Lowland Technology International 2015; 17 (13.): 189-196
International Association of Lowland Technology (IALT): ISSN 1344-9656

Research Paper

Effect of trenches on the habitat of aquatic organisms in a salt marsh in Saga, Japan

Y. Nagahama [1], K. Nishimura [2] and H. Yamanishi [3]

ARTICLE INFORMATION

Article history:

Received: 03 January, 2015
Received in revised form: 21 March, 2015
Accepted: 26 November, 2015
Published: December, 2015

Keywords:

Tidal river
Ilyoplax deschampsi
Exopalaemon orientis
Tridentiger bifasciatus
Shannon–Wiener index

ABSTRACT

Trenches were constructed to control the growth of *Phragmites australis* on a riverbank in the Ushizu River in Saga, Japan. However, the effect of these trenches on the habitat of aquatic organisms is unclear. The purpose of this study is to clarify the effect that trenches have on aquatic organisms in the tidal river. The burrow density of a type of sand crab (*Ilyoplax deschampsi*) and the abundance of aquatic organisms (such as fish and shrimp) in our trenches were measured. The number of *I. deschampsi* burrows around trench D was similar to that observed before trench construction. However, mud sedimentation was accelerated in shallow trench D', which created a suitable habitat for this species. Additionally, we found shrimp and gobies in all our trenches. This indicates that artificial trenches do provide habitat for shrimp and gobies in riverside marshes. Moreover, an endangered species and many aquatic insects were collected. Our results suggest that trenches provide important habitats for rare fishes and aquatic insects, similar to that of a lagoon.

1. Introduction

The Ariake Sea possesses a vast tidal flat zone with a comparatively large tidal range, approximately 6 m. The river that flows into the Ariake Sea also has a large estuary, and seawater containing suspended solids intrudes into the river during high tide. As a result, most of the suspended sediments accumulate on the riverbanks. In the Ushizu River, the average sedimentation speed of suspended solids was approximately 1 cm/day on the riverbanks (Yamanishi et al., 2012). This sedimentation of mud soil causes narrowing of the river. Mud sedimentation encourages the growth of *Phragmites australis* on the riverside, which poses a serious problem to the river administrator by preventing outward river flow. To solve this problem, river administrators have excavated the riverbed and mowed or burnt off the surrounding vegetation. Mowing and burning are suboptimal solutions, for two reasons: 1) mowing may increase stem density (Yamanishi et al., 2013), and 2) burning generates smoke, which causes harm to the nearby human population. Excavation and development are comparatively costly, and sedimentation masks the effects of excavation after several years. A sustainable and economical method for solving this problem has yet to be developed. Yamanishi et al., (2013) proposed using artificial trenches similar to a lagoon to control *P. australis* growth. Typically, *P. australis* vegetation spreads by rhizomes, and Yamanishi et al., (2013) found that *P. australis* spreads by two rhizome layers at approximately 0.3 m and 0.8 m belowground. Moreover, *P. australis* does not sprout from

[1] Corresponding author, IALT member, Ibaraki Kasumigaura Environmental Science Center, Ibaraki 300-0023, JAPAN, y.nagahama@pref.ibaraki.lg.jp
[2] Graduate School of Science and Engineering, Saga University, Saga 840-8502, JAPAN (previous)
[3] Professor & IALT member, Institute of Lowland and Marine Research, Saga University, Saga 840-8502, JAPAN, yamanisi@ilt.saga-u.ac.jp
Note: Discussion on this paper is open until June 2016.

rhizomes in ponds of approximately 0.5 m in depth. This research shows that *P. australis* vegetation may be controlled by constructing riverbank trenches 0.5 m in depth, with boarders 0.8 m in depth.

Salt marshes along the riverbanks provide important habitat for many species in the river ecosystem. The sand crab *Ilyoplax deschampsi* only occurs in an inner part of the Ariake Sea. *Ilyoplax deschampsi* species status is near threatened, and its habitat must be preserved. Additionally, the water pockets found along the riverside marshes (similar to a backwater lagoon) are important for river ecosystems. Artificial trenches may act like ponds or lagoons, providing backwater areas in river ecosystems. It is necessary that we clarify the effect of artificial trenches on aquatic organisms the tidal river.

In this study, we constructed artificial trenches in the tidal river, which emptied into the Ariake Sea. Subsequently, we investigated how these trenches influenced aquatic species found within these habitats.

2. Material and methods

2.1 Trench construction

In June 2013, four types of trenches in the Ushizu River, which emptied into the Ariake Sea, were constructed. The trenches were constructed on the eastern bank approximately 4.8 km from the river mouth (Fig. 1).

Trenches A, B, C, and D were of similar size (6 × 4 m) and depth (1m), but differed in boarders and openings (Figs. 2 and 3). Trench A was excavated without surrounding boarders as our control. Trench B was surrounded by a boarder, which was approximately 0.15 m above ground, and had an opening into the river. Trench C was the same as trench B but lacked an opening into the river. Trench D consisted of two trenches connected by a shallow channel; the smaller of these trenches (trench D', 6 × 3 m, 0.5 m depth) had two openings into the river. The ground levels on each trench were as follows: Trench A was Tokyo Peil(T.P.) 2.59 m, the bottom of the opening of trench B was T.P. 2.36 m, the top of the boards of trench C was T.P. 2.78 m, the bottom of the opening of trench D was T. P. 2.56 m, and the bottom of the opening of trench D' was T. P. 2.47 m. High Water Level of this area was T. P. 2.47 m, though, these trenches connected river approximately twice a month, as the periods for a flood tide from the medium tide.

The accumulated mud in these trenches was dredged up on December 11 to 12, 2013 and October 30, 2014.

2.2 Habitat investigation

The burrow density of a small sand crab (*I. deschampsi)* was measured using the transect-quadrat method. We established sampling points as seen in Fig. 4 and measured the burrows in 0.5 m × 0.5 m quadrats at

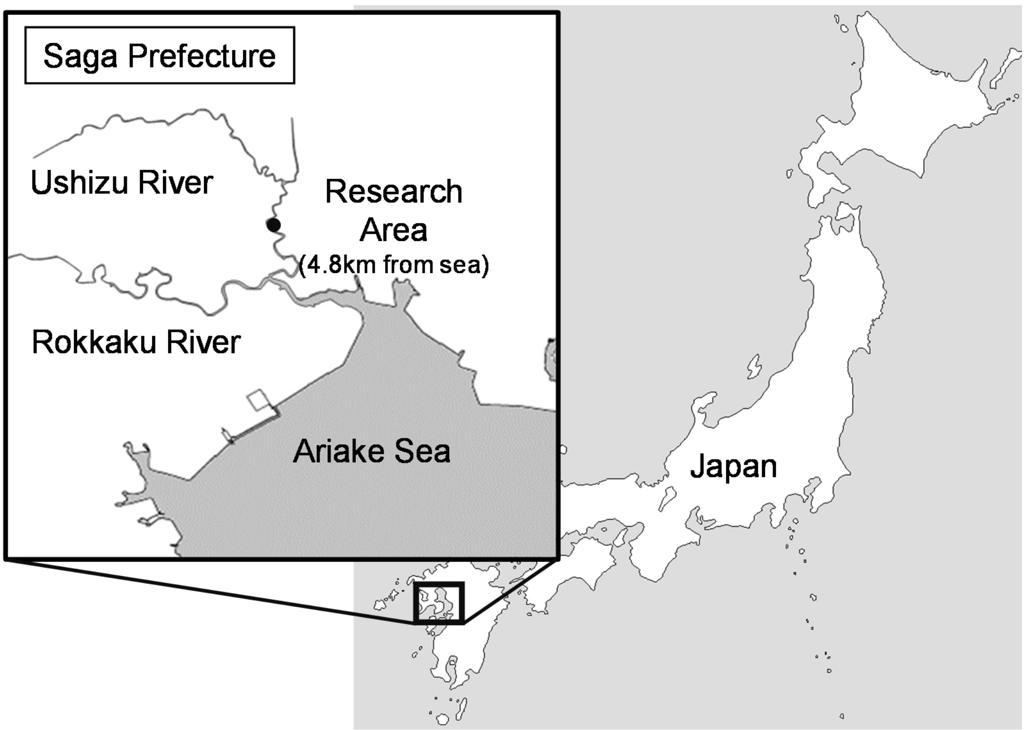

Fig. 1. Research area that construction of the trenches.

these points. We first measured burrow density before trench construction, in July, August and September 2011. We then measured burrow density after trench construction in July, August, and September 2013.

We also documented the presence of organisms such as fish and shrimp in our trenches. We drained the trenches and collected the organisms in the mud sediment with 1mm mesh D-flame nets on July 23 and October 3, 2014. The samples were fixed with 10% formalin. The organisms were classified based on species, and counted and measured for wet weight in the laboratory. Then, we used the Shannon–Wiener index to evaluate biodiversity.

Additionally, we drained our trenches on October 30, 2014. Then, on November 5, 2014, after river water had flowed in with four tidal cycles, we drained our trenches and counted the number of immigrant organisms in the mud sediment for each trench.

We measured water temperature, salinity, DO, pH, chlorophyll-*a*, T-N, and T-P in each trench on July 23 and October 3, 2014.

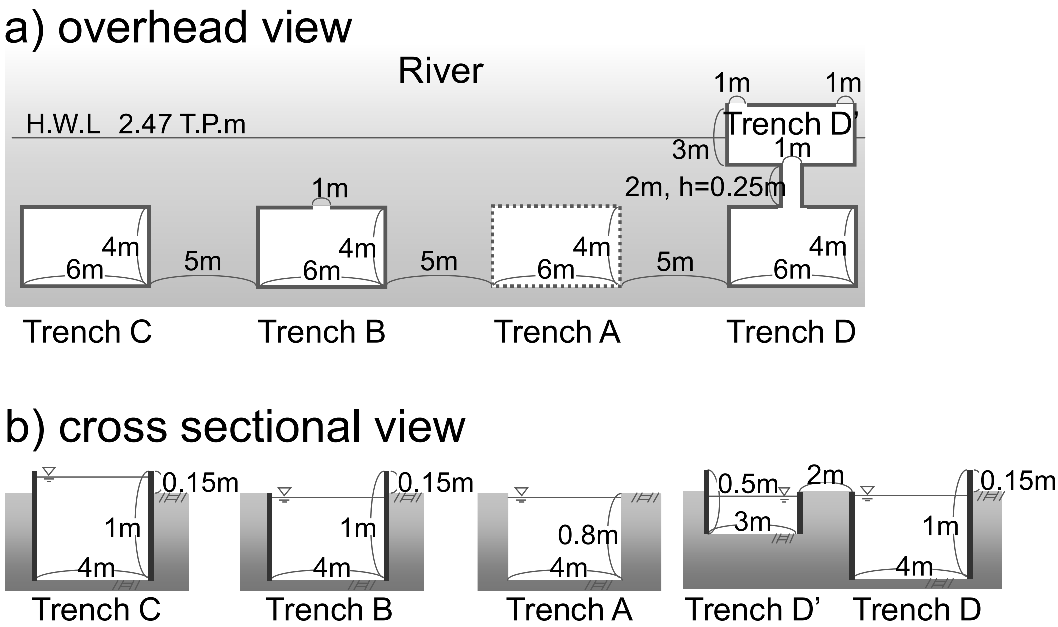

Fig. 2. Trench A, B, C, D and D' as viewed. **a)** overhead, and **b)** in cross section trough the center. All dimensions are provided and the solid lines indicate trenches with artificial boarders

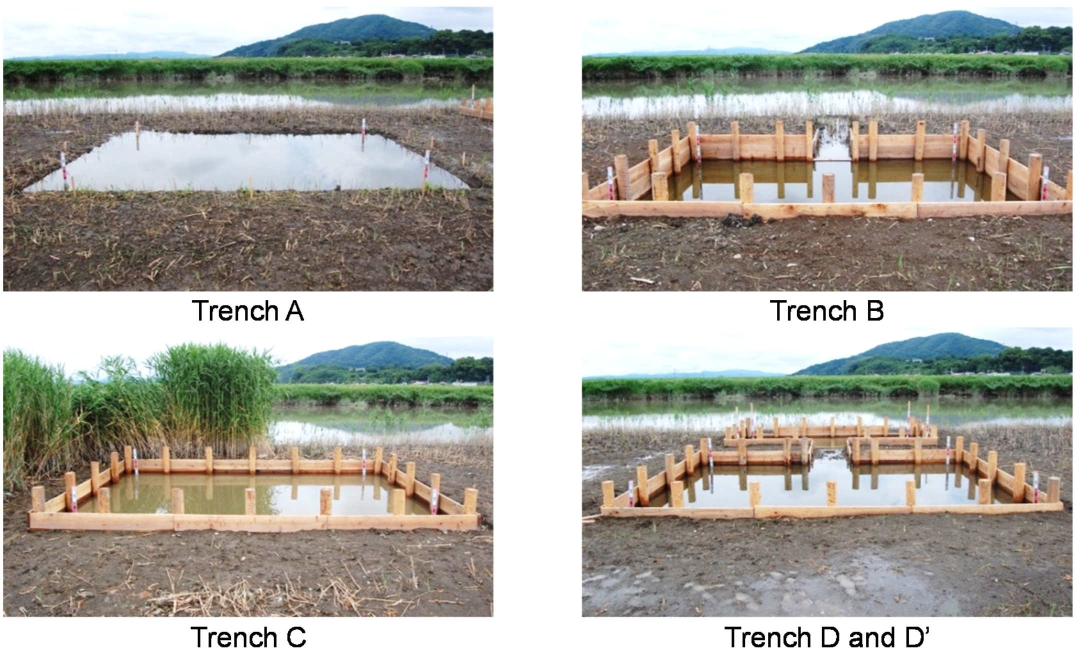

Fig. 3. Photos of trench A, B, C, D, and D' (June 2013).

3. Results and discussions

3.1 Habitation of *I. deschampsi*

Figure 5 shows the average burrow density of *I. deschampsi* for each transect before trench construction. In September, the burrow density before trench construction was 41 burrows/0.25 m^2. Previous work found that *I. deschampsi* actively burrows in the summer (Kosuge, 1999). Another study observed that burrow density ranged from 10.2 to 27.8 burrows/0.0625 m^2, with an average of 17.6 ± 6.3 burrows/0.0625 m^2 (Wada, 1992). Compared with these results, our average burrow density of 41 burrows/0.25 m^2 (164 burrows/m^2) is low than previous work of 17.6 burrows/0.0625 m^2 (281.6 burrows/m^2). This low burrow density may be because our averages included the values of the supratidal zone. Figures 6a and 6b display the burrow density of *I. deschampsi* for transects A-D before and after trench construction for July and September. Burrow density was lower near the supratidal zone and higher near the high water zone. We found that the burrow density of *I. deschampsi* was approximately 70 burrows/0.25 m^2 (280 burrows/0.25 m^2) when sampled the nearest point to the river, which is similar to previous findings (17.6 ± 6.3 burrows/0.0625 m^2, Wada 1992).

As seen in Fig. 5, the average burrow density in transect A was seems that similar to that observed before trench construction. Average burrow densities had trend that greater in transects B and D than those observed before trench construction. In addition, these trends were more pronounced in September than in July. The construction of trenches B and D seems to have positively influenced the habitat of *I. deschampsi*. Furthermore, average burrow density was lower in transect C than that observed before trench construction. Trench C seems to have negatively influenced the habitat of *I. deschampsi*.

We shall discuss the reactions of trench type and *I. deschampsi* in detail. We will now focus on transect C in Fig. 6. In July, average burrow densities for transect C were less than our before trench construction values, especially at 5-28m. In September, average burrow density from 23-28m for transect C was clearly less than our before trench construction values. The 23m, 25.5m, and 28 m sampling points were on the riverside of trench C (Fig. 4). Trench C was boarded and did not open to the river, thereby differing from the other trenches (Figs. 2 and 3). These results suggest that such structures negatively influenced the habitat of *I. deschampsi*. Additionally, our measurements indicate that the ground level after trench C was constructed was not significantly different from the ground level before trench construction.

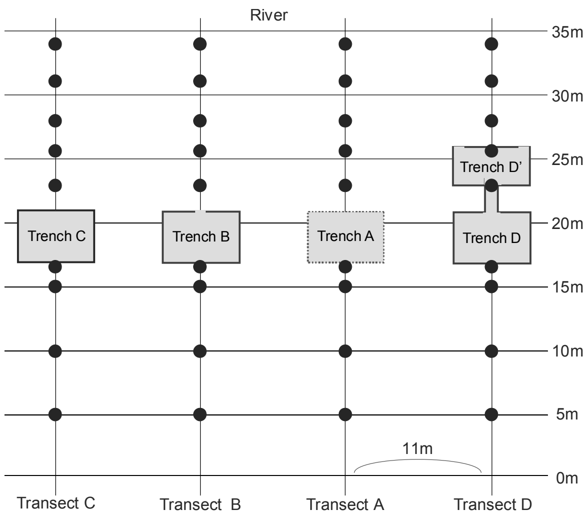

Fig. 4. We sampled burrow density of *I. deschampsi.* along a distant gradient for transects A-D.

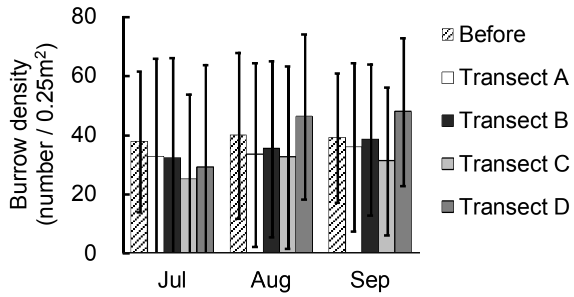

Fig. 5. The average burrow density of *I. dechampsi* before (2011) and after (2013) trench construction for transects A-D. The burrow densities were countered in July, August and September. Error bar show S.D. (n = A;7, B;11, C;11, D;9).

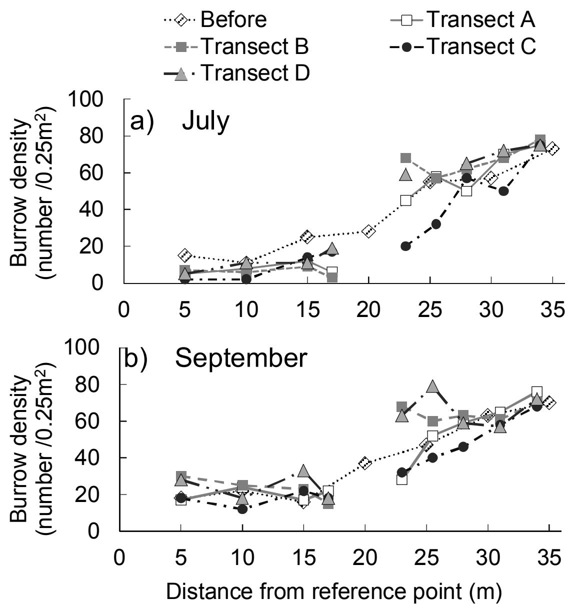

Fig. 6. The burrow density of *I. dechampsi* before (2011) and after (2013) trench construction in transects A-D. Results are shown for **a)** July, and **b)** September.

This indicates that the negative influence on the crab habitat was not due to changes in ground level, rendering the mechanism unidentified.

For transect B, burrow density was greater before trench construction at 23 m in both July and September. In September, the burrow density at 25.5 m and 28 m was greater before trench construction. Trench B was open to the river, but our sampling points were in front of the opening. This suggests that areas in front of the opening positively influenced the habitat of *I. deschampsi*. Average burrow density in transect D was greater than that observed before trench construction at 23 m in both July and September. Additionally, no burrows were observed at 25.5 m in July since this point on transect D was in the shallow trench D'. In July, *I. deschampsi* could not burrow in trench D' because it had pooled over with river water. In September, trench D' became filled with mud, and resembled a tidal flat, which provided an ideal habitat for *I. deschampsi*.

The number of individuals

3.2 *Habitat for aquatic organisms*

We observed many gobies, fish, shrimp, and aquatic insect in every trench. Table 1 is a summary of all species classified and counted in the trenches in July and October. In total, 46 species were collected during our study. Aquatic organisms were categorized into eight types: Pisces into Gobiidae and Other fishes; Crustacea into Brachyura, Caridea, and other Crustacea; Aquatic insects; Polychaeta; and Mollusca. *Oryzias latipes*, which is an endangered species in Japan (Ministry of the Environment, 2012), was also collected. Moreover, many aquatic insects such as Dytiscidea and water striders were collected but we were unable to identify these at the species level. However, our results suggest that artificial trenches provide a habitat for rare fishes and aquatic insects, similar to a backwater area.

Figure 7 displays the number of individuals we collected for each trench in July and October. Our results show that trench A, B, and D had abundant Caridea and Gobiidae in July. The dominant species of Caridea is *Exopalaemon orientis*. *E. orientis* represented between 36.2 and 41.8% of all aquatic organisms collected in trench A, B, and D. Meanwhile, *E. orientis* was collected

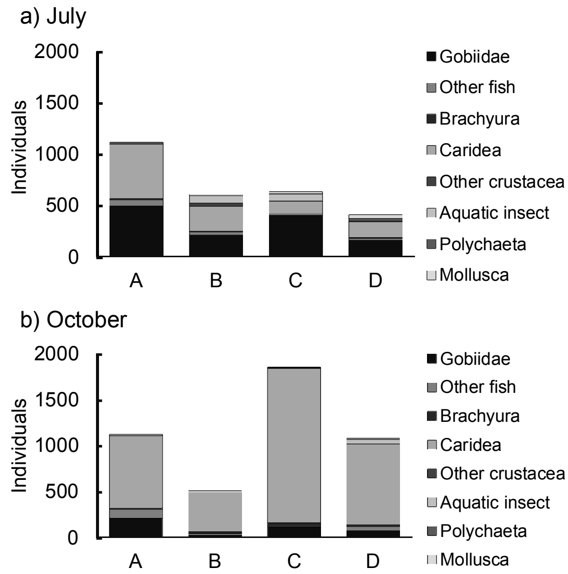

Fig. 7. The number of individual organisms within each category for trenches A–D in **a)** July, and **b)** October.

Table 1. A summary of all species collected and counted in trenches A, B, C, and D for July and October.

Order	Category	Species	Indibisuals number July	Indibisuals number October
Actinopterygii				
	Gobiidae	*Acanthogobius flavimanus*	5	
		Acanthogobius hasta	60	8
		Boleophthalmus pectinirostris	2	3
		Mugilogobius abei	348	218
		Periophthalmus modestus	28	
		Tridentiger bifasciatus	822	176
		Glossogobius olivaceus	1	31
		Other Gobiidae	12	
	Other fishes	*Trachidermus fasciatus*	3	
		Gambusia affinis	6	36
		Abbottina rivularis	2	
		Carassius auratus langsdorfii	3	
		Pseudorasbora parva	26	2
		Rhodeus ocellatus kurumeus	1	0
		Rhodeus sp.		1
		Lateolabrax japonicus	1	
		Oryzias latipes	37	103
		Mugil cephalus	4	
		Liza haematocheila	14	
		Other Actinopterygii	22	3
Malacostraca				
	Branchyura	*Ilyoplax deschampsi*	2	9
		Chiromantes dehaani	2	10
		Parasesarma erythodactyra		1
		Helice tridens		1
		Deiratonotus cristatus	20	31
		Cleistostoma dilatatum	7	54
Mal[...]	Total number of individuals Total number of species			
		[...]emon orientis	889	3596
		[...]achium nipponense	7	11
		Palaemon paucidens	41	19
		Metapenaeus ensis	4	145
		Other Caridea	100	1
	Other crustacea	*Platorchestia pacifica*	6	
		Monocorophium insidiosum	2	1
		Gnorimosphaeroma sp.		2
		Other Crustacea	37	
Insecta				
	Aquatic insect	*Ranatra chinensis*	1	
		Anisops ogasawarensis	9	58
		Hemiptera	21	
		Eretini sticticus	2	1
		Chironomidae	112	
Araneae				
		Araneae	1	3
Polychaeta				
	Polychaeta	*Hediste sp.*	49	1
Gastropoda				
	Mollusea	*Neripteron cornucopia*	4	8
		Pseudomphala latericea miyazakii	40	26
		Stenothyra sp.	3	
Bivalvia				
		Bivalvia	3	
	Total individuals number		2759	4559
	Total species number		42	30

in trench C at only 8.4%, and the dominant proportion of Gobiidae increased relatively. The dominant Gobiidae species was *Tridentiger bifasciatus* in each trench. Especially in trench C, *T. bifasciatus* represented 48.6% of all aquatic organisms. *E. orientis* and *T. bifasciatus* were more abundant in trench A than in trench B, C, or D. River water flowed easily into trench A because trench A had no boarders. This suggests that these organisms move into the trench with river water as tides flow. Meanwhile, in October, all trenches had high proportions of Caridea, which represented 66.5 to 87.5% of all aquatic organisms. The abundance of *T. bifasciatus* was high in July but decreased in September by 2.0 to 6.4%. This difference is a question to be considered later.

Figure 8 shows the numbers of species and Shannon–Wiener Index for each trench in July and October. Although trench C had abundant species in each season, the Shannon–Wiener Index for this trench was not higher than that for other trenches. Furthermore, the number of species decreased from July to October, especially the fishes (both Gobiidae and other fish), which decreased greatly. We noted this trend in number of individuals as shown in Fig. 7.

It is possible that the differences we observed in species and individuals resulted from seasonal variation. Water quality is shown in Table 2. Decreasing the water temperature and chl-*a* from July to October shows that the photosynthesis of phytoplankton was not as active from July to October. Moreover, these trenches were connected to the river more than once a month. At that time, the water of these trenches affected river water as observed in the trench salinity (Table 2). Figure 9 shows the standard length (SL) of *T. bifasciatus* in July and October. The average SL was significantly different (n = 40, $p < 0.05$) in July (1.8 ± 50 cm) compared to October (3.0 ± 0.51 cm). Usually, spawning season of *T. bifasciatus* is from spring to summer around the Ariake Sea (Kawahara, 2009). Our results show that many juvenile fish live in the river stream in July, and this population decreased from July to October with maturation of juveniles. Therefore, the number of

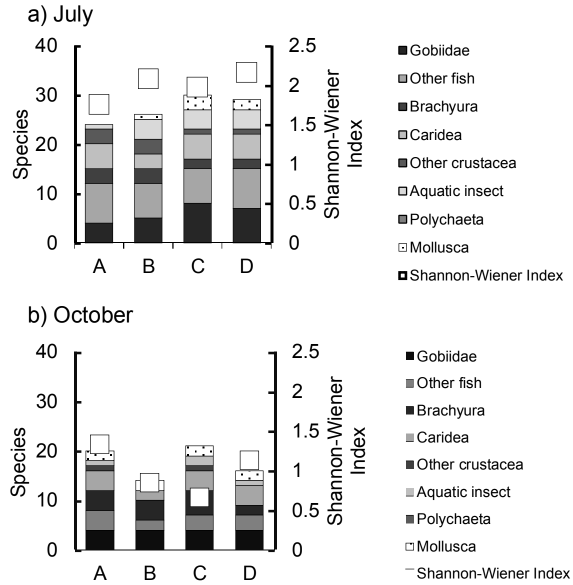

Fig. 8. The number of species and Shannon-Wiener Index for trenches A–D in **a)** July, and **b)** October.

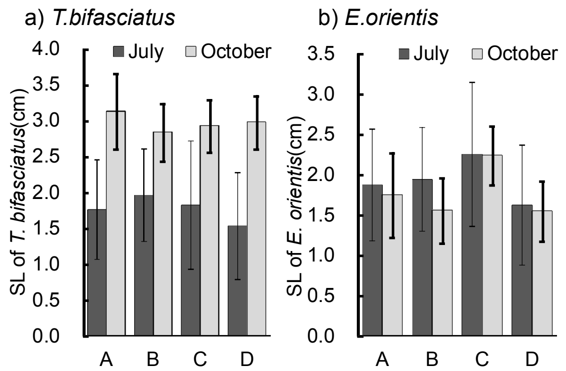

Fig. 9. The standard length of **a)** *T. bifasciatus* and **b)** *E. orientis*. Errow bar show S.D.

Table 2. A summary of water quality for trenches A–D in July and October, 2014.

Date	2014.07.23				2014.10.03			
Trench	A	B	C	D	A	B	C	D
Temparature(ºC)	28.2 ± 0.28	28.5 ± 0.20	28.6 ± 0.29	29.2 ± 0.28	22.3 ± 0.07	22.4 ± 0.47	22.5 ± 0.12	22.7 ± 0.08
Salinity (psu)	0.99 ± 0.16	0.94 ± 0.23	0.77 ± 0.04	1.01 ± 0.03	2.80 ± 1.50	2.33 ± 1.15	2.73 ± 1.08	2.17 ± 1.64
DO (mg/L)	6.74 ± 0.05	6.75 ± 0.02	7.56 ± 0.06	7.97 ± 0.59	-	-	-	-
pH	7.68 ± 0.09	7.90 ± 0.25	8.07 ± 0.27	7.60 ± 0.03	7.69 ± 0.04	7.83 ± 0.10	7.50 ± 0.06	7.72 ± 0.04
Chl-*a* (μg/L)	13.29 ± 9.27	10.00 ± 12.25	7.74 ± 6.52	8.31 ± 4.08	3.24 ± 3.08	6.72 ± 10.69	5.72 ± 5.02	5.77 ± 6.36
T-N (mg/L)	-	0.88	0.64	-	1.02	-	0.56	0.61
T-P (mg/L)	0.28	0.86	0.56	1.48	0.31	0.44	0.19	0.18
NO_3-N (mg/L)	ns	ns	ns	0.01	ns	ns	0.04	0.06
NO_2-N (mg/L)	ns	ns	ns	0.00	ns	ns	0.00	0.01
NH_4-N (mg/L)	0.06	0.27	0.13	0.12	0.44	0.34	0.21	0.21
PO_4-P (mg/L)	0.22	-	-	-	0.15	0.23	0.13	0.12

individuals in our trenches decreased from July to October as shown in Fig. 7. Meanwhile, the average SL of *E. orientis* was not significantly different (n = 40, ns) from July (1.9 ± 0.75 cm) to October (1.8 ± 0.49 cm;. Our results suggest two possibilities: 1) the parent population of *E. orientis* showed no seasonal valuation, or 2) the trenches provided suitable habitat for *E. orientis* of approximately 2 cm SL.

3.3 Immigration for each trench

Figure 10 shows the number of individuals categorized for each trench in November. The total number was lower by 1/5 to 1/10 when compared with July and October, respectively (Fig. 7). These low individual numbers may be because each trench was only connected to the river stream four times by the tide. The quantity of fish (Gobiidae and other fish) was lower in November than in July and October. Furthermore, the quantity of aquatic insects was higher in November compared to July and October.

Trench A had less immigration than other trenches. Our previous study (Nagahama et al., 2014) suggested that Caridea had a positive relationship with total opening length. However, the results of the present study did not support our previous findings. It may be that our results were affected by current speed and time. In our study, every trench was empty on October 30. The river water then flowed into these trenches at the first tide. This high volume of water flowed into our trenches with high speeds and long duration of flooding, especially trenches B and D, which had openings to the river. *E. orientis* has a low swimming ability (Kawahara, 2009). The high speed and long duration of flooding around the openings may carry *E. orientis* into trenches, as we observed for trenches B and D.

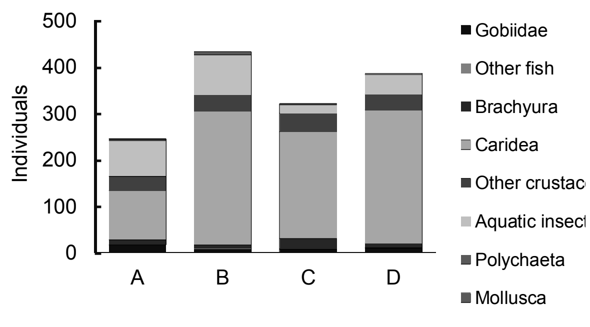

Fig. 10. The number of individual organisms within each category for trench A-D in November.

4. Conclusions

Experimental trenches were constructed in the Ushizu tidal river, and their influence on the habitat was investigated.

1) Trenches with openings provided good habitat for *I. deschampsi,* as observed in trench B. Trenches without openings (such as trench C), may have a negative influence on *I. deschampsi* habitat.

2) Shallow trench D' provided habitat for *I. deschampsi* by accumulation of mud.

3) We collected 46 species of aquatic organisms. There were many gobies and Caridea in these trenches. *E. orientis* was the dominant species of Caridea, and *T. bifasciatus* was the dominant species among gobies.

4) An endangered species and many aquatic insects were collected. Our results suggest that these trenches were important habitat for rare fishes and aquatic insects, similar to a backwater area.

5) The number of individuals and species of both Gobiidae and other fishes decreased from July to October. The difference in SL of *T. bifasciatus* suggests that the population of juvenile fish in the river stream decreased from July to October, owing to the maturation of juveniles.

6) We did not detect a relationship between Caridea abundance and total opening length, as shown in previous work. Our results may have been affected by the current speed and duration of flooding around the opening for trenches B and D.

Acknowledgements

This research was supported in part by a grant from the MLIT (Ministry of Land, Infrastructure, Transport and Tourism) and the River Fund in charge of The River Foundation, Japan. I thank Takeo Office of River, MLIT. Thanks are due to Aya KITSUKA, Takahiro OMINE, Zhisheng GAO, Honami FUKUSHIMA, Yuki HIGASHI, Kodai UMEZAKI, and Noriyuki INOUE for their assistance in sampling.

References

Kawahara, J., Aoki, S., Inui R., Kitani, M., Takekawa, D., Nakajima, A., Hamada. S. and Yamanaka, C., 2009. The picture book of aquatic organisms in Kitakyusyu tidal flat. Ichthyology club of Fukuoka Prefectural Kitakyushu High School (in Japanese), pp 67.

Kosuge, T. 1999. Preliminary report on the life history of the ocypodid crab *Ilyoplax deschampsi* (Rathbun) (Crustacea, Brachyura, Ocypodidae) in the Rokkaku River, Saga Prefecture, Western Japan. Nankiseibutu. **41** (2): 101-105 (in Japanese).

Ministry of the Environment. 2012. The 4th version of the Japanese red lists.

Nagahama, Y., Nishimura, K., Kitsuka, A. and Yamanishi, H., 2014. The effect of artificial trenches for contorting *Phragmites australis* on aquatic organisms. Proc. of Environmental Engineering Research Forum, **51**: 133-135 (in Japanese).

Yamanishi, H., Matsuoka, Y., Hasuo, N., Sakai, F., Yamasaki, T., Takaagi, K., and Kawasaki, H., 2012. Study on the countermeasure against mud sedimentation in riverbank and spreading of *Phragmites australis* affecting on a river flow. Advanced in River Engineering. **18**: 23-28 (in Japanese).

Yamanishi, H., Yamashita, S., Nakamura, Y., Narikiyo, K., Sato, H., Takagi, K., and Kawasaki, H., 2013. Interaction of Phragmites australis and mud sedimentation and the effect of measures to curb the spread. Advanced in River Engineering. **19**: 399-404 (in Japanese).

Wada, K., Kosuge, T., and Takayama, J., 1992. Distributions of *Ilyoplax pusilla* and *I. deschampsi*. Research on Crustacea. **21**: 139-146 (in Japanese).