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Biometry and demography of *Procambarus clarkii* in Rharb Region, Morocco

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Abstract. This study was carried out to determine some morphological characteristics and the length-length and length-weight relationships of freshwater crayfish *Procambarus clarkii* (Girard, 1852). We selected two types of localities: 1. Nador canal and 2. Merja Zerga in Rharb region in Morocco. Specimens of both sexes (541 males and 407 females) were collected from March 2013 to April 2014. The study was conducted monthly. 948 specimens were analyzed for sex, weight, and length. The sex ratio (males:females) in whole material available was (1.29:1). No significant differences in the total body length of crayfish were found between the two sites (Merja Zerga and Nador canal). The results of this study evidenced that the population is in expansion, showing that Nador Canal and Merja Zerga in Rharb region in Morocco is an optimal habitat for this species. There was a significant difference between male and female body weight-length relations. Males were found to be more numerous than females.
Key Words: red swamp crawfish, mudbug, Louisiana crayfish, Nador Canal, Merja Zerga.

Introduction. *Procambarus clarkii* is widely regarded to be the most invasive of all crayfish species (Capinha et al 2011), but its life history at higher latitudes is poorly understood (Chucholl 2011) although a series of studies on population structure and dynamics have just been performed on crayfish. *P. clarkii* causes several types of damages to the natural ecosystem and agriculture. *P. clarkii* causes serious damage in agricultural areas (*e.g.* rice fields), rivers and lakes, where destabilize the banks (Fonseca et al 1997). The burrowing behavior of *P. clarkii* is often problematic to levees, dykes, and irrigation systems which can result in water loss and damage of the fields (Holdrich 1999). If *P. clarkii* is present in irrigation structures including reservoirs, channels of rice fields, may cause significant economic loss due to its burrowing activity, which alters soil hydrology and causes water leakage, beside its feeding behavior, which cause damages in rice plantations (Correia 1993). Nowadays, *P. clarkii* is widespread in Western Europe, Africa, Asia and North America; the only continents where the crayfish has never been recorded are Australia and Antarctica (Gherardi 2006). In Italy, *P. clarkii* was documented in the wild for the first time in 1989 in Banna River, in Spain it was imported in 1973 for human consumption (Hobbs 1989; Geiger et al 2005). It has become the dominant freshwater crayfish species in almost all areas it occupies (Henttonen & Huner 1999).

P. clarkii is a polytrophic omnivore, and its ecological impact on native ecosystems can be devastating (Rodríguez et al 2005; Gherardi 2006; Souty-Grosset et al 2006). It is highly tolerant to unfavorable conditions (*e.g.* poor water quality, temperature fluctuations, low oxygen concentrations and drying) and as a consequence has an extraordinary frequency rate. It is a migratory crustacean and dominant with other crayfishes (Laurent 1997). *P. clarkii* is considered to be a generalist, being a keystone species in aquatic ecosystems (Huner & Barr 1991; Ilhéu & Bernardo 1993, 1995; Gutiérrez-Yurrita et al 1998, 1999). The introduction of *P. clarkii* generally has a negative impact on the invaded areas (Hobbs 1989) due to the physical damage to natural and semi-natural ecosystems caused by the burrowing activity (Correia 1993; Anastácio & Marques 1996; Gutiérrez-Yurrita et al 1999).

The crayfish (Decapoda) has many biological traits, such as the ability to live out of water for long periods (Gherardi & Barbaresi 2007). Studies showed that both species (red swamp crayfish and signal crayfish) are capable of surviving exposure to air for long periods of time, with an LT90 (namely the LT90 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) of 17.6 and 21.5 h, respectively, for red swamp crayfish and signal crayfish (Banha & Anastácio 2013).

P. clarkia has high reproductive potential (Aquiloni et al 2010; Barbaresi & Gherardi 2006; Savini 2007), and tolerance to environmental pollution (Aquiloni et al 2011). One of the key factors of the success of *P. clarkii* is its ability of the expansion. The aim of this study was to evaluate some aspects of the biology of *P. clarkii*, and to examine differences in the weight and length biometric parameters of the population. The first observation of the species is accidental in late 2008 early 2009 in Merja zerga coincides with the introduction in 2007 by the Spanish company ALFOCAN (large company of production and international marketing of crayfish from Louisiana).

Material and Method

Merja Zerga 34°86'N/06°28'W Biological Reserve, Ramsar site (1980) is a tidal lagoon located 70 km north of Kenitra on the Atlantic coast (Wariaghli et al 2013). The lagoon has a semi-diurnal tidal cycle (Benhoussa 2000). The hydrology of Merja Zerga is an exchange of water with the ocean through the ''gullet'' which is driven by the large Atlantic tides (Thompson et al 2009). Merja Zerga can be classified as a marine wetland since the basin is now permanently tidal (Morgan 1982; Green et al 2002). The lagoon system receives drainage mainly from the Drader River to the east and the Nador Canal to the south. The Drader River has a drainage area of 750 km^2 and an annual runoff volume of about 31 x 10^6 m^3 yr^{-1} or 85 x 10^3 m^3 d^{-1} (Beaubrun 1976) (Figure 1).

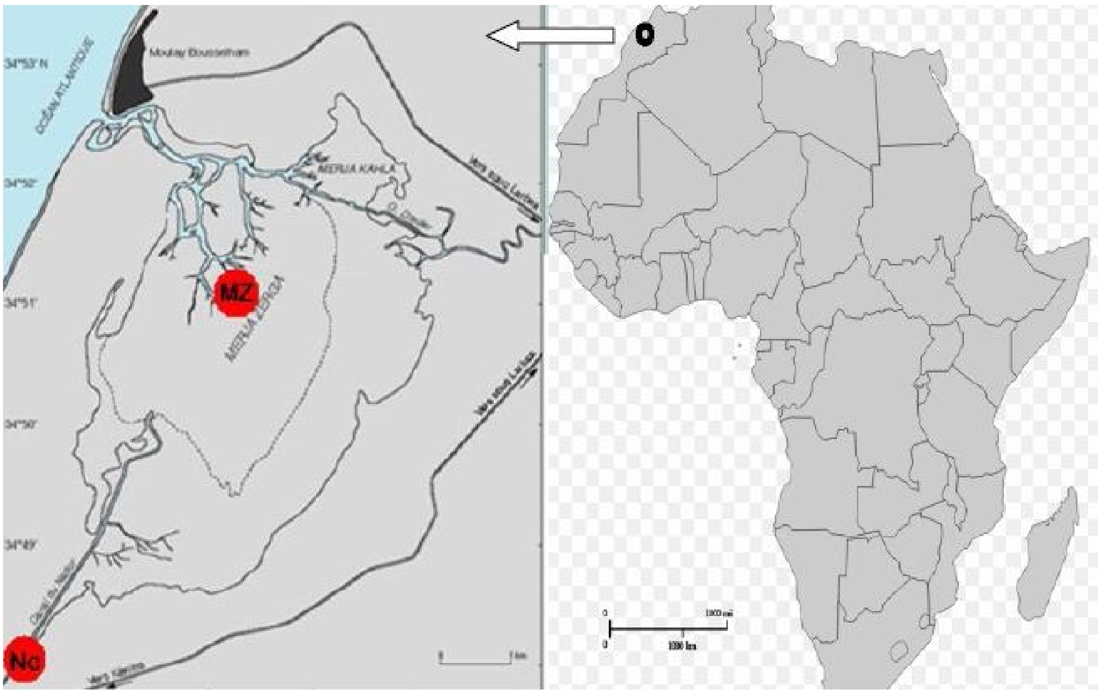

Figure 1. Map showing sampling locations of Merja Zerga (MZ) and Nador canal (NC).

Merja Zerga was the excavation of the Nador Canal in the 1950s which means that the Oueds Mda and Sebou and their tributaries now drain into the lagoon although the direct hydrological impacts of irrigation development upon Merja Zerga may be relatively small, construction of the Nador Canal has had a significant impact upon the geomorphological characteristics of the lagoon (Ayache et al 2009). The Nador Canal was built in 1953 to drain flooded depressions and cultivated areas of the Rharb coastal plain. Its mean annual discharge to the Moulay Bousselham lagoon has been estimated to be 150 x 10^6 m^3 $year^{-1}$ or 411 x 10^3 m^3 d-^{1} (Carruesco 1989).

The study sites were located in Rharb region in Morocco. We collected samples of *P. clarkii* at lagoon Merja Zerga and the Nador Canal. The mean annual salinity fluctuates between (8 and 36 psu), the annual average inputs of Nador channel are estimated at approximately 150,106 m^3/year (Carruesco 1989; Fekhaoui et al 2009). Temperature in the Merja Zerga shows (16-20.9°C) and in Nador Canal (20.5-25°C), pH (8.46-8.48), salinity at Merja Zerga (28-34.2 g/L) and 3 g/L, BOD5 Nador Channel: 73 mg/L, dissolved O_2: 7.6 to 9.2 mg/L (Fekhaoui et al 2009).

Catching and measuring crayfish. Individuals of *P. clarkii* were caught in Merja Zerga and Nador Canal in Rharb region in Morocco. The specimens were captured monthly from March 2013 to April 2014 by a professional fisherman using cylindrical traps with a side entrance (one or two entrances) at night for 48 h. For each captured specimen sex, weight (W) using an electronic balance within 0.1 g accuracy and total body length (TL) (from the tip of the rostrum to the tip of the telson) were recorded, as suggested by Scalici & Gherardi (2007), carapace length (CL) (from the tip of the rostrum to the cephalothorax), chelae length (ChL), measured with a digital calliper within 1 mm accuracy. Crayfish were sexed and their maturation stage determined. Form I males were identified by the hooks on the ischia of the third and fourth pereiopods (Suko 1953; Hobbs 1974, 1989). Sexually females were distinguished by the presence of tan, brown and black eggs in the ovary (Romaire & Lutz 1989) and the grooved annulus ventralis (Hunner & Barr 1991). Post-ovigerous females were also considered mature. The number of eggs was counted in ovigerous females, and cheliped loss or regeneration to 75% of the normal cheliped growth was noted.

Statistical analysis. Differences in total body length in the main types of localities: The two main selected types of localities and the sex were used as factors determined with SPSS. Growth classes of crayfish were analyzed for all crayfish collected in the selected water types, as well as separately for males and females in these waters.

Length-weight relationships for weight were calculated using the equation:

$$W = aL^b \text{ (Mousavi-Sabet et al 2013)}$$

Where: W is the weight; a and b are constants.

Results. The 948 crayfish were captured during the survey between 2013-2014, with a total of 407 specimens (42.93%) in Merja Zerga and 541 specimens (57.07%) in Nador canal. The sex ratio in both sets was evaluated and it was same in both sets. The material from 2013-2014 contained in total specimens 413 females (43.56%) and 535 males (56.44%). Same analyses were conducted on the material from Merja Zerga with a 159 females (39.07%), 248 males (60.93%) and from Nador Canal 254 females (46.95%), 287 males (53.05%), including 3 ovigenous individuals.

The total length (TL) of the largest males in both datasets Merja Zerga and Nador Canal were 116 and 121 mm, and the largest females 117 and 120 mm, respectively. The heaviest male weighted 50 g (TL 100 mm) and 62.74 g (TL 121 mm), the heaviest female 37.8 g (TL 110 mm) and 46.29 g (TL 113 mm). The proportion of males in the material was significantly higher than the proportion of females. The sex ratio (males: females) in whole material available was (1.29:1) (535 males and 413 female individuals). The sex ratio for specimens from Merja Zerga was (1.35:1) (248 males and 159 female individuals) and from Nador Canal was (1.13:1) (287 male and 254 female individuals).

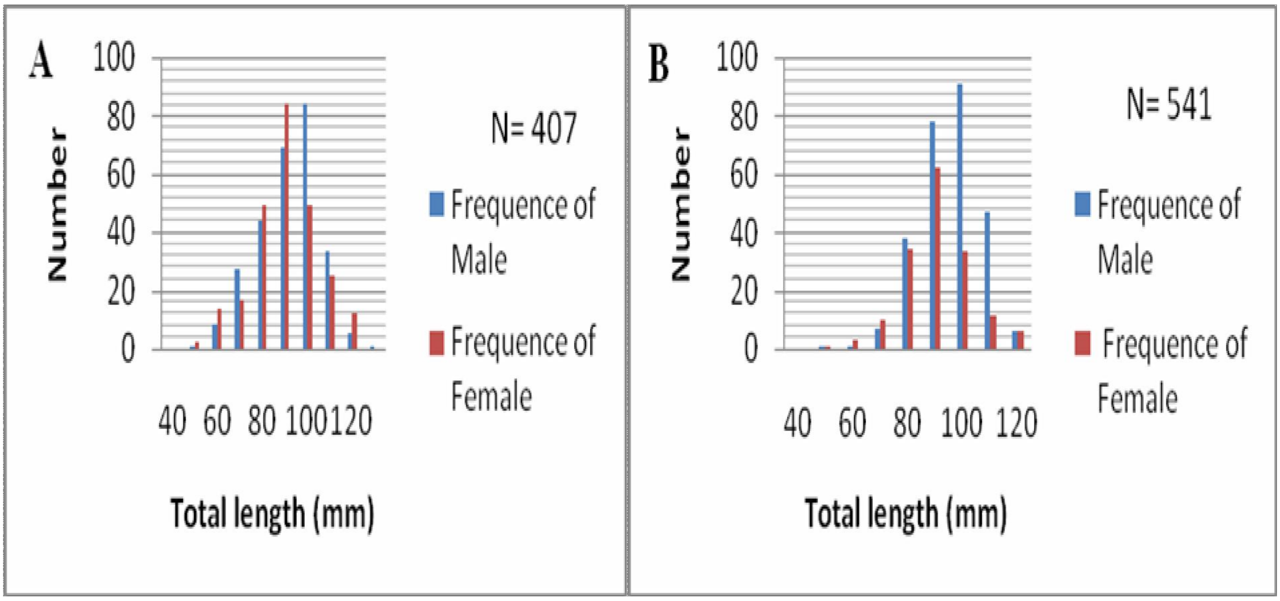

Figure 2. Growth classes of *Procambarus clarkii* caught in MZ (A) and NC (B).

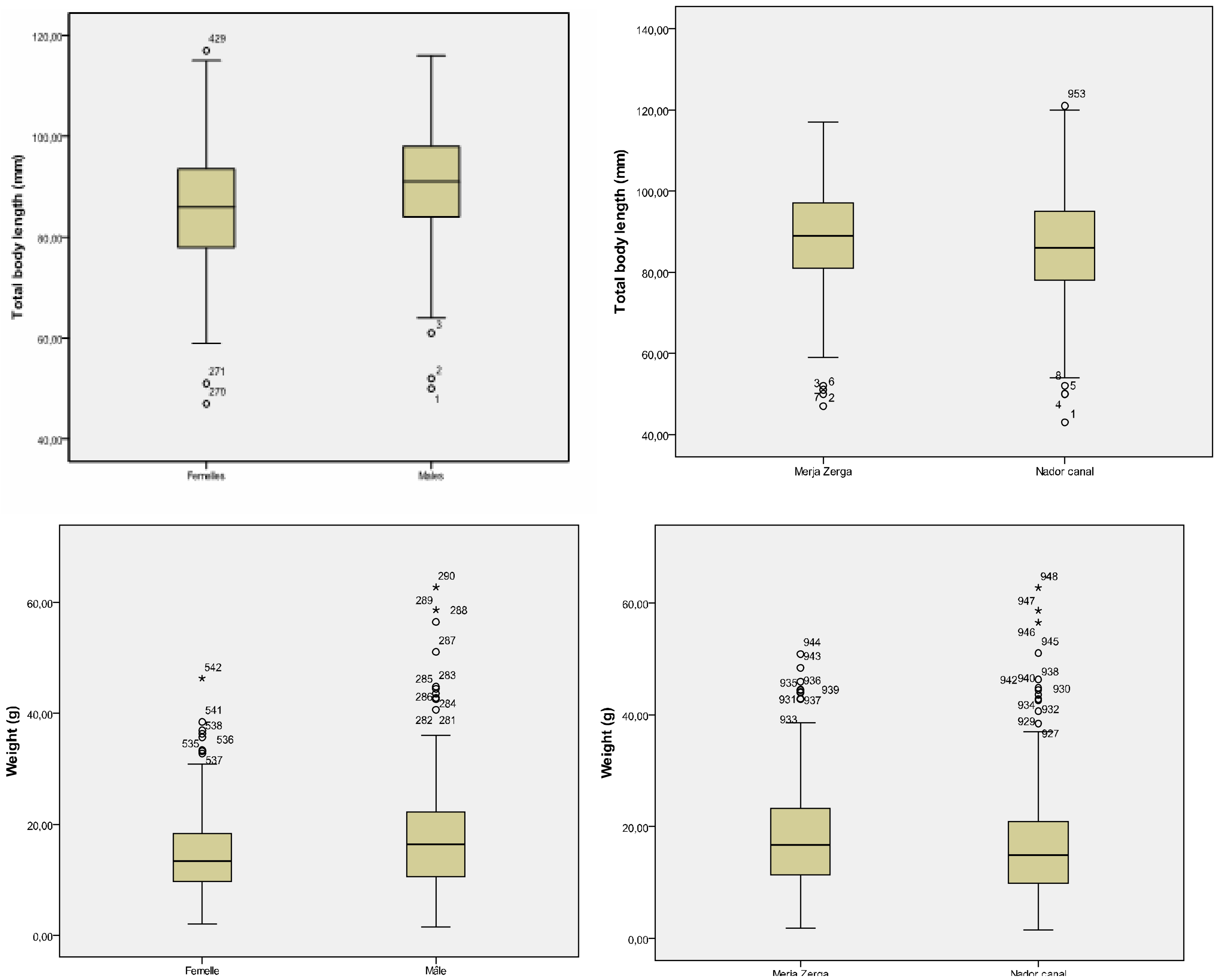

Figure 3. Box plots of weights and total body lengths of *Procambarus clarkii* caught in main water types, and in males and females from the whole material.

Ovigerous females were caught on May 15 2013 (Merja Zerga, 2 females) and on June 12 2013 (Nador Canal, 1 female). The smallest ovigerous had a total length of 45.9 mm, and the largest 98.1mm. The highest fecundity (544 pleopodal eggs) was recorded for a female with TL 101 mm in Merja Zerga.

The rate of cheliped loss collected from Merja Zerga (12.13%) and in Nador Canal (10. 01%).

The analyses of the size classes based on the total body length (Figure 2) show a peak of unimodal distribution of body length, with the modes of specimens 40-70 and 80-130 mm long from Merja Zerga, and 40-80 and 90-120 mm from Nador canal.

Differences in the mean total body length of males and females crayfish in main water types is showed in the boxplots of Figure 3. Merja Zerga containing the largest crayfish showed the highest difference in body length in comparison with population from Nador Canal. They are quiet similar by means but are different in size distributions.

The relation of wet weight of males and females to TL was not different in various types of water (t-test student <0.0001). Among factors influencing the weight of the crayfish, after body length, the type of water was more important than the sex of the individual. There is no significant difference between both sites.

Analyses of interactions between weight and either total body length (TL) or carapace length (CL) for males and females (Table 1) show significant differences between parameters for both sexes in the case of TL (t test =-3.686; P value <0.05). It is likely that CL is less variable for both sexes and better correlated with their weights than TL.

Table 1

Interaction between weight and either total body length (A) or carapace length (B) in males and females of *Procambarus clarkii*

Specification	*Males*	*Females*
	A	
Equation	Y=3.929x-14.78	Y=3.473x-12.86
R^2	0.990	0.993
t-test student	>0.05	<0.0001
	B	
Equation	Y=3.034x-8.459	Y=2.784x-7.603
R^2	0.993	0.994
t-test student	<0.0001	<0.0001

Discussion. The population structure and dynamics can become an essential instrument in the management of aquatic living resources, since they can be used in the evaluation of population status (Dörr & Scalici 2013). The size structure of a population is useful in predicting its stunting and harvestable potential (Momot & Romaire 1981). Specimens collected in Lake Trasimeno had a TL equal to 140 mm with a weight over 76 g. The crayfish population was characterized by a maximum length greater than 15 cm. The three main size classes we recorded suggest that most animals reach the age of three years, and that the largest specimens may be up to four years old (Dörr et al 2006). In Louisiana no individuals of wild populations exceeded 116 mm TL and 47 g body weight (Peen 1943). In Italy size class distribution analysis over the whole year showed that the most frequently captured specimens measured between 90-99 mm and 100-109 mm. Smaller specimens (size class between 40 and 49 mm) were captured during late winter-early spring (February-March 2010) (Garzoli et al 2014). In Doňana National Park (SW Spain) and in Săo Miguel (Azores, Portugal), *P. clarkii* did not exceed 105 mm and 98.6 mm in total body length, respectively (Bravo et al 1994; Costa et al 1996). The mean body length was 93.2 mm and the mean individual weight was 22.2 g (Dörr et al 2006). The population is divided into seven age groups; the first is called Newborn, the next three Yearlings and the last three Adults. This choice is suggested by literature in which *P. clarkii* is always divided into various classes of size or age. Each age group has an average duration of 80 days, as suggested by Anastácio et al (1999), Huner (2002) and

Scalici & Gherardi (2007) maintains or conserve that the lifespan of *P. clarkii* has a maximum duration of 4 years. In literature it is reported that in laboratory animals live more than 4 years, while in the wild life expectancy rarely exceeds 12-18 months (Martelloni et al 2012). *P. clarkii* individuals have two mating periods, one in spring and one in summer (Martelloni et al 2012). In Germany, where is found the most north-eastern range of *P. clarkii* in Europe, the mean life span is 3.5 to 4 years (Chucholl 2011; Chiesa et al 2006). Ligas (2008) described that the number of age classes can vary in number across *P. clarkii* populations. Frutiger et al (1999) found, that in a eutrophic pond in Switzerland (with stable habitat conditions) *P. clarkii* could even grow up to five years (Dörr et al 2006). In general, length-frequency analysis confirmed the stable structure of our crayfish population with a clearly defined age-class composition of slightly more than five age classes for both females and males (Dörr & Scalici 2013). Length-frequency histograms showed that 55.8 % of the total populations (54.0 % of males and 57.9 % of females) were smaller than the minimal acceptable harvestable size of 35 mm CL (Romaire & Lutz 1989). The bigger specimens could live for around 5 and more than 6 years, respectively (Frutiger et al 1999; Chucholl 2011).

P. clarkii is able to produce at least two generations a year in its native range (Huner 2002) and in parts of its invasive range in southern Europe (Gherardi et al 1999; Gherardi 2006; Scalici & Gheradi 2007). Females were less abundant in the months with maximum ovarian egg maturation. In October and November 2000, females accounted for 39.33% and 42.68% of the samples, respectively. In December 2000, however, their portion raised to 77.77% before decreasing again from January to April 2001, from 61.36% to 56.57%, respectively (Dörr et al 2006). In optimal conditions, over 600 pleopodal eggs per berried female have been observed (Huner 2002).

The sex ratio is similar in crayfish from waters occupied by the populations of *P. clarkii* in the Gharb region. Ligas (2008) observed that in southern Tuscany the sex ratio of a *P. clarkii* population was extremely variable both geographically and seasonally (Dörr et al 2006). Sex ratio for the whole population was 1.15:1 in favor of the females. The latter were more abundant in December 2000 and January 2001, which is the period following the hatching of the juveniles (Dörr et al 2006). As regards the population structure; we found a sex ratio of 2.42 males to 1 female. According to previous studies conducted in central Italy, a stable population of *P. clarkii* has a sex ratio of 1:1 (Gherardi et al 1999; Scalici & Gherardi 2007). The sex ratio of the analyzed population varied markedly during the study period. When it differed from 1:1, the sex ratio was always in favor of males, in particular in October and November 2007, February, May, August and November 2008, and June 2009. Females never significantly prevailed over males, the opposite of what (Dörr et al 2006) reported (Dörr & Scalici 2013). The sex ratio near 1:1 is in accordance with other reports (Penn 1943; Huner & Romaire 1978), but varied throughout the seasons (Dörr et al 2006). This is likely explained by the reproductive behavior of *P. clarkii*; low numbers of females in samples correspond with high carrying juveniles were found in November and December 2000 and in November 2001. This also suggests that spawning and reproduction takes place mainly in autumn (Dörr et al 2006).

Analyses of the length-weight relationship of *P. clarkii* revealed that males gained weight with increasing length faster than females. Similar relations were found for *Austropotamobius torrentium* (Streissl & Hödl 2002) and for *Orconectes limosus* (Ďuriš et al 2006) and *Pasifastacus leniusculus* (Mason 1979). Length-weight relationships showed a non-isometric growth for males plus mature and immature females (Correia 1994). Romaire et al (1977) and Correia (1993) reported that the length-weight relationships analysis showed non-isometric growth for FI, FII males, mature and immature females.

Conclusions. The relation of wet weight of males and females to TL was not different in various types of water. These results suggesting that *P. clarkii* is well acclimated because the topography of the region and its hydrographical characteristics, that's why seem propitious for the natural spreading of the species. The spatial distribution of *P. clarkii* in Merja Zerga and Nador Canal suggests that the ability of this crayfish species to disperse is not limited this hindrance to a possible colonization of a large number of sites may permit to develop strategies to limit the expansion of *P. clarkii* in all freshwater ecosystems of the Gharb Region and to protect local aquatic biodiversity. We now have to follow the evolution of *P. clarkii* spatial distribution in all ponds and streams within a sampling strategy to detect potential sources of dispersal and to better understand its dispersal processes between water bodies. The introduction of this species in plantations should be avoided since the red swamp crayfish is known as pest in those ecosystems.

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