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LIVING LIMITS OF DRAGONFLY LARVA IN RIVERS WITH DOMESTIC SEWAGE INFLOW IN THE SOUTHERN PART OF OSAKA

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SYNOPSIS

Living limits about Na^+ and Cl^- concentrations of dragonfly larva were studied. As Na^+ and Cl^- concentrations in river water increased, the number of dragonfly larva decreased and species composition of larva changed from *Stylogomphus suzukii* to *Calopterx atrata*. Na^+ and Cl^- concentrations were good indicators of the mixing ratio of domestic sewage which was thought to contain toxic substances. *Davidius nanus* was distributed in the river water under wide range mixing ratio of domestic sewage. The maximum living limits of Na^+ and Cl^- concentrations for *Calopterx atrata* and *Davidius nanus* were 50 and 80 mg/l. The values were living limits of all dragonfly larva observed in the southern part of Osaka. After a long-term observation, the maximum living limits of Na^+ and Cl^- concentrations for dragonfly larva were found to be 38 and 59 mg/l. When the anionic surface active agent was 3.8 to 6.2mg/l, dragonfly larva was not found.

INTRODUCTION

The decrease of organisms of rivers in the southern part of Osaka prefecture is believed to be caused by inflow of pollutant derived from domestic sewage into rivers and river improvement using concrete structure. The inflow of pollutants into the rivers has decreased because of sewage work maintenance and control. The river conditions have recovered back to their natural environment by the revision of the river law in 1997 (7). However, most domestic sewage flows directly into the rivers, creating a high concentration of pollutants in the rivers. The total number of organisms and species is low and the water quality is also not acceptable now (8), (10), (11). The Makio River, the Chichioni River (6), the Ishi River, the Ishimi River, the Chihaya River (1), the Ban River, the Oh River and the Onosato River in the southern part of Osaka prefecture were selected because mixing ratio of sewage was very high

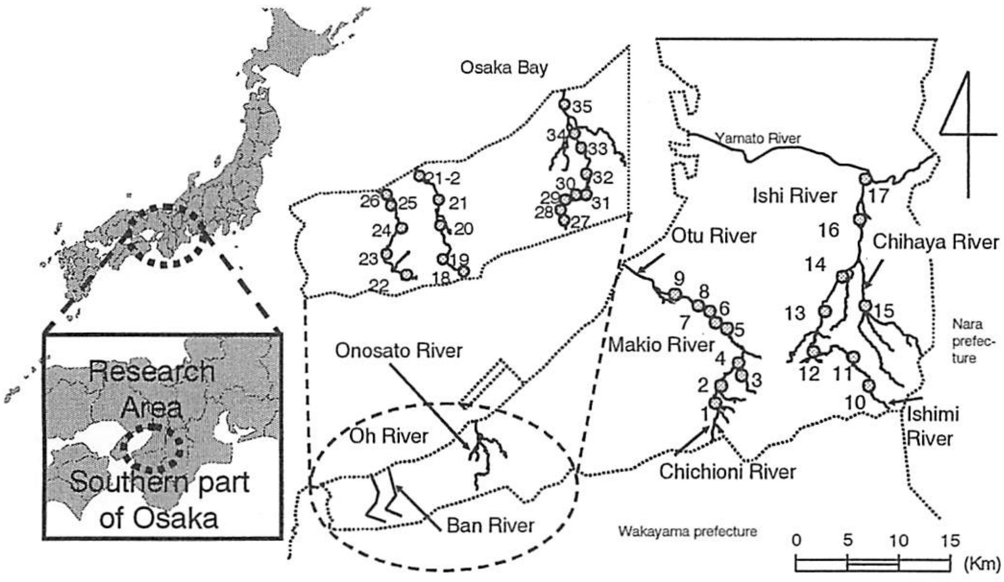

Fig. 1 Research Area

and in fact, the Yamato River was found to contain the Ishi River was the worst grade of water quality of the Japanese first class rivers. Therefore, the purpose of study is to clarify the relation between organisms and water quality. In fact, water quality depends on the inflow of domestic sewage, and the relation between domestic sewage and organisms is examined in this work. Domestic sewage contains much Na^+ and Cl^- compared to both rainwater and mountain stream water from the forest (9), (12). Therefore, Na^+ and Cl^- contents are thought to be good indicators for the mixing ratio of domestic sewage with natural river water. BOD is usually an important indicator for water quality, and the number of species and organisms are also important for evaluating river conditions. However, BOD has no relation with the inflow of domestic sewage in river (2) and fertilizer for agriculture may increase BOD values. The main purpose of this study is to clarify the influence of domestic sewage on organisms in rivers. However, it is very difficult to survey the total number of organisms in a river so the dragonfly larva was selected as a representative of organisms in rivers. Dragonfly larva in rivers is sensitive to water quality because it lives in water till it becomes an adult. Also, it is easy to identify the species and the living limit of dragonfly larva depends on long-term conditions because term of life for dragonfly larva in river is from 2 to 5 years. This study focuses on the relation between dragonfly larva and Na^+ and Cl^- concentrations as an indicator of sewage flow rate.

RESEARCH AREA AND METHOD

The research areas covers the Makio River, the Chichioni River (3), the Ishi River, the Ishimi River, the Chihaya River, the Ban River, the Oh River and the Onosato River of the southern part of Osaka prefecture(Fig. 1). The population in the Makio River and the Chichioni River increases in downstream areas. Sewage treatment along the Makio River is not sufficient and domestic sewage in some areas flows directly into the river. The amount of housing sites is large at the junction of the Ishi River, the Ishimi River and the Chihaya River and at the downstream of the Ishi River. The land use along the Ban River, the Oh River and the Onosato River is mainly forest, and there are fewer housing sites in comparison with the Ishi River, the Ishimi River, the Chihaya, the Makio River and the Chichioni River.

Along the river, water sampling, pH, EC, DO and ORP measurements of river water and estimations of the

Table. 1 Sampling days and creature surveys of the Makio River and the Chichioni River

	Point								
Sampling data	1	2	3	4	5	6	7	8	9
19-Apr-04			O	O					
7-May-04								O	O
24-May-04		O	O	O				O	
28-Jul-04		O	O	O	O			O	
4-Aug-04								O	O
17-Oct-04		O	O	O	O			O	O
29-Oct-04	O	O	O	O	O	O	O	O	O
1-Dec-04								O	O
23-Dec-04	◎	◎	◎	◎	◎			O	
28-Dec-04						△	△	◎	△
29-Dec-04	O	O		O				O	
2-Sep-05	O	O	O	O	O	O		O	O

◎: The same day of water sampling and creature surveys
O:Only water sampling days
△:Only creatures surveys

number of species of dragonfly larva were taken. After filtering with 0.45μm, Na^+ and Cl^- were analyzed by means of ion chromatography (DIONEX's Corporation). The anionic surface active agent measurement was analyzed with an absorbance meter (DR/2500 HACH). Analysis method was Crystal Violet Method.

Species, numbers and sizes of dragonfly larva were determined in an area about 50 meters long in the river. Three people with a collection nets collected the samplings of dragonfly larva for 30 minutes with same condition such as people and distance. Each 50 meters sampling point contains various river bed conditions such as river sediment and vegetation.

Table. 1 shows details of survey points and water quality survey data of the Makio River and the Chichioni River. Double circles indicated the same day of both water samplings and creature surveys. The circles indicate only water sampling days. Triangles indicate only creature surveys day, December 2004. There are two types of sampling. Long-term samplings of the water quality were collected from 15th-April 2004 to 2nd-November 2005 at point 8 along the Makio River. Short samplings for water quality and creature were followed as Table. 1. Water quality surveys and organisms surveys were conducted at the Ishi River, the Ishimi river, Chihaya River, the Ban River, the Oh River and the Onosato River.

RESULTS AND DISCUSSION

Living limit of dragonfly larva for Na^+ and Cl^- Concentration

Fig. 2 shows the relation between dragonfly larva at each river and Na^+ and Cl^- concentration. Water quality and organisms surveys were conducted. As a whole, the total number of dragonfly larva decreased as Na^+ and Cl^- concentrations increased. However, at the Chichioni River, the number of dragonfly larva increased as Na^+ and Cl^- concentrations increased. When the total number of dragonfly larva reached the minimum, the Na^+ and Cl^- concentrations in each river were 24 mg/l and 30 mg/l in the Makio River and the Chichioni River system, 30 mg/l and

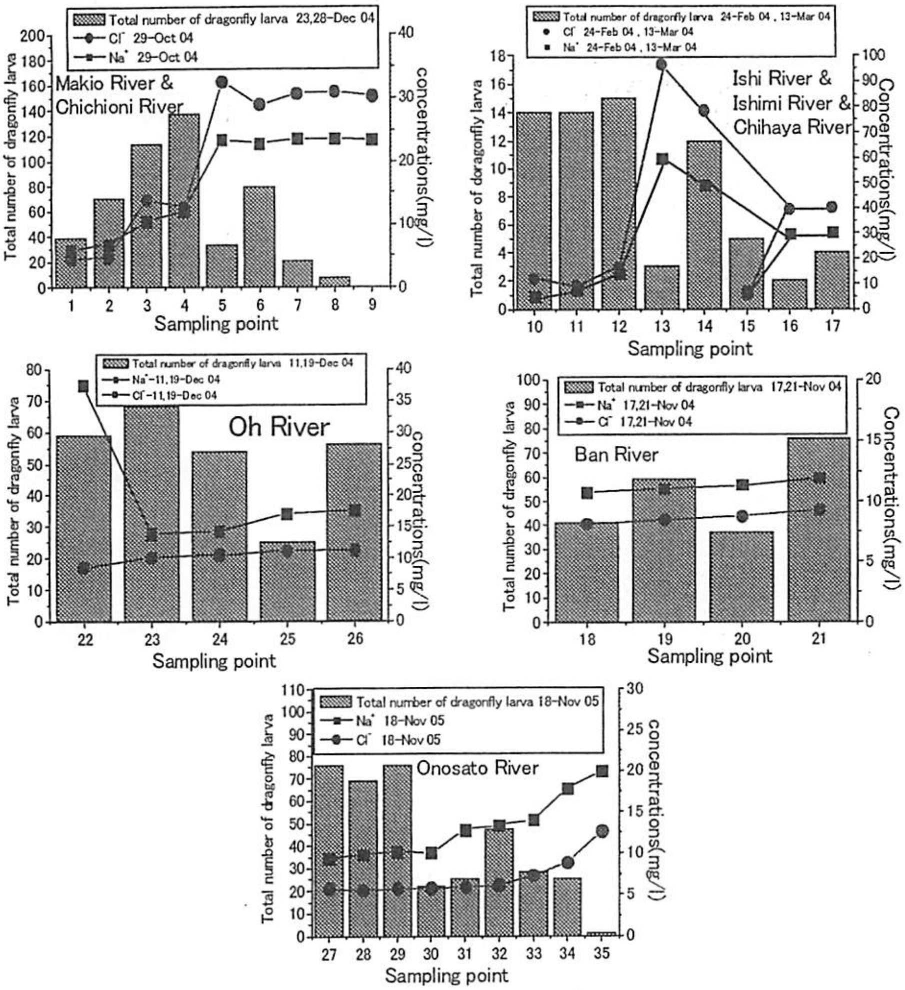

Fig. 2 Total number of dragonfly larva and Na^+, Cl^- concentrations

40 mg/l in the Ishi River, the Ishimi River and the Chihaya River system 12 mg/l and 8 mg/l in the Ban River, 18 mg/l and 10 mg/l in the Oh River, and 20 mg/l and 12mg/l in the Onosato River. On the other hand, when the total number of dragonfly larva reached the maximum, Na^+ and Cl^- concentrations of each river were 12 mg/l and 12 mg/l in the Makio River and the Chichioni River system, 15 mg/l and 15 mg/l in the Ishi River, the Ishimi River, and the Chihaya River system, 12 mg/l and 9mg/l in the Ban River, 15 mg/l and 10mg/l in the Oh River, and 10 mg/l and 6mg/l in the Onosato River.

Fig. 3 shows the relation between the number of dragonfly larva and Na^+ concentration. Fig. 4 illustrates relation between the number of dragonfly larva and Cl^- concentration. When the number of dragonfly larva is over two and the highest Na^+ or Cl^- concentrations in the river water are defined as the Na^+ or Cl^- living limit concentration for dragonfly larva. The living limit of dragonfly larva in Na^+ and Cl^- concentrations are summarized in Fig.5. Living limit of *Davidius fujiama* in Na^+ concentration was 10mg/l. Each Na^+ values were 15 mg/l for *Planaeschna milnei*, 20mg/l for *Stylogomphus suzukii*, 38mg/l for *Mnais pruinosa pruinosa, Sieboldius albarda* and *Asiagomphus melaenops* and 50mg/l for *Calopteryx atrata* and *Davidius nanus*. The living limits of *Davidius fujiama, Planaeschna milnei* and *Mnais pruinosa pruinosa* in Cl^- concentration were 15mg/l. Each Cl^- value was 30mg/l for

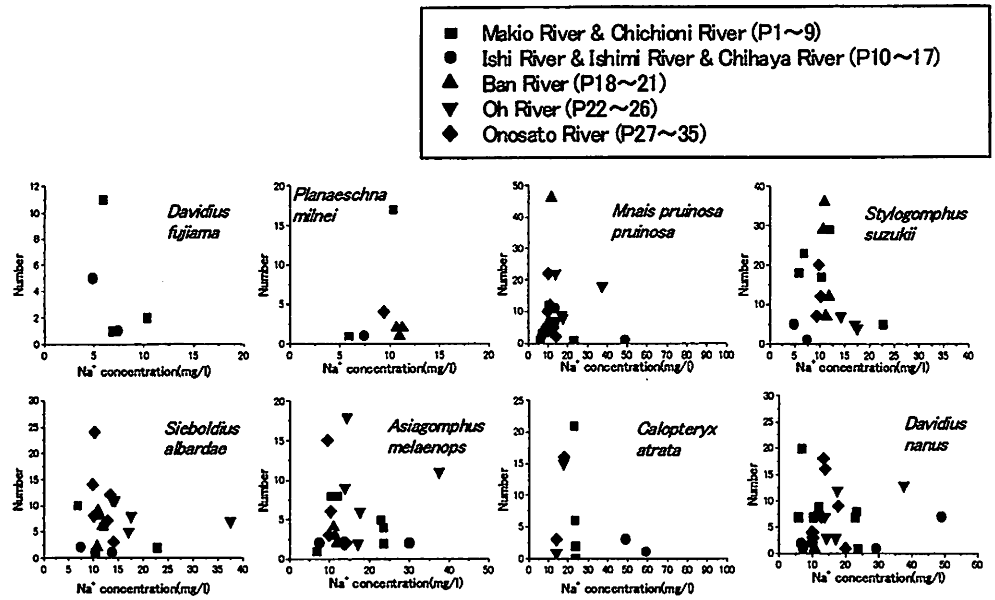

Fig. 3 Na^+ concentration and species of dragonfly larva

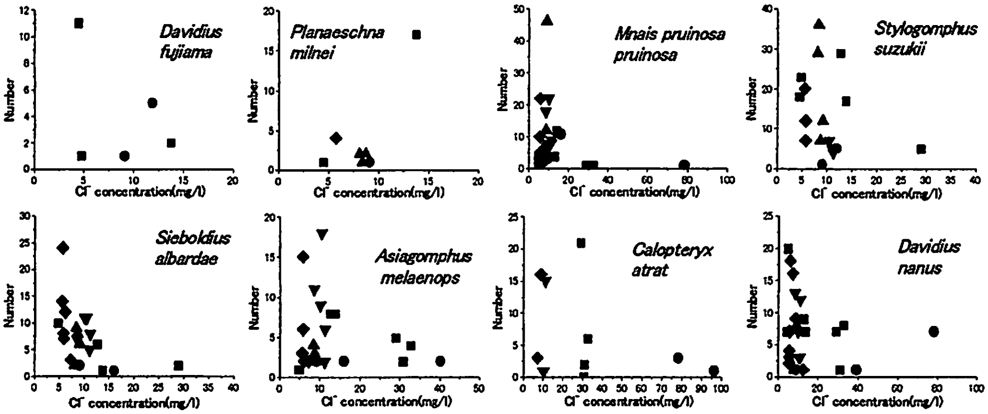

Fig. 4 Cl^- concentration and species of dragonfly larva

Stylogomphus suzukii, Sieboldius albardae and *Asiagomphus melaenops* and 80mg/l for *Calopteryx atrata* and *Davidius nanus*. From the living limits of Na^+ and Cl^- concentrations, species of dragonfly larva could be divided into 5 groups, "*Davidius fujiama* and *Planaeschna milnei*", "*Mnais pruinosa pruinosa*", "*Stylogomphus Suzukii*", "*Sieboldius albardae* and *Asiagomphus melaenops*", "*Calopteryx atrata* and *Davidius nanus*". *Davidius fujiama*, and *Planaeschna milnei* had the lowest living limit. *Mnais pruinosa pruinosa, Stylogomphus suzukii, Sieboldius albardae* and *Asiagomphus melaenops* were in the middle level of the living limit. *Calopteryx atrata* and *Davidius nanus* had the highest living limit. In particular, *Calopteryx atrata* could live under the maximum Na^+ and Cl^- concentration condition. *Planaeschna milnei, Mnais pruinosa pruinosa* and *Stylogomphus suzukii* were 1st class according to the biological indicator of the Japanese Environmental Basic Law. *Sieboldius albardae, Asiagomphus melaenops, Calopteryx atrata* and *Davidius nanus* were 2nd class. Na^+ and Cl^- concentrations may be good indicators of domestic sewage content. The class based on Na^+ and Cl^- concentrations was in line with the biological indicator of the Japanese Environmental Basic Law (5). Therefore, Na^+ and Cl^- concentrations are also good indicators of river conditions.

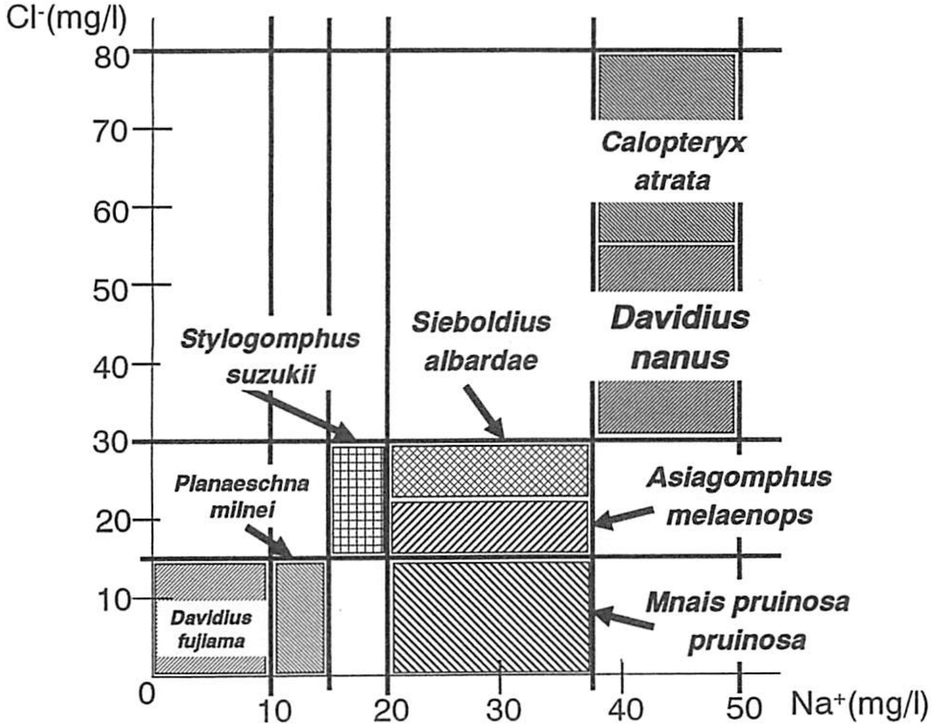

Fig. 5 Living limit of dragonfly larva for Na^+, Cl^- concentrations of sampling day

Change species composition of dragonfly larva for Na^+ Cl^- concentrations

Along the Makio River and the Chichioni River, Na^+ and Cl^- concentrations at sampling from points 5 to 9 are uniform. However, the number of dragonfly larva changed remarkably. The total number of dragonfly larva decreased from points 1 to 4 gradually where Na^+ and Cl^- concentrations decreased. Fig. 6 shows the number and species of dragonfly larva along the Makio River and the Chichioni River. *Davidius fujiama* and *Planaeschna milnei* revealed the lowest Na^+ and Cl^- concentrations of the living limit and they can be find at the from points 1 to 3 of the upper part of the river. The number of *Davidius fujiama* and *Planaeschna milnei* decreased with each increase in Na^+ and Cl^- concentrations. On the other hand, *Stylogomphus suzukii* indicated that the middle level of the living limits was the dominant species for from points 1 to 4. *Calopteryx atrata* and *Davidius nanus* indicated the highest living limits of Na^+ and Cl^- concentrations increased with Na^+ and Cl^- concentrations downstream from points

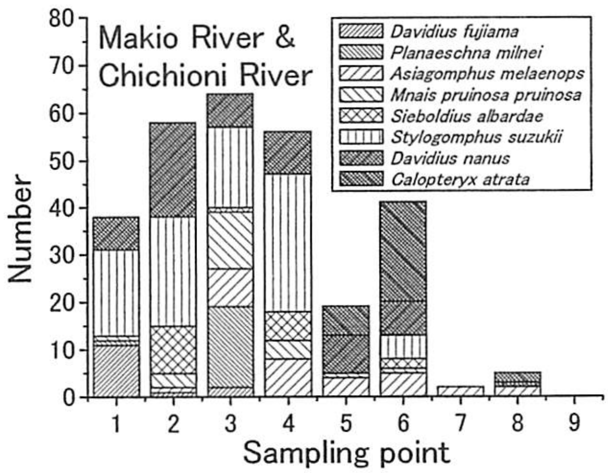

Fig. 6 Change of species constitution at the Makio River and the Chichioni River system

1 to 7. The change of the total number of dragonfly larva did not agree with the number of each species. When the total number of dragonfly larva was the same, species changed according to water quality. Therefore, at point 6, the total number was large, but Na^+ and Cl^- concentrations were high and the dominant species were *Calopteryx atrata* and *Davidius nanus* indicated the highest Na^+ and Cl^- concentrations of living limit.

Fig. 7 shows the number and species of dragonfly larva along the Ishi River, the Ishimi River and the Chihaya River as well as Fig. 6 along the Makio River and the Chichioni River. At the point 10, *Stylogomphus suzukii* and *Davidius fujiama* were the dominant species. However, at the point 12, *Mnais pruinosa pruinosa* and *Asiagomphus melaenops* were the dominant species. The point 10 to point 12 species changed remarkably downstream and Na^+ and Cl^- concentrations increased gradually. When Na^+ and Cl^- concentrations increased remarkably points 12 to 13, the total number of dragonfly larva decreased and *Calopteryx atrata* indicated the highest Na^+ and Cl^- concentrations of living limit remained. Down at the point 13, *Calopteryx atrata, Davidius nanus, Asiaeschna milnei* and *Mnais pruinosa pruinosa* indicated revealed the middle and highest Na^+, and Cl^- concentrations of living limit were dominant when Na^+ and Cl^- concentrations changed.

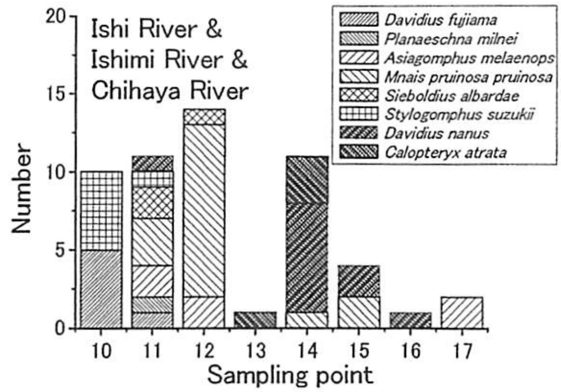

Fig. 7 Change of species constitution at the Ishi River, the Ishimi River and the Chihaya River system

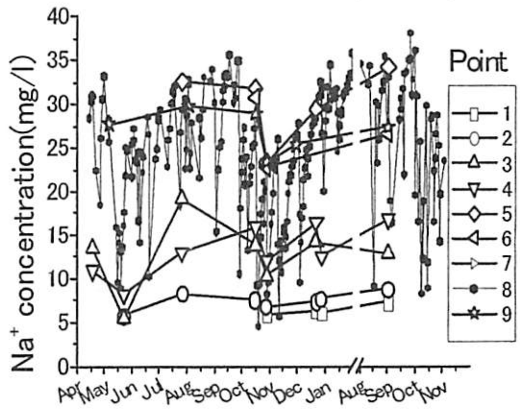

Fig.8 Na^+ concentration change in the Makio River and Chichioni River system

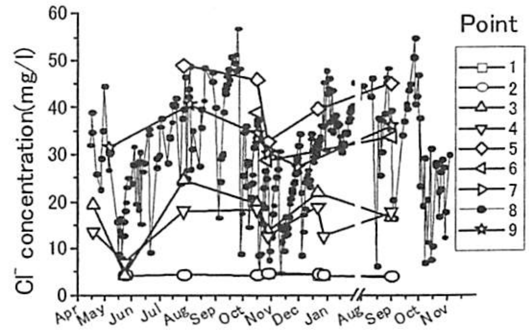

Fig.9 Cl^- concentration change in the Makio River and Chichioni River system

In the Makio River and the Chichioni River, species composition and annual fluctuations of Na^+, Cl^- concentrations

Na^+ and Cl^- concentrations, the total number of dragonfly larva and species composition were clarified at each river but Na^+ and Cl^- concentrations were thought to change remarkably seasonally and daily because of dilution by rain and agricultural activity changes. Na^+ and Cl^- concentrations in Fig.5 were measured on the 23rd and 28th of December 2004 with surveys of larva. The long-term Na^+ and Cl^- concentrations were measured from 15th-April 2004 to 2nd of November 2005. Fig.8 and 9 show annual fluctuations of Na^+ and Cl^- concentrations in the Makio River and the Chichioni River based on the long term

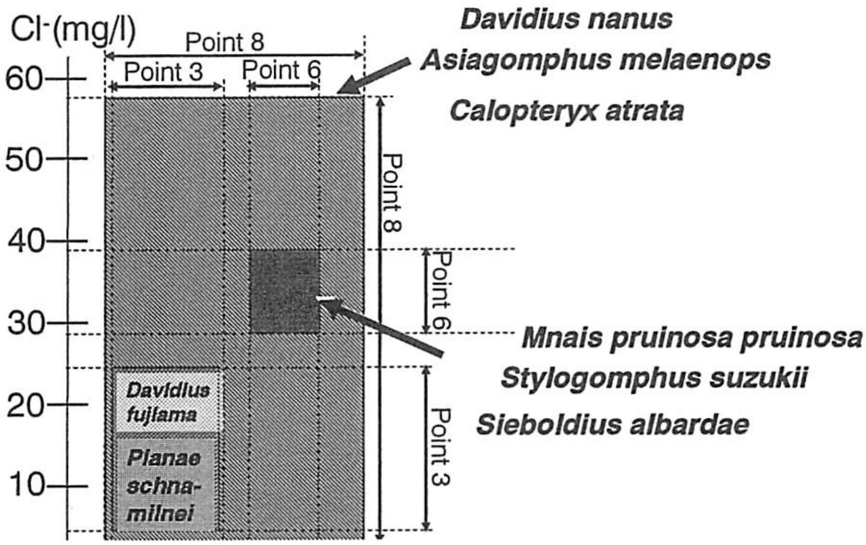

Fig. 10 Maximum and minimum of annual fluctuations in Na^+, Cl^- concentrations at the Makio River and the Chichioni River system

sampling. Daily measurements were taken at the point 8 to grasp the change of the whole Otsu River water system that consists of the Makio and the Chichioni Rivers. Point 8 shows high fluctuations of Na^+ and Cl^- concentrations and high concentrations from July to September and low concentrations in June and from October to November with rain. *Davidius fujiama* and *Planaeschna milnei* could be found from the upstream to point 3. Na^+ concentration in point 3 ranged from 5 to 19 mg/l and Cl^- concentration ranged from 4 to 24 mg/l. Similarly, *Mnais pruinosa, Sieboldius albardae* and *Stylogomphus suzukii* can be found from points 3 to 6. Na^+ concentration at the point 6 ranged from 23 to 31 mg/l and Cl^- concentration from 29 to 39 mg/l. *Asiagomphus melaenops, Calopteryx atrata* and *Davidius nanus* can be found from the upstream to point 8. The Na^+ concentrations at point 8 ranged from 5 to 38 mg/l and Cl^- concentration from 4 to 59 mg/l. Fig. 10 shows the relationships of points 3, 6 and 8 and species of dragonfly larva. From the long-term Na^+ and Cl^- concentrations changed, species composition of dragonfly could be divided into 3 groups, "*Davidius fujiama* and *Planaeschna milnei* ", "*Mnais pruinosa pruinosa, Stylogomphus suzukii* and *Sieboldius albarda* ", and "*Asiagomphus melaenops, Calopteryx atrata* and *Davidius nanus* ". The "*Davidius fujiama* and *Planaeschna milnei*" group was determined by the long term Na^+ and Cl^- concentrations that agreed with those determined from Na^+ and Cl^- concentrations in the dragonfly larva surveys day. "*Mnais pruinosa pruinosa, Stylogomphus suzukii* and *Sieboldius albarda* " group was determined by the long-term Na^+ and Cl^- concentrations that correspond to the middle class determined from Na^+ and Cl^- concentrations in the larva survey day. Finally, the "*Calopteryx atrata* and *Davidius nanus*" group was determined by the long-term Na^+ and Cl^- concentrations which correspond to the last class determined from Na^+ and Cl^- concentrations in the larva surveys day. Although *Asiagomphus melaenops* was the last class determined from the long-term Na^+ and Cl^- concentrations, the middle class determined from Na^+ and Cl^- concentrations in the larva surveys day.

Influence of anionic surface active agent for Dragonfly larva

Na^+ and Cl^- concentrations are thought to be an indicator of domestic sewage ratio of total water. As well as anionic surface-active agent is only included in sewage water, and it is thought to be toxic material for dragonfly larva (4). LAS (Linear Alkylbenzene Sulfonates), ABS (alkyl Benzene Sulfonates) and synthetic detergent were analyzed

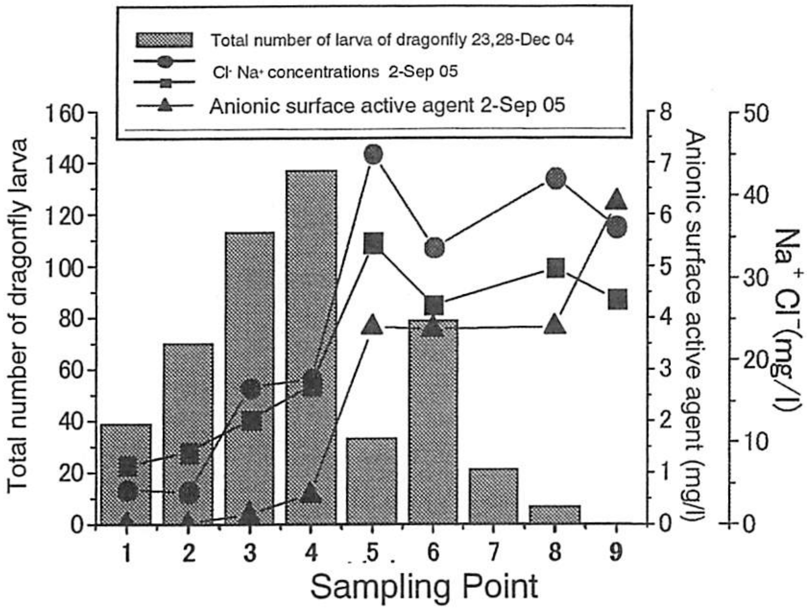

Fig. 11 In the Makio River and Chichioni River system, total number of dragonfly larva, anionic surface active agent, Na^+ and Cl^-,

as a total amount of Anionic surface active agents. LAS are in the main anionic surface active agent in Japan. Fig. 11 shows the relation between Na^+ and Cl^- concentrations, anionic surface active agents, and the total number of dragonfly larva in the Makio River and the Chichioni River. Surveys of anionic surface active agent were 2nd-September 2005. As both Na^+ and Cl^- concentrations and anionic surface active agents increased until the 5th points down the stream, the total number of dragonfly larva increased till the point 4. However, at the point 5, the total number of dragonfly larva decreased remarkably. Downstream at point 5, both Na^+ and Cl^- concentrations and anionic surface active agents kept high values, the total number of dragonfly larva decreased gradually. As the anionic surface active agent reached maximum values, 6.2 mg/l, dragonfly larva could not be found.

CONCLUSION

Living limits of Na^+ and Cl^- concentrations for dragonfly larva in rivers with inflow of domestic sewage were studied. As the study areas of the southern part of Osaka are mainly divided into forest area and housing sites, river water chemistry mainly depends upon domestic sewage. Na^+ and Cl^- concentrations are thought to be good indicators of sewage water content in river water. As Na^+ and Cl^- concentrations in river water increased, the number of larva and species composition of larva changed.

While Na^+ and Cl^- concentrations increased till 12mg/l, the number of dragonfly larva increased. In particular, the number of some dragonfly larva such as *Calopteryx atrata* and *Davidius nanus* increased with the increase of Na^+ and Cl^- concentrations in river water. They were thought to have a strong tolerance for domestic sewage. Over 12mg/l, Na^+ and Cl^- concentrations in river water increased, the number of larva decreased. Domestic sewage is thought to contain organic substances and toxic substances such as anionic surface active agents for dragonfly larva. Therefore, the change of the number of larva and species of larva with each increase of Na^+ and Cl^- concentrations were thought to have been caused by an increase of domestic sewage content. *Davidius nanus* was distributed widely in the river water from low to high mixing ratio of domestic sewage. The maximum living limits of Na^+ and Cl^-

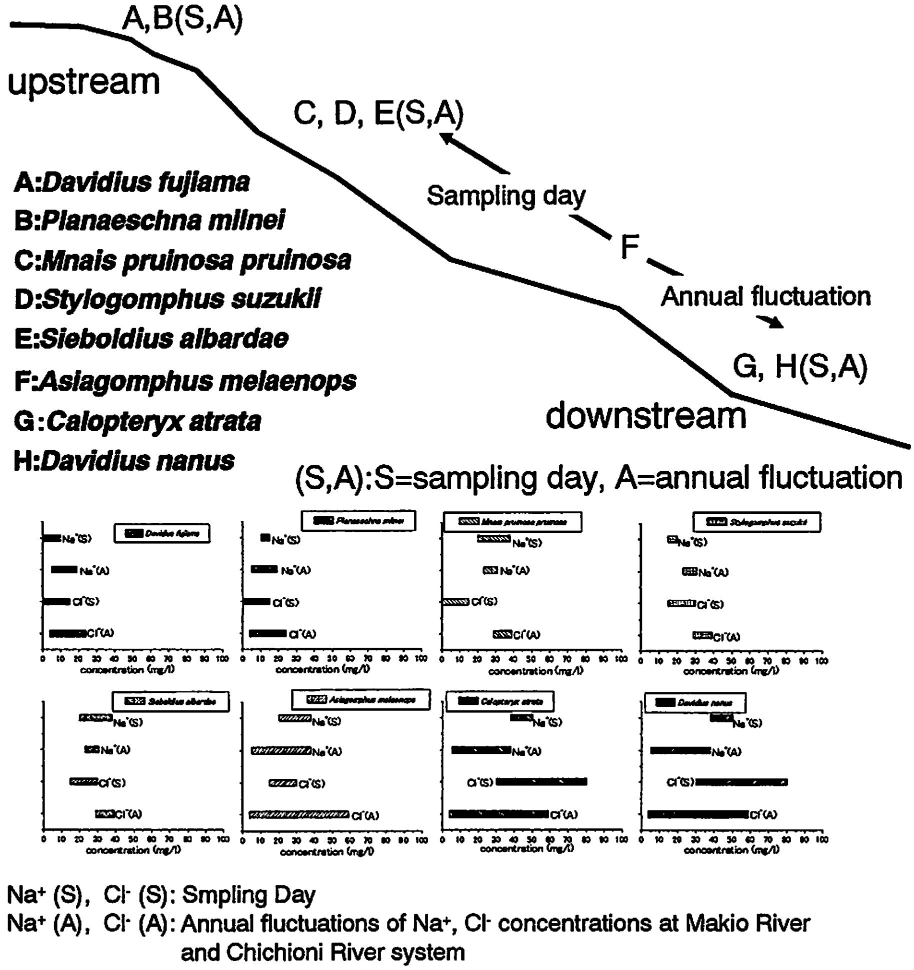

Fig. 12 Summary of this study

concentrations for *Calopteryx atrata* and *Davidius nanus* were 50 and 80 mg/l. The values of living limits were determined for all dragonfly larva observed in the southern part of Osaka. Maximum living limits of Na^+ and Cl^- concentrations for *Sieboldius albardae, Asiagomphus melaenops* and *Mnais pruinosa pruinosa* were 40 and 30 mg/l. Maximum living limits of Na^+ and Cl^- concentrations for *Stylogomphus suzukii* were 20 and 30 mg/l. Maximum living limits of Na^+ and Cl^- concentrations for *Planaeschna milnei* and *Davidius fujiama* were both 15 mg/l.

The annual fluctuations of Na^+ and Cl^- concentrations were studied in the Makio River and the Chichioni River system in the southern part of Osaka. Annual fluctuations of Na^+ and Cl^- concentrations at the sampled point where *Davidius fujiama* and *Planaeschna milnei* were observed were 4~20 mg/l and 3~22 mg/l, respectively. Annual fluctuations of Na^+ and Cl^- concentrations at the sampled points where *Mnais pruinosa pruinosa, Stylogomphus suzukii* and *Sieboldius albardae* were observed were 22~32 mg/l and 28~38 mg/l, respectively. The annual fluctuations of Na^+ and Cl^- concentrations at the sampled point where *Asiagomphus melaenops, Calopteryx atrata* and *Davidius nanus* were observed were 4~38mg/l and 4~60mg/l, respectively. Living limit of dragonfly larva in Na^+ and Cl^- concentrations for *Asiagomphus melaenops* were in agreement with those for *Sieboldius albardae, Mnais pruinosa pruinosa* and *Stylogomphus suzukii*. However, the annual fluctuations of Na^+ and Cl^- concentrations at the sampled points where *Asiagomphus melaenops* were observed were in line with those for *Calopteryx atrata* and *Davidius nanus*. When anionic surface active agents reached 3.8 to 6.2 mg/l, the dragonfly larva disappeared.

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