

## Chrysophytes in the southern part of Hyogo Prefecture, Japan (I) Chrysophyte flora in three ponds and a reservoir

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In a total of 472 samples collected from Doro-ike Pond, Hoshino-ike Pond, Sengari Reservoir and Yasuba-ike Pond in the southern part of Hyogo Prefecture, Japan between April 1975 and March 1987, 105 taxa of chrysophytes were found by light and electron microscopy: 37 species, 2 varieties, 2 forms and 2 unidentified species of *Mallomonas*; 7 species of *Synura*; 2 species each of *Chrysococcus* and *Uroglena*; 7 species, 1 variety and 1 unidentified species of *Dinobryon*; 4 species of *Pseudokephyrion*; 11 species and 2 unidentified species of *Spiniferomonas*; 19 species, 1 subspecies and 1 form of *Paraphysomonas*; and 1 species each of *Chrysodidymus*, *Kephyrion*, *Chrysolykos* and *Chrysosphaerella*. Out of them, 20 taxa were new to Japan: *Mallomonas bangladeshica*, *M. calceolus*, *M. rasilis*, *M. insignis*, *M. retifera*, *M. pillula* f. *valdiviana*, *M. ocellata*, *M. mangofera* var. *sulcata*, *Chrysococcus triporus*, *Kephyrion globosum*, *Uroglena lindii*, *Dinobryon urceolatum*, *Pseudokephyrion cylindricum*, *P. pseudospirale*, *P. conicum*, *P. hypermaculatum*, *Spiniferomonas silverensis*, *Paraphysomonas subrotacea*, *P. stephanolepis* and *P. eiffelii*. The number of taxa of chrysophytes found was 51 in Doro-ike Pond, 38 in Hoshino-ike Pond, 68 in Sengari Reservoir and 76 in Yasuba-ike Pond, occupying respectively 38.6, 27.0, 31.9 and 33.9% of the total number of algal species found in each pond or reservoir.

Key Index Words: chrysophytes—flora—Hyogo Prefecture—Japan—pond—reservoir.

Chrysophytes mainly inhabit in freshwater as plankton. Though many workers have been studying algal flora in Japanese ponds and lakes with the light microscope, only one to five species of *Dinobryon*, *Mallomonas* and *Synura* have been found in one locality (KOKUBO and MASIKO 1939, HADA 1959, MIZUNO 1961, NEGORO 1968, YASUDA *et al.* 1975, IMAZU 1979). TAKAHASHI (1978a), however, reported 74 taxa of chrysophytes from about one hundred Japanese ponds and lakes by electron microscopy, and ITO (1988) 42 taxa from Lake Biwa. These results indicate that electron microscopy is necessary to study chrysophyte flora.

In Hyogo Prefecture, *Dinobryon divergens* has been found from Sara-ike Pond in the Kan-zaki district (IMAZU 1979), many ponds in Nishinomiya City, Itami City, the Hojo district and the Tsuchiyama district (MIZUNO 1961), and 22 taxa of scale-bearing chrysophytes from 6 ponds and lakes in-

cluding Doro-ike Pond and Sengari Reservoir (TAKAHASHI 1978a). ITO and TAKAHASHI (1982) reported the seasonal fluctuation of 8 taxa of *Spiniferomonas* including 3 taxa previously recorded in Doro-ike Pond and Hoshino-ike Pond. In total, 28 taxa of chrysophytes have been found in Hyogo Prefecture up to now, but many taxa are thought to be still overlooked.

The purpose of this paper is to report chrysophyte flora found by light and electron microscopy in three ponds and a reservoir situated in the southern part of Hyogo Prefecture.

### Materials and Methods

A total of 472 samples were collected by plankton net (Rigosha NXX25) and 1 l bottles from the surface in Doro-ike Pond, Hoshino-ike Pond, Sengari Reservoir and Yasuba-ike Pond (Fig. 1). Immediately after

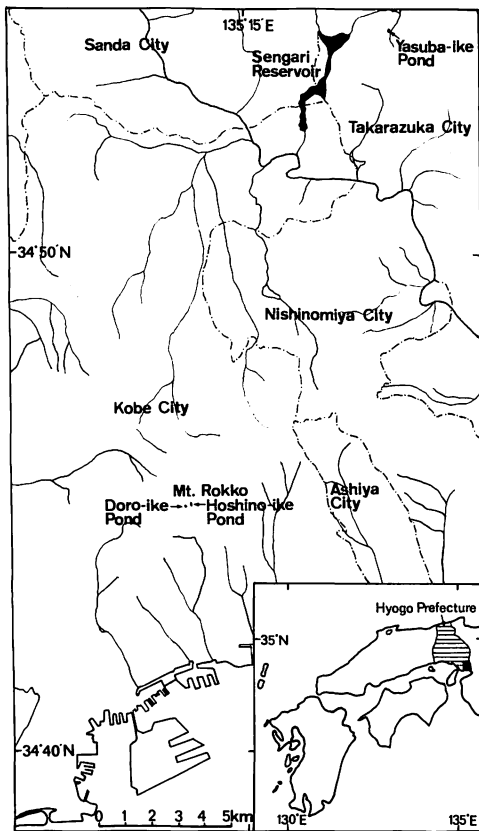


Fig. 1. Locations of three ponds and a reservoir investigated in the southern part of Hyogo Prefecture, Japan.

collection, net samples and 0.5 l of each water sample were fixed with 0.5% Lugol's solution and subsequently with 2% formalin. These fixed samples were settled for a week and concentrated to 10 or 20 ml. The concentrated samples were used for identification of algae including chrysophytes with light and electron microscopes. Unfixed water sample of 0.5 l each was centrifuged at 3,000 r.p.m. for 10 min. and concentrated to 1 to 2 ml. For transmission electron microscopy, 10  $\mu$ l of each concentrated fixed and unfixed samples was mounted on collodion-carbon coated grids, desiccated in an oven, and then shadowed with chromium or Pt-Pd alloy at an angle of about 20°C. Additional observations of some chrysophyte specimens were made on samples isolated with a micropipette and transferred to collodion-carbon coated grids.

For scanning electron microscopy, 10 or 20 ml of each unfixed water sample were filtered by Nuclepore filter (25 mm in diameter, 0.4  $\mu$ m in pore size), desiccated in an oven and then coated with gold. Electron microscopes, JEM-100B and JSM-U<sub>3</sub>, at Faculty of Science, Kobe University, and a scanning electron microscope, JEM-T200, in Water Quality Laboratory, Kobe City Waterworks Bureau, were used for the study.

## Study Areas

### *Doro-ike Pond*

This pond, which was made to obtain ice between 1873 and 1874, is situated 800 m above sea level on Mt. Rokko in Kobe City. It has a surface area of about 600 m<sup>2</sup> and a maximum depth of 1 m. The pond fronts the road on the west and is surrounded by a coniferous forest on the other sides. Pond water looked always brown in color. *Potamogeton distincus* covered about 70% of the pond surface throughout the year. Samples were collected at a distance of 1 m from the shore once a month from April 1975 to October 1976 and once a week or two weeks from November 1976 to August 1977. The material consists of 42 water samples and 42 net samples. In the study period, ice covered the pond from 19 December 1975 to 23 January 1976 and from 10 December 1976 to 5 March 1977, reaching a maximum thickness of 23 cm on 17 February 1977.

### *Hoshino-ike Pond*

This pond is 200 m to the east of Doro-ike Pond. It has a surface area of about 2,800 m<sup>2</sup>. Until 1975, this pond was polluted by the sewage from bungalows around it. Pond water looked always greenish brown in color. *Hydrilla verticillata* covered the bottom of the pond between July and August. Samples were collected at a distance of 1 m from the shore on the same days as in Doro-ike Pond. The material consists of 42 water samples and 42 net samples. The ice-covered period in Hoshino-ike Pond was the same as in Doro-ike Pond.

### *Sengari Reservoir*

This reservoir is situated over three cities, Kobe, Sanda and Takarazuka. It was made in 1919 and has a surface area of 112 ha, a volume of 11,610,000 m<sup>3</sup> and a maximum depth of 31 m. Water looked green/brown in color. Samples were collected at the center of the reservoir, where the depth is about 14 m, once a month from April 1978 to March 1987. The material consists of 108 water samples and 108 net samples. Light and electron microscopy were done from December 1980 to May 1981 and from April 1982 to March 1983, and only light microscopy was done in other period.

#### *Yasuba-ike Pond*

This pond is situated in the northwestern part of Takarazuka City. It is an irrigation pond and has a surface area of 2,500 m<sup>2</sup> and a maximum depth of 2 m. Pond water looked always brown in color. In summer, *Trapa natans* var. *bisinosa* covered the pond surface near the shore. Samples were collected at a distance of 50 cm from the shore once to five times a month from November 1978 to December 1983. The material consists of 80 water samples and 8 net samples. Light and electron microscopy were done in November and December 1978, January, November and December 1979 and from February 1980 to January 1981, and only light microscopy was done in other period.

## Results and Discussion

In total 105 taxa were found: 37 species, 2 varieties, 2 forms and 2 unidentified species of *Mallomonas*; 7 species of *Synura*; 2 species each of *Chrysococcus* and *Uroglena*; 7 species, 1 variety and 1 unidentified species of *Dinobryon*; 4 species of *Pseudokephyrion*; 11 species and 2 unidentified species of *Spiniferomonas*; 19 species, 1 subspecies and 1 form of *Paraphysomonas*; and 1 species each of *Chrysodidymus*, *Kephyrion*, *Chrysolykos* and *Chrysosphaerella* (Table 1). Out of them, 20 taxa were new to Japan: *Mallomonas bangladeshica*, *M. calceolus*, *M. rasilis*, *M. insignis*, *M. retifera*, *M. pillula* f. *valdiviana*, *M. ocellata*, *M. mangofera* var. *sulcata*, *Chrysococcus*

*triporus*, *Kephyrion globosum*, *Uroglena lindii*, *Dinobryon urceolatum*, *Pseudokephyrion cylindricum*, *P. pseudospirale*, *P. conicum*, *P. hypermaculatum*, *Spiniferomonas silverensis*, *Paraphysomonas subtrotacea*, *P. stephanolepis* and *P. eiffelii*. Species belonging to *Kephyrion* and *Pseudokephyrion* have not been reported previously. From the results of this study and 110 species, 1 subspecies, 3 varieties and 8 forms belonging to 24 genera of chrysophytes which have been reported hitherto (TAKAHASHI 1959, 1960, 1972, 1977, 1978a, PREISIG and TAKAHASHI 1978, ITO and TAKAHASHI 1982, WAKABAYASHI and ICHISE 1986, ITO 1988), it becomes that in total 128 species, 1 subspecies, 4 varieties and 9 forms belonging to 26 genera have been found in Japanese freshwater bodies.

Out of 100 taxa excluding 5 unidentified species found in this study, 90 taxa are found widely in the world (TAKAHASHI 1978a, PREISIG and HIBBERD 1982a, 1982b, STARMACH 1985, ASMUND and KRISTIANSEN 1986, ITO 1988). *Mallomonas conspersa* has been found only in New Zealand (DÜRRSCHMIDT 1986), *M. mangofera* var. *sulcata* in Chile (DÜRRSCHMIDT 1983), *Dinobryon urceolatum* in Switzerland (REVERDIN 1919), *Pseudokephyrion hypermaculatum* in Czechoslovakia (ETTL 1978), and *Spiniferomonas minuta* and *S. silverensis* in Canada (NICHOLLS 1984). Although these six species have been recorded respectively only from one different country, finding of them in Japan, which is far away from the above-mentioned countries, suggests that they are also distributed widely in the world. *Mallomonas grata* which was reported only in Japan (TAKAHASHI 1963) was recently found in Thailand (ITO unpublished) and China (KRISTIANSEN 1989) and *M. ocellata* only in Malaysia (DÜRRSCHMIDT and CROOME 1985). These two species of *Mallomonas* were found only in Asia. *M. harrisiae* and *M. reticostata*, which are found widely in Japan (TAKAHASHI 1978a), have not been found in other countries and they seem to be endemic to Japan.

The number of taxa of chrysophytes found in this study was 51 in Doro-ike Pond, 38 in

Table 1. Chrysophytes found in three ponds and a reservoir (D, Doro-ike Pond; H, Hoshino-ike Pond; S, Sengari Reservoir; Y, Yasuba-ike Pond) in the southern part of Hyogo Prefecture, Japan.

Taxa	D	H	S	Y	Taxa	D	H	S	Y
<i>Mallomonas matvienkoeae</i>	●	●		●	<i>Kephyrion globosum</i> *				●
<i>M. parvula</i>	●	●	●	●	<i>Uroglena lindii</i> *				●
<i>M. ouradion</i>	●				<i>U. volvox</i>				●
<i>M. peronoides</i>				●	<i>Dinobryon sertularia</i>	●	●	●	●
<i>M. bangladeshica</i> *			●		<i>D. cylindricum</i>			●	
<i>M. multisetigera</i>	●	●			<i>D. sociale</i>	●	●	●	●
<i>M. calceolus</i> *			●		<i>D. bavaricum</i>			●	●
<i>M. conspersa</i>			●		<i>D. divergens</i>	●	●	●	●
<i>M. paxillata</i>			●		<i>D. korsikovii</i>		●		●
<i>M. papillosa</i> var. <i>ellipsoidea</i>	●	●	●	●	<i>D. suecicum</i> var. <i>longispinum</i>			●	●
<i>M. rasilis</i> *			●		<i>D. urceolatum</i> *	●			
<i>M. guttata</i>				●	<i>D. sp.</i>				●
<i>M. caudata</i>			●		<i>Chrysolynos planktonicus</i>	●	●		●
<i>M. insignis</i> *				●	<i>Pseudokephyrion cylindricum</i> *	●	●		●
<i>M. punctifera</i>	●	●	●	●	<i>P. pseudospirale</i> *	●	●	●	●
<i>M. heterospina</i>		●	●	●	<i>P. conicum</i> *			●	●
<i>M. harrisiae</i>	●	●	●	●	<i>P. hypermaculatum</i> *	●	●		●
<i>M. akrokomos</i>	●	●	●	●	<i>Chrysophaerella brevispina</i>			●	●
<i>M. striata</i>	●	●	●	●	<i>Spiniferomonas trioralis</i>	●	●	●	●
<i>M. retifera</i> *			●		<i>S. minuta</i>	●			●
<i>M. flora</i>			●		<i>S. silverensis</i> *	●			
<i>M. cristata</i>	●				<i>S. bilacunosa</i>	●	●	●	●
<i>M. alpina</i>			●		<i>S. cornutus</i>	●		●	●
<i>M. areolata</i>			●	●	<i>S. crucigera</i>	●			●
<i>M. elongata</i>		●	●	●	<i>S. takahashii</i>				●
<i>M. tonsurata</i>	●	●	●	●	<i>S. alata</i>			●	
<i>M. portae-ferreae</i>			●		<i>S. bourrellyi</i>	●	●	●	●
<i>M. crassisquama</i>	●	●	●	●	<i>S. coronacircumspina</i>	●		●	●
<i>M. lelymene</i>	●	●			<i>S. abei</i>	●	●	●	●
<i>M. pillula</i> f. <i>valdiviana</i> *	●			●	<i>S. sp. No. 1</i>	●			
<i>M. annulata</i>			●	●	<i>S. sp. No. 2</i>	●			●
<i>M. pumilio</i>	●	●	●	●	<i>Paraphysomonas subrotacea</i> *			●	●
<i>M. alata</i>				●	<i>P. circumvallata</i>			●	
<i>M. eoa</i>	●		●		<i>P. punctata</i>	●		●	●
<i>M. ocellata</i> *	●				<i>P. runcinifera</i>				●
<i>M. mangofera</i> f. <i>mangofera</i>	●	●	●	●	<i>P. subquadrangularis</i>			●	●
<i>M. mangofera</i> f. <i>foveata</i>	●			●	<i>P. diademifera</i>		●	●	●
<i>M. mangofera</i> var. <i>sulcata</i> *				●	<i>P. butcheri</i>	●			●
<i>M. grata</i>			●		<i>P. stephanolepis</i> *			●	●
<i>M. recticostata</i>			●	●	<i>P. morchella</i>			●	●
<i>M. splendens</i>	●	●	●	●	<i>P. eiffelii</i> *	●			●
<i>M. sp. No. 1</i>			●	●	<i>P. quadrispina</i>				●
<i>M. sp. No. 2</i>	●	●		●	<i>P. poteriophora</i> ssp. <i>manubriata</i>			●	
<i>Synura petersenii</i>	●		●	●	<i>P. coronata</i>				●
<i>S. glabra</i>		●	●	●	<i>P. stelligera</i>			●	
<i>S. sphagnicola</i>	●	●	●	●	<i>P. capreolata</i>			●	●
<i>S. mammillosa</i>	●	●	●		<i>P. glandiata</i>			●	●
<i>S. uwella</i>				●	<i>P. imperforata</i> f. No. 2	●	●	●	●
<i>S. curtispina</i>			●	●	<i>P. bandaiensis</i>		●	●	●
<i>S. spinosa</i>	●	●	●	●	<i>P. vestita</i>	●	●	●	●
<i>Chrysodidymus synuroides</i>	●		●		<i>P. takahashii</i>			●	
<i>Chrysooccus rufescens</i>		●			<i>P. caelifrica</i>				●
<i>C. triporus</i> *			●	●	Total number of taxa	51	38	68	76

\* Taxa new to Japan.

Hoshino-ike Pond, 68 in Sengari Reservoir and 76 in Yasuba-ike Pond, occupying respectively 38.6, 27.0, 31.9 and 33.9% of the total number of algal species found in each pond or reservoir. Several studies on freshwater algal flora with light and electron microscopes covering a long period of time have been done. In three ponds at Tsuruoka Park, Yamagata Prefecture, Japan, 24 to 27 taxa of chrysophytes have been reported and their percentage to the total number of algal species was from 19.4 to 21.8% (TAKAHASHI 1978b). In Lake Biwa, Shiga Prefecture, Japan, 60 taxa of chrysophytes have been reported and its percentage to the total number of algal species found was 17.1% (NEGORO 1968, WAKABAYASHI and ICHISE 1986, ITO 1988). In other countries, three localities, a pond of Oude Waal in the Netherlands (ROIJACKERS 1984, 1986), Lake Tystrup Sø in Denmark (KRISTIANSEN 1985) and Lake Trummen in Sweden (CRONBERG 1982) have been investigated. The number of taxa of chrysophytes found was 49 in a pond of Oude Waal, 40 in Lake Tystrup Sø and 44 in Lake Trummen, occupying respectively 25.0, 19.0 and 13.8% of the total number of algal species found. Though many studies with the light microscope only on freshwater algal flora have been done, no or only a few species of chrysophytes have been found in each lake (SMITH 1920, KOKUBO and MASIKO 1939, HADA 1959, PRESCOTT 1962, HORTOBÁGYI 1973). From this and the above-mentioned results, however, it is clear that chrysophytes are commonly found in freshwater localities and constitute an important group of algal flora if examinations by electron microscopy are carried out for a long period of time.

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#### 伊藤裕之：兵庫県南部産黄金藻（I）3池と1ダム湖における黄金藻フローラ

兵庫県南部の泥池，星野池，千疋貯水池，安場池において，1975年4月から1987年3月の間採集した合計472試料から，光学顕微鏡と電子顕微鏡を用いて黄金藻105種類を見出した。その内訳は，*Mallomonas* 属37種2変種2品種2未同定種，*Synura* 属7種，*Chryso-didymus* 属1種，*Chrysococcus* 属2種，*Kephyrion* 属1種，*Uroglena* 属2種，*Dinobryon* 属7種1変種1未同定種，*Chryso-lykos* 属1種，*Pseudokephyrion* 属4種，*Chryso-sphaerella* 属1種，*Spiniferomonas* 属11種2未同定種，*Paraphysomonas* 属19種1亜種1品種であった。その内，*Mallomonas bangladeshica*，*M. calceolus*，*M. rasilis*，*M. insignis*，*M. retifera*，*M. pillula* f. *valdiviana*，*M. ocellata*，*M. mangofera* var. *sulcata*，*Chrysococcus triporus*，*Kephyrion globosum*，*Uroglena lindii*，*Dinobryon urceolatum*，*Pseudokephyrion cylindricum*，*P. pseudospirale*，*P. conicum*，*P. hypermaculatum*，*Spiniferomonas silverensis*，*Paraphysomonas subrotacea*，*P. stephanolepis*，*P. eiffelii*の20種類は日本新産であった。黄金藻は，泥池では51種類，全藻類種類数の38.6%を占め，星野池では38種類，27.0%，千疋貯水池では68種類，31.9%，安場池では76種類，33.9%であった。(652 神戸市兵庫区楠谷町37-1 神戸市水道局水質試験所)