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Hodnocení environmentálních rizik okrasné akvakultury

doktorská disertační práce

(soubor vědeckých prací s komentářem)

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Čestné prohlášení

Prohlašuji, že svou disertační práci "Hodnocení environmentálních rizik okrasné akvakultury" jsem vypracoval samostatně pod vedením doc. Ing. Lukáše Kalouse, Ph.D., a s použitím odborné literatury a dalších informačních zdrojů, které jsou v práci citovány a uvedeny v seznamu literatury. Jako autor uvedené disertační práce dále prohlašuji, že jsem v souvislosti s jejím vytvořením neporušil autorská práva třetích osob.

V Praze dne Podpis

Poděkování

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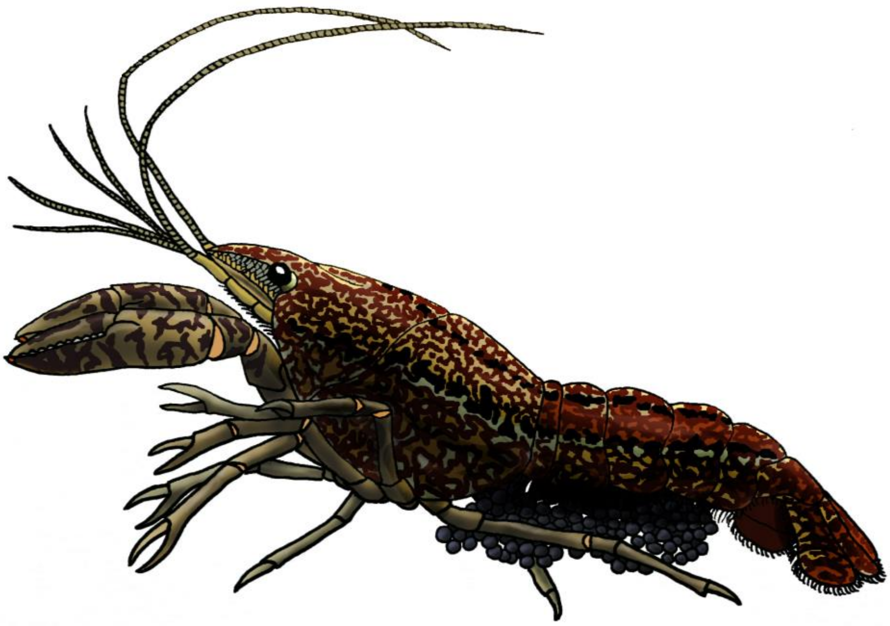

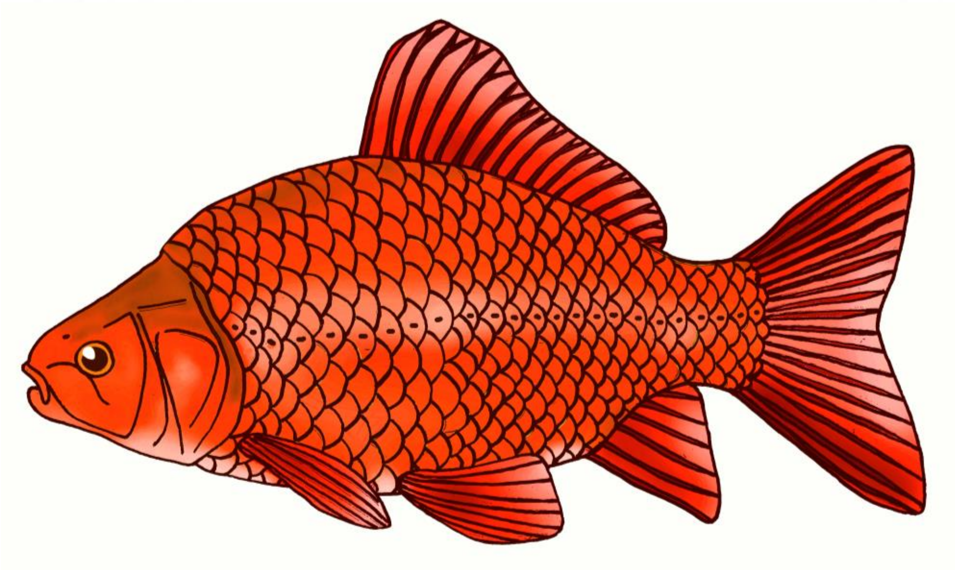

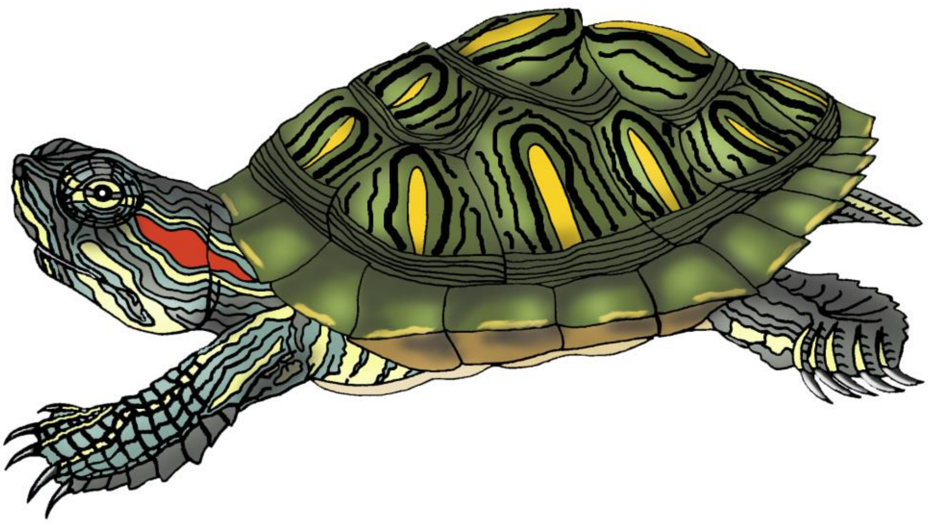

Obsah

1. Úvod

Jedním z hlavních environmentálních rizik ohrožujících biodiverzitu jsou biologické invaze. Pojmem biologická invaze se rozumí proces, při kterém je nepůvodní (alochtonní či vetřelecký) živočišný nebo rostlinný druh úmyslně či neúmyslně zavlečen (introdukován) na novou lokalitu mimo svůj areál původního výskytu, na této lokalitě se uchytí (etabluje) a dále se šíří. Takový druh se označuje jako invazní nebo též invazivní. Biologické invaze mají negativní dopad na druhy původní (autochtonní), které mohou v jejich důsledku i zcela vymizet.

Invazní chování zavlečených druhů a jeho negativní konsekvence zdaleka nejsou jen předmětem studia zainteresovaných odborníků, ale mnohé mají dopad na lidskou společnost jako takovou. Jako příklad je možné uvést všeobecně známou invazi divokých králíků (*Oryctolagus cuniculus*) v Austrálii, z evropského kontinentu pak invazi tzv. amerického brouka mandelinky bramborové (*Leptinotarsa decemlineata*), plzáka španělského (*Arion vulgaris*) či bolševníku velkolepého (*Heracleum mantegazzianum*).

Z hlediska biologických invazí stála okrasná akvakultura dlouhou dobu stranou zájmu odborníků. Tato situace se sice postupem času pomalu měnila, avšak mnohé aspekty nadále unikaly pozornosti. Proto si předložená disertační práce klade za cíl na tyto aspekty poukázat a kromě hlediska biologických invazí rovněž zhodnotit i další environmentální rizika spojená s okrasnou akvakulturou.

2. Literární přehled

1.1. Okrasná akvakultura

Pod pojem okrasná akvakultura se zahrnují tzv. zájmové chovy sladkovodní i mořské fauny, akvarijní i rybniční produkční chovy druhů určených k zájmovým chovům, dále chovy těch druhů, které se v zajetí nedaří rozmnožit a pocházejí z odchytu z přírody, a také pěstování vodních rostlin (e.g. Duggan, 2010). Samotný pojem zájmový chov je ale do jisté míry zavádějící. Přesnější definice je chov živočichů a pěstování rostlin pouze pro okrasné účely, proto jsou v následujícím textu používány termíny okrasná akvakultura a okrasný chov (viz např. Kam et al., 2008). Je tedy zřejmé, že při určení typu chovu není důležitý chovaný druh, ale právě účel chovu. Chovy vodních živočichů pro okrasné účely jsou celosvětově velice populární volnočasovou aktivitou, která je úzce spjata s dynamicky se rozvíjejícím trhem s chovatelskými potřebami (Turkmen and Karadal, 2012). Kromě tradičních druhů ryb se chovatelé stále častěji zaměřují i na druhy raritní či na jiné živočišné skupiny včetně bezobratlých (Chucholl, 2013; Papavlasopoulou et al., 2014). Více než 90 % sladkovodních druhů pochází z odchovu v zajetí, zatímco naprostá většina chovaných mořských živočichů je odchytávána v přírodě a v zajetí se nemnoží vůbec nebo jen ve velice omezené míře (Tlusty, 2002).

Celosvětově je obchod s akvatickými druhy určenými pro okrasné chovy dynamicky se rozvíjejícím sektorem akvakultury a mezinárodního obchodu s průměrným meziročním nárůstem 14 % od roku 1985 (Padilla and Williams, 2004; Rani et al., 2014). Celkově se ročně za tyto živočichy utratí přibližně 3-6,5 mld. USD, z toho většina za sladkovodní akvaristiku (e.g. Silas et al., 2011; Magalhães and Jacobi, 2013). Přibližně 80 % druhů využívaných v okrasných chovech se vyskytuje na území států v tropických oblastech. Až 68 % ryb a dalších živočichů využívaných v okrasných chovech je produkováno či odchytáváno přímo v tropech, přičemž 50-79 % připadá na produkci v zemích jihovýchodní Asie a Japonsku (Chapman et al., 1997; Olivier, 2003). Mezi pět hlavních dodavatelů na světě patří Singapur, Malajsie, Thajsko, Japonsko a hlavním exportérem a producentem mimo Asii je Česká republika (Maceda-Veiga et al., 2013; Ploeg, 2013; Saha and Patra, 2013). Jen v Singapuru tvoří akvarijní ryby 40 % celkového exportu této země (Tlusty, 2002). Export z tzv. rozvojových zemí meziročně roste o 7,5 %. V ekonomicky vyspělejších zemích je nárůst výrazně nižší a pohybuje se okolo 0,3 % za rok. Hlavními odběrateli těchto živočichů jsou USA, Evropská unie a Japonsko (Padilla and Williams, 2004; Ploeg, 2007; Lukhaup and Herbert, 2008; Ploeg, 2013). Statistiky uvádějí, že ve Velké Británii je poměr chovatelů k ostatním obyvatelům 1:18 (3,5 mil. chovatelů), v Německu 1:22 (3,7 mil. chovatelů), a ve Francii 1:32 (2,1 mil. chovatelů) (Rana, 2007). Největším trhem z hlediska okrasné akvakultury je tradičně USA, statistiky počtu chovatelů vůči ostatním obyvatelům ale uvádějí různé odhady: 1:8 (39,9 mil. chovatelů) (Duggan, 2010) až 1:29 (11 mil. chovatelů) (Padilla and Williams, 2004).

1.1.1. Historický vývoj okrasné akvakultury

Prvními sladkovodními živočichy v okrasné akvakultuře byli zlatí karasi (*Carassius auratus*), jejichž chov je doložen z Číny z roku 1163 n. l. (Brunner, 2012). Poprvé se tyto ryby objevily v chovech v Evropě patrně již v 17. století v Nizozemí (Copp et al., 2005b), odkud se v následujících letech rozšířili do nádrží a jezírek v dalších evropských zemích. Rostoucí zájem o okrasné ryby vedl k budování veřejných akvárií, přičemž první akvárium v Evropě bylo otevřené v roce 1853 v londýnské zoo (Kisling, 2001). V dalších letech následovala akvária v Paříži (1859), Hamburku (1864), Hannoveru (1866), Bruselu (1868), Kolíně nad Rýnem (1868), Berlíně (1869), Brightonu (1872), Manchesteru (1874), Southportu (1874), Yarmouthu (1876), Westminsteru (1876), Edinburghu (1878), Amsterdamu (1880) a Sevastopolu (1897). V USA bylo první veřejné akvárium otevřeno v Bostonu (1859), pak ve Washingtonu (1873), San Francisku (1894) a v New Yorku (1896). Celá řada dalších sladkovodních i mořských akvárií byla otevřena ve 20. století (Kisling, 2001).

Přelomovým se stal rok 1868, kdy byly do Evropy importovány první tropické ryby. Jednalo se o rájovce dlouhoploutvé (*Macropodus opercularis*) dovezené z jihovýchodní Asie do Paříže (Goodrich and Smith, 1937). Vzhledem k tomu, že rájovci patří mezi tzv. labyrintky, a dokážou tudíž přijímat vzdušný kyslík (Dutta and Munshi, 1985), mohly tyto ryby úspěšně přečkat dlouhý transport a následně přežívat i v tehdejších technicky nevybavených akváriích, kde se je dokonce ještě v tom samém roce po importu podařilo poprvé rozmnožit a odchovat v zajetí. V roce 1876 byla poblíž Berlína založena první komerční líheň okrasných ryb, popularita okrasných chovů ryb rychle rostla a chovatelé zároveň získávali praktické informace o biologii, ekologii a etologii vodních organizmů, což jim spolu s technickým rozvojem umožnilo udržet na živu a případně i rozmnožit v zajetí další a další druhy (Kisling, 2001). Do roku 1910 bylo dovezeno do Evropy přibližně 180 druhů sladkovodních exotických ryb, v roce 1950 to bylo již 800 druhů a v současné době se na trhu objevuje až 5000 druhů, i když některé jen velice vzácně (Collins et al., 2013). Z obratlovců se v akváriích v menší míře chovají i ocasatí obojživelníci, žáby, červoři a želvy (Masin et al., 2014).

Kromě ryb patří mezi tradičně chované živočichy větší druhy plžů s atraktivně zbarvenou ulitou, jako jsou například ampulárky rodu *Pomacea*. Spolu s rostlinami se do nádrží dostává i několik druhů drobných plžů, které většinou nejsou v chovu žádoucí, protože mají tendenci se rychle přemnožovat a zhoršovat kvalitu vody svými exkrementy (Duggan, 2010). Oproti plžům byli mlži v okrasných chovech dlouho vzácností. Několik druhů se začalo chovat teprve v posledních letech (Lois, 2010). Ve srovnání s plži se počtem chovaných druhů jedná o minoritní skupinu.

Desetinozí korýši se poprvé objevili v akváriích v posledním desetiletí dvacátého století (Chucholl, 2013). Prvním chovaným druhem byla kreveta *Caridina multidentata*, která byla vysazena do nádrží za účelem požírání řas (Amano, 1994). Postupně se na trhu objevilo mnoho druhů krevet, raků i krabů a jejich barevných variet (e.g. Chucholl, 2013). Některé chované druhy jsou agresivní, teritoriální, případně dravé, a proto se nehodí do společenské nádrže. Z toho vyplývá, že desetinozí korýši již nejsou pouze doplňkem rybí obsádky (Mazza et al., 2015). Někteří akvaristé se naopak specializovali přímo na chov těchto tzv. problémových druhů (Turkmen and Karadal, 2012).

Při správné péči je dlouhodobý chov určitých sladkovodních druhů živočichů možný i v malém objemu vody. Oproti tomu stabilita mořského prostředí vhodného pro chov živočichů byla dlouho podmíněna velkým objemem vody v nádrži. Kvůli vysokým pořizovacím nákladům na zařízení takové nádrže byl tento typ chovu donedávna realizován takřka výlučně ve veřejných akváriích a reprezentativních prostorách firem. Technický pokrok a klesající ceny živočichů a vybavení umožnily chov mořských živočichů i v menších nádržích dostupných pro hobby akvaristy (Wabnitz et al., 2003). I když obchod s mořskými živočichy ekonomicky stále ještě zaostává ve srovnání s obchodem s živočichy sladkovodními, mořská akvaristika si získává stále více příznivců a tento trend bude pravděpodobně pokračovat i v dalších letech. Hlavním rozdílem oproti akvaristice sladkovodní ovšem zůstává původ chovaných živočichů, kteří v naprosté většině pocházejí z odchytu z volné přírody (Tlusty, 2002).

1.2. Pozitivní vliv okrasné akvakultury

Exaktně definovat pozitivní přínos okrasné akvakultury není jednoduché a některé níže uvedené body se dají za jistých okolností interpretovat i v negativním světle, což je také u příslušných pasáží uvedeno.

1) Výchovný a vzdělávací efekt: Stejně jako chov jakéhokoliv zvířete přispívá i okrasný chov vodních živočichů k vytváření pozitivního vztahu a odpovědnosti k živé přírodě (Kisling, 2001). Vodní fauna obývá pro člověka obtížně dostupné prostředí, proto chov v akváriích nabízí unikátní příležitost pozorovat a případně zkoumat životní projevy chovaných živočichů (Tlusty et al., 2013).

2) Popularizace: Chov v domácích i veřejných akváriích a zahradních jezírkách umožňuje i laické veřejnosti detailně se seznámit s nároky a životními projevy jinak těžko pozorovatelných vodních živočichů (Tlusty et al., 2013). Na popularizaci ale musí být navázána i osvěta, protože jinak může mít zvýšená poptávka po konkrétním druhu velice negativní dopad na divoké populace kvůli zintenzivnění odchytu, jako se tomu stalo v případě mořských korálových ryb klaunů. Klaun zdobený (*Amphiprion percula*) sehrál hlavní roli ve filmu „Hledá se Nemo“, a díky tomu enormně vzrostla popularita tohoto a příbuzných druhů mezi hobby chovateli (Rhyne et al., 2012). Avšak kvůli absenci osvěty měla zvýšená poptávka za následek natolik masivní odlovy, že v následujících letech dramaticky poklesly početní stavy klaunů. Odhaduje se, že pro okrasné účely je ročně celosvětově vyloveno mnoho set tisíc klaunů náležících k různým druhům (Shuman et al., 2005; Schmidt et al., 2005; Jones et al., 2008).

3) Ekonomický profit: Obchod spojený s živočichy v okrasných chovech je významným zdrojem příjmů pro část obyvatel v dodavatelských tzv. rozvojových zemích (Tlusty, 2002), pro importéry, exportéry, producenty a maloobchody v zemích tzv. vyspělých (Tlusty et al., 2013) a také pro výrobce krmiv a chovatelských potřeb (Bartley, 2000). Ovšem nadměrná touha po zisku může vést k intenzivnímu odchytu živočichů ve volné přírodě, což v některých případech vedlo až k úplnému vymizení lokálních populací daného druhu. Takto došlo například v Brazílii k dramatickému poklesu početnosti místních populací sladkovodních ryb patřících k oblíbeným akvarijním druhům, jako jsou např. trnuchy rodu *Potamotrygon* (Araújo et al., 2004).

4) Potlačení odchytů z volné přírody: Stoupající produkce některých druhů z odchovů v akváriích či ve venkovních nádržích účinně snižuje poptávku po jedincích odchycených ve volné přírodě (Tlusty, 2002).

5) Produkce jedinců prostých parazitů: Živočichové odchycení v přírodě či odchovaní na farmách jsou hostiteli celé řady ekto- i endoparazitů. Oproti tomu živočichové odchovaní v akváriích jsou prostí většiny parazitů, a proto jsou mnohem vhodnější pro další chov. Dobrým příkladem jsou závojnatky, tedy šlechtěné formy karase zlatého (*Carassius auratus*). Závojnatky pocházející z rybničních chovů v jihovýchodní Asii jsou zpravidla velice silně promořeny žábrohlísty rodů *Dactylogyrus* a *Gyrodactylus*, zatímco závojnatky produkované v akváriích těmito parazity napadené nejsou (Shinn and Tun, 2013).

6) Nové poznatky: V přímé souvislosti s okrasnými chovy bylo popsáno několik nových druhů bezobratlých i obratlovců (e.g. Lukhaup and Pekny, 2006; Roberts, 2007; Lukhaup and Pekny, 2008; Klotz and Von Rintelen, 2014; Lukhaup, 2015). Rovněž díky akvarijním chovům byla objevena partenogeneze u raků (Scholtz et al., 2003).

7) Zachování druhů: Okrasné chovy se přímo podílejí na zachování některých ohrožených druhů. Jedná se především o cichlidy z jezera Ukerewe, jejichž početnost dramaticky poklesla v důsledku introdukce nepůvodního predátora robalo nilského (*Lates niloticus*) (Ogutu-Ohwayo, 1990), a také o gudeovité ryby rodů *Ameca* a *Xenotoca* (López-López and Paulo-Maya, 2001) a trpasličí raky rodu *Cambarellus* (Gutiérrez-Yurrita, 2004) ze Střední Ameriky, které ohrožuje lidská činnost, kvůli níž dochází k destrukci habitatu, znečištění vody a rozkolísání hydrologického režimu prostředí.

1.3. Negativní dopad okrasné akvakultury a environmentální rizika

1) Zavlečení nepůvodních druhů: Celosvětově patří biologické invaze mezi aktuální témata z hlediska ochrany původních druhů a jejich stanovišť (Hulme, 2006), protože výskyt druhů nepůvodních má často negativní dopad na biodiverzitu (Ricciardi, 2007). Mezi hlavní příčiny vytlačování původních druhů druhy nepůvodními a invazními patří: 1) kompetice o zdroje, 2) hybridizace, 3) zavlečení nepůvodních nemocí a 4) predace (Williamson, 1996; Magalhães et al., 2005). Nepůvodní druhy mohou být na nové lokality zavlečeny úmyslně i neúmyslně a jedním ze zdrojů těchto druhů je mezinárodní obchod včetně obchodu pro okrasné účely (e.g. Copp et al., 2005a; Strecker et al., 2011). Ačkoliv je okrasná akvakultura

jedním z významných zdrojů nepůvodních druhů, dlouho byla vědci i zákonodárci z tohoto hlediska přehlížena (Padilla and Williams, 2004).

2) Ohrožení některých druhů nadměrným odlovem z přírody: Intenzivní odlov jedinců z volné přírody může negativně ovlivnit početnost populací a především endemické druhy mohou být tímto způsobem snadno vyhubeny (Raghavan et al., 2013; Vitule et al., 2014). Například početnost veleraků tasmánských (*Astacopsis gouldi*) kvůli nadměrnému odlovu i kvůli okrasným chovům poklesla za posledních padesát let o 80 %, a proto byl tento druh zařazen do seznamu druhů v červené knize IUCN jako ohrožený (Endangered) a jeho lov je zakázán (Walsh and Doran, 2010). Převážně kvůli okrasným účelům jsou dováženy i různé druhy mořských korálů, případně tzv. živé kameny, což jsou staré korálové skelety oživené mikroorganizmy a vývojovými stadii bentických druhů (Wabnitz et al., 2003). Korálové útesy tak byly vystaveny přímé destrukci, což vedlo k regulaci obchodu a k mezinárodní ochraně těchto živočichů, respektive celých unikátních ekosystémů (Harriott, 2003). Dalším příkladem ohrožení druhu vlivem nadměrného odlovu jsou korálové ryby klauni. Jak již bylo zmíněno výše, po premiéře filmu „Hledá se Nemo“ velice stoupla poptávka po klaunech zdobených (*Amphiprion percula*) a v důsledku nadměrného odchytu v následujících letech početnost těchto ryb a příbuzných druhů klaunů poklesla v přírodě přibližně o 75 %. Navíc se k odlovu klaunů používají i značně destrukční metody včetně aplikace omračujícího množství kyanidu, což poškozuje celé druhové spektrum v daném prostředí (Prosek, 2010). Mnoho druhů odchytávaných v přírodě kvůli okrasným účelům je díky chybějícím informacím o jejich početnosti a stabilitě populací zařazeno podle IUCN v kategorii DD (Data Deficient) (Papavlasopoulou et al., 2013; Raghavan et al., 2013) a zhodnotit dopad lovu na tyto druhy je tedy nemožný. Proto je nutné tyto informace co nejdříve zjistit a doplnit, aby nedošlo ke zdecimování divokých populací (Lin et al., 2006). Na trhu se také objevují druhy, které mají pouze komerční názvy (Chucholl, 2013). Dokud tyto druhy nebudou vědecky popsány, jejich monitoring bude nerealizovatelný.

3) Záměrné mezidruhové křížení: Někteří chovatelé kvůli vytvoření jedince tvarově či barevně atraktivního z hlediska prodejnosti záměrně podporují křížení chovaných druhů (Hill and Yanong, 2010). Tato aktivita je nežádoucí, protože znehodnocuje čisté genetické linie. Patrně nejznámějším mezidruhovým křížencem v okrasných chovech je tzv. cichlida papouščí prodávaná pod komerčním názvem „Blood Parrot“. Tento hybrid kančíka citrónového (*Amphilophus citrinellus*) a kančíka červenohlavého (*Vieja synspila*) je neplodný a má

deformovanou páteř, která mu neumožňuje zavřít tlamu (Hanneman, 2000). Mezidruhové křížení je tedy i problémem etickým, jelikož vzniklý hybrid je často slabý, deformovaný, málo životaschopný či neschopný rozmnožování (De Caprona and Fritzsch, 1983). Proto je produkce takto postižených kříženců ryb v řadě zemí nelegální. V České republice je tato problematika ošetřena zákonem č. 246/1992 Sb. na ochranu zvířat proti týrání, ve znění pozdějších předpisů.

1.3.1. Okrasná akvakultura jako zdroj nepůvodních druhů

Ne všechny introdukované druhy se chovají invazně, případně se jako invazní projeví jen za určitých podmínek (Allendorf and Lundquist, 2003). Za invazní se označují ty druhy, které jsou v daném areálu nepůvodní, snadno se rozmnožují, rychle se šíří, obsazují všechna příhodná stanoviště, jsou velmi odolné a přizpůsobivé k podmínkám prostředí, vytlačují původní druhy a mohou způsobit až jejich úplné vymizení či destrukci ekosystému (Williamson, 1996). Mohou také přenášet a šířit nepůvodní choroby a parazity, případně asociované komenzály (e.g. Ďuriš et al., 2006; Svoboda et al., 2014). Po etablování na nové lokalitě se introdukované druhy mohou dál šířit již samovolně. Introdukce nepůvodních druhů spolu s klesajícími početními stavy druhů původních a s destrukcí habitatů vede k nežádoucí ztrátě druhové diverzity, a tedy k homogenizaci přírody (McKinney and Lockwood, 1999).

Většina nepůvodních druhů vázaných na vodní prostředí byla záměrně vysazena či vypuštěna z různých důvodů lidmi, unikla do volné přírody z produkční akvakultury (Kolar and Lodge, 2001), případně byla nechtěně rozšířena v balastní vodě lodní dopravou (Werschkun et al., 2014). Jak již bylo naznačeno výše, v současné době je stále významnějším zdrojem nepůvodních druhů i okrasná akvakultura včetně akvaristiky (e.g. Padilla and Williams, 2004; Loureiro et al., 2015).

Z okrasné akvakultury uniklé nepůvodní druhy patří mezi bezobratlé, obratlovce i rostliny. Většina chovaných a pěstovaných druhů pochází z tropického pásma, proto je jejich etablování reálné především v teplých oblastech, případně jen na lokalitách s oteplenou vodou, jako je tomu například u raka *Cherax quadricarinatus* a babelky řezanovité (*Pistia stratiotes*) ve Slovinsku (Jaklič and Vrezec, 2011), dvou druhů krevet v Německu (Klotz et al., 2013) či několika druhů ryb a raků na Slovensku (Koščo et al., 2010) a v Maďarsku (Weiperth et al., 2015). Některé druhy se ale ukázaly být natolik adaptovatelné, že mohou přežít a rozmnožovat se i v chladnějších oblastech. Patrně nejznámějším příkladem je želva nádherná (*Trachemys scripta elegans*). Tato želva se přirozeně vyskytuje od jihovýchodu Severní Ameriky až po severozápad Jižní Ameriky a kromě Antarktidy byla zavlečena na všechny světadíly včetně ostrovů Velké Británie, Japonska (e.g. Ramsay et al., 2007), Nového Zélandu (Feldman, 2007), Bermud (Outerbridge, 2008) či Tchaj-wanu (Chen, 2006). Na seznamu 100 nejinvazivnějších druhů světa náleží přibližně jedna třetina k druhům, které byly zavlečeny na nové lokality právě v souvislosti s okrasnou akvakulturou (Lowe et al., 2000; Padilla and Williams, 2004).

Biologické invaze jsou obecně mnohem běžnější u rostlin než u živočichů (Pyšek and Richardson, 2010). Z hlediska využití v okrasné akvakultuře ovšem nalezneme jen několik příkladů, kdy se zavlečená rostlina začala invazně šířit. Jedná se především o pleustofytní rostliny tokozelku nadmutou (*Eichhornia crassipes*) a již výše zmíněnou babelku řezanovitou (*Pistia stratiotes*) (Wolverton and McDonald, 1979; Adebayo et al., 2011). Tokozelky nadmuté jsou řazeny mezi sto nejinvazivnějších druhů na světě (Lowe et al., 2000). Ze submerzních rostlin patří k invazním či potenciálně invazním druhům především v substrátu nekořenující makrofyta jako douška (*Egeria*) a chebule (*Cabomba*) (Jacobs and MacIsaac, 2009).

Invazními druhy uniklými z okrasné akvakultury nejsou ohroženy jen sladkovodní ekosystémy, ale rovněž mořské prostředí. V roce 1992 poškodil hurikán Andrew akvárium na pobřeží Floridy, ze kterého uniklo pouhých šest jedinců perutýna ohnivého (*Pterois volitans*), (Schofield, 2009). Tyto dravé, jedovaté, velice plodné a rychle dospívající ryby nemají v Atlantském oceánu přirozeného predátora a začaly se velice rychle množit. V následujících letech se perutýni rozšířili v Karibiku, podél pobřeží od Floridy až po Severní Karolínu a juvenilní jedinci byli nalezeni až u Long Islandu ve státu New York (Whitfield et al., 2002; Schofield, 2009). Na některých lokalitách, kde byli perutýni spatřeni, se neočekává jejich etablování kvůli nízkým teplotám v zimním období (Kimball et al., 2004). Přesto jejich stoupající počty velice negativně ovlivňují druhovou diverzitu a ohroženy jsou především citlivé ekosystémy korálových útesů, kde se perutýni živí širokým spektrem živočišné potravy s převahou drobných druhů krevet (Jud et al., 2011). Příklad perutýna dobře demonstruje zpoždění, se kterým se biologická invaze projeví oproti objevu prvních jedinců na nové lokalitě. Jak uvádí ve své publikaci Schofield (2009), zpočátku nebylo jasné, jaký bude mít tento nepůvodní predátor efekt na původní biotu, protože jeho početnost začala stoupat až v roce 1999, tedy sedm let po introdukci. Pozdější studie již přinesly alarmující výsledky (e.g. Jud et al., 2011) a někteří autoři vzhledem k očekávanému negativnímu dopadu na původní druhy označují tuto invazi za nejhorší z biologických invazí zapříčiněných člověkem (Albins and Hixon, 2013).

V invazní biologii bylo zavedeno tzv. pravidlo deseti („tens rule“), které říká, že každý desátý dovážený druh překoná všechny bariéry a unikne do přírody, z uniklých druhů se každý desátý etabluje a vytvoří perzistentní populaci, a konečně z etablovaných druhů se každý desátý začne šířit a vykazuje invazní chování (Booth et al., 2003). I když je etablování nepůvodního druhu na nové lokalitě ve většině případů podmíněno větším množstvím zavlečených jedinců, má pravidlo deseti mnoho výjimek (Jeschke and Strayer, 2005). Z výše uvedeného příkladu perutýna je patrné, že za vhodných okolností postačí na etablování a následné šíření jen několik jedinců. V extrémním případě to může být dokonce i jediná samice. Takto se například teoreticky může etablovat partenogeneticky se množící rak *Procambarus fallax* f. *virginalis*. Tento druh se šíří na Madagaskaru (Jones et al., 2009; Kawai et al., 2009), v Německu (Chucholl and Pfeiffer, 2010), Itálii (Nonnis Marzano et al., 2009) a Nizozemí (Soes and Koese, 2010). Jedna populace byla objevena na Slovensku (Janský and Mutkovič, 2010) a nově byl tento druh zaznamenán i v Maďarsku (Weiperth et al., 2015). V Japonsku (Faulkes et al., 2012) a překvapivě i ve Švédsku (Bohman et al., 2013) bylo objeveno jen několik jedinců, ne však etablovaná populace. Vzhledem k tomu, že zmíněný rak není využíván jako konzumní zvíře, je téměř jisté, že jeho zavlečení na nové lokality přímo souvisí s únikem z okrasné akvakultury.

Některé druhy využívané v okrasné akvakultuře se chovají i pro jiné účely, jako je produkce na maso (e.g. Holdich, 2010), testy akutní toxicity (e.g. Hermens and Leeuwangh, 1982), kontrola kvality vody (e.g. Geller, 1984) a biologická regulace nežádoucích druhů (e.g. Krumholz, 1948). V případě úniku těchto druhů do přírody proto není v některých případech jednoduché jednoznačně určit zdroj introdukce. Například u raka červeného (*Procambarus clarkii*) se předpokládá, že jeho šíření ve Španělsku, Portugalsku a Itálii zapříčinily úniky z produkční akvakultury (Ackefors, 1999; Barbaresi and Gherardi, 2000), zatímco výskyt v západní a střední Evropě souvisí s akvakulturou okrasnou (Chucholl, 2013). Přesto nelze vyloučit částečný podíl okrasné akvakultury i na zavlečení těchto raků do jižní Evropy. Podobně i akvatický plž *Bellamya chinensis*, jenž je oblíbeným konzumním živočichem v Asii, byl patrně z tohoto důvodu zavlečen do Severní Ameriky, zatímco výskyt v Evropě je spojován s únikem z okrasné akvakultury (Soes et al., 2011).

Kromě přímé konkurence a vytlačování mohou nepůvodní druhy negativně ovlivnit početnost druhů původních zavlečením nepůvodního patogenu a v takovém případě se ani nemusí na nové lokalitě nutně etablovat (e.g. Lowe et al., 2000; Svoboda et al., 2014; Mazza et al., 2015). Invazní druhy také mohou působit jako vektor onemocnění na lokalitě se již vyskytujícího. Například severoameričtí raci jsou přenašeči račího moru (Alderman, 1996; Kozubíková et al., 2008) a želva nádherná je rezervoárovým hostitelem bakterií rodu *Salmonella*, které mohou vyvolat salmonelózu či paratyfus B i u člověka (Nagano et al., 2006; Hidalgo-Vila et al., 2008).

Vedle importu organizmů pro akvarijní účely se některé druhy dováží i pro chov či pěstování ve venkovních zahradních jezírkách, jejichž popularita v posledních letech stoupá (Peay, 2009). Touto cestou se živočichové i vodní rostliny dostávají do venkovních nádrží bez jakékoliv regulace (Lowe et al., 2000; Adebayo et al., 2011). Ze zahradních jezírek mohou organizmy unikat na nové lokality samovolně či při povodních, což zmiňuje Peay (2009) v případě nepůvodních druhů raků nasazovaných pro okrasné účely do zahradních jezírek v Rakousku. Únik ze zahradních jezírek byl také nepravděpodobnější cestou zavlečení akvatického plže *Viviparus acerosus* z povodí Dunaje do Nizozemí (Soes et al., 2009).

Mnoho hobby akvaristů není dostatečně poučeno o biologii, ekologii a etologii druhů, které si pro chov pořídí. Často se tak stane, že se daný druh začne projevovat agresivně, dravě, dorůstá velkých rozměrů, rychle se množí apod. Chovatelé jsou pak postaveni před otázku, jak s takto se projevujícími živočichy naložit. V domnění, že konají dobro, mají pak tendenci nechtěné živočichy vypouštět do přírody, a přímo se tak podílejí na nových introdukcích nepůvodních sladkovodních i mořských druhů (Magalhães and Jacobi, 2013; Tlusty et al., 2013).

Celosvětově se počet introdukcí za posledních třicet let přibližně zdvojnásobil a na řešení následků biologických invazí je celosvětově vynakládáno velké množství finančních prostředků (Pimentel et al., 2005). Eradikace druhů etablovaných mimo původní areál rozšíření je velice obtížná, a proto je v současnosti kladen důraz zejména na preventivní zamezení introdukcí potenciálně nebezpečných organizmů (Clout and Veitch, 2002). Základem je správná identifikace druhů s vysokým invazním potenciálem. K tomuto účelu byly vyvinuty predikční modely (Bomford, 2008; Copp et al., 2009), z nichž získané výstupy se dají využít jako podklad pro rozhodnutí zavést restrikce cílené přímo na konkrétní vysoce rizikové druhy.

1.4. Legislativa regulující okrasnou akvakulturu

V souvislosti s minimalizací environmentálních rizik souvisejících s okrasnou akvakulturou jsou na národní i mezinárodní úrovni zaváděna legislativní opatření včetně přímých zákazů dovozu, prodeje či držení určitých nepůvodních druhů, rodů či celých skupin organizmů (e.g. Ficetola et al., 2009; Mazza et al., 2015). V legislativě je také zakotvena ochrana ohrožených druhů a regulace obchodu s nimi. Jedná se především o Úmluvu o mezinárodním obchodu ohroženými druhy volně žijících živočichů a planě rostoucích rostlin (CITES). Efektivita těchto opatření je ovšem sporná a některé vědecké studie jasně ukazují, že bez potřebné osvěty jsou restrikce málo účinné či zcela neúčinné (e.g. Magalhães and Andrade, 2014). Například zákaz chovu kaprovce čínského (*Myxocyprinus asiaticus*) na území Velké Británie se nijak výrazně neprojevil na poklesu prodejnosti tohoto i nadále na trhu dostupného druhu (Magalhães, 2014). V krajních případech může dokonce dojít k naprosto opačnému efektu, než byl původní záměr, a nevhodně zvolená legislativní opatření se tak mohou přímo či nepřímo podílet na nových případech introdukce nepůvodních druhů (Courtenay Jr et al., 1974).

Některé evropské státy uvedly v platnost legislativní opatření zaměřené na regulaci či plošný zákaz dovozu vybraných druhů či celých živočišných skupin. Takto je například zakázán dovoz živých raků do Francie, Švédska, Finska, Norska, Irska a Estonska (Edsman, 2004; Svobodová et al., 2010). Ve Velké Británii a ve Švýcarsku je možné obchodovat jen s druhy z rodu *Cherax* a do Polska je zakázáno dovážet vybrané druhy raků (Svobodová et al., 2010). V České republice je vypouštění nepůvodních druhů řešeno v zákonech č. 114/1992 Sb., o ochraně přírody a krajiny, ve znění pozdějších předpisů, č. 254/2001 Sb., o vodách a o změně některých zákonů (tzv. vodní zákon), ve znění pozdějších předpisů, a také v zákonu č. 99/2004 Sb., o rybníkářství, výkonu rybářského práva, rybářské stráži, ochraně mořských rybolovných zdrojů a o změně některých zákonů (tzv. zákon o rybářství), ve znění pozdějších předpisů. Je nutné poznamenat, že v zákonu o rybářství je nepůvodní akvatický druh definován odlišně od předchozích dvou zákonů, a to jako „geograficky nepůvodní nebo geneticky nevhodný anebo neprověřený druh či populace, která se vyskytuje na území jednotlivého rybářského revíru méně než tři po sobě následující generační populace“. Podle tohoto zákona by se tedy severoameričtí raci *Orconectes limosus* a *Pacifastacus leniusculus* již řadili mezi druhy původní, což je absurdní (Svobodová et al., 2010). Podle zákona č. 78/2004 Sb., o nakládání s geneticky modifikovanými organizmy a genetickými produkty, se chov těchto organizmů pro jiné účely než pro potravu lidí zakazuje. Porušení zákazu je sankcionováno vysokými pokutami. Z hlediska okrasné akvakultury se tento zákaz týká tzv. GloFish, což jsou drobné kaprovité rybky druhu *Danio rerio*, které mají přenesen gen z medúzy rodu *Aeguorea* do svého genomu. Tento gen způsobuje fosforeskování ve vodě zatížené dusíkatými látkami. Zákon ošetřující přímo okrasnou akvakulturu v české legislativě ale zatím chybí, i když v posledních letech sílí tendence plošně omezit či zcela zakázat dovoz živých raků (Svobodová et al., 2010; Kozák pers. comm.).

Mezi plošné zákazy dovozu a šíření druhů využívaných pro okrasné účely do celé EU patří především opatření týkající se želvy nádherné (*Trachemys scripta elegans*) (nařízení Rady ES č. 338/97) a plžů rodu *Pomacea* (prováděcí rozhodnutí Evropské komise č. C(2012) 7803) 2012/697/EU). Tyto mezinárodní legislativní restrikce bývají často provázeny doplňujícími opatřeními lokálního charakteru, jako je například nařízení Státní rostlinolékařské správy č. SRS 053592/2012 o mimořádných rostlinolékařských opatřeních k ochraně proti zavlékání a rozšiřování plžů rodu *Pomacea* (Perry).

Nařízení Evropského parlamentu a Rady (EU) č. 1143/2014 o prevenci a regulaci zavlékání či vysazování a šíření invazních nepůvodních druhů má za cíl stanovit pravidla pro prevenci, minimalizaci a zmírnění nepříznivých účinků invazních nepůvodních druhů na biologickou rozmanitost a související ekosystémové služby a na lidské zdraví a bezpečnost, jakož i pro omezení jejich sociálního a hospodářského dopadu. Pro tyto účely je nutné vytvořit seznam živočišných a rostlinných invazních druhů, na které následně budou uplatněny účinné restrikce. S největší pravděpodobností budou do tohoto tzv. unijního seznamu zahrnuty i některé druhy, které jsou využívány v okrasné akvakultuře.

1.5. Minimalizace environmentálních rizik spojených s okrasnou akvakulturou

Z výše napsaného vyplývá, že okrasná akvakultura a s ní spojený mezinárodní obchod s chovanými živočichy a rostlinami může mít za jistých okolností negativní dopad na druhy v místě odchytu, ale i na původní biotu v zemích, kam jsou okrasné druhy dovážené. Na minimalizování těchto rizik a na zmírnění dopadů biologických invazí vynakládají vlády dotčených zemí každoročně značné úsilí a velké finanční prostředky (Pimentel et al., 2005). Okrasná akvakultura, tuzemský i mezinárodní obchod lze alespoň do jisté míry regulovat, ale eradikace etablovaných a invazně se projevujících druhů je záležitost velice obtížná a v mnoha případech prakticky nemožná.

Proto musí být kladen důraz především na prevenci (Magalhães, 2014). Předcházet environmentálním rizikům spojeným s okrasnou akvakulturou lze několika způsoby: i) monitoringem trhu s okrasnými organizmy, ii) taxonomickým popisem druhů prodávaných jen pod komerčními názvy a navazujícím monitoringem divokých populací, iii) identifikací potenciálně invazních druhů a iv) osvětou zaměřenou na zodpovědné chování akvaristů – a to jak vzhledem k potenciální nebezpečnosti nepůvodních druhů a zacházení s nimi, tak i z hlediska ochrany druhů původních (e.g. Schlegel and Rupf, 2010; Magalhães and Andrade, 2014).

1.5.1. Predikční modely invazivity

Aby bylo možné z hlediska biologických invazí správně vytipovat potenciálně nebezpečné druhy ještě před tím, než by mohly být zavlečené, byly vyvinuty tzv. predikční modely invazivity. První z nich byly zaměřené na rostliny (Pheloung et al., 1999). Postupně byly kalibrované na živočichy či byly vytvářeny jako zcela nové, rostlinnými modely v některých případech jen inspirované (e.g. Copp et al., 2009; Veer and Nentwig, 2014). Modelování invazivity se postupně zpřesňuje, což s sebou nese zahrnutí detailnějších informací z různých oborů včetně ekonomiky. Správné použití určitého modelu je také podmíněno znalostí nezbytných informací – většinou se jedná o biologii, ekologii, etologii a zoogeografii hodnoceného druhu, informace o introdukcích, případně o introdukcích příbuzných druhů, využití lidmi, ekotoxikologii apod. Důležitá je i znalost klimatických podmínek a jejich shoda mezi původním areálem výskytu hodnoceného druhu a mezi podmínkami v cílové oblasti zvané též „target“ či „risk area“. Pro zjištění a kvantifikování této shody se používají klimatické nástroje založené na dlouhodobě sbíraných datech z celosvětově dostupných meteorologických stanic. Pokud má být výsledek přesný, je obzvláště u druhově bohatých skupin příprava na modelování náročná na znalosti experimentátora. Oproti tomu samotné skórování jednotlivých druhů ve vybraném modelu probíhá za použití příslušného softwaru zpravidla rychle a bývá otázkou několika dnů. Správné modelování a interpretace dat ve výsledku umožní poukázat na potenciálně nebezpečné druhy bez nutnosti restrikcemi omezit import druhů, které jsou nebezpečné výrazně méně.

2. Vědecké hypotézy a cíle práce

Nulová hypotéza

Okrasná akvakultura a činnosti s ní spojené nejsou vážnou hrozbou pro původní druhy vázané na vodní prostředí.

Alternativní hypotéza

Okrasná akvakultura v některých aspektech představuje vážná environmentální rizika pro původní vodní druhy i pro prostředí, které tyto druhy obývají. Z hlediska biologických invazí je okrasná akvakultura stále významnější cestou introdukce nepůvodních druhů.

Cíle práce

Hlavním cílem předložené disertační práce je zhodnocení environmentálních rizik, která představuje okrasná akvakultura.

Dílčí cíle

- Detailní monitoring trhu s okrasnými živočichy a rostlinami
- Demograficko-ekonomická studie zaměřená na akvaristy včetně analýzy jejich chování ve vztahu k ochraně původních druhů či naopak k šíření druhů nepůvodních
- Taxonomické zařazení vědecky nepopsaných druhů, které jsou předmětem mezinárodního obchodu s okrasnými živočichy

3. Publikované práce

Získané výsledky byly průběžně publikovány jako samostatné studie ve vědeckých časopisech. Uvedení článků v této práci nelze považovat za jejich publikování. Jsou určené výhradně pro obhajobu disertační práce autora na České zemědělské univerzitě v Praze. Veškerá nepublikovaná data jsou ve vlastnictví autora a spoluautorů jednotlivých vědeckých prací, všechna práva vyhrazena.

3.1. Patoka, J., Kalous, L., Kopecký, O. 2014. Risk assessment of the crayfish pet trade based on data from the Czech Republic. Biological Invasions, 16, 2489-2494.

[Hodnocení rizik obchodu s okrasnými raky založené na datech z České republiky]

Publikace je zaměřena na okrasnou akvakulturu, respektive na mezinárodní obchod s desetinohými korýši a predikci potenciální invazivnosti prodávaných druhů raků. Na základě dat získaných z velkoobchodů s akvarijními živočichy a z celní správy byl sestaven seznam druhů raků, které jsou nabízeny pro okrasné účely v ČR, jejich dostupnost na trhu a komerční názvy, pod kterými se prodávají. Na seznam bylo zařazeno 27 druhových taxonů, což řadí ČR z hlediska obchodu s těmito živočichy na druhé místo po Německu nejen v Evropě, ale i celosvětově. Pomocí aplikace Climatch v.1.0 (Bureau of Rural Sciences, 2008) byla zjištěna shoda klimatických podmínek v původním areálu rozšíření jednotlivých druhů a mezi ČR. S použitím predikčního modelu The Freshwater Invertebrate Invasiveness Scoring Kit (FI-ISK v.1.19, CEFAS) byla následně vypočítána potenciální invazivnost prodávaných nepůvodních druhů. Bylo zjištěno pět vysoce rizikových druhů a jako nejnebezpečnější byl označen rak *Procambarus fallax* f. *virginalis*. Jako prokazatelně nejnebezpečnější se jednoznačně ukázali raci ze Severní Ameriky. V predikci invazivnosti nepůvodních druhů akvarijních raků doplnila prezentovaná publikace předchozí práce zaměřené na Itálii, Německo a Řecko.

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INVASION NOTE

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

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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) (Barbaresi 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

(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 thread 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 km^2 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; Papavlasopoulou 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
Pacifastacus leniusculus	Astacidae	Very rare	Old	19	High
Cambarellus diminutus	Cambaridae	Very rare	New	3	Medium
Cambarellus patzcuarensis	Cambaridae	Common	New	3	Medium
Cambarellus puer	Cambaridae	Very rare	New	3	Medium
Cambarellus schufeldtii	Cambaridae	Very rare	New	3	Medium
Cambarellus texanus	Cambaridae	Very rare	New	3	Medium
Orconectes limosus	Cambaridae	Very rare	Old	25	High
Orconectes nana	Cambaridae	Very rare	New	15	Medium
Procambarus alleni	Cambaridae	Rare	New	13	Medium
Procambarus clarkii	Cambaridae	Very common	Old	26	High
Procambarus cubensis	Cambaridae	Very rare	New	7	Medium
Procambarus fallax f. *virginalis*	Cambaridae	Common	New	27	High
Procambarus milleri	Cambaridae	Very rare	New	3	Medium
Cherax albertisii	Parastacidae	Rare	New	6	Medium
Cherax boesemani	Parastacidae	Common	New	3	Medium
Cherax cainii	Parastacidae	Very rare	New	7	Medium
Cherax destructor	Parastacidae	Common	New	18	High
Cherax holthuisi	Parastacidae	Common	New	3	Medium
Cherax lorentzi	Parastacidae	Very rare	New	3	Medium
Cherax monticola	Parastacidae	Very rare	New	3	Medium
Cherax peknyi	Parastacidae	Very common	New	6	Medium
Cherax preissii	Parastacidae	Very rare	New	3	Medium
Cherax quadricarinatus	Parastacidae	Very common	New	14	Medium
Cherax sp. Blue Moon	Parastacidae	Rare	New	3	Medium
Cherax sp. Hoa Creek	Parastacidae	Common	New	3	Medium
Cherax 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. *virginalis* (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. *virginalis* 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. *virginalis* 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. *virginalis* 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
Astacus astacus	L., 1758	*Pacifastacus leniusculus*	
Cambarellus diminutus	Hobbs, 1945		
Cambarellus patzcuarensis	Villalobos, 1943		Orange Mini, Mexican Dwarf
Cambarellus puer	Hobbs, 1945		
Cambarellus schufeldtii	Fitzpatrick, 1983		
Cambarellus texanus	Albaugh & Black, 1973		rak texaský
Cherax albertisii	Nobili, 1889	*Cherax albertsi*	Blue Tiger
Cherax boesemani	Lukhaup & Pekny, 2008		Red Chilli, Red Brick Papua
Cherax cainii	Austin & Ryan, 2002	*Cherax tenuimanus*	
Cherax destructor	Clark, 1936		
Cherax holthuisi	Lukhaup & Pekny, 2006		Apricot, Orange Coral
Cherax lorentzi	Roux, 1911		
Cherax monticola	Holthuis, 1950		Brown Coral
Cherax peknyi	Lukhaup & Herbert, 2008	*Cherax papuanus*, *C. quadricarinatus*	Zebra, Tiger, Papua Tiger
Cherax preissii	Erichson, 1846		Black Coral
Cherax quadricarinatus	von Martens, 1868		rak modrý, Blue Claw
Cherax sp.			Blue Moon, Blue Pearl
Cherax sp.		*Cherax lorentzi*, *C. quadricarinatus*	Hoa Creek, Pink Coral
Cherax sp.			Red Tip
Orconectes limosus	Rafinesque, 1817		rak pruhovaný
Orconectes nana	Williams, 1952		
Pacifastacus leniusculus	Dana, 1852		rak signální
Procambarus alleni	Faxon, 1884		Electric Blue
Procambarus clarkii	Girard, 1852		rak červený
Procambarus clarkii (coloured morphs)	Girard, 1852		Blue Pearl, Electric Red, Orange, Snow White
Procambarus cubensis	Erichson, 1846	*Procambarus troglodytes*	
Procambarus fallax f. *virginalis*	Martin et al., 2010	*Procambarus fallax*	rak mramorový, Fallax
Procambarus milleri	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 FI-ISK 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. *virginalis*, *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

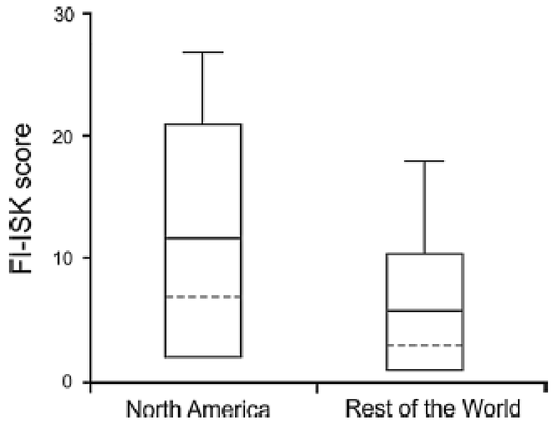

Fig. 1 Differences between FI-ISK score of ornamental crayfish originated from North America and from rest of the world. *Solid line* in the *box* represents mean; *dashed line* represents median; *box* is for range of standard deviation; *whiskers* show non-outlier range

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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Electronic Supplementary Material

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

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Materials and Methods

Data collection

Discussions with five wholesalers who are the leading importers of live crayfish in the Czech Republic were conducted during the period 9–30 September 2012. Records were made of written responses, including additional oral explanations that helped to clarify certain queries or provided supplementary information on the crayfish trade. To ensure correct identification of species handled by those wholesalers interviewed, crayfish were photographed and determination keys (Füreder and Machino 2002) as well as new species descriptions (Lukhaup and Pekny 2006, 2008; Lukhaup and Herbert 2008) were used.

According to the laws and regulations in force in the Czech Republic, the import of live animals and their products is registered by the Czech Customs Administration.

Each species' availability for wholesale was assessed in accordance with Chucholl (2013) using the following criteria: i) species available only for a short period and in low quantities were rated "very rare"; ii) species available occasionally in low quantity 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".

Risk assessment

The risk related to the crayfish trade in the Czech Republic was evaluated with the help of the Freshwater Invertebrate Invasiveness Scoring Kit produced by the UK Centre for Environment, Fisheries & Aquaculture Science (FI-ISK, v.1.19). FI-ISK was especially calibrated for freshwater invertebrates (Tricarico et al. 2010). This tool had previously been used for risk scoring of crayfish species in Germany (Chucholl 2013) and Greece, respectively (Papavlasopoulou et al. 2014). FI-ISK is able to accurately distinguish potentially invasive and non-invasive NICS by invasiveness score and subsequently by classification of species into the following three risk categories: i) low (score <1), ii) medium (score ≥1 but <16), and iii) high (score ≥16) (35). Climate data for the native and risk area (including 16 stations for the Czech Republic) of evaluated crayfish species were obtained using the Climatch tool (v.1.0; Invasive Animals Cooperative Research Centre, Bureau of Rural Sciences, 2008). Zoogeographical, biological and ecological data for the species were obtained from previous studies (Hobbs 1971, 1974; Huner 1984; Holthuis 1986; Hendrix and Loftus 2000; Scholtz 2003; Beatty et al. 2005; Lukhaup and Pekny 2006; Petrusek et al. 2006; Souty-Grosset et al. 2006; Lukhaup and Pekny 2008; Buřič et al. 2011). Characteristics such as indigenous range, fecundity and minimum age at maturity of the *Cherax* spp. for which such data are not available were assumed to correspond with those of *Cherax holthuisi*, as recommended by Chucholl (2013).

Statistical analysis

We used a generalized linear model (GLZ in StatSoft) with availability in the wholesale trade as the categorical variable and FI-ISK score as the numeric variable; their significance was tested using Type III likelihood ratio test. Origin of particular crayfish species was used as binary dependent variable (North America vs. rest of the world). Statistical significance was determined at the level $\alpha = 0.05$. The test was computed using Statistica 12.0 (Statsoft Inc., 2012).

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[Zahradní jezírka jako zdroj nepůvodních druhů raků]

Publikace je zaměřena na okrasnou akvakulturu, respektive na analýzu chování akvaristů v ČR a jejich nakládání s raky. Na základě dat získaných z dotazníkového průzkumu byly mimo jiné identifikovány nejčastěji chované druhy raků. Druh *Procambarus fallax* f. *virginalis* chovalo 36,3 % respondentů, druh *Cambarellus patzcuarensis* chovalo 33,9 % respondentů a druh *Procambarus clarkii* 20,2 %. Díky vhodně zvoleným otázkám se také podařilo zjistit následující nechtěné či přímo nelegální činnosti chovatelů: odchyt raků ve volné přírodě ČR, především vypouštění nepůvodních druhů raků do zahradních jezírek, dále také vypouštění juvenilních raků do volné přírody a splachování nechtěných juvenilních raků do odpadu. Všechny tyto činnosti mohou napomáhat šíření nepůvodních onemocnění (např. račího moru) i samotných nepůvodních druhů raků a mohou mít negativní dopad na recentní populace původních evropských raků. Popularita zahradních jezírek stoupá a výsledky v prezentované studii prokázaly, že touto cestou mohou být zavlečeny nepůvodní a případně i invazní druhy raků na nové lokality. Důležité je zjištění, že nejčastěji chovaný je druh raka, který byl vyhodnocen v předchozí publikaci jako nejnebezpečnější z hlediska biologických invazí. Proto bylo v publikaci navrženo zavedení osvětových opatření, která by mohla zlepšit informovanost chovatelů o zmíněných nebezpečích.

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Garden ponds as potential introduction pathway of ornamental crayfish

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ABSTRACT

Key-words: *alien species, introduction pathway, ornamental animal, pond, release*

The private stocking of ornamental crayfish in garden ponds was discussed in previous studies, but there is a lack of detailed analysis for better understanding of this introduction pathway. The Czech Republic is one of leading EU countries in trade with ornamental crayfish and private garden ponds are popular among people. The crayfish keepers in the country were interviewed by self-administered questionnaire to gather data about principal characteristics of the keepers and detailed information about crayfish breeding that are of interest for conservation managers. Besides of releasing crayfish into garden ponds, alarming illegal behavior such as releasing of juvenile crayfish into the wild, and capturing of indigenous crayfish from wild populations, were registered. Therefore focusing on public education to increase awareness of possible unwanted consequences of crayfish release and introduction of an obligation to inform customers about hazardousness of non-indigenous crayfish species for retailers and wholesalers is recommended.

RÉSUMÉ

Les bassins de jardin comme voie potentielle d'introduction d'écrevisses ornementales

Mots-clés : *espèces exotiques, voie d'introduction, animal d'ornement, étang, relâcher*

Le stockage privé d'écrevisses ornementales dans les bassins de jardin a été discuté dans des études précédentes, mais il y a un manque d'analyse détaillée pour une meilleure compréhension de cette voie d'introduction. La République tchèque est l'un des principaux pays de l'UE pour les échanges d'écrevisses d'ornement et les bassins de jardin privé sont populaires. Les détenteurs d'écrevisses dans le pays ont été interrogés par questionnaire auto-administré pour recueillir des données sur les caractéristiques principales de ces détenteurs et des informations détaillées sur la reproduction des écrevisses qui sont d'intérêt pour les responsables de la conservation. En plus de mettre des écrevisses dans les bassins de jardin, des comportements illégaux alarmants tels que la libération des écrevisses juvéniles dans la nature, et la capture d'écrevisses indigènes de populations sauvages, ont été enregistrés. Par conséquent, mettre l'accent sur l'éducation du public pour mieux faire connaître les éventuelles conséquences indésirables de propager des écrevisses et l'introduction d'une obligation pour les détaillants et les grossistes d'informer les clients sur la dangerosité des espèces d'écrevisses non indigènes sont recommandés.

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INTRODUCTION

The keeping of aquatic animals in home aquariums and garden ponds is globally very popular hobby with many followers (Turkmen and Karadal, 2012). However, it is also one of the main pathways for introduction of alien species on new localities (Holdich *et al.*, 2009; Kopecký *et al.*, 2013). Crayfish became in last decades popular pet species that is often kept in indoor aquaria but also stocked in the private garden ponds (Peay, 2009). With regard to crayfish biology, it is obvious that there is a high probability of their escapes from gardens into the wild. This is particularly important for non-indigenous crayfish species (NICS), which can dramatically harm the ecosystems and many of the native species (Peay, 2009). Besides to direct competition, very dangerous for indigenous crayfish species (ICS) in Europe is crayfish plague caused by the fungus *Aphanomyces astaci*, which is carried by usually resistant North American species of crayfish (Edgerton *et al.*, 2004).

Following NICS which most probably originated from aquarium release have been recorded in EU countries: *e.g. Procambarus fallax* f. *virginalis* in Germany (Chucholl and Pfeiffer, 2010) and Italy (Nonnis Marzano *et al.*, 2009), Netherlands (Soes and Koese, 2010), Slovakia (Janský and Mutkovič, 2010) and surprisingly in Sweden (Bohman *et al.*, 2013), *Cherax destructor* in Italy (Scalici *et al.*, 2009), and *Cherax quadricarinatus* in Slovenia (Jaklic and Vrezec, 2011). The introduction pathway of successful invader *Orconectes immunis* into Europe is unknown and pet trade is one of possible eventualities (Chucholl, 2012). Certain naturalized populations of commercially important *Procambarus clarkii* were most probably introduced in the same pathway (Chucholl, 2013). Moreover Chucholl (2013) warns, that NICS as *Pacifastacus leniusculus*, *Orconectes limosus*, *O.* cf. *virilis*, and *Cambarellus patzcuarensis* are advertised for garden pond stocking in Germany; and Stloukal (2009) reported about stocks of *P. fallax* f. *virginalis* which were found in garden ponds in Slovakia. The information about NICS in terms of their occurrence, abundance and introduction pathways is very important for the correct management and conservation of ICS (Souty-Grosset and Reynolds, 2009).

The Czech Republic is considered as one of the leading European countries with ornamental crayfish trade (Patoka *et al.*, 2014) and small ponds with live crayfish are popular among crayfish keepers in the Central Europe (Peay, 2009). The local ICS in the Czech Republic are under the threat of already introduced NICS (*Orconectes limosus* and *Pacifastacus leniusculus*) and the future establishment of newly introduced NICS cannot be excluded under mentioned conditions.

Although there already exists risk assessment for ornamental NICS in the Czech Republic (Patoka *et al.*, 2014) and the garden ponds are considered as important pathway for introduction, more detailed data could help to elucidate main causes of the NICS potential spreading and identified behavior and habits of the crayfish keepers for further consideration in legislation, public education and environmental management.

MATERIALS AND METHODS

Ornamental crayfish keepers living in the Czech Republic were interviewed with a questionnaire. A self-administered two-page questionnaire containing 14 close-ended questions was designed to collect data on socio-demographic characteristics of keepers and details of crayfish keeping and breeding. The questionnaire distribution was performed from February to August 2013. The goal of the questionnaire was to collect as many responses from crayfish keepers as possible. Therefore, questionnaires were distributed among respondents in pet exhibitions, in pet shops, at the Czech Aquarium and Terrarium Association, at the Czech University of Life Sciences Prague and they were inserted at the internet forums focused on keeping of ornamental animals. The respondents were guided to fill the questionnaire on the web or on paper. The anonymity of the data was obviously guaranteed. In according to experience of Arlinghaus and Mehner (2003), the publication of our results in specialized aquarium breeding magazine was offered to reduce skepticisms and encourage participation of respondents. A total of 124 crayfish keepers from all regions of the Czech Republic

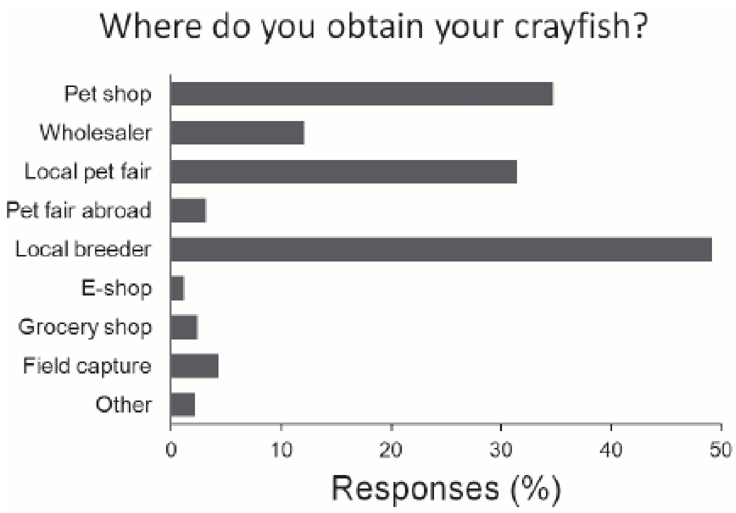

Figure 1
Origin of crayfish which are kept as ornamental – given in % (N = 124). Note: Since the multiple-answer type of this question, the total percentage of responses is higher than 100.

responded. The gathered data set would be insufficient for statistical analysis; hence the percentage approach was implemented according to Arlinghaus and Mehner (2003). Percentage values were approximated on one decimal position.

RESULTS

Based on gathered data, most responses characterize the keeper of ornamental crayfish as male (56.5%, *N* = 70) which lives in capital city Prague (21.0%, *N* = 26), he is aged 21–30 years old (40.3%, *N* = 50) and high-school educated (66.1%, *N* = 82). Vast majority of crayfish keepers responded, that their annual costs for crayfish keeping are less than 200 EUR (85.5%, *N* = 106). Most respondents (75.0%, *N* = 93) obtain information about crayfish keeping and breeding on internet. Altogether 3.8% (*N* = 11) of respondents feed crayfish with fresh or frozen shrimps. Most frequent crayfish in keeping is *Procambarus fallax* f. *virginalis* (36.3%, *N* = 45), *Cambarellus patzcuarensis* (33.9%, *N* = 42) and *Procambarus clarkii* (20.2%, *N* = 25). Other species are kept in less than 10% of cases: *Astacus astacus*, *A. leptodactylus*, *Cambarellus diminutus*, *Cam. montezumae*, *Cam. puer*, *Cam. texanus*, *Cherax albertisii*, *Cher. boesemani*, *Cher. cainii*, *Cher. destructor*, *Cher. holthuisi*, *Cher. monticola*, *Cher. quadricarinatus*, *Cher. peknyi*, *Cher. preisii*, *Cherax* sp., *Orconectes limosus*, *Pacifastacus leniusculus, Procambarus alleni*, *P. cubensis*. Altogether 12.1% (*N* = 15) of respondents were unable to determine kept species. Three respondents keep in captivity ICS protected by law: *Astacus astacus* in two cases, *Astacus leptodactylus* in one case. Many respondents have been keepers of ornamental crayfish less than period of one year (41.1%, *N* = 51) or from one to five years (38.7%, *N* = 48). Just over half of kept crayfish originated from private breeders (49.2%, *N* = 61) and from pet shops (34.7%, *N* = 43). Only 2.4% (*N* = 3) of keepers bought crayfish marketed for consumption purposes. Surprisingly 5.4% (*N* = 10) of respondents admitted illegal field capture of crayfish (Figure 1). The crayfish are mostly kept in low quantities: 2–5 individuals in 40.3% (*N* = 50) and just only one individual in 29.8% (*N* = 37). More than 10 individuals are kept in 21.0% (*N* = 26). Vast majority of respondents keep the crayfish in indoor aquarium (91.9%, *N* = 114), but 8.1% (*N* = 10) released them into the garden ponds (Figure 2). When crayfish reproduce, most of breeders keep them for rearing or advertise them for sale or give them away to friends. But 2.1% (*N* = 4) release juveniles into the wild and 1.5% (*N* = 3) flush them down the toilet (Figure 3). Just 4.0% (*N* = 5) of respondents keep

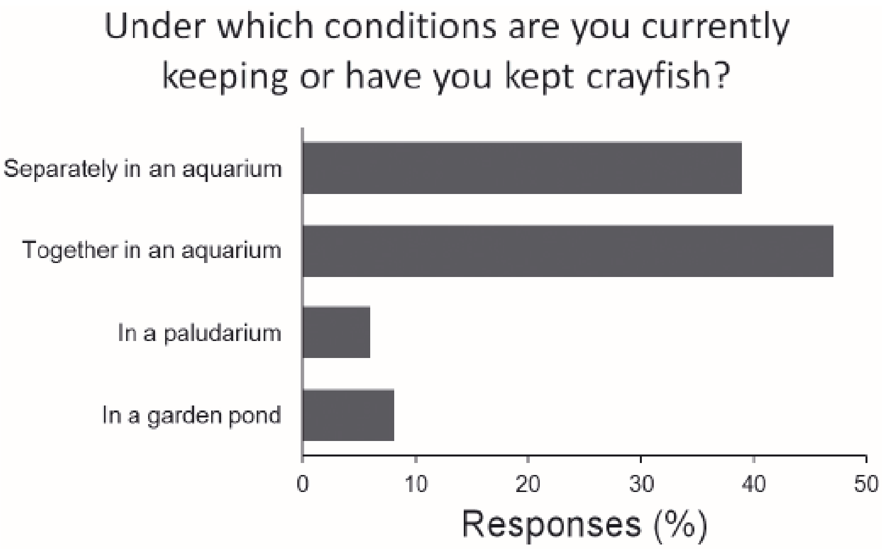

Figure 2
Types of environment where ornamental crayfish are kept – given in % (N = 124). First three options together show keeping in indoor tanks.

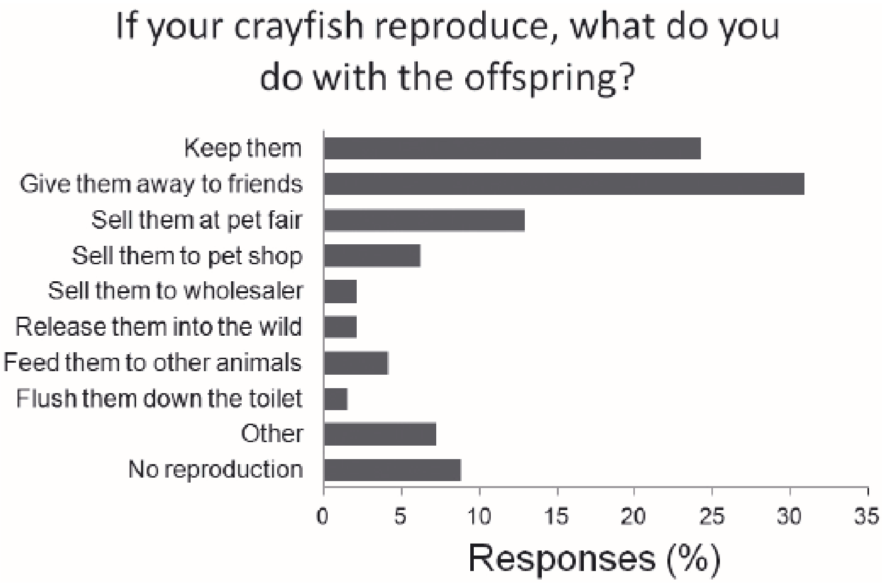

Figure 3
Handling with offspring of kept crayfish – given in % (N = 124).

in captivity crayfish only and the others prefer to keep more animals as pet or ornamental, especially fish (76.6%, *N* = 95).

DISCUSSION

Most common ornamental crayfish is *Procambarus fallax* f. *virginalis* which is inexpensive, easily bred, with low intraspecies aggressiveness and thus very popular (Chucholl, 2013; Patoka *et al.*, 2014). Popularity of the *Cambarellus patzcuarensis* which is the second most preferred species for keeping is related with its orange coloration and small body length and thus it has low requirements for space. In addition to previous study (Patoka *et al.*, 2014), we recorded one new species *Cambarellus montezumae* kept in the Czech Republic. This crayfish is very rare in crayfish keeping and it most probably originates from private import from Germany, where this crayfish was frequently available in online pet shops (Chucholl, 2013).

People who like wildlife also often prefer to keep animals in facilities close to natural conditions as it is in case of garden ponds (Peay, 2009). In many EU countries, stocking of NICS in ponds is banned without exception from the law, but small private garden ponds are not controlled in any way (Peay, 2009). Although vast majority of crayfish keepers rear ornamental crayfish strictly in home aquarium, part of them commonly release crayfish into garden ponds at least for the summer period. These irresponsible activities are considerably dangerous for ICS and other native biota, because there is non-negligible probability that NICS escape from ponds spontaneously or during a flood (Peay, 2009).

Moreover part of keepers introduces offspring of ornamental crayfish directly into the wild or flush them down the toilet. These illegal activities can participate on spreading of NICS. Although, crayfish most probably do not survive passage through the toilet downspouts, it can be one of the pathways of crayfish plague transmission.

Capturing and trapping of ICS in the wild is also forbidden in many EU countries (including the Czech Republic) by the law number 92/43/EEC. ICS are advertised as ornamental very rarely in the Czech Republic (Patoka *et al.*, 2014), anyway we identified that two ICS are sporadically kept by crayfish keepers. Therefore it is evident, that these species are occasionally illegally taken away from wild populations.

It appears from above mentioned that garden pond stocking of ornamental crayfish and related activities are in many cases undesirable and hence we recommend intensive public education to increase general awareness of possible unwanted consequences of NICS escapes from garden ponds or even their release into the wild. The retailers and wholesalers should be obliged to inform customers about hazardousness of NICS and provide the information with the advertised crayfish species for sale.

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QUESTIONNAIRE

1. Please check the region of your residence:
   - Praha
   - Jihočeský
   - Jihomoravský
   - Karlovarský
   - Královéhradecký
   - Liberecký
   - Moravskoslezský
   - Olomoucký
   - Pardubický
   - Plzeňský
   - Středočeský
   - Ústecký
   - Vysočina
   - Zlínský
2. Please check your age group:
   - 10 to 20
   - 21 to 30
   - 31 to 40
   - 41 to 50
   - 51 to 60
   - more than 60
3. Please check appropriate sex:
   - male
   - female
4. Please check your highest completed education:
   - elementary
   - secondary school
   - higher education
5. Specify which species of crayfish you currently keep or have kept:
   - Rak mramorový (*Procambarus fallax* f. *virginalis*)
   - Rak červený (*Procambarus clarkii*)
   - *Procambarus alleni*
   - Trpasličí mexický rak (*Cambarellus patzcuarensis* - CPO)
   - *Cherax destructor*
   - *Cherax quadricarinatus*
   - *Cherax peknyi* (*C. papuanus, C. misolicus, C.* sp. Zebra)
   - *Cherax holthuisi* (Apricot, Orange Coral)
   - Other (please specify)
6. How long have you been involved with the keeping of ornamental crayfish?
   - less than 1 year
   - 1–5 years
   - 6–10 years
   - more than 10 years
7. What is your preferred source of information with respect to ornamental crayfish?
   - internet
   - printed materials (publications)
   - breeders
   - pet exhibitions
   - hobby organisations
   - acquaintances
   - information not available
   - other

8. Where do you obtain your crayfish?
   - pet shops
   - wholesalers
   - local pet fair
   - pet fair abroad
   - breeders
   - e-shops
   - grocery shops
   - field capture
   - other
9. Please check the quantity of crayfish you are currently keeping or have kept:
   - 1 individual
   - 2 to 5 individuals
   - 6 to 10 individuals
   - more than 10 individuals
10. Under which conditions are you currently keeping or have you kept ornamental crayfish?
    - separately in an aquarium
    - together in an aquarium
    - in a paludarium
    - in a garden pond
    - other
11. If your crayfish reproduce, what do you do with the offspring?
    - keep them
    - give them away to friends
    - sell them at pet fair
    - sell them to pet shop
    - sell them to wholesaler
    - release them into the wild
    - feed them to other animals
    - flush them down the toilet
    - other
    - no reproduction
12. What are your annual expenses associated with keeping crayfish?
    - less than 200 EUR
    - 200 to 400 EUR
    - more than 400 EUR
13. What do you feed your crayfish?
    - vegetables (fresh, dried, frozen)
    - fish (fresh, dried, frozen)
    - insect larvae, worms or snails (live, frozen)
    - shrimp meat (fresh, frozen)
    - artificial feed for aquarium fish
    - artificial feed for aquarium crustaceans
    - other
14. Are you currently keeping aquarium or terrarium animals other than crayfish?
    - fishes
    - crustaceans (*e.g.* shrimps, crabs, hermit crabs)
    - molluscs (*e.g.* snails)
    - amphibians (*e.g.* frogs, newts)
    - reptiles (snakes, lizards, turtles, crocodiles)
    - insects (*e.g.* beetles, mantises, leaf insects)
    - spiders or scorpions
    - other
    - nothing

3.3. Patoka, J., Kalous, L., Kopecký, O. 2015. Imports of ornamental crayfish: the first decade from the Czech Republic's perspective. Knowledge and Management of Aquatic Ecosystems, 416, 04.

[Import akvarijních raků: První dekáda z pohledu ČR]

Publikace je zaměřena na dovoz raků do ČR pro okrasné účely. V publikaci jsou zahrnuta data od roku 2003 až do roku 2012, přičemž první import těchto raků do ČR byl zaregistrovaný právě v roce 2003. Publikace tedy shrnuje situaci za prvních deset let: dovezené množství raků v jednotlivých letech a nákupní cenu za jedince i celkovou cenu zásilky včetně linií trendu a predikce vývoje ceny v budoucnu, maloobchodní cenu prodávaných raků (obvyklou, nejnižší a nejvyšší cenu), jejich velikostní kategorie, původ a dostupnost na trhu. Dále byly identifikovány dodavatelské země. Majoritním dodavatelem do ČR je Indonésie a celkové množství dovezených raků se ročně pohybuje okolo tří tisíců dospělých jedinců. Produkce raků v ČR je realizována výhradně soukromými chovateli a byla odhadnuta na šedesát až sto tisíc raků ročně. Naprostá většina odchovávaných raků patří do severoamerických rodů *Procambarus* a *Cambarellus*, z nichž někteří byli v první uvedené publikaci identifikováni jako vysoce rizikové druhy z hlediska biologických invazí. Proto byl navržen detailnější monitoring zaměřený na tento sektor okrasné akvakultury.

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

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ABSTRACT

Key-words: *pet trade, aquarium, crustaceans, non-indigenous species, price*

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 d'animaux, aquarium, crustacés, espèces non 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 ± 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 I
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
Cambarellus diminutus	1–1.5 1.5–2	4.37 (4.25–4.81) 6.29 (4.60–9.35)	import	very rare
Cambarellus patzcuarensis	1.5–2 2–3	4.44 (1.90–12.96) 5.00 (3.14–22.25)	domestic, import	common
Cambarellus puer	1.5–2	6.29 (5.74–9.25)	import	very rare
Cambarellus shufeldtii	1–1.5	5.00 (4.44–6.29)	import	very rare
Cambarellus texanus	2–3	6.29 (3.70–12.77)	import	very rare
Cherax albertisii	8–10	9.35 (8.51–11.77)	import	rare
Cherax boesemani	8–10	14.29 (12.77–14.63)	import	common
Cherax cainii	5–6 10–12	8.51 18.51 (18.51–25.37)	import	very rare
Cherax destructor	6–8 12–15	12.29 (4.88–21.22) 24.81	import	common rare
Cherax holthuisi	6–8 8–10	9.85 10.37 (9.40–12.88)	import	common
Cherax lorentzi	6–8 8–10	8.33 (7.40–16.25) 15.92 (14.29–18.66)	import	very rare
Cherax monticola	8–10	12.96	import	very rare
Cherax peknyi	8–10	12.85 (10.74–14.57)	import	very common
Cherax preissii	6–8 8–10	24.37 25.81	import	very rare
Cherax quadricarinatus	4–5 5–6 8–10	3.88 (2.96–6.22) 5.45 (3.59–7.07) 7.83 (6.88–9.25)	import	very common
***Cherax* sp. Blue Moon**	8–10 10–15	14.29 (11.77–25.92) 14.81 (13.44–16.96)	import	rare
***Cherax* sp. Hoa Creek**	8–10 10–15	13.33 (11.77–14.29) 14.11	import	common rare
***Cherax* sp. Red Tips**	7–10	11.77 (9.40–14.29)	import	common
***Orconectes limosus*[1]**	?	?	capture	very rare
***Orconectes nana*[2]**	5 cm	?	import	very rare
Pacifastacus leniusculus	8–10 cm	5.92	import	very rare
Procambarus alleni	4–5 6–8	5.03 (4.70–6.12) 8.51 (5.70–14.29)	domestic, import	rare
Procambarus clarkii	3–4 5–6 6–7 8–10	3.14 (2.96–5.37) 3.33 (3.29–9.62) 4.25 (4.03–5.44) 5.00 (3.88–6.70)	domestic, import	very common
***Procambarus clarkii* Blue Pearl**	5 6–8	7.07 9.07 (8.51–22.79)	import	rare
***Procambarus clarkii* Electric Red**	3–5 5–6	2.61 8.62 (3.00–11.22)	import	rare
***Procambarus clarkii* Orange**	3–5 6–8	5.81 (3.29–6.74) 9.47 (9.25–9.96)	domestic, import	rare
***Procambarus clarkii* Snow White**	5–6	6.74 (5.88–9.25)	import	rare
Procambarus cubensis	2–3	0.55	domestic	very rare
Procambarus fallax f. virginalis	2–3 5–6	0.92 (0.70–1.10) 2.59 (2.00–3.14)	domestic	common
Procambarus milleri	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.

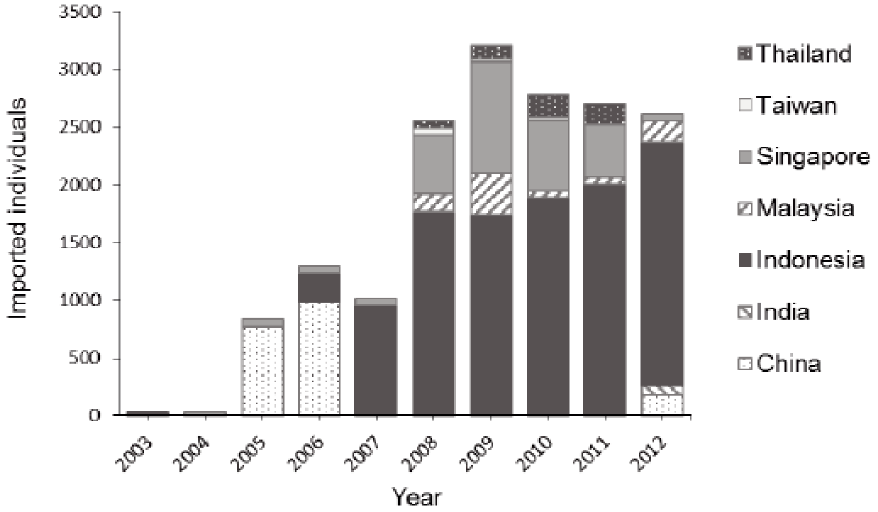

Figure 1
Market share of supplying countries based on imported quantities of ornamental crayfish for the years 2003–2012 in the Czech Republic.

> 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. *virginalis*, 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. *virginalis* 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 I) 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 to help stakeholders to adopt a position on imports of crayfish and initiate potential necessary restrictions.

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[Potenciální invazivnost želv prodávaných pro okrasné účely v EU]

Publikace je zaměřena na potenciální invazivnost želv dovážených do Evropské unie pro okrasné účely. Česká republika je významným dovozcem těchto želv do Evropy, proto byl seznam obchodovaných druhů sestaven na základě dat z celní správy ČR a především na základě povolení k dovozu vydaných veterinární správou ČR. V publikaci jsou zahrnuta data od roku 2008 až do roku 2012 včetně dovezeného množství jednotlivých druhů a zemí jejich původu. Jednoznačně nejvíce importovaným druhem byla po celé hodnocené období *Trachemys scripta*, a to i přesto, že její poddruh *T. s. elegans* se do EU od roku 1997 nesmí dovážet (pro ČR vešel zákaz v platnost po vstupu do EU, tedy 1. ledna 2005). Z důvodu zákazu dovozu se poddruh *T. s. elegans* dále nehodnotil. Kromě ostatních druhů želv byly v analýze ovšem zahrnuty ty poddruhy *T. scripta*, které se i nadále mohou legálně dovážet. Na základě dovezeného množství (min. 500 jedinců za sledované období) byly vybrány druhy, které se dále hodnotily na potenciální invazivnost. Pomocí aplikace Climatch v.1.0 (Bureau of Rural Sciences, 2008) byla zjištěna shoda klimatických podmínek mezi původním areálem rozšíření těchto dovážených druhů želv a mezi EU. Potenciální invazivnost byla vypočítána pomocí predikčního modelu Bomford (2008). Celkem bylo identifikováno pět vysoce nebezpečných druhů z hlediska biologických invazí. Nejrizikovějším se ukázala být kajmanka dravá (*Chelydra serpentina*). Podle klimatické shody byla vytvořena mapa zobrazující pravděpodobnost etablování vysoce rizikových druhů želv v různých regionech EU a v ohrožených oblastech byl doporučen monitoring zaměřený především na nádrže a řeky v okolí větších měst, jelikož tam je nejpravděpodobnější, že dojde k úniku nepůvodních druhů do přírody.

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Establishment risk from pet-trade freshwater turtles in the European Union

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ABSTRACT

Key-words: *pet market, Czech Republic, introduction pathway, invasive species, climate*

The pet-turtle market has grown in recent years and become an important pathway for the introduction of alien species in Europe. The import of *Trachemys scripta elegans* has been banned by European Commission Regulation due to its species' expanding territory and negative impact on native species. Since the demand from hobby breeders persists, however, blocking imports of this popular subspecies opens up the possibility for the introduction of other potentially invasive turtles. We determined those turtle species most common in the pet trade within the Czech Republic, which is the most important producer, importer and exporter of ornamental aquatic animals in the EU. The determination of establishment risk for the EU as a whole was then individually evaluated for turtle species based on known establishment models. *Chelydra serpentina*, *Apalone spinifera*, *Apalone mutica*, and *Sternotherus odoratus* were considered most problematic, because these species have serious establishment risk and are imported to the EU in substantial numbers. Also localities in the EU were identified where probability is highest for establishment of non-native turtles.

RÉSUMÉ

Le risque d'implantation des tortues d'eau douce, issues du commerce d'animaux de compagnie, dans l'Union européenne

Mots-clés : *marché des animaux de compagnie, République tchèque, voie d'introduction, espèces envahissantes, climat*

Le marché des tortues de compagnie a augmenté ces dernières années et devient une voie importante pour l'introduction d'espèces exotiques en Europe. L'importation de *Trachemys scripta elegans* a été interdite par le règlement européen en raison du territoire d'expansion de cette espèce et de son impact négatif sur les espèces indigènes. Depuis, la demande des éleveurs amateurs persiste, et l'interdiction de l'importation de cette sous-espèce populaire ouvre la possibilité pour l'introduction d'autres tortues potentiellement envahissantes. Nous avons déterminé les espèces de tortue les plus courantes dans le commerce des animaux de compagnie au sein de la République tchèque, qui est le plus important producteur, importateur et exportateur d'animaux aquatiques ornementaux dans l'UE. La détermination du risque d'implantation dans l'UE dans son ensemble a ensuite été évalué individuellement pour les espèces de tortues sur la base de modèles d'implantation connus. *Chelydra serpentina*, *Apalone spinifera*, *Apalone mutica*, et *Sternotherus odoratus* ont été considérées comme les plus problématiques, car ces espèces ont un risque d'implantation sérieux et sont importées dans l'UE en nombre substantiel. De plus, les lieux dans l'UE où la probabilité est la plus forte pour l'établissement des tortues non indigènes, ont été identifiés.

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INTRODUCTION

Alien invasive species are among the major causes of biodiversity loss (Dukes and Mooney, 1999; Strayer *et al.*, 2006; Ricciardi, 2007), and conservation agencies around the world devote various degrees of attention to this phenomenon (Hulme, 2006). Time, money and considerable effort are spent each year in eradication, control and mitigation of alien species impacts (Pimentel *et al.*, 2005), mainly for reasons that these invaders may displace native species from their ecological niches through 1) competition for resources, 2) hybridization, 3) introduction of pathogens, or 4) predation (Williamson, 1996; Manchester and Bullock, 2000; Kraus, 2009).

In contrast to plants, the invasiveness of animals, and especially vertebrates, has attracted much less attention in the past (Pyšek *et al.*, 2010). Reptiles, in particular, have been widely overlooked in systematic invasion studies (Kraus, 2009; Bomford *et al.*, 2009; Henderson *et al.*, 2011), and their establishment potential and invasion dynamics remain poorly understood (Ernst *et al.*, 2011). Delivering Alien Invasive Species Inventory for Europe – DAISIE (2012) recognizes in Europe 72 alien reptile species. While not all of these reptiles are exotic to Europe, many of them, such as the European pond turtle (*Emys orbicularis*) and slow worm (*Anguis fragilis*), were translocated within the continent into several countries where they are not native (McGuire and Marnell, 2000; Mlíkovský and Stýblo, 2006; Kark *et al.*, 2009).

Turtles, which constitute a relatively species-poor order, comprise the group with the globally highest number of introduction events among reptiles (Kraus, 2009). It is not surprising, therefore, that the highest densities of alien reptiles in Europe are found in aquatic habitats (Pyšek *et al.*, 2010), and 13 of 17 species of introduced alien turtles are of freshwater origin (DAISIE, 2012).

Turtles of the family Emydidae – with 2,108 recorded introduction events – are the most commonly introduced reptile taxon in the world. Within Emydidae, moreover, 68% of the aforementioned introduction events involve pond sliders (*Trachemys scripta*) (Kraus, 2009). This species is taxonomically sorted into three subspecies (Fritz and Havaš, 2007) from which the red-eared slider (*Trachemys scripta elegans*) is the most common subspecies with the greatest native range, encompassing the Mississippi Valley in the USA and northern parts of Mexico (Ernst *et al.*, 1994).

Mainly due to its appearance, *T. s. elegans* is also one of the most popular reptile pets worldwide (Franke and Telecky, 2001). When it reaches adulthood, however, it loses its attractive coloration, and hobby keepers often release their turtles into local waters (Cadi and Joly, 2003). At these locations, the released individuals may indirectly exclude or outcompete native turtle species (Cadi and Joly, 2003; Cadi and Joly 2004; Polo-Cavia *et al.*, 2008) and can indeed negatively affect other species in aquatic communities (Mlíkovský and Stýblo, 2006; Teillac-Deschamps and Prevot-Julliard, 2006; Pešát, 2008). Therefore the import of *T. s. elegans* was banned by the EU's Commission Regulation No 338/1997 (EC, 1997). However southern and western states of the European Union (EU) have already established vital populations of *T. s. elegans* including Spain (Martínez-Silvestre *et al.*, 1997), France (Cadi *et al.*, 2004), and Italy (Sindaco *et al.*, 2006). Although it seems reasonable to stop import of the pond slider, this does open up the possibility for introduction of other invasive species, inasmuch as the demand for aquatic turtles by hobby keepers still persists. Since 1997, other species of turtles may have met the market demand while replacing *T. s. elegans* in the EU pet trade, but, due to a lack of information (among other factors), these turtles may pose the same problem as the forbidden *T. s. elegans*.

Identifying the potential danger posed by alien species and then preventing new introductions is currently considered the most effective management approach (Mack *et al.*, 2000; Thuiller *et al.*, 2005; Keller *et al.*, 2008). In accordance with this view, we determined which turtle species are now most common in the pet trade and their trade quantities. Data from the Czech Republic authorities were utilized, since the Czech Republic is the main producer, importer and exporter of aquatic ornamental animals in the EU (Livengood and Chapman, 2007; Miller-Morgan, 2009; Peay, 2009). Establishment risk for the EU as a whole was then evaluated individually for important turtle species within the pet trade based upon a known establishment model (Bomford, 2008; Bomford *et al.*, 2009).

The present paper aims to highlight the possible problems with imports of other turtle species which should be regulated at EU level as is the case for *T. s. elegans*. The relationship among zoogeographical or family origin with obtained establishment risk ranks was additionally tested.

METHODS

> EXAMINING DATA ON TURTLE IMPORTS

Under Czech Republic laws and regulations, the importation of animals and their products is subject to reporting to the Customs Administration as well as the State Veterinary Administration. We used more precise data from the Veterinary Administration, where importers' requests for import authorization are evaluated and processed. Information about species or genera of live turtles imported into the Czech Republic is available since 2008. While these data represent issued permits, the actual numbers of imported individuals might be smaller because shipments do not always reach the maximum permitted quantity due to supply issues. Nevertheless, the true numbers may not be larger than those quantities stated in the permits (Zhou and Jiang, 2008). On the other hand, it cannot be excluded that other individuals entered EU via the black market but true numbers are obviously unknown. The proportions of the various turtle species imported were approximated based on interviews with six important wholesalers in the Czech Republic that are known to be the main importers of live turtles. The information thus obtained was combined with that from the permits and the imported numbers of each species per year were accordingly estimated.

> DETERMINATION OF ESTABLISHMENT RISK FOR EU

We used a model designed by Bomford (2008) and Bomford *et al.*, (2009), which is based on parameters: (i) climatic similarity of source (native distribution of species) and target regions (termed *climate match risk* score), (ii) species' ability to establish populations elsewhere (termed *prop.species* value), (iii) establishment success of the other species from the same family (termed *family random effect*), and constant value characteristic (iv) jurisdiction score, which accounts for expected variability in establishment success rate due to the effect of particular jurisdiction (country, state or province).

Climate match risk scores were computed using the program Climatch v1.0 (Bureau of Rural Sciences, 2008). A Euclidean algorithm and 16 temperature and rainfall variables with sum of scores for classes 6–10 was used (Bomford, 2008).

Due to fact that some introductions events occurred after 2008, we cannot take original *prop.species* values from Bomford (2008). Therefore values of *prop.species* scores were computed anew for this study using the Kraus (2009) database and following instructions given by Bomford (pers. comm.). When values for calculating *prop.species* or *prop.genus* were insufficient (*i.e.* fewer than 3 introduction attempts), we did not compute a *prop.family* value (Henderson *et al.*, 2011) but instead used approximation according to phylogenetically related genera (*i.e.* the closest branches on an up-to-date turtle phylogenetic tree (Guillon *et al.*, 2012)).

Family random effect was taken from Bomford (2008).

As the target region we utilized all states of the EU, including the autonomous islands of Macaronesia (namely the Azores, Madeira, and Canary Islands) in a manner similar to Arnold (2003), while, due to their geographical remoteness, the overseas departments and regions of France were not included into our study as parts of the EU. The target region contained 1113 climate stations. The jurisdiction data for the entire EU did not exist and no jurisdiction score is available for the EU as a whole. Therefore we used a combined jurisdiction score,

Table I
Estimated annual numbers of the most marketed turtle species imported by pet wholesalers into the Czech Republic during 2008–2012.

Species	2008	2009	2010	2011	2012	sum	origin
Trachemys scripta	28000	59900	44000	38500	41200	**211600**	USA
Graptemys pseudogeographica	15000	27500	23500	23000	26000	**115000**	USA
Sternotherus odoratus	9000	26060	21000	11120	10762	**77942**	USA
Pseudemys concinna	9000	22000	20000	10000	10600	**71600**	USA
Pseudemys peninsularis	9000	20135	20012	11000	10000	**70147**	USA
Sternotherus carinatus	4000	10800	16010	11050	7600	**49460**	USA
Apalone ferox	4000	5035	10000	5006	3500	**27541**	USA
Apalone spinifera	4000	5035	10000	5000	3000	**27035**	USA
Apalone mutica	4000	5000	10000	5000	3000	**27000**	USA
Chelydra serpentina	500	1170	1280	1767	500	**5217**	USA
Mauremys sinensis	1000	250	2400	1000	0	**4650**	Taiwan
Pelodiscus sinensis	1000	0	0	0	0	**1000**	Taiwan
Kinosternon scorpioides	10	50	37	195	550	**842**	USA
Platemys platycephala	60	40	37	60	600	**797**	Surinam
Malaclemys terrapin	500	70	0	0	0	**570**	USA

Note: Listed are only species with sum of more than 500 imported individuals. Data from 2012 are for January–September only. *Trachemys scripta* species include only subspecies *scripta* and *troostii*.

based on published values for previously tested countries or states (Bomford, 2008; Bomford *et al*., 2009). Before we applied our modification, the model was calibrated on *Trachemys scripta scripta* for EU and we got presumable serious risk rank.

> STATISTICS

For testing the dependence of establishment risk for the EU upon zoogeographical and family origin, we used only risk ranks from the model. Risk ranks were evaluated as low = 0, moderate = 1, serious = 2, and extreme = 3. When risk rank categories had ranges, we used the mean value. Due to a great number of categories (6 zoogeographical regions, 9 families) and low number of dependent variables (34 turtle species), we used separate non-parametric Kruskal–Wallis tests. To determine if there is a balanced, market offer of turtles from different zoogeographical regions or families, we computed chi-square tests of homogeneity (observed vs. balanced expected values). Tests were computed using Statistica 10 (Statsoft, 2010). We used $\alpha = 0.05$ to evaluate statistical significance.

> RESULTS

Based on data from the Czech Republic (Table I) we postulate that species of turtles imported into the EU in substantial numbers are *Trachemys scripta* (subspecies *scripta* and *troosti*), *Graptemys pseudogeographica, Sternotherus odoratus*, *Pseudemys concinna* and *Pseudemys peninsularis*. Turtle origins were not evenly distributed among zoogeographical regions ($\chi^2 = 33.42$, $df = 5$, $P < 0.001$), which is true also for turtle families ($\chi^2 = 17.36$, $df = 8$, $P < 0.05$). Most species were from the Nearctic zoogeographical area (53%) and Emydidae family (29%). The results from the model (Table II), revealed no differences among families (*K–W* test, $df = 8$, $H = 11.88$, $P = 0.16$) or zoogeographical regions (*K–W* test, $df = 5$, $H = 1.12$, $P = 0.95$) in ranks for establishment risk.

Table II
Results of computed establisment risk model for individual species of turtles imported to EU. Conversion of establishment risk score to establishment risk ranks follows set up values: low ⩽ 0.16, moderate 0.17–0.39, serious 0.40–0.85, extreme ⩾ 0.86.

Species	Family	Risk score	Risk rank
Pelomedusa subrufa	Pelomedusidae	0.51	serious
Pelusios sinuatus	Pelomedusidae	0.24	moderate
Pelusios subniger	Pelomedusidae	0.11	low
Podocnemis unifilis	Podocnemididae	0.03 – 0.40	low - serious
Hydromedusa tectifera	Chelidae	0.15 – 0.78	low - serious
Chelodina reimanni	Chelidae	0.05 – 0.49	low - serious
Macrochelodina rugosa	Chelidae	0.05 – 0.49	low - serious
Platemys platycephala	Chelidae	0.11 – 0.72	low - serious
Chelus fimbriatus	Chelidae	0.16 – 0.79	low - serious
Chelydra serpentina	Chelydridae	0.83	serious
Carettochelys insculpta	Carrettochelyidae	0.02 – 0.27	low - moderate
Apalone ferox	Trionychidae	0.27	moderate
Apalone mutica	Trionychidae	0.49	serious
Apalone spinifera	Trionychidae	0.75	serious
Pelodiscus sinensis	Trionychidae	0.32	moderate
Kinosternon baurii	Kinosternidae	0.06	low
Kinosternon scorpioides	Kinosternidae	0.06	low
Kinosternon subrubrum	Kinosternidae	0.16	low
Sternotherus odoratus	Kinosternidae	0.64	serious
Sternotherus carinatus	Kinosternidae	0.19	moderate
Clemmys guttata	Emydidae	0.13	low
Chrysemys picta	Emydidae	0.34	moderate
Graptemys geographica	Emydidae	0.28	moderate
Graptemys pseudogeographica	Emydidae	0.06	low
Malaclemys terrapin	Emydidae	0.05	low
Pseudemys concinna	Emydidae	0.12	low
Pseudemys nelsoni	Emydidae	0.06	low
Pseudemys peninsularis	Emydidae	0.05	low
Pseudemys rubriventris	Emydidae	0.06	low
Trachemys scripta	Emydidae	0.36	moderate
Cyclemys dentata	Geoemydidae	0.07	low
Mauremys reevesii	Geoemydidae	0.09	low
Mauremys sinensis	Geoemydidae	0.05	low
Rhinoclemmys pulcherrima	Geoemydidae	0.05	low

Note: We present range of values of establishment risk scores for families Carettochelyidae, Chelidae, Podocnemididae due to the absence of the family random effect (Bomford, 2008).
No introduction of *Carettochelys insculpta* is known, moreover this species belongs to monotypic family, therefore it was not possible to compute prop.species value due to specific environment demands (Doody *et al.*, 2003) therefore we decided to set it as 0.
Trachemys scripta species includes only subspecies *scripta* and *troosti*.

Number of imported individuals (more than 500 individuals among 2008–2012) (Table I) combined with establishment risk (serious and extreme risk rank) (Table II), suggests that reproduction will be recorded in the future in the following species: *Sternotherus odoratus*, *Apalone spinifera*, *Apalone mutica* and *Chelydra serpentina*.

DISCUSSION

The pet trade is growing in intensity globally, and its contribution to new introductions of amphibians and reptiles exceeds by almost four times any other recognizable pathway (Kraus, 2009). Hence, pet-trade species of amphibians and reptiles also have the highest absolute numbers among species established worldwide (Kraus, 2009).

Generally, introduced species are successful in establishing new populations or invading within non-native ranges only when a combination of several variables is favourable. These are 1) propagule pressure, also recognized as introduction effort (Lockwood *et al*., 2005; Simberloff, 2009; Wilgen and Richardson, 2012); 2) biotic factors like life history, but also including presence of predators, pathogens and competitors (Bomford, 2003; Strauss *et al*., 2006; Proches *et al*., 2008); and 3) abiotic factors, especially the climatic similarity of the native and non-native ranges (Thuiller *et al*., 2005; Hayes and Barry, 2008; Bomford *et al*., 2009).

In the models by Bomford (2008), and partially Bomford *et al.* (2009) used in this study, biotic and abiotic factors were taken into account. Biotic factors are represented by the variables *prop.species* value and *family random effect*. Abiotic factors are included into the *climate match risk* score, which reflects similarity of native and non-native range in terms of temperature and rainfall variables. We do not incorporate propagule pressure into the models, which can be viewed as a weakness of our approach. Although the propagule pressure is considered to be a major factor in establishment or invasion studies (Lockwood *et al*., 2005; Bomford *et al*., 2009; Simberloff, 2009; Wilgen and Richardson, 2012), precise information about the number of released individuals is rarely available (Kolar and Lodge, 2001; Hayes and Barry, 2008; Bomford *et al*., 2009). In accordance with Copp *et al.* (2010), however, the data on turtle imports presented in Table I can be used as a roughly correlating measure for propagule pressure, although we are cognizant of the approximate value of the presented data. Such correlation between high propagule pressure and imports can be seen in the example of *T. s. elegans*, as more than 52 million individuals of this species were imported from the USA between the years 1989 and 1997 and the majority of these ended up in Europe as pets (Cadi *et al*., 2004). Due to the mass imports, these turtles were sold for relatively low prices and thus were available to almost anyone. When pets are sold to a large number of people, the proportion of those who do not have proper information about their breeding potential and their release into the wild is likely to be high (Fujisaki *et al*., 2010). High propagule pressure in combination with favourable biotic and abiotic factors can be presumed to explain the successful establishment of *T. s. elegans* in Europe (Ficetola *et al*., 2009).

There is generally a non-random pattern in the origin of introduced vertebrate species, with most of these coming from the Northern Hemisphere (Jeschke and Strayer, 2006; Kraus, 2009). The majority of pet-trade freshwater turtles (50%) came to Europe from the Nearctic zoogeographical region. This bias reflects the historical and modern trade connections between Europe and North America (Kraus, 2009). While until the 19th century species introductions from Europe to North America dominated, the reverse was true in the 20th century (Jeschke and Strayer, 2006). Our results confirm the findings of Kraus (2009) and of Wilgen and Richardson (2012) that most pet-trade species among turtles are members of the Emydidae family. This pattern is probably associated with their attractive coloration (Thornhill, 1993). On the other hand, it could be also an artefact of the Emydidae family's origin, because it demonstrates the greatest diversity in North America (Ernst *et al*., 1994).

While our conclusions about the rankings of establishment risk and their association with family or zoogeographical regions is limited due to the small data set, our results seem relevant for the EU. When looking at the family origins of the most risky species, the most dangerous turtles (*i.e.* likely to establish if released) are from families other than Emydidae (*Chelydra serpentina* – Chelydridae, *Apalone spinifera* – Trionychidae, *Pelomedusa subrufa* – Pelomedusidae, *Sternotherus odoratus* – Kinosternidae). Due to the absence of *family random effect* values in Bomford (2008), we compute ranges of potential establishment risk scores for the families Carettochelyidae, Chelidae and Podocnemididae by inserting lowest and highest theoretical values (taken from Bomford 2008) of the *family random effect* into the model formula. It is surprising that the model computations rate no other member of the *Emydidae* family as serious except *T. s. elegans* that is already established in the EU. This finding suggests that the establishment potential of this family (Wilgen and Richardson, 2012) may be overestimated due only to the success of *T. s. elegans* (see also the Kraus, 2009 database). While taxonomic levels are sometimes useful predictors of establishment success for introduced species (Bomford *et al.*, 2009; Fujisaki *et al.*, 2010), our *post hoc* comparison for freshwater turtles in the EU pet trade did not confirm that members of particular families have higher risk ranks then others here shown on the *Emydidae* family.

Establishment risk rank for turtles is not significantly connected with their zoogeographical origin, thus suggesting that particular species' niche breadth plays a more important role in establishment potential. This is consistent with the finding that the most risky species (*Chelydra serpentina, Apalone spinifera, Sternotherus odoratus*, and *Pelomedusa subrufa*) exhibit among the most extensive native ranges. Greater range usually means – and especially so in the temperature zone – that a species must face various biotic and abiotic conditions (Angiletta *et al.*, 2004). Since we use the whole territory of the EU as the target region, and as this territory has a large climatic amplitude, it is not surprising that species whose native ranges cover the most distinctive climatic conditions (Kolar and Lodge, 2001) were evaluated as most dangerous.

As in several analogous studies (Thuiller *et al.*, 2005; Bomford *et al.*, 2009; Fujisaki *et al.*, 2010), *climate match risk* score was the strongest predictor of establishment risk. In agreement with Wilgen *et al.* (2009), we show that some species have small areas predicted as suitable (*e.g. Mauremys reevesii* – south Germany, *Hydromedusa tectifera* – Po Valley in Italy, *Chelus fimbriatus* – Galicia in Spain) but low average establishment risk score. On the EU maps of climate match risk, some areas appear more frequently as suitable for pet-trade freshwater turtles (Figure 1). These include the vicinity of Rome and Foggia on the west and east coast of central Italy; the Danube Valley in Slovakia, Hungary, Romania and Bulgaria; lowlands of the rivers Maritsa and Tundzha in Bulgaria; and the lowlands of northern Greece. Other important areas are the Po Valley in Italy; the Sava and Krka valleys in Slovenia; as well as the coasts of the Mediterranean Sea of Northern Italy, France and Spain, including Corsica, and Sardinia (compare with Ficetola *et al.*, 2009).

The limitation of presented approach lies in fact, that we used only variables discussed above (prop.species value, family random effect and climate match risk score). Therefore it must be mentioned that establishment-risk scores cannot be viewed as precise estimates of probability for establishment but they rather provide a relative ranking of establishment risk for freshwater turtle species introduced into EU.

Several non-native freshwater turtles in the pet trade have been reported from the wild in EU states, but these findings are rather recent (Burgert *et al.*, 2011). Reproduction in the wild has been confirmed heretofore only for *T. s. elegans*, but this does not necessarily mean that other turtles are not able to reproduce. Reproduction could be easily overlooked (Hulme, 2006) or postponed in time due to the relatively long period in life before turtles reach sexual maturity (de Magalhaes and Costa, 2009). Based on our results we tentatively predict that reproduction will be recorded in the future in the following species: *Sternotherus odoratus*, *Apalone spinifera*, *Apalone mutica*, and *Chelydra serpentina*. Allee effects can dramatically influence establishment success (Taylor and Hastings, 2005), and the expectation of reproduction in turtles which were (or will be) released in substantial numbers will be also impacted spatially. Copp *et al.* (2010) demonstrated that urban areas, with their characteristically high population density, are also the most affected by animals introduced from the pet trade. It is noteworthy that after fishes, amphibians and reptiles are relatively invisible to the public when they escape or are released into the wild. These animals have the advantage of more time to establish vital populations before any eradication action comes into force. Therefore, standing waters close to large agglomerations within the suitable climatic regions of the EU should be given greater attention in monitoring. Data from these areas should be evaluated further before any new restrictions will be applied.

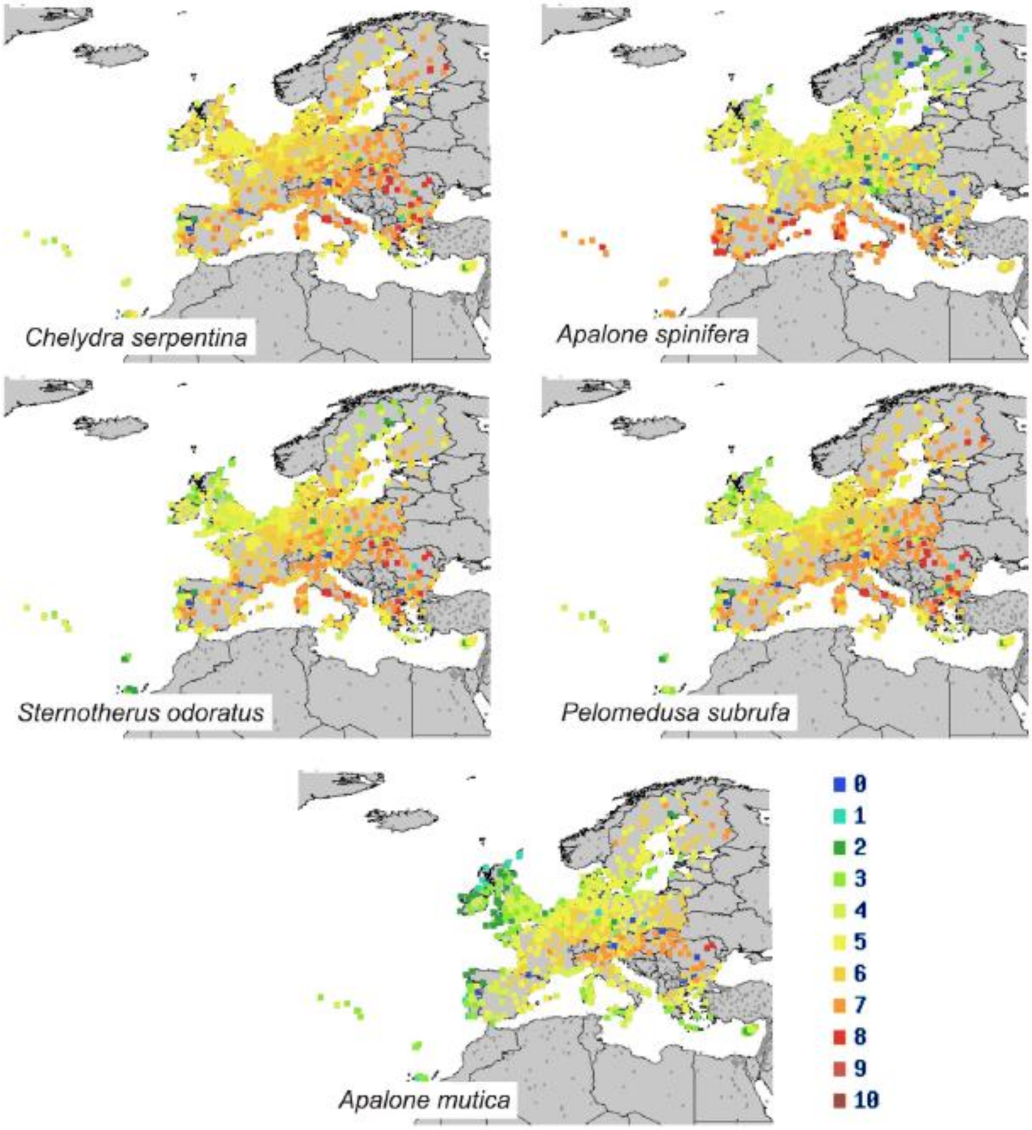

Figure 1
Climate match risk maps showing those places with highest probability of establishment for the five most dangerous species of freshwater turtles (evaluated by model as serious).

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3.5. **Patoka, J., Bláha, M., Kouba, A. 2015. *Cherax* (*Astaconephrops*) *gherardii*, a new crayfish (Decapoda: Parastacidae) from West Papua, Indonesia. Zootaxa, 3964 (5), 526-536.**

[*Cherax* (*Astaconephrops*) *gherardii*, nový druh raka (Decapoda: Parastacidae), Západní Papua, Indonésie]

Publikace je vědeckým popisem nového druhu raka vyskytujícího se na poloostrovu Ptačí hlava na Nové Guinei. Popsaný druh patří do rodu *Cherax* a je jedním z druhů raků, které se odchytávají ve volné přírodě pro okrasné účely. Intenzivní a nekontrolovaný odchyt z volné přírody může mít za následek dramatický pokles početnosti loveného druhu, což může vést až k nenávratnému poškození divokých populací a případně i k zániku celého druhu. Management ochrany dosud nepopsaných druhů je nerealizovatelný, a proto je důležité vědecky nepopsané druhy, které se objevují na trhu, co nejdříve zařadit do systému. Teprve potom je možné začít monitorovat divoké populace, zjišťovat trendy a dopad odchytu, případně přijímat legislativní restrikce omezující odchyt. Po nashromáždění dostatečného množství informací o biologii, ekologii, etologii a zoogeografii popsaného druhu může být vyhodnocena jeho potenciální invazivnost. Příkladem popisu, který je prvním krokem k případnému omezení obchodu či k ochraně druhu, je právě tato publikace.

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Cherax (*Astaconephrops*) *gherardii*, a new crayfish (Decapoda: Parastacidae) from West Papua, Indonesia

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Abstract

Cherax (*Astaconephrops*) *gherardii* **n. sp.** is a moderate burrowing crayfish endemic to the Ajamaru Lakes of West Papua, Indonesia. This species is one of the crayfish species from this region that are exploited for ornamental purposes. Its commonly used commercial name in the pet trade is "Rainbow Crayfish" or "Blue Moon Crayfish", and its native name is "udang kuku biru". The new species is genetically and morphologically similar to *Cherax boesemani*, however, both species may be easily distinguished morphologically or by using sequence divergence, which is substantial for considering *C. gherardii* **n. sp.** to be a valid species.

Key words: *Cherax gherardii* **n. sp.**, new species, taxonomy, morphology, phylogeny, pet trade

Introduction

Crayfish from the genus *Cherax* belong to a group of freshwater decapod crustaceans that are exploited for ornamental purposes (Chucholl 2013; Papavlasopoulou *et al.* 2014; Patoka *et al.* 2014). *Cherax* crayfish from West Papua are captured in the field and subsequently exported by Indonesian wholesalers to European, USA and Japanese pet markets (Lukhaup & Herbert 2008; Patoka *et al.* 2015). Inasmuch as certain traded *Cherax* crayfish from West Papua are scientifically undescribed and their captured quantities are not registered by relevant authorities, the related potential decline of abundance of these species can be easily overlooked. Scientifically undescribed species are advertised only under trade names as noted by Patoka *et al.* (2014). The new species of *Cherax* crayfish presented in our paper is known under the commercial name "Rainbow Crayfish" (Mendoza Alfaro *et al.* 2011) and "Blue Moon Crayfish" (Schäfer 2014). However these names are also used for certain other scientifically undescribed *Cherax* crayfish. Three crayfish species native in regions of West Papua and adjoining Papua (formerly known as Irian Jaya), *Cherax boesemani* Lukhaup and Pekny, 2008, *C. holthuisi* Lukhaup and Pekny, 2006, and *C. peknyi* Lukhaup and Herbert, 2008, were described following their ornamental exploitation in recent years (Lukhaup & Pekny 2006; Lukhaup & Herbert 2008; Lukhaup & Pekny 2008). The new species complements this collection and its description is crucial for proper management of this crayfish in its native range.

The new species, *Cherax* (*Astaconephrops*) *gherardii* **n. sp.**, is genetically and morphologically most similar to *Cherax boesemani*, which is endemic to the Ajamaru Lakes and the Ajamaru River in West Papua, Indonesia (Lukhaup & Pekny 2008). Both species may be easily distinguished using sequence divergence or by coloration; chelae shape; position and color of the uncalcified patch on the outer margin of chelae of adult males; rostral reaching; and large teeth on propodal cutting edges.

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Material and methods

All specimen morphometric measurements were taken with digital calipers with an accuracy 0.1 mm (e.g. Cooper & Boyko 2006; Thoma *et al.* 2014). Weight was taken using a digital pocket scale with an accuracy of 0.01 g. The following abbreviations are used below: TL, total body length; TCL, total carapace length; PCL, postorbital carapace length.

Specimen and tissue collection. Obtained crayfish were captured in the field for ornamental purposes in West Papua, Indonesia and consequently imported with other *Cherax* species into the Czech Republic between October 2013 and February 2014. We collected altogether three individuals (two adult males and one adult female) from one of the leading Czech wholesalers of ornamental aquatic animals, including crayfish. All specimens were photographed and kept alive separately in indoor tanks until samples of haemolymph were obtained for DNA analysis. After this procedure, the specimens were preserved in 80% ethanol. One male was designated as holotype, the female as allotype, and the second male as paratype.

DNA extraction, amplification and sequencing. DNA was extracted using the NucleoSpin® Tissue kit (Macherey-Nagel GmbH & Co. KG. Düren, Germany) following the manufacturer's protocol. Two molecular markers were amplified, namely cytochrome oxidase subunit I (COI) and 16S rRNA. Primers LCO and HCO (Folmer *et al.* 1994) and 1471 and 1472 (Crandall & Fitzpatrick 1996) were used for COI and 16S rRNA amplification, respectively. All PCR reactions were carried out in a Biometra T3000 thermocycler (Göttingen, Germany) with the following cycling conditions: 5 min at 95 °C; 40 cycles of 30 s at 94 °C, 30 s at 50 °C, 45 s at 72 °C; 10 min at 72 °C. PCR reactions were run in 10 µl of 5 µL of PPP Master mix [50 mM Tris–HCl, pH 8.8, 40 mM $(NH_4)2SO_4$, 0.02% Tween 20.5 mM $MgCl_2$, 400 lM dATP, 400 lM dCTP, 400 lM dGTP, 400 lM dTTP, and 100 U/mL Taq-Purple DNA polymerase], 0.3 µL of each primer (10 pmol / µL), 1 µL genomic DNA. For sequencing, the PCR products were run on an electrophoresis agarose gel, the relevant bands excised and purified using the Nucleospin® (Macherey-Nagel) kit. Purified products were subsequently sequenced on an ABI automatic capillary sequencer (series 373; Macrogene, Inc., Korea).

Genetic data analysis. Nucleotide sequences were aligned using MAFFT v7.017 (Katoh *et al.* 2002) implemented in GENEIOUS 8.0.5 (www.geneious.com, Kearse *et al.* 2012), further the alignment of COI sequences was checked by translating into aminoacids. For the concatenated dataset, partial gene fragments were downloaded from the National Center for Biotechnology Information (NCBI) available sequences (*C. holthuisi* KJ950520, KJ950521—COI, KJ920804; KJ920805—16S, *C. boesemani* KJ950507—COI, KJ920783—16S; and *C. peknyi* KJ950533—COI, KJ920835—16S). Further particular gene fragments were extracted from available *Cherax* mitogenom sequences available on NCBI to get fragments corresponding to ours (*C. monticola* KF649851; *C. quadricarinatus* KF649850; *C. bicarinatus* KM501041; *C. robustus* NC023478; and *Euastacus spinifer* NC026214). The sequence divergences were estimated in MEGA6 (Tamura *et al.* 2013) using the Kimura 2-parameter model. The HKY+G model of evolution was chosen by AIC and BIC (Akaike and Bayesian information criterion, respectively) estimated in jModelTest 2.1.7 (Darriba *et al.* 2012) for combined dataset as well as for both gene fragments datasets. A maximum likelihood (ML) tree was constructed in PHYML (Guindon & Gascuel 2003) implemented in GENEIOUS 8.0.5 (Kearse *et al.* 2012), while Bayesian analyses was conducted in MrBayes 3.2.4. (Ronquist *et al.* 2012).

Systematics

Cherax (*Astaconephrops*) *gherardii* Patoka, Bláha and Kouba, new species

Figs. 1–2

Diagnosis. Carapace surface smooth with exception of one to five small spiniform tubercles posterior cervical groove on lateral carapace. Eyes large, pigmented, cornea slightly broader than eyestalk. Rostrum lanceolate in shape with excavated margins. Rostral margins with three prominent teeth. Rostral carinae prominent. Postorbital ridges prominent with one acute tubercle at anterior terminus. Scaphocerite regularly narrows into apex with a single distinct spine at terminus. Antennular peduncle reaching slightly behind acumen, antennal peduncle reaching slightly behind apex of scaphocerite. Uncalcified patch on lateral margin of chelae of adult male pale, translucent, extending from about middle of palm to about one fifth of opposable propodus (fixed finger). Propodal cutting edge with row of small granules and one large tubercle. Chelipeds blue with orange joints. Palm of chelae blue in basal part, pale in distal part. Fingers orange, in distal third black with hooked orange tips. Row of blunt spines on inner lateral margin of palm light blue. Other walking legs deep blue in color. Gonopores of both sexes normal in shape and position.

Description of holotypic male. (Figs. 1, 2B–G, 3A). Body and eyes pigmented. Eyes not reduced. Body subovate, slightly compressed laterally. Cephalothorax 1.2 times broader than pleon.

FIGURE 1. *Cherax gherardii* **n. sp.**, holotype.

Rostrum (Fig. 2D) relatively slender, lanceolate in shape, 3.6 times as long as wide, reaching slightly beyond end of second segment of antennular peduncle. Terminus of acumen straight, not deflected or upturned. Median carina absents. Rostral margins elevated, anteriorly convergent throughout length to acumen, posteriorly forming rostral carinae. Each lateral margin bearing three slightly upturned prominent teeth on distal half. Upper surface smooth and without setae, sparsely short setose hairs present on outer rostral margins and on ventral side of rostrum. Rostral carinae prominent, extending as slight elevation posteriorly on to carapax, gradually fading and indistinct behind middle of PCL (a well-developed rostral carinae is characteristic to subgenus *Astaconephrops*). Postorbital ridges (Fig. 2D) prominent, strongly elevated posteriorly, gradually fading, remaining 1/3 of PCL indistinct. Anterior terminus of postorbital ridges with slightly upturned spiniform tubercle. Eyes (Fig. 2D) relatively large; cornea globular, darkly pigmented, about as long as eyestalk and slightly broader.

Antennulae and antennae normal in shape; the antennae similarly long as TL. Antennular peduncle reaching slightly behind acumen, antennal peduncle reaching slightly behind apex of scaphocerite. Coxicerite of antennal peduncle with spiniform tubercle anteriorly; basicerite with one lateral and one ventral spiniform and hooked tubercles (Fig. 2B). Scaphocerite (Fig. 2G) horizontal, with lamina 2.7 times as long as broad, broadest at midlength; convex in distal part becoming narrower at base, but otherwise is straight; reaching slightly behind the antennular peduncle; regularly narrows into the apex; thickened outer lateral margin with prominent spiniform tubercle at apex reaching distinctly beyond the lamina; rounded inner margin strongly covered by setae.

Epistome (Fig. 2F) with subcordiform cephalis lobe bearing weak cephalomedian projection and constricted at base; lateral margins of lobe not thickened; each lateral margin covered with two groups of small tubercles separated by smooth area; central part smooth with fovea, not pitted; inner side of cephalomedian projection strongly setose, ventral surface smooth with sparse short hairs, not pitted; epistomal zygoma prominent and thick, moderately arched with oblique arms.

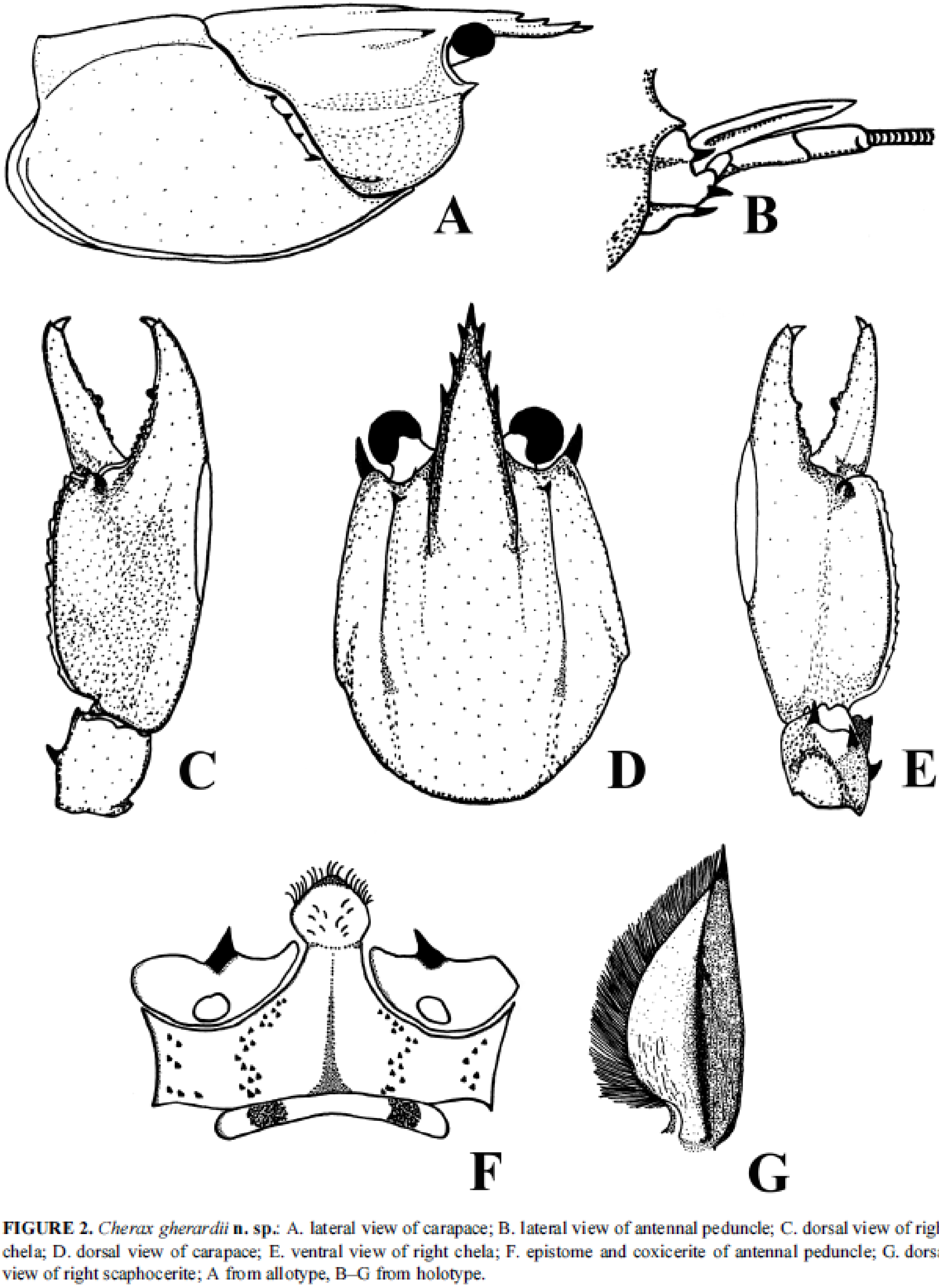

FIGURE 2. *Cherax gherardii* **n. sp.**: A. lateral view of carapace; B. lateral view of antennal peduncle; C. dorsal view of right chela; D. dorsal view of carapace; E. ventral view of right chela; F. epistome and coxicerite of antennal peduncle; G. dorsal view of right scaphocerite; A from allotype, B–G from holotype.

Areola 1.8 times as long as broad at narrowest part. Length of areola 28% of TCL; surface smooth and pitted. Cervical groove distinct, non-setose. Carapace surface smooth, pitted, with set of 4 anteriorly directed small spiniform tubercles laterally just posteriorly to cervical groove at level of antennae and below, only the lowest one prominent.

Male chelipeds and chelae (Fig. 2C, E, 3A) equal in form and size. Chelae 2.6 times as long as broad and 7.1 times as long as deep, strongly compressed; chela surface smooth, pitted; palm 1.6 times longer than fingers; carapace 1.2 times longer than chela; fingers slightly gaping; dactyl broad at base, tapering slightly towards tip; opposable propodus triangular, merging gradually into palm of chela; opposable propodus 1.8 times broader than dactyl at base. Outer lateral margin of chelae with swollen soft and uncalcified patch which extends from about middle of palm to about one fifth of opposable propodus, surface of the uncalcified patch slightly pitted (Fig 3); entire inner lateral margin of palm covered with slender row of more than ten bluntly topped teeth. Dactyl cutting edge with small granular teeth mainly near base, and with one large prominent tooth near middle of cutting edge; setose in posterior part of ventral surface. Dactyl tip with acute, hooked spine pointing outwards at an angle of approx. 45°. Propodal cutting edge with numerous denticles which are more distinct near base; one large prominent tooth at middle of cutting edge; setose in posterior part of ventral surface. Propodal tip with acute, moderate hooked spine. Propodal and dactyl tips slightly crossing when fingers clasp. Carpus smooth, pitted; with one well-developed acute and hooked spiniform tubercle in the middle of dorsolateral inner margin (mentioned tubercle is characteristic for genus *Cherax*); terminated with one spiniform tubercle oriented straight. Ventral carpal surface covered with tiny hairs and with fovea; fovea not pitted; margins slightly elevated; inner margin with set of 3 or 4 small granules and one acute spiniform tubercle oriented almost straight; outer margin with one spiniform tubercle oriented straight. Merus laterally depressed in basal part; surface smooth and pitted; single directly oriented spiniform tubercle present on dorsal surface; row of three directly oriented spiniform tubercles present on ventral surface; row of small granules on entire inner ventrolateral margin; chela 2.0 times longer than merus. Merus laterally strongly depressed; surface smooth and pitted; single spiniform tubercle present on ventral margin.

Second pereiopod reaching slightly behind apex of scaphocerite. Palm as long as fingers; fingers and palm sparsely setose; tips of fingers hooked. Carpus 2.0 times longer than palm. Merus 1.6 times longer than carpus and 2.7 times longer than ischium.

Third pereiopod 1.4 times longer than second pereiopod. Palm 1.2 times longer than fingers. Fingers sparsely setose; tips of fingers hooked. Carpus 1.5 times longer than palm. Merus 1.6 times longer than carpus and 2.6 times longer than ischium.

Fourth pereiopod reaching in to middle of the scaphocerite. Propodus and dactyl setose. Dactyl slightly hooked. Propodus 1.7 times longer than carpus. Merus 2.1 times longer than carpus and 2.1 times longer than ischium.

Fifth pereiopod reaching proximal end of scaphocerite. Propodus and dactyl setose. Dactyl slightly hooked. Propodus 2 times longer than carpus. Merus 2.4 times longer than carpus and 2 times longer than ischium.

Dorsal surface of pleon smooth in median region; pleura smooth, densely pitted. Each pleomere strongly setose with short hairs on posterior margin. Telson with two posteriorly directed spiniform tubercles in caudolateral corners. Protopod of uropod with single posteriorly directed spiniform tubercle on distal margin. Endopod of uropod with two posteriorly directed spiniform tubercles in middle and outer margin of mesial lobe. Exopod of uropods with transverse row of posteriorly directed diminutive spiniform tubercles ending in two bigger posteriorly directed spiniform tubercles on outer margin of mesial lobe.

Description of allotypic female. (Fig. 2A, 3B). Differing from the holotype in the following respects: soft uncalcified patch on palm absent; the chelae 3.0 times as long as broad, 8.7 times as long as deep; palm of chela 1.2 times longer than fingers; pleon equally broad as cephalothorax; tubercles on propodal cutting edges smaller and less prominent than in holotype; cervical groove with set of four (right side) and three (left side) anteriorly directed prominent tubercles.

Description of paratypic male. Differing from the holotype in the following respects: left chela 3.4 times as long as broad and 7.5 times as long as deep; one large tooth at about middle propodal cutting edge of left chela not so prominent; single straight spiniform tubercle on dorsal surface of ischium of left cheliped poorly developed. Cervical groove with set of four (left side) and five (right side) anteriorly directed small tubercles. Endopod of uropods without spiniform tubercles.

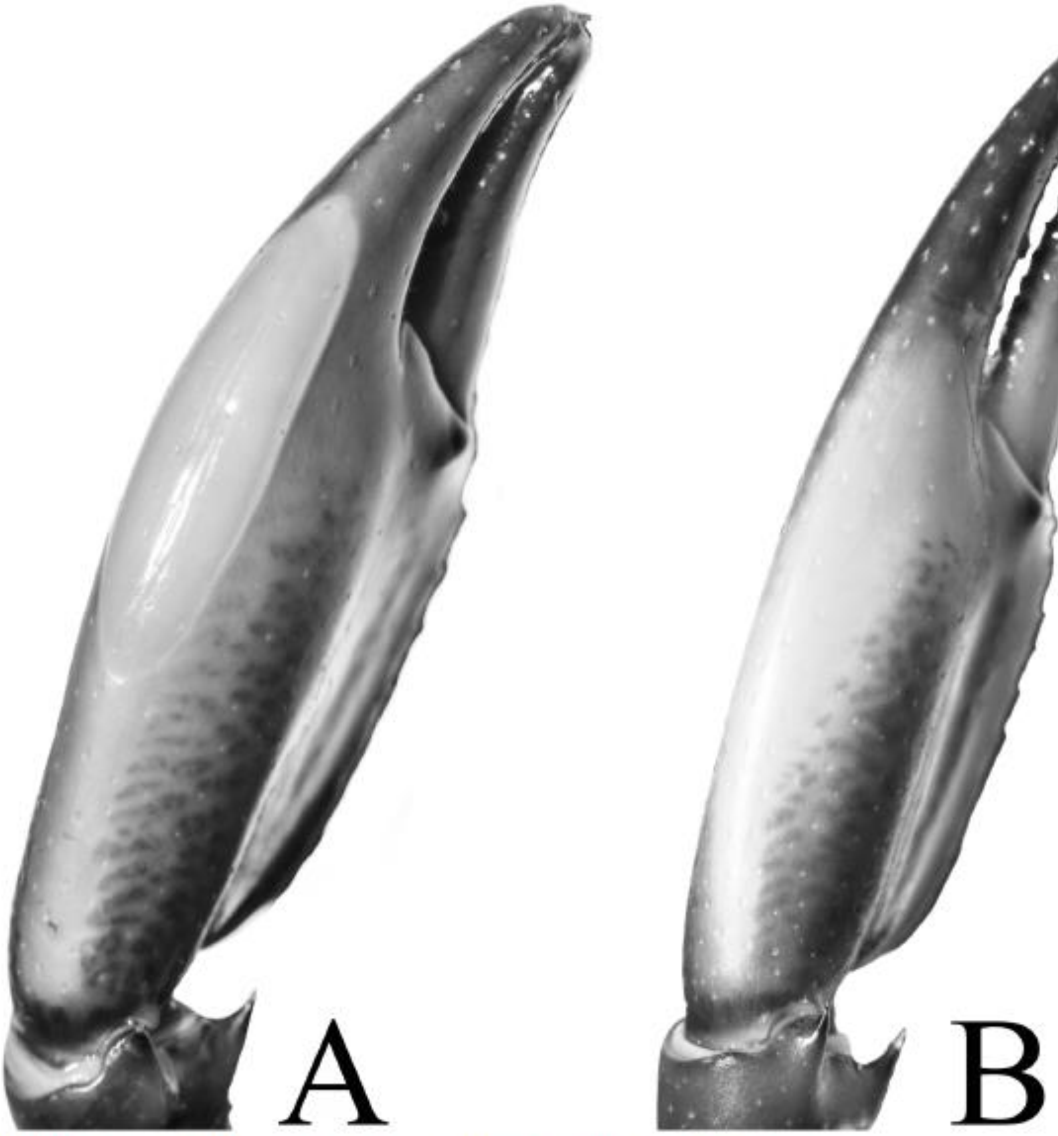

FIGURE 3. Outer lateral margin of chela: A. holotype (adult male); B. allotype (adult female).

Remarks. The single well-developed acute and hooked spiniform tubercle in the middle of dorsolateral inner margin of carpus is characteristic for the genus *Cherax*. The well-developed rostal carinae and triangular shape of scaphocerite is characteristic for adult males from the subgenus *Astaconephrops*. Both holotype and allotype chelae were without visible damage. The paratype has a regenerated right chela, left chela 1.5 times longer than right chela; this specimen has prominent erosion with soft tissue on inner lateral side of ischium of left cheliped, right chela with indistinct tubercles on propodal and dactyl cutting edges; uncalcified patch on outer lateral margin of palm of right chela absent; the anterior part of the carapace, before cervical groove on left lateral side with large swollen ulcer.

Size. Holotype TL = 94 mm, TCL = 43 mm, PCL = 31 mm, and weight = 20.61 g; allotype female TL = 97 mm, TCL = 45 mm, PCL = 32 mm, and weight = 27.07 g; paratype TL = 78 mm, TCL = 35 mm, PCL = 26 mm, and weight = 18.09 g.

Coloration of live specimens. Background color of live individuals dark brown, marbled on sides of carapace with pale brown spots. Cervical groove and distal end of carapace orange. Pleon with prominent orange spot on both lateral sides on each pleomere. Soft distal part of caudal fan orange. Chelipeds blue with orange joints, palm of propodus blue in basal part, pale in distal part. Fingers orange, distal third black with orange tips. Row of blunt spines on inner lateral margin of palm light blue. Ventral surface of chela pale orange with bluish basal margin, fingers black in distal third with orange tips. Remaining pereiopods deep blue. Both antennal and antennular peduncle blue, flagella reddish-brown. Swollen uncalcified patch on outer lateral margin of palm pale and translucent, the rest of the margin whitish. Maxillipeds deep blue, ventral surface of cephalothorax and pleon pale.

Deposition of types. Holotype, allotype, and paratype are deposited at the Czech University of Life Sciences Prague. Holotype, No. JP2014/10-20: ♂, Indonesia, West Papua; collected by anonymous supplier of John's Aquatic wholesaler, TL 94 mm. Allotype, No. JP2014/10-21: ♀, Indonesia, West Papua; collected by anonymous supplier of John's Aquatic wholesaler, TL 97 mm. Paratype, No. JP2014/10-24: ♂, Indonesia, West Papua; collected by anonymous supplier of John's Aquatic wholesaler, TL 78 mm.

Systematic position. *Cherax gherardii* belongs to the subgenus *Astaconephrops* due to well-developed rostral carinae and triangular shape of scaphocerite (Holthuis 1949, 1950, 1982; Munasinghe *et al.* 2004). This subgenus includes eight Papuan species, namely: *Cherax* (*Astaconephrops*) *albertisii* (Nobili, 1899), *C.* (*A.*) *boesemani* Lukhaup and Pekny, 2008, *C.* (*A.*) *lorentzi* Roux, 1911, *C.* (*A.*) *minor* Holthuis, 1996, *C.* (*A.*) *misolicus* Holthuis, 1949, *C.* (*A.*) *monticola* Holthuis, 1950, *C.* (*A.*) *quadricarinatus* (von Martens, 1868), and *C.* (*A.*) *rhynchotus* Riek, 1951. The new species, *Cherax* (*A.*) *gherardii* **n. sp.**, differs from all others in the *Astaconephrops* subgenus in its coloration.

Cherax (*A.*) *gherardii* is morphologically most similar to *C.* (*A.*) *boesemani* and differs from this species in the following characters: chelae in *C.* (*A.*) *boesemani* are 2.3 to 2.4 times as long as broad and 5.4 times as long as deep while 2.6 to 3.4 times as long as broad and 7.1 to 8.7 times as long as deep in *C.* (*A.*) *gherardii*; uncalcified patch on outer lateral margin of chelae of adult males extends from middle or distal third of opposable propodus to about middle of palm and is yellowish or pale to white in *C.* (*A.*) *boesemani* while it is pale, translucent and extends from about middle of palm to about one fifth of opposable propodus in *C.* (*A.*) *gherardii*; in *C.* (*A.*) *boesemani* rostrum reaches close to the end of the ultimate antennular peduncle while reaching slightly beyond end of second segment of antennular peduncle in *C.* (*A.*) *gherardii*; propodal cutting edge without large teeth in *C.* (*A.*) *boesemani* while there is one prominent large tooth in *C.* (*A.*) *gherardii*; no setose hairy parts present on chelae except for ventral cutting edge of opposable propodus in *C.* (*A.*) *boesemani* while setose hairs developed in posterior ventral surface of dactyl in *C.* (*A.*) *gherardii*.

Cherax (*A.*) *gherardii* differs from *C.* (*A.*) *albertisii* in shape of chelae, and color of uncalcified patch on outer lateral margin of chelae of adult males. Chelae 5.0 to 5.8 times as long as broad in *C.* (*A.*) *albertisii* while 2.6 to 3.4 times in *C.* (*A.*) *gherardii*. Uncalcified patch red in *C.* (*A.*) *albertisii* while pale and translucent in *C.* (*A.*) *gherardii*.

Cherax (*A.*) *gherardii* differs from *C.* (*A.*) *lorentzi* in shape of chelae, number of rostral teeth, and color of uncalcified patch on outer lateral margin of chelae of adult males. Chelae in *C.* (*A.*) *lorentzi* 2.1 to 3.3 times as long as broad while 2.6 to 3.4 in *C.* (*A.*) *gherardii*. Each lateral margin of the rostrum with 2 teeth in *C.* (*A.*) *lorentzi* while with 3 teeth in *C.* (*A.*) *gherardii*. Uncalcified patch red in *C.* (*A.*) *lorentzi* while pale and translucent in *C.* (*A.*) *gherardii*.

Cherax (*A.*) *gherardii* differs from *C.* (*A.*) *minor* in shape of chelae, size of eyes, number of rostral teeth, and position of uncalcified patch on outer lateral margin of chelae of adult males. In *C.* (*A.*) *minor* chelae less than 2.0 times as long as broad while 2.6 to 3.4 in *C.* (*A.*) *gherardii*. Eyes are small and cornea is narrower than eyestalk in *C.* (*A*) *minor* while eyes large and cornea slightly broader than eyestalk in *C.* (*A.*) *gherardii*. Each rostral lateral margin bears no teeth except for 2 or 3 small subapical denticles in *C.* (*A*) *minor* while 3 large teeth present in distal third of rostrum in *C.* (*A.*) *gherardii*. Uncalcified patch extends from middle or distal third of opposable propodus to about middle of palm in *C.* (*A.*) *minor* while from about middle of palm to about one fifth of opposable propodus in *C.* (*A.*) *gherardii*.

Cherax (*A.*) *gherardii* differs from *C.* (*A.*) *misolicus* in shape of chelae, number of rostral teeth, and in spination on lateral carapax. Chelae of *C.* (*A.*) *misolicus* 2.0 to 2.4 times as long as broad while 2.6 to 3.4 in *C.* (*A.*) *gherardii*. Each rostral lateral margin with 2 to 3 teeth in *C.* (*A.*) *misolicus* while with 3 in *C.* (*A.*) *gherardii*. Both lateral sides of carapax with 7 to 8 tubercles in *C.* (*A.*) *misolicus* while 3 to 5 spiniform tubercles in *C.* (*A.*) *gherardii*.

Cherax (*A.*) *gherardii* differs from *C.* (*A.*) *monticola* in shape of chelae, number of rostral teeth, and in number, position and color of uncalcified patch of chelae in adult males. Chelae 2.3 to 2.7 times as long as broad in *C.* (*A.*) *monticola* while 2.6 to 3.4 times in *C.* (*A.*) *gherardii*. Each rostral margin with 0 to 3 small but distinct lateral teeth in *C.* (*A*) *minor* while with 3 large teeth in *C.* (*A.*) *gherardii*. In *C.* (*A.*) *monticola* one large whitish uncalcified patch extending from extreme anterior part of palm proper to short distance before top of opposable propodus.

Furthermore, one minor uncalcified area present in proximal half of the lower margin of palm. In *C.* (*A.*) *gherardii* only one pale and translucent uncalcified patch extending from about middle of palm to about one fifth of opposable propodus.

Cherax (*A.*) *gherardii* differs from *C.* (*A.*) *quadricarinatus* in shape of chelae, length and elevation of rostral carinae, and in color and position of uncalcified patch on outer lateral margin of chelae of adult males. Chelae slender and long in *C.* (*A.*) *quadricarinatus* while 2.6 to 3.4 times as long as broad in *C.* (*A.*) *gherardii*. Rostral carinae with strongly elevated margins reach behind end of postorbital ridges in *C.* (*A.*) *quadricarinatus* while rostral carinae gradually fade before postorbital ridges, margins are not so elevated in *C.* (*A.*) *gherardii*. Uncalcified patch consists of a red to whitish-orange membrane, extending close to tip of propodus in *C.* (*A.*) *quadricarinatus* while it is pale and translucent, extending from about middle of palm to about one fifth of opposable propodus in *C.* (*A.*) *gherardii*.

Cherax (*A.*) *gherardii* differs from *C.* (*A.*) *rhynchotus* in width of areola, size of eyes, number of rostral teeth, and color of uncalcified patch on outer lateral margin of chelae of adult males. Areola narrow, 4.0 to 5.0 times as long as broad in *C.* (*A.*) *rhynchotus* while 1.8 times as long as broad in *C.* (*A.*) *gherardii*. Eyes small in *C.* (*A.*) *rhynchotus* while large in *C.* (*A.*) *gherardii*. In *C.* (*A.*) *rhynchotus*, each rostral margin with two teeth while three in *C.* (*A.*) *gherardii*. Color of uncalcified patch white in *C.* (*A.*) *rhynchotus* while pale and translucent in *C.* (*A.*) *gherardii*.

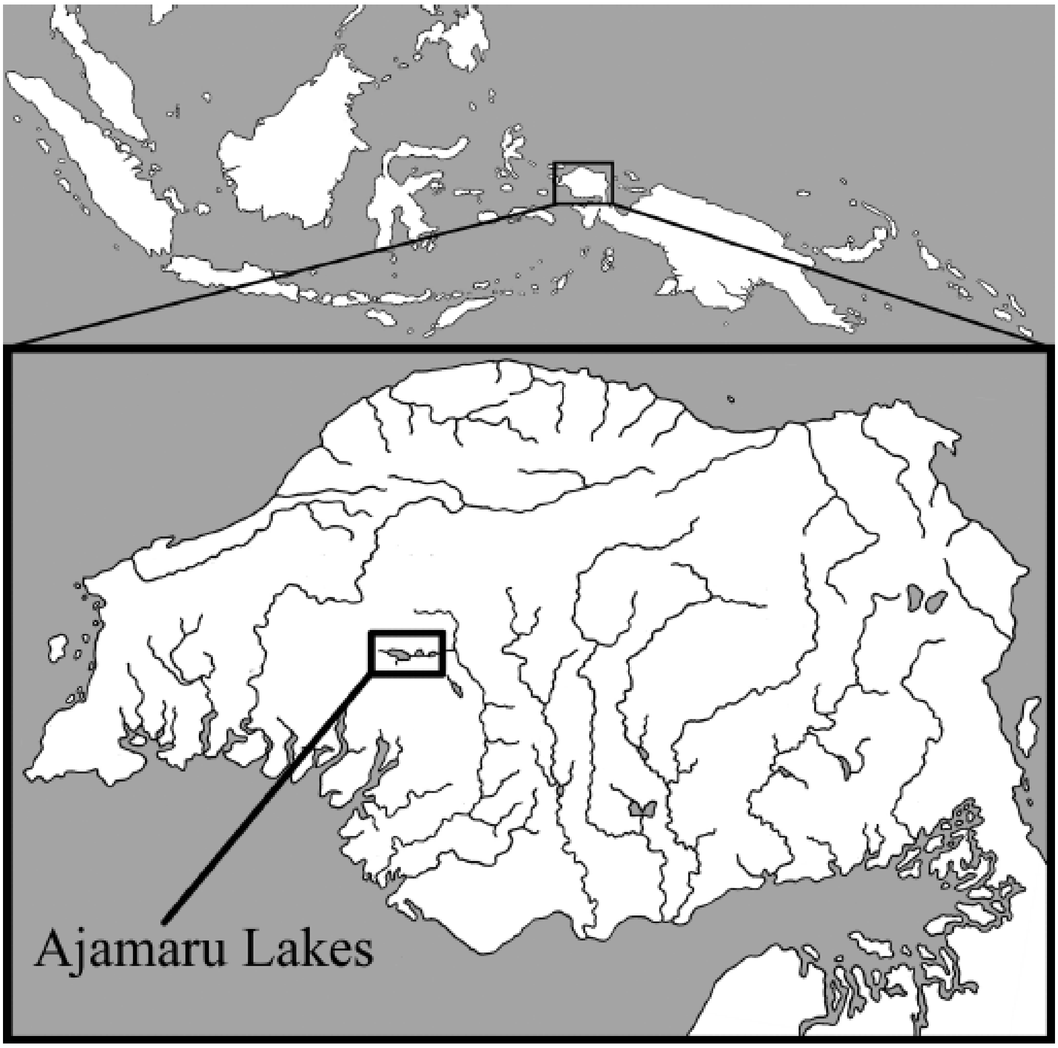

FIGURE 4. The Bird's Head Peninsula, West Papua, Indonesia, and the indicated locality of the Ajamaru Lakes.

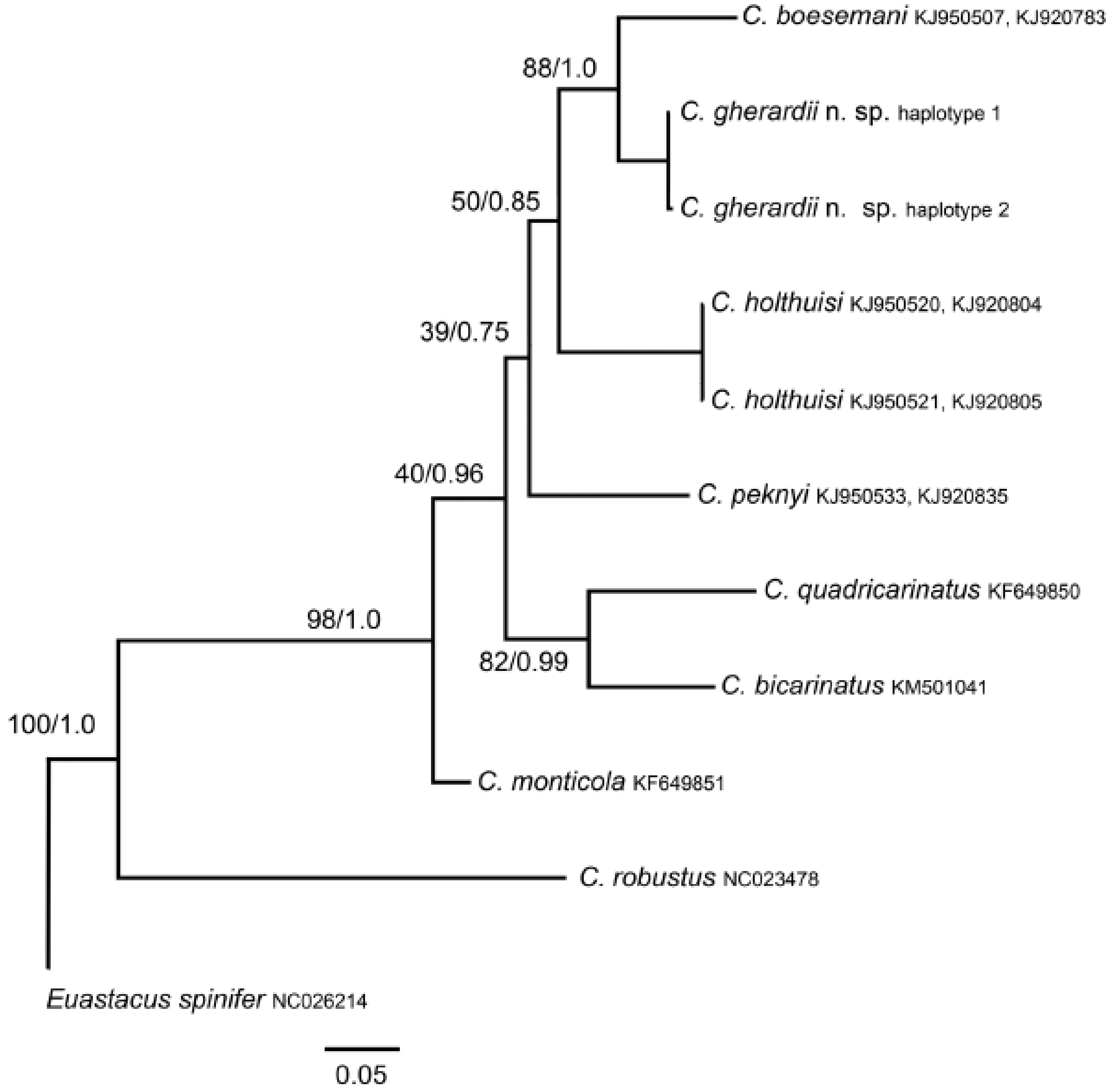

FIGURE 5. Bayesian analysis consensus phylogram of selected *Cherax* species based on combined COI and 16S dataset. ML bootstrap values and posterior probabilities are displayed next to each node.

Etymology. The specific name corresponds to the Latin form, singular genitive of Gherardi, in honor of Francesca Gherardi (Florence, Italy, 1955–2013), Associate Professor at the University of Florence, a brilliant astacologist and ethologist, interested in the behavior and ecology of freshwater decapod crustaceans including crayfish.

Common name. Both trade names of the new species, "Rainbow Crayfish" and "Blue Moon Crayfish," are used for other scientifically undescribed *Cherax* species. The local name used by native inhabitants is "udang kuku biru" (crayfish with blue legs). Therefore we proposed a new name, Blue-Legged Crayfish, as a common name for the new species, *Cherax* (*A.*) *gherardii* **n. sp.**

Distribution. Based on information from the supplier, *C. gherardii* occurs in surrounding tributary streams to Ajamaru (also Ayamaru or Aiamaru) Lakes, West Papua, Indonesia (GPS S1°16'23.18" E132°12'21") (Fig. 4), where also *Cherax boesemani* occurs (Lukhaup and Pekny, 2008). The three connected Ajamaru Lakes are located in the west-central part of the Bird's Head Peninsula at the western extremity of West Papua on the Ajamaru limestone plateau about 250 m a.s.l. The shallow well-vegetated lakes are situated at the headwaters of the Ajamaru

River which is a tributary of the Kais River. The lakes are surrounded by low and rounded hills covered with low rainforest and the gardens of the Mejprat people who live close by and in a relatively dense population (Allen & Boeseman 1982; Bartstra 1998). A collecting trip along with a detailed survey is recommended to improve the knowledge of *C.* (*A.*) *gherardii* distribution.

Phylogenetics. The phylogenetic relationship inferred from two mitochondrial gene fragments (COI and 16S) results in a phylogram with a clearly defined species, *C. gherardii* **n. sp.** (Fig. 5). The new species forms a strongly supported (88–100%) monophyletic clade with *C. boesemani* differing at 9.2% (COI+16S dataset) from each other. *Cherax gherardii* and *C. boesemani* form a sister clade to *C. holthuisi* and, together with *C. peknyi*, *C. quadricarinatus*, *C. bicarinatus*, and *C. monticola*, belong to the northern group of *Cherax* species occurring in Papua and North Australia. *Cherax robustus* and *Euastacus spinifer* (NC026214.1) here represent an outgroup. The detailed phylogenetic relationships within the northern *Cherax* species group are described in Bláha *et al.* (In Prep). From three analyzed specimens, two haplotypes were identified at COI sequence; however all three specimens share the same haplotype for 16S rRNA. In addition, patristic distance based on the COI data set among *C. gherardii* and the others ranges from 0.280 (*C. boesemani*) to 0.781 (*C. robustus*). These values are beyond the crustacean species level threshold of a 0.16 substitutions per site (Lefébure *et al.* 2006). Both the high level of sequence divergence, along with the morphological differences described above, suggests that *C. gherardii* **n. sp.** is distinct from the closely related *C. boesemani* and supports the view that it can be described as a separate species.

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[Evropské centrum pro invazní druhy: Vyhodnocení rizik, která představují akvarijní ryby vyvážené z České republiky]

Česká republika patří dlouhodobě mezi pět předních celosvětových producentů, importérů a exportérů akvarijních ryb. Oproti produkční akvakultuře je ale tento sektor dlouhodobě přehlížený, a proto dosud nebyla vyhodnocena míra rizika, kterou akvarijní ryby představují z hlediska biologických invazí. Celkem bylo na trhu v ČR zaznamenáno 1118 druhů exotických sladkovodních a brakických ryb z 51 čeledí. V publikaci je dále uveden seznam nejvíce prodávaných druhů akvarijních ryb. Na základě shodnosti klimatických podmínek v původním areálu rozšíření a v EU byla u těchto druhů vyhodnocena šance na přezimování, a tedy na úspěšné etablování v přírodě. Druhy, které by přezimovat mohly, byly následně analyzovány pomocí predikčního modelu potenciální invazivnosti FISK (Freshwater Invasive Scoring Kit, CEFAS) a podle dosaženého skóre byly tyto druhy rozděleny do tří kategorií: 1) málo nebezpečné, 2) středně nebezpečné a 3) vysoce nebezpečné. Jako vysoce nebezpečné byly označeny čtyři druhy, přičemž nejvyššího skóre dosáhl karas zlatý (*Carassius auratus*).

European hub for invaders: Risk assessment of freshwater aquarium fish exported from the Czech Republic

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Background. The aquarium fish trade is characterized by an enormous number of species Aquarium fish may have an impact on native biota by means of their invasiveness as well as through pathogen or parasite transfer. The Czech Republic has become a gateway for aquatic pets into the European Union. The aims of the study are to identify the most common aquarium fish species on the wholesale market, estimate temperature suitability for seasonal (winter and summer) survival in the EU, and also assess the invasiveness risk of the most common aquarium fish with the strongest temperature matching.

Materials and methods. List of aquarium fish species, their origin, and availability from producers and traders situated in the Czech Republic were collected. The target area was established as EU states. Estimation of the temperature suitability for each species was done using Climatch 1.0 software. The Freshwater Fish Invasiveness Screening Kit (FISK) was employed for species with temperature suitability within the target area exceeding 10% in the coldest quarter of the year.

Results. In total, 1,118 species belonging to 51 families were identified. Thirty-three species belonging to 13 families were assessed as "very common". Three sources of origin were

Although most freshwater aquarium fishes in Europe are kept within indoor closed systems, some are released into the wild – usually by hobbyist (Copp et al. 2007, Patoka et al. 2014b). Released animals may sometimes form viable populations (Elvira and Almodóvar 2001, Koščo et al. 2010, Papavlasopoulou et al. 2013).

Potential invasiveness for the EU has already been assessed for freshwater turtles used as pets (Kopecký et al. 2013, Masin et al. 2014) and crayfish (Chucholl 2013, Papavlasopoulou et al. 2014, Patoka et al. 2014a), but the risk from freshwater aquarium fish has been evaluated only from local perspectives (Copp et al. 2005b, Copp et al. 2005c, Papavlasopoulou et al. 2013, Simonović et al. 2013). Although there is an intuitive assumption that the majority of released fish cannot survive winter in a large part of the EU, the presence of non-native species in the natural environment for only a short period may still affect native biota and aquaculture through such means as pathogen transfer (Peeler et al. 2011). Imported aquarium fishes could be infected by viruses (Vesely et al. 2011), antibiotic-resistant bacteria (Dobiasova et al. 2014, Gerzova et al. 2014) or parasites (Kennedy 1993, Sobecka et al. 2012), some of which may have zoonotic potential (Weir et al. 2012, Mehrdana et al. 2014).

Eradication of invaders, diseases, and parasites in aquatic ecosystems is usually very difficult and costly. It is easier to prevent a new introduction than subsequently to try and mitigate its environmental impacts (Copp et al. 2005a, Maceda-Veiga et al. 2013). Obviously, early identification of potential invaders, their origins, and the reasons for their possible introductions is crucial for proper environmental management (Kolar and Lodge 2001). The commercial aquarium fish trade sector is directly connected to potential release into the wild of non-native fish. This is because the distribution channel ends with live fish, which are sold to customers in pet shops (e.g. Duggan 2010).

We focused data collection on wholesale trading within an EU trade hub, because later tracking of fish is very problematic or nearly impossible. The aims of the present work are to: 1) identify the most common aquarium fish species on the wholesale market in the Czech Republic, 2) estimate temperature suitability to survive on EU territory in winter and summer for the most common aquarium fish, and 3) assess the invasiveness risk of the most common aquarium fish with the strongest temperature matching.

MATERIALS AND METHODS

<u>Identification of the most common aquarium fish species</u>

identified: domestic production within the EU, farm production outside the EU, and wild harvests in the region of origin. The major suppliers outside the EU are in South-east Asia. Only one common species originated from wild harvests. FISK scoring divided the 11 species evaluated as having the strongest temperature suitability in the EU (TSEU) into seven species bearing medium risk and four species representing high risk. The family Cyprinidae was the most frequent among all evaluated taxa (seven species), but the majority of high-risk fishes belonged to the family Poeciliidae (three species). The highest score was obtained by *Carassius auratus* (Linnaeus, 1758).

Conclusion. The risk potential of aquarium fishes most traded in the EU seems to be not alarming. Attention should be focused on the possibility of novel pathogen and/or parasite transfer to native aquatic biota as an important aspect of regulating the aquarium fish trade.

Keywords: introduction pathway, aquarium trade, invasive species, freshwater fish, risk assessment, FISK

INTRODUCTION

Aquaculture, recreational fisheries, and trade in aquatic pets are considered the main driving forces behind the introduction of non-native aquatic species (Copp et al. 2005a). The aquarium fish trade in particular includes an enormous number of species, of which ca 5,300 and ca 1,800 are of freshwater and marine origin, respectively (Hensen et al. 2010, Rhyne et . 2012). Approximately 90% of freshwater aquarium fish originate from aquaculture production (Tlusty 2002) and breeding in captivity is steadily growing, especially in Asia (Jayalal and Ramachandran 2012, Raghavan et al. 2013).

In contrast to the immense diversity of fishes and locations of their native ranges, the international trade is characterized by just several re-exporting hubs that encompass the majority of the world's aquarium fish supply (Livengood and Chapman 2007, Jayalal and Ramachandran 2012). By far the most important hub is Singapore, which covers about 30% of the total trade (Jayalal and Ramachandran 2012, Rani et al. 2014). The Czech Republic, in addition to its own production, has become a gateway to the European Union (EU) (Livengood and Chapman 2007, Jayalal and Ramachandran 2012, Maceda-Veiga et al. 2013) and constitutes an important hub for imports into the largest markets for aquatic pets (Livengood and Chapman 2007).

Over the period of June 2013 to May 2014, we collected list of aquarium fish species, their origin, and availability from producers and traders situated in the Czech Republic. Data were obtained from the offers of five major wholesalers and 93 private producers of aquarium fish who sell their fish abroad. Based on personal consultations and/or physical inspections, we clarified numerous misnomers and market names from the preliminary summary list. We used the Catalog of Fishes (Eschmeyer 2014) to validate scientific names. Availability on the market was evaluated according to Chucholl (2013).

Target area

The EU states were taken as the target area, including the autonomous islands of Macaronesia (namely the Azores, Madeira, and the Canary Islands) in a manner similar to Kopecký et al. (2013). Due to their geographical remoteness, overseas departments and regions were not included into our study as parts of the EU.

Estimation of temperature suitability within the target area

We examined the temperature match between source area and target area for very common aquarium fish. We computed climate match data (Bomford 2008) in Climatch 1.0 (Bureau of Rural Sciences) by source region versus target region for each species. Besides the whole year (used for FISK only) we compared 1) the warmest, and 2) the coldest quarter of the year. Where the model predicted a relatively close climate match between the source area and the meteorological station in the target area according to the temperature variable (score $\geq$ 7.0), this was interpreted as meaning that temperature is not a constraint for the species survival (Britton et al. 2010). We calculated the temperature suitability in the EU (further referred to as TSEU) for each species as the percentage of meteorological stations with Climatch score $\geq$ 7.0 within the target area. Additionally, a paired *t*-test in R statistical software (R Development Core Team, 2014) was employed to reveal differences between the warmest and coldest periods of the year for all analysed species of fish.

Assessment of invasiveness risk

To evaluate potential invasiveness, we employed the Freshwater Fish Invasiveness Screening Kit (FISK) (Copp et al. 2005b, Copp et al. 2009, Lawson et al. 2013) on species with TSEU over 10% in the coldest quarter of the year. We used 10% threshold of TSEU as demonstrative criterion based on qualified estimate of the obtained data for FISK. Information regarding the biology, ecology, biogeography, exploitation by humans, invasive history, and presence of 'undesirable traits' of each evaluated species were obtained through a review of the scientific literature (Nelson 2006, Froese and Pauly 2014).

RESULTS

In total, we credibly identified 1,118 species of aquarium fish belonging to 51 families. Thirty-three species belonging to 13 families were assessed as 'very common' due to their being available in large quantities through the entire season.

Traded aquarium fish had three sources of origin: i) domestic production within the EU, ii) farm production outside the EU, and iii) wild harvests in region of origin (Table 1).

The major suppliers outside the EU are located in South and Southeast Asia (China, India, Indonesia, Malaysia, Singapore, Taiwan, Thailand, and Vietnam), South America (Brazil, Colombia, and Peru), Africa (Congo and Nigeria) and the Middle East (Israel). Just one very common species, *Chromobotia macracanthus* (Bleeker, 1852), endemic to Borneo and Sumatra (Indonesia), originated exclusively from wild harvest.

Evaluation of temperature suitability with target area

When comparing all 33 fishes classified as very common, the warmest period of the year in the target area showed a stronger climate match with the source area (paired t-test, t = 6.98, $P < 0.0001$). The particular temperature suitability for each species in the warmest and coldest periods of the year within the target area is given in Table 1.

Assessment of invasiveness risk

FISK scoring divided the 11 species evaluated with the highest TSEU in winter (over 10%) into seven species representing medium risk for the EU and four species bearing high risk (Table 1). The family Cyprinidae occurred most frequently among all evaluated taxa (seven species), but the majority of high-risk fishes belonged to the family Poeciliidae (three species).

Of all the evaluated fishes, the highest risk score was obtained by *Carassius auratus* (Linnaeus, 1758) from family Cyprinidae, commonly known as goldfish.

DISCUSSION

In total, we identified 1,118 traded freshwater aquarium fish species, a number which is slightly higher than that published by Livengood and Chapman (2007), who recognized 1,100 species. The finding underscores the importance of the Czech Republic as a distribution hub for the aquarium fish trade. Although not all of the fish are continuously present in the Czech Republic, they can be imported upon customer request and redistributed to other European countries.

Gozlan et al. (2010) has suggested that the survival and spread of most aquarium fish is unlikely throughout the EU due to their ecological and physiological requirements, as they mostly come from tropical or subtropical climates. This was undoubtedly proven by the test of 33 fish species classified as very common on the market. Only 13 species displayed TSEU exceeding 10%. Within the territory of the EU, such locations are apparently situated in southern European countries. Only one species, *Carassius auratus* (family Cyprinidae), which is tolerant to cold water (Rixon et al. 2005, Kottelat and Freyhof 2007), had TSEU of at least 95% in winter. Traded varieties of goldfish clearly form a genetically monophyletic lineage (Rylková et al. 2010), therefore we analysed *C. auratus* sensu stricto separately from other representatives of the *C. auratus* complex (*sensu* Takada et al. 2010). The area of lower Yangtze River in China, which is considered as the only source of *C. auratus* for domestication (Rylková et al. 2010, Wang et al. 2013) was used for comparison of climate conditions between the target area (EU) and the region of origin. In contrast Veer and Nentwig (2014) in their evaluation used *Carassius auratus* and *Carassius gibelio* (Bloch, 1782) together.

Although the probability of freshwater aquarium fish being established within the EU is relatively low, their survival during summer is likely (Elvira and Almodóvar 2001, Ellis 2006). Our results show that during the warmest period of the year, aquarium fish are not very much affected by temperature over most of the territory of the EU (Table 1). Twenty-six species out of 33 evaluated showed TSEU of at least 25% in summer, and 8 species had summer TSEU of at least 70%. This may be conducive to short-term survival in natural habitats where aquarium fish are released by hobby keepers. This finding supports concerns as to possible transfer of novel pathogens into the native fish assemblage through uncontrolled release of infected aquarium fish. This is most likely to happen in areas of high population density, where higher propagule pressure could be expected (Copp et al. 2005b, Kalous et al. 2013). Go and Whittington (2006) already presented that ornamental gouramis from Southeast Asia are the source of megalocytivirus (Family Iridoviridae) causing losses on native *Maccullochella* peelii (Mitchell, 1838) in Australia.

Human-mediated introduction of pathogens into new areas is recognized as one of the most important factors driving disease emergence in wildlife populations (Daszak et al. 2001). Not much attention has been devoted to possible disease and/or parasite transfer from introduced aquarium fish to local native fishes in Europe even though the problem has already been noted by Peeler et al. (2011).

The presented list of 33 aquarium fish species could be used as a starting point for examining the pathogen control process.

The risk assessment is meaningful only for species with considerable propagule pressure and which may survive winter in the target area. Duggan et al. 2006 proved the existence of the relationships between frequency of occurrence of aquarium fishes in shops and likelihood of their introduction and of establishment. We therefore evaluated 11 of the most traded aquarium fish species having TSEU of at least 10%. The fishes evaluated as medium risk are: South American catfish *Corydoras paleatus* (Jenyns, 1842) with the second highest TSEU, reaching 38% in winter, but so far with no records in the wild; South Asian catfish *Clarias batrachus* (Linnaeus, 1758) with TSEU reaching 24%, already found in England but only in channels sustained by the heated waters from a power station or dead due to temperature intolerance (Zięba et al. 2010); as well as three cyprinids, *Danio rerio* (Hamilton, 1822), *Tanichthys albonubes* Lin, 1932, and *Trigonostigma heteromorpha* (Duncker, 1904), and two gouramis, *Trichogaster lalius* (Hamilton, 1822) and *Trichopodus leerii* (Bleeker, 1852), with TSEU over 10%.

The highest FISK score among the most common aquarium fish was obtained by *Carassius auratus*. The evaluation of this fish by FISK as high risk is in accordance with observed reproduction of the species in open waters, e.g. in England and the Iberian Peninsula (Copp et al. 2005c, Ribeiro et al. 2008). Three high-risk species belonged to the family Poeciliidae. *Poecilia latipinna* (Lesueur, 1821) has already been introduced and established in Greece (Papavlasopoulou et al. 2013). In contrast, *Poecilia sphenops* (Valenciennes, 1846) has been established only in thermal water springs in Hungary and Romania (Petrescu-Mag et al. 2008), which could reflect its higher temperature demands (see Table 1). The same seems to apply for *Xiphophorus helleri* Heckel, 1848, which is occasionally recorded in Slovakia but is probably not established there (Májsky 2000, Koščo et al. 2010). Interestingly, *Poecilia reticulata* Peters, 1859, which was introduced and established in some regions of Spain (Elvira and Almodóvar 2001), was evaluated by our model as having 0% TSEU, probably pointing to some weaknesses in our approach. While we compared the air temperatures of source and target areas, these do not completely reflect water temperatures (Britton et al. 2010). In addition, the temperature suitability of particular species might not be completely explained by the minimum and maximum air temperatures of the region of origin (Tojo et al. 2010). In any case, several prediction models, including FISK, are based on the same climate data (Bomford 2008, Henderson et al. 2011).

It might be advisable to test also the climate data of regions where fish have been introduced and established, but this approach discriminates against species that have not yet been established outside of their regions of origin or in places which do not correspond to their minimum or maximum temperature suitability. Unfortunately, the scientific literature also lacks information regarding the minimum survival temperature for the majority of aquarium fishes as either adults or larvae. Such information could play an important role in any risk assessment model.

The aforementioned weaknesses notwithstanding, this is the first comprehensive assessment of potential risks of aquarium fish species within the territory of the EU. More detailed studies are needed to evaluate risks within specific areas, where more precise data on water temperature and propagule pressure are available. Although the risk potential of the most traded fishes in the EU seems to be not alarming, attention should nevertheless be directed to the possibility of novel pathogen transfer to native aquatic biota as an important aspect of regulating the aquarium fish trade.

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Table 1

List of the most traded ornamental fishes, including family, authority; origin (D – domestic production in EU, O – farm production outside EU, F – field capture in region of origin), temperature suitability in the EU in % (TSEU), FISK score and FISK category (low-, medium-, and high-risk)

Species name	Family	Authority	Main origin	TSEU		FISK	
				winter	summer	score	category
Carassius auratus	Cyprinidae	(Linnaeus, 1758)	D, O	95	73	26	high
Corydoras paleatus	Callichthyidae	(Jenyns, 1842)	D	38	38	4	medium
Poecilia latipinna	Poeciliidae	(Lesueur, 1821)	D, O	35	29	22	high
Tanichthys albonubes	Cyprinidae	Lin, 1932	D, O	29	39	5.5	medium
Clarias batrachus	Clariidae	(Linnaeus, 1758)	O	24	99	16.5	medium
Poecilia sphenops	Poeciliidae	Valenciennes, 1846	D, O	20	98	20	high
Trichopodus leerii	Osphronemidae	(Bleeker, 1852)	D	17	83	12	medium
Trigonostigma heteromorpha	Cyprinidae	(Duncker, 1904)	D	16	91	1	medium
Xiphophorus helleri	Poeciliidae	Heckel, 1848	D	15	78	21	high
Trichogaster lalius	Osphronemidae	(Hamilton, 1822)	O	14	93	13	medium
Danio rerio	Cyprinidae	(Hamilton, 1822)	D, O	14	93	4.5	medium
Thorichthys meeki	Cichlidae	Brind, 1918	D	9	33		
Astronotus ocellatus	Cichlidae	(Agassiz, 1831)	D, O	8	15		
Xiphophorus maculatus	Poeciliidae	(Günther, 1866)	D, O	4	25		
Gymnocorymbus ternetzi	Characidae	(Boulenger, 1895)	D	3	20		
Trichopodus trichopterus	Osphronemidae	(Pallas, 1770)	D	2	51		
Paracheirodon innesi	Characidae	(Myers, 1936)	D, O	2	30		
Pangasianodon hypophthalmus	Pangasiidae	(Sauvage, 1878)	O	2	24		
Epalzeorhynchos frenatum	Cyprinidae	(Fowler, 1934)	O	2	23		
Pangio kuhlii	Cobitidae	(Valenciennes, 1846)	O	1	51		
Balantiocheilos melanopterus	Cyprinidae	(Bleeker, 1850)	O	1	49		
Puntius tetrazona	Cyprinidae	(Bleeker, 1855)	D	1	49		
Megalechis thoracata	Callichthyidae	(Valenciennes, 1840)	D	1	33		
Ancistrus dolichopterus	Loricariidae	Kner, 1854	D	1	30		
Piaractus brachypomus	Characidae	(Cuvier, 1818)	O	1	30		
Paracheirodon axelrodi	Characidae	(Schultz, 1956)	D	1	28		
Gyrinocheilus aymonieri	Gyrinocheilidae	(Tirant, 1883)	O	1	15		
Chromobotia macracanthus	Botiidae	(Bleeker, 1852)	F	0	31		
Poecilia reticulata	Poeciliidae	Peters, 1859	D, O	0	30		
Mikrogeophagus ramirezi	Cichlidae	(Myers & Harry, 1948)	D	0	27		
Pterophyllum scalare	Cichlidae	(Schultze, 1823)	D	0	27		
Synodontis nigriventris	Mochokidae	David, 1936	D, O	0	24		
Betta splendens	Osphronemidae	Regan, 1910	O	0	3		

3.7. Neimpaktované výstupy

3.7.1. Certifikovaná metodika

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3.7.2. Chovatelské příručky

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- Patoka, J. 2008. Chováme sladkovodní raky. Grada Publishing. Praha. pp. 128. ISBN: 978-80-247-1836-1.

3.7.3. Příspěvek ve sborníku

- Patoka, J., Petrtýl, M., Kalous, L. 2012. Raci v České republice: přehled komerčně využívaných druhů. In: Kubík Š., Barták M. (eds), Workshop on Biodiversity, Jevany, ČZU v Praze, pp. 133-142. ISBN: 978-80-213-2343-8.

4. Diskuze

Okrasná akvakultura je zdrojem chovatelsky atraktivních druhů, z nichž některé ale mohou představovat vážnou hrozbu z hlediska biologických invazí (Padilla and Williams, 2004; Lipták and Vitázková, 2015). Někteří autoři v této souvislosti hovoří o „časované bombě“ (Faulkes, 2014). Zásadním faktorem pro nepůvodní druhy včetně těch využívaných v okrasné akvakultuře, na němž závisí možnost etablovat se na nové lokalitě, jsou vhodné klimatické podmínky a především teplota vody (Rixon et al., 2005). Klimatické podmínky nelze hodnotit jen podle prostého zeměpisného umístění posuzovaných lokalit, ale také podle místních podmínek, které jsou často velmi specifické. Například Nový Zéland má mírné oceánské klima, avšak teploty během zimy klesají více než v jiných oblastech podobně vzdálených od rovníku (McDowall, 2004). Je tedy zřejmé, že pro správné určení pravděpodobnosti uchycení konkrétního nepůvodního druhu na nové lokalitě je velice důležité pracovat s co možná nejpřesnějšími klimatickými daty srovnávajícími obě hodnocené oblasti, tedy oblast původního rozšíření druhu a oblast ohroženou introdukcí. Proto byla klimatická shoda vyhodnocována pomocí aplikace Climatch v1.0 (Bureau of Rural Sciences, 2008), což je běžně používaný nástroj v publikacích zaměřených na biologické invaze (Chucholl, 2013; Stott, 2015). Naprostá většina druhů využívaných v okrasné akvakultuře náleží mezi druhy teplomilné až tropické, některým se ale nádrže nevytápějí a jsou vůči nižším teplotám tolerantní. Především ve státech Jižní Evropy je etablování těchto tolerantních druhů poměrně pravděpodobné. Na většině území Evropy jsou invazím nepůvodních druhů z okrasné akvakultury vystaveny především přirozeně či antropogenně oteplené vody (Koščo et al., 2010; Jaklič and Vrezec, 2011; Weiperth et al., 2015). Ovšem kvůli postupně se měnícím klimatickým podmínkám, kdy se mimo jiné zkracuje studené období, nelze vyloučit ani etablování zmíněných druhů v oblastech, kde to je v současnosti nereálné (Walther et al., 2002).

Ačkoliv okrasná akvakultura představuje určitá environmentální rizika, jakékoliv snahy o nápravná opatření, legislativní restrikce a osvětovou činnost musí být podpořeny detailní analýzou těchto rizik. Vzhledem k tomu, že okrasné chovy mají nepopiratelně i pozitivní stránky, a také proto, že neuvážené „ochranářské“ aktivity mohou naopak skončit přesně opačným efektem, než je žádoucí (Jud et al., 2011), je nutné správně posoudit míru rizika a určit nebezpečné druhy (Peay, 2009; Papavlasopoulou et al., 2013). Jedná se zejména o vytipování druhů potenciálně nebezpečných z hlediska biologických invazí, což je důležité kvůli zabránění novým introdukcím, které by mohly mít negativní dopad. Prevence biologických invazí je celosvětově řešeným tématem a na tento trend s jistým zpožděním reaguje i legislativa. V rámci EU se jedná především o nařízení Evropského parlamentu a Rady (EU) č. 1143/2014 ze dne 22. října 2014 o prevenci a regulaci zavlékání či vysazování a šíření invazních nepůvodních druhů. Toto nařízení iniciuje vytvoření seznamu druhů nebezpečných pro území EU.

Aby mohla být okrasná akvakultura komplexně vyhodnocena ve vztahu k environmentálním rizikům, musel být proveden detailní monitoring trhu a dovážených a prodávaných druhů. Nejpodrobněji byl v rámci předložené práce prozkoumán trh s raky určenými pro okrasný chov, a to jak ve vztahu k ČR, tak i k celé EU. Oproti daty nepodloženému navrhovanému plošnému zákazu dovozu a chovu exotických druhů raků, který navrhuje (Svobodová et al., 2010), prezentované výsledky z predikčního modelu invazivity raků prodávaných v ČR pro okrasné účely ukazují, že prokazatelně nebezpečné jsou severoamerické druhy. Z těchto druhů se jako málo nebezpeční ukázali trpasličí raci rodu *Cambarellus* (Obr. 1) a jako vysoce nebezpeční především zástupci rodu *Procambarus*. Jako potenciálně vysoce nebezpečný byl označen rak červený (*Procambarus clarkii*) (Obr. 3) a hlavně partenogeneticky se množící (Scholtz et al., 2003) *P. fallax* f. *virginalis* (Obr. 4). Důležité je zjištění, že stejně jako v Německu (Chucholl, 2013), tak i v ČR je nejlevnějším a zároveň běžně dostupným druhem raka na trhu právě *P. fallax* f. *virginalis*, což značně zvyšuje možnost, že bude tento rak vypuštěn do přírody.

Obr. 1: Samice trpasličího raka druhu *Cambarellus patzcuarensis*

(foto autor)

Raci pocházející ze zbytku světa tedy nepředstavují natolik vážné nebezpečí, aby důvod k zákazu dovozu převážil nad pozitivním přínosem okrasných chovů. Jedinou výjimkou je australský *Cherax destructor* (Obr. 2), který byl vyhodnocen jako vysoce nebezpečný. Je ovšem vnímavý k račímu moru, jak bylo dříve experimentálně ověřeno (Unestam, 1975), a proto lze tento druh označit jako též méně nebezpečný, než jsou raci pocházející ze Severní Ameriky. I když byl *C. destructor* vinou okrasné akvakultury zavlečen na jednu lokalitu v Itálii (Scalici et al., 2009), jeho šíření je z výše popsaného důvodu nepravděpodobné.

Obr. 2: Australský rak *Cherax destructor* je jediným druhem z čeledi Parastacidae a zároveň jediným druhem nepocházejícím ze Severní Ameriky, který byl vyhodnocen jako potenciálně nebezpečný pro astakofaunu v České republice

(foto autor)

Nebezpečí biologických invazí a dalších environmentálních rizik spojených s okrasnou akvakulturou zvyšuje i nezodpovědné chování akvaristů, konkrétně vypouštění nepůvodních druhů do zahradních jezírek i přímo do přírody a nelegální odchyt původních druhů pro následný chov. Tyto nežádoucí činnosti byly na základě dotazníkového šetření zjištěny u chovatelů raků v ČR, čímž byl potvrzen předpoklad Peay (2009), že okrasná akvakultura a speciálně chov nepůvodních druhů raků v zahradních jezírkách je značným environmentálním rizikem ohrožujícím především původní astakofaunu.

Obr. 3: Rak červený (*Procambarus clarkii*) je jedním z vysoce nebezpečných druhů z hlediska biologických invazí. Zároveň se jedná o jednoho z nejvyužívanějších raků v okrasných chovech

(foto autor)

Želvy jsou druhově poměrně chudým řádem, ovšem celosvětově byly introdukovány nejčastěji ze všech plazů a celkem třináct ze sedmnácti zavlečených druhů obývá sladkovodní prostředí (Kraus, 2009). Nejčastěji introdukovaným druhem byla želva nádherná (*Trachemys scripta elegans*). Mezi lety 1989 a 1997 bylo do EU dovezeno přibližně 52 mil. jedinců těchto želv. Po uniknutí či záměrném vypuštění se želvy nádherné často začaly projevovat invazně, proto byl import do EU v roce 1997 plošně zakázán (Cadi and Joly, 2004). Z tohoto důvodu byl tento poddruh z analýzy vyřazen. Z prodávaných druhů byly jako vysoce nebezpečné druhy z hlediska biologických invazí vyhodnoceny: kajmanka dravá (*Chelydra serpentina*), kožnatka trnitá (*Apalone spinifera*), pelomedúza africká (*Pelomedusa subrufa*) a klapavka obecná (*Sternotherus odoratus*). Tyto výsledky z velké části odpovídají zjištění Masin et al.

(2014), kteří následně provedli celosvětové hodnocení potenciální invazivnosti nejprodávanějších druhů želv pro okrasné účely.

Tradiční a zároveň nejpočetnější skupinou živočichů prodávaných pro okrasné účely jsou sladkovodní ryby. V ČR bylo na trhu zjištěno celkem 1118 druhů náležejících k 51 čeledím, což je podobné jako ve Španělsku a Portugalsku (Maceda-Veiga et al., 2013) a více než v Řecku (Papavlasopoulou et al. 2013). Naprostá většina zaznamenaných druhů ryb má původní areál rozšíření v tropických regionech. Proto není překvapením, že jen malá část byla vyhodnocena jako schopná etablovat se alespoň na části území EU. Predikce invazivnosti byla aplikována na druhy schopné etablování, u nichž bylo zároveň zjištěno, že patří mezi nejprodávanější a nejdostupnější na trhu. Jako nejnebezpečnější z hlediska biologických invazí byl vyhodnocen *Carassius auratus* a tři druhy z čeledi Poeciliidae: *Poceilia latippina*, *P. sphenops* a *Xiphophorus helleri*. Ačkoliv není žádoucí podceňovat invazní potenciál u těchto druhů ryb, protože už byly zaznamenány případy zavlečení do Evropy (e.g. Koščo et al., 2010; Papavlasopoulou et al., 2013), z porovnání s nebezpečím hrozícím ze strany introdukcí raků využívaných pro okrasné účely vyplývá, že tzv. akvarijní ryby jsou poměrně málo nebezpečnou skupinou.

Analýzou trhu s okrasnými druhy, tedy importu, exportu a produkce, bylo v souladu s předchozími studiemi prokázáno, že Česká republika zaujímá spolu se Singapurem, Thajskem, Malajsií a Japonskem celosvětově přední pozici (Maceda-Veiga et al., 2013; Ploeg, 2013; Saha and Patra, 2013) a zároveň je hlavní dodavatelskou zemí pro ostatní státy EU. Oproti jiným evropským státům, jako je například Německo (Chucholl, 2013), jen malá část chovaných exemplářů pochází z on-line obchodů. To je dáno s největší pravděpodobností vysokou produkcí místních chovatelů, což je faktor v ostatních evropských státech z velké míry absentující.

Obr. 4: *Procambarus fallax* f. *virginalis* je druhem, který byl vyhodnocen jako potenciálně nejnebezpečnější ze všech druhů raků nabízených k prodeji v rámci České republiky

(foto autor)

Část druhů, které se objevují na trhu s okrasnými živočichy a rostlinami, pochází z odchytu z volné přírody. Druhy, které nemají vědecké jméno, není možné sledovat v rámci monitoringu, zjišťovat jejich biologické a ekologické nároky a také nelze vyhodnotit dopad případného odchytu na početnost volně žijících populací (Lukhaup, 2015). V neposlední řadě rovněž nelze posoudit nebezpečnost těchto druhů z hlediska biologických invazí. V rámci analýzy trhu s okrasnými živočichy byl objeven jeden nový druh raka z čeledi Parastacidae, *Cherax gherardiae* (Obr. 5), který je odchytáván a dovážen ze západní části ostrova Papua Nová Guinea. Tento rak je blízce příbuzný s rovněž v okrasné akvakultuře využívaným *C. boesemani* (Obr. 6) a doplňuje kolekci nově popsaných druhů pocházejících ze zmíněné oblasti (Lukhaup and Pekny, 2006, 2008; Lukhaup and Herbert, 2008; Lukhaup, 2015).

Obr. 5: *Cherax gherardiae* patří mezi druhy raků odchytávané pro okrasné účely ve volné přírodě. Vědecky popsán byl v jedné z publikací, které jsou součástí předložené disertační práce (foto Miloslav Petrtýl)

Obr. 6: *Cherax boesemani* je blízce příbuzným druhem nově popsanému *C. gherardiae* (foto autor)

5. Závěry a doporučení pro využití poznatků v praxi

S ohledem na stanovenou hypotézu lze na základě získaných výsledků konstatovat, že okrasná akvakultura a činnosti s ní spojené představují určitá environmentální rizika. Především se jedná o riziko zavlečení nepůvodních druhů na nové lokality, zavlečení organizmů asociovaných s dováženými druhy živočichů a rostlin, a v neposlední řadě o nekontrolovaný odlov z volné přírody. Všechny vyjmenované aspekty mohou mít velice negativní dopad na původní biotu i životní prostředí obecně. Proto je nutné iniciovat nová ochranářská a legislativní opatření a především rozšířit osvětovou činnost, která by pomohla prohloubit informovanost chovatelů a laické veřejnosti o dané problematice. Jak bylo zmíněno výše, je nutné mít na paměti, že neuvážený plošný zákaz chovu vybraných živočišných skupin může mít paradoxně zcela opačné účinky, než bylo původně zamýšleno. Proto je žádoucí potenciální restrikce cílit na konkrétní druhy označené jako nebezpečné predikčními modely invazivity.

Tato disertační práce představuje soubor publikací zaměřených právě na zmiňovaná rizika spojená s okrasnou akvakulturou včetně výsledků predikčních modelů, a proto může posloužit jako podklad pro přípravu a zavádění opatření, která by tato rizika minimalizovala. Takovým opatřením je i Nařízení evropského parlamentu a Rady (EU) č. 1143/2014 o prevenci a regulaci zavlékání či vysazování a šíření invazních nepůvodních druhů. Výsledky obsažené v předložené disertační práci mohou napomoci při sestavování seznamu invazních nepůvodních druhů s významným dopadem na EU (tzv. „unijní seznam“), na jehož základě mají být uvedené druhy prioritně sledované a má být omezen či zakázán obchod s nimi a dovoz do EU. Navazující výzkum zaměřený na monitoring sektoru okrasné akvakultury, trendů s tímto odvětvím spojených, asociovaných environmentálních rizik a sestavování podkladů pro případná další legislativní opatření lze na základu výsledků uvedených v předkládané práci jen doporučit.

6. Seznam citovaných legislativních předpisů

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Nařízení Rady (ES) č. 338/97 ze dne 9. prosince 1996 o ochraně druhů volně žijících živočichů a planě rostoucích rostlin regulováním obchodu s nimi

Nařízení Státní rostlinolékařské správy č. SRS 053592/2012 ze dne 10. ledna 2013 o mimořádných rostlinolékařských opatřeních k ochraně proti zavlékání a rozšiřování plžů rodu *Pomacea* (Perry)

Prováděcí rozhodnutí Komise č. C(2012) 7803) 2012/697/EU ze dne 8. listopadu 2012 o opatřeních proti zavlékání rodu *Pomacea* (Perry) do Unie a jeho rozšiřování na území Unie

Úmluva o mezinárodním obchodu ohroženými druhy volně žijících živočichů a planě rostoucích rostlin (CITES) ze dne 3. března 1973

Zákon č. 78/2004 Sb., o nakládání s geneticky modifikovanými organizmy a genetickými produkty

Zákon č. 99/2004 Sb., o rybníkářství, výkonu rybářského práva, rybářské stráži, ochraně mořských rybolovných zdrojů a o změně některých zákonů (tzv. zákon o rybářství)

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Zákon č. 246/92 Sb., na ochranu zvířat proti týrání

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