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Food Source for Hydropsychid Larvae during an Algae Bloom in Nan River, Nan Province, Thailand (Trichoptera: Hydropsychidae)

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Abstract

During November–March, blooms of Kai algae genera are commonly seen on rocks and cobblestones in the Nan River, providing habitat for hydropsychid larvae. This study attempted to determine a dietary relationship between the caddisflies and Kai algae by comparing gut contents of hydropsychid larvae between areas with and without Kai algae (Kai-blooming and Control sites). Fourteen specimens of *Hydropsyche* and *Potamyia* larvae were collected in the Kai-blooming and Control sites, respectively. Food items in the foreguts were classified as Kai algae (KA), other filamentous algae (OFA), diatoms (DT) and other items (OI). Although the main food type of larvae in both sites was Kai algae, the proportion of KA in larval foreguts from Kai-blooming sites was significantly higher than in those from Control sites ($p < 0.05$). In addition, larvae in the Kai-blooming area had a significantly lower proportion of OI than in the Control area ($p < 0.05$). Therefore, hydropsychid larvae tended to consume more Kai algae than diatoms and other filamentous algae during blooming periods. They tended to consume more Kai algae than would be expected by chance alone, even in the area with a small amount of Kai algae.

Key words: Kai algae, caddisfly, *Cladophora*, gut content, Hydropsychidae

Introduction

Green algae are primary producers in aquatic ecosystems, serving as a food source for aquatic animals as well as helping increase dissolved oxygen concentration that supports their respiration processes. Algae in family Cladophoraceae are distribute in both tropical and temperate zones (tropical zone: Thailand, Laos, Mexico, Brazil, and east coast of South Africa; temperate zone: Austria, Michigan, France, Netherlands, New York, and Switzerland) (Van den Hoek 1963; Whitton 1970; Chaiyasuk & Waiyaka 2001; Higgins *et al.* 2008; Lee 2008; Traichaiyaporn 2012). In northern Thailand, *Cladophora* and *Rhizoclonium* spp., macro-filamentous green algae, are locally called 'Kai' (Traichaiyaporn 2012) and grow on hard substrates, such as cobblestones and rocks, in running water, such as streams and rivers. Kunpradid (2005) and Pruetiworanan (2008) reported that the dominant species of macro-green algae in the Mekong River, Chiang Rai Province, and the Nan River, Nan Province, were *Cladophora* and *Rhizoclonium* spp. Both provinces are in northern Thailand. The algae occur most often in medium to good water quality at water velocity 0.33–0.8 m/s, depth 0.2–0.8 m, temperature 23.5–28.5 °C, turbidity 10–33 NTU, conductivity 226.2–272.8 µS/cm, total dissolved solid 225.1–245.5 mg/L, pH 7.90–8.21, dissolved oxygen (DO) 7.0–8.8 mg/L, biochemical dissolved oxygen (BOD) 0.4–2.0 mg/L, nitrate-nitrogen 0.1–0.7 mg/L, ammonia-nitrogen 0.12–0.23 mg/L, and orthophosphate 0.01–0.18 mg/L. The water velocity and turbidity affected the algal production more than DO, BOD, and nutrient concentrations (Kunpradid & Tagun 2016). The algae are used as a food source by local people in Nan and Chiang Rai provinces during the Kai algae blooming period (November–March or cool season) in the Nan and Mekong Rivers (Chaiyasuk & Waiyaka 2001; Peerapornpisal *et al.* 2005; Traichaiyaporn 2012). The Mekong River is the longest river in Southeast Asia. The Nan River originates on Luang Prabang Mountain and is one of four

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main tributaries that flow into the Chao Phraya River, the major river of Thailand. The elevation of the Nan River is 418–540 m above sea level (Wangpimool *et al.* 2013).

Adult caddisflies in Thailand have been studied since 1987 (Malicky & Chantaramongkol 1999) and larval studies first mentioned *Rhyacophila* and *Ugandatrichia* (Malicky 1987, 1999). Caddisflies were found in a wide range of altitudes, from 400–2,300 m asl. (Malicky & Chantaramongkol 1993). Studies on caddisflies were accomplished in Doi Inthanon, Phu Hin Rongkla National Park, Doi Suthep-Pui National Park, Mae Jam River, and Ping River in Thailand (Changthong 2005; Silalom 2008; Takeaw 2014; Thongdej 2012).

Caddisfly larvae of family Hydropsychidae are commonly found. High abundances of hydropsychid larvae have been reported in the Tapee River (Laudee & Prommi 2011), the Mae Tao and Mae Ku watersheds (Prommi & Thamsenanupap 2015), and Phu Kradueng National Park (Thawaroroit & Sangpradub 2016). Hydropsychidae also were the most abundant in Dak Pri stream, Vietnam (Hoang & Bae 2006). *Hydropsyche* and *Potamyia* were founded in the streams of Gunung Tebu, Malaysia, at water velocity 0.00–0.30 m/s, depth 0.20–0.66 m, DO 6.50–7.80 mg/L, BOD 0.63–1.43 mg/L, and ammonia-nitrogen 0.00–0.08 mg/L (Rawi *et al.* 2013). Hydropsychidae mostly live on hard substrates. Highly stable substratum (e.g., gravel, cobble, rock, and bedrock) is a proper habitat for many aquatic insects, such as larvae of mayflies, stoneflies, and caddisflies. *Potamyia* larvae construct their net retreats on the tops of rocks or other solid surfaces (Oláh *et al.* 2006).

Both Kai algae and hydropsychid larvae are abundant on hard substrates in the Nan River during the algal blooming period. Little information is available concerning the coexistence of Kai algae and caddisfly larvae in the Nan River. Therefore, this study explored the relationship of hydropsychid larvae and Kai algae growing in the same habitat in the Nan River. The study will provide information for the biodiversity database of Trichoptera and also help improve understanding of the importance of Kai algae blooms on the feeding habits of hydropsychids and possibly other benthic organisms.

Materials and methods

Caddisfly larvae in family Hydropsychidae were collected from two study sites (Kai-blooming and Control sites) in the Nan River, Chiang Klang District, Nan Province, Thailand (19.23˚N, 100.82˚E) during a Kai bloom in January 2018. The Kai-blooming site had more than 80% coverage of Kai algae on the stones, whereas the Control site had less than 20% coverage. The substrate and water depth at the Kai-blooming and Control sites were similar (Figure 1). Water velocity at the Control site was slightly lower than the Kai-blooming site. Characteristics of the Control site showed the normal condition of the Nan River during non–algal blooming periods that nevertheless have some algae on stones on the streambed.

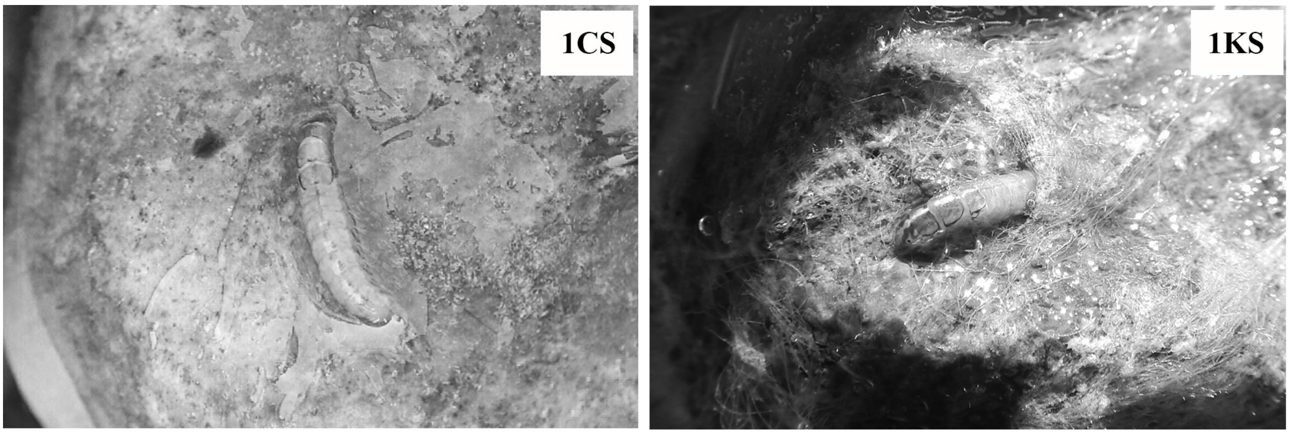

FIGURE 1. Hydropsychidae larvae on cobblestones. 1CS, hydropsychid larva on a cobblestone at a Control site, 1KS, hydropsychid larva on a cobblestone at a Kai-blooming site.

Potamyia and *Hydropsyche* were dominant groups in the Control and Kai-blooming sites, respectively. Fourteen living specimens with larger than 1 cm of body size (fourth and fifth instar larvae) from each sampling site were selected by hand picking and then preserved in an ice box at 6–10 °C for genus-level identification in the laboratory according to Dudgeon (1999). Their foreguts were dissected in the Aquatic Insect Research Unit (AIRU), Chiang Mai University. Foreguts were excised from larval bodies by using surgical

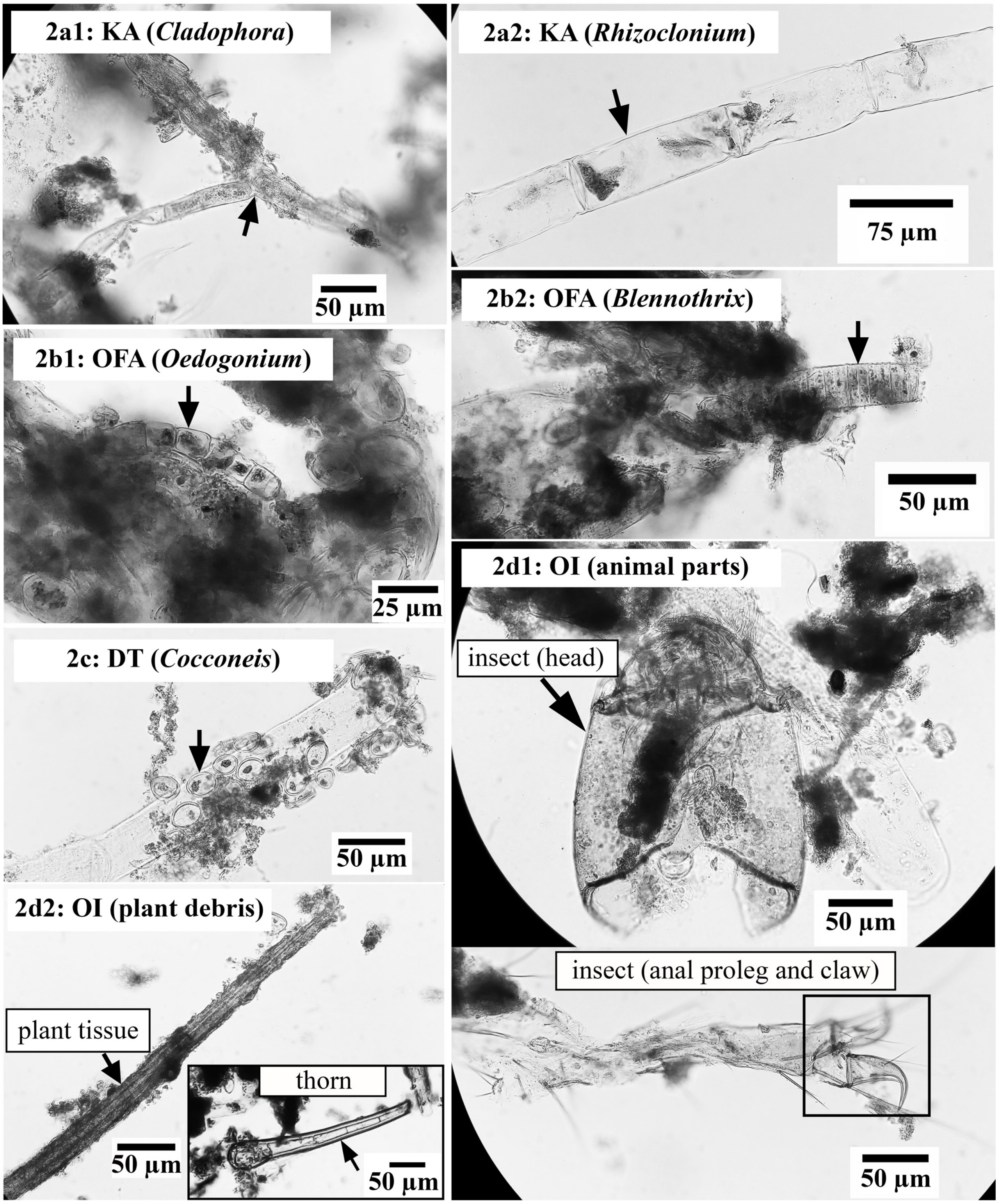

FIGURE 2. Food items in *Potamyia* larval foreguts from the Control site. 2a, Kai algae (KA): 2a1, *Cladophora* sp.; 2a2, *Rhizoclonium* sp. 2b, other filamentous algae (OFA): 2b1, *Oedogonium* sp.; 2b2, *Blennothrix* sp. 2c, diatoms (DT): *Cocconeis* sp. 2d, other items (OI): 2d1, animal parts; 2d2, plant debris.

scissors and forceps under a stereomicroscope according to a method modified from that of Wallace *et al.* (1987). All food items were removed and put on a glass slide that was then photographed under a compound microscope at 40x magnification for classification. Four types of food items were identified according to Peerapornpisal (2013): Kai algae (KA), other filamentous algae (OFA), diatoms (DT), and other items (OI). The proportion of each food type was calculated by counting items in numbered squares of a grid placed on an enlarged photo (10.3 cm of diameter) according to a haemocytometer method (Moheimani *et al.* 2013). A paired t-test was run with R program version 3.3.3 to compare the percentages of four food types between Kai-blooming and Control sites.

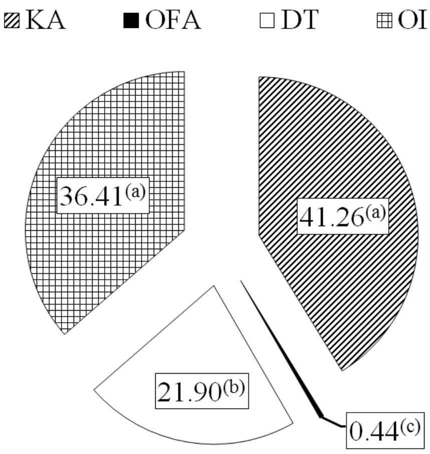

FIGURE 3. Average percentage of four food types in foreguts of 14 *Potamyia* larvae at the Control site. Different letters (a), (b), and (c) indicate significant difference ($p < 0.05$). KA = Kai algae, OFA = other filamentous algae, DT = diatoms, OI = other items.

Neither the species-level identity nor the number of species captured in our samples of *Potamyia* and *Hydropsyche* were observed. Voucher specimens of the *Potamyia* and *Hydropsyche* larvae captured and studied in this research are deposited in the Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand.

Results and discussions

Food types of Potamyia *larvae in the Control site*

All four food types were found in the foreguts of larvae from the Control site, including Kai algae genera *Cladophora* (with branching filaments) and *Rhizoclonium* (with non-branching filaments) (Figures 2a1 and 2a2). Diatoms of genus *Cocconeis* were attached to most algal filaments (Figures 2a1 and 2c) and were consumed together with the algae. Other filamentous algae (OFA) found were *Oedogonium* and *Blennothrix* (Figures 2b1 and 2b2). Diatom (DT) genera *Eunotia*, *Gomphonema*, *Pinnularia*, and *Synedra* were found in the foreguts. Other items (OI) consisted of animal parts (e.g., head capsules, anal prolegs, and other insect body parts) and plant debris (e.g., plant tissue and thorns) (Figures 2d1 and 2d2). The results showed that *Potamyia* larvae in the Control site were omnivores (consuming both plants and animals).

The proportions of Kai algae (KA) (41.26%) and other items (OI) (36.41%) were significantly higher than of DT and OFA (21.90% and 0.44%, respectively; $p < 0.05$) (Figure 3). The proportion of DT significantly differed from OFA. Thus, although the Control site had low abundance of Kai algae, *Potamyia* consumed Kai algae more than diatoms and other filamentous algae. However, although the collected larvae might move from the areas with high abundance of Kai algae, the results show that Kai algae were an important food source for *Potamyia* larvae.

Food types of Hydropsyche *larvae in Kai-blooming site*

Foreguts of larvae at the Kai-blooming site contained all food items, including Kai algae (KA) genera *Cladophora* and *Rhizoclonium* (Figures 4e1 and 4e2). Kai algae filaments in the foreguts were mostly without attached diatoms because most of the algae in the Kai-blooming site were young algae. Broken cells of Kai algae seemed to have been bitten by *Hydropsyche* larvae, probably to reduce digestion time. Cytoplasm from the broken cells was more easily digested into absorbable nutrients.

Other filamentous algae (OFA) genera *Oedogonium* and *Blennothrix* (Figure 4f) and diatom (DT) genera *Cocconeis* (Figure 4g), *Synedra*, and *Eunotia* were found. Pieces of aquatic insect legs, categorized as other food items (OI), indicate that the larvae might hunt living aquatic insects or consume dead parts (Figure 4h). Thus, *Hydropsyche* larvae in the Kai-blooming site were omnivores, like *Potamyia* larvae in the Control site, because they consumed several food types including algae, diatoms, and insects.

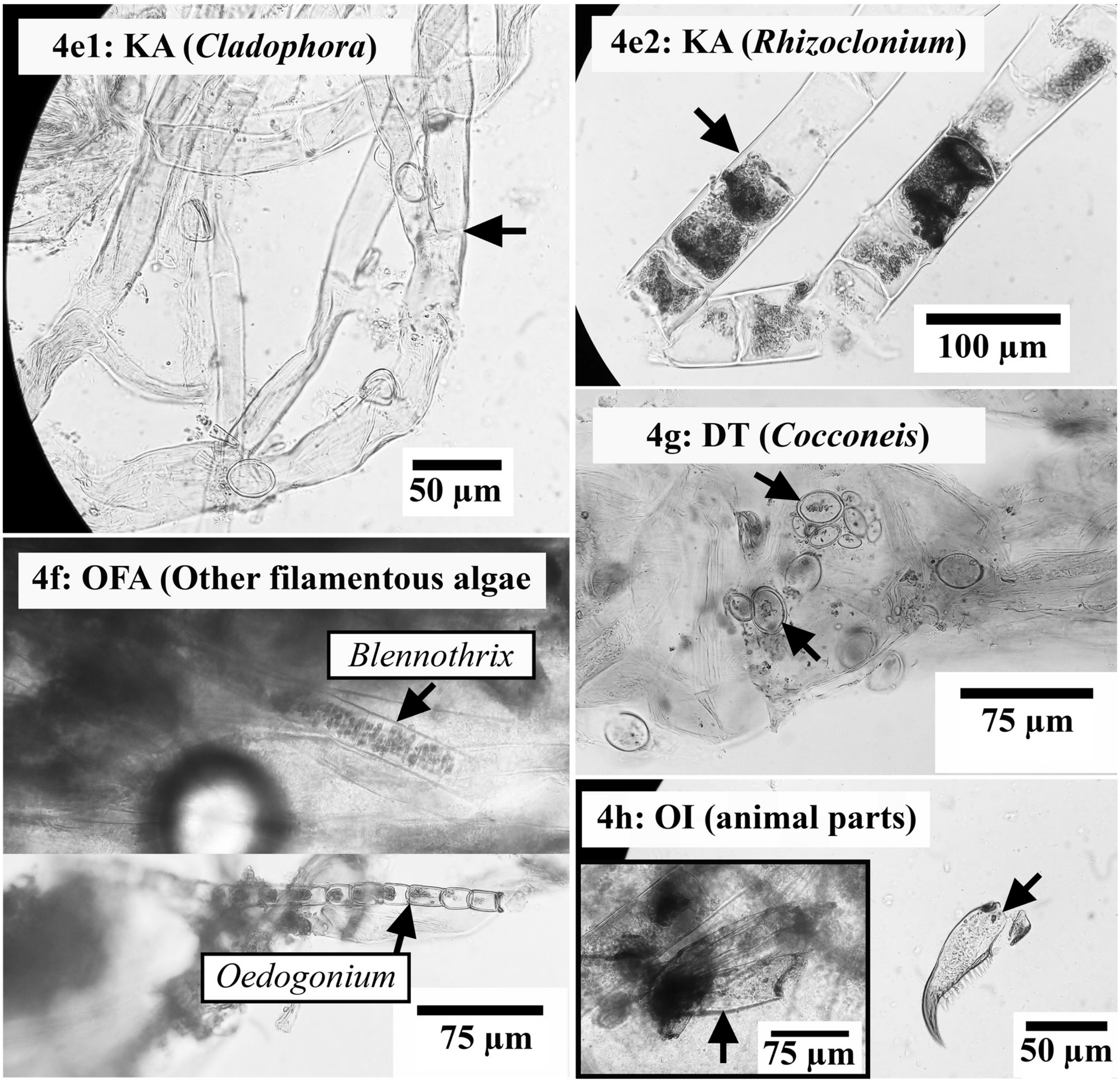

FIGURE 4. Food items in *Hydropsyche* larval foreguts from the Kai-blooming site. 4e, Kai-algae (KA): 4e1, *Cladophora* sp.; 4e2, *Rhizoclonium* sp. 4f, other filamentous algae (OFA, *Oedogonium* spp. and *Blennothrix* spp.). 4g, diatoms (DT, *Cocconeis* spp.). 4h, other items (OI, animal parts).

Kai algae (KA) were significantly the main food type (77.34%) consumed by *Hydropsyche* larvae at the Kai-blooming site, followed by DT, OI, and OFA (14.85%, 4.38%, and 3.44%, respectively; $p < 0.05$) (Figure 5), among which the proportions of OI and OFA were not significantly different.

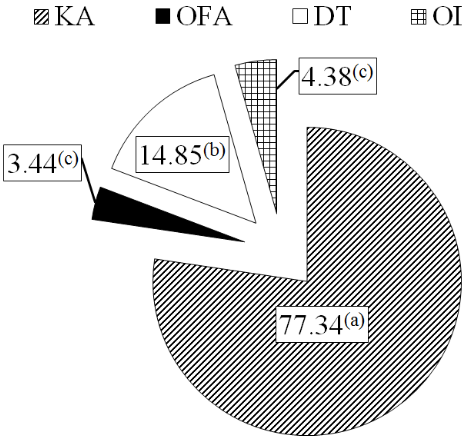

FIGURE 5. Average percentage of four food types in foreguts of 14 *Hydropsyche* larvae at the Kai-blooming site. Different letters (a), (b) and (c) indicate significant difference ($p < 0.05$). KA = Kai algae, OFA = other filamentous algae, DT = diatoms, OI = other items.

Comparison the food-type percentage between the Control and Kai-blooming sites

Proportions of KA and OI at the Control site significantly differed from those at the Kai-blooming site (Table 1). Kai algae in the gut contents from the Kai-blooming site were proportionally higher than from the Control site. Similarly, proportions of diatoms and other items in the gut contents from the Control site were higher than at the Kai-blooming site because the Control site had more open area for diatom growth. However, Kai algae constituted the highest proportion of food items in both *Potamyia* and *Hydropsyche* foreguts at both sites, indicating that hydropsychid larvae purposefully consumed Kai algae during the Kai bloom period. Fairchild & Holomuzki (2002) also reported that hydropsychid larval density was significantly greater in microhabitats of *Cladophora* than on biofilm-covered patches. In addition, algae help entrap other food for larvae. For example, Dudley *et al.* (1986) found that *Hydropsyche* spp. living in areas of macro-algae genera *Cladophora* and *Nostoc* consumed other organic components, such as leaves entrapped by the macro-algae. On the other hand, the studies of Benke & Wallace (1980) and Wallace *et al.* (1987) found that although hydropsychid larvae were identified as omnivores, they consumed animal tissues and diatoms more than filamentous algae in subtropical blackwater streams.

TABLE 1. Percent comparisons of four food types in hydropsychid larval foreguts from the Control site and Kai-blooming site (The mean differences are significant at $p < 0.05$). KA = Kai algae, OFA = other filamentous algae, DT = diatoms, OI = other items.

	Average percentage of four food types (n = 14 at each site)			
	KA	**OFA**	**DT**	**OI**
Control site	41.26 ± 14.06	0.44 ± 0.73	21.90 ± 5.20	36.41 ± 15.26
Kai-blooming site	77.34 ± 10.82	3.44 ± 6.07	14.85 ± 10.04	4.38 ± 5.21
Significance (p)	0.000	0.111	0.081	0.000

Conclusions

Hydropsychid larvae were identified as omnivores due to their consumption of filamentous algae, diatoms, insects, and vascular plants. During the Kai-blooming period, Kai algae genera *Cladophora* and *Rhizoclonium* in the Nan River are consumed by most hydropsychid larvae as the main food source, even in the areas with low abundance of algae. More studies about the feeding behavior and trophic relation of hydropsychid larvae in the Nan River during low Kai-algae-blooming periods may be required to confirm the selective feeding of the larvae on Kai algae.

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