Yamato-Shijimi and Environmental Changes in Lake Jusanko, Northern Japan, Over the Past Several Thousand Years

Naoto Koiwa and Mio Takahashi

Abstract This work involves the reconstruction of environmental changes regarding Yamato-shijimi (*Corbicula japonica*) over the past several thousand years based on a geomorphological study. Although a large amount of *Corbicula japonica* is currently available in Lake Jusanko located in northern Japan, a brackish lake, the environment has been observed to have experienced significant changes over the past several thousand years. In the study area, the effects of seawater became strong about 6,000 years ago because of the Holocene transgression. However, a period from 4,000 to 2,500 years ago, a stratified lake was formed in which has the halocline between epilimnion strongly affected by freshwater and predominant hypolimnion of seawater. During this period, an unsuitable environment for the growth of *Corbicula Japonica* spread. Subsequently, rivers transported large amounts of sediments through heavy rains generated in monsoon Asia, and the lake became shallow. Seasonal winds that are characteristic of East Asia frequently agitated the lake water, leading to the development of a brackish water environment that supported the conditions for *Corbicula japonica* to thrive.

Keywords Lagoon · Brackish water · Diatom analysis · Holocene

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S. Yokoyama et al. (eds.), *Nature, Culture, and Food in Monsoon Asia*,
International Perspectives in Geography 10,
https://doi.org/10.1007/978-981-15-2113-3_5

1 Introduction

In Aomori Prefecture, there are television commercials in the early morning showing catches of Yamato-shijimi (*Corbicula Japonica*, commonly known as Japanese basket clam[1]) and powder products extracted from basket clams simmered in large pots. The authors of this chapter, residents of this prefecture, frequently experience hangovers, and the images of these commercials have the amazing effect of restoring upset stomachs. Several years ago, we drank an ample amount of alcohol, but also consumed a cup of basket clam soup, dried basket clams, and basket clams braised in soy sauce as side dishes. The next morning, we felt invigorated, which appeared to be an effect of *Corbicula japonica*. The amino acids alanine and glutamine found in the body of *Corbicula japonica* activate alcohol dehydrogenase enzymes in the human body,[2] giving the clams restorative properties.

Lake Jusanko in Aomori Prefecture holds top records for catches of *Corbicula japonica* in Japan. The Tsugaru Plain, located next to the lake, is home to numerous archaeological sites from the Jomon period and onward, such as the Kamegaoka Ruins. A large amount of *Corbicula japonica* shells have been discovered at these sites. Having a palliative effect on the stomach, the shellfish must have played an unmistakable role in the health of people since the Jomon period. Furthermore, *Corbicula japonica* diggers appeared to have been able to earn high incomes. In a section of a settlement near Lake Jusanko, large houses called “basket clam palaces” can be seen. Therefore, *Corbicula japonica* brought not only health benefits to people but also economic benefits to the region.

Our research interest is geomorphology, which seeks to understand how the terrain of a region is formed. Unlike the other chapters, here we describe the historical formation of Lake Jusanko and its environmental changes impacting *Corbicula japonica* over a long time scale of several thousand years.

2 Locality of *Corbicula Japonica* in Lake Jusanko

Lake Jusanko is a brackish lake located in the northernmost part of Honshu (Fig. 1). Although it has a surface area of 18.6 km^2, its depth is only 2 m at most, yielding a volume of just 16 million m^3. Considering its wide surface area, the lake has a small volume.

Lake Jusanko has a long barrier separating it from the Sea of Japan. Many brackish lakes have mouths where lake water flows out and seawater flows in. In the

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[1]For purposes of general descriptions and cases, this paper will use the term basket clams. For purposes of the paper’s scientific theme, this paper will use *Corbicula japonica.*

[2]Fisheries Cooperative Association of Lake Jusanko http://www.trace-info.jp/jusanko/大和シジミとは/. Accessed 28 Jan 2018.

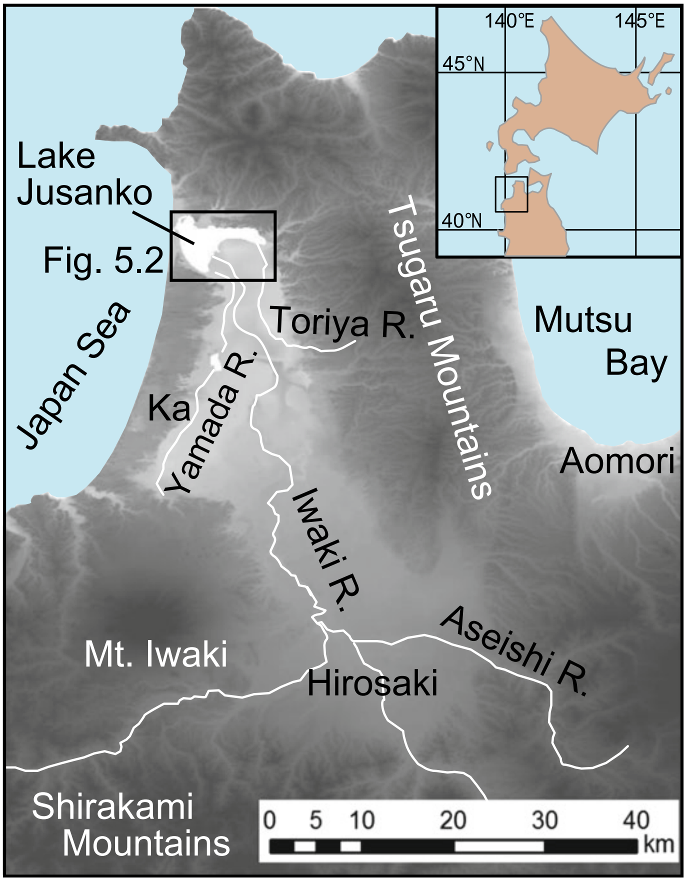

Fig. 1 Location map of the study area. Ka: Kamegaoka Ruins

case of Lake Jusanko, a large amount of sand is deposited at its mouth by strong winter winds and turbulent waves, blocking the exit of lake water to the sea. This blockage has induced frequent flooding upstream of the river flowing into the lake. To address these issues, a breakwater and training dike structure has been constructed. Currently, a moderate amount of seawater enters from this structure, creating a brackish water environment (Sasaki et al. 2011).

Corbicula japonica live in shallow water regions (depth of 4–5 m or less) (Ishikawa 2001). From the standpoint of depth, Lake Jusanko is perfectly suited as a habitat for *Corbicula japonica*. In brackish lakes, seawater from the open seas flows in and settles at the bottom of the lake because it is relatively heavier than fresh water, forming a halocline. This induces a dysoxic environment in the hypolimnion. If this dysoxic state continues for a long period of time, the lake would no longer be a suitable habitat for brackish water clams such as *Corbicula japonica* (Ishikawa 2001). In the Lake Jusanko region, cold winds called the

Yamase blow in from the Pacific Ocean (eastern) side several times from spring to summer. During winter, strong seasonal winds also blow in from the Sea of Japan side. These winds cause the mixing of seawater flowing in from the Sea of Japan and freshwater supplied by the Iwaki River, preventing the formation of a halocline in Lake Jusanko.

A delta has been formed in the lowest downstream region of the Iwaki River, where sediments transported by the river to water regions, such as the lake and the sea, accumulate. The gradient of the delta is finely divided into the foreset bed, where coarse sand from the large amount of dirt and sand flowing into the lake during flooding is deposited near the river mouth, and the bottomset bed, where fine sediment particles such as dirt in the inflow are suspended and slowly settle near the center of the lake. *Corbicula japonica* prefer sandy soil composed of less than 10% dirt (Nakamura 2000). Combining the topographical map of Lake Jusanko presented by Hirai (1994) and the density distribution of *Corbicula japonica* habitation from the Inland Water Fisheries Research Institute (2010), the habitat density of *Corbicula japonica* was found to be the highest at the delta plain and delta front (foreset bed), composed of sand, and on shelves near lakeshore areas (Fig. 2). Meanwhile, the distribution density of *Corbicula japonica* is low in areas corresponding to the bottomset bed, where dirt accumulates.

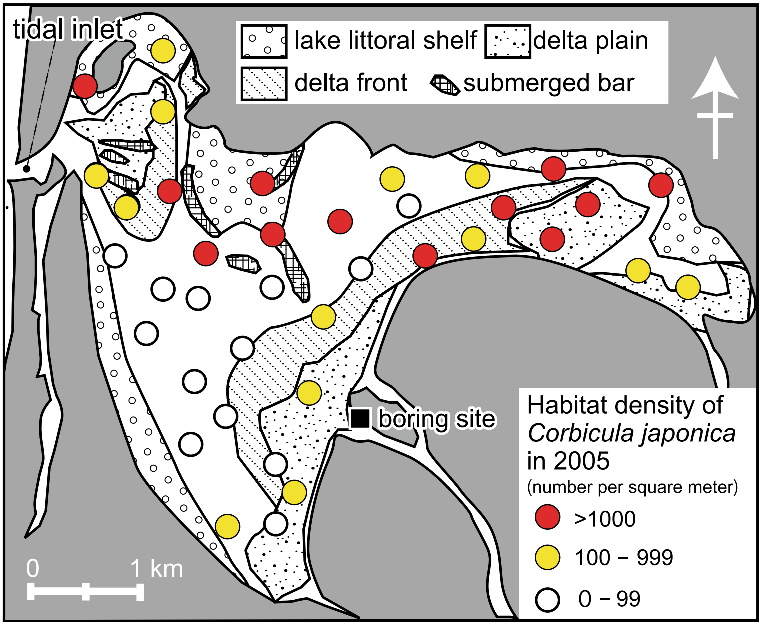

Fig. 2 Topography of Lake Jusanko and habitat density of *Corbicula japonica*. Modified from Hirai (1994) and Aomori Prefectural Industrial Technology Center's Inland Water Fisheries Research Institute (2010)

3 Changes in the Topographical Environment of Lake Jusanko Over Long Time Scale

3.1 Borehole Core Dating

To study the formation of Lake Jusanko, boring was carried out at the mouth of the Iwaki River (where the river flows into Lake Jusanko) to a depth of 58 m (Fig. 3). Sediments exhibited wide differences above and below a depth of 27 m. At depths below 27 m, layers of pebbles and relatively coarse sand intercalated between muddy layers were observed. A large amount of organic substances, such as wood fragments, could also be found in these layers. Considering these characteristics, it is surmised that these layers accumulated on land. Meanwhile, sediments at depths above 27 m were assumed to have been accumulated in water, such as the sea and the lake, because they contain many layers of sandy and muddy layers mixed with clam shells.

These clam shells and wood fragments were dated using accelerator mass spectrometry (AMS). Because AMS can measure ages with a small amount of samples, *Corbicula japonica* shells can be dated using only one sample for each layer. The wood fragments in the silt layers considered to be land sediments gave estimated ages of 12,250 ± 50 years BP (depth of 57.1 m) and 9,410 ± 50 years BP (38.6 m), and *Corbicula japonica* shells found between sandy layers at depths of 24–26 m, directly on top of the land sediments, gave ages of about 8,190 ± 50 years BP (Fig. 3). The age of the *Corbicula japonica* shell indicates the period of the Holocene glacial retreat, when the sea rapidly encroached on land after the Ice Age as the climate warmed. In addition, muddy layers containing *Corbicula japonica* shells and other clam shells were found at depths of 6–24 m. These fine-grained sediments can be inferred to be lake or sea bottom deposits accumulated when water regions formed after the Holocene glacial retreat. AMS results gave estimated dates of 5,760 ± 40 years BP at 18.6 m, 2,450 ± 30 years BP at 9.5 m, and 610 ± 30 years BP at 6.8 m, showing that the higher the layer of sediment, the younger its age. The layers of silt and clay demonstrate the progress of sedimentation in the water region.

The top portion of the borehole core shows a sandy layer of about 5 m thick. This layer is considered to be the layer that comprises the foreset bed of the lake delta. In this sandy layer, particles become larger with decreasing depth of the level, showing the gradual approach of the once-distant river mouth to the bore site. Overall, the results show the development of the delta. The bottom portion of this sandy layer contains *Corbicula japonica* clams dated to be about 220 ± 30 years BP (Fig. 3). These results show that the development of the delta at the mouth of the Iwaki River is extremely recent.

As mentioned above, many different types of clam shells, including those of *Corbicula japonica*, were found in the borehole core (Fig. 4). *Corbicula japonica* shells occurred frequently in multiple horizons at depths of 6–12 m and in the sandy layer at depths of 24–25 m. However, the clam shells did not occur

Fig. 3 Columnar section of boring core collected from the mouth of the Iwaki River. The boring site is shown in Fig. 2

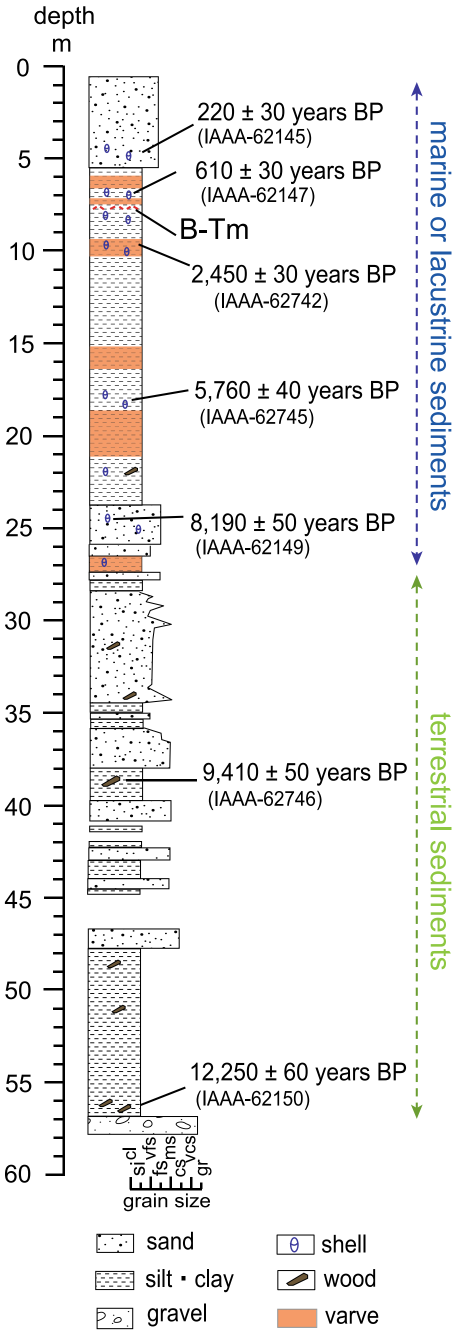

Fig. 4 *Corbicula japonica* shell collected from borehole core

continuously throughout the core; none could be found at depths of 12–18 m. In addition, at the depth of 18.6 m, the observed bivalves were clearly different from *Corbicula japonica*. There is a possibility that these shellfish were transferred by streams from the area they actually inhabited and redeposited here. While the habitat cannot be precisely identified, there is no doubt about the time period of their habitation from the age of their shells.

3.2 Lake Jusanko's Water Environment as Reconstructed from Fossils

To understand changes in the water environment of Lake Jusanko, we conducted an analysis of diatoms in about 20 horizons of fine sediments at depths of 6–24 m. Diatoms are single-celled algae with siliceous skeleton, and they are adapted to living in saline, acidic, streaming, and other types of environments. The water environment of a past time period can be reconstructed from fossilized diatoms in sediments. For analysis, about 1 cm^3 of sample was taken from sediments. After treatment, the sample was magnified by about 1,000 times using a microscope to identify and quantify the genus or species of the diatoms.

Here, we omit detailed entries of the diatom genera or species. Instead we group the identified diatoms by their habitat environment and describe the changes in the time period of each environment (Fig. 5). The following five findings can be deduced:

(a) From 8,000 to 6,000 years ago, marine/brackish water diatoms gradually increased, and the percentage of freshwater diatoms, which had been predominant previously, dropped suddenly.

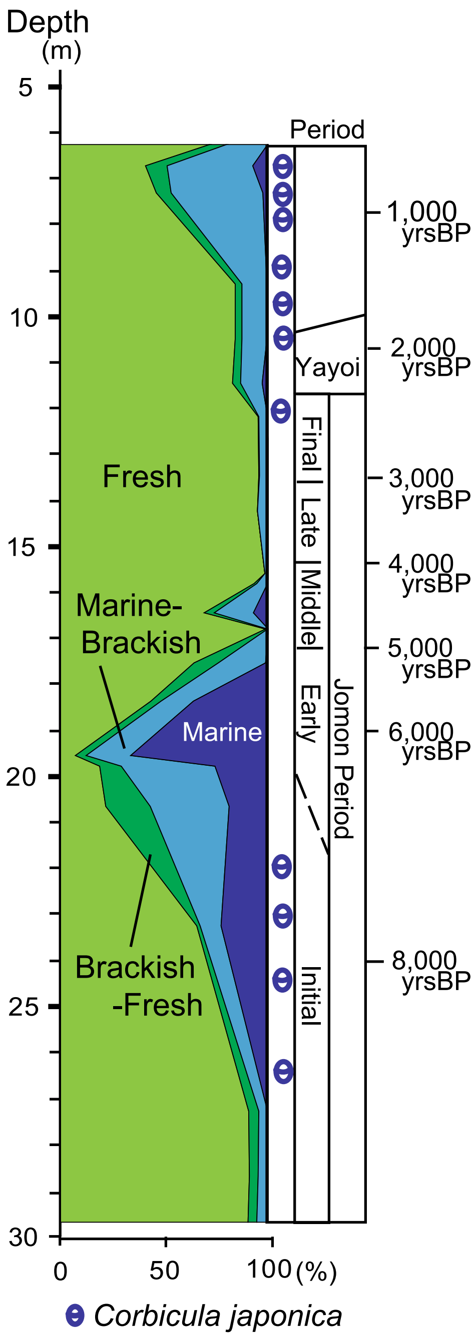

Fig. 5 Changes in the lake environment since the early Holocene based on diatom analysis of borehole core. The boring site is shown in Fig. 2. The Jomon period that indicates a prehistoric culture in Japan began approximately 15,000 years BP after the end of the Last Glacial age. The Jomon period is subdivided into five stages. This figure shows these stages except for the first stage called Incipient Jomon

(b) About 6,000 years ago, seawater diatoms became predominant, and freshwater diatoms decreased to an extremely small amount.
(c) From 4,000 to 2,500 years ago, freshwater diatoms became predominant.
(d) From 2,500 to 1,100 years ago, freshwater diatoms continued to be predominant. However, brackish water diatoms increased slightly.
(e) Since 1,100 years ago, brackish water diatoms have been increasing.

Although large amounts of *Corbicula japonica* are currently found in Lake Jusanko, over the past several thousand years the environment experienced significant changes, as summarized in (a)–(e) above. Based on these results, we recreated the geomorphic environment of Lake Jusanko and its surroundings over the course of time (Fig. 6).

As shown in Fig. 6, an area that had been land (near the mouth of the Iwaki River today) became part of the sea about 8,000 years ago. At that time, there was brackish water, and the environment supported the inhabitation of *Corbicula japonica*. Subsequently, the advance of the sea reached its peak (about 6,000 years), and the salinity of the environment was as high as that of the open sea or the inner harbor. This period was unfavorable for the growth of *Corbicula japonica*.

During the time period of (d), the effects of freshwater continued to be extremely strong (Figs. 5 and 6). The predominance of freshwater diatoms suggests that the epilimnion must have been completely freshwater (Kashima 2001). In agreement with this conclusion, *Corbicula japonica* shells were not found at all in the borehole core corresponding to this time period.

What about the bottom of the lake? Was it also freshwater? To further study the lake water environment, we conducted a sulfur analysis of its sediments. In sulfur analysis, the amount of pyritic sulfur produced from the effects of the sulfur ion concentration in sediments is measured. Sediments deposited in seawater or brackish water would contain a greater amount of pyritic sulfur that those deposited in fresh water. The results of the analysis revealed that not only sediments predominated by marine and brackish water diatoms but also sediments of time period (d) predominated by freshwater diatoms were marine sediments. The finding indicates that even though the diatom analysis indicates a freshwater epilimnion, sedimentation at the lake bottom was strongly affected by seawater.

Overall, the following scenario can be deduced. Shortly after the Holocene transgression, the water region of Lake Jusanko was partially filled by sediments. Subsequently, a tidal inlet formed in the sandbar, separating Lake Jusanko from the Sea of Japan and allowing lake water to flow out and seawater to flow in. During that time, the depth of Lake Jusanko was than the present depth. Seawater that flowed in gathered near the lake bottom, while freshwater supplied from rivers and streams predominated at the epilimnion. The layers could not mix, forming a halocline formed. Afterwards, sediments from rivers and streams accumulated, and the lake became shallower. As a result, winds could agitate the lake water down to the lake bottom, creating a brackish water environment favorable for the growth of *Corbicula japonica*.

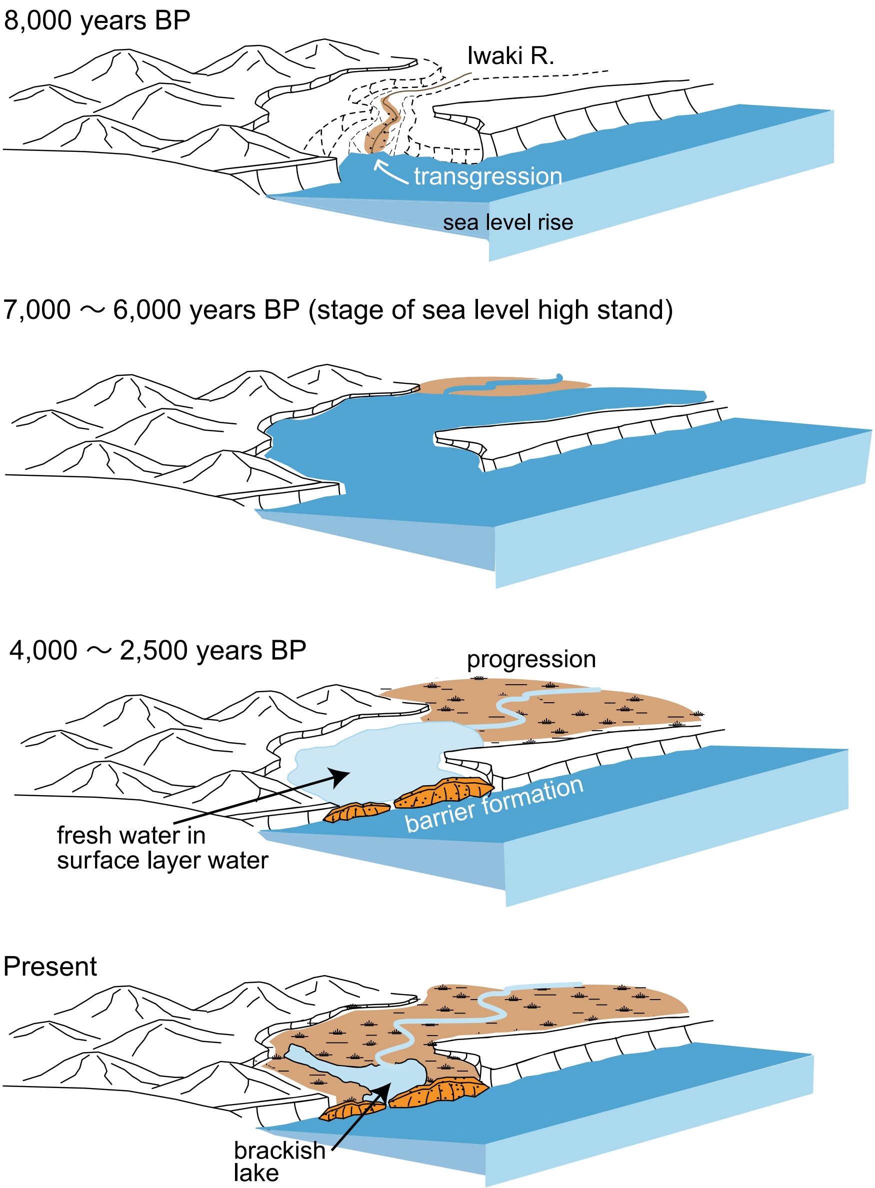

Fig. 6 Schematic diagram of the geomorphic changes in the lake environment. This figure shows a bird's-eye view from the northwest direction, indicating landform development since the past 8,000 years in the lower part of the Iwaki River

4 Conclusion

As described above, a brackish water environment formed in Lake Jusanko during the Holocene glacial retreat. Afterwards, the effects of seawater became strong about 6,000 years ago. The water environment then became brackish for a while. However, for a period from about 4,000 to 2,500 years ago, fresh water strongly affected the epilimnion, and a deep lake was formed, in which a halocline of seawater distributed in the hypolimnion was evident. An environment unfavorable for the growth of *Corbicula japonica* spread. Afterwards, rivers and streams such as the Iwaki River transported and deposited dirt and sand, and the lake became shallow. Seasonal winds frequently agitated the lake water, leading to the development of a brackish water environment that supported the conditions for *Corbicula japonica* to thrive.

Japan, located in monsoon Asia, also lies on a mobile belt. It is a region with dynamic tectonic changes and volcanic activities. Furthermore, the frequency of intensive torrential rain is high because of typhoons and the seasonal rain front. With torrential rains, large amounts of sediments from protruding mountains formed by active tectonic movements are transported by rivers and streams. These sediments are deposited at river mouths and basins and form plains. Lake water in shallow lagoons not fully filled with sediments through such a process is agitated by seasonal winds, creating brackish water environments. This can be said to be a particular product of monsoon Asia's mobile belts.

Nevertheless, the influence of human actions in sustaining the habitat environment of *Corbicula japonica* in Lake Jusanko should not be ignored. Currently, sand produced in mountains is trapped by dams constructed upstream and cannot be transported downstream by rivers and streams. As a result, Lake Jusanko is not completely filled by sediments. Furthermore, the closure of tidal inlets is artificially prevented, promoting the moderate inflow of seawater. If human beings are "involved in the natural environment as they assert themselves" (Preface), humans have asserted themselves in the Lake Jusanko region by preventing flooding to increase agricultural production. As a by-product, *Corbicula japonica*'s environment is sustained, and the economy of the region also reaps benefits.

From the perspective of a long time scale, Lake Jusanko has repeatedly been an environment inhospitable to *Corbicula japonica*. While it is undoubtedly true that the environment surrounding *Corbicula japonica* will change greatly in the future, we quietly hope that *Corbicula japonica*, which has satisfied the appetite of people since the Jomon period, will continue to comfort the stomachs of those who enjoy alcohol.

Acknowledgements We thank Prof. Mikio Sasaki of Hachinohe Institute of Technology, and Prof. Nobuyuki Azuma of Hirosaki University for useful suggestions. We also appreciate the first Research Division of Aomori office River and National Highway for their special support.

References

Hirai Y (1994) Geomorphological Development of the Lagoons in Japan. Bulletin of the Faculty of Education, Ehime University. Series III, Natural science 14–2:1–71 (in Japanese with English Abstract)

Inland Water Fisheries Research Institute (2010) Jusanko Yamato shijimi genzonryo chousa houkokusho [Report on existing amount of *Corbicula Japonica* in the Lake Jusanko]. Aomori Prefectural Industrial Technology Center, Towada, Aomori (in Japanese)

Ishikawa T (2001) Fluid dynamics in Lake Ogawara related to the propagation of *Corbicula Japonica*. Nagare 20:346–353 (in Japanese)

Kashima K (2001) Salinity changes during the Late Holocene at coastal brackish lakes in Japan. LAGUNA 8:1–14 (in Japanese with English Abstract)

Nakamura M (2000) Nihon no shijimiryo: Genjo to mondaiten [Corbicula fishery in Japan: The present conditions and its problems] Tatara Books. Yasugi, Shimane (in Japanese)

Sasaki M, Tanaka H, Umeda M (2011) Study on aquatic environment of Lake Jusan in investigating LCA. Tohoku Journal of Natural Disaster Science 47:219–224 (in Japanese)