

Public Awareness and Community-Based Conservation for the Horseshoe Crab at Saikai National Park in Nagasaki Prefecture, Japan

Chikako Iwaoka and Toshinao Okayama

Abstract Formerly horseshoe crabs (*Tachypleus tridentatus*) were commonly distributed in Japan. However, the horseshoe crab population has been decreasing due to habitat loss caused by coastline development. The Saikai Pearl Sea Center Aquarium (SPSCA) has been conducting many activities for horseshoe crab conservation at Kujukushima Islands in Japan. In SPSCA, we attach great importance to cooperation with local fishermen for public awareness. Because there is so much by-catch of horseshoe crabs in the Kujukushima area, local fishermen bring us much useful information on distribution and habitat. Basically, horseshoe crabs are a burden to fishermen. We make much effort to deepen their understanding of horseshoe crabs. Recently local fishermen are recognizing that horseshoe crabs are endangered and valuable animals. We also exhibit living horseshoe crabs at SPSCA, give lectures to local schools, conduct excursions to observe the habitat of horseshoe crabs, engage in cooperation with local government, and publicize our work in newspapers and TV. For research activities, we measure morphology for all individual by-caught horseshoe crabs and submit blood samples for DNA analysis in Kyushu University. We report on the public awareness and research activities at SPSCA.

1 Introduction

1.1 Background

The horseshoe crab (*Tachypleus tridentatus*) is well known as a “living fossil” in Japan. Formerly horseshoe crabs were commonly distributed from the northern part of Kyushu Island to the Inland Sea of Japan (Sekiguchi, 1998). However, the population has recently decreased due to habitat loss caused by coastline development and environmental degradation including water

C. Iwaoka (✉)

Saikai Pearl Sea Center Aquarium (SPSCA), Kashimae 1055, Sasebo,
Nagasaki 858-0922, Japan
e-mail: parubo7@yahoo.co.jp

pollution (Itow, 1997; Itow et al., 1998). The populations of the Inland Sea of Japan in particular, once containing the largest habitats in Japan, have decreased dramatically and consequently the Inland Sea population is almost extinct now (Nagasaki Prefecture, 2001). As a result, obvious spawning sites are now observed only at Yamaguchi, Fukuoka, Saga, Oita, and Nagasaki in Japan. The horseshoe crab is listed as an endangered species in many red data books in Japan (Nagasaki Prefecture, 2001; Sasebo City, 2001; Ministry of the Environment of Japan, 2006).

The Saikai Pearl Sea Center Aquarium (SPSCA) is located in Nagasaki Prefecture in the northwestern part of Kyushu Island. Nagasaki Prefecture is famous for horseshoe crabs in Japan. The Saikai Pearl Sea Center Aquarium has been undertaking various conservation activities such as education, raising public awareness, carrying out research and surveys of the horseshoe crab population for about 8 years. In this chapter, we report our activities, especially about raising public awareness among the local population and research activities on the horseshoe crab at the SPSCA.

1.2 The Distribution of Horseshoe Crabs in Nagasaki Prefecture

Nagasaki Prefecture (Fig. 1a, b) is not so large in area (4,094 km²) but its coastline is very complicated, having what is called a “saw-tooth coastline.” Because of this, Nagasaki Prefecture has the longest coastline (4,137 km) in all the administrative divisions of Japan. The notable horseshoe crab habitat feature in Nagasaki is that many small habitats are scattered along the saw-tooth coastline. Because of its complicated coastline, there are many undiscovered habitats where surveys have not yet been conducted so there is the possibility of finding new habitats and spawning sites in the future. Because the habitats of the Inland Sea of Japan are almost all gone, the main horseshoe crab habitat now is Kyushu Island. Conservation activities in Nagasaki Prefecture are especially important for the survival of horseshoe crabs in Japan.

1.3 The Kujukushima Islands in the Saikai National Park

The field work undertaken in this study takes place in the Kujukushima Islands (Figs. 1c and 2) in Nagasaki Prefecture. The Kujukushima Islands are located within the Saikai National Park and consist of many small islands which have saw-tooth coastlines. Though “Kujukushima” means “99 islands” in Japanese, there are in fact 208 islands in the area. The Kujukushima Islands have a relatively large number of natural coastlines and various environments like rocky beaches, sand beaches, tidelands, and algae sea beds. Such diverse environments seem suitable for the survival of the horseshoe crab.

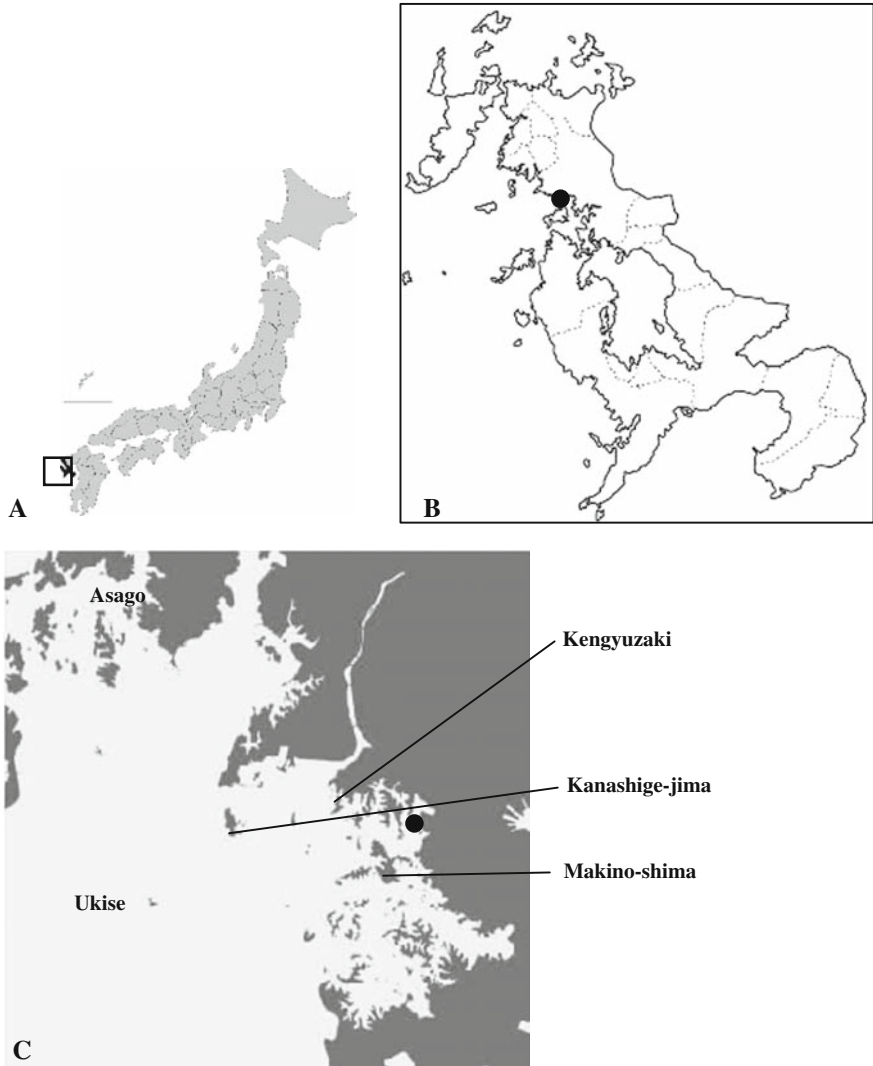


Fig. 1 Location of Nagasaki Prefecture (A: a map of Japan, B: a map of Nagasaki Prefecture, C: a map of study area). Nagasaki Prefecture is located at west end of mainland of Japan (*square* in A). *Black circle* indicates the location of SPSCA (B and C)

2 Public Awareness Activities

2.1 Cooperation with Local Fishermen

The fishing industry is very active in the Kujukushima Islands. The local fishermen bring us much useful information on distribution and habitat



Fig. 2 Kujukushima Islands in the Saikai National Park

and also specimens of horseshoe crabs. Therefore, we attach great importance on cooperation with local fishermen. Many horseshoe crabs are by-caught with gill nets and trawl nets from spring to autumn in the Kujukushima Islands. However, for the fishermen, horseshoe crabs are simply a burden because they disturb fishing and sometimes their spine breaks the fishing nets. Consequently, many fishermen have just disposed of by-caught horseshoe crabs.

We frequently visit local fishermen and sometimes help them in their work to deepen their understanding of horseshoe crabs and we ask them to inform us when they catch horseshoe crabs. As a result, awareness of the horseshoe crabs among local fisherman has been rising. Recently, local fishermen have been recognizing that the horseshoe crab is an endangered and valuable animal. For example, in 2006, we were able to collect a total of 132 by-caught horseshoe crabs based on information from local fishermen. These individuals were used for research activities (see below).

But of course not all fishermen recognize the importance of the horseshoe crab. Occasionally we find carcasses of horseshoe crabs that have most likely been discarded by fishermen. Enlightenment activities concerning the local fishermen are still important and should be continued.

2.2 Exhibition at SPSCA

The SPSCA has a permanent water tank for horseshoe crabs to display the living animals. The animals inside the tank are also by-caught crabs from around the Kujukushima Islands by local fishermen. Explanation boards, touchable stuffed specimens, and other materials are also exhibited in SPSCA so that visitors can study the importance and significance of horseshoe crabs. Recently visitors from abroad from areas such as Korea, China, and Taiwan also have been increasing.

2.3 Environmental Education Activities at the SPSCA

The SPSCA has a regular environmental education program which is entrusted by the Sasebo Municipal Office. All the third grade elementary school children in Sasebo City attend this program every year. The total number of children is around 2,300 every year. The main purpose of this program is to study not only horseshoe crabs but also the total rich environment of the Kujukushima Islands in which horseshoe crabs are brought up. This environmental education program has been going on for 10 years. Children who took this program the first year will enter the 12th grade of high school this year. Such a large-scale environmental education program should be very effective for local children.

2.4 Delivering Lectures at Elementary and Junior High Schools

The SPSCA has an original lecture program for local elementary and junior high schools. The lectures delivered by the SPSCA staff comply with the requests from each school and the local government. The requests for this program have been increasing recently. We held 15 such classes in 2006. This reflects the rising awareness of horseshoe crabs and the natural environment of the Kujukushima Islands.

Sometimes we bring living horseshoe crabs and dried specimens to the lectures. Usually, most students are willing to take the class. We also enjoy holding such classes but it is a little difficult for us to manage both ordinary aquarium tasks and giving lectures. Because members of the aquarium have limited time, how to deal with classes is a problem. It is expected that trained volunteer staff and local NGOs will hold such classes in the future.

2.5 Field Excursions

Education activities at SPSCA and delivering the lectures mentioned above are the so-called ex situ programs. The SPSCA also has an in situ activity program.

In this program, people can see wild horseshoe crabs and their eggs on the beach (Fig. 3). Recently, there are many children and citizens who have not had the experience of walking around tidelands and who do not know about the horseshoe crab. It is a good opportunity for them to go to the field to feel the rich environment and observe horseshoe crabs in their own environment. We conducted such field excursions 10 times in 2006. The problem is the same as with holding classes. The demand to hold such field excursions exceeds our capacity. To meet such demand, it is necessary to increase trained volunteer staff and local NGOs who can act as a moderator of the excursion.



Fig. 3 Field excursion activities at the SPSCA

2.6 Using Mass Media

The SPSCA frequently issues press releases to mass media outlets when we have some new topics related to horseshoe crabs. After the broadcasting of TV programs or news on horseshoe crabs, inquiries and information input to the aquarium increase. There are many local people that become aware of the importance of horseshoe crabs through TV and newspapers. Such news also becomes a cue for requests for delivering lectures and field excursions. Mass media is very effective for broadening the dissemination of information.

2.7 Collaboration with Local Government

For conservation of local natural resources, including horseshoe crabs, public awareness activities as mentioned above are very important on one hand and collaboration with local government is necessary on the other. The SPSCA maintains a close relationship with the local government. Many classes and environmental education at SPSCA are carried out by request from the Sasebo Municipal Government and the Nagasaki Prefectural Government.

Some SPSCA staff are members of the Natural Environment Council of Nagasaki Prefecture. We can make interventions for both conservation and development policy to the government through the council. We gave advice on protective levee construction and coastline conservation to the Nagasaki Prefectural Government and the Ministry of Land, Infrastructure and Transport through the Council in 2006.

3 Research Activities

3.1 Materials and Methods

As mentioned above (Section 2.1), many by-caught horseshoe crabs have been brought to SPSCA mainly by local fishermen. These individuals were captured by gill net and trawl net in the Kujukushima Islands. The capture date, locations, and the sizes of these individuals were recorded. Measured regions for each individual were total length including tail (ToL), body length (combined prosoma and opisthosoma) (BL), tail length (TaL), and carapace (prosoma) width (CW). Tail ratio (TR) and flatness of carapace (FC) were calculated ($TR = TaL/ToL$, $FC = CW/BL$). The TR and CW were compared with those of individuals from the Kitakyushu population (Hayashi, personal communication). Blood samples from these animals were sent to Kyushu University to study genetic structure of Japanese horseshoe crab populations using mitochondrial DNA analysis.

The total number of by-caught individuals was 82 from May 2000 to November 2005. In this chapter we report on the capture locations for all 81 individuals and morphological data for 32 individuals (13 adult males, 9 adult females, and 10 subadults) that were brought to the SPSCA in 2005.

3.2 Results

Main by-caught locations were (1) between Ukise and Kanasige-jima, (2) off Asago, (3) off Kengyuzaki, and (4) south of Makino-shima (Fig. 1c). Though fishermen set their nets all through the year, many horseshoe crabs were

by-caught between May and August. May was the month for the highest number captured (Table 1).

Table 1 Monthly number of by-caught horseshoe crab in Kujukushima area from 2000 to 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000					2	1				2			5
2001					3	2		1	1				7
2002					5	2		2					9
2003		1	1	3	2	3	1	3	2	1			17
2004					2	1		3		2		3	11
2005				4	7	7	3	3	4	1	3		32
total	0	1	1	7	21	16	4	12	7	6	3	3	81

The ToL of the biggest individual was 600 mm for males and 800 mm for females. The average ToL was 537.8 mm for males and 626.3 mm for females (Table 2). Both ToL and CW of Kujukushima individuals were larger than those of Kitakyushu individuals.

Table 2 Comparison of ToL and CW of the horseshoe crab from Kujukushima and those from Kitakyushu. The numbers without parentheses indicate average size. The numbers in parentheses indicate the range

	Kujukushima (n = 19 for ToL, n = 22 for CW*)	Kitakyushu (n = 85)
ToL (♂)	537.8 mm (445–600 mm)	514.7 mm (430–581 mm)
ToL (♀)	626.3 mm (530–800 mm)	589.9 mm (511–680 mm)
CW (♂)	252.9 mm (240–270 mm)	242.9 mm (225–267 mm)
CW (♀)	297.5 mm (250–355 mm)	281.3 mm (250–305 mm)

* CW were measured for all the adult individuals (n = 22) that were brought to the SPSCA in 2005. Three individuals whose tails were broken were excluded from ToL.

The individuals for which the TR was 0.86 or less were all female, individuals for which the TR was 0.87 or over and 1.00 or less were a mixture of males and females, and individuals for which the TR was 1.08 or over were all males (Table 3). Males have a tendency to have longer tails than females. The individuals for which the FC was 0.89 or less were all female, individuals for which the FC was 0.90 or over and 0.95 or less were a mixture of males and females, and individuals for which the FC was 0.96 or over were all males (Table 4). Males have a tendency to have a flatter shape than females. These data suggested that males have proportionately longer tails and a more flattened shape than females.

Table 3 Tail Ratio (TR) of the horseshoe crab (ToL: Total length, BL: Body length, TaL: Tail length)

No	sex	ToL (mm)	BL (mm)	TaL (mm)	TR
104	♀	570	335	235	0.70
132	♀	625	350	275	0.79
125	♀	590	320	270	0.84
128	♀	590	320	270	0.84
134	♀	530	285	245	0.86
110	♂	504	269	235	0.87
127	♂	520	270	250	0.93
112	♀	630	325	305	0.94
114	♀	675	348	327	0.94
129	♂	530	270	260	0.96
135	♀	800	400	400	1.00
108	♂	520	260	260	1.00
122	♂	520	260	260	1.00
131	♂	600	300	300	1.00
126	♂	520	250	270	1.08
117	♂	505	240	265	1.10
136	♂	537	252	285	1.13
109	♂	570	260	310	1.19
118	♂	590	260	330	1.27

3.3 Discussion

There were a large number of by-caught horseshoe crabs in the late spring (May and June) and the late summer (September and August) in the Kujukushima area. The horseshoe crabs in this area spawn on flood tide days from June to September. The horseshoe crabs may be by-caught before and after the spawning season when they go back and forth between their usual habitat (seabed) and spawning sites (sand beach). Most of the by-catch was observed from May to October in Omura Bay which is located southeast of the Kujukushima area (Kai and Morikawa, 1999), which is almost in accord with the results in this study for the Kujukushima area. However, the most abundant by-catch was observed in August which is the middle of the spawning season in Omura Bay (Kai and Morikawa, 1999), while the most by-catch for the Kujukushima area was observed before spawning season (May). This may be because of the difference in their range of activity and location of fishing gear between the Kujukushima area and Omura Bay.

Two individuals were by-caught off Asago and one individual was by-caught off Ukise in November 2005. Three individuals were by-caught off Ukise in December 2004. The horseshoe crabs stop their activities beneath the sand or mud of the seabed. It is suggested that off shore of Asago and Ukise are wintering places in the Kujukushima area.

Both the ToL and CW of the individuals of the Kujukushima population were larger than those of the Kitakyushu population for both males and females. The

Table 4 Flatness of carapace (FC) of the horseshoe crab (BL: Body length, CW: Carapace width)

No	sex	BL (mm)	CW (mm)	FC
132	♀	350	300	0.86
112	♀	325	280	0.86
128	♀	320	280	0.88
134	♀	285	250	0.88
135	♀	400	353	0.88
125	♀	320	285	0.89
104	♀	335	300	0.90
130	♂	290	260	0.90
131	♂	300	270	0.90
127	♂	270	250	0.93
119	♀	325	310	0.95
114	♀	348	332	0.95
113	♂	250	240	0.96
126	♂	250	240	0.96
136	♂	252	242	0.96
109	♂	260	250	0.96
118	♂	260	250	0.96
122	♂	260	253	0.97
129	♂	270	265	0.98
108	♂	260	260	1.00
117	♂	240	240	1.00
110	♂	260	262	1.01

largest female measured at Kasaoka City in Okayama Prefecture which fronts on the Inland Sea of Japan was 630 mm in ToL (Kasaoka City Horseshoe Crab Museum, personal communication), which is a little larger than the female average size of the Kujukushima population. The largest individual from Kujukushima was an 800 mm female which was captured off Asago on November 19, 2005. There are no previous records of such large horseshoe crabs in Japan. This individual was reported on by many news outlets as being the largest horseshoe crab in Japan. It is suggested that the horseshoe crabs of the Kujukushima population are larger than those of other regions in Japan.

It is known that female horseshoe crabs are larger than males (Yamasaki et al., 1988). In addition to the total body size, our data suggest that the body shape of horseshoe crabs is different for males compared to females. Males have shorter tails and a flatter body and females have longer tails and an elongated body. Statistical analysis for the sex difference for the TR and the FC could not be conducted because of the limited sample size. To ensure the results of the sex differences in horseshoe crabs it is necessary to increase the number of measured individuals.

The DNA analysis done at Kyushu University indicated there are some population subdivisions among Japanese horseshoe crabs (Nishida and Koike, 2006, 2009). Such information is very useful to help make a conservation plan for the horseshoe crab in Japan.

4 General Discussion

4.1 Population Status of Horseshoe Crabs in Nagasaki Prefecture

Although formerly horseshoe crabs were commonly distributed in the northern part of Kyushu Island and the Inland Sea of Japan, the population of the Inland Sea of Japan is almost extinct now (Nagasaki Prefecture, 2001). The major horseshoe crab populations in Kyushu Island are located at the Sone-Tideland in Kitakyushu, Imari-Bay in Saga and Morie-Bay in Kitsuki (Sekiguchi, 1993; Sato, 2000). Kita-Matsuura, Sasebo, Nishishonogi, Hirado, Omura Bay, Iki Island, and Tsushima Island are reported as being horseshoe crab habitats in Nagasaki Prefecture (Ikezaki, 1980; Yamaguchi, 1989, 1993; Ikezaki, 1977, 1995; Kai and Morikawa, 1999; Sekiguchi, 1999; Hisano et al., 2005). A feature of the horseshoe crab populations in Nagasaki Prefecture is that many small populations are scattered along the coastlines. This is simply because Nagasaki Prefecture has a very complicated coastline. Consequently, it is very difficult to find all the horseshoe crab populations in Nagasaki, and there are still many possible habitats and spawning sites where scientific surveys have not yet been undertaken. Searching out new habitats and spawning sites should be continued.

4.2 The Population Status of Horseshoe Crabs in the Kujukushima Area

The Kujukushima Islands are located in the northwestern part of Kyushu Island and within the Saikai National Park which consist of many small islands which have long saw-tooth coastlines (Fig. 2). The Kujukushima area has still many natural coastlines and various environments such as rocky beaches, sand beaches, tideland, and algae sea beds. Consequently, the Kujukushima area has rich fauna and flora including other endangered species such as mollusks (*Onchidium hongkongensis*, *Anomalodiscus squamosa*, *Meretrix lusoria*), sea grasses (*Zostera marina*, *Z. japonica*), seed plants (*Hibiscus hamabo*, *Mucuna sempervirens*) in addition to horseshoe crabs (Otani, 2004; Hashiguchi, 2004; Otani, 2005; Kawakubo et al., 2005). The diverse and rich environment seems suitable for the survival of the horseshoe crab.

4.3 Public Awareness for Horseshoe Crab Conservation

How can a local aquarium like the SPSCA contribute to local environmental conservation? Public awareness for local people is one of the answers. Conducting awareness raising activities for the public concerning the local environment is one of the most important tasks for a local aquarium. To conserve horseshoe crabs and their habitats in the Kujukushima area, it is essential for local people to realize the importance of their local environment and be proud

of it. Based on this point of view the SPSCA has been conducting such activities described above.

Because horseshoe crabs are famous as a living fossil in Japan and most of the Japanese know that it is an endangered species now, horseshoe crabs can become a good “tool” for public awareness. To continue public awareness activities through horseshoe crabs it is necessary to collect more information, to explore new habitats, and to conduct further study and research.

Acknowledgments This study was conducted under the total support by Sasebo Pearl Sea Center Aquarium (SPSCA). This study could not be completed without the cooperation of the Ainoura Fishermen’s Cooperative Association and the Sasebo Fishermen’s Cooperative Association. We thank Professor S. E. Rife of Nagasaki Prefectural University for his review and correction of the English manuscript.

References

- Hashiguchi K (2004). Schooling of the ice gogy, *Leucopsarion petersi* observed in the coastal water of an isle, Makinoshima of Kujukushima Isles, Nagasaki Prefecture. *Trans Nagasaki Biol Soc* 57: 35–37
- Hisano C, Maeda K, Okuma T, Yamaguchi Y, Kawakubo A, Hashiguchi K (2005). Kujukushima ni okeru Kabutogani no Sanranjokyo oyobi Sanranchi Chosa no Kekka. Kabutogani, 25
- Ikezaki Y (1977). Nagasakiken Matsuurashi ni okeru Kabutogani Sanranchi no Hkken. *Trans Nagasaki Biol Soc* 13: 49–50
- Ikezaki Y (1980). Fukushima no Dobutsu, In “Fukushumacho Kyodoshi” Ed by Fukushima-macho Kyodoshi Hensan Iinkai, 115–116. Fukushima Municipal Office, Fukushima
- Ikezaki Y (1995). Asase no Ikitakaseki – Kabutogani, In “Mizube He Youkoso – Nagasakiken No Mizu To Seibutsu”, 48–51. Nagasakiken Shizenhogo Kyokai, Nagasaki
- Ito T (1997) The pollution of coastal waters and malformations of horseshoe crab embryos caused by heavy metals. *Arch Environ Contamin Toxicol* 35: 33–40
- Kai S, Morikawa J (1999). The horseshoe crab, *Tachypleus tridentatus*, collected from the coast of Nagasaki Prefecture and the East China Sea. *Trans Nagasaki Biol Soc* 61: 91–94
- Kawakubo A, Otani T, Nakarhara Y, Yone H, Shimojo K, Hashiguchi K, Ito T, Kurusaki Y, Yamaguchi Y (2005). Record of the crustacean and the mollusks from south Kujukushima isles area. *Trans Nagasaki Biol Soc* 60: 17–27
- Ministry of the Environment of Japan (2006). Threatened Wildlife of Japan: Red Data Book, Ministry of the Environment of Japan, Tokyo
- Nagasaki Prefecture (2001). Red Data Book 2001, Nagasaki Prefectural Government, Nagasaki
- Nishida S, Koike H (2006). Population subdivision of the horseshoe crab (*Tachypleus tridentatus*) in Japanese coast from mtDNA sequences. “Genetics of Speciation” American Genetics Association Annual Symposium. Vancouver, Canada. July 21–24
- Nishida S, Koike H (2009). Genetic structure of Japanese populations of *Tachypleus tridentatus* by mtDNA AT-rich region sequence analysis. In: Tanacredi JT, Botton ML, Smith DR (eds) *Biology and Conservation of Horseshoe Crabs*. Springer, New York, pp 183–196
- Otani T (2004). Growth of the hard clam, *Meretrix lusoria* at the Ainoura River estuary, western Kyushu. *Trans Nagasaki Biol Soc* 57: 38–42

- Otani T (2005). Habitats of the hard clam, *Meretrix lusoria* in the vicinities of Sasebo. Trans Nagasaki Biol Soc 60: 33–38
- Sasebo City (2001). Red Data Book Sasebo 2002, 182. Sasebo Municipal Office, Sasebo
- Sato M (2000). Ariake Kai no Ikimonotachi, Higata Kakoiki no Seibututayousei, 306. Kaiyusha, Tokyo
- Sekiguchi K (1993). 1989 Nen Ikou no Nihon no Kabutogani. In Sekiguchi, K (ed), Nihon Kabutogani No Genkyou, Japanese Horseshoe Crab Preservation Society, Kasaoka, pp 179–222
- Sekiguchi K (1998). Biogeography. In: Sekiguchi, K (ed), Biology of Horseshoe Crabs. Science House, Tokyo, pp 22–49
- Sekiguchi K (1999). Kabutogani No Seibutsugaku, 14. Seisakudoujinsha, Tokyo
- Yamaguchi T (1989). Nagasakiken no Kabutogani, in Nagasakiken no Seibutsu, 266. The Nagasaki Biological Society, Nagasaki
- Yamaguchi T (1993). Nagasakiken ni okeru Kabutogani no Sanchi. In Sekiguchi, K (ed), Nihon Kabutogani No Genkyou, Japanese Horseshoe Crab Preservation Society, Kasaoka, pp 167–170
- Yamasaki T, Makioka. T, Saito J (1988). Morphology. In: Sekiguchi, K (ed), Biology of Horseshoe Crabs. Science House, Tokyo, pp 69–132