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Research Article

Aquatic non-native invertebrate species in large river basins of southern Iraq

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Abstract

This paper presents the first overview of aquatic alien invertebrate species (AIS) in the three major river basins (Tigris, Euphrates and Shatt Al-Arab) in southern Iraq. The results are based on field studies undertaken in 2021 and 2022. Thirteen AIS have been recorded. Three of them are "old invaders" (first recorded in the early 19^{th} century to 1970), two species are "intermediate invaders" (first recorded between 1970 to 1990) and eight are "new invaders" (first recorded after 2000). The number of AIS has been growing substantially since 2000. The highest AIS number is recorded in the Shatt-Al-Arab (11 species), a middle number in the Euphrates basin (10 species) and the lowest number in the Tigris (6 species). On the whole, 31% of the recorded species originate from Southern America or Northern America, 23% from Asia, 8% from Southern Europe, Africa and Southern Asia, the Atlantic Ocean, Africa and Northern America, 7% from New Zealand, and the Caspian Sea. Most AIS were likely introduced unintentionally. The study demonstrated that many AIS, like e.g. *Macrobrachium nipponense*, have been collected both from the upper and the lower sections of the study rivers providing successful examples of aquatic AIS that can establish populations in fresh and brackish waters. The compiled species list is a first step toward the management of the invasive species that are now present in rivers of southern Iraq. It provides a basis for the creation of monitoring programs, early detection initiatives, and quick responses to prevent future invasions in the Tigris-Euphrates and Shatt Al-Arab basins.

Key words: Euphrates, invasive species, inventory, invertebrates, Shatt Al-Arab, Tigris

Introduction

An alien (or non-native) species is any species intentionally or accidentally transported and released by humans outside its native current range (Blackburn et al. 2011; Haubrock et al. 2024). It has become increasingly accepted knowledge that invasive alien species as a serious ecological hazard (IPBES 2023). High economic damages caused by numerous successful invaders have also been reported (Bacher et al. 2018; Ahmed et al.

2022). Within an assessment unit, a thorough understanding of the diversity and distribution of alien species is necessary for the assessment of associated risks (Servello et al. 2019; Lipinskaya et al. 2020; Dobrzycka-Krahel and Medina-Villar 2023; Haubrock et al. 2023; Soto et al. 2023). Aquatic alien species have been introduced into Iraq's water bodies through various pathways, with interbasin canal shipping being the most significant one represented by the Shatt Al-Arab that connects the Persian-Arabian Gulf with the internal water bodies (Naser et al. 2011). Through this canal, shipping activities regularly pass through the inland waterways of the Tigris-Euphrates basins.

In recent decades, several alien invertebrate species have newly invaded waterbodies in Iraq (Jaweir et al. 2006; Salman et al. 2006; Naser and Son 2009; Haase et al. 2010; Naser et al. 2012, 2015; Marrone et al. 2014; Yasser et al. 2022, 2023). However, so far, biological invasions have been studied only in a fragmented manner. To address the gaps in our understanding of alien species distributions, we use newly collected field data to examine the aquatic alien invertebrate species (AIS) composition and distribution patterns in the Tigris, Euphrates and Shatt Al-Arab basins.

Materials and methods

Study area

The sampling design included 20 sites along the Tigris, Euphrates and Shatt Al-Arab rivers and in connected marshes. The total length of the Tigris River is about 1900 km, of which 1415 km are located in Iraq, while the total length of the Euphrates River is 2940 km, of which 1160 km are situated in Iraq. The Al-Hammar marsh receives water from the transboundary Euphrates River, the Al-Huwaizah marshe is fed by the Tigris River which originates from the mountains of Eastern Anatolia of Turkey. The Al-Sweap River is a 35 km long canal draining water from the Al-Huwaizah Marshes and feeding the Shatt Al-Arab River (Yasser et al. 2024). The Al-Eizz River is fed by two canals of the Tigris. Finally, the Euphrates and Tigris rivers form the Shatt Al-Arab waterway which flows into the Persian Gulf.

The information from the literature (Holthuis and Hassan 1975; Salman et al. 2006; Naser and Son 2009; Haase et al. 2010; Naser et al. 2012, 2015, Marrone et al. 2014; Bogan et al. 2022; Yasser et al. 2022), and the findings of our survey conducted in the rivers and southern Iraqi marshes were combined to create a list of alien species. Twenty locations were sampled in these basins between 2021 and 2022 (Figure 1, Table 1). All benthic samples were collected using a hand net drawn over a 5-meter transect in three replicates at a water depth of 15 to 40 cm along the river bank. Bottom samples were collected utilizing a dredge (50 cm broad, 15 cm high, and 120 cm long). A quadratic plot (1 m × 1 m) was used to collect upper intertidal invertebrates. The collected invertebrate species were identified based on literature (Holthuis

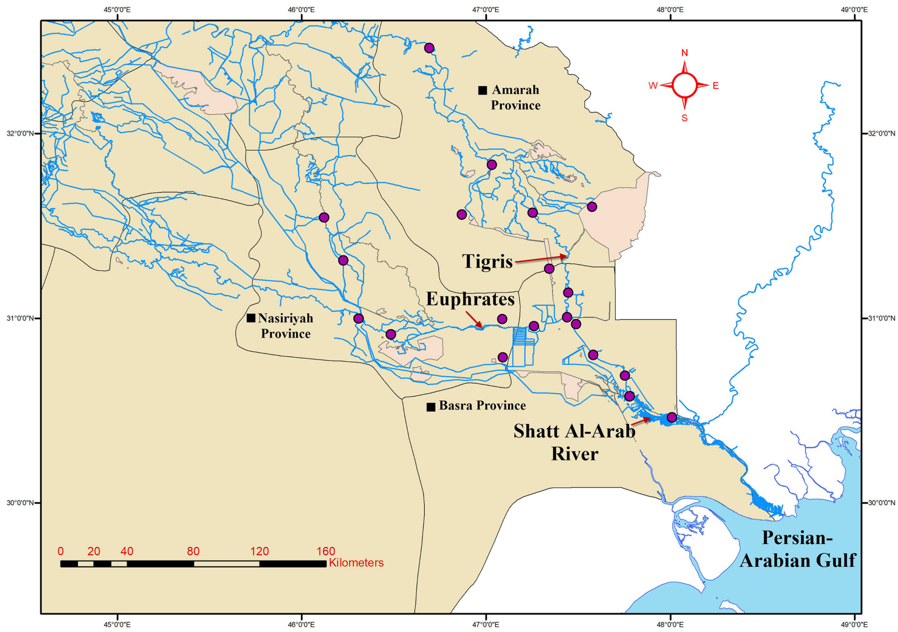

Figure 1. Sampling sites (purple dots) along rivers and in marshes in southern Iraq. Red arrows denote the three main river basins. Black squares represent the provinces of Iraq.

Table 1. Geographic locations of sampling sites in rivers and marshes of southern Iraq.

Basin	Sites	Longitude [°]N	Latitude [°]E
Shatt Al-Arab (6 sites)	Abu Al-Khasseb	48.00806	30.46264
	Firuziyah	47.77796	30.57827
	Al-Hartha	47.75504	30.68872
	Ad Dayr	47.58255	30.80181
	Al Swaib	47.4893	30.96786
	Qurna	47.44101	31.00543
Euphrates (7 sites)	Chibayish marshes	47.0886	30.99487
	Nasiriyah	46.30875	30.99858
	Gharraf River	46.22693	31.31295
	Ukaikah	46.48414	30.91337
	Gharraf Canal	46.12174	31.54405
	Hammar marsh	47.09137	30.78741
	Al Madina	47.26113	30.95666
Tigris (7 sites)	Al-Majer Al-Kaber	47.25399	31.57002
	Ptera dam	47.03193	31.83091
	Al-Huwaizah marshes	47.57581	31.60309
	Ali Al-Garbi	46.69286	32.46344
	Al-Eizz River	47.34289	31.26746
	Auda marsh	46.86961	31.56179
	Muzaybilah	47.44606	31.13739

and Hassan 1975; Salman et al. 2006; Naser and Son 2009; Haase et al. 2010; Naser et al. 2012, 2015, Marrone et al. 2014; Bogan et al. 2022; Yasser et al. 2022). The habitats of these species from the southern of Iraq are summarized in Table 2.

Results

In total, thirteen alien invertebrate species were detected from the examined river basins. The number and distribution of alien species differed strikingly between the basins. The highest alien species richness was recorded in the

Table 2. Habitats of alien species from southern Iraq.

Species	Habitat
Potamopyrgus antipodarum	In bottom deposits, on macrophytes (submerged and floating), in filamentous algae mats. Sometimes found on artificial stones covered by algae, subtidal or in the intertidal zone.
Melanoides tuberculata	Stones and vegetation, organic matter and mud.
Ecrobia grimmi	Mud and vegetation substrats.
Physella acuta	Different substrats: stones and vegetation, organic matter and mud.
Sinanodonta woodiana	Subtidal, muddy vegetation and stony substrates
Ferrissia californica	Subtidal, muddy substrats, on vegetation
Mytilopsis leucophaeata	Stones, boats, pilings, and ropes.
Palaemon elegans	vegetation, man-made structures
Eriocheir hepuensis	Broad range of riverine and wetland environments, on floating vegetation, and stony substrates.
Macrobrachium nipponense	Mud and vegetation
Amphibalanus subalbidus	Intertidal fouling communities with hard substrates, including rocks, pier pilings, ship hulls, molluscs
Amphibalanus amphitrite	Intertidal fouling communities and with hard substrates, including rocks, pier pilings, ship hulls
Amphibalanus improvisus	rocks, man-made structures, ships' hulls, the shells of crabs and molluscs

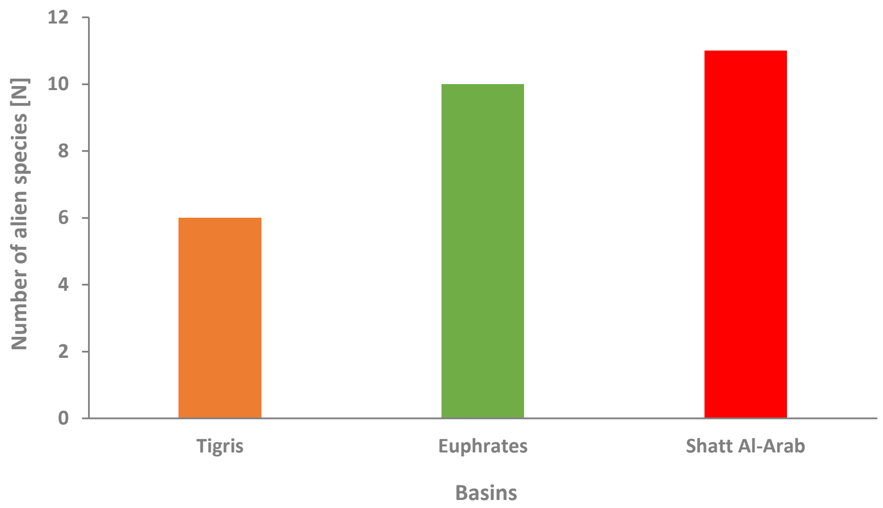

Figure 2. Number of aquatic alien invertebrates in the Tigris, Euphrates and Shatt-Al-Arab in southern Iraq.

Shatt Al-Arab, indicating that this waterway plays an important role as a corridor for the invasion of aquatic alien invertebrates in Iraq (Figure 2). Recently, the number of AIS in the rivers of southern Iraq has increased substantially (Figure 3).

There are substantial uncertainties as to how and when an alien species arrived in a river basin (Table 3). For example, it is not known exactly when *Physella acuta* (Draparnaud, 1805) appeared in the three basins. However, based on the years of first records or publications, the alien species from our checklist (Table 2) can be assigned to the following three groups: "old invaders" (from the early 19th century to 1970), "intermediate invaders" (1970–1990) and "new invaders" (after 2000).

The first group includes two species, i.e. *Amphibalanus amphitrite* (Darwin, 1854) and *Palaemon elegans* Rathke, 1836 that might have invaded the water bodies of southern Iraq in 1960 and 1968, respectively. The second

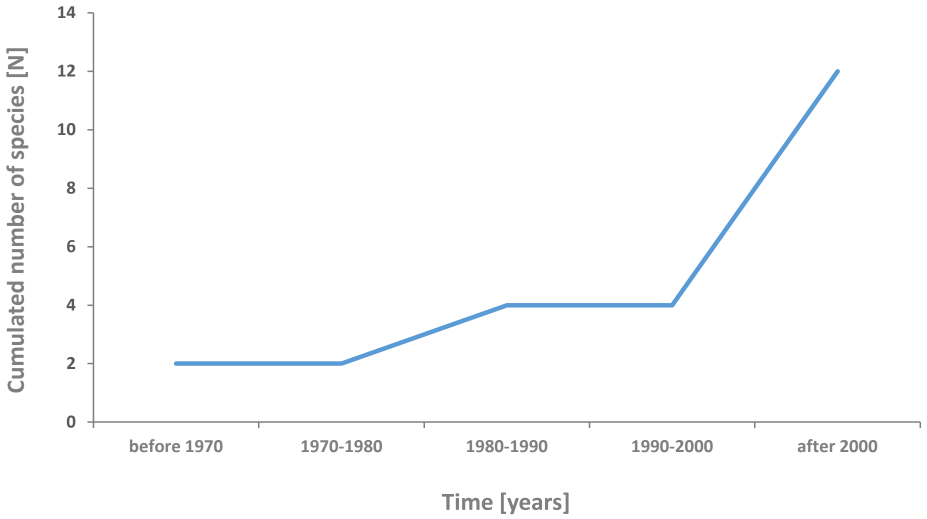

Figure 3. Cumulative number of aquatic alien invertebrates in rivers of southern Iraq recorded over time (based on the first record).

Table 3. List of aquatic alien invertebrate species from rivers and marshes of southern Iraq.

Groups	Species name (based on WoRMS)	Native range	First record in Iraq	Pathway of introduction	References
Mollusca	*Potamopyrgus antipodarum* (J. E. Gray, 1843)	New Zealand	2009	birds, shipping	Naser and Son 2009
	Melanoides tuberculata (O. F. Müller, 1774)	Africa and Southern Asia	It might have been invaded before 1950	-	Facon et al. 2003
	Ecrobia grimmi (Clessin, 1887)	Caspian Sea	2010	birds	Hasse et al. 2010
	Physella acuta (Draparnaud, 1805)	Northern America	1986	-	-
	Sinanodonta woodiana (I..Lea, 1834)	Asia	2022		Bogan et al. 2022
	Ferrissia californica (Rowell, 1863)	Northern America	2014	aquarium trade; birds	Marrone et al. 2011; Marrone et al. 2014
	Mytilopsis leucophaeata (Conrad, 1831)	Northern America	2021	shipping activities from the Persian-Arabian Gulf pathway	Yasser and Naser
Crustacea	*Palaemon elegans* Rathke, 1836	Atlantic Ocean	1968	human activities	Holthuis and Hassan 1975
	Eriocheir hepuensis Dai, 1991	Asia	1980	shipping activities from the Persian-Arabian Gulf pathway	Naser et al. 2012
	Macrobrachium nipponense (De Haan, 1849)	Asia	2006	unintentional escapes from Iranian aquaculture	Salman et al. 2006
	Amphibalanus subalbidus (Henry, 1973)	America	2022	shipping activities from the Persian-Arabian Gulf pathway	Yasser et al. 2022
	Amphibalanus amphitrite (Darwin, 1854)	Southern Europe	1960	-	-
	Amphibalanus improvisus (Darwin, 1854)	America	2015	shipping activities from the Persian-Arabian Gulf pathway	Naser et al. 2015

Legend:

old invaders	intermediate invaders	new invaders

group includes also two species, i.e. *Eriocheir hepuensis* Dai, 1991 and *P. acuta* which represent the "intermediate invaders" recorded from 1980 to 1986, respectively. The group of "new invaders" includes the recent recorded alien species in the Shatt Al-Arab: *Potamopyrgus antipodarum* (J.E. Gray, 1843), *Sinanodonta woodiana* (I. Lea, 1834), *Mytilopsis leucophaeata* (Conrad, 1831),

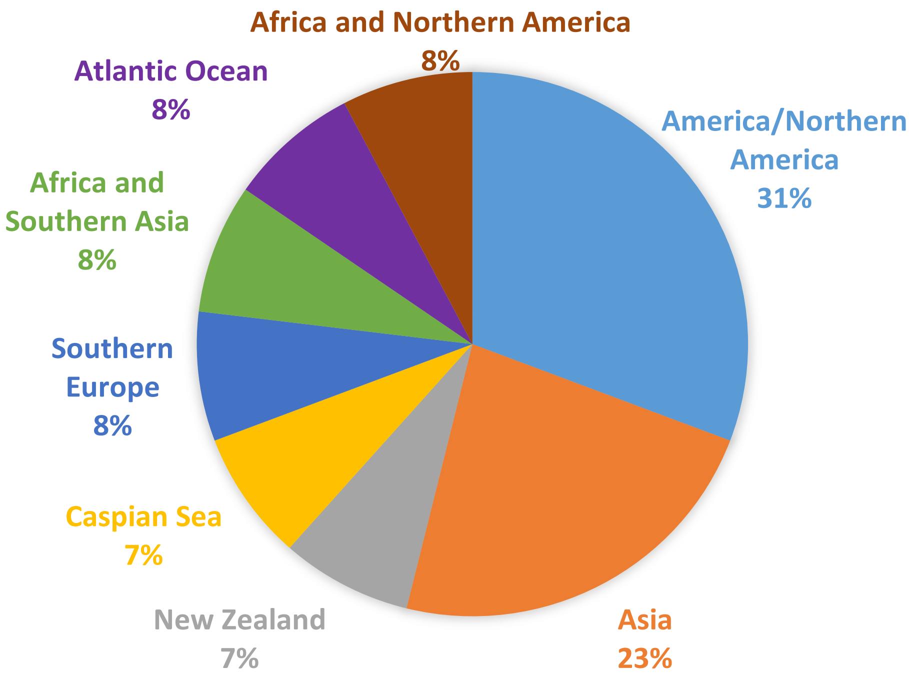

Figure 4. Geographical origin of aquatic AIS in southern Iraq.

Macrobrachium nipponense (De Haan, 1849), *Amphibalanus subalbidus* (Henry, 1973), *Amphibalanus improvisus* (Darwin, 1854). In Euphrates: *S. woodiana*, and for the first time *P. elegans*, *M. leucophaeata*, *E. hepuensis*, *M. nipponense*, *A. subalbidus* and *Ecrobia grimmi* (Clessin, 1887). Seven alien species were collected from Tigris as new invaders to the river: *S. woodiana*, *M. nipponense*, *Ferrissia californica* (Rowell, 1863), *E. hepuensis* and in addition to the other "old invaders": *Melanoides tuberculata* (O.F. Müller, 1774), *P. acuta*, *A. amphitrite*. In total, 31% of species originate from America or Northern America, 23% from Asia, 8% from Southern Europe, 8% from Africa and Southern Asia, 8% from the Atlantic Ocean, 8% from Africa and Northern America, 7% from New Zealand, and 7% from the Caspian Sea (Table 2, Figure 4).

Distribution patterns of AIS

Within a basin, the highest number of aquatic AIS was usually observed in the lower reaches of the rivers (Figure 5A–D). For instance, 11 species were recorded in the Shatt Al-Arab River in the Basra province (Figure 5), 10 species in the lower reaches of the Euphrates River in the Nasiriyah province (Figure 5), and 6 species in the lower reaches of Tigris in the Amarah province. Only six species, i.e., *P. acuta*, *M. tuberculata*, *S. woodiana*, *E. hepuensis*, *M. nipponense* and *A. subalbidus*, appeared to be common in all examined river basins. The distribution maps (Figure 5) show that crustaceans and gastropods are distributed both in the lower and upper rivers' sections (Figure 5A–C), while bivalves occur mainly in the lower and middle parts of the rivers (Figure 5D).

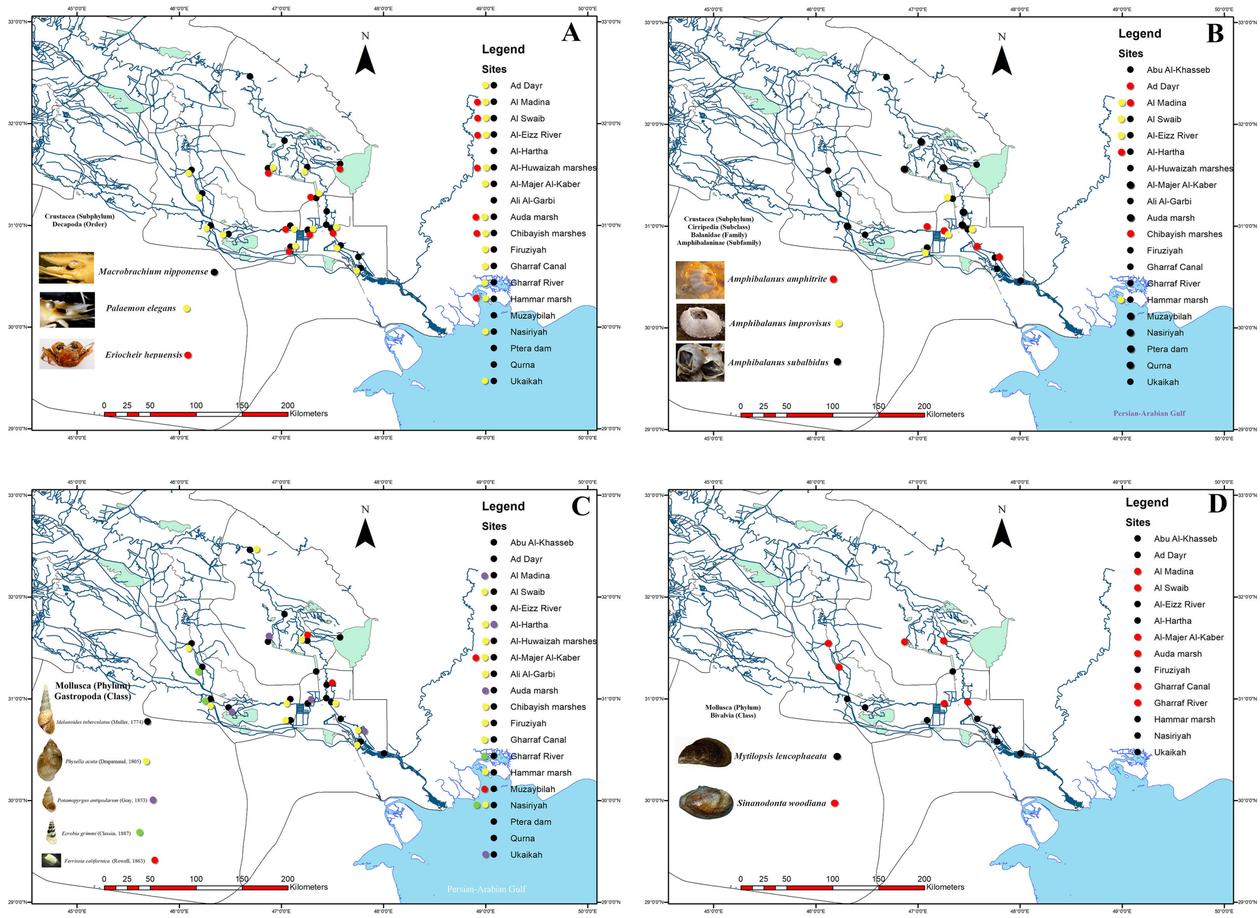

Figure 5. The distribution of aquatic alien invertebrate species in large river basins of southern Iraq: crustaceans (Decapoda) A; crustaceans (Cirripedia) B; molluscs (Gastropoda) C; and molluscs (Bivalvia) D.

Mobile crustaceans are more widespread than sessile ones. The mobile *M. nipponense* is the most often recorded crustacean present at 17 sampling sites, *P. elegans* is recorded at 13 sites, while *E. hepuensis* is observed at 7 sites. The sessile crustacean cirriped *A. subalbidus* occurs at 16 sites, *A. improvisus* and *A. amphitrite* are recorded at four sites. The gastropod *M. tuberculata* is widely distributed in all river basins, while *F. californica* is restricted to two sites at the Tigris River, as is *E. grimmi* which is found at two sites at the Euphrates River. The distribution of *S. woodiana* was restricted to the upper reaches of the Shatt Al-Arab and is present in both Tigris and Euphrates, whereas it is not recorded from the lower reaches of the Shatt Al-Arab. The other alien bivalve is *M. leucophaeata* (record under preparation) which was listed from different river basins but with restricted distribution in the Tigris River basin where it was collected from only one site at Al-Eizz River where the salinity is 1.9 part per thousand (ppt).

The salinity in the three basins was as follows: 1.2–2.5, 1.1–1.6 and 0.5–1.9 ppt for Shatt Al-Arab, Euphrates and Tigris, respectively (Figure 6). The results show that the highest aquatic AIS number was noted in the Shatt

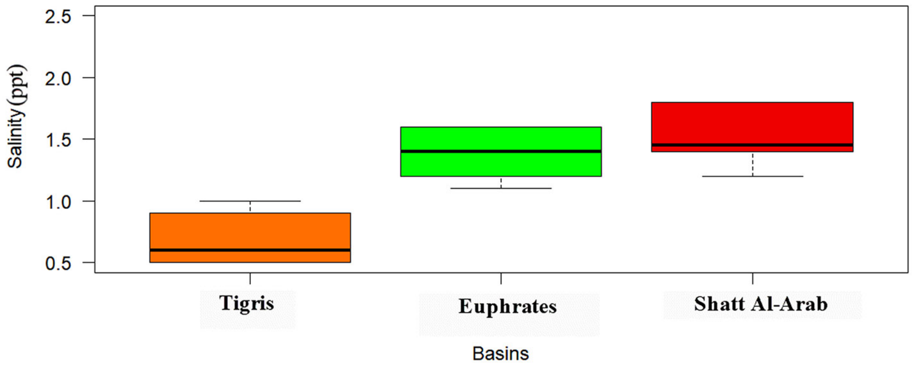

Figure 6. Boxplots showing the salinity values in the three river basins.

Al-Arab characterised by the highest salinity, the average number of aquatic AIS was in the Euphrates, characterised by mean values of salinity among the studied rivers, and the lowest number of aquatic AIS was in Tigris, where salinity values at the sampling sites were the lowest.

Discussion

The majority of the alien species from the checklist belong to the "new invaders" group. Eight of the thirteen alien species were first recorded in Iraq in the period 2006 to 2022 (Salman et al. 2006; Naser and Son 2009; Hasse et al. 2010; Naser et al. 2012, 2015; Marrone et al. 2014; Bogan et al. 2021; Yasser et al. 2022). Most of them were recorded from the Shatt Al-Arab basin with few records from the Tigris-Euphrates basins. Most introductions of these species likely occurred by intensive shipping that takes place in the southwest of the Persian-Arabian Gulf.

On a West Asian scale, the Shatt Al-Arab seems to be a hotspot for aquatic invasions, as it connects the Persian-Arabian Gulf to Iraq's interior waterbodies. Many euryhaline or oligohaline marine species, for example, *E. hepuensis*, *P. elegans* and the barnacle *A. subalbidus*, became more common in the Tigris, Euphrates and Shatt Al-Arab.

In southern Iraq, the Mesopotamian Marshes were historically the largest wetland ecosystem of Western Eurasia, but now are almost completely drained. Iraq suffers from river salinization caused by anthropogenic changes: decreasing water flow through the construction of dams for hydroelectric energy and irrigation purposes, agricultural activity and climate change (Kordić and Milanković 2016; Olson and Speidel 2024). In Iraq, freshwater flow from Turkey's headwaters has been reduced as a result of the construction of numerous dams and barrages on the Tigris-Euphrates basins in recent decades, causing water levels in the Tigris and Euphrates fall to dangerously low levels (Adamo et al. 2018; Kibaroglu 2019). Because of the decreased freshwater flow, the Shatt Al-Arab River's water has become brackish, allowing alien species like *E. hepuensis* (Naser et al. 2012) to survive there and spread their ranges to inland water bodies. Moreover,

Figure 7. The alien barnacle *Amphibalanus improvisus* attached at another alien species (*Sinanodonta woodiana*); collected from the Euphrates.

the Tigris and Euphrates Rivers have suffered greatly as a result of climate change, and degraded habitats have been created, aggravating environmental problems in Iraq in recent decades (USAID 2017). Further, annual rainfall has declined, contributing to the decline in water discharge (Issa et al. 2014). Due to climate change, water temperatures have increased by 1–2 °C (Rahi and Halihan 2010; Issa et al. 2014; Abdullah et al. 2016; Rahi 2018).

The recorded alien species show different tolerances to salinity. The species of the genus *Amphibalanus* showed different distribution patterns in brackish and fresh aquatic environments. For example, *A. subalbidus* has an oligohaline distribution and tolerates prolonged exposure to fresh water. The species flourishes at salinities ranging from 0.5 to 10 ppt, with occasional occurrences up to 18 ppt, but has never been recorded at higher salinities (Poirrier and Partridge 1979; Kennedy and DiCosimo 1983; Dineen and Hines 1994; Naser et al. 2024). *Amphibalanus subalbidus* was collected from salinities ranging from 2.3 ppt at Abu Al-Khaseeb at the lower reaches of the Shatt Al-Arab River to 1 ppt at Al-Hammar marsh and 1 ppt from the lower reaches of the Euphrates River in southern Iraq, and it could establish itself at any of these salinities. This is backed by studies that show the species can establish populations even in freshwater because it can survive low salinity and withstand prolonged contact with fresh water (Dineen and Hines 1994).

Another species of this genus is *A. improvisus*, which was collected from the intertidal banks of the rivers from different sites in the Shatt al-Arab and Euphrates and on the surface of crabs *E. hepuensis* or attached to *S. woodiana* (Figure 7), and it also was recorded from one site at the Tigris, where salinity reaches 1.9 ppt. The global success of *A. improvisus* as an invasive barnacle has been linked to its euryhaline and eurythermal habitat preferences, its ability to self-fertilize and develop rapidly, its high reproductive capacity, its protracted settling period, and an opportunistic diet (Stasolla et al. 2021). *Amphibalanus amphitrite* is a marine species that was able to establish populations in the upper part of the Shatt al-Arab and even in the lower Euphrates River; further, this species was recorded and genetically confirmed in the upper Euphrates River by Abd Al-Rezzaq et al. (2015).

Sinanodonta woodiana is a mussel native to East and Southeast Asia. It is reported that this species poses a major threat to the local Unionidae bivalves population (Lajtner and Crnčan 2011). According to Fabbri and Landi (1999), the native species *A. anatina* had been completely replaced by *S. woodiana* in several channels with a soft substrate and high trophic level. Indeed, this applies to the local species *Anodonta vescoiana* Bourguignat, 1856, which almost disappeared in the Tigris and Euphrates basins, as no specimen of this species was recorded in this study or even in previous studies, giving further evidence that the species is on its way to extinction (Lopes-Lima 2014). Numerous studies conducted in the last few years have demonstrated that *S. woodiana* is comprised of several cryptic species and genetic lineages (Kondakov et al. 2018; Douda et al. 2024). This also holds for Middle Asia, where two species, the temperate clade of *S. woodiana* and *S. lauta* have been molecularly discovered. Middle Asia may be one of the donor regions for the invasion of Iraq (Kondakov et al. 2018). Since *S. woodiana* from Iraq was first listed by Bogan et al. (2022), this problem was overlooked. Although it is a freshwater species, it could establish populations in both the Tigris-Euphrates basins and in the upper reaches of the Shatt Al-Arab River where the salinity is more than 1 ppt.

The brackish water mussel, *M. leucophaeata*, is a mytiliform bivalve native to Northern America. It is also referred to as Conrad's fake mussel (Mondadori 1982) or the dark false mussel (Verween et al. 2010). This species from oceanic tidal estuaries is very well adapted to rapid changes in salinity (Zhulikov et al. 2018). It can withstand a wide range of oligo- to mesohaline conditions (Siddall 1980). *Mytilopsis leucophaeata* was found recently in the lower reaches of the Shatt Al-Arab (record under confirmation by molecular analysis). The species established large populations in the Shatt Al-Arab and Euphrates rivers with no records from Tigris until now. However, the species can survive at very low salinity (Verween et al. 2010). Therefore, a further spread towards the fresh waters of the Tigris River can be expected.

Anthropogenic disturbances, such as drainage, pollution, and hydrotechnical structures, have led to the introduction and spread of alien gastropod species such as *P. antipodarum*, *P. acuta*, and *F. californica*, whose abundances are currently increasing (Sowa et al. 2019). Introduced species, such as the invasive New Zealand mud snail *P. antipodarum*, which arrived in Iraq via commercial shipping, can quickly spread to inland waters. Piscart et al.

(2011) suggest that the species' tolerance to high salinity contributes to its invasion success. The species may have diverse clonal lineages with different salinity tolerance (Butkus et al. 2020).

Some previous studies have shown that increasing salinity results in the elimination of sensitive taxa and their replacement by eurytopic species (Patnode et al. 2015). Thus, the current study confirms that increasing salinity may contribute to the success of alien species in freshwater environments.

Melanoides tuberculata is an exotic freshwater gastropod and one of the most successful colonizers, whose invasion success is facilitates by being parthenogenetic (Okumura and Rocha 2020). According to Plaziat and Youris (2005), *M. tuberculata* is an euryhaline species that inhabits low-salinity environments (0.2–3 ppt, but tolerates high salinities over 23 ppt). The species could establish populations in fresh and brackish waters of southern Iraq where it is collected from 19 sites in the three river basins.

Brackish-water snails such as *E. grimmi* may establish in appropriate environments, isolated populations that are separated not only by land but also by the sea's complete salinity (Wilke 2003). A previous study by Haase et al. (2010) found that *E. grimmi* from Lake Sawa (Iraq) may have been introduced by migrating birds from the Caspian Sea. The species is likely restricted to a small distribution area in the Euphrates River. Although Ponto-Caspian species are usually euryhaline (Dobrzycka-Krahel et al. 2023) and increasing salinity of rivers probably facilitated their spread (Dobrzycka-Krahel and Graca 2014), they are vulnerable to abrupt changes in salinity (Gogaladze et al. 2021).

Numerous studies have demonstrated that throughout the past few decades, the rates of alien species introduction and spread have dramatically increased (e.g., Seebens et al. 2018). This pattern is common in southern Iraq river basins as well. Moreover, in recent years, the East Asian river prawn *M. nipponense* has spread from the lower reaches of the Shatt Al-Arab upstream to the lower reaches of the Tigris-Euphrates basins. Furthermore, this alien species was able to establish populations in the distant Greater Zab River north of Iraq where the salinity is less than 0.5 ppt (Shekha et al. 2017). In the present study, *M. nipponense* has been collected from the lower reaches of Euphrates and Tigris with high abundance providing an example of a successful invasive species that can establish populations in fresh and brackish waters. *M. nipponense* is known to exhibit a high environmental adaptability (Chen et al. 2009) and can tolerate some level of salinity for larval development. Also, many other species recorded in this study like cirripeds and gastropods occur both in the upper and lower reaches of rivers that indicate their euryhalinity. Understanding this adaptability may be important for further management of these species.

Previous studies from other regions showed that *Potamopyrgus antipodarum* can become abundant and dominate mollusc communities (Gerard et al. 2003). It may also reduce the growth of native molluscs (Riley et al. 2008) due to competition for space and food. *Melanoides tuberculata* is a well-known host for trematodes that cause diseases both for humans and animals (Post et al. 2022). It has been reported to displace several gastropods when introduced (Pointier and McCullough 1989). *Physella acuta* is globally a highly invasive snail. This species is host to many trematode species causing foodborne diseases in humans (Jayachandran et al. 2021). Additionally, it has been documented to displace native snail fauna in some areas where it is introduced (Dobson 2004).

Sinanodonta woodiana can impact native species through competition for host fish for food, larval parasitism and parasite transmission (Douda et al. 2024). *Palaemon elegans* due to its progressively increasing densities and wide habitat range can exhibit strong predation pressure on native gammarids (Kuprijanov et al. 2015). *Eriocheir* species have been reported as invasive, mostly due to their burrowing activity destabilising river banks and leading to erosion (ISSG 2021). Their wide dispersal capabilities and predation on native biota are also of concern (Naderloo 2014). Some AIS are biofouling species (e.g., *M. leucophaeata, A. subalbidus*, *A. amphitrite* and *A. improvisus*) that cause unwanted attachment to ships and hydroengineering constructions (Gwak et al. 2024; Ubagan et al. 2021). Biofouling species may cause large economic impacts due to increasing vessel fuel consumption and greenhouse gas emissions (Nakano and Strayer 2014). Our study shows that the number of aquatic AIS in large river basins of southern Iraq has recently increased substantially and that the impacts of alien species on native biota are extensive.

Authors' contribution

MDN, AGY and NMA equally contributed to research conceptualisation, sampling design and methodology. MDN, AGY, ADK, SLB and FE conducted all data analyses and wrote the original draft. All the co-authors contributed to reviewing and editing the manuscript.

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