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Research Article

Established population of the North American Harris mud crab, *Rhithropanopeus harrisii* (Gould, 1841) (Crustacea: Brachyura: Xanthidae) in the Panama Canal

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Abstract

Rhithropanopeus harrisii (Gould, 1841) is an estuarine crab native to the East Coast of North America. This species has invaded both the West Coast of the United States and several European countries since the late 1800s where it has reportedly altered native ecosystems. This crab can tolerate a broad range of salinities and temperatures, which probably contributes to its success as an invader. In 1969, five specimens of *R. harrisii* were recorded in Panama, but subsequent surveys suggest it was not established. Here, evidence is reported of an established, reproducing population of *R. harrisii* in the Panama Canal. The crab's entire distribution within this waterway remains to be determined and potential changes in its ecology, especially given the imminent expansion of the Canal, need to be evaluated.

Key words: *Rhithropanopeus harrisii*, Brachyura, Xanthidae, Panama Canal, estuaries, nonindigenous, invasion

Introduction

Alongside the notorious green crab, *Carcinus maenas* (Linnaeus, 1758), and the Chinese mitten crab, *Eriocheir sinensis* (H. Milne Edwards, 1853), the Harris mud crab, *Rhithropanopeus harrisii* (Gould, 1841), is among the most widely distributed brachyuran invaders worldwide (Grosholz and Ruiz 1996, Pagad 2007 pers. comm.). In its native range, this species inhabits fresh to brackish waters along the East Coast of North America from New Brunswick, Canada, to Veracruz, Gulf of Mexico (Williams 1984). Although recent publications cite a record of this species from Brazil, (Morgan et al. 1988, Abele and Kim 1989, Gonçalves et al. 1995, Zaitsev and Öztürk 2001), the specimens originally reported by Williams (1965) were later re-examined and reclassified as another species by the same author (Williams 1984).

Rhithropanopeus harrisii is a small (< 26 mm carapace width), euryhaline crab typically associated with sheltered estuarine habitats. This crab usually inhabits oyster reefs, woody debris and shoreline vegetation and it occurs to a depth of approximately 37 m (Turoboyski 1973, Williams 1984, Petersen 2006). Currently, *R. harrisii* is reported as a nonindigenous species in 21 different countries (Annex). Initial reports of introduction in the Americas (Jones 1940) and in Europe (Wolff 1954) date back to the first half of the 20th century. It is noteworthy that Maitland (1874) initially described this crab as a native species, *Pilumnus tridentatus*, in the Netherlands and that the synonym *Rhithropanopeus harrisii tridentatus* has often been used to designate this species in Europe (Buitendijk and Holthuis 1949, Christiansen 1969).

In the United States, *R. harrisii* invaded San Francisco Bay between the late 1800's and the

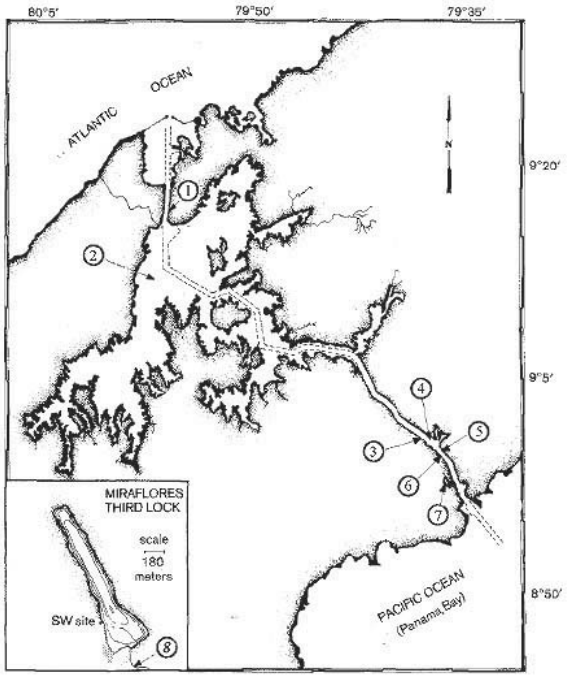

Figure 1. Map of the Panama Canal showing the location of the Miraflores Third Lock Lake (modified from McCosker and Dawson 1975). From the Pacific coast to the Atlantic coast: (1) Gatun Locks, (2) Gatun Lake, (3) Pedro Miguel Locks, (4) Miraflores Lake, (5) Miraflores Locks, (6) Miraflores Spillway; (7) Miraflores Third Lock Lake, (8) drainage stream present in 1971.

early 1900's presumably via translocations of the Atlantic oyster, *Crassostrea virginica* (Gmelin, 1791), from Chesapeake Bay in an attempt to initiate commercial oyster aquaculture (Cohen and Carlton 1995, Ruiz et al. 1997, Wasson et al. 2001). Since, *R. harrisii* has spread along the coast of California and Oregon, reaching several bays and rivers where populations persist (Petersen 2006). Interestingly, the crab also appears to have expanded its native coastal range inland and has successfully invaded freshwater reservoirs in Texas, where it has established reproducing populations (Howells 2001, Keith 2007 pers. comm.).

While no studies were found quantifying the impact of *R. harrisii* on the communities where it is introduced, there is evidence that it may alter species interactions and cause some economic damage. In Europe and on the West Coast of North America, it competes with native crabs (Marchand and Saudray 1971, Jazdzewski and Konopacka 1993, Cohen and Carlton 1995) as well as benthophagous fishes (Zaitsev and Öztürk 2001) and alters food webs by acting as a predator and serving as prey of native species (Turoboyski 1973, Cohen and Carlton 1995, Zaitsev and Öztürk 2001). Furthermore, in the Caspian Sea, where it has reached very high densities, the crab is responsible for pipe fouling and causes economic loss to fishermen by spoiling fishes in gill nets (Zaitsev and Öztürk 2001). In Texas, *R. harrisii* has also caused fouling problems in intake pipes and may have displaced a native species of freshwater crayfish (Keith 2007 pers. comm.). Finally, this species can host white spot baculoviruses, making it a potential vector for crustacean diseases (Payen and Bonami 1979).

Abele and Kim (1989) reported five specimens (one male, three non-ovigerous females and one juvenile) of *R. harrisii* from Panama, collected in the Pedro Miguel Locks in 1969 (Figure 1). According to more recent studies, however, the crab was not considered to be established (Cohen 2006). The purpose of this study is to report a reproducing population of *R. harrisii* in the Miraflores Third Lock Lake on the Pacific side of the Panama Canal.

Results and Discussion

Collection Site

Rhithropanopeus harrisii was discovered on the southwestern shore of the Miraflores Third Lock Lake on February 6, 2007 (8°58'45"N, 79°35'04"W - Figure 2). The crab was common under stones and on woody debris along the shore. One of the authors (MET) immediately recognized this species as *R. harrisii*. Identification was confirmed with photographs and live specimens by A Anker, JH Christy and LG Abele.

The general habitat features of the Miraflores Third Lock Lake were first described by Rubinoff and Rubinoff (1968) in a study reporting the occurrence of an Atlantic fish species crossing the Panama Canal and successfully establishing on the Pacific Coast. McCosker and Dawson (1975) also recognized the distinctiveness of this lake, which they characterized as "a unique Pacific habitat which supports a mixed biota of Atlantic and Pacific organisms". The Miraflores Third Lock project was initiated by the Panama Canal Company in the early 1940's in order to build an auxiliary set of locks. However , these efforts were rapidly

Figure 2. Satellite image (Google Earth™ mapping service 2007) of the collection site where *Rhithropanopeus harrisii* was found in Panama – the Miraflores Third Lock Lake adjacent to the Panama Canal: (1) Miraflores Third Lock Lake, (2) location of the underground culverts connecting the Lake to the Pacific Ocean, (3) Miraflores Locks, (4) fresh water lake, (5) Miraflores Lake, (6) Pacific entrance to the Panama Canal, (∗) site where crabs were collected.

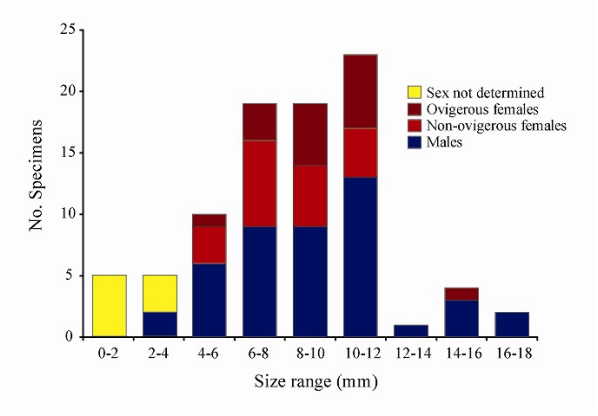

Figure 3. Size distribution of *Rhithropanopeus harrisii* collected in the Miraflores Third Lock Lake, Panama, on 2 March 2007.

abandoned in 1943. The resulting excavation, 1,340 m long by 90-150 m wide and 18-26 m deep, was filled with Pacific sea water and fresh-water runoff from the Canal (Rubinoff and Rubinoff 1968). The lake was initially connected to the Pacific Ocean below the Miraflores Lock via five metal culverts and a drainage stream two to three meters wide (McCosker and Dawson 1975; Figures 1 and 2).

Currently, the drainage stream no longer exists, and the condition of the underground culverts is uncertain. According to Rubinoff and Rubinoff (1968) and McCosker and Dawson (1975), the lake experiences very small tidal oscillations, but Pacific water may enter several times a month during exceptionally high spring tides. In contrast to the higher salinity measurements taken by these authors at the time, salinities of 0 ppt at the surface and 4 ppt at 0.75 m depth were recorded along the southwestern shore of the Lake, where crabs were collected (Figure 2).

Specimens collected

On 2 March 2007, 88 crabs were collected within an hour of examining the shoreline of the Miraflores Third Lock Lake. These were measured, sexed and preserved in 95% ethanol (Figure 3). Of the 88 crabs collected, 45 were males (avg cw = 9.3 mm, range cw = 3.1-17.7 mm), 19 were non-ovigerous females (avg cw = 8.0 mm, range cw = 4.9-10.9 mm), 16 were ovigerous females (avg cw = 9.3 mm, range cw = 5.8-12.8 mm) and eight were juveniles of undetermined sex (< 2.5 mm cw; Figure 4 a-d). Ovigerous females with late-stage eggs were kept alive to observe larvae. Within one week of collection, six females released their zoeae. Voucher specimens of adult crabs were deposited at the University of Panama (CRU-07-01) and will also be deposited at the National Museum of Natural History, Smithsonian Institution, Washington D.C.

Vectors of introduction

Ship activity through the Canal is a likely mechanism of introduction of *R. harrisii* to Panama, either via hull fouling or release of ballast water. Vectors responsible for other

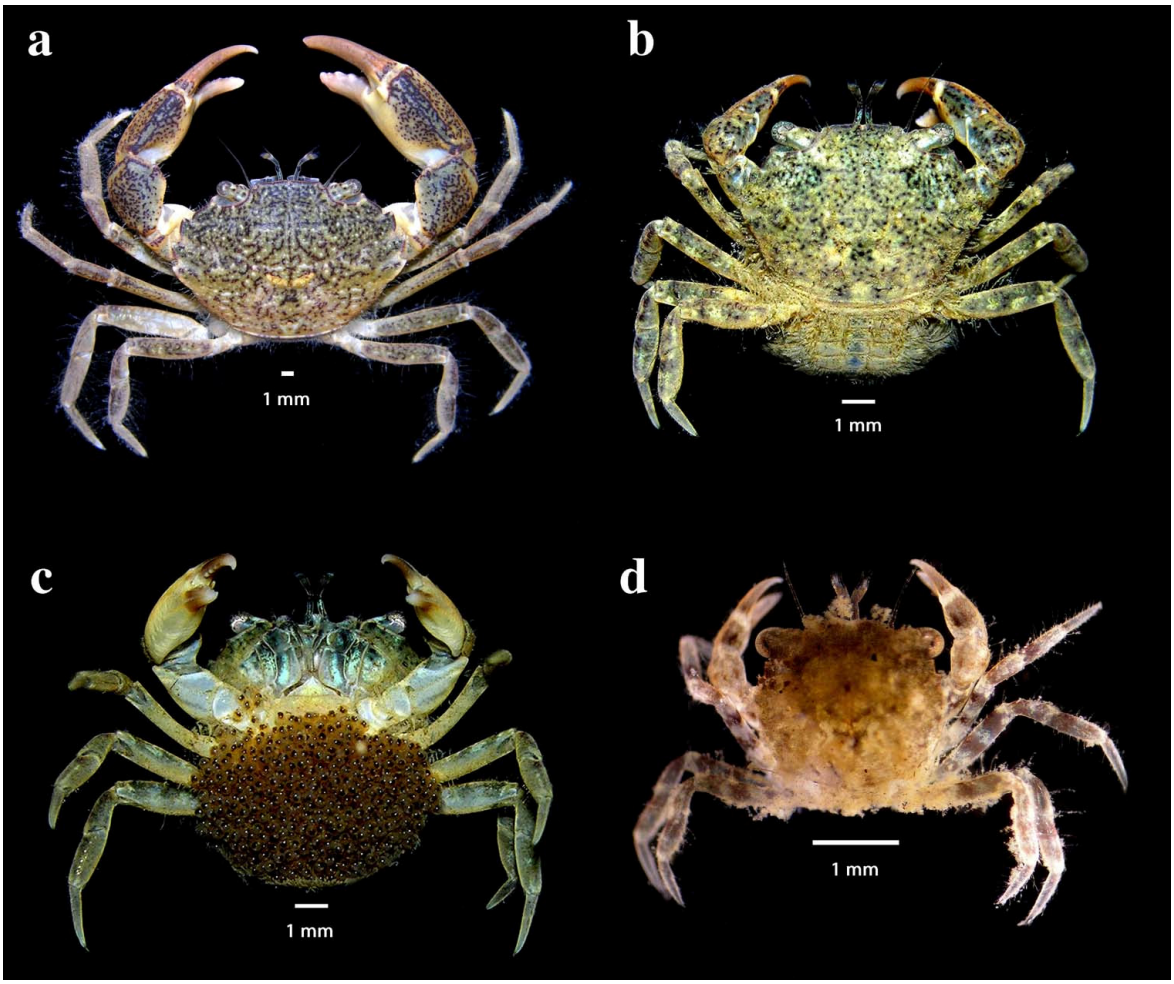

Figure 4. *Rhithropanopeus harrisii* collected in the Miraflores Third Lock Lake adjacent to the Panama Canal: (a) male specimen, 17.1 mm carapace width, dorsal view (photo by A. Anker); (b) ovigerous female specimen, 7.8 mm carapace width, dorsal view and (c) ventral view; (d) juvenile, 2.25 mm carapace width, dorsal view (photos by D.G. Roche).

introductions of the crab, such as aquaculture on the west coast of the U.S. (Ruiz et al. 2000; Wasson et al. 2001), are considerably less probable. The Panama Canal is a major center of shipping activity in the Americas, allowing transit of approximately 13 to 14 thousand vessels per year from around the globe (Ruiz et al. 2006). In Panama, little is known about ballast water exchange on either side of the waterway. However, sightings of ships discharging bilge and ballast within the Canal have been documented, despite regulations of the Autoridad del Canal de Panama prohibiting such activities (Cohen 2006). Carlton (1985) suggests that ballast water is a probable transport mechanism of *R. harrisii* into the Canal. However, boats do not transit via the Miraflores Third Lock Lake; thus, crabs (either adults or larvae) likely entered from adjacent Canal waters, perhaps during a spring tide flooding event.

Rhithropanopeus harrisii has an extensive history as a world-wide invader and its potential impacts where it is introduced warrant further evaluation of its distribution throughout the entire Panama Canal. Currently, *R. harrisii* is established in a semi-contained lake, which is designated as an area for future expansion of the Canal (ACP 2006). Further research will determine the probability that imminent changes will promote its spread as well as identify the possibility of eradicating localized populations within Panama.

Conclusion

A population of *R. harrisii* is now established in Panama, almost four decades after the first specimens were observed in the Pedro Miguel Locks. This population may have established after a different introduction event or perhaps from a larger population of this species that has remained undetected in the Canal. Given the many world-wide locations where *R. harrisii* has established, the source population of this invasion remains to be determined with the use of molecular genetics. In view of the impending expansion of the Panama Canal through the Miraflores Third Lock Lake, it is crucial to consider the potential spread of this crab and the possibility for its eradication, although the latter may prove difficult.

Acknowledgements

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Supplementary material

The following supplementary material is available for this article:

Annex. List of the countries where *Rhithropanopeus harrisii* has been reported as a nonindigenous species.

Annex. List of the countries where *Rhithropanopeus harrisii* has been reported as a nonindigenous species.

Country	Ocean / Sea	First report	Reference
Netherlands	North Sea	1874	Maitland 1874
Germany	Baltic Sea	1936	Schubert 1936
Ukraine	Black Sea	1936	Makarov 1939
	Azov Sea	1948	Zaitsev and Öztürk 2001
United States	NE Pacific	1937	Jones 1940
Russia	Black Sea	late 1800s	Marchand and Saudray 1971
	Azov Sea	1948	Zaitsev and Öztürk 2001
	Caspian Sea	1959	Gadzhiev 1963
Bulgaria	Black Sea	1948	Marchand and Saudray 1971
Romania	Black Sea	1951	Băcescu 1967
Poland	Baltic Sea	1951	Demel 1953
Denmark	Baltic Sea	1953	Wolff 1954
France	NE Atlantic	1955	Saudray 1956
	Mediterranean	2000	Noël 2001
Iran	Caspian Sea	---	Zaitsev and Öztürk 2001
Azerbaijan	Caspian Sea	1961	Gadzhiev 1963
Turkmenistan	Caspian Sea	1961	Zaitsev and Öztürk 2001
Panama	Panama Canal	1969	Abele and Kim 1989
Kazakhstan	Aral Sea	1971	Andreyev and Andreyeva 1988
	Caspian Sea	---	Zaitsev and Öztürk 2001
Uzbekistan	Aral Sea	1971	Andreyev and Andreyeva 1988
Spain	NE Atlantic	1990	Mariscal et al. 1991
Portugal	NE Atlantic	1991	Goncalves et al. 1995
Italy	Adriatic Sea	1994	Mizzan and Zanella 1996
England	NE Atlantic	1996	Eno et al. 1997
Tunisia	Mediterranean	2003	Ben Souissi et al. 2004