Species Composition and Abundance of Craneflies (Diptera: Tipulidae) in the Highland Lakes of Japan

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ABSTRACT

We evaluated the relative abundance of tipulids in the Nishina Three Lakes and Lake Suwa, Japan, by capturing adult flies with light traps set around the shores of the lakes. Of 149 individuals collected, 49 species were identified, and we described 19 newly recorded genera around these lakes. We collected seven species of adults at Lake Suwa, 27 species at Lake Aoki, 19 species at Lake Nakatsuna, and 16 species at Lake Kizaki. The most abundant species were *Antocha bifida*, *Gonomyia (Leiponeura) incompleta*, and *Gonomyia* sp. However, the most abundant species of each lake differed. Only *A. bifida* was collected from all the lakes. We calculated the Shannon-Wiener diversity index to compare the tipulid fauna among the lakes. The diversity index was the highest at 4.24 in Lake Aoki (an oligotrophic lake) and the lowest at 2.81 in Lake Suwa (a hypereutrophic lake). These results suggest that the diversity and relative abundance of adult tipulid species may be useful biological indicators for water quality assessment.

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INTRODUCTION

Aquatic insects have been used extensively as integrators of environmental conditions in lakes (Rosenberg and Resh 1993). Chironomids especially can provide much information about lake classification and water quality assessment (e.g., Sæther 1979, Iwakuma et al. 1988). Nishina Three Lakes and Lake Suwa provide good fields for comparative study of the species composition of aquatic insects in relation to the trophic status because of their similar geographic and climatic conditions. Many biological and ecological studies on aquatic insects, especially Chironomidae, have been reported from these lakes (e.g., Hirabayashi 2001, Hirabayashi et al. 2001, Nakazato et al. 2001, Yoshida and Uenishi 2001). Tipulidae, the craneflies, is one of the largest families of Diptera, including more than 15,000 known species (Oosterbroek 2010). Larval tipulids have been able to adapt to nearly every kind of aquatic environment except open oceans and deep freshwater lakes (Byers and Gelhaus 2008). Tipulid communities reportedly differ in relation to trophic status (Brunhes and Villepoux 1990, Brunhes and Dufour 1992, Salmera and Ilmonen 2005); however, almost nothing is known of them in Japan. In addition, data on tipulid fauna in the Japanese highland area are still very scarce.

In the present study, adult tipulids were investigated by light traps throughout a year (i.e., four seasons), and tipulid communities were compared among the highland lakes in relation to trophic status.

MATERIALS AND METHODS

Study area

Lake Aoki (36°37’N, 137°51’E), Lake Nakatsuna (36°36’N, 137°51’E), and Lake Kizaki (36°33’N, 137°50’E) form a chain of lakes called the Nishina Three Lakes. From the end of the 1970s to the end of the 1980s, the watershed of these lakes was developed for tourism, and the biota and environmental conditions of the lakes changed drastically (Saijo 2001, Okino and Watanabe 2001). The Nishina Three Lakes are among the most intensively investigated lakes in Japan (Saijo and Hayashi 2001). The lakes are located in the central highlands of Honshu at an altitude of 764-822 m a.s.l. The trophic status of each lake differs; Lake Aoki is oligotrophic, and Lake Nakatsuna and Lake Kizaki are mesotrophic (Tanaka 1992 and 2004).

Lake Suwa is a hypereutrophic lake also located in the central highlands of Honshu (36°03’N, 138°05’E; 759 m a.s.l.) (Tanaka 1992). During the 1960s and the 1970s, the lake underwent a period of intense eutrophication due to the increase in the human population and the development of industry along the shores (Okino 1982, Satoh et al. 1984). Lake Suwa is also one of the most intensively investigated lakes in Japan (Okino 1990).

Field and laboratory procedures

Four Nozawa-type light traps were set up on the banks of the each lake. Each trap was equipped with a 6-W black fluorescent lamp. The traps were operated during the following periods: 17-18 May, 19-20 July, and 12-13 October 2005 and 23-24 February 2006. However, Lake Suwa was not investigated in February because of ice cover. Each trap was hung about 1.5 m above ground level and activated during the night throughout each investigation period. Insects that entered the traps were killed with insecticide spray. The adult tipulids were separated from the other insects, and the individual numbers of each species were recorded. Adult tipulids were identified to species using mainly the taxonomical keys provided by Alexander and Byers (1981), Nakamura (2005), and Byers and Gelhaus (2008). Currently, craneflies are taxonomically grouped into four families ─ Cylindrotomidae, Limoniidae, Pediciidae, and Tipulidae (Stary 1992). In this study, the classification of the four families is accepted because of its support from the latest catalog of the craneflies (Oosterbroek 2010). In order to compare the cranefly fauna among the lakes, we calculated the Shannon-Wiener diversity index (*H'*).

RESULTS AND DISCUSSION

This is the first report on tipulid fauna in the highland lakes of Japan, Nishina Three Lakes and Lake Suwa, using quantitative data. During the sampling periods, the total number of trapped adult tipulids was 149 individuals (Table 1). The highest number of individuals was trapped at Lake Aoki (59 individuals), followed by Lake Nakatsuna (43) and Lake Kizaki (40). The least number was trapped at Lake Suwa (seven individuals). The individual number of adults increased from May to July and decreased from July to October in the Nishina Three Lakes.

We identified 21 genera and 49 species belonging to three families [i.e., six species of Tipulidae (12.2 %), 39 species of Limoniidae (79.6 %), and four species of Pediciidae (8.2 %)]. We collected 15 genera and 27 species in Lake Aoki, 13 genera and 19 species in Lake Nakatsuna, 12 genera and 16 species in Lake Kizaki, and seven genera and seven species in Lake Suwa. The number of species of adult tipulids also increased from May to July and then decreased from July to October in the Nishina Three Lakes. The most abundance genus was *Antocha* (38 individuals, three species) followed by *Gonomyia* (25 individuals, four species), *Dicranomyia* (16 individuals, five species), and *Tipula* (eight individuals, four species) in all three lakes. In November of 1973, Chino (1975) collected species of *Tipula* and *Antocha* from the upper and middle Nogu River, which connects the Nishina Three Lakes. In addition, he also collected *Tipula* species in the Togawa River that flows into Lake Suwa. Their species names were rather ambiguous because only the larvae of craneflies were examined. In this study, we collected 19 newly recorded genera at these lakes. *Antocha bifida* was the most abundant species among the lakes (34 individuals, 22.8 %), followed by *Gonomyia (Leiponeura) incompleta* (13 individuals, 8.7 %) and *Gonomyia* sp.1 (10 individuals, 6.7 %, only females). However, the most abundant species differed in each lake. *A. bifida* was the most abundant species in Lake Nakatsuna and Lake Kizaki, and *G. incompleta* was most abundant in Lake Aoki. In addition, only *A. bifida* was common to all of the lakes.

A few studies suggested differences in tipulid fauna in terms of trophic status (Brunhes and Villepoux 1990, Brunhes and Dufour 1992, Salmera and Ilmonen 2005). Our results are in agreement with their results. That is, members of the genus *Dicranota*, a low-tolerance genus (Gelhaus and Byers 1994), were collected from oligotrophic/ mesotrophic lakes, and the genus *Antocha*, a middle-tolerance genus (Gelhaus and Byers

1994), from oligotrophic/mesotrophic lakes. However, the trophic indicator value remains to be determined for almost all genera of Tipulidae. According to Hirabayashi et al. (2007), the genera *Antocha* and *Tipula* are distributed over wide altitudinal ranges between about 400 m a.s.l. and about 1100 m a.s.l. in the Shinano River. *Antocha* is one of the truly aquatic genera among the tipulid species, and its species are distributed in riffles, especially cobbles and log substrata of rivers and streams (Torii 1992). On the other hand, species in the genus *Tipula* are well known to inhabit a wide variety of inland waters (Byers and Gelhaus 2008). Nakamura (2005) reported that larvae of *Tipula bubo* were observed in wetlands or small mountain streams and those of *Tipula nova* were found in rice fields or small lowland streams. Chino (1975) reported that the larvae of *Antocha* and *Tipula* distributed in the inflows and/or outflows of lakes. These facts suggest that inflows and/or outflows and the surrounding area of lakes also provide a good habitat for larval tipulids.

Shannon-Wiener diversity index (*H'*) was highest at 4.24 in Lake Aoki and lowest at 2.81 in Lake Suwa. Moreover, *H'* was the highest in Lake Aoki from May to October. The diversity index tends to increase from eutrophic to mesotrophic lakes. It has been recognized that chironomids constitute one of the most useful biological indicators in water quality assessment (e.g., Sæther 1979, Iwakuma 1988). Our results are in concordance with those of Kawai et al. (1989), who showed that species richness and diversity of chironomid fauna generally decline from oligotrophic to eutrophic waters. Tipulidae is one of the largest groups of Diptera. Due to its high species richness, Tipulidae may be an excellent study group to examine patterns of local and regional diversity (de Jong et al. 2008). Moreover, the members of Tipulidae are of economic and ecological importance because their larvae feed on roots and seedlings of crops and organic detritus and both larval and adult tipulids are fed on by predators (Byers and Gelhaus 2008). Our results suggest that Tipulidae is not only an important family in aquatic ecosystems but it also may be a useful tool in aquatic biomonitoring. Further collection of data is warranted to elucidate the relationships of various dominant Tipulidae species emerging on the basis of lake trophic status and various trophic stages of lakes. This would enable us to record manifold Tipulidae species to serve as indicator species of water quality.

ACKNOWLEDGMENTS

We express our thanks to T. Nakamura of the Shirakami Nature Garden, Hirosaki University, for his valuable taxonomical advice. We also thank M. Yamamoto at the Research and Education Center for Inlandwater Environment, Shinshu University and K. Shimura, K. Oga, and colleagues at the Department of Applied Biology, Faculty of Textile Science and Technology, Shinshu University for their generous support.

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Table heading

Table 1. Occurrence of tipulid fauna in light traps at Nishina Three Lakes and Lake Suwa, Japan, presented as number of total of all adults collected during four separate sampling periods during 2005-2006. % = relative abundance.

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	Lake Aoki		Lake Nakatsuna		lake Kizaki		Lake Suwa	
	Number	%	Number	%	Number	%	Number	%
Tipulidae								
Nephrotoma cornicina			1	2.3				
Nephrotoma virgata							1	14.3
Tipula (Yamatotipula) nova	2	3.4						
Tipula (Yamatotipula) latemarginata platyspatha			4	9.3				
Tipula sp. 1			1	2.3				
Tipula sp. 2					1	2.5		
Limoniidae								
Antocha bifida	7	11.9	12	27.9	14	35.0	1	14.3
Antocha sp. 1	1	1.7						
Antocha sp. 2	2	3.4	1	2.3				
Cheilotrichia (*Empeda*) sp. 1					1	2.5		
Cheilotrichia (*Empeda*) sp. 2			1	2.3				
Cheilotrichia (*Empeda*) sp. 3	2	3.4						
Dicranomyia (Dicranomyia) consimilis	3	5.1	2	4.7				
Dicranomyia (Dicranomyia) frontalis	2	3.4			1	2.5		
Dicranomyia (Dicranomyia) modesta	1	1.7			3	7.5		
Dicranomyia (*Dicranomyia*) sp. 1	2	3.4			1	2.5		
Dicranomyia (*Dicranomyia*) sp. 2					1	2.5		
Erioconopa elegantula							1	14.3
Erioptera (*Erioptera*) sp. 1			1	2.3				
Erioptera (*Erioptera*) sp. 2			1	2.3				
Erioptera (*Erioptera*) sp. 3			1	2.3				
Geranomyia multipuncta	1	1.7						
Geranomyia gifuensis	2	3.4	1	2.3	1	2.5	1	14.3
Gonomyia (Leiponeura) incompleta	11	18.6	2	4.7				
Gonomyia sp. 1	3	5.1	7	16.3				
Gonomyia sp. 2	1	1.7						
Gonomyia sp. 3	1	1.7						
Helius (Helius) sp.					1	2.5		
Idiocera (Idiocera) nigrilobata	5	8.5						
Idiocera (*Idiocera*) sp.			1	2.3				
Ilisia asymmetrica	1	1.7			2	5.0	1	14.3
Limnophila (Dicranophragma) formosa			1	2.3				
Limonia sp.	1	1.7						
Molophilus sp. 1			3	7.0				
Molophilus sp. 2					2	5.0		
Molophilus sp. 3	1	1.7						
Molophilus sp. 4	1	1.7						
Nippolimnophila sp.	2	3.4						
Ormosia sp. 1							1	14.3
Ormosia sp. 2	1	1.7						
Rhipidia maculata	2	3.4			1	2.5	1	14.3
Scleroprocta sp.					6	15.0		
Symplecta (Symplecta) hybrida			1	2.3	2	5.0		
Symplecta (*Psiloconopa*) sp.	1	1.7						
Limoniidae sp.	1	1.7						
Pediciidae								
Dicranota (Eudicranota) dicranotoides	1	1.7						
Dicranota (*Rhaphidolabis*) sp. 1			1	2.3				
Dicranota (*Rhaphidolabis*) sp. 2	1	1.7	1	2.3	2	5.0		
Dicranota (*Rhaphidolabis*) sp. 3					1	2.5		
Total	59	100.0	43	100.0	40	100.0	7	100.0