Modelling of non-native fish species responses to climate change (PIEF-GA-2008-219707)
Project acronym and dates: AlienFish&ClimChange (1 April 2008 to 31 March 2010)
Marie Curie Fellow and project coordinator: Dr. Grzegorz Zięba (Prof. Gordon H. Copp)

This fellowship further investigates the potential impacts of the pumpkinseed *Lepomis gibbosus* (L.), building upon work initiated during a previous Marie Curie (MC) Fellowship (Stakėnas 2006). The present MC fellowship aimed to address two important and timely questions relevant to the assessment of risks posed by non-native fishes in general (Ross 1991, Copp *et al.* 2009, Gozlan *et al.* 2010), and of pumpkinseed in particular (Copp & Fox 2007): 1) Will climate warming increase the risk of non-native fish establishing self-sustaining populations? 2) Will increased variability in precipitation and river discharge increase the risk of non-native fishes expanding their current ranges? The specific objectives of this post-doctoral fellowship were to: 1) acquire estimates of spawning event frequency via a novel telemetry array system; 2) assess pumpkinseed growth and reproductive traits in nature; 3) determine pumpkinseed dispersal rates from floodplain water bodies into receiving streams (using drift nets to estimate propagule pressure). All stated objectives were achieved or exceeded (though drift net sampling and analysis of reproductive strategy of wild populations are ongoing), and these milestones were complemented by field studies on: i) the decline of the threatened native pond fish, crucian carp *Carassius carassius* (L.), and ii) the environmental biology of crucian carp and of its introduced nemesis, the goldfish *Carassius auratus* (L.). This supplementary research contributed to an existing research project, funded by *The British Council* as part of an international network initiated by a *N.A.T.O.* 'Collaborative Linkage Grant' (www.cefas.co.uk/4200.aspx).

Objective 1a: Laboratory studies on spawning event frequency
To examine the likelihood of enhanced pumpkinseed reproduction (Fox & Crivelli 2001) and thus increased invasiveness (Klaar *et al*. 2004, Villeneuve *et al*. 2005) under climate change scenario, wild fish under controlled conditions, pumpkinseed were held in six artificial ponds (three heated by 2–3 °C, three at ambient temperature). For over 6 month beginning with 15 May 2009 fish spawning activity was monitored. 24/7 behaviour activity at the pumpkinseed's nest for fish individually identified with passive integrated transponder (PIT) tags and monitored using a PIT Multi-Point Decoder system (Riley *et al*. 2003). In the heated ponds, pumpkinseed demonstrated: a) an earlier onset of spawning, b) no significant difference in the frequency of spawning visits by females to nests; c) spawning bouts of significantly longer duration; and c) a significantly higher number of spawning bouts early in the season compared with later on. Early spawning and longer spawning bouts are likely to result in a higher number of larger young-of-year fish, leading to greater over-winter survival (Zięba, Fox & Copp, submitted). Thus, pumpkinseed are likely to become more invasive in the UK under warmer climatic conditions.

Objective 2: Field studies on pumpkinseed growth and reproductive traits in nature
To examine under natural conditions the likelihood of enhanced pumpkinseed reproduction, and thus increased invasiveness, under warmer conditions, wild-living populations (both under heated and ambient conditions where possible) were sampled over the reproductive period from populations in Poland (Zięba, Przybylski, Heese, Fox, Kováč & Copp, unpublished) and France (Dembski *et al.* 2006, Valente 2008), with a one-off sample from a population in Slovenia (see Šumer *et al.* 2005). Initial data suggest that faster juvenile growth, higher fecundity and early maturation occurs in populations from warmer temperature regimes compared to ambient conditions. Data from on-going field sampling indicates a link between pumpkinseed dispersal and the establishment of new populations, with pumpkinseed in the UK expected to shift from non-invasive to invasive under the predicted warmer climatic conditions.

Objective 3: Field studies on dispersal rates

To estimate the frequency and intensity of pumpkinseed dispersal (i.e. propagule pressure) from floodplain water bodies into receiving streams under the greater hydrological variability predicted for climate change conditions in the UK (Hulme *et al*. 2002), sampling was conducted at three type of outflows using drift nets, pipe nets and electrofishing. Pumpkinseed and three other non-native species (*Leucaspius delineatus, Oncorhynchus mykiss, Pacifastacus lenusculus*) were observed. Data from on-going samples of alien species, captured in the outflows from on-line lakes and floodplain water bodies, indicate an increase in alien species dispersal with increasing stream discharge. Evidence was also collected of alien fish transfers via anglers' keep nets, with subsequent dispersal during flood events (Zięba *et al.* 2010). These results highlight the risks of dispersal of alien species under the more variable discharge regimes predicted for climate change.

Supplementary activities: Field studies on the environmental biology of *Carassius* species

Two separate surveys of ≈20 ponds, conducted during 2008 and 2010 in north Norfolk, an historical part of the species native English range, revealed that crucian carp to have disappeared from >70% of ponds it was known to have previously occupied (up to the 1960–70s). Data on age, growth and reproductive character of native crucian carp and introduced feral goldfish in six ponds of Epping Forest (Essex) revealed early maturation in both species (as early as age 1), but with differences in growth performance: feral goldfish grew faster when in sympatry with crucian carp, crucian carp growth was similar regardless of feral goldfish presence or absence, but crucian body condition and relative fecundity was greatest in sympatry with feral goldfish.

References cited

Copp GH, Fox MG (2007) Growth and life history traits of introduced pumpkinseed (Lepomis gibbosus) in Europe, and the relevance to invasiveness potential. pp. 289–306 In: *Freshwater Bioinvaders: Profiles, Distribution, and Threats*. (F. Gherardi ed.) Springer, Berlin.

Copp GH, *et al*. (2009) Calibration of FISK, an invasive-ness screening tool for non-native freshwater fishes. *Risk Analy*. **29**, 457–467.

Dembski S, *et al.* (2006) Consequences of elevated temperatures on life-history traits of an introduced fish, pumpkinseed *Lepomis gibbosus*. *J. Fish Biol.* **69**, 331–346.

Fox MG, Crivelli AJ (2001) Life history traits of pumpkinseed (*Lepomis gibbosus*) populations introduced into warm thermal environments. *Arch. Hydrobiol.* **150**, 561–580.

Gozlan RE, *et al.* (2010) Current knowledge on non-native freshwater fish introductions. *J. Fish Biol.* **7c**, 751–786.

Hulme M, *et al*. (2002) *Climate change scenarios for the United Kingdom: the UKCIP02 Scientific Report*. Tyndall Centre for Climate Change Res., Univ. East Anglia. 120 pp.

Klaar M, *et al.* (2004) Autumnal habitat use of non-native pumpkinseed *Lepomis gibbosus* and associations with native fish species in small English streams. *Folia Zool.* **53**, 189–202.

Riley WD, *et al.* (2003) A portable passive integrated transponder multi-point decoder system for monitoring habitat use and behaviour of freshwater fish in small streams. *Fish. Manag. Ecol*. **10**, 265–268.

Ross ST (1991) Mechanisms structuring stream fish assemblages: are there lessons from introduced species? *Environ. Biol. Fish.* **30**, 359–368.

Stakėnas S (2006) Final activity and Management Report. EC-MEIF-CT-2003-501750.

Šumer S, *et al.* (2005) External morphology of a Slovenian population of pumpkinseed *Lepomis gibbosus* (L.) from a habitat with extreme thermal conditions. *J. Appl. Ichthyol.* **21**, 306–311.

Valente E (2008) Traits biologiques d'une espèce invasive, la perche soleil (*Lepomis gibbosus*), dans un reservoir artificial aux eaux échauffées : reproduction, croissance, longévité. Thèse de doctorat, Université de Metz. 205 pp. + Annexes

Villeneuve F, *et al.* (2005) Interpopulaton variation in the growth and life history traits of the introduced sunfish, pumpkinseed *Lepomis gibbosus*, in Southern England. *J. Appl. Ichthyol.* **21**, 275–281.

Zięba G, (see Section 4.1 for papers in which the MC fellow is a co-author).