# Community and Distribution of Living Coccolithophores in the Yellow Sea and East China Sea

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Abstract: Based on the investigation and study on the community and distribution of Living coccolithophores (LC) in the Yellow Sea and East China Sea in summer and winter 2016. In summer, 21 species of LC were found in the survey area, and their dominant species were E. huxleyi, G. oceanica, U. tenuis and F. profunda. The cell abundance ranged from 0.023 to 1.762 × 104 cells/L, with an average of 0.284 × 104 cells/L. In winter, 20 species of LC were found in the survey area, and their dominant species were E. huxleyi, G. oceanica, F. profunda and U. tenuis. The abundance of LC ranged from 0.012 to 3.535×104 cells/L, with an average of 0.384×104 cells/L. This thesis investigated and analyzed the LC community and distribution in two seasons (summer and winter) of the Yellow Sea and East China Sea, which enriched the LC studies in the coastal seas of China and also provided the basic data for understanding carbon cycle and carbon flux in China Sea waters.

## 1 INTRODUCTION

Living coccolithophores (LC) refer to those who live in the sea today, with calcium carbonate shells at certain stages of life history, and play an important role in the marine ecosystem (Billard & Inouye, 2004). LC take a great part in the marine carbon cycle process, and as one of the most important producers in the marine ecosystem. With its unique carbonate counter pump and organic carbon pump, LC take a great part in the ocean's carbon cycle (Sun, 2007). So far, the community and distribution (especially vertical distribution) of LC is still not clear in China Sea. Based on the investigations of the communities and distribution of LC in the Yellow Sea and East China Sea in summer (20th July to 1st September) and winter (23th December to 5th February) in 2016, we made a report about the LC species composition, cell abundance, dominant species, horizontal distribution, vertical distribution, diversity index and evenness index from upper body water (0 ~ 200m). Lacking of internationally harmonized method for quantitative sampling and sample analysis, This study applied the polarizing microscope method (Bollmann et al., 2002) which is widely recognized internationally and can truly reflect quantitative information, and its description and analysis was made in order to provide reliable information on the basis of the study of LC community about distribution, and for China's coastal waters follow-up studies of carbon fluxes, coccolithophores calcification and its response to global climate change and other support.

## 2 SURVEY AREAS AND RESEARCH METHODS

### 2.1 The Survey Areas

This study was based on China's coastal waters investigation. Respectively, in summer (July 20 to September 1) and winter (December 23 to February 5th) of China Sea waters (27.00 ° ~ 36.50 ° N, 121.50 ° ~ 127.00 ° E), including water chemistry, chemical and biological, with a comprehensive field investigation nested two quarters of the month. In summer and winter, 17 and 19 survey sampling stations were set up in the survey areas (Figure 1, Figure 2). Meanwhile, there were four sections (section 1, section 2, section 3, section 4) located in the survey area. The information of sampling stations was listed in Table 1 and Table 2. LC samples were collected from the surface (~ 2 m) below the natural



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water by using CTD, and then poured into the sea to get a 1L polyethylene bottle, immediately adding the right amount of weakly alkaline solution of formalin, making the concentration of formaldehyde in the sample of 1% to 2% (Sun, 2007). Temperature and salinity were determined by the ship's CTD.

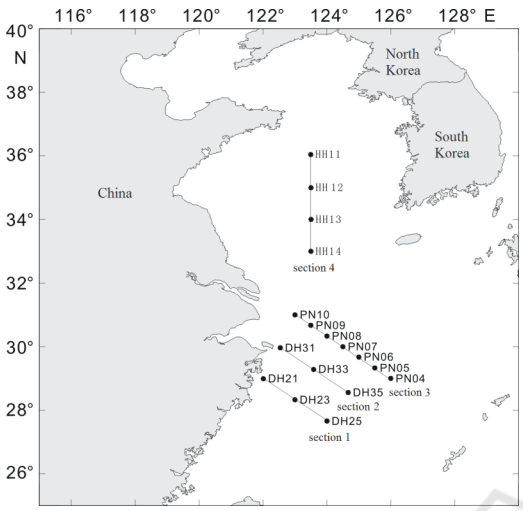


Figure 1: 2016 summer survey stations bitmap.

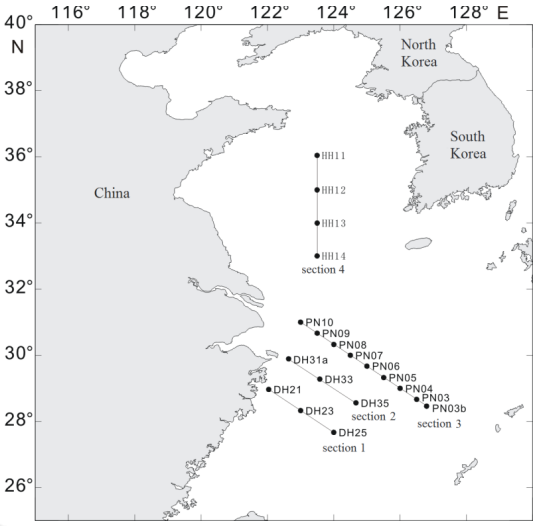


Figure 2: 2016 winter survey stations bitmap.

Table 1: Summer survey stations of 2016.

| Stations | Regions | Date | Time | Longitude | Latitude | Depth |
|---|---|---|---|---|---|---|
| DH21 | ECS | 2016-8-20 | 8:29 | 122.0113 | 28.9926 | 15 |
| DH23 | ECS | 2016-8-20 | 15:41 | 123.0002 | 28.3306 | 74 |
| DH25 | ECS | 2016-8-20 | 23:40 | 124.0016 | 27.6627 | 97 |
| DH35 | ECS | 2016-8-22 | 3:55 | 124.6662 | 28.5573 | 89 |
| DH33 | ECS | 2016-8-22 | 11:07 | 123.5851 | 29.2843 | 69 |
| DH31 | ECS | 2016-8-22 | 20:00 | 122.5414 | 29.9651 | 23 |
| PN10 | ECS | 2016-8-24 | 17:57 | 123.0006 | 31.0004 | 49 |
| PN09 | ECS | 2016-8-24 | 21:38 | 123.4950 | 30.6715 | 59 |
| PN08 | ECS | 2016-8-25 | 2:19 | 124.0011 | 30.3325 | 51 |
| PN07 | ECS | 2016-8-25 | 6:10 | 124.4998 | 29.9981 | 66 |
| PN06 | ECS | 2016-8-25 | 10:41 | 124.9993 | 29.6716 | 83 |
| PN05 | ECS | 2016-8-25 | 15:04 | 125.4994 | 29.3309 | 94 |
| PN04 | ECS | 2016-8-25 | 20:25 | 125.9969 | 29.0026 | 117 |
| HH14 | YS | 2016-8-29 | 14:06 | 123.4990 | 32.9972 | 37.4 |
| HH13 | YS | 2016-8-29 | 23:30 | 123.5035 | 34.0009 | 70 |
| HH12 | YS | 2016-8-30 | 9:00 | 123.5012 | 34.9981 | 77.8 |
| HH11 | YS | 2016-8-31 | 12:23 | 123.4938 | 36.0400 | 75 |

Table 2: Winter survey stations of 2016.

| Stations | Regions | Date | Time | Longitude | Latitude | Depth |
|---|---|---|---|---|---|---|
| PN03b | ECS | 2016-12-26 | 16:30 | 126.8008 | 28.4618 | 209 |
| PN03 | ECS | 2016-12-26 | 19:59 | 126.5000 | 28.6667 | 134 |
| PN04 | ECS | 2016-12-27 | 0:58 | 126.0000 | 29.0000 | 118 |
| PN05 | ECS | 2016-12-27 | 5:11 | 125.5067 | 29.3256 | 94 |
| PN06 | ECS | 2016-12-27 | 9:55 | 125.0000 | 29.6710 | 83 |
| PN07 | ECS | 2016-12-27 | 13:28 | 124.5000 | 30.0000 | 68 |

| | | | | | | |
|---|---|---|---|---|---|---|
| PN08 | ECS | 2016-12-28 | 8:30 | 124.0028 | 30.3266 | 50 |
| PN09 | ECS | 2016-12-28 | 11:50 | 123.5003 | 30.6683 | 58 |
| PN10 | ECS | 2016-12-28 | 16:29 | 123.0000 | 31.0000 | 49 |
| DH31a | ECS | 2016-12-29 | 5:06 | 122.6394 | 29.8914 | 36 |
| DH33 | ECS | 2016-12-29 | 12:16 | 123.5792 | 29.2799 | 69 |
| DH35 | ECS | 2016-12-29 | 19:42 | 124.6691 | 28.5618 | 92 |
| DH25 | ECS | 2016-12-31 | 7:51 | 124.0000 | 27.6689 | 98 |
| DH23 | ECS | 2016-12-31 | 19:52 | 123.0022 | 28.3286 | 78 |
| DH21 | ECS | 2017-01-01 | 4:40 | 122.0384 | 28.9669 | 13.7 |
| HH14 | YS | 2017-02-04 | 15:00 | 123.4989 | 33.0030 | 38 |
| HH13 | YS | 2017-02-04 | 20:00 | 123.5014 | 33.9980 | 70 |
| HH12 | YS | 2017-02-05 | 1:33 | 123.4990 | 35.0004 | 77 |
| HH11 | YS | 2017-02-05 | 6:45 | 123.4990 | 36.0442 | 77 |

## 2.2 Research Methods

### 2.2.1 Sample Preparation

The samples were carried back to the laboratory, taking 400ml to filter through polycarbonate membrane (diameter 25mm, pore size 0.45μm), the filter pressure is less than 100mmHg. Immediately wash the filter membrane with weak alkaline distilled water to remove excess salt after filtered. Then, placed the filter in a plastic Petri dish, and set aside in oven at 50 ℃ for drying treatment. Finally, removed the filter after drying, clipping appropriate size with scissors, and placed on glass slides, dropping appropriate amount of Canada neutral resin, and then mounted the coverslips. After the production is finished, the samples were then put into the oven (50 ℃) for 2~3 days.

The quantity of LC was carried out under the polarizing microscope (MoticBA300pol) 1000×. According to the characteristics of birefringence, free pellets and stone balls were identified and counted. According to the statistical requirements, the visual field should be randomly selected and 300 stone or 100 stone balls should be detected as far as possible. The dominant species are identified based on morphological characteristics of coccolithophores (Heimdal, 1993) by using scanning electron microscopy (Jordan & Kleijne, 1994), and determined the ation of the average maximum and average grain length ball diameter.

### 2.2.2 The Main Formulas

The formula for calculating cell abundance of LC is modified by Bollmann's formula (Bollmannet al., 2002):

$$\mathrm{A} = \frac{a \times S \times 1000}{N \times b \times s} \tag{1}$$

A is the cell abundance of LC (cells / L); *N* is the number of horizons observed on each slide; *a* is the number of LC in the *N* field of vision; *b* is the volume of the filtered sample (ml); *S* is the effective filtration area of membrane; *s* is a single vision for the polarizing microscope under 1000× area. According to the number of stone grains per unit cell, each species of stone balls will be transformed into cell numbers.

Diversity index of Species (*H'*) is calculated by Shannon - Wiener index:

$$H' = -\sum_{i=1}^{S} P_i \log_2 P_i \tag{2}$$

Evenness index of Species (*J*) is calculated by Pielou:

$$J = \frac{H'}{\log_2 S} \tag{3}$$

Dominance index (*Y*), which is calculated as:

$$Y = \frac{n_i}{N} f_i \tag{4}$$

*N* for total number of LC cells, *S* is the total number of species in the sample, *ni* is the total number of individuals of the *i* species, *Pi* = *ni* / *N* is the first species in the sample *i* cell abundance probability, *fi* for the frequencies present in each sample.

Using surfer9.3 and CorelDRAW to map out the

data, we can get the distribution map of LC.

## 2.3 Results and Discussion

### 2.3.1 Species Composition and Dominant Species

In summer, 21 kinds of living coccolithophores were found in the survey area, most of them are heterococcolithophores, only a handful of holococcolithophores (Winter & Siesser, 1994). The dominant species were *Emiliania huxleyi*, *Gephyrocapsa oceanica*, *Umbellosphaera tenuis*, *Florisphaera profunda*, *Helicopontosphaera carteri* and *Umbilicosphaera sibogae*. *Emiliania huxleyi* and *Gephyrocapsa oceanica* were the dominant species, and the relative abundance of the cells were 36.77% and 32.90%. The frequency of occurrence were 1.00; The relative abundance of Umbellosphaera tenuis was 14.87%, the frequency of occurrence was 0.69. Species composition of LC is shown in Table 3.

Table 3: Species composition of living coccolithophores in summer of 2016.

| Species | Abundance | Frequency | Dominant |
|---|---|---|---|
| *Emiliania huxleyi* | 36.77 % | 1.00 | 0.36774 |
| *Gephyrocapsa oceanica* | 32.90 % | 1.00 | 0.32896 |
| *Umbellosphaera tenuis* | 14.87 % | 0.69 | 0.10223 |
| *Florisphaera profunda* | 3.66 % | 0.38 | 0.01374 |
| *Calcidiscus leptoporus* | 3.02 % | 0.34 | 0.00913 |
| *Umbilicosphaera sibogae* | 2.09 % | 0.30 | 0.00719 |
| *Calciosolenia murrayi* | 1.20 % | 0.22 | 0.00263 |
| *Syracosphaera pulchra* | 1.14 % | 0.17 | 0.00171 |
| *Algirosphaera robusta* | 1.03 % | 0.16 | 0.00166 |
| *Discosphaera tubifera* | 0.93 % | 0.15 | 0.00145 |
| *Oolithotus antillarum* | 0.42 % | 0.13 | 0.00052 |
| *Helicosphaera carteri* | 0.41 % | 0.11 | 0.00049 |
| *Rhabdosphaera clavigera* | 0.38 % | 0.10 | 0.00039 |
| *Umbilicosphaera foliosa* | 0.30 % | 0.09 | 0.00026 |
| *Syracosphaera rotula* | 0.28 % | 0.07 | 0.00019 |
| *Calicasphaera disconstricta* | 0.25 % | 0.06 | 0.00018 |
| *Umbellosphaera irregularis* | 0.14 % | 0.06 | 0.00008 |
| *Florisphaera profunda var. elongata* | 0.09 % | 0.05 | 0.00003 |
| *Gephytocapsa ericsonii* | 0.06 % | 0.03 | 0.00003 |
| *Pontosphaera discopora* | 0.05 % | 0.01 | —— |
| *Michaelsarsia adriaticus* | 0.01 % | 0.01 | —— |

In winter, 20 kinds of living coccolithophores were found in the survey area. Most of them are heterococcolithophores, a small number of holococcolithophores. The dominant species is *E. huxleyi*, *G. oceanica*, *F. profunda*, *U. tenuis*, *S. pulchra* and *U. sibogae*. The relative abundance of cell density in *E. huxleyi* and *G. oceanica* has an absolute advantage in the survey area, respectively, accounted for 42.97% and 32.06%, both the frequency of 1.00 and 0.98, respectively; *F. profunda*'s cell abundance was 5.60%, the frequency of occurrence is 0.64. *U. tenuis*'s relative abundance and frequency of cells respectively 3.54% percentage, abundance 0.51. Species composition of living coccolithophores is shown in Table 4.

Table 4: Species composition of living coccolithophores in winter of 2016.

| Species | Abundance | Frequency | Dominant |
|---|---|---|---|
| *Emiliania huxleyi* | 42.97 % | 1.00 | 0.42971 |
| *Gephyrocapsa oceanica* | 32.06 % | 0.98 | 0.32064 |
| *Florisphaera profunda* | 5.60 % | 0.64 | 0.05597 |
| *Umbellosphaera tenuis* | 3.54 % | 0.51 | 0.03545 |
| *Syracosphaera pulchra* | 0.61 % | 0.26 | 0.00612 |
| *Umbilicosphaera sibogae* | 0.44 % | 0.31 | 0.00444 |
| *Helicosphaera carteri* | 0.31 % | 0.22 | 0.00306 |

| | | | |
|---|---|---|---|
| *Algirosphaera robusta* | 0.15 % | 0.17 | 0.00146 |
| *Discosphaera tubifera* | 0.10 % | 0.15 | 0.00101 |
| *Calcidiscus leptoporus* | 0.08 % | 0.20 | 0.00077 |
| *Gephytocapsa ericsonii* | 0.04 % | 0.15 | 0.00044 |
| *Calciosolenia murrayi* | 0.04 % | 0.12 | 0.00043 |
| *Florisphaera profunda var. elongata* | 0.03 % | 0.10 | 0.00029 |
| *Pontosphaera bigelowi* | 0.02 % | 0.09 | 0.00021 |
| *Umbellosphaera irregularis* | 0.01 % | 0.07 | 0.00007 |
| *Oolithotus antillarum* | 0.01 % | 0.08 | 0.00006 |
| *Pontosphaera discopora* | 0.00 % | 0.03 | 0.00001 |
| *Syracosphaera rotula* | 0.00 % | 0.02 | —— |
| *Pontosphaera discopora* | 0.00 % | 0.03 | —— |
| *Michaelsarsia adriaticus* | 0.00 % | 0.01 | —— |

### 2.3.2 Horizontal Distribution

In summer 2016, the cell abundance of LC in the survey area was between 0.23 ~ 17.62 × $10^3$ cells / L, with an average of 2.84 × $10^3$ cells / L. Cell abundance of *Emiliania huxleyi* was between 0.79 ~ 7.4 × $10^3$ cells / L, with an average of 1.04 × $10^3$ cells / L. Cell abundance of *Gephyrocapsa oceanica* was between 0.29 ~ 7.6 × $10^3$ cells / L, with an average of 0.93 × $10^3$ cells / L. *Umbellosphaera tenuis* was between 0 ~ 2.22 × $10^3$ cells / L, with an average of 0.42 × $10^3$ cells / L. (Figure 3)

In summer, the distribution of LC in the study area is uneven, and a high value suddenly appears at a certain site in the investigation area. This is due to the fact that the distribution of LC in summer is not only affected by light and nutrients, but also influenced by the interaction of the warm Kuroshio in the South and the cold water mass of the Yellow Sea in the north. At the same time, as the largest diluted water runoff in the coastal areas of China, the influence of Yangtze River on the distribution of LC can not be ignored (Honjo, 1976).

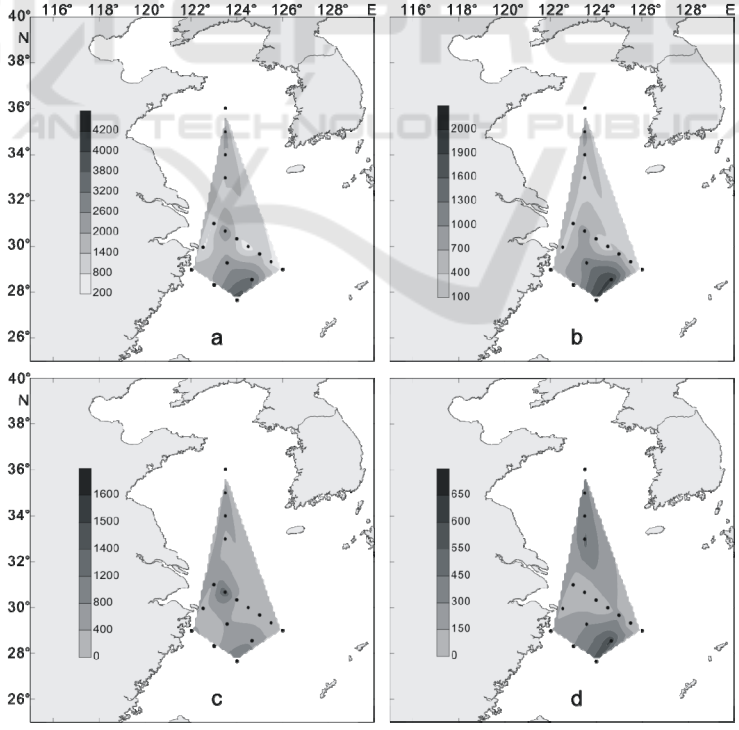


Figure 3: The distribution of living coccolithophores' cell abundance at surface water in summer of 2016 (cells / L, a: coccolithophores; b: *Emiliania huxleyi*; c: *Gephyrocapsa oceanica*; d: *Umbellosphaera tenuis*)

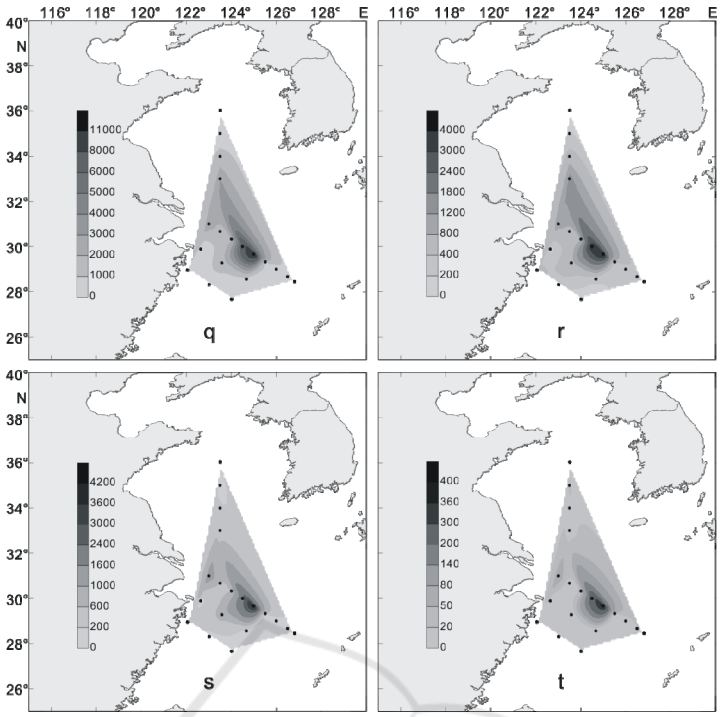


Figure 4: The distribution of living coccolithophores' cell abundance at surface water in winter of 2016 (cells / L, q: coccolithophores; r: *Emiliania huxleyi*; s: *Gephyrocapsa oceanics*; t: *Florisphaera profunda*)

### 2.3.3 Vertical Distribution

In summer, LC were mostly located in 35 m, 50 m and 75 m water layer, the maximum cell abundance appears in DH25 station of section 1 of 50 m layer of water, reaching 17.62 × $10^3$ cells / L, and in the stations of 35 m and 75 m layer, layer respectively reached 14.83 × $10^3$ cells / L and 12.46 × $10^3$ cells / L of higher value. Meanwhile, in the section 3 of PN09 station, there's a high value of 10.28 × $10^3$ cells / L. (Figures 5-8) Vertical distribution of the survey area presents a patchy and "bull's eyes" distribution mode (Zou et al., 2001), a sudden abundance of high value appears in a water layer in some stations.

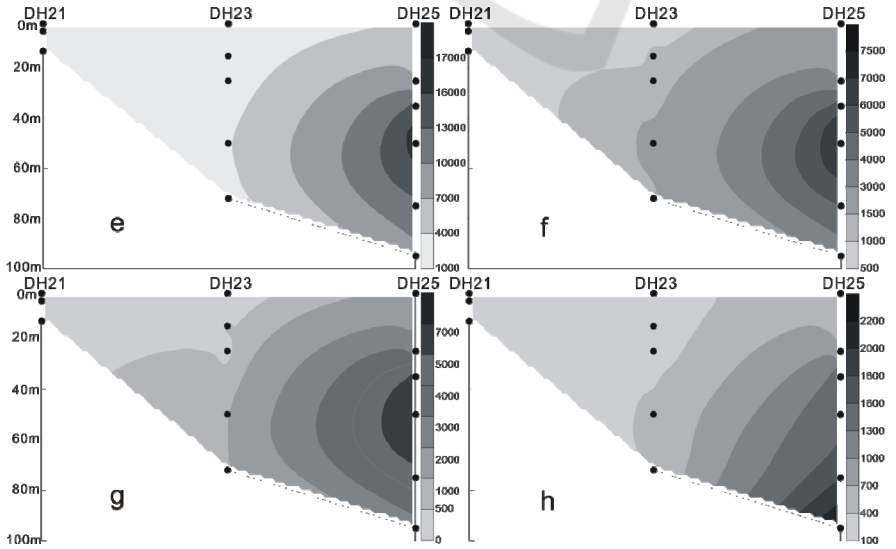


Figure 5: The vertical distribution of living coccolithophores' cell abundance in section 1 in summer of 2016 (cells / L, e: coccolithophores; f: *Emiliania huxleyi*; g: *Gephyrocapsa oceanica*; h: *Umbellosphaera tenuis*) .

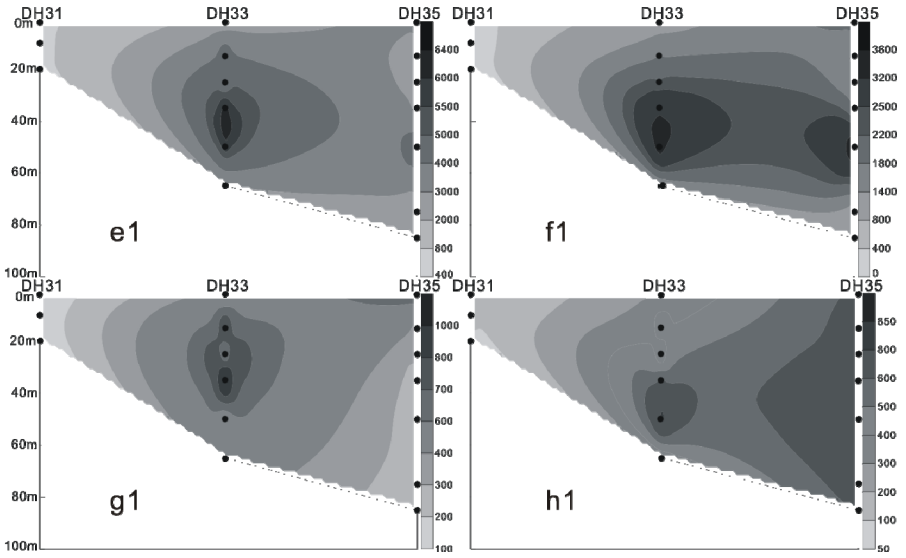


Figure 6: The vertical distribution of living coccolithophores' cell abundance in section 2 in summer of 2016 (cells / L, e1: coccolithophores; f1: *Emiliania huxleyi*; g1: *Gephyrocapsa oceanica*; h1: *Umbellosphaera. tenuis*).

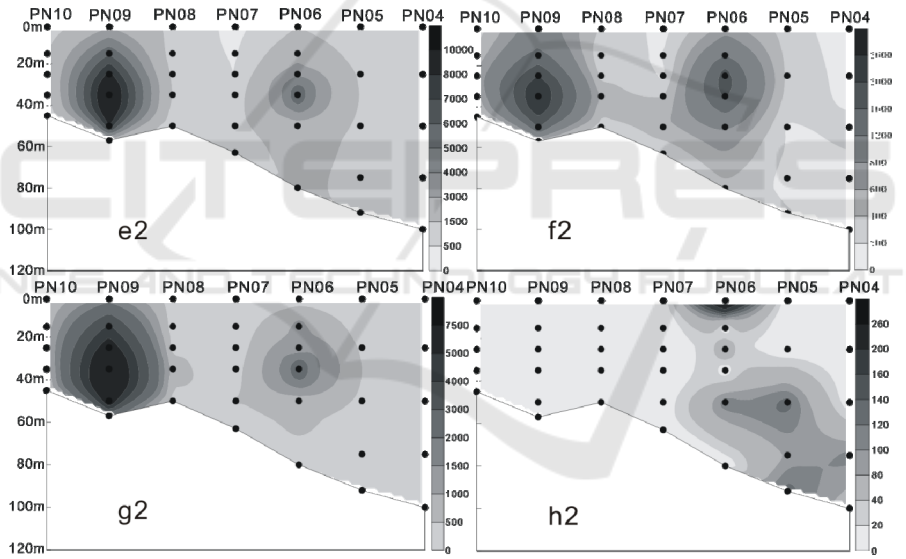


Figure 7: The vertical distribution of living coccolithophores' cell abundance in section 3 in summer of 2016 (cells / L, e2: coccolithophores; f2: *Emiliania huxleyi*; g2: *Gephyrocapsa oceanica*; h2: *Umbellosphaera tenuis*).

In the winter of 2016, the LC in the Yellow Sea and East China Sea were distributed in the 3 water layers of 25 m, 50 m and 75 m. The maximum abundance of LC appeared in the 50 m layer of the PN06 station of section 3, and reached 35.35 × $10^3$ cells / L.At the same time, the 25 m and 75 m layer of the sation also reached 26.45 × $10^3$ cells / L and 20.67 × $10^3$ cells / L. In addition to the PN06 station, the high values of 8.66 × $10^3$ cells / L and 8.47 × $10^3$ cells / L were achieved at the 55 m layer of PN09 and the 65 m layer of PN07. Different from summer, the higher value of the abundance of LC appeared in the section 4 of the survey area, which appeared respectively at the 50 m layer of HH13 station and the 35 m layer of the HH14 station, and the value reached 6.97 × $10^3$ cells / L and 5.56 × $10^3$ cells / L. (Figures 9-12) The vertical distribution of LC in winter is similar to that in summer, also showing the characteristics of uneven distribution, high value abundance will suddenly appear at a certain water level in some stations.

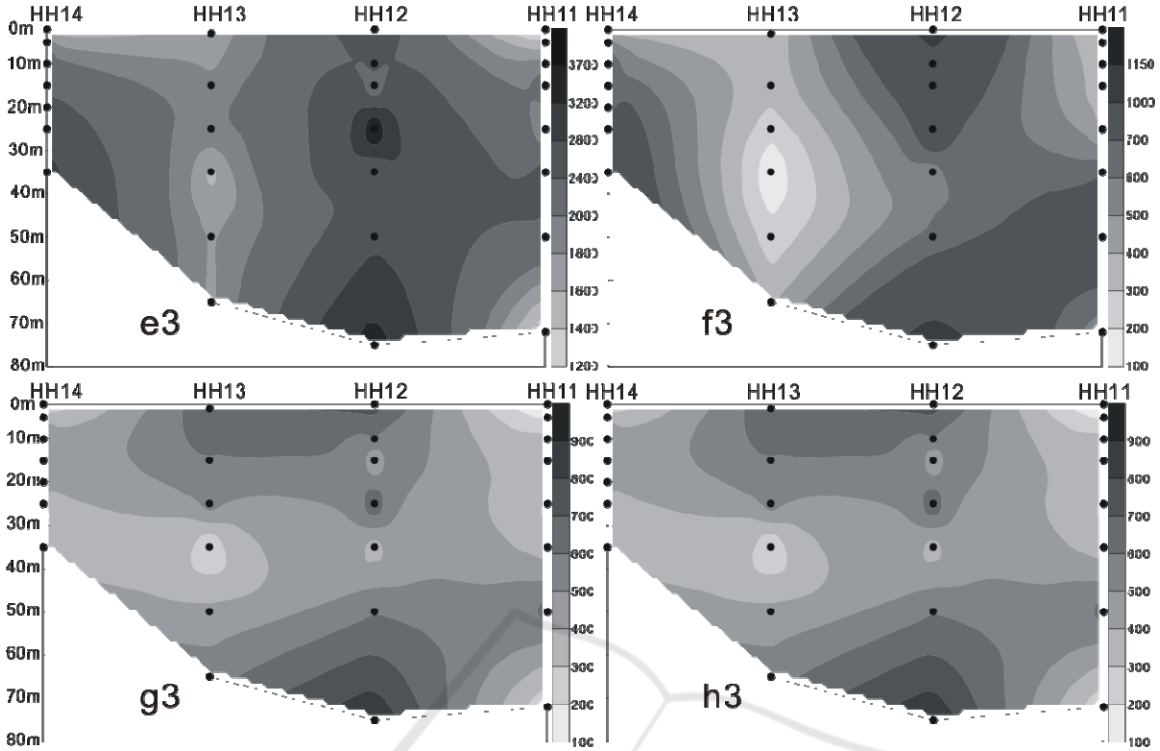


Figure 8: The vertical distribution of living coccolithophores' cell abundance in section 4 in summer of 2016 (cells / L, e3: coccolithophores; f3: *Emiliania huxleyi*; g3: *Gephyrocapsa oceanica*; h3: *Umbellosphaera tenuis*).

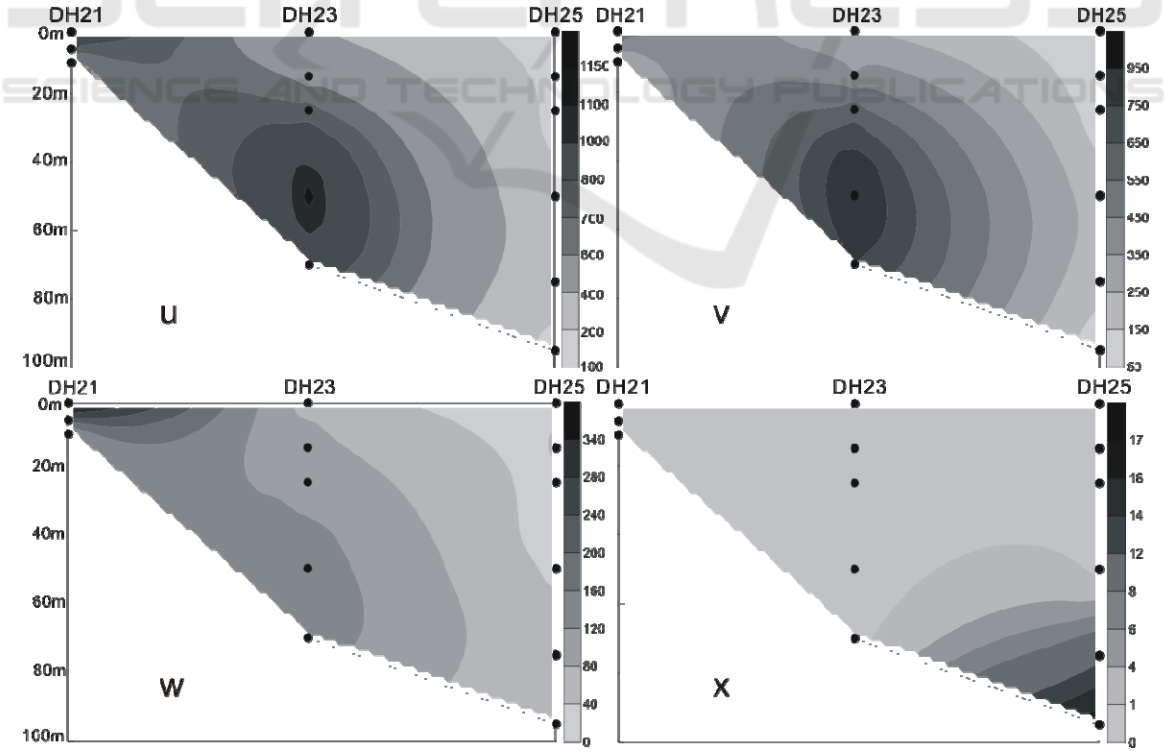


Figure 9: The vertical distribution of living coccolithophores' cell abundance in section 1 in winter of 2016 (cells / L, u: coccolithophores; v: *Emiliania huxleyi*; w: *Gephyrocapsa oceanica*; x: *Florisphaera profunda).*

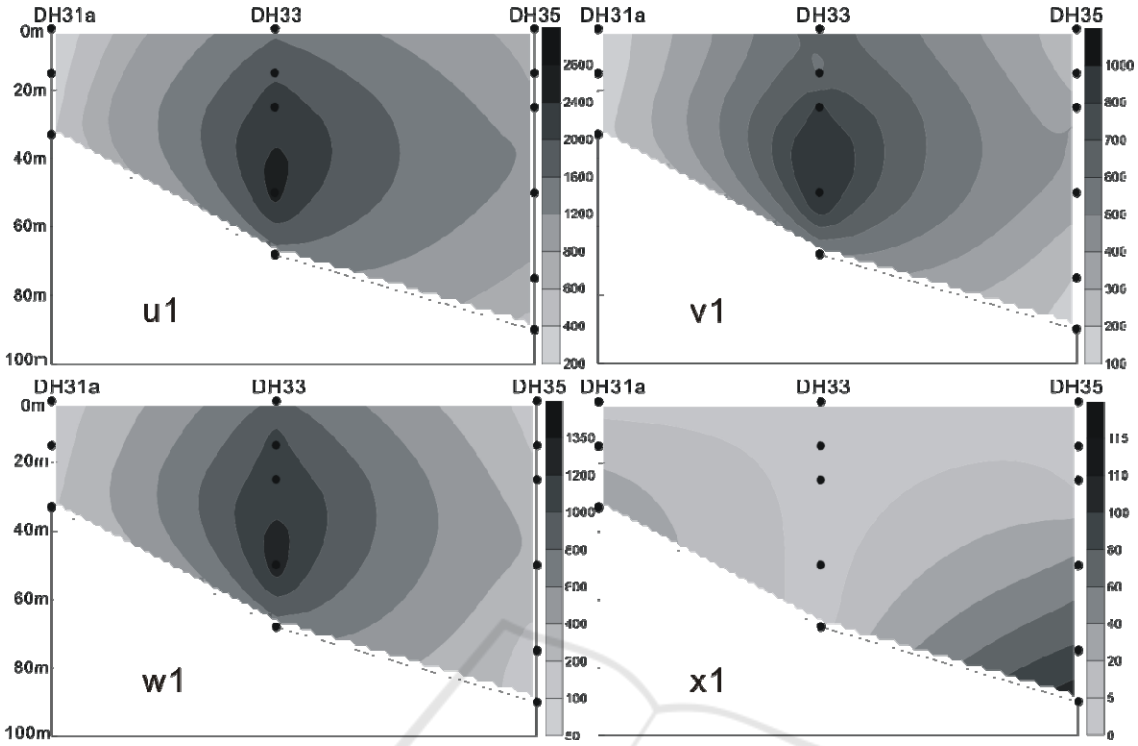


Figure 10: The vertical distribution of living coccolithophores' cell abundance in section 2 in winter of 2016 (cells / L, u1: coccolithophores; v1: *Emiliania huxleyi*; w1: *Gephyrocapsa oceanica*; x1: *Florisphaera profunda*).

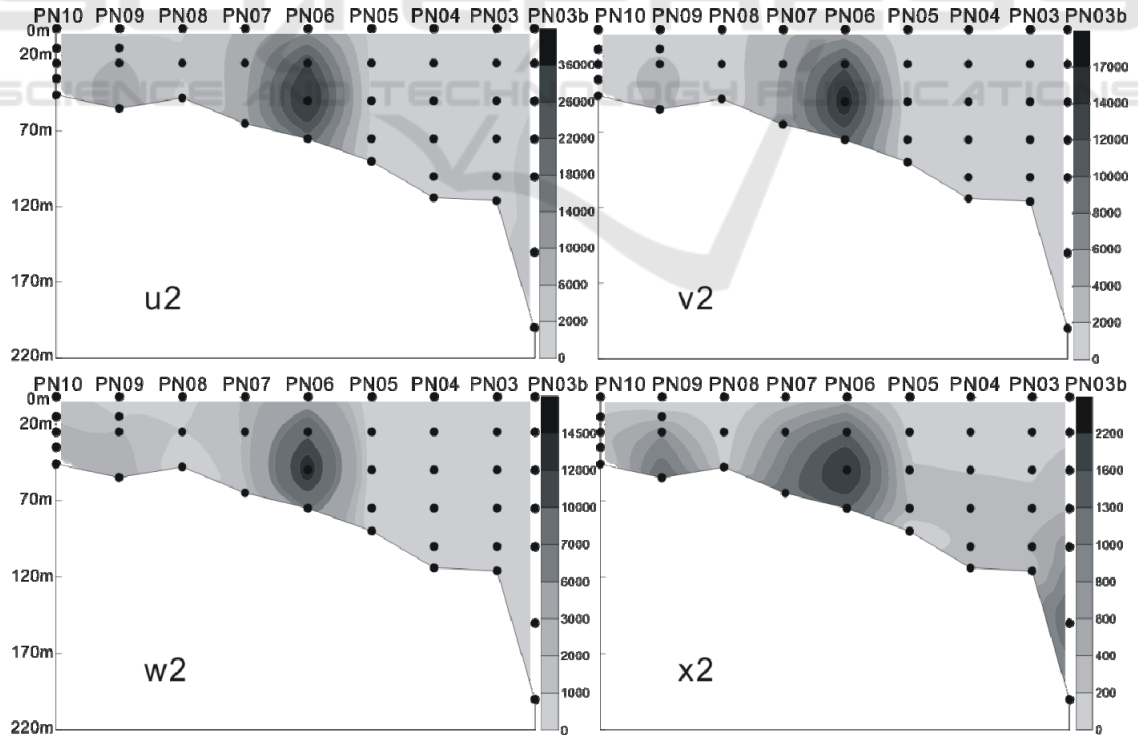


Figure 11: The vertical distribution of living coccolithophores' cell abundance in section 3 in winter of 2016 (cells / L, u2: coccolithophores; v2: *Emiliania huxleyi*; w2: *Gephyrocapsa oceanica*; x2: *Florisphaera profunda*).

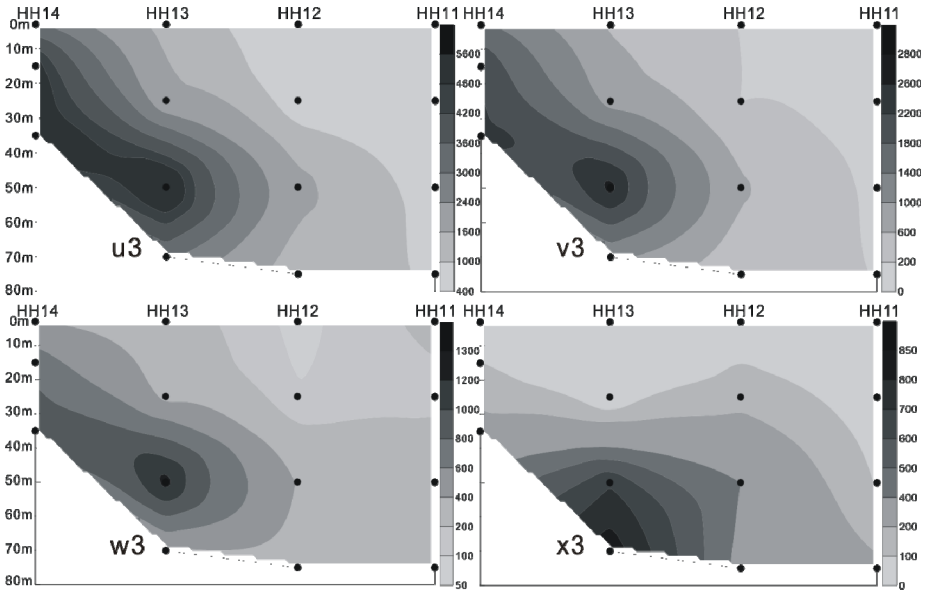


Figure 12: The vertical distribution of living coccolithophores' cell abundance in section 4 in winter of 2016 (cells / L, u3: coccolithophores; v3: *Emiliania huxleyi*; w3: *Gephyrocapsa oceanica*; x3: *Florisphaera profunda*).

### 2.3.4 Diversity Index and Evenness

In summer, the community diversity index (Figure 13i) of LC was between 0.72 to 2.35, with an average of 1.84. The diversity index is higher in the north and south of the investigation area and the adjacent sea area, and there is a high value in the PN08 station in the central area. The evenness index (Figure 13j) was between 0.49 to 0.99, with an average of 0.82, which has a higher value in the central and eastern waters of the study area.

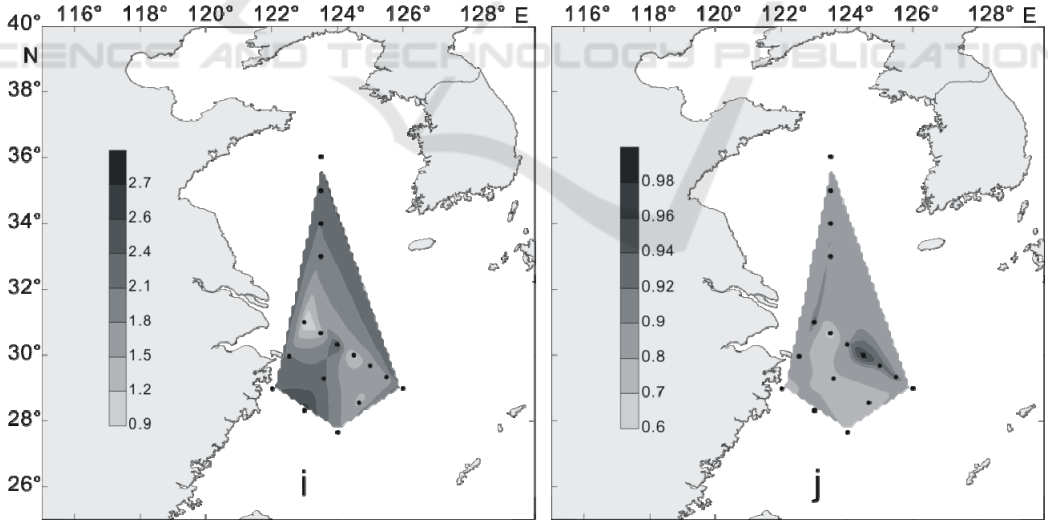


Figure 13: Distribution of Shannon-Wiener diversity index and Pielou evenness index at surface water of survey area in summer of 2016 (i: Shannon-Wiener diversity index; j: Pielou evenness index).

In the winter of 2016, the species diversity index (Figure 14y) in the Yellow Sea and East China Sea was between 1.11~ 2.62, with an average of 1.85. The highest value of species diversity index appears in HH12 station and its adjacent waters. The diversity index of the whole survey area is higher in the northern, Eastern and southern areas and adjacent sea areas, and the stations with higher values are HH12, PN06 and DH35.The distribution of Pielou evenness index and the distribution of

diversity index in the investigation area showed a more consistent feature, with a value of 0.57~0.95, with an average value of 0.78 (Figure 14z), which had a higher value in the middle and adjacent waters of the investigation area.

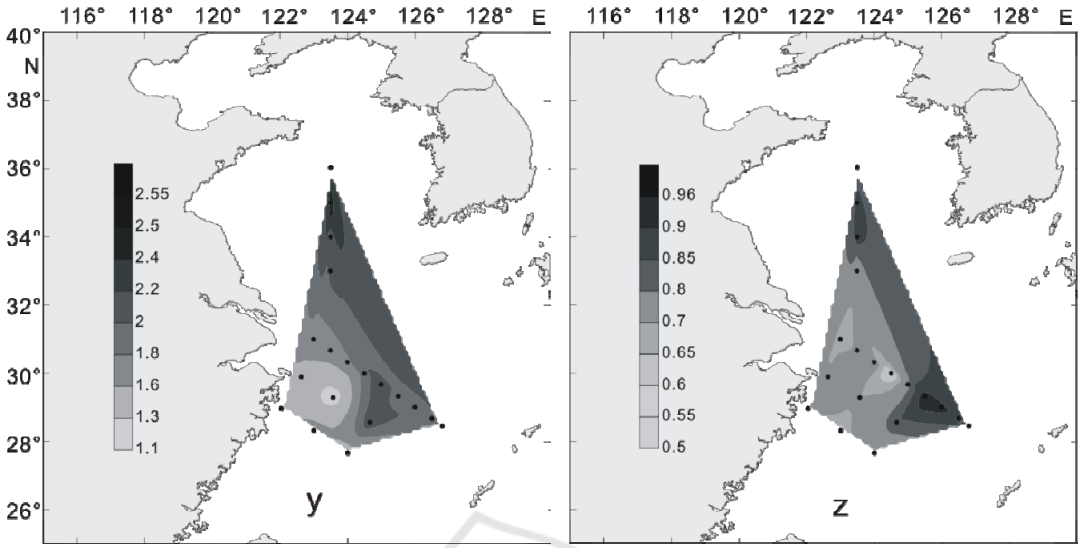


Figure 14. Distribution of Shannon–Wiener diversity index and Pielou evenness index at surface water of the survey area in the winter of 2016(y: Shannon-Wiener diversity index; z: Pielou evenness index).

### 2.3.5 Distribution of Surface Temperature and Salinity of the Survey Area

In the summer of 2016, the distribution of surface temperature and salinity in the Yellow Sea and East China Sea was shown in figure 15. The surface temperature of the investigated area is 25.52 ℃ ~ 29.99 ℃, with an average value of 28.34 ℃. The highest value of temperature appeared in the eastern and southern parts of the investigation area, and the highest value appeared at DH33 station, with a value of 29.99 ℃. At the PN10 station closest to the Yangtze River Estuary, the temperature reaches a minimum of 25.52 ℃. As can be seen from figure 15o, the trend of surface temperature distribution in the Yellow Sea and East China Sea area in summer is from north to south, from nearshore to distant sea, and the temperature is getting higher and higher.

The salinity of the surface layer in summer survey area is 22.39~33.69, with an average of 29.96. The high salinity area appeared in the eastern part of the survey area, and the highest value appeared at PN04 station, reaching 33.69. At the southern DH35 station, salinity reached a minimum value of 22.39. As can be seen from figure 15p, the surface salinity of Yellow Sea and East China Sea in summer is greatly influenced by the Yangtze River fresh water. The surface salinity of the near shore is low, and it is increasing along the direction of fresh water to the outer sea.

In the winter of 2016, the distribution of surface temperature and salinity in the Yellow Sea and East China Sea was shown in figure 16. The surface temperature of the investigated area is 7.63~22.87 ℃, with an average value of 15.73 ℃. The highest value of temperature appeared in the southeastern part of the investigation area, and the highest value appeared at PN03b station, with a value of 22.87 ℃. Meanwhile, at the North HH11 station, the temperature reached a minimum of 7.63 ℃. As can be seen from figure 16E, the surface temperature distribution trend in winter is similar to that in summer, which is from north to south, from near shore to far sea, and the temperature is getting higher and higher.

The salinity of the surface layer in winter survey area is 27.06~34.58, with an average of 33.24. The high salinity area appeared in the eastern part of the survey area, and the highest value appeared at PN03 station, reaching 34.58. At the DH21 station near the Gulf of Hangzhou, salinity reached a minimum value of 27.06. As can be seen from figure 16F, the surface salinity in winter is still influenced by inland runoff, and the surface salinity is low in the near shore, increasing along the direction of fresh water to the outer sea.

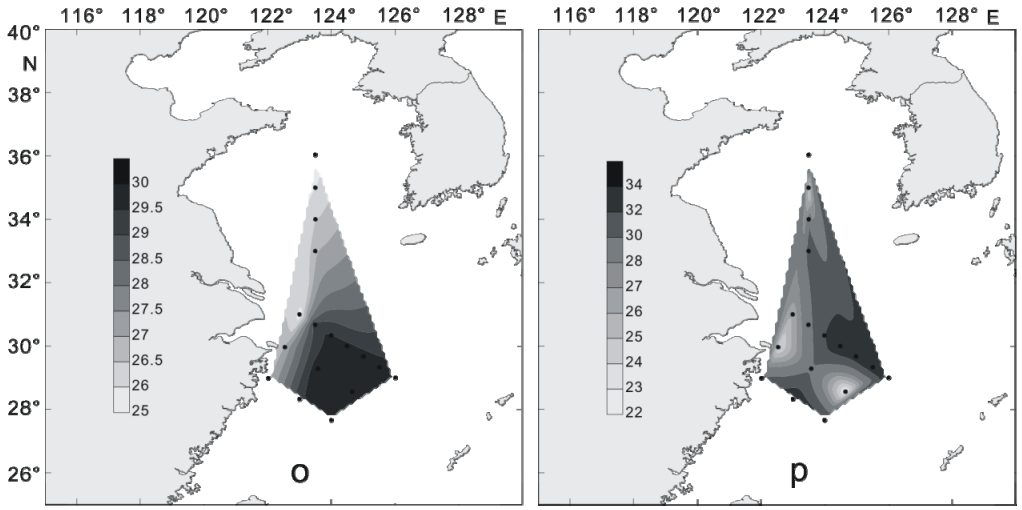


Figure 15. The distribution of temperature and salinity in surface layer of the survey area in summer of 2016 (o: the distribution of temperature in surface layer (℃); p: the distribution of salinity in surface layer)

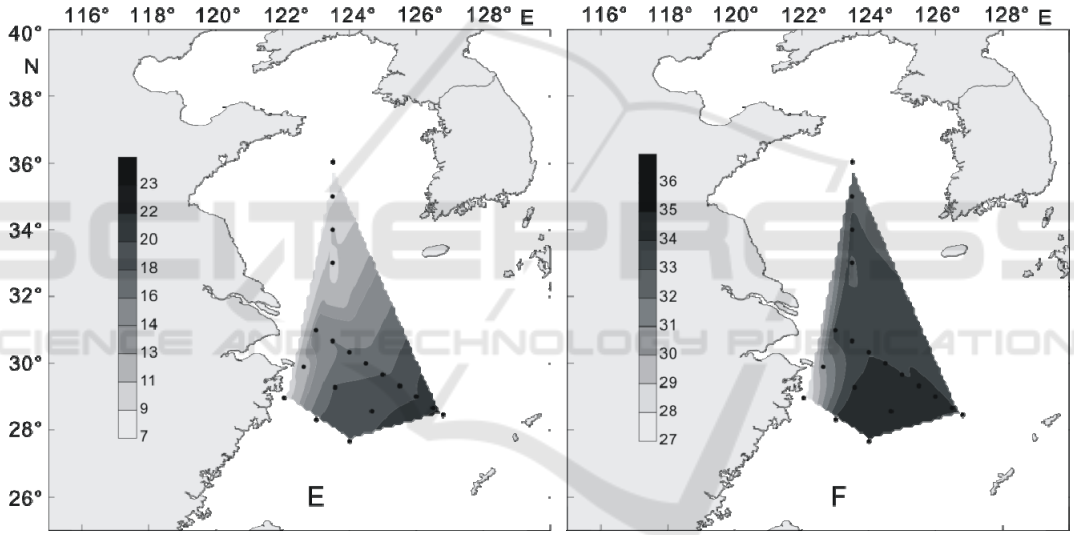


Figure 16: The distribution of temperature and salinity in surface layer of the survey area in winter of 2016 (E: the distribution of temperature in surface layer (℃); F: the distribution of salinity in surface layer).

## 3 SUMMARY

This paper mainly studied the community and distribution of LC in the summer of 2016 (July 20th to September 1st) and winter (December 23rd to February 5th) of the Yellow Sea and East China Sea in China.

21 kinds of living coccolithophores were found in the survey area in summer, most of them are heterococcolithophores, only a few of holococcolithophores. The dominant species were *Emiliania huxleyi*, *Gephyrocapsa oceanica*, *Umbellosphaera tenuis*, *Florisphaera profunda*, *Helicopontosphaera carteri* and *Umbilicosphaera sibogae*. The cell abundance of LC in the survey area was between 0.23 ~ 17.62 × $10^3$ cells / L, with an average of 2.84 × $10^3$ cells / L.The high value areas of these dominant species usually appear in the southern part of the investigation area and the surrounding waters. This is due to the fact that the distribution of LC is not only affected by light and nutrients, but also influenced by the interaction of the warm Kuroshio in the South and the cold water mass of the Yellow Sea in the north (Yang & Wei, 2003). At the same time, the influence of the Yangtze River is very significant.

20 kinds of living coccolithophores were found in the survey area in winter, and Most of them are heterococcolithophores. The dominant species were *E. huxleyi*, *G. oceanica*, *F. profunda*, *U. tenuis*, *S. pulchra* and *U. sibogae.* The cell abundance of LC was between 0.12 ~ 35.35 × $10^3$ cells / L, with an average of 3.84 × $10^3$ cells / L. Compared with summer, the abundance of LC increased greatly in winter, but the species of the dominant species changed little. The high value area of the abundance of LC appeared in the middle and eastern waters, and its abundance coverage is much wider than that in summer.

The reasons for the difference between summer and winter were mainly due to the effect of strong monsoon in the sea area in winter, and the effect of upwelling in the shelf of Yellow Sea and East China Sea was remarkable. The upwelling transported nutrients from bottom of the sea water to the upper water body in a certain area (Yu et al., 2006)., and the warm Kuroshio water also changed the living environment of LC to a great extent. Together, they give the necessary nutrients and environment for the growth of the algae, resulting in higher cell abundance.

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