Aquatic Invasions (2010) Volume 5, Issue 3: 323-330
doi: 10.3391/ai.2010.5.3.11

Proceedings of the Symposium on non-native freshwater species introduction in the Iberian Peninsula
12-13 November 2009, Pamplona, Spain

Management in Practice

Management of the Chinese mitten crab, *Eriocheir sinensis* (H. Milne Edwards, 1853) in the Guadalquivir Estuary (Southern Spain)

Juan Garcia-de-Lomas[1*], Elías D. Dana[1], Javier López-Santiago[2], Rubén González[1], Guillermo Ceballos[3] and Fernando Ortega[3]

[1]*Programa Andaluz para el Control de las Especies Exóticas Invasoras. Egmasa. Consejería de Medio Ambiente, C/Américo Vespucio 5, Puerta 2, Bloque C, Local 5, 41092 Sevilla, Spain*

[2]*Propuesta de Actuaciones para la Conservación del Salinete en Andalucía. Egmasa. Consejería de Medio Ambiente, C/Américo Vespucio 5, Puerta 2, Bloque C, Local 5, 41092 Sevilla, Spain*

[3]*Dirección General de Gestión del Medio Natural. Consejería de Medio Ambiente. Avda. Manuel Siurot 50, 41927 Sevilla, Spain*

E-mail: jgarciadelomas@egmasa.es (JG-L), edana@egmasa.es (ED), jlopezsa@egmasa.es (JL-S), rgonzalezp@egmasa.es (RG), guillermo.ceballos.ext@juntadeandalucia.es (GC), fernando.ortega@juntadeandalucia.es (FO)

**Corresponding author*

Received: 3 December 2009 / Accepted: 24 June 2010 / Published online: 11 August 2010

Abstract

The Chinese mitten crab *Eriocheir sinensis* was first recorded in the Guadalquivir Estuary in 1987. Management actions by the Andalusian Regional Government were implemented in 2001 to contain and reduce the population of this invasive crab in the estuary and also to prevent its dispersal to neighbouring natural protected areas. Our results showed a heterogeneous distribution of the mitten crabs in the estuary, concentrated in the Sevilla port area. The catch-per-unit-effort (CPUE) in traps was significantly higher in October-April. Annual CPUE decreased from 0.04 crabs net^{-1}d^{-1} to minimum values of 0.006 crabs net^{-1}d^{-1} in 2008, thus reducing the dispersal potential to neighbouring areas. However, given that a number of stochastic factors may be involved in fluctuations in population size and that ships´ ballast water remains uncontrolled, the management of *E. sinensis* needs to be continued. Based on the results obtained and the expected sequence of the invasion process in the Guadalquivir Estuary, we propose further management improvements. These results may help to optimize the management of this invasive species both in the Guadalquivir estuary and in comparable scenarios in different parts of the world.

Key words: *Eriocheir sinensis*; management; containment; invasion; ballast water; Guadalquivir

Introduction

The Chinese mitten crab *Eriocheir sinensis* (H. Milne Edwards, 1853) (Crustacea, Brachyura, Varunidae) is a catadromous crab native to the East Coast of China, from Hong Kong to the border of North Korea (Hymanson et al. 1999). The crab, outside its native range, is rapidly colonizing worldwide, as a consequence of ships´ ballast water discharges and subsequent dispersal (Herborg et al. 2007). Mitten crabs were first introduced in Germany in 1912, and the species is now dispersed throughout Northern Europe. Current distribution includes the North Sea, Baltic Sea and North Atlantic coast (Gollasch 1999; Herborg et al. 2003, 2005; Ojaveer et al. 2007), the Seine Estuary in France (Vincent 1996), the Tagus river in Portugal (Cabral and Costa 1999) and the Mino (Ferdinand-Martinez and Carrera 2003) and the Guadalquivir rivers (Cuesta et al. 2006) in Spain, the Dalaeven river in Sweden (Peters 1938), Lake Ladoga in Russia (Panov 2006), and the Tyne river in the U.K. (Herborg et al. 2002) also Ireland (Minchin 2006). The crab has also been reported in North America, from San Francisco Bay (Rudnick et al. 2003, 2005), Chesapeake Bay (Ruiz et al. 2006), Lake Erie (Nepszy and Leach 1973), the Mississippi Delta (Horwath 1989) and the St. Lawrence River in Canada (de Lafontaine 2005), Delaware Bay, and the Hudson River (Schmidt et al. 2009). Other recent reports include two different areas in Western Asia, the Tazeh Bekandeh River in Northern Iran (Robbins et al. 2006) and the Shatt Al-Basrah Canal in Iraq (Clark et al. 2006).

Despite the increasing number of regions invaded and the subsequent adverse ecological and socio-economic impacts (e.g. Rudnick et al. 2005; Gollasch 2006; Gilbey et al. 2008; Dittel and Epifanio 2009), management or control actions have been scarce. In Germany in the 1930s, massive efforts to control mitten crabs stemmed from its interference with net and trap fisheries and the damage to riverbanks caused by its burrowing. The total catch of crabs in Germany was estimated at 262,600 kg in 1936 and 190,400 kg in 1937. In some locations, over 100,000 crabs were trapped per day (Panning 1939). Traps placed on the upstream side of dams captured juvenile crabs as they migrated upstream. More recently, a management plan for the *Eriocheir* genus was developed in California (Chinese mitten crab Control Committee 2002). Actions included early detection in the Columbia River by using baited crayfish traps and the production of outreach and educational materials (e.g., videos, pamphlets, a web site) designed as aids to identify and report sighting of mitten crabs. Among the control methods, physical barriers such as bars, K-rails and metal screens (1.2-1.8 m high with 2.5 cm openings) have been used to prevent impacts in fish salvage facilities (Chinese mitten crab Control Committee 2002). The present paper summarizes the first results on management and control of *E. sinensis* implemented by the Regional Andalusian Government (Consejeria de Medio Ambiente) from 2001 to 2008. Based on the results obtained, we propose management improvements to enhance efficiency of the catch and a better use of resources.

Materials and methods

The Guadalquivir Estuary is a temperate, non-stratified estuary with a gradual horizontal change in water salinity, located in the Southwest region of the Iberian Peninsula (Figure 1). The estuary is subjected to mixing-zone changes due to daily and seasonal tidal variations, with a mean sea water upstream incursion of ≈ 20 km (Drake et al. 1999). A dam located 108 km upstream regulates the fresh-water input to the estuary. The estuary bifurcates as it passes through the city of Seville, forming a channel 11.5 km long. This channel contains the port area and is connected to the open estuary through a sluice dock, which opens and closes with the arrival and departure of ships (on average, 7 times a day). The bottom composition is highly variable. Natural substrates (silts and clays) are dominant, but some rocks and submerged scrap is frequently found. The estuary banks alternate between marsh vegetation (*Phragmites australis*, *Typha* spp, *Eucalyptus camaldulensis*, *Arundo donax*, etc.) and artificial substrates such as concrete walls.

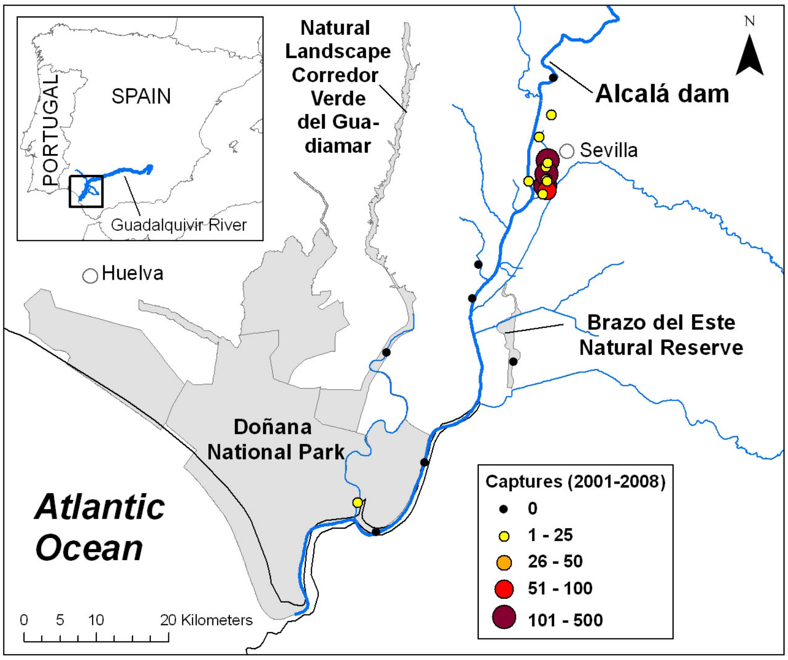
Nylon fyke nets arranged perpendicular to the shore, at the bottom of the channel, in water depths of 2–5 m, were used to capture the crab specimens (Figure 2). Fyke nets had 6 m leads, three rings per net (1, 0.95 and 0.85 m diameter), a throat diameter of 15, 10 and 8 cm, respectively, and 7 mm square mesh. Nets were left in the river and emptied every 48 h. This sampling frequency allowed the release of accidental captures of native species and prevented algae from clogging the nets. Moreover, if the nets were left for longer, Chinese mitten crabs were able to destroy the nets and escape.

Capture attempts were carried out during January and December in 2001; January to May in 2002; March to December in 2005; January to April and December in 2006; January to June in 2007, with additional samplings in October to December in 2007 and 2008. No fishing was done in 2003 and 2004. Sampling stations were initially (2001-2005) located throughout the Guadalquivir Estuary, but given the concentration of captures in the upper stretch of the estuary (Figure 1), nets were progressively placed within Seville harbour (N37º20´N; 06º01´W). In 2007 and 2008, 90% of the nets were set inside the port area, whereas the rest were placed near the river mouth.

Once collected, specimens of *E. sinensis* were weighed (to the nearest 1 g), measured (carapace width, CW, to the nearest mm) using callipers and sexed. The catch-per-unit-effort (CPUE) was the number of crabs caught, divided by the total number of nets, multiplied by the number of months of work and the number of times the nets were checked every month (crabs $net^{-1}d^{-1}$). Additionally, female gonads were extracted and examined under the dissecting microscope. Based on the gonadogenesis report for *Eriocheir japonicus* (de Haan, 1835) (Kalinina et al. 2008), five stages of gonad maturation were differentiated (Table 1).

Finally, considering the lack of knowledge about the invasion history and the most likely date of introduction, we interviewed the local elderly fishermen, who were shown some photos and/or specimens of the Chinese mitten crab.

Figure 1. Distribution of *Eriocheir sinensis* captures in the Guadalquivir Estuary. Data obtained from 2001-2008.



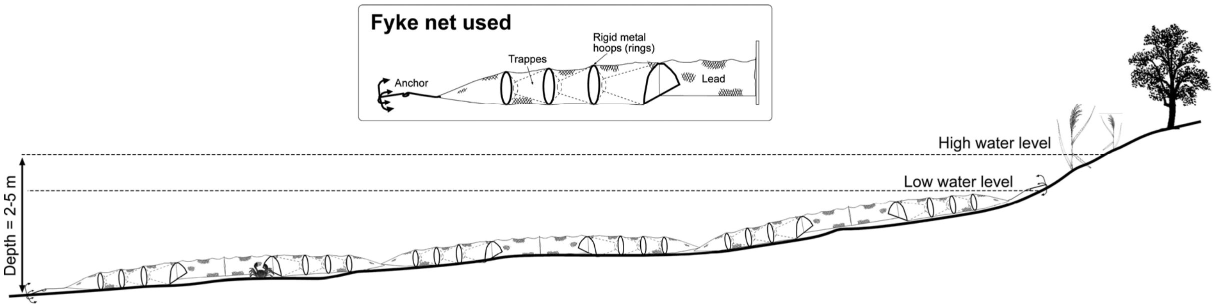


Figure 2. Details of a fyke net used (upper drawing). Typical arrangement consisted of lines of fyke nets set on the estuary bottom. Each line was composed of 6 fyke nets attached to each other. At each fishing station, 4 lines (total number of fyke nets = 24) were used.

Table 1. Gonad maturity stages recognized under the dissecting microscope in adult females of Chinese mitten crabs (*Eriocheir sinensis*).

Stage code	Aspect	Colour	Location
G1	No visible oocytes	Light yellow	Inside carapace
G2	Oocytes visible at least on the surface of the gonad and forming a compact mass	Yellowish, beige	Inside carapace
G3	Oocytes forming a compact mass, but separable from the outer layers of the gonad	Beige	Inside carapace
G4	Oocytes forming a soft mass, showing trophoplasmic growth (yolk accumulation) and being easily detachable from the mass	Light purple, light brown	Inside carapace
G5	Easily separable eggs filled with large yolk globules and brooded in a mass (prespawning)	Dark purple, brown	External, in pleopodal setae of abdomen

Results and discussion

Captures and spatial distribution of E. sinensis within the estuary

The first *E. sinensis* was reported by a local elderly fisherman in 1987. Based on this date, a minimum residence time of 20 years may be considered for this species in southern Spain.
A total of 888 crabs were caught between 2001 and 2008 (Figure 3). Most captures (99%) were made inside the port area of Seville (Figure 1). Interestingly, the catches also showed a heterogeneous distribution within the port area. Most *E. sinensis* specimens (91%) were captured within the first 3.7 km alongside the sluice dock, coinciding with the berthing area of large vessels, which are potential vectors of introduction. However, given the high dispersal capacity in this species (Herborg et al. 2005), it is unlikely that the distribution observed is only due to the proximity of vessels. Further studies on the availability of suitable habitat or the salinity gradients within the port area (that could attract the crabs to the open estuary during the migration period) are needed to determine the reasons for the heterogeneous distribution observed.

With the exception of 2007, there was a downward trend in CPUE over time. A sharp drop in CPUE was noted in 2008, reaching minimum values of 0.006 crabs net^{-1}d^{-1} (Figure 3). Thus, the captures of Chinese mitten crab during the past 4 years have contributed to the reduction in the population stock in the port area and consequently, also to the reduction of dispersal potential to neighbouring areas. However, sharp fluctuations in Chinese mitten crab populations have been reported in some regions, as a consequence of stochastic factors. For example, in the Seine estuary (France), a cold spell occurred during the winter of 1963. After that winter, no crabs were captured until 1975. Although adult crabs can tolerate 0°C temperatures for up to seven days, the severe weather conditions were probably fatal for the juvenile crabs residing in freshwater (Vincent 1996). In other areas, such as the Netherlands, periodic localized population explosions

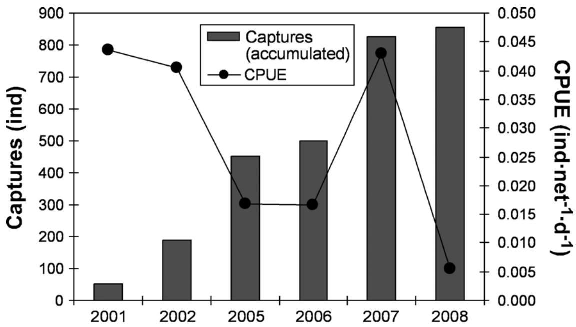


Figure 3. Cumulative captures and catch-per-unit-effort (CPUE) of *Eriocheir sinensis* in the Guadalquivir Estuary.

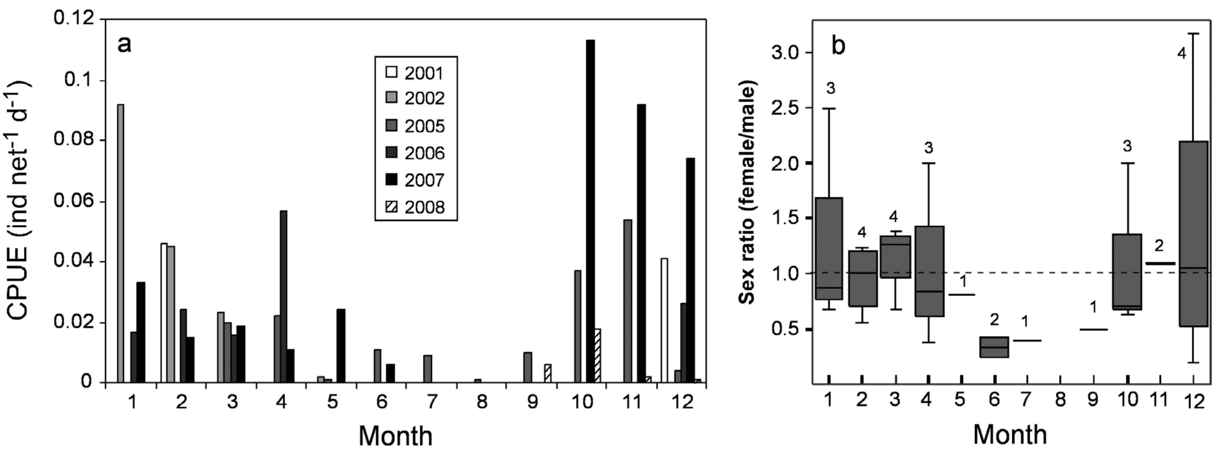


Figure 4. a) Monthly CPUE for *Eriocheir sinensis* captured in the Guadalquivir Estuary for the years 2001-2008. b) Box plot of monthly sex ratio (female/male). The dashed line indicates a sex ratio = 1. The number of data (months) used for calculations is indicated above each bar. Months with less than 5 crabs captured were not considered for calculations.

occurred (Ingle 1986): the population decreased after 1981 coinciding with a lower population level in neighbouring areas and an increasing demand for crabs by Chinese restaurants (Veldhuizen and Stanish 1999). In south-east England' estuaries, the population increased from 1989 to 1992 coinciding with a decrease in outflow and an increase in salinity (Attrill and Thomas 1996). The population declined substantially for unknown reasons and only a few crabs were sighted each year. Therefore, we cannot exclude the possibility that management work can coincide with environmental conditions mitigating against Chinese mitten crabs during key periods in life-history (migration, reproduction, settlement of early juveniles, etc.). This demographic unpredictability suggests the need for regular monitoring in order to respond quickly to potential population explosions.

Considering the lack of prior experience on the management of the Chinese mitten crab in the Guadalquivir Estuary (or similar scenarios) and the lack of knowledge of the optimal period of capture, different months were selected for sampling during 2001-2005. These results showed that the CPUE maximum was during October-April (Figure 4a). Accordingly, capture attempts were concentrated during Autumn and Winter in 2007 and 2008. Since captures occurred mostly in the port area, which is partially isolated from the open estuary, we cannot assume that these months match the breeding period. However, peak captures obtained here are quite similar to those reported for either the native range (Zhang et al. 2001) or invaded areas (Panning 1938; Rudnick et al. 2003; Herborg et al. 2006) and suggest periods of activity associated with reproduction. Sex ratio analysis showed no significant differences among the different months (Figure 4b).

With respect to the population structure, the occasional appearance of young crabs (CW < 3 cm) (Jin et al. 2001) (Figure 5) suggested the need to assess whether there was effective reproduction within the port area (under freshwater conditions). Our results showed at least three pieces of evidence that render this hypothesis unlikely: (i) no ovigerous females were captured, (ii) the analysis of gonads extracted from adult females showed that they were immature (stages *G*2, *G*3), (iii) the salinity of water in the port is <5 ‰ (Baldó et al. 2005) and at least some larval stages require high salinities to complete development (Anger 1991). Therefore, we suggest that young crabs reached the port area either by shipment (ballast waters) or from reproduction in the open estuary followed by upstream migration.

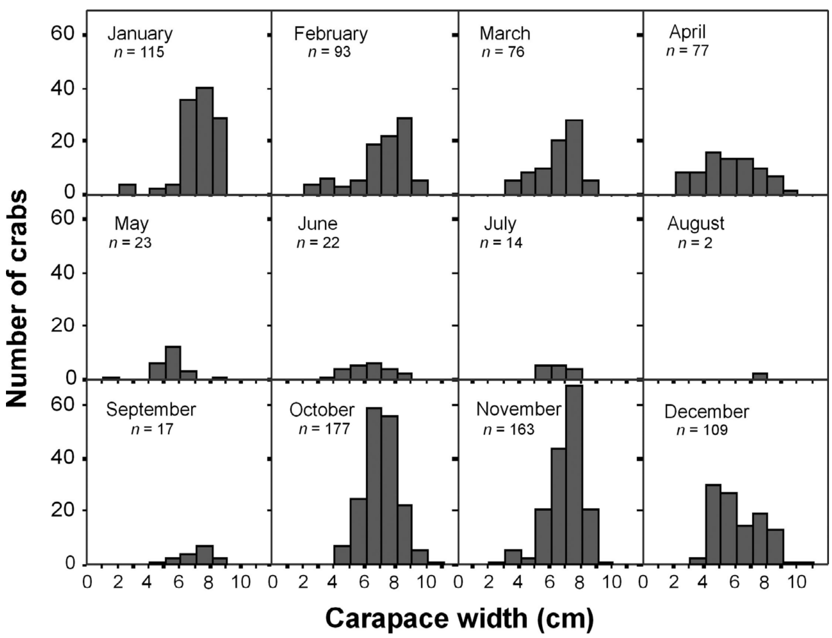


Figure 5. Monthly histograms for carapace width of Chinese mitten crabs collected in the period 2001-2008. Total sample size (n) of each month is indicated.

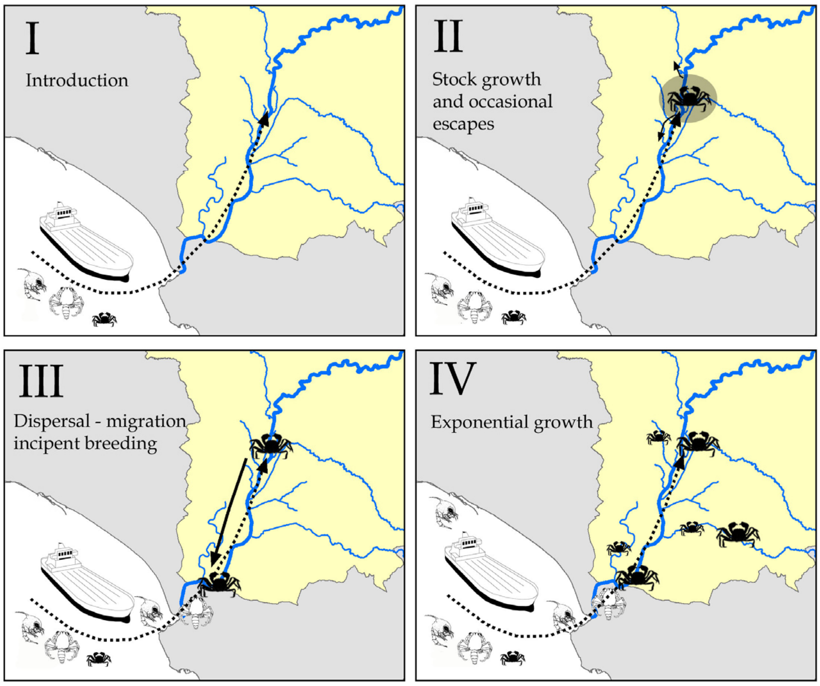


Figure 6. Expected sequence of the invasion process for the Chinese mitten crab in the Guadalquivir Estuary: I) Initial introduction of *Eriocheir sinensis* (megalops or juveniles) by ballast water discharges; II) establishment of a stock in the port area and occasional escapes to the open waters; III) migration of breeding individuals and incipient reproduction in the estuary mouth; IV) upstream migration of megalops and juveniles. Spread and colonisation of tributaries and neighbouring estuaries. At all stages, external introductions (ballast water discharges) are expected. The dashed line indicates the route used by ships. Solid lines show the expected movements of mitten crabs.

Invasion and management perspectives

The Guadalquivir Estuary is a highly suitable area for the Chinese mitten crab (Herborg et al. 2007). This species has also shown high rates of dispersal in different areas internationally that have been invaded (Herborg et al. 2005). Therefore, there is a potential risk of progression of this invasion within the estuary that calls for proactive management. Both for this purpose, and given the experience of invasion elsewhere in the world, it is relevant to pose an expected invasion process sequence (Figure 6). This exercise will guide the necessary decisions to anticipate likely events. Since the first introduction (stage I, Figure 6), our distribution data suggest the establishment of a population in the port area (stage II). Occasional escapes of adult individuals from the port area and its subsequent migration would explain the specimens found near the mouth of the estuary (stage III). This is the current framework assumed in the Guadalquivir Estuary. The next expected stage would be an effective breeding and dispersion of megalops and juveniles throughout the estuary and its tributaries (stage IV, Figure 6). The presence of megalopae was reported in the Guadalquivir Estuary in the 1998-2000 period (Cuesta et al. 2006) but have not been caught again in 2001-2008 (J.A. Cuesta, pers. comm.), coinciding with the decrease in CPUE. Therefore, we can assume that the population size has diminished either by management carried out and/or a combination of different factors (some of them stochastic). In any case, we consider management essential to prevent *E. sinensis* from reaching stage IV.

This framework, together with the fact that ships´ ballast water remains an uncontrolled vector of introduction into the estuary, calls for management measures to be taken for this species at least until the input vectors stop. Based on the results obtained, efforts (number of nets) were increased near the mouth in 2009 in order to catch breeding crabs. Further improvement to management includes the involvement of local fishermen and other stakeholders (e.g., managers of protected areas, farmers, research institutions,) in monitoring the Chinese mitten crab population within the estuary and its vicinity. They have been provided with brochures including photos and information about the Chinese mitten crab and have been asked to report any new findings or captures.

The Guadalquivir Estuary is a highly productive ecosystem that provides permanent habitats for estuarine species. It also plays an important role as breeding and feeding grounds for adults of marine species (Baldó and Drake

2002; González-Gordillo and Rodríguez 2003), providing a number of ecosystem services to local communities. It is therefore important to maintain the current management efforts in order to contain and reduce the population, as well as to prevent new introductions from ballast water discharges. Our results may help to optimize the management of this invasive species both in the Guadalquivir estuary and in comparable scenarios in different parts of the world.

Acknowledgements

This work was funded by the Environmental Council of the Regional Government (Consejeria de Medio Ambiente, Junta de Andalucía), through the Andalusian Programme for the Control of Invasive Alien Species. We are grateful to the port authorities for providing facilities and permission to carry out the work, and to anonymous reviewers for their comments and suggestions on an earlier version of the manuscript.

References

Anger K (1991) Effects of temperature and salinity on the larval development of the Chinese mitten crab *Eriocheir sinensis* (Decapoda: Grapsidae). *Marine Ecology Progress Series* 72: 103–110, doi:10.3354/meps072103

Attrill MJ, Thomas RM (1996) Long-term distribution patterns of mobile estuarine invertebrates (Ctenophora, Cnidaria, Crustacea: Decapoda) in relation to hydrological parameters. *Marine Ecology Progress Series* 143: 25–36, doi:10.3354/meps143025

Baldó F, Drake P (2002) A multivariate approach to the feeding habits of small fishes in the Guadalquivir Estuary. *Journal of Fish Biology* 61: 21–32, doi:10.1111/j.1095-8649.2002.tb01758.x

Baldó F, Cuesta JA, Fernández-Delgado C, Drake P (2005) Effect of the regulation of freshwater inflow on the physical-chemical characteristics of water and on the aquatic macrofauna in the Guadalquivir estuary. *Ciencias Marinas* 31: 467–476

Cabral HN, Costa MJ (1999) On the occurrence of the Chinese mitten crab, *Eriocheir sinensis*, in Portugal (Decapoda, Brachyura). *Crustaceana* 72: 55–58

Clark PF, Abdul-Sahib IM, Al-Asaki MS (2006) The first record of *Eriocheir sinensis* H. Milne Edwards, 1853 (Crustacea: Brachyura: Varunidae) from the Basrah area of southern Iraq. *Aquatic Invasions* 1: 51–54, doi:10.3391/ai.2006.1.2.1

Cuesta JA, González-Ortegón E, Rodríguez A, Baldó F, Vilas C, Drake P (2006) The decapod crustacean community of the Guadalquivir Estuary (SW Spain): seasonal and inter-year changes in community structure. *Hydrobiologia* 557: 85–95, doi:10.1007/s10750-005-1311-1

Dittel AI, Epifanio CE (2009) Invasion biology of the Chinese mitten crab *Eriocheir sinensis*: A brief review. *Journal of Experimental Marine Biology and Ecology* 374: 79–92, doi:10.1016/j.jembe.2009.04.012

Drake P, Baldó F, Cuesta JA, García-González D, Silva-García A, Arias AM, Rodríguez A, Sobrino I, Fernández-Delgado C (1999) Initial effects of the toxic waste spill (Aznalcóllar mine accident) on the aquatic macrofauna of the Guadalquivir Estuary. *Science of the Total Environment* 242: 271–280, doi:10.1016/S0048-9697(99) 00395-2

Ferdinand-Martinez MA, Carrera AG (2003) Estatus de las poblaciones de cangrejos de rio exoticos, *Procambarus clarkii*, *Pacifastacus leniusculus*, y *Eirocheir sinensis*, en el Noreste de la peninsula Iberica. In: Capdevila-Arguelles L, Zilletti B, Perez Hidalgo N (eds), Contribuciones al conocimiento de las especies exoticas invasoras-1. Grupo Especies Invasoras Serie Técnica, León, Spain, pp 220–221

Gilbey V, Attrill MJ, Coleman RA (2008) Juvenile Chinese mitten crabs (*Eriocheir sinensis*) in the Thames estuary: distribution, movement and possible interactions with the native crab *Carcinus maenas*. *Biological Invasions* 10: 67–77, doi:10.1007/s10530-007-9110-4

Gollasch S (2006) NOBANIS – invasive alien species fact sheet – *Eriocheir sinensis*. From: Online Database of the North European and Baltic Network on Invasive Alien Species, NOBANIS. http://www.nobanis.org (accessed 30 November 2009)

Gollasch S (1999) *Eriocheir sinensis* (Milne-Edwards, 1854), the Chinese mitten crab. In: Gollasch S, Minchin D, Rosenthal H, Voigt M (eds) Exotics across the ocean. Case histories on introduced species: their general biology, distribution, range expansion and impact, Logos, Berlin, pp 55–60

González-Gordillo JI, Rodríguez A (2003) Comparative seasonal and spatial distribution of decapod larvae assemblages in three coastal zones off the south-western Iberian Peninsula. *Acta Oecologica* 24: 219–233, doi:10.1016/S1146-609X(03)00032-8

Herborg L-M, Bentley MG, Clare AS (2002) First confirmed record of the Chinese mitten crab (*Eriocheir sinensis*) from the River Tyne, United Kingdom. *Journal of the Marine Biological Association of the U.K.* 82: 921–922, doi:10.1017/S0025315402006379

Herborg L-M, Bentley MG, Clare AS, Last KS (2006) Mating behaviour and chemical communication in the invasive Chinese mitten crab *Eriocheir sinensis*. *Journal of Experimental Marine Biology and Ecology* 329: 1–10, doi:10.1016/j.jembe.2005.08.001

Herborg L-M, Rudnick DA, Siliang Y, Lodge DM, MacIsaac HJ (2007) Predicting the range of Chinese mitten crabs in Europe. *Conservation Biology* 21: 1316–1323, doi:10.1111/j.1523-1739.2007.00778.x

Herborg L-M, Rushton SP, Clare AS, Bentley MG (2003) Spread of the Chinese mitten crab (*Eriocheir sinensis*, H. Milne Edwards) in Continental Europe: analysis of a historical data set. *Hydrobiologia* 503: 21–28, doi:10.1023/B:HYDR.0000008483.63314.3c

Herborg L-M, Rushton SP, Clare AS, Bentley MG (2005) The invasion of the Chinese mitten crab (*Eriocheir sinensis*) in the United Kingdom and its comparison to Continental Europe. *Biological Invasions* 7: 959–968, doi:10.1007/s10530-004-2999-y

Horwath JL (1989) Final Rule on importation of injurious wildlife: mitten crabs. *Federal Register; Rules and Regulations* 54: 22286–22289

Hymanson Z, Wang J, Sasaki T (1999) Lessons from the home of the Chinese mitten crab. *Interagency Ecological Program Newsletter* 12: 25–32

Ingle RW (1986) The Chinese mitten crab *Eriocheir sinensis* H. Milne Edwards – a contentious immigrant. *The London Naturalist* 65: 101–105

Jin G, Li Z, Xie P (2001) The growth patterns of juvenile and precocious Chinese mitten crabs, *Eriocheir sinensis* (Decapoda, Grapsidae), stocked in freshwater lakes of China. *Crustaceana* 74: 261–273, doi:10.1163/156854001505505

Kalinina MV, Vinnikova NA, Semen'kova EG (2008) Gonadogenesis and color characteristics of ovaries in Japanese mitten crab *Eriocheir japonicus*. *Russian Journal of Developmental Biology* 39: 52–58

de Lafontaine Y (2005) First Record of the Chinese Mitten Crab (*Eriocheir sinensis*) in the St. Lawrence River, Canada. *Journal of Great Lakes Research* 31: 367–370, doi:10.1016/S0380-1330(05)70267-7

Minchin D (2006) First Irish record of the Chinese mitten crab *Eriocheir sinensis* (Milne-Edwards, 1854) (Decapoda: Crustacea). *Irish Naturalists' Journal* 28: 303–304

Nepszy SJ, Leach HJ (1973) First records of the Chinese mitten crab, *Eriocheir sinensis* (Crustacea: Brachyura) from North America. *Journal of the Fisheries Research Board of Canada* 30: 1909–1910

Ojaveer H, Gollasch S, Jaanus A, Kotta J, Laine AO, Minde A, Normant M, Panov VE (2007) Chinese mitten crab *Eriocheir sinensis* in the Baltic Sea-a supply side invader? *Biological Invasions* 9: 409–418, doi:10.1007/s10530-006-9047-z

Panning A (1938) Üer die Wanderung der Wollhandkrabbe. Markierungsversuche. *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* 47: 32–49

Panning A (1939) The Chinese mitten crab. Annual Report Smithsonian Institution, 1938, pp 361–375

Panov VE (2006) First record of the Chinese mitten crab, *Eriocheir sinensis* H. Milne Edwards, 1853 (Crustacea: Brachyura: Varunidae) from Lake Ladoga, Russia. *Aquatic Invasions* 1: 28–31, doi:10.3391/ai.2006.1.1.6

Peters N (1938) Ausbreitung und Verbreitung der chinesischen Wollhandkrabbe (*Eriocheir sinensis* H.M.-Edw) in Europa im Jahre 1933 bis 1935. *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* 47: 1–31

Robbins RS, Sakari M, Nezami Baluchi S, Clark PF (2006) The occurrence of *Eriocheir sinensis* H. Milne Edwards, 1853 (Crustacea: Brachyura: Varunidae) from the Caspian Sea region, Iran. *Aquatic Invasions* 1: 32–34, doi:10.3391/ai.2006.1.1.7

Rudnick DA, Hieb K, Grimmer KF, Resh VH (2003) Patterns and processes of biological invasion: The Chinese mitten crab in San Francisco Bay. *Basic and Applied Ecology* 4: 249–262, doi:10.1078/1439-1791-00152

Rudnick DA, Veldhuizen T, Tullis R, Culver C, Hieb K, Tsukimura B (2005) A life history model for the San Francisco Estuary population of the Chinese mitten crab, *Eriocheir sinensis* (Decapoda: Grapsoidea). *Biological Invasions* 7: 333–350, doi:10.1007/s10530-004-2286-y

Ruiz GM, Fegley L, Fofonoff P, Cheng Y, Lemaitre R (2006). First records of *Eriocheir sinensis* H. Milne Edwards, 1853 (Crustacea: Brachyura: Varunidae) for Chesapeake Bay and the mid-Atlantic coast of North America. *Aquatic Invasions* 1: 137–142, doi:10.3391/ai.2006.1.3.7

Schmidt RE, Daniels RA, Swift EL, Shadis IB (2009) Inferences on the biology of juvenile Chinese mitten crab (*Eriocheir sinensis*) from exuviae in a Hudson River tributary, New York, USA. *Aquatic Invasions* 4: 613–617, doi:10.3391/ai.2009.4.4.7

Veldhuizen TC, Stanish S (1999) Overview of the life history, distribution, abundance, and impact of the Chinese mitten crab, *Eriocheir sinensis*. California Department of Water Resources. Environmental Services Office, USA, 26 pp

Vincent T (1996) Le crabe Chinois *Eriocheir sinensis* H. Milne-Edwards 1854 (Crustacea, Brachyura) en Seine-maritime, France. *Annales de l'Institut Oceanographic* 72: 155–171

Zhang TL, Li ZJ, Cui YB (2001) Survival, growth, sex ratio, and maturity of the Chinese mitten crab (*Eriocheir sinensis*) reared in a Chinese pond. *Journal of Freshwater Ecology* 16: 633–640