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Rapid Communication

First records of the red swamp crayfish *Procambarus clarkii* (Girard, 1852) (Decapoda Cambaridae) from a small circum-Sardinian island (central Mediterranean Sea)

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Abstract

The occurrence of the red swamp crayfish *Procambarus clarkii* (Girard, 1852) is documented for the first time in a small artificial lake located in a small circum-Sardinian island (San Pietro, South Sardinia, Italy), testifying the ongoing diffusion of this invasive crayfish also in a remote rural site. The presence of this species is a cause for concern given that this island is a hot-spot for herpetological endemism at a regional level. Our records, in conjunction with a number of recent observations made in inner Sardinia, indicate that the species is far more widespread in the area than previous studies have suggested. Because of its invasive history, eradication of this population is urgent and still economically profitable.

Key words: artificial lake, endemism, invasive species, Italy, range expansion

Introduction

Biological invasions are one of the big five issues of concern in conservation biology (Sala et al. 2000) and have attracted the attention of scientists, policy makers and the general public because they may inflict detrimental effects on the freshwater communities' species richness (Nyström 2002; Geiger et al. 2005; Rodríguez et al. 2005; Gherardi et al. 2008), posing serious threats on both natural capital and human health as well (Souty-Grosset et al. 2016).

Crayfish, with a long history of intentional or accidental introductions (Lodge et al. 2000), is one of the most frequently introduced taxon, with the red swamp crayfish *Procambarus clarkii* (Girard, 1852) becoming a global species due to its plastic life cycle, high fecundity, ability to rapidly disperse in the habitat, and tolerance to a wide range of environmental conditions (Gherardi 2006; Gherardi et al. 2008; Scalici and Gherardi 2007; Scalici et al. 2010; Dörr and Scalici 2013; Bissattini et al. 2015).

Most European countries have today at least one non-indigenous crayfish, still localized around the point of introduction or having spread

across the invaded area (Souty-Grosset et al. 2006). This is particularly true in Italy where most of the introduced crayfish species rapidly form self-sustaining populations in the colonized habitats (Kolar and Lodge 2001; Gherardi 2006; Scalici et al. 2009). From 1989 *P. clarkii* occurs in Italy, in both peninsula and the large islands Sicily and Sardinia (Delmastro 1992; Aquiloni et al. 2010; Morpurgo et al. 2010; Orrù et al. 2009; Kouba et al. 2014) and it is to date the most abundant crustacean decapod within the national territory (Gherardi et al. 2008).

Regarding Sardinia, there are evidences of presence in the South-Western and Northern-Eastern sector: i.e. in territories of Sassari, Olbia-Tempio and Cagliari (lake Coghinas, Riu Oschiri, Rizzolu de sa Coghinadolzu, Padrogiano river, Riu Badu Alzolas in Gallura) (Holdich et al. 2009; Morpurgo et al. 2010; Puzzi 2010). More in particular, in Southern Sardinia this species occurs in the Cagliari surrounding, as in the humid areas of Simbirizzi, Maracalagonis, Molentargius, San Vito, Villaputzu and Quirra, Molentargius marshland (Palmas et al. 2018; Bazzato et al. 2017). However, to date this species has never been found in any of the circum-Sardinian islands. We will shortly discuss the observation of *P. clarkii* in the Sulcis archipelago, in relation to the high amphibian and reptilian diversity of the investigated area.

Materials and methods

During August 2016, we conducted a non-standardized biological survey in the Island of San Pietro (Sulcis archipelago, Province of Carbonia-Iglesias; South-Western Sardinia; Special Area of Conservation: code ITB040027; Figure 1, right). We carried out random sampling in two representative sites along the banks of the lake, with presence of extended reedbeds of *Typha* sp. We used a fine mesh screen (1 mm). The specimens were then placed in sterile containers with ether. Animals captured have been preserved at the Laboratories of University of Rome III (Dept. of Science).

San Pietro island is a hot-spot for herpetological endemism at a regional level since here five Tyrrhenian species occur: two amphibians, *Discoglossus sardus* Tschudi, 1837 and *Hyla sarda* (De Betta, 1857), and three reptiles, *Euleptes europaea* (Gené, 1839), *Algyroides fitzingeri* (Wiegmann, 1834), *Podarcis tiliguerta* (Gmelin, 1789). In addition, local Sardinian sub-species such as *Chalcides c. vittatus* Leuckart, 1828 and *Podarcis siculus cetti* (Cara, 1871) are present (Sindaco et al. 2006).

On the island, a limited number of irregular/seasonal streams and temporary natural or anthropogenic ponds (e.g., water tanks for agriculture and sheep/cattle grazing) are present, all highly suitable for *P. clarkii.* However, excluding the salt marshes of Carloforte, the largest wetland located on this island is an inland artificial water reservoir in a rural context along the Northern area (Nasca lake; coordinates: 39.1666N; 8.2571E;

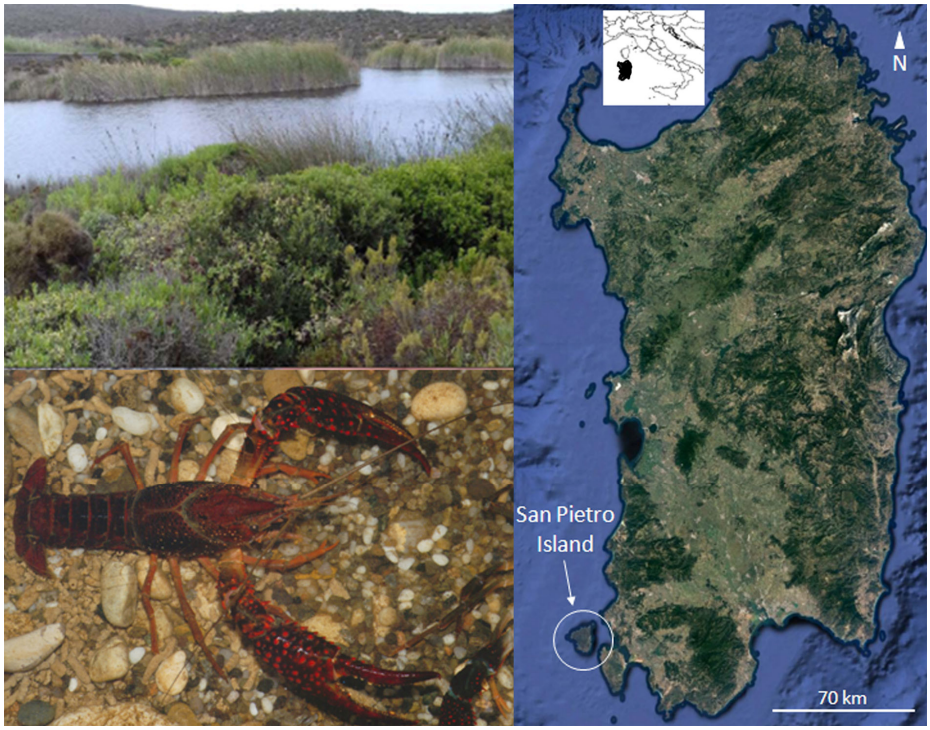

Figure 1. The study area (on the right). On the left: Above: Lake Nasca (San Pietro island, South Sardinia); down: specimen of *Procambarus clarkii* collected in the Island of San Pietro. Photos by M. Scalici.

size area 3 ha; Figure 1, left). It was built during the first half of 20th Century as a water supply. The shores of the basin are occupied by a continuous *Typha* reed bed. In the surroundings, a Mediterranean maquis with *Erica arborea, Pistacia lentiscus, Genista ephedroides, Juniperus turbinata* and *Arbutus unedo* is present (Erico-Arbutetum unedonis and Oleo lentiscetum-genistetosum associations), alternating with Mediterranean open prairies (Thero-Brachipodietea).

The sexual maturation pattern in *P. clarkii* males was assessed by recording the frequency of specimens with the reproductive phenotype (Form I) and those with a juvenile-like non-reproductive form (Form II). Male reproductive phenotypes can be easily recognized by the presence/absence of the spines on the third and fourth walking legs. In particular, the presence of spines was observed in all adult males displaying mating behaviour (Taketomi et al. 1990). For females, the sexual maturation was assigned based on literature (Huner 2002; Scalici and Gherardi 2007; Dörr and Scalici 2013), specifically using 21 mm of the cephalothorax length (CTL) as size at maturity.

Results and discussion

In August 2019 we captured 3 juveniles (2 males and 1 female) having 14 < CTL < 20 mm, 2 adult males with CTL = 25 and 33 mm (Figure 1), and 1 adult female with CTL = 26 mm, along the banks of the lake in a *Typha* reed bed. Although few specimens were collected, we may speculate on the

population acclimation. In particular, the presence of both juveniles and adults leads to hypothesize that the local population may have been naturalized: this record is particularly relevant from two points of view.

First, the presence of this crustacean is added to other non-native species which have been already recorded as syntopic in this site (Battisti 2017): *Trachemys scripta* (Schoepff, 1792), *Ameiurus melas* (Rafinesque, 1820) and *Carassius auratus* (Linnaeus, 1758). To our knowledge, excluding data from Malta (Deidun et al. 2018), our evidence is the first for a small Mediterranean island, highlighting the intense animal trade covering this area as well. This water reservoir could be thus considered a hot-spot of allodiversity (Battisti 2017). The original introduction for these invasive aquatic species was probably related to ornamental purposes, such as for the human mediated translocation of the red swamp crayfish successfully introduced all over the world (Huner 2002). Carloforte (> 5000 inhabitants), the only town of this island, is a destination for a large number of tourists and there is a commercial exchange between the inhabitants and the Sardinia island which could have facilitated the voluntary or involuntary introduction of these animals into this lake (e.g., following the release of other non-native pet species such as *Trachemys scripta, Ameiurus melas* and *Carassius auratus*). Local sources report that the lake, being the only freshwater reserve on the island, was the destination for the release of individuals of these pet species (M. Masnata *pers. comm.*).

Although some native and non-native species may impede its natural spreading, preying overall on juvenile crayfish, there are no solutions against its intentional translocation into natural waters by man, except improving the awareness on the threats due to the ornamental trade (through Citizen Science activities, overall on children) within the European Community, and overall imposing adequate regulations to reduce new arrivals of high-risk species, such as *P. clarkii*. Even if it is difficult to eradicate in a cost-effective manner, its inclusion in the Union List of the European Regulation No 1143/2014 becomes more and more important. Once introduced, beyond its role as vector of many parasites (such as the crayfish plague responsible for large-scale disappearance of native crayfish species: Dörr et al. 2011, 2012a, b), it causes severe impacts on several aquatic ecosystems, due to its (i) grazing on macrophytes and (ii) predation on several species, driving a native multi-species assemblage to an unbalanced condition (Gherardi 2006).

Second, from a conservation view, the presence of this invasive species in the small island of San Pietro, rich of water-related endemics (i.e., two amphibians) could imply an impact on eggs and frog tadpoles as widely reported in literature (e.g. Souty-Grosset et al. 2016; Oficialdegui et al. 2019): for example, *P. clarkii* could act as reservoir of *Batrachochytrium dendrobatidis,* impacting on local populations of endemic amphibians (e.g. Brannelly et al. 2015; Oficialdegui et al. 2019). Further research could be

also conducted to investigate the stomach contents to verify a possible impact also on local benthic communities (e.g. grazing on periphyton, and consequent on periphyton-associated invertebrates as insect larvae of mayflies, chironomids, snails, and microcrustaceans: e.g. Alcorlo et al. 2004; Klose and Cooper 2012),

However, this context seems one of the few cases for invasive crayfish in which, due to the still confined distribution and the enormous costs that this species might inflict to the society in the near future, eradication is still feasible and economically profitable. Possible methods/techniques of eradication may involve mechanical removal or the use of chemicals (e.g. natural pyrethrum: Cecchinelli et al. 2012), but a preventive risk analysis must be carried out in advance to ensure that these approaches do not affect other sensitive components (e.g. endemic taxa) of the site.

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References

Aquiloni L, Tricarico E, Gherardi F (2010) Crayfish in Italy: distribution, threats and management. *International Aquatic Research* 2: 1–14

Alcorlo P, Geiger W, Otero M (2004) Feeding preferences and food selection of the red swamp crayfish, *Procambarus clarkii*, in habitats differing in food item diversity. *Crustaceana* 77: 435–453, https://doi.org/10.1163/1568540041643283

Battisti C (2017) Xenodiversity in a hot-spot of herpetological endemism: first records of *Trachemys scripta*, *Ameiurus melas* and *Carassius auratus* in a circum-Sardinian island. *Belgian Journal of Zoology* 147: 55–60, https://doi.org/10.26496/bjz.2017.4

Bazzato E, Cillo D, Nuvoli MT, Fois F, Scaravelli D (2017) New distributional data of genus *Hydrophilus* Leach, 1815 in Sardinia (Coleoptera, Hydrophiloidea, Hydrophilidae). *Natura Rerum* 4(2015–2016): 71–77

Bissattini A, Traversetti L, Bellavia G, Scalici M (2015) Tolerance of increasing water salinity in the red swamp crayfish *Procambarus clarkii* (Girard, 1852). *Journal of Crustacean Biology* 35: 682–685, https://doi.org/10.1163/1937240X-00002366

Brannelly LA, McMahon TA, Hinton M, Lenger D, Richards-Zawacki CL (2015) *Batrachochytrium dendrobatidis* in natural and farmed Louisiana crayfish populations: prevalence and implications. *Diseases of Aquatic Organisms* 112: 229–235, https://doi.org/10.3354/dao02817

Cecchinelli E, Aquiloni L, Maltagliati G, Orioli G, Tricarico E, Gherardi F (2012) Use of natural pyrethrum to control the red swamp crayfish *Procambarus clarkii* in a rural district of Italy. *Pest Management Science* 68: 839–844, https://doi.org/10.1002/ps.2335

Deidun A, Sciberras A, Formosa J, Zava B, Insacco G, Corsini-Foka M, Crandall KA (2018) Invasion by non-indigenous freshwater decapods of Malta and Sicily, central Mediterranean Sea. *Journal of Crustacean Biology* 38: 1–6, https://doi.org/10.1093/jcbiol/ruy076

Delmastro GB (1992) Sull'acclimatazione del gambero della Louisiana *Procambarus clarkii* (Girard, 1852) nelle acque dolci italiane. *Pianura* 4: 5–10

Dörr AJM, Scalici M (2013) Revisiting reproduction and population structure and dynamics of *Procambarus clarkii* eight years after its introduction into Lake Trasimeno (Central Italy). *Knowledge and Management of Aquatic Ecosystems* 408: 10, https://doi.org/10.1051/kmae/2013045

Dörr AJM, Rodolfi M, Scalici M, Elia AC, Garzoli L, Picco AM (2011) *Phoma glomerata*, a potential new threat to Italian inland waters. *Journal for Nature Conservation* 19: 370–373, https://doi.org/10.1016/j.jnc.2011.06.006

Dörr AJM, Elia AC, Rodolfi M, Garzoli L, Picco AM, D'Amen M, Scalici M (2012a) A model of co-occurrence: segregation and aggregation patterns in the mycoflora of the crayfish *Procambarus clarkii* in Lake Trasimeno (central Italy). *Journal of Limnology* 71: 135–143, https://doi.org/10.4081/jlimnol.2012.e14

Dörr AJM, Rodolfi M, Elia AC, Scalici M, Garzoli L, Picco AM (2012b) Mycoflora on the cuticle of the invasive species of the crayfish *Procambarus clarkii*. *Fundamental of Applied Limnology* 180: 77–84, https://doi.org/10.1127/1863-9135/2012/0175

Geiger W, Alcorlo P, Baltanas A, Montes C (2005) Impact of an introduced Crustacean on the trophic webs of Mediterranean wetlands. *Biological Invasions* 7: 49–73, https://doi.org/10.1007/s10530-004-9635-8

Gherardi F (2006) Crayfish invading Europe: the case study of *Procambarus clarkii*. *Marine and Freshwater Behaviour and Physiology* 39: 175–191, https://doi.org/10.1080/10236240600869702

Gherardi F, Bertolino S, Bodon M, Casellato S, Cianfanelli S, Ferraguti M, Lori E, Mura G, Nocita A, Riccardi N, Rossetti G, Rota E, Scalera R, Zerunian S, Tricarico E (2008) Animal xenodiversity in Italian inland waters: distribution, modes of arrival, and pathways. *Biological Invasions* 10: 435–454, https://doi.org/10.1007/s10530-007-9142-9

Holdich D, Reynolds J, Souty-Grosset C, Sibley P (2009) A review of the ever increasing threat to European crayfish from non-indigenous crayfish species. *Knowledge and Management of Aquatic Ecosystems* 11: 1–46, https://doi.org/10.1051/kmae/2009025

Huner JV (2002) *Procambarus*. In: Holdich DM (ed), Biology of freshwater crayfish. Blackwell, Oxford, pp 541–584

Klose K, Cooper SD (2012) Contrasting effects of an invasive crayfish (*Procambarus clarkii*) on two temperate stream communities. *Freshwater Biology* 57: 526–540, https://doi.org/10.1111/j.1365-2427.2011.02721.x

Kolar CS, Lodge DM (2001) Progress in invasion biology: predicting invaders. *Trends in Ecology and Evolution* 16: 199–204, https://doi.org/10.1016/S0169-5347(01)02101-2

Kouba A, Petrusek A, Kozák P (2014) Continental-wide distribution of crayfish species in Europe: update and maps. *Knowledge and Management of Aquatic Ecosystems* 413: 05, https://doi.org/10.1051/kmae/2014007

Lodge DM, Taylor CA, Holdich DM, Skurdal J (2000) Nonindigenous crayfishes threaten North American freshwater biodiversity: lessons from Europe. *Fisheries* 25: 7–20, https://doi.org/10.1577/1548-8446(2000)025<0007:NCTNAF>2.0.CO;2

Morpurgo M, Aquiloni L, Bertocchi S, Brusconi S, Tricarico E, Gherardi F (2010) Distribuzione dei gamberi d'acqua dolce in Italia. *Studi Trentini di Scienze Naturali* 87: 125–132

Nyström P (2002) Ecology. In: Holdich DM (ed), Biology of freshwater crayfish, Blackwell, Oxford, pp 192–235

Orrù F, Deiana AM, Cau A (2009) Conservazione della biodiversità e specie alloctone invasive: il gambero *Procambarus clarkii* nelle acque interne della Sardegna. *Studi Trentini di Scienze Naturali* 86: 162

Oficialdegui FJ, Sánchez MI, Monsalve-Carcaño C, Boyero L, Bosch J (2019) The invasive red swamp crayfish (*Procambarus clarkii*) increases infection of the amphibian chytrid fungus (*Batrachochytrium dendrobatidis*). *Biological Invasions* 21: 3221–3231, https://doi.org/10.1007/s10530-019-02041-6

Palmas F, Frau G, Serra M, Cani MV, Peddio S, Solari P, Sabatini A (2018) Small-scale crayfish distribution modelling of the invasive crayfish *Procambarus clarkii* in the Molentargius-Saline Regional Natural Park (Sardinia, Italy) in response to environmental variables. Conference proceedings of XXVIII Congresso della Società Italiana di Ecologia. Società Italiana di Ecologia, 108 pp

Puzzi CM (2010) Carta Ittica della Provincia di Olbia-Tempio. Provincia di Olbia Tempio - Settore Tutela Ambiente, 190 pp, http://www.infeagallura.it/Progetto/Pubblicazioni/cartaittica/libro_carta_ittica.pdf

Puzzi C, Ippoliti A, Columbano A, Gentili G, Bardazzi MA (2010) Prima caratterizzazione della fauna ittica d'acqua dolce della Provincia di Olbia Tempio. *Studi Trentini di Scienze Naturali* 87: 249–252

Rodríguez CF, Bécares E, Fernández-Aláez M, Fernández-Aláez C (2005) Loss of diversity and degradation of wetlands as a result of introducing exotic crayfish. *Biological Invasions* 7: 75–85, https://doi.org/10.1007/s10530-004-9636-7

Sala OE, Chapin FS III, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sannwald E, Huenneke L, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH (2000) Biodiversity scenarios for the year 2100. *Science* 287: 1770–1774, https://doi.org/10.1126/science.287.5459.1770

Scalici M, Gherardi F (2007) Structure and dynamics of an invasive population of the red swamp crayfish (*Procambarus clarkii*) in a Mediterranean wetland. *Hydrobiologia* 583: 309–319, https://doi.org/10.1007/s10750-007-0615-8

Scalici M, Pitzalis M, Gibertini G (2009) Crayfish distribution updating in central Italy. *Knowledge and Management of Aquatic Ecosystems* 394–395: 1–8, https://doi.org/10.1051/kmae/2009017

Scalici M, Chiesa S, Scuderi S, Celauro D, Gibertini G (2010) Population structure and dynamics of *Procambarus clarkii* (Girard, 1852) in a Mediterranean brackish wetland (Central Italy). *Biological Invasions* 12: 1415–1425, https://doi.org/10.1007/s10530-009-9557-6

Sindaco R, Doria G, Razzetti E, Bernini F (2006) Atlante degli Anfibi e Rettili d'Italia. Societas Herpetologica Italica, Edizioni Polistampa, Firenze, 789 pp

Souty-Grosset C, Holdich DM, Noël PY, Reynolds JD, Haffner P (2006) Atlas of Crayfish in Europe, Muséum national d'Histoire naturelle, Paris, 87 pp

Souty-Grosset C, Anastàcio PM, Aquiloni L, Banhab F, Choquer J, Chucholl C, Tricarico E (2016) The red swamp crayfish *Procambarus clarkii* in Europe: Impacts on aquatic ecosystems and human well-being. *Limnologica* 58: 78–93, https://doi.org/10.1016/j.limno.2016.03.003

Taketomi Y, Murata M, Miyawaki M (1990) Androgenic gland and secondary sexual characters in the crayfish *Procambarus clarkii*. *Journal of Crustacean Biology* 10: 492–497, https://doi.org/10.2307/1548339