EFFECTS of SOUND TRAPS on CAPTURE of CHIRONOMID MIDGES near a HYPER-EUTROPHIC LAKE in an URBAN AREA in JAPAN

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Abstract In the area of Lake Suwa in central Japan, massive swarms of chironomid midges have repeatedly caused problems for local residents. Until now, light has been used as the customary countermeasure against chironomids wherever they occur, e.g., around natural lakes. In recent years, large numbers of swarming males of chironomid midges, *Rheotanytarsus kyotoensis* (Tokunaga) and *Chironomus yoshimatsui* (Martin et Sublette), were caught by traps emitting artificial wingbeat sounds. The present study was carried out to trap adult midges by wingbeat sounds in the field for the purpose of developing a new control method against these species using their acoustic response. Trials were conducted in 2000 from 30 May to 10 June (*Chironomus* (*Lobochironomus*) *dissidens* Walker), in 2000 from 2-5 June (emergence period of *Chironomus plumosus* (L.); summer generations) and in 2000 from 16 October to 6 November (*Propsilocerus akamusi* (Tokunaga)). A speaker connected to a cassette tape recorder was placed in the center of a cylinder of transparent polyethylene. Glue was sprayed on the inside wall of the cylinder. The sticky area was about 900 cm^2. Two cylindrical traps, one emitting sound and the other not, were set in parallel about 30 cm apart. The traps were placed in the vicinity of swarm. Sinusoidal sounds at various frequencies recorded from a sound generator were emitted at intervals of 10 s on/5 s off for 2 min by a cassette tape recorder. The sound intensity was kept at 90-dB sound pressure level at the cylinder edge. Most swarming males of *C. dissidens* were caught by cylindrical sound traps emitting a sound frequency of 240 HZ at 20.5±3.1°C , and *C. plumosus* were caught by 270 Hz (range 240-300) at 17.6±1.2°C On the other hand, *P. akamusi* were caught by 165 (150-180) Hz at 14.6±1.2°C. It is concluded that the most attractive frequency differed among species according to air temperature.

Key Words Chironomidae midge acoustic response swarm wingbeat sound

INTRODUCTION

It has long been known that many kinds of insects use sound as a means of communication with the opposite sex (reviewed by Belton, 1986; Downes, 1969). Many studies have been done on the sound trapping of mosquitoes in the field (reviewed by Roth, 1948). Wishart and Riordan (1959) reported that males of *Aedes aegypti* (L.) are attracted to an artificial sinusoidal wave of the same frequency as the female wingbeat. In contrast, such reports concerning chironomid midges are rare.

In the area of Lake Suwa in central Japan, massive swarms of adult midges *Chironomus plumosus* (L.) and *Propsilocerus akamusi* (Tokunaga) have repeatedly caused problems for local residents (Hirabayashi, 1991a). According to Hirabayashi (1991b), more than 10% of residents, about half of whom live within 500 m of the lakeshore, said that they can no longer tolerate such swarms of chironomid midges. Additionally, more than 30% of tourists in this area felt such swarms to be a significant nuisance (Hirabayashi and Okino, 1998). In recent years, massive emergence of *Chironomus* (*Lobochironomus*) *dissidens* Walker has also occurred from the littoral zone during the summer season and caused new problems for tourists (Nakazato and Hirabayashi, 1998).

Until now, lights have been used as the customary countermeasure against chironomid midges wherever they occur, e.g., around natural lakes (Ali et al., 1986; Hirabayashi et al., 1993a, 1993b,

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1998). Recently, Ogawa (1992), and Ogawa and Sato (1993) reported that large numbers of swarming males of chironomid midges, *Rheotanytarsus kyotoensis* (Tokunaga) and *Chironomus yoshimatsui* Martin et Sublette, near a river in an urban area were caught by traps emitting artificial wingbeat sounds. Thus, it appeared to be quite feasible to utilize this method for midge control.

For the purpose of developing a new control method of the chironomid midges using their acoustic responses, the present study was carried out to trap adult midges of *C. dissidens*, *C. plumosus*, and *P. akamusi* by sounds in a field.

MATERIALS and METHODS

Study Site

Lake Suwa is a tectonic lake in the central highlands of Honshu, Japan, 759 m above sea level (36° 03' N, 138° 05 ' E) about 160 km W of Tokyo. The surface area of the lake is 13.3 km^2 and its maximum depth is 6.5 m. A single outlet, the Tenryu River, flows south into the Pacific Ocean. Lake Suwa is a hyper-eutrophic lake surrounded by the municipalities of Okaya City, Shimosuwa Town, and Suwa City, with a total population of 140,000. Many resort hotels and businesses have been severely affected by the dense swarms of adult chironomids emerging from the lake. Densities of larvae at the lake bottom are high, e.g., *C. plumosus*, about 1200-5400 and *P. akamusi*, about 700-4800 per m^2 in the profundal region (Yamagishi and Fukuhara, 1971).

Adult Midge Collection

Field studies were conducted in 2000 from 30 May to 10 June (emergence period of *C. dissidens*), in 2000 from 2-5 June (*C. plumosus*; summer generations) and in 2000 from 16 October to 6 November (*P. akamusi*), along the east shore of Lake Suwa (ca. 20 m off shore and 2 m above the water level).

The trap was the cylindrical type used by Ogawa (1992). A speaker (9 cm diam.; 0.7W, 8W) connected to a cassette tape recorder was placed in the center of a cylinder of transparent polyethylene (ca. 9 cm diam. and ca. 66 cm long). Glue (Kinryu®, Maruzen-kakou K.K., Tokyo) was sprayed on the inside wall of the cylinder. The sticky area was about 900 cm^2. Two cylindrical traps, one emitting sound and the other with no sound, were set in parallel about 30 cm apart. The traps were placed nearby or close to the swarm (ca. 2.5 m above ground). Sinusoidal sounds at various frequencies (90-510 Hz at intervals of 30 Hz) recorded from a sound generator were emitted at intervals of 10 seconds on / 5 seconds off for 2 minutes (total: 8 times emitted) by a cassette tape recorder. The sound intensity was kept at 90 decibels sound pressure level at the cylinder edge. The captured midges were identified and counted in the laboratory. The recorded number of midges caught by the sound trap was expressed as the catch difference between the sound trap and the no-sound trap. The air temperature and light intensity were measured about 1 m above the ground just after each trap period. At least three replicate captures on different nights were conducted for each sound frequency. All collected data were analyzed using analysis of variance (ANOVA) and a multiple comparison test (Tukey's test) (Sokal and Rohlf, 1995).

RESULTS

Swarms

Table 1 shows the characteristics of chironomid midges, *C. dissidens*, *C. plumosus* and *P. akamusi*, forming massive swarms around Lake Suwa. Adult *C. dissidens* appeared from the end of May to early October in 2000, with no marked emergence peak. Almost all swarms observed were 1 m to 3 m above the terrain, which was colored more conspicuously than the surrounding area, such as a light-colored jogging trail, at the margin of the lake. The swarms formed before

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Table 1. Characteristics of chironomid midges forming massive swarms around Lake Suwa

Scientific name:	*Chironomus dissidens*	*Chironomus plumosus*	*Propsilocerus akamusi*
Swarming			
Distance above ground (m)	1 – 3	1 – over 5	1 – over 10
Begin to form			
Time (h)	around 1830	around 1900	around 1530
Air temperature (?)	21.0±2.9	17.8±1.5	16.7±1.0
Light intensity (Lx)	51.3±6.1	40±12	4215±1365
Become to compact			
Time (h)	around 1900	around 1930	around 1720
Air temperature (?)	20.8±2.9	17.1±1.5	13.9±0.7
Light intensity (Lx)	0	0	4±3
Mean temperature (?)	20.5±3.1	17.6±1.2	14.6±1.2

sunset (ca. 1830 h) and lasted for 30 min. The swarms began to form around 1830 h (21.0±2.9^{o} C, 51.3±6.1 Lx) and subsequently intensified in density and numbers. The swarms then became more compact as illumination decreased (around 1900 h, 20.8±2.9^{o} C, 0 Lx). During the experimental periods, the wind condition from 1800 to 2000 h was very calm.

Adult *C. plumosus* appeared from June to July (summer generation) in 2000. Almost all observed swarms, consisting of more than a thousand males, were 1 m to over 5 m above ground at the margin of the lake. The swarms formed just after sunset (around 1900 h, 17.8±1.5^{o}C, 40±12 Lx) and subsequently intensified in density and numbers. They became more compact as illumination decreased (around 1930 h, 17.1±1.5^{o}C, 0 Lx). During the experimental periods, the wind from 1800 to 2000 h was very calm.

Adult *P. akamusi* appeared from the end of October to early November in 2000. Almost all swarms were observed at 1 m to over 10 m above the terrain that had more conspicuous color than the surrounding area, such as a light-colored jogging trail, at the margin of the lake. The swarms began to form around 1530 h (16.7±1.0^{o}C, 4215±1365 Lx) and subsequently intensified in density and numbers. The swarms then became more compact as illumination decreased (around 1730 h, 13.9±0.7^{o}C, 4±3 Lx). During the experimental periods, the wind condition from 1500 to 1800 h was very calm, except on October 20 and 21. The swarm of *P. akamusi* did not form on October 20 and 21, due to the winds (wind velocity was 5-6 m/s at 1500 h) and low air temperature (less than 12.5^{o}C at 1500 h and less than 9.8^{o}C at 1730 h) during swarming time.

Sound Trapping of Males

Figure 1 shows the mean number of mail *C. dissidens*, *C. plumosus,* and *P. akamusi* caught by a sound trap.

C. dissidens. The sound traps caught a large number of males at frequencies between 240 to 270 Hz at 20.5±3.1^{o} C. There was a significant difference in the number of midges captured by a sound trap depending on the frequency of sinusoidal sounds emitted (F = 9.06; df = 12, 19; P < 0.001 in ANOVA). Trap catch peaked at a sound frequency of 240 Hz (a mean of 89 per 2 min at 23.3^{o}C). Less than 3.4±2.6 males per 2 min were caught at sound frequencies between 150 and 210 Hz, or between 360 and 510 Hz. 240 Hz was significantly different from the catches using other sound frequencies (P<0.05, Tukey's test).

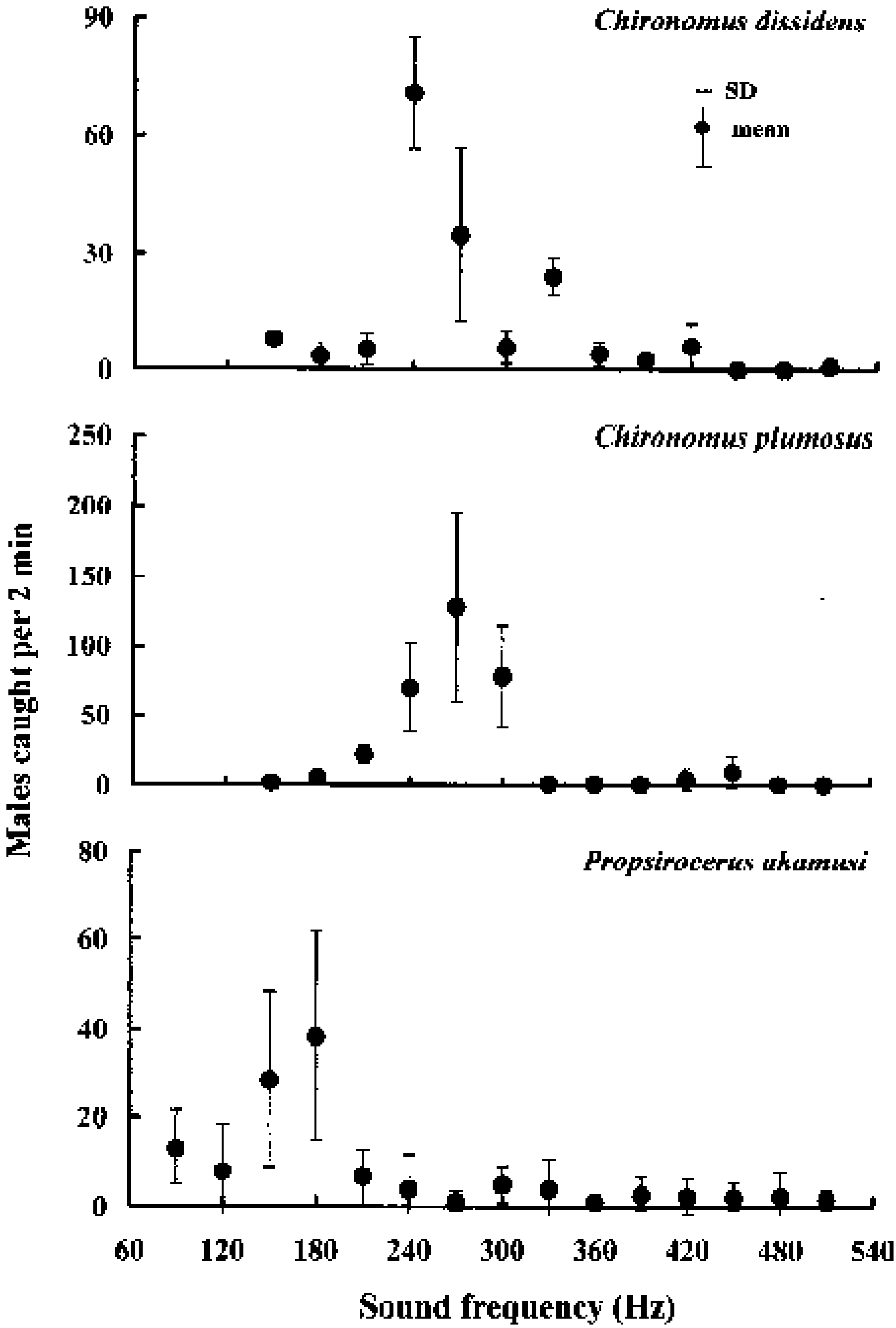

Figure 1. Mean number of male Chironomus dissidens, Chironomus plumosus, *and* Propsilocerus akamusi *caught by a sound trap.*

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C. plumosus. The sound traps caught a large number of males at frequencies between 210 to 300 Hz at 17.6±1.2°C. There was a significant difference in the number of midges captured by a sound trap depending on the frequency of sinusoidal sounds emitted ($F = 7.47$; df = 12, 25; $P < 0.001$ in ANOVA). Most of the traps caught many males with sound frequencies of 240 (70.0±31.8, mean ± SD) to 300 (78.0±36.7) Hz. Less than 2.8±3.0 males per 2 min were caught at sound frequencies of 150 and 180 Hz, and between 330 and 510 Hz. A 270 Hz sound trap caught the highest number of males (a mean of 113 per 2 min at 17.9°C). Although there was no significant difference between catches at 240, 270, and 300 Hz, these frequencies were significantly different from the catches using other sound frequencies ($P<0.05$, Tukey's test).

P. akamusi. The sound traps caught a large number of males at frequencies of 150 (28.6±19.6 / min, mean males ± SD) and 180 Hz (38.3±23.3) at 14.6±1.2 ° C of the air temperature. There was a significant difference in the number of midges captured by a sound trap depending on the frequency of sinusoidal sounds emitted ($F = 12.19$; df = 14, 125; $P < 0.001$ in ANOVA). On the other hand, fewer than 4.1±3.3 mean males per 2 min were caught at sound frequencies of 90 and 120 Hz, and between 210 and 510 Hz. A 180 Hz sound trap caught the highest number of males, i.e., a mean of 74 per 2 min at 14.4°C. Although there was no significant difference between catches at 150 and 180 Hz, they were significantly different from the catches using other sound frequencies ($P<0.05$, Tukey's test).

DISCUSSION

Adult midges are visually attracted to the swarming site by species-specific swarm markers. Furthermore, circadian rhythm also plays an important role in flight activity (Armitage, 1995). In several chironomid species, swarming sites and the times of swarming have been observed in Japan. According to Ogawa and Sato (1993), a swarm of *C. yoshimatsui* formed close to a tree serving as a swarm marker above ground, and was observed toward evening in fall to early winter or just after sunset in summer. A swarm of *R. kyotoensis* formed above the water surface of a river and was observed from about noon to sunset (Ogawa, 1992). Hirabayashi and Ogawa (2000) reported that the swarm of *P. akamusi* formed above ground and was observed in the afternoon (about 1510-1720 h). The present study is in agreement with the results of Hirabayashi and Ogawa (2000) (Table 1).

A possible control method for Chironomid midges uses their acoustic responses. Various midge control methods have been developed in the past several decades (Ali, 1991). Studies in this area have focused on chemical control (Tabaru et al., 1987; Ali ,1995). In a small area such as a stream, a sewage disposal plant, an eel pond, etc., chemical control is practical (Edwards et al., 1964; Yasuno et al., 1982). However, in natural lakes covering a large area, chemical control is not economically feasible because of the large volume of water to be treated, as well as the undesirable impact on other organisms. Therefore, the development of physical and biological control strategies is urgently needed. Based on midge biology, physical control may be possible by manipulating adult behavior. Ali et al. (1984, 1986) reported that light intensity was a more important factor in attracting midges than the wavelength of light in the visible spectrum. Hirabayashi et al. (1998) also reported that the flying behavior of *P. akamusi* was greatly influenced by lamps with strong light intensity. In addition, according to Hirabayashi et al. (1993a), *C. plumosus* and *P. akamusi* were attracted by wavelengths of 300-390 nm (in the near-ultraviolet region). Hirabayashi et al. (1993b) also tried to capture *P. akamusi* in the field using electrocuting insect traps with black light lamps emitting near-ultraviolet rays to which huge numbers of adults were attracted. These studies indicate that there may be species-specific preferences for wavelength or intensity that need to be determined on an individual basis, and that clarification of appropriate light wavelengths is important for the development of an overall integrated strategy

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to control chironomids. On the other hand, wingbeat sounds to control some insect pests have been attempted (Khan and Offenhauser 1949; Ikeshoji, 1986). In the case of chironomids, there have been few reports on the behavior and ecology of adults (Ikeshoji, 1982; Armitage, 1995). Ogawa (1992) reported that sound traps were the only efficient capture method when the midges were swarming. Therefore, he suggested that joint-use with other attractive devices and swarm markers is necessary. Hirabayashi and Ogawa (1999) reported combining black-light and wingbeat sounds to capture *C. plumosus*. This combination method was based on midge biology and on the manipulation of their adult behavior, i.e., wingbeat sounds utilize the sexual instincts of chironomid midges, and lights utilize their phototaxis. The result was that many males of *C. plumosus* were attracted and eventually captured in sound traps equipped with a black light lamp emitting near-ultraviolet rays. Here sound traps caught a large number of *C. dissidens* and *P. akamusi*, because the swarming male responded to a narrow range of sound frequency (Figure 1). Consequently, these acoustic responses (in a fairly narrow range) of male *C. dissidens* and *P. akamusi* are quite similar to those of male *C. plumosus*. Thus, the attraction of light and the application of audio-frequency sounds for *C. dissidens* and *P. akamusi* control seem to be feasible, assuming the availability of a suitable collecting device. Further laboratory and field investigations are necessary to perfect these methods for large-scale practical application.

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