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Observations about *Neomys milleri* (Mammalia: Soricidae) predation on *Austropotamobius pallipes* (Crustacea: Astacidae)

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Abstract – In this work, we report the results of some movies regarding the predation of *N. milleri* on *A. pallipes*. It was a useful opportunity to observe some behavioral strategies. Skillful maneuvers by *N. milleri*, combined with toxic saliva, allow it to attack a large prey in relation to its size.

Key words: behaviour, crayfish, shrew.

Riassunto – Osservazioni sulla predazione di *Neomys milleri* (Mammalia: Soricidae) su *Austropotamobius pallipes* (Crustacea: Astacidae).

In questo lavoro, si riportano i risultati di filmati riguardanti la predazione di *N. milleri* su *A. pallipes*. È stata un'utile occasione per osservare alcune strategie comportamentali. Abili manovre da parte di *N. milleri*, unite alla saliva tossica, consentono di attaccare una preda di grandi dimensioni rispetto alla sua taglia.

Parole chiave: comportamento, gambero, toporagno.

Shrews are a group of mammals comprising 448 species (Burgin & He, 2018), with some of the smallest mammals in the world. In Italy, for example, *Suncus etruscus* (Savi 1822), with a head-body length of 35-50 mm and a weight of 1.2-2.7 g, *Sorex minutus* Linnaeus 1766, with a head length body of 40-64 mm and a weight of 2.6-7 g (Burgin & He, 2018).

Their small size involves a high energy expenditure and the need to feed frequently. For these reasons, shrews are very interesting from a physiological point of view, and they can attack even very large prey, in relation to their size (Churchfield, 1990; Vogel, 1980; Vogel et al., 1981; Genoud, 1988). Regarding this last strategy, the present work describes the predation of *Neomys milleri* Mottaz 1907 on *Austropotamobius pallipes* (Lereboullet 1858) in Northern Italy.

The observations were carried out in an artificial reservoir of approximately 50 m^2, surrounded by riparian vegetation, at 400 meters above sea level, in the municipality of Sestola (Modena province) (Fig. 1). Over the years, fish such as *Cyprinus carpio* Linnaeus 1758, *Tinca tinca* (Linnaeus 1758), *Carassius carassius* (Linnaeus 1758) have been here released without any control.

The predation episodes were filmed between January and April 2016, from 6.00 pm to 9.00 pm, for a total number of eight sessions. To carry out the filming, a frequency of 100 frames per second was chosen, which then allowed the videos to be viewed in slow motion mode to better observe the predation techniques.

N. milleri, previously considered a subspecies of *N. anomalus* Cabrera 1907, has recently been proposed as a good species (Igea *et al.*, 2015); considering this new taxonomic assessment, *N. milleri* is distributed in Europe (except Iberian Peninsula) and SW Asia while *N. anomalus* is restricted to the Iberian Peninsula. For this reason, the bibliographic research about morphology, ecology and ethology was carried out referring, more generally, to *N. anomalus*. The specific identification was carried out by examining the bristles distributed on the feet and tail, following the indications of Amori (2008).

The individual (maybe, the individuals) of *Neomys* considered in this work presents a scarce presence of bristles on the feet and tail after analysing the film stills. This pattern, compared with that of *N. fodiens* (Pennant 1771), the other species present in Italy, confirms its identification as *N. milleri* (Fig. 2) (Amori, 2008).

The identification of the crayfish was carried out following the indications of Morolli and Quaglio (2006).

All in all, we documented three attacks on crayfish, of which brief descriptions are reported below.

Attack 1 (prey size approximately 4 cm, water depth approximately 10 cm). The shrew arrives on site and begins to probe the submerged environment, clinging to the shore with its hind limbs and completely immersing the front part of its body. The action is repeated twice without result. On the third attempt, the shrew abandons its grip on its hind limbs, immerses itself completely for a few seconds, comes up with the prey clamped between its jaws and heads unhesitatingly for a sheltered spot where it disappears.

Attack 2 (prey size approximately 10 cm, water depth approximately 3 cm). The shrew arrived on site and apparently headed confidently towards the prey which put itself in a defensive position by raising its claws and the front part of its body. The shrew approached carefully, moving left and right and then grabbed the crayfish by a claw and tried to drag it away. When it was pinched by the other claw, it abandoned its grip. The shrew came back after about twenty seconds and tried again, this time managing to detach the claw after grabbing it and rolling over itself several times. The amputated claw was then taken away. The shrew returned almost immediately and repeated the action with the remaining claw, after which it amputated two of the prey's legs and took them away. On the fourth return it grabbed the crayfish firmly by the cephalothorax and dragged it with extreme vigour for short stretches, overcoming the force with which the crayfish clang to the pond bottom with its hind limbs. Every time the crayfish struggled, it was momentarily released and then retaken. Upon reaching a semi-submerged stone, the shrew dived under it, dragging the shrimp with it.

Attack 3 (prey size approximately 8 cm, apparently clawless or only very small, water depth approximately 1 cm). The shrew arrived on site and walked several times over the area where the motionless prey was standing, apparently without noticing it. At a further step he approached it and tried to grab it by the cephalothorax. The prey suddenly recoiled and the shrew jumped backwards. Shortly afterwards, it returned to the attack and, after biting the prey on the cephalothorax, dragged it for a few centimetres, depositing it on the bank. The prey tried to get back into the water. The same sequence was repeated a few times. After 4/5 attempts, the prey is then firmly dragged towards a higher point on the bank, where it was partially consumed before being hidden.

The dynamics of the observed predation events highlighted an unsuspected fierceness and boldness towards a prey almost the same size as the predator, but also the feeling of a precise strategy calibrated to the prey's size. In fact, with adult crayfish, the limbs and especially the claws were first targeted, and only after several attacks, once the crayfish had been rendered harmless, was it dragged away. In practice, the shrew launched an attack, tore off a limb and retreated, repeating the sequence several times until the crustacean, harmless and devoid of energy, was dragged away.

It should be considered that shrews of the genus *Neomys* possess toxic saliva capable of paralysing their prey, particularly large ones (Pucek, 1967, 1969; Churchfield, 1990); in fact, in the final stages

of the observed predations, the crayfish appeared partially paralyzed and therefore transported without too much effort by the shrew. A study conducted in the laboratory on the feeding behaviour of *N. milleri* (Rychlik, 1999) showed that this species prefers large food items and the most plausible hypotheses to explain this choice are maximum energy yield, low risk of predation and lower competition for food; finally, it is precisely the toxic saliva that facilitates this type of predation. However, we cannot rule out other factors, such as stress or injury of the prey during the encounter, which could also contribute to the predation success.

It is interesting to compare the episodes of predation here considered with what was observed in the laboratory in another shrew species, *Crocidura leucodon* (Hermann 1780), in this case against prey equipped with chemical and thermal defences: bombardier beetles *Brachinus* spp. (Bonacci *et al.*, 2003). Before concluding the predation sequence, *Crocidura* individuals repeatedly attacked the beetles in order to neutralize their physico-chemical defences (quinones and water sprayed at a temperature of 100 °C). Behavioural plasticity in predation and knowledge of the prey characteristics are issues to be investigated in more depth in soricides, mammals obliged to constantly search for food to counteract their high energy expenditure.

Another aspect that seems important to emphasize here is the conservation interest of these two species. *N. milleri* is a Data Deficient species which deserves conservation actions (Rondinini *et al.*, 2022), whereas *A. pallipes* is protected according to the Habitats Directive (AA.VV., 2014). For these reasons, the presence of introduced fish species in the study area could represent a threat to *N. milleri*, as suggested by a study on the congeneric *N. fodiens* (Tiberti & Mori, 2016).

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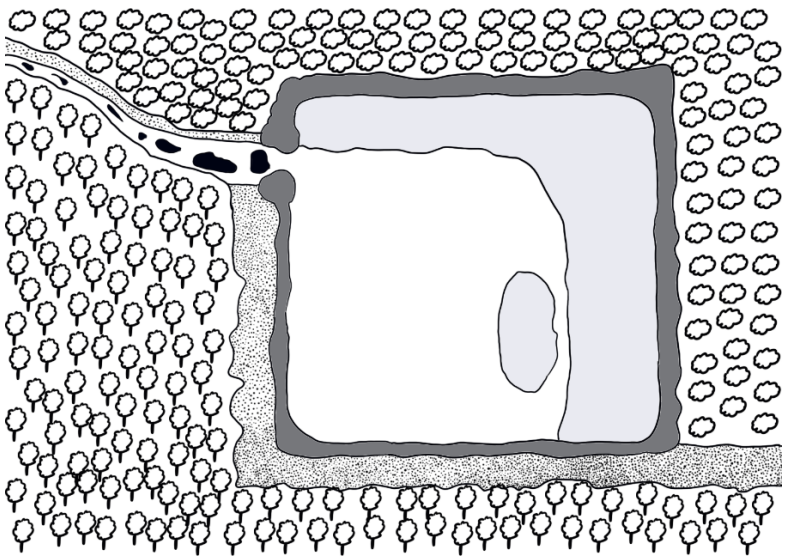

Fig. 1 – Map of the study area. In black: rocks; in white: water; in pale grey: *Arundo*, *Thypha*; in dark grey: *Carex*, *Juncus*, grass; dotted pattern: path; tree pattern: wood; cloud pattern: shrubby area. / Mappa dell'area di studio. In nero: rocce; in bianco: acqua; in grigio chiaro: *Arundo*, *Thypha*; in grigio scuro: *Carex*, *Juncus*, erba; area puntinata: sentiero; pattern con alberi: foresta; pattern con nuvole: arbusti.

Fig. 2 – Tail and foot of *Neomys milleri* caught in the study area (left, photo F. Ballanti) and *N. fodiens* from Val Masino, Sondrio province (right, photo A. Nappi). / Coda e zampa di *Neomys milleri* catturato nell'area di studio (a sinistra, foto F. Ballanti) e di *N. fodiens* della Val Masino, provincia di Sondrio (a destra, foto A. Nappi).