Italian aquaculture and the diffusion of alien species: costs and benefits

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Abstract

The aim of this review is to clarify the relation between Italian aquaculture and the introduction on alien species in Italy. In Italy the most common aquatic alien species are rainbow trout and Manila clam and they represent main economic product of Italian aquaculture. Wels catfish and red clawed crayfish have been voluntarily or involuntarily introduced for aquaculture scope and they are now the most invasive alien aquatic species. Other alien naturalized species, as some salmonid species, are important economic resources in North Italy for inland professional fishery and are considered worthwhile of conservation. Thus, aquaculture is directly or indirectly responsible of the introduction of several alien species in Italy, but its effect on alien species diffusion is peculiar, as few successfully farmed species have become rapidly common. Until now conventional aquaculture has played main role in the diffusion of alien species in Italy, while ornamental aquaculture will be the main source of alien introductions in the future.

Introduction

Biological invasions are indissolubly related with human society (Simberloff , Martin, Genovesi, Maris, Wardle, Aronson, Courchamp, Galil, Garcıa-Berthou, Pascal, Pysek, Sousa, Tabacchi & Vila 2013; Bellard, Thuiller, Leroy, Genovesi, Bakkenesk & Courchamp 2013; Essl, Dullinger, Rabitsch, Hulme, Hülber, Jarošíke, Kleinbauer, Krausmann, Kühn, Nentwig, Vilà, Genovesi, Gherardi, Desprez-Loustau, Roques & Pyšek 2011). In particular, in the aquatic ecosystems these invasions are caused by alien species that are species introduced to areas beyond their natural range of distribution by humans, directly or indirectly. Aquaculture plays a key role in alien species diffusion at international level (Casal 2006; De Silva, Nguyen, Turchini, Amarasinghe & Abery 2009; Diana 2009; Turchini & De Silva 2008), FAO database on introductions of aquatic species (DIAS) shows that aquaculture is worldwide the most often cited reason for alien fish species introduction (FAO, 2009), (Gherardi, Bertolino, Bodon, Casellato, Cianfanelli, Ferraguti, Lori, Mura, Nocita, Riccardi, Rossetti, Rota, Scalera, Zerunian & Tricarico 2008). Aquaculture can also increase the diffusion parasites from reared fish to wild ones (Krkosek, Gottesfeld, Proctor, Rolston, Carr-Harris, & Lewis 2007). From the quantitative point of view, aquaculture and restocking activities are the main causes of introduction of alien species in Europe, as showed by IMPASSE (Impacts of Alien Species in Aquaculture) project funded by EU Sixth Framework Programme in 2008. Some alien species were initially reared and successively escaped in the wild, as goldfish or catfish or red claw crayfish, others unintentionally transferred with target farmed species as wels catfish, others deliberately released in the natural environment, as Manila clams. In Italy, the greater part of freshwater alien species have been introduced primarily for angling and secondarily for aquaculture scopes, while marine alien species have arrived by international maritime trade or penetration through Suez

Canal (lessepsian species) (Andaloro, Falautano, Perzia, Maricchiolo & Castriota 2012). Consequently, the geographical distribution of aquatic alien species in Italy markedly differs in marine and freshwater ecosystems. The great number of marine species were introduced in the 1980s and 1990s in the lagoon of Venice (NE Italy) and in the gulf of Taranto (SE Italy) that are considered "hot spot" of xenodiversity. These introductions were mainly caused by the intercontinental naval traffic due to tourism, commerce and the presence of an Italian Navy base in Taranto (Felline, Caricato, Cutignano, Gorbi, Lionetto, Mollo, Regoli & Terlizzi 2012; Occhipinti-Ambrogi, Marchini, Cantone, Castelli, Chimenz, Cormaci, Froglia, Furnari, Gambi, Giaccone, Giangrande, Gravili, Mastrototaro, Mazziotti, Orsi-Relini & Piraino 2011). Moreover, it should be considered that Italy has about 7,000 km of coastline and a central position in Mediterranean, these facts naturally expose to marine alien species invasion. Between 1945 and 2009, 165 alien marine species have been recorded in Italy, mostly originating from tropical regions of the world (Occhipinti-Ambrogi *et al.* 2011) while 112 established alien aquatic species have been recorded in inlands waters (Gherardi *et al.* 2008). The Italian Ministry of the Environment has published an atlas of Mediterranean alien species (http://www.sidimar.tutelamare.it/distribuzione_alieni.jsp). Meroplanktonic microscopic larvae naturally favor the spread of aquatic alien species, both in marine than in inland water ecosystems. Marine species are often transferred along great distances, principally by means ballast waters and keen fouling. The voluntary release of fish for recreational fishing or aquaculture, in particular in freshwater ecosystems, is particularly diffused in Italy where controls on legal and illegal stocking have been largely ineffective in the past (Gherardi *et al.* 2008).

Moreover, ornamental aquaculture is an emerging sector that has caused several alien species introduction, particularly in western countries (Rhyne, Tlusty, Schofield,

Kaufman, Morris & Bruckner 2012). In Italy, the shortage of clear rules, the increase of internet trade (Mazza *et al.* 2015) and the continuously increasing number of ornamental species favors illegal trade and international black market (Mazza, Tricarico, Genovesi & Gherardi 2013). In general terms, it is very well known that animal farming is one of the principal direct or indirect cause of diffusion of alien species, but it should be also remembered the economic relevance of animal farming and aquaculture (Diana 2009; Perdikaris & Paschos, 2010). Considering the close relation between the introduction of aquatic alien animal species and aquaculture activities, this review is principally focused on the clarification of the role of Italian aquaculture in the diffusion of alien species in Italy.

Freshwater fish

In general, the most common alien Italian species of freshwater fish is the rainbow trout (*Onchorynchus mykiss*) (Table 1). It was introduced in the beginning of 20th century and currently is the first species for Italian aquaculture; in 2013 the rainbow trout production in Italy accounted for 136.5 Mln € (Italian Association of fish farmers, http://www.api-online.it/index.cfm/en/home). Rainbow trout doesn't make natural reproduction in Italy, consequently its presence is exclusively dependent from artificial restocking, with exception of a population in Trentino region (NE Italy). Its impact on native salmonids species is related to competition with native species and potential diffusion of diseases. Salmonids are generally considered high value species in Italy and several introductions have been attempted in the last decades. Some species of salmonids have been introduced in the late 60's in some alpine lakes and rivers in North Italy, such as arctic charr (*Salvelinus alpinus*), native to Artic region and Brook trout (*Salvelinus fontinalis*) native to North America (Magnea, Sciascia, Paparella, Tiberti & Provenzale 2013).

European whitefish, *Coregonus lavaretus* and *C. macrophtalmus*, are zooplanktophagus salmonid imported in Italy from North Europe at the beginning of 20th century and currently acclimatized in some great lakes in the Italian alpine region (Regione Lombardia, 2014) (Figure 2). All the catfish currently present in Italy are alien, some species are naturalized and farmed. Black bullhead catfish (*Ameiurus melas*) and channel catfish (*Ictalurus punctatus*) native to North America and brown bullhead catfish (*A. nebulosus*), native to North America, colonized Italian freshwater ecosystems. Black bullhead catfish and channel catfish and are important species for aquaculture in Central Italy. Wels catfish (*Silurus glanis*) was reported as accidentally escaped from angling ponds in 1956 (Gandolfi & Giannini, 1979). After an initial phase of expansion, in the 1980s it became established in the Po basin in North Italy (Gandolfi, Zerunian, Torricelli & Marconato 1991) and in the Tiber Arno rivers, in Central Italy (Figure 1). Several cyprinids have been recently introduced in Italy as the common bream (*Abramis brama*) and *Pseudorasbora parva* (Volta, Jeppesen, Leoni, Campi, Sala, Garibaldi, Lauridsen & Winfield 2013). The common roach (*Rutilus rutius*), recently introduced by Danube basin, has stably colonized Maggiore and Lugano lakes, that are among the bigger Italian lakes (Regione Lombardia, 2012). The most invasive cyprinid is the asp (*Aspius aspius*) (Zerunian, Goltara, Schipani & Boz 2009), introduced in Italy from central Europe, the only example of carnivorous cyprinid that stably colonized some areas of Po river basin and currently considered a species highly appreciated for recreational fishing. Few species of Asian alien ciprinids are occasionally farmed in Italy: grass carp (*Ctenopharingodon idellus*), bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*). Largemouth bass (*Micropterus salmoides*) has been introduced in Italy at the beginning

147 of 20th century, it is an active predator that inhabits lentic waters (Marinelli, Scalici &
148 Gibertini 2007; Zerunian *et al.* 2009).

149 **Marine fish**

150 Due to the mentioned geographical reasons, the situation of alien marine fish species is
151 radically different from freshwater and there are several alien fish species with low or
152 unknown impact. Until December 2011, 48 fish alien species have been recorded along
153 Italian coasts, of which only one species is probably originated by aquaculture
154 (Occhipinti-Ambrogi *et al.* 2011). Between the alien marine species, some Carangidae
155 species recently arrived along Italian coasts, as *Seriola carpenteri*, *S. fasciata* and
156 particularly *S. rivoliana* (Andaloro *et al.* 2012), are potentially interesting for farming,
157 similarly to *S. dumerilii*, fish currently farmed in Japan. In other Mediterranean
158 countries, the presence of some alien species is already considered an opportunity for
159 aquaculture, for example in Cyprus, where a lessepsian fish, rabbit fish (*Siganus*
160 *rivulatus*) is actively farmed (Stephanou & Georgiou, 2000). Differently from
161 freshwaters, marine finfish aquaculture in Italy is based on Mediterranean species:
162 European sea bass (*Dicentrarchus labrax*) and gilthead sea bass (*Sparus aurata*).

163

164 **Freshwater invertebrates**

165 One of the most invasive alien species recently introduced in Europe and in Italy is the
166 red swamp crayfish (*Procambarus clarkii*) (Aquiloni *et al.* 2010), that is listed among
167 the 100 worst invasive alien species (DAISIE 2008). It that has been introduced for
168 farming in the 1980s from Atlantic coasts of North America (Figure 1). Between
169 bivalves, a particularly invasive species is zebra mussel (*Dreissena polimorpha*) that
170 was introduced in Garda lake at the end of ’60 and successively had a rapid diffusion in

171 other Italian lakes (Binelli *et al.*, 1997; Lancioni and Gaino, 2006). Asian basket clam,
172 (*Corbicula fluminea*), native to Southeast Asia has become a serious treat for freshwater
173 bivalves of North America and successively introduced in Europe (Araujo, Moreno &
174 Ramos 1993). Similarly to red swamp crayfish, *C. fluminea* is also listed among the 100
175 worst invasive alien species. It was initially found in the Po River in the late 1990's and
176 rapidly invaded many waterways in Northern Italy and arrived in the largest Italian
177 lakes, Garda lake and Maggiore lake (Kamburska, Lauceri, Beltrami, Boggero,
178 Cardeccia, Guarneri, Manca & Riccardi 2013b). Another freshwater alien bivalve
179 introduced in Italy is Chinese pond mussel (*Sinanodonta woodiana*) which is an
180 unionids endemic to China (Colomba, Liberto, Reitano, Grasso, Di Franco & Sparacio
181 2013; Lancioni & Gaino 2006; Kamburska, Lauceri & Riccardi 2013a). Between
182 freshwater gastropods, the most invasive species is probably the mud snail
183 *Potamopyrgus antipodarum*, native to New Zealand, that has colonized all regions of
184 Italy, except Sardinia (Mazza, Agostini, Aquiloni, Cianfanelli, Tricarico & Gherardi
185 2011), reaching in some cases densities of 800,000 individuals/m2.

186 **Marine invertebrates**

187 Marine alien invertebrate species are the largest and diversified group of alien species in
188 Italy. These include crustaceans, ascidians, ctenophore, bryozoans, cnidarians,
189 decapods, mollusks and polychaetes for a total number of 401 species (Andaloro *et al.*
190 2012). The lagoon of Venice is the Italian hotspot for marine invertebrate xenodiversity:
191 39 species, including 9 mollusks, and 9 crustaceans. Crocetta (2012) stated that marine
192 mollusks is the group with the highest number of marine alien species in Italy: 35
193 species including 18 Gastropoda, 16 Bivalvia and 1 Cephalopoda (up to December
194 2010). Few species of bivalves have been intentionally introduced for aquaculture: the

oysters *Crassostrea gigas*, *C. angularis*, *Saccostrea glomerata* and the Manila clam (*R. philippinarum*).

Bivalves

The most common marine alien Italian bivalve is the Manila clam (*R. philippinarum*) that was deliberately introduced for aquaculture in 1983 in the Venice lagoon and quickly substituted the Italian clam species (*Venus gallina*) (Chiesa, Nonnis Marzano, Minervini, De Lucrezia, Baccarani, Bordignon, Poli, Ravagnan & Argese 2011; Pranovi, Franceschini, Casale, Zucchetta, Torricelli & Giovanardi 2006). Today Manila clam is the first species for Italian aquaculture in value and in 2011 accounted for 222 Mln €. After its introduction, Manila clams rapidly became an important economic resource and Italy is first producer country in Europe and second in the world, after China (Perdikaris & Pascos 2010; Chiesa *et al.* 2011).Its typical farming method is a capture - based aquaculture and the Manila clam aquaculture is based on harvesting from naturalized wild population, principally along the coasts of North East Italy, Veneto and Emilia Romagna regions. Other marine bivalve species introduced for aquaculture are the Pacific oysters (*Crassostrea gigas*) and (*C. angulata*), but their diffusion has been not successful as Manila clam and their distribution in the wild is limited to some areas in northern and central Italy (Macali, Conde, Smeriglio, Mariottini P Crocetta 2013). The Asian date mussel (*Arcuatula senhousia*), previously known as *Musculista senhousia* or *Musculista senhousia*, is a alien marine mytilid that was introduced in the early 1990s in the northeastern Adriatic Sea and currently is spread in the Po River deltaic area, northeastern Italy (Mistri 2004; Munari 2008). This mussel sometimes reach densities up 10,000 individuals/sqm in the northern Adriatic, where it is threatening Adriatic shellfish farms (Crocetta 2012). The soft-shell clams (*Mya arenaria)*, a bivalve native of New England coasts, where it is commercially important

for fisheries and aquaculture, is considered among the 100 Mediterranean worst invasive and outcompetes native bivalves (Crocetta & Turolla 2011). Fortunately it is suitable for human consumption and its harvesting can represent a valid method for contrasting its diffusion. The rayed pearl oyster (*Pinctada radiata*), commonly known as pearl oyster, has recently colonized the coasts of a small island in South Italy, Linosa island (Lodola, Nicolini, Savini, Deidun & Occhipinti-Ambrogi 2013). In Greece, *P. imbricata* was intentionally introduced during the last century for aquaculture purposes and has established in the wild.

Other marine invertebrates

In Italy there are several alien marine species of invertebrates and, between these, the blue crab (*Callinectes sapidus*) (Thessalou –Legaki, Aydogan, Bekas, Bilge, Boyaci, Brunelli, Circosta, Crocetta, Durucan, Erdem, Ergolavou, Filiz, Fois, Gouva, Kapiris, Katsanevakis, Kljajić, Konstantinidis, Konstantinou, Koutsogiannopoulos, Lamon, Mačić, Mazzette, Meloni, Mureddu, Paschos, Perdikaris, Piras, Poursanidis, Ramos-Esplá, Rosso, Sordino, Sperone, Sterioti, Taşkin, Toscano, Tripepi, Tsiakkiros & Zenetos 2012) recently observed in South Italy (Mancinelli, Carrozzo, Costantini, Rossi, Marini & Pinna 2013) is spreading. The blue crab comes from the Western Atlantic coast of North America and it was reported for the first time in Mediterranean in 1931. Its first presence was dated back to 1971 and successively in Venice lagoon and in Apulia in January 2001 (Florio, Breber, Scirocco, Specchiulli, Cilenti & Lumare 2008). This species has a great economic value along southern U.S. Atlantic coasts where farming initiatives are starting. Another portunid, the chinese mitten crab (*Eriocheir sinensis*) has been found also in the Venice lagoon (Mizzan 2005). Polychaete anellids are introduced unintentionally by ballast waters or for bait trade and represent a numerous group of marine alien invertebrates, between them *Branchiomma*

245 *bairdi* that has been recently found along Tyrrenian coasts, reaching very high densities
246 (c.a. 400 individuals/m^2), particularly in polluted areas (Arias, Giangrande, Gambi &
247 Anadon 2013). Another example of invasive sabellid polychaete is *Branchiomma*
248 *luctuosum*, that outcompetes the Mediterranean native tubeworm *Sabella spallanzanii*
249 (Occhipinti *et al.* 2011). One species of alien ctenophore jellyfish, recently found along
250 Italian coasts, is *Mneniopsis leidyi* that is an effective plankton feeder particularly active
251 on fish eggs and larvae, native to Atlantic coast of US (Boero 2013).

252

253 **Amphibians and aquatic reptiles**

254 Alien amphibians and aquatic reptiles represents a limited phenomenon in Italy and
255 their presence is almost completely caused by ornamental aquaculture. At least eight
256 species of alien amphibians and 13 species of aquatic alien reptiles have been
257 introduced in Italy, but only five species introduced during the last century are
258 considered invasive (Ficetola, Thuiller & Padoa-Schioppa 2009). Main alien reptiles
259 diffused in Italy are red-eared slider, (*Trachemys scripta elegans* Wield, 1839) and
260 yellow-eared slider (*T. s. scripta*), as well as hybrids between them (Agosta & Parolini
261 1999). Among amphibians, American bullfrog (*Lithobates catesbeianus*) was
262 introduced in Italy during the 1930s for food. Moreover green frogs (genus *Pelophylax*),
263 were introduced for farming purposes (Ficetola et *al.* 2009) and their real diffusion is
264 difficult to assess, being able to hybridize with native green frog species.

265

266 **Impact of aquatic alien species**

267 It is widely recognized that the diffusion of alien species result in a loss of biodiversity
268 and sometimes local extinctions (Diana 2009; Ribeiro & Leunda 2012). In Italy, the
269 most common alien species among fish and mollusks, *i.e* rainbow trout and Manila
270 clam, generate a great economic income being the first and second species of Italian
271 aquaculture for economic value (Italian Association of fish farmers, http://www.api-
272 online.it/index.cfm/en/home) (Table 1). Due to the success of rainbow farming, Italian
273 inland aquaculture is dominated by alien species, as happens in neighbor countries
274 (Perdikaris & Pascos 2010; Turchini & De Silva 2008). For instance, in 2011 the 92.3
275 % of quantity (that corresponded to 84.2% of value) of freshwater fish farmed
276 production was based on alien species. Naturalized alien salmonids, mainly spread in
277 northern Italian inland waters (whitefish, arctic char and brook trout) (Figure 2), are
278 important species for recreational and professional fisheries (Table 1) and did not
279 apparently affect lake productivity (Zerunian *et al.* 2009). European whitefish is one of
280 the dominant fish species in the bigger Italian lakes (Garda and Maggiore lakes) and it
281 is considered a typical product of local gastronomy (Regione Lombardia 2012). Being
282 unable to make natural reproduction, rainbow trout is occasionally released in controlled
283 conditions for recreational fishing, without significant effect on autochthonous
284 salmonids, with the exception of one population in Trentino region that encompass
285 natural reproduction. Other species as wels catfish (*S. glanis*) and red swamp crayfish
286 have an tremendous impact on local aquatic fauna and in the freshwater ecosystems.
287 Wels catfish is an active predator and its presence in Italy caused several problems in
288 the Po River basin to native species (i.e. *Alburnus arborella* and *Scardinius*
289 *erythrophthalmus*), causing in some cases local extinctions (Castaldelli, Pluchinotta,
290 Milardi, Lanzoni, Giari, Rossi & Fano 2013; Zerunian *et al.* 2009). Wels catfish
291 outcompetes native predators, the northern pike (*Esox lucius*) and European perch

292 (*Perca fluvitilis*), that have become extremely rare after its introduction, thus affecting
293 recreational and professional fishing activities. Wels catfish impact is also evident on
294 those fish species that lay eggs on bottom vegetation, as tench (*Tinca tinca*) (Milillio,
295 2012). The diffusion of wels catfish induced also decline in other alien species as the
296 largemouth bass (*Micropterus salmoides*, Lacépède), black bullhead catfish, (*Ameiurus*
297 *melas* Rafinesque, 1820) and goldfish, (*Carassius auratus* L.,) that were appreciated for
298 farming or recreational fishing. Red swamp crayfish has a high ecological plasticity and
299 it reduces biomass and species richness of macroinvertebrates, inducing drastic habitat
300 changes (Liu, Guo, Ke, Wang & Li 2011; Scalici, Chiesa, Scuderi, Celauro & Gibertini
301 2010). This species can outcompete the autochthonous crayfish, white-clawed crayfish
302 (*Austropotamobius pallipes*), and introduced in Italy the crayfish pest, a fungal disease
303 carried by *Aphanomices astaci*, lethal for European species of crayfish (Aquiloni *et al.*
304 2010). Red swamp crayfish make burrows in the pond and causes a noticeable physical
305 impact on freshwater ecosystems (Scalici *et al.* 2010; Garzoli, Paganelli, Rodolfi,
306 Savini, Moretto, Occhipinti-Ambrogi & Picco 2014; Scalera and Zaghi, 2004; Barbaresi
307 *et al.* 2004). Some marine alien or lessepsian fish species belonging to Tetraodontids
308 such as *Sphoeroides pachygaster* and *Lagocephalus sceleratus* are known for their
309 toxicity due to the neurotoxin tetrodotoxin that may produce paralysis of the diaphragm
310 and death (Andaloro *et al.* 2012) and they can also introduce pathogens for other fish
311 species. Uncontrolled harvests of Pacific oysters (*Crassostrea gigas*) eventually
312 contaminated by toxic algae can lead to diseases in humans. Between freshwater
313 bivalves, zebra mussel can accumulate biotoxins and sometimes favors the bloom of
314 *Microcystis aeruginosa*, a toxic microalga (Mazza *et al.* 2013). Similarly to the red
315 clawed crayfish, alien amphibians can spread fungal diseases as chytridiomycosis and
316 *Batrachochytrium dendrobatidis*, that can cause autochthonous amphibian decline

(Ficetola & Scali 2010). Concerning aquatic reptiles, sliders outcompetes for food and basking places the autochthonous European pond turtle (*Emys orbicularis)* (Ficetola *et al.* 2009) and, being active predators, sliders have heavy impact on fish and amphibians species, in particular in those species that lay eggs in shallow waters (Ferri & Soccini 2003).

Impact of exotic species and aquaculture: an ecological perspective

Dominance and diversity are two key concepts of basic ecology that define the relations between species in natural ecosystems and in particular they represent the ecosystems answer to environmental perturbations. These concepts can be adopted in this context in order to better explain the relation between aquaculture and diffusion of exotic species. The role of aquaculture has been dual, in fact few successfully farmed species have become rapidly common, these species can be considered "xenodominant", while the species involuntarily introduced are much more numerous, never reach considerable amounts and increase xenodiversity. The diffusion of species such as tilapia or carps has been enormously increased for farming purposes (Diana 2009). Conventional aquaculture (and in an historic perspective, any traditional zootechnic activity) acts as a kind of key of success for few alien species and in several cases the introductions of freshwater fish have resulted in great societal benefits (Diana 2009; Gozlan 2008). Ornamental aquaculture and escaped species increase xenodiversity. Therefore, xenodominance is the first ecological effect of successful alien species and xenodominant species have beneficial economic effect on local communities, as the rainbow trout or Manila clam.

Management of alien species: status and perspective

Until this moment the main solution proposed for alien invasive species has been the control of international trade or containment measures against diffusion of alien. Most common proposed measures regard on one hand rules and international directives that discipline the import of ornamental species and farmed animals, on the other hand suggestions on alternative methods against unattended transfers, such as the substitution of ballast waters in open ocean areas and the removal of fouling organisms, for marine species. In Italy main conservation efforts and/or management project have been focused on freshwater ecosystems that are much more fragile (Gherardi *et al.* 2008). Upon our knowledge, there are not management initiatives on marine fish species. Freshwater ecosystems lacking native piscivorous fishes, or being highly altered by humans, appear to be the most vulnerable to biological invasions (Casal 2006; Castaldelli *et al.* 2013). This vulnerability could also increase in the future, as consequence of climatic conditions change and it is likely that will favor the spread of introduced species not only in Europe, but also in northeastern North America, and Oceania (Bellard *et al.* 2013). In these last two decades, several UE projects in North Italy, have been focused on freshwater alien species management, in particular targeted against wels catfish diffusion. Between 2010 and 2012, an intensive fishing activity in collaboration with local associations of non-professional fisherman produced a significant harvest of wels catfish biomass. (http://www.progettosiluro.altervista.org/opuscolo_siluro.pdf). Other containment measures have been adopted for wels catfish as selective fishing and exportation of live fish toward eastern European markets (Castaldelli *et al.* 2013), exportation in areas where wels catfish angling is a rooted touristic activity, (as Slovenia) and promoting direct consumption. Containment strategies have been proposed for red swamp crayfish

366 control (Garzoli *et al.* 2014) and two LIFE projects have been recently funded for this
367 purpose: RARITY (http://www.life-rarity.eu/pages/rarity_en.htm) and SOS TUSCAN
368 WETLANDS (http://www.life-sostuscanwetlands.eu/index.php/it/?lang=en). The
369 management of alien salmonids is completely different from above mentioned species,
370 some of these naturalized species are important for local freshwater fishery and
371 consequently worth of conservation and protection. In Trentino region (NE Italy) the
372 arctic charr is even protected by a UE disciplinary (Official Journal of the European
373 Union, September 24th, 2013) and it is considered typical product of regional
374 gastronomy. Re-introduction projects have been carried out in areas where these alien
375 salmonids decreased, due to over exploitation and environmental pollution.

376 Economic opportunities can arise from alien species presence thus partially
377 transforming the nuisance into a opportunity such as aquaculture, recreational fishing
378 and fishing tourism. In Italy fishing tourism is a modern and well known activity
379 (Alberini, Zanatta & Rosato 2007; Picchi, Scalera & Zaghi 2006; Scalera & Zaghi
380 2004) and in 2012, in the Lombardy region, a significant increase of fishing tourism
381 practiced by German fisherman has been noticed, as a consequence of wels catfish
382 increase. Fisherman often collaborated in conservation projects as happened during
383 LIFE projects in 2003 and 2004 in Emilia region, but, more interestingly, they are
384 available to pay extra admission fees in order to do selective fishing in protected areas.
385 It should be remembered that recreational fishing in Italy regards nowadays almost 2
386 Mln persons only in freshwaters.

387 Novel products and activities can be developed from alien species, as happens in
388 France, Croatia and Poland, where wels catfish is farmed (Turchini et al., 2008;
389 Ulikowski, Szczepkowski & Szczepkowska 2003), or Cyprus where rabittfish is farmed
390 in marine cages (Stephanou & Georgiou, 2000). Selective fishing targeted on low-value

391 species as pumpkinseed bass (*Lepomis gibbosus*), can be eventually oriented for the
392 production of forage/bait fish, following the experience of bluegill sunfish (*Lepomis*
393 *macrochirus*) farming in southern US states. The recent diffusion of alien blue crab (*C.*
394 *sapidus*) along Italian coasts could be turned from ecological trouble into opportunity,
395 by crab farming under controlled conditions, considering that along eastern coasts of
396 U.S. it is one of most expensive seafood. Freshwater mollusks, when not directly
397 suitable for human consumption, are potentially utilizable for farmed animal feeds
398 (Sicuro, Abete, Forneris, Mioletti, Panini & Amedeo 2010). Zebra mussel farming plant
399 has been proposed as a potential system for a bioremediation project in the Baltic area
400 (Schernewski, Stybel & Neumann 2012). Chinese pond mussel (*S. woodiana*) in Central
401 Italy (Tuscany region) was used in 2003 for freshwater pearl production
402 (http://prometeo.adm.unipi.it/temp/4_Pisa.pdf). As showed until this point, potential
403 utilization of exotic species is an attractive option, but it must be handled with care as
404 potential exploitation could promote the further diffusion of exotic.

405 As regards as reptiles species, the ban to import *T. s. scripta* was imposed by EU since
406 1997 via the Protection of Species of Wild Fauna and Flora by Regulating Trade. Only
407 one of the two subspecies of exotic sliders (*T. s. scripta* and *T. s. elegans)* is curiously
408 considered dangerous, while other species can be legally imported and traded. This fact
409 has not biological reason as the two subspecies have similar ecological features and
410 hybrids are fecund and spread in the wild.

411 **Conclusions**

412 In Italy several alien aquatic species are currently present and some of them have
413 documented relevant ecological and economic impact, both negative than positive.

From 2009, the adoption of the EU regulation 708/2007, concerning the use of alien and locally absent species in aquaculture, has disciplined this sector. However, it is not sufficient to prevent the diffusion of aquatic alien species as Italian aquaculture encompasses a multiplicity of aspects that include conventional finfish aquaculture, bivalve aquaculture, ornamental aquaculture and the relation with introduction of alien species is consequently a multiple facets issue. Basically, there are two main groups of exotic aquatic species originated by aquaculture: the invasive ones with wels catfish and Louisiana red swamp crayfish and another heterogeneous group of exotic species that have beneficial effects. The most common Italian aquatic alien species are rainbow trout and Manila clams and they represent main economic products of Italian aquaculture. Moreover other species of naturalized salmonids are important economic resources for inland professional fishery in North Italy. As regard as ornamental aquaculture, including aquatic reptiles and amphibians, the consequences on alien species diffusion are currently more limited, but it should not be underestimated in perspective. The introduction of new exotic species in Italy is almost completely forbidden by a recent Italian law (n.1143/2014, applied from January 2015), consequently ornamental aquaculture will be the main future source of exotic aquatic species diffusion. In this context, the internet trade (currently uncontrolled) will represent the real challenge of future. In this moment Italian ornamental aquaculture is almost exclusively based on alien species, in freshwater and marine species, moreover there are few ornamental aquaculture farm in Italy and it can be estimated that more than 90% of this sector is dominated by importation from foreign countries. Advisable solution could be the encouraging of locally – reared ornamental species farming, that in this moment is not yet economically convenient in Italy.

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652 Table 1. List of species of Italian aquaculture in 2011 (Italian Association of fish

653 farmers, http://www.api-online.it/index.cfm/en/home)

Species	tons	Mln €	Origin
Rainbow trout (*Onchorynchus mykiss*)	41000	149.7	A
European seabass (*Dicentrarchus labrax*)	8700	64	I
Gilthead seabream (*Sparus aurata*)	9700	72	I
Gray mullets (mugilids)	3500	9.8	I
Sturgeons (Acipenserids)	1660	14.8	I + A
Eel (*Anguilla anguilla*)	1100	11.4	I
Common carp (*Cyprinus carpio*)	750	2.9	I
Catfish (*Ictalurus sp*.)	550	3.3	A
Arctic charr (*Salvelinus alpinus*)	400	1.6	A
Meagre (*Argyrosomus regius*)	300	2.1	I
Other fish species	5150	32.4	I + A
Blue mussels (*Mytilus galloprovincialis*)	100000	78	I
Manila clams (*Ruditapes philippinarum*)	33000	144	A
TOTAL	205810	586	

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655 A, exotic species; I, autochthonous species; I + A autochthonous + exotic species

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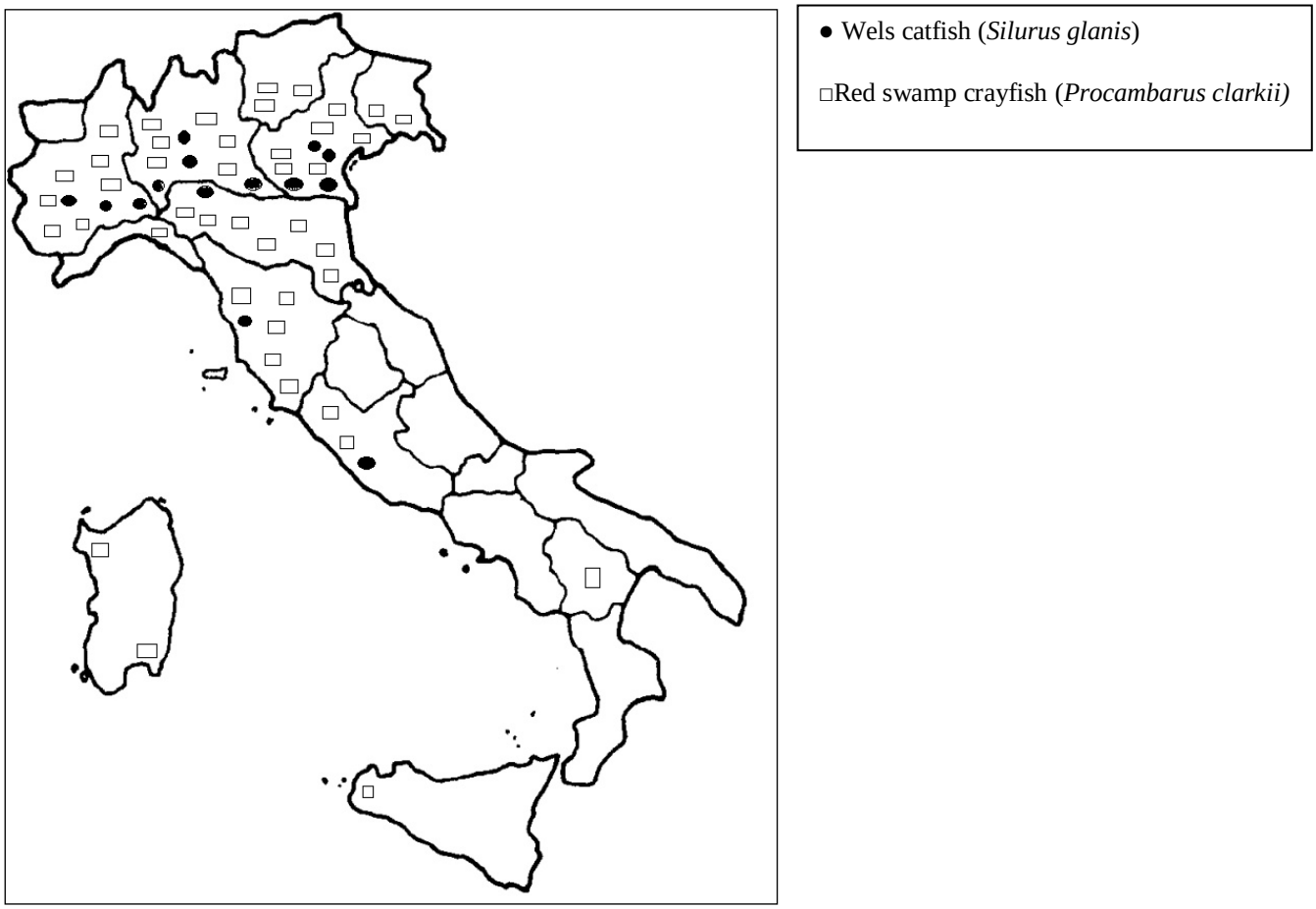
Figure 1. Wels catfish and red swamp crayfish distribution



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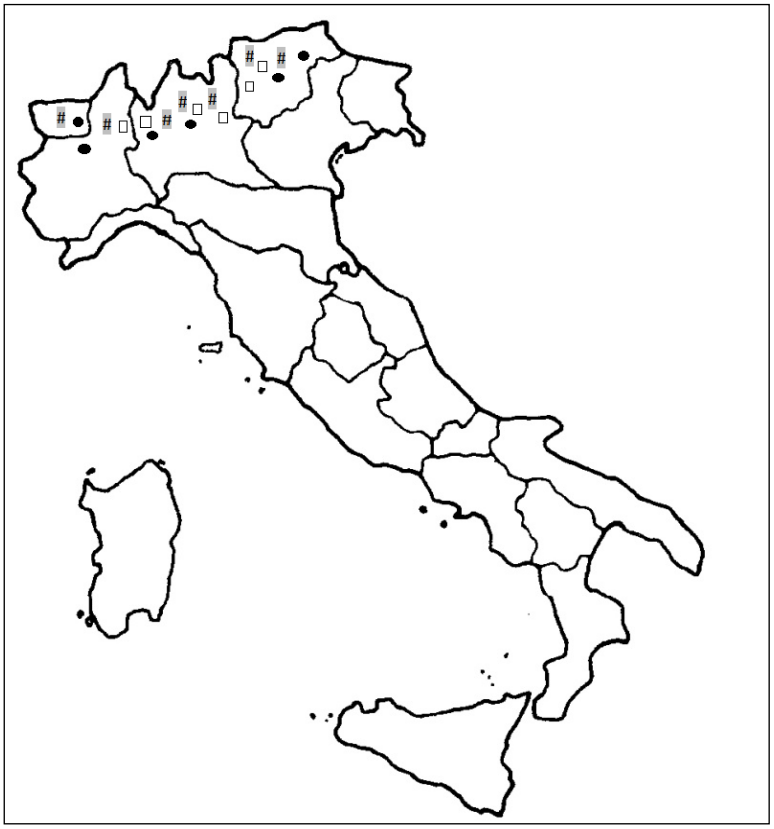
670 Figure 2. Naturalized exotic salmonid distribution



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