Herpetological Journal

Nest predation of the yellow-spotted Amazon River turtle (*Podocnemis unifilis*, Troschel, 1848) by the fire ant (*Solenopsis geminata*, Fabricius, 1804) in the Brazilian Amazon

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We report the effect of predation by the fire ant *Solenopsis geminata* on nests of the turtle *Podocnemis unifilis* in the Piagaçu Purus Sustainable Development Reserve, Amazonas, Brazil. During three consecutive breeding seasons (between September and October of 2012, 2013 and 2014), 492 nests were monitored and 95 (19.3%) were predated. *Solenopsis geminata* was the main predator, accounting for 65.26% (*n*=62) of the losses. Nest predation by ants was not correlated with soil exposition time. However, all *P. unifilis* nests predated by *S. geminata* were entirely covered by vegetation, suggesting that ants may select nests at specific microhabitat conditions. Studies on larger scales, including areas where *S. geminata* is naturally absent, are needed to develop an adequate management of *P. unifilis*.

Key words: fire ant, flooded forest, freshwater turtle, offspring

For most chelonians, the characteristics of nesting sites can have direct consequences on reproductive success, and the development and survival of offspring after hatching (Weisrock & Janzen, 2000; Ferreira-Júnior & Castro, 2010). For example, lower nest temperature due to dense vegetation coverage can reduce metabolic activity of hatchlings (Janzen, 1994; Ferreira-Júnior & Castro, 2006). Therefore, clutches with longer incubation periods can be characterised by male-biased sex ratios (Souza & Vogt, 1994; Mrosovsky et al., 1999), may suffer from higher mortality due to elevated humidity (Packard et al., 1987), and are exposed to higher predation risks (Pignati et al., 2013a). A range of vertebrates have been reported as predators of chelonian nests (lizards: Escalona & Fa, 1998; birds: Ferreira-Júnior & Castro, 2010; canines: Boarman, 1997; Longo et al., 2009; felines: Escalona & Fa, 1998). Nest predation by invertebrates are predominately reported for open areas or sandy soils (cockroaches: Ohba, 2011; crabs: Frick, 2003; ants: Allen et al., 2004; Pignati et al. 2013b). Predation intensity ranges from a small proportion of eggs per nest (lizards: Escalona & Fa, 1998) to complete nest predation by ants (Allen et al., 2004).

Ants (Hymenoptera: Formicidae) are considered dominant in most ecosystems (Wilson & Hölldobler, 2005). In tropical forests, they represent up to 25% of the animal biomass (Fittkau & Klinger, 1973) and interact with a large number of other species. Eusocial behaviour maximises the monopolisation of resources (Moloney & Vanderwoude, 2002), and colonies serve as a buffer against environmental changes (Kaspari & Vargo, 1995). Such characteristics make ants important predators impacting on vertebrate populations including turtles (Allen et al., 2004).

Females of the yellow-spotted Amazon River turtle (*Podocnemis unifilis*) can lay up to 47 eggs (Erickson & Kaefer, 2015), with mean incubation time around 60 days (Pritchard & Trebbau, 1984; Pignati et al., 2013a). *Podocnemis unifilis* can spawn in different substrates such as beaches, clayed slopes, the banks of lakes or rivers, and areas covered with vegetation (Escalona & Fa, 1998; Rueda-Almonacid et al., 2007); a considerable variation of nesting substrates is associated with a broad distribution of this species (Pritchard & Trebbau, 1984). While *P. unifilis* is listed as Vulnerable by the IUCN, it still occurs in the basins of the Amazon, Tocantins-Araguaia and Orinoco rivers (Rueda-Almonacid et al. 2007).

The intensive hunting of adults, consumption of eggs and illegal trade of members of the family Podocnemididae increasingly requires active conservation measures (Kemenes & Pezzuti, 2007; Waldez et al., 2013; Erickson et al. 2015). One project concerns the monitoring of nesting areas carried out in the Piagaçu Purus Sustainable Development Reserve in the state of Amazonas, Brazil (04°15'28.1" S; 061°55'52.9" W) directly involving local residents. In the present study, we report on the predation intensity of the fire ant (*Solenopsis geminata*) on *P. unifilis* nests over three consecutive breeding seasons.

Field work was conducted during three consecutive dry seasons (September–December 2012-2014). In total,

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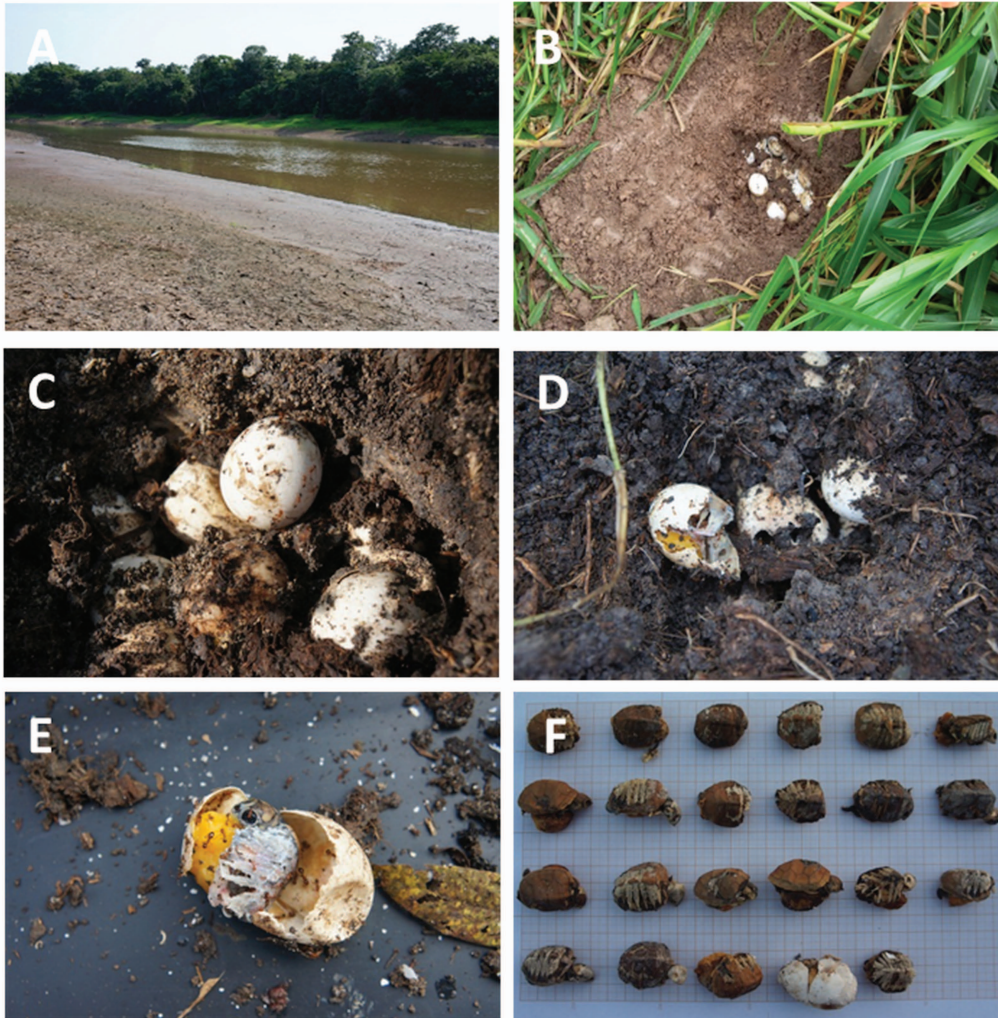
Fig. 1. A) Nesting area of the *Podocnemis unifilis* in the Piagaçu Purus Sustainable Development Reserve. B) Nest in clayed soil. C, D) Nests of the *P. unifilis* preyed by *Solenopsis geminata*. E, F) Eggs and hatchlings in development killed by ants. Note the ants walking everywhere inside the nest.

492 nests were monitored from egg laying until hatching of offspring. The area is characterised by forests that are periodically flooded and grow on clayed soils (Fig. 1 A-B). Location of nests was possible during the first 30 days after the first recorded spawning, when the river receded and the soil was exposed. The distance from the nest to the river and to the forest border served as a measure of soil exposition time: as the water recedes, areas close to the vegetation are available earlier for nesting.

In total, 19.3% of the nests (*n*=95) were attacked by predators. The lizard *Tupinambis teguxin* and the primate *Cebus apella* were responsible for 28.4% (*n*=27) and 6.3% (*n*=6) of predated nests. The fire ant (*Solenopsis geminata*) was the principal predator, accounting for 65.3% (*n*=62) of losses. In all cases, ants moved part of their colonies to the *P. unifilis* nest and killed all hatchlings. Predation occurred from early egg stages until hatching (Fig. 1C, D). No significant association was found between *P. unifilis* nests predation and distance to the river (*p*=0.701, Fig. 2A) or to the forest (*p*=0.098, Fig. 2B), suggesting that predation by ants is not correlated to soil exposure time. However, all nests predated by ants were entirely covered by vegetation, growing after water recession.

Predation of turtle nests has been reported to be lower in vegetated areas (Escalona & Fa, 1998; Spencer, 2002), whereas nests with lower vegetation cover have a reduced incubation time (Pritchard & Trebbau, 1984; Broderick et al., 2000; Ferreira-Júnior & Castro, 2006; Pignati et al., 2013a). However, most previous studies focused on species with gregarious behaviour (*P. expansa*: Ferreira-Júnior & Castro, 2010, *Lepidochelys olivacea*: Ortiz et al., 1997; *Caretta caretta*: Godley et al., 2001), for which the risk of predation is highest when the offspring leaves the nests (Ferreira-Júnior & Castro, 2010). Due to predation by *S. geminata*, our findings suggest that nesting sites covered by vegetation can also be at considerable risk for *P. unifilis*.

Solenopsis geminata exhibits polydomous nesting behaviour, enabling to increase its foraging area (Debout et al., 2007). It is possible that *P. unifilis* nests offer favourable conditions to *S. geminata* for colony establishment. In approximately 40% of the cases, part of the *S. geminata* colony invaded the nests soon after spawning, residing in nests until eggs hatch (Fig. 1E, F). Ants were regularly attracted to *P. unifilis* nests during the spawning process, feeding directly on cloacal mucus surrounding the eggs.

Microhabitat conditions of the turtle nest may also play an important role. Ants are in general thermophilic (Kaspari & Weiser, 2000), although behaviourally
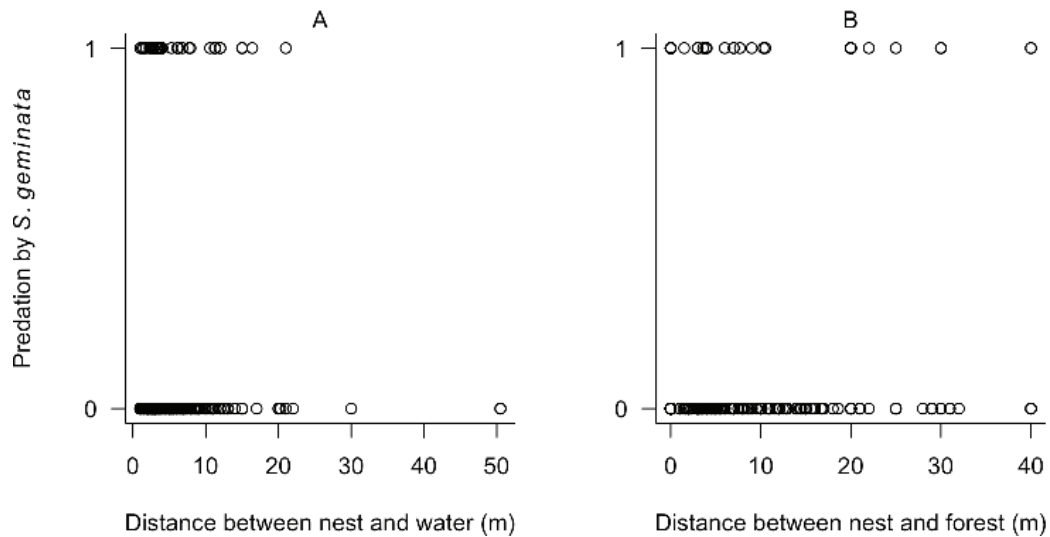
Fig. 2. *Podocnemis unifilis* nests predated (1) or not predated (0) by the fire ant *Solenopsis geminata* as a function of (A) distance to water and (B) distance to the forest in the Piagaçu Purus Sustainable Development Reserve. *n*=492 nests in each figure.

dominant ants such as *S. geminata*, are more active at low temperatures, likely because higher temperatures cause a rapid chemical decay of pheromones (Van Oudenhove et al., 2012). Despite the lack of a relation between predated nests and the distance to the forest, all predated nests were found under vegetation, suggesting that ants could be selecting nests with more suitable microhabitat conditions. Once *S. geminata* occupy the nest, *P. unifilis* hatchlings become an easy prey for ants which can perforate eggs and eat them (Diffie et al., 2010).

The optimisation of conservation strategies with the aid of traditional communities increases the access to important information on the natural history of species (Erickson et al., 2015). However, despite the adaptability of *P. unifilis* to different environmental conditions (Pritchard & Trebbau, 1984), the advantages and disadvantages of spawning in different substrates is not yet well understood. The impact of *S. geminata* may increase a male bias of offspring, as most *P. unifilis* nests established under vegetation and subjected to lower temperatures during incubation are preyed upon. As estimates of hatching success are essential to population studies, understanding the ecological compensation by *P. unifilis* through spawning in different substrates is crucial to the management and conservation of the species.

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