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CORRESPONDENCE

The management of small, isolated salmonid populations: do we have to fix it if it ain't broken?

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In their recent paper, Sato & Harada (2008) pointed out that for isolated salmonid populations with low effective population size N_e it would be necessary to retain gene flow artificially. Using as a case study small and isolated populations of the freshwater salmonid Kirikuchi charr, Sato & Harada (2008) proposed artificial translocation of individuals within or among populations as a measure to mitigate immediate genetic threats occurring due to low effective population size and suspected inbreeding depression. They acknowledged the risk of outbreeding depression with reciprocal translocations (e.g. Hard, 1995; Gharrett *et al*., 1999; McGinnity *et al*., 2003; Tallmon *et al*., 2004), but claimed the close geographical proximity, similar habitat and small genetic differences among remnant populations might considerably reduce this risk. In a recent review, Edmands (2007) stated that concerns over outbreeding should be taken seriously, as the effects of outbreeding can be, in some cases, as damaging as severe inbreeding.

Here, we raise concerns about mixing of populations as a strategy to increase genetic variation, and we bring evidence of likely outbreeding depression observed in the rehabilitation project of the endangered freshwater salmonid marble trout *Salmo marmoratus*, started in Slovenia in 1993 (Crivelli *et al*., 2000). Since the beginning of the rehabilitation project, four marble trout populations went extinct due to landlsides (Predelica) and severe flood events (Gorska, Sventarska and Zakojska). The seven remnant populations of marble trout living in Slovenian streams are genetically distant ($F_{ST} = 0.66$, Fumagalli *et al*., 2002), present a very low effective population size (for the Huda Grapa population a total population size ranging from 29 to 60 individuals was estimated between 2000 and 2007) and very low genetic variability estimated at 14 microsatellite loci (for Huda Grapa $H_o = 0.046$, Fumagalli *et al*., 2002). In order to expand the genetic variability of marble trout living in the watershed, a new population (Gatsnik) was created in 1998 in a previously fishless stream by mixing the progeny of marble trout from two remnant populations from isolated streams with similar habitat (Trebuscica and Lipovesck). After two generations, the population of Gatsnik presented the typical features associated with maladaptation and outbreeding depression, that is lower annual survival rate (0.39 ± 0.02 for trout born in the stream, higher than 0.55 for other marble trout populations living in the study area, Vincenzi *et al*., 2008), reproductive underperformance at the F2 generation and unusual morphological abnormalities (Fig. 1). Moreover, preliminary results from a egg-to-fry experiment performed in the fish farm for the F1 generation of Gatsnik showed 80.4% of mortality from fertilization to hatching ($35.6 \pm 29.2\%$ for the remnant populations) (D. Jesenšek, pers. comm.). The translocation experiment in Gatsnik is still ongoing and may provide unequivocal evidence of outbreeding effects in 3–4 years. Nevertheless, despite the striking contrast of salmonid species in life-history traits may hinder generalizations, what we observed in the marble trout population of Gatsnik urges now further considerations on the opportunity of mixing populations of salmonids to increase their genetic variability.

As recently reviewed by Willi *et al*. (2006), small populations are predicted to have low potential to adapt to environmental changes, as genetic variation and potential response to selection should be positively related to population size. Moreover, individuals in small populations may have lower fitness and be inbred, which may decrease an adaptive response to unpredictable environmental changes. Apart from the obvious cases of overexploitation, pollution and human-induced fragmentation, the small population size and low heterozygosity frequently observed in endemic

Figure 1 Unusual morphological abnormalities in marble trout living in Gatsnik. In both marble trout the caudal part is underdeveloped, causing difficulties in resisting fast currents and slower movements, making the individuals more susceptible to floods and predators, respectively. Moreover, as the caudal fin is used by females to dig the reed in which they lay their eggs, spawning may be also impaired.

salmonids in the US and in Europe, mostly located in headwaters, may be a natural consequence of their ecology, life-history traits and typical habitat (Hendry & Stearns, 2004). Actually, many salmonid populations with low genetic variability prove to be viable and well adapted to their environment. Also, the correspondence between molecular and quantitative genetic variation may be weak (Wang *et al*., 2002). For instance, despite the small populations size, low genetic variability estimated at 14 microsatellite loci and strong impact of genetic drift, the remnant marble trout populations described by Fumagalli *et al.* (2002) are viable and no evidence of inbreeding depression has been observed (A. J. Crivelli, pers. comm.). On the contrary, local extinctions of marble trout populations were caused by exogenous events, that is landslides and major flood events, that at least in the short term represent a more relevant threat for marble trout viability than inbreeding depression. In a recent study, Valiente *et al.* (2007) suggested that low variability at eight microsatellite loci has not hindered the successful adaptation of Atlantic salmon, brown trout and rainbow trout in Patagonian lakes.

We should probably start to think about the role of genetics in small populations more in an evolutionary framework of local adaptation and not just in terms of inbreeding depression and low adaptive potential (Fox *et al*., 2008; Reed, 2007). In this sense, low heterozygosity within salmonid populations may be primarily viewed as an adaptation to local ecological constraints rather than an erosion of adaptive potential. In addition, populations that have survived substantial inbreeding are often largely resistant to further inbreeding depression because of the purging of genetic load (e.g. Crow & Kimura, 1970; Fox *et al*., 2008).

Therefore, contrary to the recommendation by Sato & Harada (2008), we suggest a more conservative management strategy for local salmonid populations at risk of extinction. Specifically, when both financially and strategically possible, the creation of new populations in streams suitable in terms of habitat and not subject to landslides and severe flood events – a major risk for salmonids living in mountain streams (also for Kirikuchi charr, Sato, 2006) –, should be preferred to the risky *in situ* translocation between remnant populations (Harig & Fausch, 2002). This conservation measure will also provide 'insurance' against the impact of catastrophic events frequently responsible for the loss of salmonid populations, an increasingly important issue given the expected increase in frequency and intensity of these events with climate change (e.g. Christensen & Christensen, 2003).

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