



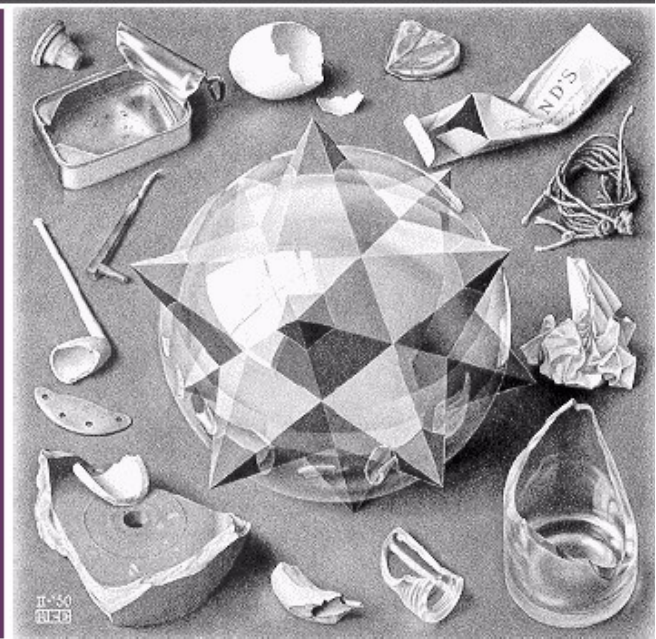
International  
Outgoing  
Fellowships (IOF)  
Call: FP7-  
PEOPLE-IOF-2009  
GA 251801

Fellow: Prof. Francesca Gherardi

Host scientists:

Prof. Dianna K. Padilla (Stony Brook  
University, USA)

Prof. Marco Vannini (University of Florence,  
Italy)



## **CHAOS**

### ***CLIMATE CHANGE AND SPECIES INVASIONS IN AQUATIC SYSTEMS: A COMPARATIVE PERSPECTIVE***



#### **Final summary report of the project:**

PEOPLE: MARIE CURIE ACTIONS International Outgoing Fellowships (IOF) Call:  
FP7-PEOPLE-IOF-2009 Agreement No. 251801

Prof. Francesca Gherardi

Outgoing host institution: Department of Ecology and Evolution, Stony Brook University, NY, USA  
Prof. Dianna K. Padilla

Ingoing host institution: Department of Evolutionary Biology, University of Florence, Italy  
Prof. Marco Vannini

CLIMATE CHANGE AND SPECIES INVASIONS IN AQUATIC SYSTEMS: A COMPARATIVE  
PERSPECTIVE (CHAOS)

Climate change and invasive species are two of the most pervasive components of global environmental change. The effects of climate change on aquatic ecosystems are manifold. These include changes in water temperature, rainfall and habitat availability, and modifications of pathways within the biogeochemical cycles and food webs. Increased temperatures and changed salinity will induce shifts in species' geographic ranges, affect ecosystem assemblages, and exert profound impacts on the exploitation of living resources.

Particularly in coastal areas and transitional waters, sea level rise and changes in current and rainfall patterns will strongly alter the composition of communities. Finally, climate change is expected to decouple an organism's phenology (i.e. the timing of life cycle events), thus modifying essential interactions with competitors, mutualists, predators, prey, or pathogens. By definition, invasive species are alien species (i.e. species intentionally or accidentally introduced by man outside their native range) that exert negative ecological, economic or human health impacts. Aquaculture, stocking, aquarium industry, canal construction, shipping, and other human activities are known to have greatly facilitated the spread of aquatic invaders, but the role of climate change on their expansion is only now being considered. Indeed, altered thermal regimes, reduced ice cover in lakes, changed streamflows, and increased salinity, along with increased water-use activities (e.g. canal and reservoir construction), are expected to greatly alter the transport of new species, the climatic constraints on invaders, the distribution of existing aliens, and their impacts on the native biota. They may also reduce the effectiveness of management actions to mitigate their damages, such as biological control. Among the numerous possible effects of climate change on aquatic communities, climate warming is expected to favor the establishment of many warm-water species introduced to temperate regions for aquaculture or for the aquarium trade; the impacts of alien predators on indigenous prey will be magnified and the virulence of alien pathogens to indigenous species augmented; an increased magnitude and frequency of floods will induce the natural dispersal of some aliens (e.g. zebra mussel, *Dreissena polymorpha*), whereas more prolonged droughts will favour species that survive desiccation by burrowing (e.g. the globally invasive crayfish *Procambarus clarkii*); and salinity changes in coastal waters will allow for greater invasion risks by, for example, the Chinese mitten crab *Eriocheir sinensis*. Unexpected results are likely, including loss of invasiveness by a number of alien species. Besides, some indigenous species will possibly expand their range of distribution or will counteract the spread and establishment of alien species (e.g. the blue crab *Callinectes sapidus* vs. the European green crab *Carcinus maenas* along the eastern coast of North America). However, all these effects are just hypothetical: a synthetic approach that specifically addresses the interactions between multiple invaders and the multitude of changes expected with climate change is urgently needed.

CHAOS' major objective was to provide a scientifically supported comprehensive view in aquatic ecosystems of the likely links between climate change and species invasions as two primary drivers of global environmental change. These links were analyzed in conjunction with other important correlates of biological invasions, including geographical variables, land-use, human disturbance, transport networks, and other socio-economic factors. The specific objectives of the project were: (1) synthesize historical data on the climate of inland waters, transitional waters, and coastal areas in the Mid-Atlantic Region of North America and Mediterranean Europe, examining the identity of the animal species introduced into these systems along with geographical, ecological, and socio-economic variables; (2) detail, by collecting in situ first-hand data, the synergistic effects of climate change and targeted invasive species on a range of ecosystems and their services for an area in North America selected as a model system; and (3) explore, through laboratory-based experiments, the influence of temperature and salinity on some biological traits of an invasive crustacean species of particular concern for both North America and Europe, the Chinese mitten crab, *Eriocheir sinensis*.

CHAOS' main focus --to unravel the links between climate change and invasive species in aquatic systems — was achieved by the means of a comparative approach. In this respect, Europe and North America are well matched for comparison because these regions are relatively well investigated, databases on aquatic biodiversity were accessible to the IO fellow Francesca Gherardi and to her supervisors, Marco Vannini and Dianna Padilla, and historical records on regional climate characteristics were readily available to them. A comparative approach also facilitated the analysis of the biology and ecology of species in native and introduced ranges, and in introduced ranges subject to diverse ecological and anthropogenic pressures. In fact, several aquatic species native to North America have been introduced into Europe (e.g. the crayfish *Procambarus clarkii* and *Pacifastacus leniusculus*) and vice versa (e.g. the green crab *Carcinus maenas*) and some species have invaded both regions inducing similar/different impacts (e.g. the Ponto-Caspian zebra mussel, *Dreissena polymorpha*). Additionally, many of the scientific needs in Europe regarding problems generated by invasive species are equally relevant to North America, as are the needs for developing common policies and legislative measures.

Project objective 1 was accomplished by gathering both ecological and societal information from a number of sources, including international and regional databases, grey-literature, scientific publications, and interviews of experts in invasion biology. These data also provided the basis for an extensive meta-analysis using different meta-regression models, in part originally developed by the IO fellow Francesca Gherardi. Knowledge about the several drivers of change have been supplemented with information available from the “Global Invasive Species Database”, managed by the Invasive Species Specialist Group (ISSG) of the IUCN Species Survival Commission. Other sources of information were the “European Alien Species Databases” being developed within the EU-funded projects DAISIE and IMPASSE, with which the IO fellow was associated. A fruitful interaction was also achieved with PESI, “A Pan-European species-directories infrastructure” (FP7-INFRASTRUCTURES). Experts in the field of invasions in aquatic systems were consulted, e.g. James Carlton, Alexander Karatayev, David Lodge, Hugh MacIsaac, and Greg Ruiz in North America, and Gordon Copp, Ian Cowx, Bella Galil, Stephan Gollasch, Anna Occhipinti-Ambrogi and Sergej Olenin in Europe and in the Mediterranean basin.

The project had an early termination because the IO fellow Francesca Gherardi suddenly passed away while she was carrying on an outstanding research. Her collaborators in grief are carrying on the activities that had been started in the framework of the CHAOS project.

The activities undertaken by Francesca in the framework of the CHAOS project are continuing at the Department of Biology of the University of Florence, being carried on under the supervision of Felicita Scapini by the research group, Elena Tricarico, Laura Aquiloni and Alberto Francesco Inghilesi, who share her enthusiasm for science and the skills in the study of crustacean behaviour and the impacts of alien species with relation to climate change. Also the international scientific partners of Francesca recognise her contribution to the subjects of interest and are preparing relevant publications in her memory.

The outcome of Francesca’s activities in the framework of the CHAOS project is published or under publication as listed below. The CHAOS project is having also a considerable impact in the environmental management as several still on-going activities address managers, practitioners and the public in general, highlighting the importance and urgency of the eradication of alien species or mitigation of their negative effects to the ecosystems.

#### **Scientific papers published in the framework of CHAOS:**

1. Capinha C., Larson E.R., Tricarico E., Olden J.D., **Gherardi F.** 2013. Effects of Climate Change, Invasive Species, and Disease on the Distribution of Native European Crayfishes. *Conservation Biology*, Volume 00, No. 0, 1–10 2013 Society for Conservation Biology, DOI: 10.1111/cobi.12043
2. **Gherardi F.**, Coignet A., Souty-Grosset C., Spigoli D., Aquiloni L., 2013. Climate warming and the agonistic behavior of invasive crayfishes in Europe. *Freshwater Biology* 58:1958-1967.
3. Mazza G., Tricarico E., Genovesi P., **Gherardi F.**, 2013. Biological invaders are threats to human health: an overview. *Ethology, Ecology and Evolution*, doi:10.1080/03949370.2013.863225

#### **Presentations to meetings in the framework of the CHAOS project**

4. **Gherardi F.**, Aquiloni L., Tricarico E. 2011. Vincitori e vinti nel mondo che cambia: le specie alloctone nelle acque interne. “Le interazioni tra cambiamento climatico e specie invasive: rischi e opportunità”, Florence, 11 November 2011.
5. **Gherardi F.**, Galil B., Innocenti G., Padilla D., Tricarico E. 2012. Climate change and alien crustaceans: the winners and the losers. Crustacean Society Summer Meeting and 10<sup>th</sup> Colloquium Crustacea Decapoda Mediterranea, Atene (Grecia), 3-7 June 2012.
6. Aquiloni L., Spigoli D., Souty-Grosset C., Coignet A., Pinet F, **Gherardi F.** 2012. Global warming and the agonistic behavior of invasive crayfish. International Association of Astacology (IAA) 19<sup>th</sup> Symposium, Innsbruck (Austria), 26–31 August 2012.
7. Tricarico E., Ferretti G., Foggi B., Giuliani C., Occhipinti-Ambrogi A., Marchini A, **Gherardi F.** 2012. The impacts of invasive alien species on ecosystem services in Italy. 73<sup>o</sup> Congresso dell’Unione Zoologica Italiana, Firenze, 24-27 Settembre 2012.