Studies on the Shipworms II
Monthly Settlement of Shipworm Larvae

Kunio TSUNODA* and Koichi NISHIMOTO*

Abstract——Monthly settlement of shipworm larvae for a year from May, 1974 through April, 1975, and the existing species were investigated at three test sites in Japan: Onagawa (38° 26′N, 141° 30′E), Miyagi Pref., Tatoku Island (34° 18′N, 139° 49′E), Mie Pref., Noto (37°8′N, 137°E), Ishikawa Pref.

The following species were found : *Teredo navalis* LINNAEUS and *Limnoria lignorum* (RATHKE) at Onagawa, *T. navalis, Lyrodus pedicellatus* (QUATREFAGES), *Bankia carinata* (GRAY) and *L. lignorum* at Tatok Island, *T. navalis, L. pedicellatus, Teredo furcifera* VON MARTENS and *L. lignorum at* Noto.

Monthly settlement of shipworm larvae was determined by test panel method (pine wood, 5 × 20 × 2 cm) in which the number of borer apertures on wood surfaces was counted under stereo-microscope. Very light larval settlement was observed for only two months (September and October, 1974) at Onagawa. Shipworm attack on wood at Tatoku Island occurred for six months from June through November, 1974. The extent of larval settlement was very light, fewer than 10 borer apertures per 100 cm^2. Occurrence of larval settlement at Noto began in June when water temperature rose up to around 20°C, and continued for nine months with a peak in September, 1974. The more larval settlement was recorded on the lower surfaces than on the upper surfaces.

Introduction

The amount of imported logs into Japan has been increasing recently. The imported logs are generally stored in the sea for a while before landing[1]. During sea water log storage, the logs are inevitably exposed to marine borer attack such as genus *Teredo* (commonly called shipworm or pileworm) and *Limnoria* (gribble) and so forth. However, the distribution of marine borers along the coasts of Japan has not been investigated recently since TAKI and HABE[2,3], and HABE[4,5,6] worked on the problem under the auspices of the 22nd special committee organized by the Japanese Association for Academic Advancement for the prevention of marine borer attack.

QUAYLE[7] reported that *Teredo navalis* LINNAEUS and *Limnoria tripunctata* MENZIES introduced into British Columbia waters from other places. It is, therefore, possible that the imported logs from other countries may bring unknown borer species into Japanese waters. As an example, big shipworm tunnellings longer than 15 cm were found in the imported logs from Pacific coast of U.S.A., though the logs

* Divison of Wood Biology.

had been stored in the sea for a month by then.

In consequence, it is necessary to survey the existing species of marine borers and their breeding season at each log-storing site for preventing marine borer damage. Because supervision or practical application of log storage area enables to reduce the economic loss on the basis of the data on the influence of marine borers[8].

Reviewing the early papers[2~6,9~14] on the shipworms from Japan shows that over twenty species are distributed along the coasts of Japan. Of these species, *Teredo navalis* and *Lyrodus pedicellatus* (QUATREFAGES) are commonly found.

In this investigation, existing species and monthly settlement of shipworm larvae were examined at three test sites in Japan : Onagawa, Miyagi Pref., Tatoku Island, Mie Pref., and Noto, Ishikawa Pref.

Experimental

A test panel (sapwood of *Pinus densiflora,* 5×2 cm in section and 20 cm in length) with a hole for rope penetration was used in the present investigation. Three test panels constituted a test string for obtaining the precise information on the monthly settlement of shipworm larvae at given test sites : Onagawa (38°26′N, 141°30′E), Miyagi Pref., Tatoku Island (34°18′N, 136°49′E), Mie Pref. and Noto (37°8′N, 137°E), Ishikawa Pref. A test string consisting three test panels was submerged in the sea from the floating experimental raft, as three panels were between 30 and 100 cm below the surface of water.

The test string was replaced every month to examine monthly settlement of shipworm larvae for a year from May, 1974 through April, 1975. After removal of test panels, surface debris, barnacle and other fouling organisms were scraped off for counting the number of shipworm apertures on both lower and upper surfaces under stereo-microscope. Two laminated panels were additionally employed for identification of the existing species at each test site. They were exposed to marine borer attack for about two months (August and September, 1974). Laminated panels are suitable for easy procurement of whole animals or pallets out of wood. Pallets are the most important factors for identification. In addition, water temperature and salinity were measured for discussion.

Results and Discussion

1. *Water temperature and salinity*

Water temperature at the surface level was measured. Mean monthly water temperatures at two test sites (Onagawa and Tatoku Island) from May, 1974 through April, 1975 are shown in Table 1 together with the lowest and highest temperatures of each month.

Table 1. Water temperature (°C) at the surface level (May, 1974~April, 1975).

Month \ Test site		Onagawa	Tatoku Island
May	1974	11.0 (8.2~13.7)*	19.5 (17.1~23.0)
June		15.5 (13.2~18.6)	23.8 (21.9~26.5)
July		18.4 (16.7~19.5)	26.0 (24.3~28.3)
Aug.		21.5 (18.9~24.0)	29.1 (26.5~30.7)
Sep.		21.2 (19.9~23.2)	26.6 (22.3~28.5)
Oct.		18.7 (16.9~20.8)	22.5 (20.5~23.9)
Nov.		14.5 (12.7~16.6)	17.9 (12.9~21.1)
Dec.		10.1 (7.7~12.9)	12.8 (10.7~15.3)
Jan.	1975	7.1 (6.4~ 7.6)	12.9 (12.7~13.1)**
Feb.		6.4 (5.0~ 7.4)	11.7 (9.9~12.3)
Mar.		5.8 (4.9~ 7.1)	10.3 (9.3~11.8)
Apr.		6.6 (6.4~11.7)	14.6 (10.9~17.5)

*: The lowest and highest temperatures of the month.
**: Measurement was made only twice in the period.

Mean monthly water temperature at Tatoku Island ranged from 10.3°C in March to 29.1°C in August. Water temperatures at Onagawa began to rise from April, and the highest water temperature measured 24.0°C in August. At these two test sites, the lowest and highest mean monthly water temperatures were recorded in the same months, March and August, respectively, though higher water temperatures were generally measured at Tatoku Island than at Onagawa through the year.

Salinity averaged 30-35 permill at Onagawa with relatively low salinity in June and July (28-32 permill). Salinity at Tatoku Island averaged 30-35 permill with the exception of lower salinity of under 30 permill in July. This seems to correspond well with the typical rainy season in Japan.

Water temperature and salinity at Noto were measured only once a month when a test string was replaced. Table 2 shows the results at Noto.

Table 2. Water temperature and salinity at Noto.

Measurement \ Date	25 May 1974	25 June	26 July	27 Aug.	27 Sep.	25 Oct.	25 Nov.	25 Dec.	25 Jan. 1976	27 Feb.	27 Mar.	25 Apr.
Water temperature (°C)	17.4	21.8	24.4	26.0	23.2	21.3	15.6	11.8	10.7	10.5	10.6	14.6
Salinity (‰)	35	37	36	36	35	36	34	33	33	34	34	33

2. *Existing species*

Though IMAI *et al.*[15,16] reported two teredine species from Onagawa: *Teredo navalis* and *Teredo yatsui* MOLL (=a synonym of *Lyrodus pedicellatus* after TURNER[17]),

only very few specimens of *T. navalis* were found in the present survey. As a crustacean borer, *Limnoria lignorum* (RATHKE) was collected.

At Tatoku Island, the preliminary investigation in which test panels were submerged in the sea for about three months from September to November, 1973 revealed the existence of three teredine species: *Teredo navalis, Lyrodus pedicellatus,* and *Bankia carinata* (GRAY). The same species were found this time, and *Limnoria lignorum* also existed. *Teredo navalis* was commoner among three teredine species.

The following species were found at Noto : *Teredo furcifera* VON MARTENS, *Teredo navalis, Lyrodus pedicellatus* and *Limnoria lignorum.*

The extent of limnorial attack was very slight at three test sites.

The summarized results on existing species of each month at given test sites are shown in Table 3.

Table 3. Existing species at three test sites. (P : present, A : absent)

Monsh / Test site and species	May 1974	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1975	Feb.	Mar.	Apr.
Onagawa												
Teredine sp.	A	A	A	A	P	P	A	A	A	A	A	A
Limnorial sp.	A	A	P	A	A	A	A	A	A	A	A	A
Tatoku Island												
Teredine sp.	A	P	P	P	P	P	P	A	A	A	A	A
Limnorial sp.	P	A	A	A	A	A	A	A	P	P	A	A
Noto												
Teredine sp.	A	P	P	P	P	P	P	P	P	P	A	A
Limnorial sp.	P	P	P	P	A	P	P	P	P	A	P	P

3. *Settlement of shipworm larvae*

Teredine larvae at pediveliger stage are ready to settle on the wood surface. After setting, they begin to bore into wood with rasping movement of valves. The initial apertures on the wood surface is smaller than 1 mm in diameter so that it is quite difficult to find tiny initial apertures without any tools, though they can be occasionally detected with naked eyes.

In this investigation, a string consisting of three test panels was submerged vertically in the sea from the experimental raft every month. Monthly larval settlement, therefore, was given as the average number of borer apertures (per 100 cm^2) on the surfaces of three test panels removed at the same time. The number of borer apertures on both lower and upper surfaces of each test panel was counted under stereo-microscope at low magnification.

3-a. *Monthly settlement of shipworm larvae at Onagawa*

Shipworm attack on wood occurred only in September and October, 1974, though heavy attack appeared in the past[15,16]. The decrease of wooden ships and marine wooden structures, which used to give suitable habitats to shipworms, have apparently resulted in the decline of shipworm activity at Onagawa. However, if the good conditions are returned once again to shipworms, they might recover their incredible destructing power. Table 4 shows the results at Onagawa.

Table 4. Monthly settlement of shipwormlarvae at Onagawa (number of borer apertures/100 cm^2).

Wood Surface \ Month	May 1974	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1975	Feb.	Mar.	Apr.
Upper Surface	0	0	0	0	6	1	0	0	0	0	0	0
Lower Surface	0	0	0	0	2	1	0	0	0	0	0	0

3-b. *Monthly settlement of shipworm larvae at Tatoku Island*

Results on monthyl settlement of shipworm larvae at Tatoku Island are shown in Table 5.

Table 5. Monthly settlement of shipworm larvae at Tatoku Island (number of borer apertures/100 cm^2).

Wood Surface \ Month	May 1974	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1975	Feb.	Mar.	Apr.
Upper Surface	0	1	5	5	4	3	0	0	0	0	0	0
Lower Surface	0	0	3	3	0	3	1	0	0	0	0	0

Occurrence of shipworm attack was observed for six months from June through November, 1974. Number of borer apertures was much fewer than the number that was expected from the result of the preliminary investigation. In spite of the fact that test panels were exposed to marine borer attack for a longer period, test panels in the preliminary investigation were infested with over 200 borers per 100 cm^2 on each wood surface.

3-c. *Monthly settlement of shipworm larvae at Noto*

Borer apertures were observed for nine months from June, 1974 through February, 1975 with a remarkable peak in September. The peak of settlement of larvae did not agree with the period of the highest water temperature. It seems to appear in a transition stage when water temperature begins to fall. The result obtained at Uchiura Port, Fukui Pref., Japan presented the similar tendency[1]. The first settle-

ment of shipworm larvae occurred in June when water temperature was over 20°C. However, the larvae succeeded in penetrating into wood even at low water temperatures below 15°C in December, January, and February. Though a rise of water temperature must obviously stimulate the reproductive ability of the adult shipworms,

Table 6. Monthly settlement of shipworm larvae at Noto (number of borer apertures/100 cm²).

Wood Surface \ Month	May 1974	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1975	Feb.	Mar.	Apr.
Upper Surface	0	4	6	59	223	31	18	3	1	0	0	0
Lower Surface	0	5	9	372	1097	232	189	25	7	1	0	0

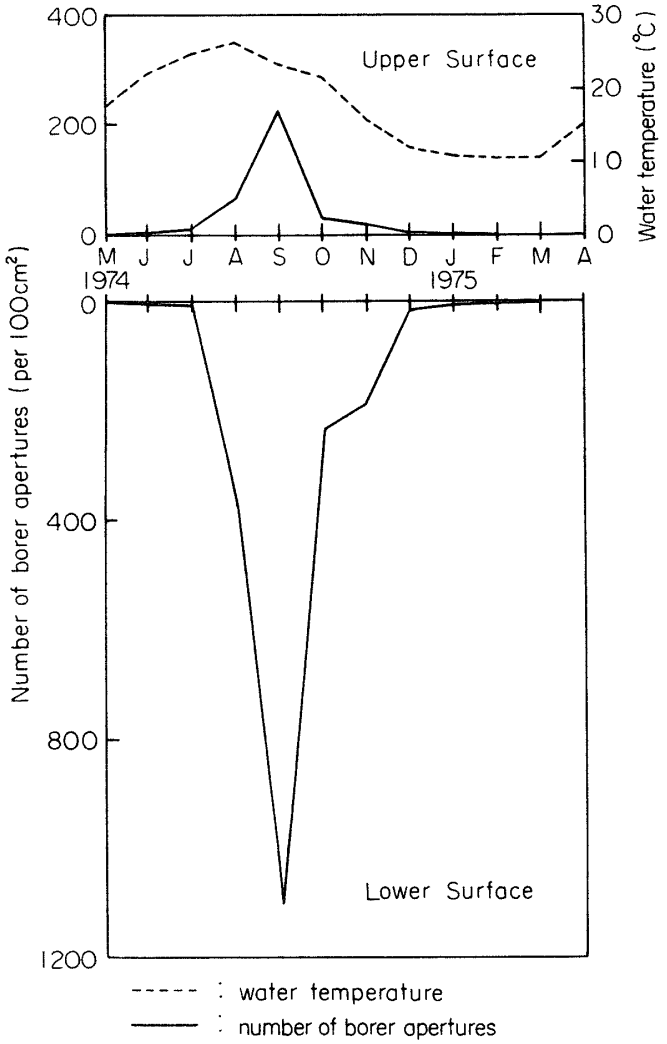

Fig. 1. Monthly settlement of shipworm larvae at Noto in relation to water temperature (May, 1974-April, 1975).

the foregoing fact evidenced that shipworms could survive and breed posterity below 15°C.

The more larval settlement is generally recorded on the upper surfaces than on the lower surfaces[18]. This is proven by the results obtained at the following sites in Japan: Naruto, Tokushima Pref., Maizuru, Kyoto Pref., Aioi, Hyogo Pref., Uno, Okayama Pref., and Sakaide, Kagawa Pref.[19] On the contrary, the lower surface was infested with shipworm larvae more than the upper surface at Noto. Unfortunately, there was no finding to demonstrate it.

Results are shown in Table 6 and Fig. 1.

References

1) K. TSUNODA and K. NISHIMOTO, Wood Research, No. 53, 1 (1972).
2) I. TAKI and T. HABE, Venus, **14**(1-4), 11 (1945).
3) I. TAKI and T. HABE, Damage and the method of protection against wood boring animals (in Japanese, edited by Okada), 43, (1958).
4) T. HABE, Genera of Japanese shells, Pelecypoda **3** (1952).
5) T. HABE, Venus, **17**(3), 140 (1953).
6) T. HABE, Publications from the Akkeshi Marine Biological Station, **4**, 25 (1955).
7) D. B. QUAYLE, Proceedings of international congress on marine corrosion and fouling, 407 (1965).
8) A. BOHN, Material und Organismen, **10**(2), 155 (1975).
9) S. CLESSIN, Conchylien-Cabinet **2**, **11**(4), 78 (1893).
10) F. ROCH and F. MOLL, Mittelungen aus dem zoologischen Staatsinstitut und zoologischen Museum in Hamburg, **44**, 1 (1919).
11) K. KURONUMA, Venus, **2**(6), 294 (1931).
12) F. MOLL, Venus, **11**(1), 11 (1941).
13) S. MAWATARI and H. KITAMURA, Miscellaneous Report of Res. Inst. Natur. Resources, **52-53**, 68 (1960).
14) S. MAWATARI and H. KITAMURA, Rep. Res. Inst. Natur. Resources, **1009**, 129, (1961).
15) T. IMAI *et al.*, Kagaku (Science) (Tokyo), **14**(8), 285 (1944).
16) T. IMAI *et al.*, Tohoku Jour. of Agricultural Res., **1**(2), 199 (1950).
17) R. D. TURNER, A survery and illustrated catalogue of the Teredinidae, Museum of Comparative Zoology, Harvard Univ. (1968).
18) C. C. WALDEN *et al.*, J. Fish. Res. Bd. Canada, **24**(2), 261 (1967).
19) K. TSUNODA, unpublished