



Update of the distribution of the alien species *Potamopyrgus antipodarum* (Gray, 1853) (Gastropoda: Tateidae) in Catalonia (NE Iberian Peninsula)

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ABSTRACT

The mud snail *Potamopyrgus antipodarum* is among the main invaders in continental aquatic ecosystems. Despite a huge number of articles dealing with this species, there is no good knowledge of its distribution range, which is aggravated by its quick spread. While a huge update has been published in 2019 on its presence in the Iberian Peninsula, with a total of 352 bibliographic citations, 44 of them in Catalonia, this seems an underestimation of its true distribution. In this paper, 83 new localities for this species are given in Catalonia, further extending its presence to previously unrecorded areas. Since this work has not comprehensively examined all likely habitats, the actual distribution range of this species could be still much bigger. This may have important consequences in a near future for the rich biodiversity of the aquatic ecosystems, and particularly on native endemic molluscan species.

RESUM

El cargolí del fang *Potamopyrgus antipodarum* és un dels principals invasors dels ecosistemes aquàtics continentals. A pesar de l'important nombre de publicacions relatives a aquesta espècie, no hi ha un bon coneixement del seu rang de distribució, la qual cosa s'agreuja per la seva ràpida expansió. Tot i que el 2019 es va publicar una important actualització de la seva distribució a la península Ibèrica, amb un total de 352 citacions bibliogràfiques, 44 d'elles a Catalunya, aquesta sembla una subestimació de la seva distribució real. En el present article es reporten 83 noves citacions per a aquesta espècie a Catalunya, estenent la seva presència a àrees prèviament no reportades. Com que aquest treball no ha examinat exhaustivament tots els possibles hàbitats, la distribució real podria ser encara molt més extensa. Això pot tenir importants repercussions en un futur immediat per a la rica biodiversitat dels ecosistemes aquàtics, i molt particularment sobre les espècies de mol·luscs nadius endèmics.

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Introduction

Biological invasions are an ever-growing challenge for biodiversity conservation. Different approaches have been used to quantify this problem, and also to categorize the aggressiveness of alien species, in order to facilitate their management. Thus, it is well known the list of “100 worst” alien species from IUCN (Global Invasive Species Database, 2022), mainly based on subjective expert opinions, but also different algorithms have been used to analyze this problem. However, while on average they can be useful, they do not necessarily reflect the real situation, particularly on a microscale. In this sense, some species could be much more dangerous than previously thought, particularly when data are accumulating at a very fast pace. This could clearly be the case of the small freshwater gastropod *Potamopyrgus antipodarum* (J.E. Gray, 1853), absent in the previously commented list on worst invasive species, and ranked in position #42 in a recent categorization of global alien species using a Generic Impact Scoring System (Nentwig *et al.*, 2018), but whose direct effects on local extinction of microfauna probably have still not been

properly addressed. This species is indeed included in the “Catálogo Español de Especies Exóticas Invasoras (BOE, 2013), so its management should be paramount.

The small mud snail *P. antipodarum* is native from New Zealand and adjacent islands, and has spread all over the world in the last 150 years. It was already found in England by 1859, and subsequently in many different countries from Europe, Americas and Asia (Alonso & Castro-Díez, 2008). In Spain it was first found in the Llobregat Delta in 1924, on the basis of six specimens, pointing to an introduction through ballast water at Barcelona harbor at the beginning of 20th century (Orozco *et al.*, 2001; Alonso & Castro-Díez, 2008). Further research has allowed finding it at many stations in almost all hydrographic basins in the Iberian Peninsula (Alonso & Castro-Díez, 2012 & 2015). The last comprehensive work considered 352 registered citations in 12 watersheds in Iberia (Alonso *et al.*, 2019), with a total of 44 citations for Catalonia. However, this seems to be a clear underestimation of the actual situation.

In this paper, we report a number of new locations for the species in Catalonia based on our personal observations all over the last years. While this is not a comprehensive work of searching the species at any suitable habitat, and many gaps are yet to be filled, it may add relevant information for studying the spread of the species.

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This may also give a better picture of the problems that this species could represent, particularly those related to the conservation of high priority aquatic habitats or species.

Materials and methods

Field expeditions in search of other water snails, mainly crenobionts and stygobionts, were done between 2005 and 2022 in many different places along the Catalan geography, including rivers, streams, natural or modified fountains, and irrigation channels. Observations reported are derived from visual inspections, or after analyzing material at the laboratory for the study of other species, mainly obtained by sorting mud and sediments with the help of sieves of different mesh sizes (0.2 to 5.0 mm).

Results

Table 1 and figure 1 show the new localities where *P. antipodarum* has been found in the context of the present work, with altitude and coordinates annotated. In some places, high accumulations of shells were found (figure 2), although no quantification was obtained in the field. A total of 83 new localities for 71 different municipalities are reported, registering its presence in some rivers or tributaries previously unreported. The invasive species has been repeatedly found along with other native species. Representative shells from different localities are depicted in figure 3.

Additionally, figure 1 shows the new citations of this work alongside the known bibliographic citations, to reflect the expansion of the species in the last years and its present known distribution range.

Discussion

In a recent paper, Alonso *et al.* (2019) gave a comprehensive revision of all the Iberian published citations for *P. antipodarum*. This was a great improvement on the knowledge on the spread of the species, compared to previous works, such as Alonso *et al.* (2012) who reported only 7 localities, with only one in Catalonia.

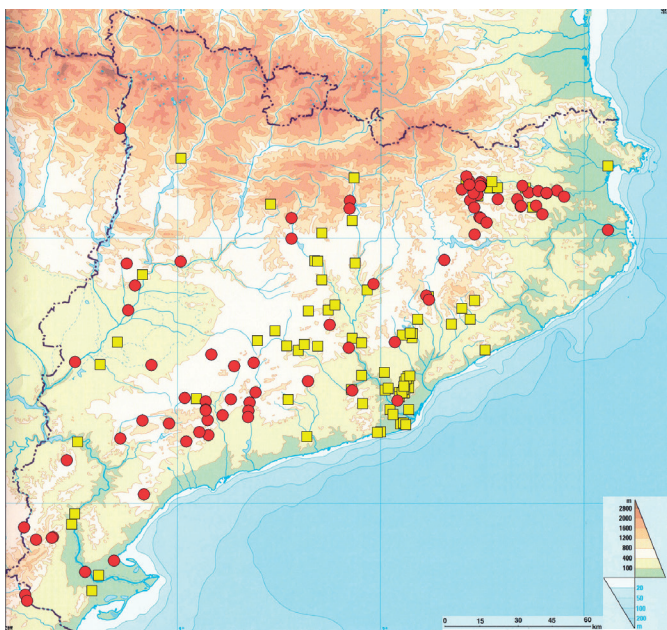


Figure 1. Map of Catalonia with the known distribution of *Potamopyrgus antipodarum*. Yellow squares: bibliographic citations, based on Vilella (1967); Altimira (1968, 1969); Bech (1974); Bech & Fernández (1984a,b); Altaba *et al.* (1988); Bros (1992), Bros (2004); Guillén & Corbella (1995); Neckheim (1995); Orozco *et al.* (2001); Abella Ciuraneta (2005); Ortiz *et al.* (2005); Campos *et al.* (2013); Quiñonero Salgado & López Soriano (2013); López i Pla (2014); Roig *et al.* (2016); Quiñonero Salgado *et al.* (2019). Red circles: new citations from this work.

Our field experience makes us think that the work by Alonso *et al.* (2019), despite the huge increase in citations from previous works, underestimates the present distribution range of the species. We have concentrated only in Catalonia, which is the territory we may cover with some guarantees, even if only partially. Alonso *et al.* (2019) reported for Catalonia a total of 44 citations, which can finally be grouped in six main areas: Ebro Delta; Llobregat Delta and adjacent streams; Fluvià River and tributaries; Tordera River; Banyoles Lake; and a scattered population in Lleida in a tributary of the Ebro River. Almost all of them were dated back to 2010 or earlier, with the only exceptions of Banyoles (Campos *et al.*, 2013) and Ebro Delta (Quiñonero Salgado & López Soriano, 2013). This calls for a lack of recent updates in the bibliography.

In this work, we report a total of 83 new citations, further expanding the presence of the species to places previously unreported, such as the Gaià River basin, and notably increasing the number of localities in Ebro River (main watercourse), and Ter, Fluvià or Francolí rivers, mostly upstream of previous populations (most of the new ones are indeed over 100 m a.s.l.). This is in accordance with the statement by Alonso *et al.* (2019) that *P. antipodarum* is “in a clear spreading phase in the Iberian Peninsula”, with which we totally agree. However, a huge number of likely habitats have not been properly examined in the present work, so it is expected that the list could be enlarged as soon as new field works are undertaken. In any case, this is not a comprehensive work aimed at visiting all likely populations of the species, which would need a much bigger sampling effort, clearly out of our possibilities, and should be undertaken by research organizations with the full operational and financial capability.

Potamopyrgus antipodarum is a prototypical invasive species, which shows the main characteristics that make the species a true and successful alien: sexual and asexual reproduction (mostly parthenogenetic in non-native populations); high resistance to environmental changes, including tolerance to contamination; high reproductive rate (up to six generations/year); high expansion capabilities, including passive transport by waterfowl; and varied diet, including periphyton, macrophytes and detritus (Alonso & Castro-Diez, 2008; Verhaegen *et al.*, 2018). As a consequence, it has invaded all type of aquatic systems, including streams, lakes, reservoirs, estuaries and even open seas (Alonso & Castro-Diez, 2008). Our observations, however, seem to correlate to some degree the abundance of the invader with rather warm waters, being the species almost absent in the colder waters of high mountains. These results fit well with those of Gallardo *et al.* (2020), who reported a preference of this species for waters rich in nitrates and temperatures over 10°C. Further research is needed to verify this assertion, in any case.

The main impact on ecosystems may be attributed to its high reproductive rate, by altering the primary production and competing with other species (Alonso & Castro-Diez, 2008; 2015). However, there are no clear estimates on the impacts it may have on native species, particularly endemic invertebrates. Our field observations point to a rather very high impact on some native mollusks, since the localities where *P. antipodarum* is abundant are almost completely depleted of other native species, mainly crenobiont gastropods. Sometimes this displacement can be very fast, as seen from one visit to another in some localities. Some examples of personal observations have been found in Font de Querol, at Querol (Tarragona) where a huge population of *P. antipodarum* is present, and *Bythinella batalleri* Bofill, 1925 has completely vanished out, and only empty shells can

Figure 2: Main habitats where *Potamopyrgus antipodarum* was located. A) Irrigation channel at Pont d’Armentera (Tarragona). B) Fountain basin and drain Font de Querol, Querol (Tarragona). C) Fountain basin and drain Font del Ledoner, Fontscaldes, Valls (Tarragona). D) Gaià River at Pont d’Armentera (Tarragona). E-G) specimens photographed *in situ* on aquatic vegetation: E) Brugent River, La Riba (Tarragona), F, G) Bianya stream at Sant Joan les Fonts (Girona).



Table 1. List of the newly localities reported in this work for *Potamopyrgus antipodarum* in Catalonia. D: dead collected specimens; L: live collected specimens

Num.	Locality	Municipality	Province	Specimens	Coordinates	m a.s.l.
1	Font de Pinós	Aiguafreda	Barcelona	L	31TDG373246	403
2	Font de Can Pèlags	Castellar del Vallès	Barcelona	L	31TDG232070	275
3	Font de Llobató	Centelles	Barcelona	L	31TDG363263	484
4	Font de la Bòrnia	Cercs	Barcelona	L	31TDG058665	644
5	Font del Tagastet	Cercs	Barcelona	L	31TDG055632	707
6	Font de la Senyora	Esplugues de Llobregat	Barcelona	L	31TDF240824	200
7	Font Freda	Gelida	Barcelona	D	31TDF056868	259
8	Font de Sant Jaume	Horta d'Avinyó	Barcelona	L	31TDG149315	341
9	Fountain at Aeri de Montserrat	Monistrol de Montserrat	Barcelona	L	31TDG044048	141
10	Riera de Rupit	Rupit i Pruit	Barcelona	D	31TDG562519	756
11	Les Set Fonts	S. Julià de Vilatorca	Barcelona	L	31TDG437413	575
12	Font del Molí	S. Salvador de Guardiola	Barcelona	L	31TCG967145	293
13	Font de la Rajoleria	Banyoles	Girona	D	31TDG811639	184
14	Font del Castell	Bàscara	Girona	L	31TDG924676	60
15	Fluvià River	Besalú	Girona	L	31TDG756721	130
16	El Remença	Cornellà del Terri	Girona	L	31TDG837260	102
17	Font d'Esponellà	Esponellà	Girona	L	31TDG820700	118
18	Font del Guitart	Hostalnou de Bianya	Girona	D	31TDG541728	412
19	Font del Tortonell	Les Preses	Girona	D	31TDG544662	460
20	Deu d'en Noc d'en Cols	Olot	Girona	L	31TDG586721	372
21	Fluvià River	Olot	Girona	L	31TDG558692	436
22	Font d'en Noc	Olot	Girona	L	31TDG586872	373
23	Font de Bufaganyes	Olot	Girona	L	31TDG575685	437
24	Resclosa d'Orfes	Orfes	Girona	L	31TDG896701	66
25	Font Fresca	Riudaura	Girona	D	31TDG511707	549
26	Font de l'Arn	S. Martí de Campmajor	Girona	L	31TDG750636	246
27	Torrent de l'Arn	S. Martí de Campmajor	Girona	L	31TDG749636	242
28	Font del Gat	Sant Esteve d'en Bas	Girona	L	31TDG555646	487
29	Font de la Teula	Sant Feliu de Pallerols	Girona	L	31TDG586588	472
30	Fountain near Gorg de la Mola	Sant Feliu de Pallerols	Girona	L	31TDG610569	375
31	Font del Mosquer	Sant Feliu de Pallerols	Girona	D	31TDG581590	479
32	Font de les Molleres	Sant Joan les Fonts	Girona	L	31TDG584732	354
33	Riera de Bianya	Sant Joan les Fonts	Girona	L	31TDG588739	321
34	Font del Mas Seguer	Sant Martí del Clot	Girona	L	31TDG529762	404
35	Riera de Bianya	Sant Martí del Clot	Girona	D	31TDG540743	420
36	Font Calenta can Patxet	Santa Pau	Girona	L	31TDG656666	417
37	Font Fresca	Santa Pau	Girona	L	31TDG657666	129
38	Ser River	Serinyà	Girona	L	31TDG781693	89
39	Ter River	Torroella de Montgrí	Girona	D	31TEG103536	2
40	Font de Beu i Tapa	Vilert	Girona	L	31TDG853691	341
41	Fluvià River	Vilert	Girona	D	31TDG854691	85
42	Font de Sant Pere	Baldomar	Lleida	L	31TCG365423	239

Num.	Locality	Municipality	Province	Specimens	Coordinates	m a.s.l.
43	Font de Portell	El Pont de Suert	Lleida	L	31TCG134987	852
44	Unnamed trough	Gerb	Lleida	L	31TCG177326	496
45	Corb River	Guimerà	Lleida	L	31TCG482029	567
46	Font de les Avellanes	Les Avellanes	Lleida	L	31TCG146419	280
47	Font Vella	Les Borges Blanques	Lleida	L	31TCF236991	420
48	Font de la Boixassa	Navès	Lleida	L	31TCG819596	668
49	Sant Ponç reservoir	Olius	Lleida	L	31TCG817510	527
50	Segre River	Tèrmens	Lleida	L	31TCG148223	189
51	Segre River	Torres de Segre	Lleida	L	31TBG924012	109
52	Gaià River	Albareda de S. Creus	Tarragona	L	31TCF627763	261
53	Glorieta River	Alcover	Tarragona	L	31TCF462691	229
54	Gorg de la Parada Fonda	Alcover	Tarragona	L	31TCF426704	353
55	Barranc del Llop	Alfara de Carles	Tarragona	L	31TBF806277	300
56	Font Vella	Alfara de Carles	Tarragona	L	31TBF810279	286
57	Font de la Carrova	Amposta	Tarragona	L	31TBF941130	5
58	Ermita Sta. Madrona	Arnes	Tarragona	L	31TBF693324	507
59	Font de Baix	Cabacés	Tarragona	L	31TCF101686	340
60	Font de la Salut	Cabra del Camp	Tarragona	L	31TCF558840	490
61	Seniol River	Conesa	Tarragona	L	31TCF574978	694
62	Gaià River	El Pont d'Armentera	Tarragona	L	31TCF634825	335
63	Font del Lledoner	Fontcaldes	Tarragona	L	31TCF522773	402
64	Font de la Barrinà	Horta de Sant Joan	Tarragona	L	31TBF742271	588
65	Font del Llop	L'Aleixar	Tarragona	D	31TCF371667	694
66	Font de Sant Joan	La Fatarella	Tarragona	L	31TBF879601	447
67	Channels at Font Gran	La Riba	Tarragona	L	31TCF460754	361
68	Font de Quicoli	La Sènia	Tarragona	D	31TBF690041	359
69	Font del Riu	La Sènia	Tarragona	L	31TBF697016	318
70	Bassa de les Olles	L'Ampolla	Tarragona	L	31TCF061174	0
71	Estret de la Vall	Montblanc	Tarragona	L	31TCF454799	430
72	Font d'Andraga	Montblanc	Tarragona	L	31TCF454796	444
73	Font de la Ceba	Montblanc	Tarragona	L	31TCF456833	339
74	Francolí River	Montblanc	Tarragona	L	31TCF455833	338
75	Font del Pou	Prades	Tarragona	L	31TCF303743	1029
76	Font de Santa Marina	Pratdip	Tarragona	L	31TCF191448	659
77	Font de Querol	Querol	Tarragona	L	31TCF660867	539
78	Font de la Teula	S. Miquel de Campmajor	Tarragona	D	31TDG735666	196
79	Torrent del Duc	Sant Quintí de Mediona	Tarragona	L	31TCF876911	321
80	Font de les Canelles	Santa Coloma de Queralt	Tarragona	L	31TCF654991	662
81	Font Massat	Santes Creus	Tarragona	L	31TCF630790	290
82	Les Cadolles Fondes	Ulldemolins	Tarragona	L	31TCF194760	517
83	Font dels Gorgs	Vimbodí	Tarragona	L	31TCF369849	469

now be found. By contrast, in the north and south of Catalonia, in places with rather cold waters, healthy populations of some *Bythinella* species can still be found, where *P. antipodarum* is still absent. Similarly, at Font de la Salut, at Cabra del Camp (Tarragona), a competition with the autochthonous *Pseudamnicola spiratus* (Paladilhe, 1869) has been observed, with only a single alive specimen, but hundreds of empty shells of this species, since the arrival of the invader, which could be due to direct competition between them.

We have however no quantitative data on this effect, the competition, which could be an interesting field for future research. Particularly, endemic species of mollusks (but likely also from other taxonomic groups) from streams and crenobiont habitats, very rich in Mediterranean ecosystems, could be among the most endangered species in this interaction, and consequently they should be considered as a top priority in the management of this invasion. Authorities and ecosystem managers should pay more attention to it, before the consequences on native biota are irreversible.

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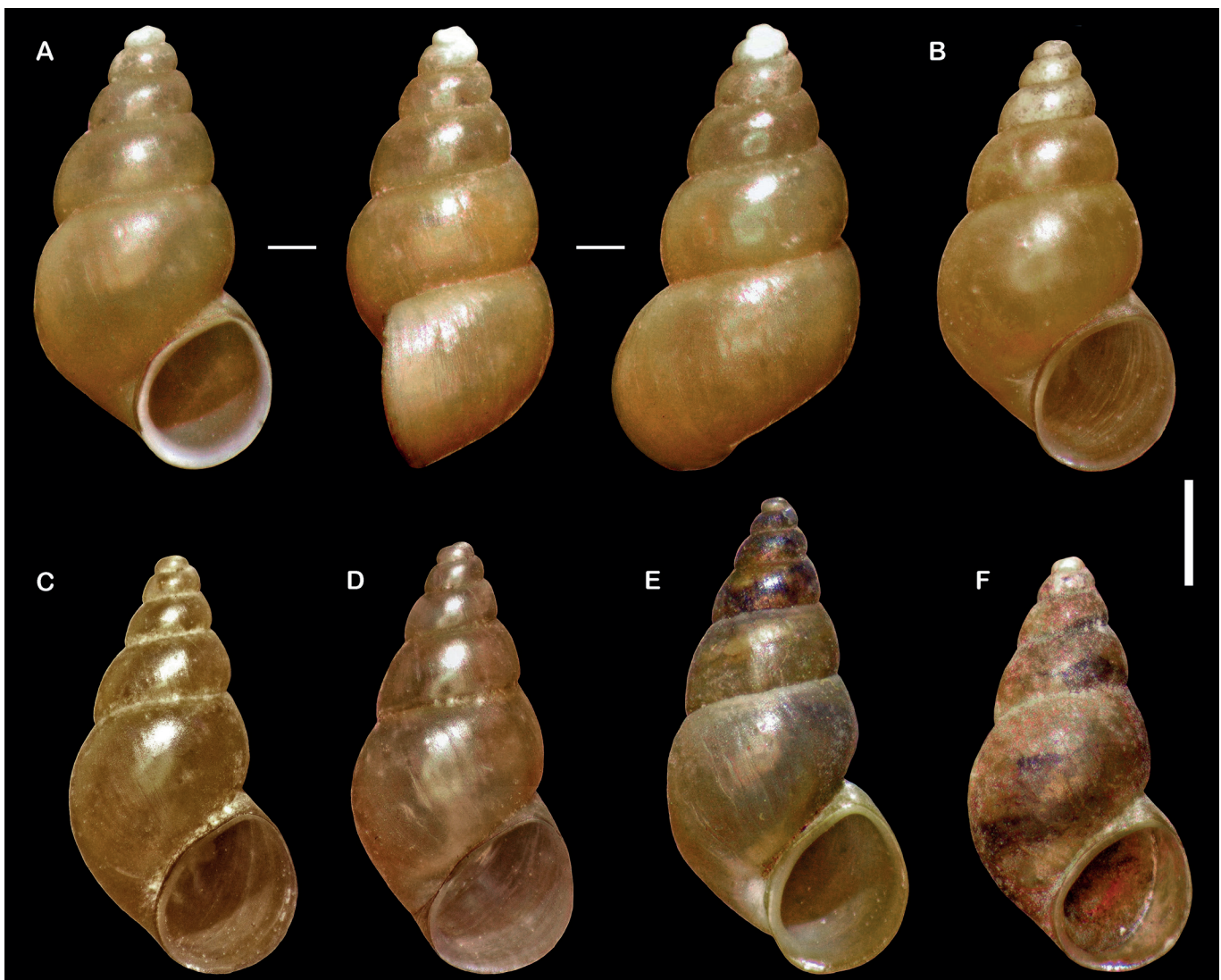


Figure 3: Specimens of *Potamopyrgus antipodarum* from different Catalan localities. A) Canal de la Font Gran, La Riba (Tarragona). B) Font del Lledoner, Fontscaldes, Valls (Tarragona). C) River Francolí at Montblanc (Tarragona). D) Font de la Salut, Cabra del Camp (Tarragona). E) Font de les Avellanés, Les Avellanés (Lleida). F) Font de Portell, El Pont de Suert (Lleida). Scale: 1 mm.

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