Historical occurrence of the short-neck clam, *Ruditapes philippinarum* (Adams & Reeve, 1850), on the sandy flats of Ariake Bay, Kyushu, western Japan

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Abstract: Long plate-like sediment samples were collected using a Geoslicer technique at five different sites on the sandy tidal flats along the eastern coast of Ariake Bay, Kyushu, western Japan, where there are major harvesting sites of the edible clam *Ruditapes philippinarum*. The deposition process of the sediment and fossil contents of the shellfish in these Geosliced samples were examined, dating the deposition process of the sediment to at least 400 years ago with a trace of a giant tsunami that occurred in 1792, and radio-active matters (¹⁴C contained in the wood pieces, ²¹⁰Pb and ¹³⁷Cs), and describing the distribution of the fossil contents of the shellfish in the sediment samples. These results indicate that dense patches of *R. philippinarum* were established later than 180 to 190 years ago at the sampling sites, and it is very likely that this species was introduced to the sandy tidal flats in Ariake Bay in an anthropogenic way. This conclusion coincides with archaeological evidence collected from shell mounds established in the coastal areas of Ariake Bay during the Jomon and Tumulus Periods (13,000 BC to 600 AD). *Ruditapes philippinarum* was very rare among fossil shells collected from the shell mounds except one created at the mouth of the bay. This species does not favor the water conditions in the estuary where the salinity tends to be variable due to the inflow of freshwater from rivers. It seems that various kinds of human manipulation are essential for *R. philippinarum* to be maintained in large numbers on the tidal flats at the mouths of the rivers in the inner parts of Ariake Bay.

Key words: Ariake Bay, Geoslicer cores, *Ruditapes philippinarum*, shell mounds, tidal flats

Introduction

The Japanese carpet shell, *Ruditapes philippinarum* (Adams & Reeve, 1850), a species of edible clam, is one of the most common species in the macro-benthic communities occurring on sandy tidal flats throughout the coastal areas of Japan, Korea and China (Magni et al. 2000, Ishii et al. 2001, Kakino 2006, Kudo et al. 2006, Komorita et al. 2009, Mizuno et al. 2009). It is a northern West Pacific species, the known distribution of which includes the Philippines, the South and East China Seas, the Yellow

Sea, the Sea of Japan, the Sea of Okhotsk, and the southern Kuril Islands. In those areas, mariculture was initiated from traditional fishing activities by seeding with animals collected in the wild. Of considerable commercial value, *R. philippinarum* has been introduced also to other parts of the world including the Pacific coast of North America and European waters, where they have become permanently established (FAO 2015).

This species often establishes colonies with a density of over 1 kg m⁻² in Ariake Bay (Tsutsumi 2006, Tsutsumi et al. 2003). The total harvest of this species in Japan fluctuated between approximately 120,000 and 160,000 tons in the 1970s and the early 1980s but decreased drastically from the latter half of the 1980s (Ishii et al. 2001, Seki-

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guchi & Ishii 2003, Matsukawa et al. 2008, Mizuno et al. 2009). Various causes for this decline have been suggested, including: loss of the tidal flats; occurrence of hypoxic water (Kakino 2006, Yamaguchi & Uchikawa 2005); drastic decrease in salinity due to heavy rain (Kakino 2006); deposition of mud and/or high concentration of manganese (Fujimori et al. 1983, Tsutsumi 2005, Tsukuda & Tsutsumi 2008); infection by protozoan parasites (Hamaguchi et al. 2002, Choi & Park 2010); increase in mortality of planktonic stage (Sekiguchi & Ishii 2003); predation by rays and gastropods (Nakahara & Nasu 2002, Ohkoshi 2004); competition with ghost shrimp (Tamaki 2004). However, the actual mechanism(s) causing the drastic decrease in the harvest are still not clear. In 2010, only about 27,000 t were harvested from Japanese coasts (Ministry of Agriculture, Forestry and Fisheries 2014).

Some of the most popular harvesting sites for *R. philippinarum* in Japan are the sandy tidal flats of Ariake Bay, in western Kyushu (Fig. 1). There, vast areas of sandy tidal flats of over 7,000 ha in total area still remain along the eastern coast of the bay, although approximately 40% of the tidal flats in the area have disappeared during the last half-century (Takahashi 1994). In the 1970s, the annual harvest of *R. philippinarum* on the sandy tidal flats of Ariake Bay reached over 100,000 t per year, which accounted for more than 70% of the national total harvested in those days. However, the clam harvesting fishery in Ariake Bay collapsed in the 1980s, and the annual harvest has declined to less than 10,000 t per year since the 1990s (Sasaki 1999, Kikuchi 2000, Tsutsumi 2005, Ministry of

Environment 2006, Shinohara et al. 2009), even though the total area of sandy tidal flat habitat favored by *R. philippinarum* has decreased only slightly in Ariake Bay since the 1960s (Environment Agency 1994). Therefore, the drastic decrease of the national total harvest of this species is mainly due to the collapse of the clam harvest in Ariake Bay since the 1980s (Tsutsumi 2006).

The present study focuses on changes in the sedimentation of sand and silt and the occurrence of shellfish including *R. philippinarum* on the sandy tidal flats in Ariake Bay over the past 400 years from the standpoint of geological history. Long plate-like sediment samples over 5 m in length were collected using a Geoslicer technique at five different sites on the sandy tidal flats along the eastern coast of Ariake Bay, at major harvesting sites of *R. philippinarum*. The deposition process of sediment and the fossil contents of the shellfish in these geosliced samples were examined, calibrated by deposits from a tsunami caused by the eruption of a volcano, Mt. Unzen, located on the Shimabara Peninsula facing Ariake Bay in 1792. Radioactive content (^{14}C contained in pieces of wood; and ^{137}Cs , and ^{210}Pb in the sediment samples) was also measured, and used to describe the distribution of the fossil component of shellfish in the sediment samples. Excavation records of shell mounds found in the coastal areas of Ariake Bay (which were established during the Jomon and Tumulus Periods; 13,000 BC to 600 AD) were examined to compare the species composition of edible shellfish in ancient times with that of the present. From these results, historical changes in the occurrence of *R. philippinarum* on the san-

Fig. 1. Map of the sampling areas.

dy tidal flats in Ariake Bay were obtained as a contribution towards understanding the drastic decrease in the harvest independent of the decrease of potential habitats since the 1980s.

Table 1. GPS information for the five different coring sites in Ariake Bay.

Tidal flat sampling site	Map coordinates	Date
Off Kawazoe, Saga Pref.	33° 07' 43.75" N 130° 17' 55.67" E	Sept. 29, 2005
Off Yanagawa, Fukuoka Pref.	33°06'34.65"N 130°22'11.97"E	July 14, 2008
Arao, Kumamoto Pref.	32°58'56.99"N 130°25'37.32"E	April. 24, 2004
Kikuchi River Tamana, Kumamoto Pref.	33°51'35.79"N 130°30'50.14"E	May 16, 2007
Midorikawa (River Midori), Kumamoto City, Kumamoto Pref.	33°43'12.13"N 130°33'48.92"E	Aug. 26, 2011

Materials and Methods

Study areas

Ariake Bay is located on the western side of Kyushu (33°00'N, 130°20'E; Fig. 1). It is the largest enclosed bay in Kyushu with an area of about 1,700 km². The maximum tidal range reaches over six meters in the innermost areas of the bay during spring tides, and includes large areas of tidal flats totaling over 20,000 ha. On the eastern coast of the bay, the sediment of the tidal flats is mostly sand and silt. Five sampling points were allocated (at Kawasoe, Yanagawa, Arao, Ohama, and Midorikawa; Table 1) to collect the geoslice sediment samples on the sandy tidal flats, which are popular harvesting sites for *R. philippinarum*.

Sediment sampling

Samples were taken using the geoslicer technique, which has been commonly applied to soil sampling at alluvial lowlands composed of unconsolidated water-saturated soft

Fig. 2. Sediment sampling with the geoslicer technique: (a) from a workbench ship with a crane in shallow coastal waters; (b) using a crane standing on the tidal flats; (c) using a portable geoslicer; and (d) A sediment core sample collected with the geoslicer technique.

sediments (Nakata & Shimazaki 1997, Haraguchi et al. 1998). This technique enables large, plate-like sediment samples to be obtained with the inherent structure of the sediment profile retained intact. The sampling gear consists of three parts: a sampling tray with narrow flanges, a shutter plate, and two clips that fasten the shutter plate to the sampling tray. At Kawazoe, Yanagawa, and Midorikawa, the sampling tray, about 5 m in length, was suspended from a crane on a workbench ship, and inserted in the sediment with a vibrating hammer (Fig. 2a). At Arao, it was inserted from a mobile crane standing directly on the tidal flats (Fig. 2b). At Ohama, a portable sampling tray, about 1 m in length, was inserted into the sediment by hand (Fig. 2c). For each sample, a shutter plate was inserted along the sampling tray in the sediment with the same methods as the sampling trays, and was fastened to the sampling tray with two clips. Finally, the apparatus was lifted out to remove the sediment sample (Fig. 2d).

Sediment sampling was conducted at Arao on April 24 in 2004; at Kawazoe on September 29, 2005; Ohama on May 16, 2007; Yanagawa on July 14, 2008; and Midorikawa on August 26, 2011. At each site, 3 to 5 of the geoslice samples were collected for observation of the sedimentary structure; 3 to 5 samples for dating of sediment; and 4 to 11 samples for fossil shell analysis. The sedimentary structure of the geoslice samples was observed on land adjacent to the sampling site within a few days of obtaining the sample, and schemata of the distribution of sediment types within the profiles were drawn. A sub-sample of approximately 30 g of sediment from one geoslice was used for gamma spectrometry and 22–65 g of sediment was sub-sampled from a separate geoslice at 5 cm depth intervals to determine the faunal composition of fossil shells. Pieces of wood in the geoslice samples collected at Midorikawa were used for ^{14}C dating.

Dating the sediment with ^{14}C

A Libby half-life of 5,568 years was used to determine the ^{14}C age of wood samples, following Stuiver & Polach (1977). Carbon was recovered as CO_2 by combustion of the wood pieces and acid decomposition of the shell pieces, and then converted to graphite for accelerator mass spectrometry (AMS) analysis. The isotope ratio of $^{14}\text{C}/^{12}\text{C}$ was obtained using a IAA-AMS 3MV AM spectrometer at the Shirakawa Analysis Center of the Institute of Accelerator Analysis Ltd., Kawasaki, Japan (IAA). The ^{14}C year was calculated from the $^{14}\text{C}/^{12}\text{C}$ ratio and $\delta^{13}\text{C}$ value to calendar years Before Present (yBP) using IntCal09 (Reimer et al. 2009), where 1950 AD is defined as “Modern” by convention. The ^{14}C age was determined by the IAA.

Dating the sediment with ^{137}Cs and ^{210}Pb

Sub-sampled sediment for gamma spectrometry was dried at 105°C in an air oven. After removing pieces of shell by hand, samples were grounded with a pestle and mortar, and each sub-sample was placed into a plastic U-8

container (48 mm in inner diameter) to a maximum height of 25 mm. The radioactivity of the sample was measured using a gamma spectrometer equipped with a low-background type Ge detector (GMX, relative efficiency 55.4%, EG&G ORTEC Ltd., USA) shielded with massive lead blocks (15 cm in thickness) and 4 mm thick oxygen-free copper inside. The spectrum was stored in a 4096 multi-channel analyzer for more than 48 h, and analyzed with a computer program, “Gamma Studio” (SEIKO EG&G Ltd., Japan). The counting efficiency for each gamma energy peak was estimated from counting efficiency curves which were prepared using a set of gamma standard U-8 sources with different heights certified by the Japan Radioisotope Association. The sedimentation mass was calculated from the wet and dry weights of each increment. The depth profiles of ^{210}Pb and ^{137}Cs against the cumulative sedimentation mass from the surface of the sediment were constructed to calculate the sedimentation rate, and to estimate the sedimentation year.

Fossil shell analyses

Sediment samples of 35 cm in width and 10 cm in thickness were subsampled for fossil shells from the geoslice samples every 20 cm, except for samples from Ohama (where sample sizes were 9 cm in width and 2 cm in thickness because sampling used the portable geoslice technique). Each sediment subsample was sieved on a 2 mm mesh and fossil shells were picked out by hand. All molluscan fossil shells were identified to species level. Complete and damaged shells of each species were counted as one specimen where the umbonal area was preserved for bivalve species. Dominant species in each sediment sample were determined by differences between the theoretical and the measured values, according to the law of MacArthur series (MacArthur 1960; see Shimoyama & Hamano 1980 for details). In the other words, the species where the measured individual number was larger than the theoretical numbers was treated as a dominant species. The deepest bivalve assemblages with *R. philippinarum* were determined in all of the geoslice samples for fossil shell analysis in order to estimate the earliest date of colonization by *R. philippinarum* at each of the five sampling sites.

Results

Historical structure of the sediment samples

Fig. 3 shows images of the sedimentary slice profiles obtained at the five different sampling sites in Ariake Bay. In four of these five samples, a disturbed layer was identified at depths of 150 cm at Kawazoe, 90 cm at Yanagawa, 130 cm at Arao, and 220 cm at Midorikawa. Fig. 4a is a magnified image at the disturbed layer of the sample collected at Midorikawa. Current ripples (Ts) are indicative of flow from the offshore side toward the onshore side. Scoria gravels produced by a volcanic eruption or the reworking

Fig. 3. Images of the sediment profiles collected at the five different sampling sites in Ariake Bay. Arrows indicate the presence of the disturbed layer made by the tsunami resulting from the eruption of Mt. Unzen, in 1792.

Fig. 4. (a) A magnified image around the disturbed layer created at a depth of about 220 cm in the sediment profile collected at Midorikawa on August 26, 2011. Abbreviations: Ts deposits made by the 1792 tsunami; M mud; S sand. (b) Scoria gravels collected from the disturbed layer (Ts).

were found in this Ts layer (Fig. 4(b)).

Table 2 lists the results of ^{14}C dating of wood pieces sampled, which were found in three different layers of the sediment profile collected at Midorikawa. The wood sample from the 210 cm layer was apparently deposited between 1798 and 1850 (2σ , 41%). This estimated age is immediately after the time when Mt. Unzen (located in Shimabara Peninsula facing Ariake Bay) partly collapsed due to an explosion halfway up the volcano, which in 1792 caused a massive tsunami exceeding 20 m in height (Katayama 1974). These events, including the collapse of the mountain and occurrence of the tsunami, are referred in Japan as the Shimabara Catastrophe, which appears to cor-

respond to the disturbed layer at 220 cm in the sediment profile from Midorikawa. All of other disturbed layers characterized by the presence of current ripples and scoria gravels in sediment profiles collected at three other sites (Kawasoe, Yanagawa, and Arao) are also best interpreted as being made by the tsunami, although the depth of the disturbed layer varies, apparently due to different sedimentation rates. The sample collected at Ohama apparently did not reach the disturbed layer made by the tsunami.

Table 3 shows the age indices recognized in the sedimentary slice profiles with the results of dating with radioactive intensities of ^{137}Cs and ^{210}Pb and the trace of the tsunami of 1792. The peak of the radioactive intensity of ^{137}Cs

Table 2. Results of ^{14}C dating of wood pieces found in the sediment samples at Midorikawa in Ariake Bay.

Core	Depth (m)	Labo number	^{14}C age	Cal yBP (2σ)	Calibrated age* (2σ : AD/BC)	Material dated
MDGS3	0.5	IAAA-121287	Modern			Wood fragment
MDGS3	0.7	IAAA-121288	160 $\pm$ 20	252–284 (0.16) 166–225 (0.41) 135–184 (0.11) 72–115 (0.09) 0–34 (0.19)	AD 1666–1698 (0.16) AD 1725–1784 (0.41) AD 1796–1815 (0.11) AD 1835–1878 (0.09) AD 1916–1952 (0.19)	Wood fragment
MDGS3	1.3	IAAA-121289	340 $\pm$ 20	314–478 (0.95)	AD 1472–1636 (0.95)	Wood fragment
MDGS3	1.5	IAAA-121290	300 $\pm$ 20	445–454 (0.16) 348–438 (0.67) 297–334 (0.27)	AD 1496–1505 (0.16) AD 1512–1602 (0.67) AD 1616–1653 (0.27)	Wood fragment
MDGS3	1.9	IAAA-121291	520 $\pm$ 20	609–622 (0.06) 511–555 (0.90)	AD 1328–1341 (0.06) AD 1395–1439 (0.90)	Wood fragment
MDGS2	2.1	IAAA-111783	140 $\pm$ 20	241–274 (0.15) 172–233 (0.23) 100–152 (0.41) 9–40 (0.17)	AD 1676–1709 (0.15) AD 1717–1778 (0.23) AD 1798–1850 (0.41) AD 1910–1941 (0.17)	Wood fragment
MDGS2	2.3	IAAA-111784	1,000 $\pm$ 20	906–964 (0.84) 827–853 (0.09) 801–810 (0.02)	AD 986–1046 (0.84) AD 1093–1121 (0.09) AD 1140–1149 (0.02)	Wood fragment
MDGS2	2.9	IAAA-111785	1,250 $\pm$ 20	1128–1270 (0.93) 1090–1108 (0.03)	AD 680–822 (0.93) AD 842–860 (0.03)	Wood fragment
MDGS2	4.9	IAAA-111786	2,290 $\pm$ 20	2306–2351 (0.81) 2205–2233 (0.12) 2185–2195 (0.03)	BC 402–357 (0.81) BC 284–256 (0.12) BC 246–235 (0.03)	Wood fragment

* Ages were calibrated used with Intcal09 programs (Reimer et al. 2009)

2σ shows 95.4 % probability

Table 3. Age indexes in the sediment samples collected at the five different coring sites in Ariake Bay.

Criteria of age	Age index	Kawazoe	Yanagawa	Arao	Ohama	Midorikawa
Peak of Cs-137 intensity	1963 AD	15	25	10	40	60
Detection limit of Pb-210	150 years ago	no data	60	75	110	unknown
Depth of Tsunami event	1792 AD	150	90	150	no data	210
Head		Kawazoe	Yanagawa	Arao	Ohama	Midorikawa
Colonized depth of <i>R. philippinarum</i> (cm)		50	80	100	108	80
Colonized age of <i>R. philippinarum</i> (yBP)		1915 AD	1815 AD	1825 AD	1865 AD	1935 AD

Fig. 5. Ten dominant species of fossils bivalves collected from the sediment profiles at Midorikawa in Ariake Bay on August 26, 2011. Bars indicate 10 mm.

contained in the sediment indicates 1963 AD, which was the global peak of ash deposition from nuclear tests (Hirose et al. 2008, Richie & McHerry 1990). It was found at depths between 10 and 60 cm in the sediment profiles from the five sampling sites. The radioactive intensity of ^{210}Pb is maximal when lava has appeared on the surface of the Earth, decreasing with half-life of 22.3 y to background levels less than 1% of the initial value within 150 years (cf. Kanai 2000). Background level was recognized at a depth of 60 cm from the surface at Yanagawa, 75 cm at Arao, and 110 cm at Ohama. Both the peak of radioactive intensity of ^{137}Cs and the depth of detectable radioactivity of ^{210}Pb were located above the traces of the tsunami marked at 1792 AD.

Fossil shell analysis

Fig. 5 shows the ten dominant species in the fossil shell assemblages, including *R. philippinarum*, collected from the samples at Midorikawa, and Fig. 6 indicates the vertical profiles of the number of each species collected and the total numbers of fossil shells in one of the sediment samples. There were two peaks for the occurrence of fossil bivalves in the sample: between 50 and 70 cm; and between 220 and 350 cm. The former peak was composed mainly shells of *R. philippinarum*, and *Macra veneriformis*. The latter was composed of shells of *Cadella delta* and *Nuttallia japonica*. Very few fossil shells of *R. philippinarum* were found in the layers below a depth of 80 cm.

The occurrence of fossil shells of *R. philippinarum* was examined also in sediment samples collected at the other four sampling sites. Fig. 7 indicates the sediment deposition process and occurrence of fossil *R. philippinarum* were at all five sampling sites. Fossil shells of *R. philippinarum* were concentrated in the layers above depths of around 50 cm at Kawazoe, 80 cm at Yanagawa, 100 cm at Arao, 108 cm at Ohama, and 80 cm at Midorikawa. The limit of occurrence of fossil *R. philippinarum* was located above the trace of the 1792 tsunami at all five sampling sites.

Estimation of the age of the first occurrence of gregarious *R. philippinarum*

Fig. 8 illustrates the relationships between the age of different sediment layers and depth. Information on the occurrence of the fossil *R. philippinarum* (Figs. 6 & 7) enables estimation of the year of first colonization of this species at each sampling site (see Figs. 8 & 9). Thus, *R. philippinarum* should be treated as an introduced species in the macro-benthic communities on the sandy tidal flats on the eastern coast of Ariake Bay from the view point of archaeology, although it is currently a dominant bivalve of the macro-benthic community.

Fig. 6. Vertical profile and numbers of dominant fossil bivalve shells in a sediment profile collected at Midorikawa on August 26, 2011.

Fig. 7. Shema illustrating the vertical distribution of sediment types and deposits made by the tsunami of 1792 in the five sampling sites.

Discussion

Archaeological evidences of the occurrence of *Ruditapes philippinarum*

It is deduced from the results of this study that *R. philippinarum* was introduced to the sandy tidal flats of Ariake Bay about 180 to 190 years ago. This conclusion coincides

Fig. 8. Relationships between sedimentation depth and age in the sediment profiles from the 5 sampling sites, derived from 3 calibration points: the tsunami of 1792 (cf. Figs. 3 & 4), and the radioactive isotopes ^{137}Cs and ^{210}Pb (see text and cf. Tables 2 & 3). The arrow on the ordinate and corresponding dashed line indicate the deepest depth of occurrence of fossil shell *Ruditapes philippinarum* (cf. also Figs. 6 & 7); those on the abscissa indicate the corresponding estimated age.

also with the archaeological evidences from shell mounds (middens) established in the coastal areas of Ariake Bay, which were established during the Jomon to Tumulus Periods (13,000 BC to 600 AD). The species composition of the shell mounds reflects that of the most popular edible mollusks in those periods. Fig. 10 shows the species compositions of the mollusks in the shell mounds established in coastal areas of Ariake Bay (History of City Editing Committee of Arao City 2012, History of City Editing Committee of Itsuwa Town 2000, Editing Committee of Jyonan Town 1965, History of City Editing Committee of Tensui Town 2005, Isahaya City Education Board 2011, Itsuwa Town Education Board 2000, Kumamoto Prefecture Education Board 1978a, 1978b, 1980, 1986, 1998, 2005, Misumi Town Education Board 1979, 1984, 1998,

Oomuta City Education Board 2012, Saga Prefectural Museum 1981, Saga City Education Board 1978, Uto City Education Board 2008, 2011). According to these records, one or more of the bivalves *Meretrix lusoria*, *Tegillarca granosa*, *Crassostrea gigas*, or *Corbicula japonica* were dominated the species composition of shells in Ariake Bay middens. The dominance of *R. philippinarum* shells was particularly noticeable at shell mounds from Futowo in Amakusa Shimoshima, which is located at the mouth of Ariake Bay (Itsuwa Town Education Board 2000). These records suggest that the distribution of *R. philippinarum* was limited at the mouth of Ariake Bay (between 13,000 BC and 600 AD).

Fig. 9. The estimated range of ages at which *Ruditapes philippinarum* occurred at the five different sampling sites and a location with the shell mounds (Goryo) in Ariake Bay.

Fig. 10. Species compositions of mollusks from shell mounds (kitchen middens) in coastal areas of Ariake Bay, which were established between the Jomon and Tumulus Periods (13,000 BC to 600 AD).

Extension of sand flats in Ariake Bay after the tsunami of 1792

The sediment samples collected at the five different sites in Ariake Bay in this study provide more detailed information on the possibility of colonization by *R. philippinarum*. Sediment below traces of the 1792 tsunami consists mainly of fine particles, changing to sandy above this region (Fig. 7). The muddy sediment below the tsunami trace is not a suitable environment for the most dominant bivalves of recent sandy tidal flats, *R. philippinarum* and *Mactra ven-*

eriformis (Fig. 6). This suggests that the tsunami caused changes to the bottom environment favoring colonization by *R. philippinarum* well before the anthropogenic introduction of *R. philippinarum* to the tidal flats in Ariake Bay about 180 to 190 years ago. It is worth noting that initial colonization by *R. philippinarum* was on the central sand flat but not mouth of Ariake Bay. It is very likely that this species was introduced to the sandy tidal flats by human hands in order to develop the coastal shellfish fishery about 180 to 190 years ago, during the mid nineteenth century.

Although the result of this study enabled deduction of an anthropogenic introduction of *R. philippinarum* to the tidal flats of Ariake Bay, the spontaneous colonization by arrival of planktonic larvae remains a probability.

Conclusion

Analysis of sediment samples was carried out to investigate the history of the *R. philippinarum* fishery in the Ariake Bay, with the results showing that it occurred within the last 200 years. The composition of shell assemblages from shell mounds dating from ca 15,000 to 1400 years ago in the areas adjacent to Ariake Bay strongly support this conclusion. Although the tsunami in 1792 enlarged the sand flats and provided a suitable habitat for *R. philippinarum* in Ariake Bay, colonization began at the innermost part of Ariake Bay, which strongly suggests that it was introduced artificially.

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