
SPATIAL DISTRIBUTION OF RED-SWAMP CRAYFISH *PROCAMBARUS CLARKII* (GIRARD, 1852) IN WETLAND RAMSAR SITES IN MOROCCO

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ABSTRACT

RAMSAR sites are a wetlands that have specific criteria, internationally recognized, and very important not only in the countries where they are located but for all humanity.

Recently, the introduction of a species of crayfish classified as invasive in Morocco: *Procambarus clarkii* has created a debate among the local population, wetland conservators, wetland conservation NGOs, farmers and fishermen at regional and even national level, this study was essential to answer some questions and to enrich scientifically this discussion.

The notion of presence/absence of *Procambarus clarkii* and its dispersal has been monitored in Ramsar wetland sites in Morocco for 4 years.

The main objectives of this present study are to understand how this species was introduced in the wetlands Ramsar site of Morocco, identify the points of presence and absence of this species, and establish a presence map.

The study showed that everywhere it appear *Procambarus clarkii* in Morocco is resistant to different living conditions, and easily colonizes various habitats. The results support the hypothesis of illegal intentional introduction, and a rapid colonization upstream and downstream with high speed.

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KEYWORDS:

Procambarus clarkii;

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1. INTRODUCTION

Wetlands are considered to be the most biodiverse and fragile ecosystems as well [1]. They face many threats whose invasive species exist in the first degree.

Anthropogenic activities facilitate the transport of non-native species [2], [3], such as the red swamp crayfish (*Procambarus clarkii* (Girard, 1852)), which has been introduced in several countries, usually for gastronomic or commercial reasons [4], [5], [6], [7].

As a result, this species, which is native to north-eastern Mexico and south-central USA, is nowadays the most cosmopolitan freshwater crayfish species in the world [8], [9], [10].

The red swamp crayfish (*Procambarus clarkii* (Girard, 1852)), was first introduced in Africa, Kenya around 1960, and then into Portugal in the late 1970's [11], [12] and their numbers increased without control, invading most of the rice fields and wetland areas [13]. Then, a few years later the species was observed in Spain [14]. Thanks to massive imports of live crayfish from these countries [15], the species was introduced into France in 1976 [16] where it is freely sold to consumers.

In Morocco, *Procambarus clarkii* it occurs on the Atlantic border of the northwestern part of the country, and was first detected in the Sebou River [17].

The success of *Procambarus clarkii* invasion may be the result of its r-selected strategy, its ecological plasticity as well as its high dispersal ability [6], [8], [18], [19]. Indeed, movements of this species can exceed several kilometers per day in rice fields during wandering periods [20].

This article presents the results of the surveys and summarizes in the form of a distribution map all the data collected on the different areas of the national territory.

The main objectives of this study were to confirm the presence of this invasive species in the wetland Ramsar sites in Morocco, investigate the origin of its introduction, and establish a coherent mapping of the spread of the species in these sites.

The natural importance of Ramsar wetlands in Morocco and their need for protection make this study very important.

It is therefore important to understand how *Procambarus clarkii* uses the artificial and natural water bodies to spread. Such knowledge will provide a better understanding of the ecology of the species and important information on how nature of the biotope may be linked to the spread of *Procambarus clarkii*.

2. MATERIALS AND RESEARCH METHOD

2.1. Study area

The Kingdom of Morocco, located in the extreme northwest of Africa, is bordered to the north by the Mediterranean, to the west by the Atlantic, and to the south and east by the Sahara. Morocco includes twelve regions; it supports habitats ranging from high-altitude moorland through cork-oak forests to wetlands, deltas, arid steppes and deserts [21].

The present study was conducted in 38 wetlands of international conservation importance, with a total area of 316'086 hectares (Figure 1).

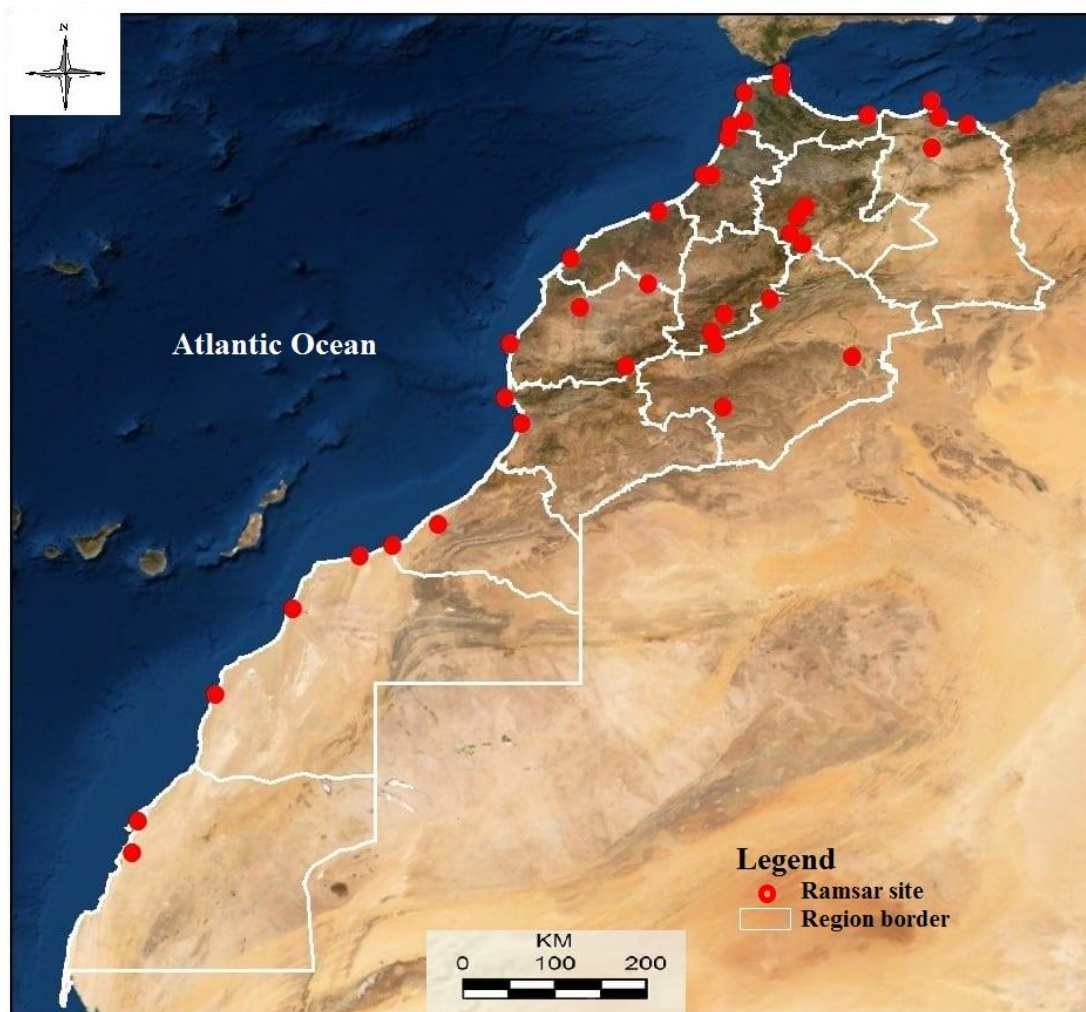


Figure 1. Location of the 38 Ramsar site wetlands in Morocco, 2019

2.2. Sampling methods

To collect the first information on the presence of the species, and the date of first observation an anonymous survey approved by the Regional Department of Water and Forests and the Fight against Desertification North West Kenitra Moroccan collaboration with the University Abdelmaled Essaadi Faculty of Science Tetouan Morocco was used.

A survey was distributed to the local population, fishermen, farmers, NGOs, and the administrations concerned at a national level. Forty-three NGOs active at the national level in the field of environment, education and awareness replied to the survey. 1531 people were interviewed in Morocco, including 927 farmers, 386 local people and 218 fishermen between April 2015 and December 2018 (one field trip per month).

To verify the responses of survey respondents who confirmed the presence of *Procambarus clarkii* in their areas, it was necessary to take samples of the crayfish and then confirm it in the laboratory using the freshwater invertebrates determination key [22].

The red swamp crayfish populations were caught per unit of effort (p.u.e.), we used the manual fishing technique to catch crayfish. It was necessary to wait for crayfish to start moving on the surface of the land or water to catch it. In water, two methods were used depending on depth. For rivers, lakes, shallow streams (less than 0.30 m), it is possible to catch crayfish by hand. Conversely, in rivers, lakes, dams, water sources (more than 0.30

m deep), it is therefore necessary to use another fishing technique, using a landing net and a trap that remains submerged for 24 hours to catch crayfish.

An initial verification of the data collected was carried out at the level of each Directorate of Water and Forestry and the Fight against Desertification, and the Regional Offices for Agricultural Development, this stage gave rise to many exchanges between the Scientific Committee, NGOs and the administration.

The map presented in this article summarize information regarding the notion of presence/absence (Figure 2).

2.3. Statistical analysis :

The data collected by the questionnaire concerning the presence/absence of *Procambarus clarkii*, the date of first observation and the origin of its introduction in Morocco required a qualitative analysis using XLStat and Nvivo software.

2.4. Cartographic analysis :

The data collected on the concept of the Presence/absence of *Procambarus clarkii* in Ramsar sites in Morocco are analysed and organised in map form using the ArcGis software.

2.5. Difficulties encountered

Establishing a national distribution map of red swamp crayfish at Ramsar sites is an ambitious project that faces various challenges. The general level of knowledge of this species varies greatly from one region to another. Information on the location of the species is often scattered, no database currently exists at the national level.

3. RESULTS AND DISCUSSION

Surveys on the distribution of red swamp crayfish in Morocco conducted in 2015, 2016, 2017 and 2018 revealed that the spread of red swamp crayfish populations was rapid resulting by its natural characteristic and helped by two identified trends: displacement of the species by uninformed people and the presence of rivers.

The last survey conducted in 2018 therefore covers the period from 2008 to 2018. It should make it possible to verify these trends and acquire new knowledge about the geographical situation of the species.

In the twelve regions of Morocco, the crayfish is absent in ten regions and present in two regions depending on the people surveyed and the field work by our research team to confirm the absence or presence (Figure 2).

In the area where the red swamp crayfish is present, the question on the origin of its introduction has been crucial, a survey was conducted among the local population, farmers, fishermen, NGOs and the administration.

54% of the people surveyed answered that the introduction of this species was by people, 42% they do not know, and 3.3% think that the crayfish was introduced in other areas and it followed the watercourses to arrive in their areas.

Communicate the result of this question with Regional Directorate of Water and Forests and the Fight Against Desertification North West – Kenitra was important to test the credibility of the survey respondents' replies. So, Regional Directorate replied; that Between 2005 and 2010, it has received request for temporary occupation of a State land given to the Waters and Forests called Laachachba, which was under the jurisdiction of the

rural commune of Morgane province of Kenitra for the purpose of breeding Tilapia fish and red swamp crayfish. However, the administration refused this request.

The hypothesis put forward by the Provincial Directorate of Water and Forests and the Fight against Desertification of Kenitra, after these requests, is that the presence of the red swamp crayfish in the Sidi Allal Tazi area could only be a clandestine introduction made, in all probability, by one of the candidates. The administration's response confirms and explains the response of 54% of the people surveyed.

The presence of *Procambarus clarkii* in Morocco could be due to a clandestine introduction to test the degree of acclimatization. The area was chosen given its ecological conditions and, as expected, the acclimatization was very successful.

The species has rapidly spread into the tributaries of the Sebou River, the Gharb rice fields, and the wetlands that lie downstream. With the exception of isolated areas, particularly in the northern and central region, Currently, *Procambarus clarkii* is present in most river systems in northwestern Morocco and in the four wetlands Ramsar site considered in the study, confirming the high plasticity of the species[10] (Figure 2).

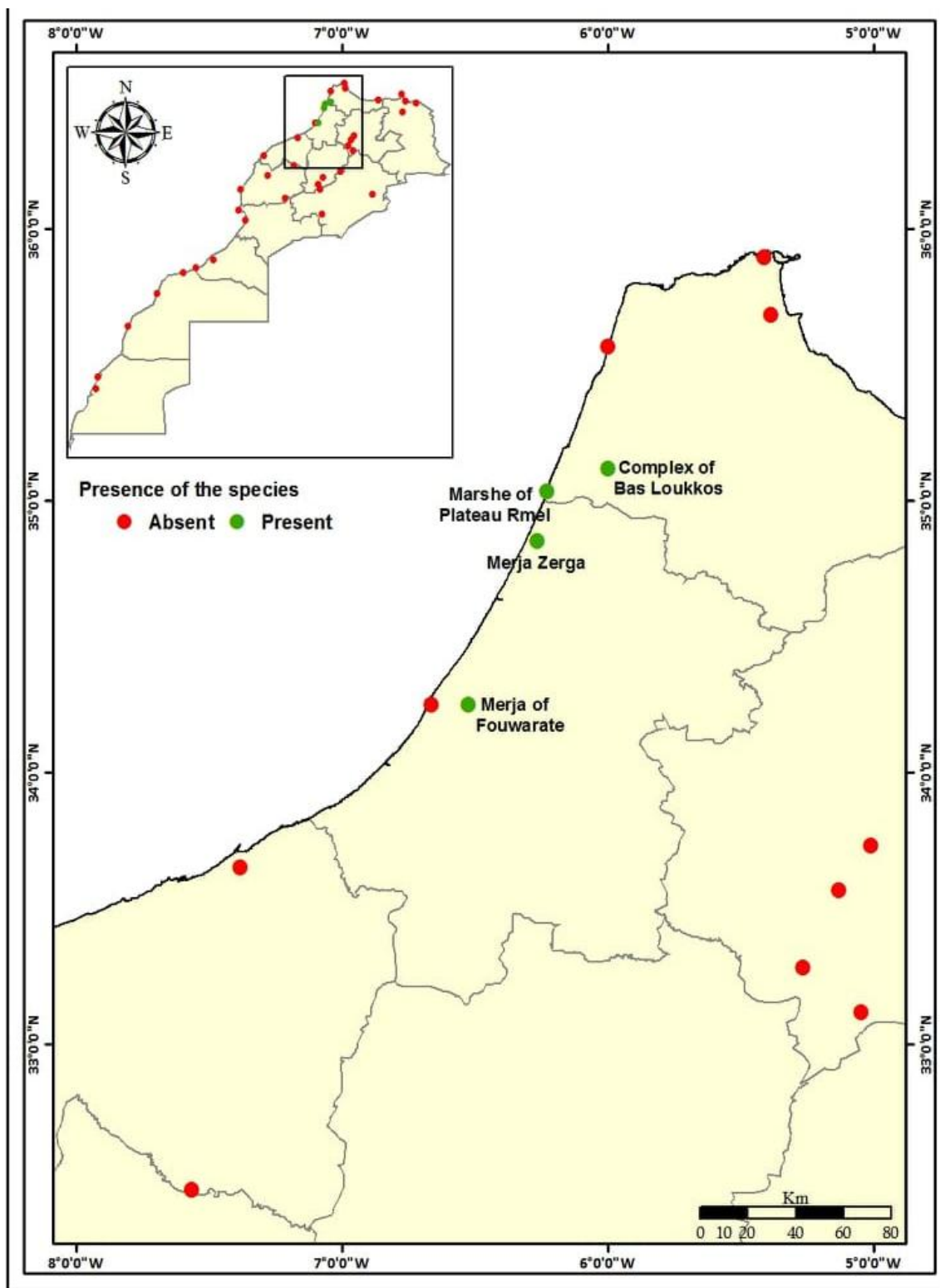


Figure 2. Presence map of the red swamp crayfish (*Procambarus clarkii*) in the Ramsar site, 2019, Morocco.

The question on the date of first appearance was essential to understand the rate of spread of red swamp crayfish in the study area. 91% of respondents in the regions where *Procambarus clarkii* is present replied to this question and only 8% of them replied that they don't know.

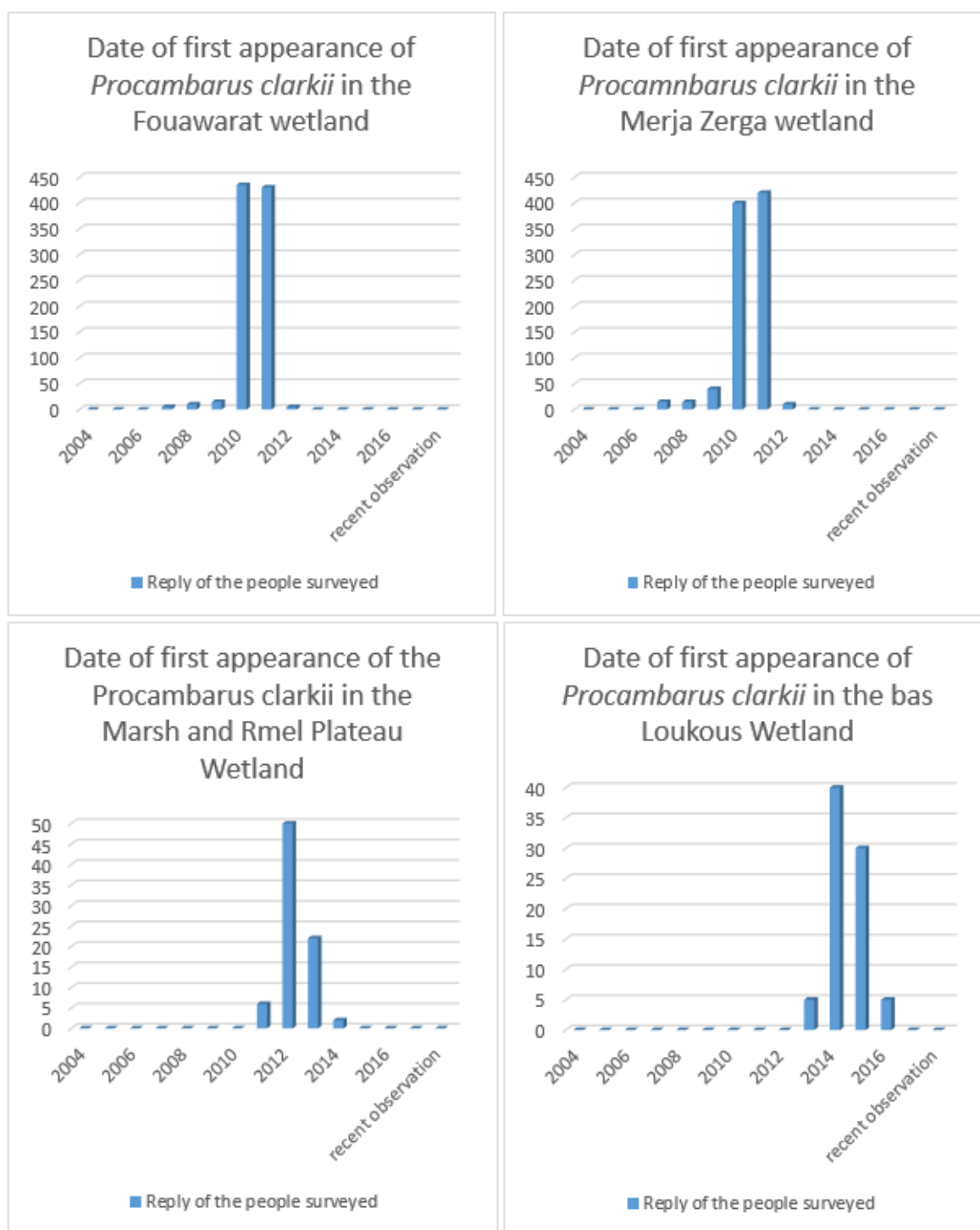


Figure 3. The distribution of responses from survey respondents on the date of first appearance of *Procambarus clarkii* in their wetlands, Survey 2015, 2016, 2017, 2018, Morocco.

The Red swamp crayfish was observed in the Merja Fouwarate site, a wetland area located at the southwestern end of the Gharb coastal plain. The population of Fouwarate and some researchers from Ibn Tofail University Faculty of Science Kenitra have confirmed that the presence of this species dates back to 2010/2011, it was during the flooding of Oued Sebou in 2010 that it was widespread (Figure 3).

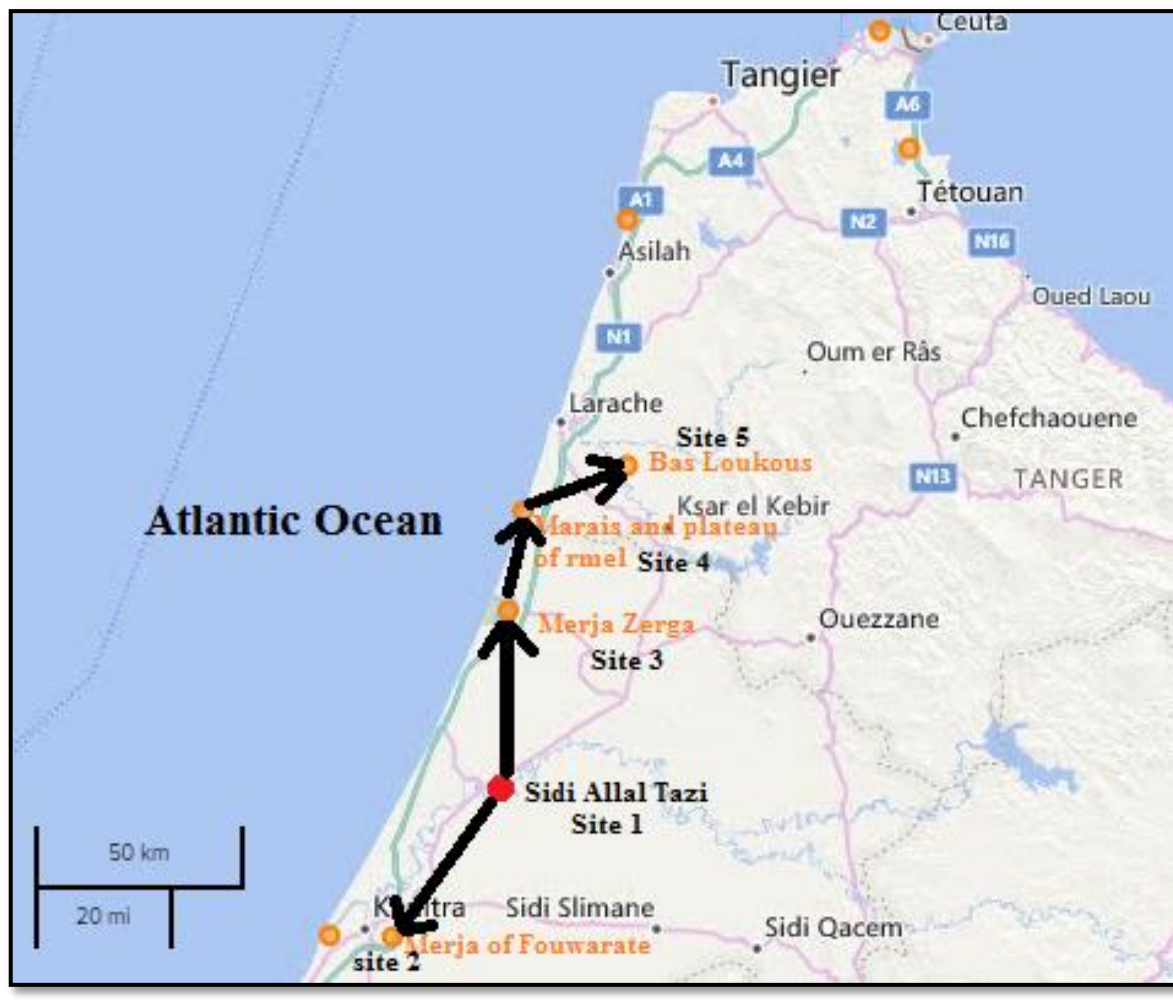


Figure 4. Location of Ramsar sites in northwestern of Morocco and distribution expansion of *Procambarus clarkii* (black lines). Red mark in the map is the point of the first introduction of *Procambarus Clarkii* in the area.

According to the local inhabitants, the first indicators of the presence of the species was detected in 2008/2009 in the Sidi Allal Tazi area [17]. This means the crayfish took two years to travel 43.8 km from the site of introduction to site 2 at a distance of 21.9 km per year (Figure 4).

Several studies reported crayfish were more likely to spread downstream at higher rates [23], [24], [25], [26], which is consistent with the results of this study.

The high speed of the crayfish downstream can be linked to the high flow of the Sebou river, which reaches an average flow rate of 137 m³/s. Nevertheless, an anterior study, high flows appear to have no effect on downstream displacement of adult crayfish [27]. The effect of high flows may depend on the current velocity and on the presence of larger substrate fractions which provide shelter for crayfish, decreasing the probability of being washed downstream. But small crayfish may be more easily transported downstream over long distances thus promoting downstream colonization [28].

From then on, the upstream expansion gradually progressed. In 2010/2011 and with a distance of 44.6 km between site 1 and site 3, the red crayfish arrived in the Merja Zerga wetland with an average rate of 22.3 km per year (Figure 4). The discovery of crayfish in wells and water sources between the commune of Sidi Allal Tazi and the commune of Moulay bousham, the local community and fishermen of the rural commune of Moulay

Bousselham, supports the idea that the presence of Louisiana crayfish in Merja Zarga and the Canal Nador is directly linked to its underground spread from Oued Sebou.

The high speed of crayfish from site 1 to site 3 is difficult to understand, but considering its high ecological plasticity, high resistance to extreme conditions of drought and oxygen, high speed outside water [29], this act seems compressible and acceptable. *Procambarus clarkii* is able to survive fluctuating hydroperiods, retreating into self-constructed burrows during the dry periods [8], [18]. Then it exits the water searching for new areas during the first rains [30].

The Ramsar Marais site and the Rmel plateau site 4 are a complex of three freshwater coastal lakes, the adjacent sandy beach and coastline, inter-dunal marshes, and irrigated areas. It colonized by the red swamp crayfish in 2012/2013 (Figure 3) which is far from site 3 by 35.5 km. So the average rate is 17.7 km per year (Figure 4).

In 2014/2015, the red swamp crayfish arrived at the Ramsar Bas Loukous site (site 5)(Figure 3), including estuarine waters, shallow marine waters, salt steppes, freshwater swamps and floodplains, in addition to rice paddies in drained areas and a number of abandoned salines. Which is far from site 4 by 40.3 km, this means that the crayfish has travelled at a rate of 21.9 km per year (Figure 4).

The presence of this crayfish in the merja zerga, Marais and the Rmel plateau, bas Loukous wetlands confirms its adaptation to estuarine ecosystems since the species is able to breed in brackish water [31], [32].

In Northeast Portugal, The mean spread rate of signal crayfish was faster for the downstream expansion, 2.8 km per year, while the upstream rate was 1.7 km per year. Exceptionally, in one period, the rate of spread reached 6.7 km per year [28].

Higher downstream expansion rates were reported for Austria, up to 7 km per year [33] and for Croatia, 18–24.4 km per year [34].

The mean spread of *Procambarus clarkii* is higher than the observed in other studies in other countries, which may also be related to linked to the richness of Morocco's northwestern region in groundwater and surface water, its temperate climate, high rainfall, abundant agricultural land, abundant dikes and irrigation channels. these factors provides favourable conditions for a fast upstream and downstream colonisation.

The survey conducted in 2018 confirms the continued spread of this species, which is now a topic of discussion in all regions of Morocco. In about ten years, the species has been able to colonize a large area in the Rabat-Salé-Kenitra region called Gharb, which is one of the largest regions in the country, confirming its extraordinary capacity for expansion. Between 2008 and 2018, the crayfish was able to colonize four wetlands designated as Ramsar sites in Morocco, in addition to other rivers, wells, and springs.

4. CONCLUSION

Overall, the 2016 survey shows two trends: An increase in the colonized area is reflected in a continuous progression of the species towards the north and center of the country and the high rate of dispersion.

The expansion of this recently introduced species in Morocco encourages specific ecological monitoring at the national level.

Looking for the origin and circumstances under which this species arrived in Morocco is no more important than the future status of our wetlands with the presence of this invasive species. For this reason an awareness and enforcement of the law prohibiting the import of this species in its living state is strongly recommended.

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