Research article

First European record of the invasive brackish water clam *Rangia cuneata* (G.B. Sowerby I, 1831) (Mollusca: Bivalvia)

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Abstract

A population of *Rangia cuneata* (G.B. Sowerby I, 1831), an estuarine bivalve, has been recorded in the harbour of Antwerp, Belgium. This species is new to the European brackish water fauna. After initially finding only a few small individuals in August 2005, *R. cuneata* was encountered frequently in the pipes of the cooling water system of an industrial plant from February 2006 onwards. Before this present record, *R. cuneata* was only known from the Gulf of Mexico and the Atlantic coast of North America.

Key words: Belgium, biofouling, Europe, first record, invasive species, Mactridae, *Rangia cuneata*

Introduction

During an intensive monitoring study of the biology of the invasive bivalve, *Mytilopsis leucophaeata* (Verween et al. 2005), a test-installation for biomonitoring was installed at an industrial plant in the harbour of Antwerp (51°21.37'N, 4°17.30'E), along the Schelde River, Belgium (Figure 1). Monitoring was undertaken on a weekly basis from February 2000 onwards. In August 2005, some small individuals (10-15 mm) of an unknown bivalve were found in the test-installation and were later identified as *Rangia cuneata* (G.B. Sowerby I, 1831) (Mollusca, Mactricae). This species had never been encountered during previous samplings.

The identification was hampered by the fact that we were dealing with young individuals not fully exhibiting all morphological characters of the adults. Several typical characters such as the heavy shell, the specifically bended umbos and the heavy chestnut periostracum were thus not apparent in this material. The first specimens collected resembled the indigenous surf clam *Spisula subtruncata* (da Costa, 1778) but this

species does not occur in brackish waters. Larger specimens (20-25 mm), collected in September 2005 had a more robust shell with a specific bended umbo, a clear pallial sinus - both characteristics not present in *Spisula* - and transversally striated lateral teeth. Therefore these specimens could be referred to the Mactridae, but not to any European species.

As the weekly sampling programme continued, more and larger individuals were found in the test installation, thus facilitating its identification as *Rangia cuneata*. Early in 2006, a dense population of *R. cuneata* was finally detected in the silt in the inlet pipes of an industrial cooling water system (current velocity: 6-6.5 m/s). Although these pipes, more than 2 m in diameter, consist of concrete, a layer of soft substrate is present at the bottom, as such creating an ideal habitat for the clams. In this particular case, the inlet pipes had to be cleaned to restore an optimal water flow, indicating that *R. cuneata* can be identified as a true nuisance fouling species. The first and to our knowledge only report of *R. cuneata* causing biofouling problems in pipes was in the Getty oil refinery in Delaware City DE, USA, where it clogged fire hoses (Counts 1980).
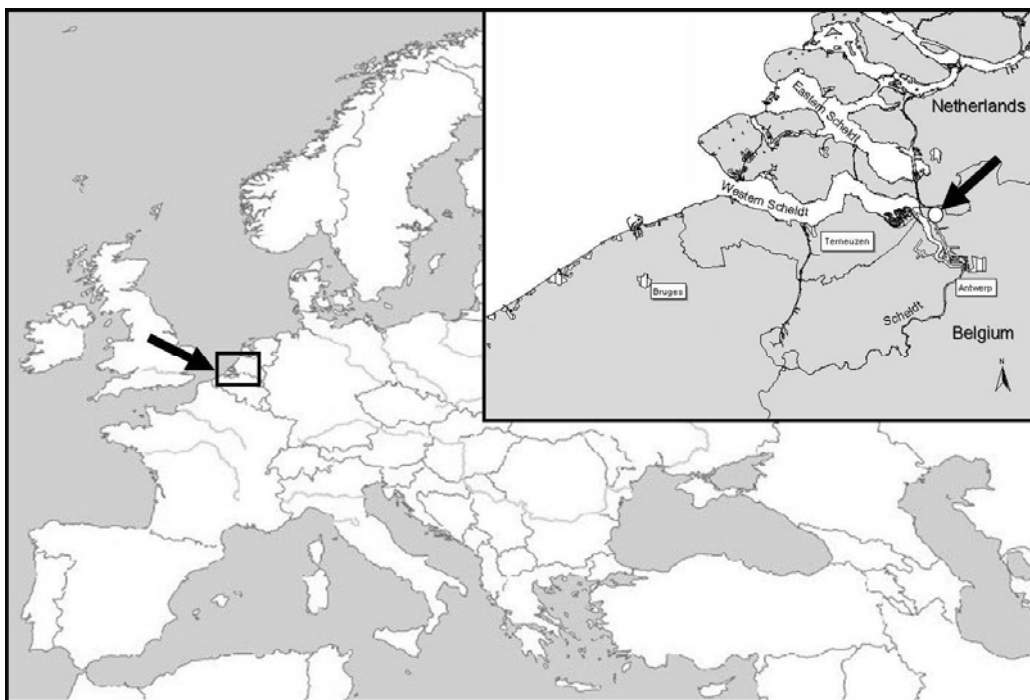

Figure 1. Harbour of Antwerp, Belgium, location where *Rangia cuneata* was collected.

Identification

The identification of *R. cuneata* (Wedge clam, Atlantic Rangia, common Rangia) was based on characteristics presented in Abbott (1974) and LaSalle and de la Cruz (1985). In addition, specimens were compared with samples contained in the collections of the Royal Belgian Institute of Natural Sciences and the National Museum of Natural History in The Netherlands. The valves are thick and heavy, with a strong, rather smooth pale brown periostracum (Figure 2a). The shells are equivalve, but inequilateral with the prominent umbo curved anteriorly (Figure 2b). An external ligament is absent or invisible, but the dark brown internal ligament lies in a deep, triangular pit immediately below and behind the beaks. Both valves have two cardinal teeth, forming a Λ-shaped projection (Figure 3b). The upper surface of the long posterior lateral teeth is serrated (LaSalle and de la Cruz 1985). The inside of the shell is glossy white, with a distinct, small pallial sinus, reaching to a point halfway below the posterior lateral (Figure 3a). The pallial line is tenuous (Garcia-Cubas 1981).

Figure 2. Rangia cuneata, lateral (A) and dorsal (B) outside view. Note the anteriorly curved umbo. Photographed by De Smet G.
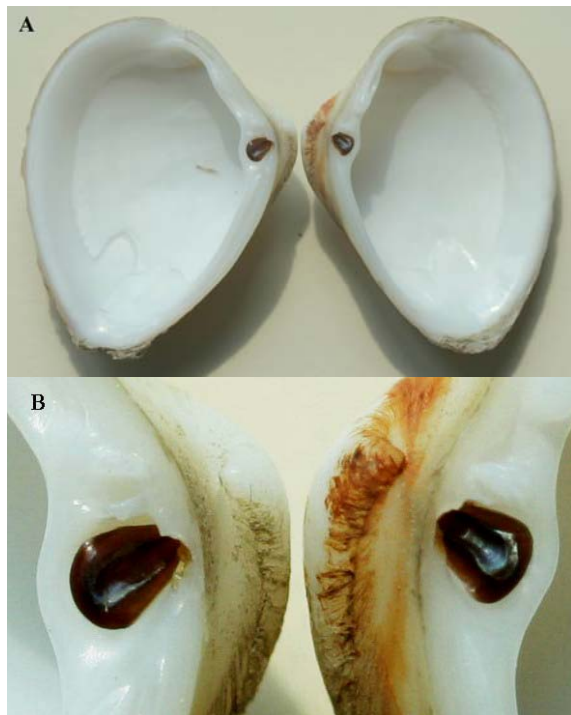

Figure 3. Rangia cuneata, inside view (A) and detail of the internal hinge (B). Photographed by De Smet G.

To facilitate the identification of *R. cuneata*, a key for the identification of all current European Mactridae is presented. This key combines the diagnostic features, as provided by Tebble (1966) (native European mactrids) and LaSalle and de la Cruz (1985):

1. Lateral teeth smooth; external and internal ligaments separated by a very small calcareous septum……………………………………………2
 - Upper and lower surfaces of the lateral teeth of the left valve and upper surfaces of the right valve laterals serrated; external and internal ligaments not separated by a calcareous septum………………………………………3
2. Anterior cardinal tooth of right valve almost parallel with the hinge line; adult shells normally <6.35 cm in length……………..*Mactra corallina* (Linnaeus, 1758)
 - Anterior cardinal tooth of right valve not parallel with the hinge line; adult shells normally >6.35 cm in length ………………..*Mactra glauca* (Born, 1778)
3. Pallial sinus comparatively deep, reaching to a point below and in front of the middle of the posterior lateral tooth or teeth …………………..4
 - Pallial sinus comparatively shallow, reaching to a point below and behind the middle of the posterior lateral tooth or teeth……………………. …………………………………*Spisula subtruncata*
4. Beaks in the midline and turned inwards and slightly forward………………………………….5
 - Beaks in front of the midline clearly turned inwards and forward……………..*Rangia cuneata*
5. In the left valve the projecting Λ-shaped cardinals reach more than half-way down the hinge plate; dorsal areas about the beaks with fine concentric lines …………………*Spisula elliptica* (Brown, 1827)
 - In the left valve the projecting Λ-shaped cardinals reach no more than half-way down the hinge plate; dorsal areas about the beaks with fine concentric grooves ………………...*Spisula solida* (Linnaeus, 1758)

Misidentifications are possible with other young mactrids living in low salinity areas such as *Rangianella* (native range from Louisiana to Terminos Lagoon) and *Mulinia* (native in Florida, Texas and the Gulf of Campeche) superficial resembling each other and *Rangia* (Dall 1894). Montagna and Kalke (1995) noted that *Mulinia lateralis* is morphological similar to juvenile *R. cuneata* and that numerous misidentifications have occurred. However, in *Mulinia* the lateral

teeth are not crenulated and *Rangianella flexuosa* lacks the pallial sinus.

Habitat characteristics

Rangia cuneata inhabits low salinity estuarine habitats (Parker 1966) and is as such most commonly found in areas with salinities from 5-15 PSU (Swingle and Bland 1974). Along the Mexican Gulf coast, they form the basis for an economically important clam fishery (Wakida-Kusunoke and MacKenzie 2004). *Rangia cuneata* possesses both extracellular (blood and body fluid) and intracellular mechanisms of osmoregulation, which enables it to respond to sudden salinity changes in many estuaries (Bedford and Anderson 1972). They can cross the 'horohalinicum', the 5-8 PSU salinity boundary which usually divides fresh and salt-water invertebrates, making them one of the few freshwater clams to become established in brackish water (Ladd 1951) as such thriving in a zone unfavourable for many animals. Competition and predation may explain its scarcity in high salinity environments (Cooper 1981).

A combination of low salinity, high turbidity and a soft substrate of sand, mud and vegetation appears to be the most favourable habitat for *R. cuneata* (Tarver 1972). Although larvae prefer coarser sediment for settlement, adults are often found in muddy sediments (Fairbanks 1963, Cain 1975, Jordan and Sutton 1984). In the harbour of Antwerp, salinity ranged in 2005 from 4.3 to 10.3 PSU, ideal for the species, and temperature varied seasonally between 6.4 and 23.5 °C.

Rangia cuneata is a non selective filter-feeder, turning large quantities of plant detritus and phytoplankton into clam biomass (Darnell 1958) but the species also appears to obtain organic matter and phosphate from the sediment by direct ingestion or by feeding on bacteria associated with these materials (Tenore et al. 1968). Having a low mobility, its shell provides hard substrate for epifaunal taxa (Hoese 1973). Possible predators are fish, crabs, gastropods and ducks (LaSalle and de la Cruz 1985).

Life history

In the USA, *Rangia cuneata* has two spawning periods ranging from March-May and late summer-November in Louisiana (Fairbanks 1963) and February-June and September-November in Mexico (Rogers and Garcia-Cubas 1981),

although in both areas, spawning may be continuous. Cain (1975) found that gametogenesis was initiated when the water temperature rose above 15 °C and with salinities above 0 PSU or below 15 PSU (Hopkins 1970).

Despite the broad tolerance of adults to environmental changes, embryos are much more vulnerable; they do not develop at 0 PSU, with 18-29 °C and 6-10 PSU being optimal conditions. Larvae however, tolerate 8-32 °C and 2-20 PSU (Cain 1973). Growth of larvae was best at high salinities and high temperatures as the survival of the larvae is reduced by the interaction of temperature and salinity at low salinity – high temperature and high salinity – low temperature combination (Cain 1973). Larvae are capable of selecting substrates, based on physical, biological and chemical factors (Sundberg and Kennedy 1993) but although they prefer coarser sediment, this is not necessary for settlement and metamorphosis.

In the harbour of Antwerp, individuals of different lengths were found, ranging from 4 to 40 mm. In Mexican waters, adults range from 25 to 60 mm in length. Minimum length for mature adults ranges between 24 mm in Louisiana (Fairbanks 1963) and 14 mm in Virginia (Cain 1972). Wolfe and Petteway (1968) modeled clam growth with an L_∞ of 75.6 mm, which would represent a 10 year old individual. In Louisiana however, a maximum length of 94 mm was reported for *R. cuneata* (LaSalle and de la Cruz 1985). In fact these clams grow to their largest size in slightly brackish water that is too fresh to allow them to reproduce.

Distribution and invasion history

The known geographic distribution of *R. cuneata* ranges in the Gulf of Mexico from Laguna de Terminos, Campeche, Mexico in the east to north western Florida in the north and along the Atlantic coast of North America from Florida up to the lower portion of the Hudson River, New York (Dall 1894, Andrews 1971, Ruiz 1975, Carlton 1992, Wakida-Kusunoke and MacKenzie 2004). *Rangia cuneata* is considered to be native to the Gulf of Mexico and introduced to the NW Atlantic, where it is predominantly found in estuaries.

There were no sightings along the U.S. Atlantic coast until 1956, where *R. cuneata* was thought to be extinct since the Pleistocene (Hopkins and Andrews 1970). Along the Atlantic coast the

species was first observed again in Chesapeake Bay in the 1960s (Pfitzenmeyer and Drobeck 1964, Hopkins and Andrews 1970) where it might have been present before 1955 (Hopkins and Andrews 1970). Prior to the 1960s *R. cuneata* was not observed, while in the 1960s *R. cuneata* was extremely abundant and widespread in many estuaries on the U.S. Atlantic coast, reoccupying the whole distributional range occupied during the Pleistocene or warmer recent times (Hopkins and Andrews 1970). *Rangia* may owe its reappearance on the U.S. Atlantic coast to the transportation of *Crassostrea virginica* from the Gulf of Mexico to Chesapeake Bay (Pfitzenmeyer and Drobeck 1964) or to the transportation as larvae in ballast water from the Gulf of Mexico. However, it is also possible that the species is not a recent invader and had always been present in its historical range, but was overlooked. Thus, small populations of this species may always have been present in the Potomac drainage system but restricted to the headwaters of the small tributaries. Some unknown ecological change may have sparked the resurgence of a small undiscovered population surviving since the Pleistocene (Pfitzenmeyer and Drobeck 1964). The first observation further north, in the lower portion of the Hudson River, New York dates from 1988, where the species has probably been introduced through ballast water (Carlton 1992).

Discussion

Rangia cuneata has some history as an invasive species and specific environmental conditions may trigger a sudden outburst of the species, thus its sudden presence in the harbour of Antwerp is not really a surprise.

Similar to the recent invasion along the northern part of the U.S. Atlantic coast, the way of introduction in European waters is most likely as larvae in ballast water. The species has not been previously observed in Belgian waters, not even in the whole European brackish water scene. Two questions can be raised; (1) why *R. cuneata* was first found along the Schelde estuary and (2) why it did not appear or has been detected in European waters earlier.

Nehring (2006) hypothesized that estuaries, often being a combination of brackish water with its unsaturated niches and intensive international shipping, have the highest potential infection rate with alien species of all aquatic systems. Brackish water species also have, due to specific physio-

logical characteristics making them more resistant to external circumstances, a better chance of being transported alive than marine or freshwater species and they probably have a higher establishment potential after release (Wolff 1999). Indeed, in the oligohaline region of estuaries, *R. cuneata* occupies an otherwise rather "open niche" and as the species diversity is usually low, species adapted to this environment such as *R. cuneata* and the co-occurring *M. leucophaeata* (Verween et al. in press) may occur in large numbers (Cain 1975).

The species may have been misidentified in the past. Harbours are often difficult to sample biologically and infected industries mainly focus on destroying the species without fully identifying the species. There is no doubt about the new arrival of the species in the industrial plant of Antwerp harbour because of the ongoing monitoring study, but it cannot be excluded that *R. cuneata* was already present in the harbour prior to its current detection, but had never been found or identified as such.

Rangia cuneata should thus be considered a hazardous biofouling species. The presence of a layer of soft substrate however is expected to be a conditio sine qua non to initiate fouling of the inlet pipes of an industrial cooling water system. We hypothesize that the process of *Rangia* fouling may occur as follows: (1) *R. cuneata* settles into the (thin) layer of substrate, (2) once present the species will create hydrodynamically benign conditions, leading to an increased accumulation of substrate and (3) this extension of *Rangia*'s habitat leads to an increase of *Rangia* invasion. As such, *R. cuneata* infestation is hypothesized to progress through a vicious circle and will finally lead to a malfunctioning of the cooling water system, as observed in the study site. To avoid such problems, a more frequent cleaning of the pipes might be advisable: the lack of suitable soft sediment for settlement in the tubes is believed to be an effective measure against *R. cuneata* biofouling.

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