESM	0.067	0.041		0.08	0.0233
November	Eastern	B (Ciechocinek)	Male	leaf	8	KP	0.022	0.006		0.037	0.0156
November	Eastern	B (Ciechocinek)	Female	leaf	8	KP	0.014	0.008		0.035	0.0055
November	Eastern	B (Ciechocinek)	Female	leaf	4	KP	0.016	0.013		0.092	0.0022
November	Eastern	B (Ciechocinek)	Female	leaf	7	KP	0.028	0.007		0.044	0.0205
November	Eastern	B (Ciechocinek)	Male	leaf	3	KP	0.007	0.003		0.087	0.0038
November	Eastern	B (Ciechocinek)	Male	leaf	7	KP	0.01	0.006		0.048	0.0036
November	Eastern	B (Ciechocinek)	Female	leaf	3	KP	0.013	0.009		0.028	0.0034
November	Eastern	B (Ciechocinek)	Female	leaf	5	ESM	0.037	0.032		0.027	0.0029
November	Eastern	B (Ciechocinek)	Male	leaf	5	ESM	0.065	0.04		0.064	0.0224
November	Eastern	B (Ciechocinek)	Male	leaf	6	ESM	0.048	0.037		0.057	0.0086
November	Eastern	B (Ciechocinek)	Female	leaf	6	KP	0.009	0.006		0.041	0.0026
March	Western	A (Brzeg)	Female	leaf	2	KP	0.065	0.055		0.053	0.004
March	Western	A (Brzeg)	Female	leaf	1	KP	0.036	0.036		0.096	0
March	Western	A (Brzeg)	Male	leaf	2	KP	0.056	0.056		0.105	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Western	A (Brzeg)	Male	leaf	4	KP	0.048	0.028		0.062	0.017
March	Western	A (Brzeg)	Male	leaf	8	KP	0.063	0.063		0.034	0
March	Western	A (Brzeg)	Female	leaf	4	AD	0.065	0.053		0.111	0.0063
March	Western	A (Brzeg)	Female	leaf	8	AD	0.058	0.047		0.046	0.0059
March	Western	A (Brzeg)	Male	leaf	3	AD	0.071	0.062		0.045	0.0023
March	Western	A (Brzeg)	Female	leaf	3	KP	0.073	0.059		0.053	0.0076
March	Western	A (Brzeg)	Male	leaf	7	KP	0.064	0.064		0.041	0
March	Western	A (Brzeg)	Female	leaf	7	KP	0.057	0.046		0.085	0.006
March	Western	A (Brzeg)	Male	leaf	5	KP	0.067	0.05		0.036	0.0116
March	Western	A (Brzeg)	Female	leaf	5	KP	0.048	0.037		0.065	0.007
March	Western	A (Brzeg)	Female	leaf	6	AD	0.074	0.064		0.056	0.0031
March	Western	A (Brzeg)	Male	leaf	6	AD	0.067	0.055		0.086	0.006
May	Western	A (Brzeg)	Male	leaf	2	KP	0.019	0.01		0.122	0.0078
May	Western	A (Brzeg)	Female	leaf	1	AD	0.054	0.052		0.082	0
May	Western	A (Brzeg)	Male	leaf	1	AD	0.05	0.034		0.107	0.012
May	Western	A (Brzeg)	Male	leaf	4	KP	0.027	0.018		0.134	0.0069
May	Western	A (Brzeg)	Male	leaf	8	KP	0.035	0.021		0.133	0.0115
May	Western	A (Brzeg)	Female	leaf	4	AD	0.054	0.043		0.121	0.006
May	Western	A (Brzeg)	Male	leaf	7	KP	0.045	0.029		0.025	0.0126
May	Western	A (Brzeg)	Male	leaf	3	KP	0.023	0.021		0.086	0
May	Western	A (Brzeg)	Female	leaf	7	AD	0.047	0.025		0.099	0.0191
May	Western	A (Brzeg)	Female	leaf	3	AD	0.036	0.024		0.095	0.0092
May	Western	A (Brzeg)	Male	leaf	6	KP	0.025	0		0.141	0.025
May	Western	A (Brzeg)	Female	leaf	5	AD	0.07	0.042		0.113	0.0231
May	Western	A (Brzeg)	Female	leaf	6	AD	0.041	0.018		0.068	0.0209
May	Western	A (Brzeg)	Male	leaf	5	AD	0.036	0.012		0.12	0.0226
July	Western	A (Brzeg)	Female	leaf	2	KP	0.025	0.021		0.015	0.0017
July	Western	A (Brzeg)	Male	leaf	2	KP	0.042	0.029		0.056	0.0098
July	Western	A (Brzeg)	Male	leaf	4	KP	0.025	0.005		0.037	0.0195

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Western	A (Brzeg)	Male	leaf	8	KP	0.038	0.016		0.032	0.0202
July	Western	A (Brzeg)	Female	leaf	8	KP	0.027	0.025		0.023	0
July	Western	A (Brzeg)	Female	leaf	4	SH	0.035	0.03		0.029	0.0017
July	Western	A (Brzeg)	Male	leaf	7	KP	0.044	0.012		0.05	0.0307
July	Western	A (Brzeg)	Male	leaf	3	KP	0.039	0.035		0.035	0.0002
July	Western	A (Brzeg)	Female	leaf	7	SH	0.031	0.014		0.029	0.0155
July	Western	A (Brzeg)	Female	leaf	3	SH	0.03	0.03		0.031	0
July	Western	A (Brzeg)	Male	leaf	6	KP	0.02	0.02		0.078	0
July	Western	A (Brzeg)	Female	leaf	5	SH	0.035	0.026		0.046	0.0061
July	Western	A (Brzeg)	Female	leaf	6	SH	0.036	0.032		0.023	0.0005
July	Western	A (Brzeg)	Male	leaf	5	SH	0.034	0.031		0.03	0
September	Western	A (Brzeg)	Male	leaf	2	KP	0.022	0.016		0.042	0.0047
September	Western	A (Brzeg)	Male	leaf	1	KP	0.022	0.016		0.046	0.0047
September	Western	A (Brzeg)	Female	leaf	1	KP	0.007	0.004		0.034	0.0027
September	Western	A (Brzeg)	Female	leaf	2	KP	0.012	0.006		0.072	0.0055
September	Western	A (Brzeg)	Female	leaf	8	ESM	0.017	0.011		0.041	0.0051
September	Western	A (Brzeg)	Male	leaf	8	KP	0.009	0.006		0.079	0.0025
September	Western	A (Brzeg)	Female	leaf	4	KP	0.022	0.004		0.061	0.0177
September	Western	A (Brzeg)	Male	leaf	4	KP	0.013	0.004		0.071	0.0087
September	Western	A (Brzeg)	Female	leaf	7	ESM	0.018	0.014		0.034	0.0028
September	Western	A (Brzeg)	Male	leaf	7	ESM	0.042	0.031		0.07	0.0084
September	Western	A (Brzeg)	Female	leaf	3	KP	0.017	0.011		0.058	0.0051
September	Western	A (Brzeg)	Male	leaf	3	KP	0.024	0.02		0.055	0.0023
September	Western	A (Brzeg)	Female	leaf	6	ESM	0.016	0.013		0.086	0.0019
September	Western	A (Brzeg)	Female	leaf	5	KP	0.026	0.019		0.037	0.0054
September	Western	A (Brzeg)	Male	leaf	5	KP	0.01	0.006		0.036	0.0035
November	Western	A (Brzeg)	Female	leaf	2	ESM	0.055	0.055		0.032	0
November	Western	A (Brzeg)	Male	leaf	2	ESM	0.073	0.06		0.063	0.0091
November	Western	A (Brzeg)	Female	leaf	1	KP	0.019	0.015		0.041	0.003

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Western	A (Brzeg)	Male	leaf	1	KP	0.022	0.016		0.099	0.005
November	Western	A (Brzeg)	Male	leaf	4	ESM	0.024	0.011		0.04	0.0123
November	Western	A (Brzeg)	Male	leaf	8	KP	0.022	0.017		0.069	0.0039
November	Western	A (Brzeg)	Female	leaf	8	KP	0.025	0.02		0.05	0.0037
November	Western	A (Brzeg)	Female	leaf	4	KP	0.014	0.011		0.029	0.0023
November	Western	A (Brzeg)	Male	leaf	7	ESM	0.012	0.01		0.161	0.0013
November	Western	A (Brzeg)	Male	leaf	3	ESM	0.024	0.017		0.124	0.0059
November	Western	A (Brzeg)	Female	leaf	7	KP	0.021	0.016		0.029	0.004
November	Western	A (Brzeg)	Male	leaf	6	ESM	0.024	0.01		0.085	0.0133
November	Western	A (Brzeg)	Female	leaf	5	KP	0.018	0.008		0.043	0.0095
November	Western	A (Brzeg)	Female	leaf	6	KP	0.021	0.016		0.036	0.004
November	Western	A (Brzeg)	Male	leaf	5	KP	0.013	0.005		0.087	0.0077
March	Western	B (Zdzieszowice)	Female	leaf	1	KP	0.041	0.04		0.06	0
March	Western	B (Zdzieszowice)	Female	leaf	2	KP	0.046	0.032		0.07	0.0105
March	Western	B (Zdzieszowice)	Male	leaf	1	KP	0.033	0.02		0.092	0.0108
March	Western	B (Zdzieszowice)	Male	leaf	2	AD	0.056	0.043		0.084	0.0083
March	Western	B (Zdzieszowice)	Male	leaf	8	KP	0.041	0.027		0.069	0.0111
March	Western	B (Zdzieszowice)	Female	leaf	8	KP	0.045	0.043		0.051	0
March	Western	B (Zdzieszowice)	Male	leaf	4	AD	0.065	0.05		0.068	0.0096
March	Western	B (Zdzieszowice)	Female	leaf	4	AD	0.056	0.023		0.059	0.0305
March	Western	B (Zdzieszowice)	Female	leaf	7	AD	0.058	0.04		0.068	0.0137
March	Western	B (Zdzieszowice)	Male	leaf	7	AD	0.058	0.043		0.088	0.0103
March	Western	B (Zdzieszowice)	Male	leaf	3	KP	0.049	0.044		0.098	0.0002
March	Western	B (Zdzieszowice)	Male	leaf	5	KP	0.057	0.05		0.091	0.0016
March	Western	B (Zdzieszowice)	Female	leaf	5	KP	0.035	0.025		0.063	0.0073
March	Western	B (Zdzieszowice)	Male	leaf	6	AD	0.05	0.03		0.083	0.0167
March	Western	B (Zdzieszowice)	Female	leaf	6	AD	0.048	0.041		0.054	0.0026
May	Western	B (Zdzieszowice)	Male	leaf	1	KP	0.03	0.019		0.105	0.0088
May	Western	B (Zdzieszowice)	Female	leaf	1	KP	0.071	0.046		0.068	0.0196

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Western	B (Zdzieszowice)	Male	leaf	2	AD	0.058	0.013		0.168	0.0435
May	Western	B (Zdzieszowice)	Female	leaf	2	AD	0.047	0.025		0.053	0.0191
May	Western	B (Zdzieszowice)	Male	leaf	8	KP	0.024	0.014		0.096	0.0084
May	Western	B (Zdzieszowice)	Male	leaf	4	AD	0.065	0.04		0.109	0.0203
May	Western	B (Zdzieszowice)	Female	leaf	4	AD	0.059	0.042		0.076	0.0121
May	Western	B (Zdzieszowice)	Female	leaf	8	AD	0.056	0.019		0.072	0.0348
May	Western	B (Zdzieszowice)	Female	leaf	3	KP	0.021	0.014		0.067	0.0054
May	Western	B (Zdzieszowice)	Female	leaf	7	KP	0.023	0.015		0.05	0.0062
May	Western	B (Zdzieszowice)	Male	leaf	3	AD	0.047	0.02		0.093	0.0247
May	Western	B (Zdzieszowice)	Male	leaf	7	AD	0.058	0.01		0.135	0.0468
May	Western	B (Zdzieszowice)	Male	leaf	6	KP	0.04	0.024		0.109	0.0132
May	Western	B (Zdzieszowice)	Male	leaf	5	AD	0.041	0.005		0.091	0.0354
May	Western	B (Zdzieszowice)	Female	leaf	5	AD	0.044	0.022		0.067	0.0194
July	Western	B (Zdzieszowice)	Male	leaf	1	KP	0.024	0.006		0.054	0.0173
July	Western	B (Zdzieszowice)	Female	leaf	1	KP	0.031	0.026		0.028	0.0021
July	Western	B (Zdzieszowice)	Male	leaf	2	SH	0.032	0		0.048	0.032
July	Western	B (Zdzieszowice)	Female	leaf	2	SH	0.034	0.032		0.023	0
July	Western	B (Zdzieszowice)	Male	leaf	8	KP	0.041	0.041		0.076	0
July	Western	B (Zdzieszowice)	Male	leaf	4	SH	0.037	0.022		0.085	0.0126
July	Western	B (Zdzieszowice)	Female	leaf	4	SH	0.037	0.024		0.031	0.0104
July	Western	B (Zdzieszowice)	Female	leaf	8	SH	0.031	0.029		0.038	0
July	Western	B (Zdzieszowice)	Female	leaf	3	KP	0.017	0	8	0.055	0.017
July	Western	B (Zdzieszowice)	Female	leaf	7	KP	0.06	0.054		0.042	0.0001
July	Western	B (Zdzieszowice)	Male	leaf	3	SH	0.031	0.016		0.071	0.0132
July	Western	B (Zdzieszowice)	Male	leaf	7	SH	0.034	0.02		0.053	0.0118
July	Western	B (Zdzieszowice)	Female	leaf	6	KP	0.025	0.013		0.036	0.0106
July	Western	B (Zdzieszowice)	Male	leaf	6	KP	0.04	0.035		0.034	0.0012
July	Western	B (Zdzieszowice)	Male	leaf	5	SH	0.034	0.02		0.062	0.0118
July	Western	B (Zdzieszowice)	Female	leaf	5	SH	0.034	0.016		0.057	0.0162

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Western	B (Zdzieszowice)	Female	leaf	1	ESM	0.011	0.01		0.011	0.0002
September	Western	B (Zdzieszowice)	Male	leaf	1	ESM	0.024	0.019		0.066	0.0034
September	Western	B (Zdzieszowice)	Female	leaf	2	KP	0.062	0.045	1.5	0.024	0.0132
September	Western	B (Zdzieszowice)	Male	leaf	2	KP	0.009	0.001		0.071	0.0079
September	Western	B (Zdzieszowice)	Male	leaf	8	ESM	0.039	0.026		0.058	0.0108
September	Western	B (Zdzieszowice)	Female	leaf	8	ESM	0.023	0.016		0.032	0.0057
September	Western	B (Zdzieszowice)	Female	leaf	4	ESM	0.026	0.016		0.04	0.0087
September	Western	B (Zdzieszowice)	Male	leaf	4	KP	0.03	0.025		0.099	0.0029
September	Western	B (Zdzieszowice)	Male	leaf	3	ESM	0.037	0.028		0.056	0.0066
September	Western	B (Zdzieszowice)	Male	leaf	7	ESM	0.014	0.014		0.055	0
September	Western	B (Zdzieszowice)	Female	leaf	7	ESM	0.02	0.018		0.043	0.0005
September	Western	B (Zdzieszowice)	Female	leaf	3	ESM	0.047	0.032		0.042	0.0123
September	Western	B (Zdzieszowice)	Female	leaf	5	ESM	0.026	0.023		0.022	0.0011
September	Western	B (Zdzieszowice)	Male	leaf	6	KP	0.026	0.022		0.043	0.0021
September	Western	B (Zdzieszowice)	Male	leaf	5	KP	0.01	0.01		0.038	0
September	Western	B (Zdzieszowice)	Female	leaf	6	KP	0.016	0.01		0.023	0.0052
November	Western	B (Zdzieszowice)	Male	leaf	1	ESM	0.034	0.022		0.085	0.0106
November	Western	B (Zdzieszowice)	Female	leaf	1	ESM	0.031	0.026		0.061	0.0033
November	Western	B (Zdzieszowice)	Male	leaf	2	KP	0.025	0.007		0.089	0.0175
November	Western	B (Zdzieszowice)	Female	leaf	2	KP	0.009	0.007		0.067	0.0015
November	Western	B (Zdzieszowice)	Male	leaf	8	ESM	0.026	0.022		0.043	0.0026
November	Western	B (Zdzieszowice)	Male	leaf	4	KP	0.044	0.007		0.093	0.0365
November	Western	B (Zdzieszowice)	Female	leaf	4	KP	0.022	0.013		0.033	0.0082
November	Western	B (Zdzieszowice)	Female	leaf	8	KP	0.037	0.018		0.033	0.0178
November	Western	B (Zdzieszowice)	Female	leaf	3	ESM	0.016	0.016		0.036	0
November	Western	B (Zdzieszowice)	Female	leaf	7	ESM	0.053	0.024		0.067	0.0274
November	Western	B (Zdzieszowice)	Male	leaf	3	KP	0.013	0.01		0.11	0.0023
November	Western	B (Zdzieszowice)	Female	leaf	6	ESM	0.019	0.005		0.056	0.0137
November	Western	B (Zdzieszowice)	Male	leaf	6	ESM	0.036	0.032		0.134	0.0019

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Western	B (Zdzieszowice)	Male	leaf	5	KP	0.012	0.002		0.098	0.0099
November	Western	B (Zdzieszowice)	Female	leaf	5	KP	0.014	0.006		0.027	0.0076

Table 2. The measurements in control treatments from food consumption experiment. T1 - the amount of food (g) before the experiment; T2 - the amount of food (g) after the experiment. Initials for operator: AD - Andrea Desiderato, ESM - Eliza Szczerkowska-Majchrzak, KP - Krzysztof Podwysocki, SH - Sylwia Holak.

season	food	replicate	operator	T1	T2
March	chironomid	1	KP	0.048	0.048
March	chironomid	2	AD	0.04	0.038
March	chironomid	3	KP	0.032	0.032
March	chironomid	4	AD	0.04	0.04
March	chironomid	5	KP	0.051	0.044
March	chironomid	6	AD	0.035	0.032
March	chironomid	7	KP	0.061	0.054
March	chironomid	8	AD	0.035	0.035
March	fish	1	KP	0.364	0.3
March	fish	2	AD	0.319	0.255
March	fish	3	KP	0.314	0.262
March	fish	4	AD	0.306	0.229
March	fish	5	KP	0.241	0.236
March	fish	6	AD	0.324	0.268
March	fish	7	KP	0.381	0.316
March	fish	8	AD	0.291	0.224
March	leaf	1	KP	0.076	0.076
March	leaf	2	AD	0.038	0.029
March	leaf	3	KP	0.06	0.06
March	leaf	4	AD	0.06	0.05
March	leaf	5	KP	0.104	0.1
March	leaf	6	AD	0.037	0.03

season	food	replicate	operator	T1	T2
March	leaf	7	KP	0.048	0.048
March	leaf	8	AD	0.078	0.072
May	chironomid	1	KP	0.031	0.031
May	chironomid	2	KP	0.041	0.026
May	chironomid	3	KP	0.032	0.029
May	chironomid	4	AD	0.035	0.036
May	chironomid	5	KP	0.026	0.022
May	chironomid	6	AD	0.035	0.035
May	chironomid	7	KP	0.033	0.033
May	chironomid	8	AD	0.036	0.036
May	fish	1	KP	0.124	0.098
May	fish	2	KP	0.193	0.169
May	fish	3	KP	0.206	0.149
May	fish	4	AD	0.125	0.085
May	fish	5	KP	0.161	0.143
May	fish	6	AD	0.127	0.091
May	fish	7	KP	0.11	0.094
May	fish	8	AD	0.247	0.197
May	leaf	1	KP	0.019	0.017
May	leaf	2	KP	0.017	0.016
May	leaf	3	KP	0.023	0.022
May	leaf	4	AD	0.062	0.058
May	leaf	5	KP	0.035	0.035
May	leaf	6	AD	0.042	0.032
May	leaf	7	KP	0.069	0.052
May	leaf	8	AD	0.026	0.026
July	chironomid	1	KP	0.044	0.027
July	chironomid	2	KP	0.034	0.033
July	chironomid	3	KP	0.035	0.025

season	food	replicate	operator	T1	T2
July	chironomid	4	KP	0.035	0.034
July	chironomid	5	KP	0.027	0.014
July	chironomid	6	SH	0.029	0.029
July	chironomid	7	KP	0.041	0.025
July	chironomid	8	KP	0.033	0.028
July	fish	1	KP	0.144	0.141
July	fish	2	KP	0.069	0.06
July	fish	3	KP	0.076	0.065
July	fish	4	KP	0.065	0.061
July	fish	5	KP	0.073	0.06
July	fish	6	SH	0.18	0.18
July	fish	7	KP	0.092	0.048
July	fish	8	KP	0.039	0.032
July	leaf	1	KP	0.044	0.044
July	leaf	2	KP	0.025	0.025
July	leaf	3	KP	0.021	0.021
July	leaf	4	KP	0.032	0.029
July	leaf	5	KP	0.016	0.013
July	leaf	6	SH	0.034	0.034
July	leaf	7	KP	0.025	0.019
July	leaf	8	KP	0.027	0.022
September	chironomid	1	ESM	0.036	0.032
September	chironomid	2	KP	0.045	0.045
September	chironomid	3	ESM	0.046	0.048
September	chironomid	4	KP	0.038	0.035
September	chironomid	5	ESM	0.054	0.053
September	chironomid	6	ESM	0.055	0.052
September	chironomid	7	ESM	0.058	0.055
September	chironomid	8	ESM	0.054	0.048

season	food	replicate	operator	T1	T2
September	fish	1	ESM	0.036	0.037
September	fish	2	KP	0.047	0.038
September	fish	3	ESM	0.077	0.072
September	fish	4	KP	0.03	0.03
September	fish	5	ESM	0.049	0.046
September	fish	6	ESM	0.149	0.14
September	fish	7	ESM	0.141	0.14
September	fish	8	ESM	0.073	0.065
September	leaf	1	ESM	0.031	0.03
September	leaf	2	KP	0.02	0.02
September	leaf	3	ESM	0.016	0.014
September	leaf	4	KP	0.017	0.014
September	leaf	5	ESM	0.02	0.02
September	leaf	6	ESM	0.06	0.059
September	leaf	7	ESM	0.05	0.05
September	leaf	8	ESM	0.019	0.015
November	chironomid	1	ESM	0.04	0.038
November	chironomid	2	KP	0.027	0.027
November	chironomid	3	ESM	0.032	0.033
November	chironomid	4	ESM	0.039	0.038
November	chironomid	5	KP	0.028	0.027
November	chironomid	6	ESM	0.026	0.026
November	chironomid	7	ESM	0.026	0.029
November	chironomid	8	KP	0.034	0.034
November	fish	1	ESM	0.037	0.034
November	fish	2	KP	0.024	0.017
November	fish	3	ESM	0.087	0.083
November	fish	4	ESM	0.08	0.082
November	fish	5	KP	0.046	0.044

season	food	replicate	operator	T1	T2
November	fish	6	ESM	0.054	0.052
November	fish	7	ESM	0.054	0.054
November	fish	8	KP	0.041	0.034
November	leaf	1	ESM	0.043	0.043
November	leaf	2	KP	0.018	0.015
November	leaf	3	ESM	0.061	0.058
November	leaf	4	ESM	0.052	0.058
November	leaf	5	KP	0.016	0.012
November	leaf	6	ESM	0.079	0.078
November	leaf	7	ESM	0.037	0.036
November	leaf	8	KP	0.01	0.01

Table 3. The measurements from food preference experiment. Measurements are displayed only for specimens used for the analyses (ovigerous females, dead specimens or those that moulted during the experiment were excluded). The outlying measurements exluded from the analyses are marked with yellow colour. Q1 - the amount of food (g) before the experiment; Q2 - the amount of food (g) after the experiment; consumption - the response variable used in the analyses. Initials for operator: AD - Andrea Desiderato, ESM - Eliza Szczerkowska-Majchrzak, KP - Krzysztof Podwysocki, SH - Sylwia Holak.

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	A	Male	leaf	2	KP	0.021	0.015		0.038	0.0057
May	Eastern	A	Male	fish	2	KP	0.135	0.108		0.038	0.0005
May	Eastern	A	Male	chironomid	2	KP	0.033	0.017	2	0.038	0.0148
May	Eastern	B	Male	leaf	1	KP	0.012	0.012		0.125	0
May	Eastern	B	Male	fish	1	KP	0.214	0.162		0.125	0.0122
May	Eastern	B	Male	chironomid	1	KP	0.033	0.022	0	0.125	0.0095
May	Eastern	A	Female	leaf	2	KP	0.029	0.029		0.029	0
May	Eastern	A	Female	fish	2	KP	0.116	0.086		0.029	0.0089
May	Eastern	A	Female	chironomid	2	KP	0.024	0.007	6	0.029	0.0165
May	Eastern	B	Female	leaf	2	KP	0.048	0.047		0.07	0.0001
May	Eastern	B	Female	fish	2	KP	0.189	0.133		0.07	0.0234

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	B	Female	chironomid	2	KP	0.029	0.015	4	0.07	0.013
May	Eastern	B	Female	leaf	1	AD	0.067	0.052		0.078	0.014
May	Eastern	B	Female	fish	1	AD	0.167	0.167		0.078	0
May	Eastern	B	Female	chironomid	1	AD	0.035	0.02	3.5	0.078	0.0136
May	Western	A	Female	leaf	2	AD	0.058	0.049		0.086	0.0081
May	Western	A	Female	fish	2	AD	0.185	0.165		0.035	0
May	Western	A	Female	chironomid	2	AD	0.041	0.016	3.5	0.078	0.0239
May	Western	A	Female	leaf	1	AD	0.047	0.042		0.082	0.0042
May	Western	A	Female	fish	1	AD	0.217	0.187		0.082	0
May	Western	A	Female	chironomid	1	AD	0.036	0.016	4	0.082	0.0189
May	Western	B	Male	leaf	2	AD	0.058	0.058		0.083	0
May	Western	B	Male	fish	2	AD	0.182	0.161		0.083	0
May	Western	B	Male	chironomid	2	AD	0.038	0.01	6	0.083	0.0273
May	Western	A	Male	leaf	1	AD	0.064	0.06		0.058	0.0028
May	Western	A	Male	fish	1	AD	0.135	0.123		0.058	0
May	Western	A	Male	chironomid	1	AD	0.047	0.03	1.5	0.058	0.0149
May	Western	A	Male	leaf	2	AD	0.067	0.053		0.066	0.013
May	Western	A	Male	fish	2	AD	0.146	0.123		0.066	0
May	Western	A	Male	chironomid	2	AD	0.035	0.019	3.5	0.066	0.0147
May	Eastern	B	Male	leaf	2	AD	0.056	0.046		0.105	0.0091
May	Eastern	B	Male	fish	2	AD	0.151	0.117		0.105	0.0053
May	Eastern	B	Male	chironomid	2	AD	0.037	0.02	2	0.105	0.0156
May	Eastern	A	Male	leaf	1	AD	0.065	0.048		0.134	0.0161
May	Eastern	A	Male	fish	1	AD	0.156	0.125		0.134	0.0003
May	Eastern	A	Male	chironomid	1	AD	0.043	0.023	2	0.134	0.0184
May	Western	B	Female	leaf	2	AD	0.056	0.052		0.053	0.003
May	Western	B	Female	fish	2	AD	0.161	0.137		0.053	0
May	Western	B	Female	chironomid	2	AD	0.045	0.02	2	0.053	0.0236
May	Eastern	A	Female	leaf	1	AD	0.055	0.053		0.12	0.001

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	A	Female	fish	1	AD	0.192	0.169		0.12	0
May	Eastern	A	Female	chironomid	1	AD	0.037	0.014	4.5	0.12	0.022
May	Western	B	Male	leaf	1	AD	0.049	0.034		0.147	0.0143
May	Western	B	Male	fish	1	AD	0.191	0.139		0.147	0.0179
May	Western	B	Male	chironomid	1	AD	0.038	0	7.5	0.147	0.038
May	Eastern	A	Female	leaf	4	KP	0.035	0.03		0.07	0.0044
May	Eastern	A	Female	fish	4	KP	0.222	0.154		0.07	0.0302
May	Eastern	A	Female	chironomid	4	KP	0.035	0.015	3	0.07	0.019
May	Eastern	B	Male	leaf	4	KP	0.029	0.029		0.141	0
May	Eastern	B	Male	fish	4	KP	0.158	0.126		0.141	0.0011
May	Eastern	B	Male	chironomid	4	KP	0.028	0.016	3.5	0.141	0.0109
May	Eastern	B	Female	leaf	8	KP	0.037	0.034		0.079	0.0023
May	Eastern	B	Female	fish	8	KP	0.203	0.187		0.079	0
May	Eastern	B	Female	chironomid	8	KP	0.025	0.014	2	0.079	0.01
May	Eastern	B	Male	leaf	8	KP	0.023	0.012		0.101	0.0108
May	Eastern	B	Male	fish	8	KP	0.136	0.11		0.101	0
May	Eastern	B	Male	chironomid	8	KP	0.044	0.021	2.5	0.101	0.0215
May	Eastern	A	Male	leaf	8	KP	0.03	0.029		0.087	0.0004
May	Eastern	A	Male	fish	8	KP	0.178	0.163		0.087	0
May	Eastern	A	Male	chironomid	8	KP	0.034	0.029	1	0.087	0.003
May	Western	B	Female	leaf	8	KP	0.02	0.022		0.099	0
May	Western	B	Female	fish	8	KP	0.228	0.181		0.099	0.0026
May	Western	B	Female	chironomid	8	KP	0.042	0.013	4	0.099	0.0281
May	Western	B	Female	leaf	4	AD	0.065	0.055		0.085	0.0089
May	Western	B	Female	fish	4	AD	0.174	0.117		0.085	0.0283
May	Western	B	Female	chironomid	4	AD	0.029	0.008	6.5	0.085	0.0204
May	Western	B	Male	leaf	4	AD	0.068	0.054		0.149	0.013
May	Western	B	Male	fish	4	AD	0.164	0.114		0.149	0.022
May	Western	B	Male	chironomid	4	AD	0.035	0.011	5	0.149	0.0232

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	A	Male	leaf	4	AD	0.05	0.043		0.149	0.0062
May	Eastern	A	Male	fish	4	AD	0.169	0.126		0.149	0.0121
May	Eastern	A	Male	chironomid	4	AD	0.035	0.017	2	0.149	0.0168
May	Eastern	A	Female	leaf	8	AD	0.053	0.03		0.03	0.0224
May	Eastern	A	Female	fish	8	AD	0.204	0.143		0.03	0.0259
May	Eastern	A	Female	chironomid	8	AD	0.037	0.035	0.5	0.03	0
May	Western	A	Male	leaf	4	AD	0.06	0.055		0.077	0.0039
May	Western	A	Male	fish	4	AD	0.173	0.123		0.077	0.0198
May	Western	A	Male	chironomid	4	AD	0.035	0.016	4.5	0.077	0.0179
May	Western	A	Male	leaf	8	AD	0.052	0.047		0.157	0.0041
May	Western	A	Male	fish	8	AD	0.163	0.129		0.157	0.0023
May	Western	A	Male	chironomid	8	AD	0.026	0.019	1	0.157	0.0057
May	Western	B	Male	leaf	8	AD	0.049	0.036		0.146	0.0123
May	Western	B	Male	fish	8	AD	0.167	0.134		0.146	0.0001
May	Western	B	Male	chironomid	8	AD	0.04	0.001	6	0.146	0.0389
May	Eastern	B	Female	leaf	4	AD	0.047	0.042		0.06	0.0042
May	Eastern	B	Female	fish	4	AD	0.137	0.119		0.06	0
May	Eastern	B	Female	chironomid	4	AD	0.04	0.031	0.5	0.06	0.0068
May	Eastern	B	Female	leaf	7	KP	0.038	0.032		0.064	0.0054
May	Eastern	B	Female	fish	7	KP	0.161	0.11		0.064	0.024
May	Eastern	B	Female	chironomid	7	KP	0.031	0.021	3	0.064	0.0085
May	Western	B	Female	leaf	7	KP	0.027	0.022		0.071	0.0046
May	Western	B	Female	fish	7	KP	0.188	0.148		0.071	0.0037
May	Western	B	Female	chironomid	7	KP	0.04	0.005	7	0.071	0.0347
May	Western	A	Male	leaf	7	KP	0.051	0.042		0.026	0.0082
May	Western	A	Male	fish	7	KP	0.23	0.202		0.026	0
May	Western	A	Male	chironomid	7	KP	0.038	0.008	6	0.026	0.0294
May	Eastern	B	Female	leaf	3	KP	0.025	0.025		0.067	0
May	Eastern	B	Female	fish	3	KP	0.215	0.17		0.067	0.0033

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	B	Female	chironomid	3	KP	0.035	0.032	0	0.067	0.0008
May	Western	B	Male	leaf	3	KP	0.016	0.015		0.034	0.0007
May	Western	B	Male	fish	3	KP	0.125	0.095		0.034	0.0067
May	Western	B	Male	chironomid	3	KP	0.031	0.008	5.5	0.034	0.0224
May	Western	A	Male	leaf	3	KP	0.032	0.028		0.125	0.0035
May	Western	A	Male	fish	3	KP	0.118	0.089		0.125	0.0072
May	Western	A	Male	chironomid	3	KP	0.035	0.03	2	0.125	0.0029
May	Eastern	B	Male	leaf	3	KP	0.062	0.05		0.138	0.011
May	Eastern	B	Male	fish	3	KP	0.135	0.126		0.138	0
May	Eastern	B	Male	chironomid	3	KP	0.029	0.012	4	0.138	0.0162
May	Western	B	Male	leaf	7	KP	0.031	0.026		0.077	0.0045
May	Western	B	Male	fish	7	KP	0.136	0.127		0.077	0
May	Western	B	Male	chironomid	7	KP	0.038	0.016	4	0.077	0.0209
May	Eastern	A	Female	leaf	3	KP	0.033	0.022		0.127	0.0106
May	Eastern	A	Female	fish	3	KP	0.104	0.067		0.127	0.0206
May	Eastern	A	Female	chironomid	3	KP	0.034	0.024	3	0.127	0.0083
May	Eastern	A	Male	leaf	3	KP	0.022	0.022		0.193	0
May	Eastern	A	Male	fish	3	KP	0.131	0.106		0.193	0
May	Eastern	A	Male	chironomid	3	KP	0.023	0.014	2	0.193	0.008
May	Eastern	A	Male	leaf	7	AD	0.041	0.028		0.046	0.0125
May	Eastern	A	Male	fish	7	AD	0.146	0.111		0.046	0.0078
May	Eastern	A	Male	chironomid	7	AD	0.032	0.022	2.5	0.046	0.0085
May	Eastern	A	Female	leaf	7	AD	0.068	0.042		0.074	0.0252
May	Eastern	A	Female	fish	7	AD	0.149	0.107		0.074	0.0157
May	Eastern	A	Female	chironomid	7	AD	0.025	0.02	1	0.074	0.0036
May	Western	B	Female	leaf	3	AD	0.053	0.043		0.077	0.0092
May	Western	B	Female	fish	3	AD	0.155	0.116		0.077	0.0105
May	Western	B	Female	chironomid	3	AD	0.041	0.026	1.5	0.077	0.0132
May	Western	A	Female	leaf	7	AD	0.044	0.034		0.066	0.0093

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Western	A	Female	fish	7	AD	0.151	0.115		0.066	0.0078
May	Western	A	Female	chironomid	7	AD	0.038	0.019	3.5	0.066	0.0177
May	Western	A	Female	leaf	3	AD	0.046	0.032		0.05	0.0134
May	Western	A	Female	fish	3	AD	0.163	0.116		0.05	0.0185
May	Western	A	Female	chironomid	3	AD	0.034	0.026	2.5	0.05	0.0062
May	Eastern	B	Male	leaf	6	KP	0.054	0.047		0.041	0.0061
May	Eastern	B	Male	fish	6	KP	0.148	0.135		0.041	0
May	Eastern	B	Male	chironomid	6	KP	0.029	0.01	3	0.041	0.0183
May	Eastern	A	Male	leaf	5	KP	0.035	0.034		0.068	0.0003
May	Eastern	A	Male	fish	5	KP	0.141	0.14		0.068	0
May	Eastern	A	Male	chironomid	5	KP	0.03	0.015	2	0.068	0.014
May	Eastern	B	Female	leaf	6	KP	0.058	0.043		0.074	0.0142
May	Eastern	B	Female	fish	6	KP	0.083	0.052		0.074	0.0182
May	Eastern	B	Female	chironomid	6	KP	0.045	0.025	2.5	0.074	0.0183
May	Western	B	Female	leaf	6	KP	0.023	0.019		0.049	0.0036
May	Western	B	Female	fish	6	KP	0.217	0.21		0.049	0
May	Western	B	Female	chironomid	6	KP	0.027	0.025	1	0.049	0.0003
May	Western	B	Male	leaf	6	KP	0.017	0.017		0.115	0
May	Western	B	Male	fish	6	KP	0.091	0.083		0.115	0
May	Western	B	Male	chironomid	6	KP	0.033	0.07	1	0.115	0
May	Eastern	A	Male	leaf	6	KP	0.048	0.03		0.066	0.0174
May	Eastern	A	Male	fish	6	KP	0.193	0.168		0.066	0
May	Eastern	A	Male	chironomid	6	KP	0.035	0.006	7	0.066	0.0286
May	Western	A	Male	leaf	5	KP	0.05	0.05		0.056	0
May	Western	A	Male	fish	5	KP	0.174	0.174		0.056	0
May	Western	A	Male	chironomid	5	KP	0.023	0.013	4	0.056	0.0091
May	Eastern	A	Female	leaf	5	AD	0.046	0.029		0.035	0.0164
May	Eastern	A	Female	fish	5	AD	0.157	0.143		0.035	0
May	Eastern	A	Female	chironomid	5	AD	0.034	0.018	3.5	0.035	0.0147

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
May	Eastern	B	Male	leaf	5	AD	0.037	0.026		0.062	0.0105
May	Eastern	B	Male	fish	5	AD	0.137	0.113		0.062	0
May	Eastern	B	Male	chironomid	5	AD	0.034	0.013	4	0.062	0.0201
May	Western	A	Male	leaf	6	AD	0.059	0.047		0.047	0.0111
May	Western	A	Male	fish	6	AD	0.211	0.182		0.047	0
May	Western	A	Male	chironomid	6	AD	0.025	0.008	5.5	0.047	0.0164
May	Eastern	A	Female	leaf	6	AD	0.058	0.058		0.067	0
May	Eastern	A	Female	fish	6	AD	0.182	0.153		0.067	0
May	Eastern	A	Female	chironomid	6	AD	0.037	0.034	0.5	0.067	0.0006
May	Western	B	Male	leaf	5	AD	0.062	0.04		0.101	0.0212
May	Western	B	Male	fish	5	AD	0.181	0.149		0.101	0
May	Western	B	Male	chironomid	5	AD	0.03	0.017	3	0.101	0.0118
May	Eastern	B	Female	leaf	5	AD	0.037	0.029	3	0.077	0.0074
May	Eastern	B	Female	fish	5	AD	0.167	0.135		0.077	0
May	Eastern	B	Female	chironomid	5	AD	0.037	0.025	2	0.077	0.0103
July	Eastern	A	Male	leaf	2	KP	0.02	0.014		0.034	0.0048
July	Eastern	A	Male	fish	2	KP	0.156	0.121		0.034	0.0068
July	Eastern	A	Male	chironomid	2	KP	0.035	0.019	1	0.034	0.0121
July	Eastern	B	Male	leaf	1	KP	0.016	0.016		0.067	0
July	Eastern	B	Male	fish	1	KP	0.257	0.229		0.067	0
July	Eastern	B	Male	chironomid	1	KP	0.066	0.011	3	0.067	0.0527
July	Eastern	A	Female	leaf	2	KP	0.17	0.035		0.014	0.1319
July	Eastern	A	Female	fish	2	KP	0.156	0.064		0.014	0.0771
July	Eastern	A	Female	chironomid	2	KP	0.038	0.029	1	0.014	0.0031
July	Eastern	B	Female	leaf	2	KP	0.035	0.035		0.025	0
July	Eastern	B	Female	fish	2	KP	0.069	0.061		0.025	0
July	Eastern	B	Female	chironomid	2	KP	0.03	0.014	3.5	0.025	0.0131
July	Western	B	Female	leaf	1	KP	0.031	0.031		0.037	0
July	Western	B	Female	fish	1	KP	0.098	0.077		0.037	0.0031

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Western	B	Female	chironomid	1	KP	0.035	0.005	5.5	0.037	0.029
July	Eastern	B	Female	leaf	1	KP	0.025	0.023		0.027	0
July	Eastern	B	Female	fish	1	KP	0.079	0.076		0.027	0
July	Eastern	B	Female	chironomid	1	KP	0.034	0.015	2	0.027	0.0159
July	Western	A	Female	leaf	2	KP	0.016	0.014		0.053	0.0008
July	Western	A	Female	fish	2	KP	0.121	0.12		0.053	0
July	Western	A	Female	chironomid	2	KP	0.038	0.012	2	0.053	0.0235
July	Western	A	Female	leaf	1	SH	0.03	0.03		0.033	0
July	Western	A	Female	fish	1	SH	0.171	0.152		0.033	0
July	Western	A	Female	chironomid	1	SH	0.031	0.012	3	0.033	0.0165
July	Western	B	Male	leaf	2	SH	0.037	0.037		0.063	0
July	Western	B	Male	fish	2	SH	0.174	0.158		0.063	0
July	Western	B	Male	chironomid	2	SH	0.028	0.022	1	0.063	0.0015
July	Western	A	Male	leaf	1	SH	0.036	0.036		0.041	0
July	Western	A	Male	fish	1	SH	0.194	0.159		0.041	0
July	Western	A	Male	chironomid	1	SH	0.03	0.01	6	0.041	0.0179
July	Western	A	Male	leaf	2	SH	0.035	0.025		0.074	0.0078
July	Western	A	Male	fish	2	SH	0.181	0.164		0.074	0
July	Western	A	Male	chironomid	2	SH	0.04	0.011	3	0.074	0.0267
July	Eastern	A	Male	leaf	1	SH	0.03	0.03		0.039	0
July	Eastern	A	Male	fish	1	SH	0.185	0.151		0.039	0
July	Eastern	A	Male	chironomid	1	SH	0.028	0.016	2	0.039	0.0087
July	Eastern	A	Female	leaf	1	SH	0.036	0.032		0.024	0.0012
July	Eastern	A	Female	fish	1	SH	0.165	0.155		0.024	0
July	Eastern	A	Female	chironomid	1	SH	0.035	0.035	0	0.024	0
July	Western	B	Male	leaf	1	SH	0.031	0.03		0.054	0
July	Western	B	Male	fish	1	SH	0.188	0.163		0.054	0
July	Western	B	Male	chironomid	1	SH	0.028	0.016	2	0.054	0.0087
July	Eastern	A	Female	leaf	4	KP	0.028	0.022		0.028	0.0041

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Eastern	A	Female	fish	4	KP	0.061	0.045		0.028	0.0055
July	Eastern	A	Female	chironomid	4	KP	0.056	0.016	4.5	0.028	0.0367
July	Eastern	B	Male	leaf	4	KP	0.039	0.03		0.038	0.0064
July	Eastern	B	Male	fish	4	KP	0.146	0.128		0.038	0
July	Eastern	B	Male	chironomid	4	KP	0.032	0.003	5	0.038	0.0284
July	Eastern	B	Female	leaf	8	KP	0.027	0.027		0.019	0
July	Eastern	B	Female	fish	8	KP	0.099	0.082		0.019	0
July	Eastern	B	Female	chironomid	8	KP	0.038	0.013	4	0.019	0.0223
July	Eastern	B	Male	leaf	8	KP	0.03	0.021		0.043	0.0072
July	Eastern	B	Male	fish	8	KP	0.052	0.032		0.043	0.0126
July	Eastern	B	Male	chironomid	8	KP	0.029	0.003	7	0.043	0.0254
July	Eastern	A	Male	leaf	8	KP	0.026	0.02		0.014	0.0042
July	Eastern	A	Male	fish	8	KP	0.051	0.039		0.014	0.0029
July	Eastern	A	Male	chironomid	8	KP	0.031	0.013	5	0.014	0.0153
July	Western	A	Female	leaf	8	KP	0.042	0.042		0.052	0
July	Western	A	Female	fish	8	KP	0.148	0.128		0.052	0
July	Western	A	Female	chironomid	8	KP	0.032	0.02	3	0.052	0.0079
July	Western	B	Female	leaf	8	KP	0.033	0.033		0.026	0
July	Western	B	Female	fish	8	KP	0.113	0.099		0.026	0
July	Western	B	Female	chironomid	8	KP	0.034	0.015	2.5	0.026	0.0159
July	Western	B	Female	leaf	4	SH	0.03	0.029		0.053	0
July	Western	B	Female	fish	4	SH	0.17	0.132		0.053	0.0073
July	Western	B	Female	chironomid	4	SH	0.036	0.01	3	0.053	0.0239
July	Western	B	Male	leaf	4	SH	0.03	0.026		0.029	0.0017
July	Western	B	Male	fish	4	SH	0.193	0.163		0.029	0
July	Western	B	Male	chironomid	4	SH	0.026	0.019	3	0.029	0.0031
July	Eastern	A	Female	leaf	8	SH	0.031	0.03		0.03	0
July	Eastern	A	Female	fish	8	SH	0.198	0.188		0.03	0
July	Eastern	A	Female	chironomid	8	SH	0.206	0.02	0	0.03	0.1819

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Western	A	Male	leaf	4	SH	0.035	0.035		0.06	0
July	Western	A	Male	fish	4	SH	0.183	0.183		0.06	0
July	Western	A	Male	chironomid	4	SH	0.029	0.016	3	0.06	0.0097
July	Western	A	Female	leaf	4	SH	0.032	0.028		0.05	0.0015
July	Western	A	Female	fish	4	SH	0.182	0.173		0.05	0
July	Western	A	Female	chironomid	4	SH	0.029	0.01	4	0.05	0.0169
July	Western	A	Male	leaf	8	SH	0.034	0.034		0.041	0
July	Western	A	Male	fish	8	SH	0.168	0.151		0.041	0
July	Western	A	Male	chironomid	8	SH	0.034	0.031	0	0.041	0
July	Eastern	B	Female	leaf	7	KP	0.019	0.018		0.024	0
July	Eastern	B	Female	fish	7	KP	0.13	0.107		0.024	0
July	Eastern	B	Female	chironomid	7	KP	0.035	0.007	6	0.024	0.0266
July	Western	B	Female	leaf	7	KP	0.028	0.019		0.03	0.0073
July	Western	B	Female	fish	7	KP	0.079	0.073		0.03	0
July	Western	B	Female	chironomid	7	KP	0.041	0.018	3	0.03	0.0193
July	Western	A	Male	leaf	7	KP	0.026	0.02		0.036	0.0042
July	Western	A	Male	fish	7	KP	0.035	0.034		0.036	0
July	Western	A	Male	chironomid	7	KP	0.023	0.014	4	0.036	0.0061
July	Eastern	B	Female	leaf	3	KP	0.029	0.02		0.064	0.0072
July	Eastern	B	Female	fish	3	KP	0.058	0.048		0.064	0
July	Eastern	B	Female	chironomid	3	KP	0.032	0.012	4	0.064	0.0175
July	Western	B	Male	leaf	3	KP	0.031	0.027		0.073	0.0016
July	Western	B	Male	fish	3	KP	0.098	0.071		0.073	0.0105
July	Western	B	Male	chironomid	3	KP	0.035	0.017	2	0.073	0.0145
July	Eastern	B	Male	leaf	3	KP	0.042	0.042		0.025	0
July	Eastern	B	Male	fish	3	KP	0.081	0.067		0.025	0
July	Eastern	B	Male	chironomid	3	KP	0.029	0.01	2	0.025	0.0169
July	Western	B	Male	leaf	7	KP	0.029	0.027		0.051	0
July	Western	B	Male	fish	7	KP	0.094	0.094		0.051	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Western	B	Male	chironomid	7	KP	0.027	0.004	7	0.051	0.0222
July	Eastern	A	Female	leaf	3	KP	0.02	0.019		0.034	0
July	Eastern	A	Female	fish	3	KP	0.045	0.039		0.034	0
July	Eastern	A	Female	chironomid	3	KP	0.041	0	7	0.034	0.041
July	Eastern	A	Male	leaf	3	KP	0.04	0.04		0.05	0
July	Eastern	A	Male	fish	3	KP	0.059	0.05		0.05	0
July	Eastern	A	Male	chironomid	3	KP	0.057	0.017	2	0.05	0.0365
July	Eastern	B	Male	leaf	7	KP	0.024	0.024		0.049	0
July	Eastern	B	Male	fish	7	KP	0.149	0.133		0.049	0
July	Eastern	B	Male	chironomid	7	KP	0.034	0.004	5	0.049	0.0292
July	Eastern	A	Male	leaf	7	SH	0.031	0.023		0.035	0.006
July	Eastern	A	Male	fish	7	SH	0.177	0.116		0.035	0.034
July	Eastern	A	Male	chironomid	7	SH	0.032	0.014	3	0.035	0.0151
July	Eastern	A	Female	leaf	7	SH	0.038	0.03		0.016	0.0054
July	Eastern	A	Female	fish	7	SH	0.185	0.179		0.016	0
July	Eastern	A	Female	chironomid	7	SH	0.032	0.02	0	0.016	0.0079
July	Western	B	Female	leaf	3	SH	0.03	0.029		0.026	0
July	Western	B	Female	fish	3	SH	0.17	0.163		0.026	0
July	Western	B	Female	chironomid	3	SH	0.032	0.08	3	0.026	0
July	Western	A	Female	leaf	7	SH	0.032	0.029		0.037	0.0005
July	Western	A	Female	fish	7	SH	0.194	0.189		0.037	0
July	Western	A	Female	chironomid	7	SH	0.035	0.019	1	0.037	0.0121
July	Western	A	Female	leaf	3	SH	0.034	0.03		0.033	0.0014
July	Western	A	Female	fish	3	SH	0.163	0.144		0.033	0
July	Western	A	Female	chironomid	3	SH	0.028	0.019	1	0.033	0.0051
July	Western	A	Female	leaf	5	KP	0.017	0.011		0.024	0.005
July	Western	A	Female	fish	5	KP	0.086	0.063		0.024	0.0083
July	Western	A	Female	chironomid	5	KP	0.033	0.018	2	0.024	0.0113
July	Western	B	Female	leaf	5	KP	0.018	0.016		0.029	0.0006

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Western	B	Female	fish	5	KP	0.058	0.04		0.029	0.0087
July	Western	B	Female	chironomid	5	KP	0.046	0.019	2	0.029	0.0231
July	Eastern	B	Male	leaf	6	KP	0.019	0.007		0.051	0.0114
July	Eastern	B	Male	fish	6	KP	0.129	0.069		0.051	0.0439
July	Eastern	B	Male	chironomid	6	KP	0.031	0.008	6.5	0.051	0.0214
July	Eastern	A	Male	leaf	5	KP	0.013	0.013		0.04	0
July	Eastern	A	Male	fish	5	KP	0.036	0.031		0.04	0
July	Eastern	A	Male	chironomid	5	KP	0.031	0.021	2	0.04	0.0057
July	Eastern	B	Female	leaf	6	KP	0.022	0.019		0.048	0.0013
July	Eastern	B	Female	fish	6	KP	0.039	0.02		0.048	0.0143
July	Eastern	B	Female	chironomid	6	KP	0.03	0.012	5	0.048	0.0155
July	Western	A	Female	leaf	6	KP	0.025	0.023		0.037	0
July	Western	A	Female	fish	6	KP	0.158	0.141		0.037	0
July	Western	A	Female	chironomid	6	KP	0.025	0.009	4	0.037	0.0142
July	Western	B	Female	leaf	6	KP	0.027	0.025		0.035	0
July	Western	B	Female	fish	6	KP	0.067	0.055		0.035	0
July	Western	B	Female	chironomid	6	KP	0.028	0.007	5	0.035	0.0196
July	Western	B	Male	leaf	6	KP	0.03	0.023		0.035	0.005
July	Western	B	Male	fish	6	KP	0.121	0.109		0.035	0
July	Western	B	Male	chironomid	6	KP	0.037	0.01	7	0.035	0.0249
July	Eastern	A	Male	leaf	6	KP	0.022	0.019		0.01	0.0013
July	Eastern	A	Male	fish	6	KP	0.095	0.083	5	0.01	0
July	Eastern	A	Male	chironomid	6	KP	0.032	0.01	7	0.01	0.0199
July	Western	A	Male	leaf	5	KP	0.018	0.022		0.038	0
July	Western	A	Male	fish	5	KP	0.083	0.057	1	0.038	0.0127
July	Western	A	Male	chironomid	5	KP	0.038	0.026	1	0.038	0.0067
July	Eastern	A	Female	leaf	5	SH	0.032	0.029		0.022	0.0005
July	Eastern	A	Female	fish	5	SH	0.153	0.109		0.022	0.0186
July	Eastern	A	Female	chironomid	5	SH	0.025	0.02	2	0.022	0.0009

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
July	Eastern	B	Male	leaf	5	SH	0.032	0.02		0.053	0.0102
July	Eastern	B	Male	fish	5	SH	0.169	0.141		0.053	0
July	Eastern	B	Male	chironomid	5	SH	0.034	0.028	0	0.053	0.0003
July	Western	A	Male	leaf	6	SH	0.031	0.031		0.071	0
July	Western	A	Male	fish	6	SH	0.164	0.135		0.071	0
July	Western	A	Male	chironomid	6	SH	0.031	0.022	0	0.071	0.0045
July	Western	B	Male	leaf	5	SH	0.031	0.024		0.047	0.0049
July	Western	B	Male	fish	5	SH	0.165	0.138		0.047	0
July	Western	B	Male	chironomid	5	SH	0.026	0.013	2	0.047	0.0103
July	Eastern	B	Female	leaf	5	SH	0.032	0.028		0.024	0.0015
July	Eastern	B	Female	fish	5	SH	0.171	0.137		0.024	0.0021
July	Eastern	B	Female	chironomid	5	SH	0.036	0.031	0	0.024	0
September	Western	A	Male	leaf	1	ESM	0.01	0.005		0.126	0.005
September	Western	A	Male	fish	1	ESM	0.084	0.079		0.126	0.0006
September	Western	A	Male	chironomid	1	ESM	0.037	0.004	6.5	0.126	0.0329
September	Eastern	B	Male	leaf	2	ESM	0.01	0.007		0.059	0.003
September	Eastern	B	Male	fish	2	ESM	0.055	0.052		0.059	0.0001
September	Eastern	B	Male	chironomid	2	ESM	0.032	0.019	3	0.059	0.0124
September	Western	A	Male	leaf	2	ESM	0.01	0.01		0.062	0
September	Western	A	Male	fish	2	ESM	0.089	0.061		0.062	0.0246
September	Western	A	Male	chironomid	2	ESM	0.048	0.037	1	0.062	0.0099
September	Eastern	A	Female	leaf	2	ESM	0.048	0.019		0.029	0.0289
September	Eastern	A	Female	fish	2	ESM	0.023	0.028		0.029	0
September	Eastern	A	Female	chironomid	2	ESM	0.032	0.014	4	0.029	0.0176
September	Eastern	A	Male	leaf	2	ESM	0.023	0.012		0.064	0.0109
September	Eastern	A	Male	fish	2	ESM	0.013	0.056		0.064	0
September	Eastern	A	Male	chironomid	2	ESM	0.067	0.037	1	0.064	0.0289
September	Western	B	Male	leaf	2	ESM	0.036	0.014		0.052	0.0219
September	Western	B	Male	fish	2	ESM	0.018	0.022		0.052	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Western	B	Male	chironomid	2	ESM	0.024	0.007	6	0.052	0.0168
September	Eastern	A	Female	leaf	1	ESM	0.022	0.02		0.019	0.0019
September	Eastern	A	Female	fish	1	ESM	0.066	0.065		0.019	0
September	Eastern	A	Female	chironomid	1	ESM	0.031	0.029	2	0.019	0.0011
September	Eastern	A	Male	leaf	1	KP	0.01	0.006		0.09	0.004
September	Eastern	A	Male	fish	1	KP	0.081	0.076		0.09	0.0008
September	Eastern	A	Male	chironomid	1	KP	0.035	0.011	5.5	0.09	0.0237
September	Western	B	Female	leaf	2	KP	0.015	0.011		0.03	0.0039
September	Western	B	Female	fish	2	KP	0.062	0.049		0.03	0.0103
September	Western	B	Female	chironomid	2	KP	0.039	0.037	1	0.03	0.0009
September	Western	A	Female	leaf	1	KP	0.021	0.02		0.023	0.0009
September	Western	A	Female	fish	1	KP	0.05	0.05		0.023	0
September	Western	A	Female	chironomid	1	KP	0.041	0.028	1.5	0.023	0.0122
September	Western	A	Female	leaf	2	KP	0.014	0.013		0.016	0.0009
September	Western	A	Female	fish	2	KP	0.06	0.056		0.016	0.0009
September	Western	A	Female	chironomid	2	KP	0.044	0.043	0	0.016	0
September	Western	B	Female	leaf	1	KP	0.014	0.013		0.022	0.0009
September	Western	B	Female	fish	1	KP	0.07	0.07		0.022	0
September	Western	B	Female	chironomid	1	KP	0.056	0.051	1	0.026	0.0035
September	Western	B	Male	leaf	1	KP	0.01	0.009		0.083	0.0009
September	Western	B	Male	fish	1	KP	0.054	0.054		0.083	0
September	Western	B	Male	chironomid	1	KP	0.04	0.035	1.5	0.083	0.004
September	Eastern	B	Female	leaf	2	KP	0.011	0.01		0.035	0.0009
September	Eastern	B	Female	fish	2	KP	0.07	0.07		0.035	0
September	Eastern	B	Female	chironomid	2	KP	0.04	0.019	4	0.035	0.0204
September	Western	A	Male	leaf	8	ESM	0.032	0.032		0.08	0
September	Western	A	Male	fish	8	ESM	0.07	0.066		0.08	0.0003
September	Western	A	Male	chironomid	8	ESM	0.042	0.026	3	0.08	0.0152
September	Eastern	B	Male	leaf	4	ESM	0.02	0.02		0.062	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Eastern	B	Male	fish	4	ESM	0.047	0.045		0.062	0
September	Eastern	B	Male	chironomid	4	ESM	0.034	0.034	0	0.062	0
September	Eastern	A	Male	leaf	8	ESM	0.029	0.018		0.073	0.0109
September	Eastern	A	Male	fish	8	ESM	0.06	0.058		0.073	0
September	Eastern	A	Male	chironomid	8	ESM	0.042	0.012	4	0.073	0.0296
September	Eastern	A	Female	leaf	4	ESM	0.017	0.017		0.048	0
September	Eastern	A	Female	fish	4	ESM	0.07	0.069		0.048	0
September	Eastern	A	Female	chironomid	4	ESM	0.036	0.035	0	0.048	0
September	Eastern	A	Male	leaf	4	ESM	0.042	0.036		0.067	0.0058
September	Eastern	A	Male	fish	4	ESM	0.085	0.074		0.067	0.0069
September	Eastern	A	Male	chironomid	4	ESM	0.049	0.026	4.5	0.067	0.0222
September	Western	B	Male	leaf	4	ESM	0.035	0.031		0.068	0.0038
September	Western	B	Male	fish	4	ESM	0.025	0.023		0.068	0.0007
September	Western	B	Male	chironomid	4	ESM	0.042	0.005	7	0.068	0.0369
September	Eastern	B	Female	leaf	4	ESM	0.011	0.011		0.031	0
September	Eastern	B	Female	fish	4	ESM	0.038	0.037		0.031	0
September	Eastern	B	Female	chironomid	4	ESM	0.041	0.035	2.5	0.031	0.005
September	Western	B	Female	leaf	8	ESM	0.04	0.04		0.031	0
September	Western	B	Female	fish	8	ESM	0.078	0.072		0.031	0.002
September	Western	B	Female	chironomid	8	ESM	0.045	0.029	3	0.031	0.0151
September	Eastern	A	Female	leaf	8	KP	0.01	0.008		0.035	0.0019
September	Eastern	A	Female	fish	8	KP	0.036	0.032		0.035	0.0022
September	Eastern	A	Female	chironomid	8	KP	0.046	0.033	2	0.035	0.012
September	Western	A	Female	leaf	4	KP	0.015	0.015		0.041	0
September	Western	A	Female	fish	4	KP	0.037	0.037		0.041	0
September	Western	A	Female	chironomid	4	KP	0.046	0.029	2	0.041	0.0161
September	Eastern	B	Male	leaf	8	KP	0.016	0.01		0.058	0.0059
September	Eastern	B	Male	fish	8	KP	0.077	0.063		0.058	0.0105
September	Eastern	B	Male	chironomid	8	KP	0.049	0.031	2	0.058	0.0171

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Western	A	Male	leaf	4	KP	0.014	0.01		0.078	0.0039
September	Western	A	Male	fish	4	KP	0.035	0.025		0.078	0.0086
September	Western	A	Male	chironomid	4	KP	0.043	0.026	4	0.078	0.0162
September	Eastern	B	Female	leaf	8	KP	0.01	0.009		0.048	0.0009
September	Eastern	B	Female	fish	8	KP	0.028	0.021		0.048	0.0058
September	Eastern	B	Female	chironomid	8	KP	0.04	0.038	1	0.048	0.0009
September	Western	B	Male	leaf	8	KP	0.028	0.019		0.067	0.0089
September	Western	B	Male	fish	8	KP	0.038	0.036		0.067	0
September	Western	B	Male	chironomid	8	KP	0.048	0.021	4	0.067	0.0264
September	Eastern	B	Female	leaf	3	ESM	0.071	0.053		0.053	0.0177
September	Eastern	B	Female	fish	3	ESM	0.102	0.097		0.114	0
September	Eastern	B	Female	chironomid	3	ESM	0.047	0.03	2	0.114	0.0161
September	Western	B	Male	leaf	3	ESM	0.031	0.03		0.114	0.0008
September	Western	B	Male	fish	3	ESM	0.089	0.077		0.114	0.0077
September	Western	B	Male	chironomid	3	ESM	0.042	0.005	7	0.114	0.0369
September	Western	A	Female	leaf	7	ESM	0.026	0.026		0.05	0
September	Western	A	Female	fish	7	ESM	0.043	0.042		0.05	0
September	Western	A	Female	chironomid	7	ESM	0.034	0.008	6	0.05	0.0258
September	Eastern	A	Male	leaf	3	ESM	0.056	0.051		0.135	0.0047
September	Eastern	A	Male	fish	3	ESM	0.113	0.105		0.135	0.0021
September	Eastern	A	Male	chironomid	3	ESM	0.042	0.032	1.5	0.135	0.009
September	Western	B	Female	leaf	3	ESM	0.029	0.022		0.022	0.0069
September	Western	B	Female	fish	3	ESM	0.102	0.098		0.022	0
September	Western	B	Female	chironomid	3	ESM	0.053	0.041	2	0.022	0.0108
September	Eastern	A	Male	leaf	7	ESM	0.031	0.028		0.059	0.0028
September	Eastern	A	Male	fish	7	ESM	0.078	0.065		0.059	0.0094
September	Eastern	A	Male	chironomid	7	ESM	0.034	0.02	3	0.059	0.0134
September	Eastern	A	Female	leaf	3	ESM	0.05	0.04		0.016	0.0097
September	Eastern	A	Female	fish	3	ESM	0.095	0.091		0.016	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Eastern	A	Female	chironomid	3	ESM	0.052	0.038	3.5	0.016	0.0129
September	Western	A	Male	leaf	3	KP	0.021	0.021		0.074	0
September	Western	A	Male	fish	3	KP	0.037	0.034		0.074	0.0011
September	Western	A	Male	chironomid	3	KP	0.041	0.032	3	0.074	0.008
September	Western	B	Female	leaf	7	KP	0.008	0.008		0.032	0
September	Western	B	Female	fish	7	KP	0.023	0.022		0.032	0
September	Western	B	Female	chironomid	7	KP	0.043	0.026	1.5	0.032	0.0162
September	Eastern	B	Male	leaf	7	KP	0.013	0.01		0.049	0.0029
September	Eastern	B	Male	fish	7	KP	0.046	0.042		0.049	0.0017
September	Eastern	B	Male	chironomid	7	KP	0.043	0.032	4	0.049	0.01
September	Western	A	Male	leaf	7	KP	0.01	0.008		0.043	0.0019
September	Western	A	Male	fish	7	KP	0.045	0.042		0.043	0.0007
September	Western	A	Male	chironomid	7	KP	0.038	0.031	2	0.043	0.0061
September	Eastern	B	Male	leaf	3	KP	0.018	0.016		0.046	0.0019
September	Eastern	B	Male	fish	3	KP	0.056	0.054		0.046	0
September	Eastern	B	Male	chironomid	3	KP	0.047	0.032	4	0.046	0.014
September	Western	A	Female	leaf	3	KP	0.011	0.011		0.073	0
September	Western	A	Female	fish	3	KP	0.075	0.051		0.073	0.0212
September	Western	A	Female	chironomid	3	KP	0.044	0.031	3	0.073	0.0121
September	Eastern	B	Female	leaf	7	KP	0.008	0.008		0.013	0
September	Eastern	B	Female	fish	7	KP	0.044	0.035		0.013	0.007
September	Eastern	B	Female	chironomid	7	KP	0.041	0.02	3	0.013	0.0204
September	Eastern	A	Female	leaf	7	KP	0.037	0.023		0.032	0.0139
September	Eastern	A	Female	fish	7	KP	0.048	0.037		0.032	0.0089
September	Eastern	A	Female	chironomid	7	KP	0.03	0.012	6	0.032	0.0176
September	Eastern	A	Female	leaf	6	ESM	0.017	0.017		0.031	0
September	Eastern	A	Female	fish	6	ESM	0.107	0.097		0.031	0.0046
September	Eastern	A	Female	chironomid	6	ESM	0.037	0.02	1	0.031	0.0164
September	Eastern	A	Male	leaf	6	ESM	0.024	0.017		0.064	0.0069

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Eastern	A	Male	fish	6	ESM	0.036	0.036		0.064	0
September	Eastern	A	Male	chironomid	6	ESM	0.054	0.037	1	0.064	0.0159
September	Eastern	B	Female	leaf	6	ESM	0.053	0.04		0.026	0.0127
September	Eastern	B	Female	fish	6	ESM	0.119	0.118		0.026	0
September	Eastern	B	Female	chironomid	6	ESM	0.053	0.038	2	0.026	0.0139
September	Western	B	Female	leaf	5	ESM	0.037	0.032		0.038	0.0048
September	Western	B	Female	fish	5	ESM	0.096	0.092		0.038	0
September	Western	B	Female	chironomid	5	ESM	0.046	0.041	0	0.038	0.0038
September	Western	B	Male	leaf	6	KP	0.024	0.021		0.062	0.0029
September	Western	B	Male	fish	6	KP	0.036	0.033		0.062	0.0012
September	Western	B	Male	chironomid	6	KP	0.054	0.044	2	0.062	0.0087
September	Western	B	Male	leaf	5	KP	0.027	0.014		0.055	0.0129
September	Western	B	Male	fish	5	KP	0.048	0.048		0.055	0
September	Western	B	Male	chironomid	5	KP	0.051	0.036	3	0.055	0.0139
September	Western	B	Female	leaf	6	KP	0.014	0.011		0.018	0.0029
September	Western	B	Female	fish	6	KP	0.06	0.06		0.018	0
September	Western	B	Female	chironomid	6	KP	0.051	0.03	3	0.018	0.0201
September	Eastern	B	Male	leaf	6	KP	0.026	0.02		0.037	0.0059
September	Eastern	B	Male	fish	6	KP	0.078	0.07		0.037	0.0041
September	Eastern	B	Male	chironomid	6	KP	0.076	0.023	4	0.037	0.0523
September	Western	A	Male	leaf	5	KP	0.019	0.015		0.043	0.0039
September	Western	A	Male	fish	5	KP	0.049	0.047		0.043	0
September	Western	A	Male	chironomid	5	KP	0.028	0.019	3	0.043	0.0084
September	Eastern	A	Male	leaf	5	KP	0.018	0.018		0.082	0
September	Eastern	A	Male	fish	5	KP	0.042	0.039		0.082	0.0008
September	Eastern	A	Male	chironomid	5	KP	0.044	0.017	5	0.082	0.0265
September	Western	A	Female	leaf	5	KP	0.011	0.011		0.041	0
September	Western	A	Female	fish	5	KP	0.054	0.049		0.041	0.0023
September	Western	A	Female	chironomid	5	KP	0.072	0.041	3	0.041	0.0298

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
September	Eastern	B	Female	leaf	5	KP	0.013	0.007		0.014	0.006
September	Eastern	B	Female	fish	5	KP	0.044	0.044		0.014	0
September	Eastern	B	Female	chironomid	5	KP	0.046	0.024	3	0.014	0.0213
September	Western	A	Male	leaf	6	KP	0.013	0.01		0.043	0.0029
September	Western	A	Male	fish	6	KP	0.032	0.031		0.043	0
September	Western	A	Male	chironomid	6	KP	0.049	0.005	6.5	0.043	0.0439
September	Eastern	A	Female	leaf	5	KP	0.035	0.019		0.058	0.0159
September	Eastern	A	Female	fish	5	KP	0.059	0.05		0.058	0.0062
September	Eastern	A	Female	chironomid	5	KP	0.039	0.029	2	0.058	0.0091
September	Western	A	Female	leaf	6	KP	0.017	0.015		0.043	0.0019
September	Western	A	Female	fish	6	KP	0.032	0.031		0.043	0
September	Western	A	Female	chironomid	6	KP	0.043	0.01	5	0.043	0.0327
November	Eastern	A	Male	leaf	2	ESM	0.043	0.037		0.06	0.0011
November	Eastern	A	Male	fish	2	ESM	0.06	0.061		0.06	0
November	Eastern	A	Male	chironomid	2	ESM	0.043	0.028	1	0.06	0.0147
November	Eastern	B	Male	leaf	1	ESM	0.082	0.071		0.052	0.0016
November	Eastern	B	Male	fish	1	ESM	0.066	0.06		0.052	0
November	Eastern	B	Male	chironomid	1	ESM	0.042	0.038	0	0.052	0.0036
November	Eastern	A	Female	leaf	2	ESM	0.044	0.038		0.066	0.001
November	Eastern	A	Female	fish	2	ESM	0.046	0.047		0.066	0
November	Eastern	A	Female	chironomid	2	ESM	0.035	0.034	0	0.066	0.0007
November	Eastern	B	Female	leaf	2	ESM	0.026	0.028		0.035	0
November	Eastern	B	Female	fish	2	ESM	0.055	0.05		0.035	0
November	Eastern	B	Female	chironomid	2	ESM	0.034	0.03	0	0.035	0.0037
November	Western	B	Female	leaf	1	KP	0.014	0.01		0.062	0.0027
November	Western	B	Female	fish	1	KP	0.038	0.034		0.062	0
November	Western	B	Female	chironomid	1	KP	0.037	0.032	1	0.062	0.0047
November	Eastern	B	Female	leaf	1	KP	0.049	0.041		0.028	0.0026
November	Eastern	B	Female	fish	1	KP	0.051	0.048		0.028	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Eastern	B	Female	chironomid	1	KP	0.031	0.022	3	0.028	0.0088
November	Western	A	Female	leaf	2	KP	0.015	0.012		0.019	0.0014
November	Western	A	Female	fish	2	KP	0.051	0.044		0.019	0.0002
November	Western	A	Female	chironomid	2	KP	0.04	0.031	2	0.019	0.0087
November	Western	A	Female	leaf	1	KP	0.017	0.011		0.047	0.0045
November	Western	A	Female	fish	1	KP	0.043	0.034		0.047	0.0038
November	Western	A	Female	chironomid	1	KP	0.033	0.024	2	0.047	0.0088
November	Western	B	Male	leaf	2	KP	0.022	0.021		0.048	0
November	Western	B	Male	fish	2	KP	0.103	0.08		0.048	0.0107
November	Western	B	Male	chironomid	2	KP	0.026	0.016	4	0.048	0.0098
November	Western	A	Male	leaf	1	KP	0.016	0.012		0.082	0.0024
November	Western	A	Male	fish	1	KP	0.049	0.047		0.082	0
November	Western	A	Male	chironomid	1	KP	0.034	0.029	2.5	0.082	0.0047
November	Western	A	Male	leaf	2	KP	0.027	0.022		0.066	0.0021
November	Western	A	Male	fish	2	KP	0.049	0.037		0.066	0.0063
November	Western	A	Male	chironomid	2	KP	0.028	0.022	1	0.066	0.0058
November	Eastern	B	Male	leaf	2	KP	0.019	0.014		0.034	0.0031
November	Eastern	B	Male	fish	2	KP	0.068	0.066		0.034	0
November	Eastern	B	Male	chironomid	2	KP	0.037	0.018	4	0.034	0.0188
November	Eastern	A	Male	leaf	1	KP	0.012	0.009		0.072	0.0018
November	Eastern	A	Male	fish	1	KP	0.05	0.048		0.072	0
November	Eastern	A	Male	chironomid	1	KP	0.032	0.012	3.5	0.072	0.0199
November	Western	B	Female	leaf	2	KP	0.018	0.014		0.027	0.0021
November	Western	B	Female	fish	2	KP	0.086	0.086		0.027	0
November	Western	B	Female	chironomid	2	KP	0.038	0.019	3	0.027	0.0188
November	Eastern	A	Female	leaf	1	KP	0.029	0.025		0.037	0.0007
November	Eastern	A	Female	fish	1	KP	0.078	0.077		0.037	0
November	Eastern	A	Female	chironomid	1	KP	0.04	0.033	1	0.037	0.0067
November	Western	B	Male	leaf	1	KP	0.013	0.013		0.091	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Western	B	Male	fish	1	KP	0.119	0.119		0.091	0
November	Western	B	Male	chironomid	1	KP	0.034	0.018	4.5	0.091	0.0158
November	Eastern	A	Female	leaf	4	ESM	0.024	0.02		0.058	0.0014
November	Eastern	A	Female	fish	4	ESM	0.061	0.058		0.058	0
November	Eastern	A	Female	chironomid	4	ESM	0.035	0.024	2	0.058	0.0108
November	Eastern	B	Male	leaf	4	ESM	0.022	0.011		0.041	0.0095
November	Eastern	B	Male	fish	4	ESM	0.03	0.03		0.041	0
November	Eastern	B	Male	chironomid	4	ESM	0.028	0.028	0.5	0.041	0
November	Eastern	B	Female	leaf	8	ESM	0.062	0.053		0.027	0.002
November	Eastern	B	Female	fish	8	ESM	0.089	0.086		0.027	0
November	Eastern	B	Female	chironomid	8	ESM	0.042	0.024	1.5	0.027	0.0178
November	Eastern	B	Male	leaf	8	ESM	0.011	0.011		0.063	0
November	Eastern	B	Male	fish	8	ESM	0.038	0.035		0.063	0
November	Eastern	B	Male	chironomid	8	ESM	0.036	0.03	0	0.063	0.0057
November	Eastern	A	Male	leaf	8	ESM	0.011	0.013		0.068	0
November	Eastern	A	Male	fish	8	ESM	0.011	0.011		0.068	0
November	Eastern	A	Male	chironomid	8	ESM	0.036	0.033	0	0.068	0.0027
November	Western	A	Female	leaf	8	ESM	0.019	0.017		0.05	0
November	Western	A	Female	fish	8	ESM	0.078	0.077		0.05	0
November	Western	A	Female	chironomid	8	ESM	0.038	0.026	2	0.05	0.0117
November	Western	B	Female	leaf	8	ESM	0.038	0.038	2	0.029	0
November	Western	B	Female	fish	8	ESM	0.079	0.081		0.029	0
November	Western	B	Female	chironomid	8	ESM	0.036	0.035	0	0.029	0.0007
November	Western	B	Female	leaf	4	KP	0.019	0.018		0.071	0
November	Western	B	Female	fish	4	KP	0.016	0.013		0.071	0.001
November	Western	B	Female	chironomid	4	KP	0.035	0.018	4	0.071	0.0168
November	Western	B	Male	leaf	4	KP	0.032	0.019		0.102	0.0105
November	Western	B	Male	fish	4	KP	0.05	0.046		0.102	0
November	Western	B	Male	chironomid	4	KP	0.03	0.021	2	0.102	0.0088

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Eastern	A	Male	leaf	4	KP	0.021	0.011		0.078	0.0085
November	Eastern	A	Male	fish	4	KP	0.028	0.011		0.078	0.0153
November	Eastern	A	Male	chironomid	4	KP	0.038	0.015	4	0.078	0.0229
November	Eastern	A	Female	leaf	8	KP	0.022	0.016		0.025	0.0039
November	Eastern	A	Female	fish	8	KP	0.068	0.058		0.025	0.0011
November	Eastern	A	Female	chironomid	8	KP	0.031	0.02	4	0.025	0.0108
November	Western	A	Male	leaf	4	KP	0.023	0.02		0.087	0.0004
November	Western	A	Male	fish	4	KP	0.037	0.033		0.087	0
November	Western	A	Male	chironomid	4	KP	0.034	0.018	4	0.087	0.0158
November	Western	A	Female	leaf	4	KP	0.014	0.014		0.022	0
November	Western	A	Female	fish	4	KP	0.105	0.099		0.022	0
November	Western	A	Female	chironomid	4	KP	0.03	0.016	4	0.022	0.0138
November	Western	A	Male	leaf	8	KP	0.024	0.024		0.088	0
November	Western	A	Male	fish	8	KP	0.033	0.024		0.088	0.0053
November	Western	A	Male	chironomid	8	KP	0.026	0.003	7	0.088	0.023
November	Western	B	Male	leaf	8	KP	0.027	0.02		0.106	0.0044
November	Western	B	Male	fish	8	KP	0.073	0.048		0.106	0.0176
November	Western	B	Male	chironomid	8	KP	0.041	0.03	2	0.106	0.0107
November	Eastern	B	Female	leaf	4	KP	0.019	0.019		0.101	0
November	Eastern	B	Female	fish	4	KP	0.037	0.032		0.101	0.0001
November	Eastern	B	Female	chironomid	4	KP	0.033	0.027	0.5	0.101	0.0057
November	Eastern	B	Female	leaf	7	ESM	0.02	0.017		0.029	0.0008
November	Eastern	B	Female	fish	7	ESM	0.083	0.083		0.029	0
November	Eastern	B	Female	chironomid	7	ESM	0.042	0.029	1.5	0.029	0.0127
November	Western	B	Female	leaf	7	ESM	0.011	0.011		0.108	0
November	Western	B	Female	fish	7	ESM	0.079	0.073		0.108	0
November	Western	B	Female	chironomid	7	ESM	0.028	0.007	6	0.108	0.0209
November	Western	A	Male	leaf	7	ESM	0.059	0.047		0.104	0.0058
November	Western	A	Male	fish	7	ESM	0.065	0.065		0.104	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Western	A	Male	chironomid	7	ESM	0.046	0.04	1	0.104	0.0056
November	Eastern	B	Female	leaf	3	ESM	0.05	0.042		0.03	0.0024
November	Eastern	B	Female	fish	3	ESM	0.062	0.062		0.03	0
November	Eastern	B	Female	chironomid	3	ESM	0.026	0.016	2.5	0.03	0.0098
November	Western	B	Male	leaf	3	ESM	0.018	0.017		0.067	0
November	Western	B	Male	fish	3	ESM	0.085	0.073		0.067	0.0008
November	Western	B	Male	chironomid	3	ESM	0.029	0.012	3.5	0.067	0.0169
November	Western	A	Male	leaf	3	ESM	0.028	0.024		0.117	0.0008
November	Western	A	Male	fish	3	ESM	0.059	0.059		0.117	0
November	Western	A	Male	chironomid	3	ESM	0.035	0.03	1	0.117	0.0047
November	Eastern	B	Male	leaf	3	ESM	0.048	0.042		0.061	0.0004
November	Eastern	B	Male	fish	3	ESM	0.064	0.064		0.061	0
November	Eastern	B	Male	chironomid	3	ESM	0.026	0.025	0	0.061	0.0008
November	Western	B	Male	leaf	7	ESM	0.036	0.031		0.102	0.0009
November	Western	B	Male	fish	7	ESM	0.042	0.039		0.102	0
November	Western	B	Male	chironomid	7	ESM	0.034	0.029	1	0.102	0.0047
November	Eastern	A	Female	leaf	3	ESM	0.046	0.038		0.063	0.003
November	Eastern	A	Female	fish	3	ESM	0.086	0.086		0.063	0
November	Eastern	A	Female	chironomid	3	ESM	0.03	0.028	0	0.063	0.0017
November	Eastern	A	Male	leaf	3	ESM	0.025	0.024		0.032	0
November	Eastern	A	Male	fish	3	ESM	0.049	0.049		0.032	0
November	Eastern	A	Male	chironomid	3	ESM	0.038	0.03	1.5	0.032	0.0077
November	Eastern	A	Male	leaf	7	KP	0.02	0.02		0.096	0
November	Eastern	A	Male	fish	7	KP	0.037	0.032		0.096	0.0001
November	Eastern	A	Male	chironomid	7	KP	0.03	0.029	0.5	0.096	0.0007
November	Eastern	A	Female	leaf	7	KP	0.013	0.01		0.058	0.0017
November	Eastern	A	Female	fish	7	KP	0.043	0.038		0.058	0
November	Eastern	A	Female	chironomid	7	KP	0.029	0.026	1	0.058	0.0027
November	Western	B	Female	leaf	3	KP	0.013	0.011		0.055	0.0005

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Western	B	Female	fish	3	KP	0.058	0.044		0.055	0.0072
November	Western	B	Female	chironomid	3	KP	0.032	0.014	4	0.055	0.0179
November	Western	A	Female	leaf	7	KP	0.022	0.008		0.058	0.0129
November	Western	A	Female	fish	7	KP	0.044	0.035		0.058	0.0036
November	Western	A	Female	chironomid	7	KP	0.029	0.017	3	0.058	0.0118
November	Western	A	Female	leaf	3	KP	0.01	0.008		0.05	0.0009
November	Western	A	Female	fish	3	KP	0.029	0.025		0.05	0.0002
November	Western	A	Female	chironomid	3	KP	0.035	0.033	0	0.05	0.0017
November	Western	A	Female	leaf	5	ESM	0.049	0.037		0.027	0.0071
November	Western	A	Female	fish	5	ESM	0.08	0.077		0.027	0
November	Western	A	Female	chironomid	5	ESM	0.027	0.026	0.5	0.027	0.0007
November	Western	B	Female	leaf	5	ESM	0.029	0.028		0.062	0
November	Western	B	Female	fish	5	ESM	0.08	0.078		0.062	0
November	Western	B	Female	chironomid	5	ESM	0.028	0.029	0	0.062	0
November	Eastern	B	Male	leaf	6	ESM	0.043	0.044		0.098	0
November	Eastern	B	Male	fish	6	ESM	0.092	0.084		0.098	0
November	Eastern	B	Male	chironomid	6	ESM	0.025	0.026	0	0.098	0
November	Eastern	A	Male	leaf	5	ESM	0.054	0.049		0.13	0
November	Eastern	A	Male	fish	5	ESM	0.056	0.05		0.13	0
November	Eastern	A	Male	chironomid	5	ESM	0.034	0.022	1	0.13	0.0118
November	Eastern	B	Female	leaf	6	ESM	0.019	0.018		0.016	0
November	Eastern	B	Female	fish	6	ESM	0.09	0.087		0.016	0
November	Eastern	B	Female	chironomid	6	ESM	0.037	0.037	0	0.016	0
November	Western	A	Female	leaf	6	ESM	0.049	0.047		0.025	0
November	Western	A	Female	fish	6	ESM	0.084	0.082		0.025	0
November	Western	A	Female	chironomid	6	ESM	0.025	0.018	3	0.025	0.0068
November	Western	B	Female	leaf	6	ESM	0.025	0.019		0.056	0.0035
November	Western	B	Female	fish	6	ESM	0.068	0.062		0.056	0
November	Western	B	Female	chironomid	6	ESM	0.022	0.022	0	0.056	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
November	Western	B	Male	leaf	6	ESM	0.044	0.04		0.106	0
November	Western	B	Male	fish	6	ESM	0.065	0.055		0.106	0.0015
November	Western	B	Male	chironomid	6	ESM	0.022	0.003	7	0.106	0.019
November	Eastern	A	Male	leaf	6	ESM	0.044	0.032		0.127	0.0078
November	Eastern	A	Male	fish	6	ESM	0.043	0.043		0.127	0
November	Eastern	A	Male	chironomid	6	ESM	0.024	0.024	0	0.127	0
November	Western	A	Male	leaf	5	ESM	0.04	0.038		0.111	0
November	Western	A	Male	fish	5	ESM	0.09	0.088		0.111	0
November	Western	A	Male	chironomid	5	ESM	0.025	0.026	0	0.111	0
November	Eastern	A	Female	leaf	5	KP	0.014	0.009		0.039	0.0038
November	Eastern	A	Female	fish	5	KP	0.038	0.03		0.039	0.0034
November	Eastern	A	Female	chironomid	5	KP	0.025	0.022	1	0.039	0.0028
November	Eastern	B	Male	leaf	5	KP	0.01	0.006		0.03	0.0032
November	Eastern	B	Male	fish	5	KP	0.031	0.022		0.03	0.0056
November	Eastern	B	Male	chironomid	5	KP	0.032	0.017	3.5	0.03	0.0148
November	Western	A	Male	leaf	6	KP	0.015	0.007		0.127	0.0071
November	Western	A	Male	fish	6	KP	0.055	0.041		0.127	0.0077
November	Western	A	Male	chironomid	6	KP	0.027	0.018	2	0.127	0.0088
November	Eastern	A	Female	leaf	6	KP	0.016	0.011		0.068	0.0035
November	Eastern	A	Female	fish	6	KP	0.035	0.03		0.068	0.0004
November	Eastern	A	Female	chironomid	6	KP	0.035	0.034	0	0.068	0.0007
November	Western	B	Male	leaf	5	KP	0.01	0.008		0.114	0.0009
November	Western	B	Male	fish	5	KP	0.044	0.039		0.114	0
November	Western	B	Male	chironomid	5	KP	0.039	0.079	0	0.114	0
November	Eastern	B	Female	leaf	5	KP	0.021	0.019		0.029	0
November	Eastern	B	Female	fish	5	KP	0.018	0.015		0.029	0.0007
November	Eastern	B	Female	chironomid	5	KP	0.038	0.034	1	0.029	0.0037
March	Western	B	Male	leaf	2	KP	0.079	0.068		0.128	0.0097
March	Western	B	Male	fish	2	KP	0.387	0.307		0.128	0

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Western	B	Male	chironomid	2	KP	0.047	0.027	3.5	0.128	0.0154
March	Western	B	Female	leaf	1	KP	0.045	0.035		0.081	0.0093
March	Western	B	Female	fish	1	KP	0.239	0.192		0.081	0
March	Western	B	Female	chironomid	1	KP	0.029	0.02	1	0.081	0.0056
March	Eastern	B	Female	leaf	2	KP	0.073	0.051	4	0.073	0.021
March	Eastern	B	Female	fish	2	KP	0.215	0.199		0.073	0
March	Eastern	B	Female	chironomid	2	KP	0.051	0.029	4	0.073	0.017
March	Eastern	A	Male	leaf	1	KP	0.07	0.064		0.083	0.0048
March	Eastern	A	Male	fish	1	KP	0.312	0.225		0.083	0.0279
March	Eastern	A	Male	chironomid	1	KP	0.056	0.028	3	0.083	0.0232
March	Western	A	Male	leaf	2	KP	0.066	0.057		0.062	0.0079
March	Western	A	Male	fish	2	KP	0.301	0.225		0.062	0.0169
March	Western	A	Male	chironomid	2	KP	0.06	0.029	4	0.062	0.026
March	Western	A	Female	leaf	1	KP	0.052	0.049		0.055	0.0021
March	Western	A	Female	fish	1	KP	0.239	0.195		0.055	0
March	Western	A	Female	chironomid	1	KP	0.051	0.023	4	0.055	0.024
March	Western	B	Male	leaf	1	AD	0.064	0.052	7	0.134	0.011
March	Western	B	Male	fish	1	AD	0.357	0.27	1	0.134	0.0161
March	Western	B	Male	chironomid	1	AD	0.041	0.023	2.5	0.134	0.014
March	Western	B	Female	leaf	2	AD	0.055	0.049		0.067	0.0051
March	Western	B	Female	fish	2	AD	0.325	0.243		0.067	0.0182
March	Western	B	Female	chironomid	2	AD	0.04	0.026	2.5	0.067	0.0095
March	Western	A	Male	leaf	1	AD	0.055	0.048		0.064	0.0061
March	Western	A	Male	fish	1	AD	0.301	0.242		0.064	0
March	Western	A	Male	chironomid	1	AD	0.036	0.074	4	0.064	0
March	Eastern	B	Male	leaf	1	AD	0.065	0.065		0.032	0
March	Eastern	B	Male	fish	1	AD	0.336	0.268		0.032	0
March	Eastern	B	Male	chironomid	1	AD	0.041	0.031	1	0.032	0.0047
March	Eastern	B	Male	leaf	2	AD	0.06	0.038		0.067	0.0213

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Eastern	B	Male	fish	2	AD	0.315	0.248		0.067	0.0019
March	Eastern	B	Male	chironomid	2	AD	0.047	0.043	0	0.067	0
March	Eastern	A	Male	leaf	8	KP	0.029	0.028		0.125	0.0005
March	Eastern	A	Male	fish	8	KP	0.203	0.156		0.125	0.0061
March	Eastern	A	Male	chironomid	8	KP	0.045	0.04	1	0.125	0
March	Eastern	B	Female	leaf	4	KP	0.084	0.074		0.086	0.0086
March	Eastern	B	Female	fish	4	KP	0.351	0.315		0.086	0
March	Eastern	B	Female	chironomid	4	KP	0.032	0.032	0	0.086	0
March	Western	A	Male	leaf	8	AD	0.06	0.053		0.078	0.006
March	Western	A	Male	fish	8	AD	0.272	0.197		0.078	0.0233
March	Western	A	Male	chironomid	8	AD	0.046	0.032	1	0.078	0.0085
March	Western	B	Male	leaf	8	AD	0.053	0.044		0.121	0.0082
March	Western	B	Male	fish	8	AD	0.385	0.284		0.121	0.0265
March	Western	B	Male	chironomid	8	AD	0.041	0.035	1	0.121	0
March	Eastern	B	Male	leaf	4	AD	0.061	0.06		0.076	0
March	Eastern	B	Male	fish	4	AD	0.302	0.237		0.076	0.0028
March	Eastern	B	Male	chironomid	4	AD	0.04	0.039	0	0.076	0
March	Eastern	B	Female	leaf	8	AD	0.061	0.061		0.032	0
March	Eastern	B	Female	fish	8	AD	0.279	0.23		0.032	0
March	Eastern	B	Female	chironomid	8	AD	0.044	0.026	2	0.032	0.0135
March	Eastern	B	Male	leaf	8	AD	0.056	0.049		0.042	0.0061
March	Eastern	B	Male	fish	8	AD	0.32	0.262		0.042	0
March	Eastern	B	Male	chironomid	8	AD	0.04	0.037	0.5	0.042	0
March	Western	B	Female	leaf	8	AD	0.061	0.054		0.073	0.006
March	Western	B	Female	fish	8	AD	0.3	0.255		0.073	0
March	Western	B	Female	chironomid	8	AD	0.046	0.019	4	0.073	0.0237
March	Western	A	Female	leaf	7	AD	0.056	0.043		0.04	0.0122
March	Western	A	Female	fish	7	AD	0.325	0.26		0.04	0
March	Western	A	Female	chironomid	7	AD	0.035	0.011	5.5	0.04	0.0221

season	lineage	site	sex	food	replicate	operator	Q1	Q2	chironomid larvae eaten (n)	amphipod weight	consumption
March	Eastern	A	Male	leaf	3	KP	0.065	0.058		0.031	0.0059
March	Eastern	A	Male	fish	3	KP	0.377	0.336		0.031	0
March	Eastern	A	Male	chironomid	3	KP	0.054	0.022	4	0.031	0.0282
March	Eastern	A	Male	leaf	5	KP	0.054	0.048		0.069	0.0051
March	Eastern	A	Male	fish	5	KP	0.197	0.147		0.069	0.0114
March	Eastern	A	Male	chironomid	5	KP	0.047	0.022	4	0.069	0.0212
March	Western	B	Male	leaf	6	AD	0.064	0.059		0.121	0.0039
March	Western	B	Male	fish	6	AD	0.331	0.243		0.121	0.0242
March	Western	B	Male	chironomid	6	AD	0.041	0.041	0	0.121	0
March	Eastern	B	Female	leaf	6	AD	0.066	0.054		0.051	0.011
March	Eastern	B	Female	fish	6	AD	0.296	0.246		0.051	0
March	Eastern	B	Female	chironomid	6	AD	0.032	0.072	0	0.051	0
March	Eastern	B	Male	leaf	5	AD	0.061	0.058		0.053	0.0019
March	Eastern	B	Male	fish	5	AD	0.32	0.267		0.053	0
March	Eastern	B	Male	chironomid	5	AD	0.038	0.018	4.5	0.053	0.0169
March	Western	A	Male	leaf	6	AD	0.065	0.062		0.06	0.0018
March	Western	A	Male	fish	6	AD	0.344	0.26		0.06	0.0158
March	Western	A	Male	chironomid	6	AD	0.042	0.02	3	0.06	0.0186

Table 4. The measurements in control treatments from food preference experiment. T1 - the amount of food (g) before the experiment; T2 - the amount of food (g) after the experiment. Initials for operator: AD - Andrea Desiderato, ESM - Eliza Szczerkowska-Majchrzak, KP - Krzysztof Podwysocki, SH - Sylwia Holak.

season	food	replicate	operator	T1	T2
March	leaf	1	KP	0.077	0.072
March	leaf	2	AD	0.05	0.048
March	leaf	3	KP	0.073	0.07
March	leaf	4	AD	0.058	0.049
March	leaf	5	KP	0.081	0.058
March	leaf	6	AD	0.059	0.038

season	food	replicate	operator	T1	T2
March	leaf	7	KP	0.037	0.034
March	leaf	8	AD	0.066	0.066
March	fish	1	KP	0.153	0.112
March	fish	2	AD	0.291	0.227
March	fish	3	KP	0.304	0.209
March	fish	4	AD	0.284	0.225
March	fish	5	KP	0.225	0.197
March	fish	6	AD	0.382	0.327
March	fish	7	KP	0.244	0.219
March	fish	8	AD	0.422	0.322
March	chironomid	1	KP	0.041	0.04
March	chironomid	2	AD	0.032	0.032
March	chironomid	3	KP	0.035	0.035
March	chironomid	4	AD	0.036	0.035
March	chironomid	5	KP	0.041	0.041
March	chironomid	6	AD	0.046	0.045
March	chironomid	7	KP	0.055	0.051
March	chironomid	8	AD	0.04	0.04
May	leaf	1	KP	0.029	0.024
May	leaf	2	KP	0.025	0.024
May	leaf	3	KP	0.018	0.018
May	leaf	4	AD	0.055	0.041
May	leaf	5	KP	0.032	0.032
May	leaf	6	AD	0.043	0.036
May	leaf	7	KP	0.035	0.03
May	leaf	8	AD	0.053	0.041
May	fish	1	KP	0.206	0.162
May	fish	2	KP	0.158	0.118
May	fish	3	KP	0.226	0.175

season	food	replicate	operator	T1	T2
May	fish	4	AD	0.15	0.12
May	fish	5	KP	0.217	0.202
May	fish	6	AD	0.119	0.079
May	fish	7	KP	0.13	0.127
May	fish	8	AD	0.192	0.159
May	chironomid	1	KP	0.03	0.026
May	chironomid	2	KP	0.032	0.029
May	chironomid	3	KP	0.029	0.022
May	chironomid	4	AD	0.029	0.029
May	chironomid	5	KP	0.036	0.032
May	chironomid	6	AD	0.035	0.041
May	chironomid	7	KP	0.043	0.036
May	chironomid	8	AD	0.03	0.037
July	leaf	1	KP	0.067	0.067
July	leaf	2	KP	0.04	0.038
July	leaf	3	KP	0.041	0.041
July	leaf	4	KP	0.017	0.017
July	leaf	5	KP	0.021	0.019
July	leaf	6	SH	0.036	0.036
July	leaf	7	KP	0.017	0.011
July	leaf	8	KP	0.011	0.011
July	fish	1	KP	0.094	0.072
July	fish	2	KP	0.119	0.098
July	fish	3	KP	0.048	0.044
July	fish	4	KP	0.072	0.067
July	fish	5	KP	0.063	0.045
July	fish	6	SH	0.164	0.163
July	fish	7	KP	0.11	0.072
July	fish	8	KP	0.118	0.095

season	food	replicate	operator	T1	T2
July	chironomid	1	KP	0.037	0.031
July	chironomid	2	KP	0.029	0.027
July	chironomid	3	KP	0.035	0.032
July	chironomid	4	KP	0.026	0.025
July	chironomid	5	KP	0.037	0.023
July	chironomid	6	SH	0.028	0.028
July	chironomid	7	KP	0.033	0.032
July	chironomid	8	KP	0.032	0.02
September	leaf	1	ESM	0.011	0.011
September	leaf	2	KP	0.003	0.003
September	leaf	3	ESM	0.046	0.044
September	leaf	4	KP	0.011	0.011
September	leaf	5	ESM	0.02	0.021
September	leaf	6	ESM	0.047	0.05
September	leaf	7	ESM	0.049	0.044
September	leaf	8	ESM	0.014	0.014
September	fish	1	ESM	0.087	0.079
September	fish	2	KP	0.048	0.048
September	fish	3	ESM	0.072	0.064
September	fish	4	KP	0.072	0.072
September	fish	5	ESM	0.144	0.135
September	fish	6	ESM	0.162	0.157
September	fish	7	ESM	0.121	0.119
September	fish	8	ESM	0.105	0.095
September	chironomid	1	ESM	0.041	0.044
September	chironomid	2	KP	0.043	0.043
September	chironomid	3	ESM	0.04	0.04
September	chironomid	4	KP	0.043	0.043
September	chironomid	5	ESM	0.043	0.04

season	food	replicate	operator	T1	T2
September	chironomid	6	ESM	0.041	0.039
September	chironomid	7	ESM	0.05	0.045
September	chironomid	8	ESM	0.062	0.058
November	leaf	1	ESM	0.032	0.032
November	leaf	2	KP	0.022	0.021
November	leaf	3	ESM	0.046	0.044
November	leaf	4	ESM	0.08	0.076
November	leaf	5	KP	0.012	0.007
November	leaf	6	ESM	0.053	0.051
November	leaf	7	ESM	0.026	0.028
November	leaf	8	KP	0.016	0.013
November	fish	1	ESM	0.079	0.08
November	fish	2	KP	0.039	0.03
November	fish	3	ESM	0.052	0.049
November	fish	4	ESM	0.076	0.073
November	fish	5	KP	0.069	0.047
November	fish	6	ESM	0.038	0.036
November	fish	7	ESM	0.061	0.062
November	fish	8	KP	0.048	0.036
November	chironomid	1	ESM	0.037	0.036
November	chironomid	2	KP	0.029	0.026
November	chironomid	3	ESM	0.03	0.03
November	chironomid	4	ESM	0.029	0.032
November	chironomid	5	KP	0.035	0.035
November	chironomid	6	ESM	0.037	0.036
November	chironomid	7	ESM	0.031	0.031
November	chironomid	8	KP	0.025	0.025

Supplementary file 3

Table 1. Post hoc pairwise comparisons for the effect of the **season** in the GLMM analysis for **leaf consumption**. Significant effects (p.value ≤ 0.05) are in **bold**. Marginally significant effects (0.05 < p.value < 0.1) are in *Italic*. SE - standard error; df – degrees of freedom.

No.	contrast	ratio	SE	df	z.ratio	p.value
1	*March / May*	*0.62*	*0.11*	*Inf*	*-2.65*	*0.08*
2	March / July	0.87	0.16	Inf	-0.75	1.00
3	March / September	1.00	0.18	Inf	-0.01	1.00
4	March / November	1.01	0.18	Inf	0.05	1.00
5	May / July	1.39	0.18	Inf	1.73	0.83
6	May / September	1.60	0.18	Inf	2.57	0.10
7	**May / November**	1.62	0.18	Inf	2.79	**0.05**
8	July / September	1.15	0.18	Inf	0.77	1.00
9	July / November	1.16	0.18	Inf	0.82	1.00
10	September / November	1.01	0.18	Inf	0.06	1.00

Table 2. Post hoc pairwise comparisons for the effect of the **season** in the GLMM analysis for **fish tissue consumption**. Significant effects (p.value ≤ 0.05) are in **bold**. SE - standard error; df – degrees of freedom.

No.	contrast	ratio	SE	df	z.ratio	p.value
1	March / May	2.01	0.60	Inf	2.32	0.20
2	March / July	2.19	0.68	Inf	2.55	0.11
3	**March / September**	3.28	1.04	Inf	3.75	**<0.01**
4	**March / November**	3.87	1.24	Inf	4.22	**<0.01**
5	May / July	1.09	0.36	Inf	0.27	1.00
6	May / September	1.64	0.55	Inf	1.47	1.00
7	May / November	1.93	0.65	Inf	1.95	0.51
8	July / September	1.50	0.47	Inf	1.27	1.00
9	July / November	1.76	0.60	Inf	1.67	0.95
10	September / November	1.18	0.41	Inf	0.47	1.00

Table 3. Post hoc pairwise comparisons for the effect of the **season** in the GLMM analysis for **chironomid larvae consumption**. Significant effects (p.value ≤ 0.05) are in **bold**. SE - standard error; df – degrees of freedom.

No.	contrast	ratio	SE	df	null	z.ratio	p.value
1	March / May	0.90	0.14	Inf	1	-0.66	1.00
2	**March / July**	0.59	0.09	Inf	1	-3.66	**<0.01**
3	**March / September**	0.53	0.07	Inf	1	-4.60	**<0.01**
4	March / November	1.10	0.17	Inf	1	0.65	1.00
5	**May / July**	0.65	0.10	Inf	1	-2.85	**0.04**
6	**May / September**	0.58	0.08	Inf	1	-3.81	**<0.01**

No.	contrast	ratio	SE	df	null	z.ratio	p.value
7	May / November	1.22	0.18	Inf	1	1.32	1.00
8	July / September	0.90	0.11	Inf	1	-0.89	1.00
9	**July / November**	1.88	0.26	Inf	1	4.52	**<0.01**
10	**September / November**	2.10	0.28	Inf	1	5.48	**<0.01**

Table 4. Post hoc pairwise comparisons for the effect of the **season** in the GLMM analysis for **food preference**. Significant effects (p.value ≤ 0.05) are in **bold**. SE - standard error; df – degrees of freedom.

No.	contrast	ratio	SE	df	z.ratio	p.value
1	March / May	1.06	0.13	Inf	0.42	1.00
2	March / July	1.25	0.17	Inf	1.61	1.00
3	March / September	1.35	0.17	Inf	2.29	0.22
4	**March / November**	2.26	0.30	Inf	6.17	**<0.01**
5	May / July	1.19	0.14	Inf	1.44	1.00
6	May / September	1.27	0.13	Inf	2.33	0.20
7	**May / November**	2.14	0.23	Inf	7.19	**<0.01**
8	July / September	1.07	0.12	Inf	0.68	1.00
9	**July / November**	1.81	0.21	Inf	5.15	**<0.01**
10	**September / November**	1.68	0.18	Inf	4.96	**<0.01**

Table 5. Post hoc pairwise comparisons for the effect of the **interaction between lineage and season** in the GLMM analysis for **food preference**. Significant effects (p.value ≤ 0.05) are in **bold**. Marginally significant effects (0.05 < p.value < 0.1) are in *Italic*. SE - standard error; df – degrees of freedom.

No.	level	contrast	estimate	SE	df	z.ratio	p.value
1	*Food = leaf*	*Eastern / Western*	0.23	0.12	Inf	1.89	*0.06*
2	Food = fish	Eastern / Western	0.04	0.16	Inf	0.28	0.78
3	Food = chironomid	Eastern / Western	-0.13	0.10	Inf	-1.38	0.17
5	**Lineage = Western**	**Chironomid / Fish**	0.64	0.13	Inf	4.92	**<0.01**
6	**Lineage = Western**	**Chironomid / Leaf**	1.12	0.11	Inf	9.96	**<0.01**
7	**Lineage = Western**	**Fish / Leaf**	0.49	0.14	Inf	3.48	**<0.01**
8	**Lineage = Eastern**	**Chironomid / Fish**	0.46	0.13	Inf	3.56	**<0.01**
9	**Lineage = Eastern**	**Chironomid / Leaf**	0.76	0.11	Inf	6.89	**<0.01**
10	*Lineage = Eastern*	*Fish / Leaf*	0.30	0.14	Inf	2.20	*0.08*

Załącznik nr 2

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(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji artykułu; uczestniczeniu w badaniach terenowych; przeprowadzeniu eksperymentów oraz pomiarów; zaplanowaniu metod analiz statystycznych; przeprowadzeniu analiz statystycznych; przygotowaniu przeglądu literatury i przygotowaniu wstępu do artykułu; opisaniu materiału i metod użytych w artykule; opisaniu wyników w artykule; przygotowaniu dyskusji i wniosków w artykule; przygotowaniu tabel i grafik; korekcie artykułu zgodnie z uwagami współautorów; wysłaniu artykułu do czasopisma naukowego; byciu autorem korespondencyjnym; korekcie artykułu zgodnie z uwagami recenzentów; koordynowaniu prac zespołu; organizowaniu spotkań celem dyskusji nad analizami oraz manuskryptem; współzarządzaniu i koordynacji planowania i realizacji działań badawczych w projekcie.

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pomocy w przeprowadzeniu eksperymentów oraz pomiarów; pomocy w przygotowaniu tabel i grafik; przesłaniu uwag do artykułu pierwszemu autorowi.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

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OŚWIADCZENIE

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(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji badań; przeprowadzeniu części analiz statystycznych; interpretacji wyników; krytycznej rewizji wstępnej wersji manuskryptu; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

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podpis

Acknowledgements

Work was supported by the National Science Centre in Poland (grant: 2018/31/D/NZ8/03061). KP's PhD grant was funded by the University of Lodz. We are grateful to Łukasz Trębicki (University of Lodz), who helped us with the sampling. We send our gratitude to Michał Gruberski (University of Lodz), who helped us with setting up the cameras and software for recording. We are especially grateful to Carl Smith (University of Lodz) for help in the statistical analysis. We would like to thank Eglė Šidagytė-Copilas (Nature Research Centre in Vilnius), who gave some advice on statistical analysis. The authors are grateful to Monika Kuna-Majewska (University of Lodz) for her help in administrating the project that funded samplings and experiments.

Supplementary Table 1

Table 1. The results of the experiment. The aquaria are numbered: A-D. Symbols for treatments (first letter - the lineage affiliation of the exact individual, second letter - the lineage affiliation of the accompanying lineage): WW - the Western Lineage accompanied by the Western Lineage, WE - the Western Lineage accompanied by the Eastern Lineage, EW - the Eastern Lineage accompanied by the Western Lineage, EE - the Eastern Lineage accompanied by the Eastern Lineage. Symbols for populations (first letter - the population affiliation of the exact individual, second letter - the population affiliation of the accompanying population): A - Brzeg (the Western Lineage), B - Lubiąż (the Western Lineage), C - Wyszogród (the Eastern Lineage), D - Nieszawa (the Eastern Lineage). Microsporidia presence is marked with plus sign. Individuals removed from the analyses are marked with yellow colour.

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
1	18-19	A	WW	BB	1	blue	Male	14	0.042		
2	18-19	A	WW	BB	1	blue	Female	13	0.042		
3	18-19	A	WW	BB	1	blue	Male	12	0.062		
4	18-19	A	WW	BB	1	blue	Male	10	0.067		
5	18-19	A	WW	BB	1	blue	Female	10	0.026		
6	18-19	A	WW	BB	1	red	Female	6	0.026	dead	
7	18-19	A	WW	BB	1	red	Female	4	0.079		
8	18-19	A	WW	BB	1	red	Male	2	0.067		
9	18-19	A	WW	BB	1	blue	Male	2	0.046		
10	18-19	A	WW	BB	1	blue	Female	2	0.06		
11	18-19	A	WW	BB	1	red	Female	2	0.029		
12	18-19	A	WW	BB	1	blue	Female	1	0.044		
13	18-19	A	WW	BB	1	blue	Female	1	0.059		
14	18-19	A	WW	BB	1	red	Female	1	0.099		
15	18-19	A	WW	BB	1	red	Male	1	0.065		
16	18-19	A	WW	BB	1	blue	Male	1	0.054		
17	18-19	A	WW	BB	1	red	Female	1	0.067		
18	18-19	A	WW	BB	1	red	Male	1	0.067		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
19	18-19	A	WW	BB	1	red	Male	1	0.047		
20	18-19	A	WW	BB	1	red	Male	1	0.026		
21	18-19	B	WW	BB	2	blue	Female	14	0.03		
22	18-19	B	WW	BB	2	red	Male	14	0.037		
23	18-19	B	WW	BB	2	blue	Female	12	0.012		
24	18-19	B	WW	BB	2	blue	Male	6	0.071		
25	18-19	B	WW	BB	2	blue	Male	2	0.029		
26	18-19	B	WW	BB	2	red	Male	2	0.04		
27	18-19	B	WW	BB	2	red	Female	1	0.032		
28	18-19	B	WW	BB	2	blue	Male	1	0.076		
29	18-19	B	WW	BB	2	red	Male	1	0.024		
30	18-19	B	WW	BB	2	blue	Female	1	0.029		
31	18-19	B	WW	BB	2	blue	Male	1	0.056		
32	18-19	B	WW	BB	2	red	Female	1	0.064		
33	18-19	B	WW	BB	2	red	Female	1	0.046		
34	18-19	B	WW	BB	2	blue	Male	1	0.079		
35	18-19	B	WW	BB	2	red	Female	1	0.036		
36	18-19	B	WW	BB	2	blue	Male	1	0.05		
37	18-19	B	WW	BB	2	red	Female	1	0.044		
38	18-19	B	WW	BB	2	red	Male	1	0.052		
39	18-19	B	WW	BB	2	red	Female	1	0.034		
40	18-19	B	WW	BB	2	blue	Female	1	0.064		
41	18-19	C	EE	DD	1	red	Female	14	0.025		
42	18-19	C	EE	DD	1	red	Male	11	0.061		
43	18-19	C	EE	DD	1	red	Male	5	0.06		
44	18-19	C	EE	DD	1	blue	Male	5	0.049		
45	18-19	C	EE	DD	1	blue	Female	5	0.028		
46	18-19	C	EE	DD	1	blue	Female	3	0.049		
47	18-19	C	EE	DD	1	blue	Male	2	0.029		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
48	18-19	C	EE	DD	1	red	Male	2	0.074		
49	18-19	C	EE	DD	1	blue	Female	2	0.032		
50	18-19	C	EE	DD	1	blue	Male	1	0.018		
51	18-19	C	EE	DD	1	blue	Male	1	0.073		
52	18-19	C	EE	DD	1	blue	Female	1	0.035		
53	18-19	C	EE	DD	1	red	Female	1	0.022		
54	18-19	C	EE	DD	1	red	Male	1	0.084		
55	18-19	C	EE	DD	1	red	Female	1	0.031		
56	18-19	C	EE	DD	1	red	Male	1	0.02		
57	18-19	C	EE	DD	1	blue	Female	1	0.05		
58	18-19	C	EE	DD	1	blue	Female	1	0.025		
59	18-19	C	EE	DD	1	red	Male	1	0.049		
60	18-19	C	EE	DD	1	red	Female	1	0.035		
61	19-20	A	EE	CC	1	red	Male	14	0.135		
62	19-20	A	EE	CC	1	red	Female	14	0.04		
63	19-20	A	EE	CC	1	red	Female	14	0.053		
64	19-20	A	EE	CC	1	blue	Male	13	0.072	dead	+
65	19-20	A	EE	CC	1	blue	Male	10	0.108		
66	19-20	A	EE	CC	1	red	Female	8	0.072		
67	19-20	A	EE	CC	1	red	Female	7	0.053		
68	19-20	A	EE	CC	1	blue	Male	5	0.058		
69	19-20	A	EE	CC	1	blue	Female	5	0.047		
70	19-20	A	EE	CC	1	blue	Male	5	0.083		
71	19-20	A	EE	CC	1	blue	Male	5	0.059		
72	19-20	A	EE	CC	1	blue	Male	4	0.072		
73	19-20	A	EE	CC	1	red	Female	2	0.062		
74	19-20	A	EE	CC	1	red	Female	1	0.06		
75	19-20	A	EE	CC	1	red	Male	1	0.044		
76	19-20	A	EE	CC	1	red	Female	1	0.074		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
77	19-20	A	EE	CC	1	red	Female	1	0.029		
78	19-20	A	EE	CC	1	blue	Male	1	0.032	dead	
79	19-20	A	EE	CC	1	blue	Male	1	0.061	dead	
80	19-20	A	EE	CC	1	blue	Female	1	0.097		
81	19-20	B	EE	CD	1	red	Female	14	0.068		
82	19-20	B	EE	CD	1	red	Male	14	0.072		
83	19-20	B	EE	CD	1	red	Male	14	0.104	after moulting	
84	19-20	B	EE	DC	1	blue	Male	14	0.097		
85	19-20	B	EE	CD	1	red	Male	14	0.061		
86	19-20	B	EE	DC	1	blue	Male	14	0.084		
87	19-20	B	EE	DC	1	blue	Female	14	0.047		+
88	19-20	B	EE	CD	1	red	Male	8	0.053		
89	19-20	B	EE	DC	1	blue	Male	7	0.077		
90	19-20	B	EE	CD	1	red	Female	1	0.03		
91	19-20	B	EE	DC	1	blue	Female	1	0.028		
92	19-20	B	EE	DC	1	blue	Male	1	0.066		
93	19-20	B	EE	CD	1	red	Female	1	0.049		
94	19-20	B	EE	DC	1	blue	Female	1	0.026		
95	19-20	B	EE	DC	1	blue	Female	1	0.017		
96	19-20	B	EE	CD	1	red	Female	1	0.058		
97	19-20	B	EE	CD	1	red	Female	1	0.031		
98	19-20	B	EE	CD	1	red	Male	1	0.024		
99	19-20	B	EE	DC	1	blue	Female	1	0.04		
100	19-20	B	EE	DC	1	blue	Male	1	0.041		
101	19-20	C	WE	AD	1	red	Male	14	0.129		
102	19-20	C	EW	DA	1	blue	Male	14	0.046		
103	19-20	C	EW	DA	1	blue	Male	1	0.083		
104	19-20	C	WE	AD	1	red	Female	1	0.062		
105	19-20	C	EW	DA	1	blue	Female	1	0.038		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
106	19-20	C	EW	DA	1	blue	Male	1	0.031		+
107	19-20	C	WE	AD	1	red	Male	1	0.048		
108	19-20	C	WE	AD	1	red	Male	1	0.067		
109	19-20	C	EW	DA	1	blue	Male	1	0.066		
110	19-20	C	WE	AD	1	red	Male	1	0.036		
111	19-20	C	WE	AD	1	red	Female	1	0.048		
112	19-20	C	EW	DA	1	blue	Female	1	0.053		
113	19-20	C	EW	DA	1	blue	Female	1	0.036		
114	19-20	C	WE	AD	1	red	Female	1	0.026	dead	
115	19-20	C	EW	DA	1	blue	Female	1	0.037		
116	19-20	C	EW	DA	1	blue	Female	1	0.026		
117	19-20	C	WE	AD	1	red	Male	1	0.042		
118	19-20	C	WE	AD	1	red	Male	1	0.077		
119	19-20	C	WE	AD	1	red	Female	1	0.031	after moulting	
120	19-20	C	EW	DA	1	blue	Female	1	0.037		
121	19-20	D	EW	DB	1	red	Male	1	0.064		
122	19-20	D	EW	DB	1	red	Male	1	0.134		
123	19-20	D	WE	BD	1	blue	Female	1	0.016		
124	19-20	D	WE	BD	1	blue	Male	1	0.041		
125	19-20	D	WE	BD	1	blue	Female	1	0.034		
126	19-20	D	EW	DB	1	red	Male	1	0.03		
127	19-20	D	EW	DB	1	red	Female	1	0.03		
128	19-20	D	EW	DB	1	red	Female	1	0.035		
129	19-20	D	WE	BD	1	blue	Female	1	0.031		
130	19-20	D	WE	BD	1	blue	Female	3	0.053		
131	19-20	D	EW	DB	1	red	Male	3	0.058		
132	19-20	D	WE	BD	1	blue	Male	3	0.062		+
133	19-20	D	EW	DB	1	red	Male	3	0.073		
134	19-20	D	EW	DB	1	red	Female	3	0.046		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
135	19-20	D	WE	BD	1	blue	Female	3	0.04		
136	19-20	D	EW	DB	1	red	Male	3	0.089		
137	19-20	D	WE	BD	1	blue	Female	3	0.036		
138	19-20	D	EW	DB	1	red	Female	3	0.032		
139	19-20	D	WE	BD	1	blue	Male	3	0.066		
140	19-20	D	WE	BD	1	blue	Male	4	0.059		
141	20-21	A	WW	AB	1	blue	Male	13	0.201		
142	20-21	A	WW	AB	1	blue	Female	13	0.062		
143	20-21	A	WW	AB	1	blue	Female	3	0.108	dead	
144	20-21	A	WW	AB	1	blue	Female	3	0.035		+
145	20-21	A	WW	BA	1	red	Male	3	0.044	preacopula	+
146	20-21	A	WW	AB	1	blue	Female	3	0.03	preacopula	
147	20-21	A	WW	BA	1	red	Male	3	0.062		
148	20-21	A	WW	BA	1	red	Female	2	0.023		
149	20-21	A	WW	BA	1	red	Male	1	0.024	dead	
150	20-21	A	WW	BA	1	red	Female	1	0.013	dead after moulting	
151	20-21	A	WW	AB	1	blue	Female	1	0.034		
152	20-21	A	WW	BA	1	red	Male	1	0.061		
153	20-21	A	WW	BA	1	red	Male	1	0.086		
154	20-21	A	WW	BA	1	red	Female	1	0.062		
155	20-21	A	WW	AB	1	blue	Male	1	0.107		
156	20-21	A	WW	AB	1	blue	Male	1	0.084		
157	20-21	A	WW	AB	1	blue	Female	1	0.099		
158	20-21	A	WW	BA	1	red	Male	1	0.061		
159	20-21	A	WW	BA	1	red	Female	1	0.05		
160	20-21	A	WW	AB	1	blue	Male	1	0.079		
161	20-21	B	EW	CB	1	red	Male	12	0.079		
162	20-21	B	EW	CB	1	red	Male	12	0.041		
163	20-21	B	WE	BC	1	blue	Female	12	0.031		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
164	20-21	B	WE	BC	1	blue	Male	12	0.091		
165	20-21	B	WE	BC	1	blue	Male	5	0.105		
166	20-21	B	WE	BC	1	blue	Female	5	0.043		
167	20-21	B	WE	BC	1	blue	Male	3	0.052		
168	20-21	B	EW	CB	1	red	Male	2	0.076	dead	
169	20-21	B	EW	CB	1	red	Female	2	0.029	after moulting	
170	20-21	B	WE	BC	1	blue	Male	1	0.064		
171	20-21	B	EW	CB	1	red	Female	1	0.06		
172	20-21	B	WE	BC	1	blue	Male	1	0.05		
173	20-21	B	EW	CB	1	red	Female	1	0.025		
174	20-21	B	EW	CB	1	red	Female	1	0.06		
175	20-21	B	EW	CB	1	red	Female	1	0.031		
176	20-21	B	WE	BC	1	blue	Male	1	0.054		
177	20-21	B	EW	CB	1	red	Female	1	0.067		
178	20-21	B	EW	CB	1	red	Female	1	0.047		
179	20-21	B	WE	BC	1	blue	Female	1	0.036		
180	20-21	B	WE	BC	1	blue	Male	1	0.054		
181	20-21	C	WE	AD	2	blue	Male	10	0.102		
182	20-21	C	EW	DA	2	red	Male	10	0.056		
183	20-21	C	WE	AD	2	blue	Male	10	0.046		
184	20-21	C	WE	AD	2	blue	Female	7	0.078		
185	20-21	C	WE	AD	2	blue	Male	3	0.041	dead	+
186	20-21	C	EW	DA	2	red	Female	3	0.048		
187	20-21	C	WE	AD	2	blue	Female	3	0.046		
188	20-21	C	WE	AD	2	blue	Female	2	0.024		+
189	20-21	C	WE	AD	2	blue	Male	1	0.122		
190	20-21	C	EW	DA	2	red	Male	1	0.029	preacopula	
191	20-21	C	EW	DA	2	red	Male	1	0.044	preacopula	
192	20-21	C	EW	DA	2	red	Female	1	0.056		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
193	20-21	C	EW	DA	2	red	Female	1	0.052		
194	20-21	C	EW	DA	2	red	Female	1	0.071		
195	20-21	C	WE	AD	2	blue	Male	1	0.026		+
196	20-21	C	WE	AD	2	blue	Male	1	0.101		
197	20-21	C	WE	AD	2	blue	Female	1	0.026		
198	20-21	C	EW	DA	2	red	Female	1	0.038		
199	20-21	C	EW	DA	2	red	Male	1	0.078		
200	20-21	C	EW	DA	2	red	Female	1	0.029		
201	20-21	D	WE	BD	2	red	Female	14	0.055		
202	20-21	D	WE	BD	2	red	Male	12	0.044		
203	20-21	D	WE	BD	2	red	Female	9	0.047		
204	20-21	D	EW	DB	2	blue	Male	7	0.074		
205	20-21	D	EW	DB	2	blue	Female	2	0.018		
206	20-21	D	WE	BD	2	red	Male	1	0.048		
207	20-21	D	EW	DB	2	blue	Male	1	0.034		
208	20-21	D	WE	BD	2	red	Male	1	0.064		
209	20-21	D	WE	BD	2	red	Male	1	0.068		
210	20-21	D	EW	DB	2	blue	Male	1	0.02		
211	20-21	D	WE	BD	2	red	Female	1	0.025		
212	20-21	D	WE	BD	2	red	Female	1	0.062		
213	20-21	D	EW	DB	2	blue	Male	1	0.044		
214	20-21	D	WE	BD	2	red	Female	1	0.046		
215	20-21	D	EW	DB	2	blue	Female	1	0.036		
216	20-21	D	EW	DB	2	blue	Male	1	0.038		
217	20-21	D	WE	BD	2	red	Female	1	0.04		
218	20-21	D	EW	DB	2	blue	Female	1	0.024		
219	20-21	D	EW	DB	2	blue	Male	1	0.041		
220	20-21	D	EW	DB	2	blue	Female	1	0.04		
221	21-22	A	WW	BA	2	red	Female	10	0.032		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
222	21-22	A	WW	BA	2	blue	Female	7	0.025		
223	21-22	A	WW	BA	2	red	Male	3	0.071		
224	21-22	A	WW	AB	2	blue	Male	3	0.114		
225	21-22	A	WW	BA	2	red	Female	2	0.048	dead	
226	21-22	A	WW	BA	2	red	Female	2	0.048		
227	21-22	A	WW	AB	2	blue	Male	1	0.086	preacopula	
228	21-22	A	WW	AB	2	blue	Female	1	0.044	preacopula	
229	21-22	A	WW	BA	2	red	Male	1	0.041		
230	21-22	A	WW	AB	2	blue	Male	1	0.024		
231	21-22	A	WW	AB	2	blue	Male	1	0.049		
232	21-22	A	WW	BA	2	red	Male	1	0.036		
233	21-22	A	WW	AB	2	blue	Female	1	0.068		+
234	21-22	A	WW	BA	2	red	Female	1	0.049		
235	21-22	A	WW	BA	2	red	Female	1	0.042		
236	21-22	A	WW	AB	2	blue	Female	1	0.048		
237	21-22	A	WW	BA	2	red	Male	1	0.064		
238	21-22	A	WW	AB	2	blue	Male	1	0.044		
239	21-22	A	WW	AB	2	blue	Male	1	0.079		
240	21-22	A	WW	BA	2	red	Female	1	0.028		
241	21-22	B	WE	BC	2	red	Male	1	0.046		
242	21-22	B	EW	CB	2	blue	Male	1	0.087		
243	21-22	B	EW	CB	2	blue	Male	1	0.07		
244	21-22	B	EW	CB	2	blue	Female	1	0.037		
245	21-22	B	WE	BC	2	red	Male	1	0.085		
246	21-22	B	WE	BC	2	red	Female	1	0.043		
247	21-22	B	WE	BC	2	red	Male	1	0.067		
248	21-22	B	WE	BC	2	red	Female	1	0.064	dead	
249	21-22	B	EW	CB	2	blue	Female	2	0.086	dead	
250	21-22	B	EW	CB	2	blue	Male	3	0.107	dead	

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
251	21-22	B	WE	BC	2	red	Female	3	0.031		
252	21-22	B	EW	CB	2	blue	Male	3	0.115	preacopula	
253	21-22	B	EW	CB	2	blue	Female	3	0.052	preacopula	
254	21-22	B	WE	BC	2	red	Female	3	0.038		
255	21-22	B	WE	BC	2	red	Female	3	0.041		
256	21-22	B	WE	BC	2	red	Female	3	0.062		
257	21-22	B	EW	CB	2	blue	Female	3	0.038		
258	21-22	B	EW	CB	2	blue	Male	7	0.133		
259	21-22	B	EW	CB	2	blue	Male	14	0.127		
260	21-22	B	WE	BC	2	red	Male	14	0.053		
261	21-22	C	WW	BA	3	blue	Male	1	0.064		
262	21-22	C	WW	AB	3	red	Female	1	0.096		
263	21-22	C	WW	AB	3	red	Female	1	0.06		
264	21-22	C	WW	BA	3	blue	Female	1	0.055		
265	21-22	C	WW	AB	3	red	Male	1	0.031		
266	21-22	C	WW	AB	3	red	Male	1	0.049		
267	21-22	C	WW	BA	3	blue	Male	1	0.082		
268	21-22	C	WW	AB	3	red	Male	1	0.082		
269	21-22	C	WW	BA	3	blue	Female	1	0.04		
270	21-22	C	WW	AB	3	red	Female	1	0.038		
271	21-22	C	WW	AB	3	red	Male	1	0.041		
272	21-22	C	WW	BA	3	blue	Female	1	0.044		
273	21-22	C	WW	BA	3	blue	Female	1	0.046		
274	21-22	C	WW	AB	3	red	Male	2	0.103		
275	21-22	C	WW	AB	3	red	Female	2	0.076		
276	21-22	C	WW	AB	3	red	Male	3	0.048		
277	21-22	C	WW	BA	3	blue	Female	3	0.062		
278	21-22	C	WW	BA	3	blue	Male	5	0.04		
279	21-22	C	WW	BA	3	blue	Male	10	0.058		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
280	21-22	C	WW	BA	3	blue	Female	1	0.019	dead	
281	21-22	D	EE	CD	2	blue	Female	1	0.08		
282	21-22	D	EE	DC	2	red	Female	1	0.044	preacopula	
283	21-22	D	EE	CD	2	blue	Male	1	0.05	preacopula	
284	21-22	D	EE	CD	2	blue	Male	1	0.095		
285	21-22	D	EE	DC	2	red	Male	1	0.031		
286	21-22	D	EE	DC	2	red	Female	1	0.026		
287	21-22	D	EE	DC	2	red	Female	1	0.04		
288	21-22	D	EE	CD	2	blue	Female	1	0.029		
289	21-22	D	EE	CD	2	blue	Male	1	0.092		
290	21-22	D	EE	DC	2	red	Female	1	0.029	preacopula	
291	21-22	D	EE	DC	2	red	Male	1	0.06	preacopula	
292	21-22	D	EE	DC	2	red	Male	1	0.04		
293	21-22	D	EE	CD	2	blue	Female	1	0.082		
294	21-22	D	EE	CD	2	blue	Female	6	0.038		
295	21-22	D	EE	CD	2	blue	Male	10	0.149		
296	21-22	D	EE	CD	2	blue	Male	14	0.083		
297	21-22	D	EE	DC	2	red	Male	14	0.046		
298	21-22	D	EE	DC	2	red	Male	14	0.105		
299	21-22	D	EE	CD	2	blue	Female	14	0.041		
300	21-22	D	EE	DC	2	red	Female	13	0.035		
301	22-23	A	EE	CC	2	red	Male	1	0.141		
302	22-23	A	EE	CC	2	red	Male	1	0.065		
303	22-23	A	EE	CC	2	blue	Male	1	0.086		
304	22-23	A	EE	CC	2	blue	Female	1	0.024		
305	22-23	A	EE	CC	2	blue	Female	1	0.032		
306	22-23	A	EE	CC	2	red	Female	1	0.044		
307	22-23	A	EE	CC	2	blue	Female	1	0.046		
308	22-23	A	EE	CC	2	red	Male	1	0.059		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
309	22-23	A	EE	CC	2	blue	Male	1	0.061		
310	22-23	A	EE	CC	2	red	Male	2	0.038		
311	22-23	A	EE	CC	2	blue	Female	2	0.074		
312	22-23	A	EE	CC	2	blue	Male	3	0.073		
313	22-23	A	EE	CC	2	blue	Male	3	0.038		
314	22-23	A	EE	CC	2	blue	Male	3	0.047		
315	22-23	A	EE	CC	2	red	Female	3	0.065		
316	22-23	A	EE	CC	2	red	Male	4	0.071		
317	22-23	A	EE	CC	2	blue	Female	4	0.047		
318	22-23	A	EE	CC	2	red	Female	14	0.041		
319	22-23	A	EE	CC	2	red	Female	14	0.096		
320	22-23	A	EE	CC	2	red	Female	14	0.052		
321	22-23	B	EW	CA	1	red	Female	1	0.049		
322	22-23	B	EW	CA	1	red	Male	1	0.065		+
323	22-23	B	EW	CA	1	red	Male	1	0.077		
324	22-23	B	EW	CA	1	red	Female	1	0.08		
325	22-23	B	WE	AC	1	blue	Male	1	0.029		
326	22-23	B	EW	CA	1	red	Female	1	0.056		
327	22-23	B	WE	AC	1	blue	Female	2	0.053		
328	22-23	B	WE	AC	1	blue	Male	2	0.037		
329	22-23	B	WE	AC	1	blue	Female	2	0.055		
330	22-23	B	EW	CA	1	red	Male	2	0.067		
331	22-23	B	WE	AC	1	blue	Female	3	0.017		
332	22-23	B	WE	AC	1	blue	Male	3	0.053		
333	22-23	B	WE	AC	1	blue	Male	3	0.096		
334	22-23	B	WE	AC	1	blue	Male	4	0.122		
335	22-23	B	WE	AC	1	blue	Male	14	0.091		
336	22-23	B	EW	CA	1	red	Female	14	0.048		
337	22-23	B	EW	CA	1	red	Female	14	0.032		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
338	22-23	B	EW	CA	1	red	Male	14	0.071		
339	22-23	B	WE	AC	1	blue	Female	12	0.064		
340	22-23	B	EW	CA	1	red	Female	11	0.026		
341	22-23	C	WW	BA	4	red	Female	1	0.048		
342	22-23	C	WW	AB	4	blue	Male	1	0.04		
343	22-23	C	WW	BA	4	red	Female	1	0.026		
344	22-23	C	WW	AB	4	blue	Male	1	0.064		
345	22-23	C	WW	BA	4	red	Female	1	0.046		
346	22-23	C	WW	BA	4	red	Male	1	0.04		
347	22-23	C	WW	AB	4	blue	Female	1	0.024		
348	22-23	C	WW	AB	4	blue	Female	1	0.126		
349	22-23	C	WW	BA	4	red	Female	1	0.089		
350	22-23	C	WW	BA	4	red	Male	2	0.093		
351	22-23	C	WW	BA	4	red	Male	2	0.06		
352	22-23	C	WW	AB	4	blue	Male	2	0.047		
353	22-23	C	WW	AB	4	blue	Female	2	0.036		
354	22-23	C	WW	AB	4	blue	Male	2	0.095		
355	22-23	C	WW	BA	4	red	Female	2	0.03	after moulting	
356	22-23	C	WW	AB	4	blue	Female	2	0.034		
357	22-23	C	WW	BA	4	red	Female	6	0.035		
358	22-23	C	WW	AB	4	blue	Male	10	0.031		
359	22-23	C	WW	BA	4	red	Male	14	0.054		
360	22-23	C	WW	AB	4	blue	Male	5	0.08		
361	22-23	D	EW	CB	3	red	Male	1	0.043		+
362	22-23	D	EW	CB	3	red	Female	1	0.09		
363	22-23	D	EW	CB	3	red	Female	1	0.048		
364	22-23	D	EW	CB	3	red	Female	1	0.03		
365	22-23	D	EW	CB	3	red	Male	1	0.067		
366	22-23	D	EW	CB	3	red	Female	1	0.055		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
367	22-23	D	WE	BC	3	blue	Female	1	0.028		
368	22-23	D	WE	BC	3	blue	Male	1	0.042		
369	22-23	D	WE	BC	3	blue	Male	1	0.022		
370	22-23	D	EW	CB	3	red	Male	1	0.036		
371	22-23	D	WE	BC	3	blue	Female	1	0.043		
372	22-23	D	WE	BC	3	blue	Male	1	0.042		
373	22-23	D	WE	BC	3	blue	Female	1	0.026		
374	22-23	D	WE	BC	3	blue	Female	2	0.056		
375	22-23	D	EW	CB	3	red	Male	2	0.018	dead	
376	22-23	D	EW	CB	3	red	Male	3	0.096		
377	22-23	D	WE	BC	3	blue	Male	3	0.026		
378	22-23	D	WE	BC	3	blue	Male	3	0.044		
379	22-23	D	WE	BC	3	blue	Female	4	0.037		
380	22-23	D	EW	CB	3	red	Female	3	0.053	dead	
381	23-24	A	EW	CB	4	red	Male	1	0.056		
382	23-24	A	WE	BC	4	blue	Female	1	0.04		
383	23-24	A	WE	BC	4	blue	Female	1	0.016		
384	23-24	A	WE	BC	4	blue	Male	1	0.076		
385	23-24	A	EW	CB	4	red	Male	1	0.066		
386	23-24	A	WE	BC	4	blue	Female	1	0.026		
387	23-24	A	EW	CB	4	red	Female	1	0.03		
388	23-24	A	EW	CB	4	red	Female	1	0.054		
389	23-24	A	EW	CB	4	red	Female	2	0.035		
390	23-24	A	EW	CB	4	red	Male	2	0.05		
391	23-24	A	WE	BC	4	blue	Male	2	0.084		
392	23-24	A	WE	BC	4	blue	Female	2	0.031		
393	23-24	A	WE	BC	4	blue	Male	3	0.086		
394	23-24	A	WE	BC	4	blue	Female	4	0.029		
395	23-24	A	WE	BC	4	blue	Female	8	0.058		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
396	23-24	A	EW	CB	4	red	Male	11	0.093	dead	
397	23-24	A	WE	BC	4	blue	Male	12	0.078		
398	23-24	A	EW	CB	4	red	Male	14	0.048		
399	23-24	A	EW	CB	4	red	Female	2	0.013	dead	
400	23-24	A	EW	CB	4	red	Female	5	0.038		
401	23-24	B	WW	BB	4	blue	Female	1	0.026	dead	
402	23-24	B	WW	BB	4	red	Female	1	0.044		
403	23-24	B	WW	BB	4	blue	Male	1	0.044		+
404	23-24	B	WW	BB	4	blue	Female	1	0.019		
405	23-24	B	WW	BB	4	red	Female	2	0.029		
406	23-24	B	WW	BB	4	red	Female	2	0.038		
407	23-24	B	WW	BB	4	red	Female	2	0.026		
408	23-24	B	WW	BB	4	red	Male	2	0.022		
409	23-24	B	WW	BB	4	blue	Male	3	0.047		
410	23-24	B	WW	BB	4	blue	Male	3	0.04		
411	23-24	B	WW	BB	4	red	Male	4	0.114		
412	23-24	B	WW	BB	4	red	Male	4	0.059		
413	23-24	B	WW	BB	4	red	Female	4	0.062		
414	23-24	B	WW	BB	4	blue	Female	4	0.026		
415	23-24	B	WW	BB	4	blue	Female	5	0.058		
416	23-24	B	WW	BB	4	red	Male	5	0.072		
417	23-24	B	WW	BB	4	blue	Male	5	0.028		
418	23-24	B	WW	BB	4	blue	Male	5	0.054		
419	23-24	B	WW	BB	4	blue	Female	14	0.035		
420	23-24	B	WW	BB	4	red	Male	6	0.019		
421	23-24	C	EE	CD	3	blue	Female	11	0.058		
422	23-24	C	EE	DC	3	red	Male	11	0.065		
423	23-24	C	EE	DC	3	red	Male	11	0.053		
424	23-24	C	EE	DC	3	red	Male	11	0.058		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
425	23-24	C	EE	CD	3	blue	Female	11	0.02		
426	23-24	C	EE	CD	3	blue	Male	5	0.037		
427	23-24	C	EE	DC	3	red	Male	5	0.028	dead	
428	23-24	C	EE	CD	3	blue	Female	2	0.064		
429	23-24	C	EE	DC	3	red	Female	2	0.011		
430	23-24	C	EE	CD	3	blue	Male	2	0.056		+
431	23-24	C	EE	DC	3	red	Female	2	0.01		
432	23-24	C	EE	DC	3	red	Male	2	0.071		
433	23-24	C	EE	DC	3	red	Female	2	0.023		
434	23-24	C	EE	CD	3	blue	Male	1	0.091		
435	23-24	C	EE	DC	3	red	Female	1	0.036		
436	23-24	C	EE	CD	3	blue	Female	1	0.056		
437	23-24	C	EE	CD	3	blue	Male	1	0.042		
438	23-24	C	EE	CD	3	blue	Female	1	0.037		
439	23-24	C	EE	CD	3	blue	Female	1	0.041		
440	23-24	C	EE	DC	3	red	Male	1	0.053		
441	23-24	D	EW	DB	3	red	Female	1	0.018		
442	23-24	D	EW	DB	3	red	Male	1	0.072		
443	23-24	D	EW	DB	3	red	Male	1	0.062		
444	23-24	D	WE	BD	3	blue	Male	1	0.096		
445	23-24	D	WE	BD	3	blue	Male	1	0.048		
446	23-24	D	EW	DB	3	red	Female	1	0.04		
447	23-24	D	WE	BD	3	blue	Male	1	0.026		
448	23-24	D	EW	DB	3	red	Female	1	0.019		
449	23-24	D	WE	BD	3	blue	Male	1	0.077	preacopula	
450	23-24	D	EW	DB	3	red	Male	1	0.053	preacopula	
451	23-24	D	WE	BD	3	blue	Female	1	0.023		
452	23-24	D	EW	DB	3	red	Male	2	0.02		
453	23-24	D	WE	BD	3	blue	Female	7	0.018		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
454	23-24	D	WE	BD	3	blue	Female	9	0.024		
455	23-24	D	EW	DB	3	red	Female	10	0.03		
456	23-24	D	EW	DB	3	red	Female	10	0.024		
457	23-24	D	EW	DB	3	red	Female	10	0.035		
458	23-24	D	WE	BD	3	blue	Female	11	0.048		
459	23-24	D	WE	BD	3	blue	Male	11	0.059		
460	23-24	D	WE	BD	3	blue	Male	14	0.046		
461	24-25	A	WW	AA	1	red	Male	1	0.074	dead	+
462	24-25	A	WW	AA	1	blue	Female	1	0.054		
463	24-25	A	WW	AA	1	blue	Female	1	0.029		
464	24-25	A	WW	AA	1	blue	Female	1	0.048		
465	24-25	A	WW	AA	1	red	Male	1	0.041		
466	24-25	A	WW	AA	1	red	Female	1	0.023		
467	24-25	A	WW	AA	1	blue	Male	1	0.174	dead	
468	24-25	A	WW	AA	1	red	Male	1	0.073	dead	
469	24-25	A	WW	AA	1	red	Male	1	0.099		
470	24-25	A	WW	AA	1	red	Male	1	0.062		
471	24-25	A	WW	AA	1	red	Female	1	0.04	dead	+
472	24-25	A	WW	AA	1	red	Female	1	0.035		
473	24-25	A	WW	AA	1	blue	Male	1	0.067		
474	24-25	A	WW	AA	1	blue	Female	2	0.029	dead	
475	24-25	A	WW	AA	1	red	Female	2	0.055		
476	24-25	A	WW	AA	1	red	Female	3	0.067		
477	24-25	A	WW	AA	1	blue	Male	4	0.054		
478	24-25	A	WW	AA	1	blue	Female	5	0.07	dead	
479	24-25	A	WW	AA	1	blue	Male	6	0.077		
480	24-25	A	WW	AA	1	blue	Male	11	0.066		
481	24-25	B	WW	AA	2	blue	Female	1	0.042		
482	24-25	B	WW	AA	2	blue	Female	1	0.031		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
483	24-25	B	WW	AA	2	blue	Male	1	0.056		
484	24-25	B	WW	AA	2	blue	Female	1	0.042		
485	24-25	B	WW	AA	2	red	Male	1	0.095		
486	24-25	B	WW	AA	2	red	Female	1	0.024		
487	24-25	B	WW	AA	2	blue	Female	1	0.055		
488	24-25	B	WW	AA	2	blue	Female	1	0.019		
489	24-25	B	WW	AA	2	red	Male	1	0.018	dead	
490	24-25	B	WW	AA	2	red	Male	1	0.062		
491	24-25	B	WW	AA	2	blue	Male	1	0.09		
492	24-25	B	WW	AA	2	blue	Male	1	0.018	dead	
493	24-25	B	WW	AA	2	red	Male	1	0.056		
494	24-25	B	WW	AA	2	red	Male	1	0.022		
495	24-25	B	WW	AA	2	blue	Male	2	0.072		
496	24-25	B	WW	AA	2	red	Male	3	0.074		
497	24-25	B	WW	AA	2	blue	Female	3	0.012		+
498	24-25	B	WW	AA	2	red	Female	4	0.026		
499	24-25	B	WW	AA	2	red	Female	4	0.029		
500	24-25	B	WW	AA	2	red	Female	4	0.058		
501	24-25	C	EE	CC	3	red	Female	1	0.038		
502	24-25	C	EE	CC	3	red	Male	1	0.07		
503	24-25	C	EE	CC	3	red	Male	1	0.07		
504	24-25	C	EE	CC	3	blue	Female	1	0.026		
505	24-25	C	EE	CC	3	blue	Female	1	0.048		
506	24-25	C	EE	CC	3	blue	Male	1	0.048		
507	24-25	C	EE	CC	3	blue	Male	1	0.062		
508	24-25	C	EE	CC	3	blue	Male	1	0.049		
509	24-25	C	EE	CC	3	blue	Male	1	0.048		
510	24-25	C	EE	CC	3	blue	Female	1	0.016		
511	24-25	C	EE	CC	3	blue	Male	2	0.04		+

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
512	24-25	C	EE	CC	3	red	Female	2	0.013		
513	24-25	C	EE	CC	3	red	Female	3	0.065		
514	24-25	C	EE	CC	3	blue	Female	3	0.019	dead	
515	24-25	C	EE	CC	3	red	Female	4	0.018	dead	
516	24-25	C	EE	CC	3	blue	Female	8	0.018		
517	24-25	C	EE	CC	3	red	Male	14	0.029		
518	24-25	C	EE	CC	3	red	Male	14	0.023		
519	24-25	C	EE	CC	3	red	Male	14	0.04		
520	24-25	C	EE	CC	3	red	Female	14	0.019		
521	24-25	D	EE	DD	2	red	Female	1	0.034		
522	24-25	D	EE	DD	2	red	Male	1	0.024		
523	24-25	D	EE	DD	2	red	Male	1	0.038		
524	24-25	D	EE	DD	2	blue	Male	1	0.028		
525	24-25	D	EE	DD	2	blue	Female	1	0.019		
526	24-25	D	EE	DD	2	blue	Female	1	0.024		
527	24-25	D	EE	DD	2	blue	Female	1	0.026		
528	24-25	D	EE	DD	2	red	Male	1	0.036		
529	24-25	D	EE	DD	2	red	Female	1	0.038		
530	24-25	D	EE	DD	2	red	Male	1	0.061		
531	24-25	D	EE	DD	2	red	Male	1	0.068		
532	24-25	D	EE	DD	2	blue	Male	1	0.048		
533	24-25	D	EE	DD	2	blue	Female	1	0.048		
534	24-25	D	EE	DD	2	blue	Female	1	0.055		
535	24-25	D	EE	DD	2	blue	Female	1	0.026		
536	24-25	D	EE	DD	2	blue	Male	2	0.04	dead	
537	24-25	D	EE	DD	2	red	Male	3	0.072		
538	24-25	D	EE	DD	2	red	Male	3	0.056		
539	24-25	D	EE	DD	2	red	Female	14	0.046		
540	24-25	D	EE	DD	2	blue	Female	14	0.029		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
541	25-26	A	EE	DD	3	red	Female	1	0.046		
542	25-26	A	EE	DD	3	red	Female	1	0.078		
543	25-26	A	EE	DD	3	red	Male	1	0.03		
544	25-26	A	EE	DD	3	red	Female	1	0.028		
545	25-26	A	EE	DD	3	blue	Female	1	0.017		
546	25-26	A	EE	DD	3	blue	Male	1	0.019		
547	25-26	A	EE	DD	3	blue	Male	1	0.056		
548	25-26	A	EE	DD	3	blue	Male	1	0.038		
549	25-26	A	EE	DD	3	blue	Female	1	0.017		
550	25-26	A	EE	DD	3	blue	Male	1	0.029		
551	25-26	A	EE	DD	3	red	Female	1	0.028		
552	25-26	A	EE	DD	3	red	Female	1	0.029		
553	25-26	A	EE	DD	3	blue	Male	1	0.014	dead	
554	25-26	A	EE	DD	3	red	Female	2	0.029		
555	25-26	A	EE	DD	3	blue	Male	2	0.018		
556	25-26	A	EE	DD	3	red	Female	2	0.025		
557	25-26	A	EE	DD	3	red	Male	14	0.056		
558	25-26	A	EE	DD	3	blue	Male	14	0.026		
559	25-26	A	EE	DD	3	red	Male	7	0.017		
560	25-26	A	EE	DD	3	blue	Female	7	0.024		
561	25-26	B	WE	AD	3	blue	Female	1	0.059	dead	
562	25-26	B	WE	AD	3	blue	Male	1	0.058		
563	25-26	B	WE	AD	3	blue	Female	1	0.018		
564	25-26	B	WE	AD	3	blue	Female	1	0.035		
565	25-26	B	WE	AD	3	blue	Male	1	0.046		
566	25-26	B	WE	AD	3	blue	Male	1	0.03		
567	25-26	B	WE	AD	3	blue	Male	1	0.035		
568	25-26	B	WE	AD	3	blue	Male	1	0.043		
569	25-26	B	EW	DA	3	red	Male	1	0.103		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
570	25-26	B	EW	DA	3	red	Female	1	0.012		
571	25-26	B	EW	DA	3	red	Male	1	0.062		
572	25-26	B	EW	DA	3	red	Female	1	0.025		
573	25-26	B	EW	DA	3	red	Female	1	0.024		
574	25-26	B	EW	DA	3	red	Female	1	0.038		
575	25-26	B	WE	AD	3	blue	Male	1	0.05		
576	25-26	B	EW	DA	3	red	Female	2	0.064		
577	25-26	B	EW	DA	3	red	Male	3	0.019		
578	25-26	B	WE	AD	3	blue	Male	14	0.019		
579	25-26	B	EW	DA	3	red	Female	14	0.025		
580	25-26	B	EW	DA	3	red	Female	1	0.016		
581	25-26	C	EW	CA	2	blue	Female	1	0.013		
582	25-26	C	EW	CA	2	blue	Male	1	0.073		
583	25-26	C	WE	AC	2	red	Female	1	0.025		
584	25-26	C	EW	CA	2	blue	Female	1	0.03		
585	25-26	C	EW	CA	2	blue	Female	1	0.025		
586	25-26	C	EW	CA	2	blue	Female	1	0.024		
587	25-26	C	WE	AC	2	red	Female	1	0.024		
588	25-26	C	EW	CA	2	blue	Female	1	0.022		
589	25-26	C	EW	CA	2	blue	Female	1	0.036		
590	25-26	C	EW	CA	2	blue	Male	1	0.059		
591	25-26	C	WE	AC	2	red	Male	1	0.032		
592	25-26	C	WE	AC	2	red	Female	1	0.029		
593	25-26	C	WE	AC	2	red	Male	1	0.02		
594	25-26	C	WE	AC	2	red	Male	2	0.024	dead	
595	25-26	C	WE	AC	2	red	Male	2	0.068		
596	25-26	C	WE	AC	2	red	Female	2	0.028		
597	25-26	C	WE	AC	2	red	Male	3	0.03		
598	25-26	C	EW	CA	2	blue	Male	3	0.05		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
599	25-26	C	WE	AC	2	red	Male	4	0.058		
600	25-26	C	EW	CA	2	blue	Male	7	0.024		
601	25-26	D	WW	AA	3	blue	Female	1	0.062		
602	25-26	D	WW	AA	3	blue	Male	1	0.109		
603	25-26	D	WW	AA	3	blue	Male	1	0.052		
604	25-26	D	WW	AA	3	red	Female	1	0.022		
605	25-26	D	WW	AA	3	red	Male	1	0.037		
606	25-26	D	WW	AA	3	red	Female	1	0.02		
607	25-26	D	WW	AA	3	red	Female	1	0.031		
608	25-26	D	WW	AA	3	blue	Female	1	0.013		
609	25-26	D	WW	AA	3	blue	Female	1	0.023		
610	25-26	D	WW	AA	3	blue	Female	2	0.036	dead	
611	25-26	D	WW	AA	3	blue	Male	2	0.072		
612	25-26	D	WW	AA	3	blue	Female	3	0.049	dead	
613	25-26	D	WW	AA	3	red	Female	10	0.089		
614	25-26	D	WW	AA	3	red	Male	13	0.023		
615	25-26	D	WW	AA	3	blue	Male	14	0.056		
616	25-26	D	WW	AA	3	blue	Male	14	0.047		
617	25-26	D	WW	AA	3	red	Male	14	0.064		
618	25-26	D	WW	AA	3	red	Male	14	0.038		
619	25-26	D	WW	AA	3	red	Male	14	0.044		
620	25-26	D	WW	AA	3	red	Female	14	0.036		
621	26-27	A	WE	AC	3	red	Male	1	0.054		+
622	26-27	A	EW	CA	3	blue	Male	1	0.025		+
623	26-27	A	EW	CA	3	blue	Female	1	0.018		
624	26-27	A	WE	AC	3	red	Female	1	0.019		
625	26-27	A	WE	AC	3	red	Male	1	0.016		
626	26-27	A	EW	CA	3	blue	Female	2	0.005	dead	+
627	26-27	A	EW	CA	3	blue	Female	2	0.036		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
628	26-27	A	WE	AC	3	red	Male	2	0.139		
629	26-27	A	WE	AC	3	red	Female	2	0.018		
630	26-27	A	EW	CA	3	blue	Male	2	0.016		
631	26-27	A	EW	CA	3	blue	Female	2	0.013		
632	26-27	A	WE	AC	3	red	Male	2	0.013		
633	26-27	A	EW	CA	3	blue	Male	4	0.018	dead	
634	26-27	A	EW	CA	3	blue	Female	8	0.042		
635	26-27	A	WE	AC	3	red	Male	8	0.062		
636	26-27	A	WE	AC	3	red	Female	8	0.047		
637	26-27	A	EW	CA	3	blue	Female	8	0.018		
638	26-27	A	EW	CA	3	blue	Male	8	0.049		
639	26-27	A	WE	AC	3	red	Female	14	0.047		
640	26-27	A	WE	AC	3	red	Male	14	0.113		
641	26-27	B	EE	DC	4	red	Female	1	0.028		
642	26-27	B	EE	DC	4	red	Male	1	0.038		
643	26-27	B	EE	DC	4	red	Male	1	0.016		
644	26-27	B	EE	CD	4	blue	Male	1	0.023		
645	26-27	B	EE	CD	4	blue	Female	1	0.023		
646	26-27	B	EE	CD	4	blue	Female	1	0.017		+
647	26-27	B	EE	CD	4	blue	Female	1	0.024		
648	26-27	B	EE	DC	4	red	Female	1	0.023		
649	26-27	B	EE	CD	4	blue	Female	1	0.049		+
650	26-27	B	EE	CD	4	blue	Female	1	0.034		
651	26-27	B	EE	CD	4	blue	Male	1	0.02		
652	26-27	B	EE	DC	4	red	Female	1	0.017		+
653	26-27	B	EE	CD	4	blue	Female	1	0.014		
654	26-27	B	EE	DC	4	red	Male	2	0.037		
655	26-27	B	EE	CD	4	blue	Male	2	0.017		
656	26-27	B	EE	CD	4	blue	Male	3	0.016		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
657	26-27	B	EE	DC	4	red	Male	4	0.04		
658	26-27	B	EE	DC	4	red	Female	6	0.04		
659	26-27	B	EE	DC	4	red	Male	14	0.043		
660	26-27	B	EE	DC	4	red	Male	14	0.03		+
661	27-28	A	WW	BB	3	red	Male	1	0.022		
662	27-28	A	WW	BB	3	blue	Male	1	0.091		
663	27-28	A	WW	BB	3	blue	Female	1	0.052		
664	27-28	A	WW	BB	3	red	Female	1	0.038		
665	27-28	A	WW	BB	3	blue	Male	1	0.049		
666	27-28	A	WW	BB	3	blue	Female	1	0.007		
667	27-28	A	WW	BB	3	red	Female	1	0.023		
668	27-28	A	WW	BB	3	red	Male	1	0.059		
669	27-28	A	WW	BB	3	blue	Male	2	0.052	dead	
670	27-28	A	WW	BB	3	red	Male	2	0.043		
671	27-28	A	WW	BB	3	red	Male	3	0.07		
672	27-28	A	WW	BB	3	red	Male	7	0.087		
673	27-28	A	WW	BB	3	red	Female	8	0.016		
674	27-28	A	WW	BB	3	blue	Female	11	0.017		
675	27-28	A	WW	BB	3	red	Female	11	0.007		
676	27-28	A	WW	BB	3	blue	Female	12	0.038		
677	27-28	A	WW	BB	3	blue	Male	13	0.038		
678	27-28	A	WW	BB	3	red	Male	14	0.031		
679	27-28	A	WW	BB	3	blue	Female	14	0.031		
680	27-28	A	WW	BB	3	blue	Female	14	0.032		
681	27-28	B	EE	CC	4	red	Female	1	0.016	dead	
682	27-28	B	EE	CC	4	red	Male	1	0.005	dead	
683	27-28	B	EE	CC	4	blue	Female	1	0.012		
684	27-28	B	EE	CC	4	blue	Male	1	0.013		
685	27-28	B	EE	CC	4	red	Female	1	0.011		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
686	27-28	B	EE	CC	4	red	Female	1	0.031		
687	27-28	B	EE	CC	4	blue	Male	1	0.013		
688	27-28	B	EE	CC	4	blue	Female	1	0.02		
689	27-28	B	EE	CC	4	blue	Male	1	0.013		
690	27-28	B	EE	CC	4	blue	Male	1	0.023		
691	27-28	B	EE	CC	4	blue	Male	1	0.023		
692	27-28	B	EE	CC	4	red	Female	2	0.011	dead	
693	27-28	B	EE	CC	4	red	Female	2	0.017	dead after moulting	
694	27-28	B	EE	CC	4	blue	Male	2	0.038		
695	27-28	B	EE	CC	4	blue	Male	2	0.022		
696	27-28	B	EE	CC	4	red	Female	3	0.025	dead	
697	27-28	B	EE	CC	4	red	Female	3	0.017		
698	27-28	B	EE	CC	4	red	Male	6	0.025		
699	27-28	B	EE	CC	4	red	Female	7	0.02		
700	27-28	B	EE	CC	4	blue	Male	13	0.026		
701	27-28	C	EW	DA	4	blue	Female	1	0.019	dead	
702	27-28	C	WE	AD	4	red	Female	1	0.017		
703	27-28	C	WE	AD	4	red	Female	1	0.026		
704	27-28	C	EW	DA	4	blue	Female	1	0.022		
705	27-28	C	WE	AD	4	red	Male	1	0.014		
706	27-28	C	EW	DA	4	blue	Male	1	0.038	dead after moulting	
707	27-28	C	WE	AD	4	red	Female	1	0.052		
708	27-28	C	WE	AD	4	red	Female	1	0.023		
709	27-28	C	EW	DA	4	blue	Male	1	0.032		
710	27-28	C	WE	AD	4	red	Female	1	0.037		
711	27-28	C	EW	DA	4	blue	Female	1	0.047		
712	27-28	C	EW	DA	4	blue	Male	1	0.036		
713	27-28	C	EW	DA	4	blue	Male	1	0.041		
714	27-28	C	EW	DA	4	blue	Male	1	0.114		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
715	27-28	C	EW	DA	4	blue	Male	1	0.054		
716	27-28	C	WE	AD	4	red	Female	2	0.026		
717	27-28	C	WE	AD	4	red	Female	7	0.037		
718	27-28	C	EW	DA	4	blue	Male	7	0.03		
719	27-28	C	WE	AD	4	red	Male	7	0.023	dead	
720	27-28	C	WE	AD	4	red	Male	11	0.084		
721	27-28	D	EE	DD	4	red	Female	1	0.02	dead	
722	27-28	D	EE	DD	4	blue	Female	1	0.024		
723	27-28	D	EE	DD	4	blue	Female	1	0.016		
724	27-28	D	EE	DD	4	red	Male	1	0.067		
725	27-28	D	EE	DD	4	blue	Male	1	0.036		
726	27-28	D	EE	DD	4	red	Male	1	0.046		
727	27-28	D	EE	DD	4	red	Male	1	0.019		
728	27-28	D	EE	DD	4	blue	Female	1	0.016		
729	27-28	D	EE	DD	4	red	Male	1	0.016		
730	27-28	D	EE	DD	4	blue	Female	1	0.032		
731	27-28	D	EE	DD	4	red	Female	1	0.016		
732	27-28	D	EE	DD	4	blue	Female	1	0.026		
733	27-28	D	EE	DD	4	red	Male	1	0.028		
734	27-28	D	EE	DD	4	red	Male	2	0.041	dead after moulting	
735	27-28	D	EE	DD	4	red	Female	2	0.024	dead	
736	27-28	D	EE	DD	4	blue	Male	2	0.023		
737	27-28	D	EE	DD	4	blue	Male	2	0.024		
738	27-28	D	EE	DD	4	red	Female	6	0.037		
739	27-28	D	EE	DD	4	blue	Male	6	0.044		
740	27-28	D	EE	DD	4	blue	Female	6	0.025		
741	28-29	A	WW	AA	4	red	Male	1	0.017		
742	28-29	A	WW	AA	4	red	Female	1	0.019		
743	28-29	A	WW	AA	4	red	Female	1	0.022		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
744	28-29	A	WW	AA	4	blue	Female	1	0.022		
745	28-29	A	WW	AA	4	red	Female	1	0.023		
746	28-29	A	WW	AA	4	blue	Male	1	0.089		
747	28-29	A	WW	AA	4	blue	Male	1	0.09		
748	28-29	A	WW	AA	4	blue	Male	1	0.02		
749	28-29	A	WW	AA	4	blue	Female	1	0.012		
750	28-29	A	WW	AA	4	blue	Male	1	0.019		
751	28-29	A	WW	AA	4	blue	Male	1	0.03		
752	28-29	A	WW	AA	4	blue	Female	1	0.036		
753	28-29	A	WW	AA	4	red	Male	1	0.032		
754	28-29	A	WW	AA	4	red	Female	1	0.016		
755	28-29	A	WW	AA	4	blue	Female	1	0.053		
756	28-29	A	WW	AA	4	blue	Male	2	0.074		
757	28-29	A	WW	AA	4	red	Male	2	0.047		
758	28-29	A	WW	AA	4	red	Female	2	0.023		
759	28-29	A	WW	AA	4	red	Male	4	0.03		
760	28-29	A	WW	AA	4	red	Female	4	0.024		
761	28-29	B	EW	CA	4	red	Female	1	0.046		
762	28-29	B	WE	AC	4	blue	Female	1	0.01	dead	
763	28-29	B	WE	AC	4	blue	Male	1	0.018		
764	28-29	B	WE	AC	4	blue	Female	1	0.025		
765	28-29	B	WE	AC	4	blue	Male	1	0.023		
766	28-29	B	EW	CA	4	red	Female	1	0.005		
767	28-29	B	EW	CA	4	red	Female	1	0.028		
768	28-29	B	WE	AC	4	blue	Male	1	0.017		
769	28-29	B	EW	CA	4	red	Male	1	0.03		
770	28-29	B	WE	AC	4	blue	Male	1	0.024		
771	28-29	B	EW	CA	4	red	Female	1	0.011		
772	28-29	B	WE	AC	4	blue	Female	1	0.014		

No. of individual	Experiment date (in 2021)	Aquarium	Treatment	Populations	Replica	Colour	Sex	Compartment number (1-14)	Gammarid weight (g)	Comments	Microsporidia presence (+)
773	28-29	B	EW	CA	4	red	Female	1	0.032		
774	28-29	B	WE	AC	4	blue	Male	2	0.036		
775	28-29	B	EW	CA	4	red	Female	4	0.029		
776	28-29	B	EW	CA	4	red	Male	7	0.037		
777	28-29	B	EW	CA	4	red	Male	8	0.011		
778	28-29	B	WE	AC	4	blue	Male	10	0.024		
779	28-29	B	EW	CA	4	red	Female	14	0.035		
780	28-29	B	WE	AC	4	blue	Male	14	0.012		
781	28-29	C	EW	DB	4	blue	Female	11	0.035	dead	
782	28-29	C	WE	BD	4	red	Female	1	0.111		
783	28-29	C	EW	DB	4	blue	Female	1	0.012		
784	28-29	C	WE	BD	4	red	Male	1	0.073		
785	28-29	C	WE	BD	4	red	Male	1	0.044		
786	28-29	C	EW	DB	4	blue	Female	1	0.005		
787	28-29	C	EW	DB	4	blue	Male	1	0.014		
788	28-29	C	WE	BD	4	red	Male	1	0.036		
789	28-29	C	EW	DB	4	blue	Male	1	0.011		
790	28-29	C	WE	BD	4	red	Male	2	0.078		
791	28-29	C	WE	BD	4	red	Female	2	0.047		
792	28-29	C	EW	DB	4	blue	Female	3	0.024		
793	28-29	C	EW	DB	4	blue	Female	4	0.022		
794	28-29	C	WE	BD	4	red	Female	4	0.054		
795	28-29	C	WE	BD	4	red	Female	5	0.053		
796	28-29	C	EW	DB	4	blue	Male	6	0.011		
797	28-29	C	WE	BD	4	red	Male	14	0.08		
798	28-29	C	WE	BD	4	red	Male	14	0.035		
799	28-29	C	EW	DB	4	blue	Male	14	0.023		
800	28-29	C	EW	DB	4	blue	Female	14	0.022		

Supplementary Table 2

Table 2. The results of the analysis of recording. Symbols for treatments: WW - the Western Lineage accompanied by the Western Lineage, EE - the Eastern Lineage accompanied by the Eastern Lineage. Symbols for populations: AA - population from Brzeg accompanied by population from Brzeg, AB - population from Brzeg accompanied by population from Lubiąż, BB - population from Lubiąż accompanied by population from Lubiąż, CC - population from Wyszogród accompanied by population from Wyszogród, CD - population from Wyszogród accompanied by population from Nieszawa, DD - population from Nieszawa accompanied by population from Nieszawa

Treatment	Population	Replica	Speed (cm/s)
EE	CC	1	3.97
EE	CD	1	8.20
WW	AB	2	6.71
EE	CC	2	9.18
WW	AA	1	4.57
WW	AA	2	4.94
EE	DD	3	4.16
EE	CD	4	8.22
WW	BB	3	1.60
EE	CC	4	4.81
WW	AA	4	16.60
WW	AB	3	6.86
EE	CD	2	7.66
WW	AB	4	6.48
EE	CD	3	4.66
EE	CC	3	6.22
EE	DD	2	5.87
WW	AA	3	3.05
EE	DD	4	29.73

Załącznik nr 2

Krzysztof Podwysocki Łódź, 21.08.2024 r.

imię i nazwisko *miejscowość i data*

Katedra Zoologii Bezkręgowców i Hydrobiologii, Uniwersytet Łódzki, Łódź, Polska

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Desiderato A., Szczerkowska-Majchrzak E., Jermacz Ł., Kobak J., Bącela-Spychalska K., Rewicz T. (2024). The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). W trakcie recenzji w Animal Behaviour.

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji artykułu; uczestniczeniu w badaniach terenowych; dostosowaniu technicznym laboratorium na potrzeby eksperymentów, m.in. systemu kamer nagrywających eksperyment; przeprowadzeniu eksperymentów oraz pomiarów; zaplanowaniu metod analiz statystycznych; przeprowadzeniu analiz statystycznych; przygotowaniu przeglądu literatury i przygotowaniu wstępu do artykułu; opisaniu materiału i metod użytych w artykule; opisaniu wyników w artykule; przygotowaniu dyskusji i wniosków w artykule; przygotowaniu tabel i grafik; korekcie artykułu zgodnie z uwagami współautorów; wysłaniu artykułu do czasopisma naukowego; byciu autorem korespondencyjnym; korekcie artykułu zgodnie z uwagami recenzentów; koordynowaniu prac zespołu; organizowaniu spotkań celem dyskusji nad analizami oraz manuskryptem; współzarządzaniu i koordynacji planowania i realizacji działań badawczych w projekcie.

(osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy).

....

Appendix 2

Andrea Desiderato Lodz, 21.08.2024

name and surname *place and date*

Department of Invertebrate Zoology and Hydrobiology, University of Lodz, Lodz, Poland

affiliation

DECLARATION

I declare that in the work: Podwysocki K., Desiderato A., Szczerkowska-Majchrzak E., Jermacz Ł., Kobak J., Bącela-Spychalska K., Rewicz T. (2024). The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). Under review in Animal Behaviour.

(authors, year of publication, title, journal or publisher, volume, pages)

my contribution consisted of:

contributing to the conceptualization of the study; co-designing methodology; technical adjustments to the laboratory for experiments; conducting field work; help in analysing the data; validating the results; supervising; reviewing and editing the manuscript; providing feedback to the first author; and participating in meetings to discuss analyses and the manuscript.

(*the applicant for a doctoral degree should provide a detailed description of their contribution to the thesis)*

....

signature

Załącznik nr 2

Eliza Szczerkowska-Majchrzak | Łódź, 21.08.2024 r.

imię i nazwisko | *miejscowość i data*

Katedra Ekologii i Zoologii Kręgowców, Uniwersytet Łódzki, Łódź, Polska

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Desiderato A., Szczerkowska-Majchrzak E., Jermacz Ł., Kobak J., Bącela-Spychalska K., Rewicz T. (2024). The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). W trakcie recenzji w Animal Behaviour.

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

pomocy w przeprowadzeniu pomiarów; pracy w laboratorium molekularnym; pomocy w przygotowaniu tabel i grafik; przesłaniu uwag do artykułu pierwszemu autorowi.

(osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy).

Eliza Szczerkowska-Majchrzak

podpis

Załącznik nr 2

Łukasz Jermacz Toruń, 21.08.2024 r.

imię i nazwisko *miejscowość i data*

Katedra Ekologii i Biogeografii, Uniwersytet M. Kopernika, Toruń, Polska

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Desiderato A., Szczerkowska-Majchrzak E., Jermacz Ł., Kobak J., Bącela-Spychalska K., Rewicz T. (2024). The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). W trakcie recenzji w Animal Behaviour.

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji badań; opracowaniu metod; analizie nagrań eksperymentu; weryfikacji wyników; przesłaniu uwag do artykułu pierwszemu autorowi; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem.

(osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy).

Jermacz

podpis

Załącznik nr 2

Jarosław Kobak Łódź, 21.08.2024 r.

imię i nazwisko *miejscowość i data*

Katedra Zoologii Bezkręgowców i Parazytologii, Uniwersytet M. Kopernika, Toruń, Polska

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Desiderato A., Szczerkowska-Majchrzak E., Jermacz Ł., Kobak J., Bącela-Spychalska K., Rewicz T. (2024). The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). W trakcie recenzji w Animal Behaviour.

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji badań; opracowaniu metodologii; weryfikacji wyników; krytycznej rewizji wstępnej wersji manuskryptu; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem.

(osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy).

....

podpis

Załącznik nr 2

Karolina Bącela-Spychalska Łódź, 21.08.2024 r.

imię i nazwisko *miejscowość i data*

Katedra Zoologii Bezkręgowców i Hydrobiologii, Uniwersytet Łódzki, Łódź, Polska

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Desiderato A., Szczerkowska-Majchrzak E., Jermacz Ł., Kobak J., Bącela-Spychalska K., Rewicz T. (2024). The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). W trakcie recenzji w Animal Behaviour.

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji badań; przesłaniu uwag do artykułu pierwszemu autorowi; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem; opiece nad pracą doktoranta.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

....

podpis

Załącznik nr 2

Tomasz Rewicz Łódź, 21.08.2024 r.

imię i nazwisko *miejscowość i data*

Katedra Zoologii Bezkręgowców i Hydrobiologii, Uniwersytet Łódzki, Łódź, Polska

afiliacja

OŚWIADCZENIE

Oświadczam, że w pracy: Podwysocki K., Desiderato A., Szczerkowska-Majchrzak E., Jermacz Ł., Kobak J., Bącela-Spychalska K., Rewicz T. (2024). The dispersal potential of freshwater invasive amphipod species is population-dependent: A case study of *Dikerogammarus villosus* (Sowinsky, 1894). W trakcie recenzji w Animal Behaviour.

(autorzy, rok wydania, tytuł, czasopismo lub wydawca, tom, strony)

mój udział polegał na:

współtworzeniu koncepcji badań; pobraniu prób w terenie; przesłaniu uwag do artykułu pierwszemu autorowi; uczestniczeniu w spotkaniach celem dyskusji nad analizami oraz manuskryptem; opiece nad pracą doktoranta; zapewnieniu finansowania badań; zarządzaniu i koordynacją planowania i realizacji działań badawczych projektu.

(*osoba ubiegająca się o nadanie stopnia doktora, powinna opisać szczegółowo swój udział w powstaniu pracy*).

Tomasz Rewicz

podpis