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CHIRONOMID (DIPTERA, CHIRONOMIDAE) FAUNA IN A FILTRATION PLANT IN JAPAN

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Abstract Flights of chironomid midges have caused some problems for residents around water treatment works. The development of physical and biological control strategies against chironomid midges is needed because chemical control is not feasible in slow sand filter beds. In this study seasonal changes in the abundance and species composition of chironomid larvae were investigated in slow sand filter beds in a subtropical region. Through the year, Chironominae was the dominant subfamily (45.3-93.7%), followed by Tanypodinae (6.3-54.7%). No Orthocladiinae were collected. *Hanochironomus* and *Polypedilum* were the dominant genera, whereas Tanypodinae, *Ablabesmyia* was the dominant genus. *Polypedilum* has been the major pest genus in Japan. The overall factor influencing the abundance of chironomids is water temperature in slow sand filter beds.
Key Words chironomid larvae, nuisance insect, slow sand filter bed

INTRODUCTION

Slow sand filter beds are used to purify water passing from rivers or storage reservoirs into the drinking water supply (Graham, 1988). Due to a continuous supply of particulate food passing through, and becoming trapped at, the filter surface, the macroinvertebrate fauna inhabiting the sand surface is dominated by chironomid larvae (Diptera: Chironomidae) (Lodge, 1979; Wotton et al., 1996). Wotton et al. (1996) reported that many water company managers are concerned by the huge numbers of midges swarming and flying around water treatment works, and local residents complain when midges cover washed, recently-painted or cleaned surface, and generate allergic reactions (Ali, 1995; Cranston, 1995a). Furthermore, according to Ali (1995), the constant high numbers of flying adults are a nuisance that is difficult to avoid.

Ali (1991) reported the various midge control methods that have been developed in the past several decades. Studies in this area have focused on chemical control (Tabaru et al., 1987; Ali, 1995). However, in slow sand filter beds, chemical control is not feasible because the beds are used to purify water for drinking purposes. 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 (Hirabayashi and Nakamoto, 2001; 2002).

There are few reports on the seasonal change in chironomid communities on slow sand filter bed associated with the water temperature for chironomid larvae. In the present study, in order to collect basic data to prevent the massive flights of chironomid midges, seasonal changes in the abundance and species composition of chironomid larvae were investigated in slow sand filter beds at the Ishigaki filtration plant in subtropical southwestern Japan.

MATERIALS AND METHODS

Description of Slow Sand Filter Beds

Slow sand filter beds are water-filled containers used by municipalities to purify water for drinking purposes. The beds consist of enclosed rectangular ponds which have a concrete base overlain with gravel and then a thick layer of sand. The surface of the sand is a smooth, markedly homogeneous, level substratum. The depth of water is also uniform, varying from 1.0-2.0 m. With a continuous supply of particulate food passing through and becoming trapped at the filter surface, very large populations of animals accumulate.

Sampling Site

The Sakishima group consists of a large number of islands in the western Pacific forming a chain between Okinawa and Taiwan in the subtropical zone (24°N-25°N). There islands are further divided into the Miyako group (Miyako Island, etc.) and the Yaeyama group (Ishigaki Island, Iriomote Island, Yonaguni Island, etc.). Both groups are in Okinawa Prefecture. The fauna and flora of Sakishima are mainly those of the Oriental region, but are also known to include many indigenous species, some of which are the same as those recorded from the Palaearctic part of Japan by many workers. In this study, the Ishigaki filtration plant at Ishigaki City in the southern part of Ishigaki Island was chosen for investigation. This filtration plant (58 m above sea level) is the southernmost part of Japan (24°21' N. 124°10' E). It consists of 22 filter beds onto which water is pumped for treatment from the Omotogawa River. All beds receive water of a similar quality. At intervals, the sand filter loses efficiency because they become clogged with accumulated organic matter; water is then drained away, and the surface of the sand layer is removed (= bed run length). The pond is subsequently re-filled. In the Ishigaki plant, the run length ranged from 38 to 51 days, and mean values (±S.D.) were 44.8±4.5 days.

Chironomid Larval Density in Filter Beds

Samples of chironomid larvae were collected every month from April through December 2001. They were taken from drained filter beds by pushing petri dishes (9 cm in diameter, 1 cm in depth) into the substratum, digging into the sand using a plasterer's trowel, and inverting the dishes upon removal. 70% alcohol was added to kill larvae, and each dish was covered with a companion dish, the whole being sealed with insulating tape. On each occasion, three samples were taken in an apparently clean area of the sand and three samples where there was algal growth. At the same time, surface water temperature of the filter bed was recorded. Because the current is constant toward the bottom, the variation in surface water temperature is very small throughout the day (Ishigaki filtration plant staff, personal communication). Moreover, we measured the chlorophyll-a content of the surface of the filter beds. Three substratum samples of equal area and volume were taken by pushing a metal frame (diameter 18 cm, height 3 cm) into the substratum and then, after careful removal, put into plastic bags. In the laboratory, dishes were unsealed and chironomid larvae picked out and counted using a binocular microscope. In the April samples all individuals were counted, but from the May samples onwards, a 25% subsample (sand in one quadrant) was used from each dish. This cut down the sorting time. Larvae were identified to the generic level using the keys provided by Wiederholm (1983), Saether et al. (2000) and Kondo et al. (2001). Chlorophyll-a content was measured by UNESCO standard methods. Moreover, the dominant algal genera in each chlorophyll sample were identified under a microscope using the keys provided by Mizuno (1964) during the investigation period.

Data Analysis

All collected data were analyzed using analysis of variance (ANOVA) and a multiple comparison test (Tukey's test) (Sokal and Rohlf 1995).

RESULTS

Physical Factors in Filter Beds

Figure 1 shows the seasonal change in water temperature and chlorophyll-a content on the filter beds at the Ishigaki filtration plant. Water temperature ranged from 20.5°C (December) to 28.5°C (August), and the mean value (from April through December) was 25.0±3.1°C (n = 8).Thus, water temperature varied little through the year. Chlorophyll-a content ranged from 60.7±0.1 mg / m^2 (August, n = 3) to 516.0±13.7 mg / m^2 (September, n = 3), and the mean value was 211.4±158.8 mg / m^2 (n = 27). There was a significant difference in the chlorophyll-a content depending on the month (F = 28.5; df = 8, 18; P <0.001 in ANOVA), and it peaked in September and October. Although there was no significant difference between September and October, these months differed markedly from the other months (P <0.01, Tukey's test). Small single cell diatoms, *Cymbella* spp., were the dominant algal genera on the sand filter beds from April through December. *Spirogyra* also appeared on some beds from April to December.

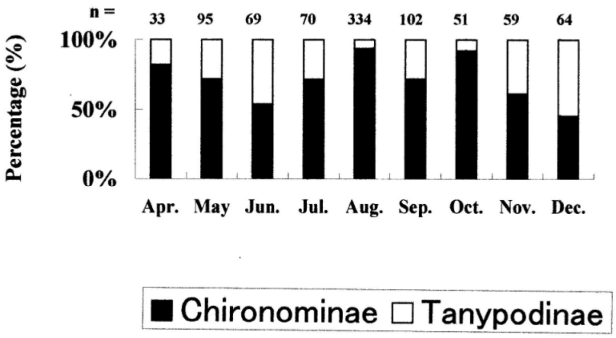

Figure 1. Seasonal change of water temperature and chlorophyll-a content on the filter beds in Ishigaki Island. Vertical bars indicate standard deviations.

Seasonal Change in Chironomid Larval Density

The density of chironomid larvae ranged from 10,229.3±3,174.5 individuals / m^2 (April, n = 3) to 44,797.3±3,174.5 individuals / m^2 (August, n = 3), and the mean value was 22,183.0±12,316.1 individuals / m^2 (n = 27) (Figure 2). There was a significant difference in their density depending on the month (F = 18.6; df = 8, 18; P <0.001 in ANOVA), and it peaked in May and August. Although there was no significant difference between May and August, these months differed markedly from the other months (P <0.01, Tukey's test). Moreover, there was a significant difference between November and the other months (except April, July and December) (P <0.05, Tukey's test). As a result, the population varied little through the year except in May, August and November. In addition, pupae were found during the year.

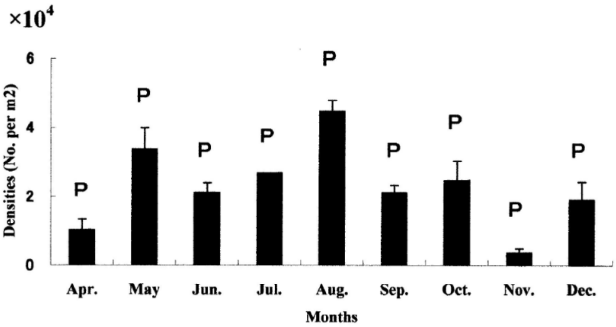

Figure 2. Seasonal change of chironomid larval density on filter beds in Ishigaki Island.Vertical bars indicate standard deviations. "P" indicates presence of pupae on the sampling occasion.

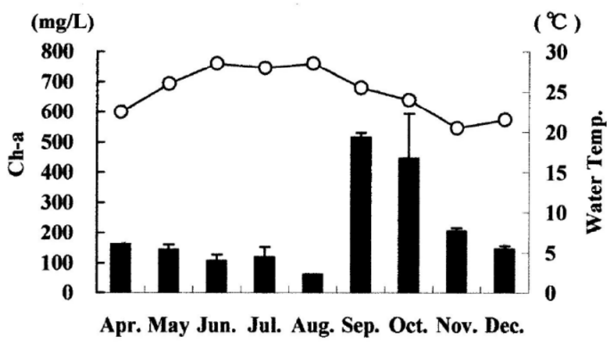

Figure 3. Seasonal change of chironomid communities at the subfamily level. *n*: individual no. of chironomid larvae.

Figure 3 shows the seasonal change in chironomid communities at the subfamily level. 77.5% of the larvae were Chironominae and 22.5% were Tanypodinae during the investigation period. Chironomidae was the dominant subfamily in the filter beds from April to November. In December, Tanypodinae was the dominant subfamily (54.7% of the total chironomid communities). Orthocladiinae was not collected during the investigation period. The most abundant genus was *Polypedilum* and *Hanochironomus* in Chironominae and *Ablabesmyia* in Tanypodinae during the year. From April to July, in addition abundant genera were *Chironomus, Cryptochironomus, Glyptotendipes* and *Tanytarsus*. During the summer, almost all larvae were *Polypedilum* and *Hanochironomus*. In December, Tanypodinae (mainly *Ablabesmyia*) dominated. The fauna in the Ishigaki filter beds was mainly dominated by three genera (in order of abundance), *Polypedilum*, *Hanochironomus* and *Ablabesmyia* through the year. As a result, the dominant chironomid fauna did not change much throughout the year.

DISCUSSION

The slow sand filter beds have a substratum of sand on which a rich coating of organic particles (*schmutzdecke* layer) accumulates during the passage of water through the bed. The invertebrates, oligochaetes, nematodes and protozoans, inhabiting the interstices of the sand grains have been studied by Duncan (1988). However, the chironomids living in and partly responsible for developing the organically rich coating of the sand surface have been little studied, despite being known to reach impressively high numbers (Wotton et al., 1992; Hirabayashi et al., 2004). Recently, chironomid larvae in the filter beds play an important role in the filtration process (Hirabayashi and Wotton, 1998; Wotton and Hirabayashi, 1999).

Numerous studies of the distribution and seasonal abundance of chironomids in relation to environmental factors (water temperature, dissolved oxygen concentration and food abundance) have been conducted in lentic/lotic habitats (e.g., see literature reviews by Pinder, 1995). In this study, the dominant chironomid fauna and their densities varied little on the slow sand filter beds at Ishigaki through the year (Figures 2 and 3). In natural condition, especially in lentic habitats, lakes and ponds, it has been reported that the dissolved oxygen concentration was a key factor controlling the distribution and seasonal abundance of chironomids (e.g., Jonasson, 1965; Lindegaard, 1995). However, in slow sand filter beds at Ishigaki, there was always sufficient dissolved oxygen in water through the year (Ishigaki filtration plant staff, personal communication). Oxygen is the byproduct of photosynthesis during daytime by algae (Graham and Collins, 1996). On the slow sand filter bed in the Ishigaki filtration plant, the mean chlorophyll-a content was more than 200 mg/m^2 (Figure 1). The chlorophyll-a levels reflected algal growth on the filter bed and the accumulation of plankton on the filter surface. As a result, there was active formation of bubbles on the sand bed under conditions of dissolved oxygen supersaturation, and the oxygen in the bubbles on the bottom maintained aerobic conditions in the sand layer even at night (Graham and Collins, 1996). In addition, as there was a constant downward current of about 10-20 cm / h in the filter beds, the bottom of the beds did not reach the anaerobic condition. Thus, the apparent oxygen concentration did not have as much influence on the seasonal abundance of chironomid community on slow sand filter beds.

On the other hand, water temperature was also one of the important key factors controlling the seasonal abundance of chironomids (Cranston, 1995b). According to Cranston (1995b), the ratios of taxon richness between subfamilies of chironomids reflect the variation in the proportions of cold stenothermic taxa (Diamesinae and Orthocladiinae) in relation to warm eurytherms (Chironominae), i.e., Diamesinae and Orthocladiinae prefer cold water, while Chironominae prefer warmer water (except in Australia and much of the southern hemisphere). According to Hirabayashi et al. (2004), Orthocladiinae were dominant in spring and late fall, while Chironominae were dominant in summer in slow sand filter beds of the Someya filtration plant in the eastern part of Nagano Prefecture (36°24' N. 138°16' E) where is located at the center of the main island of Honshu in an inland climate region (500 m above sea level). Water temperature ranged from 3.6±1.2°C (December) to 21.9±0.5°C (August), and the mean (from April through December) was 13.0±5.6°C (n =36). In Someya filtration plant, the density of chironomid larvae ranged from 1,622.6±1,330.2 individuals / m^2 (May, n = 3) to 38,589.1±6,944.1 individuals / m^2 (October, n = 3), and the mean value was 15,066.0±14,675.7 individuals / m^2 (n = 25). Moreover, the emergence periods of Chironomidae started at the beginning of August, ended at the beginning of October, and seasonal change occurred in chironomid communities on the slow sand filter beds (Hirabayashi et al., 2004).

In this study, the water temperature, which varied little through the year, showed a mean value of 25.0±3.1°C (Figure 2). The larval population varied little through the year except in May, August and November, when the mean value was 22,183.0±12,316.1 individuals /m^2. In addition, pupae were found, suggesting emergence periods throughout the year (Figure 3). The fauna in the Ishigaki filter beds was mainly dominated by three genera (in order of abundance), *Polypedilum* and *Hanochironomus* belonging to Chironominae, and *Ablabesmyia* belonging to Tanypodinae. Not one Orthocladiinae was caught through the year. These species are well suited to what is a temporary habitat, as they each have a relatively short life cycle (Wotton et al., 1996). Wotton et al. (1996) reported some chironomid species on slow sand filter beds able to complete their development in a mean period of about 20 days in the conditions provided by slow sand filter beds. In the Ishigaki plant, the run length (with the surface of the sand layer removed) ranged from 38 to 51 days, with a mean of about 45 days. This means that a significant proportion of the larvae emerge as adult midges before the filter bed is drained for cleaning (Wotton et al., 1992; Wotton and Armitage, 1995). According to Kondo (2001), *Polypedilum* was the major pest genus in Japan. In recent years, Hirabayashi and Ogawa (1999) reported that the swarming males of chironomid midges were caught by sound-light field traps which attracted many males. This combination method was based on midge biology and on the manipulation of their adult behavior. Thus, the application of audio-frequency sound plus light to control chironomid midges around slow sand filter beds seems to be quite feasible, assuming a suitable collecting device.

This is the first report on the seasonal change in the chironomid fauna of slow sand filter beds in subtropical areas in Japan. However, since the present study was carried out at only one filtration plant, further follow-up field investigations of other filtration plants are necessary in subtropical areas. Such studies should be conducted in a different climate area for a more precise understanding of the chironomid fauna of slow sand filter beds. In a separate study presently underway, we are attempting to compare the chironomid fauna in subtropical areas with those in subarctic areas for a more precise understanding of such fauna in slow sand filter beds.

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