STUDIES ON THE GENUS *CHAETOCEROS* EHRENBERG FROM THE FISHING GROUND OF THE MACKEREL, *PNEUMATOPHORUS JAPONICUS* (HOUTTUYN), OFF THE SHANTUNG COAST FROM CHEFOO TO WEIHAI. PART II. AN ECOLOGICAL STUDY.

(Abstract)

S. P. Chu (*Huanghai Fisheries Research Institute, Ministry of Fisheries*)

Y. C. Kuo (*Institute of Marine Biology, Academia Sinica*)

The difference in the plankton composition in oceanic and coastal waters attracted the attention of scientists more than half a century ago. Thus Häckel (1890) devided planktonic organisms into oceanic and neritic species which occur in oceanic and coastal waters respectively. Then Schütt (1893), Cleve (1896, 1897a, 1897b, 1900) Aurivillius (1898) and Gran (1902) went a little further in using planktonic organisms for the identification of water masses. In the last twenty years both zooplankton (Russell, 1935; Fraser, 1952) and phytoplankton (Gran & Braarud, 1935; Braarud, Gaarder & Grøntved, 1953; Holmes, 1956) have been used rather extensively for similar purposes. The relationship of phytoplankton to fisheries has also been frequently reported and discussed (Bullen, 1908; Bearcey, 1885; Hardy, 1926; Savage, 1930; Savage and Hardy, 1935; Savage and Wimpenny, 1936; Henderson, Lucas and Fraser, 1936; Graham, 1938; Б. П. Монтейфель, 1955; Кагановский, 1955; Cushing, 1956). It is clear that ecological studies of marine phytoplankton have an important bearing on both hydrography and fisheries.

While carrying out the oceanographic investigation of the mackerel fishing ground off the northern coast of Shantung, special attention has been given to the distribution of phytoplankton which sometimes shew some relationship to the distribution of water masses and also of mackerel shoals (Chu, 1957) In the present report special reference is given to the distribution of the species of the Genus *Chaetoceros* and its bearing on hydrography.

Both sedimentation and net methods have been used in this investigation as mentioned in Part I of this paper. The sedimented material is not counted with the aid of a reverted microscope. The counting method described by Chu (1942) has been used for the sedimented material as well as the net material. In the net samples only the important species with largest number of cells is actually counted, while the cell number of other species and the total *Chaetoceros* cells are computed from their ratio (as percentage) to the number of cells of the species actually counted.

For those species the cells of which are rather large in size but small in number at the time of collection, the error in the sedimentation method is remarkable, as they may be present in one of the duplicate sedimentation samples and absent in the other. For such organisms vertical net haul often gives a more representative picture, though small organisms may not be collected; while the sedimentation method is particularly good for these small organisms. Each of these methods has its own advantages and disadvantages, and rather good results have been obtained by using both methods simultaneously. The samples for sedimentation were collected at the same time and the

same place where observations on temperature were made and samples for the determination of chlorenity were collected, so that comparison between the distribution of the species of *Chaetoceros* and hydrographical conditions can be made feasibly. The conclusions drawn here are, however, only tentative, as the investigation has been carried out only during the fishing season from April to July and, besides, the area investigated is so small.

1. The variation with time and space of the total number of cells of *Chaetoceros* in various regions of the mackerel fishing ground.

The variation of the total number of cells of *Chaetoceros* in various regions of the fishing ground is found to be in close connection with the distribution of water masses. Ordinarily the largest number of *Chaetoceros* cells occurs near the shore and consists mainly of the species of Subgenera *Monochromatophorus* and *Dichromatophorus* as well as the following species of the Subgenus *Polychromatophorus*: *Chaetoceros lorenzianus*, *Ch. compressus*, *Ch. castracanei*, *Ch. peruvianus* and *Ch. densus*. *Chaetoceros densus* and *Ch. peruvianus* have often been recorded as oceanic species, but they do also occur abundantly here in the near-shore water. The cells of *Ch. densus* is sometimes more abundant than those of any other species of the Genus *Chaetoceros*.

The dense population of *Chaetoceros* near the shore is sometimes greatly diluted by water masses pushing forward against the shore. For example, during the period from 11th to 15th of April, 1954, such a diluted region was distinctly formed south of 38°00′N along 122°00′E by the insertion from the central region of the northern part of the Yellow Sea of a tongue-shaped water mass into the near shore water (fig. 2). The salinity of this tongue-shaped water mass is higher than that of the near shore water and *Chaetoceros* cells here are very scanty in number. At this time cells of *Ch. convolutus* carried westward by the warm current in the north of the Shantung peninsula has not yet reached as far as 122°00′E, while the front line of *Ch. convolutus* is more or less coincide with the 7°C isothermal line reaching southward about 38°10′N.

The density of the whole *Chaetoceros* population in the area studied is the greatest during April and the first part of May, beginning to drop from the later part of May with a slight increase in Autumn. The proportion of the total number of cells of each species to the total number of *Chaetoccros* cells differs in different years and also in different times of the year.

2. Distribution of the species of Subgenera *Monochromatophorus* and *Dichromatophorus* in the mackerel fishing ground.

The *Monochromatophorus* species most frequently accountered in this fishing ground are *Ch. cinctus* and *Ch. affinis*, while *Ch. subsecundus*, *Ch. debilis*, *Ch. curvisetus* and *Ch. pseudocurvisetus* are also very common. The *Dichromatophorus* species often occuring in this area are *Ch. didymus*, *Ch. laciniosus*, *Ch. constrictus*, *Ch. vanheurckii* and *Ch. siamense*; the first mentioned species being most common. All these species are neritic many of them occurring abundantly in the nearshore water before and during the earlier part of the mackerel fishing season. The density of these *Chaetoceros* species here may increase remarkably under suitable conditions. Thus in 1954 in the region north of Chinshankong (金山港) the number of cells increased from 42 to 427 during the interval between two cruises carried out from April 11th to April 15th and from April 27th to May 5th. Here we have a good illustration of the influence of the movement of water masses on the distribution of *Chaetoceros*. The outside sea water pushing southward against the shore first devided the *Chaetoceros* community into two sections (fig. 3) during the period from the 11th to the 15th of April, then the eastern section north of Weihai was greatly diluted and scarcely noticeable (27/IV-5/V, 1954; fig. 4). At the same time, the western section of the dense *Chaetoceros* community centering about a point 37°50′N, 121° 50′E during the period from April 27th to May

5th was greatly scattered and diluted after May 17th. While another densely populated region near Chefoo Island (芝罘島) observed in May was later on diluted and pushed eastward by a water mass pushing against the shore. (Figs. 5 & 6)

The influence of the distribution and movement of water masses on the distribution of these species of *Chaetoceros* and the dilution effect were also observed here in the year 1955 (fig. 8). The material collected in 1956 and 1957 is being studied, and the result will be published later on.

The number of cells of these species is often greatly reduced in the later part of June. This obvious decrease of *Chaetoceros* cells is found to be due to dilution of the population and of the nutrients in sea water by the outside sea water. The precipitation of phosphates in the near-shore water caused by mixing with outside sea water with higher salinity as well as by the rise of water temperature is also an unfavourable effect for these neritic species. Sinking of *Chaetoceros* cells is a general phenomenon under these unfavourable conditions. Experiments are being carried on in order to show whether the rise of temperature itself can exert a direct disadvantageous influence on the growth of these species.

It is obvious that the distribution of these neritic species of *Chaetoceros* has a close relationship to the distribution and movement of water masses, and hence may be helpful in the study of hydrographical conditions in this coastal region. As the distribution of mackerel shoals is often closely related to the distribution of water masses, *Chaetoceros* distribution can also be useful in locating the region where concentrated mackerel shoals can possibly occur, especially during the period from the beginning of the fishing season to the time for optimum catching when the near-shore water is densely populated with these neritic species and the distribution of water masses can be detected by the distribution of *Chaetoceros* cells. Later on the number of *Chaetoceros* cells often decreases to such an extent that detection of the distribution and movement of water masses by the distribution of these cells becomes impossible.

3. Distribution of the species of Subgenus *Polychromatophorus*.

The two sections of this subgenus, *Achromatocerae* and *Chromatocerae*, differ not only morphologically, as discussed in Part I of this paper, but also ecologically. It is therefore abvisable to deal with their ecology separately.

(1) Section *Achromatocerae*. The five species of this Section found in this mackerel fishing ground and its vicinities all occur in the near-shore water. *Ch. decipiens*, though generally considered as oceanic, was found here occasionally in the near-shore water in very small number. The other four species, *Ch. lorenzianus*, *Ch. teres*, *Ch. nipponica*, and *Ch. compressus* are practically all neritic growing well in the near-shore region of the fishing ground.

Ch. lorenzianus, although frequently observed, never occurred in large numbers, usually much below 100 cells per litre of sea water. The effect of the distribution and movement of water masses on its distribution is however sometimes noticeable. For example, a water mass inserted into the near-shore water from outside pushing toward Chutao (岱島) divided distinctly the comparatively dense community of *Ch. lorenzianus* into two sections in the middle of April, 1954. The number of cells then decreased from 48 per litre in April to one cell per litre in May. In the year 1955 it was very scanty in the fishing ground all through the fishing season.

This species was considered by Cleve (1900) as temperate oceanic (Styli-plankton) occurring in waters with temperature varying from 11°C to 28.4°C and salinity 34.79 to 36.96. This temperature range does not differ very much from that of the mackerel fishing ground during the fishing season. But this species often occurs before the fishing season when the water temperature is much lower than this range. The mean

values of the surface temperature of each cruise carried out from April to July in four successive years, 1953 to 1956, being varied from 5.6° C(April 10th to 12th, 1956) to 25.0°C (July 28th to 29th, 1953). The range of salinity of this mackerel fishing ground is always much lower than Cleve's salinity range for this species, mean values of surface salinity of each cruise varying from 29.47 (26-29/VII, 1955) to 31.57 (10-12/IV, 1956) and those of bottom salinity varying from 30.93 (8-11/VII, 1953; 27/IV to 2/V and 17-22/V, 1955) to 31.74 (10-12/IV, 1956). Hence the temperature range for this species should be not less than 5.6°C to 28.4°C, and the salinity range, not less than 29.47 to 36.96.

Ch. teres occurred in this fishing ground rather late, and was not observed in noticeable number until July in 1954, with a comparatively dense region, 7 cells per litre of water, situated north of Chefoo Island (芝罘島).

Ch. nipponica appeared early before the fishing season reaching its maximum in the middle of April, 1954, 94 cells per litre, in the near-shore water near Weihai; then almost completely disappeared about the end of April, reappearing again in the middle of July at the end of the fishing season.

Ch. compressus occurred very widely in this fishing ground but not in large numbers. In the year 1954 it occurred in small numbers in April, not more than 2 cells per litre of sea water, reaching its maximum, 20 cells per litre, in the middle of May; then greatly decreased in number during June and nearly all cells dropped to the bottom layer in July. While in the year 1955 it appeared rather early in April and disappear in May.

This species has been considered as either oceanic (Cleve, 1900) or neritic (Gran, 1902). Evidently it can tolerate a wide range of salinity.

So far as shown by our data this section as a whole is not very valuable for the detection of the distribution of water masses in this fishing ground during the fishing season, as they did not occurred in large numbers during the fishing season. *Ch. lorenzianus* is the only species of this section which could be possibly helpful in this connection, but only occasionally and not so valuable as some species of the Section *Chromatocerae*.

(2) Section *Chromatocerae*. Six of the species here studied belong to this section. Two of them, *Ch. castracanei* and *Ch. eibenii* are neritic and four of them, *Chaetoceros densus*, *Ch. peruvianus*, *Ch. convolutus* and *Ch. coarctatus*, are generally considered as oceanic. *Ch. densus* and *Ch. peruvianus*, however, often grow in large numbers inside the Chefoo Wharf as well as in the near-shore region of the fishing ground, *Ch. densus* being often more abundant than *Ch. peruvianus*. *Ch. coarctatus* has been observed only occasionally in samples collected near Chefoo Island and only in small number, while the other five species are common and frequently observed in this fishing ground.

The distribution of *Ch. castracanei* is often comparable to the distribution of water masses, and obviously effected by the dilution and scattering influence of sea water masses (fig. 10). This species often occurs in large numbers all over this fishing ground from the very beginning of the fishing season, flourishing over the main part of it. The density of cells of this species can be effected unfavourably not only by outside sea water masses but also by the coastal current flowing out from Pehai Bay. This coastal current pushed the dense region of *Ch. castracanei* from the south of 38°00'N to the north of it during the period from May 22nd to June 8th, 1954.

Ch. eibenii was observed at the beginning of the fishing season in the year 1954, becoming abundant and wide spread before the end of May when the cells were up to 227 per litre in the surface water and 665 per litre in the bottom layer. At this time a diluted region was formed as a result of a outside sea water mass pushing south-

westward from the point 38°00′N, 122°00′E. The number of cells decreased in June particularly in the near-shore region where the coastal current flowing out from Pohai Bay greatly diluted the population of this species. Its density dropped to only three cells per litre in the most dense region in the middle of July. In the year 1955 this species did not occur so abundantly as in the year 1954.

Ch. densus often occurs very abundantly, being distributed nearly all over this fishing ground and lasting through nearly the whole fishing season. Its distribution can be correlated very well with the distribution and the movement of different water masses. It seems to be one of the most useful species to be studied in connection with hydrography and fisheries in this fishing ground.

Ch. peruvianus is also distributed very widely in this fishing ground lasting through the main part of the fishing season. It was very abundant in the year 1955, being up to 13,680 cells per litre (24-28/IV). Its distribution in this fishing ground may also have some connection with hydrographical conditions, but so far our data are not yet sufficient to make good correlations with hydrography.

Ch. convolutus usually occurs first in the northeastern region of the fishing ground and can be used possibly as an indicator for outside sea water during the first period of the fishing season.

These five species of Section Chromatoceraе, as mentioned above, deserve particularly further study from the point of view of fisheries. *Ch. convolutus* has the possibility to be used as an indicator for outside sea water early in the fishing season. *Ch. castracanei* and *Ch. densus* both occur almost all over this fishing ground in great number last through the main period of the fishing season and often have a good correlation in their distribution with hydrographical conditions. As a result of further investigation it may also be possible to get some correlation between the distribution of *Ch. peruvianus* and *Ch. eibenii* and hydrographical conditions.

The hydrographical data of this fishing ground are from the "Report of the Committee for Marine Fisheries Research in the Yellow Sea and Pohai Bay, 1954 & 1955 (In chinese, mimeograph).

Many thanks are due to the Research Institute of Marine Fisheries and Oceanography of the Soviet Union (BHNPO) for its library facilities available for the writing of this summary.