Large-scale tidal flats, facing the Yellow Sea, exist around the western coasts of South Korea (Hong 2000, Sato & Koh 2004). However, within South Korea, many reclamation projects are being carried out, with the largest being the Saemangeum Reclamation Project (Fig. 1). The goal of this project was the conversion of 401 km² of tidal flats and shallow sea into rice-fields and land for industry and tourism. The reclamation was facilitated by the construction of a 33 km long 6 m high dike over the tidal flats in the estuarine confluence of the Dongjin and Mangyeong Rivers (Fig. 2A). Therefore, it is not surprising that the Saemangeum reclamation is the world’s largest ongoing coastal reclamation project (Hong & Miller 2006).

The project was originally conceived in 1987, as a campaign promise of the former President Noh Tae-woo, and begun in 1991. Since June 2003, the northern part of the reclamation dike has been isolated, and the southern part of the dike was finally completed on April 21, 2006. Although the water gates, as yet, have not been closed completely, the tidal range inside the dike has decreased drastically after the dike’s completion. The intertidal zone inside the dike, therefore, gradually dried out a few months after the dike’s completion. In June 2006, it was confirmed that numerous shells of dead mollusks and other benthic animals were exposed on the dried mud flat (Fig. 2B–D).

The benthic animals in the Saemangeum area, especially mollusks, have been the subject of many of our recent studies (Yamashita 2001, Sato 2002, 2005, 2006, Sato & Yamashita 2006, Yamashita et al. 2006). About a hundred mollusk species from the sea and brackish waters in this area have been recorded (Yamashita et al. 2006). Around this area, the dominant mollusk species are: *Umbonium* (U) *thomasi* (Crosse, 1863), *Bullacta exarata* (Philippi, 1849), *Mactra veneriformis* (Reeve, 1854), *Tellina (Moerella) rutila* (Dunker, 1860), *Solen* (*Solen*) *strictus* (Gould, 1861), *Tellina (Moerella) rutila* (Dunker, 1860), *Meretrix petechialis* (Lamarck, 1818), *Cyclina sinensis* (Gmelin, 1791) and *Laternula* (*Exolaternula*) *martiala* (Reeve, 1860) in the tidal flats (Yamashita 2001, Sato 2002, 2006, Sato & Yamashita 2006), and *Glossaulax didyma* (Röding, 1798), *Rapana venosa* (Valenciennes, 1846) and *Ostrea denselamellosa* (Lischke, 1869) in the subtidal zone (Yamashita et al. 2006). *Umbonium* (U) *thomasi*, *Bullacta exarata* and *Meretrix petechialis* are endemic species in the Yellow and Bohai Seas, indicating that the Saemangeum area belongs to the biogeographical zone including the Yellow and Bohai Seas (Yamashita et al. 2006). Moreover, some possibly undescribed species, such as *Assimineidae* gen. et sp. 1 (Fig. 3A), *Assimineidae* gen. et sp. 2 (Fig. 3B), *Stenothyra* sp. (sensu Tamaki et al. 2002, Fig. 3C) and *Onchidiidae* gen. et sp. (sensu Fukuda 2000, Fig. 3D) and many others have been collected from this area (Yamashita et al. 2006).

A unique bivalve species, *Montacutidae* gen. et sp. (Fig. 4), attached to the shell of *Lingula anatina* (Lamarck, 1818).
Fig. 1.  A–B: Locality maps of the Saemangeum Reclamation Project in South Korea. Black bars represent the dike completed in each area. C: Location of the fixed stations in the tidal flats around Okbong-ri, Okseo-myeon, Gunsan City. (a) 57 stations studied in June 1987 by Hong & Lim (1988) and (b) 8–12 stations studied between Aug. 2002 and June 2006 by Sato (2006). D: Location of 10 stations in the tidal flats around Simpo-ri, Jinbong-myeon, Gimje City, studied between May 2000 and June 2006 by Sato (2006).

1801) was also found in our previous studies (identified as Galeommatidae gen. et sp. in Sato 2002, Sato & Yamashita 2006, Yamashita et al. 2006), with a shell length and width of 3–6.5 and 1–2 mm, respectively. The shell is long from the anterior to posterior portions, with a ventral margin curve inside (Fig. 4).

This species was found at three local tidal-flats inside the reclamation dike in the Saemangeum area; Okbong-ri, Okseo-myeon, Gunsan City (35°55′11032N, 126°36′11032E, Fig. 1C), Simpo-ri, Jimbong-myeon, Gimje City (35°50′37′′N, 126°40′21′′E, Fig. 1D) and Gaehwa-ri, Gaehwa-myeon, Buan-gun (35°47′11′′N, 126°37′09′′E). They were also found outside the dike near the Saemangeum area; Yubudo Is., Seocheon-gun, Buan-gun (35°55′55′′N, 126°36′15′′E, Fig. 1C), Simpo-ri, Jimbong-myeon, Gimje City (35°50′37′′N, 126°40′21′′E, Fig. 1D) and Gaehwa-ri, Gaehwa-myeon, Buan-gun (35°47′11′′N, 126°37′09′′E). They were also found outside the dike near the Saemangeum area; Yubudo Is., Seocheon-gun (36°00′20′′N, 126°37′09′′E, Kai et al. 2006) and Hajeon tidal flat, Gomso Bay (35°30′30′′N, 126°30′50′′E), but this species is very rare around the other coastal areas of South Korea and Japan. The existence of similar species attached to the shell of Lingula anatina has also been reported from the Philippines (as Mysella sp. in Savazzi 2001). However, taxonomic examinations of these bivalve species remain to be performed. Our current studies are preparing to describe these species, coupled with more thorough microanatomical studies in collaboration with Professor Jørgen Lützen, University of Copenhagen.

Depending on the abundance of Lingula anatina, the ectosymbiotic small bivalve, Montacutidae gen. et sp., is very rare, but of great importance in this very peculiar habitat. This species most likely feeds on mucus and/or detritus trapped in the mucus secreted by their host, L. anatina, and their preferential adaptive placement is near the inhalant currents of the host (Savazzi 2001). This unusual and remarkable microhabitat of the montacutid bivalve has been seriously threatened by the huge reclamation project around the Saemangeum area, which has very rapidly led to the decrease and eventual collapse of the biodiversity in this unique tidal flat habitat.

The density and vertical distribution patterns of Lingula anatina have altered dramatically during the last two decades, as based on the density measurements of Hong & Lim (1988) and Sato (2006) from the tidal-flats around Okbong-ri (Fig. 1C and 5, respectively). Lingula anatina were collected in abundance from many stations in the tidal-flats area between June 1987 and September 2003. However, their abundance has decreased since September 2003, and they had finally disappeared from this area by June 2006 (Fig. 5). Also, in Simpo-ri (Fig. 1D), a large number of Lingula anatina and Montacutidae gen. et sp. were collected from quadrat samples (size 25 cm × 25 cm, depth 20 cm) between May 2000 and September 2003 (Fig. 6). The mean densities of Montacutidae gen. et sp. are between 1.0 and 6.4 indiv. m−2, with attachment rates of 1.69 to 5.97% (Table 1). The calculation of the attachment rate assumed that each bivalve attaches to a separate Lingula shell. However, the numbers of Lingula anatina in this area have decreased drastically since September 2003, and Montacutidae gen. et sp. have also not been collected from
samples since this time (Fig. 6). The other bivalves and gastropods in this area have also rapidly decreased since the completion of the northern part of the reclamation dike in June 2003 (Sato 2006). Moreover, the southern part of the dike was finally completed in April 2006. Although some *Lingula anatina* are still alive 2 months after the completion of the dike (Fig. 6), they will soon die off when the water gates are closed. In fact, numerous dead shells of *Lingula anatina* were found on the dried mud flat in June 2006 (Fig. 2D).

In addition, when the water gates are closed, about one hundred mollusk and numerous other species of other marine animals will be extinct in this area. It is an especially serious problem that the huge tidal flats, the habitats of benthic animals, will be destroyed. Biological information about some of the unique mollusks from this area is still limited. For example, *Montacutidae* gen. et sp. may have important implications in the evolutionary histories of both mollusks and brachiopods, although their most significant habitat in South Korea, Saemangeum, will be destroyed. Many important biological resources are now suffering great losses due to the Saemangeum Reclamation Project.

This area also supports the livelihoods of an estimated 25,000 people and some of the largest and most important concentrations of migratory birds in Asia. For example, some mollusk species that live in tidal flats, such as *Glosaulax didyma*, *Mactra veneriformis*, *Solen strictus*, *Meretrix petechialis* and *Cyclina sinensis*, are of practical use as Korean foods, but nevertheless these fishery and food resources will simultaneously vanish.

In 1997, the Korean government signed onto the Ramsar Convention in order to protect wetlands, and in January 2006, the Suncheon Bay tidal-flat on the southern coast of Korea was registered in the Ramsar list. Given these conservation efforts, it is incomprehensible to many scientists, environmental activists and other observers that the governance...

**Fig. 5.** Temporal changes in the individual densities of *Lingula anatina* in the tidal flats around Okbong-ri, Okseo-myeon, Gunsan City, between 1987 and 2006. The 1987 data are modified from those of Hong & Lim (1988); those between 2002 and 2006 are from Sato (2006).

**Table 1.** Temporal changes in the individual densities of *Lingula anatina* and *Montacutidae* gen et sp. and their attachment rates in the tidal flats around Simpo-ri, Jinbong-myeon, Gimje City, between 2000 and 2006.

<table>
<thead>
<tr>
<th>Sampling date and number of sampling stations (in parentheses)*</th>
<th>Mean density (indiv. m(^{-2}) of <em>Lingula anatina</em>)</th>
<th>Mean density (indiv. m(^{-2}) of <em>Montacutids</em>)</th>
<th>Attachment rate (%) of <em>Montacutids</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>May 4, 2000 (12)</td>
<td>44.0</td>
<td>1.0</td>
<td>2.27</td>
</tr>
<tr>
<td>Sep. 1, 2001 (4)</td>
<td>32.0</td>
<td>12.0</td>
<td>37.50</td>
</tr>
<tr>
<td>Aug. 16, 2002 (8)</td>
<td>36.0</td>
<td>2.0</td>
<td>2.78</td>
</tr>
<tr>
<td>May 5, 2003 (10)</td>
<td>46.0</td>
<td>3.2</td>
<td>1.69</td>
</tr>
<tr>
<td>July 20, 2003 (9)</td>
<td>64.0</td>
<td>3.6</td>
<td>5.56</td>
</tr>
<tr>
<td>Sep. 25, 2003 (10)</td>
<td>107.2</td>
<td>6.4</td>
<td>5.97</td>
</tr>
<tr>
<td>Oct. 2, 2004 (10)</td>
<td>28.8</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>May 8, 2005 (10)</td>
<td>16.0</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>Dec. 6–7, 2005 (10)</td>
<td>4.8</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>Mar. 14, 2006 (10)</td>
<td>4.8</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>June 13, 2006 (10)</td>
<td>11.2</td>
<td>0.0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* In each station, a quadrat sample (size 25 cm × 25 cm, depth 20 cm) was collected.
* The calculation of the attachment rate assumed that each bivalve attached to a separate *Lingula* shell.
A crisis of unique mollusk in South Korea

Fig. 6. Temporal changes in the individual densities of *Lingula anatina* and Montacutidae gen. et sp. in the tidal flats around Simpo-ri, Jinbong-myeon, Gimje City, between 2000 and 2006.

all kinds of estuarine-dependent wildlife—from polychaete worms and shellfish to water birds—will disappear. Ultimately the removal of such a vast wetland will have an impact on the entirety of the Yellow Sea over the long-term (Hong & Miller 2006).

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