Knowledge and Management of Aquatic Ecosystems (2014) 413, 01 http://www.kmae-journal.org

DOI: 10.1051/kmae/2013084

Desiccation survival capacities of two invasive crayfish species

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Received June 25, 2013
Revised October 21, 2013
Accepted October 24, 2013

ABSTRACT

Key-words: *Pacifastacus leniusculus, Procambarus clarkii, desiccation survival, invasive species, dispersal*

The signal crayfish, *P. leniusculus* and the red swamp crayfish, *P. clarkii* are two invasive crayfish species with widely world distribution, being both present at Iberian Peninsula. In this work we study the desiccation survival capacities of both species at 24 °C. Our results showed that both species are capable of surviving exposure to air for long periods of time, with an LT_{90} of 17.6 and 21.5 h, respectively, for red swamp crayfish and signal crayfish. Our findings are in accordance with the great overland dispersal capacities attributed to these crayfish species.

RÉSUMÉ

Capacités de survie à la dessiccation des deux espèces d'écrevisses invasives

Mots-clés : *Pacifastacus leniusculus, Procambarus clarkii, survie à la dessiccation, espèces envahissantes, dispersion*

L'écrevisse signal, *Pacifastacus leniusculus* et l'écrevisse rouge des marais, *Procambarus clarkii* sont deux espèces d'écrevisses exotiques avec une distribution mondiale, toutes deux présentes dans la péninsule ibérique. Dans ce travail, nous étudions la capacité de survie à la dessiccation de *P. clarkii* à 24 °C et 30 % d'humidité relative et de *P. leniusculus* également à 24 °C, mais à une humidité relative de 50 %. Nos résultats ont montré que les deux espèces sont capables de survivre à l'exposition à l'air pendant de longues périodes de temps, avec une LT_{90} de 17,6 et 21,5 h pour l'écrevisse rouge des marais et l'écrevisse signal, respectivement. Nos résultats sont en accord avec les grandes capacités de dispersion par voie terrestre attribuées à ces espèces d'écrevisse.

Crayfish are one of the most commonly introduced freshwater organisms and are responsible for declines and extinctions of native species throughout the world (Guan and Wiles, 1997; Lodge *et al.*, 1998, 2000; Nyström *et al.*, 2001, Westman *et al.*, 2002). The signal crayfish *Pacifastacus leniusculus* (Dana, 1852) and the red swamp crayfish, *Procambarus clarkii* (Girard, 1852) are two North America native crayfish species with worldwide distribution due to their economic importance, but also due to their high dispersal abilities, fast growing populations and wide niches (Hobbs *et al.*, 1989). Severe negative impacts on invaded areas are attributed to these two crayfish species, such as competition with native species (Nyström, 1999), dissemination of the crayfish plague (Diéguez-Uribeondo *et al.*, 1997), habitat and ecosystem changes (Geiger *et al.*, 2005), negative effects on amphibian populations (Nyström, 1999;

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Cruz *et al.*, 2008) and losses on economic activities such as rice production (Anastácio *et al.*, 2005). In the Iberian Peninsula these two crayfish were first introduced into Spain nearly at the same time, *P. clarkii* in 1973 and *P. leniusculus* in 1974 respectively, for aquaculture purposes (Diéguez-Uribeondo *et al.*, 1997; Alonso *et al.*, 2000). In Portugal, the fist records of these species were in 1979 for *P. clarkii* in the Caia river (Ramos and Pereira, 1981) and in 1997 for *P. leniusculus* at the river Maçãs (Bernardo *et al.*, 2001). Currently these species have a wider distribution, with *P. clarkii* being present across all the Iberian Peninsula, and *P. leniusculus* having a more restricted distribution. The present distribution of these species reflects their high dispersal capabilities, high population growth rates and wide niches, which makes them very successful invaders (Hobbs *et al.*, 1989) but also years of successive illegal translocations (Alonso *et al.*, 2000; Diéguez-Uribeondo, 2006).

The desiccation survival capacities of aquatic species are intrinsically related with their passive dispersal capacities (Figuerola and Green, 2002), but also with their active dispersal capacities on dry land (Correia and Ferreira, 1995; Cruz and Rebelo, 2007). In this work, we assess the desiccation survival capacities of *P. clarkii* and *P. leniusculus*.

Red swamp and Signal crayfish were collected using baited traps, respectively in the Divor (38° 52′56.58″N; 8°10′.21.84″W) and the Maçãs rivers (41°40′36.00″N; 6° 38.06.00″W). Specimens of both species were separately acclimated during 5 days in aerated plastic containers (60 × 40 × 40 cm) with dechlorinated tap water at an 12:12 h light:dark cycle and carrots were fed to both species. We performed two separate laboratory experiments to check how long each of these two invasive crayfish could survive out of water, under controlled conditions at 24 °C. This temperature was chosen because it falls on the top of the range for the annual average maximum temperatures in the Iberian Peninsula (Ninyerola *et al.*, 2005). Eighty-one red swamp crayfish (cephalotorax length = 44.36 mm ± 4.53 SD; weight = 19.38 g ± 6.63 SD; Fulton index = 0.23 ± 0.03 SD) and Signal crayfish (cephalotorax length = 37.88 mm ± SD; weight = 16.64 g ± 7.90 SD; Fulton index = 0.29 ± 0.08 SD) were distributed into 9 groups of 9 individuals for each species. Each crayfish was individually placed into a plastic box (20 × 20 cm) and the boxes were kept at 24 °C with a relative humidity (RH) of 30% and 50% for the experiments with the red swamp crayfish and the signal crayfish respectively. The experiments lasted 27 h and every 3 h, the number of crayfish alive in one randomly selected group was checked. Crayfish were considered alive if we could detect movement of pereiopods, antenulles or maxillipeds. This procedure started by visually searching, during 30 s, for the presence of movement. If no movement was detected the individual was removed manually from the box, holding it by the pleon on an "upside down" position. Under these circumstances, many of the alive crayfish presented a reflex movement of pleon, if they did not we would then watch more closely for vestigial movement of pereiopods, antenulles or maxillipeds. Also, alive individuals in this position presented the pereiopods flexed and dead ones presented all pereiopods downturned by gravity. Statistical analyses were performed using IBM SPSS Statistics 20.

Our results show that both species presented no mortality until a period of 3 h out of water Red swamp crayfish started to die after 6 h of desiccation (Figure 1) but signal crayfish only started to die at 9 h (Figure 2). The number of crayfish alive was registered for a maximum of 18 and 21 h for red swamp and signal crayfish, respectively. Probit analysis indicated for red swamp crayfish an LT_{50} of 11.9 h (95% C.L. = 9.9–13.7) and an LT_{90} of 17.6 h (95% C.L. = 15.4–21.6) (Figure 1). The statistical model fitted adequately our observed data (Pearson goodness-of-fit test: $X^2 = 1.289$, $d.f = 8$, $P = 0.996$). For signal crayfish a probit analysis indicated an LT_{50} of 15.8 h (95% C.L. = 13.9–17.7) and an LT_{90} of 21.5 h (95% C.L. = 19.2–25.6) (Figure 2). The statistical model also fitted adequately our observed data (Pearson goodness-of-fit test: $X^2 = 1.661$, $d.f. = 8$, $P = 0.990$).

Our study shows that both *P. clarkii* and *P. leniusculus* can survive out of water easily more than 10 h in severe conditions, which are typical of the Iberian summer. Although our findings show an apparent higher desiccation survival capacity of *P. leniusculus* face to the *P. clarkii,* the observed differences may simply reflect different conditions, namely the higher relative humidity (almost the double) during the *P. leniusculus* experiment. Under similar conditions,

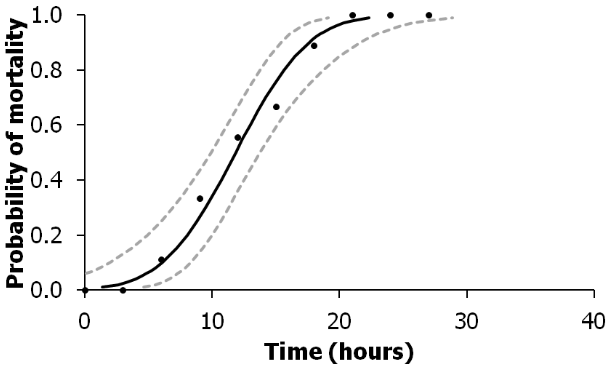

Figure 1
Probability of P. clarkii mortality as a function of the time spent out of water at 24 °C and 30% relative humidity. The black dots are the observed proportions of dead P. clarkii; the black line was obtained by Probit analysis, with the respective 95% confidence intervals (dotted line).

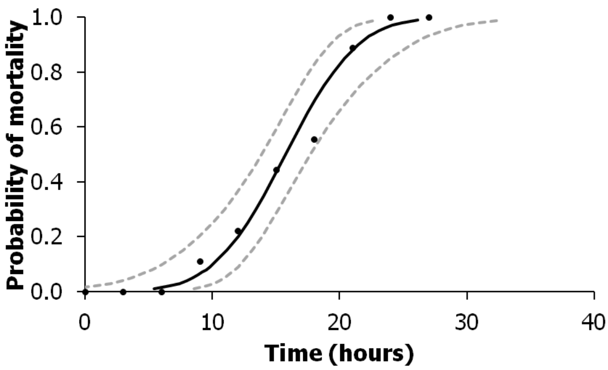

Figure 2
Probability of P. leniusculus mortality as a function of the time spent out of water at 24 °C and 50% Relative humidity. The black dots are the observed proportions of dead P. leniusculus; the black line was obtained by Probit analysis, with the respective 95% confidence intervals (dotted line).

namely of temperature, other exotic freshwater crustaceans with a wide distribution across Europe, the Mediterranean river shrimp, *Athyaephyra desmarestii* (Banha and Anastácio, 2012) and the North American amphipod, *Crangonyx pseudogracilis* (Rachalewski, 2013) presented a survival capacity approximate 10 times lower than the presently studied species. These findings have several implications for the dispersal of these crayfish species both by active and passive means, including Human mediated transport. For active dispersal, namely walking over dry land, a great capacity to survive out of water means a great capacity to cover large distances out of their natural environment. According to Pond (1975) the white-clawed crayfish (*Austropotamobius pallipes*), a native European crayfish species, presented a mean walking speed on dry land of 54 m/h, so in 10 h a crayfish would walk 540 m. For *P. clarkii* the maximum observed walking speed on dry land was of 90 m/h (Ramalho, 2012) although the mean values are lower. Taken our results for this species, namely the LT_{90} value, the maximum distance for active dispersal on dry land would be of approximately 1.6 km if walking continuously and always heading in one direction. This distance is enough to surmount natural or Human-made barriers on a stream, but also, under drought situations, it allows crayfish to escape from a drying pool and reach a more permanent water body. So, the desiccation survival capacities of *P. clarkii* and *P. leniusculus* are important features that can explain their great dispersal capacities. Our findings have also implications for passive dispersal, namely Human translocations; it is known that crayfish introductions and translocations that allowed many crayfish species to invade large geographic areas are due to illegal bucket transport by fishermen (Holdich *et al*., 2009; Lodge *et al*., 2000; Taylor 2000; Souty-Grosset *et al*., 2006). For a fisherman, the transport of crayfish specimens out of water is simpler and involves less equipment, but it also allows the transport of more individuals from one point to another. Therefore according to our results on the survival capacities of *P. clarkii* and *P. leniusculus*, both species can be easily transported for long distances in a small bucket or a cloth bag, undetected by the authorities. The distances involved in this process can easily overcome river basins, separated by dozens of kilometers if a car is involved. In conclusion, any management actions directed to these invasive species should take into account the great desiccation survival capacity of these invasive crayfish species.

ACKNOWLEDGEMENTS

This study was partially financed by FEDER funds through the "Programa Operacional de Factores de Competitividade – COMPETE" and by national funds through "FCT – Fundação para a Ciência e Tecnologia" on the scope of the project DID (Dispersal of Invasive Decapoda) (PTDC/BIABEC/105182/2008). F. Banha holds a PhD grant from FCT (SFRH/BD/81378/2011).

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