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Recent advances in the environmental and medical sciences achieved by the biosystematic studies—with special reference to the chironomids

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Abstract - Among a number of freshwater animal and plant groups, the non-biting midges, or the insect family Chironomidae (Diptera) has been shown through our recent studies as being one of the most useful, sensitive and widespread indicators of the quality of waters, especially in relation to the degree of pollution with sewage waters. We have already confirmed the presence of over 300 species of the family Chironomidae in Japan, and the breeding places of each species are highly characterised by the chemical, physical or biological quality of the water. For example, in the survey of the distribution of the chironomid species along the entire length of River Tama and its tributary, in which the value of BOD varied from below 1 ppm at the unpolluted upstream part to as high as 25 ppm in the urban area, a total of 55 chironomid species were recovered from the stream beds, and their distribution was shown to be highly correlated with the BOD values. The species breeding in unpolluted mountain lakes, and those found in shallow, polluted lakes were also quite different. It has also been shown through these surveys that the chironomids play significant roles in the removal of nutrients from rivers and lakes by their growth and emergence. On the other hand, they are often serious nuisances to the people living near eutrophicated lakes or rivers. It has further been demonstrated that some chironomid species emerging massively from lakes, rivers or rice paddies are important causes of human allergic diseases, such as bronchial asthma. The biosystematics, which constitute one of the most classical and primitive fields of biology, is still a very useful tool in some aspects of the environmental and medical sciences.

INTRODUCTION

The animals, plants and microorganisms now breeding on the earth includes millions of different species. As a rule, each of these species does not interbreed with other species, and can be identified by examination of the external or internal structures. They also differ from each other in some aspects of behavior. Therefore, many of the animal, plant or microorganism species can be utilized as biological indicators of the environmental characters, together with some chemical or physical measures. When the National Institute for Environmental Studies (NIES) was founded in Tsukuba Science City in 1974, an integrated research program for characterization and control of landwater pollution was organized by participation of chemists, physicists and biologists concerned. My present study on the taxonomy, ecology and medical importance of a small group of insect called the chironomid midges was initiated as a part of this research program, and has so far yielded large amounts of new and unexpected contributions to these fields of studies.

HIGHLIGHTS OF OUR STUDIES

1. Taxonomic studies on the chironomids

The insects of the family Chironomidae belongs to the suborder Nematocera of the order Diptera, and is colsely related to the mosquitoes, the family Culicidae, but the adult female does not suck blood, nor take any other food. Their life cycle consists of the four stages, egg, larva, pupa and adult. The eggs are laid on certain types of waters characteristic to each species, presumably by special sensory behavior of the pregnant female. The larvae usually live in the bottom of water or on the suface of water plants, eat algae, microorganisms or other nutrients, and eventually become pupae, which usually appear on the surface of water, and the adults emerge by casting the pupal skin. The males and females usually form swarms and copulate in the air, and the pregnant females deposite eggs on water. It takes from about two weeks to a year or more in some species to complete one life cycle.
The larvae of some groups (subfamily Chironominae and genus Tokunagayusurika of subfamily Orthocladiinae) contain haemoglobin in order to catch low concentration of oxigen in the bottom mud, and thus called the blood worm.

When I wanted to start the study of chironomids in japan in relation to the environmental pollution, I first thought that at least several chironomid species must be found in this small country. However, after starting a search for references in the taxonomy of Chironomidae in Japan, I was really surprised to find out that as many as over 170 species had already been recorded and described from the present territory of Japan by Tokunaga (1933-1965). It was further surprising to us that many of the chironomid species collected by us commonly in ponds, streams and lakes in the Tsukuba Science City area were not included in the above reports by Tokunaga, and it became clear that there existed many species not yet recorded from Japan. Actually, the family Chironomidae includes large number of species, presumably several thousands or more for the entire world, and there seems to exist large numbers of unrecorded and new species in many regions of the world, excepting in some limited areas such as northern Europe, where most of the common species seem to have been already recorded and described. In a key to British Chironomidae prepared by Pinder (1978), a total of 439 species were listed. The numbers of certain groups of animals or plants found in Japan are usually several times or more than 10 times larger than those found in Great Britain, and thus at least several humdreds, or maybe several thousands of chironomids seem to be breeding in Japan, the land of which is rather small but is distributed from the northern Palaearctic to the southern, subtropical Oriental regions, with a variety of natural environments.

In studying the chironomid species found associated with certain types of land waters, we must, first of all, collect the specimens, preferrably with some quantitative measures. The adult chironomids are usually collected easily by sweeping their resting places (such as bushes, trees or walls on the shore of lakes and rivers) with insect net, or directly with a sucking tube. The adults swarming in the air in the vicinity of their breeding places can be captured with insect net. They can also be collected on light, or with light traps. The pupal skin casts are found, often in large numbers, on the surface of stagnant waters. The larvae living in the bottom sediments of lakes, ponds, rivers, etc. are collected and carried together with the mud, sand or stones to the laboratory, and the adults can be reared in plastic containers. The specimens of adults, papae and larvae are examined under a stereomicroscope, and then dissected and mounted on slides for the species identification. The methods for collection, preservation, and mounting of the chironomid specimens are described in a series of papers by Sasa (1978-1985).

For identification of the species, genus, tribe and subfamily to which the specimen belongs is made usually by studies of its external structure. In the case of Chironomidae, it can usually be made for sure only by the adult males. The structure of female, pupa or larva is also sometimes useful or necessary for the diagnosis of species or higher taxa. On the other hand, the study of larval specimens collected and examined directly from various types of waters usually does not provide information sufficient for differentiating related species, and thus often quite misleading. Therefore, I always examine the adult specimens obtained after the laboratory rearing of the larval materials for comparison of the chironomid fauna of various types of waters.

Some chironomid species with clearcut morphological characters can be identified under low power magnification of a stereomicroscope, but in most cases examination of dissected and mounted specimen under high power magnification of the compound microscope is necessary for the confirmation. The specimens which look like belonging to the same species in examination of larvae, or of the adults under low power magnification, are often shown to belong to different species under high power magnifications. In the identification of adult chironomids, the morphological studies of various external organs such as eyes, antenna, wing, legs, etc. is quite useful, and especially important is the structure of various appendages on the male copulatory organ called the hypopygium.

2. Distribution of chironomids in nature

The range of distribution of the insect family Chironomidae is extremely wide, covering almost all types of land waters, although the habitat of each chironomid species is usually quite limited and specific. The breeding of chironomids have been confirmed from the extremely cold countries, such as the northern Scandinavia, to all types of tropical environments, wherever some collection of waters are found. The larvae of certain species groups have been collected from the marine environment, such as on the seaweeds on the shoreline, or in tide pools of rocky coasts where the salt contents are higher than the sea water. Some species belonging to the subfamily Orthocladiinae develop in the terrestrial environments, such as in wet soil or in decayed leaves. However, the larvae of the majority of species develop in freshwater. Lakes are one of the most favorite breeding places of the chironomids, and enormouns amounts of larvae belonging to large numbers of species are usually found in the bottom of various types of lakes. Rivers are another important sources of their breedings, and large numbers of species, mostly different from those found in lakes, can be collected from along the almost entire length of the stream, and the species found at each site of the river differ usually according to the chemical and physical characters of the water, such as the degree of pollution with sewage waters, the velocity of the stream, or the kind of substrates such as mud, sand or stone. Sewage ditches containing highly polluted waters are also favorite breeding places for species such as Chironomus yoshimatsui Martin et Sublette, causing serious nuisance on people residing in the nearby areas. Rice paddies are another important breeding sources of the chironomids in countries such as Japan, and a total of 41 species were collected with light traps set in a rice paddy area in Tokushima by Kikuchi and others (1985). As reported by Sasa & Kawai (1985), the adults of certain species of the subfamily Diamesinae and Orthocladiinae are called "the snow midges", and their adults have been observed to appear only during the winter season on the snow.

The geographic distribution of the chironomid species throughout the world is only poorly known, because extensive studies on the chironomid fauna have been carried out only in the northern European and the North American regions, and little is known about the species breeding in other regions of the world. As for the comparison of the Japanese chironomid fauna with that of the European and other regions of the world, for exapmle, a total of 121 species or 72% among 168 species recorded from Japan by Tokunaga (1933-1965) were described as new species, and only 47 (28%) were regarded as the species already known from other regions of the world, especially from Europe. The same trend was observed with the species newly recorded by us from Japan, and some 60% among 170 additional species were judged as indigenous to this country. However, there also exist a number of chironomid species which show more or less wider ranges of the geographical distribution. For example, Chironomus plumosus (Linnaeus), commonly called the giant lake midge, has been found from almost all the eutrophicated lakes throughout the world, including Europe, North America, Japan and continental Asia. On the other hand, another giant midge species known in Japan by the name of "akamushi", emerges from all eutrophicated large and small lakes in Japan in the month of November, and its larvae are sold as baits for fishing, has not been recorded from other regions of the world, and because of its peculiar and unusual structure of male hypopygium, a new genus, Tokunagayusurika, was created by Sasa (1978) within the subfamily Orthocladiinae, in order to place it into a new group different from other already known genera. Some species, such as Polypedilum nubifer (Skuse), has been recorded from large geographic areas including Africa, southern Asia, Micronesia and Japan, but not from Europe and North America. Another species called by a scientific name of Heterotrissocladius subpilosus (Kieffer), which is known to represent an important bottom fauna of the many mountain lakes of northern Europe, was recently collected also in large numbers from mountain lakes of Hokkaido, the northernmost main island of Japan. On the other hand, it is very interesting in view of the geographic distribution that Chironomus yoshimatsui Martin et Sublette, the most common species breeding in all sewage ditches and polluted rivers in the mainland of Japan, has never been collected from the Ryukyu Islands, southernmost parts of Japan, as well as from the similar environments of other regions of the world.

3. Chironomids as indicators of water quality

Our recent studies on the chironomid fauna of certain rivers and lakes in Japan have shown that the chironomids are very sensitive indicators of the chemical and physical characters of various types of land waters. Along with the progresses of studies on this line, I believe we shall be able to establish a system by which the presence or absence of certain species of the chironomids indicates certain physical, chemical or biological status of the land water. For example, we have found, at least in Japan, that the presence of the larvae of Chironomus yoshimatsui Martin et Sublette indicates that the water is highly polluted with sewage contamination with BOD values ranging from about 5 to 40 ppm, and that the water is not stagnant but running. On the other hand, another species, Chironomus samoensis Edwards, is found in polluted but stagnant waters. The presence of larvae of Chironomus salinarius Kieffer is an indication that it is a brackish water. The larvae of certain species of the subfamilies Chironominae and Orthocladiinae are found associated with pure or concentrated sea waters in tide pools and sandy shores. Chironomus acerbiphilus Tokunaga has been found breeding in highly acidic waters in the active volcano areas, even in a lake containing water showing pH 2.0 or less. As a rule, the chironomids have ranges of their distributions in nature widest among the freshwater insect families.

Tables 1, 2 and 3 show results of chemical analysis of river waters, and the species of chironomids (Chironominae and Orthocladiinae) collected at 6 stations selected at distances of about 2 kilometers along the River Minamiasakawa (Tokyo). It is a tributary of River Tama, originated from small, unpolluted mountain streams such as Station No.1, accepts a small amount of sewage waters from a sanatorium at Station 2, and the amount of sewage waters running into this river becomes gradually increased, until it runs through the large city of Hachioji at Station 6. Various values of chemical analysis carried out by Dr. Ogura shown in Table 1 indicate the changes in connection with the degree of pollution with sewage waters. The distribution of chironomid species of the subfamily Chironomidae (Table 2) and Orthocladiinae (Table 3) is highly correlated with the results of the chemical analysis of the waters.

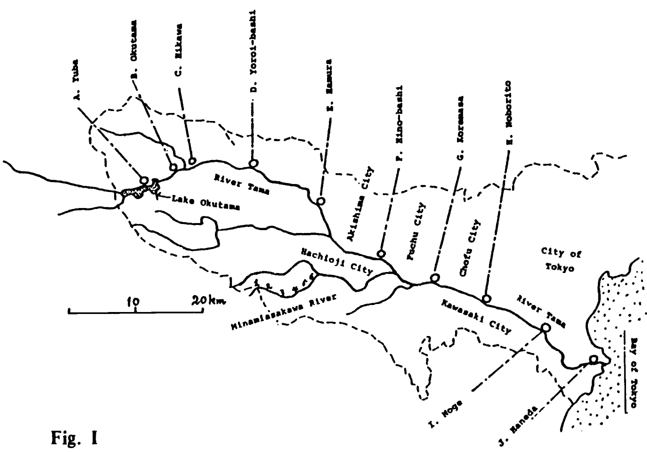

Fig. I

Map of the River Tama and its main tributaries, showing collection sites of chironomid samples

Table 1.

Results of analysis of water quality at 6 stations of the Minamiasakawa River reported by Ogura (1978)*.
Date of collection of water: 26 May 1977 (Thursday).

Station	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Time	10:50	11:25	12:05	13:10	14:45	15:20
T_A °C	16.8	16.6	19.5	20.5	20.3	20.1
Tw °C	12.8	12.8	16.5	20.3	22.6	21.8
pH	6.3	6.7	6.5	8.5	7.7	7.4
ECμυ/cm	66	147	170	176	384	352
DO ml/l	6.81	7.05	7.34	7.97	4.10	7.08
(%)	(91)	(95)	(107)	(125)	(67)	(114)
SS mg/l	-	-	2.9	4.9	13.5	31.5
DOC mg/l	0.51	0.48	4.22	3.67	8.33	8.50
TOC mg/l	-	-	4.80	4.50	-	10.9
T-CO_2-C mg/l	6.2	4.6	6.3	3.8	11.7	12.6
TPμg at/l	-	-	5.7	12.9	25.0	28.8
TDPμg at/l	0.54	0.66	4.9	12.6	22.5	22.5
RPμg at/l	0.32	0.52	3.3	8.9	14.7	16.4
NH_4-Nμg at/l	0.0	0.0	0.0	0.0	200	222
NO_2-Nμg at/l	0.0	0.08	0.86	5.4	10.4	11.1
NO_3-Nμg at/l	83.5	90.0	113	86.7	62.9	67.8
SiO_2-si mg/l	7.2	8.3	8.0	7.3	7.5	6.1
Cl mg/l	2.9	3.2	7.9	8.9	28.6	29.2
Flux m^3/sec	0.0011	0.0033	0.21	0.16	0.28	0.48

* Quoted from "The effects of human activity on the ecosystem of the Tama River" (B11-R12-12, Kankyokagaku Kenkyuhokokushu), p. 37, 1978.

Table 2. Number of adult chironomids emerged from bottom samples collected at each station of Minamiasakawa River, August 1979 (M. male; F. female)

Subfamily CHIRONOMIDAE

Species	Station of collection: No. 1 M	No. 1 F	No. 2 M	No. 2 F	No. 3 M	No. 3 F	No. 5 M	No. 5 F	No. 6 M	No. 6 F
1. *Micropsectra tamaprima*	1		1	2						
2. *Rheotanytarsus tamasecundus*	3	2								
3. *Rheotanytarsus tamatertius*	2		2							
4. *Rheotanytarsus tamaquartus*			16	5						
5. *Rheotanytarsus tamaquintus*			9	7	4					
6. *Rheotanytarsus kyotoensis*							203	209		
7. *Tanytarsus tamaseptimus*	3									
8. *Tanytarsus tamaoctavus*	2				4	2				
9. *Tanytarsus tamanonus*					1					
10. *Tanytarsus tamadecimus*					1					
11. *Tanytarsus tamaundecimus*					2	1				
12. *Tanytarsus oyamai*							3			
13. *Microtendipes britteni*				1	11	17				
14. *Polypedilum takaoense*	1	1								
15. *Polypedilum unifascium*	9	3	3	2						
16. *Polypedilum asakawaense*					3	2				
17. *Polypedilum tamagoryoense*							2	1		
18. *Polypedilum ureshinoense*							3	1	16	16
19. *Chironomus kiiensis*									15	12
20. *Chironomus yoshimatsui*									55	55

Table 3. Number of adult chironomids emerged from bottom samples collected at each station of Minamiasakawa River, August 1979 (M. male; F. female)

Subfamily ORTHOCLADIINAE

Species	Station Number: 1 M	1 F	2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Total M	Total F
1. *Brillia japonica*	1												1	
2. *Eukiefferiella tamaflavus*		1	3	2		2							3	5
3. *Synorthocladius tamaparvulus*				1	8	7							8	8
4. *Cricotopus bicinctus*									1		31	23	32	23
5. *Cricotopus sylvestris*											25	19	25	19
6. *Cricotopus tricinctus*									1				1	
7. *Cricotopus triannulatus*									2				2	
8. *Cricotopus tamannulatus*	1	1											1	1
9. *Cricotopus metatibialis*	5	2											5	2
10. *Cricotopus tamasimplex*					1								1	
11. *Paratrichocladius tamaater*	5	2											5	2
12. *Nanocladius tamabicolor*							3	6	18	20	35	31	56	57
13. *Parametriocnemus stylatus*	2	3	2	1	4	1							8	5
14. *Corynoneura* sp. *A*	4	3											4	3
15. *Corynoneura* sp. *B*			21	10	5	7							26	17
16. *Corynoneura* sp. *C*									3	1			3	1
17. *Corynoneura* sp. *D*	1												1	
18. *Thienemanniella* sp. *F*					3	1							3	1
19. *Thienemanniella* sp. *G*									2	3			2	3
20. *Pentaneura* sp. nr. *maculipennis*			2	1	3	6							5	7
21. *Pentaneura* sp. nr. *melanopus*			2	1									2	1
22. *Pentaneura kyotoensis*				1		1			1				1	2

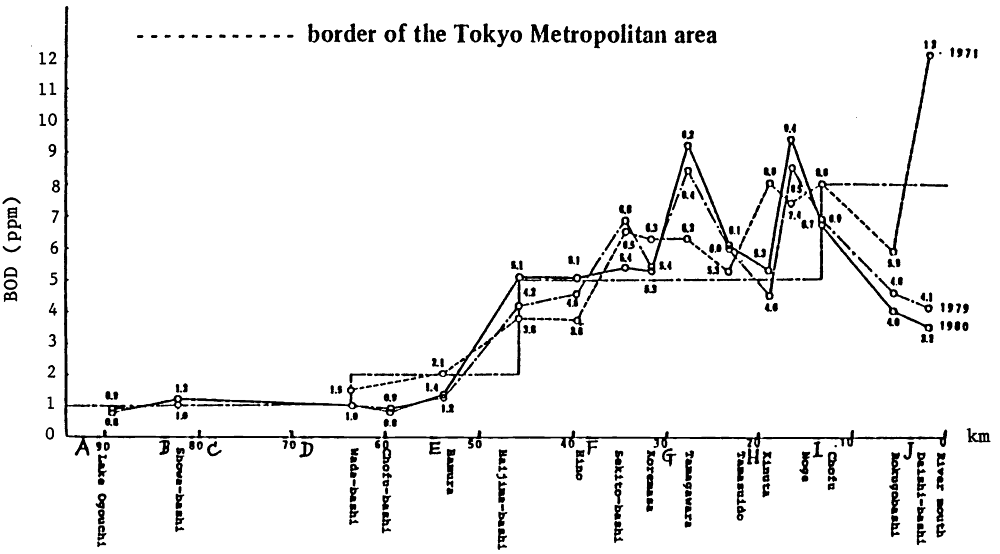

Fig. II BOD values of the Tama River water at different collection sites. (Annual average values of monthly data for years 1971, 1979 and 1980). A to J: Collection sites of chironomid samples in the present study. Data quoted from "Water quality of Tokyo Metropolitan area" 1980. Compiled by Bureau of Environmental Conservation, Tokyo-to.

As shown in Table 2, the species 1, 2, 3, 4, 5, 7, 14 and 15 of the subfamily Chironominae were collected from the uppermost stations Nos. 1 and 2, where the river water is not contaminated by sewage waters. Species 8, 9, 10, 11, 13 and 16 were collected mainly at stations 3, where the river is slightly contaminated. Very interesting is the species 6, which was found in large numbers at Station 5 and not at other stations. Species 18, 19 and 20 were collected only or mainly at station 6, where the stream is highly polluted. Similar trend was seen with the species of the subfamily Orthocladiinae in Table 3. Species 1, 2, 8, 9, 11, 13, 14 and 17 were collected from the upstream, unmpolluted parts of the river, while species 4, 5, 12, 16, 19 were from the most polluted, downstream parts, and the rests were from the intermediate portion of the river.

The surveys with similar purposes but in larger scales were carried out in 1981 and 1982, on the mainstream of River Tama (Tokyo). This river is originated from the mountain districts of Yamanashi Prefecture, connected with a large man-made lake of Ogouchi, then runs through the entire length of Tokyo Prefecture, and flows into Bay of Tokyo at the Haneda airport, as shown in the map of Fig. 1. The total length of the river is 123 kilometers, and the basin area is 1,240 km^2. Altogether 10 collection sites were selected along the main stream, from A (a small mountain stream running into Lake Ogouchi), to J at the mouth of the river. The annual average values of BOD of the river water at these collection sites are shown in Fig. 2. The BOD level is about 1 ppm from A to E, then gradually increases from E to G, and stays at the level of about 10 ppm from G to J. A total of 55 species of Chironomidae were collected and identified as the results of a survey carried out in June 1981, and their distribution to the collection sites A to I is shown in Table 4. Similar trends of the distribution of each species in correlation with the degree of pollution, or BOD levels, were observed with additional chironomid species and in a much larger scale of the environments than observed with its tributary, Minamiasakawa.

It should be noted here that most of the chironomid species collected from these rivers were the species indigenous to Japan and the neighboring regions, and only 4 out of 34 Chironominae and Orthocladiinae species collected from River Minamiasakawa, or only 4 out of 49 species collected from the mainstream of River Tama were common with the European fauna. This seems to suggest that the trends to the evolution of new species have taken place very actively in the isolated environments such as the rivers in Japan.

The chironomids seem to be excellent indicators of the water quality of the lakes, too. Until now, surveys were made by us on the lakes of Hokkaido (the Akan group in June 1982, the Toya-Shikotsu group in June 1986, Lake Utonai in December 1981 and June 1986), Akita (Lake Hachirogata in June 1979), lakes in the Nikko National Park (Tochigi) in April and November 1979, lakes in the Fuji-Hakone National Part (Yamanashi and Kanagawa) in July 1981, Lake Biwa (Shiga) 4 times in 1985, and lakes in southern Kyushu in February and November 1981. As the results, large numbers of chironomid species, including those new to Japan, have been collected and identified (Sasa, 1984, 1985a, b, c). However, our present information is still insufficient for drawing a conclusion on the mode of distribution of the chironomids in various lakes of Japan in relation to the differences in environmental factors, such as the degree of pollution, chemical or physical conditions of lake waters, etc. The followings are some of the results obtained through our previous surveys conducted with the above lakes in Japan.

Table 4 Species and numbers of adult chironomids recovered from bottom samples collected at each survey stations along the River Tama, June 1981 (left: number of males; right: females)

Code No.	Species name	A Yuba		B Okutama		C Hikawa		D Yoroi		E Hamura		F Hino		G Koremas		H Noborito		I Noge	
1	*Chironomus yoshimatsui*											229	245	76	94	253	286	457	553
2	*Chironomus circumdatus*							0	2							4	16		
3	*Kimius hoonsooi*															1	1		
4	*Paracladopelma tamahikawai*					1	0												
5	*Paracladepelma tamanipparai*					1	0												
6	*Parachironomus tamacutus*			1	0														
7	*Microtendipes tamaogouti*	15	41	14	19														
8	*Microtendipes britteni*			1	1	2	2												
9	*Paratendipes tamayubai*	80	37	4	1														
10	*Pentapedilum tamahamurai*									1	0								
11	*Polypedilum unifascium*	36	26	0	1			0	1			1	0	0	1				
12	*Polypedilum tsukubaense*	96	78	7	3	0	1												
13	*Polypedilum takaoense*	2	0																
14	*Polypedilum tamaharaki*	21	41	12	15														
15	*Polypedilum tamanigrum*	159	160	35	56	16	20												
16	*Polypedilum tamasemusi*	6	5																
17	*Polypedilum tamahosohige*			3	2	1	1												
18	*Polypedilum tamaculatum*			2	3	11	6												
19	*Polypedilum asakawaense*			2	0	3	2												
20	*Polypedilum tamagoryoense*							4	1	2	0	3	1			2	0		
21	*Polypedilum ureshinoense*											3	1						
22	*Polypedilum nubifer*															1	1		
23	*Rheotanytarsus kyotoense*															2	0		
24	*Tanytarsus tamaoctavus*									1	0								
25	*Tanytarsus tamanonus*					1	3												
26	*Tanytarsus tamaundecimus*					1	0	5	1										
27	*Tanytarsus tamaduodecimus*					5	2												
28	*Tanytarsus tamakutibasi*			1	0			5	3	3	2								
29	*Tanytarsus tamagotoi*			2	1			4	2										
30	*Paratanytarsus tamanegi*			1	3			4	0	23	18	1	0						
	Subtotal	415	388	85	105	42	37	22	10	30	20	237	247	76	95	263	304	457	553

Code No.	Species name	A Yuba		B Okutama		C Hikawa		D Yoroi		E Hamura		F Hino		G Koremasa		H Noborito		I Noge	
31	*Brillia japonica*	21	26	19	36														
32	*Orthocladius tamanitidus*			31	38	14	14												
33	*Paratrichocladius tamaater*	7	5	1	9	31	51												
34	*Paratrichocladius rufiventris*							2	3	1	1	7	18	4	6	6	3	19	13
35	*Cricotopus tamadigitatus*	25	35																
36	*Cricotopus metatibialis*	65	61	7	5			3	2										
37	*Cricotopus bicinctus*							2	0					2	1	2	0	20	13
38	*Cricotopus triannulatus*					4	3											3	6
39	*Cricotopus* sp. "noge"													2	2			11	3
40	*Cricotopus* sp. "yoroi"							2	1	1	2								
41	*Rheocricotopus tamabrevis*	1	0																
42	*Rheocricotopus tamahumeralis*											1	0	1	1				
43	*Nanocladius tamabicolor*													1	0	13	20	11	2
44	*Eukiefferiella tamaflavus*	7	21	5	14														
45	*Parakiefferiella tamatriangulatus*	2	0																
46	*Metriocnemus tamaokui*	1	0	1	0														
47	*Parametriocnemus stylatus*	2	2	1	0														
48	*Limnophyes tamakireides*	3	0																
49	*Limnophyes tamakiyoides*	1	0																
50	*Corynoneura* sp.	1	3	19	18														
51	*Pentaneura* nr. *alba*			1	4	15	8			1	0								
52	*Pentaneura* nr. *maculipennis*			9	17	27	14												
53	*Pentaneura* nr. *multifascia*			3	3	2	2												
54	*Procladius* nr. *crassinervis*											0	1						
55	*Tanypus* nr. *punctipennis*															2	1		
	Subtotal	136	153	97	144	93	92	9	6	3	3	8	19	10	10	23	24	64	37
	Grand Total	551	541	182	249	105	129	31	16	33	23	245	266	86	105	286	328	521	590
	No. of Species	20		25		17		11		8		8		7		10		6	

Two lakes in the Nikko National Park (Tochigi) were most extensively studied (Yasuno et al., 1984; Sasa, 1984). Yunoko is a small and shallow lake with the surface area of 0.32 km^2 and the maximum depth of 12.5 m, situated at an altitude of 1,475 m above sea level, and the water is rather eutrophicated by the introduction of untreated sewage waters from a hot-spring town on the shore. Another lake, Chuzenjiko, is located some 10 km south of Yunoko at an altitude of 1,269 m, and is much larger and deeper, with the surface area of 11.62 m^2 and the maximum depth of 163 m, containing much less polluted water. As the results of repeated surveys covering various seasons of the year, a total of 15 chironomid species were collected from the former, and 38 species from the latter, altogether 46 species from both lakes, showing that only 7 species were common to both lakes, although they belong to the same river system. It was also demonstrated in the surveys of Lake Yunoko, that although it is one of the typical shallow and eutrophicated lakes, the chironomid fauna are quite different from similar lakes situated in the lowland of Japan. For example, the most common species found in the latter types of lakes, such as Chironomus plumosus (Linnaeus) and Tokunagayusurika akamusi (Tokunaga), were absent, and another species, Chironomus nipponensis Tokunaga, was one of the predominant chironomids in this highland lake.

Similar interesting results were obtained as the results of surveys on five lakes in the Fuji National Park (Sasa, 1985c). Fron these lakes, a total of 45 chironomid species were collected from these lakes, and their distribution among these lakes also reflected the degree of pollution of waters, and certain differences were observed between the more eutrophicated group (Ashinoko, Kawaguchiko, Shojiko) and the oligotrophic group (Motosu, Saiko and Yamanakako). Further interesting was the fact that the former group contained species found in Lake Yunoko in Nikko, while the latter had species in common with the more oligotrophic lake of Chuzenji.

4. Role of chironomids in the improvement of water quality

The chironomids have also attracted our attention because of their significant role in nature of improving the water quality through removal of organic as well as inorganic pollutants in connection with the massive growth of the larvae in the bottom of lakes and rivers. In the studies by Yamagishi & Fukuhara (1971) in Lake Suwa (Nagano), where two large chironomid species, Chironomus plumosus and Tokunagayusurika akamusi, were found massively breeding, the population density in the bottom mud of the former in June was 1,200 - 5,400 larvae per sq. m., or 15 - 90 g in wet weight, and that of the latter was 700 - 4,800 larvae, or 10 - 96 g, respectively, and the total amount of pupae produced per year was estimated to 268 - 354 tons in the former and 10 - 168 tons in the latter for the entire surface area of 14.45 sq. km. of this lake. Because most of the pupae emerge into adults and leave the lake water, tremendous amount of organic nutrients are estimated to be removed every year by the activity of these midges. In another study by Iwakuna & Yasuno (1983) in Lake Kasumigaura (Ibaraki), an average of 4,400 mature larvae of T. akamusi was shown to be present per sq. m. of the bottom of this lake, which corresponded to 19.3 tons in dry weight per sq. km, or about 4,000 tons for the entire surface of this lake; it was also observed that about 50% of these larvae were eaten by fish, and about 20% emerge and leave the lake as the adults once a year during the month of November, also contributing a great deal for the fixation and removal of the nutrients from the lake water.

It has also been demonstrated that large quantities of the chironomid larvae are growing in the bottom of rivers and streams. Chironomus yoshimatsui is a species exclusively and massively breeding in highly eutrophicated rivers and ditches in Japan, and I have observed that their population density reaches sometimes to as many as several thousands larvae per sq. m. in the bottom mud of sewage ditches. In an observation made by Tabaru (1975) in a river running through the city of Ohgaki (Gifu), the population density of larvae of C. yoshimatsui in the bottom was 126 - 186 per 20 sq. cm, or 6,300 - 9,300 per sq. m. In our observations in River Tama and River Minamiasakawa in Tokyo or River Ohta in Hiroshima, the chironomid larvae were found in enormous masses from the uppermost parts of small mountain streams to near the mouth of the river. As shown in Tables 2, 3 and 4, the number of chironomid species were usually higher in the less polluted upstream parts than in the lower, more polluted portions of the river, but the number of individuals as well as the weight of biomasses became much larger in the more eutrophicated downstream parts than in the upper, oligotrophic portions. The number and weight of chironomid larvae as well as those of other macro-organisms found at 6 stations in the middle and lower parts of River Tama as observed by Moriya & Muto (1983) are shown in Table 5. The values varied remarkably by the season of the year even at the same sites, but were generally highest at stations No.3 and No.4, where the contamination with sewage waters were the highest, and much lower in the upstream sites where the river waters were much less polluted, as well as in the more downstream portions where the velocity of the stream became much slower. In these rivers, the chironomid larvae were developing in the bottom mud or on the surface of stones and water plants, and large numbers of their adults were found resting on the bank or swarming in the air, thus contributing also a great deal for the removal of nutrients from the river waters.

In the observations of the hightly eutrophicated streams and sewage ditches on Okinawa Island by Sasa & Hasegawa (1983), large numbers of larvae of several species of the genus Chironomus were found in the bottom mud, and the degree of pollution as estimated by the values of BOD and other barometers indicated that the quality of water becomes gradually improved towards the downstreams, presumably due to the biological activities of the chironomid larvae and other organisms.

Table 5. The numbers and biomass (gram in wet weight) of chironomid larvae and other macroorganisms collected per sq. m. from bottom sediments of River Tama, Tokyo

Collection site	Date of collection	Chironomid larvae		Other macroorganisms	
		number	weight (g/m^2)	number	weight (g/m^2)
D. Yoroibashi	'81.6.12	6,811	0.556	4,589	56.889
	'82.3.12	33	0.033	1,067	50.967
	'83.3. 7	444	0.622	1,378	22.587
E. Hamura	'81.6.11	2,200	0.744	7,389	234.467
	'82.3.11	1,022	0.489	1,244	41.533
	'83.3. 7	689	0.278	911	48.967
D' Nagatabashi	'81.6.12	35,378	25.956	4,800	2.044
	'82.3.11	1,933	6.511	1,244	6.522
	'83.1.19	3,356	15.133	211	0.078
	'83.3. 8	589	3.033	89	0.067
	'83.3. 8	3,822	21.911	211	0.044
	'83.6. 2	256	0.700	500	0.289
	'83.6. 2	356	1.911	133	0.733
D" Tamabashi	'83.1.19	2,233	6.344	389	6.778
	'83.3. 8	4,711	21.333	67	2.167
	'83.6. 2	5,067	14.589	211	0.611
D" Mutsumibashi	'83.1.19	922	3.644	1,989	6.022
	'83.3. 8	2,656	7.856	922	9.187
	'83.6. 2	1,633	6.722	1,222	9.467
E. Hinobashi	'81.6.11	2,067	5.533	1,044	5.689
	'82.3.11	2,900	4.622	811	19.356
	'83.3. 7	1,522	5.322	956	5.100

5. Chironomids as public nuisance

The adult midges of several chironomid species have been known, in many regions of the world, as serious nuisances to the people residing near their breeding places. One of the early examples of my own experiences was in 1956 in the area around Lake Kojima, Okayama, where enormous masses of the giant midge, Chironomus plumosus, appeared soon after the dike for separating the lake from the sea was completed and the lake water changed from brackish to almost fresh. Inoue (1975) made a review on the nuisance problems due to mass breeding of the chironomids which had occurred in various regions of Japan. In the city of Tokyo, for example, massive emergence of C. yoshimatsui from River Kanda has become a serious nuisance to the people living on or near the bank. In Gifu City, it was observed in a district on the bank of River Arata that the population density of adult of this species were extremely high, and the number of adults resting on a wall was as many as 21,364 per sq. m.

The number of chironomid species that have caused the nuisance problems in various regions of the world have been rather limited, in comparison with the large numbers of species breeding in the same areas. In Japan, Chironomus yoshimatsui which emerges from sewage ditches and eutrophicated rivers, has been the most common species causing nuisance, especially in the urban areas. Two large midges, Chironomus plumosus and Tokunagayusurika akamusi, have often caused serious nuisance problems among people residing on the shore of eutrophicated lakes. Species such as Polypedilum nubifer and Glyptotendipes tokunagai emerged massively from eel culture ponds in Sizuoka, and have caused serious nuisance to the people in the surrounding areas. Likewise, Chironomus longilobus, a species breeding in sea water, have established enormous colonies in the prawn culture farms in Okinawa, causing unexpected nuisance to the people. In such cases, the owners of the fish culture farms are requested by the municipality for the control of these nuisance midges. In the rice growing areas of Japan, the emergence of enormous numbers and quantities of chironomids from rice paddies has been a problem since old times, as many of them invade into houses attracted by light. Polpedilum kyotoense is one of the most common species emerging from rice paddies. Another small midge breeding massively in rice paddies, Tanytarsus oyamai, frequently forms large swarms in the air, and is a nuisance to the farmers engaged in rice growing.

Massive emergence of chironomid midges from eutrophicated lakes and large rivers is usually difficult to be controlled. They may be nuisances, but at the same time their activity in cleaning the lake or river waters cannot be ignored. On the other hand, certain midge nuisances are man-made problems, such as occurring after construction of fish or prawn culture ponds. The most serious and widespread problem of this kind is the mass emergence of C. yoshimatsui after construction of sewage treatment plants in the urban areas. The water discharged from the plants still contain nutrients at levels of several ppm., and is most fitted for the growth and breeding of this particular midge species, and it becomes new nuisance to the residents along the downstream areas. Many municipalities in Japan are now obliged to spend lot of expences for the control of midges resulting from the construction of sewage treatment plants.

6. Chironomids as a causative agent of bronchial asthma

Bronchial asthma is a common and serious disease especially in the more civilized countries. It is a kind of allergic disease caused by inhalation of dust containing certain allergens. Mites of the genus Dermatophagoides breeding in house dust have been incriminated as the most common allergens causing such disease, but our recent observation in Toyama and Tokyo have revealed that the chironomids are another important causes, and presumably so also in all over the world, especially in areas near lakes, rivers, sewage ditches, rice paddies, etc.

One of the earliest episodes of occurrence of this type of bronchial asthma was reported from Sudan by Freeman (1950), Lewis (1956) and more recently by Kay et al. (1982) and Cranston et al. (1983). The occurrence of large numbers of bronchial asthma patients became notices after construction of man-made lakes in desert areas, and a species of chironomid midge, Cladotanytarsus lewisi, which started to be emerging massively from the lakes, was incriminated as the causative agent. In Germany, Baur et al. (1982) reported on the common occurrence of allergic reactions to the larvae of Chironomus thummi among the workers engaged in preparing pet fish food from this midge. In both cases, a kind of haemoglobin similar in structure to those of man was identified as the main allergen.

In June 1984, an unusual and massive mergence of chironomid midges was observed in Toyama. It was identified as Polypedilum kyotoense, and was found breeding in rice paddies surrounding our University Hospital. It was shown by Igarashi et al. (1985) that extracts prepared from dead bodies of the adult midges caused positive reactions in skin prick test as well as in RAST reaction for the presence of specific IgE, in about 30% of the asthmatic patients visiting our hospital. The extract was also confirmed as causing bronchial asthma attacks in more than 10 cases tested. The positive reactions in the hypersensitivity test were obtained not only with this species, but also with other chironomid species, such as Chironomus yoshimatsui and Tokunagayusurika akamusi. More noteworthy was the highly active allergenicity of Chironomus plumosus, the cosmopolitan giant lake midge occrring abundantly in lakes in Europe and America, too. Ito et al. (1985) also demonstrated that some 38% of the asthmatic patients in the city of Tokyo gave positive reactions against the chironomid midge antigens. In Toyama, it was further observed by Igarashi et al. (1986) that a 19 year old woman inhaled adult midge of Tanytarsus oyamai while jogging in a rice paddy area, and caused severe attack of dyspoea after about 30 minutes; she was also confirmed as highly allergic to the extract of this midge. From these evidences, it has been confirmed that the chironomid midges also constitute an important allergen causing various diseases in hypersensitive patients.

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