Odonate Larvae as an Indicator of Pesticide Contamination

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The abundance of odonate larvae was surveyed in a river system at two upstream stations surrounded by rice fields lacking aerial spraying of pesticides, two midstream stations surrounded by rice fields with and without aerial spraying, and four downstream stations surrounded by sprayed fields. Species diversity and numbers of individuals were much lower at the downstream stations. Pesticide contamination from ground spraying occurred at one upstream station as well as one midstream and all downstream stations. Damage to the odonate larvae was not clearly evident except at one downstream station. Damage by the aerially sprayed insecticides seemed appreciable at the downstream stations. The distribution of odonate larvae in a river may be restricted by pesticide contamination and thus can indicate pesticide contamination.

Key words: odonate larvae, pesticide contamination, river, rice field, indicator

INTRODUCTION

Pesticide contamination causes severe damage to the invertebrate fauna of rivers, as has been reported through the studies on pest control and faunal surveys in agricultural or forestry areas (e.g. HATAKEYAMA et al., 1990; IWAKUMA et al., 1988b; MUIRHEAD-THOMSON, 1987; SATAKE and YASUNO, 1987). These reports show that some aquatic insects are more sensitive to pesticides than others. For instance, IWAKUMA et al. (1988b) designated two Baetis ephemeropterans as sensitive species; baetids and some other aquatic insects are sensitive to temephos (YASUNO et al., 1982a, b). The baetids can, however, recover their previous level of abundance after the contamination ceases (HATAKEYAMA et al., 1990; YASUNO et al., 1982b).

Odonate larvae are also sensitive to pesticides (MARSHALL and RUTSCHKY, 1974; TAKAMURA and YASUNO, 1986; WALLACE et al., 1987). Due to their long life-cycles, they are assumed to be unable to recover in abundance as quickly as baetids. They may therefore provide good indicator species for pesticide contamination.

The present study reports on the abundance of odonate larvae in a stream flowing from an area with no aerial spraying of pesticides through a sprayed area.

STUDY AREA AND METHODS

Odonate larvae were collected at eight stations of the Sunakawa river system in Takahata Town, Yamagata Prefecture, in the Tohoku area of Japan (Fig. 1). The river originates from mountains covered by coniferous and deciduous forest. Stas. 3 and 35 were on the Inakogawa River. Sta. 4 was on the Motomiyagawa River. Sta. 5

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was 0.5 km downstream from the confluence of the two rivers on the Sunagawa River. Stas. 6, 7, 8 and 9 were downstream of Sta. 5.

The area east of line A in Fig. 1 which included Stas. 3 and 35, was occupied by rice fields that were not aerially sprayed with pesticides. The area west of line A was occupied by sprayed and unsprayed fields. Spraying levels increased to the west of Sta. 5, and nearly all the area west of Sta. 6 was sprayed.

Rice was cultivated from late May to September. The aerial spraying of pesticides was done by helicopter four times from late July to late August. The pesticides sprayed were the insecticides, BPMC, fenitrothion and fenthion, and the fungicides, edifenphos, fthalide, IBP, mepronil and tricyclazole. Besides the aerial spraying, pesticides were applied through ground spraying in rice fields. The herbicide, butachlor, was applied before rice transplanting. Other herbicides, pretilachlor, bensulfuronmethyl and mefenacet, were applied after rice transplanting. Unconfirmed herbicides and insecticides were also applied (Table 1).

Odonate larvae were collected at each station once in each season on 1 June, 19 October, 14 and 16 December 1989 and 22 and 23 March 1990. The collection was made with a hand net over a distance of 15 m along a margin of instream emergent vegetation. In June, October and March, the net used had a 2 mm mesh with a mouth measuring 25 cm × 20 cm. Eleven 5 cm claws were attached to the lower edge of the mouth. The claws helped to comb the larvae from roots, stems and leaves of the vegetation. In December, a hand net of similar size without claws was used.

Vegetation on the shore varied among the stations. *Phragmites* belts were present

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**Fig. 1.** Map of the study area. Numerals are station numbers. Hatched areas are rice fields. Areas enclosed by dashed lines are mountains. The dotted line A indicates the border between the area free of aerial spraying and the area which includes both sprayed and unsprayed fields. The rivers flow toward the northwest.
Odonate Larvae and Pesticide

Fig. 2. Water temperatures measured at eight stations in the Sunagawa river system. In each season, the points are connected in the order of Sta. 3, 35, 4, 5, 6, 7, 8 and 9 and arrows indicate downstream direction. Points taken in June are marked with station numbers.

at Stas. 4 and 5. Phragmites vegetation was also present at Sta. 3 in a much sparser quantity.

Lower grasses of other kinds were dominant at Stas. 35, 6, 8 and 9. Typha also composed part of the vegetation at Stas. 8 and 9. Willows (Salix sp.) were dominant at Sta. 7.

Water temperature, pH and conductivity were monitored at each sampling. Pesticide residues were monitored once a month from May to September. They were extracted with an ODS column (Bond-Elut C18) from 0.25l of river water and quantified with a NPD detector of GC.

RESULTS AND DISCUSSION

Water temperature of samples is shown in Fig. 2. It was highest in June, and higher in October than in December and March. The discrepancy (10°C) between Stas. 35 and 5 in June seems to exceed the natural daily fluctuation (Takamura, 1979). The river water was generally warmer in the downstream direction except between Stas. 35 and 5 in the summer. The pH was mostly in the range of 6–7. Conductivity was higher downstream, exceeding 100 μS/cm at downstream stations in June.

Pesticides detected from river water are shown in Table 1. They were detected most frequently at Sta. 9. Herbicide contamination from rice transplanting was obvious downstream of Sta. 6. The concentration of butachlor increased downstream while that of pretilachlor decreased. Pesticides were detected on two occasions at Sta. 35 and once at Sta. 5: the insecticides, diazinon and malathion, and the herbicide chlornitrofen.

Pesticide contamination from aerial spraying was barely detected at Stas. 8 and 9 on 19 August (Table 1). The concentration of fenthion increased between Sta. 8 and Sta. 9, although the concentrations detected were low since they were measured eight days after the spraying. Hatakeyama (unpublished) measured insecticide concentrations at the time of aerial spraying at Stas. 5 and 9 in 1990. The maximum concentration of insecticides detected was as high as 50 ppb at Sta. 9. The concentrations at Sta. 5 were 1/6 to 2/3 of the concentrations at Sta. 9.

Five species of odonate larvae were collected (Table 2). Three species were collected at Stas. 3, 35 and 4 and two at Stas. 5 and 6. Only one species was collected at Stas. 7, 8 and 9.
Table 1. Pesticides detected at six stations in the Sunagawa river system in 1989

<table>
<thead>
<tr>
<th>Station</th>
<th>20 May</th>
<th>1 Jun.</th>
<th>13 Jul.</th>
<th>19 Aug.</th>
<th>12 Sep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta. 35</td>
<td>M (0.26)</td>
<td>C (1.71)</td>
<td></td>
<td>D (0.01)</td>
<td></td>
</tr>
<tr>
<td>Sta. 5</td>
<td></td>
<td></td>
<td></td>
<td>C (6.52)</td>
<td></td>
</tr>
<tr>
<td>Sta. 6</td>
<td>P (6.76)</td>
<td>T (2.56)</td>
<td>F (0.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sta. 7</td>
<td>P (0.94)</td>
<td>B (0.82)</td>
<td>M (0.59)</td>
<td>F (0.05)</td>
<td>C (1.94)</td>
</tr>
<tr>
<td>Sta. 8</td>
<td>B (0.86)</td>
<td>M (0.69)</td>
<td>M (0.59)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sta. 9</td>
<td>B (0.86)</td>
<td>M (0.69)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Residue concentrations (ppb) are shown in parentheses. Pesticides were not detected at Stas. 3 and 4. B, butachlor; C, chlornitrofen; D, diazinon; F, fenthion; M, malathion; P, pretilachlor; S, simetryn; T, thiobencarb.

Table 2. Numbers of odonate larvae collected from underwater vegetation at eight stations in the Sunagawa river system (Takahata, Yamagata, 1989–1990)

<table>
<thead>
<tr>
<th>Station No.</th>
<th>Dividius moiwanus moiwanus</th>
<th>Mnais pruinosa costalis</th>
<th>Other spp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2 D 1 M</td>
<td>J O D M</td>
<td>I**</td>
</tr>
<tr>
<td>35</td>
<td>4 1 8 3</td>
<td>J O D M</td>
<td>I**</td>
</tr>
<tr>
<td>4</td>
<td>6 8 3 2</td>
<td>J O D M</td>
<td>I**</td>
</tr>
<tr>
<td>5</td>
<td>8 3 2</td>
<td>J O D M</td>
<td>I**</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>J O D M</td>
<td>I**</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>J O D M</td>
<td>I**</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>J O D M</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>J O D M</td>
<td></td>
</tr>
</tbody>
</table>

a Date of survey; J, 1 June; O, 19 October; D, 14 and 16 December 1989; M, 22 and 23 March 1990.

b Anotogaster sieboldii; c Orthetrum japonicum japonicum; d Macromia amphigena amphigena

The gomphid Dividius moiwanus moiwanus was the most abundant. It was collected at each sampling at Stas. 35 and 4, twice at Stas. 3 and 5, and once at Stas. 6, 7, 8 and 9. The totals collected were more than ten larvae at Stas. 35, 4 and 5, three at Sta. 3 and only one at Stas. 6, 7, 8 and 9.

The calopterygid Mnais pruinosa costalis was collected upstream. It was not collected at Stas. 6, 7, 8 or 9. The corduregastid Anotogaster sieboldii was also collected upstream at Stas. 3 and 4. Only one larva each of the libellulid Orthetrum japonicum japonicum and the corduliid Macromia amphigena amphigena was collected at Stas. 35 and 6, respectively.

Odonate larvac were low in diversity and numbers at Stas. 6, 7, 8 and 9. Pesticide contamination occurred through aerial and ground spraying at these stations. The
pesticide concentrations in river water were probably higher from aerial spraying than through ground spraying (Table 1; Hatakeyama, unpublished). Periods of high concentration from aerial pesticide spraying can be as short as several hours (Hatakeyama et al., 1990). On the other hand, pesticide contamination through ground spraying continues for as long as one month, although the concentrations are low (Iwakuma et al., 1988a).

The sensitivity of odonate larvae to pesticides has been tested in a few cases. Shukla and Mishra (1980) assessed the sensitivity of the larva of the libellulid Brachythemis contaminata to three carbamates, carbaryl, carbofuran and mexacarbate. The 48 hr LC50 values were <1 ppb. Saxena and Saxena (1986) reported that >50% larvae of the dragonfly Bradinopyga geminata died in 24 hr when exposed to malathion solutions of 0.6 and 0.8 ppm, whereas <50% died from 0.2 and 0.4 ppm. Federle and Collins (1976) reported 48 hr LC50 values of six pesticides for the larva of the lestid Lestes congener. Larvae were sensitive to parathion (LC50=0.02 ppm) >dieldrin >lindane >DDT >propoxur (0.7 ppm). Although the odonate species and insecticides tested vary and do not conform to those of the present study, it is possible that insecticide concentrations of as high as 50 ppb are acutely lethal to odonate larvae.

As mentioned before, insecticide concentrations can rise as high as 50 ppb at the stations surrounded by aerially sprayed fields. These concentrations may have been lethal to odonate larvae even in brief applications of several hours. From ground spraying, insecticides were detected at <1 ppb. Herbicides were detected in higher concentrations (Table 1). At Sta. 9, insecticides or herbicides from ground spraying were detected in four of the five samples. The damage to odonate larvae from the contamination at Sta. 9 cannot be neglected since sublethal concentrations of pesticides become lethal after long-term exposure.

Odonate larvae were collected in rather constant numbers at Sta. 4, but not at Stas. 3, 35 and 5 (Table 1). Numbers of species and individuals were only a little larger at Sta. 3 than at Stas. 6, 7, 8 and 9. This may be not only because aquatic vegetation was sparser, but because the flushing effect of flooding was regarded as stronger due to steeper gradient at this station.

The low numbers of odonate larvae at Stas. 35 and 5 were harder to explain. It is doubtful that the pesticide contamination at Sta. 35 in June as shown in Table 1 caused the low number in October, since the number of odonate larvae collected in June was high in spite of the pesticide contamination. The river water was warmer at Sta. 35 than at Stas. 4 and 5 in the summer season. The high water temperature might be unfavorable to D. moiwanus moiwanus, the northern subspecies of the D. moiwanus subspecies group. If this is the case, the same effect of high temperature may be expected at some, not all, downstream stations below Sta. 6 (Fig. 2).

It is probable that the aerial spraying of pesticides did not cause the low numbers at Sta. 35, due to the large distance between the station and sprayed area. Nor were effects of the aerial spraying observed at Stas. 4 or 5. We expected stronger effects on the number of odonate larvae collected in October, but the October numbers turned out to be the highest in four months (Table 2).

Odonate species with univoltine or semivoltine life cycles are common in temperate regions (Corbet, 1980). The gomphid Dividius moiwanus moiwanus showed two discrete peaks in the frequency distribution of larval head width (Takamura, unpublished). On the other hand, pesticide contamination occurs frequently during
the cultivating season, and is an annual event. If odonate larvae are damaged once by contamination, recovery will take a long time. For example, Takamura and Yasuno (1986) found that repeated applications of pesticides in a rice field destroyed most odonate larvae, while chironomid larvae were able to regain their previous abundance between the applications. It is probable that odonate larvae are damaged by pesticide contamination and cannot recover even without pesticide contamination. Their low numbers can be a long-term indicator of pesticide contamination in rivers.

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REFERENCES


