

Imports of ornamental crayfish: the first decade from the Czech Republic's perspective

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ABSTRACT

Key-words:
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The import of aquarium animals has been increasing worldwide in recent years. Despite its contribution to world trade and the economy, this trade also comprises one of the main pathways for the introduction of non-indigenous animals. In the past decade, crayfish has become a popular pet as well as a potential threat to the environment upon its escape or release. Since the Czech Republic is one of the world's leading importer, exporter, and producer of aquatic ornamental animals, we prepared a detailed analysis of crayfish imports. The present paper provides a complete list of countries supplying ornamental crayfish and examines trends of their prices and imported quantities during the past decade (2003–2012). Indonesia has been identified as the leading supplier in recent years. The annual average price of imported crayfish has varied over the evaluated period within the range of €0.76–4.72 per individual and it is rising annually by €0.15. The quantity of live crayfish imported for aquarium purposes has not been affected significantly by the price per individual and it has grown rapidly. Therefore a constant monitoring of this pet trade sector is strongly recommended for the future.

RÉSUMÉ

Les importations d'écrevisses ornementales : une première décennie analysée en République tchèque

Mots-clés :
*commerce
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indigènes,
prix*

L'importation d'animaux d'aquarium a augmenté dans le monde entier au cours des dernières années. Malgré sa contribution au commerce mondial et à l'économie, ce commerce représente également l'une des principales voies d'introduction des animaux non-autochtones. Dans la dernière décennie, l'écrevisse est devenue un animal de compagnie populaire ainsi qu'une menace potentielle pour l'environnement lors de son échappement ou de son déversement dans le milieu naturel. Depuis que la République tchèque est devenue l'un des premiers importateurs, exportateurs et producteurs d'animaux aquatiques ornementaux du monde, nous avons préparé une analyse détaillée des importations d'écrevisses. Le présent document fournit une liste complète des pays fournisseurs d'écrevisses ornementales et examine les tendances de leurs prix et les quantités importées au cours de la dernière décennie (2003–2012). L'Indonésie a été identifiée comme le principal fournisseur au cours des dernières années. Le prix annuel moyen des écrevisses importées a varié au cours de la période évaluée dans la fourchette de 0,76 à 4,72 € par individu et il est en hausse chaque année de l'ordre de 0,15 €. La quantité des écrevisses vivantes importées à des fins d'aquariophilie n'a pas été affectée de manière significative par les prix et elle a connu une croissance rapide. Par conséquent, une surveillance constante de ce secteur du commerce des animaux de compagnie est fortement recommandée pour l'avenir.

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INTRODUCTION

The keeping of aquatic animals in aquaria is one of the most popular hobbies worldwide (Perdikaris *et al.*, 2012; Turkmen and Karadal, 2012), and there is no surprise that the international aquarium pet trade has been growing rapidly in recent decades (Miller-Morgan, 2010). Four of the world's top five exporting countries are from Asia (Singapore, Japan, Malaysia, and Thailand) and one is from Europe (the Czech Republic) (Ploeg, 2013). The European Union (EU) and the United States of America are the largest and traditional importer of aquarium animals (Turkmen and Karadal, 2012). Given that the Czech Republic is a member of the EU and it is a dominant exporter of aquatic animals in Europe, it is also becoming the main re-export hub for other countries in the EU (Ploeg, 2007).

The pet trade in aquatic animals consists predominantly of fish, but trade in other freshwater animals, including crayfish, has increased rapidly in the past decade (Lin *et al.*, 2006; Faulkes, 2010; Chucholl, 2013; Kopecký *et al.*, 2013). In addition to its economic importance, pet trade is also recognized as one of the main pathways for the introduction of new species: including "hitch-hiking" species *via* the transportation water and pathogens (Rixon *et al.*, 2005; Peay, 2009; Mrugała *et al.*, 2014). Although the pet trade in freshwater crayfish is relatively new in the EU, some of the ornamental crayfish species have already been recorded from the wild. Most probably, these originated from aquarium releases and include, for example, *Procambarus fallax* f. *virginalis* in Germany (Chucholl and Pfeiffer, 2010), Italy (Nonnis Marzano *et al.*, 2009), the Netherlands (Soes and Koese, 2010), Slovakia (Janský and Mutkovič, 2010) and, surprisingly, Sweden (Bohman *et al.*, 2013); *Cherax destructor* in Italy (Scalici *et al.*, 2009); and *Cherax quadricarinatus* established in one location in Slovenia (Jaklic and Vrezec, 2011). While *Procambarus clarkii* is the most popular species for human consumption, it is probably equally important and popular in the aquarium trade and certainly highly invasive based on predictive evaluation in all studied countries (Italy, Germany, Greece, and Czech Republic) (Tricarico *et al.*, 2010; Chucholl, 2013; Papavlasopoulou *et al.*, 2014; Patoka *et al.*, 2014a). Certain established populations of this species in the EU also originate from aquarium releases (Dehus *et al.*, 1999; Chucholl, 2013). Although no ornamental crayfish have been detected in the wild the Czech Republic, two species are already in neighbouring countries namely in Germany and in Slovakia (Chucholl and Pfeiffer, 2010; Janský and Mutkovič, 2010; Kouba *et al.*, 2014).

The introduction of non-indigenous species (hereafter referred to as NICS) can result in serious direct and indirect negative impacts on ecosystems and native biota (Peay, 2009). In addition to obvious direct competition that is very harmful for indigenous crayfish species (hereafter referred to as ICS) in Europe, there is crayfish plague caused by the oomycete *Aphanomyces astaci* which is transmitted by North American crayfish species which are asymptomatic carriers (Edgerton *et al.*, 2004; Kozubíková *et al.*, 2007). The danger of unintended introduction of NICS is reflected on France, Ireland, Norway, Scotland, Spain, and Sweden, where the import of live ornamental crayfish is completely banned (Edsman, 2004; Holdich and Pöckl, 2005; Peay, 2009). Two feasible solutions were suggested in previous studies in perspective of the Czech Republic Svobodová *et al.* (2010) preferred totally banned trade with ornamental crayfish, whereas Patoka *et al.* (2014a) proposed selective restrictions focused on high-risk species only.

Management and conservation of ICS require information about NICS, e.g. the safe distance for reintroduction, determination and monitoring of crayfish distribution and abundance, and detection of new introductions (Souty-Grosset and Reynolds, 2009; Gherardi *et al.*, 2011) as well as the rate of NICS spread (Peay and Füreder, 2011; Perdikaris *et al.*, 2012). Propagule pressure of NICS is recognized as one of the main factors of establishment (Capinha *et al.*, 2013). Consequently, the quantity of NICS in the pet trade is directly correlated with the probability of their release into the wild and their possible establishment similarly to fish released from aquaria (Duggan *et al.*, 2006).

Although a risk assessment for ornamental NICS in the Czech Republic (Patoka *et al.*, 2014a) and an analysis of keeper behaviour (Patoka *et al.*, 2014b) have been published, detailed information focused on the origin of imported ornamental crayfish and their prices and quantities

has not yet been available. Keeping in mind that the Czech Republic is an important export hub for the entire EU, we analysed the available information and present it here in an integrated form.

MATERIALS AND METHODS

We surveyed statistical databases from the Czech Customs Administration and the Czech Statistical Office, which, according to laws and regulations in the EU and the Czech Republic, register the import of live animals and animal products. Additionally, we initiated interviews with five wholesalers who are known to be leading importers of live crayfish in the Czech Republic and with four important local private breeders. Based on the data obtained, we summarized a list of international suppliers of ornamental crayfish, average annual prices per individual and imported quantities over the years 2003 to 2012.

> SUPPLIER IDENTIFICATION

The list of supplying countries which export ornamental crayfish into the Czech Republic for each year was compiled using evidence from the relevant authorities and confirmed by the responses of wholesalers.

> QUANTITY ESTIMATION

Since the authorities keep records only for the total weight of imported shipments, we estimated the quantity (number of crayfish) based on a calculation of the average weight of imported individuals. We weighed individual crayfish to the nearest gram at two wholesalers during 2012. The average weight \pm standard deviation ($n = 250$) of individuals from 6 species – *Procambarus clarkii* (50 individuals), *P. alleni* (30 individuals), *Cherax destructor* (50 individuals), *C. holthuisi* (20 individuals), *C. peknyi* (50 individuals), and *C. quadricarinatus* (50 individuals) was calculated to be 30 ± 7 g. We used species imported in higher numbers only, thereby excluding rarely imported species such as *Cambarellus* spp.

Domestic production of ornamental crayfish has not been monitored by any competent authority in the Czech Republic and the quantity of locally produced ornamental crayfish was therefore based on data obtained from interviews with leading private breeders and wholesalers.

> IMPORT PRICE ESTIMATION

The authorities record only the total price of each shipment. We calculated the price of imported individuals by dividing the total price by the estimated number of individuals. Prices are stated in Euro (€).

> RETAIL PRICE

Retail prices were obtained from online price lists of about 30 pet shops. Table I lists the offered species, as well as their sizes, prices, origins, and availabilities.

> AVAILABILITY ON MARKET

Each species' availability on the market was assessed in accordance with Chucholl (2013) using the following criteria: (i) species available only for short periods and in small quantities were rated "very rare"; (ii) species available occasionally in small quantities were rated "rare"; (iii) species available frequently in low numbers were rated "common"; and (iv) species always available in high numbers were rated "very common".

Table 1

List of retailed species of ornamental crayfish, their size classes (in cm), prices (usual and range from minimum to maximum, in €), origin (import, domestic production, field capture) and availability on market (very common, common, rare, and very rare).

Species	Size class (cm)	Price (€)	Origin	Availability
<i>Cambarellus diminutus</i>	1–1.5	4.37 (4.25–4.81)	import	very rare
	1.5–2	6.29 (4.60–9.35)		
<i>Cambarellus patzcuarensis</i>	1.5–2	4.44 (1.90–12.96)	domestic, import	common
	2–3	5.00 (3.14–22.25)		
<i>Cambarellus puer</i>	1.5–2	6.29 (5.74–9.25)	import	very rare
<i>Cambarellus shufeldtii</i>	1–1.5	5.00 (4.44–6.29)	import	very rare
<i>Cambarellus texanus</i>	2–3	6.29 (3.70–12.77)	import	very rare
<i>Cherax albertisii</i>	8–10	9.35 (8.51–11.77)	import	rare
<i>Cherax boesemani</i>	8–10	14.29 (12.77–14.63)	import	common
<i>Cherax cainii</i>	5–6	8.51	import	very rare
	10–12	18.51 (18.51–25.37)		
<i>Cherax destructor</i>	6–8	12.29 (4.88–21.22)	import	common rare
	12–15	24.81		
<i>Cherax holthuisi</i>	6–8	9.85	import	common
	8–10	10.37 (9.40–12.88)		
<i>Cherax lorentzi</i>	6–8	8.33 (7.40–16.25)	import	very rare
	8–10	15.92 (14.29–18.66)		
<i>Cherax monticola</i>	8–10	12.96	import	very rare
<i>Cherax peknyi</i>	8–10	12.85 (10.74–14.57)	import	very common
<i>Cherax preissii</i>	6–8	24.37	import	very rare
	8–10	25.81		
<i>Cherax quadricarinatus</i>	4–5	3.88 (2.96–6.22)	import	very common
	5–6	5.45 (3.59–7.07)		
	8–10	7.83 (6.88–9.25)		
<i>Cherax sp. Blue Moon</i>	8–10	14.29 (11.77–25.92)	import	rare
	10–15	14.81 (13.44–16.96)		
<i>Cherax sp. Hoa Creek</i>	8–10	13.33 (11.77–14.29)	import	common rare
	10–15	14.11		
<i>Cherax sp. Red Tips</i>	7–10	11.77 (9.40–14.29)	import	common
<i>Orconectes limosus</i> ¹	?	?	capture	very rare
<i>Orconectes nana</i> ²	5 cm	?	import	very rare
<i>Pacifastacus leniusculus</i>	8–10 cm	5.92	import	very rare
<i>Procambarus alleni</i>	4–5	5.03 (4.70–6.12)	domestic, import	rare
	6–8	8.51 (5.70–14.29)		
<i>Procambarus clarkii</i>	3–4	3.14 (2.96–5.37)	domestic, import	very common
	5–6	3.33 (3.29–9.62)		
	6–7	4.25 (4.03–5.44)		
	8–10	5.00 (3.88–6.70)		
<i>Procambarus clarkii</i> Blue Pearl	5	7.07	import	rare
<i>Procambarus clarkii</i> Electric Red	3–5	2.61	import	rare
	5–6	8.62 (3.00–11.22)		
<i>Procambarus clarkii</i> Orange	3–5	5.81 (3.29–6.74)	domestic, import	rare
	6–8	9.47 (9.25–9.96)		
<i>Procambarus clarkii</i> Snow White	5–6	6.74 (5.88–9.25)	import	rare
<i>Procambarus cubensis</i>	2–3	0.55	domestic	very rare
<i>Procambarus fallax</i> f. <i>virginalis</i>	2–3	0.92 (0.70–1.10)	domestic	common
	5–6	2.59 (2.00–3.14)		
<i>Procambarus milleri</i>	6–8	14.07 (12.22–16.70)	import	very rare

¹ Field captured only and kept by private hobbyists; therefore size class and price are unknown. ² Private import from Germany; price is unknown.

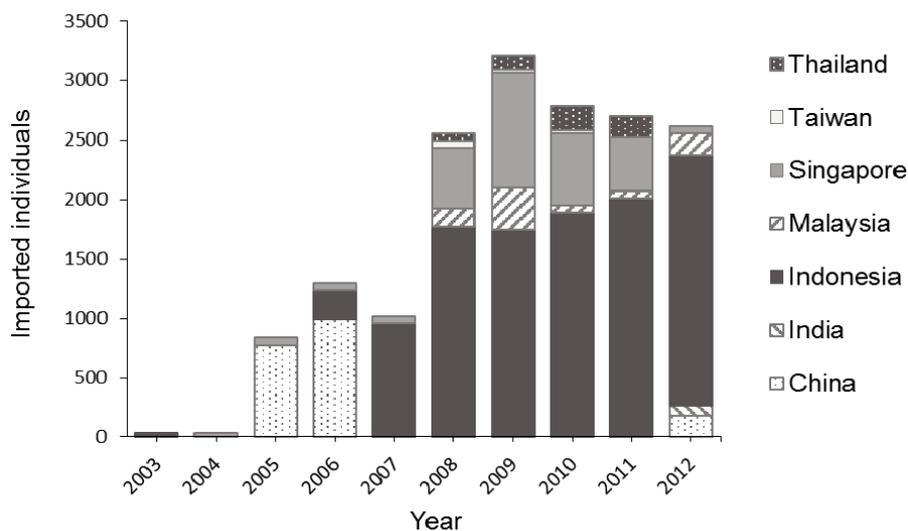


Figure 1

Market share of supplying countries based on imported quantities of ornamental crayfish for the years 2003–2012 in the Czech Republic.

> STATISTICAL ANALYSIS

Equality in the distribution of shipments among supplier countries that import ornamental crayfish into the Czech Republic was tested using a chi-square test (observed vs. expected). The relationship between the number of crayfish imported in each year and the average price per individual was tested by linear regression, and this method was used also to predict the development of crayfish prices. All tests were performed in STATISTICA 9.0 (Statsoft, 2009), and we used $\alpha = 0.05$ as the cut-off for statistical significance.

RESULTS

> SUPPLIER IDENTIFICATION

The first import of ornamental crayfish into the Czech Republic was registered in 2003. China was identified as a major supplier in 2005–2006, and it accounted for more than 92% in 2005 and more than 76% in 2006 of all imported ornamental crayfish in this period. China's leading position was taken over by Indonesia beginning in the year 2007. Currently, more than 80% of ornamental crayfish are imported from Indonesia. The complete list of countries from which ornamental crayfish are imported, contains: India, Malaysia, Singapore, Taiwan, and Thailand (Figure 1). No crayfish were imported from the United States over the evaluated period.

> QUANTITY ESTIMATION

Very small quantities of ornamental crayfish were imported in the first two years (2003–2004). Those numbers increased rapidly, however, and peaked in 2009, when more than 3200 individuals were imported (Figure 1). The distribution of shipments was not equal among countries which export ornamental crayfish into the Czech Republic ($\chi^2 = 207.35$, $df = 6$, $P < 0.01$), mainly due to the large quantity of crayfish imported from Indonesia (Figure 1). The names of imported crayfish species are not registered by relevant authorities, and wholesalers sold them often under commercial names or under misnomers (see Patoka *et al.*, 2014a). Therefore an exact evidence of numbers of individuals of each species imported from particular countries is not available.

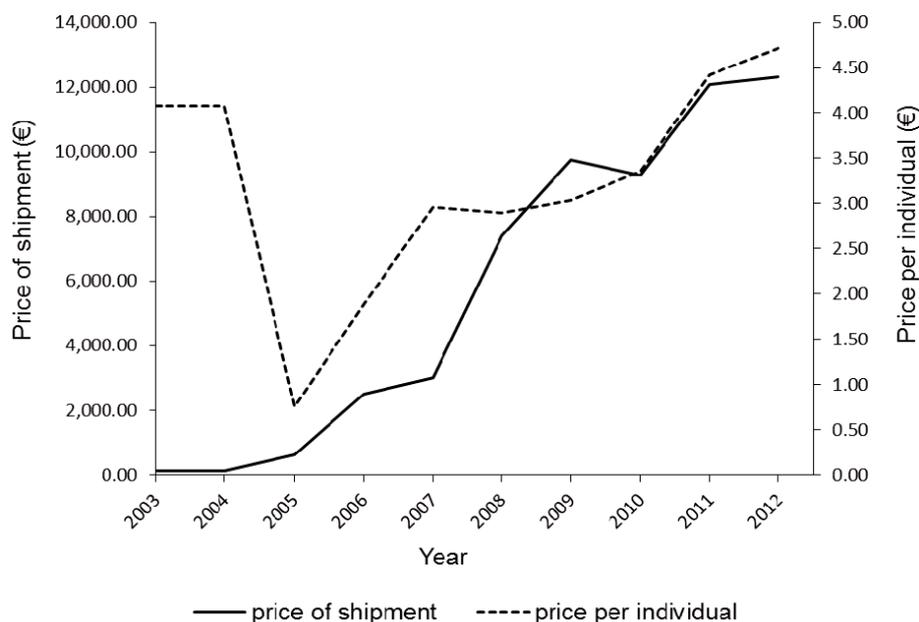


Figure 2

Total price of shipments of imported ornamental crayfish (in €) and average annual price of imported individuals (in €) for the years 2003–2012 in the Czech Republic.

Based on interviews, vast majority of crayfish imported from Indonesia belongs to the genus *Cherax*. These crayfish species originated from farm production (*C. destructor*, *C. quadricarinatus*) and from field captures in West Papua (*C. boesemani*, *C. holthuisi*, *C. peknyi*, *C. sp. Blue Moon*, *C.sp. Hoa Creek*, and *C.sp. Red Tips*).

We estimated the total number of domestically produced ornamental crayfish to vary between 60,000–100,000 individuals per year consisting mainly of following species: *Procambarus clarkii* and *P. fallax f. virginialis*, and in smaller numbers also *Cambarellus patzcuarensis* and *P. alleni*. Domestic production of other species such as *Cherax* spp., *P. cubensis* and *Cambarellus* spp. appears to be currently negligible.

> PRICE ESTIMATION

The influence of the total number of crayfish imported each year on the average price per individual was not significant ($R^2 = 0.14$, $F = 1.28$, $P = 0.29$). The prediction of average price per individual based on linear regression shows that the price increases by about €0.15 annually. The price per imported individual of ornamental crayfish varied from year to year over the evaluation period within the range €0.42–7.14. The average annual price per individual was lowest in 2005 (€0.76) and rose continuously after 2008. It was close to €5 per individual in 2012 (Figure 2). The lowest prices were offered by suppliers from China. The total annual price of imported shipments of ornamental crayfish was rapidly increasing over the years from €122.45 in the first two years to €12,326.52 in 2012 (without administrative fees). Also the imported crayfish retail price depended on the advertised species and its size class and varied from about €2.0 to €25.92 per individual in 2012. Due to domestic production of species such as *Procambarus clarkii* and *P. fallax f. virginialis* and the availability of small size classes, the lowest observed retail price was €0.55 per individual.

DISCUSSION

The vast majority of live ornamental crayfish imported into the EU originate from farms and wholesalers in Southeast Asia, and limited numbers are imported from the United States

(Chucholl, 2013). This accords generally also with the situation in the Czech Republic, except that there are no records of crayfish being imported directly from the United States over the entire decade 2003–2012. Nevertheless, species indigenous to North America are produced and imported from Southeast Asia and China (e.g. *Procambarus clarkii*, *P. alleni*, and *Cambarellus* spp.) (Patoka et al., 2014a). The main supplier in the early years was China, but Indonesia took over the leading position in 2007 and was the source for more than 80% of the total quantity of ornamental crayfish imports in 2012. This fact might be surprising at first sight, inasmuch as China offered the lowest price per individual of all suppliers. It has been determined, however, that Indonesia exports more expensive species (e.g. crayfish from the genus *Cherax*) that are popular among hobby keepers in Europe (Patoka et al., 2014a).

The price per imported individual has been rising continuously and we can predict that it will exceed the threshold of €5 in coming years. Because demand continues to grow, this price increase is not likely to cause a decline in the quantities of imported ornamental crayfish. In many countries, the minimum retail price of ornamental crayfish is slightly higher than €3 per individual, as noted by Turkmen and Karadal (2012) and by Belle and Yeo (2010). We found the lowest retail price per individual of imported crayfish was close to €3 in the Czech Republic. The highest recorded retail price per individual was slightly above €25 (for *Cherax cainii*, *C. preissii* and *C.sp.* Blue Moon) (Table 1) similarly to German market (Chucholl (2013)). Retail price of certain domestically produced ornamental crayfish from the genus *Procambarus* is lower, but apart from this exception, we suggest that the retail pricing of ornamental crayfish is similar across Europe.

The decline in price per individual to a record-low value in 2005 prompted an increase of imported quantities in subsequent years, and since that time crayfish have become more and more popular among hobby keepers (Chucholl, 2013; Patoka et al., 2014a).

The higher species richness results in a higher invasiveness potential of NICS, and new ornamental crayfish species have been imported into the EU in greater quantities during recent years (Chucholl, 2013).

In contrast to ornamental fish, crayfish are transported in cartons and plastic boxes without water and the declared weight of shipments is therefore much lower relative to the number of transported animals. This information should be taken into consideration when imports are evaluated. Our estimation of crayfish imports into the Czech Republic is close to 3000 individuals per year.

The trade of ornamental crayfish is an expanding sector of pet trade with aquatic animals worldwide including the Czech Republic which is an export hub for the EU countries. Beside the economical scope, *via* this pathway new NICS can be introduced and released into the wild. While the number of imported crayfish cannot be regarded as representing an alarming situation, it is not negatively impacted by rising price per individual. Thus we assume that the amount of imported crayfish will grow or stagnate in the next few years. On the other hand, domestic production of North American species, which were assessed as high-risk (Patoka et al., 2014a), is considerably higher. Since North American crayfish species are significantly more dangerous than species from the rest of the world (Patoka et al., 2014a), a constant monitoring of this pet trade sector is recommended for the future. The present paper, along with previous publications (Patoka et al., 2014a; 2014b), should help stakeholders to adopt a position on imports of crayfish and initiate potential necessary restrictions.

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