

Risk assessment of the crayfish pet trade based on data from the Czech Republic

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Abstract The pet trade in freshwater crustaceans, including crayfish, has grown rapidly in recent decades and become an important pathway for introducing new non-indigenous species into Europe. This paper provides the first overview of non-indigenous crayfish species (NICS) traded as ornamental and their potential impact in the Czech Republic, which is the second leading importer into Europe. The paper presents a full list of traded crayfish species, their market availability, and trade names or misnomers used in the country. In total, 27 crayfish species from all three families are advertised and marketed, of which *Astacus astacus* is the only indigenous species. Only three NICS were recognized as very common on the market. The invasiveness and risk associated with ornamental crayfish trade were assessed using the Freshwater Invertebrate Invasiveness Scoring Kit. Five NICS were classified into the high-risk category, the highest score being for *Procambarus fallax* f. *virginalis*. The invasiveness of crayfish indigenous to North America is significantly greater than that of

crayfish from the rest of the world, and therefore regulation in this regard is recommended.

Keywords Ornamental animal · Invasiveness · FI-ISK · Aquarium · Trade names

The knowledge of the risks and negative consequences associated with the occurrence, translocation and trade of live non-indigenous crayfish species (NICS) is very important for conservation of indigenous crayfish species (ICS) (Barbatesi and Gherardi 2000; Chucholl et al. 2012). Holdich et al. (2009) divided European NICS into two groups: ‘old’ for species introduced early (prior to 1975) for aquaculture and harvest for human consumption and ‘new’ for species which were mostly introduced for ornamental purposes (after 1980). This is mainly because live freshwater crustaceans have in recent years become increasingly popular in hobby breeding (Chucholl 2013). The ‘new’ NICS established in the wild come mainly from aquarium releases or escapes from garden ponds (Peay 2009). Following NICS which most probably originated from aquarium release have been recorded in EU countries: *Procambarus fallax* f. *virginalis* in Germany (Chucholl and Pfeiffer 2010), Italy (Nonnis Marzano et al. 2009), Netherlands (Soes and Koese 2010), Slovakia (Janský and Mutkovic 2010) and surprisingly in Sweden (Bohman et al. 2013), *Cherax destructor* in Italy (Scalici et al. 2009) and *Cherax quadricarinatus* established in one locality in Slovenia

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(Jaklic and Vrezec 2011). Part of them formed established populations. Certain ‘old’ crayfish species are sold also as pets and can therefore be released into nature by hobby breeders, such as *Procambarus clarkii* in Germany (Holdich 2002). In contrast to large-scale crayfish farming, the ornamental crayfish trade is not perceived as a serious threat to freshwater ecosystems in many countries (Turkmen and Karadal 2012), including the Czech Republic.

Marketed crayfish species native to North America are considered very dangerous due to their role as vectors of crayfish plague (*Aphanomyces astaci*), which seriously endanger European ICS (Vogt 1999). Moreover, chytrid fungus (*Batrachochytrium dendrobatidis*), which is also potential threat for native biota could be transmitted by certain NICS (McMahon et al. 2013). The release of ornamental crayfish into the wild is therefore undesirable (Taugbøl and Skurdal 1999; Holdich et al. 2009).

Although the pet trade in Germany (with 120 marketed NICS) is the main pathway for live crayfish imported into the European market (Pekny and Lukhaup 2005; Chucholl 2013), the Czech Republic is one of the world’s leading producers, importers and exporters of ornamental aquatic animals generally (Livengood and Chapman 2007; Peay 2009; Miller-Morgan 2010). Despite the large numbers of marketed NICS, risk assessments of the crayfish pet trade have heretofore never been prepared for the Czech Republic. In view of the country geographical location on the borders of three European drainage basins: the North Sea (the Elbe river basin), Baltic Sea (the Oder river basin), and Black Sea (the Morava river basin), information about NICS is very important for regulation of possible biological invasions in the risk area and adjoining countries. Due to human activities, non-indigenous aquatic species can rapidly spread in all three hydrological systems within this densely populated area of less than 50,000 km² and therefore we focus on potential invasiveness of ornamental crayfish marketed in the Czech Republic. Together with a similar report from Germany (Chucholl 2013), this note completes an overview of the two leading European countries in the crayfish pet trade.

Collected data set was based on discussion with wholesalers with ornamental crayfish and on evidence of the Czech Customs Administration. The first imported ornamental crayfish in the Czech Republic were registered by the Czech Customs Administration in 2003. The

amount of traded crayfish has displayed an increasing trend through subsequent years of about 3,000 imported individuals and 60,000 locally produced individuals. About 2/3 of imported crayfish were re-exported abroad: mainly to Italy, Austria, Germany and Slovakia. A total of 27 crayfish species from all three families (Astacidae, Cambaridae, Parastacidae) are marketed in the Czech Republic, of which *Astacus astacus* (Astacidae) is the only ICS and the remaining 26 are NICS. Thirteen offered species are indigenous to North America; all marketed species are from the family Cambaridae except for *Pacifastacus leniusculus*, which is from the family Astacidae. The other 13 NICS are indigenous to Australia and New Guinea; all marketed species are from the family Parastacidae. Three species are categorized as ‘old’ and 23 species as ‘new’ NICS (Table 1). Our research uncover that crayfish are imported and advertised under misnomers, names of other species, outdated names or only by a trade names, attaining accurate species identification is therefore problematic (Table 2). A similar situation has been noted of the wholesale trade in Germany (Chucholl 2013).

For the assessment of potential invasiveness of ornamental crayfish in the Czech Republic we used the screening tool (Freshwater Invertebrate Invasiveness Scoring Kit, FI-ISK, v.1.19), which consists of the 49 questions divided in biogeography/history and biology/ecology sections. The FI-ISK score for NICS ranged between 3 and 27, with the highest value obtained for *P. fallax* f. *virginalis* (Table 1). No species were classified into the low-risk category but 21 species were classified as medium-risk, and five species were classified as high-risk in accordance with FI-ISK calibration (Tricarico et al. 2010) (Table 1). In agreement with our results, Chucholl (2013) evaluated *C. destructor*, *Orconectes limosus*, *P. clarkii*, *P. fallax* f. *virginalis* as high-risk species in Germany; Pappalopoulos et al. (2014) considered *P. clarkii* and *C. destructor* as high-risk species in Greece. All five high-risk species in the Czech Republic had been introduced to freshwater habitats in Central Europe. *P. clarkii* (Holdich 2002) and *P. fallax* f. *virginalis* (Chucholl and Pfeiffer 2010) are probably of pet trade origin but none of them have been recorded in the wild in the Czech Republic. In addition to Australian *C. destructor*, four of the high-risk species are native to North America and they are often vectors of crayfish plague (Holdich et al. 2009). All ‘old’ NICS advertised in the Czech pet trade are classified as high-risk,

Table 1 Complete list of non-indigenous crayfish species offered in the Czech Republic: species name, family, availability in wholesale trade, non-indigenous species (NICS) status, potential invasiveness (FI-ISK score), and risk category (FI-ISK category)

Species name	Family	Wholesale availability	NICS status	FI-ISK score	FI-ISK category
<i>Pacifastacus leniusculus</i>	Astacidae	Very rare	Old	19	High
<i>Cambarellus diminutus</i>	Cambaridae	Very rare	New	3	Medium
<i>Cambarellus patzcuarensis</i>	Cambaridae	Common	New	3	Medium
<i>Cambarellus puer</i>	Cambaridae	Very rare	New	3	Medium
<i>Cambarellus schufeldtii</i>	Cambaridae	Very rare	New	3	Medium
<i>Cambarellus texanus</i>	Cambaridae	Very rare	New	3	Medium
<i>Orconectes limosus</i>	Cambaridae	Very rare	Old	25	High
<i>Orconectes nana</i>	Cambaridae	Very rare	New	15	Medium
<i>Procambarus alleni</i>	Cambaridae	Rare	New	13	Medium
<i>Procambarus clarkii</i>	Cambaridae	Very common	Old	26	High
<i>Procambarus cubensis</i>	Cambaridae	Very rare	New	7	Medium
<i>Procambarus fallax f. virginialis</i>	Cambaridae	Common	New	27	High
<i>Procambarus milleri</i>	Cambaridae	Very rare	New	3	Medium
<i>Cherax albertisii</i>	Parastacidae	Rare	New	6	Medium
<i>Cherax boesemani</i>	Parastacidae	Common	New	3	Medium
<i>Cherax cainii</i>	Parastacidae	Very rare	New	7	Medium
<i>Cherax destructor</i>	Parastacidae	Common	New	18	High
<i>Cherax holthuisi</i>	Parastacidae	Common	New	3	Medium
<i>Cherax lorentzi</i>	Parastacidae	Very rare	New	3	Medium
<i>Cherax monticola</i>	Parastacidae	Very rare	New	3	Medium
<i>Cherax peknyi</i>	Parastacidae	Very common	New	6	Medium
<i>Cherax preissii</i>	Parastacidae	Very rare	New	3	Medium
<i>Cherax quadricarinatus</i>	Parastacidae	Very common	New	14	Medium
<i>Cherax</i> sp. Blue Moon	Parastacidae	Rare	New	3	Medium
<i>Cherax</i> sp. Hoa Creek	Parastacidae	Common	New	3	Medium
<i>Cherax</i> sp. Red Tip	Parastacidae	Common	New	3	Medium

Astacus astacus was not evaluated by the FI-ISK, hence it is a protected species and its sale is forbidden without permission, therefore it is offered only exceptionally (incorrect determination; importers' ignorance of the law)

but it is a 'new' species, *P. fallax f. virginialis* (known as Marbled Crayfish or Marmorkrebs), that has the highest FI-ISK score. This species reproduces parthenogenetically and probably it could be also vector of crayfish plague (Scholtz et al. 2003; Martin et al. 2010; Chucholl et al. 2012). Marbled Crayfish is potentially the most invasive of all marketed species because the release of a single female into the wild could lead to establishment of an abundant population (Scholtz et al. 2003). While there is no record of this species in the Czech Republic, the feral population of *P. fallax f. virginialis* has been found in neighbouring Germany (Chucholl et al. 2012). The species' future naturalization in the Czech Republic is expected, as it is often considered as successful invasive species (Martin et al.

2010; Chucholl et al. 2012). Although the risk of parthenogenetic reproduction of *P. fallax f. virginialis* was discussed in the paper by Nonnis Marzano et al. (2009), FI-ISK rating done by Tricarico et al. (2010) evaluated this crayfish as only medium-risk for Italy probably because just one individual was recorded in the wild. Anyway we conclude that the FI-ISK score and high-risk category for *P. fallax f. virginialis* obtained in our study are more up-to-date and realistic based on aforementioned facts.

The Australian crayfish *C. destructor* was classified into the high-risk category. The serious risk of its introduction is disputable since *P. leniusculus* had scored just one point higher. In our opinion, vectors of crayfish plague should be considered more dangerous

Table 2 Marketed crayfish species, species authority, recorded scientific misnomers, and trade names frequently used in the Czech pet trade

Species	Species authority	Scientific misnomers	Trade names
<i>Astacus astacus</i>	L., 1758	<i>Pacifastacus leniusculus</i>	
<i>Cambarellus diminutus</i>	Hobbs, 1945		
<i>Cambarellus patzcuarensis</i>	Villalobos, 1943		Orange Mini, Mexican Dwarf
<i>Cambarellus puer</i>	Hobbs, 1945		
<i>Cambarellus schufeldtii</i>	Fitzpatrick, 1983		
<i>Cambarellus texanus</i>	Albaugh & Black, 1973		rak texaský
<i>Cherax albertisii</i>	Nobili, 1889	<i>Cherax albertsi</i>	Blue Tiger
<i>Cherax boesemani</i>	Lukhaup & Pekny, 2008		Red Chilli, Red Brick Papua
<i>Cherax cainii</i>	Austin & Ryan, 2002	<i>Cherax tenuimanus</i>	
<i>Cherax destructor</i>	Clark, 1936		
<i>Cherax holthuisi</i>	Lukhaup & Pekny, 2006		Apricot, Orange Coral
<i>Cherax lorentzi</i>	Roux, 1911		
<i>Cherax monticola</i>	Holthuis, 1950		Brown Coral
<i>Cherax peknyi</i>	Lukhaup & Herbert, 2008	<i>Cherax papuanus</i> , <i>C. quadricarinatus</i>	Zebra, Tiger, Papua Tiger
<i>Cherax preissii</i>	Erichson, 1846		Black Coral
<i>Cherax quadricarinatus</i>	von Martens, 1868		rak modrý, Blue Claw
<i>Cherax</i> sp.			Blue Moon, Blue Pearl
<i>Cherax</i> sp.		<i>Cherax lorentzi</i> , <i>C. quadricarinatus</i>	Hoá Creek, Pink Coral
<i>Cherax</i> sp.			Red Tip
<i>Orconectes limosus</i>	Rafinesque, 1817		rak pruhovaný
<i>Orconectes nana</i>	Williams, 1952		
<i>Pacifastacus leniusculus</i>	Dana, 1852		rak signální
<i>Procambarus alleni</i>	Faxon, 1884		Electric Blue
<i>Procambarus clarkii</i>	Girard, 1852		rak červený
<i>Procambarus clarkii</i> (coloured morphs)	Girard, 1852		Blue Pearl, Electric Red, Orange, Snow White
<i>Procambarus cubensis</i>	Erichson, 1846	<i>Procambarus troglodytes</i>	
<i>Procambarus fallax</i> f. <i>virginialis</i>	Martin et al., 2010	<i>Procambarus fallax</i>	rak mramorový, Fallax
<i>Procambarus milleri</i>	Hobbs, 1971		

than *C. destructor*, which has sensitivity to this disease similar to European ICS (Hefti and Stucki 2006). We therefore propose the addition of a query into the FISK design on NICS' resistance to infectious diseases in the risk area, which would result in a shift of category intervals. Scores of North American crayfish species should considerably increase after such modification, and *C. destructor* could then fall into the lower category.

Corresponding to trends abroad (Holdich et al. 2009), the most available (Table 1) and popular ornamental species are *P. fallax* f. *virginialis*, *P. clarkii*, *C. quadricarinatus*, and *Cherax peknyi*. The last three species are also registered among the most available ornamental

crayfish in Germany (Chucholl 2013) and in Greece (Papavlasopoulou et al. 2014). Based on this fact we suggest, that focusing on *P. clarkii*, *C. quadricarinatus* and *C. peknyi* is highly recommended for future surveys of trade with ornamental crayfish in Europe. Availability in the wholesale trade is similar for North American crayfish species and species from the rest of the world (GLZ, $\chi^2 = 7.08$, $df = 3$, $P = 0.07$), but potential invasiveness of North American species was significantly higher (GLZ, $\chi^2 = 6.76$, $df = 1$, $P < 0.01$) (Fig. 1).

Although import of live crayfish to certain European countries is strictly regulated (Holdich and Pöckl 2005; Peay 2009), legislation is not sufficient to reduce

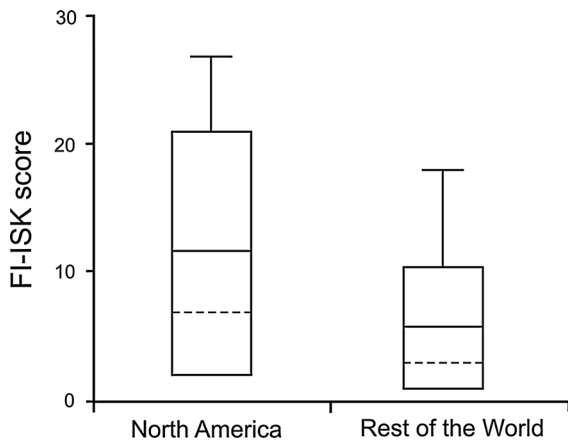


Fig. 1 Differences between FI-ISK score of ornamental crayfish originated from North America and from rest of the world. *Solid line* in the *box* represents mean; *dashed line* represents median; *box* is for range of standard deviation; *whiskers* show non-outlier range

the quantity of ornamental crayfish marketed in leading pet trade countries, as powerful interest groups lobby to resist such efforts (Peay 2009). Many of North American crayfish are adaptable to European climatic conditions, including those of the Czech Republic, and could therefore be established in the wild (Holdich et al. 2009). Svobodová et al. (2010) have proposed a complete ban on import of live crayfish into the Czech Republic in order to prevent the introduction of NICS, similarly as it is in France, Ireland, Norway, Poland, Scotland, Spain, and Sweden (Holdich and Pöckl 2005; Peay 2009). The justification for such a step appears to be well-founded in the case of North American species, while allowing an exception to keep them for scientific purposes. Although they are similarly available on the market, invasiveness of species from the family Parastacidae, which are sensitive to crayfish plague, is indeed significantly lower in the Czech Republic, and their naturalization is improbable. The approach taken in England, Wales and Switzerland, where pet trade in crayfish from the family Parastacidae is allowed (Peay 2009), thus seems to be the best solution for the Czech Republic.

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