Int. J. of GEOMATE, Sept., 2013, Vol. 5, No. 1 (Sl. No. 9), pp. 628-633
Geotec., Const. Mat. & Env., ISSN:2186-2982(P), 2186-2990(O), Japan

IMPACT OF FLOOD DISTURBANCE EVALUATION ON THE STRUCTURES OF GROUND-BEETLE ASSEMBLAGE AT BIOTOPES

Michiko Masuda[1], Rina Sakakibara[1], Nao Sugimura[1] and Fumitake Nishimura[2]
[1]Department of Civil Engineering, Nagoya Institute of Technology, Japan; [2]Department of Environment Engineering, Kyoto University, Japan

ABSTRACT: In September 2011, the flood of the Shonai and Yada Rivers in the center of Japan brought lots of earth and sand into their biotopes and caused serious damage to their vegetation. Comparing our data of their ground-beetle assemblage in 2010, we could assess the impact of the flood disturbance. After the spring of 2012, when the damage to the assemblage and vegetation was found to be serious, the number of insects gradually increased as the vegetation recovered, and recovered to the original state by the end of the summer. However, the structure of the fauna was very different from the original. The recoverability of the ground beetle fauna was different in each river; the structures of ground-beetle fauna in the Shonai wetland and Yada grassland recovered soon, but those of floodplain forests in both rivers, which were controlled by people, remained the damage till the end of the autumn. Among these, the structure of fauna in the Shonai grassland was nearly at the level of urbanized areas. Since the number of insects increased along with the recovery of vegetation, we believe the recovery of river vegetation is important. Furthermore, in preparation for the possible disasters, we suggest to extend the non-mowing areas for the recovery of insect fauna.

Keywords: River management, Biodiversity, Biological indicator, Environment assessment

1. INTRODUCTION

The river ecosystem is easily affected by flood disturbance [1]-[3], and the vegetation succession goes back to the initial state. It is known that in case of herbaceous ruderal species the recovery takes about one year [4]-[7], and perennial or tree species invasion starts in the following year. Vegetation recovery is essential for the river ecosystem, but researches on other species, especially ground beetles, are limited [8]. Previous researches have shown that the ground-beetle community reflects the characteristic of the area and can be used for environment assessment as an index to show degrees of maturity and disturbance [9]-[11]..

In September 2011, the typhoon No. 15 attacked the center of Japan, and the Shonai River overflowed its banks (Fig.1). As a result, a lot of soil flowed out, and its two biotopes, where we investigated the ground-beetle assemblage in 2010 [9] using the technique "Nature Oriented River Works," were seriously damaged. The cover of the vegetation was removed, and the surface of the whole biotopes was covered with a lot of sand. As approximately 80% of the biotope was open, the flood was thought to have caused a serious damage to the ground-beetle assemblage.

As there was no research on ground-beetle assemblage after river disturbance, we decided to analyze the structure of the ground-beetle community before and after the disturbance. We focused on following three questions. 1) How did the ground-beetle community recover after the disturbance of the fluvial environment? 2) Did the ground-beetle community serve as invasive pioneer-types by disturbance? 3) When did stable forest-type insects invade to the disturbed area? With these questions in mind we conducted field surveys. The aim of the research was to propose a new biotope management approach based on the obtained information.

Fig. 1. The condition of Shonai River in July (upper) and Sep (lower) 2011.

2. MATERIALS AND METHODS

2.1 Study Site

Two biotopes were studied: the left bank of the Yada River, Joganji, Nagoya City (35° 21’ 60”N, 136° 91’ 70”E, altitude 9m), and the left bank of Shonai River, Nishibiwajima, Kiyosu City (35° 19’ 03”N, 136° 85’ 80” E, altitude 3m) in the center of Japan. The Yada River is an urban river in the water system of the Shonai River with the extension of 25km and the area of 115km^2 in the valley. The Shonai River is also an urban river with the extension of 96km and the area of 1010km^2 in the valley. We selected two plots in the Yada River to collect ground beetles: the grassland with a high degree of disturbance and the floodplain forest with a low degree of disturbance. As for the Shonai River, we selected three plots: the grassland with high disturbance degree, the floodplain forest with low disturbance degree, and the wetland with high disturbance degree. In all of the grassland plots, grass was mown 2 or 3 times a year.

2.2 Field Census

For the census of the ground-beetle, we used the pitfall trap method at all the 5 plots. This is the method of collecting insects with a buried pitfall, a plastic vessel with the diameter of 7 cm, the depth of 10 cm, and the capacity of 280 ml. There was no bait on the ground. In every plot, ten traps were set at a distance of 2 m from each other, and 50 traps in total were buried and were set for a day for one census. Then we identified the species and the number of collected ground beetles. Collected beetles were released after the identification. We carried out the censuses every week from April 6, 2012 to December 10, 2012, and 32 censuses in total were conducted.

Simultaneously with the census, we also investigated the vegetation environment, as the state of vegetation was thought to have a big influence on the trend of the ground-beetle assemblage. In order to investigate the vegetation restoration after disturbance, we surveyed the vegetation of every plot in April, July, and October. Investigation of flora was also conducted.

2.3 Statistical Analysis

In order to analyze the result of census, we used two diversity indexes, an evenness index, an expected value, and disturbance index. Each index was calculated along with the equations listed in Table 1, and indexes in 2010 and those in 2012 were compared..

We rearranged the Detrended Correspondence Analysis (DCA) (using quick-R: correspondence analysis program) and obtained the score to evaluate variations in the ground-beetle assemblage of each vegetation plot.

Table 1. The equations of each statistical value.

Statistical value	Equations
Diversity	
Simpson index	$\lambda = \sum \frac{n_i(n_i - 1)}{N(N-1)}$
Shanon-Winner index	$H' = -\sum \frac{n_i}{N} \log_2 \frac{n_i}{N}$
Evenness	
Pielou index	$J' = N\ H'$
Expected	
Chao species richness index	$ES = S + \frac{a^2}{2b}$
Disturbance	
Ishitani index	$ID = \frac{\sum N_{ij} \cdot I_i}{\sum N_j}$
	$niche\ breadth = \frac{1}{I_i}$, $I_i = \sum_i \left(\frac{N_{ij}}{N_I}\right)^2$

n_i : the number of entities belonging to the ith type, N : the total number of entities, S : the total number of species, a : the number of species observed only one individual per species, b : the number of species observed more than one individual per species. I_i : Environmental index value of the ith type, N_{ij} : the number of the ith species in jth investigated plots, nich breadth: a reciprocal of I_i.

3. RESULTS

3.1 Field Census

In the census, we collected a total of 843 individuals, 48 species, of ground beetles. The number of species observed in all of the plots was only two: *Labidura riparia haponica* and *Gonolabis marginalis*. Some were collected only in one plot. Also, the forest plot in the Yada River biotope had 8 peculiar species.

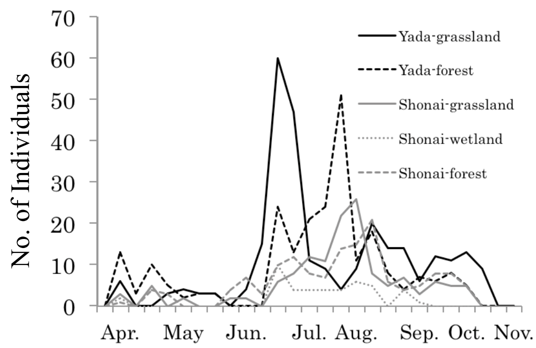

Fig. 2 The seasonal schedules of number of individuals.

Fig. 2 shows the seasonal changes of the number of individuals in each plot. For ground beetles, emerging peaks are generally known to be in spring and summer, but Fig. 2 showed a small peak in spring and a big peak in summer: more serious damage in spring. Although there was a big peak in summer, the damage of the disturbance was thought to be continued because the total number of individuals from July to December 2010 was 3707. Other ground-beetle assemblages are shown in the appendix table.

The vegetation area was extending with the passage of time. Nearly 20% of the biotope was covered with short vegetation with 45 species in April, 80% with 62 species in July, and 100% with 73 species in October.

3.2 Statistical Analysis

The statistical analysis of the census is shown in Fig. 3-6. The Simpson's diversity value of each plot was around 1.2 in 2010, but in 2012 the value was very low except the Shonai grassland plot, whose value was still low. The value of Shannon- Winner index in 2012 was also lower than in 2010. This diversity index showed that the diversity was seriously damaged by the flood disturbance.

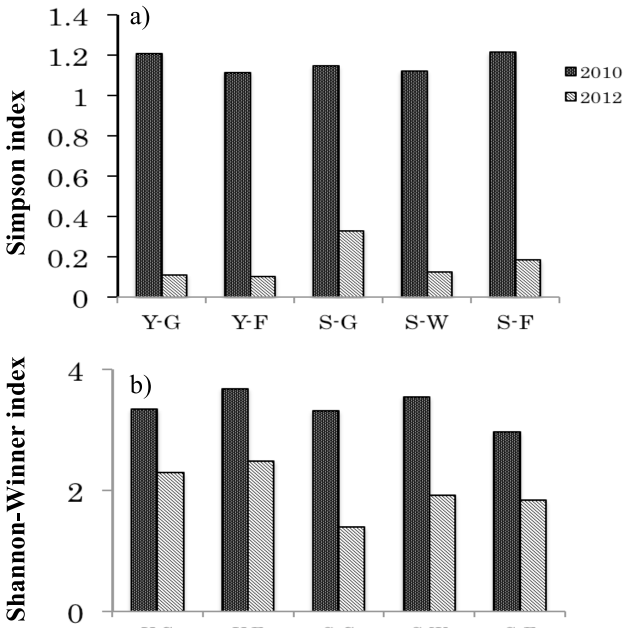

Fig. 3. Comparison of the diversity index in 2010 and 2012. a): the Simpson index, b): Shannon Winner index, Y: the Yada River, S: the Shonai River, G: the grassland, W: the wetland, F: the forest..

As for the value of evenness, Pierou's index, in Fig.4, the difference between 2010 and 2012 was small. The increased value after the flood disturbance showed that there was no priority species in each plot..

The richness of species is shown in Fig.5. Chao species richness indexes in 2012 were 9 to 18, almost a quarter to a half compared with those of 2010. That of the Yada grassland was almost a half, and the richness of the Shonai forest was very low. The condition of the species richness was almost at the same level, irrespective of the vegetation..

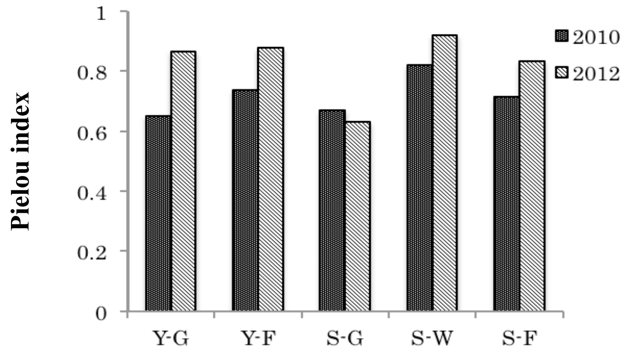

Fig. 4 Comparison of the evenness: Pielou index in 2010 and 2012. Y: the Yada River, S: the Shonai River, G: the grassland, W: the wetland, F: the forest.

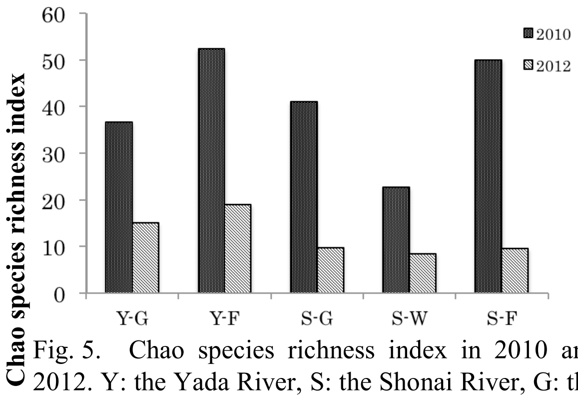

Fig. 5. Chao species richness index in 2010 and 2012. Y: the Yada River, S: the Shonai River, G: the grassland, W: the wetland, F: the forest.

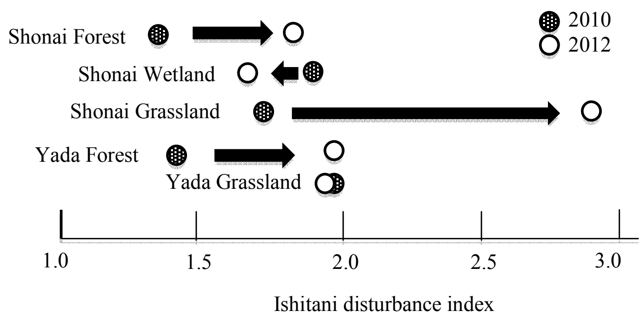

Fig. 6. The relationship between the vegetation type and Ishitani disturbance index in 2010 and 2012. The value of the index in each plot is shown in a circle.

Ishitani's disturbance index of each plot is shown in Fig. 6. Except for the Shonai wetland, values increased in 2012. Especially, that of the Shonai grassland plot was 2.9, almost the city area level.

The flood disturbance affected the disturbance index. All the values were over 1.7, the rice field level of disturbance.

The result of DCA of ground-beetle assemblages in Fig.7 did not clearly indicate the different vegetation plots or river systems, as all the species scattered irrespective of their life cycle. No general trend was observed. All the plots' areas were overlapped, and this meant no difference of the plots. The ground-beetle assemblage was completely removed in September 2011, and initiated the secondary succession. The insect fauna was not dependent on the vegetation succession, and started from the disturbance dependence species.

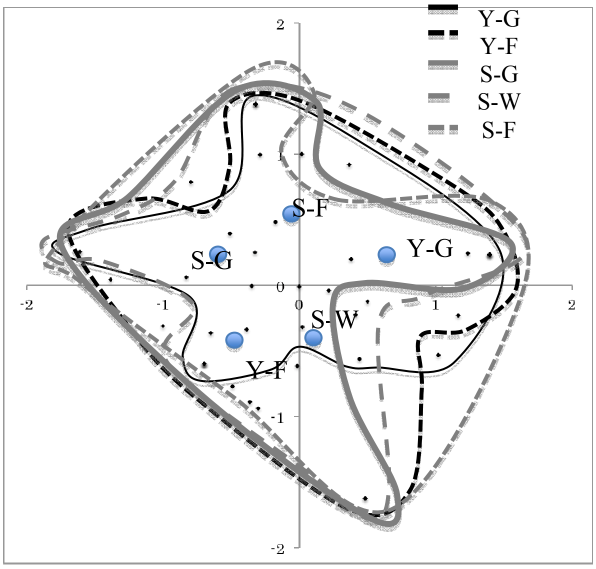

Fig. 7. DCA of the ground beetles. ・: species collected in all plots, ○: the average of each plot, Y: the Yada River, S: the Shonai River, G: the grassland, W: the wetland, F: the forest.

4. DISCUSSION

A lot of studies on ground-beetle assemblage of stable forests and fields are available [12]-[15], but few researchers pay attention to the river flood disturbance. Our study analyzed whether ground beetles would be subject to some kinds of influence of the flood disturbance.

Dominant and unique species observed in all the area were pioneer species with strong flight capability and resistance to disturbance, and are considered to have spread from the surrounding area promptly after disturbance. After the summer, in both the Yada and Shonai biotopes, several generalists, *Pheropsophus jessoensis*, *Campalita chinense, Carabus arrowianus,* and *Necrophila japonica* t were observed. It was also possible that insect fauna other than the pioneer species gradually invaded from the assemblage.

Compared to the data of 2012, the number of individuals in 2010 was large and the variation of species was very rich. Almost all of the dominant species were observed in both years before and after disturbance, but they did not overlap as dominant species. That is, the composition of the species in 2010 and 2012 differed notably.

The spring peak of the ground beetle assemblage was not observed at all till 2012, and was different from the seasonal rise and fall of the insects generally observed in a riverbed. The disturbance in 2011 greatly affected the biological community. A big peak observed from July to September indicated the quick recovery of the ground beetle fauna from the disturbance of the river. As the collection of the ground beetles was for two days for the 2010 census, and one day for 2012, we compared the half of the individual number of 2012 with that of 2012. As the result, the number of individuals in 2012 was about 50% of 2010, and fit was considered that there was not a full recovery in one year. Furthermore, it turned out that even the ground-beetle community in places such as the floodplain forest that seemed not to be affected by the flood was seriously affected by the flood disturbance.

Recovery of the ground-beetle community was observed along with the recovery of vegetation. However, the recovery of its quality was slower. Both the Shonai and Yada forest communities were seriously affected by flood disturbance, and the damage to the species richness in two plots was more severe than that of other areas. The number of ground beetles recovered was the same as other plots, but the diversity and evenness were more affected there than other plots. The Shonai grassland plot was carefully managed by mowing, and the non-mowing area occupied less than 10%, thus preventing the invasion of the generalist species. Therefore, for this reason, we propose the method of biotope maintenance management after flood disturbance; after flood disturbance, mowing should be refrained for two years or more, or non-mowing areas should be extended for various vegetation.

5. CONCLUSION

The following conclusions are drawn from the study.

1) The number of the ground beetles recovers very quickly after the flood disturbance, but the quality of the community recovers slowly.

2) The recovery of the ground-beetle community is mainly made by invasive pioneer species, irrespective of the vegetation types.
3) Few ground beetles of stable-forest-types invade the disturbed area within a year.
Based on these conclusions, we propose two methods of biotope management.
1) The mowing of the floodplain forest should be stopped for two years after the disturbance.
2) Non-mowing areas should be extended in order to let the invasion of stable forest ground beetles.

6. ACKNOWLEDGEMENTS

We express our thanks to the members of the Shonai River Office, the Ministry of Land, Infrastructure and Transport for their support and permission to work in the river. We also thank the members of our laboratory for their assistance in the field works.

7. REFERENCES

[1] Nakamura F, Shin N, Inahara S, "Shifting mosaic in maintaining diversity of floodplain tree species in the northern temperate zone of Japan", Forest Ecology and Management Vol. 241, 2007, pp.28-38.
[2] Shimada M, Ishihama F, "Asynchronization of local population dynamics and persistence of a metapopulation: a lesson from an endangered composite plant, *Aster kantoensis*", Population Ecology,Vol. 42, 2000, pp.63-72.
[3] Masuda M, Washitani I, "Comparative ecology of the schedules for 'reproduction by seeds' in a moist tall grassland community", Functional Ecology, Vol. 4, 1990, pp.169-182.
[4] Cesresnyes I. Csontos P, "Soil seed bank of the invasive *Rvinia pseudoacacia* in planted P*inus nigra* stands", Acta Botanica Croatia, Vol. 71, 2012, pp.249-260.
[5] Masuda M. Ito Y, Nishimura F, "Process of invading the alien plant species into the river ecosystem", in Proc. first Int. Conf. on GEOMAT, 2011, pp.437-442.
[6] Miyawaki C, Washitani I, "The contribution of agricultural weeds, revegetation species and aquacultural species", Grobal Environmental Research, Vol. 8, 2004, pp89-101.
[7] Nilsson C, Grelsson G, Jahansson M, Sperens U, "Patterns of plant species richness along river banks", Ecology, Vol. 70, 1989, pp.77-84.
[8] Flecker AS, Feifarek B, "Disturbance and the temporal variability of invertebrate assemblages in two Andean streams", Freshwater Biology, Vol. 31, 1994, pp.131-142.
[9] Masuda M, Tsukada T, Nishimura F,"Change in structure of ground-beetle assemblage on river areas after construction of biotopes using the technique, Nature oriented river works", in Proc. 2nd Int. Conf. on GEOMAT, 2012, pp. 839-844.
[10] Bonni A, Hagen K, Wohlegenuth-von Reiche D, "The significance of flood regimes for carabid beetle and spider communities in riparian habitats-a comparison of three major rivers in Germany", River Res. Appl. Vol. 18, 2002, pp43-64.
[11] Boscaini A, Franceschini A, Maiolini B, "River ecotones: carabid beetles as a tool for quality assessment", Hydrobiologia, Vol. 422/423, 2000, pp173-181.
[12] Thiele HU, Carabid beetles in their environment. A study of habitat by selection adaptation in physiology and behavior. Springer-Verlag: 1977.
[13] Lenski RE, "The impact of forest cutting on the diversity of ground beetles (Coleoptera: Carabidae) in the southern Appalachians", Ecol. Entomol., Vol. 7, 1982, pp.385-390.
[14] Niemela J, "Effect of changes in the habitat on carabid assemblages in a wooded meadow on the Aland Islands", Not. Entomol., Vol. 69, 1990, pp.169-174.
[15] Ishitani M, "The ecological research of the ground beetles: different vegetation area affect the community," Chugoku area Insect, Vol. 17, 2004, pp.13-18.

Int. J. of GEOMATE, Sept., 2013, Vol. 5, No. 1 (Sl. No. 9), pp. .628-633.
MS No. 3154 received on June 14, 2013 and reviewed under GEOMATE publication policies.

Pertinent discussion including authors' closure, if any, will be published in the Sept. 2014 if the discussion is received by March, 2014.
Corresponding Author: Michiko Masuda

Appendix table
The list of collected ground beetle at each plot

		Yada		Shonai		
family	species	grassland	forest	grassland	wetland	forest
Carabidae	*Lebia retrofasciata*	0	0	0	1	0
	Pterostichus noguchii	0	1	3	0	5
	Platynus magnus	0	12	0	0	0

	Harpalus corporosus	0	10	0	0	0
	Dolichus halensis	0	2	6	0	0
	Notiophilus impressifrons	1	0	0	0	0
	Harpalus eous	0	0	1	0	0
	Pterostichus longinquss	0	15	0	0	2
	Pterostichus plolongatus	0	0	0	0	1
	Harpalus sinicus	0	1	0	2	1
	Chlacnius palliper	26	16	1	0	10
	Harpalus niigatanus	0	8	2	4	0
	Harpalus sinicus	0	9	0	0	0
	Amara gigantea	11	11	1	0	2
	Laenius pallipers	1	0	0	0	0
	Campalita chinense	2	0	0	0	3
	Pterostichus samurai	0	1	0	0	1
	Amara congrua	5	2	9	4	3
	Chlaenius virgulifer	1	2	0	2	3
	Chlaenius variicornis	0	1	0	1	11
	Lesticus magnus	4	3	0	0	0
	Scarites terricola pacificus	6	0	0	2	0
	Carabus arrowianus	10	0	0	7	0
	Chlaenius micans	0	10	0	0	0
	Chlaenius pallipes	0	1	0	0	0
	Chlaenius inops	0	2	0	0	0
	Camaster blaptoides blaptoides	0	4	2	0	0
Brachinidae	*Pherosposophus jessoensis*	102	3	2	0	3
Elateridae	*Agrypuns scrofa*	0	5	0	2	0
Labiduridae	*Labidura riparia haponica*	51	38	58	1	31
Anisolabididae	*Gonolabis marginalis*	10	28	45	3	10
Silphidae	*Eusilpha japonica*	14	25	1	1	0
Pentatomidae	*Nezara antennata*	2	0	0	0	0
Gryllotalpidae	*Gryllotalpa fossor*	6	4	0	8	2
Hydrophilidae	*Regimbaria atteunata*	2	0	1	1	0
Cicincelidae	*Mriochile speculifera*	0	0	1	0	0
Lucanidae	*Dorcus rectus*	0	0	0	0	2
Chrysomelidae	*Plagiodera versicolora*	1	12	0	2	3
Histeridae	*Saprinussplendens*	2	0	0	0	0
Dragonfly	*Odonata*	2	0	0	0	0
Gryllidae	*Teleogryllus emma*	10	0	3	0	26
	Velarifictorus micado	6	9	2	0	13
Blattidae	*Periplaneta japonica*	0	0	0	0	12
Scarabaeidae	*Popillia japonica*	0	0	0	1	0
Curculionidae	*Lixus acutipennis*	0	4	0	2	0
	Scepticus griseus	1	0	0	0	0
Tenebrionidae	*Gonocephalum persimile*	0	0	0	0	1
Staphylinidae	*Philonthus haponicus*	1	0	0	0	0