NUISANCE MIDGES (DIPTERA: CHIRONOMIDAE) AND THEIR CONTROL IN JAPAN

YUICHIRO TABARU,[1] KIYOKI MORIYA[2] AND ARSHAD ALI[3]

ABSTRACT. In recent years, adult Chironomidae (particularly *Chironomus yoshimatsui* and *Tokunagayusurika akamushi*) emerging from polluted natural and man-made aquatic habitats in urban areas of Japan have become intolerable because they pose severe nuisance and economic problems. Several organophosphorus (OP) insecticides and insect growth regulators (IGRs) including methoprene and diflubenzuron were tested in the laboratory against *C. yoshimatsui* and several other midge species. The OP insecticides were effective against the midge larvae except for *Procladius* sp. Both IGRs were highly effective against *C. yoshimatsui* at concentrations <0.001 ppm; diflubenzuron showed superior activity over methoprene. In field studies, temophos has been successfully used at rates ranging from 0.1 to 2 ppm against *C. yoshimatsui* and several other species in a variety of habitats. Diflubenzuron at 1 ppm rate of treatment provided excellent control of *C. yoshimatsui* in polluted rivers while methoprene at the same rate was less effective. Frequent field use of temephos and fenthion has led to increased tolerance of these insecticides (particularly the latter) by *C. yoshimatsui*.

INTRODUCTION

Until a few decades ago, the phenomenon of chironomid midge emergence from natural and man-made aquatic habitats in Japan was unnoticed because of the low and tolerable levels of adult emergence. In the past 10–15 years, however, the intensity and frequency of midge emergence from many of these habitats in different parts of Japan have grown to intolerable levels (Inoue 1975, Inoue and Mihara 1973, Ohkura and Tabaru 1975, Tabaru 1975). The main reason for this change is the relative improvement of water quality after enforcement of the Water Pollution Control Act in 1972. Prior to 1972, most rivers and other drainage systems in urban areas were so heavily polluted that they supported very little animal life (Anonymous 1975, Inoue 1976, Tabaru 1975). Since the enforcement of the act, the improved quality of water has provided ideal conditions that are conducive to the rapid colonization and profuse breeding of chironomids. This is particularly true in the rapidly urbanizing and industrial growth areas where large quantities of discharges from widespread and increasing number of wastewater treatment plants are generated (Anonymous 1974, 1975; Inoue 1976, Tabaru 1975).

NUISANCE AND ECONOMIC IMPACT

Adult chironomids pose a variety of nuisance and economic problems for the public remaining within the flight and dispersal range of midges. Generally, the visitors, workers or residents along lakes and riverfronts, wastewater treatment plants and ponds utilized for fish (eel) culturing are affected. Dense swarms of midges are a common sight in these areas often precluding outdoor human activity since the adults can be inhaled or fly into the mouth, eyes and ears of an individual. During summer, midges seek cool and shady places during the daytime leaving behind stained stucco, paint and other wall finishes on which they rest. They also soil automobiles, cover the headlights and windshields, causing traffic accidents. At night, the adults are attracted to light, swarming around indoor and outdoor fixtures. Adults of some small species pass through standard screens on doors and windows and thus enhance nuisance and economic problems indoors, such as staining laundry, walls, ceilings, draperies and other furnishings as well as causing discomfort for the residents. Accumulations of dead midges and the unsightly spider web in which midges are trapped require frequent washing and maintenance of properties. The dead midges give a stench similar to rotting fish; this odor persists in damp weather for several days even after the insects have been removed. At times, the dead adults accumulate on the roads in such quantities that they make the roads slippery, causing traffic hazards. They clog automobile radiators and air-conditioning wall units, and are also a problem for paint, pharmaceutical and food processing industries where hordes of adult midges fly into the final products. The nuisance and economic impact of chironomids in various problem situations in Japan were presented by Ohkura and Tabaru (1975) and Shimizu (1978), while Ali (1980) and Ali et al. (1985) had provided details of nuisance and economic aspects of midge related problems in the U.S.A. and elsewhere.

PROBLEM SPECIES

Among the species which cause severe nuisance problems, *Chironomus yoshimatsui* is the

[1] Sankyo Company, Limited, No. 7-12, 2-Chome, Ginza, Chou-ku, Tokyo 104, Japan.

[2] Kanagawa Prefecture Public Health Laboratory, Nakao-cho, Ashahi-ku, Yokohama 241, Japan.

[3] University of Florida, IFAS, Central Florida Research and Education Center, P. O. Box 909, Sanford, FL 32771. Send reprint requests to Arshad Ali.

most important and is generally distributed throughout mainland, Japan, extending from Sapporo in the north to Kagoshima in the south (Moriya 1977, 1980; Sasa and Yamamoto 1977). It is particularly abundant and established in channels and polluted rivers draining residential districts throughout Japan except Okinawa (Inoue 1975, Tabaru 1975, Sasa 1978a, 1984, 1985; Sasa and Hasegawa 1983), where the biochemical oxygen demand (BOD) levels range from 10 to 20 ppm (Inoue and Mihara 1973, Tabaru 1975, 1985b). According to some population estimates, the larval densities of *Chironomus yoshimatsui* range from 50,000 to 93,000/m^2 in urban areas (Tabaru 1975, Tabaru et al. 1978, Moriya 1977, Ohno and Shimizu 1982). Other estimates of this species are 7–9 larvae/gm of sludge in overflow gutters of sewage treatment plants (Tabaru 1985b) and 150/cm^2 on the walls of disinfecting tanks of the plants (Tsumuraya et al. 1982a).

Other midge species inhabiting polluted rivers in various parts of Japan include species of *Cricotopus*, especially *C. bicinctus*, which emerges in phenomenal numbers but is less noticed due to its smaller size than *Chironomus yoshimatsui.* Yasuno et al. (1985a) provided a list of 60 species of chironomids inhabiting three streams polluted with heavy metals.

In static eutrophic waters, *Tokunagayusurika akamusi* and *Chironomus plumosus* are common and abundant (Iwakuma and Yasuno 1981). The former species was first described by Tokunaga (1938) under the name of *Spaniotoma* (*Orthocladius*) *akamusi* and was also given the Japanese common name "akamusiyusurika." Sasa (1978b) transferred the species to the newly created genus, *Tokunagayusurika*. The larva is readily distinguishable from other Orthocladiinae because of its deep red color. The larval density of this species exceeds 5000/m^2 in shallow eutrophic lakes and the larvae are vertically distributed in the bottom sediments reaching depths up to 90 cm (Yamagishi and Fukuhara 1971, 1972). This species is univoltine and its larvae migrate to the sediment surface around mid-October and massive emergences of *T. akamusi* occur in late fall. The larvae are commonly used as bait for freshwater fish and sold throughout the year as "akamusi" in most fishing equipment shops in Japan.

Midge species occurring in a variety of habitats and posing sporadic nuisance problems in various parts of Japan include *Chironomus salinarius* (saltwater ponds, Hyogo), *Chironomus circumdatus* (mildly polluted rivers, southern Japan), *Chironomus nipponensis* (Kawaguchi-ko lake, Yamanashi), *Chironomus tainanus* (eel culturing ponds, Shizouka and Mie), *Glyptotendipes glaucus* (brackish water ponds, eel culturing ponds, eutrophic lakes and sewage ponds, Kochi, Shiga, Shizouka, Mie, and Osaka), *Glyptotendipes tokunagai* (eel culturing ponds, sewage channels, and polluted rivers, Kyoto, Saitama and Shizouka), *Polypedilum octoguttatum* (eel culturing ponds and moats, Hiroshima, Shizuoka and Mie), and *Tanytarsus* sp. (seawater swimming pools, Kanagawa) (Inoue 1975, Inoue and Hashimoto 1977, 1978; Sasa 1979, Sugaya and Yasuno 1980, Tabaru 1986).

The intensity of midge nuisance around eel culturing ponds has greatly increased since the early 1970s because of the substitution of fish meal for raw fish as eel food. The former food has contributed to the organic enrichment of pond sediments and has proven conducive to the profuse breeding of *Polypedilum nubifer*, *Cricotopus bicinctus*, *Chironomus tainanus* and *Chironomus kiiensis* (Ohkura and Tabaru 1975, Yasuno et al. 1982). According to Hashimoto (1984), *Cricotopus javanus* is a recent introduction to Japan from the tropics and may attain nuisance levels in the near future.

In addition to causing nuisance problems, chironomids are associated with human allergic reactions, such as asthma and rhinitis, and it is believed that midges are potentially a worldwide cause of allergy (Cranston et al. 1981, 1983). They may even cause anaphylactic shock (M. Sasa, personal communication) in some individuals. The medically-related chironomid problems are presently being investigated by Sasa and others in Japan.

Larvae of several midge species are implicated as agricultural pests. For example, *Stenochironomus nelumbus* feeds on floating leaves of lotus (*Nelumbo nucifera*), members of the subfamily Orthocladiinae injure roots of Japanese horseradish and Chironominae (particularly Chironomini) damage rice seedling (Tokunaga and Kuroda 1935, 1936; Yokogi and Ueno 1971, Ishihara 1972).

CONTROL METHODS

The increasing problems of the midges in the past two decades have necessitated research on chironomid control. In laboratory studies, Kudamatsu (1969) reported on the larvicidal activity of some insecticides against field-collected *Chironomus plumosus.* Sato and Yasuno (1979) evaluated several insecticides against larvae of *Chironomus yoshimatsui*, *Polypedilum nubifer*, *Paratanytarsus parthenogeneticus*, *Psectrocladius* sp. and *Procladius* sp. These midges, except for *Procladius* sp., were susceptible to temephos with LC_{50} values ranging from 0.0003 to 0.015 ppm. Tabaru (1985a) has reported the activity of chlorphoxim, chlorpyrifos, chlorpyrifos methyl and temephos against *Chironomus yosh-*

imatsui and has also provided a unique criterion for determining midge larval mortality by observing the tube-building inability of intoxicated larvae provided with 0.1 mm glass beads. Recently, the IGRs methoprene and diflubenzuron were tested against *Chironomus yoshimatsui*. Both IGRs proved highly effective at concentrations of <0.001 ppm (Kamei et al. 1982), with diflubenzuron showing superior activity over methoprene (Tabaru 1985d).

In outdoor model streams, temephos and chlorphoxim applied at 5 and 2 ppm, respectively, caused drastic larval reductions of *Thienemanniella majuscula*, *Paratrichocladius rufiventris* and *Chironomus flaviplumus*, but these species recovered within 2–3 weeks posttreatments (Yasuno et al. 1985b); *Procladius* sp., however, was affected only by chlorphoxim.

In field studies, temephos has been successfully used at 2 ppm maintained for 20 min to control *Chironomus yoshimatsui* in wastewater gutters (Inoue and Mihara 1975). The same rate of temephos and chlorpyrifos methyl maintained for 30 min in the gutters, disinfective tanks and discharge channels of sewage treatment plants gave excellent control of *Chironomus yoshimatsui* (Tabaru 1985b). In similar habitats, methoprene tested at rates of 0.13 and 4 ppm was effective only at the latter rate (Tsumuraya et al. 1982b). Tabaru (1975) and Tabaru et al. (1978) had reported satisfactory control of *Chironomus yoshimatsui* in polluted rivers by using temephos at rates of 0.69 to 1 ppm maintained for 60 min; the insecticide was carried up to 3,000 m downstream from the application site and the larval populations in the treated areas recovered after 3 weeks of a treatment. At rates of 0.9 to 2 ppm of temephos maintained for 60 min, *Chironomus yoshimatsui* in another river was successfully controlled (Ohno and Shimizu 1982). Applications of temephos at 0.1 ppm in eel culturing ponds resulted in satisfactory control of *Polypedilum nubifer*, *Cricotopus bicinctus*, *Chironomus kiiensis*, and *Chironomus tainanus* (Yasuno et al. 1982). The same chemical, even at a lower rate of 0.05 ppm was lethal to midge larvae inhabiting the ponds but the eels, *Anguilla anguilla* and *Anguilla rostrata* were also adversely affected, while *Anguilla japonica* remained unaffected (Ohkura and Tabaru 1975). Treatments of two rivers with diflubenzuron at 1 ppm maintained for 60 min resulted in excellent control of *Chironomus yoshimatsui* for 3 weeks, however, methoprene at the same dosage proved less effective than diflubenzuron in the same rivers (Tabaru 1985d).

The frequent and extensive field use of temephos, and to an extent fenthion, has caused the development of resistance in *Chironomus yoshimatsui* in the Kanda River, Tokyo (Ohno and Okamoto 1980). The laboratory studies of Tabaru (1985c) also indicate a widespread acquired resistance to fenthion in *Chironomus yoshimatsui* collected from 10 different rivers; however, larvae from all these rivers were susceptible to chlorpyrifos methyl, and temephos was considered still economically effective as a larvicide in about 50% of the habitats exposed to the organophosphate insecticides.

Very few cultural and biological control studies have been conducted on chironomids of Japan. The removal of sludge and, in turn, egg masses of chironomids from the sides of the rivers by using metal scratchers gave unsatisfactory results (Shimizu 1978); disturbing the riverbeds by dredging and mixing the substrate materials also was ineffective in producing midge control. Although carp have been used as a predator of midge larvae in many habitats (Anonymous 1974), no quantitative data on their effectivenness in reducing midges are available.

CONCLUSION

At present chemicals are the main tool for controlling midges in Japan. More research on cultural and biological control techniques, with minimum dependence on chemicals is needed for the integrated control of nuisance Chironomidae of Japan.

ACKNOWLEDGMENTS

This is Florida Agricultural Experiment Stations Journal Series No. 7718. Gratitude is expressed to Dr. Masayuki Yasuno, National Institute for Environmental Studies, Yatabe, Tsukuba, Japan, for providing a critical review of an earlier draft of this article.

REFERENCES CITED[4]

Ali, A. 1980. Nuisance chironomids and their control: a review. Bull. Entomol. Soc. Am. 26:3–16. (C).

Ali, A., G. Majori, G. Ceretti, F. Dandrea, M. Scattolin and U. Ferrarese. 1985. A chironomid (Diptera: Chironomidae) midge population study and laboratory evaluation of larvicides against midges inhabiting the lagoon of Venice, Italy. J. Am. Mosq. Control Assoc. 1:63–68. (C).

Anonymous. 1974. A report on the midge in the Kanda River. Rep. Dept. Sewer Syst., Metropolitan Tokyo, Tokyo. 80 pp. (A).

Anonymous. 1975. On the important factors for habi-

[4] At the end of each reference the letter A, B, or C in parentheses denotes the following: A = article in Japanese with no summary in English; B = article in Japanese with summary in English; C = article in English.

tation of the midge larvae in the Kanda River. Rep. Dept. Sewer Syst., Metropolitan Tokyo, Tokyo. 52 pp. (A).

Cranston, P. S., M. O. Gad El Rab and A. B. Kay. 1981. Chironomid midges as a cause of allergy in the Sudan. Trans. R. Soc. Trop. Med. Hyg. 75:1-4. (C).

Cranston, P. S., R. D. Tee, P. F. Credland and A. B. Kay. 1983. Chironomid haemoglobins: their detection and role in allergy to midges in the Sudan and elsewhere. Mem. Am. Entomol. Soc. 34:71-87. (C).

Hashimoto, H. 1984. Notes on *Chironomus javanus* Kieffer from Japan. Proc. Jap. Soc. Syst. Zool. 29:24-29. (A).

Inoue, Y. 1975. Chironomidae as nuisance insects. Kankyo Eisei 22:6-12. (A).

Inoue, Y. 1976. Changes of aquatic environments and chironomid midges. Iden 30:25-31. (A).

Inoue, Y. and H. Hashimoto. 1977. A survey of chironomid midges in Biwa-ko lake. Jap. J. Sanit. Zool. 28:20. (A).

Inoue, Y. and H. Hashimoto. 1978. A survey of chironomid midges in eel breeding ponds. Jap. J. Sanit. Zool. 29:29. (A).

Inoue, Y. and M. Mihara. 1973. On an unusual emergence of chironomid midges in the center of Tokyo city. Jap. J. Sanit. Zool. 23:315. (A).

Inoue, Y. and M. Mihara. 1975. Studies on the Japanese chironomid midges as a nuisance. I. Larvicidal effects of some organophosphorus insecticides against the last instar larvae of *Chironomus yoshimatsui* Martin and Sublette. Jap. J. Sanit. Zool. 26:135-138. (B).

Ishihara, T. 1972. An introduction to the study of agricultural insects of Japan, Yokendo, Tokyo. 310 pp. (A).

Iwakuma, T. and M. Yasuno. 1981. Chironomid populations in highly eutrophic Lake Kasumigaura. Verh. Int. Verein. Limnol. 21:664-674. (C).

Kamei, M., H. Shimada, S. Ohokubo and T. Ishii. 1982. Effects of Altosid 10F on the chironomid midge, *Chironomus yoshimatsui* Martin et Sublette (Diptera: Chironomidae) of Tokushima city. Jap. J. Sanit. Zool. 33:207-212. (B).

Kudamatsu, A. 1969. Larvicidal activity of some insecticides against *Chironomus plumosus*. Jap. J. Sanit. Zool. 20:129-130. (A).

Moriya, K. 1977. Seasonal prevalence of *Chironomus yoshimatsui*. Jap. J. Sanit. Zool. 28:63. (A).

Moriya, K. 1980. Biometrics and identification of a nuisance chironomid midge in Kanagawa prefecture. Bull. Kanagawa Publ. Health Lab. 10:21-31. (A).

Ohkura, T. and Y. Tabaru. 1975. Control of chironomids breeding in eel culture ponds. Suisan Zoshoku 23:1-7. (A).

Ohno, M. and H. Okamoto. 1980. Test on the susceptibility of the last instar larvae of *Chironomus yoshimatsui* Martin and Sublette (Diptera, Chironomidae) collected at the Kanda River to two organophosphorus insecticides. Annu. Rep. Tokyo Metropolitan Pub. Health Res. Lab. 31:261-264. (B).

Ohno, M. and K. Shimizu. 1982. On changes in numbers of larvae and imagos of *Chironomus yoshimatsui* Martin and Sublette (Diptera, Chironomidae), and drift of larvae after applications of temephos in the Kanda River. Annu. Rep. Tokyo Metropolitan Pub. Health Res. Lab. 33:314-321. (B).

Sasa, M. 1978a. A comparative study of adults and immature stages of nine Japanese species of the genus *Chironomus* (Diptera, Chironomidae). Res. Rep. Nat. Inst. Environ. Stud. No. 3:1-63. (C).

Sasa, M. 1978b. Taxonomical and biological notes on *Tokunagayusurika akamusi* (Tokunaga), with description of immature stages (Diptera, Chironomidae). Jap. J. Sanit. Zool. 29:93-101. (C).

Sasa, M. 1979. A morphological study of adults and immature stages of 20 Japanese species of the family Chironomidae (Diptera). Res. Rep. Nat. Inst. Environ. Stud. 7:1-149. (C).

Sasa, M. 1984. Studies on the chironomid midges in the lakes of the Nikko National Park. Part II. Taxonomical and morphological studies on the chironomid species collected from lakes in the Nikko National Park. Res. Rep. Nat. Inst. Environ. Stud. 70:19-214. (C).

Sasa, M. 1985. Studies on chironomid midges of some lakes in Japan. Res. Rep. Nat. Inst. Environ. Stud. 83:1-160. (C).

Sasa, M. and H. Hasegawa. 1983. Chironomid midges of the tribe Chironomini collected from sewage ditches, eutrophic ponds, and some clean streams in the Ryukyo Islands, southern Japan. Jap. J. Sanit. Zool. 34:305-341. (C).

Sasa, M. and M. Yamamoto. 1977. A checklist of Chironomidae recorded from Japan. Jap. J. Sanit. Zool. 28:301-318. (C).

Sato, H. and M. Yasuno. 1979. Tests on Chironomidae larvae susceptibility to various insecticides. Jap. J. Sanit. Zool. 30:361-366. (B).

Shimizu, K. 1978. On the nuisance midge in Kanda river. Seikatsu to Kankyo 23:25-38. (A).

Sugaya, Y. and M. Yasuno. 1980. On a chironomid midge breeding in the moat of Hiroshima castle. Jap. J. Sanit. Zool. 31:139. (A).

Tabaru, Y. 1975. Outbreak of chironomid midge in a polluted river and the chemical control of the larvae. Jap. J. Sanit. Zool. 26:247-251. (B).

Tabaru, Y. 1985a. Studies on chemical control of a nuisance chironomid midge (Diptera: Chironomidae). I. Larvicidal activity of organophosphorus insecticides against *Chironomus yoshimatsui*. Jap. J. Sanit. Zool. 36:285-290. (B).

Tabaru, Y. 1985b. Studies on chemical control of nuisance chironomid midge (Diptera: Chironomidae). 2. Chemical control of the midge larvae in a sewage treatment plant by dripping technique and effects of the chemicals on microorganisms in activated sludge. Jap. J. Sanit. Zool. 36:291-298. (B).

Tabaru, Y. 1985c. Studies on chemical control of a nuisance chironomid midge (Diptera: Chironomidae). 3. Susceptibility of *Chironomus yoshimatsui* collected from various rivers to the three kinds of organophosphorus larvicides and larval control trials with chlorpyrifos methyl in the field. Jap. J. Sanit. Zool. 36:299-304. (B).

Tabaru, Y. 1985d. Studies on chemical control of a nuisance chironomid midge (Diptera: Chironomidae). 4. Efficacy of two insect growth regulators to *Chironomus yoshimatsui* in laboratory and field. Jap. J. Sanit. Zool. 36:305-309. (B).

Tabaru, Y. 1986. On the chemical control of the midge larva. Kankyo Eisei 31:55-61. (A).

Tabaru, Y., H. Matsunaga and A. Sato. 1978. Chemical control of the chironomid larvae (Diptera: Chironomidae) in the polluted river in reference to the controlled area and the mortality of the intoxicated larvae carried by the stream. Jap. J. Sanit. Zool. 29:87–91. (B).

Tokunaga, M. 1938. Chironomidae from Japan. X. New or little known midges, with descriptions of the metamorphoses of several species. Philipp. J. Sci. 65:318–383. (C).

Tokunaga, M. and M. Kuroda. 1935. Unrecorded chironomid flies from Japan (Diptera) with a description of a new species. Trans. Kansai Entomol. Soc. 6:1–8. (C).

Tokunaga, M. and M. Kuroda. 1936. *Stenochironomus* midge from Japan (Diptera), with notes on controlling methods of a leaf mining midge. Trans. Kansai Entomol. Soc. 7:1–6. (C).

Tsumuraya, T., T. Mori and T. Matsumoto. 1982a. The ecology and control of *Chironomus yoshimatsui* in the sewage water treatment plant. Yosui to Haisui 24:331–335. (A).

Tsumuraya, T., K. Moriya, T. Matsumoto and T. Mori. 1982b. The ecology and control of *Chironomus yoshimatsui* in the sewage water treatment plant. Yosui to Haisui 24:1356–1362. (A).

Yamagishi, H. and H. Fukuhara. 1971. Biological studies on chironomids in Lake Suwa. I. Population dynamics of two large chironomids, *Chironomus plumosus* L. and *Spaniotoma akamusi* Tokunaga. Oecologia 7:309–327. (C).

Yamagishi, H. and H. Fukuhara. 1972. Vertical migration of *Spaniotoma akamusi* larvae (Diptera: Chironomidae) through the bottom deposits of Lake Suwa. Jap. J. Ecol. 22:226–227. (C).

Yasuno, M., S. Hatakeyama and Y. Sugaya. 1985a. Characteristic distribution of chironomids in the rivers polluted with heavy metals. Verh. Int. Verein. Limnol. 22:2371–2377. (C).

Yasuno, M., Y. Sugaya, and T. Iwakuma. 1985b. Effects of insecticides on benthic community in a model stream. Environ. Pollut. 38:31–43. (C).

Yasuno, M., J. Hasegawa, T. Iwakuma, N. Imamura and Y. Sugaya. 1982. Effects of temephos on chironomid and plankton populations in eel culture ponds. Jap. J. Sanit. Zool. 33:207–212. (B).

Yokogi, K. and R. Ueno. 1971. Wasabi (Japanese horseradish, *Wasabia japonica*). Nohson-Gyoson Bunka Kyoukai, Tokyo. 136 pp. (A).