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A Study of the Brackish-Water Plankton in Japan, with Special Reference to the Relation between the Plankton Fauna and the Salinity of the Water

By

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Introduction

The writer has carried out the limnological studies on the brackish-waters in Japan, mainly in the Hokuriku District, these several years (MASHIKO, 1949, 1950, 1951; MASHIKO, NOZAKI and INOSHITA, 1951; MASHIKO and INOUE, 1951). The present paper deals with a general consideration of the results thus obtained as well as those added later on, especially on the relation between the salinity of the waters and the plankton fauna found there.

One of the most characteristic features of the brackish-water environment is that the salt content and the various conditions related to it are very variable. Even in the same lake, the salinity often markedly varies horizontally as well as vertically and also according to the time of observation. The relation between the water temperature and the specific gravity is also very complex, especially in the winter season, because there is often considerable difference between the temperature of the back flowing sea water and that of the inflowing cold river water. From these facts, a plankton fauna found in a brackish-water lake may often be regarded as a compound assemblage of different communities rather than a single one. In some lakes, therefore, it was often difficult to recognize the exact relationship between the plankton organisms collected and the salinity observed, even at the same station. And, for the same reason, the records given by the previous authors are occasionally difficult to be referred to.

The influence of the salt content on the composition of the fauna of brackish-waters depends not only upon the amount itself, but also upon its fluctuation. This is another difficulty in presuming the optimum range of the plankton in relation to the salinity.

Brackish-Waters Investigated

The water bodies investigated by the writer are as shown in Table 1. The

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chlorine content of the waters was not always measured every time the plankton collection was made, but so far as has been observed, the chlorinity of the respective waters was found to be in the range given in the table.

Lake	Prefecture	Chlorinity g/l	Max. Depth	Date
Kahoku-gata	Isikawa	surface: 1.45–8.45 3.5m: 11.8–13.9	3.75	1946–51
Otsi-gata	Isikawa	0.070–1.035	1.7	1949–50
Imae-gata	Isikawa	1.532–4.540	2.5	1946,49
Kiba-gata	Isikawa	0.057–0.271	3.5	1946,49
Sibayama-gata	Isikawa	0.050–0.279	2.5	1946,49
Ryujin-ike, Hegura-jima	Isikawa	5.730	0.5	3/VIII/1948
Nameless pool, Hegura-jima	Isikawa	3.301	0.3	3/VIII/1948
Hôshôzu-gata	Toyama	0.224–8.373	1.6	1949,52
Kita-gata	Hukui	1.40–2.27	3.1	1951,52
Koyama-ike	Tottori	0.41–0.63	8.9	1954–55
Tôgô-ike	Tottori	surface: 1.739–1.824	7.5	29/V/1955
Isizu, pond A	Osaka	8.80	—	3/X/1954
Isizu, pond B	Osaka	0.50	—	3/X/1954
Abura-ga-huti	Aiti	surface: 0.33–0.47 5 m: 9–12	6	1951

Table 1. Brackish-waters investigated

In most cases, these lakes seem to have been formed by the remarkble develepment of the sand dunes which dammed up streams or valleys along the sea coast. Accordingly, the lake basins are very flat and shallow, and the depth is generally 2 or 3 meters for the greater part, rarely reaching beyond 4 meters.

Lake Kahoku-gata is the largest one in the present study, its surface area being 23.1 km^2. The chlorinity was, roughly speaking, 3.5 g/l in the main portion during the period the investigation was made*, but it was as high as 6–8 g/l in the part near the outlet, from which the lake water flows into the Sea of Japan through a canal of about 5 km in length. At several depressions which were found in some parts of the very flat basin of the lake, about 1–2 m deeper than the general bottom, the chlorinity of the bottom layer was no less than 11–13 g/l.

Lake Otsi-gata is uaually an oligohaline lake, ranging from 200 to 500 mg/l in chlorinity, but the chlorinity was observed to become often less than 100 mg/l and rarely more than 1 g/l. The plankton fauna met with in it, therefore, often con-

* Recently, the salinity of this lake seems to have become markedly lower owing to the control of the inflow of sea water by the lock-gate.

tained a large number of fresh-water forms and it was sometimes difficult to distinguish the endogenetic forms from the temporary migrants transported by the river waters.

Lake Imae-gata, Lake Kiba-gata and Lake Sibayama-gata make a group of lakes and only L. Imae-gata is directly connected with the sea through a canal. The other two are connected with L. Imae-gata respectively through other canals. In L. Imae-gata, accordingly, the salinity is comparatively high and very variable, ranging from 1.53 to 4.5 g/l in chlorinity. The other two lakes may be safely regarded as fresh-water lakes except for some limited portions. In L. Kiba-gata, however, when the observation was made, somewhat remarkable stagnant water of relatively high salinity was found in the deeper layer.

Hegura-jima is a small solitary island in the Sea of Japan, 48 km distant from the north end of the Noto Peninsula. There are two pools, of which one is Ryujin-ike and the other is nameless. The chlorinity of these pools as seen in the table may be due to the sea water which has been blown over it by the wind. The faunae found there are worthy of some notice.

Lake Kita-gata is a mesohaline lake, ranging from 1.42 to 2.27 g/l in its chlorinity, and the lake water seems to be in a considerably stable condition. Some weak stratification of the water was observed in the summer period.

Lake Hôshôzu-gata is a lakelet in Toyama Prefecture. Owing to the smallness of the lake basin, the condition of the lake water is extremely variable since it is easily influenced by the inflow of the sea- or river water. The chlorinity was in the range from 224 to 8373 mg/l when the measurements were made by the writer, but, as a matter of fact, a fluctuation of much greater range may often take place.

Lake Koyama-ike is an oligohaline lake in Tottori Prefecture, being connected with the estuary of the Sendai-gawa near the coast of the Sea of Japan by the Koyama-gawa, a canal of about 4 km in length. The chlorinity of the lake water was about 400 mg, in September of 1954 and 500–600 mg/l during the period from May to August, in 1955. The greater part of the lake basin is shallow and flat, being roughly 2–4 meters deep, except for part of the channel where the maximum depth reaches beyond 8 meters.

Lake Tôgô-ike is a mesohaline lake of low degree in Tottori Prefecture, lying near the coast of the Sea of Japan. The depth of the basin is about 2 meters for the greater part, but in the central part, there is a remarkable depression of spring-funnel where the maximum depth reaches 7.5 meters (Yoshimura, 1929).

Pond A and B, Isizu, are small ponds without any inlet and outlet, lying near the estuary of the Isizu-gawa, Osaka Prefecture.

Lake Abura-ga-huti is a brakcish-water lake in Aiti Prefecture. According to the study carried out by M. Sugiura and O. Nakajima (MS), by whom the materials in the present study were given, a very remarkable stratification of the lake water was observed, the chlorine content markedly increasing in the layer deeper than 2

meters.

Plankton Fauna Observed

The plankton faunae observed by the writer in the respective waters are as follows (* means that the occurrence of the species was very narrowly limited):

Lake Kahoku-gata (1946-1951)

Sinocalanus tenellus, Pseudodiaptomus inopinus, Paracyclopina nana, Oithona sp.*, *Limnoncaea genuina; Brachionus plicatilis, Keratella cochlearis* var. *tecta**, *K. cruciformis* var. *eichwaldi, K. valga.*

Lake Otsi-gata (1949-1950)

*Sinocalanus tenellus, Acanthodiaptomus pacificus**, *Eodiaptomus japonicus, Pseudodiaptomus inopinus, Eucyclops serrulatus, Mesocyclops leuckarti, Thermocyclops hyalinus, Th. taihokuensis, Paracyclopina nana, Oithona* sp., *Limnoncaea genuina; Diaphanosoma brachyurum, Daphnia longispina, Scapholeberis mucronata, Ceriodaphnia rigaudi, Moina dubia, Bosmina longirostris, Bosminopsis deitersi, Alona rectangula, Chydorus sphaericus; Asplanchna sieboldi, Synchaeta* sp., *Filinia longiseta, Polyarthra trigla, Trichocerca* sp.*, *Trichotria* sp.*, *Euchlanis dilatata, Lecane acronycha**, *L. luna, Monostyla furcata**, *Corurella obtusa**, *Lepadella* sp.*, *Pompholyx complanata, Brachionus angularis, Br. calyciflorus, Br. falcatus, Br. quadridentatus, Br. quad.* var. *entzii, Br. rubens, Br. urceolaris**, *Platyias patulus, Pl. quadricornis, Keratella cochlearis, K. valga, Pedalia mira.*

Lake Imae-gata (1946, 1949)

*Sinocalanus tenellus, Pseudodiaptomus inopinus, Mesocyclops leuckarti, Thermocyclops taihokuensis; Diaphanosoma brachyurum, Bosminopsis deitersi**; *Brachionus angularis, Br. forficula, Br. plicatilis, Schizocerca diversicornis**, *Keratella cochlearis**.

Lake Kiba-gata (1946, 1949)

*Sinocalanus tenellus**, *Acanthodiaptomus pacificus, Pseudodiaptomus inopinus, Limnoncaea genuina**, *Paracyclopina nana**, *Eucyclops serrulatus, Thermocyclops taihokuensis; Sida crystallina, Diaphanosoma brachyurum, Bosmina longirostris, Bosminopsis deitersi, Pleuroxus trigonellus, Chydorus sphaericus, Dunhevedia crassa; Asplanchna brightwelli, Asp. sieboldi, Polyarthra trigla, Euchlanis dilatata, Lepadella* sp., *Brachionus forficula, Br. plicatilis**, *Schizocerca diversicornis, Platyias patulus, Keratella cochlearis, K. c.* var. *tecta, K. valga, Pedalia mira.*

Lake Sibayama-gata (1946, 1949)

Acanthodiaptomus pacificus, Pseudodiaptomus inopinus, Mesocyclops leuckarti, Thermocyclops hyalinus, Th. taihokuensis; Sida crystallina, Diaphanosoma brachyurum, Bosmina longirostris, Bosminopsis deitersi, Alona quadrangularis, Graptoleveris testudinaris, Chydorus sphaericus, Dunhevedia crassa; Asplanchna sieboldi, Polyarthra trigla, Diurella stylata, Trichocerca sp., *Euchlanis dilatata, Lecane luna, Corurella obtusa, Testudinella patina, Brachionus calyciflorus, Br. forficula, Br. plicatilis**, *Br. quadridentatus, Schizocerca diversicornis, Platyias patulus, Keratella cochlearis, K. c.*

var. *tecta, K. valga, Anureopsis fissa, Pedalia mira.*

Ryujin-ike, a pond in the islet Hegura-jima (3/VIII/1948)

Paracyclopina nana, Halicyclops sp.** *Idya ?* sp*.; *Moina rectirostris ; Lecane hegurensis****, *Pedalia fennica.*

Nameless pool, Hegura-jima (3/VIII/1948)

Brachionus plicatilis

Lake Hôshôzu-gata (1948, 1949, 1952)

Sinocalanus tenellus, Pseudodiaptomus inopinus, Mesocyclops leuckarti, Paracyclopina nana, Limnoncaea genuina, Oithona sp*., *Laophonte* sp*.; *Diaphanosoma brachyurum, Scapholeberis mucronata, Moina rectirostris, M. dubia, Bosmina longirostris, Chydorus sphaericus, Penilia schmackeri*; Oikopleura* sp*.; *Asplanchna brightwelli, Asp. sieboldi, Brachionus plicatilis, Br. angularis, Br. calyciflorus, Notholca acuminata.*

Lake Kita-gata (1951, 1952)

Sinocalanus tenellus, Pseudodiaptomus inopinus, Paracyclopina nana, Limnoncaea genuina ; Diaphanosoma brachyurum ; Brachionus angularis, Br. calyciflorus, Br. plicatilis, Keratella valga, Filinia longiseta.

Lake Koyama-ike (1954-1955)

Sinocalanus tenellus, Pseudodiaptomus inopinus, Mesocyclops leuckarti, Thermocyclops hyalinus, Th. taihokuensis, Eucyclops serrulatus, Paracyclopina nana, Limnoncaea genuina ; Sida crystallina*, Diaphanosoma brachyurum, Bosmina longirostris, Chydorus sphaericus; Asplanchna herricki, Trichocerca rattus*, Lecane* sp.*, *Mytilina* ventralis*, Platyias quadricornis*, Polyarthra trigla*, *Keratella cruciformis* var. *eichwaldi, K. valga, K. cochliaris, Pedalea mira ; Ceratium hirundinella.*

Lake Tôgô-ike (1954, 1955)

Sinocalanus tenellus, Pseudodiaptomus inopinus, Paracyclopina nana, Limnoncaea sp.; *Diaphanosoma brachyurum: Brachionus angularis, Br. plicatilis, Filinia longiseta, Keratella cruciformis* var. *eichwaldi, K. valga.*

Isizu, pond A (1954)

Sinocalanus tenellus ; Brachionus plicatilis.

Isizu, pond B (1954)

Thermocyclops taihokuensis ; Daphnia pulex, Moina sp., *Chydorus sphaericus ; Brachionus calyciflorus.*

Lake Abura-ga-huti (1951-1952)

Sinocalanus tenellus, Pseudodiaptomus inopinus ; Diaphanosoma brachyurum, Moina dubia ; Asplanchna sieboldi, Brachionus plicatilis, Platyias quadricornis, Keratella valga.

** This was recently found by T. ITO in the writer's collection, and it will be described as a new species by him.

***This species was described as a new by K. YAMAMOTO (1951), having been found in the writer's collection.

Remarks on the Species

Copepoda

Sinocalanus tenellus (Kikuchi). This species was first described by Kikuchi (1928) under the name of *Limnocalanus sinensis* var. *tenellus* as occurring in L. Sibayama-gata, and later, was recognized as a distinct species of the present genus by Smirnov (1929, 1932). There is a number of records reporting the occurrence of *Limnocalanus sinensis* in Japanese brackish-waters, but they have all to be revised as *S. tenellus*.

S. tenellus is one of the most predominant forms in Japanese brackish-waters, being found most abundantly in water of a chlorinity usually from about 1.0 to 3.5 g/l. According to the writer's observations, the occurrence of this species seems to diminish more or less remarkably when the chlorinity becomes more than 3.5 or less than 1.0 g/l and it is markedly rare in waters of which the chlorinity is more than 8 g/l or less than 0.5 g/l.

Eodiaptomus japonicus (Burckhardt). This species was abundantly found in L. Otsi-gata on July 14 and Oct. 23 in 1949, but the salinity at that time was not measured. Kikuchi (1928, 1936) reported this species from two brackish-water lakes in Hukui Prefecture, L. Suigetu-ko and L. Mikata-ko.

Acanthodiaptomus pacificus (Burckhardt). Two species of this genus, *A. pacificus* and *A. yamanacensis* (Brehm), have hitherto been known in Japan. In recent years, however, they have generally been regarded as synonumous and the writer, therefore, adopts here the name *pacificus* for its priority. This species seems to be able to live in the water where the chlorinity is less than 100 mg/l in usual.

Pseudodiaptomus inopinus Burckhardt and *Ps. japonicus* Kikuchi. Three species of this genus have hitherto been recorded from Japanese inland waters. However, the present writer is of the opinion that it may be very difficult to distinguish *Ps. japonicus* from *Ps. inopinus* (Mashiko and Inoue, 1952). The third species, *Ps. forbesi* Poppe *et* Richard, was once reported by Kikuchi (1928) as occrring in L. Sibayama-gata without any description. The identification seems to have been done only by the female specimen. This may be a form endemic to the fresh-waters of the Yangtse-kiang region, Central China, and according to the later study of the present writer, this record seems to be very questionable (Mashiko and Inoue, 1952).

Ps. inopinus is a typical brackish-water form, being widely distributed in Central China (Burckhardt, 1913; Tsuge *et al.*, 1939), Siberia (Smirnov, 1929), and Japan. This species has occasionally been found in waters which can be regarded as fresh-water, such as the lowermost reaches of the Yangtse-kiang, Central China, and Lake Kasumi-ga-ura, Japan (Brehm, 1925; Kokubo, 1944). The salinity, however, at the very stations where the plankton collections were made is not always exactly known.

In any case, this species has been found only in the water bodies which are situated near the sea, having more or less connection with it. In the Yangtse-kiang,

this species is found only in the lowermost reaches of the river, while the closely related species, *Ps. forbesi*, occurs even in the inland areas far from the sea (MASHIKO, 1951).

Paracyclopina nana SMIRNOV. This species seems to be distributed, so far as is known at present, only in the coastal regions of the surrounding territories of the Sea of Japan (SMIRNOV, 1935: MASHIKO and INOUE, 1952; MASHIKO, 1954). The optimum range of the salinity of this species is apparently higher as compared with *S. tenellus*.

Mesocyclops leuckarti (CLAUS). This species seems to have a comparatively high ability to adapt to the brackish-water. It was often found in waters where the chlorinity was about 500–600 mg/l, and occasionally met with even in waters where it reached beyond 1 g/l.

Thermocyclops hyalinus (REHBERG) and *Th. taihokuensis* (HARADA). These two species have rather high adaptability to the brackish-water, being often found in waters of a chlorinity from 200 to 300 mg/l and occasionally more than 600 mg/l.

Limnoncaea genuina KOKUBO. This seems to be a comparatively common one in Japanese brackish-waters, but the material in the writer's hand is not sufficient to give any conclusive result at present. Further study on the taxonomy of this species may also be needed.

Cladocera

Diaphanosoma brachyurum (LIÉVIN). This species was widely found not only in various oligohaline waters, but also was found rather commonly even in such mesohaline lakes as L. Kita-gata, L. Tôgô-ike, and L. Abura-ga-huti where the chlorinity ranged from 1.4 to 2.27, from 1.74 to 1.82 (surface), and from 0.33 (surface) to 12 (bottom) g/l, respectively. This cladoceran seems, accordingly, to be a remarkable euryhaline animal, having a conspicuous ability of osmoregulation.

Bosmina longirostris (O. F. MÜLLER). This species was very abundantly found in L. Koyama-ike where the chlorine content of the lake water was from about 400 to 600 mg/l, especially in the period from summer to autumn.

Bosminopsis deitersi RICHARD. This species was found in L. Otsi-gata, L. Kiba-gata, and L. Imae-gata. In L. Kiba-gata, it was found abundantly in the part of 57 mg/l chlorinity, and less abundantly in the part of 271 mg/l chlorinity, and in L. Imae-gata, it was rarely collected in the part of 1.53 (surface) to 2.73 (2m deep) g/l chlorinity. The individuals found in L. Imae-gata were probably those which had been derived from L. Kiba-gata through the canal connecting these two lakes.

Moina dubia DE GUERNE *et* RICHARD. In Eastern Asia, this species is rather widely known in Central China (UÉNO, 1944; MASHIKO, 1953), Formosa, Manchuria (UÉNO, 1940), and Southern Kyushu, Japan (UÉNO, 1947), and the writer and his coworkers (MASHIKO *et al.*, 1951) found it in L. Otsi-gata and L. Abura-ga-huti. In the former lake, it was very abundantly found especially in the summer period of 1950,

when the chlorinity there ranged from 113 to 504 mg/l. UÉNO (1940) formerly recorded this species from the Muton River (an outlet of Dalai Nor, a salt lake in Manchuria). From these facts, this species seems to possess an ability to live in brackish-water of a certain degree, at least up to about 500 mg/l in chlorinity.

Moina rectirostris LEYDIG. A few specimens which were recognizable as this species were found in the collection of Ryujin-ike, a pond in Hegura-jima, together with the typical brackish-water forms such as *Paracyclopina nana* and *Pedalia fennica*. The chlorinity of the pond water was 5.73 g/l at that time. This species was also met with in L. Hôshôzu-gata, and UÉNO (1940) recorded its occurrence in Dalai Nor, a salt lake in Manchuria. Accordingly, it may be presumed that this cladoceran can occasionally occur in brackish-waters of considerably high salinity.

Dunhevedia crassa KING. According to DECKSBACH's study (1930), this species is a wide-spread form, having been found at 75 localities in the world before that time. In Eastern Asia too, we have the following several records of this species: Kwantung, Sonth China (SPANDL, 1925); Hangchow (UÉNO, 1944), Hankow and Riuchia (MASHIKO, 1953), Central China; Tsitsihar, Manchuria (UÉNO, 1940); L. Sibayama-gata and L. Kiba-gata, Japan (MASHIKO and INOUE, 1952).

BREHM (1914) pointed out that this species had a close relation with *Arctodiaptomus salinus* in its distribution. According to FADEEW, *D. crassa* was found in a salt-water lake (Solenoje-See) near Tiflis together with such forms as *Arctodiaptomus salinus*, *Brachionus plicatilis* and *Pedalia fennica* (cited from DECKSBACH, 1930).

Of three localities recorded from Central China, two, Hangchow and Hankow, are apparently of the fresh-water. In the case of Riuchia, this species was rather abundantly found in a small weedy drain by a hot spring. The temperature of the water there ranged from 34° to 38°C, but the salinity was not measured. The condition of the water in the case of Kwantung and Tsitsihar is uncertain.

In Japan, the writer and his coworker have found this species in L. Sibayama-gata and L. Kiba-gata, and these two lakes were both of very low salinity at that time. The adaptable range of *D. crassa* in salt water in Eastern Asia is accordingly difficult to presume at present.

Rotatoria

Brachionus plicatilis O. F. MÜLLER. This species is one of the most remarkable forms in the brackish-water fauna in Japan. In the present study, this rotifer was abundantly found in L. Kahoku-gata (Cl, up to 8.45 g/l), Isizu, pond A (8.8 g/l), a pool of Hegura-jima (3.3 g/l), and L. Kita-gata (1.40-2.27 g/l), but it was found very rarely in L. Tôgô-ike (1.7-1.8 g/l) and it was entirely missing in L. Otsi-gata (usually less than 0.5 g/l).

Br. calyciflorus PALLAS. This species was abundantly found in L. Kita-gata, Isizu pond B, L. Otsi-gata, and L. Sibayama-gata. The predominant occurrence especially in L. Kita-gata suggests that this rotifer is a remarkably halophilous form.

Br. angularis GOSSE. This species was found in L. Imae-gata, L. Kita-gata, L. Tôgô-ike and L. Otsi-gata. Judging from the fact that it was abundantly collected in L. Imae-gata and L. Tôgô-ike, this species seems to be able to live in a chlorinity of about 2 g/l. HADA (1939) recorded this species from L. Harutori-ko, L. Koyama-ike and L. Sindi-ko.

Asplanchna sieboldi (LEYDIG). This species was found in L. Otsi-gata, L. Kiba-gata, and L. Abura-ga-huti.

Asp. herricki DE GUERNE. This species was often rather commonly found in L. Koyama-ike.

Keratella cruciformis (THOMPSON) var. *eichwaldi* LEVANDER. In the present study, this brackish-water rotifer was found only in L. Kahoku-gata, L. Koyama-ike, and L. Tôgô-ike. However, this was recorded by HADA (1939) from many brackish-waters in Japan. According to him, it occurred in waters ranging from 1.8 to 13.0 ‰ in salinity, the optimum being about 2-4 ‰.

HADA recorded this variety from the following nine brackish-waters in Japan: L. Hikiusu-numa, L. Onne-numa, L. Hijirippu-numa, the estuary of the Oboro-gawa, L. Harutori-ko, L. Mokoto-numa, L. Hamana-ko, L. Koyama-ike, L. Sindi-ko.

K. valga (EHRENBERG). This species was found in L. Kahoku-gata, L. Otsi-gata, L. Sibayama-gata, L. Kiba-gata, L. Kita-gata, L. Koyama-ike, L. Tôgô-ike, and L. Abura-ga-huti. In Kita-gata, it was rather abundantly found together with such rotifers as *Br. plicatilis*, *Br. calyciflorus*, and *Br. angularis* when the chlorinity of the lake water was 2.00-2.27 g/l, and in L. Tôgô-ike, this species commonly occurred together with *K. c.* var. *eichwaldi*. Most of the specimens found in the writer's study belonged to *f. tropica*.

Notholca acuminata (EHRENBERG). This species was found only in L. Hôshôzu-gata in the present study, but it was already recorded by HADA (1939) from the following six brackish-waters in Japan: L. Bettobu-numa, L. Hikiusu-numa, L. Hijirippu-numa, the estuary of the Oboro-gawa, L. Harutori-ko, L. Hamana-ko.

Pedalia fennica LEVANDER. This species is well known as a salt water rotifer, but, in Japan, it has been recorded by the writer only from Ryujin-ike which is a small and shallow pond in Hegura-jima, an isolated islet in the Sea of Japan. A vast number of this species was found in the pond in 1948 (MASHIKO, 1951), but in 1951, none of the plankton organism was found there. This phenomenon may have taken place owing to the large amount of hydrogen sulphide which had already been observed in the deeper layer of the pond water in 1948.

The closely related species, *P. mira*, was widely found in many oligohaline waters in the writer's study.

Discussion

The plankton fauna in brackish-waters contains both the endogenetic and allogenetic forms. Here, the endogenetic forms mean those which can maintain their population

for a certain durtain of time in the brackish-water environment. The allogenetic forms are temporary migrants derived from sea or fresh-waters.

In Japanese brackish-waters, generally speaking, the plankton fauna may be most characteristic as a brackish-water fauna when the chlorinity of the water is in the range from about 1 to 10 g/l, being sharply distinguished from the marine as well as the fresh-water ones. The forms which are found mainly in the waters of this range may accordingly be regarded as the typical brackish-water forms. This range of chlorinity falls within the mesohaline brackish-water of REDECKE*.

The plankton fauna of the waters where the chlorinity is always more than 10 g/l over nearly the whole area consists mainly of marine forms with adaptability to the lower salinity, and such waters have been excluded from the object of the present study. Some marine diatoms, shch as *Chaetoceros*, were occasionally observed to occur in striking abundance in waters of relatively low salinity as about 5 g/l in Cl. However, in the case of plankton animals, such a phenomenon was not observed except for the temporary migrants from the sea.

In the waters where the maximum chlorine content is less than 50 mg/l, it may be difficult to recongnize any distinct difference in the composition of the plankton faunae found there according to the salt content. When the chlorinity is in the range from 50 to 100 mg/l, the fauna found there generally consists of common fresh-water forms, but it is more or less limited in the number of species. In waters where the chlorinity scarcely reaches beyond 500 mg/l, the forms found there are much more narrowly limited, but the occurrence of the typical brackish-water forms is as yet very rare. If the minimum chlorinity rises beyond 1 g/l, the plankton fauna is very narrowly restricted in its composition. The forms found there more or less abundantly are characteristic euryhaline ones, and the dominant forms of the fauna are always the typical brackish-water ones.

In the writer's study, the following copepods and rotifers were found to belong to the typical brackish-water form occurring mainly in waters where the chlorinity was always more than 1 g/l.

Sinocalanus tenellus, Pseudodiaptomus inopinus, (Ps. japonicus), Paracyclopina nana, Limnoncaea genuina ; Brachionus plicatilis, Keratella cruciformis var. *eichwaldi, Notholca acuminata, Pedalia fennica, (Lecane hegurensis).*

S. tenellus, Ps. inopinus and *Br. plicatilis* are the representative forms in Japanese brackish-waters, occurring widely and very commonly. *P. nana* is sometimes found very abundantly, but its distribution seems to be limited to the coastal regions of the Sea of Japan, so far as known at present. *L. genuina* seems to be distributed widely but it does not occur very abundantly in general. *K. c.* var. *eichwaldi* also

* REDECKE (1922) has divided the brakish-waters in Holland into three types, viz., the oligohaline water (Cl : 0.1 - 1.0 g/l), the mesohaline water (Cl : 1.0 - 10 g/l) and the polyhaline water (Cl: more than 10 g/l) (cited from THIENEMANN, 1926).

seems to be a wide-spread rotifer in Japanese brackish-waters. Two rotifers, *P. fennica* and *L. hegurensis*, were found only in Hegura-jima, an isolated islet in the Sea of Japan.

Besides these typical brackish-water forms, there is a number of remarkable euryhaline forms which seem to have considerably high ability to adapt themselves to the brackish-water, being often important constituents of the fauna. The following cladocerans and rotifers were found to belong to this group:

Diaphanosoma brachyurum, (*Dunhevedia crassa*); *Brachionus angularis*, *Br. calyciflorus*, *Keratella valga*.

Except for *D. crassa*, these species were often and more or less abundantly found in various brackish-waters and even in the waters of more than 2 g/l chlorinity such as L. Kita-gata, L. Imae-gata, L. Hôshôzu-gata, L. Tôgô-ike, and L. Abura-ga-huti. In Japan, *D. crassa* has been found only by the writer in L. Kiba-gata and L. Sibayama-gata where the salinity was very low, but this cladoceran has often been recorded from brackish-water together with other typical brackish-water forms such as *Arctodiaptomus salinus*, *Brachionus plicatilis*, or *Pedalia fennica* (DECKSBACH, 1930).

Next to this group, there is another group of species which has the adaptability to a certain degree to the brackish-water environment, and is found sometimes very abundantly in waters of low salinity such as L. Otsi-gata or L. Koyama-ike. Among them, the forms which were frequently met with in water having chlorinity of about 500-600 mg/l are as follows:

Eodiaptomus japonicus, *Mesocyclops leuckarti*, *Thermocyclops hyalinus*, *Th. taihokuensis*, *Eucyclops serrulatus*; *D. pulex*, *Moina dubia*, (*M. rectirostris*), *Bosmina longirostris*, *Bosminopsis deitersi*; *Asplanchna herricki*, *Asp. sieboldi*, *Brachionus forficula*, *Br. quadridentatus*, *Schizocerca diversicornis*, *Filinia longiseta*, *Polyarthra trigla*, *Keratella cochlearis*, *Pedalia mira*.

Some of these species, *e.g.*, *M. leuckarti*, *Br. forficula* or *F. longiseta*, were occasionally met with in waters where the chlorinity reached beyond 1 g/l. It may also be possible that *F. longiseta* belongs to the second group mentioned before, since this rotifer has been collected in such lakes as L. Kita-gata, L. Tôgô-ike and L. Otsi-gata, though not abundantly.

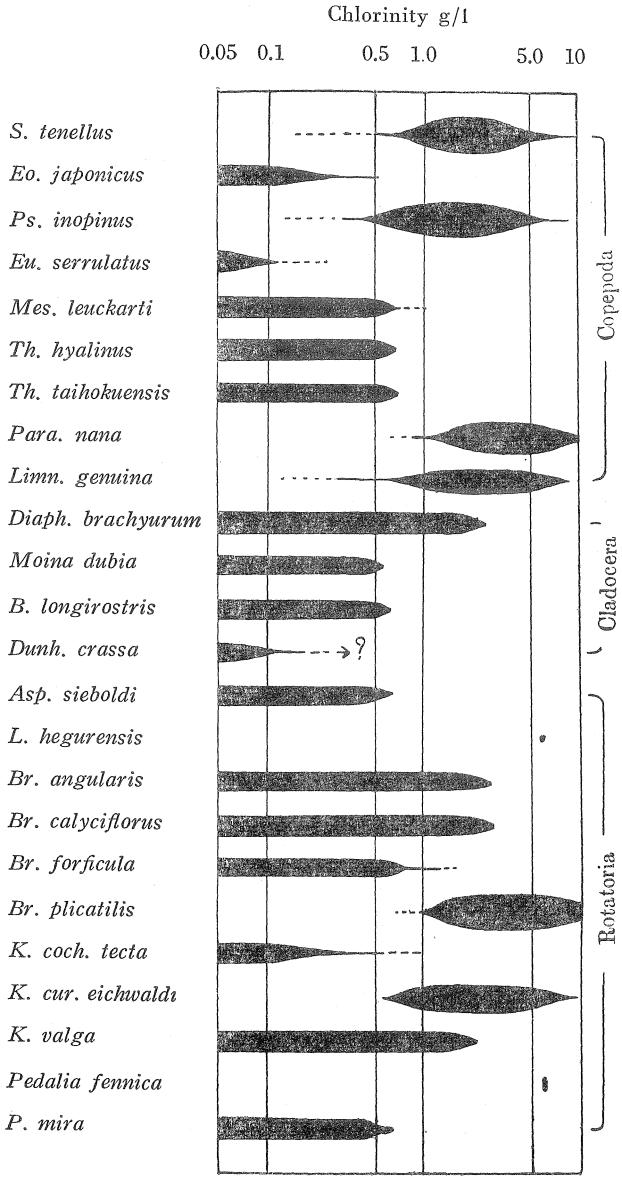
Finally, there is a group of plankton animals which is rather commonly found in waters of a chlorinity more than 50 mg/l but scarcely reaching 100 mg/l. The following forms were found to belong to this group in the writer's observation:

Acanthodiaptomus pacificus; *Asplanchna brightwelli*, *Euchlanis dilatata*, *Lecane luna*, *Platyias patulus*, *Pompholyx complanata*.

Forms other than those mentioned above were not found in sufficient number, so that it is difficult to make a presumption on the range of their adaptability to the brackish-water, at present.

The presumable ranges of chlorinity in which the principal forms are found in their usual condition may be as shown in Fig. 1. And thus, the result as seen in Fig. 2 may be obtained, showing the relation between the chlorinity and the principal components of the fauna found there.

Fig. 1



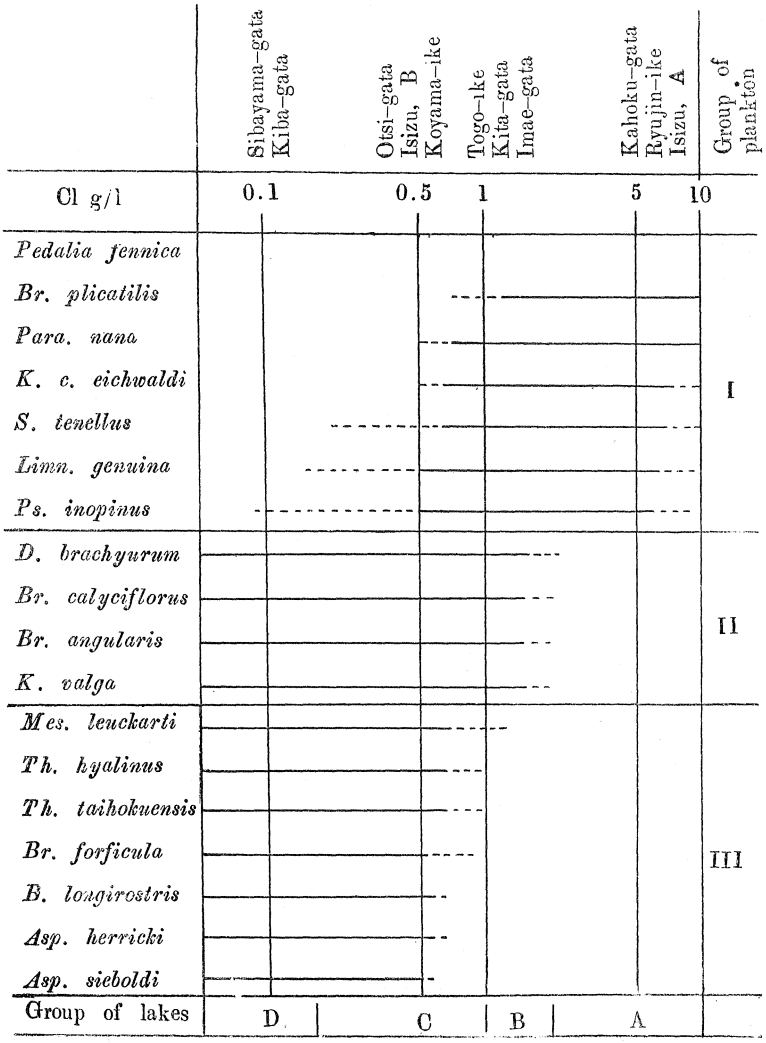


Fig. 2

Summary

1. The present paper deals with a general consideration of the plankton fauna of the brackish-waters in Japan, especially on the relation between the salinity of the waters and the plankton fauna found there.

2. The plankton animals in brackish-waters are divided into the endogenetic forms and allogenetic forms. Here, the endogenetic forms mean those which can maintain their population for a certain duration of time in the brackish-water environment.

3. The plankton fauna of the brackish-waters in Japan is most characteristic when the chlorinity of the water ranges from about 1 to 10 g/l, being sharply distinguished from the marine as well as the fresh-water ones. In the writer's

investigation, the following copepods and rotifers were found to belong to this group:

Sinocalanus tenellus, Pseudodiaptomus inopinus, (Ps. japonicus), Paracyclopina nana, Limnoncaea genuina; Brachionus plicatilis, Keratella cruciformis var. *eichwaldi, Notholca acuminata, Pedalia fennica.*

4. Besides these typical forms mentioned above, there is a number of species which are often important constituents of the brackish-water fauna in Japan. They are widely distributed in fresh-waters but likewise occur in brackish-waters of lower salinity. Their adaptable range reaches beyond 2 g/l in chlorinity. The following cladocerans and rotifers were found to belong to this group:

Diaphanosoma brachyurum, (Dunhevedia crassa); Brachionus angularis, Br. calyciflorus, Keratella valga.

The distribution of *D. crassa* in brackish-waters in Eastern Asia, however, is not ascertained at present.

5. Next to the above mentioned group, there is another group of species which are found commonly in fresh-water and often or occasionally occur in oligohaline waters. Their adaptable range of chlorinity reaches up to 600 mg/l or more. The following forms may be included in this group:

Eodiaptomus japonicus, Mesocyclops leuckarti, Thermocyclops hyalinus, Th. taihokuensis, Eucyclops serrulatus; Daphnia pulex, Moina dubia, Bosmina longirostris, Bosminopsis deitersi; Asplanchna herricki, As. sieboldi, Brachionus forficula, Br. quadridentatus, Schizocerca diversicornis, Keratella cochlearis, Filinia longiseta, Polyarthra trigla, Pedalia mira.

It may be possible that *F. longiseta* belongs to the 2nd group mentioned above.

6. When the chlorinity is more than 10 g/l, the plankton fauna found there mainly consists of marine forms with adaptability to lower salinity.

7. The presumable ranges of chlorinity in which the principal forms are found are as shown in Fig. 1. And thus, the result as seen in Fig. 2 may be obtained, showing the relation between the chlorinity and the dominant forms found there.

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