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INCREASE IN ENVIRONMENTAL LIGHT CONDITIONS BOOSTS MASSIVE FLIGHTS OF AQUATIC INSECTS

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Abstract In the middle of June, 2010, we received the following requests from the manager of a bookstore along an irrigation canal which drew water from the Chikuma River. "During the night, massive flights of aquatic insects are attracted to the lights of my shop." The abundance of aquatic insects was monitored by a daily catch using two light traps equipped with a black light of 6W (BL lamp) and a fluorescent lamp of 6W (FL lamp) set up near the entrance of the shop, from the end of June to the beginning of July 2010 and 2011. As a result, more than 12,000 individual aquatic insects were collected by the two light traps during the investigation periods in 2010. The most abundant taxa were Trichoptera (about 50% of the overall number) followed by Chironomidae, Tipulidae, and Ephemeroptera. The same number of Trichoptera were captured by the BL and FL lamps. However, more Chironomidae and Tipulidae were captured by the BL lamp. In addition, 3 times as many Ephemeroptera were captured by FL lamp compared to BL lamp. In April, 2011, a large shopping center opened on the other side of the bookstore. After its opening, the environmental light condition greatly changed around the investigation place. As a result, the number of aquatic insects attracted to the bookstore observed a very large change in 2011. The number of aquatic insects / 9 day increased compared with 2010, especially, due to the BL lamp. In 2011, the most captured insect was Chironomidae in the bookstore, and the individual number was 12.8 times that of 2010 by BL lamp, against 1.1 times by FL lamp. The captured number of Ephemeroptera also increased to 18 times that of 2010 by BL lamp, against decreased to 0.6 times by FL lamp. As mentioned above, if the number of aquatic insects emerging from the canal was the same in 2010 and 2011, 74.6% of the aquatic insects attracted to the bookstore in 2010 moved to the new shopping center.

Key words Chironomid midges, light attraction, light quantity, mayfly, nuisance insect, Trichoptera

INTRODUCTION

Aquatic insects include a number of species whose larvae live in almost all types of water bodies (reviewed by Ward, 1992). They are often dominant in mesotrophic / eutrophic urban river/ stream/canal ecosystems, and massive emergence of adults sometimes is a serious nuisance, as well as creating economic problems for people living near water bodies (Tabaru et al., 1987; Ali, 1995; Kondo et al., 2001; Sekine et al., 2013). Furthermore, in recent years many researchers have found that aquatic insect-related particles / hair (e.g., microtrichia) are among the important allergens, especially chironomidae and Trichoptera and so on, taking the form of an inhalant antigen which causes asthma and other respiratory problems (Cranston, 1995).

According to Hienton (1974), many nocturnal insects, including almost all adult aquatic insects, showed peak responses to radiant energy in both the near ultraviolet and visible regions of the electromagnetic spectrum, but these responses varied with the energy levels of the sources. Ali et al. (1984, 1986) reported that some chironomid species were generally most attracted by highest-intensity lamps and least by low-intensity lamps.

These chironomid species responded more to the power or intensity than to the color or wavelength of the visible area of the electromagnetic spectrum.

In mid-June of 2010, we received the following requests from the manager of a bookstore along an irrigation canal which drew water from the Chikuma River. “During the night, massive flights of aquatic insects are attracted to the lights of my shop. Many books are polluted by them. Please take measures immediately.” In April, 2011, a large shopping center opened on the other side of the bookstore. After its opening, the environmental light condition greatly changed around the investigation place. Light quantity increased. In the present study, we examined the effects of the increase in light conditions on the number of flight insects and taxa composition of the adult aquatic insect population in this area. The aquatic insects were monitored by a daily catch using two light traps equipped with a black light of 6W (BL lamp; control) and a fluorescent lamp of 6W (FL lamp) set up near the entrance of the shop, from the end of June to the beginning of July 2010 (before opening shopping center) and 2011 (after opening). It was expected that the number of aquatic insects attracted by FL lamp was effected by the light intensity of the shopping center.

MATERIALS AND METHODS

Study Site

The investigation was performed in the bookstore 20-car parking lot along Masuami-yohsuiro canal (about 15 m between the bookstore and canal) in Ueda City, Nagano Prefecture, Central Japan (Figure 1 A). The water of Masuami-yohsuiro canal (same water quality as the Chikuma River COD = 3.5-4.1 mg/l; Ueda City, 1999) branch and was used as the agricultural water for the paddy region of the south-west part of Ueda City (Figure 1 B). The bookstore located at 600 m west of the Japan Railway Ueda Station (JR Ueda Station) was open 24 hours. On the other side of the bookstore, a railway and Shinkansen tracks run parallel to the canal (ca. 20-30 m). The canal water flow by culvert runs partly between JR Ueda Station and this bookstore parking lot, and an open canal downstream of the parking lot. The canal width was about 3 m and the depth about 5 m. During the investigation the water level was 20-30 cm. Hirabayashi et al. (2016) reported that almost all aquatic insects attracted to the bookstore emerged from the canal in 2010.

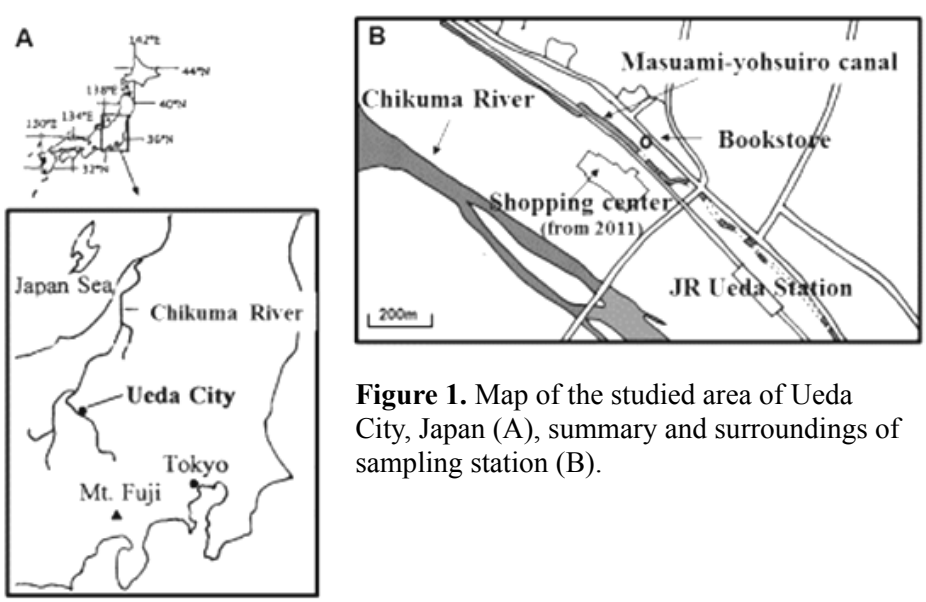

Figure 1. Map of the studied area of Ueda City, Japan (A), summary and surroundings of sampling station (B).

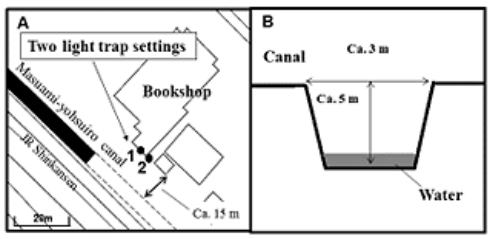

Figure 2. Light trap setting locations at bookstore area (A) and layout of Masuami-yohsuiro canal (B).

During the investigation period, in April, 2011, a large shopping center (ca. 20,000m^2 area including an extremely well-lit thousand-car parking lot) opened on the other side of the bookstore, making a great change in environmental light conditions around the investigation site.

Collection of Aquatic Insects in 2010 and 2011

The abundance of aquatic insects was monitored by daily catches using two light traps with a suction mechanism (Nozawa NH-5 type, Tokyo As Corporation, Tokyo, Japan) equipped with a 6-W black-fluorescent lamp (BL lamp, peaks at ca. 345-355 nm; control) and 6-W white-fluorescent lamp (FL lamp, peaks at ca. 450 and 550 nm) set up in the parking lot along the Masuami-yohsuiro canal of the bookstore in Ueda City, Nagano Prefecture, Central Japan, from 29 June to 7 July (9 days) in 2010, and from 24 June to 2 July (9 days) in 2011. Each trap was hung from a pole 1.5 m above ground level. At positions 1 and 2 traps with two different lamps were set and rotated by changing location. Traps 1 to 2 were located about 5 m apart, and the distance from the canal to each trap was about 15 m, respectively (Figure 2 A). The width of the canal was ca. 3 m, depth was ca. 5 m, and water depth was ca. 10 to 20 cm (Figure 2 B). To attract adult aquatic insects emerging from the canal, the traps were activated about 4 p.m. (half an hour before sunset) and the insects trapped in the field were left until the next morning. Insects that had entered the cage were killed with insecticide spray every morning at about 8 a.m. After being stored away from the terrestrial insects, the aquatic insects (the numbers of chironomid midges (Chironomidae: Diptera), crane flies (Tipuridae: Diptera), caddis flies (Trichoptera), and mayflies (Ephemeroptera)) were counted separately in each taxa in the laboratory. Environmental data, i.e., daily mean air temperature and daily precipitation and daily mean water temperature from the Ministry of Land, Infrastructure and Transport, Hokuriku Regional Development Bureau, the Ueda Meteorological Observatory Station, and Nagano Prefecture were used during the investigation periods.

RESULTS AND DISCUSSION

Temporal changes in physical environmental conditions in 2010 and 2011

Figure 3 shows the records of daily mean water temperatures and the daily mean air temperature and daily precipitations during the study in 2010 and 2011.The daily mean water temperature and daily mean air temperatures showed almost the same pattern during the two years. The daily mean water temperatures were 18.2° C (July 5) and 24.6° C (July 2) in 2010 and 19.9° C (June 26) and 22.8° C (June 29) in 2011, averaging 20.7±2.1°C in 2010, and 21.3±1.1°C in 2011. There was significant difference both years (U=16, Z=2.17, P=0.030<0.05 in Mann-Whitney U test). The daily mean air temperatures were 22° C (July 2) and 24.1°C (June 30 and July 5) in 2010, and 22.2° C (June 25) and 27.2° C (June 28) in 2011, averaging 23.4±0.7°C in 2010, and 25.1±1.6° C in 2011. There was no significant difference both years (U=33, Z=0.66, P=0.508>0.05 in Mann-Whitney U test). However, the daily precipitations showed a different pattern, i.e., 29.5 mm (max. July 2) in 2010 and 4.5 mm (max. July 2) in 2011, averaging 9.0±9.4 mm in 2010, and 1.1±1.7 mm in 2011. There was a significant difference both years (*U*=18, Z=2.03, *P*=0.043<0.05 in Mann-Whitney *U* test).

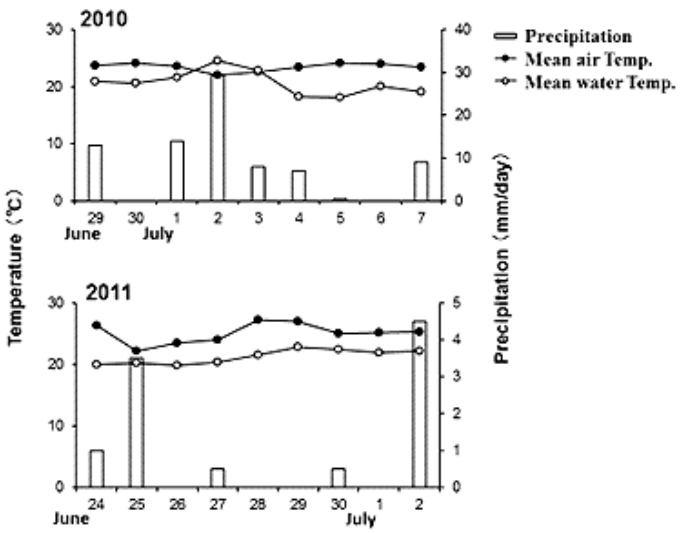

Figure 3. Environmental factors, daily mean air temperature, daily mean water temperature, and precipitation during the investigation periods in 2010 and 2011.

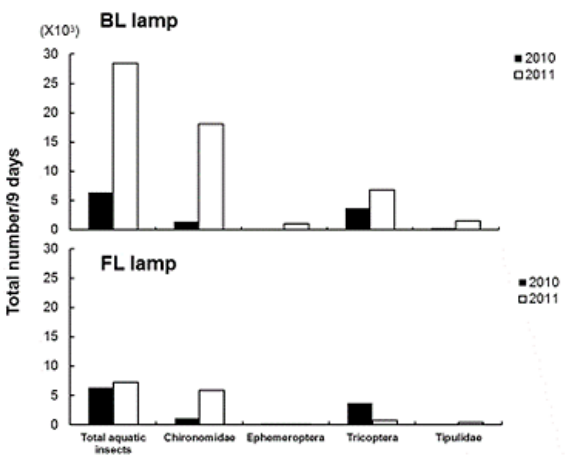

Figure 4. Attraction of each taxa of the total number of adult aquatic insects by two different light source traps, BL lamp (upper) and FL lamp (lower) during the investigation periods.

Abundance of adult aquatic insects collected with two light traps

Most of the studies on attraction of light have been conducted on nocturnal insects (reciewed by Glick and Hollingsworth, 1954; Hienton, 1974). Moreover, there have been several studies on phototaxis of harmful insects of agricultural and economical importance. Hirabayashi et al. (1993) and Ali et al. (1984, 1986) reported that light intensity was an important factor in attracting chironomid midges than the wavelength of visible light. Waringer (1989) reported that the adult caddisflies (Trichoptera) were strongly attracted to light. Hirabayashi et al. (2011) and Kimura et al. (2008) also reported that many adult caddisflies were attracted to the vending machine equipped with fluorescent lamps on the river bank.

Figure 4 shows the attraction of each taxa of the total number of adult aquatic insects by two different light source traps, BL lamp; control (upper) and FL lamp (lower) during the investigation periods. The number and fauna of aquatic insects attracted to the bookstore evidenced a very great change in 2011. The mean number of aquatic insects/day increased 2 – 15 times compared with 2010, especially, due to the BL lamp. Focused on BL lamp, the total number of aquatic insects collected was 28,480/9 days in 2011 and 6,345/9 days in 2010 (Table 1). In 2011, the most captured insect was Chironomidae (63.3%) at the bookstore, and the individual number was ca 12.8 times that of 2010. The captured number of Trichoptera also increased to 1.8 times that of 2010. As mentioned above,

if the number of aquatic insects emerging from the canal was the same in 2010 and 2011, around 4.5 (28,480/6,453 total number per 9 days) times the number of aquatic insects attracted to the bookstore in 2010 moved from the other habitats (except for the canal, and probably from the Chikuma River) by the large shopping center.

Figure 5 shows the attraction of the total number of adult aquatic insects in two different light conditions in 2010 (before opening shopping center; upper) and in 2011 (after opening; lower). Focused on FL lamp, we collected 6,343 aquatic insects in 2010. Trichoptera was the dominant taxa (58.1% of the total aquatic insects), followed by Chironomidae (17.2%) and Ephemeroptera (2.9%) in 2010. We also collected 7,226 aquatic insects by FL lamp in 2011. During the investigation period, Chironomidae was the dominant taxa (81.6% of the total aquatic insects), followed by Trichoptera (9.7%) and Tipulidae (5.3%) in 2011.

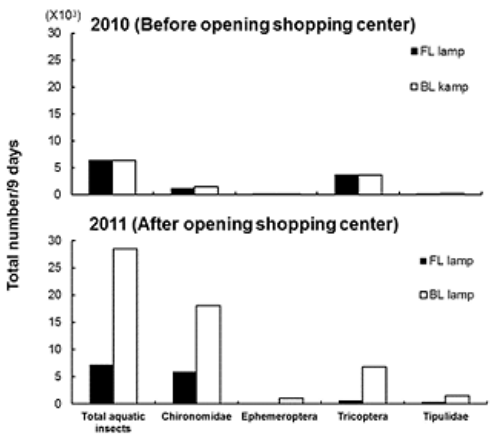

Figure 5. Attraction of adult aquatic insects in two different light conditions in 2010 (before opening shopping center; upper) and in 2011 (after opening, lower).

Before the shopping center opened (in 2010), both lamps collected the same number of adult aquatic insects. However, after opening, the BL lamp collected 4 times as many adult aquatic insects as the FL lamp one. In all the taxa, the BL lamp collected more than the FL lamp. 9.7 times the Trichoptera followed by 8.8 times the Ephemeroptera, 3.8 times the Tipulidae and 3 times the Chironomidae, respectively.

Before the shopping center opening, since the BL lamp collected as many adult aquatic insects as the FL lamp, probably the difference between the FL lamp and BL lamp might have been attracted by the strong light intensity of the shopping center opened thereafter in 2011. We estimated that value as follows (see Table 1), multiply the ratio (5) (number of aquatic insects attracted by FL (1)/number of aquatic insects attracted by BL (2)) in 2010 by BL in 2011 (4); this values means that estimation of the number of aquatic insects attracted by FL lamp in 2011 (if the shopping center was not open in 2011) (6), and (6) – number of aquatic insects attracted by FL in 2011 (3) = adult aquatic insects which attracted to the shopping center in 2011 (7). For example, we estimate the total number of adult aquatic insects attracted by the shopping center. The number of aquatic insects attracted by BL lamp in 2010 was 6,345, against 6,343 by FL lamp in 2010; in 2011, the BL lamp attracted 28,480, while the FL lamp attracted 7,226. The equation is as follows, (6,343/6,345) x 28,480 – 7,226 = 21,254 individual number/9 days. As mentioned above, if the number of aquatic insects emerging from the canal was the same in 2010 and 2011, 74.6% (21,245/28,471 total number per 9 days) of the aquatic insects attracted to the bookstore in 2010 moved to the new shopping center.

	2010		2011					
	FL lamp	BL lamp	FL lamp	BL lamp	Ratio	Estimated No. of aquatic insects were collected by FL lamp (if the shopping center was not open in 2011)	Estimated No. of aquatic insects attracted to the shopping center in 2011	
	(1)	(2)	(3)	(4)	(5) = (1)/(2)	(6) = (5)*(4)	(7) = (6)-(3)	(%)
	Total number/9 days (%)							
Chironomidae	1092 (17.2)	1412 (22.3)	5899 (81.6)	18028 (63.3)	0.7734	13943	8044	(42.1)
Ephemeroptera	185 (2.9)	60 (0.9)	116 (2.3)	1024 (3.6)	3.0833	3157	3041	(15.9)
Tricoptera	3687 (58.1)	3644 (57.4)	699 (9.7)	6808 (23.9)	1.0118	6888	6189	(32.4)
Tipulidae	163 (2.6)	272 (4.3)	383 (5.3)	1473 (5.1)	0.5993	883	500	(2.6)
Others	1216 (19.2)	957 (15.1)	129 (1.8)	1147 (4.0)	1.2706	1457	1328	(7.0)
Total aquatic insects	6343 (100)	6345 (100)	7226 (100)	28480 (100)	0.9997	28471	21245	(100)

Table 1. Summary of aquatic insect collection by two different light sources (FL lamp and BL lamp) in 2010 and 2011.

Moreover, the taxa most attracted to the shopping center might be Chironomidae (8,044 individual number/9 days; possibly 42.1% of the total number attracted), followed by Trichoptera (6,189, 32.4%), and Ephemeroptera (3,041, 15.9%), respectively.

In conclusion, it was revealed that the reaction to strong light intensity varied with each taxa of adult aquatic insects. It was suggested that Chironomidae and Trichoptera were attracted by strong light intensity. The present findings are in agreement with those of Heinton (1974) and Hirabayashi et al. (1983). These findings were very important to prevent the massive flight of aquatic insects, especially adult chironomid midges and adult caddisflies, around the river area.

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