Plankton Community in the Upwelling Regions of Taiwan

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Patchiness of plankton distribution has been shown by Hardy and Gunther (1935) for Antarctic plankton, and by Hardy (1944) and his coworkers for North Sea plankton. The interests of these studies. however,lay in the distribution of organisms over a wide area.

It is a well known fact that the quantity of plankton in different areas of tropical regions depends on the supply of nutrients to the upper waters, and the distribution of different groups of organisms in these areas varies greatly depending on their position in the food chain. (Vinogradov and Voronina,1962) . Steemann Nielsen (1937) has shown that near Iceland the waters which have just reached the surface are poor in plankton. During the time necessary for the development of algae the water which carried them along moves away from the the region of upwelling, and the bulk of zooplankton appears still farther from it. As a result, the zones of upwelling and the bulk of plankton are divided in space.

Plankton develops more rapidly in tropical waters than in polar and temperate seas. The main transfer on the equatorial divergence is in the zonal direction, and the meridional components of the currents are small. It therefore seemed likely that in the equatorial zone the bulk of phyto-and zooplankton would be situated quite near the zone of divergence Indeed, in the equatorial Pacific the shift of the bulk of zooplankton for the region of divergence was discovered by the expedition"Eastropic", which made a very detailed investigation of this region (King, 1958) .

The animals which feed on plankton and whose position in the food chain is farther from the source than the herbivores need more time for their development than the grazing copepods. Murphy and Shomura (1958)

Becklemishev and Pasternak (1960), when studying the distribution of the last link of the food chain, i.e. of the fishes,observed that areas of their abundance also shifted away from the region of upwelling. These authors, studying the horizontal distribution of areas with high plankton abundance and upwelling regions had comparatively limited material that dealt with the total concentration of plankton (King and Demond, 1953; King and Hida, 1957; Bogorov and Vinogradov, 1960) or with the quantity of fishes, or the concentration of meso-and macroplankton (King, 1958).

In most cases (King and Demand, 1953; King and Hida, 1957; Bogorov and Vinogradov, 1960), the regions rich in zooplankton and the zones of upwelling coincided. This means that the distance between them was so small that it could not be observed because the distance between the oceanographical stations was more than 60-90 miles.

Material and Methods

Samples taken on cruise no. 14 of the "Chui Lien" R/V southeast and southwest of Taiwan in May of 1970 were used for the present study. The position of the stations is shown in Figure 1.

The plankton was collected by vertical hauls at depths up to 1,000m with Norpac nets of silk gauze with 0.33mm mesh aperture and with a mouth opening of 45cm in diameter.

The volume of each sample was measured by a flowmeter in the mouth of the net, and the quantity of the six large zooplankton groups was counted from 1/2, 1/4 or 1/8 of each sample. The biomass of the total plankton was measured by using settling volume (Marumo, 1965), displacement volume (Motoda, 1963) and wet weight (Motoda, 1961). The hydrographical and hydrochemical materials were taken from CSK Report Nos. 1 and 2. The results of settling volumes have more significance in discussing plankton biomass in this paper. The zooplankton were divided into six large groups such as: copepoda, chaetognaths, crustacea larvae, medusae, tunicates and other zooplankton.

Results and Discussion

The data for the distribution of plankton biomass and zooplankton in comparison with those on the environmental conditions are given in Figures 2-13. It is obvious that the maximum amount of plankton is connected with the zones of upwelling, as seen by the deepening of the thermocline, the decrease in temperature and the increase in the concentration of phosphate at the depth of 100m (CSK Report Nos. 1 and 2). Regions with such peculiarities in the Kuroshio Current area off east of Taiwan are the zone of divergence between the Bashi Channel and the eastern coast of Taiwan near Taitung, and the zone of divergence between the Lan Yu and the Bashi Channel, and the region of inshore upwelling south of Taiwan.

In the major part of the area investigated there is a well defined conformity between the abundance pattern of plankton biomass and zooplankton. This is observed especially along sections I and II, and in the west parts of section III, where each maximum of plankton biomass corresponds to a maximum of animals, even insignificant increases or decreases in the plankton biomass are followed by analogous chances in the quantity of zooplankton biomass are followed by analogous chances in the quantity of zooplankton organisms. Thus, the present data show that, in most cases, the maxima of biomass and zooplankton and the zones of upwelling coincide.

The distribution of zooplankton in the upwelling regions off the southeastern area of abundance.

It is obvious that the maximum amount of plankton everywhere is connected with the zones of upwelling. Off the east coasts of Taiwan plankton is more abundant in the areas of sections I,II and the western part of section III from 50m depth to the surface. The most abundant area was section II, especially at Station 2 with 1,256 animals/m^3. and Station 3 where 699 individuals of zooplankton/m^3, were recorded. The next abundant area was Section I, 3 stations had 306 to 397 animals/m^3, This phenomenon of the abundance of zooplankton with the front of the upwelling line in front of Stations 2 and 3, and the upwelling widely to section I, Station 1, 4 and 5. This phenomenon may be due to the upwelling of nutrient salts bringing about an increase in abundance of the herbivororous copepodsalso. The copepods comprised 65.6% to 76.5% of the total samples. Chaetognaths were not abundance. Tunicates were second in abundance to the copepods in this area. Crustacean larvae, meduseae and other zooplankton organisms were limited in numbers in the surface waters in this region.

Judging from the present biological data, the upwelling region extended from Lan Yu and Taitung to Sanshintai, an area of approximately 1,296 km^2. The lower water upwelling to the surface come from depths of 100-150m.

Off the southwestern coast of Taiwan, the phenomenon of upwelling was not as clearly marked as off the southeastern coast.

The lower water of 1.50m depth was going up to the surface by decreasing temperature. (Tseng, 1966, 1967, 1968 and 1969). Several plankton investigations, there showed by measuring the abundant occurrence of zooplankton in this area. (Tseng, 1967-1970), that upwelling extended from Tungkang to Taiwan.

The present data also showed that in this area the plankton biomass has an increase and decrease gredient coinciding with the region and not the region of the area of upwelling.

In general, the plankton biomass and the abundance of zooplankton coincided with the regions of upwelling both southeast and southwest of Taiwan. In other words, plankton is abundant in the upwelling regions off Taiwan.

It is obvious that the maximum amount of plankton everywhere is connected with the zones of upwelling.

The data for zooplankon distribution in the southwestern sea of Taiwan showed phenomena of divergence in section V near Taiwan (Stas. 14-16), and of upwelling in the area of Section VII (Stas. 21-22). The plankton abudance in the surface waters of these areas and these organisms descending to the 50-150m, (Figure 3, Section VI) then, ascending to the surface again (Figure 2, Secton VII).

The zooplankton southwest of Taiwan was dominated by copepods which constituted 47~84% of the total numbers of zooplankton. Chaetognaths were next, tunicates and other zooplankton were third and fourth, respectively. Medusae and crustacea larvae were the least abundand. In general, in these areas the zooplankton was predominate by oceanic type.

From figures 8 to 10 for the stratification of plankton biomass (settling volume) distribution southwest and southeast of Taiwan, from 150m to the surface. We can see that the occurrence of plankton started from the divergent region east of Lanyu, and extended to the eastern coast Tulan from 150m to surface. Off the western coast of Taiwan, the evidence of divergence was minimal in sections V and VI, and from the minimum of Section VI to the maximum again at Section VII. Figures 11 to 13, provide more evidence using three kinds of biomass methods of upwelling occurring near the coast from Taitung to Chenkuangao and extending northeast of Lutao. Off the southwest coast of Taiwan, there was evidence good of divergence at Sections V to VI, and of upwelling from Sections VI to VII.

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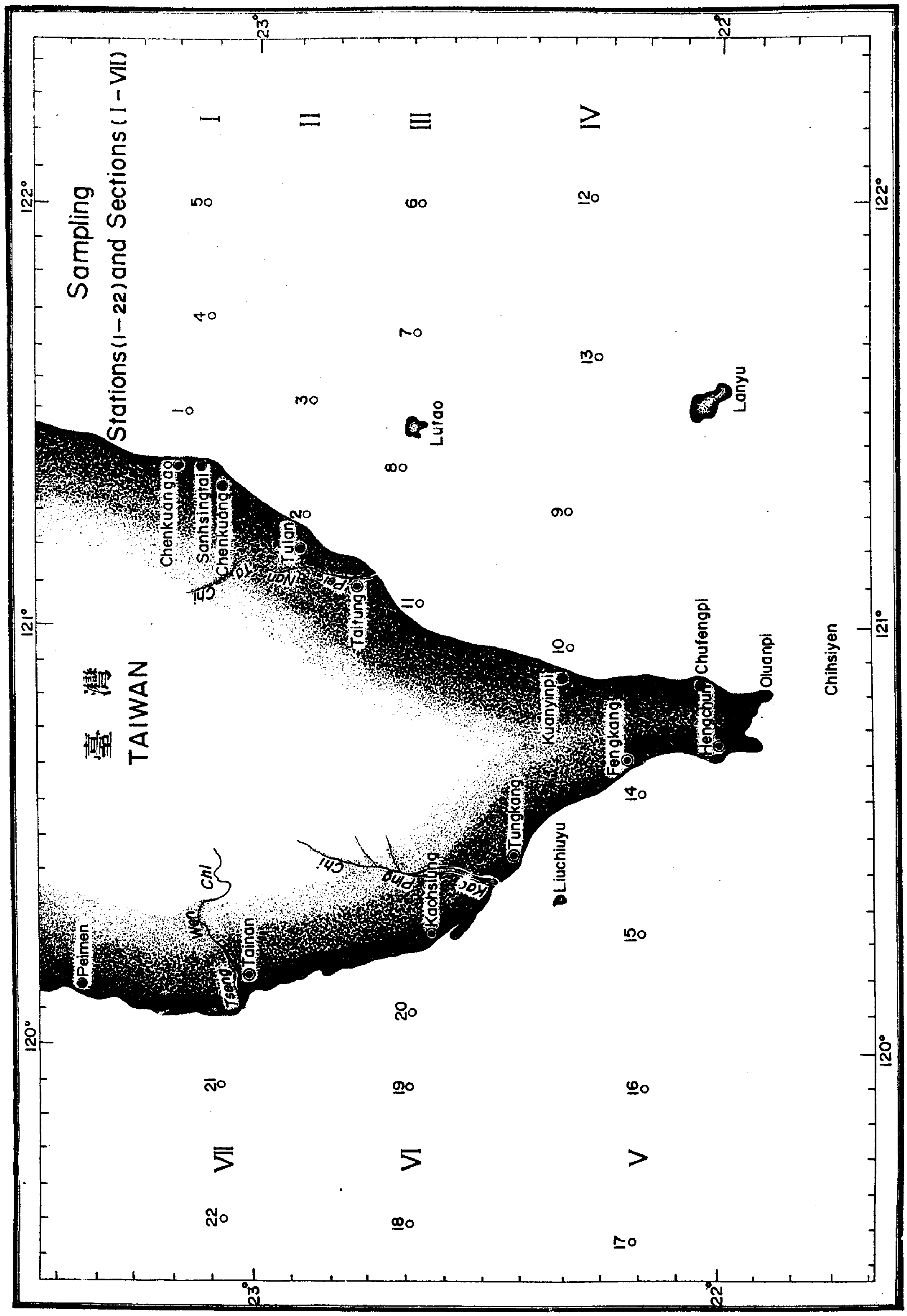

Sampling
Stations (1–22) and Sections (I–VII)
臺灣
TAIWAN
I
II
III
IV
V
VI
VII
Lutao
Lanyu
Chenkuangao
Sanhsingtai
Chenkuang
Tulan
Taitung
Kuanyinpi
Chufengpi
Oluanpi
Chihsiyen
Hengchun
Fengkang
Tungkang
Liuchiuyu
Kaohsiung
Tainan
Peimen
Tseng
Wen
Chi
Ping
Kao
Pei
Nan
120°
121°
122°
22°
23°

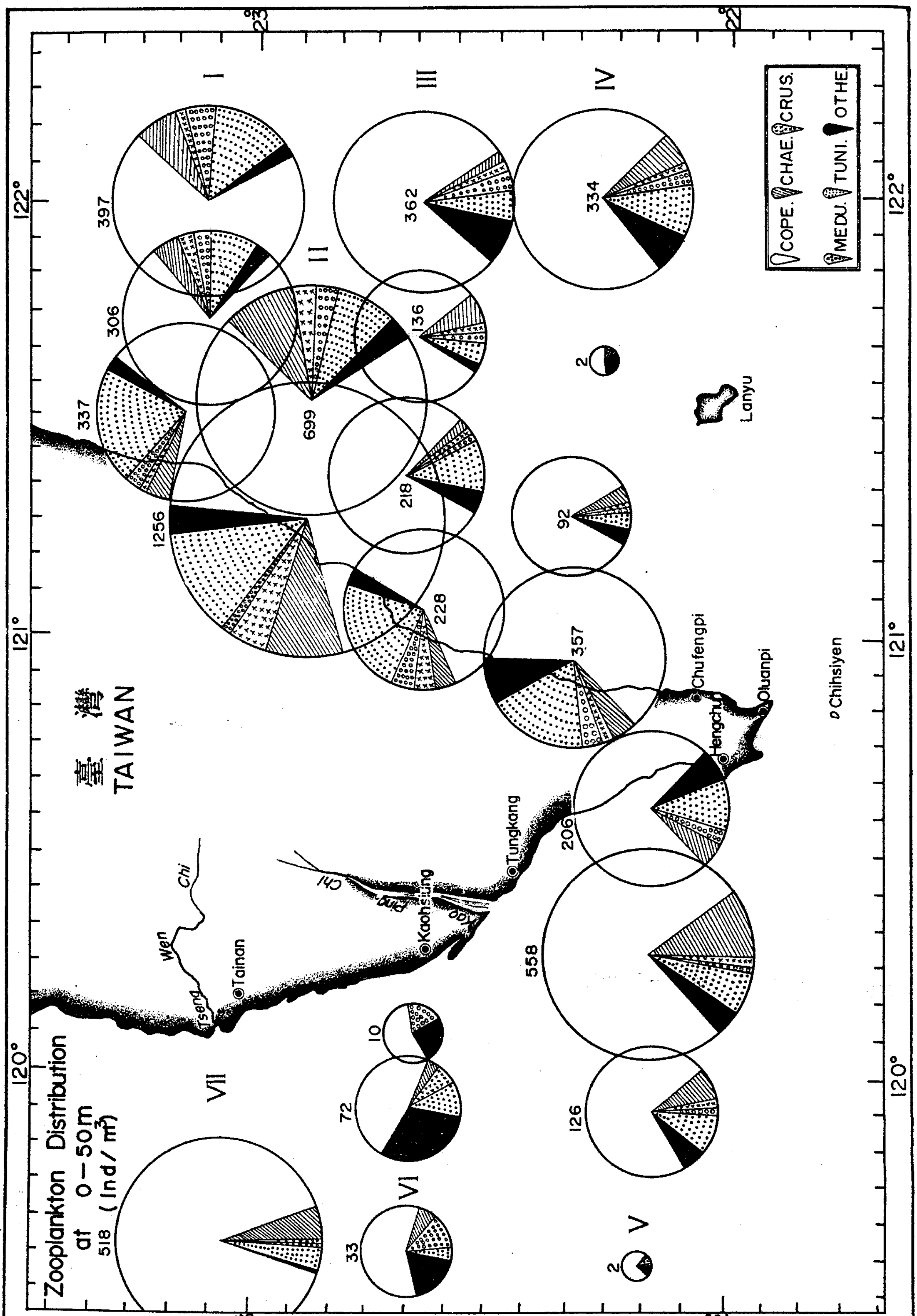

Zooplankton Distribution
at 0-50m
(Ind/m³)
COPE.
CHAE.
CRUS.
MEDU.
TUNI.
OTHE.
臺灣
TAIWAN
I
II
III
IV
V
VI
VII
397
306
337
699
136
362
334
2
218
92
1256
228
357
206
558
126
10
72
33
518
Lanyu
Chufengpi
Hengchun
Oluanpi
Chihsiyen
Tungkang
Kaohsiung
Tainan
Tseng
Wen
Chi
Ping
Kao
120°
121°
122°
22°
23°

Fig 2

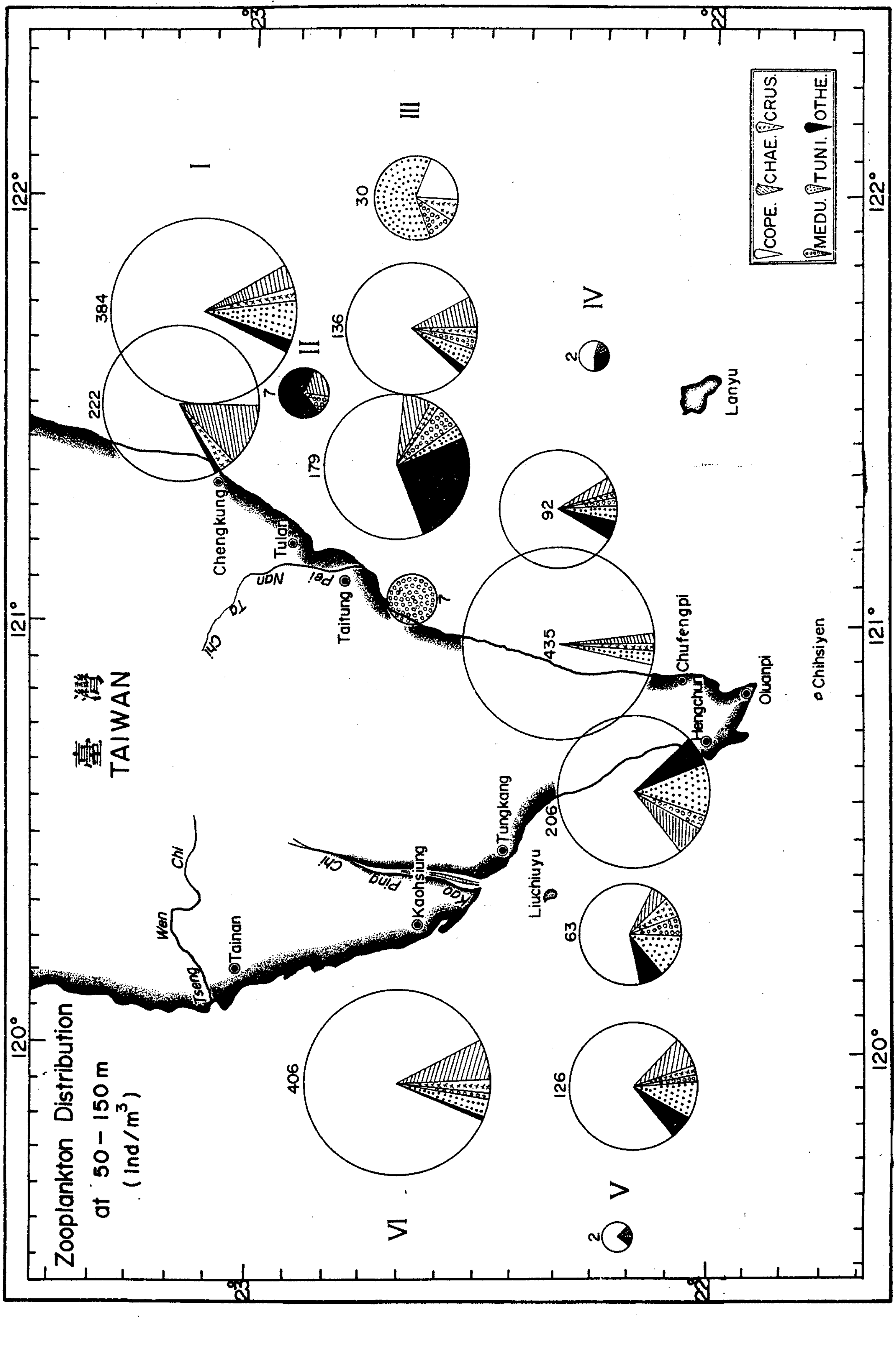

Zooplankton Distribution
at 50 - 150 m
(Ind/m3)
臺灣
TAIWAN
COPE. CHAE. CRUS.
MEDU. TUNI. OTHE.
I
II
III
IV
V
VI
384
222
7
136
30
179
92
435
206
63
406
126
2
2
Chengkung
Tulan
Taitung
Chufengpi
Hengchun
Oluanpi
Chihsiyen
Tungkang
Kaohsiung
Liuchiuyu
Tainan
Lanyu
Ta Nan Chi
Pei
Ping Chi
Kao
Wen Chi
Tseng
120°
121°
122°
23
22

Fig. 3

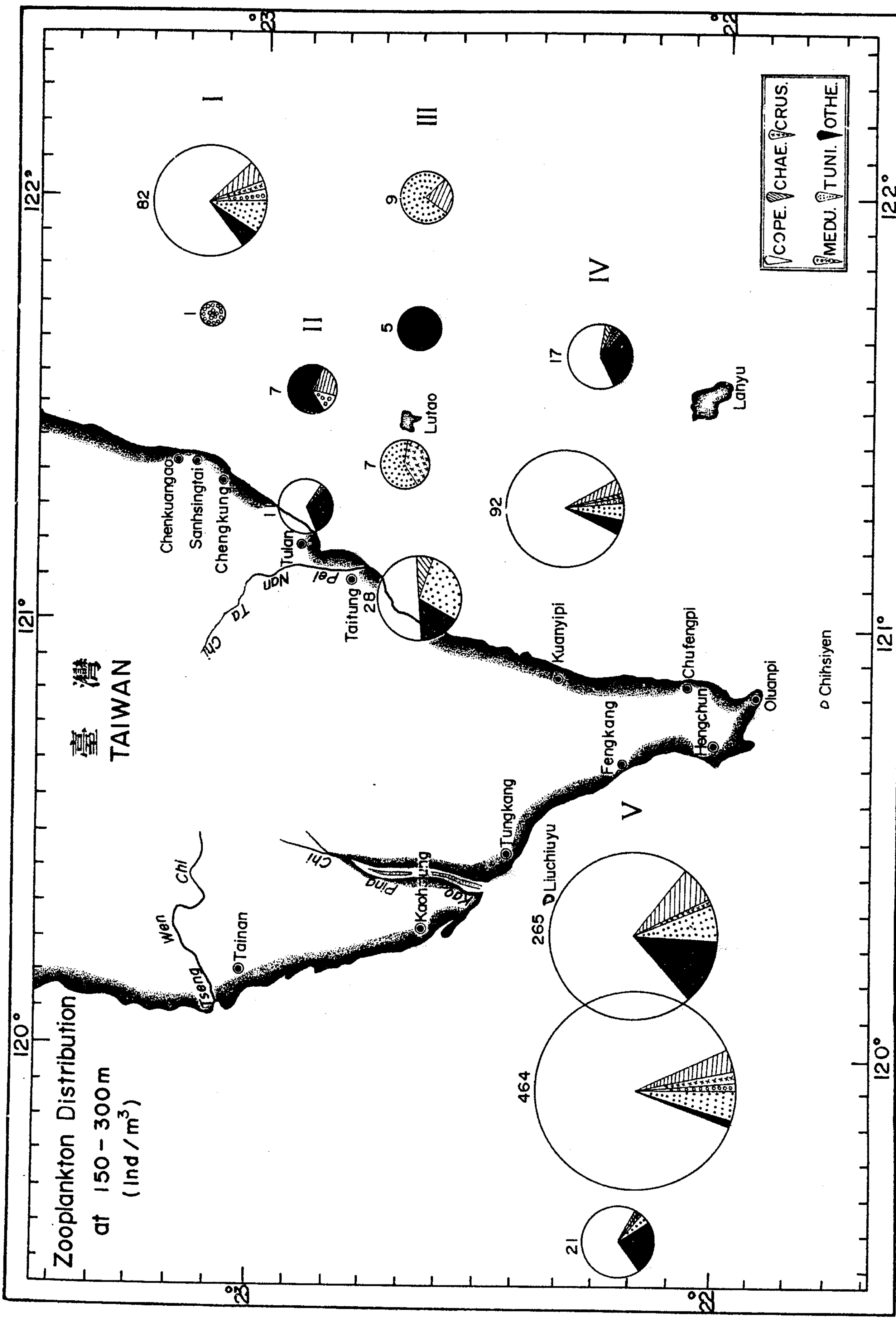

Zooplankton Distribution
at 150 - 300 m
(Ind / m^3)
臺灣
TAIWAN
COPE.
CHAE.
CRUS.
MEDU.
TUNI.
OTHE.
I
II
III
IV
V
82
1
9
7
5
17
7
1
92
28
265
464
21
Chenkuangao
Sanhsingtai
Chengkung
Tulan
Taitung
Lutao
Lanyu
Kuanyipi
Chufengpi
Oluanpi
Chihsiyen
Hengchun
Fengkang
Tungkang
Liuchiuyu
Kaohsiung
Tainan
Pei Nan
Ta Chi
Wen Chi
Tseng
Ping
Chi
Kao
120°
121°
122°
22
23

Fig 4

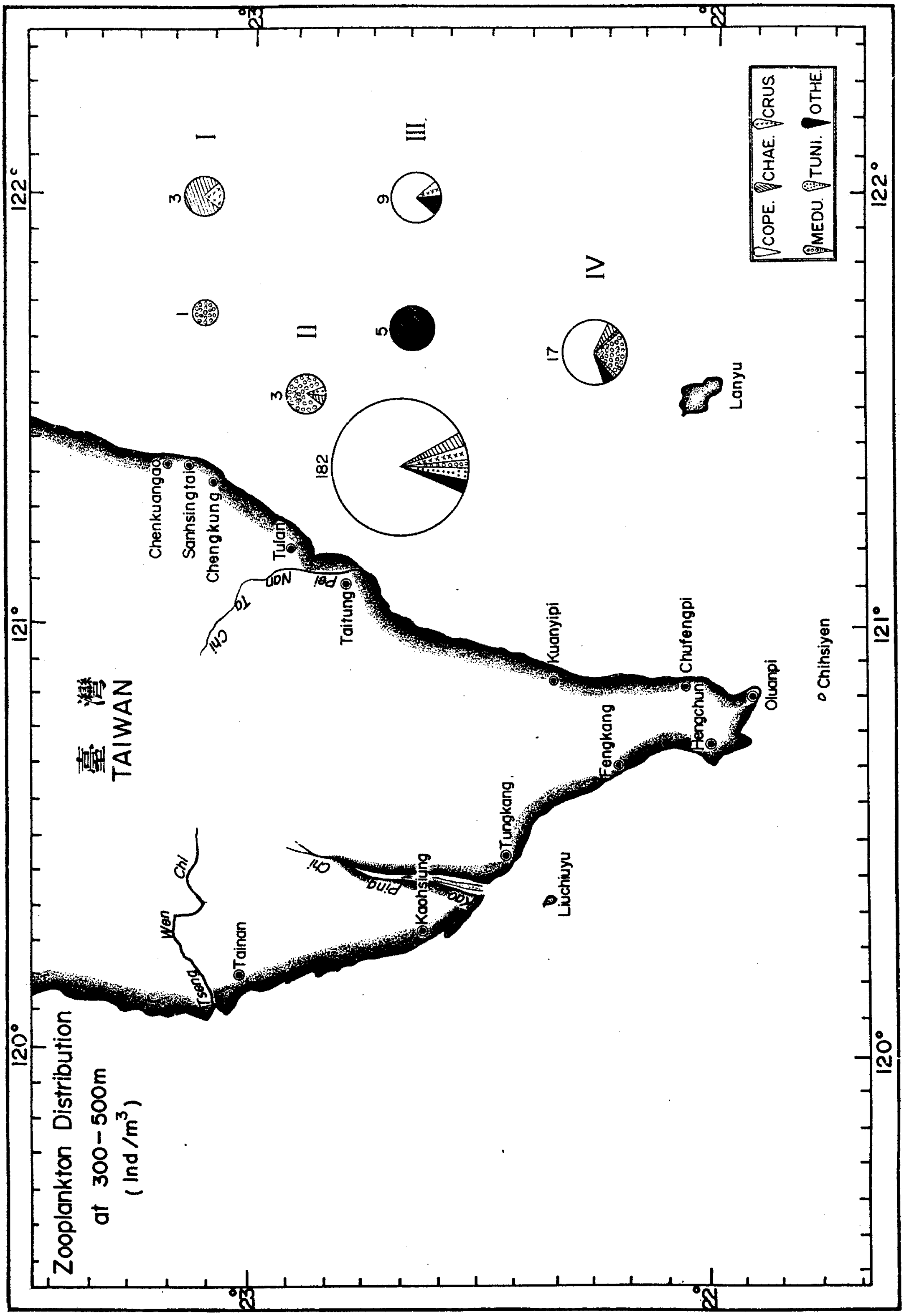

Zooplankton Distribution
at 300–500m
(Ind/m^3)
臺灣
TAIWAN
COPE.
CHAE.
CRUS.
MEDU.
TUNI.
OTHE.
I
II
III
IV
3
1
3
9
5
182
17
Chenkuangao
Sanhsingtai
Chengkung
Tulan
Taitung
Pei
Nan
Ta
Chi
Kuanyipi
Chufengpi
Oluanpi
Chihsiyen
Hengchun
Fengkang
Tungkang
Kaohsiung
Kao
Ping
Chi
Liuchiuyu
Tainan
Tseng
Wen
Chi
Lanyu
120°
121°
122°
22°
23°

Fig 5

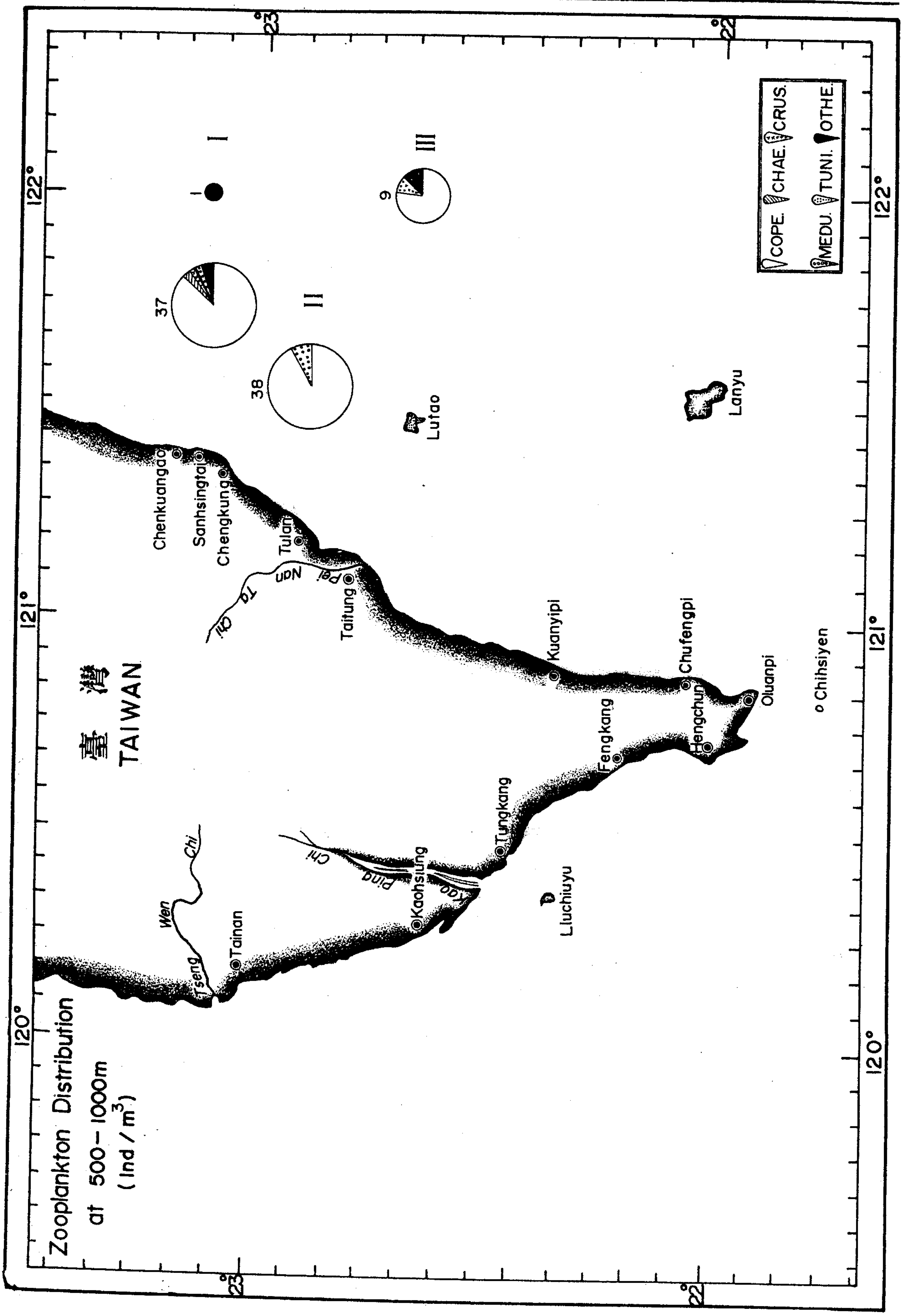
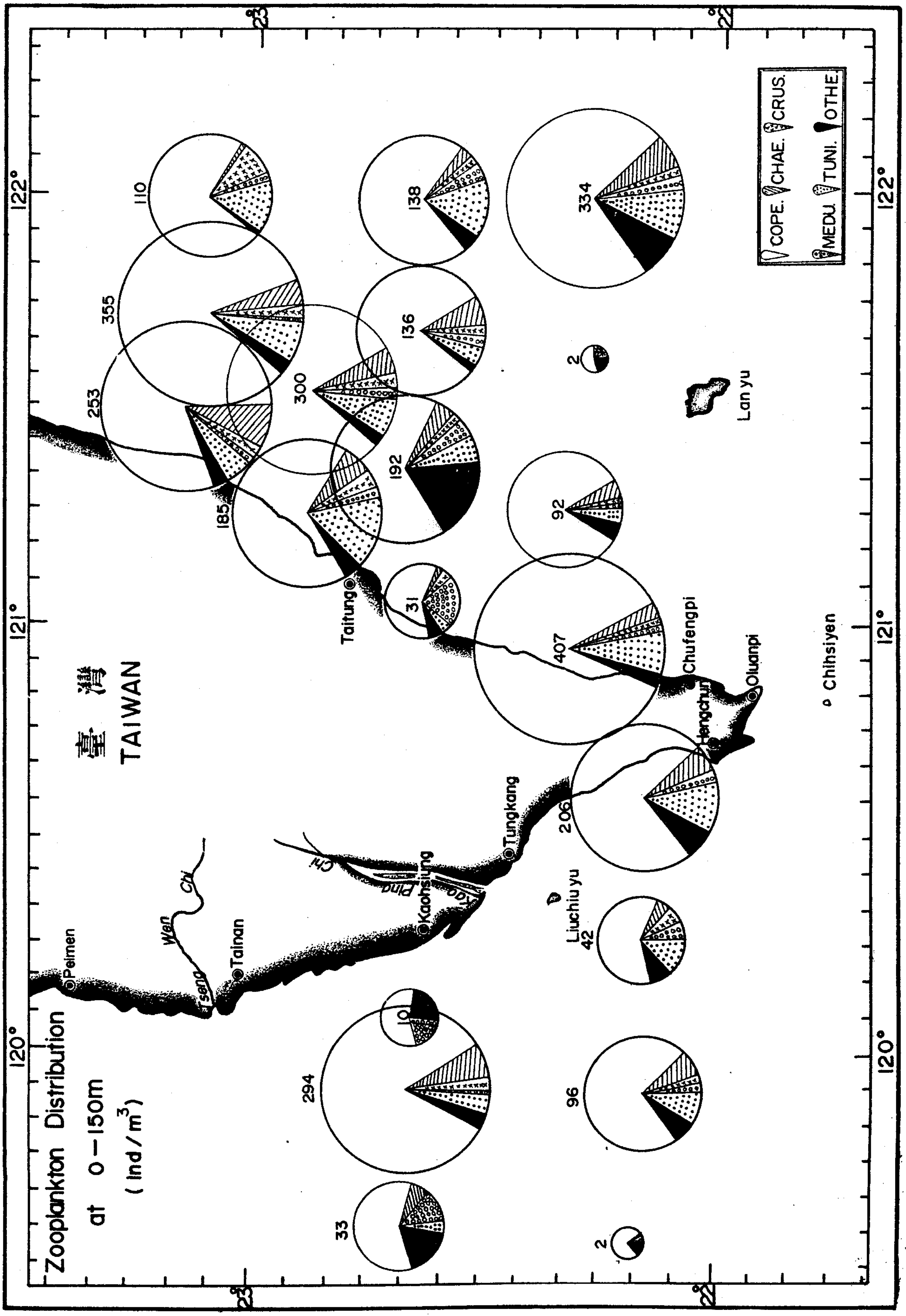

Zooplankton Distribution
at 500-1000m
(Ind/m3)
COPE.
CHAE.
CRUS.
MEDU.
TUNI.
OTHE.
I
II
III
1
37
38
9
臺灣
TAIWAN
Chenkuangao
Sanhsingtai
Chengkung
Tulan
Taitung
Pei Nan Ta Chi
Kuanyipi
Chufengpi
Oluanpi
Hengchun
Fengkang
Tungkang
Kaohsiung
Ping Chi
Tainan
Tseng Wen Chi
Liuchiuyu
Lutao
Lanyu
Chihsiyen
120°
121°
122°
22°
23°

Fig 6


Zooplankton Distribution
at 0–150m
(Ind/m³)
臺灣
TAIWAN
COPE. CHAE. CRUS.
MEDU. TUNI. OTHE.
120°
121°
122°
22°
23°
Peimen
Tainan
Kaohsiung
Tungkang
Hengchun
Oluanpi
Chufengpi
Taitung
Lan yu
Liuchiu yu
Chihsiyen
Tseng
Wen
Chi
Pina
Kao
Chi
110
355
253
300
185
192
31
138
136
334
2
92
407
206
42
33
294
10
96
2

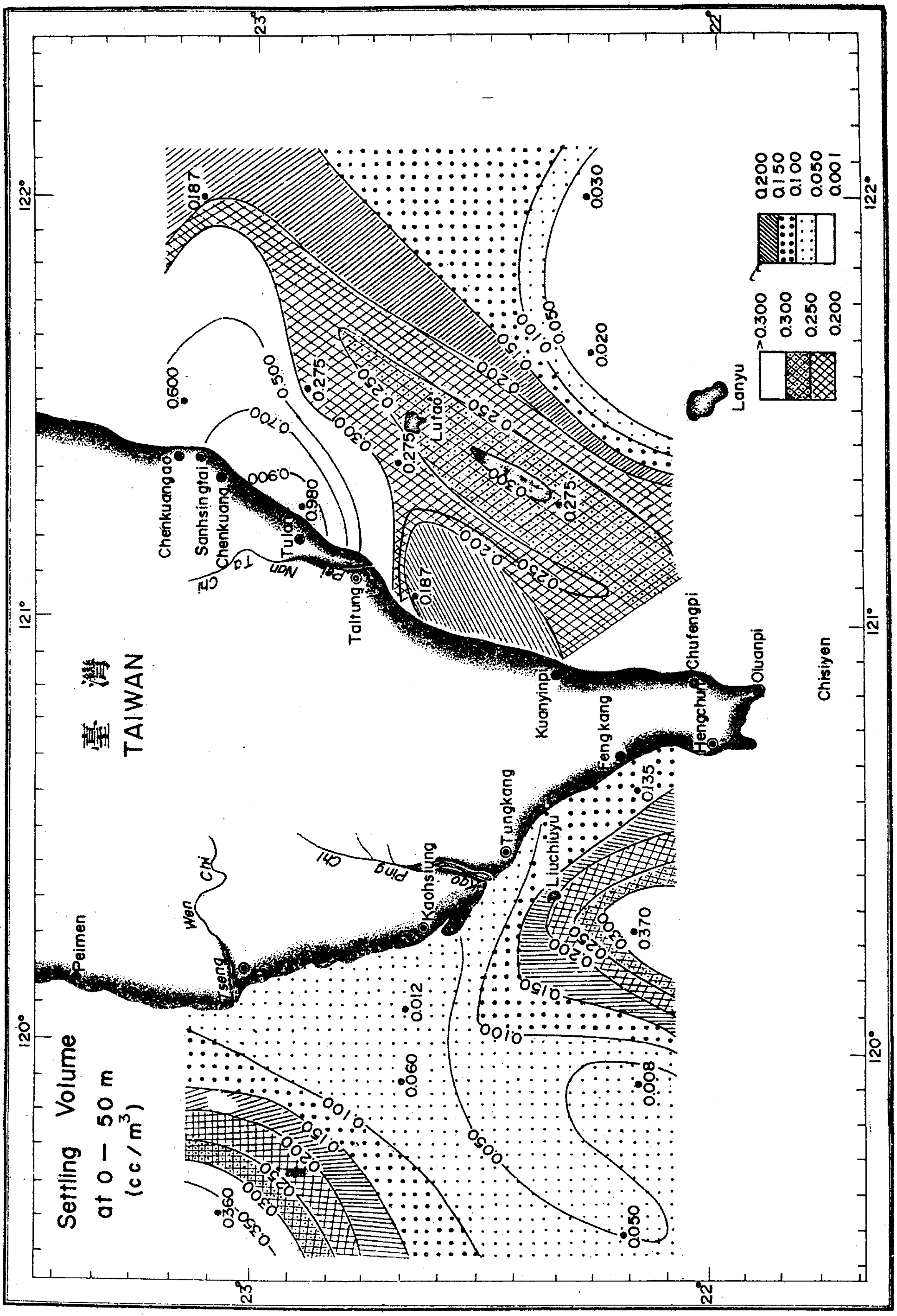

Settling Volume
at 0 – 50 m
(cc/m³)
臺灣
TAIWAN
Peimen
Kaohsiung
Tungkang
Liuchiuyu
Fengkang
Hengchun
Oluanpi
Chufengpi
Kuanyinpi
Taitung
Tulan
Chenkuang
Sanhsingtai
Chenkuangao
Lutao
Lanyu
Chisiyen
Ping Chi
Wen Chi
Ta Nan Chi
>0.300
0.300
0.250
0.200
0.200
0.150
0.100
0.050
0.001
120°
121°
122°
22°
23°

Fig 8

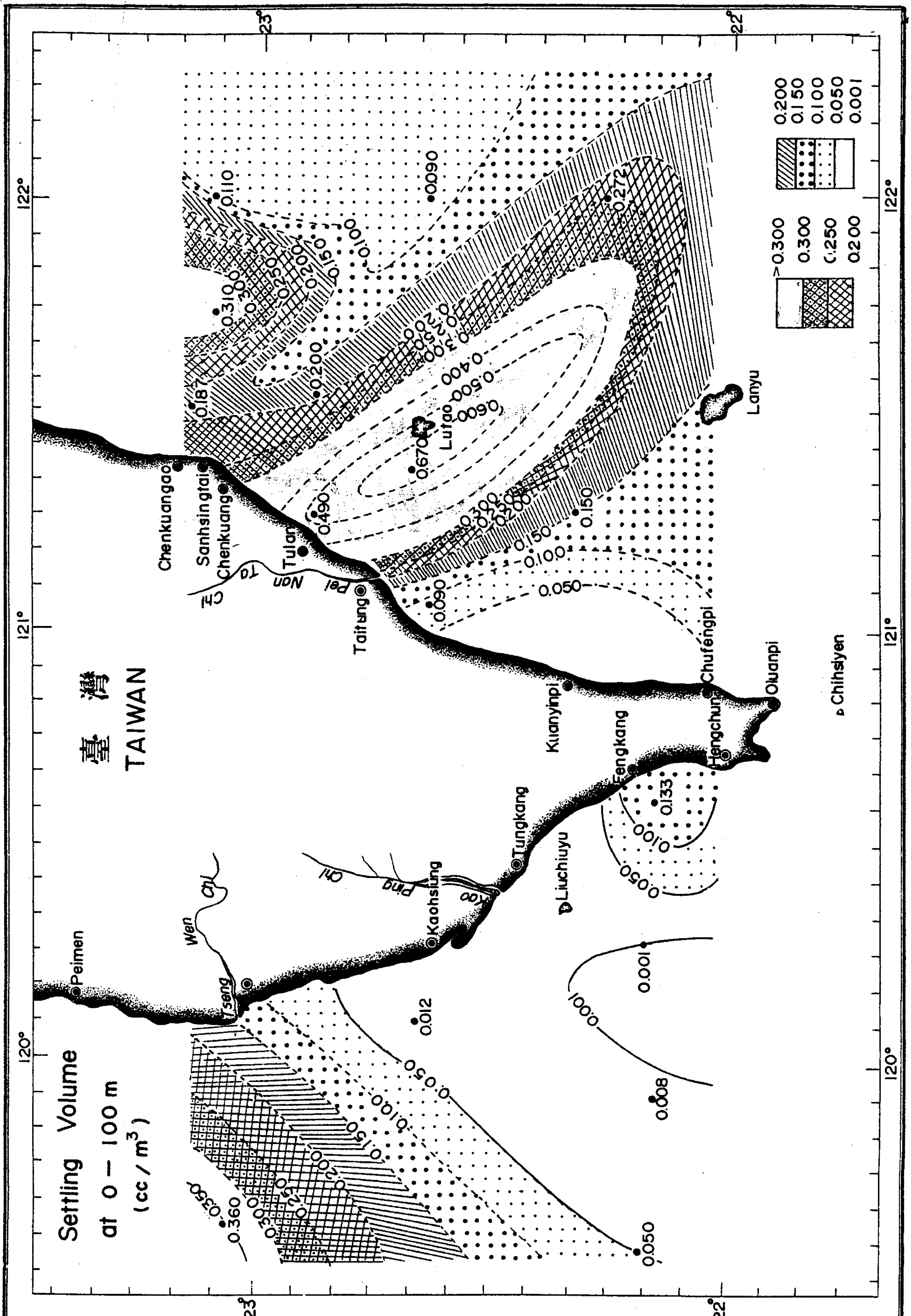

Settling Volume
at 0 – 100 m
(cc / m3)
臺灣
TAIWAN
Chenkuangao
Sanhsingtai
Chenkuang
Tulan
Taitung
Lufao
Lanyu
Kuanyinpi
Chufengpi
Oluanpi
Chihsiyen
Hengchun
Fengkang
Tungkang
Liuchiuyu
Kaohsiung
Peimen
Pei Nan Ta Chi
Kao Ping Chi
Tseng Wen Chi
>0.300
0.300
0.250
0.200
0.200
0.150
0.100
0.050
0.001
23°
22°
122°
121°
120°

Fig 9

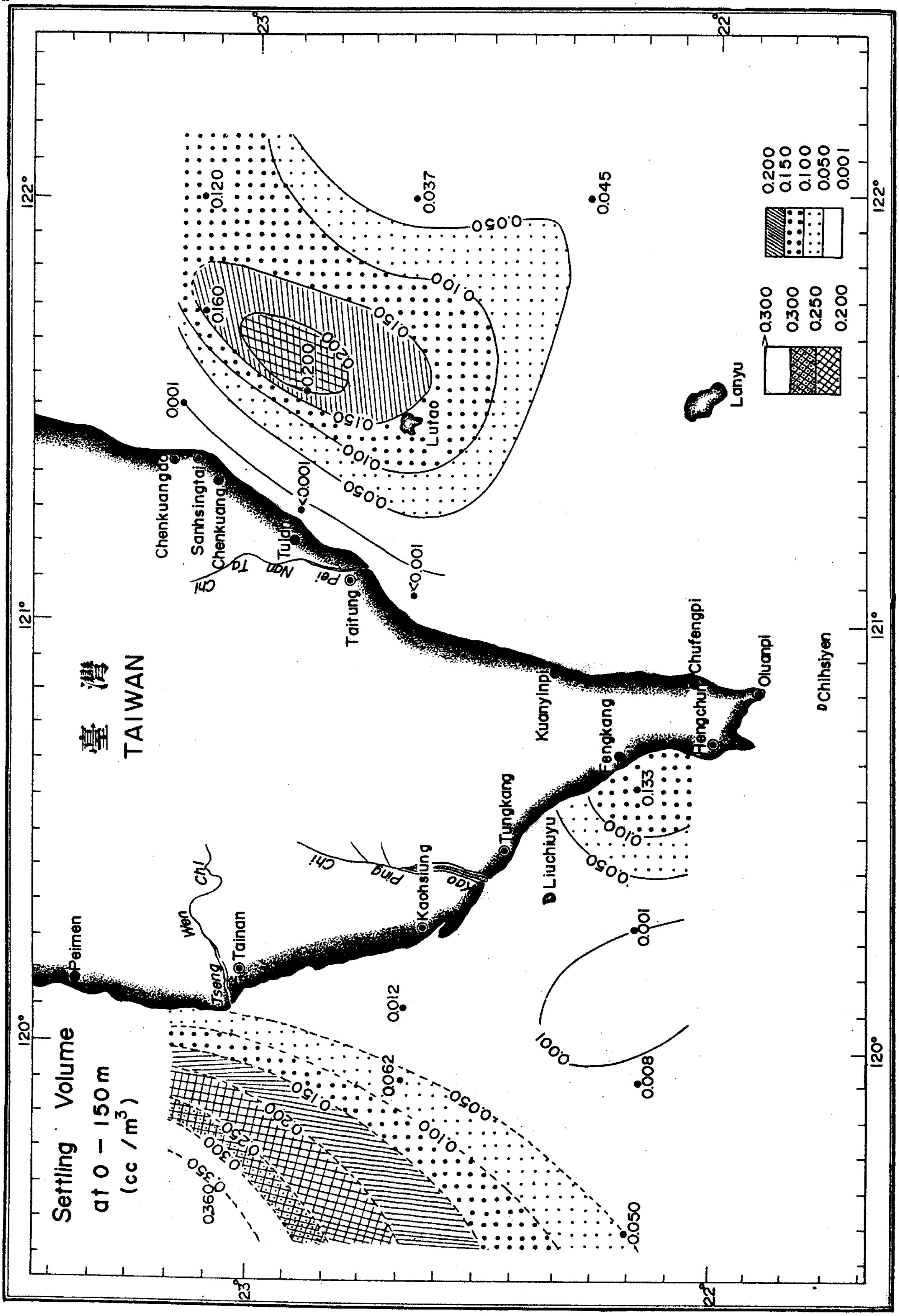
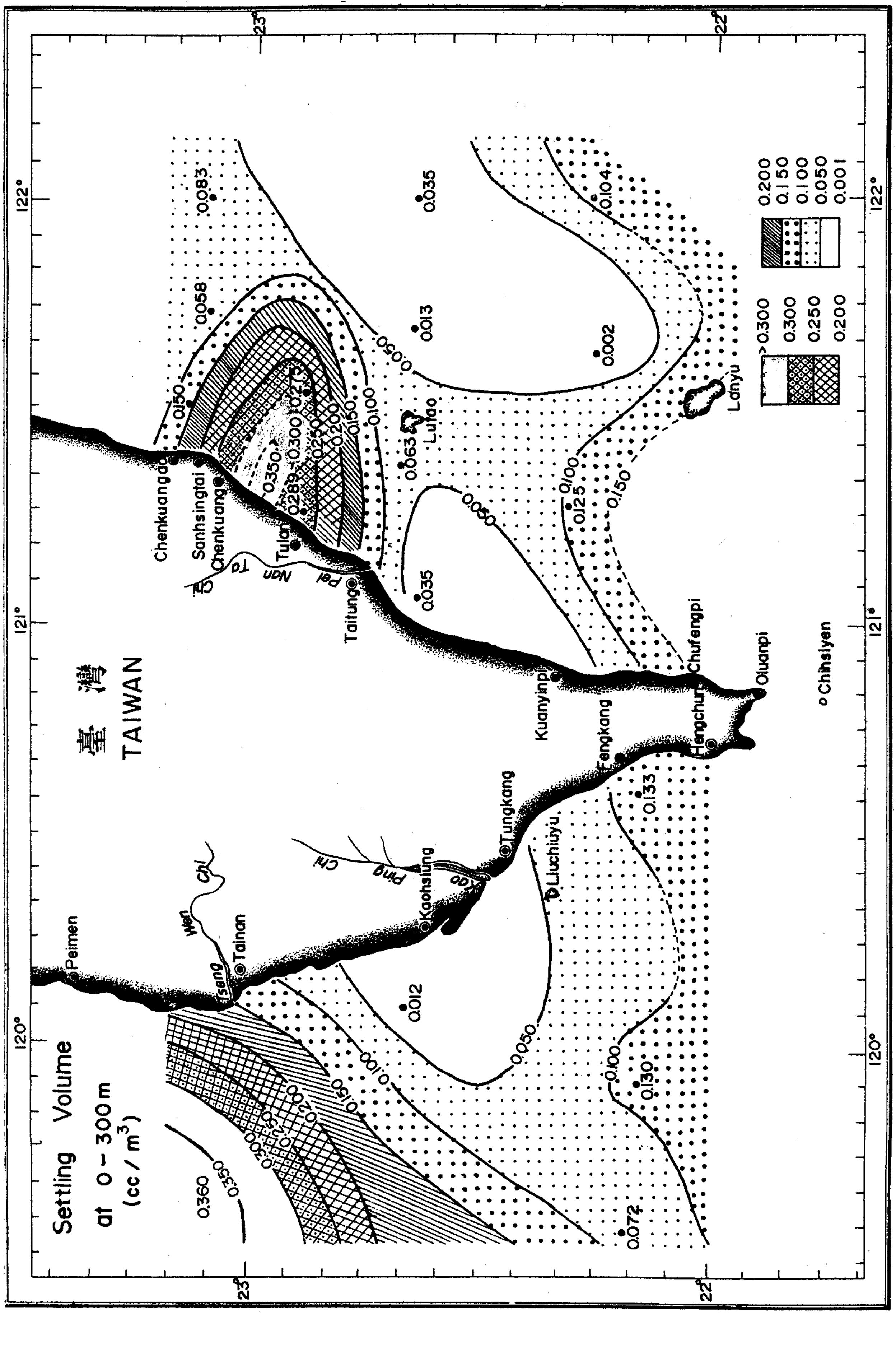

Settling Volume
at 0 – 150 m
(cc/m3)
臺灣
TAIWAN
Peimen
Tainan
Kaohsiung
Tungkang
Liuchiuyu
Fengkang
Hengchun
Oluanpi
Chufengpi
Kuanyinpi
Chihsiyen
Taitung
Tulan
Chenkuang
Sanhsingtai
Chenkuangao
Lutao
Lanyu
Tseng
Wen Chi
Ping
Kao
Pei Nan Ta Chi
120°
121°
122°
22°
23°
0.360
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.062
0.012
0.001
0.008
0.133
0.120
0.160
0.037
0.045
<0.001
>0.300
0.300
0.250
0.200
0.200
0.150
0.100
0.050
0.001

Fig 10


Settling Volume
at 0 – 300 m
(cc / m³)
臺灣
TAIWAN
Chenkuangao
Sanhsingtai
Chenkuang
Tulan
Taitung
Lutao
Lanyu
Kuanyinpi
Fengkang
Hengchun
Chufengpi
Oluanpi
Chihsiyen
Tungkang
Liuchiuyu
Kaohsiung
Tainan
Peimen
Pei Nan Ta Chi
Kao Ping Chi
Tseng Wen Chi
>0.300
0.300
0.250
0.200
0.200
0.150
0.100
0.050
0.001
23°
22°
122°
121°
120°

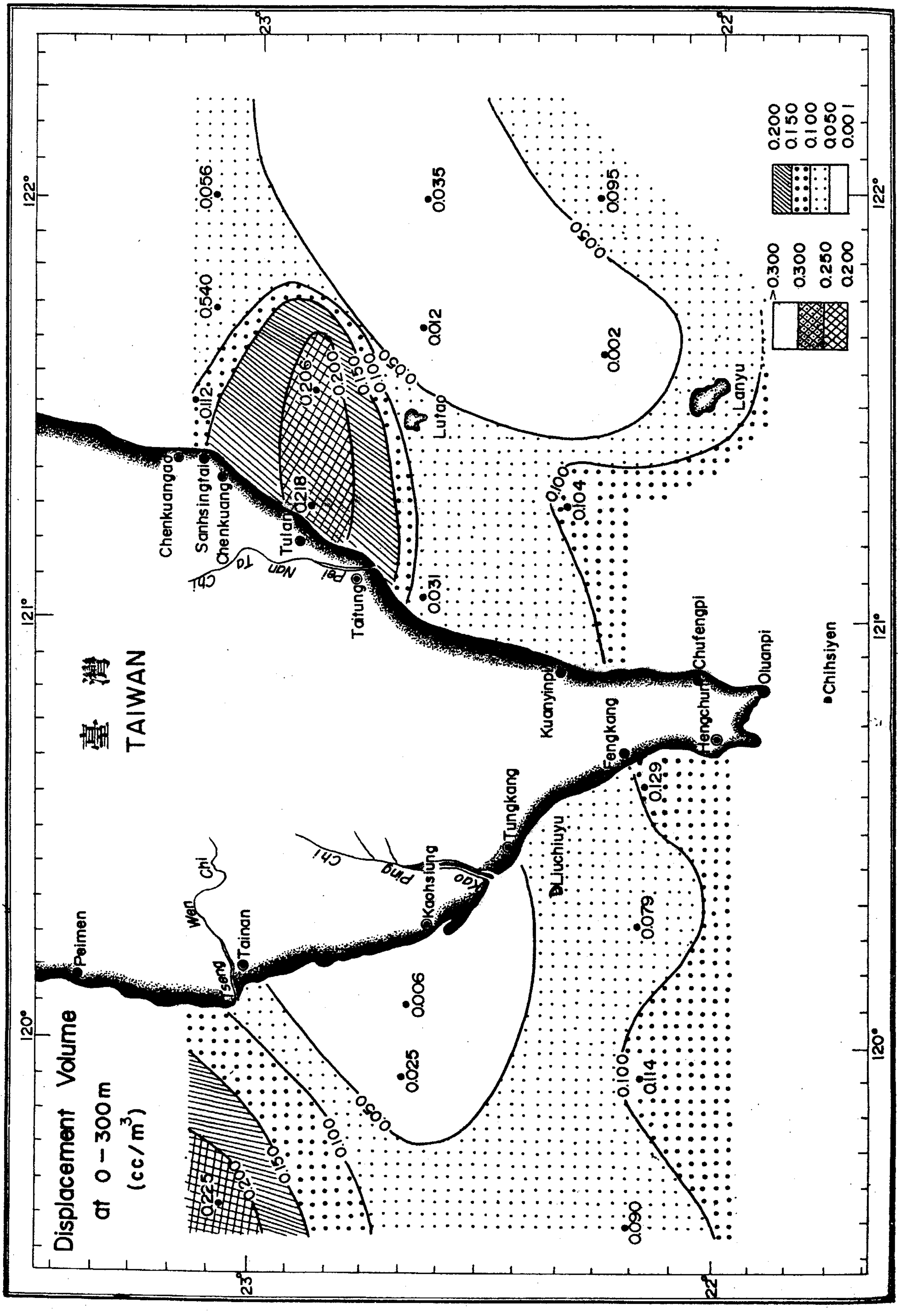
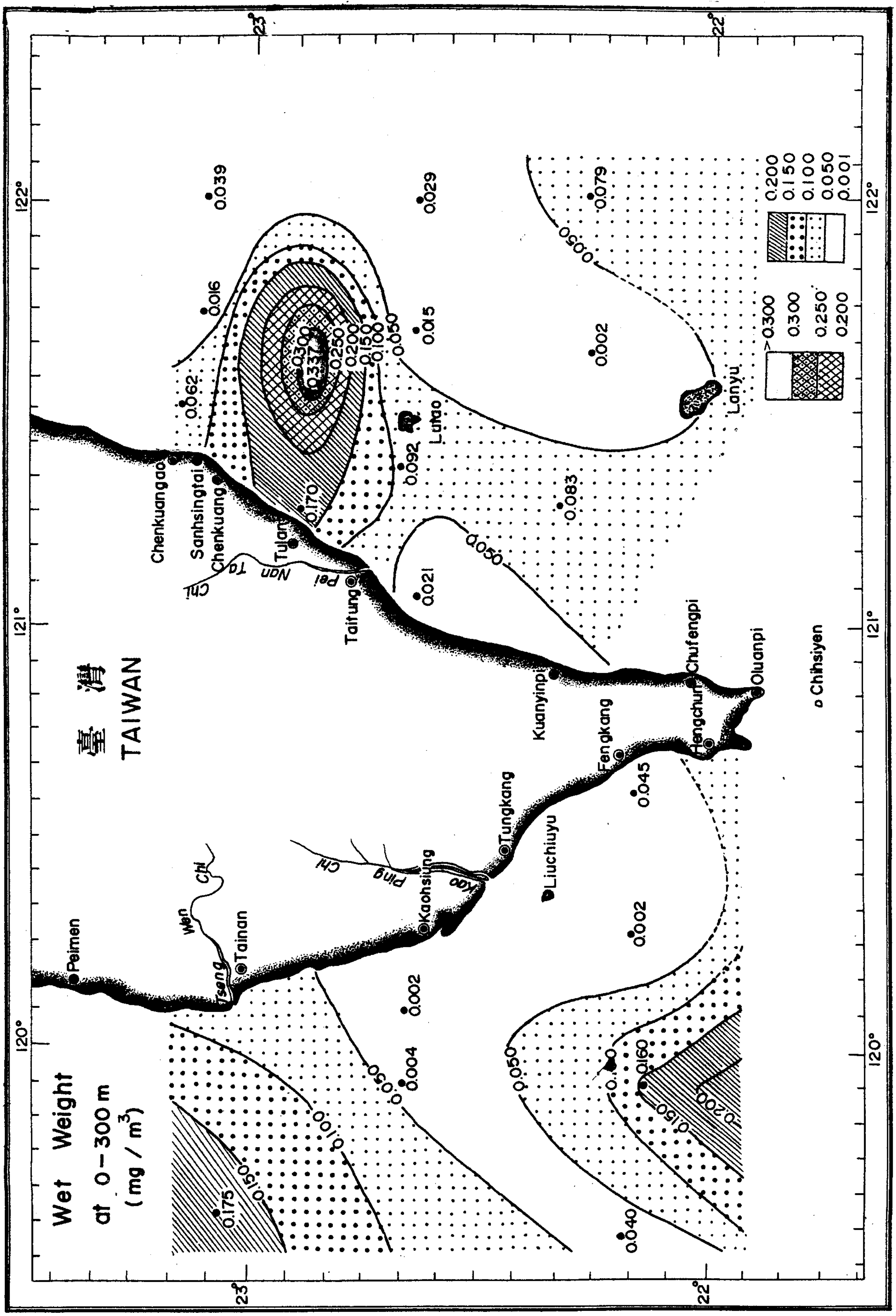

Displacement Volume
at 0 – 300 m
(cc/m³)
臺灣
TAIWAN
>0.300
0.300
0.250
0.200
0.200
0.150
0.100
0.050
0.001
Chenkuangao
Sanhsingtai
Chenkuang
Tulan
Taitung
Lutao
Lanyu
Kuanyinpi
Chufengpi
Oluanpi
Hengchun
Fengkang
Chihsiyen
Tungkang
Liuchiuyu
Kaohsiung
Tainan
Peimen
0.056
0.540
0.112
0.035
0.012
0.095
0.002
0.206
0.218
0.104
0.031
0.129
0.079
0.006
0.025
0.114
0.090
0.225

Fig 12


Wet Weight
at 0 – 300 m
(mg / m³)
臺灣
TAIWAN
Peimen
Tainan
Tseng
Wen
Chi
Kaohsiung
Kao
Ping
Chi
Tungkang
Liuchiuyu
Fengkang
Hengchun
Oluanpi
Chihsiyen
Kuanyinpi
Chufengpi
Taitung
Pei
Nan
Ta
Chi
Tulan
Chenkuang
Sanhsingtai
Chenkuangao
Lutao
Lanyu
>0.300
0.300
0.250
0.200
0.200
0.150
0.100
0.050
0.001
120°
121°
122°
22°
23°