

On the Geographical Distribution of Some Brackish- and Fresh-water

Copepods in and around Japan

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Introduction

Cosmopolitanism is one of the well-known features of the fresh-water plankton. Some copepods such as Calanoida of inland waters, however, are taken as a conspicuous exception, each species of them having more or less its own limited distribution. This characteristic feature of the geographical distribution of such copepods may be explained from the fact that the adaptation or migration of these species from sea to inland waters has taken place in an age comparatively recent.

From this point of view, our attention may be drawn to the brackish-water copepods, because they may be regarded as the important links connecting those in the fresh-waters with those in the sea.

In Japan, there are many brackish-water lakes or lagoons which are situated along the coast of the Pacific Ocean as well as the Sea of Japan and are connected with the sea by rivers or canals. These lakes are supposed to offer more or less convenience for the plankton animals to migrate from sea to inland waters (or *vice versa*). From a similar point of view, the Yangtse-kiang in Central China and many lakes connected with it may also be a matter of our great interest. Thus, the geographical distribution of a number of copepods found in these brackish- and fresh-waters in Japan and the adjacent territories arouses our special interest.

Remarks on the Principal Species

Gen. *Sinocalanus*. Two closely related species which belong to this genus are known at present. One of them is *S. mystrophorus* BURCKHARDT which is endemic to the Yangtse-kiang region of Central China, and the other is *S. tenellus* (KIKUCHI) which is found in various brackish-waters in the territories surrounding the Sea of Japan.

S. mystrophorus was first found by BURCKHARDT (1913) in the lowermost reaches of the Yangtse-kiang, the River Sutschau-ho and Lake Tai-hu, and was also recorded later by TUGE and others (1949) from several stations of the lower reaches of the Yangtse-kiang (Wusung, Kiang-in, Chinkiang and Nanking). The present writer (1951) found this species even in such a remote inland region as Hankow (the Yangtse-kiang and four lakelets in the suburbs of the city) as well as Lake Tungting-hu which is situated about 1,000 km away from the river mouth.

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S. tenellus, on the other hand, is one of most typical brackish-water copepods abundantly found in most brackish-water lakes in Japan. According to the writer's studies (1952) on the brackish-water lakes in the Hokuriku District, Japan, this species is commonly found in the waters of which the chlorinity ranges from about 500 to 5,000 mg/L, but rarely met with in waters less than 200 or more than 8,000 mg/L in chlorinity. This species, however, was reported to be commonly found in Lake Kasumi-ga-ura which is situated near the Pacific coast of Ibaraki Prefecture and is generally recognized as a fresh-water lake. *S. tenellus* has also been reported from Siberia (SMIRNOV, 1929), Sachalin (RYLOV, 1932; UENO, 1935, 1936) and the Kurile Islands (KIKUCHI, 1933).

In 1932, SMIRNOV divided this species into two subspecies, *insulanus* and *continentalis*. The former is the form found in the Japanese Islands and the latter is that in the Suifun River.

Gen. *Eodiaptomus*. In 1913, BURCKHARDT described two closely allied species of this genus, *E. sinensis* and *E. japonicus*, as occurring in Central China and in Japan, respectively.

The former, *E. sinensis*, was first found in the material from the River Sutschau-ho near Shanghai by BURCKHARDT, and later TUGE and others (1939) found it in their collections from the Yangtse-kiang, ranging from Wusung to Nanking. And recently, the writer also reported the occurrence of this species in his collections from the Yangtse-kiang at Hankow and Kiukiang, and that from Lake Tungting-hu (MASHIKO, 1951). Judging from these records, *E. sinensis* seems to be distributed in the Yangtse-kiang and its tributaries, ranging from the lowermost part to such an inland region as Tungting-hu.

E. japonicus, on the other hand, was first described by BURCKHARDT from Lake Biwa-ko, Middle Japan, and afterwards it was found in various fresh-water as well as brackish-water lakes in Japan such as L. Biwa-ko, L. Suigetsu-ko, L. Mikata-ko, L. Suga-ko (KIKUCHI, 1929, 1936), L. Kasumi-ga-ura (BREHM, 1925), L. Otsi-gata (MASHIKO et INOUÉ, 1952), L. Abura-ga-huchi (MS) and in small ponds in the vicinity of Otsu, Kyoto, Osaka, Akashi and Takamatsu (KIKUCHI, 1928, 1936).

Judging from these facts, *E. sinensis* may be presumed to be almost entirely a fresh-water form, while *E. japonicus*, though not a typical brackish-water form, is found in fresh- as well as brackish-waters.

Gen. *Pseudodiaptomus*. Among many species hitherto known, most of the species are found in brackish-waters; and a small number of them is known to occur in brackish-water and fresh-water or fresh-water only. In Eastern Asia, three species of this genus have been recorded, *viz.*, *Ps. inopinus* POPPE et RICHARD, *Ps. forbesi* BURCKHARDT and *Ps. japonicus* KIKUCHI.

Ps. forbesi was first described by BURCKHARDT (1913) as occurring in the Yangtse-kiang. According to later studies, this species is found in this river, ranging from the

lower part to comparatively upper reaches. In 1928, KIKUCHI reported an occurrence of this species in Lake Shibayama-gata, Ishikawa Prefecture, Japan. This is the only record of this species' being found in any other locality than the Yangtse-kiang region. In his case, however, the identification seems to have been made by female specimens only. In spite of many collections made over the past several years, none of this species has been found by the present writer, though *Ps. inopinus* was often met with (MASHIKO et INOUÉ, 1952).

Ps. inopinus is widely distributed in Central China, Siberia and the Japanese Islands. This species is one of the commonest ones in the brackish-waters in Japan, but it seems to be found sometimes even in the fresh-waters which lie near the sea coast. In the Yangtse-kiang, Central China, this species is found only in the lowermost reaches of the river, but, so far as known at present, is never found in the inland region,

Ps. japonicus was first described by KIKUCHI (1928) and it is a species closely related to *Ps. inopinus*, but according to the writer's study (MASHIKO et INOUÉ, 1952), it seems very difficult to distinguish these two species from each other, because the thickness of the furcal spines of these species are sometimes very variable and the differences in other characters are also often very indistinct.

Paracyclopina nana SMIRNOV. Besides such Calanoida as stated above, there are some other copepods which are found in brackish-waters in Eastern Asia. BURCKHARDT (1913) described two Cyclopoid copepods, *Cyclops* (*H.*) *aquoreus* (= *Halicyclops sinensis* KIEFER) and *Oithona* (*L.*) *sinensis* (= *Limnoithona sinensis* (BURCKHARDT) KIEFER), as occurring at the lowermost part of the Yangtse-kiang.

In recent years, *Paracyclopina nana* was known to occur very commonly in various brackish-waters in Japan. This small-shaped copepod was first described by SMIRNOV (1935) from the Suifun River, Siberia. So far as known at present, this species is found only in the brackish-waters in the peripheral region of the Sea of Japan, viz., many brackish-water lakes in Ishikawa, Hukui, Toyama and Aomori Prefecture in Japan (MASHIKO et INOUÉ, 1952). Such a geographical distribution of this species at present is supposed to have some close relation to the formation of the Sea of Japan as will be later discussed.

Discussion

In regard to the problem of the migration of animals from sea to inland waters, the following considerations may possibly be given. i) The brackish-waters at the estuaries of large rivers or lakes near the sea coast may be one of the most possible passages through which the marine animals migrate or adapt themselves to the inland waters. ii) When a species which has originally inhabited the sea migrates into inland waters, the physiological adaptation may bring with it more or less morphological changes.

And if the migration of the same species had taken place at different places, the morphological differentiations which occurred at respective places would be similar to each other, but not quite the same. Then, it will necessarily follow that closely allied races, varieties or species are found to be endemic in the surrounding district of the respective estuaries or places of that sort. iii) A form which is met with in a narrowly limited area near an estuary may be considered to be that which has adapted itself to the inland water in a more recent age than those which are found in a large inland area extending far from the sea.

The present geographical distribution of the principal copepods mentioned before in Eastern Asia and the division of the waters in which they occur are as seen in Table 1.

	Central China						Manchuria	Siberia	Sachalin	Japanese Islands	Fresh-water	Oligohaline	Mesohaline	Polyhaline
	Yangtse-kiang			Sutschau-ho R.	L. Tai-hu	L. Tungting-hu								
	Wusung	Nanking	Hankow											
<i>S. myrstophorus</i>	+	+	+	+	+	+					⊙			
<i>S. tenellus</i>							+	+	+	+		⊙	⊙	○
<i>Eo. sinensis</i>	+	+	+	+		+					⊙			
<i>Eo. japonicus</i>										+	⊙	○	?	
<i>Ps. inopinus</i>	+						+	+		+	?	○	⊙	
(<i>Ps. japonicus</i>)										+		○	⊙	
<i>Ps. forbesi</i>	+	+	+			+				?	⊙	?		
<i>Para. nana</i>							+	+	+			○	⊙	○

Table 1.

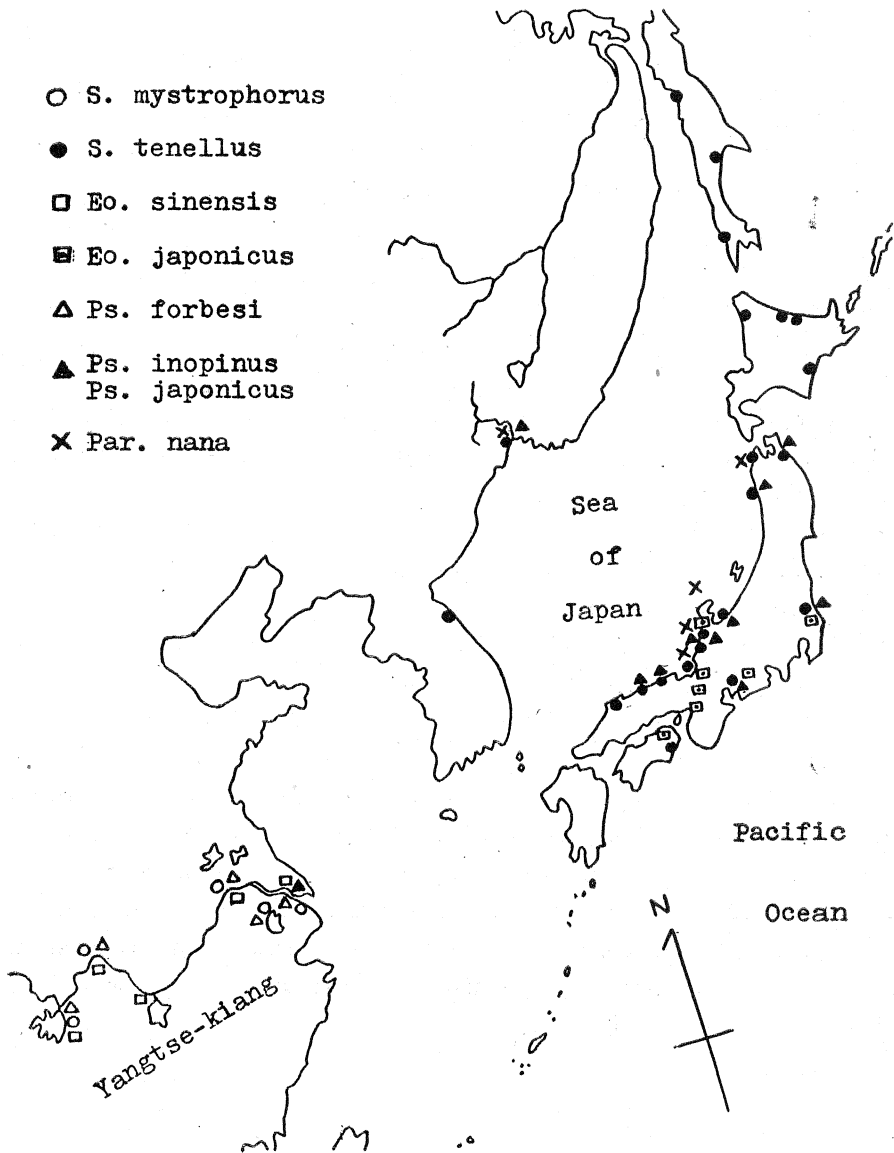
In the Yangtse-kiang region of Central China, *Ps. inopinus* is found only in the lowermost region, and *Ps. forbesi*, *S. myrstophorus* and *Eo. sinensis* are found in a wider area extending from Wusung to L. Tungting-hu. And, *S. myrstophorus* and *Eo. sinensis* (and probably *Ps. forbesi* too) are endemic to the Yangtse-kiang Valley. According to TUGE and others (1939), the chlorinity of the river water at the time when their collections were made is as shown in Table 2.

Thus, judging from the present geographical distribution, the order of the landward extension of these copepods from the sea may be arranged as follows:

Limnoithona sinensis, *Halicyclops sinensis* → *Ps. inopinus* → *Ps. forbesi* → *Eo. sinensis* → *S. myrstophorus*

In the territories surrounding the Sea of Japan, on the other hand, we may see a closely related and parallel but different series of copepods. Namely, there occur *S.*

tenellus instead of *S. mystrophorus*, *Eo. japonicus* instead of *Eo. sinensis* and, though a very questionable species, *Ps. japonicus* instead of *Ps. forbesi*. And it may be possible to correlate *Halicyclops sinensis* with *Paracyclopsina nana*. The Sea of Japan, therefore, seems to have played in this case the same rôle as the Yangtse-kiang in Central China. This fact may be explained by the assumption that the Sea of Japan must have remained in a brackish-water condition for a considerably long period in the



depth	Station		
	Wusung	Nanking	Wuhu
0 m	4.31	3.81	4.20 mg/L
10 m	3.99	3.56	4.48 mg/L

Table 2. The chlorinity of the Yangtse-kiang (TUGE, KOKUBO and IMAI, 1939)

early stage of its formation, offering a convenient environment to the migration of animals. *Ps. inopinus*, however, is widely found in the areas near the sea coast in both regions. In regard to this fact, a further discussion will be given later.

Conclusion

In Eastern Asia, a number of copepods are found in the brackish-waters which have connections with the sea directly or indirectly, having more or less its own limited geographical distribution. From the view point of the migration of animals from sea to inland waters, these copepods may be considered as the important links connecting those of the fresh-water with their fellows in the sea. Two series of such copepods are observed in Eastern Asia, one in the Yangtse-kiang Valley, Central China, and the other in the territories surrounding the Sea of Japan. In this case, the Sea of Japan, in the early stage of its formation, seems to have played the same rôle as the estuary of the Yangtse-kiang in Central China.

These two series show an obvious parallelism, consisting of closely related species respectively. The order of the adaptation from sea to inland waters in these two series may presumably be as follows:

Yangtse-kiang: *L. sinensis*, *H. sinensis* → *Ps. inopinus* → *Ps. forbesi* → *Eo. sinensis* → *S. mystrophorus*

Sea of Japan: *P. nana* → *S. tenellus* → *Ps. inopinus* (*Ps. japonicus*) → *Eo. japonicus*

Among these copepods, *Ps. inopinus* only is widely found in the two regions of Central China and the surrounding territories of the Sea of Japan, but it occurs only in the zones near the sea, showing no wide landward extension of its distribution. BREHM (1930) is of the opinion that this species may have been widely distributed before the Japanese Islands were separated from the Asiatic Continent by the formation of the Sea of Japan. If it is true, *Ps. inopinus* must be considered to have adapted itself to the brackish-water in a very early age, and to have remained there for a long time, attempting little landward migration.

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