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Perspectives on invasive species control: lessons from Hungary's first red swamp crayfish removal day (Crustacea: Decapoda)

Áron Székely[1,2,*], Bence Péter Schlitt[1,2,3], Mihály Jásdi[1,2,4,5], Zsolt Lóczi[2,6,7] & Ádám Mészáros[2,8]

[1]*Institute of Biology, ELTE Eötvös Loránd University, Pázmány Péter sétány 1/C, H-1117 Budapest, Hungary*

[2]*ArtEnto Foundation – Young Entomologists' Club Research Group, Baross utca 32, H-1088 Budapest, Hungary*

[3]*Hemiptera Collection, Department of Zoology, Hungarian National Museum Public Collections Centre – Hungarian Natural History Museum, Baross utca 13, H-1088 Budapest, Hungary*

[4]*HUN-REN Institute of Aquatic Ecology, Centre for Ecological Research, H-1113 Budapest, Karolina út 29, Hungary*

[5]*MTA-ÖK Lendület 'Momentum' Fluvial Ecology Research Group, H-1113 Budapest, Karolina út 29, Hungary*

[6]*Department of Zoology, Plant Protection Institute, HUN-REN Centre for Agricultural Research, Brunszvik utca 2, H-2462 Martonvásár, Hungary*

[7]*Doctoral School of Biology, Hungarian University of Agriculture and Life Sciences, Páter Károly utca 1, H-2100 Gödöllő, Hungary*

[8]*Doctoral School of Environmental Sciences, ELTE Eötvös Loránd University, Pázmány Péter sétány 1/C, H-1117 Budapest, Hungary*

[*]*E-mail:* aronszekely2@gmail.com

Abstract: Biological invasions are among the most significant ecological challenges of the 21st century. One of the most notorious invertebrate freshwater invaders in Europe is *Procambarus clarkii* (Girard, 1852), the red swamp crayfish native to North America. In this study, we organized a large-scale citizen science crayfish removal event in Békásmegyer, Budapest, Hungary, involving local residents in specimen collection using a novel, standardized protocol. In addition to evaluating the effectiveness of the method and engaging the public, we aimed to calculate allometric growth based on field-collected morphological data and to explore further research perspectives arising from such initiatives. Based on the analysis of the 1,194 specimens collected, we found the collection protocol to be highly effective and suitable for further removal events. Over 150 local participants were able to join the collection and follow the protocol, while trained volunteers could measure large-scale biotic data between sampling phases. Our results revealed negative allometric growth in both sexes of *P. clarkii*, suggesting suboptimal habitat conditions and raising further questions about the studied population. Overall, we conclude that citizen science-based removal events could serve as a valuable supplement to professional habitat management efforts.

Keywords: allometry, Barát-patak, citizen science, crayfish, field measurements, invasive species, urban ecology

Introduction

Biological invasions are one of the most imminent and ever-increasing challenges in conservation biology (Roy *et al.* 2024). Invasive alien species (IAS) are organisms that are introduced into new environments intentionally or unintentionally by humans, where they become abundant and harm the local ecosystems (Polce *et al.* 2023). The management of invasive alien species poses a significant challenge worldwide, particularly in Europe, where their establishment has profound ecological, economic, and public health consequences (Blackburn *et al.* 2011, Simberloff *et al.* 2013, Ricciardi *et al.* 2017).

The red swamp crayfish, *Procambarus clarkii* (Girard, 1852) (Arthropoda: Malacostraca: Decapoda: Cambaridae) is a remarkable example of a species capable of such expansion. It is native to North America, particularly the USA and Mexico (Loureiro *et al.* 2015), and has become an invasive species in many European countries (Gherardi 2007, Souty-Grosset *et al.* 2016) since its first introduction to Europe in Spain in 1973 (Oficialdegui *et al.* 2019, Oficialdegui 2020). The first record of *P. clarkii* in Hungary was reported by Weiperth *et al.* (2015), and it rapidly became one of the most concerning invasive freshwater invertebrate species in this country (Weiperth *et al.* 2020a, 2020b), raising several conservation warnings. Ecological challenges associated with invasive crayfish species are also demonstrated by the fact that whereas only three crayfish species are considered native to Hungary (Árva *et al.* 2024), altogether eight invasive decapods have been reported from the country as of 2025, originating from three continents (Weiperth *et al.* 2020b, Árva *et al.* 2024). The three native crayfish species (all from the family Astacidae) are *Austropotamobius torrentium* (Schrank, 1803), *Astacus astacus* (Linneaus, 1758) and *Pontastacus leptodactylus* (Eschschaltz, 1823), each of which are protected in Hungary (13/2001 (V.9.) KÖM).

The biological invasion of *P. clarkii* can be explained by several of its ecological traits. Its rapid lifecycle allows it to mature in just a few months, leading to fast population growth (Gherardi 2006). *P. clarkii* produces a high number of offspring, as females can store sperm and reproduce multiple times a year (Hobbs *et al.* 1989). Its wide-range diet, including plants, detritus, invertebrates, amphibians, and small fish, disrupts native ecosystems (Alcorlo *et al.* 2004). Additionally, it is a vector of the crayfish plague (*Aphanomyces astaci* Schikora, 1906 (Oomyces: Leptolegniaceae)), which threatens native crayfish species (Holdich *et al.* 2009).

Its burrowing activity damages riverbanks, irrigation systems, and dikes, causing water management issues (Correia and Ferreira 1995). Detailed categorization of the negative impacts of *P. clarkii* is given by Loureiro *et al.* (2015); its diet habits, habitat preferences, and other ecological characteristics are well discussed by several authors (e.g. Gherardi and Barbaresi 2008, Oficialdegui *et al.* 2020).

While there are numerous reports about the establishment and impacts of the red swamp crayfish in Hungary (e.g. Weiperth *et al.* 2019, Weiperth *et al.* 2020b), there are hardly any studies about the population characteristics of this species. Studying morphometric parameters is crucial to understand crustacean biology (Zhang *et al.* 2024). For example, describing allometric growth (the differential growth rates of various body parts or traits, such as total body length or chela length) is an important factor in characterising a population of a crayfish species (Lindqvist and Lathi 1983, Anderson *et al.* 1996). Allometric parameters vary between different types of habitats (Karachle and Stergiou 2012), therefore it is important to conduct studies in different locations to gather knowledge about invading populations. Although traditionally laboratory studies are associated with this approach, field studies are also emerging as a cheaper and simpler option. However, field methodologies also present significant challenges, for example the reliability of data collection often hinges on the spatial and temporal dimensions of the investigation, and factors such as weather conditions and animal behaviour may cause variability in data quality. Despite this, there are fields where studies are traditionally associated with precise field measurements, for example bird banding where the fieldworkers collect physical data such as body length, head and bill length, or weight of the caught birds. This suggests that precise measurements are possible to obtain in the field, and while the challenges and perspectives need to be carefully considered during the analyses, these cases can show us interesting biogeographical and ecological patterns of the examined populations (e.g. Monticelli *et al.* 2021).

Since preventing the introduction of non-native species is one of the most effective ways to fight biological invasions (Mack *et al.* 2000), citizen science projects are often used to raise awareness and engage the public in these conservation efforts (Encarnação *et al.* 2021a, Potgieter *et al.* 2024). A good means to achieve this is encouraging locals to take part in field activities. Citizen science is often associated with monitoring species, with a number of examples from Hungary as well (e.g. Turóci *et al.* 2020, Földvári *et al.* 2022, Garamszegi *et al.* 2023, Báthori *et al.* 2024, Soria *et al.* 2024), but it is more scarcely applied in habitat management activities or collecting biotic data like morphological traits. However, citizen science can also contribute to the eradication of locally established populations of invasive species (Encarnação *et al.* 2021b).

Based on the above, it seemed likely that citizen science could also be used in the case of the *P. clarkii* invasion in Hungary. With a proper collection design, not only would it be possible to raise awareness, but citizens could actively participate in the collection of specimens, thereby facilitating further scientific analyses and measurements, even if they are performed later by experts. We do not know of any similar events ever performed, especially not in Hungary, therefore the sampling design, collection success and other aspects of such a hypothetical field-work citizen science event clearly lack background knowledge and research.

Recognising the ecological and conservation concerns of the occurrence of the red swamp crayfish in Hungary, and considering the lack of published knowledge about its populations (e.g. morphological variations) as well as the opportunity of developing and testing a novel citizen science approach, a large-scale crayfish removal event was organized at the end of February in 2025 in Budapest, Hungary, through a public engagement campaign via a social media event on Meta – Facebook. The aim of the event was to systematically remove invasive red swamp crayfish specimens from the designated study area while collecting morphometric, especially allometric data in the field for characterising the inspected population, by engaging volunteers in a standardized collection protocol. In this study, we had the following two objectives: (1) test and recommend a novel collection protocol suitable for large-scale crayfish removal with a large number of amateur participants, including children, and (2) calculate allometric growth of the studied *P. clarkii* population, and test what challenges and research questions could emerge from such field events.

Material and methods

Study site

The site for the event was the Téglagyári-árok, a ditch located in Budapest, Békásmegyer (District III), which is a well-known habitat of an established *P. clarkii* population (Gál *et al.* 2018) (Fig. 1). The ditch is an approximately 800-metre-long straight water body, paved with concrete. The ditch flows into the Barát-patak, a brook flowing straight into the Danube approximately one kilometre away from the study site. Water reaching the Barát-patak from the Téglagyári-árok is controlled by a flood gate. We chose this site because of its easy accessibility for citizens, and also because of the fact that a large number of people could easily be distributed along a straight line, which significantly helps logistics, and setting up and controlling a large-scale event. Unlike many aquatic ecosystems in Budapest, the ditch is not locally protected by local authorities, therefore there was no legal concern about removing animals from it.

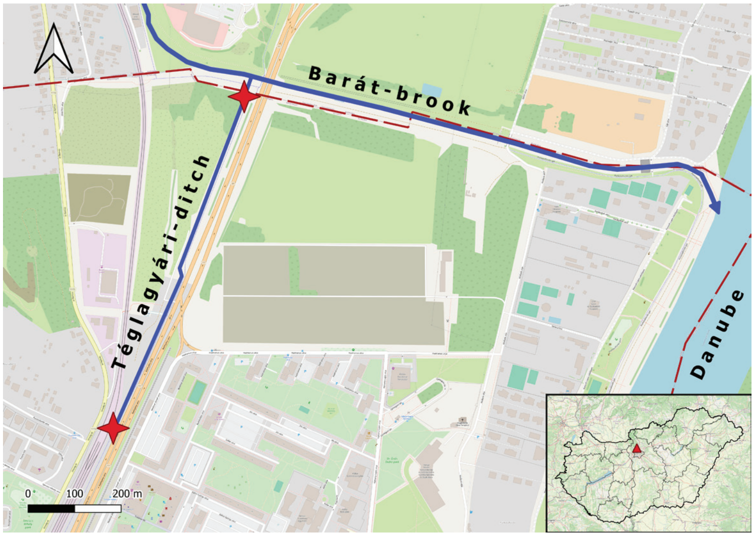

Figure 1. Map of the study site (large map) with its location in Hungary (smaller map, represented by a red triangle), with the relevant water bodies nearby. The blue line between the two red stars represents the Téglagyári-árok, the sampling site, flowing into the Barát-patak. The border of Budapest (Békásmegyer) and Budakalász (Pest county) is marked with a red dashed line. Basemap: OpenStreetMap Standard (https://openstreetmap.org).

1. ábra. A kutatási terület és a közeli víztestek elhelyezkedése (nagy térkép) és pozíciója Magyarországon belül (kisebb térkép, piros háromszöggel jelölve). A piros csillagok közti kék vonal a Téglagyári-árok mintavételi területet jelöli, amely a Barát-patakba csatlakozik. A Budapestet (Békásmegyer) és Budakalászt (Pest vármegye) elválasztó közigazgatási határt szaggatott vörös vonal jelzi. Alaptérkép: OpenStreetMap Standard (https://openstreetmap.org).

The event took place on the 22nd of February 2025. Based on our observations, due to the colder water, crayfish tend to be the most inactive during this time of the year, therefore they are the most easily captured in this period. In winter, vegetation cover is also less developed, making it easier to collect specimens. Upon preliminary evaluation, the area was divided into eight distinct sections, each measuring approximately 100 metres. This was in order to have a balanced collection design and an ideal distribution of the expectedly large number of participants across the site. We could assign trained volunteers to supervise a specific 100-metre section; this would have been difficult if the sections were longer. While the length of each section was standardized, environmental characteristics varied among them, particularly in terms of vegetation cover and shading. To optimize collection efforts and maintain consistency, eight teams were formed with an equal number of attendants, and each team was assigned to a section of the study area. Each section was supervised by two designated organizers ("crayfish coordinators") responsible for standardized methodology and addressing any logistical challenges during the event. Participants were registered upon arrival at the site (Fig. 2a), and were subsequently assigned to designated teams to facilitate a structured and coordinated approach of crayfish removal.

Figure 2. Moments of the first red swamp crayfish removal day in Hungary: (a) registering participants, (b – c) collecting specimens, (d) measuring the crayfish individuals.
2. ábra. Életképek az Első Budapesti Rákász Nap eseményéből: (a) helyszíni regisztráció, (b – c) a példányok gyűjtése, (d) a példányok mérése.

Conduction of the event

Participants were recruited using a Facebook event with a distinctive cover image (Fig. 3a). The event was shared in local Facebook groups. We did not pay for any ads, trying to reach citizens organically. We advertised the event in thematic Facebook groups as well as general ones, in order to have as many participants as possible.

On the removal day, early morning, we gave crayfish coordinators a general briefing about supervising their team, the collection protocol, and the precise schedule of the event. To increase precision, each coordinator performed a measurement of the same crayfish with their own measurement tape. We also showed them a pair of male and female specimens to help identify sex. After registration of the participants, coordinators led their teams to the specific section

Figure 3. Cover image of the Facebook event used to popularize the event (in Hungarian) (a), and a register of the morphological data collected by the coordinators of the third section (b).
3. ábra. Az Első Budapesti Rákász Nap Facebook-esemény borítóképe (a) és az egyik szakasz adatrögzítő terepi jegyzőkönyvének részlete (b).

which had been previously indicated using marker cones. When all participants got to their section, the coordinators gave a briefing to their team about the collection process, ethical rules as well as a safety training. As collecting was possible from the edge of the ditch, we encouraged participants not to get into the water. This was also important for preventing the spread of the possibly present crayfish plague.

The design for the removal process was chosen during a preliminary field evaluation, where ten volunteers tested each section separately by continuous collecting. The removal was carried out in three distinct collection phases. Each phase consisted of 25 minutes of active collection by the team members, followed by a 20-minute break. The break was installed to prevent crayfish from burrowing into the substrate as a response to continuous disturbance during the collecting, thereby increasing capture efficiency. From the social aspect, another purpose of this break was to make the event more children- and family-friendly, making sure that participants can get some rest while still following a strict protocol. The collection was conducted using the same type of plastic mesh strainers (d = 17 cm), which were planned to be standardized in number across teams giving each section 8 strainers. However, minor variations occurred due to some participants bringing additional strainers. During the three phases, participants searched for specimens from the whole area of their section without additional obligations, and stopped when the coordinators announced the end of the current phase (Fig. 2b, 2c). The collected crayfish were systematically recorded and quantified after each collection phase by the crayfish coordinators (Fig. 2d, 3b). The following characters were measured and determined on every captured individual: total length (TL) from the apex of the rostrum to the basal part of the telson obtained with measuring-tape, left chela length (CHL, Fig 4c and 4d) from the basal part of the propodus to the apex of the pollex obtained with measuring-tape, and weight (W) determined using an electronic MH-500 Pocket Scale (maximum capacity 500 g) with an accuracy of 0.01 g. Sex was identified by the crayfish coordinators on every individual over 30 mm of TL based on external morphological characters according to Zhang *et al.* (2024) as shown on Fig. 4a and 4b: presence of a tubular appendage on the first and second pairs of pleopods (=males), or first pair of pleopods specialized as sperm receptacles (=females). The terminology of the morphometric variables follows Odhano *et al.* (2015) and Zhang *et al.* (2024).

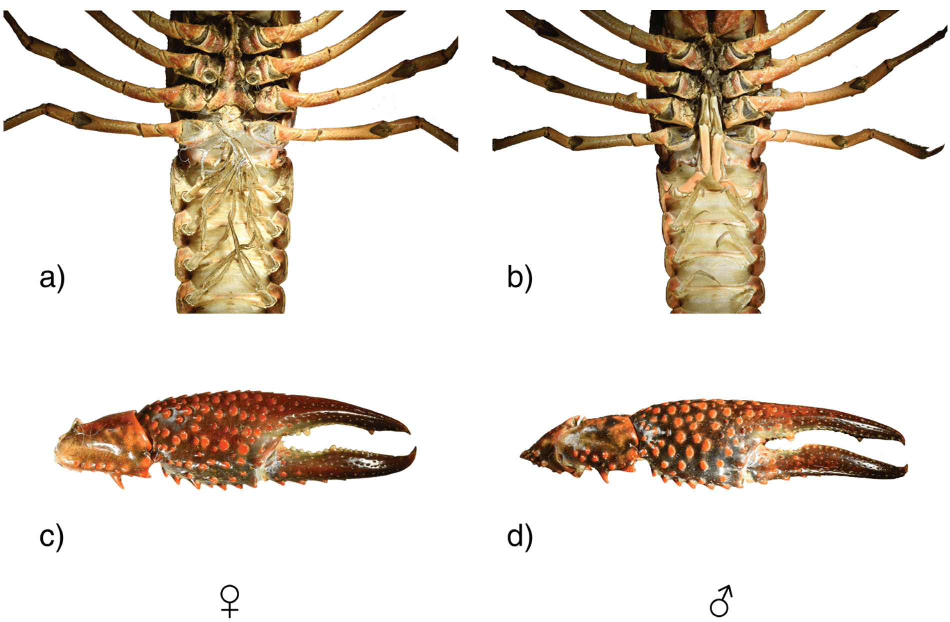

Figure 4. Specimens of *Procambarus clarkii* (Girard, 1852) captured on 22nd of February during the crayfish removal event, female and male: (a – b) ventral view; (c – d) left chela. Not to scale.
4. ábra. Két, az esemény ideje alatt begyűjtött *Procambarus clarkii* (Girard, 1852) példány, nőstény és hím: (a – b) ventrális nézet, (c – d) bal olló. Az egyes képek nem méretarányosak.

Data analysis

All statistical analyses and data visualization were carried out in the R program (version 4.4.3, R Core Team 2025).

To visualize data, we created scatter plots and mean with standard error plots using the packages “ggplot2” (Wickham 2016), “gridExtra” (Auguie 2017), “dplyr” (Wickham *et al.* 2023) and “tidyr” (Wickham *et al.* 2024). We checked for sexual dimorphism in total length (TL) and chela length (CHL).

To quantify sexual dimorphism, Wilcoxon rank sum test was conducted using the “wilcox.test” function on the measurements of TL and CHL in relation to sex.

To analyse the distribution of TL across sections, Shapiro-Wilk normality test (“shapiro.test”) was applied to the data to assess normality. As normality was not met ($p < 0.001$), we used the non-parametric Kruskal-Wallis rank sum test (“kruskal.test”) to determine whether TL differed significantly between sections. To compare specific sections, Tukey’s range test was used. Linear models were applied to TL, CHL and weight as response variables in relation to collection phases to check differences over time. These changes may reflect a bias in the sampling process, where certain age groups of crayfish were collected less successfully over time, possibly indicating a flaw in the sampling design.

Allometric growth

To examine the allometric relationship between total length (TL) and weight (W) on both sexes of *P. clarkii* individuals, we used the classical allometric formula shown in Equation 1. We applied the formula to both sexes separately, as multiple studies mentioned the sexual dimorphism in allometric growth (e.g. Györe 2024, Zhang *et al.* 2024). Due to the heteroscedastical variance in the data, a decimal logarithmic transformation of the two data variables was necessary (Packard 2017). A linear regression was conducted on the log-transformed data on a log-log scale, in accordance with the method generally used in literature (e. g. Jisr *et al.* 2018, Asmamaw *et al.* 2019, de Carvalho-Souza *et al.* 2023). The parameters ‘a’ and ‘b’ were calculated, as ‘a’ representing the intercept and ‘b’ representing the slope of the relationship. Due to outliers caused by the inaccuracies of field measurements, only individuals larger than 20 mm were included in the model, which caused the removal of five data points. We calculated the hypothetical weight values according to the formula of Györe (2024), a recent morphometric study from Hungary, and compared our measurements with them.

$$\text{(A) } W = a^*TL^b \qquad \text{(B) } \log(W)=\log(a)+b^*\log(TL)$$

Equation 1. (A) The classical allometric model: W = weight of live body mass; TL = total length; a = initial parameter; b = allometric parameter; (B) Log-log scale linear regression model: a = intercept, b = slope of linear regression model, log(W) = decimal logarithm of body mass, log(TL) = decimal logarithm of total length.

1. egyenlet. (A) A klasszikus allometrikus modell: W = testtömeg; TL = teljes testhossz; a = kezdeti paraméter; b = allometrikus paraméter; (B) Log-log transzformált lineáris regressziós egyenlet: a = tengelymetszet, b = a lineáris regressziós modell meredeksége, log(W) = a testtömeg tízes alapú logaritmusa, log(TL) = a teljes testhossz tízes alapú logaritmusa.

For visual analysis we plotted the data points on a graph with the trendline derived from the measurements, as well as a hypothetical trend line calculated from the measured body length based on parameters found in the work of Györe (2024) (Fig. 5a, 5b).

The exact same analysis was conducted using chela length (CHL) instead of weight to examine patterns and trends in the growth of chela in relation to total length. Similarly, the formula of Györe (2024) was used to visualize relationships observed in the literature, and 10 data points were removed due to being shorter than 20 mm (Fig. 5c, 5d). The slopes of the resulting models were examined for comparison.

Results

Overall, 162 people registered on-site and attended the event on the 22nd of February, 2025. This is approximately half of the responses to the Facebook event (326 citizens), but almost three times the number of people responding “going” (67 citizens). Participants followed the protocol, and everyone could collect multiple specimens across every section in each of the three phases. Coordinators could successfully watch over a 100-metre long section, supervising their team. Children could contribute equally well as their parents or teachers; however, additional strainers brought by the participants resulted in an inequality across sections.

In total, 1194 crayfish specimens were collected in three collection phases, of which 440 were males, 464 were females, and 290 were of unknown sex. During the three phases, 268, 363, and 445 specimens were collected, respectively; the remaining 118 specimens originating from section 7 were not given a phase classification due to recording errors. The most specimens caught in a section were 301 (section 5), while the least specimens caught were 43 (section 8).

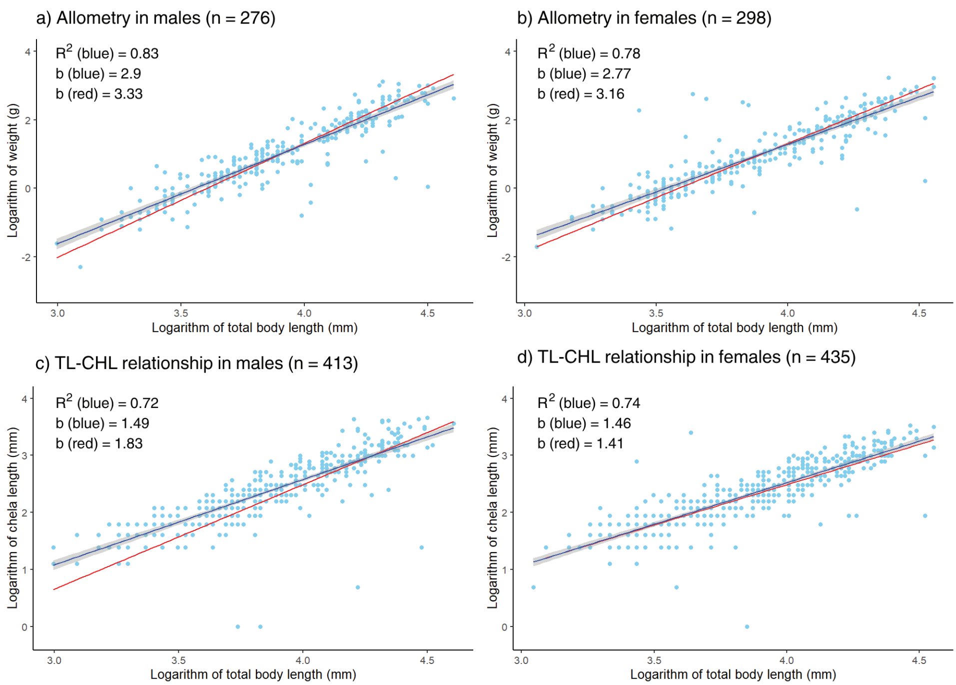

Figure 5. (a – b): Allometric growth in both sexes of *P. clarkii* in the Téglagyári-árok; (c – d): relationship between total body length (TL) and chela length (CHL). All data are logarithmically transformed using base-ten logarithm. Blue dots represent field measurements, the blue line shows a linear trend fitted to the measurements with a 95% confidence interval. The red line represents a hypothetical allometric trend calculated using the formula of Györe (2024).

5. ábra. (a – b) Allometrikus növekedés az esemény alatt gyűjtött *P. clarkii* példányok terepi mérései alapján ivaronként, (a) hím, (b) nőstény (vízszintes tengely: teljes testhossz, függőleges tengely: testtömeg). (c – d) A teljes hossz (total body length, TL) és az ollóhossz (chela length, CHL) kapcsolata ivaronként, (c) hím, (d) nőstény. Az összes adat tízes alapú logaritmikusan transzformált. A kék pontok a méréseket, a kék vonal az azokra illesztett lineáris trendvonalat jelöli 95%-os konfidencia-intervallumokkal; a vörös vonal a Györe (2024) által meghatározott hipotetikus trend.

The total length was measured for 1102 specimens (440 males, 464 females, 198 of unknown sex), chela length for 1009 specimens (418 males, 440 females, 151 of unknown sex), and weight for 684 specimens (277 males, 302 females, 105 of unknown sex). Due to field circumstances and limited capacity of measurement equipment, three-quarters of the weight measurements came from section 1, 4 and 6. In contrast, the other five sections contributed one-quarter of the total data number. The smallest and largest TL were 4.5 mm and 100 mm; CHL ranged from 1 mm to 39 mm, and weight from 0.08 g to 25.2 g. Mean of TL, CHL and weight were 46.74 mm (SE 0.52 mm), 11.35 mm (SE 0.20 mm), and 3.99 g (SE 0.13 g), respectively; median values for these variables were 44 mm, 9 mm, and 2.20 g.

We found that TL differed significantly between sections (Kruskal-Wallis rank sum test, $\chi^2 = 79.18$, df = 7, $p < 0.001$). Tukey's range test concluded that sections 1 and 2 ($p = 0.002$), sections 2 and 5 ($p = 0.021$), and section 8 and the rest of the sections differed significantly ($p < 0.001$ for all comparisons). The value of TL did not differ significantly between collection phases (linear model, residual df = 1026, $p = 0.15$) (Fig. 6). We have not found a significant difference in CHL or weight between the three phases, either (linear model, residual df = 939 and 676, p = 0.20 and 0.69) (Fig. 6).

Sexual dimorphism was not detected neither in TL (Wilcoxon rank sum test, p = 0.55), nor in CHL (Wilcoxon rank sum test, p = 0.13).

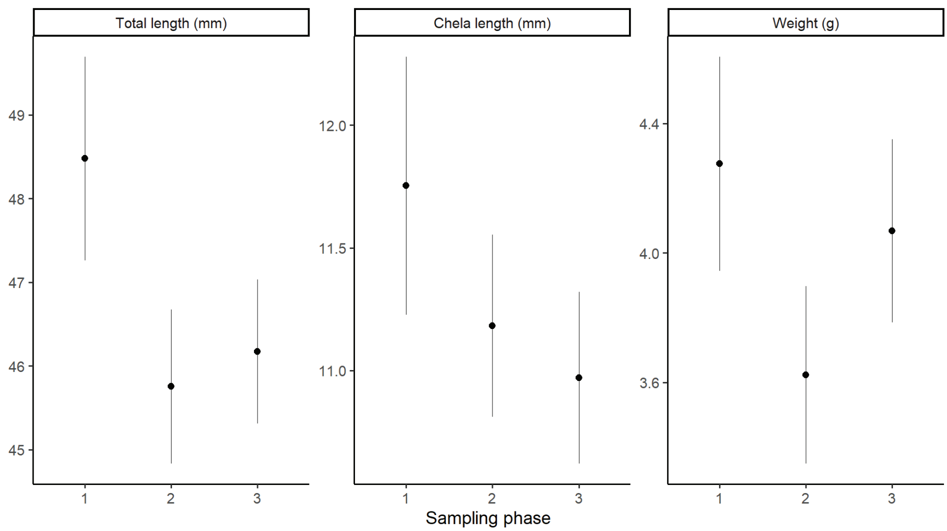

Figure 6. Mean values (± standard error) of total length (TL), chela length (CHL), and weight of the measured *Procambarus clarkii* specimens across the three sampling phases. Each point represents the mean value of all individuals measured within a phase, while vertical lines represent the standard error.

6. ábra. A három időbeli gyűjtési blokk különféle morfometriai változóinak átlagértékei (±standard hibák) a mért *Procambarus clarkii* egyedekre vonatkozóan: teljes hossz (total length, TL), ollóhossz (chela length, CHL), testtömeg (weight). Mindegyik pont az adott blokkban mért összes egyed adott változójának átlagértékét jelöli, a vertikális vonalak pedig a standard hibákat.

Allometric growth and chela length analysis

Based on our calculations, we found an allometric relationship between the weight and the total length of the specimens of *P. clarkii* (log-log scale regression analysis, females: n = 298, b = 2.77, $R^2 = 0.78$; males: n = 276, b = 2.9, $R^2 = 0.83$), in accordance with previous literature data (Györe 2024, Zhang *et al.* 2024). Similarly to the above, the allometric parameter (the slope of the model) was greater in males than in females. We found the allometric parameter less than 3 in both cases, indicating a negative allometric growth (Zhang *et al.* 2024) (Fig. 5a and 5b).

Chela length showed a positive correlation with total length (Fig. 5c and 5d). From the regression analysis conducted on the log-transformed data, we can state that males ($n = 413$, $b = 1.49$) are growing a slightly longer chela in relation to total length than females ($n = 435$, $b = 1.46$), in accordance with the data of Györe (2024).

Discussion

Biological invasions are of public interest because of the potential environmental and economic harm they cause (Simberloff *et al.* 2013, Zenni *et al.* 2021). Involving citizens in such problems is a key to raising social awareness and spreading science-based information about the threats and risks of these processes. A number of biological invasions originate from pets intentionally released by citizens (Maceda-Veiga *et al.* 2019). This attitude still persists and causes a serious problem in Hungary (e.g. Bódis *et al.* 2012, Weiperth *et al.* 2020b); in fact, the appearance and establishment of *P. clarkii* in Hungary were attributed to aquarists who released them into natural habitats (Weiperth *et al.* 2015). In this sense, applying citizen science for a project (and species) of a similar kind is always a good way to try and reduce this issue, acting as a form of prevention. Citizen science is traditionally associated with monitoring taxa and collecting large datasets, mainly about taxonomic diversity (Theobald *et al.* 2015), and management events receive less attention. If we consider the educational value surrounding the first-hand experience of removing invasive species from a local habitat, the project was definitely successful, considering the hundreds of citizens joining and talking about the event.

Apart from the social side, by taking a look at the analyses conducted, we can state that we could measure total length and chela length as well as weight in the field above a certain body length, and could detect important trends in the variables in question. This suggests that measurements in the field can serve as an alternative, if laboratory measurements are not available.

Evaluation of the sampling design and protocol

To evaluate the success of the collection protocol, and its suitability for future removal events, many aspects need to be considered. Overall, based on the experiences of working with the attendants, we suggest that sections of the length used by us are ideal for an event of similar proportions: we suspect that in a longer section, participants would have been scattered, leading to more difficult communication between the members, while in a shorter section they would not have had enough space for collection. In future events, it may also be necessary to distribute the additional strainers more equally; this can be done with a better organized registration process or stricter rules about extra equipment.

The sections as spatial replicates differed significantly from each other when considering the total length of the caught specimens; however, only 9 of the conducted 28 comparisons resulted in significant differences. The majority of the differences were caused by section 8 versus every other section (7 comparisons), which could be explained by the sample size, which turned out to be the lowest here ($n = 43$). Section 8 is also the most downstream section, located at the end of the site, next to the Barát-patak; however, since we have not found a significant trend along a spatial gradient, we suggest that the disturbance coming from upstream sections is negligible to the inspected downstream section. We also found a difference between sections 1 and 2, and sections 2 and 5. This could possibly be traced back to the environmental parameters characteristic to the specific sections, such as water temperature, water depth, type of bottom or shading tree cover. These parameters are important factors determining crayfish abundance (Weiperth *et al.* 2020b, Zhang *et al.* 2024), therefore recording and linking them to the observed patterns may help to understand their ecology more deeply.

The sample size (number of collected specimens) did not change considerably between phases, in fact, it slightly even increased with the same level of collection effort, which means that we could mitigate the effects of disturbance on the crayfish caused by the participants. This could also raise some future discussion about extending the event with one or more collection rounds, provided that this trend continues. Since no measured variable (TL, CHL and weight) differed significantly between collecting phases (Fig. 6), we suggest that we could collect specimens without crayfish disproportionately hiding within specific size groups; in other words, participants did not collect all large specimens first for they are easier to detect. This indicates that participants could collect crayfish of all sizes the same way during the entire event, which is important because proper removal of young and therefore small crayfish is essential in a successful management measure, as highlighted by García-de-Lomas *et al.* (2020). For the reasons above, we suggest that this three-phase experimental design was effective, and it could be used in future studies to collect large numbers of individuals. We plan adding control sections, where the collection is continuous, in order to see if the breaks are in fact essential for collection efficiency, or only serve the comfort of the citizens.

An experiment by Loureiro *et al.* (2018) concluded that continuous removal of *P. clarkii* prolonged in time results in a more intense population growth as part of a feedback mechanism leading to specimens investing more in reproduction, therefore it is not suitable for conservation and habitat management, and suggested that “one intensive removal event might be more effective”. Further studies are needed to assess the effects of this removal from the Téglagyári-árok; monitoring and calculating population growth may be necessary before and after a future removal event.

Allometric growth in the Téglagyári-árok and future research perspectives

In accordance with other studies such as Györe (2024) and Zhang *et al.* (2024), we found that there is an allometric relationship between total length (TL) and weight (W) in the case of *P. clarkii*. While sexual dimorphism was not detected in the measured traits, the allometric parameter of the males was slightly higher than females. The allometric parameter or weight-growing rate of our sample population differed from the studies listed above, in the sense that we found negative allometric growth ($b < 3$) instead of a positive one ($b > 3$). On the other hand, both above studies collected samples from various locations, not taking into consideration the effect of the specific habitat. In a similar manner, we found smaller parameters for chela length growth than in the laboratory study of Györe (2024). Both results indicate a less favourable habitat for crayfish than in the two recent studies, which raises further questions which could be further examined in removal events, for example:

(1) Food availability: McClain (1995) showed that the allowance of food greatly impacts crayfish growth. Téglagyári-árok is a small watercourse inside the capital of Hungary, which essentially lacks diversity and reduces allowance for food; therefore, we can hypothesize that the lack of resources causes a negative allometric growth. In the course of a future removal event, participants could also collect other animals that coordinators could identify, which later could be analysed and linked to the growth of *P. clarkii.*

(2) Population density: McClain (1995) also showed that population density has an even greater impact on the growth of the crayfish population than food shortage, and these two effects may further enhance the effect of each other. If we manage to collect a robust data set, which requires a large number of specimens which can be easily provided by a removal event, we could inspect the effect of population density on growth.

As we performed the measurements on the field, not in the classic laboratory environment, we need further studies to evaluate the accuracy of our results. We plan to carry out the same analysis in a future event, measure the specimens in a laboratory, analyse the data for a second time, and compare the two results to evaluate the difference or bias possibly present in the field. However, by looking at the R^2-values of the four models, with 0.72 being the smallest and 0.83 being the largest, we can suggest that our models already have a strong fit. The value of total length also did not differ significantly in most sections, as discussed above; this could show that in most cases there was no detectable individual variance among the coordinators, showing that they could perform the measurements at an equally accurate level. While the response of a *P. clarkii* population was quantified by Loureiro *et al.* (2018) by comparing growth rates, we do not know of a study that assessed the same with allometric growth. Therefore, we plan to monitor it in the Téglagyári-árok with the help of future removal events, highlighting possible changes and trends in the long run.

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Perspektívák az inváziós fajok gyérítésében: Tanulságok az I. Budapesti Rákász Napról (Crustacea: Decapoda)

Székely Áron [1,2,*], Schlitt Bence Péter [1,2,3], Jásdi Mihály [1,2,4,5], Lóczi Zsolt [2,6,7] és Mészáros Ádám [2,8]

[1]*Eötvös Loránd Tudományegyetem, Biológiai Intézet, 1117 Budapest, Pázmány Péter sétány 1/C*

[2]*ArtEnto Alapítvány – Fiatal Entomológusok Klubja Kutatócsoport, 1088 Budapest, Baross u. 32.*

[3]*Magyar Nemzeti Múzeum Közgyűjteményi Központ – Magyar Természettudományi Múzeum, Állattár, 1077 Budapest, Baross u. 13.*

[4]*HUN-REN Ökológiai Kutatóközpont, Vízi Ökológiai Intézet, 1113 Budapest, Karolina út 29.*

[5]*Magyar Tudományos Akadémia – Ökológiai Kutatóközpont Lendület Folyóvízi Ökológia Kutatócsoport, 1113 Budapest, Karolina út 29.*

[6]*HUN-REN Agrártudományi Kutatóközpont, Növényvédelmi Intézet, Állattani Osztály, 2462 Martonvásár, Brunszvik u. 2.*

[7]*Magyar Agrár- és Élettudományi Egyetem (MATE), Biológia Tudományi Doktori Iskola, 2100 Gödöllő, Páter Károly u. 1.*

[8]*Eötvös Loránd Tudományegyetem, Környezettudományi Doktori Iskola, 1117 Budapest, Pázmány Péter sétány 1/C*

A biológiai inváziók a 21. század legsúlyosabb ökológiai kihívásai közé tartoznak. Az egyik leghírhedtebb édesvízi gerinctelen özönfaj Európában az észak-amerikai eredetű vörös mocsárrák (*Procambarus clarkii* [Girard, 1852]). Jelen tanulmány során egy nagyszabású "citizen science" rákgyérítő eseményt szerveztünk Budapesten, a Barát-patak befolyójánál, ahol a résztvevők egy új, standardizált gyűjtési protokoll alapján vehettek részt a példányok begyűjtésében. A módszer hatékonyságának tesztelése és a lakosság bevonása mellett célunk volt a terepen gyűjtött morfológiai adatok alapján az allometrikus növekedés kvantitatív meghatározása, valamint az ilyen típusú eseményekből kiinduló további kutatási lehetőségek feltérképezése. A több, mint 150 önkéntes résztvevő által gyűjtött összesen 1194 példány elemzése alapján megállapítható, hogy a tesztelt protokoll igen hatékonynak bizonyult, és a jövőbeli gyérítési akciók alapját képezheti. A résztvevők sikeresen követték a protokollt, miközben a képzett koordinátorok képesek voltak nagy mennyiségű biotikus adat mérésére az egyes gyűjtési blokkok között. A morfometriai elemzések alapján mindkét ivarnál negatív allometrikus növekedést találtunk, ami szuboptimális tulajdonságú élőhelyre utal, és további kérdéseket vet fel a vizsgált populációval kapcsolatban. Összességében úgy véljük, hogy az ilyen lakossági részvételen alapuló gyérítési események értékes kiegészítői lehetnek a professzionális élőhelykezelési gyakorlatnak.

Kulcsszavak: allometria, Barát-patak, citizen science, inváziós fajok, terepi mérés, tízlábú rákok, városökológia

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