Relazione finale del progetto:

Response of native and invasive mussels to trematode infection: Exploring adaptive response of native and invasive mussels to trematode infection in northern and southern European ecosystems

The introduction of novel parasites or diseases to native biota is one of the most devastating impacts of non-indigenous invasive species (NIS), which poses a serious threat to ecosystem functioning and to human health (reviewed by Davis 2009). In addition, biological invasions can trigger and sustain emergence of previously existing diseases. The link between biotic invasions and disease emergence is not random, but closely linked to the mechanisms that underpin the dynamics of invasion. In fact, as disease shaped human history often playing a decisive role in the conflicts generated by the movements of peoples, so disease may also be a common factor mediating species invasions. The presence/absence of parasites hosted by the NIS and the different resistance against disease of exotic and native species can be determinant for the invasion outcome. Invader success can be facilitated either by the loss of parasites or by the co-introduction of its own parasites. Leaving behind parasites can give an important advantage to the invading species if this enhances its reproduction and survival (*Enemy Release Hypothesis*, Keane & Crawley 2002; Colautti et al. 2004). Invader establishment can be facilitated from the co-introduction of its parasites, if those parasites subsequently infect native species reducing their competitive or predatory impact on the NIS (*Novel Weapon Hypothesis*, Daszak et al. 2000; Ricklefs 2010). Introduced species must also face with native parasites for which they can act as competent hosts. If the parasites do not prevent the NIS from establishing, then the non-indigenous host can act as a reservoir in which infection is amplified and then 'spilled back' to native hosts. In contrast, if introduced species are not suitable hosts for endemic parasites but become infected anyway, they may act as sinks for parasites and thus dilute disease risk for native hosts.

Numerous examples show that exotic species can potentially alter the dynamics of endemic parasites either triggering and sustaining endemic disease emergence, or, contrarily, mitigating disease impact on native hosts (Poulin et al., 2011; Strauss et al. 2012). The scientific interest in the role of parasites in biotic invasions and in the role of biotic invasions in triggering disease emergence is being stimulated by the need to prevent/mitigate both human and ecosystem health impact (Conn, 2014). Nonetheless, recent exhaustive reviews concluded that empirical information is scant and more studies are needed to provide predictive tools for legislators to target prevention and control efforts towards those invasive species most likely to impact ecosystems and the economy, including those probable to initiate emerging diseases.

Freshwater mussels (Family Unionidae) populations are declining globally due to alteration in habitat, contamination, climate change and the introduction of exotic species (Lopes-Lima et al. 2016). Invasive bivalves are rapidly spreading to almost all European countries causing a remarkable decline of already threatened freshwater native mussel species (Karatayev et al. 1997; Ward and Ricciardi 2007). It is mainly under stress conditions, such as those increasingly impacting freshwater habitats (ecosystems), that invasive bivalves can become a serious competitor of native mussels. Due to their K-selected life history traits, the native mussels are, indeed, highly vulnerable to environmental change and manifest slow recovery from habitat disturbances (Strayer et al. 1999, McMahon and Bogan 2001). By contrast, invasive bivalve species are usually r-selected and adapted to unstable, unpredictable habitats (McMahon 2002). Due to their high reproductive and growth rate the invasive mussels can reach high densities when invading a new habitat and rapidly re-establish huge populations after experiencing catastrophic declines.

In Italy three highly impacting invasive mussel species (*Corbicula fluminea*, *Sinanodonta woodiana*, *Dreissena polymorpha*) are spreading and have already colonized the larger northern Italian lakes. Lake Maggiore, the second deepest and largest subalpine lake in Italy, is already permanently colonized by all of these invaders. *Dreissena polymorpha* is present since the 1990's, *Sinanodonta woodiana* and *Corbicula fluminea* were

detected for the first time in 2010 but likely started invading Lake Maggiore around 2000 (Kamburska et al. 2013a) and 2007 (Kamburska et al. 2013b) respectively. A strong decline of native mussels was evidenced by the periodic surveys of bivalves populations along the lake perimeter which were undertaken since 2010. Multiple mechanisms may be at play in determining the observed decline, including the combined effects of hydrological modifications, parasitic diseases and the impact of competiting invasive species.

Trematode parasites are known to infest freshwater mussels affecting both reproduction and physiological condition (e.g. Taskinen et al. 1991, 1994, 1995, 1997; Taskinen, 1998a, b). Digentic (host-castrating) trematodes target gonadal tissue and also affect growth rate and larval production in freshwater mussels. Trematode parasites also induce mortality in their mussel host (Jokela et al. 2005), and it has been observed that physiologically compromised mollusks are more susceptible to parasite-induced mortality (e.g. Sousa and Gleason 1989). Given the important role of temperature on cercariae production (Choo and Taskinen 2015), a vital component of the parasite's transmission and life cycle success, an increase in parasite densities can be expected to be associated with global warming. The higher frequency and intensity of heat waves and drought events in southern European countries may have favored a greater capacity of native mussel populations to adapt to climate change, the major factor triggering both invasive species success and parasite transmission. The present project aims at exploring the hypothesis that southern native mussel populations have actually evolved a greater resistance to parasite infection, an adaptation that could enhance their capacity to cope with both the thermal-induced increase of cercariae production and the increased competition by alien invasive species. To explore this hypothesis the NIS-parasite interaction in a selected number of freshwater environments, used as case studies, in Northern (Poland) and Southern Europe (Italy) was studied. The project was directed at two main tasks:

Task 1)

Occurrence of parasites and frequency of shared parasites in invasive and native bivalve species;

Task 2)

Effects of parasites on host metabolism and reproduction;

The first task was afforded by comparing the prevalence of trematode infestation in coexisting European native mussels (*Unio elongatulus*, *Unio tumidus*, *Unio pictorum*, *Anodonta* cygnea and *Anodonta anatina*)and invasive species (*Sinanodonta woodiana, Corbicula fluminea, Dreissena polymorpha*) in Lake Maggiore and in 3 Polish water bodies. 30 specimens per each mussel species in each site were dissected to detect the presence and quantify the number of parasites stages (eggs, larvae, adults) in the different animal organs (gonad, digestive gland, palps, gills, mantle). The following parasites were detected and counted: trematodes (*Rhypidocotyle campanula, R. fennica, Bucephalus polymorphus, Aspidogaster conchicola*), oligochaetes (*Chaetogaster* sp.) water mites (Unionicola spp.), bitterlings (*Rhodeo* spp.). Native species showed the highest parasite prevalence – while invasive alien species showed a lower to null prevalence - in both in Italian and polish water bodies.

The second task was attained by comparing the reproductive output (amount of oocytes/glochidium larvae) and physiological condition (relative dry weight) of infested and uninfested native and invasive mussel species. The highest degree of parasite impact was observed in native species, which reproduction resulted to be impaired to a large degree.

The project was carried out by Polish and Italian researchers in collaboration with Prof. Jouni Taskinen (University of Jyväskylä, Finland), a recognized outstanding expert in trematode parasites affecting freshwater mussels. During the Professor Taskinen stay at Poznan University (from 25 May to 3rdJune) over 500 mussels samples were dissected and examined to achieve the transfer/standardization of methods of analysis of the different life stages of the parasite and the morpho-functional alterations

induced in host tissues. After Prof. Taskinen departure, a field sampling was performed in thermal polluted polish canals and about 100 mussels from 3 native and 1 invasive species were analysed according the previously standardized protocol.

The data obtained are in process for the preparation of a joint publication in an appropriate scientific journal.

Literature cited

Choo, J.M. and Taskinen, J. 2015. Effect of short-term temperature change on cercarial release by *Rhipidocotyle fennica* (Trematoda, Bucephalidae) from the freshwater bivalve host, *Anodonta anatina*. *Ecological and Immunological Parasitology* doi:10.4303/epi/235932.

Conn, DB 2014. Aquatic invasive species and emerging infectious disease threats: A One Health perspective: Aquatic Invasions, 9: 383-390

Colautti, R.I., Ricciardi, A., Grigorovich, I.A. & MacIsaac, H.J. (2004). Is invasion success explained by the enemy release hypothesis? Ecol. Lett., 7: 721–733.

Davis, MA 2009. Invasion Biology. Oxford University Press, Oxford.

Daszak P., Cunningham A.A. & Hyatt A.D. (2000) Emerging infectious diseases of wildlife- Threats to biodiversity and Human health. Science, 287: 443–449.

Kamburska et al. 2013a

Kamburska et al. 2013b

Karatayev AY, Burlakova LE, Padilla DK (1997) The effects of Dreissena polymorpha (Pallas) invasion on aquatic communities in eastern Europe. J Shellfish Res 16: 187–203

Keane RM, Crawley MJ 2002. Exotic plant invasions and the enemy release hypothesis. Trends Ecol Evol 17: 164–170.

Lopes-Lima M, Sousa R, Geist J, Aldridge DC, Araujo R, Bergengren J, Bespalaja Y, Bódis E, Burlakova L, Van Damme D, Douda K, Froufe E, Georgiev D, Gumpinger C, Karatayev A, Kebapçi Ü, Killeen I, Lajtner J, Larsen BM, Lauceri R, Legakis A, Lois S, Lundberg S, Moorkens E, Motte G, Nagel K-O, Ondina P, Outeiro A, Paunovic M, Prié V, Von Proschwitz T, Riccardi N, Rudzīte M, Rudzītis M, Scheder C, Seddon M, Sereflisan H, Simić V, Sokolova S, Stoeckl K, Taskinen J, Teixeira A, Thielen F, Trichkova T, Varandas S, Vicentini H, Zajac K, Zajac T, Zogaris S 2016. Conservation Status of Freshwater Mussels in Europe: State of the Art and Future Challenges. Biological Reviews, doi: 10.1111/brv.12244

Jokela, J., Taskinen, J., Mutikainen, P. and Kopp, K. 2005. Virulence of parasites in hosts under environmental stress: experiments with anoxia and starvation. *OIKOS* 108:156-164.

McMahon RF, 2002. Evolutionary and physiological adaptations of aquatic invasive animals: r selection versus resistance. Can J Fish Aquat Sci., Vol. 59: 1235-1244

McMahon, R. G. & A. E. Bogan. 2001. Mollusca: bivalvia. In: J. H. Throp, & A. P. Covich, editors. Ecology and classification of North American freshwater invertebrates, 2nd ed. New York: Academic Press. pp. 331–430.

Poulin R, Paterson RA, Townsend CR, Tompkins DM, & Kelly DW, 2011. Biological invasions and the dynamics of endemic diseases in freshwater ecosystems. Freshwater Biology, 56: 676–688.

Ricklefs, R.E. (2010). Host–pathogen coevolution, secondary sympatry and species diversification. Phil. Trans. R. Soc. Lond. B, 365: 1139–1147

Sousa, W. P. and Gleason, M. 1989. Does parasitic infection compromise host survival under extreme environmental conditions? The case for *Cerithidea californica* (Gastropoda: Prosobranchia). Oecologia 80: 465-470.

Strauss A, White A & Boots M 2012 Invading with biological weapons: the importance of disease-mediated invasions. Functional Ecology, 26: 1249–1261

Strayer DL, Caraco NF, Cole JJ, Findlay S, & Pace ML 1999. Transformation of freshwater ecosystems by bivalves. Bioscience, 49: 19–27.

Taskinen J, Valtonen ET, & Gibson DI 1991. Studies on bucephalid digeneans parasitizing molluscs and fishes in Finland I. Ecological data and experimental studies. Syst. Parasitol. 19: 81-94.

Taskinen J., Valtonen E.T. and Mäkelä T. 1994. Quantity of sporocysts and seasonality of two Rhipidocotyle species (Digenea: Bucephalidae) in *Anodonta piscinalis* (Mollusca: Bivalvia). Int. J. Parasitol. 24: 877-886.

Taskinen J. & Valtonen E.T. 1995, Age-, size-, and sex-specific infection of *Anodonta piscinalis* (Bivalvia: Unionidae) with Rhipidocotyle fennica (Digenea: Bucephalidae) and its influence on host reproduction. Can. J. Zool. 73: 887–897.

Taskinen J., Mäkelä T. & Valtonen E.T, 1997. Exploitation of Anodonta piscinalis (Bivalvia) by trematodes: parasite tactics and host longevity, Ann. Zool. Fennici. 34: 37-46.

Taskinen J. 1998. Cercarial production of the trematodes *Rhipidocotyle fennica* kept in the field. J. parasitol. 84: 345-349.

Taskinen J. 1998. Influence of trematode parasitism on the growth of bivalve host kept in the field. Int. j. parasitol. 28: 599-602.

Ward JM, Ricciardi A, 2007. Impacts of *Dreissena* invasions on benthic macroinvertebrate communities: a meta-analysis. Divers Distrib 13: 155–165.