

Unusual amplexuses between anurans and caudates

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Animals developed various means of communication and mutual recognition. Among amphibians, means of communication are manifold, but still not fully comprehended. Anurans are known to use vocal, visual and chemical signals for species and sex recognition (Wells, 2007; Bowcock et al., 2008; Belanger and Corkum, 2009). However, these cues are not always effective. Many male anurans attempt to mate with conspecific males, heterospecific anurans, and even inanimate objects (Banta, 1914; Storm, 1960; Pearl et al., 2005; Mollov et al., 2010). Their search for a mate is often a trial-and-error endeavour – they “attempt to clasp practically any moving object” (Wells, 1977; Berven, 1981). In these animals fertilization is external; female choice is often precluded, and coercive mating is commonplace (Howard and Kluge, 1985; Sztatecsny et al., 2006; Sullivan and Kwiatkowski, 2007; Hettyey et al., 2009). Male frogs often mount heterospecific female frogs trying to grasp the largest ones among the available females (e.g., Schmeller et al., 2005). To discourage erroneous amplexuses, male and non-receptive female anurans can use specialized signals, such as “release” calls and characteristic body vibrations or inflating (Bowcock et al., 2008; Bruning et al., 2010; Mollov et al., 2010; Izzo et al., 2012).

In contrast to imperfect species and sex recognition cues of anurans, caudates developed more accurate mechanisms of discrimination: ground-borne pheromones and sophisticated courtship performances (e.g., Howard et al., 1997; Verrell, 1985; Caspers and Steinfartz, 2011). Fertilization is almost exclusively internal, and mate choice by females prevails (Greven, 1998; Wells, 2007). Although their sound perception is poor, caudates can vocalize, but it is unclear if vocalizations are used in intersexual communication (e.g., Menges, 1951; Franzen and Glaw, 1999).

In anurans, inter-specific amplexuses have been recorded, even between families (e.g., Storm, 1952; Waterstrat et al., 2008; Mollov et al., 2010). There are also few records of amplexus between representatives of different amphibian orders (Nussbaum et al., 1983; Moldowan et al., 2013). Here, we present two cases of mating behaviours by anurans towards caudates.

During our fire salamander (*Salamandra salamandra*) survey at Avala Mt. (Serbia: 44.691451°, 20.515257°, 506 m a.s.l.) on March 10th 2013, we observed an inter-specific “mating” attempt: an agile frog (*Rana dalmatina*) was firmly grasping a fire salamander, in axillary amplexus. This was observed for 15 minutes, but probably lasted longer. On the same day, we observed another pair, in inguinal amplexus (Figure 1 A,B). The first observation was made at app. 9:30 am, along a brook in a forest crowded with fire salamanders and agile frogs. All streams and small pools were swarming with *S. salamandra* females giving birth: in less than a half hour, we counted almost 70 adults. At the same location and time, *R. dalmatina* was also in its reproductive explosion: we observed mating frogs and frogspawn in every small pool we checked.

While conducting breeding surveys for wood frogs (*Lithobates sylvaticus*) in the Miquelon Lake Provincial Park (Alberta, Canada: 53.243244°, -112.872988°, app. 768 m a.s.l.), we observed wood frogs in amplexus with barred tiger salamanders (*Ambystoma mavortium*). On May 4th 2011 at a wood frog breeding aggregation (103 egg masses) a barred tiger salamander (possibly a

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Figure 1. Two *Rana-Salamandra* pairs from the Avala Mt., Serbia (Photos: A. Simović).

mature male, judging by the swollen vent) was being grasped by seven male wood frogs, although several of these did not have a firm grip (Figure 2 A,B). On April 25th 2012, at a wood frog breeding aggregation (127 egg masses) on a different pond, a salamander (possibly a female or juvenile) was found being grasped by five male wood frogs, although two of these did not have a firm grip (Fig. 2 C, D). Both observations were made during daylight (10:30 am and 12:15 pm, respectively), but the duration of these amplexuses is not known. Salamanders were rendered immobile by the male wood frogs, and their short limbs did not appear to be effective in dislodging amplexant frogs.

Male anurans can be extremely persistent in their mounting attempts (e.g., Storm, 1952; Berven, 1981; Machado and Bernarde, 2011). This is usually explained by male-biased operational sex ratios in these animals, which typically breed during a brief period of the year (e.g., Hettyey *et al.*, 2005). For almost a century researchers have been reporting on both normal and unusual sexual interactions in various frogs and toads, sometimes even between native and introduced species (Banta, 1914, D’Amore *et al.*, 2009; Gómez-Hoyos *et al.*, 2012). Reviews and possible explanations of “mating” attempts between different anuran and other animal species are given in Gröning and Hochkirch (2008), and Mollov *et al.* (2010). However, we found only three records of “sexual” interaction between Anura and Caudata (Nussbaum *et al.*, 1983; Vences *et al.* 1992; Moldowan *et al.*, 2013).

Sexual interactions between species are known as reproductive interference (Gröning and Hochkirch, 2008). Several types of these interactions have been described, and they impose different costs to the involved individuals. Sometimes the animals waste

only time and energy; in other cases individual survival and reproductive success, and even the persistence of populations or entire species are at stake (Hochkirch *et al.*, 2007; Gröning and Hochkirch, 2008). Several studies on anurans reported decreased reproductive success in the presence of heterospecifics and reproductive interference was proposed as one of the causes (e.g., Hettyey and Pearman, 2003; D’Amore *et al.*, 2009). In the cases we described, salamanders presumably suffer little or no damage, but male frogs wasted time and energy, and they probably missed opportunities to mate with females of their own species.

Anurans usually mate and lay eggs in the same place, in a single, short period during a year. Conversely, breeding and egg laying/parturition in caudates are often separated both spatially and temporally, with long-term sperm storage being quite usual (Houck, 2009). Male frogs usually use the restraining, while male salamanders exhibit persuasive approach to females, with pheromones playing a pronounced role (Houck, 2009). The agile frog is not a typical “explosive breeder”, but its mating period lasts no longer than a month (Hettyey *et al.*, 2005). Females are stated to mate once per reproductive period; males are territorial and guard fertilized egg masses (Lodé and Lesbarrères, 2004; Lodé *et al.*, 2005). Wood frogs are “explosive, synchronised breeders”; males are not territorial, but they often mate only once in a season (Berven, 1981; Stevens and Paszkowski, 2004). In these two frog species, as far as we know, no clear trends of mate choice – neither male nor female – have been reported (Berven, 1981; Hettyey *et al.*, 2005 and references therein). Larger males tend to be more successful, due to purely physical factors of their size relative to the size of females; however, smaller males also manage



Figure 2. Two *Lithobates*–*Ambystoma* groups (A, B: 2011; C, D: 2012) from the Miquelon Lake Provincial Park, Alberta, Canada (Photos: S. Olson and M. Patchell).

to fertilize certain proportion of eggs (Berven, 1981). The absence of clear preference for larger females could be explained from two viewpoints: these species often live in sympatry with other larger anuran species, and preference for larger females would be maladaptive, or the breeding period is too short to allow for sophisticated procedures of choosing a mate (Hettyey et al., 2005). Therefore, amplexing salamanders by male frogs might simply be a mistake.

Frogs and salamanders often occupy common pools, and salamanders are known to feed on anuran eggs and tadpoles (e.g., Wilbur, 1972). In the cases we described, salamanders may have encountered frog-breeding aggregations while searching for mates, but could also have been attracted to these places by acoustic or olfactory cues (Sinsch, 2006). If such is the case, the “misdirected affection” of male frogs could in fact interfere with potential predation of their offspring.

On the other hand, amphibian chemical communication is still insufficiently studied (Houck, 2009; Caspers

and Steinfartz, 2011). Recent research (Willaert et al., 2013) revealed that some anuran pheromones resemble those of certain salamanders. However, the function of these “amplexins” is, at the moment, not fully explained (Willaert et al., 2013).

Adaptive values/costs of misguided mating attempts by male frogs still cannot be unambiguously interpreted. To properly address this question much more investigation needs to be performed on amphibian communication by visual, tactile, acoustic and chemical cues (Houck, 2009), as well as on costs and benefits of different mating strategies, reproductive interference, competition and predation.

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