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FACULTÉ DES SCIENCES

LABORATOIRE D'ANATOMIE COMPARÉE ET D'OCÉANOLOGIE

CONTRIBUTION TO THE ECOLOGICAL STUDY OF PLANKTON IN THE SOUTHERN OCEAN

J. STEYAERT

Lic. en Sciences U.L.B

Directeur de mémoire:
Monsieur le Professeur
J. BOUILLON.

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A Papy.

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INTRODUCTION

From the Renaissance on, people got interested in the "terra australis nondum cognita" and most various opinions about its existence were enounced. Bouvet, in 1738, organized an expedition to the south and discovered an island to which his name was given ultimately. The first properly antarctic expedition was undertaken by the english man, Cook, (1772-1775), who reached the 71st degree of latitude south.

During the whole 19th century, many expeditions explored, little by little, parts of that unknown continent : Palmer Peninsula, Bellinghausen Sea, Ross Sea, South Orkneys Islands... The first overwintering blocked up in the ice along the Palmer Peninsula, was accomplished by the Belgica expedition, under the leadership of de Gerlache (1897-1899).

During the 20th century, with the increasing interest for the Antarctic Continent, numerous raids were organized to attempt to reach the South Pole (Amundsen-Scott,1912) and to gain knowledge on the topography of the land itself.

Gradually, with the quickening development of technology, antarctic expeditions became more complex and began to take new dimensions.

The world's scientists were more and more looking to the Antarctic as an ideal laboratory for geophysical investigations and in 1957-1958, with the International Geophysical Year (I.G.Y.), scientists of 12 nations, established an international scientific program, with the Antarctic as main objective.

Although this huge continent has an important geopolitical position, and notwithstanding that some nations did claim some territorial rights, an Antarctic Treaty was signed by twenty nations in 1959, recognizing the internationality of Antarctica and the surrounding waters up to the 60th degree of latitude South. A Scientific Committee on Antarctic Research (SCAR) was established to promote scientific work in this area.

> ... Recognizing that it is in the interest of all nations that Antarctica shall continue to be used exclusively for pacific purposes and shall not become the scene or object of international discord...
>
> From the preamble of the Antarctic Treaty 1959.

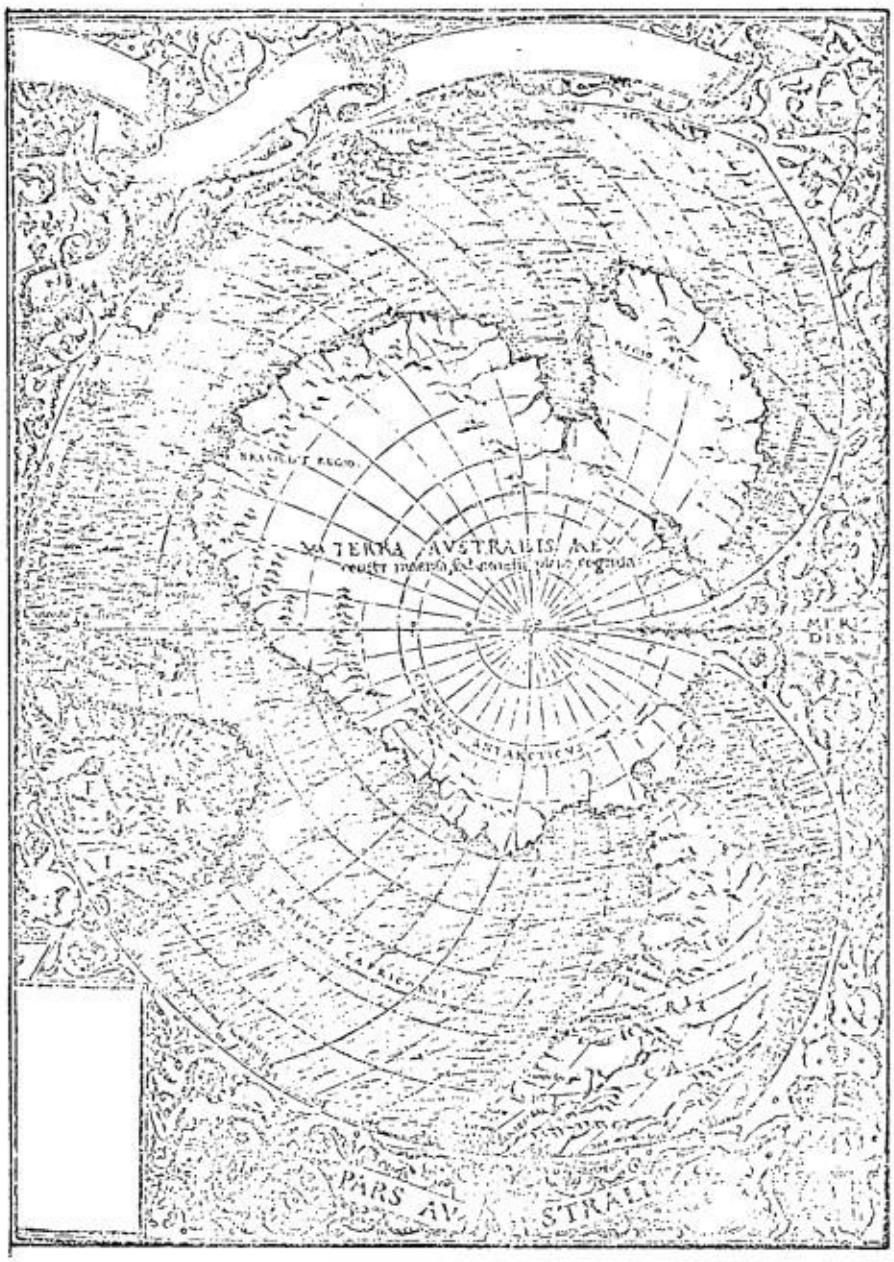


Fig. 1 : SOUTHERN HEMISPHERE – MAP OF ORONTIUS 1531

THE ANTARCTIC CONTINENT

Antarctica is a large continent of nearly 12,5 million km2, covered on about 98 % of its surface by a thick ice cap. In first approximation, the Antarctic is round shaped, with the South Pole as centre; however, the circle outline is altered by the Palmer Peninsula or Graham Land (in front of South America) and two marked indentations, the Weddell Sea and the Ross Sea (Fig. 2). Two regions are commonly recognized : Eastern Antarctica (in front of the Atlantic and Indian Oceans) and Western Antarctica (in front of the Pacific Ocean). The subdivision in Eastern and Western Antarctica is not only made on basis of geographical features, but corresponds also to geological and glaciological differences. The subglacial floor lies for the major part in the Western Antarctic beneath the adjusted sea level, while nearly everywhere in the Eastern Antarctic it lies above the adjusted sea level (level of the sea after total melting of the ice cap).

The total mass of ice, covering the Antarctic Continent, represents, approximately, 90 % of the total ice in the world, which means that, suddenly melting, it would raise the ocean level of about 60 meters.

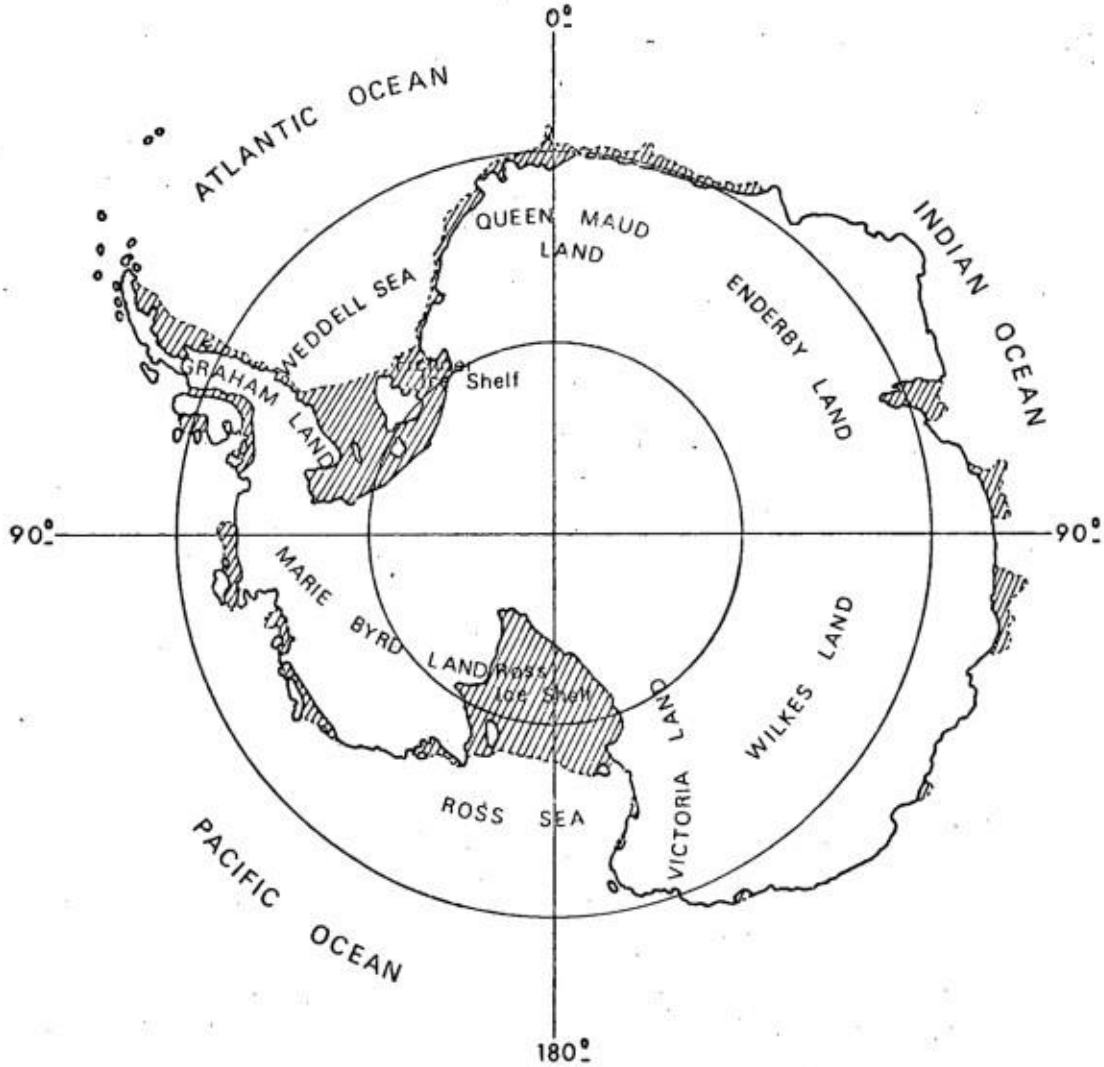


Fig.2: General map of Antarctica (hatched : ice shelves).

The thickness of the ice sheet over the continent is estimated of an average of 2 000 meters. This sheet is nourrished essentially by snow precipitations which are closely linked to the movements of low pressure around Antarctica.

The main precipitation occurs near the coast and decreases with the distance inland and, in the centre of the continent, truly desert conditions exist. But winds redistribute freshly fallen snow over great distances. On basis of differences between summer and winter snow layers, glaciologist were able to count annual bands and to determine the importance of the seasons for each year. In deeper ice, the stratification method is replaced by dating procedures which gives information on the past history of the ice conditions and of the antarctic climate.

More than one third of the Antarctic coastline is fringed by ice shelves, extending to about 1,4 million km2. The ice shelves are floating ice sheets. The two largest are the Ross Ice Shelf (Ross Sea) and the Filchner Ice Shelf (Weddell Sea) (Fig. 2). Their thickness varies from 200 m at the ice front, up to 1 300 m at the junction with land ice, sometimes some hundred kilometers inland. These floating sheets break up regularly and form icebergs.

Moreover Antarctica is surrounded by a belt of sea ice or pack ice, formed by the freezing of sea water. The extension of this pack ice varies with seasons.

Forming a compact and fast belt at its maximum extension during the winter season, (26.10^6 km2) it starts melting at its northern limit and regresses southwards during the summer season, leaving large masses of ice only in the Bellinghausen Sea and in the Weddell Sea. Rough estimations show that, by the end of the summer, the sea ice area is reduced to between one half and one third of the maximum winter extension. The major work on Antarctic sea ice distribution was published by Mackintosh and Herdmann in 1940. This work is based on observations made during the Discovery Expeditions, and on board various whaling factory ships as well as during other expeditions. It gives only the ice edge position and nothing about the variation of ice concentration inside these limits. If the general features of the seasonal variation of the pack ice edge are known, less is known concerning its interannual variations. The pack ice is affected by movements, generally from east to west, excepted in the Weddell Sea, were a clockwise circulation is observed. These movements are correlated with the general oceanic circulation, and are dependent on the pressure fields and on the wind circulation around the Antarctic. The Antarctic pack ice, although younger in general than the Arctic pack ice, has sometimes been found to be older than one year.

Very little is known aboutthis fact.

The ice cap, the atmosphere and the ocean are linked through complex energy interchanges. The Earth intercepts a small portion of the sun radiation into space. The incident solar radiation varies with latitude and with seasons and is deplated in many ways, before reaching the Earth's surface. The mean annual temperatures on the Earth's surface remains roughly unchanged from year to year, which means that the planetary radiation budget is in balance. Therefore, because the low latitudes have an annual excess of incoming radiation energy, the polar regions serve as an heat sink. The balance is essentially made up by atmospheric circulations to the poles. It is materialized, in the south, by complex circumpolar pressure fields and wind systems. On an average, westerly winds predominate in the whole Southern Ocean, as far south as 65°S (West Wind Drift), while easterly winds cover most of the coastal areas (East Wind Drift) (Fig. 3). The pathways of the main winds influence on the Southern ocean currents leading to the West Wind Drift Current and the East Wind Drift Current around the Antarctic Continent (Fig. 4).

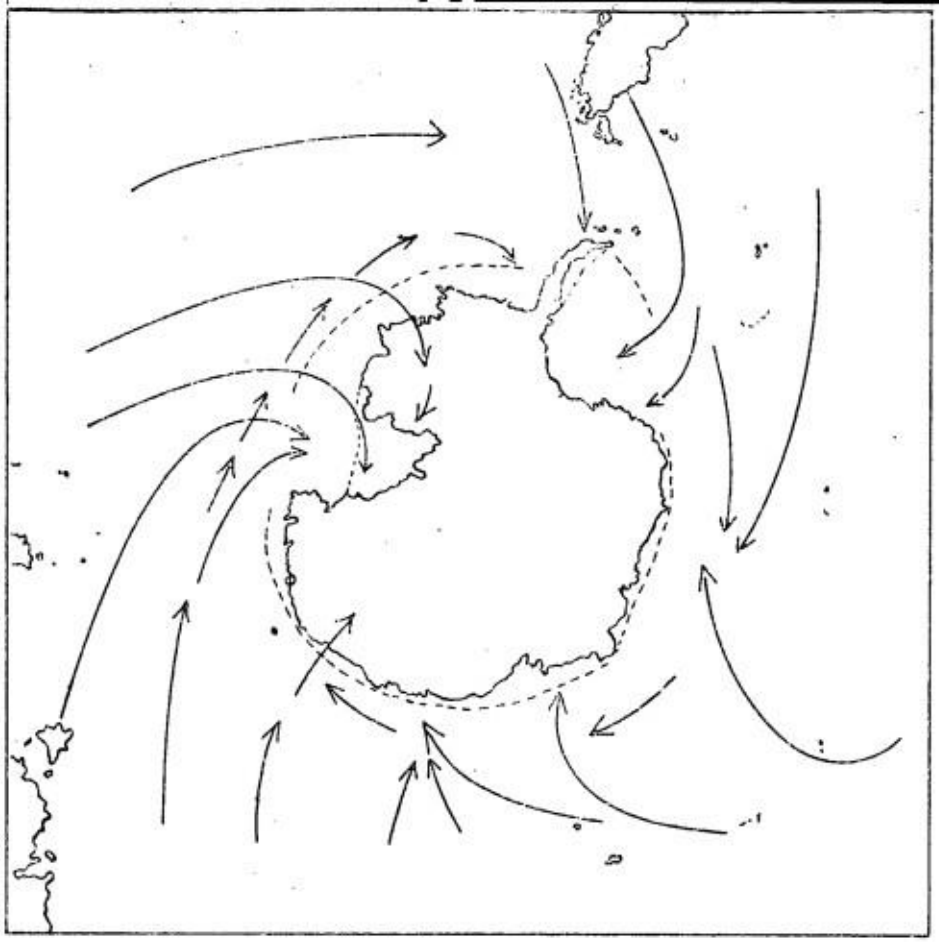


Fig. 3: Winter Storm tracks plotted schematically (Rubin Scient. Am.).

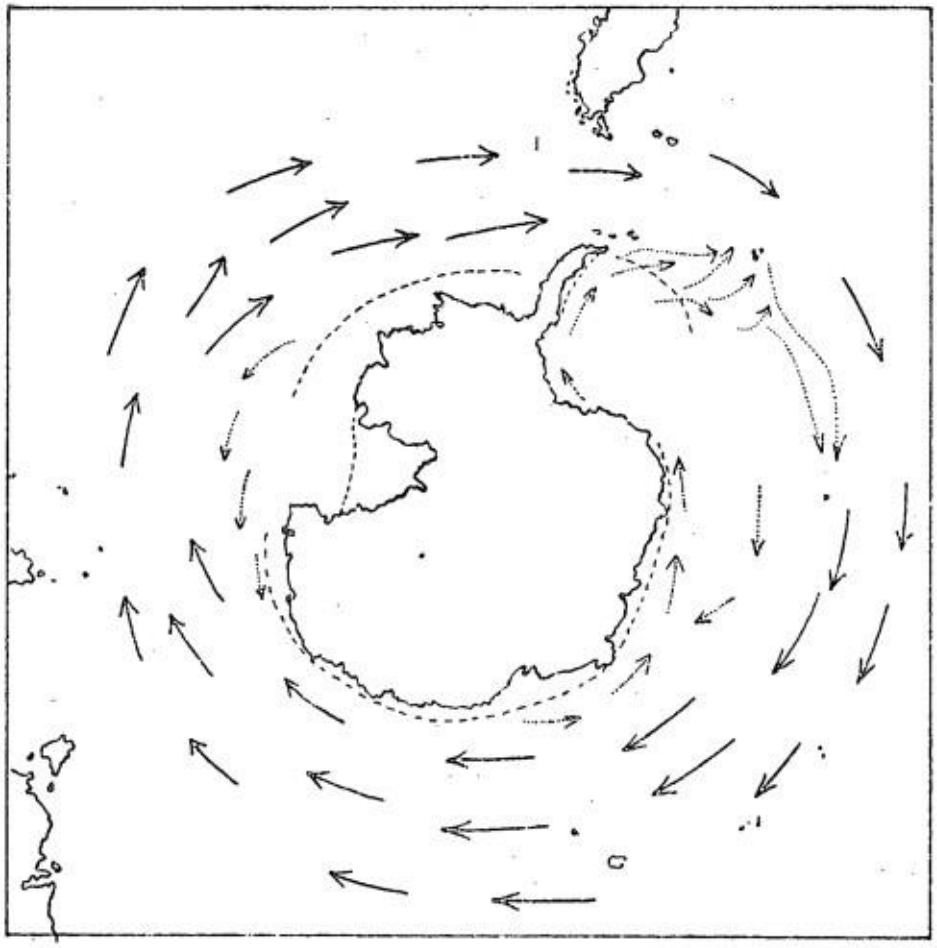


Fig 4 Antarctic Surface Currents (Knox-Ant. Ecol.).

THE SOUTHERN OCEAN

The Antarctic Continent is surrounded by a vast oceanic area, almost free of circulation. Different opinions have been expressed about the geographical nature of this oceanic area. Some authors advocate that the Atlantic, Indian and Pacific Oceans extend south to the margins of the continent, while others consider the existence of a Southern Ocean, as a separate entity. This last point of view is most generally admitted in the literature. More controverted, is the northern limit of the Southern Ocean. On basis of hydrological features, some authors (Herdmann and al. 1956) proposed the northern limit of the Antarctic Surface Waters (Antarctic Convergence), as an acceptable boundery for the Southern Ocean. However, other authors looking at the Southern Ocean in terms of ocean dynamics and circulation, consider that the Antarctic Convergence cannot be designated as the northern limit, since the eastward moving circumpolar current extends further north, through the Antarctic Convergence, up to the Subtropical Convergence (around 40°S) where they do place the northern boundery of the Southern Ocean. During the last conference of the Intergovernmental Oceanographic Commission working group on the Southern Ocean (Brussels, november 1970), the term of Southern Circumpolar Waters was proposed for the whole Southern Ocean, from 40°S (Subtropical Convergence) up to the Antarctic Continent, reserving the

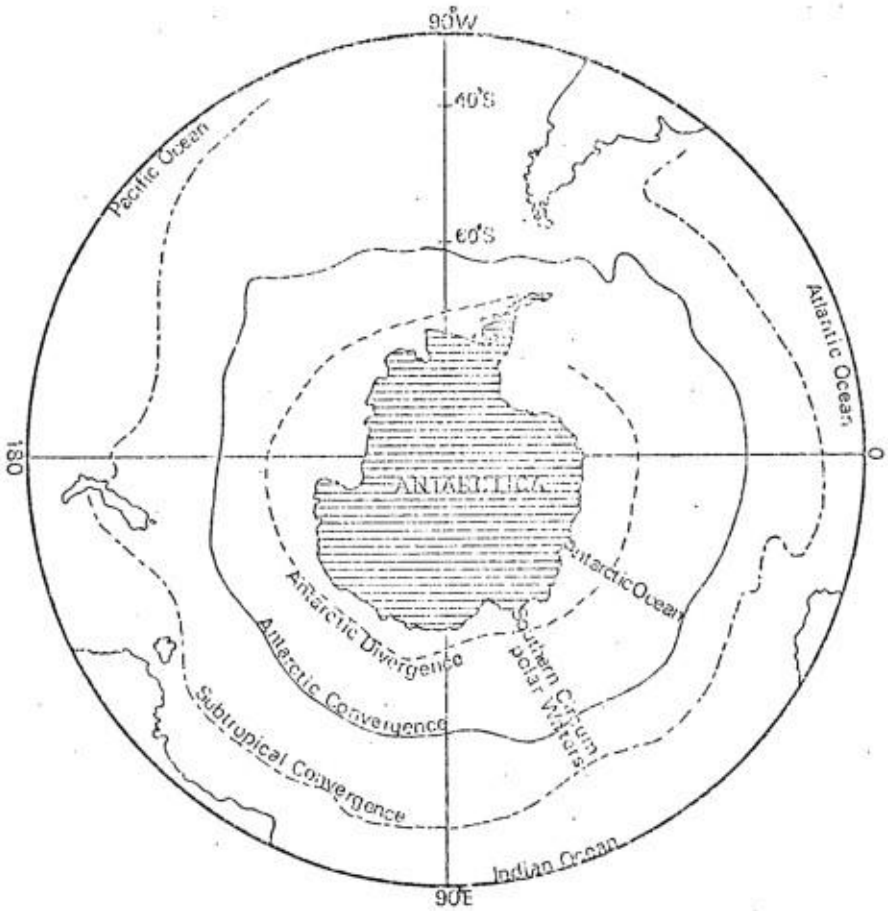


Fig. 5 : Locations of Antarctic and Subtropical Convergences and Antarctic Divergence (Easterly Winds) (Sverdrup 1942).

term Antarctic Ocean to the part south of the Antarctic Convergence (Fig. 5). In fact, the difficulties encountered for the definition of the northern boundery of the Southern Ocean are due to the relative importance, which separate investigators give to different variables. Deacon (1937) and Sverdrup (1942), outlined the patterns of circulation in the Southern Ocean, essentially, on basis of the temperature and salinity distribution (Fig.6). The observation of the latitudinal orderly spreaded isotherms at some definite latitudes, shows abrupt changes in the surface temperature.

Indeed, when progressing southward, two main sharp temperature changes are encountered, the first one at about 40°S, and the second between the 50° and 60°S. These sharp gradients of temperature, correspond with convergence zones, where the surface waters are sinking. The northernmost convergence is called, the Subtropical Convergence and separates the Subtropical Waters from the Subantarctic Waters. The position of this convergence is variable, especially in the eastern part of the oceans and its existence between 60°W and 120°W is apparently unknown (Koopman, 1953; Deacon,1963). The second convergence is called the Antarctic Convergence (or Polar Front) and makes the boundary between the Subantarctic Waters and the Antarctic Surface Waters. Various authors found the Antarctic Convergence fluctuating with the seasonal variations. For instance, Mackintosh (1946) found a northerly displacement of the Antarctic Convergence during cold months and a southward displacement during warm months, as well as variations within same month. Ivanov (1961) reports variation amplitudes of 4 degrees latitude. Beside these two convergences, a zone of divergence has been recognized at the limit between the West Wind Drift and the East Wind Drift.

Under the influence of the wind circulation and of the Earth's rotation, the ocean surface waters move, on each side of the Antarctic Divergence, in an opposite direction, creating an upwelling of the subsurface waters. The position of this divergence, its occurence and strength are variable and strongly depending on the prevailing meteorological conditions (Ivanov, 1961).

During the last decade, more detailed investigations based on temperature, salinity and other variables, have brought to light a more complex picture of the hydrological feature of the Southern Ocean, which diverge in some respects from the general scheme suggested by Sverdrup. Ostapoff (1962) and Houtman (1967) found a Subantarctic Front north of the Antarctic Convergence and Gordon (1967) an northern and a southern branch of the Antarctic Convergence with warmer water between the two zones. Ivanov (1961) suggested a Subantarctic Divergence between the Subtropical and the Antarctic Convergence. Koopman (1953) demonstrated the existence of a Continental Convergence between the Antarctic Divergence and the Continent, and considered the Antarctic Divergence as corresponding to a silicate maximum in the surface waters. Burling (1961) observed that the sinking of surface water, forming Antarctic Intermediate Waters, occurs over a broad zone north of the Antarctic Convergence.

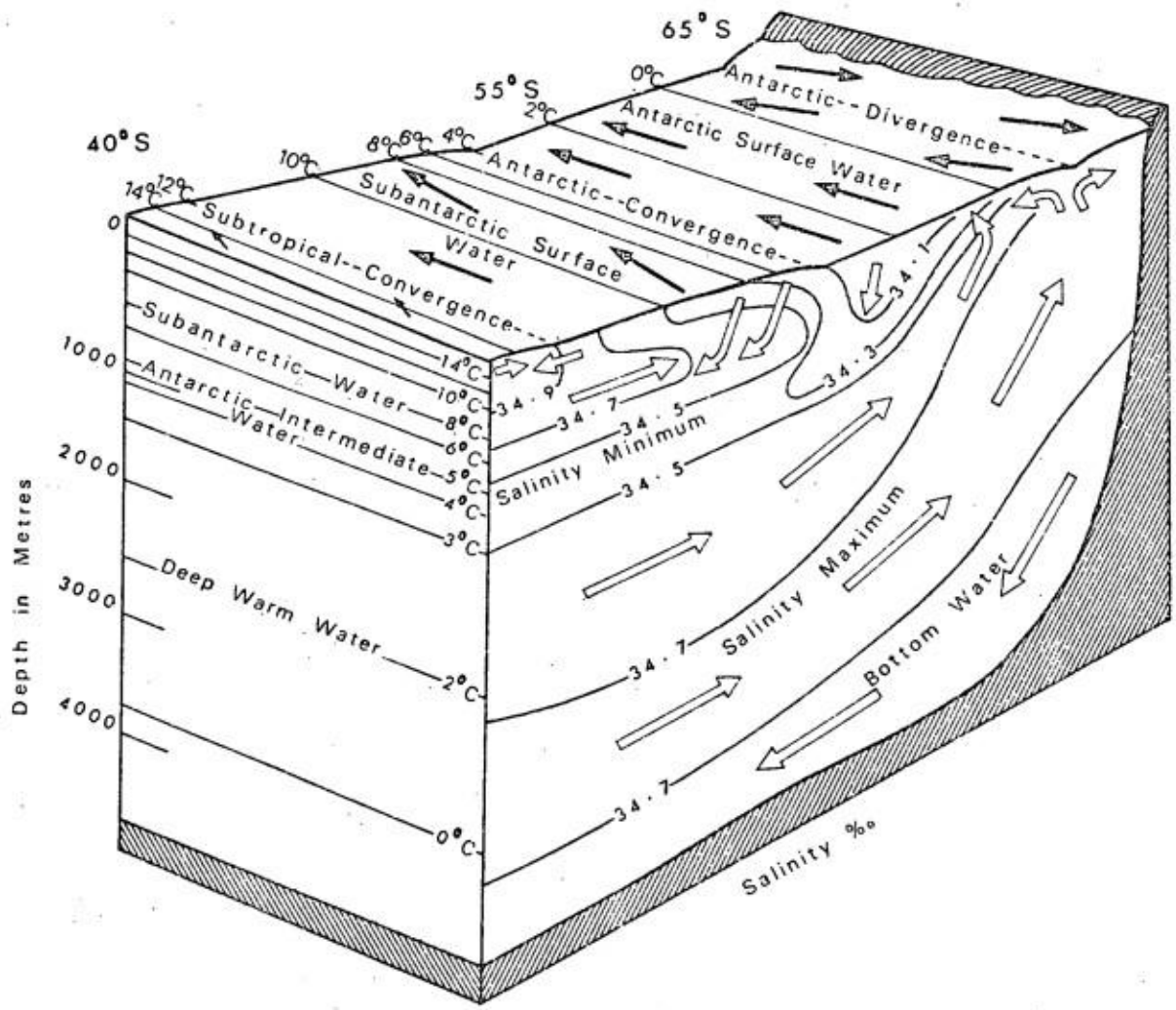


Fig. 6: Schematic diagram of the meridional and zonal flow in the Southern Ocean (Sverdrup, 1942)

Wyrtki (1960) described the distribution of divergent and convergent motions at the surface of the Southern Ocean, under varying conditions of the westerly winds.

All the above mentioned subdivisions are primarily surface features, although the deeper layers of the ocean are, in fact, in continuation with the deep circulation, extending to the north of the major ocean basins. It must be also noted that the meridional water transport is less important than the transport along the zonal Circumpolar Current, which involves the whole depth of waters in the Southern Ocean.

DIATOM INVESTIGATIONS IN THE SOUTHERN OCEAN

"Biological studies, and especially marine biology, have received the least attention of the sciences in Antarctic. The major efforts have been made into geographical, physical and geophysical sciences and into physical and chemical aspects of oceanography. Oceanographers and marine biologists need a ship as working base and the use of the ships in the Antarctic have usually been controlled with the priorities of logistics first foremost, then for other scientific investigations, then for oceanography, with marine biology fitted in as opportunity offered" (Dell, Antarctica, 1970).

In addition to the lack of opportunities, biological work, ecological as well as physiological, needs a background of systematic, which, for all the marine organisms in this southern area, is very unsufficiently known and requires time and patient work.

The Southern Ocean, in addition of being of great interest for pure science, is a favorable field of investigation, particularly for planktonic organisms. Indeed, the Southern Ocean waters exhibit, over great distances, remarkably uniform and regular features, all around the continent. This gives the opportunity, on a scale impossible to find in other areas, of broad investigations on the distribution of fauna and flora and their interrelationships. It gives also the chance to verify general principles of marine ecology. Moreover, the existence of an extended pack ice, over a long winter period, gives the possibility for interesting physiological investigations on reduced light and cold water adaptation.

Studies on sediments of the Southern Ocean floor has revealed, in the whole part south of the Antarctic Convergence, the presence of Diatom oozes, replaced, a little north of the Antarctic Convergence, by Globigerina oozes.

Lisitzin (1960, 1962) and Kozlova (1966) have demonstrated that the horizontal transport of dead cells was less important than their sedimentation rate and that the Diatom composition, for the strongest silicified species, was nearly the same in the sediments as in the upper water layers. Diatom oozes were found in deep cores, taken in the Subantarctic Region (near Crozet Island), underlying Globigerina oozes, typical of warmer water. This finding would let thinking that the extension of the Antarctic Waters to the north was perhaps greater in earlier times. The study of typical Diatom populations, corresponding to specific water conditions, compared to the Diatoms found in deep cores, might probably help in understanding the past oceanic and climatic regimes of the Antarctic.

Phytoplankton, composed in the Southern Ocean, for more than two thirds by Diatoms, is the ultimate food for all marine organisms. In this respect, investigations on Diatom biomass, productivity and abundance periodicity are desirable for the understanding of the antarctic ecosystems. Although of a high individual biomass, the number of marine species is relatively reduced in the Antarctic Ocean and the food chains are often very short. One of the most important food chains - at least one of the best known, because its economical importance - is, the Diatom - Euphausia - Baleen Whale food chain.

The average biomass of Euphasia (krill) was estimated by Vinogradov and Naumov (1958), in a first approximation, to account for half of the Southern Waters zooplankton biomass. Some authors consider that, whales being actually decimated in the Southern Ocean, the krill might be an interesting exploitable resource. Some estimations put forward that the surplus of krill would be no less than 30 million tons. Investigations on krill resources are mainly worked out by Soviet and Japanese scientists. In this respect, it has been stated at the Symposium on Antarctic Ecology (1970) that "before commercial exploitation of krill, one has to know more about all the elements concerned in the life cycle of krill" and consequently to investigate on the avaible quantity (in time and space) of their primary food resource i. e. mainly Diatoms.

The reputation of extreme richness of the phytoplankton in the Antarctic Waters, dates back to the time when Hooker, the botanist of the Erebus and Terror Expedition (1839-1843), reported that "they occured in such countless myriads, as to stain the Berg and the Pack-Ice". Some of the samples taken during this expedition were sent to Ehrenberg, who published the first paper on Antarctic Diatoms, in 1844.

Since that time, numerous phytoplankton investigations were carried out and some 100 papers have been published on marine microscopic algae of the Southern Ocean, most of them concerning Diatoms. Quantitative data on Diatom standing stock, is only reported in less than half of these contributions, of which a good deal only mention the relative abundance of species encountered. Quantitative data, related to cell numbers, were given by Hentschel (1936), Hasle (1956,1960,1969), Marumo (1957), Bunt (1961,1964), Klyashtorin (1961), Kozlova (1961,1966), Zernova (1970), Fukase (1962). Other methods of investigation, like the analysis of pigment concentration, were employed to evaluate the phytoplankton standing stock (Bunt,1961,1964; Burkholder and Sieburth,1961; Ichimura and Fukushima,1963; El-Sayed, Mandelli and Sugimuro,1964; Sayo and Kawashima,1964; Burkholder and Mandelli,1965; El-Sayed and Mandelli,1965; El-Sayed,1966a, 1966b,1970; Mandelli and Burkholder,1966).

Most of the quantitative investigations were carried out in the open ocean extending sometimes to the coastal waters (Pacific sector : Hasle,1956,1969; Marumo, 1957; Klyshtorin,1961; El-Sayed,1966; Fukase,1962 - Indian and Pacific sectors : Kozlova,1966 - Atlantic - Indian sector : Saijo and Kawashima,1964 - Drake Passage, Weddell Sea, Bellinghausen Sea : Hentschell,1932,1936; El-Sayed and Mandelli,1965; Burkholder and Mandelli,1965; El-Sayed 1966a).

Few of them were done in inshore waters (Bunt at Mawson and Mac Murdo Sound; Burkholder and Sieburth, Mandelli and Burkholder in the Gerlache and Bransfield Strait) and on ice algae (Bunt, 1963; Burkholder and Mandelli, 1965; Meguro, 1965; Fukushima and Meguro, 1966).

With regards to the period of the year, nearly all the quantitative studies were performed during the austral summer season.

Although various methods have greatly contributed to give valuable estimations on the size of the phytoplankton standing stock, it is only occasionally that very recent works give an absolute measurement of the total standing stock, based on quantitative countings of phytoplankton, while the same computation for each species contributing to the total bulk, was only done by Kozlova (1966) and Hasle (1969).

Finally, no quantitative studies were done simultaneously on phytoplankton populations living in open and inshore waters and in the ice.

Beside our fundamental interest for planktonic Diatoms, the present work is the result of the conjunction of circumstances, of which the principal one was the opportunity to investigate in a very little known area of the Southern Ocean, namely the Zone situated at

the limit between the Atlantic and the Indian Ocean sectors, materialized by the transect between Cape-Town (South Africa) and the Breid Bay (Antarctic Continent), along approximately 20-25 degree longitude East. In fact, this work is part of a larger research programme on the pelagic ecosystem in this area of the Southern Ocean. It must be considered that a such programme of research is essentially based on field survey and that ideal conditions of investigation are nearly always impossible to meet and, in fact, depend on many practical factors, including shipboard facilities and time, weather conditions, coordination with other programmes etc... To remember also that the sea is, with regard to planktonic organisms, a tridimentional substrat, in continuous motion, with the consequence that it is impossible to get twice exactly the same water sample. Nevertheless, the material we had to study, was particularly interesting, as it corresponds to repeated sampling on the same transect, during the same season of three different years and that we had also the chance to study simultaneously the Diatom population in open oceanic and inshore waters and in the ice.

Therefore, the purpose of this work has been defined as follows :

1. to give an estimation of the Diatom biomass along the transect, in the inshore waters of the Breid Bay and in the sea ice;

2. to study the possible relationships between the various Diatom populations and the hydrological conditions in the open oceanic and inshore waters, and with a special reference to the ice habitat;
3. to describe, if any, the relationship between the Diatom populations living in the above mentioned environments;
4. to point out, if any, the interannual variations in the Diatom population distribution as related to the general hydrological conditions;
5. to define selected species, caracteristic of specific areas;
6. to check our results with those of the literature, within the limit of comparable data.

I. MATERIALS - METHODS

MATERIALS.

Phytoplankton material has been collected during the 1960-61 Belgian and 1964-65, 1966-67 Belgian-Dutch Antarctic Expeditions, along a transect between the 20° and 25° Longitudes East, joining up Cape-Town (South Africa) to Breid Bay (Antarctic Continent) and in Breid Day itself. All three expeditions cover approximately the same period of the year; phytoplankton sampling was done only dyring the south-bound cruises, the earliest of all on the 31st December and the lastest on the 4th February. A total of 65 stations were sampled, of which 33,13 and 19 belong to the 1960-61,1964-65 and 1966-67 expeditions, respectively. 55 samples were taken at the 1960-61 stations, all by net. During the two last expeditions, the samples were collected with "Nansen" - type water bottles and by net. The samples of the two last cruises divide up as follows : in 1964-65, 80 water bottle samples and 12 net samples; in 1966-67, 131 water bottle samples and 19 net samples. In total, for the three years, 96 net samples and 211 water bottle samples were analysed.

Water bottles were also used to sample sea water from the different standard depths in view of analyses of physical (temperature, salinity, density) and bio-chemical (primary production, pigmentconcentration, phosphates, nitrates, nitrites, silicates, pH, oxygen) environmental factors. The phytoplankton analyses from water bottle samples refer to the standard depths of 0,20,30,50,75 and 100 meters (in some cases also 10 and 150 meters). The net samplings were done on the basis of a tow from 200 meters down to the surface up. Figures 7 and 8 show the stations along the transect and in the Breid Bay and Table I gives the station numbers with their corresponding position and date of sampling.

Samples of sea ice were also taken at various occasions during the three expeditions (detailed in Chapter III).

In view to estimate the importance of the light penetration below the sea surface, Secchi disc measurements were made at most stations.

METHODS

Collection

The water bottles used were "Nansen" type reversing water bottles of 1,2 l capacity.

1960-1961		
Station	Position	Date
(113) P43 *	39°25'S-19°25'E	1-1-61
(114) P44	40°30'S-19°31'E	1-1-61
(115) P45	41°37'S-19°53'E	1-1-61
(116) P46	43°55'S-20°32'E	2-1-61
(117) P47	46°21'S-21°08'E	2-1-61
(118) P48	48°41'S-21°45'E	3-1-61
(119) P49	51°24'S-22°42'E	3-1-61
(120) P50	53°44'S-22°53'E	4-1-61
(121) P51	56°28'S-23°43'E	4-1-61
(122) P52	59°10'S-24°43'E	5-1-61
(123) P53	61°45'S-24°57'E	5-1-61
(124) P54	64°32'S-25°00'E	6-1-61
(125) P55	65°45'S-25°00'E	6-1-61
(126) P56	68°13'S-25°04'E	7-1-61
(127) P57	69°04'S-24°40'E	7-1-61
(128) P58	69°32'S-24°46'E	8-1-61
(129) P59	Leopold III Bay	10-1-61
(130) P60	"	10-1-61
(132) P61	"	11-1-61
P63	"	13-1-61
(137) P64	"	14-1-61
(138) P65	"	14-1-61
(140) P66	"	15-1-61
(141) P67	"	16-1-61
(142) P68	"	16-1-61
(144) P70	"	17-1-61
P71	"	19-1-61
P73	"	20-1-61
P74	"	21-1-61
P76	"	24-1-61
P77	"	25-1-61
P78	"	26-1-61
P79	"	27-1-61
(157) P80	"	28-1-61
P82	"	28-1-61

* Station numbers in brackets refer to hydrological stations. Station numbers preceded by "P" refer to phytoplankton samplings.

Table I : Station numbers, location and date of sampling of the 1960-61 cruise.

1964-1965		
Station	Position	Date
182	40°25'S-19°24'E	3-1-65
183	43°35'S-20°05'E	4-1-65
184	54°04'S-20°15'E	8-1-65
185	57°32'S-21°20'E	9-1-65
186	65°09'S-23°47'E	11-1-65
187	68°11'S-25°35'E	12-1-65
188	70°19'S-24°12'E	17-1-65
189	70°19'S-24°12'E	18-1-65
190	70°19'S-24°12'E	19-1-65
192	70°19'S-24°12'E	21-1-65
194	70°20'S-24°12'E	25-1-65
196	70°15'S-24°07'E	28-1-65
197	70°06'S-23°46'E	30-1-65

Table I A : Station numbers, location and date of sampling of the 1964-65 cruise.

1966-1967		
201	38°00'S-18°15'E	31-12-66
202	41°47'S-19°40'E	2- 1-67
203	52°04'S-22°50'E	6- 1-67
204	49°50'S-22°50'E	7- 1-67
205	55°44'S-24°03'E	9- 1-67
206	59°06'S-24°27'E	10- 1-67
207	62°28'S-25°17'E	11- 1-67
208	66°47'S-25°30'E	13- 1-67
209	68°50'S-26°31'E	14- 1-67
210	69°56'S-24°45'E	18- 1-67
211	70°10'S-23°48'E	21- 1-67
212	70°11'S-24°06'E	24- 1-67
213	70°16'S-24°05'E	26- 1-67
214	70°18'S-24°15'E	27- 1-67
215	70°19'S-24°12'E	28- 1-67
216	70°19'S-24°15'E	1- 2-67
217	70°17'S-24°15'E	2- 2-67
218	70°16'S-23°57'E	3- 2-67
219	70°18'S-24°15'E	4- 2-67

Table I B : Station numbers, location and date of sampling of the 1966-67 cruise.

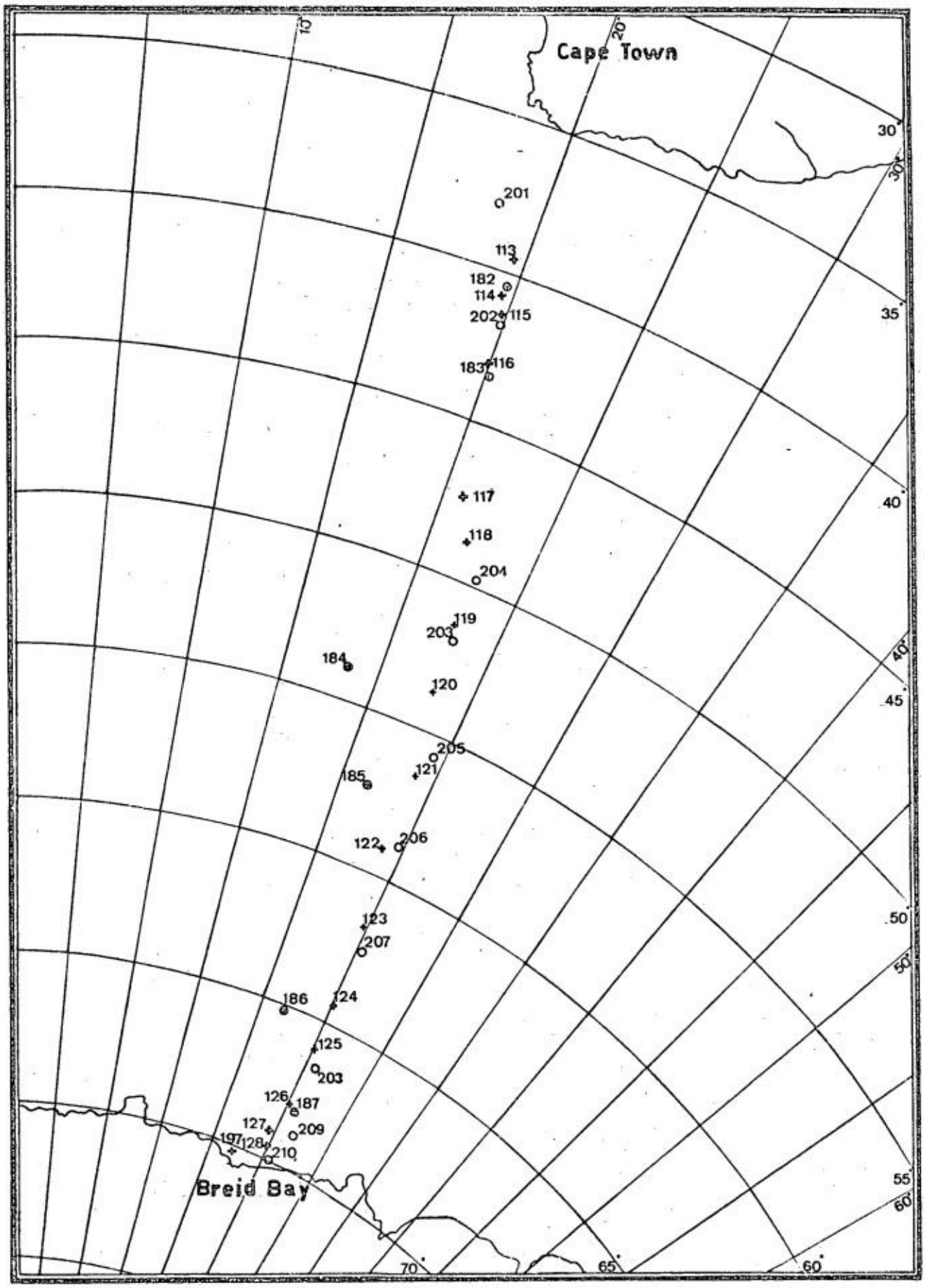


fig.7: Position of stations

+ : 1960 - 61 cruise

• : 1964 - 65 cruise

o : 1966 - 67 cruise

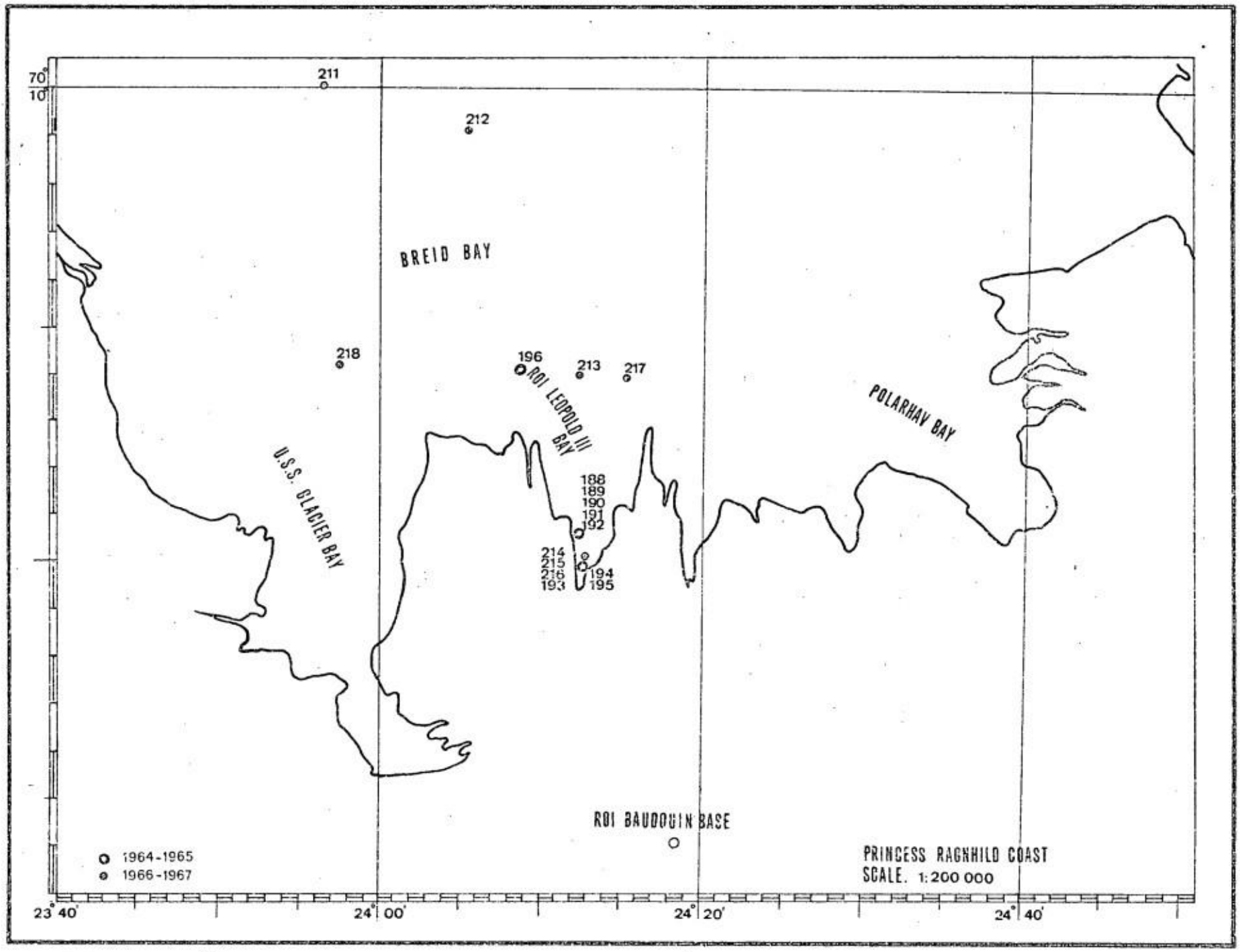


Fig. 8: Position of Breid Bay stations.

The net was a simple conical tow net of 2,20 m length and 0,45 m diameter at the mouth, terminated with a detachable bucket. The upper one third of the net was made of a 300µmesh size nylon gauze and the last two thirds of the same nylon gauze, but with a 60µ mesh size.

Preservation

The samples provided from water bottles were stored in glass bottles of 150 ml. They were preserved by adding a potassium iodine-sodium acetate solution. The net samples were stored in plastic bottles and preserved with 4 % neutralized formalin. Some duplicated net samples of the 1960-61 cruise were preserved with a Bouin solution.

Concentration - Enumeration

The technique of concentration and enumeration used was the one described as the Utermöhl's method. After thoroughly shaking of the samples, they were each transfered into a 100 ml sedimentation tube, adapted to a counting chamber. After 48 hours sedimentation (passive settling), the upper liquid was removed by mechanical handling of the sedimentation tube, leaving the settled organisms within the counting chamber. The counting chambers (diameter : 26 mm. height : 4 mm) were than examined with an inversed microscope Zeiss.

Most of the countings were done always on the same definit area of the chamber (between the 15-25 vertical scale and the 70-90 horizontal scale) and using a magnification of 200 times (occ : x10, obj : x20). In some cases an objectif of 10 was used to made countings of the whole surface of the chamber.

With regards to the net samples, after a thorougly mixing of each sample, a drop of liquid was deposited on a slide and examined with a Reichert phase contrast microscope. A minimum of 500 specimen were determined and counted for each sample. This counting was duplicated 3 to 5 times and only slight differences between the results obtained.

We had therefore a good estimation of the percentage of each species, as they were retained by the net. Those results were compared with similar countings and percentage obtained with water bottle samples.

II. HYDROLOGY AND ENVIRONMENTAL FACTORS

Phytoplankton, living in open water, is directly linked to the tridimentional pelagic environment, which must therefore be taken into consideration when studying the phytoplankton populations. In addition, in the Antarctic region, attention must be given to the extension to which the pack ice breaks up and regresses, as well as to the importance of the warming up of surface water.

The intention, here, is not to describe the hydrology of the Southern Waters, but just to give the main features, indispensable to understand the distribution of the phytoplankton populations and their behaviour.

The chapter will be divided in three parts : A : The transect; B : The Breid Bay; C : The ice. This subdivision will also be adopted in the following chapters.

A. TRANSECT

The main components of the Antarctic Surface Water circulation are made of : an easterly current, in latitudes north of approximately 65°S, a westerly current between this latitude and the Antarctic Continent, and a northward displacement throughout both zones.

The Antarctic Surface Water is a light water, particularly during the summer season, when the salinity decreases and the temperature increases, due to the melting of sea ice and to the warming of the water by sun radiation, respectively. Below this surface water, two other water masses are recognized : the Deep Warm Current, flowing southwards and lying above the Bottom Antarctic Water, flowing northwards (Fig. 6 p. 14). The Deep Warm Current has its origin in the northern hemisphere and is characterized by relatively high temperature and salinity, while the Bottom Antarctic Water is formed, mainly during the winter season, near the Antarctic Continent, and is cold and has a relatively high salinity. Schematically, the meridional circulation constitutes a balanced system in which the Surface and Bottom Antarctic Waters, flowing to the north, are replaced in the south by the Deep Warm Water. The Antarctic Water is limited, in surface to the north, by the Antarctic Convergence, where it sinks suddenly from the surface to a deeper level. In fact, the Antarctic Surface Waters have a greater density, compared with the warmer surface waters further north and tend to sink below these last ones which are called, Subantarctic Water. Continuous records of surface water temperature, taken during a northbound cruise, show that the temperature increases gradually towards the north, away from the continent, until approximately 1° to 2°C in winter and 3° to 4°C in summer, and then rises about 2°C in a very short distance.

In practical, it is on basis of this sudden increase (or drop when southbound cruise) in the surface water temperature that the position of the Antarctic Convergence is defined. However, the reason of the actual position of the Antarctic Convergence is to be found in the movements of the Deep Warm Water and the Antarctic Bottom Water. Further north in the Subtropical Region, the Deep Warm Water flows southward at great depth, but in the vicinity of the Antarctic Region it climbs above the Bottom Water steeply towards the surface, where it continues its way to the south below the Antarctic Surface Water, extending to within 100-200 m of the surface, usually in the zone of the Antarctic Divergence. Actually, the surface water, flowing northwards above the Deep Warm Water, is prevented to sink until the Deep Warm Water has a deeper position; in other words, until the surface water reachs the zone where the Deep Warm Water climbs above the Bottom Water. This zone corresponds usually with the Antarctic Convergence as defined by the observation of the surface water temperature.

After crossing the Antarctic Convergence, northwards in the Subantarctic Region, a second very sharp increase of the surface water temperature, of about 5°C, is encountered. The existence of this sharp boundary, called the Subtropical Convergence, is due to the sinking of the Subtropical Water and the Subantarctic Water, both having a componement of their circulation towards the south and towards the north, respectively (Fig. 6, p 14).

Figures 9,10,11 and 12 established for both years 1964-65 and 1966-67, borrowed from the study of the hydrology made by M.Steyaert, give a schematic representation of the isotherm and isohaline distribution within the top first 100 meters of the transect, during the southbound cruise Cape-Town - Breid Bay. The position of the Antarctic Convergence, defined on basis of surface temperatures, was approximately at latitude 49°55'S in 1964-65 and 49°45'S in 1966-67. In 1960-61, the Antarctic Convergence was some further north, at about latitude 49°00'S. However, the convergence is not a so sharp line and most probably constitutes a zone of intense mixing between two water masses, extending over several miles. Even patches of Subantarctic Water may be found, occasionally, south of the Convergence. We shall see in following chapters, that study on phytoplankton from station 204, situated at latitude 49°50'S, give good reasons to consider this station as belonging to the Subantarctic Waters, or at least, composed for a great proportion of Subantarctic Water.

The Subtropical Convergence, to the contrary of what has been found in other sectors of the Southern Circumpolar Waters, is particularly well defined in the region we investigated; this is probably due to the proximity of the South African tip, which forces the circulation of the Subtropical Waters between the Atlantic and Indian Ocean, within a narrow band of few degrees latitude.

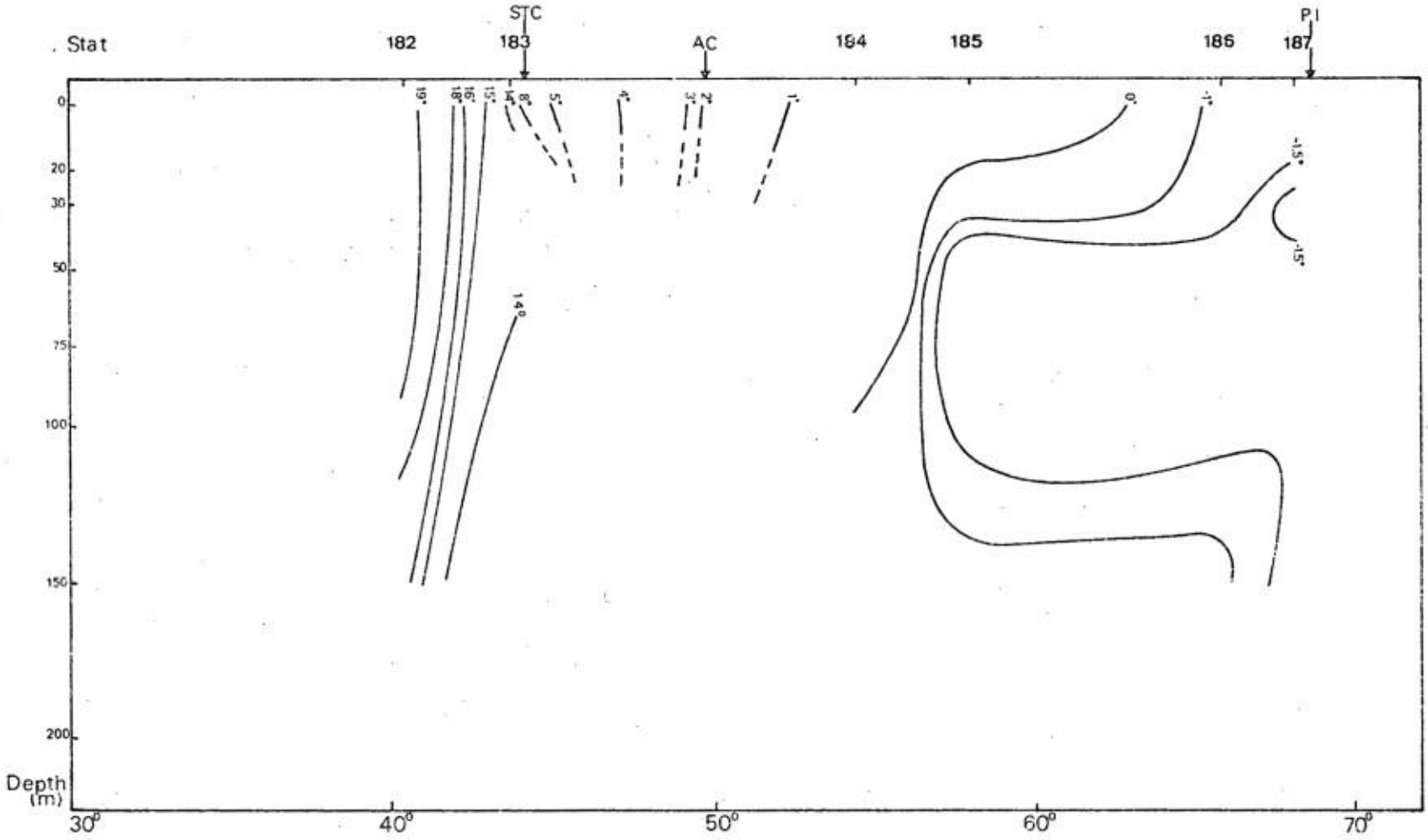


Fig. 9: Isotherm (T°C) Distribution along the transect Cape-Town — Breid Bay. Cruise 1964-65

STC : location of Subtropical Convergence

AC : location of Antarctic Convergence

PI : location of pack ice edge

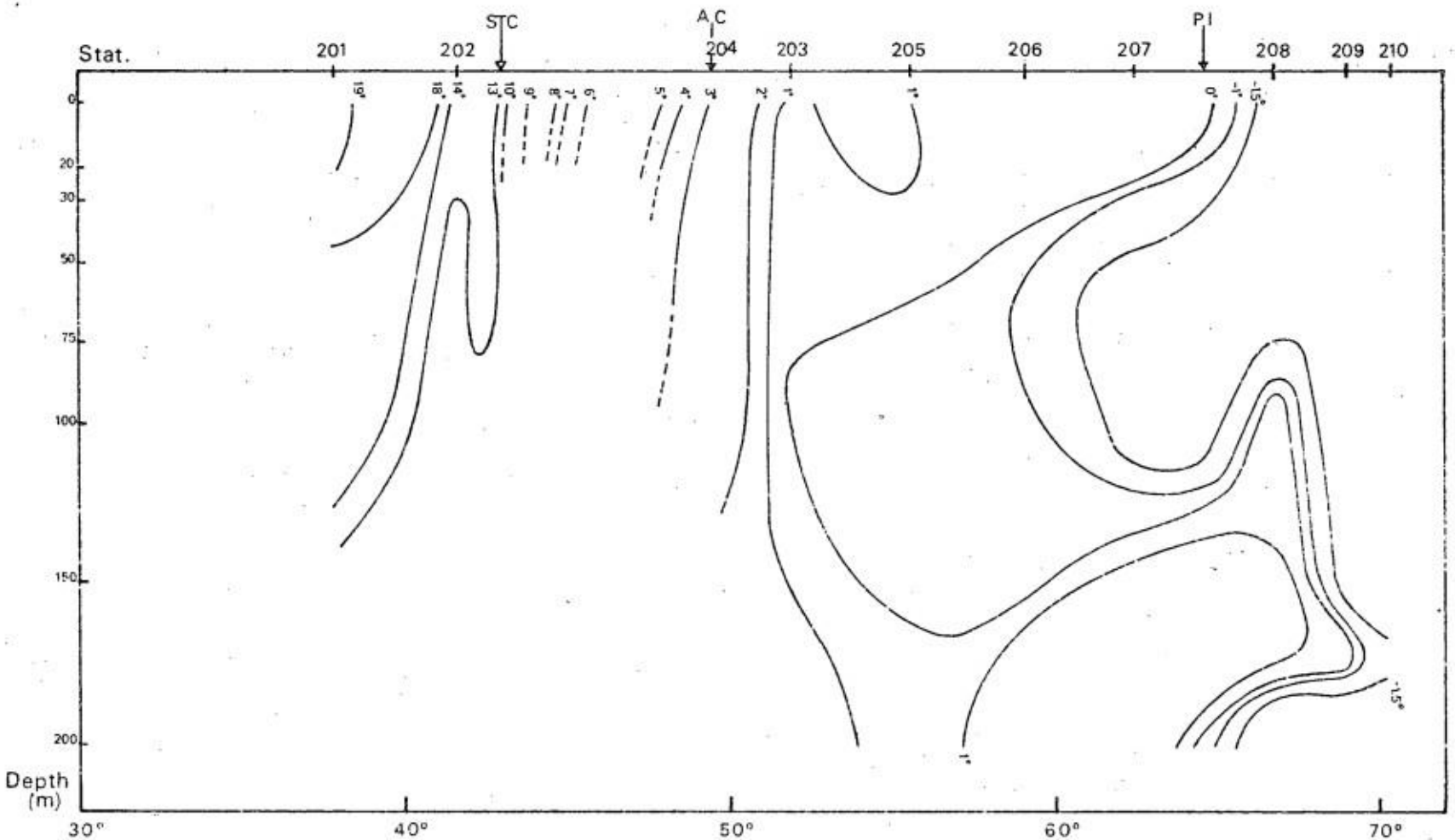


Fig. 10: Isotherm (T°C) distribution along the transect Cape-Town - Breid-Bay. Cruise 1966-67
STC : location of Subtropical Convergence
AC : location of Antarctic Convergence
PI : location of pack ice edge

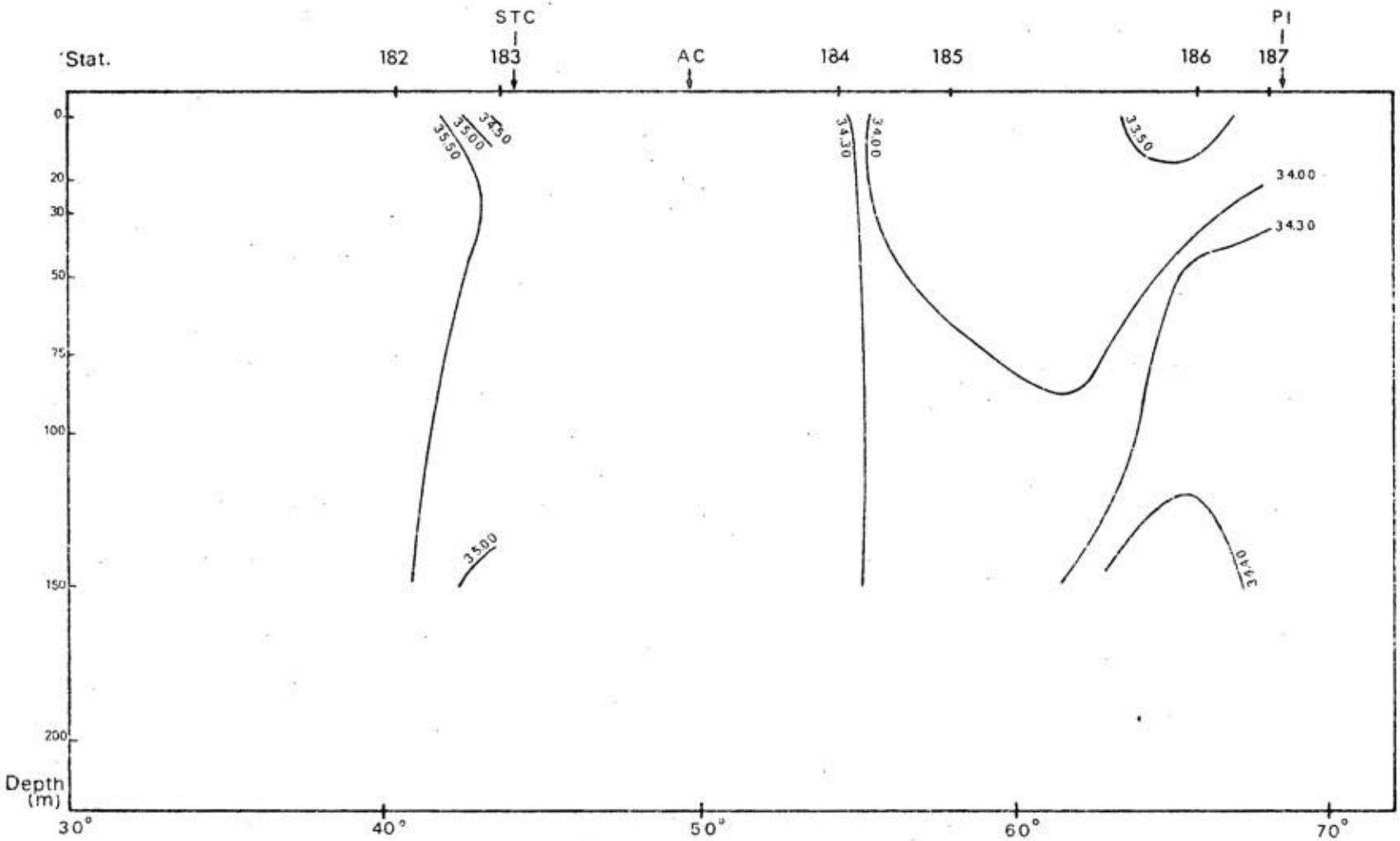


Fig. 11: Isohaline (Sal. ‰) distribution along the transect Cape-Town – Breid Bay. Cruise 1964-65
STC : location of Subtropical Convergence
AC : location of Antarctic Convergence
PI : location of pack ice edge

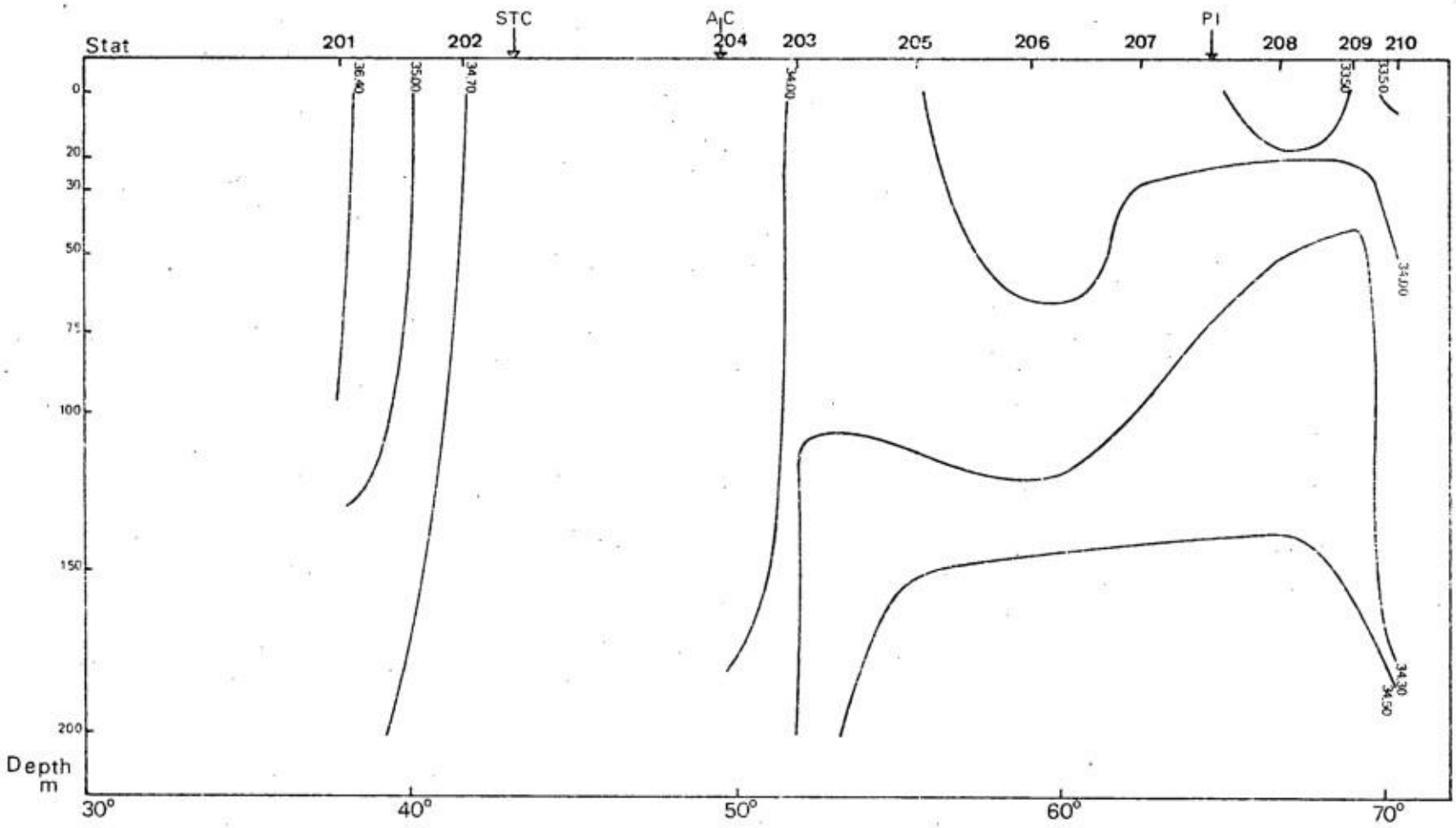


Fig. 12: Isohaline (Sal‰) distribution along the transect-Cape-Town Breid-Bay. Cruise 1966-67
STC: location of Subtropical Convergence
AC : location of Antartic Convergence
PI : location of pack ice edge

The Subtropical Convergence was located at about latitudes 44°00'S, 44°00'S and 43°20'S for the years 1960-61, 1964-65 and 1966-67, respectively.

Some interesting remarks can be made, when comparing the temperature profiles for the two last years, especially in the Antarctic Region, south of the Antarctic Convergence. First of all, the extension of the pack ice was still very large in 1966-67, while it was already much reduced in 1964-65 (see paragraph B of this chapter). In addition, the pack ice in 1964-65 was more open. This probably accelerates its melting and the warming up of the surface water, which are two factors favorable for the formation of the Antarctic Surface Water. The observation of the two profiles on Fig. 9 and 10 shows that, in fact, the Surface Water was more developed in 1964-65 than in 1966-67, and in particular, that the superficial waters had more uniform temperature in 1964-65 as shown by the position of the isotherms, which suggest a greater extension of the Surface Water towards the north, during that year. Similarly, the two profiles on Fig. 11 and 12 show a deeper extension of the reduced salinity (below 34°/oo) during the year 1964-65. To note at station 204, lower salinity than at station 203. This illustrates the phenomenon of patches that may appears in the vicinity of the Antarctic Convergence.

B. BREID BAY

I. The general topography of the Breid Bay.

The Breid Bay is situated on the Antarctic Continent, at the limit between the Atlantic and the Idian Ocean sectors, in the region called Queen Maud Land, which is comprised between the longitudes 20°W and 45°E. The coastal region of the Queen Maud Land, itself, has been subdivided in five coastal zones. The Breid Bay lays is one of these, called the Princess Ragnhild Coast (Fig. 13) and covers an area delimitated approximately by the 23°45'E - 24°45'E and the 70°10'S - 70°25'S. In fact, the Breid Bay is an indentation in the ice shelf, which, in this region extends, some 20 km over the continental shelf as a continuation of the continental ice cap (FiG. 14). The Breid Bay is subdivised in several small bays, which are, from west to east : the U.S.S. Glacier Bay, the Leopold III Bay and the Polarhav Bay (Fig. 8). Of these, the U.S.S. Glacier Bay is extending the most southwards.

The depth of the Breid Bay varies between 120 and 320 meters, with a mean of about 250 meters. The continental slope is situated approximately at latitude 70°08'S, where the depth decreases rapidly below the 1000 meters.

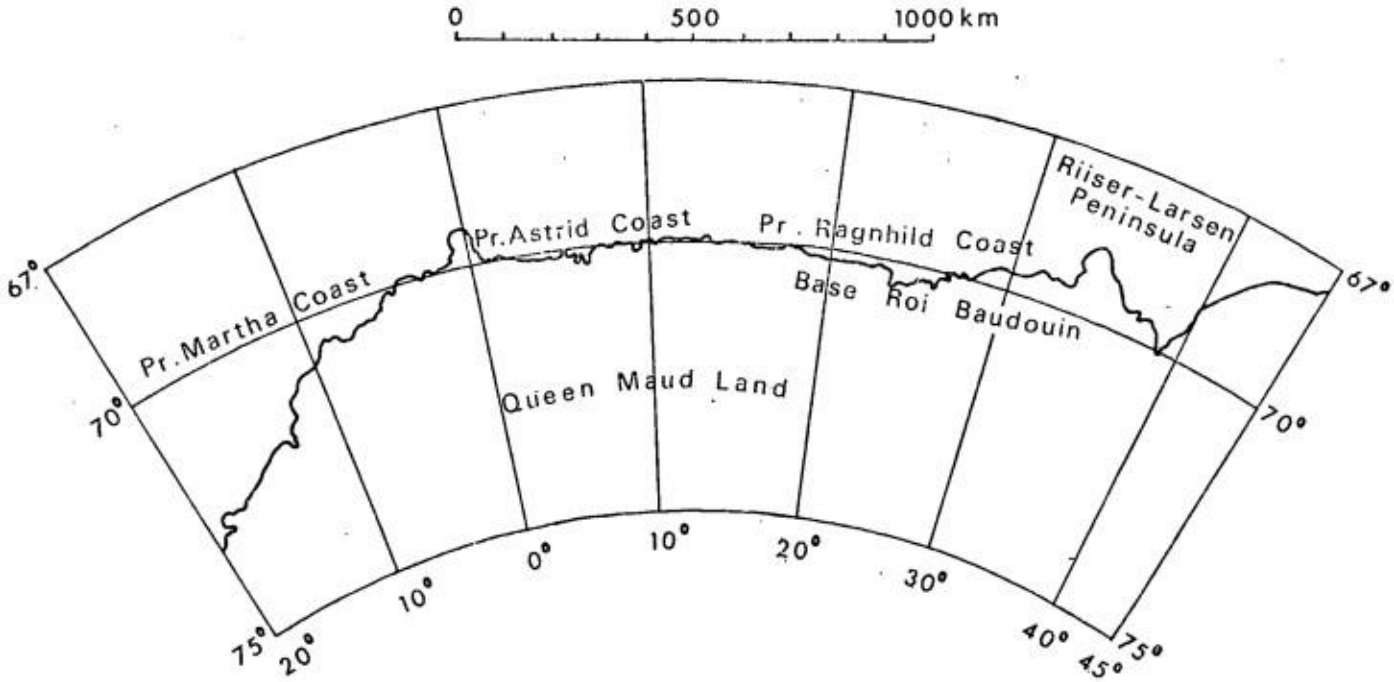


Fig. 13: Queen Maud Land (from map of the Norsk Polarinstitutt, 1959)

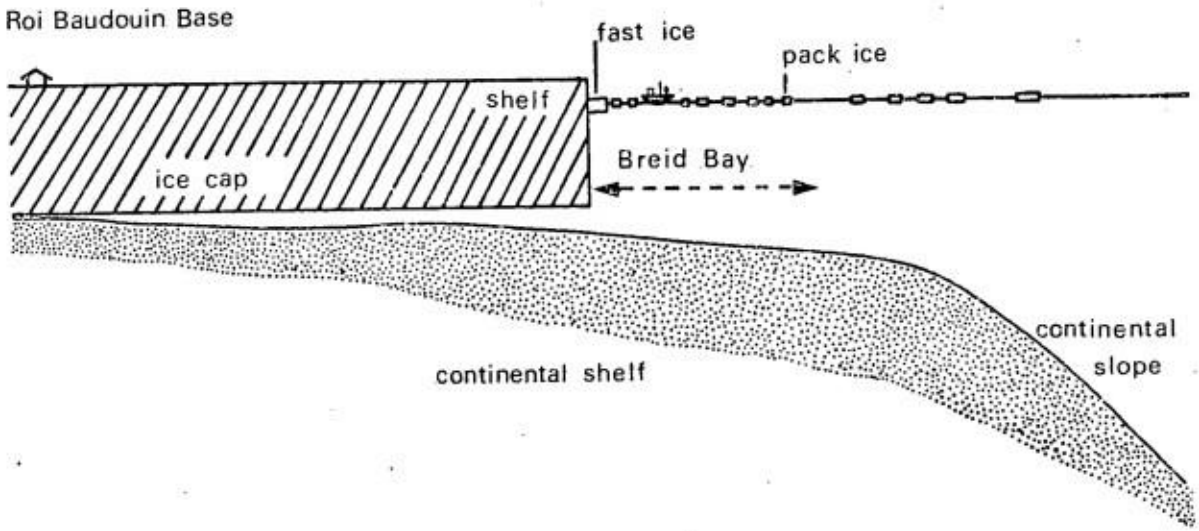


Fig. 14: Schematic section along a transect Breid Bay - Roi Baudouin Bases.

2. The ice covering.

During winter period, the Breid Bay is filled with fast sea ice connected to the north with the pack ice, which forms a belt surrounding the whole Antarctic Continent. During summer period, most of the Breid Bay is free of sea ice, but the "openingsdegree" of the bay varies greatly from year to year. The most southern part of the U.S.S. Glacier Bay has been observed filled up with several years old, compact and unbroken sea ice of a thickness probably not less than 5 meters. In the other parts of the Breid Bay, and especially in the Leopold III Bay, the sea ice breaks off each year. The time at which the sea ice starts breaking, as well as the extension of the open water in the Breid Bay, depend on complex interactions between the meteorological and oceanographical factors. Even when the winter sea ice has been broken and droven away within the westerly Current, other floes, and sometimes icebergs, coming from the east, are puched by the same westerly Current into the Breid Bay, where they may accumulate for some hours or days, being afterwards droven away and continuing their westward travel. The immediate consequence of what preceeds is that the sea ice in the bay may vary in age and origin : floes encountered in the bay may come from other coastal areas east of the Breid Bay, even from pack ice outside the coastal areas, depending on the weather conditions which have prevailed.

The extension of the pack ice, as well as the ice concentration in the Breid Bay were quite dissimilar during both 1964-65 and 1966-67 expeditions. In 1964-65, the northern edge of the pack ice was encountered at latitude 68°38'S, some 155 kms away from the ice shelf, east of the Breid Bay, and at about 195 kms from this last one. The percentage of covering of the pack ice was not more than 5/10 to 6/10. On the way back there was nearly no more pack ice. In 1966-67, the pack ice was encountered at latitude 65°12'S, some 525 kms away from the ice shelf, east of the Breid Bay and at 565 kms from this one. Clearly, the pack ice was much more extended than in 1964-65. The percentage of covering varied from 6/10 to 9/10. The bay itself was closed by fast and pack ice. On the way back the ice covering was limited, but still extended some 200 kms to the north of the bay.

3. The hydrology of the Breid Bay.

In fact, if the hydrology of the Antarctic and Subantarctic waters has already received the attention of several authors, very little is known about the inshore waters, Obviously this is due to the presence of the pack ice which, in winter, forms a uniform and more or less extended field of fast ice all around the continent. Even in summer, when the pack ice brokes partly or completely, the continuous motion of the floes impede greatly on the development of any regular program of sampling.

Fig. 15A : View of Breid Bay 1964-65.

Fig. 15B : View of Breid Bay 1966-67.

Nevertheless, with some luck, hydrological measurements were done in the Breid Bay at 6 stations in 1964-65 and 9 stations in 1966-67 (Fig. 8). As it can be seen on Fig. 8, it was not possible to sample all over the Breid Bay with the result that all stations were concentrated in the Leopold III Bay or very near this one. We shall assume, for our purpose, that all the sampling was done at the same station (called "Breid Bay").

Table II gives for both years, the average values of the temperature, salinity and sigma-t, at 0,10,20,30,50, 75 and 100 meters depth. The mean values of temperature and salinity, were in 1964-65, 0,77°C and 33,74°/oo, and, in 1966-67, 1,66°C and 33,99°/oo respectively. The mean temperature and mean salinity were, therefore, 0,89°C higher and 0,25°/oo lower, in 1964-65 than in 1966-67 (Fig. 16). Furthermore, the stability (see Chapter III p. 83) was much more developped in 1964-65 than in 1966-67. Obviously, during this last year, the winter conditions (corresponding to an homogeneity of the density towards the whole water column) were very little affected by the summer season. Only in the first 30 meters we can observe a raise of the temperature due to the sun radiation and a decrease of the salinity due to the melting of the sea ice, still very limited. On the contrary, in 1964-65, at least the first 100 meters of the watercolumn were greatly influenced by the sun radiation and by the thawing.

	m T (C°)	m Sal. (°/oo)
1964-1965 (6stations)		
0 m	-0.88 (0.67)	33.45 (0.15)
10 m	-0.45 (0.24)	33.49 (0.13)
20 m	-0.48 (0.23)	33.58 (0.11)
30 m	-0.41 (0.27)	33.66 (0.16)
50 m	-0.60 (0.38)	33.85 (0.15)
75 m	-1.05 (0.66)	34.04 (0.12)
100 m	-1.42 (0.29)	34.18 (0.03)
1966-1967 (9stations)		
0 m	-1.36 (0.25)	33.69 (0.18)
10 m	-1.57 (0.11)	33.87 (0.17)
20 m	-1.69 (0.16)	33.97 (0.13)
30 m	-1.66 (0.10)	34.06 (0.13)
50 m	-1.78 (0.04)	34.14 (0.05)
75 m	-1.77 (0.04)	34.16 (0.03)
100 m	-1.87 (0.11)	34.17 (0.02)

Table II : Average value of temperature (T), salinity (Sal.) at different depths for all the 'Breid Bay' stations in 1964-65 and 1966-67 respectively. Numbers in brackets are the σ (sigma) or standard deviations(error of the mean).

There is a marked variation in these phenomena, from station to station, which reflect the continuous changing aspect of the ice 'debacle'.

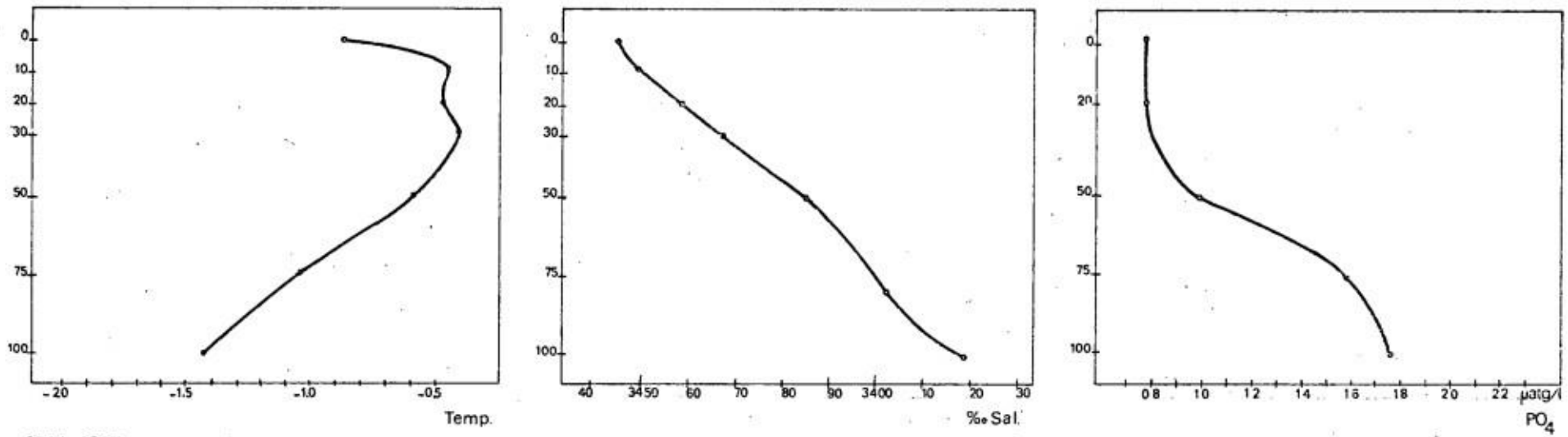
This is confirmed by the difference of the values of the standard deviations computed for temperature and salinity between the two years (Table II). It may be also that watermasses coming from outside the bay has flown into this one at occasion, and has influenced the actual conditions. That seems not to be the case for the year 1966-67. In definite, the most interesting feature of the hydrology of the Breid Bay to retain for our purpose, is the great difference in the environmental conditions encountered between the two years. In 1964-65, the summer season, we would say, was normally developed and leaded to a marked change in the water caracteristics, while in 1966-67 this phenomenon was very superficially and never developed further on.

As we shall see, this difference between the two years reflects very well in the distribution of the Diatoms.

C. SEA ICE

The sea ice is a dominant aspect in the Antarctic Ocean : in winter time, the Antarctic is surrounded by an unbroken ice field of about 25 million km2; during the summer, the ice covering is still very large and extends approximately from 2 -6 million km2.

1964-1965



1966-1967

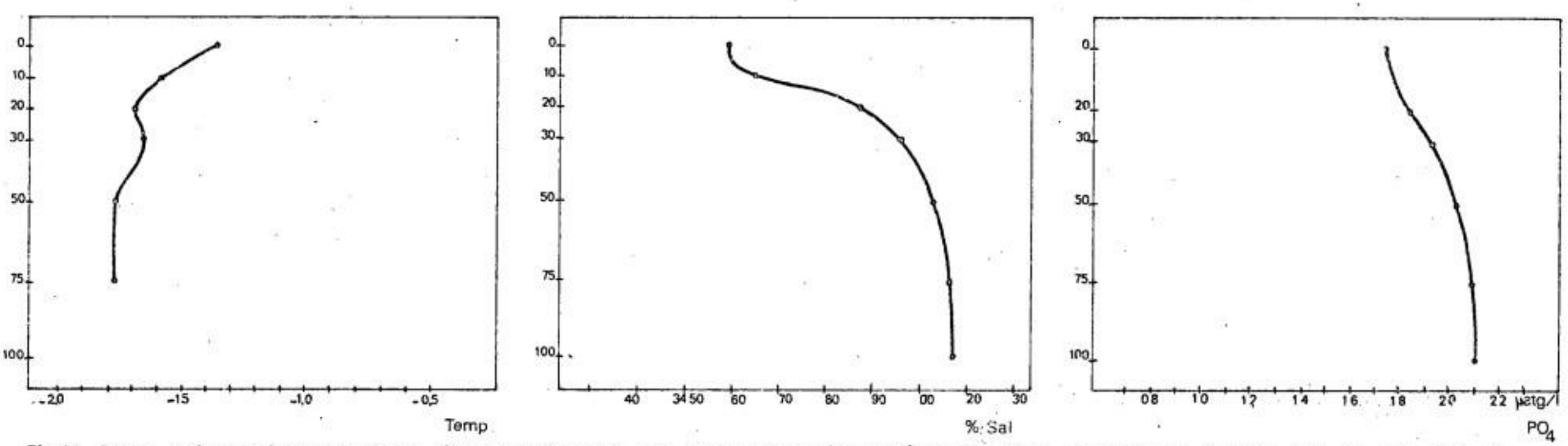


Fig. 16 Mean values of temperature (°C), salinity (‰) and phosphates (µatg/l) in function of depth (m), for the 1964-65 and 1966-67 Preid Bay Stations.

In spring and summer, most of the ice is broken up and forms pack ice. The nature and the distribution of this pack ice varies from location to location and from year to year. Normally it occurs as floes of various sizes, pulled together and, if lateral pressure is important enough, 'hummocks' are formed. When the sea water starts freezing, typical flat floes appears, called 'pancakes'. A snowlayer of various thickness, depending on the meteorological conditions, may cover the sea ice. The weight of this snow influences on the soaking depth of the sea ice, and even may be responsible for the lower parts of the snow layer coming in contact with sea water and getting salty by infiltration. Some authors call this lower part of the snowlayer, 'infiltrational ice'. In addition to the freezing of surface water, ice cristals are formed within the water column. These cristals rise to the surface and become loosely associated with the undersurface of the sea ice (Bunt, 1963). Vtyurin (1965) found the thickness of this low layer to be of 2 to 20 cm, in the vicinity of Mirny, while studies made (with scuba diving) by Bunt (1962) reported a thickness of at least 50 cm, in Mc Murdo Sound.

Since many years, green and brown bands have been observed in sea ice (Heiden and Kolbe, Hart...) and were found to correspond to "phytoplankton" populations. Studies have been carried out to understand the physical, chemical, as well as the biological aspects of the sea ice, but these studies are very scarce and, in fact, very little is known about the mechanism of the freezing and melting processes.

Pure water freezes at zero degree. The addition of various salts lowers the freezing point. For example, a water having a salinity of 35°/oo freezes at -1,9°C. Theoretically, if the freezing occurs infinitively slowly, all salts would be rejected. In natural conditions, the freezing of seawater occurs at various speeds, depending on the climatic conditions, so that, often, saltbrine is trapped into pockets and the total salinity of the ice varies from 2°/oo to 20°/oo, and more frequently from 3°/oo to 8°/oo. When seawater freezes, small discoids of various shapes are formed at the surface. With the lowering of temperature and the effects of winds and waves, these discoids solidifie and vertical oriented cristals grow. Laboratory examinations of sea ice cristals have shown the existence of parallel platelets of pure ice and intercristallinelayers of brine. In addition, large vertical brine pockets are present between cristals (Pounder 1962). The structure of sea ice has been studied for winter fast ice by Vtyurin (1959- Elsevier 1964). He makes the distinction between : 1. infiltrational ice, which is formed on the top of the floe and which results from the infiltration of seawater into soaking snow; 2. ordinary brine sea ice with typical vertical striation; 3. underwater sea ice, which is very porous and containing a great abundance of air and brine inclusions.

Studies have been conducted in view to know the brine composition. Laboratoty experiences have demonstrated that, in an enclosed seawater system, the lowering of the

temperature corresponds to the following sequence in the separation of salts : first 80 % of pure water freezes, followed by the sodium sulfate decahydrate at -8,2°C and the sodium chloride dihydrate at -22,9°C. But these results are not reproduced in natural systems. Bennington (1963) has demonstrated that, in natural conditions, no selection for individual salts occurs and that the proportions of the salts remain the same as for seawater. Brine pockets trapped in young sea ice are highly saline. With time, brine escapes, partly by gravitation, partly by migration of salts, depending on the temperature gradient (Kingery and Goodnow, 1963), with the result that old sea ice is more 'pure' at the surface. Long time ago, whalefisherman were aware of this phenomenon and use to make drinkwater from old surface ice. Meguro, Ito and Fukushima (1967) stuying arctic sea ice, found phosphate concentration of about 1,8 µatg/l in the bottom ice and 0,6 µatg/l in the middle part of the sea ice, while for the open seawater the phosphate concentration was of 1,1 µatg/l. During the 1964-65 belgian expedition, the phsophate content was analysed in two samples of melted ice, taken at the bottom of a floe of 160 cm thickness. The mean value of 2,2 µatg/l phosphate was found, while the mean phosphate concentration in the surface waters of the Breid Bay was 0,8 µatg/l. This confirms, to a certain extent, the results of Meguro, Ito and Fukushima, that there is a greater concentration of phosphates in the bottom part of the ice floes than in the surrounding surface waters :

1,6 times more in the Arctic sea ice, 2,7 times more in our samples from Breid Bay.

Because of the great extent of the fast ice and pack ice and because of the existing relation between phytoplankton and light, light intensity measurements were attempted, not only in the open waters, near and beneath the ice, but also in the ice. However, these studies are very scarce and various methods were used by different authors. The fact that ice cristals are capable to polarize the light, in addition to the differences existing in the ice structure, increases the difficulty to make reliable measurements. Meguro (1962) Burkholder and Mandelli (1965) maintain that 25 % of the incident light reaches the top plankton populations. Apollonio (1965), measured light intensities at 170 cm depth, in arctic sea ice for different snow coverrings and at different periods of the year (from March to June). The results he obtained ranged from 3,7 footcandles under 8 cm snowcovering, in March, to 240 footcandles without snowcovering, in mid-June. The corresponding incident surface light intensity was, respectively of, 595 and 1680 footcandles; this means that 0,6 % in March, and 14,3 % in June, of the surface light intensity reached the 170 cm level, inside the floes. Bunt (1963) found a mean of about 8 footcandles at the bottom of the sea ice, at Mc Murdo Sound. Littlepage (1965), measuring the light transmission at 1 meter below a 3 meter thick solid ice floe, covered with 5 cm compact snow, found that the light penetration below the ice is not only determined by physical factors, but also by the phytoplankton growing in the ice.

Indeed, extensive plankton growth in the lowest ice layer and in the underlaying loose ice-cristal aggregation, in mid-summer, occuring during the peak surface illumination, prevents the light penetration in such a way that there is more light available in the waters, under the sea ice, in early and late summer. Very little is known about the absorption characteristics of the ice for light of different wavelenghts. Thomas (1963) showed that there seems to be a marked decrease of absorption toward the shorter wavelenghts. Appolonio (1965) compared Strickland's findings, that chlorophyll c is at least 6 times as efficient as chlorophyll a for the absorption of blue light, with results of Meguro and Bunt, who show that the underwater ice algal population contains twice chlorophyll c as do the planktonic Diatoms.

The upshot of this chapter is that the hydrological conditions prevailing in the environment of the phytoplankton populations, both in the transect and in Breid Bay, suggest a more advanced establishment of the summer conditions during the 1964-65 than during the 1966-67 cruises, although both were accomplished during the same period of the year. This was evidenced in 1964-65 by a reduced and loosier pack ice, corresponding to a more pronounced thawing and to formation of more extended Antarctic Surface Water.

In the Breid Bay, the warming up of the water and the melting of the ice, affected a greater proportion of the water column, and were more pronounced in 1964-65 than in 1966-67.

III. TOTAL DIATOM ABUNDANCE

The study of living matter can be approached by quite a number of ways. One of the main interests may consist in the study of the different fudamental mechanisms (biophysical, biochemical, physiological,etc..) by which the living processes are going on. It may also consist in simply searching for the more suitable and the more abundant form through which organic matter accumulate the energy for human consumption. It may finally consist in investigating how the different living processes organized themselves in different species and groups of vegetals and animals and how, in function of the environmental conditions, they accumulate and transfer energy. The last approach is based, essentially, on the study of the distribution of natural populations and their relation with the environment. The natural selection has resulted in the actual general distribution of different types of populations, corresponding to different environmental conditions.

In the cold Antarctic Waters, the Diatoms appear to be the dominant group among the phytoplankton populations and it is, therefore, important to have a record, as precise as possible, of the distribution of their abundance and to know how this abundance vary in function of the environmental conditions. In this chapter we will discuss the total abundance of the Diatoms,their horizontal (in function of latitu-

de) and their vertical (in function of depth) distribution, for the oceanic area (along the transect Cape-Town - Breid Bay), in the inshore waters (Breid Bay) and in the particular biotope of the ice.

The sampling methods, as well as the expression of the results of the standing stock of Diatoms, vary mostly in the literature on the Southern Ocean. Often the results are expressed as cell numbers per liter (Fukase,1962; Marumo,1957), sometimes as gram biomass per m3 (Ivanov,1964; Zernova,1970), or as average settling volume of plankton samples in cm3 and m3 (Marumo,1953), sometimes also as cell numbers per unit haul (Fukase and El-Sayed,1953). In some cases the results are given only for the surface waters (Fukase,1962; Marumo,1957). We decided to express our results as cell numbers per liter (n_1), as well as cell numbers per m2 (n_2), using the same integration formulae than those utilized by Rytter Hasle (1969); although limited to the level of 100 meters haul cable, because of the great decrease of the population stock beneath this depth. The formulae are :

$$n_1 = \frac{1}{2d_n} (N_1 + N_2)(d_2 - d_1) + \dots (N_{n-1} + N_n)(d_n - d_{n-1})$$

$$n_2 = \frac{10^3}{2} (N_1 + N_2)(d_2 - d_1) + \dots (N_{n-1} + N_n)(d_n - d_{n-1})$$

where n_1 represents the total cell number per liter

n_2 represents the average cell number per m2

$N_1, N_2, \dots N_{n-1}, N_n$ represent the cell number per liter at the respective depths $d_1, d_2, \dots d_{n-1}, d_n$;

the results obtained with the two expressions depend on the

height of the seawater column on which the analyses are done. The expression of the average cell number per liter, which is more commonly used in the phytoplankton studies, increases when the sampling depth is shortened and consequently is less appropriate when dealing with stations of different vertical extension (Rytter Hasle,1969,p32). In the present study, the results obtained for n_1 (expressed as cell numbers/liter) and n_2 (expressed as cell numbers/m2) are incidently identical, because of the choice of the maximum depth of 100 meters; except that n_1 is to be multiplied by 10^3, while n_2 is to be multiplied by 10^8. This similitude does not exist when, in cases of no available values for the 100 meter depth, other depths were used for the integration.

Evidence of correlation between Secchi disc measurements and phytoplankton abundance (expressed as plant pigments : Atkins, Jenkins and Warren,1954 - Hart,1962, or as cell numbers : Smayda,1963) being demonstrated, we did verify the validity of the correspondance between the Diatom abundance we recorded, and the depth of Secchi disc readings available for 20 stations. The correlation found between the mean Diatom abundance in the upper 20 meters, expressed as log cell number per liter and the Secchi disc readings expressed in meters , was highly significative (r=-0,8055 at 95 % level) (Fig. 17). This means, in particular, that in the area studied the computation of the Diatom abundance is a valuable measurement of the whole phytoplankton biomass.

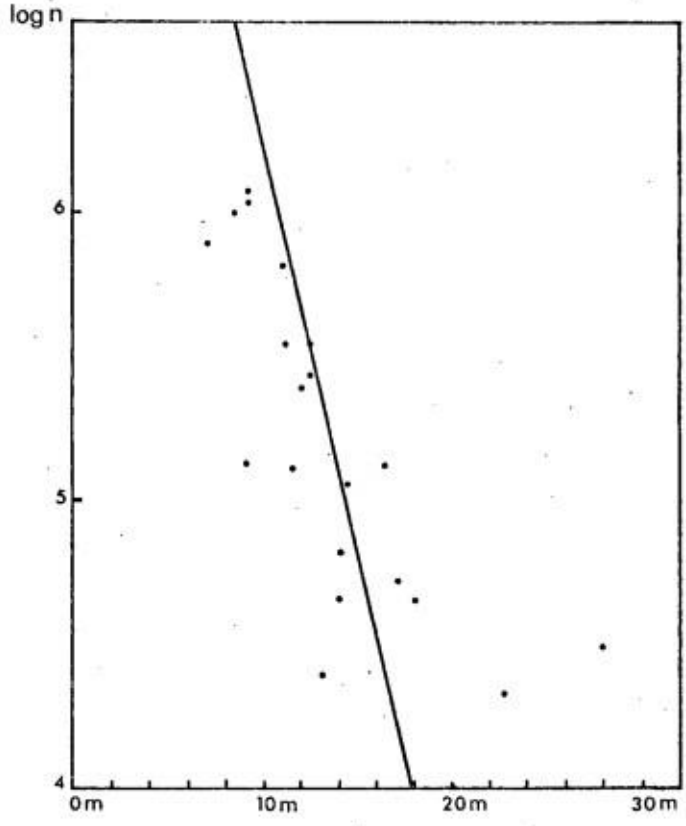


Fig.17 Mean Diatom abundance in upper 20 m layer expressed as log. cell number per liter in function of Secchi disc deph in meters
(r = -0,8055 Prob: 95% - regression line: y = 31,75 - 3,47 x)

The Secchi disc measurements were also used for the calculation of the depth of 1 % light intensity (u), using the simplified formula : u = 2,7 x d, where d represents the depth indicated by the Secchi disc.

A. TRANSECT

1. Total abundance in the oceanic area.

The total abundance of Diatoms along the transect Cape-Town - Breid Bay, for the two expeditions 1964-65 and 1966-67, are reported in Table III, expressed as mean cell numbers per liter (n_1) and mean cell numbers per m2 (n_2). All values were computed on the water column from 0 to 100 meter, except for station 206 and 207 (1966-67) where the 100 meter level has been replaced by the 150 meter level. The highest values obtained, along the transect, are 4.3×10^5 cell numbers per liter (433×10^8 cells/m2) for 1964-65 and 3.4×10^5 cell numbers per liter (366×10^8 cells/m2) for 1966-67. This makes for both years, an average value of 10^4 to 10^5 cells per liter.

Comparisons with results from other authors, in the Atlantic-Indian Ocean sector are quite limited. Zernova (1970) reports a mean of 10^3-10^5 cells per liter, in the 0-100 meter layer along the 20°E longitude. Kozlova (1970) found an average of 1.4×10^4 to 1.5×10^5 cells per liter in the region between the Antarctic Convergence and the Antarctic Divergence. On basis of surface samples taken during the 4th Japanese expedition, along the transect South Africa - Enderby Land, Fukase (1962) found an average of 10^4 Diatoms per liter, with a maximum of 225.000 cells per liter near the pack ice edge and a minimum of 360 cells

St.	n_1	n_2	D_{max}	S.m.	D. 1% L.I
		1964-1965			
182	43.5	43.5	20	14	38
183	86.0	86.0	20	11	30
184	50.9	50.9	30	14	38
185	432.9	432.9	30	11	30
186	41.5	41.5	20	17	46
187	26.9	26.9	20 m	18	48
		1966-1967			
201	36.5	36.5	75	-	-
202	167.5	167.5	75	9	24
204	336.5	336.5	50	12.5	34
203	294.0	294.0	20	12	32
205	147.2	147.2	75	14.5	40
206	49.8* (52.6)	74.7* (52.6)	0	20.5	56
207	30.0* (35.4)	45.0* (35.4)	20	13	35
208	19.4	19.4	20	23	62
209	11.6	11.6	0	28.5	78
210	93.5	93.5	0	-	-

Table III : Total Diatom standing stock expressed as cell number per liter (n_1) and as cell number per m2 (n_2) calculated for the 0-100 meter layer.

n_1 : total Diatom cells x 10^3 per liter

n_2 : total Diatom cells x 10^8 per m2

* : values calculated for the 0-150 m layer in brackets; for purpose of comparison, the extrapolated value for the 0-100 m layer

D_{max} : depth in meters of the maximum Diatom abundance

Secchi m : depth in meters corresponding to the Secchi disc measurements

Depth 1% L.I : depth in meters corresponding to 1% of surface light intensity (2.7 x Secchi disc depth).

per liter on the return cruise at about latitude 63°S. It must be taken into account that the analyses of Kozlova, report on Diatoms, collected by membrane filters and separators and submitted to a rather complex treatment which might have involved a loss of cells (loc. cit. R.Hasle,1969,p.38). The results of Fukase (1962) concern only surface samples, while the maximum biomass occurs, in many cases, beneath the surface, as is shown in Table III. In both cases, the differences in the techniques used, may account for the differences observed with the cell concentration we recorded.

Other areas in the Southern Ocean however, were more extensively investigated. Among them, the Western Atlantic sector, including the Drake Passage, the Bransfield Strait, the Weddell Sea, and the Scotia Sea. Hart (1934) found 10^8 Diatoms per 0-100 meter haul, in the Weddell Sea, Fukase and El-Sayed (1965) reported 10^6 to 10^7 cells per unit haul, in the Drake Passage. Because of the different units used, no comparison can be made between those results and ours. It may only be assumed that, on the basis of pigment analyses and primary production measurements, (Hart, 1942-El-Sayed et al.,1964 - El-Sayed and Mandelli,1965 El-Sayed,1967), the Western Atlantic sector is richer than the other areas of the Southern Ocean investigated. The Eastern Pacific sector, investigated by Rytter Hasle (1969), shows an average of 10^5 cells per liter, with a maximum of 2.10^6 cells per liter.

These results are very near, although some what higher, than those we found in the African-Antarctic sector. The results of R. Hasle (1969) are in opposition with those, done in the same Pacific sector, by Hart (1942) and El-Sayed (1966), based on chlorophyll analyses, and by Kozlova (1966), based on diatom counting. This discrepancy is probably due to the different methods used (Rytter Hasle p.37). In the Western Pacific, Marumo (1957), analysing the biomass of Diatoms in the surface layers, found an average of 10^3 to 10^4 cells per liter, with a maximum of 10^5 cells per liter, near the pack ice edge.

It may be concluded that the results we obtained within the African-Antarctic sector are in good agreement with the general figures already available in the literature, with the exception of the richer South-West Atlantic sector. Moreover, because of the fact that the data of the literature were obtained by using quite dissimilar methods (Utermöhl sedimentation method : Rytter Hasle (1969); Filter membrane and separator : Kozlova (1966); settling and centrifugation for surface samples : Marumo (1957), Fukase (1962); net samples : Hart (1942), Fukushima and El-Sayed (1965))and also during investigations undertaken at different periods of the year, we believe that it is too early to subdivise already the Antarctic Ocean in poorer and richer areas.

The Antarctic Ocean has the reputation of being one of the richest regions in the world. However, when we compare the results obtained from the Atlantic-Indian sector,

with those of other sectors, situated at similar latitudes in the Northern hemisphere, we note, for example, that Braarud et al. (1953) found 123. 10^8 cells per m2 for the Norwegian Sea and Cupp. E.E. (1934), 10^5 diatoms per liter in the north eastern Pacific, near the coast of Alaska. The results are similar to ours. Hart (1942), on basis of pigment analyses, compared the oceanic areas, south of the Antarctic Convergence, with the English Channel, excluding the South Georgia and Scotia area. He found, for both and during the period of the main increase, a similar average pigments content. Rytter Hasle, comparing with results obtained in the Norwegian Sea and in waters of the East Greenland coast, concluded "that the Southern Ocean was not found to exceed other areas in quantity" (loc. cit. p. 39).

In conclusion, if the Antarctic Ocean shows a markedly high quantity of plankton in some definite areas, it seems not to be so exceptionally rich as sometimes believed.

2. Latitudinal distribution of Diatoms along the transect.

Using the data set in Table III, figures 18 and 19 represent the distribution of the mean Diatom abundances in function of the latitude, along approximately the 20st. degree longitude, for both years, 1964-65 and 1966-67, respectively. The very limited number of stations in the Subtropical and the Subantarctic regions, does

not allow definite conclusions, and the results are only reported as a matter of comparison with those of other authors. With reference to the hydrology, studied by M.Steyaert, the transect can be subdivided in different regions (see Chapter II), for each of which, we give, below, the average Diatom abundance within the 0-100 meter layer.

1964-65

Subtropical region	Stat. 182	43×10^3 Diat. /1
Subtropical Convergence	Stat. 183	86×10^3 Diat. /1
Antarctic region	Stat. 184	138×10^3 Diat. /1
	Stat. 185	
	Stat. 186	
	Stat. 187	

1966-67

Subtropical region	Stat. 201	36×10^3 Diat. /1
Vicinity Subtropical Convergence	Stat. 202	168×10^3 Diat. /1
Antarctic Convergence	Stat. 204	337×10^3 Diat. /1
Antarctic region	Stat. 203	98×10^3 Diat. /1
	Stat. 205	
	Stat. 206	
	Stat. 207	
	Stat. 208	
	Stat. 209	
	Stat. 210	

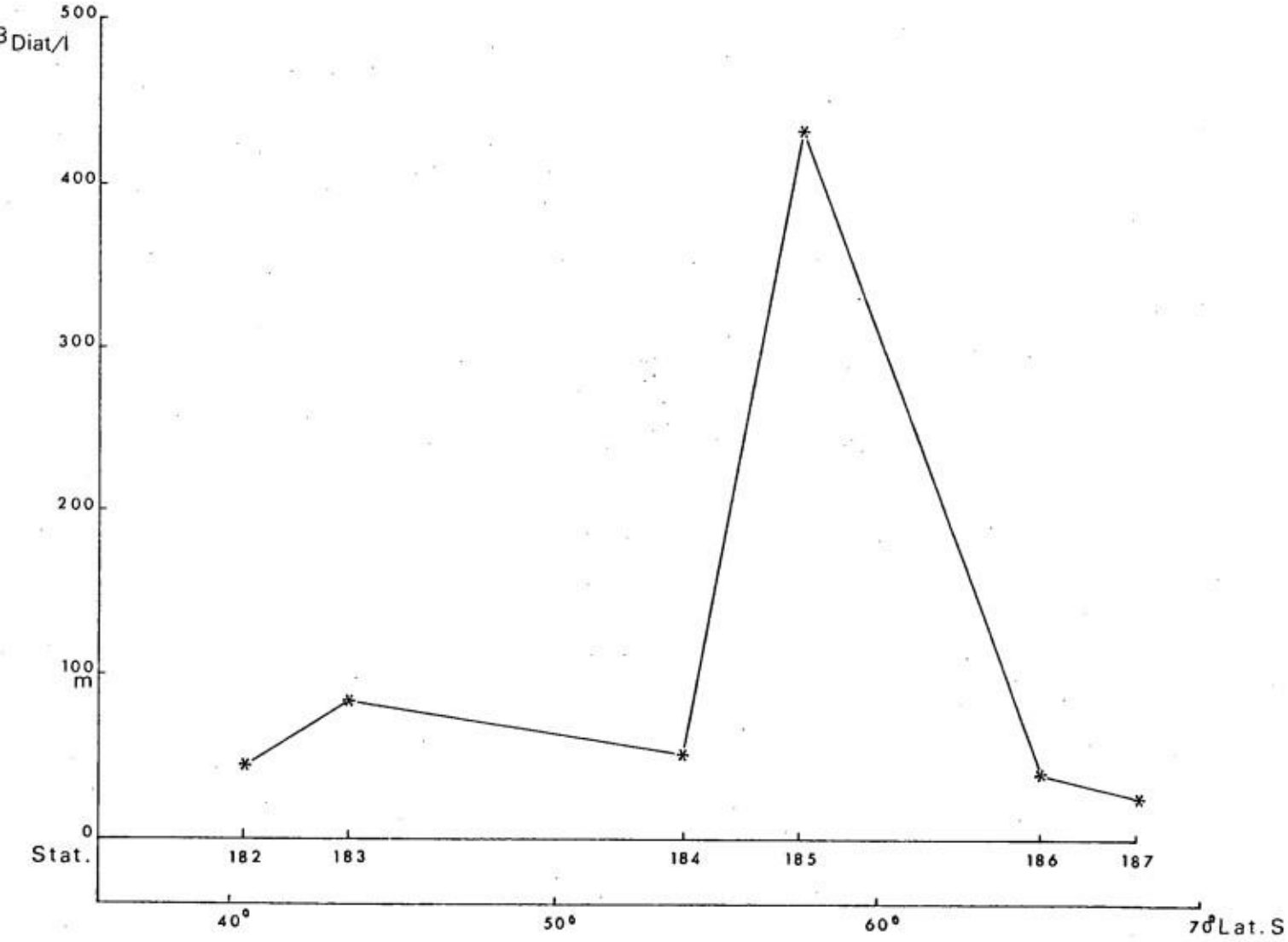


Fig.18 Number of Diatoms per liter
(value integrated for the 0 - 100 layer)
Cruise 1964 - 1965

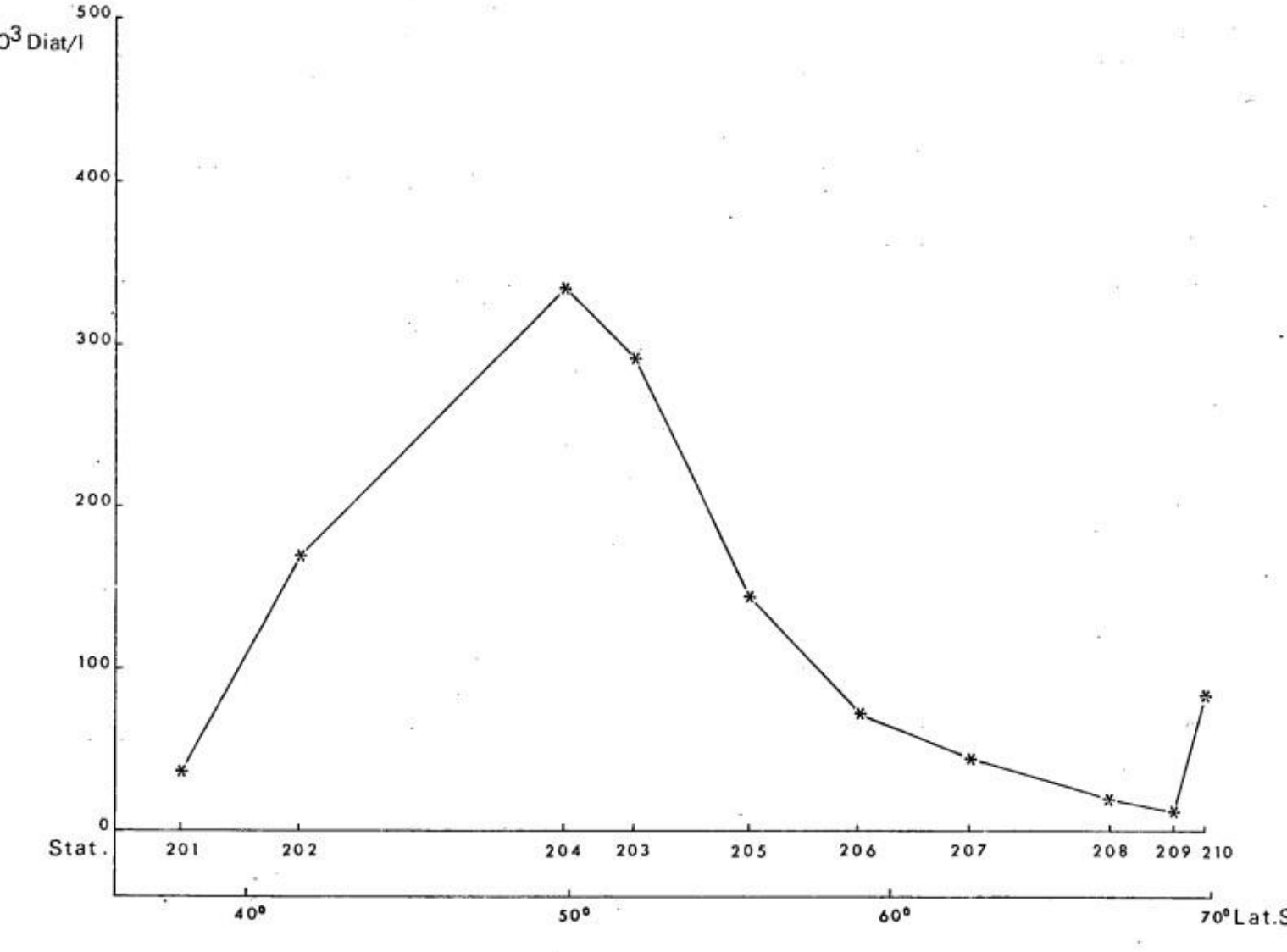


Fig.19 Number of Diatoms per liter
(value integrated for the 0 - 100 layer)
Cruise 1966 - 1967

The examination of these figures suggests several observations. The Subtropical region (Stat. 182, Stat. 201) shows lower values than the Subantarctic and the Antarctic regions, as generally confirmed by the literature. To the Subtropical Convergence, and for both years, correspond higher values, compared to stations north of it. Moreover, a marked difference is noticeable between the results obtained in 1964-65 (Stat. 183 : 86 x 10^3 Diat/l) and in 1966-67 (Stat. 202 : 168 x 10^3 Diat/l). The zone of the Antarctic Convergence gives the maximum recorded cell number of 3 x 10^5 Diatoms per liter, of the whole transect, in 1966-67, while no data are available for the corresponding zone in 1964-65, due to the impossibility to sample in the heavy stormy weather. For the Antarctic region, the difference between the two years is also pronounced : in 1964-65, the relative low value (51 x 10^3 Diat./l) obtained at latitude 54°04'S (Stat. 184) is followed by a very high value (433 x 10^3 Diat./l) at latitude 57°32'S (Stat. 185), while in 1966-67 a high value (294 x 10^3 Diat./l) at latitude 52°04'S (Stat. 203) is followed by a decrease (corresponding to a mean of 98 x 10^3 Diat./l, for the whole Antarctic region south of the Convergence). To note however, the relatively high value (93,5 x 10^3 Diat./l) at station 210 (Lat. 59°36'S), which was near the continent.

The two cruises, nothwithstanding the fact that they were made during the same period of the year, give a quite different record of the latitudinal distribution of the Diatom biomass. The most striking feature is the relative poverty of the Antarctic region south of the Antarctic Convergence, during the 1966-67 cruise, compared to the high abundance recorded near the Subtropical and the Antarctic Convergence. This interannual variability will be discussed in Chapter VI.

Here again, the possibility of comparison with the existing literature, is very limited, because of the different methods used. Fukase (1962), working in the African-Antarctic sector at, approximatively, the same period of the year than we did, but only on surface samples, found three peaks in the Diatom abundance distribution during the Japanese southbound cruise (late December) (Fig.20) : one near the Subtropical Convergence (approximatively 41°S) and two in the Antarctic region; during the homebound cruise (February), he observed two peaks : one in the Subtropical region, the second in the Antarctic region. Comparing our results, for surface samples (Fig. 21), we find a three peaks distribution for the year 1966-67 and a two peaks distribution for 1964-65, although the lack of sampling between St. 183 and St.184 left an uncertainty on the values in the Subtropical region during that year. From the data reported by Zernova (1970), summarizing the results of the first three cruises of the RS Ob in the Indian and Pacific

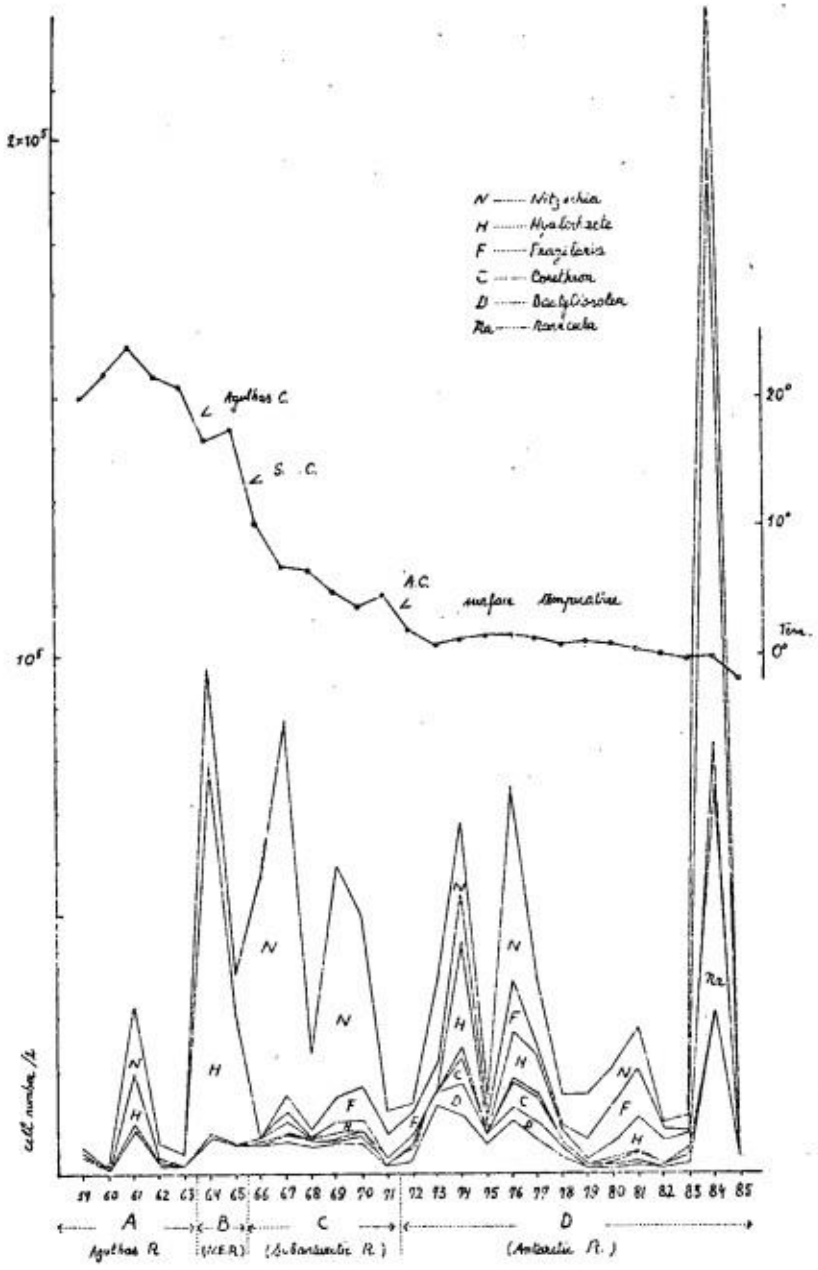


Fig. 20:

Cell number of Diatoms important genus and surface water temperature (Fukase, 1962, p.83).

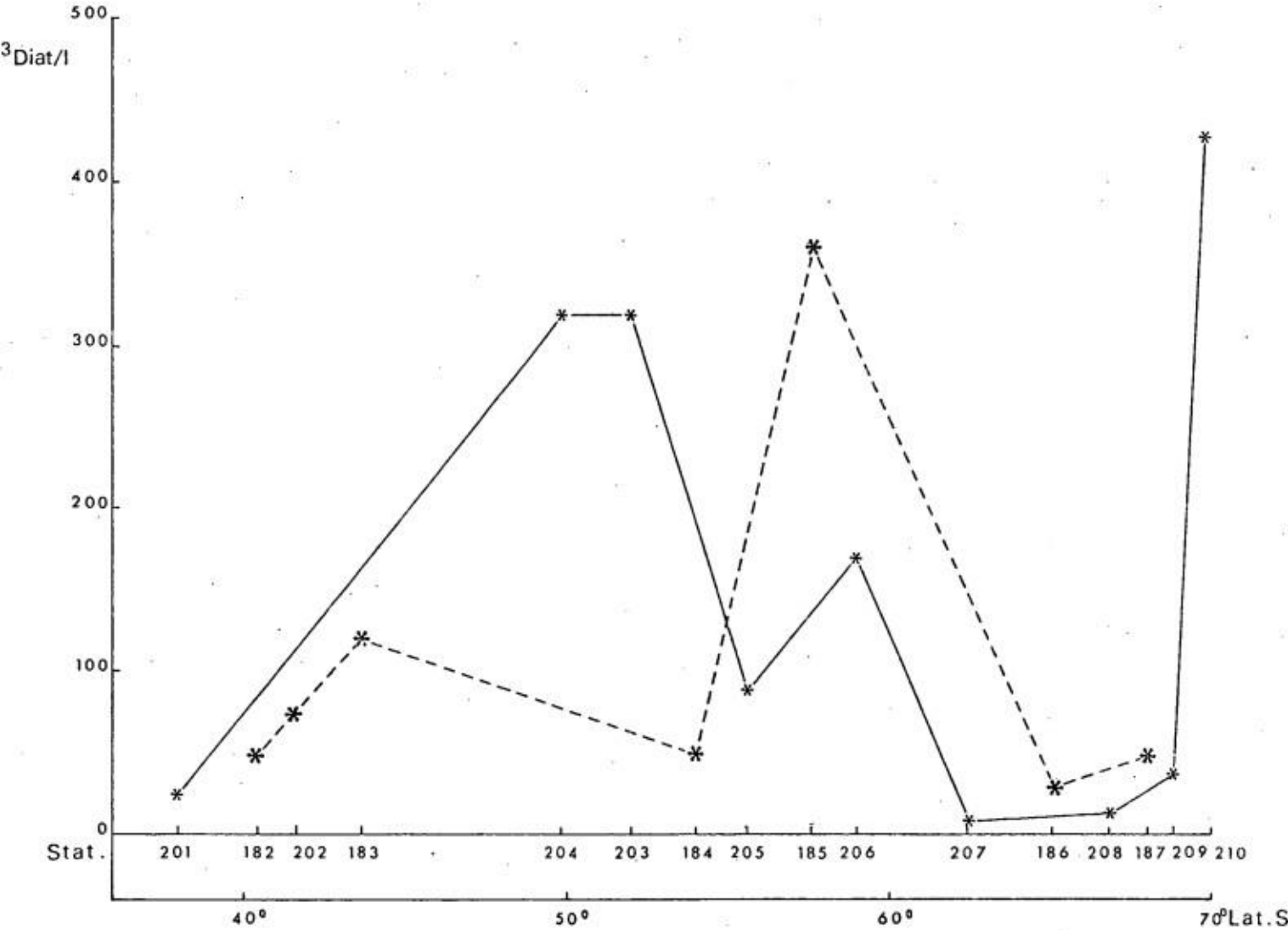


Fig. 21 Number of Diatoms per liter (surface samples)

---- Cruise 1964 - 1965

—— Cruise 1966 - 1967

sector of the Antarctic Ocean during the southern summer and autumn of 1956-58, three maxima are shown on the section between Africa and Antarctica : a first between Lat. 40°S and Lat. 41°S (near the Subtropical Convergence), a second between Lat. 49°S and Lat. 57°S, and a third south of Lat. 60°S. Kozlova (1966) report for the same section but during the 4th RS Ob cruise, only one maximum between the 50° and 60° lat. S and a marked increase near the continent. The results obtained by the Japanese and the Russian authors on the distribution of the maximum Diatom abundance along the African-Antarctic sector, corroborate with our data (although the values reported by Kozlova are inferior to ours) and demonstrate the existence of a variability in the results between different periods of the year (Fukase) or between different years (Kozlova).

The results obtained by Rytter Hasle (1969) in the East Pacific sector show a greater biomass in the Antarctic region than in the Subantarctic region. El-Sayed (1964) and El-Sayed and Mandelli (1965), on basis of pigment analyses, arrive to the same conclusion for the Drake Passage. Similar results than those obtained during our 1966-67 cruise were found by Rytter Hasle for the first section of the Brategg Expedition (December 1947 - 90°W longitude).

3. Vertical distribution of Diatom abundances.

The vertical distribution of phytoplankton depends mainly on the light penetration and on the stability of the water. Diatoms have no way of moving by mechanical means. Normally, they are slightly heavier than water and tend to sink. Margalef (1961) has made a review of the experiences done on the sinking rate of Diatoms, in natural as well as in experimental conditions, and reports that the most common values are 1,5 to 5 meters per 24 hours. This sinking rate does not only depend on the shape and size of species, but also on the physico-chemical properties of the water masses. Some diurnal variations in the vertical distribution of Diatoms has been reported. Wimpenny (1966) interpreted the diurnal ascension of Diatoms as due to variations in the buoyancy of the cells (variations in oil and fat réserve and in the ionic composition of cell sap vacuoles). However, if the sinking does normally occur, the trend is often disturbed by turbulence.

The stability of oceanic waters, of which the simplified expression is $E' = 10^{-3} \frac{d\sigma_t}{dz}$ (σ_t : density at temperature t; z : corresponding depth), plays an important role in the vertical distribution of the phytoplanktonic organisms. The greater the stability, the more stratified are the water layers. If the stability is very low or unconsiderable, the waters are mixing over a greater depth and the phytoplankton is more uniformely distributed. The

stability of the waters is often subjected to local and seasonal variations. In the Southern Ocean, this the case in the mixing areas encountered in the Convergence zones and in the upwelling region associated with the Divergence, as well as in areas where melting of ice occurs.

Table III, p. 60, gives the depth of maximum cell numbers (D_{max}) for each station. It may be observed, from the data reported in this table, for the 1966-67 cruise, that the depth of maximum cell numbers decreases from north to south and is situated within the first 20 meters for most of the stations, south of the Antarctic Convergence. This observation has some similitude with results mentioned by Kozlova (1966), according to which "the depth in which the reduction of diatom density appeared increased from south to north, along with the position of the discontinuity layer". For the 1964-65 cruise, the depth of maximum Diatom abundance, lays for all stations between the 20 and 30 meter layer. However, most of the observations reported in the literature give mean maximum abundance values within the upper layers (Hart, 1942 : 5-10 meter; Rytter Hasle, 1969 : 25 meters in the Subantarctic region, 10 meters in the Antarctic region), a still appreciable number of stations have shown a maximum number of cells at greater depths (75 and 100 meters). Ivanov (1964) stated that "although bloom generally occured in the upper layers of the water, it was also observed at a depth of 50-70 meter, at some stations richer in phytoplankton" (loc. cit. p. 395) and he

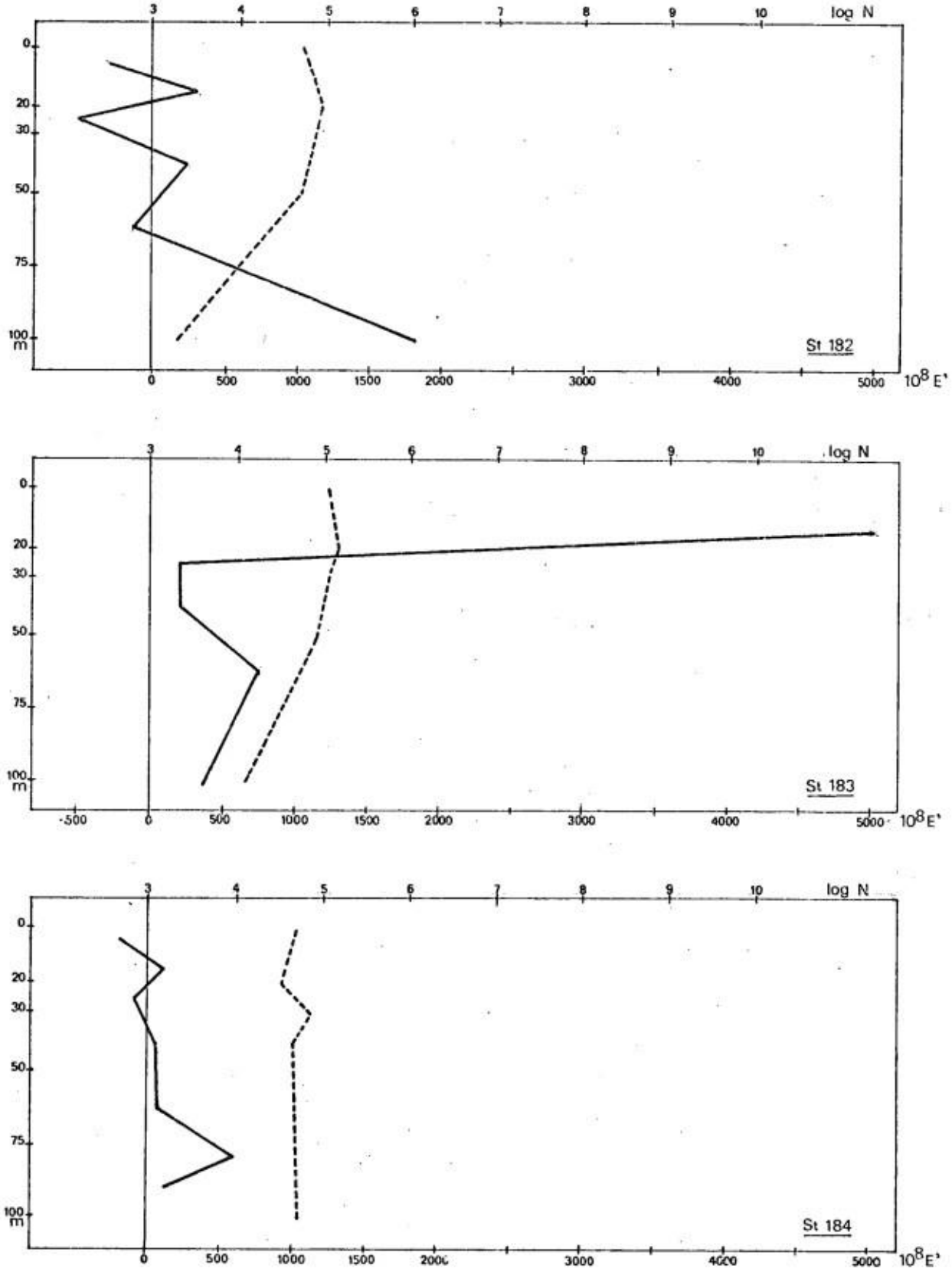


Fig. 22 : Stability (expressed as $10^8 E'$; $E' = 10^{-3} \frac{d\sigma_t}{dz}$) and Diatom abundances (in log. cell numbers per liter) profiles. —— Expedition 1964-65 (Transect).

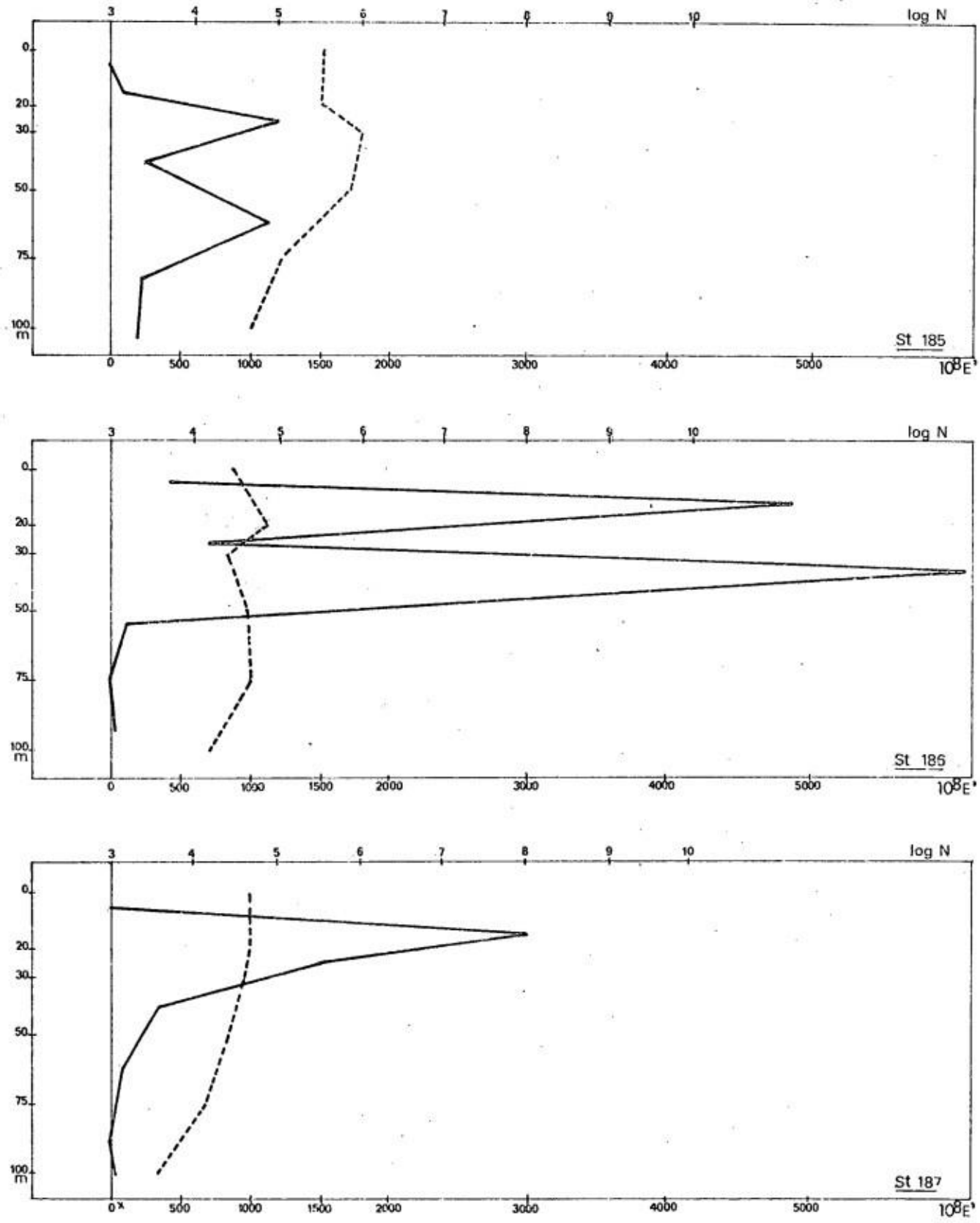


Fig. 22 (continued) : Stability (expressed as $10^8E'$; $E' 10^{-3} \frac{d\sigma_t}{dz}$) and Diatom abundances (in log cell numbers per liter) profiles. —— Expedition 1964-65 (Transect).

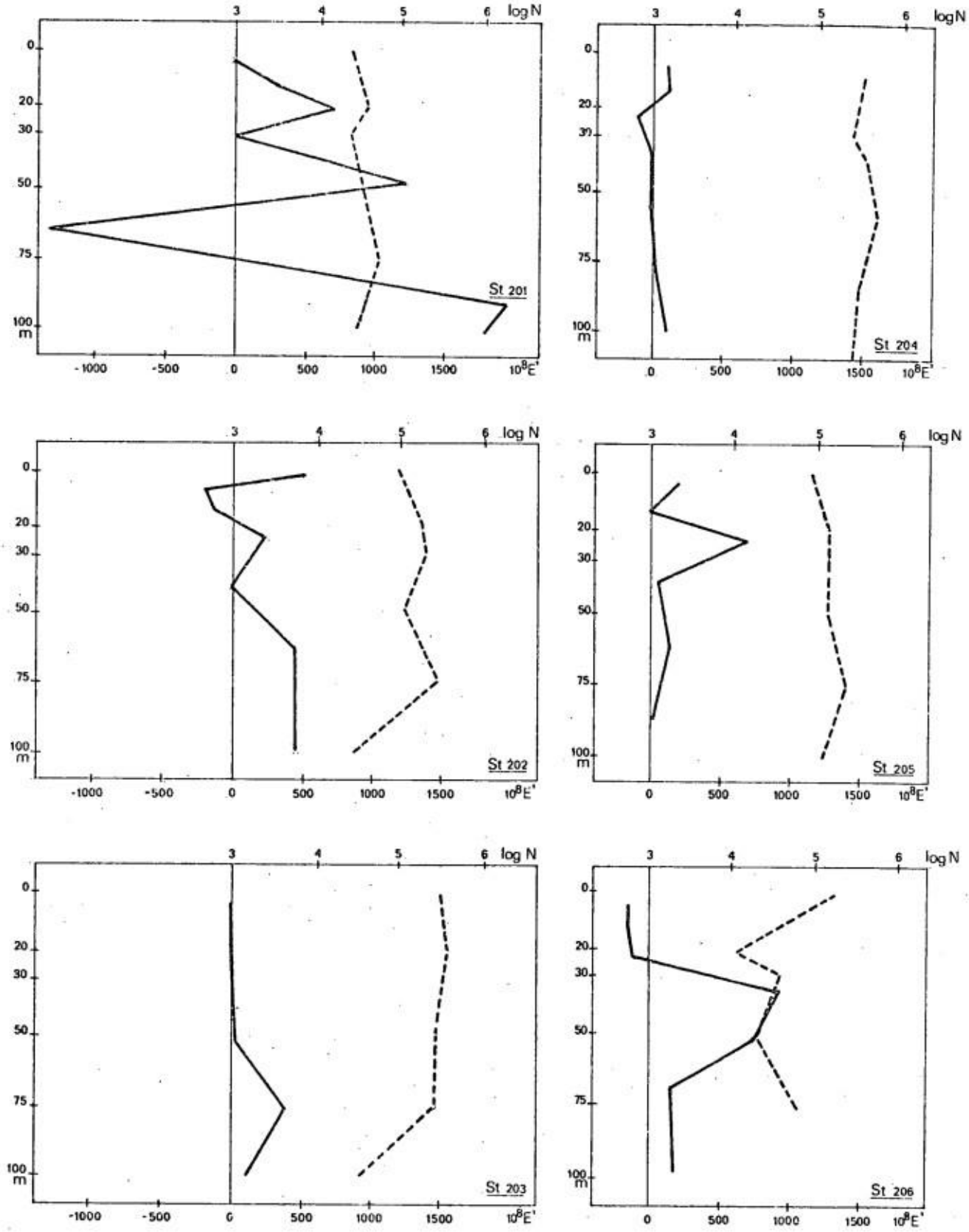
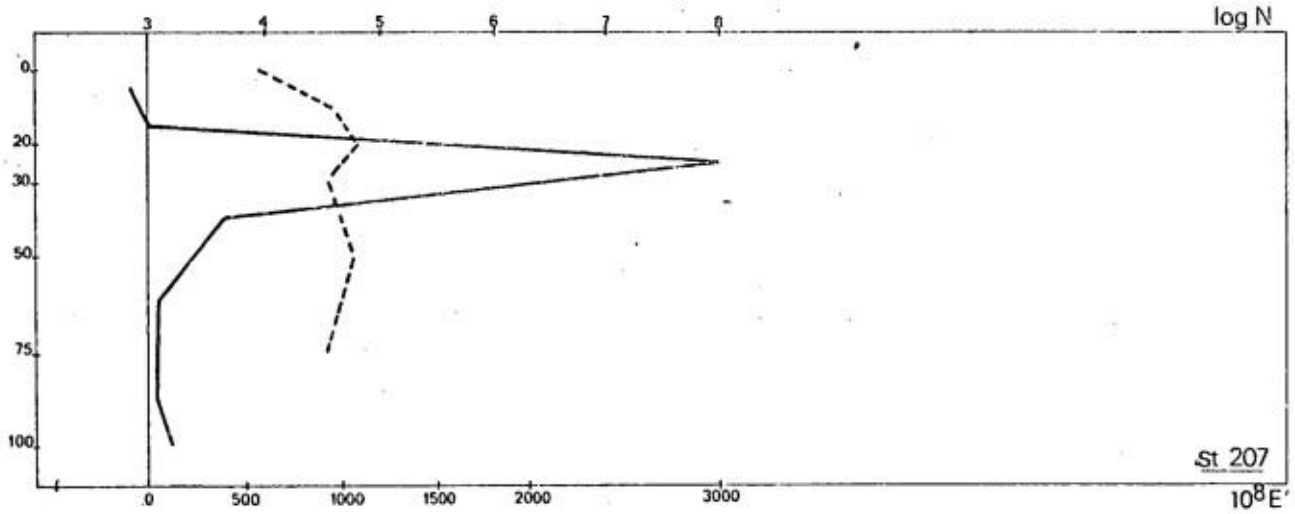
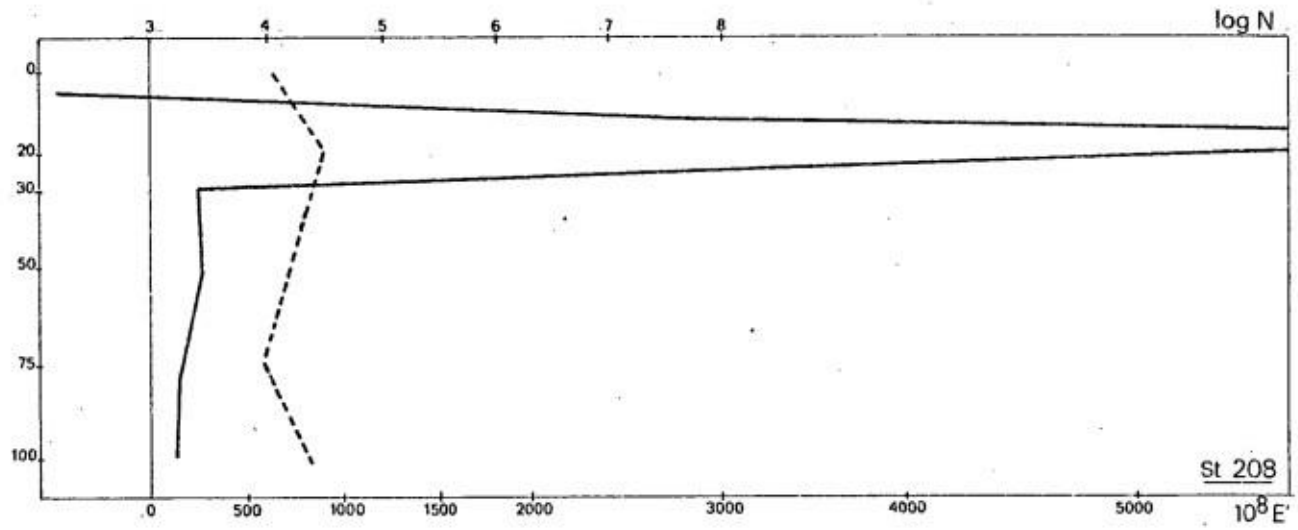
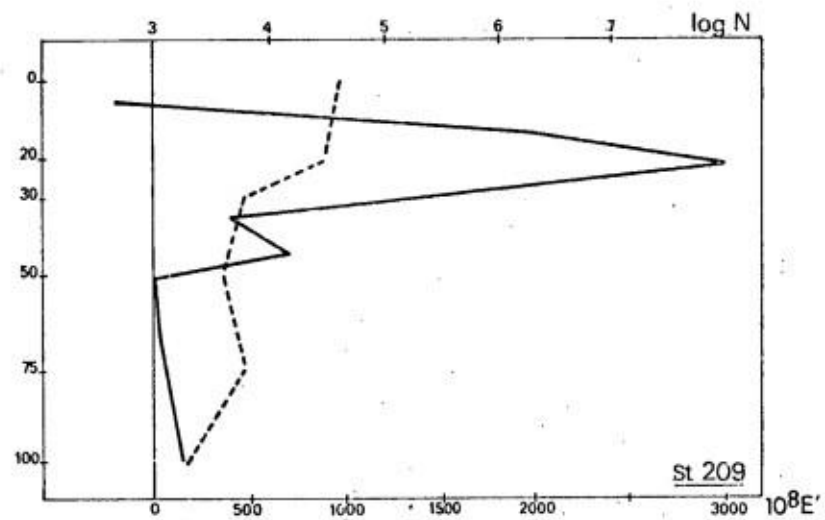


Fig. 23 : Stability (expressed as $10^8E'$; $E' = 10^{-3} \frac{d\sigma_t}{dz}$) and Diatom abundances (in log. cell numbers per liter) profiles. ____ Expedition 1966-67 (Transect).







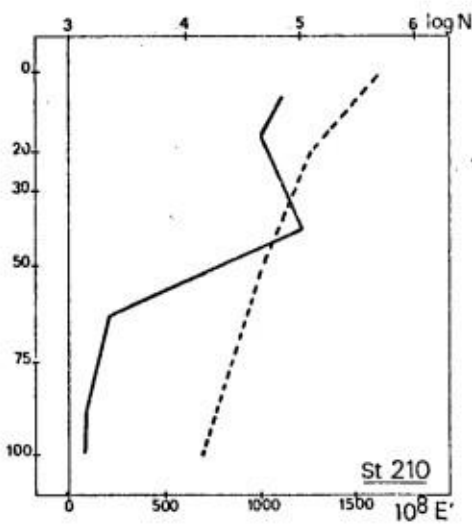


Fig. 23 (continued) : Stability (expressed as $10^8 E'$; $E' = 10^{-3} \frac{d\sigma_t}{dz}$) and Diatom abundances (in log. cell numbers per liter) profiles. — Expedition 1966-67 (Transect).

interpreted this phenomenon as due to a settling, after the blooming period. The differences in depth of maximum phytoplankton abundance is most certainly to be attributed to the action of several factors. In the Antarctic Waters two of these factors are of particular great importance : the light intensity and the stability of the water (or its inverse : the turbulence), both of them depending directly on the sun radiation; the last one, at least, in the southern part of the Antarctic region.

Figures 22 and 23 give, for all the stations along the transect of the 1964-65 and 1966-67 cruise, respectively, the vertical distribution of Diatom abundances (expressed in log. cell numbers), compared to the stability profile (borrowed from the work of M.Steyaert). These figures show, highly positive stabilities, within the 20-30 meter layer, at all stations situated south of the Antarctic Convergence and,especially, for stations within the pack ice zone or under its influence (Stat. 208,209,186 and 187). With the exception of Stat. 207, all these stations also show a maximum cell number located within the upper 30 meters. On the contrary, for stations situated within the Antarctic Convergence or not far from it (Stat. 204,203 and 184), the stability is nearly null, within the 100 meter water column. The high stability and the maximum cell numbers per liter in the superficial waters of the southern part of the Antarctic region, are directly attributable to the establishement of the summer conditions

(increase of the sun radiation and melting of the ice). In the Convergence zone, the stability null and the uniform distribution of the Diatom abundance within the whole 100 meter water column, are linked to the mixing of the waters due to the convergent motion itself.

B. BREID BAY

The stations in the Breid Bay are plotted on Fig. 8 and their coordinates, for both expeditions, are reported in Table I : 7 stations were sampled in 1964-65, 9 in 1966-67.

The geography and the hydrology of the Breid Bay has been described in Chapter II/B. For the purpose of plankton study, the Breid Bay will be considered as one homogeneous area, with respect to the environmental conditions. This is possible, as the hydrology is very similar, at all the stations in the Bay for a same year. Consequently, the results will be analysed in function of time and not in function of their geographical position.

The total Diatom cell number for the Breid Bay stations, sampled during both years, 1964-65 and 1966-67, are reported in Table IV. The mean Diatom cell number for the 0-100 meter layer being 564 x 10^3 cells per liter (or 564 x 10^8 cells per m2) in 1965 and 5 x 10^8 (or

5×10^8 cells per m2) in 1967, we may conclude that the mean concentration of Diatoms between the two years, and for the same period, differs within a proportion of 1 to 100. The maximum cell number per liter of 1.4×10^6, was recorded in 1965, at the 20 meter depth at both stations, 190 and 194. In 1967, the maximum recorded was 3.5×10^4 cells per liter at the surface, at station 211.

For both years, the Diatom biomass found in the Bay, differed from that found in the Oceanic Antarctic Waters. Indeed, in 1964-65, the very rich Diatom populations encountered in the Breid Bay are in striking contrast with those relative poor, found at the oceanic stations 186 and 187. Similarly, in 1966-67, the exceptional low abundance found in the Bay shows a striking contrast with the data obtained at station 210 and, to a lower degree, at the other antarctic oceanic stations.

Previous work on phytoplankton biomass in inshore waters has been done at Mawson (67°36'S - 62°52'E), where Bunt (1960) investigated at two stations, from July to January. The data reported by this author, for the 5 and 15 meter levels, varies from $0.1 - 0.4 \times 10^6$ cells per liter, in mid-November, to 10.5×10^6 cells per liter in early January, then decreasing in late January, till $0.9 - 1.5 \times 10^6$ cells per liter. For the corresponding period, our 1967 results obtained in the Breid Bay, corroborate the findings of Bunt, at Mawson.

St.	n_1	n_2	D_{max}	S.D.m	D. 1% L.I
			1964-1965		
188	544	544	20 m	11	30
189	822.7	822.7	0 m	9	24
190	758.6	758.6	20 m	9	24
192	459.8	459.8	20 m	7	19
194	828.2	828.2	20 m	85	23
196	259.4	259.4	30 m	12	32
197	289.0	289.0	30 m	-	-
			1966-1967		
211	45	45	*	-	-
212	12.3	12.3		-	-
213	5.7	5.7		-	-
214	6.7	6.7		-	-
215	4.7	4.7		-	-
216	4.7	4.7		-	-
217	4.2	4.2		-	-
218	<1			-	-
219	7.4	7.4		-	-

Table IV : Total number of Diatoms per m2 ($n_1 x 10^3$) and per liter ($n_2 x 10^8$) calculated for the 0-100 m layer - Breid Bay Stations.

$n_1 \times 10^3$: number of cells per liter

$n_2 \times 10^8$: number of cells per m2

D_{max} : depth of maximum abundance of Diatom cells

Secchi m : depth in meters measured for the extinction of the Secchi Disc

Depth 1% L. Int : depth in meters corresponding to 1 % of the surface light intensity (calculated with the formula u = 2,7 x d)

* : depth of maximum abundance not reported, as differences between abundances of all depths were slight.

Figures 24 and 25 give, for the years 1965 and 1967, respectively, the vertical distribution of the Diatom abundances, opposite to the stability profiles. We have already brought the attention to the great differences in the total mean cell numbers existing in the Bay between the two years investigated. These differences correspond to a difference in the vertical distribution of the stability profiles between the two years, although the condition of water stability is not the only factor responsable for the more or less important development of phytoplanktonic populations. In 1964-65, the stabilities are almost positive and both, the magnitude of the stabilities and the depth of maximum stability, vary greatly. This situation results from a deep re-arrangement of the different layers, due to the establishment of the summer conditions, and corresponds in this case to an important Diatom biomass. In 1966-67, the stability profiles are quite different. For all stations, except stations 218 and 219, which lay a little outside the Bay, the stability profiles are composed of two distinct parts : a highly stable upper layer, limited approximately to the 30 meters depth, and a lower layer, from 30 meters down, where the stability is nearly null. Assuming that the winter conditions correspond to a null stability (high turbulence) for the whole profile (uniformity in the distribution of temperature and salinity), the aspect of the stability profiles would confirm that, during that year, 1966-67, in the Bay,

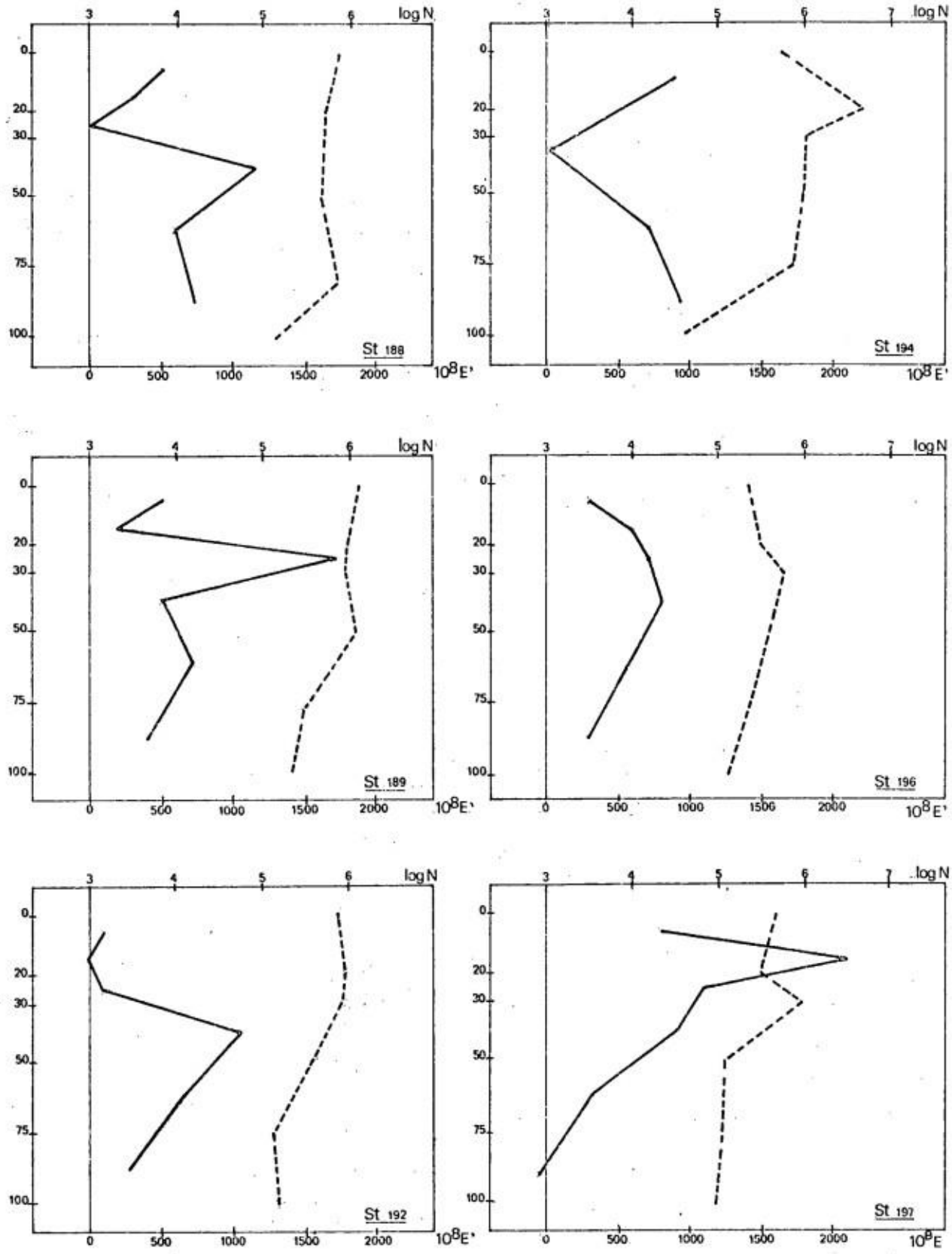


Fig. 24: Stability (expressed as $10^8 E'$; $E' = 10^{-3} \frac{d\sigma_t}{dz}$) and Diatom abundances (in log. cell numbers per liter) profiles. — Expedition 1964-65 [Breid Bay].

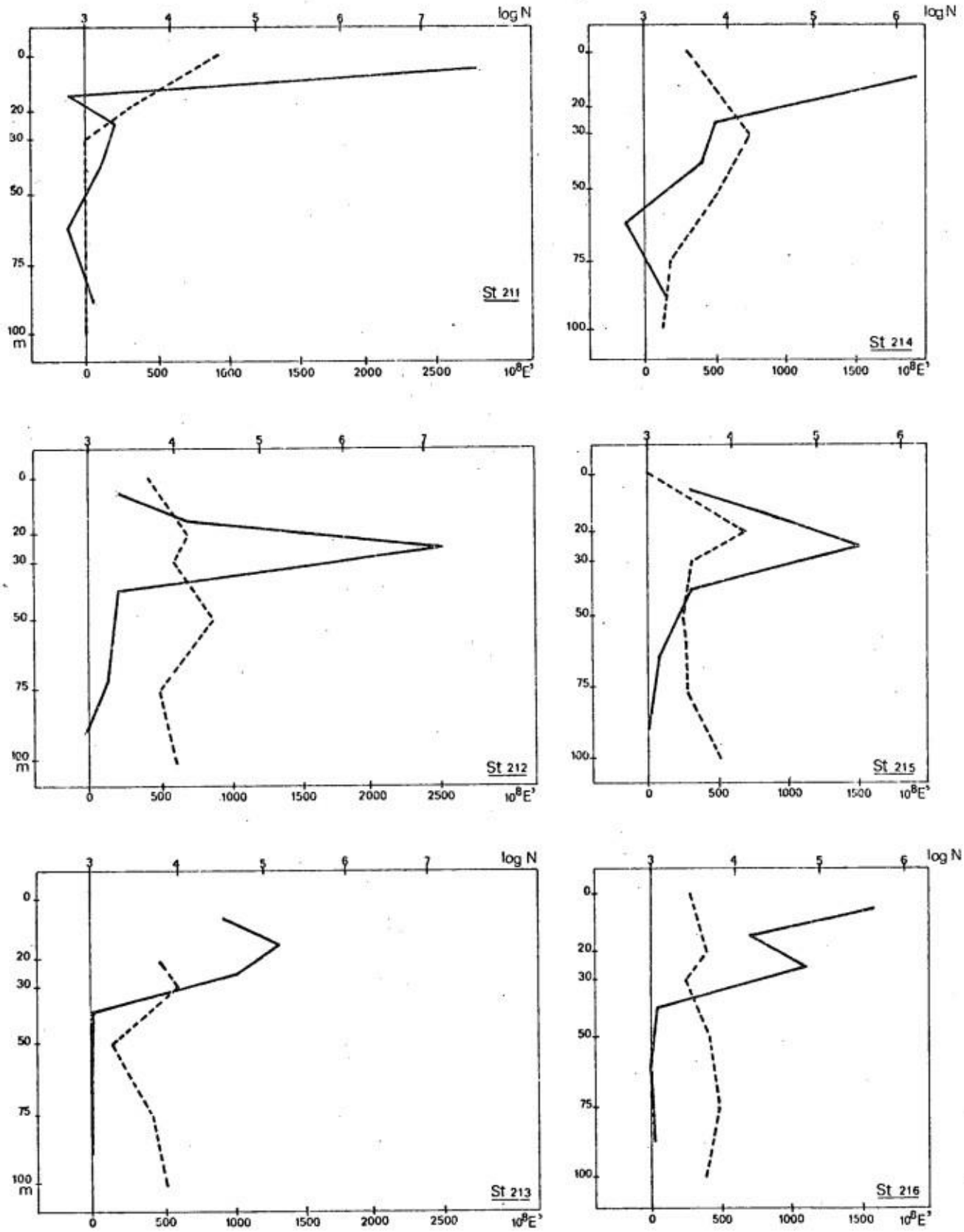


Fig. 25: Stability (expressed as $10^8E'$; $E' = 10^{-3}\frac{d\sigma_t}{dz}$) and Diatom abundances (in log. cell numbers per liter) profiles. ——— Expedition 1966-67 (Breid Bay).

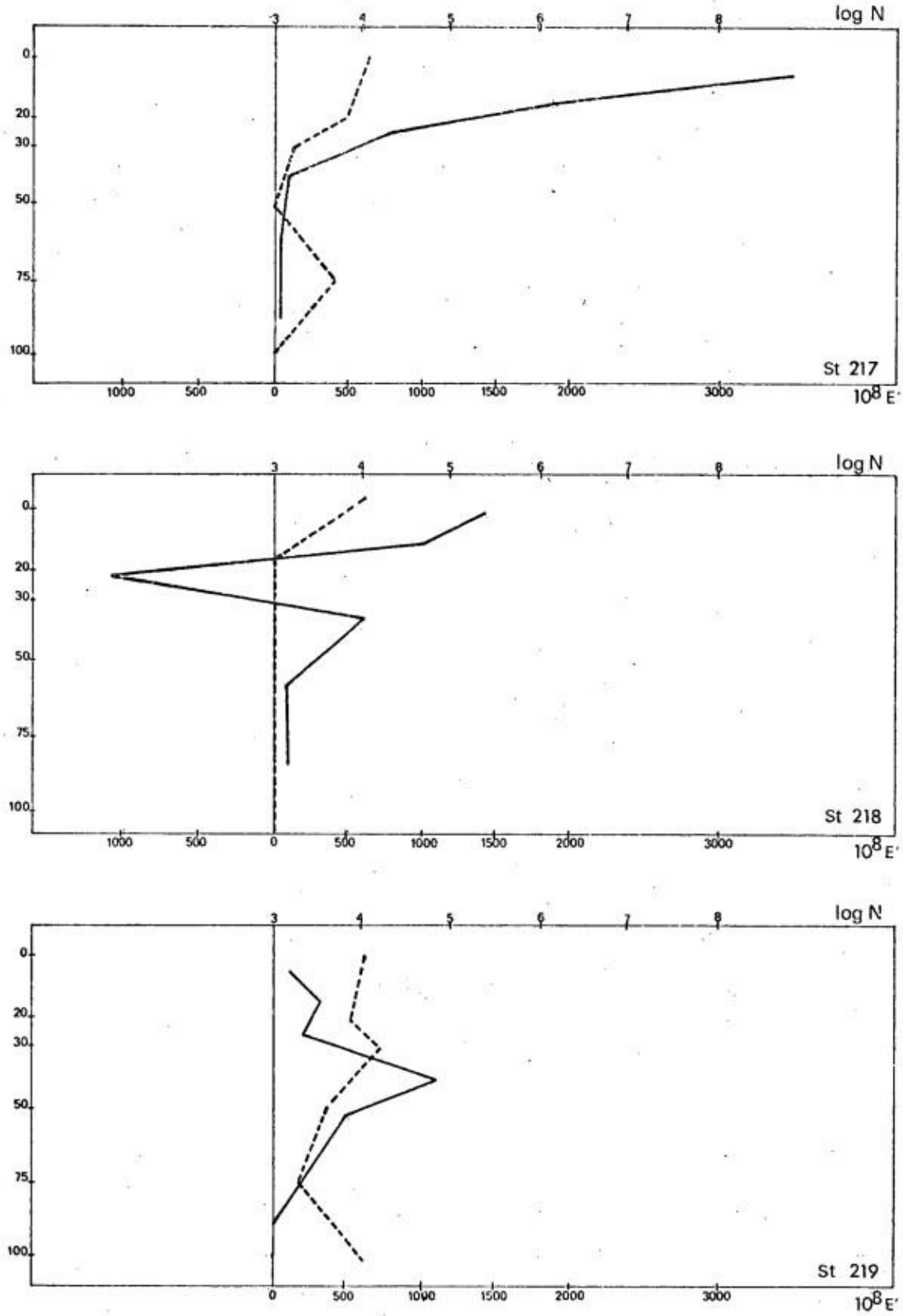


Fig. 25 (continued) : Stability (expressed as 10^8E ; $E' = 10^{-3} \frac{d\sigma_t}{dz}$) and Diatom abundance (in log cell numbers per liter) profiles. — Expedition 1966-67 (Breid Bay).

only the upper 30 meters were influenced by the summer conditions (warming up by sun radiation and reduction of salinity due to the melting of the ice). These conditions of stability did correspond to a reduced Diatom biomass.

Usually, high turbulence (weak stability) is associated with high production, while to high stratification corresponds low production. This is apparently in contradiction with the results we obtained in the Bay, but may be explained by the Sverdrup effect. Indeed, a good correlation exists between our results and those obtained by Sverdrup (1953) in the North Atlantic (66°N, 2°E) where he demonstrated that vertical mixing which is too deep, does not allow Algae to stay long enough in the illuminated zone; on the other hand, stabilized layers of mixing above the critical depth (depth above which the total algae production would exceed the total destruction by respiratory breakdown; and consequently depending on light) increase in efficiency as they get shallower on account of the greater intensity of the light energy available. Sverdrup was able to show that plankton did in fact only develop in spring at times when the depth of the mixed layer is less than the critical depth. In case of the Breid Bay (Fig. 26) in 1966-67, the situation as observed, is very close to winter conditions. There is an homogenuous distribution of densities within almost the whole water column, except the subsurface layer where a first stratification appears and to which corresponds a local and limited increase in phytoplankton (as for example at station 211).

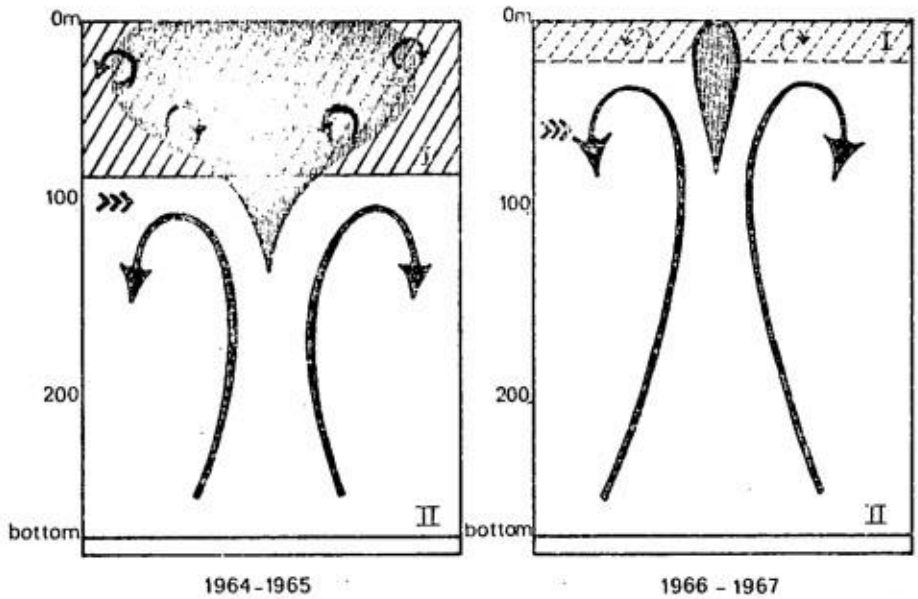


Fig 26 : Schematic representation of the relation between depth of mixed layer and Diatom abundance Breid Bay.

I: upper mixed layer.

II: homogenuous winter layer.

dark: Diatom abundance.

»» : probable critical depth.

This first start of phytoplankton growth in the subsurface layer is already not important enough to influence on the existing situation; we must still consider, as dominant, the fact that the mixing layer extends within the whole water column down to the bottom and, consequently, also below the critical depth. To these conditions correspond a reduced Diatom biomass. In 1964-65, the situation has evolved towards the establishment of a mixed layer within approximately the first 75 meters, most probably above the critical depth, and would explain, according to the Sverdrup effect, the important growth within this layer.

C. ICE

Table V gives the total amount of Diatoms and Phaeocystis (Chrysophyceae), for each sample of ice analysed, expressed in cell numbers per liter of melted ice. The sampling period is quite similar for the two years : 16 and 29 January in 1965, and 14 and 26 January in 1967.

The samples of the 16th January 1965 were taken in fast ice at the 15,35 and 45 cm levels below the top of the floe. No Diatoms were found in it, the population being entirely composed of Phaeocystis. At the 15 cm level, Phaeocystis cells were found sporadically, while, at the 35 and 45 cm levels they amount to 4×10^6 and 6.7×10^6 cells per liter. The ice samples of the 29th January were taken in the pack ice, from an ice floe of 160 cm height; only the lower part, from 120 to 160 cm, was examined at three successive levels (Table V : VIII,IX,X), duplicated by a sample corresponding to the lowest 15 cm. From an other part of the same floe, which looked particularly rich, two samples were taken, corresponding to the inferior 10 and 5 cm layers. From the data reported in Table V an increase in Diatom abundance can be observed (from 1.3×10^6 to 12.7×10^6 cells per liter) with the diminution of the distance to the bottom. We note also that the abundance of Diatoms seems maximum in a layer, few centimeters from the bottom.

Date	Position	Level	Diat./l.	Phaeocyst. cells/l
		1964-1965		
16-1-65	70°19'S 24°12'E	15 cm from top (Fast ice)	-	few
16-1-65	"	35 cm from top (Fast ice)	-	$\pm$ 4.0x10^6
16-1-65	"	45 cm from top (Fast ice)	-	$\pm$ 7 x10^6
29-1-65	70°15'S 24°20'E	VIII layer 112-128 cm from top ice floe	1.10^6	$\pm$ 0.3x10^6
"	"	IX layer 128-144 cm from top ice floe	4.3x10^6	present
		X layer 144-160 cm from top ice floe	7.5x10^6	present
"	"	15 inferior cm same floe	6.6x10^6	"
"	"	10 inferior cm same floe	12.2x10^6	"
"	"	5 inferior cm same floe	10.2x10^6	"
		1966-1967		
14-1-67	68°50'S 26°31'E	surface pack ice	23 x10^6	$\pm$ 2.10^6
26-1-67	70°18'S 24°12'E	undersurface of young pack ice (brown-green coloured)	176x10^6	few
26-1-67	"	undersurface of young pack ice (different floe)	331x10^6	present
26-1-67	"	undersurface of young pack ice (different floe)	458x10^6	present

Table V : Diatom (and Phaeocystis) cell numbers per liter recorded in sea ice samples.

The sample of the 14th January 1967 was taken from the surface "plankton icelayer" of pack ice, north-east to the Breid Bay (68°50'S - 26°31'E). The abundance of organisms found was 25. 10^6 cells per liter. All samples of the 26th January 1967 were taken from the bottom plankton ice layer of a one year old floe. The abundance in Diatoms ranged from 1,8.10^8 to 4,6.10^8 cells per liter.

The comparison of the results obtained for the two years shows that the data obtained from bottom plankton ice samples, taken in 1967, were 100 times higher than for corresponding samples, taken in 1965. The comparison between densities of organisms from bottom pack ice and from surrounding seawater, for both years, gives the following results :

	1964-65 (cells per liter)	1966-67 (cells per liter)
bottom ice	7,0 . 10^6	320 . 10^6
seawater	0,5 . 10^6	0,005 . 10^6

The Diatoms were, in 1965, 10 times more dense in the bottom ice layer than in the surrounding water, 100.000 times in 1967.

The literature concerning the microalgae of the ice is very sporadic and the main difficulty which prevents comparisons is due to the differences in the ice levels studied. Interest for the ice flora began with Gran (1900), who described Diatoms recovered from Arctic ice floes.

In the Antarctic, Bunt (1963, 1964, 1965, 1968), Bunt and Wood (1963), Buinitsky (1965), Bunt and Lee (1970) have made investigations on the lower layer of the ice and especially on the undersurface icelayer (or brash layer). Burkholder and Mandelli (1965) and Meguro (1962) have studied the plankton icelayer at the sea level (between ice and snow). Most of these studies deal essentially with productivity measurements and pigment analyses. Very few data about cells number are given by these authors. Bunt reported, at Mc Murdo Sound, for the undersurface layer, $4,5.10^6$ Diatoms, in December '62 and $16,8.10^6$ Diatoms per liter, in January '63. In more recent investigations (1967), Bunt report up to 10^9 cells per liter, in November. Andriashev (1966) reports for the same layer in the vicinity of Mirny, 37.10^6 Diatoms per liter. No comparison is made by these authors with the surrounding waters. Burkholder and Mandelli (1965), investigating the chlorophyll content of the ice layers, found, for the surface plankton ice layer, a chlorophyll a content and a productivity 30 times greater than in the seawater. Appolonio (1961), in the Arctic, found that the high chlorophyll content in the ice layer preceeded and, in some respect, limited the growth of plankton in the watercolumn, beneath the floes.

From our figures as well as from the data available in the literature, it can be concluded, that the ice milieu is really favorable to algal development, especially at two levels : the lowest layer of the floes and the sea level layer.

These two levels are probably characterized by a high gradient of nutrients concentration. Of both levels, the sea level is the most illuminated one, but is the one with the poorest nutrient content. Because of the development of the Algae at that level, a constant supply of nutrients is brought in, from the surrounding water. On the other hand, the bottom level is less illuminated but is very rich in nutrients, as demonstrated by nutrient analyses (see Chapter II/C). The contact of this bottom layer with surrounding water containing less nutrients makes that this level is subjected to an intens flow of nutritive elements. This may be related to the important development of Algae at that layer. The high cells content corresponds to a real growth and cell division activity, as could be demonstrated by the high pigment content and productivity values, and also infered from comparisons between growth constants, deduced from cell counts, in natural conditions, as well as from results obtained with pure cultures of ice species grown, in similar conditions. The algal development in the ice preceeds the phytoplankton growth in the surrounding water area. Therefore it seems logical that it was during the still 'winter' conditions of 1967 that we found great quantities of algae in sea ice and a very low sea water population density, and an inversed situation during the more "Summer" conditions of 1965. Bunt (1970) has shown that the ice algal development starts early in the season. In August, under continuous darkness, he found up to 10^5 cells per liter, within the interstitial water and 5.10^4 cells per liter for melted ice cristals.

IV. SPECIES DISTRIBUTION AT EACH STATION

As stated in the introduction of previous chapter, one of the ways to approach knowledge on the organization of living matter, is the study of natural populations as a response to their environment. This refers not only to a quantitative, but also to a qualitative aspect. Indeed, it is important to know the quality of the different elements which build up a given population and to measure its complexity in relation to the environmental factors.

In this chapter we shall proceed with the analyses of the different populations encountered at the different stations, and we shall investigate a tentatively correlation between the population composition and some of the environmental factors.

For all stations, temperature and salinity measurements (M. Steyaert) will refer to Fig.9,10,11,12. Sometimes reference will be made to chlorophyll content and primary production (M. Steyaert). For some stations we will include phosphate content results investigated by A. Ballester and M. Steyaert.

A. TRANSECT

The total Diatom quantity recorded at

all standard depths (0,20,30,50,75 and 100 meters) of each station along the transect Cape-Town - Breid Bay, is reported, for both expeditions, in Table VI and represented on a log. scale, on Fig. 27. For all stations, the depth of 1 % light intensity (u), calculated from the Secchi disc measurements (see Table III) is represented by arrows. From Fig. 27 it can be seen that, in 1964-65, the depth of 1 % light intensity lies within the upper 30-50 meters and increases slightly for the two southernmost stations. In 1966-67, this phenomenon is more pronounced and the position of the 1 % light intensity clearly lowers southward, standing below the 75 meter depth at station 209.

1. 1964-65 cruise

Station 182

Position : 40°25'S - 19°24'E

Total mean abundance : 43.500 Diatom cells/liter

Species composition : see Table VII.

This station is situated in the Subtropical Waters, north of the Subtropical Convergence. The depth of the maximum abundance is at 20 meters, above the 1 % light transmission, while the quantity of Diatoms decreases until the 100 meter level. In the first 20 meters, Chaetoceros neglectus, Chaetoceros affinis and Dactyliosolen are the dominant species, while Nitzschia gr. Pseudonitzschia is dominant at 50 and 75 meters.

1964-65

	182	183	184	185	186	187
0	.50	.120	.50	.360	.29	.45
20	.88	.149	.36	.352	.76	.45
30	.	.124	.72	.969	.26	.40
50	.50	.85	.45	.736	.44	.25
75	.10	.	.50	.609	.46	.14
100 m	.2	.13	.55	.47	.15	.4

1966-67

	201	202	204	203	205	206	207	208	209	210
0	.24	.114	.320	.320	.87	.170	.8	.12	.37	.430
20	.41	.171	.247	.397	.143	.12	.61	.32	.29	.117
30	.24	.201	.365	.	.139	.38	.34	.	.6	.
50	.35	.120	.494	.304	.134	.22	.57	.17	.4	.45
75	.51	.278	.277	.298	.206	.65	.34	.10	.6	.
100 m	.30	.31	.258	.37	.116	.	.	.24	.2	.13

40° 50° 60° 70°

Table VI : Distribution of Diatom cells per liter (N x 10^3) along the transect Cruise 1964-65 and 1966-67.

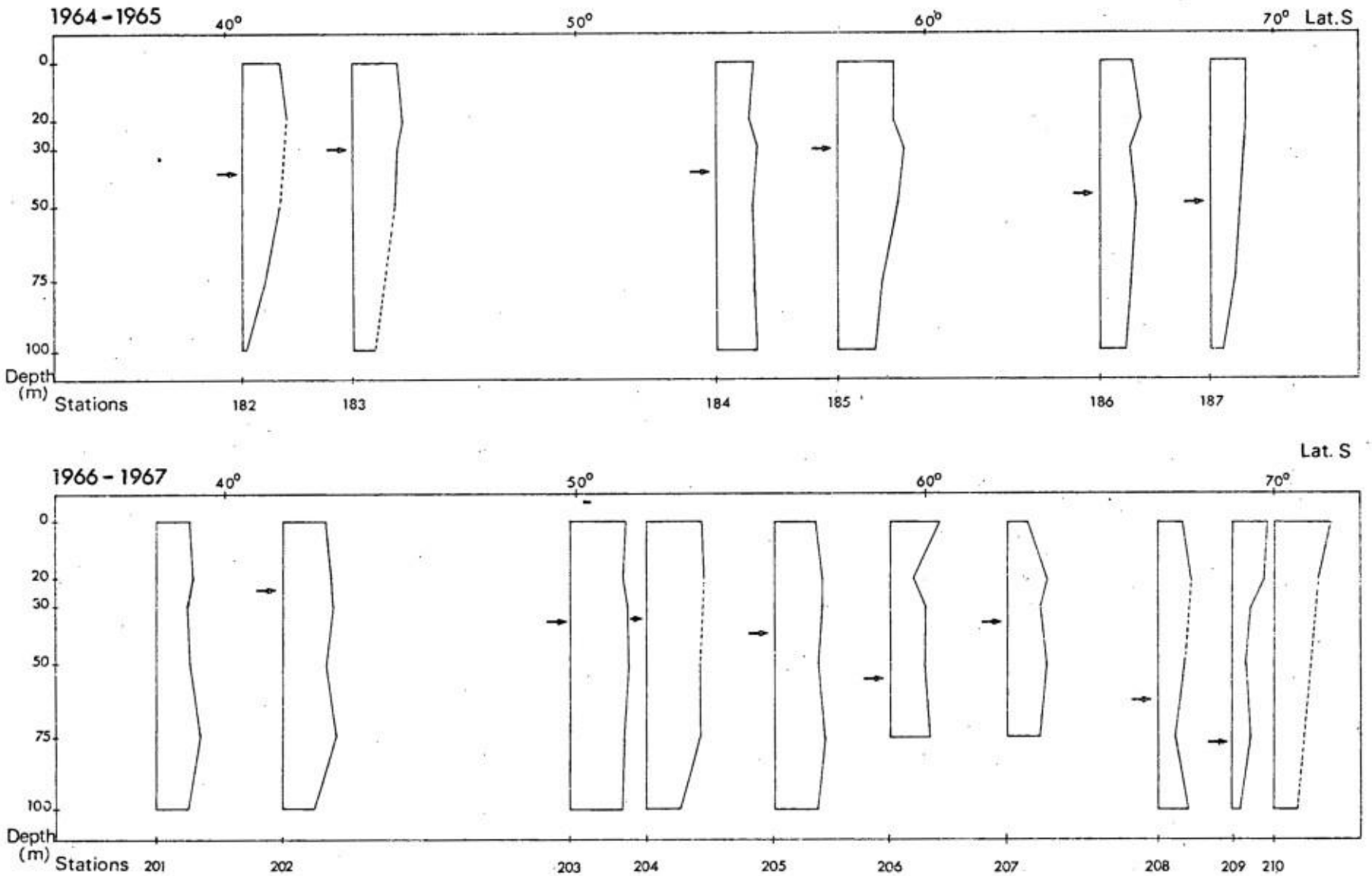


Fig. 27: Vertical distribution of Diatom abundances, expressed as log N (N x 10^3 = cell numbers per liter) at each station along the transect during the 1964-65 and 1966-67 expeditions. The arrows represent the depth of 1‰ surface light.

The hydrology shows uniform temperature and salinity pattern within the first 100 meters (19,69°C and 35,53°/oo sal. at 0 meter), resulting in a marked absence of stratification of the waters within these depths.

Station 183

Position : 43°35'S - 20°05'E

Total mean abundance : 85.950 Diatom cells/liter

Species composition : see Table VIII.

This station faces within the Subtropical Convergence zone. The depth of maximum abundance, only slightly appearent, is at 20 meters, above the 1 % light transmission depth; up to 50 meters the quantity of cells remains important, decreasing regularly below this depth. Nitzschia gr. Pseudonitzschia is dominant at all depths; at the 0 meter the species is associated with Chaetoceros neglectus (?), Chaetoceros affinis and Thalassionema nitzschioides, the latter increasing in relative importance from 20 meters on. By net hauls N. gr. Pseudonitzschia was by far the most dominant species. There is a marked difference between the temperature at 0 meter (13.37°C) and 10 meters (16.17°C) corresponding to a strong instability at this station in the first 30 meters which implies that Station 183 lies in a zone of great turbulence and of possible vertical mixing. The turbulence in this layer seems to correspond to a uniform high Diatom abundance to a large extent due to Nitzschia gr. Pseudonitzschia and Thalassionema nitzschioides.

STATION 182 (40°25'S - 19°24'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Nitzschia gr. Pseudon.	2 600	7 620		13 870	2 600	+
Dact. antarcticus (var)	1 730	4 360		+	+	-
Chaet. affinis	12 140	7 990		10 400	-	-
Chaet. neglectus	7 800	19 240		-	-	-
Rhiz. curvata	6 070	720		-	+	-
Rhiz. alata						
Rhiz. setigera	870	720		-	260	-
Corethron criophilum	2 600	4 360		1 730	+	-
Thallassiothrix mediter.	870	1 820		-	+	-
Thallassiothrix frauenf.						
Thallassion. nitzschioid.	+	3 620		-	500	-
Chaet. atlanticus (var)	1 730	360		-	-	-
Chaet. peruvianus	1 730	1 450		-	+	-
Chaet. messanensis	+	3 990		5 200	780	-
Bacteriastrum	-	3 270		+	260	-
Hemiaulus Hauckii	-	720		870	-	-
Navicula sp.	-	720		870	-	-
Thalassiosira	-	2 100		-	500	+
Tropidoneis	870	-		-	+	-
Rhiz. styliformis	+	-		-	-	-
Chaet. sp. divers	6 070	-		-	+	-
Nitzschia closterium (long)	-	1 000		-	520	-
Chaet. anastomasans	-	1 450		-	-	-
Chaet. socialis	-	3 300		-	-	-
Nitzschia Nitzschiella	-	720		6 000	-	-
Melosira	-	+		-	520	-
Coscinodiscus sp.	-	300		-	-	-
Chaet. pendulum	-	360		-	500	-
Lauderia borealis	-	-		1 700	-	-
Stephanopyxis	-	-		-	+	-

Table VII

STATION 183 (43°35'S - 20°05'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Nitzschia gr. Pseudon.	34 000	58 500	34 000	37 200		+
Chaet. neglectus	16 500	2 500	2 400	-		+
Chaet. affinis	12 100	12 500	10 400	-		-
Chaet. messanensis	4 300	700	1 600	1 700		-
Thallassiosira	1 730	4 280	1 600	-		-
Chaet. peruvianus	3 450	-	1 060	-		-
Thallassion. nitzsch.	11 000?	32 500	22 880	1 700		-
Nitzschia closterioid.	2 000	6 100	3 700	1 730		-
Chaet. brevis	4 000	-	-	-		-
Dact. antarcticus var	870	2 100	1 330	4 340		-
Thallass.thrix med.	2 600	5 710	3 990	870		-
Navicula membranacae	800	1 000	-	-		-
Rhiz. curvata	3 500	350	-	-		-
Rhiz. alata	870	2 500	2 390	-		-
Rhiz. delicatula	+	-	-	-		-
Rhiz. styliformis	1 730	-	270	1 700		+
Rhiz. hebetata	2 600	-	+	-		-
Chaet. pendulum	+	-	-	-		-
Nitzschia bicapitata	+	-	-	-		-
Asterionella japonica	+	-	-	-		-
Eucampia cornuta	-	1 780	1 330	-		-
Chaet. didymus	-	+	-	-		-
Chaet. atlanticus	-	1 800	300	-		-
Thallass.thrix (long)	-	2 900	2 500	-		-
Thallass.thrix frau.	-	6 780	2 930	3 470		-
Coscinodiscus sp.	-	+	2 900	-		-
Rhiz. Bergonii	-	2 100	500	-		-
Corethron criophilum	-	1 070	270	1 700		-
Hemiaulus Hauckii	-	400	-	4 340		-
Navicula sp.	-	-	2 400	-		+
Chaet. socialis	-	-	1 000	-		-
Frag. "nana"	-	-	500	-		-
Chaet. criophilum	-	-	-	1 700		-

Table VIII

A great primary production was recorded in the first 50 meters, associated with a rapid decrease below this depth. This corroborate the results on Diatom abundances. When comparing the two stations 182 and 183, no marked difference is found in the species composition. Also must be noted the presence of Peridinea, Coccolitophoridae abundant species of Tintinnidae and a few Cyanophyceae.

Station 184

Position : 54°04'S - 19°20'E

Total mean abundance : 50.850 Diatom cells/liter

Species composition : see Table IX.

Station 184 is located at about 4° latitude south of the Antarctic Convergence. Fig. 26 shows a quite homogeneous distribution of the Diatom abundance with a slight maximum at 30 meters which lay above the 1 % light intensity. The dominant species in the Nansen bottles samples were Chaetoceros atlanticus and Nitzschia gr. Pseudonitzschia, associated, with Fragilariopsis kerguelensis and Fragilariopsis rhombica in the 0-50 meter layer, and with Chaetoceros dichaeta and Fragilariopsis curta below this depth. The results obtained with the net give a quite different picture : Chaetoceros criophilum, Corethron criophilum, Thalassiothrix antarctica and some colonies of Fragilariopsis kerguelensis forming clumps, visible with the naked eye, together, they represent more than 3/4 of the total bulk. The net hauls

STATION 184 (54°04'S - 19°20'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Nitzschia gr. Pseudon.	13 000	4 680	7 000	11 300	8 400	4 340
Chaet. atlanticus	6 940	10 800	14 210	8 670	8 750	6 900
Frag. kerguelensis	6 930	3 600	3 260	3 470	700	4 340
Frag. curta	-	2 880	11 650	5 200	5 950	2 600
Frag. rhombica	1 730	2 800	10 000	2 600	2 800	3 460
Dact. ant. (var)	800	360	470	-	+	-
Chaet. dichaeta	870	-	930	+	6 300	+
Nitzsch. Nitzschiella	800	-	-	-	-	-
Nitzschia bicapitata	4 340	-	-	-	-	-
Chaet. neglectus	2 600	-	-	-	+	-
Chaet. criophilum	1 730	1 080	2 100	3 470	1 400	-
Navicula sp.	1 700	300	200	-	-	+
Chaet. peruvianus	800	-	-	-	-	-
Thallass.thrix ant.	1 730	360	930	-	1 400	-
Rhiz. alata	-	2 100	1 150	870	350	2 600
Rhiz. hebetata	-	1 080	1 400	-	-	-
Rhiz. Chunii	-	300	-	-	-	2 600
Frag. "nana"	-	2 500	9 800	2 600	300	17 300
Asteromph. heptactis	-	720	230	-	+	-
Chaet. flexuosus	-	360	230	-	-	-
Melosira	-	300	200	4 300	1 400	+
Nitzschia closterium	-	-	700	-	700	-
Coscinod. tumidus	-	-	+	-	-	-
Chaet. convolutus	-	-	700	-	1 400	-
Corethron criophilum	-	-	200	+	350	-
Thalassiosira	-	-	1 600	-	3 150	+
Tropidoneis	-	-	230	-	-	-
Eucampia balaustium	-	-	-	+	+	-
Synedra reinboldii	-	-	-	-	+	-
Charcotia actinoch.	-	-	-	-	-	1 730

Table IX

STATION 185 (57°32'S - 21°20'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Nitzschia gr. Pseudon.	45 950	32 720	133 950	92 800	17 000	9 500
Fragilariop. kerguelensis	64 160	55 150	190 950	79 460	18 700	+
Frag. rhombica	20 810	15 150	49 590	30 160	7 650	+
Frag. "nana"	7 800	5 450	16 530	20 300	1 270	1 730
Chaetoceros atlanticus	38 150	19 390	62 130	96 280	10 620	10 400
Frag. obliquecostata	10 400	?	?	?	?	?
Chaet. dichaeta	17 340	15 760	60 420	34 800	5 950	-
Corethron criophilum	3 470	3 640	6 270	8 700	2 120	-
Navicula	11 270	12 120	55 290	60 320	8 500	5 200
Frag. cylindrus	870	1 210	10 260	4 060	850	-
Dact. antarcticus	2 600	600	5 700	5 220	420	-
Synedra reinboldii	20 810	1 210	14 250	10 440	1 700	-
Chaet. neglectus	19 940	17 570	59 280	77 140	6 800	6 940
Asteromphalus parvulus	2 600	600	3 420	580	420	-
Thallasiothrix antarct.	4 340	14 540	81 510	33 640	8 500	-
Rhizosolenia Chunii	1 730	4 850	6 270	4 060	850	-
Rhizosolenia alata	870	600	10 260	5 220	-	+
Chaet. criophilum	870	1 210	1 140	-	-	-
Tropidoneis	1 700	1 820	5 130	3 480	850	-
Nitzschia "closterioides"	45 950	33 290	34 200	42 340	-	-
Melosira	1 700	+	-	2 320	-	-
Micropodisc. Oliverianus	2 600	-	2 280	1 160	-	-
Rhiz. styliformis	1 730	-	9 120	-	420	-
Dactylios. antarc. (var)	2 600	-	-	-	-	-
Coscinodiscus sp.	1 700	-	+	-	-	-
Coscin. lentiginosus	-	600	2 850	580	-	-
Thalasiosira	-	4 850	18 810	8 120	2 970	-
Frag. cf. sublinearis	-	4 850	6 270	6 960	-	-
Chaet. convolutus	-	3 030	+	2 900	850	-
Chaet. Castrac·	-	1 210	14 250	11 020	1 700	-
Chaet. flexuosus	-	1 820	-	5 800	-	-
Charcotia actinoch.	-	600	570	580	-	-
Chaet. Hendeyi	-	+	12 540	-	-	-
Eucampia balaustium	-	-	+	+	-	-
Nitzschia closterium	-	-	1 140	2 900	420	
Asteromphalus heptactis	-	-	3 990	1 160	-	-
Rhiz. hebetata	-	-	-	1 100	-	-

Table X

taken from 250 to 0 meter give, in this case, a very false idea of the relative composition of species. The hydrology shows also an homogeneity of the densities within the 0-100 meter water column with a slight increase at the 100 meter level reflected by the homogeneity in the Diatom abundance and a quite uniform distribution of the species in the whole 100 meter water column. The surface temperature was 0,25°C, passing 0°C below the 75 meter level, while the salinity was nearly 34,06°/oo within the whole first 100 meters. The chlorophyll and the productivity curves are in good correlation with Diatom abundance profile.

Station 185

Position : 57°32'S - 21°20'E

Total mean abundance : 432.870 Diatom cells/liter

Species composition : see Table X.

Station 185 is located in the Antarctic Waters, before the pack ice edge and before the Antarctic Divergence. This station shows greatest abundance among all the stations examined, with a pronounced maximum at 30 meters, which was also the depth of 1 % light transmission. The dominant species were Fragilariopsis kerguelensis and Nitzschia gr. Pseudonitzschia in the first 30 meters, while at 50 meters and below, the abundance of each species was equally shared between Chaetoceros atlanticus, Nitzschia gr. Pseudonitzschia, Fragilariopsis kerguelensis and Fragilariopsis curta.

It must be observed that quite a lot of south antarctic species (Frag. curta, Frag. cylindrus, Eucampia balaust., Chaet. flexuosusum, Synedra reinboldii...) appears at Station 185, while they were found only occasionally at ST. 184. The first 30 meters form an homogeneous layer of density (σ_t = 27) due, partly to the summer heating (temperature around 0°C) and partly to the melting of the sea ice (33,62 °/oo salinity). Below, the temperature dropped quickly to -1,61°C at 75 meter, the salinity being 34,11°/oo at the same depth. Obviously the bulk of phytoplankton was between 30 and 50 meters, at the transition between the surface layer of equal density and the layer below. This is confirmed by the productivity curve.

Station 186 - 187

Position	: St. 186	: 65°09'S - 23°47'E
	St. 187	: 68°11'S - 25°35'E
Total mean abundance	: St. 186	: 41.470 Diatom cells/liter
	St. 187	: 26.870 Diatom cells/liter
Species composition	: St. 186	: see Table XI
	St. 187	: see Table XII.

Station 186 and station 187 are both in the area influenced by the melting pack ice. The vicinity of the ice floes is reflected in the phytoplankton composition by the presence of ice originated species as Amphiprora Kufferathii, Fragilariopsis curta.

STATION 186 (65°09'S - 23°47'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Nitzschia "closterioides"	6 940	3 610	+	-	1 720	+
Frag. "nana"	1 730	25 580	1 910	1 730	7 170	1 760
Frag. curta	4 340	8 340	1 900	5 200	1 720	2 640
Frag. rhombica	+	560	-	-	+	880
Nitzschia Pseudon.	+	2 500	+	+	3 400	3 520
Corethron criophilum	3 470	18 630	14 740	8 670	5 400	1 100
Amphiprora Kuffercthii	1 700	-	-	-	-	-
Frag. antarcticus	+	500	-	5 000	+	-
Chaet. convolutus	+	-	550	1 730	570	-
Chaet. neglectus	-	1 950	-	6 940	12 050	2 420
Thalasiothrix antarct.	-	+	+	-	860	-
Chaet. criophilum	-	1 950	4 090	5 200	600	-
Nitzschia closterium	-	+	550	-	-	-
Rhizosolenia alata	-	-	+	-	1 720	+
Rhizosolenia Chunii	-	-	-	+	+	-
Synedra reinboldii	-	-	-	+	+	440
Dactyl. mediter. ?	-	-	-	-	+	880
Chaet. atlanticus	-	-	-	-	1 150	-
Coscind. pseudodent.	-	-	-	-	+	-

Table XI

STATION 187 (68°11'S - 25°35'E)

	0 m	20 m	30 m	50 m	75 m	100 M
Frag. "nana"	8 670	7 260	18 810	+	1 060	-
Frag. cylindrus	7 800	4 400	-	-	-	-
Rhiz. rhombus.	870	220	+	-	+	
Frag. curta	12 140	12 760	11 970	6 940	3 600	+
Nitzschia "closteroides"	2 600	+	2 850	-	640	-
Frag. antarcticus	2 600	-	+	-	-	-
Amphiprora Kuffercthii	870	-	-	-	-	-
Rhiz. alata	870	-	-	-	+	-
Thalasiosira antarct.	1 730	2 420	7 410	1 730	2 330	-
Charcotia actinoch.	-	+	-	-	-	-
Chaet. neglectus	-	1 300	-	-	-	-
Corethron criophilum	3 470	8 800	27 930	6 070	1 910	-
Frag. rhombica	-	2 640	2 850	1 700	800	-
Eucampia balaustium	-	+	-	-	-	+
Chaet. convolutus	-	-	+	-	-	-
Nitzschia gr. Pseudon.	-	-	1 100	1 700	850	-
Chaet. atlanticus	-	-	+	-	-	-
Chaet. criophilum	-	-	1 140	1 730	-	-
Asteromphalus Hookeri	-	-	+	-	420	-
Dact. mediter. ?	-	-	-	+	-	-
Coscinoduscus pseudodent.	-	+	1 100	-	-	-
Rhiz. styliformis	-	-	-	-	+	-

Table XII

As a whole, the biomass is rather poor compared to that at station 185, which is confirmed by a reduced productivity. We also note that the 1 % light transmission is deeper than for all the other stations. At station 186, Corethron criophilum and Fragilariopsis "nana" represent together about 60 % of the bulk at 20 meters. At 50 meters, Chaetoceros neglectus, Fragilariopsis curta and Corethron criophilum are more or less equally distributed, while at the 75 and 100 meters, Chaetoceros neglectus is the dominant species. Station 187 is comparable to Station 186, except that, if Corethron criophilum, Fragilariopsis cylindrus, Fragilariopsis "nana", Nitzschia "closterioides" and Fragilariopsis curta are still the dominant species, Chaetoceros neglectus does occur in less quantity than at Station 186. The main feature of the hydrology of the surface waters for both stations 186 and 187 are related to the presence of melting ice floes as reflected in the low surface salinity of, respectively, 33.09 and 33.68°/oo. As for station 185, the first 30 meters are directly influenced by the melting of the ice; this creates an important stratification between the upper water and the water below (see Fig. 22).

2. <u>1966-67 cruise</u>

<u>Stations 201 and 202</u>

Position	: St. 201	: 38°00'S - 18°15'E
	St. 202	: 41°47'S - 19°40'E

Total mean abundance : St. 201 : 36.500 Diatom cells/liter
St. 202 : 167.600 Diatom cells/liter

Species composition : St. 201 : see Table XIII
St. 202 : see Table XIV.

Station 201 is situated north of the Subtropical Convergence, while station 202 is close to this one. Therefore the locations of these two stations are similar to those of the 1964-65 stations 182 and 183, respectively.

Station 201

The abundance of Diatoms at this station is comparatively week, while the distribution is rather uniform within the first 100 meters, with a slight maximum at 20 and 75 meters. The dominant species are Nitzschia gr. Pseudonitzschia, Rhizosolenia alata forma indica (both species highly dominant especially at the 20 and 75 meter) associated with Thalassiothrix frauenfeldii and several species of Chaetoceros and Rhizosolenia. Temperature and salinity are rather uniform in the 0-100 meters (19°C and 35,42°/oo), except for a marked decrease at 75 meters (16,55°C and 35,23°/oo), which corresponds also to a marked decrease in the phosphate content.

Station 202

This station has a Diatom abundance 4 to 5 times greater than that of station 201, with a maximum situated at 75 meters. A second maximum is also apparent at 30 meters. Both of them are below the 1 % light transmission level. At this station the dominant species are Nitzschia gr. Pseudonitzschia, Thallasionema nitzschioides and several species of

STATION 201 (38°00'S - 18°15'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Nitzschia gr. Pseudon.	5 200	6 690	3 470	4 340	11 780	5 200
Rhiz. alata	5 200	10 780	2 600	+	18 210	2 600
Bacteriastrum	900	750	-	-	-	+
Dact. antarct.(fo.laevis)	1 730	2 230	1 700	-	-	-
Chaet. affinis	1 700	1 860	900	3 500	+	-
Thall.thrix frauenf.	2 600	1 120	-	1 700	1 800	-
Thall.thrix mediterr.	870	400	-	-	700	-
Chaet. sp. divers	-	3 720	2 600	2 600	1 000	1 700
Rhiz. setigera	900	400	-	870	1 000	850
Rhiz. delicatula	1 700	740	2 500	900	1 000	800
Chaet. messanensis	870	-	-	-	-	-
Nitzschia closterium	-	1 120	-	-	700	-
Hemiaulus Hauckii	-	350	-	-	+	-
Coscinod. tumidus	-	1 490	-	+	-	-
Rhiz. styliformis	-	1 100	4 000	-	-	-
Stauroneis	-	300	-	-	-	-
Rhiz. hebetata	+	370	1 300	-	-	-
Rhiz. curvata	+	1 100	900	-	+	850
Thalassiosira	-	2 230	-	-	2 500	-
Lauderia borealis	-	-	-	-	+	-
Asterionella japonica	-	-	-	-	1 000	-
Nitzschia bicapitata	-	-	-	-	+	-
Corethron criophilum	-	-	-	-	+	-

Table XIII

STATION 202 (41°47'S - 19°40'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Nitzschia gr. Pseudon.	60 690	60 650	104 910	52 000	31 160	3 470
Thall.nema nitzsch.	7 800	27 130	24 270	71 090	167 960	-
Thall.thrix frauenf.	3 470	4 790	900	-	12 920	-
Thall.thrix mediter.	3 500	3 190	1 730	3 400	+	-
Nitzschia bicapitata	1 730	400	-	-	-	-
Rhiz. hebetata	2 600	400	-	-	1 500	-
Rhiz. alata	900	4 390	-	-	3 000	-
Chaet. affinis	4 340	15 560	26 600	25 700	9 800	+
Chaet. brevis	+	+	-	-	-	-
Nitzsch. "closterioid."	7 800	1 200	-	-	3 000	-
Rhiz. Bergonii	1 700	-	1 730	-	-	-
Corethron criophilum	870	400	-	-	760	+
Chaet. atlanticus	2 600	5 990	1 700	-	-	+
Eucampia zoodiacus	-	+	-	-	-	-
Chaet. messanensis	+	3 200	870	-	5 300	-
Dact. antarct. (var)	3 470	2 000	3 400	2 600	1 520	-
Lauderia borealis	-	-	1 700	3 400	1 500	
Bacteriastrum del.	-	2 700	-	-	3 800	-
Chaet. dichaeta	-	-	1 700	-	-	-
Asteromphalus heptac.	-	-	-	+	-	-
Chaet. criophilum	-	-	-	+	+	-
Hemiaulus Hauckii	-	2 000	-	1 700	1 500	-
Chaet. convolutus	-	2 390	-	-	-	-
Chaet. neglectus	6 940	800	1 650	-	9 100	-
Chaet. anastomasans	-	800	1 700	-	+	-
Chaet. peruvianus	-	-	-	+	3 800	-
Thalassiosira	-	2 000	1 700	-	1 520	-
Coscin. excentricus	-	400	-	-	-	+
Chaet. Lorenzianus	-	4 390	1 730	-	3 800	-
Navicula	-	800	-	+	-	+
Frag. "nana"	-	-	-	-	-	1 700

Table XIV

Chaetoceros, among which Chaetoceros affinis and Chaetoceros atlanticus. Also to be noted, Thalassiothrix frauenfeldii in appreciable quantity. This station shows uniform temperature (13,0°C) and salinity (34,69°/oo) within the top first 100 meters. A minimum in phosphate content was recorded at the depth of 30 and 50 meters which also corresponds to the maximum in Diatom abundance. Finally, the distribution of the chlorophyll and of the primary production curves are in good correlation with the diatom abundance. All in all, the results obtained at this station show that the Subtropical Convergence creates conditions which favour the growth of Diatoms as expressed by a relative high productivity rate. Further on, we will discuss how the Subtropical Convergence, which is defined as a boundery between the Subtropical Waters and the Subantarctic Waters constitute also a natural boundery for the distribution of certain Diatom species. A great quantity of fragments of Diatom cells were observed at station 202. This must probably be attributed to the dislocation of fecal pellets as consequence of an intense grazing.

Stations 204 and 203

Position	: St. 204	: 49°50'S - 22°50'E
	St. 203	: 52°04'S - 22°50'E
Total mean abundance	: St. 204	: 336.500 Diatom cells/liter
	St. 203	: 294.000 Diatom cells/liter
Species composition	: St. 204	: see Table XV
	St. 203	: see Table XVI

STATION 204 (49°50'S - 22°50'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Chaet. atlanticus	77 160	27 340	23 410	26 880	27 590	8 670
Nitzschia Pseudon.	88 430	86 030	162 130	160 000	90 390	65 000
Thall.nema nitzschia	20 810	25 730	32 080	43 350	31 900	16 470
Chaet. neglectus	32 950	3 620	27 740	92 770	18 510	67 000
Dact. antarcticus	13 870	3 220	13 870	14 740	4 720	4 340
Rhiz. Chunii	2 600	+	1 700	+	2 900	1 730
Frag. kerguelensis	23 410	25 730	21 680	32 000	22 510	12 140
Thall.thrix antarct(long)	6 900	6 800	?	9 540	7 260	6 900
Rhiz. antarctica	3 470	1 210	6 940	6 070	-	2 600
Tropidoneis	1 730	400	-	-	+	-
Frag. rhombica	10 400	14 470	13 000	12 140	7 990	2 600
Nitzschia sicula	-	1 200	-	-	-	-
Chaet. (bulbosus)	+	+	-	+	+	-
Chaet. socialis	-	1 200	-	-	-	-
Rhiz. hebetata	-	-	+	-	360	-
Corethron criophilum	7 800	6 430	1 730	4 340	3 630	3 470
Rhiz. alata	2 600	+	-	2 600	700	-
Chaet. dichaeta var tenuis	-	-	-	-	13 430	-
Chaet. dichaeta	-	4 420	-	41 620	5 810	-
Rhiz. styliformis	-	2 000	-	-	-	-
Dact. mediterraneus	+	800	-	1 700	-	-
Chaet. convolutus	3 500	2 800	+	4 340	3 400	+
Melosira	-	-	22 000	11 000	2 540	
Frag. "nana"	-	-	-	-	1 000	-
Eucampia balaustium	-	-	-	-	300	-
Chaet. Castracanei	-	1 210	-	-	1 000	-
Asteromph. heptactis	-	800	-	-	-	-

Table XV

STATION 203 (52°04'S - 22°50'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Chaet. atlanticus	99 710	128 860		68 490	70 230	1 700
Nitzschia pseudon.	110 980	95 000		109 240	104 040	8 670
Asteromphalus heptactis	+	2 700		870	-	-
Corethron criophilum	11 270	3 280		-	3 470	-
Rhiz. Chunii	35 550	2 180		21 680	15 610	1 780
Rhiz. alata	3 470	-		2 600	1 700	+
Thall.thrix antarctica	2 600	21 840		9 540	9 500	-
Frag. rhombica	16 470	16 970		17 300	10 400	3 400
Frag. kerguelensis	26 000	31 670		16 470	23 410	4 340
Chaet. convolutus	-	11 470		-	-	-
Chaet. dichaeta	-	9 280		6 070	-	-
Chaet. Schimperianum		+		870	-	-
Dact. antarct. (var-leav)	-	1 090		-	1 730	
Dact. antarcticus	900	2 730		5 200	4 340	+
Chaet. neglectus	10 400	8 190		22 540	17 340	8 700
Rhiz. imbricata var tenuis.	-	18 560		-	-	-
Rhiz. styliformis	-	4 370		3 500	4 300	-
Chaet. Castracanei	-	3 300		-	-	-
Rhiz. antarctica	-	-		2 600	-	-
Eucampia balaustium	+	-		-	+	-
Rhiz. hebetata	1 700	-		-	-	-
Coscin. lentiginosus	-	500		-	-	-
Chaet. criophilum	5 200	-		1 750	-	-
Melosira	-	5 400		-	6 000	1 700
Thall.nema nitzschioides				8 670	3 470	-

Table XVI

Station 204

The abundance of Diatoms for this station is the greatest over the whole transect during the 1966-67 cruise, with a well marked maximum at 50 meters depth, below the 1 % light transmission level. Dominant species are beside the ever present marked dominant Nitzschia species : Chaetoceros atlanticus in the first 30 meters substituted in relative importance by Chaetoceros neglectus and Chaetoceros dichaeta from 50 to 100 meter. Fragilariopsis kerguelensis appears as subdominant species representing about 10 % at the total bulk. The hydrological conditions within the first 100 meters are exceptionally uniform (temperature : 2.7°C and salinity : 33.86°/oo). The distribution of the chlorophyll a content in function of the depth is similar and in good correlation with the distribution of the cell numbers, while the primary production values are appreciable but uniform from 0 to 70 meters with a decrease on to a zero value at 100 meters.

Station 203

The abundance of Diatoms is also great at this station but here the maximum is situated above the 1 % light transmission, while the quantity of cells is rather nil at 100 meters. The dominant species are Chaetoceros atlanticus and Nitzschia gr. Pseudonitzschia in equal quantity associated with Fragilariopsis antarcticus, Fragilariopsis rhombica and Rhizosolenia Chunii.

Here also, Chaetoceros atlanticus is replaced in relative importance by Chaetoceros neglectus at 100 meter. The density of the waters is the same at all depths within the 0-75 meters and increases suddenly at 100 meters, corresponding to a decrease of the temperature which falls below 0°C at 100 meter. The profiles of the chlorophyll a content and of the primary production, in general, are in good agreement with the number of cells, excepted a relatively high concentration of chlorophyll a at 20 meters. For all of the three profiles, cell number, chlorophyll a and primary production, a marked decrease, but still limited for chlorophyll a, is recorded a 100 meter, corresponding to the decrease in temperature.

Stations 205-206-207

Position	: St. 205	: 55°44'S - 24°03'E
	St. 206	: 59°06'S - 24°27'E
	St. 207	: 62°28'S - 25°17'E
Total mean abundance	: St. 205	: 147.200 Diatom cells/liter
	St. 206	: 49.800 Diatom cells/liter
	St. 207	: 30 000 Diatom cells/liter
Species composition	: St. 205	: see Table XVII
	St. 206	: see Table XVIII
	St. 207	: see Table XIX

Stations 205,206,207, are all three situated in the Antarctic Waters, between the Antarctic Convergence and the Antarctic Divergence.

Station 205

This station, the northernmost of the three, has an abundance of cell numbers, still appreciable, but already reduced, compared to Stations 204 and 203.

The maximum of cell numbers, as well as the maximum of the chlorophyll a content, are recorded at the 75 meter level, below the 1 % light transmission. The dominant species are Chaetoceros atlanticus, Nitzschia gr. Pseudonitzschia associated in the upper 50 meters with Fragilariopsis kerguelensis. Chaetoceros atlanticus is replaced in relative importance by Chaetoceros dichaeta at 20 meters and to some extent by Chaetoceros neglectus at 100 and 150 meters. The temperature shows a marked decrease at depth of 75-100 meter, corresponding to the Antarctic Intermediate Waters which are formed at the surface in the south, close to the continent during wintertime and which spread gradually to the north by sinking under the Antarctic Surface Waters. The phosphate content was reduced in the upper 50 meters (mean of 1.71 μ atg/l) while it was of a mean of 2.3 μ atg/l for the 50-100 meter layer. It has been observed through examination of the samples, that specimens of several Diatom species were in bad conditions and may be related to the result of grazing. Copepods, Tintinnids, Silicoflagellates, Peridians and Coccolithophorids were counted in appraciable quantity. This phenomenon was also observed at the following stations 206 and 207.

Station 206

The abundance of Diatoms is reduced, in comparison with the preceeding stations and the distribution of cell numbers in function of the depth is rather erratic.

STATION 205 (55°44'S - 24°03'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Chaet. atlanticus	32 950	16 560	26 010	45 950	42 470	15 610
Chaet. neglectus	3 470	8 090	4 340	17 340	20 340	20 810
Frag. kerguelensis	5 200	19 250	21 680	7 800	9 800	5 200
Corethron criophilum	1 730	5 010	1 730	-	4 720	2 600
Nitzschia Pseudon.	12 000	21 180	32 950	13 870	23 230	15 610
Rhiz. Chunii	3 470	1 540	-	6 070	370	-
Dact. antarcticus	900	1 500	2 600	6 000	1 090	1 730
Chaet. criophilum	10 400	6 550	1 750	8 700	9 800	10 000
Rhiz. alata	900	1 930	870	1 700	1 820	900
Rhiz. hebetata	2 600	-	1 700	-	-	-
Rhiz. styliformis	-	3 470	900	-	1 800	-
Dact. antarcticus (var)	-	770	4 300	-	-	-
Chaet. dichaeta	+	22 720	2 600	+	13 000	4 340
Chaet. dich. (var-tenuis.)	2 600	2 700	-	-	2 180	-
Navicula sp.	-	4 620	3 470	5 200	18 150	900
Chaet. Hendeyi	-	2 300	-	-	10 160	8 600
Asteromphalus heptactis	-	1 160	5 200	1 700	21 000	5 200
Rhiz. antarctica	-	-	2 600	-	300	-
Melosira	-	780	6 000	2 600	3 300	1 700
Actinoc. curvatulus	-	390	-	-	-	-
Chaet. (bulbos) infl.	-	-	-	-	730	-
Chaet. flexuosus	-	-	-	-	4 360	-
Frag. curta	-	1 160	3 500	900	4 000	-
Frag. "nana"	-	-	-	2 500	700	-
Frag. sublinearis	-	+	-	-	700	-
Thall.thrix antarctica	-	780	4 300	7 800	21 000	5 200
Chaet. convolutus	-	7 700	-	-	-	-
Chaet. Schimperianum	-	-	1 730	870	-	-

Table XVII

STATION 206 (59°06'S - 24°27'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Dact. antarct. (var-laev)	70 760	-	-	-	1 630	
Rhiz. curvata	31 210	-	-	900	-	
Chaet. criophilum	3 470	1 470	3 470	6 940	-	
Frag. curta	870	370	3 500	-	410	
Frag. "nana"	15 610	-	3 500	2 600	2 840	
Nitzschia "closterioid."	18 210	-	-	-	3 200	
Nitzschia gr. Pseudon.	900	-	2 600	-	12 180	
Corethron criophilum	7 000	2 950	900	850	1 220	
Frag. kerguelensis	1 900	370	6 000	-	11 770	
Rhiz. antarctica	2 600					
Dact. antarcticus	1 700	400	-	870	4 000	
Chaet. dichaeta	-	4 430	6 940	-	-	
Chaet. atlanticus	-	-	4 300	1 700	2 000	
Rhiz. Chunii	-	-	2 600	-	410	
Asteromphalus heptactis	-	-	2 600	-	1 200	
Chaet. dichaeta (var-tenu)	-	-	-	-	5 200	
Coscinod. pseudondent.	-	-	-	-	+	
Frag. rhombica	-	-	2 500	-	1 600	
Charcotia actinoch.	+	-	-	-	-	

Table XVIII

STATION 207 (62°28'S - 25°17'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. kerguelensis	2 080	2 160	900	6 900	3 600	
Nitzschia Pseudon.	500	5 700	12 140	19 000	9 880	
Dact. antarcticus	2 600	4 300	-	-	1 000	
Rhiz. alata	500	720	-	1 700	1 000	
Frag. cylindrus	1 040	1 800	-	-	-	
Frag. curta	+	12 240	10 400	870	2 800	
Corethron criophilum	+	3 200	-	-	500	
Frag. "nana"	+	11 500	-	6 000	4 400	
Chaet. neglectus	-	360	-	3 470	520	
Frag. rhombica	+	7 200	4 300	4 340	1 040	
Chaet. criophilum	-	300	800	-	-	
Chaet. dich. (var-ten)	-	400	-	2 000	-	
Rhiz. antarctica	-	-	-	-	500	
Rhiz. Chunii	-	-	-	-	500	
Chaet. dichaeta	-	1 500	-	-	-	
Melosira	500	1 440	+	6 000	-	
Thalassiosira	500	2 100	800	6 900	3 600	
Chaet. atlanticus	500	1 080	-	-	520	
Chaet. flexuosus	-	1 400	-	800	260	
Asteromphalus heptact.	-	400	-	850	200	
Synedra reinboldii	-	-	-	900	-	

Table XIX

No one species is really dominant and each sampling depth gives a different dominant species : Dactyliosolen antarcticus (0 meter), Corethron criophilum (20 meters), Chaetoceros dichaeta (30 meters), Chaetoceros criophilum (50 meters), Fragilariopsis kerguelensis (75 meters) and Chaetoceros convolutus (150 meters). Appreciable amounts of Peredinea have been recorded. There is no correspondance between the curve of cell numbers and the chlorophyll a content; the primary production is low (not recorded at 30 and 50 meters). Here also a minimum of temperature is recorded between 50 and 100 m. To note also a diminution of the salinity in the surface waters which shows that this station is already situated in the iceberg zone and approachs the pack ice zone. The phosphate concentration in the water was 1.64 μatg/l at the surface, while the mean value for the 10-100 m layer was of 2.36 μatg/l.

Station 207

The abundance of cell numbers is of the same order than for Station 206, although more homogeneous in function of the depth. The distribution of the species according to the dominance, shows a marked change, compared to Station 206, with the appearance of species like Fragilariopsis curta, Fragilariopsis "nana" which will be shown increasing in dominance toward the south; Nitzschia gr. Pseudonitzschia recovers the dominance only from 30 m on. To a limited number of cells per liter corresponds a reduced chlorophyll a content and low primary production. The layer of minimum temperature is found at 30 meters below the surface. The

phosphate content was relatively low (mean of 1.86 μ atg/l) in the upper 30 meters and increases to 2.3 μ atg/l in the remaining 50-100 m portion of the column.

Station 208

Position : 66°40'S - 26°00'E

Total mean abundance : 19.400 Diatom cells/liter

Species composition : see Table XX

This station is actually situated within the pack ice. The total abundance is very poor, corresponding to a 1 % light transmission below the 50 meter level. The dominant species is Fragilariopsis curta, associated with Fragilariopsis "nana" and in the upper layer with Fragilariopsis cylindrus. The chlorophyll a content and the primary production are also low and the layer of minimum temperature has reached the surface. The phsophate concentration in the whole water column was high (mean of 2.24 μ atg/l).

Station 209

Position : 68°50'S - 26°31'E

Total mean abundance : 11.600 Diatom cells/liter

Species composition : see Table XXI

This station is the poorest of the transect, regarded to the total abundance of Diatoms. The highest cell number is concentrated in the 0-20 meter layer. To note also that the 1 % light transmission, being below 75 meters,

STATION 208 (66°40'S - 26°00'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	3 470	7 600		3 400	2 210	2 600
Frag. cylindrus	2 500	3 400		-	740	-
Frag. rhombica	870	-		850	370	-
Nitzschia Pseudon.	900	1 500		870	350	-
Corethron crioph.	850	1 520		-	300	-
Frag. kerguelensis	900	6 400		4 340	400	1 700
Chaet. criophilum	900	750		-	1 400	-
Nitz. closterium	-	+		-	-	-
Synedra reinboldii	-	-		-	+	-
Chaet. Castracanei	-	-		-	-	4 000
Rhiz. Chunii	-	-		900	-	-
Chaet. dichaeta	-	1 140		-	-	-
Frag. "nana"	-	5 000		5 200	+	2 500
Asteromphalus hept.	-	-		+	+	-
Nitzsch. "closter."	+	-		-	-	-
Navicula	+	1 900		-	700	-

Table XX

STATION 209 (68°50'S - 26°31'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Nitzsch. Pseudon.	1 700	-	800	800	-	-
Frag. curta	13 870	11 810	3 400	2 600	3 300	-
Corethron crioph.	5 200	3 690	900	-	-	-
Frag. cylindrus	7 800	6 640	-	-	+	+
Amph. Kufferathii	900	-	-	-	-	-
Frag. obliquecostata	+	-	+	-	-	-
Nitzsch. "closter."	900	-	-	-	-	-
Frag. rhombica	800	300	-	-	+	-
Frag. "nana"	+	2 200	-	-	1 850	-
Nitzsch. closter.	-	350	-	-	-	-
Frag. kerguelensis	-	750	-	-	+	-
Charcotia actinoch.	-	300	-	-	+	-
Coscinodiscus sp.	870	350	-	-	+	-
Chaet. dichaeta	+	700	-	-	+	-
Chaet. neglectus ?	2 500	-	-	-	-	-
Chaet. criophilum	-	-	-	-	+	-
Thalasiosira	-	-	-	-	-	+

Table XXI

STATION 210 (70°01'S - 25°18'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	53 750	16 800	13 000		2 000	3 400
Frag. "nana"	131 780	820	76 700		+	+
Frag. oblique.+ subli.	14 740	2 050	1 730		170	-
Chaet. neglectus	125 720	2 870	7 800		-	2 500
Nitzschia "closter." ?	7 800					(sp)
Chaet. dichaeta	15 610	1 230				
Nitzschia Pseudon.	37 280	7 790	14 740		600	800
Frag. cylindrus	7 800	-	-		-	-
Rhiz. (alata)	9 540	2 460	1 700		-	-
Frag. kerguelensis	1 700	-	-		-	500
Biddulphia. weissfl.	2 600	-	-		-	-
Rhiz. antarctica	1 700	-	-		-	-
Charcotia actinoch.	-	400	-		-	-
Nitzsch. stellata	-	410	-		-	-
Chaet. dich. (var-ten.)	+	400	-		-	-
Amph. Kufferathii	1 600	+	-		-	-
Eucampia balaustium	1 730	800	850		10	-
Corethron crioph.	-	2 500	800		80	-

Table XXII

is at the deepest level compared to the other stations of the 1966-67 cruise. The dominant species is, by far, Fragilariopsis curta associated with Fragilariopsis cylindrus and Corethron criophilum. The chlorophyll a content and the primary production are both very limited, like for the two previous stations. Negative temperatures are recorded at all depths within the 0-100 meter column (-1.7°C) as at station 208; a slight increase (-1°3°C) in the surface waters is due to local solar heating. The phosphate concentration, as for previous station, was high in the whole watercolumn (mean of 2.25 µatg/l).

Station 210

Position : 70°01'S - 25°18'E

Total mean abundance : 104.300 Diatom cells/liter

Species composition : see Table XXII.

An important increase of the Diatom abundance is observed at this station, especially in the surface layer. The dominance alternates between Fragilariopsis "nana" and Fragilariopsis curta; were observed also, but in more limited quantities the presence of Chaetoceros neglectus, Rhizosolenia alata (+ R. truncata), Chaetoceros dichaeta and Corethron criophilum. A close relation is observed between the curves of chlorophyll a and primary production and the curve of Diatom abundance. Obviously, an active growth of Diatoms has taken place at this station which is situated

some 15 miles from the continent. As at previous station, a slight increase of temperature at the surface must be due to the solar heating.

DISCUSSION

A tentative relationship, between the distribution of Diatoms and phosphate content, has been investigated. The actual phosphate content is depending on two factors : the initial concentration of phosphates in the water, and the amount of phosphates depleted by phytoplankton consumption. Normally, in high latitudes, the phosphates always occur in great quantity and, in general, never became a limiting factor for the phytoplankton growth, even when the waters are highly stratified (which is the usual condition to prevent the replenishment of the surface layer from the water below).

In figure 28, the values of Diatom cell numbers are plotted in function of the phosphate concentrations, for stations 203 to 207 (1966-67). At first glance, it seems that a direct relationship between the quantity of cells and the phosphate concentration does not exist. This results from the fact that other factors are involved, in particular, the water stratification (see Chapter V). Indeed we observe, on Fig. 28, two groups of stations. A first one composed by St. 203 and 204.These stations, both, hold a very great amount of Diatoms and correspond to a weak stability of the waters.

In particular, St. 204, which is situated close to the Antarctic Convergence, shows a similar phosphate concentration at all depths sampled. This suggests a rapid mixing of the waters, and, consequently, a continuous replenishment of the surface water with phosphates from below. An other group of stations consist of St. 205, 206 and 207. They are characterized by an important stratification of the waters with the consequence of a reduced exchange of properties between the upper and lower layer. This phenomenon is probably the cause of the inverted relation observed between Diatom abundance and phosphate concentration. Indeed, at those stations we found a reduced Diatom biomass resulting from intense grazing which let presume a previous higher Diatom abundance.

The analysis of the Diatom distribution along the South-African-Antarctic section, shows that the main bulk is essentially made up by a few species of the genus Nitzschia, Fragilariopsis and Chaetoceros, this being in perfect agreement with the literature. Among the most abundant Nitzschia species recorded were Nitzschia gr. Pseudonitzschia (mainly Nitzschia barkleyi and N. heimii) and Nitzschia "closterioides" (mainly Nitzschia subcurvata in the southern region). The genus Fragilariopsis was essentially represented by Fragilariopsis "nana" (Fragilariopsis pseudonana and Fragilariopsis cylindrus var. nana), Fragilariopsis kerguelensis (synonyme : Fragilariopsis antarctica) and Fragilariopsis curta.

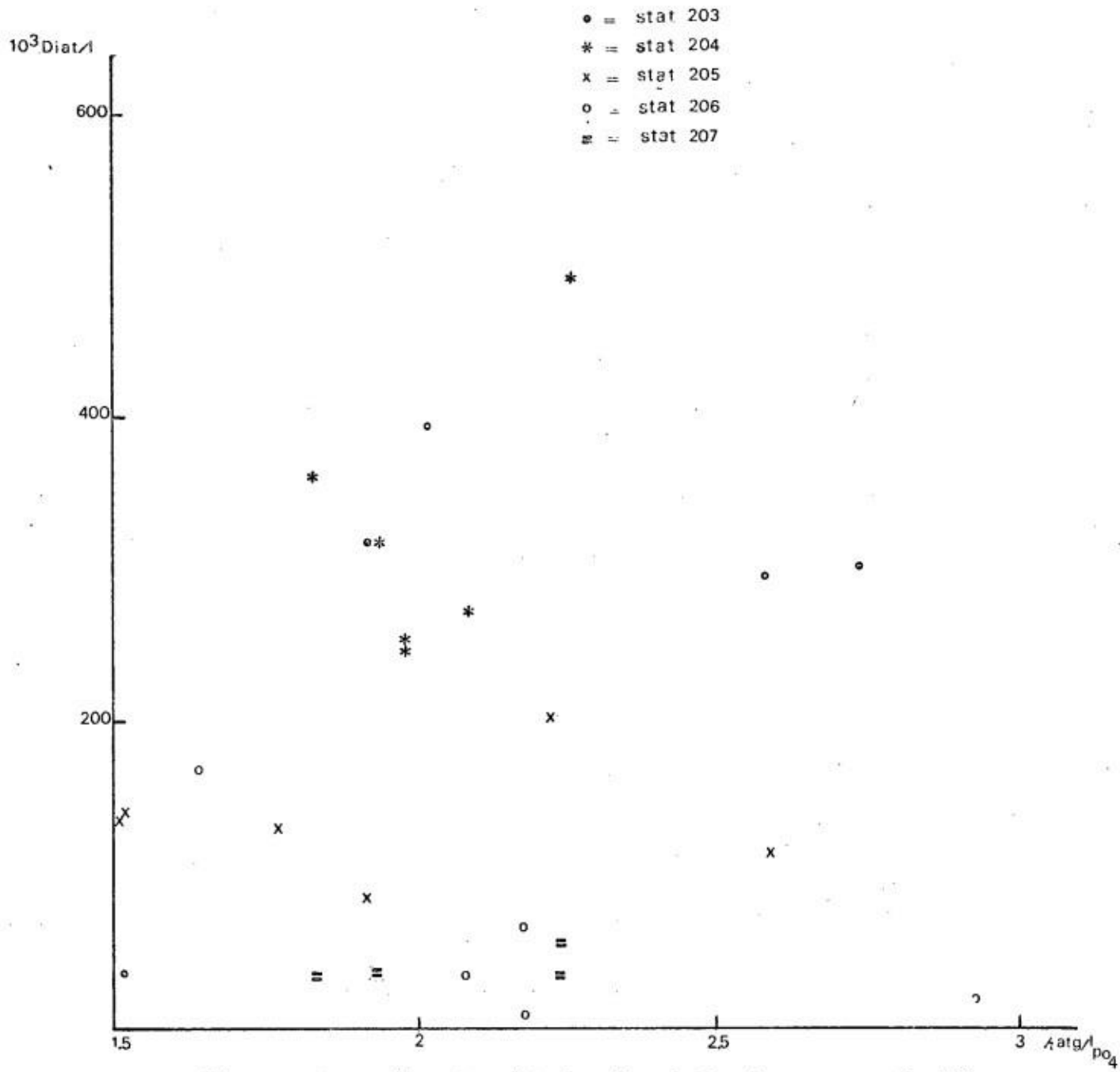


Fig. 28 : Diatom cells per liter plotted in function of Phosphate content for different stations along the transect (1966-67).

The greatest quantities of Chaetoceros species were made of Chaetoceros neglectus, Chaetoceros atlanticus and Chaetoceros dichaeta (including a little form determined as Chaetoceros dichaeta var. tenuicornis).

Table XXIII gives, for both years, the species which, at each station, occur in the greatest proportion. Nitzschia Pseudonitzschia (N. barkleyi + N.heimii) associated with Chaetoceros neglectus is for the period late December-early January, by fare, the most dominant species in the waters north of the Antarctic Convergence. Thallassionema nitzschioides, as subdominant species, is restricted to the stations situated just north or near the Antarctic Convergence. Progressing southwards, Nitzschia gr. Pseudonitzschia shares, in the northern antarctic waters, the dominance with Chaetoceros atlanticus associated with Chaetoceros neglectus and Chaetoceros dichaeta. Further south, but still before the Antarctic Divergence, Fragilariopsis kerguelensis, Nitzschia "closterioides" and Fragilariopsis "nana" became dominant. Finally, Fragilariopsis curta, Fragilariopsis "nana" and Nitzschia "closterioides" compose the main bulk of the southernmost stations. If differences appear between the two years, in the relative proportions of the dominant species, it is nevertheless obvious that a certain degree of similitude does exist in the successive dominances, as we progress southwards. In Chapter VII, we shall discuss the quantitative distribution of the main species.

1964 – 1965			1966 – 1967	
Stat.				Stat.
182	N. Pseud. Chaet. div.	40°	Rhiz. alata.- N. Pseud.	201
183	N. Pseud.-Thln. nitzsch-Chaet. negl.		N. Pseud.-Thln. nitzsch-Chaet. div. Thalthr. fravenf.	202
		50°	N. Pseud.- Ch. negl.- Ch. atl.-Thln. nitz.- Frag. rhomb.- Coreth.	204
			N. Pseud- Ch. atlant. Rhiz. Chunii Ch. negl. Frag. kerg. Frag. rh.	203
184	Ch. atl.- N. Pseud.- Frag. kerg.			
			Chaet. atl.- N. Pseud. Ch. dich. Ch. negl.- Ch. crioph.	205
185	Frag. kerg.- N. Pseud-N."clost"-Ch. negl.- Ch. dich.		N."Clost."-Frag."nana" Frag. kerg. Ch. dich.-Corethr. crioph.	206
		60°		
			Frag. curta - Frag. "nana" N.Pseud.	207
186	Frag "nana" Ch. negl- N."clost" Coreth. cr.- Ch. crioph.		Frag. curta - Frag. "nana"	208
187	Frag. curta- frag."nana" Frag. cyl. - Corethr. crioph.			
			Frag. curta - Corethr. crioph.	209
		70°	Frag."nana"-Frag. curta- N. Pseud.	210
		Lat.S		

Table XXIII Distribution of the relative dominant (full line), subdominant (dashed line) and abundant species (not underlined) along the transect South-Africa - Breid Bay. (Nansen bottles) - Expeditions 1964-65 and 1966-67.

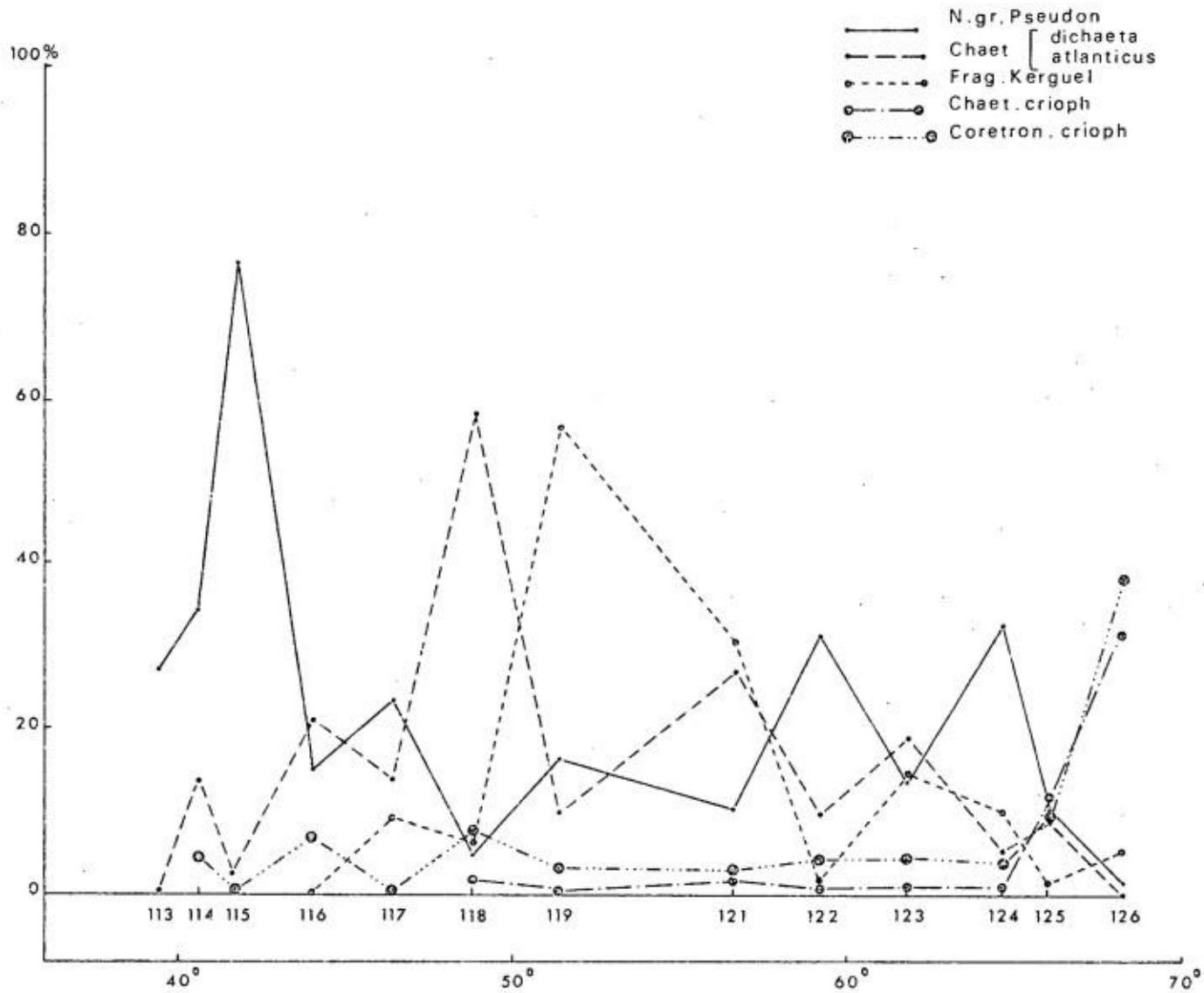


Fig. 29 Percentages of species (net haul samples)
Cruise 1960–1961

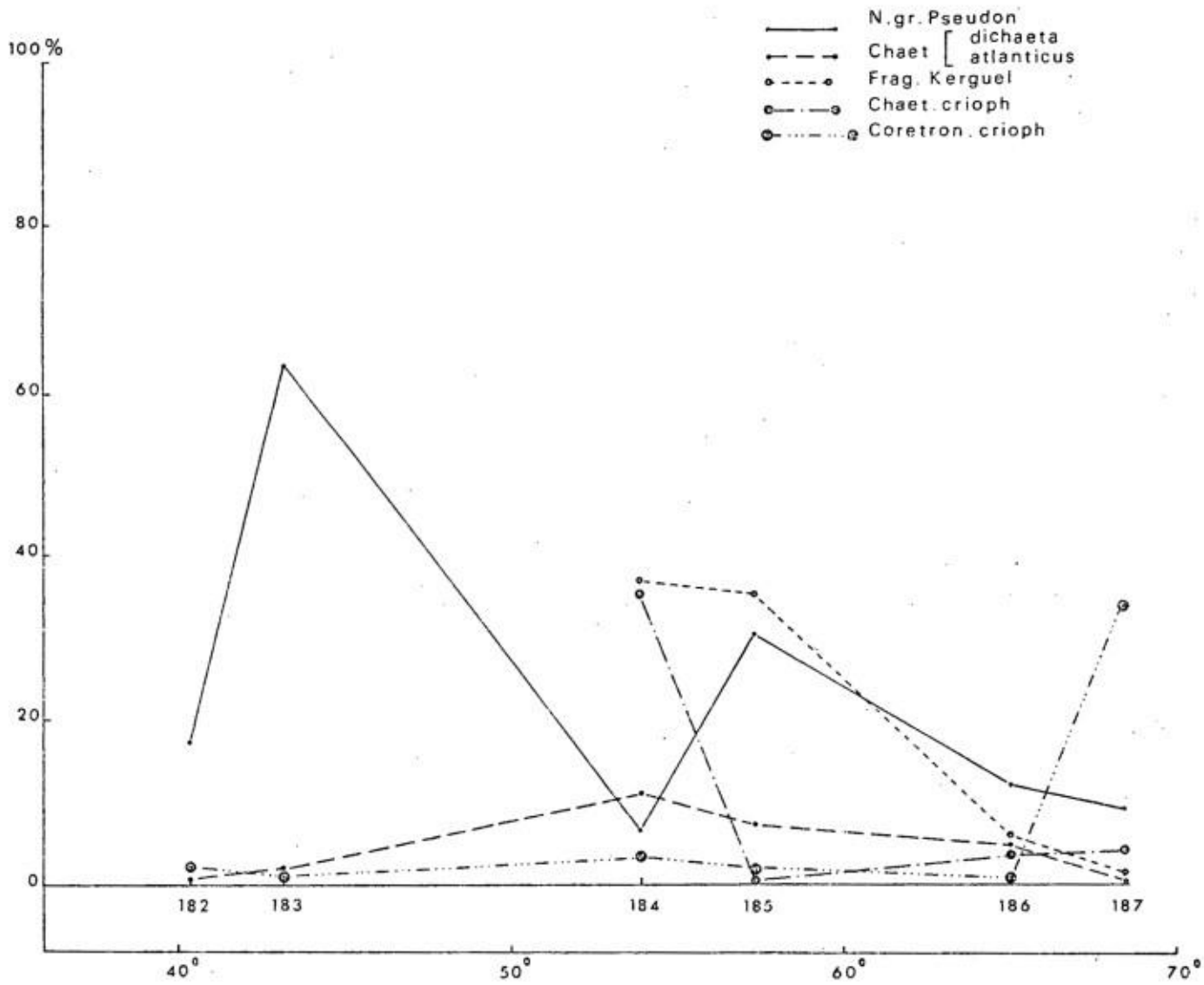


Fig. 30 Percentages of species (net haul samples)
Cruise 1964 – 1965

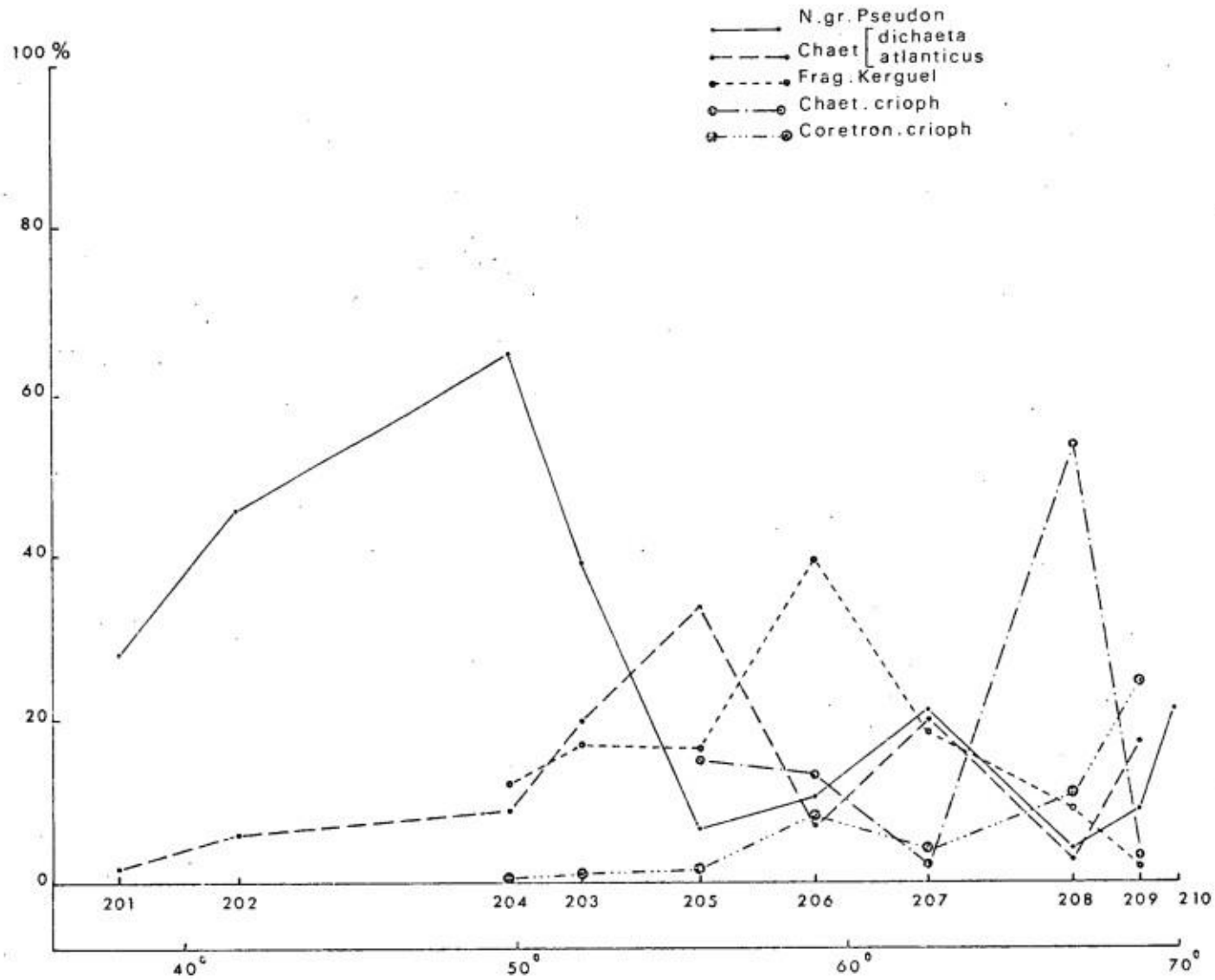


Fig.31 Percentages of species (net haul samples)
Cruise 1966 – 1967

If, on the other hand, we compare the results obtained by using net hauls with those obtained by using Nansen bottles, we observe some similitudes, but also some discordances. Figures 29,30 and 31 give the percentage of Nitzschia "Pseudonitzschia", Chaetoceros atlanticus and Chaetoceros dichaeta, Fragilariopsis kerguelensis, Chaetoceros criophilum, Corethron criophilum in net haul samples, at each station along the section, for the years 1960-61, 1964-65 and 1966-67, respectively. These three figures show Nitzchia gr. Pseudonitzschia as the dominant genus in the Subantarctic Waters, while the minimum percentage value of this species coincides with the Antarctic Convergence. Chaetoceros atlanticus and Chaetoceros dichaeta take over the dominance, just south of the Convergence, replaced afterwards by Fragilariopsis kerguelensis. Near 60° Lat. S., a second, but reduced maximum of Nitzschia gr. Pseudonitzschia appears, replaced by Corethron criophilum near the continent. The sequential distribution of dominances, as one progress southwards, is roughly similar to the distribution obtained with bottle sampling, but the main difference is the absence, as dominant or subdominant, of minute species, like Chaetoceros neglectus, Fragilariopsis "nana" and Nitzschia "closterioides" In addition, species like Corethron criophilum recorded as subdominant species with bottle sampling at St. 187 (1964-65) became dominant at the same station when using net hauls sampling (Up to 49 %).

Stations	203	204	207	208	209	*
Frag. curta +	6	-	5	3	15	1
Frag. cyl.	0.6	-	8	21	43	2
Frag. nana	-	-	-	0.4	2.5	1
	-	-	16	16	7	2
Nit. Pseudon.	39	72-42	20	4	9	1
	35	34	27	3.5	4	2
Coreth. crioph.	0.8	0.6	3	10	23	1
	1	2	1	3	10	2
Chaet. crioph.	-	-	1.5	52	3	1
	+	+	0.4	4	+	2
Frag. kerguel.	17	12	20	9	2	1
	7	7	6	2	1	2

Table XXIV : Comparison between % of species calculated on net haul samples (*1) (0-250 m) and on Nansen bottles samples (*2) (integrated value for 0-100 m layer).

The same does occur with Chaetoceros criophilum, which never appears in great proportion (4%) with bottle sampling, but which makes more than 50 % of the total bulk in 1966-67 with net haul sampling. Chaetoceros criophilum form long chains with numerous long bristles (up to one m/m) and Corethron criophilum is a large form having bristles at each end. These two species are probably retained in greater proportion by the net, than tiny forms like Nitzschia and Fragilariopsis (Table XXIV). Therefore, it seems important to us to emphasize on the differences in the sampling methods used. In particular, because most of the phytoplanktonic literature on the Southern Ocean report on the presence of large spinuous (Chaetoceros criophilum, Corethron criophilum) or very long species (Thallassiothrix antarctica, Synedra Reinboldii).

The high value of the amount of these species, as reported by several authors, might be attributed to the selective action of the net.

The comparison of our results with those of Fukase (1962), who investigated on surface samples, during the same period and approximatively in the same area, is very instructive. Fukase found the Nitzschia genus to be dominant in the whole area investigated, with a marked peak (more than 60% of the total bulk) for Nitzschia "seriata", which probably corresponds to our Nitzschia gr. "Pseudonitzschia" since R. Hasle has proved that Nitzschia "seriata" does not occur in the Southern Ocean. Fukase also found that the maximum percentage value of Nitzschia coincides with the Antarctic Convergence. The North Antarctic Region was characterized by Fukase by the dominance of Nitzschia sp., Fragilariopsis kerguelensis, Chaetoceros neglectus, Corethron criophilum and Dactyliosolen antarcticus and Chaetoceros neglectus, the southern-most part of the section being characterized by Navicula sp. and Nitzschia closterium.

With the exception of the greater abundance of minute forms as Fragilariopsis nana, and of Nitzschia closterioides, and of a marked quantity of Fragilariopsis curta that we recorded in the southernmost part of the section, there is a good correspondance between our results and those of Fukase.

Another interesting comparison could be made with the results obtained by R.Hasle (1969) (Table XXV),

using similar methods than ours for the analysis of the material of the Brategg Expedition (Nov. 1947- Feb. 1948) in the Eastern Pacific.

Dominant species
Subantarctic Zone
Chaetoceros neglectus Nitzschia "barkleyi"
North Antarctic Zone
Chaetoceros dichaeta Chaetoceros neglectus Fragilariopsis "nana" Nitzschia "closterioides"
South Antarctic Zone
Fragilariopsis curta Fragilariopsis cylindrus Nitzschia subcurvata

Table XXV : Dominant Diatom species - Ryther Hasle (characteristics of phytoplankton populations encountered in section I-IV R.Hasle 1969-p.73).

Here also, a great similitude is found with our results, in particular what concerns the relative abundance of little forms.

Notwithstanding the fact of appreciable differences in the total abundance, we may conclude, from the above results, on similar general pattern of distribution of the

main species between the two expedition years along the section South Africa-Breid Bay. In addition, this general pattern of distribution is similar to those found in the eastern Pacific and western Indian Ocean sectors, which supports the idea of a similitude in the sequential distribution of the species in function of the latitude within the whole Southern Ocean.

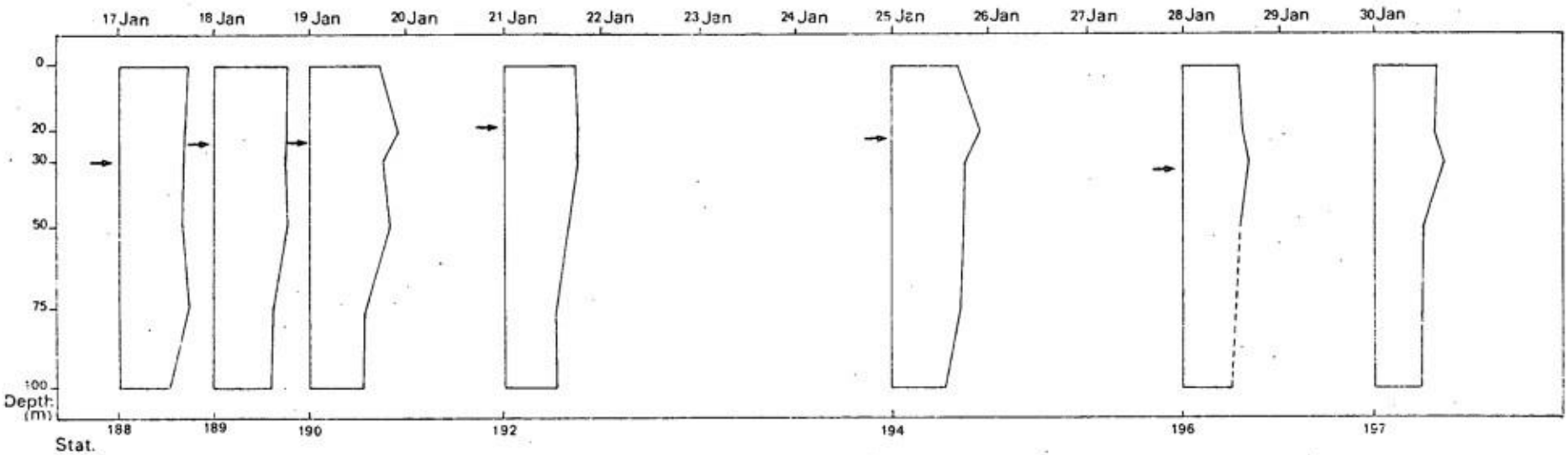
B. BREID BAY

Table XXVI gives, for both years 1965 and 1967, the vertical distribution, in function of depth, of the Diatom biomass expressed as cells per liter.

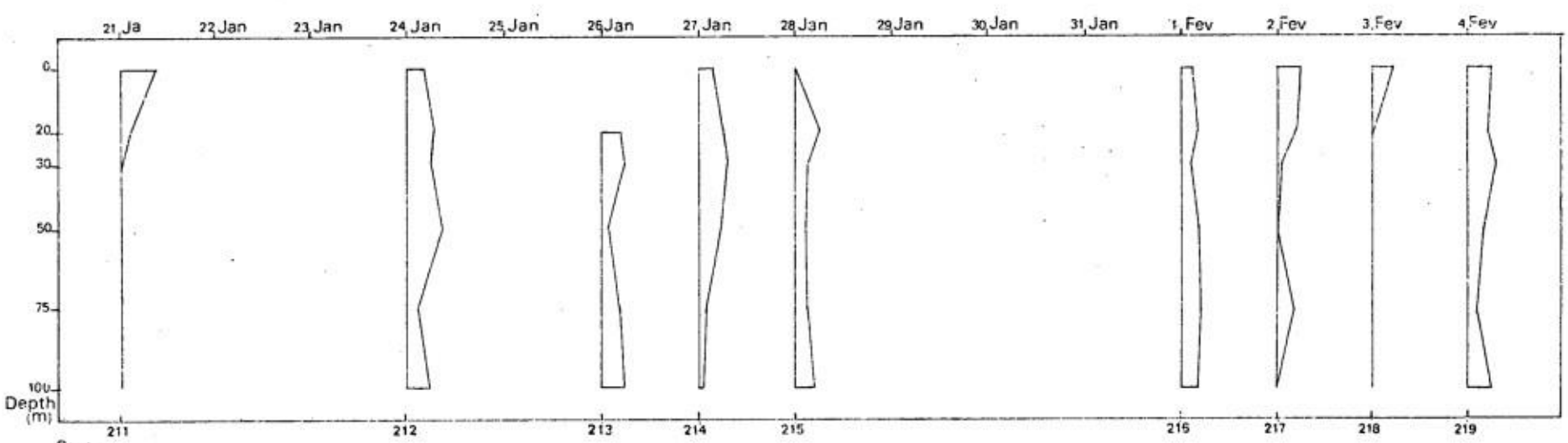
The difference between the two years in the total Diatom biomass and its vertical distribution corresponds to differences in the environmental factors, which were summarized in Chapter III/B. Similarly, primary production rates and concentrations in chlorophyll a, showed differences between the two years. Being of a subst antial magnitude during 1964-65, both chlorophyll a and primary production were nearly inexistant in 1966-67. The values of chlorophyll a (mg/m3) and carbon fixation (mg C/m3/h) were in 1964-65, respectively of 1,28 and 1,10 at 0 meter; 1,45 and 1,09 at 50 meters; 0,59 and 0,11 at 100 meters. In 1966-67, only the surface waters gave some significant values (chlorophyll a : 0,12;primary production : 0,12), the mean values, for all

	17-1	18-1	19-1	20-1	21-1	22-1	23-1	24-1	25-1	26-1	27-1	28-1	29-1	30-1	31-1	1-2	2-2	3-2	4-2
1964-65	188	189	190		192				194			196		197					
0	7120	1280	770		712				549			204		460					
20	632	1144	1399		862				1441			314		315					
30	517	918	990		806				997			537		878					
50	456	1250	1095		385				950			233		117					
75	729	302	214		135				699			–		110					
100	130	228	196		145				171			119		84					
1966-67					211			212		213	214	215				216	217	218	219
0					35			5			3	1				3	12	10	11
20					3			13		6	10	11				5	7	–	7
30					1			10		10	17	3				3	2	X	16
50					X			27		2	7	3				5	1	1	4
75					–			3		5	2	3				6	5	X	2
100					X			10		7	2	7				4	1	X	10

Table XXVI : Distribution of Diatom cells per liter ($N \times 10^3$) in Breid Bay. Cruise 1964-65 , 1966-67.



Breid Bay. 1964—1965



Breid Bay 1966—1967

Fig. 32: Vertical distribution of Diatom abundances, expressed as log N ($N \times 10^3$: cell numbers per liter) in Breid Bay during the 1966 67 expeditions; stations plotted in function of time. The arrows represent the depth of 1‰ surface light.

stations and depths were : chlorophyll a : 0,065; primary production : 0,06. The difference between the two seasons is also confirmed by differences in the phytoplankton composition. The important total abundance during 1964-65 was mostly contributed by a great development of a few dominant species. The first one of these species, and by far the most abundant - more than 50 % of the total bulk - was Fragilariopsis curta, followed by Nitzschia gr. Pseudonitzschia, Fragilariopsis "nana" (essentially Fragilariopsis cylindrus var. nana) and Nitzschia "closterioides" (essentially Nitzschia subcurvata). The other species were, among the most regularly present : Fragilariopsis obliquecostata; Fragilariopsis rhombica, (including Frag. separanda), Fragilariopsis Van Heurckii, Fragilariopsis sublinearis, Rhizosolenia alata (possibly also Rh. truncata), Eucampia balaustium, Chaetoceros neglectus, Chaetoceros dichaeta var. tenuicornis, Tropidoneis antarctica, Rhizosolenia imbricata var Shrubsolei (?), Thalasiosira antarctica, Chaetoceros flexuosus. Stations 188 to 194, situated in the southermost part of the Breid Bay, have a very similar curve of abundance (Fig. 32), all characterized by a marked decrease from 75 m on and below. This similarity is well reflected in the species composition (Table XXVII to XXXI). In addition it has to be noted, that, if the abundance varies in function of the depth, the relative species composition (Table XXXIV) remains the same in the 0-100 m water column. For the two stations 196,197, which are situated a little outside the Breid Bay (Fig. 7 and 8), Fragilariopsis curta is replaced as dominant species

STATION 188 (70°19'S - 24°12'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	626 000	328 000	298 760	260 970	415 800	78 000
Nitz. "closterioides"	57 270	61 850	43 840	72 830	73 920	6 000
Frag. "nana"	36 440	77 960	41 130	14 740	76 860	6 000
Nitz. gr. Pseudon.	65 000	92 960	78 760	11 270	90 720	8 700
Frag. rhombica + separ.	23 430	14 640	11 250	6 000	10 000	3 450
Frag. sp. divers	6 500	11 200	14 700	11 200	10 000	7 000
Nitzschia stellata	2 500	-	-	-	-	-
Eucampia balaustium	2 600	2 200	3 490	6 000	2 940	900
Thalasiosira antarct.	7 810	7 320	1 160	7 800	5 880	4 330
Rhiz. alata (+truncata)	2 000	2 550	-	7 800	2 100	1 730
Dact. antarcticus	2 600	-	-	900	-	-
Rhiz. cf imbr. var Shr.	2 500	3 300	3 900	-	1 680	1 700
Amphiprora	1 300	1 830	2 700	+	1 600	+
Tropidoneis	+	4 800	1 500	12 140	630	-
Frag. antarcticus	-	1 000	-	+	2 000	+
Thalasiosira sp.	-	1 460	1 550	2 600	2 100	2 500
Chaet. neglectus	-	1 800	2 720	900	2 100	-
Frag. cylindrus	+	8 050	+	7 800	1 200	-
Biddulphia weissfl.	-	1 100	1 100	1 700	-	-
Corethron criophilum	-	2 500	400	3 470	1 700	+
Amphipleura rutilans	-	1 800	+	-	-	-
Navicula	-	1 450	-	-	800	-
Chaet. dichaeta	-	2 200	900	900	1 600	+
Rhiz. antarctica	-	+	-	-	-	-
Coscinodiscus sp.	-	350	+	850	+	-
Amphora antarct.	-	-	380	-	-	-
Chaet. flexuosus	-	-	-	2 500	-	-
Chaet. Hendeyi	-	-	-	4 000	-	-
Asteromphalus par.	-	-	-	-	+	-
Synedra reinboldii	-	-	-	-	+	-
Coscinosira sp.	-	-	-	-	+	-
Chaet.Schimper (atlant)	-	-	1 100	900	1 200	-

TableXXVII

STATION 189 (70°19'S - 24°12'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	760 240	773 260	565 600	647 530	220 400	134 400
Nitz. "closterioides"	110 500	91 400	88 000	81 770	1 600	14 400
Frag. "nana"	30 940	102 500	75 600	68 510	11 600	22 800
Nitzschia gr. Pseudon.	75 140	112 750	116 800	181 220	44 400	28 400
Frag. rhombica + separ.	11 050	22 960	17 600	15 470	6 800	3 200
Frag. sp. divers	2 200	11 890	9 200	15 470	8 000	10 400
Nitzschia stellata	6 630	400	-	6 000	+	-
Eucampia balaustium	-	2 870	7 200	4 420	800	2 400
Thalass. antarctica	+	5 330	3 600	-	-	+
Rhiz. alata (+truncata)	4 400	2 050	5 200	8 840	+	2 000
Dact. antarcticus	-	-	+	-	-	-
Rhiz. cf var imbr. Shr.	+	1 640	-	4 000	+	-
Amphiprora Kufferathii	2 200	2 460	+	+	-	+
Tropidoneis	+	5 740	4 800	-	800	2 000
Frag. antarcticus	-	-	-	2 000	-	-
Thalasiosira sp.	6 630	+	1 200	2 000	2 000	1 500
Chaet. neglectus	+	+	3 600	2 200	-	2 400
Frag. cylindrus	-	800	1 200	-	-	400
Biddulphia weissfl.	-	+	2 400	2 200	-	-
Corethron criophilum	2 000	-	+	-	+	+
Amphipleura rutilans	-	800	-	-	-	-
Navicula	-	+	400	2 000	-	-
Chaet. dichaeta	4 430	+	2 880	6 630	+	-
Rhiz. antarctica	-	-	-	-	-	-
Coscinodiscus sp.	-	+	+	+	+	-
Chaet. flexuosus	2 200	-	-	-	-	-

Table XXVIII

STATION 190 (70°19'S - 24°12'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	354 320	725 840	417 960	591 140	130 000	93 890
Nitz. "closterioides"	193 500	186 620	237 360	115 300	9 830	25 420
Frag. "nana"	79 980	196 940	92 880	91 350	23 440	26 650
Nitzschia gr. Pseudon.	72 240	161 680	155 660	141 690	26 460	29 930
Frag. rhombica + separanda ?	3 440	28 810	7 740	26 800	6 800	4 510
Frag. sp. divers	11 180	19 100	12 000	21 920	7 560	3 280
Nitzschia stellata	-	-	-	-	-	-
Eucampia balaustium	10 320	12 470	6 020	5 680	2 270	-
Thalasiosira antarctica	+	5 600	+	64 960	1 130	-
Rhiz. alata (+ truncata)	2 580	3 010	7 740	7 310	1 100	+
Dact. antarcticus	1 700	+	(folaev)	800	-	-
Rhiz. cf imbric. var Shrub.	2 500	850	2 600	+	-	2 000
Amphiprora Kufferathii	+	3 440	+	4 870	+	+
Tropidoneis	-	-	-	-	-	-
Frag. antarctica	1 700	400	-	1 220	-	-
Thalasiosira sp.	+	+	860	2 800	750	+
Chaet. neglectus	9 460	8 170	-	6 090	1 890	2 460
Frag. cylindrus	-	+	-	+	1 500	-
Biddulphia weissfl.	2 580	1 720	840	1 250	-	+
Corethron criophilum	-	3 400	+	2 800	-	+
Amphipleura rutilans	+	-	-	+	-	-
Navicula	-	2 150	2 580	+	-	+
Chaet. dichaeta	5 160	5 590	-	3 250	-	800
Rhiz. antarctica	+	-	-	-	-	-
Coscinodiscus sp.	-	-	-	-	-	-
Chaet. flexuosus	+	-	-	-	-	-

Table XXIX

STATION 192 (70°19'S - 24°12'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	378 300	465 320	383 760	174 760	77 080	67 650
Nitz. "closterioides"	126 100	93 740	101 270	55 040	9 840	22 550
Frag. "nana"	29 900	95 630	100 450	14 620	17 220	16 810
Nitzschia gr. Pseudon.	101 400	105 000	95 530	60 200	17 200	25 000
Frag. rhombica + separanda ?	18 200	13 990	28 700	16 340	3 690	3 280
Frag. sp. divers	13 000	6 800	9 000	19 700	2 000	2 800
Nitzschia stellata	2 000	-	+	-	-	+
Eucampia balaustium	5 200	3 400	3 700	+	+	+
Thalasiosira antarctica	+	38 180	35 670	2 580	+	2 050
Rhiz. alata (+ truncata)	3 900	4 490	2 000	4 300	+	+
Rhiz. antarctica	-	-	-	+	+	-
Rhiz. cf imbric. var Shrub.	-	2 500	3 690	1 700	-	-
Amphiprora Kufferathii	1 300	+	2 400	+	-	+
Tropidoneis	-	3 000	-	-	1 200	-
Frag. antarctica	-	-	-	2 500	-	-
Thalasiosira	+	3 000	12 000	+	1 000	-
Chaet. neglectus	1 000	11 340	11 070	6 020	3 690	1 640
Frag. cylindrus	+	700	+	+	-	-
Biddulphia weissfl.	1 300	+	1 200	-	-	-
Corethron criophilum	+	750	800	+	-	-
Amphipleura rutilans	-	-	+	-	-	-
Navicula	5 200	-	2 460	-	-	-
Chaet. dichaeta	14 300	4 910	3 280	3 440	2 000	-
Rhiz. antarctica	-	-	-	+	+	-
Chaet. flexuosus	3 900	-	-	+	-	-
Chaet. (Shimper)	-	4 500	3 690	-	-	-

Table XXX

STATION 194 (70°20'S - 24°12'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	291 200	795 340	555 960	503 100	372 280	84 870
Nitz. "closterioides"	74 100	156 860	126 280	49 880	44 690	23 370
Frag. "nana"	37 700	65 320	101 270	58 480	99 630	25 420
Nitzschia gr. Pseudon.	46 800	113 160	91 020	107 500	79 130	20 000
Frag. rhombica + separanda ?	18 200	?	36 900	43 000	27 880	3 300
Frag. sp. divers	13 000	23 000	16 400	67 940	9 430	4 510
Nitzschia stellata	3 900	-	-	-	-	-
Eucampia balaustium	6 500	6 000	7 790	6 020	5 330	2 000
Thalasiosira antarctica	-	34 500	-	-	-	1 500
Rhiz. alata (+truncata)	3 900	5 980	5 300	6 900	2 900	+
Dact. antarcticus	-	+	+	+	-	-
Rhiz. cf var Shrub.	1 300	2 300	1 230	2 580	400	-
Amphiprora Kufferathii	-	2 700	4 100	4 300	-	+
Tropidoneis	+	3 200	4 090	10 320	2 000	+
Frag. antarctica	3 800	-	-	-	-	-
Thalasiosira	+	4 000	2 000	-	2 400	-
Chaet. neglectus	3 900	17 480	4 900	-	6 100	+
Frag. cylindrus	2 600	65 820	1 640	-	-	+
Biddulphia weissfl.	-	-	1 200	1 700	+	-
Corethron criophilum	1 300	3 600	1 600	1 700	+	-
Amphipleura rutilans	-	-	800	850	-	-
Navicula	-	2 000	2 800	1 720	+	-
Chaet. dichaeta	5 200	13 340	3 870	28 380	2 000	+
Chaet. flexuosus	3 900	-	-	7 700	-	-

Table XXXI

STATION 196 (70°15'S - 24°07'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	33 540	93 440	134 640	66 220		37 540
Nitz. "closterioides"	?	91 450	107 280	1 720		16 500
Frag. "nana"	34 400	85 980	87 480	55 900		34 590
Nitzschia gr. Pseudon.	34 000	35 290	34 960	39 560		16 560
Frag. rhombica + separanda ?	+	9 940	16 200	1 700		-
Frag. sp. divers	2 580	2 980	2 160	9 460		16 500
Nitzschia stellata	-	-	-	-		-
Eucampia balaustium	2 600	1 990	3 600	1 600		1 100
Thalasiosira antarctica	3 440	3 900	7 900	-		-
Rhiz. alata (+ truncata)	5 160	2 000	4 700	+		+
Dact. antarcticus	-	2 500	1 000	-		-
Rhiz. cf imbric. var Shrub.	2 500	5 900	4 600	2 600		3 600
Amphiprora Kufferathii	-	+	+	5 100		1 800
Tropidoneis	-	+	3 000	4 000		1 400
Frag. antarctica	-	-	-	-		-
Thalasiosira	-	+	2 000	-		1 000
Chaet. neglectus	20 600	12 400	17 300	31 000		+
Frag. cylindrus	+	1 900	1 400	-		-
Biddulphia weissfl.	-	-	980	-		-
Corethron criophilum	+	+	+	-		-
Amphipleura rutilans	-	-	-	-		-
Navicula	-	+	+	5 000		1 860
Chaet. dichaeta	9 400	9 400	11 160	3 400		1 470
Chaet. flexuosus	3 400	-	3 250	1 500		-

Table XXXII

STATION 197 (70°06'S - 23°46'E)

	0 m	20 m	30 m	50 m	75 m	100 m
Frag. curta	92 850	65 500	259 720	56 760	34 780	23 760
Nitzschia "closterioides"	105 780	22 450	35 690	+	3 300	2 000
Frag. "nana"	122 120	66 980	206 400	+	21 460	18 000
Nitzschia Pseudon.	50 740	58 880	124 700	31 820	22 200	15 100
Frag. rhombica + separanda ?	+	12 510	24 940	2 580	4 000	1 800
Frag. sp. divers	12 040	3 680	20 640	1 720	1 800	1 400
Nitzschia stellata	-	-	-	-	-	-
Eucampia balaustium	+	6 990	13 330	5 160	2 960	1 380
Thalasiosira antarctica	1 700	1 800	13 760	+	-	-
Rhiz. alata (+truncata)	4 300	4 050	9 460	1 720	+	+
Dact. antarcticus	2 500	1 100	3 000	-	-	-
Rhiz. cf imbric. var Shrub.	2 600	1 000	2 600	-	+	+
Amphiprora Kufferathii	2 590	5 900	12 900	-	1 100	1 080
Tropidoneis	+	3 600	10 900	+	+	+
Frag. antarctica	2 600	-	-	-	-	-
Thalasiosira	-	-	4 370	-	+	+
Chaet. neglectus	12 000	17 300	89 870	13 700	5 900	7 500
Frag. cylindrus	-	-	11 180	-	1 400	-
Biddulphia weissfl.	+	+	2 000	-	-	+
Corethron criophilum	+	2 480	1 420	-	-	-
Amphipleura rutilans	-	-	1 260	-	-	+
Navicula	-	+	-	+	+	+
Chaet. dichaeta	16 340	27 240	20 100	+	4 010	+
Rhiz. antarctica	1 500	-	-	-	-	-
Chaet. flexuosus	-	+	-	+	+	-
Chaet. (Shrub.)	-	1 800	3 000	-	-	+

Table XXXIII

	St. 188						St. 189						St. 190						St. 192					
	0	20	30	50	75	100	0	20	30	50	75	100	0	20	30	50	75	100	0	20	30	50	75	100
Frag. curta	75	52	58	57	58	60	74	68	62	62	74	59	47	52	43	54	61	48	57	54	48	46	57	47
N. Pseud.	8	15	15	19	13	7	9	10	13	17	15	13	9	12	16	13	13	15	14	12	12	16	13	17
N. "clost."	7	10	9	3	10	5	10	8	10	8		6	25	13	24	11	5	13	18	11	13	14	7	16
Frag. "nana."	5	12	8	3	17	5	3	9	8	6	4	10	10	14	10	8	11	14	4	11	13	4	13	12
Frag. (rh. + sep.)	3	3	2	1	1	3	2	2	2	1	2			2	1	3	3	2	3	2	4	4	3	2
Frag. sp.div.			3	2	2	6			1	1	3	5	1	1	1		4	1	2			7	1	2
Thalas. ant.		1		2	1	3														4	4	1		1
Tropid.				3					1		1	1									1	2	1	
Rh. alata				2					1			1			1	1						1		
Euc. bal.				1					1				1	1	1	1	1							
Ch. negl.						3							1	1		1	1	1		1	1	2	3	1
Thalas. sp.						2					1	1						1			2		1	
Rhiz. imbr.																								
Ch. dich.																			2	1			2	

	St. 194						St. 196						St. 197					
	0	20	30	50	75	100	0	20	30	50	75	100	0	20	30	50	75	100
Frag. curta	53	55	56	54	54	50	17	25	26	29		32	20	21	30	49	32	31
N. Pseud.	9	8	9	12	12	12	17	9	16	17		14	11	19	14	27	20	20
N. "clost."	14	11	13		7	14	21	24	21			14	25	7	4		3	3
Frag. "nana."	7	13	10	6	14	15	17	23	17	24		29	27	21	24		20	23
Frag. (rh. + sep.)	3	5	4	5	4	2		3	3	1			4	4	3	2	4	2
Frag. sp.div.	2	2	2	7	1	3	1						3	1	3	1	2	
Thalas. ant.	2	2	3	3	4	1	2	1	2						2			
Tropid.				1					1	2		1		1	1			1
Rh. alata							3		1				1	1		1		
Euc. bal.			1		1	1	1		1			1		2	2	4	3	2
Ch. negl.		1			1		10	3	3	13			3	6		12	5	10
Ch. flexuos.		1	1				2	2	2	1		3						
Ch. dich.				3		1	5	4	4	4		1	4	9	1		5	
Rhiz. imbr.							1	2	1	1		1						
Amph. Kuff.										2		2	2	2				1

Table XXXIV : Percentages of the most abundant species taken with Nansen Bottles (Breid Bay - 1964-1965).

	211	0	20	30	50	75	100	212	0	20	30	50	75	100	213	0	20	30	50	75	100
Frag. curta		x	45						x	35	x		66					x	x	45	x
Frag. "nana"		x										x	x	x						x	x
Frag. sp. div.			11							37	x	x	12	x			21	x	-	20	x
N. Pseud.		x	22							6			12				x			9	
N. "clost."												x									
Corethr. cr.									x	7	x		2				10				
N. stellata												x					12			4	x
Amph. Kuff.			x										2				34			6	
Thalas. ant.			4										2				1				
Amphipl. rut.																					
Ch. negl.											x			x							

	214	0	20	30	50	75	100	215	0	20	30	50	75	100	216	0	20	30	50	75	100
Frag. curta			56	x	x	37	x			45	x	x	32			x	18	x	x	49	x
Frag. "nana."				x									x							x	
Frag. sp. div.		x	7		x	16				6			7				x		x	27	
N. Pseud.		x	2	x		17				2						x	5	x	x	9	
N. "clost."																					
Corethr. cr.		x	25							15			7	x		x	50		x	8	
N. stellata			4							13			7	x			x			x	
Amph. Kuff.			2	x		4			x	9	x		28	x			5				
Thalas. ant.											x			x							
Amphipl. rut.			x														5				
Ch. negl.						x						x									

	217	0	20	30	50	75	100	218	0	20	30	50	75	100	219	0	20	30	50	75	100
Frag. curta		x	x	x		68	x		x	x			x			x	18	x	x	x	x
Frag. "nana."			x			x											x			x	
Frag. sp. div.			x		x	10	x		x				x			x	9				
N. Pseud.										x			x				6			x	x
N. "clost."									x												
Corethr. cr.		x	x	x		9			x	x			x				18	x		x	
N. stellata			x									x				x	11	x			
Amph. Kuff.		x	x														30	x			x
Thalas. ant.			x													x			x		
Amphipl. rut.		x																		x	
Ch. negl.							x										x		x		

Table XXXV : Percentages of most represented species taken with Nansen Bottles (1966-67).
The very low abundance allow to consider the figures only as indicative.

by Nitzschia "closterioides" and Fragilariopsis "nana" (see Table XXXII and XXXIII) with the net hauls samples (Fig.33), a dominance of Fragilariopsis curta, Fragilariopsis oblique-costata and Fragilariopsis "nana" was recovered, this last minute species in a slightly less degree, probably because its possibility to escape.

In 1966-67, the situation was fairly different. The conditions of an important photosynthetic activity were not met, as reflected by the chlorophyll a content, the primary production and the Diatom abundance. But the difference is also well established in the species composition. If Fragilariopsis curta, Fragilariopsis "nana" and Nitzschia gr. Pseudonitzschia are still present, they are mixed with species like Amphiprora Kufferathii, Nitzschia stellata, Fragilariopsis cylindrus, Amphora antarctica, Amphipleura rutilans, Navicula (Table XXXV), which belong to the ice habitat (see same chapter C). The spectrum of the species composition in 1966-67 is consequently the result of the superposition of two different populations. The net haul samples of 1966-67 (Fig. 33) taken from 250 to 0 meter, show for stations 211 to 214 a dominance of Amphiprora Kufferathii and Nitzschia stellata and Nitzschia gr. Pseudonitzschia, while for Stations 215 to 219, the bulk consists of 30 % of Corethron criophilum and of 20 % of Amphiprora Kufferathii. The relatively week abundance of the ice species in the Nansen bottles compared to high quantity recorded using net hauls may perhaps be explained by the fact that, by the melting of the ice,

Date : Jan.-Febr.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4
	P59			P63	P64		P67	P70		P71	P73	P74			P76	P77	P78	P79	P80					P83		
A.nphiprora Kufferathi	x							x		o		o			o		o	x	x					x		
Nitzschia Stellata	x																									
Fragil. sublinearis (obliq).	▲			▲	▲		●	▲		●	▲	▲			o	o	o	+						o		
Chaetoceros neglectus	x														o			o	x							
Fragilariopsis curta	▲			o	+		▲	▲		+	+	+			●	●	●	+	+					+		
Corethron criophilum	x			x						o	x	x			▲	▲	▲	▲	▲					▲		
Biddulphia weissflogii	o			x			o	o			o	o			o	o	o							x		
Coscinodiscus Bouvet	o			▲	o		o	o		o	o	o			o	x	x	x	x							
Eucampia balaustium	●			▲	●		●	●		▲	▲	▲			o	o	+	o	+					x		
Nitzschia closterioides	x			o	o		o	o		o	o	x			o	x	x	x	o					o		
Fragilariopsis "nana"	x			x								o			o	x		x	o					o		
Nitzschia gr. Pseudon	o			o	o		o	o		o	x	o			o	o	o	x	o					o		
1964 - 1965								188	189	190						194	195		196		197					
Amphiprora Kufferathii								o	o	o							x									
Nitzschia stellata										x																
Fragil. sublinearis (obliq)								o	o	+							o		o		+					
Chaet. neglectus									x								o		o							
Fragilariopsis curta								+	●	▲							+		+		+					
Corethron criophilum								o	x	x							x		o		+					
Biddulphia weissflogii								o	x								o		o							
Coscinodiscus Bouvet								x	x																	
Eucampia balaustium								o	o	o							o		o		x					
Nitzschia "closterioides"								o	o	o							x		o		x					
Fragilariopsis "nana"								o	o	o							o		+		o					
Nitzschia gr Pseudon								▲	+	+							●		+		o					
1966 - 1967												211			212		213	214	215				216	217	218	219
Amphiprora Kufferathii												▲			o		▲	+	+				▲	+	o	▲
Nitzschia stellata												o			x		+	+	+				+	+	o	o
Fragil. sublinearis (obliq.)												+			+		+	o	o				+	+	o	o
Chaet. neglectus												o			o		o		o				x	o	o	o
Fragil. curta												o			+		o	o	o				o	o	o	x
Corethron criophilium												o			+		o	+	●				●	▲	▲	▲
Biddulphia weissflogii												x			x		x						x	x	x	x
Coscinodiscus Bouvet																										
Eucampia balaustium															x		x	x	x				x	x	x	
Nitzschia "closterioides"												o			o		o	o	o				o	x		
Fragil "nana"															x		o									
Nitzschia gr. pseudon												●			+		+	+	+				+	o	+	x

x	< 1%
o	1%-9%
+	10%-19%
●	20%-25%
▲	>25%

Fig. 33: Percentage of most represented species
Net haul samples.

Nitzschia stellata, Amphiprora Kufferathii, and Amphipleura rutilans were observed to form gelatinuous clusters which probably sink to the bottom, being catched on their way down by the net hauls. This also could explain their relative scarcity in 1964-65.

DISCUSSION

The relationship between the Diatom abundances and the phosphate content has been investigated in the Breid Bay. Fig. 34 gives the log. of Diatom cell numbers per liter, plotted in function of the phosphate content, for all stations and all depths of both years, 1964-65 and 1966-67. We can see that the points of this figure are distributed in two distinct groups (I and II). A first one (I), corresponding to values of log. N superior to 5 (N being the cell number per liter); a second (II) with values of log. N inferior to 5. The group I, which corresponds to values of 1964-65, shows a clear inverted relationship between log. N and phosphate concentration, while group II, composed of the 1966-67 values, does not show significative variation of the phosphate content in regards to the different values of log. N recorded (although the variation of these values was limited between 3 and 4). Clearly the inverted relationship shown by group I corresponds to a deplation of the phosphate content by Diatoms; this is to compare with the study of the stability in the Bay and with the existence of a surface mixing layer (see Chapter IV, Fig. 24).

In group II, the limited amount of Diatoms was not able to influence on the phosphate content which staid particularly unchanged, within the range of 2 to 2.5 µatg/l. This is also to compare with the almost homogenuous distribution of properties in the entire column in the Breid Bay in 1966-67 (see Chapter IV,Fig.25).

The data obtained by Nansen bottles (Table XXXIV and XXXV) as well as those obtained by net hauls (Fig.32) show that for the three expeditions 1961-1965-1967, only a very limited number of species occur in great abundance in the Breid Bay; mainly : Fragilariopsis curta, Fragilariopsis obliquecostata (here not distinguished from Frag. sublinearis), Fragilariopsis cylindrus, including Fragilariopsis cylindrus var. nana Corethron criophilum, Nitzschia gr. Pseudonitzschia, Nitzschia "closterioides" (mainly subcurvata), Amphiprora Kufferathii and Nitzschia stellata. In most cases, Fragilariopsis curta was the dominant species.

One important point to put forward is that the differences between our 3 expeditions (only 1965 and 1967 with Nansen bottles) were more pronounced in the Bay than in the transect. This is consistant with the marked hydrological differences observed in the Bay. If 1964-65 shows a quite homogenuous distribution of the dominances, 1966-67 on the contrary, was characterized by a high degree of patchiness due to the presence of ice floes. This is reflected in bottle samples as well as in net haul samples.

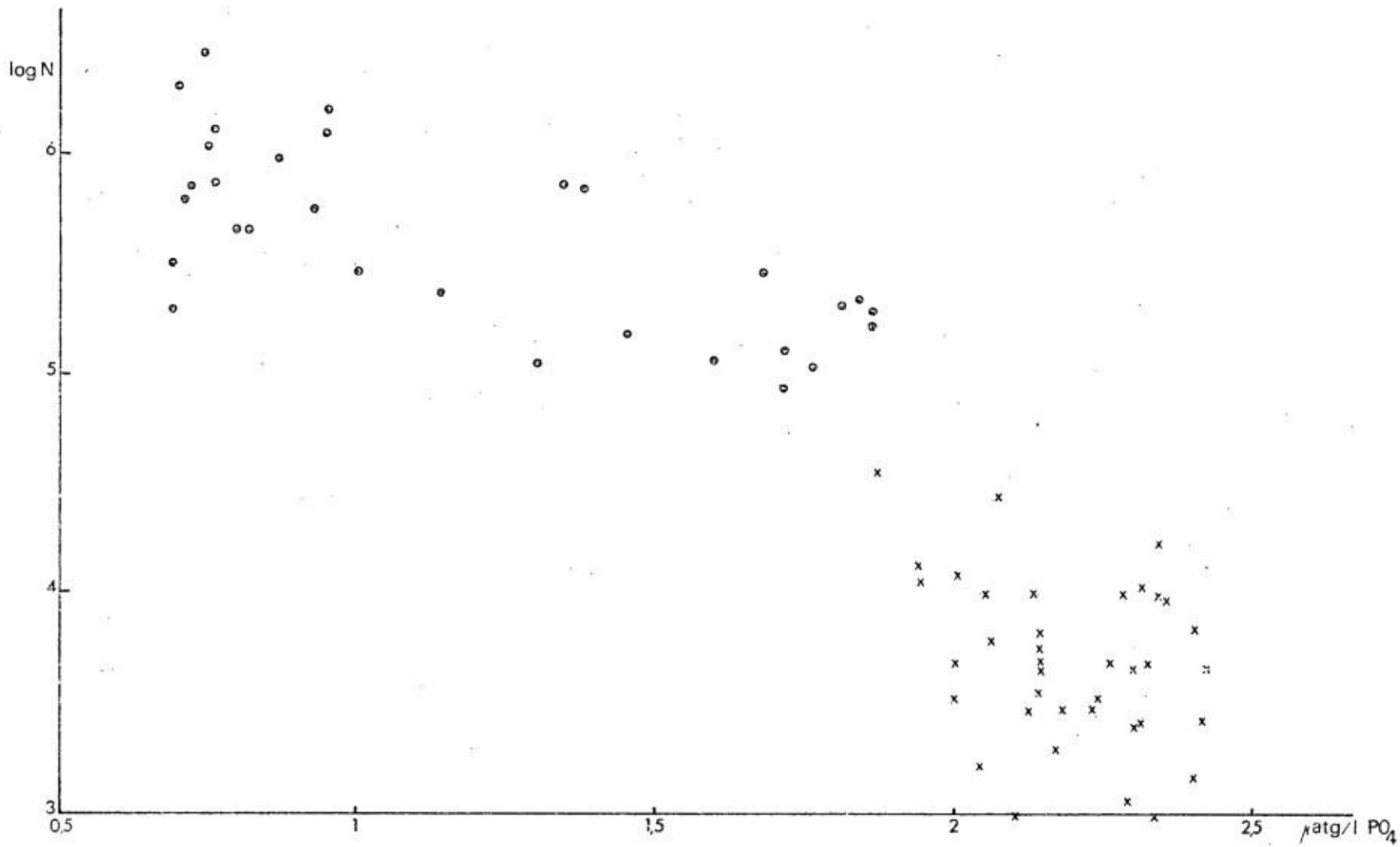


Fig. 34: Relation between Phosphate content (µatg/l) and Diatom abundances (log cell numbers per liter).
• 1964-1965 samples.
* 1966-1967 samples.

The populations in the Breid Bay waters in 1966-67 were, as seen previously, composed of mixed Diatom communities : ice linked species and open water species. The total abundance (Fig. 31) of Diatoms was, that year, very low. These facts, linked to more pronounced hydrological "winter" conditions, inclined us to consider the Diatom population of 1966-67 as being at his 'starting' point. The Diatom community of 1964-65, on the contrary, was characterized by a very high abundance (100 times more than in 1964-65) due to the active growth of a few species. The hydrology of the bay in 1965 being in more "summer"conditions, it allows us to consider that the Diatom population of that year was in a more advanced stage than in 1966-67. Consequently, we may consider Fragilariopsis curta, Fragilariopsis obliquecostata, Fragilariopsis cylindrus and in a less degree Corethron criophilum as "early"forms, while species like Biddulphia weissfl., Eucampia balaustium, Coscinodiscus are elements of more advanced communities.

The analysis of the net haul samples gives a slightly different aspect of the populations and increases the percentage of species as Amphiprora Kufferathii, Nitzschia stellata, Amphipleura rutilans and Corethron criophilum. Fragilariopsis obliquecostata as well as Corethron criophilum appear by net hauls in larger proportion in 1967 than in 1965; species like Eucampia, Biddulphia, Coscinodiscus only occur in the 1964-65 samples.The investigations of 1960-61 showed from the hydrological point of view, the most advanced summer characteristics of the three expeditions,

with nearly no ice in the bay. The net haul samples of the 1960-61 cruise give for St.P 59 to St.P74, a dominance of Fragilariopsis obliquecostata, Eucampia balaustium and Fragilariopsis curta, while St.P 76 to St.P 82 show a different population constituted by a dominance of Corethron criophilum and Fragilaiopsis curta. The sudden difference observed in 1960-61, between the two series of stations, all located in the Leopold III Bay, is most interesting because they reflect modifications in the hydrological conditions. Indeed, on the 22th of January, a sudden massive inflow of pack ice from outside, invased the bay and modified very quickly the water characteristics. The Diatom community of the first series of stations in 1960-61 can be considered, on basis of the perfect correspondance between the hydrology and the plankton populations, as being in an even more advanced stage than that of 1964-65.

Being aware of the heavy patchiness always present in inshore waters and of the marked influence of particular environmental conditions on the development of the populations, we propose nevertheless the following scheme as a probable evolution pattern of the populations in the Breid Bay during the summer season as reported in figure 35.

Studies made in inshore waters along the Antarctic Continent, are very scare and no detailed data are, by our knowledge, reported in the literature. Bunt (1960) studied at Mawson, at two points, and with net hauls, the evolution of th phytoplankton, from mid-September till end January.

He menshions Fragilariopsis sublinearis, Amphiprora striolata and Nitzschia sp. as first signs of the phytoplankton growth, followed by an active growth, end October, with Fragilariopsis sublinearis as dominant; at the end of January he reports a shared dominance of 6 species (Fragilariopsis sublinearis, Eucampia balaustium, Biddulphia, Coscinodiscus..). Those results confirmed partly our findings (the early appearence of Fragilariopsis sublinearis($\pm$ = Frag. obiquecostata), the late appearence of Eucampia, Biddulphia and the increasing complexity with time). The main difference consist in the fact that Bunt does not mention Fragilariopsis curta. This last species is recorded in the literature as an 'ice-edge' species (Hendey, Hart, Karsten, Rytter Hasle, Kozlova). It is also found by Fukishima and Meguro (1966) occuring in ice and open waters in the Lützow Holm Bay.

C. ICE

The sea habitat being a very particular one, we would have expected to find a micro-algae community, specialized to this habitat and more or less constant in its composition. In fact, excepted for few species, as Amphiprora Kufferathii and Nitzschia stellata for the bottom layer and Fragilariopsis cylindrus for the sea layer of the floes, a variable composition of the species has been observed between the different types of ice samples, especially

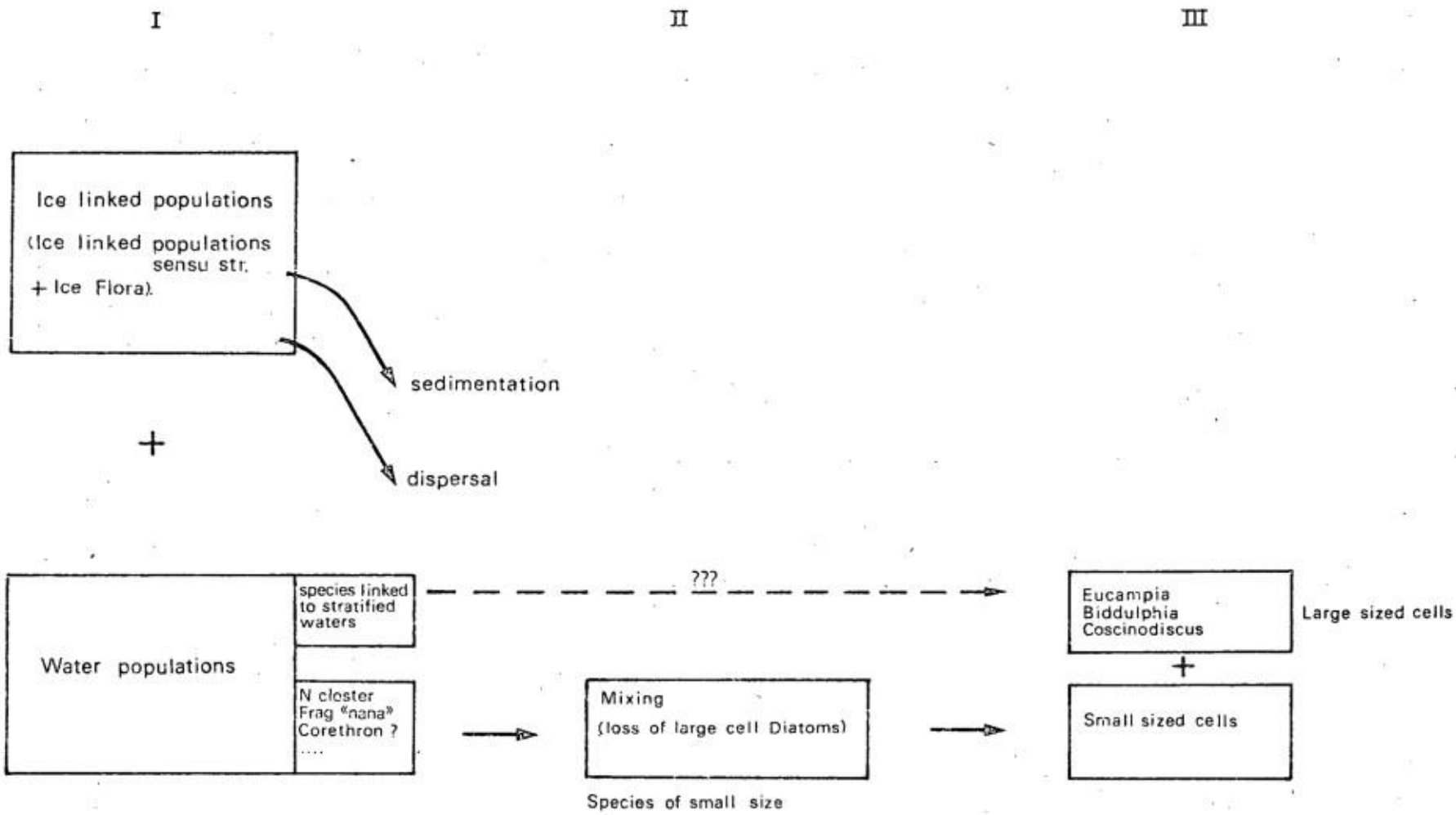


Fig. 35 : Schematic representatior of supposed evolution of Diatom population in the inshore waters of Breid Bay.

for those corresponding to different years.

Table XXXV gives the species composition of the various sea ice floes sampled in 1960-61, 1964-65, and 1966-67. The ice samples taken in 1960-61 refer to the colored layers of the floes, melted and filtered on a silk. Only the percentages of abundance could be calculated and the figures are therefore only an estimation of the Algae composition at the different levels. P. 62 and P.75 refer to the green sea level layer, P.72 and P.81 to the brown bottom layer. All samples were taken in the Leopold III Bay. The sea level layer was characterized by the abundance of Fragilariopsis cylindricus and Fragilariopsis curta, while the bottom layer showed a marked different association, mostly composed by Nitzschia stellata and Amphiprora Kufferathii. The samples of 1964-65, reported under Ia,Ib,Ic have been taken in the still unbroken fast ice of the Leopold III Bay. Those three samples are composed respectively of the 15,35 and 45 first centimeters of the fast ice (after removal of the 10 cm upper layer of covering snow), which total thickness was about 1,5 m. They also comprised a pure Phaeocystis (Chrysophyceae) population. Phaeocystis sp. has been mentionned in the literature, either found in the ice, associated with other Diatoms (Burkholder and Mandelli, 1965) or found in open waters (Hart, 1942; Bunt, 1963; Rytter Hasle, 1969). Hart considered Phaeocystis as an early coloniser after the melting of the pack ice and believed its origin to be within his "intermediate zone".

Date	Samp. refer.	Species comp.	%	Div. Index
		1960-1961		
8-1-1961 LeopIII Bay	P62 Green coloured layer (filtered on net silk)	Frag. curta Frag. cylindrus Frag. div. Nit. closter.	52 32	
19-1-1961 LeopIII Bay	P72 Green layer (greenish brown) (filtered on net silk)	Nit. stellata	76	
24-1-1961	P75 Green coloured layer (sea level) (filtered on net silk)	Frag. curta Frag. cylindrus	88	
28-1-1961	P81 Brown bottom layer (filtered on net silk)	Amph. Kuffer. Nit. stellata	73 16	
		1964-1965		
16-1-1965 (70°19'S 24°12'E)	Ia Fast ice Bay 15 cm from top	Phaeocystis	100	
"	Ib Fast ice Bay 35 cm from top	Phaeocystis	100	
"	Ic Fast ice Bay 45 cm from top	Phaeocystis	100	
29-1-1965 (60°15'S 24°20'E)	Id Ice floe of 160 cm thickness (VIII) 112cm -128cm	(Pha. present) Frag. Van Heurck. Biddulphia Coscinod. fur. Char. actinoch. Amphipr. rutilans Coreth. crioph. Euc. balaust.	 37 10.8 10.8 7 7 3 1.4	I=3.2

.../...

"	Ie Same floe (IX) 128cm -144cm	Amphi. Kuffer.	54	
		Nit. stellata	8.4	
		Frag.obl. (sub.)	8	I=2.6
		Frag. curta	4	
		Coreth. crioph.	3	
		Coscinodiscus	1.5	
"	If Same floe (X) 144cm-160cm	Amphi. Kuffer.	51	
		Frag. Van Heurck	14	
		Frag. sublinearis	3.6	
		Biddulphia		I=2.6
		Coscinodiscus		
		Charcotia		
		Nitzschia		
		Amphipleura		
"	Ig Same floe (X) inferior 15 cm	Amphi. Kuffer.	43	
		Frag. Van Heurck	21	
		Frag. subl.	13	
		Frag. curta	6	
		Biddulphia		I=2.7
		Coscinodiscus		
		Navicula		
		Pleurosigma		
		Amphipleura		
"	Ih Same floe inferior 15 cm (X) (filtered on net silk)	Amphi. Kuffer.	56	
		Frag. curta	12	
		Nit. stellata	5.6	
		Navicula	2	I=2.6
		Biddulphia		
		Corethron		
		Pleurosigma		
		Charcotia		
"	Ii Same floe inferior 10 cm	Amphi. Kuffer.	30	
		Frag. subl.(obl)	20	
		Frag. Van Heurck	11	
		Frag. curta	5	
		Biddulphia	3.6	I=3.1
		Charcotia		
		Biddulphia		
		Coreth. crioph.		
		Pleurosigma		
		Navicula		
"	Ij Same floe inferior 5cm	Frag. Van Heurck	41	
		Amphi. Kuffer.	26	I=2.6
		Frag. sublinearis	12	

.../...

1966-1967				
17-1-1967 (68°50'S 26°31'E)	IIk Surface pack ice	Frag. cylindrus Nit. closter.	95 4.8	I=0.3
26-1-67	III Inferior part brown layer	Amphi. Kuffer. Navicula Fragilariopsis Nit. stellata	82 10 7	I=0.9
26-1-67	IIm Inferior part brown layer	Amphi. Kuffer. Navicula	87 10	I=0.7
26-1-67	IIn Inferior part brown layer	Amphi. Kuffer. Fragilariopsis Navicula	83 3.5 3.5	I=0.9
26-1-67	IIo Inferior part (filtered on net silk)	Amphi. Kuffer. Navicula Nit. stellata Fragilariopsis Amphipl. rutil.	75 12 4.4 3.4 2.4	I=1.3
26-1-67	IIp Inferior part (filtered on net silk)	Amphi. Kuffer. Navicula Amphipleura Fragilariopsis	80 9.4 3.4 3	I=1.2

Table XXXVI : Main species composition in ice samples (1960-1961; 1964-1965; 1966-1967). All samples without special mention, refer to melted ice investigated with the sedimentation method.

We found it associated with Diatom populations of some top and bottom floe layers, as well as in open water, but in limited amount. While no conclusion can be inferred from the three ice samples, the observation is an indication that Phaeocystis may be adapted to live in the top layer of the fast ice.

The other samples (1964-65 and 1966-67) originated from various floes, either from the bottom side (Id,Ie,If,Ig, Ih,Ii,Ij,; IIl,IIm,IIn,IIo,IIp) or from the upper side (IIk). In particular, samples Id,Ie and If have been taken respectively in the three last successive 15cm layers at the bottom side of the same floe. When considering the species composition of these various samples, it is clear that Amphiprora Kufferathii is the dominant species for all the bottom side samples, for both years (associated in the lowest layers with Frag. sublinearis and Frag. Van Heurckii), while Fragilariopsis cylindrus is dominant in the unique sample taken in the upper side of a floe. The differences between the two years are found at the level of the subdominant species. Indeed, in 1965, the specie spectrum was made of large species among which Biddulphia, Coscinodiscus, Corethron criophilum, Charcotia, Pleurosigma, Tropidoneis, Eucampia balaustium and other little forms like Fragilariopsis curta, Fragilariopsis obliquecostata, Fragilariopsis Van Heurckii... among the most abundant. In 1967, th dominance of Amphiprora Kufferathii was more pronounced and the associated species were little forms (Navicula, Amphipleura Fragilariopsis).

DISCUSSION

Comparing the results of investigation in the open water of the Bay with those of the ice samples, th following scheme can be established :

	ICE	SURROUNDING WATER	
		bottle sampling	net sampling
1960	(1) Frag. curta		Eucamp. balaust.
	(1) Frag. cylind.		
	(1) Nit. closterium		Frag. curta
	(2) Nit. stellata		Frag. obliquec.
	(2) Amphipr. Kuffer.		Coscinod. Biddul.
1964	(2) Amphipr. Kuffer.	Frag. curta	Frag. curta
	(2) Frag. Van Heurck	Nit. closter.	Frag. nana
	(2) Frag. obliquec.	Frag. nana	Nit. Pseudon.
	(2) Biddulph. Charc.		
	(2) Corethron.Nit.		
1966	(3) Amphipr. Kuffer.	Frag. curta	Amphipr. Kuffer.
	(3) Nit. stel. Navi.	Frag. obliquec.	Nit. stellata
	(3) Amphipl. Pleuro.	Coreth. crioph.	Frag. obliquec.
	(3) Frag. curta		
	(2) Frag. cylind.		
	(2) Nit. closter.		

(1) : surface layer (2) : inferior layer (3) : brown inf. layer

Although the number of ice samples investigated was limited, a certain number of observations may be put forward :

- Some species occur in the ice in large quantities and do not remain for long time in the open water; this is the case for Nitzschia stellata, and Amphiprora Kufferathii. These species may be considered as ice-linked species. Moreover, we observed that those species, as also Amphipleura rutilans (sometimes found in large amounts) are all species which form, after their release in the water, large gelatinuous masses, visible from shipboard. This phenomenon may be related to the fact - at least for the two first species - they were observed in the ice rolled round the

ice cristals in large ribbonshaped colonies (Amphiprora) or organized in networks (Nitzschia stellata). Perhaps the mucilaginous formation reflects their particular spatial organisation in the ice.

- Other species, as Fragilariopsis obliquecostata (sublinearis), Fragilariopsis Van Heurckii, Pleurosigma, Navicula and Fragilariopsis cylindricus occur abundantly in the ice, but are also found in great quantity in the open water. These species may perhaps start their growth in the ice and develop in the open water afterwards. No answer has already been given to this important question. They perhaps contribute, with the melting of the ice, to the increase of the open water plankton abundance. Fragilariopsis curta occurs in variable quantities in the sea-ice samples investigated; although never dominant, it is found in this habitat in appreciable quantities (see Ch. VI.). In the open water Fragilariopsis curta is the dominant species.
- A third category of species, of appreciable size (Biddulphia, Coscinodiscus, Eucampia, Charcotia, Corethron criophilum) are also present in ice floes, but in few quantity. Those species are perhaps accidental species which enter in the ice from outside.
- Comparing the total abundance in the ice (10^8 cells/liter in 1967, beginning of the establishment of summer conditions; 10^6 cells/liter in 1965, well developed summer

conditions), with the total abundance in the open water (10^3 cells in 1967, beginning of the establishment of summer conditions; 10^5 cells/liter in 1965, well developed summer conditions), we are inclined to attribute the higher number of Diatoms in the open water, in 1965, to a greater melting of the ice. Nevertheless it has to be pointed out that the dominant species in the ice are not those which are dominant in the sea.

- The very large quantities of Diatoms recorded in the ice samples correspond to very high values of chlorophyll content. High values of pigments were also found by Burkholder and Mandelli (1965) at the sea level of the ice, corresponding to high productivity rates. Bunt (1964) recorded also, for bottom flora (underice flora), high values of chlorophyll (especially chlorophyll c), but with a limited productivity. He demonstrated, through laboratory cultures, that species from the epontic community (Fragilariopsis sublinearis) were shade adapted and able to fix CO_2 slowly at low light intensities. Micro-Algae growing on ice are less subjected to loss by sinking (this is also the case for neuston). Therefore species, even with a lower rate of increase, can survive (shade-adapted species forcilly devide slowly) (personal communication of R. Margalef).
- There are still a lot of unanswered questions : are Amphiprora Kufferathii, Amphipleura rutilans and Nitzschia stellata shade-adapted species, as it was demonstrated by Bunt for Fragilariopsis sublinearis ? Are they, on the

contrary, heterotrophe as some Amphora species (this genus is represented by Amphora antarcticus but by very few individuals) ? Are the other "trapped" species in resting stade or, on the contrary, growing in a favorable milieu ?

The literature on the subject is very scarce. Bunt (1963,1964) did a lot of investigations on the ice flora and in particular on productivity and chlorophyll content of Algae populations in the slush ice which hangs beneath the ice floe. Bunt and Wood (1963) distinguished in the brown ice layer : Pleurosigma, Nitzschia, Amphiprora and Fragilaria to be constituents of the epontic community. Burkholder and Mandelli (1965) recognized in the ice "large amounts of small diatoms, moderate amounts of Fragilaria curta and Nitzschia seriata and traces of many other species". Fukushima and Meguro (1966) distinguished essentially two types of ice flora : the bottom type plankton ice with Amphipleura rutilans, Amphiprora Kufferathii, Nitzschia stellata and Pleurosigma as dominant species; the surface type plankton ice with Fragilariopsis cylindrus, Nitzschia stellata, Fragilariopsis curta. From the presence of one or the other serie of Diatoms in the open oceanic waters, they did conclude on the existence of "bottom type plankton ice area" (open waters where the population originated from the bottom layer of the ice) and "surface type plankton ice area (oceanic waters where the population originated from the surface layer of the ice).

V. INDEX OF DIVERSITY

The observation of natural populations and, in particular, the observation of the species distribution in function to space - time, has brought to light the existence of some kind of organization within natural populations. This organization is the result of interdependent relationship between organisms - at the level of individuals, species groups of species...etc - and the whole system, either as such or at the level of each individual, being under the influence of the environmental factors. In particular, the distribution of individuals in different categories of species has shown to follow some regularity. Indeed, when we consider each individual within a sample of plankton, there are two extreme possibilities, with all the intermediates between these two extremes. Either all individuals belong to the same species and the "species diversity" is minimum, or each individual considered, belongs to a different species, and the "species diversity" is maximum. Several functions have been proposed to express this "species diversity". Among them, Margalef (1961,1968) proposed the following "Index of diversity" : $D = p\sum \log_2 p$ which is borrowed from the information theory. By proposing this, Margalef compares the ecosystem to a message transmitted along a chanel of information. D, expresses the average information

content per individual, considering that the probability that one individual belongs to the species i, is p_i. Basically, this function has a minimum value when all individuals belong to the same species and a maximum value, when each individual belongs to a different species.

The interest in computing the index of diversity, is the fact that it represents a "measure" of the organization of the population, which organization is under controle of intra - and interspecific relationships and of environmental factors. The index of diversity is therefore related to basic properties of the population and will follow its evolution. For example, it is frequently observed that, the early stage of development of a population, corresponds to a low index of diversity. This may be due, either to the fact that the new population comprises only few different species or because few species are rapidly growing and dominate, in quantity, all the others. On the contrary, a population reaching a situation of stability corresponds normally to a higher index of diversity. However, the organization of a system is not fully described when computing the index of diversity, which, in fact, gives only a measure based on the relative abundance of individuals falling in different categories of species. For example, two samples having complete different species, can exhibit the same index of diversity. This one also depends on the size of the sample, in the sense that the index may evolve continuously when adding new individuals to the sample, and may behave

differently, in this respect, from sample to sample; it is therefore, more appropriate to refer to a spectrum of diversity. Moreover, the index of diversity may vary in function of the sampling techniques used, as it is the case when comparing net haul samples with water bottle samples. Diversity concerns a division of a set in subsets. Since net makes a selection of some subsets among the set - in particular by retaining a greater proportion of larger species and of those with bristles and spines, while most of the little species like Fragilariopsis "nana" (3-10μ) and Fragilariopsis cylindrus (6-50μ) are escaping - diversity computed on those subsets, cannot be identified with diversity of all the subsets of the set, like it does for water bottle sampling. However, the sample taken with water bottles is very limited and nearly punctual in function to space and therefore some species may even not be represented in the sample.

A. TRANSECT

Figure 36 gives the index of diversity computed on net haul samples and on water bottle samples of all standard depths at the stations along the 1964-65 and 1966-67 transects.

From the data recorded by water bottle samples we observe for both years, a higher value of the diversity index in the North Antarctic region than in the South Antarctic regions.

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For both years, the region of the Subtropical Convergence (St. 183, St. 202) shows lower diversity values than at stations north to it. This decrease is found by net samples as well as by water bottle samples and corresponds, at both stations, to a dominance of Nitzschia gr. Pseudonitzschia as a consequence of a high productivity. The Antarctic Convergence zone (St.204 and to a less extent St. 203) corresponds to a relative higher Productivity-Biomass ratio (productivity measured by C_{14} uptake; biomass measured by pigment content) than station 205. The lower index of diversity recorded at these stations agree with the general rule of inverse relationship between Productivity-biomass ratio to index of diversity (Margalef). This relationship was also verified at St.185 : very low Productivity-Biomass ratio and high value of diversity index. The southernmost stations (St.186,187,206,207), on the contrary, showed very low Productivity-Biomass ratio associated to low indexes of diversity. At these stations of diversity index computed was probably influenced by the few amounts of Diatoms counted. Moreover, the computation on Diatoms only, reflects not the diversification, already appearent, due to the presence of other phytoplankton organisms (Peridinea, Silicoflagellatae...).

The data obtained by net samples were quite different and did not vary in the same way as those obtained by water bottle samples. this most probably due to the selective action of the net.

Water bottle samples	182	183	184	185	186	187	188
0	3,2	3,2	3,4	3,9		3,0	1,5
20	3,7	3,2	3,3	3,2	2,8	2,9	2,4
30		3,2	3,6	3,9	2,4	2,9	2,2
50	3,0	2,7	3,1	4,0	3,5	2,9	2,3
75	3,8	–	3,7	3,7	3,5	3,5	2,2
100	–	–	3,3	3,1	3,1	–	2,4
net	2,9	2,4	2,4	3,0	3,5	2,8	

30° 40° 50° 60° 70°

Water bottle samples	201	202	204	203	205	20	207	208	209	210
0	3,1	2,6	3,3	3,1	3,1	2,6	2,7	2,9	2,4	2,8
20	3,6	3,6	3,4	3,2	3,9	2,6	3,8	3,0	2,7	2,4
30	3,4	2,7	3,0		3,5	3,3	2,2	–	–	
50	3,2	2,4	3,7	3,0	3,3	2,7	2,9	2,5	–	1,8
75	3,3	2,5	3,5	3,1	3,6	3,9	3,2	3,3	2,2	
100	3,2	3,4	3,0	3,1	3,1	–	–	2,7	–	2,7
net	3 3	2 9	3 8	3 1	3 4	3 0	3 0	2 9	2 2	2 6

30 40 50 60 70

Fig. 36: Index of Diversity in bits ($-\Sigma P \log_2 P$) computed on water bottle and net samples for both expeditions (1964-1965 1966-67) along the transect Cape Town-Breid Bay.

Indeed, at Station 184 for example, the dominant species recorded with water bottle sampling were Nitzschia gr. Pseudonitzschia and Chaetoceros atlanticus, while the net sampling showed a pronounced dominance of Fragilariopsis kerguelensis and Chaetoceros criophilus. The low index of diversity on the net sample of this station is probably due to the fact that species forming long chains, like Fragilariopsis kerguelensis, or species with long bristles, like Chaetoceros criophilus, are selectively retained by net. The same phenomenon is observed at St. 187, where the dominant species with the net sampling is Corethron criophilum, another species with spines, while the dominance with water bottles is made of Fragilariopsis curta and Fragialriopsis "nana", which certainly escaped partly from the net hauls. Similarly, the relative low index of diversity , by net sample, at St. 208 is to be related to the dominance of Chaetoceros criophilus.

B. BAY

The diversity in the Breid Bay was computed, in 1964-65, on both, net and water bottle samples, while it was computed only on net samples in 1966-67, because the number of individuals taken with water bottles, that year, was not large enough to allow significant calculation of the diversity index.

The values of diversity are reported in Figure 37.

Comparing the data of the diversity index on water bottle samples of the Breid Bay (Fig.37) with those of the transect (Fig.36), a general lower value is observed for the first ones. This reflects the high productivity of the inshore waters at that period of the year. Moreover, in the Bay, the index value shows a slight increase in function to time which corresponds to the establishment of a more complex population and a decrease in the total Diatom abundance.

The diversity computed on net samples shows quite uniform values, comprised between 3.00 and 3.54, except for St. 218 (2.5) and St. 219 (1.87). This uniformity reflects a more or less uniform distribution of the relative species abundances, although the dominant species in 1964-65 were different from those in 1966-67 (see Chapter IV). The diversity of 2.5 (St.218) and 1.8 (St.219) corresponds to a high dominance of Corethron criophilum (47%) and Amphiprora Kufferathii (43%) respectively. It is interesting to note that the diversity index values computed on water bottle sampling were, in general, lower than those computed on net sampling (the contrary has been observed for the transect). This may also be explained by the selective action of the net. Indeed, the dominant species, in the Breid Bay in 1964-65, were composed of little forms like Fragilariopsis "nana", Fragilariopsis curta, Nitzschia closterioides, which are escaping in important proportion from the net haul; their lower percentage value in net samples increases the index value.

		10-1	11-1	12-1	13-1	14-1	15-1	16-1	17-1	18-1	19-1	20-1	21-1	22-1	23-1	24-1	25-1	26-1	27-1	28-1	29-1	30-1	31-1	1-2	2-2	3-2	4-2
1960-61		P59 60	P61		P63			P68 69	P70		P71	P73	P74			P76	P77	P78	P79	P80					P83		
NET		.20	.21		.24			.20	.22		.25	.21	.29			.27	.22	.25	.24	.20					.22		
1964-65									188	189	190			193			194			196		197					
WATER BOTTLE	10								.15	.14	.22			.24			.23			.31		.29					
	20								.24	.18	.22			.23			.23			.30		.34					
	30								.22	.20	.23			.26			.22			.30		.33					
	50								.23	.20	.23			.27			.25			.25		.21					
	75								.22	.15	.21			.23			.23			.		.30					
	100								.24	.21	.24			.25			.23			.26		.28					
NET									.34	.33	.30			.			.31			.35		.33					
1966-67																											
NET														.31		.34		.33	.33	.30				.30	.33	.26	.18

Fig. 37 : Index of Diversity in bits ($-\Sigma P \log_2 P$) computed on net and water bottle samples in Breid Bay.

C. ICE

The diversity of Diatom populations living in ice was computed for different floes studied in 1964-65 and 1966-67. The values are reported in Table XXXVI.

Although the number of samples was limited, we may clearly observe that the diversity values recorded in the 1964-65 floes, were higher (of about one unit) than the corresponding values in the 1966-67 floes. The diversity values correspond to lower values of biomass in 1964-65 than in 1966-67. Most probably, the greater diversity of the 1964-65 ice populations is the consequence of the presence, in addition to the specific ice species, of species originated from the surrounding water. This imput of external species does not have occured in the 1966-67 floes, and is also to be related to the difference in the development of the summer season between the two years.

VI. DISTRIBUTION OF SOME SELECTED DIATOM SPECIES

During our investigations several Diatom species were encountered in considerable amounts, some of which are reported in the literature as characteristic for the Southern Ocean. This fact has prevailed in the choice of the species studied here. Most of the authors give only a species list with no quantitative figures: others mention ranges of frequency and percentages; very few give the bulk contituted by each species. This last method seems important to us. Indeed, Diatoms, making more than the two thirds of the total phytoplankton in the Southern Waters, are a major component in the food chain. Hustedt (1952), studying the stomach content of Euphausia and Salpa species in the South Atlantic, noted that some Diatoms were more commonly grazed than others. Consequently, although Diatom species in general are much less discriminated by zooplankton than other organisms, it is worthwhile to know, when and where, the maximum quantity of each Diatom species occur and how this maximum evolute with time and with regard to the hydrological changes.

In this kind of study, the percentage or frequency of each species is meaningfull, but of less importance than the total quantity. Indeed, the percentage of a species reflects only the relative abundance of that species, compared

to the total amount of all species present; the great quantity of a species can be "covered"by an even greater quantity of an other species, which is-not necessarely linked with the same hydrological conditions. This leads to some apparent contradictions : a maximum bulk of a species may correspond to a low percentage, while a low quantity may correspond to a high percentage. The percentage of a species does not give any information about its quantity. Moreover percentage values have technical defects in statistics.

If we want to know how species evolute with time, the total value is to be considered and not the percentage. When a great quantity of a given species is found in spring, in a northern area and if this species appears in great quantity in the south, at the autumn, we may deduce that there is a southward displacement of the bulk; however, it does not mean at all that the species is "going" or drifted to the south. In the particular case of the Southern Ocean a surface Antarctic current component is flowing from South to the Antarctic Convergence (from south to north), while the establishment of the summer season is proceeding from north to south. Consequently, in function of the different factors involved, we can expect that different species may behave in different ways.

The establishment of the summer season in the Antarctic Ocean follows a sequence that is function of the warming up of the surface layers. The conditions

met in 1964-65 were corresponding to a later stage in the sequence of the summer establishment: the break up of the pack ice, the position of its edge; the water properties in the Bay (temperature, salinity and stability profiles) reflected summer conditions. The situation observed in 1966-67 has clearly not reached this stage ; the pack ice belt extended more northwards, the pack ice in the Bay was more or less close, the water properties in the Bay reflected nearly winter conditions. With regards to the establishment of the summer conditions, 1966-67 can, therefore, be considered as an earlier stage compared to 1964-65.

Being aware of this fact, the differences observed in the behaving of the phytoplankton, between the two years can be explained in the same way. The phytoplankton development being linked to an alternance between winter and summer conditions, the results obtained on Diatom investigations in 1966-67 would correspond to a situation (for what concerns the seasonal sequence) anterior to that one encountered in 1964-65. This means that, in the inshore waters, a marked poverty (1966-67) in close ice conditions, would preceed a phytoplankton bloom when ice opens (1964-65). Although little is known about the winter behaviour of the phytoplankton, especially in the far south, some observations of Bunt (1960) from shore-based stations confirm that no phytoplankton growth occurs during winter.

This means also that, along the transect, a northern position of the main phytoplankton bulk preceeds (see Chapter III) a more southward position in proceeding summer conditions. This idea, firstly mentioned by Hart (1942) on basis of chlorophyll data, was also proposed by Rytter Hasle (1969) for Diatom countings. Our data confirm this hypothesis and let presume that the reponse of the phytoplankton (main bulk) to the different stages in the establishment of the summer season, is similar in different areas of the Southern Ocean : Atlantic-Indian, West Atlantic and West Pacific Ocean Sectors. We may even suppose, that it is a general rule for all Antarctic Circumpolar Waters.

From the above statements we may presume that the phytoplankton development encountered in 1964-65 was preceeded by an abundance distribution similar to that of 1966-67. About the real further development of phytoplankton along the transect in 1966-67 (which theoretically would reach a similar state than in 1964-65) we know nothing; on the contrary, in the Breid Bay, we observed, by time of leaving, the establishment of new winter conditions (freezing of the pack and formation of new ice), which means that phytoplankton will again met with infavourable conditions without having proceeded through a maximum bulk. It would lead to the idea of the existence of "poor" and "rich" years.

Assuming the sequence 1966-67 toward 1964-65 corresponds with the progression of the summer establishment, we shall discuss, in the present chapter, for some species, the seasonal variation of their bulk.

This of course is not to be taken in a too strict sence : the development of populations is related to the hydrological, meteorological or other measurable factors, but it depends also on historical events. Consequently, a population state is the result of an historical evolution and a response to the milieu. The present study will deal with the most abundant and most characteristic species. Only species recorded in appreciable quantity can be considered here, because, the error of estimation on the quantity increases as species are less abundant. Nitzschia is, by far, the most dominant genera. This genus is followed in importance by Chaetoceros, under which the subgenus hyalochaetae is the most representative with Chaetoceros atlanticus, Chaetoceros dichaeta and Chaetoceros neglectus. Typical for the Southern Ocean are a series of Fragilariopsis species among which Fragilariopsis kerguelensis, Fragilariopsis curta, Fragilariopsis cylindrus, Fragilariopsis "nana" (Frag. pseudonana and Frag. cylindrus fo. minor) are the most abundant. Other species are locally abundant like : Eucampia balaustium, Biddulphia, Charcotia actinochylus, Coscinodiscus.... Sometimes in very great abundance are Corethron criophilum and Chaetoceros criophilus. Other species are frequently represented, but in less quantity like Rhizosolenia Chunii, Rhizosolenia styliformis, Navicula species.... The next discussion will deal with the following species : Nitzschia gr. Pseudonitzschia

(Nitzschia bicapitata)

(Nitzschia turgidula)

(Nitzschia stellata)

(Nitzschia "closterioides")

Chaetoceros atlanticus

Chaetoceros neglectus

Chaetoceros criophilus

Corethron criophilum

Fragilariopsis kerguelensis

Fragilariopsis curta

Fragilariopsis "nana"

Eucampia balaustium

Biddulphia weissflogii

NITZSCHIA Hass.

The Nitzschia species are quite difficult to determine. The very complete revision of the genus made by Rytter Hasle (1964-65) is an enormous step in the knowledge of the characteristics of this genus. It shows by the same time that the determination of Nitzschia species requires, at least for some of them, exceptional clear preparations. In her work on antarctic phytoplankton, the author of this revision indicate at several occasions, that the determination of some species is impossible with the inverted microscope. Most of previous literature on the Southern Ocean do refer to Nitzschia seriata and Nitzschia

delicatissima as dominant species. These two species were found by R. Hasle not to occur in the Antarctic Waters. To avoid any mistake and because of the difficulties encountered, we determined, with the inverted microscope only the genus Nitzschia to the level of the group Pseudonitzschia for the species N. heimii, N. turgidula, N. barkleyi. In the Nitzschia gr. Nitzschiella we could recognize N. closterium and N. "closterioides". In the Nitzschia gr. Lanceolatae we could determine N. bicapitata and N. stellata

Nitzschia gr. Pseudonitzschia.

Figures 38A and 38B give the quantitative distribution of the N. gr. Pseudonitzschia for 1966-67 and 1964-65 respectively. These figures represent a summation of results for different species and consequently allow only to deduce generalities about the genus. In both cases (1964-65 and 1966-67), the contribution of the Nitzschia gr. Pseudonitzschia is important in the total phytoplankton bulk. The total quantity and the percentage of this group is higher in 1966-67 than in 1964-65, in the Subantarctic zone as well as in the Antarctic zone and in the very south. This incline us to think that N. gr. Pseudonitzschia, considered as a whole, develops in the early stage of the bulk increase, with the beginning of the summer season.

- In the Subtropical Convergence zone, N. gr. Pseudonitzschia is present in 1966-67 as well as in 1964-65 in a very great

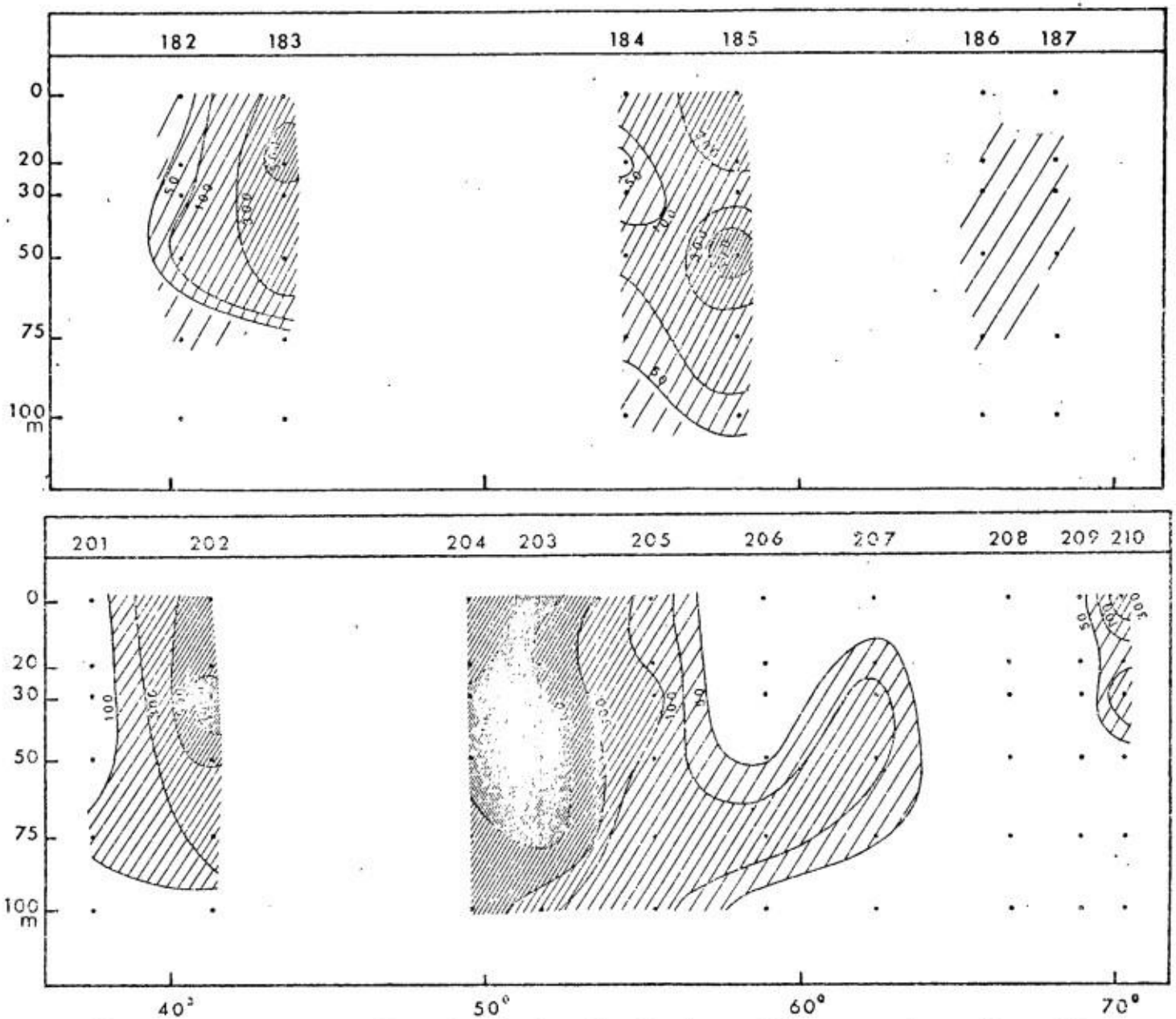


Fig. 38: Distribution of Nitzschia gr. Pseudonitzschia Numbers $\times 10^2$ correspond to cells per liter.

	182	183	184	185	186	187
0	.5	.30	.26	.13	.	.+
20	.9	.39	.13	.9	.3	.2
30	.	.27	.10	.14	.1	.2
50	.27	.44	.25	.13	.2	.7
75	.26	.	.17	.15	.7	.6
100 m	.+	.+	.8	.20	.23	.
II	17	63	6	29	12	9

	201	202	204	203	205	206	207	208	209	210
0	.21	.54	.88	.37	.14	.0,5	.13	.7	.5	.8,7
20	.17	.37	.35	.24	.15	.29	.9	.5	.	.17
30	.14	.52	.14	.	.49	.6	.35	.	.	.
50	.12	.64	.33	.36	.34	.	.33	.	.	.
75	.23	.11	.32	.39	.35	.18	.29	.	.	.
100 m	.17	.22	.25	.23	.13	.	.	.	.	.
II	33	54	42	39	10	9	2	9	9	22

40° 50° 60° 70°

Table XXXVII: Relative abundance; numbers correspond to percentages of Nitzschia or Pseudonitzschia along the transect (1964-65 – 1966-67). Water bottle samples (I) and net samples (II).

proportion (see percentages on Table XXXVII), but in less quantity than south of the Antarctic Convergence. Fukase (1962) recorded the highest percentage of Nitzschia "seriata" near the Subtropical Convergence in December, while it was a little displaced in February, although still in the Subantarctic waters. Rytter Hasle also found great quantities of Nitzschia heimii and Nitzschia barkleyi (both belonging to the gr. Pseudonitzschia) in the Subantarctic waters. If the very high percentage of Nitzschia gr. Pseudonitzschia in this zone was verified over long periods and in different sectors, with the same method, it could perhaps be an interesting characteristic of the Subantarctic waters.

- In the Antarctic zone, the high quantities of N. gr. Pseudonitzschia correspond to the main bulk increase (St. 203-204-185), what means that this species group is linked to the factors of main growth. This is also confirmed by the high quantities recorded in the far south (St. 210) were N. gr. Pseudonitzschia is present up to 37.000 cells per liter. Also in the inshore waters, the species is present in high quantities, just after the melting of the ice(see Tables XXXIV and XXXV). In the north Antarctic Waters (north of the Antarctic Divergence) Nitzschia gr. Pseudonitzschia follows the southward displacement of the main phytoplankton bulk with a decrease in quantity and in relative importance.

Nitzschia bicapitata Cl.- Nitzschia turgidula Hust.

Nitzschia bicapitata and Nitzschia turgidula (see Table LI) were regulary recorded in net and bottle samples only in the waters north of the Antarctic Convergence. This is in complete agreement with the findings of R. Hasle; Kozlova (1966) found on the contrary, N. bicapitata south of the Antarctic Divergence and N. turgidula south of the Antarctic Convergence.

Nitzschia stellata Manguin.

N. stellata was described by Manguin (1960) in mud samples from cap Margerie and also recorded by this author in few quantities in plankton samples from the coast of Adelie land. This species, very peculiar by its starformed colonies, was found by us to be abundant in ice samples (Table XXXVI) and plankton net samples from the Breid Bay, but in less quantity in Nansen bottles samples from the same area. Nitzschia stellata was not recorded outside the inshore waters. As already dicussed previously, we do consider Nitzschia stellata as belonging to the ice flora and being unable to persist as planktonic species when released from the melted ice. The species was only mentioned by Fukushima and Meguro (1966) as released from the ice habitat in south oceanic areas.

Nitzschia "closterioides"

Poorly represented in 1966-67, in the Bay as well as along the transect (except St. 210) it makes about 10 to 20 % of the bulk in the Bay and in the southern part of the Antarctic Waters in 1964-65. We did not recorded the species in the ice samples as did R. Hasle.

The quantitative studies on Nitzschia species given by the literature are not comparable with our results, essentially because the determination difficulties. Hart (1942) considered N. seriata as the main species, convinced that all the different forms were in reality belonging to the same species. Kozlova (1966) reports the presence of N. barkleyi but does not mention N. heimii.

Further investigations are needed concerning the quantitative distribution of the different species of the genus Nitzschia, especially because they seem to be linked to the main bulk increase. The fact that the species are minute forms make them a good prey for zooplankton. Hustedt (1952) reports in his conclusion that "die Fragilariopsisen Arten bilden daher auch mit einigen Nitzschien die wesentlichste Nahrungsquelle der untersuchten Tiere...."

CHAETOCEROS ATLANTICUS Cleve

Chaetoceros atlanticus occurs under different varieties. Chaetoceros var. neapolitana (Schrôd) Hust. was found in the Subtropical and northern Subantarctic Waters and will not be considered in this analysis. In the south Subantarctic and Antarctic waters it is the type variety which represent the species. Fig. 39A and B gives, for both expeditions, the quantitative distribution of the species along the Antarctic transect. Table XXXVIII gives the corresponding relative abundances (percentages).

In 1966-67, Chaetoceros atlanticus is extremely abundant just south of the Antarctic Convergence with a marked maximum at station 203 (129 x 10^3 cells per liter) where it represents about 30 % of the total phytoplankton bulk. The maxima are located at 0,10 and 50 meter for station 204, 203 and 205, respectively. No specimen were found in appreciable quantity in the southern part of the section, as well as in the Bay. During the 1964-65 cruise, the total abundance of the species is less than in 1966-67. It must be pointed out that the large phytoplankton bulk at station 185, gives a lower percentage of Chaetoceros atlanticus at station 184, where the quantity of this species is less important. Also in this expedition the species does not occur in the southern part of the section (only a few specimen at 75 and 30 meter).

From the above figures it can be deduced that the main bulk of Chaetoceros atlanticus appears during the

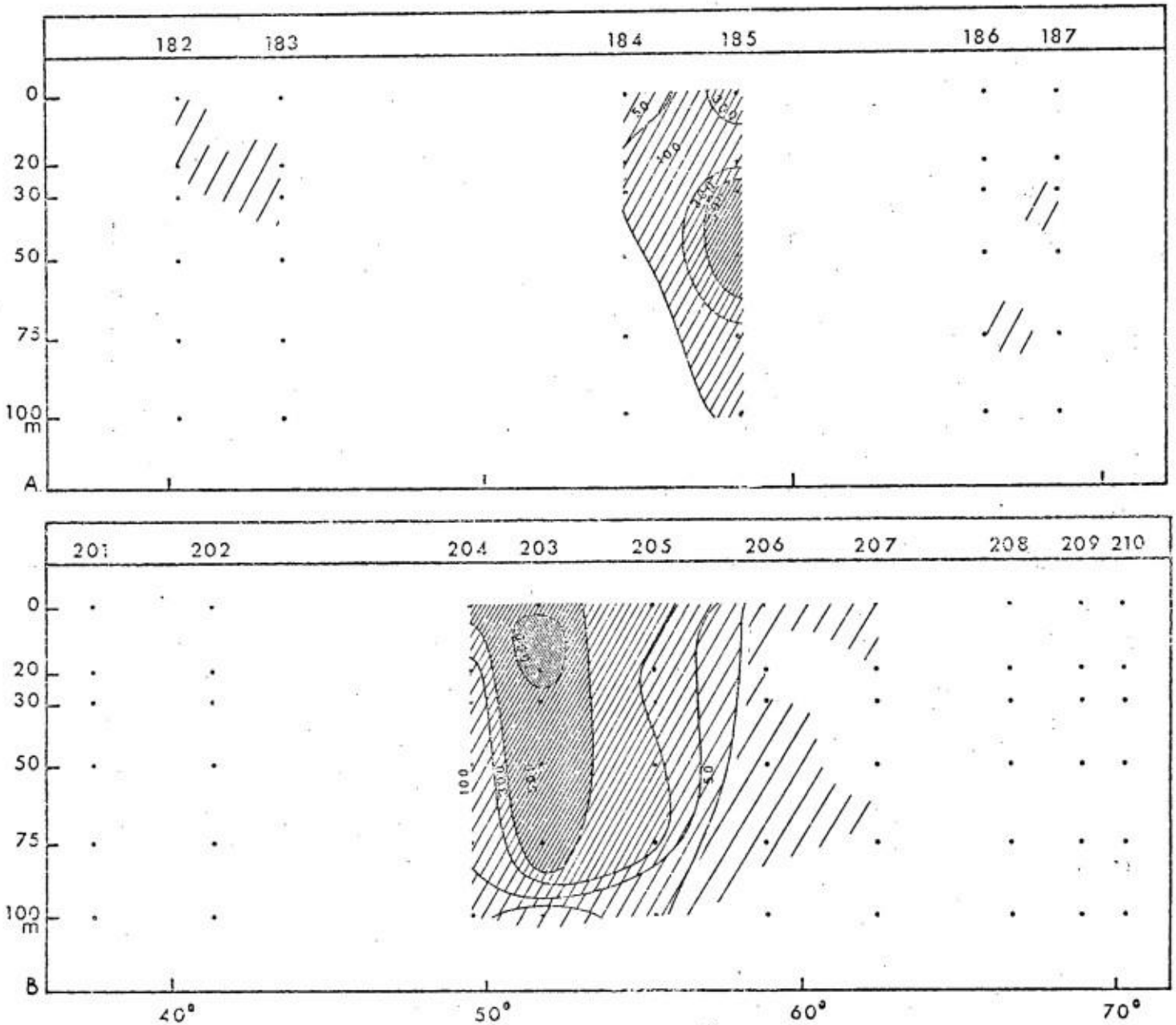


Fig. 39: Distribution of Chaetoceros atlanticus. Numbers x 10^2 correspond to cells per liter.

	182	183	184	185	186	187
0	.	.	.14	.10	.0	.0
20	.	.	.30	.6	.0	.0
30	.	.	.20	.6	.0	.1
50	.	.	.19	.13	.0	.0
75	.	.	.17	.10	.3	.0
100 m	.	.	.13	.22	.0	.
I						
II			9	3	0,4	0

A

	201	202	204	203	205	206	207	208	209	210
0	.	.	.24	.31	.38	.2	.+	.0	.0	.0
20	.	.	.11	.32	.12	.0	.4	.0	.0	.0
30	.	.	.7	.	.19	.+	.0	.	.0	.0
50	.	.	.5	.23	.34	.+	.0	.0	.0	.0
75	.	.	.10	.23	.20	.+	.08	.0	.0	.0
100 m	.	.	.3	.5	.13	.	.	.0	.0	.0
I										
II			6	.18	25	4	2	0	0	0

B

40° 50° 60° 70°

Table XXXVIII: Relative abundance; numbers correspond to percentages of Chaetoceros atlanticus (1964-65 – 1966-67). Water bottle samples(I) end net samples (II).

early phase of the main increase of the phytoplankton bloom, just south of the Antarctic Convergence. At that time, the species is present at the Convergence throughout the whole 100 m water column, but with a marked maximum in the 0-20 meter level. With the evolution to more summer conditions, the maximum bulk of the species is displaced southwards, but decreases in quantity and is situated at a greater depth (50 m). In no cases this species was found in the far south or in the inshore waters, at this time of the year.

The location of Chaetoceros atlanticus in the northern Antarctic Waters is reported by several authors (Fukase, 1962 - Beklemishev,1958 - Marumo,1957 - Fukase and El-Sayed, 1965 - Rytter Hasle,1969). Kozlova (1966) reports an exceptional richness of Chaetoceros atlanticus along the 20°E compared to the Indian and Pacific sectors. From our results, which demonstrate the rapid diminution with the progress of the summer season - confirmed by R.Hasle who described the maximum bulk of the species from mid-December to end January - we do think that the length of the period of the year during which Chaetoceros atlanticus has its maximum bulk, is very important. This fact is perhaps to be related with the results of Kozlova who integrated the results for the whole Indian and Pacific area, from November till December, while the 20th E longitude was only investigated during a short period. In contradiction to our results are those of Hart (1942) who found the greatest abundance of Chaetoceros atlanticus during the postmaximal decrease of the main bulk in autumn (results expressed in rela-

tion abundances of net haul samples).

CHAETOCEROS NEGLECTUS Karsten

Chaetoceros neglectus is a very minute form that has probably been confused with the smallest phases of Chaetoceros dichaeta in the past (Hart, 1942, p291) (Hustedt, 1958). Its distribution seems most likely to be the Southern Ocean, although Hendey (1937) recorded it near the South African coast. If most of the authors agree on its wide distribution and frequent occurence, even in very large amounts, the most diverse figures are given about the distribution pattern of the species. Hart (1942) and Kozlova (1966) consider the species as a neretic and coastal form; R.Hasle found a maximum abundance near the Convergence (897.000 cells/liter), while Fukase (1962) recorded a maximum before the pack ice belt.

Figure 40 and Table XXXIX report the results we obtained for the both expeditions. In 1966-67 a maximum was recorded at St. 204 and an other at St. 210 individuals were found in the Bay. In 1964-65, a maximum was found at St. 185 and large quantities were recorded at all stations in the Breid Bay with a maximum of 899.000 cells per liter at station 197 (Table XXXIX A). Comparing Fig. 40 with Fig. 41 a perfect correspondance is evident between the amin increase of the total phytoplankton and the maximum quantities

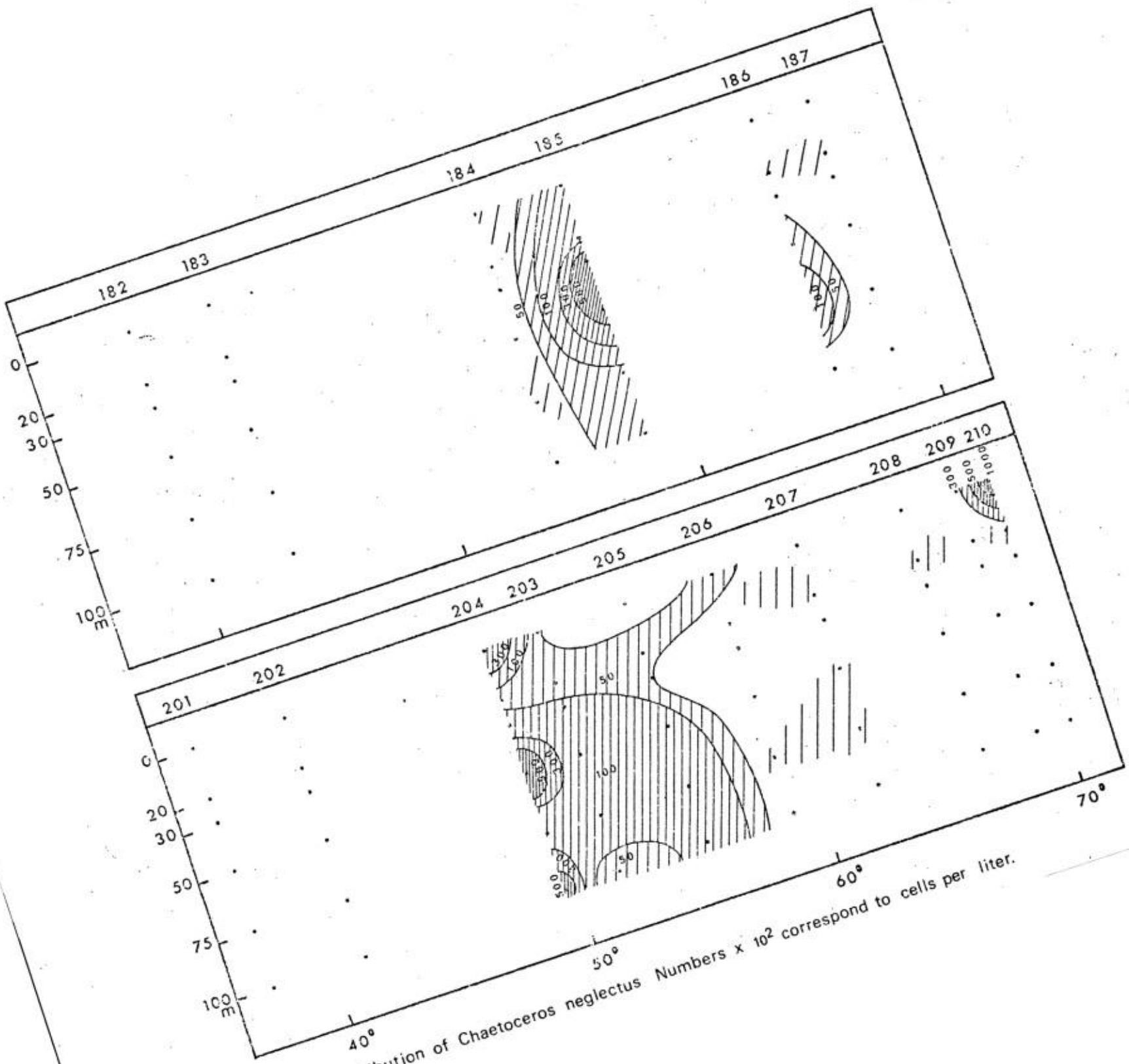


Fig.40: Distribution of Chaetoceros neglectus Numbers x 10^2 correspond to cells per liter.

Sta: (1964-65)

10^2 x cells per liter	188	189	190	192	194	196	197
0	0	0	95	13	39	206	163
20	18	8	82	113	175	124	173
30	27	36		111	49	173	899
50	9	22	61	60	215	310	138
75	21	0	19	37	61		59
100	9	24	25	16	4	37	76
% cells (water bottle samples)							
0	0	0	1.2	0.2	0.7	10	4
20	0.3	0.07	0.6	1.3	1.2	3.3	5
30	0.5	0.4		1.4	0.5	3.3	10
50	0.2	0.2	0.6	1.6	2	13	11
75	0.3	0	0.9	2.7	0.9		5
00	0.7	1.1	1.3	1.1	0.2	3.1	10

Table XXXIX : Distribution of Chaetoceros neglectus in Breid Bay (cells per liter x 10^2 and percentage) Cruise 1964-65

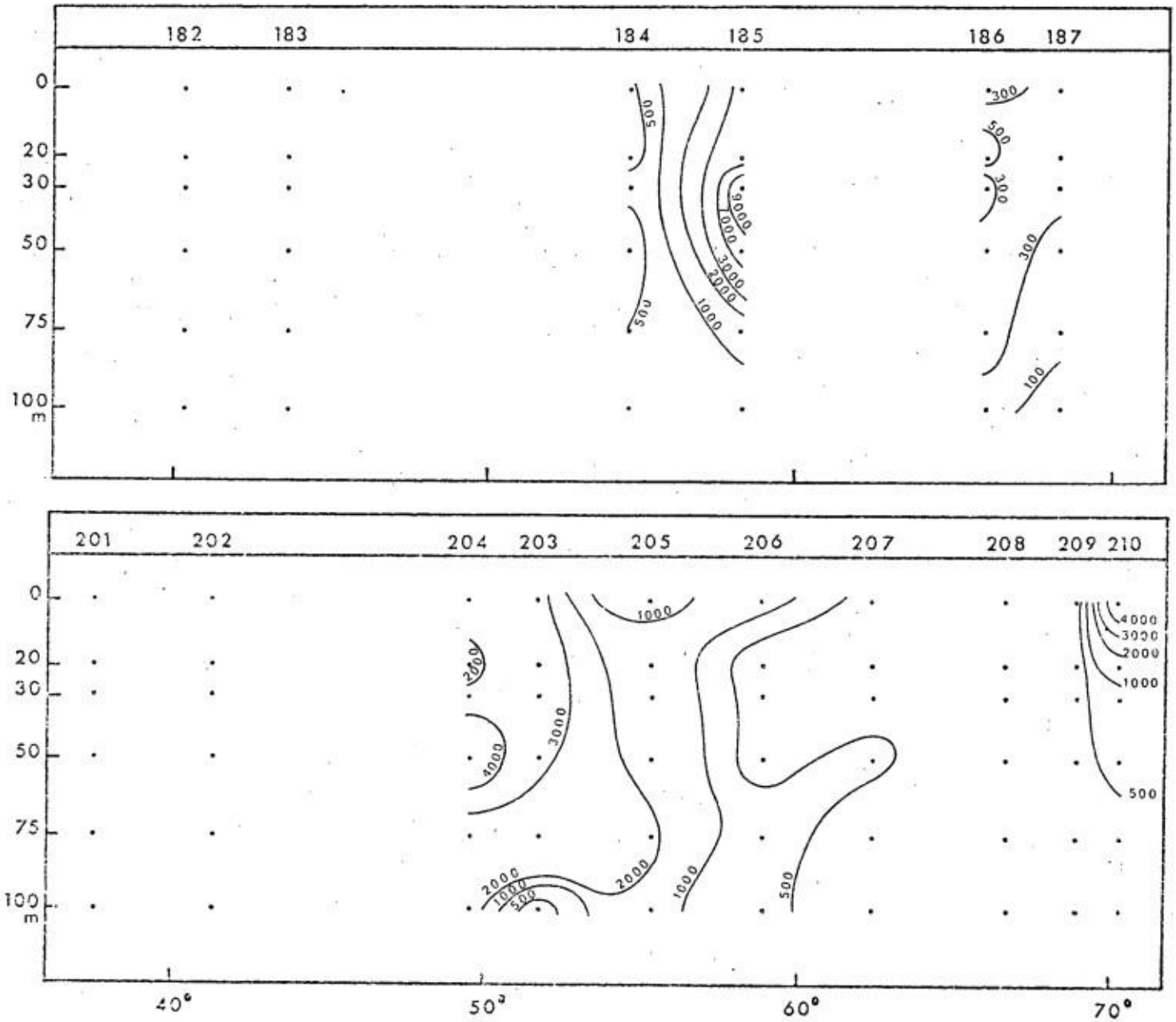


Fig. 41: Distribution of total Diatom cell numbers per liter along the transect (numbers $\times 10^2$ = cells per liter).

of the species Chaetoceros neglectus recorded. Consequently we do consider Chaetoceros neglectus as a species linked to the first stage of main phytoplankton increase and characterized by a considerable development within a short time period and a rapid decline after its main increase (this last statement was also reported by Hart, 1942 and Rytter Hasle, 1969). From our results appears that Chaetoceros neglectus is neither a inshore water or coastal species, nor a typical oceanic species, but could better be described as a pioneer active producer, present in the whole Antarctic Ocean, in great number where a high phytoplankton development takes place. This could probably explain the differences in distribution pattern recorded in the literature.

CHAETOCEROS CRIOPHILUS Castr.

First described by Castracane, Chaetoceros criophilus, was distinguished from a very similar species Chaetoceros concavicornis, by Manguin; this last one is an arctic species, while Chaetoceros criophilus is an antarctic species. Chaetoceros criophilus is many times considered as one of the most widespread and abundant of all the Antarctic Diatoms (Hart, 1934). Dense concentrations of the species are also reported by Hustedt (1956); Manguin (1960) Fukase and El-Sayed (1965). The maximum recorded cell number we found was only 10.000 cells/liter (St.205); Rytter Hasle (1969) reports a maximum of 5.500 cells/liter. These figures demonstrate that in

water samples, concentrated by sedimentation, "Chaetoceros criophilus, is greatly exceeded by smaller species" (R.Hasle p.143) and is not so important as stated by authors who worked with net samples.

With Nansen bottle samples, the highest quantity of Chaetoceros criophilus was observed in 1966-67 south of the Antarctic Convergence (St. 205) between 55°S and 60°S; only sporadic specimen were found north of these latitudes. In 1964-65, the maximum quantity is recorded at St. 186 but is half of that recorded in 1966-67. For both years, no specimen were found in the inshore waters, excepted a few at St. 217,218,219. From the results related in Fig. 42 Chaetoceros criophilus is mainly restricted between the Antarctic Convergence and the Antarctic Divergence (?), which corroborate the findings of Hustedt who found it most abundant between 53°S and 61°S. In opposition to Hart's statement about "the doubtless greatest abundance at peak of main increase", we did find the maximum abundance of Chaetoceros criophilus not to coincide with the main phytoplankton bulk (St. 203, 204,185). Except some dense concentrations (St. 205-0m, St. 186-30 m), the relative abundance of Chaetoceros criophilus (Table XL) is inferior to 10 % and in many cases inferior to 5 %. With net hauls, on the contrary, the species was present in the highest quantity just south of the Antarctic Divergence: 53 % at St. 208 and 78 % at a station on the return cruise (68°S-22°E) in 1964-65.

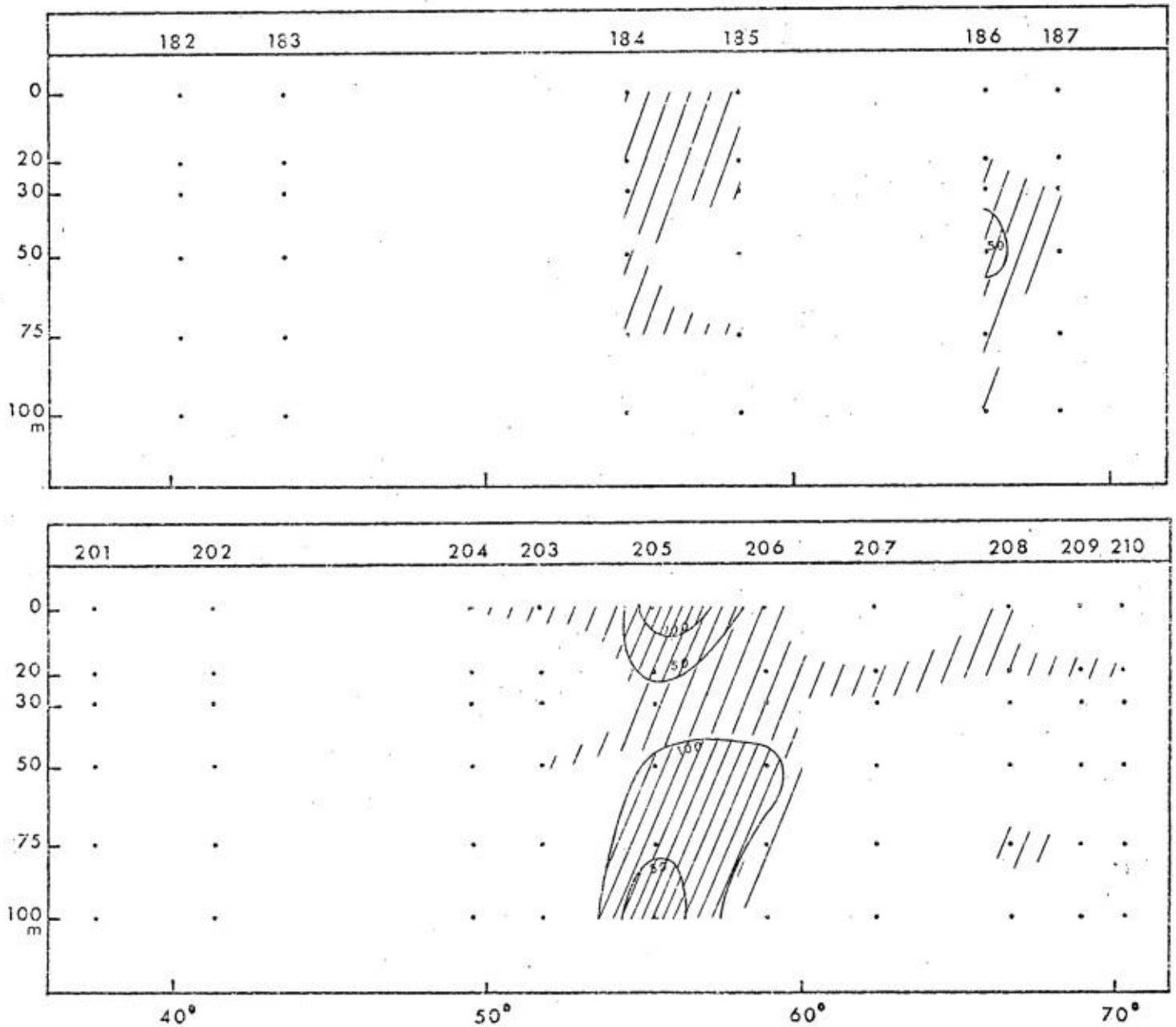


Fig. 42: Distribution of Chaetoceros criophilus. Numbers x10^2 correspond to cells per liter.

	182	183	184	185	186	187
0	.	.	.3,4	.0,2	.0	.0
20	.	.	.3	.0,3	.2,5	.0
30	.	.	.3	.	.16	.1,4
50	.	.	.7	.	.10	.6
75	.	.	.3	.	.1,2	.0
100 m	.	.	.	.	.1	.0
I						
II			35,6	0,2	3	34

	201	202	204	203	205	206	207	208	209	210
0	.	.	.+	.+	.12	.2	.0	.7	.0	.0
20	.	.	.0	.0	.4,6	.28	.0,6	.2	.+	.+
30	.	.	.0	.0	.1	.9	.2,6	.	.0	.
50	.	.	.0	.+	.6,5	.35	.0	.0	.0	.0
75	.	.	.0	.0	.5	.7	.0	.14	.+	.
100 m	.	.	.35?	.	.9	.	.	.	.	.0
I										
II					14,6	12,6	5,4	52,8	2,8	

40° 50° 60° 70°

Table XL: Relative abundance: numbers correspond to percentages of Chaetoceros criophilus along the transect (1964-65 – 1966-67). Water bottle samples (I) and net samples (II).

The differences between net and water bottle samples were already discussed in previous chapters.

From the above figures, the maximum bulk of Chaetoceros criophilus seems to follow a slight southward progression with the progression of the summer conditions, together with a decrease in total quantity. Finally it has to be pointed out that, although this species is very spinous, the bristles are frequently found in Euphausia and Salpa stomach content (Hustedt); "the long strong bristles contain chloroplastids and are triturated and swallowed by some common Calanoids and Euphausians in spite of their formidable spinose armature" (Hart, 1942, p.287).

CORETHRON CRIOPHILUM Castr.

Corethron criophilum Castr. is a species comprising many forms (phases) : hystrix, inermis, hispidum, pelagicum and criophilum, of which the hystrix and inermis are present in the Southern Ocean. In the present study, no distinction was made between the different phases and the species was considered as an entity.

For both years (see Fig.43), the species was recorded all along the section, but in larger quantities in the Antarctic Waters. In 1966-67, the maximum cell number occured, using the Nansen bottle sampling, atSt.205 and 203 in the upper 20m layer. This maximum corresponds to the phytoplankton increase; but a second, weaker peak is noticable in the pack ice zone

In 1964-65, the maximum quantity of Corethron criophilum, was more southwards (St. 186-187) and did not correspond to the main phytoplankton bulk increase. In the inshore waters of the Breid Bay, Corethron criophilum was always present : in 1966-67 it reaches sometimes 10 % of the bulk; in 1964-65, on the contrary, it was never exceeding 2 % of the total phytoplankton quantity present (see Table XLII). With the net haul samples (Table XLI), as already stated before the presence of this large species, was emphasized : 49,6 % at St. 181 in 1964-65 and 23 % at St. 209 in 1966-67; in the Breid Bay the species was recorded by net haul samples in less than 1 % of the total bulk in 1964-65 (excepted St. 197) while it occured up to 45 % at the end of the investigation period in 1966-67. The particular selective effect of net on this species was already discussed previously.

Corethron criophilum might be regarded as present in the whole Antarctic sector along the 20°E with a maximum, displaced southwards and increasing with the advancing of the summer conditions. This species gives a good example of what we said in the introduction of this chapter, about the difference between relative importance and total quantity. Indeed, if in 1964-65, the maximum of the two values coincides at the same station (St. 186), on the contrary in 1966-67, the maximum quantity recorded at St. 203 does not correspond to the maximum relative value.

In the literature, the distribution patterns of Corethron criophilum are interpreted in different ways,

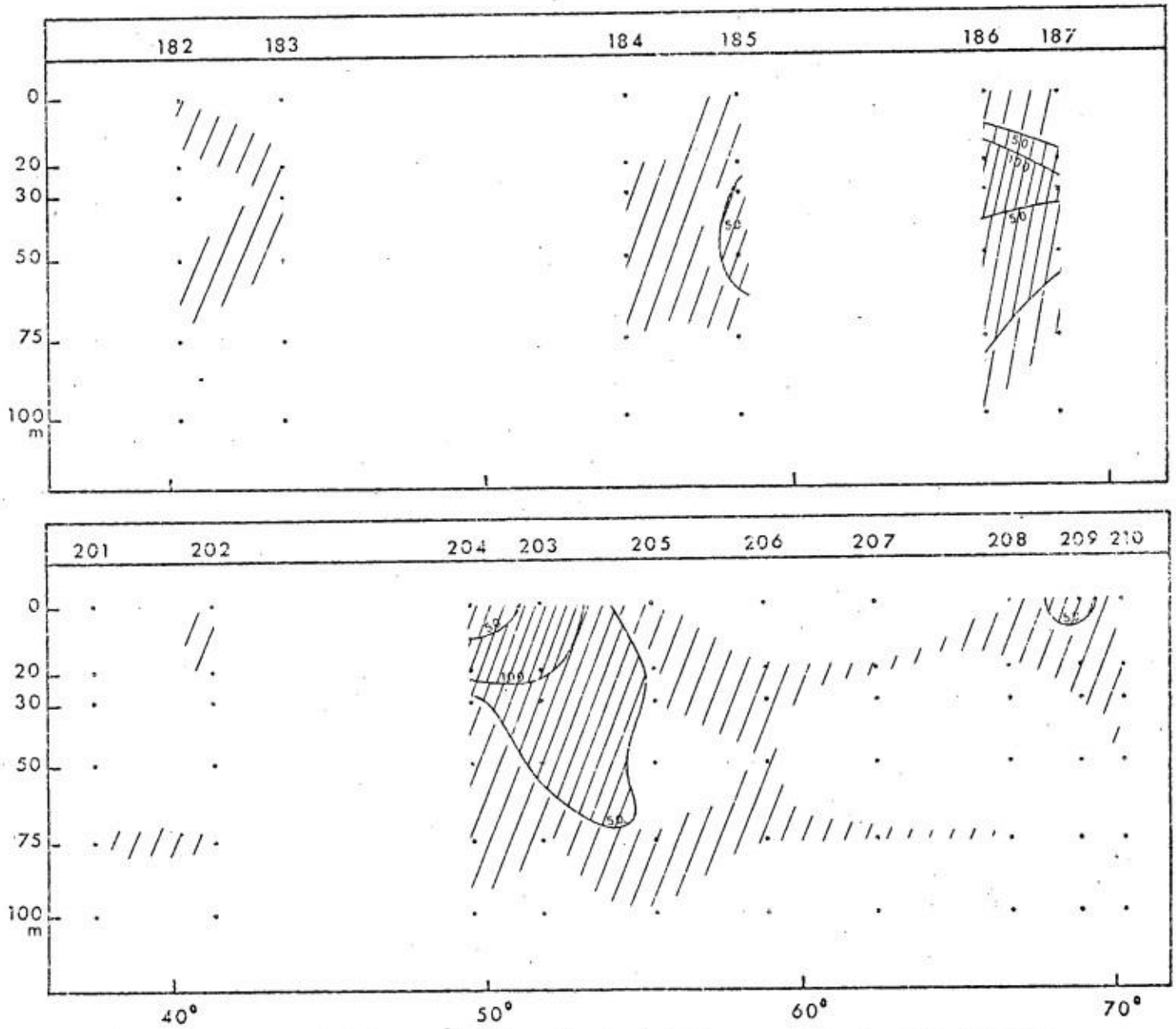


Fig. 43: Distribution of Corethron criophilum. Numbers × 10^2 correspond to cells per liter

	182	183	184	185	186	187
0	5,3	0	0	1	12	8
20	5	0,7	0	1	24	20
30		0,2	0,3	0,6	59	33
50	3,4	2	1	1	20	24
75	2,6		0,7	1,9	12	13
100 m			0	0	7	
II	0,6	0,4	2,4	0,4	0,4	49,6

	201	202	204	203	205	206	207	208	209	210
0			2,5	3,5	2			7	14	0,6
							2			
20			2,6	2,6	3,5	25	5	5	12	5
30			0,7		1	2,3	0			
50			0,9	2,0		4	0	0	0	
75			1,3	1,2	2,3	2	0,8	3	0	
100 m			1,3		2,3			0		
II		0,2	+	0,8	1	7,8	3	10	23	10

40° 50° 60° 70°

Table XLI: Relative abundance: numbers correspond to percentages of Corethron criophilum along the transect (1964-65 1966-67). Water bottle samples(I) and net samples(II).

Stat. 1964-65	188	189	190	192	194	196	197
Cells per liter (x 10^2)							
0	.0	.22	.0	.13	.13	.8	.0
20	.11	.0	.34	.7	.37	.5	.26
30	.4	.4	.17	.8	.16	.4	.17
50	.34	.0	.28	.9	.17	.0	.0
75	.8	.4	.0	.4	.4	.	.0
100 m	.8	.4	.8	.0	.0	.0	.0
% of cells (water bottle samples)							
0	.	0.2.	.	.	.	0.4.	.
20	0.2.	.	0.1.	.	0.3.	0.1.	0.8.
30	0.1.	0.04.	0.1.	.	0.2.	0.1.	0.2.
50	0.1.	.	0.2.	.	0.2.	.	.
75	0.1.	0.1.	0.3.	.	0.06.	.	.
100 m	0.7.	0.2.	.	.	.	.	.

Table XLII : Distribution of Corethron criophilum in Breid Bay (cells per liter x 10^2 and percentages) Cruise 1964-65.

probably partly due to the different methods of sampling and different ways of expressing the results. Fukase (1962) report for the Western Indian ocean sector, a relative abundance of 9 % with an increase to 10 to 30 % towards the south. Kozlova, on the contrary, found the species not exceeding 1,4 % along the 20°E, in open waters, and less than 0,1 % in the coastal waters of the same section. Beklemishev (1964) considered Corethron criophilum as restricted to the area between the Antarctic Divergence and the Antarctic Convergence, while Hart (1942) found it, although widely distributed, mostly in neretic areas. The only results which, to the best of our knowledge are perfectly comparable with ours, because of the same methodology, are those of R.Hasle in the Western Pacific; these results are indeed, similar to ours : they show a southward displacement of the bulk in function of time and a increasing maximum to 10.000 to 36.000 cells/liter (we did found a maximum of 27.900 cells/liter) between 65° and 68°S.

FRAGILARIOPSIS Hust.

The genus Fragilariopsis Hust. belongs to the family of the Nitzschiaceae and is closely related to Nitzschia gr. Pseudonitzschia. In fact, the differences between Nitzschia and Fragilariopsis are more indicative of a transition and a close relationship between two groups of a genus rather than a distinction between two genera (R.Hasle,1965

p.7). The Fragilariopsis genus is essentially characterized by a reduction of the canal raphe, the tendency towards a heteropole apical axis and the formation of ribbonlike colonies. The determination of the species is based on the valvar shape, the structure of the intercoastal membrane, the number of coastae, the presence of poroids.., all characteristics which can only be distinguished on the valve side of the individuals (sometimes only with an electron microscope). The determination difficulties in addition to the frequent occurence of ribbon-like shaped colonies, make the distinction of a lot of different species with the inverted microscope impossible. With net sample preparations we could determine, in the Antarctic sector we investigated, the following species : Fragilariopsis curta, Fragilariopsis kerguelensis, Fragilariopsis cylindrus, Fragilariopsis linearis, Fragilariopsis cylindrus fo. minor, Fragilariopsis rhombica, Fragilariopsis separanda, Fragilariopsis pseudonana, Fragilariopsis ritscheri, Fragilariopsis Van Heurckii, Fragilariopsis sublinearis, Fragilariopsis oblique-costata. The most abundant of those were : Fragilariopsis kerguelensis, Fragilariopsis curta and Fragilariopsis "nana" (comprising Frag. pseudonana and Frag. cylindrus fo. minor).

FRAGILARIOPSIS KERGUELENSIS (O'Meara) Hust.

Fragilariopsis kerguelensis, synonym of Fragilariopsis antarctica, is characterized by strong silicified frustules, which are very resistant and which "are

the most plentiful recognizable remains in the stomachs of herbivorous zooplankton, in diatomaceous oozes and muds, and in the guano of carcinophagous birds" (Hart,1942,p.286). Hustedt (1958), considered the species as an important element in the feeding of Euphausia and Salpa.

Fragilariopsis kerguelensis was found to be widespread during the two expeditions, throughout the whole Antarctic Waters, from north of the Antarctic Convergence until the coastal region. In 1966-67, the maximum quantity of Fragilariopsis kerguelensis was found (with Nansen bottles) at St. 204 and 203, near the Antarctic Convergence, while in 1964-65, it was found in increased quantity more southwards at St. 185. In both cases the maximum bulk of Fragilariopsis kerguelensis coincides with the main phytoplankton bulk (Fig. 44). The species was not found in the inshore waters of the Breid Bay in 1966-67 and was only scarcely represented by solitary forms in 1964-65. We did not find it in ice samples.

From our results it seems that Fragilariopsis kerguelensis is linked to the main bulk increase and follows this one in its southward displacement and increasing. Its very rare presence in the very south lead to the idea that the species is an open oceanic species. This idea is confirmed by the literature (Kozlova(1966), Hart (1942,1934), Marumo (1957), Ivanov (1959)). Fukase (1962) found it in the greatest quantity in the surface waters of the Western Indian Ocean sector near 65°S and in the greatest proportion (52,3 %) near the coast of Enderby Land (but he does not

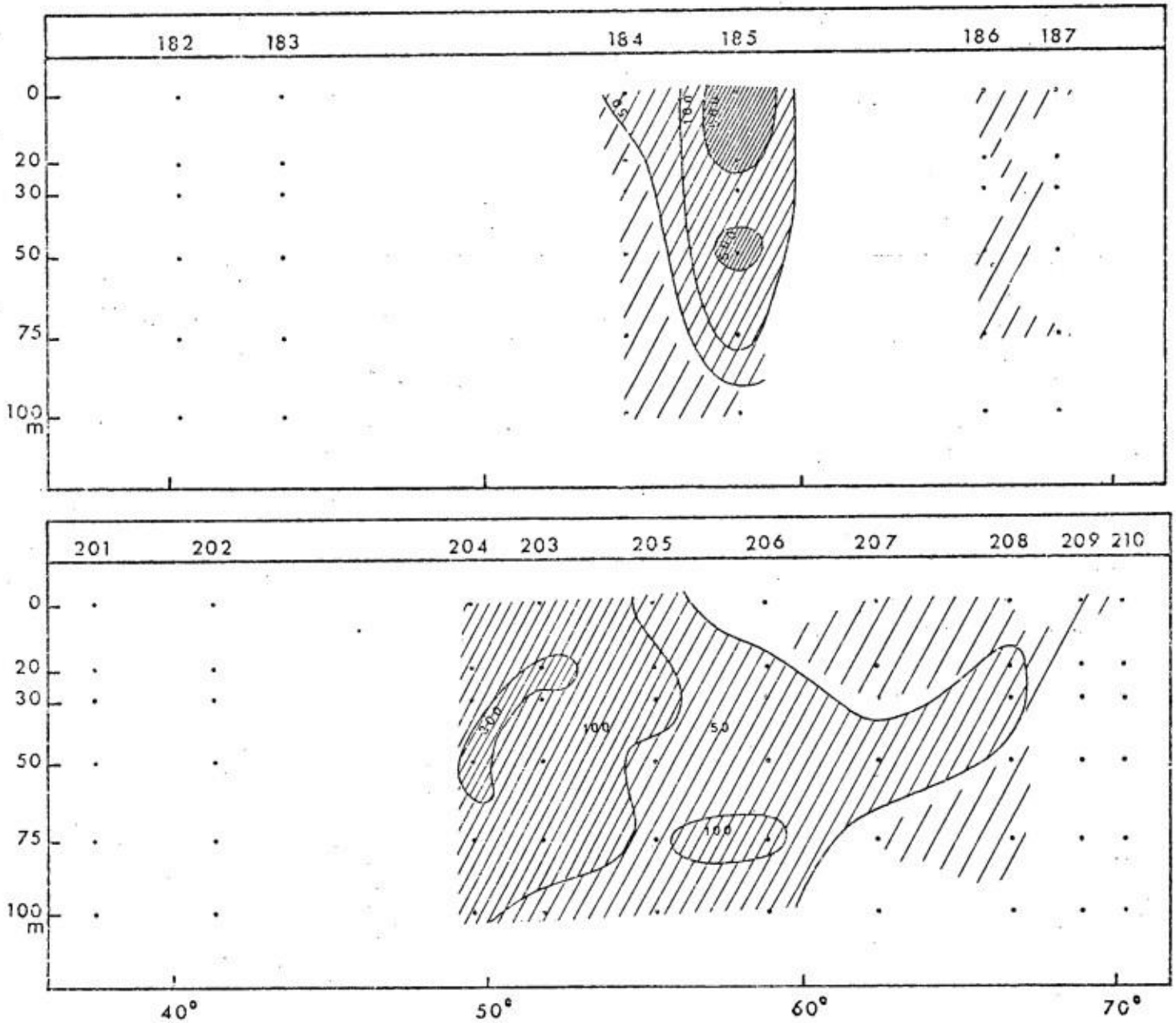


Fig. 44: Distribution of Fragilariopsis kerguelensis, Numbers x 10^2 correspond to cells per liter.

mention the species Fragilariopsis curta; perhaps he considered them together).

FRAGILARIOPSIS CURTA (Van Heurck.) Hust.

Although present at all stations of the Antarctic Ocean south of the Convergence, Fragilariopsis curta (Fig.45) has a dominant bulk in the southern zone and in the inshore waters. In 1966-67, the main quantity of the species is recorded at St.210 and 209 in the surface layer, while in 1964-65 a maximum is recorded at St.185 at the 50 and 75 m level. In the Breid Bay, the quantity of Fragilariopsis curta recorded in 1966-67 is very low because of the general poverty of the Diatom standing stock; nevertheless it was present in all the samples. On the contrary, the quantities found in the Bay during 1964-65 were extremely large (Table XLIII) with a maximum reaching 800.000 cells/liter which corresponds to 50-75 % of the total Diatom bulk. In the ice, Fragilariopsis curta was found either in 1964-65 and in 1966-67, but the quantities recorded were of a different order of magnitude : in 1966-67, although representing less than 1 % of the total Diatoms, Fragilariopsis curta was found up to 1.000.000 cells/liter of melted ice; in 1964-65, the mean quantity was about 200.000 cells /liter. As stated in Chapter IV we do consider Fragilariopsis curta as a species released from the ice and able to grow afterwards in open water, for a certain time.

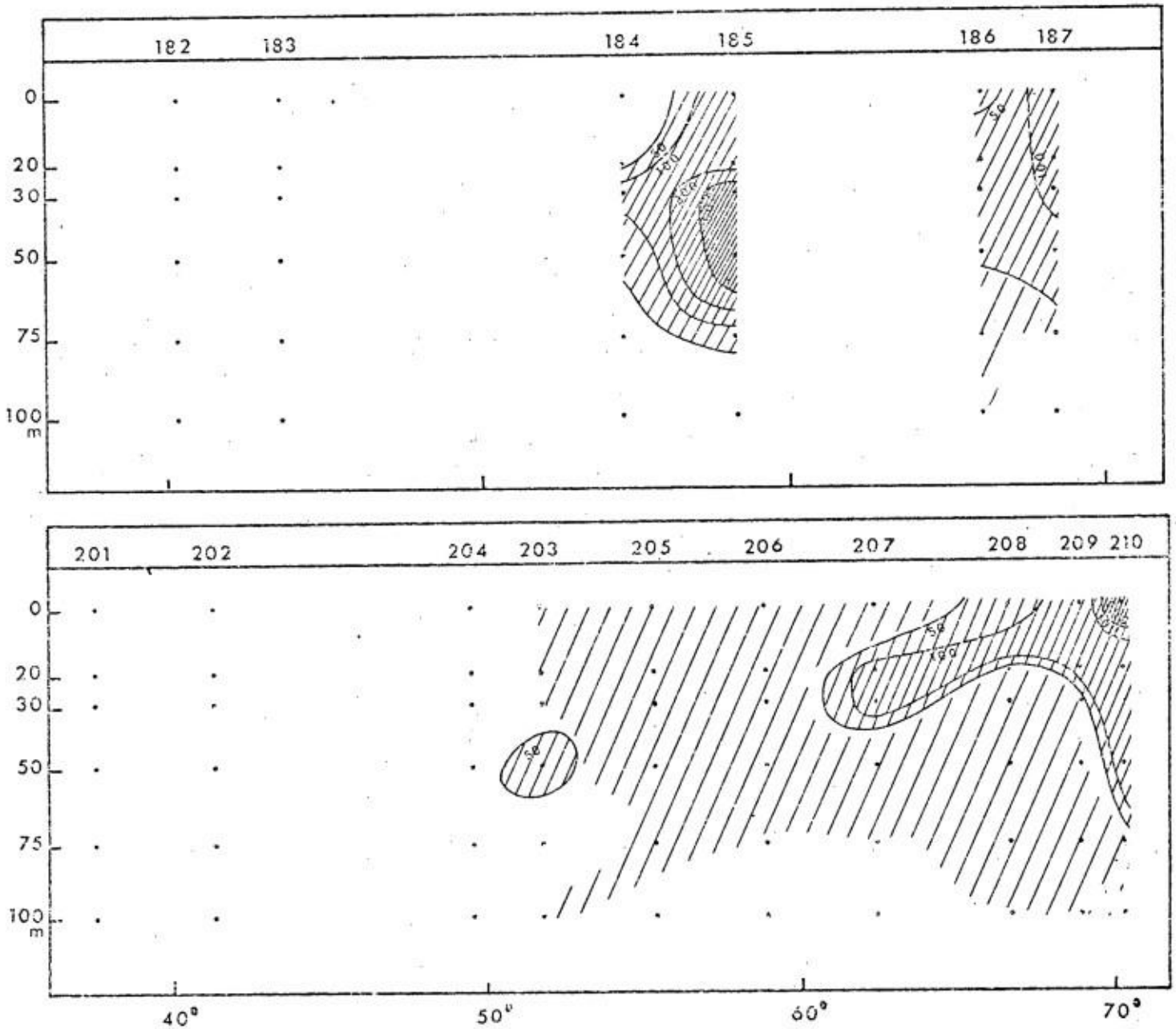


Fig.45: Distribution of Fragilariopsis curta. Numbers $\times 10^2$ correspond to cells per liter

St.	0 m	20 m	30 m	50 m	75 m	100 m
188	626 000	329 000	299 000	261 000	416 000	78 000
189	760 000	773 000	566 000	648 000	220 000	134 000
190	354 000	725 000	418 000	591 000	130 000	94 000
192	378 000	465 000	384 000	175 000	77 000	68 000
194	291 000	795 000	556 000	503 000	372 000	85 000
196	34 000	93 000	135 000	66 000	-	38 000
197	93 000	66 000	260 000	57 000	35 000	24 000

Table XLIII : cell numbers (per liter) of Fragilariopsis curta recorded in the Breid Bay during the 1964-65 cruise. Underlined : maximum cell number at each station.

It is interesting to note (Table XLIII) that the depth of maximum quantity of Fragilariopsis curta increases with time (at the surface on the 17 January it reaches the 30 meter level at the end of the month) and confirms its release from the ice. Considering this point of view, we can explain the maximum recorded at station 185 and the secundary maximum recorded at station 207 as a consequence of the melting of the pack ice edge : the difference of distances between these stations and the pack ice edge (nearer for St. 207 than for St. 185) corresponds to the differences in maximum depth (20-30 m for St. 207; 30-50 m layer for St. 185).

Although some authors recorded (Kozlova, Hustedt, Frenguelli) Fragilariopsis in few amounts as north as 40°S, all agree on its maximum occurence in the far south (Kozlova,1966 - R.Hasle,1965,1969 - Hart,1942 - Fukase and Meguro,1965). Some authors do report the presence of Fragilariopsis curta in the ice : R.Hasle (1965) found it predominant together with Fragilariopsis cylindrus in undersurface pack ice; Fukushima and Meguro (1966) recorded it as dominant in the upper ice layer; Burkholder and Mandelli (1965) encountered the species 'in moderate amounts' in the brown ice layer.

From the above statements we may conclude, that Frag. curta seems to be an "ice" species; when released from the pack ice it is able to grow or remain in suspension in the open water where it constitutes, for an important part food for the zooplankton, especially in the southern part of the Antarctic Ocean. Linked to the Antarctic Surface Waters, it follows, a northwards progression with the advancing of the summer season.

FRAGILARIOPSIS 'NANA'

The name Fragilariopsis 'nana' was attributed to little forms of Fragilariopsis, of about 3-10 μ length occuring mostly in short colonies. In fact, it included two species, one similarly shaped like Frag. rhombica and an other like Frag. cylindrus.

They were identified as Fragilariopsis pseudonana R. Hasle and Fragilariopsis cylindrus (Grun.) Helmcke and Krieger f. minor Manguin. For Fragilariopsis cylindrus f. minor, the distinction between the dwarf form and the normal form was sometimes difficult, because of the existence of intermediate sizes. In girdle view, the two species cannot be distinguished and counts with the inverted microscope will refer to both. The difficulty is increased by the fact that these dwarf forms sometimes agglutinate round mineral particles or cover Tintinnid shells in great quantity.

Figure 46 gives the quantities of Fragilariopsis 'nana' recorded in the Antarctic Waters. No distribution pattern can be given, although the 'species' occured in great quantities and made up to 52 % of the total Diatom bulk (St. 210). The only general conclusion that can be given is that, although it is widely distributed, the greatest quantities of this composite species are found in the very south where it was probably constituted mainly of Fragilariopsis cylindrus f. minor.

Excepted from R. Hasle (1969), no quantitative records, to our knowledge, are given in the literature concerning these dwarf forms, which is mainly due to the fact that they escape from the net hauls. This is the more to be regretted as their little size and their great amounts make them an easy prey for zooplankton organisms.

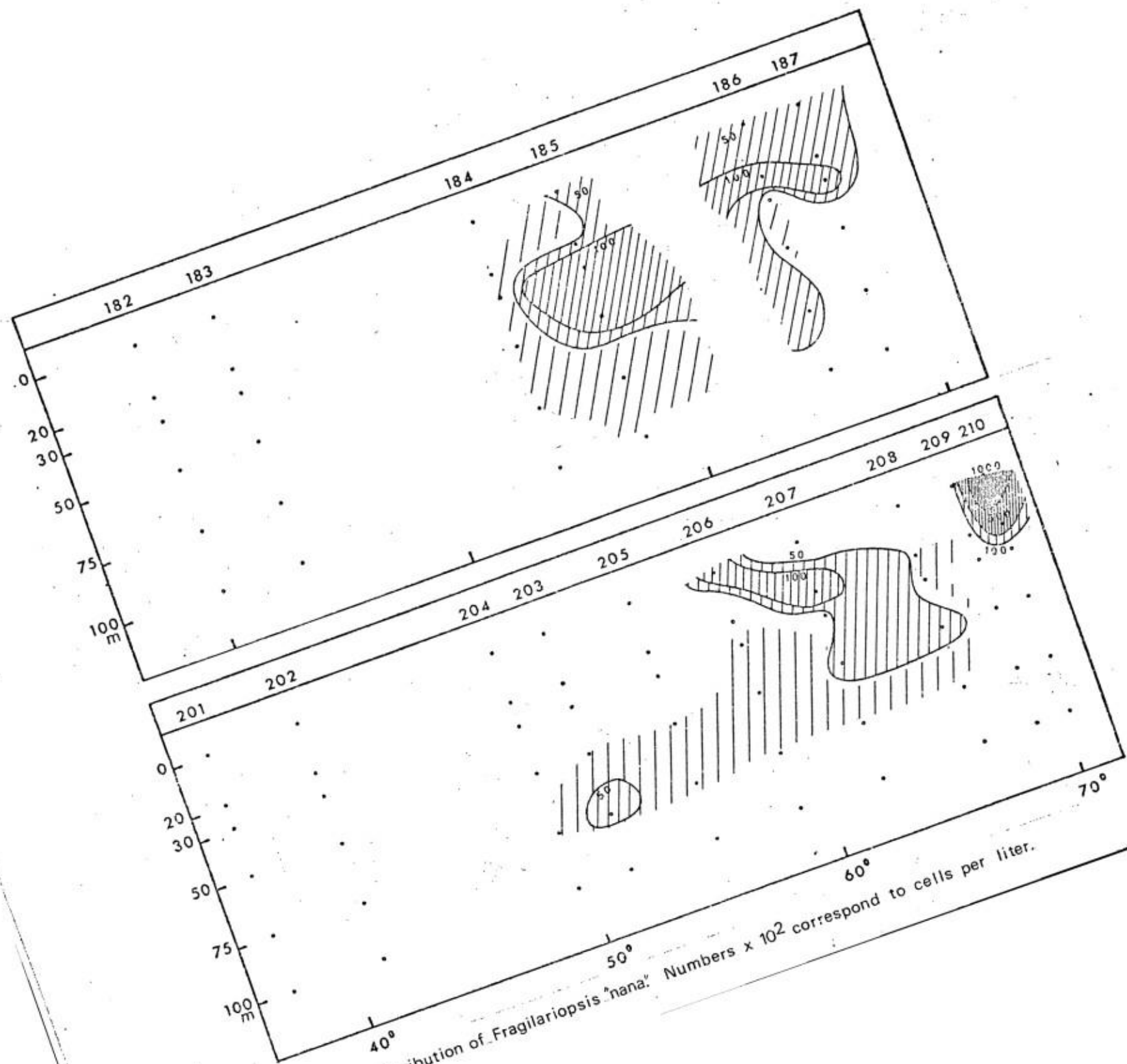


Fig. 46: Distribution of Fragilariopsis "nana". Numbers x 10^2 correspond to cells per liter.

EUCAMPIA BALAUSTIUM Castr.

Eucampia balaustium is a typical Antarctic species. It has never been recorded outside the Southern Ocean. This species was found regularly by Hustedt in the intestin of some Salpa species.

During our 1966-67 cruise we did not at all recorded Eucampia balaustium in the Transect South-Africa - Antarctica, either with the Nansen bottles, nor with the net hauls, with the exception of a very limited amount (500 to 1.500 cells per liter) at St.210, near the Bay. In the Bay itself, no specimen were found with Nansen bottles, but few percentages were recorded with net samples (0,2 to 1,2 %). In 1964-65, the species was very sporadically represented by a few individuals (maximum 500 cells/liter) only at St.185 and 187, representing 0,008 to 0,06 % and 1,4 % of the total Diatom bulk, respectively. In the Breid Bay (TableXLIV), in 1964-65, Eucampia balaustium was found in appreciable quantity, up to 13.000 cells/liter; although representing, most of the time, less than 1 % of the total Diatom bulk. In 1960-61, we recorded with net samples some sporadic specimen near the Antarctic Convergence and in the southern part of the section; in the Bay, on the contrary, we found Eucampia balaustium very abundant, making sometimes 35 % of the total bulk (net samples). From these figures it would appear that Eucampia balaustium is a neretic species, only scarcely found outside the inshore or coastal waters.

DATE : Jan - Febr.		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5
1960-61		P59			P63	P64	P66	P67	P70		P71	P73	P74			P76	P77	P78	P79	P80	P82				P83			
net		22.			25.	20.	20.	20.	20.		35.	25.	25.			3.	5.	14.	5.	4.	10.							
1964-65									188	189	190		192				194			196		197						
water bottle	0								0.3.	-.	1.4.		0.4.				1 .			1.3.		0.1.						
	20								0.4.	0.3.	0.9.		0.4.				0.4.			0.5.		2.2.						
	30								0.7.	0.8.	0.2.		0.3.				0.8.			1.7.		1.5.						
	50								1 .	0.4.	0.5.		0.2.				0.5.			0.8.		4.4.						
	75								0.4.	0.3.	1 .		0.9.				0.8.			-.		2.7.						
	100								0.7.	1 .	-.		1.4.				1.2.			0.9.		1.9.						
net									5.	8.	1 .		-.				6 .			7 .		0.4.						
1966-67													211			212		213	214	215				216	217	218	219	
net													.				04.	1.	02.	04.				04.	06.			

Table XLIV: Percentage of Eucampia balaustium. Breid Bay (1960-61 1964-65 1966-67).

This opinion is shared by some authors : Hart (1942) and Kozlova (1966). Other authors report the presence of Eucampia balaustium only in the open Antarctic Waters, either restricted to the area south of the Antarctic Convergence, or even in the Subantarctic Waters. Hasle reports a maximum quantity of 6.000 cells/liter near the Antarctic Convergence. The contradiction in the distribution pattern of the species, is perhaps only apparent. Indeed, allthe authors who did work in the high latitude inshore waters do report the abundant occurence of this species (Burkholder and Mandelli,1965; Bunt,1960), those who worked in the inshore waters and in the open ocean, on a marked dominance in the first area. Probably, the maxima recorded on basis of very low quantities in the open waters are without comparison with the quantities found in the inshore waters of high latitudes. This example emphasizes on the need of simultaneous studies of the inshore and open oceanic zones.

BIDDULPHIA WEISSFLOGII Grun. (syn. Biddulphia striata Karst.)

Although reported as occuring sometimes in large masses in neretic areas (Hart,1942), Biddulphia weissflogii was found by Hustedt only sparsely in the stomach contents of Euphausia and Salpa species. This is probably due to the big size of the species.

Except very few quantities at St. 209 and 210, we did not find Biddulphia weissflogii along the transect, neither in 1964-65, nor in 1966-67. Probably due to the very reduced quantity of phytoplankton in 1966-67 in the Bay, we did not find the species in Nansen bottles samples, although the species was present in few quantity in the net samples. During that year we did not find Biddulphia in the ice. In 1964-65, the species was recorded at all stations in the Bay, but did not exceed 2.500 cells per liter (ranging from 0,04 to 0,5 % with the Nansen bottles) (Table XLV). In the lower part of the ice, we did find Biddulphia weissflogii up to 10.000 cells per liter (1,5 to 2 % of the total Diatom population). During the 1960-61 investigation, a maximum record of 3 % was found with net hauls in the Bay, while the species was scarcely present in the ice samples and not at all in the open waters. From the above data Biddulphia seems strictly restricted to the neritic area and to start its development only with the main increase of the phytoplankton. This was also the opinion of Hart (1942) and R. Hasle (1969). The occurence of Biddulphia weissflogii in the ice samples was reported by several authors, but always in few quantity, compared to other species. This inclined us to think that Biddulphia, like Charcotia, Pleurosigma, and other big forms, are secundarely trapped in the ice and released again in the water by complete melting of the floes.

Stat. 1964-65

Cells/liter (x 10^2)	188	189	190	192	194	196	197
0	•	.22	.25	.13	•	•	.9
20	.11	.8	.17	.4	.18	•	.7
30	.12	.24	.9	.12	.12	.10	.25
50	.17	.22	.12	•	.17	•	•
75	•	•	•	•	.4	•	•
100	•	.4	.4	•	•	•	•
% of cells (water bottle samples)							
0	•	.0.2	.0.5	.0.2	•	•	.0.2
20	.0.2	.0.04	.0.1	.0.04	.0.1	•	.0.2
30	.0.2	.0.3	.0.2	.0.2	.0.1	.0.2	.0.3
50	.0.4	.0.2	.0.1	•	.0.2	•	•
75	•	•	•	•	.0.06	•	•
100	•	.0.1	.0.2	•	•	•	•

Table XLV: Distribution of Biddulphia weissflogii in Breid Bay (cells/liter x 10^2 and percentages)
Cruise 1964 – 1965

DISCUSSION

From the above study of some selected species, all participating in a large amount to the total phytoplankton bulk of the Southern Ocean, some points can be put forward :

1. For all the species studies, although they were effectuated at the same period of the year, the maximum quantities were different for the two expeditions, in location as well as in magnitude. This demonstrates clearly the relations existing between the hydrological conditions and the Diatom distribution.
2. The variation in the bulk between the two years, for some species, was very important. This brings the attention on the rapidity of the change in this area. Consequently, we ought to think that one has to be careful in interpreting the important quantities recorded for some species as "typical" for the latitude where it occurs.
3. Being conscious that two surveys in one sector can hardly lead to general conclusions, but integrating our results with those of comparable literature, we note that, although the main Diatom bulk increase follows a southward progression together with the establishment of the summer season, different species behave in different ways :
    - Some species (Corethron criophilum, Fragilariopsis kerguelensis), have a maximum bulk in the North Antarctic region which increases with and follows the southward displacement, closely

linked to the change of the increasing summer conditions;

- Other species (Chaetoceros atlanticus, Nitzschia Pseudonitzschia, Chaetoceros criophilus) show also a southward displacement in function of time, while their maximum quantity decreases;
- Some species (Nitzschia Pseudonitzschia, Fragilariopsis kerguelensis) have their maximum coinciding with the main phytoplankton increase, while others (Chaetoceros criophilus, Corethron criophilum) have a maximum cell number which does not coincide with the main phytoplankton increase;
- Some species (Fragilariopsis curta, Eucampia balaustium, Biddulphia weissflogii, Fragilariopsis 'nana'?, Nitzschia 'closterioides'?) have their maximum bulk in the far south. Either they are released from the ice (Frag. curta) or are linked to the neritic conditions of the coastal and inshore waters, or are even linked to the phytoplankton increase near the ice edge. From those some species are drifted northwards, while others are apparently not transgressing the coastal waters or even (?) the Antarctic Divergence. The differences in the distribution pattern of species in function of the seasonal progression is schematically represented on figure 47, the time

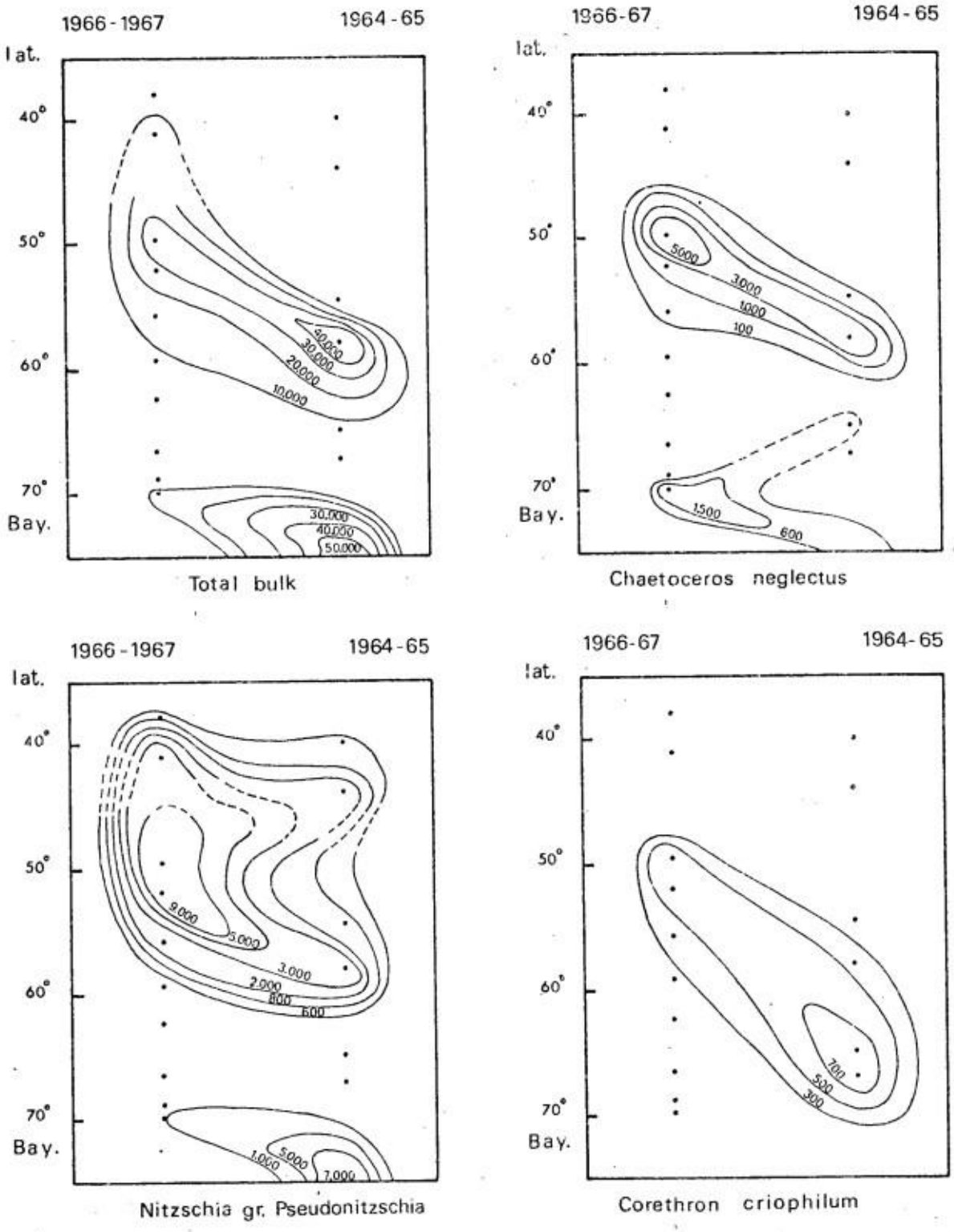
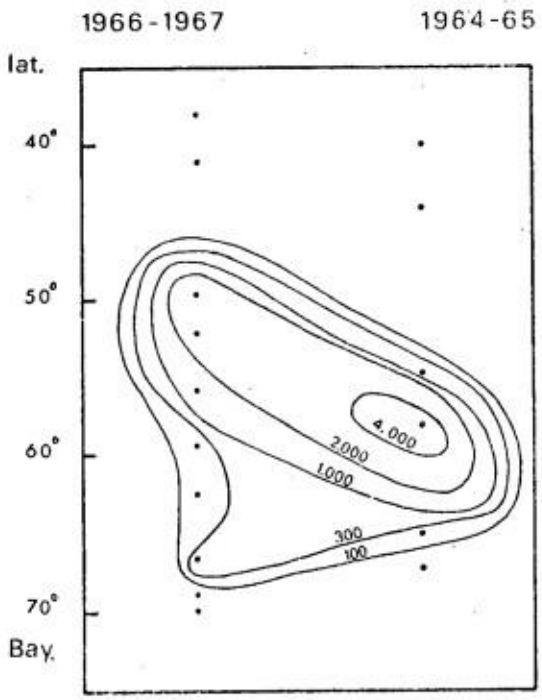
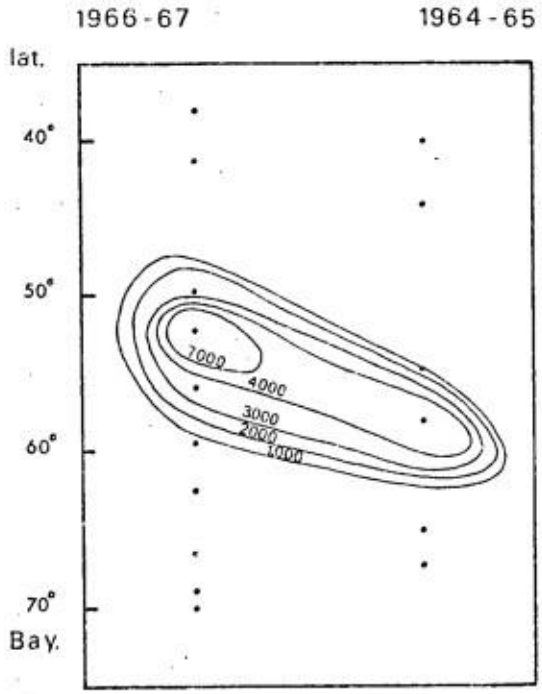


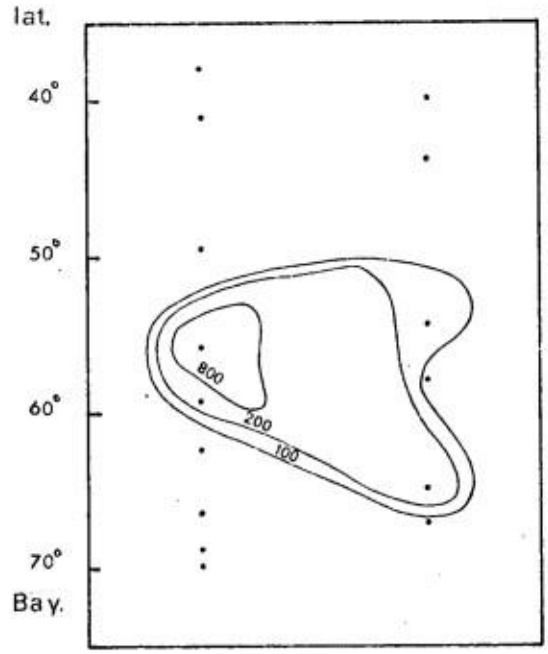
Fig. 47: Probable seasonal evolution of species. Lines correspond to numbers of Diatoms expressed as total cell number per m^2



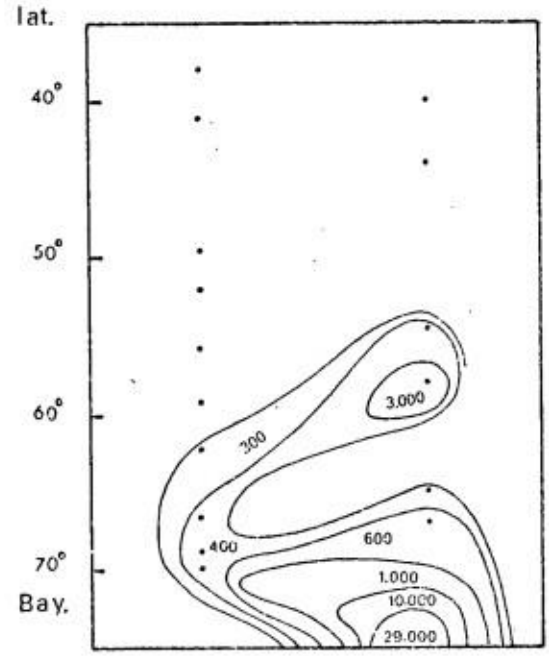
Fragilariopsis kerguelensis



Chaetoceros atlanticus



Chaetoceros criophilus



Fragilariopsis curta

Fig. 47 (continued).

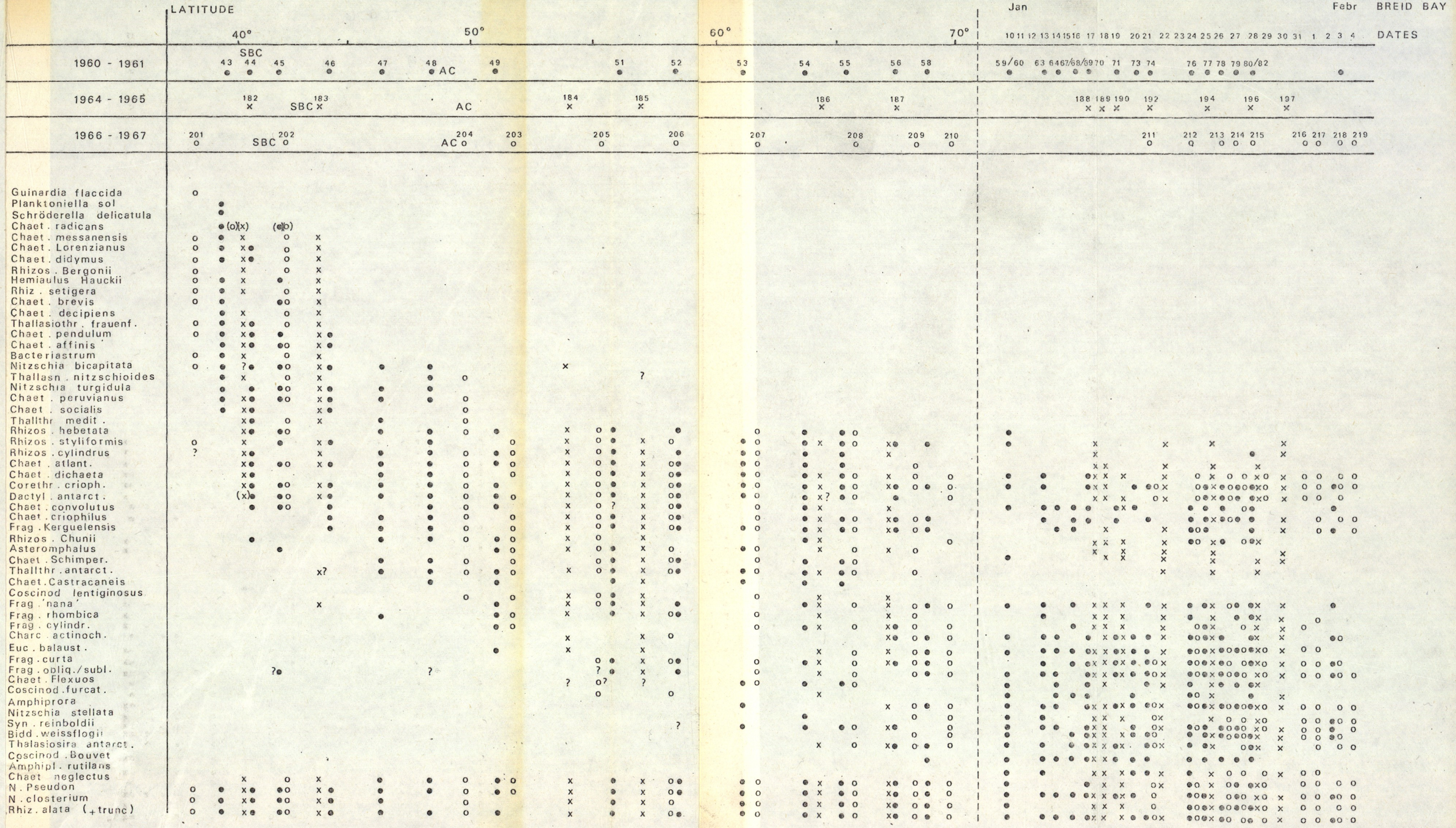


Table. XLVI: General distribution of Diatom species

scale corresponding to the establishment of the summer season.

4. A comprehensible analysis of the bulk of each species seems possible only when the distribution of that species is examined simultanuously in open waters (Subantarctic and Antarctic Waters) in high latitude inshore waters and, for some, in the ice.

To conclude, we say that, an investigation of quantitative distribution of Diatoms on a large scale and in a wide space-time frame (open ocean, inshore waters, ice-from early spring to late autumn), correlated with the simultanuous recording of the hydrological conditions, would probably elucidate the ecological patterns of most of the important species in the Southern waters.

VII. GENERAL DISTRIBUTION OF DIATOM SPECIES IN THE SOUTHERN CIRCUMPOLAR WATERS

1. Biogeographical studies within the Southern Ocean.

A number of authors have tried to subdivide the Southern Waters in biogeographical areas. Ideally a biogeographical scheme should be based on the distribution of species, throughout the different seasons and in the widest area as possible. The resulting biological picture should be compared (by a canonical analysis) to the environmental factors. In the Southern Ocean the main difficulty was considered to be the choice of the limiting environmental factors (Hart, 1942; Beklemishev, 1964). Different principles for classification of biogeographical areas in the Southern Ocean were adopted by different authors.

Hendey (1937) recognized a cold - and a warm - water flora in the Southern Waters, although not based on specified thermal conditions. The dividing line between the two floras do coincide with the Subtropical Convergence. For further classification, Hendey applied the Haeckellian principles and subdivided the species in oceanic, neretic, meroplanktonic and holoplanktonic forms.

Hart (1942), considered the classification of Hendey too wide, to be applied in the Antarctic Zone, where the temperature gradients are only slight. In addition, Hart

found difficulties in applying the subdivision (sensu stricto) of Hendey and attributed it mainly to variations of the ice edge, which he considered probably used by meroplanktonic forms in a similar way as a coast, bringing these forms within the oceanic areas. Therefore, Hart (1942) established his own system, based on the interaction of two factors : light and the distribution of the pack ice. He divided the Antarctic Ocean in a northern region (330 sea miles south of the Antarctic Convergence all the way round the world, with exclusion of special areas; this region being never invaded with continuous pack ice), an intermediate region (from the southbound of the Northern region to the Antarctic Circle; region largely covered by pack ice in winter and spring and mainly free during summer and early autumn) and a southern region (between the Antarctic Circle and the Antarctic Continent, excluding the immediate coastal areas).

Ivanov (1959), found that the major factors in the composition and the development of the predominant phytoplankton species, were the distance from the ice edge and the time of the year, latitude and distance from the convergence being lesser factors. Furthermore he considered that "the phytoplankton in the Atlantic, Indian and Pacific sectors of the Antarctic shows very little variation in the latidudinal direction as to qualitative composition and quantitative proliferation of the principal species, forming a single unit, as it were ", and distinguished only two regions : a northern zone without ice and a southern zone, free of ice during a certain period of the year.

Beklemishev (1958,1960) found that all basic hydrological bounderies in the Antarctic were floristic bounderies as well : the Subtropical Convergence, dividing the tropical from the preboreal (= Subantarctic) phytogeographical regions, and the Antarctic Convergence separating the preboreal from the Antarctic regions. The Antarctic region was subdivided in an upper and lower Antarctic subregion, along the line of the Antarctic Divergence. Moreover, Beklemishev (1960) found that Ekman's concept of propagation area (were a species is numerous and able to propagate normally) and expatriation area (were a species is scarce and unable to propagate or propagates weakly) has to be taken into account in biogeographical studies in the Southern Waters. This last area has not to be considered as belonging to the area of distribution in the strict sense of the word.

Several authors (Hart,1934 - Beklemishev,1960 - Fukase,1962 - Kozlova,1966 - Rytter Hasle,1969) made some correlations between the species encountered and the different types of water in the different zones of the Southern Ocean. Fukase (1962), showed that the Subtropical Convergence was, during the fourth Japanese expedition, a more pronounced boundery for some Diatoms than the Antarctic Convergence. Marumo (1957) and Fukase and El-Sayed (1965) refering to the Antarctic Convergence, observed that this front was associated with quantitative and qualitative changes in the Diatom composition. Rytter Hasle (1969) distinguished, on the basis of Diatom distribution patterns, eight groups (mainly six) of Diatoms. The patterns showed that, for some

species, the Subtropical Convergence and the Antarctic Convergence were real bounderies, while other species did transgress these fronts. Subgroups were distinguished according to location and timing of maximum standing stock of the species.

2. Species distribution during the three belgian antarctic expeditions.

Our purpose is not to attempt to establish biogeographical subdivisions, even not to pretend to draw up a general scheme of the occurence of species relevant to the different sectors of the whole Southern Circumpolar Ocean. Even taking into account the numerous Antarctic Diatom investigations already achieved, it seems too early to establish definite biogeographic zonations, for the time being, in the Southern Waters. Mainly because, neither the actual number of Diatom species present in the Southern Ocean, nor the number of those species which are endemic to this ocean, nor the quantitative distribution patterns of the Diatoms, can be specified with enough precision.

Our study intends to investigate if, along the same north-south section (including the coastal waters), a certain regularity could be recognized in the occurence of the species throughout successive years, in spite of variations in environmental conditions encountered.

As for the Brategg Expedition (Rytter Hasle) we did have the advantage, during our two last expeditions (1964-65 and 1966-67) to sample at each station simultanuously with Nansen bottles and with net. This duplicated sampling gives some security in avoiding the selective effect of the Nansen bottles (poorly efficient for rare species) and the net (poorly efficient for small species). Table XLVI gives the distribution of most species encountered, on basis of presence-absence, and this for all stations investigated during the three expeditions (1960-61, 1964-65, 1966-67). The data refer to 60 stations covering the area from north of the Subtropical Convergence, up to the inshore waters of the Antarctic Continent (Breid Bay). The stations along the transect are plotted according to the latitude, while the stations in the Breid Bay are plotted in function of time. The examination of the species distribution reveal that 7 groups may be distinguished :

- Diatoms clearly limited in their distribution to the subtropical waters and not encountered south of the Subtropical Convergence;
- Diatoms encountered in the Subtropical as well as in the Subantarctic Waters and for which the southern limit of their distribution coincides with the Antarctic Convergence;
- Diatoms limited in their distribution to the Subantarctic Waters;
- Diatoms restricted in their distribution to the Antarctic Waters and not encountered north of the Antarctic Convergence;

- Diatoms encountered in the Subantarctic as well as the Antarctic Waters but never north of the Subtropical Convergence;
- Diatoms encountered only in the inshore or coastal waters;
- Diatoms encountered in the whole area investigated.

Although Rytter Hasle's investigations refer to the Western Pacific and this for a sampling period from mid-December till end February, a nearly complete overlapping exists between her subdivision and our results. The main differences are due to the fact that we investigated also in the vicinity of the Subtropical Convergence and were able to add more data of the inshore waters. The similitude in the methods employed, has certainly contribute greatly to the concordance of the results. The fact that investigations, in a large area in the Western Pacific over a wide time scale, give results similar to those we obtained along the 20°E transect, during a one month survey, and this repeated for 3 different years, do suggest that the distribution pattern of the Diatoms proposed is of a larger value and may probably be circumpolar in its great lines.

Considering Table XLVI no more from the point of view of the distribution pattern of each of the species, but from the point of view of the populations occuring at the different stations, four groups of populations can distinctly

be recognized. The first of these groups comprises St. 201, 43,44,45,202,183 and occupies the area between 38°S and 45°S; the second covers the stations 46,47,48,204 corresponding to the area between 45°S and 50°S; the third, the largest one, corresponds to the stations between 50°S and 70°S, the fourth group covers the whole Breid Bay. Comparing with the hydrological data, we do observe a correspondance between the areas delimitated by Diatom populations and the hydrological bounderies. Indeed, the first area coincides with the Subtropical Waters, the second with the Subantarctic Waters, the third with the Antarctic Waters and the last area clearly covers the inshore waters. It may consequently be decuded that the different water masses are not only characterized by their hydrological features, but also by different types of Diatom communities. The boundery line for the two first groups coincides with the Subtropical Convergence and the Antarctic Convergence, respectively. However some species do cross these bounderies, the differences in the population composition seem more pronounced in the case of the Subtropical Convergence than for the Antarctic Convergence. It has to be reminded that, although the convergences are theoretically fronts were two water masses flow one towards another, these frontlines are not always sharply delimitated, and a large area, Convergence zone, can only be recognized. Consequently, we may expect for some years different populations at both sides of the front, while for other years a broad mixed population will be found.

Subtropical Convergence

In 1960-61 the Subtropical Convergence was located near station 44. The differences in species composition between station 43 and 44 is great, while stations 44,45,46,47 and 48 show a certain affinity. By means of Diatom species we would be inclined to consider the Subtropical Convergence between station 43 and 44.

In 1964-65, stations 182 and 183 are similar in species composition which realizes a "summation" between the species encountered at stations 43 and 44. From the point of view of the Diatom composition the populations of station 182 and 183 realize a perfect mixing or "convergence" and the area as a whole may be considered as a Subtropical Convergence zone.

In 1966-67, the Subtropical Convergence was located in the vicinity of station 202. Station 201 shows a population similar to that found at station 43, while station 202 has a mixed Diatom composition and corresponds to the Convergence.

Antarctic Convergence

The Antarctic Convergence seems a less pronounced boundery, in terms of Diatom composition, than the Subtropical Convergence (as also stated by Fukase,1962). If a lot of species do only occur in the southernmost part of the Subantarctic Waters, a good deal are able to cross the boundery. Only few species, in case of our three summer expeditions, are limited to the area north of the Antarctic Convergence. Although station P48 (1960-61) and station 204 (1966-67) were both located in the Antarctic Convergence zone, none of both show a mixed populations; from the point of view of the Diatom composition, they appear more "Subantarctic" than "Antarctic".

Antarctic Divergence - Ice edge - Inshore waters

Without any doubt a marked difference dosexist between the Diatom composition of the inshore waters of the Breid Bay and the open waters of the Southern Antarctic Ocean. Moreover, stations 56,57,58,187,209,210, all located south of the Antarctic Divergence, show a presence of species not occuring further north. Are they linked to the waters of the East wind drift Current, is their presence due to the pack ice, or influenced by nearby inshore waters, the question can not be solved, essentially because the sampling was to scarce and limited to a short summer period. Nevertheless, for certain species who were regularly recorded in the Breid Bay and only scarcely outside, we are inclined to think they are limited to the inshore waters. For other species the Antarctic Divergence may probably act as a boundery.

If the distribution of some species corresponds to oceanic areas defined by frontal zones, or to the limit between inshore waters and open waters, on the contrary, other species transgress these fronts. These last species do probably respond to other ecological factors than those used to define the convergencies. Most interesting would be the study of the environmental features in correlation with the quantities of all the species encountered. This would probably confirm that the most relevant factors are turbulence, nutrient content, light, and to a certain extent the presence of ice. This work we are intented to achieve in the future.

CONCLUSION

During the Belgo-Dutch Antarctic Expeditions of 1960-61, 1964-65 and 1966-67, we have been able to study the Diatoms of the Southern Ocean, in open and inshore waters, as well as in sea ice. On the basis of 307 samples taken along the transect Cape-Town (South Africa) - Breid Bay (Antarctica), approximately along the 24th longitude East, and in the Breid Bay itself. Quantitative analyses were only performed during the 1964-65 and 1966-67 expeditions.

1. The mean total abundance of Diatoms recorded for both years, 1964-65 and 1966-67, was within the range of respectively, 10^4 to 10^5 cells per liter in the Antarctic Waters, 5.10^3 to 5.10^5 cells per liter in Breid Bay and 10^6 to 10^8 cells per liter in sea ice.

- The value of 10^4 to 10^5 cells per liter in the Antarctic waters was similar to those found, by other authors, in the Atlantic, Pacific and Indian Ocean sectors, which suggests the idea of a uniform distribution all around in the Southern Circumpolar Waters (exception made of some special areas as the Weddell Sea). The maximal Diatom population was not found to exceed corresponding values from the Northern hemisphe-

re and confirms the idea that the Antarctic Ocean is not as rich as was sometimes stated.

- The quantities of Diatoms recorded in the Bay (1964-65) exceed those recorded along the transect and suggest that the abundance of plankton is restricted to inshore waters.
- The ice habitat was an exceptional rich milieu, especially at the level of the sea surface and at bottom level. The quantities of cells/l of melted ice exceed those recorded in open water and confirms the assessments of some authors relying on pigment analyses.

2. The establishment of the summer season, especially in the zones covered by pack ice, has been proven to play an important role in the development of the phytoplankton bloom.

- Indeed, high Diatom biomasses were found in conditions of reduced pack ice, higher temperature, lower salinity and a well developed stratification of the upper photosynthetic layers (where nutrients were not limiting factors: Sverdrup effect).
- Relative high Diatom abundances were also encountered in the vicinity of the Subtropical and Antarctic Convergence which, on the contrary, were characterized by an absence of stratification in the upper 100 m layer, leading most probably, to a vigoreus mixing within this layer.
- The maximum concentration of Diatoms tended to occur at lower levels in the southern than in the northern regions

3. A distinct year to year variation, regarding the species distribution and their abundance, was recorded. This variation was found to be in relation with differences in conditions from one summer to another. As the summer conditions were more fully developed during the year 1964-65, the data collected during this year should therefore be considered as succeeding those of the year 1966-67, in terms of seasonal succession.

- In this respect, along the transect, there was a displacement and an increase of the main total Diatom bulk towards the south, in relation with the advance of the season.
- At the level of the species, with the progress of the summer season, some have their maximum bulk displacing itself southwards, but for some others this maximum decreases and for still others it increases. On the other hand, for some species, the movement is northwards as the season progresses. Moreover, the maximum bulk for each species may or may not correspond with the total maximum bulk.
- In the Bay, one hundred times more Diatoms were recorded in 1964-65 than in 1966-67. This impressive difference was demonstrated to be clearly related to the well established summer conditions in 1964-65; the Sverdrup effect was probably applicable in this case.

In the Bay in 1964-65, a negative correlation between number of cells per liter and phosphate content was recorded. This negative correlation was not observed in 1966-67.

In the Diatom population of the Bay, for both expeditions, the free water species were mixed with those released from the ice, but the proportions of the two varied from one expedition to another.

- Diatoms in the ice, at the level of the sea surface as well as at the bottom level, were found in greater abundance in 1966-67 than in 1964-65. This means that the ratio of the water population to that for the ice was in 1964-65 equivalent to 10 whereas the same ratio in 1966-67 was 100.000.

4. <u>The dominant Diatom genera</u> encountered in the Southern Ocean were : Nitzschia, Fragilariopsis and Chaetoceros.

- Along the transect, the sequence in the dominant species was found to be roughly similar for both years and did correspond with the results obtained by Rytter Hasle in the Western Pacific. A similar sequence in the whole of the Southern Ocean probably exists.
- The Breid Bay showed a dominance of smaller sized species (Fragilariopsis curta, Fragilariopsis "nana", Nitzschia "closterioides"), compared to the species of

oceanic waters. An increase in diversity and the appearance of larger forms (Eucampia, Biddulphia, Coscinodiscus) at the end of the summer season was recorded in the inshore waters.

- The Diatoms living in the ice at sea surface level were essentially Fragilariopsis cylindrus and (?) Fragilariopsis curta; those of the bottom level were of a mixed population : specific ice-linked species (Amphiprora Kufferathii, Nitzschia stellata), which released in water form clots sinking to the bottom, and ice bottom flora species (Fragilariopsis sublinearis, Fragilariopsis curta) which, when released by the melting of the ice, remain in the free water and even may continue to develop and become dominant.

5. The index of diversity, computed from water bottle samples, showed slightly higher values along the tansect than in inshore waters. Variations in the diversity index where found to correspond to variations in the productivity-biomass ratio. Considering some records, species could be admitted as the main contributors to productivity.

6. Differences have been observed in the relative proportion of species when sampling the same populations, either by net or by water bottle. As a rule, small sized species escape in large

amounts, whereas the bigger sized are retained in undue proportion. The differences recorded in species diversity index, computed at the same station on both net and water bottle sampling may find its explanation in the failings of the net sampling method. This bears out the discrepancies on the results obtained by different authors which are based on varying sampling methods. Moreover big species, (Chaetoceros criophilus, Corethron criophilum) considered by some authors as occuring in great amount in the Southern Ocean, were found to be less abundant, whereas small species (Fragilariopsis "nana", Nitzschia "closterioides", Fragilariopsis curta) were found, on the contrary, in greater quantities.

7. The distribution boundery of some Diatom species coincided with oceanic fronts or with the limit between oceanic waters and inshore waters (? or with the Antarctic Divergence). Stations near the Subtropical and the Antarctic Convergence revealed that they correspond to zones where a mixing of species occured; the Subtropical Convergence delimited more sharply the distribution bounderies of certain species than the Antarctic Convergence. Nevertheless a great number of species transgressed the convergencies. Considering the

extension of the distribution and localizations, 7 groups of species stand out.

8. The Diatom distribution studied during both expeditions, has pointed out that oceanic, inshore water and ice populations were related. The results of future ecological work in the Southern Ocean would probably be improved if those areas were studied simultaneously.

9. Antarctic Diatoms were found to be linked to environmental conditions. Moreover the year to year variation observed demonstrates that investigations in the Antarctic Ocean could more properly be related to seasonal succession than the time of the year. The great differences in abundance recorded between the two years, particularly in the coastal area, lead to the assumption that their may be "poor" and "rich" years.

BIBLIOGRAPHY

ANDRIASHEV,A.P. - 1966 : The problem of life community associated with the lower layers of the Antarctic Fast Ice.
- Symposium on Antarctic Oceanography - Santiago-Chili.

APOLLONIO,S. - 1965 : Chlorophyll in arctic sea ice.
- Arctic. : 18 pp 118-122.

ATKINS,W.R.G., JENKINS,P.G. and WARREN,F.J. - 1954 : The suspended matter in sea water and its seasonal changes as affecting the visual range of the Secchi disc.
- Journ. Mar. biol. Ass. U.K. 33 : pp 497-500.

BALECH,E. and EL-SAYED,S.Z. - 1965 : Microplankton of the Weddell Sea - Biology of the Antarctic Seas. II
- Antarctic Research Ser. : 5 pp 107-124.

BEKLEMISHEV,K.W. - 1964 : Latitudinal zoning of antarctic phytoplankton.
- Sov. Antarct. Exp. Inf. Bull. 1958 (Transe. from Russian 1 : pp 113-114.

" 1964 : Concerning the phytogeographic division of the Antarctic pelagic region.
- Sov. Antarct. Exp. Inf. Bull. 1960 (Transl. from Russian 2 : pp 272-276.

BENNINGTON,K.O. - 1963 : Some chemical composition on Artic Sea Ice.
- In Ice and Snow. W.D. Kingery Ed. M.I.T. Press pp 248-257.

BRAARUD,et al. - 1953 : The phytoplankton of the North Sea and adjacent waters in May 1948.
- Rapp. Proc-Verb. C.I.E.M., 133 : pp 1-87.

BRODIE,J.W. - 1965 : Oceanography.
- T. Hatherthon [ed.] Antarctica,London : pp 101-127.

BUINITSKY,V.CH. - 1965 : The influence of diatoms upon the structure and strengh of sea ice.
Trudy Sov. Antarct. Exp.44 : pp 83-88.

BUNT,J.S. - 1960 : Introductory studies : Hydrology and Plankton, Mawson.
- Austr. Nat. Ant. Research Exp. (ANARE) Ser. B. III : pp 1-135.

" 1963 : Diatoms of Antarctic sea ice as agents of primary production.
- Nature London 199 : pp 1255-1257.

" 1964 : The phytoplankton and marine productivity in some inshore waters in Antarctica.
- In Biologie Antarctique (R. Carrick, M. Holdgate and J. Prevost eds) Hermann Parcs.

" 1964 : Primary production under sea ice in Antarctic Waters. 1. Concentration and photosynthetic activities of microalgae in the waters of Mc Murdo Sound Ant. 2. Influence of light and other factors on photosynthetic activities of antarctic marine microalgae.
- In "Biology of the Antarctic Seas" (M.O. Lee. ed.) Antarct. Res. Series 1 : pp 13-31.

" 1967 : Thermal energy as a factor in the biology of the polar regions.
- In Thermobiology : pp 555. Ed. A.H. Rose. N4 : Academic Press.

" 1968 : Microalgae of the Antarctic pack ice zone.
- In Symposium on Antarctic Oceanography-Santiago-Chili. p 198. Ed. R.I. Currie, Cambridge, Scott Polar Research Institute.

BUNT,J.S. and LEE,C.C. - 1970 : Seasonal primary production within Antarctic sea ice.
- J. Mar. Res.

BUNT,J.S. and WOOD,E.F.J. - 1963 : Microalgae and Antarctic Sea ice.
- Nature, vol 199 : pp 1254-1255.

BURKHOLDER,P.R. and MANDELLI,E.F. - 1965 : Carbon assimilation of marine phytoplankton in Antarctica.
- Proc. natur. Acad. Sci. U.S. 54 : pp 437-444.

" 1965 : Productivity of microalgae in Antarctic sea ice.
- Science N.4 149. N°3686 : pp 872-874.

BURKHOLDER,P.R. and SIEBURTH - 1961 : Phytoplankton and chlorophyll in the Gerlache and Bransfield straits of Antarctica.
- Limnolog. and Oceanogr. 6 : pp 45-52.

BURLING,R.W. - 1961 : Hydrology of Circumpolar Waters South of New Zealand.
- N.Z. Oceanogr. Inst. Mem. 10.

CASSLE,V. - 1963 : Distribution of surface phytoplankton between New Zealand and Antarctica. December 1957.

CASTRACANE,F. - 1886 : Report on the Diatomaceae collected by H.M.S. Challenger during the years 1873-1876.
- Rep. Voy. Challenger 1873-1876. Bot. 2 : pp 1-178.

CLEVE,P.T. - 1900 : Plankton from the southern Atlantic and the southern Indian Ocean.
- Öfvers, Svensk: Vetensk. Akad. Handl. 1900(8) : pp 919-938.

CUPP,E.E. - 1934 : Analysis of marine plankton diatom collections taken from the Canal Zone to California during March,1933.
- Trans. Am. Micr. Soc. vol. LIII,n°1 : pp 22-29.

" 1943 : Marine plankton diatoms of the west coast of North America.
- Bull. Scripps. Inst. Oceanogr. 5 (1) : pp 1-238.

DEACON,G.E.R. - 1937 : The hydrology of the Southern Ocean.
- Discov. Rep. 15 : pp 1-124.

" 1963 : The Southern Ocean.
- In M.N. Hill (ed) The Sea Vol 2 London : pp 281-296.

DELL,R.K. - 1965 : Marine Biology.
- In Antarctica (T.Hatherton,ed). Methuen London. A.H. and A.W. Reed, Wellington; Fred. A. Praeger N 4.

EHRENBERG,C.G. - 1844 : Einige vorläufize Resultate der Untersuchungen der von der Südpolreise des Capitain Ross, sowie von den Herren Schayer und Darwin zugekommen Materialien.
- Mber. Preuss. Akad. Wiss. : pp 182-207.

EL-SAYED,S.Z. - 1966a : Biologie der Antarktischen Meere.
- Umschau 8 : pp 1-7.

" 1966b : Phytoplankton production in Antarctic and sub-Antarctic waters (Atlantic and Pacific sectors).
- 2nd Int. Oceanogr. Congr. Moscow 1966 : pp 106-107.

" 1967 : Biological productivity investigations of the Pacific Sector of Antarctica.
- Antarctic J. U.S. 11 : pp 200-201.

" 1968 : On the productivity of the Southern Atlantic Ocean and the waters west of the Antarctic Peninsula.
- Antarctic Res. Ser. 11,15.

" 1969 : Ecological studies of Antarctic Marine Phytoplankton.
- Antarctic Journal of United States vol.IV n° 5 : pp 193-194.

" 1968 : On the productivity studies in Antarctic Waters. (Prospects of Primary Productivity studies in Antarctic Waters).
- Symposium on Antarctic Oceanography -Santiago-Chili : p 227. Cambridge Scott Polar Research Inst.

" 1970 : On the Productivity of the Southern Ocean (Atlantic and Pacific Sectors).
- In M.W. Holgate (ed) Antarctic Ecology I : pp 120-135.

EL-SAYED,S.Z. and MANDELLI,E.F. - 1965 : Primary production and standing crop. of phytoplankton in the Weddell Sea and Drake Passage. Biology of the Antarctic Seas II.
- Antarctic Res. Ser. 5 : pp 87-106.

EL-SAYED,S.Z., MANDELLI,E.F. and SUGIMURA,Y. - 1964 : Primary organic production in the Drake Passage and Bransfield Strait. Biology of the Antarctic Seas.
- Ant. Research Ser. 1 : pp 1-11.

FRENGUELLI,J. - 1960 : Diatomeas y Silicoflagelados recogidas en Tierra Adélia durante las Expediciones Polares Francecas de Paul-Emile Victor (1950-1952).
- Rev. algol. N.S. 5 : pp 3-48.

FRENGUELLI,J. and ORLANDO,H.A. - 1962 : Diatomeas y silicoflagelados del sector Antartico Sudamericano.
- Antarctic Record. 15.

FUKASE,S. - 1962 : Oceanographic Condition of Surface Water between the South End of Africa and Antarctica.
- Antarctic Record 15 : pp 53-110.

FUKASE,S. and EL-SAYED,S.Z. - 1965 : Studies on diatoms of the Argentine coast, the Drake Passage and the Bransfield Strait.
- Oceanogr. Mag. 17 : pp 1-10.

FUKUSHIMA,H. - 1965 : Preleminary report on diatoms from coloured sea ice in Point Barrow Alaska.
- Antarct. Rec. (in Japanese. Engl. abstract.) 24 : pp 31-35.

FUKUSHIMA,H. and MEGURO,H. - 1966 : The plankton ice as basis factor of the primary production in the Antarctic Ocean.
- Antarctic Rec. 27 : pp 99-101.

GORDON,A.L. - 1967 : Structure of Antarctic Waters between 20°W and 170°W.
-In V. Bushnell (ed) Antarctic Map Folio Ser. Folio : pp 1-10.

GRAN,H.H. - 1902 : Das Plankton der Norwegischen Nordmeeres.
- Rep. Norweg. Fish. Invest. 2 (5) : pp 1-222.

GRAN,E.H. - 1904 : Diatomaceae from ice floes and plankton of the Arctic Ocean.
- In F. Nansen Scient. Results,Norw. N. polar. Exp. 4 (11

GULLAND,J.A. - 1970 : The development of the Resources of the Antarctic Seas.
- In Antarctic Ecology vol I, M.W. Holdgate : pp 217-223.

HARDY,A.C. and GUNTHER,E.R. - 1935 : The plankton of the South Georgia whaling grounds and adjacent waters 1926-1927.
- Discovery Rep. 11 : pp 1-456.

HART,T.J. - 1934 : On the phytoplankton of the South-West Atlantic and the Bellinghausen Sea 1929-1931.
- Discovery Rep. 8 : pp 1-268.

" 1942 : Phytoplankton periodicity in Antarctic Surface Waters.
- Discovery Rep. 21 : pp 261-356.

" 1962 : Notes on the relation between transparency and plankton content of the surface waters of the Southern Ocean.
- Deep Sea Res. 9 : pp 109-114.

HASLE,G.R. - 1956 : Phytoplankton and hydrography of the Pacific part of the Antarctic Ocean.
- Nature 177 : pp 616-617.

" 1964 : Nitzschia and Fragilariopsis species studied in the light and electron microscopes. I. Some marine species of the groups Nitzschiella and Lanceolatae
- Vidensk. Akad. I. Mat-Nat. Kl. N.S. 16 : pp 1-48.

" 1965 : Nitzschia and Fragilariopsis species studied in the light and electron microscopes II. The group Pseudonitzschia.
- Vidensk. Akad. I. Mat-Nat. Kl. N.S. 18 : pp 1-45.

" 1965 : Nitzschia and Fragilariopsis species studied in the light and electron microscopes III. The genus Fragilariopsis.
- Vidensk. Akad. I. Mat-Nat. Kl. N.S. 21 : pp 1-49.

" 1968 : Distribution of marine diatoms in the southern oceans.
- In V.C. Bushnell (ed) Antarctic Map. Folio Ser. Fol. 10 pp 6-8.

" 1969 : An analysis of the phytoplankton of the Pacific Southern Ocean : Abundance, Composition and Distribution during the Brategg Expedition 1947-1948.
- Hvalradets Skrifter. Scientific Results of Marine Biological Research N° 52 Oslo.

HASLE,G.R. and HEIMBAL,B.R. - 1968 : Morphology and distribution of the marine centric diatom Thalassiosira antarctica Comber.
- J.R. micro. Soc. 88 : pp 357-369.

HEIDEN,H. and KOLBE,R.W. - 1928 : Die marinen Diatomeen der Deutschen Südpolar Expedition 1901-1903.
- Dtsch. Südpolar Exped. 8 (Bot) : pp 447-715.

HENDEY,N.I. - 1937 : The plankton diatoms of the Southern Seas
- Discov. Rep. 16 : pp 151-364.

HENTSCHEL,E. - 1932 : Die biologischen Methoden und das biologische Beobachtungsmaterial der Meteor Expedition.
- Inss. Ergebn. Dtsch. atlant. Exped. 'Meteor' 10 : pp 1-274.

" 1936 : Allgemeine Biologie des Süddatlantischen Ozeans.
- Wiss. Ergebn. Dtsch. atlant. Exped. 'Meteor' 11 : pp 11-344.

HOOKER,J.D. - : The Botany of the Antarctic voyage of H.M. Discovery Ships Erebus and Terror in the Years 1839-1843. I. Flora Antarctica.
- pp 574 (Reprint. 1963) Weinheim.

HOUTMAN,TH.J. - 1967 : Water masses and fronts in the Southern Ocean south of New Zealand.
- N. Z. Dep. sci. industr. Res. Bull. 174 : pp 1-39.

HUSTEDT,F. - 1930 : Die Kieselalgen Deutschlands, Osterreichs und der Schweiz.
- Rabenhorst Krypt. Flora. 7 (1) : pp 1-920.

" 1958 : Diatomeen aus der Antarktis und dem Südatlantik.
- Dtsch. Antarkt. Exped. 1938-1939 (2) : pp 103-191.

ICHIMURA,S. and FUKUSHIMA,H. - 1963 : On the chlorophyll content in the surface water of the Indian and Antarctic Oceans.
- Bot. Mag. Tokyo 76 : pp 395-399.

IVANOV,YA.A. - 1961 : O frontal' nykh zonakh v Antarkticheskikh vodakh (in Russian, English abstract).
- Oceanol. res x sect. IGY Progr. 3 : pp 30-51.

IVANOV,A.I. - 1964 : Characteristics of the phytoplankton in antarctic waters at the whaling grounds of the flotilla Slava in 1957-1958.
- Sov. Ant. Exped. Inf. Bull. (Transe. from Russian) 1 : pp 394-396.

KARSTEN,G. - 1905 : Das Pytoplankton des Antarktischen Meeres nach dem Material der deutschen Tiefsee-Expedition 1898-1899.
- Dtsch. Tiefsee-Exped. 1898-1899 2(2) : pp 1-136.

KINGERY,W.D. and GOODNOW,W.H. - 1963 : Brine migration in salt ice.
- In Ice and Snow, Kingery Ed. : pp 237-247.

KNOX,G.A. - 1970 : Antarctic Marine Ecosystems.
- In M.W. Holdgate (ed) Antarct. Ecol. I : pp 69-96.

KOOPMAN,G. - 1953 : Entstehung und Verbreitung von Divergenzen in der oberflächen nahen wasserbewegung der antarktischen gewässer.
- Dtsch. hydrogr. Z. Erg. h. 2 : pp 1-39.

KLYASHTORIN,L.B. - 1961 : Primary production in the Atlantic and Southern Oceans according to the data obtained during the fifth Antarctic voyage of the diesel-electric Ob
- Dokl. Akad. Nauk. USSR 141 (5) : pp 1204-1207.

KORT,W.G. - 1962 : The Antarctic Ocean.
- Scient. Am. 207 : pp 113-128.

KOZLOVA,O.G. - 1961 : Kolichestvennoe soderzhanie diatomeĭ v vodakh Indüskogo sektora Antarktiki.
- Dokl. Akad. Nauk. SSSR 138 : 207-210.

" 1966 : Diatoms of the Indian and Pacific Sectors of the Antarctic.
- (Transl. from Russian) fr. Nav. Sc. Found. Wash. by Israel Program for Scientific Translations.

KOZLOVA,O.G. - 1970 : Diatoms in Suspension and in Bottom Sediments in the Southern Indian and Pacific Oceans.
- In M.W. Holdgate (ed) Antarctic Ecology I : pp 145-153.

LISITZIN,A.P. - 1960 : Bottom sediments of the Eastern Antarctic and Southern Indian Ocean.
- Deep Sea Res. 7 : pp 89-99.

" 1962 : Bottom sediments of the Antarctic.
- Geoph. Monogr. 7 : 81-88 American Geophys. Union.

LITTLEPAGE,J.L. - 1965 : Oceanographic investigations in Mc Murdo Sound, Antarctica.
- Biology of the Antarctic Seas II, Ant. Res. Ser. 5 : pp 1-38.

MACKINTOSH,N.A. - 1946 : The Antarctic Convergence and the distribution of surface temperatures in Antarctic Waters.
- Discovery Report 23 : pp 177-212.

MACKINTOSH,N.A. and HERDMANN,H.F.P. - 1940 : Distribution of the pack ice in the Southern Ocean.
- Discovery Rep. 19 : pp 287.

MANDELLI,E.F. and BURKHOLDER,P.R. - 1966 : Primary productivity in the Gerlache and Bransfield straits of Antarctica.
- J. mar. Res. 24 : pp 15-27.

MANGIN,L. - 1915 : Phytoplancton de l'Antarctique.
- Deux Exp. Antarct. Franç. (1908-1910) Paris : p 95.

" 1917 : Sur le Chaetoceros criophilus Castr., espèce caractéristique des mers antarctiques.
- C.r. hebd. Séanc. Acad. Sc. Paris 164 : pp 1-9.

" 1922 : phytoplancton Antarctique. Expedition Antarctique Scotia 1902-1904.
- Mém. Acad. Sc. Paris 57 : pp 1-134.

MANGUIN,E. - 1960 : Les Diatomés de la terre Adelie;campagne du 'Commandant Charcot' 1949-1950.
- Ann. Sc. nat. Bot. : pp 223-363.

MARGALEF,R. - 1958 : Temporal succession and spatial heterogeneity in natural phytoplankton.
- Perspectives in marine biology : pp 323-349. Berkeley and Los Angeles : Univ. of Calif. Press.

MARGALEF,R. - 1959 : Mode of evolution of species in relation to their places in ecological succession.
- XV. Intern. Congr. Zool. (London) Section X paper 17.

" 1960 : Valeur indicatrice de la composition des pigments du phytoplancton sur la productivité, composition taxonomique et propriétés dynamiques des populations.
- Rapport.Proc. verb. C.I.E.S.M.M. 15 : pp 277-281.

" 1961 : Velocidad. de sedimentacion de organismos pasivos de fitoplancton.
- Invest. Pesq. Tomo XVIII; Barcelona.

" 1961 : Correlations entre certains caractères synthétiques des populations de phytoplancton.
- Hydrobiologia 18 : pp 155-164.

" 1965 : Ecological correlations and the relationship between primary productivity and community structure.
- Rem. Ist. Ital. Idrob. suppl. 18 : pp 355-364.

" 1967 : Communication of structure in planktonic populations.
- Limn. Oceanogr. 6 : pp 124-128.

" 1968 : Perspectives in Ecological Theory.
- The University of Chicago Press. Chicago London.

MARUMO,R. - 1957 : The surface distribution of plankton diatoms in the western part of the Pacific Ocean and the Antarctic Ocean in 1954-1955.
- Oceanogr. Mag. 9 : pp 143-147.

MEGURO,H. - 1962 : Plankton ice in the Antarctic Ocean.
- Antarctic Rec. 14 : pp 72-79.

MEGURO,H., ITO,K. and FUKUSHIMA,H. - 1966 : Diatoms and the ecological conditions of their growth in sea ice in the Arctic Ocean.
- Science 152 : pp 1089-1090.

" " " 1966 : Ice Flora (bottom type) : A mechanism of primary production in Polar Seas and the growth of diatoms in sea ice.
- Arctic20 : pp 114-133.

MOISEEV,P.A. - 1970 : Some aspects of the commercial use of the Krill Resources of the Antarctic Seas.
- In Antarctic Ecology vol I, M.W. Holdgate ed : pp 213-223.

OSTAPOFF,F. - 1962 : The salinity distribution at 200 meters and the Antarctic frontal zones.
- Dtsch. Hydrogr. Z. 15 : 133-142.

PERAGALLO,M. - 1921 : Diatomées d'eau douce et Diatomées d'eau salée.
- Deux. Exped. Ant. Française 1908-1910.

POUNDER,E.R. - 1962 : The physics of sea ice.
- In The Sea M.N. Hill ed. Interscience Publishers (John Wiley and Sons N 4) : pp 826-840.

RYTHER,J.H. - 1963 : Geographic variations in productivity.
- In M.N. Hill (ed) The Sea vol. 2 London : pp 347-380.

SAIJO,Y. and KAWASHIMA,T. - 1964 : Primary production in the Antarctic Ocean.
- J. Oceanogr. Soc. Japan 19 : pp 190-196.

SMAYDA,T.J. - 1958 : Biogeographical studies of marine phytoplankton.
- Oikos. 9 : pp 158-191.

STEEMANN,NIELSEN,E. - 1933 : Uber quantitatise Untersuchung von marinen Plankton mit Utermöhls umgekehrten Mikroskop.
- J. Cons. 8 : pp 201-210.

SVERDRUP,P.H.U., JOHNSON,M.W. and FLEMING,R.H. - 1942 : The Oceans.
- Prentice Hall. Inc. N 4.

THOMAS,CH.W. - 1963 : On the transfer of visible radiation through sea ice and snow.
- Journal of Glaciology 4 : pp 481-484.

VAN HEURCK,H. - 1909 : Diatomées.
- Antwerp. : pp 127.

VINOGRADOV,M.R. and NAUMOV,A.G. - 1958 : Quantitative distribution of plankton in Antarctic waters of the Indian and Pacific ocean. (in Russian).
- Inf. Byull. sov. antarkt. Eksped. 1955-1958 (3) : pp 31-34.

VTYURIN,B.I. - 1959 (1964) : Structure of Winter Fast Ice in East Antarctica.
- Soviet. Antarctic Expedition Inform. Bulletin 1959 - English translation 1964 (Elsevier) : pp 198-203.

WEXLER,H. - 1959 : The Antarctic Convergence or Divergence ?
- In the Rossby Memorial Volume N 4 : pp 107-120.

WIMPENNY,R.S. - 1966 : The Plankton of the Sea.
- London : pp 426.

WYRTKI,K. - 1960 : The Antarctic Circumpolar Current and the Antarctic Polar Front.
- Dtsch. hydrogr. Z. 13 : pp 153-174.

ZENKOVICH,B.A. - 1970 : Whales and Plankton in Antarctic Waters
- In Antarctic Ecology vol I, M.W. Holdgate ed. vol I. : pp 123-185.

ZERNOVA,V.V. - 1970 : Phytoplankton of the Southern Ocean.
- In Antarctic Ecology I, M.W. Holdgate (ed) : pp 136-142.

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