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Research article

Inferences on the biology of juvenile Chinese mitten crab (*Eriocheir sinensis*) from exuviae in a Hudson River tributary, New York, USA

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Abstract

Exuviae of Chinese mitten crab were collected in the Saw Kill, a small tributary to the fresh-tidal Hudson River, in summer and early fall 2008. Most exuviae were found in July when water temperatures exceeded 21ºC and numbers declined with subsequent decreasing water temperatures. Sizes ranged from 12 to 45 mm CW and all were considered to be in their second summer (1+). Very small exuviae (≤ 15 mm CW) were present from early June through mid-August indicating recruitment to the Saw Kill all summer. Live mitten crabs were difficult to collect and therefore data from exuviae were useful in observing the early stage of this invasion.

Key words: *Eriocheir sinensis*, Chinese mitten crab, Hudson River, exuviae, invasive species

Introduction

Chinese mitten crab (*Eriocheir sinensis* Milne Edwards 1853) is a catadromous species native to temperate East Asia from China north to the Korean Peninsula (Panning 1939). This invasive species was first reported in Europe in 1912 and rapidly expanded its range becoming abundant throughout the Baltic drainages by the 1920s (Panning 1939) and establishing itself in other parts of Europe in subsequent decades (Hänfling et al. 2002). In North America, it has been in San Francisco Bay since the early 1990s (CMCWG 2003) and more recently in the Great Lakes and the St. Lawrence River (de Lafontaine et al. 2008), Chesapeake and Delaware Bays, and now tributaries to Raritan Bay and the tidal Hudson River and its tributaries (G. Ruiz, Smithsonian Inst., pers. comm.). In northern Europe, the crab exhibits cyclic population outbursts (10-14 y) reaching very high abundances. Mitten crabs damage stream banks by burrowing (up to 30 burrows/m^2) and subsequently cause erosive collapse and they interfere with commercial fisheries when at high densities (Rudnick et al. 2005a).

Crabs spawn in waters at salinity > 25 PSU (Panning 1939, Ingle 1986). Newly settled juveniles are 2-3 mm carapace width (CW) and are found in salinities of 1-20 PSU (Culver and Walton 2002; Rudnick et al. 2005b). These small crabs molt frequently (every two weeks in the laboratory at 17ºC) with an average size increase of 22% CW per molt (Rudnick et al. 2005b). They remain in brackish water habitats through the next winter (Panning 1939; Rudnick et al. 2005b). Upstream migration begins in their second spring. These second year crabs are 15-30 mm CW (Rudnick et al. 2005b) and can move at 1-3 km/day (Panning 1939).

Five mitten crab specimens were collected in the tidal Hudson River prior to the summer of 2008. Collection of a single individual on June 3, 2008 clearly signaled that there were juvenile mitten crabs in the Saw Kill, a Hudson River tributary, and that it had moved upstream past a 16 m waterfall. We decided to put some effort into looking for mitten crabs in the Saw Kill. The purpose of this paper is to document the presence of juvenile mitten crab and document population characteristics in a small tributary of

the Hudson River in summer and fall 2008, a period soon after the discovery of this invasive species in the Hudson River drainage.

Material and Methods

Study Area

This study was done in the Saw Kill, a small (68.2 km^2 watershed) tributary to the fresh tidal Hudson River, New York, USA (42.01721N, 73.91746W). The Saw Kill is located in Annandale, northern Dutchess County on the east side of the Hudson River 158.5 km north of the southern tip of Manhattan Island.

The Saw Kill empties into a tidal freshwater marsh, Tivoli South Bay. The marsh is completely inundated at high tide and is dominated by the exotic Eurasian Water Chestnut (*Trapa natans* Linnaeus 1753) in the summer. The Bay is circumscribed by a railroad bed built on fill and tidal exchange with the main Hudson River occurs through three culverts in the railroad bed.

Above the head of tide, the Saw Kill is a rocky stream, 7 m wide and mostly < 0.6 m deep. Approximately 85 m upstream of the head of tide, there is a 16 m high natural waterfall. A small mill dam (about 3 m high) is situated 35 m upstream of the top of the waterfall where a small American eel ladder is located (Schmidt et al. 2009). There are deep pools below the waterfall and the dam (~ 1.5 m). The mill dam forms a shallow (< 2.5 m deep) 0.4 ha impoundment with sand and gravel substrate. At the head of the impoundment, there is approximately 60 m of rocky stream and then a second natural waterfall, about 5 m high.

Procedures

On June 3, 2008, a live juvenile (21 mm CW) mitten crab was found in the holding trap of the eel ladder. The Saw Kill was visited twice a week from June 1 through August 22, 2008, which was our schedule for monitoring the eel passage facility, and once weekly thereafter. Visits were not on consecutive days but day and time of day sampled varied. During each visit, one or several people walked the stream from the mill dam to the first waterfall and from the first waterfall to the tidal mouth. On three occasions, we walked the Saw Kill from the mill dam impoundment upstream to the second waterfall. During each of these surveys, all the exuviae that we found were collected and preserved in 95% ethanol. The carapace width (CW) was measured with a ruler, and the sex determined by visual inspection of the shape of the abdomen (when available). All specimens were deposited at the New York State Museum. We attempted to capture live mitten crabs in the Saw Kill by the following methods: trap in the eel ladder, flipping rocks, snorkeling, searching with lights at night, traps baited with sardines, unbaited traps after Rudnick et al. (2005b), and with a Smith-Root backpack electroshocker.

Water temperature, specific conductance, salinity, water level, pH, turbidity, and dissolved oxygen were measured at 15 min intervals by a YSI 6600 multisensor probe moored at 1 m depth on the upstream side of the mill dam and monitored by the New York State Department of Environmental Conservation, Hudson River National Estuarine Research Reserve (HRNERR) personnel.

The minimum number of live crabs estimated to produce the number of exuviae found during our surveys was calculated by assuming a two week molt interval and a size increase of 22% per molt (Rudnick et al. 2005b). We looked at each exuvia, calculated the crab's size at the next molt, and compared that size to the exuviae collected two weeks later. If an exuvia was within 1-2 mm of the calculated size, we considered it to be from the same individual.

Results

During this study, twelve live juvenile mitten crabs were collected in the Saw Kill (Table 1). Half were collected above the waterfall (five in the eel ladder, the 53 mm female taken electroshocking, and the 48 mm female with a dip net).

Table 1. List of live Chinese mitten crabs (*Eriocheir sinensis*) collected in the Saw Kill, Hudson River, New York, USA in 2008. CW is Carapace width (mm)

Date	CW and Sex	Collection method
June 3	21♀	Eel ladder
June 9	17♂	Eel ladder
July 18	20♂, 26♂	Electroshocker
July 29	20♂, 25♂, 53♀	Electroshocker
August 4	19♂	Eel ladder
August 11	33♀	Eel ladder
August 15	24♂	Electroshocker
September 30	34♀, 48♀	Eel ladder, dip net

A total of 130 Chinese mitten crab exuviae was collected from the Saw Kill between June 13 and September 30, 2008. At each sampling event, we found at least one exuvia and collected 15 on one occasion (July 3). Slightly more than half of the specimens (67) were collected between July 3-22, when water temperature was between 21 and 24.5°C (Figure 1). Numbers of exuviae collected per visit subsequently fell concomitant with a general decline in water temperature. The majority (83%) were collected below the waterfall, most of the rest (17%) were collected above the waterfall and below the dam, and one (<1%) above the dam.

Mitten crab exuviae collected ranged from 12-45 mm CW. Mean size increased from mid-June through late September (Figure 2) with large variability in the size range. Very small exuviae (≤ 15 mm CW) were collected on 52% of the trips from June 13 through August 21.

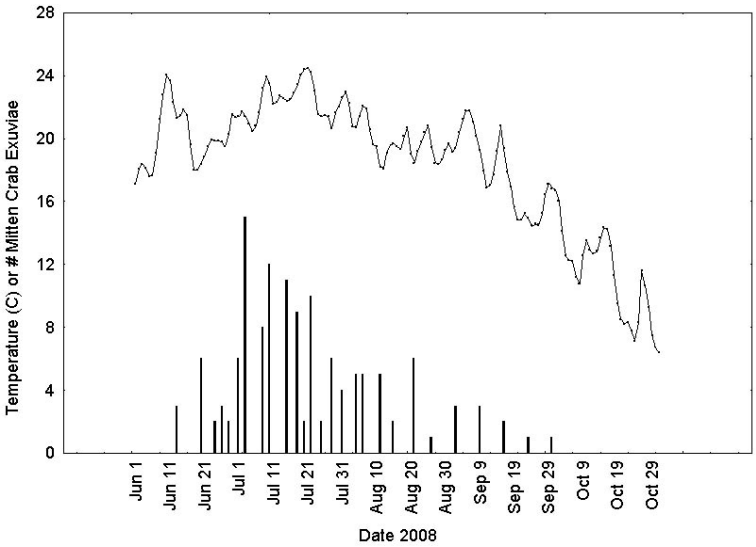

Figure 1. Mean water temperature (solid continuous line) and number of mitten crab exuviae (vertical bars) collected in the Saw Kill, Dutchess County, New York between June 1 and October 30, 2008

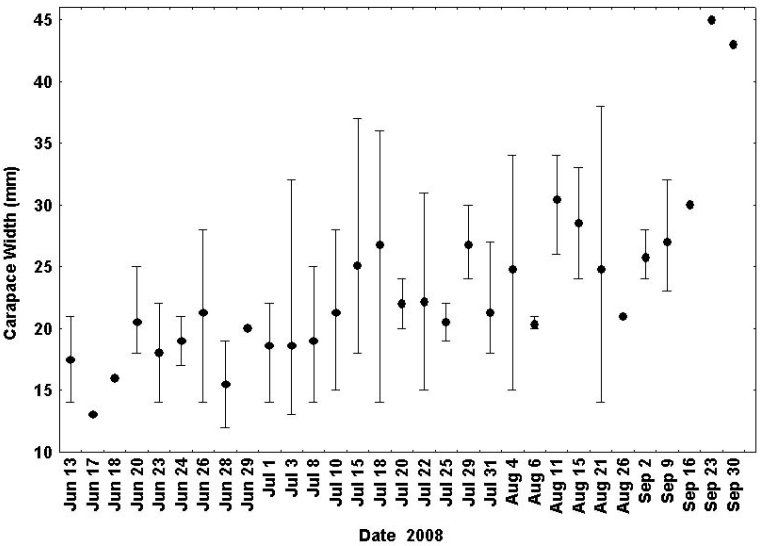

Figure 2. Mean (solid dot) and range (capped lines) of carapace widths of mitten crab exuviae collected in the Saw Kill, Dutchess County, New York in 2008. A dot with no range indicates a single specimen

Of the 130 exuviae collected in the Saw Kill, 49 (37.7%) were fragmentary, lacked an abdomen, and therefore could not be sexed. There were 45 males and 36 females found.

The minimum population size in the Saw Kill was estimated to be 80 individuals, corresponding to a density of about 1 crab/10.5 m^2. Such a low density might be expected early in an invasion. Mitten crabs are not distributed evenly in the Saw Kill, however. The crabs appear to be concentrated just below the barriers; the waterfall and the mill dam.

In 2008 the mean and range of water quality parameters measured were (S.Fernald, HRNERR, pers. comm.); specific conductance- 0.42 $mScm^{-1}$ (0.27-0.6), pH - 8.3 (7.9-8.7), turbidity - 2.60 NTU (-2-412), dissolved oxygen - 9.97 mgl^{-1} (7.6-14.3), dissolved oxygen - 98.9 % saturation (90.4-115.4).

Discussion

The live juvenile Chinese mitten crabs collected in the Saw Kill (Table 1) provided some information about the population, but did not really indicate the magnitude of the invasion in 2008. The exuviae gave us more information than the live crabs, especially regarding recruitment pattern, size and spatial distributions, and total numbers.

The smallest crabs in the Saw Kill (≤ 15 mm CW) were in the range of sizes reported for upriver migrants (Rudnick et al. 2005b), suggesting that immigration of juvenile crabs to the Saw Kill occurred regularly throughout the summer months. Whether these immigrants were moving directly from the brackish water in the lower river (approximately 80 km away) or staging elsewhere in the fresh-tidal Hudson estuary was not determined.

Based on the sizes of the mitten crab exuviae (Figure 2), the crabs in the Saw Kill are in their second summer (1+). Mitten crabs ≥ 38 mm CW can be sexually mature (Panning 1939; Hoestlandt 1948; Ingle 1986) given that this size is reached shortly after the summer solstice (Rudnick et al. 2005b). Specimens found in the Saw Kill during 2008 were probably not mature. Downstream migration of mitten crabs in a Hudson River tributary was observed in fall 2008 (S. Fernald, HRNERR, pers. comm.) and several ovigerous females were collected in the Hudson River in spring 2009 (M. Dufour, New York State Department of Environmental Conservation, pers. comm.).

The waterfall and the mill dam are barriers to upstream movement of mitten crabs, nevertheless crabs did circumnavigate both barriers in their first year of occurrence in the Saw Kill. Upstream movements are likely to be stimulated by high population densities (Panning 1939, Ingle 1986). If the Saw Kill population increases in the next few years, we should expect more crabs to be found farther upstream.

Our population estimate is a minimum since we assumed that all the available exuviae were found and collected effectively and that there was no mitten crab mortality between censuses. Neither assumption was tested and both are unlikely, but both are reasonable if the goal is to compute a minimal estimate for a relatively confined area. We never found a dead crab, but large numbers of American eel, *Anguilla rostrata* (Leseuer 1817) are present in the Saw Kill (Schmidt et al. 2006) and they are capable of preying on small mitten crab. Large eels can feed heavily on large crustaceans, such as crayfish (Machut et al. 2007). Raccoons are also present along the Saw Kill although we never saw signs of crabs being consumed on the shore.

The capture of twelve live crabs in the Saw Kill would therefore represent 15% of the estimated population and would be a moderately significant reduction in numbers. The fact that we did not notice a population drop over the summer suggests that our estimate is very conservative.

The density of mitten crabs reported in this study is low compared to some qualitative historical reports from Europe (Herborg et al. 2003). Herborg et al. (2003) described a fifteen year establishment phase of the mitten crab invasion in northern Europe characterized by a slow inland spread. The population documented here in the Saw Kill is similarly in the establishment phase, typical of an early invasion (Drake and Williamson 1986).

Collecting live mitten crabs was very difficult in the Saw Kill. Finding the exuviae was relatively easy since most were deposited in the shallow stream margins. Inferences about the population drawn from the exuviae are therefore more robust than any drawn from collecting live crabs because the sample size of the latter was small.

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